Āryabhaṭa's Possible Rebuttal to Objections to his Theory of the Rotation of the Earth

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I. Āryabhaṭa's Idea

Well known is the fact that Āryabhaṭa, an Indian astronomer born in 476 A.D., maintained the idea of the diurnal rotation of the earth on its axis. In his *Āryabhaṭīya*[1] (*Abh*) written in 499 A.D., we come across four passages which unmistakably reveal this challenging idea.

(1) *ku ñiśibuṇḷṣkhr prāk* (*Abh* I, 1b)[2]
   'The earth (rotates) 1,582,237,500 (times) eastward (in a Yuga).'

(2) *prāṇenaiti kalām bhūḥ* (*Abh* I, 4c)
   'The earth moves one *kalā* in one *prāṇa*.'[3]

(3) *ravibhūyogā divasā kvāvartāś cāpi nākṣatrāḥ* (*Abh* III, 5cd)
   'Civil days are conjunctions[4] of the Sun and the earth. The sidereal days are revolutions of the earth.'

(4) *anulomagatir nausthaḥ paśyaty acalaṃ vilomagaṃ yadvat /*
   acalāni bhāni tadvat samapaścimagāni laṅkāyām // (*Abh* IV, 9)
   'Just as a man going forward in a boat sees a motionless object moving backward, so (he sees) in Laṅkā[5] the motionless asterisms moving westward in a straight line.'

II. Objections

Few astronomers[6] in ancient and medieval India accepted Āryabhaṭa's revolu-

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[1] For the *Āryabhaṭīya*, its translations and studies, see D. Pingree, *Census of the Exact Sciences in Sanskrit*, Series A, Volume 1, American Philosophical Society, 1970, pp. 50–53, and D. Pingree, 'Āryabhaṭa' in the *Dictionary of Scientific Biography*. I have used four printed editions (Notes 15, 17, 19, and 21 below) and a manuscript (Note 16 below).

[2] For the numbering of the verses I have followed Clark's English translation (Chicago 1930).

[3] 1 *kalā*=1/21600 rotation, 1 *prāṇa*=1/21600 sidereal day.

[4] The word 'conjunction' may also imply the rotation of the earth. cf. Clark, p. 52. This word occurs again in *Abh* IV, 48.

[5] Laṅkā is the geographical point where the terrestrial equator and the Indian prime meridian intersect.

[6] According to Shukla's translation (New Delhi 1976), p. 8, Pṛthūdaka (860 A.D.), Makkibhaṭṭa (1377 A.D.), and the *Skanda-purāṇa* held the same view.

tionary view. There are numerous passages of the later astronomers criticizing, directly or indirectly, the theory of the rotation of the earth. The criticism might well go back to Āryabhaṭa's own time. The earliest recorded criticism is found in the *Pañcasiddhāntikā*[7] (*PS*) of Varāhamihira (*ca.* 550 A.D.)——

> *bhramati bhramasthiteva kṣitir ity apare vadanti noḍugoṇaḥ /*
> *yady evaṃ śyenādyā na khāt punaḥ svanilayam upeyuḥ //*
> *anyac ca bhaved bhūmer ahnā bhramarahaṃsadhvajādīnām /*
> *nityaṃ paścāt preraṇam athālpagā syāt kathaṃ bhramati //* (*PS* XIII, 6–7)
>
> 'Others say; "The earth, as if situated on a potter's wheel (*bhrama*), revolves, not the constellations." If that were so, hawks and so on would not come back again to their abodes from the sky. Another thing: if there were (a revolution) of the earth (every day), bees, geese, flags, and so on would always be driven to the west; if it were moving slowly, how would it revolve (once a day)?'[8]

Brahmagupta, in his *Brāhmasphuṭasiddhānta* (*BSS*),[9] written in 628 A.D., directly quoting the above (2), raises the objection——

> *prāṇenaiti kalāṃ bhūr yadi tarhi kuto vrajet kam adhvānam /*
> *āvartanam urvyāś cen na patanti samucchrayāḥ kasmāt //* (*BSS* XI, 17)
>
> 'If "the earth moves one *kalā* in one *prāṇa*", then from where and on what path does it go? And if there is a revolution (in a day) of the earth, why don't high buildings fall down?'

Similar discussions are found in Lalla's (*ca.* 800 A.D.) *Śiṣyadhīvṛddhidatantra*,[10] *Mithyājñāna* 42, 43; Govindasvāmin's (*ca.* 800 A.D.) commentary on the *Mahābhāskarīya*[11] V, 4; Śrīpati's *Siddhāntaśekhara*[12] (written 1039 A.D.) XV, 15–17 *etc.*

As far as mathematical astronomy is concerned, "the rotation of the earth does in no way impair the value of astronomy, as all appearances of an astronomical character can quite as well be explained according to this theory as to the other," as Al-Bīrūnī (b. 973 A.D.) says in his *India*.[13] Thus all the objections to the theory of the revolution of the earth are substantially of the same nature, that is, to resort to physical and observable reality or to *deductio ad absurdum*. In this respect one can naturally find a close similarity between the arguments in India and those in Greek astronomy, the latter being clearly presented in Ptolemy's *Almagest* I, 7.[14]

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[7] O. Neugebauer and D. Pingree, The *Pañcasiddhāntikā* of Varāhamihira, Part I (Text and translation), 1970 and Part II (Commentary), 1971, Copenhagen.

[8] Translation of Neugebauer-Pingree, *op. cit.*

[9] The *Brāhmasphuṭasiddhānta*, ed. by S. Dvivedin, *The Pandit*, Benares, 1902.

[10] *Śiṣyadhīvṛddhidatantra*, ed. by S. Dvivedin, Benares 1886.

[11] *Mahābhāskarīya* of Bhāskarācārya with the *Bhāṣya* of Govindasvāmin and the Supercommentary of Padameśvara, ed. by T. S. Kuppanna Sastri, Madras 1957.

[12] *Siddhāntaśekhara* of Śrīpati, edited with his own commentary by Babuāji Miśra, University of Calcutta 1947, p. 143f.

[13] *Alberuni's India*, translated by E. C. Sachau, London 1910, I, p. 277.

[14] *Syntaxis Mathematica*, ed. by J. L. Heiberg, Leipzig (Teubner) Vol. I, 1898, pp. 24–25. German translation by K. Manitius (Teubner 1912), I. pp. 19–20.

III. Commentators' Forced Readings and Interpretations

Commentators of the *Āryabhaṭīya*, on the other hand, reluctant to admit Āryabhaṭa's 'failure', tried to rescue him from severe criticism either by changing the reading of the text (2 and 3) or by imposing a forced interpretation (1 and 4).

(1) Bhāskara I[15] (629), Someśvara[16] (fl. 1040), Sūryadevayajvan[17] (b. 1191) take the word *prāk* ('eastward') as modifying the planets' motion[18] and not the motion of the earth. Parameśvara[19] (*fl. ca.* 1430) is forced to explain this passage in quite the opposite sense——"Why here is mention of the rotation of the earth in spite of the established fact that the earth is stationary? We say:——Because of the false knowledge about the circle of the constellations which is turning westward by the *pravaha*-wind, the revolution of the earth is (wrongly) assumed. Taking this into account, rotation of the earth is being referred to (by the anthor). In reality, however, there is no rotation of the earth."[20] The same discussion is repeated in his commentary on *Abh* IV, 9.

(2) The original reading *bhūḥ* ('the earth'), which is confirmed by Brahmagupta's quotation mentioned above, was changed into *bham* ('asterism') by all the commentators. In this case, as well as in the next, the variant reading does not affect the rule of meter.

(3) All the commentators mentioned, and Nīlakaṇṭha,[21] as well, read *bhāvartāś* ('rotations of the asterism') instead of *kvāvartāś* ('rotations of the earth'), the 'variant reading' *kv-*, however, being known to Bhāskara I.[22]

(4) Someśvara[23] first interpretes the stanza as it should be, but thereafter he says: 'This is not his (Āryabhaṭa's) view . . . , therefore I will explain this *sūtra* in another way.'[24] According to his 'true' interpretation (which Sūryadeva, Nīlakaṇṭha, and Parameśvara share), 'moving asterisms driven by the *pravaha*-wind, because of their velocity, see

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[15] *Āryabhaṭīya with the Commentary of Bhāskara I and Someśvara*, ed. by K. S. Shukla, New Delhi 1976.

[16] I have used a microfilm of Bombay Manuscript (BS 272) through the kindness of Prof. Pingree.

[17] *Āryabhaṭīya with the Commentary of Sūryadevayajvan*, edited by K. V. Sarma, New Delhi 1976.

[18] *prāk: ya ete grahā vivasvadādayaḥ prāṅmukhā bhramanti |* (Bhāskara, p. 20).

[19] *The Āryabhaṭīya with the Commentary Bhaṭadīpikā of Paramādīśvara*, ed. by H. Kern, Leiden 1874, reprint, Biblio Verlag 1973.

[20] *bhūmer hy acaleti prasiddhā tasyāḥ katham atra bhramaṇakathanam? ucyate | pravahākṣepāt paścimābhimukhaṃ bhramato nakṣatramaṇḍalasya mithyājñānavaśād bhūmer bhramaṇam pratīyate | tad aṅgīkṛtya bhūmer bhramaṇam uktam | vastutas tu na bhūmer bhramaṇam asti|*

[21] Ed. by K. Sambaśiva Sastrī (Chap. II and III) and Suranand Kunjan Pillai (Chap. IV), *TSS* 101, 110, and 185, Trivandrum 1930, 1931, and 1957.

[22] *op. cit.* p. 187.

[23] Bhāskara I's commentary is missing after the middle of *ad* IV, 6. Someśvara's commentary is considered an abridgement of Bhāskara's.

[24] *idam asyādarśanam| bhūmaṇḍale bhramati jagaj jaladhināplavyetā|* (folio 33a).

those objects in Laṅkā (as if) moving backward (=eastward).'[25]

IV. Possible Rebuttal

That Āryabhaṭa expected such kind of criticism can be surmised by the fact that immediately after the stanza cited above (2) he propounds the traditional theory of the *pravaha*-wind as the cause of the diurnal rotation of the constellations,[26] thus seemingly preparing a compromising escape. If, however, he did maintain the theory of the rotation of the earth, how can this contradictory verse be interpreted? No modern scholar has ever suspected that a possible answer to the objection might be concealed in this very dilemma. It should be noted that this celestial wind is the counterpart of the terrestrial wind (*kuvāyu* 'earth-wind') mentioned in *Abh* I, 9d. The major part of *Abh* I, 9, as well as the preceeding one, gives the size of the planetary epicycles, while the last part of the stanza forms an independent context. It reads——

> (5) *giyiṅaśa kuvāyukakṣyāntyā*
> where *giyiṅaśa* stands for a number 3375 (yojanas). As for the remaining part, Bhāskara I explains——
> *kuḥ bhūḥ, kuvāyuḥ bhūsambandhī vāyuḥ, tasyeyam antyā kakṣyā | etāvato vāyukakṣyāparicchinnākāśapradeśāt parato niyata vāyur, yena niyatagatinā pravaheṇa jyotiścakram idaṃ bhrāmyate | kuvāyupramāṇaparicchinnād ākāśapradeśād ārād aniyatā vāyava itas tataḥ paribhramanti |*[27]
> 'ku is the earth, *kuvāyu* is the wind related to the earth. Its periphery is a shell (*kakṣyā*). Beyond the part of the sky which is circumscribed by the earth-wind shell of such extent, there is the wind of eternal and constant motion by which this stellar sphere is turned around. Within the part of the sky which is circumscribed by this size of the earth-wind (shell), irregular winds whirl around here and there.'

This would have been a convincing answer to the objections described above, if *jyotiścakram idam* ('this stellar sphere') had been replaced by *bhūr iyam* or similar words expressing 'this earth'. Such, I would suggest, must have been the reply by Āryabhaṭa himself, had he not yielded to the objections. Thus the above passage, together with *Abh* IV, 10, allows us to conjecture Āryabhaṭa's cosmological idea. As stated in *Abh* I, 5, the diameter of the earth is 1050 yojanas. The earth is covered with a layer of earth-wind of which the peripheral circumference is 3375 yojanas. If we divide this number by Āryabhaṭa's value of $\pi = 62832/20000$ (*Abh* II, 10),

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[25] *evaṃ bhāni calāni pravahānilākṣiptāni vegavaśād laṅkāyāṃ yāni vastūni tāni pratilomagāni paśyanti|* (*loc. cit.*).

[26] *Abh* IV, 10—'The cause of their rising and setting is due to the fact that the circle of the asterisms, together with the planets, driven by the provector wind, constantly moves straight westward at Laṅkā' (tr. by Clark).

[27] *op. cit.* p. 40.

the result is the diameter of the earth-wind shell of about 1074 yojanas.[28] This would give us some 12 yojanas as the distance (altitude) of the shell from the surface of the earth. Inside this shell terrestrial winds blow freely, and objects thrown up or bees and birds flying in the sky can come back to their nests again. Beyond this shell is the wind which eternally drives the shell, including the earth, eastward at a constant velocity. It follows that this shell, concentric with the earth, must be fixed to the earth, say, by an axis. Both the shell and the axis must have been considered as being transparent, though I can give no textual evidence.

One could well consider the possibility that Āryabhaṭa learned this theory, as well as the other topics of mathematical astronomy, from some sources of Greek origin, but why he *had to* make the trouble of holding such a controversial view is another question.

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[28] *BSS* XI, 15 gives us further trouble. Dvivedin's edition does not make any sense. Very interesting is a reading reported by Shukla (probably based on some manuscripts) in footnote 2 on p. 28 of his translation of the *Āryabhṭīya*——

gasagiyi yojanaparidheḥ ṣañi bhūvyāsaḥ punar ñilā vadatā/

ātmajñānam khyāpitam aniścayasvamatikṛtakatvāt//

'The diameter of the earth comes to be 1080 from the circumference 3393 yojanas, while again he (Āryabhaṭa) says it is 1050 yojanas. He has exposed his (poor) knowledge because of the uncertainty of his mind.'

D. Pingree, probably misguided by Brahmagupta, says, "Āryabhaṭa states that the diameter of the earth is 1050 yojanas but its circumference 3375 yojanas; this yield 3 3/14 as the value of π, . . ." (*DSB* Supplement I, 1978, p. 591).

It is obvious that Brahmagupta is laboring under double misunderstandings, viz., 3393 instead of 3375 and the circumference of the earth instead of that of the earthwind. If the above text is correct, then 3393/1080 is sexagesimally 3; 8, 30, exactly Ptolemy's value of π. Is this rather accidental, or is this a result of some another forced emendation?

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gaṇyāt yojanapariṇāhaḥ yaḥ bhūvyāsaḥ puṇar ahā redaṇ/
dīvaṣṭāśon ṣoṣaṣṭam antaḥparaṇamanīyatārvaṇī//

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