Air and Space this Week

Item of the Week

Giuseppe Piazzi and the Discovery of Ceres

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Last Week's Item was about Clyde Tombaugh, the discovery of Pluto, and how amazing in must have been to have discovered a new, significant, body in the Solar System. But there is a second, earlier, part of the whole "swim into one's ken" story. It began on the very first night of the 19th Century, near Palermo, Sicily.

HISTORICAL SETTING

The True Size of the Solar System

Telescopic astronomy had made great advances in the 1600s and 1700s. The heliocentric model of the Solar System was fully accepted almost everywhere. Astronomers had used a variety of trigonometric methods to determine the spacing of the planets, and the overall size of the known Solar System. The key problem remaining arose because those methods gave the size of the orbits of the Sun's other planets ***in terms of the size of the Earth's orbit only***, but not in terms of common linear units, such as miles or kilometers.

Astronomers did know of more refined methods that would reveal the actual scale of the Solar System, but the measurements were difficult to make with the necessary precision. The first attempts were by measuring the parallax of Mars from different locations, but they failed due to Mars' distance from the Earth, even at opposition. But Venus was closer.

Edmund Halley, of comet fame, described another method, this one using Venus, which is larger than Mars and gets closer to the Earth, especially at inferior conjunction. The most extreme case of inferior conjunction was when Venus was directly between the Sun and Earth, and could be seen in silhouette against the face of the Sun; a situation called a "transit." Halley then suggested that expeditions be sent out to observe the upcoming Venus transits on June 6, 1761 and June 3, 1769. [Perhaps you recall the most recent Venus transit, back in summer of 2012. I hope so, because it's the last one in our lifetimes!]

The key to finding the actual distance to Venus required simultaneous observations from points widely-separated on Earth. An attempt in 1761 to make the necessary observations was made by several groups, but the observers had some difficulties and the data were not good enough. [One of the teams doing so became rather well known afterward, for surveying, not astronomy; see the Didja Know? section of the website for the rest of the story.] Captain James Cook was

sent out to make Venus transit observations from Tahiti in 1769, from a location that is to this day still known as "Point Venus." He and his team were much more rigorous in their observational approach, but alas, the prevailing telescope technology of the day was simply not up to making the observations, no matter how well conducted, with the precision necessary for success.

The issue of the Solar System's actual size would continue to frustrate astronomers for the next few decades.

Bode's "Law"

Astronomers had worked out the separation between the Sun and planets, in terms of Earth's distance, by the start of the Eighteenth Century. By 1715, they began to try to find a mathematical expression for the spacing in orbit sizes, one of the first steps of a scientific inquiry. Several astronomers discussed the patterns they were finding though the mid-1700s in print. Johann Daniel Titius added his own bit when translating one of the earlier works, giving a mathematical description of the spacing. It was relatively unnoticed until Johann Elert Bode referenced it in a 1772 compendium on the topic. The formula for the spacing was strictly a mathematical description; there was no tie to the underlying physics. Because the compendium enjoyed broad distribution, the formula became generally known as "Bode's Law," but Titius' priority is often shown by referring to the formula as the "Titius-Bode Law." Here it is:

Start with a series progression: 0, 3, 6, 12, 24, 48, 96, 192, 384 and so on. Add four to each number in the series to produce: 4, 7, 10, 16, 28, 52, 100, 196, 388 and so on. Divide each number by 100 and you have the spacing of the planets in terms of the Sun-Earth distance (the "Astronomical Unit," here "AU").

Two things were readily apparent. The size of planetary orbits was described by the T-B relationship pretty accurately, but there was a gap between the T-B position between that for Mars and Jupiter, at 2.8 AU. The oddness of the gap in spacing was even noticed by Kepler years earlier, and became considered to be unacceptable by most of the astronomers of the time, some on theological grounds. Titius is quoted in the Bode compendium as saying about the gap, "…but so far no planet was sighted there. But should the Lord Architect have left that space empty? Not at all."

Photography lay decades in the future. Any search for the "missing" planet at 2.8 AU would have to rely on eyes, telescopes, and hand-drawn maps.

THE "CELESTIAL POLICE"

The feature on face of the Moon with the highest albedo is a crater named for Aristarchus. Near it lies a sinuous lava channel called Schröter's Valley, named for the German astronomer who is important in this story. Johannes Hieronymus Schröter had established an observatory

in the town of Lilienthal, and he was well-known for his detailed drawings of the lunar surface. He had able assistants, too; one of them was soon-to-be-famous Friedrich Wilhelm Bessel.

Drawing maps of lunar topography was not Schröter's only astronomical interest. The gap at 2.8 AM was calling to him. And he wasn't the only one. He hosted a group of like-minded astronomers from all over Europe at Lilienthal, who met for the purpose of coordinating a search for the "missing" planet. Their group, established on September 20, 1800, was informally named the "celestial police ("Himmels Polizei")," and their leader was Baron Franz Xavier von Zach. There would be a total of 24 "Policemen" over the course of the group's activities. The initial members split up the Zodiac and would look for the "missing" planet in their own section.

The Police faced three problems. The first was that any planet in the 2.8 AU slot had to be either very small, very dark, or both. If it were anywhere near as big and reflective as the other planets, it would have been discovered in antiquity. The second problem was the lack of star maps of sufficient detail to allow the look for newcomer or moving objects; in most cases, those searching would have to map their own star maps as the first step of their task. And the third was the slow pace of communications in those days, especially between countries.

One of those whose invitations to join the "Police" was "in the mail" was Giuseppe Piazzi, a Sicilian astronomer with an observatory near Palermo. He embarked on his own search of the Zodiac and starting mapping an area in Taurus in the necessary detail. On the night of January 1, 1801, the first full night of the 19th Century, he mapped a star-like object that, when observed on subsequent nights, had moved against the background stars.

Piazzi was excited, thinking he had discovered a distant, as-yet-tailless, comet. He carefully plotted the object's position over the next two weeks, before a combination of the object approaching the Sun in the sky and an illness forced Piazzi to stop observing. The last night in the sequence of his observations was **January 14**.

Planets, schmanets. Comets were big news in those days. The fear of dangerous celestial portents was still quite strong. Piazzi immediately reported his find to the regional media. His colleagues were slow to hear of his observations, and it was too late to confirm them.

However, Piazzi sent his two-week's worth of observations to famed mathematician, Karl Friedrich Gauss, who was able to work out an orbit from them well enough to predict when and where it would be seen again. Exactly one year later, astronomers recovered Piazzi's object right where Gauss predicted. Gauss' calculations showed that Piazzi's object had a mean distance from the Sun of 2.8 AU. Bingo! The missing planet was found!

The honor of naming this new planet fell to Piazzi. Retaining the Roman god/goddess naming scheme for the other planets, and recognizing that his native Sicily's patron goddess was Ceres, the goddess of the harvest, Piazzi recommended Ceres as the new planet's name. It stuck. BTW: Ceres also gives us our word for the word "cereal."

Piazzi proved to be a diligent observer of the skies. In addition to Ceres, he also measured the unusually-large "proper motion" of the star 61 Cygni and correctly identified it to the

astronomical community as an excellent candidate to have its parallax measured and distance determined. Astute advice it was; Bessel, once the genius assistant of Schröter, won the Royal Astronomical Society's Gold Medal in 1841 for doing just what Piazzi suggested (see also here)!

Ceres was so faint that it had to be much smaller than the other planets. Many considered the Solar System to now be "complete," but many wondered if there might be more than one "planet" in the 2.8 AU slot.

The Celestial Police, to be on the safe side, stayed active with their mapping/searching program. In March, 1802, just over a year after the discovery of Ceres was confirmed, Heinrich Olbers (of "Paradox" fame) found another small object at 2.8 AU that he named "Pallas." Now things were starting to get a bit weird. Ceres, like any respectable planet, orbited the Sun in the Plane of the Ecliptic, the Earth's orbital plane. But Pallas' orbit was inclined to the Ecliptic by over 34°, unlike any Solar System object known at that time. Nor was this the end of it. Karl Harding, one of Schroter's assistants, discovered another 2.8 AU body ("Juno") in 1804, and Olbers scored again in 1807 with the discovery of "Vesta," which actually was the brightest of any of the four. But all were much fainter, hence smaller, than the planets known for millennia.

The small size of the newly-discovered quartet suggested that astronomers had discovered a new class of objects for which a new term was necessary. The four became known as "minor planets" due to their small size. But Herschel (who would discover Uranus in 1781) used the dreadful term "asteroid," which came into general use, sad, because there is nothing "aster"(star)-like any of them. More on the nomenclature issue was last week, and will be revisited (briefly) later in this Item.

The discovery of Uranus, at a distance from the Sun of ~20 AU, close to the Bode prediction of 19.6. But the relation broke down with Neptune, which orbits the Sun at ~30 AU, rather than the Bode-predicted distance of 38.8 AU. The Titius-Bode "Law" is now considered an inconsequential relic.

However, computer modeling of planet spacing has shown us much about how the Solar System has evolved. The notion that the Solar System has always been exactly the way we see it today is not correct. In the decades following the discovery of Ceres, hundreds of other asteroids were found in a zone between Mars and Jupiter, spread over the 2.8 AU Bode gap. In 1866, astronomer Daniel Kirkwood noticed that there were gaps in the size of the orbits of those asteroids, and correctly surmised that Jupiter's gravity was the reason. The "Kirkwood Gaps" occur at orbit radii that produce an orbital period in whole-number resonance with Jupiter. A similar mechanism, resonance with Saturn's inner moon, Mimas, is responsible for the observed gaps in Saturn's ring system, and modeling resonances asteroid belt and in the Solar System in general has revealed much about how the Solar System has evolved over time.

CERES TODAY

The period from 1760 to 1810 must have been a very exciting time for astronomy and Solar System science! Uranus, Ceres, and three other asteroids were discovered, and it was proved

that “rocks can actually fall out of the sky,” with the meteor fall at L’Aigle, France (see more here).

The first two decades of the 21st Century were exciting times, too, especially went it came to understanding more about Ceres!

The decision by the International Astronomical Union in 2006 to define a new category of Solar System body, “dwarf planet,” resulted in the “demotion” of Pluto, IMHO a natural consequence of the process of scientific inquiry. But the same decision ended up “promoting” Ceres in status, from “asteroid” to “dwarf planet.” But regardless of category, Ceres, like Pluto, has proved to be a very interesting place!

The topics of Ceres as seen by the *DAWN* spacecraft and planetary migration over time are more than worthy of separate Item of the Week treatments and more, but those will be topics for another time.

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