Frank Keim

The Discovery of Jupiter's Four Largest Satellites 105 Years before Galileo Galilei

Abstract. In his painting *The Three Philosophers,* Giorgio da Castelfranco (aka Giorgione, 1478-1510) portrayed Aristarchus of Samos, a great mathematician and astronomer of his time, the astronomer and geographer Ptolemy of Alexandria, and Pythagoras of Samos, antiquity's most renowned mathematician.[1] Almost as an aside, Giorgione's painting captured a revolutionary discovery, which is shown on the document that Aristarchus holds in front of his chest: The observation of Jupiter's four largest satellites, 105 years before Galileo Galilei's discovery.[2]

1. Aristarchus' document

In the black-and-white scan of the document one can identify the word " J o v i s " in the upper right-hand corner. Jovis is the Latin nominative and genitive case of Jupiter. The word " J u v i s ", which also stands for "Jupiter" can be seen in the middle of the document.[3] The of the reference is clear now: It is Jupiter, the fifth planet of our solar system seen from the Sun.

The original size of the document is 4 by 5 inches (reddish-brown paint on a yellow background, Fig. 1).- The document contains an astronomical drawing. It illustrates two stages of a solar eclipse involving two celestial bodies, the Sun and the Moon. First, one can make out a small oval object to the left of the Sun. Second, the Moon has passed in front of the Sun; the result is a partial solar eclipse. Both positions of the Moon are illustrated by reference lines (Fig. 2). Giorgione may have observed this eclipse on 1 October 1502.

---

1 c. 1506, Kunsthistorisches Museum, Wien.

2 See for details Frank Keim, *Die Entdeckung der Jupitermonde 105 Jahre vor Galileo Galilei* (Frankfurt: Peter Lang, 2009).

3 S. Ferino-Pagden, G. Nepi Scirè, , eds., *Giorgione: Mythos und Enigma* (Wien: 2004) [hereafter Ferino-Pagden, *Giorgione*, 2004], p. 78.

The phenomenon of an eclipse of the Sun was important for the assessment of the sizes of the celestial bodies. During a total eclipse the Moon stands right in front of the Sun. As she is seen from Earth under the same angle than the Moon, namely under 0.5°, both bodies appear to have the same angular size in the moment of the eclipse. But because the Sun stands 400 times (according to Aristarchus: 19 times) "deeper" in space, she is also 400 times (19 times accordingly) bigger than the Moon. Because of this assessment, it was more likely that the smaller bodies, the Earth and the Moon, revolve around the larger one.

The part of the drawing hidden behind the philosopher's left hand is not a celestial object. It also does not depict a "cogwheel"[4], but rather an orb, a human eye with lid and lashes. The digits 1 - 7 are inscribed in the eyelid.[5] If we share this view, the two lines crossing each other can be interpreted as light rays entering the observing eye. We can distinguish a right and a left light ray (Fig. 2).

2. Astronomical objects and a calendar date

The question is, which "objects" are being reflected by these rays?- There are three small, very delicate lines that have been applied next to the end of the rightmost light ray. Further above, there are two mysterious pairs of points. Notice that the point furthest to the right stands out the most. In the upper left-hand corner one can make out the digit sequence 5 * 4 * . The sequence could be interpreted as a calendar date. It is conspicuous, that the digits on this projection plane are twice as large as those on the eye.- Obviously, the two pairs of points represent the four moons of Jupiter, whose discovery is associated with a specific date.

---

4 R. Eisler, *The royal art of astrology* (London: 1946) [hereafter Eisler, *astrology*, 1946], p. 121.

5 The digits „Eins bis Sieben" were confirmed by A. Boesten-Stengel, *Über den Zusammenhang von Stil und Bedeutung in der Malerei Giorgiones* (Diss., Freiburg, 1987), p. 131. Even Gabriele read here „die durch Punkte voneinander getrennten arabischen Ziffern 1 bis 7." (in Ferino-Pagden, *Giorgione*, 2004, p. 81). I feel not secured that the ciphers on the eye are in fact in each case separated through dots. Between the ciphers 1, 2, 4 and 4 there are no dots to recognize. They could have come through a projection space, to show a date in any case.

How did Giorgione form the correlation between the astronomical constellations and the dates? The answer is: a line connects the right ray with the left ray, a connecting line (Fig. 2, dashed arrow). The line begins near the word " J u v i s ", runs underneath the Greek word and then merges vertically with the first auxiliary line forming the Earth's Moon. In that moment, the Moon is in the waxing crescent phase. During this phase, the Moon is traversed by the left ray, resulting in a calendar date. Therefore, the line connects: First, the perception of the stellar constellation around Jupiter, second, the perception of the phase of the Moon and third, a specific date. Therefore, if the first perception is connected to the second perception, and the second to the third, then the first perception (the stellar constellation) is connected to the third (the date).

3. The calendar date: 7 April 1505

Earlier I mentioned that the digits 1 - 7 are inscribed in the eyelid. The week of 1 - 7 April 1505 was very convenient for observations of Jupiter. On 4 April, there was New Moon. Let's try to determine the date that Giorgione had focused on. There are three signs which make us assert that the first documented observation of Jupiter's satellites took place in April 1505, on 7 April 1505 to be more precise:

1) The digit 7 is located in the eye to the right. This most likely represents the specific day. By placing the 7 in the sequence of digits, we come up with: 5 * 4 * 7, and if we reverse the sequence: 7 April 1505 (Fig. 2, t1).[6] Giorgione must have used two convex lenses for his observations by a magnification factor of two.

2) An important identifier for the assignment of the observation day is the phase of the Moon on that day. The small oval form is known to stand for the Moon. The phase on 7 April 1505

[6] This date perfectly fits the other data we have about the genesis of the masterpiece. Starting from a x-ray-examination, Wilde asserted: "Unser Bild muß in den Jahren unmittelbar vor 1506 entstanden sein." ('Röntgenaufnahmen der "Drei Philosophen"', (1932), p. 50). The year "c. 1506" was also confirmed by D. A. Brown, S. Ferino-Pagden, eds., *Bellini, Giorgione, Titian* (Washington/Wien: 2006), p. 165.

was the waxing crescent (at 8 p.m.: 12,8 %).[7] The Moon was about 50° west of the planet. The digit 7 stands underneath the crescent. Gabriele confirmed that the sign "der Ziffer 7 ähnelt […]."[8]

3) In order to determine that constellation around Jupiter as seen from Earth, the Redshift Planetarium Software was used. Universal Time is 7 April 1505, 8 p.m. The location is Venice. It has the longitude lg = 12° 19' 48" East and the latitude lt = 45° 25' 48" North. The glimpse is fixed on Jupiter. Jupiter's angular distance to the Sun was approximately 110 degrees. The distance between Jupiter and the Earth was about 5 astronomical units. Jupiter's position was to the east of Saturn, approximately 60 degrees above the southwest horizon. The four moons were positioned in this order:

Ganymede Callisto <Jupiter> Io Europa

Ganymede was about 4', and Callisto about 2' distant from Jupiter.

4. The second date: 8 April 1505

The singular observation of the Jupiter-System is not enough to identify the four dot-objects as satellites. Giorgione must have made more observations to prove he had found out the "moon-character" of the objects. Now we will try to reconstruct the course of the second observation with the help of the drawing.

Next to the top of the right ray of light we recognize three tiny lines, applied in one row. Although they are very inconspicuous, they are clear to distinguish. Just one day later, on 8 April 1505, the moons' positions had changed significantly (Fig. 2, t2). At the evening of that day, about 8 p.m., the satellites had the following positions:

Callisto Ganymede Europa <Jupiter>

---

[7] Calculation of the phase of the Moon on 7 April 1505, 8 p.m.: on 7 April, midnight = 7 %; on 8 April, midnight = 14 %; => difference 7 % / 24 = 0,29 % * 20 (8 p.m.) = 5,8 % => 7 % + 5,8 % = 12,8 %.

[8] In Ferino-Pagden, *Giorgione*, 2004, p. 83.

Callisto was about 5', Ganymede about 4', and Europa about 2' 30'' away from the planet's limb. Europa had moved close to Ganymede and Callisto and now stood east of Jupiter. Giorgione drew attention to this fact by painting three fine lines. While the first two lines stand for the positions of Europa and Ganymede, the third one stands for Callisto. If one imagines that the "eye-wheel" moves by one position in anti-clockwise direction, there will be the cipher 8 instead the 7 at the lid-verge.[9]

On 11 April, there was a Moon-Jupiter conjunction. Giorgione depicted this by placing the symbol for Jupiter on the Moon's surface (Fig. 2, t3).[10] Besides the phase of the Moon, this conjunction was the second important astronomical event that he used as a reference to the series of observations.

5. The cognition of the Jupiter Satellites: 14 April 1505

Above the four dots we can read the latin word Jovis. Jovis serves as a reference to them. So the dots must represent the satellites of Jupiter. There are signs that the date of the "third" glimpse at Jupiter, the glimpse of the decisive cognition, 14 April 1505, one week after the first observation, was a Monday again (Fig. 2, t4). On this day, about 8 p.m., there was a similar constellation of the four satellites around Jupiter like on 7 April:

Ganymede Callisto <Jupiter> Io Europa

Ganymede and Callisto are positioned to the east, and Io and Europa to the west. The distance of the satellites from Jupiter's limb was: Ganymede about 3' 30'', Callisto 1' 49'', Io about 1' and Europa 1' 40''. The Moon was about 60° east of Jupiter.[11]- This is how Giorgione portrayed the situation: First, by employing two pairs of points, he was the first to depict the

[9] In contrast to its size on 7 April the crescent has grown on 8 April by 8,7 %; its value has totally increased up to 21,5 %. The phase of the Moon on 8 April 1505: on 8 April, midnight = 14 %; on 9 April, midnight = 23 %; => difference 9 % / 24 = 0,37 % * 20 (8 p.m.) = 7,5 %; => 14 % + 7,5 % = 21,5 %.

[10] The symbol was painted! Not plotted in or embedded, which is why the vertical and horizontal line are difficult to distinguish; both more or less blur in each other. Eisler was probably the first person who recognized and mentioned this symbol (Eisler, *Astrology,* 1946).

[11] Phase of the Moon on 14 April 1505, 8 p.m.: on 14 April, midnight = 77 %; on 15 April, midnight = 86 %; => difference 9 % / 24 = 0,37 % * 20 (8 p.m.) = 7,5 %; => 77 % + 7,5 % = 84,5 %.

thus “identified” moons of Jupiter in the order: Europa Io Callisto Ganymede (from left). Second, he applied a pointer and the astronomical symbol for the Moon to the beam of the last observation. By doing so, he is telling us that the four points he had observed were truly satellites, analogous to the Earth and its satellite. The complex chronological order is to be analysed again. We want to make clear that every subsequent observation brought a plus in insight:

1) At the evening of 7 April 1505 four little stars were observed. The status of the stars was not yet acquainted at that moment.

2) One day later three stars were seen left of Jupiter on a straight line. Because of the fact that the body, which was on 7 April still seen right of Jupiter, now was seen left of the planet, Giorgione supposed that this “star” could be a satellite, the three others could be satellites of Jupiter.

3) On 14 April Ganymede and Europa had almost returned to their positions that they had already one week before. With this return it was proven that the bodies must have made one or more revolutions around Jupiter. One could conclude that they had to be satellites wandering around the planet, all four had to be satellites.

The speculation: “Moon” (8 April) became a complete certainty on 14 April, on the occasion of the last observation, which is in fact depicted on Aristarchus’ emblem in the *Three Philosophers* by Giorgio da Castelfranco. The order of the four dot-objects corresponded at this evening to the one of 7 April. The cognition of the four dots as “satellites” and their equation with the Moon “according to their natures” has even more consequences. In fact, not only the Moons are equated to each others, but especially the planets they wander around, Earth and Jupiter. Thanks to that equation the Earth lost its special position within the

cosmos. According to the 6th axiom of Copernicus' *Commentariolus* it revolves "ceu aliquo alio sidere"[12], like Mercury, Venus, Mars and Jupiter, within its course around the Sun.

6. The "eye-wheel" as a date-generator

I now want to explain how Giorgione's chronometer, the "eye-wheel" works. It is possible to generate the various dates with it. The special difficulty is that the painter only recorded directly the beginning situation: 7 April 1505. The chronology of the following observations can be guessed only indirectly, with the help of the astronomical constellations.

On the image of the eye we see the ciphers: 1 2 3 4 5 6 7 (from left). The lower half of the eye is "covered" by the left hand. We suppose that there might be holding other ciphers from 8 to 14 below the hand. This would be some kind of "eye-wheel" that could be used to generate time periods. Such a wheel would explain why on the date-projection the third place was quasi realized as a gap. We can just see the cipher 7. Should the eye "rotate" in anti-clockwise, then other ciphers would take this position. The third place is like a variable that, after the initial value 7, can take on other values. If the eye rotates by one position, we would have the 8 at the right side. There even was a third observation leading to the certainty about the "moon-character". If you switch ahead the eye, we would again have the correct result: the 14 for the time position.

7. The Greek word σεληνη

The right hand of the old philosopher points to a word, which was up to present read as "celus"[13] or also "eclisi"[14] (eclipse). The word is a "key-word", which I have identified as the greek word σεληνη (Greek: Moon). The first letter looks like an " o " with a little tail: a

---

[12] Nikolaus Kopernikus, *Erster Entwurf seines Weltsystems*, trans. F. Rossmann (Darmstadt: 1986), p. 11.

[13] Eisler, *Astrology,* 1946, p. 121;264 and Settis, S., *La "Tempesta" interpretata* (Torino: 1978), p. 25.

[14] Ferino-Pagden, *Giorgione*, 2004, p. 62. Wasiutyński deciphered the word as "eclipsis" (Italian: eclipse) (*The Solar Mystery,* 2003), p. 242.

lowercase σ (Sigma). The second letter is most likely an ε (Epsilon), and the third is a λ (Lambda). The remaining letters are hardly legible. The word summarizes what the drawing is all about: the discovery of Jupiter's moons, and, going a further step, the argument that both the Jupiter and the Earth are planets.

8. Jupiter and Saturn

In the *Three Philosophers* we can recognize Aristarchus of Samos in the role of the old philosopher.[15] The man with the turban in the middle is Ptolemy of Alexandria; Pythagoras of Samos is seated next to him. Earlier I mentioned that between 7 and 14 April 1505 Saturn was positioned west of Jupiter. It is hard to imagine that Giorgione would have failed to take the proximity of both planets into account in his painting. The astronomical symbol for the planet Saturn ist hidden in the figure of the seated philosopher: he forms it using his index finger and thumb.

Conclusions: I think I have made it clear that Giorgione is to be viewed as an artist who fused painting with astronomy. Regarding the formulation of the heliocentric theory, he as an Italian played a complementary role next to Copernicus, the man from the North. I hope that the history of astronomy will be rewritten to include the perspective of this astronomer, who unfortunately died far too young.

I am grateful to Prof. Dr. Hilmar Duerbeck (Münster, Germany) for a critical reading of the manuscript.

[15] The angle of Aristarchus' pair of compasses shows 23.5°. This value corresponds exactly to the inclination angle of the earth around 1500 (I owe this important indication to Mr. Berthold Holzschuh, Aschaffenburg).- At the end of the fifteenth century, the manuscript περι μεγεθων και αποστηματων ηλιου και σεληνης (On the sizes and distances of the sun and the moon) appeared in print, published in 1498 in Venice in the Latin translation of Giorgio Valla (~1430-1499). Its author was the famous Greek mathematician and astronomer Aristarchus of Samos (~310-230 B.C.). Aristarchus was the first in antiquity who put forward the heliocentric theory.

Bibliography

Anderson, J., *Giorgione* (Paris: 1996).

Boesten-Stengel, Albert, *Über den Zusammenhang von Stil und Bedeutung in der Malerei Giorgiones* (Diss., Freiburg, 1987).

Brown, D. A., Ferino-Pagden, S., eds., *Bellini, Giorgione, Titian and the Renaissance of Venetian Painting* (Washington/Wien: 2006).

Eisler, Robert, *The royal art of astrology* (London: 1946).

Ferino-Pagden, S., Nepi Scirè, G., eds., *Giorgione: Mythos und Enigma* (Wien: 2004).

Ferino-Pagden, S., (ed.), *Giorgione entmythisiert* (Turnhout: Brepols, 2008).

Keim, Frank, *Die Entdeckung der Jupitermonde 105 Jahre vor Galileo Galilei* (Frankfurt: Peter Lang, 2009).

Kopernikus, Nikolaus, *Erster Entwurf seines Weltsystems*, trans. F. Rossmann (Darmstadt: 1986).

Redshift Planetarium Software, United Soft Media Verlag 1994-2004.

Settis, S., *La "Tempesta" interpretata: Giorgione, I committenti, il soggetto* (Torino: 1978).

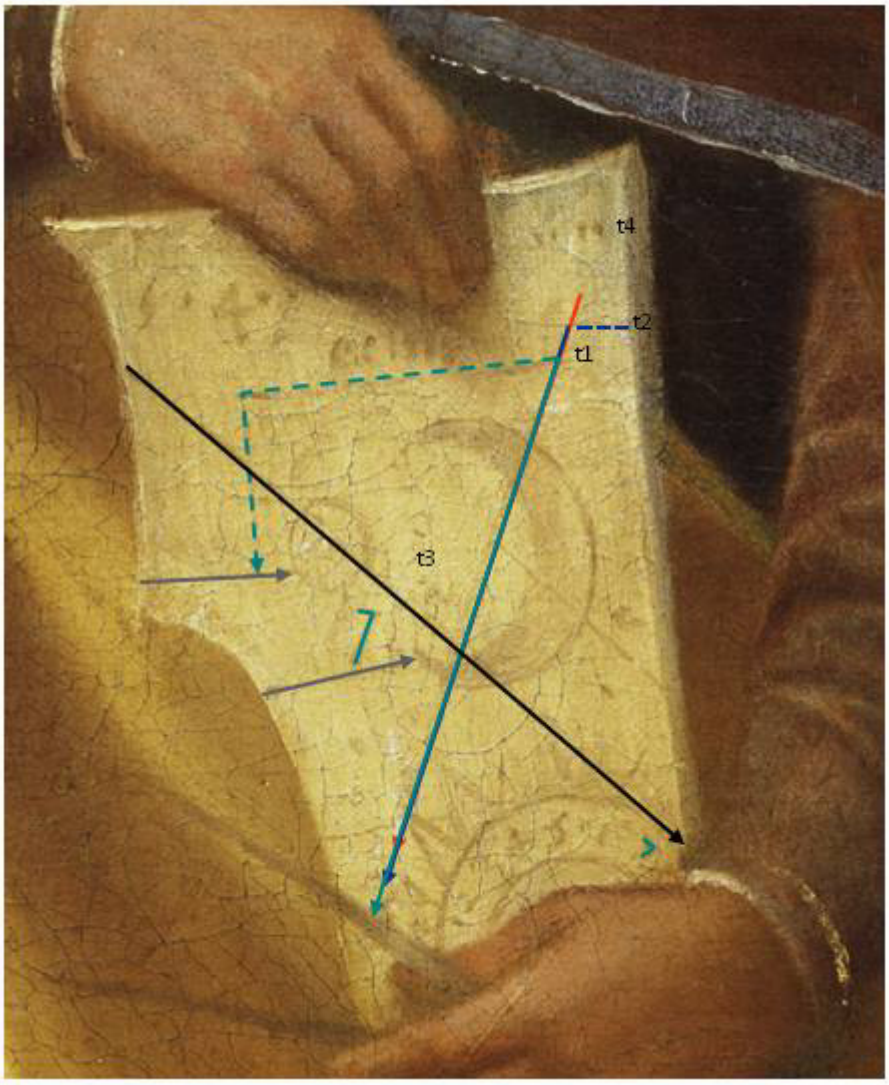
Wasiutyński, J., *The Solar Mystery* (Oslo: Solum Forlag, 2003).

Whitmell, C. T., Visibility of Jupiter's Satellites, *Journal of the British Astronomical Association*, Vol. XIV, (1904), pp. 361-366.

Wilde, J., 'Röntgenaufnahmen der "Drei Philosophen" Giorgiones und der "Zigeunermadonna" Tizians', *Jahrbuch der kunsthistorischen Sammlungen in Wien,* (1932), pp. 141-154.

Figure 1. Giorgione, The Three Philosophers, detail

Figure 2. Four Observations



Preprint:

INSAP VII: Bath Royal Literary & Scientific Institution, Bath, UK (2010).

Publication (tentative):

The Inspiration of Astronomical Phenomena VII -- Proceedings

[To be Published in *Culture and Cosmos* Vol. 15 Nos. 1 & 2 ISSN 1368-6534 (2011).

Nicholas Campion and Rolf Sinclair (eds.).] With permission from Nicholas Campion