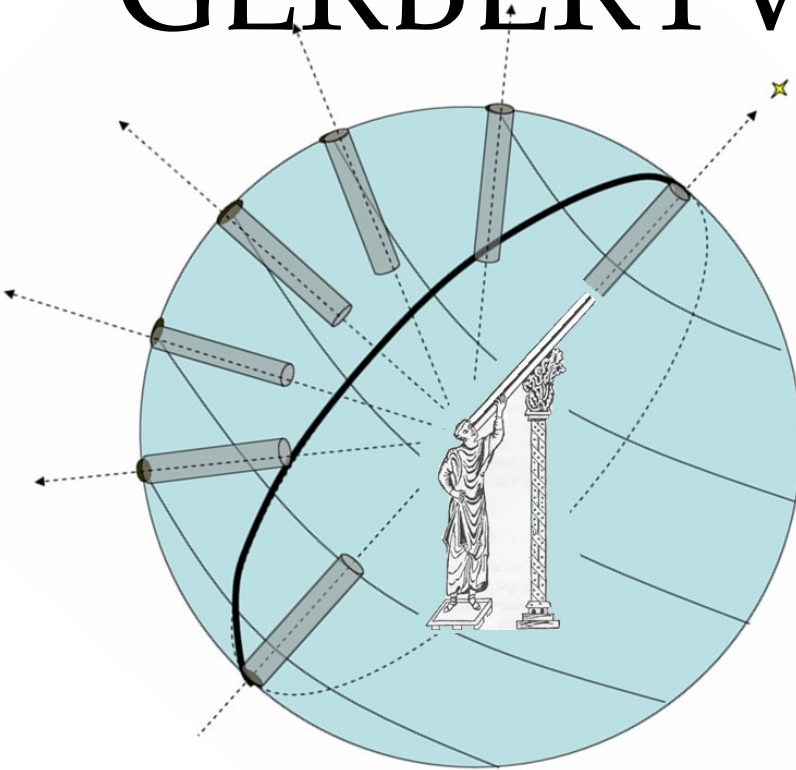


GERBERTVS



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**International academic online publication
on History of Medieval Science
vol. 6/2014**

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Prefazione al numero 6 di GERBERTVS

Costantino Sigismondi

(ICRANet, Ateneo Pontificio Regina Apostolorum,
UFRJ e Observatório Nacional Rio de Janeiro)

Abstract:

The volume 6 of GERBERTVS is dedicated to the Astronomy in the Gospels dealing with the Star of Bethlehem and Mira and on the Good Friday events related to Astronomy, say the eclipses of Sun and Moon, and the liturgical onset of Saturday in Jewish tradition.

A paper on the Easter calculus complete the role of astronomy in the New Testament and in the history of Catholic Church. The common denominator of these papers can be considered the observation of celestial bodies at naked eye, with a timing accuration of one second. Unlike astrological and historical approaches, do not consider primary the observation of the sky and the interest for stellar variability before the telescope's era, this set of papers invite to check the phenomena presented going also beyond the possible theological and biblical implications. The 14 pointed silver star on the birthplace of Jesus in Bethlehem is also presented.

GERBERTVS 6 contiene due aggiornamenti di articoli di Costantino Sigismondi apparsi su Quodlibet (2002) e ArXiv (2012) riguardo la Stella di Betlemme e l'Astronomia del Venerdì Santo sviluppati rispettivamente al Laterano (1997-1998) e Yale (2000-2004) il primo e alla Regina Apostolorum (2011-2012) il secondo.

In entrambi i saggi astronomici di approccio storico-biblico è presente l'osservazione ad occhio nudo come punto di partenza. Questa ipotesi è contrastata da vari autori che considerano la Stella di Betlemme una predizione astrologica, senza necessario confronto visuale, ed una produzione letteraria di un libro per anno continua su questo tema da tutto il mondo degli astronomi professionisti e amatori.

Resta comunque molto interessante lo sviluppo che ha preso questo studio, incominciato nel 1997, sulla possibile identificazione di Mira come la Stella di Betlemme. Proposto come Tesi di Laurea in Sacra Teologia al Laterano nel 1998 è stato ripreso a Yale insieme alla professoressa Hellen Dorrit Hoffleit e a Riccardo Coccioli tra il 2000 e

il 2002, per verificare da un punto di vista probabilistico se Mira avesse potuto essere sufficientemente brillante in due massimi consecutivi da essere notata come stella nuova non solo da specialisti. Questa ricerca statistica ha messo inaspettatamente in evidenza una proprietà comune alle stelle di tipo Mira, mai trovata prima d'ora: l'autocorrelazione dei massimi successivi è negativa.

Nel 2002 e nel 2004 sono stati pubblicati due articoli su JAAVSO che hanno mostrato questa proprietà prima per Mira e poi anche per R Leonis, R Hydrae e Chi Cygni, che sono le variabili a lungo periodo note da più tempo e osservate più a lungo, per più di 3 secoli.

La ristampa dell'articolo di Quodlibet viene integrata con alcuni necessari aggiornamenti, inclusi i dati visuali di Mira dal 1997 in poi e la straordinaria scoperta della coda di Mira nell'UV avvenuta dall'équipe di GALEX e riprosta insieme ad elementi storico artistici sulla stella di Betlemme, quella in argento di 14 punte che si trova nella basilica della Natività.

Meanwhile the production on the Star of Bethlehem continues, and the most relevant recent paper is from Bradley Schaefer, *The Observatory*, 2013, vol. 133, pp. 227-231. He refuses the hypothesis of Mark Kidger (1999) about the identification of the Bethlehem's star with DO Aql and any other star according to the astrological hypothesis of Michael Molnar (1999). Among the stellar hypotheses Franck Tipler *The Observatory* 125, 168 (2005) proposed an hypernova in Andromeda galaxy, zenithal for the wise men.

Schaefer e Tipler sono molto dettagliati nel discutere l'accordo con i testi sacri delle loro ipotesi e discussione di natura astronomica.

L'articolo originale sull'Astronomia del Venerdì Santo è del Novembre 2012, ma conteneva il progetto di nuove osservazioni della Luna equinoziale dal Monte degli Ulivi. Queste osservazioni sono state fatte nel 2013 e qui se ne presentano i risultati, dopo le riduzioni dei dati video e fotografici fatte il 26 aprile 2014. Chiudono il volume due contributi dell'Osservatorio Astronomico «Papa Silvestro II» di Bukowiec in Polonia, presentati al meeting della IAU CAP2013, *Communicating Astronomy with the Public*, di Varsavia.

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Mira Ceti and the Star of Bethlehem

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updated reprint from Quodlibet Journal: Volume 4 Number 1,
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Abstract:

We consider the probability that the Gospel of Matthew could report the earliest observation of Mira Ceti. Some biblical remarks have to be considered in order to distinguish a scientific text in the modern acceptation and the content of Gospels regarding some astronomical arguments.

Mira fulfills the basic requirements to be the Star of Bethlehem as described in the Gospel according to Matthew (Mt 2:1-12). In fact it was visible at least two times with a time interval (not specified in Mt text) in which it disappeared. Moreover Mira was close to the position where the triple conjunction of Jupiter and Saturn occurred in the years 7-6 b. C. and it could be observed during that period by ancient astronomers. The discovery of Mira in 1596 and its second observation 12.5 years later, made by David Fabricius, occurred when Jupiter approached it.

Because of those reasons we study the maxima of Mira in order to evaluate both the frequency of one and of two consecutive bright apparitions eventually as observed by the Magi. We did an evaluation of the correlation between two following maxima in order to verify the probability of occurrence of two consecutive bright maxima, because that condition would have been indeed the most favorable for the candidature of Mira as the Bethlehem Star.

Analyzing the maxima of Mira we found a probability of seeing it brighter than α Ceti once every 21 years. In this case, as in February 1997, Mira can be detected at the first sight as a new component near

the most significant asterism in its zone, composed by α , γ and δ Ceti. This condition could have happened in the case of the Bethlehem Star.

We found also a correlation between the magnitude of two consecutive maxima: if a bright maximum occurs it is more probable that the following is a faint one.

Summary:

The work is presented in the following order:

An overview on the Sacred Text, for being acquainted with the episode of the Star of Bethlehem as presented in the Gospel of Jesus Christ according to St. Matthew, 2:1-12.

The Kepler's Hypothesis, which connects the Bethlehem Star with the triple conjunction of Jupiter and Saturn.

The natural candidature of Mira, where we consider the proximity of Mira to that long-lasting planetary conjunction as a favorable condition for being noticed by the ancient astronomers.

Methods of verification: we explain how and why we studied the maxima of Mira and their temporal sequence. We limit the analysis to the correlation of the magnitude of the maxima after one cycle, because the triple conjunction elapsed no more than one cycle.

Results: we present the statistical results of our analysis. Mira is the brightest star of its neighborhood every 22 years in average, and two consecutive maxima are negatively correlated.

Discussion: Psychological mechanisms involved in the discovery of a new star are examined for understanding the

rather late discovery of Mira as variable star. The exogenous attention, produced by the sudden apparition of the new star in a familiar contest, is the more reliable mechanism. The proximity of Jupiter, and the need of measuring its position, were the causes of the first observations made by the discoverer of Mira, David Fabricius in 1596 and 1609.

The correlation between consecutive maxima suggests the existence of a servomechanism in the star, which keeps the oscillations of Mira nearly of the same amplitude. This servomechanism acts in competition with the energy release which produces bright maxima. Percy and Au (1999) in particular have found no trends in the period of Mira, telling that its variability is not changing upon the centuries.

Conclusions: The main interest of the previous statistical works was to find time correlations with maximum brightness. This is the first time in which the correlation between magnitudes of consecutive maxima is presented. Nevertheless we give a complete panorama of the behavior of Mira around its maxima as arises from the last four centuries. If we assume the same behavior two millennia ago we have statistical arguments to add to our hypothesis on the identification of Mira as the Bethlehem Star.

Introduction

Mira Ceti is a variable star, in the constellation of Cetus (the 'Sea Monster') well visible to the naked eye at its maxima, officially discovered in 1596 by the Lutheran pastor and astronomer David Fabricius (1564-1617) in the little town of Oostede, East Frisia (northwest Germany). He was a correspondent of Johannes Kepler. We have considered the possibility that the Gospel of Matthew could report the earliest observation of Mira. In fact Mira fulfills the basic requirements to be the Star of Bethlehem as described in the Gospel according to Matthew (Mt 2:1-12). Mira was visible at least two times with a time interval (not specified in Mt text) in which it

disappeared. Moreover Mira was close (15^o) to the position where the triple conjunction of Jupiter and Saturn at 1^o occurred in the years 7-6 b. C. and it could be the new object, '*aliquid novi*', which Kepler considered a direct consequence of the conjunction (Kepler 1614). Mira could have been observed during that period by ancient astronomers, as probably the Magi were, who studied the same conjunction. The discovery of Mira in 1596 and its second observation 12.5 years later also occurred when Jupiter approached it at 20^o.

We studied the maxima of Mira in order to evaluate both the frequency of one and of two consecutive bright apparitions. We did an evaluation of the correlation between two successive maxima in order to verify the probability of occurrence of two consecutive bright maxima, because that condition would have been indeed the most favorable for the candidature of Mira as the Bethlehem Star.

An overview on the Sacred Text:

The episode of the Star of Bethlehem appears in the Canonical Books of the Bible only in the Gospel according to St. Matthew 2:1-12.

Here we want to point out some basic concepts of Theology and Biblical Exegesis, for a correct approach to the text. In fact the text of Mt 2:1-12 cannot be approached as a scientific report according to modern criteria.

The episode of the Magi, in which the Star plays a guiding role, is considered the first Epiphany of Jesus to the gentiles. In the economy of the inspired text the Epiphany of Jesus to the gentiles was successful not only due to the quest of the Magi and the guidance of the Star: the mediation of God's Revelation, already present in the Bible (Micah 5:1) and recalled by the priests of the Temple, completed the guidance of the Star and helped the Magi to find the Infant Jesus and His Mother Mary.

The prophecy of the Star made by Balaam in Numbers 24:17 is another reference in the Old Testament to be considered in exegetical studies: the Gospel according to St. Matthew shows, even in details,

that the Old Testament is fulfilled in Jesus. Furthermore, a Star rising to herald the birth of a king was a typology common enough in the literature preceding and contemporary to the Gospels to suggest the same origin for the account of the Star of Bethlehem (Brown, 1977, Driver, 1965).

There are no indications of how much time elapsed between the first and the second sighting of the Star. Regarding the Star we can say only that it had:

- 1) to be visible to the naked eye, but not bright enough to outshine the other stars and thereby to be known by Herod and the chief priests and scribes of the people;
- 2) to be visible again after having disappeared for a time.

Further attempts to seek a correspondence of the text to the astronomical phenomena would force the Sacred Scriptures to be a technical report. Therefore we will not deal either with the interpretations of the Greek word *anatole* in Mt 2:2 as heliacal rising, or with the interpretation of (*estathe* in Mt 2:9 as a station in right ascension. The motion of the Star could be simply due to the motion of the observers with respect to a point-like source at infinity (Casanovas, 2000). It is worth noting that the word *anatole* appears in the New Testament only four times, three of which are in Mt 2:1-12. In Luke 1:1,78 *anatole ex upsous* refers to the coming Messiah. It can be literally translated 'rising from the heavens' exactly as a new star does. In our opinion this could also be a vestige of the episode of the Star present in the Gospel according to Luke. For the Magi the Star was both the initial cause of their journey and an unexpected confirmation at its conclusion: 'When they saw the Star, they were greatly overjoyed. And entering the house, they saw the Child with Mary his mother; and they bowed down and paid him homage (Mt 2:10-11)'. Therefore we consider the Star of Bethlehem to have been a real, visible star, truly observed by the Magi and not only calculated (Molnar, 1999).

The Hypothesis of Kepler

In the years 7-6 b. C. a triple conjunction of Jupiter and Saturn

occurred. That peculiar configuration of planets lasted eight months in the constellation of Pisces.

Johannes Kepler in 1611-4 demonstrated that king Herod died in 4 b. C., calculating the occurrence of a lunar eclipse before Easter mentioned by the historian Flavius Josephus, and recalling that Herod ordered to kill all the two-years-old children, he obtained the years 7-6 b. C. as a suitable range for the birth of Jesus.

He postulated that **the Star of Bethlehem was 'aliquid novi' = 'something new' in addition to that triple conjunction**, similarly to what he saw in 1604 before the explosion of the Supernova in Ophiuchus. In fact in 1604 he observed the Supernova in Ophiucus, which has actually his name, after a close planetary configuration made by Jupiter Saturn and Mars. Both the new stars (the Supernova and the Bethlehem Star) were a consequence of the planetary conjunction in his cosmological vision. We have to consider that at the beginning of the seventeenth century the speed of light was considered infinite and the heavens were thought much smaller than now, therefore the connection between the conjunction and a new star was a viable scientific hypothesis. The Magi could be astronomers who studied carefully this triple conjunction, already predicted at that time, in order to define better the parameters of their models for planetary motions. Only the "aliquid novi" could justify the motion of the Magi, according to Kepler; in fact a planetary conjunction does not require particular sites of observation nor can it be confused with a single star, as it is reported in the Gospel. Therefore the Magi were studying, very reliably, the triple conjunction of Jupiter with Saturn, which occurred in 7-6 b.C. and calculated by contemporary astronomers as it appears in the 'Star Almanac' of Sippar written in cuneiform tablets (Zani, 1973).

The natural candidature of Mira

The candidacy of Mira as Bethlehem Star has never been connected with the position of Jupiter and Saturn in 6-7 B.C.. Mira Ceti is located 30 degrees East of that planetary conjunction; it could have been a

favorable condition for its early discovery and it could be fairly witnessed during those months of accurate monitoring.

The observation of the planets from a month before to a month after the eight-months conjunction could permit the identification of the 'new star' in any case.

The most famous variable star, the 'Wonderful' as Hevelius called it, giving in Latin the name of Mira, has in fact the properties of being visible to the naked eye for a couple of months each eleven months and to reappear quite suddenly, taking ~100 days as the mean rising time from 6th magnitude to maximum (Fisher, 1969).

The above time indications of Mira's activity are not to be used for fitting the chronology of the episodes presented in the Gospel according to Matthew 2:1-12, simply because such chronology is not indicated in the text.



Fig. 1. Mira Ceti on the night sky, direction South up to the zenith, of January 6th year 5 b. C. at 17:40 local time in Jerusalem. (Ephemerides of Stellarium 12.4, 2014).

Mira fulfills the requirements:

- 1) to be visible to the naked eye, but not bright enough to outshine the other stars and to be known by Herod and the chief priests and scribes of the people.

2) to be noticed by astronomers, who studied carefully a nearby long-lasting planetary conjunction.

3) to become visible again after a period of disappearance.

With respect to the basic characteristics listed in the previous section here there is the fact that it is close to a zone of sky carefully examined for one year in the period in which Jesus was born.

As far as we can verify in the immense literature that flourished around the Star of Bethlehem (Sinnott, 1968; Clark et al., 1977; Ferrari d'Occhieppo, 1978; Seymour and Seymour, 1978; Cullen, 1979; Freitag, 1979; Hughes, 1979; Banos, 1980; Mosley, 1980; Henbest, 1992; Kidger, 1999; Massey, 2001; U. S. Naval Observatory, 2001; Teres, 2001) the present work (Sigismondi, 1998) is the first in which Mira is associated to Kepler's hypothesis. It is recalled that Kepler did not know of the variability of Mira.

Methods of Verification

We studied two aspects of its variability: its maxima and their time correlation, and the probability of seeing two consecutive bright maxima.

Databases

We did this study on the data gathered from the books of Paul Guthnick (1901) covering the period 1596-1899, E. W. Pickering (1900), Müller and Hartwig (1920) and in the works of Leon Campbell (1918, 1955) for covering the period at the turn of the nineteenth century and the AAVSO database (Mattei et al. 1990, Mattei, 2001) covering the period 1906-2000. We gathered the largest record of Mira maxima nowadays available: 212 values. Among those maxima 175 are consecutive.

The work of Paul Guthnick

Guthnick (1901) gathered several observations of Mira made before and after the introduction of the method of Argelander (1838)

(Argelander 1839) for determining the magnitude of a variable star. Different observers used different reference stars. Guthnick converted to Argelander units all the determinations of Mira's magnitudes made by comparison with known stars by different observers; he used the least squares method for calculating the magnitudes of the reference stars observed by them. The whole dynamical range from maximum to minimum for Mira is 70 Argelander units. Guthnick gives a table of the observed maxima of Mira (1596-1899); a table of minima spans the years 1855-1900.

Calibration

The visual magnitudes of the reference stars used in Guthnick's sample and by the AAVSO (assumed homogeneous with the Campbell's magnitudes) have been calibrated with the photometric Visual magnitudes presented in the Bright Star Catalogue, fifth edition (Hoffleit and Warren 1996). The magnitudes in Müller and Hartwig (1920) were obtained by several visual observers taking the average value for each maximum with its variance as intrinsic uncertainty. All the other uncertainties have been considered ± 0.1 magnitudes.

Results

The average of Mira's maxima

William Herschel observed the maximum brightness of Mira (1.3) on Nov 9, 1779 (Guthnick 1901). Friederich W. A. Argelander (1869) observed the faintest which occurred Nov. 11, 1868 (5.1). The range of Mira maxima is 3.8 magnitudes. The average magnitude of maximum calculated for 212 values spanning 404 years is 3.40 with a standard deviation of 0.66.

We defined bright maximum when Mira is as bright as δ Ceti which is magnitude 2.5 and is the brightest neighboring star in a region fairly poor of bright stars. In those cases, in the past ages, Mira could have been easily spotted if one was looking in its direction. In fact it appears at first sight as a new component near the most significant asterism, composed by α , γ and δ Ceti. Because Mira is not observable when in conjunction with the Sun (from April to June) for

about 3 cycles out of 12, the probability to see Mira, in a given year, shining as a bright star is 4.2%, namely once every 24 cycles or 22 years.

The correlation between two consecutive maxima In order to determine the probability of having two consecutive bright maxima we have to verify if the brightness of the maximum of Mira is a random function of time. In this case the probability would be the square of the probability of a single bright event. We plotted the brightness of the maxima M_i as abscissa and the difference between $M_{i+1} - M_i$ as ordinate and we found a linear dispersion of the data with correlation parameter $r = -0.74$. That yields an indication of time correlation between Mira maxima on a time scale of a single period. The best fit of the linear regression is the following law (Sigismondi, Hoffleit and Coccioli, 2001):

$$M_{i+1} = -0.1M_i + 3.7$$

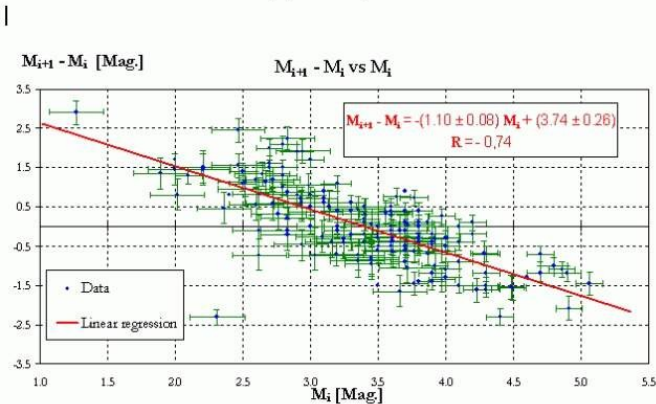


Fig 2. Autocorrelation of successive Mira maxima from 1636 to 2001.

This law express the property that if a maximum of Mira is particularly bright (left side of the plot) the following will be faint and in any case in the average, because the magnitude will increase of a large increment (about 2 magnitudes).

Discussion

Perception in ancient Astronomy: psychological implications

The problem of understanding why Mira was discovered so late remains open. Helen L. Thomas (1948) suggested that in ancient Astronomy a general lack of interest in magnitude determinations and the lack of good star charts made possible only the discovery of a few bright novae, leading to a late discovery of Mira. We examined statistically the brightness of Mira maxima and its eventual time correlation: those parameters could have been crucial for allowing an earlier discovery of Mira.

Different kinds of attention in Psychology

The statistical results on Mira maxima leave an open question: why Mira was discovered as variable only in 1596. It was fairly probable at least once every 24 cycles, or 22 years, for ancient astronomers who observed during all the night, or every 44 years if we want to consider also occasional observations made before midnight. In other words the question can be posed "If a new star of average magnitude appears in the heavens (not too bright, neither too faint), what is the most probable condition for a nova to be discovered by naked-eye observers: to appear in a constellation made by bright stars - as in Orion for example- with well known geometries, or to appear in a region fairly poor of bright stars, -like Pisces-?"

According to modern Psychology in order for an item to be noticed in a field of other items, it must be attended (Mack and Rock 1998). In general, we tend not to see things that we do not expect. There are two ways for an item to be attended: either a person can voluntarily allocate attention to it: the endogenous attention, obtained typically via a search; or the item can automatically capture attention: the exogenous attention. Examples of the former include searching around your desk for your lost keys. Examples of the latter include items which suddenly appear from nowhere, items which suddenly loom toward you, such as a single red item in a field of blue items (Egeth and Yantis 1997). If a new star (or supernova) were to appear suddenly in the sky precisely when somebody happened to be looking up, then it would be more likely to capture attention, and

thus be noticed, in a relatively sparse region, because the sudden change in luminance would create a larger transient due to the greater contrast with the surrounding area (Scholl 2001).

Mira rises from sixth magnitude to maximum in about 100 days (Fisher 1968), not quickly enough to be a sudden apparition and to justify a case of exogenous attention by the observers, unless the maximum appears just after the period of the conjunction with the Sun. This happened to the discoverer, David Fabricius in August, 13 1596 (Fabricius 1605, Kepler 1606). However, in the far more likely case where somebody is only stargazing after the fact, the star would only be noticed via endogenous attention. It would have to appear in an area which somebody is likely to watch, and to be noticed as a 'new' star, it would have to conflict with a stored representation of that area of the sky. It would be more likely to be noticed in Orion, since the representation of Orion is relatively robust and specific -- in that each star plays a distinct role (these are the waist, these are the shoulders, etc.). In the case of Pisces, these roles are not so distinct, and so the observers' internal representations would be fuzzier: i.e. the circlet in Pisces would be stored as 'as circle', rather than as a specific arrangement of stars. A new star could thus just be added to the circle, without being noticed. A perception-memory experiment could be set up for evaluating those statements from a statistical point of view (Scholl 2001).

Psychology evidences how a discovery of a 'new star' among a field of relatively faint stars would be possible if the attention of the observers is already oriented to look for small modifications of that field. Good star charts could have improved the endogenous attention of ancient astronomers, in agreement with the conclusions of the earlier study of H. L. Thomas.

The discovery of Mira by David Fabricius

The discussion on perception in Astronomy is confirmed by the circumstances reported by the discoverer himself (Fabricius 1605) in the correspondences with Tycho in 1596 and Kepler in 1609. Here we

report the integral text of the letters of David Fabricius included in the volume *De Stella Nova in Pede Serpentarii* of Kepler, for describing the supernova of 1604 (Kepler 1606):

Agnosco testimonium tuum in Opticis de novis stellis et item de illa stella anni 96. Ceti et adjungo observations D. Tychoni **aliquando** communicates: Cum 3/13. Aug. a. 96. mane γ observarem, vidi claram stellam versus merid., paulo majorem stellis 3 in capite Arietis eratque rubri coloris. γ distabat ab ea $20^{\circ}31'$. γ tunc in alt. merid. in ortu $\odot$ erat $50^{\circ}7'$. 11/21. Aug. stellae hujus novae altitudinem merid. quadrante capiebam $31^{\circ}30'$, γ tunc ab ae distabat $20^{\circ}35'$, decl. mer. datur $4^{\circ}51'$, locus in $25^{\circ}47'Y$, lat. mer. $15^{\circ}54\frac{1}{2}'$, asc. recta $29^{\circ}39'$. Oriebatur in elevatione nostra $53^{\circ}38'$ cum $13^{\circ}15'X$, occidebat cum $14^{\circ}45'Y$, culminabat cum $1^{\circ}51'X$, distabat a cauda Ceti $27^{\circ}50'$, a mandib. Ceti $12^{\circ}51'$, a tertia $Y26^{\circ}36'$. Erat secunda magnitudinis. Hae observationes sunt certae. Post Michaelis festum disparuit.

Ex literis d. 12.22 Mart. 1609. Cum 5. Feb. β γ et δ futuram observarem, animadverti in Cete stellam insolitam, quam statim observavi. Cum in globo quaererem distantis, vidi eas convenire ad locum stellae in globo annotatae, quam anno 96. in Aug. et Sept. observavi, quae ab eo tempore a me visa non erat. **Res mira.** Testor Deum ne ita bis diversis temporibus vidisse et observasse, et quod notandum, Jupiter fere ad eundem locum pervenerat, in quo anno 96. erat. **Non possum satis mirari Dei Opera admiranda**, et vides hinc mi Keplere, meam de novis stellis et cometis esse veram, quod non de novo creentur, sed priventur saltem interdum lumine et sic cursus suos nihilominus perficiant.

Quando vero Deo visum fuerit, nobis aliquid praeter ordinem significare, accendit illa corpora invisibilia, ut appareant et in publicum prodeant. Ego puto, me non falso conjectasse antea de istis corporibus aethereis.

In fine Februarii adhuc vidi, nunc ob Lunae radios animadvertere non potui. Quaero an vos eam quoque videritis aut quemquam observasse audiveritis? Sententiam tuam de his scire aveo. **Res mira et vera.** Locus ejus, ut in tractatu Germanico de nova stella scripsi, in $25^{\circ}47'Y$, lat. aust. $15^{\circ}54'$.

■

I know your report in Optics regarding the new star [of 1604] and also of that star of year [15]96 of Cetus and I add the observations sent sometime to Tycho: When in the morning of 3 [Julian calendar] / 13 [Gregorian Calendar] of August of 1596 I observed Jupiter, I have seen a bright star towards South, slightly brighter than the star 3 in the head of Aries and it was of red color. Jupiter was $20^{\circ}31'$ from it. At that time Jupiter was $50^{\circ}7'$ of altitude in the South meridian, when the Sun rose. On August 11/21 I have measured $31^{\circ}30'$ with the quadrant the meridian altitude of this new star. Then Jupiter was $20^{\circ}35'$ from it, being [this new star] at South declination of $4^{\circ}51'$ in the $25^{\circ}47'$ locus of Aries, South latitude $15^{\circ}54'1/2$ [with respect to the ecliptic], right ascension $29^{\circ}39'$ [all coordinates are consistent with the equinox epoch of 1600]. In our latitude of $53^{\circ}38'$ it rose with the $13^{\circ}15'$ [locus] of Gemini, it set with $14^{\circ}45'$ of Aries, the transit occurred with $1^{\circ}51'$ [locus] of Taurus, it was $27^{\circ}50'$ from the tail of the Cetus, $12^{\circ}51'$ from its mouth, $26^{\circ}36'$ from the third star of Aries. It was of second magnitude. Those observations are certain. After the feast of Michael [the Archangel, on September 29, reliably of Julian Calendar] it disappeared.

From the letter of 12/22 of March 1609. On February 5 observing the incoming conjunction of Jupiter and Venus [occurred on March 26], I have seen an unusual star in Cetus. Measuring with the sphere (globe) the distances, I have seen that they were showing the place of the star I have noted on the sphere (globe), which I observed in August and September [15]96, and which I have not seen since that epoch. Wonderful thing!. I witness to God to have seen and observed twice in so different times and, what is to be noticed, Jupiter was almost in the same place of that one of [15]96. I can't enough contemplate the admirable Work of God, and see here, my Kepler, that my [star] among new stars and comets is real, it is not created ex novo, but they are sometimes deprived of the light, and nevertheless they complete in this way their motions. When actually God wants to show to us something that is beyond the [normal] order mean, he enlightens these invisible bodies, letting them to appear and to move in public. I think that I have not wrongly argued regarding those bodies of ether. At the end of February up to now I have seen, now I could not observe because of the Moonlight. I ask: do you have observed it or you know someone who observed it? I desire to know your opinion on those facts. Admirable thing and true! Its position, as I wrote in the German treatise on the new star, is $25^{\circ}47'$ of Aries and $15^{\circ}54'$ of austral latitude [South from the ecliptic].

According to the text, the presence of Jupiter in the neighborhood of Mira was crucial for both those observations of David Fabricius. His attention was captured by the new star only because he was studying Jupiter. And after 12 whole years he again saw Mira because Jupiter was again approaching that zone of sky.

Johannes Bayer in 1603 evaluated Mira of magnitude 5, assigning to it the fifteenth letter of the Greek alphabet 'omicron', so its magnitude was between that of one of the stars before 'omicron' and one after 'omicron': comparing with the modern values of the magnitudes of λ , μ , ν , π , σ , τ Ceti (Hoffleit and Warren 1996) the magnitude of Mira was probably 4.6 ± 0.5 when Bayer observed it during the compilation of his Uranometria (Bayer 1603).

The measurements of position of Jupiter prompted David Fabricius to measure angular distances to nearby bright stars; among them there was one new at 20° (a case of exogenous attention). Johannes Bayer in 1603 recorded Mira in his charts, without recognizing that it was not present in the Ptolemy catalogue (Grasshoff, G. 1990). This is a case of endogenous attention, not fully attentive.

Ancient observations of Mira recorded by Hipparchus?

Another indication that ancient astronomers could have observed Mira is present in the only one work of Hipparchus (II century b. C.) nowadays existing: the Commentary of the three books of Phenomena of Aratus (c. 315-c. 245 b. C.) and Eudoxus (c. 400- c. 347 b. C.) . In the astronomical appendix in the Greek-German edition of this book (1894) K. Manitius identifies the star *epi tes lopsias* 'over the finbacks' in the constellation of Cetus as Mira (Manitius 1894). Müller and Hartwig (1920, vol. 2, p. 324) quoted Manitius' hypothesis and even identified Mira as the Nova Hipparchi in 134 b. C.. The hypotheses of Manitius (1894) and of Müller and Hartwig (1920) are in good agreement with our conclusions on the relatively high probability to see Mira at its maxima through the centuries.

Conclusions

This study on Mira, with the particular perspective of the fulfillment of Kepler's hypothesis on the Bethlehem Star (Kepler 1614) has enlightened three main aspects on Mira itself, adding new insights on its history (Hoffleit 1997).

- 1) The frequency of bright maxima of Mira is $\sim 4.2\%$ of the total; on average they are seen once every 22 years. Its discovery has been surprisingly late.
- 2) The fact that the earliest observations of Mira made by David Fabricius (1596 and 1609) are connected with the observation in the neighborhoods of Jupiter, and Mira was the new component among known asterisms.
- 3) The brightness of the maxima of Mira is correlated with the brightness of the immediate following or preceding peak. The correlation between $M_{i+1} - M_i$ and M_i in the variable star Mira has been presented here for the first time; while all previous statistical studies were concentrated on the time variations of the pulsation period.

And, regarding the hypothesis, that Mira could be the Bethlehem Star?

- 1) The neighborhood with Jupiter and Saturn in conjunction in 7-6 b. C. could help the Magi to see Mira twice, being Mira at 15° from the two planets. Moreover the circumstances are fairly similar to the ones of the discovery made by David Fabricius with Jupiter at 20° .
- 2) This hypothesis is simple, parameters-free and in agreement with what is reported in the Sacred Scriptures, once we consider all the motions of the Star simply as the reflection of the motion of the observers with respect to the objects in the foreground.

Kepler was thinking about a nova for fulfilling the requirement of the apparition of 'aliquid novi', 'something new', in his hypothesis, but nothing similar has been found in the ancient Korean (Cullen 1979) and Chinese records (Ho Peng-Yoke 1962 and Cullen 1979) in those years. The same thing applies to comets.

Being near the ecliptic, the favorable conditions for the discovery of Mira occurred several times; nevertheless we cannot have the certitude that Mira did not undergo pulsations systematically different from the ones observed in the last four centuries.

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Addenda

This work continued with the publication of 2004 in JAAVSO of the same statistical analysis performed on Mira extended to three other long period variable stars: Chi Cygni, R Leonis and R Hydrae.

In all cases the results was similar to Mira, the following maxima are negatively autocorrelated.

C. Sigismondi, Correlation of Successive Maxima in Mira, Chi Cygni, R Leonis, and R Hydrae, JAAVSO 32, 34 (2004), available freely on the internet. Here the figures of the results are reprinted.

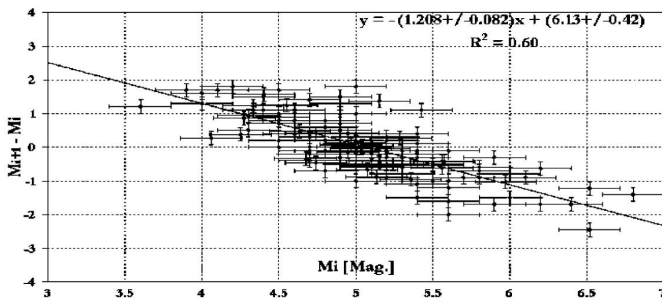


Fig. 4. Chi Cygni autocorrelation of successive maxima 1686-2001.

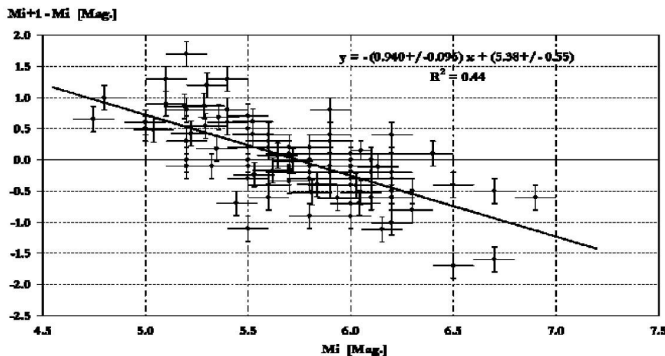


Fig. 5. R Leonis autocorrelation of successive maxima 1847-2001.

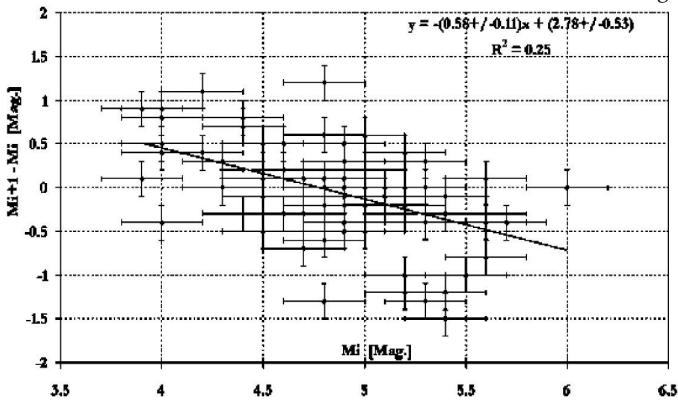


Fig. 6. R Hydrae autocorrelation of successive maxima 1842-2001.

Surprisingly the GALEX team found Mira having a tail visible in UV. This image, realized between Nov 18 and Dec 15, 2006 is reported hereinafter.¹



Fig. 7. Mira Ceti from GALEX mission. The tail is formed by the material left by the star during the last 30000 years of pulsations.

Finally the last 16 years of Mira's light curves, 20 complete cycles, with the blue crosses are indicated the observation of the Author,

SGQ in AAVSO code: they are 76 in total and cover 4 cycles: 1998, 1999, 2003 and 2014 (near the minimum). All observations have been made from Rome with naked eye or 12x50 binoculars. The last one near the minimum has been made with a 20 cm Schmidt Cassegrain

¹ C. Martin (Caltech) and M. Seibert (OCIW),

http://www.galex.caltech.edu/media/glx2007-04r_img03.html (2007)

telescope in January 2014.

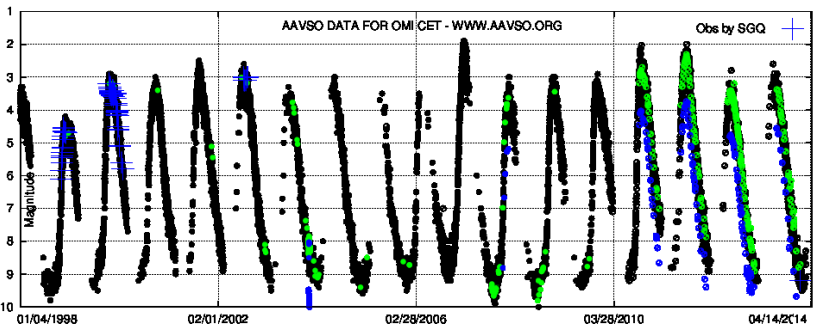


Fig. 8. Mira light curves since 1998 to 2014, in blue crosses the observations of the Author [SGQ AAVSO code].