MEET PLUTO AND CHARON ... AND NIX ANDHYDRA!

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In July 2015, eighty-five years after the discovery of Pluto, NASA's New Horizons spacecraft flew through the Pluto system and sent back the first high-resolution pictures of the planet and its five moons. The stunning images and spectroscopic data revealed that Pluto and its large moon Charon have diverse geological terrains and surface compositions. Pluto's atmosphere also held surprises: hazes more extensive than expected were illuminated by sunlight during departing observations (Fig. 1D). Thus far, only a tiny fraction of the New Horizons data has been returned thus far, but our understanding of the Pluto system is already being revolutionized.

New Horizons' encounter with Pluto and its moons began in January 2015, with the closest approach to Pluto occurring at 11:50 UTC on July 14. New Horizons dove through the Pluto system well inside the orbit of Charon. New Horizons is equipped with a visible imager, a four-color imager (blue at 400–550 nm, red at 540–700 nm, near-infrared at 780–975 nm, and a narrow methane absorption band at 860–910 nm); a high spectral resolution camera (1.25–2.5 µm range), an ultraviolet instrument for atmospheric airglow and occultation observations; a radio science experiment for more atmospheric studies; and instruments for detecting energetic particles, plasma, and dust (Stern 2008 and references therein).

Before New Horizons arrived at Pluto, the best images of the planet had been taken by the Hubble Space Telescope and were only 11 pixels across. These images had been combined to produce the best maps of Pluto, which revealed a surface of featured highly contrasting dark and bright splotches (Buie et al. 2010). New Horizons imaged all of the illuminated parts of Pluto and Charon in the weeks and months before closest approach. And, as it sped past, even better resolution was achieved for one hemisphere than for the other (shown in Figs. 1 and 2). The highest resolution images (~80 m per pixel {px^{-1}} for Pluto; ~160 m px^{-1} for Charon) were taken over a narrow strip and have not yet arrived back on Earth, but images already a thousand times better than those from the amazing Hubble have come back—at 400 m px^{-1}. New Horizons data has shed light on a number of unknowns but also raised some new, and very interesting, questions.

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PLUTO

The brightest spot (~1,187 km in radius) seen in the Hubble maps of Pluto turned out to be an expanse of nearly-flat ice the size of Texas (USA) (Fig. 1A) without any obvious craters visible at the available image resolution (Figs. 1B, 1C). This terrain displays polygonal subareas, often bounded by dark material or shallow troughs, and also shows signs of material flow. Water ice (H_2O) would be completely rigid and stiff at Pluto's surface temperatures (~35 K), but N_2 ice could exhibit glacier-like flow. Indeed, spectroscopic measurements from New Horizons detected carbon monoxide (CO), methane (CH_4), and molecular nitrogen (N_2) in the region, all of which are volatile ices at Pluto's temperatures. From its density, we know H_2O makes up about one-third of Pluto, but this water-ice bedrock is overlain by at least a veneer of more volatile ices. New Horizons also discovered the more complex hydrocarbons of ethylene and acetylene in Pluto's atmosphere. As these, and other heavy hydrocarbons, settle to cooler parts of the atmosphere they condense into the icy haze seen in Figure 1D.

Pluto also has cratered terrains and terrains of intermediate and dark albedos. However, much of the surface seems to have been modified because we see few fresh-looking craters. It was predicted that surface modification could occur through atmospheric interaction over Pluto's complex seasonal cycles and, potentially, through relatively recent

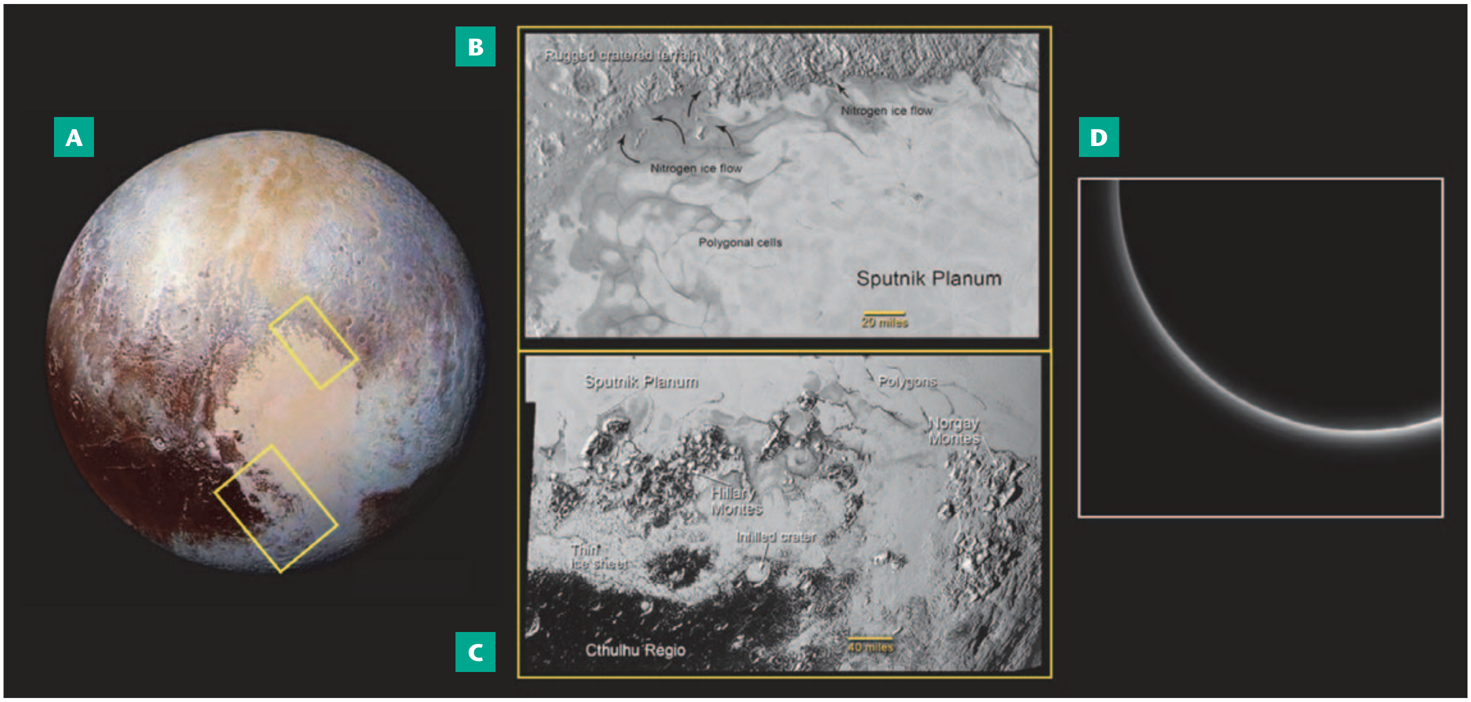

Figure 1 (**A**) Base map of Pluto at 2.2 km per pixel (px^{-1}) resolution, color-enhanced, showing the compositional diversity of Pluto's surface. (**B**) Close-up of the upper rectangular inset from 1A showing the contact of the bright, smooth region informally known as Sputnik Planum, with degraded cratered terrains to the north (400 m px^{-1}). (**C**) Close-up of the lower rectangular inset from 1A showing the two sets of mountain ranges found near the southwestern edge of Sputnik Planum (400 m px^{-1}). (**D**) Pluto's hazes backlit by the sun in a departing image (1.8 km px^{-1}). These hazes extend up to 80 km above the surface, several times higher than predicted. Image Credits: NASA/JHUAPL/SWRI.

geologic activity (Moore et al. 2015, and references therein). We see hints of both surface modification agents with the current data. As more data is returned from New Horizons, we will have better constraints on the atmospheric structure, the escape rate of molecules into space, and the style and timing of geologic activity.

CHARON: PLUTO'S LARGEST MOON

At ~606 km in radius, Charon is Pluto's biggest moon. And as befits such a moon, it displays its own set of unique and varied terrains, including smooth expanses, a swath of subparallel cliffs stretching ~1,000 km, and various cratered landforms (Fig. 2). It has two unusually striking features: a dark polar region, and several sharp mountain peaks that appear to be jutting out of moats (Fig. 2 inset). Large-scale topography can be seen on the limb of Charon, with the most prominent feature being a deep canyon (upper right in Fig. 2 main image). The craters on Charon are more obvious than those on Pluto; nevertheless, the evidence of widespread tectonic activity and a number of younger-looking surfaces indicate that Charon has also seen a fair amount of internally driven geologic activity.

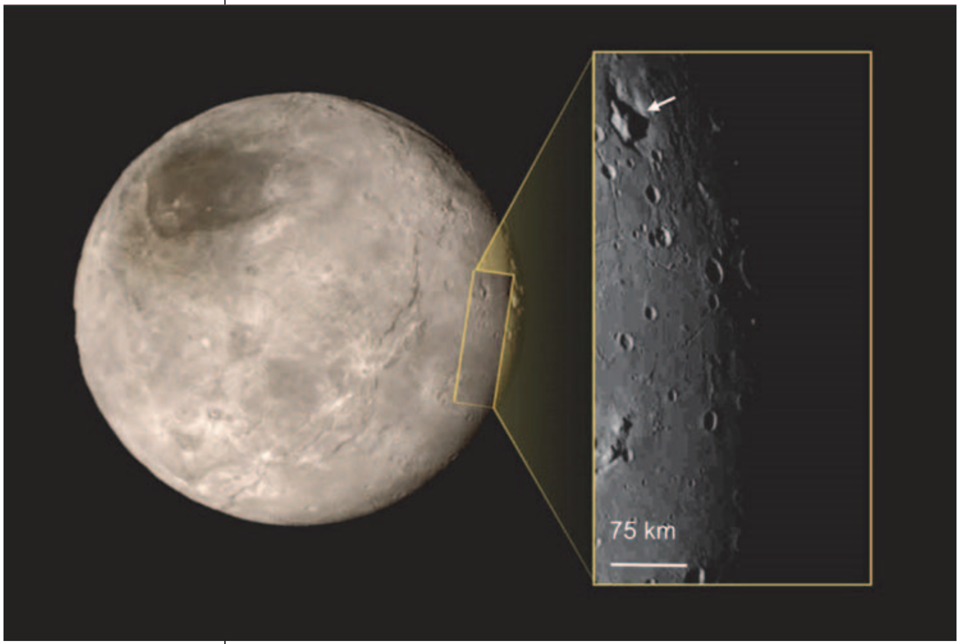

Figure 2 Charon (2.3 km px^{-1}) and higher resolution inset (~400 m px^{-1}) illustrating a smooth area with superimposed impact craters and an unusual mountain in a moat (white arrow). Image Credit: NASA/JHUAPL/SWRI.

NIX AND HYDRA: TWO OF PLUTO'S SMALL MOONS

In addition to the large round moon of Charon, Pluto also has four irregularly shaped moons: Nix, Hydra, Kerberos, and Styx. The larger two irregular moons are Nix and Hydra (~30–45 km in diameter) and were discovered from Hubble data in 2005 (Stern et al. 2006, Weaver et al. 2006, and references therein): this was shortly before New Horizons was launched in January 2006. The two smaller moons, Kerberos and Styx, were discovered in 2011 and 2012, respectively, from additional Hubble observations (Showalter et al. 2011, 2012). New Horizons imaged all four moons at variable resolutions, but only Nix and Hydra images have been returned to date (Fig. 3). These moons show their own interesting features, such as bright and dark surfaces and color splotches that might be associated with impact features.

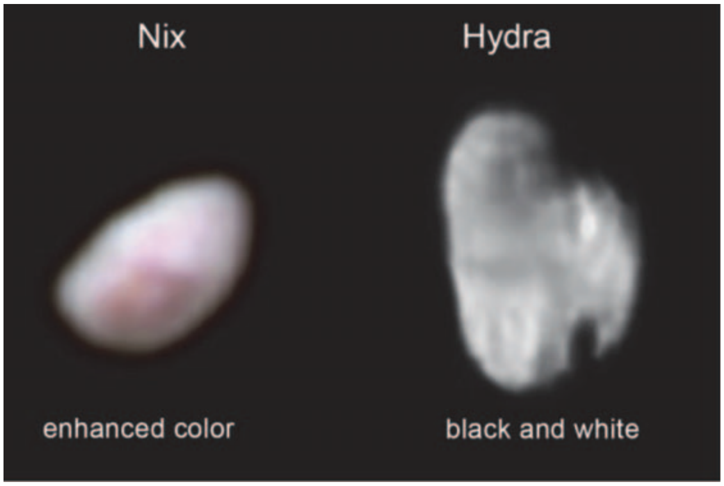

Figure 3 The small moons Nix (3.14 km px^{-1}) and Hydra (1.13 km px^{-1}) show compositional diversity and potential impact craters. This is the best image of Hydra, as taken by New Horizons. Nix images at ~300 m px^{-1} are still onboard the spacecraft waiting to be sent back. Image Credit: NASA/JHUAPL/SWRI.

SUMMARY

The unique features of Pluto and its five moons are expanding our knowledge of how the Solar System formed and how the Pluto system formed and evolved. The young-looking surfaces of Pluto and Charon are also forcing us to reconsider how mid-sized bodies retain or expend internal heat and so allow for geologic activity into relatively recent times. Stay tuned as New Horizons returns more data over the coming months. For all the latest news, videos, and updates from New Horizons, please visit www.nasa.gov/newhorizons and pluto.jhuapl.edu.

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