Peering into the heart of planet formation

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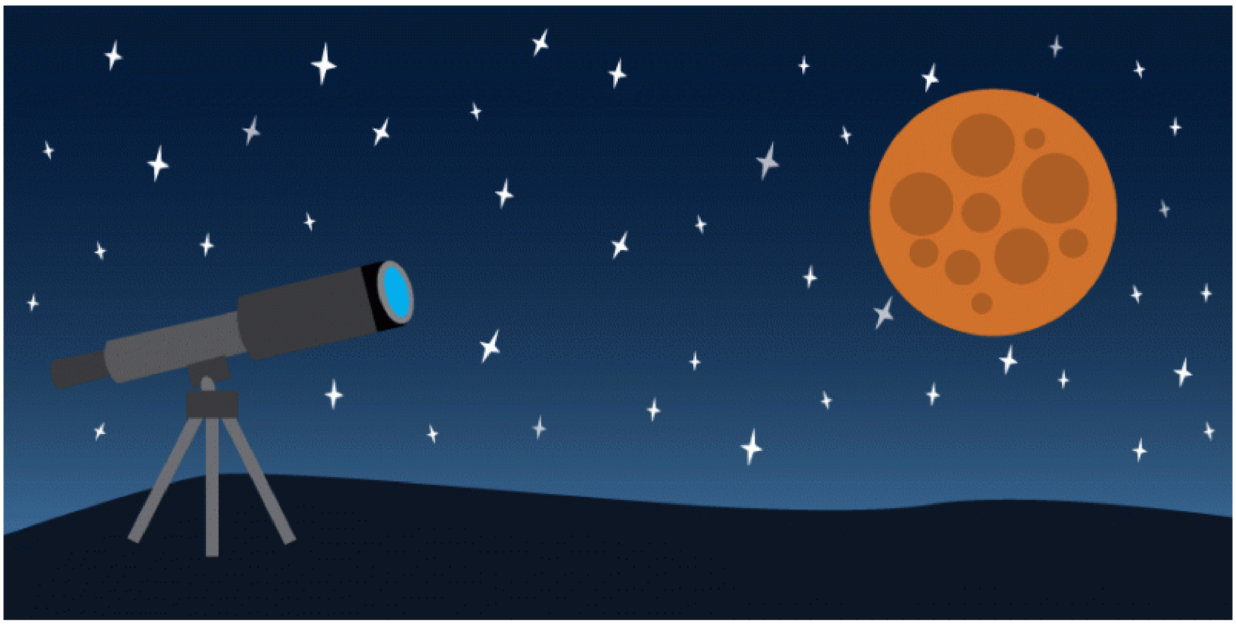

Credit: University of Michigan

For the first time, astronomers have been able to peer into the heart of planet formation, recording the temperature and amount of gas present in the regions most prolific for making planets.

Planets form in flared disks of gas and dust—small particles composed of dust and ice—surrounding young stars. More specifically, planets form in the midplane of this disk, or the middle of the disk viewed edge-on. But until now, astronomers have not been able to observe this midplane because gases in the disk were too opaque.

"We have previously observed disks in the process of making planets but our observations were only scratching the surface," said Edwin Bergin, chair of the U-M department of astronomy. "When we inferred density, temperature and gravitational velocity—what the physics of planet birth are—we weren't sampling the region where planets are being born."

Instead, researchers had to rely on observations made on the surface of the disk. Now, Bergin and his team, which includes postdoctoral fellow Ke Zhang, have developed a method that allows them to peer into that midplane—in this case, a disk about 180 light years away with a star about 0.8 times the mass of our own sun.

To observe temperature and other conditions of planet birth, astronomers could use molecular hydrogen, which is the most abundant molecule in a planet or star-formation region. But molecular hydrogen doesn't emit at the cold temperatures associated with planet births. So the astronomers have to focus on a different molecule that exists alongside molecular hydrogen. They call this different molecule a "tracer molecule"—a proxy to molecular hydrogen. In this paper, the team uses a rare form of carbon monoxide as a tracer molecule.

Their findings show that the millimeter-wavelength light naturally emitted from this rare form of carbon monoxide clearly traces the midplane—revealing for the first time planet formation to our telescopes. In this case, the astronomers' observations relied on the Atacama Large Millimeter/submillimeter Array, an international astronomy facility based in Chile that measures radio wavelengths emitted by molecules in these distant disks.

Based on the distribution of this carbon monoxide, the astronomers were able to calculate how much mass is available at the planet-forming midplane. Using a different rare form of carbon monoxide, the researchers also measured the temperature of the region based on how brightly the molecule was glowing.

"If you want to understand the formation of our solar system and why there are so many different exoplanet systems, we need to understand the midplane," Zhang said. "That is the plane where you have most of the mass concentrated at—that is where the magic happens."

Another key finding of the paper is the first direct measurement of what's called the carbon monoxide snowline. This snowline is the radius at which carbon monoxide freezes in the midplane. Beyond this radius, the heat from the star can no longer keep carbon monoxide as a vapor at the midplane and carbon monoxide freezes as ice onto the surface of dust grains.

Being able to directly observe the midplane snowline is also important in understanding the conditions under which planets form, Zhang says. Carbon monoxide may have a similar role as water in the forming of our own solar system.

"Water, once it condenses, adds a lot of solid mass into the building of a planet core," Zhang said. "Water makes those solids more sticky so they can grow faster. Astronomers suspect the carbon monoxide snowline has a similar impact as the water snowline."

The researchers hope next to use their observations of this disk's snowline to test theories about how snowlines facilitate planet formation in other disks.

"With the capabilities of the Atacama Array and this new technique, astronomers can finally trace planet formation in action," Bergin said. "This is critical information needed to confirm theories of planetary birth, and our mass accounting suggests that planet formation has begun and this disk is well on its way to making new planets."

More information: Ke Zhang et al. Mass inventory of the giant-planet formation zone in a solar nebula analogue, *Nature Astronomy* (2017). [DOI: 10.1038/s41550-017-0130](https://doi.org/10.1038/s41550-017-0130)

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