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Study of a compact source with an enhanced NH_2D/NH_3 abundance ratio in the S187 region

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Abstract. When analyzing data obtained with the Onsala 20-m radio telescope (Sweden) in 2018, a compact peak of NH_2D emission with an enhanced ratio of NH_2D/NH_3 column densities was discovered in the S187 region. This peak is not associated with any known astronomical object from the SIMBAD database, but previously obtained dust emission maps have a peak in this region. Additional observations of this region were carried out in 2023 with the Onsala telescope. The kinetic temperature in the center of the source was determined using the rotational diagrams of the CH_3CN and CH_3CCH molecules, and it turned out to be quite high (according to various estimates, approximately from 30 K to 50 K). Based on the spectra of the $C^{18}O$ molecule and dust emission, estimates of the column density of molecular hydrogen were obtained. Deuterated NH_2D and DCO^+ molecules were detected in this region, while no noticeable emission of the DCN molecule was detected. Estimates of the column densities at the center of the source were obtained by processing the spectra of NH_2D, DCO^+, $HC^{18}O^+$ and HC_3N molecules. Maps of the integral intensities of these molecules were also constructed. The ratio of the abundances of ortho- and para-NH_2D, as well as the ratio of NH_2D and the main isotopologue of NH_3 were found. The possible nature of the source is discussed.

Keywords: ISM: clouds, molecules; individual: S187

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1 Introduction

Study of molecular deuteration in various interstellar environments represents an important part of astrochemical research. In 2017–2018 we performed a survey of a large sample of high-mass star-forming regions with the Onsala 20-m radio telescope in the lines of several deuterated molecules and their hydrogenated isotopologues (Trofimova et al. 2020; Trofimova et al., Astronomy Reports, accepted). During this survey we tentatively detected a compact peak of the ortho-NH_2D emission in the S187 region far away from the NH_3 peak. Later this peak was also observed with the IRAM 30-m radio telescope (Pazukhin et al. 2023). However, it was located at the very edge of the map. Here we present preliminary results of additional observations of this area with the Onsala radio telescope in 2023.

2 Observations and main results

The observations with the Onsala 20-m radio telescope were carried out in several frequency ranges: 71.8–74.2 GHz, 83.8–86.2 GHz, 97.1–99.5 GHz and 109.1–111.5 GHz. The area was mapped at the lower frequencies. At the higher frequencies only the peak was observed. Details of the observations will be presented in forthcoming publications. The emission of about 20 molecules was detected, such as ortho- and para-NH_2D, CH_3CN and CH_3CCH, DCO^+, HC_3N, H_2CO, $HC^{18}O^+$, $C^{18}O$ and other molecules. For several of them the estimates of column densities were obtained and also the maps of integral intensities were constructed. The DCO^+ emission peak coincides with the NH_2D peak. At the same time the DCN emission was not detected. We also analyze data obtained with the 100-m Effelsberg radio telescope (Pazukhin et al. 2023). A weak $NH_3(1,1)$ line emission was detected toward the NH_2D peak that was discussed here.

In Fig. 1, we present the mosaic map of the ortho-NH_2D emission and an overlay of the ortho-NH_2D emission contours on the image of this region in continuum at 1.2 mm (Zinchenko et al. 2009). The data confirm a compact source centered at RA(J2000) = $01^h23^m30\overset{s}{.}1$, Dec(J2000) = $61°48'06''$ with the size comparable to or smaller than the beam size (about $40''$). This NH_2D peak is not associated with any known astronomical object in the SIMBAD database, but map of the dust emission shows a peak at this location.

Using the rotational diagrams of CH_3CN and CH_3CCH, the gas kinetic temperature (T_k) in the source was estimated to be 32.5 ± 2.2 K and 47.1 ± 0.2 K respectively. The molecular hydrogen column density $N(H_2)$ from the $C^{18}O$ data under the usual assumptions about the $C^{18}O$ abundance, is $5.3 \pm 0.02 \times 10^{22}$ cm^{-2} for $T_k = 32.5$ K and $7.3 \pm 0.02 \times 10^{22}$ cm^{-2} for $T_k = 47.1$ K. From the dust emission $N(H_2) \sim 3 \times 10^{22}$ cm^{-2}.

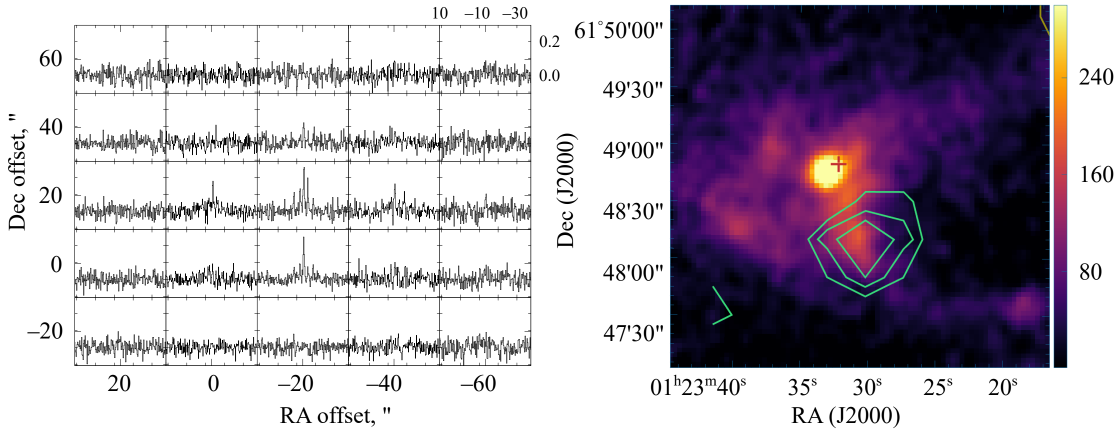

Fig. 1. Left panel: the mosaic map of the ortho-NH_2D emission toward the compact source discussed in this paper. Right panel: contours of the ortho-NH_2D emission overlaid on the image of this region in continuum at 1.2 mm (Zinchenko et al. 2009). The position of the IRAS source is marked with a cross.

In Fig. 2, we present spectra of the ortho- and para-NH_2D as well as NH_3(1,1) at the ortho-NH_2D emission peak. The line width is 0.74 ± 0.08 km/s for ortho-NH_2D, 0.49 ± 0.04 km/s for para-NH_2D and 1.49 ± 0.29 km/s for NH_3(1,1). The optical depth of the main component in the ortho-NH_2D line is 2.1 ± 0.6.

The ortho/para ratio for NH_2D varies approximately from 2.5 to 4.6 depending on the assumed gas density (in the range of 10^4 cm^{-3} to 10^6 cm^{-3}) and kinetic temperature. It increases with increasing both of them. Further, we assume this ratio equal to 3, according to the spin statistics (Sipilä et al. 2015).

Then, we estimate the full NH_2D column density and relative abundance. The relative abundance varies from 1.2×10^{-9} to 5.1×10^{-11} for $T_k = 32.5$ K and from 5.3×10^{-10} to 3.5×10^{-11} for $T_k = 47.1$ K.

The estimates of the column densities of the main isotopologue of NH_3 at the peak of ortho-NH_2D were obtained. The NH_2D/NH_3 abundance ratio is 6.4–3.7 for the assumed gas density of 10^4 cm^{-3}, 0.8–0.6 for the gas density of 10^5 cm^{-3}, and 0.4–0.35 for the gas density of 10^6 cm^{-3}. With increasing gas density this ratio estimate noticeably decreases. In any case it is very high.

3 Discussion and conclusions

In general, the data show a rather compact (less than 0.2 pc) and quite warm (approximately from 30 K to 50 K) source without any indication of the star formation activity. The observed very high ammonia deuteration at such a temperature is un-

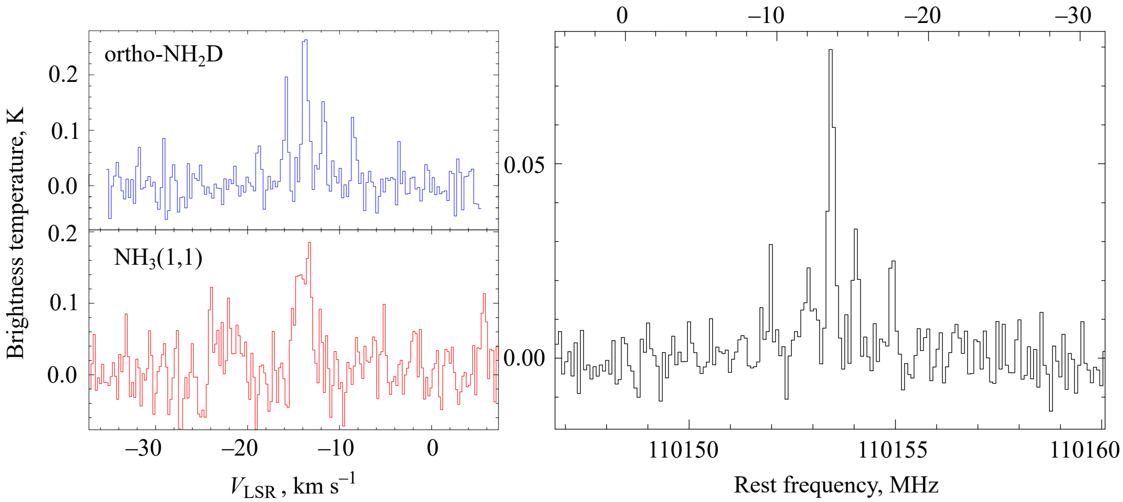

Fig. 2. Left panel: spectra of ortho-NH_2D (blue) and NH_3(1,1) (red) toward the ortho-NH_2D emission peak. Right panel: spectrum of the para-NH_2D at the same position.

usual. It is worth noting that all these estimates refer to the rather large beam of the 20-m antenna. A presence of a much more compact (and probably cold) core in the interiors is not excluded. Observations with a significantly higher angular resolution would be very helpful in this respect.

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References

Pazukhin A.G., Zinchenko I.I., Trofimova E.A., et al., 2023, Monthly Notices of the Royal Astronomical Society, 526, 3, p. 3673

Sipilä O., Harju J., Caselli P., et al., 2015, Astronomy & Astrophysics, 581, id. A122

Trofimova E.A., Zinchenko I.I., Zemlyanukha P.M., et al., 2020, Astronomy Reports, 64, 3, p. 244

Zinchenko I., Caselli P., Pirogov L., 2009, Monthly Notices of the Royal Astronomical Society, 395, 431, p. 2234