The Star of Bethlehem: a Type Ia/Ic Supernova in the Andromeda Galaxy

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I shall argue that the account in Matthew's Gospel suggests the Star of Bethlehem may have been a Type Ia supernova or a Type Ic hypernova, located either in the Andromeda Galaxy, or if Type Ia, in a globular cluster of this galaxy. Matthew's account may give the SN remnant to within 1′ in declination, and should be detectable with current techniques: the remnant should be 6′ in radius, and if Type Ia, possibly visible in the Fe I absorption line at 3860 Å.

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I shall argue that if the account in Matthew's Gospel is taken literally, then the Star of Bethlehem must have been a Type Ia supernova or a Type Ic hypernova, located either in the Andromeda Galaxy, or if Type Ia, in a globular cluster of this galaxy. The account in Matthew may give the location of the SN remnant to within an arcminute, at least in declination. The remnant would be 6′ in radius today, and could be searched for in the Fe I resonance line at 3860 Å. SN 1885 (S And) was first observed[10] as an absorption line extended object at this wavelength.

Let me be blunt. In this paper I am going to concentrate on two aspects of the Matthean description of the Star of Bethlehem. These I consider of vital importance. First, I am going to assume the word "star" means exactly that. The Star of Bethlehem is a star. It is not a planet, or a comet, or a conjunction between two or more planets, or an occultation of Jupiter by the Moon. I shall assume that the Star of Bethlehem was an actual point of light *fixed* on the celestial sphere. Second, I am going to assume that the Matthean expression "stood over" means exactly that. The star went through the zenith at Bethlehem. It did not hover vaguely in the general southerly direction as seen from Jerusalem. The expression "stood over" is not some wishy washy term applied to any old comet that happened to be close to the horizon around 0 A.D. It is specific. It applies to the Star of Bethlehem, and the Star was there, in the sky, directly above the Magi, at the time of their visit to the baby Jesus.

More precisely, Matthew 2:2 refers unequivocally to a "star", and as the biblical scholar R. Brown has pointed out ([3], pp.165-201, 608-613), this can mean only a nova or supernova/hypernova if taken literally. D. W. Hughes[14] has pointed out that Matthew 2:9 "the star which they [the Magi] saw in the east [in the first rays of dawn] went before them, till it stood over where the young child was" if taken literally, means that the Star of Bethlehem must have passed through the zenith at Bethlehem. Since the latitude of Bethlehem is 31°43′ north, the declination of the Star in the first decade B.C. (the range of estimates of Jesus' birth year) must have been 31°43′ N.

Matthew 2:9 also suggests the right ascension of the Bethlehem star. Matthew 2:2 tells us that the Magi were astrologers, who believed in a correspondence between celestial and terrestrial events. It is plausible that they would identify the zero of R.A. the vernal equinox with what they would regard as the natural zero of longitude. The zero of longitude is usually taken as the longitude of the main observatory (we use the location of the Greenwich observatory, though in the 19th century, the French unsuccessfully fought to use the location of the Paris observatory([29], p. 168). In the centuries prior to Jesus' birth, the central observatory of the ancient world was the Babylon observatory, and indeed a Persian map has Babylon as the zero of longitude ([23], p. 8). Bethlehem and Babylon have longitudes of 35° 12′ east and 44° 26′ east, respectively. Setting Babylon as the zero of longitude and identifying it with the zero of R.A. would give the R.A. of the Star of Bethlehem as 23 hours 23 minutes in 5 B.C.

This position in the first decade B.C. is far away from the galactic plane (the likely location of a galactic nova/supernova), but it is very close to the Andromeda Galaxy, whose center in 5 B.C. was $(\delta, \alpha) = (30^\circ\, 13', 23\mathrm{h}, 1\mathrm{m})$. The galactic halo of the Andromeda Galaxy would have definitely included the declination of the zenith of Bethlehem. The R.A. of the Andromeda Galaxy would correspond to a position in the Mediterranean Sea, but the nearest large city with the indicated declination/latitude is Jerusalem, the city to which the Magi first traveled. The nearest small city is Jaffa, the main port of Palestine, and in Greek mythology, the home city of Andromeda, princess of Jaffa. Any astronomer of the first decade B.C. would immediately associate an event in the constellation Andromeda with Palestine. Our system of constellations is essentially that of Ptolemy, which can be traced back at least to Eudoxus of Cnidus (c. 350 B.C.) (through the poet Aratus), before the Seleucid period of Greek rule over Babylon ([9], pp. 17-18). Astronomical techniques at the time ([6], p. 164, footnote) were sufficiently accurate to allow observers to determine that a star's declination was at the zenith of a given location to within a minute of arc, or within a nautical mile, using a dioptra ([9], pp. 34-36) and plumb bob. A supernova in M31 could indeed have "stood over" Bethlehem.

Matthew's statement that the Magi first observed the

Star in the east can also be translated at helical rising (in the first rays of dawn), as pointed out by Hughes[14]. I suggest that both interpretations are appropriate. Andromeda appears in the eastern sky only in the late winter and early spring months in the first decade B.C. We would expect naked eye observers to notice a fifth magnitude star (see below) only if they happened to be concentrating on that part of the sky, so a date near the vernal equinox is suggested. Also, such a faint star would likely be seen only if it was in the east well up in the sky at dawn. On 22 March 8 B.C,, the day after the equinox, there was a conjunction of Mars with the Sun. On this date, Venus was in Aries, and located at its rising almost exactly below M31 and only about 20 degrees in azimuth north of east at Babylon. Venus on that day rose shortly after dawn, and had magnitude -4.2, so it would be visible after sunrise. On the local Babylon horizon, an observer would use the stars in Andromeda as guides for the soon-to-rise Venus, and would see the supernova in Andromeda, in the east, in the first light of dawn.

Ptolemy, in his astrological treatise *Tetrabiblos* ([26], p. 143), associated every nation with a zodiacal constellation and a planet, and he associated Judea with Aries and Mars. He also associated Andromeda with a single planet, Venus ([26], p. 57). Thus on this date Andromeda would be triply associated with Judea. Ptolemy associated ([26], p. 259) the birth of Kings with the presence of Saturn, Jupiter, and Mars in a bicorporal sign (Gemini, Virgo, Sagittarius and Pisces). On 22 March 8 B.C., Mars, the Sun, and Saturn were in Pisces. Jupiter was in Aquarius, but Ptolemy assigns Jupiter to both Sagittarius and Pisces ([26], p. 81), and he asserts that both the Sun and Jupiter rule the N.W. triangle. So the Sun in Pisces can act as a stand-in for Jupiter. In 8 B.C., Augustus ordered a census of all Roman citizens ([3], p. 549), so this year agrees with Luke 2:1. The great nineteenth century archeologist, Sir William M. Ramsay ([27], p. 295, p. 302; see [25] for a more recent discussion, but supporting Ramsay), has provided additional arguments for 8 B.C. as Jesus' birth year. Hughes[14] also associates this 8 B.C. census with the census mentioned in Luke. But none of these scholars points out the truly fascinating implication of this association: it would mean that Joseph and hence Jesus as Joseph's son would be a Roman citizen. Thus Jesus could have avoided the scourging and crucifixion, since both punishments were forbidden to be used on Roman citizens. Jesus went willingly to his horrible death, as claimed in traditional Christian theology.

Ptolemy([26], p. 61, p. 197) asserts that the vernal equinox is present at the beginning of nativities, so a supernova at this equinox would naturally suggest a birth. Hughes[14] points out that 20 June is one (of three) traditional dates for Jesus' conception. Nine months later is 20 March. Hughes[14] points out that March and April are the lambing season, and the most common time for shepherds to be with their flocks. Thus 22 March would be consistent with Luke 2:8. A date slightly later than the vernal equinox — one of the two solar points associated with a birth — would render understandable the Church's later decision to move Jesus' birthday to a date slightly later than the other solar date associated with a birth: the winter solstice.

The 22 March 8 B.C. date for Jesus' birth is consistent with the date of his crucifixion, which can also be fixed by astronomy. Schaefer[28] points out that the Jewish lunar calendar fixes the Passover date, and this in turn requires the crucifixion to have occurred on either 7 April 30 A.D. or 2 April 33 A.D. However, in Acts 2:20, Peter quotes Joel 2:31 word for word: "The sun shall be turned into darkness, and the moon into blood, *before* [my emphasis] that great and notable day of the Lord come." J.C. Humphreys and W. G. Waddington[16] point out that "moon into blood" is often used to describe a lunar eclipse, and a lunar eclipse visible from Jerusalem occurred on 9 December 29 A.D. The astronomer F. Espenak[8] has calculated that a total solar eclipse occurred just two weeks earlier, on 24 November 29 A.D., with Palestine in the penumbra and within 2 degrees of the umbra. Matthew 27:45 (or Luke 23:44; Mark 15:33) records a "darkness over the land", and a near contemporary, Thallus, writing about 52 CE, asserts this "darkness" recorded in Matthew, Mark and Luke was in fact a solar eclipse([31], pp. 84–85). Luke 23:45 says explicitly that the Sun was darkened. A solar eclipse followed two weeks later by a lunar eclipse is very rare, and would explain the impact of Peter's words on his listeners, a few months after the crucifixion on 7 April 30 A.D: they would be impressed that the claim of Jesus' resurrection — the day of the Lord — came just *after* the two eclipses which everyone in Palestine saw. Joel 2:10 asserts that an earthquake would occur before the sun and moon darkening, and a contemporary Greek, Phlegon, records([21], p. 13, footnote 45; [31], p. 85, footnote 67) that an earthquake, felt all over the near east, occurred in the same year as the 29 A.D. solar eclipse. Matthew 27:51 and Luke 23:45 record such an earthquake. (The corresponding verse in Mark, 15:38, does not mention an earthquake.) We are told in Luke 3:23 that Jesus began his public ministry when he was "about thirty years of age", which would mean that he was between 25 and 35. His public ministry lasted between one and three years. A birth date of 22 March 8 B.C. would mean he was 34 years old in 27 A.D., consistent with a three–year ministry, ending in 30 A.D.

The brightest novae have an absolute visual magnitude of -9, so a nova in the Andromeda Galaxy would be invisible to the naked eye. A Type Ia supernova[2] and a Type Ic hypernova[11] have maximum absolute visual magnitudes of -19.5 and -19.4 respectively, which would correspond to an apparent visual magnitude of 4.5 at a distance of 750 kpc. The subluminous[32] SN 1885 (S And, the first Type I SN observed in M31, had[10] a peak visual magnitude of 5.8. Supernova 1987A was initially identified by Ian Skelton with the naked eye([12], p. 16-17) when it had apparent visual magnitude of 5. The limit of naked eye observation is an apparent visual magnitude of 6. But such a faint "new star" would be noticed by very few (most ancient recorded supernovae have[30] an apparent magnitude brigher than −2), consistent, as pointed out by Hughes[14], with the statement in Matthew that Herod and his court were unaware of the "new star". Hughes[14],[15] also mentions a tradition that the "new star" disappeared, and was only re-discovered by the Magi observing the Star from a well (or cave). A SN will rapidly dim, and if the Magi took two weeks to reach Bethlehem, as Edwards[7] has pointed out is physically possible, this could be easily explained. Recall the tradition that the Magi arrived in Bethlehem 12 days after first sighting the Star. The tradition that the Magi rediscovered the Star by seeing it in a well in Bethlehem[14] could also explain how they could determine that the Star passed through the zenith at Bethlehem even though it passed through the zenith in the daytime, which it would do if indeed it rose just before dawn, as indicated above.

But there is another possible astronomical meaning of the Greek phrase translated "in the east." As pointed out by Hughes ([15], p. 3) in his later book *The Star of Bethlehem*, the Greek *en te anatole* can also have the translation "acronychal rising", which means rising in the east just as the Sun sets. If this translation is used, then another date for the Star is indicated: the autumnal equinox in 6 B.C. Hughes[14], [15], Molnar[22], and Kidger[17] have emphasized that astrologers would naturally associated the triple conjunction of Jupiter and Saturn in Pisces in 6 B.C. with the birth of a King of the Jews. Pisces is associated with the Jews and Jupiter is associated with kingship in Babylonian astrology. In Jewish astrology, Saturn was regarded as a protector of Israel. For the Babylonian astronomers, the two equinoxes were the most important dates of the years, and so they would be especially focused on the astronomical events occurring on both the eastern and western horizons on these two dates. The second of the triple conjunction is very close to the autumnal equinox (September 29 according to Hughes[14]. Jupiter and Saturn rose about 5:45 PM in the Babylon sky on September 21 in 6 B.C.

All astronomers locate interesting sky positions using asterisms. The brightest stars that could be used as guides to locate the rising point of Jupiter and Saturn on September 21 in 6 B.C.: α Cassiopeiae (magnitude 2.23), and β Cassiopeiae (magnitude 2.27), and α and β Andromadae (both magnitude 2.06). Using these four stars as rough guide stars would point the eye toward the rising location of Jupiter and Saturn on the autumnal equinox in 6 B.C. in Babylon and an observer's eye would pass directly through M31, as an observer's eye moved from Cassiopeia through Andromeda, to the horizon just before the rise of the conjoining Jupiter and Saturn. Thus if these guide stars were used, an observer would have a good chance of seeing a SN in Andromeda, just as Jupiter and Saturn were rising. That is, the SN would be first seen just as the Sun was setting, which is to say, at the acronychal rising of Jupiter and Saturn.

Seeing such a SN under these conditions would immediately suggest to an astrologer a connection with a King of the Jews. The SN would be seen near the second of the triple conjunction, which is already associated with the Jews, and in Andromeda, which is associated with Palestine, as I described above. On the autumnal equinox, M31 transits the zenith at Babylon at 11:12 PM, (a similar time in Bethlehem) so the Magi would have no difficulty determining that a SN passed directly over Bethlehem, since it would transit near midnight. If Jesus were born on the autumnal equinox, he would have been conceived nine months earlier, on the winter solstice, which as Hughes[14] has pointed out, was thought to be December 25 in ancient times. Christian doctrine has always[24] held that life begins at conception, not at birth. For Christians, then, God entered the world at the instant of Jesus' conception, which should be the key date to be celebrated. If Jesus' birth was on the autumnal equinox, then the celebration on December 25 indeed is a celebration of his conception.

SN remnants have recently been detected in the Andromeda Galaxy[20], and with improvements in technology, we may expect the number to increase substantially. This note is to alert SN remnant observers to look for a SN remnant in M31 (or its halo) that can be dated to an explosion first visible on Earth 2000 years ago. Extending the calculation of de Vaucouleurs & Corwin[5] for S And, the SN should today have a radius of $6'$, and if Ia should have iron rich ejecta, and so may be visible as an absorption nebula in the Fe I resonance line at 3860 Å, as S And was visible[10]. With substantial improvements in our knowledge of how SN remnants evolve, it might even become possible to obtain a date of SN denotation sufficiently precise to distinguish between the date 22 March 8 B.C. and 21 September 7 B.C. Such dating precision is of course impossible today.

The SN might have been a type Ic hypernova, a SN type which is physically a Type II but from a progenitor missing its outer hydrogen envelope. Hypernovae are rare — 10^5 SN occur for each hypernova[1] — but hypernova are much brighter — they are believed[11] to be the energy source for gamma ray bursters, which have a top electromagnetic power output[11] of 10^{52}erg/s, and if hypernova are like Type II SN in having 99% of their peak power output in the form of optically invisible neutrinos[18], then the true peak power would be $10^{21}\mathrm{L}_\odot$, which means that at peak a hypernova outshines all the stars in the entire visible universe of 10^{20} stars. (Estimate of number of stars in visible universe $= \rho_c(4\pi/3)R^3\Omega_{sb}/M_\odot = (1.88 \times 10^{-29}h^2\,\mathrm{gm/cm^3})(4\pi/3)(10\,\text{billion light years})^3(0.02)/M_\odot \approx 10^{20}$, where $h = 0.65$ is the Hubble factor, and Ω_{sb} is the fraction of mass in the form of baryons which are also in stars — roughly half of the universe's baryons are in stars, and the baryonic mass fraction is 0.04.) Christians might find a hypernova which is barely visible on Earth but which intrinsically (and mainly invisibly) outshines all the stars in the entire visible universe an appropriate star to announce the birth of a carpenter's son who was, they believe, actually God born of a virgin.

Most expect the central remnant of a hypernova to be a black hole rather than a neutron star, which is the typical central remnant of a SN II. But some have argued for a neutron star (e.g, [13]). In either case, we might expect a remnant much like the Crab Nebula (M1): a neutron star whose rotational energy excites an emission nebula. The Crab Nebula has an absolute visual magnitude of -3.2 and its pulsar has an absolute visual magnitude of $+4.5$. Were M1 in M31, the corresponding apparent visual magnitudes would be $+20.8$ and $+28.5$ respectively. The sensitivity of the Hale Telescope is $+23$ visual magnitude, while the Hubble Space Telescope is $+28$ visual magnitude, as is the Keck II. The Next General Space Telescope is expected to have sensitivity $+31$ K magnitude. So the Hale Telescope could see an M1 in M31, while the HST and the Keck would be marginal for detecting the Crab pulsar in M31, even if it were beaming toward us. Of course, a smaller telescope than the 5 meter Hale will be sufficient for the emission nebula. The 2.4 m MDM Hiltner telescope with CCD imaging was adequate[19] for detecting and studying the hypernova remnant MF 83 in the Galaxy M101.

Other meanings can be given to the word star in Matthew 2:2 — see Brown[3], Hughes[14], [15], Clark, Parkinson & Stephenson[4], Molnar[22], and Kidger[17] for other alternatives — and these yield other interpretations of the Bethlehem event: the triple conjunction I discussed above. But by looking for a SN remnant in M31 at the indicated declination, the literal interpretation becomes uniquely testable.

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