

DOI 10.36074/logos-14.02.2025.047

PLUTO'S SATELLITE HYDRA

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Abstract: The "New Horizons" team suspected that Pluto and Charon might have other small moons and rings around them. Remote sensing data from the Hubble Space Telescope were used to test this hypothesis. In May 2005, this led to the discovery of the Nix and Hydra satellites. It is believed that all of Pluto's smaller moons were formed from debris ejected from a powerful collision between Pluto and another Kuiper Belt object. The debris from this collision eventually coalesced into Pluto and all of its moons. Due to tidal interactions, Hydra's orbit around the Pluto-Charon barycenter gradually became more circular over time. Images from the "New Horizons" spacecraft in July 2015 with detailed images of the satellite Hydra, for the first time allowed us to determine the dimensions of this satellite quite accurately: 50.9 km × 36.1 km × 30.9 km. Hydra turned out to be the second largest satellite of Pluto. In terms of distance, Hydra is the fifth and most distant satellite of Pluto with a semi-major axis of its orbit of 64738 km. Its mass is $(3.01 \pm 0.30) \times 10^{16}$ kg, with an average density of 1.220 ± 0.150 g/cm³. The synodic period of rotation around the axis is 10.37^h. The average temperature of its surface is close to 23 K. In general, the surface of Hydra turned out to be very bright with a high degree of reflection, although with significant variations in brightness. On average, it reflects almost 83% of the sunlight falling on it. This means that Hydra's surface should be covered with water ice. Like other small satellites of Pluto, Hydra's surface has a neutral spectrum. And the water ice on the surface of Hydra is quite clean and therefore does not show significant darkening. One explanation for this state is that Hydra's surface is frequently updated by micrometeorite impacts, which eject lighter material from beneath the surface of the satellite. According to crater counting data from observations by the "New Horizons" space probe, the age of Hydra's surface is estimated at about four billion years. Studies of Hydra show that it rotates chaotically. Its rotation period and axial tilt vary to the point that its axis of rotation regularly flips. The chaotic nature of Hydra's motion is largely due to the different gravitational influences of Pluto and Charon. The chaotic nature of the satellite's motion is also enhanced by its rather irregular shape. During the "New Horizons" flyby of Pluto and its moons, Hydra had a rotation period of about 10 hours; its axis of rotation was tilted nearly 110 degrees to the plane of its orbit. Like all Pluto's moons, Hydra's orbit is nearly circular and coplanar with Charon's orbit. Hydra is in a 2:3 orbital resonance with Nix, a 6:11 resonance with Styx, and a 1:6 resonance with Charon. These resonances are maintained by periodic local fluctuations in the Pluto-Charon gravitational field strength of about 5%.

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The "New Horizons" team suspected that, like the giant planets [10-13, 16-18, 28], Pluto [23] and Charon might be accompanied by small moons [2] and rings [27] associated with the Pluto system [25]. To test this hypothesis, they used remote sensing data [1, 5] from the Hubble Space Telescope. This led to the discovery of the moons Nix and Hydra [21]. Both of them were found to be quite close to Pluto and Charon. The images used for their discovery were obtained on 15 and 18 May 2005. The moons Hydra and Nix (Fig. 1, left) were discovered independently by M. Mutchler and E. Steffl. The discovery of these objects was announced on October 31, 2005, after confirmation of this fact by previous archival images of Pluto obtained with the Hubble Space Telescope in 2002. The newly discovered moons were provisionally designated S/2005 P 1 for Hydra and S/2005 P 2 for Nix. The name Hydra was approved on June 21, 2006, by the International Astronomical Union (IAU) and was announced along with the name Nix.

Hydra was named after the Lernaean Hydra, a nine-headed serpent that fought Hercules in Greek mythology. In particular, Hydra's nine heads subtly hint at Pluto's former status as the ninth planet. In addition, the names of these two moons were chosen so that their first letters, "N" and "H", commemorate the "New Horizons" space mission to Pluto. The name Hydra was also chosen so that its first letter, "H," would honor the Hubble Space Telescope, which was used to find this moon of Pluto.



Fig. 1. **Left – Pluto and its satellites, Nix, Hydra, and Charon** ([https://en.wikipedia.org/wiki/File:Pluto_and_its_satellites_\(2005\).jpg](https://en.wikipedia.org/wiki/File:Pluto_and_its_satellites_(2005).jpg)). **Right – Taken on 14.07.2015 by “New Horizons” near true-color image of Hydra** (https://commons.wikimedia.org/wiki/File:Hydra_reprocessed.png).

The names of the features on the surface of bodies in the dwarf planet system [14, 15] Pluto [19, 22] are supposed to be related to mythology, literature, and the history of exploration of this dwarf planet. In particular, the names of the features on the surface of Hydra are supposed to be related to the legendary snakes and dragons in literary sources, mythology, and history. It is believed that all of Pluto's smaller moons, including Hydra, were formed from debris ejected as a result of a powerful collision [20, 28] between Pluto and another Kuiper belt object [7]. The ejecta from such a collision eventually merged into Pluto and all of its moons. It has even been thought that Hydra originally formed closer to Pluto, and its orbit underwent changes due to its tidal interactions [8]. In this case, Hydra, along with Pluto's smaller moons, would have migrated outward with Charon to their current orbits around the Pluto-Charon barycenter. Due to "tidal damping" by mutual tidal interactions with Charon, Hydra's orbit around the Pluto-Charon barycenter gradually became more circular over time.

Images obtained in July 2015 from the "New Horizons" spacecraft with detailed images of Hydra (Fig. 1, right) for the first time allowed us to determine the size of this moon with a fairly high degree of accuracy: $50.9 \text{ km} \times 36.1 \text{ km} \times 30.9 \text{ km}$ [9]. Hydra turned out to be the second largest moon of Pluto. In terms of distance, Hydra is the fifth and most distant moon of Pluto, with a semi-major axis of its orbit of 64,738 km [6]. Its mass is $(3.01 \pm 0.30) \times 10^{16} \text{ kg}$, with an average density of $1.220 \pm 0.150 \text{ g/cm}^3$. The synodic rotation period is 10.31^{h} . The average surface temperature is close to 23 K. In general, the surface of Hydra turned out to be very bright with a high degree of reflectivity, although with significant variations in brightness. On average, it reflects almost 83% of the sunlight falling on it. This means that the surface of Hydra should be covered with water ice. The surface of Hydra, like other small satellites of Pluto, has a neutral spectrum. And the water ice on the surface of the satellite Hydra is quite clean and therefore does not show significant darkening, compared to the satellite Charon (Fig. 2). One explanation for this state is that the surface of Hydra is more often updated by micrometeorite impacts, which eject lighter material from under the satellite's surface. Hydra's surface composition, reflectivity, and other basic physical properties were measured during the close flyby of the "New Horizons" space probe through the Pluto system on July 15, 2015. A detailed image of Hydra, taken from a distance of 640,000 km, revealed changes in brightness on its surface and a rather dark circular formation with a diameter of about 10 km.

The spectrum of Hydra appears slightly bluer because Hydra has a higher concentration of water ice on its surface. This fact also explains its relatively high geometric albedo.

According to crater counts from the "New Horizons" spacecraft, Hydra's surface is estimated to be about four billion years old [30]. The large craters and



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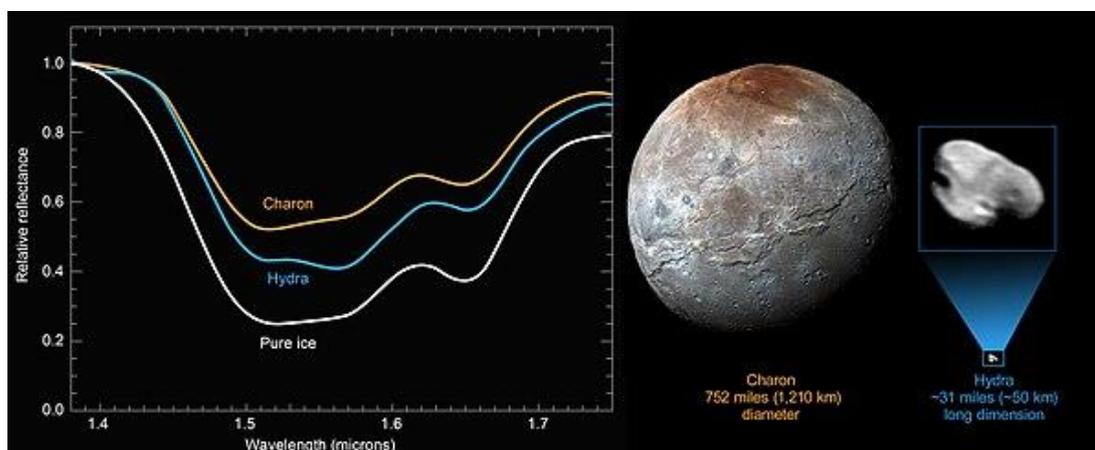


Fig. 2. **Spectra comparison of Charon and Hydra. Hydra's spectrum closely matches that of pure water ice, which is shown for comparison (https://photojournal.jpl.nasa.gov/jpegMod/PIA20581_modest.jpg).**

depressions on Hydra's surface indicate that it may have lost some of its original mass through impacts since its formation [30].

Studies of Hydra have shown that its surface is not tidally locked and rotates erratically; its period and axial tilt vary rapidly on astronomical timescales, to the point that its axis of rotation regularly flips. The erratic motion of Hydra is largely due to the varying gravitational effects of Pluto and Charon, which orbit their barycenter. The chaotic motion of the satellite is also enhanced by its rather irregular shape, which creates significant rotational moments [3, 24]. During the flyby of Pluto and its moons by the "New Horizons" spacecraft, Hydra's rotation period was about 10 hours; its axis of rotation was tilted by almost 110 degrees to the plane of the orbit [30].

Compared to the rest of Pluto's moons, Hydra rotates quite quickly. After all, the rotation period of other moons exceeds one Earth day. Such a rapid rotation of Hydra is typical for the rotation periods of most objects in the Kuiper belt. Like all Pluto's moons, Hydra's orbit is nearly circular and coplanar with the orbit of Charon [6]. Because of such circular orbits, it is assumed that Pluto's moons should have undergone tidal evolution since their formation [4, 8].

Hydra has an orbital period of approximately 38.2 Earth days and is in resonance with other moons of Pluto. Thus, the satellite Hydra is in a 2:3 orbital resonance with the satellite Nix and in a 6:11 resonance with the satellite Styx [3]. And with Charon, the orbit of Hydra is close to an orbital resonance of 1:6. It is believed that such resonances arose at the beginning of Charon's migration immediately after the formation of all five known satellites of Pluto; and these

resonances are supported by periodic local fluctuations in the Pluto-Charon gravitational field strength by approximately 5% [29].

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