Combined Array for Research in Millimeter-wave Astronomy

Proposal Number

c0664

Combined Array for Research in Millimeter-wave Astronomy

Observing Proposal Cover Sheet

General Proposal Information

Title	Date	TOO/Time Critical
Large scale Mapping of Complex Molecules along the TMC-1 Ridge	2010-08-29	—

Scientific Category	1cm Project	3mm Project	1mm Project	Level of Help Required
Chemistry / Interstellar Medium	—	X	—	Consultation

Authors List

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Advisor must send a supporting letter if Thesis is checked. See Instructions.

Abstract

The Taurus Molecular Cloud (TMC-1) is of particular interest because of its quiescent and early stage of star formation. Due to its proximity ($\sim$140 pc), it is possible to probe the physical, chemical and kinematic conditions on size scales similar to stellar systems like the Solar System. The primary goals of this proposal is to map the entire TMC-1 molecular ridge complex in several molecular species including HCN, $H^{13}CN$, $H^{13}CO^+$, HCS^+, CS (or $C^{34}S$), HC_3N, HC_5N, c-C_3H_2, and CH_3NC. To this end, we will then be able to: 1) Detect the compact emission of the well known and abundant cyanopolyynes and compare that to the distribution of HCN and $H^{13}CN$; 2) The high resolution observations should uncover higher density clumps ($\sim 10^{6-7}$ cm^{-3}) of molecular material that have eluded detection with the lower resolution observations. This is important to test the chemical formation models of molecules in the TMC-1 complex; 3) Mapping these optically thin molecular species will enable us to calculate the squared velocity dispersion as a function of the length-scale for both cospatial ion and neutral molecules. Thus, we will calculate the turbulent ambipolar diffusion length-scale and an estimation for the magnetic field in the plane of the sky. Therefore, we are requesting a total of 40 hours to perform 5, 19 point mosaics along the TMC-1 ridge.

Source Information

#	Source	RA	DEC	Freq	A[1]	B[1]	C	D	E	SL	# Fields	Species	Imag/SNR	Flex.HA
1	TMC-1 - Pointing 1	04:41	25:41	96	0	0	0	8	0	0	19	HCN, etc...	Imaging	—
2	TMC-1 - Pointing 2	04:41	25:41	96	0	0	0	8	0	0	19	HCN, etc..	Imaging	—
3	TMC-1 - Pointing 3	04:41	25:41	96	0	0	0	8	0	0	19	HCN, etc...	Imaging	—
4	TMC-1 - Pointing 4	04:41	25:41	96	0	0	0	8	0	0	19	HCN, etc...	Imaging	—
5	TMC-1 - Pointing 5	04:41	25:41	96	0	0	0	8	0	0	19	HCN, etc...	Imaging	—
	Total Hours: 40.0													

Special Requirements

None

Status of Prior CARMA Observations

c0449 - High Resolution Mapping of HCOOH and CH_3OCHO toward G19.6-0.23 - Data have been analyzed and paper is in preparation.

Scientific Justification

The Taurus Molecular Cloud (TMC-1) is of particular interest because it is in a very early stage of star formation and due to its proximity of ∼140 pc, it is possible to probe the physical, chemical and kinematic conditions on size scales similar to stellar systems like the Solar System. As such, mapping observations have taken place since the late 1970's however with very low spatial resolution. The first map of the "entire" TMC-1 complex was made in NH_3 and HC_5N with a spatial resolution of greater than $2'$ [1]. Even from these low resolution observations, it was shown that the cyanopolyynes (i.e. molecules with molecular formulae like HC_nN where n=1,3,5,7,9,11, etc...) show a different spatial distribution than NH_3. Subsequent mapping shows similar spatial abundance gradients between the points along the ridge known as the "cyanopolyyne peak" and the "ammonia peak" (hereafter CP and AP, see figure 1) to exist in many molecules with the most pronounced being CS, SO, HCN, HNC, C_2H, HC_3N [2,3]. There have been several attempts to explain the origins of this molecular gradient. Some of the earliest interpretations included differences in excitation between the CP and AP, but it appears the most probable explanation is a true variation in the abundances of species along the ridge between the CP and AP [4,5,6].

Embedded in this region lies the protostellar source IRAS 04381+2540 towards the northwestern end (Figure 1). The most complete model which attempts to replicate the molecular abundance gradients and explain the organic diversity in the CP region was presented by Markwick et al. (2000). The model is based on the assumption that shear Alfvén waves are propagating in TMC-1, perhaps from IRAS 04381+2540. Alfvén waves are shown to be capable of desorbing grain ice mantles, releasing the carbonaceous species C_2H_2, C_2H_4 and CH_4 into the gas phase, which then react in a complex chemistry to enhance the abundances of other organic compounds. After some time, the carbon chain species are destroyed and molecules like NH_3 are formed. If the waves propagate along the ridge from the IRAS source through AP to CP, releasing mantles as they go, the CP region will be younger than the AP in chemical terms, and the observed gradients in molecular abundance are reproduced.

There is circumstantial evidence for the propagation of MHD waves in TMC-1 and, the dissipation length of the waves, which is the length over which chemistry is affected, is similar to the clump sizes observed in CCS [7]. The distance between the CP region and the IRAS source is ∼0.27 pc which is about the length-scale for the dissipation of long Alfvén waves[6]. In addition, the dissipation of Alfvén waves might lead to class C shocks which could heat the grain surfaces releasing carbonaceous molecules to the gas phase[8]; supporting the hypothesis of Markwick et al. (2000). It has also been proposed that in weakly ionized molecular clouds, the linewidth of ion molecular species should be in general less than their coexistant neutral molecular counterparts[9]. Applying this principle, Li & Houde (2008) devised a novel way to estimate the strength of the magnetic field in the plane of the sky and to calculate the length-scale for turbulent ambipolar difussion, by comparing the downward shift seen between the ion and neutral spectra. By mapping the TMC-1 ridge at higher resolution with CARMA, we will be able to test this further as the interferometer will show the regions where both ion and neutral molecules coexist. Also, it is well known that ambipolar diffusion will damp Alfvén waves thereby dissipating the necessary energy to heat the gas, which will increase the collisions between dust grains and likely releasing complex molecules to the gas phase. ***Overall, depletions of gas-phase molecules, grain mantle evaporation,***

and shock interactions actively drive chemical processes in different regions around young stars that need to be further investigated at high resolution.

The initial findings of surveys of the small scale structures and fragmentation is that many of the clumps that are still unresolved at 10-20″ resolution in the TMC-1 complex are not gravitationally bound and will undergo expansion if they are not pressure bound[11]. The only way for these clumps to be bound is if they contain a density of $\sim 10^7$ cm^{-3} which could not be determined by existing chemical tracers or spatial resolution. ***Thus, higher resolution observations of different chemical tracers probing higher molecular densities known to exist at small spatial scales are necessary.***

Technical Justification

The primary goals of this proposal is to map the entire TMC-1 molecular ridge complex in several molecular species including HCN, $H^{13}CN$, $H^{13}CO^+$, HCS^+, CS (or $C^{34}S$), HC_3N, HC_5N, c-C_3H_2, and CH_3NC. These molecular tracers were chosen because 1) all can be observed in one correlator setup; 2) many have been observed toward the TMC-1 region previously; 3) trace high density regions and 4) have comparable low spatial resolution observations or single dish observations (see Figures 2 and 3). This mapping campaign will involve 5, 19 point mosaics along the entire TMC-1 molecular ridge and encompass both the CP and AP (illustrated in Figure 1). Using the CARMA RMS sensitivity calculator, in the CARMA D-array configuration centered around 96 GHz, for a 19 point mosaic at any one location, we should achieve a synthesized beam of $\sim 5.''8 \times 4.''8$, a central mosaic coverage of 141″, and a RMS noise level of 0.5 K with 0.23 km/s spectral resolution. This noise level and spectral resolution is adequate to detect the molecular species of interest in this proposal in one sidereal pass of each mosaic field. *Therefore, we are requesting a total of 40 hours to perform 5, 19 point mosaics along the TMC-1 ridge.*

To this end, we will then be able to: 1) Detect the compact emission of the well known and abundant cyanopolyynes and compare that to the distribution of HCN and $H^{13}CN$. The high resolution observations ($\sim 5''$) will be compared to the lower resolution ($\sim 50''$) observations[3]; 2) The high resolution observations should uncover higher density clumps ($\sim 10^{6-7}$ cm^{-3}) of molecular material that have eluded detection with the lower resolution observations. This is important to test the chemical formation models of molecules in the TMC-1 complex. Current models are run at constant temperatures and densities of 10K and $\sim 10^4$ cm^{-3}, respectively[12]; 3) Mapping these optically thin molecular species will enable us to calculate the squared velocity dispersion as a function of the length-scale for both cospatial ion and neutral molecules. Thus, we will calculate the turbulent ambipolar diffusion length-scale and an estimation for the magnetic field in the plane of the sky.

If successful, these will be the first large, high resolution mosaic of complex molecules in the TMC-1 region which will lead to the further understanding of the physical and chemical evolution of various regions along the ridge.

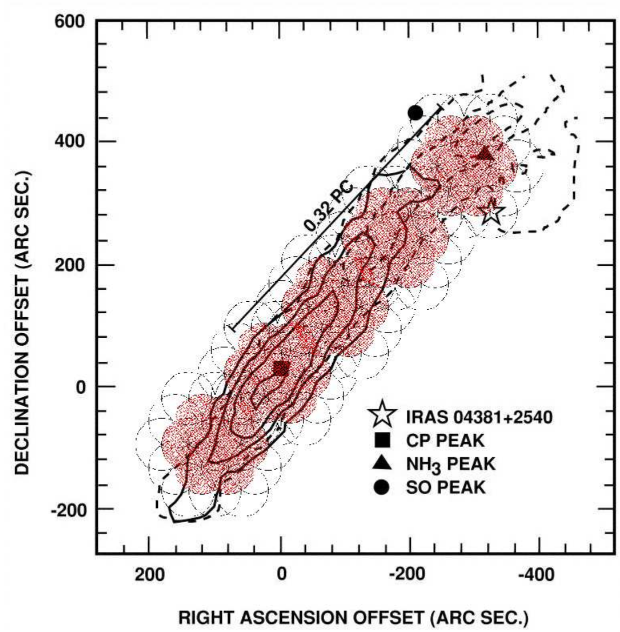

Fig. 1.— Schematic diagram of the TMC-1 ridge, taken from Markwick et al. (2000) and adapted from Fig. 6 of Olano et al. (1988, A&A, 196, 194). Spanning nearly 0.32 pc from the CP to the AP, we can cover this entire region using 5, 19 point mosaics as illustrated by the red overlays.

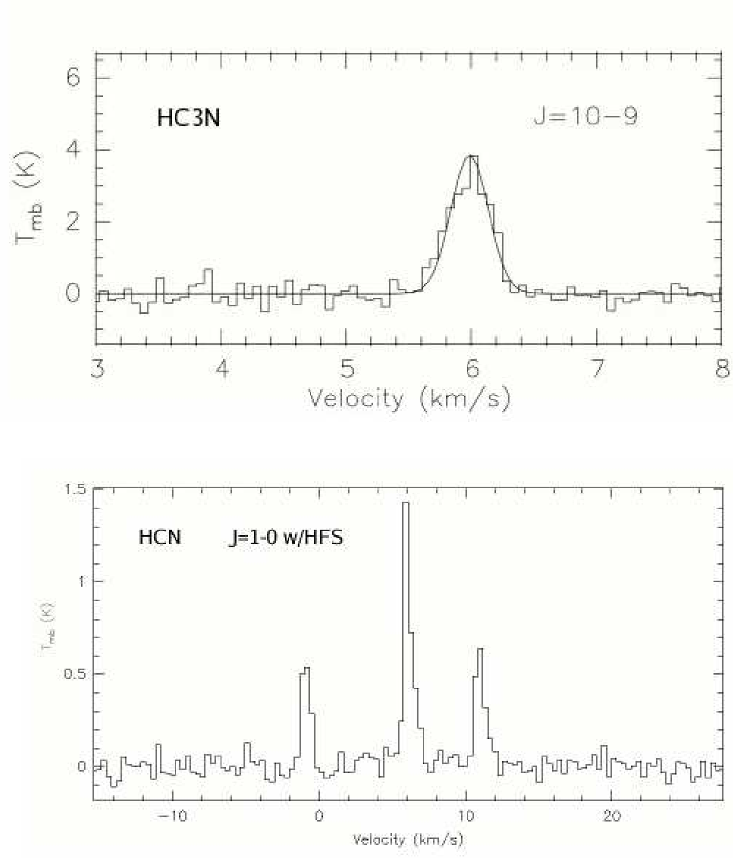

Fig. 2.— HC_3N and HCN single dish observation taken toward a single pointing position centered on the CP.

REFERENCES:

1. Little et al. 1979, MNRAS, 189, 539
2. Langston et al. 2010, BAAS, 216, 309.07
3. Pratap et al. 1997, ApJ, 486, 862
4. Hirahara et al. 1992, ApJ, 394, 539
5. Suzuki et al. 1992, ApJ, 392, 551
6. Markwick et al. 2000, ApJ, 535, 256
7. Peng et al. 1998, ApJ, 497, 842
8. Zweibel et al. 1983, ApJ, 270, 511
9. Houde et al. 2000a ApJ, 536, 857
10. Li & Houde 2008, ApJ, 677, 1151
11. Langer et al. 1995, ApJ, 453, 293
12. Millar et al. 2007, ApJ, 622, L87