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Diagnosing the ISM in star-forming regions

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Abstract. A report on studies using the observed line ratios of high-density molecular tracers to diagnose the physics and chemistry of the ISM in star-formation environments.

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Molecular line emissions may be used for the diagnostics of physical and chemical conditions of the Interstellar Medium (ISM) and for understanding the dominant heating processes. Molecular species react differently to environmental influences but the ensemble of their line ratios provides a most sensitive probe of the physics and chemistry. A multi-molecule multi-transition interpretation serves to estimate densities, temperatures, radiation fields, and chemical abundances of the emission regions. The observed line ratios (of HCN, HNC, HCO^+, CN, and CS) will be interpreted using an extensive physical/chemical modeling network, which includes large numbers of molecular species and reactions as well as the radiation transfer. The objective of these studies is to establish a benchmark for modeling the ISM variations in star-formation regions in resolved Galactic sources, in partially resolved nearby galaxies, and in unresolved distant sources.

Isolated Galactic star-formation regions (Loenen *et al.* 2008) can be consistently diagnosed using observed line ratios as a distance-dependent mixed signature of a PDR and a warm molecular envelope. A single CS transition already shows the Sulpher depletion, while the HCO^+ reveals a variation in the CR flux with galacto-centric distance.

The integrated ISM in starburst nuclei observed over a large range of FIR luminosities shows distinct excitation regimes relating to the mean density and the nature of heating source (Loenen *et al.* 2008). The HCO^+/HCN and HCO^+/HNC ratios are sensitive to density. The HNC/HCN ratio discriminates between heating by X-rays (XDRs), UV-photons (young PDRs), and added mechanical heating due to star-formation feedback.

Molecular emissions of high-density tracer molecules also provides insights into the time-evolution of a starburst and the nuclear ISM. The extragalactic data displays clear relations between molecular emissions of high-density tracer molecules from the starburst nucleus and the FIR luminosity. This behavior and the observed variation in the line ratios can be explained with a simple model for the evolution of the starburst and of the depletion and destruction of the high-density ISM during the outburst (Baan *et al.* 2008). In this picture, the observed ratio of the (nuclear) HCN over the (extended) CO(1-0) emissions may serve as an evolutionary time scale. Modeling results suggest that the observed line ratios vary with time (during the evolution of the starburst) as a function of mean nuclear density and of variation of the heating sources (Baan *et al.* 2009).

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