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For IRAM use
Registration N°:
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PROPOSAL FOR 30m RADIOTELESCOPE

Deadline: March 6th, 1997 – Period: May 15 1997 - Nov. 15 1997

TITLE *(self-explanatory)*

How "Coherent" are Dense Cores?

Type: extragalactic: continuum○ CO lines○ other○

galactic: continuum○ lines● circumstel. env. ○ young stel. obj. ● cloud struct. ● chem. ● other○

ABSTRACT

We plan to construct a suite of new spectral-line maps of the TMC-1C dense core, which will allow us to **test our model of "velocity coherent dense cores."** The model was proposed to explain the *observed* differences between cores and their environs. The cores appear to have nearly constant line widths, and sharply peaked column density distributions, while their environs, like most of the molecular ISM, exhibit a power-law relation where line width increases with size scale (Larson 1981), and nearly constant column density. Our model predicts that the level of density and velocity sub-structure inside the cores should be diminished in comparision with its surroundings.

(max. 8 lines)

Is this a resubmission of a previous proposal ? no● yes○ ; proposal number: ...

Is this a continuation of (a) previous proposal(s) ? no● yes○ ; proposal number(s): ...

hours requested for this period: **70**

LST range(s): from: 0h to: 10h number of intervals: 7
from: to: number of intervals:

Number of hours foreseen for full completion of this proposal: ☐ of which ☐ were already allocated

Special requirements *(dates, etc...)*: really none ?

Receivers: 3mm1● 2mm● 230G1● 0.8mm○ bolometer○
3mm2○ 230G2○ *(see Table of Compatibilities)*

Frequencies*: (to 0.1 GHz and corrected for redshift) 93.2 112.4 144.1 144.6 216.1 224.7

List of Objects (give most common names) with equatorial coordinates

EPOCH:1950

Source	RA	DEC	
TMC-1C	4:38:34.4	25:55:00.0	5.2

(continue on next page, if needed)

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Expected observer(s) Goodman + 2 others

join to this form: scientific aims(≤ 2 typed pages + 1 page Figs., Tables) and list of related publications **imperatively*

How “Coherent” are Dense Cores?

What are “Coherent Dense Cores?”

We have recently proposed a physical picture of star-forming dense cores and their environs where the **cores can be identified in velocity space** as regions of nearly constant line width (Barranco & Goodman 1997). As part of the picture, we also offer a self-consistent **explaination of the differences in** the power-law slopes among various Types of **“line width-size” relations** in the literature (Goodman et al. 1997a).

We call the regions the regions of nearly constant line width “velocity coherent dense cores.” These cores, previously identified as regions of high extinction ($A_V > 5$) and as density peaks ($n \gtrsim 10^4$ cm^{-3}) in spectral-line maps, are associated with the formation of stars like our Sun (Beichman *et al.* 1986; Benson and Myers 1989; Myers and Benson 1983). Although many theories of low-mass star formation begin with an isothermal sphere (e.g. Shu 1977), the line width inside the coherent cores is *not* purely thermal. A clearly measureable turbulent component remains even in these “coherent” regions.

Figure 1 presents a summary of the velocity coherence picture, using some of our recent (low-resolution) observations of TMC-1C as an example. The coherent cores are distinguished from their environs by two features. First, as already mentioned, the line width inside a coherent core is nearly constant–but, outside the core, line width increases with distance from the core’s center as a power law $\Delta v \propto R^a$ with slope $a \sim 0.2 - 0.3$ (please consult Figure 1)[1]. Second, the column density inside the core rises rapidly toward its center, wheras the column density in the environs is nearly constant, rising only very slowly toward the core. These factors imply that the gas filling factor inside the cores is much higher than in their surroundings, and that the cores are condensation centers.

The physical picture we propose for cores and their environs is analogous to each core representing an “island of calm in a turbulent sea” (see the painting in Figure 1). We, and others, have speculated that a decrease in the magnetic field’s ability to control gas motions in regions of very low ionization is responsible for the buildup of gas which leads to the formation of a coherent dense core. Our goal here is to see just how “coherent” this built-up gas is.

A More Thourough Investigation of the Coherence Scenario: Existing, Current, and Proposed Observations

Our papers on Velocity Coherhence have raised a number of questions. First and foremost among them is: “how much density and velocity sub-structure is there within a coherent core?” If these cores represent regions of higher filling-factor and lower velocity dispersion than their surroundings, then **there should be markedly less contrast in the density and velocity structure within the cores.**

To date, we know of only two dense cores having been mapped in single-dish multi-transition observations with spatial resolution high enough to see significant structures within the 0.2 pc scale typical of a half-power NH_3 contour (often used to define core size): TMC1 “Core D” (Langer *et al.* 1995; Kuiper *et al.* 1996) and L1498 (Lemme *et al.* 1995). Both studies do find identifiable structures in the high-resolution maps, but they also point out that those structures may be highly transient–and thus different than structures seen on larger scales. In an extensive set of new interferometric observations of the 1.3 cm transitions of NH_3 with a $10''$ synthesized beam at the VLA, we only find detectable flux in cases where a core harbors an embedded young star (Goodman et al. 1997b). The interferometer is only sensitive to the highest spatial frequencies, and the flux we find around the young stars is typically $\sim 10\%$ of the single-dish flux and is probably produced by warm, dense circumstellar material.

Thus, existing observations have shown: 1) potentially transient structures, and 2) structures associated with circumstellar gas. (Note that small, transient, but significant structures have also been observed far from cores at cloud edges in multi-transition CO 30-m observations (Falgarone et al. 1992).) We seek data which will allow us to do a **quantitative** analysis (e.g. Figure 1) of the density and velocity structure inside the FWHM NH_3 contour of a dense core, for the explicit purpose of comparing the core to its environs. The 30-m telescope is optimally suited to mapping out the core interior. As for the environs, we have already been awarded time at the FCRAO 14-m telescope to map out multiple transitions in TMC-1C with $40''$ resolution.

We would like to emphasize that the observations detailed below are not just “exploratory.” Our coherence picture makes very specific predictions (e.g. about how line width will depend on scale) about the differences between cores and their environs, and the 30-m observations we request below, along with our upcoming and existing FCRAO observations are carefully aimed at providing a stringent test of the picture. If the picture is

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[1] The power-laws shown in Figure 1 are for line width as a function of antenna temperature. Goodman et al. 1997a explains our conversion from antenna temperature to size.

correct, the "fractal" nature of the ISM changes within cores, which may fragment, but are not as self-similar as their surroundings. If the coherence picture turns out to be incorrect, these new observations will give us all a much better idea of what the correct picture looks like!

Observing Plan

To investigate the internal structure of dense cores we plan to map N_2H^+(1-0), DCO^+(2-1), DCO^+(3-2), $C^{17}O$(1-0), $C^{17}O$(2-1), and $C^{34}S$(3-2) inside the half-power NH_3 contour of the TMC-1C core.

N_2H^+, DCO^+, and $C^{34}S$ are good tracers of high density gas ($n \sim 10^4$ to 10^5 cm^{-3}). In particular, N_2H^+ and DCO^+ are easily detected in low mass cores with typical brightness temperatures of $\sim$ 2 K, as recent observations have shown (e.g. Butner *et al.* 1995; Caselli et al., in preparation; Tafalla et al., in preparation). Observations of the J=1-0 rotational transition of N_2H^+, which presents hyperfine structure, will also provide a direct measure of the line optical depth. The two transitions of DCO^+ will allow us to estimate the volume density and excitation conditions in the densest part of the core. $C^{17}O$ lines are optically thin and are needed to make accurate column density estimates.

Time requirements

We plan to use the 3mm, 2mm, and 230G1 receivers simultaneosly to map N_2H^+(1-0), DCO^+(2-1), and DCO^+(3-2). From recent 30-m observations in L1544, a core with characteristics similar to TMC-1C (Tafalla et al., in preparation; Caselli et al., in preparation), we expect peak brightness temperatures of all the three lines of about 2 K. This translates in the following values of antenna temperature: 1.5 K at 3 mm, 1.2 K at 2 mm, and 1.0 K at 1 mm. By frequency switching at the three frequencies, and assuming a spectral resolution of 20 kHz at 3 mm and 40 kHz at 2 and 1 mm, we will need to integrate the signal for 5 min in each position to reach a S/N ratio > 5 ($\Delta T_{A,\rm rms}$=0.11, 0.16, and 0.20 K at 3, 2, and 1 mm, respectively).

The second part of the project consists of mapping the J=1-0 and J=2-1 transitions of $C^{17}O$, and $C^{34}S$(3-2) by simultaneously using the three receiver in a setup similar to the one described in the previous paragraph. Our estimates of the $C^{17}O$ antenna temperature are based on previous $C^{18}O$ observations by Myers, Linke & Benson (1983) and assuming the interstellar abundance ratio $[^{18}O]/[^{17}O] \sim 4$ (Penzias 1981). We obtain $T_A^*[C^{17}O] = 0.8$, and 0.5 K for the J=1-0 and J=2-1 transitions, respectively. For $C^{34}S$ we used recent 30-m observations in similar cores to find $T_A^*[C^{34}S] = 0.3$ K. To obtain a peak S/N > 5 we need to integrate 20 min ON source (by frequency switching). At the frequencies of the three lines, 20 min of integration time give $\Delta T_{\rm A,rms} = 0.1$, 0.06, and 0.1 K at 3, 2, and 1 mm, respectively.

The total requested time, 70 hours, will allow us to fully map out the $\sim$ 4 square arcmin area within the FWHM NH_3 contour shown in Figure 1 with good S/N in the DCO+ setup, and to map about 50% of this area (e.g. in strips or with coarser sampling) in the $C^{17}O$ setup.

References to Relevant Work

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*See cfa-www.harvard.edu/~agoodman/vel_coh.html for preprints.