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MOPRA AND NANTEN STUDIES OF HESS J1825-137 NORTHERN CLOUD*

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The Pulsar Wind Nebula (PWN) HESS J1825-137 is one of the most extended TeV PWN and its morphology is influenced by the molecular gas located north of the TeV sources. In order to refine the composition and dynamics of the cloud, we have used the telescope Mopra in the 7 and 12 mm bands. Our results highlight dense regions and also perturbations in the southern part of the dense cloud.

Keywords: HESS J1825-137; PWN; PSR J1826-1334; ISM; diffusion.

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1. Introduction

Located 3.9 kpc away from Earth, the 20 kyr old Pulsar Wind Nebula HESS J1825-137 powered by the pulsar PSR J1826-1334 is one of the largest TeV source discovered by HESS.[1] Its apparent assymetry is caused by a reverse shock, created by the interaction of a supernova shock with a dense molecular cloud, crushing the expanding PWN.[2]The northern molecular cloud, located between 45-53 km/s was revealed via the Dame CO survey by Lemière *et al.*[3] Figure 1 displays the integrated intensity of the emission line CO(1-0) in this region between 41 and 55 km/s as seen by the Nanten telescope, which surveyed the southern sky with a beam size

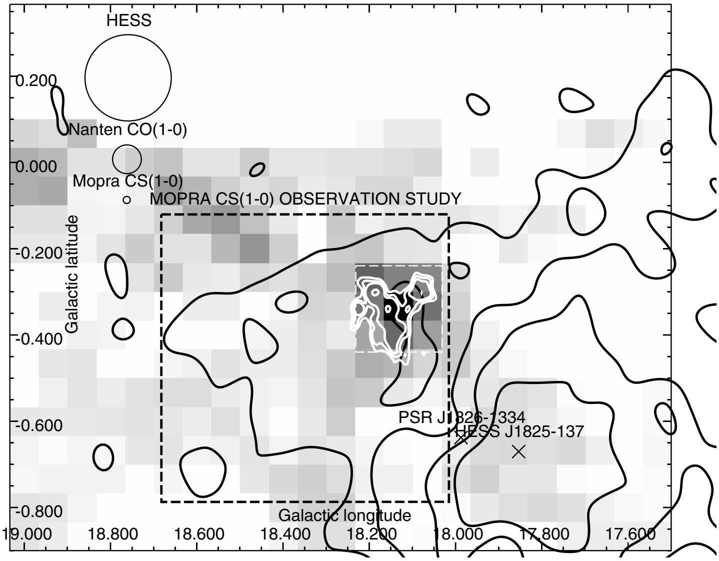

Fig. 1. Map of the region (in galactic coordinates) as seen by the Nanten CO(1-0). The black dashed box indicates the area observed by our Mopra CS(1-0) survey. The white contour displays the integrated intensity of CS(1-0) of the cloud of interest whereas the HESS TeV source is shown in black contours.

of 2.6'. Figure 1 shows the Nanten CO(1-0) image along with our Mopra observations of CS(1-0). Using the Nanten data and conversion factor[4] X= 1.5×10^{20} $cm^2(K.km.s^{-1})^{-1}$ between CO brightness temperature and the H_2 column density, we derived the mass of the dense region encompassing the CS emission in white contours to be $1.1{\times}10^5 M_\odot$ (see white dashed box in Fig. 1.). Also, this region overlaps with the TeV emission presumably from HESS J1825-137. The PWN TeV emission is lepton dominated[1] although the spatial overlap of the TeV emission and the ISM gas in the north may suggest a hadronic component. Such a hadronic component may come from the progenitor SNR and/or from the pulsar wind.[5] Thus, we made use of the $\sim$ 1 arc-min resolution 22 meter Mopra telescope and its ability to observe a wide range of spectral lines to refine the geometry, physical properties and dynamics of the molecular cloud located at the north of HESS J1825-137.

2. Study of the Cloud with Mopra

Mopra first observed the region in 12mm as part of HOPS,[6] and we continued observations in February 2012 and April 2013 in the 12 and 7mm bands respectively. Then, several deep pointings in May 2013 allowed better quality spectra in key regions. Figure 2 displays the extended cloud (0.1 deg diameter) in integrated intensity as seen by the molecular lines NH_3(1,1), CS(1-0), and H62α. The extended CS region has been observed encompassing the HII regions seen by Spitzer, also detected by the H62α signal. We also observe that the CS(1-0) peaks do not appear

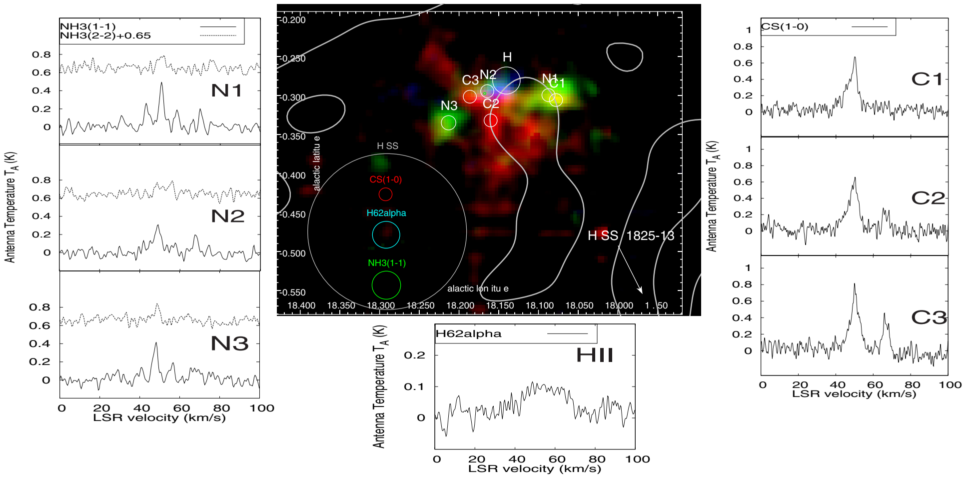

Fig. 2. Three colour map (in galactic coordinates) of the northern region of HESS J1825-137, showing CS(1-0) (red), NH_3(1,1) (green), and H62α (blue) integrated intensity are displayed. The regions studied (where the signal was strongest) have been respectively named C[number], N[Number] for CS and NH_3 regions. The HII region is detected by the recombination line H62α. The spectra of the respective regions are shown on the left for NH_3(1,1) and NH_3(2,2)(with an apparent offset value of 0.65K), on the bottom for H62α and right for CS(1-0) (see online version for colours).

to spatially match with the NH_3(1,1) peaks. Assuming local thermal equilibrium, we estimated the H_2 mass for the CS(1-0) emission to be $2\times10^4 M_\odot$. Figure 2 also displays the spectra of regions inside the dense complex having a centroid velocity of 49 km/s, with a kinematic distance of 3.9 kpc. Finally, we assume the gas detected by CS(1-0) to have a density close to the critical value of $3\times10^4 cm^{-3}$. This density may enhance the γ-ray emission produced by any high-energy protons. More detailed studies of the cores will be described in a later publication.[7]

3. Cloud Dynamics

Figure 3 shows a complex structure in CS(1-0) where signals peak in three different velocity regions. The peaks located between 46 and 51 km/s (green) are spatially separated from peaks located between 41-46 km/s (red) and 51-56 km/s (blue). From our deep pointing observations, Fig. 3 shows that the spectra closest to the pulsar (right) highlights two peaks with respective kinematic velocities of 43 and 53 km/s. However, the signal merges into a single wider peak at 49 km/s (kinematic velocity of the pulsar) as we move further into the cloud. Also, the asymmetry of the spectra labeled as C1 and C2 (see Fig. 2) may indicate the directionality of a shock going through the cloud. Although this indicates turbulence inside the cloud, other shock indicators such as SiO(1-0) have not been detected. Further studies of the available mm-radio and IR data are planned to investigate the nature of perturbations and understand the relation between the TeV flux and the cloud.

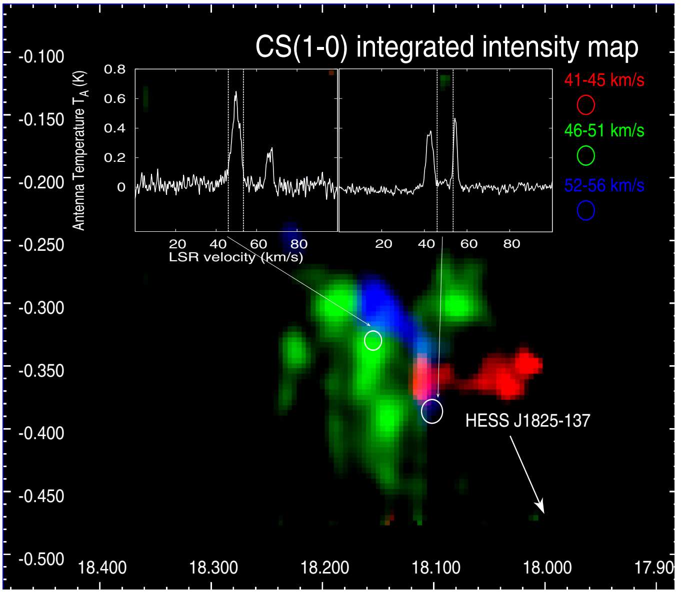

Fig. 3. Three colours map (in galactic coordinates) displaying the integrated intensity of CS(1-0) in 41-46km/s (red), 46-51 km/s (green), 51-56 km/s (blue) and the CS(1-0) spectra observed in 2 regions with Mopra. The white vertical lines represent the position and width of the signal in the left panel (see online version for colours).

4. Summary and Conclusions

We studied the molecular cloud north of the PWN HESS J1825-137 in the 7 and 12mm bands with Mopra (and in CO(1-0) with Nanten) and detected extended CS emission surrounded by HII regions, and with broad and multi-peaked spectral lines indicating turbulence inside the dense cloud. These regions may provide suitable target sites for the enhanced hadronic TeV γ-ray emissions and would be a good laboratory to study the diffusion of cosmic-rays inside the dense cloud.[8]

Acknowledgments

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