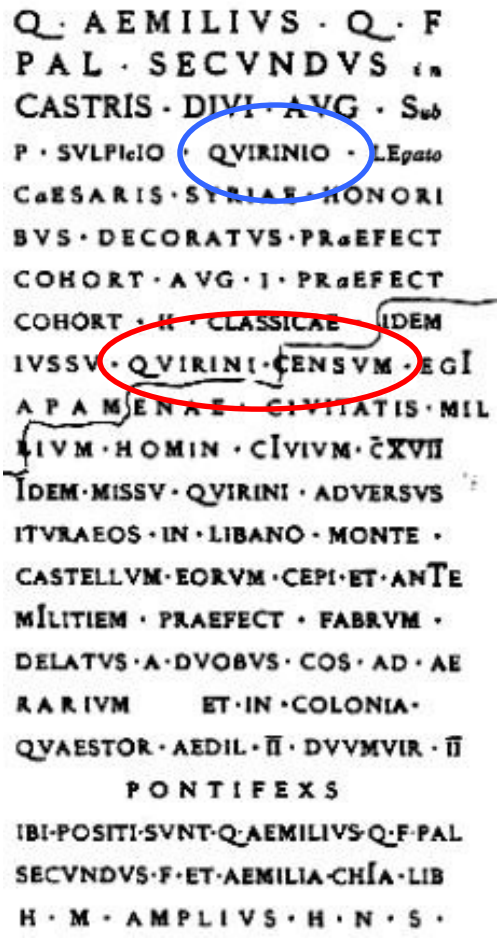
Some Notes on the Visibility of the 5BC Chinese Star

The 5 BC Chinese star is often associated with the Star of Bethlehem due to the coincidence in dates and the time of year that it was observed. As such it is interesting to examine its visibility, based on what little is known about it from the contemporary chronicles, combining them with weather data and other astronomical information.

Chronology

The evidence that King Herod the Great died in late March or early April 4BC is generally regarded as conclusive. Thus it is thus generally supposed that the birth of Jesus took place between one and three years beforehand, between 7 and 5BC. This date is also coherent with the known date of a census that was ordered by Caesar Augustus in 8BC. We also know from an inscription called the "Lapis Venetus" (left) that Publius Sulpicius Quirinius, legate of the emperor in Syria, carried out a census for Augustus, although the date is not given.


Q · AEMILIVS · Q · F
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BVS · DECORATVS · PRaEFECT
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COHORT · II · CLASSICAE · IDEM
IVSSV · QVIRINI · CENSVM · EGI
APAMENAE · CIVITATIS · MIL
LIVM · HOMIN · CIVIVM · CXVII
IDEM · MISSV · QVIRINI · ADVERSVS
ITVRAEOS · IN · LIBANO · MONTE ·
CASTELLVM · EORVM · CEPI · ET · ANTE
MILITIEM · PRAEFECT · FABRVM ·
DELATVS · A · DVOBVS · COS · AD · AE
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We know though that Augustus ordered censuses only in 28BC, 8BC and 14AD, none of which coincide with the dates of Quirinus's period as governor of Syria in 6-7AD. An alternative suggestion that the census was ordered on the annexation of Judea by Caesar Augustus, but this is also untenable as this annexation took place in 14AD, the same year that Augustus was known to have ordered a census, but long after Quirinius had left Syria.

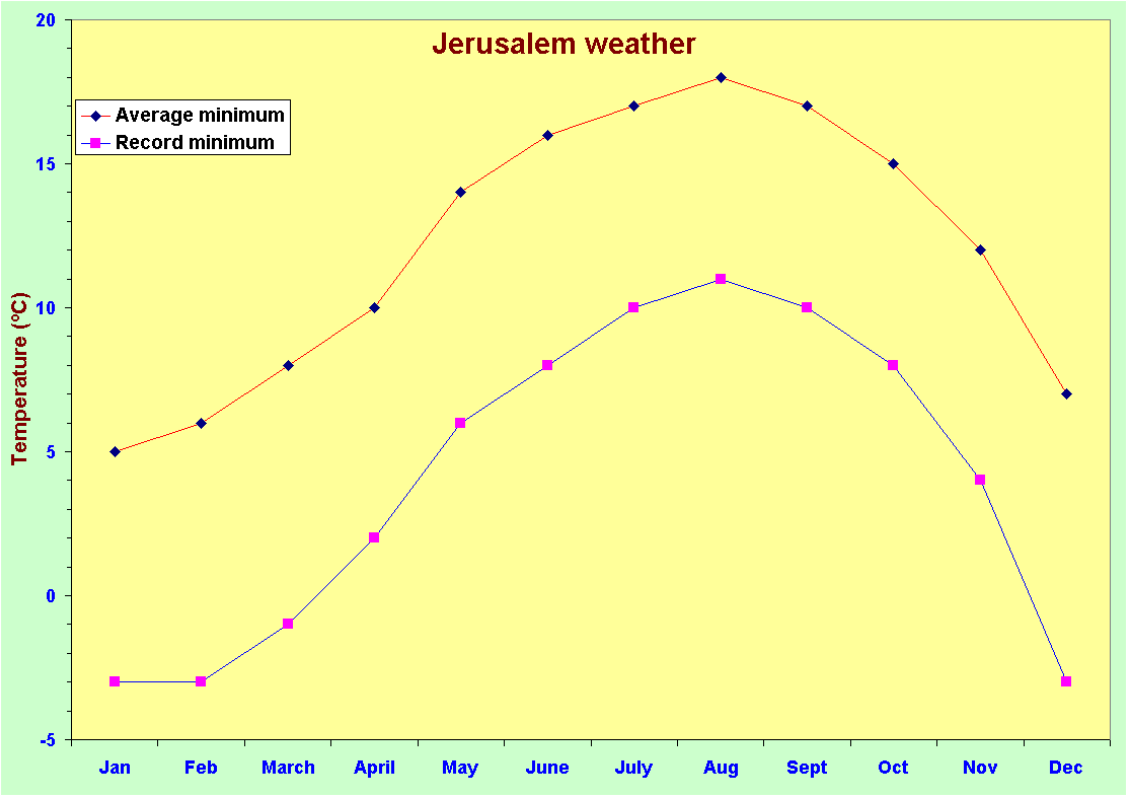
Although it cannot be proved beyond all doubt, it seems reasonable that the census described in Lapis Venetus was the same one that was ordered by Augustus in 8BC.

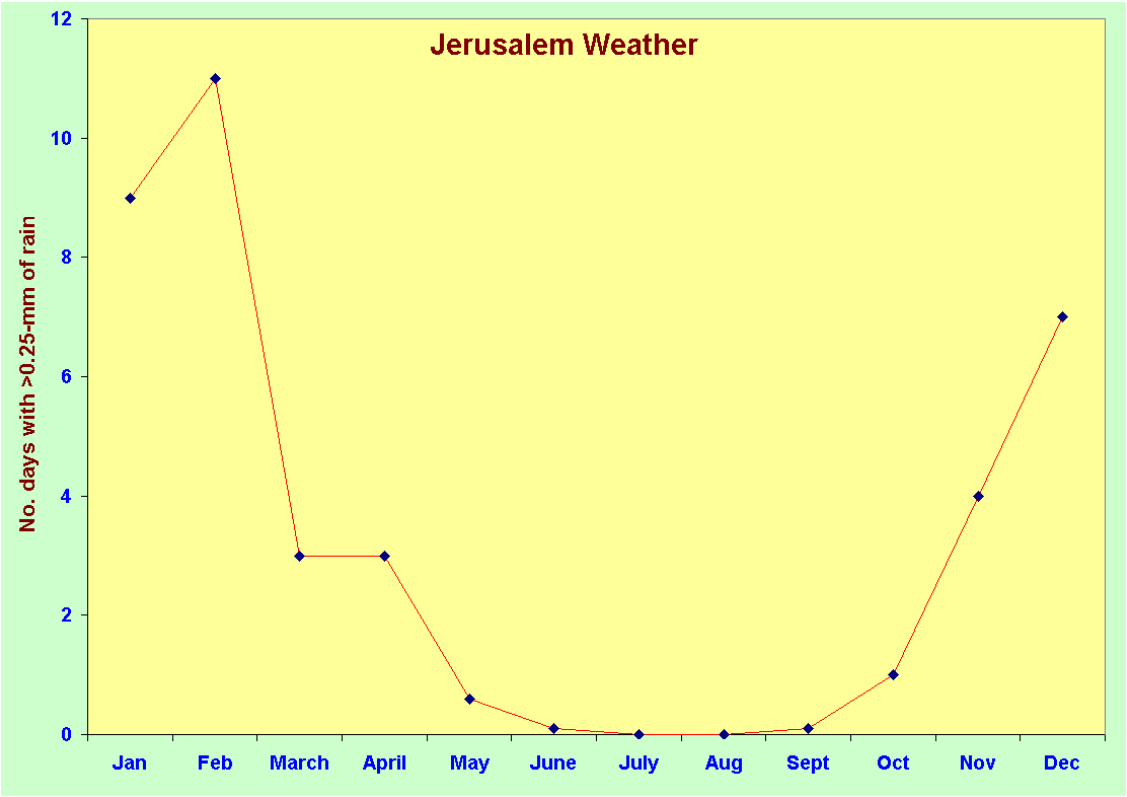
It is also a safe assumption that Augustus Caesar ordered the census long before it was to be executed, perhaps several years, to allow the Imperial burocracy time to promulgate, plan and execute the census successfully in all corners of the Roman Empire, however distant.

Finally, we know that the chronology of Dionisius Exiguus has a built-in error of 5 years and that his date for the Nativity of December 25th 1AD, when corrected, is December 25th 5BC, just three years after Caesar Augustus's census decree.

However, Luke's comment that shepherds were in the mountains around Bethlehem tending their flocks by night is totally inconsistent with the Nativity having taken place in winter. The weather in Jerusalem, which is 6km north of Bethlehem and at similar

altitude, is cool and humid between October and March; moderate frosts and heavy snowfall are by no means unknown. A comparison with shepherds that use traditional methods in the central plateau of Spain, where the altitude and climatic conditions are similar, suggests that night-time vigil is a feature of lambing time in spring and possibly of summer if there are large predators such as wolves in the region of the pastures.





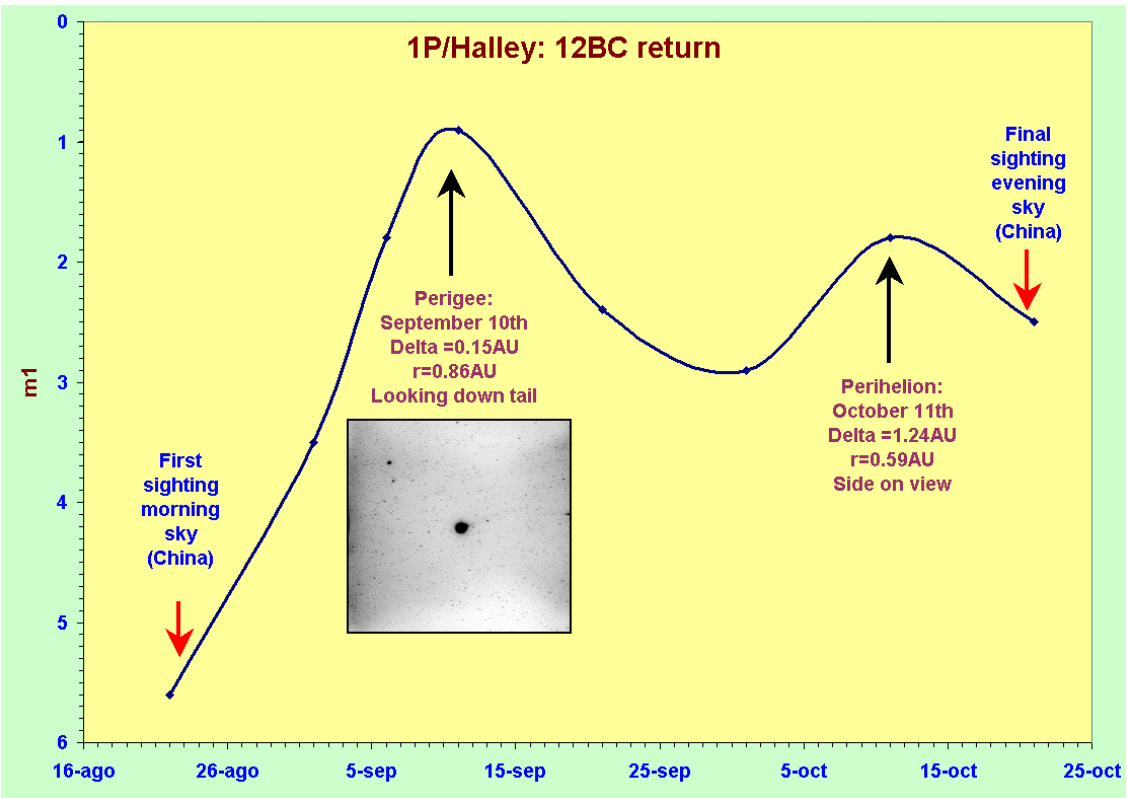
As we can see from the temperature and rainfall graphs for Jerusalem (above), December, January and February are cold, wet months, totally unsuited to sleeping outdoors on a hillside. The range of dates when Spanish shepherds may sleep outdoors with the flocks is from March through to September. Any shepherd who attempted to sleep outside with his flock in December would have risked pneumonia. However, multiple contextual clues in Luke suggest that the Nativity occurred during lambing time, in spring and, probably, around the date of Passover, which is given below for the years from 7BC to 4BC.

Jewish year	Date of Passover	Gregorian year	Notes
3754	April 12th	7BC	Earliest plausible date of Nativity.
3755	April 1st	6BC	
3756	March 21st	5BC	Most probable date of Nativity.
3757	April 10th	4BC	Herod's death occurred during the previous lunar month.

The Chinese description of the Star

If we accept mid to late March 5BC as the most likely date of the Nativity, we discover that there is an interesting coincidence in date with one of the very few Chinese records that exist from the period between 1BC and 20BC.

The records dated 10BC and 12BC are both known to be of Comet Halley. The former is a so-called "ghost record" with a date error. However, the Chinese records allow us to get an excellent idea of the movement and brightness of Comet Halley in 12BC



We know from the extremely early sighting in the morning sky that Halley must have been unusually bright in 12BC to have become visible to the naked eye at this time without prior knowledge of its position. The Chinese observations allow us to track the comet's movement from the first sighting in Gemini to its final disappearance in twilight in Scorpio. However, it is evident that this was not a particularly good return of the comet for naked-eye observations, as its greatest brightness would have come well before perihelion when the comet would have had only a faint tail and even that would have been pointed almost directly at the Earth, making the comet appear like a large, dim, nebulous patch of light in the sky.

The fact that the Chinese give such a good description of what was not a spectacular return of Comet Halley acquires additional significance given the paucity of detail in the other Chinese records around the time of the Nativity.

The chronicle, the "Ch'ien-han-shu" states that:

"In the second year of the period of Ch'ien-p'ing, second month, a hui-hsing appeared in Ch'ien-niu for more than 70 days"

This record can be translated as:

"During the interval between March 10th and April 7th of 5 BC, a comet that was visible for more than 70 days appeared close to Alpha and Beta Capricornii"

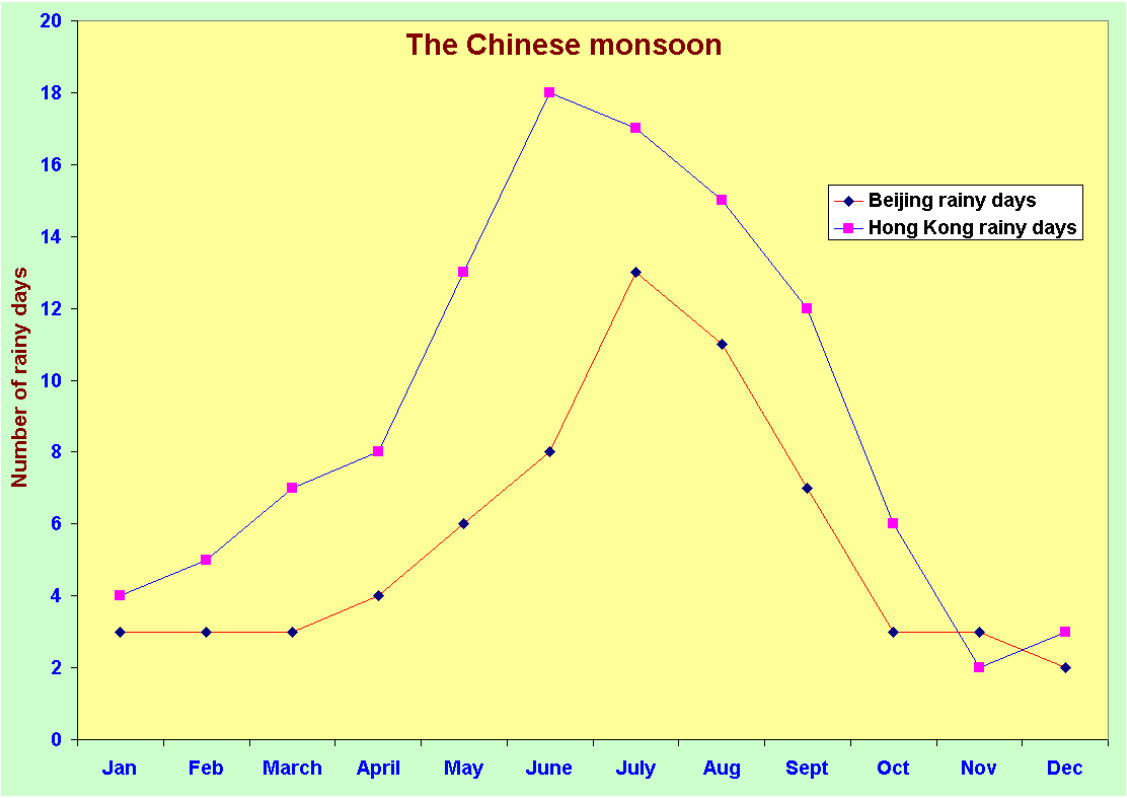
Despite the use of the term "hui-hsing", or "tailed comet", the chronicle contains several elements that are inconsistent with this object being a comet.

The chronicle gives a fixed position over two and a half months, not reasonable if the object really was a comet. Remember that the dim and relatively unspectacular appearance of Halley's Comet in 12BC was described in some detail, with the comet's path in the sky clearly described. The same chroniclers are, seven years later, give almost no detail at all, despite the fact that this 5BC object was supposedly a bright, tailed comet. Bright comets were usually described in some detail in the oriental chronicles with the comet's movement, tail length, form and even sometimes even the comet's colour described; here though we have none of this information.

However, although the Chinese had a special term, "ko-hsing", or Guest stars, for such events their use of this term was often inconsistent. Sometimes, "hui-hsing" was used to describe bright novae such as Tycho's Star. Such confusion was not limited to China; when Tycho's star, the supernova of 1572, appeared, European astronomers, like their Chinese counterparts, also regularly used the word "comet" to describe it.

We must also take into account that May marks the start of the monsoon season in China, although there are wide regional variations across the country with the monsoon in general starting earlier in the south. In Beijing, for example, average rainfall is 20-mm in April, 30-mm in May, 80-mm in June and a staggering 190-mm in July. In Hong Kong, the number of days with significant rainfall increases from 7 in March, to 8 in April and 13 in May (see the graph below). If observations of the object extended into late May and June, bad weather would almost certainly have curtailed them before the nova finally disappeared.

If we measure a 10 week interval from the date of the first sighting the object would have been observed until May 19th (assuming it appeared on March 10th) or June 16th and well into the rainy season assuming that it appeared on April 7th. The comment that the object was visible for "more than 70 days" hints strongly that it was still clearly visible when lost to bad weather.



A second, but more controversial record is found in the Korean "History of Three Kingdoms - the Chronicle of Silla (Samguk Sagi)"

"Year 54 of Hyokkose Wang, second month, (day) Chi-yu, a po-hsing appeared in Ho-Ku"

Korean records from that epoch are less detailed and far less reliable, a fact clearly betrayed by this chronicle, as the date that is given was inexistent in the Chinese calendar. It is as if the chronicler had unknowingly written February 30th. It is now believed that "Chi-yu" really should be "I-yu", a character written in an almost identical fashion in Chinese and easily confused with it. If so, this can be translated as:

"On March 31st of 4 BC a bushy star appeared close to Altair"

We thus have a Chinese object in the north of Capricorn in March 5BC and a Korean object in the constellation of Aquila in March 4BC. The apparent observation of two separate objects in consecutive years has and still causes considerable confusion.

However, this interpretation has several serious problems. Why did the Chinese chroniclers not observe the Korean star of 4BC? Given that Chinese chronicles are far

more detailed and complete than their contemporaries in Korea in that epoch, it seems odd that only the less reliable Koreans observed the 4BC object.

It also seems to be a quite remarkable coincidence for two objects to appear in consecutive years in adjoining constellations in the same month and for one to be seen *only* from China and the other *only* from Korea. It is much more plausible to assume that the Chinese recorded the star accurately and that the Koreans simply gave the name of the nearest bright star and even recorded the wrong year of observation.

There is also though a relatively simple explanation for difference in position. The Chinese constellation of Ho-Ku includes Altair, by far the brightest star in this region of the sky and various stars from the south of the constellation of Aquila, which borders on Capricorn. In fact, the region between the Chinese constellations of Ho-Ku and Chi'en-Niu, which groups the northernmost stars of Capricorn, is rather barren and contains almost no naked-eye stars, thus Altair and Alpha and Beta Capricornii are the obvious local reference points in the sky. If a new object appeared in the barren region between southern Aquila and Alpha and Beta Capricornii it is quite logical for the, at that time less sophisticated Koreans to have taken the simplest solution of giving the nearest really bright reference point; as we will see there are other reasons for believing this too.

We thus have a probable position of the star in a circle of radius approximately 5 degrees in southern Aquila or northern Capricorn with it appearing in mid to late March 5BC. The reference position is very approximately:

R.A. 18h30m, Dec. –12º (J2000)

This is between Theta Aquilae and Alpha Capricornii.

The visibility of the Nova Bethlehem from Persia

It is now widely assumed that the Magi were not Babylonian (as had been widely believed previously, although not based on any solid evidence), but instead Zoroastrian priests from northern Persia. Thus we must assume that the Magi initially saw Nova Bethlehem from there. However, we also know from Matthew's account that the Magi were able to see the nova on their journey from Jerusalem to Bethlehem.

First we will calculate its visibility from Persia around the time that it was first sighted. As the first observation comes close to the Spring Equinox the time of morning twilight in Persia changes rapidly at this time. Astronomers define three types of twilight:

- Astronomical, when the upper limb of the Sun is 18º below the horizon. This is the moment when the horizon first begins to brighten although the zenith is dark.

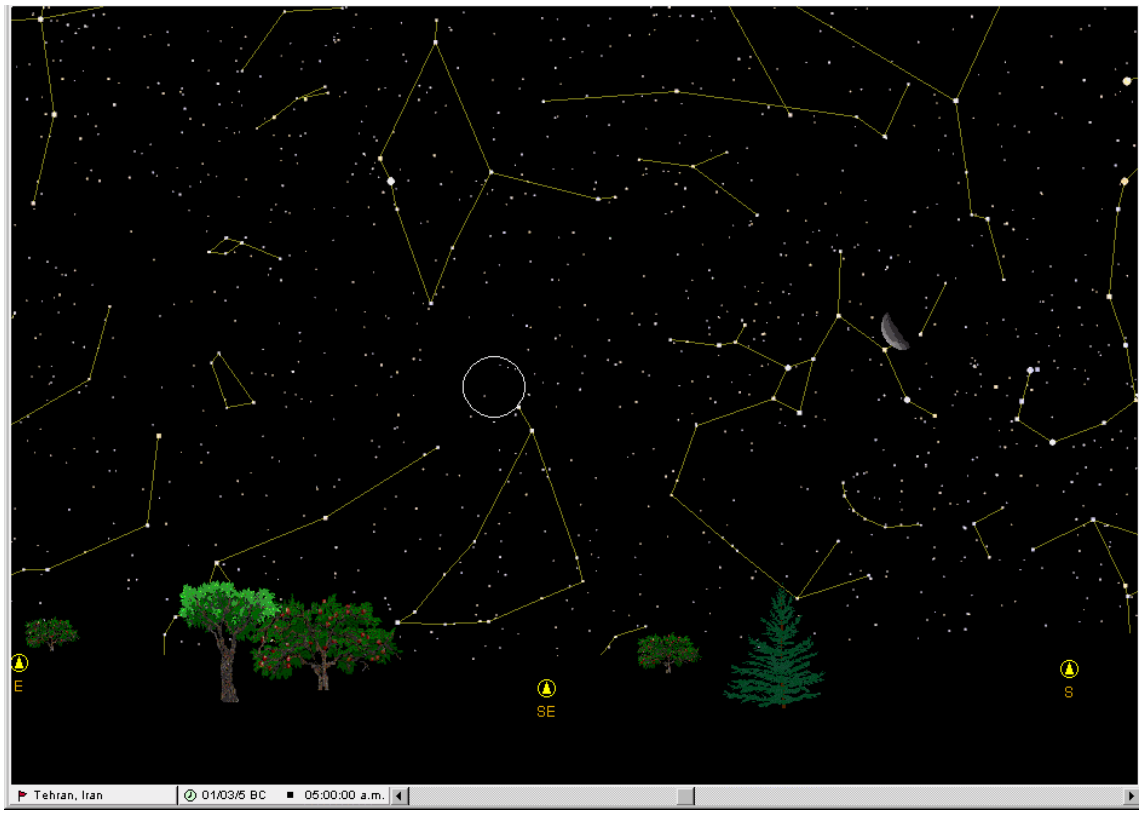
- Nautical, when the upper limb of the Sun is 12º below the horizon. This is used by the navy as the moment for dawn action stations and in the army for the dawn stand-to. At this point the eastern horizon is bright and light is extending up towards the zenith.

- Civil, when the upper limb of the Sun is 6º below the horizon. Better known to drivers as “lighting up time”, this is when effectively the transition from day to night occurs.

The local time of twilight in Tehran was:

Tehran	Nautical twilight	Astronomical twilight
March 1st 5BC	06:13	05:44
March 15th 5BC	05:53	05:24
April 1st 5BC	05:27	04:57

The (very approximate) hypothetical position of the nova at 5am local time in Tehran on March 1st 5BC would have been:



The nova would have appeared low in the east or southeast in the pre-dawn sky. The earlier the date that the nova appeared and the further to the south that it was located, the later it would rise and the lower it would be in the sky at dawn.

If it appeared close to the star SAO 144144, dimly visible near the centre of the circle as a magnitude 6.5 star, its circumstances would have been:

Date	Astronomical twilight	Altitude	Azimuth	Time of rising
March 1st 5BC	05:44	28º	133º	03:01
March 15th 5BC	05:24	33º	142º	02:06
April 1st 5BC	04:59	37º	152º	01:03

In contrast, had it appeared alongside Alpha Capricornii, it would have been significantly lower in the sky and would have risen a quarter of an hour later.

Date	Astronomical twilight	Altitude	Azimuth	Time of rising
March 1st 5BC	05:44	24º	135º	03:17
March 15th 5BC	05:24	29º	143º	02:22
April 1st 5BC	04:59	33º	153º	01:20

From Medea, in the north of Persia, the presumed home of the Magi, the duration of twilight would have been a little longer, the altitude of the nova a few degrees lower and the time of rising another 15-20 minutes later.

However, this cannot explain a much-commented problem with the nova: unless the nova appeared at least a month earlier than the *Ch'ien-han-shu* suggests, it is hard to square its position in the sky as a heliacal rising according to the modern translation of Matthew. The nova would have been seen in the east in the pre-dawn sky, but would have reached a significant altitude by that time.

One possibility is that Matthew is being over-interpreted and that he intended to say that the Magi had first seen the Star in the first light of dawn. However, there is another possibility. The months from December to March are rainy season in Iran, the ancient Persia. Although the conditions cannot be compared to the Chinese monsoon, the highest rainfall of the year occurs in March, just when the Chinese nova appeared. With a significant number of cloudy nights, the sudden appearance of a bright nova in the dawn sky, maybe sighted between clouds, could easily have fooled the Magi into thinking that they were seeing its heliacal rising.

Visibility from Jerusalem

We assume that the Magi took anything from 6 to 8 weeks from first sighting the Star to arrival in Bethlehem. Part of this time would have been spent in preparations for the journey, part in the journey itself and part waiting for their audiences with King Herod in Jerusalem. Even if the Magi took as much as 8 weeks to arrive in Bethlehem, we are still well within the period of visibility of the Chinese nova that we know to be more than 10 weeks.

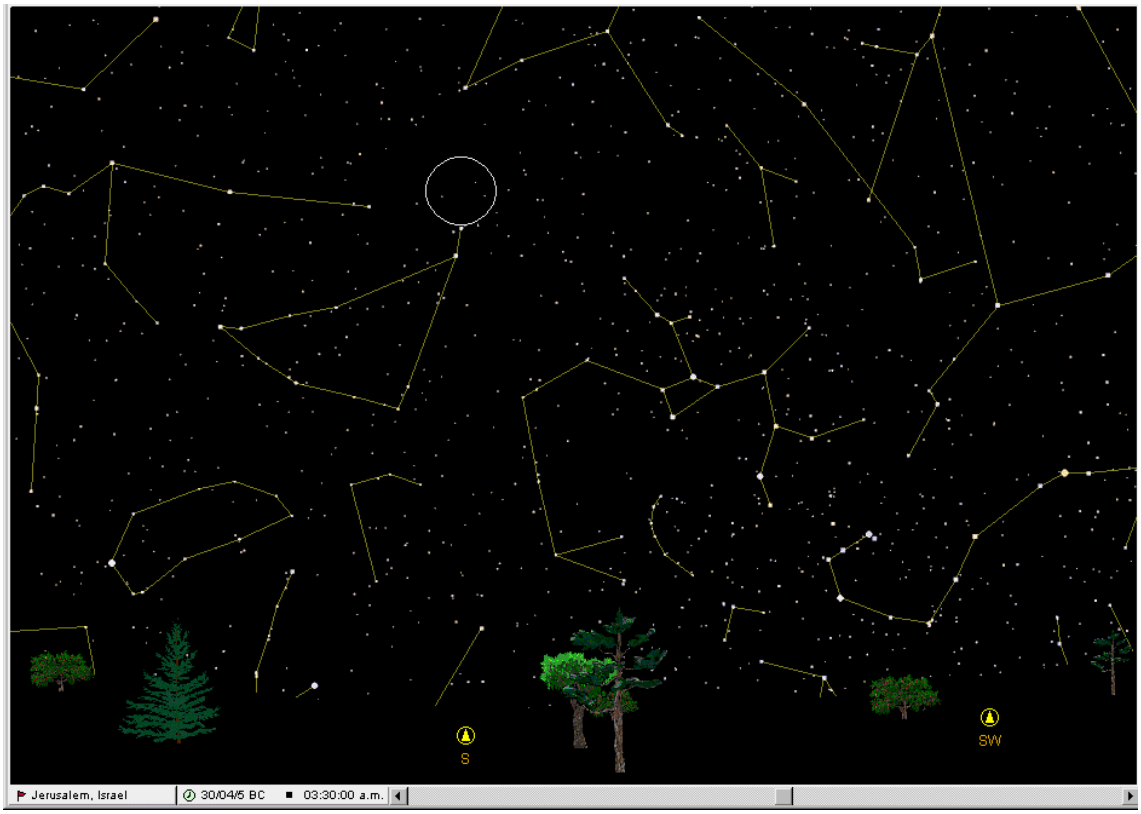
A star rises 2 hours earlier each month as a result of the change of perspective caused by the Earth's orbital motion. Nova Bethlehem would thus be further south at dawn with each passing day. Thus a star initially seen in the east at dawn will, in time, be seen in the south at dawn. For Nova Bethlehem, by April 30th it would have been due south at dawn in Jerusalem, as shown in the example above. Had the Magi set out for Bethlehem from Jerusalem at dawn around this date, the Star would have been directly in front of them on the road.

At astronomical twilight, as seen from Jerusalem, the approximate position of the Star in the sky would have been:

Date	Local time	Altitude	Azimuth
30/04/5BC	04:26	46º	176º

15/05/5BC	04:07	45º	190º

So, effectively, had the Magi headed for Bethlehem as the first light of dawn broke on the eastern horizon at any time in the first half of May, the nova would have been almost exactly due south and ahead of them on the road as we see in the following figure.



Other factors affecting visibility

The factors that affect the visibility of a nova such as Nova Bethlehem are various:

- The nova's peak brightness
- Its rate of decline
- The phase of the Moon
- Lunar conjunctions

Attempts have made to calculate the peak brightness of the nova based on its period of visibility. These have no scientific validity as the rate of decline of novae is highly variable from object to object. Astronomers generally define a fast nova as any that declines from maximum by 3 magnitudes or more in 50 days, whereas a slow nova takes longer than 50 days to decline by 3 magnitudes from maximum.

Even within the fast novae the range of behaviour is enormous. Nova Herculis 1991 (V838 Herculis) had the fastest rate of decline of any known nova falling 3 magnitudes in just 2.8 days. Nova Persei 1901 (GK Persei) was magnitude +0.2 at maximum, but declined beyond naked eye visibility in just 2 weeks. Nova Aquilae 1918 (V603

Aquilae) was the brightest recorded nova, with its peak magnitude of –1.8; it was a fast nova, dropping six magnitudes in three weeks, but it then took a further 8 months to drop below naked-eye visibility.

In other words, apart from guessing that the widespread visibility of the nova means that it must have been quite bright, we can make no other statement about it, other than it was almost certainly a fast nova. There is a relationship between the luminosity of a nova and the time taken to decline the first two magnitudes from maximum, but we need to know the brightness and distance of the nova to use it, which we most obviously do not, so this relationship is no help whatsoever.

Much has been made of the fact that King Herod was unaware of the Star. In fact, there is no mystery in this either. Herod was an old man of 68 in an age when the life expectancy was far less than this; he was infirm and soon to die and was facing the growing threat of the split of his kingdom on his death (Judea was duly divided between his three sons on his death and they duly rules it so badly that Caesar Augustus was obliged to take over direct rule of the province, in part at the petition of its disgruntled citizens). Had Herod taken to observing the night sky before dawn in winter it would only have hastened further his soon to arrive death.

Similarly, we know that despite their high level of culture, there are very few Roman records of comets, unless exceptionally brilliant, and few Roman astronomical records of any kind, so it is not particularly usual that in a region subject to such strong Roman influence a moderately bright, or even a bright nova should go almost unnoticed and uncommented.

However, even for assiduous sky watchers, other factors could also severely affect the nova's visibility. It appeared at a low ecliptic latitude; this means that apart from the days around Full Moon when moonlight drowns out all but the brightest stars and planets in the sky, once a month the Moon would also have passed close to the nova.

The dates of Full Moon (poor visibility) and New Moon (excellent visibility) would have been:

New Moon	Full Moon
March 8th 5BC	March 23rd 5BC
April 6th 5BC	April 22nd 5BC
May 6th 5BC	May 21st 5BC

Note that after Full Moon an object only visible in the morning sky would be even more seriously affected as the waning Moon would come closer to it night by night.

Conditions for discovery of the nova would thus have been best either at the start or at the end of the interval given in the *Ch'ien-han-shu*, that is, early March or early April. Interestingly, the Korean chronicle gives a specific date for its first observation of March 31st 5BC, but this date coincides with the nova's conjunction with the waning quarter Moon, which would have been no more than 15º away in the sky at the time. Unless the nova was still relatively bright when the conjunction occurred, moonlight would have been a severe impediment to its observation. This Korean date seems unlikely to have been a coincidence; rather than being the true date of the first

observation it seems more likely to have been given as a significant date of observation due to the conjunction. It also explains why the Koreans gave Altair as the reference for the position, as the presence of the bright Moon in Capricorn would have made the rather faint nearby stars of Capricorn and Aquarius totally invisible on this date; only Altair would have been visible through the Moon's glare.

On dates when the Moon passed through Capricorn and thus passed close to the nova its visibility could be seriously affected according to the Moon's phase and thus brightness. When we look at these dates we notice an important effect:

Date of lunar conjunction	Moon's phase	Moon's age
March 2nd-3rd 5BC	25%	24 days
March 30th-31st 5BC	50%	22 days
April 26th-27th 5BC	69%	20 days
May 23rd-24th 5BC	90%	18 days

Over the period of visibility of the nova the Moon's phase would have got progressively larger at each monthly conjunction and thus Moon interference would have been correspondingly more severe. In late May, with the nova fading severely, the Moon would have been just past full at conjunction, thus the nova might well have been invisible due to moonlight for a week and a half in total. Even in late April the waxing gibbous Moon would have been a severe impediment to observe the nova if, by then, it was third magnitude or fainter. Between Full Moon, lunar conjunction and possibly the odd cloudy night it is again quite plausible that the nova could have been invisible visually for 8-10 days. However, by May 1st, the Moon would have waned sufficiently and moved sufficiently far away make the nova easy to see again with the naked eye. This provides a simple, natural explanation why the Magi may have lost sight of the Star for what was, for them, a worryingly long time before recovering it as they left Jerusalem. This would possibly place the arrival of the Magi in Bethlehem in the first few days of May 5BC, with Jesus about 6 weeks old and the nova due south over Bethlehem as dawn broke in the sky over Jerusalem.

Conclusions

All the known aspects of the observations of the Star of Bethlehem can be understood in a simple fashion if it was a simple bright nova observed in northern Capricorn or southern Aquila in mid-March 5BC and chronicled by the Chinese and Koreans. Oriental and biblical references are consistent with each other and the Star described in Matthew and in other early documents can be explained in a perfectly natural way.