WELCOME SPEECH

A. G. JHINGRAN

Foreign Secretary
Indian National Science Academy, New Delhi

I feel very happy to offer a welcome to all of you at this gathering. We have assembled here for a symposium which is being organized by the Academy in collaboration with Unesco. As you are aware, the object of this project which has been sponsored by Unesco is to study the Central Asian science, literature, religion and other cultural aspects of Central Asia, and to make them well known to the people of the present times. We are very happy that you are trying to look into the past in a systematic manner.

We, in India, are quite familiar with the fact that the Indian culture dates back to several thousand centuries, and that it is one of the most ancient civilizations of the world. But modern people really do not have any idea as to how much really the ancients knew. Broadly speaking, I may say that many educated young men today do not like to believe that science had really advanced in the past, while we like to believe in the story of their ability to fly in the air or to handle sophisticated mathematical calculations which led to astronomical studies.

I happen to be a geologist and, in my opinion, I feel certain that the advances made in the past were very significant. Although modern science of mineralogy has undoubtedly made very significant advances, there is no denying the fact that the ancient Indians also knew quite a lot about mineralogy, particularly from the point of view of search for mineral deposits. It is a fact that, in spite of all the modern advances today after 150 years of active search for deposits, we have not located any new, fundamentally new, deposits of those metals which were known to civilizations in earlier days, that is, like those of copper, lead, zinc and iron. These deposits which were known in the ancient past and the slags that have been left behind have given us clues to further exploration of these deposits. No doubt, modern science has made us known of new elements. The ancient Indians did not know about manganese and were dealing with iron ores which were associated with manganese. But, the ancient smelters knew how to distinguish a good iron ore from a bad one which was associated with manganese, so that in modern search for manganese we have taken advantage of those slags which were abandoned by the ancient metal-workers because they were rich in manganese.

Many uses for new minerals have been found by modern science, for example, of uranium and thorium. But of the old metals like gold and copper, the ancient people surely had developed a sense, it may be called a horse sense, which was developed very acutely. I will give you one good example, that is, of mica. While mica has been known to be occurring in India in sheets and we have 90 per cent of the monopoly of the world supply of sheet-mica, the ancient people knew the use of that mica which was decorative. They used it for painting, for producing wonderfully good miniature paintings of the Rajasthan School of Art of 9th and 10th century A.D. which have been recorded in the art collections. Biotite, the black mica, which modern science finds useless, however, had been found extremely useful by the ancient Indians. The *abhraka bhasma* is one of the patent medicines in Āyurveda, which has been known for many centuries. I really do not know how long back it was discovered. Since it was found useful as a medicine, they made intensive studies on biotite, the kind of which we have not made even in modern times. In one of the ancient works I have found biotite having been described as of 8 varieties by the effect that it produced by heating it. For example, sodium biotite, when heated, produces a sound like the croaking of a frog, and this variety was called *dādur* variety, *dādur* being a Sanskrit word for frog. Yet another variety of mica was called *pinaga* which means that, when heated, it produces a sound similar to that of pulling a bow—a weapon which people used for fighting or *śikār* or warfare. Thus, the ancient people made intensive studies on minerals.

I do feel that intensive studies of the kind initiated by Unesco will undoubtedly help us in appreciating or understanding our past. I am quite sure that this Symposium which is devoted to the time of al-Bīrūnī—about one thousand years from today—will certainly lead to useful discoveries and appreciation of the knowledge prevalent in those ancient times. I am, therefore, very happy that we are organizing the Symposium, and I take this opportunity to welcome all these scholars who have come from different places, some of them from overseas. We do hope that your stay here would be enjoyable and useful With these words, once again I offer a hearty welcome to all of you.

INTRODUCTORY REMARKS

F. C. AULUCK

Member-Secretary
National Commission for the Compilation of History of Sciences in India
Indian National Science Academy

It gives me great pleasure to see here a number of scholars who have come not only from different parts of our country but also from several other countries. I am particularly happy that we have amidst us the noted scholars from Central Asia, Kuwait and Lebanon, who have very kindly accepted our invitation to participate in the Symposium.

This Symposium is being held under the Unesco Project relating to the study of civilizations of Central Asia. The Indian National Science Academy has been associated with this Project in so far as the development of Science during 9th to 13th century A.D. in Central Asia is concerned. It may be emphasized that the purpose of Unesco Project, as succinctly stated in the Unesco Document, is 'to make known better the civilization of the peoples of Central Asia through studies of their archaeology, history, science and literature.' The Central Asian region includes Afghanistan, northern part of India, Iran, Mongolia, Pakistan and several Asian Soviet Republics.

There is no denying the fact that the peoples of Central Asia contributed in no small measure to the growth and ramification of many scientific ideas and technological practices in the ancient and medieval periods. The period chosen for the study of the development of science in Central Asia under the Unesco Project is one which was noted not only for the intellectual synthesis of many strands of scientific knowledge, but also for bringing to light a number of important ancient works in Arabic, Persian and Sanskrit. There was, in this period, a cultural and scientific communication among the various countries of the region.

The contributions of the peoples of Central Asia seem to have been practically unknown beyond scholarly circles. The Unesco Project envisages a two-way effort, viz. specialized studies on the one hand and better, but critical, information for the general public on the other. Keeping this in view, the Indian National Science Academy has taken up studies leading to publications of value concerning the development of science and technology in this part of Central Asia, and in the perspective of the Central Asian contributions.

The Unesco Project pertaining to science also emphasized that special attention should be devoted to al-Bīrūnī who, as you all know, occupies a distinct place in the phalanx of the versatile scholars of this period. He was undoubtedly eminent in the field of 'rational science', as the Islamic qualification goes. Although we know little about his ancestry and childhood, he seems to have commenced scientific studies very early and he had the good fortune to be taught by the eminent Khwarazmian astronomer and mathematician, Abu Nasr Mansar. He was well versed in the religious as well as technical literature of the time.

Al-Bīrūnī has a special appeal to the Indians. He came to India in the early 11th century A.D., spent some years traversing the regions of modern Rajasthan, Haryana, the Punjab, and even some parts of the Gangetic Valley. His thirst for knowledge was so great that he learnt Sanskrit, studied the important religious and scientific texts and held discussions with the traditional *paṇḍits* with whom he came in contact. He presented, in the true tradition of a scholar, the knowledge he acquired. In his important work on India, we find a good deal of information on Indian astronomy, eras, arithmetic, meteorology, geography, mineralogy, chemical practices and the like. In particular, his account of Indian astronomy, mostly based on the works of Brahmagupta who preceded him by some 400 years, is of great significance to scholars who are interested in the historical evaluation of Indian astronomy. I need not go into the details of al-Bīrūnī's account of Indian sciences, as they will be discussed today and tomorrow. Here and there, perhaps, there may be some omissions in his presentation; even so this book stands as a testimony to acumen of the true knowledge-seeker that al-Bīrūnī undoubtedly was.

It is indeed gratifying to note that in this Symposium a number of scholars are participating. They have made special studies on al-Bīrūnī and Indian Sciences. We are particularly happy that the scholars from the Asian Soviet Republics of the USSR, Afghanistan, Iran, Kuwait and Lebanon have been able to attend the Symposium. We are eagerly looking forward to fruitful discussions at the Symposium.

As you would see in the programme of the Symposium, copies of which have been circulated to you, the themes to be discussed at the Symposium are: Al-Bīrūnī's Sources, Indian Sciences as Reflected in al-Bīrūnī's Works; Al-Bīrūnī as a Synthesizer and Transmitter of Scientific Ideas of his Time, and any other subject of value on al-Bīrūnī from the point of view of the history of scientific ideas. We have 18 papers from the Indian scholars and there will be some papers from the foreign scholars also. The titles of the papers, I am sure, would indicate the spectrum of knowledge that al-Bīrūnī possessed and presented, and the discussions at the Symposium, it is hoped, will enable the participants to appreciate the range and hues of this spectrum.

In India we have over 25 manuscripts of the works of al-Bīrūnī preserved in the libraries at Patna, Bombay, Ahmedabad, Calcutta, Aligarh and Hyderabad. Photocopies of some of them are on display at the exhibition which has been organized as part of the Symposium. Thanks to the co-operation of the Indian Institute of Islamic Studies, New Delhi. In addition, books by, and on, al-Bīrūnī are also displayed.

In the end, I must make a special reference to the Indian National Commission for Co-operation with Unesco and the concerned authorities of the Unesco Headquarters, Paris, through whose help and valuable co-operation, it has been possible to organize the Symposium at an international level. It has been the endeavour of our Academy to make the Symposium a forum for exchange of ideas among scholars in different disciplines, who have assembled here. We are happy to note that the deliberations of the Symposium will also be utilized in an appropriate manner in the compilation of an Anthology of al-Bīrūnī's works which is being undertaken in a comprehensive way by the Unesco.

The Symposium has five Sessions including the Plenary Session. It is hoped that our ideas will assume a crystallized form, and that we will be able to identify areas of study to be undertaken in future in a systematic way, so that more light will be thrown on the role of al-Bīrūnī in the development of science in Central Asia. It is proposed to send the proceedings of the Symposium to Unesco for publication as envisaged by them.

As I said earlier, the main objective of the Unesco Project, viz. to make better known the significant contributions of different cultures in the field of science, should be our beacon light. It is my view, and I hope you will agree with me, that studies and symposia are only a means towards this objective. In the history of science, particularly that of Arabic Science, we have evidences of a fusion of ideas belonging to different cultural traditions in a spirit of accommodation and assimilation. I have no doubt that that spirit will guide the deliberations of the Symposium.

INAUGURAL SPEECH

B. R. SESHACHAR

President, Indian National Science Academy

I join Professor A. G. Jhingran in extending a welcome to all the participants in the Symposium which has been organized in co-operation with the Unesco as part of its Central Asian Project.

The Academy has been involved in the study of history of sciences for almost 20 years. In 1950 we had organized, in co-operation with Unesco, a Symposium on the History of Sciences of South-east Asia and, from that time onwards, we have had a considerable involvement in the field of history of sciences in this country. Many of you may recall that in 1958 a Board of History of Science was constituted in the Academy and, as a result of considerable amount of bibliographic work done since then, a National Commission for the Compilation of History of Sciences in India was constituted in 1965 in the Academy. The Government of India is providing support for the work being done, and we have been carrying on studies on the history of sciences in India. I have been a member of this Commission almost from the beginning, and I now find that perhaps we have not made a great deal of advance, as much as we would have liked to do. But we have for the first time a systematic attempt being made in the Academy for a study and a chronicle of history of science. There is a great deal of material, but there are not many qualified people to undertake this task. It needs a synthesis of several disciplines—Sciences, Social Sciences, History and so on—and, it has so happened we do not have in the country adequate facilities for meeting this great challenge of a study of the history of science of this country.

I believe, however, we have made a beginning and perhaps even some progress. As many of you know, several monographs on the history of sciences in India have been published already. We have a journal, the *Indian Journal of History of Science* which is now at least 5 or 6 years old—a journal which has been acclaimed all over the world as one of the best in the field anywhere. I had hoped we would have had copies of 'A Concise History of Science in India' available today on this occasion, but certain logistic difficulties have come in the way of its production. This book presents for the first time an integrated account of the history of science in this country. We have also under preparation four more volumes of history of science on Chemistry, Mathematics, Astronomy and Medicine—and we are proposing to publish three periodwise volumes—ancient, medieval and modern periods. We hope we will be able to get these done as soon as possible.

But, as I said earlier, the only constraint is the expertise that is needed for presenting an authentic account of history of science in India. The Academy has organized critical studies on history of science in order to emphasize the scientific tradition of this country. Friends from abroad and many others consider, perhaps correctly, that India's contribution in the past was largely in the fields of religion, philosophy and literature. That this country had also a very rich scientific tradition is not well known. I believe that it should be our endeavour, not only through Symposia of this type but even otherwise, to get materials together and present to other countries in the world an integrated picture of India's contributions to science.

In this connection, I have to make a plea that we must have more intensive studies on the history of sciences and it is my view that no science can be taught, understood or comprehended except against the background of its own history. Obviously this can be done most effectively in the universities I must admit that in this country there are certain universities where some sort of history of science is being taught. But it is my view that this type of teaching is entirely inadequate. In fact, very often I feel quite sad that, of the three great areas of science development in the world in the past, viz. Central Asia, China and India, it is a pity that while the Americans, the British and the Europeans are teaching history of science, we in the country belonging to a region where science developed in the past, have neglected very considerably the teaching of history of science. As I said before, the present state of affairs of teaching of history of science in the universities of this country is far from being satisfactory. Of course, it is a vicious circle. We must train the people before we get the experts to be able to do teaching and research. But if you want to get the people, we must teach and do research, as in several other disciplines. But we must break this circle somewhere and in some way. It is probably true that there are not enough men in this country to be able to teach as well as to do research. But then, how do we start and make a beginning? I believe our universities must play a very important role in this direction. I recall how in the Delhi University, we tried to organize teaching as well as research in the history of science, and a department of History of Science, and we came scross a great difficulty because we did not have trained men to undertake this. I believe the Delhi University still needs a good department or a unit of History of Science. While it is true that there are extremely competent people who could teach any particular branch of the history of science, what we need is an attempt at teaching in an integrated manner the history of sciences in the context of our social, economic and political developments.

Having said this, I want to make a plea. At a recent meeting of the National Commission for the Compilation of History of Sciences in India, we discussed at length the collection of source materials and the presentation of the knowledge contained therein. We found that it is time to think of some place where groups of scholars of different disciplines could come together and work intensively in this field over a period of time. I am allergic, traditionaly, to institutes. But as I have, during the past few years, come into close contact with the amount of material that is available and the rather *ad hoc* manner in which we are trying to get these materials together, I feel that we should seriously consider now the establishment of a unit or an organization either in a university or under the auspices of the Academy to study history of science very intensively and permanently. While the Government are providing funds, they are doing so from one Plan Period to another. But the material available for studies is so vast that it should last for a long time to come.

I have seen in some universities like Mysore, Madras and Annamalai enormous attention is being given to studies in the languages of the regions. While such attention is relevant in their own regions, the history of science in India which encompasses the whole country needs to be studied under some central organization or a central university. Again, I am allergic to analogies. But what has happened in the USSR in this regard should merit our attention, because the Soviet Academy of Science has institutes of research under it. I would, therefore, like to make a plea that, if the government is interested and so feels, the Indian National Science Academy would be very happy to have under its auspices this central organization for studies in history of science, because the Academy has gone on in this field already for about 10 years. The first institute to be organized under the Academy should be an Institute of History of Science in India. In this central place where an integrated study could be fostered, scholars from different parts of the country and also from other countries could work together—in an inter-disciplinary manner.

In this context the present Symposium, I believe, is an important step. Al-Bīrūnī was born almost exactly 1000 years ago in Central Asia. A man of colossal intellectual proportions whose sweep and breadth of vision encompassed such vastness that holds us in wonder even today, it shows that geniuses are not uncommon. It seems to me that there is a very important additional circumstance in so far as al-Bīrūnī is concerned. In the eleventh or twelfth century, Indian science was at its peak and so was Arab science, and the circumstance was that an Arab scientist came to our country, because he found here a soil where his genius could flower. He came as an iconoclast, but he stayed behind to see what idols are, how they are made, what they signify and what they are meant to be. As one of the messages significantly said, al-Bīrūnī was a great synthesizer, a man of constructive abilities, a true scientist of that age, 1000 years ago, when most of Europe was in darkness. He learnt Sanskrit; perhaps he knew some Sanskrit before. He learnt Sanskrit in this country in order to be able to converse with our *paṇḍits,* for there were no British then, nor was there any other means of communication except through this language. He travelled widely, met a number of people and his contribution to the understanding of sciences in India is outstanding. He covered astronomy, zoology, geodesy, mathematics, medicine, pharmacology, mineralogy, geology and the like.

These two days we would be spending our time extremely usefully in discussing about this man of great intellectual output and going into his works critically. I see that your programme is very wide and it contemplates several intensive discussions on al-Bīrūnī's works.

I want to pay a special tribute to our foreign delegates and, while doing so, I do not wish to minimize in any way the effort and trouble that our own scholars have taken in coming here. Probably, this is the first time that such a discussion is being held on this subject. I do hope that this would not be the only one but a beginning, because the Academy is interested in furthering studies in history of science in India.

I have great pleasure in inaugurating the Symposium on al-Bīrūnī, and I hope your discussions will be very fruitful.

AL-BĪRUNĪ
AN INTRODUCTION TO HIS LIFE AND WRITINGS ON THE INDIAN SCIENCES

MAQBUL AHMAD,* RAM BEHARI† AND B. V. SUBBARAYAPPA‡

Abū al-Rayḥān Muḥammad b. Aḥmad al-Bīrūnī (Bērūnī), also called al-K͟hwārizmī, was born on the 3rd of Dhu 'l-Ḥijja, A.H. 362/4th September, A.D. 973, in a suburb or outside (Persian, *berūn*) the city of Kāt͟h (also spelt Kāzh), the ancient capital of K͟hwārazm (modern Khiva which is now the Kara-Kalpaskaya A.S.S.R., on the southern shores of the Aral Sea.[1] Little is known of his ancestry except that he was Persian by origin and spoke the K͟hwārizmian dialect. In his later life when he had acquired eminence, a poet wrote a lampoon against him ridiculing him for being of 'unknown origin', and al-Bīrūnī retorted in verse using heavy sarcasm:

> Oh poet, who came to me ridiculing my manners,
> Intending to praise me, but finding faults with my manners;
> I found him foolishly passing out wind in my beard
> As though the length of his beard was my tail !
> And describing my genealogy in his verses;
> By God, I am unaware of my ancestry,
> For I do not know my grandfather the way I should know him.
> And how can I know my grandfather when I am ignorant even of my father ?
> Verily, I am an Abū Lahab, an old man without much manners;
> Yes, and my mother is a porter of fire-wood ![2]

Al-Bīrūnī seemed to have passed his life as a bachelor. Like a scholar truly devoted to his subject, he once remarked about his early writings: 'I have neither discarded nor considered as disgraceful all those works which I had written during my youth, although later I accumulated much knowledge, for all of these were, my sons, and many people are found to be intensely in love with their poetry and sons.'[3] From his early youth, he displayed extraordinary intelligence and a scholarly bent of mind. He used to visit a Greek in K͟hwārazm and to carry to him different varieties of plants, seeds and fruits with a view to learning from him their Greek names which he used to record.[4]

It was in K͟hwārazm that he received his scientific training from masters such as Abū Nasr Mansūr b'Alī b. 'Iraq Jīlānī, the mathematician. It was from here that he went in person to see the Sāmānid Sultān Manṣūr II b. Nūh

* Director, Centre of West Asian Studies, Aligarh Muslim University, Aligarh
† Vice-Chancellor, Jodhpur University (Retd.). 80 Darya Ganj, Delhi 6
‡ Supervisor, National Commission for the Compilation of History of Sciences in India, Bahadur Shah Zafar Marg, New Delhi 1.

(387-389/997-999) whom he praised as his first benefactor.[5] Whatever be his ancestry, al-Bīrūnī was not a well-to-do person in his early life, and he was rather touchy about it. He relates an incident in his life which reminded him of the verses of Aḥmad b. Fāris:

A wise man of by-gone times has said:
'The importance of a man lies in his smallest things.'
I on my part also speak like a wise man, saying:
'The importance of a man lies only in his two dirhams.'
If he has not his two dirhams with him,
His bride does not care for him,
In consequence of his poverty he is despised,
So that people's cats piss at him.

This occurred when he was separated from the court of Khwārazmshāh and was 'bereft of the happiness of the royal service'. He met a man in Rayy who was counted among the learned astronomers and, discussing an astronomical problem with him, disagreed with him. The astronomer told him that his theory was a lie and behaved very rudely with him, 'being very lengthy about the difference between us in wealth and poverty, which changes subjects for glory into subjects for blame. For at that time I was in a miserable condition, tried (troubled) on all sides; afterwards, however, when my troubles had subsided (ceased) to some extent, he chose to behave in a friendly way with me.'[6]

Al-Bīrūnī lived in Khwārazm up to the age of twenty-five under the patronage of the 'Āl-i 'Irāq, and after a revolution in the country and the assassination of Abū 'Abd Allāh Muḥammad, the last ruler of the House of 'Irāq in 385/995, he left the country. Al-Bīrūnī called Abū 'Abd Allāh 'the martyr', and Abū Naṣr Manṣūr b. 'Alī b. 'Irāq, maulā Amīr al-Mu'minīn his 'master'. In an eulogy to the dynasty, he says:

I passed most of the time under their blessing,
Occupying positions high.
The 'Āl-i 'Irāq nourished me with their milk, and
Among them, Manṣūr planted my roots.[7]

That Abū Manṣūr wrote a number of books in the name of al-Bīrūnī shows the deep regard that the master had for his pupil. Of these, twelve are mentioned by al-Bīrūnī in his letter. And by this time, al-Bīrūnī was already the author of at least ten works.[8]

After leaving Khwārazm, he visited Rayy and probably the province of Gilan, and was back in Kāth in A.D. 997. His next sojourn was in Gurgan where he was received with warmth and affection by Abu'l-Ḥasan Qābūs b. Washmgīr Shams al-Ma'ālī, who was a great patron of the arts and sciences. He was keenly interested in literature, mathematics and philosophy, and was himself the author of an Epistle on Astrolabe.[9] Al-Bīrūnī dedicated his first major work, *al-Āthār al-Bāqiya 'an al-Qurūn al-Khāliya* to this ruler, probably about 390/

1000[10] as also another work, *Risāla Tajrīd al-Sh a'aāt.*[11] But in spite of his generosity towards the savants, Shams al-Ma'ālī, possessed a tyrranical and harsh nature which al-Bīrūnī did not appreciate much. After praising the 'Āl-i 'Irāq, he says:

> 'Shams al-Ma'ālī sought my services
> In spite of my hatred towards him, for he was harsh'.

He also resented the ruler's habit of showering gifts upon the poets who assembled in his court on the two occasions of Naurūz and Mahrajān without hearing their eulogies to him personally and instead assigned the job of distributing the gifts to Abū'l-Layth al-Tabarī.[12]

Thus, al-Bīrūnī returned to his native place in about 400/1010[13] and was received by Abū'l-Ḥasan 'Alī b. Ma'mūn whose father had overthrown the 'Āl-i 'Irāq dynasty in Khwārazm earlier. Here he served for seven years the brother of this prince, the Khwārazmshāh Abū'l-Ḥasan Ma'mūn b. Ma'mūn and was entrusted, because of his 'golden and silver tongue' with delicate political missions.[14] 'Alī b. Ma'mūn was also a great patron of learning and his minister Abū'l-Ḥusayn Aḥmad b. Muḥammad al-Suhaylī al-Khwārazmī was specially devoted to philosophy. The court of the Khwārazmshāhs, at this time, was unique in the sense that there assembled here a galaxy of men of learning and science, among whom were Abū Naṣr 'Irāq, Ibn al-Khammār (b. 331/941), Abū Shal 'Īsā b. Yaḥyā Masīḥī al-Jurjānī (d. between 403-405/1012-1013), Abū Manṣūr al-Tha'ālabī, etc.[15] Al-Bīrūnī lived in Khwārazm, but it was a short respite; he was destined to be disturbed and uprooted again from his homeland, this time for the rest of his life.

It is said that Sulṭān Maḥmūd of Ghazna, who had by now become a powerful potentate in the east, was jealous of the concentration of eminent men of learning of the time at the court of the Khwārazmshāhs. So he asked Ma'mūn to send some of them to his court. At the arrival of the news, some escaped while some others agreed to go and among them was al-Bīrūnī. However, Maḥmūd's political intrigues and desire to secure suzerainty over Khwarazm, ultimately led to the murder of the ruler by his own troops and the passing of the kingdom under Maḥmūd's rule. Maḥmūd took away innumerable captives along with him to Ghazna. Thus did all-Bīrūnī come to Ghazna in the spring of 408/1017. It was unfortunate for him in a way, but also auspicious in another, for he came so close to a country that was so near and dear to his heart. But he always had nostalgia for his homeland and remembered his benefactors:

> The family of Ma'mūn and among them, 'Alī
> Were my benefactors and were compassionate and helpful to me.
> And the last of them, Ma'mūn made me prosperous,
> Made me famous and raised me to a high position.[16]

There are conflicting views about the attitude of Sulṭān Maḥmūd to al-Bīrūnī. According to one, Maḥmūd spared his life for he wanted to retain him as a court astrologer, but according to the other, Maḥmūd respected and honoured him.[17] One need not wonder, however, if Maḥmūd was suspicious of him and bore some grudge against him, for he was deeply involved in the palace politics at Khwārazm and occasionally advised the ruler on intriguing political problems.[18] Al-Bīrūnī himself is silent; on the other hand, he did praise Sulṭān Maḥmūd.

> Maḥmūd did not withhold any blessing from me;
> He made me rich, gave me in abundance and connived at my costly demands;
> He forgave me my ignorance and honoured me;
> Because of his glory I became happy and prosperous.[19]

But he was often a target of criticism by other courtiers, who were jealous of his knowledge and erudition, to which he refers from time to time in his writings. At one stage, he probably escaped death and he was mentally perturbed for he had to give up his academic pursuits for a while.[20] For the first time, al-Bīrūnī must have left Ghazna around 410/1019, or after, and the last time he was in India was in 420/1029. He seemed to have accompanied Sulṭān Maḥmūd several times on his campaigns against India.[21] India attracted al-Bīrūnī since his youth and he was full of respect and admiration for the people and the fact that India still kept up the traditions of learning and whose philosophy, religions and culture were still flourishing and were continuous from the ancient times, must have acted as an additional incentive for him to visit the country.[22] He stayed in India for nearly ten years, teaching the Graeco-Muslim sciences, learning Sanskrit and other local dialects, making astronomical observations and studying all aspects of Indian life. But for his researches and studies, the Islamic world and the Arabic-knowing people of the time, especially, might have remained ignorant of the achievements of India in the spheres of science and philosophy in the ancient times. His studies are relevant for us in India even today, for his work on India, namely *Kitāb Taḥqīq mā li-'l-Hind* (completed in 421/1030, shortly after the death of Maḥmūd), is a comprehensive, scientific guide to India of the ancient period. The merit of the work lies in its comparative study of the Indian, Greek, Iranian, Islamic as well as Ṣūfī thought, in all of which al-Bīrūnī was proficient. The work represents the *summum bonum* of knowledge of an educated man of the time on India and is a mirror of universal knowledge, excluding perhaps the Chinese. What S. Radhakrishnan achieved in modern times by way of projecting Indian thought and philosophy to the western world, al-Bīrūnī had achieved in the eleventh century by projecting it to the Arabic-knowing world. Yet, let us not presume that he was all praises for India. He studied India objectively and dispassionately. He is critical of the Indian *paṇḍits* for their narrow outlook and for superiority complex from which they suffered at the time, while the ancient Indian scientists and philosophers were more liberal and open-minded; the former were unaware of the progress made by the outside world of the time.[23] In fact, what al-Bīrūnī studied in India was the legacy of ancient India of the times of the Mauryas and the Guptas mainly, and hence the remarks. It seems, however, that he commanded great respect and honour in the subcontinent, for criticising the contemporary Muslim scholars for not being able to appreciate the real value of his contributions to knowledge, he says: 'I have surpassed these leaders of knowledge, they have not acquired the degree of knowledge that I have and they do not sit down to discuss problems as I do, nor do they indulge in the solution of intricate problems like I do. Ask about my value from the Hindus in the East and in the West, from those who have assessed the high quality of my work.'[24] Al-Bīrūnī is truly worthy of our admiration and praise, for he studied India soberly at a time when relations between the Muslims and the Indians were greatly strained due to the political campaigns of his benefactor in the country. He seemed to have worked for presenting the true image of India to the Islamic world. He is even credited with being responsible for the introduction of the Islamic *kalima* on the coins promulgated by Sulṭān Maḥmūd in his domains in India. The *kalima, Lā ilāha illā Allāhu Muḥammad Rasūl Allāh,* was rendered into Sanskrit as: *avyaktam ekam, Muhammada avatāra.*[25] This was no mean achievement. Al-Bīrūnī seemed to have travelled extensively in northern and north-western India, and probably also visited some places in the south, but his travels need to be worked out in greater detail. After his return to Ghazna, in 1029, he completed his work on India and also finished writing his *magnum opus, al-Qānūn al-Mas'ūdī.* Sulṭān Maḥmūd died after a year of his return and was succeeded by his son Sulṭān Mas'ūd (421-432/1030-1041). Al Bīrūnī dedicated to him, in 421/1030, the most important achievement of his academic career, *al-Qānūn* and the Sulṭān was so pleased that he offered him an elephant-load of silver coins which the Master humbly refused and instead was granted all amenities of life and full facilities for research and investigation till the end of his life. Sulṭān Mas'ūd was succeeded by Sulṭan Maudūd (432-441/1041-1049) to whom he dedicated his work on mineralogy, *Kitāb al-Jamāhir fi Ma'rifat al-Jawāhir.* The last work produced by him was *Kitāb al-Ṣaydala* (or *al-Ṣaydana*), a kind of materia medica of the time, wherein he declared that he had reached the ripe age of over eighty (lunar) years.[26] Al-Bīrūnī died some time after 442/1050,[27] most probably in Ghazna, but there are no traces of his grave today. Thus came to an end the life of a great scientist of medieval Islam and one of the greatest of the middle ages.

Al-Bīrūnī was a prolific writer and his fields of research were vast and varied. He was primarily a mathematician and astronomer, but he also wrote on physical and natural sciences, history, geography, chronology, linguistics and a variety of other subjects. He also wrote poetry though not of a very high order. So far he is known to have written 183 works,[28] including major and minor works. Of these, 27 are on India or relating to Indian sciences and philosophy, which also include translations from Sanskrit into Arabic and from Arabic into Sanskrit.[29] Apart from his mother tongue, the Khwārazmian, he knew Persian and Arabic thoroughly well and had sufficient knowledge of Greek, Syriac and Hebrew. He had a working knowledge of the

Sanskrit language. But he preferred to write in Arabic as it was the scientific and cultural language of the Islamic world at the time. On the practical side, he seemed to have constructed scientific instruments for observation and research and was acquainted with the technique of making them. There is little doubt that al-Bīrūnī was a sincere Muslim. Whether he was a Shī'a or an orthodox Sunnī is a moot point.

Mathematical and Astronomical Concepts

When al-Bīrūnī came to India, he had knowledge of Indian astronomy, which he had acquired by studying Arabic translations of some Sanskrit texts. In India, he held detailed discussions with Sanskrit scholars and studied in original some of the Sanskrit texts. He made a thorough study of Hindu philosophy and several branches of Indian science.

To al-Bīrūnī, the Hindus were good mathematicians and astronomers. He gave a fairly correct account of Indian astronomy and mathematics and made valuable contributions to the study of the history of Indian science, particularly astronomy and mathematics. This information about India was projected by him to the world outside especially to the Arabic-speaking world of the period. Here we shall touch upon only mathematical and astronomical concepts as given in *Al-Beruni's India*.

As regards astronomy, al-Bīrūnī has mentioned Varāha Mihira's *Pañcasiddhāntikā* (6th century) dealing with *Romaka, Puliśa, Vāśiṣtha, Pitāmaha* and *Sūrya Siddhāntas*; Brahmagupta's *Brāhma Siddhānta* (7th century A.D.); Āryabhaṭa I's *Daśagītikā* and *Āryāṣṭaśatā* (5th Century A.D.); works of Āryabhaṭa II (10th century A.D.) and Muñjala (10th century) and a few other works of less importance. He also studied Brahmagupta's *Khaṇḍakhādyaka*, and *Karaṇasāra* of Vaṭeśvara and *Karaṇatilaka* of Vijayananda. He has dealt with the following topics:

Nature of the globe and figures of the heaven and earth; revolution of planets, their mean places and conjunctions; the time for different longitudes and latitudes; solar and lunar eclipses; appearance of the moon and shadow; four measures of time, viz. the solar, the lunar, the civil and the sidereal; instruments of observations; and numeral notation in the metrical books. Al-Bīrūnī notes that the universe is spherical, and that the earth is at the centre of the universe and is globular in shape. The earth is fixed and the whole universe moves around it from east to west. In terms of their radial distances from the earth, the planets are in the order Moon, Mercury, Venus, Sun, Mars, Jupiter and Saturn. The stars are above the planets. He gives the mean positions of the planets and calculates the circumferences in *yojanas* (1 *yojana* = 8 miles) of the orbits of the different planets, according to the method given by Brahmagupta and that given in the *Puliśa Siddhānta*.

According to al-Bīrūnī, the Indian astronomers generally divided the zodiac into 27 or sometimes 28 lunar stations or *naksatras* and gave the number of stars in each *nakṣatra*. The necessary distance of each star from the sun for its heliacal rising and setting, and the extension of each *nakṣatra* are also given.

Al-Bīrūnī gives details about *kalpa*, and enumerates the number of revolutions of sun and planets in a *kalpa*. This *kalpa* is generally divided into 1000 *caturyugas*. He then records the revolutions of the moon and planets, of their apses and nodes in a *caturyuga*. He also gives the number of solar months, etc., in a *caturyuga*. He gives conversion of solar years, months, etc., into lunar years and conversely. He speaks of the computation of the mean positions of the planets.

Al-Bīrūnī mentions corrections to the positions of planets due to the differences in terrestrial longitudes. The 0° longitude passes through Laṅkā, Ujjayinī, Rohitaka, Kuru, Yamuna, mountains of Himavant and Mount Meru. The latitude of 0° passes through Laṅkā, with Yamakoṭi on the east and Romaka on the west, each at the distance of 90° from Laṅkā, and Siddhapura lying on this line diametrically opposite to Laṅkā. When it is sunrise in Laṅkā, it is sunset in Siddhapura, noon in Yamakoṭi and midnight in Romaka. He also gives methods for finding the correct circumference at any particular place both according to *Khaṇḍakhādyaka* and *Karaṇatilaka*. He explains the methods followed by Indian astronomers for calculating *tithis* or lunar days, and *karaṇas* or half lunar days, and *yogas*. He appended the table giving the names of *tithis* and *karaṇas*. *Yoga* is the time during which the motion of the sun and moon in longitude amounts to 13° 20′ or 800′. There are 27 *yogas*, the most important of these are *vyatīpātā* and *vaidharta*, when the declinations are also equal. He gives detailed description of the method for calculating the durations of these two *yogas*.

Al-Bīrūnī notes that the Indian astronomers knew the real cause of the solar and lunar eclipses, and that their calculations are scientific. He expresses surprise that they should mix up science with popular and religious beliefs. Two methods given in the *Khaṇḍakhādyaka* for ascertaining the approximate time for the occurrence of an eclipse are also recorded.

Al-Bīrūnī makes passing reference to the precession of equinoxes. He mentions that the rate of precession, according to Muñjala, is one minute a year.

As regards Indian arithmetic and metrology, al-Bīrūnī quotes that the decimal place-value system and the symbol for zero were known to Indians. They knew the names of the order of numbers from 1,10,100, etc. right up to 10^{17}. They generally expressed numbers by words. For example, zero was expressed by heaven; one by moon; two by eyes; and 12 by the synonyms of the sun. Al-Bīrūnī mentions that $\pi = \sqrt{10}$ according to Brahmagupta and also gives the value of π given by Āryabhaṭa as $\frac{62832}{20000}$ which comes to $3\frac{177}{1250}$. In addition, there are various tables of measures in the chapter on metrology.

Physical Sciences

Al-Bīrūnī's insatiable thirst for knowledge led him to gather and evaluate even, in his own way, certain strands of the Indian physical ideas and chemical practices prevalent in the regions which he traversed. He studied the *purāṇas,* like the *Matsya, Āditya* and *Vāyu,* and endeavoured to have information about the other important *purāṇas* from the local scholars. The classical *Sāṃkhya* doctrine, as dealt with in these texts, seem to have appealed to him specially, as evidenced by his methodical enumeration of the *Sāṃkhya tattvas.* Of particular interest from the standpoint of the Indian physical world-view are the five *tanmātras* of the *Sāṃkhya,* corresponding to the five gross elements (*pañcamahābhūtāni; pṛthvī, ap, tejas, vāyu* and *ākāśa*). Upaniṣadic in origin, the *tanmātras* share the characteristics of both mind and matter. Although al-Bīrūnī's account of the *tanmātra* has on it a layer of confusion inasmuch as the world *mātra* is rendered as *mātara* (?) which has the plural connotation of mother, he doubtless had the precise knowledge of the formation of gross bodies from these subtile states of matter. However, it is rather surprising that the most important texts of the Indian physical concepts, viz. of the *Nyāya-Vaiśeṣika* system, have not been dealt with by him. There is a stray reference to the *Nyāya-bhāṣya* erroneously attributed to Kapila. The author of this work was Vātsyāyana who lived about 600 years earlier than the time of al-Bīrūnī's visit to India. A plausible reason might be that the *Nyāya-Vaiśeṣika* literature was not so assiduously studied by the local *paṇḍits* with whom he came into contact. A rational intellect and a dedicated scholar that he was, al-Bīrūnī would have been undoubtedly fascinated by the logical postulates and physical ideas, such as the atomism, impetus theory and concepts of space and time of the *Nyāya-Vaiśeṣika.*

In his account of the Indian views of the origin of the world, he says that 'matter is the origin of the world and its action in world rises from an innate disposition, as a tree sows its own seed by an innate disposition, and that according to the *Sāṃkhya,* 'action is derived from matter and the forms of matter depend upon the three primary sources (*sattva, rajas* and *tamas*)'. He was well aware of the *Sāṃkhya* exposition of the spirit in relation to matter.

Though al-Bīrūnī's major work on India does not throw enough light on his knowledge of physical science, it is interesting to note that he was well versed in the determination of specific gravities of metals, precious stones and liquids, based on the principle of Archimedes.

As to the chemical practices, al-Bīrūnī says: 'Hindus do not give much importance to *rasavidyā,* i.e. alchemy' and that 'their interest is centred round the chemistry of minerals'. He knew the different aspects of the *rasavidyā* and *rasāyana* (elixirs for rejuvenation), as also the methods of preparing the latter, even though he does not give their specific details. He refers to the use of minerals, and precious stones by the local people. From the point of view of the history of alchemy in India, al-Bīrūnī's detailed account of three alchemists, viz Bhānuvaśas, Nāgārjuna and Vyādi, are important as it throws light on their respective dates and places. It may be emphasized that at the time of al-Bīrūnī's visit to India, alchemy was flourishing particularly in the eastern and southern parts of India.

Al-Bīrūnī's encyclopaedic knowledge of India embraced the different methods of weighing and measuring as practised in India at his time. He has given a vivid account of them and his sources of this information include the works of Varāhamihira, Caraka, Śrīpāla and the *purāṇas*. In addition, he has described the types of balance in vogue, and also the methods of computing the weights. Furthermore, he has given details of mensuration and standards of measurements.

Eras

Al-Bīrūnī's is indeed an informative account of the eras followed by the Indians. He says: 'The eras serve to fix certain moments of time which are mentioned in some historical or astronomical connections. The Hindus do not consider it wearisome to reckon with huge numbers, but rather enjoy it.' The eras depicting numbers of very high order relate to the *kalpas* and as part of the latter the *caturyugas,* an account of which is found in the *purāṇas* and the astronomical *siddhāntas*. It may be emphasized that in Hindu astronomy, the concept of cosmic cycle in terms of a *mahāyuga* of 12000 divine years or a *kalpa* of 1000 or 1008 *caturyugas* running to 43.20,000,000 or 43,54,560,000 solar years is of great significance inasmuch as that all the moving celestial bodies are considered to return to their original positions, after having completed a whole number of revolutions. Al-Bīrūnī knew how the Hindus regarded the different astronomical periods in terms of eras, such as the beginning of the *kalpa,* 28th *caturyuga* and the *Pāṇḍava Kāla*. *Kaliyuga* is recknoned to have begun, according to the *auḍāyika* system of Āryabhaṭa I, on the 18th February 3102 B.C. Al-Bīrūnī also refers to *kālayavana* era, which, according to his knowledge, began at the end of the *Dvāparayuga*. In addition, he has described the eras of Śrī Harṣa, Vikramāditya, Śaka, Vallabha and Gupta Choosing the year 400 of *Yazdajird* as a guage, he computed the corresponding years of the beginning of the eras, as also the eras pertaining to such astronomical works as *Khaṇḍakhādyaka*, *Pañcasiddhāntikā*, *Karaṇasāra* and *Karaṇatilaka*. Although al-Bīrūnī differentiates between Valabhi and the Gupta eras, it is now known that they are one and the same, with this difference that the former is reckoned from the first day of the bright half of the month of Kārtika, Śaka 240 (21st Oct. 318 A.D.), and the latter from the first day of the bright half of Caitra, Śaka 241 (8th March, 319 A.D.).

His descriptions of reckonings of dates by common people include the *Samvatsara or Lokakāla*.

Geography of India

His knowledge of Indian geography can be divided into two categories: (1) ancient Indian geographical concepts and information; (2) his own concepts and information. As for the first category, B.C. Law has thoroughly dealt with it in his article, 'Al-Biruni's knowledge of Indian Geography'.[30] We will present below, in brief, some of the important concepts and views of al-Bīrūnī on the physical and political geography of India.

Al-Bīrūnī conceived of India as a plain surrounded on three sides, north, east and west, by a chain of high and wide mountains which stretched from

China in the east up to the country of the Franks and the 'Jalāliqa' (Gallicians) in Europe in the west, passing through Tibet, the country of the Turks, Kabul, Adharbā'ījān, Armenia and the Roman Empire. On the south, India was surrounded by the Indian Ocean. The above long chain of mountains, cutting across Asia and Europe, formed many plains, and one of these was India. Again, from these mountains arose many rivers which flowed southwards in the plain of India, watering the whole region. This plain, he conceived, must have been a sea at some time in the geological period. He says: 'But if you have seen the soil of India with your own eyes and meditate on its nature—if you consider the rounded stones found in the earth however deeply you dig; stones that are huge near the mountains and where the rivers have a violent current; stones that are of smaller size at greater distance from the mountains, and where the streams flow more slowly; stones that appear pulverized in the shape of sand where the streams begin to stagnate near their mouths and near the sea—if you consider all this, you could scarcely help thinking that India has once been a sea which by degrees has been filled up by alluvium of the streams.'[31] This observation of his must have been based on his personal knowledge and experiments for which he must have travelled in the mountainous regions of northern India. His observations fitted well with his general information on the subject and the theories in this regard which he elaborates in *al-Taḥdīd*, namely, that over a long period of time, the geological period as we understand today, land changes into sea and sea into land. He gives several examples of such phenomena taking place in different parts on earth in the past, like Egypt, the desert of Arabia, the desert between the Arabian and the Caspian Seas, etc.[32]

According to al-Bīrūnī, India was surrounded in the north-west, north and north-east by mountains: these were the Himalayas and the Jayanti Hills (Qāmarūn) in Assam which, according to him, spread from north to south up to the Bay of Bengal. As for the political boundaries in the north the Kularjak mountains (Pir Panjal Range, southern Kashmir) which, according to him, were perennially snow-bound, formed the northern boundary of India. The fortress of Rajagiri lay south of it which he had visited. Rajawari (Rajapuri), which was 3 *farsakh* (9 miles) from the peak, formed the last point reached by the Muslim merchants.

Like all the rest of the Arab geographers, he conceived of Sind and India as two separate regions. If one wanted to enter India, one had to cross from the Kabul side; but if one wanted to go to Sind one went via Sijistān (Southern Afghanistan). But, he points out, that one could march into India from all sides, provided one removed the obstacles. In the north, from Tilwat or Tanwat, one reached Nepal, and from there to Bhoteshar, in all a distance of 100 *farsakh* (300 miles) Bhoteshar was the first frontier of Tibet. From there, to the top of the highest peak (*al-Qubbat al-'Uẓmā*) was 20 *farsakh*. From the top of this mountain, he was told, India appeared as a black expanse below the mist, the mountains lying below this peak like small hills, and Tibet and China appeared as red. The descent towards Tibet and China was less than one *farsakh*. It seems, therefore, that for him the boundaries of India in the north-east stretched up to this high mountain and the adjoining areas of high altitude.

However, the most important contribution of al-Bīrūnī to physical geography was his concept of the seas, and particularly his theory about a sea-route between the Indian Ocean and the Atlantic, south of the Mountains of the Moon, the traditional sources of the Nile in Africa. Following the Ptolemaic concept of the Indian Ocean being surrounded by *terra incognita* in the southern hemisphere, the Ocean was drawn by Greek as well as Muslim cartographers as a lake on their maps, with only a single water channel in the east that connected the Ocean with the Pacific. The 'unknown land' was joined on to Africa in the west. Thus, there was no connection between the Indian Ocean with any other sea except with the Pacific. Al-Bīrūnī propounded a theory that just as the sea in the east pierces the Asian land-mass forming water channels and islands, similarly, the 'land-mass' of Africa must pierce the Indian Ocean in the west, and there must be water channels and islands there, connecting the Ocean with the Atlantic; but nothing was known about that region because the sailors were afraid of sailing in those seas due to strong winds and high currents. Al-Bīrūnī's concept was taken over by Arab geographers like Abu'l-Fidā' in Syria, and the concept must have then travelled to Spain and Portugal in the later period. Ultimately, it was this belief of the existence of a channel south of the sources of the Nile connecting the Indian Ocean with the Atlantic that seems to have facilitated the entry of Vasco da Gama into the Indian Ocean in the 15th century[33] The 'unknown land' does not appear on the map of the seas by al-Bīrūnī. Al-Bīrūnī also gives an elaborate account of the climate, physical features, rivers and mountains of India, especially of the northern parts. He also describes, for the first time, the net-work of roads spreading out from Kanauj into all the four directions. But his knowledge of the peninsular India was meagre. However, it can be supplemented by the accounts of the previous Arab geographers who mainly concentrated on giving information relating to western, southern and eastern India and the coastal regions. With al-Bīrūnī's account of India, Arabs' knowledge of India became complete.

AL-BĪRŪNĪ'S WORKS ON INDIA

1. *Jawāmi' al-Maujūd Khawāṭir al-Hunūd fī Hisāb al-Tanjīm*
2. *Tahdhīb Zīj al-Arkand*
3. *Khayāl al-Kusūfayn 'ind al-Hind*
4. *Kayfīyat Rusūm al-Hind fī ta'allum al-Ḥisāb*
5. *Fī anna Ra'y al-'Arab fī marātib al-adad aṣwad min Ra'y al-Hind fīhā*
6. *Fī Rāshikāt al-Hind*
7. *Tarjumat mā fī Brāhmasiddhānda min ṭuruq al-Ḥisāb*
8. *Fī Taḥsīl al'Ān min al-Zamān ind al-Hind*
9. *Al-Jawābāt'an al-Masā'il al-wārida min Munajjimiy al-Hind*
10. *Al-Jawābāt 'an al-Masā'il al-Ashar al-Kashmīrīya*
11. *Tadhkira fi 'l-Ḥisa'b wa'l-'add bi-arqām al-Sind wa'l-Hind*

12. *Maqāla fī Ḥikāyāt Ṭarīq al-Hind fī istikhrāj al'umr*
13. *Tarjumat Kitāb al-Mawālid al-Saghir li-Barāhamīhr*
14. *Tarjumat Ḥidīth Nīlūfar fī qiṣṣat Dabistī wa Barbhākar*
15. *Tarjumat Kalbyārah wa huwamaqālatun li'l-Hind fī 'l-amrāḍ al-latī tajrimajrā l'ufūnah*
16. *Kitāb fī Taḥqīq mā li'l-Hind min maqūlatin maqbūlatin fī 'l-'aql au mardhulatin*
17. *Maqālat Bāsdev 'l-Hind 'ind maji'ihī al-adnā*
18. *Tarjumat Kitāb Bātanjal fi'l-Khalās min al-'irtibāk*
19. *Tarjumat Kitāb Shāmil (Sānk) fi 'l-maujudāt al-maḥsūsa wa'l-ma'qūla*
20. *Kitāb fi 'illat taṣnīf al-ta'dīl'ind aṣḥāb al-Sindhind*
21. *Miftāḥ 'ilm al-Hay'ah*
22. *Tarjumat Kitāb Sāṃkhiya*
23. *Tarjumat Kitāb fī uṣūl al-Handasa li-Uqlaydas 'ilā lughat al-Hind*
24. *Tarjumat Kitāb al-Majasī li-Baṭlamiyūs 'ilā lughat al-Hind*
25. *Tarjumat Kitāb fī 'l-usṭurlāb li-Abī Rayḥān ilā lughat al-Hind*
26. *Ghurrat al-Azyāj wa ma'nāhu, Zīj Bijāyānand al-Banarasī al-ladhī Sammāhu Kiranatilak*
27. *Tarjumat Pālisāsidhānta li-Brahmagupta*

References and Notes

[1] See Boilot, D.J., *Al-Birūnī, Encyclopaedia of Islam* (New ed.); cf. E. S. Kennedy, *'al-Bīrūnī', Dictionary of Scientific Biography,* Charles Scribner's Sons, New York, 1970. *Kāth* meant a *wall* in the Khwārazmian language, even if there were no buildings within it; the ruins of the old *Kāth,* east of the Amū Dar'ya, are now called Shaykh 'Abbās Walī (Barthold, W. *Encyclopaedia of Islam,* old ed.). The word *Kath* was used by the Khwārazmians for a rampart or mound in the steppe, though there might be nothing inside it; it was employed therefore with the same significance as the word *turkul* used in Central Asia. According to al-Bīrūnī, the last traces of Fīr (the citadel) disappeared in A.D. 994. (See Barthold, W. *Turkestan Down to the Mongol Invasion,* tr. and revised by the author and Gibb, H.A.R., *E. J. W. Gibb Memorial Series,* New Series, V, London 1928, pp. 144-45). According to the anonymous author of *Hudūd al-'Ālam* (A.D. 982), *Kāth* (spelt: *Kāzh*) was the capital of Khwārazm and the Gate of the Ghūz Turkistān and the emporium of the Turks, Turktstān, Transoxiana, and the Khazar. The people were active fighters for the faith and warlike. It produced covers for cushions, quilt garments, cotton stuffs, felt, snow, and *rukhbīn* (sort of cheese?), see *Ḥudūd al-'Ālam,* tr. and commentary by Minorsky, V. London, 1937, p. 121. According to al-Maqdisī (d.c. 390/1000), *Kāth* was known in the ancient times as *Sharatan;* for full description, see *Aḥasan al-Taqāsīm fī Ma'rifat al-Aqālīm,* ed. M. J. De Goeje, E. J. Brill, Leiden, 1906, BGA vii, pp. 287-288.

[2] The poet had called him Abū Lahab and his mother *ḥammālta al-ḥaṭab :* the former was the Prophet's uncle who had refused to accept Islam. See Yāqūt, *Mu'jam al-Udabā,* vol. xvii, p.189 (ed. Caino, 1937); cf. Syed Hasan Baranī, *al-Bīrūnī* (Urdu), Aligarh, 1927, pp. 34-35.

[3] Baranī, *op.cit.,* p. 108.

[4] Krachkovskiy, I. I. *Istoria Arabskoi Geograficeskoi Literaturily,* Moscow-Leningrad, 1957 (Ar. tr.: *Ta'rikh al-Adab al-Jughrāfī al-'Arabī* by Salaḥ al-Dīn 'Uthmān Hāshim, vol. I. The Arab League, Cairo, 1963, p. 246.

[5] See Boilot, *E. I.* (New ed.).

[6] See al-Bīrūnī, *al-Āthār al-Bāqiya 'an al-Khāliya, The Chronology of Ancient Nations*, tr. and ed. C. Edward Sachau, London 1879, pp. 337-38.
[7] Baranī, *op. cit.*, pp. 37-38.
[8] *Ibid.*, pp. 39-40.
[9] *Ibid.*, pp. 47-50; cf. E. S. Kennedy, *Dictionary of Scientific Biography*.
[10] Boilot, *E. I.* (New ed.).
[11] Baranī, *op. cit.*, p. 53.
[12] *Ibid.*, p. 52.
[13] Krachkovskiy. *op. cit.*, p. 246; al-Bīrūnī gives the date of return, before 399/1008 (Boilot *E. I.*, New ed.); Baranī:. the last decade of the 4th century A.H., *op. cit.*, p. 55; E. S. Kennedy fixes the date between 1003 (*op. cit.*).
[14] Boilot, *E.I.*, (new ed.).
[15] Barnī, *op. cit.*, pp. 57-59.
[16] Baranī, *op. cit.*, p. 77.
[17] *Ibid.*, pp. 78-81.
[18] *Ibid.*, pp. 68-75.
[19] *Ibid.*, p. 78.
[20] See *The determination of the Coordinates of Positions for the Correction of Distances between Cities, Kitāb Taḥdīd Nihāyīt al-Amākin li-taṣḥīḥ Masāfāt al-Masākin* of al-Bīrūnī, tr. by Jamil Ali. The American University of Beirut, Centennial Publication, Beirut 1967, pp. 11, 2, 190.
[21] Boilot, *E.I.* (New ed.).
[22] Kennedy, E. S. rightly remarks, 'It is also clear that Bīrūnī's interests in Sanskrit and Indian civilization are due to his having become an involuntary resident of an empire that had by then expanded well into the Indian subcontinent (*op. cit.*).
[23] *Alberuni's India*, pp. 22-24.
[24] Baranī, *op. cit.*, p. 84.
[25] Suniti Kumar Chaterji, "Al-Biruni and Sanskrit", in *Al-Bīrūnī Commemeration Volume*, Iran Society, Calcutta, -951, p. 96.
[26] Biolot, *E.I.* (New ed.).
[27] *Ibid.*
[28] Kennedy, *E.S.*, *op. cit.* In his veiw, all told there are 146 works by al-Bīrūnī *jop.cit.i.*
[29] (See list of his works on India).
[30] *Indo-Iranica*, vol. vii, No. 4, Iran Society, Calcutta, 1955. See also *"A Critical Analysis of the Writings of Abū 'l-Rayḥān Muḥammad Ibn Aḥmad Al-Bīrūnī Pertaining to India"*, (Ph. D. thesis) by Ghayasuddin, Aligarh University, Aligarh (unpublished).
[31] *Alberuni's India*, I. p. 198
[32] See *Determination of the Coordinates*, pp. 16-22.
[33] See Maqbul Ahmad, 'The Arabs and the rounding of the Cape of Good Hope', *Dr. Zakir Hussain Presentation Volume*, New Delhi, 1968, pp. 91-100.

SANSKRIT LITERATURE KNOWN TO AL-BĪRŪNĪ

AJAY MITRA SHASTRI

Department of Ancient Indian History and Culture
Nagpur University, Nagpur.

Many were the travellers who came to India from time to time with a variety of objectives and bequeathed to the posterity accounts of what they saw and heard in India and of their sojourn. But al-Bīrūnī combined in himself the inquisitive spirit of a traveller and an exceptionally high degree of scholarship. For him his visit to India was not merely for sightseeing but symbolised a sincere effort to know her people and their cultural and scientific attainments. With this aim in view he mastered Sanskrit, that magnificent vehicle of Indian culture, and made a painstaking study of its vast literature on a variety of subjects and set himself to the rather difficult task of its critical assessment and transmission of the scientific knowledge enshrined in it to West Asia through Arabic. For this purpose he abridged and commented on the contents of many Sanskrit works some of which have been lost. Nothing would have been known about them and their authors but for his observations. Some of his statements are of great help in fixing dates of certain texts, lack of which is a great hurdle in the study of the literary history of ancient India. He often levels comparison between two or more authors and never hesitates to give his verdict about their relative merits and demerits. As against this, some of his statements are not borne out by the relevant evidence, probably because the concerned texts were not easily accessible to him and his informants did not guide him correctly. A few of these observations can be easily checked and corrected with the help of texts once supposed to have been lost but subsequently traced. These and other questions connected with the Sanskritic sources utilised by al-Bīrūnī are proposed to be discussed in the paper.

Abu-Rayḥān Muhammed Ibn Ahmed al-Bīrūnī (973-1048 A.D.), popularly known among modern orientalists by the last word of his name, stands in a class by himself among the ancient foreign travellers who have bequeathed to the posterity accounts of their visits to India. Prior to al-Bīrūnī, India was visited by a number of foreigners accounts of many of whom are still extant. Some of them had come on diplomatic assignments or on business trips while others came to fulfil self-imposed religious mission. Some of these visitors were not acquainted with the rich cultural heritage and the way of life of the Indian people and to them everything they came across in India was a curiosity with its real meaning remaining unintelligible to them. Their narratives, which are based either on their own personal observation or on hearsay reports not properly understood by them, are, therefore, superfluous to a certain extent. Although some of the Chinese pilgrims stayed in India for many more years than al-Bīrūnī, studied and copied several Buddhist texts and thereby got opportunities of watching contemporary Indian life from close quarters, their accounts suffer from a strong religious bias, for to them everything connected with their religion, Buddhism, appeared miraculous and supremely great while they were unable to appreciate properly anything non-

Buddhistic. As against this background, al-Bīrūnī was much better equipped to comprehend and appreciate India and her glorious legacy. He tried to look at India as an Indian would. Many well-known Sanskrit texts dealing with a variety of subjects were available to him in Arabic translation and he must have studied them prior to embarking upon his self-imposed Indian mission.[1] At the time when King Mahmud of Ghazna was busy carrying on his Indian raids, al-Bīrūnī devoted all his energies to the study of Indian literature in original in which respect he surpassed all other foreign visitors to India. He experienced several hurdles in his studies,[2] but he was undeterred by them and relentlessly pursued his objective which was to afford the necessary information and training to "any one (in Islam) who wants to converse with the Hindus, and to discuss with them questions of religion, science, or literature, on the very basis of their own civilisation."[3] He resorted to several means of fulfilling this mission: he translated several Sanskrit texts into Arabic[4] and composed a number of treatises devoted to specific points of Indian astronomy before undertaking the preparation of his *Indica*,[5] which marks a departure from other accounts of a similar nature as regards approach and methodology; as far as possible he refrains from speaking himself and allows the Indians to speak for themselves through their own classical texts which are quoted in *extenso*, thereby eliminating the possibility of being accused of misrepresentation, and it is this novel approach that has invested al-Bīrūnī's work with a unique importance for the reconstruction of the cultural, particularly literary, history of ancient India. The range of al-Bīrūnī's *Indica* is extraordinarily comprehensive and covers such widely diverse subjects as religion and philosophy, grammar and metrics, astronomy and astrology, weights and measures, iconometry and iconography, *Veda* and *Dharmaśāstra*, geography and chronology, etc. Consequently al-Bīrūnī's work has become a veritable encyclopaedia of information on India not only for his compatriots for whom it was really meant but also for all serious students of Indology who are deeply beholden to him. Many a time it affords information about authors and works not known from any other source. Even as regards authors who are well-known and whose writings have come down to us it helps us solve some of the knotty problems concerning them. Except some sporadic attempts,[6] al-Bīrūnī's evidence has not been studied from this point of view.[7] As the first step in this direction it is proposed in these pages to put together all the relevant information on Sanskrit literature gleaned from *Al-Biruni's India*.[8] It is not intended here to locate the citations found in it in the extant original texts which may form the subject of an independent treatise and is beyond the scope of the present paper which is meant to provide the basic background for further researches on the subject. Occasionally, however, we shall try to supplement and examine al-Bīrūnī's statements with the help of materials gathered from other sources.

I. The *Vedas*

Al-Bīrūnī had naturally no access to the Vedic *Saṃhitās* himself and all that he tells us about them is obviously based on the information gathered from the *Paṇḍits* consulted by him.[9] Consequently his knowledge of the *Veda* is secondary and of a preliminary nature. He mentions the traditional Indian belief that the *Veda* is not a human work but comes from God and is promulgated by the mouth of Brahman (I. 125). He also knew the tradition that the *Veda* was obliterated in the *Dvāparayuga* until it was renewed and divided into four parts by Vyāsa, son of Parāśara (I. 126, 127). He further informs us that it was not allowed to be committed to writing and learnt by heart, a practice which was violated. not much before his time, by a famous Kashmirī Brahmin, Vasukra by name,[10] who committed it to writing lest it might be forgotten and entirely vanish out of human memories (I. 125-127). He gives the nomenclature of the four Vedic *Saṃhitās* correctly except that the fourth *Saṃhitā* is called *Ātharvaṇaveda* instead of *Atharvaveda* which is more popular (I. 127). The tradition that Vyāsa taught a separate *Saṃhitā* to each one of his four pupils, viz. Paila, Vaiśampāyana, Jaimini and Sumantu, is also recorded (I. 127). Reference is also made to the *ṛcs* of various lengths constituting the *Ṛgveda* and three different manners of their recitation, viz. *saṃhitāpāṭha, pada-pāṭha* and *krama-pāṭha,*[11] without mentioning this nomenclature, the division of the *Yajurveda* into *kaṇḍikās,* wrongly spelt as *kānḍin* (I. 128), the recitation of the *Sāmaveda* in a chant-like tone providing the explanation of its name (I. 129),[12] and of the fact that the *Atharvaveda* was less in favour with the Hindus than the other Vedas (I. 130).[13] Al-Bīrūnī also quotes allegedly Vedic notions about the lunar (*pūrṇimānta*) and leap months (I. 348; II.21).[14]

II. The *Purāṇas*

Al-Bīrūnī was aware of the fact that there are eighteen *Purāṇas* and gives two sets of their names. One of them, heard and committed to writing by him, includes the *Ādi, Matsya, Kūrma, Varāha, Narasiṃha, Vāmana, Vāyu, Nanda,*[14a] *Skanda, Āditya, Soma, Sāmba, Brahmāṇḍa, Mārkāndeva, Tārksya,*[15] *Viṣṇu, Brahma and Bhaviṣya.* The other list, read out to him from the *Viṣṇu-purāṇā,* comprised the *Brahma, Padma, Viṣṇu, Śiva, Bhāgavata, Nārada, Mārkāṇḍya, Agni Bhaviṣya, Brahmavaivarta, Liṅga, Varāha, Skanda, Vāmana, Kūrma, Matsya, Garuḍa* and *Brahmāṇḍa Purāṇas* (I. 130-131). Al-Bīrūnī had, however, not read all these *Purāṇas* (I. 130). This is also indicated by the fact that the second list of the *Purāṇas* given above was not verified by al-Bīrūnī himself, but had been read to him (I. 131). We may thus conclude on al-Bīrūnī's own authority that the copious passages quoted by him from the *Viṣṇudharma* (i.e. *Viṣṇudharmottara*) and the *Viṣṇu-purāṇa* are not first hand but based on the reports of his informants. He describes the *Purāṇas* as of human origin composed by the socalled *ṛṣis* (I. 130), but nowhere mentions the tradition attributing their authorship to Vyāsa, son of Parāśara. He speaks of the *Purāṇas* as codes of Hindu tradition (I. 264) but often complains of their unscientific character and accuses the students of the *Purāṇas* of multiplying numbers and as 'not men of exact learning' (I. 238). He states that the seventh heaven, *Satyaloka,* is also called *Brahmaloka* in the *Purāṇas* (I.233) which also form the basis of the story of King Hiraṇyakaśipu related in I. 364-366.[16]

We may now pass on to specific references to the *Purāṇas* found in al-bīrūnī's work. The *Āditya-purāṇa* is quoted in connection with the proportion of the diameter and the circumference which is 1:3 (I. 168), the names of the 12 suns (I. 217), the names of seven earths (1. 229-230) and the *lokas* (1. 232), the dimensions of the four sides of the *Meru* mountain (1. 248) and the connotations of the words *kalpana* and *kalpa* (1. 368).

The *Matsya-purāṇa* is referred to as regards the following topics: the ratio of diameter to circumference, 1:3 (1. 168), the names of the seven *dvīpas* (islands) and seas surrounding them (1. 235-36), Mt. Meru and its seven knots (1. 247-48), the description of the seven *dvīpas* (1. 251-56), the rivers rising in the ranges of the Himavant (Himalaya) and flowing in Jambūdvīpa (1. 258) and those of India (1. 261-62), the sun revolving round Meru (1. 271), the revolutions of the sun and the stars (1. 284-86), the destruction of the universe (1. 325), the traditional belief about the sun being the lowest of all planets (11. 62), the diameters of the sun and the moon and the circumference of the fixed stars (11. 65), why the water of the ocean remains as it is (11. 101), the black part in the moon called *Śaśa-lakṣa* being the images of the figures of mountains reflected by the light of the moon on her body (11. 102), the holy much venerated ponds round Meru (11. 142-44), and meteorological beliefs (11. 245).

Mention is made of the *Vāyu-purāṇa* with reference to the five great elements (*pañca-mahābhūtas*) and creation of the universe (1. 41-42), the relation between the diameter and the circumference (1. 168), the colour of the Garuḍa bird which is yellow (1. 194), the names and epithets of the seven earths and their spiritual beings inhabiting them (1. 230-31), the earth being held in its grasp by the water, the water by the pure fire, the fire by the wind, the wind by heaven and the heaven by its lord, the names of the seven *lokas* (1.232), the diameter of the totality of all the earths and seas, viz. 37,900,000 *yojanas* (1. 234), the heaven revolving round the pole like a potter's wheel and the pole revolving round itself without changing its own place (1. 239), the movement of the stars round the pole (1. 241), the quadrangular mountains Mālyavant, Anila, Gandhamādana and Niṣadha being situated in the east, north, west and south respectively of Mt. Meru (1. 248), the inhabitants of Madhyadeśa or Jambū-dvīpa (1. 251-52), the rivers of India rising in the seven *kula-parvatas* or principal mountains, viz. Mahendra, Malaya, Sahya, Śulti, Ṛkṣa, Vindhya and Pāriyātra and those flowing in Jambū-dvīpa and rising in the Himalayas (1. 257-58), noon in Amarāvati being sunrise in Vaivasvata, midnight in Sukha, and sunset in Vibhā (1. 271), the duration of the day in the south, 12 *muhūrtas*, and in the north, 18 *muhūrtas*, the declination of the sun between south and north, 17, 221 *yojanas* in 183 days and the march of the sun being slow during the day and rapid during the night in the north and *vice versa* in the south (1. 287), Bhāratavarṣa, its meaning (*those who acquire something and nourish themselves*), its situation in the centre of Jambūdvīpa and its extent, 9000 *yojanas* long and 1000 *yojanas* broad, and cities and countries lying in each direction (1. 295-96), the countries of the Madhyadeśa and the four directions around it (1. 299-300), the divisions of time (1. 337).

the shape, globular, of the sun and its rays (II. 62-63), the circumference of the fixed stars (II. 65), holy ponds in the cold mountains round Meru (II. 142), and rainfall (II. 245).[17]

As we have seen above, these three *Purāṇas* were personally consulted by al-Bīrūnī as against the following two *Purāṇas* which were evidently read out to him.[18]

The *Viṣṇu-dharma* claims the largest number of *Purāṇic* references met with in al-Bīrūnī's *Indica*. It is spoken of in connection with the spiritual beings (I. 54), the practical path leading to liberation or *mokṣa* (I. 77), twelve names of the sun and their meanings (I. 216-18), the story of Dhruva (I. 241-42), the relative height of the pole, planets and the fixed stars (I. 287-83), the anecdote of Atri's marriage with the directions represented as one person and the birth of the moon from her (I. 291), duration being identified with *ātma-puruṣa* and the divisions of time (I. 321), the day of the forefathers or *pitṛṇām ahorātra* (I. 329), the day of the *devas* and the *dānavas* (I. 331, 360, 372), the life of Brahman being equal to a day of *Puruṣ* (I. 332), a *nāga* (serpent) called Kulika (I. 344), the four measures of time, viz. solar, lunar, sidereal and civil (I. 353-54), the presiding divinities of the bright and black halves of each of the twelve months (I. 358), the durations of the *yugas, caturyugas* and *kalpa* (I. 372), description of conditions in the four yugas: *Kṛta, Tretā, Dvāpara* and *Kali* (I. 379-81), the names of the fourteen *Manus* and the periods of time (*manvantaras*) beginning with each of them (I. 386-87), the names and colours of Hari in the different *yugas* (I. 398-99), the life of Brahman elapsed till the performance of the *Aśvamedha* sacrifice by Vajra (II. 2), the time of Rāma, son of Daśaratha (II. 3), the relative lengths of the solar, lunar and civil years and the *adhimāsas* (leap months) resulting from their difference (II. 21), the nature and circumference of the stars (II. 64-66), the dark spot of the moon being the reflection of the earth with its mountains and trees (II. 102), the dominants of the planets and lunar stations (II. 121), the story as to how the fire became leprous (II. 140-41), religious merit accruing from fast, the determination of fast days together with the names of some of them (II. 174-76). A few other statements also appear to be based on the *Viṣṇu-dharma*. The story of Ambarīṣa (I. 113-15; II. 295), Śaunaka's report reportedly received by him from Śukra about the *Veda* being forgotten at the time of the great deluge (*pralaya*) and being redeemed by the fish (I. 126; II. 297), and a passage recording Śaunaka's statement on the inequality of created beings and the origin of patriotism (II. 145-46, 392) probably belong to this category.

Allusions to the *Viṣṇu-purāṇa* occur in connection with the theory that the action of the matter rises from an innate disposition (I, 47-48), the number of hells, 88,000, and the description of some of them (I. 60-61), the purpose of hell (I. 63-64), the renewal of the *Veda* in the beginning of each *manvantara* (I. 126), the names of the *Purāṇas* (I. 131), the names of the seven *lokas* and their description (I. 232, 237, 233), the names of the seven islands and the seas separating them from each other (I. 235), seven great mountains of the middle earth (I. 248), the account of the inhabitants of the seven *dvīpas* (I. 254-56), the great rivers of the middle earth (I. 262), the destruction of the universe (I. 325), the names of the *manvantaras,* their respective Indras and of the children of Manu (I. 387-88), the names of the seven *ṛṣis* (*saptarṣis*) in each of the fourteen *manvantaras* (I. 393-94), the various forms in which Viṣṇu appears in the different *yugas* (I. 397-98), the belief that the sun is below the moon (II. 62), the greatest height, 1500 digits, of the water of the flow of the ocean (II. 105), and the life of a Brahmin in the first three stages of life (II. 131-32).[19]

III. The Epics

Rāmāyaṇa

Al-Bīrūnī does not appear to have gone through the *Rāmāyaṇa,* and his notions about it and its author are hazy. He refers to the *Rāmāyaṇa* in four it was composed by Vyāsa, son of Parāśara, at the time of Kaurava-Pāṇḍava as separate works (I. 307, 310; II. 3) the authorship of both of which he attributed to the sage Vālmīki who, in accordance with the legends recorded in the *Ādi*-and *Uttara-kāṇḍas* of the *Rāmāyaṇa* and in a passage reportedly extracted from the *Viṣṇu-dharma,* is spoken of as a contemporary of Rāma himself (II. 3). In the only remaining reference we are told that the date of Rāma and the *Rāmāyaṇa* was known among the Hindus, but that al-Bīrūnī had not been able to ascertain it (II. 3-4). He was familiar with the tradition that Rāma flourished in *Tretāyuga* and was an incarnation of Viṣṇu (I. 397) and quotes the story of Śambūka related in the *Uttarakāṇḍa* of the *Rāmāyaṇa* (II. 137). There are some other allusions to the events of Rāma's life (I. 121, 209, 258, 306-07, 372, 380), but they need not detain us being of no importance for our purpose.[20]

Mahābhārata

Al-Bīrūnī had much more reliable knowledge of the frame and contents of the *Mahābhārata* which he refers to as *Bhārata.* He knew the tradition that it was composed by Vyāsa, son of Parāśara, at the time of Kaurava-Pāṇḍava war, that it consists of 100,000 *ślokas* divided into eighteen *parvans* names whereof are given.[21] The Hindu conviction that everything which occurs in other books is found also in this book, but not all which occurs in this book is found in other books is also recorded.[22] He also mentions the popular story of procurement by Vyāsa of the elephant-headed god Vināyaka as his scribe for writing the *Bhārata* from his dictation (I. 132-34).

The facts that the *Gītā* forms part of the *Bhārata* (I. 29) and that the *Harivamśa,* containing traditions relating to Vāsudeva, comes after the eighteen *parvans*[23] (I. 133) are also recorded. We have also some allusions to the time (I. 117, II. 152) and war of Bhārata (II. 147) and the *Pāṇḍavakāla* which is said to commemorate the life and wars of Bhārata (II. 1.). Two statements, one regarding the twenty-five elements of the universe (1. 44, 104) and the other about 2000 *caturyugas* forming an *ahorātra* (i.e. day and night) of Brahman (1. 369), are attributed to Vyāsa.

The *Gītā,* which constitutes a section of the Bhīṣmaparvan of the *Mahābhārata,* does not appear to have been known to the Arabs before al-Bīrūnī who was perhaps the first to introduce it into the world of Muslim readers.[24] Numerous passages of the *Gītā* touching upon a variety of topics are extracted by him.[25] In fact, he seems to have been profoundly influenced by its catholic spirit.

IV. *DHARMAŚĀSTRA*

Dharmaśāstra literature seems to have grown to an astonishingly stupendous size by the time of al-Bīrūnī and a large number of *Smṛtis* appear to have been in existence. Al-Bīrūnī mentions twenty *smṛtis* which are represented as composed by twenty sons of Brahman, viz. Āpastamba, Parāśara, Śātātapa, Saṃvarta Dakṣa, Vaśiṣṭha, Aṅgiras, Yama, Viṣṇu, Manu, Yājñavalkya, Atri, Hārīta, Likhita, Śaṅkha, Gautama, Bṛhaspati,[26] Kātyāyana, Vyāsa and Uśanas (1. 131). The books of Devala, Śukra, Bhārgava, Bṛhaspati, Yājñavalkya and Manu,[27] said to be pupils of Vyāsa, also probably belonged to this class (1.132). Al-Bīrūnī quotes many a statement from the book *Smṛti,* mostly of Manu, on the authority of Brahmagupta's *Brāhma-sphuṭa-siddhānta* (1.352, 372,373,374, 386; 11.110,111).

V. *PHILOSOPHY*

Of the extensive philosophical literature popularly cultivated by the Indians in the eleventh century A.D., our author mentions the following works:-

(1) *Book of Gauḍa.* It is said to have been composed by Gauḍa, the anchorite, and gone by his name (1.132). This Gauḍa may possibly be the same as the famous Gauḍapāda and the work passing by his own name may be identical with the *Gauḍapādakārikā.* It is interesting to note in this connection that most of the quotations from *Sāṅkhya* given by al-Bīrūnī differ only slightly from or are literally identical with the statements of Gauḍapāda in his *bhāṣya* on the *Sāṅkhya-kārikā.* Almost all the illustrative tales quoted by al-Bīrūnī as from the *Sāṅkhya* are found in Gauḍapāda's *bhāṣya,* being as a rule more extensive in al-Bīrūnī than in Gauḍapāda (11.267).

(11) *Sāṅkhya.* Composed by Kapila, it is said to have dealt with divine subjects (1.132). We are told that it dwelt on the *origins* and a description of all created beings and was translated into Arabic by al-Bīrūnī before undertaking the preparation of his *magnum opus* on India (1.8). The book as quoted by our author appears to have been in the form of a dialogue between a sage and an anchorite. It is cited on a variety of subjects like the relation between the action and the agent (1.30-31), matter being the cause of action (1.48-49), the reward of paradise not being a special gain as it is not eternal and not very much different from ,the life of our world (1.62), condition of the soul after leaving the body (1.64), the cause of the

separation of the soul and the body and the nature of liberation (I. 81-82), those who do not reach *mokṣa* (I. 83-84), classes and species of living beings (I. 89) and spiritual beings (I. 92). It is, however, difficult to identify the *Sāṅkhya* work utilised and translated by al-Bīrūnī. It cannot surely be the *sūtra* work *Sāṅkhya-pravacana* from which, as pointed out by Sachau, it differs in many essential points and which is younger than Īśvarakṛṣṇa's *Sāṅkhya-kārikā* which contains indications of illustrative tales extracted by al-Bīrūnī from the *Sāṅkhya* treatise consulted by him. Al-Bīrūnī's *Sāṅkhya* has a nearer relative in Gauḍapāda's *bhāṣya* which contains almost all the illustrative anecdotes narrated by the Arabic writer, the latter's versions being, however, more detailed. Therefore, as suggested by Sachau, it is possible that both Gauḍapāda and al-Bīrūnī may have taken their information from one and the same work or from two different works closely agreeing with one another (II. 266-67). Alternatively, it may be suggested that al-Bīrūnī probably derived his information from the *Sāṅkhya-kārikā* and took the help of some commentary to illustrate and elaborate it. The commentary may have been even Gauḍapāda's. But in that case we need not take citations from *Sāṅkhya* as exact extracts.

(III) *Book of Patañjali*. It is said to have been a treatise on the search for liberation and for the union of the soul with the object of its meditation (I.132), and the emancipation of the soul from the fetters of the body (I.8) and was rendered by al-Bīrūnī into Arabic prior to writing the *Indica* (I.8). It was a very famous book in his time (I.29) and passages from it are extracted by him in connection with numerous topics like the nature of God (I. 27-29), the nature, retribution and migration of the soul and its relation to action (I.55-56), eight miraculous powers attained by the *yogin* (I.68-69) and the degrees of knowledge and the *mokṣa* attainable thereby (I.69-70), the path leading to *mokṣa* (I.76-77), *rasāyana* or alchemistic tricks as a path to *mokṣa* (I.80), the nature of *mokṣa* (I.81,82), meditation on truth (I.87) and the divinities being, like mortals, subject to fruits of their actions (I.93). A commentary on the book of Patañjali is also cited at a number of places (I.232, 234,235,236,233,248; II.62), without specifying the name of the commentator anywhere.[28]

The book of Patañjali mentioned by al-Bīrūnī cannot be identified. As pointed out by Sachau, it is totally different from the celebrated *Yoga-sūtras* of Patañjali from which it differs on many essential points (II.263-64).

(IV) *Nyāya-bhāṣā*.[29] It is reported to have been composed by Kapila and dealt with the *Veda* and its interpretation, showing that it has been created, and distinguishing within the *Veda* between such injunctions as are obligatory only in certain cases and those which are obligatory in general (I.132). The work had nothing to do with the *Nyāya* system as one is wont to suppose from its title which is rather deceptive, but dealt with problems coming within the jurisdiction of the *Pūrva-Mīmāṃsā* philosophy as can be reasonably inferred from its description.[30]

(V) *Mīmāṃsā*. Composed by Jaimini, it dwelt on the same subject as the above work (I.132). It evidently refers to the celebrated *Mīmāṃsā-sūtra* attributed to Jaimini.

(VI) *Laukāyata* or *Lokāyata*. Al-Bīrūnī appears to have had reliable information about the materialistic system of philosophy passing under this name as he, in keeping with the well-known Indian tradition, credits Bṛhaspati with its promulgation and mentions its fundamental epistemological doctrine that "in all investigations we must exclusively rely upon the apperception of the senses, i.e. *pratyakṣa pramāṇa* (1.132). The doctrine, more popularly known as *Cārvāka,* is known only from citations in later works, the original text having been lost early. It is doubtful if al-Bīrūnī had seen the work himself. In all likelihood his information about it was based on hearsay reports.

(VII) *Agastya-mata*. It is represented to have been composed by Agastya and treated of the "subject that in all investigations we must use the apperception of the senses as well as tradition"[31] (1.132). The work evidently belonged to the *Nyāya* school of philosophy and dealt, among other things, with epistemological problems. The text is not known from any other source.

Al-Bīrūnī rightly refers to the *Veda, Purāṇas,* the *Mahābhārata,* the *Smṛti* texts and the philosophical works dealt with above as constituting the *national literature* of the Hindus. It is interesting to note in this connection that he does not include the *Rāmāyaṇa* in this category. Though not specifically mentioned, it was probably included in other works of this class not mentioned by him as it was not possible for him to know about them. "The Hindus", says he, "have numerous books about all the branches of science. How could anybody know the titles of all them, more specially if he is not a Hindu, but a foreigner?" (1.132).

VI. Grammar

Al-Bīrūnī correctly observed that of grammar and metrics, which are auxiliary to the other sciences, the former held the first place in the estimate of the Indians. He had not studied any work on Sanskrit grammar himself and his information was obviously based on secondary sources. He makes his position absolutely clear when he avers that "we Muslims cannot learn anything (grammar), since it is a branch coming from a root which is not within our grasp—I mean the language itself". He had been 'told' about the titles of the following works of grammar: (i) *Aindra,* attributed to Indra;[32] (ii) *Cāndra,* composed by Candra, one of the red-robe-wearing sect, the followers of Buddha;[33] (iii) *Śākaṭa,* so called by the name of its author. His tribe, too, is called by a name derived from the same word, viz. Śākaṭāyana;[34] (iv) *Pāṇini,* so called from its author;[35] (v) *Kātantra,* composed by Śarvavarman;[36] (vi) *Śaśideva-vṛtti,* composed by Śaśideva;[37] (vii) *Durga-vṛtti*;[38] and (viii) *Śiṣya-hita-vṛtti,* composed by Ugrabhūti[39] (1. 135).

Our author gives no information about any of these grammarians except only an anecdote about the last one who, it is said, was a teacher and instructor of the Sāhi king Ānandapāla, son of Jayapāla and a contemporary of al-Bīrūnī himself. We are told that after composing the book he sent it to Kashmir where, however, the people did not adopt it, being in such matters haughtily conservative. When he complained of it to the Sāhi king, the latter promised him to make him attain his wish and sent rich presents to Kashmir to be distributed among those who studied the book of his master. The result was that they all rushed upon the book, and would not copy any other grammar but this one which became the fashion and highly prized (1. 135-36).

Al-Bīrūnī also gives an interesting story about the origin of grammar. According to it, king Samalvāhana-Śātavāhana was once in a pond playing with his wives when he told one of them *Māudakam dehi*=do not sprinkle water upon me. The woman, however, understood it as if he had said *modakam dehi*=bring sweetmeats, and went away and brought him sweetmeats. And when the king disapproved of her doing so, she replied him angrily, using coarse language towards him. Being deeply offended, he abstained from food and concealed himself in a corner until he was called upon by a sage who consoled him, promising him that he would teach people grammar and the inflexions of the language. Thereupon the sage went off to Mahādeva, praying, praising and fasting devoutly. Mahādeva appeared before him and communicated to him some rules and further promised to assist him in the development of this science. The sage then returned to the king and taught it to him. Thus began the science of grammar (1. 136).

The above story about the origin of grammar, however, is in reality a confused version of the story of the composition of the *Kātantra,* also called *Kālāpa* and *Kaumāra,* Śarvavarman at the behest of king Śātavāhana, related at length in Somadeva's *Kathāsarit-sāgara* (Lambaka I, *Taraṅga* 6,7), to which has been added part of the anecdote of the receipt by Pāṇini of the *Pratyāhāra-sūtras,* which form the basis of his system, from god Mahādeva.

VII. METRICS

Our author was fully aware of the importance of prosody in the Indian context as a majority of scientific works in India were composed in metres. He tried his hand on the *śloka* metre and was, at the time of writing his *Indica,* engaged in translating into Sanskrit the books of *Euclid* and of the *Almagest* and was dictating to the Hindus a treatise on the construction of the astrolabe (1. 137). In keeping with the indigenous Indian tradition, he attributes the invention of this science to Piṅgala and to another person whose name has been doubtfully read as *C L T* ?.Of the numerous works available on the subject, the book the name of which has been doubtfully transcribed as *Gaisita* (? G-AI-S-T), so called from its author, is said to have been the most famous; famous to such an extent that even the whole science of metrics was called by this name. Other books on the subject mentioned by the Arabic author were those of Mṛgalāñchana, Piṅgala, and that of one whose name has been tentatively deciphered as? U (Au)-L-Y-A-N-D. That the subject is also dealt with in a chapter (xxi) of Brahmagupta's *Brāhma-siddhānta* was also known to al-Bīrūnī who, however, frankly confesses that he neither knew much of this chapter of the *Brāhma-siddhānta* nor saw any of the other books mentioned by him (1. 137-38). The subject is also represented to have been treated of by one Haribhaṭṭa (?) in a lexicographical work known after the author's own name which has been quoted by our author; but whether he had actually consulted it or quoted it on the basis of some secondary source cannot be ascertained for want of necessary evidence (I. 141). He devotes considerable space to giving a general introduction to this science (I. 136-151).

VIII. Astronomy and Astrology (*Jyotiṣa*)

If we were to single out the science works on which al-Bīrūnī refers to most frequently and which he had studied most assiduously, it is *Jyotiṣa*. He had himself perused some important texts dealing with all the three branches of *Jyotiṣa*, viz. mathematical astronomy, horoscopy and natural astrology, and gathered a good deal of information about them. As will be shown in the sequel, in some cases he affords us very valuable information about certain authors and works, though instances where he has gone astray are not wanting.

Al-Bīrūnī rightly recognised that among the Hindus astronomy was reckoned as one of the most famous and important sciences, particularly because their religious affairs were, as they even now are, connected with it in various ways. Further he rightly observed that in order to get recognition as an astronomer in India one had to master not only mathematical astronomy, but also astrology (I.152-153).

Al-Bīrūnī refers to three classes of works on mathematical astronomy. Of these, those coming under the category of *Siddhānta* commanded the highest respect. According to our author, every standard work on astronomy, even though it did not come to the level of the Arabs' *Zif*, i.e. handbooks on mathematical astronomy, was called by this name. Anyone familiar with Indian astronomical literature will be stunned by this biassed observation which is born of a false sense of the Arabs' superiority. Similarly, al-Bīrūnī's statement that the term *siddhānta* meant '*straight*, not crooked, nor changing' (II.153) is not correct. The word, when it forms part of the caption of a text, really denotes an established text-book resting on conclusive evidence.[40] He also mentions the categories of astronomical texts called *Tantra* and *Karaṇa*. As in the case of the *Siddhāntas*, he had no correct information about the meaning of these two words also.[41] But he was close to the truth when he said that such books as do not reach the standard of a *Siddhānta* were called *Tantra* (I.155) In fact *Karaṇa* denotes astronomical treatises supplying a set of concise rules sufficient for the speedy performance of all the more important astronomical calculations[42] while *Tantras* fall between the two categories of *Siddhānta* and *Karaṇa*. He rightly understands *Jātaka* as denoting books of nativities (I.157). His observation that *Samhitās* are books containing something of everything and that they also contain an exposition of the whole science of meteorology and cosmology (I.157) is fully vouched for by *Bṛhatsaṃhitā* 1.9, and the enumeration of the contents of the *Saṃhitā* by Varāhamihira.[43]

We may now proceed to outline the information about ancient Indian astronomical literature supplied by al-Bīrūnī classified under the names of authors or titles of works arranged in an alphabetical order. For this purpose as far as possible all information will be studied under the names of authors given as headings; but where the names of authors are not known titles of texts will be used as captions.

(I) *Āryabhaṭa*. Al-Bīrūnī clearly distinguished earlier Āryabhaṭa whom he calls 'elder' from his later namesake who is invariably styled 'Āryabhaṭa of Kusumapura'. He mentions the titles of two works of Āryabhaṭa, viz. *Daśagītikā* and *Āryāṣṭaśata*, both of which are extant.[44] His famous *Tantra* work mentioned elsewhere (1.156) is probably the same as the *Āryabhaṭīya*. Al-Bīrūnī had not been able to find anything of Āryabhaṭa's books and all that he knew of him was based on quotations from him found in a work of Brahmagupta (1.370; 11.16, 33). Āryabhaṭa's views, evidently as quoted by Brahmagupta,[45] are mentioned in connection with the relation between diameter and circumference (1.168), the space reached by solar rays (1.225,327); Mt. Meru (1.244-46), the earth being round (1,266-68), *Manvantaras* and *Kalpas* (1.370), star-cycles in the *Kalpa*, *caturyugas* including *Kali* (11.16-17), the method of finding out *ahargaṇa* (the number of civil days elapsed from a given date, 11.33), solar and lunar eclipses (11.111), and the length of the solar year (11.190). Al-Bīrūnī did not relish the harsh criticism levelled by Brahmagupta against Āryabhaṭa (1.374, 376) whose views he appreciates in some cases (1.227). At one place he refers to the name Āryabhaṭa, Arabic *ārjabad*, being misunderstood by the Arabs in the sense of a thousandth part and being ultimately further mutilated and written as *āzjabhar* (11.18-19).

(II) *Āryabhaṭa of Kusumapura*. Al-Bīrūnī informs us that Āryabhaṭa of Kusumapura belonged to the followers of elder Āryabhaṭa whom he quoted and whose example he followed (1.246; 370). He quotes a passage on the day of *Brahman* and *utsarpiṇī* and *avasarpiṇī* from 'a small book' of Āryabhaṭa of Kusumapura the title of which has been unintelligibly transcribed as *Al-ntf* (?) which appears to have been personally consulted by our author (1.370-71).[46] At another place, however, he mentions the view of Āryabhaṭa as quoted by Balabhadra but is unable to ascertain as to which of the two Āryabhaṭas is intended (1.244-46). Āryabhaṭa the junior is also quoted in connection with the names of the orders of 10 to 10 *koṭi* (1.176), the meridian of Ujjain (1.316), the *ahorātras* of the gods, demons, fathers and human beings (1.330), and the seconds being known as *vināḍī* (1.335).[47]

(III) *Balabhadra*. Balabhadra is very frequently cited by al-Bīrūnī who represents him as the author of (i) a *Tantra*, which was 'famous' in his time (I.156), (ii) a *Saṃhitā* (iii) commentary on Varāhamihira's *Bṛhajjātaka* (I158), and (iv) a commentary on Brahmagupta's *Khaṇḍa-khādyaka* (II.187). The *Khaṇḍa-khādyakaṭippā*, which is said to have explained 'the reasons and the nature of the calculations employed in the *Khaṇḍa-khādyaka*', and supposed to be 'a work of Balabhadra' (I.156) is probably no other than the commentary on the *Khaṇḍa-khādyaka* and seems to be an error for something like *Khaṇḍa-khādyaka-ṭippaṇa*. Sachau's conjecture that Balabhadra also possibly wrote a commentary on the books of Patañjali which is often quoted by our author has nothing to support itself.[48] Al-Bīrūnī invariably styles him 'commentator' and mostly cites him without specifying the work from which he quotes. He is quoted by al-Bīrūnī in connection with the extent of *Brahmāṇḍa* (1.225), the earth and Mt. Meru (1.243, 244, 246), the rotundity of the earth (1.273-74), the world being not without beginning and end (1.279,281), the latitude of Kanoj, 26° 35', and Thaneshar 30° 12' (1.317), the computation of the distances of planets (11.70), the method of the computation of the bodies of the sun and the moon (11.75), the merits of *puṇya-kāla* (11.187), etc. Al-Bīrūnī is often very critical of Balabhadra whom he accuses of preferring tradition to eye-sight (1.227) and whose statement he styles 'foolish both in words and matter' and could not understand' why he felt himself called to write a commentary if he had nothing better to say' (1.244).

Bhaṭṭotpala quotes a few verses of Balabhadra in his commentary on Varāhamihira's *Bṛhatsaṃhitā* which, according to my view, was composed in 831 A.D.,[49] so that we may conclude that Balabhadra must have flourished before the ninth century A.D.

(IV) *Baṅgāla.* The art of taking auguries from the flight or cries of birds, and of the foretelling by means of piercing a needle into a book is said to have been propounded in a work called *Srudhava* by Baṅgāla (1.158). Sachau is not sure about the reading of the name of the author which may even be Puṇya-kāla (11.308). No work with this title or one resembling it is known from any other source.[50] As there were also other works of this name, it is difficult to decide the author of the work *Srudhava* which is quoted regarding the names of twenty-four *horās* (1.344) and the description of the *viṣṭis* (11.201) without specifying the author's name.

(V) *Bhānuyaśas.*[51] Two works, viz. *Rasāyana-tantra* (1.56) and *Karaṇa-para-tilaka* (1.157), are said to have been composed by Bhānuyaśas. Al-Bīrūnī was told that the latter work showed how the corrected places of the stars are derived from one another.

(VI) *Bhaṭṭila.* He is said to have composed a *Karaṇa* work known as *Bhaṭṭila* after himself. He is reported to have been a Brahmin (1.57) and is quoted in connection with the *yogas* (11.208-209).[52] Al-Bīrūnī does not appear to have seen his works.

(VII) *Brahman.* He is mentioned as one of the *Saṃhitākāras* (1.157). It may be mentioned in this connection that Brahmā was traditionally regarded as the promulgator of the science of *Jyotiṣa,* and works supposed to emanate from him were current in ancient India.[53]

(VIII) *Brahmagupta.* Brahmagupta claims the largest number of references made to any single author by al-Bīrūnī who possessed fairly reliable information about his life and had personally seen some of his writings. Brahmagupta, we are rightly told, was son of Juṣṇu and a native of Bhillamāla, modern Bhinmal, Rajasthan, which is said to have been situated between Multan and Anhilwara, 16 *yojanas* from the latter place ?) (1.153, 267). The following works of Brahmagupta are mentioned:—(i) The *Brāhma-siddhānta* which was composed by Brahmagupta when he was just thirty (11.112). It is wrongly included in the list of the five *Siddhāntas* (1.153), obviously because al-Bīrūnī had heard that there were five *Siddhāntas* while he did not know anything about the original

Paitāmaha-siddhānta which is named by him only casually.[54] Al-Bīrūnī had personally studied it and had commenced translating it into Arabic, but had not yet finished it at the time of writing his *Indica* (1.154). He has given chapterwise contents of this work (1.154-55) and specifically referred to it in connection with metrical calculations (1.138)[55] the eight heaven (1.223), the *yojanas* of the shpere of the zodiac (1.224), the earth and heaven being globular in shape (1.267-68), refutation, though on wrong premises, of Āryabhaṭa's view that the earth moves and the heaven rests (1.276-77), the epic and *Smṛti* tradition that *kalpa* is a day of Devaka or Brahman and also a night of his (1.352), and solar and lunar eclipses (11.110-12). Brahmagupta's *Siddhānta* is more popularly known now as *Brāhma-sphuṭa-siddhānta,* (ii) *Karaṇa-khaṇḍa-khādyaka,* also called *Khaṇḍa-khādyaka* the contents whereof are said to represent the doctrine of Āryabhaṭa (1.156).[56] It is said to have been commented upon by Balabhadra (11.137).[57] As a manual of astronomical calculations it seems to have enjoyed great popularity in the 11th century A.D. Referring to it, our author avers that "this calendar is the best known of all, and preferred by the astronomers to all others" (11.46), and that it was "most universally used among them (Hindus)" (11.119). It is referred to regarding the era of the astronomers beginning 587 years later than the *Śaka-kāla* (11.7),[58] the method of finding out *ahargaṇa* (the number of civil days elapsed from a given date, 11.46-47) and the mean places of the planets (11.60-61), the computation of the diameters of the sun and the moon (11.79), the numbers and positions of the lunar stations in longitude and latitude (11.83-85), computations of the sun and the moon (11.86-87), the heliacal rising of Canopus (11.91-92), rules for the computation of the *parvan* (11.116), the computation of the dominant of the year (11.119), and the determination of the day of the festival called *Śāmbapura-yātrā* (11.184). (iii) *Uttara-khaṇḍa-khādyaka,*[59] i.e. the explanation of the *Khaṇḍa-khādyaka,* composed after the last-mentioned work (1.156). Elsewhere it is also described as *the emendation of the Khaṇḍa-Khādyaka* (11.87, 91) or as the *emended edition* of the *Khaṇḍa-khādyaka* (1.312), and is mentioned regarding the earth's circumference (1.312), the lunar stations (11.87) and classification of the stars from the point of their heliacal rising (11.91). This is not really an independent work, but the second part (*uttara*) of the *Khaṇḍa-khādyaka,* (iv) *Critical Research on the basis of the Canons.* It is represented as having quoted Āryabhaṭa as holding that the sum of the days of a *caturyuga* is 1,577,917,500 (1.370). This is also not an independent text, but only the *Tantra-parīkṣādhyāya* of the *Brāhma-sphuṭa-siddhānta.* (v) *Khaṇḍa-khādyaka-ṭippa.* Our author was not sure whether it was composed by Brahmagupta or somebody else but supposed that it was a work of Balabhadra (1.156). As suggested earlier, it was probably the same as Balabhadra's gloss on the *Khaṇḍa-khādyaka* mentioned above. Brahmagupta is spoken of without mentioning the source in connection with several astronomical topics such as the use of arithmetic in metrical system (1. 147-50), the sameness of the subject-matter of all the *Siddhāntas* (1. 153-54), the ratio between the diameter and the circumference (1. 168, 11.117), the Śiśumāra (1.241), Mt. Meru (1.243), the law of gravitation (1.272), the revolutions of the stars and the spheres (1.279-80), the divisions of the meridian, the wind causing the revolutions of the fixed stars and the planets, the direction of the heavenly motion (1.282), the circumference and diameter of the earth (1.312-14, 11.67), the seconds being called *viṇāḍī* (1.335), the *kalpa and aharātra* of Brahman (I. 368-71), the *yogas* (I. 372-73), the length of the solar year (1.376-77), the *Manvantaras* and *kalpas* (1.386), the *kalpas* of the life of Brahman elapsed before the present *kalpa* (11.4), the star-cycles in a *kalpa* and a *caturyuga* (11.15-19), the period required for the formation of a leap month (11.24), the time elapsed from the beginning of Brahma's life (11.28-32), the computation of the *ūnarātra* days (11.37-42), finding out mean places of the planets (11.59), the distance traversed by the moon in a *kalpa* and a *caturyuga,* the circumferences and radii of the planets together with their diameters (11.71-75), the method of the computation of the distance of the shadow (11.75-77), the refutation of the tradition about the inhabitants of Mt. Meru seeing two suns, two moons, 54 lunar stations and having double the number of days (11.82), the civil days, solar and lunar months and lunar and *ūnarātra* days contained in a *caturyuga* (11.186), the length of the solar year (11.189), the summing up of the *ūnarātra* into one complete day (11.192), and the timing of a complete leap month (11.192), and the expression of numbers by words (1.177). Although al-Bīrūnī speaks of Brahmagupta as 'the most distinguished of their (Hindus') 'astronomers' (11.110), he was very indignant at the latters' lack of sincerity. He accuses him of lending support to imposture in order to mock the Brahmin priests and ignorant masses given to superstitions, probably with the object of avoiding a calamitous fate—like the one which befell Eocrates, notwithstanding his abundant knowledge and sharp intellect (11,110-17). At another place Brahmagupta is charged with harbouring hatred for and being rude towards Āryabhaṭa (1.376).

Brahmagupta occupies a unique position in the history of the Arabic literature. Before being acquainted with Ptolemy, the Arabs derived all their knowledge of astronomy from Brahmagupta's *Brāhma-sphuṭa-siddhānta* which was translated into Arabic under the title of *Sindhind* (1; 153,332,368; 11.90, 191),[60] which has not yet been discovered, and the only other text on Indian astronomy known to them was the *Khaṇḍa-khādyaka,* the Arabic translation whereof was known as *Al-arkand* (11.7,49)[61]

(IX) *Buddha.* Buddha, the originator of the sect of the red-robe-wearers, the Shamanians, i.e. Buddhism, is credited with the composition of a text called *Gūḍhāmaṇa* (?) wherein the art of taking auguries from various occurrences was dealt with (1.158). It is called *Jūrāman* in Arabic, and the Arabic characters may even be read as *cūḍāmaṇi* (11.308). The statement is evidently based on wrong information or some misconception on the part of al-Bīrūnī.

(X) *Deva. The Puliśa-siddhānta* is represented to have quoted Deva as saying that the earth is round (1.266).

(XI) *Devakīrti.* He is included among those Hindu scholars whose names alone were known, but not the title of any of their books (1.158). He is mentioned in Kalyāṇavarman's *Sārāvali* and Utpala's commentary on it (1.19).[62]

(XII) *Divākara.* He is also included in the same category as Devakīrti (1.158).[63]

(XIII) *Divyatattva* is mentioned as the writer of a *Saṃhitā* (1.157) Nothing is known about it from any other source.

(XIV) *Durlabha.* Durlabha, who was a native of Multan, is represented to have composed a canon wherein he dealt with the method of finding out the *Śaka-kāla* (11.9), and *ahargaṇa* (11.54) and stated that the year commenced with *Mārgaśīrṣā,* but that the astronomers of Multan began it with *Caitra* (11.10). It was available to al-Bīrūnī (11.9).

(XV) *Garga.* He is mentioned as one of the *Saṃhitākāras* (1.157). His views as quoted by Puliśa (1.342) and Varāhamihira (1.390-91; II. 96,110,235) are mentioned.[64]

(XVI) *Jina.* Brahmagupta is said to have quoted him as saying that Mt. Meru is quadrangular, not round (1.243). Al-Bīrūnī regards him as the same as Buddha, and possibly the work caled *Gūḍhāmaṇa,* mentioned above, is intended.

(XVI-A) *Kalyāṇavarman.* The author of a large book on the astrology of nativities called *Sārāvali,* Kalyāṇavarman is said to have gained high credit for his scientific works (1.158)[65] His work with Utpala's commentary is extant.

(XVII) *Karaṇa-cūḍāmaṇi.* The name of its author was not known to our author (1.157).

(XVIII) *Lāṭa.* Al-Bīrūnī credits him with the composition of the *Sūrya-siddhānta,* one of the five *Siddhāntas,* which was not seen by our author (1.153, 154). He said to have held that the world is round (1.268) and to have been quoted by Brahmagupta in support of his view about the revolutions of the fixed stars and the planets (1.280). We have no means to verify al-Bīrūnī's statement regarding Lāṭa's authorship of the *Sūrya-siddhānta.* In any case, it has no relevance as regards the original *Sūrya-siddhānta* epitomised by Varāhamihira and known to Brahmagupta which differs from the modern work of that name on many a fundamental point. Moreover, Varāhamihira, who knew Lāṭa's scholia on the *Pauliśa* and *Romaka Siddhāntas* and also perhaps an independent work of his, and Brahmagupta clearly distinguished between the *Sūrya-siddhānta* as known to them and Lāṭa in certain important matters. It is possible, however, that Lāṭa may have had a hand in remodelling the original *Sūrya-siddhānta* and giving it its modern form. But even if this is conceded, the modern *Sūrya-siddhānta* does not appear to have been so called till at least the ninth century A.D. as is evidenced by the fact that five stanzas cited by Utpala in his commentary on Varāhamihira's *Bṛhat-saṃhitā* (V.11) as from the *Sūrya-siddhānta* are not traceable in the modern work of this name

(XIX) *Lokananda* is said to have composed a work known after his own name (1.157).

(XX) *Mahādeva.* He is credited with the composition of the three works called *Srudhava* dealing with the art of auguries from the flight or cries of birds, and of the foretelling by means of piercing a needle into a book (1158).[66] *Srudhava* of Mahādeva is represented to have called Vikramāditya by the name Candrabīja (11.6) and is referred to in connection with the dominants of the thirds of the day and night (11.120) and the burning days (11.192-193). Nothing whatsoever is known about Mahādeva or his *Srudhava* from any other source.

(XXI) *Māṇḍavya*. He is spoken of as one of the *Saṃhitākāras* (1.157). Utpala cites a few verses of Māṇḍavya in his commentary on the *Bṛhajjātaka* (VI. 6; XI. 3,5,6; XIII. 2; XV. 4), but nothing is known about his *Saṃhitā*.

(XXII) *Maṇittha* is mentioned as the writer of a *Jātaka* work (1.157). Varāhamihira refers to him in *Bṛhaj-jātaka* (VII.2,9; XII.2). It is probably a Sanskritised form of Manetho, the author of the *Apotelesmata*.[67] Mahamahopadhyaya Dr. P. V. Kane thinks it possible that 'an Indian scholar became familiar with the astrological work of a foreigner and reproduced it in Sanskrit after adopting for himself the foreigner's name' (i.e. Maṇittha).[68] Maṇittha's *Jātaka* has not come down to us.

(XXIII) *Manu*. His work called *great Mānasa* belonging to the category of *Karaṇas* is mentioned by al-Bīrūnī, who also knew that it was commented upon by Utpala (1.157). Both the text called *Bṛhanmānasa* and Utpala's scholium thereon are extant.[69]

(XXIV) *Mau*, the Greek, is credited with the composition of a *Jātaka* (1.157).

(XXV) *Parāśara*. The *Saṃhitā* of Parāśara mentioned by al-Bīrūnī (1.157) is no longer extant. But Varāhamihira mentions his work called *Parāśaratantra* and refers to him on various topics an analysis whereof shows that *Parāśara's Saṃhitā* traversed the same ground as the *Bṛhat-saṃhitā*. The *Pārāśarīyā Saṃhitā* was seen by Utpala also.[70]

(XXVI) *Pareśvara*. The title of his work was not known (1.158).

(XXVII) *Pīruvāna*. He is included in the list of those authors whose names were known, but not the titles of their works (1.158). The Sanskrit equivalent of the name cannot be determined.

(XXVIII) *Pradyumna*. The title of his work was not known (11.158).

(XXIX) *Pṛthūdakasvāmin*. He was also one of those authors the titles of whose works were unknown to al-Bīrūnī (1.158). His commentary on Brahmagupta's *Brāhma-sphuṭa-siddhānta* is still available, and it is possible that he wrote a commentary on Brahmagupta's other work, the *Khaṇḍa-khādyaka*, also. He is obviously the same as *Pṛthūsvāmin* who, according to a passage reportedly quoted from Āryabhaṭa of Kusumapura, is represented as having given the distance between the longitudes of Kurukṣetra and Ujjain as 120 *yojanas* (1.316). As pointed out by S. B. Dikshit, Pṛthūsvāmin is not named by any of the two Āryabhaṭas; the quotation may, therefore, have been taken from some commentary on Āryabhaṭa's work. It must be remembered in this connection that al-Bīrūnī has often misunderstood commentatorial statements as belonging to original texts.[71]

(XXX) *Puliśa*. The *Puliśa-siddhānta*, composed by Puliśa, is said to have been so called from Paulisa,[72] the Greek, from the city of Saintra, which al-Bīrūnī supposed to be Alexandria (1.153). Elsewhere in the work, both Pauliśa (1.266) and Puliśa (1.166) are styled Greek. Mention is also made of a commentator of the *Puliśa-siddhānta* (1.339) and is quoted on the length of the *muhūrta.* The text was available to al-Bīrūnī[73] who had commenced translating it into Arabic but had not finished it till the completion of the *Indica* (1.156). Elsewhere we are told that the translation of the whole of the *Puliśa-siddhānta* into Arabic had not till then been undertaken, because in its mathematical calculations there was an evident religious and theosophical tendency (1.375).

The work is quoted in connection with the measures of distance (1.166), relation between the diameter and the circumference (1.168,169), the *orders* of the numbers (1.177), the heaven (1.224), the earth being globular or in the shape of a cover (1.266), the world being round (1.268), the arc of the quarter of a circle being divided into 24 *kardajāt* (1.275), the earth being held by an axis (1.276), the circumference: 5026 14-15: and diameter of the earth: 1600 *yojanas* (1.312, 11.67), the life of Brahman being a day of Puruṣa (1.333), the divisions of time (1.335,340,341-42), the civil days: 1,577,917,800: constituting a *caturyuga*, *caturyugas*: 72: constituting a *manvantara*, and 14 *manvantaras* constituting a *kalpa* (1.370), rules for the computation of the sum of the years of a complete *caturyuga* (1.374), years and *kalpa* of the life of Brahman elapsed being explained as the super numerary month (11.23), the computation of the *Kaliyuga* (1.375; 11.4), the length of the solar year (1.376-77), the revolutions of the planets (11.18-19), the numbers of the solar, lunar and civil and *ūnarātra* days and leap months contained in a *caturyuga* (11.24,187), the *adhimāsa* being explained as the super numerary month (11.23), the computation of the *ūnarātra* days (11.26,37), the method of finding out *ahargaṇa* (11.31-33) and *adhimāsas* (11.41-45), the determination of the mean places of the planets (11.58), the circumference and radius of the sphere of each planet (11.69,70), the radii of the planets or their distances from the centre of the earth (11.72), the diameters of the planets (11.73-74), the heliacal rising of Canopus (11.91), the method of finding out the *saṅkrānti*, the length of the solar year (11.190), the summing up of the *ūnarātra* into one complete day (11.192), and the method of computing the *vaidhṛti* and *vyatipāta yogas* (11.206,208).

From 1.266 it appears that the *Puliśa-siddhānta* was redacted by Puliśa on the basis of the teachings of Pauliśa. The name has a non-Indian ring. Possibly the text was actually composed by an Indian astronomer proficient in Greek astronomy with the object of familiarising his fellow compatriots with Puliśa's precepts.[74] It is noteworthy in this context that Brahmagupta, as quoted by al-Bīrūnī, is all praise for Puliśa on account of the latter following the *Smṛti*, i.e. tradition (1.374). Puliśa is represented to have quoted Garga and Parāśara (1.370; 11.208)[75] and is himself quoted by Brahmagupta and Āryabhaṭa of Kusumapura (1.374,316).

The *Puliśa-siddhānta* is a work of considerably high antiquity and is epitomised by Varāhamihira (505 A.D.) in his *Pañca-siddhāntikā* wherein (1.3) it is said to have been commented upon by Lāṭadeva. Two versions of the work, called *Puliśa-siddhānta* and *Mūla-Puliśa-siddhānta*, were known to Utpala. Both these versions were, however, different from that abridged by Varāhamihira.[76] Which of these versions was consulted by al-Bīrūnī connot be ascertained in the present state of insufficient information. However, it was certainly distinct from that known to Varāhamihira.

(XXXI) *Puñcāla*.[77] The Small Mānasa, an epitome of Manu's *Bṛhanmānasa,* is said to have been composed by Puñcāla (1.157). The *Small Mānasa* is quoted as saying that in the year 854 of the *Śakakāla* the real solstice preceded the author's calculation by 6°50′, and that this difference will increase in future by one minute every year (1.366-67). This theory is said to have been taken by Utpala from Puñjāla (1.367). Al-Bīrūnī is all praise for him and describes him as "a man who either was himself a most careful practical observer, or who examined the observations of former astronomers which he had at his disposal" (1.367). The *Small Mānasa* is undoubtedly the well-known *Laghu-mānasa* and the correct name of its author was Muñjāla.

(XXXII) *Saṅgahila* is mentioned as an Hindu author the title of whose work was not known (1.158). Sachau suggests the possibility of Śṛṅkhala (?) being its Sanskrit equivalent (11.308).

(XXXIII) *Sārasvata* is represented as one of those authors the titles of whose works were not known (1.158). Varāhamihira states in *Bṛhat-saṃhita,* LIII, 99 that the preceding account of the art of finding out underground water-veins is based on the work of the sage Sārasvata. Sārasvata's work was extant in the time of Utpala who cites 31 verses in the *Anuṣṭubh* metre from it.[78]

(XXXIV) *Satya.* He is mentioned as the writer of a Jātaka (1.157). Satya is frequently mentioned by Varāhamihira in his *Bṛhajjātaka* and *Bṛhad-yoga-yātrā,* and Utpala mentions him in his commentary on Varāhamihira's *Yoga-yātrā* (IV.5) and quotes 90 verses from him in his gloss on the *Bṛhajjātaka* alone.[79]

(XXXV) *S M Y.* He is said to have been a learned astronomer and is mentioned in connection with the divisions of time (1.336,337). In II.188, one S-M-Y is stated to have dictated al-Bīrūnī a method for the computation of the *saṅkrānti* and is regarded by Sachau as a scholar of the time and a personal acquaintance (teacher ?) of al-Bīrūnī (11.344). Sachau further suggests that the former name in Arabic is to be read as *Shammī* or *Shamiyyu* and hints at equating both these names with *Samaya* (11.188,343).

(XXXVI) *Śrīpāla.* He is cited on the measurements of capacity (1.164), the star called *Śūla* (1.240), and the names and qualities of the *yogas* (11.2009-10) and is said to have followed Varāhamihira as regards the measurements of capacity (1.164). The title of his work is not mentioned.

(XXXVII) *Śrīṣeṇa.* He is described as the author of the *Romaka-siddhānta,* so called from the Rūm, i.e. the subjects of the Roman empire (1.153), and is reported to have been quoted by Puliśa as saying that the earth is round (1.266). He is one of those astronomers who are said to have been criticised by Brahmagupta for rejecting the superstition that the eclipse is caused by the Head or Rāhu (11.111).

Like the *Puliśa-siddhānta,* the name *Romaka* also points to some foreign source, a fact further buttressed by some internal evidences. The *Romaka-siddhānta* antedates Varāhamihira who has epitomised it in his *Pañca-siddhāntikā.* Like the *Puliśa,* it was commented upon by Lāṭadeva. This original *Romaka* was, however, not the work of *Śrīṣeṇa,* who, as we learn from the *Brāhma-sphuṭa-siddhānta* (XI. 48-50a), was responsible for its later recast which was known to al-Bīrūnī. A comparatively modern work of this name, probably emanating from Śrīṣeṇa, is now available.[80]

(XXXVIII) *Sugrīva.* A work of the *Karaṇa* class, called *Dadhi-sāgara,* is attributed to Sugrīva, who is said to have been a Buddhist (1.156). His unnamed pupil reportedly composed another book of the same kind known as *Kūra-babayā* (?) meaning 'a mountain of rice' (*ibid*). The Sanskrit equivalent of the latter title cannot be found out. Nothing is known about any early astronomer of this name from any other source.

(XXXIX) *Utpala.* Al-Bīrūnī evinces a good deal of familiarity with Utpala and his works. Utpala, we are told, was a Kashmiri (1.157,334,367) and had composed the *Rāhunrākaraṇa* (?), i e. breaking the *Karaṇas,* the *Karaṇa-pāta,* i.e. killing the *karaṇas* (1.157), the *Praśna-gūḍhāmana* (?), which is obviously an error for *Praśna-cūḍāmaṇi,* dealing with the questions of the science of the unknown (1.158), the *Srūdhava* (1.334-36, 361), and commentaries on the *Bṛhanmānasa* of Manu (1.157) and the *Saṃhitā,* i.e. Varāhamihira's the scholium on the *Bṛhat-saṃhitā.* Other works were obviously not consulted by him and his information about them was based on secondary sources. That *Bṛhat-saṃhitā* (1.298). Of these, al-Bīrūnī quotes only from the *Srūdhava* and Utpala was a native of Kashmir is also stated by Varuṇabhaṭṭa in his commentary on the *Khaṇḍa-khādyaka.*[81] Of the writings of Utpala named by al-Bīrūnī, the *Praśna-cūḍāmaṇi* is probably identical with the *Āryā-saptati,* comprising seventy stanzas in the *Āryā* metre, which is called by Utpala himself as *Praśna-jñāna* in its inaugural and concluding verses and in his commentary on the *Ṣaṭ-pañcāśikā* of Varāhamihira's son Pṛthuyaśas (11.2). It was also called *Praśn-āryā, Praśn-āryā-saptati* and *Praśna-grantha* and formed part of his larger work known as *Jñāna-mālā.* His commentaries on the *Bṛhanmānasa* and the *Bṛhat-saṃhitā* are also extant. Nothing whatsoever is known about the rest of the works. Even the correct Sanskrit equivalents of the *Rāhunrākaraṇa* and the *Srūdhava* cannot be determined.[82]

The *Srūdhava* of Utpala is cited in relation to the divisions of time (1.334-36) and the life periods of the gods (1.361-62) and the names of the horoe obliquee (1.344). Utpala is said to have followed Puñjāla, i.e. Muñjāla, in regard to the precession of equinoxes (1.367).

In 1.293 a statement about the change of names of Multan is attributed to Utpala's commentary on the *Saṃhitā* which, however, cannot be found in the extant text of the commentary. And there is no reason to believe that the commentary has not been preserved in its original form. We conclude, therefore, that al-Bīrūnī's observation is based on wrong and untrustworthy information.[83]

(XL) *Varāhamihira.* Varāhamihira is quoted almost as frequently as Brahmagupta by al-Bīrūnī who mentions as his works a *saṃhitā,* i.e. *Bṛhat-saṃhitā* (1.157), two *Jātakas,* a small and a large one, i.e. the *Laghu-jātaka* and the *Bṛhajjātaka,* the *Ṣaṭ-pañcāśikā,* said to contain fifty-six chapters on astrology, the *Horā-pañcahotrya* (?) also on astrology, the *Yoga-yātrā* and the *Ṭikaṇīyātrā* dealing with travelling, the *Vivāha-paṭala* treating of marriage and marrying, a work on architecture (1.158), and the *Pañca-siddhāntikā*, an astronomical handbook of small compass (1.153). Of these works, the *Laghu-jātaka* was translated into Arabic by al-Bīrūnī and the *Bṛhajjātaka* was commented upon by Balabhadra (1.158). Mention is also made of Utpala's commentary on the *Saṃhitā* (1.298) an extract quoted from which, however, is not traceable in the extant text of the scholium. Al-Bīrūnī's description of the *Ṣaṭ-pañcāśikā* as comprising fifty-six chapters and its ascription to Varāhamihira[84] are definitely wrong as the work is actually so called because it consists of fifty-six verses, not chapters, and was actually composed by Pṛthuyaśas, son of Varāhamihira. The text together with Utpala's commentary is even now available. No work bearing the title *Horā-pañca-hotṛya* is known from any other source. No independent work on architecture written by Varāhamihira is known so far, and in all likelihood al-Bīrūnī had in his mind Ch. 53 of the *Bṛhat-saṃhitā*[85] independent manuscripts of which, entitled *Prāsāda-lakṣaṇa,* have been found[86] The *Yoga-yātrā* is still extant,[87] and *Ṭikaṇī-yātrā* is an error for *Ṭikaṇika-yātrā* which is still extant and is a shorter work dealing with travelling.[88] Varāhamihira had composed a set of two *Vivāha-paṭalas,* the copious version called *Bṛhad-vivāha-paṭala* and the abridged version known as *Laghu-vivāha-paṭala.* A *Vivāha-paṭala* is still extant, but which of the two versions it represents is difficult to decide in the present state of our knowledge. Looking to its size, however, it appears to be the shorter version.[89] Although al-Bīrūnī refers to the *Pañca-siddhāntikā* thrice in connection with the year 400 of Yazdajird corresponding to the year 526 of its era, the method of finding out *ahargaṇa* or the number of civil days elapsed from a given date, and the *ṣaḍaśītimukha* being in the same degree propitious as the time of *saṅkrānti* (11.7, 51-52, 190), he did not have a correct idea of its contents as is amply demonstrated by his following observation: "Varāhamihira has composed an astronomical handbook of small compass called *Pañca-siddhāntikā,* which name ought to mean that it contains the pith and marrow of the preceding five *Siddhāntas* (*Sūrya, Vaśiṣṭha, Puliśa, Romaka* and *Brāhma*). But this is not the case, nor is it so much better than they as to be called the most correct one of the five. So the name does not indicate anything but the fact that the number of *Siddhāntas* is five" (1.153). The fact is that the *Pañca-siddhāntikā* does epitomise and contains 'the pith and marrow' of the five *Siddhāntas* known to him. However, these *Siddhāntas* were naturally different from their later recasts prepared long after Varāhamihira.

Varāhamihira has adopted *Śaka* 427 as the epoch of his *Pañca-siddhāntikā* and should normally be regarded as the date of its composition or very close to it. But there is much unwarranted speculation about its interpretation, some regarding it as the date of Varāhamihira's birth and others as the date of the composition of the *Romaka-siddhānta* or of a commentary thereupon or an adaptation thereof.[90] Now, the clear statement of al-Bīrūnī that the year 400 of Yazdajird corresponded to the year 526 of the era of the canon *Pañca-siddhāntikā* (11.7) should set all this controversy at rest and convince all that it was the epoch, and probably also the date of the composition, of the *Pañca-siddhāntikā* itself.

Al-Bīrūnī has translated the *Bṛhat-saṃhitā* into Arabic (1.389, 11.277). However, a statement about a holy pond at Thaneswar said to have been extracted from the *Saṃhitā* (11.145) is not to be found in the extant text of the *Bṛhat-saṃhitā* which is invariably called *Saṃhitā* by al-Bīrūnī. We may conclude that either the attribution of this statement to the *saṃhitā* is the result of some confusion or it is extracted from some commentary and wrongly ascribed to Varāhamihira.

Al-Bīrūnī was all praise for Varāhamihira whom he describes as an 'excellent astronomer' who 'did not allow himself to follow the opinion of the crowd' (1.366), whose 'foot stands firmly on the basis of the truth' and who 'speaks out the truth'. He only wishes that 'all distinguished men followed his example.' He contrasts him to Brahmagupta whom he accuses of giving support to imposture (11.110). Even when al-Bīrūnī was certain about the incorrectness of some utterances of Varāhamihira, he was so overwhelmingly impressed by Varāhamihira's sincerity that he suspected some esoteric meaning in them (11.117).

Al-Bīrūnī quotes extensively from the *saṃhitā* and at some places passages from the *Bṛhajjātaka* and the *Laghu-jātaka* also. These references need not detain us here as the same have been fully discussed by us elsewhere.[91]

(XLI) *Vasiṣṭha*. Vasiṣṭha is represented as holding that the world is round (1.268) and that Vāsudeva had killed Śiśupāla at *abhijit* (1.340) and as quoted by Brahmagupta in connection with the *brahmāṇḍa* and the revolutions of the fixed stars and the planets (1.225, 280).

(XLII) *Vijayanandin*. An inhabitant of Benares, Vijayanandin is said to have composed an astronomical handbook named *Karaṇa-tilaka*, which our author variously explains as 'the blaze on the front of the *Karaṇas*' (1.156) or as 'the first of the canons' (1.343). Al-Bīrūnī quotes Vijayanandin's work regarding the method for the computation of the longitude of a place (1.313) and finding out the dominants of the year, month and *horā* (1.343), an *ahargaṇa* (11.49-51) and the mean places of the planets (11.60), the diameter of the sun and of the shadow (11.79), the distance of the stars from the sun (11.90-91), and the method for computing the *yogas* (11.205-7, 209). Although Vijayanandin is styled 'commentator' (1.156), no commentary composed by him is mentioned. The year 400 of Yazdajird is said to correspond to the year 65 of the era of the *Karaṇa-tilaka* (11.7), which indicates that Vijayanandin known to our author preceded him by only a short period of time and must be distinguished from the homonymous author mentioned by Varāhamihira (*Pañca-siddhāntikā* XVIII. 62).

(XLIII) *Vimalabuddhi*. A work entitled *Śrūdhava* on the art of taking auguries from the flight or cries of birds, and of the foretelling by means of piercing a needle into a book is ascribed to him (1.158).

(XLIV) *Viṣṇucandra*. The *Vāsiṣṭha-siddhānta*, said to have been so called from the stars of the Great Bear, is attributed to him (1.158). In three places (1.266, 376; 11.111) he is represented as quoted or criticised by Brahmagupta in his *Brāhma-siddhānta*.

The *Vāsiṣṭha-siddhānta* attributed to Viṣṇucandra must be distinguished from the original work of that name abridged by Varāhamihira in his *Pañca-siddhāntikā* (Ch. 2). As Brahmagupta informs us, Viṣṇucandra was actually responsible for a later recast of the original *Vāsiṣṭha;* the *Vāsiṣṭha-siddhānta* now available is either the same as or based on this later version of the original text.[92]

(XLV) *Vitteśvara.* A work known as *Karaṇa-sāra is* attributed to Vitteśvara, son of Bhadatta (? Mihdatta) and a resident of the city of Nāgarapura (1.156). It had been rendered into Arabic before al-Bīrūnī undertook to write his work, and he complains that the book was badly translated (11.55). Al-Bīrūnī quotes the *Karaṇa-sāra* on the latitude of Kashmir (1.317), the rule for finding out the position of the Great Bear to any time (1.392), *ahargaṇa* (11.55-56), mean places of the planets (11.60), and the diameters of the sun and the moon (11.79). The year 400 of Yazdajird is said to correspond to the year 132 of the era of the *Karaṇa-sāra* (11.7), i.e. *Śaka* 821 was adopted in it for the purpose of calculations. We know nothing about the work or its author from any other source.[93]

(XLVI) *Yavana.* This work, which is said to have been larger than Kalyaṇavarman's *Sārāvalī,* comprehended the whole of astrological sciences (1.158). Nothing is known about a work of this name. But the views of the *Yavanas* or Greeks and an author called Yavaneśvara are frequently quoted by Varāhamihira and Utpala.[94] The work apparently contained an account of Greek astrology with which Indians had become familiar at a pretty early date.[95]

IX. Medicine

The only work on medicine clearly mentioned by al-Bīrūnī is the *Caraka,* so called by the name of its author,[96] which was considered as the best of their whole literature on medicine. It was translated into Arabic for the princes of the house of the Barmecides. It was this translation which was utilised by our author who made no special study of medicine (1.159, Also cf. I. xxxvii). He had translated into Arabic a Sanskrit treatise on loathsome diseases (1. xxxviii). The title of the text is not mentioned.

X. Fables

The *Pañca-tantra,* known among the Arabs as 'the book of Kalila and Dimna! was extra-ordinarily popular and 'far spread in various languages, in Persian, Hindi and Arabic', and in this process the text was much altered. Abdullāh ibn al-mukaffa is said to have added in his version of it a chapter about Barzoya with the intention of raising doubts in the minds of people of feeble religious belief, and to gain and prepare them for the propagation of the doctrines of the Manichaeans. Al-Bīrūnī intended to translate it into Arabic. Whether he carried out his desire is not known (1.159).

XI. Alchemy

Nāgārjuna, a native of the fort of Daihak, near Somanath, is said to have excelled in alchemy and composed a book containing the substance of the whole literature on the subject. It was very rare and obviously not seen by al-Bīrūnī. This Nāgārjuna is said to have preceded al-Bīrūnī by nearly a hundred years (1.189).[97]

To sum up. One is just amazed at the unbelieveably wide range of Sanskrit literature known to al-Bīrūnī. What is all the more surprising is that he evinces a good deal of knowledge, in some cases specialised and in others general, of literature concerning various subjects which are not mutually related. It was, of course, impossible for one single man, particularly a foreigner belonging to a nation dreaded and hated by the Indian people, to peruse personally all the important works on such a great variety of subjects. In such a situation al-Bīrūnī resorted to the best course open to him. About some disciplines in which he was not so much interested he tried to gather as much information as possible from the scholars available and willing to help him while he undertook a painstaking study of important texts treating of the subjects of his interest. It will be seen from the foregoing survey that even in respect of works of the former category the information collected by him is fairly reliable although, we must hasten to add, instances of wrong information are not lacking. In regard to the latter class of works his information is much more reliable and penetrating. His achievement in this respect is simply gigantic. There can be no two opinions that he carried out his self- imposed mission of acquainting his compatrriots with India and her cultural heritage with a remarkable success. But that is not all. For a modern Indian reader his work is of unique interest inasmuch as it furnishes useful information for the literary history of ancient India. If the present paper succeeds in focussing the attention of scholars to this aspect, I would deem my labours amply rewarded.

References

1 These must have included Brahmagupta's famous astronomical treatises *Brāhma-sphuṭa siddhānta* and *Khaṇḍa-khādyaka*, the *Karaṇa-sāra* of Vitteśvara, the well-known work on medicine, the *Caraka*, and the *Pañca-tantra or Kalila and Dimna*, *Vide* E. Sachau, *Alberuni's India*, (London, 1910), Vol. 1, Preface p. xxxv.

2 E.g. Enormous range of the language divided into a neglected vernacular and a classical one, difficulty of expressing an Indian word in the Arabic script, difficulty of pronunciation, socio-religious prejudices of the Hindus, etc. *Vide ibid.*, pp. 17-26.

3 *Ibid.*, Preface, p. xxiii; Vol. 11, p. 246.

4 He translated, among other works, a work on the Sāṅkhya system of Kapila and the *Book of Patañjali* (*Yoga-sūtra*), the *Khaṇḍa-khādyaka* and *Brāhma-sphuṭa-siddhānta* of Brahmagupta the *Puliśa-siddhānta*, the *Bṛhatsaṃhitā* and the *Laghu-jātaka* of Varāhamihira and a Sanskrit treatise on loathsome diseases. *Vide ibid.*, vol. I, pp. xxxviii, 8, 154, 158 389; Vol. 11, pp. 208, 277.

5 *Ibid.*, Vol. I, pp. 174, 277, 315; Vol. 11, pp. 83, 194, 208.

[6] For such an attempt in connection with Varāhamihira see Ajay Mitra Shastri, *India as seen in the Bṛhatsaṃhitā of Varāhamihira* (Delhi, 1969), 11-13 and 'Alberuni and Varāhamihira, in forthcoming book *Varāhamihira and Allied Studies.*

[7] Even E. Sachau, to whom we are all indebted for pioneering work on al-Bīrūnī, has given only a list of a few of the works consulted by al-Bīrūnī. *Vide* Sachau, vol. I, Preface, pp. xxxix-xl.

[8] Translated under this title by E. Sachau, 2 Vols. London, 1910. Figures without any specification refer to this work, the Roman figure indicating volume no. and English figure referring to pages.

[9] Cf. 1.348 where after quoting an allegedly Vedic statement in support of lunar months al-Bīrūnī adds that "possibly these words are only a saying of men (not really a sentence taken from the *Veda*)" and 11.21-22 where after extracting another statement from the *Veda* about leap months it is observed that "the meaning of this passage is not correct, and the fault must have risen with the man who recited and translated the passage to me." The second passage is, moreover, said to have been read to him. *Vide* also 11.345.

[10] Sachau thinks that the spelling 'Vasukra' is preferable to 'Vasukra' (11.293).

[11] Al-Bīrūnī quotes a story to explain why the *Ṛgveda* cannot be recited as a text connected by the *sandhi* rules (1.128-129).

[12] Al-Bīrūnī takes the word *sāman* to mean 'the sweetness of recitation' (1.129, while it really means a metrical hymn. *Vide* V.S. Apte, *Students Sanskrit English Dictionary, s.v. sāman.*

[13] It is said to consist of the compositions called *bhara* (1.130).

[14] For other details about the *Veda* see 1.125-130, 11.297-99, 345.

[14a] Probably the *Śiva-purāṇa* is meant.

[15] Probably the *Garuḍa-purāṇa* of the second list.

[16] Sachau refers to *Viṣṇu-purāṇa,* 2.34ff. in this connection. 11.347.

[17] Many passages from the *Vāyu-purāṇa* are 'cited by Sachau in his annotations.

[18] Sachau's suggestion that al-Bīrūnī had before him the whole of the *Viṣṇu-purāṇa* also (11.273) is contradicted by al-Bīrūnī's own statement that he had seen portions of the *Matsya*, *Āditya* and *Vāyu* only (1.130).

[19] Sachau has extracted a few parallel passages from the *Vāyu* and *Viṣṇu* Purāṇas in his annotations. For the location of some other passages see J. Gonda in *Al-Bīrūnī Commemoration Volume* (Calcutta, 1951), pp. 111-116. For a discussion of some connected problems *vide B. N. Mukherjee, IHQ,* vol. XXXV, pp. 132-138.

[20] For these references see C. Bulcke, *Alberuni and the Rāmakathā, Alberuni Commemoration Volume,* pp. 77-81.

[21] 1.133. The list does not follow the common order and mentions the *Mausala-parvan* before *Āśramavāsika*-parvan, omits *Ādi-parvan* and *Anuśāsana-parvan,* and adds two new names, *Gadā-parvan* and *Jala-pradānika-parvan.*

२२. ५· यदिहास्ति तदन्यत्र यन्नेहास्ति न तद् क्वचित् ।

[23] It is actually regarded as the *Khila-parvan* or Appendix and is sometimes also spoken of as a *Purāṇa.*

[24] Sachau, Vol. I, Preface, p. xxxviii.

[25] 1.29-30, 40, 73-74, 75, 76, 78-80, 90, 122. At some other places the *Gītā* is extracted without specifically naming it. *Vide* 1.52-54, 70-72, 86-87, 103-104, 352; 11.138.

[26] Al-Bīrūnī spells the name as beginning with V, the error being due to the confusion between *b* and *v* which was quite common in ancient India as vouched for by stupendous literary and epigraphic evidence.

[27] *Smṛti* works of most of these are still extant.

[28] Sachau's conjecture that Balabhadra was the author of this commentary (11.264) is quite untenable, for Balabhadra's statement quoted in 1.273ff. is of an astronomical character and could not have belonged to a commentary on a work on the Yoga philosophy.

[29] It may be noted, however, that Sachau was doubtful about the transcription of the title of the work, for the contents of the work have no relation with the *Nyāya* system (11.299-300).

30 If al-Bīrūnī's information be correct, its author must be distinguished from the homonymous propounder of the *Sāṅkhya* system.

31 I.e., *Pratyakṣa* and *śabda pramāṇas.*

32 The grammatical text attributed to Indra is no longer extant, though his views on grammatical matters are quoted in several available texts. For details *vide Yudhishthire Mimāṃsaka, Saṃskṛta Vyākaraṇa-śāstra kā Itihāsa* (Hindi), Vol. 1 (Varanasi, V.S. 2007), pp. 57-64.

33 It was actually composed by the Buddhist author Candragomin and is still extant.

34 He was earlier than Pāṇini who quotes him, but his work has not come down to us.

35 Pāṇini's work is styled *Aṣṭaka* or *Aṣṭādhyāyī* and his system is popularly called *Pāṇinīya* after him. For about two and a half millennia his has been the most popular system.

36 It is also known as *Kālāpa* and *Kaumāra* and is still available.

37 Nothing whatsoever is known about it.

38 It is an independent work or system but a *vṛtti* (commentary) on Śarvavarman's *Kātantra*, which is still extant. *Vide* Mimāṃsaka, *op. cit.*, pp. 407ff.

39 Correctly known as *Śiṣya-hitā-nyāsa*, it is a commentary on the *Durga-vṛtti* mentioned above. See *ibid.*, pp. 411-12.

40 *Vide* V.S. Apte, *The Student's Sanskrit-English Dictionary*, p. 603.

41 Al-Bīrūnī takes *tantra* to mean *ruling under a governor,* and *karaṇa* as meaning *following*, i.e. following behind the *Siddhānta*. He adds that "under *governors* they (Hindus) understand the *Achāryas*, i.e. the sages, anchorites, the followers of Brahman" (1.155).

42 *Pañca-siddhāntikā*, ed. by G. Thibaut and Sudhakara Dvivedi, reprinted Varanasi, 1918, Introduction P. viii; Ajay Mitra Shastri, *India as seen in the Bṛhatsamhitā of Varāhamihira*, pp. 426-47.

43 *Vide ibid.*, pp. 430-32.

44 *Āryabhaṭīya* with Paramadīśvara's commentary, ed. by H. Kern, Leyden, 1874.

45 It is possible that Balabhadra may have been another source. 1.246.

46 The manner in which names of orders from 10 till 10 *koṭis* from the book of Āryabhaṭa of Kusumapura are quoted (1.176) also seems to support this conjecture.

47 S. D. Dikshit thinks that both the Āryabhaṭas mentioned by al-Bīrūnī are really one and that al-Bīrūnī's statement that the junior Āryabhaṭa belonged to the school of elder Āryabhaṭa is not correct. His work called *Ārya-siddhānta* is still extant.. Dikshit places second Āryabhaṭa in *c Śaka* 875, i.e. early in the 9th century A.D. *Vide* his *Bhāratīya Jyosiṣa* (Hindi tr. by S. Jharakhandi, Lucknow, 1957), pp. 320-325.

48 *Vide* note 28 above. S. B. Dikshit (*op.cit.*, p. 318), however, accepts Sachau's suggestion.

49 Ajay Mitra Shastri, *IHQ*, XXXVII, pp. 247-59.

50 The title appears to have been wrongly spelt. Sachau feels it may be some relative of *śruti* and hints at the possibility of *srudhava* being identical with *śrutayas*. In Annotations, Sachau states that the reading of the author's name as Baṅgāla is prabably not correct and doubtfully suggests its equation with *puṇyakāla* (11.307-08).

51 The Arabic manuscript gives the name as Bahānarjus, and in the Annotations it is equated with Bhānurajas as against Bhānuyaśas in the body of the text (11.306).

52 The reading of the manuscript is *bahattal* which is perhaps meant for Bhaṭṭila. In Annotations, Sachau gives Bhaḍila with a question mark within parenthesis. The name is evidently a derivative from *bhaṭṭa* even as Kumārila is from Kumāra (11.307).

53 Varāhamihira gives some information about an astrological work ascribed to Brahman, also called Pitāmaha and Prathama-muni. Cf. *Bṛhatsamhitā*, 1.2-5. An astronomical work attributed to Brahman and called *Paitāmaha-siddhānta* is summarised in Varāhamihira's *Pañca-siddhāntikā*. For details *vide* Ajay Mitra Shastri, *India as seen,* etc. pp. 432-33, 446-447.

54 For the *Paitāmaha-siddhānta,* see *ibid.*, pp. 446-447. *Al-Bīrūnī* states that the authors of all the five *Siddhāntas* draw from one and the same source, the book *Paitāmaha* (1.153). This is, of course, wrong.

55 The passage on the use of arithmetic in metrical calculations quoted in 1.147-50 from a treatise of Brahmagupta may be from the *Brāhma-sphuṭa-siddhānta.* Al-Bīrūnī avers

that he had 'studied only a single leaf' of this treatise, obviously of its section on metrics (1.150; 11.303).

56 For the story giving the reason of giving this title, *vide* 1.156.

57 Probably the same as *Khaṇḍa-khādya-ṭippa* (sic) mentioned in 1.156.

58 This is actually the astronomical epoch adopted for purposes of calculations and in all likelihood the date of the *Khaṇḍa-khādyaka.*

59 Probably it refers to the latter part of the *Khaṇḍa-khādyaka* itself, for it is stated in Varuṇabhaṭṭā's commentary on it that its first part follows Āryabhaṭa while the second part follows his earlier work, the *Brāhma-sphuṭa-siddhānta.*

60 In 11.18 it is spoken of as *great Sindhind* (i.e. *Siddhānta*).

61 In 11.16 mention is made of a translation of Brahmagupta by Alfazari. Also of 11.18.

62 Dikshit, *opcit.*, p. 633. Also quoted by Utpala in his commentary on the *Bṛhajjātaka* 1.19.20,11.7; IX.8. *Vide JBBRAS* (N.S.), Vols. 24-25, p.24.

63 He must be distinguished from a later homonymous astrologer. *Vide* Dikshit, *op.cit.*, pp. 393,638-39.

64 For a full discussion on this question, *vide* Ajay Mitra Shastri, *India as seen,* etc., pp. 454-55.

65 For Kalyāṇavarman's date see Ajay Mitra Shastri, *JIH,* Vol. XLII, pp. 915-20.

66 For Sachau's efforts to find out the Sanskrit equations of the title, *vide* note 50 above.

67 A. B. Keith, *A History of Sanskrit Literature,* p. 531.

68 *JBBRAS,* NS, Vols. 24-25, pp. 10-11.

69 S. B. Dikshit, *op.cit.*, p. 318, For an abridged version of Manu's work by Muñjāla see Puñjāla below.

70 For a full discussion on Parāśara and his works, *vide* Ajay Mitra Shastri, *India as seen,* etc., pp. 447-49.

71 S. B. Dikshit, *op.cit.*, p. 325.

72 Sachau points out that the names Paulisa and Pulisa as written by al-Bīrūnī have clearly a dental *s,* and not the palatal one (*ś*) as found in Utpala's commentary on the *Bṛhatsaṃhitā* (11.304). In Varāhamihira's *Pañca-siddhāntikā* and the *Bṛhatsaṃhitā* also we have the forms with palatal *ś.*

73 Some doubt is, however, cast by a couple of al-Bīrūnī's statements: In 1.374 it is stated that 'there is a tradition that Puliśa in his *Siddhānta* specifies various new rules for the computation of' the numbers of years contained in a *caturyuga;* in 11.190 a method for finding the moment of *saṅkrānti*' is stated to have been dictated to al-Bīrūnī by Auliatta (?) the son of Sahawi (?)' on the basis of the system of Puliśa.

74 For the untenability of the suggestion that the *Pauliśa-siddhānta* is the translation of the *Esiagoge* by Pauliś Alexandrinus, *vide* H. Kern, *Bṛhatsaṃhitā,* Introduction, pp 48-49; Ajay Mitra Shastri, *India as seen,* etc., p. 450.

75 From I. 266 it appears that the version of the *Pauliśa-siddhānta* known to al-Bīrūnī quoted Varāhamihira, Āryabhaṭa, Deva, Śrīsena and Brahmā also. If so, the version cited by al-Bīrūnī was different from and later than that epitomised by Varāhamihira.

76 For a full discussion on the *Pauliśa-siddhānta vide* Ajay Mitra Shastri, *India,* etc., pp.449-51.

77 In 1.366-67, his name is given as Puñjāla.

78 For full references see Ajay Mitra Shastri, *India,* etc., p. 453.

79 *JBBRAS,* NS, Vols. 24-25, p. 16.

80 For a detailed discussion on the *Romaka, vide* Ajay Mitra Shastri, *India as seen,* etc., pp. 451-52.

81 S. B. Dikshit, *op.cit.*, *pp.* 327-28.

82 Sachau observes that as regards the title of the first work one expects the word *karaṇa* in the first place and a word for *breaking* in the second (11.307). Can it be equated to *Rāhu-nirākaraṇa?*

83 For a full discussion on Utpala, vide Ajay Mitra Shastri, 'Bhaṭṭotpala: His Date Life and Writings', *IHQ,* Vol. XXXVIII (1962), pp. 247-59.

84 Curiously enough, some manuscripts of the *Ṣaṭ-pañcāśikā* are also wrongly ascribed to Varāhamihira, indicating the existence of some confusion in this regard. Our author's statement is obviously based on some such confused tradition.

[85] References are to Sudhakara Dvivedi's edition with Utpala's commentary.

[86] *Catalogue of Sanskrit Manuscripts in Private Libraries of South India,* No. 2959. For independent manuscripts of this and othei chapters of the *Bṛhat-saṃhitā vide* Ajay Mitra Shastri, *India as seen,* etc., pp. 28-29.

[87] Edited by J. L. Shastri, Lahore, 1944.

[88] Edited by V. R. Pandit, *Journal of the University of Bombay,* Vol. XX., Pt. 11, pp.40-63.

[89] Edited by V. R. Pandit (unpublished).

[90] *Literary Remains of Dr. Bhau Daji,* pp. 240-41; G. Thibaut, *Pañca-siddhāntikā,* Introduction p. xxxviii.

[91] See note 6 above. For detailed information and full discussion about Varāhamihira, *vide* Ajay Mitra Shastri, *India as seen,* etc., Chapters I and VIII.

[92] For full discussion on the *Vāsiṣṭha-siddhānta, vide* Ajay Mitra Shastri, *India as seen,* etc., pp. 456f.

[93] Dikshit thinks that Vitteśvara is probably the same as Vaṭeśvara and that he was a native Kashmir. See Dikshit, *op.cit.,* pp. 318-19.

[94] *Vide JBBRAS,* N.S., Vols. 24-25, pp. 19-21. Also see Ajay Mitra Shastri, *India,* etc., pp. 435-36.

[95] For an acknowledgement of Greeks' proficiency in astrology, *vide Bṛhat-saṃhitā,* 11.14.

[96] In 1.159 is given a confused tradition about the development of medical science.

[97] For the story of an alchemist called Vyāḍi, see 1.189-191.

VARĀHAMIHIRA, THE BEST SANSKRIT SOURCE OF AL-BĪRŪNĪ ON INDIAN *JYOTIṢA*

GHAYASUDDIN*

Henry Martyn Institute, Hyderabad

Al-Bīrūnī is the author of a number of books in Arabic, including writings pertaining to Indian *Jyotiṣa-śāstra* based on Varāhamihira, critically analysed by myself in a study entitled "Varāhamihira, the best Sanskrit Source of Al-Biruni on Indian Jyotiṣa." What al-Bīrūnī wrote on this subject is scattered in a mass of works like *Kitāb al-Tafhīm,* and *Fi Taḥqīq mā li'l-Hind.* Al-Bīrūnī learnt *Jyotiṣaśāstra* directly from Hindu scholars during his sojourn in India. His information on it is a most important contribution of knowledge about India. He projected knowledge about India to the world outside and especially to the Arabic speaking world of the period. A selection has been made from his writings, of the material relevant to Indian *Jyotiṣa* as is based on Varāhamihira and presented comparing with the original Indian sources.

The topics discussed in the paper are as follows:—
Varāhamihira's life and works, three branches of *Jyotiṣa,* a word about Varāhamihira's *Pañcasiddhāntikā,* and its relation with the material relating to Puliśa.

The information in respect of Varāhamihira's astronomical views through Puliśa is as follows: the order of numbers, the *Prāṇa* theory, the *Kalpa.* the *Caturyuga,* the *Muhūrta,* on the rotundity of earth, that everything is around the earth, the position of the earth, the *Nirakṣa,* the situation of the Four Cardinal Cities, the Poles, the diameter and circumference of the earth, the *Ahargaṇa,* the stars cycles, the circumferences of the sphere of the planets, the distances of the planets, the length of the year. From the *Saṃhitā* are selected the ideas on inhabitable earth, the *nakṣatras,* the precession of equinoxes, the Great Bear, the heliacal rising of some planets, the *Samvatsara,* the eclipses, position of moon, *Horā, Pañcahotrīya, Tikaniyātrā, Yogayātrā,* (*Bṛhad*) *Vivāhapattal,* and one book on architecture.[3] The *Saṃhitā* is the last, and *Vivāhakaraṇ* is the first.

Al-Bīrūnī holds him in high esteem and counts him among the great *Saṃhitākāras* like Māṇḍavya, Garga, Parāśara, Balabhadra, and Divyatattva[4]

The science of *Jyotiṣa* is the most famous and essential among the Indian sciences, the best of which al-Bīrūnī introduces in his books *Fī Taḥqīq mā li 'l-Hind, Kitāb al-Tafhīm,* and *al-Qānūn al-Mas'ūdī.* He informs us that the affairs of the religion of the Hindus were in various ways connected with *Jyotiṣa.*[5]

Jyotiṣa is divided into three kinds: the *Siddhāntas,* or the astronomical treatises, the *Saṃhitās,* and the *Horā.* The astronomical treatises are again divided into three clases: actual *siddhāntas, tantras,* and *karaṇas.* The *siddhāntas* are those whose calculations start from the beginning of the creation of the universe, the *tantras* reckon time from the beginning of the *Kaliyuga* (3102 B.C.), while the *karaṇas* from any subsequent specified time. Hence *Pañcasiddhāntikā* is Varāhamihira's *karaṇa* book.

* *Present address* : Henry Martyn Institute, P.B. No. 134, Lucknow.

Al-Bīrūnī attempts to introduce first the *siddhānta* but he is silent on its origin and development, and for good reasons. For, the earliest historical reference we find is a small book called *Vedāṅga-jyotiṣa* in which there is no clear conception of planetary movement but only a simple luni-solar calendar-system for fixing the time of the Vedic sacrifices. It is only after a long time in the 5th century of the Christian Era that we find a sudden emergence of a very developed form of literature called *Siddhānta.*

The only evidence of the continued long effort during this interval is found in a collection of five small astronomical treatises—*Paitāmaha, Sūrya, Vaśiṣṭha, Puliśa* and *Romaka,* gathered together by Varāhamihira under the title, the *Pañca-siddhāntikā.* This Sanskrit word according to al-Bīrūnī ought to mean the pith and marrow of the teachings and findings of these five preceding *siddhāntas.* But he claims that they are not much better than the other available more correct *siddhāntas* composed by Brahmagupta, Puliśa, Viṣṇucandra, Śrīsena and Lāṭadeva. In this criticism al-Bīrūnī was not correct because he had not been able to see it in a complete form. He himself admits that he had read only the *Puliśa-siddhānta,* and this Puliśa according to him was a Greek and a native of Alexandria. He also mentions Varāhamihira's tribute to the scholarship of Greeks. Varāhamihira says, "The Greek though impure, must be honoured, since they were trained in sciences, and therein they excelled others"[6]

Al-Bīrūnī realised that *Paitāmaha* was the oldest one and the original source of all the five *siddhāntas.* He also knew that Pitāmaha was the First Father, i.e. Brahma. He mentions also the *Vaśiṣṭha-siddhānta.* He seems to have known that Vaśiṣṭha was one of the *Saptarṣayas* or the seven-anchorites.[7]

The *Bṛhatsaṃhitā* gives very little information on Varāhamihira's veiws on astronomy. Therefore, al-Bīrūnī's only source on these views is Varāhamihira's *Pañcasiddhāntikā.* From this work al-Bīrūnī refers only to the *Puliśasiddhānta* but he draws from it frequently as he had read only that part of the *Pañca-siddhāntikā.* This book occupies much of Varāhamihira's *siddhānta* and it is quite similar to the *Sūryasiddhānta* which is available now. Al-Bīrūnī liked this book so much that he translated some of it into Arabic.[8] In its mathematical problems there is an evidence of religious and theological tendencies.[9]

The Era of the *Pañcasiddhāntikā* according to al-Bīrūnī is *Śaka* 529 which corresponds to the Era of al-Bīrūnī which is 400 *Yazdajirdi,* but actually speaking its Era is 527 *Śakakāla.*

The information that al-Bīrūnī collected about Varāhamihira's astronomical views as found in the *Puliśasiddhānta* is as follows:—

1. *The order of numbers according to Puliśa is*

ekam = 1, *daśam* = 10, *śatam* = 100, *sahasram* = 1000
ayutam = 10 000, *niyutam* = 100 000, *prayatam* = 1000 000,
koṭi = 10 000 000, *arabudham* = 100 000 000,
kharva = 1 000 000 000.

2. *The Prāṇa theory.*

Puliśa thinks that during one breath of a healthy man the sphere revolves as far as one minute. So, the *prāṇa* is the smallest segment of time to Puliśa and corresponds to the minute of the sphere $= 60 \times 360 =$ 21,600 minutes, or *prāṇa*.[9]

3. *Kalpa or Sinu'l-Alam*

"The *kalpa* is a measure of time, says al-Bīrūnī, the unit of which is a Brahma-day". Among Arabs it is known as *al-Sin Sindhind* (*Siddahanda*).[10] Its starting point is much disputed. According to Puliśa it is midnight at *Laṅkā*.
A *kalpa* is composed of 14 *manvantaras* = 1008 *caturyugas* = 1 590 451 400 civil-days which is called al-ayyam al-alam, = 14 *manvantaras*.
Explaining the *kalpa*, al-Bīrūnī writes that 8 years, 5 months and 4 days. that is to say 6068 *kalpas* of the life of Brahma elapsed before the present *kalpa*, and = 26 425 456 204 132 years before the gauge-year of al-Bīrūnī, viz. 400 Yaza. From the present *kalpa* 6 116 544 *caturyugas* = 1 986 124 132 years have elapsed. And of *manvantara* = 119 884 132 years and until *caturyuga* = 3244132 years. Of the present *Kaliyuga* until al-Bīrūnī's gauge-year (400) the elapsed years are 4132. Between the war of *Mahābhārata* and 400 *Yazdajirdi* the years elapsed are 3479 = 26 423 470 050 000 days.[11]

4. *Caturyuga*

A *caturyuga* is a period of $\frac{1}{1000}$ of a *kalpa*. Therefore, one *caturyuga* has 4 320 000 solar-years, = 51 840 000 solar-months = 53 433 336 lunar months
= 1 593 336 *adhikmāsa*-months,
= 1 577 917 800 civil-days,
= 1 555 200 000 solar-days,
= 1 603 000 080 lunar-days,
= 25082 *ūnarātra*-days, and
= 47 800 080 *adhikmāsas*.[13]

Puliśa discusses in detail the method of calculating the *adhikmāsas*.[14]
Al-Bīrūnī's gauge-years corresponds to the elapsed years of the present *caturyuga* as = 3 244 132 years, or = 1 167 887 520 solar-days.

5. *Muhūrta*

According to Puliśa, a *muhūrta* is equal to 720 *prāṇas*, and according to the general opinion it is equal to 2 *ghaṭikās*. But according to al-Bīrūnī Puliśa is wrong when he follows the general opinion, because

Puliśa himself contradicts this opinion when he reasons about the measure of the *muhūrta*.[15]

6. *Rotundity of the Earth*

Puliśa maintained the Earth to be of globular shape, but on the authority of one *Pauliśa* he says that the Earth has a shape of a cover also. And this is right according to Puliśa, for the plane or surface of the Earth is round and its diameter is a straight line. That Puliśa believed only in the globular shape of the Earth may be proved by many passages of his work.[16]

7. *Everything is around the globe*

Puliśa says that mountains, seas, rivers, trees, cities and men are around the globe of the Earth. And if Yamakoṭi and Romaka are opposite to each other, one could not say that the one is below in its relation to the other, since the 'low' does not exist. How could one say that one place of Earth is low when it is identical in every respect with any other place on Earth, and one place could be relative to any other. Every one speaks to himself with regard to his own self "I am above, and the others are below," whilst all of them are around the globe like the blossoms of a *Kadamba*-tree. They encircle it on all sides, but each individual blossom has the same position as the other, neither the one being downward nor the other standing upright. For the Earth attracts that which is upon her; it is the below towards all directions, and heaven is above towards all directions.[17]

8. *Position of the Earth*

According to Puliśa, Earth's position is central, half being soil, half water. Mt. Meru is in the dry half, above it is the Northern pole. In the half covered by water lies *vadavāmukha* under the south pole.[18]

9. *Nirakṣa or equator*

Nirakṣa is that line which divides the two earth-halves, dry and wet, from each other.

10 *Situation of the Four Cardinal Cities*

Puliśa says that in relation to this line (*nirakṣa*) in the four cardinal directions there are four great cities—Yamakoṭi in the East, Romaka in the West, Laṅkā in the South and Siddhāpur in the North.[19]

11. Mentioning two poles Puliśa says that the Earth is fastened to the two poles and held by an axis. The motion of a globe presupposes them.

When the sun rises over the line which passes through Meru and Laṅkā that moment is noon for Yamakoṭi, midnight for Romaka, evening for Siddhāpur, and morning for Laṅkā.[20]

Why the centre of the globe is motionless is explained in the motion of the peripheric part of it. Puliśa here means to say that the motion of them keeps the Earth in its place.[21]

Explaining the extent of human vision al-Bīrūnī writes that each degree of the rotundity of the Earth represents the measure of 13 *yojanas,* 7 *kroṣas,* and 333 $\frac{1}{3}$ yards. He concludes from this that the field of vision on the Earth is 291$\frac{2}{3}$ yards.[21]

12. *Diameter and the Circumference of the Earth*

The diameter of the earth is given by Puliśa as 1600 *yojanas* while its circumference as 4800 *yojanas.*[22]

13 *Ahargaṇa*

The rule and method for finding *ahargaṇa* employed by *Puliśa* and also a method in the *Pañcasiddhāntikā* for calculating *ahargaṇa* from the *kalpa* and from the *caturyuga* are described in full length and good detail.[23]

Al-Bīrūnī concludes that since the beginning of the gauge-year there have elapsed of the years of 3 244 132 *caturyugas,*
= 1 167 887 520 solar days.[24]

Al-Bīrūnī describes a method for finding the *adhikmāsas* according to Puliśa with his own explanation and comment. He also presents a rule for converting the *ahargaṇas.*[25] Puliśa's rule for the computation of the *yugas* is mentioned by al-Bīrūnī in *Fī Taḥqīq mā li'l-Hind* p. 188.

Regarding the *sandhyā,* Varāhamihira explains it as the moment when the centre of the body of the sun stands exactly over the horizontal circle; that moment, he establishes, to be the time of the greatest power of certain zodiacal signs.[26]

Al-Bīrūnī quotes a method of Puliśa for computing the mean-places, or the *madhyamāsthitis* of the planets, and applies it.

14. *Star-cycles of caturyuga and of a kalpa*

The *kalpa* here stands as 1008 *caturyugas.*
The number of revolutions in a *kalpa* :

Sun	=	4 354 500 000
Moon	=	58 215 362 688
Apsis	=	492 124 752
Nodes	=	234 083 808
Mars	=	2 315 198 592
Mercury	=	18 080 496 000

Jupiter	=	367 133 760
Venus	=	7 078 567 104
Saturn	=	147 736 512

The number of revolutions in a *Caturyuga*:[28]

Sun	=	4 320 000
Moon	=	57 753 337
Apsis	=	488 219
Nodes	=	232 226
Mars	=	2 296 824
Mercury	=	17 937 000
Jupiter	=	364 220
Venus	=	388 022 388
Saturn	=	146 564

15 *Circumferences of the Spheres of the Planets*[29]

They are reckoned in *yojanas*

Moon	=	324 000
Mercury	=	$1\ 043\ 211 \frac{573}{1993}$
Venus	=	$2\ 664\ 632 \frac{90232}{585199}$
Sun	=	$4\ 331\ 500 \frac{1}{5}$
Mars	=	$8\ 146\ 937 \frac{181663}{83701}$
Jupiter	=	$51\ 375\ 764 \frac{4996}{18211}$
Saturn	=	$127\ 671\ 739 \frac{27301}{36641}$
Fixed stars	=	295 890 012

16. *Distances of the Planets from Earth's Centre in yojanas*

(The Sun's distance from the Earth's centre being $\frac{1}{60}$

Moon	=	51 566
Mercury	=	166 033
Venus	=	424 089
Sun	=	690 295
Mars	=	1296 624
Jupiter	=	8 176 689
Saturn	=	20 319 542
Fixed stars	=	41 417 700

17. *Length of the Year*

Puliśa gives the length of the year as follow:
365 days, 15 *ghaṭikās*, 30 *kālas.*

18. Some information about other astronomical views of Varāhamihira can be gathered from his *Bṛhat-saṃhitā,* which is as follows:

i. *The Inhabitable Earth :*

The inhabitable part of the Earth resembles a tortoise because its borders are round, because it rises above the water and is surrounded by water, and because it has a globulary convexity on its surface. It is called *Kūrma-cakra.* The tortoise shell is divided into nine parts, so the inhabitabie world is also of nine parts. The *Kūrmavibhagā* of the *Saṃhitā* is important because its special objects is to provide an arrangement by which it can be determined as to countries and peoples might suffer calamity when particular *nakṣatras* are vexed and so is the Earth.[30]

ii. *The Nakṣatras*

How many stars form the *nakṣatra* in each lunar-station is given in a list.

iii. *Precession of Equinoxes*

Varāhamihira took the motion of it as one day for 45 years. According to al-Bīrūnī, the revolution of the fixed-stars is now more rapid than in former times due to the peculiarity of the shape of the celestial sphere. So it was one degree in 66 years (more rapid than it is at present). Varāhamihira's time preceded him by only 525 years. Al-Bīrūnī thinks that the notion of the Hindus regarding the stars are not free from confusion. To establish this he quotes to Varāhamihira's statement on the fixed-stars and adds his own comment to it.[31]

iv. *The Saptarṣayas or the Great Bear*

The *Saṃhitā* describes them with *epitheta ornantia.* Al-Bīrūnī on his own part, identifies them with great care and criticises the theory of Gārga given by Varāhamihira.[32]

v. *Heliacal Rising of Jupiter*

Al-Bīrūnī describes us the special method of Varāhamihira for computing the heliacal rising of *Mushtari* with which the *Saṣṭyābda* begins.[33] The same method is used for *Agastya* or *'Suhayl'.* In the case of *Mṛgavyādha* or *al-Shi'ra al-Yamaniya* the same thing was done. Al-Bīrūnī describes their rising and setting as well as the way to know them.

vi. *The Saṣṭyābda or Samvatsara*

This is based on the centennium system of calculation of time. *Mushtari* or Bṛhaspati's rising is the beginning of this year. This happens every sixty years. The way of finding it is based on the *Saṃhitā* of Varāhamihira.[34]

vii. *Eclipses*

The ancients knew the actual reason of the eclipses of the sun and the moon. On the Authority of Varāhamihira al-Bīrūnī gives an account of *Rāhu*. Varāhamihira presents some varied views regarding the *Rāhu's* nature, as also the reasons given for the eclipses. He then criticises these opinions and declares them as baseless. Varāhamihira then gives a correct view of the learned sages,[35] namely that the moon's eclipse is due to the Earth's shadow on the moon, and that the eclipse of the sun is due to the moon being between the Earth and the sun.

viii. *Position of Moon*

Varāhamihira says that the moon is always below the sun, which throws light upon her and lights up the one half of her body, whilst the other remains dark and in shadow. The moon is watery; therefore the rays of the sun which fall on her are reflected as they are reflected from the water and the mirror towards the wall. If the moon is in conjunction with the sun, the white part of her turns towards the sun, the black-part towards us, then the white-part sinks downwards towards us slowly, as the sun marches away from the moon.[36]

ix. *The Parva*

Parva is the period of time at the beginning and end of which there occurs lunar-eclipse. Al-Bīrūnī mentions one revolution of the eclipse having seven *parvas*. Its dominants and the astronomical characters are also described by him in detail on the authority of Varāhamihira along with some comment on his astrological views. This comment must not be counted as his own because it is based on the other ancient *saṃhitās*.[37]

The *saṃkrānti*, the time of eclipses and *Ṣaḍaśītimukha* are the 4 days of the sun's entering 18° of *Jauza*, 14° of *Sunbula*, 26° of *Qaus*, and 28° of *Hut*, is full of innumerable rewards.[38]

x. *Metrology*

Svarṇa was used as a weight for gold. The measure of weight are as follows:

1 *reṇu* = 1 *raja*, 8 *rajas* = 1 *bālāgra*, 8 *bālāgra* = 1 *likhya*, 8 *likhyas* = 1 *yūka*, 8 *yūkas* = E *yava*, 8 *yaves* = 1 *aṇḍi*, 4 *aṇḍis* = 1 *māsa*, 16 *māsas* = 1 *svarṇa*, 4 *svarṇas* = 1 *pala*.

Measures of liquid substances:

4 *palas* = 1 *kuḍava,* 4 *kuḍavas* = 1 *prastha,* 4 *prasthas* = 1 *anḍaka.*

Measures of dry substances :

8 *palas* = 1 *kuḍava,* 8 *kuḍavas* = 1 *prastha,* 4 *prastha* = 1 *āḍhaka,* 4 *āḍhakas* = 1 *droṇa.*

Measures of Distances :

8 *yavas* = 1 *aṅgula,* 4 *aṅgulas* = 1 *rama,* 24 *aṅgulas* = 1 *hasta* = 2 *miqyasas* (yards), 4 *hastas* = 1 *dhanu,* 40 *dhanus* = 1 *nalva,* 24 *nalvas* = 1 *krośa* = (Puliśa: 4000 yards = 1 Arab-mile). *yojana* = 8 miles (Arab) = 32000 yards.[39]

xi. *The Brahmāṇḍa*

Turning to the Hindu conception of the creation of the world, al-Bīrūnī informs us that, the condition that existed from all eternity is darkness, a kind of non-existence which is expressed by the state of the Sleeping Brahma for whom God created this world as a capula consisting of two parts, higher and lower. The sun, the moon and all the stars and planets are supposed to be in it. The creation is said to begin with the existence of Brahma.[40]

Puliśa philosophises further on the *Brahmāṇḍa* and says that the *Brahmāṇḍa* is the totality of the spheres, and that the totality of the world is the sum of the five elements—earth, water, fire, wind, and *ākāśa,* the last was created behind the darkness. Puliśa explains that the sky appears blue because it is not reached and illuminated by the rays of the Sun. Puliśa believed that the sun is only light-giver and that all other bodies receive light from it.

xii. *Two Motions of the Fixed-stars*

He says that the *wind* makes the sphere of the fixed-stars revolve. The two poles keep it in its place and its motion appears to the inhabitants of Meru as a motion from the left to the right and to the inhabitants of *vaḍavāmukha* as one from the right to the left. The reason why this westwardly motion appears different is explained in this way: it depends upon the position of the spectator. The people of the equator regard it as westward, while those between the poles and the equator see it more or less depressed. The whole of this motion compels the planets and stars to rise in the east and to set in the west (to the east from *al-Shurtan* to *al-Buttayn*). The westwardly motion is the first motion and does not belong to earth; otherwise a bird would never return to its nest as soon as it had flown away from it towards west.

Degrees of the Stars

The third part of this science is based on the principle that all the changes occuring in the sublunary world are connected with the particular nature of the movements and influences (*al-tathirat*) of the celestial bodies. They serve as *al-dala'l* or indicators of the future events.

Al-Bīrūnī introduces his readers to the kernel of this branch of *Jyotiṣa*. The source of his information are the works of Varāhamihira, viz. two books of *Jātakas*. All the fundamentals are grouped in three sections: *al-Kawakib, al-Buruj,* and *al-Buyut,* that is to say, *grahas, rāśis and gṛhas.*

i. *Al-Kawakib :*

Varāhamihira adhered to the opinion that the number of planets is seven. In preparing a list for his personal use al-Bīrūnī depended on Varāhamihira. The order of the planets is that of the week-days. The list prepared by al-Bīrūnī regardnig the influence of elements does not tally with that of Varāhamihira, but is based on him.[43] 'Fire' can be subtituted for the element of the sun, and 'water' for the moon. Their influences on subjects which are male, female, or neuter is best described in the *Kitāb-al-Tafhim.*[44] The other account of planetary influences are :-

a. On the trine-constituent on different castes where al-Bīrūnī has left a lacuna for Saturn can be filled in by *'antyaja'*;

b. on spiritual beings where his conclusion for the moon is correct, but the right place for the sun and Mercury is given by Varāhamihira;

c. on clothings and on minerals, the words supplied by him are misplaced in the Arabic text; 'al-lulu' must be used for Venus not for Mercury, the word for Mercury is 'Kansi';

d. on the six seasons, there is a lacuna for the sun which should be *'grīṣma'*;

e. on *ātma-citta-graha* two lists of the same kind are interwoven; the word for Mars is illegible in the text which must be read *'al-khayriya'*, an equivalent for *'Sattva'*;

f. influences on taste corresponds with the *Jātaka* with the exception of a lacuna for Mars which can be filled by providing the word *'tikta'*, for Mars, *'āmla'* for Venus and *'kaṣāya'* for Saturn.

g. On the directions of the compass there is one error; Venus for East-west is wrongly mentioned with the omission of *Rāhu*.

h. On *Ayanas*, on the 4 Vedas, and the periods when these influences are stronger are given in a list with a criticism on the Muslim method in *al-Tafhim*.

i. The friendly and hostile attitudes of the planets with a rule to find the nature of them.

j. On the indications to colours;

k. on the months of pregnancy from the first month to the child-birth is given.[45] The planetary aspects and *ucca-nīca-grahas,* as well as the 4 planetary-powers individually in respect to each other are based on both *Jātakas,* and discussed at full length.[45]

Al-R'as (The Rāhu):

Although *Rāhu* is not counted among the planets, still it is regarded as inauspicious and causally connected with eclipses.[46]

Adhu-Dhanab (Ketu):

They are said to be the *Rāhu's* sons. Al-Bīrūnī numbers them upto 30 and calls them *'Tāmasakīlaka'*.
He gives an extensive account of these *Rāhuputras*. They are believed to express their influences and prognostics by shapes, colours, sizes and positions. They are said to play havoc in this world at the time of their appearance. We see al-Bīrūnī maintaining that though they go up to a thousand, they may be classed into 3 kinds. Al-Bīrūnī worked out an extensive list of comments, supplying some very useful information and producing almost all of chapter eleven of the *saṃhitā*. He mentions another category of them, which though not coming within the domain of comets, are still considered as devils. Only full gnostic can recognise them. It is to be noted that they are said to be persons raised to heaven on account of their meritorious deeds in a former life, but whose period of stay there having elapsed, are now redescending to the Earth.[46]

ii. *Al-Buruj*:

They play an important role in *Jyotiṣa* as the planets themselves.[47] Al-Bīrūnī presents their astrological as well as a few mathematical aspects. He describes the measurement of the zodical-signs, of *hora,* of the *dreṣkāṇa,* of the *navāmśika,* of the *trikoṇa*, of the *vargottama*, of the *dvādaśāṃśa*, and the like. The *triṃśaka* and the *mūlatrikoṇa* with their dominants are also dealt with. The *lagna* is also described.

The zodiacal-signs with their names are twelve. Their images are similar to the *Jātakas*. Varāhamihira, in his opinion, identifies *Mithuna* with *al-Jabbar*, and *Meṣa* as *al-Awwa*.'

The colours and the rulers of the *Buruj* and their characters and influences, altitudes, being lucky or unlucky, the directions, in what manner they rise, whether turning, fixed or double-bodied, whether at night or during day, what parts of the body they indicate, seasons, what kinds of beings they are, and the times of their strongest influence according to the different kind—are described in extensive detail.

As a rule the *buruj* which night rule are *priṣṭodaya* (*Mustalqi*) and day-rule *śirṣodaya* (*Muntasib*). In the light of *al-Tafhīm* and *Fī Taḥqīq māli'l-Hind* a guiding rule for the *Buruj* getting stronger either in day or in night can be formulated in this way:

The first four and ninth and tenth *buruj* can be grouped in one, and the rest in the other.[48] *Jawza, Sunbula, Mizan, Dalw* and half the *Qaus* are *Nararasis* to Varāhamihira but to al-Bīrūnī it is only *al-jawza*. That this aspect of astrology was no doubt much more elaborated by Indians than others (Arabs), is asserted in his *al-Tafhīm*. Al-Bīrūnī follows Varāhamihira in connecting the signs with certain parts of the body. Only some slight deviations are detectable.

In respect of the relationship of the *buruj* he asserts that *hora* = 15°, *dreṣkāṇa* = 10°, *navāmśika* = 30° 20′, *dvādaśāṃśa* = 30°20′, *trimśaka* = 1. The other five aspects are: *ṣadvarga* = 5th part of *buruj* (each ascribed to each of the five *'nutahayyira*). If the planet is in this part and in its *hora* it is called *svavarga-śuddhastha*. *Trikoṇa* = (i) 1,5,9; (ii) 2,6,10; (iii) 3,7,11; (iv) 4,8,12. *Mūlatrikoṇa* = for Sun 5th, for Moon = 2nd, for *Maṅgala* 1st, *Budha* 26th, *Bṛhaspati* 9th, *Śukra* 7th, and for *Śani* 11th *buruj* *Śatāṃśa* = 1/7 of a *buruj*.

Vargottama (*al-Murabba' al-A'zam*) happens when a planet is in *buruj* and in its *Navāṃśika*.[47]

iii. ***Al-Buyut*** :

Al-Bīrūnī's accounts are based on Varāhamihira's *Jātakas*, according to which each house consists of 30° of ecliptic as was the case with the *rāśis*. They are also 12 and divided in several ways: in the form of *'Chatra'* 6 houses from 7 to 12 standing above; in *'Navaka'* in the opposite way; in *'Dhanusas'* (a) ascending = 10 to 3, (b) descending = 4 to 9 *buyut*.

Al-Bīrūnī is silent on some of the names of the houses, but Varāhamihira describes them in this way:

1. *al-tali'* or *Lagna* = 1st.	2. *Svana* = 2nd,
3. *Duścikya* = 3rd,	4. *Anbu* (*Sukha*, *Hibuka* etc.) = 4th.
5. *Dhi* (*Trikoṇa*) = 5th.	6. No description.
7. *Jāmitra* = *al-Gharib*) = 7th.	8. *Citra*
9. *Tapa* (*trikoṇa*).	10. *Karma* (*Mesurana*).
11. No description.	12. *Rittapham*.

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[4] Ibid. p. 75, cf. B.J. 28:5.
[5] Ibid. pp. 72, 73.
[6] Ibid. p. 11.
[7] Ibid. p. 171, 188.
[8] Ibid. p. 84.
[9] Ibid. p. 170
[10] Ibid. p. 169,
[11] Ibid. p. 204,
[12] Ibid. p. 187,
[13] Ibid. p. 214,
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[24] Ibid. p. 227,
[25] Ibid. p. 223,
[26] Ibid. p. 124,
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[28] Ibid. p. 211,
[29] Ibid. p. 328,
[30] Ibid. p. 148f, cf. *Sam.* 14,
[31] Ibid. p. 244ff, cf. *Sam* 4:7.
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[33] Ibid. p. 263, cf. *Sam.* 8:20-23.
[34] Ibid. p. 247, cf. *Sam.* 12: 1-8.
[35] Ibid. p. 253, cf, *Sam.* 5: 10-15.
[36] Ibid. p. 233, cf. *Sam.* 4: 1-3,
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[38] Ibid. p. 293, cf. *Sūrya-S.* 14:6,
[39] Ibid. pp. 77, cf. *Sam.* 58:2
[40] Ibid. pp. 164, 122, cf. *Sam.* 1:.
[41] Ibid. p. 110,
[42] Ibid. p. 139, cf. *Sam.* 12:55,
[43] Ibid. p. 302ff, *Taf.* p. 354, cf. *L.J.* 2: 4:,
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[45] Ibid. p. 302-*Taf.* pp. 367-92, cf. *B.J.* 4:16 *L.J.* 3:5, 9.
[46] Ibid. p. 308, cf. *Sam.* 3: 7ff, 11: 22,
[47] Ibid. p. 302, *Taf.* p. 317, cf. *B.J.* 1:5, 8, 11, 14, 20. *L.J.* 1:67.
[48] Ibid. p. 307. *Taf.* p. 318, cf. *L.J.* 1:15ff.

AL-BĪRUNĪ AND THE AUTHORITIES ON SANSKRIT PROSODY

BALKRISHNA K. NAYAR *

Indian National Science Academy
New Delhi

An attempt has been made to identify of the Sanskrit authorities on prosody referred to in Chapter XIII of *Al-Beruni's India*.

Al-Bīrūnī refers to a number of authorities not all of whom have been properly identified. In chapter XIII of *Al-Beruni's India*,[1] while dealing with prosody, reference has been made to a number of Sanskrit authorities, who form the subject matter of this paper. In addition to Sanskrit authorities on metres, al-Bīrūnī refers to Arabic writers like al-Khalil Ibn Ahmad,[2] Persian metricians whose names are not mentioned,[3] and Greeks[4] of whom Galenus alone appears to be mentioned in the above chapter.[5]

"The first who invented this art were Piṅgala and (? CLT). The books on the subject are numerous. The most famous of them is the book *Gaisita* (?G-Al-S-T) so called from its author, famous to such a degree that even the whole science of metrics has been called by this name. Other books are that of Mṛga lāñchana, that of Piṅgala, and that of (?U(Au)-L-Y-Ā-N-D). I, however, have not seen any of these books nor do I know much of the chapter of the *Brahmasiddhānta*, which treats of metrical calculations and, therefore, I have no claim to a thorough knowledge of the laws of their metrics. Nevertheless, I do not think it right to pass by a subject of which I have only a smattering, and I shall not postpone speaking of it until I shall have thoroughly mastered it."[6]

In the above excerpt, names of a number of authorities are mentioned. Al-Bīrūnī does not claim personal familiarity with their works. He, however, gives a long quotation from Brahmagupta,[7] ending with "Of this above-mentioned treatise of Brahmagupta, I have only seen a single leaf: it contains, no doubt, important elements of arithmetic"[8]. In his discussion on the Sanskrit *gaṇas*, al-Bīrūnī starts with a reference to "a lexicographical work to which the author Hariudd (Haribhaṭṭa) has given his own name"[9] from which he quotes extensively.

Piṅgala is well known to every student of Sanskrit Prosody. He is one of the ultimate authorities. "What are the Sanskrit forms of the names Calitu, Gaisitu, Aulivāndu" asks Sachau[10] in his note on page 137 *of Al-Beruni's India*. The chapter of Brahmagupta's *Brahmasiddhānta* of which the author here (p-147-150) communicates a few extracts is chapter XXI, "On the Calculation of the Measures of Poetry and on Metrics, (v.i. 155)". Regarding

* *Present address* : Assistant Director, Manpower Division, Council of Scientific and Industrial Research, N,4, N.D.S.E. Part I, New Delhi 110049.

Haribhaṭṭa, Sachau says: "This name is not known to me as that of an author of lexicographical work. The ms. clearly writes Hariuddu, which may represent various other forms of Sanskrit names."[11]

Of the Sanskrit authorities that al-Bīrūnī mentions in Chapter XIII in connection with metrics, we are certain about Piṅgala and Brahmagupta. The other names mentioned are the following:

Calita (u)
Gaisita (u)
Mṛgalāñchana
U (Au) liyānda (u)
Hariudd

Of these, Gaisita is said to have been famous to such a degree that even the whole science of metrics was called by his name according to al-Bīrūnī. Hariudd was a lexicographer. These are the only internal evidences regarding the identity of the authorities mentioned by al-Bīrūnī. Let us see what external evidence we can adduce to assist a proper identification.

Jayakīrti, a Jain monk of the Digambar sect from a Kannada speaking province who lived about 1000 A.D., and who was a contemporary of al-Bīrūnī, refers to leading authorities on Sanskrit prosody while dealing with the metrical pause (*yati*) in his book *Chandonuśāsanam*.[12]

Vānchhanti yatim Piṅgala Vaśiṣṭha Kauṇḍinya Kapila Kambala munaya.

Nechhanti Bharata Kohala Māṇḍavya-Aśvatara Saitavadya kechid.

Yati or the metrical pause introduced in the middle of a line is an important feature of the *varṇa vṛttas*.[13] According to Jayakīrti, the metrical pause was considered compulsory by Piṅgala, Vaśiṣṭha, Kauṇḍinya, Kapila and Kambala. Prominent among those who do not consider it necessary are listed Bharata, Kohala, Māṇḍavya, Aśvatara, Saitava, etc.

Of the names mentioned the two most renowned have been Piṅgala and Bharata. Piṅgala is mentioned as the younger brother of Pāṇini in *Vedārtha dīpikā*[14]. Piṅgala describes the Sanskrit metres in terms of the ten units, viz. *ga, la, ma, ya, ra, sa, ta, ja, bha, na* consisting of the long, the short, and the eight triplets (*gaṇas*)[15]. Bharata apparently considers the long and the short as adequate,[16] without recourse to the triplets which are merely permutations of long and short taken three at a time.

Bharata thus belongs to a school differing from that of Piṅgala in certain basic concepts. Jayakīrti refers to him as the first among those who do not consider *yati* essential. The possibility that the author referred to by al-Bīrūnī as Calita might be Bharat appears to merit consideration.

Neither Piṅgala, nor Bharata is the inventor of the art (or science) of prosody in Sanskrit as reported by al-Bīrūnī.[17] Piṅgala in his *Chandaḥsutram* refers to the view of a number of his predecessors. They include Kaustuki,[18] Yaska,[19] Tandi[20] Saitava,[21] Kāśyapa,[22] Rata[23], and Māṇḍavya.[24] We shall have occasion to refer to some of them later.

The name corresponding to Gaisita appears even more difficult to decipher. This word has been translated into Malayalam[25] as Agastya, which bears a close resemblance to Gaisita. Agastya was a profound scholar. Agastya wrote a vedic grammar, mentioned in *Ṛk Pratiśakhya* (1/2). Agastya was a scholar in the Āyurveda and is listed among the disciples of Bhāskara in *Brahmavaivarta purāṇa* (ch 16). The *Agastya Saṃhitā* is a compendium on tantric literature. The name Agastya has also been associated with the spread of Aryan influence to the south. Agastya was a profound grammarian in Tamil. Agastya was an expert in Archery. Agastya was an engineer. Agastya wrote a book on the science of Birds, the *Pañca Pakṣi Śāstram.*

Agastya was thus a man of many parts. Agastya might have been one man, or a host of men. He does not, however, find mention as an expert in the science of Sanskrit prosody. Gaisita according to al-Bīrūnī was famous to such a degree that even the science of metrics has been called by his name. Jayakīrti, a contemporary of al-Bīrūnī, does not however even include the name Agastya as an authority among a dozen or so of others.

Jayakīrti, in fact, includes Vaśiṣṭha as an authority. The word, Vaśiṣṭha has also a close similarity to Gaisita. The authorship of various works including an *upapurāṇa* has been attributed to him. Vaśiṣṭha was a predecessor of Pāṇini. Yet Pāṇini does not include him among the 7 authors he quotes as authorities. It therefore, appears unlikely that al-Bīrūnī was referring to Vaśiṣṭha as Gaisita, one of the most outstanding authorities.

Aśvatara, mentioned by Jayakīrti, has some slight phonetic resemblance to Gaisita, but does not appear to merit serious consideration for the same reason. Aśvatara appears to have been a Nāga king like Piṅgala. Aśvatara is said to have gained the blessings of Sarasvatī, the goddess of learning and music, and become a great authority on musicology. There are a number of metres like *aśvagati,* and *aśvakrānta* which are related to *aśva* (horse) and not to Aśvatara. They have a tempo resembling the galloping of a horse. Gaisita does not appear to represent Aśvatara.

There is one more name is our list which has some similarity to Gaisita. That is Saitava. Saitava is an authority to whom both Jayakīrti and Pāṇini refer. His identity does not appear to be clearly known. Saitava's views are given in *Vṛttaratnākara*[26] of Kedāra Bhaṭṭa, an eminent commentator of the 15th century A.D.

But his name does not appear to be a synonym of the science of metres. The word, *setu,* means a passage, a help to the understanding of a text, an explanatory commentary. Several commentaries on prosody are known as *Setu's.* Can it be that the association of some famous *Setu* with Saitava might possibly have led to the statement of al-Bīrūnī that the author was famous to such a degree that even the whole science of metrics has been called by his name?

In any case, it would appear that of the four possible choices Agastya, Vaśiṣṭya. Aśvatara and Saitava, the name Gaisita appears closest, in physical similarity to Agastya, but in significance to Saitava, to whom al-Bīrūnī's contemporary Jayakīrti refers in more than one place.[27]

Mṛgalāñchana is a name which it has not been possible to locate as a writer on Metres. Before we discuss this, let us deal with the other name U (Au) lyānd. Examining the list of authorities quoted by Jayakīrti, we find there are two names which resemble U (Au) lyānd. They are Kauṇḍinya and Māṇḍavya.

Kauṇḍinya was a ṛṣi. Anyone born in the *Kauṇḍinya gotra* could also be called by that name. One Viṣṇugupta appears to be known as Kauṇḍinya. No one of this name appears to be so famous as to be included in the list of half a dozen top celebrities enumerated by al-Bīrūnī.

Māṇḍavya was reputed as a teacher, an astronomer, author of the *Māṇḍavya Śruti, Māṇḍavya Saṃhitā* etc. Māṇḍavya is referred to by Pāṇini also among the few he quotes. Utpala Bhaṭṭa who wrote a famous commentary on *Varāhamihira's* called the *Bṛhat Saṃhitā vivṛtti* quotes Māṇḍavya.[28] Utpala Bhaṭṭa wrote his commentary on the *Bṛhat Saṃhitā* in 966 A.D., some time before the advent of al-Bīrūnī. The *Bṛhat Saṃhitā* was a book which had received the special attention of al-Bīrūnī. It is, therefore, not unlikely that Māṇḍavyā might come in for greater appreciation at al-Bīrūnī's hands.

There is some doubt as to whether Kohala and Māṇḍavya, are to be deemed as two entities or as one. Kohala is the name of a *ṛṣi.*, supposed to be an inventor, or first teacher of Drama. Kohala is also the name of a Prākṛt grammarian, of a writer on Music. The word, Kohala means one who speaks indistinctly. The association of Kohala and Māṇḍavya as one could give a very close approximation to the name U (Au) lyānd referred to by al-Bīrūnī.

Māṇḍavya is remarkable in another respect also. According to a *śloka* quoted by Yadav Prakash,[29] the science of metres was first acquired by Bṛhaspati, the preceptor of the *Devas,* from Lord Śiva. It was then passed on to Duścyavana Indu, and from him to Māṇḍavya. This places Māṇḍavya among the earliest masters of the science of metres.

It may thus appear legitimate to link U (Au) lyānd with Māṇḍavya.

Let us now consider the name Mṛgalāñchana. It has already been mentioned that no writer on prosody of this name appears to be well known. The word Mṛgalāñchana means the moon, which has the semblance of a deer mark on its face. An effort was made to see if any famous writer on metres prior to al-Bīrūnī had a name with the word "*Candra*" in it. Synonyms and similar appellations were sometimes used to indicate the name of a person in verse. Jayadeva, an early writer on metres, who lived much before al-Bīrūnī has been referred to in more than one place by Bhaṭṭa Halāyudha (a commentator of Piṅgala) as Śvetapata, the white robed, because Jayadeva apparently was a jaina monk. No well known writer on metres prior to al-Bīrūnī with a name ending in Candra could be located. Hema Candra who wrote the *Chandonuśāsanam* belonged to the latter part of the 11th century A.D.

The legend about the transmission of knowledge of metres, quoted in an earlier paragraph contains possible clue, Duścyavana Indu, the master between Bṛhaspati and Māṇḍavya is noteworthy. Indu means moon. It is for consideration whether Duścyavana Indu could possibly be the name referred to by al-Bīrūnī as Mṛgalāñchana. The fact that the name is closely linked with Māṇḍavya in the legend, and in the listing by al-Bīrūnī may lend some support. No other lead appears available at present.

The last name, but the most important, that al-Bīrūnī quotes is that of Hariudd. Sachau has transliterated it as Hari Bhaṭṭa. But he frankly admits that name is not known to him as that of an author of any lexicographical work.

The person with a similar name who is famous as a lexicographer is Halāyudha. The *Halāyudhakośa* has come down to us, and is well known. Halāyudha appears close to Hariudd. Halāyudha Bhaṭṭa has written a famous commentary on Pingala's *Chandaḥsūtram*. Halāyudha Bhaṭṭa lived in the latter half of the 10th Century A.D.[30] Hence he was a close predecessor of al-Bīrūnī.

Thus Halāyudha would appear to be the person referred to by al-Bīrūnī as Hariudd, the lexicographer who dealt with metres.

What might have been a happy ending has been thoroughly spoilt by the fact that the text referred to by al-Bīrūnī does not appear to be traceable in the extant commentary in the name of Halāyudha.

This raises two possibilities. One is that the identification of Hariudd, the lexicographer who wrote on metres as Halāyudha is in error. The other is that the extant commentary is different from the one referred to by al-Bīrūnī.

There is some confusion regarding the identity of the author of the current commentatory on Piṅgala. There was one Halāyudha a poet, and author of *Abhidhāna Ratnamālā* and *Purāṇa-Sarvasva*. Halāyudha was the name of various writers. There are three views about the identity of Halāyudha, the commentator on Piṅgala.

1. That Halāyudha was a courtier of Lakshman Sen Singh, ruler of Bengal in the 10th Century.
2. That Halāyudha came from Gaur-desh and was the son of Purushottam Bhatt, and
3. That Halāyudha was a southerner.

Is it possible that more than one commentary was written by persons who bore that name Halāyudha? The portion referred to by al-Bīrūnī and the method of calculation of the order of the *gaṇas* is not in accordance with the current practice of Sanskrit prosodists. The present method, as has been pointed out in another paper[31] is more simple and appears to be the only one prevalent. Is it possible that an earlier commentary by some Halāyudha which contained material at variance with current practices came to be supplemented by another version later? Or is it that Hariudd, the lexicographer, is different from Halāyudha? This is a matter which needs further examination.

A preliminary examination of the available data thus seems to indicate that the authorities on the science of metrics quoted by al-Bīrūnī are as follows:

Name given by Al-Bīrūnī	*As in Sanskrit Texts*
Piṅgala	Piṅgala
Calita	Bharata
Gaisita	Saitava
Mṛgalāñchana	Duścavana Indu
U (Au) lyanda	(Kohala) Māṇḍavya
Hariudd	Halāyudha

Much more work remains to be done before the exact identities of the authorities quoted by al-Bīrūnī are established.

References

[1] E. C. Sachau, *Alberuni's India*, pp. 137-38
[2] *ibid*, p. 138, p 147
[3] *ibid*, p. 138
[4] *ibid*, p. 143
[5] *ibid*, p. 151
[6] *ibid*, pp. 137-38
[7] *ibid*, p. 147
[8] *ibid*, p. 150
[9] *ibid*, p. 141
[10] *ibid*, p. 301
[11] *ibid*, p. 302
[12] Jayakīrti, *Chandonuśāsanam* ch. 1, verse 13
[13] H. D. Velankar, *Jayadaman*, p. 19
[14] *Vedārthadīpika*, p. 97
[15] Halāyudha Bhaṭṭa: Commentary on Piṅgala *Chandaḥ-sūtram* ch. 1, verse 5.
[16] Bharata. *Nātya Śāstra* chs. XIV and XV
[17] E. C. Sachau, *AlBeruni's India*. p. 137
[18] Piṅgala: *Chandaḥsūtram*, 2/29
[19] *ibid*, 3/30
[20] *ibid*, 3/36
[21] *ibid*, 5/18; 7/10
[22] *ibid*, 7/9
[23] *ibid*, 7/13
[24] *ibid*, 7/34
[25] *AlBiruni's Kantd India* trs. Mohiaddin Alwaye p 89 (Apparently translated from the Arabic Text)
[26] Kedāra Bhaṭṭa, *Vṛttaratnākara*, ch. 2.
[27] Jayakīrti, *Chandonuśāsanam*, ch. 4, verse 15.
[28] Utpala Bhaṭṭa, *Bṛhatsaṃhitā Vivṛtti*, p. 1248
[29] P. Bhagwas Dutt. *Vaidik Vangmayaka Itihas* (*brahmanabhag*) p 246
[30] H. D. Velankar, *Jayadaman*, p. 31
[31] B. K. Nayar, *AlBīrūnī and the Arithmetical sequence of the Sanskrit gaṇas* (presented at this Seminar.

SESSION I

DISCUSSION

(1) SANSKRIT LITERATURE KONWN TO AL-BĪRUNĪ by AJAY MITRA SHASTRY

Dr. (Mrs) Bina Chatterjee contended that Bhaṭṭotpala should be assigned to the 10th century A.D. on the basis of the date given in the *Śaka* era in the colophon of his work.

In reply, the author referred to an article of Prof. P. V. Kane in the *Journal of the Bombay University* on the subject and stated that Bhaṭṭotpala's date was prior to the 10th century A.D. Further Dr. Shastri pointed out that there was epigraphical evidence where *Śaka* or *Śāka* is used in two meanings (i) the *śaka* era, and (ii) in a generalised way as any era. The word, *śaka* has found in some inscriptions also means the Vikrama era. So Bhaṭṭotpala's *śaka* has to be taken as the Vikrama era and the colophon of his work has to be worked out as 831 A.D. Dr. Shastri further added that he had dealt with the whole question in one of his articles published in the *Indian Historical Quarterly*.

Prof. S. Maqbul Ahmad enquired whether, according to al-Bīrūnī's concept, the universe was regarded as finite or infinite as suggested by Bīrūnī in his preface to the *Al-Qānūn*.

Dr. S. R. Sarma pointed out the significance of word-numerals añd alphabetic notations which anticipated decimal place-value. He was of the view that all the methods of notations co-existed according to the metre employed. Further he thought that *Kalpa* was a hypothetical point arrived at by back calculation.

Mr. M. A. Alvi thought that the question whether the universe is finite, had been answered partially by al-Bīrūnī, in his remarks on Aristotle, and that al-Bīrūnī inclined to believe that the universe was infinite.

(2) VARĀHAMIHIRA, THE BEST SANSKRIT SOURCE OF AL-BĪRŪNĪ ON INDIAN *JYOTIṢA* by SHAYASUDDIN

Dr. Ajay Mitra Shastri stressed that some of the observations of al-Bīrūnī needed to be substantially modified or rejected outright. Citing an example, he said that al-Bīrūnī had referred to a work on architecture by Varāhamihira, but it is nowhere referred to by Varāhamihira in his works. In the *Bṛhat-samhitā* there are three chapters on temple and residential architecture, which are sometimes found as independent manuscripts. It seems that al-Bīrūnī mistook such an independent ms. as a separate work of Varāhamihira, which raises doubts about the character of al-Bīrūnī's acquaintance with Varāhamihira. Dr. Shastri further clarified that al-Bīrūnī's attribution of the *Śatapañcāśikā* to Varāhamihira is incorrect and that it was composed by Pṛthuyasas.

Dr. A. K. Bag said that the *Puliśa-siddhānta* used by al-Bīrūnī is different from the known version, as already pointed out by Thibaut. Dr. Shastri elaborated that al-Bīrūnī's work is a recast of recast.

Dr. Lokesh Chandra enquired about date of the death of al-Bīrūnī which is usually placed at 1048 A.D., but which Prof. Boilot considers as being after 1050 A.D., on the basis of al-Bīrūnī's last work, the *Kitāb al-Saydala fi 'l-Tibb* on medicinal drugs, which is still unpublished.

Dr. Ghayasuddin admitted the difference of opinion, but felt that the traditional date might be retained until further evidence was forthcoming.

(3) SOURCES OF AL-BĪRŪNĪ ON INDIAN METRICS by B. K. NAYAR

Prof. Grover pointed out that before problems of details were taken up, it was essential to understand the socio-political conditions of the time of al-Bīrūnī and the places which al-Bīrūnī visited and the scholars with whom he discussed should be determined. He thought that al-Bīrūnī based his information on secondary sources and unless the original sources mentioned by al-Bīrūnī in his works were correlated and evaluated, his works would not be reliable as historical material. In the absence of such an effort, Prof. Grover thought that al-Bīrūnī's work had a limited application.

Dr. B. K. Nayar pointed out that al-Bīrūnī's treatment was selective with an accent on mathematics and astronomy which were his primary interest.

Dr. (Mrs) Pratipal Bhatia referred to Halayuddha and said that he existed in the last part of 10th century A.D. and possibly he was a contemporary of al-Bīrūnī.

Dr. Ajay Mitra Shastri commented that some of the equations and the names of writers on prosody as given by the author, though interesting, went a bit far from the spellings of the concerned words as given by al-Bīrūnī.

In his concluding remarks, Prof. A. H. Habibi said as follows: "While Persian and Arabic Sources of al-Bīrūnī are known to us in Afghanistan, we have little information about the Sanskrit sources. We are grateful for the papers and we have greatly benefitted by these discussions. We would like to publish them in Afghanistan."

Dr. R. S. Tripathi, the Co-Chairman, emphasised that it was necessary to collate all the original manuscripts and prepare a critical edition before arriving at conclusions regarding the identification of names as attempted in the 3rd paper. He indicated that the identifications of Hariudd of al-Bīrūnī with Halayudha was farfetched, and that it could well be Haribhadra, the great scholar.

Prof. Maqbul Ahmad, the Co-Chairman, referring to the stresses and strains under which al-Bīrūnī studied in India and his insatiable thirst for knowledge, pointed out that, apart from the secondary sources, al-Bīrūnī also studied during his stay in India some original Sanskrit works.

AL-BĪRŪNĪ AND BRAHMAGUPTA

BINA CHATTERJEE

Adya Jha Hostel, C3, Safdarjang
Development Area, Hauz Khas,
New Delhi

Al-Bīrūnī's quest for knowledge for Indian Science is commendable. In his own country he studied the subject from translations of Sanskrit texts and other allied Arabic works. But when he came to India in the eleventh century he went through some of the terse Sanskrit texts with the help of Indian scholars. Even complicated orthographical and grammatical forms of a foreign language rendered more difficult by mistakes of careless copyists left him undaunted in his pursuit. His *India* is a valuable contribution to the study of the history of Indian Science, especially astronomy and mathematics. The most important astronomical works that al-Bīrūnī studied are the *Brāhmasphuṭasiddhānta* (*BSS*) and the *Khaṇḍakhādyaka* (*KK*) of Brahmagupta, the outstanding astronomer of the seventh century, whose works even in al-Bīrūnī's time dominated the western and north-western parts of India. Al-Bīrūnī quotes profusely, from both these works in *India* and the object of the present paper is to trace these quotations in the available editions of the two texts. The paper will show that most of these references can be located though a few ascribed to Brahmagupta are actually the statements of his commentators.

Al-Bīrūnī came to India in the eleventh century. It appears that even then he had a general knowledge of Indian astronomy acquired probably by studying Arabic translations of some Sanskrit texts and other related works by Arab scholars. While in the country he studied the subject from the original Sanskrit treatises with the help of Indian Paṇdits, as he himself acknowledges. The most important texts are the *Brāhmasphuṭasiddhānta* (*BSS*) and the *Khaṇḍakhādyaka* (*KK*) of Brahmagupta of the seventh century, both of which had already been translated into Arabic. Al-Bīrūnī even began translating *BSS*, but it is not known whether he completed the work. He quotes from both these works in his *India*. This paper deals with these quotations.[1]

First the quotations from *BBS*, in which are given in detail the astronomical theories of Brahmagupta. There are two editions of *BSS*—Dvivedi's and Sharma's. Neither can be called strictly critical. The editions have not been prepared after collation of important manuscripts both of the text and commentaries available and detailed examination of other allied materials, though Sharma's edition gives a few variants from four or five different manuscripts. The text in both the editions is practically the same. All the references in this paper are to Sharma's text.

Both the editions of *BSS* have twenty-four chapters each, arranged in the same manner. Al-Bīrūnī's *BSS* also has twenty-four chapters though in a different order (1, pp. 153-155). *Golādhyāya*, the chapter on spherics, is the twenty-first chapter in the printed editions; it is the first chapter according to al-Bīrūnī. In al-Bīrūnī's *BSS* the twenty-first chapter is on 'calculation of the measures of poetry and metrics' and the twenty-fourth on 'numerical notation in the metrical books'; in the printed editions there is only one chapter on 'metrics' called *'Chandaśeityuttarādhyāya'* and it is the twentieth chapter. *Saṃjñādhyāya,* the twenty-fourth chapter in the printed editions, is not mentioned by al-Bīrūnī, yet he quotes from this chapter when he says that according to Brahmagupta, *Sūrya, Indu, Puliśa, Romaka, Vaśiṣṭha, Yavana* and other *Siddhāntas* (Astronomical treatises) are substantially the same, though giving different times and places while calculating mean positions of planets (xxiv. 3).

It may be observed here that the arrangement in the printed editions tallies with the number of the chapter given in the verse at the end of each chapter. It is also note-worthy that Pṛthūdaka while writing commentary on *BSS* first wrote on *Golādhyāya* and then on the remaining chapters This is evident from his own statement at the end of the commentary (Sharma's ed., IV, P. 1651).

There is another chapter, *Dhyānagrapopadeśādhyāya*, the twenty-fifth, appended to *BSS*. It is not clear what makes al-Bīrūnī say that in this chapter Brahmagupta 'tries to solve the problems by speculation, not by mathematical calculation'. This chapter gives formulas for calculating positions of planets, etc. briefly, and they can all be mathematically established as has already been shown by Dvivedi in his edition. About this chapter Brahmagupta himself says, *'Gaṇitena phale siddhirbrāhme dhyāna-grahe'* (xxiv. 9), that is, the results are mathematically calculated'. Brahmagupta's famous formula, interpolation by using the second difference, is given in this chapter.

Al-Bīrūnī then quotes (I, pp. 368-370, 386) what Brahmagupta means by *kalpa*. This is a day of Brahmā, the Creator, at the beginning of which planets, etc. come into existence and perish at the end of it (i. 28).

1 *kalpa* is 14 *manus* together with their beginning and end, and therefore, is equal to 14 × 71 *mahāyugas* plus $\frac{4 \; mah\bar{a}yugas \times 15}{10}$ or 1000 *mahāyugas* (i. 10).

The *kalpa* commences when all the planets, etc. are between *Revatī* (ζ Piscium) and *Aśvinī* (Arietis) at the beginning of the month *Caitra* and at sunrise at Laṅkā (i. 3-4).

Brahmagupta adds that some astronomers take 994 *mahāyugas* in a *kalpa* while Āryabhaṭa (fifth century) takes it to be 1008 (i. 11-12).

Al-Bīrūnī says (1, pp. 372-374) that according to Brahmagupta one *mahāyuga* consists of 4,320,000 solar years and is divided into 4 *yugas—Kṛta* (1, 728,000), *Tretā* (1,296,000), *Dvāpara* (864,000), and *Kali* (432,000) (i. 7-8). Al-Bīrūnī comments that Brahmagupta criticizes Āryabhaṭa for assuming all the four *yugas* of equal lengths and thereby going against the religious tradition of the Hindus (i. 9; xi. 10).

The revolutions of the sun, moon and planets and those of their apses and nodes in a *kalpa* as given by al-Bīrūnī (11, pp. 16, 186) occur in *BSS*, i, 15-21. The solar, lunar and intercalary months and the civil days in a *kalpa* are given in i. 22-24.

Al-Bīrūnī never saw (1, p. 370) any work of Āryabhaṭa but on the authority of Brahmagupta gives 1,577,917,500 as the number of civil days in a *mahāyuga* as calculated by Āryabhaṭa. What Brahmagupta actually says in the *Tantra-parīkṣādhyāya* (called by al-Bīrūnī as critical Research on the Basis of the Canons) is this—Āŗyabhaṭa knew that there were 4,320,000 solar years in a *mahāyuga* both according to the midnight (*Ārdharātrika*) and sun-rise (*Audayika*) systems, then how did he calculate 1,577,917,500 according to the latter (xi. 5).

Al-Bīrūnī correctly reproduces (II, pp. 28-30, 57-60) the method given by Brahmagupta for calculating the *Ahargaṇa* or civil days (i. 30-31) and the positions of the planets from the beginning of a *kalpa* (i.32). In the latter case to avoid calculation with large numbers, additive quantities till the beginning of *Kaliyuga* are given. These are identical with the data in 1. 52-57.

Al-Bīrūnī gives (I, pp. 243, 267-268, 272, 279-280) a long description of the Mount Meru, the dwelling of the gods and the demons, their day and night and of the shape of the universe and the earth according to the Hindu religious beliefs and quotes Brahmagupta in support. In fact only a few of these statements are given by Brahmagupta in the verses 1-8 of *Golādhyāya* in *BSS* and other occur in the commentary by Pṛthūdaka on these verses—this commentary unedited is appended to Sharma's edition. For instance, Brahmagupta in verse 3 says that the Mount Meru stands high on the surface of the earth but the commentary says that the stars revolve round it and the sun, moon, etc. are visible because of it. Brahmagupta describes the universe as a sphere with the round earth at its centre and it is Pṛthūdaka who says that as it is the nature of the fire to burn, that of the water to flow, and that of the wind to set things in motion, so it is the nature of the earth to stand and hold the things; and so on.

Al-Bīrūnī maintains (I, p. 158) that he never saw any work by Pṛthūdaka yet some of his statements ascribed to Brahmagupta really occur in Pṛthūdaka's commentary, which is in prose.

Brahmagupta refutes the Jaina belief that there are two suns, two moons and fiifty-four stars (xi.3). Al-Bīrūnī quotes (II, p. 82) this but erroneously says that this occurs in the book of the *Veda*.

Al-Bīrūnī knows (I, p. 276) that Brahmagupta does not agree with Āryabhaṭa about the motion of the earth (xi. 17).

The measure of circumference of a circle according to Brahmagupta is $\sqrt{10.\, d^2}$, where d is the diameter (xii. ii. 40). This has been recorded by al-Bīrūnī. (I. p. 168).

Al-Bīrūnī calculates (II, p. 71) the measures of the circumferences in *yojanas* (*yojana*=8 miles according to al-Bīrūnī) of the orbits of the sun, moon, planets and the stars following Brahmagupta's formula. The measurement of the heaven which is 18, 712, 069, 200, 000, 000 *yojanas*, when divided by the number of revolutions of each planet in a *kalpa*, gives its circumference in *yojanas*. Al-Bīrūnī's results are more or less the same as those given by Pṛthūdaka in his commentary on the verses 11-12 of *Golādhyāya* (Sharma's ed., IV, p. 1623; text is incorrect).

Al-Bīrūnī also calculates the radii of these orbits, using $\pi = \sqrt{10}$ approximately as given by Brahmagupta. Pṛthūdaka also has given these distances in his commentary on *Golādhyāya* 31 but comparison is impossible as the text is hopelessly incorrect (Sharma's ed., IV, p. 1636).

Brahmagupta gives earth's circumference as 5000 *yojanas* (i. 37). The diameters of the earth, sun and moon are respectively 1581, 6522 and 480 *yojanas* as given in *Golādhyāya* 32. Al-Bīrūnī's figures are the same (II, p. 77).

Al-Bīrūnī quotes (II, pp. 75-77) Brahmagupta as prescribing two methods for calculating earth's shadow. These are given in *BSS*, xxiii 8-10.

In *India* there are passages (II, pp. 110-112) from *BSS* (xxi. 37-48) in which Brahmagupta appears to support the views expressed in the religious works of the Hindus that the eclipse, solar and lunar, is caused by Rāhu, a demon and chides Āryabhaṭa, Varāha, Śrīṣeṇa, Viṣṇucandra and others for expressing otherwise. Al-Bīrūnī correctly observes that Brahmagupta is trying to adjust science with popular beliefs but is ready to overlook it recalling the fate of Socrates.

Al-Bīrūnī notes (I, p. 376) that Brahmagupta frequently and severely criticizes Āryabhaṭa; for instance, he blames Āryabhaṭa for making the apsis of the moon faster (al-Bīrūnī says slower, which is not correct) and the moon's node slower and thereby confusing the calculation of eclipse. Āryabhaṭa is compared to a worm in the wood, which while eating the wood draws figures without realising it. Just as a deer would not face a lion, so Āryabhaṭa and others, ignorant as they are, would not face the scholar, who understood astronomical theories correctly (i. 62-63). Al-Bīrūnī realises the injustice of this harshness.

There are two more quotations from Brahmagupta in *India* which are not traceable at the present moment. One relates to the use of arithmetic in metrics (I, pp. 147-150). As mentioned above there is a chapter on metres in *BSS*, but it is extremely difficult to decipher it without the help of a commentary.

The second reference is to the use of words signifying numerals, e.g. moon denotes 1; sun 12; etc. (I, p. 177).

So much about the quotations from *BSS*.

Now the *Khaṇḍakhādyaka*. It is, so to say, an astronomical handbook containing important formulas briefly set down and useful for everyday calculations. These start from midnight at Laṅkā. Brahmagupta wrote it thirty-seven years after his first work, *BSS*, that is, in A.D. 665.

At present three editions of *KK* are available—two incomplete and one complete,[2] containing *Pūrva* (first part) and *Uttara* (second part). Al-Bīrūnī was familar with both these parts and quotes from both. He knows (I, p. 156) that in the first part Brahmagupta uses the astronomical constants of Āryabhaṭa's *Ārdharātrika* (midnight) system but in the second book he gives improved methods (*KP*, i.1; *KU*, i.1).

Al-Bīrūnī quotes (II, pp. 46-47) the rules for calculating *Ahargaṇa* or civil days between two dates from *KP* (i. 3-5). He also describes (II, p. 60) a general method for computation of mean places of planets (*KP*, ii, 1-5).

There are two rules supposed to be from the canon *Khaṇḍakhādyaka* to find lords of a year and of a month, (II, pp. 119-120). These rules are not given in *KK* but occur in Bhaṭṭotpala's commentary on this treatise at the end of the first chapter (text p. 39; first rule slightly altered). Both the rules are claimed to be his own.

(In the manuscript used by me for my edition of Bhaṭṭotpala's commentary, the rule pertaining to the calculation of the lord of a month is not introduced by the commentator with the words, *'asmadīyāryeyam'* or 'this verse is mine'. These are, however, given in the manuscript in the Scindia Oriental Institute, Ujjain, which I have now read).

Al-Bīrūnī makes a reference to *KP*, i. 15, when he quotes (I, p. 312) 4800 *yojanas* as the circumference of the earth and also gives the method of correction, namely, corrected circumference = circumference $\times \dfrac{R \text{ sine colatitude}}{\text{radius}}$ as in *KU*, i. 6.

He is probably referring to *KP*, iv. 2, when he says (II, p. 79) that the methods to calculate the diameters of the sun, moon and the earth's shadow, as given in *KK* are the same as those given by al-khwarizmī.

Al-Bīrūnī tabulates (II, pp. 83-85) the twenty-seven *nakṣatras* (lunar mansions), the number of stars in each, the 'polar' longitude and latitude of each junction star. The table on the whole agrees with the figures given in *KP*, ix. 1-10. The extension of each *nakṣatra* (II, p. 87) is the same as in *KU*, i. 7-11. The distance of each *nakṣatra* from the sun, necessary for its heliacal rising is 14 (II, p. 90), the same as in *KU*, v. 7.

Al-Bīrūnī's data (II, p. 91) relating to the 'polar' longitude, latitude, and the distance in degrees necessary for heliacal visibility of *Mṛgavyādha* occur in *KU*, v. 6; the longitude and the distance for *Agastya* are also the same as in *KU*, v. 5 but al-Bīrūnī's latitude is 71° and not 77°.

Al-Bīrūnī describes (II, pp. 91-92) the method for calculating the times for heliacal rising and setting of a *nakṣatra*. This is a reference to *KU*, v. 8-12.

Al-Bīrūnī records (II, p. 116) two rules for calculating the possibility of an eclipse—solar or lunar. One is given in Bhaṭṭotpala's commentary and is claimed to be his own (text p. 104). The other cannot be traced.

The above references show that al-Bīrūnī was acquainted with *BSS* and some parts of Pṛthudaka's commentary though he may not have known it as such. And he was also familiar with *KK*, both *KP* and *KU*. Was al-Bīrūnī's *KK* an expanded version in which Brahmagupta's text was interspersed with Bhaṭṭotpala's explanatory verses composed in the same metre?[3]

NOTES

1 1910 edition is used.

2 This has been edited by the writer of this paper. References are to this edition.

3 For detailed discussion of the text of *KK* see writer's edition.

AL-BĪRŪNĪ AND INDIAN ERAS

R. N. RAI *

Indian National Science Academy
New Delhi

Al-Bīrūnī who visited the north-western part of India along with the armies of Sultān Mahamūd has given an account of the different historical and astronomical eras prevalent in India at that time. Some of the historical eras can be easily traced while a few are quite obscure. He has given an account of the astronomical eras depending chiefly on the *Viṣṇu-dharmottarapurāṇa* and the Brahmagupta school. He seems to have been unaware of the views of the *Vaṭeśvarasiddhānta* and the modern *Sūrya-siddhānta*. In this paper an account has been given of these eras.

Abū Raihān al-Bīrūnī, in his book on India, has discussed many aspects of Indian life, philosophy and culture. The XLIX chapter of his book he devotes to a discussion of Indian eras. He first mentions the eras which have a historical or astronomical connection. These eras are:

1. The beginning of the existence of Brahman.
2. The beginning of the day of the present nychthemeron of Brahman, i.e. the beginning of the *kalpa*.
3. The beginning of the seventh *manvantara* in which we are now.
4. The beginning of the twenty-eighth *caturyuga*, in which we are now.
5. The beginning of the fourth *yuga* of the present *caturyuga* called *Kalikāla*, i.e. the time of Kali. The whole *yuga* is called after him, though accurately speaking, his time falls only in the last part of the *yuga*. Notwithstanding, the Hindus mean by *kalikāla* the beginning of *kaliyuga*.
6. The *Pāṇḍava-Kāla*, i.e. the time of the life and the wars of *Bhārata* Regarding the first he quotes from the *Viṣṇudharmottarapurāṇa* as follows:

'Vajra asked Mārkaṇḍeya how much of the life of Brahman had elapsed; whereupon the sage answered: That which has elapsed is 8 years, 5 months, 4 days, 6 *manvantaras*, 7 *sandhis*, 27 *caturyugas*, and 3 *yugas* of the twenty-eight *caturyuga*, and 10 *divya*-years up to the time of the *aśvamedha* which thou hast offered",

The exact words of the *Viṣṇu--dharmottarapurāṇa* are: [1]

Svenāhorātramānena brahmano'sya jagatpateḥ|
samāṣṭakaṃ gataṃ rājanpañcamāsāstathaiva ca||
ahorātracatuskam ca vartamānadinādgataṃ|
atah param pravakṣyāmi tanme nigadatah śṛṇu||

* *Present address* : 10A/4 Shakti Nagar, Delhi 7.

manavah ṣaḍ gatāssapta sandhyaśca tatha gataḥ|
saptaviṃśadvyatītāśca tathaiva ca caturyugāḥ||
yugatrayaṃ tathātītaṃ Vartamānacaturyugāt|
samvatsarāṇām daśakam tathā kaliyugādgatam||

Before proceeding further I shall explain some of the terms occurring in the above passages. According to Hindu astronomers a day of Brahmā is equal to one *kalpa* and the duration of his night is also the same. So a year of Brahmā consisting of twelve months each of thirty days, contains 720 *kalpas*. On this standard he has a life of a hundred years.

Regarding the duration of one *kalpa*, there are two schools of thought. According to one, it consists of 1008 *caturyugas* divided into 14 *manvantaras*, each of 72 *caturyugas*.[2] According to the other school, it consists of 1000 *caturyugas*[3] divided into 14 *manvantaras*, each of 71 *caturyugas*. The duration equal to 6 *caturyugas* is divided into 15 *sandhis*, each equal to two-fifths of a *caturyuga*. These *sandhis* lie at the beginning of the first *manvantara*, in between the 14 *manvantaras* and at the end of the fourteenth *manvantara*. The life of Brahmā as given by the *Viṣṇudharmottarapurāṇa* is according to the second school.

A *caturyuga* is made up of 4.32×10^6 years and is divided into four parts, each called a *yuga*. These are *kṛtayuga*, *tretā*, *dvāpara* and *kaliyuga*. According to the first school of astronomers, each part is equal, i.e. each *yuga* consists of 1.08×10^6 years. According to the second school, they are divided in the ratio 4:3:2:1, i.e. the *kṛtayuga* consists of 1.726×10^6 years, the *tretā* of 1.296×10^6 years, the *dvāpara* of 0.864×10^6 years and the *kaliyuga* of 0.432×10^6 years.

Thus a day and night of Brahmā according to the second school, will consist of 2000 *caturyugas* and its duration will be 8.64×10^9 years. The duration of a month of Brahmā will be 25.92×10^{10} years and that of a year 311.04×10^{11} years. Using these values, according to the *Viṣṇudharmottarapurāṇa*, the age of Brahmā till the beginning of *Kaliyuga*, will be 26,215,732,944,000 solar years. At the time when Vajra enquired from the sage *Mārkaṇḍeya*, the age of Brahmā, 10 *divya* years of *kaliyuga* had elapsed. Each *divya* year is equal to 360 solar years. So at that time 3600 years of the *kaliyuga* had elapsed. It is to be observed that this is the very year in which the astronomer Āryabhaṭa I claims to have written his famous book the *Āryabhaṭīyam*.

The gauge year taken by al-Bīrūnī corresponds to A.D. 1031 and to the *kali* year 4132. At that time, the age of Brahmā was 26,215,732,948,132 years. At present 5072 years of *kaliyuga* have elapsed and the age of Brahmā now is 26,215,732,949,072 years.

However, all the *purāṇas* and the astronomical books are not agreed upon this age of Brahmā. The *Markaṇḍeya-purāṇa*[4] says, "for a hundred of his years is denominated by *para*, and a *parārdha* or half a *para* is well-known to be composed of fifty years. So then a *parārdha* of his life has elapsed, O Brahman, at the close of which occurred the *mahākalpa* which is named as the *padma*. Of the second *parārdha* which is now passing, O Brahman, the first *kalpa* (or cycle) ordered is this one called the *Varāha*". Similar views have been expressed by *Viṣṇupurāṇa*,[5] *Śrīmadbhāgavata Mahāpurāṇa*[6] and the astronomical work, the *Sūryasiddhānta*.[7] According to this idea, the age of Brahmā till the beginning of the present *kaliyuga* will be 155,521,972,944,000 solar years.

But, as already indicated, according to the astronomers of another school of which the first exponent was Āryabhaṭa I, each *kalpa* consists of 1008 *caturyugas*. According to this school, a day and night of Brahmā will consist of 8,709,120,00 years, a month of 261.273,600,000 years, and a year of 3,135,271,200,000 years. According to Vaṭeśvara[8], an astronomer belonging to the school of Āryabhaṭa I, the age of Brahmā should be 8 years 6 months and 15 days at the beginning of the present *kalpa*. Unfortunately, the stanza giving the information has beeen very badly edited by the editors and this fact has not been stated clearly. But evidence from the *Vaṭeśvarasidhānta* itself clearly indicates that according to Vaṭeśvara, this is the age of Brahmā. In one place he says: "to get the *ahargaṇa* at the beginning of the present day of Brahmā, multiply the number of civil days in *caturyuga* by 6,199,200[9]". This shows that according to the *Vaṭeśvara-siddhānta*, the number of *caturyugas* in the life of Brahmā. upto the beginning of the present *kalpa,* was 6, 199,200. This, when converted into years, months and days, gives 8 years, 6 months and 15 days. When we convert the *caturyugas* into solar years and add the number of years of the present *kalpa* up to the beginning of *kaliyuga,* Brahmā's age comes out to be 26.782,530,120,,000 years.

Al-Bīrūnī himself refers to a *Puliśasiddhānta*,[10] which accepts the age of Brahmā to be the same as that gives by the *Viṣṇu-dharmottarapurāṇa* in years, months and days but agrees with Āryabhaṭa and Vaṭeśvara as regards not only the number of *caturyugas* in *kalpa* but also in the division of the number of years of a *caturyuga* into the four *yugas*. According to him the age of Brahmā up to the beginning of *kaliyuga* will be 26,425,456,200,000 years. But it is very difficult to say to which *Puliśasiddhānta* al-Bīrūnī is referring to here. *Bhaṭṭotpala*, who flourished about 50 years earlier than al-Bīrūnī, in his commentary on *Bṛhatsaṃhitā* in one place has quoted from it stanza which means that the four *yugas* consist of 4800,3600,2400 and 1200 *divya* years.[11] This means that their duration is in the ratio 4:3:2:1:. This is not in accordance with the view expressed by al-Bīrūnī. However, later discussing the distance moved by the planets in a *caturyuga*, he recommended multipying this distance by 1008 to get the distance moved by the planets in a *kalpa*.[12] This he calls *ākāśa-kakṣa* (heavenly orbit). It is also to be observed that the number of revolutions made by the planets, as quoted by Bhaṭṭotpala, according to Puliśacārya, is the same as that given by Āryabhaṭa in his midnight system.[13]

There is a similar difference of opinion, as noted by al-Bīrūnī, regarding the number of solar years which have elapsed since the beginning of the present *kalpa*. According to Āryabhaṭa I and his school, the number of *caturyugas* since the beginning of the present *kalpa* is 459$\frac{3}{4}$ while according to

Brahmagupta, the *Sūrya-siddhānta* and the *purāṇas*, it is $6 \times 71 + 7 \times \frac{2}{5} + 27\frac{9}{10} = 456\frac{7}{10}$. The difference between the two is equal to $3\frac{1}{20}$ *caturyugas*. i.e 13,176,000 solar years. This difference has been noted by Brahmagupta himself.[14]

However, the number of years elapsed since the beginning of the present *manvantara* is less according to Āryabhaṭa I and his school than that according to Brahmagupta and his school According to the former the number of years elapsed till the beginning of *kaliyuga* is 119,880,000 solar years while according to the latter it is 120,528,000 solar years. There is a similar difference regarding the number of years which have elapsed since the beginning of the present *caturyuga*. According to Āryabhaṭa I and his school the number of years elapsed till the beginning of *kaliyuga* is 3,240,000 solar years while according to Brahmagupta and his school, it is 3,888,000 solar years.

As regards the beginning of *kaliyuga* there is no difference between the two schools of astronomers. According to both 5072 years of *kaliyuga* elapsed on Friday, 26th March, 1971 according to the luni-solar calendar, and on Tuesday, 13th April 1971 according to the solar calendar. *Kaliyuga* is supposed to have begun on 18th February 3102 B.C. according to the *audayika* system Āryabhaṭa I and on 17th February 3102 B.C. according to the *ārddharātrika* system of Āryabhaṭa I. The first mention of this era in an inscription is found in the year A.D. 634-35 by king Pulakeśin II of the Cāluka dynasty of Bādāmi. But some Indian and foreign astronomers are of the view that the era is a creation of Āryabhaṭa I or an earlier astronomer by back calculation of the planetary positions from the astronomical constants and the observed planetary positions of that time. According to all Indian astronomers, the planets were in the first zodiacal sign at the beginning of *kaliyuga*.

Most Hindu texts mention that the *Mahābhārata* war took place at the beginning of *kaliyuga*.[15] The Aihole inscription of Pulakeśin II mentions that the temple was constructed 3735 years after the *Bhārata* war and in the year 556 of the *Śaka* era.[16] But Varāhamihira says that we can get the *Yudhiṣṭhira-kāla* by adding 2526 to the *Śakakāla*.[17] According to this view Yudhisthira became King after 653 years of *kaliyuga* had elapsed. The only other text which supports this view is *Rājataraṅgiṇī* by Kalhana of Kashmir (A.D 1148).[18] M. N. Saha has shown that in the *Mahābhārata* the *Kṛttikās* are in many places taken as the first of the *nakṣatras* and are very nearly coincident with vernal equinox. If the date of the *Mahābhārata* war is calculated from this information, the date comes out to be very nearly 2449, B.C.

However, it does not prove that the incidents mentioned in the epic *Mahābhārata* took place in 2449 B.C. for the *Taittirīya-Brāhmaṇa* and the *Śatapatha-Brāhmaṇa* also mention that *Kṛttikā is* the first of the *nakṣatras,* and there is internal evidence in the *Mahābhārata* itself which shows that it was not composed earlier than 400 B.C.

Al-Bīrūnī next speaks of a *Kālayavana* era which, according to his informants, began at the end of the last *dvāparayuga*. There was a King Kālayavana who was a contemporary of Śrīkṛṣṇa but no text or inscription mentions this era.

After these eras which require large numbers to express them, al-Bīrūnī speaks of the eras which are in actual use.
These are the eras of

1) *Śrī Harṣa*;
2) *Vikramāditya*;
3) *Śaka*;
4) *Valabha*; and
5) *Gupta*.

About Śrī Harsa, al-Bīrūnī was misled by some people into thinking that he flourished 400 years before Vikramāditya, a legendary figure of Indian history, though he ultimately got the correct information from the Kashmirian calendar that *Vikrama Samvat* is 644 years earlier than the Harṣa era. According to al-Bīrūnī the *Harṣa era* was in use in the region of Mathura and Kanauj at that time. This is quite in accord with the fact that inscriptions in the Harṣa era have been discovered in the Punjab, Rajasthan, Uttar Pradesh, Central India and Bihar.

Regarding the *Vikrama era*, al-Bīrūnī gives a peculiar method to get the year of the era which is not very clear. In his time, it was associated with the name of Vikramāditya, though according to inscriptions, the first association of the name of Vikramāditya with the era is of the year 794 (A.D. 737) in an inscription found in Dhiniki in Kāthiāwār. In a subsequent inscription dated 795 V.E., it is designated the era of *Mālaveśas*, i.e. the lords of Mālvā. Earlier in an inscription dated 481 V.E., it is called the *Kṛta* era as well as the era of Mālavas and the first association of the name *Kṛta* with the era is in an inscription dated 282 V.E. However, some scholars think that certain inscriptions found in the Taxila and Mathura regions and dated in the years 72 to 199, have been recorded in this era.

There is no unanimity as regards the founder of the era. Some scholars think that there was a king named Gardabhilla, reigning at Ujjain, who was ousted by *Śakas* who were in turn defeated by his son Vikramāditya and the era was promulgated to commemorate this event. Others believe that the era is of foreign origin and marks the accession to the throne of the Parthian ruler Vonones. The era was first used in the Sind and Punjab by *Śakas* and their subordinates, the Mālava tribe, who later took it to Rajasthan and Mālavā when they migrated there. When the tribe was conqurred by the Gupta King Candragupta Vikramāditya, near the end of the fourth century, the era became associated with the lords of Mālavā and later with Vikramāditya.

There is a similar divergence of opinion regarding the founding of the *Śaka* era but there is now overwhelming evidence to show that the era marks the accession of Kaniṣka to the throne though some people believe that it is the continuation of an earlier era with the hundred omitted. This is supported by dates inscribed on a few Jaina and Bauddha images found near Mathura. This date of the accession of Kaniṣka is also supported by the radio-carbon dating of the charred wood of Kuṣāṇa, pre-Kuṣāṇa (Mitra) and post-Kuṣāṇa (Magha and subsequent dynasties) levels at Kauśāmbi in Uttar Pradesh and

TABLE SHOWING THE DIFFERENT ASTRONOMICAL ERAS ACCORDING TO DIFFERENT ASTRONOMERS

	According to Āryabhaṭa	According to the *Viṣṇudharmottara puraṇa* and Brahmagupta School	Accroding to Vaṭeśvara	According to the *Puliśa siddhānta*	According to the *Sūrya-siddhānta*
Age of *Brahman* upto *kaliyuga* 5,072	....	26,215,732,949,072	26,782,530,125,072	26,425,456,205,072	155,521,972,949,072
Beginning of the present *kalpa* upto *kaliyuga* 5,072	1,986,125,072	1,972,949,072	1,986,125,072	1,986,125,072	1,972,949,072
Beginning of the seventh *manvantara* upto *kaliyuga* 5,072	119,885,072	120,533,072	119,885,072	119,885,072	120,533,072
Beginning of the twenty-eight *caturyuga* upto *kaliyuga* 5,072	3,245,072	3,893,072	3,245,072	3,245,072	3,893,072

of the Kuṣāṇa period at Shaikhan Dheri near Charsada in Peshawar district of Pakistan.

The first association of the name, *Śaka,* with the era is to be found in a Jain work named, *Lokavibhāga,* composed by Siṃha-Sūri in the year *Śaka* 380 but a stone casket inscription of the Śaka Satrap Rudrasen I of the year 127 mentions the era to be that of *Kathika* kings, i.e. who are supporters of the Buddhist religion. But no other inscription of the Śaka satrapas mentions the era. The first mention of the name, Śaka, in an inscription is in the Bādāmi-inscription of Pulakeśin I of the year *Śaka* 465. Another interesting fact is the use of the era by Varāhamihira in his *Pañcasiddhāntikā* and its use by the astronomers seems to have kept the era in current use.

Regarding the *Valabhi* and *Gupta* eras al-Bīrūnī writes: "The era of Valabha is called so from Valabha, the ruler of the town Valabha, nearly 30 *yojanas* south of Anhilvara. The epoch of this era falls 241 years later than the epoch of *Śaka* era……… As regards the *Guptakāla,* people say that the Guptas were wicked powerful people, and that when they ceased to exist this date was used as the epoch of an era. It seems that Valabha was the last of them, because the epoch of the era of the Guptas, falls, like that of the *Valabha era,* 241 years later than the *Śakakāla*".[19]

A lot of confusion regarding the origin of the *Gupta era* was created by this wrong rendering of al-Bīrūnī's text by Prof. Sachau. It indicated as if the Guptas, were exterminated in the year 241 of *Śakakāla*. However, Prof. William Wright of Cambridge later showed that the translation should have been: "And as regards the *Gupta era,* (the members of the dynasty) were, it is said, a race wicked (and) strong, and so, after they became extinct, people dated by them". This shows that the intention of al-Bīrūnī was to say that people continued to use their era even after the Guptas were exterminated.

The whole thing was cleared by Fleet after the discovery of the Mandasor inscription of *Mālava-Samvat* 529 which showed that emperor Kumāragupta was living in the year 493 of Mālava era, i.e. in A.D. 436. It has now been proved that *Gupta era* and *Valabhi era* are the same. On the decline of the Gupta power in western India, their former feudatories, the *Maitrakas* of Valabhi continued to use the *Gupta era* and it came to be known as the *Valabhi era* in that part of the country. The only difference between the two eras is that the epoch of the *Valabhi era* is the first day of the bright half of the month of *Kārttika,* Śaka 240, corresponding to 21st October, 318 and the epoch of *Gupta era* is the first day of the bright half of the month of *Caitra Śaka* 241, corresponding to 8th March, 319.

Al-Bīrūnī next states that "The era of the astronomers begins 587 years later than *Śakakāla*. On this era is based the canon *Khaṇḍakhādyaka* by Brahmagupta, which among Muhammadans is known as *Al-arkand*".

Here also there seems to be some error in the translation. The era of the astronomers does not begin in *Śaka* 587. As is well-known most astronomers, beginning with Varāhamihira have written *karaṇa-granthas* which give simplified methods of calculating the *ahargaṇa* and the position of the planets. Al-Bīrūnī himself mentions five of these:

(i) *Pañcasiddhāntikā* of Varāhamihira, *Śaka* 427,
(ii) *Khaṇḍakhādyaka* of Brahmagupta, *Śaka* 587,
(iii) *Karaṇasāra* of Vaṭeśvara, *Śaka* 821,
(iv) another by Durlabha of *Śaka* 848 and
(v) *Karaṇatilaka* of Vijayanandin, *Śaka* 888. Other well-known compendiums are:

(a) The *Laghumānasa* of Muñjāla, *Śaka* 854;
(b) The *Dhīkoṭi-karaṇa* of Śrīpati, *Śaka* 961;
(c) The *Karaṇaprakāśa* of Brahmadeva Gaṇaka, *Śaka,* 1014;
(d) The *Karaṇakutūhala* of Bhāskara II, *Śaka* 1105; and
(e) The *Grahalāghava* of Gaṇeśa Daivajña *Śaka* 1442.

There must be many more which have not been brought to light. All these take a certain *Śaka* year as the starting point and then give simplified methods of calculating the number of civil days after that epoch and the calculation of the position of planets and other important astronomical constants.

Al-Bīrūnī next speaks of some other places and eras. It is very difficult to identify the places except Mārligala which he himself has identified with Taxila. The eras cannot also be identified. Perhaps the era prevalent in Nirahara can be identified with the *Bhātika era,* prevalent in the Jaisalmer area, with some of the hundreds omitted[20]. The *centennium* year referred to by him is the well-know *Saptarṣikāla* or *Pahāḍīkāla* used in ancient times in the Punjab and Kashmir and even now used by almanac makers in Kashmir and the hills around it.

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AL-BĪRŪNĪ ON INDIAN ARITHMETIC

A. K. BAG

Indian National Science Academy,
1 Park Street, Calcutta 16

Al-Bīrūnī (A.D. 973-1048), the great Islamic encyclopaedist stayed in India from A.D. 1017 to A.D. 1030 and studied critically the arts, literature and sciences of the Indians. His observations on some of the topics and concepts of Indian arithmetic namely numerals, decimal place-value, *pāṭī* and the use of dust numerals, Indian arithmetic in Arabia, rule of three and fraction have been analysed in this paper to show the type of arithmetical elements and concepts borrowed by the Arabs before al-Bīrūnī and by al-Bīrūnī himself.

INTRODUCTION

Al-Bīrūnī (A.D. 973-1048), the mathematician and astronomer, physicist and geographer, physician and historian, is generally held in high respect for his encyclopaedic knowledge. His mother tongue was Khwārazmin, an Iranian language and he acquired a remarkable knowledge of the Greek and Arabic sciences and literature and was in full command of the best scientific theories of his time. He stayed in India for nearly thirteen years from A.D. 1017 to A.D. 1030 and devoted himself to the study of arts, literature, and sciences of the Indians and tried to make a full use of all the documents that came to his hand, though there is evidence that many of the sources he used, have disappeared since then. However, from the works of Bīrūnī now available, we obtain a comprehensive account of his critical study of facts, extending from his reference to original sources to the analysis of scientific theories. Hence Bīrūnī's citations and observations may be considered more authoritative and valuable than those of the contemporary or even anterior Arab workers. The present paper discusses some of the concepts of arithmetic referred to by al-Bīrūnī and his contemporary Arabian scholars with reference to India.

NUMERALS

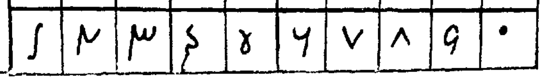
Bīrūnī wrote two books on numerals.[1] They are:

1) *Kitāb al-arqam* (Book of Numbers),

and 2) *Tazkira fi al-ḥisāb w'al-madd bi al-arqam al-Sind W'al Hind* (Description of arithmetic and system of counting with the numerals of Sind and India)

It is not known whether these two works are still extant. In his *Athār-al Bākiyā*[2] (Chronology of Ancient Nations—1000 A.D.), Bīrūnī has incidentally referred to two types of notation of numbers namely the alphabetic (*abjd*) system (*Hurūf al-jummal* or *Ḥisāb al-jummal*) and the modern numerals as *al-arqam al-Hind* (Indian numerals). Bīrūnī in his *Kītāb al-tafhim li-awā'il* *sinā'at-tanjīm*[3] (The Book of Instructions in the Art of Astrology) has given both these notations of numbers. The alphabetic system (*Hurūf al-jummal*), as used by Bīrūnī was apportioned in orderly sequence to 26 alphabets though initially there was no particular order in their use. It was based on the values of the alphabets without use of decimal place-order. This notation seems to have been used exclusively by Arabian astronomers. The other system (*al-arqam al-Hind*) expressed in symbols by Bīrūnī is shown in the following table:—

Numerical symbols used by Bīrūnī (c. 1000 A.D.)	1	2	3	4	5	6	7	8	9	0



As regards Indian numerals Bīrūnī wrote that Vyāsa, son of Parāśara, rediscovered fifty *akṣaras* (letters) from some lost and forgotten alphabets, which were originally lesser in number. These alphabets, by and large, helped to develop various forms or systems of local alphabets through their use in different regions in India. The symbols used for these alphabets were varied in shape and character. In his *Tārikh al-Hind*[4] (Chronicles of India), Bīrūnī writes: "As in different parts of India the letters have different shapes, the numerical signs too, which are called *aṅka,* differ. The numerical signs which we use are derived from finest forms of Hindu signs".[5]

As regards the sign of zero Bīrūnī[6] writes, "when zero, has to be written in places lacking a number, its circle must have a line over it 8 touching, to distinguish from *hā,* but in the Indian notation this line is unnecessary for there is no resemblance to *hā*". The dot symbol (•) was then also used as can be seen from Bīrūnī's table. Al-Khwārizmī (*c.* A.D. 825), an eminent Arabic mathematician, wrote a work on Hindu system of numeration entitled *Algoritmi de numero Indorum* (Latin translation of the 12th century is available; the original Arabic version of the work is lost). A few other Arabian scholars besides Severus Sebokht, a Christian monk, have also referred to Hindu numerals. Hence there is no ambiguity that numerical signs for nine units and zero are derived from the Hindu signs. For this reason Reinaud, Woepcke, Rosen, Strachey, Taylor and a host of other writers came to the same conclusion.[7] George Sarton,[8] remarked that al-Bīrūnī's account gave the best medieval account of the Hindu numerals.

Decimal Place-value System

The numerals (*al-arqam al-Hind*) given in the table have been used by Bīrūnī in his book, *Kitāb al-tafhim* to express decimal place-value system or concept. He kept silent over the fact whether the concept of decimal place-value was borrowed from India or developed by him independently. However, he has admitted that while the Greeks and the Arabs did not go beyond 10^3, the Indians could easily compute much beyond that with the help of a decimal scale. This leads evidently to the discussion whether the decimal place-value concept was originally known in India before Bīrūnī. In India it is well-known that from the time of the *Saṃhitās* (B.C. 1500), a decimal scale[9]: *eka* (1), *daśa* (10, *śata* (10^2), *sahasra* (10^3...... *upto* 10^{18} was known and a large number like, *ṣaṣṭiṃ sahasrā sapta śatāni navatiṃ nava* (60, 799) was expressed by placing the word-numerals of higher order to be followed by one of lower order in the scale. This successive placing of *sahasra, śata, daśa, eka* for the expression of a large number in left to right order of gradually decreasing values obviously shows that the idea of decimal place value was implied. From the second century A.D. onwards, this order of expressing a number by using word numerals was reversed with a new type of word numerals, for example, in the new type *netra* (2)—*aṣṭa* (8)—*śara* (5)—*rātri* (1) signifies actually 1582 instead of 2851. This is verified from examples available in Sanskrit astronomical and mathematical works and by the evidence derived from the Sanskrit text numerals as well as the symbols used for them in the Dinaya Inscription (A.D. 760). This order is so for no obvious reason, except possibly for emphasizing the idea that the decimal place-value concept remains unchanged in whatever order (right or left) the numerals are arranged when the number is always expressed by reading from higher to lower order in the scale (*vide* Table, 177-8). It is significant to note that a number was also invariably expressed by the use of symbolic numerals retained in a left to right order since their introduction in India from A.D. 400.

That the decimal place value concept was current has also been attested by Vyāsa[11] (before A.D. 700) in his philosophical work, *Yogadarśanabhāṣya* (ch. 3, *sū.* 13) thus: *'yathaikā rekhā śatasthāne śataṃ daśasthāne daśa ekaṃ caikasthāne'*, i.e. 'a (numerical) sign, denotes hundred in the *śata* place, ten in the *daśa* place, and one in the *eka* place'. The very similar language is used by Śaṅkarācārya (*c.* A.D. 800) in his *bhāṣya* on the *Vedāntasūtra* (II. 2. 17): *yathā caikāpi satī rekhā sthānānyatven niviśamānaika daśaśatasahasrādi śabdapratyayabhedamanubhavati* i.e 'one and the same (numerical) sign when occupying different places, is conceived as meaning either one, ten, one hundred, a thousand etc.' These two illustrations establish without any doubt that by the time of compositions of these two works, the decimal place-value concept must have been well established and was generally known.

Thus we see in India a continued tradition of a decimal scale system originally from the *Saṃhitā* period (*c.* B.C. 1500) followed by the use of symbols in the scale since A.D. 400 involving the idea of decimal place-value. There is no evidence, however, that such use of the word-numerals followed by symbolic use based on a decimal place-value scale, was known to any other country at a time before their use in India. This demonstrates that al-Bīrūnī obviously made use of this Indian concept of decimal place value in his book.

It is rather strange to note that al-Khwārizmī[12] (A.D. 825) who translated Indian work on arithmetic did not refer to the use of the decimal place-value in India, for he expressed 7586 as 7000+500+80+6, indicating thereby his

TABLE

Decimal Scale			(10^5)	(10^4)	(10^3) *sahasra*	(10^2) *śata*	(10) *daśa*	(1) *eka*	*Number*
(A) Word-numerals of the *Saṃhitā* Period (B.C. 1500)	(1)	*Ṛg. Veda* (i.53.9)	—	—	*ṣaṣṭiṃ sahasrā* (60×10^3)	—	*navatiṃ* (9×10)	*nava* (9×1)	= 60, 099
	(2)	*Ṛg. Veda* (i. 164, 11)	—	—		*sapta-śatāni* (7×10^2)	*viṃśati* (2×10)	—	= 720
	(3)	*Ṛg. Veda* (ii. 1. 8)	—	—	*sahasrāni* (1×10^3)	*śata* (1×10^2)	*daśa* (1×10)	—	= 1110

Decimal Scale			(1)	(10)	(10^2)	(10^3)	(10^4)	(10^5)	
(B) Word-numerals[18] new type from c. A.D. 200	(1)	*Pauliśa Siddhānta* (A.D 200.)	*nava* (9)	*ṛtu* (6)	*rūpa* (1)	—	—	—	= 169
	(2)	*Sūrya-Siddhānta* (A.D. 400)	*ṣaṭ* (6)	*śūnya* (0)	*indriya* (5)	*nava* (9)	*vasu* (8)	*viṣaya* (5)	= 589506
	(3)	Inscription at Cambodia (A.D. 604)	*rasa* (6)	*dasra* (2)	*śara* (5)	—	—	—	= 526 (śaka)
	(4)	Inscription at Jāvā (A.D. 732)*	*śruti* (4)	*indriya* (5)	*rasa* (6)	—	—	—	= 654 (śaka)
	(5)	Dinaya Inscription at Jāva A.D(760.)	*nayana* (2)	*vasu* (8)	*rasa* (6)	—	—	—	= 682 (śaka)

TABLE

Decimal Scale			(10^6)	(10^5)	(10^4)	(10^3)	(10^2)	(10)	(1)	*Number*
(C) Numerical Symbols from A.D. 400	(1)	*Bakhshālī Ms.* (A.D. 400) 17 verso							•	= 300
	(2)	*Bakhshālī Ms.* (A.D. 400) 56 recto							•	= 846720
	(3)	Khèmre Inscription at Sambor (A.D. 683)						•		= 605 (śaka)
	(4)	Malaya Inscription at Palembang (A.D. 684)						o		= 606 (śaka)
	(5)	Dinaya Inscription at Java (A.D. 760)								= 682 (śaka)

ignorance of decimal place-value numeration. Abu al-Wafa (10th century A.D.) in his work *Mā Yahtāj ilaihi al-'Ummāl wa al-kitāb min Sinā'at al-Ḥisāb* (The Sufficient Book on Mathematics) expressed number in words without any use of numerical symbols and used a simple dash for zero. Al-Nasavī[13] c. A.D. 1030,), however, states that the symbolism of numbers was unsettled in his day. but in his work in Hindu arithmetic, *Al-Mugni'fī al-Ḥisāb al-Hindi* (the Sufficient Account on the system of Indian Mathematics) he has made use of the decimal place-value concept. It may, therefore, be concluded that the decimal place-value concept was borrowed from India by al-Nasavī or some other scholar before Bīrūnī of which the later scholars were not aware of.

PĀṬĪ AND THE USE OF DUST NUMERALS

The Indians performed their computations on a board (*pāṭī*) with a piece of chalk or on sand (*dhūli*) spread on the ground or on the *pāṭī*. Thus, terms like *pāṭīgaṇita* (the science of calculation on the board) or *dhūlikarma* (dust numerals) came to be in use in India. The latter term has been referred to by Bīrūnī[14] and others.[15] The *pāṭī* was used by Indians for computations of fundamental operations. In the methods of multiplication, division, square, cube, square-root and cube-root etc. given by Brahmagupta (A.D. 628), Mahāvīra (A.D. 850), Pṛthūdakasvāmī (A.D. 868), *Śrīdhara* (A.D. 900), Bhāskara II (A.D. 1150)[16] etc. where the figures were large and several lines could not be fitted on the *pāṭī*, the practice of obliterating digits or rubbing out digits by fingers not required for subsequent stages of work was common. For working on the *pāṭī* the student had to commit to memory all the rules required for the solution of the problems. Along with each step in the process of calculations the *sūtra* (rule) had to be repeated by the student, as is found still in a village *pāṭhaśālā* (beginners' school) in India, under strict supervision and guidance of the teacher. The details of the methods or procedures adopted for this purpose are available to us in various commentaries, viz. the commentaries of Pṛthūdaka, Gaṇeśa, on the *Brāhmasphuṭasiddhānta* and the *Līlāvatī* etc. Saidan[17] recently after a survey of nineteen important Arabic texts and from statements of al-Uqlīdisī (A.D. 952) came to a definite conclusion that the words like *takht* (dust computing board), *ghubār* (dust numerals), *turāb* (dust numerals), and *al-hind* (Indian or Indian way) used extensively by the Arab scholars got their ideas from the Indian practice when the knowledge of the Hindu arithmetic found its way to Arabia. There is a great deal of controversy regarding the actual import of the terms.[18] But our subsequent discussion on the subject will also justify the views expressed by Saidan. It is interesting to note that it is the Arabian scholar al-Uqlīdisī (A.D. 952) who first of all used paper and ink to improve the system in a better way.

The use of *pāṭī* as a type of abacus[19] has been suggested by some European scholars like Bayley, Fleet and several others. we find no reasonable ground for such a suggestion, for it is indeed difficult to trace any connection or similarity between *pāṭī* and abacus.

Indian Arithmetic in Arabia

There were two different arithmetical systems in vogue in Arabia, one using Hindu methods and the other, the indigenous Arabic method. This view is generally held by scholars, like Cantor, Medowi (a Russian scholar) and Saidan, deeply versed in Arabic literature.[20] In a critical survey it is found that the Arabic Arithmetic received much from that of the Indians in the method of multiplication, division, square-root, cube-root, in the concept of highest common factor and lowest common multiple and probably in some other topics. The Arabians utilised the Indian methods of calculation in a more explicit form. In the computation of fundamental operations. the scholars like al-Khwārizmī (A.D. 825), Abu al-Wafa (10th century), al-Uqlīdisī (A.D. 952), al-Nasavī (*c.* A.D. 1025) and various other scholars adopted various schemes which are Hindu in disguise. To clarify this, a reference to the working in the method of multiplication adopted by the Arabians is shown below. The method is characterized by the use of paper and ink where *pāṭī* and chalk have been used by the Indians.

To multiply 324 by 753.

(A) *Hindu Method.*[21]

(i) Two numbers are arranged thus and the multiplication starts with numbers shown by arrow mark.

```
7 5 3          = multiplier
    3 2 4      = multiplicand.
```

(ii) The result 3×7, i.e. 21 is placed below 7 as put here and next two numbers to be multiplied are shown by arrow-mark.

```
  7 5 3
2 1   3 2 4
```

(iii) The product of 5 and 3, i.e. 15 is placed in such a way that 5 of the number 15 is placed under the multiplier 5 and 1 of the number 15 is carried over to the left. Evidently 1 of the number 21 is rubbed out and $(1+1)=2$ is substituted, in its place. The multiplication then starts with numbers shown by arrow-mark.

```
  7 5 3
2 2 5 3 2 4
```

(iv) Now the result 3×3, i.e. 9 is placed under the multiplier 3 giving

7 5 3

2 2 5 9 2 4

(v) The multiplier, (i.e. 753) is now moved one place to the right, and the multiplication begins with numbers joined by the mark.

7 5 3

2 2 5 9 2 4

(vi) The product of 7×2, i.e. 14 must be placed under the multiplier 7 such that 5 is rubbed out and $(5+4)=9$ is put in its place. 1 of the number 14 is carried over to the left, so that the left number 2 is replaced by $(2+1)=3$. Thus we get

7 5 3

2 3 9 9 2 4

Continuing this process upto the last digit 4 of the multiplicand, we get the result as follows:

7 5 3

2 4 3 9 7 2

∴ The result of the product is 243972.

(B) *Arabic Method*[22]:

4 3 9 7

~~3~~ ~~0~~ ~~7~~ ~~6~~

~~2~~ ~~8~~ ~~9~~ ~~8~~ 2

2 ~~1~~ ~~5~~ ~~9~~

3 2 4 = 243972

7 5 3

7 5 3

7 5 3

The multiplication starts with numbers shown by arrow-mark and placed at the top of 7. Then the remaining numbers of the multiplicand 753 are multiplied by the multiplier, number 3, following a carrying over process. Then the multiplicand 753 is shifted one place to the right and the process is repeated as in Hindu method.

The Arabic illustration is taken from the work of al-Nasavī (*c.* A.D. 1025) who calls this method *al-amal al-Hindi* and *tārikh al-Hindi* (the method of the Hindus).

Al-Uqlīdisī (A.D. 952) treated the method of extraction of cube-root at the end of his book, *Kitāb al-Fuṣūl fi al-Ḥisāb al-Hindi* (the Book having different chapters on Indian Mathematics). He pointed out that the previous scholars had no satisfactory knowledge of cube-root and he himself was the first to deal with the operation in full. Bīrūnī was also aware of this besides other fundamental operations. In this connection it must be noted that the method of square-root and cube-root based on a decimal place-value scale were already discovered by Āryabhaṭa I (A.D. *c.* 499) in India. The algebraical methods of extracting square-root and cube-root were also known to the Greeks who had no knowledge of decimal place-value. In view of the decimal and other Indian methods of calculations adopted by the Arabs, it may be presumed that the Arabic methods of extraction of square-root and cube-root were also borrowed from the Indians.

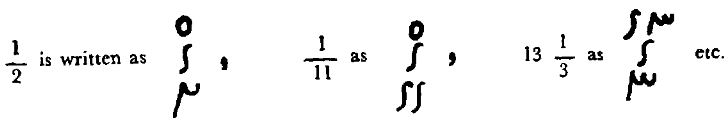
Rule of Three

The Arabs held the method of the Rule of Three (*trairāśika*) in a very high esteem as is evidenced from Bīrūnī's references. Bīrūnī himself wrote a separate treatise entitled *Fi raśikat al-Hind*[23] (The *rāśika* of the Hindus) dealing with Hindu Rules of Three. He had also used an example of *vyasta trairāśika* (the Inverse Rule of Three) in his *India.*[24] It is not yet known whether it is Bīrūnī who first introduced the Rule of Three into Arabia or was discovered by any other scholar before him. However, this rule in detail was found in the *Bakhśhālī Ms.* (4th century A.D.) and in the works of Āryabhaṭa I (A.D. 499), Brahmagupta, (A.D. 628), *Mahāvīra* (A.D. 850) etc. and was perfected before it was known to China and other parts of the world. This rule was transmitted to Arab probably in the eighth century and thence travelled to Europe where it came to be known as the Golden Rule.[25]

Fraction

Another important concept that found its way to Arabia was the use of the notation of common fraction free from linguistic and metrological limitations. Like vedic Indians[26] the Arabs used one single word-name for each of the principal fractions $\frac{1}{2}, \frac{1}{3}, \frac{1}{4}$ upto $\frac{1}{10}$. The system is basically concerned with the naming of fractions in terms of the principal ones. For $\frac{1}{12}$ is named as $\frac{1}{2}$ $\frac{1}{6}$ or $\frac{1}{3}$ $\frac{1}{4}$. Another practical system was to avoid this by expressing fractions in terms of submultiples of certain metrological unit, namely *dīrham* and *qīraṭ*. The study remained linguistic with no use of symbolic forms. The symbolic expression of fraction is first found in India in the *Bakhshālī Ms*[27].

(A.D.400). Here $\begin{matrix}2\\1\\2\end{matrix}$ represents $2\frac{1}{2}$, $\begin{matrix}1\\1\\2\end{matrix}$ as $1\frac{1}{2}$ and there are given many other similar examples. Taylor[28] who examined a number of Mss. of the *Līlāvatī* and its commentaries also informs us that this was the manner of expressing fraction of the Hindus. The Arabian scholar al-Nasavī[29] (A.D. 1034) first used $\begin{matrix}237\\8\\12\end{matrix}$ to mean $237\frac{8}{12}$. Examples of similar types are also found to appear in eleventh century Arabian works. For instance.



Bīrūnī referred to the operations of fraction and the reduction of fractions without any remarks on Indian or Arabian system. From above, there is no denying the fact that Arabian knowledge of fraction was derived from that of the Indians.

To sum up, the paper gives us a glimpse of the type of a sample survey to draw a picture of the nature of Indian arithmetic as handed down to the Arabs. To find out the actual elements and the concepts borrowed by the Arabians, the Arabic works between A.D. 800 to A.D. 1200 must be thoroughly explored.

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AL-BĪRŪNĪ ON THE DETERMINATION OF LATITUDES AND LONGITUDES IN INDIA

S. N. SEN
Indian Association for the Cultivation of Science, Calcutta

Observations of al-Bīrūnī, an outstanding astronomical geographer of his time, on the Hindu methods of finding terrestrial latitudes and longitudes are of more than ordinary interest. His statement in his *India*: 'In what way the Hindus determine the latitude of a place has not come to our knowledge' is puzzling. Likewise, his remark: 'The Hindus employ in this subject methods which do not rest on the same principle as ours. They are totally different and however different they are, it is perfectly clear that none of them hits the right mark' requires closer scrutiny. This has been done in this paper, both by reference to Bīrūnī's own citations and to Sanskrit texts now available. Bīrūnī's own method of determining longitudes from latitudes and distances as given in his *Taḥdīd* and *al-Qānūn al-Mas'ūdī* is discussed.

Abū Rayḥān Muḥammad ibn Aḥmad al-Bīrūnī's scientific interests, as is well known, covered a wide range of subjects from astronomy, mathematics and related matters to medicine, religion, philosophy and magic. The encyclopaedic nature of his writings will be abundantly clear from Boilot's excellent bibliographic studies.[1] Kennedy has estimated that about 146 titles credited to Bīrūnī, of which only 22 works are at present known and 13 available in publication, could have easily run into 13,000 printed pages, a formidable output by any standard.[2] About fifty percent of this great bulk of writings concern astronomy, mathematics, astronomical geography and mechanics, which clearly emphasize his predilection for exact sciences,—subjects readily lending themselves to mathematical treatment. As an astronomer, he was highly competent, if not an innovator in the sense of proposing new planetary schemes or astronomical theories and concentrated his energies on comparative studies of different methods and theories in vogue among peoples of different cultures, both before and during his own times. This largely accounts for the great historical value of his writings in astronomy, and for that matter in other subjects in which the same attitude of the scientist-historian is discernible.

As an astronomical or mathematical geographer, Bīrūnī was outstanding,—a giant among giants, trying to do for medieval geography what Ptolemy had attempted for the ancient. While the great Alexandrian had to depend largely on travellers' and mariners' accounts and less on results of actual experimental observations because few were available, the Khwārazmain himself determined latitudes and longitudes of a large number of places with refined techniques and consequently with greater accuracy. While still in his teens, Bīrūnī determined the latitudes of Kāth by observing through a graduated ring the meridional altitudes of the sun. Later on he collaborated with Abū-l-Wafā (940-997/98), veteran astronomer of Baghdād, in arranging for simultaneous observations of a lunar eclipse (May 24, 997) and determined the longitude difference between Kāth and Baghdād. He made similar eclipse observations from Gurgān (February 19 and August 14, 1003) and from Jurjāniyya (June 4, 1004) for the same purpose. As regards the much simpler determinations of latitudes from solar meridional altitudes observed by graduated rings, astrolabes or sun-dials, Bīrūnī carried out quite a number of them,—in fact, it appears that he did it as a matter of routine whenever he visited a new place, and utilized these results, in combination with known or measured terrestrial distances in *farasakhs*, to compute longitude differences by applying the methods of spherical triangles. His researches on the determination of longitudes and latitudes, the earth's dimension and many astronomical elements such as the obliquity of the ecliptic are set forth in his important work the *Kitāb fī* Tahdid Nihayat al-makin li-Tashih Masafat *al-Masākin*, simply the *Tahdīd*,[3] composed about 1025 A.D. some 25 years after his first major work the *Chronology of Ancient Nations* and six years before his most voluminous work on India, the *Ta'rīkh al-Hind*. These elements are also incorporated in his *Magnum opus al-Qānūn al-Mas'ūdī*.[4]

LATITUDES

In his *Tarīkh al-Hind*, Bīrūnī maintains his interest in his astronomical geography emphasizing, as one would naturally expect of him, the Indian concepts and methods and comparing and contrasting them with those of the Arabs. On latitudes and their measurements from the equator north or south he notices the Hindu definition of the equator in chapter XXVI (The shape of heaven and earth according to the Hindu astronomers) as follows: "The line which divides the two earth-halves, the dry and the wet, from each other, is called *Niraksha*, i.e. *having no latitude* being identical with our equator. In four cardinal directions with relation to this line there are four great cities:—Yamakoṭi, in the east; Laṅkā, in the South; Romaka, in the west; Siddhapura, in the north"[5]. Furthermore:

"The earth is fastened on the two poles, and held by the axis. When the sun rises over the line which passes both through Meru and Laṅkā, that moment is noon to Yamakoṭi, midnight to the Greeks and evening to Siddhapura". This, he observes, was according to Puliśa and Āryabhaṭa.

Varāhamihira in his *Pañcasiddhāntikā* expresses the above as follows:[6]
udayo yo laṅkāyāṃ so'stamayah savitureva sidhapure |
Madhyāhno yamakoṭyāṃ romakaviṣaye' rddharātrah sah||

"What is sun-rise in Laṅkā is sunset in Siddhapura, midday in Yamakoṭi and midnight in Romaka country".

In the *Āryabhaṭīya*—where the same verse is met with, *yavakoṭyāṃ* is used for *yamakoṭyāṃ* and *syāt* for *sah*.[7]

Laṅkā lies on the equator and is central, the prime meridian passing through it, Yamakoti and Romaka lie on the east and west of Laṅkā, while Siddhapura is diametrically opposite to it. Bīrūnī tried to identify these places, but was baffled by the existence of Siddhapura 180° from Laṅkā where, according to the common and general belief, there should be 'nothing but unnavigable seas'.[8]

Bīrūnī reports the following values of latitudes of a few places he was able to collect from Hindu astronomical works in original Sanskrit or Arabic translations.[9]

Ujjain (Ujjayinī)	—	24°	(according to all Hindu canons)
		22°29′	(according to the *Composition of the Spheres* by Ya'qūb ibn Ṭāriq, based on *al-Arkand*, that is *Khaṇḍakhādyaka*).
		$4\frac{3}{5}$	(do)
Kanoj	—	26°35′	(Balabhadra)
Tāneshar (Thāneśwara)	—	30°12′	(Balabhadra)
		27° (?)	(Abū-Aḥmad)
Karli (?)	—	28°	(Abū-Aḥmad)
Kashmir	—	34°9′	(according to *Karaṇasāra* of Vitteśvara).

He rejects Yākūb's low value of $4\frac{3}{5}$° for Ujjayinī. 22°29' is probably Āryabhaṭa's value which is actually 22°30'.[10] *Pañcasiddhāntikā* gives 24°.[11] Bīrūnī then gives his own findings of latitudes for a number of places as follows:

Lauhūr[(a)]	—	34°10′	Waihand (Attok)	—	34°30′
Ghazna	—	33°35′	Jailam	—	33°20′
Kābul	—	33°47′	Nandna[(d)]	—	32° 0′
Kandī[(b)]	—	33°55′	Sālkot (Sialkot)	—	32°58′
Dunpur[(c)]	—	34°20′	Mandakkakor[(e)]	—	31°50′
Lamghān	—	34°43′	Multān	—	29°40′
Purshāvar (Peshwar)	—	34°44′			

[(a) Different from Lahore. (b) On the road from Ghazna to Peshawar. (c) Unknown. (d) The fortress on the mountain Bālnāth overhanging the Jailam where Bīrūnī was kept under detention by Sultān Maḥmūd. (e) Fortress of Lahore. (See, Sachau's notes, *India*, II, 341)].

The main idea behind collecting the latitudes of a large number of places in India has been to compute their longitude differences from a knowledge of their measured distances which Bīrūnī had applied successfully as we shall see in what follows.

Bīrūnī has not discussed Hindu methods for determining latitudes, but what is very puzzling in his statement: "In what way the Hindus determine the latitude of a place has not come to our knowledge".[12] He had known the *Sindhind*, or the *Brāhmasphuṭasiddhānta*, the *al-Arkand* or the *Khaṇḍakhādyaka*, both by Brahmagupta, in the Arabic translations of al-Fazārī and Ya'qūb ibn Ṭarīq, and the works of al-Khwārizmī, al-Kindī, Abū-Ma'shar and a few others and himself translated, from the original Sanskrit versions, the

Pauliśa Siddhānta and the *Khaṇḍakhādyaka*. In all these texts, the usual methods of determining latitudes from equinoctial shadows or from the sun's zenith distances and declinations on any day are discussed. Take, for example, the following rule given in the *Khaṇḍakhādyaka* :[13]

viṣuvatkarṇavibhakte saṅkucchāyāhate pṛthak trijye|
lambākṣajye cāpaṃ viṣuvajjyāyāḥ svadeśākṣaḥ||

"The gnomon and the (equinoctial) shadow multiplied separately by the radius and divided by the hypotenuse corresponding to the equinoctial shadow give the *R*sine of the colatitude and the *R*sine of the latitude of the place respectively. The arc corresponding to the *R*sine of the latitude is the latitude"

The method involves the measurement of the shadow cast by a gnomon of the sun at the meridian on the equinoctial day. The line joining the apex of the gnomon and the tip of the shadow is the hypotenuse. The angle contained between the gnomon and the hypotenuse is the latitude ϕ, and how $\sin\phi$ and therefore ϕ are to be found is clearly indicated.

The *Pañcasiddhāntikā*[14] gives the following rules which possibly formed part of the *Pauliśa Siddhānta* :

viṣuvaddinamadhyāhūcchāyāvargātsavedakṛtarūpāt|
mūlena śataṃ viṃśa viṣuvacchāyāhataṃ chindyam||
labdhaṃ viṣuvajjīvā cāpamato'kso'tha vā yatheṣṭadine|
meṣādyapakramayutastulādiṣu vivarjitaḥ svākṣaḥ||

"The equinoctial shadow multiplied by 120 is to be divided by the square root of the sum of the square of the equinoctial midday shadow (of the gnomon) and 144. The quotient is the *R* sine of latitude and the corresponding arc the latitude. Alternatively, the sun's declination in the (six) signs beginning with Aries added to, and the same in the (six) signs beginning with Libra deducted from, the arc (determined by the above method) on any given day give the latitude of the place".

On the equinoctial day, the sun's zenith distance z = the latitude ϕ of the place. On any other day, $\phi = z \pm \delta$ where δ is the sun's declination. According to the rule, ϕ and z are given by:

$$R \sin\phi = \frac{120\ S_E}{\sqrt{S^2{}_E + 144}}$$

$$R \sin\phi = \frac{120S}{\sqrt{S^2 + 144}}$$

where S_E is the length of the equinoctial midday shadow, S the shadow length on any other given day and R the radius equal to 120′. 144 represents the square of the gnomon of 12 *aṅgulas* in height. Rules for finding the sun's declination on any day from its longitude and the greatest declination (24° assumed in *Pañcasiddhāntikā*) are given elsewhere in the text (III.35).

The *Pañcasiddhāntikā*[15] also contains rules for finding the latitude from the altitude of the Pole Star. A straight gnomon is to be inclined in such a way that the observer's eye placed at its base, its top and the Pole Star all lie in a straight line. At Laṅkā this observation can be made with the gnomon lying flat on the ground ($\phi=0$) and at the Sumeru (North Pole) with the gnomon standing upright ($\phi=90°$). At intermediate regions, the gnomon will have to be inclined, and the perpendicular from its top to the ground will represent the sine of the latitude ($g\sin\phi$, where g=length of the gnomon) and the distance from the base of the gnomon to the foot of the perpendicular the sine of co-latitude ($g\sin(90-\phi)$). The rules are:

ṛjuśaṅkubudhnavinyastalocano nāmayettathā śaṅkum |
bhavati yathā śaṅkvagraṃ dhruvatārādṛṣṭimadhyastham ||
patitena bhavati vedho laṅkāyāmūrdhvagena tu sumerau |
vinatena cāntarāle phalakacchedārdha sūtrasame ||
tatrāvalambako yaḥ so'kṣjya tasya śaṅkuvivaraṃyat |
viṣuvadavalambako'sau yāmyottaradikprasiddhikaraḥ ||

The *Brāhmasphuṭasiddhānta* which Bīrūnī constantly referred to gives rules[16] for calculating the latitude of a place from the equinoctial midday shadow of the gnomon.

LONGITUDES

Bīrūnī's discussions on longitudes are given in his *India* partly in chapters 29 and 30 entitled 'Definition of the inhabitable Earth according to the Hindus' and 'On Laṅkā, or the Cupola of the Earth', and more fully in Chapter 31 entitled ' On that difference of various places which we call the difference of longitude'. The main points are (a) the choice of the prime meridian, (b) the Hindu methods of determining longitudes and their correctness, and (c) reference to the methods he had himself followed in longitude determinations.

Regarding the choice of the prime meridian, a good deal of confusion prevailed in Bīrūnī's time, and there was no general agreement as to which meridian was to be treated as such. 'The theory of the Western astronomers on this point', writes Bīrūnī, 'is a double one'.[17] Some adopted the line passing through the coast of the Atlantic Ocean as the prime meridian, whereas, according to others, the line passing through the Islands of the Happy Ones was the beginning of longitude. In his *Taḥdīd* where he discussed the point more fully, he informed us that the confusion had really started with the Greeks who sometimes calculated the longitudes from the Canaries Islands (same as Fortunate Islands) and sometimes from the most distant points on the Atlantic Coast.[18] Bīrūnī's own preference was for the meridian passing through Susul-Aqsa, the farthest point on North Africa. Measured from this line, the longitudes of some of the places determined by him are as follows: Iskandariya (Alexandria)—51°54'; Bagdād—70°; Shirāz—78°33'; Kirman—80°.[19] The corresponding values measured from the Fortunate Islands and generally given on the astrolabes are 61°54', 80° 88° and 91°30'[20]. The longitude difference of these two prime meridians is about 10°. Apart from inaccuracies in measurements, this lack of general agreement and the omission to correct for one prime meridian longitude values taken from different tables were no doubt responsible for much confusion.

The Hindu astronomers, on the other hand, consistently, adhered to the meridian of Ujjayinī as their reference line on the belief that the inhabitable world extended in longitude in the direction of east and west through 180 degrees and that this line was central, being 90 degrees each from the western and the eastern limits of the inhabitable land mass.[21] The prime meridian extending from the North Pole (Meru) to Laṅkā on the equator was taken to pass through Ujjayinī in Mālava, Rohitaka in the district of Multān, Kurukṣetra in the plain of Thāneśvara, the river Yamunā on which Mathurā is situated and the mountains of Himavant covered with everlasting snow.[22] It appears that the above description of the prime meridian was taken by Bīrūnī from the *Pauliśa-Siddhānta*. Bhaṭṭotpala, in his commentary on the *Khaṇḍa-khādyaka,* quotes the following line from Ācārya Puliśa[23] who teaches that longitude corrections for planatory positions are not required for Ujjayinī, Rohitaka, Kurukṣetra, the Yamunā, the Himanivāsa and the North Pole as the line passing through them is centrally situated (prime meridian).

ujjayinīrohitakakuruyamunāhimanivāsamerūṇām |
deśāntaraṃ na kāryaṃ tallekhāmadhyavartitatvāt ||

In Arabic translations Ujjayinī became Arin. It is well known that Hindu astronomical texts were available to Muslim astronomers and scholars at the beginning of the Arab intellectual movement. In view of the importance of reckoning time and ascertaining the co-ordinates of terrestrial places so that prayer times can be accurately fixed and faces can be turned towards the Ka'ba during prayers, as required in their religion, these astronomical texts were highly valued and methods given therein adopted for computational purposes. Al-Khwārizmī, in his Astronomical Tables[24], states that calculations for mean positions of planets were 'made for the locality of Arin'. 'If we are removed in longitude from this (place, namely Arin)', he wrote further on, 'then the distance between our place and the locality of Arin must be taken into account. Thus having established, how many degrees and perhaps minutes our place is distant from Arin, one hour is to be reckoned for each 15 degrees'. Following the Indians, the Arab astronomers, at least in the initial phase, adopted the meridian of Ujjayinī as the reference line for longitude estimation and regarded Laṅkā as the centre of the inhabitable world,—the cupola of the earth.[25] After the introduction of Ptolemy's *Almagest* and *Geography,* the Eastern Arabs preferred the Greek methods and replaced the meridian of Arin by that of the Fortunate Islands as the prime meridian. In Spain, however, Arin and Hindu astronomical methods continued to remain important. When the need arose for adopting a new prime meridian farther west of the Fortunate Islands, the matter was decided on the basis of Toledo's longitude of 61°30′ west of Arin and Arin's longitude of 90° east of the new prime meridian.[26]

Regarding the methods of determining longitudes and expressing them, Bīrūnī observes: "The Hindus employ in this subject methods which do not rest on the same principle as ours. They are totally different; and howsoever different they are, it is perfectly clear that none of them hits the right mark"[27] Let us examine how far his observations are correct. Apart from the difference in the choice of the prime meridian discussed above, the Hindus, Bīrūnī points out, express longitude differences in *yojanas,* that is in linear measure unlike Muslim astronomers who express them 'by equatorial times corresponding to the distance between the two meridians'. Such differences are immaterial because longitude differences can be expressed in times, degrees and distances as Bīrūnī himself states: 'It is all the same whether these *equinoctial times* whatsoever their number for each meridian may be, are reckoned as 360th parts of a circle, or as its 60th parts, so as to correspond to the *day-minutes,* or as *farsakh* or *yojana*.'[28] Moreover, Hindu astronomers also gave longitude differences in time in connection with their rules for finding them from a lunar eclipse, which Bīrūnī himself notices and remarks as a correct method of calculation.[29]

In support of his statement that the Hindus express longitude, called by them *deśāntara,* in *yojanas,* Bīrūnī refers to a rule for introducing necessary corrections to the mean positions of planets when observed from a place east or west of Ujjayinī. Bīrūnī says: 'Further, they multiply the *deśāntara* by the mean daily motion of the *planet* (the sun), and divide the product by 4800. Then the quotient represents that amount of the motion of the star which corresponds to the number of *yojanas* in question, i.e. that which must be added to the mean place of the sun as it has been found for moon[30] or midnight of Ujain, if you want to find the longitude of the place in question.' This is Brahmagupta's rule given in the *Khaṇḍakhādyaka*[31] and quoted below:

ujjayinīyāmyottararekhāyāḥ prāgṛṇm dhanam paścāt |
deśāntarabhuktivadhāt khakhāṣtavedaiḥ kalādyāptam ||

Let the longitude difference of the place of observation = l *yojanas;*
the mean daily motion of the planet, *bhukti* $= v$ minutes (*kalās*);
circumference of the earth = 4800 *yojanas.*
The *deśāntara* correction λ' is given by

$$\lambda' = \frac{lv}{4800} \text{ minutes}$$

which is to be subtracted from, or added to, the calculated longitude of the planet for the meridian of *Ujjayinī* according as the observer's station is east or west of the prime meridian. This is a correct formula. The last part of Bīrūnī's statement, 'if you want to find the longitude of the place in question' is either a mistranslation or a misreading of the text, for, by the above method the longitude of the planet for the place in question and *not the longitude of the place in question* is sought to be found.

In the subsequent discussion, Bīrūnī, however, rightly points out that in the rule of the *Khaṇḍakhādyaka* given above, it is not stated whether 4800 *yojanas* represent the circumference of the earth at the equator or that of the latitude circle of Ujjayinī. In this *Uttara Khaṇḍakhādyaka*, Brahmagupta gives a rule[32] for finding the so called corrected circumference of the earth, i.e. of the circle of latitude; it directs the *jyā* of the colatitude to be multiplied by 5000 and divided by the radius. That is,

$$\odot_{\phi} = \frac{5000\ R\ \sin(90-\phi)}{R} = 5000 \cos \phi$$

Clearly, 5000 *yojanas* represent the measure of the earth's circumference at the equator, which agree with Brahmagupta's diameter of 1581 *yojanas*. Does the figure of 4800 *yojanas* then represent the correct circumference at the latitude of Ujjayinī, 'as people are frequently misled to think'? To test this, the value of ϕ can be calculated from the above formula by substituting 4800 for $\odot_{\phi}$. Bīrūnī did this and obtained the value of $16\frac{1}{4}°$ for Ujjayinī whereas, the generally accepted value is 24°[33] (modern value 23° 11′ 6″).

Bīrūnī refers to a method due to *Karaṇatilaka*, according to which the diameter of the earth in multiplied by 12 and the product divided by the equinoctial shadow of the place.[34] That is, the diameter of the latitude circle of the place, is given by:

$$D_{\phi} = \frac{12\ D}{S}, \text{ where } D = \text{diameter of the equator.}$$

This is not correct because, as Bīrūnī explains,

$$\frac{12}{S} = \frac{R \cos \phi}{R \sin \phi} = \cot \phi$$

and not equal to $\cos\phi$ as the author of the *Karaṇatilaka* erroneously supposes it to be.

Vijayanandin's *Karaṇatilaka* is now available and Rizvi has given a translation of it, with commentaries and notes. Rizvi's translation runs as follows: "The diameter of the earth is 1600 *yojanas* and accordingly its circumference is 5028 *yojanas*. So multiply the circumference of the earth by 12 and divide the product by the hypotenuse of *palabhā;* the quotient will be the corrected circumference".[35] In the manuscript Rizvi worked with, 'corrected diameter' is mentioned, which he has amended to 'corrected circumference'. This is immaterial. The important difference is that, whereas this text, if properly translated, correctly directs the gnomon length to be divided by the hypotenuse of the equinoctial shadow to obtain $\cos\phi$, Bīrūnī in his *Indica* clearly states that it is to be divided by the equinoctial shadow. Which one is correct?

The longitude difference between two places used to be determined in ancient and medieval times in two ways; (a) from the time difference of an eclipse observed from the two places concerned, and (b) from the latitude differences of and the linear distance between two places. Bīrūnī notices both the methods in Indian astronomical texts. The former method consisted in finding the difference, in day-minutes, between the time of appearance of a lunar eclipse in the two places and converting the time difference into *yojanas* by multiplying it by the circumference of the earth and dividing the product by 60.[36] The rational is that a time-difference of 60 minutes or *ghaṭikās* or *nāḍikās* (=1 day) corresponds to the circumference of the earth in *yojanas*. The rule given in the *Brāhmasphuṭa-siddhānta*[37] runs as follows (only a part is quoted);

pragrahanāntaraghaṭikābhūparidhihatā vibhājayet ṣaṣṭyā |

Brahmagupta's scholiast Pṛthūdakasvāmin, in his commentary on the *Khaṇḍakhādyaka,* while explaining rule 15 of the first chapter concerning the longitude correction of the mean position of the planets, explains the above method of determining the longitude difference in minutes between two places by the time-difference of a lunar eclipse and expressing the same in *yojanas*.[38] He illustrates the rule in the case of Kurukṣetra where the eclipse is observed $1\frac{1}{2}$ *ghaṭikās* after the calculated time for the meridian of Ujjayinī. The longitude difference between Kurukṣetra and Ujjayinī therefore works out to $(3 \times 4800)/(2 \times 60)$ or 120 *yojanas*. The figure 4800 represents the earth's circumference in *yojanas* and not any corrected circumference. It is further to be noted that Pṛthūdakasvāmin did not place Kurukṣetra on the meridian of Ujjayinī, but 120 *yojanas* east of it, to which Bīrūnī makes a reference.[39]

Regarding the second method of computing longitudes from latitudes. Bīrūnī refers to a method by al-Fazārī taken from some Hindu work, in which longitudes are sought to be calculated from latitudes alone, and very rightly observes that 'it is impossible to determine the distance between two places and the difference of longitude between them by means of their latitudes alone.[40] Bīrūnī then referred to another Hindu method 'based on the same principle', of which the inventor was not known. The method is: "Multiply the *yojanas* of the distance between two places by 9, and divide the product by (lacuna); the root of the difference between its square and the square of the difference of the two latitudes. Divide this number by 6. Then you get as quotient the number of day-minutes of the difference of the two longitudes" Compare the above method with the following rule of the *Pañcasiddhāntikā*, ascribed to Puliśa:[41]

trikṛtighnāt khavasuhṛtādyojanapiṅḍātsvatāḍitajjahyāt |
akṣadvayavivarakṛtiṃ mūlāḥ ṣaṭkoddhṛtā nāḍyaḥ ||

"Multiply (the distance between two places in) *yojanas* by 3^2 and divide by 80 and take the square (of the quotient); deduct from it the square of the difference of the two latitudes; the square root (of the remainder) divided by 6 gives (the longitude difference) in *nāḍis*."

The lacuna mentioned in Bīrūnī's reference is 80. Now 9/80 equals 360/3200 and represents the angular distance in degrees corresponding to a *yojana* on the surface of the earth whose circumference is assumed to be 3200 *yojanas*. This is also clearly explained in the *Pañcasiddhāntikā* in XII, 15. The first part of the rule seeks to convert the linear distance between two places into an angular measure. The rational of the second part of the rule is to assume a right-angled triangle formed between the latitude difference AB ($=\phi_2-\phi_1$), the longitude difference BC and the difference AC between the two places, which is the hypotenuse (Fig. 1).

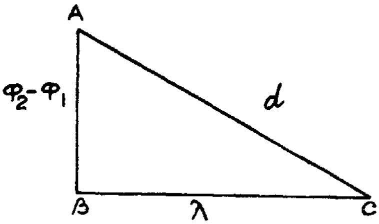

FIG. 1

This method cannot obviously be the same as that of al-Fazārī because it uses both the linear distance and the latitude difference. The method is no doubt defective in its simplified assumption where working with spherical triangles is involved, and is inferior to the procedure Bīrūnī followed in his own work on longitude measurements and explained below. But it must be stated in passing that Hindu astronomers were quite conscious of the limitations of this method. Bhāskara I, in his *Mahābhāskarīya,* for example, gives the same method as found in the *Pañcasiddhāntikā,* criticizing the rule at the same time as follows: "The distance (obtained above) has been stated to be incorrect by the disciples of (Ārya)bhaṭa, who are well versed in astronomy, on the ground that the method of knowing the hypotenuse is gross. (Those) wise people further say that on account of the sphericity of the earth (also), the method used for deriving the above rule commencing with *akṣa* is inaccurate".[42] Bhāskara I then discusses the eclipse method of finding longitudes and remarks that it is capable of yielding more accurate values.

The *Pañcasiddhāntikā* gives the longitude difference, in *nāḍikās,* between Alexandria and Ujjayinī as $7\frac{1}{3}$ and between Alexandria and Banaras as 9,[43] presumbly determined by the above mentioned approximate method. The differences work out to 44° and 54° respectively, which agree better with those based on modern longitude values than on the medieval, as the following table shows.

Table 1

	Pañca-siddhāntikā	Astrolabe	(medieval)*	Modern	
	Longitude from Alexandria	Longitude from Fortunate Island	Longitude from Alexandria	Long. from Greenwich	Long. from Alexandria
Alexandria	0	61°54′	0	29°51′	0
Ujjayinī	44°	102° 0	40° 6′	75°47′	45°56′
Banaras	54°	117°20	55°26′	83° 0	53° 9′

* Taken from Kaye, *Astronomical Observatories of Jai Singh,* pp. 128-29.

I shall conclude this paper by giving Bīrūnī's own method of computing longitude from latitudes and distances between two places as explained by Schoy.[4] Bīrūnī considered this method superior to that based on eclipses, 'because the first appearance and the end of the visibility of the eclipse, which are its most critical moments, can only be observed approximately'.[44]

Let the longitude difference between Shirāz and Baghdād be determined from the following data:

The latitude of Baghdād, $\phi_1 = 33°\ 25'$

The latitude of Shirāz, $\phi_2 = 29°\ 36'$

The distance between Baghdād and Shirāz (after corrections for straightening), $d = 153$ *farsangs* $= 8°6'$.

Bīrūnī adopted 6800 *farsangs* for the circumference of the earth, making 1 *farsang* equal $0°\ 3'\ 10.58''$[45].

In Fig. 2, N is the North Pole; NBTP is the meridian of Baghdād B and NRSQ that of Shirāz S; BR and TS are segments of parallels of latitude through B and S respectively.

Arc BP $= \phi_1$
Arc SQ $= \phi_2$
Arc BS $= d$

It is required to find the arc PQ on the equator, which is the longitude difference between B and S.

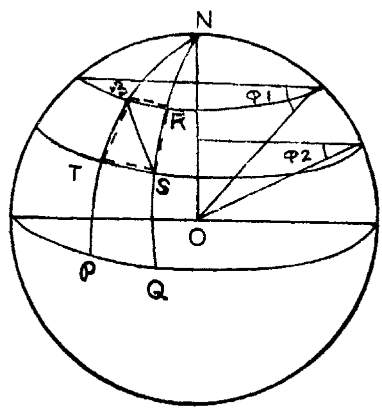

Fig. 2

The rectilinear figure obtained by joining B R S T is a cyclic trapezium, of which BR is parallel to TS, BT and RS are equal and the two diagonals are also equal. According to Ptolemy's Theorem,

$$\text{BS. TR} = \text{BR. TS} + \text{BT. RS} \quad \ldots\ldots(1)$$

or, $\text{BS}^2 - \text{BT}^2 = \text{BR. TS}$

$$\text{or,} \quad \frac{\text{BS}^2 - \text{BT}^2}{\text{BR}^2} = \frac{\text{TS}}{\text{BR}} \quad \ldots\ldots(2)$$

$$\text{Now,} \quad \frac{\text{TS}}{\text{BR}} = \frac{\text{lat. circle through S}}{\text{lat. circle through B}} = \frac{2\pi R \cos\phi_2}{2\pi R \cos\phi_1} = \frac{\cos\phi_2}{\cos\phi_1} \quad \ldots (3)$$

$$\text{Likewise,} \quad \frac{\text{BR}}{\text{PQ}} = \frac{2\pi R \cos\phi_1}{2\pi R} = \cos\phi_1 \quad \ldots (4)$$

Substituting (3) and (4) in (2),

$$\frac{\text{BS}^2 - \text{BT}^2}{\text{PQ}^2 \cos^2\phi_1} = \frac{\cos\phi_2}{\cos\phi_1}$$

$$\text{PQ} = \sqrt{\frac{\text{BS}^2 - \text{BT}^2}{\cos\phi_2 \cos\phi_1}} \quad \ldots (5)$$

By converting the arcs into chords with the help of his sine and cosine tables, Bīrūnī obtained the following values for his chords BS and BT and the cosine functions in sexagesimal units:

BS	=	0	8′	28″	32‴
BT	=	0	3′	59″	46‴
$\cos\phi_1$	=	0	50′	4″	12‴
$\cos\phi_2$	=	0	52′	10″	17‴

From (5), the value of the chord PQ works out to 0 8′ 17″ 16‴ and that of the arc PQ, that is, the longitude difference between Baghdād and Shirāz, to 8°33′ 32″[46].

This difference, as per modern longitude values of these two places, is 8° 16′, which indicates the degree of accuracy attained by Bīrūnī in his measurements.

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6 *Pañcasiddhāntikā*, **15**, 23.

7 *Aryabhaṭī, Gola*, 13.

8 *India*, I, 303-4; 308-9.

9 *India*, I, 316-17.

10 *Aryabhaṭiya, Gola*, 14.

11 *Pañcasiddhāntikā*, **13**, 19. The latitude of Ujjayinī (Avantī), is given as 21**3** *yojans*, which when converted into degrees by the rule 1° = 80/9 *yojanas* (**13**, 15), makes 24°.

12 *India*, I, 304.

13 *Khaṇḍakhādyaka, III*, 11.

14 *Pañcasiddhāntikā*, IV, 20-21.

15 *Pañcasiddhāntikā, XIII*, 31, 32, **33**.

16 *Brāhmasphuṭasiddhānta, III*, 10.

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[30] 'moon' appears to be a printing mistake; it should be 'noon'.

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[39] *India,* I, 316.

[40] *India,* I, 315.

[41] *Pañcasiddhāntikā,* III, 14.

[42] *Mahābhāskarīya,* ed. and translated by Kripa Shankar Shukla, Lucknow, 1960; II, 3, 4, 5. Rules 3, 4 give the method and rule 5 the criticism. Shukla's translation has been given in the citation.

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[44] Kramers, J.H., 'Al-Biruni's determination of geographical longitude by measuring the distances', *Al-Bīrūnī Commemoration Volume,* Calcutta, 195, p. 184.

[45] Kramers, *loc. cit.,* p. 187

[46] Kramers checked up every step of the calculation and noticed discrepancies in the conversions from arcs into chords, which are not considerable, *loc. cit.,* pp. 187-88.

ON THE PHYSICAL RESEARCHES OF AL-BĪRŪNĪ

S. M. RAZAULLAH ANSARI

Physics Department, Aligarh Muslim University, Aligarh

Much is known about al-Bīrūnī (973-1048) as an astronomer, mathematician and even as geographer. We propose that the physical researches of al-Bīrūnī should also find their due share of appreciation, as it is the case with his contemporaries Ibn-Sinā (965-1039) and al-Haytham (980-1037), his successor al-Khāzinī (?-1189) and others.

First, the determination of relative densities of precious metals, stones etc. as performed by al-Bīrūnī and reported by others is briefly reviewed. Relative densities and specific gravities of various substances are computed from the reported data and the results compared with one another. It is contended that the report of Abul Fazal in *'Ā'īn-i Akbarī* appears to be taken from al-Khāzinī rather than al-Bīrūnī directly, Incidentally, it is also found that there are mistakes in the tables of weights of various substances as given in Blochmann's and Gladwin's editions.

Second, several observations of al-Bīrūnī on the nature of heat and light (solar rays) and on the measurement of the velocity of the later are discussed. It is shown that al-Bīrūnī understood the intimate connection between heat and motion.

Finally, an attempt is made to appreciate al-Bīrūnī's awareness of the significance of the scientific method and to trace the philosophy underlying his scientific activity.

1. Introduction

As early as 1857, the year in which the American Oriental Society published in its journal (vol. 6) the contribution of N. Khanikoff, "Analysis and Extracts of the Book of Wisdom" (*Kitāb Mīzān al-Ḥikma*) of al-Khāzinī" (Abu'l-Fatḥ *'Abd al-Raḥmān al-Mānṣūr*)[1], it was known that as far as the determination of specific gravity of various substances was concerned, al-Khāzinī had drawn much from the work of Abū Rayḥān al-Bīrūnī. Then, just after a year, Clément-Mullet[2] put forward his hypothesis that *'Ā'īn* 13 and 14 in Abul Fazal's *'Ā'īn-i-Akbarī*, in which the origin of metals and the specific gravity of various substances are dealt with, are actually based on al-Bīrūnī's work. Still, three decades later, F. Rosenberger in his *Geschichte der Physik* (Braunschweig, 1882) mentioned the name of al-Bīrūnī just by a line in a foot-note (ibid pt. I, p. 82) and dealt only with the work of al-Khāzinī. More than that, neither the name of al-Bīrūnī nor that of al-Khāzinī appears at all in A. Heller's *Geschichte der Physik,* which was published incidentally in the same year. Heller goes so far as to remark (ibid vol. I, p. 167):

"Auf dem Gebiet der Physik finden wir die Araber bloss in der Optik taetig......"

As a matter of fact, the difficulty in writing a History of Physics in "Islamic Countries"—to use the nomenclature of Yushkewitch[3]—is due to the dearth of editions of various works in a modern European language. For centuries Ibn Sīnā and al-Haytham were the only "physicists" known in Europe, beecause their works were available at least in Latin translations (see Sarton[4] or Mieli[5] for references). The historian of sciences particularly of physics and mathematics, simply could not become fully aware of the scholarship of al-Bīrūnī, because only two of his works: *Taḥqīq-mā li'l-Hind* and *Āthār al-bāqiyah* were published by E. Sachau, namely "Al-Bīrūnī's India" (London, 1888) and "The Chronology of Nations" (Leipzig 1878, London 1879). At the beginning of this century at last the German scholars C Schoy, H. Suter and E. Wiedemann, to name only a few, started painstaking research to bring into light al-Bīrūnī's work on exact sciences.[6] But somehow or other al-Bīrūnī became famous as a master-mind only in the fields of mathematics and especially of astronomy. Consequently we thought to look into a neglected aspect of al-Bīrūnī's work, i.e. his physical researches. Contrary to his astronomy or astrology, on which he wrote separate treatises, e.g. *Al-qānūn al-Mas'ūdī* or *Kitāb al-Tafhīm*, there does not exist a single book exclusively on physics by him. As a matter of fact, one has to go through the whole of his writing to gauge his physical researches and especially his physical world view. Consequently it is requested that the present work should be considered just as a preliminary study. In the following we first summarize what we intend to treat in this paper:

The main body of this paper (sec. 2) deals with the result of al-Bīrūnī's determination of the specific gravity of various substances: metals, minerals and liquids. We compare the results reported by himself with those quoted by others. Finally (sec. 3) an attempt is made to reconstruct his methodology and his physical world view from his ideas as pronounced by him in his various writings.

2. Determination of Specific Gravity

2.1. *Manuscripts*

There is an entry concerning the specific gravity of substances in al-Bīrūnī's own Bibliography of his work[7]: "Book on the ratios which exist between metals and jewels with respect to their volumes" (*maqāla fī al-nasab al-latī bayn al-filizzāt wa 'l-jawāhir fī 'l-ḥajm*) The manuscript is extant in the Library of St. Joseph University, Beirut[8] It consists of 33 pages. The content of it has been fully utilised by al-Khāzinī in his *Kitāb Mīzān al-Ḥikma*. From the literature it appears, that L. Cheikho reported it in Almashriq already in 1906. Unfortunately neither the manuscript nor the communication of Cheikho is available to us here. We, therefore, base this part of our studies only on the reports of E. Wiedemann[9]. The table given in the manuscript will be called henceforth "Bīrūnī".

Not only al-K͟hāzinī reported al-Bīrūnī's results of the determination of specific gravity of various substances, but one comes across a number of other Muslim authors also, who have done the same. We list in the following the ones utilised by us in this study:

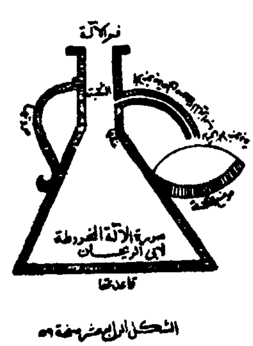
(1) G͟haffārī (yaḥyā b. Muḥammad), also called *yaḥyā al-Bizzī in his Kitāb yāqūtāt al-Makhāzin fī Jwāhir* (Turkish manuscript, extant in the City Library of Leipzig), gives a table, abbreviated in the following by "G͟haffārī".[10]

(2) Ibn Manṣūr (Muḥammad) in his *Jawahar-nāma-i Jadīd* (Persian manuscript, available in the Royal Library of Vienna); his table is abbreviated in the following by "Manṣūr".[10]

(3) No. 2468, manuscript in de Slane's catalogue of the Bibliotheque Nationale, Paris. The heading is: Measurement of surface area and volume of bodies and the determination of their weights (abbreviated in the following by "Paris-1" and "Paris-2"). Another copy of this manuscript is found in the India Office Library, London, No. 1043, Catalogue of Loth. This copy was written in India in 1722.[11]

(4) Abul Fazal in *'Ā'īn-i-Akbarī*[12], 'Ā'īn 14: In this 'Ā' īn Abul Fazal speaks about Abū Naṣr Farahī (Muḥammad Badr al-Dīn), who in his work *Niṣāb-u'ṣ-Ṣibyān* gives a list of specific weights of various metals, abbreviated in the following by "Farahī". Besides it, Abul Fazal gives two other tables and declares them to be based on al-Bīrūnī's work. We shall call these tables "Fazal-1" and "Fazal-2".

To give an idea of how al-Bīrūnī and his contemporaries obtained their data, which apparatus they used for their measurements, we would like to give in Fig. 1 a sketch of al-Bīrūnī's flask which he used for the determination of volumes. To this a remark of alk͟hāzinī is noteworthy: He states that it is difficult to weigh the amount of water displaced, because the water sticks to the sides of the outlet-tube!



in Kitāb Mīzān Al-Hikmā
by Abdur-Rehmān Abu Manṣūr Al-Khāzini
completed in 1121/22 A.D.
Mss. published, Hyderabad 1940

FIG. 1.

2.2. *Data*

In table I we give first the data as reported in the above-mentioned works. Here a few words about the various units of weight used will surely not be out of place. The largest unit of weight is *mit͟hqāl.*

1. mit͟hqāl (M) = 6 dāneq (dāng in Persian, dāniq in Turkish)

1 dāneq (D) = 4 ṭassūj

1 ṭassūj (T) = 4 arpā (A) or jaw

Another small unit is 1/60th of a ṭassūj. In different tables different units are used. In our calculation we have converted all of them into T/60: only the weights given in 'Ā'īn 14 have been converted into ṭassūj.

In the literature there is no agreement on the conversion factor of one *mit͟hqāl* into grams. The range of values is 4.80—6.0 gms.[13] Consequently we do not attempt to convert the various weights into grams.

Various representations of the data have been used by different authors. In "Bīrūnī" the weight of water displaced by 100 mit͟hqāl of substance is tabulated. This is also the case in "Fazal-1". Whereas in the former the weights are given in ṭassūj, in the latter they are in mit͟hqāl, dāng and ṭassūj. In Paris-1 the weights of a cubic ell (d͟hirā') of various substances, i.e. of equal volumes, are given. Since this unit of volume is very large, the weights are of the order of 10^5—10^6 mit͟hqāl. Taking 1 mit͟hqāl to be roughly equal to 5 gms, this amounts to 5—50 quintal of the substances used. This is certainly not possible in practice. The paradox is resolved in the next section by our calculations.[14] Finally in "G͟haffārī" and "Mansūr" the weights of various substances having the same volume as 100 mit͟hqāl of gold are given. The weights are in units of mit͟hqāl, dāneq, ṭassūj and arpā or jaw. This representation is also used in "Paris-2", with the difference, that the various weights are given in 1/60th of a ṭassūj only. It is to be noted that whereas for metals gold is usually taken to be the standard metal, for jewels either emerald (*zumurrad*) or blue *yāqūt* (sapphire) is taken as the standard mineral. The latter has been used by G͟haffārī, Ibn Manṣūr and by Abul Fazal also. For liquids, water or sometimes also mercury was taken as standard substance. It is interesting to note that it was known to al-Bīrūnī that the density of water is a function of temperature.

2.3. *Calculations and discussion of the results*

Since in Paris-1 the weights of the substances are given in numbers of 5—6 figures, it appeared to us advisable to use a computer for the calculations and tabulation of results. Consequently the calculations were performed on the IBM 1130 computer of the Computer Centre, Aligarh Muslim University. Each table was considered independently. Since the representations of specific weights in the various tables are different, as mentioned above, we have first calculated the relative densities of the metals with respect to gold, or of jewels etc. with respect to emerald (*zumurrad*) and those of liquids with respect to water. Second, we calculated the specific gravity of the various substances (i.e. relative density with respect to water) in order to compare the results with the modern ones. These calculations could not be performed, however, for "Fazal", "Ghaffārī" and "Manṣūr", since in these tables water is not listed.

Just a mere inspection of the tables (2 and 3) of relative densities shows that "Bīrūnī" and Paris-1 are identical tables, which can be very clearly seen in the case of jewels etc. This explains immediately the paradox of "5—50 quintal" mentioned in the previous section, namely: The learned author of the Parisian manuscript just took the readings of al-Bīrūnī and calculated from them the weights of a cubic ell of each of the substances. In the case of metals (table 2) the relative densities of most of the corresponding items tally only up to the 4th place of decimal. However, if the specific gravities of these metals are determined, the agreement between the two tables is again remarkable, that is upto the 5th place of decimal, gold and lead being the exceptions. In the latter cases one should assume that there is a writing mistake in one of the manuscripts. We shall come to this question again while discussing Abul Fazal's tables.

Comparing the tables Paris-1 and Paris-2 we find that, whereas for jewels (table 3) the values of relative density as well as of specific gravity agree upto the 4th place of decimal[15]: in the case of metals (table 2) the agreement cannot be claimed more than upto the second place of decimal. Consequently we assume, that Paris-2 has not been derived from "Bīrūnī" or Paris-1, but may be of independent origin, since the specific gravity of a metal depends especially upon the degree of purification of the sample used.

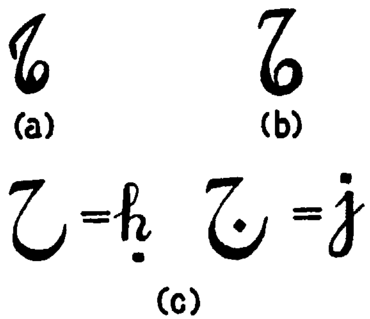
While comparing all the values of specific gravity (calculated above) with the modern ones, one should be a bit careful. For metals, it is not only the degree of purification of the sample which should be allowed for but also the type of metal used, namely cast, rolled, wrought, drawn or vacuo-distilled metal. The specific gravity for all these types turns out to be different, for instance in the case of gold it ranges from 18.88 to 19.33 and for copper from 8.30 to 8.93. Thus not much importance can be attached to the comparison of modern values with those of al-Bīrūnī, the accuracy of al-Bīrūnī's measurement can rather be visualised by the fact that al- Khāzinī in his *Kitāb Mīzān al-Hikma* claims for his balance an accuracy of 1 in 1000. That some such balance was also available to his predecessor al-Bīrūnī may not be then a pure speculation.[16]

In table 4, the data of Fazal-1 are compared with those of "Bīrūnī". In Fazal-1 the weight of water displaced by 100 M of a substance (3rd column) together with the weight in water of the same amount of the substance (4th column) are given. Abul Fazal claims that these data are taken from al-Bīrūnī. However, one notes that the values for the weight of water displaced agree only for gold, mercury, silver, iron, blue *yāqūt* and ruby—compare columns 2 and 3. The values for the other substances, as given in these columns, apart from not matching with the "Bīrūnī" (Beirut mss.) values, are also wrong in themselves, since the two weights of the same row do not always add to 100 M. There is mostly an excess of 3 *ṭassūj*: only in two cases: rocksalt and *yāqūt* (red), there is an excess of even 3 *dāng* and 3 *ṭassūj*—the numbers in excess are —marked by an "e" in our table 4.[17] Besides these mistakes, the rows corresponding to lapis lazuli and pearl seem to be exchanged with one another, when one compares the corresponding entries of "Bīrūnī" (Beirut mass.). After correcting all these errors in Fazal-l, one finds that this table is identical with the corresponding ones of al-Khāzinī as given in his Book of Balance.[18] Even the only mistake in the latter, the weight in water for Cu, which is wrongly entered 88 M, 3 D and 3 T, agrees with Fazal-l.[19] Consequently one may assume that Abul Fazal in *'Ā'īn-i Akbarī* took his table from some incorrect copy of al-Khāzinī's Book of balance.[20]

In order to check Blochmann's translation we looked for other editions of 'Āīn-i Akbarī. Fortunately we could compare the tables as given in Blochmann's translation with those given in Sir Syed Ahmed Khan's persian edition and those of British Museum's persian manuscript (Add. 7652) of *'Āīn-i Akbarī*.[21] In a marginal note Sir Sayed states:

Jidwali filizzāt kih Abū Rayḥān Bīrūnī istikhrāj namūdah dar akthari pāstānī nāmhā dīdah shud yakī bā dīgarī tafāwut dārad wa wajh tarjīḥ 'īñ bar 'āñ nā-padīd chih dar 'umūr-i naqlī ṣirf taṣḥīḥ darkār-ast qāyās wa takhmīn rā dar 'āñ dakhal-i nīst ba'd tafaḥḥuṣ wa taftīsh jidwal-i rā kih mistar Fransis Gladwin ṣāḥab mutarajjim-i 'Ā'īn-i Akbarī ba-zubān-i angrēzi bah taṣḥīḥ dar-āwurdah dākhil-i tarjumah namūdah az hamah bihtar wa ṣaḥīḥ-tar dānistam wa az kashakash-i ikhtilāfāt-i naskh wā rahīdah az'āñ jidwal bah taṣḥīḥ-i 'īñ jidwal pardākhtam wa ṭaraf-i har khānah rā ba-hindsah-i hindī mu'allam sākhtam tā raqm-o-ḥurūf az taḥrīf bāz mānad.[22]

In short, Sir Syed inserts in his edition the best corrected (!) tables of Francis Gladwin[23] and in order to avoid mistakes he writes the various weights both in persian/urdu numerals and *jummal*—a sexagesimal position system of numeration,[24] which was then preferably used by the astronomers for tabulation purposes. On comparing one finds that these tables agree with Blochmann's except that all 3's (marked by an "e" in our table 4) have been replaced by 8's. On the other hand, in the British Museum's Manuscript the corresponding entries are in fact correctly given as zero. The confusion about the numbers 3, 8 and zero is actually due to the use of *jummal*, in which the numbers 3 and 8 are symbolised by the arabic letters (only the "head" of arabic *j* and *ḥ* respectively) while zero by another symbol.[25] The shape of the latter explains obviously the wrong rendering by various copyists. However, one fact is certain: that all these authors did not understand what they were reporting. Otherwise, how could Sir Syed (or Gladwin) write 8 in the column of ṭassūj (T), if he knew that 1D=4T and therefore the entry in this column should be less than 4 in any case. Similarly, Blochmann's remark of the excess of 1D = 4T is inexplicable, since he also stated, that the two weights should add to 100M.



Fig, 2. Symbols foı Zero. for Comparison Arabic Letters Are Given in (C)

2.4. *Evaluation of al-Bīrūnī's determinations of specific gravity*

The determination of specific gravity plays a central role in al-Bīrūnī's physical researches, and his results have been reported and propagated by various scholars of the Islamic countries. As we have shown in the previous sections, the interest concentrates especially on a number of precious stones (gems) as well on precious metals. One may ask now, why this preoccupation with this very field of physics, why so much of painstaking research? In answer to such a question al-Bīrūnī says:[26]

"As to the sciences, man was naturally inclined to accept them because during his lifetime he could only fulfil certain specific functions.... Everyone needed something that can be divided into parts and another which can be accumulated by duplication. Hence labour was divided according to need. But labour and needs were disproportionate and the times of labour involved were unequal, people devised systems of prices and exchanges which were based on the intrinsic worth of metals, jewels and things resembling them .....".

The sociological imperative for such type of research might therefore be to devise means to ascertain the "intrinsic worth of metals and jewels". Certain physical properties had to be found out, on the basis of which the various varieties of these precious substances could be identified and their worth estimated.

In his *Kitāb Al-Jamāhir fī M'arifāt al-Jawāhir*[27] (completed in circa 1048), al-Bīrūnī discusses in details all about the various metals, alloys, gems and other precious substances already listed in our tables of the previous sections. As a matter of fact, this book is a small encyclopedia on mineralogy. It contains a long introduction and two chapters; the first one deals with 35 precious stones (*Jawāhir*) and other substances, the second with precious metals and alloys. In this work al-Bīrūnī proves his ingenious physical thinking by systematizing the study of metals, minerals etc. on the basis of general physical principles. He objects against the classification of gems on the basis of colour only, as was the current practice in those days, but on the contrary attaches a secondary importance to this property.[28a] To identify and classify especially the various minerals, he applied in particular the criteria of specific gravity, brilliance[28b] and hardness (the latter was determined by using a sample of a pointed shape, rubbing it and noting down the rate of wearing away of this point).[28c] The importance of introducing the idea of specific gravity for his classification scheme should be seen in the fact, that al-Bīrūnī uses a pure physical constant instead of an incidental property like the colour of a gem is. Even today specific gravity—besides refractive index, of course—is considered to be a positive feature for the identification of minerals (stones).[28d]

3. Physical World-view and Methodology

In the last part we have dealt only with one aspect of al-Bīrūnī's work—the experimental study. However, the spirit of inquiry with which he was imbued could not be confined to this practical aspect of physics alone. By questioning the prevalent superstitions and even the Aristotelian *Anschauung*, he reflected on various fundamental physical problems and emphasized the significance of experimentation along with theoretical analysis in man's activity, thereby truly qualifying himself to be called a physicist, nay even a scientist.

3.1. *On the nature of heat and light*

Aristoteles considered heat to be a fundamental quality especially of the element fire and besides that inherent in all things. Further he said, that there are two types of heat, by which the bodies can get heated: either by their own internal or by external heat.[29] On the basis of the latter view one tried to explain the advent of summer, a phenomenon, which al-Bīrūnī also dealt with. In his book *Chronology* he discusses various viewpoints regarding this topic, namely: the cause of summer being "the spreading of the heat from the interior of the earth to the surface" or "the air receiving heat from the body of the sun", in other words "the rays being the first cause of heat".[30] He comes to the conclusion that "heat is nothing but the rays of the sun detached from the body of the sun towards the earth" (p. 246). This viewpoint leads him to reflect on the nature of the (solar) rays, their motion etc. in the following pages of *Chronology*. He draws the consequence, that "the heat exists in the rays, is inherent in them" (p. 247). Though this belief should logically result in the conviction, that the air is warmed up by the solar rays, al-Bīrūnī asserts elsewhere that "the warmth of the air is the result of the friction and violent contact between the sphere, moving rapidly,[31a], and his body" (p. 247).[31b] This statement shows, that al-Bīrūnī's mode of thinking was still Aristotelian, but he adapted the later's theories according to his own physical views.[32] Thus one should consider it to be al-Bīrūnī's merit to have understood the intimate connection between motion and heat, which was the starting point for Joule (1818-1889) for his work on mechanical equivalent of heat and is, in fact, the basis of the modern Kinetic Theory of heat. Before it was spelled out in the *Chronology*, the knowledge of this relation was expressed in connection with al-Bīrūnī's eighth question to Ibn Sīnā,[33] namely: Heat is generated by motion and cold by rest. The air in contact with the sphere (*Falak of fire*) gets heated up as a result of a rapid motion of the sphere. Then heat (*Nār*), which is also called aether, is generated.[34] Al-Bīrūnī even knew, that increasing or decreasing the motion increased or decreased the amount of heat produced. Although by the above-mentioned statements he aimed to explain the hot and cold climate at the terrestrial equator and poles respectively, yet in our opinion what is again significant here, is his realization of the innate relation between heat and motion. It will be interesting to compare here the physical view of al-Bīrūnī with that of Ibn Sīnā, as is evident from the reply of the latter to al-Bīrūnī's 9th question: al-Bīrūnī asked: If heat propagates from the centre to the circumference, why is it that the heat, along with the rays, reaches us?[35] (In other words: it moves from the circumference to the centre!) To this, Ibn Sīnā replies that the heat does *not* emanate from the centre, since it does not propagate by itself. He illustrates this by the example of a man in a boat who is not moving, but only his boat is in motion. By this he means, that only the solar rays are propagated (are in motion) and therefore along with them the heat reaches us.[36]

The preoccupation with the light-heat problem leads al-Bīrūnī naturally to the questions of the nature and propagation of light. In *Chronology* (p. 247) he states:

"There is a difference of opinion regarding the motion of the rays. Some say, this motion is timeless, since the rays are not bodies.[37] Others say, this motion proceeds in very short time[38]: that, however, there is nothing more rapid in existence, by which you might measure the degree of its rapidity, e.g. the motion of the sound in the air is not so fast as the motion of the rays; therefore the former has been compared with the latter and thereby its time (i.e. the degree of its rapidity) has been determined".[39]

This is, to our knowledge, the first reference to the problem of measurement of the velocity of light. It is unfortunate that al-Bīrūnī neither cites the names of those who "say this motion proceeds in a very short time" nor is it clear from the text what is in fact his own opinion about this question. However, what we feel to be more important is, that the genius in al-Bīrūnī was not held up by the problem of experimental feasibility of a physical situation, but sets itself free from its entangle and, exchanging the consequence with the premise—he supposed the velocity of light is finite, then rays should be bodies![40]—proceeds to a fundamental physical question as to what is the nature of light! In his 9th question to Ibn Sīnā he asked whether the rays are material, "*rāḍ*,[41] or indicate the state of something else. The text is:[42]

In kānat Al-ḥarārāt sālikat[an] 'an al-markaz fa-lima ṣāra al-ḥarr yaṣilu ilaynā min al shu'ā'āt 'a-hiya 'ajsām 'am a'rāḍ 'am ghayru dhalik.

We make here no distinction between rays (shua'ā'āt) of light and heat (ḥarārāt), since it is immaterial: We have already quoted al-Bīrūnī's opinion: "the heat exists in the rays and is inherent in them"[43]. The moot point is here the reflection on the nature of solar rays. We don't know today what actually al-Bīrūnī believed himself. We know only that in his time

> "regarding the rays of the sun many theories have been brought forward. Some say that they are fiery particles similar to the essence of the sun, going out from his body. This is the theory of those who maintain that the sun is a hot fiery substance".

However, he cities also the contrary view of those

> "who maintain that the nature of the sun has nothing in common with the nature of the four elements."[44]

3.2. *Al-Bīrūnī's Philosophy and Methodology:*

If Physics is defined broadly as a study of nature (natural phenomena) and the birth of Physics may be said to have resulted from a precise quantitative observation, then a physicist will be one, who regards the physical world as understandable and predictable rather than capricious.[45] Let us quote a passage from the *Chronology* to show that al-Bīrūnī passes the test, whether being a physicist or not, successfully according to the above-mentioned definition:

"People say that on the 6th (of the Greek month of January) there is an hour during which all salt water of the earth is getting sweet. All the qualities occurring in the water depend exclusively upon the nature of the soil by which the water is enclosed, if it be standing, or over which the water flows, if it be running. Those qualities are of a stable nature, not to be altered except by a process of transformation from degree to degree by means of certain media. Therefore this statement of the water getting sweet in this one hour is entirely unfounded. Continual and leisurely experimentation will show to anyone the futility of this assertion". (p. 240)

We know today very well that it is not only the experimentation alone which decides in favour of one hypothesis or the other, but it is also the aim of a physicist to achieve a simple and unified mathematical description of several seemingly unrelated physical phenomena. That al-Bīrūnī was also conscious of this fundamental principle of theoretical physics can be seen from the following passage of *Chronology* (p. 337-338):

"... the Arabs attribute all meteorological changes to the influence of the rising and setting of the stars... It is evident that, if the science of meteorology were to depend upon the rising of the bodies of the stars,......, the times and seasons of the *Meteora* would differ in the same proportion as the stars change their places: besides they would be different in different countries and we should require for them as well as for the appearing and disappearing of the planets *various kinds of tiresome methods of calculations*" (emphasis mine).

The attempt to understand the natural phenomena both experimentally and theoretically demands a high degree of objectivity, critical and independent mind. That al-Bīrūnī was quite critical of the tradition is obvious from his ten questions which he posed to Ibn Sīnā and which were actually meant for showing the contradictions between the Aristotelian theories and observations of his time. Thus he says:

"And the trouble with these people is their extravagance in respect of Aristotle's opinions, believing that there is no possibility of mistakes in his views though they know that he was only theorizing to the best of his capacity and never claimed to be God's protected and immune from mistakes".[46]

In his own words one may say that he was in fact a worshipper of the Truth and a true seeker of knowledge who was equally concerned with "the investigation of the old and new conditions of the world". He pursued Truth by reading and pondering intelligently about the rules of order in the Universe and its parts and (moreover) investigating the validity of these rules.[47] Like all great men of time immemorial, his instinct for knowledge constantly urged him to probe the secrets of the unknown,[48] his method being "to proceed from what is near to the more distant, from what is known to that which is less known".[49] If someone from our ultra-materialistic world of today would have asked what benefit he got by this pursuit of knowledge, he would have surely replied:

"It is the knowledge in general which is pursued solely by man and which is pursued for the sake of knowledge itself because its acquisition is truly delightful and is unlike the pleasure desirable from other pursuits".[50]

May our coming gererations and we ourselves take lesson from this *savant* of all times.

ACKNOWLEDGEMENTS

I am very much indebted to Prof. Maqbool Ahmed for drawing my attention to this Symposium. In fact, this prompted me to study this aspect of al-Bīrūnī's work. I am also thankful to him for inspiration and encouragement.

It is a great pleasurq to thank also my friends Mr. M.A. Alvi, Dr. A. K. Jalaluddin and Mrs. M. Ovaise for assistance to go through the literature and for fruitful discussions. I am grateful to Mr. S. A. Khan for bibliographical hints. The allotment of computer time by the Computer Centre of the Aligarh Muslim University as well as Mr. Badre Alam's help in carrying out the boring part of the computation are herewith also acknowledged.

Last but not least I owe much to Prof. Rais Ahmed for providing me facilities to carry out this piece of work and to my wife for going through the manuscript critically.

Notes and References

1 The arabic text is published by Osmania Oriental Publication Bureau, Hyderabad 1940; hereafter referred to as Hyderabad Text. (See also note 20).

2 *J. Asiatique*, Ser. 5, *11* (1858).

3 A. P. Juschkewitsch: *Geschichte der Mathematikin Mitelalter* (B. G. Teubner, Leipzig 1964) p. 185. Transl. from Russain.

4 G. Sarton: *Introduction to the History of Science.* (Baltimore, 1927) vol. 1, p. 709 and 721.

5 A. Mieli: *La Science Arabe* (E. J. Brill, Leiden, 1966), p. 102 and 105.

6 Recently, much work is being done also in the Soviet Union on al-Bīrūnī. We would like to mention here, that almost all of his important works have been published in Russian translations, even *al--Qānūn al-Mas'ūdī* is being edited now by Prof. B. A. Rosenfeld (Moscow): Prof. M. S. Azimov (President, Academy of Sciences of Tajikstan) has informed me that its publication is being planned for 1973. [Note added in proof: Book I of al-Qānūn has already been published]

7 H. Suter and E. Wiedemann: Beitraege zur Geschichte der Naturwissenschaften (published in the *Sitz. Ber. d. Phys. Mediz. Soz. zu Erlangen*), LX, 1920/21, pp. 55—96, esp. p. 75, entry 3. See also *ibid* VIII, 1906, pp. 163—180. Hereafter we shall refer to this simply as *Beitraege*.

8 cf. D. J. Boilot: L'oeuver d'Al-Bérūnī: *MIDEO* 2 (1955), pp. 161—256.

9 E. Wiedemann: *Beitraege* XXXIV, 1913, pp. 168-173.

10 E. Wiedemann: *Beitraege* XXXI, 1913, pp. 31-34.

11 *Ibid.* XIV, 1908 pp. 60—61.

12 English translation by M. Blochmann, Asiatic Society of Bengal, Calcutta 1927, second edition. We are using here the English orthography for Fazal and not the Arabic one: Faḍal.

13 Al-Bīrūnī in his "India" gives himself, that 1 *tolā*=2.1 mit͟hqāl: cf. E. Sachau: *Al-Bīrūnī's India* (London, 1910) vol. 1, chapt. XV, p. 160 Unfortunately a *tolā* differs from 11 to 13 gms in various parts of India.

14 We thank Dr. A. K. Jalaluddin to draw our attention towards this paradox.

15 For ruby there seems to be a writing mistake in the original manuscript.

16 F. Rosenberg: *Geschichte der Physik*, Braunschweing (1882), Part 1, p. 81. For the problem of accuracy cf. also: G. G. Lemmlein: *Biruni Sbornik Statey,* Ed. S. P. Tolstova, Moscow (1950), pp. 106—127, esp. 1111—114.

17 Strange enough, Blochmann remarks in a footnote that in most items there is an excess of one *dāng*, i.e. 4 *ṭassūj*. Cf. ref. 12, vol. 1, *'Ā'īn* 14, p. 42.

18 Cf. Hyderabad text, ref. 1: tables (*shakl*) facing page 62, 63, 68 and 69.

19 Al-K͟hāzinī takes extra care to write each weight, partial as well as total, in words (in arabic): the total weight in *ṭassūj* is also given in numerals.

20 In Abul Fazal's time, many copies of this book were surely available throughout India. The Hyderabad text (cf. ref. 1), for instance, is edited with the help of three manuscripts, two of which are of Indian origin: one from the Asafia Library, Hyderabad, and the other from the Library of Jama Masjid of Bombay. The compiler of the afore-mentioned mss. of India Office appears also to draw from some copy of Al-K͟hāzinī's book.

[21] A micro-film of the latter and a lithograph copy of the former are available here at the Advanced Centre for History, Aligarh Muslim University, Aligarh. Here, I must sincerely thank my friend Mr. M. A. Alvi, who not only drew my attention to them but also assisted me in going through them.

[22] Sir Syed Ahmed Khan: *'Ā'īn-i Akbarī*, Persian text (Delhi 1272 A. H./1856 A.D.), p. 30. See also the text edition published by the well-known Nuwul Kishore Press, Lucknow (1893). The table in question in this edition is just a copy from Sir Syed's text. Even the above quoted marginal note is copied. As a matter of fact, Nuwul Kishore claims not only to have consulted Sir Syed's edition, but also the following manuscripts/editions: i) A manuscript belonging to the late Col. G. W. Hamilton, ii) A large folio parchment manuscript, the property of the Asiatic Society of Bengal, iii) A large quarto manuscript belonging to Nawab Ziauddin of Loharu (Delhi), iv) A manuscript belonging to Raja Prasad, v). The translation of Gladwin. At the end of his Preface 3rd Edition, 1893) he even thanks H. Blochmann, then Principal, Calcutta Madrasah, "for his valuable and accurate notes on his (Blochmann's) text edition". It is not understandable that, in spite of consulting so many manuscripts and especially Blochmann's text also, Nuwul Kishore apparently did not collate the tables in question: otherwise, why did he not comment on the obvious contradictions in the tables of various sources?

[23] Francis Gladwin was probably the first to translate *'Ā'īn-i Akbarī* in English, which he did as early as 1783. His translation was published in London in 1800. In contradistinction to what Sir Syed claimed above, Gladwin, according to Blochmann, translated from an uncollated manuscript, see ref. 12, preface p. vii.

[24] Cf. also A. K. Bag's contribution in these Proceedings.

[25] The symbol (see fig 2a) is used in the British Museum's manuscript. Another variation is in fig 2b cf. ref. 3, p. 327 or Riḍa A. K. Irani, Arabic Numeral forms, *Centaurus* 4 (I) 1955.

[26] Al-Bīrūnī: *Kitāb Taḥdīd Nihāyāt al-Amākin li-Taṣḥīh Masāfāt al-Masākin*, Transl. from the Arabic Text (Mss. Sultan Fatih 3386) by Jamil Ali, Beirut, 1967, p. 4 (hereafter referred to as *Taḥdīd*).

[27] The arabic text based on a number of manuscripts has been published under the supervision of S. Krankow by Osmania Oriental Publication Bureau, Hyderabad (1937). Cf. also the contributions of G. G. Lemmlein and A. M. Belenitskii in *"Biruni Sbornik Statey"*, Ed. S. P. Tolstova, Moscow, 1950. A Russian edition of the book has presumably been published by Belenitskii.

[28a] In fact, it is known today that very few gems are idiochromatic. Most of them are colourless, when in a pure state, and owe their colour to the existence of minute impurities only, which act as pigmenting agent.

[28b] Today, brilliance is defined with respect to the amount of incident light that is reflected not only from the surface but also from the interior of the stone. The latter depends, of course, on the refractive index of the medium.

[28c] We measure hardness, presently, as the resistance to scratching, resistance to indentation, with respect to an arbitrary reference scale, the Mohs' scale. On this scale, for instance, talc, quartz and diamond have the hardness numbers 1, 7 and 10. For more details, see *Encycl. Britannica* under the heading "gems".

[28d] In the West, Georgious Agricola is recognised as the "father of mineralogy", since he classified also minerals on the basis of physical properties in his work *De natura fossilium* published in 1546—nearly 500 years after the scientific mineralogy *"Al-jamāhir"* of Al-Bīrūnī.

[29] F. Rosenberg: *Geschichte der Physik* (Braunschweig, 1882), pt. I, p. 27.

[30] Al-Bīrūnī: *The Chronology of Ancient Nations*, English translation by E. Sachau (London,

1879), p. 243. Hereafter the references to the pages of this book will be given in parenthesis in the body of the text.

31a This is to be understood in the context of Aristotelian view of the physical reality as a system of homocentric spheres. According to this view there are 11 spheres around the earth which—as the heaviest element—is at the centre of the spherical (and therefore finite) universe. The natural place of the remaining three elements are the three innermost spheres, their natural order, depending upon their relative heaviness, being: water—air—fire. This is defined as the sublunar world, which is surrounded by the celestial spheres of the moon, the six planets (sun included) and by the outermost sphere of the fixed stars. According to Aristoteles only the celestial bodies are moving; the sublunar bodies are at rest (Cf. G. Sarton: *Ancient Science through the Golden Age of Greece* (Science Edition, John Wiley, New York, 1964) chapt. XX, p. 509). Cf. also note 35.

31b To define the word "body", we cite al-Bīrūnī: "Regarding the body that touches the inside of the sphere, i.e. the fire, people maintain that is a simple element like earth, water and air" (loc. cit. p. 247).

32 In the questions he posed to Ibn Sinā, he even objected to certain theories of Aristoteles.

33 Cf. Al-Risālat al-ḥādiyat 'asharat ajwibat al shaykh al-ra'īs 'an masā'il 'Abī al-Rayḥān al-Bīrūnī in *Jāmi'ul-Badā''i*, Ed. Muhīuddīn Ṣābri Alkurdī, Cairo (1917), especially pp. 139—140, questions no. 8 and 9. Hereafter this reference will be tacitly understood. The same correspondence is also translated into Persian by Ali Akbar Dehkhuda: *Life of Bīrūnī*, Teheran, pp. 29-64. Cf. also Zabihullah Safa: *Indo-Iranica*, vol. V, no 4, 1952, persian section p. 5, where other references are also given. We should further like to mention here, that H. Barni in his article: *Ibn Sīnā and Alberūnī* (Avicenna commemoration volume, Iran Society, Calcutta, 1956) gives in a footnote a rendering of al-Bīrūnī's questions. However, this should be utilised with caution.

34 Here aether can not be understood in the Aristotelian sense, since according to the latter aether is a fifth element or *quinta essentia*, from which the celestial (non-sublunar) bodies are made, which is neither heavy nor light, eternal and changeless—it cannot be transformed into the earthly elements (E. J. Dijksterhuis: *Die Mechanisierung des Weltbildes* (Springer Verlag, Berlin, 1956), part I, Chapter II, p. 36)

35 Cf. the text which is cited at the end of this section, p. 247. According to Aristoteles, the sublunar bodies are at rest if they are in their natural places (sphere). Otherwise they have a tendency to return to natural place (G. Sarton, loc. cit., p. 516). This means that heat—which al-Bīrūnī has already equated with fire (Nār)—within the sublunar world should proceed from the centre to the circumference only. (Cf. ref. in note 31a).

36 See ref. 33, p. 141; we cite:
Yajibu 'an ta'lama 'anna al-ḥarārāt laysat bi-sālikat[in] 'an al-markaz li-'anna al-ḥarārat ghayru mutaḥarrikat[in]-Allāhumma-'illā bi'l-'arḍi li-kawnihā fī jism[in] mutaḥarrik[in] ka-kawni 'insan[in] sākin[in] fī safīnat[in] mutaḥarrikat[in].

37 Most probably, al-Bīrūnī is referring here to Ibn Sīnā (loc. cit.). However, the latter has also remarked elsewhere that if the perception of light is due to the emission of some sort of particles by the luminous source, the speed (velocity) of light must be finite (see ref. 4, p. 710). On the contrary, Descartes (1595—1650) believed in the instantaneous propagation of light, although light for him also consisted of small elastic spherical particles.

38 We would like to remark here that although the finiteness of the velocity of light was assumed by G. Galilei (1564-1642) and this was also the opinion of J. Kepler (1571-1630) yet this view did not gain any ground due to the authority of Descartes, untill O. Roemer (in 1676) calculated the velocity of light for the first time by observing the time delay in the actual disappearance of the eclipse of the Jupiter-moon and that calculated theoretically on the basis of a previous observation. Only with the support of Huygens and Newton did the finiteness of the velocity of light become an accepted view.

[39] The Jesuit M. Mersenne (1588-1648) is generally accepted as the first who according to a suggestion of Roger Bacon determined the velocity of sound by noting the time-difference between seeing the flame and hearing the sound when a gun was fired. Now, this is exactly what al-Bīrūnī means by "comparing the propagation of sound and light". Therefore some such method as that of Mersenne must have been used by contemporaries or even predecessors of al-Bīrūnī to determine the velocity of sound.

[40] Cf. ref. 37.

[41] According to *Almutakallimūn* *'rḍ* is a thing that subsists in, or by, another thing. In Philosophy it is a thing that exists in its subject or substance (*Jawhar*); see E. W. Lane: *Arabic-English Lexicon,* Book I, Part 5, p. 2008. Without going into detail, which is out of place here, we may remark that the Aristotelian view of nature comprises a dichotomy of "material" and "formal". The latter is to be identified with *'rḍ*. The consummation of the form is the aim, and it cannot be effected except through matter or kinds thereof; see Sarton, (note 31a), p. 515.

[42] See ref. 33, p. 140.

[43] According to the contemporary view, light as well as heat is nothing but electromagnetic waves. Whereas the visible light comprises waves of shorter wavelengths, heat consists of waves of longer wavelengths.

[44] *Chronology* p. 247.

[45] See under "Physics", *Encyclopedia Britannica,* 1966.

[46] Quoted by S. H. Barni: *Indo-Iranica* V, No. 4 (1952), p. 41. It is not very clear from which writing of al-Bīrūnī this excerpt is taken.

[47] *Taḥdīd,* p. 3.

[48] *ibid,* p. 5.

[49] *Chronology,* p. 4.

[50] *Taḥdīd,* p. 2.

TABLE 1

DATA FROM VARIOUS REPORTS

METALS

Substance	Bīrūnī	—Fazal-1—					—Paris-1—			Paris-2	Ghaffārī	Manṣūr	—Fazal-2—					Farahi
	T	M	D	T	=	T	M	T	T/60	T/60	T	T	M	D	T	=	T	M
Au	126	5	1	2	=	126	544896†	11	7	144000	2400	2400	100	10	0	=	2400	100
Hg	177	7	2	1	=	177	387873	4	15	102546	1712	1709	71	1	1	=	1709	71
Pb	212	8	5	3	=	215	325837‡	12	15	85560	1423	1426	59	2	2	=	1426	52
Ag	233	9	4	1	=	233	294650	10	30(32)	77883	0	0*	54	3	3	=	1311	—
Cu	277	11	3	3	=	279	247846	18(19)	12	65520	1112	1112	45	3	3	=	1095	45
Br	280	11	4	3	=	283	245191	6(7)	12	64800	1080	1080	45	3	5	=	1097	45
Fe	310	12	5	2	=	310	221463	1	45(32)	58500	975	975	40	0	0	=	960	40
Sn	328	13	4	3	=	331	209309	14	40(50)	55320	900	888**	38	2	2	=	922	38
							† 69 in Khazini ‡ 73 in Khazini		(Khāzini's values.)			* Khāzinī gives 1298 **Khāzinī gives 922						

JEWELS

Substance	Bīrūnī	—Fazal-1—					—Paris-1—			Paris-2	Ghaffārī	Manṣūr	—Fazal-2—					Farahi
	T	M	D	T	=	T	M	T	T/60	T/60	T	T	M	D	T	=	T	M
Emr	872	36	2	3	=	875	78731	3	9	20807	67(A)		69	3	3	=	1671	
Yqt (b)	606	25	1	2	=	606	113289	16	34	29940	96 ,,		94	3	3	=	2271	
Yqt (r)	624	26	3	3	=	639	110021	17	17	29077	92 ,,		94	3	3	=	2271	
Ruby	670	27	5	2	=	670	102467	23	42	24081	86 ,,		90	2	3	=	2171	
Lp. Lz.	892	38	3	3	=	927	76965	20	48	20341	0 ,,		65	3	2	=	1574	
Prl	924	37	1	3	=	895	74300	9	11	19636	67 ,,		67	5	2	=	1630	
Crn	936	38	3	3	=	927	73347	19	41	19384	63 ,,		64	4	2	=	1554	
		(Amber)																
Crl	939	39	3	3	=	951	73113	11	25	19323	63 ,,		64	3	1	=	1549	
Rcks	960	40	3	3	=	975	71514	2	50	18902	62 ,,		63	3	3	=	1527	
Gls	964						71217	9	6	18822	62	(Onyx)						
Enm	610						112546	19	45	0								
Ivr	1464						46894	12	0	12393								
Ebn	2124						61079	16	10	16142								
Pshl	968										64 ,,							

LIQUIDS

Wtr	1200	28605	15	32	7560
Vin	1232	29367	18	55	7763
Cmlk	1332	31917	12	18	8430
Oil	1104	24334	7	30	6970

Notation :

Au = Gold; Hg = Mercury; Pb = Lead; Ag = Silver; Cu = Copper
Br = Brass; Fe = Iron; Sn = Tin; Emr = Emerald; Yqt = Yaqut (sapphire)
b = blue; r = red; Lp.Lz = Lapis lazuli; Prl = Pearl; crn = cornelian

Crl = Coral; Rcks = Rock salt; Gls = Glass; Enm = Enamel; Ivr = Ivory
Ebn = Ebonite; Pshl = Pearl shell; Wtr = water; Vin = vinegar; Cmlk = cow milk

TABLE 2

RELATIVE DENSITY

Substance	Bīrūnī	Fazal-1	Paris-1	Paris-2	Fazal-2	Manṣūr	Ghaffārī	Farahi
Au	1·00000	1·00000	1·00000	1·00000	1·00000	1·00000	1·00000	100(M)
Hg	0·71186	0·71186	0·71182	0·71212	0·71208	0·71208	0·71333	71
Pb	0·59433	0·58604	0·59798	0·59416	0·59416	0·59416	0·59291	52
Ag	0·54077	0·54077	0·54074	0·54085	0·54625	—	—	—
Cu	0·45487	0·45161	0·45485	0·45500	0·45625	0·46333	0·46333	45
Br‡	0·44999	0·44522	0·44997	0·45000	0·45708	0·45000	0·45000	45
Fe	0·40645	0·40645	0·40643	0·40625	0·40000	0·40625	0·40625	40
Sn	0·38414	0·38066	0·38412	0·38416	0·38416	0·37000†	0·37500	38

‡ Br = Brass

† Al-Khāzinī's value gives 0·38416

SPECIFIC GRAVITY

						Modern	
Au	19·04761	19·04761	19·04856	19·04761	19·04833	18·88—19·3	
Hg	13·55932	13·55932	13·55932	13·56428	13·56399	13·546	
Pb	11·32075	11·16279	11·39067	11·31746	11·31788	11·347	(compressed)
Ag	10·30042	10·30042	10·30042	10·30198	10·40515	10·31	(coin), 10·42—10·6
Cu	8·66425	8·60215	8·66425	8·66666	8·69080	8·30 —8·95	
Br‡	8·57142	8·48056	8·57142	8·57142	8·70667	8·44 —8·70	yellow
						8·60	red
Fe	7·74193	7·74193	7·74193	7·73809	7·61933	7·03 —7·88	
Sn	7·31707	7·25075	7·31707	7·31746	7·31773	7·29 —7·30	

TABLE 3

RELATIVE DENSITY

Substances	Birūnī (Beirut) Mss.	Paris-1	Paris-2	Fazal-1	Fazal-2	Ghaffārī
Emr	1·00000	1·00000	1·00000	1·00000	1·00000	1·00000
Yqt (b)	1·43894	1·43894	1·43893	1·44389	1·35906	1·43283
Yqt (r)	1·39743	1·39743	1·39746	1·36932	1·35906	1·37313
Ruby	1·30149	1·30149	1·15735	1·30597	1·29922	1·28358
LpLz	0·97757	0·97757	0·97760	0·94390	0·94195	0·00000
Prl	0·94372	0·94372	0·94372	0·97765	0·97546	1·00000
Crn	0·93162	0·93162	0·93160	0·94390	0·92998	0·94029
Crl	0·92864	0·92864	0·92867	0·92008 (Amber)	0·92698 (Amber)	0·94029
Rcks	0·90833	0·90833	0·90844	0·89743	0·91382	0·92537
Gls	0·90456	0·90456	0·90459			(Onyx) 0·92537
Enm	1·42950	1·42950	0·00000			0·00000
Ivr	0·59562	0·59562	0·59561			0·00000
Ebn	0·41054	0·77580	0·77579			0·00000
Pshl	0·90082	0·00000	0·00000			0·95522

SPECIFIC GRAVITY

						Modern
Emr	2·75229	2·75229	2·75224	2·74285	2·75229	2·5—2·7 (Emery)
Yqt (b)	3·96039	3·96039	3·96031	3·96039	3·74054	3·75—4·31
Yqt (r)	3·84615	3·84615	3·84616	3·75586	3·74054	3·95—4·10
Ruby	3·58208	3·58208	3·18531	3·58208	3·57583	3·5—3·6
LpLz	2·69058	2·69058	2·69060	2·58899	2·59252	2·38—2·45
Prl	2·59740	2·59740	2·59735	2·68156	2·68475	2·684 (Rosenberg)
Crn	2·56410	2·56410	2·56402	2·58899	2·55958	
Crl	2·55591	2·55591	2·55595	2·52365 (Amber)	2·55134 (Amber)	
Rcks	2·50000	2·50000	2·50026	2·46153	2·51510	2·135—2·170
Gls	2·48962	2·48962	2·48968			2·4—2·6 (window)
Enm	3·93442	3·93442	0·00000			
Ivr	1·63934	1·63934	1·63928			1·83—1·92
Ebn	1·12994	2·13523	2·13518			1·15
Pshl	2·47933	0·00000	0·00000			

LIQUIDS

Wtr	1·00000	1·00000	1·00000			
Vin	1·02666	1·02664	1·02685			1·049
Cmlk	1·11000	1·11577	1·11507			1·028—1·035 (Rosenberg: 1·42—1·04
Oil	0·92000	0·85068	0·92195			0·918

TABLE 4

Data reported in Ain-i-Akbari and their Correction

Substance	Bīrūnī (Beirut Mss)	Fazal-1							
		Weight of water displaced					Weight in water		
	T	M	D	T	=	T	M	D	T
Au	126	5	1	2	=	126	95(4)	4	2
Hg	177	7	2	1	=	177	92	3	3
Pb	212	8	5	3(e)	=	215	91	1	3(e)
Ag	233	9	4	1	=	233	90	1	3
Cu	277	11	3	3(1)	=	279	88	3(2)	3†
Br	280	11	4	3(e)	=	283	88	2	3(e)
Fe	310	12	5	2	=	310	87	3(0)	2‡
Sn	328	13	4	3(e)	=	331	86	2	3(e)
Rcks	960	40	3(e)	3(e)	=	975	60	3(e)	3(e)
Emr	872	36	2	3(e)	=	875	63	4	3(e)
Yqt (b)	606	25	1	2	=	606	74	4	2
Yqt (r)	624	26	3(e)	3(e)	=	639	74	3(e)	3(e)
Ruby	670	27	5	2	=	670	72	3(e)	2
Lp.Lz.	892	38	3	3(e)	=	927	61	3	3(e) } *
Prl	924	37	1	3(e)	=	895	62	5	3(e) } *
Crn	936	38	3	3(e)	=	927	61	3	3(e)**
Amber	—	39	3	3(e)	=	951	60	3	3(e)

1M=6D; 1D=4T: e=excess; ( )=correction:

† Same wrong value by Al-Khāzinī; even the total weight 2125 T, also given by him, is wrong.
‡ The corrected value is given by Al-Khāzinī.
* In *'Ā'in-i-Akbari* rows are exchanged.
** 936 T=39 M; then 61-0-0 tallies with Al-Khāzinī.

AL-BĪRŪNĪ AND HINDU SPECULATIONS ON GRAVITATION

SOURIN ROY
Department of Economics
Delhi University
Delhi 7

The paper deals with the Hindu speculations on gravitation, particularly with reference to those of Āryabhaṭa, Varāhamihira, Bhāskara and their commentators. Al-Bīrūnī's own reactions to these speculations are examined.

The term gravitation has two distinct connotations: (1) the force that causes stones and other objects to fall to earth; and (2) that which keeps the planets and other celestial bodies in their path. The first was known in some form or other to ancient cosmology. The second appears to have totally eluded pre-Newtonian speculators. It was Newton's unique achievement to discover that the force that causes a stone to fall is that which keeps the planets in their courses, and to identify terrestrial attraction (gravity) as only a special case of universal gravitation.

That terrestrial attraction loomed large in Hindu astronomical speculations hardly requires much elaboration. What, however, is not so very certain is whether, or to what extent, if at all, the ancient Indian astronomer was aware of the role of cosmic gravitation in the ordering of planetary movements In his last discourse to the Asiatic Society Sir William Jones no doubt made the apparently extravagant claim that the whole of the Newtonian theory and part of his philosophy 'may be found in the Vedas......' and that the Vedas abound in allusions 'to a force universally attractive' which they ascribed to the Sun called *Ādytya* or attractor.[1]

Less elusive in this context would appear to be some of the expressions occurring in a fragmentary[2] text of Āryabhaṭa, which do seem to imply on his part some awareness of the idea of universal gravitation, albeit in a very rudimentary and embryonic form. The text reads: 'Surrounded by the vault of the celestial dome and girdled by the equator, exists the terrestrial gloge, entirely round, a compound of earth, water, fire and air, held in grip in space' ((*kha-madhya-gata*).[3] The expression, *kha-madhya-gata* is interpreted by the commentator Nīlakantha as implying "the absence of any need for a physical support" (*kha-madhya-gatetyanenādhāranairapekṣyamuktam*)[4] By these words Āryabhaṭa was apparently trying to silence those who contended that the earth was running off into space. That there was a school of thought which held such a view will become evident from Bhāskarācārya's reply to the former's argument in his *Siddhānta-śiromani* (*Golādhyāya* I.2.4.7,9). Bhāskara, who did not believe in any kind of terrestrial motion, tried to tackle the problem by affirming that the earth stands firm 'by its own power', without other support in space." It is doubtful if that was also the view of Āryabhaṭa. His text is fragmentary and we do not know what precise shape his thinking on the subject ultimately took. It would appear, however, that he did think in terms of some kind of universal force which held the earth firmly in space. Some indication of this is provided by Varāhamihira who, while paraphrasing Āryabhaṭa's text already quoted says: "Surrounded by the celestial vault, the earthly globe, a compound of five elements, remain suspended in the sky, even as a piece of iron is held in the grip of a magnet.[5]" It is pertinent to remember here that in Indian astronomical literature examples are not wanting in which the earth's own gravitational pull has been likened to magnetic attraction.[6] Varāhamihira thus, to all appearance, had some kind of gravitational force in mind when he compared to magnetic pull the force which tended to keep the earth in its path. Since Varāhamihira was not much of an innovator himself, it stands to reason that he lifted the idea in its entirety from his illustrious predecessor.

Much of what we know of ancient Indian astronomical thinking is derived from what al-Bīrūnī has to say on this subject in his monumental work on India. It does not appear, however, that the great Khhwārizmīan savant ever had any opportunity to learn anything precise regarding Indian thinking on the force which kept the earth in space. He knew that the law of terrestrial gravitation played an important role in Indian discussions on astronomy. He was aware that according to the Indian view, "everything heavy gravitates towards the earth". It also appears that he had gathered that the applicability of this so called law of gravitation, according to the Indian way of thinking, somehow extended even beyond the earth's gravitational field; for he says: "Evidently on account of this law of gravitation they (Hindu) consider heaven too as having a globular shape".[7] But nothing further on the subject can be gleaned from his work.

Though virtually silent on the Hindu view of cosmic gravitation, al-Bīrūnī furnishes us with very precise information not only on Indian speculations with regard to the relatively limited problem of terrestrial attraction, but, what is more important, on Indian thinking on the bearing of the question on the earth's own motion. It will be interesting to reproduce here a passage from Varāhamihira which he has cited in this connexion:

"Mountains, seas, rivers, trees, cities, men and angels are all around the globe of the earth. And if Yamakoṭi (Yavakoṭi?) and Rome are opposite to each other, one could not say that the one is low in its relations to the other, since the 'low' does not exist. How could one say of one place of the earth that it is low as it is in every particular identical with any other place on earth, and one place could have as little fall as any other. Every one speaks to himself with regard to his own self, 'I am above and the others are 'below', whilst all of them are around the globe like the blossoms of the *kadamba* flower. They encircle it on all sides but each individual blossom has the same position as the other, neither the one hanging downwards nor the other standing upright. For it is the below towards all directions, and heaven is the above towards all directions". (*Indica*. 1, 25).

One can at once recognise that the ideas adumbrated above are an elaboration of the following text of Āryabhaṭa:, whom Varāhamihira is known to have been faithfully imitating: "As the ball formed by the blossoms of the *kadamba* flower is on every side (*samantataḥ*) beset with flowerets, so is the earth-globe with all the creatures terrestrial and aquatic".[8] What further matter Āryabhaṭa's original text might have contained we do not know. The text as we have it appears to be only too full of lacunae. But what he must have evidently intended is sufficiently clear from the text of Varāhamihira as reproduced by al-Bīrūnī. That Āryabhaṭa anticipated the former in formulating that there was no up and down in the universe any more than one would think of such things in an ordinary sphere would also become evident from the passage in which he sarcastically refers to the denizens of the North Pole and those of the South pole deeming "each other to be the under-most" (*manyante parasparam adhahṣthitān niyatam*).[9] Once we accept that Varāhamihira's text in question is no more than a rehash of his distinguished predecessor, the sole credit of pioneering the idea of terrestrial gravitation in the Indian astronomical world has fairly and squarely to be attributed to the latter.

In yet another citation al-Bīrūnī shows how another of Āryabhaṭa's distinguished successors, Brahmagupta, further expanded the same idea of gravitation: "Scholars have declared that the globe of the earth is in the midst of heaven and that the North pole is the home of the *devas,* as well the South pole 'below' is the home of their opponents. But this 'below' is without any meaning. Disregarding this we say that the earth on all sides is the same; all people on earth stand upright and all heavy things fall down to the earth by a law of nature, for it is the nature of the earth to attract and to keep things, as it is the nature of water to flow, that of the fire to burn and that of the wind to set in motion. If a thing wants to go beyond the earth let it try. The earth is the only low thing, and seeds always return to it in whatever direction you may throw them away; and never rise upwards from the earth". (*Indica* I, 276).

Al-Bīrūnī's own comment on the passages is: "As readers will observe, these theories of the Hindus are based on the correct knowledge of the law of nature".[10] The significance of the statement will become at once evident if we contrast with Hindu views of gravitation those of the Platonists of ancient and medieval Europe. By the Platonists of *Chartres,* for instance, the falling of bodies was explained by way of supposing that bodies of like nature tended to come together. A detatched part of any element would thus tend to rejoin its main mass. A stone fell to the earthly sphere at the centre of the universe, whereas fire shot upwards to reach the fiery sphere at the outermost limit of the universe. (Thierry of Chartres—*De Septem Diabus et Sex Operum Distinctionibus.* 1153-A.D., as cited by A. C. Crombie in *Augustin to Galileo,* I, p. 48). The theory is borrowed from Plato's *Timaeus,* and is also deeply influenced by Aristotle's view of cosmos, according to which, the earth was surrounded by a good number of concentric spheres, the first three being those of water, air and fire respectively. Indian speculation on the subject was refreshingly free of such mythological lumber. It is interesting to note that Āryabhaṭa and his followers completely discarded the idea of concentric spheres. Nor did they feel any necessity for imagining an unmoved mover to explain planetary movements.

Yet, when one ponders on the subject, what emerges as remarkable is not that an astronomer like Āryabhaṭa should hit upon the idea of gravitation, but that he should make effective use of it in propping up an equally remarkable theory of his, viz. that of a rotating terrestrial globe. It is well-known that Āryabhaṭa started out with the assumption that the earth was stationary and that it was the planetary spheres which revolved round it. To explain such irregularities in the planetary motions as were apparent he devised a system of eccentrics and epicycles akin to that of Ptolemy, though with important differences. Firstly, he avoided having an endless number of circles which the Ptolemaic system needed in order to save the apperance. He also, as Colebrooke has pointed out gave an oval (as opposed to circular) shape both to his eccentric and his epicycles.[11] But he must have ultimately found this system unsatisfactory, as it very clearly appears that he took the bold step of replacing it drastically by the theory of a moving earth and a stationary universe surrounding it. The proof of this is provided by a lost text of his conserved in Pṛthūdakasvāmin's commentary on the *Brāhmasphuṭa-siddhānta* The text reads: "The celestial world is stationary. It is the earth which by its continuous rotation causes the daily rising and the setting of the planets as well as the stars (*bha-panjarah sthiro bhūrevāvrityā-vṛtya prātidaivāsikau udapāsta-samayau sampādayati nakṣatra-grahāṇām*"[12]—This view naturally contradicted what one appeared to see with his own eyes. But Āryabhaṭa anticipated the objection by arguing: "As a person in a boat, while moving forward sees immobile objects (on the banks) moving backward, in the same manner do the heavenly bodies, however immobile, seem to move towards the west". (*Āryabhaṭīyam-golapāda,* v. 9). It is interesting to note that prior to Nicole Oresme (d. 1382) nobody even thought of using this particular argument to justify earth's motion (*Le Livre de Ciel et du Monde,* chapt. 25)

More serious objections were advanced by Āryabhaṭa's opponents and it would appear that it was in order to silence them that both he and his followers confronted them with the theory of gravitation. Traces of the debate which took place between the two conflicting schools can be detected, albeit, in a somewhat mutilated form, both in Utpala's commentary on the *Bṛhatsaṃhitā,* and in Pṛthūdakasvāmin's scholium on Brahmagupta. In Utpala, for instance, occurs the objection: "If the earth moved, birds after having soared to the sky should not be able to find their nests (*Syenādyā na khāt punah sva-nilayam-upeyuh*).[13] This is, to all appearance, an echo of Varāha-mihira himself, who in his *Pañcasiddhāntikā* (XIII. 6-7) had already raised the same objection. If the earth rotated, he observed, 'falcons etc. could not return from the sky to their nests...... and flags and similar things would, owing to the quickness of the revolution, stream constantly to the west". A somewhat different type of objection is referred to by Pṛthūdakasvāmin, viz. "If the earth rotates constantly how is it that lofty objects do not fall (i.e. are not thrown out in space)? (*āvartanamarvāk cet na patanti saucchrayāh Kasmāt?*)[14] While we are not aware of Āryabhaṭa's answer to the question raised by Varāhamihira (it having obviously been lost), Pṛthūdakasvāmin acquaints us with the great astronomer's refutation of the objection which he himself had high-lighted. "The objection that lofty (heavy?) things could fall," says he, "is contradicted; for everywhere the under-part of the earth is also the upper. Since wherever the spectator stands on the earth's surface even that spot is the uppermost part".[15]

The answer, it would seem is not complete. It is here that al-Bīrūnī comes to our aid. Not only does he give a lucid exposition of the objections of the Varāhamihira school, but with equal perspicuity he acquaints us with the answer to the objections advanced by the school of Āryabhaṭa. Quoting from *Brāhmasphuṭasiddhānta,* he says, "Some people maintain that the first motion (i.e. the motion of the celestial sphere) from east to west does not lie in the meridian, but belongs to the earth. But Varāhamihira refuted them by saying: "If that were the case a bird would not return to its nest as soon as it had flown away from it towards the west. And in fact it is precisely as Varāhamihira says" (*Indica* I, 276). Al-Bīrūnī also cited another passage bearing on the problem from the same book: 'The followers of Āryabhaṭa maintain that the earth is moving and heaven resting. People have tried to refute them by saying that if such were the case, stones and trees would fall from the earth' (*Ibid*). The answer of the *Āryabhaṭīya* school is given by al-Bīrūnī in the following words: "That (viz. the earth's leaving behind heavy objects) would not necessarily follow from their theory because ..... all heavy things are attracted towards the centre of the earth" (*Ibid*). This argument was no doubt put in a more refined form by the medieval scientist Oresme, who also propounded a theory akin to the Newtonian law of motion. Yet what Āryabhaṭa achieved was, on any showing, extremely amazing, and stands out as a distinct advance on all that had even thought of or formulated on the subject prior to him.

Before I conclude it would be interesting to enquire into the precise nature of al-Bīrūnī's own reaction to these speculations. "The rotation of earth", he observes, "does, in no way impair the value of astronomy, as all appearances of an astronomic character can quite as well be explained according to this theory as to the other. There are, however, other reasons which make it impossible. This question is most difficult to solve. The most prominent of both modern and ancient astronomers have deeply studied the question of the moving of the earth and have tried to refute it. We too have composed a book on the subject called *MIFTA'H—'ilm-al-haja'* (Key to Astronomy) and have surpassed our predecessors, if not in the words ..... at all event in the matter".[16] How the great Khwārizmīan astronomer actually refuted the arguments based on the law of gravitation I have no means to know. Sachau thinks that the "Key of Astronomy" dealt with the question whether the sun rotated round the earth or the earth round the sun, and that probably the book also made use of the notions of Indian astronomers. (*Indica*—Introduction, I, XXXVI—XXXVII). It is evident that the book was not accessible to Sachau when he published his translation of al-Bīrūnī's masterpriece on India. It would advance the cause of research materially if the contents of the work could be available to the student interested in India's past astronomical achievements.

Although al-Bīrūnī did not see eye to eye with Āryabhaṭa or his school with regard to this particular problem all students of the history of scientific activities in India should feel grateful to him for having conserved for us a very lucid account of the debate which took place in classical India on the question of the rotating motion of the earth and also on the related question of gravitation.

Notes and References

1 *Asiatick Researches*, IV, pp. 176-7.

2 Hardly any writings of Āryabhaṭa relating to his mature period have survived in full. To have a clear idea of his many innovations one has to depend mostly on a text which on any showing is of a fragmentary character, or on stray citations from him occurring in later writers, most of whom were his opponents. None of his writings was available to al-Bīrūnī in the 11th century. "I have not been able", says he in *Indica* "to find anything of the books of Āryabhaṭa. All I know of him I know through the quotations from him given by Brahmagupta". That the original works of Āryabhaṭa were either not available or existed only in much mutilated condition in the 14th century is indicated in the following passage from the *Mahā-Ārya-Siddhānta*: "That (knowledge) from the *Siddhānta* propounded by Āryabhaṭa which was destroyed, in recensions, by long time I have in my own language thus specified" (*J.R.A.S.* 1864 p. 392). Even Bhāskara, it would appear, had no access to the original texts of Āryabhaṭa and quoted him only second hand. Bhāskara knew of the relation established by Āryabhaṭa between the diameter and the circumference of a circle. But on his own showing he obtained this idea from Pṛthūdakasvāmin's gloss on Brahmagupta (*Siddhānta-Śiromaṇi—Golādhyāya*. p. 264. line 15).

3 *Āryabhaṭīyam* (*Golapāda*) v. 6, University of Travancore Sanskrit series, edited by S. K. Pillai (1957).

4 *ibid*, p. 21.

5 Quoted by Nīlakaṇṭha in his commentary on *Golapāda* (Ibid p. 21).

6 *Vide* Marīci's commentary on Bhāskara's *Golādhyāya* (1.7) where the former likens terrestrial attraction to "attraction of loadstone on iron" (quoted in *Asiatick Researches* XII p. 229).

7 *Indica* I p. 265.

8 *Golapāda*, V. 7.

9 *ibid*, v. 12.

10 *Indica* I. 276. It is to be noted that al-Bīrūnī here is quoting not from Brahmagupta but from his commentator Pṛthudakasvāmin.

11 *Asiatick Researches* XII pp. 235-6.

12 *ibid*, p. 227.

13 *JRAS* 1863 (Vol XX).

14 *Asiatick Researches* XII p. 227.

15 *ibid*

16 *Indica* I p. 277.

METROLOGY IN AL-BĪRŪNĪ'S *INDIA*

V. B. MAINKAR *
Director, Weights & Measures, Ministry of
Industry and Civil Supplies
New Delhi

Al-Bīrūnī[1] has devoted Chapter XV of his book on India to an elaboration of the metrology prevailing in the part of India around Multan, in which he was conducting his studies of Indian traditions, around 1030 A.D. From the caption of the chapter, (Notes on Hindu Metrology, intended to facilitate the understanding of all kinds of measurements which occur in this book) it is obvious that he was aware of the basic importance of a good knowledge of units of weights and measures for understanding the sciences as they existed in India during his time.

He also realised that, besides knowledge of metrology, it was necessary to understand the Indian system of numeration, as results of scientific investigations have to be expressed in terms of a unit of weight or measure and a number. Very large numbers, extending to even 56 digits, were handled without any hesitation by the Indian astronomers even in those days (363, chapter XXXIX). Al-Bīrūnī, therefore, devoted chapter XVI to the elucidation of the system of numeration as he comprehended it.

YOJANA-BASE-UNIT FOR ASTRONOMY

Before embarking on an analysis of al-Bīrūnī's metrological data, it is necessary to establish the limitations under which he had to carry out his studies of Indian sciences, among which he has devoted special attention to astronomy and geography. A short historical sketch of Indian metrology would be helpful.

In the history of India, until al-Bīrūnī's time, there were only two periods during which uniformity of weights and measures prevailed over large parts of India. The first such period, as we know today, existed during the Indus Valley Civilization, i.e. from about 3000 B.C. to about 1500 B.C. The uniformity on weights and measures in the vast region over which that civilization spread was astonishing. The next period was during the Mauryan reign in the fourth and third century B.C., when the system of weights and measures adumbrated by Kauṭilya in his *Arthaśāstra* was in use. After the Mauryas, this uniformity of weights and measures gave place to a variety which became bewildering in the course of time. By the time al-Bīrūnī came to India this variety had reached such magnitude that weights and measures used differed even from commodity to commodity, and in the case of astronomy, from one school of thought to another. No wonder that al-Bīrūnī found himself at a loss in this frightening confusion of weights and measures, particularly in his study of astronomy.

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* Since deceased.

It is against this background of confusion, to which al-Bīrūnī has himself made a pointed reference in chapter XV and XVI, that his metrological tables and data have to be examined. To simplify examination, it is proposed to analyse the unit of *yojana,* to which he constantly refers, as it was related to a physical constant, namely, the circumference of the earth, a quantity that could have been measured with a certain amount of accuracy even in ancient times. The circumference of the earth is variously given as 4800 *yojana,* 6596 *yojana,* 3393 or 3200 *yojana* by the Indian savants whose works al-Bīrūnī studied (Chapter XXXI). Certain other Indian authorities not quoted by al-Bīrūnī, reckon the circumference of the earth as follows:—

S. No.	Authority	Period A D	Circumference of earth *yojana*	*Yojana* / km.
(1)	*Āryabhaṭīyam*[2]	499	3300	12.12
(2)	*Mahābhāskarīya*[3]	628	3298.68 (Polar)	12.13
(3)	*Vaṭeśvarasiddhānta*[4]	880	3374	11.86
(4)	*Sūrya-Siddhānta*[5]	400	5029	7.95
(5)	*Brāhma-Sphuṭa-Siddhānta*[6]	628	5000	8.00
(6)	*Siddhānta-Śekhara*[7]	1039	5000	8.00
(7)	*Mahāsiddhānta*[8]	950	6625	6.04

The actual magnitude of *yojana* as given by al-Bīrūnī is 32,000 yards (*hasta*). But we know, that it could also be 16,000 *hasta,* as seen in the two versions of the *Arthaśāstra*[9] and in many other ancient work on astronomy.

Further, the *hasta* had also varying lengths. The *Arthaśāstra* which had served as the base for Indian administration for many centuries, refers to two *hasta* measures directly, namely, one of 24 *aṅgula* and the other of 28 *aṅgula.* The author of the present paper has established, on an analysis of metrological practices in India, that the *hasta* of 28 *aṅgula* had possibly a length of about 500 millimetres, and consequently, the *hasta* of 24 *aṅgula* was equal to 429 mm. Later on, every *hasta* measure was equated to 24 *aṅgula,* but the width of the *aṅgula* was varied as 6, 7, or 8 *yava* (barley-corns placed side by side). This division of *aṅgula* ino *yava* units is referred to by al-Bīrūnī. Under this system the *hasta* with 8 *yava* would be 500 mm, 7 *yava* 438 mm (and not 429 mm) and 6 *yava* 375 mm. The *yojana* based on 16,000 *hasta* each, would thus be 8 kilometres (for 500 mm *hasta*), 6.864 km (for 438 mm *hasta*), 7.008 km (for 429 mm *hasta*) and 6 km (for 375 mm *hasta*). The circumference of the earth which may be taken as about 40,000 km would then be as indicated below in terms of *yojana*:

Sl. No.	*Hasta*/mm	*Yojana*/km		Circumference of earth	
		16000 *hasta* (A)	32 000 *hasta* (B)	*hasta* (A)	*yojana* (B)
1.	500	8.000	16	5000	1500
2.	438	7.008	14.016	5700	2850
3.	429	6.864	13.728	5828	2914
4.	375	6.000	12.000	6667	3334

There are references to *aṅgula* of 5 and even 4 *yava*, but they may be neglected because they appear to have been rarely, if ever, used, in practice.

The above discussion would indicate that the *yojana* could vary sharply from one authority to another and utmost care has to be taken while analysing Indian astronomical data. It is to the credit of al-Bīrūnī that he has managed to study systematically the astronomical data made available to him. To simplify his task, he has related the *yojana* directly with the *farsakh*, a unit which was in use in the middle-eastern countries in those days. According to the information given by al-Bīrūnī, the *krośa* was equal to one mile (the mile is not the English mile, but the *'meel'* of the Arabs) and is equal to 4000 yards (here also the yard is not the English yard, but the *'hasta'* measure). He says that the *yojana* was equal to 8 miles (*meels*) or 32,000 yards (*hasta*). He also warns "Perhaps somebody might believe that 1 *kroh* $=\frac{1}{4}$ *farsakh*, and maintain that the *farsakhs* of the Hindus are 16,000 yards long. But such is not the case. Or the contrary 1 *kroh* $=\frac{1}{8}$ *yojana*". He does not define either the mile or the *farsakh* or the yard. Sachau has given the relation of *farsakh* with the *yojana*, on the basis of other studies. Sachau's calculations show that one Arabian mile is approximately 2,000 metres. Thus

1 *yojana*	=	32,000 yards		
	=	8 miles	=	16 km
1 mile	=	4000 yards	=	2000 metres
1 *farsakh*	=	4 miles	=	1 *kuroh*
	=	16,000 yards	=	8 km

According to Indian metrology, the *yojana* is either 16,000 *hasta* or 32,000 *hasta*. This duality of *yojana* stretches back to 300 B.C., as was indicated earlier in this paper. The *yojana* could, therefore, also be equal to the *farsakh*. This point has eluded al-Bīrūnī.

It is thus obvious that equating the *yojana* to a value of 16 km may not be correct. The astronomical data of al-Bīrūnī needs to be carefully sorted out to establish the truth of his findings.

Al-Bīrūnī's data on length measures of denominations lower than the *yojana* and the *krośa* has to be analysed carefully in the light of the confusion about the *yojana* and its magnitude in terms of the *hasta*. In view of the fact that the units like *hasta, dhanu* etc. are not mentioned by al-Bīrūnī in his book, they have not been examined in this paper.

Units of Time

The case of the unit of time is similar to the *yojana*. It is basically derived from the duration of the night and day or the diurnal rotation of the earth (nychthemeron). This period is subdivided into very small units and multiplied into very large numbers, some of them running into as many as 56 digits. Al-Bīrūnī has stated that while the Greeks and Arabs hardly ever counted beyond 1000 (that is, 3 places), the Indians had developed separate names for decimal denominations right upto the 18th place. Such large numbers were commonly used in Indian reckoning of time because complicated calculations involved manipulation of large numbers. The concept of time was basically related with the nychthemeron, which was divided into 'minor particles of time' (see Chapter XXXIV) and multiplied into very large periods like the month, and year of the fathers, *devas, Brahma, Puruṣa* and *Kha*. (see Chapters XXXV, and XXXVIII). He has given the subdivisions of the day as adumbrated by a number of authorities. As a result, like weights and measures, there is a variety of units of time, and these vary considerably among themselves. The usual tradition of 60 *ghaṭi* to a day, making *ghaṭi* equal to 24 modern minutes is mentioned by al-Bīrūnī. The smallest unit of time is given as *aṇu* of which 88, 473, 600 are contained in a day. For the purpose of comparison, a day has 86,400 modern seconds. Thus the *aṇu* is approximately equal to a millisecond.

A study of the measurement of time as related to astronomy reveals that al-Bīrūnī had considerable knowledge of astronomy which enabled him to analyse systematically the complicated system of astronomy practised in India.

Weights and Dry Measures

The field of study relating to ancient Indian weights and capacity measures is always tricky. These units are not related to any natural phenomenon like the duration of the day and night or the circumference of the earth. They are usually arbitrary in the sense that, for example, the unit of weight is represented by the weight of an object like a seed (*guñja*) or a piece of metal. If the metal object is lost the very basis of the system of weight is lost. The seeds can vary considerably in weight in different atmospheric conditions. As a result, any description of a system of weights is not useful in deriving the values of its constituent units. For example, al-Bīrūnī mentions the *tolā*. It is quite clear that it has no relation with the *tolā* equivalent to 180 grains (11.638 grams) standardized by the British in 1835. He also refers to a *māna*, of which there appear to be two varieties. In fact, in the same system of weights, there are two names of weights which are very similar to *māna*. The system of weights used in India was subject to more variation than other units. This confusion had become so great in our time that modern India discarded it in favour of the metric system of weights and measures. But in al-Bīrūnī's time, the variety of weights and measures was still developing. It is, therefore, no fault of al-Bīrūnī that he found them puzzling. It is a tribute to his scholarship that he tried sincerely to understand them.

In his time, it would appear that transactions were mainly based on count or heap in the region around Multan. According to him, the *tolā* was in common use. It was equal to 2.1. *mithkal*. The value of *mithkal* is, however, not known realiably. The value of the *tolā* varied from 11 grams to 13 grams. Unless a specific value can be derived from known values, an evaluation of units of weight is likely to prove a guess-work. Al-Bīrūnī himself when faced with this difficulty, concluded that "such are the results when people, instead of translating, indulge in wild conjecture and mingle together different theories in an uncritical manner".

Any critical analysis is further hindered by the fact that works of some of the authors he has referred to are not available today, or are not found in the original works. The case of the system of weights quoted from Varāhamihira would illustrate this point. Some of the names of weights do occur in Varāhamihira but not others.

The description of balances given by al-Bīrūnī corresponds substantially with that given in the *Arthaśāstra* of Kauṭilya who mentions two types of balances. The first type is somewhat like the modern steelyard, while the second type is like the modern equal-armed beam scale.

So far as dry measures are concerned he has noted that the method of using dry measures was important. The method of filling, determination of surface and their arrangement were important for achieving reliable results. The table of dry measures and liquid measures he has given, agrees substantially with that given in the *Arthaśāstra,* but it is doubtful whether the values are similar to those quoted in the *Arthaśāstra.*

The system of weights and capacity measures has not been analysed in detail in this paper because, al-Bīrūnī has rarely used them in his book.

It may be worth recording that a new translation of al-Bīrūnī's India is overdue in the light of the new information discovered since 1888 with regard to Indian metrology as well as Arabian metrology. There are many obvious lacunae in the book which can be removed by modern scholars, who are now much better equipped with a variety of literature than was available to Sachau. Such a critical edition should be prepared by a panel of scholars drawn from countries concerned, under the sponsorship of a body like the UNESCO. This critical translation would be a significant addition to the literature on the history of sciences in India and the world.

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AL-BĪRŪNĪ'S CONTRIBUTION TO PHYSICAL GEOGRAPHY

S. M. ZIAUDDIN ALAVI

Aligarh Muslim University, Aligarh

Al-Bīrūnī considered geographical knowledge as important as the other branches of science. Even though some of his geographical ideas are not so scientific, his observations on the formation of mountain chains, origin of the Indian plain, climatological factors and the like are very close to the corresponding modern concepts. The paper attempts to bring out al-Bīrūnī's understanding of certain aspects of physical geography.

Al-Bīrūnī ranks high in any list of great scholars of the middle ages. No history of science is complete without acknowledging his immense contribution to science. He was well-versed in Greek sciences and philosophy and familiar with other sciences as well. As a mathematician and as historian his position is pre-eminent. He shows an amazing grasp of the fundamental geographical factors. He thought geography was basic to all knowledge as evidenced by his method of treatment of various subjects—giving geography pride of the place. Principles of physical geography attracted his attention more as he considered them as of fundamental importance to the understanding of both history and astronomico-mathematical problems. Al-Bīrūnī was not a lone figure in this field, for he was preceeded by great Arab scholars like Al-Kindī, Abu Ma'shar, T͟habit bin Qurra Ibn al'-Amid, Abul 'Abbas Iran-Shahri and others whom he quoted in his works. In this paper it is intended to give an account of his ideas on the principles of physical geography as well as on the physical geography of India.

Sculpturing of the earth's surface

In this respect al-Bīrūnī held similar views as held by his predecessors. The central idea was that in course of time spreading over thousands of years the mountain tops were broken up by internal splitting and external collusion. Stones wear off by the effect of running water and by wind. The soft fragments and pebbles were accumulated in the beds of valleys thus forming plains. Then after long periods of time owing to earth movement the ground rose again forming mountains.[1]

Origin of landforms

Al-Bīrūnī was of the view that the lands and seas changed their relative positions in the past. Some of the lands which we find today were buried deep beneath the sea but they came up because of the emergence of land. To quote from his example of the steppes of Arabia: "This steppe was at one time sea, then it was upturned so that traces are still visible when wells and ponds are dug, for they begin with layers of dust, sand and pebbles; they are found in the soil shells, glass and bones which cannot possibly be said to have been buried there on purpose. Nay even stones are brought up in which are embedded shells, cowries and fish-ears, sometimes well preserved or the hollows are of their shape while the animals have decayed".[2]

Another example of a lake turning into land is as follows: "We find similar stones in the centre of which are enclosed fish-ears in the sandy desert between Jurjan and Khwārizm which must have been a lake in the past because the river Jaihun (Oxus), I mean the river of Balkh, ran through them to the Caspian sea past a district known as Balkhan. Thus Ptolemy mentions in his book *'Geography'* that the mouth of the Oxus is at the sea of Hyrcania, i.e. Jurjan. The time that has elapsed since the days of Ptolemy is about eight hundred years, and in those days the Oxus ran through the region, which is now a complete desert".[3]

Climatic changes

Al-Bīrūnī observed that not only fertile places turn into deserts but hot places become cold: "In Kirman, stems of date palm were found although in his days the palm was not grown. This means that the climate of the place has grown colder".[4]

Another example of change of climate is from Syria: "Change of climate has occurred in the dry district of Syria which lack water, plants and animals but the ancient traces speak of their having been inhabited at one time and this could be possible only because of ample water which failed later".[5]

Origin of lakes and inland seas

According to al-Bīrūnī the major cause of the formation of lakes and inland seas was the blocking of the river courses because of earthquakes of great intensity which caused crumbling of mountain tops and blocking of their passage. Here are his words: "An earthquake occurred in al-Ruyan long ago and upset two mountains so that they banged together and hindered the course of the rivers which used to flow between them. So the water accumulated and formed the lake. In the same way was formed the Dead Sea which has its origin in the accumulated waters of Jordan."[6]

Earth's equilibrium

The explanation of the modern geographers for balancing the location of high mountains at one place and deep seas at another is contained in the theory of Isostasy. Al-Bīrūnī was also intrigued by this problem and his explanation is as follows:

"When big masses move from one side to another, their weights move with them, and the earth cannot keep its stability unless its centre of gravity varies in position with the variation of the distribution to keep its stability.

Now the distance of different regions from its centre of gravity are not invariable over long periods of time. If the land adjoining a district has risen up or had sunk then the water in that district would be diminished."[7]

Origin of ocean basins

Al-Bīrūnī's explanation of the origin of oceans is more religious than scientific. Here are his words: "When God Almighty intended the creation of mankind, He purposely designed the creation of earth at first, and gave it the consolidating force to evolve its natural shape. I mean that which is truly spherical. He also elevated parts of the earth above the water and this made the water run down into parts of the earth which were sunk, because of the elevation of others. He called the water that gathered in depression a sea and gave it the taste of salinity"[8]

The tidal phenomena

Like other Arab geographers al-Bīrūnī believed that the tides were controlled by the moon and the sun. He explained in his book on India how the ebb and flow develop periodically and directly correspond to the phases of the moon.

The concept of antipodes

Arab geographers in general believed that the southern hemisphere was predominently a barren land and uninhabitable because of rigours of climate. Al-Bīrūnī differed from this view. He asserted that if a place like that exists and its position relative to the South Pole is analogous to the North Pole, then the winds and all other vestiges there must certainly be similar to what we have This clearly shows that he had a clear conception of the antipodes on the basis of which he determined the type of climate, flora and fauna of the southern hemisphere."[9]

Physical Geography of India

The northern mountain chain

Al-Bīrūnī had a correct idea of the vastness and the great extent of the chain of mountains traversing the heart of Asia, as evidenced by his following account.

"As to the orographical configuration of the habitable world, imagine a range of towering mountains like the vertibrae of a spine stretching through the middle latitude of the earth and in longitude from east to west passing through China, Tibet, the country of Turks, Kabul, Badakshan, Turkistan, Bamiyan, Al-Ghor, Khurasan, Media, Adherbijan, the Roman Empire, the country of Franks and the Gallicians. These mountains form the northern boundaries of India and they are the snow covered Himavant (Himalayas), part of the drainage of which is directed towards central Asia and part towards India. The northern and the eastern mountains of India in reality form one and the same chain extending towards the east and then turning towards the south until they reach the great ocean". This quotation clearly shows that al-Bīrūnī rightly connects the Alpine system of Europe with the Himalayan system of Asia."[10]

The origin of the great Indian plain

Al-Bīrūnī was of the view that the northern plains of India were once ocean bed. It was with the deposition of detritus from the mountains that the sea bed was filled up and became habitable. Here are his words: "But if you have seen the soil of India with your own eyes and meditated on its nature-if you consider the rounded stones found in the earth, however deeply you dig, stones that are huge near the mountains and where the rivers have a violent current; stones that are of smaller size at greater distance from the mountains and when the streams flow more slowly; stones that appear pulverised in the shape of sand when the streams begin to stagnate near the mouths and near sea—if you consider all this you could scarcely help thinking that India has once been a sea which by degrees has been filled up by the alluvium of the streams".[11] Al-Bīrūnī's discussion of the possible origin of the plain is highly scientific and closely resembles with the modern view.

Physical setting—frontiers, rivers, mountains and climate[12]

The sea which borders the continent of India is called Indian Ocean. The coast of India begins with Tuz, the capital of Makran and extends in a south-west direction to al-Daibul and onwards to kutch and Somnath, Gulf of Cambay, western coast of Thana and then follows a great bay in which lies Sarandib. Along this southern coast are mentioned a number of places such Baroi (Baroda), Kambayat, Bihroj (Broach), Tana (Thana) etc. Along the northern frontier of India Kashmir is described in detail in terms of its high mountains, their peaks and everlasting snows. South of the Himalayas is mentioned the vast plain of India which is being described in detail from Multan to Kanauj. describing and naming all the rivers of northern India which include the Jhelum, the Chenab, the Ravi, the Ganga, the Jumna and the mythical Sarasvati. He is, however, wrong in showing the Ganga emptying into the Arabian sea near the Narbada. He also names many of the southern rivers like the Krishna, the Narbada and the Tapti.

Speaking of the seasons of India,[13] al-Bīrūnī says that the uneducated people used two divisions because they could observe two solstices. A more scientific division was the division of the ecliptic into two halves which was less known to the common people because it rested on calculation. Each half was called *'Kula'*. That which had northern declination was called *'uttara Kula'* and the one with the southern declination was called *'dakṣiṇa Kula'*. By both these divisions the ecliptic was divided into four parts and the period during which the sun traverses them was called season—spring, summer, autumn and winter. Al-Bīrūnī, however, adds that the Hindus did not divide the year into four but six parts and called them, *ṛtu*, each *ṛtu*, comprising two solar months. As to the rainfall of India, he says that the rains fall in summer and the period is called *Varṣākāla*. These rains are more copious and last the longer the more northern the situation of the province, and the less if intersected by mountain ranges. He points out that Multan has no *Varṣākāla* but more northern provinces nearer the mountains have the rainy season. In Bhatal and Indraveda (lower doab of the Ganges and the Jumna) it begins with the month of *Āṣāḍha* (June—July) and it rains constantly for four months. In provinces still farther north-wards around mountains of Kashmir, there is copious rain during two and a half months beginning with the month of *Śrāvana*. However, on the other side of the peak there is no rainfall therefore Kashmir has no *varṣākāla*, but continual snowfall during the period of two and a half months beginning with *Māgh* (January—February). Al-Bīrūnī also points out that a certain extraordinary meteorological occurrences are peculiar to every province of India.

As to the merit of al-Bīrūnī's geographical ideas it may be said without fear of contradiction that he reveals himself as a keen observer of geographical phenomena and his remarks on geological, meteorological and climatological aspects were scientific and very close to the corresponding modern concepts. His ideas must have been of great value to the European scholars who placed the subject on scientific footing. It may, however, be admitted that sometimes he puts forward certain unscientific ideas also for which he quotes the authorities concerned. But we should not forget that al-Bīrūnī was primarily a historian and synthesiser of knowledge, and it was his duty to record all the informations that he could gather from books or from people, although he sometimes exceeds his limits by examining such ideas critically and exposing their hollowness

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AL-BĪRŪNĪ AND THE THEORY OF TIDES

N. K. PANIKKAR* AND T. M. SRINIVASAN**

History of Marine Sciences Unit of I.N.S.A., National Institute of Oceanography, Panjim, Goa

The phenomenon of the 'ebb and flow' of the waters of the Indian Ocean attracted the attention of the ancients from the earliest times. Early Hindus had expressed their ideas about this oceanic phenomenon in the philosophical and semi-scientific terminologies of the time. There are passages in ancient Indian literary texts which prove that they had not only observed this phenomenon, but also evolved a causal concept by linking it with the moon. Similarly, the Greek and Roman writers and the early medieval Arab geographers left detailed reports of their observations about tides.

Al-Bīrūnī who is our authority for the eleventh century devotes a separate chapter to explain the phenomenon of 'how ebb and flow follow each other in the ocean'. His sources are of a *Purāṇic* kind, particularly, the *Matsya* and *Viṣṇu*. The chapter deals initially with the question why the waters of the ocean always remain constant. He then tries to explain the 'ebb and flow' in the Indian Ocean by citing passages from the *Viṣṇu Purāṇa*. He use the terms *bharna* and *vuhara* to signify the 'ebb and flow' respectively, which are written *baharr* and *vuhar* in Arabic. Like all the Arab travellers, he also includes popular legends about the causes of the tides.

It is interesting to note how Somanāth, the great religious centre, owes its name to the 'ebb and flow'. Al-Bīrūnī covers these points by quoting extensively from the above said *Purāṇas*. This paper is, therefore, intended to throw more light on the knowledge of tides and is based chiefly on his work and the sources which he had cited.

INTRODUCTION

Since the beginning of the Proto-historic period, the phenomenon of the 'ebb and flow' of the waters of the Indian Ocean attracted the attention of the ancients. The Harappans were the first to observe and utilize this oceanic phenomenon effectively on the coast of Kathiawar for berthing ships in the dockyard which they had constructed at Lothal in the present day Ahmedabad district of Gujarat. But there is no positive evidence to prove that they had any critical understanding of the phenomenon. That the early Hindus had a clear understanding of the tides and that they evolved a causal concept by linking it with the different phases of the moon is amply testified by evidence from the *Vedas* down to the *Purāṇas*.[1] Although the Hindus had given the best established tidal concepts, they do not appear to have made regular observations at specific places. On the other hand, the classical Greek authors

Present address: *Vice-Chancellor, Cochin University, Hill Palace, Tirupunithura, Cochin 682301.

**Indian National Science Academy, New Delhi 110001.

and travellers had observed this phenomenon and specified precisely the places of occurrences as well. Herodotus (450 B.C.), the Father of History, recounts the periodical occurrence of tides in the Arabian Gulf (what we now term as the Red Sea).[2] Similarly Arrian in the *Anabasis* leaves an interesting account of the 'ebb and flow' at the Gulf of the Indus as observed by Alexander the Great.[3] The anonymous author of the *Periplus of the Erythraean Sea* (*c.* 65 A.D.) records a factual account of the causes and effects of the phenomenon taking place in the Gulf of Barygaza (Broach).[4]

With the economic decline of the Roman empire and the fall in intrinsic value of the Roman and other mediterranean coins, the Greek and Roman sailors ceased to voyage the Arabian Sea and, consequently there have been few accounts from them of the Indian Ocean. Our sources, therefore, for the third, fourth, and fifth centuries are very poor. Under the Caliphates, however, Muslim scholars left reports of their voyages. We may confidently trace their knowledge of tides occurring in different parts of the Indian Ocean from the Arabic geographic texts written between the ninth and tenth centuries. Sulaiman the Merchant (851 A.D.) a persian scholar, who was engaged in the coastal trade from Siraf on Persian Gulf around to South China was certainly aware of the semi-diurnal tides.[5] Two Arab scholars known as Al-Djahiz (d. 869 A.D.) and Ahmed ibnal Tayab (d. 899 A.D.) discussed tides in their works. Ibn Al Fabih (902 A.D.) in his geographical work entitled *Kitab-al Buldan* ('Book of Countries') leaves a discussion on tides and refers to the semi-diurnal tides in the South China Sea. Towards the end of the tenth century an Arab explorer named Al-Mukaddasi (958 A.D.) in his work Ahsan-al-Takaseem ('*The Best Divisions in Recognising the Region*') discusses tides and stresses the tidal cycle also.[6]

Constancy of Volume of the Ocean Waters

Abu-Al-Rayhan Muhammad Ibn Ahmad Al-Bīrūnī, or as his compatriots called him, Abu Rayhan, is our authority for the eleventh century. As a chronicler and traveller, al-Bīrūnī devotes a separate chapter in his famous work *"Kitab-ul-Hind"* for explaining the phenomenon of 'how ebb and flow follow each other in the Ocean', that is, the Indian Ocean.[7] What first induced him to write this chapter we do not know. It seems that it is the effects of the waters of the Indian Ocean at the mouth of the lower Sindh and Somanāth that might have fascinated him to dwell on this topic. Otherwise, his interest in oceans and tides might have been simply because he came across fascinating mythological accounts in the *Purāṇas*.

It must be admitted that al-Bīrūnī was the first Muslim scholar who took up the study of the later Sanskrit works like the *Purāṇas*. The *Purāṇas* which he adduces for explaining the theory of tides are mainly the *Matsya* and *Viṣṇu*.

In the introductory part of the chapter of his work, al-Bīrūnī deals with the question why the waters of the ocean always remain constant. To explain the phenomenon of the constancy of volume of the ocean waters, he cites from the *Matsya Purāṇa* a non-historical legendary account which is as follows:-

"At the beginning there were sixteen mountains, which had wings and could fly and rise up into air. However, the rays of Indra, the ruler, burned their wings, so that they fell down, deprived them, somewhere about the ocean, four of them in each point of the compass—in the east, *Ṛṣabha, Balāhaka, Cakra, Maināka*; in the north, *Candra, Kaṅka, Droṇa, Suhma*; in the west, *Vakra, Vadhra, Nārada, Parvata;* in the south, *Jīmūta, Drāviṇa, Maināka, Mahāśaila* (?). Between the third and the fourth of the eastern mountains there is the fire *Saṃvartaka,* which drinks the water of the ocean. But for this the ocean fills up, since the rivers perpetually flow to it".[8] He further says that the fire was the fire of one of the kings called *Aurva* who threw it into the ocean. "It is this fire which absorbs the waters of the ocean".[9] Of course, it is mostly legendary and contains only traces of scientific truth. But al-Bīrūnī does not leave us in darkness, for subsequently he quotes from an anonymous source about the real cause for the constancy of volume of the ocean waters. "The water of the stream does not increase the ocean, because Indra, the ruler, takes up the ocean in the shape of the cloud, and sends it down as rains".[10] This passage may have been drawn from the texts of the early Vedic period, for the importance of Indra, the dominant deity in the realm of air, is significantly mentioned; and we find that one-fourth of the *Ṛg Veda* is devoted to his praise.

That the constancy of volume of the ocean waters is due mainly to the phenomena of evaporation, cloud formation, precipitation and rainfall can very well be traced from the texts of the Vedic literature, and that the rain is a phenomenon of ocean, wind, and moisture, is clearly attested by the *Taittīriya Saṃhitā*:- "From the ocean, O Maruts, Ye make (the rain) to full, O ye that one rich in moisture".[11] The *Viṣṇu Purāṇa* very clearly enumerates four sources of atmospheric moisture, "the glorious Sun, O *maitreya,* exhales moisture from four sources, namely—seas, rivers, the earth and living creatures".[12] Furthermore, the theory of cloud formation and precipitation is more fully detailed in the *Vāyu, Liṅga* and *Matsya Purāṇas.*

The Theory of Tides

Now al-Bīrūnī draws our attention to the phenomenon of the "ebb and flow" in the Indian Ocean. He uses two terms *bharṇa* and *vuhara* to signify the 'ebb' and 'flow' respectively. The annotator, Sachau, says that these two terms have no Indian equivalents and are written as *baharr* and *vuhar* in Arabic.[13] But there must be some specific terms to denote the 'ebb and flow' in early Sanskrit texts. In later Vedic texts like the *Taittīriya Saṃhitā,* we find that the term *'pinva'* is used to mean 'cause to swell' or 'overflow' in the context of the phenomenon of tides:- *'Samudramābhita: pinvamānam.*[14] Hence when the *'pinva'* means swell, there should have been also some specific terms to describe the opposite, that is, to 'ebb'; but we have not been able to trace these words so far. It is to be noted here that in Arabic there is no one word for tide, but there are words for 'flux' and 'reflux' or 'flow' and 'ebb' and the word *Madd* was often used to denote 'flow' until the sixteenth century.[15] In the anonymous geographical work called *Hudud al-'Alam*[16] ('The Regions of the World') compiled in 372 A.H/982-3 A.D., the words *Madd* and *Jazg* are used in the sense to ascribe 'flow' and 'ebb' respectively.

Al-Bīrūnī records his observation that it is the educated Hindus who evolved the theory of tides. He adds further that they "determine the daily phases of the tides by the rising and setting of the moon, the monthly phases by the increase and waning of the moon".[17] While emphasising the Hindu theory of tides, he remarks that "the physical cause of both phenomena is not understood by them".[18] For that matter, no geographer, including the medieval Arab geographers, had given any explanation for these phenomena, as the concept of gravitation was not known for several centuries till the appearance of Newton.

One notable point in al-Bīrūnī's account is that he completely omits or misses some important information given in the *Viṣṇu* and *Matsya Purāṇas*. If he had seen the full texts of both these *purāṇas,* he would not have failed to state all the information. Probably, he had seen only portions of these *purāṇas*. However, it is necessary to present the relevant passages from the above said *purāṇas,* for they are of topical importance in this context. The *Viṣṇu Purāṇa* says that "in all the oceans the water remains at all times the same in quantity and never increases or diminishes; but like the water in a cauldron, which in consequence of its combination with heat expands, so the waters of the oceans swell with the increase of moon. The waters, although really more nor less dilate or contract as the moon increases or wanes in the light and dark fortnights."[19] The comparison of the swelling of the waters of the ocean to the expansion of water in a kettle or boiler due to heat is interesting.

A further interesting information is preserved in the *Matsya Purāṇa* and the passage is as follows:- "When the moon is in the east, the sea begins to swell. The sea becomes low when the moon wanes. When it swells it does so with its own waters (and not with additional waters), and when it subsides, its swelling is lost in its own waters (that is, does not lose any water). On the rising of the moon, the sea increases as if its waters have really increased During the bright and dark fortnights. the sea heaves at the waring of the moon and becomes placid at the wane of it, but the store of the water remains the same. The sea rises and falls according to the phases of the moon".[20] This important statement is a parallel of the fundamental concepts of *"continuity and conservation of mass"* in modern hydrodynamics.

Beliefs and Legends

Like all the Arab travellers, he is also prone to include popular beliefs and legends to explain away the causes of the natural phenomenon like the "ebb and flow". He says that "according to notions of the common Hindus, there is a fire called *vaḍavānala* in the ocean, which is always blazing. The flow is caused by the fire's drawing breath and its being blown up by the wind, and the ebb is caused by the fire's exhaling the breath and cessation of its being blown up by the wind". The other citation, which he draws, is from the "*Book of Mysteries*" by Māni and he adds that "Māni has come to a belief like this, after he had heard from the Hindus that there is a demon in the sea whose drawing breath and exhaling breath causes the flow and the ebb".[21] Such legends, however, seem to have arisen in early medieval Arab folklore from sea stories of sailors. Examples of these are often found in the cosmographic works of al-Massoudi (943 A.D.), al-Edrisi (1154 A.D.), Ibn al-Fakih (902 A.D.) and '*Mirabilia*' which had an outstanding popularity among Arabs in those days.[22]

Tidal Range

It is curious to find an erroneous statement in al-Bīrūnī's work regarding the computation of the amplitude of tides which he seems to have culled from the *Viṣṇu Purāṇa*. The cited passage in his work is as follows:-

"The greatest height of the water of the flow is 1500 digits". About this figure of 1500 digits he had his own doubt and remarks that "this statement seems rather exaggerated; for if the waves and the mean height of the ocean rose to between sixty to seventy yards, the shores and bays would be more overflown than has ever been witnessed". But, at the same time, al-Bīrūnī does not want to reject this information as incorrect; for, he adds with a sense of satisfaction that "this range is not entirely improbable, as it is not in itself impossible on account of some law of nature."[23] But we cannot consider this *Purāṇic* communication as correct. The reason is that in the original text of the same *Purāṇa* it is mentioned that "the rise and fall of the waters of the different seas is five hundred and ten (not 1500 digits) *aṅgulas*",[24] that is, nearly 9.75 metres. This *Purāṇic* account finds corroboration in the *Matsya Purāṇa*, which in all probability corresponds to the highest tidal range occuring even today at the Gulf of Cambay.

Somanath and the "Ebb and Flow"

In the concluding part of his account on tides, al-Bīrūnī highlights the importance of the great religious centre, Somanāth, which was also an important port next only to Bhṛgukachcha (Broach) and Stambhatīrtha (Cambay) on the coast of Gujarat. His estimation of Somanāth as a port is as follows:-

"The reason why in particular Somanāth has become so famous is that it was a harbour for seafaring community, and a station for those who went to and from between Sufala (Supara) in the country of Zanj (the nations of Eastern Africa) and China".[25]

"Somanāth" is named after the moon, under whose influence the tidal phenomena are formed. Al-Bīrūnī" explanation for this is quite interesting. He says that the "stone (or *liṅga*) of Somanāth was originally erected on the coast. a little less than three miles west of the mouth of the river Sarśutī (Saraśwatī Nadī), east of the golden fortress Bāroī (Baroda)". "Each time when the moon rises and sets, the water of the ocean rises in the flood so as to cover the place in question. When, then, the moon reaches the meridian of moon and midnight, the water recedes in the ebb and the place becomes again visible".[26] In other words, the sea does not by itself washes the stone *liṅga*. Because, it is a well-known fact that *Soma*, the moon, is the influencing factor in the phenomenon of tides. And naturally the sea washes the stone *liṅga* with tidal cycles which are produced by the moon's influence on the sea water. Here, importance is given to the moon and not to the sea. "Thus (*Soma*) the moon (as servant) was perpetually occupied in serving (Nātha) the idol (the master) and bathing it". Therefore, the place considered as sacred to the moon was appositely named *Somanāth*, that is, the *master* of the *moon*.

Conclusion

A word about al-Bīrūnī. He does not blindly accept tales and legends as such; in fact, he wants to understand them before commenting on them. He neither exaggerates nor criticises the Hindu theory of tides. In fact "it is the method of our author not to speak himself, but to let the Hindus speak, giving extensive quotations from their classical authors".[27] By doing this, al-Bīrūnī surpasses all this predecessors as a faithful chronicler.

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SESSION II

DISCUSSION

(1) AL-BĪRŪNĪ AND THE INDIAN ERAS by R. N. RAI

Dr. Ajay Mitra Shastri pointed out that the statement of the *Viṣṇudharmottara Purāṇa*, viz. at the time when Vajra enquired of Mārkaṇḍeya the age of Brahma, ten *divya* years (=3,600 solar years of *Kaliyuga*) had elapsed, might indicate that the relevant portion of the *Purāṇa* was composed about the same time as Āryabhaṭa I wrote the *Āryabhaṭīya*.

As regards the Harṣa Era, he said that according to some scholars the epigraphs which have been generally regarded as having the dates in the Harṣa Era, were really dated with reference to the *Bhatika* Era beginning about 623-24 or 624-25 A.D.

Stating that there is no evidence for the use of the Harṣa Era in Indian literature or inscriptions, Dr. (Miss) Pratipal Bhatia wondered whether Harṣa came to the throne in 606 A.D. or 612 A.D., in keeping with the rather ambiguous evidence of Huien-Tsang, and pointed out that Harṣa was not associated with the foundation of any era. The *Bhatika* Era which was in use in western Rajasthan, specially in the region of Jaisalmer, might have begun between 612 and 619 A.D. Some scholars would opine that this Era could well be the *Hijera* Era.

As to the *Vikrama Era*, Dr. Ajay Mitra Shastri said that the fact that the Era was not named after Vikrama for some centuries after Chandragupta II Vikramāditya seemed to go against the view of some scholars associating it with the Gupta Emperor. It appeared more likely that Chandragupta II assumed the *Viruda* of Vikramāditya in imitation of an earlier king of that name after he had emulated his exploit, i.e. victory over the *Śakas*.

Dr. Shastri also referred to the recent discovery of the Andhau inscription of *Mahakṣatiapa* Castana, dated *Śaka* 11, seems to support Castana's claim to have been the founder of the *Śaka* Era.

Dr. (Miss) Pratipal Bhatia emphasised that Kaniṣka's association with *Śaka* Era beginning in 78 A.D. had been seriously challenged by knowledgeable scholars.

Prof. F. C. Auluck suggested that, as the numbers mentioned by ancient astronomers had the factors 2, 3, 5 and 7, the eras might have been calculated with them as the basis.

(2) AL-BĪRŪNĪ ON INDIAN ARITHMETIC by A. K. BAG

Dr. Ajay Mitra Shastri questioned the dates given by the author to the *Puliśa Siddhānta* as A.D. 200 and the *Sūrya Siddhānta* as A.D. 400, for the works passing now under these names were admittedly very late. He thought that the *Sūrya Siddhānta*, utilised by Varāhamihira, should be dated earlier than A.D. 400.

Dr. V. R. Shastry threw light on the system of representation of large numbers.

(3) METROLOGY IN AL-BĪRŪNĪ'S INDIA by V. B. MAINKAR

Dr. S. M. R. Ansari desired to know how one *tolā* was computed as being equal to 11-13 gms. He said that *Gay* (*Yava*) was a unit of weight used by Arabs. 1 *mithqal*=96 *gay*. Why was it that this unit of weight did not figure in al-Bīrūnī's enumeration of weights in his *India*? he asked.

(4) AL-BĪRŪNĪ CONTRIBUTION TO GEOGRAPHY by S. M. ZIAUDDIN ALAVI

Prof. N. K. Saha sought clarification as to how far the idea of al-Bīrūnī, viz. shifting of the land masses and restoration of the earth's equilibrium differed from or similar to the modern concept of continental drift.

Dr. S. Varadarajan wanted that al-Bīrūnī's ideas relating to isostasy and origin of mountains as well as land forms be evaluated from the modern standpoint.

Dr. S. P. Gupta argued that the author should have critically examined al-Bīrūnī's geographical knowledge. He also brought out the fact that the river Sarasvatī was not a mythical one, but a river of the past.

AL-BĪRŪNĪ AS A SYNTHESIZER AND TRANSMITTER OF SCIENTIFIC KNOWLEDGE

S. MAQBUL AHMAD
Centre for West Asian Studies,
Aligarh Muslim University, Aligarh

Al-Bīrūnī lived in an age when scientific knowledge and enquiry had reached its zenith in the east. In the present paper, an effort will be made to trace the genesis and growth of science in the three major areas of the then known world, namely, India, the Islamic east (West and Central Asia, North Africa, and Southern Spain), and Europe (including the Byzantine empire), so that we know the approximate degree of knowledge possessed by the scientists up to the tenth century, or the time when al-Bīrūnī lived, and then to judge the position of al-Bīrūnī as a scientist and his role as a synthesizer and transmitter of the cumulative results of the total knowledge that had developed before him.

India's main achievements in science and technology were made during the Maurya and the Gupta periods. It was during this golden period of scientific and technological progress that India had close contacts with the western world and notably from the time of Alexander's invasion of India. Some aspects of the nature and extent of the exchange of the scientific knowledge between India and Greece and the Roman world have come to light, but much still remain to be worked out. By the third century A.D., India's trade relations with the west had declined, causing a break in the relations, and consequently, in the exchange of scientific ideas. But from the seventh century onwards, we notice progressive decline in scientific activity in India, and it would not therefore be incorrect to say that what al-Bīrūnī studied and examined of Indian science during his sojourn in India, was by and large and with a few exceptions, the result of the investigations and theoretical contributions of the scientists of the Maurya and the Gupta periods. No doubt original contributions continued to be made by the Indian scientists until the twelfth century or so, but by the time of al-Bīrūnī the golden period had already passed.

In the Islamic world, science may be said to have begun from about the middle of the eighth century, especially since the establishment of the Abbasīd rule. From the rise of Islam in Hajāz (Saudi Arabia) in the early decades of the seventh century up to the eighth century, the Muslims had mainly concentrated on the growth of Islamic Law, interpretation of the *Qur'ān* and the *Hadīth* literature, or on language and literature, the art of government and such other subjects as were related to government and the society. Science occupied a secondary position in the field of education and no special effort was made to translate into Arabic or to transmit the scientific knowledge that was available in Greek, Syriac or Hebrew. For several centuries before the rise of Islam, Greek science and philosophy was studied in Egypt and Syria which formed parts of the Byzantine empire. In Egypt, Alexandria was the main centre of learning where Cludius Ptolemy worked.[1] In Syria, the Nestorian Christians and the Jewish scholars worked and rendered Greek works into Syriac and other languages. Although these provinces had become parts of the Islamic empire in the seventh century, the work done here hardly exercised any impact on the growth of science in the Islamic world. Another centre of great importance at this time was Harrān (in Iraq), where there was an old tradition of astronomical studies among the Sabaeans, who were star-worshippers before the rise of Islam and conquest of Iraq by the Muslims. Similarly, Iran was another centre of scientific studies, particularly, medical and astronomical, and Jund-i Shāpūr was a well known centre of learning. But during the period in question, the Muslims' interest lay mainly in the ancient Iranian works dealing with government and administration or medicine. Like Egypt, Syria, Iraq and Iran, Sindh and western Punjab had also become parts of the Islamic empire during this period, but the Arabs in Sindh or the Umayyad caliphs of Damascus, hardly paid any attention to transmitting the scientific knowledge of the Indians as was available there, probably for the same reasons as given above. They were more interested in filling the coffers of the central treasury than in the sciences and arts of India.

In the Islamic world, the credit goes to the early Abbāsid caliphs who ruled from Baghdad for acquiring and reviving the legacies of the ancient Greeks, the Romans, the Iranians and the Indians in the fields of science and philosophy and other subjects in the eighth and the subsequent centuries. The intellectual interests of the caliphs like al-Ma'mūn, their patronage and financial assistance to the scientists, and that of their ministers, surnamed *Barāmika*, resulted in what is termed by historians of science 'the period of renaissance' in the Islamic world. It may be pointed out here that the *Barāmika* (Arabic form of *Pramukh*; the Arabic form should be transliterated as *Bramuk* and not *Barmak* as is usually done), before their conversion to Islam during the Umayyad period, were the guardians of the Buddhist *vihāras* in Balkh (Central Asia), and after the rise of the Abbāsids took keen interest in the transmission of Indian scientific knowledge and thought to the Arab world. Scientific activity began with the translations of Greek, Syriac, Hebrew, Sanskrit, and Pahlawi works on science into Arabic in which a gallaxy of translators participated and which lasted for several centuries. Thus, almost all the sciences were rendered into Arabic—mathematics, astronomy, physics, chemistry, geography, medicine, optics, ophthalmology, mechanics, botany, zoology, etc. which the Muslims studied. In some of these they made original contributions. It is sometimes argued that the Arabs merely preserved Greek sciences and transmitted them to Europe; facts however do not substantiate the view. From the eighth till about the twelfth century, the scientists of the Islamic east continued to experiment and investigate the scientific theories and advanced scientific knowledge, especially in the fields of chemistry, optics, ophthalmology, medicine, surgery, astronomy, mathematics, geography, cartography, navigation and also invented equipment for scientific experiments and instruments of works, specially in astronomy, chemistry, surgery and navigation. They also applied these sciences to practical uses in crafts and industries. This period of the history of Islam was the golden period and al-Bīrūnī lived in its apogee.

The above survey of the progress of science would therefore help to appreciate the fact that by the tenth century, the world scientific literature available in Arabic was enormous and fairly well representative of the various efforts of the different nations in the previous ages. Again, Arabic had by this time evolved as a mature language as far as expression and communication of scientific ideas between the various scientists speaking different languages as mother-tonuges, was concerned. It had evolved its own terminology, using the Arabicized forms of the original Greek, Pahlawi or Sanskrit terms and expressions and new Arabic terms and words representing different scientific connotations and concepts which had become standardized by this time. This scientific language could be written and understood from the shores of the Atlantic to the banks of the Amu Dar'ya, and from the Caucasus mountains to the coastal regions of East Africa. No wonder al-Bīrūnī adopted Arabic as the medium for his scientific writings.

It is evident from the Arabic written sources utilized by al-Bīrūnī that he was fully acquainted with most of the available literature on astronomy, mathematics, geography and other sciences, and before visiting India, he was already well versed with the classical works on Indian astronomy, mathematics, geography, etc. through their Arabic translations, like *Brāhmasiddhānta*, and *Khaṇḍakhādyaka*. Besides, a number of important works of the earlier scientists who dealt with Indian sciences, were available to him which he utilized. However, it seems that he always wanted to get first-hand knowledge of the Indian scientific literature, and make his information up-to-date. This he was able to accomplish during his stay in India. Thus, not only did he assimilate additional knowledge on India, but he tried to disseminate to India the advancement made by the Muslim scientists, including his own through the translations of some of the Arabic works into Sanskrit. Conversely, he made supreme efforts to present fresh knowledge on India, through the translations of Sanskrit works into Arabic, to the Arabic knowing world. And his own survey of the ancient and contemporary culture of India, her philosophy, religions, sciences and many other aspects of Indian life and thought, is a laudable academic task performed by few learned men of his time. This work is embodied in his *Taḥqīq mā li'l-Hind*, etc. commonly called *India* wherein he compared and contrasted Indian scientific thought with that of the ancient Greeks, the Romans, the Muslims, the Sūfīs and so on, and presented it a synthesized form. Other examples of his broader synthetic works are his *al-Athār al-Bāqiya 'an al-Qurūn al-Khāliya* which he wrote long before he came to India, and al-*Qānūn al-Mas'ūdī*. His knowledge may therefore be described as both comprehensive and universal, for except for those of China, he was conversant with almost all the theories and views of the scientists from the ancient times up to his own age. He added on to it his own concepts and original contributions, which at times are difficult to discern from the vast amount of material accumulated by him in his works, and passed on the whole to posterity. It is difficult in such a brief paper to analyse and point out the influence of his scientific achievements on the later scientists, but there is enough material available on this aspect.

Al-Bīrūnī lived in an age when scientists had to work under difficult conditions. Their work and peace of mind not only depended upon the sweet will of their patrons, they had also to face all types of prejudices and jealousies. One of these and the most important was the criticism levelled against the study of science by the obscurantist section of the society and especially by the *ulemā* (theologians) who equated the study of science with heresy. Al-Bīrūnī himself refers to it. But he tried to remove this prejudice by emphasizing the practical utility of science. To satisfy those who considered the study of mathematical geography as of no value, he furnished examples in favour of its utility of knowing distances and directions of places where one desires to reach.[2] Then he discussed, most intelligently, the benefits of what we call economics to-day, of mathematics and specially of geometry, of medical and veterinary services, of the principles of the science of music discovered by the mathematicians, of the science of astronomy, of logic and grammar, of Arabic rhetoric, etc.[3] He, therefore, declares in defence of science, "As to the sciences, man was naturally inclined to accept them, ..."[4], and "......they were created by the urgent needs of man and developed accordingly. Their benefits are the satisfactions of those needs, for neither silver nor gold can satisfy them."[5] He says that he felt like accepting astrology when "I behold how the people of our time, in different parts of the world, reflect such forms of ignorance, and how proud of it they are; how antagonistic to people of excellent virtues they are; how they plot against a learned scholar and inflict on him all sorts of harm and persecution."[6] "The greedy and the opportunists among the people who accepted the worst code of morals discarded the sciences and persecuted the custodians of learning".[7] "The extremist among them would stamp the sciences as atheistic, and would proclaim that they lead people astray in order to make ignoramuses, like him, hate the sciences. For this will help him to conceal his ignorance, and to open the door for the complete destruction both of sciences and scientists".[8] How true is this analysis of al-Bīrūnī's even for our own times! These most revealing views of al-Bīrūnī reflect the plight of science and the scientist in his time, and he did not mince words.

In his method of treatment of a subject, of a scientific problem, al-Bīrūnī strictly followed the scientific method. His mind was free from any theological or mythological prejudices, and he kept his mind open. Again, he was not a 'traditionalist' in the sense that he did not look upon the 'ancients' (al-mutaqaddimun), or the Greek philosophers and scientists, as the final authorities on a subject nor their views as the final word. Thus, from his early youth he objected to certain concepts held by Aristotle, and praised certain other views of his.[9] Again, he did not adhere to certain views of Ptolemy and was critical of his findings in geography.[10] In this respect he was a very outstanding thinker of his time, for there were many among the astronomers and geographers who followed these Greek philosophers without questioning their authority, among whom the most outstanding example was that of

Ibn Sīnā (Avecina). Again, al-Bīrūnī was always ready to accept new ideas and inventions; when al-Sijzi constructed his new spherical astrolabe based on the concept of the rotation of the earth, he appreciated the novel idea even though he did not have full belief in the concept of the rotation of the earth.[11] He was similarly, very secular in his outlook on science; he once invented a time-machine based on Roman calendar which he desired to be installed in the mosque, but the *imam* of the mosque refused to have it installed there on the grounds that it was based on a calendar other than Islamic.[12] However, there is little doubt that he was a firm believer in Islam.

In his methodology and scientific treatment of subjects, he followed the deductive method. In his *al-Qānūn,* he unravels the basic principles, demonstrates the propositions enunciated in the book, adduces the proofs of his deductions and indicates his personal observations and researches. He "gratefully benefitted himself by the previous researches and theories, but fearlessly criticised where he thought they (his predecessors) had missed the mark or gone astray".[13] Thus, his "firm belief in the laws of nature, his insistence on continuous observations and collection of reliable data and the successful application of all these principles, mark him out as one of the greatest exponents of the true scientific method".[14]

REFERENCES

1 (c. 90-168 A.D.)

2 *Taḥid Nihāyat al-Amākin li-Tashīh Masāfāt al-Masākin,* Eng. tr: *the Determination of the co-ordinates of distances between cities,* by Tamil Ali, Beirut 1967, pp. 8-11.

3 *Ibid,* pp. 4-8.

4 *Ibid,* p. 4.

5 *Ibid,* p. 7.

6 *Ibid,* p. 1.

7 *ibid.*

8 *Ibid,* p. 2.

9 He firmly believed that the universe was not eternal (*gadīm*), but that it must have come into existence at a given time (*hadīth*), but this cannot be measured by the means at the disposal of man. Thus, he refuted the Aristotelian theory of eternity of the universe and supported the Biblical or Islamic theory of the creation of the universe at a given time. He had, in the youth asked Ibn Sinā to explain to him the Aristotelian concept, (See Syed Hassan Biruni, *Al-Bīrūnī* (urdu), Aligarh, 1927, pp. 60-63; cf. *Taḥdīd,* pp. 14-16; Syed Hassan Barani's comments on *al-Qānūm, al-Qānūm al-Mas'ūdī,* vol. II, Hyderabad, 1955, pp. xix-xx). Cf. *Tahīd,* p. 25; 23;

10 *Taḥdīd,* pp. 14, 191. Al-Bīrūnī's map of the Seas (Yusuf Kamal, *Momementa Cartographica*) does not show the "unknown land" south of the equator as does the world map of Ptolemy in which the African continent stretches from the west to the east reaching as far as China and covering the whole of the southern hemisphere.

11 See *al-Qānūn al-Mas'ūdī,* pp. xvii-xviii.

12 See *al-Qānūn,* p. xv.

13 See *al-Qānūn,* p. lxxi.

14 See *al-Qānūn,* p. lxxi.

AL-BĪRŪNĪ AND SCIENCE COMMUNICATION IN SANSKRIT

BALKRISHNA KARUNAKAR NAYAR *
Indian National Science Academy,
New Delhi

Most of the scientific books of the Hindus in India in the eleventh century were composed in poetry, largely in certain favourite metres, to facilitate their being learnt by heart, and to preserve them from additions or omissions. The use of the metrical form, and the stress on poetic quality, often led to misty phraseology, and verbosity. The adoption of foreign words, their transformations according to Sanskrit rules, and the profuse use of synonyms to assist metrical composition, added to the difficulty of understanding. This made it arduous for foreign scholars who visited India to master the available knowledge or to transmit their own ideas effectively for a permanent impact. Al-Bīrūnī composed a translation of the Books of Euclid and the *Almagest* and dictated a treatise on the construction of the astrolabe, which do not appear to have become well known.

"Most of their books are composed in *śloka*", wrote al-Bīrūnī "in which I am now exercising myself, being occupied in composing for the Hindus a translation of the books of Euclid and of the *Almagest,* and dictating to them a treatise on the construction of the astrolabe, being simply guided herein by the desire of spreading science. If the Hindus happen to get some book which does not yet exist among them, they set at work, to change it into *ślokas* which are rather unintelligible, since the metrical form entails a constrained affected style, which will become apparent when we shall speak of their method of expressing numbers. And if the verses are not sufficiently affected, their authors meet with frowning faces, as having committed something like mere prose, and then they will feel extremely unhappy. God will do me justice in what I say of them."[1]

Abū-Rayhān Muḥammad Ibn Aḥmed al-Bīrūnī, or al-Bīrūnī, a fascinating Iranian scholar from Khwārizm, who travelled and wrote extensively in India in the 11th century A.D., sought to present "an accurate description of all categories of Hindu thought, as well those which are admissible as those which must be rejected",[2] in his invaluable book *Kitāb-ul-Hind,* commonly known as *Al-Bīrūnī's India.* In the chapter XIII of *India,* al-Bīrūnī wrote at some length on certain aspects of Sanskrit metres. "If we here take so much trouble with Indian metres, we do it for the purpose of fixing the laws of the *śloka,* since most of their books are composed in it".[3]

The importance of the metrical form in ancient and medieval Indian works on science in Sanskrit is further elucidated by al-Bīrūnī in his introductory remarks in the above chapter which deals with the grammatical and metrical literature of the Hindus. "Grammar is followed by another science,

* *Present address* : Assistant Director, Manpower Division, C.S.I.R., N. 4, N.D.S.E. Part I, New Delhi 49

called *chandas,* i.e. the metrical form of poetry, corresponding to our metrics—a science indispensable to them, since all their books are in verse. By composing their books in metres, they intend to facilitate their being learned by heart, and to prevent people in all questions of science ever referring to a written text, save in a case of dire necessity. For, they think the mind of man sympathises with everything in which there is symmetry and order, and has an aversion to everything in which there is no order. Therefore, most Hindus are passionately fond of their verses, and always desirous of reciting them, even if they do not understand the meaning of the words, and the audience will snap their fingers in token of joy and applause. They do not want prose compositions, although it is much easier to understand them".[4]

Al-Bīrūnī deals with the advantages and disadvantages of poetic rendering of authoritative works, again and again. "The scientific books of the Hindus are composed in various favourite metres, by which they intend, considering that the books become corrupted by additions and omissions, to preserve them exactly as they are, in order to facilitate their being learned by heart, because they consider as canonical only that which is known by heart, not that which exists in writing. Now it is well known that in all metrical compositions, there is much misty and constrained phraseology merely intended to fill up the metre and serving as a kind of patch work, and this necessitates a certain amount of verbosity. This is also one of the reasons why a work has sometimes one meaning and sometimes another.

"From all this, it will appear that the metrical form of literary composition is one of the causes which makes the study of Sanskrit literature so particularly difficult."[5]

Al-Bīrūnī describes also the tendency to use synonyms profusely as an aid to versification. The use of synonyms according to him extended even to words from foreign languages also, by a process of translation and then of gradual transformation. "Of course in all this, the Hindus are actuated by the desire to have as many names as possible, and to practice on them the rules and arts of their etymology, and they glory in the enormous copiousness of their language which they obtain by such means."[6] This adds to the difficulties of understanding. Referring to the tendency of calling one and the same thing by a multitude of names, al-Bīrūnī says "If, in fact, one single name would be sufficient, all the other names save this one are to be classified as mere nonsense, as a means of keeping people in the dark, and throwing an air of mystery about the subject. And in any case this copiousness offers painful difficulties to those who want to learn the whole of the language, for it is entirely useless, and only results in a sheer waste of time."[7]

Synonyms have their uses. Not all synonyms have the same meaning, though they may ultimately connote the same thing. Al-Bīrūnī gives one possible explanation for the plentitude of Sanskrit synonyms. "These names have been invented simply to facilitate the versification of their metrical books. For this purpose they have invented so many names that one may fit into the metre if the others will not."[8]

The main points made out by al-Bīrūnī are the following:

(i) The science of *Chandas* dealing with metrical form of poetry was indispensable to Hindu writers since all their books were in verse, most of them in *ślokas;*

(ii) the Hindus placed great emphasis on symmetry and had aversion to everything in which there was no order;

(iii) the use of the poetic form alone was not adequate for acceptability even of science books, there had to be poetic quality as well;

(iv) the metrical form was intended to reduce corruption of the text by additions and omissions as well as to enable their being learnt by heart; and

(v) the liberal use of synonyms to facilitate metrical form rendered understanding difficult.

There were several important consequences of the insistence on poetic quality in the presentation of scientific results in metric form. One was that effective communication was impossible by a scientist unless he was a poet of some eminence as well. Some of the writings of Bhāskarācārya, which have had popular appeal are well known for their poetic excellence.[9] Examples of the different metres given in Sanskrit treatises on the science of metrics are choice specimens of poetry, mostly written by the authors themselves. Poetic quality generally meant the use of imagery and figures of speech, often giving rise to multiplicity of meaning. Further, workers in the practical fields of science other than Āyurveda, who had lower social status, and were not adequately learned in the niceties of the Sanskrit tongue, could not produce any scientific literature. Even if some of them had produced anything of poor or average quality, it would not endure. Thus important contributions to knowledge would come to the notice of the interested public only when some gifted encyclopeadist presented all the available knowledge in the field, in poetic form as a *saṃhitā.*

The use of the poetic form for scientific communication also made it difficult for scholars from other parts of the world to transmit new ideas to the Indians unless they had acquired mastery of Sanskrit or had the assistance of good Indian versifiers.

Al-Bīrūnī himself appears to have been instrumental in translating or otherwise rendering some works into Sanskrit. According to Professor Suniti Kumar Chatterji, the Sanskrit *Paṇḍit* was in evidence in rendering into Sanskrit verse, the subject matter explained to him.[10] Al-Bīrūnī's rendering into Sanskrit of the *Euclid,* the *Almagest,* and the construction of the astrolabe do not appear to have come down to us.

The remarks of al-Bīrūnī about the tragedy of prosaic translations—that if the verses are not sufficiently affected their authors meet with frowning faces as having committed something like more prose—may not have been untained by a personal element.

References

1 *Al-Beruni's India,* tr: Edward C. Sachau, p. 137.

2 The full title of the book *Alberuni's India* is "Taḥqīq māli'I-Hind min maqūlatin maqbūlatin fī'l-'aql au mardhulatin".

3 *Alberuni's India,* p. 147.

4 *ibid,* p. 136

5 *ibid,* p. 19

6 *ibid,* p. 299

7 *ibid,* p. 229

8 *ibid,* p. 140

9 "Out of a swarm of bees, one fifth part settled on a blossom of *Kadamba;* one third on a flower of *Silindhri;* three times the difference of those numbers flow to the bloom of a *Kutaja.* One bee, which remained, hovered and flew about in the air, allured at the same moment by the pleasing fragrance of a jasmin and a pandanus. Tell me charming woman, the number of bees." *Līlāvatī* by bhāskarācārya. Quoted by A. K. Biswas in *Science in India,* p. 12.

10 Chatterji, Suniti Kumar. "Al-Bīrūnī and Sanskrit", *Al-Beruni commemoration Volume,* p. 87.

SESSION III

DISCUSSION

(1) AL-BĪRŪNĪ AS SYNTHESISER AND TRANSMITTER OF SCIENTIFIC KNOWLEDGE by S. MAQBAL AHMAD.

Dr. (Miss) Pratipal Bhatia pointed out that al-Bīrūnī had not taken into account the scientific literature in India of the eight, ninth and eleventh centuries.

Illustrating with examples, Dr. V. R. Shastry said that al-Bīrūnī appeared to be inaccurate regarding the fundamentals of the *Sāṅkhya* philosophy.

Dr. B. R. Grover wanted information on the scientific developments in the Islamic world in the art of warfare, and felt that the author's statements about the scientific growth among the Arabs were of general nature. Dr. S. P. Gupta questioned the basic assumption of the author, viz. there was decline in the scientific development in India after the twelfth century A.D.

Prof. R. S. Sharma, Co-Chairman, emphasised the need for bringing out critical editions of al-Bīrūnī's works concerned. He remarked that though al-Bīrūnī did play an important role in the synthesis and transmission of scientific ideas of his time, the symposium pointed out that in-depth studies of critical editions of his works should be undertaken.

AL-BĪRŪNĪ'S ASTRONOMICAL TREATISE *IN THE* DARI LANGUAGE

M. S. ASIMOV
Academy of Science of Tadjikistan,
Dushanbeh, USSR

The general opinion is that the Arabic language was the language of science in the medieval Middle East. Indeed, the bulk of treatises on natural sciences and philosophy were written in Arabic. The Arabic language may be considered the Latin language of the East. But, beginning with the first half of the eleventh century, the Dari language (*Pārsiyi-i Dari*) emerged, alongside Arabic, as the international language of arts and sciences in the Middle East. This tradition was founded by two outstanding scientists of Central Asia, Abū Rayhān Bīrūnī of Khorezm (Khwārizm) and Abu Ali Ibn-Sina of Bukhara. After them this language was used in scientific works not only by Tajiks and Persians, but also by Aserbaijanians, Uzbeks and Moslems of India.

Dari was spoken by East-Iranian peoples. According to Malik-shuaro Bahor, inhabitants of Bukhara and Balkh also spoke this language. During the Samanid Period Dari was recognized as the official language of the state. The same period saw the emergence of the Tajik people, and the Central Asian Tajiks called Dari the Tajik language.

Poetry of world renowned was created in this language, adorned by the great names of Rudaki (a Tajik from the village of Panjrud, founder of this literature), Firdousi, Omar Khayam, Nizami, Saadi, Amir Hosrow Dehlavi, Hafiz, Rumi, Jami.

Being patriots, of their native Ibn-Sina and al-Bīrūnī wrote in also Dari their original scientific works. Ibn-Sina's "Donish-Nameh" was far-famed among the Persian-speaking peoples of the East.

Prior to him, al-Bīrūnī had written in Dari his well-known work *Kitab at-Tafhim li avail sano'at at-Ianjim* (The Book of Learning the Elements of the Astrology). It is assumed that this book had been written in the year 420 of Hijra (1029) in the Persian language and that in the same year Bīrūnī himself translated it into Arabic.

"The Book of Learning" is a popular introduction to the sciences to be learned by experts on astrology (*Tanjim*). The art of prediction by stars (*sana'a ahkam an-nujum*), called "judiciary astrology" in Europe, is dealt with only in the last part of the book. Besides this particular art the medieval astrology comprised also the "natural astrology", i.e. the branches of astronomy which were of a special significance for the astrological predictions. Every astronomer and mathematician had to have mastery of astrology in the Middle Ages and even in later periods. The rulers who financed astronomical and mathematical research were interested not in the research as such, but in the predictions made with its help. Even Kepler had to be engaged in astrology, and calling it "the silly daughter of astronomy", he used to say bitterly: "Oh, my God, what would have become of the mother, the highly intelligent astronomy, had not she got this silly daughter! .... The old intelligent mother, astronomy, must live supported by her daughter. The incomes of mathematicians are so rare and meager that the mother would have certainly starved, if her daughter had earned nothing."

Al-Bīrūnī also had to be engaged in astrology, though he was quite sceptical as regards its merits. He considered himself one of those "who has no faith in astrology." Al-Bīrūnī was one of the greatest scientists, who, as George Sarton put it, is closer to our time. Sarton wrote that Bīrūnī, a traveller, philosopher, mathematician, astronomer, geographer and erudite, was one of the greatest scientists of all times. His critical mind, patience, love for truth and intellectual courage were almost unique in the Middle Ages. He maintained that the phrase "Allah the omniscient" could not justify ignorance.

Al-Bīrūnī wrote his "Astrology" at the request of a Khorezmian lady Raykhane, daughter of Al-Hasan, probably a friend of this youth. There are 530 questions and answers in the "Astrology". Of them 71 questions deal with geometry (the basic notions of geometry, planimetry, theory of relations, steremetry and spherical geometry); 48 questions deal with arithmetics (theory of numbers, arithmetics, algebra, literal numeration; 87 questions deal with astronomy (the picture of the world, measurement of time, spherical astronomy, the visible motion of the Moon and planets, astral astronomy, the theory of the movement of the Moon and planets, dimensions and distances of the heavenly bodies); 35 questions deal with geography (the dimensions of the Earth, the inhabited part of the Earth, mathematical geography, gnomonics, climates, lands and towns); 27 questions deal with the "natural astrology", i.e. problems of astronomy having a special significance for astrology (the rising of the celestial bodies and their movement across the meridian, the "horoscope" and the "astrological houses", the combinations of the celestial bodies, the Sun's and Moon's eclipses)", 55 questions deal with chronology (months, eras, calenders of various peoples and ephemerides of the Sun, Moon and planets); 23 questions deal with the astrolabe, the principal instrument of astronomers and astrologers (its mechanism, usage, field measurements); and the rest—84 questions deal with the "judiciary astrology" (astrological meaning of the signs of the Zodiac, planets and "astrological houses", astrological predictions).

Taken as a whole, the book (with the exception of the last chapter) had been written as a reflection of the advanced scientific thought of al-Bīrūnī's time.

In certain matters al-Bīrūnī is close to the science of the modern times He, for instance, adhered to the view on the relativity of directions in space. Against the recognition of the sphericity of the Earth the Mutakalimi advanced the thesis on antipodes. Al-Bīrūnī spoke of them with biting sarcasm. A Mutakalim is unable to realise that a Chinese and an Andalusian are in such a position that the soles of their feet are against each other. To understand this al-Bīrūnī proposes the following mental experiment: make a sphere and put flying ants on its surface. Make them fly. The Mutakalimi would call the ants' flight in the lower part of the sphere a fall, while it is a flight, because the reading point is related to the sphere.

Al-Biruni's book, besides its historical and scientific significance, is of a very great value as a specimen of popular-scientific literature. The style of the book is perfect. All difficult problems are stated in an easily understood language which at the same time is quite beautiful. The book is a most valuable source of scientific terminology in the Dari language. It is known that Ibn-Sina and Abū Rayḥān Bīrūnī made a great contribution to the working out of scientific terminology in their native language.

This work of theirs was continued by their followers. Quite a number of treatises on medicine, astronomy, geography, history and philosophy were written in the Dari language. Suffice it to mention the medical treatise by Zahirai Khorazmshahi Jurjani or the works by Nasiriddin Tusi, Durratultaj Kutbitdin Shirazi, Ziji Ulugbek written in the Persian language.

We, in Tajikistan, while working on contemporary scientific terminology make an extensive use of these sources.

The value of al-Bīrūnī's book lies also in the fact that it contains comparisons of astronomical terms in the Greek, Latin Arabic, Persian and Sanskrit languages. The names of stars, week days and months are given in these languages.

As regards its grammatical structure and vocabulary, the language of the book differs very little from the contemporary Tajik. In this respect the book is also of great value to us.

In conclusion we would like to pay tribute to the Iranian scientist Jalāli Khumāi who fulfilled the great work and published the critical text of the book. At present a Russian translation of the text has been made. Simultaneously the book will be published in the Tajik (original) and the Uzbek languages on the occasion of the anniversary of the great scientist and thinker, which will be widely celebrated in the USSR.

WHERE WAS AL-BIRUN SITUATED?

ABDUL HAYEE HABIBI
"Tarith Tolana"
Afghan Historical Society
Kabul, Afghanistan

Abu Raiḥān Mohmmad son of Ahmad al-Bīrūnī was one of the most prominent figures of Eastern Scholarship in Central Asia.

In spite of plenty of research carried about his life and works both in the eastern and western languages no research has been conducted about his native country or the city al-Birun.

It is notewrothy to say that some authors namely Shahrazuri in Nuzhat-al-Arwah, Ibn Abi Osaibaa'h in Cyunal-Anba, Abu-al-Fide in Taqweem-al-Buldān and Abd-al-Ghani in the History of Persian Literature have confused the Birun of Khowārezm with Nirun of the Sindh valley, two cities belonging to two different countries. From ancient times there has been disagreement among authors regarding Birun, the birthplace of al-Bīrūnī.

Samā'ni who died about A.D. 1166 says that Birun means outside in the Persian language, since Persian speakers say that "filān Birunist" meaning he dwells outside the city. Thus the Persian word Bīrūnī is a relative adjective for Birun.

From this it is evident that Birun was not a particular place but in Khowārezm the word was referred to those who lived outside the city. Yāqut, the author of Mu'jam-al-Buldān also agrees that Bīrūnī means those who lived outside the city. This reveals that Yāqut has not used the word as the name of the city.

Contrary to Samā'ni and Yāqut, Imam Ali Zaid-al-Baihaqi, a contemporary of Samā'ni has clearly written that Birun where Bīrūnī was born and raised is a clean city with lots of mysterious things. This fact states that Birun was the name of a separate city in Khowārezm.

Eastern and western scholars who have conducted research in al-Bīrūnī's life have however not done any work on Birun and its where-abouts. They have been briefly contented with that Birun was a place in Khowārezm. Sayed Hassan Barni, the Indian scholar regrets that scholars have paid little attention to Birun and have not mentioned anything about it.

Now I will present some information about the geographical situation of the city in the light of some historical facts. This city was situated in southern Khowārezm or northern Khorasan. Birun has been mentioned in an ancient geographical work of the Islamic period. The manuscript of a Persian translation of *Ashkāl-al-Ālam* related to Abu-al-Qāsim Ahmad-Al-Jaihani is present in Kabul museum. This book has been translated from Arabic into Persian by Ali son of Abd-al-Salām.

Describing the eighteenth climate and the regions of Khorāsān the author says that Birun was situated eight manzils from Busht, a city in Bādghīs region.

Ashkāl-al-Alam is an ancient geographical work of the period of the Sāmānid kings of central Asia and was written before the birth and life of al-Bīrūnī. From the description of Birun in the work of Aljaihāni it is evident that Birun was a city about eight manzils from the Busht of Khorāsān in the Samanid and Ghaznavid periods. The name was used up to the Safawid period in the sixteenth century. The Safawids of Iran were rivals of the Uzbek monarchs of Transoxiana in northern Khorāsān. Iskandar Beg Turkmān, historian during the reign of Shah Abbās, the Safavid king, in his book *Ā'-lam-Arāe-Abbāsi* has several times mentioned the name of Darun fort in northern Khorāsān and the regions of Nasā, Abiward and Merv. The zail of the same work says; Isfandyar Sultan a ruler of Transoxiana went to occupy Merv, Nasa, Darun and Abiward. A messenger was sent to his brother to attack the fort of Birun.

Now we can confirm with assurity that Birun was a city in northern Khorāsān in the region of Nasā and Abiward, which at one time belonged to Khowārezm and later on to Khorāsān. A fortress existed by this name even upto the Safawid period in the sixteenth century.

This also is remarkable that al-Bīrūnī says in his work *Taṣḥiḥ Masāfi āt al-Masākin* that he was in year three hundred ninety Hijra in the Jaghur region at one side of Kabul for taking the *rasad* of the place.

Now in present days there is a region between Kabul and Ghazni by name of Jaghori and in this place a mountain Biruni is situated. Perhaps this mountain is named after al-Bīrūnī who dwelt at the Jaghur some times for his scientific researches.

AL-BĪRŪNĪ AND THE ARITHMETICAL SEQUENCE OF THE SANSKRIT *GAṆAS*

BALKRISHNA KARUNAKAR NAYAR*
Indian National Science Academy
Bahadurshah Zafar Marg, New Delhi 1

Al-Bīrūnī's surmise regarding inaccuracy of the text of a maunscript on Sanskrit prosody, referred to by him in Chapter XII of his book *Kitāb-ul-Hind,* has been examined in the light of the material presented by al-Bīrūnī in the said chapter. Based on the text quoted, an arithmetical sequence of Sanskrit *gaṇas* has been worked out. This turns out to be the mirror image of the accepted form of *Prastara* in Sanskrit and other Indian Languages, used for depicting the permutations of metrical forms having a given number of letters. The result is found to be applicable to metres containing any number of letters.

Chapter XIII of *Al-Beruni's India* deals with the grammatical and metrical literature of the Hindus. An analysis of some of the material presented by al-Bīrūnī is discussed in this paper. An attempt has also been made to work out a logical sequence of the Sanskrit *gaṇas* based on the text presented by al-Bīrūnī.

The Long and the Short

The basic units in the classical Sanskrit prosody are the short and long letters or sounds, called *laghu* and *guru* respectively. A long letter is roughly double the short in respect of sound value, syllabic quantity, and the time taken for utterance. Metrical music is produced not by the mere presence of long and short letters in a line, but by their order of succession. In the Vedic metres, the music depended upon the modulation of voice in the pronunciation of letters, and so the essential features of these letters, i.e. whether they were short or long, did not matter, and were not taken into account.[1] In classical Sanskrit metres on the other hand, the music depended on the essential features of the letters themselves, on their variation, and their order of succession. A single letter could no longer form the unit of a metrical line as in the Vedic metres. A mere mention of the number of letters, which were all independent units, sufficed to give an idea of the metrical line in the Vedic metres. There was no need to give the essential features of these letters, and how they stood related to each other. Both these points are vital in the case of classical metres. Hence a new unit which would take into account these things had to be devised and adopted for the scanning of lines in these metres.

* *Present address* : Assistant Director, Manpower Division, CSIR, N. 4, NDSE Part I, New Delhi 49.

It is possible to describe in detail the order of short and long letters in a line, as has been done by Bharata in his *Nāṭya Śāstra*, and by Vīrataṅka in his *Vṛtta-Jātisamuccaya*. That, however, is a very cumbersome process, and sacrifices brevity for no corresponding advantage.[2]

Doublets and Triplets

A unit of two letters, in its four different forms SS, SI, II, IS, is conceivable for this purpose where S stands for long and I stands for short. *The Ratnamañjuṣā*,[3] has adopted this system based on the four doublets with long and short in addition.

The unit of two letters is comparatively small to express the basic constituents of the music, specially in the case of long lines. So a new unit of triplets or *trikas* which is neither too short nor too long was adopted by the classical poet-prosodists.

In ancient India, the number 3 was generally admitted as the smallest among the large, and largest among the small numbers. Multiplicity was considered as starting with 3, not with 2. The smallest number which constitutes *bāhulya* is 3 according to Pāṇini. So both as a matter of principle, and for the sake of convenience, a new unit of three letters called *trika*. (or triplets) was adopted for metrical scanning. These triplets consisting of the permutations of longs and shorts taken three at a time are called *gaṇas*.

Sequence of the triplets (gaṇas)

'In a lexicographical work to which the author has given his own name' wrote al-Bīrūnī, 'the feet composed of three *laghu* or *guru* are called by single consonants, which in the following diagram are written on their left.

Diagram I

m	S	S	S
y	I	S	S
r	S	I	S
t	S	S	I
s	I	I	S
j	I	S	I
bh	S	I	I
n	I	I	I

'By means of these signs, the author teaches how to construct these eight feet by an inductive method (a kind of algebraic permutation) saying:

"Place one of the two kinds (*guru* or *laghu*) in the first line unmixed (that would be SSS if we begin with a *guru*). Then mix it with the second kind, and place one of this at the beginning of the second line, whilst the two other elements are of the first kind (ISS). Then place this element of admixture in the middle of the third line (SIS), and lastly at the end of the fourth line (SSI). Then you have finished the first half.

"Further place the second kind in the lowest line unmixed (III), and mix up with the line above it one of the first kind, placing it at the beginning of the line (SII), then in the middle of the next following line (ISI), and lastly at the end of the next following line (IIS). Then the second half is finished, and all the possible combinations of three *mātrās* have been exhausted".

Diagram II

	First Half				Second Half		
1.	S	S	S	5.	I	I	S
2.	I	S	S	6.	I	S	I
3.	S	I	S	7.	S	I	I
4.	S	S	I	8.	I	I	I

Calculation of the position in the sequence

'This system of composition of permutation is correct, but his calculation showing how to find that place which every single foot occupies in this series of permutations is not in accordance with it. For he says: "Place the numeral 2 to denote each element of a foot (i.e. both *guru* and *laghu*). Multiply the left (number) by the middle, and the product by the right one. If this multiplier, (i.e. this number on the right side) is a *laghu,* then leave the product as it is; but if it is a *guru,* substract one from the product".

'The author exemplified this with the sixth foot, i.e. ISI. He multiplies 2 by 2, and from the product 4 he substracts 1. The remaining 3 he multiplies by the third 2, and he gets the product 6.

'This, however, is not correct for most of the feet, and I am rather inclined to believe that the text of the manuscript is corrupt.

'The proper order of the feet would accoringly be the followings:

Diagram III

	No. 1	No. 2	No. 3
1.	S	S	S
2.	I	S	S
3.	S	I	S
4.	I	I	S
5.	S	S	I
6.	I	S	I
7.	S	I	I
8.	I	I	I

The mixture of the first line (No. 1) is such that one kind follows the other. In the second line (No. 2) two of one kind are followed by two of the other, and in the third line, four of one kind are followed by four of the other.[3]

Then the author of the above mentioned calculation goes on to say: "If the first element of the foot is a *guru,* subtract one before you multiply. If the multiplier is a *guru,* subtract one from the product. Thus you find the place which a foot occupies in this order"'.[4]

Modes of representations

The number r of permutations of n things when each may be repeated up to r times, is n^r The permutation of *laghu* and *guru* taken three at a time can be done in 2 or eight ways. The eight permutations of *guru* (S) and *laghu* (I) taken three at a time, form the *gaṇas.* Each of these is referred to by a Sanskrit letter for convenience. The accepted names of the *gaṇas* are as indicated by al-Bīrūnī in Diagram I.

The sequence of these *gaṇas* has been given differently by different Sanskrit authors.[5] One of the common rules is the following, given by Halāyudha Bhaṭṭa among others.

I	S	S	*ya*	S	I	I	*bha*	S	S	S	*ma*
S	I	S	*ra*	I	S	I	*ja*	I	I	I	*na*
S	S	I	*ta*	I	I	S	*sa*				

This nomenclature stresses the group relations. The first group consists of the three permutations of the *laghu* and two *gurus.* The second group gives the permutations of one *guru* and two *laghus.* The third group gives the two permutations in which all the three are of one kind or the other.

Another system followed by Jayadeva (who is found mentioned by writers about 1000 A.D.) and others, is to group pairs of *gaṇas* in which the *laghu* and *guru* have changed places.[6]

S	S	S	*ma*	S	I	I	*bha*	I	S	I	*ja*	I	I	S	*sa*
I	I	I	*na*	I	S	S	*ya*	S	I	I	*ra*	S	S	I	*ta*

The symmetry aspect of the individual *gaṇas* finds greater stress in this presentation.

Piṅgala, the great master says that the eight *gaṇas ma, ya, ra, sa, ta, bha,* and *na* along with *laghu* and *guru* form the basic components of the entire literature of prosody.[7]

The sequence of eight *gaṇas* as given in diagram III by al-Bīrūnī corresponds to the sequence given by Piṅgala. The first row has one *guru* and one *laghu* alternating. In the second row, two *gurus* alternate with two *laghus.* In the third row, four *laghus* come after four *gurus.*

Diagram I given by al-Bīrūnī is closely related to the arrangement stressing the group relations as given by Halāyudha and others. The first triplet is all *guru*. The next three triplets have 2 *gurus* and 1 *laghu*. The next three triplets have 2 *laghus* and 1 *guru*. The last triplet is all *laghu*.

The visible difference between diagram I and diagram III is only that items 4 and 5 have been interchanged.

There is, however, a more fundamental difference. While diagram I indicates the triplets of Sanskrit prosody, classified according to the number and position of the fundamental elements *laghu* and *guru*, diagram III follows the broader rules of *prastara*.

Prastara

The proper delineation of all the permutations of longs and shorts in a class of metres containing a given number of letters is called *prastara* Two metres are possible with 1 letter in each line, 4 with 2 letters per line, 8 with 3 letters each, 16 metres with 4 letter lines, and so on. They follow the series 2^1, 2^2, 2^3, 2^4,...... The number of metres with n letters in each line is 2^n.

The accepted form for working out the logical sequence of the various metres containing a given number of letters is to alternate *guru* and *laghu* in column one, 2 *gurus* and 2 *laghus* in column two, 4 *gurus* and 4 *laghus* in column three, 8 *gurus* and 8 *laghus* in column four etc. till all the metres are worked out. The first form will, by convention, have all *gurus*, and the last form, therefore, will have all *laghus*.

Diagram III given by al-Bīrūnī is the *Prastara* for metres containing 3 letters. In fact Jayakīrti who lived about 1000 A.D. refers to this, in his *Chando'nuśāsanam*.[8]

The class of metres having 3 letters in a line is called *Madhyama chandas*. The number of metres in *Madhyama chandas* is 2^3 or 8. *Ma, ya, ra, sa, ta, ja, bha,* and *na gaṇas* give the *prastara* (or logical sequence) of the various metres in *Madhyama chandas*.

Since the position of each individual permutation in a logical sequence is fixed. it should be possible to calculate the position of each in a unique way. The method given in current books on prosody in Sanskrit and Indian languages differs from the one given by al-Bīrūnī.

The current system follows a gradual change from a combination containing only *gurus* to one containing only *laghus*. The logical sequence for metres containing one, two, three or four letters in a line is given in Diagram IV.

Diagram IV

Prastara of metres having one, two, three and four letters

Metres with one letter in each line

S
I

Metres with two letters in each line

S	S
I	S
S	I
I	I

Metres with three letters in each line

S	S	S
I	S	S
S	I	S
I	I	S
S	S	I
I	S	I
S	I	I
I	I	I

Metres with four letters in each line

S	S	S	S
I	S	S	S
S	I	S	S
I	I	S	S
S	S	I	S
I	S	I	S
S	I	I	S
I	I	I	S
S	S	S	I
I	S	S	I
S	I	S	I
I	I	S	I
S	S	I	I
I	S	I	I
S	I	I	I
I	I	I	I

System in current use

The calculation of the position of a given permutation in the series appears to be based on the binary system of numbers. From the left, place on top of each *laghu* or *guru* the number 1.2,3.4,8, etc. in geometric progression, each number being double the previous one. Cross out the number above the *gurus*. Add the numbers above the *laghus*. The result obtained *plus* 1 denotes the position of the permutation in the series.

For example, in the case of S I I, we have the following calculation:

1	2	4
S	I	I

1 is over a *guru* and is to be omitted. 2+4 gives 6. This plus 1 gives the position of S I I as 7th in the series.

Mathematically, the system may be explained as a series of reversed binary numbers in which I stands for 1 and S for 0, numbers to be read from right to left. Thus S I I may be rewritten as 011 which if read from right to left is six according to the binary system.

This method of calculation can be extended to the metres with any number of letters in a line. Each permutation is easily and uniquely determined.

Application of the rules quoted by al-Bīrūnī

Let us now consider whether the rules enunciated by the Sanskrit lexicographer as quoted by al-Bīrūnī give a unique value to each of the combinations, and whether they follow a logical order.

If the *laghus* and *gurus* are represented by 2's, and multiplied from left to right, subtracting 1 from the product if the multiplier is a *guru*, we get the following values.

S. No.	*Representation*			*Calculation*		*Value*
1.	S	S	S	$(2\times2-1)\times2-1$	=	5
2.	I	S	S	$(2\times2-1)\times2-1$	=	5
3.	S	I	S	$(2\times2\quad)\times2-1$	=	7
4.	S	S	I	$(2\times2-1)\times2$	=	6
5.	I	I	S	$(2\times2\quad)\times2-1$	=	7
6.	I	S	I	$(2\times2-1)\times2$	=	6
7.	S	I	I	$(2\times2\quad)\times2$	=	8
8.	I	I	I	$(2\times2\quad)\times2$	=	8

The instance quoted by the lexicographer (serial No. 6) happens to be correct. But there is only one other case (serial No. 8) where the numerical value of the representation indicates the position in the list also.

Examination of diagram III shows that these are the only two cases in the arrangement due to al-Bīrūnī also where the values correspond to the position in the list.

The rules of the lexicographer as we have applied are obviously unsatisfactory.

One thing which deserves special notice is that it is not merely a case of lack of correspondence between the value of each permutation and its positional number. None of the values calculated is below 5. Several items have identical values. There are two 5's, two 6's two 7's and two 8's.

We have now to consider whether some important rule which could reduce the value of some of these permutations to 1,2,3 or 4 has been lost sight of. Each permutation ought to give a unique value.

The vital link

In the paragraph which al-Bīrūnī has added after his calculations proved unsatisfactory, and gave what he thought as the correct arrangements, there are two important provisos. "If the first element of a foot is a *guru*, subtract one before you multiply. If the multiplier is a *guru*, subtract one from the product. Thus you find the place which a foot occupies in this order."[8] Let us apply these two rules also and evaluate the positions again.

S. No.	*Representation*			*Calculation*		*Value*
1.	S	S	S	$(2-1\times 2)-1\times 2-1$	=	1
2.	I	S	S	$(2\quad\times 2)-1\times 2-1$	=	5
3.	S	I	S	$(2-1\times 2)\quad\times 2-1$	=	3
4.	S	S	I	$(2-1\times 2)-1\times 2$	=	2
5.	I	I	S	$(2\quad\times 2)\quad\times 2-1$	=	7
6.	I	S	I	$(2\quad\times 2)-1\times 2$	=	6
7.	S	I	I	$(2-1\times 2)\quad\times 2$	=	4
8.	I	I	I	$(2\quad\times 2)\quad\times 2$	=	8

The application of the new rules has resulted in bringing serial nos. 1 and 3 against their numerical values, in addition to serial numbers 6 and 8 which continue to be correct. This is true of both the arrangements, that given by the lexicographer, and that given by al-Bīrūnī.

There is however another important improvement. No two permutations have the same numerical value. Each permutation is uniquely determined.

The difference between the first set of rules and the second set of rules is the clause about subtracting one before multiplying, if the first element happens to be a *guru*. This is an essential condition which somehow appears to have got overlooked, before diagram III was worked out.

Let us now arrange the permutations according to the numerical value.

Diagram V

	No. 1	No. 2	No. 3
1.	S	S	S
2.	S	S	I
3.	S	I	S
4.	S	I	I
5.	I	S	S
6.	I	S	I
7.	I	I	S
8.	I	I	I

We now get a system in which 4 *gurus* are followed by 4 *laghus* in the first line, two *gurus* alternate with two *laghus* in the second, and one *guru* and one *laghu* alternate in the third.

A closer examination will reveal that the present arrangement is a mirror image of the arrangement given in al-Bīrūnī's *India*. If columns III and I are interchanged in diagram III, we get the correct arrangement given in diagram V.

Al-Bīrūnī and Metrology

The present instance highlights certain aspects of the character and credibility of al-Bīrūnī. Although he apparently failed to obtain correct results based on the formula he applied, he did not on that account seek to brand the lexicographer as incorrect. Al-Bīrūnī only says "I am inclined to believe that the text of the manuscript is corrupt."[9] This is truly the attitude of a seeker after truth, with becoming modesty.

Al-Bīrūnī did not dispose of the matter there. He gave additional material which had either escaped his attention earlier, or came to his notice later. He gives it, to keep the record straight.

He gives new data. But strangely he does not seem to apply it. This was obviously additional information, very relevant to the discussion. The condition regarding the character of the first element has a controlling influence on the whole calculation.

Metrology was not a subject which al-Bīrūnī had mastered, although his reference to Arabic and Persian Metricians[10-11] shows his basic knowledge of the subject. He refers to various Sanskrit books[12] on Metrics. "I, however, had not seen any of these books, nor do I know much of the chapter of the *Brāhma-siddhānta* which treats of metrical calculations and therefore I have no claim to a thorough knowledge of the laws of their metrics. Nevertheless I do not think it right to pass by a subject of which I have only a smattering, and I shall not postpone speaking of it until I shall have mastered it."[13] As Sachau says in his introduction, "Himself perfectly sincere, it is sincerity which he demands from others. Whenever he does not fully understand a subject, or only knows part of it, he will at once tell the reader so, either asking the reader's pardon for his ignorance, or promising, though a man of fifty-eight years, to continue his labours and to publish their results in time, as though he were acting under a moral responsibility to the public."[12]

Al-Bīrūnī criticizes manuscript tradition like a modern philologist. He sometimes supposes the text to be corrupt, and enquires into the cause of the corruption.[13] As in the case of chapters on Indian Astronomy and Chronology, in the chapter on grammatical and metrical literature, al-Bīrūnī continues a literary movement, which at his time had already gone on for centuries; but he surpassed his predecessors, by going back upon the original Sanskrit sources, trying to check his paṇḍits by whatever Sanskrit he had contrived to learn, and by his conscientious method of testing the data by calculation.. As Sachau says, "Al-Bīrūnī's work represents a scientific renaissance."[14]

Elegance of the rule quoted by al-Bīrūnī

The elegance of the rules quoted by al-Bīrūnī lies in the possibility of getting the position of the metrical permutation directly. In the current method of calculation, 1 has to be added to the number obtained by the binary procedure. The binary classes are one short of the power of 2, while the total numbers of metrical permutations are in powers of two.

The scheme for the representation of the Sanskrit *gaṇas* quoted by al-Bīrūnī can be extended to the unique representative of any number from 1 to 2^n in the form of a permutation of two different things taken '*n*' at a time.

Importance of proper translation

The examination of an Arabic reprint[17] appears to indicate that it may be possible to differ from the representation given by Sachau and to construe the representation given by al-Bīrūnī in Arabic as consistent with the mathematical text. This is a matter which is being further investigated. It may be mentioned that a Malayalam translation of *Al-Beruni's India* published by the Sahitya Akademi,[18] which appears to be from the Arabic original, does give a representation different from that of Sachau, but agreeing with the Sanskrit text.

This highlights the need for a proper study of manuscripts in foreign languages by persons competent both in the language and the subject. The Malayalam translation referred to above shows lack of understanding, or studied disregard of even common knowledge, which makes the retranslation of Indian terms from Arabic into an Indian language look ridiculous. There is obvious need for closer study of the original and for better translations of the painstaking and invaluable works of al-Bīrūnī by individuals, or groups, with adequate mastery of the media and of the matter.

Al-Bīrūnī appears on the Indian horizon as a star of rare brilliance, shedding its light on many a dark page of medieval history. Being an eminent scholar himself, he developed great zeal for a comparative study of the religions, cultures, philosophies and scientific achievements of other nations. E.C. Sachau, his able translator, says about him: "The Hindus and their world of thought have a paramount fascinating interest for him." Al-Bīrūnī appreciates scientific statements wherever they are found. In mathematics and architectural constructions, he considers the Hindus to have reached a high degree of art, though he ridicules their superstitions and practices.

REFERENCES

[1] *Jayadamān*, ed. H.D. Velankar, Foreword: p. 16.

[2] *Vṛtta Jātisamuccaya, Vīrataṅka*, Ch. 5.

[3] *Ratnamañjuṣā*, Unknown Jaina author, referred to by D. H. Velankar in his Foreword to *Jayadaman*, p. 17.

[4] *Al-Beruni's India*, Tr. E. C. Sachau, p. 141.

[5] *"Ādi madhyavasāneṣu*
Ya ra tā yānti lāghavam
Bha ja sā gauravam yānti
Ma nau tu guru lāghavam"
—Commentary on Piṅgala *Chandas* by Halāyudha Bhaṭṭa, p. 2.
Ādi madhyavasānesu
Bha ja sa yānti gauravam
Ya ra ta lāghavam yānti
Ma nau tri guru lāghavam
—*Jayadevachandas*, ch. 6.

[6] *"Sarvādi madhyānta glau*
Trikau mnau bhyau jrau stau"
Jayadevachandas, ch. 1. *Sū* 2.

[7] *Ma ya ra sa ta ja bha na la ga*
Sammatam bhramati vāṅmayam jagati yasya.
Sa jayati Piṅgala naga: Śivaprasādādviśuddhamtiḥ
Trigurum Viddhi makāram
Laghvādi Samanvitam yakārākhyam
Laghu madhyamam to refam
Sakāramantya gurunibaddham.
Laghvantam hi takāram

Jakāramubhayor laghum vi-jānīyat
Adi gurum Ca bhakāram
Nakāramiha paiṅgale tri laghum.
Commentary on Piṅgala's *Chandas* by
Halāyudha Bhaṭṭa, p. 1.

8 *Al-Beruni's India,* p. 142.

9 *ibid,* p. 142

10 "In counting the syllabus (*gaṇa chandas*) they use similar figures to those used by Alkhalid Ibn Ahmad and our metricians" *ibid,* p. 132.

11 "The Persian metricians, for instance, call such a consonant *moved by* a *light vowel* (i.e. pronounced with a sound like the Hebrew Schwa)" ibid pp. 138-39.

12 *ibid,* pp. 137-138

13 *ibid, p.* EAB

14 *ibid,* p. xx

15 *ibid,* p. xxvi

16 *ibid,* p. xxxvii

17 *Al-Beruni's India* published by the Osmania Oriental Publications Bureau, p. 110

18 *Al-Beruni Kanda India,* Malayalam translation by A. M. Mohiuddin Alwaye of al-Bīrūnī's *Kitāb-ul-Hind,* Sahitya Akademi, p. 93.

AL-BĪRŪNĪ'S TREATMENT OF THE *LAGHUJĀTAKA* AND COMETS : A CRITIQUE

M. RAMAKRISHNA BHAT*
44 U. B. Jawahar Nagar,
Delhi 7

Al-Bīrūnī appears as a grand bridge between the Hindu culture and the western scholarship in the middle ages. He has done yeoman service to the cause of comparative religion and scientific thinking, especially in the sphere of astronomy and astrology. He appreciates the scientific approach of Varāhamihira in many instances, though he condemns his as well as Brahmagupta's servility to the ancient theologians. He has helped the cause of international co-operation and understanding by translating the *Laghujātaka* and the *Bṛhat Saṃhitā* despite his handicap in the form of corrupt manuscripts. Al-Bīrūnī's works would provide research scholars with much food for thought and light to guide their steps in the area of ancient Hindu achievements.

In the section on astrology he has given many useful tables explaining planetary characteristics, the signs of the zodiac with their aspects, which are alien to Varāhamihira and the houses of natal charts. He has also given three excellent charts for the three kinds of comets with all their qualities.

In this paper some of the statements of al-Bīrūnī have been reviewed in the light of Varāhamihira's works. For example, his descriptions of the forms of Gemini, Capricorn, Aquarius and Pisces may be cited. Next, his translation of IV 5, 7, 8 is examined with corrections wherever necessary. His reading, *Triśāla* instead of *Viśāla,* in verse 8 appears more correct. Verse 12 relating to women attendants at a confinement, as interpreted by him is reviewed. In XIII 5 the word *Tiraścaḥ* is translated by him as *Vṛścikaloka* and *Nāraka* as *Bhṛguloka*. In XIII 4 the words *"Janmani maraṇe vā"* is interpreted wrongly.

In the *Bṛhat Saṃhitā* too he commits errors of omission and commission while translating verse 7 of XI. Next his descriptions of the *ketus,* comets, are examined wherever he departs from the spirit of the text.

Al-Bīrūnī appears on the Indian horizon as a star of rare brilliance, shedding its light on many a dark page of medieval history. Being an eminent scholar himself, he developed great zeal for a comparative study of the religions, cultures, philosophies and scientific achievements of other nations. E. C. Sachau, his able translator, says about him: "The Hindus and their world of thought have a paramount fascinating interest for him." Al-Bīrūnī appreciates scientific statements wherever they are found. In mathematics and architectural constructions he considers the Hindus to have reached a high degree of art, though he ridicules their superstitions and practices This does not mean that he is quite free from religious intolerance and arrogance, which come to the surface in a few places.

* Department of Sanskrit Hindu College, University of Delhi (Retired)
Present address : Vittal P.O., Via Mangalore.

Though al-Bīrūnī's work on astrology is based on corrupt manuscripts and interpretations of Hindu scholars, he has achieved remarkable success in the field of astrology-cum-astronomy, among others. It is known that he has translated into Arabic the *Laghujātaka* and *Bṛhatsaṃhitā* as well as written works on the "Lunar Stations", "Chronology" etc. His translation of these works is likely to open up a vast vista of research possibilities in the field of textual variations and interpretations.

Al-Bīrūnī's *India* consisting of 80 chapters deals with Hindu astrology in the last three chapters, quoting many verses in translation from the *Laghujātaka* and Chapter XI of the *Bṛhatsaṃhitā* bearing on *comets*. We do not understand why al-Bīrūnī considers the comets to have no astronomical significance, as he has relegated this topic to the astrological section rather than to the astronomical one. Actually they do have a scientific, astronomical basis which was visualized by ancient Hindu sages and which is being proved by modern theories and experiments on meteorites.[1] He states in this connection that his aim in writing this work is to remove the misunderstanding of his own people about the glorified nature of Hindu astrology, and to present to them the real state of affairs as they are. In this paper I shall address myself to the task of examining the performance of al-Bīrūnī in translating and presenting Indian astrological classics such as the *Laghujātaka* and the *Bṛhatsaṃhitā*.

In this section he has given very useful tables pertaining to the *Karaṇas*, *yogas*, planets, signs and comets for the benefit of students of astrology. In the tables of planets the author has shown the several months of pregnancy that are presided over by the planets. In a table on page 221 (of Vol. 11) he speaks of the aspects exercised by the signs of the zodiac, which is an alien subject to Varāhamihira who knows only planetary aspects. Al-Bīrūnī does not mention the source of his information. However, the details of this topic must have been supplied to him by local astrologers well-versed in the *Horā* of the sage Parāśara.[2]

While describing the physical forms of the various *rāśis*, i.e. signs of the zodiac he says about *Gemini*: "The word applies to a man holding a lyre and a club", which is not correct. It ought to be "A man holding a club and a woman a lyre." About the description of Capricorn as *Goat-Cum-Crocodile*, he says, it is true only according to Greek astrology. He says the same thing about *Kumbha*, Aquarius, as it means only a 'Pot' but the figure is that of a human being holding a pot, which answers to the Greek representation of the sign. The name *Mīna*, Pisces, too means a single fish, not a pair of fishes according to him.

His translations of the verses of the *Laghujātaka* in many places are more of an explanatory nature than faithful renderings, there being some omissions and many additions. In IV-5 of *L.J.* the author gives a planetary configuration necessary for predicting an illegitimate birth, but al-Bīrūnī takes it to indicate short life for the child.

In verse 7 the house of confinement is described by Varāhamihira as *adṛḍha*—not strong or stable—if the Sun be the strongest planet in the chart, but al-Bīrūnī construes the word as "will be destroyed". Similarly the word *nava*—new—is taken by him in the sense of 'beneficent'. The word *dagdha*—burnt— means, 'burning' according to him. The word *citra*— colourful or variegated—is taken in the sense of "bow-shaped". He has omitted the meaning of "*manoraman*"—charming—corresponding to Venus. Similarly he has not translated the expression, "*Prativeśma sannikṛṣṭaiśca*" which means, the house in the vicinity is to be predicted through the planets situated nearby.

While translating verse 8 of chapter IV he interprets the word *bhūmikā* meaning storey as 'wing'. Another word *viśālam* meaning broad or spacious, is translated by him as "having three wings". I should think that his manuscript must have had the reading, *triśālam*, which is quite correct as contrasted with the following expression, *dviśālam*.

He has completely omitted verses 10 and 11 of this chapter. He translates verse 12 as follows: — "The number of women who will be present in a house corresponds to the number of stars which are in the signs of the ascendant and of the moon. Their qualities correspond to the images of these constellations".[3] The correct meaning of this would be—"The number of women (in the lying-in-chamber) should be judged from the number of planets situated between the Ascendant and the Moon." The second half of the verse too is misconstrued by him. For he uses the expression, *go away*, for *bāhyāḥ* which means, those that are standing outside, and 'enter it', for *Abhyantaragāḥ* meaning those that are inside.

Next he takes up the last verse, i.e. the 5th, of chapter XIII dealing with the soul's previous place of residence. He takes the word *Tiraścaḥ* to mean *Vṛścikaloka*, whereas it is the world of birds and beasts. The word *nārakīvaḥ* means, according to him, those hailing from *Bhṛguloka*, whereas it means only those that come from the other world.

Al-Bīrūnī does not take the verses in order. It is possible that he thought of giving his readers a succinct and connected account of Hindu astrology, and so changed the sequence of the materials to suit his pattern of writing. While translating XIII-4 dealing with *mokṣa* or liberation he omits the expression, *Śeṣair abalaiḥ*, (with the rest being weak), which is an important condition. Similarly he errs in construing the expression, *janmani maraṇe vā*, as he says:- "If the constellation of the moment of death is the same as that of the moment of birth, in that case the spirit is liberated". It should mean only "at birth or death". He points out that these features are alien to the system prevalent in his country.

While discussing the phenomenon called comets he says that the theories and methods of the Hindus are very lengthy and very subtle. First he takes up III-7-12 of the *Bṛhatsaṃhitā* which describe the *Tāmasakīlakas* numbering 33 and their effects.[4] Then he skips over the succeeding seven chapters and treats of the comets in chapter XI. He translates the first seven verses barring the sixth. The second half of the seventh stanza is wrongly construed thus: "If the appearance of a comet lasts longer than 1½ months, subtract from it 45 days. The remainder represents the months of its influence". He must have been misguided by the expression, *pakṣatrayāt parataḥ*. The right meaning of the verse is—"The effects of a comet last for so many months as the number of days it remains visible, and for so many years as the number of months it is visible. These effects will be felt after a month and a half. Here he adds another sentence as" If the appearance lasts longer than two months,..." which is not warranted by the text. I presume that the astrologers whom al-Bīrūnī cross-examined gave him this queer explanation. In this connection we cannot but commend the pains the Arab scholar has taken in analysing materials given in this chapter of the *Saṃhitā* and tabulating the minute details in appropriate columns. He has tabulated the properties etc. of the three categories of comets described in verses 8 to 41. We shall take up these tables for consideration later on.

Under verse 42 of this chapter which describes the comet *Dhruvaketu*, al-Bīrūnī translates the word *Deśānām* as *empire* instead of countries. Varāhamihira means to say that there will be destruction in all the countries where this comet has been sighted on houses, trees or mountains. Similarly he gives two meanings for the word *upaskāreṣu,* the second being "sweepings of the house". According to Bhaṭṭotpala it means house-hold utensils and the like such as ladles, winnowing baskets and brooms. Then he jumps to verse 61. Of course he utilizes the ideas of the intervening verses in the tables of comets. Another peculiarity of this scholar is that he takes the word *śikhā* or *cūḍā* throughout to mean, *tail,* and not crest. This verse too he translates wrongly thus: "If a shooting star falls down opposite to the tail of a comet. health and well-being cease, the rains lose their beneficial effect, and likewise the trees which are holy to Mahādeva and the conditions in the realm of Cola... are troubled". Is it possible that al-Bīrūnī had different readings or was his manuscript illegible, which necessitated a strained construction? Our reading is "*Śivaḥ śivataro'tivṛṣṭo yaḥ*". Hence there is no chance of Śiva's tree creeping in. It only means *auspicious* and more *auspicious*. No doubt, he has translated the second half of the verse correctly, though he has omitted the word, *Avagāṇa* (Afghan?) from the list of countries affected adversely.

Next he translates verse 62. Here too he goes off at a tangent from the text. For, he says, "Examine the direction of the tail of the comet, it being indifferent whether the tail hangs down or stands erect or is inclined, and examine the lunar station, the edge of which is touched by it. In that case predict destruction... and that its inhabitants will be attacked by armies which "devour them as the peacock devours the snakes".[5] Here the first line is misinterpreted. It should be— "The quarter where the crest of the comet is bent, where it is projecting..." He has not only omitted the word *"Divya-prabhā-vinihatān"* (destroved by divine power) but has taken *garutmā* meaning *garuḍa,* as peacock.

Tables of Comets

Kiraṇas:—These comets number 25. Al-Bīrūnī calls them "Children of *Kiraṇa*", but actually they are the sons of the Sun. Their effect is *Śikhibayadāḥ*, i.e. creating danger from fire, but he gives pestilence as the effect.
The 22 comets, children of the Earth :—He omits the adjective *Kiraṇānvitāḥ* (full of rays). For the effect, *Kṣudbhayadāḥ*, he gives "fertility and wealth" which applies to the succeeding set of 3 comets.
Sons of the Moon numbering three:—He quotes evil effects as "The world will be turned topsy-turvy". This applies to the next comet called *Brahma-daṇḍa*, which causes, acording to him, wickedness and destruction.
Kanakas:—These are 60 comets, children of Saturn. They are omitted by al-Bīrūnī.

Taskaras:—They are *Nātivyaktāḥ*, not quite clear, but he says, "the eye is dazzled by them", which is wrong. It is possible that he could not find the negative particle *Na* in his manuscript.
Tāmasakīlakas:—Al-Bīrūnī includes them in the tables of comets. Though they are 33, it is given here as 36. Their effect, according to him, is 'fire', while Varāhamihira gives their effects under "The Sun's Transit" in five verses as "famine, trouble to kings, theft, drought etc.".[6]
Viśvarūpas: He gives their effect as 'evil', but it should be "acute danger from fire."

Aruṇas : Children of Wind numbering 77. Their quality *Vikīrṇadīdhitayaḥ* meaning "possessed of scattered rays" is translated by him as 'their rays are united so that these appear as rivulets.' About their colour *Śyāmāruṇaḥ*, dark red, he says "reddish or greenish."

Gaṇakas and *Caturaśras* are both children of the Creator, the former being 8 clusters and the latter 204 in number. Al-Bīrūnī takes *Gaṇaka* as the name and *Caturaśra* as its epithet, and gives their number as 204. According to Bhaṭṭotpala *Caturaśra* is a descriptive name.

Kaṅkas : Al-Bīrūnī extends their effects, viz. *tīvraphalāḥ*, by bringing in the effects of *kabandhas*, viz. *pundrabhayapradāḥ*. Even here he has taken the word *māraka*—mortality.
or danger, while *abhaya*, protection.

Asthiketu: He reads it as *aṣṭi*, and translates *rūkṣa* as 'less bright'.
Śastraketu: It appears in the east, but he says west. In its effect he leaves off *māraka*-mortality,

Raudraketu: It is to be seen in the *Dahanavīthi*, which has been mentioned in connection with the transit of Venus. This Avenue consists of the two stars, *Pūrvāṣāḍha* and *Uttarāṣāḍha*, but al-Bīrūnī gives the three stars, viz. *Pūrvāṣāḍha*, *Pūrvabhādrapada* and *Revatī*. This is against Varāhamihira's rule given in IX 3. Though the author has told us that its effects are the same as those of *Kapālaketu*, i.e. hunger, mortality, drought and diseases, yet al-Bīrūnī gives only "fighting among kings."

Śvetaketu : It is visible in the east at midnight, but according to him in the *south* at the *beginning of the night*. He was misled by the words *prāk* and *yāmyāgrah*.

Ka : Al-Bīrūnī omits its form, *Yugākṛti,* like the yoke. He says that it appears in the 'first part of the night.' It should be 'midnight'. The adjectives, *Saptadinadṛśyau*—visible for seven days—and *Snigdhau subhikṣasivadau*—glossy and conducive to good crops and benefits—are applicable to this and the previous comet. He describes *Ka* as: 'its flame is like scattered peas. He applies the evil effects of *Ka*. when it is visible for more than a week, to both *Ka* and *Śvetaketu* against the textual specific statement. He also gives the effect, viz. destruction of two-thirds of the population, of the following *Ketu Śveta* (which is omitted by him), as belonging to this pair of comets. Varāhamihira says clearly about the distinctness of *Śvetaketu* and *Śveta*. Still al-Bīrūnī takes them as identical.

Raśmiketu: It is similar to *Śveta* in effects, but al-Bīrūnī gives a different version of it as "ruining all human affairs and creating revolutions." In reality it is 'destruction of two-thirds of humanity.'

Dhruvaketu: He does not give the evil effects of this, given in verse 42 which he applies to the entire class of atmospheric comets.

Kumuda: He construes the word *Prākśikhā,* meaning, with its crest turned to the east, as having its 'tail directed towards the south.'

Maṇiketu: He omits its characteristic of being a tiny little star.

Bhavaketu : Here too he omits its glossiness and form of a tiny star.

Padmaketu: He takes the direction of its appearance as South, but it ought to be *Apareṇa,* the West.

Āvarta: It is *aruṇanibha*, red in colour, but he takes it as 'light gray.'

Samvarta: It is described as "Śūlāgrāvasthitah"—situated like the trident—and dreadful. He omits the latter quality and alters the former as "with a tail with a sharp edge."

My above-mentioned criticism of al-Bīrūnī is not meant to belittle his yeoman service to the cause of international understanding and of enriching the knowledge of his countrymen, but to show that there is a vast field of research for scholars to prove the veracity and justness of the statements made by the great Arab savant, to whom the world of scholars and lovers of culture owe a deep debt of gratitude.

References

[1] *Bṛhatsaṃhitā* translated by V. S. Sastri & M. R. Bhat, P. 146.

[2] See Chapter IV of *Bṛhatparāśarahorāsārā.*

[3] Page 233 Vol. II.

[4] Al-Bīrūnī follows Varāhamihira in clubbing together the *Tāmasakīlakas* and the comets mentioned in Ch. XI, simply because they have the same generic name, *Ketu*. Varāhamihira however, knew that they were sunspots, solar flares and the like. Hence they are of a different type.

[5] P. 289 vol. II.

[6] *Br. Saṃ.*, III 12-16.

SESSION IV

DISCUSSION

ASTRONOMICAL WORK OF AL-BĪRŪNĪ IN DARI by M. S. ASIMOV

Mr. M. A. Alvi referred to a fable in which the astrological writings of al-Bīrūnī were criticised by Ibn-Sīnā. However, the author of the paper refuted by saying that the fable was current in later times and this did not justify al-Bīrūnī's faith in Astrology.

AL-BERUN: WHERE WAS IT SITUATED? by ABDUL HAYEE HABIBI

Prof. Maqbul Ahmad enquired about the exact geographical position of north Khorasan and the authenticity of al-Berun as a city. He also wanted to know whether Al-Zahini wrote the manuscript of the work mentioned by the author to which the author replied in the affirmative.

Dr. R. R. Grover argued, on the basis of the association of the name with the native town of the author concerned, that al-Bīrūnī belonged to a town which was in the north Khorasan.

Dr. S. M. R. Ansari drew attention to the points discussed by Inayatullah in one of his papers as early as in 1896, viz. (i) 'Berūn' was derived from Neroom, a city mentioned in the battles of Mohammed Kasim; (ii) Al-Bīrūnī was born in Berūn which was a city of Sindh as mentioned by Shamsuddin Shah; and (iii) Al-Bīrūnī was born in a fashionable city in Sindh according to the authority of Ibn Said as referred to by Khalfa Ibn abi Asiba. In reply, the author emphasised that al-Berūn was actually situated in north Khorasan, and in the light of the recent archaeological excavations which have laid bare the encircled walls in that area, it was probably a city.

AL-BĪRŪNĪ'S TREATMENT OF THE LAGHUJĀTAKA AND THE COMETS by M. R. BHAT

Mr. M. A. Alvi questioned about the idea of sun-spots as described by the author, and wanted to know whether the dark spots referred to by him really meant the sun-spots.

Dr. S. M. R. Ansari emphasised that sun-spot could not be seen by naked eyes and, in his opinion, most probably the Sanskrit term concerned (*tāmasakīlaka*) should be interpreted in some way other than in terms of sun-spot.

Prof. F. C. Auluck thought that the ancients might have adopted certain devices to observe the sun-spots through reflection in some media.

AL-BĪRŪNĪ AND THE ARITHMETIC SEQUENCE OF THE SANSKRIT GAṆAs by B. K. NAYAR

Dr. A. K. Bag drew the attention of the author to the algebraical implications of the metrical problems. He explained in detail how the rule of finding the variations of sounds helped Halāyudha in his scheme for minimising the complications while computing different variations.

Dr. V. R. Shastry threw light on the system of representation of large numbers.

ANNOUNCEMENT

The XVth International Congress of the History of Science will be held in Edinburgh, Scotland, between 10 and 19 August 1977.

A first circular announcing preliminary arrangements for this Congress and associated activities within the United Kingdom will be widely distributed in March 1976. To this will be added a reply slip, *which must be returned* if further communications are desired. Copies of this first circular, and public notices advertising the Congress, will be supplied on request by the Honorary Secretary, Dr. Eric G. Forbes, History Department, University of Edinburgh, 50 George Square, Edinburgh EH8 9JY, Scotland.