THERMALIZATION OF INTERSTELLAR CO

TAKESHI OKA, *Department of Astronomy and Astrophysics and Department of Chemistry, The Enrico Fermi Institute, University of Chicago, Chicago, IL 60637*; HAN XIAO, and PHILLIP LYNCH, *Department of Statistics, University of Chicago, Chicago, IL 60637*.

Unlike radio emission of CO, infrared absorption of CO give column densities in each rotational level directly when weak transitions like overtone bands or ^{13}CO or C^{18}O isotope bands are used. This allows more straightforward determination of temperature (T) and density (n) of the environment than the large velocity gradient (LVG) model used to determine them from antenna temperatures of radio emission. In order to facilitate such determination, we have solved the steady state linear simultaneous equations for thermalization of CO and calculated population ratios of rotational levels as a function of T and n as we did for H_3^+.[a] We thus get two-dimensional graph of column density ratios, for example, $N(J{=}1)/N(J{=}0)$ and $N(J{=}2)/N(J{=}0)$ as a function of T and n or variation of it when other population ratios are used. As for H_3^+ we can invert the graph to obtain graphs of T versus n as functions of population ratios which is more convenient to apply to observed data.[b]

We use rate constants of collision-induced transitions between CO and ortho- and para-H_2 theoretically calculated by Fowler[c] and Wernli et al.[d] which have been compiled and extended by Schöier et al.[e] As the first approximation, only spontaneous emissions are considered and other radiative effects such as induced emission and absorption are ignored. The results are applied to CO column densities observed toward the Galactic center, that is, CO in the three spiral arms, 3-kpc (Norma), 4.5-kpc (Scutum), and local arms (Sagittarius), and in the Central Molecular Zone.

[a] T. Oka and E. Epp, ApJ, 613, 349 (2004)
[b] M. Goto, Usuda, Nagata, Geballe, McCall, Indriolo, Suto, Henning, Morong, and Oka, ApJ, 688, 306 (2008)
[c] D. R. Fowler, J. Phys. B: At. Mol. Opt. Phys. 34, 2731 (2001)
[d] M. Wernli, P. Valiron, A. Faure, L. Wiesenfeld, P. Jankowski, and K. Szalewicz, A & A, 446, 367 (2006)
[e] F. L. Schöier, F. F. S. van der Tak, E. F. van Dishoeck, and J. H. Black, A & A, 432, 369 (2005)