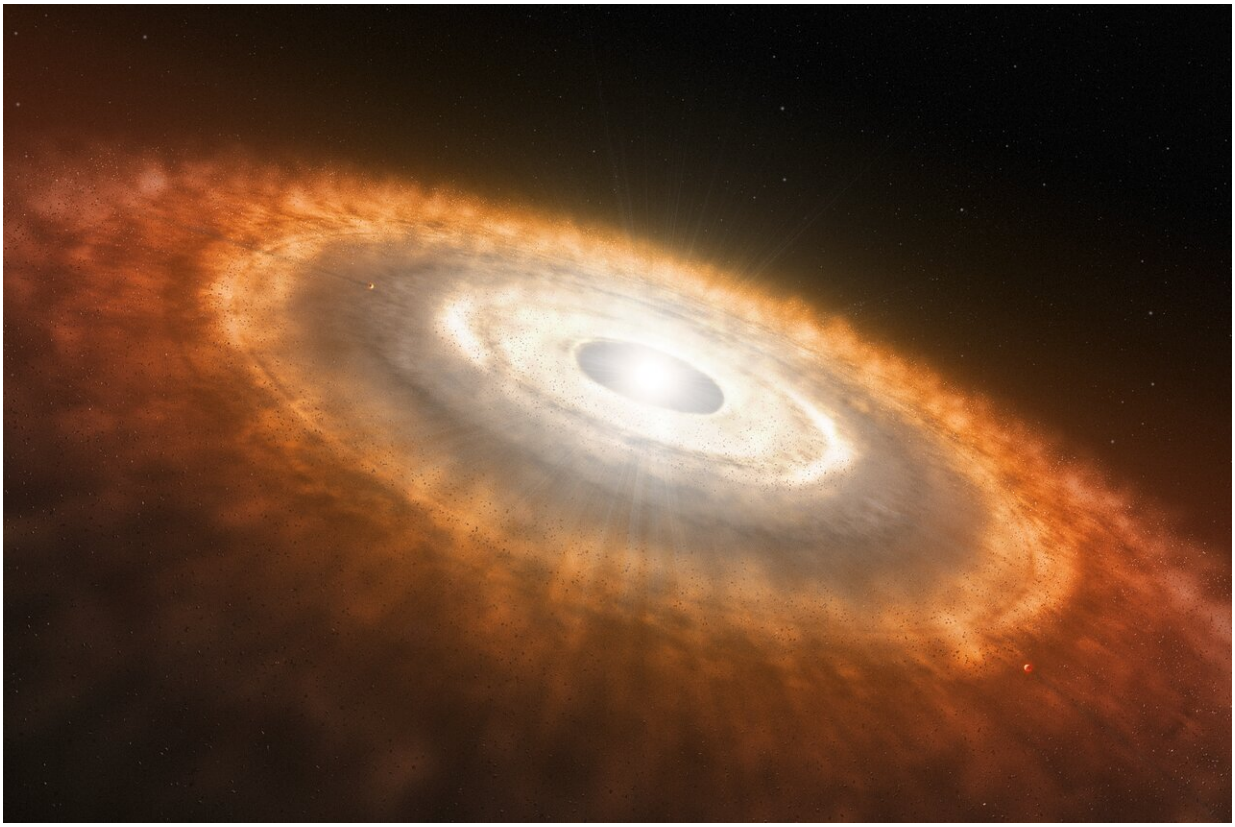
Webb study reveals rocky planets can form in extreme environments

November 30 2023



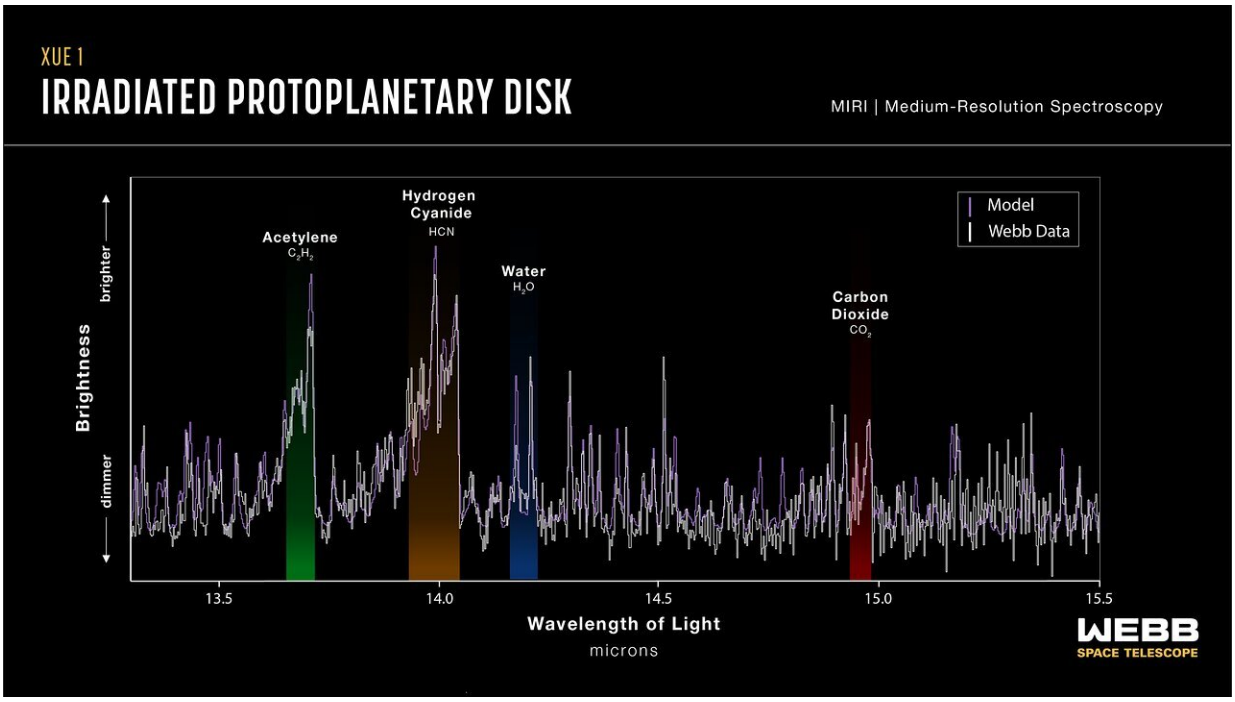
Artist's impression of a young star surrounded by a protoplanetary disk in which planets are forming. Credit: ESO/L. Calçada

An international team of astronomers have used the NASA/ESA/CSA James Webb Space Telescope to provide the first observation of water

and other molecules in the inner, rocky-planet-forming regions of a disk in one of the most extreme environments in our galaxy. These results suggest that the conditions for rocky-planet formation, typically found in the disks of low-mass star-forming regions, can also occur in massive-star-forming regions and possibly a broader range of environments.

These are the first results from the eXtreme UV Environments (XUE) James Webb Space Telescope program, which focuses on the characterization of planet-forming disk in massive-star-forming regions. These regions are likely representative of the environment in which most planetary systems formed. Understanding the impact of environment on planet formation is important for scientists to gain insights into the diversity of the observed exoplanet populations.

The XUE program targets a total of 15 disks in three areas of the Lobster Nebula (also known as NGC 6357), a large emission nebula roughly 5,500 light-years away from Earth in the constellation Scorpius. The Lobster Nebula is one of the youngest and closest massive star formation complexes, and is host to some of the most massive stars in our galaxy.



Protoplanetary disc XUE 1 (MIRI emission spectrum: 13.3–15.5 microns). Credit: European Space Agency

Massive stars are hotter, and therefore emit more ultraviolet (UV) radiation. This can disperse the gas, making the expected disk lifetime as short as a million years. Thanks to Webb, astronomers can now study the effect of UV radiation on the inner rocky-planet-forming regions of protoplanetary disks around stars like our sun.

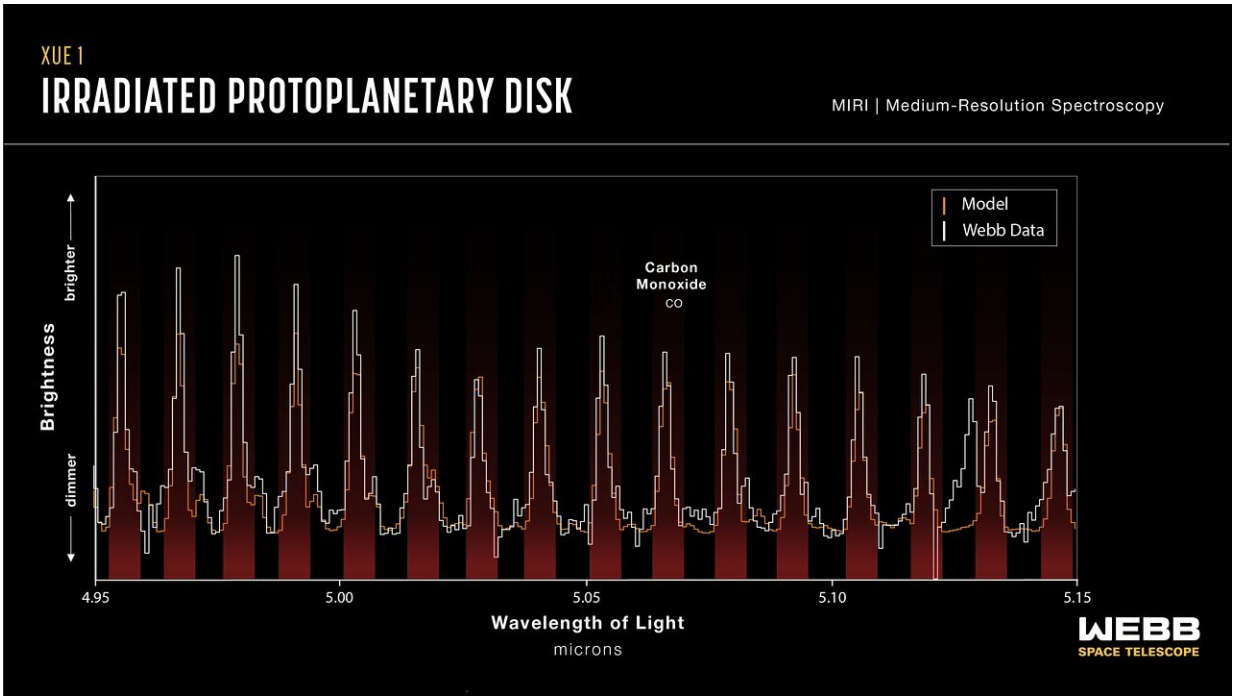
"Webb is the only telescope with the spatial resolution and sensitivity to study planet-forming disks in massive-star-forming regions," said team lead María Claudia Ramírez-Tannus of the Max Planck Institute for Astronomy in Germany.

Astronomers aim to characterize the physical properties and chemical composition of the rocky-planet-forming regions of disks in the Lobster

Nebula using Webb's Medium Resolution Spectrometer (MRS) of the Mid-InfraRed Instrument (MIRI). This first result focuses on the protoplanetary disk termed XUE 1, which is located in the star cluster Pismis 24.

"Only the MIRI wavelength range and spectral resolution allow us to probe the molecular inventory and physical conditions of the warm gas and dust where rocky planets form," said team member Arjan Bik of Stockholm University in Sweden.

Because of its location near several massive stars in NGC6357, scientists expect XUE 1 to have been constantly exposed to a high ultraviolet radiation field throughout its life. However, in this extreme environment the team still detected a range of molecules that are the building blocks of rocky planets.



Protoplanetary disc XUE 1 (MIRI emission spectrum: 4.95–5.15 microns).

Credit: European Space Agency

"We find that the inner disk around XUE 1 is remarkably similar to those in nearby star-forming regions," said team member Rens Waters of Radboud University in the Netherlands. "We've detected water and other molecules like carbon monoxide, carbon dioxide, hydrogen cyanide and acetylene. However, the emission found was weaker than some models predicted. This might imply a small outer disk radius."

"We were surprised and excited because this is the first time that these molecules have been detected under such extreme conditions," added Lars Cuijpers of Radboud University. The team also found small, partially crystalline silicate dust at the disk's surface. This is considered to be the building blocks of rocky planets.

These results are good news for rocky planet formation, as the science team finds that the conditions in the inner disk resemble those found in the well-studied disks located in nearby star-forming regions, where only low-mass stars form. This suggests that rocky planets can form in a much broader range of environments than previously believed.

The team notes that the remaining observations from the XUE program are crucial to establishing the commonality of these conditions.

"XUE1 shows us that the conditions to form rocky planets are there, so the next step is to check how common that is," says Ramírez-Tannus. "We will observe other disks in the same region to determine the frequency with which these conditions can be observed."

These results have been published in *The Astrophysical Journal Letters*.

More information: María Claudia Ramírez-Tannus et al, XUE: Molecular Inventory in the Inner Region of an Extremely Irradiated Protoplanetary Disk, *The Astrophysical Journal Letters* (2023). DOI: 10.3847/2041-8213/ad03f8

Provided by European Space Agency