Peering into the interior of a dark interstellar cloud with the APEX telescope

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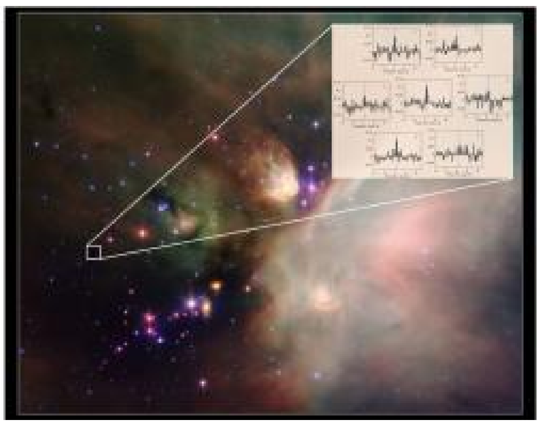

The Rho Ophiuchi dark cloud is a star forming region at a distance of approx. 400 light years. The inlet shows spectra of the rare molecule D2H+, detected with the APEX telescope in Chile, overlaid onto an infrared image of this region. Compilation: Bérengčre Parise. Background image: Spitzer Space Telescope. NASA/JPL-Caltech/L. Allen (CfA) & D. Padgett (SSC-Cattech). Inlett: D2H+ Spectra (Champ+/APEX). (Click image for higher resolution).

Rare molecular species like H_2D+ and D_2H+, built from the hydrogen atom H and its heavier isotope deuterium D have gained great attention as probes of cold and dense molecular cloud cores. Since deuterium in space is about 100000 times rarer than hydrogen, these molecules are very difficult to detect. Thanks to the conjunction of powerful instrumentation at APEX, the "Atacama Pathfinder EXperiment", and an optimal site over 5000 meters above sea level, a research team from the Max Planck Institute for Radio Astronomy in Bonn led by Bérengère Parise achieved to map the spatial distribution of the rare D_2H+ species in a prestellar core in the Rho Ophiuchi cloud, a star-forming region at a distance of approx. 400 light years.

Stars form in clouds of dust and gas. Before the birth of the star, these clouds are dense and extremely cold (temperatures of about 10 Kelvin, corresponding to approx. -260 degrees Celsius), causing most of the gaseous molecules to be frozen on the surface of solid dust grains, very similarly to the condensation of water vapor onto the solid walls of our kitchen freezers. The disappearance of most molecules from the gas makes the observation of molecular emission from these objects very difficult. At the same time, these conditions leave room for the development of a peculiar chemistry between the remaining gaseous species, leading to the formation of light molecules containing deuterium atoms, in particular the light triatomic species H_2D+ and D_2H+.

These peculiar molecules have been the target of many observational searches in the last decade. "This is because their emission can help astronomers to understand the extreme physical conditions in stellar cocoons", says Bérengère Parise, the Emmy Noether group leader driving this research project. "They can be considered as the "light in the freezer" and their study is essential for understanding the processes that lead to the formation of stars and their planetary systems."

The APEX telescope in 5100 m above sealevel in Chile where the observations were performed. Image: Bérengčre Parise (Click image for higher resolution).

The observation of these peculiar molecules is however very difficult in view of the high frequency of the light they emit. The wavelength of the emission, shorter than one millimetre and therefore referred to as "submillimetre", lies in a frequency window where the earth atmosphere is transparent only under the best weather conditions. These observations thus require the best submillimetre telescopes located at the best observing sites, conjugated with sensitive instruments that can detect those faint signals.

In this respect, the observation of D_2H+ is even more tricky than that of H_2D+, because of an even higher frequency. This explains why most observational searches for this molecule have been unsuccessful, leading to date to only one claimed detection with another submillimetre telescope, with an uncertain frequency calibration.

"Our state-of-art CHAMP+ receiver is a very sensitive and powerful submillimetre instrument", says Rolf Güsten, head of the submillimetre technology group of MPIfR where CHAMP+ was built. "It can record astronomical signal on seven different positions of the sky simultaneously, and at two different frequencies." This increased performance compared to previous instruments makes the observation of faint signals on several positions much more efficient. It was therefore possible to observe the emission of D_2H+ simultaneously on seven positions in a cold core for the first time, an observation that would have been nearly impossible with a single-pixel instrument, because of the long integration times required for the detection on a single position (a full night of observing time per position).

The observation resulted in a surprising discovery: the molecule was not only detected in the coldest center of the core, as expected by the MPIfR team, but also in some of the side pixels, showing that the distribution of this molecule is extended, and not only confined to the innermost region of the core. This finding is an important piece of information for understanding the peculiar chemistry taking place in the extreme environments from which stars form. It implies that the freezing of molecules on dust grains is extremely efficient, a result that the team will try to confirm by independent observations in the coming months.

"This is the definitive confirmation of the existence of this rare molecule in space", says Bérengère Parise. "The information on its spatial distribution provided by the CHAMP+ observation opens the possibility to investigate in details the chemical and physical processes taking place during the early phases of star formation."

More information: Extended emission of D_2H+ in a prestellar core , B. Parise, et al, 2010, *Astronomy & Astrophysics*, [DOI:10.1051/0004-6361/20101547](DOI:10.1051/0004-6361/20101547)

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