Webb helps scientists better understand solar system's origins

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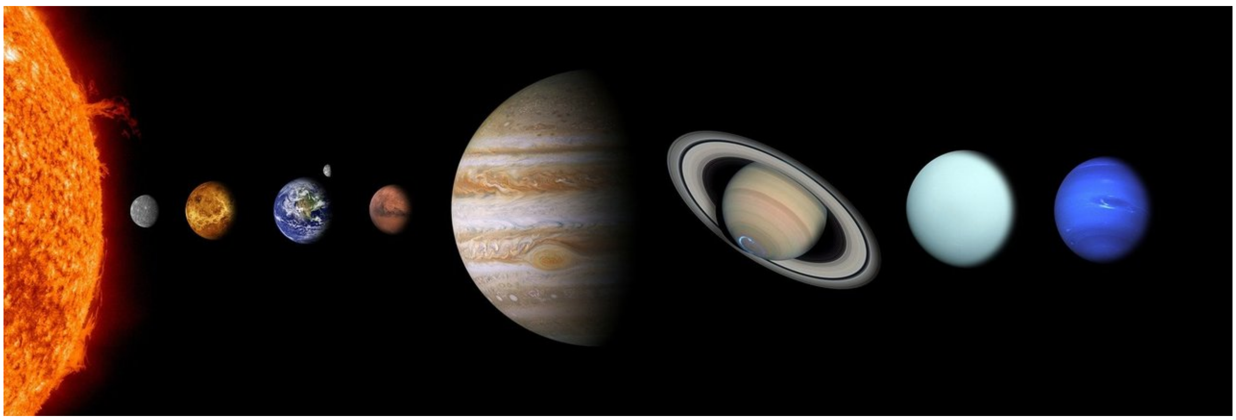

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University of Central Florida (UCF) scientists and their collaborators discovered new insights into the formation of distant icy objects in space beyond Neptune, offering a deeper understanding of our solar system's formation and growth.

Using the James Webb Space Telescope (JWST), scientists analyzed far-away bodies—known as Trans-Neptunian Objects (TNOs)—and found varying traces of methanol. The discoveries are helping them better classify different TNOs and understand the complex chemical reactions in space that may relate to the formation of our solar system and the origin of life.

The findings, published in *The Astronomical Journal Letters*, reveal two distinct groups of TNOs with surface ice methanol presence: one with a depleted amount of surface methanol and a large reservoir beneath the surface, and another—furthest from the sun—with an overall weaker methanol presence.

The study suggests that cosmic irradiation over billions of years may have played a role in the first group's varying methanol distribution, while raising new questions about the second group's muted signatures.

Reaching back in time and space

TNOs are important to our understanding of our solar system's origins because they are incredibly well-preserved remnants of the protoplanetary disk—or disk of gas and dust surrounding a young star such as the sun—and can give scientists a thorough glimpse into the past.

UCF Department of Physics Research Professor Noemí Pinilla-Alonso, who now works at the University of Oviedo in Spain, co-led the research as part of the UCF-led Discovering the Surface Compositions of Trans-Neptunian Objects (DiSCo) program which includes UCF Florida Space Institute (FSI) Associate Professor Ana Carolina de Souza-Feliciano.

Pinilla-Alonso says the research helps piece together the history of the solar system's chemistry and gain insights into exoplanets, where methanol and methane play a crucial role in shaping atmospheres and hinting at the conditions of potentially habitable worlds.

"Methanol, a simple alcohol, has been found on comets and distant TNOs, hinting that it may be a primitive ingredient inherited from the early days of our solar system—or even from interstellar space," Pinilla-Alonso says.

"But methanol is more than just a leftover from the past. When exposed to radiation, it transforms into new compounds, acting as a chemical time capsule that reveals how these icy worlds have evolved over billions of years."

Methanol ice is a key precursor that may lead to organic molecules such as sugars, and its discovery in TNOs paves the way for so much more, she says.

These spectral differences reveal that not all TNOs formed from the same molecular ingredients, Pinilla-Alonso says. Instead, their compositions reflect their origins—where and how they formed—and their transformations over time.

"What excited me the most was realizing that these differences were linked to the behavior of methanol—a key ingredient that had long been elusive on TNOs from Earth-based observations," she says. "Our findings suggest that methanol is being destroyed on the surface of TNOs by irradiation, but remains more abundant in the subsurface, protected from this exposure."

Pinilla-Alonso worked alongside UCF FSI researchers, including de Souza-Feliciano, who synthesized the laboratory data with modeling to better explain the behavior of methanol.

De Souza-Feliciano helped to better visualize the findings by reproducing some of the spectral features the scientists were seeing and therefore could give mathematical support for the data in the study.

"One of the biggest surprises came from the methanol behavior," de Souza-Feliciano says. "From laboratory data, its signatures at shorter wavelengths differ from the fundamental ones in longer wavelengths."

De Souza-Feliciano collaborated on prior DiSCo research projects using JWST that characterized binary objects and other distant TNOs.

"The main DiSCo paper addressed the main characteristics of the three groups of TNOs," she says. "This paper goes into detail about one of them, known as the cliff group, which is the nickname for the spectral group where the reflectance did not increase after approximately 3.3 microns."

Not only are these cliff group TNOs time capsules for our solar system, but the group houses cold-classical TNOs which have largely stayed in place since their formation, de Souza-Feliciano says.

"One of the reasons why this group is a key for the outer solar system understanding is [because] it contains all the cold-classical TNOs," she says. "The cold-classical TNOs are the only dynamic group that probably stayed in the place where they formed from the formation of the solar system to today."

Rosario Brunetto, an astronomer at the Université Paris-Saclay, led the research with fellow scientists Elsa Hénault and Sasha Cryan.

He says he believes this collaborative discovery will provide foundational knowledge of our solar system and ignite interest in planetary science.

"This discovery not only reshapes our understanding of TNOs but also provides a crucial reference for interpreting JWST's observations of other distant objects, such as Neptune Trojans, Centaurs and asteroids, as well as for future missions exploring the outer solar system," Brunetto says.

"Beyond its scientific significance, the search for methanol in the solar system also fuels curiosity and inspires new generations to explore the cosmos and understand the chemical evolutions in space."

UCF FSI Assistant Scientist Charles Schambeau and UCF physics graduate student Brittany Harvison also contributed to the research.

More information: R. Brunetto et al, Spectral Diversity of DiSCo's TNOs Revealed by JWST: Early Sculpting and Late Irradiation, *The Astrophysical Journal Letters* (2025). DOI: 10.3847/2041-8213/adb977

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