Astronomers capture surprising changes in Neptune's temperatures

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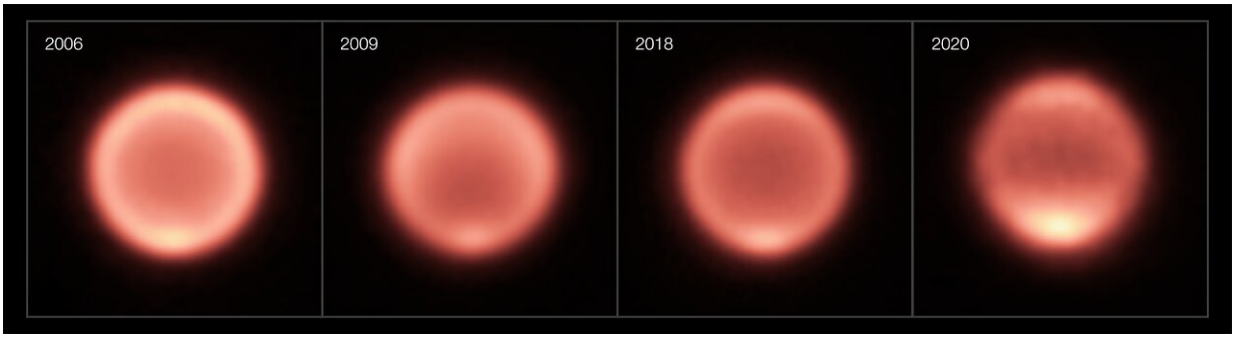


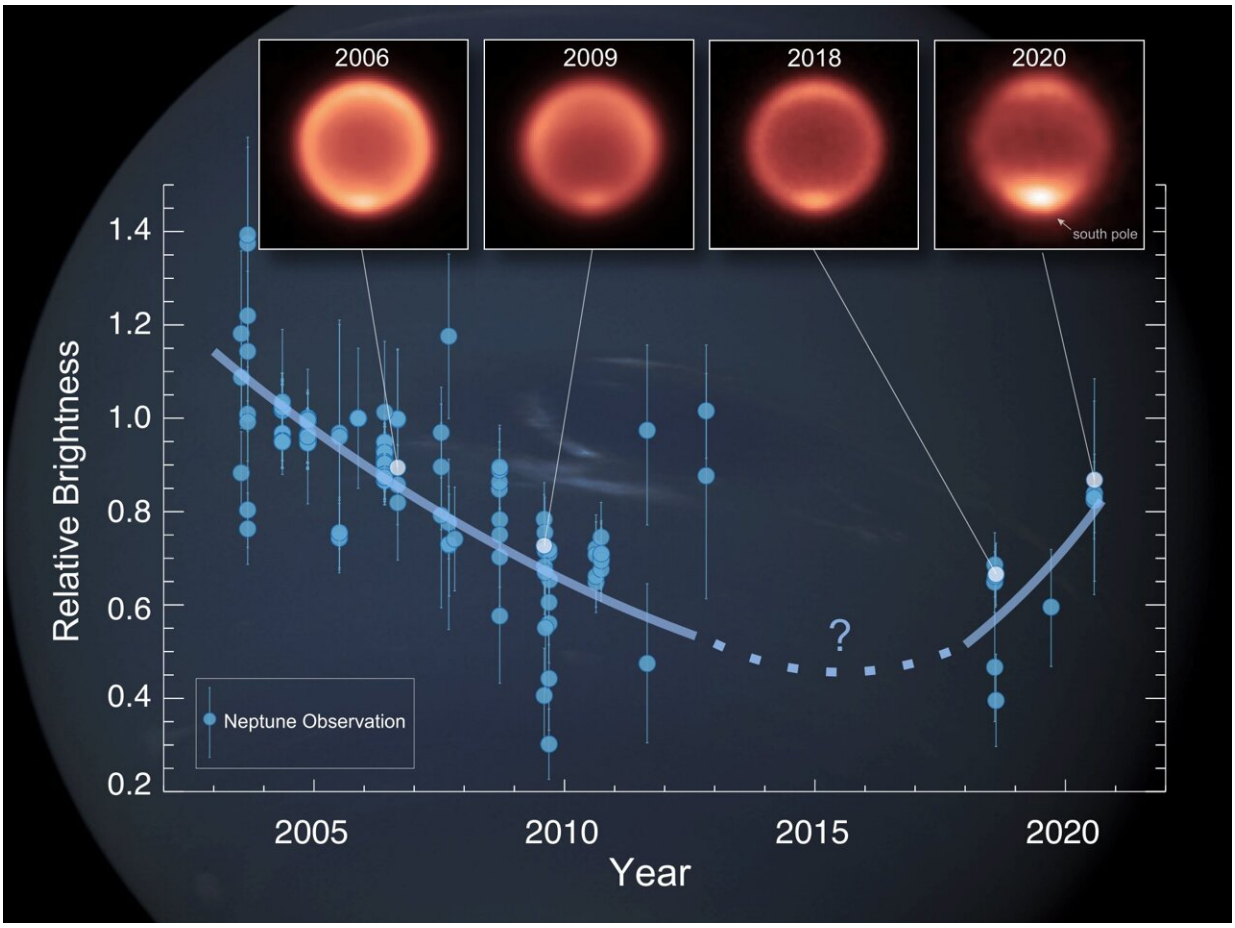
This composite shows thermal images of Neptune taken between 2006 and 2020. The first three images (2006, 2009, 2018) were taken with the VISIR instrument on ESO's Very Large Telescope while the 2020 image was captured by the COMICS instrument on the Subaru Telescope (VISIR wasn't in operation in mid-late 2020 because of the pandemic). After the planet's gradual cooling, the south pole appears to have become dramatically warmer in the past few years, as shown by a bright spot at the bottom of Neptune in the images from 2018 and 2020. Credit: ESO/M. Roman, NAOJ/Subaru/COMICS

An international team of astronomers have used ground-based telescopes, including the European Southern Observatory's Very Large Telescope (ESO's VLT), to track Neptune's atmospheric temperatures over a 17-year period. They found a surprising drop in Neptune's global temperatures followed by a dramatic warming at its south pole.

"This change was unexpected," says Michael Roman, a postdoctoral research associate at the University of Leicester, UK, and lead author of the study published today in *The Planetary Science Journal*. "Since we have been observing Neptune during its early southern summer, we expected temperatures to be slowly growing warmer, not colder."

Like Earth, Neptune experiences seasons as it orbits the Sun. However, a Neptune season lasts around 40 years, with one Neptune year lasting 165 Earth years. It has been summertime in Neptune's southern hemisphere since 2005, and the astronomers were eager to see how temperatures were changing following the southern summer solstice.

Astronomers looked at nearly 100 thermal-infrared images of Neptune, captured over a 17-year period, to piece together overall trends in the planet's temperature in greater detail than ever before.



Observed changes in Neptune's thermal-infrared brightness, a measure of temperature in Neptune's atmosphere. The plot shows the relative change in the thermal-infrared brightness from Neptune's stratosphere with time for all existing images taken by ground-based telescopes. Brighter images are interpreted as warmer. Corresponding thermal-infrared images (top) at wavelengths of ~12 μm show Neptune's appearance in 2006, 2009, 2018 (observed by the European Southern Observatory's Very Large Telescope's VISIR instrument), and 2020 (observed by Subaru's COMICS instrument). The south pole appears to have become dramatically warmer in just the past few years. Credit: Michael Roman/NASA/JPL/Voyager-ISS/Justin Cowart.

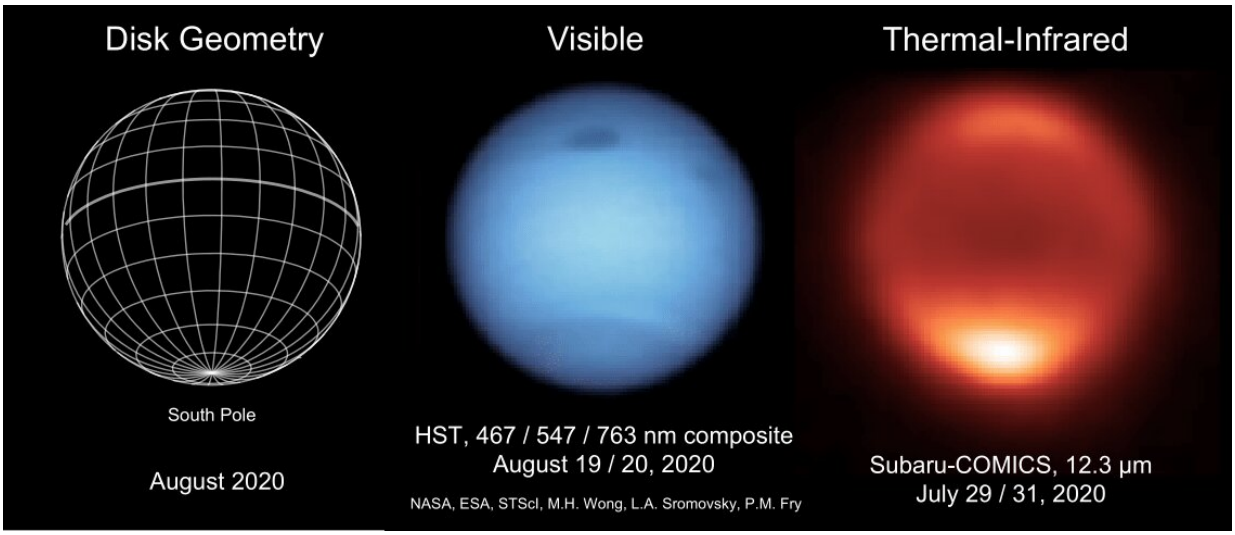
These data showed that, despite the onset of southern summer, most of

the planet had gradually cooled over the last two decades. The globally averaged temperature of Neptune dropped by 8 °C between 2003 and 2018.

The astronomers were then surprised to discover a dramatic warming of Neptune's south pole during the last two years of their observations, when temperatures rapidly rose 11 °C between 2018 and 2020. Although Neptune's warm polar vortex has been known for many years, such rapid polar warming has never been previously observed on the planet.

"Our data cover less than half of a Neptune season, so no one was expecting to see large and rapid changes," says co-author Glenn Orton, senior research scientist at Caltech's Jet Propulsion Laboratory (JPL) in the US.

The astronomers measured Neptune's temperature using thermal cameras that work by measuring the infrared light emitted from astronomical objects. For their analysis the team combined all existing images of Neptune gathered over the last two decades by ground-based telescopes. They investigated infrared light emitted from a layer of Neptune's atmosphere called the stratosphere. This allowed the team to build up a picture of Neptune's temperature and its variations during part of its southern summer.



Neptune as seen in visible light (centre) and thermal-infrared wavelengths (right), in 2020. The centre image combines multiple images from the Hubble Space Telescope, while the thermal-infrared image on the right was taken from the Subaru Telescope on Maunakea, Hawai'i. In the thermal-infrared, Neptune's warm south pole glows more brightly than ever seen before. Credit: Michael Roman/NASA/ESA/STSci/M.H. Wong/L.A. Sromovsky/P.M. Fry.

Because Neptune is roughly 4.5 billion kilometers away and is very cold, the planet's average temperature reaching around –220°C, measuring its temperature from Earth is no easy task. "This type of study is only possible with sensitive infrared images from large telescopes like the VLT that can observe Neptune clearly, and these have only been available for the past 20 years or so," says co-author Leigh Fletcher, a professor at the University of Leicester.

Around one third of all the images taken came from the VLT Imager and Spectrometer for mid-InfraRed (VISIR) instrument on ESO's VLT in Chile's Atacama Desert. Because of the telescope's mirror size and altitude, it has a very high resolution and data quality, offering the

clearest images of Neptune. The team also used data from NASA's Spitzer Space Telescope and images taken with the Gemini South telescope in Chile, as well as with the Subaru Telescope, the Keck Telescope, and the Gemini North telescope, all in Hawai'i.

Voyager 2 view of Neptune, captured in August 1989. Credit: NASA/JPL-Caltech/Kevin M. Gill.

Because Neptune's temperature variations were so unexpected, the astronomers do not know yet what could have caused them. They could be due to changes in Neptune's stratospheric chemistry, or random weather patterns, or even the solar cycle. More observations will be

needed over the coming years to explore the reasons for these fluctuations. Future ground-based telescopes like ESO's Extremely Large Telescope (ELT) could observe temperature changes like these in greater detail, while the NASA/ESA/CSA James Webb Space Telescope will provide unprecedented new maps of the chemistry and temperature in Neptune's atmosphere.

"I think Neptune is itself very intriguing to many of us because we still know so little about it," says Roman. "This all points towards a more complicated picture of Neptune's atmosphere and how it changes with time."

More information: "Sub-Seasonal Variation in Neptune's Mid-Infrared Emission" *The Planetary Science Journal* (2022). DOI: 10.3847/PSJ/ac5aa4

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