Submillimeter Line Surveys of Young Stellar Objects Using the Caltech Submillimeter Observatory
James L. Sanders, Mary L. Radhuber, Jacob C. Laas, Jay A. Kroll, and Susanna L. Widicus Weaver
Emory University, Atlanta, GA, USA

Introduction
Advancements in radioastronomical instrumentation have allowed for the identification of approximately 170 interstellar molecules, many of which are complex organic molecules (COMs). Many of the detected COMs, which include such species as glycolaldehyde and formamide, are thought to be prebiotic precursors in the chemistry of these star-forming regions. Complex organic chemistry is especially rich in hot cores/corinos where thermal evaporation during the warm-up phase of star-formation releases molecules from icy grain mantles into the gas phase. Grain surface and gas-phase astrochemical models provide predicted abundances of COMs, and these predictions can be tested through deep, broadband spectral line surveys targeting COM emission. Here we present the results of several spectral line surveys and our quantitative analysis of these sources.

Molecular Targets
We have targeted a set of COMs that serve as tracers of key chemical pathways in interstellar chemistry. Each target molecule contains functional groups that are produced in radical-radical reactions in the ices that coat interstellar dust grains. Observations of these particular molecules allows quantification of each pathway.

Observations
We have used the Caltech Submillimeter Observatory (CSO) to conduct deep λ=1.3 mm unbiased line surveys of 8 sources including hot cores, hot corinos, giant molecular clouds, and shocked regions. These line surveys cover frequencies in the range of 215 GHz to 270 GHz with an RMS noise level of ~30 mK, which is sufficiently deep to probe many of the most complex COMs that have been identified to date.

Analysis
We have performed detailed spectral analyses for these line surveys, targeting a selection of COMs that are key tracers of the prebiotic organic chemistry in star-forming regions. The spectra were first deconvolved to single-sideband spectra using the CLASS program in the GILDAS program suite [1]. The MAGIX program, written for the XCLASS analysis suite [2], was then used to perform least-squares fitting of the column density and rotational temperature for each target molecule in each spectrum. Local thermodynamic equilibrium conditions were assumed for the initial analysis.

Figure 3. Full single-sideband spectra of all sources. The intensity scale has been limited to enable a clearer view of the spectra, resulting in the strong CO line in the Orion spectrum being cut off.

Results and Future Work
Each of the molecules targeted by these observations were detected in all sources except for glycolaldehyde. Column densities and rotational temperatures were found to vary dramatically between sources.

Table 2. Column densities and rotational temperatures determined through least-squares analysis.

Table 1. A set of sources that cover a range of chemical complexity and physical conditions were targeted by these observations.

Future work will involve obtaining line surveys of more sources with a greater variety of physical conditions. Additional analysis will focus on examining possible correlations between sets of molecules, as well as correlations between physical conditions and chemical complexity.

References
[1] GILDAS, Institut de Radioastronomie Millimétrique, Grenoble, France
[2] XCLASS, Peter Schilke, University of Cologne, Germany

Acknowledgements
Derek Liu, Shinya Wang, Caltech/CSO staff
Funding provided by STWF's startup at Emory University