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Galileo and the Supernova of 1604

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Abstract. The supernova of 1604 was observed in Padua on 10 October 1604 but on account of cloudy weather Galileo did not see it until a few days later. The supernova created great excitement and Galileo, who taught mathematics and astronomy at the University, was asked to give three public lectures that were attended by a large audience. In this paper we show how Galileo explained the nature of parallax in order to demonstrate that the new star was well beyond the Moon. We also consider his attempt to determine the nature of the star, and the amusing pamphlet that he penned to lampoon professional philosophers who denied that new stars could appear in the heavens.

1. Introduction

The sky holds many surprises. Sometimes where nothing was there before, we witness the sudden and unexpected appearance of a star destined perhaps to outshine all the stars in the sky before dropping back into obscurity. At one time, the bursting of a nova, as it was called, would be greeted with trepidation, but nowadays it merely provides astronomers with interesting problems.

2. Modern Meaning of Nova and Supernova

For contemporary astronomers a nova is a star that suddenly increases enormously in brightness, then slowly fades back to its original luminosity. Novae are the result of explosions on the surface of faint white dwarfs, caused by matter falling on their surfaces from the atmosphere of larger binary companions. A supernova is also a star that suddenly increases dramatically in brightness, then slowly dims again, eventually fading from view, but it is much brighter, about ten thousand times more than a nova. A supernova produces a burst of light billions of times brighter than the Sun, reaching that brightness just a few days of the start of the outburst. The total amount of electromagnetic energy radiated by a supernova during the few months it takes to brighten and fade away is roughly the same, as the Sun will radiate during its entire 10^{10}-year lifetime.

From our modern point of view, the most important aspect of supernovae is their role in creating, and then dispersing, the heavy elements out of which our planet and our bodies are made. All the Hydrogen and most of the Helium in the Universe are primordial, that is, they date back to the very earliest times, long before the first stars were formed. All the other elements (and virtually everything we see around us on Earth) were formed later, through stellar evolution. Heavy elements are created from light ones by nuclear fusion. This is the basic process that powers the stars. Hydrogen fuses to Helium, then Helium to Carbon. Subsequently, in high-mass stars, Carbon fuses to form still heavier elements: Oxygen, Neon, Magnesium, Sulphur, Silicon, all the known elements up to and including Iron. However, this stops at Iron. How then were even heavier elements such as Copper, Lead, Gold, and Uranium formed? The answer is that they were created during supernova explosions, as neutrons and protons, produced when some nuclei were ripped apart by the almost unimaginable violence of the blast, were formed after their parent star had already died, even as the debris from the explosion signalling the star's death was hurled through interstellar space.

3. The New Star of 1604

We are stardust, and without the explosion of supernovae there would be no one to raise questions about supernovae as cosmological lighthouses. But Galileo and his contemporaries knew nothing of this. Although supernovae explode fairly frequently, the ones that are visible to the naked eye are few and far between. Between Galileo's birth in 1564 (the year Michelangelo died) and his death in 1642 (the year Newton was born) only two supernovae occurred in our own galaxy: Tycho Brahe's in 1572 and, in 1604, the one that Galileo observed. None has been seen since. The supernova of 1604 caused even more excitement than Tycho's because its appearance happened to coincide with a so-called Great Conjunction or close approach of Jupiter, Mars and Saturn. Astronomers and astrologers (the words carried pretty much the same meaning in Galileo's day) divided the ecliptic into twelve signs, and grouped these signs by groups, with each sign 120°from each other. The resulting four "trigons" were associated with the four elements; earth, water, air and fire, each of them in turn the ruling one. The supernova of 1604 appeared in the "fiery trigon" that contains Aries, Leo and Sagittarius, namely the first, fifth, and ninth sign.

The Great Conjunction takes place roughly every twenty years, each time about eight and one tenth signs from the previous place. If the Great Conjunction takes place in the beginning of Aries, the next one should take place in Sagittarius, the next in Leo, the next three tenths of the way into Aries, the next four tenths of the way into Sagittarius, and so on. Going this way it will take the conjunction two hundred years to pass over to a new trigon and eight hundred years to start the same cycle all over again.

Jupiter and Saturn were in conjunction, namely Jupiter passed just in front of Saturn, on 17 December 1603, and astronomical tables predicted a conjunction of Jupiter and Mars (with Saturn close by) in the constellation Sagittarius for 8 October 1604. Because such an event was astrologically significant, a great many astronomers, both professionals and amateurs, were observing the skies that night. Without the telescope, let us note, since this instrument was only discovered later, and not used for astronomical purposes before 1609. Nothing unusual was seen on 8 October and, in fact, the predicted conjunction did not occur until late afternoon on 9 October. It was observed by Ilario Altobelli in

Verona and by Raffaello Gualterotti in Florence on that day[1], but the sky was cloudy in Padua and no observation could be made. The supernova was first seen in Padua on the 10^{th}, not by Galileo but by a student named Baldassare Capra, his tutor Simon Mayr, and a friend, Camillo Sasso. The new star created great excitement but it soon set below the horizon, and the three friends eagerly awaited the next evening to confirm that it really was a star. But as sometimes happens in Astronomy, the sky was overcast on the 11^{th}, and again on the 12^{th}, the 13^{th} and the 14^{th}. It was not before the 15^{th} that they were able to see it again. It has already grown in size and appeared bigger than all the planets with the exception of Venus. They carefully noticed its colour because this could indicate its astrological powers.

Galileo did not hear about the supernova for several days, and his first recorded observation is dated 28 October. By then the news had become a sensation, and everyone wanted to know what the professor of Astronomy at the University of Padua had to say about it. Galileo had held that position since 1592, but this was the first time in twelve years that he was called upon to give a public lecture. The subject was so hot that he gave not one, but three lectures. Only the first page and a fragment of the end of his first lecture have survived, and we do not know exactly when he delivered these talks, but it was probably during November while the star could still be seen in the evening sky.[2] From the last week in November until after Christmas, it was too near the Sun to be visible. When it reappeared it could be seen just before dawn in the East.

4. Galileo's Lecture

Galileo later wrote that over a thousand persons came to his lectures.[3] But the great hall of the University can seat no more than four hundred, and he must have intended to say that attendance was more than three hundred at each lecture. In the holograph notes that have survived, Galileo states that the new star was initially small but grew rapidly in size such as to appear bigger than all the stars, and all planets with the exception of Venus. Its colour was reddish-brown like Mars, but it also had something of the golden brilliance of Saturn. It sparkled, namely it seemed to die out only to flare up immediately, such that it had the redness of Mars when it appeared to go out, and the splendour of Jupiter when it burst forth again. "Someone could therefore reasonably conjecture", writes Galileo, "that it was generated by the embrace of Mars and Jupiter, the more so that it seemed to be born at the time of their encounter, which took

[1] See Righini (1978, p. 14). Righini argues that Anton Lorenzo Poliziano could have observed the supernova in Pisa on 8 October 1604, and that it was probably also seen by Antonio Santucci, the professor of mathematics at Pisa, on 9 October.

[2] Galileo declared that he delivered his lectures "not many days after the appearance" of the new star. Galileo Galilei, Difesa contre alle Calunnie et Imposture di Baldessar Capra (Opere di Galileo Galilei 1890-1910, vol. 2, p. 525).

[3] Galileo Galilei, Difesa contre alle Calunnie et Imposture di Baldessar Capra (Opere di Galileo Galilei 1890-1910, vol. 2, p. 520).

place in the presence of Saturn at 5.00 p.m. on 9 October".[4] Now comes the interesting claim, "At that time we were observing the conjunction, but we saw no star near the three planets". Galileo drops the "we" in the next sentence that reads: "On the following evening, namely on 10 October, at sunset, the new light was first observed. First small and weak, it became huge within a few days, so that it might be conjectured that it was born at the very moment of the conjunction but remained concealed on account of its small size" (Opere di Galileo Galilei 1890-1910, vol. 2, p. 277).

This statement was to give rise to an unfortunate quarrel with Baldessar Capra, who felt slighted because Galileo had not given him and his two friends full credit for having been the first to observe the new star. In a polemical pamphlet of a few pages that he published in February 1605, Capra claims that he observed the sky on a daily basis, and that the sky was overcast on October 9th. There was no way that Galileo could have observed the Great Conjunction on that night. Galileo felt called upon to reply to Capra in print and he did so in a work in which he also denounced him for copying the geometrical compass that he had invented and was marketing. Galileo makes no comment about the covered sky of 9 October but declares that, in his lecture, he made a lapsus, which he immediately corrected as follows: "The star was observed on the 8th, or rather on the 10th".[5] Galileo adds that in the first lecture, which was attended by Capra and his teacher, he praised them for being the first to see the star in Padua. The point however, as Galileo goes on to say, is not who was the first to witness the event but who offered the best explanation of where it was, what it was, and what it portended. On all these questions, Capra was, at best, poorly informed.

On the location of the star, Galileo's observations and those made elsewhere in Italy and in Northern Europe indicated that it was beyond the Moon, in the region where the new star of 1572 had appeared. The appearance of a new body outside the Earth-Moon system had challenged the traditional belief, embodied in Aristotle's Cosmology, that the material of planets was unalterable and that nothing new could occur in the heavens. The supernova of 1604 added yet another threat to the received view about the nature of the Universe. In order to show that the new star was beyond the Moon, Galileo probably gave his audience a brief explanation of parallax. He could have used a homely illustration such as the following. Take a pencil and hold it at arm's length so that it is just in front of your nose. Look at it with your right eye, keeping the left one closed. Then close your right eye, and look at the pencil with the left one. What has happened? The answer is that the pencil seems to have shifted its position against the background, which could be the wall of the room, a blackboard, or the landscape. The farther the pencil, the smaller the apparent shift, and if the pencil were on the wall itself there would be no parallax.

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[4] Fragments of Lecture Notes (Opere di Galileo Galilei 1890-1910, vol. 2, p. 277) For "encounter", Galileo uses the Latin word "congressus" that also has the meaning of sexual intercourse. The conjunction of Mars and Jupiter was not a strict one since they remained separated by 1.76°.

[5] Galileo Galilei, Difesa contre alle Calunnie et Imposture di Baldessar Capra (Opere di Galileo Galilei 1890-1910, vol. 2, p. 523).

Once the principle was grasped, its application was fairly easy. When Michael Maestlin, Kepler's future teacher at Tübingen, heard of the nova of 1572, he determined the place of the new star with fair accuracy simply by picking out four stars so placed that the new star was at the point of intersection of the two lines that joined the fours stars two by two. By holding a thread before the eye, so that it passed through the three stars, Maestlin assured himself that the new star did not move relatively to the stars during the daily revolution of the heavens, and he concluded that the new star was situated among the fixed stars.

5. The Nature of the New Star

If the new star was well above the Moon, how did it get there? To say that it was generated from heavenly matter was tempting, but no one knew whether that kind of matter could indeed be altered. It appeared simpler to Galileo to appeal to the terrestrial matter with which we are familiar, and suggest that it had somehow risen to great heights. "It is not impossible", he writes in his lecture notes, "that a large amount of vapour could rise from the Earth and form an enormous mass the size of the new star". He illustrates his point with the following analogies: "We see the blue sky suddenly fill with clouds, etc. When a green log is set on fire, it produces an enormous amount of smoke although its size remains pretty much the same".[6] Galileo realized that a comparison with ordinary fire was open to criticism, and he tried to parry the blow by arguing that celestial fire was of a different nature. "That the new star was no ordinary fire is clear from the fact that what can be readily set ablaze does not burn long. A substance that burns immediately is quickly consumed. There are innumerable examples of this".[7] But in the end, Galileo seems to have rejected the analogy with fire in favour of one based on the reflection of sunlight in clouds. If the light that comes from the Sun can produce rainbows and other celestial phenomena in the sublunary region, why not extends this possibility to vapour that breaks away from the Earth and enters the celestial sphere?

The answer was not easy, and after delivering his lectures, Galileo sought the opinion of others, including Tycho Brahe whose posthumous *Progymnasmata* had appeared in 1602 (Brahe 1602), and the more recent *De Stella Nova in Pede Serpentarii* that Kepler published in 1606 (Kepler 1606). The more he pondered the question, the more Galileo hesitated. When an important person, whose name we do not known, asked him repeatedly to publish his three public lectures, Galileo excused himself from doing so. "I realize", he wrote, "how weak my arguments are and how unworthy to come into the hands of your Excellency". Galileo had convinced himself that the new star was above the Moon, "which was the main goal of my lectures", but he wanted to do more and explain what it was made of and how it was generated. "I thought I had found an explanation that was consistent and might just be right", he adds, "but I have to proceed with caution and wait for the return of the star in the east when it is far enough from the Sun [to be seen]. I must observe again very carefully

[6]Fragments of Lecture Notes (Opere di Galileo Galilei 1890-1910, vol. 2, p. 283).

[7]Fragments of Lecture Notes (Opere di Galileo Galilei 1890-1910, vol. 2, p. 280).

if there have been changes in its location, apparent size, and the quality of its colour. After giving much thought to this marvel, I now believe that I now know more than what is commonly conjectured about the star".[8] Galileo does not spell out what was commonly conjectured but it was generally said that the new star was newly seen, not newly generated. Some suggested that it could be an old and faint star that had become brighter through some sudden alteration of the air between it and the Earth, or on account of the rapid condensation of part of one of the spheres through which its light had to pass. Valesius, the physician to King Philip II of Spain, had even given a theological reason for this: God ceased creating on the sixth day, and nothing had been done since then!

6. The Motion of the Earth

Galileo's caution may have had something to do with a much more important issue than the nature of the new star. He would have found in Tycho Brahe that the English astronomer Thomas Digges had used a method similar to the one of Maestlin to determine the parallax of the new star of 1572. Digges took a straight ruler, six feet long, and suspended it vertically until he found two stars that were in the same vertical as the new star. Six hours later he tried again, holding the ruler in his hand, and saw the three stars still in a straight line, and he concluded that the new star could not have a parallax amounting to 2 seconds of an arc. Digges did not stop here but went on to see whether he could test the Copernican theory of the motion of the Earth by determining if the new star had a small parallax. He found none. There is a slight one of course, but Digges or anyone else could not determine it with the means at their disposal. It was only measured in the nineteenth century when astronomers had much more sophisticated optical instruments.

A clue that Galileo may have been thinking along the lines suggested by Digges is an extended passage that Galileo quotes from Seneca's *Natural Questions* where the study of comets and other celestial bodies is praised, in order
"that we may know whether the world revolves while the Earth stands still or whether the Earth turns while the world stands still. For some have said that we naturally turn around, although we are unaware of the fact, so that the motion of the sky does not cause the rising and the setting of the Sun, but we are the ones who rise and set. It is worth investigating the state in which we really find ourselves. Is our home at rest or moving very fast? Is God spinning everything around us or has he put us in motion?".[9]

Galileo had good reasons for associating the new star with the eventual confirmation of the heliocentric theory: the star had appeared at a distance comparable to those of Mars and Jupiter, and it exhibited no perceptible parallax. It was probably moving away and would on that account continue to dwindle in size. The star could only exhibit an appreciable loss of size by moving through

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[8]Letter of Galileo and an unknown correspondent, probably written in January 1605 (Opere di Galileo Galilei 1890-1910, vol. 10, p. 134).

[9]Seneca, Natural Questions, book 7, chapter 2, quoted by Galileo, Fragments of Lecture Notes (Opere di Galileo Galilei 1890-1910, vol. 2, p. 283).

very great distances away from the Earth. Since it had remained for a long time in the same position with respect to the fixed stars, its motion away must be nearly along a straight line through the Earth. On that basis, the question of the Earth's motion around the Sun might be settled once and for all.[10] Except in the very unlikely event that the Earth was fixed somewhere in the exact line of motion of the star, a parallactic displacement was bound to be detected. Then, since it started from a distance at least as great as Mars, its apparent position among the fixed stars would necessarily have changed. If the Earth revolved around the Sun, and was not stationary at some point outside the line of the star's motion, a different parallactic shift would occur. Unfortunately, when Galileo observed the new star after Christmas it had showed no parallax even as late as May, six months after its appearance, namely along a line of observation that was as wide as the diameter of the Earth's orbit! The 1604 star became invisible to the naked eye early in 1606. Hence it reached a condition of one-half of its original magnitude in May 1605, but without the expected displacement. Something was wrong, and Galileo was driven to silence on this score.

7. The Dialogue of Cecco di Ronchitti

Galileo may not have felt confident enough to speak of the new star's possible contribution to the Copernican debate, but he was in no mood to tolerate silliness about its nature. In January 1605, Antonio Lorenzini, an otherwise unknown writer, published a slim volume entitled *Discourse about the New Star* in which he declared that there could be no new stars in the heavens. Completely ignorant of elementary geometry, Lorenzini rehearsed the most outrageous of Peripatetic argument. For instance, he declared that if a single star were added to the heavens, they would cease to revolve because philosophers have proved that the force carrying the stars around is exactly right to move them uniformly. Galileo jested about this work with his friends and students, and one of them, the young Benedictine Girolamo Spinelli, may have suggested that it would be amusing to refute Lorenzini not in Latin, nor in the literary form of modern Italian, but in the Paduan dialect. This dialect enjoyed a special vogue among the Paduan and Venetian literati because of the writings of a Paduan named Angelo Beolco, who published under the pen name of "Ruzante", which means "the romper". Within a month, Galileo and Spinelli had written a dialogue between two peasants, who discuss the views of Lorenzini and show them to have been inane. It is a witty piece of writing and a fitting rebuttal of natural philosophers who studied Aristotle but had little time to look up at the heavens.

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[10]Galileo's argument is developed in Drake (1978, p. 28) See the excellent articles of Giostra (2003a,b).

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