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GALILEO'S OBSERVATIONS OF NEPTUNE   By Mike Frost

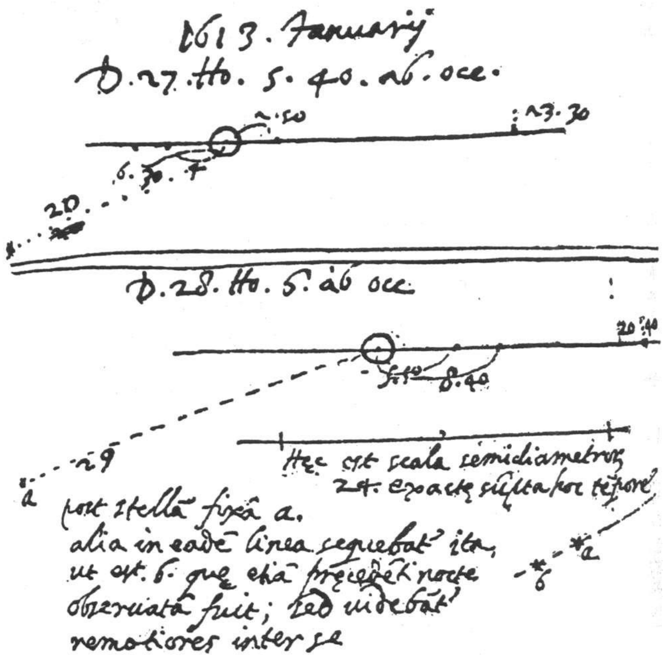

Figure 1

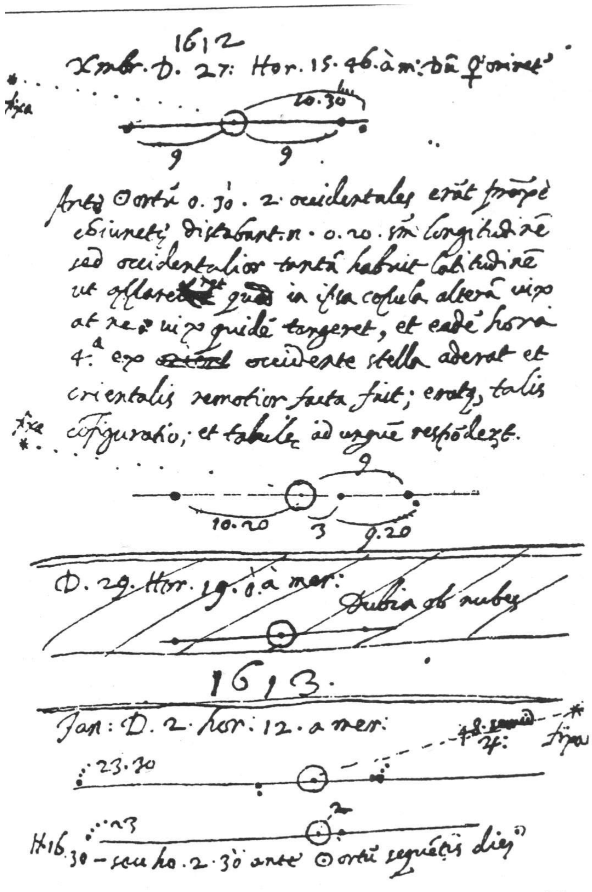

Figure 2

*Was Galileo Galilei the first person to point a telescope towards Jupiter at the end of 1609? He wasn't the first to acquire this newly invented device and not the first to look upwards to the stars. But he was the first person to make regular notes of his observations of what he saw in the heavens. **Figure 1,** is from December 1612 and shows a page from Galileo's notebook. The top diagram is for Dec 27th 1612; the bottom three diagrams for Dec 28th, Dec 29th and Jan 2nd 1613. Three satellites are shown, one to the left of Jupiter, two to the right with a reference star to the left of Jupiter, at around "10 o'clock", connected to Jupiter by a dotted line. The reference 'star' is Neptune!*

***Figure 2,** thirty-one days later, on January 28th 1613, Galileo once again noted Neptune as a fixed star. The top half of the diagram shows Galileo's observations on Jan 27th; the reference star, at 7 o'clock, is identified as SAO119234; in the bottom half, star 'a' is once again SAO119234, and then on the right hand side Galileo extends the line from Jupiter to 'a' on to star 'b', which is Neptune.*

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For this years holiday, my wife and I had a tour of the American West coast. This was our first visit to the USA and we spent two weeks on a very memorial trip. One of the many highlights was a visit to the Grand Canyon and a stay at one of the Grand Canyon Village lodges in the park near the South Rim. We arrived in the early afternoon at a point called Yavapal Observation Station. The sun was shining and the views. . . if you have never seen the Canyon, *you must!!* After getting over the overwhelming view of this amazing sight we explored the area and on a notice board in the observation station was an invitation to come along to the Grand Canyon Star Party that night.

This has been an annual event now for over a decade, held this year from June 4th to 11th, so we had luckily arrived the right week. It is run by Tucson Amateur Astronomy Association volunteers, who set aside part of the Yavapal Observation Station car park for the telescopes. This is one of the USA's premier national parks with strict control of light pollution, so this was a must visit opportunity.

After settling in our room at the Maswik Lodge we caught a shuttle bus to Hopi Point a mile or two away with a couple off our trip to watch the sun set around 7.45pm over the Canyon and the silver strip of the Colorado River a mile down in the depths. While watching the sun set, I mentioned the Star Party and although the wives declined the men thought differently. After dinner Andrew and I left our wives and hopped on a shuttle bus to Yavapal a couple of miles away along the rim from our lodge.

The sky was quite dark, almost clear of cloud, with the last of the twilight disappearing over the North Rim 10 or 12 miles away. The amount of lighting in the park is minimal so while walking, care must be taken. The moon was only a couple of days old, I had seen it two nights earlier when it was only about 30 hours old as a very thin crescent at dusk, so it didn't cast much light and would set soon. The South Rim of the Grand Canyon at Yavapal is just over 7,200 feet above sea-level, (2,200 m) so fast walking and running quickly starts to make you pant!

When we arrived it was dark, a cool breeze blew and we walked a short distance from the bus stop to the first telescope setup, a 12" SCT pointing nearly straight up with a globular cluster, M13 in Hercules, shining on a B&W monitor. The picture wobbled a bit as a gust of wind moved the scope, but the one million stars of M13 filled the screen to bursting point.

It was hard to tell how many people were there, but there certainly lots of telescopes, a couple of dozen at least set up in a curve along the edge of the parking lot. Every now and then a car or bus swept the area with headlights and all the astronomers groaned as their night vision was lost. Most of the scopes were Meade or Celestron Schmidt-Cassegrain 8", 10", 12" and even a 16" (I think) with a few Dobsonians up to 20" or so.

As we worked our way down the curve, we got the chance to look at other globular clusters, a couple of galaxies and Jupiter and its moons. Andrew was not an amateur astronomer but he was interested in what he saw and each scope was manned by amateurs who know what they were looking at and could pass on information, mostly the public seems to want to know how far away it is and how long does it take for the light to get here. Astronomy is about distance.

Nearly all the bigger telescopes had a small step ladder, sometimes lit with LED's as was the bottoms of the tripods holding the scopes. Most folk find it hard to stand still and look down into an eyepiece without wobbling if they are not holding on to something, so most scopes had a small bar to stop people touching the telescope and nudging it off target.

Near the bottom of the parking lot we came to a very large SCT with a 2" eyepiece pointing to M51 the owner said. "The Whirlpool Galaxy." I told Andrew "Discovered by, er, a guy in Ireland." I finished lamely. Don't you hate it when your mind goes blank. It took me half an hour to think of Lord Ross at Burr Castle. We queued up for a look.

I bent over the eyepiece and was astonished. There floating in the field of view was a whirlpool of soft grey light, strings and knots of material filled the arms of the galaxy and near by was the small companion connected by a wisp of light which I know is made up of millions of stars. This for me was the highlight of the evening. I have never seen such detail and structure through a telescope before, it was awe-inspiring. The best view of the night. I was truly impressed with the view and told the lucky owner so.

By now it was getting late and I was supposed to be getting up at 4.45am to watch the sunrise. I did and it didn't, well it did behind cloud. So we caught the last shuttle back to the lodge and left the keen astronomers to the stars.

Ivor Clarke

A Visit to Palomar Observatory

By Chris Longthorn

The Palomar Observatory is one of the premier research observatories in the world and houses the Hale 200 inch telescope. It is situated in the Palomar Mountains just 2 hours drive north of San Diego in California. During a recent visit to San Diego for work, I got the opportunity to visit the observatory and this is the tale of that visit.

A brief history of the Observatory

In the mid 1920's, results from Mount Wilson Observatory's 100 inch telescope demonstrated the need for a larger instrument in order to realise advances in astronomical research.

In 1928 George Ellery Hale (who was also responsible for the 100 inch telescope at Mount Wilson Observatory) obtained a grant from the International Education Board (one of the Rockerfeller Foundations) for the construction of a 200 inch telescope. This grant was awarded to the California Institute of Technology - Caltech.

As is usual in these cases a suitable site would have to be found for the telescope and numerous sites were tested for the optimum atmospheric conditions required for astronomical observations. In 1934 Palomar Mountain was selected for the site of the new instrument.

Figure 1, the location of Palomar, north of San Diego

The manufacture of the 200 inch telescope mirror was awarded to Corning Glass Works of New York State. They had been experimenting with casting Pyrex blanks for large mirrors because at these sizes the quartz used previously was difficult to handle. The 200 inch Pyrex disk was successfully cast on December 2th 1934. It took 8 months to cool down.

The glass disk weighed 20 tons and it was shipped to Pasadena for the grinding and polishing needed to transform it into the precise shape for astronomical observations.

Construction of the observatory began in the mid-1930s and was nearly complete when the US entered World War II in 1941. The dome for the observatory weighs nearly 1000 tons and the moving parts of the telescope structure weigh 530 tons.

The war delayed the polishing of the mirror. Eventually on November 18th 1947 the completed mirror (now weighing 14.5 tons) started its two day journey to Palomar Mountain where it was installed and tested. Finally on June 3rd 1948 the instrument was dedicated to the memory of George Ellery Hale who had died before the telescope was completed in 1938.

Palomar Observatory Today

Today the Hale Telescope and other telescopes at the observatory are still in the forefront of astronomical research in the world. The 200 inch Hale Telescope has been used on virtually every clear night. Its use ranges from studies of asteroids and comets within our own solar, stars within our own galaxy right up to the many galaxies beyond our own and finally to quasars. Today this telescope is equipped with sensitive electronic detectors and high-speed computers.

Getting There

Actually this was remarkably easy. The observatory is 5,500 feet high in the Palomar Mountain State Park, which is less than 2 hours drive from San Diego. I have been working with a shipyard in San Diego for about 3 years now, and for once I was able to stop over for the weekend as we had additional meetings on the Monday (23rd May 2005).

So I set off with a colleague for the journey on Sunday 22nd May at 8:00 a.m. We headed north out of San Diego on I15 and took a right turn at Escondido onto the S6. This started a windy climb up the mountain, passing many mad cyclists on the way and being passed ourselves by many large motorcycles.

We arrived at the observatory shortly after 9:30 a.m. The sky was crystal clear and the views around the surrounding mountains were spectacular.

Figure 2, the sign outside the museum

A short walk up the path was needed to get the first view of the observatory and it is BIG (unfortunately much too big for my backyard), in the shot below the dome is pointing North.

Figure 3, first view of the Observatory

The size of the building became more apparent as we got closer and approached the entrance foyer. Inside there was a bust of George Ellery Hale and a dedication plaque. To the left were the stairs leading up to the viewing gallery for the 200 inch telescope.

Figure 4, Really Big!!

Figure 5, entrance hall with bust of Hale

At the top of the stairs you enter an exhibition gallery with a view of the huge telescope towering above you. The gallery has several exhibits including a history of the observatory and telescope and some recent observation results.

The telescope itself was just too big to get into one photograph and unfortunately the glass covered gallery made taking photographs quite difficult due to reflections. Flash photography was a waste of time because there was just too much reflection from the glass so I resorted to shots without the flash and processed them to give a better view when I got home.

There now follows a series of photographs to try and convey the size and aspect of the 200 inch telescope.

Figure 6, the 200 inch mirror end of the telescope

Figure 6 above, shows the main mirror end of the telescope, and the photograph shows an array of electrical equipment attached to the telescope here.

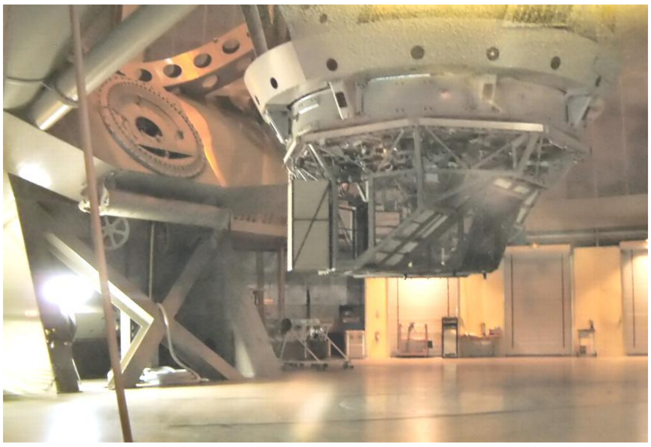

Figure 7, the lower RA bearing

This view shows the lower bearing of the horseshoe mounting off to the left or south end. In this shot it is possible to see that there was room for a tall man to walk underneath this end of the instrument.

Figure 8, the horseshoe mounting looking north

Figure 8 below, this is looking at the upper or North end of the horseshoe mounting, this structure is very impressive.

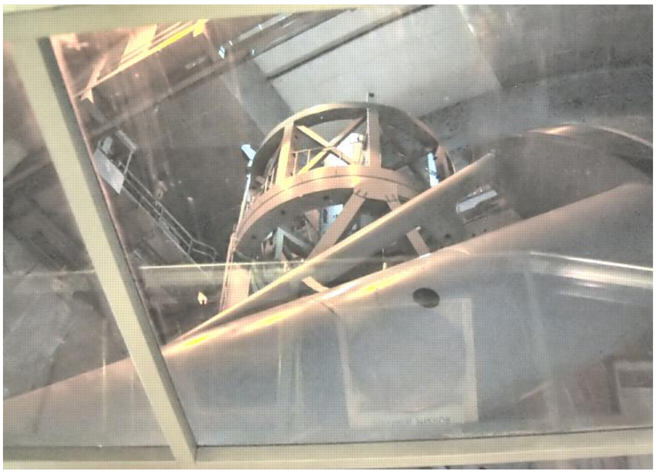

Figure 9, the top (secondary mirror) of the telescope

Here, you can see the top of the telescope where the secondary mirror is housed. It is also possible for an observer to sit here and observe at the prime focus of the telescope.

Figure 10, concrete replica of the 200 inch mirror

To test the mechanisms of the telescope before the mirror was ready a concrete replica was used and this is still in the grounds behind the main observatory building where it was placed after the testing was completed.

The observatory is open daily (except December 24th and 25th) from 9:00 a.m. to 4:00 p.m. Visitors may tour the gift shop and view the 200 inch Hale telescope from the special gallery in the dome.

Sources / Further Reading

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Palomar Observatory, California Institute of Technology self guide leaflet available from the observatory museum gift shop.

This article is based on my third essay for my course, on *"Great Astronomers in History"* run by the University of Central Lancashire. The two previous submissions have already appeared in Mira: a book review of *"Gods in The Sky"* by Allan Chapman, and my role-play letter from Jeremiah Horrocks to John Worthington. The full title of my third essay was *"Discuss the role of theory and observation in the discovery, with particular reference to the discovery of Uranus and Neptune".* The essay was rather technical, so I won't bore you with it, but in the course of researching it I came across some fascinating stories, which I'd like to share with you.

This particular article is based on a short paper published in Nature in 1980, which I asked Rugby library to obtain a copy of. The title of the paper was *"Galileo's Observations of Neptune"*, but when the paper arrived I was amused to see that the librarians had altered the title of my request to *"Galileo's Observations of Nature".* Clearly, someone thought that I had made a mistake when I made the reservation. Galileo couldn't possibly have observed Neptune, could he?! After all, he had been dead for over two centuries by the time the planet was discovered.

Well, I did get the title of the paper correct. Galileo did observe Neptune, in fact he observed it at least three times. He even saw it move night by night. So, please don't adjust your sets; let me tell you about

Galileo's Observations of Neptune

By Mike Frost

Officially, the planet Neptune was discovered in September 1846, by Johann Galle and Heinrich D'Arrest, observing from the Berlin Observatory in Germany. Galle and D'Arrest were following the predictions made by the French mathematician Urbain Leverrier and were able to locate the new planet within an hour's observing. Unknown to Leverrier, the British mathematician John Couch Adams had produced similar (but probably not as accurate) predictions and the planet might have been discovered from England by James Challis had circumstances worked out differently.

Recent discoveries have shed some fascinating light on this story, which I hope to bring to you in another Mira article.

Both Leverrier and Adams based their calculations on puzzling anomalies in the motion of Uranus, which had been discovered sixty-five years earlier in 1781 by William Herschel. Although many theories were proposed to explain these anomalies it became clear that the most likely cause was the gravitational pull of a hitherto unknown planet.

Leverrier and Adams were able to deduce approximate orbits for such a planet, and Leverrier's predictions were good enough to allow the planet to be found.

One of the problems that the two mathematicians faced was an incomplete set of data. Uranus had been observed carefully for 65 years, but this was rather less than one complete orbit (84 years) of Uranus around the Sun.

Neptune takes even longer to orbit the Sun - one hundred and sixty four years, so that it is only now about to complete its first orbit since being discovered. To see if there are any anomalies in Neptune's orbit, it would be useful to have more than one orbit's worth of data.

In 1980, Charles Kowal and Stillmann Drake had the bright idea of tracing Neptune's orbit backwards, to see if there were any times prior to 1846 when Neptune was in the vicinity of brighter objects - if it was, the planet might accidentally have been recorded as a background star. They found that Neptune had on two occasions come very close - perhaps even been occulted by - the planet Jupiter. Intriguingly, one of these occultations occurred on January 3rd 1613, during the time of Galileo was observing the planet.

Galileo Galilei first acquired a telescope at the end of 1609. Other people had already pointed this newly invented device upwards to the heavens, but Galileo was the first person to carry out a systematic investigation of what could be seen in the skies, making regular notes and sketches of his observations. Kowal and Drake searched through Galileo's notebooks, checking the position of each of the stars he noted down. Although Galileo was primarily interested in sketching the positions of Jupiter's moons, he occasionally noted down a background star for reference purposes.

Fortunately, Jupiter and Neptune were in a relatively barren part of the sky, in Virgo. And it turns out that on December 28th 1612, Galileo noted down a background star, which is not recorded in any modern-day atlas. Figure 1 (see cover) shows the relevant page from Galileo's notebook. The top diagram is for Dec 27th 1612; the bottom three diagrams for Dec 28th, Dec 29th and Jan 2nd 1613. The time on the top diagram is given as 15:46, but Galileo started his days from noon, so that in fact it is 3:46 a.m. Three satellites are shown, one to the left of Jupiter, two to the right. And a reference star to the left of Jupiter, at around "10 o'clock", connected to Jupiter by a dotted line. The reference "star" is Neptune - the very first published observation of the planet, 232 years and 8 months before it was recognised as a planet.

Thirty-one days later, on January 28th 1613, Galileo once again noted Neptune as a fixed star. Figure 2 (cover) shows this observation. The top half of the diagram shows Galileo's observations on Jan 27th; the reference star, at 7 o'clock, is identified as SAO119234; in the bottom half, star 'a' is once again SAO119234, and then on the right hand side Galileo extends the line from Jupiter to 'a' on to star 'b', which corresponds to Neptune.

It is rewarding to consider just exactly why Galileo didn't add the discovery of a completely new planet to the impressive list of discoveries that he did publish. There are several reasons.

First, Galileo's telescope, the first ever used to observe the night skies diligently, was very basic, and completely incapable of showing Neptune's disc. To Galileo, the planet would have looked just like a faint background star. The only clue that Neptune could have given Galileo was its motion. Jupiter orbits the Sun every twelve years, corresponding to an average movement of 4 minutes of arc per day. Galileo's field of view was 15', so that in usual circumstances Jupiter would move out of any given field of stars within four nights (Neptune, which takes over a century to orbit the Sun, moves by much less than a minute of arc per day relative to the stars). However, the occultation of 1613 occurred during the period where Jupiter was in retrograde motion, moving slowly across the sky, and so the two planets were in the same field of view throughout the period between Galileo's two observations.

Here's the really interesting bit. On the January 28th diagram, there's a note. Kowal and Drake translate it from the original Italian as "Beyond fixed star 'a' another followed in the same straight line, this is 'b' [Neptune] which was also observed on the preceding night, but they [then] seemed further apart from one another". So, Galileo actually spotted the motion of Neptune!

Why didn't he follow up this observation? Well, we don't know, but it's quite possible that Galileo did not even consider looking for stars that moved. Why should he? No such stars were known, and the available star maps (pre-telescopic, of course) seemed to show that the stars were in fixed positions in the sky. Galileo had riches enough to discover - lunar craters and seas, satellites of Jupiter, phases of Venus. True, Galileo had discovered the "stars" which moved around Jupiter, but these could easily be interpreted as satellites of the planets similar to our own Moon. In Galileo's experience, moons moved, stars didn't.

We can summarise Galileo's (perfectly understandable) failure to discover that Neptune was not a planet - telescope not good enough, sky maps not good enough, no inclination to search for moving stars. But let us indulge in a flight of fancy.

Suppose, by some stretch of the imagination, that Galileo had recognised the motion of Neptune. What might have been the consequence of this?

These are my guesses. First, once Jupiter had departed, Neptune would have been lost. Galileo could not possibly have followed Neptune through the sky for more than a few nights, and certainly not beyond the first spell of cloudy weather.

Second, any succeeding attempts by Galileo to find other moving stars would surely have failed. There are only a few moving objects in the sky - Uranus, Neptune, a few asteroids, the occasional comet - that were unknown to Galileo but could have been observed by him. The odds were already spectacularly against him having seen Neptune - fortune was unlikely to have favoured him again.

However, if Galileo had had the courage to announce his discovery, I believe that the subsequent history of astronomy would have read very differently. Certainly, Johannes Kepler would have been fascinated. Kepler was surely the one man alive at that time who could have used Galileo's observations to make a worthwhile prediction of what the mysterious object might be. The object was clearly in the ecliptic, and moving along the ecliptic, and therefore might well be a part of the solar retinue in the same way as the known planets. From the apparent speed of Neptune's motion through the sky, and the application of his third law, Kepler could have estimated the object's distance from the Sun to, say, within a factor of two. Certainly he would have deduced that, as the object moved more slowly than Saturn, it was probably further away from the Sun than any known planet.

It's my belief that the tantalising discovery of a faint object moving in the ecliptic would have radically changed the emphasis of astronomy during the seventeenth century; from positional star-mapping, to a comparative, repeated-mapping approach. Astronomers would not have been content to chart the positions of stars once only and then move on.

I suspect that the approach, pioneered by William Herschel, of repeatedly studying the same portion of sky would have been adopted by many of the leading astronomers of the late seventeenth century, and that this would have led to the recovery of Neptune and the discovery of Uranus before the end of that century.

It's my guess that at least one of these would have been made by John Flamsteed, who made the earliest known pre-discovery observation of Uranus in 1690. Flamsteed possessed a good enough telescope, and the capability and tenacity to map the skies accurately. His telescope was still not good enough to show a disc for either Uranus or Neptune (although he might have conceivably have been able to detect a lack of twinkling).

Of course, in reality, Flamsteed had no inkling that such objects existed. If Flamsteed hadn't spotted the motion of Uranus, perhaps Pierre Charles Le Monnier, who observed Uranus on 12 separate occasions around 1760, might have done so if he had been alert to such motion.

Which brings us to William Herschel. Herschel too had no idea that there were new planets to discover. Indeed, he initially thought that he had discovered, not a new planet, but a comet. But at least he was on the lookout for moving objects. The important factors in Herschel's discovery were twofold. First of all, and probably primarily, he possessed better quality optics than anybody else up to that point, and could discern that his new discovery was certainly not a point-like object. Second, he had the tenacity to make repeated observations and discern night-by-night motion. Both these factors indicate that Herschel's discovery of Uranus was because of observational excellence rather than blind luck or a theoretical breakthrough.

Herschel himself was in no doubt as to how he discovered a new planet. "It has generally been supposed that it was a lucky accident which brought the new star to my view; this is an evident mistake. In the regular manner I examined every star of the heavens, not only of that magnitude but many far inferior, it was that night its turn to be discovered. I had gradually perused the great Volume of the Author of Nature and was now come to the page which contained the seventh Planet. Had business prevented me that evening, I must have found it the next, and the goodness of my telescope was such that I perceived its visible planetary disc as soon as I looked at it. . ."

There's a lesson to be learned here. Discovering a new planet doesn't just involve pointing a telescope in the right direction. It helps if the observer has superb equipment, an ambitious observing program, and the tenacity to keep observing. But above all they need the presence of mind to appreciate and publicise their discovery.

Intriguingly, when Neptune was finally discovered in 1846, the British astronomer James Challis, who had failed to make the discovery, tried to claim that, as he had pointed the telescope at the right portion of the sky, in response to John Couch Adams' predictions, he deserved at least part of the credit for the discovery of the Neptune, even though he hadn't actually spotted the planet.

But that's another story. . .

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