ASTROFAX

BULLETIN OF THE ATA ASTRONOMY STUDY UNIT
VOLUME 34, ISSUE 1
Spring 2026
WHOLE NUMBER 133
https://grmajor.wixsite.com/astrostudyunit

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Planetary Environments, Part 12: Neptune and Triton

by Garry Toth and Don Hillger (Un-manned Satellite Philately)

This is the twelfth article in the *Astrofax* series on planetary environments. The first eleven in the series appeared in the previous eleven issues of *Astrofax*:

1. *Planetary Environments, Part 1: Introduction* (Volume 31, Issue 2, Summer 2023)
2. *Planetary Environments, Part 2: The Moon* (Volume 31, Issue 3, Fall 2023)
3. *Planetary Environments, Part 3: Mercury* (Volume 31, Issue 4, Winter 2023)
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5. *Planetary Environments, Part 5: Mars, Part 1* (Volume 32, Issue 2, Summer 2024)
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7. *Planetary Environments, Part 7: Jupiter* (Volume 32, Issue 4, Winter 2024)
8. *Planetary Environments, Part 8: Jupiter's Galilean Moons* (Volume 33, Issue 1, Spring 2025)
9. *Planetary Environments, Part 9: Saturn* (Volume 33, Issue 2, Summer 2025)
10. *Planetary Environments, Part 10: Saturn's Principal Moons* (Volume 33, Issue 3, Fall 2025)

11. *Planetary Environments, Part 11: Uranus and its Principal Moons* (Volume 33, Issue 4, Winter 2025)

Introduction

This article discusses the eighth planet from the Sun, Neptune, and its moon Triton, which is far larger than all the other 15 Neptunian moons combined. The planet has some similarities with Uranus, which was treated in Part 11 of this series. Both are known as the solar system's "ice giants," whose atmospheres are distinct from those of the gas giants (Jupiter and Saturn) "in terms of their driving energy sources, their circulations and their compositions" (Ref 1).

Neptune is, on average, around 30 au from the Sun (for comparison, Uranus is at 20 au, and Earth is, of course, at 1 au). One Neptunian year lasts for 165 Earth years. The planet is "so far from the Sun that high noon there would seem like dim twilight to us. The warm light we see here on our home planet is roughly 900 times as bright as sunlight on Neptune" (reference). The planet can be seen from Earth only through a telescope." There is evidence that Neptune was seen and recorded by Galileo Galilei in 1613 (Fig 1), Michel de Lalande in 1795, and John Herschel in 1830, but none are known to have recognized it as a planet" (reference). William Herschel discovered Uranus in 1781. Subsequent careful observations by Alexis Bouvard revealed irregularities in the orbit of Uranus, which he hypothesized were caused by the gravitational effects of an unknown eighth planet. In 1845 in England, John Couch Adams made the first calculations of where the mysterious planet should be, but they were not published. The French astronomer Urbain LeVerrier (Figs 2, 5 and 9), encouraged by François Arago (Fig 3), independently made similar calculations in 1846, which were enthusiastically used by Johann Galle and his assistant Heinrich d'Arrest of the Berlin Observatory to find Neptune on the night of 23-24 September 1846. It was less than one degree from the predicted position! LeVerrier was credited with the discovery, though Adams was eventually recognized as the co-discoverer of Neptune (Fig 2 includes local stamps depicting both men). Finding a planet through mathematics, using Newton's law of gravitation,

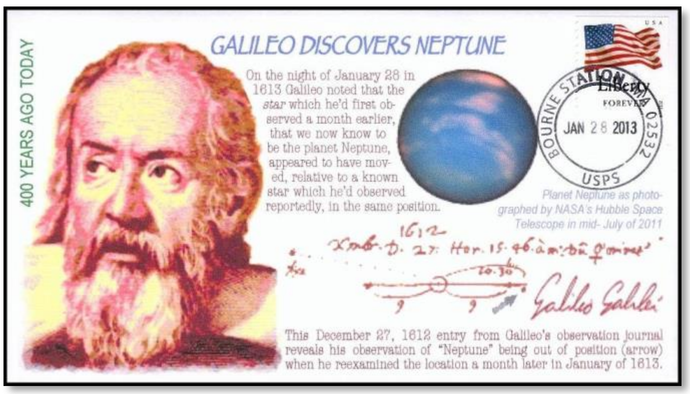

Figure 1. U.S. Coverscape Cover, Galileo & Neptune, 2013

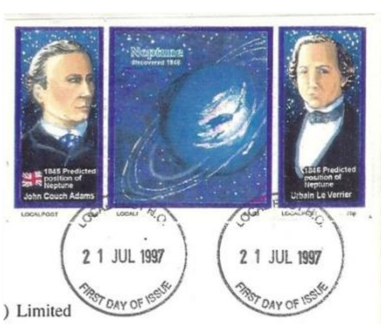

Figure 2. Great Britain, Local Post H.O. Adams & LeVerrier on partial FDC 1997

Figure 3. France, Sc B575, 1986

Figure 4. Gurnsey, Sc 449, 1991

was a revolutionary event for scientists of the time. More about these events is found here. The stamp in Fig 4 has the dual theme of the 1846 Royal Visit to Guernsey by Queen Victoria and Prince Albert, and that year's discovery of Neptune.

Because of its blue tint, like that of the sea, the new planet came to be called Neptune, after the God of the Sea, thus continuing the tradition of using mythological names for planets. The God Neptune and his trident are depicted in the upper-left margin of the SS1 (souvenir sheet of one stamp) in Fig 5 as well as in the stamp in Fig 6. Methane in Neptune's upper atmosphere "absorbs light at 600 nm, which is the red end of the spectrum of visible light" (reference). This means that sunlight bouncing back from Neptune has lost its red component, so the planet looks blue.

Figure 5. Comoro Islands, Sc 414a, 1979

Figure 6. Paraguay, Sc 1674c, 1976

The English astronomer William Lassell used a self-built 610 mm (24-inch) aperture telescope to discover Triton (diameter 2700 km) just 17 days after the discovery of Neptune itself (reference). It was only much later, on 1 May 1949, that a second Neptunian moon was discovered. Nereid, Neptune's third-largest moon (diameter 360 km) was observed on that date by Gerard Kuiper, using the 2083 mm (82 inch) telescope at the McDonald Observatory (reference). Proteus, the second-largest moon (diameter 420 km), was discovered only in 1989, from images taken by the Voyager-2 spacecraft two months before its Neptune flyby. Proteus was not discernable through Earth-based telescopes because it orbits so close to Neptune that it was lost in the glare of reflected sunlight (reference).

Voyager-2 and Neptune

Voyager-2, the only spacecraft to have studied Neptune and its principal moon Triton, provided most of the scientific information that we have about them. "The spacecraft was placed in a trajectory that allowed it to pass close to the north polar region of Neptune and (then) bend around the planet to reach Triton" (from the text in Fig 24, a Voyager-2 cover for the Triton flyby). Fig 7 is a cover issued for the spacecraft's flyby of Neptune. Its cachet depicts the epic path of Voyager-2's Grand Tour through the solar system: launched in 1977, it flew past Jupiter, Saturn, Uranus and Neptune before heading off into deep space. "Following the Uranus encounter, the spacecraft (had) performed a single midcourse correction on Feb. 14,1986 — the largest ever made by Voyager-2 — to set it on a precise course to Neptune" (reference). Fig 8 embodies that Grand Tour. Issued for the 35th anniversary of the launch of Voyager-2, it is a minisheet of four stamps (MS4) depicting the spacecraft and each of the four giant planets. On 25 August 1989, Voyager-2 flew to within 4800 km of Neptune's cloud tops (the closest approach of any of its four planetary flybys). The flyby cover of Fig 9, canceled on that date at Usuda, Japan, specifies the date of the beginning of the Neptune encounter period (5 June 1989) and summarizes the main scientific goals of the encounter: to study "Neptune's magnetosphere, atmospheric composition and weather," and to observe Triton. Its cachet also depicts wispy rings around the planet and a dark oval on it that represents what has come to be known as the Great Dark Spot (GDS). The end of the encounter period was on 2 October 1989 (Fig 10).

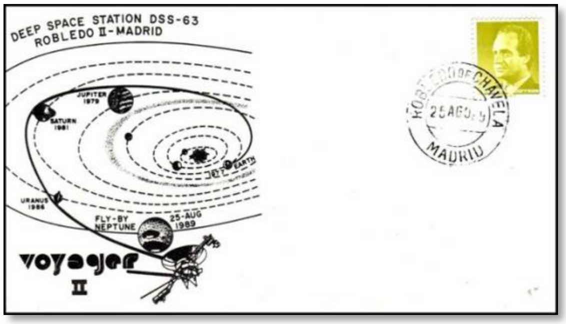

Figure 7. Voyager-2 event cover, Neptune flyby, Robledo de Chavela cachet

Figure 8. Burundi, Sc 1262, 2012

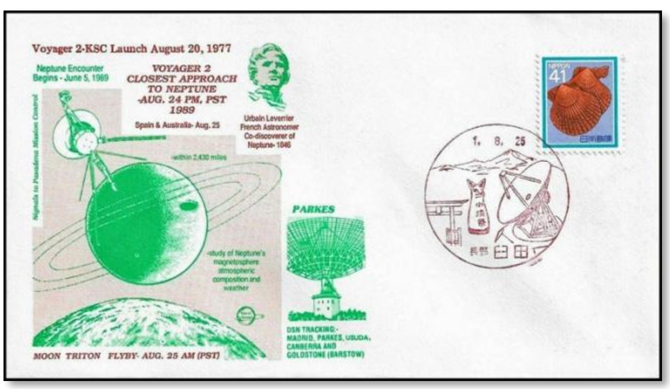

Figure 9. Voyager-2 event cover, Neptune flyby, SV Cachet, 1989

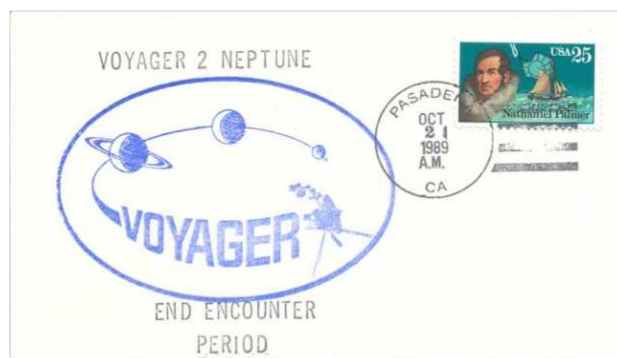

Figure 10. Voyager-2 event cover, end of Neptune encounter, 1989

"Even though Neptune receives only three percent as much sunlight as Jupiter does, it is a dynamic planet and surprisingly showed several large, dark spots reminiscent of Jupiter's hurricane-like storms. The largest spot, dubbed the Great Dark Spot, is about the size of Earth and is similar to the Great Red Spot (GRS) on Jupiter" (Ref 3). The GDS was in the

Figure 11. Maldives, Sc 2956c, 2008

planet's southern hemisphere. Small margin text in Ghana *Scott* 1226 (an MS6 issued in 1990 to commemorate Voyager-2 and its Grand Tour, not shown) refers to the GDS as a Neptunian "storm as large as Earth." Fig 11 depicts "Voyager-2 & Neptune's Great Dark Spot." The GDS was accompanied by bright patches of dense high methane ice clouds. "In June of 1994 the Hubble Space Telescope (HST) looked for it, but it was gone. Then, a few months later, a nearly identical spot appeared in the northern hemisphere" (reference). The GDSs are therefore fundamentally different from Jupiter's long-lived GRS. There also exist similar but smaller Neptunian storms, the Lesser Dark Spots (LDSs), one of which was present at the time of Voyager-2's Neptune encounter.

"A small, irregularly shaped eastward-moving cloud was observed "scooting" around Neptune every 16 hours or so; this "scooter," as Voyager scientists called it, could be a cloud plume rising above a deeper cloud deck" (Ref 3). Neptune has "high-level cirrus-like clouds, made of frozen methane, (which) give the planet its ever changing pattern of bright white dots and dashes" (reference).

Furthermore, "Long, thin bright clouds, rough analogues to jet stream cirrus clouds on Earth, were seen high in Neptune's atmosphere. At low northern latitudes, Voyager-2 captured images of cloud streaks casting their shadows on cloud decks below" (Ref 3). That was the first time that such shadows had ever been seen on another planet. Those clouds were in long east-west "lines" in a zonal pattern. They were calculated to be about 50 km above the main cloud deck (reference).

Figure 12. USA, Sc 5076, 2016

A well-known Voyager-2 image of Neptune is reproduced in the stamps in Figs 12, 13, 16 and 29. It is one of the last full-disk images obtained by the spacecraft and was taken through the green and orange filters of its narrow-angle camera (reference). Those depictions can be compared with Fig 14, the original image in which the four cloud patterns described above are identified. Figs 4, 8, 22, 26, 28 and 30 include similar full-disk images of Neptune.

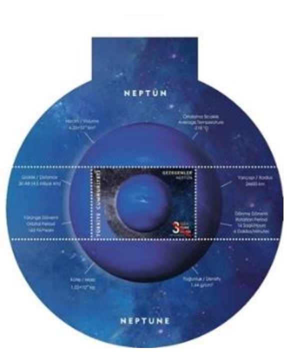

Figure 13. Turkey, Sc 3725h, 2020

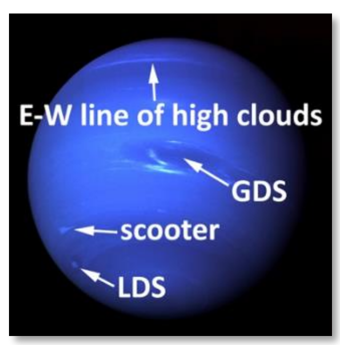

Figure 14. Voyager-2 Neptune annotated image

It has since been deduced that "Neptune's internal structure reflects its identity as an ice giant, composed of heavier elements than the gas giants and featuring a complex, multi-layered interior. Although the planet lacks a solid surface, it has distinct regions that vary in composition and physical state" (reference). Increasing pressure and density impose a gradual shift from the gaseous atmosphere to compressed "hot icy fluids" (the mantle) and finally to the core, thought to be composed of rock and metal with temperatures that exceed 5000 K. The atmosphere is composed of around 80% hydrogen and 19% helium, with methane and trace amounts of hydrocarbons such as ethane and acetylene making up the remainder. Fig 13 includes the values of various measurements for the planet, with an "average temperature" of -218 ºC. Vertical temperature profiles for Neptune and Uranus, obtained from Voyager-2 radio occultations, are found here.

"The strongest winds on any planet were measured on Neptune. Most of the winds there blow westward, or opposite to the rotation of the planet. Near the Great Dark Spot, winds blow up to 2000 km/h" (Ref 3). The winds were calculated by tracking individual cloud elements in the Voyager imagery. Later work indicated that "the winds circle the planet in bands that alternate direction between east and west" (reference). Neptune is our solar system's windiest world. "Despite its great distance and low energy input from the Sun, Neptune's winds can be three times stronger than Jupiter's and nine times stronger than Earth's. These winds whip clouds of frozen methane across the planet at speeds of more than 2000 km/h. Even Earth's most powerful winds hit only about 400 km/h" (reference).

Why are the winds so strong, despite the planet's miniscule solar insolation? There is no definitive answer. Energy flows and the planet's fast rotation may be the dominant factors, compared to others such as atmospheric composition and density, and planetary size and tilt. Solar insolation at Neptune averages only 1.5 W m^{-2} (for comparison, Uranus receives 3.7 W m^{-2} and Earth, 1366 W m^{-2}). "As a result, weak atmospheric activity might be expected, yet observations highlight intense meteorology showing numerous discrete cloud features (presumably composed of methane ice crystals) evolving on short timescales as well as long-lasting powerful storms" (reference). "The constantly shifting storms reveal Neptune's chaotic, active atmosphere, which creates one of the stormiest planetary climates" (reference). The internal heat that moves upward from Neptune's core is probably related to the planet's active atmosphere. Neptune "gives out 2.6 times more heat than it receives from the Sun" (reference). For comparison, Uranus has "hardly any heat flowing from its interior into space (reference). "The amount of sunlight at the distance of Neptune is only 2/5 of the amount at Uranus. Despite that, the effective temperature of the two planets is virtually identical at 59 K (-214 ºC), because Neptune has a substantial internal heat flow not associated with insolation, whereas Uranus has little or none" (Ref 4).

The importance of these ideas was emphasized in a little-known project of the New Horizons (NH) spacecraft (NH will be discussed in the next article in this series in the context of its Pluto flyby in 2015). This reference describes how, though far beyond the orbits of Pluto, Uranus and Neptune in September 2023, NH "turned its Multispectral Visible Imaging Camera (MVIC) back to look at both planets (the two ice giants) from a vantage point more than 8 billion km (54.5 au) from Earth. In doing so, it saw those worlds from the opposite direction to how we see them from Earth … New Horizons' primary science objective for those observations was to learn more about how the atmospheres of the two worlds absorb and emit heat energy as well as how thermal energy is transported from the planets' presumably rocky cores toward their outer atmospheres. Uranus is odd in this regard because it appears to have hardly any heat flowing from its interior into space. Neptune, despite being a similar planet, radiates over two and a half times more energy into space (than it receives from the Sun)." The authors are unaware of any postage stamps or covers for this NH event.

Neptune is tilted at 28.3°, a little more than Earth's 23.5°. This tilt is related to the seasons, but because Neptune's orbital period is so long, each season there lasts about 40 Earth years, with differences among seasons larger than one might at first think for a planet with so little sunlight. "When the northern hemisphere is tilted towards the Sun, heat builds up and releases methane gas into space. The same happens over the south pole during its sunny season" (reference). Neptune's seasonal cycles influence variables such as sunlight distribution and atmospheric composition, which in turn affect its weather patterns.

Voyager-2 determined that "Neptune has a magnetic field that is tilted at about 47º relative to its rotation axis and is offset from the planet's center. This generates a dynamic magnetosphere, interacting with charged particles, the solar wind, and Neptune's moons. The magnetic field particularly influences Triton's orbit and environment" (reference). "Voyager's studies of radio waves caused by the magnetic field revealed the length of a Neptunian day (just under 16 hours – fast rotation for the size of the planet). The spacecraft also (indirectly) detected auroras, but much weaker than those on Earth and other planets" (Ref 3). The James Webb Space Telescope (JWST) directly observed the auroras in 2023.

"The (six) new moons found at Neptune by Voyager-2 are all small and remain close to Neptune's equatorial plane … they are Naiad, Thalassa, Despina, Galatea, Larissa and Proteus" (Ref 3).

The rings of Uranus were discovered in 1977 by James Elliot and colleagues, using data from the Kuiper Airborne Observatory. Subsequent Earth-based telescopic observations of Neptune in the 1980s were tantalizing but inconclusive about its possible rings. "Something (probably incomplete arcs) definitely existed around Neptune, but the features of the ring system remained a mystery" (reference). "Voyager-2 solved many of the questions scientists had about Neptune's rings. Searches for 'ring arcs', or partial rings, showed that Neptune's rings actually are complete, but are so diffuse and the material in them so fine that

Figure 15. Malagasy, Sc 1049, 1992

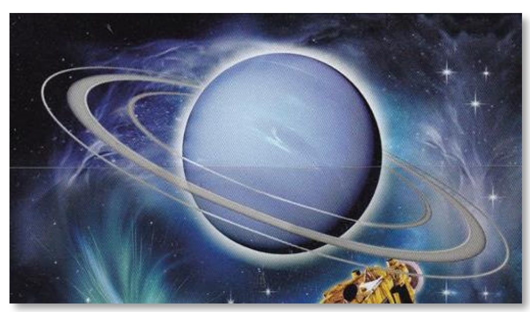
Figure 16. Antigua & Barbuda, Sc 3314, 2015

they could not be fully resolved from Earth" (Ref 3). There are five main rings (Voyager-2 discovered four of them) that were named after astronomers who were involved in the discovery of Neptune: Galle, LeVerrier, Lassell, Arago and Adams. "These rings consist of dark, likely organic-rich dust and ice particles" (reference). The cachet in Fig 9 includes three of Neptune's wispy rings. Most postage stamps do not show any of them. One depicts only a single thin ring (Fig 15). That stamp is inscribed, in French, "Voyager-2's flyby of Neptune on 25 August 1989." The stamp's circular inset shows in its background an artist's depiction of Neptune, as seen from what is probably meant to be Triton, in its foreground. In one further example, the margin of an MS4 issued for the New Horizons mission depicts, in error, that spacecraft near Neptune, which is drawn with three rings. NH did not fly by Neptune. Fig 16 presents the portion of the margin with the planet and its rings.

Figure 17. Marshall Islands, Sc 930j, 2008

Full-disk images of a blue Neptune are found on a surprising number of postage stamps. Some have already been presented. Fig 5 has an unusual (and unrealistic) yellow and green Neptune. Fig 17 includes another blue Neptune with the GDS and Voyager-2. The cachet of the FDC in Fig 18 features that same image. Some postage stamps add a supplementary Neptunian element. For example, Fig 19 features a full-disk image of the planet with a red arc around much of it. Similar pink arcs are seen in Fig 20 and in the stamp in the SS1 of Fig 28.

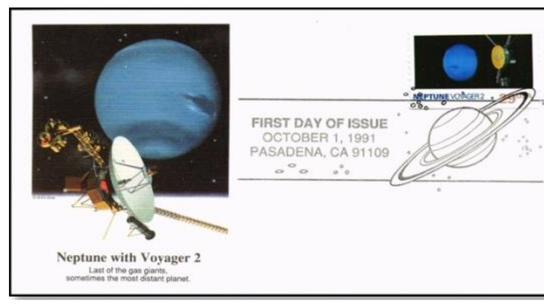

Figure 18. USA, Sc 2576, FDC, Fleetwood Cachet, 1991

Figure 19. Ghana, Sc 1226g, 1990

What are those arcs? The answer is found in this web page, which includes Fig 21, a Voyager-2 false-color image of Neptune with a red "edge" around its perimeter. "Voyager-2's original images were taken in false color using filters: a standard technique used by planetary astronomers. In this case, blue and green filters were used alongside one that passes light at a wavelength absorbed by methane gas … hydrogen and helium dominate Neptune's atmosphere, but methane gives it its blue appearance by absorbing red light. The filters make methane look dark blue in this image, but they also reveal a semitransparent haze layer across the planet. The bright red edge around Neptune is caused by the haze scattering sunlight at

Figure 20. Uganda, Sc 1107, 1992

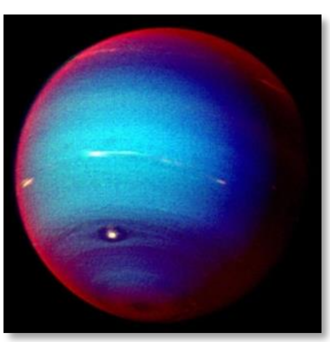

Figure 21. Voyager-2 Neptune image with red haze

Figure 22. USA, Sc 2576, 1991

higher altitudes, above most of the methane" (reference). The stamp in the SS1 of Fig 28 has the text "Voyager-2, Neptune 1989" and includes a similar arc, in pink. That stamp also depicts a small white cloud patch at its right, which might represent a "scooter" since no dark spot is visible with it. Interestingly, that patch also has a pink "edge" on one of its sides. The right margin of the SS1 has a blue Neptune in the background with a whitish (rather than pink) arc around part of the planet. It is not known why it is whitish rather than pink. Perhaps the color was lost in the SS1's design process? Triton and Voyager-2 are in the margin's foreground. In Fig 22, the blue full-disk image of the planet includes two Dark Spots, and sharp eyes will discern a subtle semitransparent "edge" around the planet. The authors interpret it to be the haze layer discussed above, but without the red or pink enhancement.

Voyager-2 and Triton

Triton was named after the son of Poseidon, the Greek god of the sea (Poseidon is equivalent to the Roman god Neptune). The god Triton is depicted in Fig 23. The moon Triton is similar in many ways to the dwarf planet Pluto.

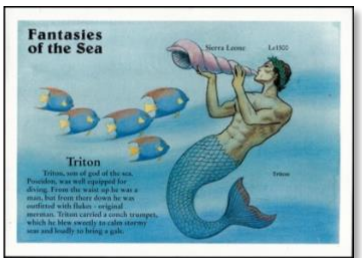

Figure 23. Sierra Leone, Sc 1969i, 1996

Voyager-2 "photographed two-thirds of Neptune's largest moon Triton, revealing the coldest known planetary body in the solar system and a nitrogen ice "volcano" on its surface. Spectacular images of its southern hemisphere showed a strange, pitted, cantaloupe-type terrain" (reference). The cachet of the cover in Fig 24 is based on one of those images (Fig 25). In it, the moon's southern region is covered by a vast nitrogen ice cap dotted with volcanic geysers, which are revealed by some dark, windblown streaks.

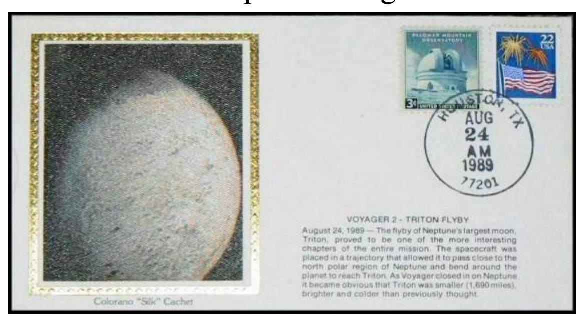

Figure 24. Voyager-2 event cover, Triton flyby, Colorano Silk Cachet, 1989

Triton is "not only the most intriguing satellite of the Neptunian system, but one of the most interesting in all the solar system. It shows evidence of a remarkable geologic history, and Voyager-2 images showed active geyser-like eruptions spewing invisible nitrogen gas and dark dust particles several kilometers into the tenuous atmosphere. Triton's relatively high density and retrograde orbit offer strong evidence that it is not an original member of Neptune's family but is a captured object … An extremely thin atmosphere extends about 800 km above Triton's surface. The atmospheric pressure at the surface is about 14 μb (microbars), 1/70,000th the surface pressure on Earth. The surface temperature is about 38 K (-235 ºC), the coldest temperature of any body

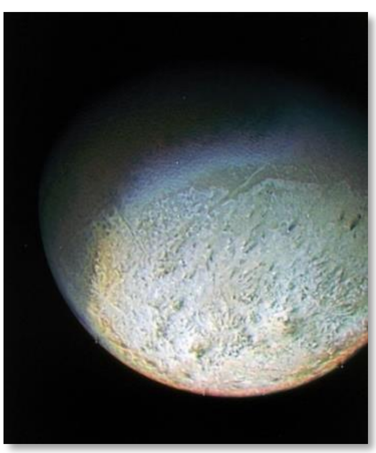
Figure 25. Voyager-2 image of Triton

known in the solar system" (Ref 3). Triton probably has another similar ice cap around its North Pole, but Voyager-2 did not "see" that area.

The moon "has a sparsely cratered surface with smooth volcanic plains, mounds and round pits formed by icy lava flows. Triton consists of a crust of frozen nitrogen over an icy mantle believed to cover a core of rock and metal. Triton has a density about twice that of water. This is a higher density than that measured for almost any other satellite of an outer planet. (Only the Jovian moons) Europa and Io have higher densities. This implies that Triton contains more rock in its interior than the icy satellites of Saturn and Uranus. Triton's thin atmosphere is composed mainly of nitrogen with small amounts of methane. This atmosphere most likely originates from Triton's volcanic activity, which is driven by seasonal heating by the Sun. Triton, Io and Venus are the only bodies in the solar system besides Earth that are known to be volcanically active at the present time. Triton is … so cold that most of its nitrogen is condensed as frost, giving its surface an icy sheen that reflects 70% of the sunlight that hits it" (reference).

"Triton's internal heat source is larger, relative to heating from the Sun, than that of any solar system satellite except Io. It has been suggested that some of this heat may arise from a 'solid state' greenhouse effect, in which sunlight penetrates through relatively clear nitrogen ice and heats the subsurface. Because the nitrogen ice is opaque to the resulting infrared radiation, the heat cannot escape, and heat buildup occurs … (so that) ice geysers erupt through the surface of this icy moon … Triton's surface temperature has been refined to 34.5 K (-235 ºC), even colder than previously thought (reference). However, its internal heat may be great enough to maintain a liquid water subsurface ocean (reference) like that hypothesized at other moons such as Europa. "Because of Triton's unusual orbital inclination, both polar regions take turns facing the Sun" (reference), so that each pole "spends about 80 years in darkness followed by 80 years of sunlight" (reference). This means that "despite Triton's distance from the Sun and cold temperatures, the weak sunlight is enough to drive strong seasonal changes on Triton's surface and atmosphere" (reference).

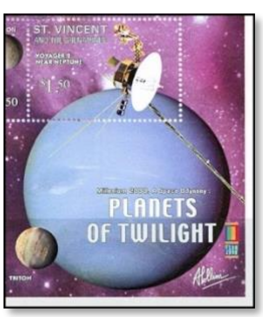

Figure 26. St. Vincent, Sc 2792f, 2000

Triton appears on a few postage stamps. Fig 26 features stamp 'f' and part of the margin of a St. Vincent MS6. Neptune and Triton are illustrated in the margin, while the stamp includes the text "Voyager-2 near Neptune." Fig 27, inscribed "Voyager-2" and "Neptune and Triton," presents an artistic depiction of the planet as seen from just above the surface of Triton. The foreground of the right margin of the SS1 in Fig 28 has Voyager-2 and Triton, whose partially white surface corresponds to its southern hemisphere's bright nitrogen ice region as seen in Fig 25. Fig 29 depicts Neptune, two tiny moons and one larger apparent moon that may be Triton, though it doesn't really look like the image of Triton in Fig 25. Since this stamp is part of a MS6 issued for

Figure 27. Ghana, Sc 1226b, 1990

Figure 28. Malagasy, Sc 967a, 1990

Figure 29. Israel, Sc 1643c, 2006

the solar system, perhaps the designer meant to depict Pluto rather than Triton in that stamp. The circular inset in the postage stamp in Fig 15, already mentioned above, depicts a possible artist's drawing of the surface of Triton with a white plume erupting from a reddish surface "hotspot" (Neptune is in the background of the inset). However, Voyager-2's observations indicated that Triton's "geysers are plumes of nitrogen gas and (dark) dust particles that erupt from the surface … and can reach heights of up to 8 km, and are responsible for replenishing the thin atmosphere of Triton" (reference). The card in Fig 30, issued for the 30th anniversary of the launch of Voyager-2, reproduces part of the 1989 painting by Brian Sullivan titled *Triton, Geyser*. Its depiction of a tall, thin and dark geyser on Triton may be a more accurate reflection of what is known of such geysers than the drawing in Fig 15.

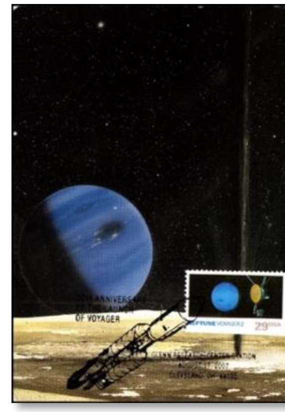

Figure 30. USA, Voyager-2 30th anniversary launch cover with Triton geyser

Neptunian Observations after the Voyager-2 Flyby

After Voyager-2's flyby, Earth-based and space telescopes became the primary sources of scientific measurements of the Neptunian system. In the year 2000 for example, astronomers took advantage of the then-new adaptive optics system of the Keck Telescope in Hawaii to obtain what were at the time the "best Keck images of Neptune ever captured" (reference). Using its NIRC2 (Near-Infrared Camera, Second Generation), the Keck Observatory obtained a series of IR images of the planet from 2002 through 2023. They are found here, and show that in the latter part of that period the high white clouds had almost completely disappeared. Why? Could the solar cycle be involved? A Keck staff astronomer recently said that "Advances in technology as well as our Twilight Observing Program have enabled us to constrain Neptune's atmospheric models, which are key to understanding the correlation between the ice giant's climate and the solar cycle" (reference).

In 2006, another Earth-based instrument, the Very Large Telescope in Chile, used an imager/spectrometer for mid-infrared wavelengths and found that part of the atmosphere around Neptune's south pole is about 10 ºC warmer than anywhere else on the planet. Those warmer temperatures provide an avenue for methane to escape upward, out of the lower atmosphere. Images and some further information are found here. "The relative "hot spot" is due to Neptune's axial tilt, which has exposed the south pole to the Sun for the last quarter of Neptune's year, or roughly 40 Earth years. As Neptune slowly moves towards the opposite side of the Sun, the south pole will be darkened and the north pole illuminated, causing the methane release to shift to the north pole" (reference).

Fig 31, from a MS12 issued for the 25th anniversary of the launch of the HST, depicts the planet and includes the text "Hubble captures Neptune". "Images of Neptune taken at six wavelengths by the HST in October and November 1994 revealed several atmospheric features (that were) not present at the time of the Voyager spacecraft encounter in 1989.

Figure 31. Nevis, Sc 1871k, 2015

Furthermore, the largest feature seen in 1989, the Great Dark Spot, was gone. A dark spot of comparable size had appeared in the northern hemisphere, accompanied by discrete bright features at methane-band wavelengths. At visible wavelengths, Neptune's banded structure appeared similar to that seen in 1989" (reference). That series of images from 1994 proved the dynamic nature of Neptune's cloud patterns, which changed over a period of days. Three of those images are reproduced in the cover in Fig 32 (and online here). They are from October 10 (upper left), October 18 (upper right) and November 2 (lower center). They were obtained with the HST's WFPC-2 (Wide Field Planetary Camera-2) using "different colored filters at visible and near-infrared wavelengths … The pink features are high-altitude methane ice crystal clouds. Though the clouds appear white in visible light, they are tinted pink here because they were imaged at near-infrared wavelengths" (reference).

The HST has continued to observe Neptune since then. For example, on 12 July 2011, the planet returned to the same location in space where it had been discovered 165 Earth years previously. To commemorate that event, the HST took a series of full-disk images of Neptune at four-hourly intervals with its Wide Field Camera-3. They are found here. In them, the pink areas are high-altitude clouds (rough analogues of Earth's cirrus clouds) composed of methane ice crystals. One of those images is reproduced in Fig 1, with the caption "Planet Neptune as photographed by NASA's Hubble Space Telescope in mid-July of 2011."

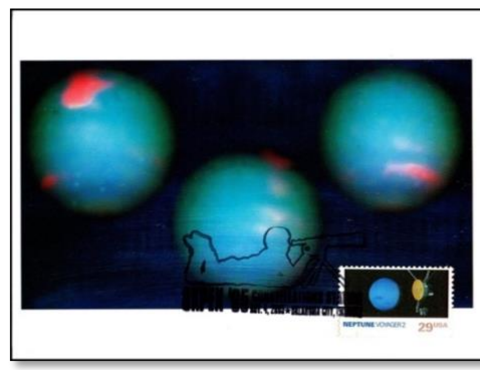

Figure 32. USA, Sc 2576, 2005

OPAL (Outer Planet Atmospheres Legacy) is a program in which the HST observes the four giant planets every year. The goals are to document long-term trends in seasonal and other cycles (such as storm activity and the variability in winds and aerosols) in the highly dynamic atmospheres of the four giant planets, and to provide regular observations that can help fill in the temporal gaps among other programs. The HST's first observations of Neptune under the OPAL program took place in September of 2015. A long dataset of HST observations, from 1994 to 2023, shows the waxing and waning of high Neptunian clouds. Those observations have been compared to the cycle of solar UV (ultraviolet) radiation (a graphic is here). There is a clear correlation between cloud amounts and the peaks and troughs in the solar cycle. There are so many interrelated physical factors, though, that causation, if it exists, has not yet been clearly established.

The JWST is a powerful infrared observing platform. The authors are not aware of any philatelic items that link it specifically to Neptune, but in the upper margin of the MS2 in Fig 33 it is depicted with the planets of the solar system, including Neptune. The JWST "observes light in the infrared portion of the spectrum, so its Near Infrared Camera (NIRCam) 2022 images of Neptune show a ghostly white planet. This is because the methane in Neptune's atmosphere absorbs reddish and infrared light … the exception to this is the planet's high-altitude methane ice clouds, which reflect sunlight before it can be absorbed by the methane. They appear as brilliant, bright features (in the NIRCam images) … Also prominent in the new image are Neptune's rings, which had not been directly observed since Voyager-2 flew by the planet in 1989. It is difficult to observe these rings from afar because they are close to the planet and obscured by its brightness. The Webb telescope found both prominent rings and bands of dust" (reference, which includes the JWST's 2022 Neptune image). Then in 2023, the JWST observed Neptune's auroras in the near infrared. Some details are found here. The HST, operating at different wavelengths, can't see the auroras. The two images can be combined, however, to produce a single image with white high clouds and green auroras above a blue planetary background. Here are the images and further discussion: "Neptune's auroras do not occur at the northern and southern poles of the planet, where we see auroras on planets like Earth and Jupiter, because of the strange nature of Neptune's magnetic field, which is tilted by 47 degrees from the planet's rotational axis."

Figure 33. Congo Republic, Illegal, No Cat. #, 2016

Conclusion

Voyager-2 gave us a tantalizing peek at the marvels and mysteries of Neptune and Triton. They are surprisingly active and from their distant perch in the solar system are almost crying out to be studied in situ. Various new spacecraft missions to further study them have been proposed (Ref 2; Trident was the most recent one), but none have come to fruition, so Earth-based and space telescopes will continue to carry the observational load for the foreseeable future.

The next article (and the last in this Planetary Environments series) will feature Pluto and its moon Charon.

Other References

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About the Authors

Garry Toth, M.Sc., now retired, was an operational meteorologist with the Meteorological Service of Canada. Correspondence to gmt.varia@gmail.com is welcome.

Don Hillger, Ph.D., now retired, was a research meteorologist with the National Oceanic and Atmospheric Administration (NOAA) and held a cooperative position at Colorado State University. Correspondence to don.hillger@colostate.edu is welcome.

We have researched and written extensively about weather, climate, and un-manned spacecraft on stamps and covers, as well as some other topics. All our philatelic publications are available online.

Stamping Cosmology

by Gene R. Major

The universe is 13.8 billion years old. It started out as an infinitesimally small and dense point and rapidly expanded in a "big bang" to contain all the stars and galaxies that we now see. New discoveries by the James Webb Space Telescope (JWST) and other telescopes are challenging our current models of the universe. Stamps have highlighted the people and ideas behind our cosmic journey back to the beginning of time.

"Island Universes"

At the dawn of the 20th century, astronomers thought the universe was just one big galaxy—the Milky Way [Fig 1]. All the stars that were seen in the sky, including those fuzzy patches called "nebula," were part of the Milky Way Galaxy. That was soon to change.

Figure 1. Canada, Sc 3103, 2018.

> The word "galaxy" has been known since Medieval times, derived from the Old French Latin *galaxia*, which came from the Greek *galaxias (kuklos),* meaning 'milky (vault)' — hence the term Milky Way.