Origin of Methanol in the Starless Core, Taurus Molecular Cloud-1

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Methanol (CH_3OH) is one of fundamental saturated organic molecules, and is widely detected in star forming regions [1]. It is generally thought that CH_3OH is produced on dust grains and is liberated into the gas phase by various star formation activities (e.g. protostellar heating and outflow shocks). However, CH_3OH is also moderately abundant in cold dark clouds, and its origin is still controversial [2]. Non-thermal evaporation processes should play an important role.

To examine this we have conducted high spectral resolution observations of CH_3OH toward the cyanopolyyne peak of Taurus Molecular Cloud-1 (TMC-1 CP). The spectral line of CH_3OH toward TMC-1 CP is found to have a double-peaked profile separated by 0.4 km s^{-1}. Since the double-peaked profile is observed for the ^{13}C species of CH_3OH, it is not due to optical depth and/or self-absorption effects. The spectral line profile of CH_3OH is much different from those of $C^{34}S$, C_3S, and HC_7N observed toward this source. Statistical equilibrium calculations are carried out for the $1_{0,0} - 0_{0,0}$ A^+, $2_{0,2} - 1_{0,1}$ A^+ and $3_{0,3} - 2_{0,2}$ A^+ lines of CH_3OH, and the H_2 density of the emitting region for the blue-shifted and red-shifted components are derived to be $(1.7 \pm 0.2) \times 10^4$ cm^{-3} and $(4.3 \pm 0.4) \times 10^4$ cm^{-3}, respectively. Although these densities are similar to or slightly lower than those found for the other molecules, CH_3OH is distributed differently. This has been confirmed by mapping observations of the CH_3OH $2_{0,2} - 1_{0,1}$ A^+ and the $C^{34}S$ $J = 2 - 1$ lines around TMC-1 CP.

Non-thermal desorption from dust grains seems to be responsible for the gas-phase CH_3OH. The grain-surface origin of CH_3OH is further confirmed by the $CH_3OH/^{13}CH_3OH$ ratio. As for the desorption mechanism, weak shocks caused by accreting diffuse gas to the TMC-1 filament, photoevaporation caused by the cosmic-ray induced UV radiation, and desorption of excess reaction energy in formation of CH_3OH on dust grain are discussed.

References

[1] Herbst, E., & van Dishoeck, E. F. 2009, ARA&A, 47, 427
[2] Takakuwa, S., Mikami, H., Saito, M. et al. 2000, ApJ, 542, 367