NOTA DE PRENSA

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Planet-forming disks around very low-mass stars are different

JWST uncovers a rich diversity of carbon-bearing gases serving as ingredients for planets around very low-mass stars

Using the James Webb Space Telescope, a team of astronomers, including CAB (Centro de Astrobiología INTA-CSIC) scientists, studied the properties of a planet-forming disk around a young and very low-mass star. The results reveal the richest hydrocarbon composition seen to date in a protoplanetary disk, including the first extrasolar detection of ethane and a relatively low abundance of oxygen-bearing species. By including previous similar detections, this finding confirms a trend of disks around very low-mass stars to be chemically distinct from those around more massive stars like the Sun, influencing the atmospheres of planets forming there.

Planets form in disks of gas and dust, orbiting young stars. The MIRI Mid-INfrared Disk Survey (MINDS), led by Thomas Henning from the Max Planck Institute for Astronomy (MPIA) in Heidelberg, Germany, aims to establish a representative disk sample. By exploring their chemistry and physical properties with MIRI (Mid Infrared Instrument) on board the James Webb Space Telescope (JWST), the collaboration links those disks to the properties of planets potentially forming there. In a new study, a team of researchers explored the vicinity of a very low-mass star of 0.11 solar masses (known as ISO-ChaI 147), whose results appear in the journal Science.

JWST opens a new window to the chemistry of planet-forming disks

“These observations are not possible from Earth because the relevant gas emissions are absorbed by its atmosphere,” explained lead author Aditya Arabhavi of the University of Groningen in the Netherlands. “Previously, we could only identify acetylene (C_2H_2) emission from this object. However, JWST’s higher sensitivity and the spectral resolution of its instruments allowed us to detect weak emission from less abundant molecules.”

The MINDS collaboration found gas at temperatures around 300 Kelvin (about 30 degrees Celsius), strongly enriched with carbon-bearing molecules but lacking oxygen-rich species.

One striking example of an oxygen-rich disk is the one of PDS 70, where the MINDS program recently found large amounts of water vapor. Considering earlier observations, astronomers deduce that disks around very low-mass stars evolve differently than those around more massive stars such as the Sun, with potential implications for finding rocky planets with Earth-like characteristics there. Since the environments in such disks set the conditions in which new planets form, any such planet may be rocky but quite unlike Earth in other aspects.

What does it mean for rocky planets orbiting very low-mass stars?

The amount of material and its distribution across those disks limits the number and sizes of planets the disk can supply with the necessary material. Consequently, observations indicate that rocky planets with sizes similar to Earth form more efficiently than Jupiter-like gas giants in the disks around very low-mass stars, the most common stars in the Universe. As a result, very low-mass stars host the majority of terrestrial planets by far.

Although it seems clear that disks around very low-mass stars contain more carbon than oxygen, the mechanism for this imbalance is still unknown. The disk composition is the result of either carbon enrichment or oxygen reduction. If the carbon is enriched, the cause is probably solid particles in the disk, whose carbon is vaporized and released into the gaseous component of the disk. The dust grains, stripped of their original carbon, eventually form rocky planetary bodies. Those planets would be carbon-poor, as is Earth. Still, carbon-based chemistry would likely dominate at least their primary atmospheres provided by disk gas. Therefore, very low-mass stars may not offer the best environments for finding planets akin to Earth.

“It is a very different chemistry to what we are used to see in other more massive discs. There is still a lot of work to be done on this and other low-mass objects to understand it well but it is exciting to think what planets formed in these environments would be like.” adds team member María Morales-Calderón, from the Centro de Astrobiología.

JWST discovers a wealth of organic molecules

To identify the disk gases, the team used MIRI’s spectrograph to decompose the infrared radiation received from the disk into signatures of small wavelength ranges – similar to sunlight being split into a rainbow. This way, the team isolated a wealth of individual signatures attributed to various molecules. As a result, the observed disk contains the richest hydrocarbon chemistry seen to date in a protoplanetary disk, consisting of 13 carbon-bearing molecules up to benzene (C_6H_6). They include the first extrasolar ethane (C_2H_6) detection, the largest fully-saturated hydrocarbon detected outside the Solar System. The team also successfully detected ethylene (C_2H_4), propyne (C_3H_4), and the methyl radical CH_3 for the first time in a protoplanetary disk. In contrast, the data contained no hint of water or carbon monoxide in the disk.

Sharpening the view of disks around very low-mass stars

Next, the science team intends to expand their study to a larger sample of such disks around very low-mass stars to develop their understanding of how common such exotic carbon-rich terrestrial planet-forming regions are.

“Only a comparison with a large sample of objects will allow us to check whether ISO

Cha 147 is an anomalous object or whether, as we hope, nature is once again showing us that there is an extraordinary diversity of planetary systems", explains David Barrado, another CAB researcher involved in the analysis. "Assuming that the Solar System represents a typical planetary system, influenced by an anthropocentric view, has been shown time and again to be a limited approximation to reality. The PLATO satellite, which will be launched in a couple of years and in which the Centro de Astrobiología and INTA, among other Spanish research institutes, play a significant role, will show to what extent Earth-like planets exist in truly analogous conditions," Barrado continues.

About CAB

The Centro de Astrobiología (CAB) is a joint research center of INTA and CSIC. Created in 1999, it was the first center in the world specifically dedicated to astrobiological research and the first non-US center associated with the NASA Astrobiology Institute (NAI), currently NASA Astrobiology Program. It is a multidisciplinary center whose main objective is to study the origin, presence and influence of life in the universe through a transdisciplinary approach. The CAB was distinguished in 2017 by the Ministry of Science and Innovation as a "María de Maeztu" Unit of Excellence.

The CAB has led the development of the REMS, TWINS and MEDA, instruments, operational on Mars since August 2012, November 2018 and February 2021, respectively; as well as the science of the RLS y RAX raman instruments, which will be sent to Mars later this decade as part of the ExoMars mission and to one of its moons in the MMX mission, respectively. It is also developing the SOLID instrument for the search for life in planetary exploration. Likewise, the CAB co-leads together with three other European institutions the
of the PLATO space telescope, and participates in different missions and instruments of great astrobiological relevance, such as MMX, CARMENES, CHEOPS, BepiColombo, DART, Hera, the MIRI and NIRSpec instruments at JWST and the HARMONI instrument at ESO's ELT..

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"A hydrocarbon factory around the very low-mass star ISO-ChaI-147"

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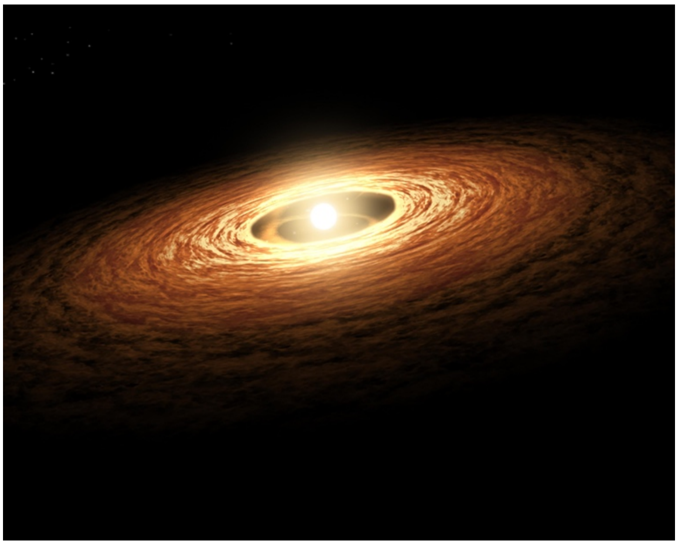
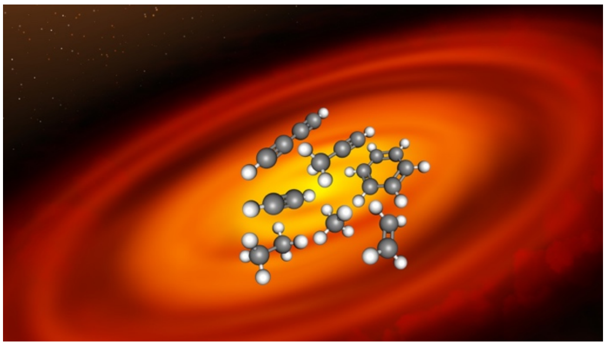
Media:



Artist's impression of a protoplanetary disk around a very low mass star.
Credit: NASA/JPL-Caltech/T. Pyle (SSC) [recortada]. https://www.spitzer.caltech.edu/image/ssc2005-06b-mini-solar-system-in-the-making



Artist's impression of a protoplanetary disk around a very low mass star. Depicts a selection of hydrocarbon molecules (methane, CH_4; ethane, C_2H_6; ethylene, C_2H_2; diacetylene, C_4H_2; propyne, C_3H_4; benzene, C_6H_6) detected in the disk around ISO-Chal 147.
Credit: ALMA (ESO/NAOJ/NRAO) / MPIA.

Credit: The MINDS Collaboration (Copyright is restricted). This is an intentional lowres version to reduce the memory load.

Links
Interactive spectrum: https://scivis.mpia.de/projects/iso_chai_147/https://cloud.cab.inta-csic.es/s/RsTY7JSEdWx8yLy
(not permanent)

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