Structure of Hot Cores traced by highly excited HCN

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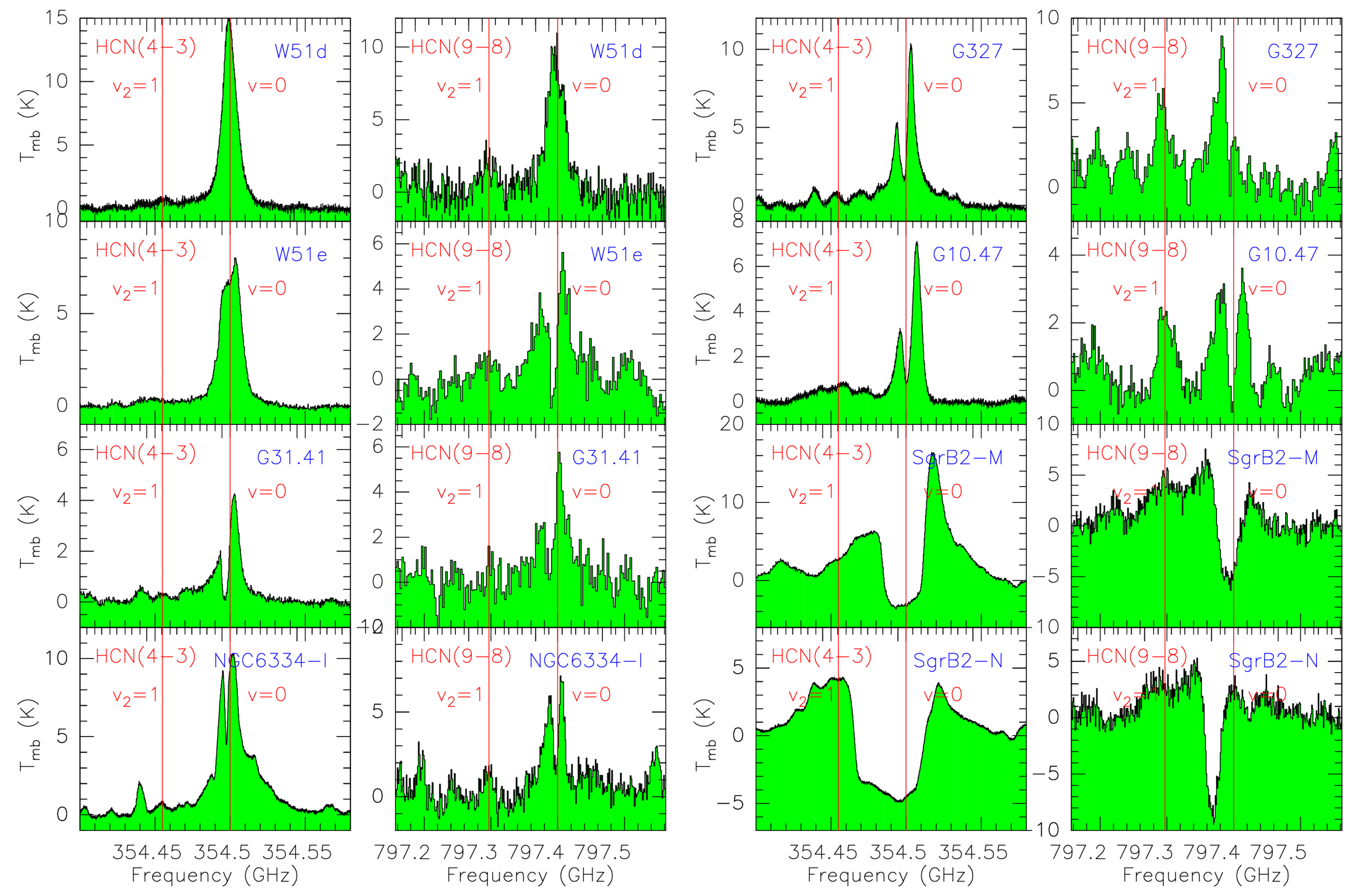
Revealing the Hot Core Structure

Our aim is the determination of the physical structure of hot cores: density, temperature, and velocity field. (see poster by Schilke et al.)
HCN, with its high critical density and observable rotational lines in vibrational states which are about 1000 K above ground, is an important tool for this. While the shape of the optically thick main line is sensitive to the line-of-sight structure, the vibrational satellite originates from the hottest regions. We have therefore observed a sample of hot cores in the (4-3) and (9-8) transitions with APEX (*right*), and complement our data with the SMA (*bottom*).

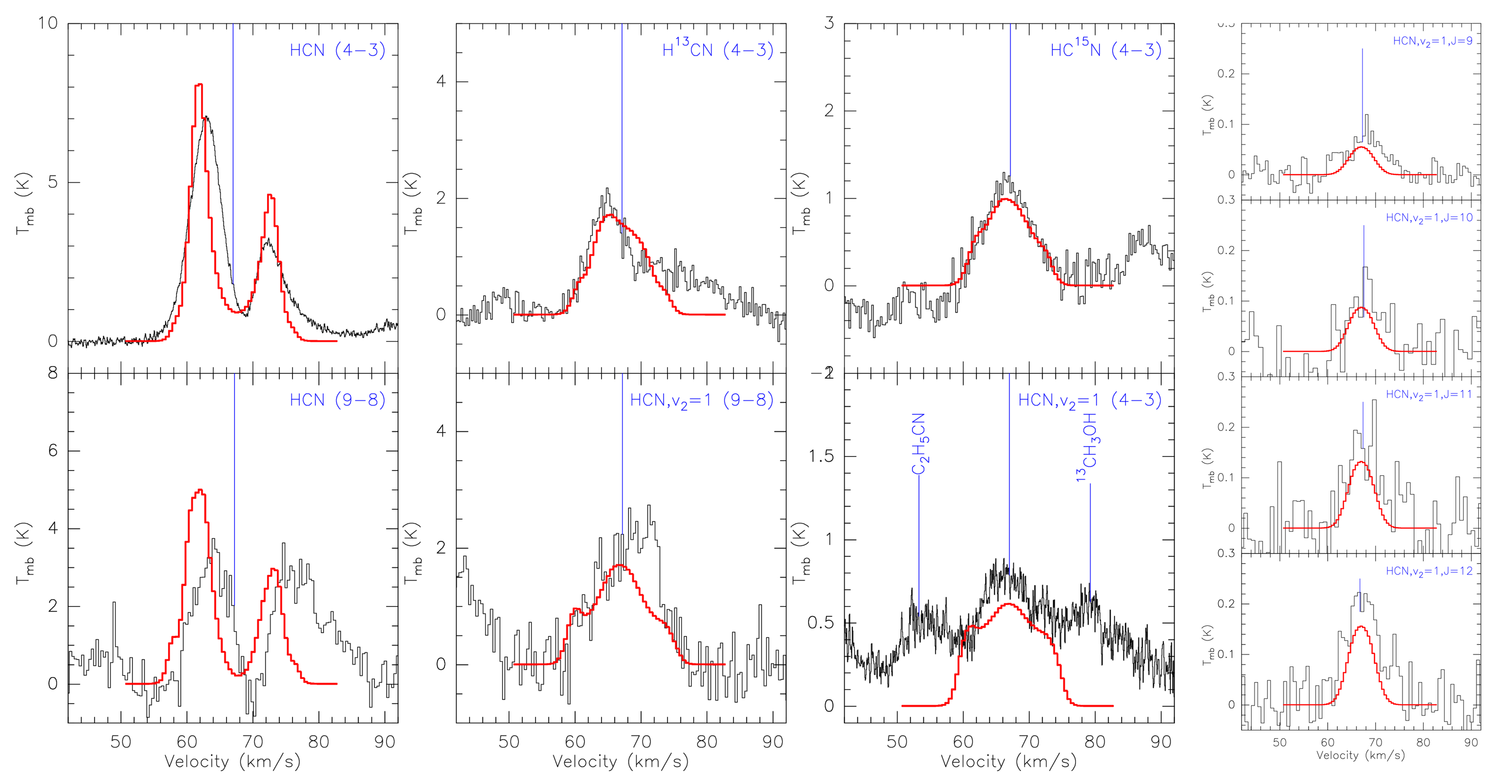
Modeling

Extracting the information contained in the lines requires radiative transfer modeling, comparing the output of different source structures to the observations. We have used RATRAN (Hogerheijde & van der Tak 2000) to try power law structures in spherical symmetry. The best fit model for G10.47 is shown below. Effelsberg data of l-type lines, optically thin transitions of vibrationally excited HCN at cm wavelengths, additionally provided us with the necessary amount of hot HCN present (strong toward G10.47, even stronger in SgrB2-N, in absorption toward SgrB2-M). The model can be adapted to fit most of the other sources, although in some cases a spherical model does not seem suitable to reproduce the spectra.



APEX spectra

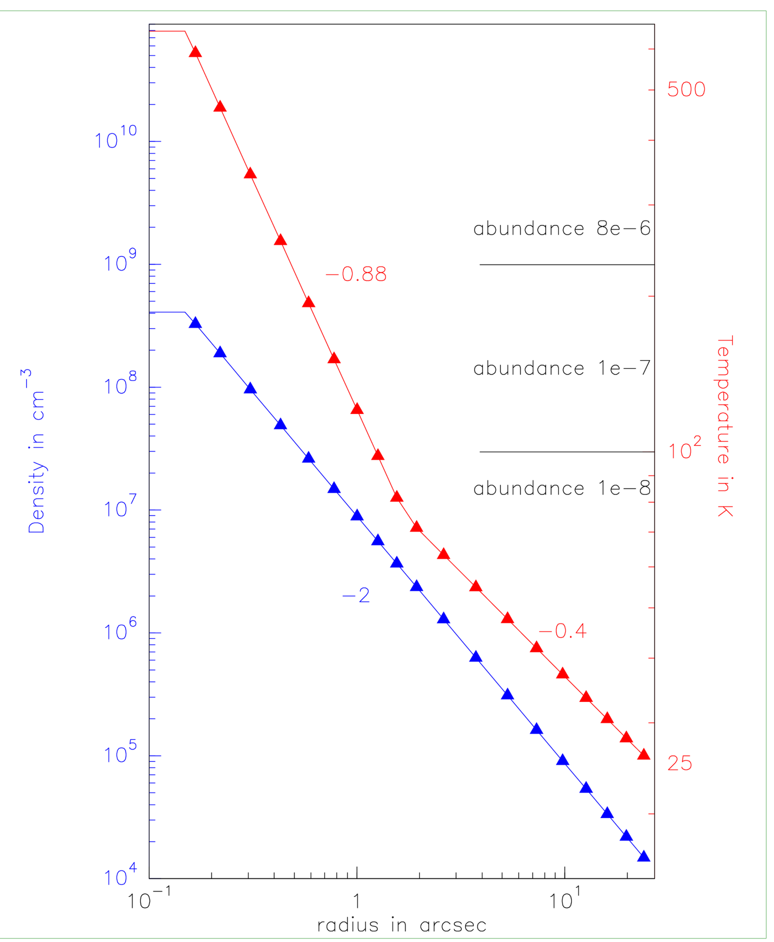
This sample of hot cores was observed by APEX in submm transitions of HCN. Many lines show infall signature. Vibrationally excited HCN is visible at 800 GHz, although the high dust column densities could have obscured the hot region.

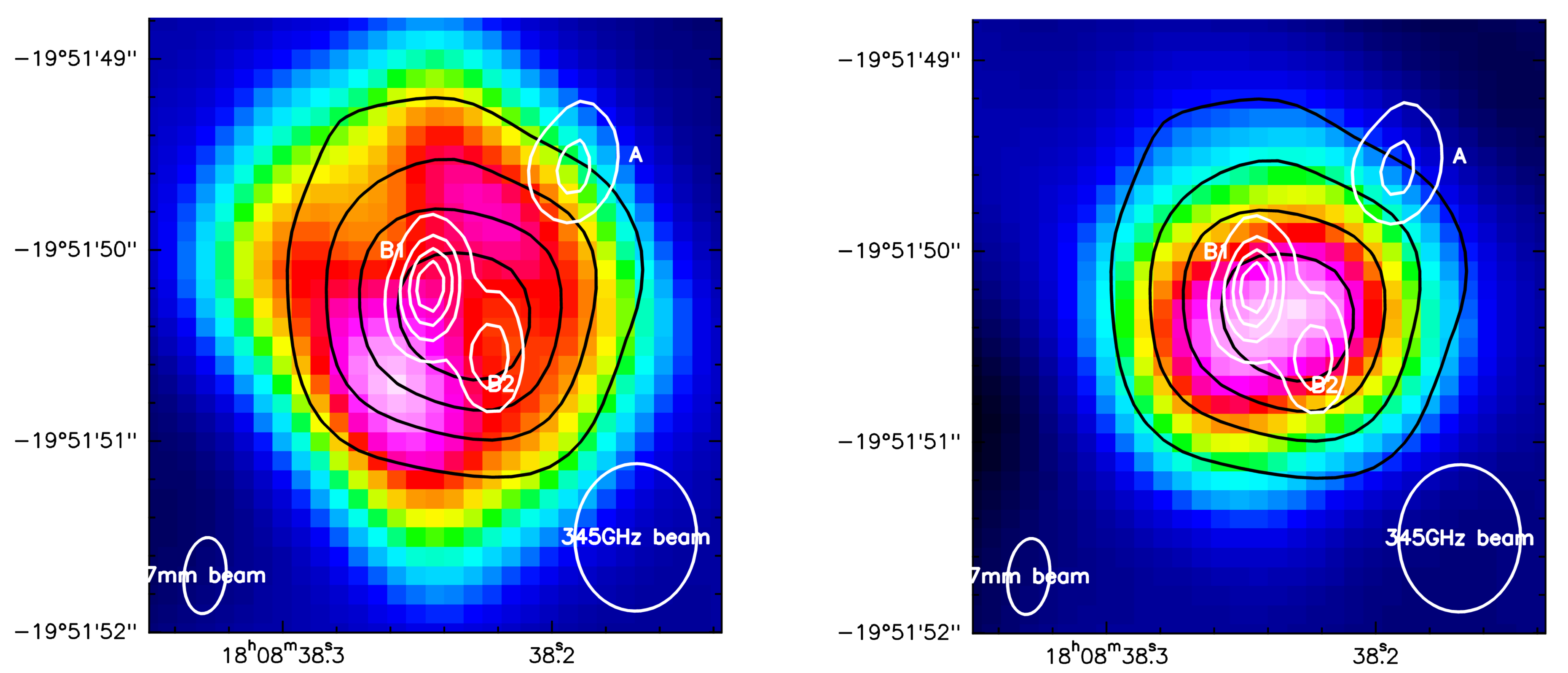


Best Fit Model for G10.47

The model structure (*right*) has abundance jumps at 100 and 230 K and a broken power law in temperature, which was guided by DUSTY radiative transfer modeling results. The velocity field is radial gravitational infall with 0.1 times the free-fall velocity.

The APEX (*left*) and Effelsberg data (*center*) show the agreement of the model with the single-dish observations.
For comparison with interferometer maps, the model is transformed to uv space fold with the uv coverage of the observations and processed the same way as the data.

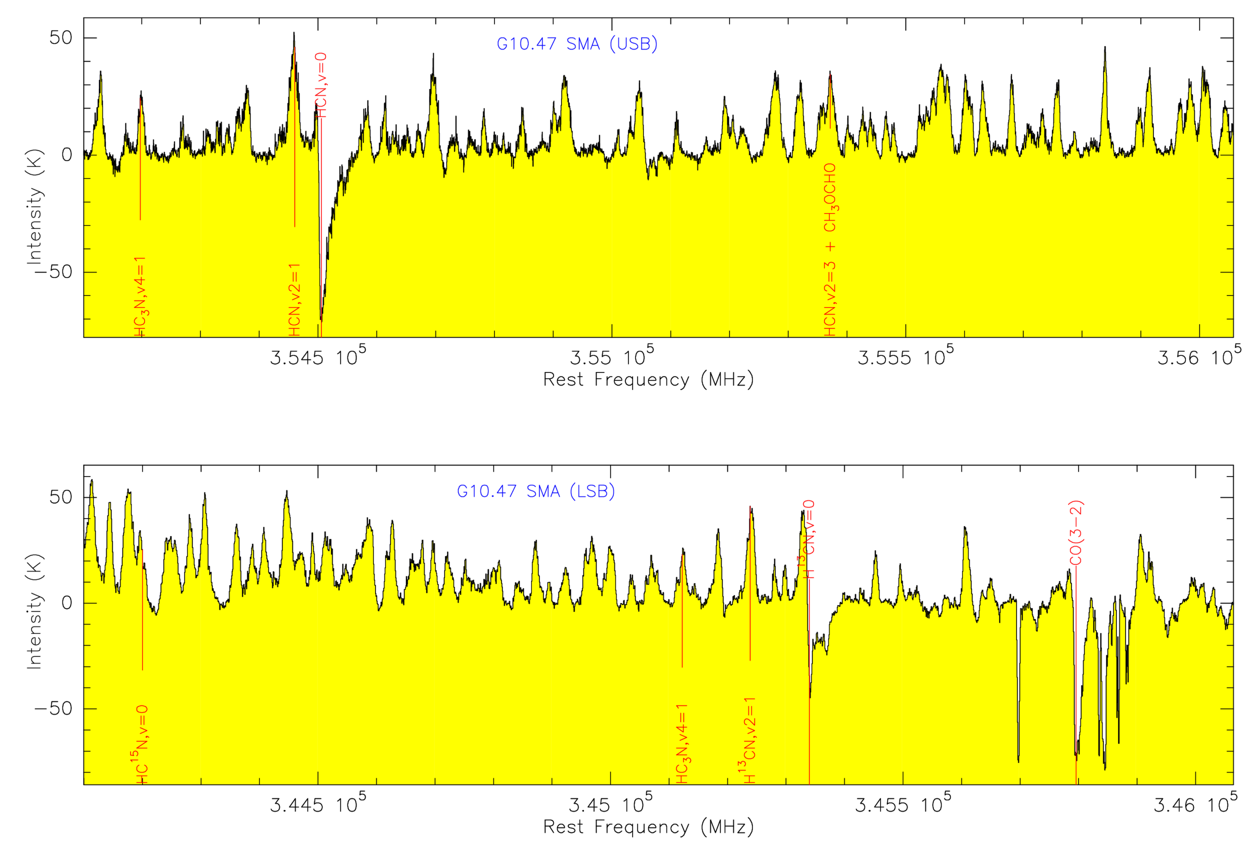




SMA

However, the above model failed to fit the spatially resolved data obtained with the SMA: It is too strongly peaked. The SMA maps of G10.47 show (in color) the 4-3 transitions of vibrationally excited HCN (*left*) and $H^{13}CN$ (*right*). In contours, the 350 GHz (black) and the 7mm continuum (white, VLA) are overlaid. The apparent weakness of the HCN line toward the center is due to its high optical depth.

The large extension of vibrationally excited HCN is difficult to explain with only one heating source, and a realistic modeling would also take the (non-spherically distributed) H II regions into account.



SMA central position

A lot of lines from highly excited molecules are seen in G10.47 (confusion-limited line identifications), illustrating the potential: Fitting all lines would constrain the model even more.

Conclusions

Already our preliminary analysis presented here shows the great potential of multi-line radiative transfer modeling, particularly of spatially resolved data. It is also obvious that spherically or axisymmetric models are too limited for modeling all the features we see, and we have to go beyond, to true 3-D radiative transfer models. These, guided by models of physics and chemistry, and in close interaction with theorists, will eventually be able to provide a realistic model of the source and its velocity field in all three spatial dimensions. One will be able to study the effects of multiple heating sources, disk-like structure etc., and will gain access to sub-beam-sized structures through modeling of line shapes. By looking at multiple sources, it will be possible to distinguish between different modes of massive star formation, all currently under debate, and determine their relative importance.

Outlook

We plan to
- conduct more single-dish and interferometric observations,
- submit a Herschel/HIFI Open Time Key Project (HIMASSS) to extend the study to higher excited lines,
- work on 3-D radiative transfer programs to fully exploit the data, at the same time extending to more molecules.

Stay tuned!