Striking Gemini images point Juno spacecraft toward discovery

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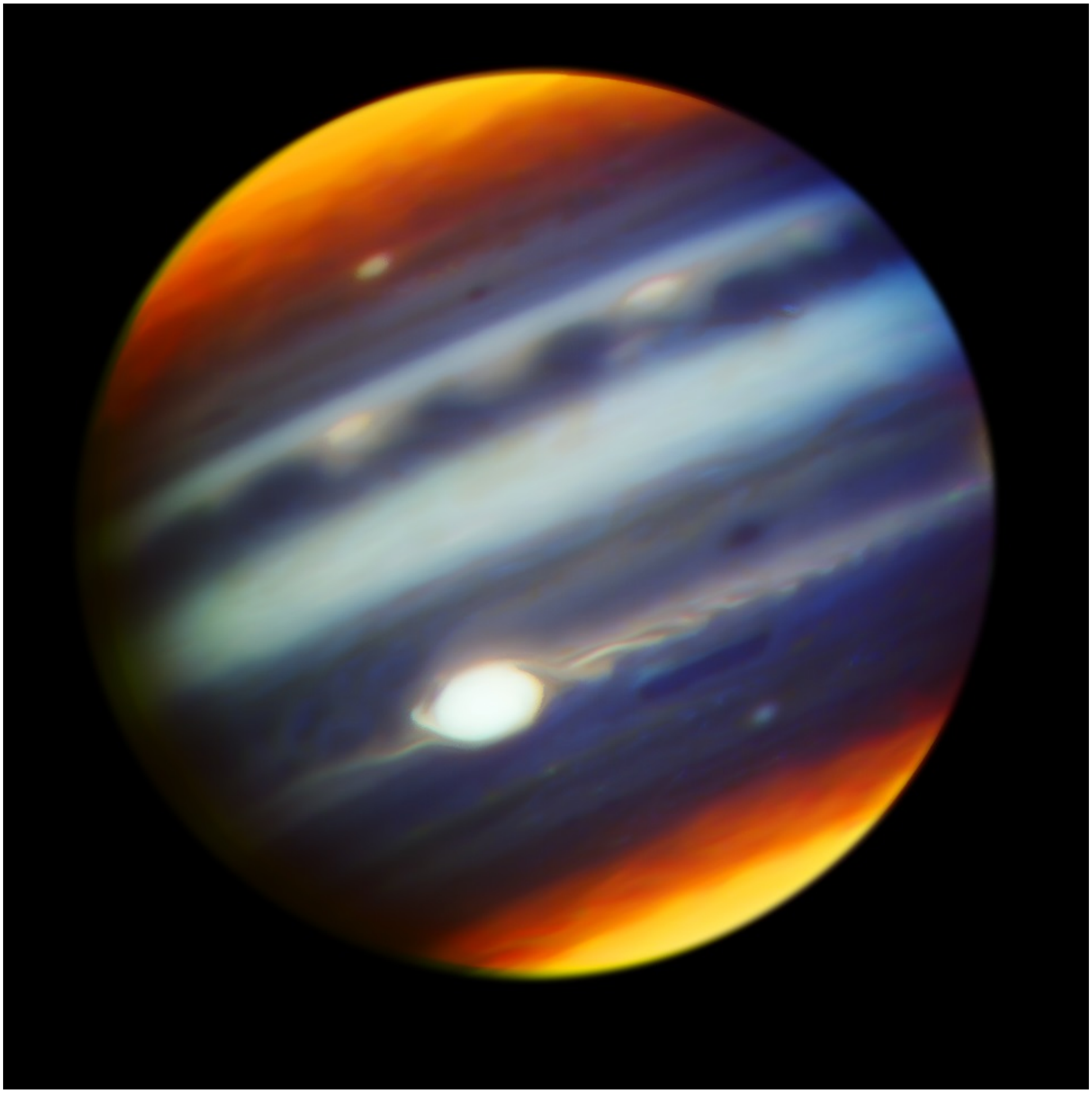

Figure 1. A composite color infrared image of Jupiter reveals haze particles over a range of altitudes, as seen in reflected sunlight. The image was taken using the Gemini North telescope with the Near-InfraRed Imager (NIRI) on May 18, 2017, one day before the Juno mission's sixth close passage ("perijove") of the planet. The color filters cover wavelengths between 1.69 to 2.275 microns and are sensitive to pressures of 10 millibars to 2 bars. The Great Red Spot (GRS) appears as the brightest (white) region at these wavelengths, which are primarily sensitive to high-altitude clouds and hazes near and above the top of Jupiter's convective region – revealing that the GRS is one of the highest-altitude features in Jupiter's atmosphere. The features that appear yellow/orange at Jupiter's poles arise from the reflection of sunlight from high-altitude hazes that are the products of auroral-related chemistry in the planet's upper stratosphere. Narrow spiral streaks that appear to lead into it or out of it from surrounding regions probably represent atmospheric features being stretched by the intense winds within the GRS, such as the hook-like structure on its western edge (left side). Some are being swept off its eastern edge (right side) and into an extensive wave-like flow pattern; and there is even a trace of flow from its north. Other features near the GRS include the dark block and dark oval to the south and the north of the eastern flow pattern, respectively, indicating a lower density of cloud and haze particles in those locations. Both are long-lived cyclonic circulations, rotating clockwise - in the opposite direction as the counterclockwise rotation of the GRS. A prominent wave pattern is evident north of the equator, along with two bright ovals; these are anticyclones that appeared in January. Both the wave pattern and the ovals may be associated with an impressive upsurge in stormy activity that has been observed in these latitudes this year. Another bright anticyclonic oval is seen further north. Juno may pass over these ovals during its July 11 closest approach. High hazes are evident over both polar regions with much spatial structure that has never been seen quite so clearly in ground-based images, with substantial variability in their spatial structure. The central wavelengths and colors assigned to the filters are:1.69 microns (blue), 2.045 microns (cyan), 2.169 microns (green), 2.124 microns (yellow), and 2.275 microns (red). Credit: Gemini Observatory/AURA/NSF/JPL-Caltech/NASA

Very detailed Gemini Observatory images peel back Jupiter's atmospheric layers to support the NASA/JPL Juno spacecraft in its quest to understand the giant planet's atmosphere.

High-resolution imaging of Jupiter by the Gemini North telescope on Maunakea is informing the Juno mission of compelling events in Jupiter's atmosphere. "The Gemini observations, spanning most of the first half of this year, have already revealed a treasure-trove of fascinating events in Jupiter's atmosphere," said Glenn Orton, PI for this Gemini adaptive optics investigation and coordinator for Earth-based observations supporting the Juno project at Caltech's Jet Propulsion Laboratory.

"Back in May, Gemini zoomed in on intriguing features in and around Jupiter's Great Red Spot: including a swirling structure on the inside of the spot, a curious hook-like cloud feature on its western side and a lengthy, fine-structured wave extending off from its eastern side," adds Orton. "Events like this show that there's still much to learn about Jupiter's atmosphere – the combination of Earth-based and spacecraft observations is a powerful one-two punch in exploring Jupiter."

Juno has now made five close-up passes of Jupiter's atmosphere, the first of which was on August 27, 2016, and the latest (the sixth) on May 19th of this year. Each of these close passes has provided Juno's science team with surprises, and the Juno science return has benefited from a coordinated campaign of Earth-based support – including observations from spacecraft orbiting the Earth (covering X-ray through visible wavelengths) and ground-based observatories (covering near-infrared through radio wavelengths).

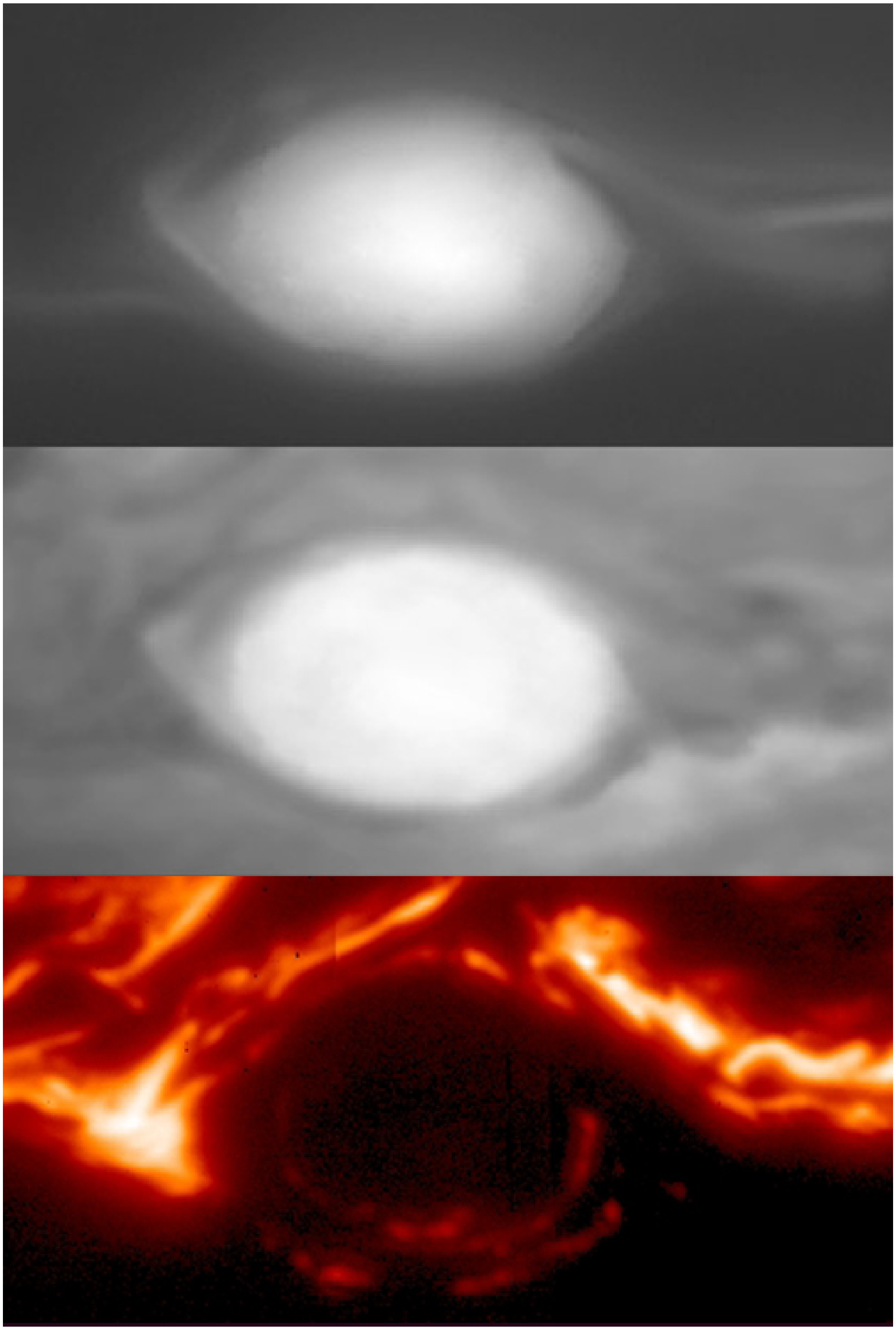

Figure 2. Close up images of the Great Red Spot from Gemini Near-InfraRed Imager (NIRI) images showing differences in the interior structure of this giant

vortex with altitude. The top image was taken with a filter at 2.275 microns that is sensitive to particles at, and above, pressures of about 10 millibars (about 1% of the pressure at sea level on the Earth) in Jupiter's lower stratosphere. It shows that particles at this level tend to increase toward the center of this gigantic vortex. The middle image was taken with a filter at 1.58 microns, sensitive to virtually no gaseous absorption, and is sensitive to the brightness of clouds, very similar to visible red light. Subtle oval-shaped banded structure going from the outside to the interior can be spotted in the image. The difference between these two images illustrates major differences in the dynamics of this vortex with altitude. The bottom image was taken with a filter at 4.68 microns, and shows bright thermal emission from the deeper atmosphere wherever there is "clear sky" (low cloud opacity in the 0.5-3 bar range). Top two panels show data from May 18, 2017, while the bottom panel shows data from January 11, 2017. Credit: Gemini Observatory/AURA/NSF/JPL-Caltech/NASA/UC Berkeley

Next up: Juno's close passages to Jupiter on July 11, 2017. "Gemini observations, which are already underway for the July flyby, are helping to guide our plans for this passage," said Orton. He adds that the types of light Gemini captures provide a powerful glimpse into the layers of Jupiter's atmosphere and provides a 3-dimensional view into Jupiter's clouds. Among the questions Juno is investigating include poorly understood planetary-scale atmospheric waves south of the equator. "We aren't sure if these waves might be seen at higher latitudes," said Orton. "If so it might help us understand phenomena in Jupiter's circulation that are quite puzzling."

"Wow – more remarkable images from the adaptive optics system at Gemini!" said Chris Davis, Program Officer for Gemini at the National Science Foundation (NSF), one of five agencies that operate the observatory. "It's great to see this powerful combination of ground and space-based observations, and the two agencies, NSF and NASA, working together on such scientifically important discoveries."

The Gemini observations use special filters that focus on specific colors of light that can penetrate the upper atmosphere and clouds of Jupiter. These images are sensitive to increasing absorption by mixtures of methane and hydrogen gas in Jupiter's atmosphere. "The Gemini images provide vertical sensitivity from Jupiter's cloud tops up to the planet's lower stratosphere," according to Orton.

The observations also employ adaptive optics technology to significantly remove distortions due to the turbulence in the Earth's atmosphere and produce these extremely high-resolution images. Specifically, the detail visible in these images of Jupiter is comparable to being able to see a feature about the size of Ireland from Jupiter's current distance of about 600 million kilometers (365 million miles) from Earth.

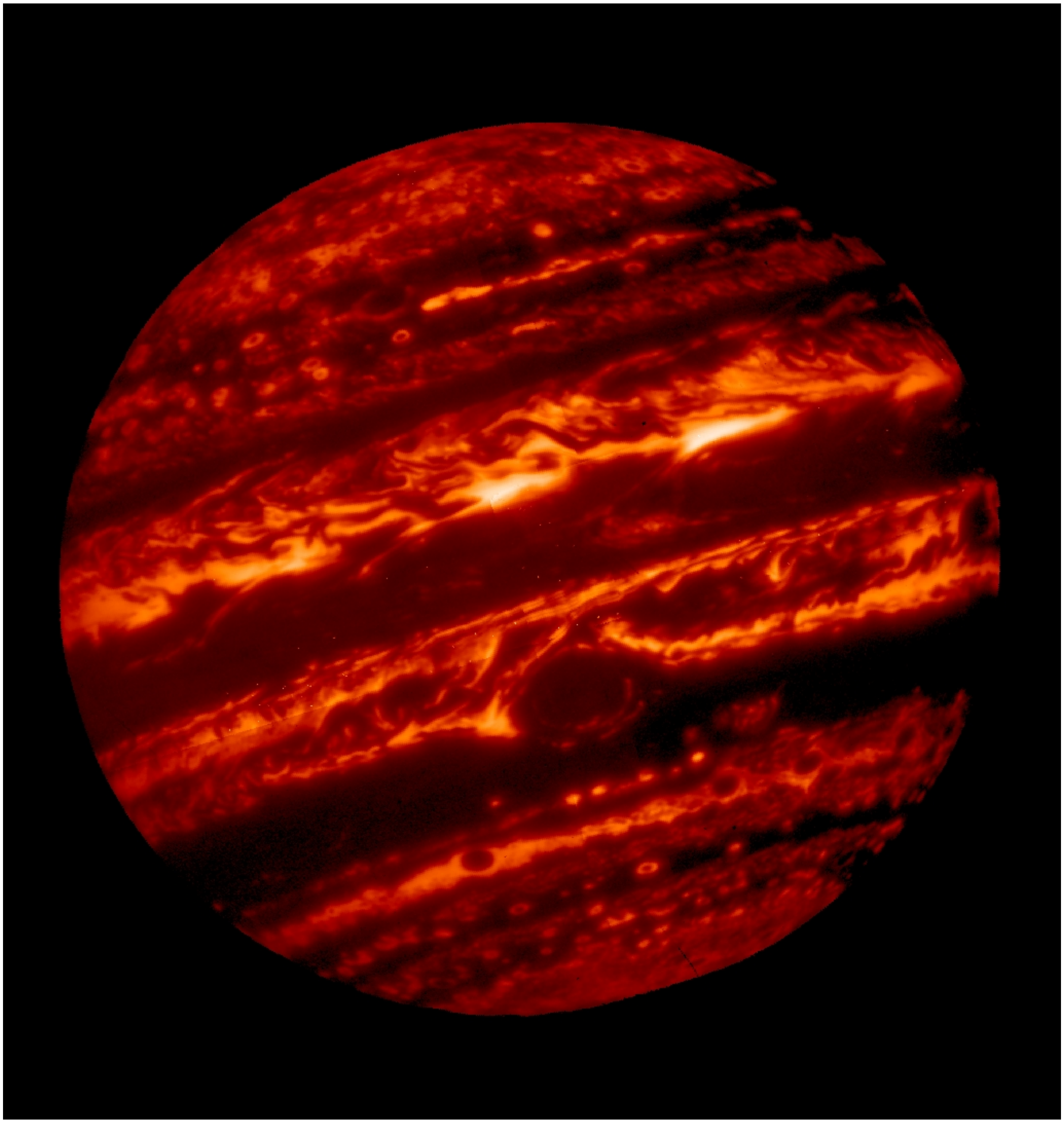

Figure 3. At longer infrared wavelengths, Jupiter glows with thermal (heat) emission. In dark areas of this 4.8-micron image, thick clouds block the emission from the deeper atmosphere. The Great Red Spot is visible just below center. This image, obtained with the Gemini North telescope's Near-InfraRed Imager (NIRI), was obtained on January 11, 2017, so the relative positions of discrete features have changed with respect to the near-infrared image in Figure 1. Credit: Gemini Observatory/AURA/NSF/UC Berkeley

In addition to images using adaptive-optics technology, a parallel Gemini program headed by Michael Wong of the University of California, Berkeley, used a longer-wavelength filter, for which adaptive optics is not needed. To obtain these data several images were made with short exposures, and the sharpest images were combined in processing - an approach commonly called "lucky imaging." Images obtained with this filter are mainly sensitive to cloud opacity (blocks light) in the pressure range of 0.5 to 3 atmospheres. "These observations trace vertical flows that cannot be measured any other way, illuminating the weather, climate and general circulation in Jupiter's atmosphere," notes Wong. This image is shown in Figure 3.

Subaru Telescope also supplied simultaneous mid-infrared imaging with its COMICS instrument – measuring the planet's heat output in a spectral region not covered by Juno's instrumentation, and producing data on composition and cloud structure that complement both the Juno and Gemini observations. For example, they show a very cold interior to the Great Red Spot that is surrounded by a warm region at its periphery, implying upwelling air in the center that is surrounded by subsidence. They also show a very turbulent region to the northwest of the Great Red Spot. The Subaru image is available at: juno.html" target="_blank">phys.org/news/2017-06-mid-infr … e-juno.html .

The NASA Juno spacecraft was launched in August 2011 and began orbiting Jupiter in early July 2016. A primary goal of the mission is to improve our understanding of Jupiter – from its atmospheric properties to our understanding of how Jupiter and other planets in the outer Solar System formed. Juno's payload of nine instruments can probe the atmospheric composition, temperature, cloud dynamics as well as the properties of Jupiter's intense magnetic fields and aurora.

Gemini's near-infrared images are particularly helpful to Juno's Jupiter Infrared Auroral Mapper (JIRAM). JIRAM takes images at 3.5 and 4.8 microns and moderate-resolution spectra at 2–5 microns. The Gemini images provide a high-resolution spatial context for JIRAM's spectroscopic observations and cover wavelengths and regions of the planet not observed by JIRAM. They also place an upper-atmospheric constraint on Jupiter's circulation in the deep atmosphere determined by Juno's Microwave Radiometer (MWR) experiment.

Provided by Gemini Observatory