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PROPOSAL FOR 30M TELESCOPE

Deadline: 11 Sep 2003 Period: 15 Nov 2003 — 15 May 2004

TITLE

A (COMPLETE) MAMBO Study of Perseus Starless Cores

Type: *Extragalactic:* continuum ○ CO lines ○ other ○
Galactic: continuum ● lines ○ circumstel. env. ○ young stel. obj. ● cloud struct. ● chem. ○ other ○

ABSTRACT

We propose to carry out the first systematic continuum study of starless cores in the Perseus molecular cloud. Perseus is a nearby cloud forming stars in an intermediate manner between Taurus and Orion, and its population of starless cores has remained unknown until recently. As part of a systematic study of this cloud, we have made the first catalog of candidate starless cores in Perseus, and here we propose to characterize these systems, in particular, their density profiles. By comparing the cores in the different areas of Perseus, and comparing the Perseus cores with cores in clouds like Taurus and Orion, we expect to better understand the relation between core internal conditions and their star-formation product. This survey is part of the COMPLETE collaboration, which aims to coordinate a number of multi tracer, multi wavelength studies by approximately a dozen of researchers to provide the first view ever of star forming regions from cloud to sub-core scales.

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

Hours requested for this period: **50**

LST range(s): from: 10 to: 22 number of intervals: 5
from: to: number of intervals:

Number of hours foreseen for full completion of this proposal: 50 of which 0 were already allocated

Special requirements: pooled obs ○ service obs ○ remote obs ○ polarimeter ○
Other requirements (dates, OTF, etc.) None

Receivers: AB ○ CD ○ AD ○ BC ○ HERA ○ Bolometer ●

Frequencies: (to 0.1 GHz and corrected for redshift) ....

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

Epoch: J2000.0

Source	RA	DEC	V_{LSR}
Pers-PSC01	03:24:48.5	30:23:53	+0
Pers-PSC02	03:25:32.4	30:43:46	+0
Pers-PSC03	03:26:14.8	30:30:28	+0
Pers-PSC04	03:32:19.3	31:21:20	+0
Pers-PSC05	03:33:17.3	31:05:46	+0
Pers-PSC06	03:36:22.1	31:11:02	+0
Pers-PSC07	03:43:26.7	31:43:42	+0
Pers-PSC08	03:43:56.7	32:00:16	+0
Pers-PSC09	03:44:47.2	31:41:47	+0
Pers-PSC10	03:47:38.0	32:53:04	+0

(for additional sources which do not fit here use the `\extendedsourcelist` macro)

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join to this form: scientific aims ≤ 2 typed pages and ≤ 2 of Figs., Tables and list of related publications

A (COMPLETE) MAMBO Study of Perseus Starless Cores

Dense cores of sizes close to 0.1 pc and central densities of a few 10^5 cm^{-3} represent the starting point of the star formation process in dark clouds (e.g., Myers 1999). These cores also represent the final stage of a process of condensation that starts at densities and sizes typical of clouds (few 10^3 cm^{-3}, > 1 pc, e.g., Snell 1981), and most likely ends when conditions of balance between self gravity and internal pressure (thermal, turbulent, and magnetic) are reached. How long this concentration process lasts (few Myr or tens of Myr?), what drives it (turbulence or ambipolar diffusion?), and what types of configurations does the gas finally achieve (stable or unstable?) are still unknowns that greatly limit our understanding of star formation even in the simplest environments.

Part of the difficulty in studying the core and star formation process results from its multiscale nature, which makes it hard for any single observation to cover all relevant sizes with adequate angular resolution. To complicate things further, observations over the last few years have shown that all but a few selected molecules freeze out onto cold dust grains at the moderate densities of dense core interiors, making the use of molecular tracers (critical for kinematic information) a non straightforward operation (e.g., Caselli et al. 1999, Tafalla et al. 2002). Overcoming these (and other) difficulties requires the non trivial approach of combining observations with different angular scales made in multiple, complementary species, all of them obtained in a coordinated manner. Such a multiple approach clearly exceeds the normal capabilities of a single person or even a small research group.

The COMPLETE Collaboration

In order to overcome the current limitations of star-formation studies, the COMPLETE collaboration was created last year. COMPLETE stands for COordinated Molecular Probe Line Extinction Thermal Emission survey of star forming regions, and consists of a number of researchers from different institutions (PI A. Goodman, co-Is: J. Alves, H. Arce, P. Caselli, J. di Francesco, M. Heyer, D. Johnstone, D. Li, N. Ridge, S. Schnee, M. Tafalla, and T. Wilson). This collaboration is an effort to coordinate the work of its members in order to achieve for the first time a full characterization of the gas and dust properties in a number of star forming regions, and thus answer (among others) the questions stated at the beginning of this proposal (see http://cfa-www.harvard.edu/COMPLETE/ for a full description of goals). COMPLETE is related to the SIRTF Legacy Project "From Molecular Cores to Planet-Forming Disks" (aka c2d, see Evans et al. 2003), which will survey in the IR (3.6 to 70 μm) 5 star forming clouds (Perseus, Ophiuchus, Lupus, Serpens, and Chamaeleon II) and a number of isolated dense cores. To maximize the synergy between these two efforts, the COMPLETE collaboration has chosen 3 clouds of the c2d project as its main targets (Perseus, Ophiuchus, and Serpens) and has already started a systematic effort to characterize them. This effort includes many square degree mapping of NIR extinction (all clouds using 2MASS data as described by Lombardi & Alves 2001), submillimeter continuum (Ophiuchus with SCUBA), and molecular emission (all clouds with FCRAO, where COMPLETE has been granted key project status).

While these arcminute-resolution efforts are ongoing and close to completion, the second step of the COMPLETE strategy is beginning. This step involves zooming into the densest and more opaque cloud regions of the clouds to achieve 10-20$''$ resolution and to study the detailed structure of the embedded cores (note that this is not possible with our SCUBA map because of its limited sensitivity). As part of this approach, here we request time to map with MAMBO a sample of Perseus fields selected to contain the best candidates for the yet-unknown population of starless cores in this cloud.

The Perseus Star Forming Region

Among the three target clouds of the COMPLETE project, the Perseus star-forming region stands out for its nearby location (300 pc), relatively compact size and high northern latitude, which simplify mapping, and the large number of Class 0 objects, which suggests vigorous ongoing star-forming activity. Perseus, in addition, is a place where both the isolated and clustered modes of star formation occur (the 300-star cluster IC348 coexists with isolated protostars like IRAS 3282), and this makes this cloud one of the most versatile nearby systems in its star formation activity.

Although several subregions of Perseus have been the subject of detailed analysis (e.g., NGC 1333, L1448), we still know very little about the global properties of this cloud. Its ability to form stars in different modes, for example, is completely mysterious, and it most likely arises from differences in the conditions of the molecular material over the cloud. As all high-resolution studies in Perseus have concentrated on regions already forming stars, the properties of the molecular material prior to star formation have not yet been characterized, and in contrast with the Taurus cloud, we even lack a basic catalog of starless cores which could be used to start such a study.

In order to improve our understanding of the star formation process in the Perseus cloud, the COMPLETE collaboration has concentrated its effort on this region. As a result of this, last winter we produced almost-finished FCRAO maps in CO and ^{13}CO (80,000 spectra each, to be completed this winter), and a large-scale 2MASS extinction map shown in Figure 1. The 2MASS extinction map, in particular, delineates in an unbiased way the regions of higher density and extinction where the star-forming material concentrates, and it forms the basis of the first catalog of starless cores in Perseus. To build this catalog, we have searched for all of the notable extinction peaks not associated with NGC1333 (to avoid confusion), setting a threshold of $A_V = 5$ mag. As a result, we have selected the 20 fields indicated by hexagons in Fig. 1, which have been further tested against the presence of embedded YSO by comparing their position with those of extremely red IRAS sources. In this way, we have selected the 10 candidates presented in the table of the cover page, which we believe to represent the best (and first) set of candidates to the yet-unknown population of starless cores in Perseus.

A MAMBO Study of Perseus Starless Cores

Given the lack of previous data on the Perseus starless core candidates, the goal of any first study should be to test their starless nature and to determine the basic core properties, and both goals can be achieved by mapping the cores in the millimeter continuum. Any embedded source that may have escaped detection by IRAS must be so red as to belong to Class 0, and therefore it should be easily detectable in the mm continuum. The proposed observations, therefore, will provide the most stringent test to the starless nature of our candidates.

With regard to the core internal properties, the millimeter continuum has become the standard tool for their study, as it is not subject to the freeze out problems that seem to affect most molecules (e.g., Tafalla et al. 2002). The approximately constant dust temperature and emissivity inside cores (e.g., Ward-Thompson et al. 1994), in addition, permits to use the millimeter continuum to easily derive accurate core density profiles (e.g., André et al. 1996). As different parts of Perseus are forming stars through different modes (isolated, clustered), and a key to that difference must lie in spatial variations of the dense core parameters, an important goal of our study will be to search for systematic changes in the core parameters (mass, density profiles) over the Perseus cloud. Finding such systematic changes would lead to the first correlation between the dense core properties and the different possible outcomes of the star formation process.

Another important result of a study of the starless cores in Perseus will be the systematic comparison with other clouds, in particular Taurus. A recent comparison of the circumstellar environment of protostars in different clouds (Motte & André 2001) shows that even those Perseus protostars forming in isolation do so differently than protostars forming in Taurus, in the sense that Perseus protostars have smaller and denser envelopes. This difference, which may explain other differences between the Taurus and Perseus protostar populations, most likely arises before star formation takes place, and it should be easily studied by comparing the properties of starless cores in both clouds. Recent work on a small sample of Taurus cores (Evans et al. 2001, Tafalla et al. 2002) has already produced radial density profiles for a sizable sample of systems forming stars in the isolated mode, and this sample will soon be increased by a recent systematic mapping project with MAMBO of Taurus and similar-to-Taurus cores (Bertoldi et al., also associated with the c2d SIRTF Legacy project, but restricted to the isolated star-formation mode). Additional progress in the mapping of group and cluster-forming clouds like Ophiuchus (Motte et al. 1998, Johnstone et al. 2000) and Orion B (Johnstone et al. 2001) has provided further data bases for comparison with the Perseus sample.

Finally, a COMPLETE MAMBO study of Perseus cores offers added value because of its coordination with other efforts. Our FCRAO mapping this coming winter of the fields in high density molecular tracers like CS and N_2H^+ will allow us to study the possible presence of infall motions, and to evaluate the degree of freeze out of different species onto cold dust grains. In addition, a detailed comparison with high resolution NIR extinction maps, soon to be obtained with a 4m class telescope, will allow us to cross check our continuum-derived density profiles (as in Alves et al. 2001), and to estimate possible radial temperature variations of the dust grains (Evans et al. 2001, Zucconi et al. 2001).

Time Estimate

To estimate the time needed for this project we have used the Time Estimator program (version 2.5) for on-the-fly mapping with typical winter conditions and no sky noise reduction (as it affects the extended emission we want to map). We have assumed a source size of $5' \times 5'$, which should be adequate to map all the core emission and reach empty sky at the map edges. To better recover the extended emission, we propose to observe each field twice, using different scan directions and chop throws. Setting the rms goal in 5 mJy/beam (to match available Taurus data), the Time Estimator program calculates that 50 hours of total observing time are required to map the 10 fields (all overheads included).

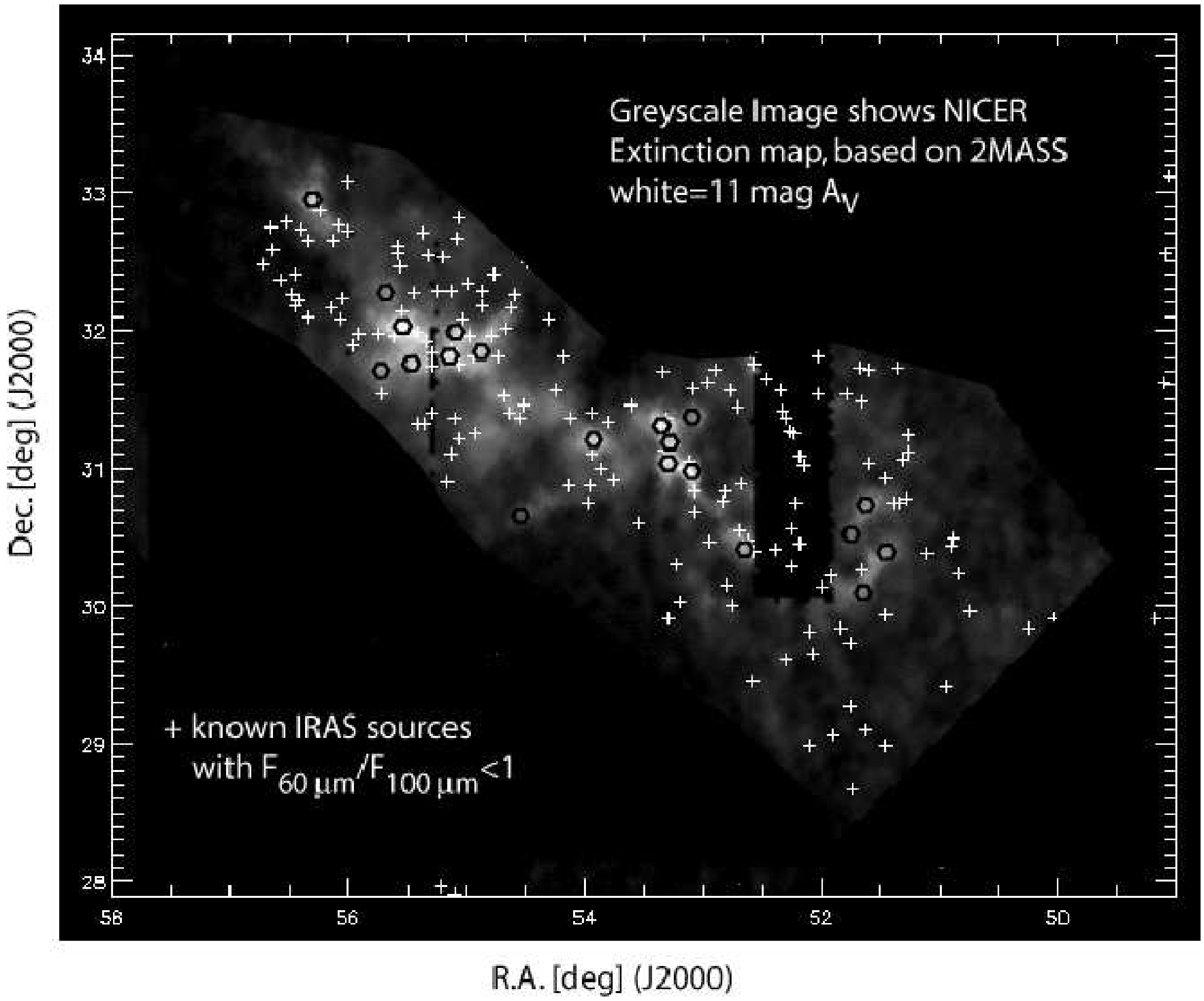

Figure 1: The grey scale is a map of the extinction in Perseus created using the NICER algorithm on the recently released 2MASS data, with the NGC 1333 region blocked. This map represents the best available view of the high opacity spots on this cloud, and it has been used to select the 20 most distinct peaks, indicated by hexagons in the figure. To test the starless nature of these peaks, the figure also shows the position of extremely red IRAS sources (crosses), most of them probably protostars embedded in the cloud. By requiring that the selected fields are not associated with red IRAS sources, we have selected the first list of (10) candidate starless cores in Perseus

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