Detection of the elusive carbonic acid (HOCOOH) in space

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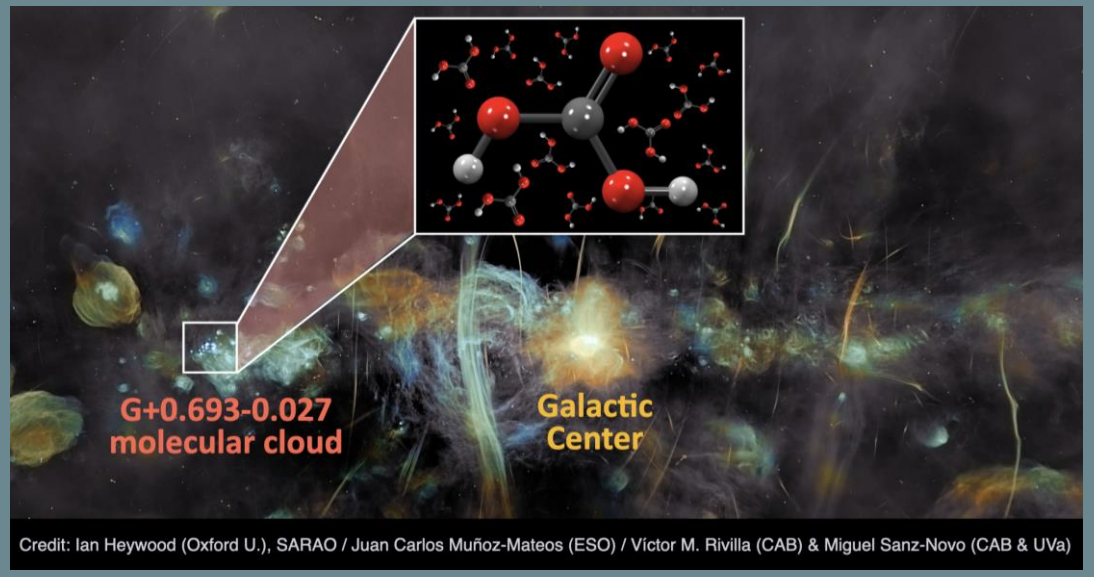

Credit: Ian Heywood (Oxford U.), SARAO / Juan Carlos Muñoz-Mateos (ESO) / Víctor M. Rivilla (CAB) & Miguel Sanz-Novo (CAB & UVa)

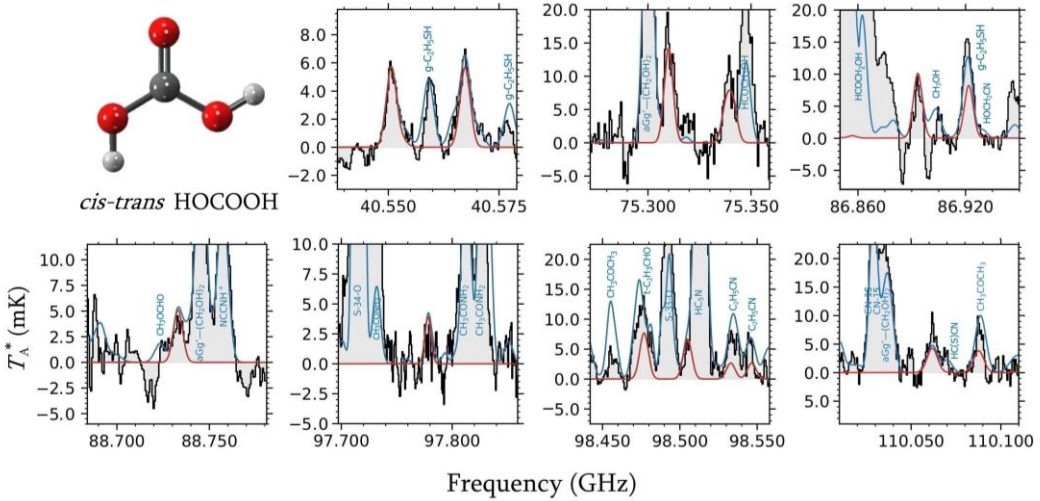

Figure. First detection of carbonic acid (HOCOOH) in the interstellar medium, based on an ultra-deep spectral survey of the G+0.693-0.027 molecular cloud.

After a quarter century since the detection of the last interstellar carboxylic acid, acetic acid (CH_3COOH), we report the **discovery** of a new one, the *cis-trans* form of **carbonic acid** (HOCOOH), toward the **Galactic Center molecular cloud G+0.693-0.027**. To achieve this new detection, we used **new astronomical data** from a **large observational project** led by the Center for Astrobiology (CAB), mainly collected with the 30-meter diameter IRAM radiotelescope in Pico Veleta (Granada) and the 40-meter one at the Yebes Observatory of the National Geographic Institute (Guadalajara).

HOCOOH stands as the **first interstellar molecule containing three oxygen atoms** and also the **third carboxylic acid detected so far in the interstellar medium**. Albeit from the limited available laboratory measurements, we have identified several pairs of unblended spectroscopic features directly in the astronomical data, which allowed us to improve the set of spectroscopic constants previously obtained in the laboratory. We derive a column density for *cis-trans* HOCOOH of $N = (6.4 \pm 0.4) \times 10^{12}$ cm^{-2}, which yields an abundance with respect to molecular H_2 of 4.7×10^{-11}.

Meanwhile, the extremely **low dipole moment** (about fifteen times lower) of the lower-energy conformer, ***cis-cis* HOCOOH**, **precludes its detection**. We obtain an upper limit to its abundance with respect to H_2 of ≤ 1.2×10^{-9}, which suggests that **cis-cis HOCOOH might be fairly abundant in interstellar space** (abundance of the **same order as that of *trans*-formic acid**, *t*-HCOOH) , although it is nearly undetectable by radio astronomical observations. We derive a *cis-cis/cis-trans* ratio ≤ 25, consistent with the smaller energy difference between both conformers compared with the relative stability of *trans*- and *cis*-formic acid (*c*-HCOOH).

We also compare the **abundance** of **formic acid** and **acetic acid** in **different astronomical environments** (i.e., star-forming regions, asteroids and comets), further suggesting a **relationship** between the **chemical content found in the interstellar medium** and the **chemical composition of the minor bodies** of the **Solar System**, which could be inherited during the star formation process.

This discovery provides relevant insight into the **actual degree of chemical complexity of the interstellar medium and** will bear significant implications to unravel the role of HOCOOH within **interstellar carbon and oxygen chemistry**, based on the large amount of HOCOOH that might be lurking in space.

Miguel Sanz-Novo, Víctor M. Rivilla,, et al. (2023), *The Astrophysical Journal*,