James Webb Space Telescope detects outgassing water from main-belt comet

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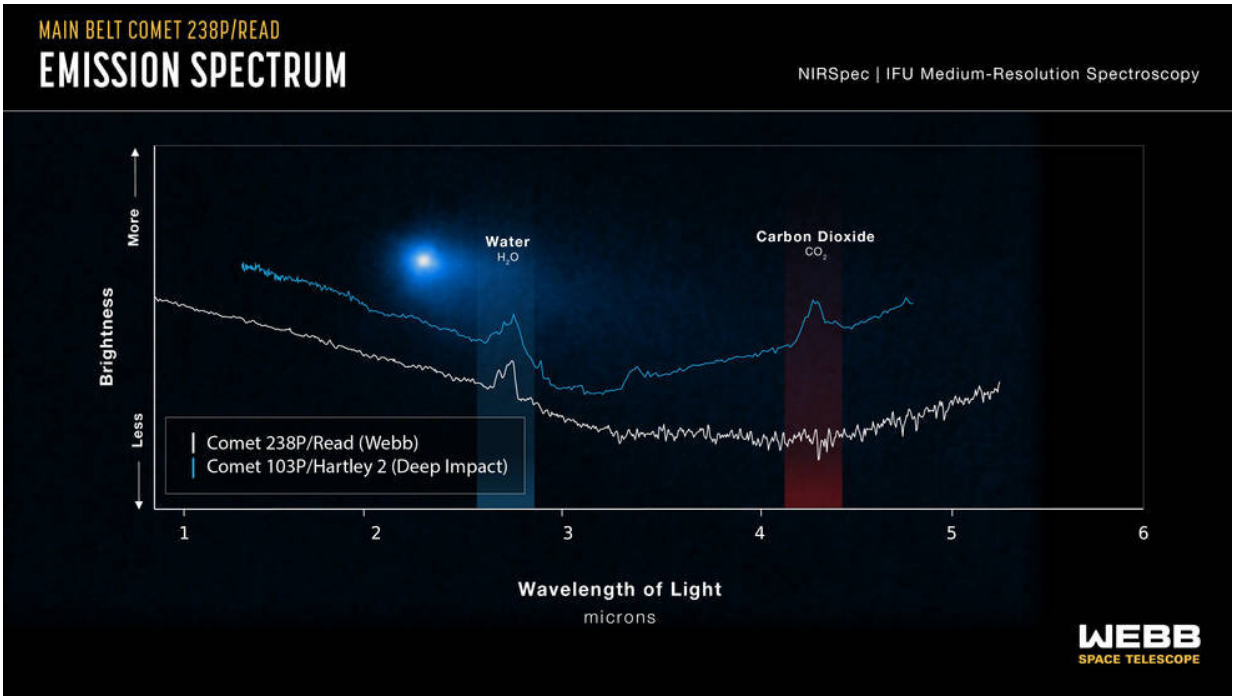


This graphic presentation of spectral data highlights a key similarity and difference between observations of Comet 238P/Read by the NIRSpec (Near-Infrared Spectrograph) instrument on NASA's James Webb Space Telescope in 2022 and observations of Comet 103P/Hartley 2 by NASA's Deep Impact mission in 2010. Both show a distinct peak in the region of the spectrum associated with water. Finding this in Comet Read was a significant accomplishment for Webb, as it is in a different class of comets than Jupiter-family comets like Hartley 2, and this marks the first time that a gas has been confirmed in such a main belt comet. However, Comet Read did not show the characteristic, expected bump indicating the presence of carbon dioxide. Credit: NASA, ESA, CSA, and J. Olmsted (STScI)

After 15 years of attempts, researchers using the James Webb Space Telescope (JWST) have for the first time successfully detected water outgassing from a main-belt comet.

A recently published *Nature* paper "Direct detection of water from a main-belt comet with JWST" led by Michael Kelley of the University of Maryland reports the first direct spectroscopic detection of water outgassing from a main-belt comet named Comet Read. Planetary Science Institute Senior Scientist Henry Hsieh is a co-author on the paper.

Main-belt comets are a rare sub-class of comets that have mostly circular orbits entirely confined to the main asteroid belt between the orbits of Mars and Jupiter, but show comet-like behavior—ejecting material that creates a fuzzy appearance and often tails—that astronomers believe is produced by sublimation—or the transition of ice directly to gas—of icy material.

Only dust has ever been detected being ejected by main-belt comets though, despite many attempts to detect escaping gases that should also accompany sublimation-powered cometary activity. Most main-belt asteroids are not expected to have much ice, given their location in the warm inner solar system where they are thought to have resided for billions of years.

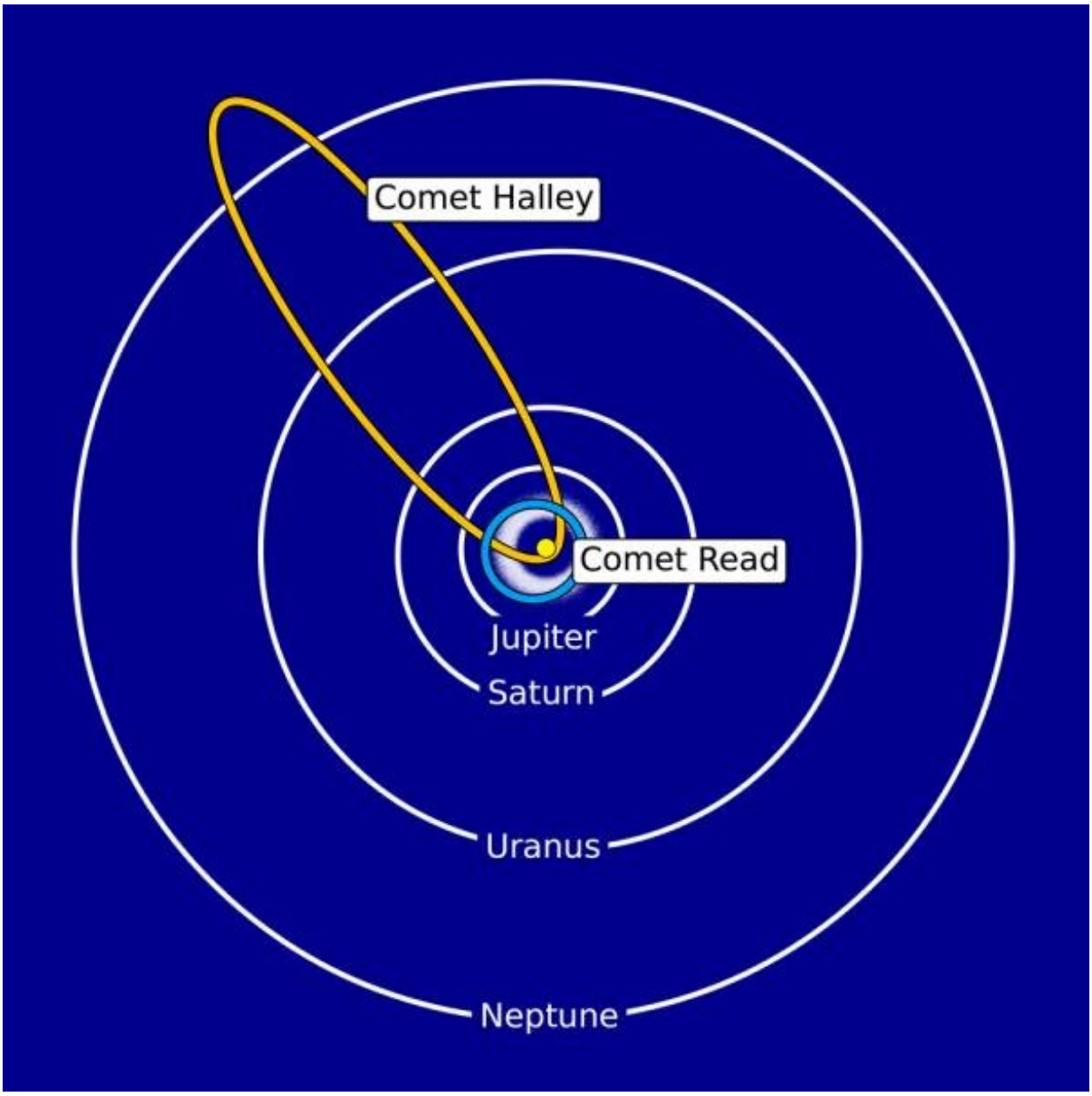


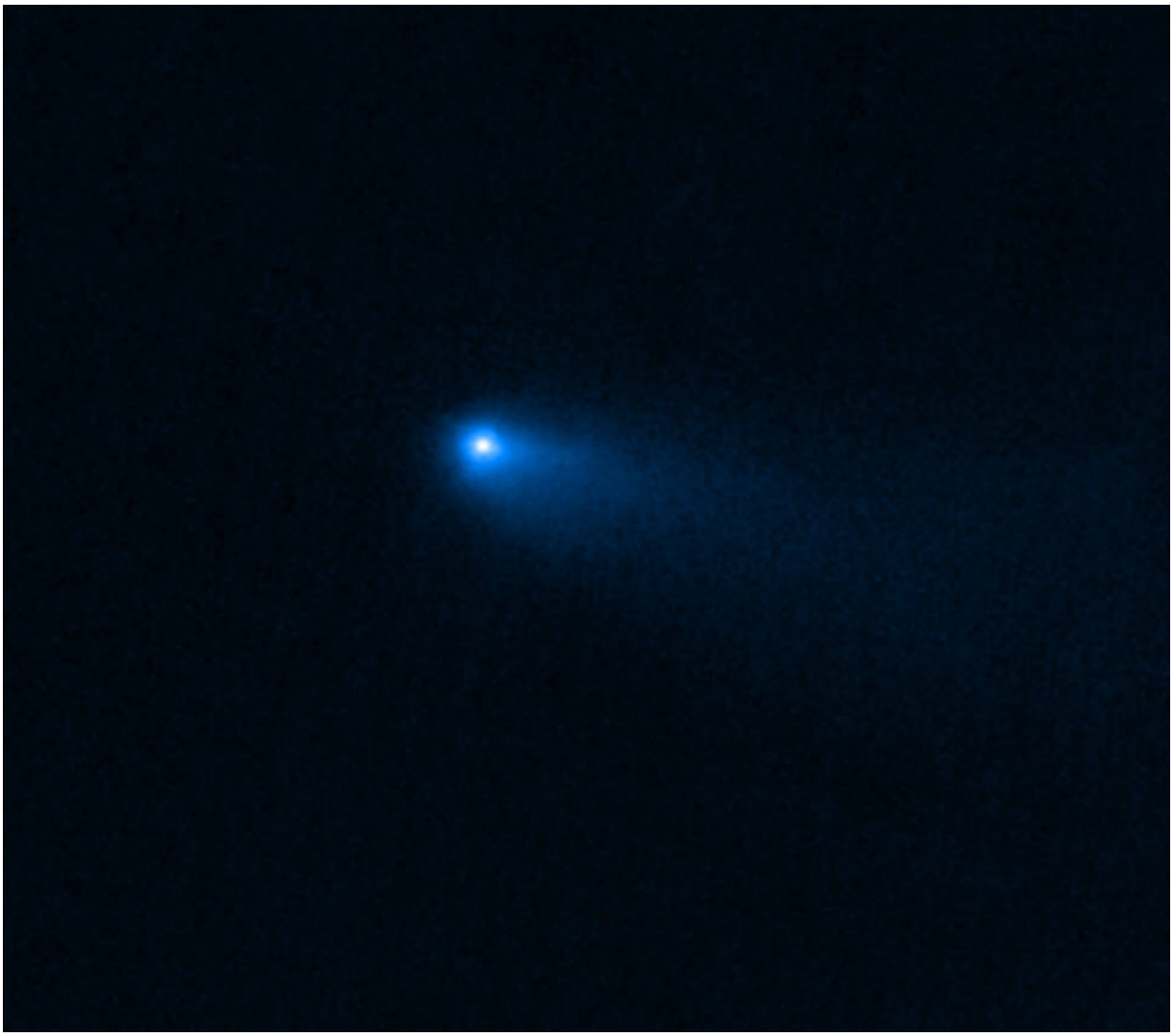
Diagram showing the orbit of Comet Read along with the main asteroid belt (shown as a white fuzzy ring at the center of the image) and the orbits of Jupiter, Saturn, Uranus, and Neptune, and Comet Halley for comparison, showing how "traditional" comets like Comet Halley spend much more time far from the Sun in the cold outer Solar System than main-belt comets like Comet Read, whose orbits keep them much closer to the Sun and therefore in a much warmer environment all the time. Credit: Henry Hsieh (Planetary Science Institute).

For comparison, most other comets that display activity caused by sublimation spend large portions of their time in the cold outer solar system on highly elongated orbits that only occasionally pass through the inner solar system. Given these considerations, doubts have persisted about whether main-belt comets could really be icy. Until now.

"Since the discovery of main-belt comets, we have collected a substantial body of evidence that their activity is produced by sublimation, but until now, it has all been indirect. This new result from JWST represents the first direct evidence of sublimation in the form of water outgassing—or outgassing of any kind—from a main-belt comet, following studies dating back to 2008 to detect outgassing in main-belt comets using some of the biggest ground-based telescopes in the world," explained Hsieh, who led the discovery of main-belt comets as a new kind of comet in 2006.

In the paper, Hsieh and his colleagues further find that Comet Read, and therefore possibly other main-belt comets as well, has a fundamentally different chemical composition from other comets, showing almost no carbon dioxide, a common component of cometary outgassing, relative to the amount of water found. Whether it experienced different formation circumstances or evolutionary history,

Comet Read is unlikely to be a recent asteroid belt interloper from the outer solar system. Based on these results, main-belt comets appear to represent a sample of volatile material that is currently unrepresented in observations of classical comets and the meteoritic record, making them important for understanding the early solar system's volatile inventory and its subsequent evolution.



This image of Comet 238P/Read was captured by the NIRCam (Near-Infrared Camera) instrument on NASA's James Webb Space Telescope on September 8, 2022. It displays the hazy halo, called the coma, and tail that are characteristic of comets, as opposed to asteroids. The dusty coma and tail result from the vaporization of ices as the Sun warms the main body of the comet. Credit: NASA, ESA, CSA, M. Kelley (University of Maryland). Image processing: H. Hsieh (Planetary Science Institute), A. Pagan (STScI)

"Because substantial water ice—which is a major component of the

volatile material that typically produces activity in 'classical' comets from the outer solar system—is unexpected in main-belt asteroids given how close to the sun they are, there has always been some doubt about whether main-belt comet activity is produced by water ice sublimation rather than some other process that doesn't involve ice, such as impacts or material being flung into space by fast-spinning asteroids," Hsieh said.

"Water in main-belt comets is important because objects from the main asteroid belt have been proposed as a potential source of Earth's water in the early solar system, where the modern day main-belt comets appear to provide an opportunity to test this hypothesis. This only works though if they do in fact contain water ice. The confirmation of water outgassing in at least one main-belt comet confirms that learning about the origin of Earth's water from main-belt comets is a viable possibility," Hsieh said.

The team used JWST to observe Read shortly after its close approach to the sun, when outgassing was expected to be at its strongest, taking both imaging and spectroscopic observations at near-infrared wavelengths in order to search for characteristic spectroscopic features of water vapor and other common gases produced by cometary sublimation.

More information: Kelley, M.S.P. et al. Spectroscopic identification of water emission from a main-belt comet. *Nature* (2023). DOI: 10.1038/s41586-023-06152-y
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