What was the comet depicted in Giotto's Adoration of the Magi?

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A minor but enduring mystery in art history is the identity of the comet depicted in Giotto di Bondone's work *The Adoration of the Magi*, painted as a fresco in the Scrovegni Chapel in Padua. Representing the Star of Bethlehem and traditionally assumed to be inspired by an object personally observed by Giotto, it has been associated with 1P/Halley's 1301 return. However, this identification has been questioned. The apparition was theoretically a poor one, with closest approach to Earth being before perihelion and the calculated magnitude always fainter than +1, although there is some evidence that the comet was brighter than would be expected from its average activity over two millennia. An alternative inspiration would be one of the two comets observed in 1304: C/1304 C1 and the 1304 Christmas Comet, C/1304 Y1. The former was observed for two and a half months, between February and April. The latter was observed for just six days but, critically, these included Christmas Eve and Christmas Day, which would have been significant to a devout catholic such as Giotto. This paper examines the three principal candidates and their visibility in detail, plus other comets that were reported in the 1300–1306 time frame. While C/1304 Y1 appears to be a likely model for Giotto's work, significant questions remain about all three candidates.

Introduction

Giotto's *The Adoration of the Magi*, one of the most recognisable artworks in the world, followed many prior representations of the Adoration. Possibly the oldest known is the 3rd-century image of the three Magi under a six-pointed star, drawn on a Christian sarcophagus. A reproduction is on display in Hall 15 of the Museo della Civiltà Romana in Rome, while the original can be found in the Vatican Museum. However, Giotto's Nativity scene, with a comet over the stable, is significant in being recognised as the first accurate depiction of an astronomical object in art.

It is generally assumed that Giotto's painting was inspired by a comet that he had seen. However, the identity of such an object has remained a mystery for over seven centuries. In popular imagination, it is often assumed that the painting represents Comet Halley (1P/Halley), and this theory resulted in the naming of the European Space Agency's mission to this body. This interpretation was doubted by Hughes *et al.* (1993),[1] who suggested the Comet of 1304 (C/1304 C1) as a more likely identification. However, they did not consider another comet seen later in the same year, C/1304 Y1, which was observed over Christmas.

Here, we re-examine the evidence for and against 1P/Halley and the two alternative identifications.

Giotto

If you go to Florence Cathedral, you may easily miss a marble medallion that hangs in the shadows of the cathedral. Translated from Latin, it says:[2]

> *I am he through whose merit the lost art of painting was revived; whose hand was as faultless as it was compliant. What my art lacked, nature herself lacked; to none other was it given to paint more or better… But what need is there for words? I am Giotto, and my name alone tells more than a lengthy ode.*

Giotto di Bondone, popularly 'Giotto', was a Florentine architect and painter born *c.* 1267. In common with many famous people of the Middle Ages, the exact date and place of his birth are unknown, with dates of birth as late as 1275 proposed. There is even some uncertainty about his name, with some authorities suggesting that Giotto is a contraction of Ambrogiotto (Eimerl, 1967).[2] His father was a farmer called Bondone, who was described in a contemporary Latin text as '*vir praeclarus*' (a distinguished man). 'Giotto di Bondone' means, literally, 'Giotto [son] of Bondone', hence his name is normally contracted just to Giotto.

Various birthplaces have been proposed for Giotto, with local authorities favouring a photogenic tower in the tiny village of Vespignano, although Eimerl points out that this is extremely unlikely as it was an administrative building at the time that Giotto was born and favours, instead, an anonymous, hilltop farm on the nearby Colle di Romagnano.

Almost the only undisputed fact about Giotto is that he died on 1337 January 8. His date of birth is mainly based on the evidence of a Florentine chronicle of the day, which said that he died at the age of 70, but, as Eimerl points out, given that the chronicle was written in verse, rounding the age to the nearest 10 fitted the metre better and thus it may be an unreliable guide to his true age.

Bartlett (1992) notes that his chronicler Giorgio Vasari – the 16th-century biographer of no fewer than 150 artists – described Giotto as:[3]

> *The most sovereign master of painting in his time, who drew all his figures and their postures according to nature.*

It is this ability to paint life-like images that makes Giotto's work so interesting and important. As Castillo-Martínez de Olcoz (2005) points out, Giotto was the first painter to represent in his works the delicate lighting effects produced by sunlight.[4] He states that Giotto was a painter who:

> *Approaches reality and presents a true modelling founded in the illumination of the sunlight.*

Although it is as a painter that he is best remembered, this was not his only talent: as an architect, he also designed the Bell Tower of Florence Cathedral.

The Scrovegni Chapel

Although many works are attributed to Giotto, there are considerable doubts about the authenticity of some of them. What is not in doubt is that he painted the frescos of the Scrovegni Chapel in Padua. Also known, possibly more correctly, as the Arena Chapel, this building was commissioned by Enrico degli Scrovegni. It was constructed as an annex to a palace that Scrovegni was restoring for his personal use. The whole complex, of which the chapel is the only surviving building, was built on the site of a former Roman arena, following its oval outline, hence the alternative 'Arena' name (Eimerl, 1967).[5]

Popular belief is that Scrovegni built the chapel as an indulgence to atone for his own sins and/or those of his father (Derbes & Santona, 2008).[6] He was a moneylender and son of Reginaldo degli Scrovegni, who was cited by Dante in *The Divine Comedy* as a usurer who was consigned to hell for his crimes. Usury was regarded as a serious sin and crime, so an accusation of usury could have important consequences for the person accused, far beyond those of simple public disgrace. It is usually believed that it was to receive absolution for his own sin of usury that Enrico degli Scrovegni commissioned the construction of the chapel.

As, due to his dubious activities, he was one of the richest men in Italy in his day, he was able to commission the finest artwork that money could buy for his chapel. Although the chapel exterior is simple, the interior is anything but.

Appropriately for a work commissioned as an atonement designed to bring absolution, the theme of the art is salvation. The walls are covered with two cycles of frescos: one on the life of the Virgin Mary and another on the life of Christ. In total, there are 37 frescos in these two cycles. They are arranged in three tiers starting, chronologically, with the upper tier, which details the life of the Virgin Mary, while the middle and lower tiers depict the life of Jesus. The importance of these frescos is such that they were inscribed on the UNESCO World Heritage List in 2021, as part of the serial site 'The frescoed cycles of the 14th century in Padua', and are now carefully protected.

However, even if the chapel bought Enrico degli Scrovegni temporary relief from public censure, he was later forced to flee Padua and, finally, a few years before his death in 1336, he was formally banished from the city of his birth.

The exact dating of the Scrovegni Chapel frescos is uncertain. Eimerl (1967) dates the frescos to 1305,[7] although the Arena Chapel's official website gives a dating in the range 1303–1305 while noting that some sources extend the range to dates as late as 1310 (Anonymous, 2024).[8] It is significant, though, that no one advances the date of the frescos to earlier than 1303.



Figure 1. *The Adoration of the Magi* fresco, painted by Giotto di Bondone in the Scrovegni Chapel in Padua. The alert viewer might note that Giotto has drawn the camel with a broad smile – symbolism of the joy of the event – while the Magi look on the baby Jesus with serious faces of reverence.

The Adoration of the Magi

The work that is the subject of this paper (Figure 1) is just one panel of the two cycles of frescos that line the Scrovegni Chapel. However, it is arguably the most famous of all.

Numerically, it is panel no. 18: the third panel of the cycle of the life of Christ. It is placed directly above *The Washing of the Feet*. From the point of view of a visitor looking down the nave towards the altar, behind which is painted *The Last Judgement*, panel no. 18 is centred in the middle tier on the left-hand side of the chapel.

In Figure 1, to the right, seated in the symbolic representation of a stable, we see Joseph and Mary, the latter holding the baby Jesus. Jesus is depicted here as a young child rather than a newborn, consistent with the tradition that Luke's Gospel treats events immediately around the birth of Jesus, while Matthew's Gospel details events that took place weeks or months later. At the extreme right of the image, we see an angel. In front of the holy family are the three barefooted Magi, or Wise Men. Behind them stand two attendants, partially hidden, who are holding their camels.

Looking closely at the work, we see numerous other details and curiosities. One suspects that Giotto had never seen a camel in real life, for these form probably the least realistic part of the



Figure 2. The Comet of 1556, depicted over the city of Constantinople after the earthquake which devastated the city that year. The comet was sighted on 1556 March 5 and seen for 12 days. In this coloured woodcut, printed by Herman Gall in Nuremberg, 1556, the ships and buildings are illustrated in considerable detail, allowing individual structures such as the Blue Mosque or Hagia Sophia to be easily identified. Even the cumulus clouds in the sky are quite accurately represented. In contrast, the comet is heavily stylised and bears little relation to its true appearance.

scene. Incongruously, he has painted the camel in the foreground with what appears to be a broad smile, consistent with the joyous nature of the event depicted, although the Magi are shown with serious faces of the utmost reverence. The boy who serves as camel-handler looks up at his spirited charges in apparent concern. One of the Magi is kneeling, while the other two are standing and look down on the scene. The unbearded Magus to the left, who carries a goblet in the left hand, with its lid being removed with the right, clearly has a woman's face, despite the tradition that the Magi were all male.

We see that Mary's cloak must originally have been blue, although only fragments of the original colour remain. Most of the background was also originally blue, but has suffered some considerable wear, leaving numerous patches of bare plaster. The reason why the blue has suffered the depredations of time more than other colours is that it required special treatment during the process of painting. Blue was the most expensive pigment in medieval painting, made from lapis lazuli mined only in Afghanistan, and was used to symbolise purity in religious imagery.

Sinclair (2019) notes that:[9]

> *... blue pigment [...] was more precious than gold. The use of such a precious pigment in artistic portrayals of Mary originates in symbolic expressions of devotion and glorification.*

Sinclair also comments that:

> *The convention of portraying Mary wearing a sumptuous blue cloak can be traced back to the Byzantine Empire, c. 500 CE, where blue was regarded as the colour of an empress and a symbol of the imperial cult.*

Until the adoption, later in the Renaissance, of cheaper pigments based on German azurite, blue pigment was so rare and expensive that painters often specified in the contract with their patron that they should be given access to an adequate supply for their work (Viñas, 2024).[10]

The use of this pigment had consequences. While other colours were painted on wet plaster (*a fresco*) and so bonded with the wall on drying, due to the expense it was necessary to paint the blue on dry plaster (*a secco*) to conserve its colour. The lack of bonding between paint and wall causes the blue paint to deteriorate and to flake with time. Since the 1970s, the frescos of the Scrovegni Chapel have been subject to careful monitoring and conservation. They are now regarded as being in a stable condition (Anonymous, 2024).[8]

However, what makes this work so important to astronomers is the representation of the comet above the stable. This is regarded as being the earliest example of a comet being naturally represented in an artwork. We see that Giotto has reproduced the degree of condensation of the coma, with increasing density and brightness towards the centre and a gradual fading of the tail at increasing distance from the comet's head. He even reproduces the subtle change in colour along the length of the tail.

We can compare this rendering with one of the Comet of 1556, illustrated by Herman Gall, which is shown in Figure 2. This highly stylised representation contrasts sharply with the detail depicted in the boats in the harbour and the buildings of Con-

stantinople, some of which, such as Hagia Sofia and the Blue Mosque, are easily recognisable. It also contrasts sharply with the quite accurately reproduced cumulus clouds.

Lest we think that it was the difficulty of reproducing nature faithfully in a medium such as a woodcut, or even, thinking of the Bayeux Tapestry, cloth, instead of with paint and canvas that was the difference between the representation of comets by Giotto and by other artists, consider Figure 3. This is taken from the illustrated manuscript *The Chronicle of Lucerne* (Schilling, 1513),[11] and is one of 443 full-page, lavish, beautifully detailed illustrations. Yet the two comets in the sky are heavily stylised, as six-pointed stars with caricature tails. Their representation is totally incongruous with the carefully depicted details of buildings, landscapes and people throughout the manuscript.

It is the superior detail in Giotto's comet that has led to the belief that he reproduced the image of an object that he himself had seen, either while painting the fresco cycle or shortly before doing so. If so, it must have been a comet that impressed him so much that he was inspired to use it as a model for the Star of Bethlehem. This implies that it must have been a bright and prominent object, or one that was particularly significant to him as a pious Catholic.

Giotto's painting offers other clues about the comet. The tail is relatively short compared to the diameter of the head and is dagger shaped, getting narrower along its length. This is suggestive of a comet seen pre-perihelion, with the gas tail developing. There is some resemblance of this morphology to images of 1P/Halley pre-perihelion in 1985 December, particularly the now iconic David Malin image that is one of the most reproduced of all 1P/Halley images from the 1986 return (Figure 4).

Comets in 1300–1306

Given that we are uncertain exactly when the Scrovegni Chapel frescos were painted, we must explore a range of several years in our search for candidates to be Giotto's comet. As we have seen, the Chapel's own website accepts that the frescos were painted around 1303–1305 (Anonymous, 2024),[5] so our search should centre around this range of dates.

Giotto would have planned the frescos very carefully, preparing sketches and distributing the images in the available space. We can gain some idea of the process, and the time required from the well-documented painting of the Sistine Chapel. We know that Michaelangelo started to paint this in 1508 July and ended in 1512 October: four years and three months later. However, as he had never painted a fresco, the early part of this time was spent learning the office. He also suffered significant problems during the work, so he would have progressed much more slowly than Giotto. Similarly, he expanded the project as he worked. His initial contract was to paint just the 12 apostles but the final work includes more than 300 figures (Museivaticani, 2024).[19] It is thus reasonable to think that Giotto was working for some two years at most on the project. In this case, panel no. 18 would have been completed about a year into the work.

To have influenced him, the comet must have appeared before work on *The Adoration of the Magi* was significantly advanced. If we accept the 1303–1305 dating for the frescos, it seems unlikely that he could have used a comet observed later than 1304 as his model. Similarly, to have so impacted his work, it was probably a comet of recent memory. It seems reasonable, then, to limit the search to the years 1300–1306.



Figure 3. A representation of the supposed disasters associated with two comets sighted in 1456, from the *Lucerne Chronicle* of 1513, by Diebold Schilling.[11] Again, the comets – which the artist could not have observed personally – are heavily stylised and more a caricature than an attempt to emphasise reality.

Hughes *et al*. based their search for alternatives to the 1301 apparition of 1P/Halley on the Marsden (1986) catalogue of comet orbits.[20] This failed to account for the possibility that there may be further candidates in the correct range of years that, for one reason or another, did not, at that time, have a calculated orbit. Yeomans (1991) publishes a full list of naked-eye comets observed up to 1700.[17] This list is based on the catalogues of Ho (1962) [H], Pingré (1783) [P], and Hasegawa (1980) [Has] and is probably the best available.[21,15,22] As well as 1P/Halley in 1301, Yeomans lists five additional comets in the 1300–1306 time frame, two of which have a calculated orbit and, thus, a formal designation. These are listed in Table 1 (below).

We see that two comets were only observed in Japan (Has 722 & Has 726) and two only in Europe (P 423 & P 424). The other two comets were multi-site, and both were observed in 1304. The first, H447, was recorded in China, Japan and Korea; the second, H448, only in Japan and Korea. At first sight, it is these multi-site comets that are most likely to have been spectacular enough to have impressed Giotto, although it is troubling that, if they were spectacular, there are no recorded European observations of either.

Herein, we look at the possible candidates, assuming for the visibility calculations (unless stated otherwise) that observations were made from Beijing. Note that the simulations of the night sky take account of the change from the Gregorian to the Julian calendar prior to 1582 (Zotti, 2023).[23]



Figure 4. The iconic image of 1P/Halley taken by David Malin at the Anglo-Australian Observatory on 1985 December 9, showing the development of the gas tail pre-perihelion. There is a clear similarity in morphology with Giotto's representation of the Star of Bethlehem. *(Anglo-Australian Observatory)*

The 1301 apparition of 1P/Halley

This comet is the one most often been associated with Giotto's painting. The European Space Agency mission to 1P/Halley in 1986 was named *Giotto* due to this association.

The 1301 apparition of 1P/Halley was, in principle, not one of the better ones. Perihelion came on October 25, with the closest approach to Earth (to 0.183 au) on September 23, 32 days before perihelion. The elongation dropped below 20° on October 30 and remained under 20° through November as the comet got more distant, fading to the limit of naked-eye visibility in Scorpius. Apart from a few days immediately after perihelion, visibility was limited to the pre-perihelion period, when it would have been less active and with a much less developed tail. It was thus a much less spectacular object to observe than it was, for example, in 1066.

At closest approach to Earth, the comet was already well inside Earth's orbit, at a heliocentric distance of 0.893 au and visible in the evening sky, 18° high at the end of astronomical twilight. This approach came with a waning gibbous Moon in the sky, three days before third quarter; however, the Moon would not have risen until 45 minutes after the end of astronomical twilight in Beijing, with the comet still 12° high in the north-west, so would not have been a serious impediment to observations. The Moon's phases for September and October of 1301 are shown in Table 2 (overleaf). Yeomans *et al.* (1986) found,[12] using the brightening formula of Bortle & Morris (1984),[13] that the maximum brightness was magnitude +1.3. This puts the 1301 apparition in the faintest third of observed historical appearances of the comet (Kidger, 2024).[14] Some confusion arises because, although

Table 1. Observed comets, 1300–1306

Date(s)	*Where observed*	*Reference(s)*	*Designation*
1301 September – October	China, Japan, Korea, Europe	H446, P420	1P/Halley
1301 November – December	Europe	P423	
1303 July 27	Japan	Has722	
1304 February – April	China, Korea, Japan	H447 & Has723	C/1304 C1
1304 December	Japan, Korea	H448 & Has724	C/1304 Y1
1305 April 15 – 21	Europe	P424	
1305 June 19 – July 1	Japan	Has726	

Comets observed between 1300 and 1306 that are listed in the catalogues of Ho (H), Pingré (P), and Hasegawa (Has). Note that no comets were seen in 1306.

From left to right: the date(s) that the comet was observed; the catalogues that list the object (here, the notation follows Yeomans (1991) such that, for example, 'H447' means 'entry 447 of Ho's catalogue'); and the IAU designation of the comet (if one exists). It is not impossible that that two comets observed in 1305 were the same object, observed first in the evening sky and then in the morning sky.

the comet was first sighted in Korea on September 14, Pingré (1783) states that it was first sighted in Europe on September 1.[15] The Bortle & Morris formula gives a magnitude of 6.3 on the former date and 3.7 on the latter. Morris & Green (1982) find that the average estimated magnitude at pre-telescopic discovery was +2.8 and that first observations fainter than +3.5 were rare for apparitions recorded between 240 BCE and 1682, in all of which the comet was recovered visually.[16] Only two conclusions are possible: (1) the 1301 apparition was unusually bright, with the comet at least three magnitudes brighter than normal, or (2) the date of the first European observation given by Pingré is an error.

On 1301 September 1, 1P/Halley would have been a morning object in Gemini, positioned a few degrees northwest of epsilon Geminorum. As seen from Padua, it would have risen at 22:30 (all times for Padua are given as local time, assuming the city to be on Central European Time = UT + 1 h) and, at the start of astronomical twilight, at 03:59, would have been 53° high in the east. The 7-per-cent illuminated waning crescent Moon, in Leo, would have risen at 03:07 and would have presented little impediment to observing.

It is hard to believe that the relatively unsophisticated European astronomers of the day could have detected a (supposedly) 6th-magnitude comet and the Chinese not. Throughout the Late Middle Ages, Chinese and other Asian reports of comets far outnumber European observations. Of 82 naked-eye comets listed by Yeomans (1991) as being observed between 1066 and 1300,[17] just 18 were observed from Europe. Even some returns of 1P/Halley were missed by European observers. However, there is an interesting inconsistency here. Of the 18 European sightings listed by Pingré (1783),[15] only eight have confirming observations from Asia: usually Chinese, but occasionally Korean, or, more rarely, Japanese. That leaves 10 of Pingré's records being of objects not observed at all by the diligent observers from Asia. This leads to the suspicion that some of the Pingré's records may be unreliable at best, or even completely erroneous.

In the specific case of the 1301 return of 1P/Halley, Simpson (2025) points out that Pingré's source is given as 'Dunthorne',[24] which appears to be a reference to a letter in *Philosophical Transactions* (Dunthorne, 1751).[25] This, in turn, quotes from an anonymous manuscript from 1301, entitled 'Judicium de stella comata [*sic*] anno Domini 1301'.[26] The text states that the comet was first sighted on '*primo die septembris*'. Simpson further notes that Thorndike (1950, p. 203) suggests that the author of this text was Peter of Limoges – a clergyman usually known by his Latin name of Petrus Lacepiera, but also referred to by no fewer than 16 variants of his name – who observed the comet and mapped its position from September 30 to October 6.[18] However, the dating of the first sighting of the comet is inconsistent with this range of dates. Simpson concludes that two explanations suggest themselves: either the Pembroke College manuscript is a later copy of the original and the date was miscopied, or, possibly, the author was the later author, Geoffrey of Meaux (Gaufridus de Meldis), who was active from 1310–1347, and he remembered the date incorrectly.

Aside from this debate, there are multiple records of the 1301 return from Asia. Despite the presence of the waxing gibbous Moon in the sky at the same time as the comet, the first Korean observations in 1301 date from September 14. The Chinese first observed it on September 16, two days prior to full moon, and followed the comet for six weeks, until six days after perihelion. Finally, for the day of closest approach to Earth, September 23, a Japanese record describes the tail as more than 15° long, so it was definitely impressive visually.[17]

As previously noted, Thorndike pointed out that there are verified European observations of the apparition made by Peter of Limoges – a week after closest approach to Earth.[18] The range of dates when Peter of Limoges observed falls around the October new moon, and the absence of the Moon from the sky may have been important in his observation of the comet. However, the comet would have been observable in a completely moonless evening sky even a week earlier than his first observation.

Even discounting Pingré's report of a September 1 sighting, the Korean observation suggests that 1P/Halley was almost certainly somewhat brighter than average in 1301. To have been detected in Korea on September 14 at magnitude 3.7 in the presence of a bright Moon, or in China on September 16 at magnitude 3.2 with the Moon almost full, seems unlikely.

Similarly, the last Chinese observation, on October 31, also suggests that the comet was somewhat brighter than normal. On October 31, it was at declination –17°, in Ophiuchus, slightly north of the Sun, but at an elongation of only 19°. By the Bortle & Morris formula, the magnitude at this time would have been +2.1. Sunset in Beijing was at 09:05 UT, corresponding to 17:05 local time, when the comet was already at less than 14° altitude. Nautical twilight ended at 18:06 local time, by which time the comet was at just over 3° altitude in a still-bright band of sky on the south-west horizon.

In Figure 5, we see how the comet might have appeared to Giotto had he been observing from Padua at 19:00 local time on September 22. This was after full moon, allowing it to be seen in a dark sky after sunset around closest approach to Earth.

Over the interval covered by Peter of Limoges, the comet was fading rapidly from 1.9 to 2.6, according to the Bortle & Morris formula. Why, though, did he cease his observations? After October 6, the decrease in brightness would have almost ceased. On October 6, the three-day-old Moon was in conjunction with 1P/Halley, passing 22° south of it. Moonlight should not have been an important issue for several more nights, with the comet maintaining its brightness and increasing in angular distance from the Moon. We can only suppose that his observations were halted by a prolonged run of poor weather, although there is no documentary evidence to back this supposition.

In summary, the evidence above is suggestive that the comet may have been about one magnitude brighter than average in 1301, although the rather short duration of observation by Peter of Limoges does cast some doubt on this conclusion.

Table 2. The Moon's phase for the period of observation of 1P/Halley in 1301

New moon	*First quarter*	*Full moon*	*Third quarter*
Sept 3	Sept 10	Sept 18	Sept 26
Oct 2	Oct 10	Oct 18	Oct 25
Nov 1			

Dates are UT.

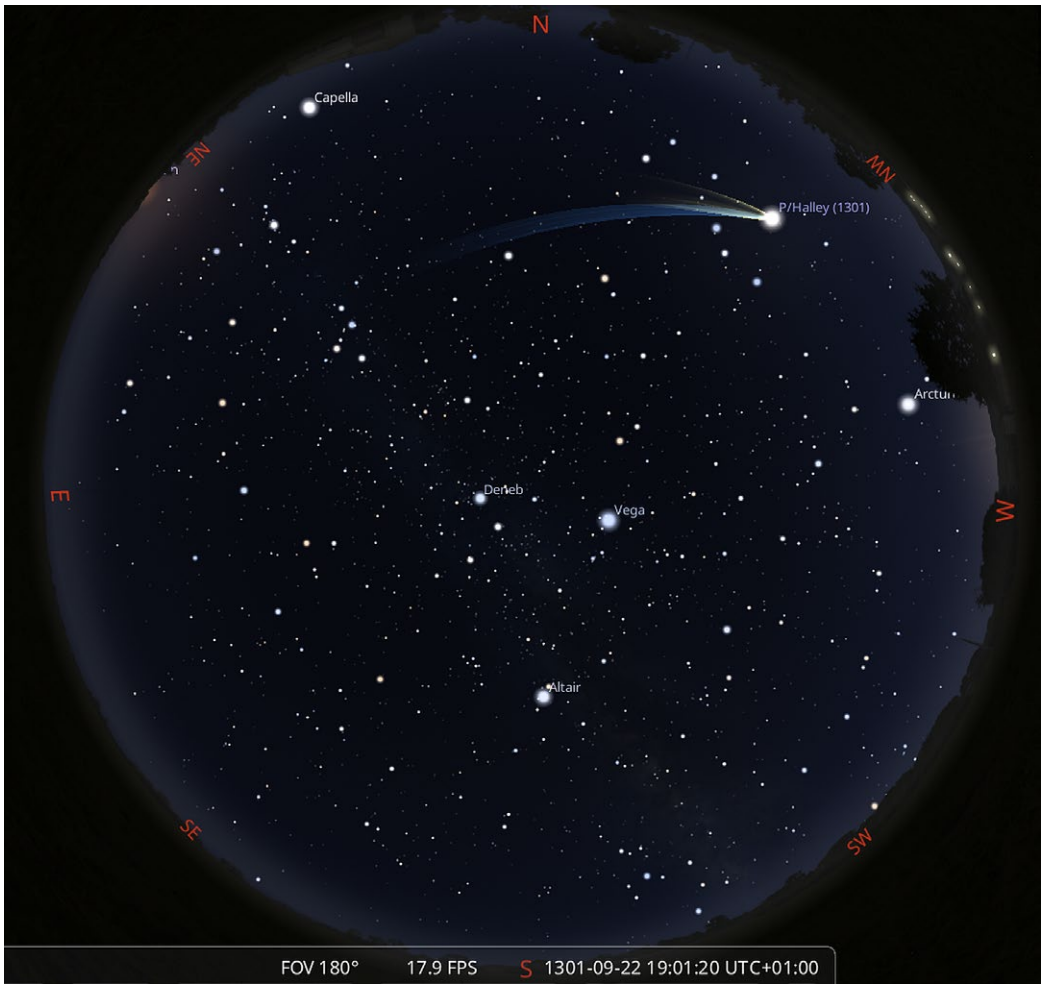


Figure 5. Simulation of the appearance of 1P/Halley as observed in a dark sky from Padua on 1301 September 22, at 19:00 local time. *(Stellarium, 2024.[29])*

The comets of 1301, 1303 & 1305

All of these objects are recorded by observations from single sites only and, in some cases, these records are extremely limited.

P423 refers to a comet observed in the evening sky for two weeks in late November and early December of 1301, with the comment that 'on December 1 it was in Aquarius or Pisces'. This implies that it was in the region around phi Aquarii, south of the Circlet of Pisces. The date is significant, because it corresponds to new moon. It is at least mildly surprising that none of the Asian observers saw a comet that was visible for so long, at a time of year when the weather is generally much drier in Asia than in late spring and early summer, the monsoon being long finished. This Pingré record seems unlikely to be a case of date confusion with observations of 1P/Halley given that, through October, 1P/Halley had tracked through Ophiuchus. Equally however, the lack of multi-site observations suggests that this was not a great comet that might have impressed Giotto.

Has722 is a very brief record of a comet with a 1-degree-long tail seen in the northeast from Japan in 1303. Again, there is nothing in this record to suggest that it was an important object. P424 and Has726 could, conceivably, be the same object, observed in 1305 April in Europe and in 1305 June from Japan. If so, it was sighted from Europe in the evening sky, pre-perihelion, and from Japan in the morning sky, post-perihelion. Pingré describes 'a large comet with a long tail' that was visible from April 15–21. Hasegawa gives a very specific record of the comet being seen at 4 am on June 19, and implying that it was visible up to and including July 1. The Moon was new on April 24, with third quarter on April 13, consistent with the observation of a comet in the evening sky before moonrise. Similarly, there was a new Moon on June 22 so, on June 19, the Moon would have been only a slim crescent in the morning sky. There was a full Moon on July 4 so, by July 1, a nearly full Moon would have been visible in the sky for most of the night, making observation of a rapidly fading comet impossible. Even if P424 and Has726 are the same object – implying a rather long interval of invisibility between the evening and morning appearances – the short period it was observed suggests it was not especially impressive, unless it had a close approach to Earth around April 18 and hence was briefly well seen.

To identify this object with Giotto's comet requires a chain of suppositions that, while not impossible, is highly improbable. It seems unlikely that we cannot find a much more plausible candidate.

The comets of 1304

Two comets were observed in 1304 that were multi-site and have calculated orbits: C/1304 C1, visible from February to April, and C/1304 Y1, observed in December. The elements of the two are shown in Table 3 (overleaf).

C/1304 C1

Perihelion was on 1304 February 5, at 0.84 au. Closest approach to Earth was 20 days beforehand, at 0.79 au on 1304 January 16. The comet tracked south to north between January and April, starting the year in Sculptor and passing through Cetus, Pisces, Andromeda, Pisces (again), Andromeda (again), Cassiopeia, Cepheus, and Draco, and crossing the plane of Earth's orbit on January 22. This object is clearly of interest because of its long duration of visibility, which was the main argument in its favour given by Hughes *et al.*[1]

First observed on February 3 as a white 'broom star' (tailed comet) in Pegasus, it was placed by Korean observers near the border between Andromeda and Pisces on February 7. Yeomans (1991) comments that the tail remained 1 degree long until April 18, after which it started to grow progressively in length. Yeomans further states that the comet 'went out of sight after 74 days', implying that it was last observed on April 18, which is seemingly inconsistent with the statement that the tail increased in length after this date.

This is an interesting case in that the comet's elongation, 53° at discovery, barely changed through February and only increasing slowly the following month, to 60° on March 15 and 69° on March 31. On April 18, the comet was at 80° elongation. The comment that the tail length increased after April 18 is inconsistent with the presentation of the comet, which was nearly side-on at discovery (70°), closed progressively to 41° on April 18, and was increasingly face-on, looking down the tail, thereafter.

Let the light curve be represented as:

$$m_1 = h_0 + 5 \log \Delta + 2.5\, n \log r \qquad (1)$$

where m_1 is the observed total visual magnitude, h_0 is the comet's absolute magnitude (the magnitude that it would have when simultaneously 1 au from both Earth and the Sun), Δ is the geocentric distance, r is the heliocentric distance, and n is the brightening parameter with r.

Using equation 1 to calculate the expected magnitude of the comet results in the plot shown in Figure 6. The value of n is typically in the range of 3–4, with the lower value typical of comets inside Earth's orbit. The long period of indicated visibility suggests a very bright absolute magnitude and/or a small value of n. Here, we plot two curves, one with a fast brightening and an absolute magnitude similar to 1P/Halley and the other with a more typical rate of brightening and an absolute magnitude one magnitude brighter than 1P/Halley, corresponding to a large and active comet.

Given the comet's rather poor observational circumstances, never being very close to Earth and with its geocentric distance increasing to 1 au by two weeks after perihelion, it would take an

Table 3. Elements of the two comets observed in 1304

Comet	C/1304 C1	C/1304 Y1
T	1304 Feb 05.5	1305 Jan 19
q (au)	0.84	0.65
Ω (°)	88.7	106
ω (°)	25	56
e	1	1
i (°)	65	99
arc (d)	75	4 (Dec 26–30)

These are taken from the JPL Horizons System.[27]

T is the date of perihelion, *q* is the perihelion distance in au, Ω is the longitude of the ascending node in degrees, ω is the argument of perihelion in degrees, *e* is the orbital eccentricity (a value of 1 assumes a parabolic orbit), *i* is the orbital inclination in degrees, and *arc* is the length of the orbital arc, in days, used to calculate the orbit.

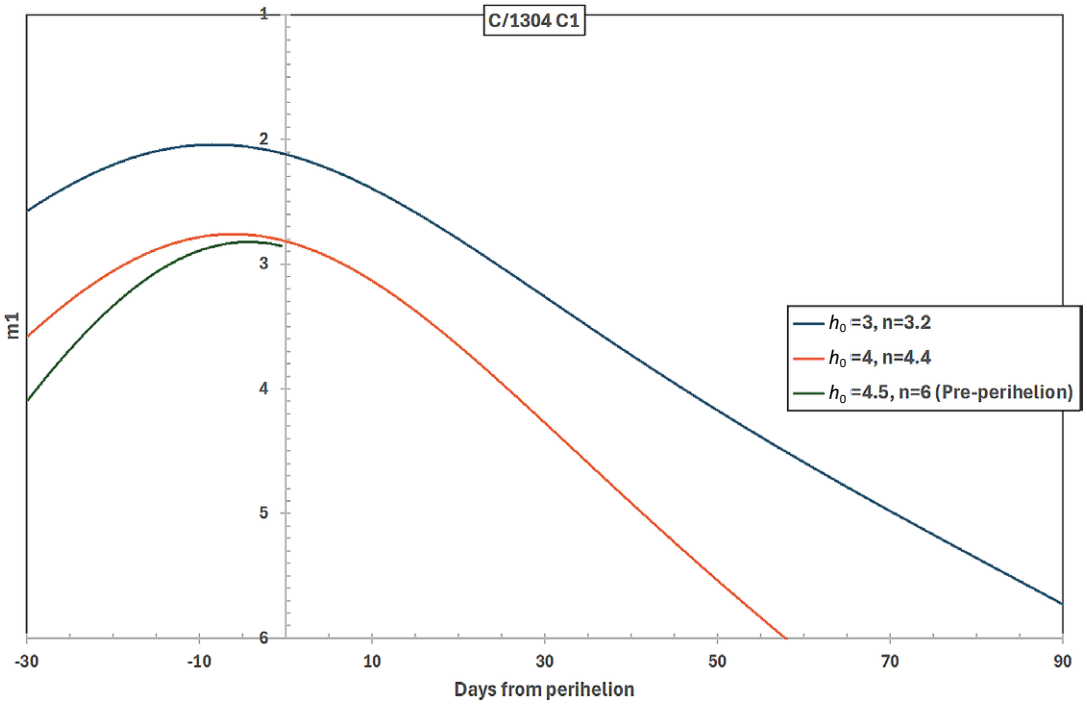


Figure 6. The predicted magnitude of C/1304 C1 based on a 'standard' brightening law and a fast brightening law (red), with absolute magnitude (h_0) assumed to be similar to that of 1P/Halley. On the standard brightening law (blue), the comet's brightness would have varied by only half a magnitude in more than a month and a half around closest approach to Earth. A third, hybrid, option is also considered (green), in which the comet had a very fast pre-perihelion brightening, followed by a slower post-perihelion decline; this option would give a light-curve discontinuity at perihelion.



Figure 7. Simulation of C/1304 C1 as it would have appeared from Padua on 1304 February 3, at 19:00 local time. If we assume similar dust and gas production parameters to 1P/Halley, it would not have been a comparable spectacle to either the 1301 apparition of 1P/Halley (Figure 5) or to C/1304 Y1 (Figure 8). *(Stellarium, 2024.[29])*

improbably bright absolute magnitude to make it reach an apparent magnitude of 1, so it is unlikely to have been a spectacular object. Similarly, it barely changes brightness – only varying by half a magnitude – in a month and a half around closest approach to Earth. It would have been the same magnitude, or even slightly brighter, for two weeks before the closest approach to Earth.

If we assume that C/1304 C1 had similar dust and gas activity parameters to 1P/Halley, the aspect of the comet around the time of its best naked-eye visibility, as observed from Padua on 1304 February 3, might have been as shown in Figure 7. This shows that such an assumption yields a comet that was not particularly spectacular. The short tail in this simulation corresponds closely to the description of a tail only ~1 degree long, suggesting that the modelled level of activity is valid.

New moons occurred on February 6, March 7, and April 5, with the corresponding full moons on January 23, February 22, March 22, and April 20. So, the comet was first seen three days before the February new moon, which is consistent.

Closest approach to Earth came at first quarter. Sunset in Beijing would have been at 17:24 local time. Even at the end of astronomical twilight, at 18:58, the comet would have been 33 degrees high in Cetus and should have been an easy naked-eye object, despite being about 40 degrees from the Moon. Why it was not discovered previously is difficult to understand.

The long duration of visibility suggests a slow fade after perihelion, but the lack of pre-perihelion visibility suggests a rapid rise in brightness. Therefore, in Figure 6, we consider the third option of a fast rise and slow decline (green curve). This would be the most consistent with the observational record, although it gives a discontinuity in the light curve at perihelion.

Table 4. The Moon's phase for late December of 1304 and early January of 1305

New moon	*First quarter*	*Full moon*	*Third quarter*
Dec 27	Jan 3	Jan 11	Jan 19

C/1304 Y1

Perihelion was on 1305 January 19, at 0.65 au. Closest approach to Earth was 0.14 au on 1304 December 21, 29 days before perihelion. These numbers suggest an object evidently more likely to have been of spectacular appearance than C/1304 C1, which was six times more distant at closest approach and had a larger perihelion distance. The fly in the ointment is that the comet approached perihelion from the southern polar sky, being at –80° declination in Apus on December 19 and –50° on the night of closest approach to Earth, and thus below the horizon from most of Europe and Asia. The comet tracked south to north, traversing 50° of declination in four days between December 20 & 24. It entered Pegasus in late December and stayed there through the whole of the first quarter of 1305.

First observed from China on December 24 as a broom star in Aquarius, Japanese observers stated that it had a white tail of more than 1 degree in length on December 26. New moon occurred on December 27, giving ideal observing conditions immediately after closest approach to Earth, with full moon on January 11. The Moon's phases for late December of 1304 and early January of 1305 are shown in Table 4.

From Beijing, the comet first rose above the horizon on the afternoon of December 22, but only in daylight, culminating



Figure 8. Simulation of the appearance of C/1304 Y1 as observed from Padua, at 18:00 local time on 1304 December 25. *(Stellarium, 2024.[29])*

1 degree high in the south, three hours before sunset. On December 23, sunset in Beijing was at 17:00 local time, with the comet less than 5 degrees high. The comet would have set at 17:43, well before the end of nautical twilight. By December 24, however, the comet was 15 degrees high at sunset and set 10 minutes after the end of astronomical twilight. With the comet just 6 degrees high in Capricorn at the end of nautical twilight, when the horizon was still bright, we can assume that the comet must have been a brilliant object to have been picked up at this first possible opportunity of observation.

The circumstances of observation from Padua would have been similar to those in Beijing. On Christmas Day, a date of great religious significance to Giotto as a catholic, the comet would have been 15 degrees high at the end of nautical twilight, exactly in the southwest, at an elongation of 29°. We can see a simulation of how it may have appeared to an observer in Padua at 18:00 local time on 1304 December 25 in Figure 8. If the skies were clear at sunset, it would have been difficult for the citizens of Padua to miss the comet as the sky darkened.

As it moved away from Earth and towards perihelion, its visibility should have improved. On January 5, which again would have been significant to a pious catholic as it is regarded as the date of the arrival of the Magi (who, in the catholic tradition, bring their gifts to children during the night of January 5/6 each year), the comet would have been at an elongation of 44 degrees in Pegasus. It would have been at 0.71 au from the Sun and 0.51 au from Earth and would have set four hours after the Sun. It should not have faded much further, since the last recorded observation was on December 30.

We have no information about the brightness of the comet but let us suppose once again that the light curve can be fitted with $h_0 = 4$, $n = 2.4$, giving an activity similar to 1P/Halley and a typical rate of brightening. The resulting *hypothetical* light curve is shown in Figure 9. For fainter absolute magnitudes, corresponding to lower activity, we simply lower the entire curve.

As it receded, the comet would have faded 1.3 magnitudes between the first sighting on December 24 and the last on December 30. The approach to perihelion would partially compensate for the increasing geocentric distance, but it would have faded a further 0.8 magnitudes between December 30 and January 5. Larger values of n would have slowed this rate of fade. In contrast, if we change the absolute magnitude to 5.6, the magnitude would have been +1 at discovery, still bright enough to be striking in good conditions, but would have faded to magnitude 3 by the evening of January 5 and, with a gibbous Moon, observation would have been problematic. That said, before we assume a fainter absolute magnitude, we must recall that the circumstances of the first Chinese observation on December 24 were far from ideal, with the comet extremely low on a still-bright horizon, suggesting that it must have been particularly bright then.

However, the very short duration of the Chinese and Japanese observations is still difficult to understand. The Moon would not have been at first quarter until January 3, so moonlight interference should not have been a factor for several more nights. On December 30, the three-day old Moon would have been 18 degrees south of the comet. By January 2, that distance would have increased to 45 degrees, even if the Moon would have been somewhat brighter on this date.

It is unclear why the observational record is so short. If the comet was so impressive to Giotto that he included it in *The Adoration of the Magi*, why is his the only European record of it? Not even Peter of Limoges, who observed 1P/Halley less than three years previously, recorded the comet. His observing may have been curtailed by advancing age and ill health (he died in 1306, at approximately 66 – again, his exact date of birth is unknown), or perhaps he did not hear of the comet in time. A bright comet in

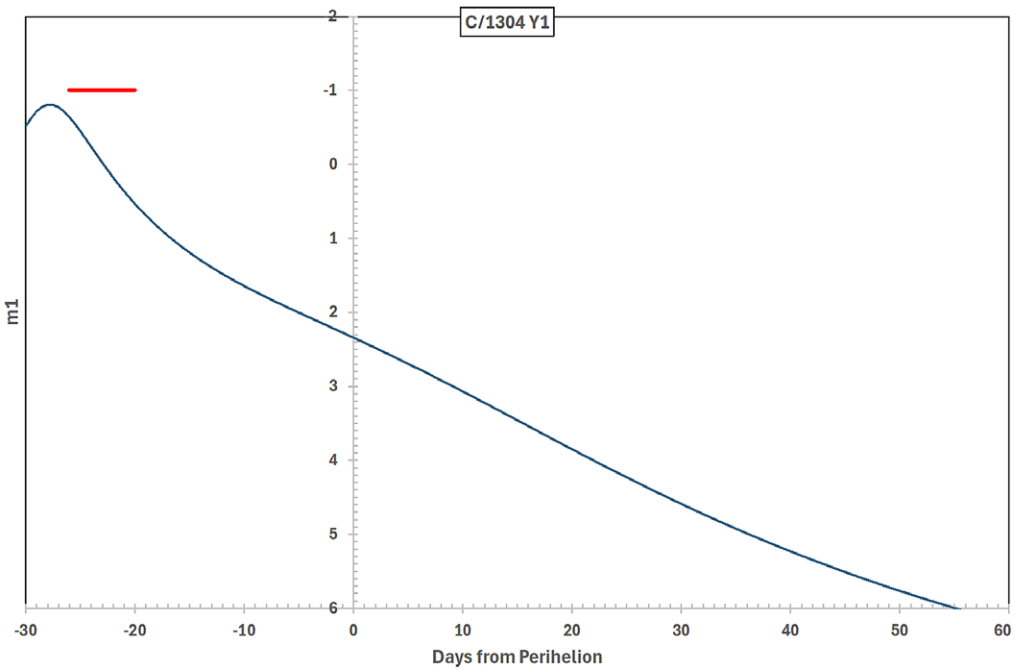


Figure 9. A hypothetical light curve for C/1304 Y1, assuming $h_0 = 4.0$ and $n = 3.2$ (adopting standard light-curve behaviour parameters). The range of dates covered by Chinese and Japanese observations are marked by the horizontal red bar.

the evening sky should have been seen by hundreds or thousands of members of the public. It appearing at such an important time of year should have caused enormous public interest, yet there are no records from Europe. Even the oriental records are extremely thin. Widespread bad weather might apply to one continent, but, to two simultaneously – including sites as widely separated as Japan, Korea, China and France – seems unlikely. Perhaps the object faded out before perihelion.

The Japanese observation of a tail just 1 degree long might be taken to indicate a comet of rather low activity, but this observation was made with the object observed almost front-on. The changes of viewing geometry and, as a result, the comet's form, were extremely fast in the days after closest approach to Earth. However, the tail of a comet is typically less well developed pre-perihelion and it may not have been particularly prominent even when best presented. Side-on presentation – i.e., maximum observable tail length – would have occurred on December 20 and January 2. In between, it was presented almost perfectly face-on on December 27, with observers looking straight down the tail.

However, timing represents a major concern with correlating this object with Giotto's comet. We know that the Scovegni Chapel was first consecrated on 1303 March 25, and this *may* have marked the moment when Giotto started to paint the frescos. As a skilled worker with a large crew of workers, he would not have faced the difficulties that Michelangelo encountered in the Sistine Chapel, so his work may have been almost complete by the time that the comet was seen. In this case, if Giotto did genuinely paint inspired by the memory of a great comet, one would have to favour an earlier object that was fresh in his memory, such as 1P/Halley in 1301.

However, against that, Eimerl (1967), who is possibly the greatest authority on Giotto, states:[27]

> *In 1305, Giotto began painting the commission that was to be his greatest achievement: the completely frescoed interior of the newly built Arena Chapel*

If this is the correct dating, Giotto could have instead started work with the memory of the 1304 Christmas Comet fresh in his mind.

Conclusions

All three potential candidate comets have some unresolved – and probably unresolvable – issues about their candidacy.

The simulations presented here suggest that the 1301 return of 1P/Halley *may* have been the most spectacular visually of the three comets, if all had similar intrinsic activity. This return also seems to have been brighter than average. 1P/Halley is the only one of the three comets to have been unequivocally observed from Europe. Even so, the European record of the comet is very short. If 1P/Halley was truly his inspiration, Giotto painted the image several years after it had appeared, and it is unclear whether it was sufficiently spectacular to have impacted him in such a way.

C/1301 C1 was the least spectacular of the three comets. Although it had long visibility, there is no evidence that it was observed from Europe, and it appears to have been of only modest brightness. However, it is hard to reconcile the observational history with its likely light curve.

Although evidently not the most spectacular of the candidates, C/1304 Y1 appeared at a significant time, with the first observations made on Christmas Eve as it receded from a particularly close approach to Earth, moving into the northern sky. There is no doubt that *if* Giotto saw the comet (something for which there is no written evidence), its timing would have impacted him greatly. That a seemingly bright comet appeared in the Christmas sky, at almost the same time that Giotto represented a comet as the Star of Bethlehem in *The Adoration of the Magi*, seems too great a coincidence to be due to random chance. It appears easier to believe that this comet was Giotto's inspiration.

The comet was well positioned to be seen in the evening sky from Padua on Christmas Day. However, the lack of any explicit

European record is concerning for such a significant object. The brevity of the observational record suggests that its absolute magnitude was probably 1–2 magnitudes fainter than 1P/Halley.

Nevertheless, of the three candidates, C/1304 Y1 appears to have the best claim to have been Giotto's comet, if allowed by the dating of the frescos.

Thus, the identification of Giotto's comet relies on the as yet unresolved age of the panels. If he started work in spring of 1303, it seems more likely that the inspiration was 1P/Halley, or perhaps an even earlier comet. If he commenced in 1305, the 1304 Christmas Comet seems the most likely inspiration.

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