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THE GREAT COMET C/1743 X1: POSSIBLE IDENTIFICATION IN HISTORIC RECORDS OF 1402, 1032, 676, AND 336

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Abstract: The great comet of 1744, C/1743 X1, is notable for its brightness, which enabled it to be seen close to the Sun during the day and exhibit an impressive tail. One of the first orbit calculators, O.P. Hiorter, had already noted the comet's resemblance to the great daylight comet C/1402 D1. This was later supported by H.W.M. Olbers and J. Holetschek. This paper re-evaluates the historic astrometry and shows that the data are fully compatible with the identity first suggested by Hiorter. Based on a tentative link of both apparitions, we show that the comets of 1032, 676, and possibly of 336 are also fully compatible with this comet based on the comparison with the historic records. We present a prediction for the next perihelion passage, which might occur at the end of 2097.

Keywords: comets, C/1743 X1, orbits, identification

1 THE APPARITION OF COMET C/1743 X1

This comet was undoubtedly the most spectacular of the eighteenth century, and it is among the greatest in history. Its discovery is usually attributed to amateur astronomers Dirk Klinkenberg (1709–1799) of the Netherlands (Struyck, 1753: 78) and Jean-Philippe Loys de Chéseaux (1718–1751) of Switzerland (de Cheseaux, 1744: 52), who found the comet on 9 and 13 December 1743, respectively. However, it would seem that the first observation was actually made by Jan de Munck from the Netherlands on 29 November 1743, when he saw it near the star α Arietis (de Munck, 1744:1–2).

The comet was already described as magnitude 2–3 by the end of December, but it would continue to brighten for the next two months as it approached perihelion, being observable in several European countries, as well as China, Japan, Korea, and the United States. Some observers indicated the tail reached a length of 40° to 50° (Pankenier et. al., 2008: 276–280). By 25 February 1744, the English astronomer G. Smith said the comet was nearly as bright as Venus, with both remaining visible after all other celestial objects were lost in morning twilight (Smith, 1744: 86). On the evening of this same day, the comet was seen near the setting Sun in Italy by Gian Paolo Guglienzi and G. Seguier. Guglienzi and Seguier (1744: 13–14) saw the comet in daylight using a telescope on 26 February and with both a telescope and the unaided eye about midday on 28 February. Eustachio Zanotti (1709–1782) and P. Mateucci saw the comet on the morning of 27 February and said it continued being visible after Venus was "… lost in the light of day." (Zanotti and Mateucci, 1744: 8–9). On 1 March, Paris Observatory's Jacques Cassini (1677–1756) said the comet's head had not yet risen, yet the tail extended to a height of over 15°. He added that part of the tail was still visible after sunrise (Cassini, 1748: 305). On 3 March, P. Thomas was sailing near the coast of Western Australia and could see the comet when the Sun was "… about one diameter above the horizon." (Thomas, 1745: 317). Zanotti and Mateucci (1744) last saw the comet in daylight using a telescope on 4 March.

Although the comet was no longer visible in daylight after 4 March, it did become a spectacular object in the morning sky, as it showed multiple tails during the first week of March. The final Northern Hemisphere observations were made on 8 and 9 March, when de Cheseaux (1744: 33, 158–161) saw multiple bands from the tail extending to a height of 22° and 30°, respectively. The head of the comet was not seen on these mornings, as it did not rise until after the Sun had risen (Figure 1).

These tail features are so-called synchrones and syndynes, which are generated by a rotating comet nucleus with localized dust release sources and different dust particle sizes. A recent example of a comet showing synchrones and syndynes was comet C/2006 P1 (cf. Figure 2).

The comet continued to be followed in the Southern Hemisphere, as Dutch navigators recorded the naked-eye comet in their journals on several mornings from 18 March to 22 April (Struyck, 1753: 90–91). After that, no further observations were reported.

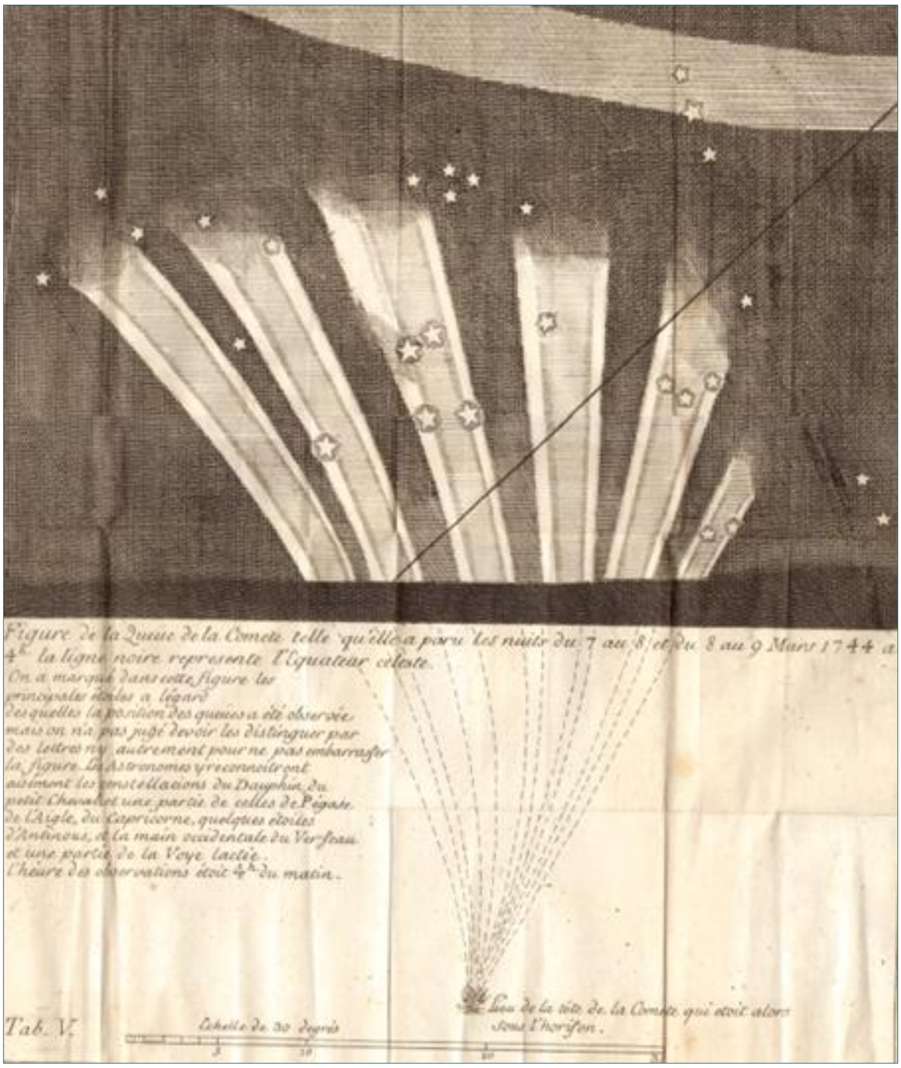

Figure 1: Observation of the tail by de Cheseaux on the mornings of 8 and 9 March 1744 (after de Cheseaux, 1744; M. Meyer Collection).

Figure 2: Comet C/2006 P1 (McNaught) on 18 January 2007, setting behind the Pacific Ocean seen from Cerro Paranal, Chile. While the comet's head has already set the curved tail is still visible (courtesy: European Southern Observatory).

2 EARLY ORBIT CALCULATIONS

Several nearly identical orbits were calculated during the weeks, months, and years following the appearance of this comet. According to J.G. Galle (1894: 17), a total of 12 parabolic orbits were calculated from 1744 to 1873. However, Galle added that two individuals had previously made efforts to find earlier apparitions of this comet, as discussed below.

De Cheseaux (1744: 83) was unable to find similar orbits to that of C/1743 X1 among earlier historical comets, but he suggested that the comet of 1301 was a possible earlier apparition, based on the time of year and location of its appearance. While he also gave only a parabolic orbit for the 1301 comet, he noted that the arc is too short to decide on a possible periodicity. Today we know that his suggested comet, now known as P/1301 R1, was an early apparition of periodic comet 1P/Halley.

The other calculator who looked for an earlier apparition was the Swedish astronomer Olaf Petrus Hiorter (1696–1750). In the second part of his work on the observations and orbit of this comet, he devoted a large portion to the possible periodicity of this comet (Hiorter, 1746: 221–244; Figure 3). He correctly stated that in general close approaches to planets may alter the orbit, and that very accurate and numerous observations spread over a long period of time would be necessary to detect a deviation from an elliptical orbit with certainty. Nevertheless, Hiorter looked up possible candidates in historical records and quickly noted that the comet of 1402 (misdated as 1401) was a very promising candidate, as it appeared around the same time of the year and presented a similar appearance to C/1743 X1, especially concerning the tail, which suggested a similar apparition with respect to the Earth–comet–Sun orientation. Based on the 343-year gap between these two apparitions, Hiorter proposed that the comets of 1058 and 715 were earlier apparitions. Hiorter then presented five points to support his suggestion about the identity. He closed by noting that if de Cheseaux would have used these five criteria he would not have arrived at the comet of 1301 as a possible earlier apparition.

a) Four apparitions which generally agree in appearance and circumstances.
b) Slight changes of appearance and circumstances based on a slightly changing period.
c) The generally stable orbit, since the comet is very large and thus not much affected by planetary perturbations especially without closer approaches to planets.
d) The extraordinary degree of brightness and size in 1402.
e) The very close agreement in morphology (especially of the tail) with the comet of 1402.

Figure 3: Olaf Peter Hiorter (courtesy: Österreichische Nationalbibliothek, https://www.europeana.eu/item/92062/BibliographicResource_1000126127614).

The possible identity with the comet of 1402 was later also supported by the German and Austrian astronomers, Heinrich Wilhelm Matthias Olbers (1758–1840) and Johann Holetschek (1846–1923)—see Olbers (1787: 450) and Holetschek (1896: 394–396). Since both de Cheseaux and Hiorter never gave formal elliptical solutions, comet catalogs and orbit collections adopted the orbit that British astronomer William Edward Plummer (1846–1923) later calculated (Plummer, 1873: 85), who used re-reduced observations provided by fellow-Britain John Russell Hind (1823–1895; see Section 3). This orbit, taken from the catalogue of Marsden and Williams (2008: 14–15), is based on 76 observations and given in Table 1.

Table 1: Previous parabolic orbits for the comets discussed in this paper.

Comet	T (TT)	q (AU)	ω (°)	Ω (°)	i (°)	Obs	Computer
C/1743 X1	1744 03 01.8397	0.222209	151.4855	49.2966	47.1417	76	Plummer
C/1402 D1	1402 03 21	0.38	91	126	55	–	Hind
C/ –43 K1	–43 05 25	0.22	17	170	110	–	Ramsey/Licht

3 NEW ORBIT CALCULATION FOR C/1743 X1

For our new determination of the orbit, we collected historical observations. One main source was the listing of re-reduced observations by Hind (1848: 137–148) which appeared in two parts in the *Astronomische Nachrichten* and contained astrometry by James Bradley (1692–1762) from Greenwich, Giacomo F. Maraldi (1665–1729) and Pierre Charles Lemonnier (1715–1799) from Paris, George Parker (2nd Earl of Macclesfield, 1697–1764) from Shirburn Castle, and Nathaniel Bliss (1700–1764) and Joseph Betts from Oxford. Another large set of observations came from Zanotti and Mateucci (1744: 11) from Bologna and Hiorter (1745: 56–67) from Uppsala. In summary, 120 observations spanning the period from 15 December 1743 to 5 March 1744 were used. These included 12 observations made during daylight, the majority by Zanotti.

For the determination of the orbit, all observations with single residuals larger than 100″ were excluded. This might seem a large limit but the quality of most of the observations was in the range of several tens of arc-seconds so that a further reduction will reduce the number of available observations. The unrestricted orbit (i.e. without any limitation in any of the orbital elements), including perturbations by Mercury to Neptune, is shown below. The residuals for each observation are presented in Table 2.

Orbital elements: C/1743 X1
Perihelion 1744 Mar 1.86042
Epoch 1744 Feb 25.0 TT
(2000.0)

q = 0.221277 au	ω = 151.76362°
e = 0.995580	Ω = 49.49944°
P = 354.27 yr	i = 47.10808°

110 of 120 observations 15 December 1743–4 March 1744; mean residual 31.9″

In comparison, the mean residual for an orbit with a forced eccentricity of e = 1, which is used for nearly parabolic comets, is 42.8″, decidedly larger than for the unrestricted orbit. It must be noted, however, that such a restricted parabolic orbit leads to a larger number of observations with residuals larger than 100″, which must be excluded, and these observations are including a large number of those that have been made during daytime, and which are expected to be of lower accuracy. Nevertheless, using this modified number of observations then for an unrestricted solution gives a period of 559 years, which is still decidedly elliptical. As a further test, the reduction of even more observations with a large residual still left an elliptical solution: the period was around 500 years when the mean residual was reduced to 20″ and 360 years when it was reduced to 10″. The latter restriction leaves only about a quarter of the initial set of observations so that a further reduction seemed not advised.

As the daylight observations are crucial due to their expected lower accuracy another calculation was made excluding them completely. Here the resulting period is about 480 years with a mean residual of 29″. Restricting this dataset for a parabolic solution increases the mean residual to about 36″. It can be concluded that the daylight observations are not a biasing factor when a decision is made between an elliptical and parabolic solution, supporting the suspicion that the comet may have a period of a few hundred years.

As a next step, we integrated the unrestricted orbit backwards to obtain an estimate for an earlier perihelion date. Perturbations by Mercury to Neptune were taken into account. This resulted in a perihelion date in 1405, surprisingly close to 1402, the perihelion year of comet C/1402 D1, which was already suspected to be an earlier apparition by Hiorter.

Since the 1402 apparition provides no clear astrometric data, we produced several backward integrated orbits by restricting the perihelion date around several most likely values and generated additional orbits that went further in the past to search for even earlier apparitions. Table 3 lists the perihelion dates for the generated orbits centered around 25 March 1402, ±4 days, and their respective earlier apparitions, as well as the prediction for the next perihelion. It should be noted that the accuracy of the backward integrations is expected to be worse the farther one goes back into the past. Furthermore, non-gravitational forces can alter the orbit of a comet in an unpredictable way.

It should be noted that different sets of selected observations have only a slight effect on the resulting perihelion date values (T) in the range of days, providing a good estimate of the uncertainty of the values for T. However, the uncertainty in the time of perihelion dates increases as we move further back in time from the 1744 apparition. But the results in Table 3 also show, that, if the assumed identity of the 1402 and 1744 comets is correct, the comet should have appeared in the summer or autumn of 1032 and around 676.

4 A BRIGHTNESS ANALYSIS FOR C/1743 X1

For the estimate of the visibility of this comet, especially regarding possible earlier apparitions, it is necessary to adopt a set of parame-

Table 2: Residuals for the new orbit for comet C/1743 X1. Obs gives the observatory code listed at the bottom of the table. dRA and dDec are the residuals in arcseconds. Observations with residuals in parentheses were excluded. Observations from 25 February onward were made during daylight.

Date	Obs	dRA	dDec	Date	Obs	dRA	dDec	Date	Obs	dRA	dDec
431215	549	76.4–	.52+	440112	007	29.4–	4.2+	440210	007	32.0–	3.8+
431217	549	55.0–	13.2+	440113	007	15.0–	42.6+	440211	007	29.5–	10.6+
431218	549	2.3–	20.7+	440116	007	5.5–	19.8+	440212	007	23.7–	18.8+
431221	549	10.8–	12.3+	440117	007	57.7–	1.5–	440212	000	1.8+	9.4+
431221	007	68.2–	61.7–	440117	549	43.1+	20.1–	440213	007	15.2–	15.8+
431222	549	26.9+	6.2+	440117	000	15.4+	13.5+	440215	007	29.6–	28.5+
431223	549	14.5–	7.0+	440118	007	34.8–	4.2–	440216	007	14.8–	52.7+
431225	549	13.7+	10.9+	440121	000	(111–	20.8–)	440216	996	11.5–	31.0+
431226	549	10.2+	8.2–	440121	281	64.3+	41.6+	440217	549	82.5–	14.3–
431230	549	1.1+	24.5–	440122	000	5.4+	4.7–	440217	000	.60–	1.3+
431230	007	9.5–	11.7–	440123	996	20.8–	6.5+	440217	007	27.4+	22.3+
431231	549	5.2+	20.7–	440124	281	1.2–	35.8+	440218	549	62.2–	43.8–
431231	007	41.1–	27.7–	440124	000	20.6+	9.7+	440218	007	16.4–	31.7+
440101	549	26.4+	1.2–	440124	996	10.4+	14.6+	440219	281	44.0–	10.6+
440101	007	23.7+	15.9+	440125	281	20.2+	15.0–	440220	000	13.0–	5.5–
440103	007	20.1+	12.8–	440126	281	37.5–	31.7–	440220	000	43.9–	50.2–
440103	996	(10.4–	126–)	440126	549	33.4–	33.0–	440221	000	29.8+	–100
440103	549	(219+	82.0+)	440126	000	16.8+	14.4+	440222	996	7.5+	74.2+
440104	549	71.9+	4.1–	440127	281	44.0+	22.4–	440223	281	38.7+	89.5–
440104	007	3.4–	9.8–	440127	000	10.7+	14.7+	440223	007	36.4–	12.7+
440105	549	40.7+	8.1+	440127	549	10.5–	13.1–	440223	549	(115–	37.9–)
440105	007	5.2–	2.4+	440127	996	9.9+	30.9+	440223	000	18.3–	16.5+
440106	549	46.1+	8.2–	440128	549	23.0–	36.5–	440223	996	43.5+	12.5+
440106	007	3.1+	16.3–	440129	281	22.2+	33.1–	440224	000	5.8+	1.9+
440106	000	20.3–	6.1+	440130	281	27.1+	.90+	440224	007	(45.6–	215+)
440107	007	4.6–	3.7+	440130	549	11.7–	42.2–	440224	996	26.0–	25.6+
440107	000	2.7–	13.6–	440131	281	5.0+	33.9+	440225	281	29.0–	38.1–
440107	996	5.7–	17.5–	440201	281	21.1+	3.0+	440225	007	(129–	29.3+)
440107	281	80.4+	62.4+	440201	000	22.9+	14.1+	440227	281	70.1+	31.2–
440108	000	2.2+	9.1–	440202	281	1.4–	16.8+	440228	281	75.9+	40.5–
440108	996	4.6–	5.0–	440203	000	19.0+	17.0+	440228	996	23.1–	44.7+
440109	549	36.3+	26.2–	440203	996	4.7+	20.6+	440229	281	62.4+	34.7–
440110	549	48.7+	10.2+	440203	007	2.1–	36.8+	440229	000	48.4–	39.9+
440110	000	1.6–	10.4+	440204	281	67.1+	12.8+	440229	996	38.5–	58.7+
440110	007	(140–	48.6–)	440206	281	13.5+	48.4+	440301	007	(255–	156+)
440111	000	.58+	8.5–	440206	549	28.7–	32.4–	440301	281	89.9+	21.0–
440111	996	18.6–	11.5+	440207	281	25.8+	42.1–	440302	281	45.7+	8.4–
440111	549	(185+	42.1+)	440207	007	7.6+	9.1+	440303	281	72.7+	8.1–
440111	007	56.7–	3.2+	440209	549	39.9–	45.5–	440304	281	28.0+	5.6+
440112	549	40.4+	26.6–	440209	000	6.1+	13.9+	440305	281	(53.7+	179–)

Observatory data:

(000) Greenwich	(N51.477376 W0.000000)	UK/England.
(007) Paris	(N48.836381 E2.336750)	France.
(281) Bologna	(N44.496412 E11.352200)	Italy.
(549) Uppsala	(N59.858036 E17.625700)	Sweden.
(996) Oxford	(N51.759750 W1.251700)	UK/England.

ters that allow the prediction of its brightness. A commonly used formula to describe the brightness analysis is $m = H_0 + 5 \log \Delta + 2.5n \log r$, with m being the apparent magnitude of the comet, H_0 the absolute magnitude of the comet, Δ the distance to Earth in AU, r the distance to the Sun in AU and n the slope coefficient which is an expression of the comet's activity. For a long time, a slope coefficient of 4 was assumed for long-periodic comets when the available data did not allow one to determine the value of n more precisely. In such cases the absolute magnitude was indicated as H_{10}, indicating a resulting factor $2.5n$ of 10. However, modern data have shown that a value of 3 for n seems more reasonable for long-period comets.

Unfortunately, reliable data about the apparent magnitude in 1743–1744 are scarce. One of the first in-depth analyses was carried out by J. Holetschek. He used a procedure which applied a value of $n = 2$, which would mean that the comet would only reflect sunlight. Since this is not the case, he noted that the val-

Table 3: Predicted perihelion dates for several apparitions prior to and after 1743/44 based on assumed perihelion dates T in 1402 based on backward integrations. The line with yellow highlighting indicates the perihelion date suggested by Holetschek (1896: 394–396).

T = Mar 1402	–4	–3	–2	–1	+1
21.0	65 Nov. 27	340 Oct. 26	675 Feb. 16	1032 Oct. 2	2097 Dec. 12
22.0	–4 Aug. 3	332 Sep. 28	675 Aug. 15	1032 Sep. 17	2097 Dec. 11
23.0	21 Jul. 12	330 Mar. 1	676 Feb. 16	1032 Sep. 1	2097 Dec. 10
24.0	–33 Aug. 26	337 Mar. 29	676 Jul. 2	1032 Aug. 17	2097 Dec. 9
25.0	–43 Aug. 20	336 Jul. 3	676 Oct. 20	1032 Aug. 2	2097 Dec. 8
26.0	–16 Jun. 27	333 Jun. 15	677 Feb. 4	1032 Jul. 18	2097 Dec. 7
27.0	–53 Sep. 8	325 Jan. 11	677 Jul. 6	1032 Jul. 4	2097 Dec. 6
28.0	10 Sep. 4	318 Oct. 11	677 Dec. 30	1032 Jun. 20	2097 Dec. 5
29.0	–81 Nov. 4	310 May 16	678 Jul. 21	1032 Jun. 6	2097 Dec. 4

ues for the absolute magnitude varied throughout the apparition. Kritzinger (1914: 127) indeed accepted that the value of n must be larger and calculated H_0 as 0.7 mag and 2.5n as 9.6, i.e. n = 3.8. It should be noted that he took the apparent magnitude for the comet as –5.3 on 1 March, while Holetschek took it as –4.3. Vsekhsvyatskii (1964: 126) derived an absolute magnitude (H_{10}) of 0.5.

A re-analysis of 20 apparent magnitudes given by Holetschek shows that a range of possible parameter combinations can be fitted with the data. In Figure 4 the green curve shows the fit for a value of n = 3 which corresponds to an H_0 of 0.97 mag, while the blue curve shows the fit for a value of n = 4, corresponding to an H_0 value of 1.06 mag. The unrestricted best-fit (red curve) gives n = 3.35 and H_0 = 0.99 mag. For the analysis carried out in this paper we therefore adopted the parameters H_0 = 1 mag and n = 3.5 for all following analyses. However, it should be noted that these parameters are still an estimate.

With that absolute magnitude, the comet belongs to the largest comets ever observed close to the Sun. Combined with the rather small perihelion distance, this results in a very bright comet around perihelion, making it visible even during daylight. For comparison, we typically consider the mean value for H_0 for visually observable comets to be magnitude 6.

The orbit indicates that, in general, perihelion dates in any given year between around April and July are the worst, with the comet being very close to the Sun when brighter than magnitude 4. However, this is being countered by the suspected larger size of the nucleus, which manifests itself in the large intrinsic brightness derived from the observations of 1743–1744. It should be noted that the apparent brightness of a comet can be strongly enhanced by so-called forward-scattering on dust particles, which occurs at large phase angles (i.e. the angle between the Earth, comet and the Sun), but this was not the case in 1744.

5 COMPARISON WITH COMET C/1402 D1

In 1402, a very bright comet appeared with an impressive tail (compared by contemporary accounts to that of a peacock); the comet was also seen in broad daylight. It remained visible for two to three months, and traces were left in numerous European, Asian, Muslim, and Russian records (Figure 5). A detailed description of the apparition can be found, e.g., in Kronk (1999: 260–263). Also, it should be noted that the dates prior to 1585 refer of course to the Julian calendar.

Unfortunately, detailed positional observations are almost non-existent, despite the comet's widespread visibility. There are no records of Chinese observations, most likely due to the civil war between 1399 and 1402 (also known as the Jingnan Campaign). Only two short records from Korea and Japan are available.

The fifteenth-century Korean text *T'aejong Sillok* says a 'broom star' was seen on 20 February 1402, with a length of about 5° or 6°. It "… appeared at the east …" of Kui (β, δ, ε, ζ, η, μ, ν and π Andromedae, and σ, τ, υ, φ, χ, ψ and 65 Piscium) "… with its rays pointing eastward." This was an evening observation, so we assume a UT date of 20.5 February 1402. The text goes on to state that the comet was seen in the East on 22 February 1402, "… measuring over 10° and with its rays radiating in all directions." This seems to be an error as the position two days earlier placed the comet in the evening sky. Kronk suggested the account should instead have still read 'East' of Kui. The Korean text then notes that on 8 March 1402, "… the rays of the comet continued to be of the same magnitude." The comet was last seen on 19 March 1402 (Ho, 1962: 200).

The Japanese observations are contained in the text *Dainihonshi* (of 1715) with only a few details. It says that on 20 February during the dusk hour, a 'broom star' was seen in the West of Kui with rays as long as about 4.5° (*ibid.*). On 19 March 1402 the comet was last seen all

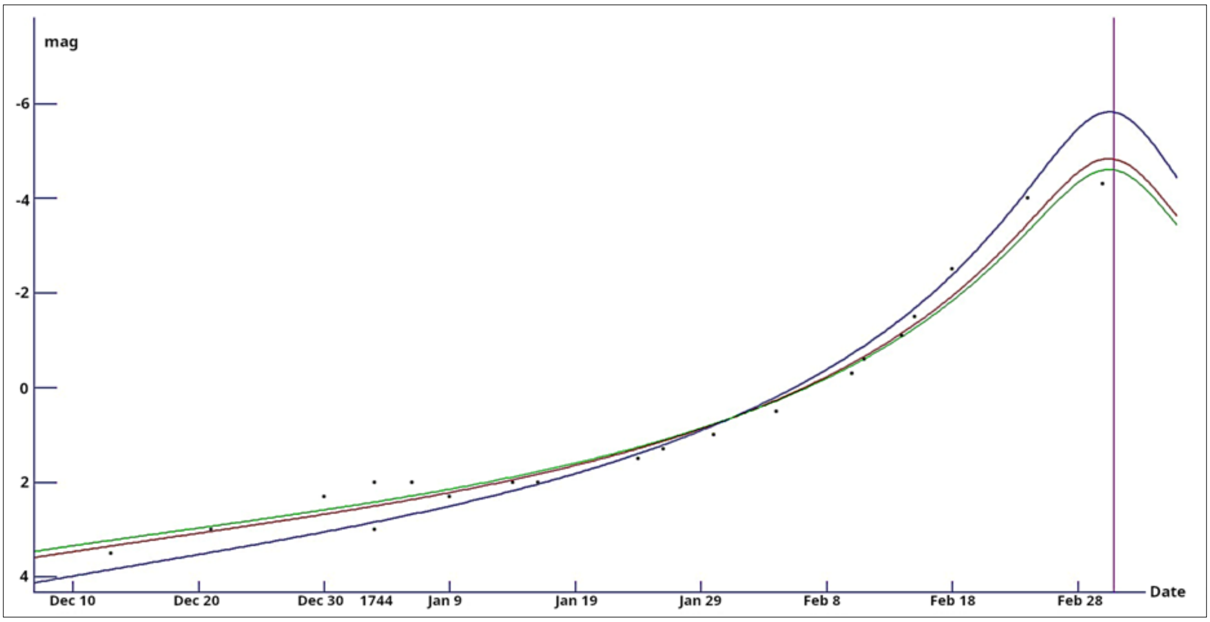

Figure 4: Light curves for C/1743 X1. The blue and green light curves correspond to slope coefficients *n* of 4 and 3, respectively. The best-fit red curve corresponds to a coefficient of *n* = 3.35.

Figure 5: Comet C/1402 D1 in the Chronicon Helveticae (1576) (Credit: Aarau, Aargauer Kantonsbibliothek, MsWettF 16: 1, p. 455 – Silbereisen: Chronicon Helvetiae, Teil I (https://www.e-codices.ch/de/list/one/kba/0016-1)).

through the night (Pankenier et. al., 2008: 177). Although no position was given for the discovery date, we can assume an evening observation with a UT date of 20.4 February 1402.

There are numerous reports on this comet in European sources, but none is as detailed as the one in the *Tractatus de Cometis* by J. Angelus (J. Engelin), a Swabian surgeon from Ulm who lived from ca. 1363 to at least 1425. Jervis (1985) carried out an in-depth analysis of this text and translated the observational section from Latin into English. There exists one manuscript version located at the University

Library in Erfurt, Germany, (signature: UB Erfurt, Dep. Erf., CA 4° 353) which was probably written not long after the apparition. An incunabulum of the manuscript was published in 1490 in Memmingen (Angelus, ca. 1490). The following are the relevant parts of Angelus' translated text (Jervis, 1985: 38). A 'lance' is about 10°, as shown later.

> In the pontifical year 1402 A.D. around the beginning of February a comet appeared here in Swabia for many days. We first saw it in Ulm the fifteenth of March. On the [22nd] day it was toward the north of west, and it set crossing the horizon at the point where the sun sets when it occupies the summer solstice point. Its size was rather greater than that of Venus when it becomes visible in our hemisphere before sunrise, but not as bright. Its color was the color of Venus, which is rather metallic.
>
> Its tail was for some time colored white and not very long, erected upwards, about as thick as a broom. And this tail at the beginning was inclined somewhat towards the south; later it inclined more to the south as the comet passed through the latitudes of the seventh climate; then the tail noticeably inclined towards the north and increased in thickness and splendor most conspicuously, so that around March 15th it appeared as long as one and a half lances, shaped like a pyramid measured linearly, whose sides came together in this comet and whose base continued toward the upper part, diffusing through the distant side of the figure. I never saw such a bright and colorful tail.
>
> On March 22, in the second hour, it was seen near the sun at a distance of one lance to the north. Whence then it is clear that it had moved from the north through a great distance toward the south, in a direction contrary to the sun's motion, where finally it disappeared on the feast of Easter, that is on the 26th or 27th. But in the east before sunrise its vestiges appeared, because I saw three long and very thick hairs, and after sunset I saw one hair in the west.

There are only a few other texts that contain helpful date or location indications. The Italian text *Annales Forolivienses* of 1473 provides the best account from the European monasteries. It says:

> … about the end of February and through early March, a fairly large comet appeared in the eastern part of Aries and was seen for two and a half hours with long hair spreading out; thereafter, the tail grew larger and brighter. It was seen for about eight days toward the end of March during daylight preceding the sun. (Muratori, 1903: 78).

The Austrian astronomer Georg von Peuerbach (1423–1461) briefly wrote of this comet in a letter to J. Bohemus on 25 June 1456:

> In 1402 around the beginning of February, a great and horrible comet appeared in the sign of Aries; its declination was 18° toward the north .... First appearing very much toward the north, it was seen to decline and later set in the sign of Libra. (Jervis, 1985: 87).

Unfortunately, it is unclear where Peuerbach got his information from, especially the declination value, which was most likely referring to the ecliptic. Also, his reference to Aries and Libra apparently relates to the zodiacal signs rather than to the actual constellations.

The *L'Historia di Milano* by Bernardino Corio (c. 1459–1519) gives the following details (but with nothing about the length of an 'arm'):

> On the eleventh of this month [February], on a Sunday, which was the first of Lent, a comet began to appear, every evening between south and west, which declined and appeared until Easter Sunday. It had a tail, which gradually grew to the length of two arms, then three, and stretched out to twelve arms, and on the third-to-last day it became like flames twenty-five arms long, on the second-to-last fifty, and on the last it seemed two hundred, and then it did not appear at night anymore, but only in the following days, the first of which was Holy Wednesday, it showed itself opposite the Sun to the length of an arm, dimming the light of the great planet. (Corio, 1554: 284–285).

Another interesting mention can be found in a gloss in a fourteenth-century manuscript preserved at the Biblioteca Universitaria at Salamanca, Spain (Juste, 2022). At the side of the text about comets in general a remark by a different hand states "I believe it was seen in the 22nd degree of Aries in the year 1402; Mars was in the same house; I saw it the following March." S. de Phares (1929: 239) said that Biagio di Parma (Biagio Pelacani, c. 1350–1416) noted that it appeared on 25 February and shone for 26 consecutive days, "… reaching up to 6 degrees from Taurus".

While the exceptional tail of the comet is mentioned in most of the historic records, a few give more details about its appearance.

The fourteenth-fifteenth century French author Bertand Boysset kept a chronicle of events that occurred in city of Arles and the geographical region of Provence, in Southern France. He died in 1416, so he was a contemporary of the comet's appearance. Although he provides a nicely detailed account of the comet, he actually jumps ahead a full year during his description. Nevertheless, it seems likely that the entire description belongs to the 1402 comet. It should be mentioned here that while this and other discrepancies in the year might indeed be errors, we know that different dates were used as the actual beginning of the calendar year and the indicated year may differ by one year in either direction. He wrote the following:

> In the year 1402, on the third day of January, as night fell, a comet appeared toward the setting Sun, and it had a long tail extending from the comet, and it stretched towards the rising Sun; and the tail had two parts, as it seemed to observers. Additionally, the comet had many rays … (Boysset, 1900: 365).

At this point, Boysset suddenly switches to 1403, and notes that on 21 March the comet "… was seen throughout all the hours of the day." He added that it "… rose in the morning after the Sun had risen and set two hours after the Sun had set."

Interestingly, contradicting the latter comment, an entry in the *Kalendarium Zwetlense*, written in the Zwettl Monastery in Lower Austria (Wattenbach, 1851b: 696) says for 1403 (but obviously referring to the comet of 1402):

> In the year 1403, a star which is called a comet was seen. It appeared at night immediately after sunset, emitting fiery tails, and shone for one month. It was seen in the northern part of the sky. In the last week, when it was about to depart, it was seen in the morning before sunrise in the east, and it always slightly preceded the sun, and around noon it was also seen near the sun.

Meanwhile, about 800 km to the north in Koksijde, in what is now Belgium, another contemporary writer included a short note in his *Chronique*. J. Brandon, a monk at the Abbey of Dunes, noted:

> In this year, in the month of February, a comet appeared towards the west, with a curved tail pointing toward the middle of the sky, and it lasted until the middle of April. (Brandon, 1870: 86).

Another impressive description of the appearance of the comet is given in the *Continuatio Claustroneoburgensis Quinta*, a chronicle written in the Klosterneuburg Monastery near Vienna for the year 1401 (but referring to the comet of 1402):

> In 1401, the omnipotent God, the maker and creator of all things, performing a new miracle and wishing to show a wonder to this world, displayed a very beautiful comet, adorned with fiery, luminous hair, streaming bands, and a helmet infused with the heavens; indeed, to speak more clearly, as a kind of manifestation of His majesty, He showed it up in the sky with a fiery brightness to all mortal eyes. (Wattenbach, 1851a: 736).

K. Schnitt completed his chronicle on the Swiss annals of Basel in the early sixteenth century. He wrote:

> In the year 1402, from Laetare Sunday to Easter, a peacock's tail appears in the sky every evening in the direction of sunset, so that everyone may see it. (Schnitt,1902: 273)

Easter occurred on 26 March in 1402. Laetare Sunday occurred 21 days prior to Easter, which would have been 5 March.

W.S. Rada (1999–2000: 71–91) compiled a catalogue of Arabic and Islamic comet observations and gave several records for this comet. These state that during February a "… star as large as the Pleiades appeared with a strongly visible tail." It was visible even in strong moonlight and visible during the day in March. The entry from the Egyptian *Inbā' al-ghumr* says:

> Among the astronomical events was the appearance of a star toward the west. It had a tail rising up to the sky. It continued to appear every night after sunset and stayed visible up to one third of the night time, It remained like this to the end of the month of Sha'ban (Apr 3). Then it rose during the day at sunrise and stayed visible up to midday and then disappeared.

In 1877, Hind (1877: 50) calculated a very uncertain orbit and said,

> … the principal circumstances of the comet's appearance, so far at least as regards track across the heavens, might be represented; but its extraordinary brightness is not easily accounted for.

While his orbit represents the general path of the comet, it fails to adequately represent some of the indicated positions, something that has also been noted by Holetschek. Comet catalogues and databases of orbital elements currently provide Hind's orbit for this comet and was the basis for the designation as C/1402 D1. The orbit is given in Table 1.

Summarizing the above reports shows that a comet appeared in early February and disappeared around the end of March 1402. In general, these accounts agree on daylight visibility toward the end of March and on an impressive tail that looked at times like that of a peacock. But not all reports can be brought into perfect agreement with one another, something that was already noted by Pingré (1783: 446–452). We also cannot bring these same outliers into perfect agreement with our orbit in Table 3. A very notable example is the remark made by Boysset, a contemporary of this comet's appearance, stating that the comet rose after the Sun and set two hours after the Sun. Boysset made this comment immediately after mentioning the comet's daytime appearance on 21 March, potentially suggesting that it occurred on the same day. He apparently lived around Arles, France. If we accept a perihelion date of 25 March, then an observer in Arles would have seen the comet rise 58 minutes before the Sun and set 53 minutes after the Sun. Moreover, Boysset's description would require the comet to have a position not North of and close to the Sun, but East of it, and at a much larger angular distance. But as we have also shown, the comment in the *Kalendarium Zwetlense* states that the comet rose before the Sun, indicating that historical records often contain uncertainties that can be hard to judge.

Besides the Asian positional observation, we can also derive the following details from Angelus' text.

a) The comet was seen first in early February, as apparently known from hearsay.
b) On 22 March 1402 it set at the same azimuth as the Sun during its Summer Solstice. The Summer Solstice was on 13 June 1402 and the Sun set at azimuth 308°.
c) On the same date it was not as bright as Venus.
d) On the same date the comet was seen between 1 and 2 p.m. local time (UT date 22.53 March 1402) North of the Sun.
e) It was last detected on 26 or 27 March 1402.

Jervis (1985: 39–42) tried to recreate the situation described by Angelus but did not realize that the observation of 22 March 1402 is actually a daytime observation. She defined the 'second hour' as two hours after sunset. This also implies that her interpretation of the length of a 'lance' was not correct, as will be shown below.

For the comparison of the orbit of the comet of 1744 with the observations of 1402, we used the perihelion date suggested first by Holetschek, namely 25 March 1402. While he gave no formal orbit solution, he said that using this perihelion date with the orbital elements of C/1743 X1 gives the best agreement with the observations of 1402. Applying this orbit, we can estimate that the comet reached naked eye visibility (brighter than magnitude 6) already in December 1401, or even earlier. However, for a comet to be an object that is easily visible with the naked eye under dark skies, it should be brighter than magnitude 4. Using our adopted brightness parameters, this might have been already in the middle of January 1402. This means that some reports which claim that the comet was already seen as early as 3 January 1402 might be correct.

On 11 February 1402 the comet was predicted to be around magnitude 2.5, situated in northern Pisces, and was visible in the evening sky between the Southwest and West, in agreement with the reports from Milan (cf. Figure 6). Its ecliptic longitude was around 17°, which agrees with the Eastern part of the zodiacal sign of Aries (0°–30°), while the ecliptic latitude was almost 13° (Peuerbach gave 18° from an unknown source). On 20 February 1402 the comet could have reached magnitude 1 and was still located in northern Pisces. This position fully fits the description given by the Korean and Japanese observers. The anonymous observation from the Salamanca Library manuscript was most likely made in the latter half of February; the longitude was given as 22° which is about 4° larger than the predicted position. The attributed statement by Biagio di Parma referring to the constellation of Taurus is problematic as it would place the comet too easterly and disagrees with the other reports.

On the date of Angelus' 22 March 1402 observation at around 13:30 local time, the comet was 11° north-northwest from the Sun, in agreement with Angelus' report, which would also mean that a 'lance' is around 10° and that the tail was thus around 15° long on 15 March 1402. The predicted magnitude was around –4.5 to –5, which is at least as bright as Venus and contradicts Angelus' statement (his point c as listed above), but it is unclear whether he might have compared a daylight comet with the night-sky Venus. It is a well-known fact that estimating brightness during daylight is very problematic. Because the comet is an extended object and Venus resembles a star to the unaided

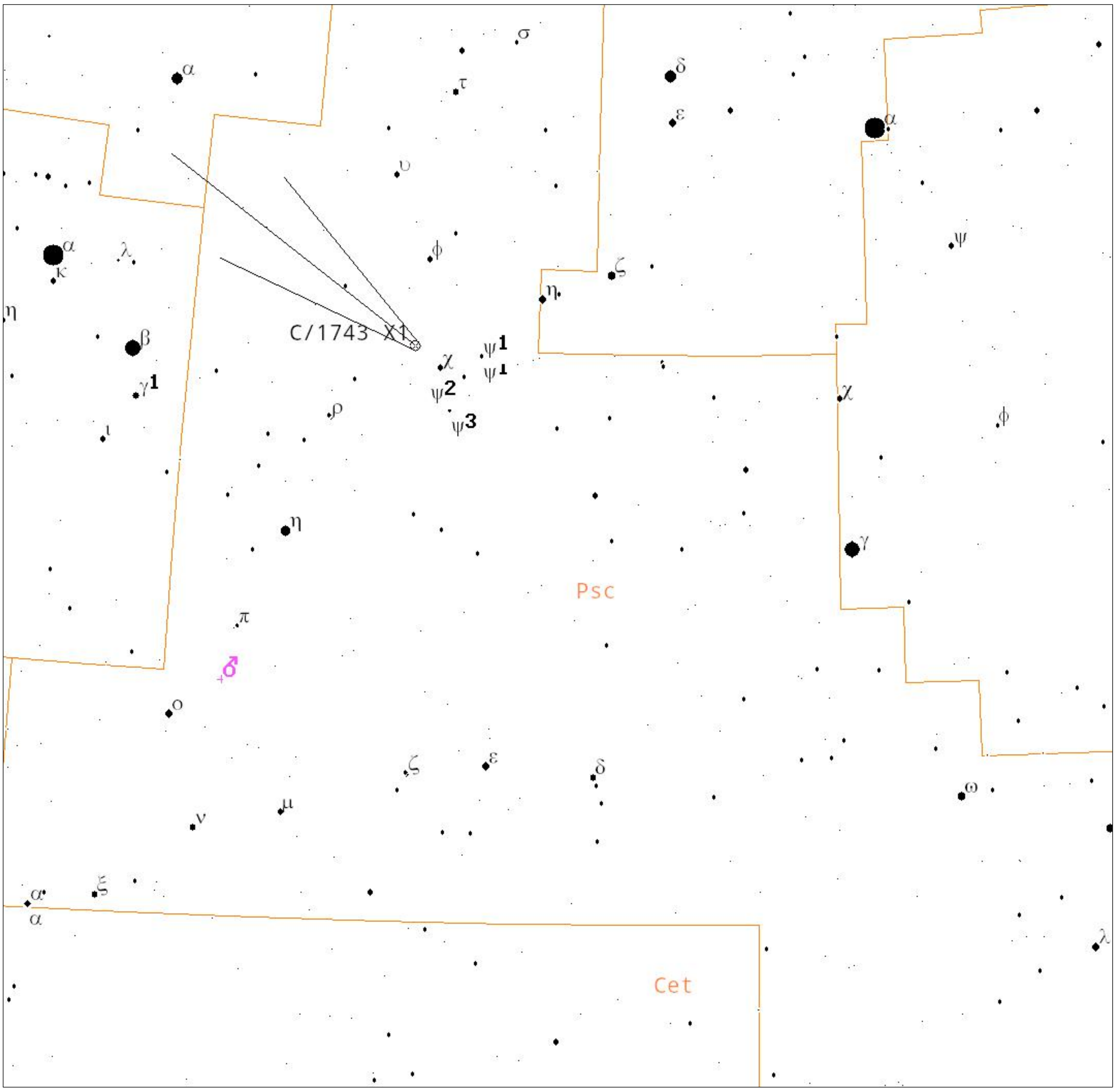

Figure 6: Position of comet C/1743 X1 on 11 February 1402, in northern Pisces. The shape of the comet is just for visualization (Chart prepared with GUIDE software).

eye, it is easy to underestimate the brightness. The observing geometry also led to a phase angle of about 125° on 22 March, indicating only a small brightness increase due to forward scattering. It reached a maximum angle of 154° on 25 March, which might have increased the apparent brightness by about 2.5 magnitudes. The daylight visibility is something that is confirmed by many of the historic records. As the comet was situated North of the Sun it rose before and set after the Sun. The comet set at azimuth 293° for Ulm, which is about 15° short of the setting point for the summer solstice Sun. While this seems like a large difference, it is not clear how Angelus derived these values. Probably his reference to the Summer Solstice setting point was just a means to indicate a general direction. Angelus said that the comet disappeared for him on 26 or 27 March 1402. On that date, the comet set earlier than the Sun. However, it is possible that he could still see it during the day, or that the tail was still visible above the horizon due to its curvature. We know from C/1743 X1 that the tail was indeed looking like that of a peacock and was bent away from the straight anti-solar direction. This can make the tail visible while the comet is already below the horizon. And indeed, Angelus said he saw "… thick hairs …" before sunrise and after sunset. Since—as mentioned earlier—this apparition was very similar to the apparition of 1744, it certainly fits that Angelus saw the multiple tails with the comet's head below the horizon in the morning and evening sky a few days after perihelion, just as de Cheseaux did (cf. Figures 1 and 7).

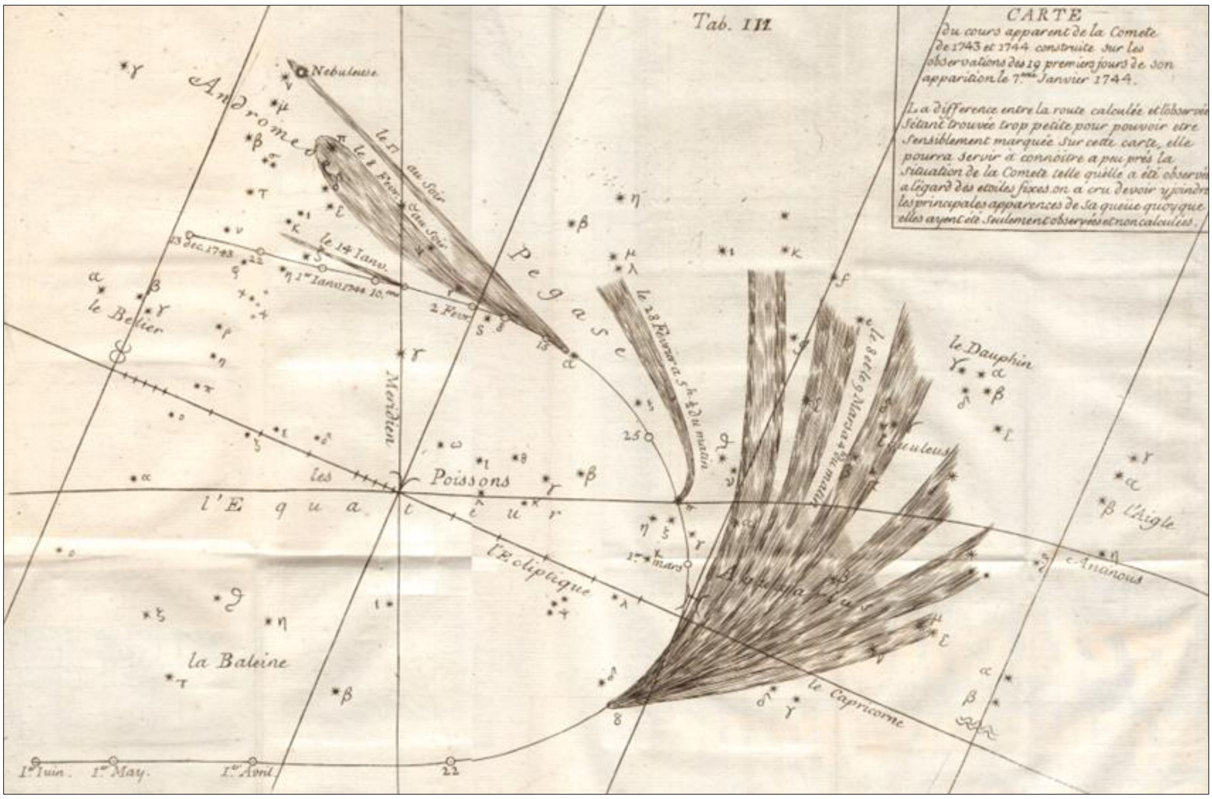

Figure 7: Movement and tail development between 14 January and 9 March 1744 according to de Cheseaux (after de Cheseaux, 1744; M. Meyer Collection).

In general, the descriptions of the tail seem to indicate that it looked very different at times. The phrase "… two parts …" sounds like the ion and dust tails, and since the dust tail is usually not as straight as an ion tail, and points in a different direction, it may indeed look curved. The reference to "… many rays …", "… streaming bands …" and the comparison with a peacock's tail could potentially refer to a tail that is dominated by synchrones and syndynes, akin to the appearance of Comet C/1743 X1 immediately after perihelion. We tested this using a tail simulation based on the Finson–Probstein algorithm, and we were able to confirm this suspicion. Not only was the tail morphology rapidly changing in March, but also Angelus should have been able to see the comet tails in the morning and evening skies on 26 and 27 March 1402.

Figure 7 shows the changing tail development for comet C/1743 X1 between 14 January to 9 March 1744, according to de Cheseaux's observations. Since the perihelion date in 1402 was just about three weeks later in the year than in 1744, the geometrical conditions are comparable, and the tail evolution is expected to have been comparable, too. Figure 8 shows the results of the tail simulations. The left image shows the view on the morning of 9 March 1744. We adjusted the parameters so as to have a roughly similar view to that shown in de Cheseaux's drawings. The same parameters were then applied to the morning and evening of 27 March 1402. The result agrees with Angelus' observations of the tail with rays at these two times.

It can be concluded that the backwards integrated orbit with a fixed perihelion date around 25 March 1402 is the best solution to fit almost all the observations. A much later perihelion date would have shifted the visibility to a later date, while a much earlier perihelion date would have moved the daylight observations earlier into March 1402.

6 POSSIBLE EARLIER IDENTIFICATIONS

As can be seen from the backwards integrated orbits from Table 3, the apparition prior to 1402 would have seen perihelion in 1032. Even assuming different perihelion dates in 1402 does not change this year. If we can find a fitting comet in this year and might even estimate a likely perihelion date, we can then use Table 3 to identify a likely candidate for the apparition preceding the one of 1032.

6.1 The Comet of 1032

There is indeed a record of a comet seen in 1032. The Chinese chronicle *Song shi*, written in 1345, says that on 15 July 1032, a guest star

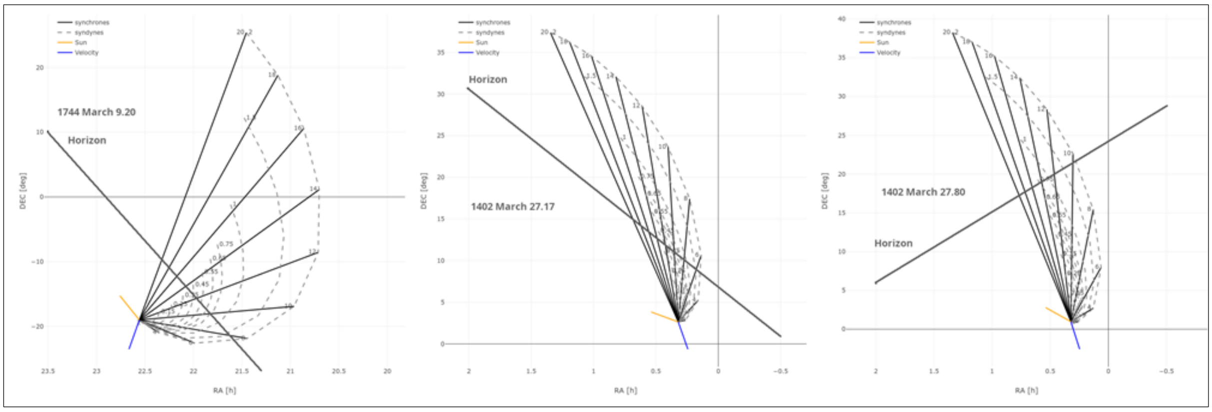

Figure 8: Simulated tail appearance for the morning of 9 March 1744 and the morning and evening of 27 March 1402. The parameters for the simulations for 1402 were the same as for 1744. The black line indicates the approximate ideal horizon. The coordinate grid refers to the equinox of the date.

with a rayed tail was seen in the northeast close to the horizon and went out of sight after 13 days (Ho, 1962: 183). Unfortunately, the period of observation would have been during a time when the geometrical observing conditions would have been very poor. Nevertheless, due to its extremely high intrinsic brightness, this comet would still have been observable even under poor conditions. Using the perihelion date of 2 August 1032, we see that the comet would indeed have been very low above the northeastern horizon with a predicted magnitude of perhaps –0.5. By 27 July 1032, the comet would have become brighter with a predicted magnitude of maybe –3, but also much closer to the Sun, making an observation only possible during bright morning twilight. No European observations exist, probably due to the unfavorable observing conditions. Figure 9 shows the view over the northeastern horizon for Beijing on 15 July 1032, with the Sun being about 10° below the horizon and the comet 8° above it.

If we assume that the Chinese observation indeed belongs to this comet, we can conclude that the perihelion date was most likely around the beginning of August 1032, in agreement with Table 3, supporting the suggested perihelion date for 1402 and pointing to a previous perihelion during the autumn of 676. Due to the few available observations from only one source the comet bears no designation.

6.2 Comet X/676 P1

When accepting the 1032 comet as a possible earlier sighting of the apparitions of 1743/1744 and 1402 and using the perihelion date of early August 1032, the previous apparition should have been in the autumn of the year 676. Interestingly, we have comet X/676 P1, a bright and impressive object seen in various parts of Europe as well as in Western and Eastern Asia and therefore received its designation as an X/ comet, which is for objects where no meaningful orbit can be calculated.

One of the earliest mentions can be found in the Japanese text *Nihongi* (Aston, 1896: 333) from the year 720, which is the second oldest chronicle of Japan. During the 7th month of the 4th year of the reign of Emperor Temmu (15 August to 12 September 676), “A star appeared in the East, seven or eight feet in length. In the 9th month (13 October to 10 November) it at length disappeared from the sky.” According to Kiang (1972: 43), one foot equals 1.5° ± 0.24°, which would translate to a tail length of 10°–12°.

Several Chinese texts mention the comet, with the *Jiu Tang shu* (of 945) and *Tang Hui yao* (of 961) being the oldest. It was first seen on 4 September 676, when it appeared in the 22nd lunar mansion, Dongjing (southwest Gemini), where it pointed toward Nanhe (α, β and γ Canis Minoris) and Jixin (κ Geminorum). This latter statement is obviously incorrect, as the orientation of the comet and its tail and the position of the Sun would not have allowed it to point towards the indicated stars. It was over 3° long and gradually turned to point toward the northeast. The comet’s ‘rays’ grew to a length of about 30° and swept Zhongtai (λ and μ Ursae Majoris), pointing toward Wenchang (θ, τ, υ and 18 Ursae Majoris). It remained visible for 58 days, or until about 1 November 676 (Ho, 1962: 169). The most likely UT date for the first observation was in the morning sky of 3.8 September 676. Pankenier et. al. (2008: 75) translated the tail descriptions as “… sinuous … [and of] great luxuriance.”

The *Chronicle of Silla*, which is part of the Korean text *Samguk Sagi* (of 1145), reports that this ‘broom star’ was seen sometime during the month of 15 August to 12 September 676, when it appeared between Beihe (α, β and ρ Geminorum) and Jishui (λ Persei) and measured 6–7 paces (Ho, 1962: 169).

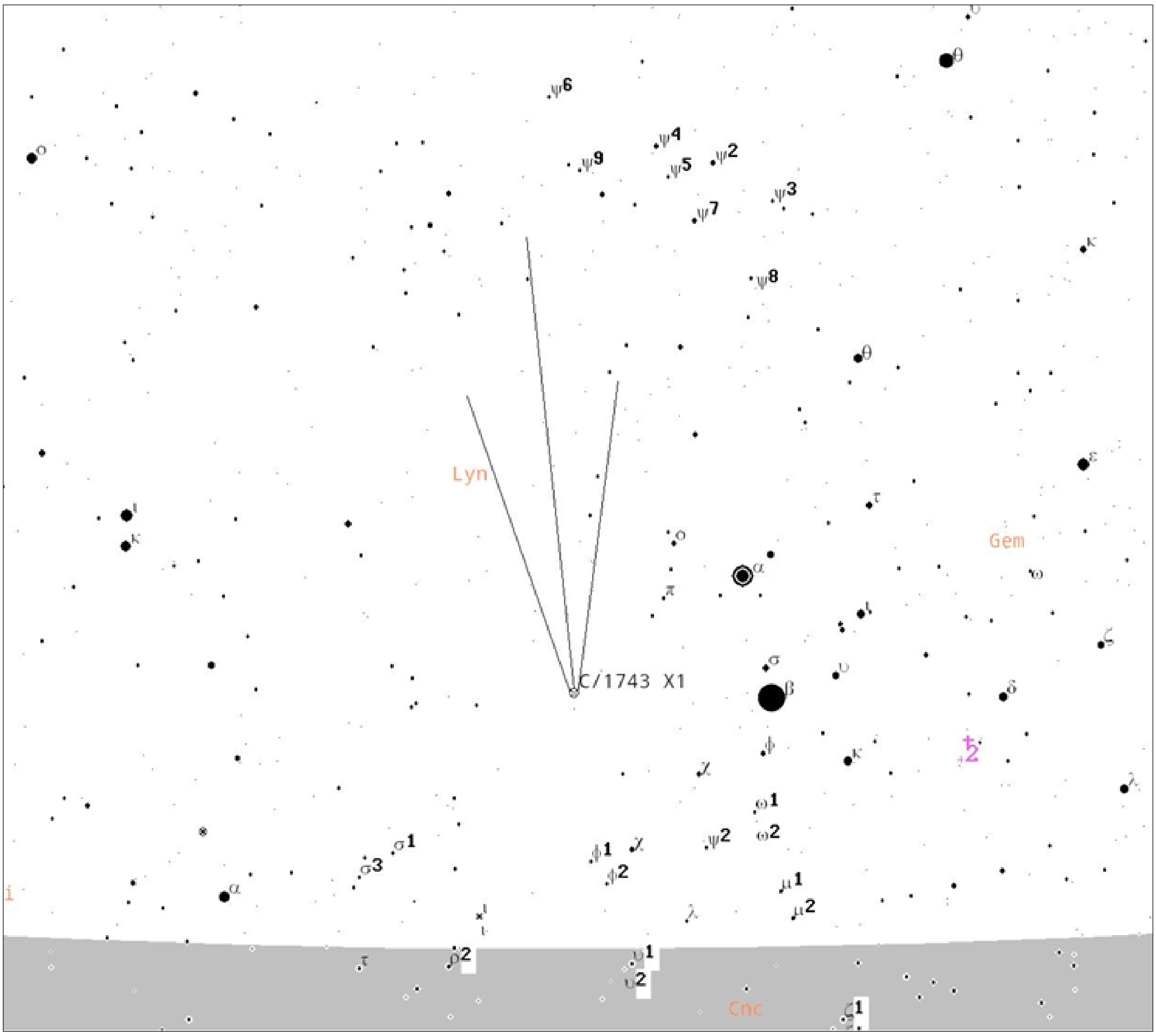

Figure 9: Position of comet C/1743 X1 on 15 July 1032, as seen from Beijing, China, in the morning sky. The comet is about 8° above the Northeastern horizon. The shape of the comet is just for visualization (chart prepared with GUIDE software).

Agapius of Manbij (Agapius of Hierapolis), a Syrian chronicler and Bishop of Manbij, lived during the tenth century and wrote a chronicle of events that included the following statement: “An awesome comet appeared every morning from 28 August to 26 October 676, sixty days in all.” (Cook, 1999). The event was dated 677, but it seems likely that it refers to comet X/676 P1, as the indicated period is similar to those reported in other sources.

Many European texts mention this comet, emphasizing that it was a bright and impressive object. Most agree that the comet was visible for three months and that it was brightest during September and October.

The *Liber Pontificalis*, a history of popes, was first compiled during the fifth or sixth century, with later biographies added into the fifteenth century. It provides the earliest account of this comet and may have been the primary source material for later accounts of this comet. It states the following in the chapter on Pope Donus, whose pontificate went from 676 to 678 (Duchesne, 1886: 348):

> While he was chosen, during the month of August, a star appeared from the east, at the time of the rooster’s crow until morning, for three months, whose rays penetrated the heavens; at the sight of which all the rising provinces and peoples marveled. Afterward, when it returned to itself, it disappeared; for which a severe and great death followed from the east.

Numerous monastic histories mention this comet, usually under dates ranging from 676 to 678. The Italian text *Historia Gentis Langobardorum* (Foulke, 1907: 235), written by Paulus Diaconus (Paul the Deacon, c. 720s–790s) before the year 796, says,

> … in the month of August, a comet appeared in the east with very brilliant rays, which again turned back upon itself and disappeared.

The Peterborough edition of the English text *Anglo-Saxon Chronicle* of 1154 (Thorpe, 1861: 33) says, "Here the star comet appeared in August, and every morning for 3 months shone like a sunbeam." The Irish text *Annals of Tigernach* of 1178 (Stokes, 1895: 204) says that in 677, "A bright comet was seen in the months of September and October."

From the listed observations, we have agreement that the comet became visible in the last days of August and first days of September and that it remained visible until the last days of October and the beginning of November. Despite the variation in the year of observation given by Agapius of Manbij and the European Monastic histories, it seems certain that a single bright comet mentioned in so many sources was seen in the year 676. The Chinese indicated that the tail lengthened after it was discovered, indicating that the comet was approaching perihelion. Earlier we adopted March 25 as the best fitting perihelion date for the comet of 1402 and Table 3 indicates that the most likely perihelion date for 676 would be close to October 20. We have assumed that the comet was close to perihelion when last seen by the Chinese on 1 November and adopted a perihelion date of 4 November. This would mean the comet might have been as bright as magnitude –4 on 1 November, assuming an identity with the apparitions of 1743/44 and 1402, and situated low above the horizon in bright twilight.

The agreement with the above-mentioned Chinese observations from the *Jiu Tang shu* and the *Tang Hui yao* is very good. They said the comet was in the lunar mansion of Dongjing on 4 September, which usually describes a range of equatorial longitude of a celestial body but says nothing about its latitude. With the adopted perihelion date and the backward integrated orbit of the 1743–1744 and 1402 apparitions, it would have been indeed placed in the right equatorial longitude range of Dongjing. The predicted magnitude was around 3 at that time. It is further said that the comet later had a tail of 30° and swept Zhongtai (λ and μ Ursae Majoris), pointing toward Wenchang (θ, τ, υ and 18 Ursae Majoris). This undated observation would then have happened around 1–6 October 676. This situation is shown for 4 October in Figure 10, when the comet should have been at magnitude 0.

Especially interesting is the description of the tail as rays that "… turned back upon itself …", which sounds very much like the peacock-like tail described for the comets of 1402 and 1744. However, simulations of the geometrical circumstances show that the chances for such a tail were not good. Applying the Finson-Probstein tail simulation with similar settings as used for C/1743 X1 and C/1402 D1 shows no large-scale synchrones and syndynes for the period covered by the observations. In fact, these same geometrical circumstances, which includes Earth remaining near the comet's orbital plane, indicate that the tail would have remained fairly straight and narrow throughout the apparition, including as it moved into strong twilight. We think the statement "… turned back upon itself …" likely refers to the apparent shortening of the tail as the comet moved deeper into the Sun's glare.

According to the *Nihongi*, the comet appeared in the East between mid-July and mid-August. This fits with the orbit, but the comet would have had a predicted magnitude of about 6.5 in mid-July and about 4.5 in mid-August in the eastern sky, which is too faint for an easy visual detection. But given the uncertain brightness parameters it could well be that the comet was a magnitude brighter in mid-August and may indeed have been detected then.

The Syrian observers claim to have seen the comet until 26 October 676. At that date, the comet would have been at 22° elongation, at a predicted magnitude of about –3, moving closer into twilight every day. It could be that bad weather or an obstructed view of the horizon prevented the comet from being followed further.

The comment from the *Chronicle of Silla*, which placed the comet between Beihe (α, β and ρ Geminorum) and Jishui (λ Persei) in the period of 15 August to 12 September 676, is also fulfilled, with the comet having a predicted magnitude of around 3.5 and 2.5 on 1 and 12 September, respectively. Taking all this into consideration, we can safely remark that the apparition of comet X/676 P1 can be represented by the backwards integrated orbit of comet C/1743 X1 with an assumed perihelion date of 4 November 676, give or take a few days.

6.3 The Comet of 336

When using the above apparitions as an anchor point, we end up in the year 336 for the next previous apparition. Here we again find a comet that was seen by Asian and European observers, but the comet has not yet received a designation.

In the Chinese chronicles *Song shu* (of the year 493) and *Jin shu* (of the year 648) and the Korean *Samguk Sagi* (of the year 1145), the

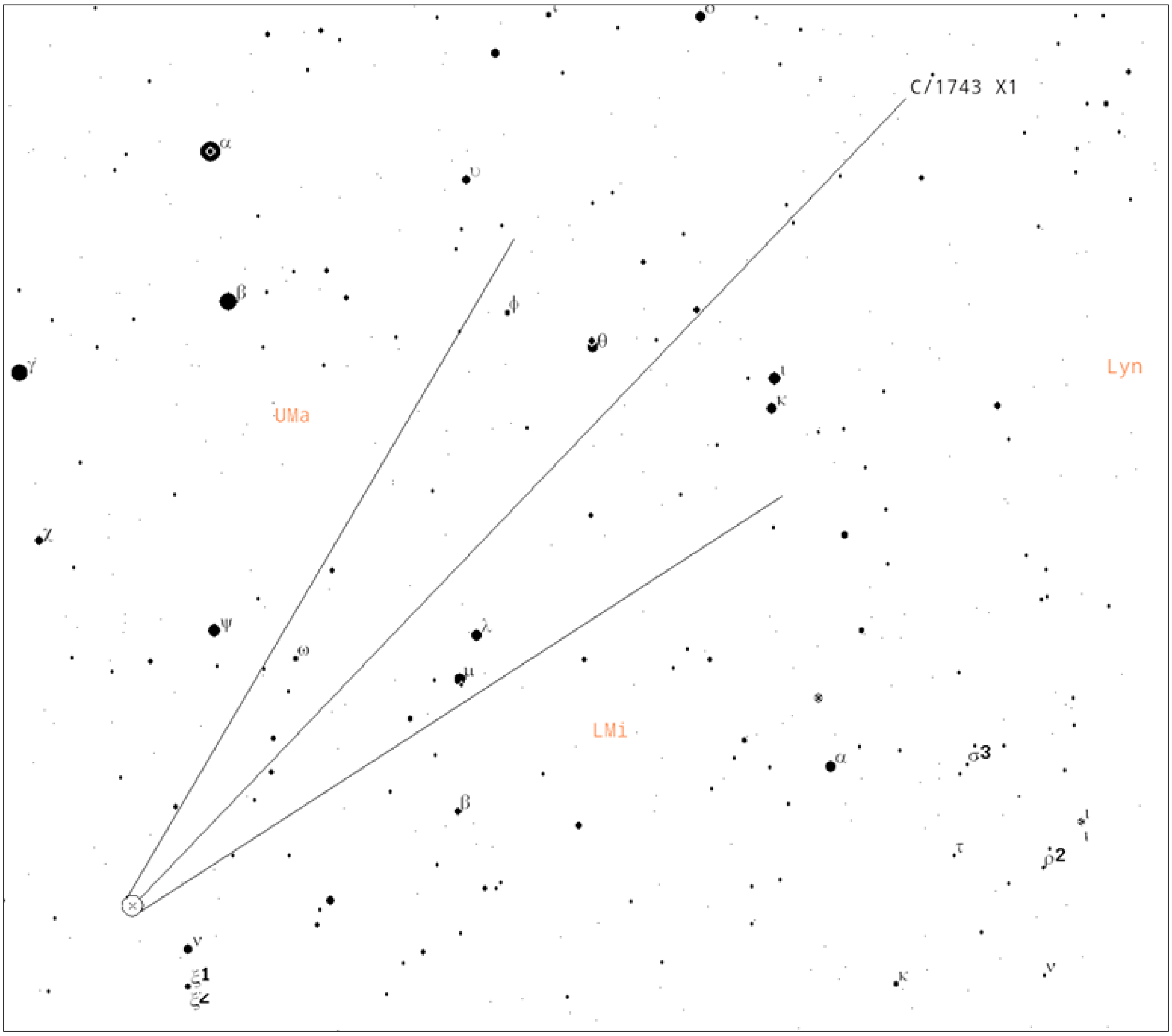

Figure 10: Position of C/1743 X1 on 4 October 676, showing the agreement with the description from Asian texts. The length of the straight middle line is about 40°. The shape of the comet is just for visualization (chart prepared with GUIDE software).

'broom star' is mentioned for 16 February 336. It is said that the comet appeared in the West in the evening in the lunar mansion of *Kui* (southern Andromeda and northern Pisces) (Ho, 1962: 159). This would perfectly fit assuming a perihelion date around 25 February to 10 March 336, with the comet being around magnitude –4 and 0, respectively.

The comet was possibly also seen from Europe. The Roman historian Eutropius (fl. 363–387) stated in his *Breviarum ab Urbe Condita*, which was published before 365, that the death of the Roman Emperor Constantine on 22 May 337, was foretold by "… a star with a tail, one of extraordinary size which shone for some time. The Greeks call it a comet." (Bird, 1993: 156–157). Even more interesting is the statement by Theophanes the Confessor (c. 759–818), a Byzantine monk and chronicler, in his *Chronographia* of 813, who said for the year 334–335 that

> In Antioch a star appeared in the eastern part of the sky during the day, emitting much smoke as though from a furnace from the third to fifth hour. (Mango and Scott, 1997: 49).

Ramsey (2006: 173–175) shows that the year is more likely to be 336. The time given is about 9:30 to 11 a.m. local time, which would mean that the comet was seen in daylight, probably at the end of February or the beginning of March. However, the description could also fit a fireball with a persistent trail.

6.4 Comet C/–43 K1

Table 3 predicts that the next previous perihelion time would be in the middle of the year –43, which looks very promising because it coincides with the appearance of the Great Comet C/–43 K1, a comet commonly associated with Julius Caesar's death.

Both the Chinese and Koreans indicate that the comet was seen during the month of 18 May to 16 June –43 (Pankenier et al., 2008: 22–23). The Chinese text *Han shu* said it emerged in the Northwest and indicated a tail length of about 12°. A few days later, it had moved "… within the space of Shen …", which defines lunar mansion 21 and basically refers to the main stars of Orion and exhibited a tail about 15° long. The Koreans, in the text *Chronicle of Silla*, specifically noted that it was "… at the fifth star of Shen …", which might be o Orionis.

According to Roman and Greek records, the death of Julius Caesar on 15 March –43, was followed by the appearance of a renowned comet in the skies above Rome, seemingly in agreement with the reports from China and Korea. Despite the Chinese and Korean records providing specific lunar month details, there is a debate surrounding the date mentioned in the Roman and Greek accounts. Consequently, there is uncertainty regarding whether the comet observed in Europe is identical to the one witnessed in Asia.

Allusions to Julius Caesar's comet began appearing in texts written a few years to a few decades after his death. There are numerous literary allusions to the 'comet' from Virgil in a poem of the year –41 and in the *Aeneid* from the years about –25 to –18, Horace in his *Odes* from the years about –29 and –22, Propertius in his elegies from the years about –23 and –20, and others slightly later that only refer to this object as a star, e.g. 'astra', 'astrum' and 'sidus' (Ramsey and Licht, 1997: 173). On the other hand, Ramsey (2006: 114–117) presents numismatic evidence on Roman coins that clearly depict a comet. Of the earliest texts that are still in existence, none provide anything substantial concerning when it was seen or what it looked like. Emperor Caesar Augustus, the adopted son of Julius Caesar, wrote *Memoirs* a few years after Julius' death, but this is lost. Fortunately, the Roman author and philosopher Pliny the Elder gave a passage from Augustus' *Memoirs* in his *Natural History* of 77 (Rackham, 1949: 237). It states the following:

> On the very days of my Games a comet was visible for seven days in the northern part of the sky. It was rising about an hour before sunset, and was a bright star, visible from all lands. The common people believed that this star signified the soul of Caesar received among the spirits of the immortal gods, and on this account the emblem of a star was added to the bust of Caesar that we shortly afterwards dedicated in the forum.

The phrase 'northern part of the sky' comes from the Latin word 'septentriones', which is sometimes translated as the seven stars of the Big Dipper. Further to reports that it was seen in the North, Ramsey (2006:108–124) presents texts that say that the comet rose at around 17:00–18:15 local time, was seen at midday, and around 13:15–14:30 local time, making this comet a daylight object.

The Roman philosopher L.A. Seneca wrote *Natural Questions* around 65 and noted that the comet "… burst forth after the death of the deified Julius, about sunset on the day of the games for Venus Genetrix." (Corcoran, 1972: 263).

Later texts seem to provide no further details about the comet, so they were probably based on Emperor Augustus' *Memoirs*, either directly or through Pliny the Elder's *Natural History*.

With respect to the seven-day duration, the French astronomer Alexandre Guy Pingré (1711–1796) made the following remark:

> It is undoubtedly this duration of the games that Augustus mainly paid attention to: according to him, the Comet had been seen all seven days of the games; but it may have been visible for a longer time. (Pingré, 1783: 278).

The date of the comet's appearance has been regarded as uncertain. It is evident that the comet was sighted "… during the games of Venus Genetrix." According to Ramsey and Licht (1997), the temple dedicated to Venus Genetrix was consecrated on 26 September –45. Previous astronomers had suggested that the comet was observed towards the end of September. However, Ramsey and Licht pointed out that within two years of the temple's inauguration, a new celebration called the ludi Victoriae Caesaris was established, occurring around 20 to 23 July –43, and the Games of Venus Genetrix were merged with the ludi Victoriae Caesaris. Hence, it is probable that Caesar's comet was seen near the end of July –43 (Ramsey and Licht, 1997: 44–47, 87).

Ramsey and Licht (1997: 126) also presented an orbit that tried to cover all the details mentioned in the available texts. They argued that the comet was bright when seen in China but faded afterwards, being invisible for about a month before undergoing a dramatic outburst that made it visible even during the daytime at the end of July. This orbit was the basis for designating it as C/–43 K1 and it is given in Table 1.

Unfortunately, this orbit requires many unusual things to coincide. The need for an outburst around the time of the Rome observations may just be acceptable, but it would have meant that the comet would have again been visible to the Asian observers, too, and there is no mention of it. According to their orbit, the comet was then at an elongation of 94°, circumpolar for Northern Hemisphere observers, at a distance of almost 1.5 AU from the Sun. An outburst of such magnitude, that far from the Sun alone would be very unusual, but also the visibility of a tail is hardly explainable. Cometary outbursts start with an almost star-like morphology, which diffuses over many days and weeks. A tail, if present at all, would take some time to develop. And a comet of maybe magnitude −4 (to be seen during the day) in dark skies would have been visible over a much, much longer time period than just the time mentioned by the Romans.

For our comparison with the orbit of comet C/1743 X1 and assuming that the comet was really seen during the day from Rome, it sounds reasonable to apply a perihelion date shortly after 23 July, e.g. 27 July −43. Using that date, we quickly see a problem with the Asian observations. First, the comet could never have been close to any star of Shen. Moreover, during that time of year, Shen was not observable at all during the night. This means that the Korean statement which places the comet near a star of Shen is incorrect. Ho (1962: 133) also stated that this source is mostly copied from Chinese texts and contains many inaccuracies.

If we accept the reference to Shen as meaning the comet was visible in the lunar mansion of Shen, i.e., in the same equatorial longitude range, then we see that using our perihelion date does place the comet in the correct region around the latter part of the indicated period (18 May to 16 June −43). While this may seem promising, we must acknowledge that the comet would then be in the morning sky, with a magnitude of about 2, contradicting the statement that it was seen in the Northwest. Also, the comet would have been at a low altitude (<10°) during twilight. With a magnitude of about 3, it would not have been a very conspicuous object. If we move the perihelion to an earlier date, we have even worse observing conditions but a brighter comet (magnitude about 0), but this would not fit the end-of-July observations from Rome. Therefore, the orbit of C/1743 X1 cannot plausibly explain the Asian observations.

On 23 July −43, the assumed time of the Rome observations, the comet would have been at a distance of just about 9° northeasterly from the Sun, the tail would be pointing towards Canes Venatici and Ursa Major. Technically, it would have been an evening sky object with a magnitude of about −4, but of course not observable in dark skies. The statement that the comet rose in the evening is also in contradiction to our assumption.

Shifting the perihelion date in the future, for instance, by one month to 26 August −43, would definitely disqualify the Asian observations as being of the same object. The comet would then be visible in the morning sky with a magnitude of about 5, now fully contradicting the historic records.

We must accept the fact that, in summary, the historic observations lead to more contradictions than agreements when comparing them with the orbit of Comet C/1743 X1. Even assuming that the Asian and Roman objects were different does not fully eliminate all contradictions to the—of course uncertain—Roman and Greek observations. Therefore, we must conclude that based on the available information the likelihood that comet C/−43 K1 is similar to C/1743 X1 is small.

6.5 Conclusion

Using the information derived from the discussed apparitions, we again carried out a backward integration, this time adjusting the perihelion time in 1402 in small increments to achieve the best fit with our suggested perihelion dates. Of course, we cannot expect an exact fit with the historic observations, especially the further we extend the calculations into the past. Minor differences in the starting conditions and unknown non-gravitational effects on the comet will lead to higher uncertainties the longer we extend the calculations into the past.

Table 4 shows the resulting orbits for our best-fitting starting conditions. We find that the perihelion date of 25.16 March 1402 almost perfectly matches most of the estimated perihelion dates when doing the backwards integrations, especially until the year 676. However, for the comet of 336, the difference is already three weeks, and despite the seemingly good fit for comet C/−43 K1 we must accept that this object is a very questionable candidate.

We tried to find possible alternative candidate objects around the years 336 and −43 but were not successful. Of course, the historic records around these two periods are scarce, and a perihelion falling in the months of April to July might have caused the comet to be completely missed.

Tables 5 to 8 list ephemerides for the apparitions of the years 1402, 1032, 676 and 336 and the estimated best-fitting perihelion dates based on the available descriptions. For the

Table 4: Orbits for all discussed apparitions from a backward integration from 1743/1744 to –43 with a fixed perihelion date for 1402 which gives the best agreement with observations for earlier apparitions. The last column indicates the difference that needs to be added to the predicted perihelion dates to receive the best representation of the observations.

Comet	T (TT)	q (AU)	e	ω (°)	Ω (°)	i (°)	P (years)	ΔT (days)
C/1743 X1	1744 Mar. 01.86	0.221460	0.995619	151.748	49.499	47.085	359.41	–
C/1402 D1	1402 Mar. 25.16	0.222630	0.995654	151.843	49.585	47.033	366.59	–
1032	1032 Jul. 31.2	0.222451	0.995719	151.79	49.53	46.87	374.62	+1
X/676 P1	676 Nov. 04	0.2199	0.99567	151.96	49.34	47.09	362.1	0
336	336 Feb. 06	0.2175	0.9958	152.1	49.7	46.7	372.5	+20…+33
C/–43 K1	–43 Jul. 30	0.221	0.996	151.7	50.3	46.1	414	(–4)

Table 5: Ephemeris for Comet C/1743 X1 at the apparition in the year 1402 based on the assumed identity with Comet C/1402 D1 for a period when brighter than third magnitude.

Perihelion date 1402-03-25.16 TT				
Date 1402	RA (2000.0) (h m)	Dec (2000.0) (° ′)	E (°)	*m* (mag)
03 Feb	01 13	+20 38	55	3.0
13 Feb	01 15	+21 50	46	2.3
23 Feb	01 19	+23 19	38	1.3
05 Mar	01 23	+24 49	31	0.0
15 Mar	01 21	+25 01	23	–2.3
25 Mar	01 01	+12 53	06	–5.2
04 Apr	01 08	–08 53	24	–2.6
14 Apr	01 34	–15 47	34	–0.3
24 Apr	01 56	–18 31	41	1.2
04 May	02 15	–20 10	46	2.3
14 May	02 30	–21 33	52	3.1

Table 6: Ephemeris for Comet C/1743 X1 at the apparition of the year 1032 based on the assumed identity with Comet C/1402 D1 for a period when brighter than third magnitude.

Perihelion date 1032-07-31.16 TT				
Date 1032	RA (2000.0) (h m)	Dec (2000.0) (° ′)	E (°)	*m* (mag)
20 Jun	05 43	+33 13	23	3.0
30 Jun	06 30	+34 30	23	1.9
10 Jul	07 33	+34 20	21	0.5
20 Jul	08 56	+30 09	15	–1.5
30 Jul	10 29	+15 42	10	–4.3
09 Aug	11 13	–09 06	22	–2.8
19 Aug	11 33	–31 45	38	–1.1
29 Aug	12 01	–51 52	54	0.2
08 Sep	12 58	–68 12	67	1.2
18 Sep	15 28	–78 26	75	2.1
18 Sep	19 20	–77 48	80	3.0

Table 7: Ephemeris for Comet C/1743 X1 at the apparition of the year 676 based on the assumed identity with Comet C/1402 D1 for a period when brighter than third magnitude.

Perihelion date 676-11-03.76 TT				
Date 676	RA (2000.0) (h m)	Dec (2000.0) (° ′)	E (°)	*m* (mag)
06 Sep	07 12	+37 10	80	3.0
16 Sep	08 10	+39 34	79	2.0
26 Sep	09 41	+40 00	73	0.8
06 Oct	11 41	+33 30	58	–0.3
16 Oct	13 32	+18 16	39	–1.4
26 Oct	14 48	+00 49	22	–2.9
05 Nov	15 54	–18 54	4	–4.3
15 Nov	17 19	–35 37	14	–1.5
25 Nov	18 47	–43 25	25	0.4
05 Dec	20 08	–45 28	31	1.7
15 Dec	21 13	–44 26	34	2.8

Table 8: Ephemeris for Comet C/1743 X1 at the apparition of the year 336 based on the assumed identity with Comet C/1402 D1 for a period when brighter than third magnitude.

Perihelion date 336-02-25.55 TT				
Date 335/336	RA (2000.0) (h m)	Dec (2000.0) (° ′)	E (°)	*m* (mag)
29 Dec	00 49	+20 19	79	3.0
08 Jan	00 40	+20 12	67	2.5
18 Jan	00 33	+20 23	56	1.8
28 Jan	00 27	+20 42	45	0.8
07 Feb	00 17	+20 33	35	–0.7
17 Feb	23 55	+17 10	22	–3.0
27 Feb	23 25	–02 14	11	–5.0
08 Mar	23 59	–16 40	24	–1.9
18 Mar	00 37	–19 57	30	0.3
28 Mar	01 06	–20 48	35	1.7
07 Apr	01 30	–21 03	39	2.7

comet of the year –43 no ephemeris is given due to the very uncertain identification.

7 PREDICTION FOR THE NEXT APPARITION

If the derived chain of apparitions until 676 (or 336) summarized in Table 4 is correct, then the following orbit is predicted for the next apparition of this comet. This will finally decide whether the presented link, first suggested by Hiorter already in 1745, and refined in this work, is indeed correct and that the comets of 336, X/676 P1, 1032, C/1402 D1, and C/1743 X1 are one and the same object.

Predicted orbital elements: C/1743 X1 for 2097
Perihelion 2097 Dec 8.61
Epoch 2097 Dec 13.0 TT

(2000.0)

q = 0.225410 AU   ω = 151.449°
e = 0.995791   Ω = 49.799°
P = 392.0 yr   i = 46.662°

This will be a very favorable apparition. Prior to perihelion, the comet will be easily visible when it is about magnitude 6 in August. It will quickly become brighter, reaching magnitude 0 at the beginning of November 2097, followed by the closest approach to Earth at about 0.6 AU in early November 2097, at magnitude –0.5 to –1. The comet might again be visible close to the Sun during the days around perihelion. The maximum magnitude from the assumed magnitude parameters is –4.4. The tail will be mostly narrow until the end of November when it will start to spread. The chances are good that the tail will also be visible after perihelion when the head of the comet is still at or already below the horizon, although probably not as widely spread as in 1744.

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Maik Meyer graduated from Chemnitz Technical University (Germany) in 1995 as an engineer. He has observed comets since 1987 and has logged almost 2000 visual observations of more than 160 comets. Always interested in the history of comet hunting and observing, he has specialized in identifying and linking historic comet apparitions with known comets and calculating new and improved cometary orbits. Identifications include the long-lost comets 157P/Tritton, 205P/Giacobini, 206P/Barnard–Boattini, 271P/van Houten–Lemmon and 273P/Pons–Gambart. In 2020, he was able to identify the historic comets of October 1385 and January 1457 as earlier apparitions of Comet 12P/Pons–Brooks.

Maik is the namesake of the 'Meyer Group' of sunskirting comets which he identified in 2002 from orbital calculations of comets found in the data of the SOHO spacecraft. In 2010 he discovered Periodic Comet 312P/NEAT in archival survey data. The minor planet (52005) was named in his honour.

Maik served as the head of the German Amateur Comet Observers working group within the Vereinigung für Sternfreunde (VdS) for several years, and is Assistant Editor of the *International Comet Quarterly*. He is also co-author with Gary W. Kronk of Volumes 5 and 6 of *Cometography : A Catalog of Comets* (Cambridge University Press) and the two-volume *Catalog of Unconfirmed Comets* (Springer Nature).

Gary W. Kronk obtained a Bachelor's degree in journalism from Southern Illinois University at Edwardsville, USA. He is an amateur astronomer who began observing comets in 1973, but the more he read about comets and meteor showers the more he became interested in their history. He has now spent nearly 50 years researching and writing about comets and meteor showers. This has led to the publication of twelve books on these subjects, which include his six-volume *Cometography* series for Cambridge University Press. He has also written articles for *Sky & Telescope*, *Astronomy*, *StarDate*, *Mercury*, *Astronomy Technology Today*, and other magazines, and authored or co-authored research papers that have appeared in this journal and in *Icarus*; *Earth, Moon, and Planets*; the *International Comet Quarterly*; and the *Journal of the International Meteor Organization*.

In 1992, Gary examined ancient Chinese observations and found that comets seen in 69 BC and AD 188 were previous observations of Periodic Comet 109P/Swift–Tuttle. In 2003, he discovered that observations of a comet made by the Reverend Leo Boethin in January 1973, but not seen by anyone else, were actually prediscovery observations of Periodic Comet 104P/Kowal, which was not discovered until 1979 (Brian Marsden confirmed both of these findings and published the details on the *IAU Circulars*).

Gary was invited to participate in Leonid MAC 99, a NASA/US Air Force mission to study the Leonid meteor shower over the Mediterranean Sea in 1999. The aircraft were equipped with cameras to photograph the meteors using various filters to learn as much about this meteor shower as possible. Minor planet '48300 Kronk' was named after him.