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A NEW AND IMPROVED ORBIT FOR COMET C/1558 P1

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Abstract: The bright comet C/1558 P1 was seen only from early August to mid-September 1558. Previous orbits for it were calculated based on a limited number of observations and failed to represent all observational reports. By including observations from Asian historical sources and from an additional European treatise a new orbit is calculated that now represents the observational data in a more satisfactory manner.

Keywords: comets, Comet C/1558 P1, orbits

1 INTRODUCTION

It is known that many of the pre-nineteenth century comets have published orbits that are relatively inaccurate. The reasons are, of course, the low precision of the observational data and the short duration of a comet's visibility. Only for the brightest comets that were seen for a sufficiently long time are the chances good for achieving an orbit that is close to the truth. Many of the older orbits were also derived in the nineteenth century, when a major portion of the Asian observations from Chinese, Japanese and Korean chronicles were not yet known. Modern tools can help calculate more precise orbits and the hope exists that those comets will eventually be identified as an early or later return of some other comet. Such a link was recently demonstrated by the author of this paper for comet 12P/Pons-Brooks, which was found to be identical with comets C/1385 U1 and C/1457 A1, respectively (Meyer et al., 2021).

In this paper we examine the orbit of Comet C/1558 P1, which was seen mainly from early August to mid-September 1558. Previously published orbits were based only on semi-accurate positions obtained over a relatively short period, and listed in a few European sources. These earlier orbits do not accommodate Asian observations that were published decades after the publication of these initial orbits.

2 THE EARLIER ORBITS FOR COMET C/1558 P1

The German astronomer Heinrich Wilhelm Matthias Olbers (1758–1840; Figure 1; Solc, 2014) attempted to calculate an orbit for this comet based on four observations (Olbers, 1812). He analysed observations made by Cornelius Gemma (1535–1578) of Leuven (Belgium) and William IV (1532–1592), Landgrave of Hesse-Kassel (Germany), which had already been discussed in 1588–1589 in letters exchanged by the Danish astronomer Tycho Brahe (1546–1601) and Christoph Rothmann (fl. 1577–1590), court mathematician in Kassel (see Brahe, 1596: 126; 144).

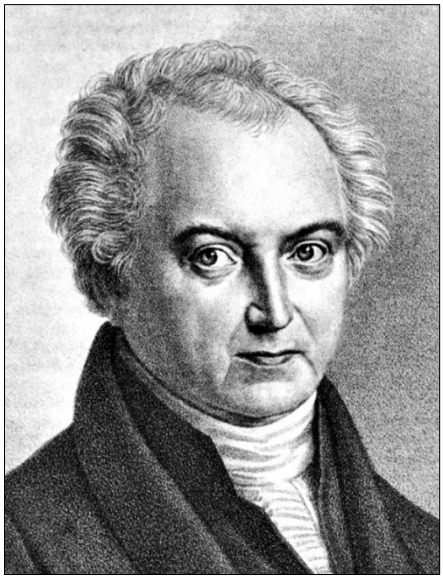

Figure 1: Heinrich Wilhelm Matthias Olbers (https://en.wikipedia.org/wiki/Heinrich_Wilhelm_Matthias_Olbers#/media/File:Heinrich_Wilhelm_Matthias_Olbers.jpg).

Olbers (1812) also presented supplementary observations by Erasmus Flock (1514–1568), who observed the comet from Nuremberg, Germany (Flock, 1558). As a result, he derived four ecliptic positions, one by Gemma on 17 August 1558, and three by William IV on 20, 21, and 23 August 1558. These are listed in Table 1. The resulting orbit for equinox 2000.0 is given in Table 2, where q is the perihelion distance in au, e the eccentricity of the orbit, ω is the argument of perihelion in degrees, Ω is the longitude of the ascending node in degrees and i is the inclination to the ecliptic in degrees.

Table 1: 1558 ecliptic positions at 2100 local time for Comet C/1558 P1 derived by Olbers (1812: 176–184).

Date	Approx. Longitude	Latitude	Location
17 August	163° 36′	+26° 23′	Leuven, Belgium
20 August	171°	+31°	Kassel, Germany
21 August	173°	+31°	Kassel, Germany
23 August	178°	+35° 50′	Kassel, Germany

Table 2: The orbital elements of Comet C/1558 P1 derived by Olbers (after Kronk, 1999: 315).

T (UT)	*q*	*e*	ω	Ω	*i*
11.035 August 1558	0.5773	1.0	2.77	338.75	106.58

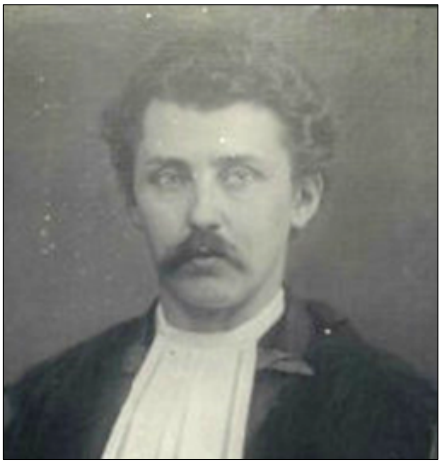

Figure 2: Utrecht astronomer Martin Hoek (http://4.bp.blogspot.com/-x48SoVQV8nU/UVQgaRga0dI/AAAAAAAABGM/7iU10lacJ-g/s1600/mh1.jpg).

In 1864, the Dutch astronomer Martin Hoek (1834–1873; Figure 2; Bolt, 2014) located a 1558 treatise by the Viennese court astronomer Paul Fabricius (1529–1589) that contained some information about observations of Comet C/1558 P1 made by Fabricius (1558) in Vienna and Prince Ferdinand from the Austrian court (see Hoek, 1866). However, the treatise contained rather poor astronomical data, and no formal measurements were given. As a result, Hoek was forced to take positions of the comet from the woodcut that formed the frontispiece of the book (see Figure 3). While admitting that the positions (listed in Table 3) were approximate, Hoek used them to calculate new orbital elements (equinox 2000), which are listed in Table 4.

Table 3: 1558 Ecliptic positions at 2100 local time for Comet C/1558 P1 derived by Hoek (1866).

Date (2100)	Approximate Longitude	Latitude	Location (Austria)
18 August	167° 48′	+34° 00′	Vienna
19 August	169° 12′	+32° 18′	Vienna
20 August	171° 06′	+30° 18′	Vienna
21 August	173° 24′	+28° 42′	Vienna
22 August	174° 48′	+27° 54′	Vienna
23 August	176° 24′	+27° 06′	Vienna
31 August	181° 42′	+22° 36′	Vienna

Table 4: The orbital elements of Comet C/1558 P1 derived by Hoek (after Marsden and Williams, 2008: 12–13).

T (UT)	*q*	*e*	ω	Ω	*i*
14.04 August 1558	0.2805	1.0	119.60	341.21	110.94

It can be seen from the positions alone in Table 3 that the resulting movement is not in agreement with the data derived by Olbers. While Olbers indicated a northward movement, Hoek showed that the comet moved southward (see Figure 4). It is interesting that Hoek put more weight on his positions, derived from the crude woodcut, and chose to dismiss Olbers' positions and orbit.

Hoek (1866: 96) closed his short text by saying:

> I regard my calculations on this comet as unfinished, but before continuing them, especially, before publishing my memoir, I take the liberty of addressing the following request to the German astronomers. I would like to know of more documents about the comet of 1558. Perhaps there are some in private or public libraries. An invitation received in the local gazettes could lead to the discovery of such documents.

Surprisingly, Hoek's orbit was adopted after its publication in 1866, and is still the orbit that is given in several comet catalogues (e.g. Marsden and Williams, 2008) and databases. Various authors have commented on the fact that Hoek's orbit seems to be worse than Olbers' orbit (Holetschek, 1896; Kronk, 1999), especially emphasizing the fact that Hoek's orbit would require the comet to become brighter throughout August and September, while in fact it became fainter, something that Olbers' orbit does support.

3 ADDITIONAL OBSERVATIONS

3.1 Asian Observations

Then unknown to Olbers and Hoek, the comet was also observed from Asia. Korean observers followed the comet over a long period and described the path in the sky. Pankenier, Xu and Jiang (2008: 223) give the following descriptions from the Joseon *Wangjo sillok: Myeongjong*:

> 8 August 1558: broom star in Taiweiyuan, which is the area including σ, ι, θ, δ Leo and β Vir, showing a tail of 6°–7.5°.
>
> 18 August 1558: within Taiweiyuan, tail larger than 6° and pointing to α CVn.
>
> 3 September 1558: north of Tianshiyuan (δ, ε, ζ Oph), tail longer than 1.5°, pointing south of CrB
>
> 13 September 1558: within Tianshiyuan, above Shilou (μ, τ Oph, ο, ν Ser), tail over 6°–7.5° pointing south of Zongren (66, 67, 68 and 70 Oph).

From these observations the two positions listed in Table 5 were derived.

The position of 8 August 1558 was determined by evaluating the geometric condit-

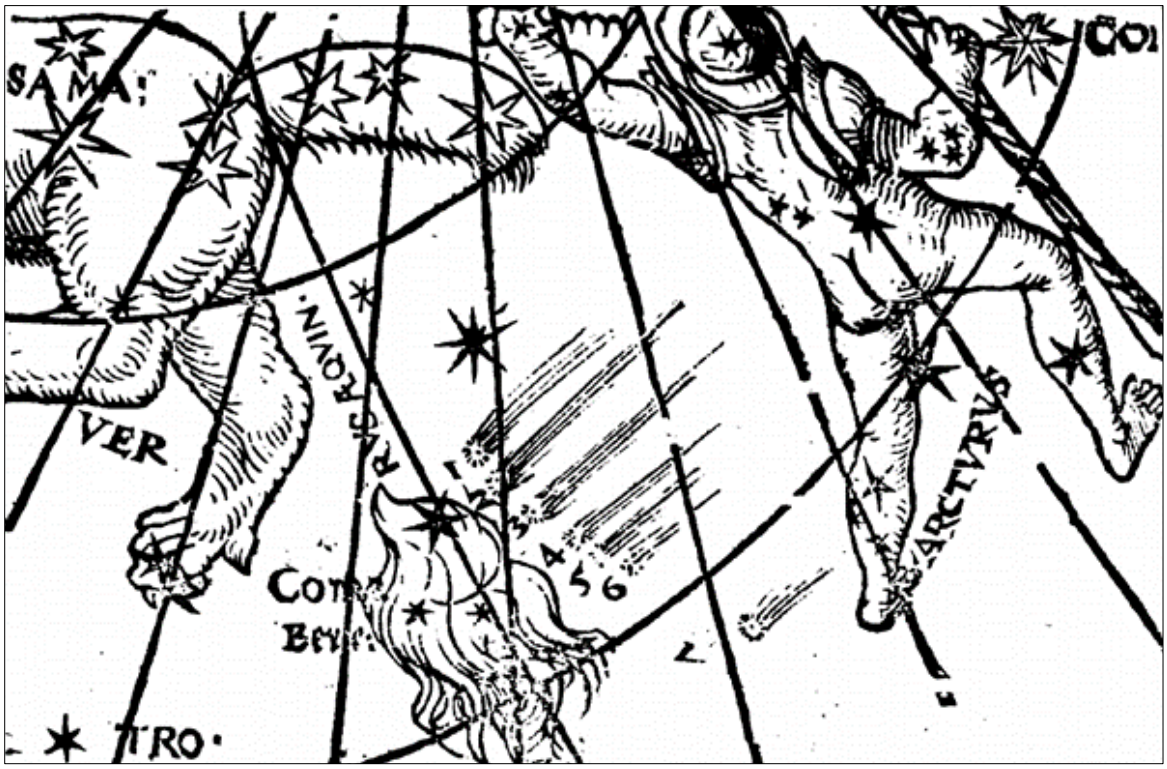

Figure. 3: Woodcut on the frontispiece of Fabricius' (1558) treatise about the comet of 1558 from which Hoek derived the cometary positions listed in Table 3.

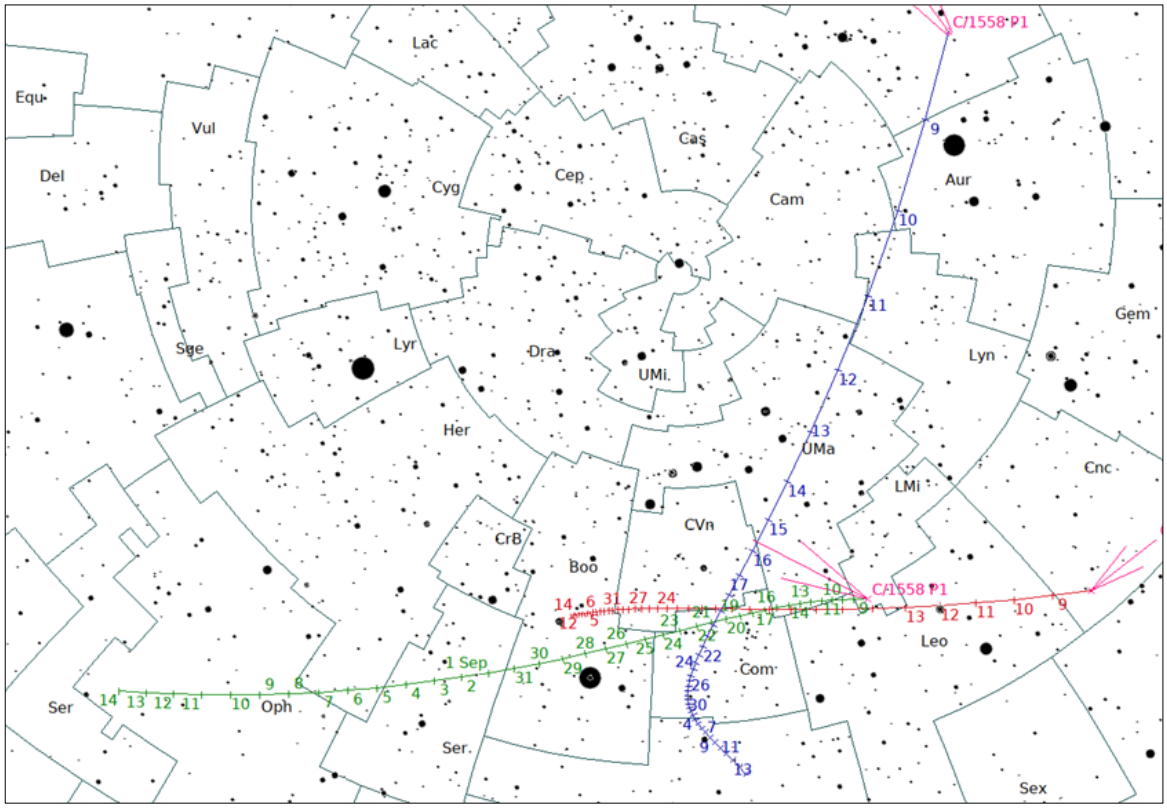

Figure 4: Paths of the three orbits for the period 8 August 1558–14 September 1558. Blue: Hoek, Red: Olbers, Green: this paper. It can be seen that Olbers' orbit shows a better agreement with the new orbit than Hoek's during the time of the European observations (chart prepared using GUIDE planetarium software.)

ions for the Korean observers. If the comet would have been closer to β Vir it would have been hardly observable. A position more north-westerly in the direction of Leo seemed geometrically more reasonable for a first sighting in the evening twilight. The position

Table 5: 1558 positions for Comet C/1558 P1 provided by Korean observers (after Pankenier et al., 2008: 223).

Date (UT)	Approx. R. Ascension	Declination	Location
08.50 August	10h 35m	+29° 00′	Korea
13.5 September	17h 15m	–05° 30′	Korea

Table 6: 1558 ecliptic positions for Comet C/1558 P1 provided by Schönfeld (1558).

Date and Local Time	Approx. Longitude	Latitude	Location (Germany)
19 August 20:45	170° 46′	+28° 38′	Marburg
21 August 22:08	172° 19′	+30° 36′	Marburg
23 August 21:45	177° 18′	+35° 43′	Marburg

of 13 September should be good to about ±5° based on the clear description.

There also exists a record from Japan, which simply says that a comet was seen from 9 August 1558 until 19 August 1558.

It might seem astonishing that no Chinese records of this comet exist. According to Pankenier (pers. comm., June, 2021) this might be connected with a devastating earthquake that struck China in January 1556, followed by three years of severe aftershocks. The relief efforts would have affected the Imperial administration, including the Bureau of Astrology and the Calendar. Additionally, frequent raids by the Mongols from the North, contributed to this disastrous situation. According to Pankenier (*ibid.*), astronomical records from the capital are comparatively sparse during the period 1550–1567.

Table 7: The new orbital elements calculated for Comet C/1558 P1.

q	*e*	ω	Ω	*i*
0.3155 ± 0.0328	1.0	55.5 ± 6	155.5 ± 2.0	76.4 ± 4.5

Table 8: Residuals of the nine observations, in degrees.

Date (1558)	Location	Approx. Longitude	Latitude
08 August	Korea	+0.13	+0.32
17 August	Leuven	–0.82	–1.79
19 August	Marburg	+1.50	–2.47
20 August	Kassel	+0.46	–0.21
21 August	Kassel	–0.45	–0.65
21 August	Marburg	–1.27	–0.71
23 August	Kassel	+0.36	+2.49
23 August	Marburg	+0.01	+2.98
13 September	Korea	–0.02	–0.17

Table 9: Residuals of the Vienna observations, in degrees.

Date (1558)	Approximate Longitude	Latitude
18 August	+3.92	+3.33
19 August	+2.07	+1.40
20 August	+0.26	–0.88
21 August	–1.10	–2.85
22 August	–3.03	–3.65
23 August	–4.92	–4.40
31 August	–28	–0.60

3.2 Additional European Observations

The comet was widely observed from Europe, but most of the observations do not include positional details (e.g., see Camerarius, 1558 and Neodomus, 1558) so they cannot be used to determine its position.

Interestingly, a further German treatise was uncovered by the author, which contains positional measurements of this comet made by using a torquetum. Victorin Schönfeld (1525–1592) observed the comet from Marburg, Germany, on 19, 21, and 23 August 1558. More observations were prevented by bad weather. Schönfeld (1558) gives ecliptic coordinates as well as his local observation times and these are listed in Table 6.

4 THE NEW ORBIT

For the determination of the new orbit of Comet C/1558 P1 only astrometry from actual observations was used, which means that Hoek's positions derived from the woodcut were omitted. The new parabolic and unperturbed orbit is given in Table 7, with perihelion at 1558 Aug 4.01 ± 0.59 TT, and the epoch 1558 Aug 20.0 TT = JDT 2290348.5.

The nine observations from 8 August to 13 September 1558 (see Table 8) have a mean residual of 1.30°.

In Table 8, the worst residual is about 3° (Marburg, 23 August). The residuals from the Vienna positions derived by Hoek from the woodcut are shown in Table 9 for comparison. The position of the comet listed for 31 August is clearly erroneous.

These new orbital elements also explain why the comet was not seen earlier. The comet might have reached naked eye visibility in July, when it was already at solar elongations below 20°. Only shortly prior to perihelion did it brighten quickly and then approach Earth (perigee was on 3 September 1558, at 0.51 au), with much better observing conditions.

5 COMPARISON WITH OTHER OBSERVATIONS

Numerous mentions of this comet have been collected, especially by Pingré (1783) and Lubinietzki (1666). Pingré gives a first sighting of the comet already on 14 July, reported by de Mezeray (1646: 707), but this date is most likely an error in the month given as there are no other mentions of the comet in July. Also, the comet would not have been visible in the night sky at that time.

Lubinietzki (1666: 354–357) cites numerous historians who mention this comet (and may have copied from each other as the contents appear very similar), and relate it to the deaths of Emperor Charles V. (on 21 September 1558) and his sisters Eleonore (on 18 February 1558) and Maria (on 17 October 1558). Most of the sources simply state that a comet was seen on 6 August within or below Coma Berenices. On this date, the comet would have appeared just above the horizon in the twilight, below and slightly towards the west of Coma Berenices. The German polymath Joachim Camerarius the Younger (1534–1598) says that the comet appeared on 9 August 1558 (Pingré gives 5 August) in the western sky in the sign of Leo below Ursa Major and near Coma Berenices (Camerarius, 1558), a statement that agrees with the new orbit. The Annales Augstburgenses (1728: 1884) reports the comet around 15 August 1558, appearing below the tail of Ursa Major, which is also in agreement with the position based on the new orbit. Pingré (1783: 507–508) adds that the comet might have been seen from Europe as late as the evening of 5/6 September 1558, but his sources do not provide additional details. There are even mentions that the comet was seen until 21 September 1558, but these are probably incorrect and clearly were aimed to raise a connection to the death of Emperor Charles V on that same day.

6 THE BRIGHTNESS EVOLUTION

Based upon the descriptions, general assumptions can be made regarding the brightness evolution of the comet. Since the comet was still seen with a tail by the Koreans on 13 September 1558, its apparent magnitude might still have been around magnitude 4. Assuming an average activity factor, n = 4, the absolute magnitude is derived as H_{10} = 4.7, which indicates that it was a brighter object than the average comet. Using these parameters, the comet had an apparent magnitude of 0.0–0.5 when seen first in early August. At the end of August, the comet would still have been as bright as magnitude 2.5–3. By mid-September, the comet had faded below the level of naked-eye visibility.

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Maik Meyer graduated from Chemnitz Technical University (Germany) in 1995 as a graduated engineer for measurement technology. 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 Kronk of Volumes 5 and 6 of *Cometography*: *A Catalog of Comets* (Cambridge University Press).