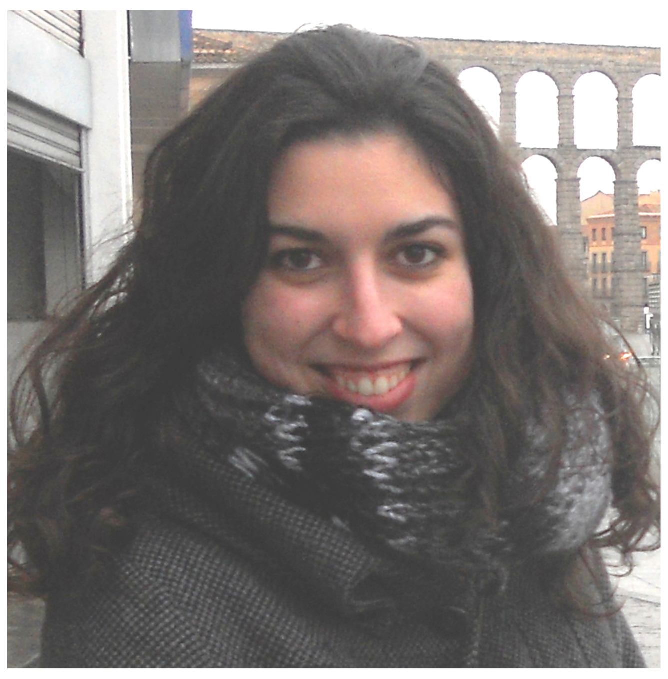

Deuterated methanol map towards L1544

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Abstract

Pre-stellar cores are self-gravitating starless dense cores with clear signs of contraction and chemical evolution (Crapsi et al. 2005), considered to represent the initial conditions in the process of star formation (Caselli & Ceccarelli 2012). Theoretical studies predict that CO is one of the precursors of complex organic molecules (COMs) during this cold and dense phase (Tielens et al. 1984; Watanabe et al. 2002). Moreover, when CO starts to deplete onto dust grains (at densities of a few 10^4 cm^{-3}), the formation of deuterated species is enhanced, as CO accelerates the destruction of important precursors of deuterated molecules. Thus, the knowledge of the distribution and abundance of CO and deuterated species in pre-stellar cores is important to understand the chemical network present in the earliest star formation phases. Here we consider the well-known pre-stellar core L1544 to observe the CH_2DOH (2-1) and (3-2) lines, together with a new map of the $C^{17}O$ (1-0) emission, with the 30-m IRAM antenna. We thus present the first map of CH_2DOH towards L1544. As methanol is formed on dust grains via hydrogenation of frozen-out CO, this work allows us to measure the deuteration on surfaces and compared it with gas phase deuteration, as well as CO freeze-out and dust properties. This is important to shed light on the basic chemical processes just before the formation of a stellar system.

CH_3OH and CH_2DOH

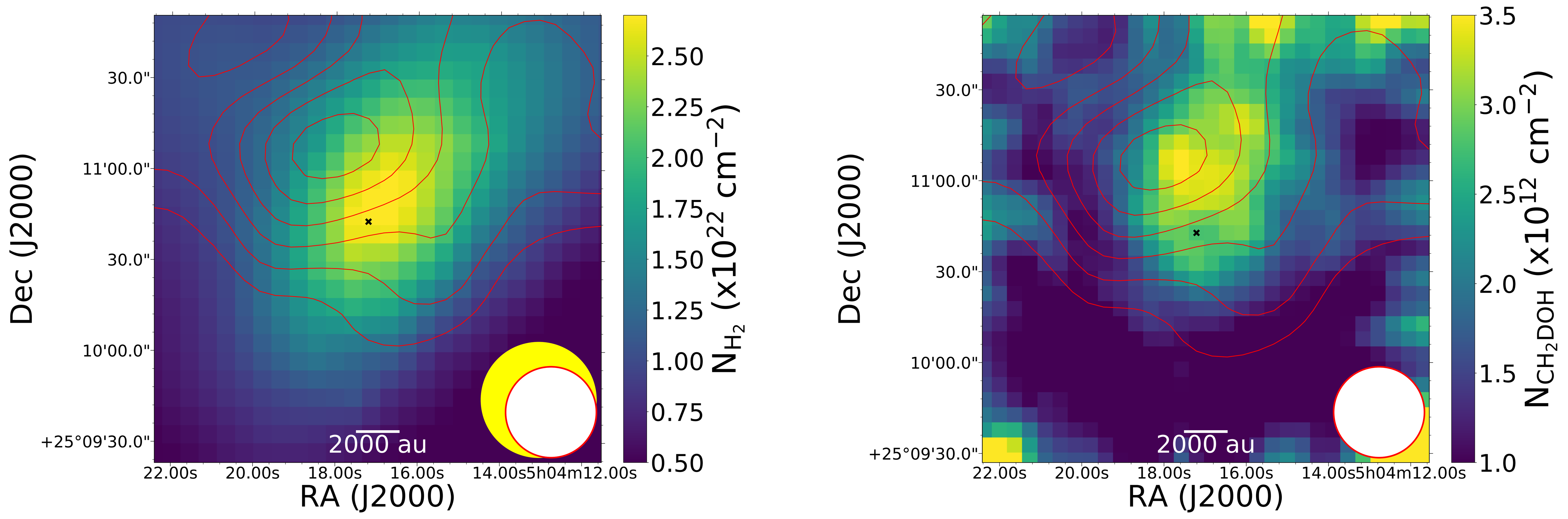

Figure 1: Comparison of H_2, CH_3OH and CH_2DOH distributions. *On the left,* Herschel/SPIRE H_2 column density map presented by Spezzano et al. (2016), superimposed with the CH_3OH column density contours. The contours are increasing by 10% intervals with respect to the peak value of the methanol column density (which corresponds to 5.9×10^{13} cm^{-2}). The black cross marks the dust emission peak at 1.3 mm. In the bottom right corner it is shown the HPBW of the Hershel/SPIRE in yellow, while the 30-m antenna HPBW is shown in white. *On the right,* deuterated methanol column density map derived and averaged from the two observed transitions and three different temperatures ranging from 5 to 8 K, as done in Bizzocchi et al. (2014). The peak value is 3.6×10^{12} cm^{-2}. The contours represent increasing 10% intervals with respect to the peak value of the methanol column density. The black cross marks the dust emission peak at 1.3 mm. The HPBW is shown in the bottom right corner.

CH_2DOH/CH_3OH

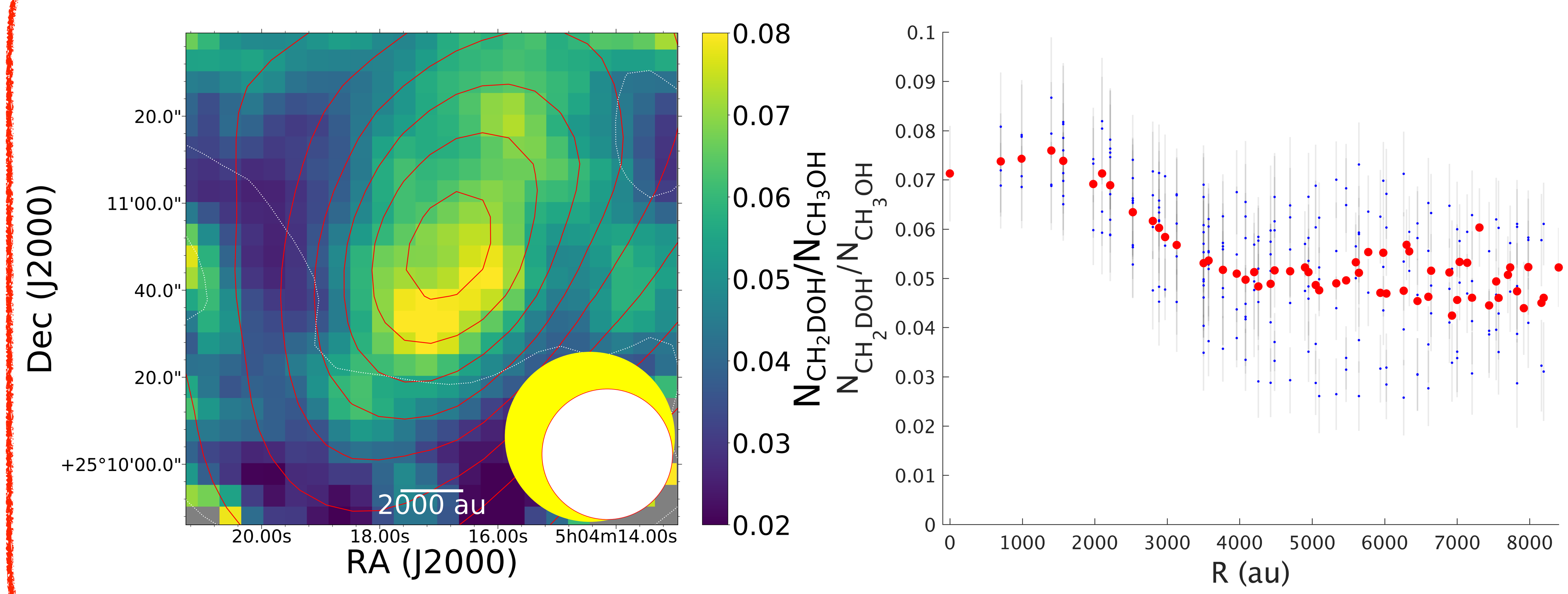

Figure 2: Methanol deuteration in L1544, CH_2DOH/CH_3OH. *On the left,* map of the ratio $N(CH_2DOH)/N(CH_3OH)$. Red contours show increasing 10% intervals with respect to the peak of the Herschel/SPIRE H_2 column density map. The white dotted contour shows the 3-σ level of CH_2DOH. The two HPBWs are shown in the bottom right corner, in yellow for Herschel/SPIRE, and in white for the 30-m antenna. *On the right,* it is shown the dependence of the ratio with the distance to the dust peak. The error bars only reflects the errors associated with the noise of the data, and the red dots show the averaged value at each distance. Only values above 3-σ detection and within the radius 60" are considered here, in order to avoid noise. It is interesting to note that while the deuteration of N_2H^+ is most efficient at the dust peak (Caselli et al. 2002), the deuteration peak of methanol is shifted from the dust peak by 1400 au.

$C^{17}O$

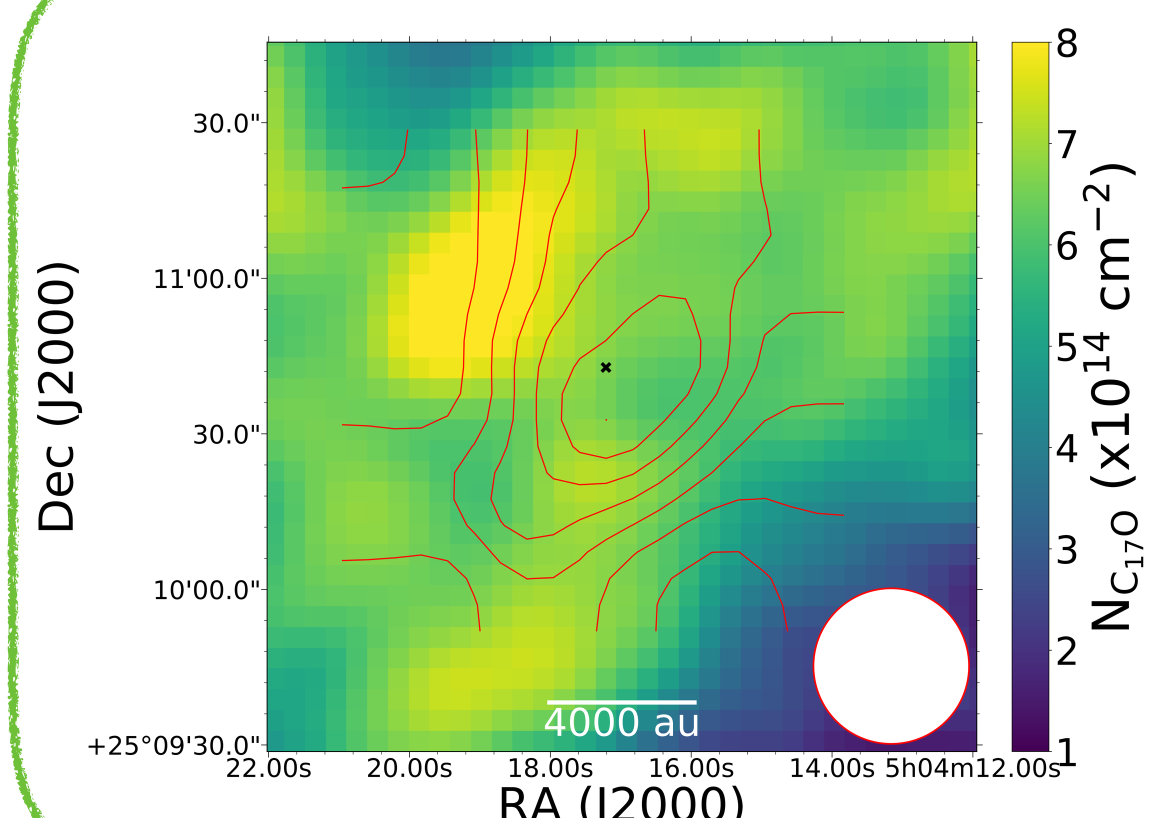

Figure 3: Distribution of $C^{17}O$ and methanol deuteration. Map of the $C^{17}O$ column density derived from the emission of the line (1-0), assuming optically thin emission and using a constant value for the temperature (10 K), superposed with the CH_2DOH/CH_3OH column densities ratio in red contours. The contours represent increasing 10% intervals with respect to the peak values of the deuterium fractionation. The HPBW is shown in the bottom right corner. The black cross marks the dust emission peak at 1.3 mm. This map shows the enhancement on the deuterium fractionation with the depletion of CO towards the center of the core.

References

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