Hubble monitors changing weather and seasons of Jupiter and Uranus

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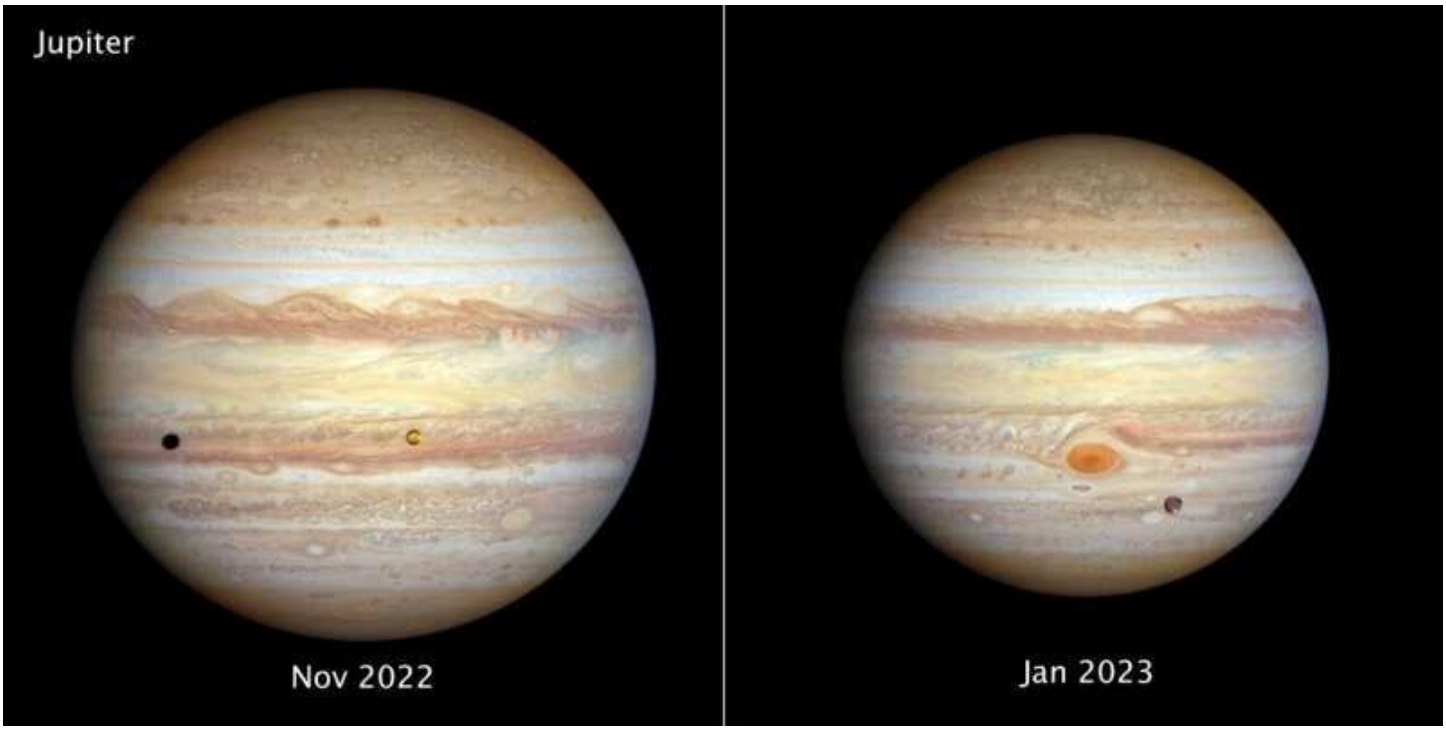
Ever since its launch in 1990, NASA's Hubble Space Telescope has been an interplanetary weather observer, keeping an eye on the largely gaseous outer planets and their ever-changing atmospheres. NASA spacecraft missions to the outer planets have given us a close-up look at these atmospheres, but Hubble's sharpness and sensitivity keeps an unblinking eye on a kaleidoscope of complex activities over time.

In this way Hubble complements observations from other spacecraft such as Juno, currently orbiting Jupiter; the retired Cassini mission to Saturn; and the Voyager 1 and 2 probes, which collectively flew by all four giant planets between 1979 and 1989.

Inaugurated in 2014, the telescope's Outer Planet Atmospheres Legacy (OPAL) Program has been providing us with yearly views of the giant planets. Here are some recent images:

Jupiter



Credit: NASA, ESA, STScI, Amy Simon (NASA-GSFC), Michael H. Wong (UC Berkeley); Image Processing: Joseph DePasquale (STScI)

The image on the left was taken on November 12, 2022. The forecast for Jupiter is stormy weather at low northern latitudes. A prominent string of alternating storms is visible, forming a "vortex street," as some planetary astronomers call it. This is a wave pattern of nested anticyclones and cyclones, locked together like in a machine with

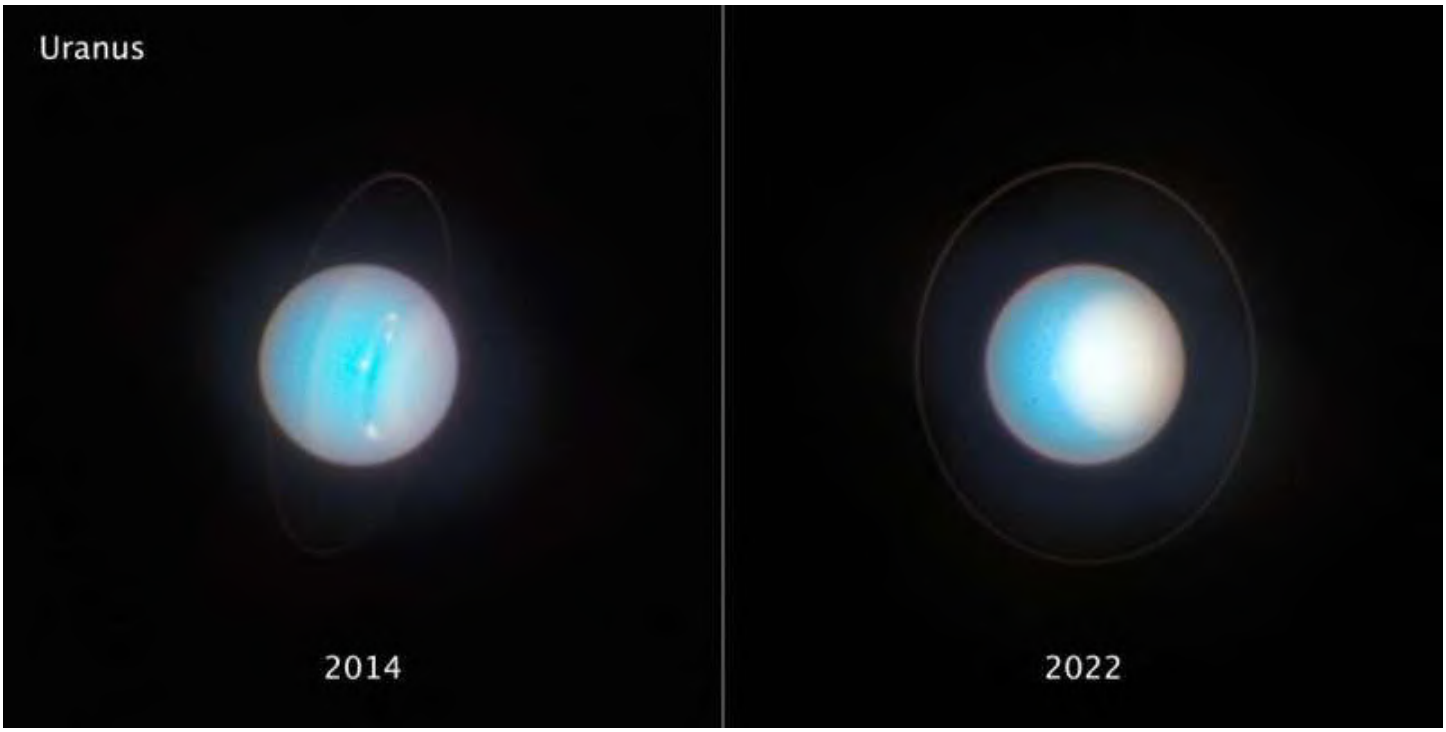
alternating gears moving clockwise and counterclockwise. If the storms get close enough to each other, in the very unlikely event of a merger, they could build an even larger storm, potentially rivaling the current size of the Great Red Spot.

The staggered pattern of anticyclones and cyclones prevents individual storms from merging. Activity is also seen interior to these storms; in the 1990s Hubble didn't see any cyclones or anticyclones with built-in thunderstorms, but these storms have sprung up the last decade. Strong color differences indicate that Hubble is seeing different cloud heights and depths as well.

The orange moon Io photobombs this view of Jupiter's multicolored cloud tops, casting a shadow toward the planet's western limb. Hubble's resolution is so sharp that it can see Io's mottled-orange appearance, related to its numerous active volcanoes. These volcanoes were first discovered when the Voyager 1 spacecraft flew by in 1979. The moon's molten interior is overlaid by a thin crust through which the volcanoes eject material. Sulfur takes on various hues at different temperatures, which is why Io's surface is so colorful.

In the image on the right, taken on January 6, 2023, Jupiter's legendary Great Red Spot takes center stage in this view. Though this vortex is big enough to swallow Earth, it has actually shrunken to the smallest size it has ever been over observation records dating back 150 years. Jupiter's icy moon Ganymede can be seen transiting the giant planet at lower right. Slightly larger than the planet Mercury, Ganymede is the largest moon in the solar system. It is a cratered world with a mainly water-ice surface with apparent glacial flows driven by internal heat. (This image is smaller in size because Jupiter was 81,000 miles farther from Earth when the photo was taken.)

Uranus



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Planetary oddball Uranus rolls on its side around the sun as it follows an 84-year orbit, rather than spinning in a more-vertical position as Earth does. Uranus has a weirdly tipped "horizontal" rotation axis angled just eight degrees off the plane of the planet's orbit. One recent theory proposes that Uranus once had a massive moon that gravitationally destabilized it and then crashed into it. Other possibilities include giant impacts during planetary formation, or even giant planets exerting resonant torques on each other over time.

The consequences of the planet's tilt are that for stretches of time lasting up to 42 years, parts of one hemisphere are completely without sunlight. When the Voyager 2 spacecraft visited during the 1980s, the planet's south pole was pointed almost directly at the sun. Hubble's latest view shows the northern pole now tipping toward the sun.

The image on the left is a Hubble view of Uranus taken in 2014, seven years after northern spring equinox when the sun was shining directly over the planet's equator, and shows one of the first images from the OPAL program. Multiple storms with methane ice-crystal clouds appear at mid-northern latitudes above the planet's cyan-tinted lower atmosphere. Hubble photographed the ring system edge-on in 2007, but the rings are seen starting to open up seven years later in this view. At this time, the planet had multiple small storms and even some faint cloud bands.

As seen in 2022, Uranus's north pole, shown in the image on the right, shows a thickened photochemical haze that looks similar to the smog over cities. Several little storms can be seen near the edge of the polar haze boundary. Hubble has been tracking the size and brightness of the north polar cap and it continues to get brighter year after year.

Astronomers are disentangling multiple effects—from atmospheric circulation, particle properties, and chemical processes—that control how the atmospheric polar cap changes with the seasons. At the Uranian equinox in 2007, neither pole was particularly bright. As northern summer solstice approaches in 2028 the cap may grow brighter still, and will be aimed directly toward Earth, allowing good views of the rings and north pole; the ring system will then appear face-on. This image was taken on November 10, 2022.

Provided by NASA's Goddard Space Flight Center