12-m Radio Telescope

Steward Observatory - University of Arizona

For official use
Date:
Proposal number:

Proposal Summary Sheet

TITLE: **The Astronomy Club Dense Gas Mapping Survey of Planck Cold Cores**

ABSTRACT: The Planck satellite is performing a multi-wavelength, multi-pass all sky survey to study the power spectrum of the CMB. Before the CMB power spectrum can be analyzed, foreground contamination, including dust emission from the Galaxy, must be removed. The Planck Cold Core Team has been cataloguing and characterizing this foreground emission. An initial catalog of over 10,000 objects (C3PO) was released from the first year data. From this catalog, a subset of 915 cold cores ($T_d < 14$ K with SNR > 15) we found (The ECC = Early Cold Core Catalog). Ground-based followup observations of these cores are needed to determine their source geometry (filamentary, multiple cores, etc.), size, mass, and kinematic properties (degree of turbulence, etc.). We propose a mapping survey at $1'$ resolution of a sub-sample of the ECC in the dense gas tracers $C^{18}O$ 1-0 and N_2H^+ 1-0 with the 12m telescope. These tracers complement each other with CO depleting in very cold, dense environments ($T < 10$ K, $n > 10^5$ cm^{-3}) where N_2H^+ may be abundant. We propose to map an initial sample of 44 cold cores that are nearby (< 1 kpc) and distributed at a wide range of Galactic longitudes and latitudes and selected to have a range of dust masses.

Investigator(s):	Institution:	Email:	Phone:	Phone:	On-Site:	Remote:
UofA Astronomy Club	Univ. of Arizona					
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The Planck Cold Core Team						

Number of hours requested: 154 **LST interval(s):** (14-18h)×8 scheduled after Jan 1, (16h-02h)×5 before Dec 1, (2h-9h)×8 (no sun avoidance)

Since this is an undergraduate observing project, please schedule on weekends or between semesters.

Scientific Category:
- ○ extragalactic
- ● galactic
- ○ planetary
- ○ atmospheric
- ● young stellar objects
- ● cloud structure
- ● stellar
- ● chemistry

Observing Mode:
- ○ continuum
- ● spectroscopy
- ○ other:

Objects	Name:	Coordinates:	V_{LSR}:
	see ECC from the Planck Collaboration		

Frequencies: N_2H^+ 1-0 93.7 GHz, $C^{18}O$ 1-0 109.782 GHz

Special requirements (dates, frequencies, etc.):

Spectral Line Receivers: ● 3mm ALMA ○ 3mm Low ○ 2mm

Backends: ● MAC

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The Astronomy Club Dense Gas Mapping Survey of Planck Cold Cores

Univ. of Arizona Astronomy Club, Yancy L. Shirley, & the Planck Cold Core Team

1 Justification

Recent surveys of the Milky Way at far-infrared and submillimeter wavelengths have discovered thousands of dense clumps within our Galaxy (i.e. HIGAL Molinari et al. 2010; BGPS Aguirre et al. 2011; ATLASGAL Schuller et al. 2009, etc.). These surveys are very sensitive to optically thin dust emission across the Galaxy; however, they are confined to very narrow Galactic latitudes ($< \pm 1$ degree) from the Galactic plane. The Planck satellite is currently surveying the entire sky at multiple submillimeter and millimeter wavelengths (Figure 1) in an effort to study the power spectrum of Cosmic Microwave Background (CMB). One benefit of the Planck survey for Galactic science is that it provides a less biased catalog of dense cores at all Galactic latitudes. Planck has extended the detection limit of cold structures to lower fluxes (hence, lower dust temperatures), and to environments not yet fully systematically explored, such as the outer Galaxy. The Planck Collaboration has catalogued 10,783 objects in their initial data release (Cold Core Catalog of Planck Objects or C3PO) using a multi-frequency algorithm (CoCoCoDeT, Montier et al. 2010). By modeling the dust continuum SEDs of C3PO objects, a smaller Early Cold Core Catalog (ECC) of 915 objects was developed that consists of very cold ($T < 14$ K) objects that have high signal-to-noise ratio detections in multiple wavebands (Figure 2). The ECC cores are the most robust detections in C3PO and are the coldest objects, potentially singling out younger objects. The ECC sources are distributed throughout the sky. Remarkable, the majority of ECC sources are newly discovered meaning that they have no SIMBAD counterpart within $5'$.

What is the physical nature of the Planck Cold Cores in the Early Cold Core Catalog? This proposal directly addresses this question with higher angular resolution molecular mapping of cores in the ECC. The resolution of Planck is $4'$ and while this is excellent for CMB studies, it is not high enough for detailed studies of individual cores. The Planck survey does a good job finding dense clumps, but these objects likely breakup into multiple cores at higher resolution. This fragmentation is observed in the Herschel imaging of three Planck cores by Juvela et al. 2011 (see Figure 2). Higher resolution observations of the ECC are clearly needed, but it is impractical to expect followup of the full ECC (let alone the larger C3PO catalog) before the end of the Herschel mission. Therefore, ground-based observatories are crucial for the followup of this population of cores. The 12m telescope is a prime instrument for the followup as it has $1'$ resolution at 3mm.

We propose to map a sub-sample of Planck cold cores with the 12m telescope in the lines of $C^{18}O$ 1-0 and N_2H^+ 1-0. These two molecular tracers provide complementary information of the physical properties of the cores (see Di Francesco et al. 2007). $C^{18}O$ emission is generally optically thin and tracing the total column density of CO gas in the cloud. However, at low temperatures and high densities, CO can freeze-out of the gas phase. In contrast, N_2H^+ is typically abundant in these cold, dense regions. We shall use the N_2H^+ emission to trace the coldest, densest cores for which CO depletion is significant. We shall map regions that are $7' \times 7'$ covering a region twice the Planck beam. From these maps, we shall study the spatial distribution of column density of the cores (are they organized in filaments or are they typically isolated?), as well as determine basic core properties such as size and virial mass. From the line profiles (i.e. first moment maps) we shall search for systematic kinematic motions such as rotation or velocity gradients. This sub-sample of cores has been proposed to be observed with the GBT 100m telescope (spring 2012) in the NH_3 inversion lines to obtain the kinetic temperature of the gas (PI Paladini et al. form the Planck Cold Core Team). When combined with our linewidth measurements, we shall calculate the non-thermal component to the linewidth and constrain the turbulent contribution to the cores. Furthermore, the core properties derived from these 12m observations can be analyzed statistically according to location, mass and morphology-type and global variations with respect to these parameters will be investigated.

Recently, Roberta Paladini (PI) and the Planck Cold Core team were awarded a Spitzer/IRAC Cycle-8 proposal to study cloudshine (Pagani et al. 2010) in a subsample of 90 cold clumps drawn from the ECC. This set of objects has been generated through Monte Carlo sampling of the Galactic longitude, latitude, and dust mass distribution of the full ECC within 1 kpc of the Sun. Over the course of the next two semesters, we propose to observe this subset of objects with the 12m. This proposal shall observe the first half of the sample (44) with a reasonable time request for the fall-winter semester.

2 Technical Justification

We propose to observe a sample of 44 Planck cold cores in the 1-0 lines of $C^{18}O$ and N_2H^+ using the ALMA Band 3 receiver. We shall first OTF map each core in $C^{18}O$ over $7' \times 7'$ with $20''$ row spacing (over-sampled). In 1 hour of mapping at $20''$/s speed, we can achieve a baseline rms of 165 mK (based on our experiences from the previous season). We shall use the OTF regridding tools developed at Arizona for OTF reduction (see Reiter et al. 2011). We expect $C^{18}O$ peak line temperatures to be > 0.5 K and therefore many of the cores should be amenable to OTF mapping. On the other hand, N_2H^+ emission may be weak based on initial observations of a small subset of cores with the IRAM 30m (L. Pagani, priv. communication). Therefore, we shall make a grid of position switched observations to reach 75 mk rms with higher spectral resolution (MAC backend) for N_2H^+ observations . We shall design the N_2H^+ mapping grid based upon the observed geometry in the $C^{18}O$ maps. We expect the N_2H^+ mapping to take approximately 2 hours for a total of 3 hours per core. Including time for tuning and calibration, we ask for a total of 154 hours to observe this initial sample of 44 cores.

This project will be observed by the Univ. of Arizona Astronomy Club. A group of 14 students have signed up as observers for the project and have been directly involved in the proposal preparation. This is an excellent opportunity for hands-on training in radio astronomy for a large group of undergraduate students. The students will be accompanied by Y. Shirley to the telescope for observing runs. The students and Y. Shirley will also have weekly organization/analysis meetings (5pm post-colloquium on Thursdays) throughout the semester. The Astronomy Club has an excellent track record with the observations from their previous 12m observing experience being used in a paper in the special A&A Herschel edition (Bally et al. 2010) and being included in the spectroscopic followup of the BGPS data paper (Shirley et al., in prep.).

Because of the unique nature of this project, we request that observations be scheduled on weekends or in between semesters.

References

Aguirre et al. 2011, ApJS, 192, 4 • Bally et al. 2010, A&A, 518, 90 • Di Francesco et al. 2007, Protostars and Planets V, 17 • Juvela et al. 2011, A&A, 525, 111 • Molinari et al. 2010, PASP, 122, 314 • Montier et al. 2010, A&A, 522, 83 • Pagani et al. 2010, Science, 329, 1622 • Plack collaboration 2011, arXiv:1101:2041 • Reiter et al. 2011, ApJS, 195, 1 • Schuller et al. 2009, A&A, 504, 415

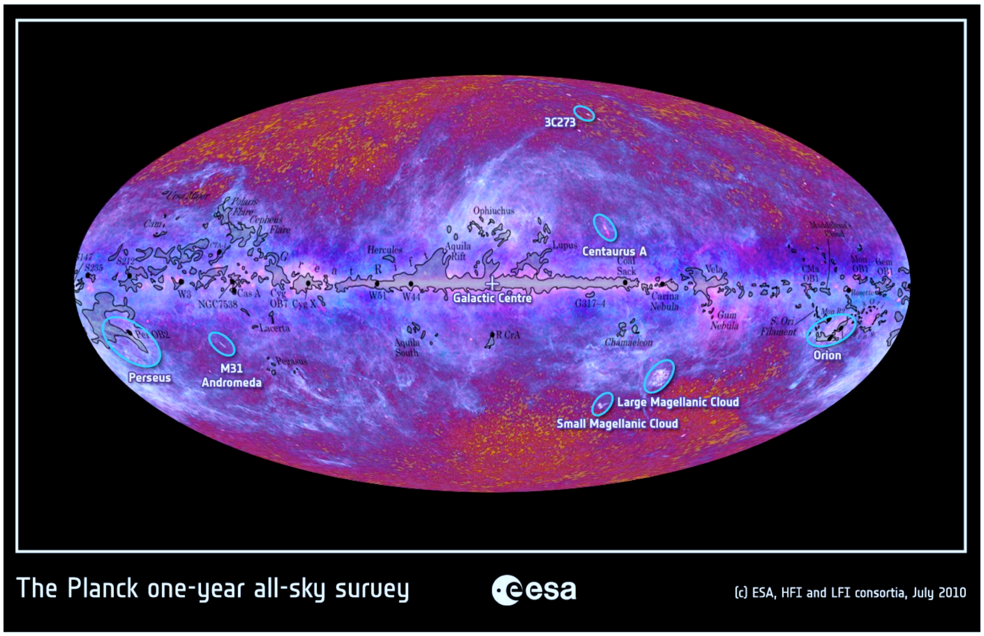

Figure 1: The Planck All Sky Survey has identified a population of over 10,000 objects from the 4′ resolution all sky map (Planck ESA Press Release). This includes hundreds of cores that are several degrees from the Galactic plane and therefore uncatalogued in previous Galactic plane surveys.

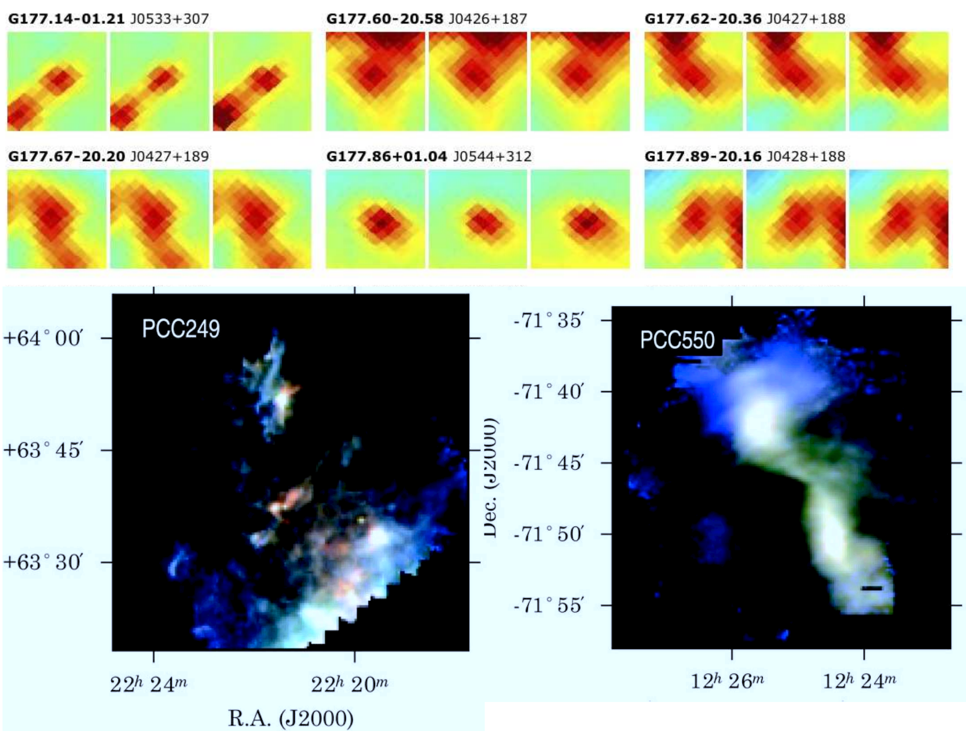

Figure 2: Top: 3 wavelength images (350, 550, 850 μm) of Planck Cold Cores from the ECC (Planck Cold Core Collaboration). Each cutout is 20′ on a side. Bottom: Herschel 3 color images (PACS and SPIRE) of two Planck cold cores showing the wealth of structure seen at higher angular resolution (Juvela et al. 2011). Our proposed molecular line observations will add kinematic information. Not every ECC source can be observed with Herschel due to mission lifetime constraints, thus ground based followup is crucial to characterizing the ECC core population.