Number ______
Priority ______

FCRAO PROPOSAL COVER SHEET

I 1) Principal Investigator:

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II **TITLE AND CATEGORY OF INVESTIGATION** *YOUNG STARS*
Follow-up of COMPLETE Cores

III ABSTRACT OF PROPOSED OBSERVATIONS

Time is requested to image the N_2H^+ 1-0 and CS 2-1 emissions from 27 targeted cores in the Perseus molecular cloud and to construct an unbiased survey ($60' \times 30'$ field) in these lines in the IC 348 sub-cloud in Perseus. These data will be used to investigate the distribution and kinematics of dense molecular material that has or will soon form stars. The data are essential to the accurate interpretation of data from the c2d SIRTF Legacy program and to dust continuum measurements being obtained at the IRAM 30m and JCMT telescopes.

IV System Configuration: ⊗ SEQUOIA ⊗ FAAS ◯ QEF ◯ Other

V BREAKDOWN OF TIME REQUESTED

Molecule (Transition)	Frequency (GHz)	Days Requested	LST Coverage	Total Hours
1) N_2H^+ J=1-0	93 GHz	10	23-9	100
2) CS J=2-1	98 GHz			
3)				
4)				

VI SPECIAL SCHEDULING REQUIREMENTS:

SCIENTIFIC JUSTIFICATION

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, in Origins of Stars and Planetary Systems, eds Lada & Kylafis). 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, ApJ, 45,121), and most likely ends when conditions of balance between self-gravity and internal pressure (thermal, turbulent, magnetic) are reached. How long this concentration process lasts (few MYr or tens of MYr?), what drives it (turbulence, 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.

The COMPLETE project is an effort to coordinate a set of observations in order to obtain, for the first time, a full characterization of the gas and dust properties in a number of star-forming regions, and thus address (among others) the questions stated above. COMPLETE is related to the c2d SIRTF legacy project (Evans et al. 2003,PASP,115, 965) that will survey five molecular clouds (Perseus, Ophiuchus, Lupus, Serpens and Chameleon II) in the mid/far-infrared. COMPLETE is carrying out a systematic study of three of the c2d regions (Perseus, Ophiuchus, Serpens), in order to characterize the gas and dust using 2MASS NIR-extinction mapping, large-scale submillimeter continuum observations as well as molecular-line data obtained at FCRAO.

During the last two semesters we have obtained ^{12}CO and ^{13}CO 1–0 maps of the Perseus region at FCRAO. These data provide the large scale distribution and kinematics of the low to moderate density substrate of molecular gas. However, a central goal of the COMPLETE program is to define the processes responsible for the formation of dense, localized regions from which newborn stars form. To achieve this, one requires a census of the dense gas distribution with respect to the larger mass reservoir of low to moderate density material. We require both targeted observations of dense gas tracers (N_2H^+ and CS) toward selected regions and an unbiased survey of these dense gas emissions over a wide field to gauge selection effects in the targeted field sample.

- Targeted Fields – Initial analysis of the ^{13}CO map, combined with the 2MASS extinction map were used to delineate regions of higher density and extinction, where star-forming material is concentrated. This forms the basis of our first catalog of starless cores in Perseus. We searched for all the notable extinction peaks not associated with NGC1333 (to avoid confusion), setting a threshold of $A_V = 5$ mag. As a result we selected 27 regions that require observations with higher-density tracers in order to determine their properties (see Figure 1). Ten of these are candidate starless cores (based on coincidence with red IRAS sources). Small ($7' \times 7'$) OTF maps will be made around each of the isolated cores. High spatial-resolution high-sensitivity observations of these cores are being obtained with MAMBO on the IRAM 30-m telescope that will enable us to determine core masses and density profiles without the problem of depletion that plagues similar molecular line observations. However, spectral-line observations are essential for investigating motions in the cores such as infall, rotation, turbulence, and the relationship to the overlying lower density material. All of these may play a role in regulating the properties of the stellar and circumstellar environment that condense from the dense core.

- Unbiased Survey – The targeted list of objects is necessarily biased and may not represent a complete list of all cores in Perseus. For example, at $2.5'$ resolution, the NICER map would likely miss a population of compact ($<1'$) dense cores. An accurate accounting of the dense core population can only be realized with a full imaging survey of the cloud. Even with SEQUOIA, such a survey at the required sensitivity is not readily feasible. Therefore, we propose a limited imaging survey of the IC 348 cluster region over a 0.5×1 degree field defined by $A_V > 5\,\mathrm{mag}$ in the 2MASS extinction map. This region contains 59% of the cores in the targeted list. With this unbiased survey, we will be able to tabulate the fraction of dense core regions that contain embedded stars and make realistic correction for missing cores in the 2MASS extinction map over the entire Perseus field.

Previous studies of dense star forming gas have utilized numerous molecular tracers, including CS, NH_3, N_2H^+, HCO^+. These tracers are used to study the morphology, kinematics, density, and temperature of the dense star forming cores. However, each tracer by itself does not provide information on the evolutionary state of the star forming core. Indeed, due to chemistry, the observation of a single tracer by itself can often be misleading. However, Ridge, Bergin & Megeath (in prep) have shown that a combination of CS 2–1 and N_2H^+ 1–0 proves an excellent tool in studying the properties of dense cores. The microfine structure of the N_2H^+ line makes it particularly useful in studies of dense cores, as it can be used to determine an independent estimate of the gas volume density and temperature. Additionally, N_2H^+ is found to be one of the only molecules that does not deplete, and remains optically thin, even in the very cold dense regions where star formation is occurring (Tafalla etal 2002, ApJ, 569, 815).

TECHNICAL DETAILS & REFERENCES

The time request is determined by the requirement to image the weaker, N_2H^+ line within 25 kHz resolution/channel at $25''$sampling. Previous observations of the N_2H^+ line in Taurus and Perseus show the antenna temperature of the satellite hyper-fine lines (necessary to derive physical conditions) is ~0.3-0.5 K. Therefore, we need to obtain $T_{rms} \sim 0.06$ K to achieve our scientific objectives. From *otfcalc*, the $7\times7'$ fields require 2 hours to achieve this sensitivity (assuming Tsys=200).

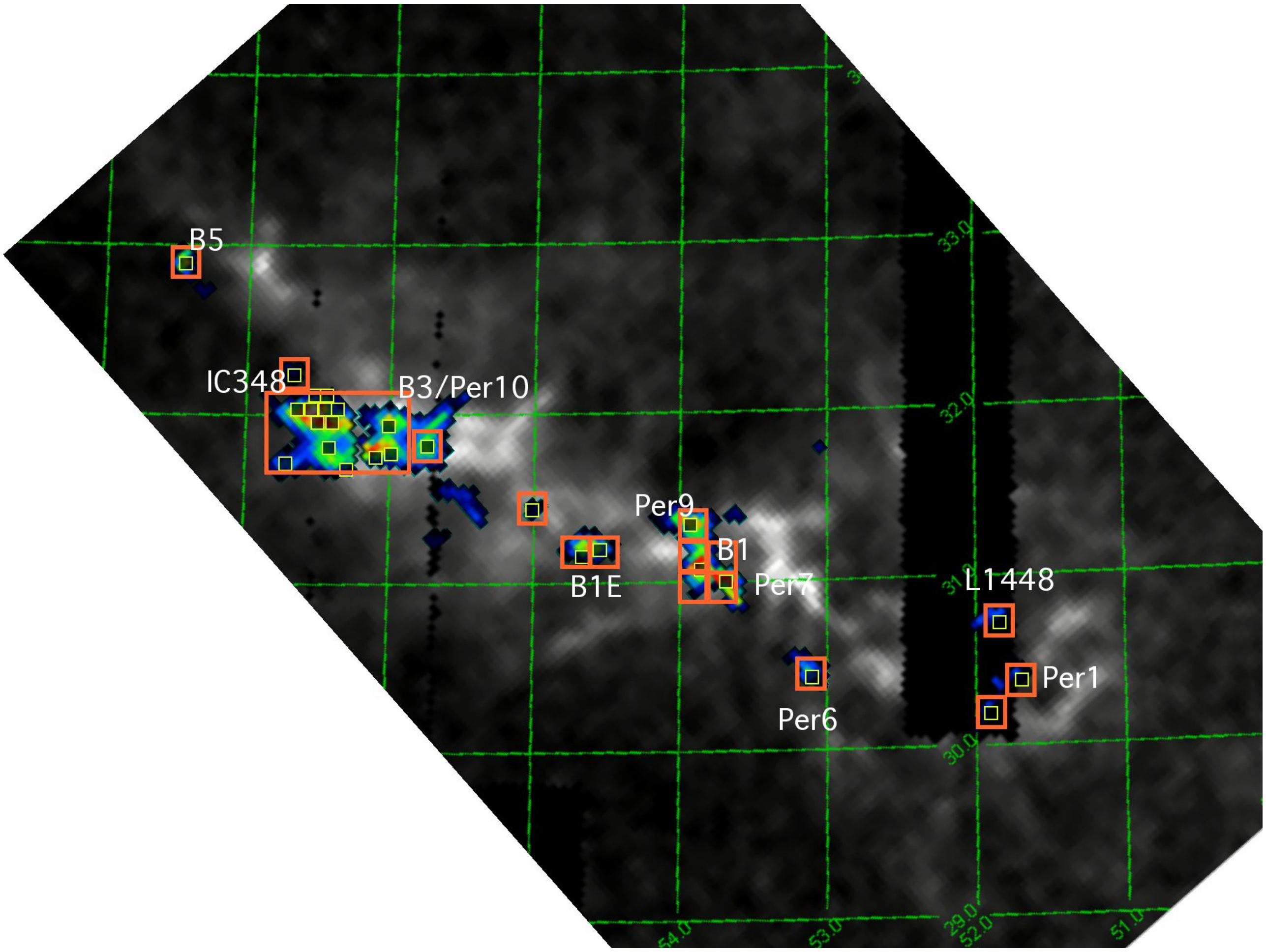

Figure 1: 2MASS NICER image of the Perseus molecular cloud and the positions and angular extents of the proposed FCRAO N_2H^+ maps

For the unbiased field, we will observe $8{\times}8'$ maps in a $8{\times}4$ mosaic. Each subfield will require 2.5 hours so the total time for the unbiased map is 80 hours. 16 of the targeted cores lie within this field. Therefore no additional time is required to image these individually. Six of the targeted cores are sufficiently isolated as to require separate $7{\times}7'$ maps (total 12 hours). Two cores can be covered with two adjacent footprints(4 hours). The remaining three can be mapped with 4 contiguous footprints (8 hours). The total request is 104 hours (10 days between LST 23 and 9 hours).