Section 3 :
Arabic and Islamic World

Special session of section 3 :
Islamic science and technology in Arabic-speaking countries, Central Asia and India

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The History of the Medieval Exact Sciences *Suggestions for Future Research*

The phenomenal development of the digital computer has made possible solutions to a number of problems in our field. In the paper, it is shown that for most of the six projects listed below, an organization operating continuously will be required, sponsored by an existing institution.

1. A Bibliography of the Islamic Exact Sciences

For generations of our predecessors Heinrich Suter's *Die Mathematiker und Astronomen der Araber...* was the ideal bibliography. By 1983 it had been for years hopelessly out of date. But in that year it was supplanted by the excellent *Matematiki i Astronomy Musul'manskovo...Trudy*, by G.P. Matvievskaya and B.A. Rosenfeld. This was out of date by the time it appeared, as the authors recognized. It is suggested that this "Russki Suter" be in turn replaced by a first "computerized Suter", to be followed by others at suitable intervals. Meanwhile the attendant database would be continuously able to respond to inquiries from historians certain to obtain the latest bibliographical information. Conversely, individual historians will be glad to contribute data.

2. A Mathematical, Astronomical, and Astrological Dictionary

Medieval mathematics and astronomy are so closely related that a work is called for which includes both subjects. Astrology is a pseudoscience, but any serious astrologer must command a great deal of astronomy. The astronomer, in turn, cannot do without mathematics. To complete the cycle, the historian of mathematics finds all manner of interesting problems solved or posed in astrology.

Since the Persian and mathematical vocabulary is predominantly Arabic, the dictionary should be in this language, But it should also contain Arabic loan words from Persian.

3. Horoscopes

All manner of astronomical and historical information may be gleaned from horoscopes. Collections of horoscopes exist but they should be consolidated and continued. This implies the use of the computer, which is uniquely capable of carrying out the various sortings of data required.

4. Star Tables

Many tables of the fixed stars have been published, principally through the efforts of Professor Paul Kunitzsch. But it would unquestionably be of great utility to have them all available in a single database.

5. Geographical Tables

For this problem the solution is in hand. It has been capably taken over by Dr. Mercè Comes of the Department of Arabic, University of Barcelona.

6. Astronomical Handbooks

These documents, known as zijes, are primarily sets of numerical tables of mathematical and astronomical functions. All of them include instructions on how to solve the standard problems of astronomy and astrology by the use of their tables. Well over two hundred zijes exist, or are known to have existed, composed in all parts of the Muslim world, over a span of eight centuries. They make up a collective source for the history of mathematics and astronomy sufficiently important to merit computer treatment.

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The Mathematician Family of Aḥmad Maʿmār and their Works

The forefathers of Ustād Aḥmad Maʿmar had migrated from Herat to India and settled down in Lahore. Ustād Aḥmad then moved to Delhi during the days of Shahjahan (reign 1627-1658) where he built a number of buildings including Red Fort with royal quarters and court rooms etc. He was the famous builder of Taj Mahal, one of the wonders of the world.

The family line of Aḥmad Māʿmar has been traced up to the reign of Emperor Muḥammad Shah (reign 1719-1748). Members of this family were held in high esteem. His sons, grand sons and great grand sons were all accomplished in architecture, astronomy and mathematics. They have left a number of works. No written work of Ustād Aḥmad himself has been traced so far but many works of his successors are extant in various libraries.

Aḥmad's eldest son Aṭāʾullah Rāshidī wrote three treatises on algebra, arithmetic including Bīj Ganit : the Persian translation of Bhāskara's treatise. He had also built the mausoleum of emperor Aurangzeb's queen Malikah Rābiʿya Durrānī at Aurangabad in 1657 A.D.

The second son of Aḥmad Maʿmar named Luṭfullāh Muhandis was also an accomplished mathematician. He was also an excellent poet. Four of this works on mathematics and on astronomy have come down to us.

Imāmuddīn Riyāḍī bin Luṭfullāh Muhandis was a famous mathematician and also expert in natural and other sciences. He is the author of more than 25 works : 11 on mathematics and 6 on astronomy. Riyāḍī's younger brother Mirzā Abul Khayr Khayrullah Kahn was well versed in astronomy and mathematics. He was the director of Delhi observatory, got built by Raja Jai Singh (1686-1743) on the order of emperor Muḥammad Shāh. He wrote 3 treatises on astronomy and 2 on mathematics. He is particularly credited with the first Persian translation of *Almagest*, and compiler of *Zīj-i Muḥammad Shāhī*, also known as Jai Singh's astronomical tables.

Muhammad ʿAlī Riyāḍī bin Khayrullāh was also accomplished in astronomy and mathematics. Two of his works on mathematics are extant in Indian libraries. According to our preliminary survey the local output of this family is about 40 mathematical-astronomical works.

In this paper, we present a brief description of the most significant works of this family.

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The Theory of the Moon in al-Zīȳ al-Kāmil fī-l-Ta'ālīm of Ibn al-Hā'im

The astronomer Abū Muḥammad 'Abd al-Ḥaqq al-Gāfiqī al-Ishbīlī, known as Ibn al-Hā'im, wrote in the beginning of the thirteenth century a *zīdj* entitled *al-Kāmil fī-l-Ta'līm* which is preserved in the Bodleian Library, Oxford, II, 2 MS Arab 285, Marsh 618.

This work gives us information about the Ptolemaic astronomy made in al-Andalus and North of Africa in his time; and, also, about the activity of the Toledan astronomers in the eleventh century. Among these astronomers we can find references to Ibn al-Zarqālluh (died c 1100), who seems to have had a considerable influence on Ibn al-Hā'im.

The aim of the paper is to examine the theory of the Moon as Ibn al-Hā'im understands it and to state its relationship to Ibn al-Zarqālluh's own theory.

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Ibn al-Kammād's Astronomical Work in Ibn al-Hā'im's al-Zīj al-Kāmil fī-l-Ta'ālīm

Abū Isḥāq Ibrāhīm ibn Yaḥyā al-Naqqāsh, known as Ibn al-Zarqālluh or Azarquiel, is one of the outstanding astronomers of al-Andalus. He worked in Toledo and Cordoba and probably died in 1100. Ibn al-Zarqālluh's astronomical work exerted a considerable influence on later astronomers in al-Andalus, North Africa, and in Europe as well. One of these astronomers was Ibn al-Kammād, probably a disciple of his who lived during the first half of the twelfth century and was the author of several astronomical handbooks or *zījes* (*al-Amad ʿalā al-Abad, al-Kawr ʿalā al-Dawr, al-Muqtabis*), some of which where translated into Latin and played an important role in the transmission of Ibn al-Zarqālluh's work into the Latin World and its reception by the astronomers of the Renaissance.

Among the Arabic astronomers who used Ibn al-Zarqālluh's solar theories in their works we can mention Ibn al-Hā'im. His complete name was Abū Muḥammad ʿAbd al-Ḥaqq al-Gāfiqī al-Ishbīlī Ibn al-Hā'im and he was the author of a work entitled *al-Zīj al-Kāmil fi-l-Ta ʿālīm*. This *zīj* was composed in the first years of the thirteenth century and dedicated to the Caliph Abū ʿAbd Allāh Muḥammad al-Nāṣir (1199-1213). All we know about his life is that he appears to have worked in North Africa under the Almohad dynasty.

Ibn al-Hā'im's *al-Zīj al-Kāmil* is included in MS Arab 285 (Marsh 618) preserved in the Bodleian Library, Oxford.

In his *zīj*, Ibn al-Hā'im gives some historical data on Ibn al-Zarqālluh, who seems to have had a considerable influence on Ibn al-Hā'im's work. He also mentions other astronomers among them Ibn al-Kammād to whom he devotes several commentaries and criticisms in many passages of his *zīj*. Since Ibn al-Kammād is not very well known, the informations given by Ibn al-Hā'im are of primordial importance and shed light on the work of that astronomer.

The communication will analyse Ibn al-Hā'im's criticisms on Ibn al-Kammād's astronomical work as shown through the commentaries found at this respect in Ibn al-Hā'im's *al-Zīj al-Kāmil fī-l-Taʿulīm*.

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Comets and Eclipses in the Rawḍ al-qirṭās of Ibn Abī Zarʿ

The historical sources offer a far from negligible material on meteorological and astronomical phenomena and the *Rawḍ al-qirṭās* of Ibn Abī Zarʿ (14th c.) is a good example of it. This text covers a period of five centuries and offers the description of solar and lunar eclipses, meteorites and comets. Arabic astronomers did not pay so much attention to meteorological phenomena, so historical works acquire, if possible, greater importance. However, few arabists have been interested, from the point of view of history of science, in these notices in an Andalusian and Maghribī context.

At any rate, it is extremely difficult to elucidate if a brilliant object is a supernova, a meteor or a comet due to the scarcity of data which the medieval chronicles present.

Once verified (with the aid of computer astronomical programs) the data on eclipses and "comets" contained in the work, two phenomena stand out : the first and more significant is the observation of the supernova (classified as a comet) of the year 1006 AD. This text has the interest of adscribing a cyclical character to the motion of comets, an idea which the author relates to the observations of the Ancients. The second event is the northern aurora observed, possibly, in Cordova in the 9th century.

Finally, the exact date of the eclipses allows to correct some erroneous dates of the Arabic text (whose manuscripts show important differences).

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Science and Scientists in al-Andalus between the mulūk al-ṭawā'if and the North-African Dynasties

A dramatic change took place in al-Andalus history at the end of the V/XIth century. A new dynasty coming from the North of Africa, the *al-Murābiṭūn,* overthrew the several kingdoms which had ruled the Muslim Spain for about a century (the so called *mulūk al-ṭawā'if*) and took the power. The ideology of the new rulers had an important influence in the highly developed Andalusian science, which did not imply a general decay or regression but, at least, a new style. To a certain extent, the religions rigorism of the *al-Murābiṭūn* changed the direction of both scientists' works and *curricula.* In regard to the exact sciences, the growth of a Ptolemaic astronomy which occupied Andalusian astronomers during the previous century, from Maslama to al-Zarqālluh, clearly declines in the VI/XIIth century, at least during its first years, and probably the refusal of astrology which characterized the new ideology has something to do with it. On the other hand, astronomy was going to be seen from the point of view of philosophy, in order to build a cosmological theory adapted to Aristotelian physics. Medicine continued flourishing in the new court, but in the *curricula* of the physicians we find more and more the presence of traditional Islamic sciences, as well as some knowledge of medicine in the training of religions men.

The aim of this paper is to analyze this changes in science and scientists, particularly with the help of the materials which biographical dictionaries supply. Special attention is paid to the biographies of secondary authors in order to obtain a general view of the period.

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New Maghribī Sources on Trepidation

The most ancient source that offers an exposition of the trepidation theory, although only a qualitatively one, is Theon's *Small Commentary to the Handy Tables.* However, Theon himself refers the theory to the "ancient astrologers", according to whom, the solsticial points would have an oscillatory motion, backward and forward, with an amplitude of 8°, at a rate of 1° every 80 years.

This theory, that had been generally rejected in Eastern Islam, was highly developed and expanded upon in al-Andalus; from there it reached North Africa and Europe, where can even be found in Copernicus.

The aim of this communication is to present some new references to the trepidation or accession and recession motion (ḥarakat al-iqbāl wa'l-idbār) in Maghribī sources. Specially the account by al-Baqqār (fl. c. 1418) in a short treatise entitled *Kitâb al-adwār fī tasyīr al-anwār* (ms. Escorial 418). This account traces the lifespan of the theory : from its mythical origins in Egypt and Babylon, via Azarqālluh's development of his geometrical models to the doubts and rejection that the author expresses in the light of his observations and Abū l-Shukr al-Maghribī's opinion on the subject.

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The Treatise on Projecting the Rays of Ibn Muʿādh Al-Jayyānī

The doctrine of astrological *aspects*, i.e. distances between two celestial objects, such as planets, is sometimes defined in terms of these objects emanating rays in certain directions of astrological significance. If one of these rays reaches an object at a particular angular distance, the two objects could be in conjunction (0°), sextile (60°), quartile (90°), trine (120°) or opposition (180°). This would be an extremely simple theory if one would measure these angular distances along the ecliptic, but this was rarely done this way. Since more complicated solutions gave more prestige to the astrologer who managed to master them, other approaches were preferred, and the problem of casting these rays led to the development of several procedures that, yielding different results, also implied a varying degree of mathematical ability. For the sake of both complexity and agreement with the system of astrological houses, the distances were most usually measured on the celestial equator or along another great circle of the celestial sphere. Thus, the computation of these *aspects* required, first, a projection of the planet onto this circle and, later, a projection of the *aspected* point back to the ecliptic.

Islamic astronomers dealt with the problem in three different ways. They

a) constructed specific astrolabe plates or instruments,

b) composed tables for given geographical latitudes that allow to find the *projection of the rays* (*maṭraḥ al-šuʿāʿāt*) as a function of the ascendant and the ecliptic degree of the object that casts the rays, and

c) developed several algorithms for a computation of these *projections.*

Concerning these algorithms, this communication presents a source dealing with the matter in medieval Spain, the *Treatise on the projection of rays* of Ibn Muʿādh al-Jayyānī (XI c.). Once he established clearly the analogy between the computations for finding the houses and the rays, Ibn Muʿādh gives two different solutions. The first one has been recently studied by J.P. Hogendijk and is also found in the Latin canons of Ibn Muʿādh's *Tabulae Jahen.* It consists of an exact trigonometric solution based on what is known as *the equatorial method* for dividing the houses, according to J. D. North's classification. The second one is an approximate arithmetic rule that requires only the disposal of tables of right ascensions and oblique ascensions for a given locality and avoids the use of trigonometric functions. This resembles, to a certain extent, the solution given by al-Biruni in his *Qānūn,* studied by E.S. Kennedy, H. Krikorian and J.P. Hogendijk, and described in many Arabic sources. Nevertheless, the particular steps of computation used by Ibn Muʿādh are not found in other sources, and only a part of the approximate rule appears in a passage of Ibn al-Kammād's *Muqtabis* (XII c.).

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Algebraische Methoden für die Lösungen von geometrischen Aufgaben bei Abu Kamil Suga ibn Aslam al-Hasib

Abu Kamil Suga ibn Aslam ibn Muhammad ibn Suga Abu Kamil al Hasib lebte von ca. 850 bis 930 u.Z. in Ägypten und ist einer der letzten Vertreter der alten algebraischen Schule in der arabischen Mathematik. Bei ihm findet man in der Theorie und auch in den Beispielen und Anwendungen viel Neues.

Er fügt den 3 Arten von Größen - Zahlen, Wurzeln, Quadrate - die höheren Potenzen der Unbekannten bis zur achten unter Überspringung der siebenten Potenz hinzu. Er löst quadratische Gleichungen mit mehreren Unbekannten. Algebraische Lösungen der Gleichungen werden bei Abu Kamil geometrisch bewiesen, aber mit dem Unterschied zu seinen Vorgängern, daß Strecken und Flächeninhalte ohne Unterschied, sowohl Zahlen als auch die erste bzw. zweite Potenz der Unbekannten bezeichnen können. Es ist der Verzicht auf die Dimensionstreue in geometrischen Beweisführungen.

Er ist der erste Algebraiker, für den die Struktur von Identitäten und ihr wechselseitiger Zusammenhang um ihrer selbst willen zum Gegenstand der Untersuchungen erhoben werden.

Abu Kamil operiert mit komplizierteren quadratischen Irrationalitäten. Diese kommen in seinen Beispielen zur Gleichungslehre ständig als Zahlen, als Objekte rein mathematischer Natur vor. Sie treten dort sowohl ais Wurzeln von Gleichungen als auch als Koeffizienten auf.

Abu Kamil wendet die Algebra auf die Geometrie an.

Von den goometrischen Sätzen benutzt er den pythagoräischen und - ptolemäischen Lehrsatz, die Sätze vom rechtwinkligen Dreieck und die Sätze des Euklides, die die gegenseitigen Beziehungen von Radius, Fünfeck-, Sechseck-und Zehneckseite behandeln.

Er kommt bei seinen Ableitungen auf Gleichungen vierten Grades, die auf quadratische reduzierbar sind, auf reine und gemischt quadratische Gleichungen und auf Gleichungen ersten Grades.

Abu Kamil hat einen erheblichen Einfluss auf die weitere Entwicklung der Mathematik ausgeübt. Am nachhaltigsten war sein Einfluss auf spätere Mathematiker durch die Vermittlung von Leonardo von Pisa, der in seinem *Liber abaci*, die "Algebra" von Abu Kamil sehr ausgiebig benutzte.

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The Solution of "Apollonius' Problem" in the Treatise of Ibrahim ibn Sinan

The treatise of Apollonius of Perga "On tangency" in which he had presented his method of construction a circle tangent to three given circles (so-called "Apollonius' problem"), was lost.

It is well known that this problem was the subject of numerous and based on quite different approaches investigations carried out by such distinguished mathematicians as F. Vieta, R. Descartes, I. Newton, L. Euler, J. Gergonne and others. On contrary the attempts of the medieval Muslim mathematicians to solve this problem haven't been discussed in the literature on the history of mathematics.

Therefore the planar analyse of Apollonius' problem given in the treatise of Ibrahim ibn Sinan (Xth c) " Selected problems ' is of great interest.

Ibn Sinan considers three cases. The first and trivial - all three given circles are equal. The second case (only two of given circles are equal) he turns to the problem of constructing a circle tangent to a given circle and passing through two given points. Analyse of Ibn Sinan allows to obtain a complete and original solution of this case not previously known. The third case (all three given circles are different) he turns to the problem of constructing a circle tangent to two given circles and passing through a given point. But here he gives an incomplete solution which applies only to the special case of given problem.

Moreover one can find the common arguments in Ibn Sinan's solution and the solution given by Vieta who was perhaps the first to obtain a complete planar solution.

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Contradictions in Taghwim, Recent Past and Present

The Islamic calendar, especially for religious purpose is based on lunar cycle. Each of the twelve lunar months of the calendar, or Lunar Higri, begins the day after a declared sighting of the youngest crescent moon.

The process of the first sighting of the new moon run into confusion and controversy in certain cases, since both physical factors and human errors in sightings are involved in this regard, especially when the crescent moon parameters such as altitude, age, dimensions, atmospheric conditions, etc. are critical.

Furthermore, Fiqh authorities over centuries have adapted two different doctrines in fixing the first day of the lunar months, namely, Ekhtilaf al-Mataal'l (difference in horizons), which allows each locality to make its own crescent sightings and Ettehaad al-Mataal'l (unity of the horizons), which accepts other countries' sighting of the new moon.

However, both doctrines could be valid under Islamic laws, but the controversy of the proved first sighting of the young crescent is sometimes a major issue.

The travel diaries of the past, written by certain authorities, are good sources to verify the authenticity of the many young crescent sightings. One of these diaries which was written in 1952 by S.M. Taleghani when he made his Haj pilgrimage, over four decades ago, is a good case in this regard.

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New Information about Scientists of Samarkand Astronomical School of Ulugh Bek

It is well known that main scientists of Samarkand astronomical school of Ulugh Bek except himself were Kazi-Zade Rumi, Jamdish Kashi and Ali Kushchi. There are inconsistent informations about Kashi in literature till today. For example, it was mentioned that Kashi firstly served Ulugh Bek's father Shahrukh in Herat, to whom he had dedicated the "Ziji Khaqani" and then Kashi was invited by Ulugh Bek to Samarkand in 1417 and where he (Kashi) died about 1430.

The manuscript # 2232 ("Ziji Khaqani") of the British Library (India Office) bringing the light on these issues. In the preface of this manuscript (on behalf of Kashi) it was mentioned that for this work Kashi collected the documents in Kashan. But he couldn't find people who are interested in his work. That is why he travelled to Samarkand (to Ulugh Bek), where he wrote "Ziji Khaqani" for the Ulugh Bek's Library. Concerning the title of his work, it was mentioned that since there are a lot of famous scholars and rulers (Khan), Kashi named his work "Ziji Khaqani".

The preface also mentioned the date and place of Kashi's death - morning of 19th Ramazan 832 of Hijra (22 June of 1429) out of Samarkand at the Observatory place.

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Une nouvelle lecture de l'algèbre arabo-islamique

La plupart des commentateurs des mathématiques arabo-islamiques transcrivent les textes littéraux de ces mathématiques en langage "moderne", c'est-à-dire à l'aide du symbolisme mathématique que nous utilisons nous-mêmes aujourd'hui. Cette méthode de transcription a, bien sûr, l'avantage de permettre aux mathématiciens ou aux historiens des mathématiques qui ne savent pas l'arabe de "lire" et de comprendre sans difficultés des textes qui leur seraient autrement difficilement accessibles. Mais, du même coup, elle ne permet pas de saisir les concepts originaux des mathématiques arabo-islamiques : ce qu'était l'algèbre pour les mathématiciens de l'Islam, sa langue, ses méthodes opératoires, la nature de ses démonstrations, etc... Dans notre exposé, nous donnerons quelques exemples pour montrer les concepts originaux que cette "nouvelle lecture" permet de mettre en lumière.

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On reconstruction the complete text of al-Biruni's treatise on specific gravities (XIth c)

The treatise of al-Biruni on specific gravities hasn't been preserved. It is known only the photocopy made from the photocopy of a manuscript disappeared during the World War I. But this photocopy also contains an incomplete text of the treatise.

Nevertheless the content of unpreserved part of this work can be restored by al-Khazini's treatise "The book of the balance of wisdom" (XIIth c).

The paper includes the reconstruction of the content of al-Biruni's treatise and its comparison with the corresponding part of al-Khazini's treatise, presents the methods of determining specific gravities with the help of water balances of different modifications and determining specific gravity according to al-Khazini.

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Géométrie, art et technique des Arabes et leur intercommunication

L'artiste musulman a détaché son regard du monde extérieur. Il s'est absorbé en une profonde contemplation mystique. La géométrie a été l'instrument admirable de ce nouveau symbolisme. Notamment dans le domaine de la sculpture, le travail est facilité par les mathématiques qui formulent avec précision et résolvent les problèmes de constructions géométriques qu'on rencontre.

A même le plâtre mort tourne le compas de l'artiste et naissent les combinaisons géométriques aux décorations extraordinaires. C'est alors l'arabesque gracieuse. Dans l'entrelac, l'impression exalte.

Le riche refouillement de la pierre ou du stuc s'entrouvre dans les ouvrages sur bois, en ivoire ou sur cuivre. Pour la technique, l'architectural arabo-musulman est caractérisé par l'arc, souvent outrepassé, l'arc en fer à cheval, la coupole et, dans les mosquées, le minaret. Compléments nécessaires de l'architecture arabe sont les pavements en mosaïque, les revêtements des voûtes et des murs en faïence.

L'apport des musulmans dans l'art et les techniques a été le syncrétisme admirable qu'ils ont créé entre le domaine du rêve, l'élégance de la géométrie et les riches acquis de la science.