Ghulām Ḥusain Jaunpūrī, an early 19th century modern Indian astronomer

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In this study, I look into the writings of Ghulām Ḥusain Jaunpūrī (1790–1862), a well-known mathematician and communicator of modern astronomy in Persian in the early 19th century, probably the first Indian traditional astronomer on record to systematically make modern astronomical observations, namely those of a bright comet in 1825 with a sextant, and of Uranus, Ceres and Pallas in 1826 with a telescope.

Many Indo-Persian writings of the early 19th century introduce new knowledge of modern astronomy and the sciences, where the authors try to establish continuity with the Islamic scientific knowledge of the earlier centuries. Their introduction to Western science came about through interactions with the officers of the early phase of the East India Company (EIC), which opened up a new world before them. One such scholar was Ghulām Ḥusain bin Fatḥ Muḥammad Karbalā'i Jaunpūrī (1790–1862), a noted mathematician and among the few communicators of modern astronomy in Persian in the early decades of the 19th century India. In one of his works where he touches upon the contemporary European astronomy, Ghulām Ḥusain puts on record his modern astronomical observations – a comet that appeared in AH 1241/AD 1825 (ref. 1) and new members of the Solar System in AH 1242 (ref. 2). What makes these observations exceptional is that he is perhaps the first Indian traditional astronomer to have made systematic astronomical observations with modern optical equipment and tried to include them in a traditional system. Mahārājā Sawāi Jai Singh II (1788–1743), the first Indian astronomer used a telescope to confirm Galileo's observations, but could not use it further for lack of micrometer and cross-wires[3].

Ghulām Ḥusain Jaunpūrī's astronomical works

Ghulām Ḥusain was the court astronomer of Iḥtishāmud Dawla Mubāriz'l Mulk Rājā Khān Bahādur Khān Nuṣrat Jang. The latter was the Muslim son of Mahārājā Mitrajīt Singh Bahādur (1762–1840; by Naib Rani Barsati Begum), Rājā of Tikari (24°56′N, 84°50′E), Gaya, Bihar, and himself had interests in astronomy. At Tikari, Ghulām Ḥusain had made astronomical observations. He later moved to Benāras, where he was appointed Chief Justice at the court of the Rājā of Benāras. A few years later, he relocated to Murshidābād in the court of its Nawāb. More about Ghulām Ḥusain and his work can be found in a series of papers by Ansari[4].

Ghulām Ḥusain finds mention in a few British writings of his times, where he has been referred to as Maulavī (scholar of Islam, a teacher). He interacted with the British and flourished in the early phase of Renaissance that had begun to put Medieval India on the path to modernity. English education had struck roots and so did the shaping up of school curricula, publishing of low-priced school books in English and Indian languages – where there were none before – at the newly acquired lithographical presses in Calcutta, Delhi, Lucknow, Kanpur, etc. Such presses were well-known where Persian and Arabic books were printed and were a boon to the students. It spread from Bengal into the neighbouring regions, as it did in the other Presidencies and Provinces, resistance from early British rulers notwithstanding. As requisitioned by the Government, a British missionary educationist, the Reverend William Adam, prepared three reports dated 1835, 1836 and 1838 on vernacular education in Bengal, Bihar and Orissa. Adam's reports provide valuable information on the state of indigenous education not only in these States, but also as it was in other parts of the country[5]. He was impressed by the fact that there existed a large number of village schools in the region. Under the heading 'District of South Bihar', Adam[5] writes: 'In this district, there is only one institution to be noticed under the present section. At Sahebgunge, the chief town of the district, a school in which English, Persian, and Arabic are taught has been established by Raja Mitrajit Singh of Tikari and is superintended by his son Mirza Bahadur Khan. Two maulavis and one English teacher are employed …'

In an earlier section Adam[5] notes that: 'Two maulavis in this district are highly distinguished for their learning and they are both authors. … Maulvi Gholam Hossein, dwelling at Sahebgunge in the thana of that name, has written in Persian, a compilation called Jam-i-Bahadur Khany from various Arab works on arithmetic, geometry, astronomy, and the natural sciences with addition of his own. This work has been printed and contains 720 pages. He is now engaged in the preparation of astronomical table to be entitled Zij Bahadur Khany. The names of both works are intended as compliment to his patron Bahadur Khan, one of the sons of Mitrajit Singh, the Raja of Tikari.'

Ghulām Ḥusain is credited with several books[6,7]; these are listed in the Box 1.

Box 1.

1. *Jāmiᶜ Bahādurkhānī* (Compendium of mathematical-astronomical sciences) in Persian, written during 1832–1833.
2. *Zīj-i Bahādurkhānī*, in 1838.
3. *Iṣṭilāhāt-i Taqwīm* (on astronomical terminology).
4. *Anīs al-Aḥbāb fi Bayān Masā'il-i Ustūrlab* (On problems of astrolabe for friendly companions), in 1818.
5. *Rā'iz un-Nūfūs: Tarjūmah-i Ukar–i Thā'ūdhūusiūs* (Translation of *Kitāb al-Ukar*, a book on the Greek philosopher and mathematician Theodosius by Naṣīr al-Dīn al-Ṭūsī (1201–1274 CE), from Arabic into Persian.
6. *Tabṣirah al-Muhandis* (A commentary on al-Ṭūsī's recension of Euclid geometry).
7. *Tanbīhāt al-Mūnkirīn* ('Admonition to those who deny'), in 1833.

As the name suggests, *Jāmi^c Bahādurkhānī* (*JBKh*) is an encyclopaedia, dedicated to his patron. The book was lithographed in Calcutta (now Kolkata) in 1835. It is in six books/parts, dealing with various scientific and mathematical topics. The fifth one has sections on modern astronomy and several astronomical instruments which Ghulām Ḥusain constructed and used for his observations. The presentation makes a comparative study of the astronomical information in the Hindu, Arab, ancient Greek and modern European systems. Details on this encyclopaedia are provided by Ansari and Sarma[8].

Ghulām Ḥusain's other notable work is a *zīj* (a handbook of practical astronomy, comprising tables of observational data on the motion of the Sun, Moon and the planets, times of day and night, and guidelines for astronomers for computations and predictions of eclipses, calendar preparation, etc.) named *Zīj-i Bahādurkhānī* written in 1838; it was printed in 1855. Ansari[7] has been the first to introduce it. Apart from the astronomical tables, it gives coordinates of 420 locations with respect to Canary Islands and the equator. The *zīj* has been in extensive use ever since, even in Iran for a long time. Details on the *zīj* are available in the literature[9,10]. *Tanbīhāt al-Mūnkirīn* is a tract in Persian. It was discovered in Aligarh by Ansari[7], who mentions that the work was aimed at students to explain the reasoning behind the stationary and revolving model of the Earth according to the Europeans.

John Tytler's commentary on the *Jāmi^c Bahādurkhānī*

Ghulām Ḥusain met John Tytler (1790–1837), an Orientalist, at Calcutta in 1835. The latter learnt that the Maulavī was in the service of Rājā Khān Bahādur Khān. Tytler was trained in anatomy and surgery at the St Bartholomew's Hospital, with a view to qualify for an appointment to the Bengal Medical Service. After being nominated as assistant surgeon in 1813, he sailed for Calcutta together with his mother. The following year he was attached to the civil station of Patna. Here, he met an extensive and intellectual European society as also the native nobles. Rājā Khān Bahādur Khān was one such among Tytler's Patna friends. Here, Tytler acquired proficiency in Arabic, Persian and the Hindustani languages, as also in medicinal and mathematical knowledge of the Asiatics[11]. Tytler was on the General Committee of Public Instruction, formed as a part of the policy of England on education in India, in 1823 at Calcutta, in order to 'equip itself with facts about the state of education in the territories under Bengal Presidency and to suggest ways and means for the better instruction of the people'[12]. In the matter of imparting education, half of the Committee, called the Orientalists, were for the continuation of the old system and favoured Arabic, Persian and Sanskrit learning as the public believed in this system. The other half, called the Anglicists, favoured English with as much of the vernacular as would be necessary to the satisfaction of local prejudices.

Tytler found Ghulām Ḥusain an accomplished scholar not only in mathematics and Islamic and Hindu (ancient Indian) astronomy, but also well-versed with European astronomy 'as far as he could gain from the interpretation of European books, as given him by European friends, he himself being ignorant of English'[13]. Ghulām Ḥusain showed Tytler the manuscript of his work *Jāmi^c Bahādurkhānī*, then under print at Calcutta. The purpose of his applying to him was to get a recommendation of the work to the Government Education Committee. Tytler felt that the work was much too long to go through then, but helped him since he found it to be of considerable merit. Tytler[13] writes: 'It commenced with the elements of geometry and arithmetic as known to the Hindus, and thence went on. In the course of the work are explained, the European methods of decimal fractions, logarithms, and trigonometrical tables. The author then gives a system of astronomy, first according to the Brahmins, then according to Ptolemy, and then according to Copernicus, together with an account of astronomical instruments, and the mode of calculating astronomical tables and almanacs. The whole MS., as will appear from the author's own computation, comprehends 900 closely-written quarto pages. To be able to recommend the work with greater confidence to the Government Committee, I requested the author to furnish me with a few short extracts, and as my hasty departure from Calcutta precluded my taking any steps in the matter there, I translated the extracts during my passage to the Cape of Good Hope, and transmitted them from thence to the Committee in Calcutta, with a letter explanatory of the nature of the work and the views of the author.'

Tytler noted that Ghulām Ḥusain's computations are based on the sexagesimal system and use the figure 3.1415903 as the value of π he himself had derived, and not 22/7 as was the practice among Muslim mathematicians. One of the extracts Tytler took from the book is about the problem of finding the place of a planet at a given time, assuming its motion about the focus where the central body is not as equable. Tytler[13] was impressed with how Ghulām Ḥusain reconciled ellipticity of the planetary orbits with Ptolemaic circular orbits, but recalled that a British astronomer Seth Ward (1617–1689) had tackled the problem of empty focus way back in the 17th century and presented a simple elliptical model, while there had also been attempts by several others before him. The problem remained unresolved though. While tackling the problem on his part, Ghulām Ḥusain was aware of the Copernican system and of the planets assigned to follow elliptical orbits (*Jāmi^c Bahādurkhānī*, p. 581; Rizvi[14]). Tytler was, however, surprised that Ghulām Ḥusain began his explanation by attributing to Mirzā Khairullāh Khān, astronomer–mathematician and an associate of Sawāi Jai Singh II, the discovery of the ellipticity of the planetary orbits, and that Khairullāh Khān was the actual author of the *Zīj Muḥammad Shāhī* (hereafter *ZMS*). For evidence regarding the authorship, one may see Ansari[15]. According to Khairullāh Khān's own testimony, he had also written a commentary on the *ZMS*. Ghulām Ḥusain refers to this commentary and mentions that Khairullāh Khān proved the existence of elliptical orbits geometrically. Probably, the underlying geometrical model of planetary system was clear to Khairullāh Khān. He was convinced of this after studying Phillipe de La Hire's *Tables* that were based on the heliocentric and elliptical model of the solar system. The latter had been brought by the embassy of astronomers of Sawāi Jai Singh II when it returned from Portugal around 1730 (S. M. R. Ansari, 2015, pers. commun.). Note that the *ZMS* was completed in about 1731–32. To Ghulām Ḥusain, Khairullāh Khān's explanation was insufficient, as it did not prove the orbit to be an ellipse but rather one akin to an ellipse. He improved upon the demonstration and using the hypothesis of a circle and epicycle, proved that motion of the planet about the empty focus was uniform, and that the true position of the planet could be determined at any time from the position of the Sun on the circle of the ecliptic. Ghulām Ḥusain concluded that this was consistent with the Western model, where the Earth followed an elliptical path around the Sun stationed at one of the foci; cf. Rizvi[14], who has translated the Persian text into English. Tytler[13] wondered about how Seth Ward's problem came to figure in Ghulām Ḥusain's work. He has cited *Vince's Astronomy* (1814; I: Ch. x) to emphasize that it was first published in Europe in 1654 and concluded that it must have arrived into India in the middle of the previous (the 18th) century only. After his return to England in 1835, Tytler[13] even communicated to the Royal Asiatic Society his analysis of the *Jāmi*ᶜ *Bahādurkhānī*.

The comet of 1825

On p. 468 of the *Jāmi*ᶜ *Bahādurkhānī*, one finds the section on *dumdār sitāré* (stars with tails). Ghulām Ḥusain mentions that the ancients regarded comets belonging to the sub-lunary sphere, whereas according to modern European astronomers these belong to the realm of superior planets and follow oval paths. On the following page (p. 469) he refers to his own observations of a comet on two dates[1]. On 13 Ṣafar, 1241 AH (26 September 1825, Monday), the first date of the observation made at Moḥammadābād (the medieval name for Benāras, now Vārāṇasi), Ghulām Ḥusain noted longitude of its centre as '1;6,20 and the latitude 20;30 south' and that the comet had its tail along its motion. When seen on 22 Ṣafar, 1241 (5 October 1825, Wednesday), the comet had moved to longitude 1;4,40 and latitude 25;55 south, and he deduced that the comet had moved by about 5°, with its tail pointing exactly towards the west[1]. The time of observations were not given though. The cited positions were in the sexagesimal system, i.e. based on the base number 60. Here the semicolon is analogue to the decimal point, comma to separate out the minutes, seconds and the letter 's' stands to denote zodiacal sign; thus 1;6,20 is 36°20′, etc. (S. M. R. Ansari, 2010, pers. commun.). Ghulām Ḥusain did not mention of the constellations in which the comet stood on the respective dates.

In the respective cometographies, Vsekhosvyatskii[16] has listed four and Kronk[17] five comets sighted in the year 1825. The extra comet in the latter was 1826 II (modern designation C/1825 V1), discovered on November 7.01 by J. L. Pons. Which one did Ghulām Ḥusain observe? Based on available information, Ansari[2] has identified it with the comet that is designated 1825 I (now C/1825 K1). Ghulām Ḥusain's observations actually relate to the fourth comet of the year, namely 1825 IV (C/1825 N1). It was discovered by Pons from Marlia on the evening of 15 July in the constellation of Taurus, and a few days later by others. At the time of discovery, it was still quite far from the Earth and the Sun. The comet passed its perihelion on December 11.185, motion retrograde[18]. Bortle[19] has described this comet as intrinsically very bright, one that was visible by naked eye over a long period from late August to late December. In early September, it was visible at 4–5 mag. with a tail about 8°, becoming brightest in October at 2–3 mag. J. F. W. Herschel found on 4 October the tail stretching 7–8°. On subsequent days, the tail length increased, being 11° on 8 October and 13–13°.5 the following day, etc. It passed closest to the Earth at 0.6177 AU on 12 October, when it showed up with a curving tail that was thin near the coma but broadened towards the end, about 14° in extent. Pons, who followed the comet constantly, has given flowery descriptions of its appearance[17]. For a perspective, note what *The Sydney Gazette and New South Wales Advertiser*[20] wrote in its issue of 6 October 1825: '…the Comet of Australia has been visible every evening and night the past week. It is to be seen in the East. Its tail has a North-western direction...'

Table 1. Observed and computed positions of the comet 1825 IV as on two specific dates

Date	Hubbard		Jaunpūrī		UT	Horizons	
	λ	β	λ	β		λ	β
1825 Sept 26.00	47.971	–17.251	36.33	20.50*s*	00:20	48.664	–16.766
1825 Oct 05.44	28.004	–28.618	34.67	25.92*s*	00:24	30.611	–27.442

Ghulām Ḥusain's observations of the comet of 1825

Ghulām Ḥusain had carried out his observations with a sextant furnished with a telescope. Ansari and Sarma[8] mention of a reflecting sextant that Ghulām Ḥusain (*JBKh*, p. 523) had used for his observations in AH 1248/AD 1832–33. His drawing of the equipment suggests it to be like one of those manufactured by George Adams of London (identified by Ansari and Sarma[8]).

Let us compare Ghulām Ḥusain's observations with those made by others and with computed positions. I have extracted from Hubbard[21], the observed positions of the comet 1825 IV corresponding to Ghulām Ḥusain's dates. His given positions are ecliptic longitude (λ) and ecliptic latitude (β) respectively. This also means that his zodiacs are tropical with longitudes counted from the vernal equinox. For a comparison, I present the two observations in Table 1 in ecliptic coordinates (in degrees) and include the corresponding values computed with JPL's Horizons system:

Herein, the UT (Universal Time) values are arbitrary, chosen to correspond to the sunrise time at Benāras on the dates and *s* is for southern declination. The computed comet positions are apparent and with respect to the Earth's true-equator and the meridian containing the Earth's true-equinox of date. Ghulām Ḥusain's observed positions turn out to be discordant with those of Hubbard and the values computed from the orbital elements.

Those were the days when communications spread around and reached relevant circles in weeks and months. For comets that could not be observed with naked eye, one had to be a chance observer. Among the comets of 1825, 1825 I (C/1825 K1) was discovered by J. F. A. Gambert at Marseilles on the night of 18/19 May in the constellation of Cassiopeia that C. K. L. Rümker observed first on 5 June and last on 15 July only.

Its epoch of apparition and the faint visual magnitudes do not match Ghulām Ḥusain's description. The comet 1825 II (C/1825 P1), discovered on 9 August by Pons, at 6 mag., was not significantly noticeable. It was not even observed after 26 August. The comet 1825 III was Encke's Comet (2P/Encke) in its sixth observed apparition that was discovered on 13 July and observed last on 7 September. At its brightest, on 30 August, it was a 5–6 mag. object. This would escape notice by the unaided eye. The comet Ghulām Ḥusain saw in September/October 1825 would have been a bright object. Rather, it should be a naked-eye one, say, as bright or brighter than a 5 mag. comet. That way, only comet 1825 IV fits in properly. Ghulām Ḥusain's positions suggest the comet's motion southwest, declining by about 5° between the dates of his observations. These are, at least qualitatively, in line with the observations made elsewhere as well as with the computed apparent positions. According to the latter, the comet would be placed a few degrees east of α Ceti, in the area near the modern border of Taurus and Eridanus with Cetus on the first of the dates of Ghulām Ḥusain's observations and a few degrees southeast of the star Mira on the latter observational date. His detail in the measured positions indicates that he was equipped to take measurements to the last arcminute. It is therefore surprising that the discord was not noticed; also not by his British friend-guides.

It is even more surprising that there are no follow-up observations by Ghulām Ḥusain when the comet of his study entered the most interesting phase of its apparition and brightened up further – in the middle of October 1825. A few years later, he missed out on observations of and writing about a bright, naked-eye comet of 1831 (C/1831 A1, Great Comet)[22], as also the most eagerly awaited apparition of the Halley's Comet in 1835. It is not clear from the available information if he was familiar with the famous comet, but he should certainly have been. The positions that he held and the European social circle he interacted with, would have enabled access to the relevant information and works. One of the works of Mirzā Abū Ṭālib (1752–1805/6), *Marāj al-Tawḥīd* (The Culmination of the Divine Unity, probably composed in 1802)[2], talks about discoveries of Uranus, Ceres and Pallas and transits of Mercury and Venus. It also provides information on comets, including the one with a period of 75 years[2] that by then was widely known as Dr Halley's Comet. Note that it was only around the mid-19th century that astronomers examined past apparitions and could assign long periods of revolution to some comets[23].

Ghulām Ḥusain's account of the new planets

Discovery of Uranus on 13 March 1781 by William Herschel was a milestone in the history of mankind. It pushed the edge of the Solar System well beyond Saturn. There soon followed discovery of a new planet Ceres. The discovery was serendipitous on 1 January 1801 by Giuseppe Piazzi (1746–1826). Its orbit lay between those of Mars and Jupiter, and came to be believed as the missing planet in the scheme of planetary distances proposed by Johann Titius in 1766 and Johann Bode in 1772. However, more bodies turned up to fill the same void. Pallas was discovered on 28 March 1802 by Wilhelm Olbers, Juno in 1804 and Vesta in 1807. The serial discoveries were sensational enough and gave rise to a multitude of theories to explain their nature. It was only after 1845, when the fifth planet Astraea was discovered, that a re-classification was worked out. As new members of the Solar System, these bodies were initially counted as planets. However, in a paper read before the Royal Society on 6 May 1802 itself, Herschel[24] had advocated the term asteroids for the new class of celestial bodies.

The new planets needed a rightful place in the Ptolemaic system which Muslim astronomers worked with. So, we may only guess how our traditional astronomer reacted when he got a chance in 1826 to telescopically observe some of the new members. In the *Jāmi*[c] *Bahādurkhānī* (1832–33), Ghulām Ḥusain incorporates newly discovered members of the Solar System; there are a few errors in his dates and credits though. He depicts on p. 474 of *JBKh*, the heliocentric planetary system in a diagram where the new planets Sarīsh (Ceres) and Pallas occupy a place between the orbits of Mars and Jupiter. Also depicted are the satellites around Jupiter and Saturn and a new planet above the orbit of Saturn discovered in March 1781, that he identifies as named after King Jārjis[2] (King George III). Its discoverer William Herschel had initially named it Georgium Sidus after the King. In the astronomical literature, the planet was also referred to as Georgian and Herschel. The name Uranus became official in Britain only from 1850.

Ghulām Ḥusain mentions (*JBKh*, p. 472)[1] about his own observations in 1242 AH (1826 CE) of the new planets with a telescope from Mirzāpur under Captain Darānīs; the latter remains unidentifiable. Mirzāpur, then a prominent centre for trade in cotton and also called the Manchester of India, is about 60 km southwest of Benāras. It was established by British officers of the East India Company in 1735 (ref. 25); the Indian Standard Time is taken with reference to the 82.5°E meridian passing through the clock tower in Mirzāpur. Incidentally, Ghulām Ḥusain makes no reference to James Prinsep (1799–1840), a British scholar and antiquarian who was at Benāras as assay master at the mint (1820–30), and had been carrying out meteorological and astronomical observations. From the publications about the solar eclipses of April 1827 and April 1828, and lunar eclipse of November 1827 he observed from Benāras, we get an idea of the kind of modern equipment then available. Prinsep had used a telescope attached to Troughton's 18-inch circle, 2½-inch aperture, a 3½-ft refractor with a land eye-piece, an astronomical clock[26] and a telescope of 15 inch focal length and 2 inch aperture by Dollond[27].

In late 1825, Ghulām Ḥusain was in Benāras. Under what circumstances he met the Captain is not known. We may assume here that the Captain was in possession of an astronomical telescope and the auxiliary equipment. None of the new planets is a naked-eye object and so how does one find them in the sky? Ghulām Ḥusain does not furnish the exact dates of observations, and so we can only make a guess. Through the year 1242 AH, i.e. 5 August 1826–24 July 1827 CE, we can use modern computations[18] to at least write-off the period when the new planets fell too close to the Sun in elongation (~30° and less) – so as to permit a comfortable view. I find that roughly, the blackout period for the Georgian is 15 December 1826–15 February 1827, for Ceres 1 January–31 March 1827, for Pallas 1 January–28 February 1827 and for Vesta 15 February–15 June 1827. However, we also note that Ceres, Vesta and Pallas had been observed just around then by Giovanni Santini at Padua when near their oppositions in 1826, through the period 26 June–1 July (Ceres; 7.3 mag.), 13–23 August (Vesta; 5.8 mag.) and 26–29 June (Pallas; 9.5 mag.) respectively[28].

We may presume that Captain Darānīs was already informed of the events. He had to know where to look for the new planets in the sky in order to identify them from among the myriads of stars. That could not be feasible without appropriate star charts, star catalogues and a time-measuring device, besides the ephemeredes (the predicted positions at different epochs). One also needed reference star positions corrected for precession and nutation, etc. Among the new planets, Pallas and Juno have much larger eccentricities and orbital inclinations, exceeding even the corresponding values for Mercury, and therefore were more difficult to trace out.

Determining planetary orbits in early 19th century

A Keplerian orbit is defined by six elements. To determine these, one needs three separate sets of angular observations (right ascension α, declination δ). The orbit determination had become a critical problem after Piazzi discovered Ceres first. He could observe it until 11 February 1801 and then it got lost in the glare of the Sun. By this time, Piazzi had only 21 observations in hand. However, the object had done just a mere 3° in the sky[29] – a short arc. Astronomers were faced with the challenge of computing its orbit from these observations alone, so as to be able to recover Ceres when it emerged from the glare of the Sun next. They had some methods at hand for orbit determination and using circular orbit, some forecasts were made. However, these did not lead to the recovery of Ceres. In those times, the entire exercise of orbit determination used to be an enormous effort. One divided the orbit into degrees and for each degree the computation performed was as arduous as that for the entire orbit. It was just around then that a young German mathematician Carl Gauss (1777–1855) devised a simple and fast method to compute an elliptical orbit from observations that covered an arc in the sky neither too large nor too small; he eventually published it in 1809 (ref. 30). Applying his method of least squares fit improved the orbit further; even today it is a cogent method for such determinations. Gauss presented the ephemerides in December 1801 and based thereupon, Franz von Zach and Wilhelm Olbers independently recovered Ceres on 31 December 1801 and 2 January 1802 respectively, close to Gauss' estimated position[29].

The time and place of opposition of a superior planet, or conjunction of an inferior planet, are important observations for determining the elements of the orbit since at that instant, the observed value of the longitude is the same as its true longitude, i.e. that seen from the Sun; this greatly simplified the formulae[31]. Oppositions were also the best occasions to follow up the new planets, since it is then that the objects would be at their brightest and moving fastest against the rich starry background. Some highly acknowledged works of astronomy then available carried planetary tables, and journals like *The Nautical Almanac*, *Astronomische Nachrischten*, *Astronomische Jahrbuch*, *Berlin Ephemeris* and *Milan Ephemeris* were publishing from time to time the ephemerides of the new planets. The predicted oppositions differed among themselves by a day or two, and the apparent positions did not agree well. Nevertheless, each opposition offered the astronomers an opportunity to further correct the elements of the orbit, with perturbations from the planets regularly applied so as to be able to predict the places with greater accuracy. Just around the time, the *Philosophical Magazine* published in April 1826 tables by Groombridge[32] of apparent places of the four minor planets at midnight about the times of the respective oppositions due a few months later, where he also mentioned that 'I have now corrected their elements from the observations made at Greenwich in the last year'. Notably, his date for Pallas opposition was ahead of Santini's[28] by a few days.

Understanding the observations by Ghulām Ḥusain *et al.*

Against this backdrop, one can imagine how Captain Darānīs worked to be able to pin-point his telescope in the right place. I believe that he not only knew of the forthcoming oppositions, but might have also been carrying out observations intentionally to determine the respective orbits. Such observations need to be made on either side of the predicted opposition to determine the exact moment. To appropriately time the observations required setting his longitude from a reference meridian, presumably Greenwich; he might have determined it from observations of the eclipses of satellites of Jupiter and culminations of the Moon. In the matter of the ephemerides, Ghulām Ḥusain would have looked into his orbit computation methods and might have also tried his hand on the calculation. I believe the episode became a prelude to his re-working Khairullāh Khān's method of determining the position of a planet in an elliptical orbit. What could have constituted the most interesting part here, no logbook or journal maintained by either of the personalities seems to be in existence. Worse still, the Captain did not publish the observations.

In his text Ghulām Ḥusain mentions that he observed with a telescope the three planets and that the planets (kaukab) exist and that their motions are the same as given by him. Thereafter, he gives their location as follows: Above the Mars orbit (falak) is the orbit of Pallas, above whose orbit is that of Sarīsh, and the orbit of Jārgīs is above that of Saturn[2]. On p. 472 of *JBKh*, Ghulām Ḥusain furnishes diurnal motion of the new planets, namely Jārgīs moving with respect to the fixed stars at 42.294 arcsec/day, Sarīsh at 12.853 arcmin/day and Pallas at 12.6835 arcmin/day[2]. The cited figures are fairly close to those in the literature of his times. These also match the mean daily motions calculable from the respective sidereal periods assuming uniform circular motion. It is therefore not clear if the figures came from his own observations since Uranus traverses a mere ~4° in a year, a rather short arc of the orbit unless, of course, the observations had been made over a long period. One may note the few popular works during Ghulām Ḥusain's time: *Astronomie par Jérôme Le Français* (*La Lande*) [in French; 3 vols; 1792], *Vince's Astronomy* by the Rev. Samuel Vince (3 vols; 1814) and Robert Woodhouse's *A Treatise on Astronomy – Theoretical and Practical* (1821); Chapter XVIII of the last work deals with the problem of finding the place of a planet in an elliptical orbit. Just in 1826, Baily[33] had published new tables of the apparent places of nearly 3000 principal fixed stars. A detailed report by G. B. Airy, who in 1835 became Astronomer Royal, gives us a fair idea of the 'progress of astronomy during the present century'[34].

One may appreciate how Ghulām Ḥusain gathered knowledge of recent developments in astronomy and placed it alongside the classical worldview. He is perhaps the first traditional astronomer in the early 19th century India to have tried his hand on astronomical observations in the real sense of the term, with modern optical equipment. That could not be solo and therefore, in the matter of the comet of 1825, the positional imbroglio is puzzling. He was a mathematician, a *zīj*-user and eventually a *zīj*-maker where his capability cannot be doubted. In 1818, he had published on astrolabe making and therefore would be more at home with its use. A *zīj* is generally specific to the latitude and longitude of a place and Ghulām Ḥusain could not have worked out one without suitable instruments and observations. The brevity of his modern observational accounts leaves us disappointed. How the mechanism of conceptual exchange worked between two frames of reference compounded by a language divide shall remain a mystery.

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