NON-THERMAL ROTATIONAL DISTRIBUTION OF INTERSTELLAR H_3^+

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The recent detection of the $R(3,3)^l$ absorption line of H_3^+ toward the Galactic center infrared sources GCS 3-2 and GC IRS 3 [a,b] has demonstrated a remarkable non-thermal rotational distribution of H_3^+. In cloud components which accommodates high H_3^+ column density on the order of 3×10^{15} cm^{-2}, the $(J,K) = (3,3)$ level which is 361.5 K above the lowest (1,1) level is populated with a comparable abundance as the (1,1) level, while H_3^+ in the (2,2) level only 151.3 K above is not detectable. This highly non-thermal distribution is the result of a fast spontaneous emission $(2,2) \to (1,1)$ with the lifetime of 27.2 days due to centrifugal distortion induced dipole moment[c] and the metastability of the (3,3) level from which spontaneous emission is forbidden.[d]
In order to understand the observed non-thermal distribution and to plan strategy for observing H_3^+ in higher metastable rotational levels (4,4), (5,5) and (6,6), we have conducted a model calculation on the H_3^+ equilibration in which spontaneous emissions and collision-induced rotational transitions are treated with steady state approximation. Accurately calculated Einstein coefficients of Neale, Miller and Tennyson [e] are used. Rates of collision-induced rotational transitions were estimated on the assumption of complete random collisional selection rules based only on the principle of detailed balancing. The results show that the preliminary observed values of $n(3,3)/n(1,1) \sim 1$ and $n(3,3)/n(2,2) \geq 5$ indicate an environment with high cloud temperature of $T \geq 300$ K and low density $n(H_2) \leq 50$ cm^{-3}. They also suggest that observations of H_3^+ in higher metastable levels are realistic.

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