Sponsored by
Ministry of Education Government of Pakistan
in co-operation with UNESCO
Under the auspices of
Hamdard National Foundation, Pakistan.

Millenary of
Abū Raihān Muhammad Ibn Ahmad Al-Birūni

34

THE EVOLUTION OF COSMOLOGY
IN THE HANDS OF MUSLIMS
UPTO THE TIME OF AL-BIRUNI

by
SYED SIBTE NABI NAQVI,
Retired Director,
Pakistan Meteorological Services.

Presented on the Occasion of

Al-Biruni International Congress

November 26, 1973 thru, December 12, 1973
Pakistan.

The Evolution of Cosmology in the Hands of Muslims Upto The Time of Al-Biruni.

By

Syed Sibte Nabi Naqvi, F.R.A.S.(London)
Retired Director Pakistan Meteorological Services.

Upto the time of advent of Islam the progress of cosmology had been extremely slow. The ancient cosmologies of the Babylonions, Egyptians and others were extremely fantastic, childish and anthropomorphic interpretation of primitive experiences and limited observations.

About 2,000 B.C. prophet Abraham (p.u.h) revolted against Babylonion polytheistic cosmology, on the basis of revelations, but the Jews during their captivity incorporated that very cosmology in their old Testament. Dreyer has given full details of this on pp 2 and 3 of his History of Astronomy from Thales to Kepler.

Greeks produced a number of Philosophers and Astronomers from Thales (640-562 B.C.) to Ptolemy (90-168 A.C.). They included Pythagorus, Plato, Eudoxus, Kalippus, Aristotle, Democretus, Herakleides, Euclid, Archimedes, Aristarchos, Hipparchos and many others. They made significant contributions for the advancement of astronomy and mathematics, but their cosmological concepts continued to have elements of fantacy and immature generalisations. These have been discussed in the treatise in some details.

Christianity and Judaism were basically opposed to acquirement of knowledge, particularly the ideas developed by pagan philosophers of Greece. A Christian mob destroyed the magnificient library of the Alexandrian Museum in 398 A.C., and another mob murdered and desecrated the corps of the most beautiful, virtuous and learned astronomer lady Hypatia to satisfy the pride and cruelty of the Archbishop of Alexandria in 415 A.C. The idea of the rotundity of the earth was particularly repugnant to the Christian church.

The geometric details of the geoheliocentric universe by Herakleides of the 4th century B.C. or of the heliocentric system proposed by Aristarchos of Alexandria in the third century, or by Seleukes of Babylonia in the second century B.C. were not worked out. In fact, Herakliedes was fond of embalishing his books by purile tales, and fantastic stories, and his suggestions carried little weight with serious thinkers. Naturally these suggestions were not accepted by philosophers living in the world depending on astronomical observations of the naked eye. Pythagorean system was a mixture of some advanced ideas and fantastic mystic theories about numbers and the harmony which ruled the world.

On the other hand, the believers in the geocentric systems had produced elaborate geometrical details for satisfying the observed motions of stars and planets.

Plato (428-347 B.C.) worked his 'Implement of Necessity', with spherical earth at the centre, by a singing bord of sirens

(future. The sirens sat at the end of [illegible] whorls of stars and planets, producing the eight notes of harmony. The daughters fate sat at equal distances from each other on their respective whorls in royal splendure, and sang song of past, presnet and futare, in harmony to the notes produced by the sirens. While Klotho turned the outer spheres (of sameness) with her right hand, Lachesis turned the inner sphere (of the Diverse) with her left hand. Atropos turned either of them with either hand at times. The stars were divine bodies made of fire, and the whole cosmos was a work of art, possessing the most godlike of all souls.

Eudoxus in his geocentric scheme of homocentric spheres tried to explain the motions of planets and stars by the motions of 27 spheres 8 of which carried stars and planets. Kalippus added 6 spheres to these to remove some lucusnas left in the scheme of Eudoxus. Aristotle added 22 counter revolving sphere to the 33 of Eudoxus and Kalippus. But with all these 55 spheres the great variation in the brightness of Mercury and Venus could bot be explained. Aristotle regarded the shooting stars, meteors and auroras to be hot exhalations rising high in the atmosphers. Comets were produced in the same way in the highest parts of the atmosphers, on the conjunction of Jupiter with the stars in the Jemine. The Milky Way was considered to be a phenomena of the same kind. He considered stars and planets to be spherical, eternal and divine, consisting of the material in which they moved. Their physical bodies were made up of either in different states of purity.

The real difference in the cosmological concepts of Pythagoras and Plato on the one hand, and Aristotle on the other, was that the former considered the motive force for running an infinite universe to be amenating from the centre, while Aristotle thought that its origin was the ninth sphere, which was the prime-mover, surrounding the eight spheres of the material universe.

Hipparchos of Rhodes (210 to 129 B.C.) was the first practicing astronomer who took pains in taking observations with instruments in which the circle was divided into 360 degrees. He prepared a catalogue of stars in 161 B.C. and examined the controversy between the heliocentric and geocentric systems objectively. Although he believed in epicycle and eccentric circles, he ceme to the right conclusion that the observational date at his command were not enough to give a conclusive result.

About two hundred years after him was Ptolemy (90-168 A.C.) He started his astronomical observations in 127 A.C., and continued them without break upto 151 A.C. Sarton has termed him to be a poor observer. However, he prepared a catalogue of 2028 stars in which his own observations of 24 years and observations of enequal correctness and significance of Happarchos and others of Alexandria and Babylonia were included, these extended back to 161 B.C. and contained observations of about 58 years in all. Then he wrote Almagest, which was a compendium of ancient astronomy and in which the astronomical and mathematical knowledge available to him was carried to its very limits. In this book he finally established the geocentric hypothesis by using epicycles, eccentrics and equants. His theory was generally accepted by the astronomers and mathematicians, and even by the common men so much so, that even the beliefs of the Christian Church were affected by it to some extent. It was such a step forward that practically no advance was made on it by any pagan, Christian or Jew astronomer for about 500 years, till the emergence of Islam. It was not a cosmology in the strict sense of the word, but only a geometric device to compute the positions of the sun, moon, and the planets, but the geocentric system propounded by him was really a cosmological concept of far reaching importance.

Propher Muhammad (p.u.h.) started receiving revelations in 610 A.C. These continued for twenty three lunar years, upto about 632 A.C. These were arranged in the form of the Holy Quran by the

Prophet (p.u.h.) himself. The Quran is silent about the system being geocentric or heliocentric, but it makes a clear statement that both the sun and moon are in motion, and the cosmological concepts are spread over the whole Book. These are summed up in the following Chapters (Surah's indented in Roman numbers) and verses (indicated in Arabic numerals):- VI: XI: 7; XXI: 30; XLI: 9 to 12; XXII: 47; LXX: 4; XXI: 105. The Quranic cosmology based on the above verses to summerised below:-

Allah, who is Omni-present, Omni-Soient and Omni-potent, brought into being Darkness (continuum) and Light (the Photons and all other elementary particles). This was a closed up mass (The yelm). He began to open out this closed up mass at a particular moment in Truth (الحق), in accordance with the requirements of wisdom. The expanding mass has passed through six cosmic periods of evolution (Days) in three stages of two cosmic periods (Days), each, which are as follows:

(1) Creation of matter in the form of gas at high temperature, its cooling and break upto into galactic masses; further break up of the galactic masses into stars and planets, i.e. birth of earth in two days.

(2) Formation ofmountains on the surface of the earth and production of food materials (compounds) in abundance for all seekers alike in two days. In this stage living cells began to develop in black mud altered, and in water, and the throne of authority of the Lord (العرش) was on water to prove which one was best in conduct.

(3) Perfection of man, and conferment of higher degrees of freedom (Lord breathing His Spirit into him) on him, to enable him to acquire knowledge, and creation of seven heavens one above the other, without any material support, and fixing their duties and commands, in the last two days. The heavens are thus only fields for the play of capacities of man in higher degrees of freedom, beyond the first heaven which has been decorated with lights of

galaxies and stars, and for which he makes himself capable by good actions in this life.

On approach of the Day of Resurrection the heavens and the earth will be rolled up like the rolling up of a written scroll by a scribe. The whole process will be repeated again. This a promise by which the God has bound Himself in the Quran.

This cosmology of the Quran is the briefest possible discription, in popular language, of an evolutionery, pulsating universe, as we understand it today, in the last half of the twentieth century. Such a cosmology had never been propounded by any philosopher or astronomer before, but the miracle of the Quran was that it could be appreciated with acastastic delight by the wandering Budoins of the Desert, by the learned philosophers of the Middle Ages, as also by the cosmologists of the 20th century.

It could, evidently, not be properly understood by even the most learned scientist in the Middle Ages. However, it goes to the credit of theMuslim learned men like al-Mamun, al-Kindi, al-Khwarizmi, al-Razi, al-Ghazzali, Ibne Muskwaily, Ibn al-Haitham, al-Biruni, Ibn Sina, Ibn Rushd, Nasir aldin al-Tusi, and others that instead of corrupting and changing the verses of the Quran, like the followers of earlier religions, each one of them concentrated his effort, in his own way, freely, in trying to understand the meanings of these verses, in an objective manner, in keeping with the injunctious of the Quran itself. Thus instead of putting themselves in the maze of primitive anthropomarphic riddles, they opened the way for un-hindered progress of science and civilization.

They made acquirement of knowledge universal and international. They adopted special symbols for numerals from

1 to 9 and introduced zero for regular use in their decimal system of numeration, and developed arithmatic to the status of a regular science. Algorism from al-Khwarizmi; and above all, they introduced empirical inductive method of research. For elucidation of this statement you may see Drapers "Conflict between Science and Religion" or my book "Islam and Contemporary Science."

They translated the scientific, philosophic, mathematical and astronomical works in Sanskirit, Pahlawi, Syriac and Greek for understanding the cosmological statements and astronomical allusions in the Quran (vide Appendix I).

They improved and invented equipment for takingmost accurate observations and developed theory to fully appreciate their meanings and implications (vide appendix II).

Unlike their predecessors before Hipparohos, they kept regular record of their observations in the form of tables and catalogues, for 500 years from 767 to 1276 and later, and published them for the benefit of all others interested in the subject (vide appendix III).

After examining the astronomical system of Indians, Iranians (in the Babylonian tradition) and all the various systems proposed by the Greeks, (Pythogoras, Plato, Exdoxus and Kalippus, Aristotle, Heracleides, Aristarchos and Ptolemy) they selected the Ptolemaic system, which was the most advanced amongst them all, as

the starting point of their research towards the middle of the eighth century. They began to reject it and started search for a new and better system before theend of the 12th century, actually in the 11th century. From study of the cosmological concepts of Al-Biruni, it is clear from Kitab al Tafhim le ullel Awail-e-Tenjim (Sections 120 to 345) that he was fully aware of the connection between movements of the planets and the sun and of the heliocentric system, but he was not convineed of the usefulness of this system in preference over the geocentric system. I think the real difficulty in his way was that the holy Quran stated that the sun was moving towards a goal, but the heliocentric system wanted it to be stationary at the centre. Thequestion of the precession of the equinoxes was still undecided and remained undecided for four centures after him. This matter could be clearly decided after themovement of the sun round the centre of our galaxy was settled on the basis of regular and accurate observations started by the Muslims themselves.

Upto the time of al-Biruni, and even afterwards, great masses of people believed in the efficiency of astrology, but the Quran and the Prophet (p.u.h.) were against it, like a true scientist. Al-Biruni learnt astrology of theGreeks, Hindus and Iranians, but at the end came to the conclusion that it was without much reality. In thelast para of Section 346 of Tafhim he says "And now .. .. it is time to deal with the expressions which the astrologers use with regards to the decrees of stars, and which are of interest to querents. By the majority of people the decrees of the

stars are regarded as belonging to an exact science. While my confidence in their results and in the profession resembles that of the least."

This shows his scientific spirit and honesty, to which I pay homage.

Appendices 1 to IV to the Book

Advances of Cosmology andAstronomy by Muslim in the MiddleAges, intwo partsp of which the paper

"Evolution of Cosmology in the hands of Muslims upto the time of al-Biruni" is a summary of Part I.

Appendix I. Works translated into Arabic with names of translators (T), Commentators (C) and abstractors or elaborators (AE) or criticisors (CR).

1. Siddhants -Sanskirit, Math. and astronomy (V-A.C) /T/ Mohammad ibn Ibrahim Al-Fazari (772/73) /AE/ - Yaqub ibn Tariq (773-778), Ibn Samah (979-1035), Ibn al Saffar of Cordora ( )

2. Vaharamihira - Sanskirit (fl.505 A.C.) - /T/ Al-Biruni (d.1048) two books.

3. Pahlawi works on astronomy: /T/ Al-Fadl ibn Naubakhat (d.816) & his two sons Umar ibn Farhan ( ) and Abu Hafz ibn Farhan (d 817).

4. Leucippos (V.B.C.) Atomist Philosopher Ali al Taiyibi al Baqilani (d. 1013) introduced in Kalam. The ideas of atom and void and conceiving time and motion essentially discontinuous introduced the idea of atomism of Time and Motion.

6. Plato (IV-I B.C) Philosopher, Mathematician /T/ (Timaeus Yahya ibn Batriq (813-833) /C/: (Republic) Ibn Rushd (1126-1198).

7. Aristode (IV-2 B.C): Encyclopaedist, Philosopher, founder of Logic /T/ : Yahya ibn Batriq (813-833), 2. Ishaq ibn Hunain (d910/11), Thabit ibn Qurra (826-901), 4. Abu Said ibn Yaqub al-Dimishqi (908-932): /C/: Al-Farabi (770. 850/857) 2. Ibn al-Haitham (965-1039) 3. Ibn Baja (1106-1138), 4. Ibn Tufail (1100-1183) /AE/ Ibn Rushd (1126-1198).

8. Autolycos (IV- 2 B.C) Mathematician (spherical geometry), Astronomer: /T/ Ishaq ibn Hunain (d 910/11), 2. Qusta ibn Luqa (d.912) Christian /AE/ Nasir al din al-Tusi (1201-1274) wrote oneof the Mutawassitats.

9. Euclid (III-I B.C): Mathematician (Elements books I-X), Physicist: /T/. Hajjaj ibn Yusuf ibn Matar (786-833), 2. Ishaq ibn Hunain (d 910/11), 3. Thabit ibn Qurra (226-901), 4. Hafiz ibn Yuman (d990) Christian 5. Al-Dimishqi (908-932) 6. Ibn Sina (980-1037), 7. Nasir aldin al-Tusi (1201-1274): /C/ Jabir Ibn Hayyan (754-776) from Greek text; 2. Abbas ibn Said al Jauhari (813-833). 3. Al-Mahani (860-874/84) 4. Al-Nairizi (892-902), 5. Qusta ibn Luqa (d 912) Christian 6. Abu-l-Wafa (940-997) 7. Abu Jaffar al Khazini (Book X) (d 961 971), 8. Muhammad ibn Abdal-Baq- (on book x) (fl. 1100-1123) /AE/ Hajjaj ibn Yusuf ibn Matar (829), notes and additions; 2. Abu Hatim al Asfuzari (d 1122) summary of books I to XIV, 3. Ibn Labudi (1210-1267) - Essential points extra, explanation of postulates, 4. Abu-l-Faraj, Christian (1268) lectures, /AE/ 5. Ibnal Banna (1256-1321) introduction, 6. Nasir al-din al-Tusi

(1201-1274) (a) for Mutawassitats (M) (b) on Euclids postulates (c) On postulate No.5 (start of non-Euclidian geometry) (d) Longer reedition with notes and additions.

10. Aristarchos (III-1 B.C) - Astronomer who suggested heliocentric system /T/ Qusta ibn Luqa (d 912) /AE/ Nasir al-din al-Tusi (1202-1274) Books for mutawessitat.

11. Archimedes (III. 2 B.C.) Mathematician, Physicist /T/ (1) Ishaq ibn Hunain. 2. Thabit ibn Qurra, 3. Yusuf ibn al Qass (902-908), 4. Nasir al-din al-Tusi /C/ 1. Al-Mahani 2. al-Naswi (XI- 1 A.C) on Lemnata. /AE/ 1. Al-Muhani made advances on Archimedes, 2. Ibrahim ibn Sinan (908-996) Simplified Quadrature - His solution simplest upto invention of Integral calculas. 3. Rustam al-Kuhi (fl.988) devoted special attention to his problems. 4. Al-Nasawi (fl. 1029-30) on Limnata, 5, Nasir al-din al-Tusi for M.

12. Apollonios (III-2 B.C) Mathematician - 8 books on Conics /T/ 1. Hilal Ibn Himsi (d.833), 2. Thabit ibn Qurra, 3. Abul Fath al-Isfahani (ft 982) 4. Nasir al-din al-Tusi - Revised T. of 1 and 2 for books 1 to 7 /C/ Ibrahim ibn sinan (908/9 - 943) on book 1. 2. Abul Fatha al-Isfahani on books 1 to 5. /AE/ Rustam al-Kuhi (ft.988) devoted attention to his problems 2. Abdal-Malik al-Shirazi (xii-2 A.C.) - A summary of Conics. 3. Nasir al-din al-Tusi (1202-1274) book for M.

13. Hypsicles (II - 1 B.C)- Mathematician, Wrote Euclid book XIV - divided arte into 360 paras /T/ 1. Ishaq ibn Hunain (d 910/11), 2. Qusta ibn Luqa (d 912) Christian. /AE/ Nasir al-din al-Tusi Wrote for M. Abu Hatim al-Asfazari (d.1122) A summary of book XIV along

with all other parts of Euclid's Elements.

14. Hipparchos (II- 2 B.C)- Astronomer, Mathematician used circles divided into 360° for astronomical observations, compiled a catalogue of 850 stars used by Ptolemy in Almagest along with his epicycles and eccentrics.

15. Theodosios (I- 1 B.C) Mathematician, Spherical geometery, 3 books 1. on Spherics 2. on Days and Nights and 3 on habitations - /T/ Thabit ibn Qurra (2) Qusta ibn Luqa /AE/ Nasir al-din al-Tusi for M.

16. Heron of Alexandria. (I - 1.B.C) Physicist /T/ 1. Qusta ibn Luqa

17. Menelaos (I- 2 A.C.) Mathematician - Spherics - area of triangles in functions of sides - Astronomer - /T/ 1. Ishaq ibn Hunain (d 910/11) 2. Thabit ibn Qurra improved 1, 3 abu Nasr Mansur ibn Ali ibn Iraq (1007/8) - an improved edition, 4. Al-Tusi (1201-1274) a new edition of 3, 5. Al Mohani (853-874/84) improved 1 and 2 /AE/ 1. Al Nasawi (ft. 1029-30) on Menelaos's theorem 2. Al-Tusi (1201-1274) wrote for M.

18. Ptolemy (II-2 A.C) Mathematician, Astronomer, Geographer made observations for 24 years, but a poor observer - Great theoretician, Wrote Almagest on (math & astr). Quadripartitum on trigonometry. /T/ 1. Hijjaj ibn Yusuf ibn Matar (829) from Syriac. 2. Rabban ibn Sahl al Tabbari (Jew) (ft. beginning IX A.C) from Greek. 3. Ishaq ibne Hunain (d.910/11), 4. Thabit ibn Qurra (926-901) 5. Yahya ibn Batriq (754-796) Al Mansurs translator. 6. Hunain ibn Ishaq al-Ibabi (800-861) translated Quadripartition. /C/ Jabir Ibn Haiyan about 754-776) from Greek text, 2. Abul Hasan ibn Ali al Tabari

(775-861) on complicated problems of almagest. 3. Umar ibn al-Farrurukan al-Tabari (815) on Quadripartitum. 4. Ahmad ibn Yusuf al-Misri (d.833) on centiloquium and a book on proportions, 5. Al-Nairizi (892-902); Al-Farabi (870-950/51) on Almagest. 7. Ibrahim ibn Sinan (908/9-943) on Almagest. 8. Al-Battani (858-929) commentary on Tetrabiblon. 9. Maslama ibn Ahmed al-Mejriti (died about 1007) on Planispherium /AE&C/1. Al-Khwarizmi (d850) improved Ptolemy's geography. 2. Al-Farghani (831-861) wrote an abstract of Almagest. 3. Al-Battani (858-929) found that long of sun's apogee has moved since the time of Ptolemy by 16" 47'; discovered solar apsides and a slow variation of equation of time; found precession 54.5"/year; inclination of ecliptic = 23".35'. 4. Abu - l-Wafa (940/997/998) wrote Kitabalkamil, a simplified version of Almagisti which is extremely thorough andcomparable to Almagest itself. 5. Abd al Jalil Sajistani (951-1029) rejected Ptolemay's system and gave a heliocentric system. 6. Ibn Tufail (1100-1185/86) gave advice to Ibn Rushd and at Batruji against Ptolemaic system and the modification of system of Homocentric spheres. 7. Ibn Bajja (1106-1138) criticised Ptolemaic assumptions. 8. Ibn Rushd (1126-1198) wrote a summary of Almagest rejected epicycles and eccentrics and advised al Bitrauji about modifications in Homocentric signs. 9. Abd al Malik at Shirazi (XII - 2) Abridged Almagest. 10. Ibn Tufail (1100-1185/86) against Ptolemaic system and suggested its modification to al Bitruji. 11. Jabir ibn Aflah (XII-2& XIII-1). He criticised Ptolemaic theory of planets vigorously and wrote Islah Almagisti (improvement of Almagest) 12. Al Hasan al Marrakeshi

(ft.1262) - developed very much the graphical methods of solving astronomical problems which had become much more important on introduction by Muslim of Planispheres, improved astrolabes, and new instruments like quadrants, sextants, etc; needs of gnomonics had also much increased since the time of Ptolemy - while Ptolemy had only touched these graphical methods in his Annalema.

13. Abul Faraj (Christian) Summary of lectures delivered at Maragha on Almagest in 1272/73. 14. Nasir al-din al-Tusi (1201-1274) (a) wrote a book on almagest for M. (b) In Tadhkire written before 1256 in Chapter 2. These criticized almagest with regard to anamolies of the moon, motion of planets in latitude (notably Mercury and Venus) and proposed a new system to replace the complicated Ptolemaic system of eccentrics and epicycles. In this he showed considerable ingenuity and obtained oval shaped orbits of planets. His new and forceful criticism was an additional step towards the emergence of heliocentric system of Kepler. 15. Thabit ibn Qurra (826-901) added 9th sphere to Ptolemy's 8.

19. Diophantos (III 2.A.C.) Mathematician (Algebra /T/Qusta ibn Luqa (910/11).
20. Pappos (III 2 A.C) Geometrician with new ideas /T/Al Dimishqi (d.932) P's Com. along with book X of Euclids Elements
21. Eutocios (VI- 1 A.C) Mathematician wrote books I to IV of Conics and XV of Euclid /T/Khabet ibn Qurra(d.901) /AE/Nasir al-din al-Tusi (1201-1274) for M.
22. Deplantis (Pseudo Aristothan) /T/ Ishaq ibn Hunain (d.910/11).
23. Many Greek Scientific Works /T/ by translators of Khalid ibn Yazid - 704 - 708.
24. Many Greek Scientific Works /T/by Al Kindi (800 - 873).
25. Two books of Varahamihra (fl. 505 A.C) /T/ Al - Biruni (973 - 1048).

(K)

Appendix II - Astronomical Instruments used at different times upto the 14th century, and the Books on their construction and use in Arabic.

1. Gnomon - In use upto 3,000 B.C.
2. Sundial - brought into use in Greece about 550 B.C.
3. Sundial - improved about 250 B.C.
4. Circle divided into 360° about 130 B.C.
5. Diopter - Earliest mention for use in surveying 210-129 B.C..
6. Universal Sundial - Invented at start of 1st century B.C.
7. Celestial capula and Celestical hemisphere made in China, 79-139 A.C.
8. Perallactic scales } used by Ptolemy 127 - 168 A.C.
9. Meridional instruments }
10. Astrolabe Earliest book written in Greek in first half of 6th century A.C.
11. " First book written in Arabic by a Christian 660 A.C.
12. " First book written in Arabic by Jabir Ibn Haiyan. 754-775.
13. " improved to read upto a degree by al Fazari 754-777.
14. Armillary sphere constructed by al Fazari - 754 - 777-
15. Qudrants capable of reading correct to a minute or less 813-833.
16. Sextants capable of reading correct to a minute or less 813-833.
17. Sadas capable of reading correct to a minue or less 813-833.
18. Improved astronomical & surveying instruments of al-Kindi813-876
19. Spherical astrolabe - a universal instrument 855 - 900
20. Astrolabes capable of reading correct to a minue or less 813-833
21. Pin-hole camera by Ibnal Haitham (905 - 1039)
22. Vernier like device invented by Ibn Sina (when at Hamadan between 1000 and 1037)
23. Sefiha - an improved astrolabe invented by Zeraqali (1029-1087)

(K)

24. Tusi's staff - a linear astrolabe invented by Muzaffar Tusi (dr1213)

25. Turquet - Two graduated circles at right angles to each other Nasir al-din-Tusi (1258 - 1274).

15 different kinds of Quadrants used by the Muslims

(a) Musattah Quadrant.

(b) Sufficient Quadrant.

(c) Dastur Quadrant.

(d) Sine Quadrant.

(e) Quadrant of hidden sines

(f) Quadrant bearing projections of parallels of latitude (circles of altitude).

(g) Rub Al-Tamm

(h) Rub Al Jami

I. Instruments used by Arab Astronomers given in an encyclopaedic treatise written for Alphanso X of Castile (1252 - 1285) in Spanish

1. Equitorial, Ecliptic and Horizontal armils - The armil being a universal instrument.
2. Spherical astrolabe - also a universal instrument.
3. Plane astrolabe.
4. Atazer - a plane astrolabe with an alidade.
5. Universal plane.

II. List of instruments in use at the Maragha Observatory (1259 - 1274) given by al Urdi in his treatise

1. Mural Quadrant
2. Armillary sphere
3. Solistical armil
4. Equitorial armil

5. Hipparchos's Diopter (Alidade)
6. Instruments with two quadrants.
7. Instruments with two limbs
8. Instruments to determine sines and versed sinces
9. Instruments for determining sines and Azimuth
10. The perfect Instrument (built by al Urdi) a universal instrument.
11. Parallactic rulers (after Ptolemy)
12. Tarquet (invented by Nasir al-din al-Tusi) a universal instrument.
13. Astrolabes (perhaps both plane and spherical)
14. Sextants.

III. Books on astronomical instruments, their construction and use, written in Arabic from 7th to 14th centuries and some part of 15th century. By 27 authors - By 1 in 7th and 8th century each, by 2 in 9th and 10th centuries each, by 6 in 11th century, 1 in 12th century, 3 in 13th century, 7 in 14th century and 6 in the beginning of 15th century.

Appendix III - Astronomical tables and Catalogues based on actual observations from earliest times upto 14th century.

S.No.	Period for which valid	Place of observation	Particulars of table or catalogue with name of compilor
1.	193-190 B.C	Alexandria	Egyptian Papyrus.
2.	161 B.C.		Earliest observations used by Ptolemy.
3.	129 "	Rhodes	Catalogue of 850 stars by Hipparchos.
4.	137 "	Alexandria, Rhodes, Babylonia.	Catalogue of 2028 stars by Ptolemy

5.	161BC-161AC	Alexandria, Rhodes, Babylonia.	Almagest used by Ptolemy containing all observations from 161BC.
6.	767-778 AC	Baghdad	Tables based on Siddhanta by Yaqub ibn Tariq.
7.	825-835 AC	Baghdad	1. Tables based on Siddhanta (2) tested tables & (3) Tables of Shah by Habash Hasib - Tables for Tangents included
8.	829-833 AC	Baghdad & Damascus	al-Mamunic Tables.
9.	850 AC	Baghdad	al Khwarismis's tables - Sine & Tan.- functions given
10.	877-890 AC	Jandishapur	Comprehensive tables by al Nahawandi.
11.	880-881 AC	Baghdad	al Battanis catalogue of fixed stars.
12.	892-900 AC	Baghdad	Al-Nairizi's tables prepared for al Mutadid.
13.	897-929 AC	Baghdad	al Battanis tables, these contain the cataloque given at No.11 above Aastonomical co-efficients of great accuracy and tables of trigobometric functions, sines, tangent and cetangents.
14.	885-933 AC	Baghdad	Four tables (1) The pure, (2) Girdled, (3) The wonderful and (4) Tables of Mars by Bannu Amajur.
15.	900-901 AC	Baghdad	Harun ibn Ali's tables.
16.	before 901 AC	Baghdad	Thabit ibn Qurra's solar observations.
17.	900-921 AC	Baghdad	Abu Hamid al Hijazi's tables
18.	"	Baghdad	Abd al Rahmanal Sufi's (903-986) Book containing catalogue of fixed stars as well as illustrations
19.	920-921 "	Baghdad	Nizam al-iqd by Ibn al Adami and his pupil.
20.	"		Ibn al Alam's (d.985) tables based on very accurate observations.
21.	940-997 "	Cairo	Abu-l-Wafa's table - Zijal Wahid
22.	990-1007 "	Cairo	Hikamite Tables by Ibn Yunus.

23.	1007 AC	Cairo	Al-Khwarizi's tables (8) brought upto date by Maslama al-Najritti.
24.	1035 "	Cordora	Ibn Saffar - tables based on Siddhantas.
25.	1035 "	Spain	Abul Qasim al-Asbagh, tables based on Siddhanta.
26.	1061-1087 AC	Toledo	Al-Zarqali's Toledoic Tables.
27.	1115-1121 AC	Marw.	Zijal Mutabar al-Sanjar by al-Khazini giving positions of stars for 1115-1116.
28.	1094-1174 AC		Abu-l-Barakats Tables.
29.	1117-1131 AC	Palace of Saljuq King	Mahumudic tables by al-Baladi al Astrolabe in 1129/30.
31.	1138-1139 AC		Al Marwarzi's conjunctions and periods of Planets.
32.	1145-1175		Zij Muhammed by Ibn Abi Barakat computed in 1266-1285.
33.	1210-1267		Ibn al Lubudi's tables.
34.	1259-1272	Maragha	Al-Khanic tables by Nasir al-din al-Tusi covering the period 161 B.C. to 1272 A.C.
35.	1272 AC	Toledo	Alphonsonian Tables by Juddah ibn Moses and Isamy ibn Sid.
	1276	Samarwand	Zij al Khaqani - Ilkhanic tables extended on the basis of Samarqand
36.	1240-1311	Milan Antwerp	Henry Bates based on his own observations.
37.	1301-1350	Damascus	Tables compiled by al Karaki based on his observations.
38.			Ibn al Kamal compiled 3 tables based on Toledi tables.
39.	1320-1437		Joseph Ben Isauq ibn Waqar (Spanish Jew) ft (1355-1375) compiled Tables in Arabic in 1357-58 for latitude of Toledi.
40.	1360		Ali Ibn ali al Qustantani wrote a poem with tables.
41.	1378-1408	Damascus	Al-Khalili al-Muadhdhin on 1378 elaborate tables on the pattern

1362 of al Murrakashi.
Ata ibn Ahmad wrote an astronomical treatise with tables.

Appendix IV. Original Books in Mathematics & Astronomy written in Arabic.

I. Seventh Century after Christ. 1. Severus Sebokht (ch.) - 1

II. Eighth Century after Christ

1. Ibn Naubakht - Astronomy	-	1
2. Mashallah - Astronomy & Astrology	-	1
3. Jabir ibn Haiyan - Astrolabe	-	1
4. Yaqub ibn Tariq - (I) Saddhamic tables (2)	-	3
5. Fadl ibn Naubakht - Iranian astronomy say	-	(5)
TOTAL.		11

III. Ninth Century A.C.

1. Al-Kindi wrote 270 books dealing with mathematics astrology, physics, music(2) medicine, pharmacy, geography, geometrical & Physiological optics(1), tides, Arabic numerals (4).	270
2. Abu Said Dariral - Jurjeni -(1) geometry (2) drewing meridian	2
3. Banu Musa - many math, mechanical and astronomical most important being & Balana 1,meaurement of sphare 1, arith 1,	6
4. Habush, Hasib many, 5 well known say	(50)
5. Umar ibn Farhan	1
6. Al-Khwarizm	4
7. Al-Farghani	1
8. Al-Dinawari many astrocal + mathcal books+tables say	(10)
9. Umar ibn Farrukhan many - 1 named. say	(10)
10. Abu Uthman Sahl ibn Bishr (Jew) on astrology	1
11. Abu Ali al Khayyat many astrological treatises say	(5)
12. Abu Abdallah al Mahaue	1
13. Thabit ibn Qurra	4
14. Sbrahim al Daya al-Misri	2
15. Al-Nairizi	2
16. Hunain ibn Ishaq	3
Total.	332

IV. Tenth century A.C.

1. Qusta ibn Luqa (christian)	1
2. Al-Battani	1
3. Al-Farabi many treatises on physics, music, meteorology, logic	(10)
4. Ibnal Adami	1
5. Shuja al hasib al-mesri+Algebra	1
6. Rabi ibn Zaid (Christian) some on Astronomy	(2)
7. Al-Balkhi- math, astrology, geography	3
8. Muhammad al-Hijazi	2

(K)

9. Ibrahim ibn sinan many books on Geometrical and astronomical.	(5)
10. Al-Imrani many treatises on algebra, astrology 1 + many =	(5)
11. Al Hamadani ibn al Haiq	2
12. Sinan ibn Thabit various mathematical & astronomical treatises	(5)
13. Mutahhar ibn Tahir al Maqdisi	1
14. Ibn Abdallah Md. al Khwarizmi	2
15. Abul Faraj - Fahrist of Books upto 1009	1
16. Abdul Rahman al Sufi	1
17. Abdul Wafa (one on astronomy complete book simplified Almagist)	(6)
18. Al-Khujandi	2
19. Maslama al Majriti	4
20. Al-Qabisi Astrologer	1
21. Abu Jafar al Khazin a no of math. & Astro treatises	(5)
Total	58
say	60

V. Eleventy Century A.C.

1. Ibn Sina Encyclopaedist on all subjects many times say	(50)
2. Al-Biruni	5
3. Ibn Muskawayh many books say	(50)
4. Abdul Jalil Sijzi	3
5. Abu Nasr Mansur ibn Iraq - many books x 4 mention say 10	
6. Ibn Tahir al-Baghdadi many books of which 2 mentioned say	(5)
7. Ibn Yunus - Compilor of Hikmite Tables	4
8. Ali Ibn Ridwan al-Misri - many treatises say	(10)
9. Abul Qasim Asbagh ibn Samh -	5
10. Al Baqilani (Astomism of time and motion)	1
11. Ibn Abi Rijal al Maghribi -	1
12. Ibn al Haitham many resalas besides 2 big books	(10)
13. Abul Hasan Kushyar ibn Labban ibn Balakhislijili	5
14. Abu Jafar Muhammad Ibn al Hasan	3
15. Abu Jud Muhammad Ibn al Lith	3
16. Al-Karakhi	2
17. Al-Nasawi	3
18. Al-Ghazzali - many books	(10)
19. Ibn Said al Andalust	2
20. Al Zarqali	1
21. Yousuf al Mutamin of Banu Hud -	1
Total	194

VI. Twelfth Century A.C.

1. Ummar Khayyam many treatises but enlisted only	4
2. Mohammed Ibn Abdul Baqi	1
3. Ibn Bajja many treatises on 7 subjects say	(15)

(K)

4. Al Khazini Books named only		2
5. Abu Hatim al Asfuzari		2
6. Abul Salt various treatises on 3 subject and on astrolabe say		5
7. Maimonides (Jew) wrote books Phil, Medicine, Astr. &		
8. Hibbat allah ibn Malaka books on 6 subjects		34
9. Abul Qasim al Badi al Asturlabi		6
10. Al Murwarzi		1
11. Adnan al Amzarbi		3
12. Ibn Tufail		1
13. Ibn Rushd		2
14. Al Bitruji		96
15. Abdul Malik al Shirzai		1
16. Muhammad Ibn al Husain		2
17. Abul Barakat Hibatallh ibn Malaka al Baladi	many	(5)
18. Abu Nasar Samuel ibn Yahya al Maghrabi		3or5
19. Abu Abbas Ahmed al Kamal		1
Total		146

VII. Thirteenth Century A.C.

1. Al Razi a very large no of books of which a few mentioned		
2. Muhammed al-Hassar	say	(100)
3. Jabir ibn Aflah		1
4. Al-Biruni		3
5. Hasan al-Marrakashi		1
6. Ibn al-Badr		3
7. Al-Muzaffar al-Tusi		1
8. Abul Faraj (Christian)		4
9. Kamal al-din ibn Yunus		2
10. Qaisas ibn abil Qasim		11
11. Ibn al Lubudi		1
12. Solomon of Basra (Christian)		8
13. Abil Tahir Ismail al Namairi al Maridini		2
14. Muhammad al Farizi		2
15. Nasir al-din al-Tusi		2
16. Al-Urdi		64
17. Muhyi al-din al-Naghribi		5
18. Shams al-din Muhammad al-Samarqandi		15
		8
Total		233

VIII. Fourteenth Century A.C.

1. Abul Kamil al-Misri		
2. Ibn Banna		1
3. John of Erzinjan (Christian)		8
4. Qutb al-din al-Shirazi		1
5. Joseph Ben Joseph. Nabshias (Jew)		17
6. Abdal Aziz al-Huwairi		1
7. Muhammad ibn al-Jazeli		1
		3

8. Abu Abdallah Muhammad ibn al-Raqqam	3 say	3
9. Nasir al-din Mohd ibn Saman various treatises		5
10. Al-Karaki		1
11. Al-Abhari		1
12. Al-Kashani (one very long book of 30 chapters)		5
13. Shams al-din Miruk		4
14. Al-Jaghmani		3
15. Ahmad Ibn Uthman al-Juzjani many but 1 mentioned		5
16. Kamal al-Din al-Farisi		4
17. Ala al-din ibnal Shatir		12
18. Ibrahim al-Hasib al-Warisi		1
19. Ata ibn Ahmed al-Samarqandi		1
20. Abdul Wahid ibn Mohammad		3
21. Abdul Qadir al-Sufi		1
Total		81

IX. Fifteenth Century about those continuing from 14th:

1. Abu Zaid Abdul Rahman al-Jadari		3
2. Muhammad ibn Ali al-Jabrati		3
3. Taqi al-din al-Hambali		1
4. Shihat al-din abul Abbas Ahmad al-Faradi	at least	3
5. Tabugh called Ibn al-Majdi		26
6. Abd allah ibn Khalil al-Maridini al-Iraqi		5
Total		41

Continued ... ...

X. Summary of all the original works from 750 to about 1450 in Arabic language.

No.	Century A.C.	No. of authors in Arabic Persian				No. of books written by Muslim Non-Muslims		Total
		Muslims	Chris	Jews	Total			
1.	7th Century	0	1	0	1	0	1	1
2.	8th " half	5	0	0	5	11	0	11
3.	9th "	15	0	1	16	331	1	332
4.	10th "	20	1	0	21	56	2	68
5.	11th "	21	0	0	21	184	0	184
6.	12th "	18	0	1	19	112	34	146
7.	13th "	16	2	0	18	229	4	233
8.	14th "	19	1	1	21	79	2	81
9.	15th " half	6	0	0	6	41	0	41
Total of 7 cen.(2) to (9) above		120	4	3	127	1043	43	1086
Average per century		17	0.6	0.4	18	149	6	155
Percent contribution from 7th to 15th centuries (first half)		95%	3%	2%		96%	4%	