

Formation Process of A Glycine's Precursor Candidate, CH₃NH₂

*Taiki Suzuki^{1,2}, Liton Majumdar³, Masatoshi Ohishi²

1. National Institutes of Natural Sciences Astrobiology Center, 2. National Astronomical Observatory of Japan, 3. NASA Jet Propulsion Laboratory (JPL)

As [1] argued, the comets and meteorites may have provided a large amount of prebiotic molecules to the early Earth. An attempt to understand the origins of life must necessarily begin with detailed studies of the formation and evolution of complex organic molecules (COMs), products of complex chemistry that most likely starts in molecular clouds and continues within the protoplanetary disk.

Since the amino acids are the essential building blocks of life, the search for amino acids and their complex organic precursors at different stages of star and planet formation is one of the exciting topics in modern astronomy. Recently, volatile glycine (NH₂CH₂COOH) was detected in the coma of comet 67P/Churyumov-Gerasimenko by the ROSINA mass spectrometer [2], also giving clues about glycine's interstellar origin. However, the survey observations of glycine toward ISM have been not successful. Therefore, revealing the formation pathways to glycine is important for astrochemistry and astrobiology not only to know the promising glycine-rich sources for future surveys but also to understand the general chemical evolution of N-bearing molecules in the ISM.

In this context, we performed the chemical modeling study for the high-mass star, with the possible formation processes of glycine with theoretically and/or experimentally suggested formation paths [3]. We suggested that glycine was efficiently formed through the following reactions: First, the hydrogenation process to HCN leads to the formation of CH₂NH and CH₃NH₂ on interstellar grain surface (HCN + 2H => CH₂NH, and then CH₂NH + 2H => CH₃NH₂). Then, the destruction of CH₃NH₂ by radicals will form CH₂NH₂. Finally, CH₂NH₂ and COOH radical react to form glycine. For this test, a key molecule would be CH₃OH, whose formation process is well known. Both experiments and theoretical works suggested that CH₃OH is built via grain surface hydrogenation processes to CO (CO + 2H => H₂CO, and then H₂CO + 2H => CH₃OH). If CH₃NH₂ is also produced through hydrogenation process, "CH₃NH₂/CH₃OH" ratio should be well reproduced by the modeling. However, it was difficult to test this formation process due to the very limited number of previous CH₃NH₂ observations.

With this motivation, we performed the observation of CH₃NH₂ and CH₃OH with ALMA toward high mass star-forming regions, G10.47+0.03, NGC6334I, W51 e1/e2, and G31.41+0.3. As a result, both of CH₃OH and CH₃NH₂ were detected toward all sources. The molecular abundances were derived with rotation diagram method. The high excitation temperatures of 100 and 200 K and compact distributions suggest that CH₃NH₂ emissions originate from the hot and dense regions. The observed molecular abundance ratio, "CH₃NH₂/CH₃OH" ranges from 0.2 to 2.1. The low "CH₃NH₂/CH₃OH" ratio of 0.2 is close to our modeling, supporting that CH₃NH₂ is the product of the hydrogenation process in those sources. However, the higher "CH₃NH₂/CH₃OH" ratio of nearly two, observed toward NGC6334I MM1, could not be reproduced with our modeling under the possible parameter range. Thus, our chemical modeling would not correctly reproduce the physics or chemistry of such CH₃NH₂-rich sources. Further studies of such sources will enable us to promote our knowledge of glycine chemistry and provide us with promising sources for future glycine surveys.

Citations:

[1] Ehrenfreund (2002), Rep. Prog. Phys. 65 1427

[2] Altwegg et al. (2016), Sci, 2, e1600285

[3] Suzuki et al, (2018), ApJ, 825, 51

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