Journal of Astronomical History and Heritage, 24(4), 993–1000 (2021).

GALILEO COULD HAVE SIMULATED HIS EARLY DATA ON THE PHASES OF VENUS

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Abstract: Galileo claimed the phases of Venus as his own discovery. His priority claim hinges on the authenticity of his December 1610 record of observations ostensibly dating back to October. Scholars have argued that Galileo's report must be truthful, since it is too accurate and detailed to have been forged after the fact. However, I show that Galileo could easily have forged these data by means of a basic simulation with a physical sphere rather than actual observations. This calls into question the received view that Galileo must have known about the phases of Venus already before it was brought to his attention by others.

Keywords: Galileo Galilei, phases of Venus, Castelli, forged data

1 INTRODUCTION

To the naked eye, Venus is just a dot of light. But telescopic magnification reveals it as a sphere, only part of which is bright, namely the part facing the Sun. Thus, the half of Venus facing us exhibits phases like the Moon, being sometimes crescent, sometimes gibbous, and so on (Figure 1). These appearances show that Venus orbits the sun, contrary to Ptolemaic cosmology. In this paper we examine Galileo's claim that he discovered the phases of Venus.

2 GALILEO'S OBSERVATIONS OF THE PHASES OF VENUS

Galileo observed the phases of Venus in 1610, and the time-line of associated events is intriguing:

(1) On 5 December Castelli wrote to Galileo and pointed out that it ought to be possible to confirm the Copernican hypothesis by observing phases of Venus with a telescope (Westfall, 1985: 11).

(2) On 11 December, perhaps right after receiving Castelli's letter,[1] Galileo announced something

> … just observed by me which involves the outcome of the most important issue in astronomy and, in particular, contains in itself a strong argument for the… Copernican system …

namely that he has observed Venus exhibiting phases like the moon (Westfall, 1985: 24).[2] Before this, there is no record that Galileo knew anything about the phases of Venus (Westfall, 1985: 25).

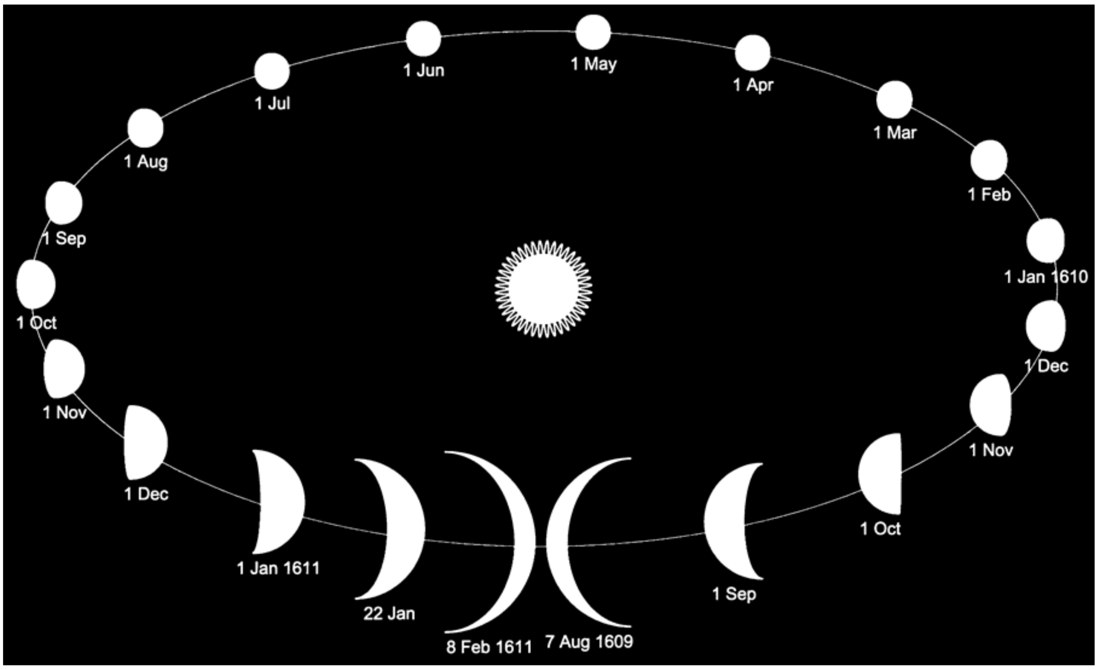

Figure 1: Actual appearance of phases of Venus around the time of Galileo's observations. Based on calculations by Rob van Gent (diagram: Viktor Blåsjö).

(3) On 30 December Galileo gave for the first time an account of his observations of Venus. At this point he claims to have observed Venus for about three months and gives an accurate and fairly detailed description of its appearance during this period (Palmieri, 2001: 109–110).

The timing of Galileo's 11 December letter raises questions. Was Galileo ignorant of the phases of Venus and their importance before this was pointed out to him? Did Galileo steal the idea from Castelli?

In a letter of 13 November 1610, Galileo seems to state expressly that he had no new planetary discoveries to report, implying that he did not yet know about the phases of Venus—contrary to his later assertions. His defenders claim that Galileo's phrase should instead be read as saying that he has made no new discoveries 'around' the planets, that is, he had not discovered any new moons (Drake, 1984: 200). Perhaps so. It would make sense for Galileo to be on the lookout for moons and the like, as he had found for Jupiter and Saturn. But that is all the more reason for him to miss Venus' phases. At this time Venus was well over half full, so its shape would not have been very remarkable unless he was specifically paying attention to it. He could easily have missed it if he was too busy moon-hunting and looking only around the planets.

But if Galileo had not observed the phases of Venus before Castelli's letter, then how could he later give an accurate description of their appearance dating back two months before this letter? He would have had to fabricate data and pass this off as actual observations. This is not in itself an implausible hypothesis since it is well-established that Galileo did so on several other occasions. For example, on the speed of falling bodies, "… in no case could Galileo have consistently achieved the results he reported." (Hill, 1984: 132). On gravitational acceleration, Galileo "… used arbitrary data …" (Drake, 1989: 70). On air resistance to motion, "… the experiment adduced in its support is fictitious …" (Drake, 1974: 226). Galileo's allegedly experimental report on pendulums in the *Discourse* was "… exaggerated …" (Renn et al., 2001: 139–140) or "… conscious deception …" (Hill, 1984: 131). Furthermore, Galileo

> … could not have observed the ring [of Saturn] at the summer solstice of 1612. Yet the picture of the Saturnian system that was accepted by Galileo implied that the ring should have been visible, so much so that he made a claim to this effect that we know must have been untrue. (Deiss and Nebel, 1998: 218).

Beyond scientific evidence, Galileo altered a crucial document in connection with Inquisittion proceedings so as to "… soften his heretical claims …" and "… then lied about his edits …", falsely asserting that the incriminating formulations (which are now known to have been accurate) were a "… fraud." (Abbott. 2018: 421–422).

Galileo was surely concerned to get the important pro-Copernican argument from the phases of Venus on the record as quickly as possible and claim it for himself, and for this purpose it would have been important to have observed Venus' fully gibbous appearance in the Fall (the next opportunity to observe it in this form would be months away). So, Galileo certainly had a strong motivation to fabricate these data. Making observations throughout most of December, after receiving Castelli's letter, would also have been enough to give him great confidence that the heliocentric explanation for the phases of Venus was right. So, faking the data was not risky.

Galileo's defenders have a counterargument to this. They claim that Galileo could not have fabricated the data in question even if he had wanted to. According to them, the changes in appearance of Venus during these months were so complex and "… non-linear …" that Galileo could never have given such an accurate account if he had not in fact made these observations. Specifically, Galileo correctly described the fact that the transition from a gibbous to semicircular phase was quite rapid, while an approximately semicircular phase lingers for a considerable time:

> Castelli's letter cannot have been the spark that ignited Galileo's programme of observation of Venus. It was simply too late. If he only then had started observing Venus, he would have seen it already nearing the exact semicircular phase, thus completely missing the non-linear patterns of change. And he could not possibly have been able to calculate the duration of one month for the "lingering" phenomenon. In other words, Galileo cannot have predicted Venus's non-linear patterns of behaviour by reconstructing them 'backwards'. For a Copernican it might have been easy to predict that Venus should display phases. However, it is one thing to predict this type of behaviour qualitatively and quite another to predict the non-linear patterns of change of Venus's phases. A quantitative analysis would have required of Galileo a sophisticated mathematical theory that he did not have. There remains only one

Figure 2: The simple setup we used to simulate the phases of Venus (photograph: Viktor Blåsjö).

> possibility, namely, that Galileo really did observe Venus's non-linear patterns of behaviour. (Palmieri, 2001: 117).

I say that, on the contrary, Galileo could easily have reconstructed these phenomena. He would not have needed any sophisticated mathematics at all. All he would have had to do would have been to simulate Venus' appearance by looking at a half-painted sphere representing Venus from vantage points corresponding to the Earth's position relative to it.

I carried out such a simulation using very simple means (Figure 2). The results are shown in Figure 3. I used a white spherical lamp as Venus. I covered half of it in black to represent the half not illuminated by the Sun. I pointed the white half toward a center point (the Sun) 4.34 meters away. I then marked off a circle of radius 6 meters with the same center, representing the orbit of the Earth. I used the fact that Venus was seen exactly semicircular on 18 December 1610 to find where the Earth must have been it its orbit that day (Peters, 1984: 212). I placed a camera at this position and photographed the Venus sphere. I then used a protractor positioned at the Sun to reconfigure the setup to correspond to other dates, counted forward and backwards from 18 December in 21-day increments using the simplest possible estimation for the motions of these planets (I simplistically assumed uniform circular motions for the Earth and Venus, so there is no advanced mathematical astronomy involved in any way, just basic calculations using the radii and orbital times of these two planets). I again photographed Venus from these positions. I did all of this in a rough-and-ready way in an empty parking lot using crude measurements. I also recreated the exact same setup using 3D software (Figure 4), which shows the results of this simulation without the accidental imperfections of my physical demonstration.

Galileo could easily have completed such a simulation from start to finish in just a few hours. And of course, the idea of illustrating the phases of the moon by an illuminated or half-painted sphere had been commonplace since Antiquity, so Galileo would not have needed much imagination to come up with this scheme.

The results of this simple simulation are very close to the true appearances.[3] In particular, the simulation is easily sufficient to re-

Figure 3: Simulated appearances of Venus as seen from the Earth for 4 September, 25 September, 16 October, 6 November, 27 November and 18 December 1610, and 8 January and 19 January 1611 (photograph: Viktor Blåsjö).

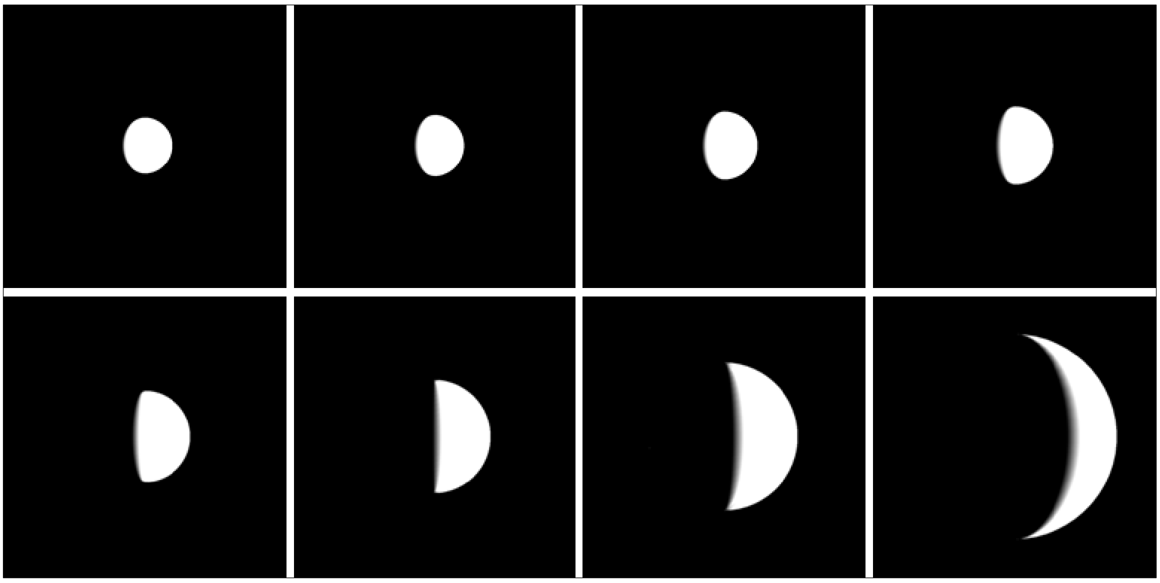

Figure 4: The same simulation as in Figure 3, carried out using 3D software (diagram: Viktor Blåsjö).

produce the allegedly so unpredictable 'non-linear' phenomena that Galileo got right in his December 30 report. So, the claim that it would have been impossible for Galileo to recreate these appearances after the fact is definitely false.

An additional argument that has been made for the authenticity of Galileo's observational report is that the language he uses in his descriptions "… has a highly visual character …", thereby giving his report "… the ring of a record of visual impressions rather than an account coloured by calculations." (Peters, 1984: 213–214). But if Galileo forged the data using a physical simulation rather than calculations, then the fake observations would be just as visual as the real thing, and hence 'visuality' can no longer be used as a mark of authenticity.

The hypothesis that Galileo simulated his Venus observations by using such a model is lent some further credibility by its close parallels with his treatment of sunspots. Galileo (1953: 348–351) argued that sunspots could be used as evidence that the Earth moves around the Sun. The Sun is spinning on its axis, making a full revolution in less than a month. As it spins, a point on its surface traces out a latitude circle. Hence, by tracking the paths of sunspots over the course of a few weeks, one in effect sees equatorial and other latitude circles being traced across the surface of the Sun. In the course of a year, the shapes of such paths vary between

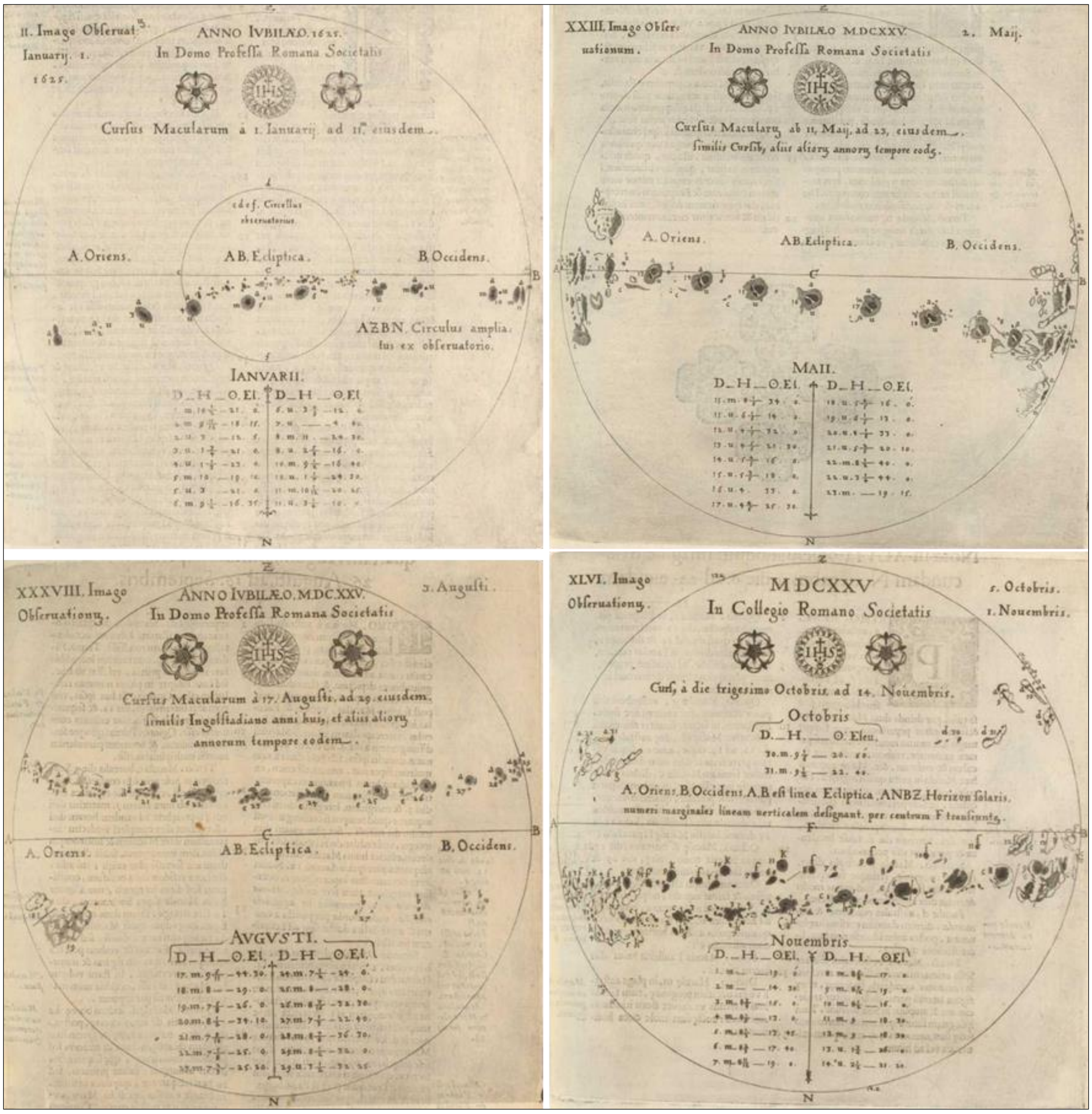

Figure 5: Paths traced by sunspots over a series of days at different times of year (after Scheiner's *Rosa Ursina* (1630).

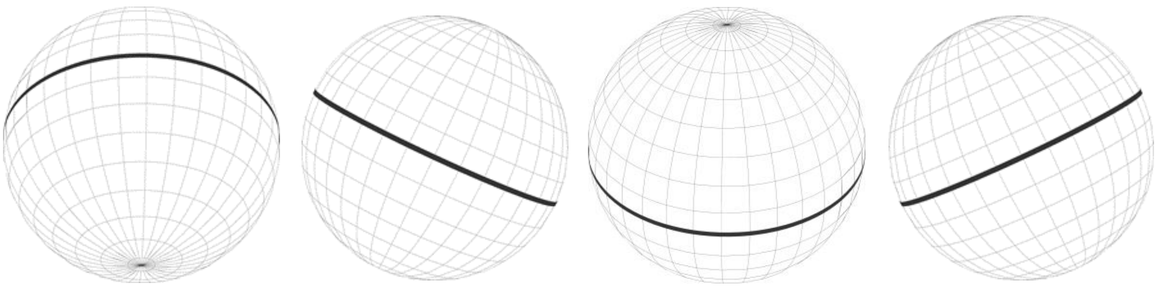

Figure 6: Equatorial circle of a sphere viewed from different vantage points (diagram: Viktor Blåsjö).

'happy mouth', 'sad mouth', and diagonal line shapes, just as one would expect if one was looking at an equatorial line drawn on a globe from an orbiting vantage point (see Figures 5 and 6).

In his *Dialogue*, Galileo (1953: 462) considered this one of his three best arguments in favour of Copernicus. However, in the 1610s, when he was first studying sunspots, Galileo had not yet realised that sunspots were relevant to this question. Instead, he believed at that time that all sunspot paths were straight lines (Reeves and Van Helden, 2010: 90, 109, 113, 255), which precludes the possibility of the pro-Copernican argument based on the paths of sunspot. Only after Scheiner's detailed study of sunspots, outlined in his *Rosa Ursina* (1630), did Galileo come to the opposite realisation. Galileo (1953: 346) did not want to admit his debt to Scheiner, so he alleged that he had come upon this discovery independently, and he claimed that he had made

> … very careful observations for many, many months, and noting with consummate accuracy the paths of various spots at different times of the year. (Galileo, 1953: 352).

But this is belied by the poor quality of Galileo's ostensible observational descriptions (Drake, 1970: 186–187; 1978: 335). Meanwhile,

> The evidence is unequivocal: Galileo … must have had a copy of Scheiner's book in front of him as he wrote this section … [and by pretending otherwise he] has deliberately set out to efface Scheiner from the historical record and to deny his debt to him. It is impossible to find any excuse for this behavior. (Wootton, 2010: 208–209).

I suggest that this is a close parallel of what happened also in the case of the phases of Venus: in both cases Galileo realised an important pro-Copernican argument only quite late, based on the input of others, and he needed to act quickly in writing something about it without having the time to make thorough observations.

This parallel undermines the common assumption that Castelli's idea must already have been obvious to Galileo. One scholar, for example, thinks it "… would be to dignify the idea beyond reasonable measure …" (Ariew, 1987: 92) to view Castelli's suggestion as a significant insight; rather, "… the thought that Venus might have phases was 'in the air' …" (*ibid*.) and hence Castelli's contribution is to be considered quite trifling.

Another scholar argues along similar lines that Galileo had no need to be spurred to action by Castelli's letter, only by news of others making advanced telescopic observations. Around a day or two before hearing from Castelli, Galileo had received another letter, reporting that Clavius and his assistants at Rome had observed the moons of Jupiter (Drake, 1984: 200–201).

So, Galileo now had serious competitors in the realm of advanced telescopic observations, or so it would have seemed to him. Presumably they would turn to the other planets next, and perhaps anticipate the discovery of the phases of Venus, whence Galileo's sudden urgency. For "… the problem was to have a good telescope, not to possess reasoning power that astronomers had never lacked." (Drake, 1984: 203).

The sunspots case is a counter-example to such an interpretation. If there was no shortage of 'reasoning power', Galileo should have realised the potential importance of sunspots much earlier and not let himself be 'beaten to the punch' about their curved appearance by his arch-rival Scheiner. The fact of the matter is that the sunspots argument for heliocentrism eluded Galileo for twenty years, despite the fact that he was passionately committed to proving heliocentrism in novel ways, and despite the fact that he himself had written specifically and in detail about the very phenomenon at stake, and despite the fact that the argument is very simple.

By analogy, this suggests that Castelli's idea about Venus could very well have been news to Galileo: if he could somehow miss the sunspots argument for twenty years despite all of this, then he could certainly have failed to think of the Venus argument during his one initial frantic year of telescopic observations, when he had a myriad of other novelties and issues to deal with all at once.

But perhaps the most interesting aspect of the parallel between the two cases is the possibility that they both involved the use of physical models to simulate celestial appearances. For, in the *Dialogue*, one speaker reports regarding the appearance of the paths traced on the surface of the Sun by sunspots as seen from the Earth that Galileo

> … assisted my understanding by representing the facts for me upon a material instrument, which was nothing but an astronomical sphere, making use of some of its circles—though a different use from that which they ordinarily serve. (Galileo, 1953: 348).

The same sentiment is repeated later: the appearance of the sunspot paths

> … will become better fixed in my mind when I examine them by placing a globe at this tilt and then looking at it from various angles. (Galileo, 1953: 352).

This is very closely analogous to the Venus simulation I outlined above, suggesting that the latter would have been quite natural to Galileo and in keeping with his style of reasoning.[4]

The following, then, are generally accepted facts about the sunspots issue: Galileo claimed to have conducted careful observations when he had not. According to his own account, Galileo simulated observations by looking at a physical sphere from a variable vantage point corresponding to the position of the Earth; Galileo failed to see an important pro-Copernican argument for a long time, despite it being simple and very naturally connected to his own work. The fact that these things did happen in the case of sunspots suggests that they very well could have happened also in the case of Venus.

3 CONCLUDING REMARKS

If Galileo had wanted to fabricate or reconstruct Venus observations he had not made, he could easily have done so. His 30 December 1610 account, where he describes appearances of Venus going back to October, is perfectly consistent with the hypothesis that he only started serious observations after receiving Castelli's letter in December and simulated earlier observations using a simple physical model.

Furthermore, there are, as we have seen, a number of circumstantial indications that this would have been in keeping with his character and habits.

Of course, none of this is evidence that Galileo actually *did* fabricate his Venus data; it shows only that the possibility of him doing so is by no means implausible.

4 NOTES

1. It is difficult to say exactly when Galileo would have received the letter from Castelli. Westfall (1985: 24) discusses evidence regarding mail delivery times and finds it "… easily possible …" that Galileo could have received the letter before 11 December. Drake (1984: 203), on the other hand, finds the probability of this "… vanishingly small …" on the basis of other evidence regarding mail delivery times, as well as arguments from other references in their correspondence.
2. Galileo's announcements were initially in the form of an anagram, the meaning of which he revealed only later.
3. Figure 1 shows exactly computed actual appearances. Such modern reconstructions of the actual appearances are also given in Gingerich (1984), Palmieri (2001) and Peters (1984).
4. For further examples of Galileo preferring to think with physical objects, see Machamer (1998: 67–71).

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