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RADIATIVE TRANSFER MODELING OF MOLECULAR CLOUDS: HCO^+ IN THE STAR-FORMING REGION W 49 A NORTH

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ABSTRACT A multi-level, non-LTE, (non-LVG) radiative transfer code has been applied to HCO^+ observations of W 49 A north. Profiles of both the J=1-0 and J=3-2 transitions are successfully reproduced with a variety of cloud models.

A multi-level, non-LTE, radiative transfer code has been applied to spectra of molecular clouds with embedded HII regions. Unlike most previous radiative transfer codes using either a Large-Velocity-Gradient or a microturbulent approximation, this code allows for non-monotonic velocity laws and "turbulent" and systematic velocities of comparable magnitude. P-Cygni-like profiles are predicted for some molecular transitions when observed towards a bright embedded HII region with sufficient resolution (Auer & Dickel 1988).

Welch et al. (1987) mapped the J=1-0 transition of HCO^+ at 89 GHz toward the thermal radio source W 49 A north with BIMA. Their observations toward the embedded HII region G show an inverse-P-Cygni profile which they interpreted as due to collapse of the overall molecular envelope onto an inner ring of ultracompact HII regions of which G is the most prominent member. We observed the J=3-2 transition of HCO^+ at 268 GHz with the NRAO 12 m telescope in February 1992. Fig. 1 shows some results of the radiative transfer modeling for free-fall collapse with a velocity law $v \propto r^{-0.5}$. The model profiles toward W 49 G have been convolved to the resolution of the observations, 7" for the J=1-0 transition and 24" for the J=3-2 transition.

While several different models, e.g. A and B below, were found to produce about the same strength and line shape for the J=1-0 transition (e.g. left side of Fig. 1 where $\sigma_{fit}/\sigma_{baseline}$ ~3 for both models), subtle differences in the models produced quite different appearances for the higher transitions (e.g. J=3-2, right side of Fig. 1) because their excitation is much more sensitive to changes in density and temperature. For example, model B has higher H_2 densities by a factor of 1.6 which nearly doubles the peak intensity of the J=3-2 transition (resulting in $\sigma_{fit}/\sigma_{baseline}$ ~ 11 compared to ~ 3 for model A). A shallower gradient in the HCO^+ density for model B (power-law exponent of -.75 instead of -1.5) changed the shape of the J=3-2 profile - there is a dip and secondary peak in the theoretical profile for model B but only a shoulder for model A. This dip/peak becomes even more pronounced with a constant HCO^+ density which is effectively ruled out by the observations.

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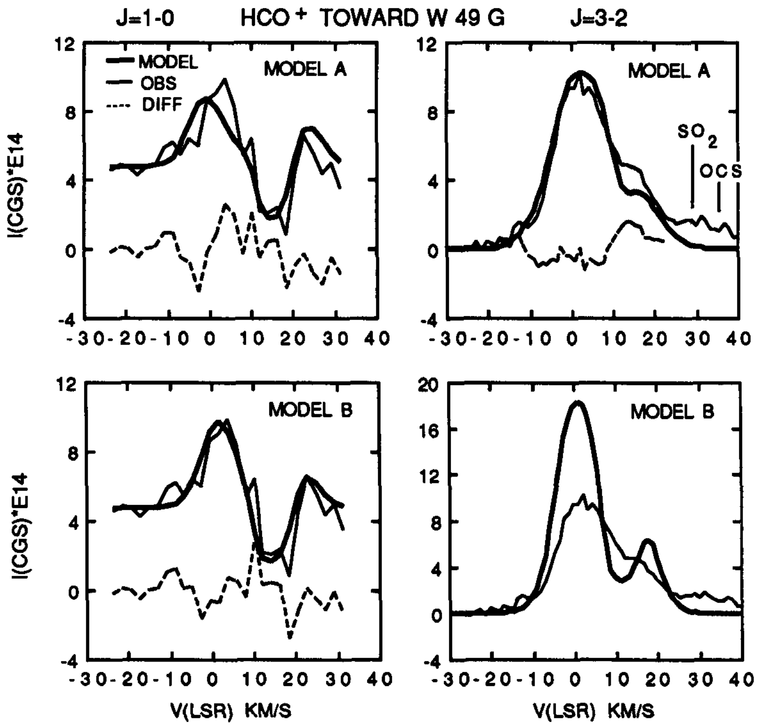

FIG. 1 OBSERVED AND THEORETICAL HCO^+ PROFILES TOWARD W 49 G

Homologous collapse models can be found which fit the J=1-0 profile of HCO^+ toward W 49 G, but such a $v \propto r$ law generally produces a too narrow and symmetrical J=3-2 line. This is partly overcome by introducing a gradient in turbulent velocity which produces large line widths in the center of the cloud.

The radiative transfer models are *not unique* as seen by the above comparison of observed and theoretical J=1-0 profiles of HCO^+ for models A and B. However, Fig. 1 illustrates the importance of observing higher transitions for significantly restricting the kinds of models and ranges of physical parameters which can fit the data. Except for possible differences in the molecular abundances and their gradients, the same model should reproduce observed profiles of other molecules such as CS as well as HCO^+.

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