Glycine in Space produced by Dark Chemistry

An international team of laboratory astrophysicists, in part active within INTERCAT, have shown that glycine, the simplest amino acid and an important building block of life, can form under the harsh conditions that govern chemistry in space. The results have been published this week in Nature Astronomy and show that glycine and very likely other amino acids are formed in dense interstellar clouds, well before these transform into new stars and planets.

Comets are the most pristine material in our Solar System and reflect the molecular composition at the time our Sun and planets were just about to form from material chemically processed in the interstellar medium. The detection of glycine in the coma of comet 67P/Churyumov-Gerasimenko and in samples returned to Earth from the Stardust mission strongly hint for a prestellar origin of amino acids. Until recently, glycine formation was thought to occur through energetic radiation, setting clear constraints to the environment in which it can be formed. New results by scientists working in the Laboratory for Astrophysics at Leiden Observatory, the Dutch partner of INTERCAT, show that it is possible to form glycine on the surface of icy dust grains through ‘dark chemistry’.

‘Dark chemistry means chemistry without the need of energetic radiation’, says Sergio Ioppolo (Queen Mary University, London), a regular visitor to Aarhus University and lead author of the article that appeared this week in Nature Astronomy. ‘In the laboratory we have simulated the conditions in dark interstellar clouds: 10-20 K cold dust particles are covered by thin layers of abundant ices - frozen CO, NH_3, CH_4 and H_2O – and subsequently processed by impacting atoms causing precursor species to fragment and reactive intermediates to recombine.’ In this way, first methylamine was shown to form, a precursor species of glycine and also detected in the coma of the comet 67P. Using a unique ultra-high vacuum setup, equipped with a series of atomic beam lines and accurate diagnostic tools, Ioppolo and coworkers were able to show that also glycine can be formed. The presence of water ice is essential in this process.

‘The important conclusion from this work is that molecules that are considered building blocks of life already form at a stage that is well before the start of star and planet formation’ says Harold Linnartz, director of the Laboratory for Astrophysics at Leiden Observatory. ‘Such an early formation of glycine in the evolution of star-forming regions implies that this amino acid can be formed more ubiquitously in space and is preserved in the bulk of ice before inclusion in comets and planetesimals that make up the material from which ultimately planets are made.’

The experiments were performed under fully controlled laboratory conditions and show that a non-energetic surface formation path for glycine at low temperatures is possible, different from previous work that required UV radiation to produce this molecule. Astrochemical models support this finding and allow to extrapolate data obtained on a typical laboratory timescale of just one day to interstellar conditions, bridging millions of years. ‘From this we find that low but substantial amounts of glycine can be formed in space with time’, says Herma Cuppen (Radboud University, Nijmegen), who was responsible for some of the modelling studies presented in the Nature Astronomy publication.

In the nearby future, scientists from the INTERCAT consortium will further focus on the catalytic role interstellar dust particles play in the formation of COMs. ‘What is the effect on COM formation when an ice contains nanometer sized grains and how can we understand the chemical processes at play’, says Prof. Liv Hornekaer (Aarhus University). Once formed, glycine can also become a precursor to other complex organic molecules. Following the same mechanism, in principle, other functional groups can be added to the glycine backbone, resulting in the formation of other amino acids, such as alanine and serine in dark clouds in space. In the end, this enriched organic molecular inventory is included in celestial bodies, like comets, and delivered to young planets, as happened to our Earth and other planets across the universe.

Publication

A non-energetic mechanism for glycine formation in the interstellar medium
S. Ioppolo, G. Fedoseev, K.-J. Chuang, H.M. Cuppen, A.R. Clements, M. Jin, R.T. Garrod, D. Qasim, V. Kofman, E.F. van Dishoeck, and H. Linnartz; Nature Astronomy, DOI number 10.1038/s41550-020-01249-0.

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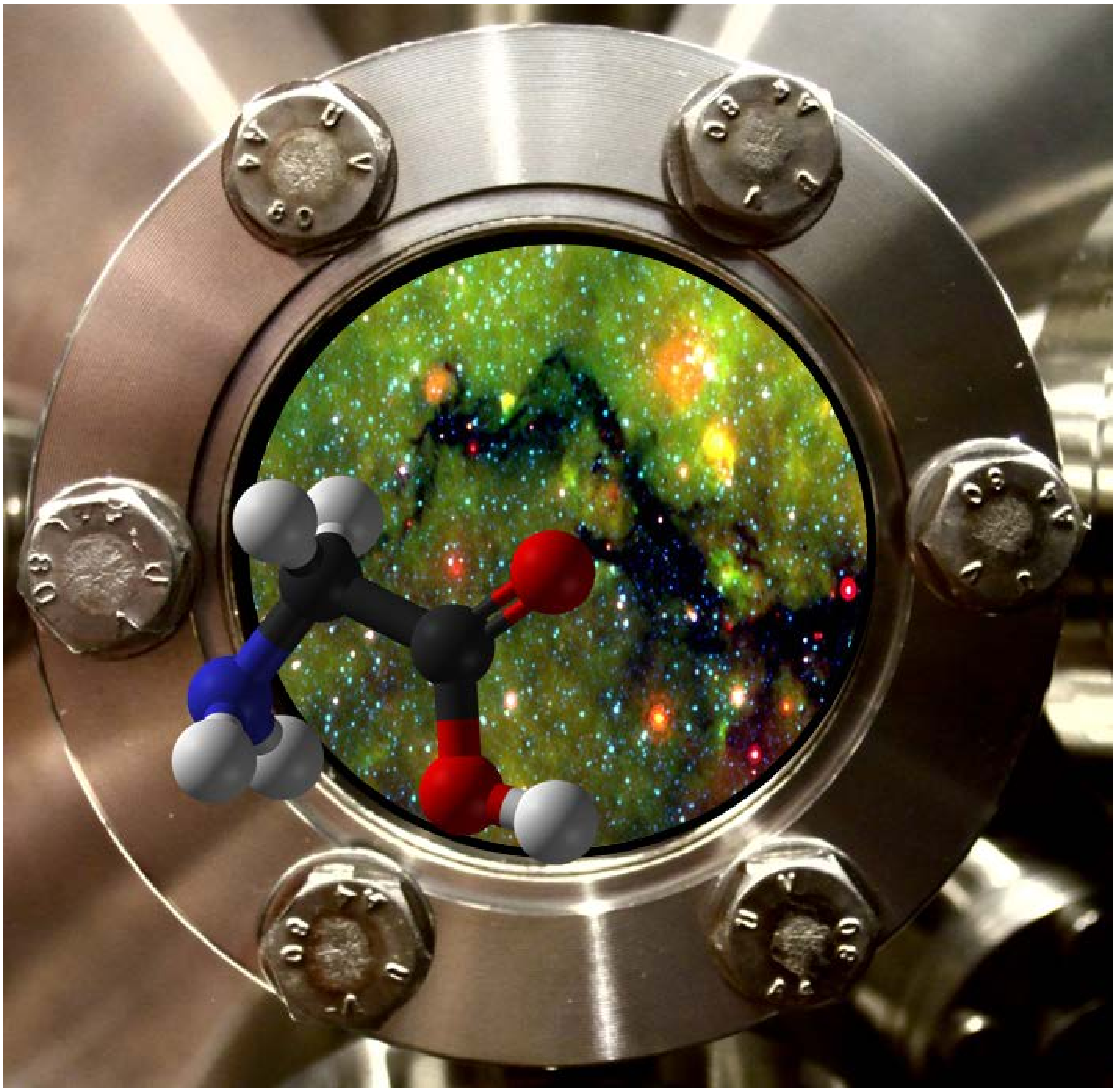

InterCat researchers participate in experiments demonstrating that glycine, the simplest amino acid, can be formed under conditions that are typical for those regions in interstellar space where new stars and planetary systems form.