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Webb Finds Primordial Interstellar Ice Older Than the Star Beta Pictoris

Environment * Climate Change * Atmospheric Physics

Using the James Webb Space Telescope (JWST), astronomers have found frozen water and carbon dioxide in the dusty debris disk around the young star Beta Pictoris that appears older than the star itself. Led by Space Telescope Science Institute astronomer Sarah Betti and published in Science , the study shows that delicate, glass-like ices formed in the cold dark clouds of interstellar space can survive the violent birth of a star and its surrounding planetary system.

Beta Pictoris is a bright, roughly 20-million-year-old star located about 64 light-years from Earth. It is surrounded by a vast debris disk -- a wide ring of dust, rock, and icy fragments left over from planet formation. Because Beta Pictoris is so young, its disk offers astronomers a direct look at the raw building blocks available to growing planets and comets.

What JWST Saw Inside the Debris Disk

To read the chemical fingerprint of the disk, the team used JWST's Near-Infrared Spectrograph (NIRSpec), an instrument that splits infrared light into a detailed spectrum. Molecules in space absorb specific wavelengths of light, allowing astronomers to identify both what substances are present and how their molecules are arranged.

The spectra revealed both water ice (H 2 O) and carbon dioxide ice (CO 2) locked inside the outer debris disk. More importantly, the observations showed that the water ice is almost entirely amorphous -- meaning its molecules are frozen in a disordered, glassy state rather than the neat, repeating crystal lattice found in ordinary freezer ice or snowflakes. Crystalline water ice accounted for less than 7 percent of the detected water ice.

| Observation Parameter | | Measured Value / Finding | | Scientific Significance |

| Host Star | | Beta Pictoris (~20 Myr old, ~64 light-years away) | | Young planetary system with an active debris disk |

| Instrument | | JWST Near-Infrared Spectrograph (NIRSpec) | | Resolves solid-state molecular absorption bands |

| Water Ice Structure | | >93% amorphous (<7% crystalline) | | Indicates ice never warmed enough to crystallize |

| CO 2 to H 2 O Mix | | ~11% (~1 CO 2 per 10 H 2 O molecules) | | Intimately blended; matches Solar System comets |

Why Glassy Ice Points to an Interstellar Origin

The structure of the ice acts like a cosmic thermometer. When amorphous water ice is warmed above roughly 100 to 140 kelvin (about minus 173 to minus 133 degrees

Celsius), its molecules gain enough energy to snap into an ordered crystal lattice. Once water ice crystallizes, it cannot revert to an amorphous state unless it is completely vaporized or blasted apart by radiation and re-condensed in extreme cold.

In addition, the carbon dioxide ice in Beta Pictoris is not sitting in separate, pure clumps. Instead, it is thoroughly mixed inside the amorphous water-ice matrix at a ratio of roughly one CO 2 molecule for every ten water molecules -- about 11 percent. That intimate blend closely matches the composition of comets in our own Solar System and icy dust grains measured in cold interstellar clouds before stars even ignite.

Implications for Comets and Water-Rich Worlds

Together, the high fraction of amorphous water ice and its comet -like mixture with carbon dioxide indicate that these ices stayed frozen through the collapse of the molecular cloud that birthed Beta Pictoris. Rather than being melted and rebuilt from scratch inside the young planetary disk, primordial interstellar ices were inherited directly by the planetesimals and icy bodies orbiting the star today.

For planetary science , the result suggests that the chemical ingredients needed to build icy comets -- and potentially deliver water and carbon-bearing compounds to rocky planets -- are surprisingly durable. If primordial ices can survive star formation intact around Beta Pictoris, similar inherited reservoirs may be common across young planetary systems throughout the Milky Way .

References & Primary Sources

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