

## Chemical Diversity of Low-Mass Star Forming Regions

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### 1. Chemical Evolution along Protostellar Evolution

Chemical evolution from a protostellar disk to a protoplanetary disk is an important subject to be addressed observationally, because it is a missing link between interstellar chemistry and planetary chemistry. A recent achievement in this direction was the discovery of complex saturated organic molecules like HCOOCH<sub>3</sub> in hot corinos around protostars (e.g. Cazaux et al. 2003; Sakai et al. 2006). It has so far been believed that the chemical composition of low-mass star forming regions is relatively uniform within various classes, and hence, that the chemical evolution could be understood with a single common picture. However, we have recently discovered a low-mass star forming region, L1527 (e.g. Sakai et al. 2008), whose chemical composition is quite different from that of hot corinos.

### 2. Discovery of Warm Carbon Chain Chemistry

In a search for HCOOCH<sub>3</sub> toward L1527, we fortuitously detected a carbon chain molecule, C<sub>4</sub>H<sub>2</sub>. Since carbon-chain molecules are only abundant in young starless cores and are generally deficient in star forming regions, this discovery was surprising. Various carbon-chain molecules like C<sub>4</sub>H, C<sub>6</sub>H, and HC<sub>7</sub>N were also found in follow-up observations. Furthermore, they were found to exist in a gas infalling to the protostar.

Deficiency of carbon-chain molecules in star-forming regions originates from gas-phase destruction and depletion onto dust grains before formation of protostars ( $\sim 10^6$  yr). One may think that the rich carbon-chain molecules in L1527 would be caused by fast contraction of the parent core, where the carbon-chain molecules could survive even after the star formation. However, the chemical composition of L1527 is systematically different from that of a young starless core, TMC-1. In particular, short carbon-chain molecules are much more abundant in L1527 than in TMC-1, indicating that they would be re-generated in a lukewarm region in L1527. Then we proposed the following mechanism. Icy grain mantles contain solid CH<sub>4</sub> abundantly. Since the sublimation temperature of CH<sub>4</sub> is 30 K, CH<sub>4</sub> cannot come out in cold clouds ( $\sim 10$  K). However, it can be evaporated efficiently in the lukewarm region. As a result, carbon-rich condition is temporally realized, resulting in re-generation of carbon-chain molecules. We call this as Warm Carbon Chain Chemistry (WCCC).

This is also seen in the low-mass protostar, IRAS15398-3359 in Lupus, which means that WCCC is not specific to L1527 (Sakai et al. 2009). WCCC attracted many researchers as a new carbon-chain chemistry, and stimulated various studies including chemical model calculations (e.g. Aikawa et al. 2008; Hassel et al. 2008). The basic mechanism of WCCC is indeed verified by the chemical models.

### 3. Chemical Diversity of Low-Mass Star Forming Regions

The discovery of WCCC clearly demonstrates that the chemical composition of star forming regions has significant diversity. Its possible origin would be the timescale of the starless core phase. A short timescale, which is close to that of the free fall, is preferable for WCCC to occur. In this case, the carbon atoms are depleted onto dust grains before they are converted into CO in the gas phase. Then CH<sub>4</sub> is efficiently produced through grain surface reactions with H. On the other hand, a longer contraction time is preferable for the hot corino chemistry to occur. In this case, the carbon atoms are converted to CO in the gas phase before depletion. As a result, saturated organic molecules are formed on dust grains by hydrogenation of CO.

If this scenario is the case, the chemical composition reflects the prestellar contraction process. This idea has recently been confirmed by observations of deuterated molecules in L1527. The diversity will be brought into the protoplanetary disks. Its detailed understanding is crucial in exploring how the environment of our solar system had been formed 4.6 billion years ago.

Keywords: interstellar chemistry, star formation, protostellar disk, carbon-chain molecules