Onsala Proposal

Law 0108.F-9309

Detection of high transition N2H+(7-6) and C18O(6-5) in Infrared dark cloud G28.37+0.07 (resubmission of accepted project 107.F-9322A)

Semester: may2021 **Science Cat.: ISM and star formation**

Abstract

Massive star formation is an important unsolved problem of contemporary astrophysics, with several different theoretical models in contention. Massive protostars are also unique laboratories for understanding the interstellar synthesis of various simple and complex organic molecules, including important prebiotic species. Here, we propose to use APEX capabilities to conduct at the high-frequency range 680 to 712 GHz to detect N2H+(7-6) (652.095865 GHz) and C18O(6-5) (658.553278 GHz) in an massive infrared dark cloud (IRDC), G28.37+0.07 to probe the excitation environment, and to understand the initial dense gas environment in the cloud.

Applicants

Name	Affiliation	Email	Country		Potential observer
Mr. Chi Yan Law	Chalmers University of Technology (Space, Earth and Environment)	chiyan.law@chalmers.se	Sweden	Pi	Yes
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Is this a long term proposal: No

No overall scheduling requirements

Observing runs

run	telescope	instrument	time request (minimal)	frequency (GHz)	weather (pwv)	LST range	comments/constraints
A	APEX	SEPIA660 (581-727 GHz)	4h (4h)	669.5	< 0.5mm	16-21	This is the tuning frequency

Targets

Source	RA	Dec	Epoch	Vlsr (km/s)	Duration (min)	Runs	Comments
G28.37+0.07-4	18:42:54.46	-04:03:10.8	J2000	79.0	105	A	Time includes overhead
G28.37+0.07-3	18:42:48.16	-04:03:52.8	J2000	79.0	105	A	Time includes overhead

Scientific Rationale

This is a follow-up/re-submission of the approved proposal (107.F-9322(A)) in the last cycle, which was not able to be carried out due to the COVID-19 related shutdown.

There are various theories to explain massive star and star cluster formation, such as Core Accretion, Competitive Accretion, the Inertial-Flow model, and Protostellar Collisions [1,2,3]. To test these models requires information on the structure, kinematics and astrochemical conditions of molecular clouds from which the stars form. This information can be gained by study of line emission from various tracers of these clouds [e.g., 4,5]. To study some of the densest phases requires observations of high excitation molecular line emission, i.e., from species that have high critical densities.

Recently, observation carried out towards the Orion OMC-1 region as part of early science of *APEX SEPIA* 660 instrument detected large-scale extended emission of high excitation transitions N_2H^+ $(J = 7-6)$ and $C^{18}O$ $(J = 6-5)$ [6] (See Figure 1 in reference). This suggests the existence of very high density gas ($n_H > 10^7$ cm^{-3}) [6]. The findings are extremely interesting as: (i) this density is much higher than previously inferred from previous studies of gas and dust in the region, which on these scales was estimated to be $n_H \sim 10^{4-5}$ cm^{-3}; (ii) it suggests the presence of large reservoirs of dense gas that are future fuel for star formation [6]; (iii) there are then global implications for how star formation has evolved and is evolving in the Orion region, i.e., it may be a much more prolonged process, which has more general implications for the star cluster formation process. It is thus important to see if similar levels of N_2H^+ $(J = 7-6)$ are present in other star-forming systems.

Here we propose to search for N_2H^+ $(J = 7-6)$ in G28.37+0.07 (Cloud C), which is a one of the most massive known Infrared Dark Clouds (IRDCs), located at a distance of 5.0 kpc. The cloud has been extensively studied by our group at different scales and with various facilities (e.g., *IRAM-30m* , *JCMT* , *ALMA*) to characterise its physical and chemical properties, including low excitation N_2H^+ $(J = 1-0)$ (Figure 1) [7,8,9,10]. However, there are only a handful of high frequency (i.e. ALMA band 9)studies toward IRDCs and none to Cloud C to date. Our previous extensive low frequency studies form a strong base to accompany this high frequency project. In particular, we aim to perform similar analyses as done in Orion by Hacar et al. [6], utilising our complementary N_2H^+ (1-0) *IRAM-30m* data.

Any detected emission will provide unique estimates on the high density components of the region [6]. We will be able to search for correspondence of these high density regions with our MIR extinction maps, which have 2" resolution [12]. The characteristics of any detected dense condensations will provide important information on the structure, kinematics, dynamics and star formation potential of this important IRDC, thus extending the use of N_2H^+ $(J = 7-6)$ to a new, more extreme star-forming environment. This pathfinder study, which first aims at basic detection, will then form the basis of follow-up observations at high velocity resolution and sensitivity study, e.g., with *APEX* or *ALMA* .

Facilities Requested

To archive our science goal, we request only using APEX 12m telescope for the high-frequency line study of IRDC G28.37+0.07 with SEPIA660 receiver.

Observing Requirements

We propose to use the *APEX* 12m telescope during the April-August season to observe two regions, each of which has size of 4.2×4.2 arcmin (Figure 1) in G28.37+0.07 with the SEPIA660 receiver. The source has DEC = -4.030, and minimum elevation of 50 deg from Jun-August. We propose to set tuning frequencies at 669.5 GHz. As this is an exploratory observation, which aims to simply detect the two target line and measure their peak intensity, thus we require slightly coarser velocity resolution of 0.2 kms^{-1}, i.e., two times lower than that used in Hacar et al. [6]. We set a similar rms noise as they used of 650 mK. Based on the instrument set up tool provided from the *APEX* website, both lines will be detected toward the image band of USB. We have used the OTF observing time calculator at APEX V9.3 to estimate the total time needed to achieve our goal. We plan to do an OTF of 252×252 arcsec and for the calculation we assume a dumptime of 0.2 seconds and a sampling corresponding to 1/3 of the beam. Using SEPIA660 tuned to 669.5 GHz in the USB, selecting a spectral resolution of 0.2 km/s and assuming a typical source elevation of 50 deg and a typical PWV of 0.5 mm, we reach down to a noise of 650 mK[Ta*] in 1.74 hours (including telescope and calibration overheads). As we will map two regions to cover the whole high extinction regions of the cloud, thus require a total time of $\sim$ 3.5 hours. If time is limited, one field would also be sufficient to archive some of our science goals.

Observing Plan

We request normal observational and calibration procedures.

References

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[5] Caselli, P. & Ceccarelli, C. Our astrochemical heritage., aapr, 2012, 20, 56.

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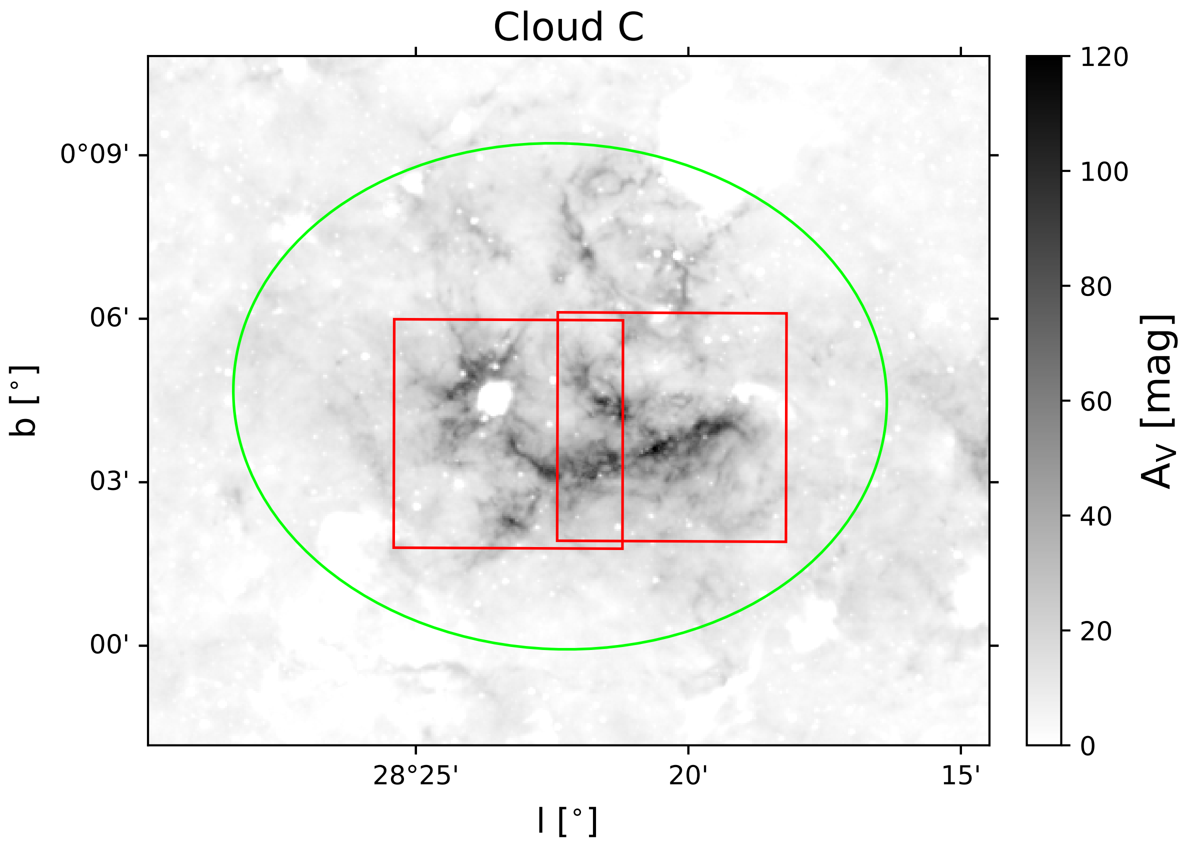

Figure 1: Grayscale: Dust extinction map from Kainulainen & Tan [12]. Green ellipse is the cloud region defined in Simon et al. [13], while the red boxes are regions to be mapped by *APEX* with each size of 4.2×4.2 arcmin.

Students involved

Student	Level	Applicant	Supervisor	Applicant	Expected completion date	Data required
Mr. Chi Yan Law	Doctor	Yes	Prof Jonathan Tan	Yes	2023/12	Yes

Linked proposal submitted to this TAC: No

Linked proposal submitted to other TACs: No

Relevant previous Allocations: Yes

107.F-9322(A),3.5 hrs, Not observed due to COVID-19 situation

No additional remarks

Observing run info :