Deuterated species in the star-forming regions

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High deuteration levels in isolated prestellar cores can be explained by gas-phase or grain surface chemistry in dense, cold regions where abundant gas-phase species are frozen onto dust grains. We argue that an alternative machanism may operate in dense gas in the vicinity of embedded young stellar objects, where slow C-type shocks associated with molecular outflows may produce conditions favorable for deuterium fractionation.

1 Introduction

High deuteration levels in isolated prestellar cores can be explained by gas-phase or grain surface chemistry in dense, cold regions where abundant gas-phase species are frozen onto dust grains. An alternative mechanism, slow C-type shocks associated with molecular outflows, may produce conditions for deuterium fractionation reactions by (i) icreasing the gas volume density and thus shortering the depletion and gas-phase reaction time-scales or (ii) sputtering/injecting the grains mantles because of the passage of a shock. $DCO^+(3-2)$ emission traced the spatial distribution of deuterated molecules is often displaced with respect to the highest column density region traced by submillimeter dust emission and sometimes associated with the high-velocity outflow activity.

2 Observations

Spectroscopic observations presented here were carried out in 2002-2007 using the 230 GHz facility receiver and spectrometers of Caltech Submillimeter Observatory (CSO) on Mauna, Kea Hawaii, as backups to various high-frequency programs. The CSO beam size at 230 GHz is $\sim 30''$ and the main beam efficiency is $\sim 60\%$ The 350 μm continuum observations were carried out in 2003 using the SHARC II bolometer camera.

3 Preliminary results

Barnard 1: DCO^+ is spatially displaced with respect to the continuum emission and clearly located in the vicinity of apex of $CO(2-1)$ outflows. The main DCO^+

peak is associated with B1-b continuum source (ND_3 detected - Lis et al. (2002)), secondary peak is associated with B1-c. The red lob of the outflow centered in B1-c encompasses the DCO^+ peak associated with B1-b. **NGC 1333**: A bright DCO^+ rigde is located NE of IRAS 4A (ND_3 detected -van der Tak et al. (2002)). Secondary DCO^+ peak corresponds to 51 (SK16)-starless core. The morphology of this region is similar to that in L1157-B1 chemically rich shocked region where dust is not heated by protostar. The secondary DCO^+ peak is located on-axis of the famous molecular outflow associated with the HH 7-11 sources, centered SSV13 and the DCO^+ source is again encompassed by the blue-shifted outflow lobe. Relatively weak ND_3 emission has also been detected at this location Roueff et al. (2005). **LDN 1641**: The DCO^+ peak near VLA 3 is located to the west of the red lobe of the VLA 3 outflow, near the edge of the redshifted high-velocity emission.

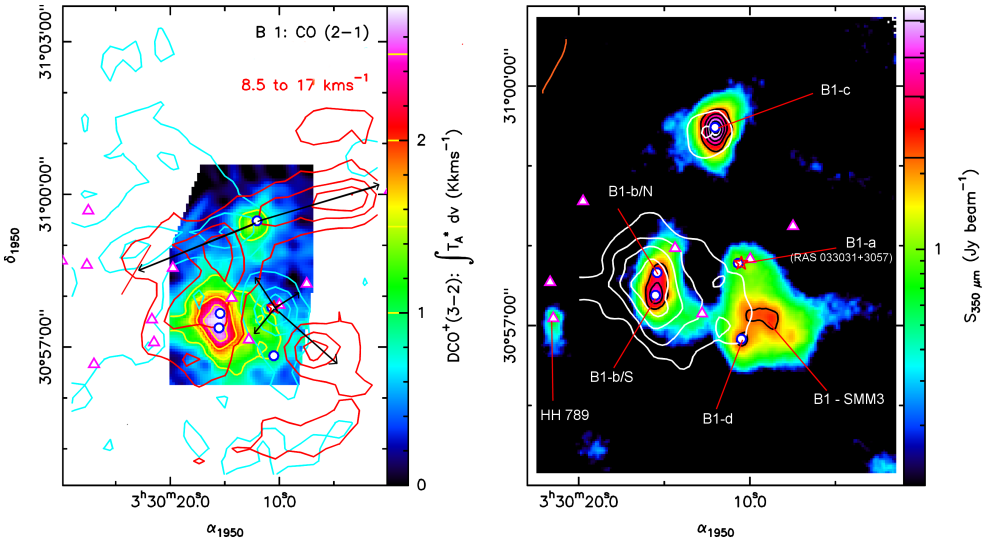

Fig. 1: (*Left*) Distribution of $DCO^+(3-2)$ emission in Barnard 1 (color image and yellow contours) with overlayed contours of high-velocity $CO(2-1)$ emission (blue and red contours respectively, dark arrows mark jets). (*Right*) Distribution of the 350 μm dust continuum emission (color image and black contours) with overlayed white contours of $DCO^+(3-2)$ emission. Red stars marks the location of IRAS 03301+3057. Magneta triangles mark locations of HH objects (Walawender et al., 2005) and blue circle mark compact continuum source B1-a to d (Hatchell et al., 2005).

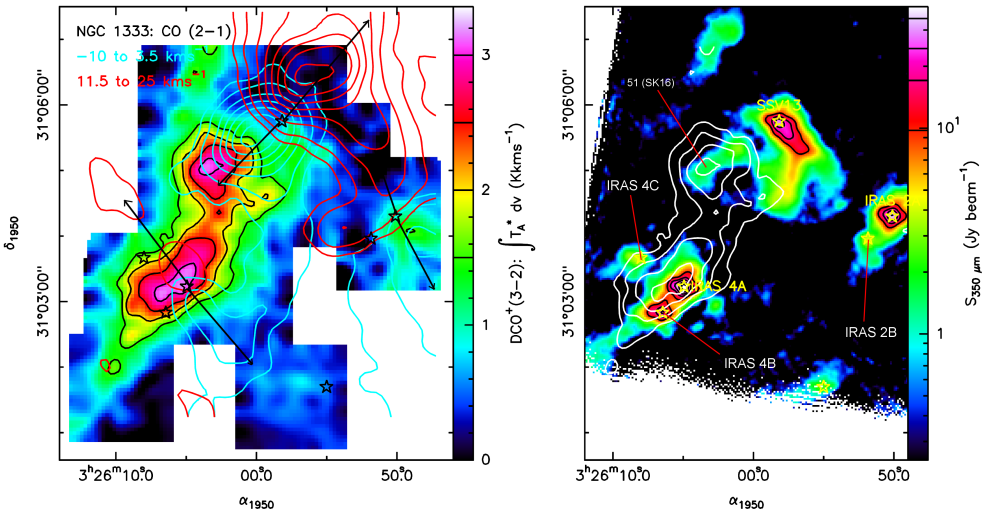

Fig. 2: (*Left*) Distribution of $DCO^+(3-2)$ emission (color image and black contours) with overlayed contours of high-velocity $CO(2-1)$ emission (blue and red contours respectively, dark arrows mark jets).(*Right*) Distribution of the 350 μm dust continuum emissiom (color image and black contours) with overlayed white contours of $DCO^+(3-2)$ emission.

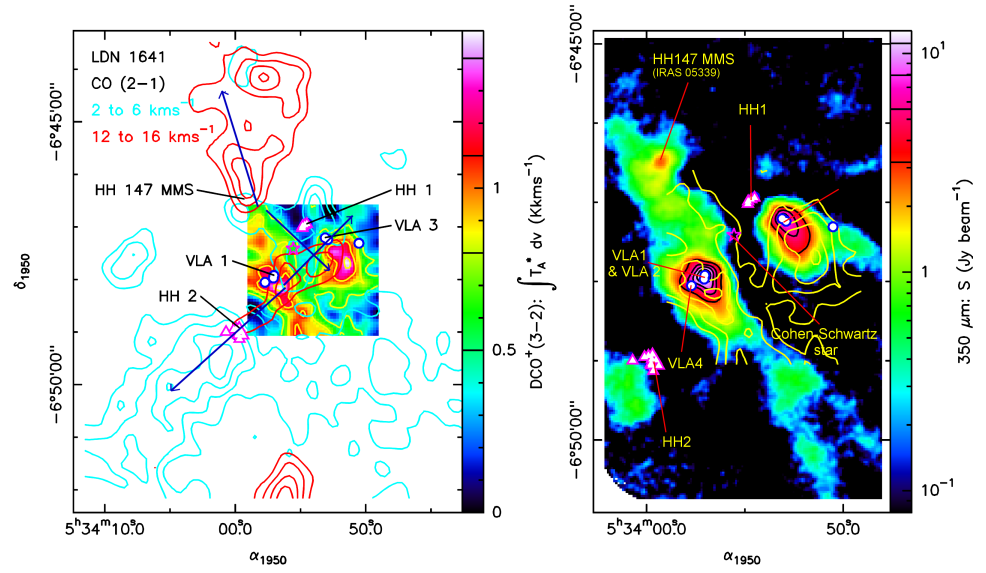

Fig. 3: (*Left*) Distribution of $DCO^+(3-2)$ emission (color image and yellow contours) with overlayed contours of high-velocity $CO(2-1)$ emission (blue and red contours respectively, dark arrows mark jets).(*Right*) Distribution of the 350 μm dust continuum emissiom (color image and black contours) with overlayed yellow contours of $DCO^+(3-2)$ emission.

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