



A Sanitizer in the Galactic Centre Region

An international group of researchers led by Arnaud Belloche (MPIfR, Bonn, Germany) reports the first identification iso-propanol in interstellar space, a substance which is used as a sanitizer on Earth. Iso-propanol is the largest alcohol detected so far, demonstrating the increasing complexity of members of one of the most abundant classes of molecule that can be found in space. The identification was made possible thanks to observations of the star forming region Sagittarius B2 (Sgr B2) close to the centre of our Galaxy where many molecules have already been detected. It is the target of an extended investigation of its chemical composition with the ALMA telescope in Chile.

The search for molecules in space has been going on for more than 50 years. To date, astronomers have identified 276 molecules in the interstellar medium. The Cologne Database for Molecular Spectroscopy (CDMS) provides spectroscopic data to detect these molecules, contributed by many research groups, and has been instrumental in their detection in many cases.

The goal of the present work is to understand how organic molecules form in the interstellar medium, in particular in regions where new stars are born, and how complex these molecules can be. The underlying motivation is to establish connections to the chemical composition of bodies in the Solar system such as comets, as delivered for instance by the Rosetta mission to comet Churyumov-Gerasimenko a few years ago.

An outstanding star forming region in our Galaxy where many molecules were detected in the past is Sagittarius B2 (Sgr B2), which is located close to the famous source Sgr A*, the supermassive black hole in the centre of our Galaxy.

“Our group began to investigate the chemical composition of Sgr B2 more than 15 years ago with the IRAM 30-m telescope”, says Arnaud Belloche from the Max Planck Institute for Radio Astronomy (MPIfR) in Bonn/Germany, the leading author of the detection paper. “These observations were successful and led in particular to the first interstellar detection of several organic molecules, among many other results.”

With the advent of the Atacama Large Millimeter/submillimeter Array (ALMA) ten years ago, it became possible to go beyond what could be achieved toward Sgr B2 with a single-dish telescope and a long-term study of the chemical composition of Sgr B2 was started that took advantage of the high angular resolution and sensitivity provided by ALMA.

So far, the ALMA observations have led to the identification of three new organic molecules (iso-propyl cyanide, N-methylformamide, urea) since 2014. The latest result within this ALMA project is now the detection of propanol (C_3H_7OH).

Propanol is an alcohol, and is now the largest in this class of molecules that has been detected in interstellar space. This molecule exists in two forms ("isomers"), depending on which carbon atom the hydroxyl (OH) functional group is attached to: 1) normal-propanol, with OH bound to a terminal carbon atom of the chain, and 2) iso-propanol, with OH bound to the central carbon atom in the chain. Iso-propanol is also well known as the key ingredient in hand sanitizers on Earth. Both isomers of propanol in Sgr B2 were identified in the ALMA data set. It is the first time that iso-propanol is detected in the interstellar medium, and the first time that normal-propanol is detected in a star forming region. The

first interstellar detection of normal-propanol was obtained shortly before the ALMA detection by a Spanish research team with single-dish radio telescopes in a molecular cloud not far from Sgr B2. The detection of iso-propanol toward Sgr B2, however, was only possible with ALMA.

“The detection of both isomers of propanol is uniquely powerful in determining the formation mechanism of each. Because they resemble each other so much, they behave physically in very similar ways, meaning that the two molecules should be present in the same places at the same times”, says Rob Garrod from the University of Virginia (Charlottesville/USA). “The only open question is the exact amounts that are present - this makes their interstellar ratio far more precise than would be the case for other pairs of molecules. It also means that the chemical network can be tuned much more carefully to determine the mechanisms by which they form.”

The ALMA telescope network was essential for the detection of both isomers of propanol toward Sgr B2, thanks to its high sensitivity, its high angular resolution, and its broad frequency coverage. One difficulty in the identification of organic molecules in the spectra of star forming regions is the spectral confusion. Each molecule emits radiation at specific frequencies, its spectral "fingerprint", which is known from laboratory measurements.

“The bigger the molecule, the more spectral lines at different frequencies it produces. In a source like Sgr B2, there are so many molecules contributing to the observed radiation that their spectra overlap and it is difficult to disentangle their fingerprints and identify them individually”, says Holger Müller from Cologne University where laboratory work especially on normal-propanol was performed.

Thanks to ALMA's high angular resolution, it was possible to isolate parts of Sgr B2 that emit very narrow spectral lines, five times narrower than the lines detected on larger scales with the IRAM 30-m radio telescope! The narrowness of these lines reduces the spectral confusion, and this was key for the identification of both isomers of propanol in Sgr B2. The sensitivity of ALMA also played a key role: it would not have been possible to identify propanol in the collected data if the sensitivity had been just twice worse.

This research is a long-standing effort to probe the chemical composition of sites in Sgr B2 where new stars are being formed, and thereby understand the chemical processes at work in the course of star formation. The goal is to determine the chemical composition of the star forming sites, and possibly identify new interstellar molecules. “Propanol has long been on our list of molecules to search for, but it is only thanks to the recent work done in our laboratory to characterize its rotational spectrum that we could identify its two isomers in a robust way”, says Oliver Zingsheim, also from Cologne University.

Detecting closely related molecules that slightly differ in their structure (such as normal- and iso-propanol or, as was done in the past: normal- and iso-propyl cyanide) and measuring their abundance ratio allows the researchers to probe specific parts of the chemical reaction network that leads to their production in the interstellar medium.

“There are still many unidentified spectral lines in the ALMA spectrum of Sgr B2 which means that still a lot of work is left to decipher its chemical composition. In the near future, the expansion of the ALMA instrumentation down to lower frequencies will likely help us to reduce the spectral confusion even further and possibly allow the identification of additional organic molecules in this spectacular source”, concludes Karl Menten, Director at the MPIfR and Head of its Millimeter and Submillimeter Astronomy research department.

Background information:

The Atacama Large Millimeter/submillimeter Array (ALMA), an international astronomy facility, is a partnership of the European Southern Observatory (ESO), the U.S. National Science Foundation (NSF) and the National Institutes of Natural Sciences (NINS) of Japan in cooperation with the Republic of Chile. ALMA is funded by ESO on behalf of its

Member States, by NSF in cooperation with the National Research Council of Canada (NRC) and the Ministry of Science and Technology (MOST) and by NINS in cooperation with the Academia Sinica (AS) in Taiwan and the Korea Astronomy and Space Science Institute (KASI). ALMA construction and operations are led by ESO on behalf of its Member States; by the National Radio Astronomy Observatory (NRAO), managed by Associated Universities, Inc. (AUI), on behalf of North America; and by the National Astronomical Observatory of Japan (NAOJ) on behalf of East Asia. The Joint ALMA Observatory (JAO) provides the unified leadership and management of the construction, commissioning and operation of ALMA.

The imaging spectral line survey ReMoCA performed with ALMA at high angular resolution and the results of a recent spectroscopic study of propanol were used to search for the iso and normal isomers of the propanol molecule in the hot molecular core Sgr B2(N2) in the neighbourhood of the Galactic centre. The interferometric spectra were analyzed under the assumption of local thermodynamical equilibrium. The reaction network of the astrochemical model MAGICCAL was expanded in order to explore the formation routes of propanol and to put the observational results in a broader astrochemical context.

The research team comprises Arnaud Belloche, Robin T. Garrod, Oliver Zingsheim, Holger S. P. Müller, and Karl M. Menten in the detection paper, furthermore Oliver Zingsheim, Jakob Maßen, Holger S. P. Müller, Bettina Heyne, Mariyam Fatima, Luis Bonah, Arnaud Belloche, Frank Lewen, and Stephan Schlemmer in the spectroscopy paper.

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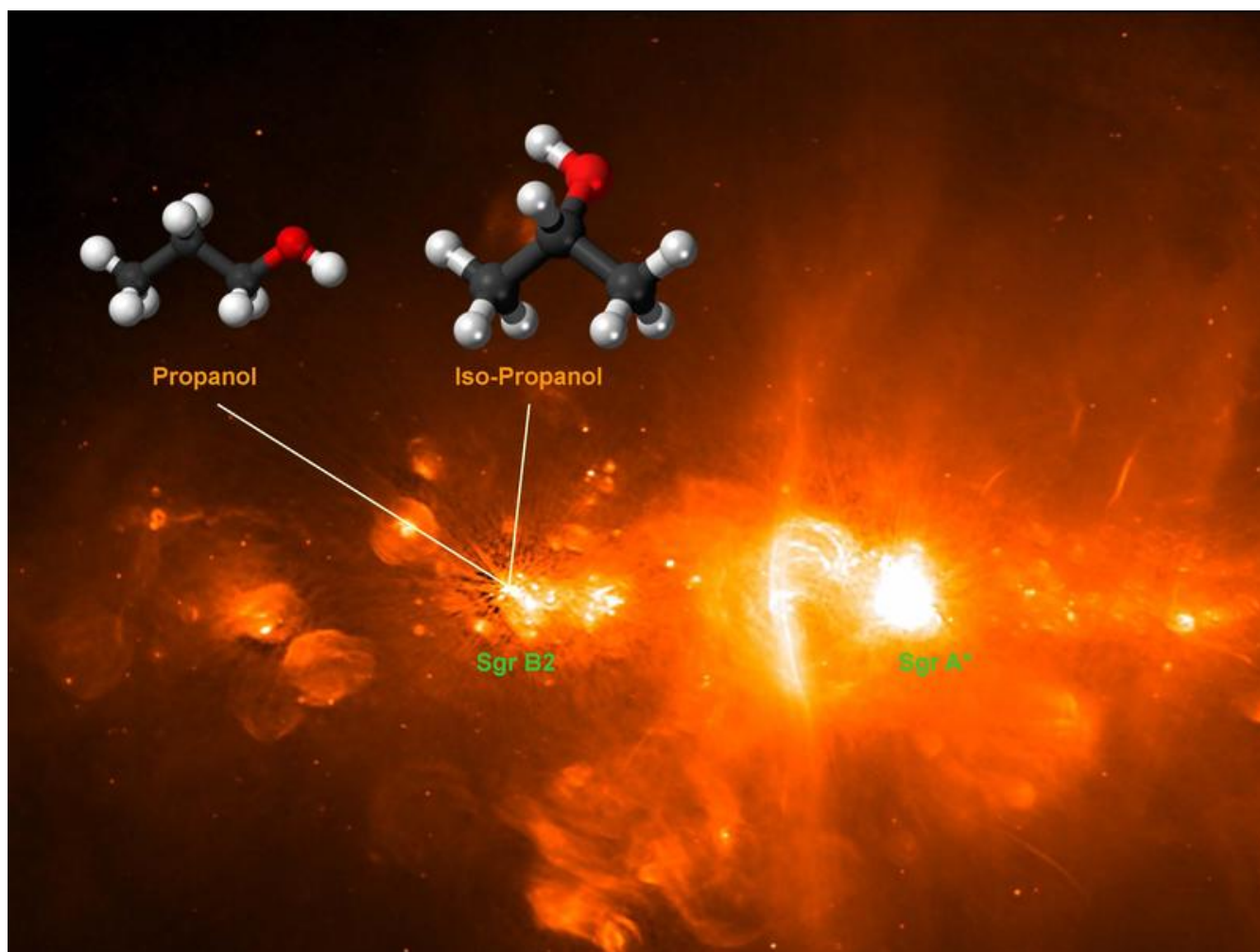
Belloche, A. et al.: „Interstellar detection and chemical modeling of iso-propanol and its normal isomer“, 2022, Astronomy & Astrophysics, June 28, 2022 (DOI: 10.1051/0004-6361/202243575).

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Zingsheim, O. et. al.: "Rotational spectroscopy of n-propanol: Aa and Ag conformers", 2022, Astronomy & Astrophysics, June 28, 2022 (DOI: 10.1051/0004-6361/202243571).

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URL for press release: <https://www.mpifr-bonn.mpg.de/pressreleases/2022/10>



The position of star-forming molecular cloud Sgr B2 close to the central source of the Milky Way, Sgr A* (Background Image: GLOSTAR). The isomers propanol and iso-propanol were both detected in Sgr B2 using the ALMA telescope. GLOSTAR collaboration (background image). Wikipedia/public domain (molecule models).



ALMA antennas with the centre of our Galaxy in the background.
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