

## Recent Progress of Carbon-Chain Chemistry in Molecular Clouds

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In this talk, we will present two recent progresses of observational carbon-chain chemistry in molecular clouds. One is the understanding of formation processes of carbon-chain molecules. So far, the abundance ratio of the <sup>13</sup>C species relative to the normal species is assumed to be the same as the elemental abundance ratio of <sup>12</sup>C/<sup>13</sup>C (60). However, we have recently observed the <sup>13</sup>C species of CCS, and have found the CCS/C<sup>13</sup>CS and CCS/<sup>13</sup>CCS ratios are 54±5(3σ) and 230±130(3σ), respectively, in TMC-1. The abundance ratio of C<sup>13</sup>CS/<sup>13</sup>CCS is not unity and <sup>13</sup>CCS is heavily diluted. This indicates that the two carbon atoms are nonequivalent in the main formation pathway of CCS. Although the isotope exchange reaction between <sup>13</sup>CCS and C<sup>13</sup>CS may be responsible in part, these results will put strong constraints on the production pathways of CCS. For instance, non-equivalent processes like CH + CS is turned out to be important to produce CCS [1]. Similarly, the <sup>13</sup>C species of CCH is observed, and the C<sup>13</sup>CH/<sup>13</sup>CCH ratios are determined to be 1.6±0.4(3σ). Again, the two carbon atoms are nonequivalent. Furthermore, C<sup>13</sup>CH and <sup>13</sup>CCH are also found to be significantly diluted [2]. The heavy dilution of the <sup>13</sup>C species is now confirmed observationally, which will provide us with rich information on physical and chemical conditions of interstellar clouds.

Second is the discovery of new carbon-chain chemistry in a lukewarm region near the protostar triggered by the evaporation of the CH<sub>4</sub> ice. We have found low-mass star forming regions, L1527 and IRAS15398-3359, which show extremely high abundances of carbon-chain molecules [e.g. 3, 4]. In particular, we have confirmed the regeneration of carbon-chain molecules in the 20-30 K region near the protostar by interferometric observation toward L1527. The new chemistry is named as Warm Carbon-Chain Chemistry (WCCC) in contrast to the conventional one which has long been applied to cold starless cores. The understanding of the anion chemistry has been accelerated by the detection of C<sub>4</sub>H<sup>-</sup> and C<sub>6</sub>H<sup>-</sup> in L1527. The discovery of the WCCC sources demonstrates that the chemical composition of low-mass star-forming regions is not uniform, but has a significant variety. A remarkable contrast can be seen between WCCC and hot corino chemistry. A possible origin for this would be the time scale of the starless-core phase; a shorter contraction time would result in WCCC. If so, chemical compositions tell us the past history of the star formation processes, which would not be derived from the conventional observations.

### References

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