The Spectral Line Survey in TMC-1 -- Progress of the Data Analysis

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Cold dark interstellar clouds have been extensively studied as the formation sites of low-mass stars and planetary systems since their identification to the interstellar molecular clouds in 1970's. A variety of exotic chemical compounds found in molecular clouds, especially those containing carbon atoms, attracted strong interests in connection with the formation of planets and the origin of life in the universe. Recent radio and IR observations towards comets collected important evidence that comets, 4.6 billion year-old fossil bodies of the proto-solar-system nebula, keep molecular composition similar to that in cold dark clouds. Therefore, the chemical evolution in cold dark clouds is basically important as the initial process of interstellar matter evolution toward the planets, and, ultimately to life.

Chemical reactions in dark clouds are not yet fully understood, and many unknown molecules might be synthesized in dark clouds. It is essential for understanding the chemical reactions in dark clouds, therefore, to make an unbiased frequency survey that can detect all molecular lines, including unpredicted lines of unknown molecules.

Kaifu et al. [1] published a molecular spectral line survey data toward a dark cloud, the cyanopolyyne peak of TMC-1, in the frequency range between 8.8 and 50 GHz (see Figure 1), using the 45-m mm-wave telescope of the Nobeyama Radio Observatory[1]. They detected 414 lines from 38 molecules. Most of the molecules are linear carbon chain species and their derivatives, and there are only a few organic species such as CH_3OH, CH_3CHO, HCCCHO and CH_2CHCN. More saturated species, e.g., C_2H_5CN and $HCOOCH_3$, were not detected.

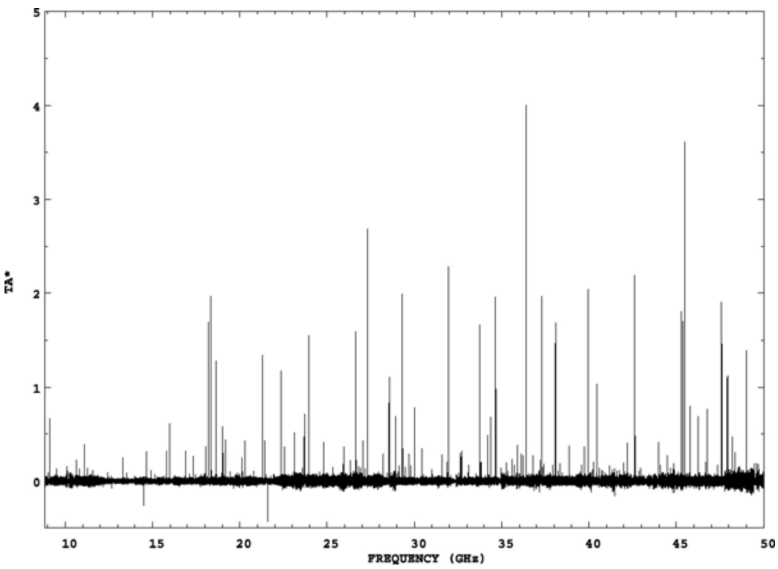

Figure 1: A compressed atlas of the 8.8--50 GHz spectrum toward TMC-1 (cyanopolyyne peak).

[1] Nobeyama Radio Observatory is an open-use facility for mm-wave astronomy, being operated under the National Astronomical Observatory of Japan (NAOJ).

We have made detailed data analyses for the 29 species out of detected 58 species by utilizing peak line temperatures that were obtained through the Gaussian fitting. The detected lines for each molecule were analyzed assuming the LTE condition with the weight of $1/\sigma^2$ where σ is the rms noise value at each line position. When available, we incorporated weaker hyper fine components in order to avoid the photon trapping effect. Figure 2 shows a comparison between old column density values [2] and present values for several carbon chain species.

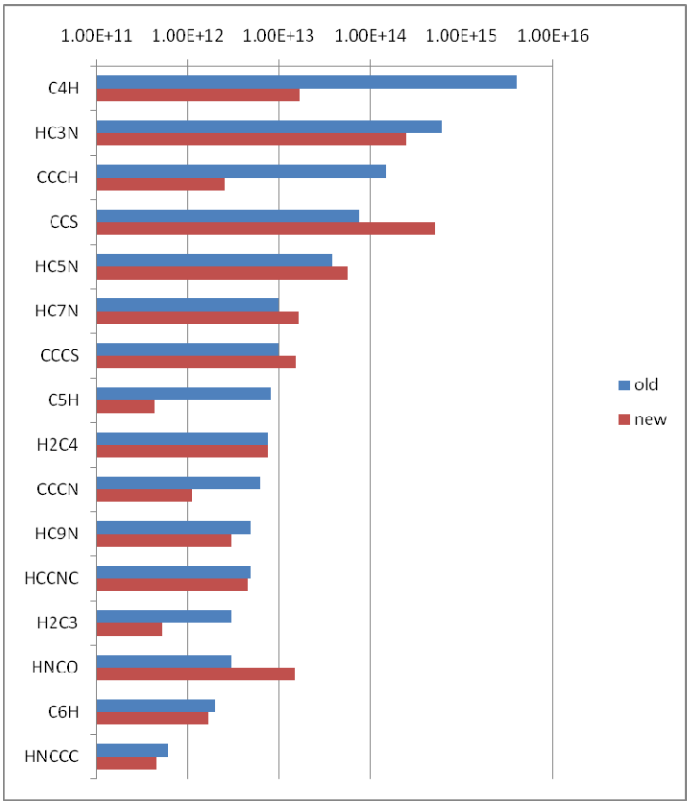

Figure 2: Comparison between old column density values and new values for several carbon chain species.

It is readily seen that the column density of C_4H has lowered by about two orders of magnitude, which is consistent with the theoretical prediction by [3] on the abundance ratio of C_4H^- to C_4H. The abundances for C_5H and C_6H have been reversed, which is consistent with the past reports. For HC_nN molecules, the old and new values do not change significantly.

We will talk the detailed procedure of the analyses, excitation temperature variation vs. number of carbon atoms, and derived isotope ratios, D/H, $^{13}C/^{12}C$, and $^{15}N/^{14}N$.

References

[1] Kaifu, N., Ohishi, M., Kawaguchi, K., Saito, S., Yamamoto, S., Miyaji, T., Miyazawa, K., Ishikawa, S., Noumaru, C., Harasawa, S., Okuda, M., & Suzuki, H. 2004, PASJ, 56, 69.

[2] Ohishi, M., & Kaifu, N. 1998, J. Chem. Soc., Faraday Discussion, 109, 205.

[3] Herbst, E., 2008, private communication.