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NŪR UD-DĪN JAHĀNGĪR AND FATHER KIRWITZER: THE INDEPENDENT DISCOVERY OF THE GREAT COMETS OF NOVEMBER 1618 AND THE FIRST ASTRONOMICAL USE OF THE TELESCOPE IN INDIA

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Abstract: The year 1618 in astronomy was a unique one in that it presented three bright cometary apparitions in quick succession. The comets created a sensation, and belonged to an era when Galileo's telescopic observations had created a paradigm shift in our perception of the heavens and Johannes Kepler was introducing a fundamental change in mathematical astronomy by redefining orbits of planets around the Sun. This paper is an account of the observations of two of the three great comets of 1618, made from India. This turned out to be a unique occasion because these same targets of opportunity were followed independently by astronomers from two very different 'schools', and their observations were recorded quantitatively. Jahāngīr, the fourth Mughal Emperor of India, recorded in the *Tūzūk-i Jahāngīrī* (*The Memoirs of Jahāngīr*), the appearance of two comets during a Royal journey from the town of Dohad in Gujarat to Agra, the capital city of the Empire, in the thirteenth year of his accession. From the recorded dates, Jahāngīr turns out to be an independent discoverer of two great comets that appeared one after the other in November 1618. Meanwhile, Father Venceslaus Kirwitzer and fellow Jesuits observed these comets from Goa, and their first observations also correspond to the discovery dates of the comets. These same comets also were followed by Father Antonius Rubinus from Cochin. Fr. Kirwitzer collated and published these observations in 1620 in a short treatise where he states that he also viewed these comets with a 'tubo optico'. This is the first recorded use of a telescope in India.

Keywords: India, Goa; Jahāngīr; Kirwitzer, Rubinus; Mughal chronicles; Great Comets of 1618; first astronomical use of a telescope in India

1 INTRODUCTION

The thirteenth century was a turning point in the history of astronomy in India with the entry of Islamic astronomy and its adoption, which flourished along with Hindu astronomy until around the nineteenth century. It led to an amalgamation of the observational techniques and instruments of the former and the computational techniques of the latter that paved the way for accurate astronomical observations. This overlapped with several stray instances of telescope use during the seventeenth and eighteenth centuries for celestial events and geographical surveys, and the establishment of a modern astronomical observatory at Madras (now Chennai) in 1786.

In the Middle Ages, astronomy in northern India was mostly under the patronage of the Delhi Sultanate (1206–1526 CE) and Mughal emperors (1526–1858 CE), and some of these rulers were interested in astronomy. In the celebrated Mughal writings of the sixteenth and seventeenth centuries, such as the *Akbarnāmā*, the *Tūzūk-i Jahāngīri* and other chronicles of the same period, there are several accounts of unexpected celestial and terrestrial phenomena, such as comets, eclipses, meteors and earthquakes. Just as in other cultures, these were regarded as ill omens for rulers and emperors and so were routinely monitored by historians and chroniclers. Astronomical observations mainly were required for astrological purposes, to precisely determine the auspiciousness of events and their timings, like Royal births, or when to embark on missions or campaigns, etc. Some of these records have little astronomical content, but they underline how these types of events got rulers seriously concerned about their auspiciousness and possible consequences, so they even sought counsel for remedial measures. At this time, generally there was no clear distinction between astrology and astronomy, and superstition remained entwined with both. Many medieval scholars considered astrology as a part of astronomy, while others were opposed, saying that this did not conform to the principles of Islam.

So, what does one say when a ruler records, virtually in own hand, accounts of some 'evil' celestial phenomena that occurred during his reign but with hardly a reference to their ominous nature? Nūr ud-Dīn Jahāngīr (1569–1627), the fourth Mughal Emperor of India (who ruled from 1605 to 1627) was such a person. He was only eight years of age when the Great Comet of 1577 (C/1577 V1) appeared, and he probably witnessed it. Jahāngīr was a great naturalist, a gifted author and in his writings he displayed an excellent command of language. We note how his father, Emperor Akbar, "… paid very great attention to the education of his sons and grandsons, and appointed learned men of very high reputation to superintend their studies." (Law, 1916: 160). Apart from ornithology, biology and lexicography, Jahāngīr had an interest in astronomy, and he maintained records of his observations in his journal *Tūzūk-i Jahāngīrī* (*Memoirs of Jahāngīr*; see Rogers and Beveridge 1909;

1914). In the other memoir that he wrote, the *Wākī'āt -i Jahāngīrī*, we find very similar descriptions (Elliot, 1867–1877; 1975). In these *Memoirs*, we find descriptions of a few solar and lunar eclipses, a meteorite impact and the two Great Comets that he observed.

In this paper we present the story of the observations of the two Great Comets of 1618 from India. Jahāngīr recorded these comets in the course of a journey from Dohad (also known as Dahod) in Gujarat to Agra, the capital of the Mughal Empire, via Ujjain, in the year 1027 A.H. (or 1618 CE);[1] for Indian localities mentioned in the text see Figure 1. The comets in question are those designated 1618 III and 1618 II, and they appeared in that order. Considering the account and the dates entered in his *Memoirs*, Jahāngīr turns out to be an independent discoverer of these two Great Comets of November 1618. If so informed later, Jahāngīr would have been amused, but his records indicate that he had the ability to carry out accurate astronomical observations, and the requisite scientific equipment.

Strikingly, India's tryst with the telescope also began at this time, when a number of Jesuit missionaries observed these same comets. Fr. Venceslaus Pantaleon Kirwitzer (1588–1626) observed Comet 1618 III from Goa, and he was soon joined by other Jesuits in Goa and in Cochin, and then in quick succession they observed the second bright comet of November 1618. Their initial observations also coincide with the discovery dates of these comets. While giving details of the observations, Fr. Kirwitzer also mentions that he used an optical device, a 'tubo optico' (telescope), to view the comets. We cannot say for certain that it was a Galilean telescope with a mounting that the group had brought from Europe, together with other astronomical instruments and books, to be carried further east to Macao. Fr. Kirwitzer and others deserve credit on several counts, as independent discoverers of the two Great Comets in succession; as the first independent users of an optical device for observing comets outside Europe; and for the first modern astronomical observations from India with telescope, and within a decade of its invention in Europe.

2 THE COMETS OF 1618

When hardly any theory of comets existed, Tycho Brahe's observations of the Great Comet of 1577 marked a milestone in the history of astronomy when he placed it at a supra-lunar location, settling the important question of the distance to comets through the parallax method. This challenged the Aristotelian perception that comets were atmospheric phenomena. The comets of 1618 belong to the era when Galileo's telescopic observations created a paradigm shift in our perception of the heavens, and Johannes Kepler introduced a fundamental change in mathematical astronomy by redefining the motions of the planets around the Sun. After Halley's Comet of 1607, here were the first significant comets to appear in the skies.

Figure 1: Indian localities mentioned in the text (Map: Baba Varghese).

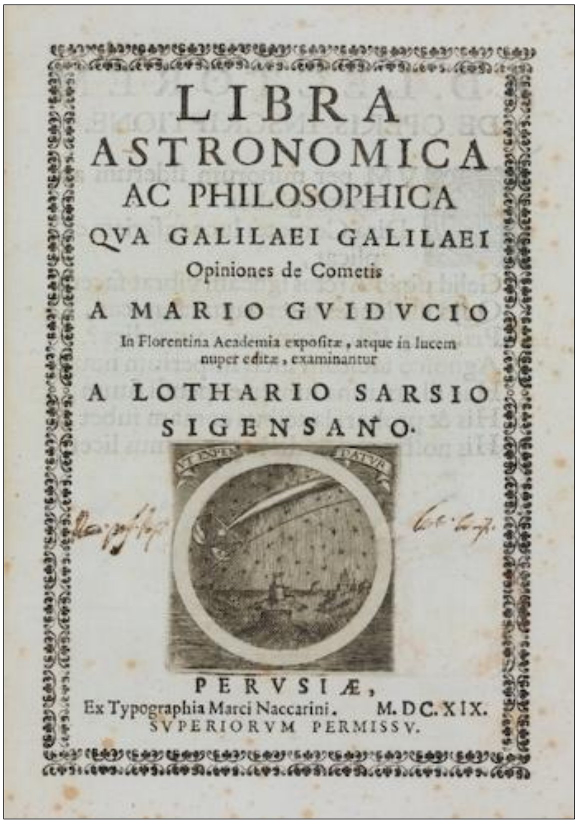

LIBRA
ASTRONOMICA
AC PHILOSOPHICA
QVA GALILAEI GALILAEI
Opiniones de Cometis
A MARIO GVIDVCIO
In Florentina Academia expositæ, atque in lucem
nuper editæ, examinantur
A LOTHARIO SARSIO
SIGENSANO.
PERVSIÆ,
Ex Typographia Marci Naccarini. M.DC.XIX.
SVPERIORVM PERMISSV.

Figure 2: Oratio Grassi's *Libra Astronomica* …, a follow up to his *De tribus cometis Anni MCDXVIII* (1619), is a critique of Galileo's ideas on the nature of comets; Grassi used Lotario Sarsi as a pseudonym. Grassi was the leading astronomer in Rome and a Professor at the Rome College (Collegio Romano). As a Jesuit, Grassi was charged with teaching nothing in science contrary to Aristotle, who said that comets were vapors located beneath the Moon. Yet Grassi's analysis demonstrated that these comets moved beyond the Moon (after *Galileo's World* … 2015).

The year 1618 was a unique one in that three bright comets were visible in the sky within a short span of just three months. That year also saw the novel use of the telescope for the observation of these three Great Comets. In order of

Figure 3: German ducat of 1618 (adapted from Faintich; http://www.symbolicmessengers.com/newfin di.htm).

occurrence and with their respective modern designations and dates of perihelion passage, the comets were 1618 I (C/1618 Q1; perihelion August 17.627 UT), 1618 III (C/1618 V1; October 27.9) and 1618 II (C/1618 W1; November 8.851). The last two were sighted within a short span of time in the same region of the sky and were visible together for several successive nights. All of these comets were naked eye objects, with tails and motion direct, and were noticed after their perihelion passages.

With three apparitions in quick succession, these comets created a sensation among astronomers, and even drew Galileo Galilei (1564–1642) into a controversy with the Jesuit mathematician Fr. Horatio Grassi (1583–1654) over the nature of comets (Figure 2). Grassi stressed the apparitions were against the Copernican worldview. Galileo was indisposed at the time, so he responded through the work *Discorso delle comete di Mario Guiducci*, which was published under the signature of his disciple Mario Guiducci (1585–1646). As Whipple (1985) put it, Galileo tried to wriggle out with a carefully-worded "… technically conformist comment." This dispute involved Galileo Galilei, Horatio Grassi, Mario Guiducci and Johannes Kepler, and it is discussed in a thought-provoking book by Drake and O'Malley (1960).

The three bright comets of 1618 generated grave concern among the general population, and also left an indelible imprint on people's minds. Figure 3 shows a German ducat (0.986 gold weighing 0.110902 oz) featuring one of the comets of 1618. The comet is depicted passing from right to left and so was a morning object. Which one of the three comets of the year does the ducat depict? According to Faintich (2007), the ducat was issued on 19 November 1618 to commemorate Comet 1618 I. The celebrated comets of 1577 and of 1680—the latter being the first to be discovered with telescope—also were commemorated with medals.

Comet 1618 III even was observed by a young John Milton (1608–1674) when he was ten (see Cunningham, 2016). How this comet made an indelible impression in Milton's young mind is reflected much later, in his poem *Paradise Lost* (1667; 1674(II): 706–711):

> On the other side,
> Incensed with indignation, Satan stood
> Unterrified, and like a comet burned,
> That fires the length of Ophiuchus huge
> In the arctic sky, and from his horrid hair
> Shakes pestilence and war.

King James I (1566–1625) registered Royal reaction to the 'Angry Starr' of late autumn of 1618 (apparently, Comet 1618 II) in what is now a famous poem that aimed to alleviate the fear that people then had that it was a sign of God's wrath (see Maclean, 1987). However, what is more interesting is what the King actually exclaimed before the Reverend Thomas Lorkin, as recorded by Sir Thomas Puckring on 1 December, 1618 (11 December Greg.; Birch 1849(II): 110):

> Concerning the blazing star, his majesty, they say, swears it is nothing else but Venus with a firebrand in her ___.

In a footnote provided by Thomas Birch (1705–1766) on the same page as this quotation he explains:

> 'The word omitted [at the end of above quotation], if proper for a king to utter and a clergyman to repeat – of which we can not entertain doubts – is certainly too objectionable to be printed.' More importantly, he adds that 'Mr. Briggs conceives it to be a perfect comet and therefore above the moon (so mathematicians have demonstrated Aristotle's tenet in this point to be false) …'

The afore-mentioned 'Mr. Briggs' was the English mathematician Henry Briggs (1561–1630), well-known for his pioneering work on common (base 10) logarithms.

The sighting of the comet of late November 1618 was, in prognostications and in retrospection, also linked to the Great Thirty Years War of 1618–1648, a religious war according to some scholars that greatly affected life in the Holy Roman Empire.

2.1 A Description of the Three Great Comets of 1618

A brief description of the three comets is in order, but for detailed accounts of the observations and contemporary discussions, one should refer to Kronk (1999), Vsekhsvyatskii (1964) and The comets of 1618 (1878).

Comet 1618 I (C/1618 Q1) was discovered at Caschau in Hungary on 25 August in the morning skies at magnitude 2–3, and by Johannes Kepler (1571–1630) at Lintz on 27 August. On 1 September, its tail was up to 5° long. It passed closest to the Earth at 0.5162AU on 19 August and was last seen on 25 September. This comet holds the distinction of being the first recorded comet to be observed with a telescope, on 6 September. This observation was made by Kepler, who described the comet as a large object that resembled a cloud. Those orbital elements of direct interest here are listed in Table 1.

Comet 1618 II (C/1618 W1; Great Comet) probably was first seen on 23 or 24 November by Garcia de Silva y Figueroa (1550–1624) from Isfahan in Persia toward the east as a diffuse object and having the colour of Venus (Kronk, 1999: 338–341). Garcia de Silva, who had travelled extensively throughout the country, including to the city of Shiraz and the ruins of Persepolis, was the Ambassador of Philip III (the King of Spain and Portugal) to the court of the renowned ruler Shāh Abbās (1571–1629; ruled 1587–1629). Some of the orbital elements of this comet are included in Table 1.

There is some confusion about the discovery date of this comet. In 1619, Fr. Horatio Grassi argued that among the most popular dates, namely 14, 26 and 29 November, the earliest observations that fitted well could be of 26 November only, although there were independent reports of its discovery on 24 November. The Danish astronomer Longomontanus also had some reservations about the correct date and the chronology presented by Garcia de Silva y Figueroa.

The first to record the comet were the Chinese who found it in the constellation of Libra on 25.9 November with a tail more than 10° long. Elsewhere, the comet was observed amongst others, by Fr. Johannes Cysatus, John Bainbridge, Johannes Kepler, the Koreans and the Japanese. It passed closest to the Earth (0.358 AU) on 6 December. Four days later it exhibited an unusually-long tail, which Longomontanus measured to be 104° (Hind, 1852: 15, 106; The comets of 1618, 1878: 247). During the month of December its brightness reached first magnitude, and subsequently it dropped to the third magnitude (Vsekhsvyatskii 1964: 113). François Arago, the French mathematician and astronomer, mentioned that the head of the comet split into several parts during December, a phenomenon observed by Cysatus (Hind, 1852: 10; Lynn, 1889: 408) and also by Wendelin and Christoph Scheiner. It then appeared as a cluster of bright stars, each with its own tail and travelling together. Comet 1618 II was last seen on 22 January 1619, by which time it had faded to between magnitude 5 and 6 (Kronk, 1999: 338–341).

Fr. Johann Cysatus (1587–1657), then at Ingolstadt, was the first to use a telescope to observe this comet, and he detected structure in the comet's head. He could resolve it into a nucleus surrounded by a nebulous envelope (coma), with yet another luminous, though relatively fainter, appearance around that. He also

Table 1: Some orbital elements* of the three Great Comets of 1618 (after JPL, 2015).

Comet	*q* (AU)	*i*	*e*
C/1618 Q1 (1618 I)	0.51298	21.494°	1.0
C/1618 W1 (1618 II)	0.38594	37.196°	1.0
C/1618 V1 (1618 III)	0.744	08.4°	1.0

* *q* = perihelion distance
i = inclination of the orbit to the plane of the ecliptic
e = eccentricity

noticed unusual movement in the tail, and he noted that the path of the comet began to deviate from the stipulated straight line:

> This curvature (of the orbit) would be a phenomenon of great importance, if it could be confirmed by more observations. (Schreiber, 1904: 100).

One may gauge the significance of this observation from the fact that cometary orbits are so acutely elliptical or parabolic that Kepler and Galileo believed that comets travelled in straight lines. From his observations of Halley's Comet in 1607, Kepler drew in his 1619 work *De Cometis Libelli Tres* the inference that this comet travelled in a straight line (Yeomans et al., 1986: 82). For a perspective, we may recall that in 1609 Kepler had published the first two of his famous laws of planetary motion. According to these, a planet orbits the Sun in an ellipse with the Sun at one of the foci, and the area swept out by a line connecting the planet to the Sun is always the same in a given time interval irrespective of its position in the orbit. The third law, relating the average orbital distance of a planet from the Sun to its orbital period, was published in his book *Harmonica Mundi* in 1619. It was only in 1687 that Isaac Newton (1642–1727) showed that cometary orbits took the form of a conic section, other than a rectilinear one. However, Jeremiah Horrox (1619–1641) was the first to conclude that the comet of 1577 followed a curvilineal path: "… in an elliptical figure or near it." (Whatton, 1859: 15–16).

Now to the third Great Comet of 1618, Comet 1618 III (or C/1618 V1). This was spotted earlier than 1618 II, on 11.04 November by Garcia de Silva y Figueroa (1550–1624) from Isfahan in Iran. It was visible in the southeastern sky, and had a tail that was about 60° long (Kronk, 1999: 335–338). These observations are mentioned in Pingré's celebrated *Cometographie* of 1784. However, Comet 1618 III is not listed in Vsekhsvyatskii (1964). It also does not figure in the lists of comets given by Hind (1852: 128), although it is mentioned on page 21. The Roman College Jesuits followed the traverse of this comet across the sky from 28 November until 9 December, during which time it may have been visible for a large part of the night (Kronk, 1999: 337). This comet also was observed by Kepler from Linz, from 20 to 29 November. On the latter date he saw it share the morning skies with the third bright comet of the year, 1618 II. Orbital elements of Comet 1618 III that are of direct interest here are included in Table 1.

Kennedy (1980) mentions a book titled *Tanbīhāt al-munajjimīn* (*Admonitions to Astrologers*) by Muzaffar b. Muḥammad Qāsim Junābādī (Gunābādī) that refers to several comets seen in history and also provides a classification. The author of the book cites Arabic, Egyptian, Greek, Indian and Iranian sources. The Indian works mentioned are:

> *Barahi (?), an Indian book, No. 17, f. 192r; Bistiham (?) the Indian, No. 25,ff. 197v, 200r*. is a name otherwise unknown to us. The author reports his views on the motion of tailed stars; Brahma and the Indian astrologers, ff. 184r, 192v.

Barahi, mentioned above, is probably the Indian astronomer Varāhamihira (485–587), and *Brahma* is Bṛhmagupta (b. 598).

Junābādī points out that he witnessed the great comet of 1577 that appeared in the west towards "… the latter part of Sha'ban (ca. 2–12 November, 1577)." Lastly, he refers to two consecutive comet sightings in the year 1027 A.H. The reference is made at two places. The first one reads as follows:

> … in the beginning of Dhu al-Hijja 1027 H. (ca. 21 November 1618), while the royal court was at Qazwin (northwest of Tehran), a *harbah* appeared in the east, in the sign of Libra.

Then in a later chapter, the author describes how

> On the morning of Monday, 8 Dhu al-Hijja (26 November 1618) of the above-mentioned year, a comet (*Au dhawaba*) appeared in the east in the middle of the sign of Scorpio and lasted for about forty days.

The Royal Court referred to above is that of Shāh Abbās of Iran to whom *Tanbīhāt al-munajjimīn* was dedicated. As for the 1027 A.H. dates, Kennedy (1980) observed that

> The two dates are practically the same, and the zodiacal signs are adjoining, but different names are used for the category of tailed star observed. We have no explanation.

We find that the references in the book *Tanbīhāt al-munajjimīn* are correct and made in respect of two different comets, which are now designated 1618 III and 1618 II.

3 JAHĀNGĪR'S INTEREST IN ASTRONOMY

Jahāngīr's *Memoirs* clearly demonstrate his interest in astronomy and the level of accuracy reached in the observations. We find the recorded information in excellent agreement with modern computations. Jahāngīr's astronomers used instruments such as *ghati-yantra* (water-driven clocks; clepsydras), astrolabes, sundials and hour-glasses. One can find depictions of many of the astronomical instruments then in use on a number of Mughal miniature paintings of the sixteenth and seventeenth centuries. One such example is presented here in Figure 4, a margin drawing from the folio of Jahāngīr's Album depicting an astrologer surrounded by his equipment.

Jahāngīr has written in the *Tūzūk-i Jahangīrī* about the circumstances of fall of an iron meteorite in a village in Jalandhar district in the Punjab on 30 Farwardin, in the 16th regnal year, i.e., 19 April, 1621 Greg. (but Howe, 1896: 296 cites the year as 1620—also see, A forgotten Indian meteorite, 1935). The iron that was extracted from the site weighed 1.93 kg (Blochmann, 1869: 167–168), and the meteorite broke under the hammer. The sword-maker got the Emperor two sword blades, a dagger and a knife using three parts of the meteorite for metal, to which the sword-maker added one part of terrestrial iron. One of these artifacts, the coveted dagger, can be seen in the Smithsonian Institution's Freer and Sackler Galleries (Sabri Ben-Achour, 2012).

There is mention in the *Tūzūk-i Jahāngīrī* of the total lunar eclipse of 1018 A.H. (Rogers and Beveridge, 1909–1914(I): Chapter 6), and the solar eclipses of 1019 A.H. and 1024 A.H. (15 December 1610 and 29 March 1615 Greg respectively, both annular) also were duly recorded. Jahāngīr put down his thoughts about them and recorded details during the eclipses. For instance, in the matter of the solar eclipse of 1024 A.H., he states that on the occasion

> Alms of all kinds, and things in the shape of metals, animals, and vegetables, were given to fakirs and the poor and people in need. On this day the offering of Rāja Sūraj Singh was laid before me; what was taken was of the value of 43,000 rupees. The offering of Bahādur Khān, the governor of Qandahar, was also laid before me on this day; its total value came to 14,000 rupees. (Rogers and Beveridge, 1909–1914(I): Chapter 12).

In connection with such marches too, an auspicious hour mattered. About the march of an advance of *Lashkar* (troops) from Gujarat to Agra in the year 1027 A.H., Jahāngīr writes:

> On Thursday, the 7th, with great joy and congratulation, the advance camp was started towards Agra. The astrologers and astronomers had already fixed the auspicious hour for the march. As excessive rain fell, the main camp could not cross the river of Maḥmūdābād (the Vātrak) and the Mahī at this hour. Out of necessity, the advanced camp was started at the appointed hour, and the 21st Shahrīwar was fixed for the march of the main camp. (Rogers and Beveridge 1914 (II): 25).

The Mahī flows north from Vadodara and eventually enters the Arabian Sea whereas the Vātrak flows through Kheda, a district bordering Ahmedabad and Vadodara. The first date above corresponds to 29 August, 1618 (Greg.). That is just

Figure 4: An early seventeenth century margin drawing from the folio in Jahāngīr's Album showing an astrologer surrounded by his equipment—an astrolabe, zodiac tables and an hour glass (courtesy: Werner Forman Archive/Naprestek Museum, Prague).

days after the bright comet 1618 I was discovered on 25 August. It is surprising that no chronicler mentions this object in his writings. No one recalled it either when later on two bright comets appeared during the month of November.

Zodiacal gold coins and silver rupees struck in the names of Jahāngīr and his queen Nūr Jahān, respectively, were issued from the thirteenth year of his reign (in the year 1027 A.H.). These coins have a zodiacal sign on the obverse and a Persian verse on the reverse. Jahāngīr ordained that rather than carry his name on the obverse and the name of the place and the month and year of his reign on the reverse, each coin should feature a zodiacal symbol for the name of the solar month it belonged to, with the Sun emerging from this symbol (Brown, 1922: 95–96). On the obverse these symbols are depicted, with the (rising) Sun in the background. These coins, which clearly reflect Jahāngīr's inclinations, are fine examples of numismatic art, and quickly became collectors' items.

Some very fine Mughal miniatures were made by Jahāngīr's court artists, like the one by Bichitr reproduced here in Figure 5 where the Emperor is shown proffering a Sufi Shaikh to kings. Jahāngīr is seated on an hour-glass throne, and the halo behind his head has a golden Sun and a crescent Moon.

4 MUGHAL WRITINGS ABOUT THE NOVEMBER 1618 COMETS

Of the numerous comet apparitions during the Mughal period, we find brief accounts of only the great comets of 1577 and 1618, namely, in the *Akbarnāmā*, in the *Tūzūk-i Jahāngīri*, and in a few chronicles. These references assume significance in view of the fact that observations from Europe of the very same comets made a decisive impact on the course of astronomy there. Abū'l Faḍl (1551–1602), the celebrated Prime Minister of the Mughal Emperor Jalāl ud-Din Muḥammad Akbar (1542–1605; ruled 1556–1605), has recorded in the *Akbarnāmā*, the highly-acclaimed biographical account of the Emperor, and the appearance of a comet during the 22nd year of his reign, in 985 A.H. From the recorded date, Abū'l Faḍl turns out to be an independent discoverer of one of the most famous comets in history–the Great Comet of 1577 (C/1577 V1). We have discussed this in detail in an earlier paper (Kapoor, 2015), and here we confine ourselves to the two great comets of November 1618.[2]

In 1910, when Halley's Comet was yet to reach naked eye visibility, it had already stirred up the *cognoscente* of India. Jivanji Jamshedji Modi (1854–1933), a renowned scholar of Sanskrit, Persian and the *Avesta* carried out a comprehensive examination of accounts by Muslim scholars and those in the books of ancient Persians of the records and sightings of comets over the ages, and on 9 February 1910 he presented his findings at meeting of the Bombay Branch of the Royal Asiatic Society. Modi (1917) gave a remarkable exposition on the "Mahomedan view of comets", and he listed comets that the Muslim scholars of the Middle Ages came to know about through historical documents, literary works and records, or they had actually observed during their own lifetimes. Modi (1917: 84–86) discussed at length Abū'l Faḍl's discourse on comets, his record in the *Akbarnāmā* of the appearance of the great comet of 1577, and, Jahāngīr having recorded two comets that occurred in the year 1618. Modi consulted Hind's (1852) book on comets and *Ferguson's Astronomy* (Brewster, 1811(II): 360) to identify the comets described in Jahāngīr's *Memoirs*. Modi identified the first of the comets as the one seen in November 1618 with perihelion on 8 November. For the other, the only candidate he could find was the comet of August 1618. These comets respectively are 1618 II (C/1618 W1) and 1618 I (C/1618 Q1). However, comet 1618 I had appeared months before Jahāngīr's dates of observation; it was discovered on 25 August and last observed on 25 September, by Kepler. The period of visibility does not match Jahāngīr's whereabouts at the time and his sighting of the two comets within a span of sixteen days.

Both Mousavi (2000: 114–115) and Ansari (2002: 257) mention that Jahāngīr recorded a comet that was visible in early November 1618, and their references correspond to comet 1618 III. Ansari (ibid.) cites the period of Jahāngīr's observations as 11 November–9 December, 1618 whereas Mousavi (2000: 115) cites the date of first observation as "… a few days before 18 Ābān 13 R.Y. [= 3 November 1618, Greg.]." The converted date of 3 November although a Saturday—just as in Jahāngīr's account—is not consistent with the course of comet 1618 III. On 3 November 1618, comet 1618 III was still an evening object whereas Jahāngīr's are morning observations. Ansari's (2002: 257) first recorded date (11 November) is acceptable, except that it is a Sunday.

So, which of the three comets of 1618 did Jahāngīr observe and on which dates? As the present study concludes, the comets in question are the ones designated 1618 III and 1618 II, appearing in that order and that the right dates of Jahāngīr's first record are, respectively, 10 November for comet 1618 III and 26 November for comet 1618 II. Muslim historians are acknowledged for their chronological precision, and Jahāngīr's dating can be relied upon. In what follows, we shall deliberate upon Jahāngīr's de-

Figure 5: *Jahangir Proffering a Sufi Shaikh to Kings*. This shows Jahāngīr seated on an hour-glass throne and presenting a book to the Sufi. This miniature by Bichitr is part of an album made for the Emperor circa 1615–1618; from the St. Petersburg album—Google Art Project.jpg (Wikimedia Commons).

scription. We then move on to the observations made by other observers from India (at times with a telescope), and then to India-related stories of the two great comets.

4.1 The Many Versions of Jahāngīr's Observations

The following passage from Jahāngīr's *Memoirs Wāki'āt-i Jahāngīrī* (Elliot, 1867–1877: 363; Elliot, 1975: 88–89), pertains to the account of the thirteenth year of his reign, i.e., 1027 A.H.:

> Saturday, 17th Zi-l Ka'da: Several nights before this, a little before dawn, a luminous vapour, in the form of a column, had made its appearance, and every succeeding night it arose half an hour earlier than on the preceding night. When it had attained its full development, it looked like a spear with the two ends thin, but thick about the middle. It was a little curved like a reaping-sickle, with its back towards the south, and its edge towards the north. On the date above mentioned, it rose three hours before the sunrise. The astronomers measured its size with their astrolabes, and, on an average of different observations, it was found to extend 24 degrees. Its course was in the empyrean heaven, but it had a proper motion of its own, independent of that firmament, as it was retrograde—first appearing in the sign of the Scorpion, then in that of the Scales. Its declination was southerly. Astrologers call such a phenomenon a spear, and have written that it portends evil to the chiefs of Arabia, and the establishment of an enemy's power over them. God only knows if this be true!
>
> Sixteen nights after its appearance, a comet appeared in the same quarter, having a shining nucleus, with a tail in appearance about two or three yards long, but in the tail there was no light or splendour. Up to the present time, nearly eight years have elapsed since its first appearance, and when it disappears, I shall take care to record it, as well as the effects which have resulted from it.

Modi (1917: 86) interpreted the above translation in Elliot (1867–1877) to mean that it is not that the comet continued to be seen for eight years, rather the reference alludes to the supposed disastrous and unlucky influences the comet had lasting as long. However, the mysterious 'eight years' appear elsewhere too, in an account of the apparitions by another historian. Modi (1917: 78) cites an account of the sighting of the two comets of 1618 from Mū'tamad Khān's *Iqbālnāmā-i Jahāngīrī* that also is available in Elliot's *History of India* (Elliot, 1867–1777(VI): 406–407). Mū'tamad Khān's description matches Jahāngīr's in the *Wāki'āt-i Jahāngīrī*. Only the date, "On the 16th of De …", differs. According to Modi (1917: 86), this may have arisen from Mū'tamad Khān mistaking the "… Mahomedan month Zi-l Kada for the 'Ilahi De'." The mismatch also could be result of paraphrasing, or translation. However, Mū'tamad Khān adds the evil aspects of the comet's appearance:

> It was in consequence of its appearance that a pestilential disorder (*waba-o-ta aun*) spread throughout this extensive country of Hindustan, which exceeded everything known and recorded in former ages, nor is there any mention made of such in the authentic works of the Hindus. The pestilence arose in the county one year before the appearance of the phenomenon and continued to rage for eight years, It was also through the effects of this phenomenon that a misunderstanding arose between His Majesty and the fortunate Prince Shah Jahan. The disturbances which thus originated lasted seven or eight years. What blood was shed in the country! and what families were ruined!

Mū'tamad Khān (d. 1049/1639) was a courtier and favourite of Jahāngīr and had taken up the task of continuation of the Royal *Memoirs* after the seventeenth regnal year, under the Emperor's supervision. *Iqbālnāmā-i Jahāngīrī* is his independent work finished in 1029/1620 (Nabi Hadi, 1995: 443).

From Rogers and Beveridge (1914(II): 48; see also Baber, 1996: 83), a translation of the part on the sighting of the comets from the *Tūzūk-i Jahangīrī* is reproduced below that does not contain the confusing 'eight years' in the crucial part of the narration:

> On Saturday the 18th (Aban), the camp was at Ramgarh. For some nights before this there appeared, at three *gharis* before sunrise, in the atmosphere, a luminous vapour in the shape of a pillar. At each succeeding night it rose a *ghari* earlier. When it assumed its full form, it took the shape of a spear, thin at two ends, and thick in the middle. It was curved like a sickle, and had its back to the south, and its face to the north. It now showed itself a watch *(pahar)* before sunrise. Astronomers took its shape and size by the astrolabe, and ascertained that with differences of appearance it extended over twenty-four degrees. It moved in high heaven, for it was first in Scorpio and afterwards in Libra. Its declination (*harakat-i-arz*) was mainly southerly. Astrologers call such a phenomenon a spear (*ḥarba*) in their books, and have written that its appearance portends weakness to the kings of Arabia, and points to their enemies prevailing over them. God knows! Sixteen nights after this phenomenon, a star showed itself in the same quarter. Its head was luminous and its tail was two or three yards long, but the tail was not luminous. It has now appeared for eight nights; when it disappears, the fact will be noticed, as well as the results of it.

A *ghari* (*ghati*) as a unit of time is equivalent to 24 minutes (1 *ghati* = 1/60 of a day). It is obvious from the above quotation that the observations refer to the sighting of two comets in quick succession.

4.2 The Royal Traverse and the Dates of the First Observations

Let us ascertain the Gregorian dates of the observations from the chronology of the traverse of the Royal *Lashkar* as entered in the *Memoirs*, keeping in mind the paths of the comets and how their positions changed, and see if these reconcile with the observations made elsewhere. The recorded dates differ but 'Saturday' is common in the English translations of both the *Memoir* extracts. A clue to the chronology could come from another part of the *Tūzūk-i Jahangīrī* wherein, while referring to a particular day, Jahāngīr enters in the same passage a date according to two calendars together. He notes that:

> On Saturday, the 11th, the auspicious equipage alighted in the pargana of Dohad … On the eve of Sunday, the 12th of the Ilāhī month of Ābān, in the thirteenth year from my accession, corresponding with the fifteenth Z̲ī-l-Qa'da of the Hijrī year 1027, in the nineteenth degree of Libra, the Giver of blessings gave my prosperous son S̲h̲āh-Jahān a precious son by the daughter of Āṣaf K. I hope that his advent may be auspicious and blessed to this everlasting State. (Rogers and Beveridge 1914(II): 47).

That is about the birth of Aurangzeb who would be the sixth Mughal Emperor in the times to come (ruled 1658–1707) and where Āṣaf K is Abdul Hasan Āṣaf Khān, the father of Arjumand Bānu Begum (Mumtāz Mahal). Corresponding to the date *15*, *Dhu-al-Qa'dah*, *1027 A.H.*, not only the day is *yawm as-sabt* (Saturday), the equivalent Persian date 12 Ābān, 997 also is a *Shanbeh* (Saturday). The corresponding Gregorian date is 3 November 1618 CE, Saturday (24 October 1618 Julian). It was a Full Moon on the night of 2/3 November, 1618. Making 12 Ābān a Sunday would be in conflict with the timetable. As for the phrase "… in the nineteenth degree of Libra …" that should be about the Ascendant. Note that while a "… formidable sign …" appeared in the heavens in a week of the Royal birth, followed sixteen days later by another one and as the two went on to dominate the morning skies, neither the Emperor nor any chronicler connected these to the Royal birth.

We see that the double entry of the crucial dates in the *Memoirs* still leaves some ambiguity. Considering that the date 15 *Dhu-al-Qa'dah*, 1027 A.H. can still be our reference, the dates in the *Memoirs* help us follow the course of the Royal traverse from Ahmedabad to Agra, through Ujjain in Madhya Pradesh. Beginning with Dohad (Saturday, the 11th day of Ābān), the Royal party halted on the way at the villages of Samarna (or Samarni/Tamarna; on the 15th day), Ramgarh (on the 18th), Sitalkhera (or Sambhalkhera; on the 20th), the parganas of Madanpur (Badhnur or Badnawar; on the 22nd) and Nawari (on the 25th), the banks of the Chambal River (on the 26th) and the banks of the Kahnar River (on the 27th) (Rogers and Beveridge, 1914(II): 48–49). Jahāngīr further notes:

> On Tuesday, the 28th, the royal standards were raised in the neighbourhood of the city of Ujain. From Ahmadabad to Ujain is a distance of ninety-eight *kos*. It was traversed in twenty-eight marches and forty-one halts—that is, in two months and nine days.

The first observations of the comet would have been made in this period. Some of the halts mentioned in the foregoing account are not readily identifiable. Dohad, about 200 km east of Ahmedabad and about the same distance from Ujjain by road (see Figure 6), is where Jahāngīr's grandson, Aurangzeb, was born. It is near the border of Gujarat and Madhya Pradesh. In the Survey of India's State Map of Madhya Pradesh (scale 1:1,000,000; 1978), Ramgarh, Nawari and and the Kahnar River do not figure but we do find the Chambal and Gambhir Rivers near Ujjain, on the stipulated route. Notably, the *Memoirs* do not refer to the Kshipra (Sipra) River that flowed to the immediate west of the city of Ujjain and lay on the royal route.

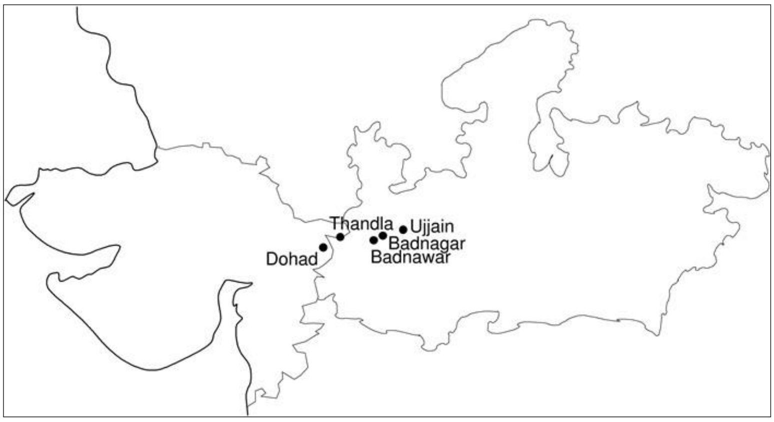


Figure 6: A map showing certain modern locations in the states of Gujarat and Madhya Pradesh that might have been on or near the route Jahāngīr took from Dohad to Agra through Ujjain in 1618.

We have looked at the *District Census Handbooks* (DCH) of the *Census of India 2011* released in 2015 by the Registrar General & Census Commissioner, India, for the districts of Dohad in the State of Gujarat and Jhabua, Dhar and Ujjain in western Madhya Pradesh. It is these districts, spread along a more-or-less west-east corridor, through which the stipulated route must lie. These DCHs list every village and town in the districts, along with the census data.

We did not find any place of interest in the DCH of Dohad. There is a state highway, SH 18, running through the last three districts and this connects to its counterpart in the State of Gujarat. We cannot say if this highway, or a part or parts of it, actually represent the medieval route between Dohad and Ujjain but we can identify two major places where halts may have occurred. SH 18 passes by the Thandla *Tehsil* (a block of a district) of Jhabua and the Badnawar *Tehsil* of Dhar, eventually reaching Ujjain. In the respective census listings, there is a Ramgarh in Thandla (DCH *Jhabua*, p. 60) and to its east is Semal Kheda (khera). The latter is joined in the east to Badnawar (DCH, *Dhar*: 66) by SH 18. On the west side of Jhabua, SH 18 stretches from the town of Thandla to join a road at the State border with Dohad. The names Madanpur and Nawari as such do not appear in any of the DCHs. However, Rogers and Beveridge (1914: 49) suggest that Madanpur is present day Badhnawar, which does fit into the sequence.

Incidentally, there is a Ramgarh in the Nalchha block of Dhar (DCH, *Dhar:* 144) and also one in the Ghatiya block of Ujjain (DCH, *Ujjain*: 134), but these are a long way from Badnawar. The Chambal River splits into the Chamla and the Chambal Rivers in the Khachrod *Tehsil* in the northern part of Ujjain district. The western component, the Chamla River, passes close to Badnagar in the district of Ujjain, and the eastern component, the Chambal River, flows between Badnagar and Kharent. The latter is situated ~10 km west of Ujjain on SH 18. Considering the geography of the region, we suggest Badnagar can be identified with Nawari. The Gambhir River passes Kharent. Finally, Samarna cannot be identified. It should be either in Dohad or in Jhabua. Both of these districts have hilly, undulating terrain.

While Figure 6 shows certain modern locations that lie on or near the route that Jahāngīr's Royal party would have followed in 1618, only modern on-site explorations, coupled with a more detailed analysis of the place names involved and the route, will allow us to confirm the identifications suggested above.

In Jahāngīr's *Memoirs*, the celestial positions of the comets are given zodiac-wise only but the comets' ephemerides generated from their orbital elements can help us fix the dates of the first sightings. Following the *Tūzuk-i-Jahangīri,* we take the first date of observation to be Saturday, 21 *Dhu-al-Qa*ʿ*dah* 1027 A.H. (corresponding to the 18th of Ābān, Saturday) at Ramgarh. The date converter www.islamicfinder.org gives this as Friday 9 November 1618 (Greg). The converter indicates that there is a small probability of a one day error in the conversion, but this date is the same as those derived using other converters (such as www.imcce.fr, www.iranchamber.com and CalendarHome.com). The last converter also gives the corresponding Persian date as Jomeh 18, Ābān, 997. As the date 21 *Dhu-al-Qa*ʿ*dah* begins at sundown (still Friday 9 November until midnight) and the observation was made ~12 hours later, the morning of 21 *Dhu-al-Qa*ʿ*dah* 1027 A.H, Saturday, corresponds to the morning of Saturday 10 November 1618 (Greg). The observation was made before the Sun rose at Ramgarh.

Since Ramgarh was located between Dohad (22º.87 N, 74º.25 E) and Ujjain (23º.18 N, 75º.78 E), we chose to use Thandla's coordinates (23.016º N, 74.579º E), and any discrepancy in the chosen latitude and longitude will be too small to influence the scenario we now present.

Comet 1618 III passed perihelion, on 27.9 October (q = 0.744 AU), about two weeks before its discovery. Jahāngīr records that the comet moved westwards from Scorpio into Libra. On 10 November, computations place the Sun in the middle of the constellation of Libra (which is ~17º in the sign of Scorpio) and a few degrees east of α Librae. The sky view shown in the Figure 7 corresponds to Saturday 10 November 1618 at sunrise (01:13 UT) at Thandla; north is at the top. The field of view is 45° and the bullseye at RA 14h 59h 24.09s and Dec. –19º 13′ 46.3″ is the apparent position of the comet with respect to the true equator and equinox of date at that moment as computed with the Horizons system (JPL 2015).

Using John Walker's *Solar System Live* and the Horizons system, we generate positions of the Sun and the comet in the sky for two crucial dates as in the Table 2.

In the Table 2, RA is for Right Ascension, Dec. for declination, r the heliocentric and Δ the geocentric distance, both in AU; the Moon's distance is in Earth radii (ER). The comet positions are apparent right ascension and declination. Also included in this Table are the computed values of the ecliptic coordinates (λ and β) of the Sun and the comet and the precessed position of Spica. In Figure 7, a line through the stars ζ Herculis, the Sun and ε Centauri (not shown) roughly defined the eastern horizon at the time of

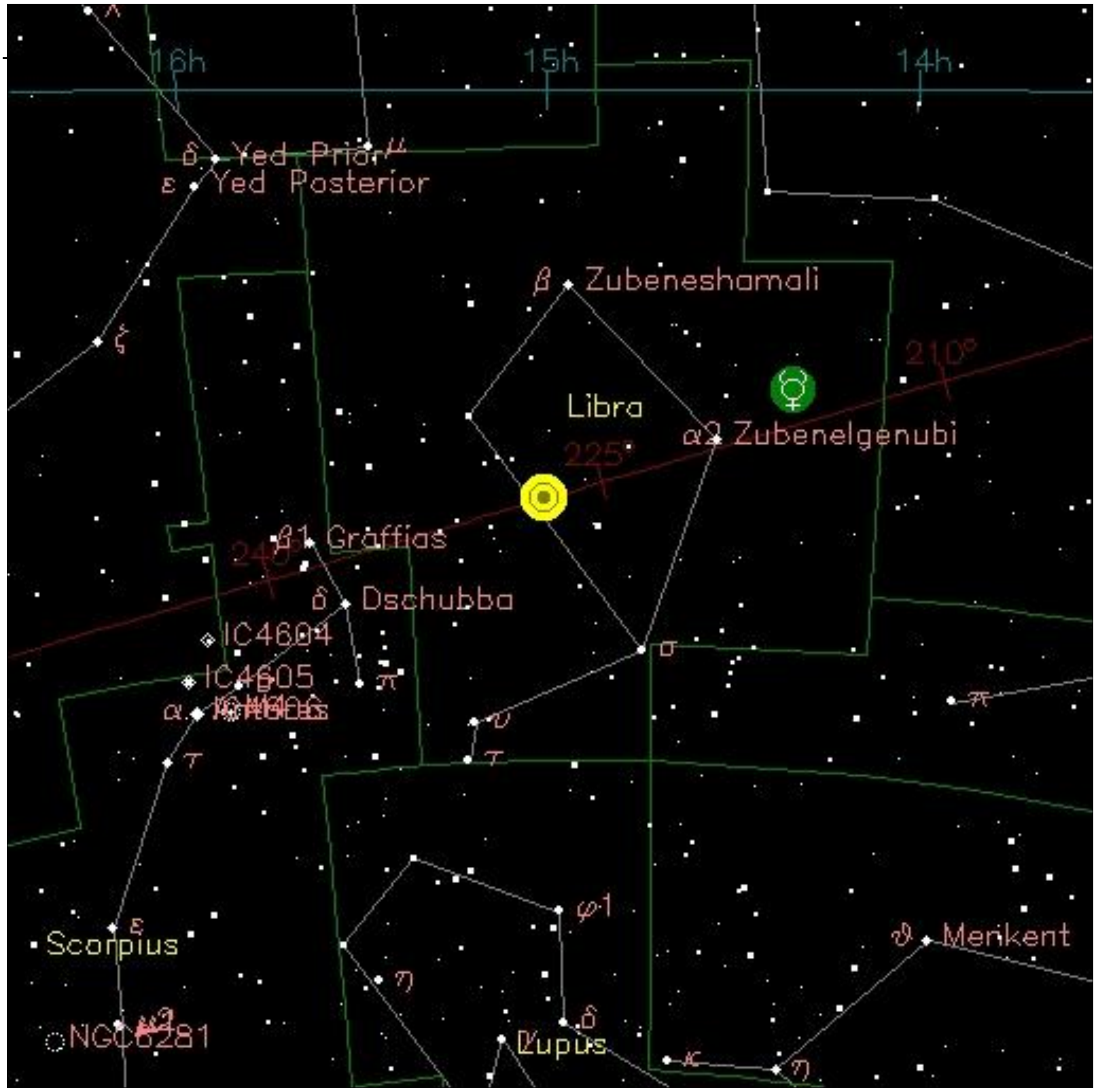


Figure 7: The bullseye at RA 14h 59m 24.09s and Dec. –19º 13′ 46.3″ is the computed position of Comet 1618 III (C/1618 V1) on Saturday 10 November 1618, 01:13 UTC, field 45°; the blue line is the equator and the red line the ecliptic; north is at the top (generated from John Walker's *Your Sky*).

Table 2: Details for the Sun, Comet C/1618 V1, the Moon, Mars and Spica on 10 and 11 November 1618 at 01.13 UT

	RA			Dec			*r*	*Δ*	Alt	Az (S-E)	Elong
	h	m	s	°	′	″					
10 November 1618											
C/1618 V1	14	59	24.09	–19	13	46.3	0.788	0.200	–1.10	–70.03	2.13L
	λ 227.945			β –2.099							
Sun	15	00	27	–17	06	54		0.989	–0.67	–71.65	Rising
	λ 227. 598										
Mercury	14	16	59	–12	04.5			0.734	10.99	–71.70	Up
Moon	09	53	10	+10	05.2			60.2 ER	75.69	–26.47	Up
Mars	10	43	22	+09	59.5			1.721	67.67	–57.44	Up
Spica									27.55	–66.13	Up
11 November 1618											
C/1618 V1	14	47	14.10	–19	39	02.7	0.795	0.194	2.53	–68.83	4.68L
	λ 225.319			β –3.335							
Sun	15	04	31	–17	23	48		0.989	–0.81	–71.40	Rising
	λ 228. 606										
Mercury	14	14	56	–11	39.9			0.754	12.49	–71.39	Up
Moon	10	39	38	+04	42.8			61.0 ER	65.38	–44.55	Up
Mars	10	45	25	+09	47.8			1.712	67.91	–56.28	Up
Spica									28.38	–65.55	Up

sunrise. The ecliptic (passing through the Sun) is roughly vertical to the line defining the eastern horizon; on location, the ecliptic would be inclined southwards.

A computation with the Horizons system shows that the comet began to lead the Sun from 9 November at 23:34 UT. At this time, the Sun was below horizon, at altitude –22º.75. As nautical twilight passed, in a dark sky[3] the comet's tail would begin to be noticeable. At sunrise, by which time the UT had changed to 10 November, the comet, about 2º south of the Sun (S-E azimuth –71º.58) was ~1º below the horizon and, as per the *Memoirs*, its tail would have been curved and located in the northwestern quadrant of the sky.

This scenario can be better visualized by referring to an observation of this comet by an observer in Rome on 11 November where the head was not noticed but the tail extended to the constellation of Corvus and remained visible until twilight. However, see Kronk (1999: 335) on ascertaining a date according to the convention of the beginning of an official day in those times, and also Section 7.2 below. The elongation of the star, say, β Corvi from the Sun that morning was ~40º, which about points to the length and position angle of the tail. In fact, between 10 November and 11 November, the PA of the tail, and its length, would change noticeably. However, the perceived length depended in part on haze and twilight. At sunrise on 10 November, the star β Crv had reached altitude 30º and azimuth –47º. With the head of the comet still very near the Sun, the tail had to be bright and intense in order to fit the description that it was long and magnificent.

In 1985, Landgraf computed the orbital elements of the Comet C/1618 V1 on the basis of observations made from 11 November to 9 December 1618. He assigned 225º and –3º to the ecliptic position of the comet's head for the observation of 11.15 November. Landgraf also claimed that the perihelion date could be wrong by ±2.5 days (Kronk, 1999: 335–337). The traverse of the comet computed with the Horizons system that uses Landgraf's orbital elements is as follows: in Libra (November 10), Libra (November 14), Libra-Virgo-Hydra (November 15), Virgo-Hydra-Corvus (November 19), Corvus (November 23), Crater-Hydra (November 29) indicating that it moved mainly westwards. In the orbit determination, Jahāngīr's observations are not part of the initial data on the comet and could affect its elements, even though by a trifling amount. Ravene (1897: 205) remarked, while presenting elements of the comet of 141 CE on the basis of the Chinese records, that diminishing the dates of observation by about one third of a day to about one day would bring the computed orbit closer to the Halley's.

The epoch of the observation, as read off the *Memoirs* account, is 72 minutes before sunrise. Since the Sun rose at 01:13 UT at Thandla (read Ramgarh) that day, this would make the observation at 00:01 UT, 10 November 1618. The observation is possibly linked with the *Al Fajr* prayer that is offered when the sky begins to lighten (with the Sun 19.5º below the horizon; see Bobrovnikoff, 1984: 18). The prayer is offered facing the direction of the *Ka'aba* and lasts about five minutes. The refraction effect is ~35 arcmin, so that the Sun would have risen about 2 minutes earlier, but this has little consequence here.

Sixteen nights after the 18th of Ābān, and therefore on the morning of 26 November, Jahāngīr observed a second comet, now designated 1618 II (C/1618 W1). It then lay in Libra. This also was a 'Great Comet' and was the third Great Comet of the year. According to Yeomans (2007), it was brightest on 29 November at magnitude 0–1. Kronk (1999: 338) gives its path as follows: Libra when discovered, Virgo (December 2), Bootes (December 5), Ursa Major (December 22) and Draco (December 31).

On 28 Ābān (19 November) Jahāngīr's party camped near Ujjain. Five days later, on 3 Azar, he marched from Kāliyādaha in Ujjain. The month following Ābān is Azar and the date Jahāngīr observed the second comet would be 5 Azar, 997 (8 *Dhu-al-Hijjah*, 1027 AH) which is 26 November. We can only guess the spectacle it may have been when another bright comet was already under observation.

The two Figure 8 images, which were generated with the Horizons System, are views of the inner Solar System from the top, and they allow us to pin-point the two comets when they were in the morning sky on 26 November 1618. At that time, Comet 1618 II moved faster in its orbit (direct motion) than Comet 1618 III, and began to lead the Sun on 16 November at 15:00 UT, the moment of its inferior conjunction, while 0.587 AU from the Earth. It passed closest to the Earth, at 0.358 AU, on 6 December at 15:00 UT.

4.3 Viewing Comets on a Bright Morning

If a comet is visible in the sky when the nucleus is below the horizon this is because it has: (1) an active nucleus; (2) the right combination of the *r* and Δ values; and; (3) an absolute magnitude H_{10} that should be on the brighter side. To that we can add the enhancement in brightness as a result of forward scattering of sunlight off the comet's dust grains when the comet passes between the Earth and the Sun (Marcus, 2007: 119). Post-discovery, Comet 1618 III was

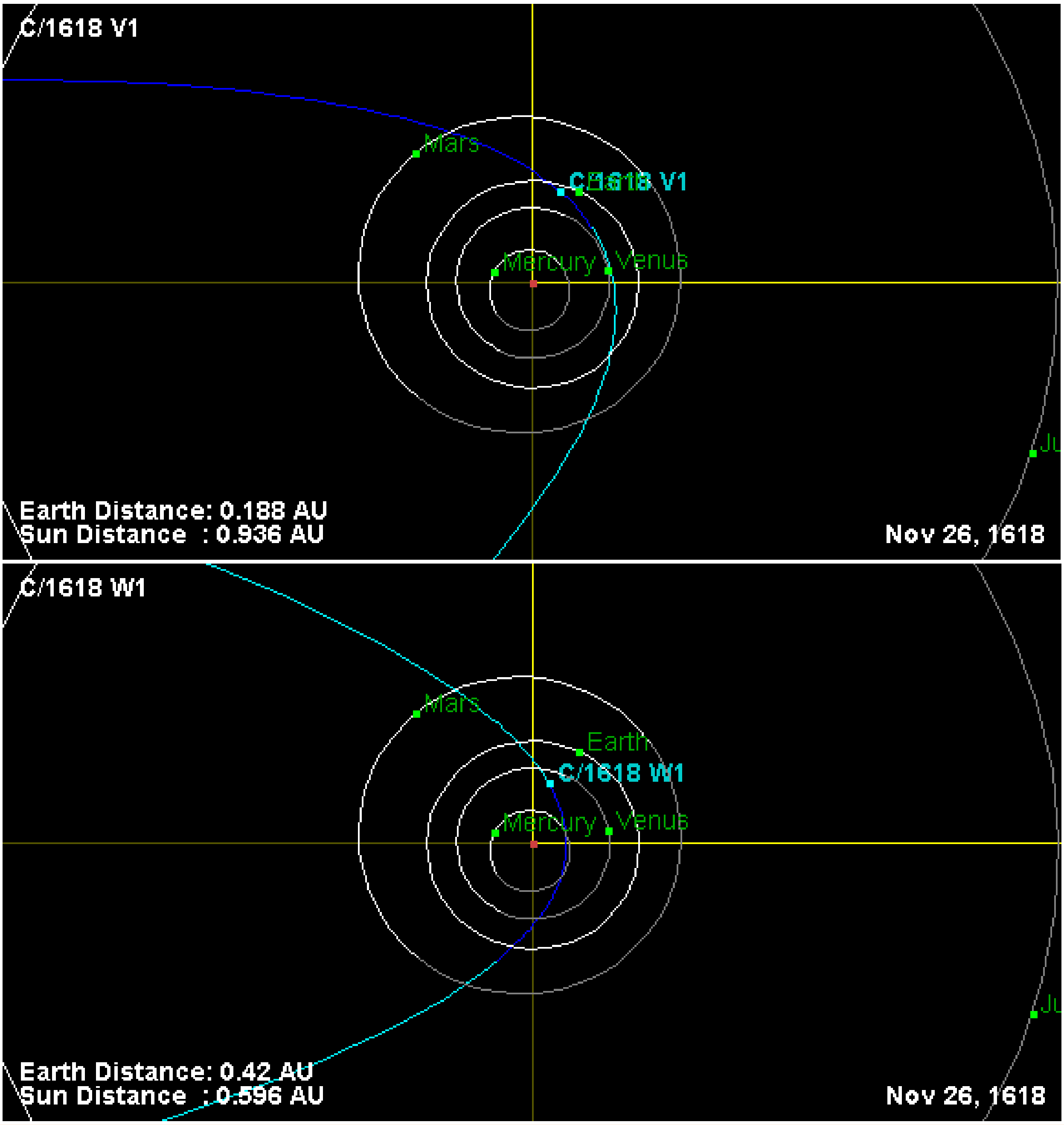


Figure 8: Comets 1618 III and 1618 II as on 26 November 1618; a bird's-eye view (generated from JPL's Horizons System).

nearing the Earth and growing into a spectacular object. It passed the closest by the Earth from 0.1706 AU on 18 November at 21:00 UT.

There are various examples in the cometary literature of comets seen just around the time of their solar conjunction. For example, Marsden (2005) writes about the comet of 1668 (C/1668 E1):

> Cassini (1668) was the first in the western world to publish observations—made from Bologna soon after sunset in March 1668—of what appeared to be the bright tail of a comet extending to more than 30° above the southwestern horizon. Neither he nor other observers located farther to the south (including some in Brazil and South Africa) were able to locate the comet's head, which evidently passed very close to the sun.

Other well-known comets seen in bright twilight are the sungrazer X/1702 D1, Great Comet C/1927 XI, Seki-Lines C/1962 C1 and Ikeya Seki C/1965 S1 (see Bortle (1998). According to R. Vasundhara (personal communication, December 2012),

> At twilight, there is surface brightness gradation from horizon to zenith. Fainter regions of the distant parts of the 60 deg tail should show up against the relatively darker (compared to horizon) sky. At the horizon the sky is brighter but the tail closer to the head is more dense (larger surface brightness) and should show up despite bright sky. In case the comet head is close to the Sun, in my opinion, the inner region will be washed out in the glare, however the rest of the tail should be visible out to great distances. Comet 1618 III (C/1618 V1)

> appears to be similar to last year's comet 'Comet Lovejoy' which had grazed the sun and then was visible in the morning … Elevation of 60 deg can be closely approximated to the zenith under conditions of negligible air pollution, as in 1618.

Figure 9 shows Comet Lovejoy (C/2013 W3) post-perihelion.

An idea of the precision that Jahāngīr's astronomers reached in their observations can be formed from the following few examples. In the *Akbarnāmā*, Abū'l Faḍl underlines Emperor Akbar's interest in the study of astronomy. A "… part of the Astronomical Tables of Ulugh Beg that

Figure 9: Comet Lovejoy (C/2011 W3) after its perihelion passage in December 2011 (adapted from: http://astronomy-vlm.blogspot.in/2011_12_01_archive.html).

we have noticed in Bābar's reign was translated under the supervision of Amīr Fatḥullāh Shīrāzī …" (Law, 1916: 150), while

> Maulāna Chānd, the astrologer … was possessed of great acuteness and thorough dexterity in the science of the astrolabe, in the scrutinizing of astronomical tables, the construction of almanacs and the interpretation of the stars. (Beveridge, 1897–1939(1): 69).

Maulāna Chānd's astronomical tables, *Tahsilāt-i-Akbar Shāhī*, later were used by Sawāi Jai Singh II (Beveridge, 1897–1939(1): 69). Sheikh Alāhā-dād's family in Lahore flourished during the period 1570–1660 CE, and was acclaimed for the production of high-precision astrolabes and other equipment (e.g. see Figure 10). An astrolabe has plates to address different latitudes; each plate is engraved with a grid marked with degrees from 0º to 90º.

Muslim astronomers measured time by measuring altitudes of the Sun or Moon or a bright clock-star that they reduced to local time using astrolabes and the *zījes*. Re an individual instrument's precision, Stephenson and Said (1991: 196–197) cite an account of the solar eclipse of 17 August 928 CE where the observers were able to measure the altitude of the eclipsed Sun, observing its reflection in water, to a third of a division of the measuring ring that itself was graduated in thirds of a degree. We may also note that medieval Muslim astronomers were able to make eclipse predictions from *zījes* accurate to a fraction of an hour (Yazdi, 2008: 79). The eclipse magnitude would be expressed as the maximum proportion of the Sun's disc obscured, and astronomers could calculate this with great accuracy, with errors averaging 0.05 of the solar disk (Stephenson and Said, 1991: 206).

In the matter of the solar eclipse of 1024 AH (29 March 1615 Greg) that he observed from Agra, Jahāngīr wrote that the maximum eclipse magnitude attained was four out of five parts of the Sun (0.8) and lasting 8 *gharis* (3h 12min) (Rogers and Beveridge, 1909–1914(I): Chapter 12). These figures are very close to those calculated using Espenak's (2015) eclipse predictions, namely, 0.794 for the magnitude and nearly three hours duration as seen at Agra. One cannot help but admire Jahāngīr's astronomers for their observational abilities, and for their attempt to 'measure' astronomical objects other than the Sun and the planets.

To conclude, we deduce from Jahāngīr's records that Comet 1618 III was first sighted on 10 November around 00 UT and Comet 1618 II on the morning of 26 November, both post-perihelion. These dates make Jahāngīr an independent discoverer of the two comets in succession. In case the Islamic date converters err by a day, for the pair of dates 11 and 27 November 1618, Jahāngīr is still an independent discoverer of the two comets, notwithstanding the fact that the week days do not suggest this. However, we believe that there is lesser room for ambiguity about the pair of dates 10 and 26 November. The sunrise times on 10 November and 11 November 1618 at Isfahan (32.6577º N, 51.6692º E) were 3:01 and 3:02 UT respectively, so Jahāngīr would have sighted Comet 1618 III several hours before de Silva y Figueroa.

4.4 The Comets in Jahāngīr's Perception

The heliocentric worldview of Copernicus (*De Revolutionibus*, published in 1543) arrived in India much later. This knowledge was known to the Jesuits missionaries at the time but, involved as they were in their missions at several places in India, their primary goal was to spread the Christian faith. When Jahāngīr ascended the throne in 1605, Father Jerónimo Xavier, a grand-nephew of St. Francis Xavier, had already spent ten years in the Royal Court as head of their mission (Guerreiro and Payne, 1930: xvi). Jahāngīr interacted with them on matters of faith and even joined in the sessions between his Moors and the priests. In fact, Abd us-Sattār ibn Qāsim Lahori, his courtier since Akbar's times, had been asked by Akbar to learn the language of the Franks. Abd us-Sattār closely interacted with Fr. Xavier with a view to translating into Persian certain Latin and Greek works about science, including astronomy, while in 1606 Jahāngīr had shown interest to establish a printing press to print books in Persian, and he was assured by Fr. Xavier on this matter (Hadi, 1995: 28; Alam and Subrahmanyam, 2009: 471, 477).

The cometary sightings of 1618 provided a rare opportunity for widespread discussions among astronomers and other scholars. While various past apparitions were recorded in many Muslim texts, here is nothing in Jahāngīr's *Memoirs* to suggest tthat there was any interaction between Jahāngīr's astronomers and the Jesuits in 1618. To Islamic astronomers, comets and meteors were regarded as atmospheric rather than heavenly phenomena, and so usually they were ignored. However, Ja'far b. Muḥammad Abū Mash'ar (787–886 CE), the famous Persian astronomer, astrologer and philosopher, considered comets to be celestial. Whether Jahāngīr' knew about this or not, on the conceptual side his writings take an exceptional departure from the conventional viewpoint. There is no concern expressed for any untoward consequences due to the apparitions, and so the Royal traverse continued.

For the first comet, Jahāngīr observed that

> It moved in high heaven, for it was first in Scorpio and afterwards in Libra. Its declination (*harakat-i-arz*) was mainly southerly …. and it had a proper motion of its own, independent of that of firmament, as it was retrograde – first appearing in the sign of the Scorpion, then in that of the Scales.

An orbital calculation indicates that the comet entered the Libra (the sign of the Scales) on 16 November. Jahāngīr's reference to the positions is according to the tropical system, and he also took due notice of the retrograde nature of the movement. It is clear that he and his astronomers conducted observations on various dates in addition to 10 and 26 November.

There are no *manāzil* or bright stars or planets mentioned by Jahāngīr near the comet's position, and nor could the position angle of the tail or its length be ascertained. While the comet's tail was rising above the horizon, bright objects like *Simāk* (Spica), *Al Ḥāris al Simāk* (Arcturus), *Al Jabhah* (Regulus), Mars and the Moon were all in the sky, whereas Mercury was hovering near the horizon. Jahāngīr also wrote that "At each succeeding night it rose a *ghari* earlier …", and that the comet had appeared a few nights prior to that date (i.e., 18 Ābān/10 November). Those 'few nights' the comet actually was trailing the Sun. For example, on 8 and 9 November calculations give its altitudes at sunset (12:18 UT, at Thandla) as ~ 4º and ~1º respectively (see also Table 2). On 10 November, around 00 UT, the comet transitted the Sun, passing ~2º below it, and was spectacular in appearance. Therefore, the word translated to

Figure 10: An astrolabe by Alāhādād, ca. 1601, at the Art Institute of Chicago (Wikimedia Commons).

mean 'night' may also mean the dark phase before twilight, and what Jahāngīr observed earlier could also mean the evening sightings of the same object. The key question is why there are no reports of evening sightings from anywhere else, even though the comet would have been nearly as bright, the change in r and Δ values through the few days being small only. Georg Dorffel, a student of Hevelius, first suggested that the two bright comets, seen in quick succession in late 1680 and early 1681, were the same comet (now designated C/1680 V1). By saying that the comet made its appearance before *and* after its perihelion passage and that it followed a parabolic path with the Sun at one focus, Dorffel provided an explanation for the pair of comets (Festou et al., 1993: 366). Even earlier, Peter Apian (1495–1552) had noted the disappearance of comets as they orbited close to the Sun and their subsequent reappearance (Hellman, 1944: 90). Jahāngīr also noticed the same thing

Jahāngīr had no knowledge of the developments that were taking place in astronomy in Europe at the time. He used astrolabes for his observations, but he did not use the prospective glass [telescope] gifted to him by Sir Thomas Roe in early 1616—see below. Jahāngīr had ascended the throne a week after Akbar's death on 17 October 1605 (Julian; Majumdar et al. 1967:

Figure 11: Edward Terry (after Foster, 1921: 288).

450, 456). He had been taught astronomy by Abū'l Faḍl's brother, Abū'l Faiẓ Faiẓī (d. 1595), a scholar and poet-laureate in Akbar's court. Jahāngīr had access to astronomical literature in the *Kitābkhānā* (the Royal Library), including the *Akbarnāmā* and the *Ā'in-i Akbari*—where Abū'l Faḍl gave a scholarly exposé on astronomical phenomena, his own sighting of the Great Comet of 1577, and current knowledge and his views on the nature of comets. Ironically, Abū'l Faḍl was assassinated in 1602 at Jahāngīr's instance (see Elliot, 1975: 13–14), much to his father's anguish. As a keen student of astronomy, we must wonder why he missed noting Kepler's Nova in 1604, the appearance of Halley's Comet in 1607 and the first bright comet of 1027 A.H. (1618 I) that appeared only a few days before Jahāngīr's entourage left Dohad for Agra.

Apart from Jahāngīr, there were others who observed the November 1618 comets from India.

4.5 The Reverend Edward Terry on the Two Bright Comets

In his travelogue *A Voyage to East India* that originally was published in 1655 the Reverend Edward Terry (1590–1660; Figure 11) records occurrence of the two comets of 1618. Terry came to India during the reign of Jahāngīr, and was the "… then Chaplain to the Right Hon. Sir Thomas Row, Knt, Lord Ambassador to the Great Mogul." (Terry, 1655: 393). He reports:

> In the year 1618, when we lived at that court, there appeared at once, in the month of November, in their hemisphere, two great blazing stars, the one of them north, the other south; which unusual sight appeared there for the space of one month. One of these strange comets, in the north appeared like a long blazing torch, or launce fired at the upper end; the other, in the south, was round, like a pot boiling over fire. The Mogul consulted with his flattering astrologers, who spake of these comets unto the King, as Daniel sometimes did of Nebuchadnezzar's dream … (ibid.).

5 INDIA'S TRYST WITH TELESCOPE

The invention of a device to see an enlarged version of objects at a distance is attributed to the German-Dutch spectacle-maker Hans Lippershey in 1608, who lived in the Netherlands. It consisted of a concave eyepiece and a convex objective lens. By the end of 1608 the so-called Dutch 'perspective glass' had entered the public domain, and in April 1609, perspective glasses magnifying 3× could be purchased in spectacle-makers' shops in Paris, and soon after in Italy.

Here was one of the most important inventions in history, which in the hands of Galileo Galilei, the Professor of Mathematics at the University of Padova, would soon evolve into a high-powered instrument (*occhiale* as he called it) and usher in an unimaginable revolution in science. It transformed our world-view forever. News of the device and Galileo's exciting findings—described in his book *Sidereus Nuncius* (*The Starry Messenger*), published on 12 March 1610—spread more quickly than anyone could have imagined at that time. The term 'telescope' was coined in 1611 by the Greek poet and theologian Giovanni Demisiani (d. 1614) from two Greek words, *tele* (far away) and *skopeo* (to look).

In August 1610 Johannes Kepler (1571–1630) acquired a telescope, and he confirmed Galileo's observations of the Jovian satellites (see van Helpern et al., 2010). In 1611 he went on to propose in his book *Catoptrics* a variation to the optics by using only convex lenses, which would produce an inverted image but give a wider field of view. Based on this innovation, the first astronomical telescope in the true sense was developed by the German Jesuit mathematician Christoph Scheiner (1573–1650) between 1613 and 1617 (Mitchell, 1915: 345). The telescope found favour with astronomers by 1630, but it was only when the English astronomer William Gascoigne (1612–1644) inserted a crosswire in the eyepiece and installed a micrometer (by 1640) that it was transformed into an astronomical measuring instrument.

Early in 1616 Emperor Jahāngīr also came to possess a telescope. One of the most important visitors to the Mughal Empire at that time was Sir Thomas Roe (1581–1644) who came to Jahāngīr's Court as Ambassador of King James I for the years 1615–1619. Sir Thomas landed at Surat in September 1615 and proceeded to have an audience with the Emperor who was then at Ajmer in Rajasthan. Sir Thomas arrived in Ajmer at Christmas and was first presented to Jahāngīr on 10 January 1616 (Wheeler, 1881: 68). Of the many valuable gifts that he had brought to India was a 'spyglass', which he presented to the Emperor (Huff, 2010: 12). A spyglass is actually a small hand-held telescope that extends when pulled out and can be adjusted to the viewer's eye (see Warner, 1998). Sir Thomas' exotic gift apparently did not impress Jahāngīr very much, so he passed it to Āṣaf Khān (the brother of Nūr Jahān and father of Mumtāz Mahal) in his court. This device then joined Khān's collection of other fascinating optical objects, like spectacles and prospective glasses [sic.] that had been purchased from a Venetian merchant in 1616 (Foster, 1928: 83). Although he was a scholar of astronomy (Khan Ghori, 2000: 33), apparently Āṣaf Khān did not realize the astronomical potential of this gift.

However, a telescope was eagerly sought after by a Jesuit missionary in India soon after news of the invention reached Indian shores. We will meet him below, but first let us learn something about the history of the Jesuits in the Indian Subcontinent and in the Far East.

Jesuit missionaries belonged to the 'Society of Jesus', which was founded by St. Ignatius of Loyola, a Spanish soldier, in 1540. Its roots were in Rome, and its purpose was to propagate Roman Catholicism. The Collegio Romano (*Collegium Romanum*) that would become the Society's main scientific centre, was founded by him in 1551, and the present-day Pontifical Gregorian University is the heir to the College. The Society has male members only, called Jesuits. During the sixteenth century, many of the Jesuits were trained in mathematics, geography and astronomy, and they carried the latest developments in European science to their missions worldwide. Missionaries heading for the Far East needed to set sail from Lisbon, with a stopover at Goa, the capital of Portuguese India, and Macao, the Portuguese commercial base further east in China. Voyages from Lisbon to Goa took six months, and Jesuits heading for Macao had to stopover in Goa for a further six months until winds became favourable again.

In due course, the city of Goa became the headquarters to many religious orders, the Franciscans, Jesuits and Dominicans being the main ones, so much so that in 1554–1555 the Portuguese King assigned different parts of Goa to them, namely Baldez (Bardez) in the north to the Franciscans, Salcete in the south to the Jesuits, with the contiguous islands of Divar and Chorão to be shared by the Jesuits and the Dominicans. The Dominicans had come to Goa in 1548, and they soon established houses in various places; the Augustinians arrived much later, in 1575 (de Mendonça, 1958: 80–81). Goa is landscaped with innumerable churches, which are affiliated with various congregations and reflect exquisite architectural splendour. An interesting feature of the Portuguese-style Goan churches built in the sixteenth and seventeenth centuries is that they incorporated certain astronomical aspects in their design. There were sundials for timekeeping, while an east-west orientation allowed sunlight to enter the eastern or western entrances at sunrise or sunset on the day of the equinox or the solstice, or on some other important day (Borkar, 2016).

The first Jesuit mission in India was established in Goa in 1542 under St. Francis Xavier (1506–1552), one of the co-founders of the Society of Jesus. In due course this was followed by more missions, which were established at various places in India, but initially in coastal regions in the south, such as Malabar, Cochin and the fishery coast of Tamil Nadu. However, missions soon spread inland. A member of the mission in Goa from 1606 was the cartographer Giovanni Antonio Rubino (Antonius Rubinus, 1578–1643), who perhaps was the first Jesuit in India to show an interest in astronomy. On 2 November 1612 after learning about the invention of the telescope, Rubino wrote to Christof Grienberger (1561–1636), a Jesuit astronomer at the Collegio Romano and a Galileo sympathizer, asking for astronomical literature and other equipment (Sharma, 1982: 346). This letter makes wonderful reading, as it shows the excitement of the Jesuits to scientific developments and the pace with which the news of these spread. This was at a time when communication with Europe took anywhere from six months to 2–3 years. An English translation of an excerpt from Rubino's letter, originally written in Italian, follows.

> Somebody wrote me from Italy that certain occhiali (eye-pieces) have been invented by means of which objects 15 or 20 miles away are seen clearly and many discoveries have been made in the heavens, particularly in the planets. Your Reverence will do me a great favor by sending me these, together with a little treatise on such occhiali, if there is demonstration of the things one sees by them. But if Your Reverence does not have the occasion or the money to send me these, please send me in writing and in figures, as clearly as possible, the manner of their construction, so

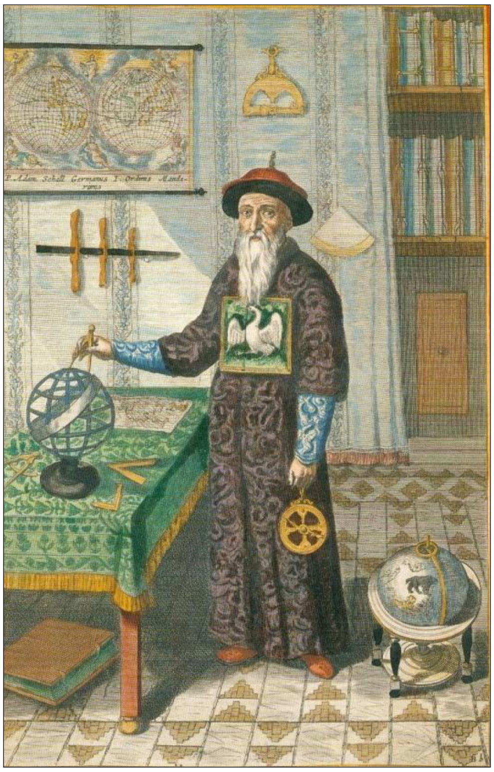


Figure 12: A portrait of Johann Adam Schall von Bell wearing mandarin attire while missionary to China during 1622–1666 and accompanied by an astrolabe, a celestial globe and an armillary sphere (Wikimedia Commons).

> that I may have them made in this land of many officials and abundance of crystals. (Leitao, 2008: 118).

On the basis of this letter, Father Rubino has been credited with introducing the telescope to India (Udias, 2003), but in fact we do not know if his request was successful.

6 OBSERVATIONS OF THE COMETS OF NOVEMBER 1618 BY THE JESUITS IN INDIA

6.1 Father Trigault's Mission to the Orient, with a Passage Through India

In its astronomical column on 24 January 1878 *Nature* carried a contribution titled "The comet of 1618" by an unnamed author stating that the Jesuit astronomer Giovanni Riccioli (1598–1671) had mentioned observations made from Goa, India, by another Jesuit astronomer named Kirwitzer of the comets of 1618. Riccioli taught in Bologna, and is acknowledged for his star catalogue, the book *Almagestum Novum* and a detailed map of the Moon. Wilhelm Olbers (1758–1840) also had received from H.G. Brandes a work by Fr. Kirwitzer which by then had become scarce, about the observations of the second comet of 1618 (The comet of 1618, 1878). Olbers was a German physician and astronomer who discovered Comet 13P/Olbers and the minor planets Pallas and Vesta. He also was the first to devise a suitable method for calculating cometary orbits. However, he is best known in astrophysics for posing the fundamental question "Why is the sky dark at night?", the famous 'Olbers Paradox', that led to great debates in astronomy. In 1821 Olbers wrote to Franz Xaver von Zach (1754–1832) about Kirwitzer's account of the comet, adding that the work he had received from Brandes unfortunately was in too bad a shape due to copying or printing for him to deduce a realistic orbit. One should consult Zach (1822: 369–371) for more on this.

The exchanges above were about the missionary and astronomer Father Venceslaus Pantaleon Kirwitzer (1588–1626), originally from Kadaň in Bohemia (present-day Czech Republic), who first saw the second comet of 1618 on 14 November and noted down his observations. He was joined in the observations on 26 November by the German Jesuit missionary Johann Adam Schall von Bell, S.J. (The comets of 1618, 1878). Fr. Adam Schall (1591–1666; Figure 12) was a mathematician and astronomer, and an expert on calendrical science. Olbers knew that in his work, Zach had stated that fourteen volumes of Fr. Schall's works were available in the library of the Vatican. Believing that these might contain information on the second comet of 1618, Olbers urged Zach to examine that aspect. However, subsequently, a search by Conti revealed nothing of the sort. Further, the paper in *Nature* noted that

> It does not appear that a more accurate copy of Goa observations has been found since Olbers wrote on the subject. There are two works by Kirwitzer in the British Museum, but they afford no assistance. It thus happens that there is as yet no orbit of the comet in question. (The comets of 1618, 1878).

Father Kirwitzer was a member of the *Collegium Romanum* at the time when in May 1611 Galileo Galilei was in Rome to state his case for the Heliocentric vs. Ptolemaic systems. The *Collegium* was then open to the Copernican views and was warm to Galileo. Father Kirwitzer was among a group of missionaries led by Nicolas Trigault (1577–1628) destined for China that included Giacomo Rho (1592–1638), Johannes Schreck-Terrentius (also Terrenz; 1576–1630) and Adam Schall. In April 1618 they set sail from Lisbon aboard the *San Carlos* (Leitao, 2008: 107), and braving the rigours of the voyage, sickness and the death of five of the twenty-two China missionaries, they sailed into Goa on 4 October 1618. The group was carrying a few telescopes and some measuring instruments, along with a large number of books. Incidentally, when he was on tour to Milan in 1616 Terrenz had received a Galilean telescope from Cardinal Federico Borromeo, and eventually he would take this precious gift to China. Along with Terrenz and Adam Schall, Kirwitzer subsequently proceeded to China, setting sail on 15 May 1619 and reached Macao on 22 July 1619 (Zettl, 2008: 29–36). In 1621, Terrenz presented the Emperor with a telescope as a gift (Udias, 1994: 467).

What kind of instruments did the Jesuits bring with them? Baichun (2003) has provided illustrations of several astronomical instruments taken to China by Trigault et al., as well as those that subsequently were made there. One may also refer to Bolt and Korey (2010) for examples of early seventeenth century telescopes, starting with the earliest-known surviving one, which dates to the year 1617 (Figure 13). This consists of a main tube and a number of draw tubes.

In Figure 14 we reproduce the sketch of a Galilean telescope that Fr. Adam Schall drew in his book *Yi Hai Zhu Cen* (*Pearl Dust of Artistic Sea*). The inscription says “Compiled by Tang Ruowang”, which was his Chinese name, and his preface is dated 1626. The book is about astronomy, and discusses Galileo’s findings on the Solar System and the Milky Way made with such a device. It also delves into general optics, optics of concave and convex lenses and their combinations, and the making and use of telescopes. The telescope that is illustrated has an altazimuth mount; recall that telescopes with equatorial mountings lay in the future.

Christoph Scheiner, who had been using an altazimuth-mounted telescope to follow sunspots, found it difficult to follow them properly, so on a suggestion from his brother Christof Grienberger, he constructed what is regarded as the forerunner of the equatorial mounting. With it Christoph Scheiner was able to observe sunspots and determine their position and motion conveniently and with precision. As outlined in the *Rosa Ursina* (1630), his great work on sunspots, Scheiner put the device to use from 4 March 1627 (Mitchell, 1916: 347–348; Woods, 2005: Chapter 5).

6.2 Father Kirwitzer’s Treatise on his Observations

Father Kirwitzer presented a detailed description of his observations of the spectacular comets that first appeared in the morning skies in November 1618 in a monograph titled *Observationes Cometarvm Anni 1618. In India Orientali Factae a Societatis iesv Mathematicis in Sinese Regnum Nauigamtibus ex Itinere eo Delatis* that was published in 1620 (Figure 15).

The treatise is short, consisting of 24 pages only and signed *ex* “Goæ in India Orientali 11. Febr. 1619.” In his *Preface*, Fr. Kirwitzer refers to being assigned to India by Muzio Vitelleschi

Figure 13: The world’s oldest-known surviving telescope, which is securely dated to 1617, is now in the Kunstgewerbemuseum/Staatliche Museen zu Berlin. The maker is unknown. This cloth and paper telescope comprises a main tube, and five draws of pasteboard. Each draw is covered in marbled paper. The end tube and ring stops are in silk velvet embroidered by gold thread. When collapsed the end tube and rings have a common outer diameter of 48mm (after http://dioptrice.com/telescopes/782).

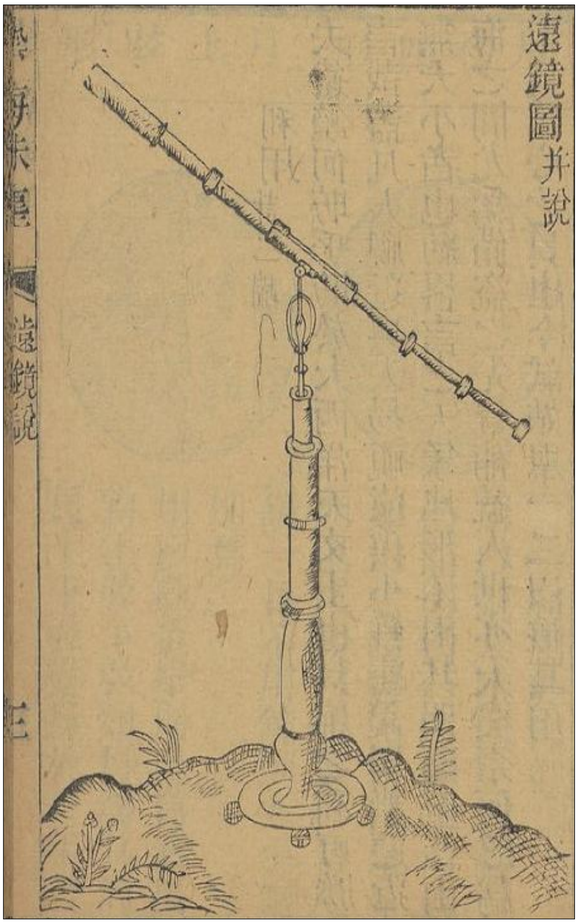
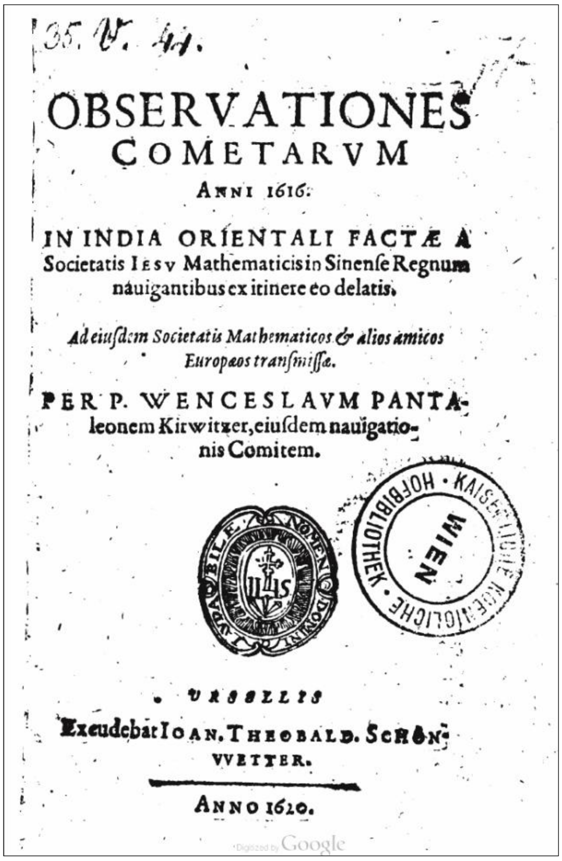


Figure 14: A drawing of a Galilean telescope by Adam Schall (after World Digital Library http://www.wdl.org/en/item/11434/).



35. V. 44.

OBSERVATIONES
COMETARVM
ANNI 1618.

IN INDIA ORIENTALI FACTÆ A
Societatis IESV Mathematicis in Sinenſe Regnum
nauigantibus ex itinere eo delatis.

Ad eiuſdem Societatis Mathematicos & alios amicos
Europæos tranſmiſſæ.

PER P. WENCESLAVM PANTA-
leonem Kirwitzer, eiuſdem nauigatio-
nis Comitem.

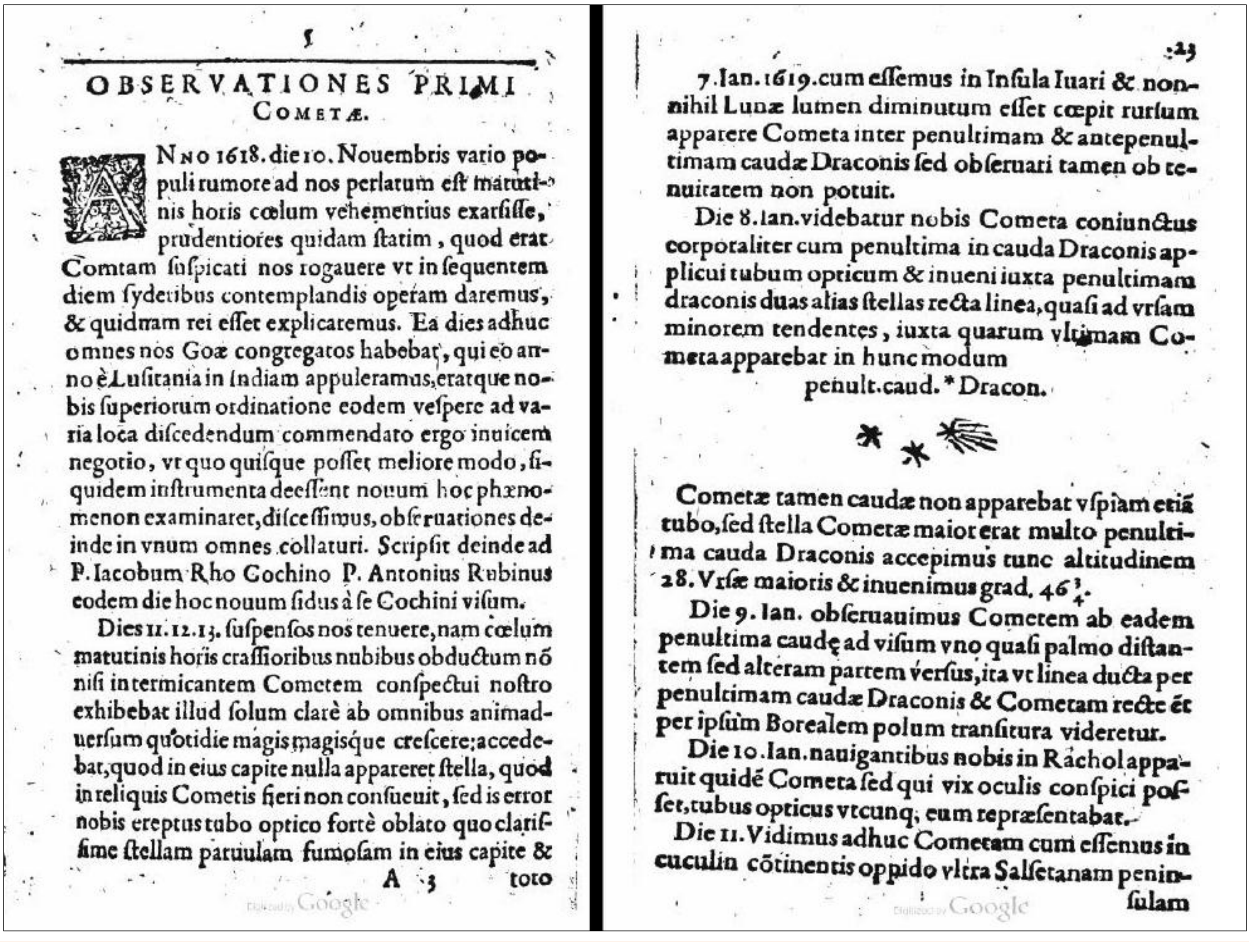
ASCHAFFENBVRGI.
Excudebat IOAN. THEOBALD. SCHÖN-
WETTER.

ANNO 1620.

Figure 15: The cover page of Fr. Kirwitzer's treatise, which was digitized in 2014 by The Austrian National Library (after Google Books).

(1563–1645), the Sixth General of the Society through 1615–1645, to bring the light of the Gospel to the great Empire of the Chinese. Fr. Kirwitzer (1620) also mentions how fellow Jesuit astronomers met with very unkind circumstances (also see Golvers, 1992: 391).

The significance of Fr. Kirwitzer's treatise lies in the fact that it reports the first-ever modern astronomical observations carried out in India and the first-ever use in India of the telescope for astronomical observations, soon after its introduction in Europe (see Figure 16). Hereinafter, the description closely follows certain relevant parts of the treatise, and we cite the dates just as given in the treatise. These match the dates given in *Nature* (The comets of 1618, 1878) and also agree with the chronology presented in the *Tūzūk-i Jahangīrī*. We shall return to this topic in Section 7.2, where we investigate the dating conventions then in use. In the following account, references to the 'first comet' and the 'second comet' refer specifically to the November 1618 comets, just as Fr. Kirwitzer described them (i.e. to Comet 1618 III and 1618 II respectively).



5

OBSERVATIONES PRIMI
COMETÆ.

ANNO 1618. die 10. Nouembris vario populi rumore ad nos perlatum eſt matutinis horis cœlum vehementius exarſiſſe, prudentiores quidam ſtatim, quod erat Cometam ſuſpicati nos rogauere vt in ſequentem diem ſyderibus contemplandis operam daremus, & quidnam rei eſſet explicaremus. Ea dies adhuc omnes nos Goæ congregatos habebat, qui eo anno è Luſitania in Indiam appuleramus, eratque nobis ſuperiorum ordinatione eodem veſpere ad varia loca diſcedendum commendato ergo inuicem negotio, vt quo quiſque poſſet meliore modo, ſiquidem inſtrumenta deeſſent nouum hoc phænomenon examinaret, diſceſſimus, obſeruationes deinde in vnum omnes collaturi. Scripſit deinde ad P. Iacobum Rho Cochino P. Antonius Rubinus eodem die hoc nouum ſidus à ſe Cochini viſum.

Dies 11. 12. 13. ſuſpenſos nos tenuere, nam cœlum matutinis horis craſſioribus nubibus obductum nō niſi intermicantem Cometem conſpectui noſtro exhibebat illud ſolum clarè ab omnibus animaduerſum quotidie magis magiſque creſcere; accedebat, quod in eius capite nulla appareret ſtella, quod in reliquis Cometis fieri non conſueuit, ſed is error nobis ereptus tubo optico fortè oblato quo clariſſime ſtellam paruulam fumoſam in eius capite &

A 3 toto

23

7. Ian. 1619. cum eſſemus in Inſula Iuari & nonnihil Lunæ lumen diminutum eſſet cœpit rurſum apparere Cometa inter penultimam & antepenultimam caudæ Draconis ſed obſeruari tamen ob tenuitatem non potuit.

Die 8. Ian. videbatur nobis Cometa coniunctus corporaliter cum penultima in cauda Draconis applicui tubum opticum & inueni iuxta penultimam draconis duas alias ſtellas recta linea, quaſi ad vrſam minorem tendentes, iuxta quarum vltimam Cometa apparebat in hunc modum

penult. caud. * Dracon.

Cometæ tamen caudæ non apparebat vſpiam etiā tubo, ſed ſtella Cometæ maior erat multo penultima cauda Draconis accepimus tunc altitudinem 28. Vrſæ maioris & inuenimus grad. $46\frac{3}{4}$.

Die 9. Ian. obſeruauimus Cometem ab eadem penultima caudę ad viſum vno quaſi palmo diſtantem ſed alteram partem verſus, ita vt linea ducta per penultimam caudæ Draconis & Cometam recte ēt per ipſum Borealem polum tranſitura videretur.

Die 10. Ian. nauigantibus nobis in Rāchol apparuit quidē Cometa ſed qui vix oculis conſpici poſſet, tubus opticus vtcunq; eum repræſentabat.

Die 11. Vidimus adhuc Cometam cum eſſemus in cuculin cōtinentis oppido vltra Salſetanam peninſulam

Figure 16: Pages 5 (left) and 23 (right) in Fr. Kirwitzer's book, which discuss his observations of the two bright comets that appeared in November 1618. Both pages mention that a telescope was used for viewing the comets (after Google Books).

In the *Præfatio*, Fr. Kirwitzer (1620) states that he was not prepared to make any observations when two bright comets suddenly appeared in the sky in the early morning hours. His first record is dated 10 November where he says that many people from the locality approached him to tell him about and seek an explanation for this strange apparition in the sky. Fr. Kirwitzer suspected that it was a comet, and he told everyone that he would explain about it on the following day after first observing it. He also felt that if it was to be examined the new phenomenon demanded suitable instruments, and that it warranted a joint effort with others, so the very same day he wrote to Fr. Jacobus Rho and to Fr. Antonius Rubinus at Cochin, 660 kilometres south of Goa, about the newcomer. Unfortunately, at that time their baggage was still on the ship, and no instruments or books were to hand, but later this would change.

6.3 The Jesuit Observing Sites

Where in Goa and Cochin were the Jesuits stationed?

In the sixteenth century Goa (Figure 17) initially was an important centre of long distance trade, but it soon became the political, cultural and religious 'central engine' of Portuguese India. The activities of all the religious orders that arrived in India in quick succession to spread the Christian faith received the backing of the Portuguese Government. The Jesuits, who were in Goa from 1542, developed an economic framework and acquired land and houses so that they could continue their mission to spread the faith and pursue scientific interests. In his treatise Fr. Kirwitzer refers to a few places from which the Jesuits made astronomical observations. One named Rachol (pronounced Rashol) is mentioned as being 5 leagues from Goa (i.e., Old Goa). It is a town on the Salcete Peninsula south of Panjim (now Panaji) and 7 kilometres north-east of Margao. The Portuguese occupied Salcete in 1543, and they fortified Rachol and placed Salcete in the care of the Jesuits. The Jesuits took up residence in a small house in Rachol where the present-day parish church is situated. Rachol has been home to the Patriarchal Seminary of Rachol since 1610, which was built by the Jesuits atop a small hillock. With the passage of time the Seminary evolved into a multipurpose institution (see Patriarchal Seminary of Rachol, 2016).

As for his own location, Fr. Kirwitzer writes of being at 'Insula Ivari' and sometimes at 'S. Paul'. Insula Ivari must be Divar Island (Figure 18), which is in North Goa 10 km north of Panjim, and was among the first places in Goa that the

Figure 17: An 1719 pictorial map of Goa by Pieter Boudewyn van der Aa (1700–1750), Divar Island is in the middle of the lower half of the image and Chorão Island is to its right; the Mandovi River flows from left to right into the Arabian Sea (adapted from British Library Online Gallery http://www.bl.uk/onlinegallery/ onlineex/apac/other/019pzz000002417u00000000.html).

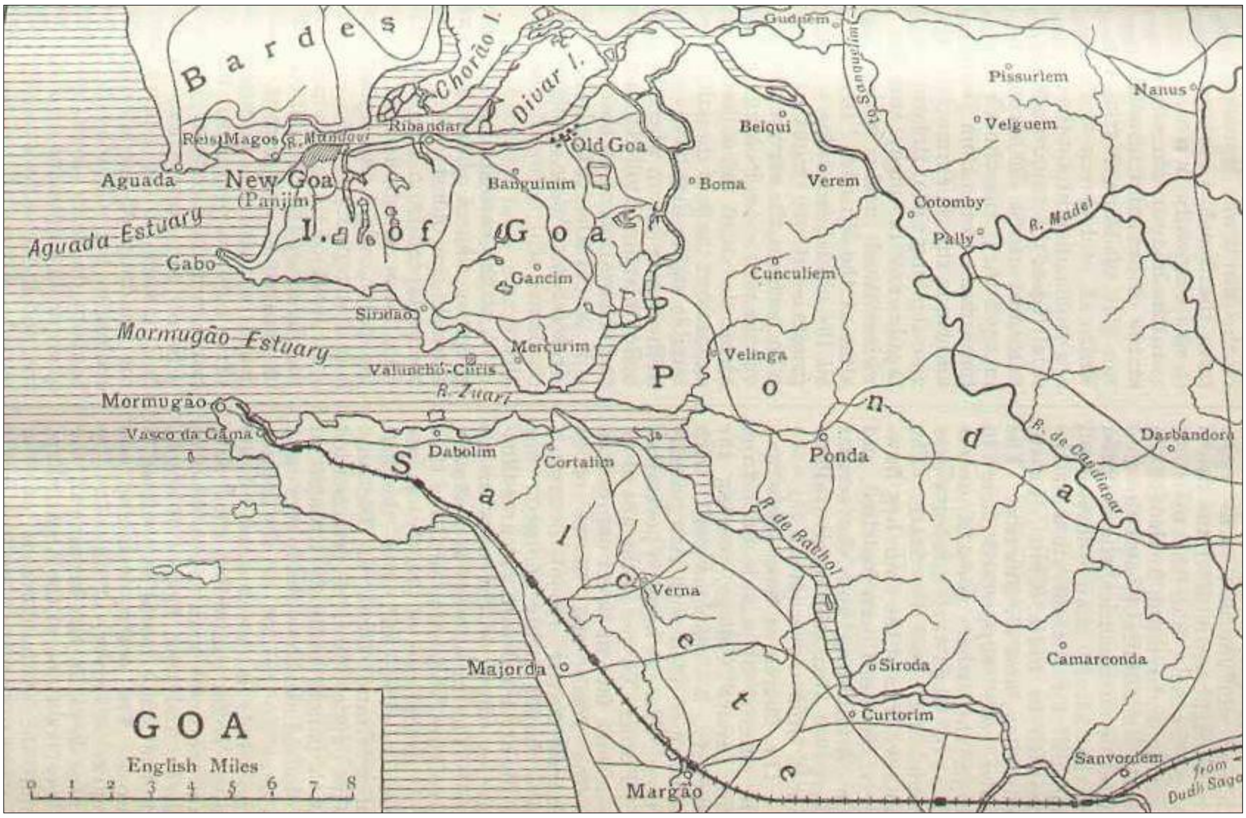


Figure 18: A map showing the Island of Goa, 'Old Goa' (centre, near the top) and above it Divar Island (after Poyntz, 1924).

Portuguese strove to spread the Catholic faith. A major portion of the island is rather flat and thickly forested, with a 49-m high hillock. At the base of the hillock is a Goan village named Piedade. On the hilltop is the Church of Our Lady of Piedade that was founded in 1541 and was rebuilt in 1625 (Lourenço, 2005: 158). The hilltop, which overlooks Old Goa, may have served as an observation point. The Mandovi River surrounds Divar Island, and the Jesuits used canoes to reach the island.

'S. Paul' would be the famous New College of St. Paul in Old Goa, east of Panjim. On the other side of the Convent of St. Augustine, it was situated on the western slopes of the hill, overlooking Divar Island. The New College was an institution of higher learning in theology, philosophy and many other disciplines. This magnificent four-storeyed building was greatly admired for its vastness and architecture. It was erected on the ruins of a house on the hill of Nossa Senhora de Rozario that the Jesuits had acquired in 1578. Initially it was known as the Convent of St. Roch, but in 1610 was changed into a college and given the name New College of St. Paul (for details see da Fonseca, 1878: 315–320), to distinguish it from an older College of St. Paul. The latter, with its church, was completed in 1542 and has been described as

> … the chief institution of the disciples of Loyola in India, to which more than three hundred churches with their colleges in different parts of Asia were subject. (da Fonseca, 1878: 262).

It is worth mentioning that the first printing press in India was introduced by the Jesuits, in Goa in 1556, at the colleges of St. Paul and Rachol (da Fonseca, 1878: 58). Because of an epidemic in 1570 that afflicted those in this locality, including 58 priests, in 1578 the Jesuits decided to move to a new house in a healthier location so that they could more effectively care for their sick. Activity at the Old College then reduced, although it remained the prime institution of the Jesuits for some time (da Fonseca, 1878: 264). All that remains today of the New College of St. Paul is a magnificent gateway on a small road south of St. Cajejan's Church in Old Goa (Figure 19). A sign board describes this as the Arch of Conception. Fr. Kirwitzer mentions S. Rochi a few times in his treatise.

After Goa, Cochin became a stronghold of the Catholic faith. The residence of the Society of Jesus was erected in Cochin in 1550 and the College of Mother of God (*Madre de Deus*) and the Seminary were established in 1560. Later, both grew to become major cultural centres. Fr. Antonius Rubinus, who carried out the astronomical observations in Cochin, probably was based here, although there is no corroborating evidence for this.

6.4 The Instruments Used by the Jesuits

Fr. Kirwitzer records in detail what the observers saw and measured, namely, the altitude and aziimuth of the comet; its angular distance from stars like Spica etc. in *grad* (degrees). He also reports the observers' visual impressions, sometimes gained with difficulty because of illumination by the Moon or sunlight. The observations are presented systematically and are divided into two sections for each comet, incorporating those by brother-priests at the other Jesuit establishments.

In those times, astronomers observed the position and direction of the tail, and they determined the position of the comet with respect to many nearby fixed stars whose positions were already known. The main objective was to determine the position of the comet on the ecliptic, and its motion. Whilst indicating the positions, Fr. Kirwitzer also refers to *informi* (unformed), which are field stars that at that time had not been grouped into designated constellations.

Astronomical instruments that these Jesuits were able to access were an astrolabe (*astrolabium*) and an astronomical radius or cross-staff (*radium astronomicum*) belonging to Goa College. A cross-staff consists of a staff with a smaller, sliding transverse arm, generally made of wood but sometimes of brass, and bearing a scale that could be read directly in degrees. One measured altitudes and angular separations between two objects by pointing it at the object and moving the transversal arm until the angle was covered. The cross-staff was introduced by the Portuguese in the mid-sixteenth century as an aid to navigation. The earliest depiction of the device that I have located is in the 1552 work on navigation, *Regimento de Navegacion* by Pedro de Medina (Figure 20; see Goldstein, 2011 for details). Even Tycho Brahe (1546–1601) used one. The instrument was handy for seafarers and astronomers of the time even though viewing added to errors that limited the precision. Notably, the measurements given by Fr. Kirwitzer were to a fraction of a degree, or minutes of arc. At this time, astronomers determined time by measuring the altitude of the Sun or Moon or a bright clock-star that they then reduced to local time by using astrolabes and astronomical tables.

Finally, these were not the only astronomical instruments that Fr. Kirwitzer and his colleagues used. Most importantly, a telescope (*tubo optico*) also was used by him to view the comets.

6.5 Observations of the First Comet of 1618 (i.e. 1618 III)

As Fr. Kirwitzer writes, dark clouds that were present before sunrise on 11, 12 and 13 November prevented them from making any observations, but providence intermittently showed the comet growing day-by-day. Fr. Kirwitzer looked for a star in the head as was typical of comets, but found none. However, when he used the telescope it clearly revealed a star, with a little 'smoke' in the head that appeared pale in colour. The comet's form was best described as like a palm leaf, and it stretched as a straight smoky column from the east to the midst of heaven, with the tip a little turned to the north.

Figure 19: The Arch of Conception in Old Goa (photograph: R.C. Kapoor, 24 February 2016).

For this comet, the observations extend from 10 to 30 November, with no observations possible on 19, 20, 22 and 25 November due to clouds.

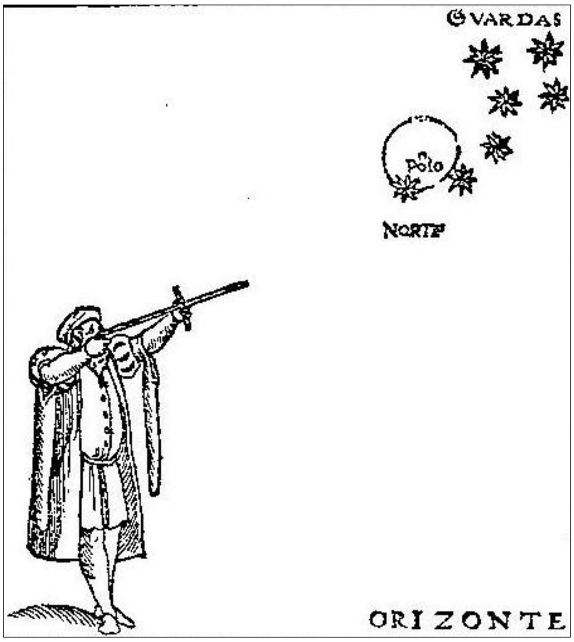


Figure 20: The cross-staff, as depicted in Pedro de Medina's 1552 treatise *Regimento de Navegacion* (Wikimedia Commons).

The date 10 November is included here since the mysterious object was first noticed that morning and Fr. Kirwitzer (rightly) suspected it to be a comet. Observations were made by Fr. Kirwitzer at Divar Island and at S. Rochi and by Fr. Jacobus Rho at Rachol and at S. Rochi. Fr. Rho used a cross-staff for his measurements. The altitude and azimuth of the comet and the first magnitude star Spica (*Alpha Virginis*), along with the length of the comet's tail, were given to the fraction of a *grad*. At times, there is reference to the constellations of Corvus, Crater, Hydra, Crux and Centaurus, with information about how the angles to these varied. On page 7 in the treatise, Fr. Kirwitzer depicts the position of Comet 1618 III on 17 November with respect to two nearby stars (which, unfortunately, are not readily identifiable). Nowhere does Fr. Kirwitzer mention the time when the observations were made, even though he refers to "… the clock of our College …"

Detailed observations began on 14 November. At Rachol that morning the altitude of the comet was recorded as 11°, the horizontal distance to the sunrise position as 14°, while at the same time *canicula* (Sirius) was 44° above the horizon. We take the word *ab ortu* in the text, the reference point for azimuth, to mean the point of 'sunrise', not east. On 15 November, Fr. Kirwitzer refers to the use of star charts:

> The comet was near the same horizon 5 degrees, but 17 degrees from sunrise. The tail ran until the second star of the *Corvi* in the right wing, counting the stars in the celestial constellations, according to the figures published by P. Christopher Gruenberger [*sic*], famous mathematician of our Society. In fact, they were on hand for the event outside of the luggage and of which we made use throughout the duration of our observations.

Christopher Grienberger (1561–1636; MacDonnell, 2014) was an Austrian Jesuit and Professor of Mathematics at the Collegio Romano. His acclaimed work on the constellations, *Catalogus veteres affixarum Longitudines, ac Latitudines conferens cum novis. Imaginum Caelestium Prospectiva duplex ...*, was published in 1612. It was illustrated, and contained astronomical tables and maps relating to 21 numbered northern constellations, 12 zodiacal constellations and 15 numbered southern constellations. It also included the new northern constellations of 'Antinous' and 'Berenices Crinis'; these, however, were not numbered (see Stoppa, 2016). These new constellations were first added to the existing 48 Ptolemaic constellations by the cartographer Casper Vopel (1511–1561) in 1536, but Antinous was later abandoned (ibid.). Fr. Kirwitzer uses the term 'Crines Berenices' several times in his treatise when describing the location of the second comet. Figure 21 depicts the constellation of Draco (numbered 3) as in the *Catalogus* …

On 26 November, Fr. Adam Schall joined Fr. Kirwitzer in observing the comet from Divar Island while Fr. Rho observed it on the 27th from Goa. The observing campaign continued until 30 November. From that day, "… the light of the moon obscured the comet and we could not observe it more." Fr. Antonius Rubinus' first measurement of this comet from Cochin was made on 28 November, when he noted a tail 40° long and a maximum width of ~3°. His last measurements were on 18 December when he noticed that the tail had increased in length from an initial 25° to 44°.

The word '*canicula'* mentioned in the observation of 14 November refers to the Dog-star (Sirius). On 14 November 1618 at Rachol (15º 18′ 29″ N, 74º 00′ 19″ E), this (precessed) star reached an altitude 44º at 00:20 UT (sunrise was at 01:08 UT). The Sun's altitude at this time was –11.38º, and the comet's apparent position, computed with the Horizons system, suggests that its altitude at that time was 4.3º. However, this does not agree with the observed value. In the Section 7.2, we shall discuss the convention of time-keeping in those days. For the moment, if we take 15 November as the first date of the measurements, then at 00:16 UT when Sirius reached an altitude of 44º, the comet was 7.7º high and the Sun was at an altitude of –12.4º. On both dates, the comet was found further away from the Sun than its orbital elements suggested. Similarly, the comet's elongation from Spica as measured by Fr. Rho with the cross-staff on 18 November, while at S. Rochi, was 15.30 *grad*, but with the Horizon's system we have the two separated by 11.6º that morning.

6.6 Observations of the Second Comet of 1618 (i.e. 1618 II)

In the second section of the treatise, Fr. Kirwitzer begins with:

> On 24 November this comet was visible from Divar Island in the dawn sky before sunrise. Its nucleus was obvious and comparable to Venus, and it had a short tail. Meanwhile, a straight line from Arcturus to Mars passed through the comet's nucleus, and the distance between Arcturus and Mars was three times that between the comet's nucleus and Mars.
>
> On the same day, Fr. Joannes Terrentius saw the comet from the fields of Rachol College. The next day before the sunrise, Fr. Kirwitzer and many other Jesuits saw it clearly, and it already had a longer tail. They also admired the sky, which was filled with many new stars Fr. Rho at S. Rochi, Goa, first noticed the comet on 25 November, and Fr. Antonius Rubinus in Co-

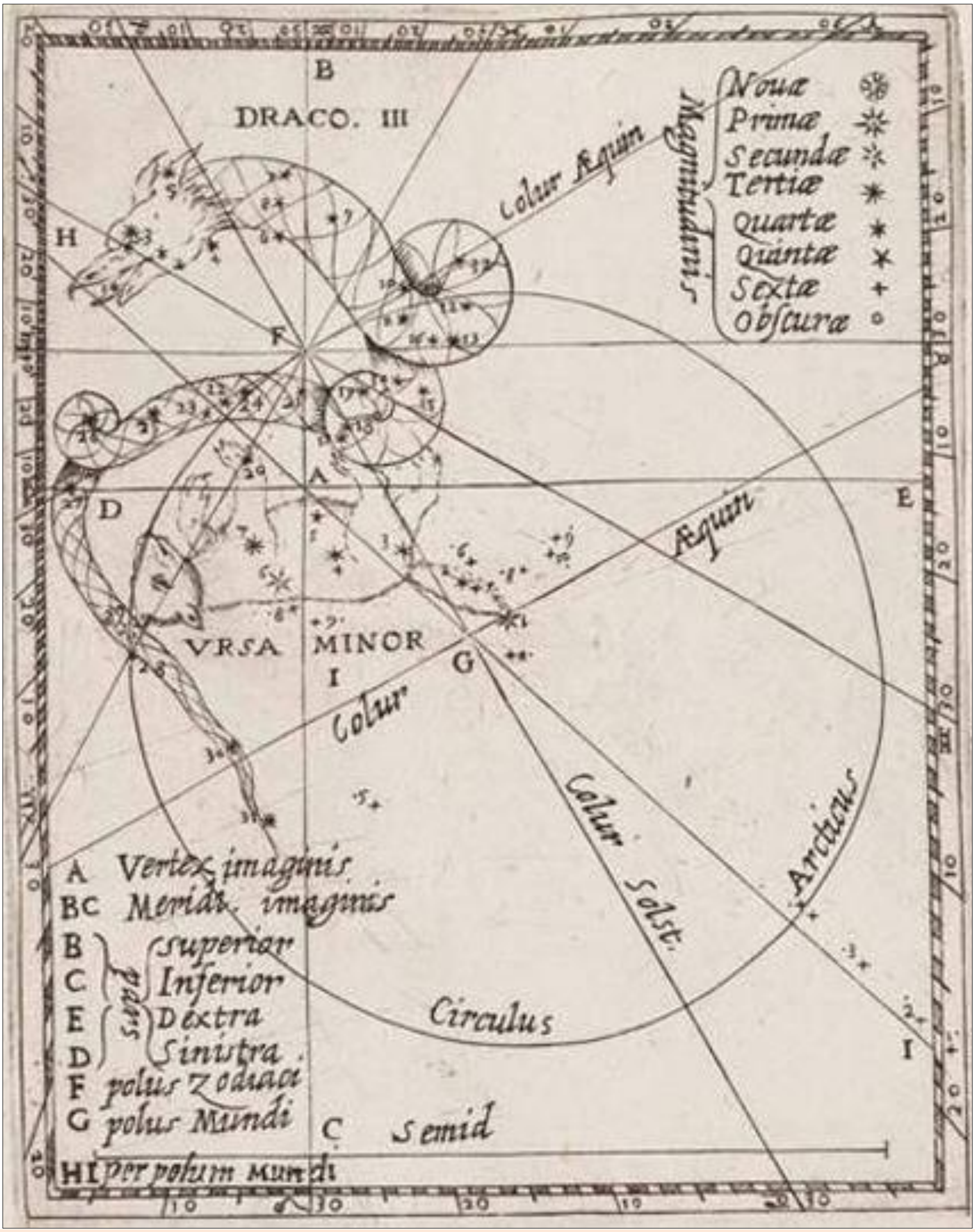


Figure 21: The constellation of Draco as depicted in Christopher Grienberger's *Catalogus … 1612* (after Stoppa, 2016).

chin saw it first on the 26th. Fr. Kirwitzer writes:

> While we watch the new comet, it appears to us in the East, another very bright star not much different from Venus, similar in color and magnitude, consider this not a little confusion many bore.

Venus was then the 'Evening Star' while Mercury was visbile in the morning sky, and confusion arose because it was close to the comet. Fr. Kirwitzer sought to explain this by quoting the *Prutenic Tables* (see below) wherein on that day Mercury was at 14º in Scorpio. The comet's magnitude was definitely much brighter than Mercury so there was no doubt about its identity.

On 26 November, Fr. Rho observed the comet from Goa as a bright object, with a tail ~2º long and similar to a beard. Its right ascension was 225° and declination –11°, and it was "… in the sign of Sagittarius …" and nearly 29.12° from Spica. The phrase *"…* in the sign of Sagittarius …" (my English translation) does not quite fit as that constellation was not even up, unless it refers to the Sun that actually was in Sagittarius at that time. Just to illustrate this, on 26 November at 00 UT the Horizons system gives the comet's right ascension as very close to 225º but with the declination at –17.35º. As per the calculation, at that time the comet had just risen and Mercury was 2º above the horizon and about 3º from the comet. Meanwhile, Spica (precessed) was 27.9º from the comet, close to the value Fr. Rho noted down.

From 28 November 1618 two sets of observations for each comet were being taken from a given location, and the comets were observed together until 30 November. The Jesuits continued to make angular measurements of Comet 1618 II until 12 January 1619, but from the end of December they could not observe it because of the bright Moon and they only recommenced their observations on 7 January. Angular distances from the comet to Mercury, Mars, Spica, Arcturus and certain stars in Crux, Corona Borealis, Ursa Major and Minor, Draco, Coma Berenices also were measured. On 7 January 1619 while Fr. Kirwitzer was on Divar Island the light of the Moon somewhat diminished and he noticed that the comet was positioned between the penultimate and ante-penultimate stars in the tail of Draco, though it could not be easily observed because it was too faint.

On 8 January 1619 the comet seemed to be joined to the penultimate star of the tail of Draco. Upon viewing it through the telescope Fr. Kirwitzer found two new stars near the penultimate star of Draco directed towards Ursa Minor, and the comet appeared close to one of these, as depicted on page 23 in his treatise (see Figure 17, where the comet's tail extends to the right from a star-like nucleus). At this time the comet's tail was not visible in the telescope, but the 'star' in the nucleus seemed much brighter than the penultimate star in Draco's tail. The apparent position of the comet computed with the Horizons system suggests that it was only 0.5° away from the star κ Draconis (precessed), and, just as stated in the treatise, the two new stars are nearly on a line directed towards Ursa Minor. Further observations were made with the telescope on 10 January (Kirwitzer, 1620: 23).

The *Prutenic Tables* that Fr. Kirwitzer refers to are an ephemeris that was prepared by the astronomer Erasmus Reinhold (1511–1553) in 1551 to compute planetary positions, eclipses, phases of the Moon etc., based on Copernicus' Heliocentric Model of the Universe as portrayed in *De revolutionibus Orbium Coelestium*. The tables helped to substantiate the Copernican model but as circular orbits were used, accuracy was limited. Elliptical planetary orbits were introduced in Kepler's *Rudolphine Tables* in 1627, which enabled one to compute solar and planetary positions in the sky for any date. It was the *Rudolphine Tables* that led to the prediction and successful observations of the transits of Mercury and Venus in the years to come.

Inclined towards astronomy as the Jesuits were, one wonders if anyone noticed the Leonid meteor shower earlier in the month, which would have peaked on about 8 November (in 1618). Dick (1998: Table 1) has shown that the Leonids can be traced back to 902 CE, while Table 1 in Brown (1999: 289) provides details of Leonid showers between 1799 and 1999, where a shift by three days in the epoch of the peak every hundred years can be easily noticed.

6.7 Fr. Kirwitzer's Concluding Remarks

Althrough Fr. Kirwitzer's treatise contains observations and descriptions of the two comets, there is no theorizing about comets or where they belong in the Universe. While summing up, Fr. Kirwitzer (1620: 24) notes that

> For a fuller understanding of those observations, it remains to make known the true longitude and latitude of the places where the observations have been made. However, we have not seen yet any lunar eclipse and from others nothing we learned that we can accept with confidence, so we will work diligently in order that no latitude and longitude of this or other places of Asia remains unknown. In the meanwhile we will respond to this lack and any other: we will rely on Johannes de Barros, the prince of Portuguese Historians.

In fact, a lunar eclipse did take place on 31 December 1618. However, it was penumbral, but with the shadow over India. Whether the Jesuits were aware of this up-coming eclipse is not clear, although among them was Fr. Adam Schall who, years later in Macao, would determine the precise details of the lunar eclipses of 8 October 1623 and 9 September 1624 (Udias, 1994: 467). As we know, eclipse and certain other records were used by astronomers to refine eclipse computations and determine longitude differences between the places of observation of the predicted eclipses.

In the indented quotation presented above, Fr. Kirwitzer refers to 'Johannes de Barros'. João de Barros (1496–1570) was the Portuguese Royal Historian, and he is best known for his multivolume classic *Décadas da Ásia*, which was published in 1552 and describes the early history of the Portuguese in India and in Asia. Fr. Kirwitzer quotes from his work a solar eclipse that was seen in Cochin

> … in the Year of Christ 1506, 13 January, series 4, the time prior to the second half and it was so clear that although it was daytime we saw the stars.

In fact, there *was* an eclipse on 13 January, but in 1507, and it was annular and not total. The path of annularity passed across Sri Lanka, not India, and from Cochin it was a partial eclipse with a magnitude of 0.83 (see eclipse predictions by Espenak, 2015), which was too bright to show stars in the daytime (except possibly for Venus at maximum eclipse, and only if one looked hard for it). However, Fr. Burke-Gaffney (1944: 127–128) adds an interesting dimension to this eclipse reference:

> In 1618 Remus wrote to Kepler that he had heard from Father Schreck that when Venus was observed in conjunction with the moon on June 6, 1617, it was further from the moon than Kepler predicted. "This observation," Father Schreck wrote from Lisbon, "was made by Father Lembo, who is now in Naples, and by Father Pantaleon, who is sailing with me to China." Father Pantaleon's full name was Wencelas Pantaleon Kirwitzer; in his signature, he omitted his surname. He, too, was a bit of a thorn in Kepler's side. He wrote to Father Ziegler (who was European Procurator for the Chinese Mission), from Goa, in February, 1619, saying that he had seen a comet in India, and, going back a hundred years, telling of an eclipse seen in Cochin on January 13, 1507. It was this eclipse which bothered Kepler. He was not sure of the facts. Father Kirwitzer's authority was Joao de Barros's *History of the Portuguese in India*. Kepler had not heard of de Barros or his history. In his *Rudolphine Tables*, he harped back on the possibility of the eclipse reported by Father Kirwitzer.

As for the Venus-Moon conjunction, it really was on 6 June 1617, when the two bodies came within 16′ of each other at around 19:30 UT. It would be interesting to find out what kind of difference was noted by Fr. Kirwitzer from the prediction in Kepler's *Ephemerides Joan. Kepleri annorum 1617, 1618, 1619 et 1620*. The ephemerides appeared in 1617, and were more accurate than any other astronomical tables available at that time.

7 FATHER CRISTOFORO BORRI'S WORK

7.1 Fr. Cristoforo Borri on the 1618 Comets

In the Indian part of the story of the comets of 1618 we also must refer to Father Cristoforo Borri S.J. (1583–1632). He was an Italian Jesuit missionary known for his magnetic observations in Asia (that came to provide an ingenious way of determining longitudes) and astronomy, as acknowledged by his peer Athanasius Kircher (1602–1680), himself an acclaimed mathematician and astronomer (Dror and Taylor, 2006: 40). Borri entered the Society of Jesus in 1601, and could speak Latin and Portuguese with ease. He left Lisbon in April 1615 for Macao, stopped over at Goa for six months, and arrived in Macao in 1617. The mission soon faced unfavourable circumstances, and he moved to Cochin-china (the southern region of Vietnam). It is from here that he observed the two bright comets of 1618. Unfortunately for him, Fr. Borri could not adapt to the local circumstances, so he decided to return to Europe. He went to Macao in 1622, and later that year left for Goa. He stayed in Goa until February 1624, when he eventually set sail for Lisbon, together with Garcia de Silva y Figueroa (Dror and Taylor, 2006: 42).

While he was in Goa in 1623, Fr. Borri befriended a well-to-do and knowledgeable Roman nobleman, Pietro della Valle (1586–1652), who had travelled far and wide and knew many languages. The celebrated traveller described Borri as a great mathematician who shared with him the Tychonic worldview and also his own perception on the three heavens. Fr. Borri had been developing his theory of tenuous heavens and recorded his views and observations in a book. An impressed Pietro translated this work into Persian in 1624, with the title *Risalah- i Padri Khristafarus Burris Isavi dar tufiq-i jadid dunya* (*Compendium of a Tractate of Father Christoforo Borri Giesuita on the New Model of the Universe according to Tycho Brahe and the Other Modern Astronomers*—see Figure 22). Later, in 1631, he was in Rome and he proceeded to translate Borri's work into Italian: *Compendio di un Trattato del Padre Christoforo Borro Giesuita della Nuova Costitution del Mondo secondo Tichone Brahe e gli Altri Astologi Modern*.

This book is preserved in the Vatican Apostolic Library (*Vat. pers. 10 fols. 7 recto - 6 verso orient18 IGH.06;* http://www.ibiblio.org/expo/vatican.exhibit/overview.html) and carries a depiction of Tycho's hybrid Universe with the planets revolving around the Sun and the Sun round the Earth. A few comets in orbits are depicted too, with tails pointing away from the Sun to demonstrate that comets could not be carried by the crystalline spheres. According to Fr. Borri, the book was well received by scholars in Persia, Armenia and Arabia. He also refers to his observations of the two comets of 1618 in a letter to Mutius Vitelleschi, General of the Society of Jesus, stressing that his precise observations substantiate

> … the tenuousness and corruptibility of the Heaven, which I already in Europe demonstrated for the sake of modern observations. This phenomenon was observed not only by myself but also by Father Giovani Vremano in China, and Father Manuel Dias in India …

and by mathematicians in Europe (Dror and Tay-

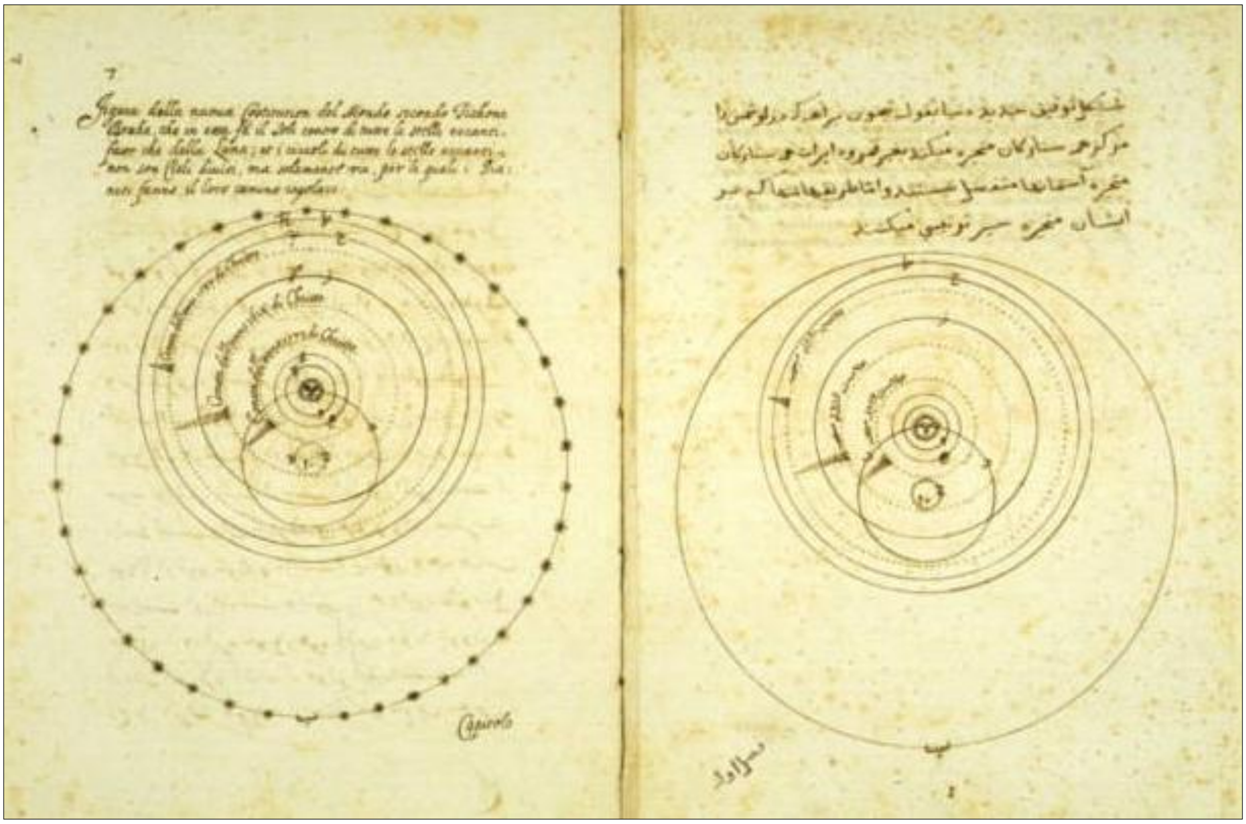


Figure 22: Two pages from the Italian version of Pietro della Valle's (1631) book (Adopted from the Library of Congress exhibition 'Rome Reborn: The Vatican Library & Renaissance Culture'; http://www.loc.gov/exhibits/vatican/images/orient18.jpg; accessed 30.11.2015).

lor, 2006: 40). Fr. Borri (op. cit.) was confident of his precision, which according to him provided "… the unique proof of truthfulness of observations, when it is found in different territories and countries, far from each other." Fr. Borri had received accounts of observations of the first comet made by the Jesuit astronomer Vremano (Jan Wremann; 1583–1621) from Macao, and by Fr. Emmanuel Diaz (Manuel Dias) of the Society of Jesus and a Portuguese philosophy professor who according to Borri had observed the first comet from the city of Cochin in India. In these accounts, the Jesuits concurred with Borri about the comet: that it was undoubtedly a celestial phenomenon (Borri, 1631: 116; Carolino, 2007: 190). Fr. Borri refers to this communication in his 1631 work *Collecta Astronomica ex Doctrina*, where he speaks of the first sighting of the comet on 9 November (Borri, 1631: 115; my English translation): it "… started to appear on 9 November and lasted up to 22 December …" This date for the first sighting account needs revision—see Section 7.2 below. Fr. Borri (ibid.) does not refer to an evening sighting, and he states that the comet was in Libra and Virgo, and with the Sun in Scorpio this would have to be a morning observation. There are no further details provided, and Fr. Borri quickly focuses his discussion on the comet's position in the sky with respect to the Moon.

From his parallax estimations derived from triangulation calculations of the observations of the comets of 1618, Fr. Borri argued that comets were located far beyond the Moon, which immediately cast doubt on the impervious nature of the celestial spheres. Borri thus tried to combine mathematical astronomy and canonical cosmology, fruitfully using it in carrying forward the Tychonic worldview that he later put forth in his work, written while in India, *De Nova Mundi Constitutione juxta Systema Tychonis Brahe aliorumque recentiorum mathematicorum* (Carolino, 2007: 190).

Here doubt arises because we come across references to Father Manuel Dias Sr. (1561–1639) and Father Manuel Dias Jr. (1574–1659). Father Dias Sr. was a Portuguese philosopher who was in Macao at the time we are discussing (see Pina, 2007: 90). Fr. Dias Jr., also a Portuguese philosopher and well known for his 1615 work *Tianwenlue* (*Epitome of Questions on the Heavens*), was in Goa during 1601–1604 and Macao in 1604–1610, before entering China in 1610. So, which Fr. Dias was Fr. Borri referring to? If Fr. Dias was also a Jesuit and was at Cochin, he and Fr. Antonius Rubinus would have known each other and about their respective cometary observations. But Fr. Kirwitzer only wrote to Fr. Rubinus, whom he knew was in Cochin and carrying out cometary observations. In the communications from Cochin, only observations by Fr. Rubinus feature in Fr. Kirwitzer's treatise.

Incidentally, in the extensive account of his travels, Pietro Della Valle too refers to sighting Comet 1618 III on 21 November, while he was journeying through Persia.

7.2 The Time Convention

The date of 9 November as given by Fr. Borri for the earliest sighting of the first comet does not align with the dates of first sighting the contemporary European astronomers came to accept. Therefore, the convention of the division of time that Fr. Borri used needs to be ascertained. In an early nineteenth century guide for navigators (Moore, 1807: 218), we do find reference to a particular convention where the civil day begins at midnight and the astronomical day begins at the noon of the civil day. Kronk (1999: 335) has used this convention when giving dates for the Great Comets of 1618. We also should apply this convention to the dates reported by Fr. Borri and Fr. Kirwitzer.

To recall: the Catholic countries of Europe were the first to adopt the Gregorian Calendar, which was introduced in 1582. As is clear from his description, Fr. Borri (1631: 115) used Gregorian dates. Any correction to the dates needs care and therefore we have cited the dates just as they are reported in the original treatises. There is no ambiguity when we convert the dates reported in Jahāngīr's *Tūzūk-i Jahāngīrī*.

8 CONCLUDING REMARKS

In this paper I have presented India-related accounts of two exquisite comets that were visible in November 1618. These observations, and those made elsewhere of the bright comet of August 1618, had an important impact on our thinking about the nature of comets. In the Indian context their significance relates to the first-ever use of an optical device, a *tubo optico* (telescope) for astronomical observations, within a decade of its invention in Europe. This was a time when the telescope was a fascinating gadget and a wonderful present—only later would it become an indispensible astronomical tool.

The Latin phrase (*tubo optico*) in Fr. Kirwitzer's (1620) treatise translates as telescope, but was it a Galilean telescope that the Jesuits had brought from Europe, like the one Fr. Adam Schall depicted in his 1626 book (see Figure 14)? In the 'Preface' to his treatise, Fr. Kirwitzer mentions that their baggage, with instruments and books, remained in the ship in unsafe condition, but they could use an astrolabe and a cross-staff from the local Jesuit establishments. That explains how the angles that they measured came to a fraction of a degree. Fr. Kirwitzer does not mention the instruments that Fr. Antonius Rubinus used in Cochin. Whether he also used a telescope to view the comets is not stated, but we do know that he was eager to obtain one. Fr. Kirwitzer also does not mention the bright comet of August 1618 (1618 I) that the missionaries would have noticed while still at sea. Once he was in Goa and armed with a telescope, Fr. Kirwitzer may have used it to demonstrate Galileo's observations to fellow-Jesuits and others.

Until now, the credit for the first use of a telescope in India for astronomical observations has rested with Jeremiah Shakerley (1626–1655) who specially came to Surat in Gujarat to observe the transit of Mercury of 3 November 1651. The following year he also observed a comet, most probably C/1652 Y1. However, we know nothing about his telescope, timing device or observing methods (Kochhar, 1989: 188). While these seventeenth-century examples did not prove to be trend-setters for modern astronomy in India, they were the first ones nevertheless.[4]

The orbits of the November 1618 Great Comets were determined on the basis of observations that were made elsewhere between 11 November and 9 December for Comet 1618 III and between 30 November 1618 and 22 January 1619 for Comet 1618 II (JPL, 2015). As we have seen, Jahāngīr's and Fr. Kirwitzer's observations were largely unknown at the time, and thus did not form part of the initial datasets assembled for these two comets. Whether their observations can be suitably used now needs to be evaluated, in order to see if they alter the orbital elements, even minutely. Equally desirable is a translation of Fr. Kirwitzer's treatise into English, supported by notes.

9 NOTES

1. Most dates listed in this paper are Gregorian and the years are CE or BCE. However, some dates, like 1027 A.H., are given using the *Hijri* or Islamic Calendar. This is a lunar calendar that consists of 12 months in a year of 354 days. The first year (1 A.H.) of the *Hijri* Calendar began in CE 622, when Muhammad moved from Mecca to Medina. For example, the Islamic year 1437 A.H. is from 14 October 2015 to 2 October 2016.
2. This study is part of the author's ongoing research since 2009 into the cometary sightings and observations from India from antiquity until 1960, where available data, however minimal, permit identification of a comet. Some of the Indian sources that are available have received little or no attention in the cometary literature.
3. To refresh, morning civil twilight commences when θ_S, the elevation of the centre of the Sun's disc, is 6º below the horizon, and lasts

until its top shows. During civil twilight the Sun is down but the sky is lit by the sunlight scattered from the upper layers of the Earth's atmosphere, and the brightest stars and planets can be seen. It is nautical twilight when θ_s lies between –6º and –12º. The sky is deep blue, the horizon is still visible and navigator's guide stars can be sighted. It is astronomical twilight when θ_s lies between –12º and –18º. When θ_s is <–18º, it is night and the sky is dark for regular astronomical observations to be made (U.S. Naval Observatory, 2012). These definitions are for a geometrical horizon that is 90º from the zenith. The length of the twilight depends on latitude and the time of the year.

4. An astronomically-significant incident in the history of Indian and international astronomy was the discovery that the brightest star in the constellation of Centaurus, α Centauri, was a double star. This discovery was made by a French Jesuit priest, Fr. Jean Richaud (1633–1693), on 19 December 1689 from Pondicherry, with a 12-ft long telescope. Although Shakerley's was an innovative use of the telescope whilst in India, Fr. Richaud made a systematic effort to introduce telescopic astronomy. He practiced and taught astronomy at the Jesuit school in São Tomé in Madras until his death (Kameswara Rao et al., 1984). Fr. Richaud also was one of the independent discoverers of the comet of 1689, a sungrazer now designated C/1689 X1. He made his discovery on 8 December1689 from Pondicherry (Vsekhsvyatskii, 1964: 121).

10 ACKNOWLEDGEMENTS

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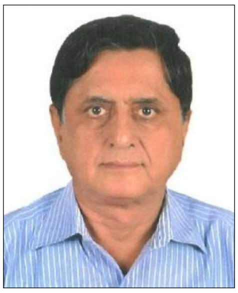
12 APPENDIX: AN INTERESTING PAINTING

In 2009, while beginning a search for old records of comet observations from India, I came across an interesting painting on the website of the Amateur Astronomers Association, Delhi. This is shown in Figure 23, and it depicts the Emperor Jahāngīr observing a comet during October 1618. According to Dr C.B. Devgun (personal communication, March, 2010), the painting featured in a book by Dr Nirupama Raghavan that was published around the time when Comet Hale-Bopp made its appearance. However, as the research presented in this paper indicates, the depiction in Figure 23 does not agree with the observations mentioned in the *Tuzuk-i-Jahangiri*.

For a feel of the style of Jahāngīr's court artists, one may look at Bichitr's 'Jahangir Profferring a Sufi Shaikh to Kings' (Figure 5) or Abū'l Hasan's 'Jahangir Embraces Shāh Abbās While Standing on a Globe'. Abū'l Hasan painted some of the best-known illustrations of the Emperor in the year 1618, and several of these are reproduced and discussed in Bailey's (2001) paper.

Figure 23: "Jahangir observing a comet in the skies in October 1618. It sported a tail of 24 degrees and was observed for 16 days." (http://delhiamateur.tripod.com/anc_refs.htm)

Professor Ramesh Kapoor began his career in 1971 at the Uttar Pradesh State Observatory (now the Aryabhatta Research Institute of Observational Sciences, ARIES) at Naini Tal, India, in observational astronomy where his main interest was flare stars. From March 1974 until September 2010, he was with the Indian Institute of Astrophysics (IIA) in Bengaluru, where he worked on various topics in relativistic



astrophysics centred round the observational aspects of black holes, white holes, quasars and pulsars, etc. He has participated as an observer and as an organizer in a few solar eclipse expeditions mounted by the IIA. Ramesh has published in international journals and presented papers at national and international conferences. His current research interest is history of astronomy, particularly comet sightings and observations from the Indian region. In addition, he has been active in popularizing astronomy, and he also has published on Indian systems of medicine. Ramesh is a member of the International Astronomical Union and a Life Member of the Astronomical Society of India.