

M.S.Khan
 Park Street Post, Box.No. 9072, Calcutta-700 016
 India.

By the time al-Bīrūnī wrote the *KH* (see al-Bīrūnī's books; see also Boillot 1960; Kennedy 1970; Khan, A.S. 1982; Khan M.S. 1975) in the first half of the eleventh century, Greek astronomy specially the *Almagest* of Ptolemy was fully diffused among the Arabs. They also had some knowledge of Persian astronomy (Pingree 1963). But he was not the first Muslim scientist to write on Indian astronomy. Before he visited India (around 408/1017) he had some knowledge of this subject derived from Arabic translations of Sanskrit astronomical works. He records that the *Brahmasphuṭa-siddhānta* of Brahmagupta (ca. A.D. 598) was translated by the order of Caliph Mansūr of Baghdad (754-775 A.D.) in 154/771 or in 156/773 (KH, p.351) and its Arabic translation was called *Sindhind al-Kabīr* or *the Great Sindhind*¹. He adds that he translated it into Arabic and wrote a treatise on it². He also studied its method of calculation in his treatise *Tarjumah mā fī Brāhma Siddhānt min Turuq al-Ḥisāb* (Khan, A.S.1982, p.20). Al-Bīrūnī states that he also retranslated the *Khaṇḍakhādya* by Brahmagupta, called in Arabic *al-Arkand* and published a new correct translation (KH, pp.346-383; Nalino 1911, p.83; Nadwi 1930, p.139). He had written a treatise entitled *Tahdhīb zij al-Arkand* in which he corrected its errors but this is not available at present (Khan, A.S. 1982, No.6, p.12). The *Āryabhaṭīya* of *Āryabhaṭa* (b. A.D. 476) called *Arjabhadh* in Arabic was translated by Abu'l-Ḥasan al-Ahwāzī and it was perhaps available to al-Bīrūnī (KH, p.357; Pingree 1970, p.308; Nalino 1911, p.172-73).

About an important astronomical work, the *Siddhānta* of Pauliśa, al-Bīrūnī records that a translation of the whole work into Arabic had not been undertaken (KH, p.119; Pingree 1975, p.69-70). At another place he writes that he had started translating it but he could not finish it at the time of writing the *KH* (p.119, 315; Kern 1913, preface p.48).

Therefore, the parameters and computational techniques of the three schools of Indian astronomy were already known to al-Bīrūnī before his sojourn in India. He knew the elements and theories of Brahmagupta as expounded in his *Brahmasphuṭa-siddhānta*. His *Khaṇḍakhādya* which followed the *Ārdharātrika* system of *Āryabhaṭa* was also known to him. Moreover, al-Bīrūnī also knew the system of *Āryabhaṭa* as explained in the *Āryabhaṭīya* and was well-versed in the Greek, Iranian and Arabic astronomical theories and methods.

When he visited India and came in direct contact with the Indian astronomers and pundits, he had first-hand knowledge of other Indian astronomical works which he has mentioned in his *KH* such as the *Karapa Tilaka* (Rizvi 1963; Baloch 1973, p.94; Rizvi 1979) of Vijayanandī of Benaras based on the original *SS*, and the fragments of the original *Pauliśa-Siddhānta* and other works. He knew the commentaries of Balabhadra, *Bhāṭṭopala*, Varāhamihira (ca. A.D. 505), Utpala, *Prthudakasvāmī* (ca. A.D. 864) and others on the works of Brahmagupta and *Aryabhaṭa*. As regards the works of Varāhamihira, his *Bṛhatsamhita* and *Laghujātaka*, the small book on nativities (astrology), were translated by al-Bīrūnī but they don't seem to be extant.

Al-Bīrūnī has discussed the Indian astronomical theories and parameters in his *KH* and other works also such as in his two *Rasā'il* in dealing with *ẓilāl* (Shadows) and *Mamar* (Transits) (RIM, No.2, pp.1-226; RTM, No.3, p.107) published in 1367/1948. Some references to this subject are also found in his *QM*, *KAB*, *KHA*, *KTNA* and the *KT*. This paper will examine the knowledge of Indian astronomy as displayed by al-Bīrūnī with special reference to his *KH*.

After having explained that the *Siddhānta* is the general name given to every standard book on astronomy, he mentions the following five well-known *Siddhāntas*³

- (1) *Sūrya-Siddhānta* i.e., the *Siddhānta* of the Sun, composed by *Laṭadeva* (505 A.D.)
- (2) *Vaśiṣṭha-Siddhānta*, so called from one of the stars, of the Great Bear, composed by *Viṣṇucandra* (200 A.D.)
- (3) *Romaka-Siddhānta* so called from Rome, composed by *Śrīsenā* (about 600 A.D.)
- (4) *Pauliśa-Siddhānta* so called after *Pauliśa* (Paulos), the Greek who composed it. (Sachau 1910, 2, pp.304-305, note).
- (5) *Brahma-Siddhānta* so called from Brahman, composed by Brahmagupta.

Al-Bīrūnī states that he is in possession of the works of *Pauliśa* and Brahmagupta. But the table of contents of the *Brahma-siddhānta* comprising twenty-four chapters as recorded by him does not fully agree with the arrangement of chapters found in its present editions (*KH* pp.119-20; see also *Dvivedi* 1902).

Al-Bīrūnī mentions the *Karaṇas* of *Āryabhaṭa* (?), Brahmagupta, Vijayanandī, *Bhānuyasa* and Utpala. Among the *Tantras* he refers to those of *Āryabhaṭa*, Balabhadra and *Bhānuyasa*. There are forty-six astronomers and astrologers mentioned by al-Bīrūnī in his *KH* (see also *Sastri*, A.M. 1975)

Al-Bīrūnī gives titles of eighteen *Purāṇas* (*KH*, pp. 100-101) of which he read parts of the *Matsya*, *Āditya*, *Vāyu* and *Viṣṇu Purāṇa* (*KH* p.101). The *Viṣṇu-dharma* or *Viṣṇudharmottara Purāṇa* was also well-known to him as he records the largest number of quotations from it concerning astronomical subjects and discusses them in detail. He takes Brahmagupta to task for accepting the statements of *Viṣṇu-Purāṇa* that the sun is lower than the moon (*KH* p.393). This is in connection with the eclipse of the Sun and the Moon and al-Bīrūnī criticizes these statements as unscientific and incorrect.

The question whether any book of *Āryabhaṭa* either in original or in Arabic translation was available to al-Bīrūnī or not may be asked here and an attempt may be made to answer it. He states in as many as three places in the *KH*, that he did not have access to any of the books of *Āryabhaṭa* adding that he knew his theories through the quotations given in the works of Brahmagupta and Balabhadra. According to the latest research, there are two *Āryabhaṭas* i.e., *Āryabhaṭa* I (b. A.D. 476) who is the same as the *Āryabhaṭa* of Kusumapura of al-Bīrūnī, and *Āryabhaṭa* II who flourished between 950 and 1100 A.D. It further complicates the issue as *Āryabhaṭa* of Kusumapura of al-Bīrūnī, is the younger and not the elder? It can reasonably be suggested here that these statements of al-Bīrūnī refer to the astronomer whom he supposed to be *Āryabhaṭa* the elder. But in the case of *Āryabhaṭa* of Kusumapura he does not make such a statement and adds that he had read a book of *Āryabhaṭa* of Kusumapura (*KH*, p. 312). Thus he mentions three titles as three different works of *Āryabhaṭa* such as (1) *Daśagītikā*, *Daśakītak* in Arabic (2) *Āryaśaśata*, Ar. *Ārjastasata* and *Tantra*, Ar. *Tantra* (*KH* p.121, 324). The first two are the titles of the two parts of *Āryabhaṭīya* of *Āryabhaṭa* (b. A.D. 476). It is this book which was translated by Abu'l Ḥasan al-Ahwāzī into Arabic (*KH* p.357; Nalino 1911, pp. 173-74).

Among Brahmagupta's works the *Brāhmasphuṭa-siddhānta*. and Balabhadra's commentaries on it were well-known to him. The *Khaṇḍakhādyaka* and *Uttara-Khaṇḍakhādyaka* were available to him in Arabic translations and used by him as has been stated in the introduction of a recently-published critical edition of *Khaṇḍakhādyaka* (Chatterjee 1970, 2, p.315).

The largest number of quotations concerning Indian astronomy found in the *KH* are from the *Brāhmasphuṭa-siddhānta*. of Brahmagupta and also from his *Khaṇḍakhādyaka*. Bina Chatterjee has compared the statements of al-Bīrūnī with the texts of the *Brāhmasphuṭa-siddhānta*. and *Khaṇḍakhādyaka* and found that by and large they are correct (Chatterjee 1975). She has pointed out a number of errors committed by al-Bīrūnī. The verses in the *Brāhmasphuṭa-siddhānta*. in the edition published by Sharma corresponding to the references of al-Bīrūnī to this text have been recorded by her (Chatterjee 1970, pp. 43-45).

According to al-Bīrūnī the *Khaṇḍakhādya* preserves the astronomical theories of Āryabhaṭa's *Ardharātrika* (Mid-night) system on which a commentary was written by Balabhadra. He writes about this book: "this Calander is the best known of all, and preferred by the astronomers to all others" (*KH* p.381). Bina Chatterjee, as already stated above, has made a comparative study of the quotations given by al-Bīrūnī with those found in the *Khaṇḍakhādya* (both *Uttara* and *Pūrva*) and this has generally speaking established the claims of al-Bīrūnī but this comparison is confined only to the *KH*.

Another astronomical work the *Pauliśa-Siddhānta* written in India was available to al-Bīrūnī⁵ who had started its translation into Arabic but could not finish it by the time he wrote the *KH* (p.119). At another place, he states that the whole *Pauliśa-Siddhānta* "has not been translated into Arabic and gives reasons for this" (*KH* p.315).

The *Karaṇa-Tilaka* of Vijayanandī, which was translated by al-Bīrūnī into Arabic, has been mentioned in 4 of his works *RIM*, *RTM*, *KH* and *QM*. He has referred to it 10 times in his *KH* (Baloch 1973; Sastri, A.M. 1975, p.132; Rizvi 1963).

There are several other works of Indian astronomers and astrologers and their commentators such as Bhānuyasa, *Bhaṭṭīla*, *Kalyāṇavarman*, Durlabha, Parāśara, *Bhaṭṭotpala*, Śrīpāla, Utpala (considered as the same as *Bhaṭṭotpala*) and others who were known to al-Bīrūnī.

It is found that al-Bīrūnī had direct access to several genuine works of the outstanding astronomers of India and their commentaries. He derived the knowledge about the contents of other works through quotations found in these works and also perhaps from oral transmission. Balabhadra's commentary on the *Brahmasphuṭa-siddhānta*, entitled *Bhaṣya* is lost but some quotations are preserved in al-Bīrūnī's works. None of the Arab or Indian Muslim astronomers who wrote on Indian astronomy after al-Bīrūnī could add anything new or substantial to the extent and the depth of the knowledge of this subject possessed by him. His knowledge about the Indian astronomy could not be more accurate and complete for various reasons. Most probably certain errors and discrepancies crept into the writings of al-Bīrūnī on account of faulty oral transmission by the Pundits.

It is evident that like a modern scientist, al-Bīrūnī follows a comparative method in his study of Indian astronomy and compares the astronomical methods and parameters of the Hindus, the Arabs, the Persians and the Greeks. He has also presented a comparative study of the 4 outstanding astronomers in India: Āryabhaṭa, Pauliśa, Varāhamihira and Brahmagupta dealing mainly with the circumference of the zodiac, the calculation of universal solar days, the Hindu tradition regarding the distances of the stars and the revolutions of planets in the *Caturyuga* and others.

Two modern scholars discuss how far al-Bīrūnī's references to the two basic works of Brahmagupta are correct. It has been stated that he was well acquainted with these two works. There are a few minor errors⁶ which have been pointed out in them. The most frequent of these errors is that some of the statements found in the commentaries of *Brahmasphuṭa-siddhānta*. and *Khaṇḍakhadyaka* have been attributed to Brahmagupta himself and full agreement is not always found between the Sanskrit texts and the statements of al-Bīrūnī. The occurrence of such minor error is quite possible in view of the fact that the commentaries contained both the original texts and their elucidations.

Al-Bīrūnī states that he never read any work by *Prthūdakasvāmī* yet he has ascribed to Brahmagupta some of the statements appearing in the former's commentary. At least two quotations from Brahmagupta found in the *KH* are not traceable at present. A statement of al-Bīrūnī giving rules for finding out the lords of a year and month which he claims to have copied from the *Khaṇḍakhadyaka* is not available in this book but found in its commentary by *Bhaṭṭotpala* in slightly altered form (Chatterjee 1975, p.165).

Al-Bīrūnī corrected the errors of the Arabic translations of Indian astronomical texts, studied them and offered his unbiased criticism on them. He also wrote original books on Hindu astronomy. The above study again confirms that al-Bīrūnī was a great synthesizer and transmitter of scientific knowledge⁷.

The most important contribution of India to oriental astronomy are the planetary corrections which was discussed by Āryabhaṭa and the author of *Surya-Siddhānta*. But it is a mystery that al-Bīrūnī did not write about these planetary corrections. Perhaps it is due to the fact that the full text of the original *Pañcasiddhāntika* of Varāhamihira was not available to him.

NOTES

- 1 It is generally believed that this book was the *Brāhma-Sphuṭasiddhānta* of *Brahmagupta* but al-Bīrūnī always mentions it as *Brahma Siddhānta* and incorrectly includes it among the five basic Siddhāntas. For the Indian delegation to the court of Caliph Mansūr see N.A. Baloch (1973, p.36), Pingree (1978,1975).
- 2 All references in this paper are to the text of the Hyderabad edition and its page numbers are given in the first bracket. Perhaps al-Bīrūnī's treatise on this book was entitled *Jawam'al-Maujud li Khawāṭir al-Hunud fi Ḥisāb at-Tanjīm*, D.J.Boilot(1960).
- 3 His explanation of the *Siddhānta* 'Straight, not crooked, nor changing' (*KH*,pp. 117-123) is incorrect. see the chapter XIV entitled *Fī Dhikr Kutubuhum fī Sā'ir al-'Ulūm* or on the Books of the Hindus on Scientific Subjects in the *KH*, pp.117-123.

- 4 *Āryabhata* I of Kusumapura (modern Patna) born A.D.476 who wrote his *Āryabhaṭīya* in 499 A.D., while *Āryabhata* II flourished between 950 and 1100 A.D. being the author of *Mahāsiddhanta*. See David Pingree (1970), Khan, M.S. (1978).
- 5 One of the works in which the citations from the original *Paulīśa-siddhanta* are preserved is the *KH* of al-Bīrūnī.
- 6 It has been proved by Bina Chatterjee on the basis of a comparison of the text of al-Bīrūnī's *KH* with those of the *BSS* and *KK*. See above. Cf. the exaggerated criticism of al-Bīrūnī's knowledge of Sanskrit astronomical texts by David Pingree (1968).
- 7 The scientific method which he followed in all his works specially in *KH* is the comparative method. The parameters and computational techniques of Indian astronomy have been compared by him with those of Greeks, Persians and Arabs.

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 - 2 *Kitāb al-Āthār al-Bāqiya 'Anil-Qurūn al-Khāliyah*, ed. by Edward C. Sachau, Berlin, 1897 (Abbreviated as KAB).
 - 3 *Kitāb Taḥdīd Nihāyat al Amākin*, ed. Md. Bin Tāwit al-Ṭanji, Ankara, 1962 (Abbreviated as KTNA).
 - 4 *Al-Qānūn al-Mas'ūdi*, 3 vols, Hyderabad, 1954-56 (Abbreviated as QM).
 - 5 *Kitāb at-Tafhīm li-Awā'il Šinā'at-Tanjīm*, Fasc. ed. and tr. English R.R. Wright as *The Book of Instructions in the Elements of the Art of Astrology*, London, 1934 (Abbreviated as KT).
 - 6 *Risāla Ifrād al-Maqāl fī Amr Az-Zilāl*, Hyderabad, 1367/1948, pp.126 (Abbreviated as RIM).
 - 7 *Risāla Tamhīd al-Mustaqar li Taḥqīq Ma'na al-Mamar* Hyderabad, 1367/1948, pp.107 (Abbreviated as RTM).
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Gnomon. This is one of China's most ancient astronomical instruments. The meridian horizontal plate with the scale on it is called gui and the higher vertical pillar is called biao. The number of days in a tropical year and the 24 divisions of the solar year can be determined by the shadow of the biao at noon. It was made in 1439, the 4th year of the Zheng-Tong Reign of the Ming Dynasty.