Fractionation of isotopes in space:
from the solar system to galaxies

Deuterium fractionation and kinematics in the Taurus molecular cloud

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Florence, Italy
11 October 2016

MAX-PLANCK-GESELLSCHAFT

MPE

Deuterium fractionation

$H_3^+ + HD \leftrightarrow H_2D^+ + H_2 + 230$ K (Millar et al. 1989)

T = 5–20 K => a lot of H_2D^+

$H_3^+ + A \rightarrow AH^+ + H_2$ (Herbst & Klemperer 1973)

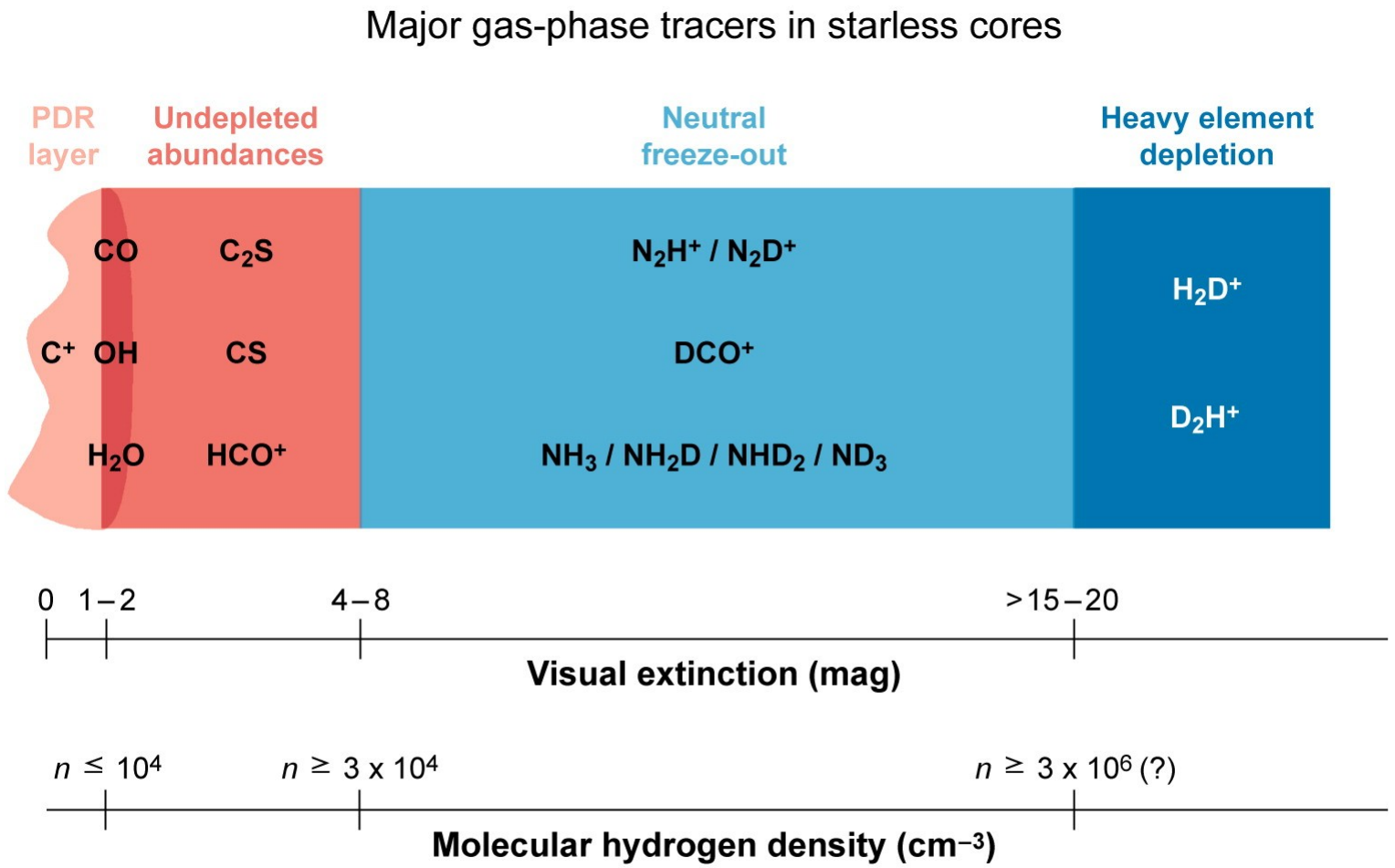
Mainly CO and O destroy H_2D^+ and H_3^+

But they are frozen onto the dust grains

$H_2D^+ + N_2 \rightarrow N_2D^+ + H_2$

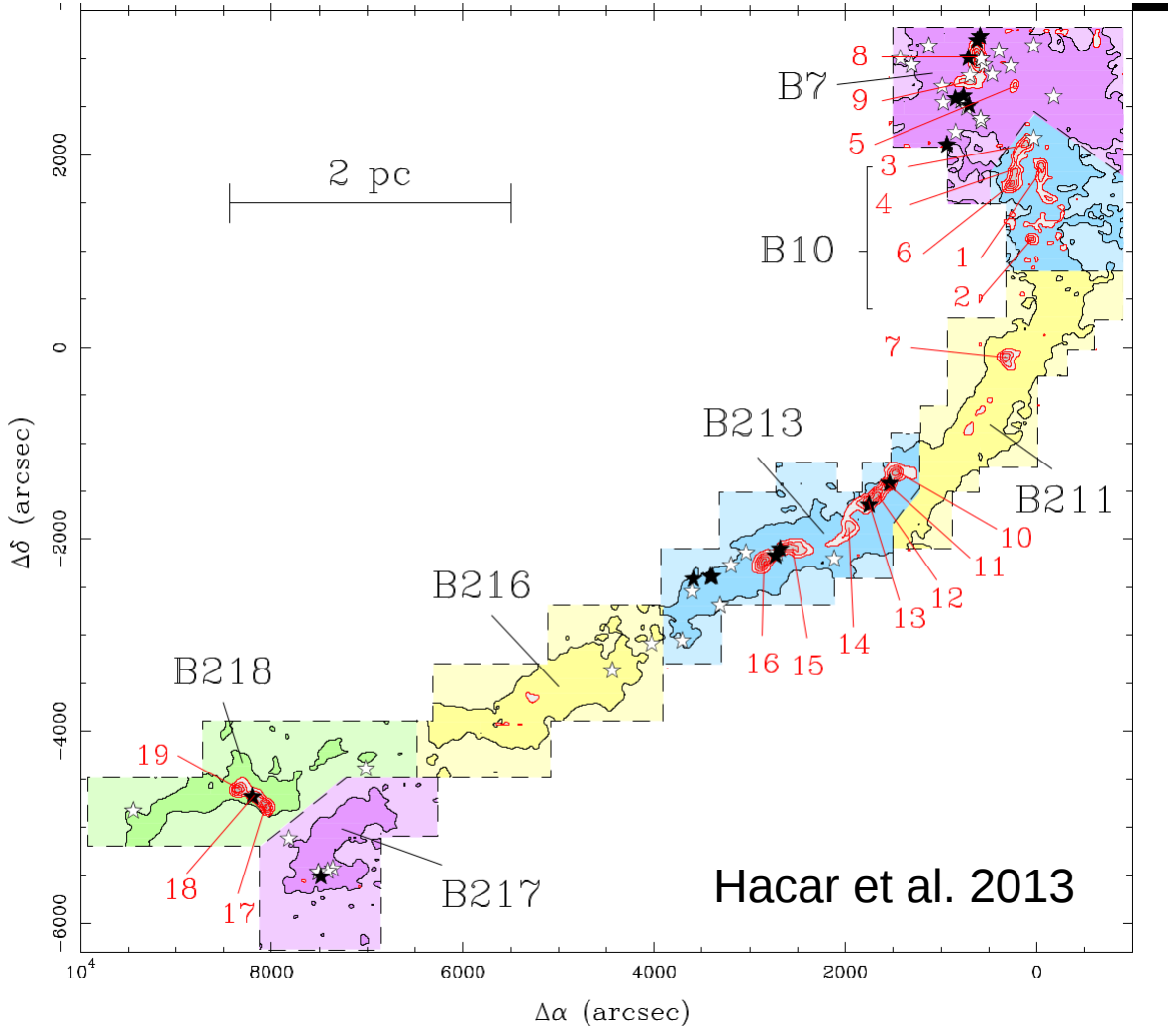
$H_3^+ + N_2 \rightarrow N_2H^+ + H_2$

Major gas-phase tracers in dense cores



Bergin EA, Tafalla M. 2007.
Annu. Rev. Astron. Astrophys. 45:339–96

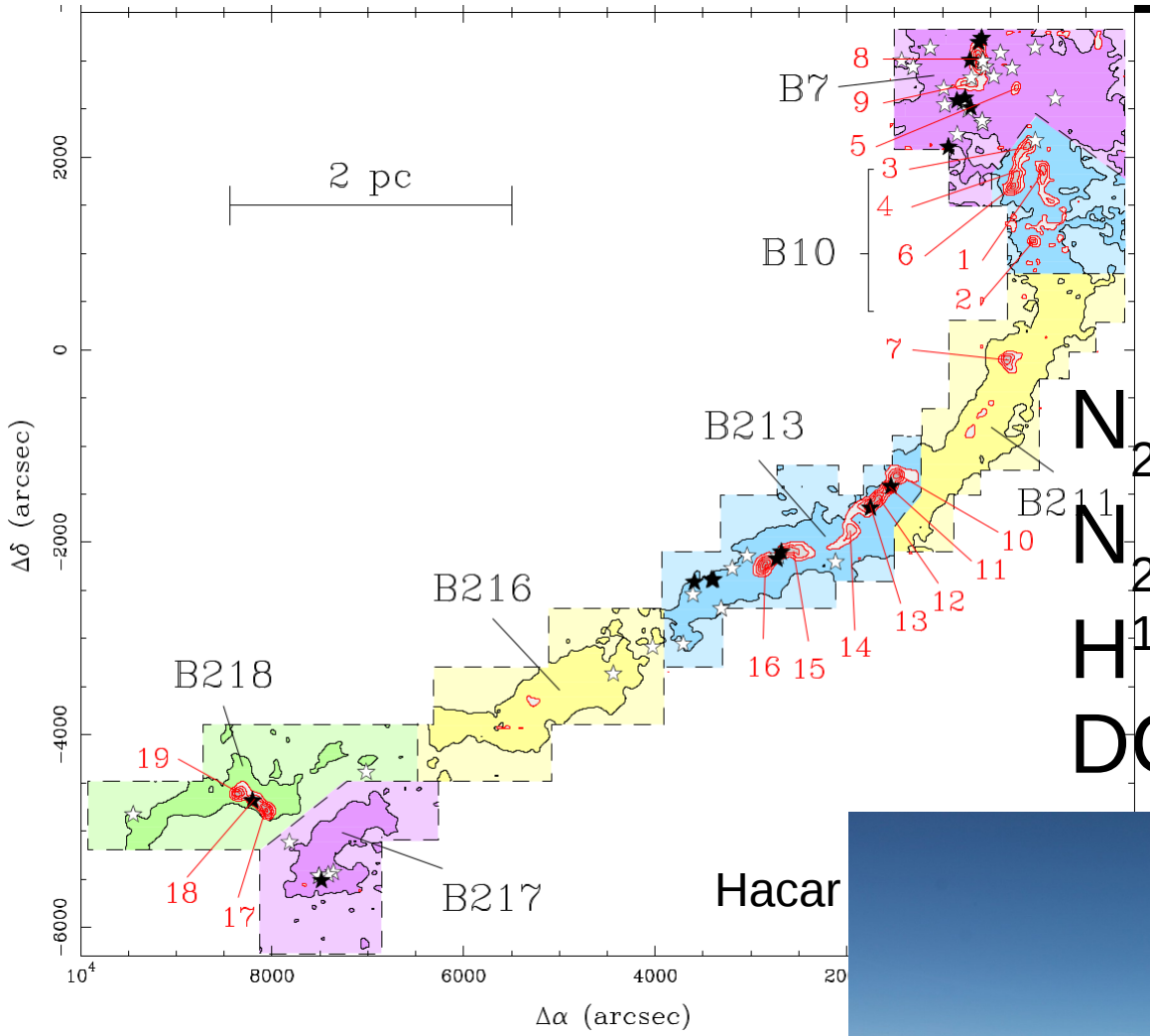
L1495 in the Taurus molecular cloud



The black solid line is the lowest $C^{18}O(1\text{-}0)$ contour, the red contours – $N_2H^+(1\text{-}0)$.

The stars – YSOs from Rebull et al. (2010).

L1495 in the Taurus molecular cloud



$N_2D^+(2\text{-}1)$

$N_2H^+(1\text{-}0)$

$H^{13}CO^+(1\text{-}0)$

$DCO^+(2\text{-}1)$

Hacar

The black solid line is the lowest $C^{18}O(1\text{-}0)$ contour,

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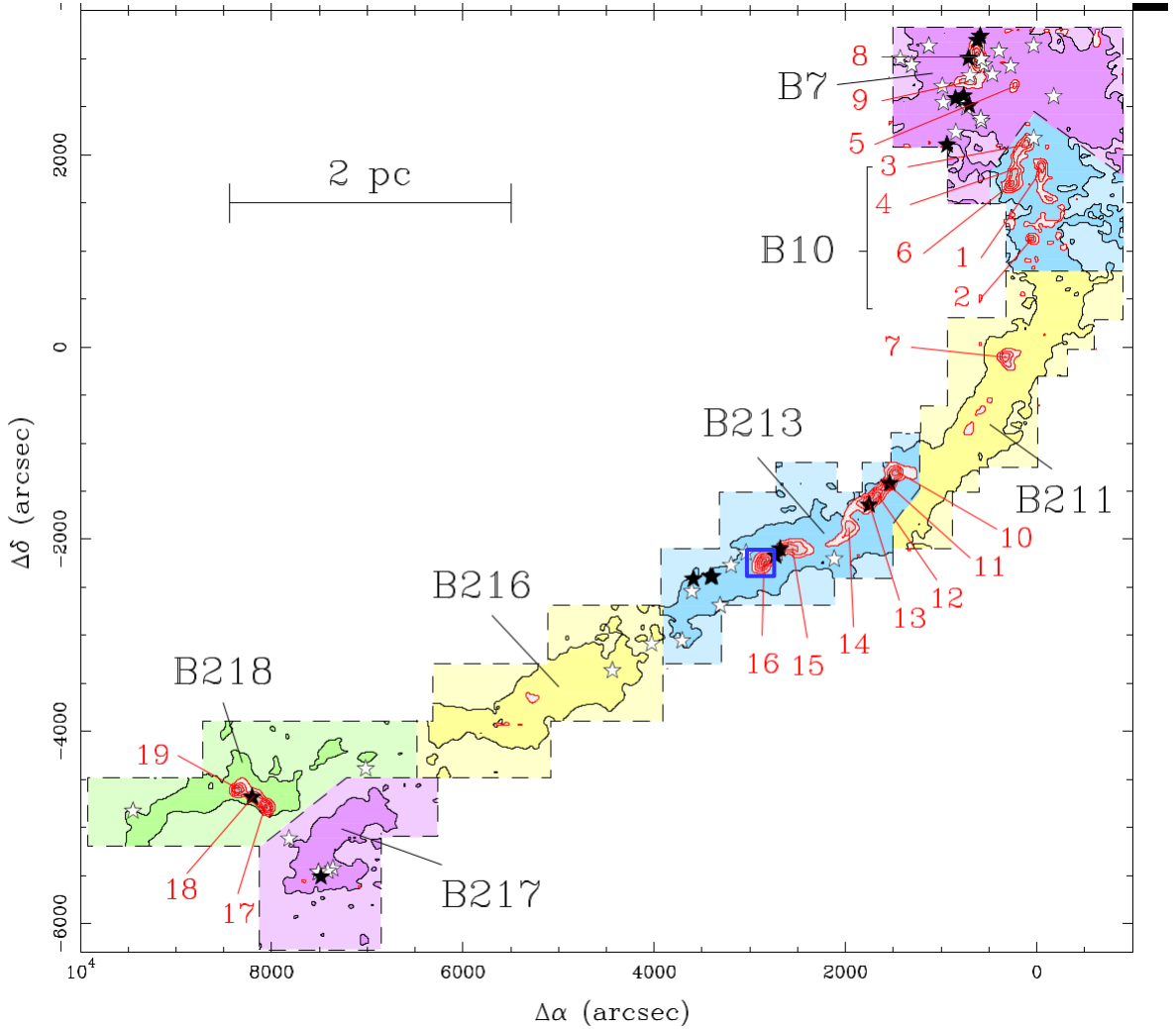
L1495 in the Taurus molecular cloud



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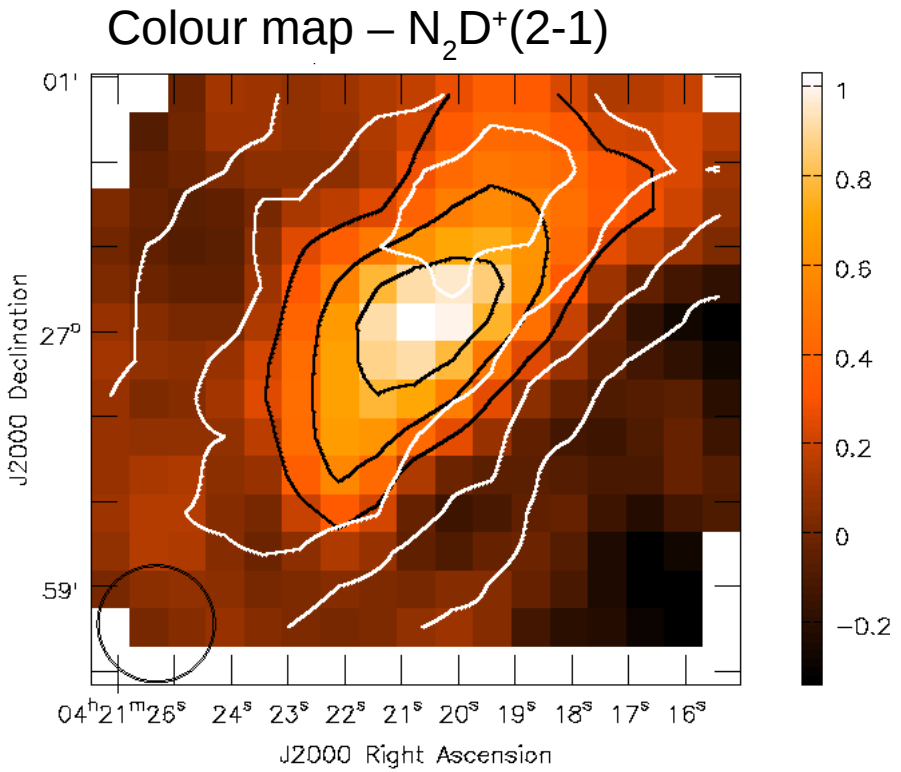
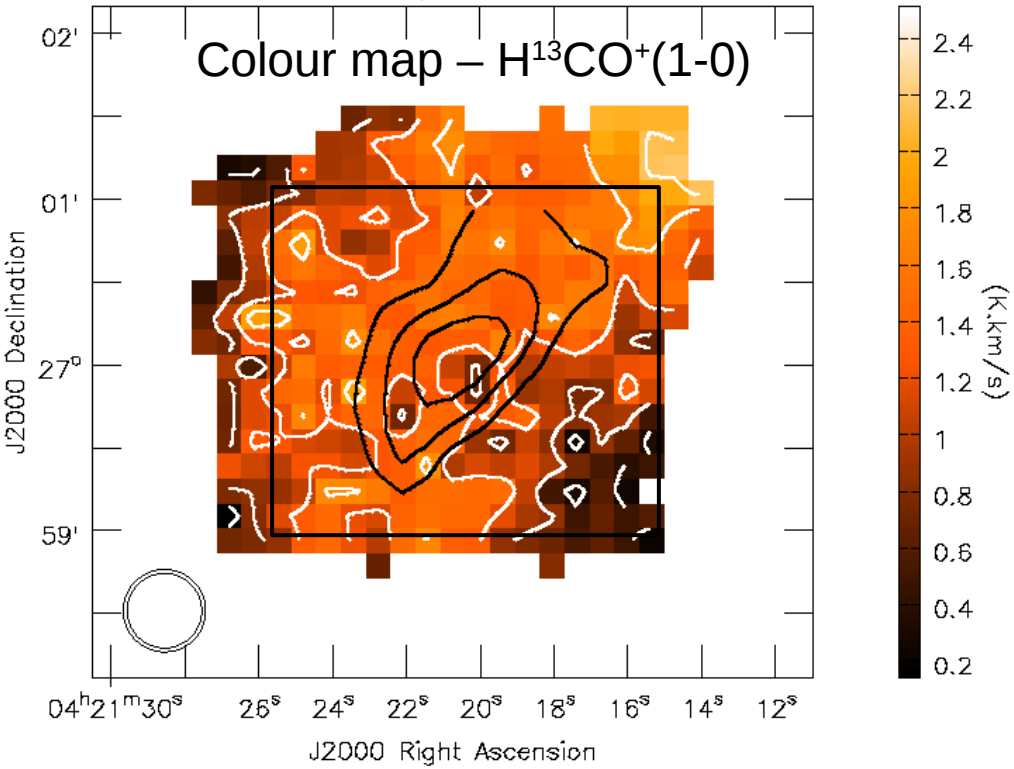
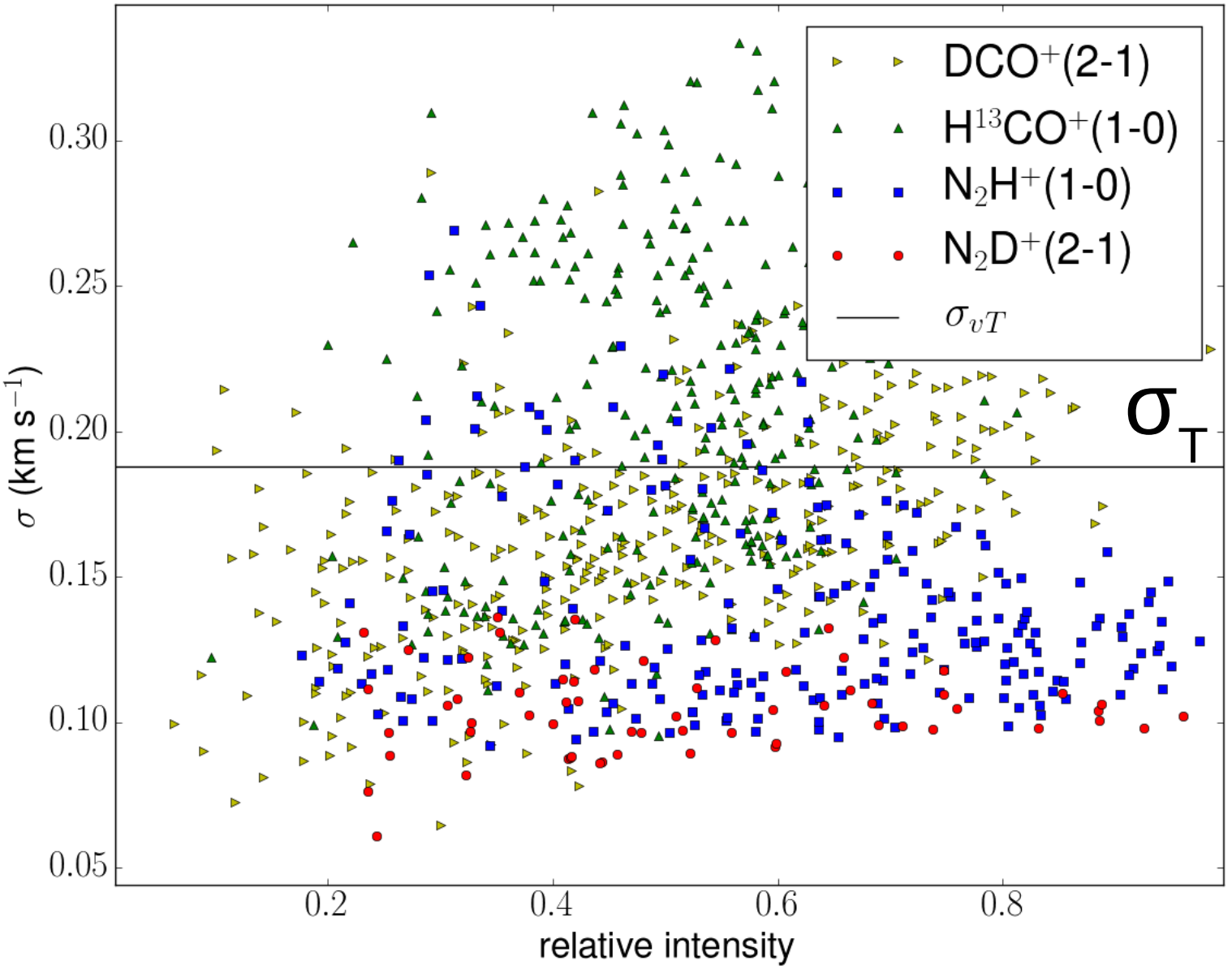
Starless core L1495-16



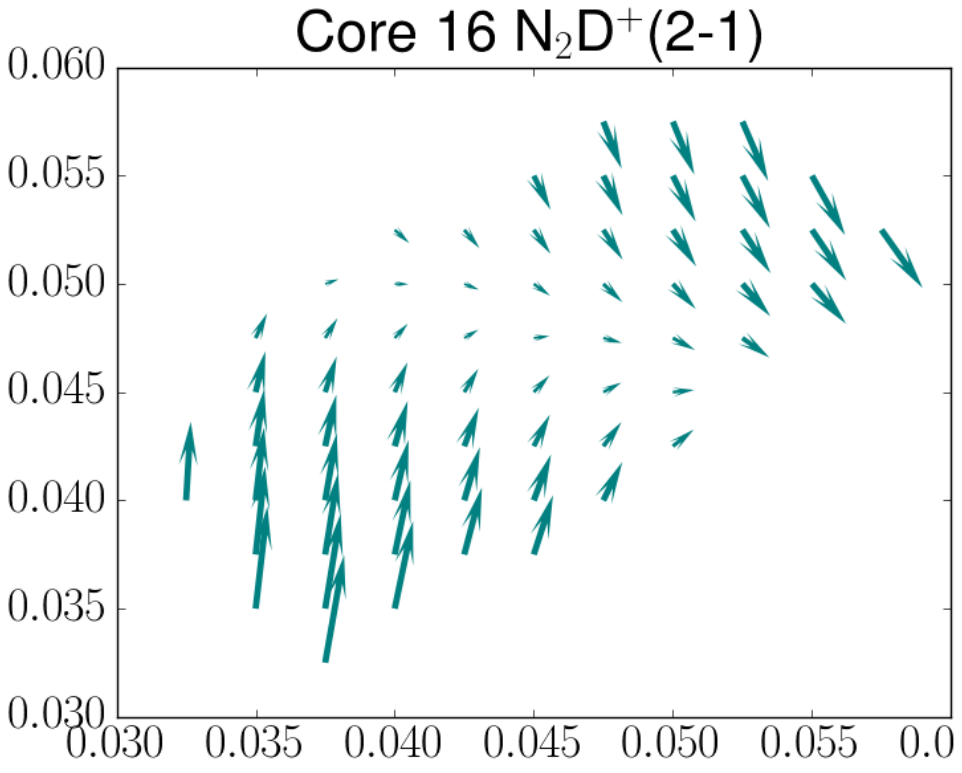


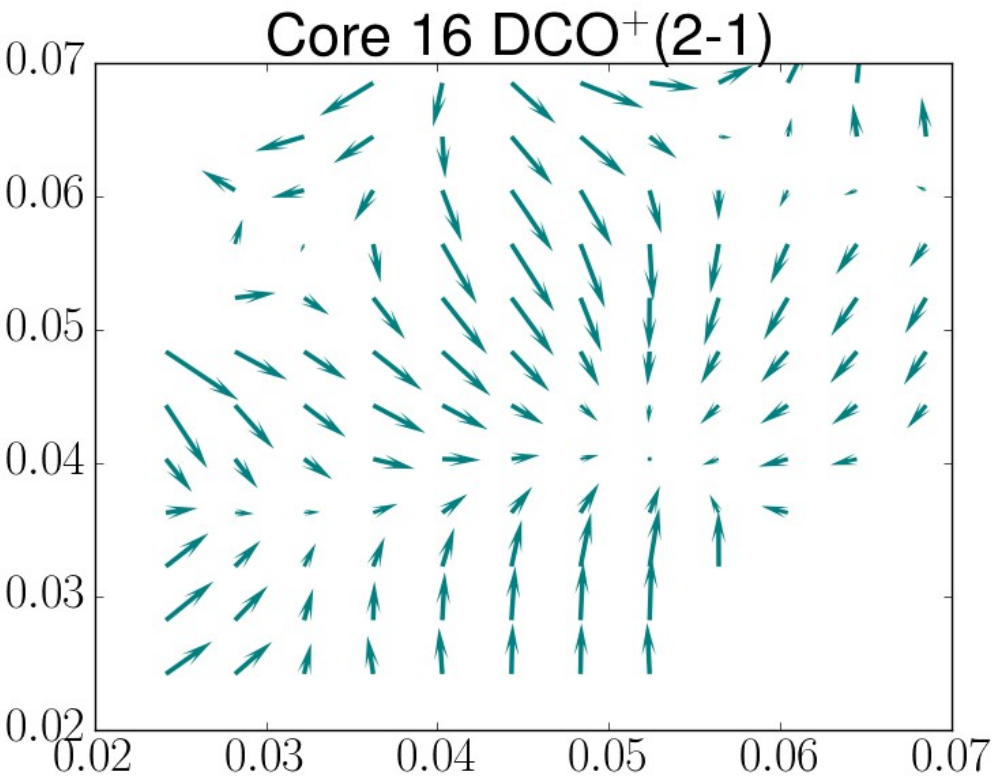
Left: N_2D^+(2-1) (black) trace denser gas than N_2H^+(1-0) (white), their emission peaks mismatch; Right: $H^{13}CO^+$(1-0) (white) trace extended filament gas and partially depleted at the N_2D^+(2-1) emission peak (black).

Velocity dispersion in the core L1495-16



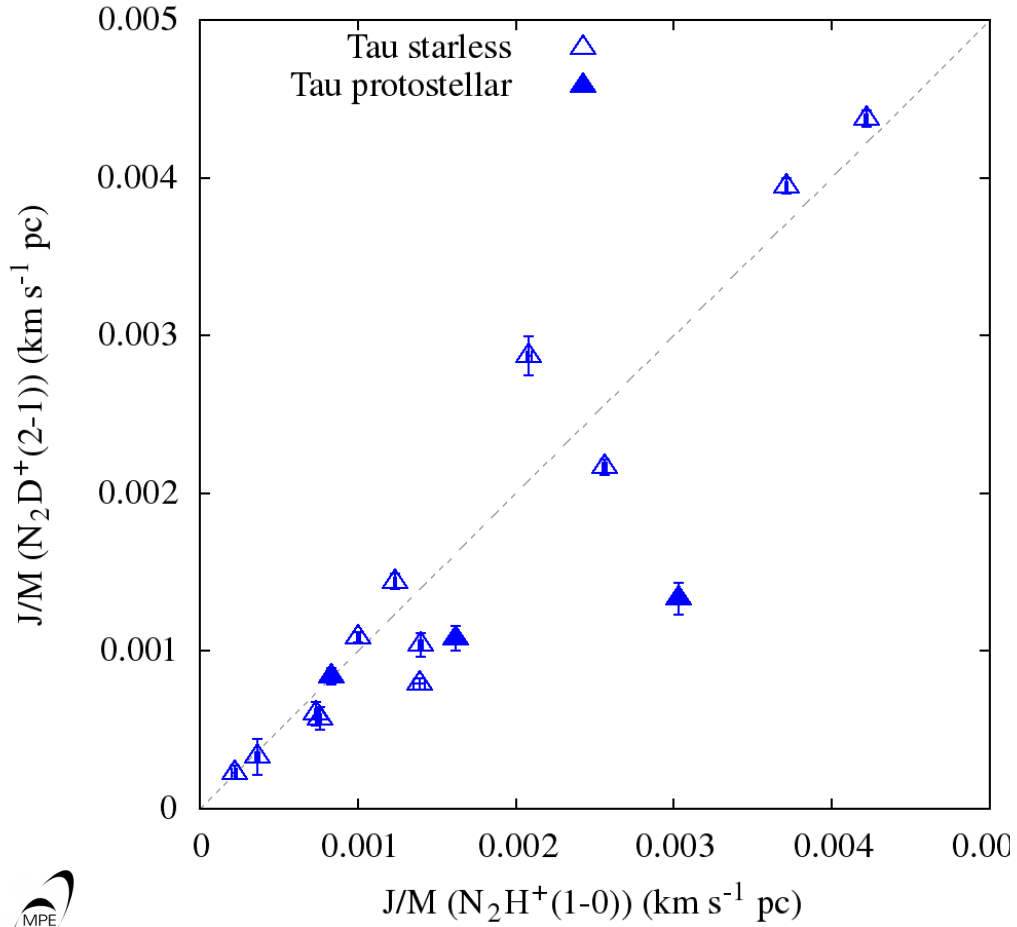
Local V_{LSR} gradients



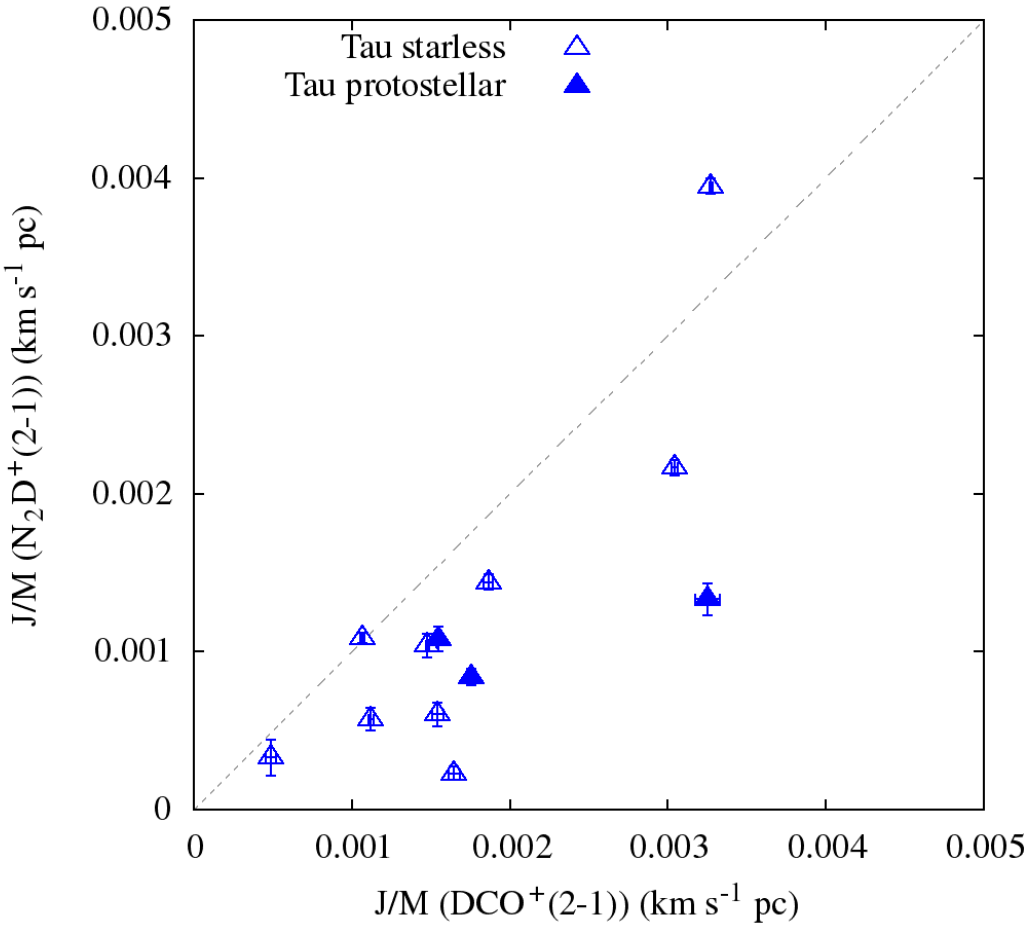


Specific angular momentum

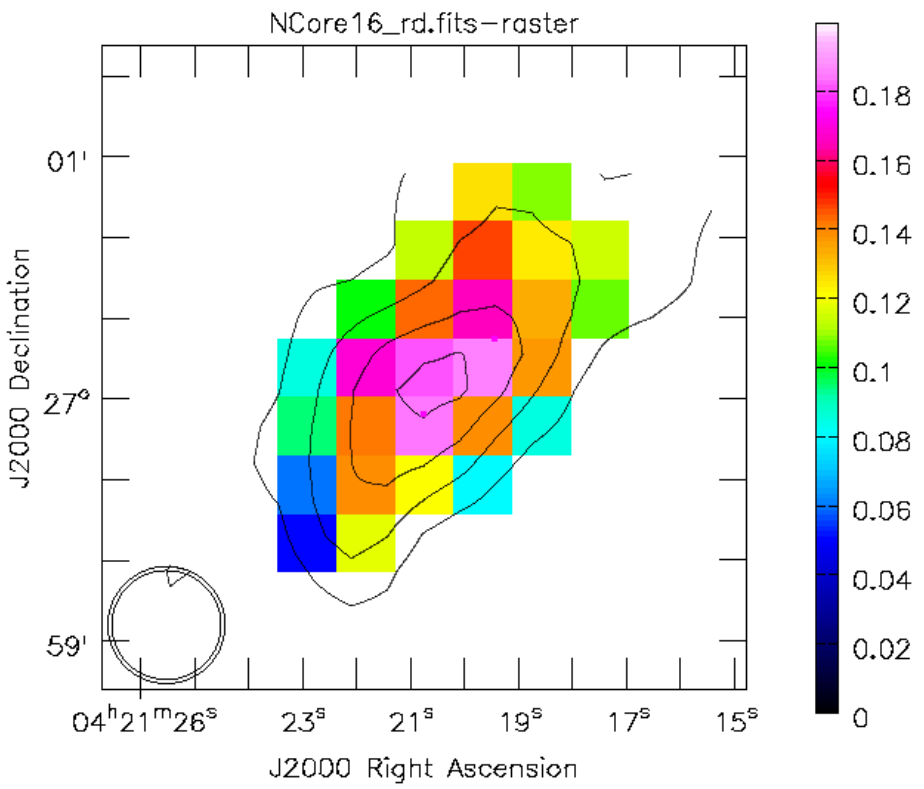
$N_2D^+(2\text{-}1)$ vs $N_2H^+(1\text{-}0)$

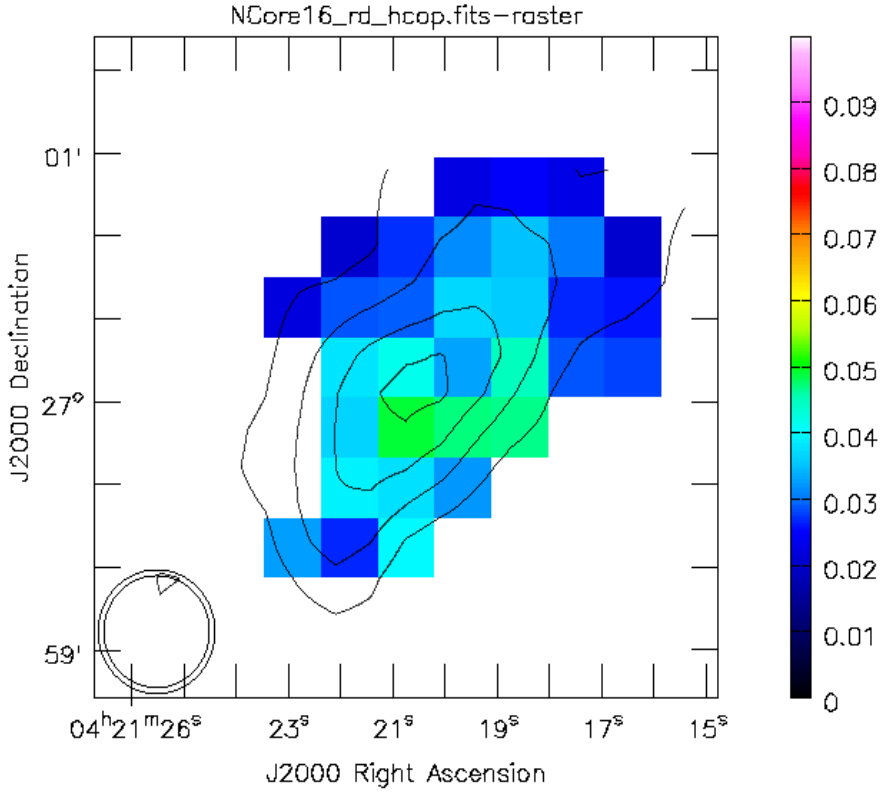


$N_2D^+(2\text{-}1)$ vs $DCO^+(2\text{-}1)$



Deuterium fraction

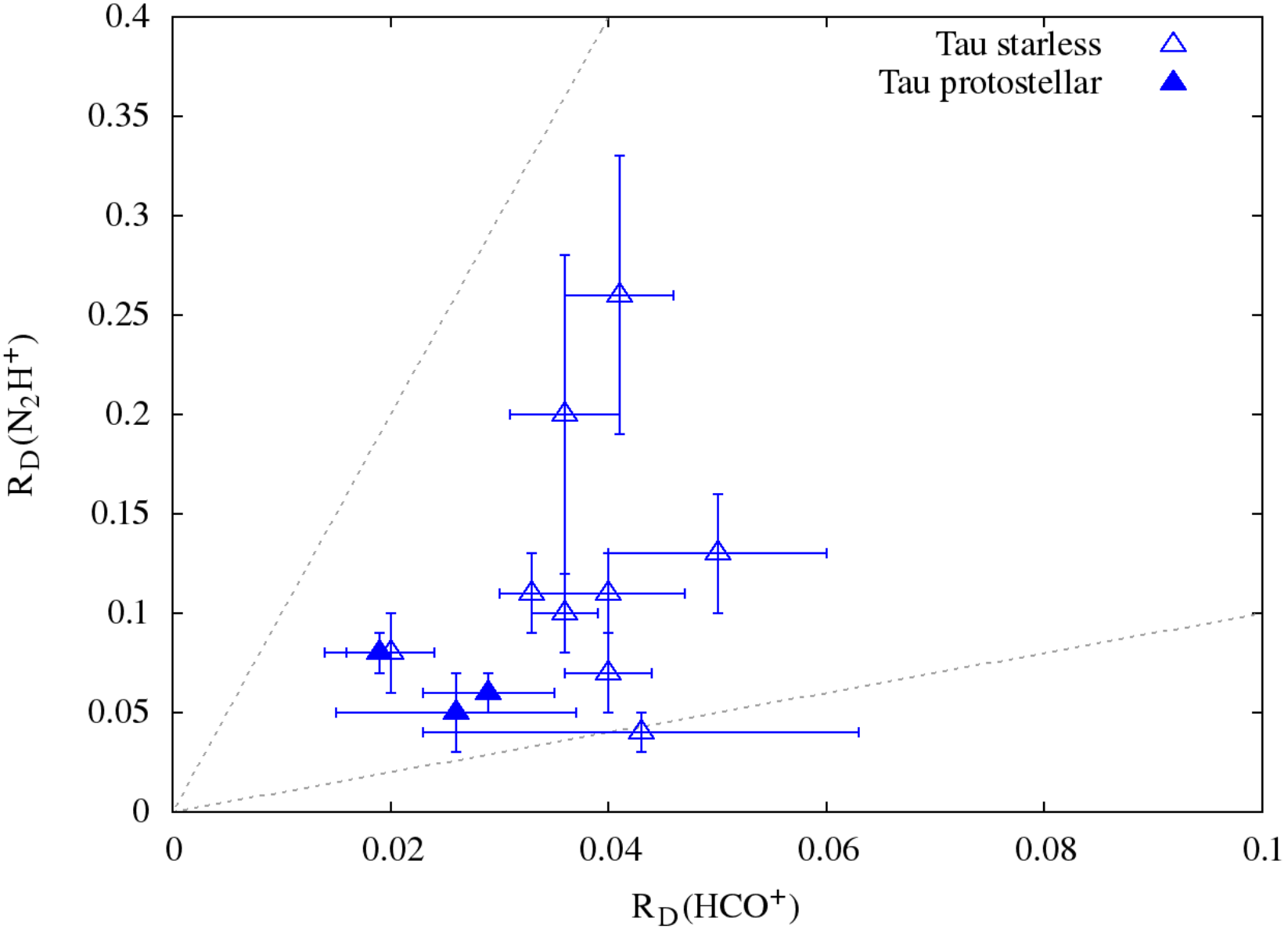




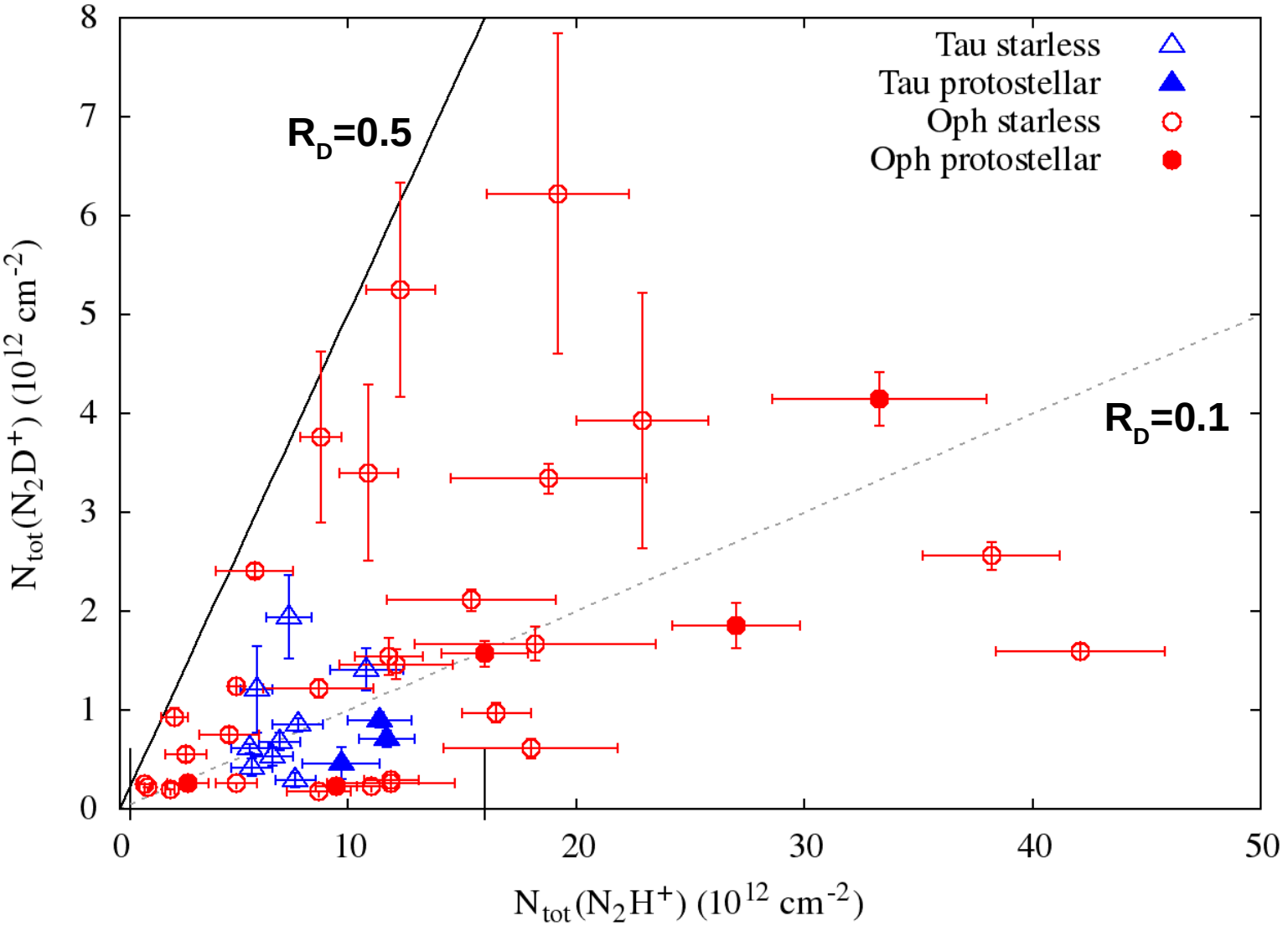
$N(N_2D^+)/N(N_2H^+)$

$N(DCO^+)/N(HCO^+)$

Deuterium fraction



Compare Taurus and Ophiuchus



$R_D = N(N_2D^+)/N(N_2H^+)$

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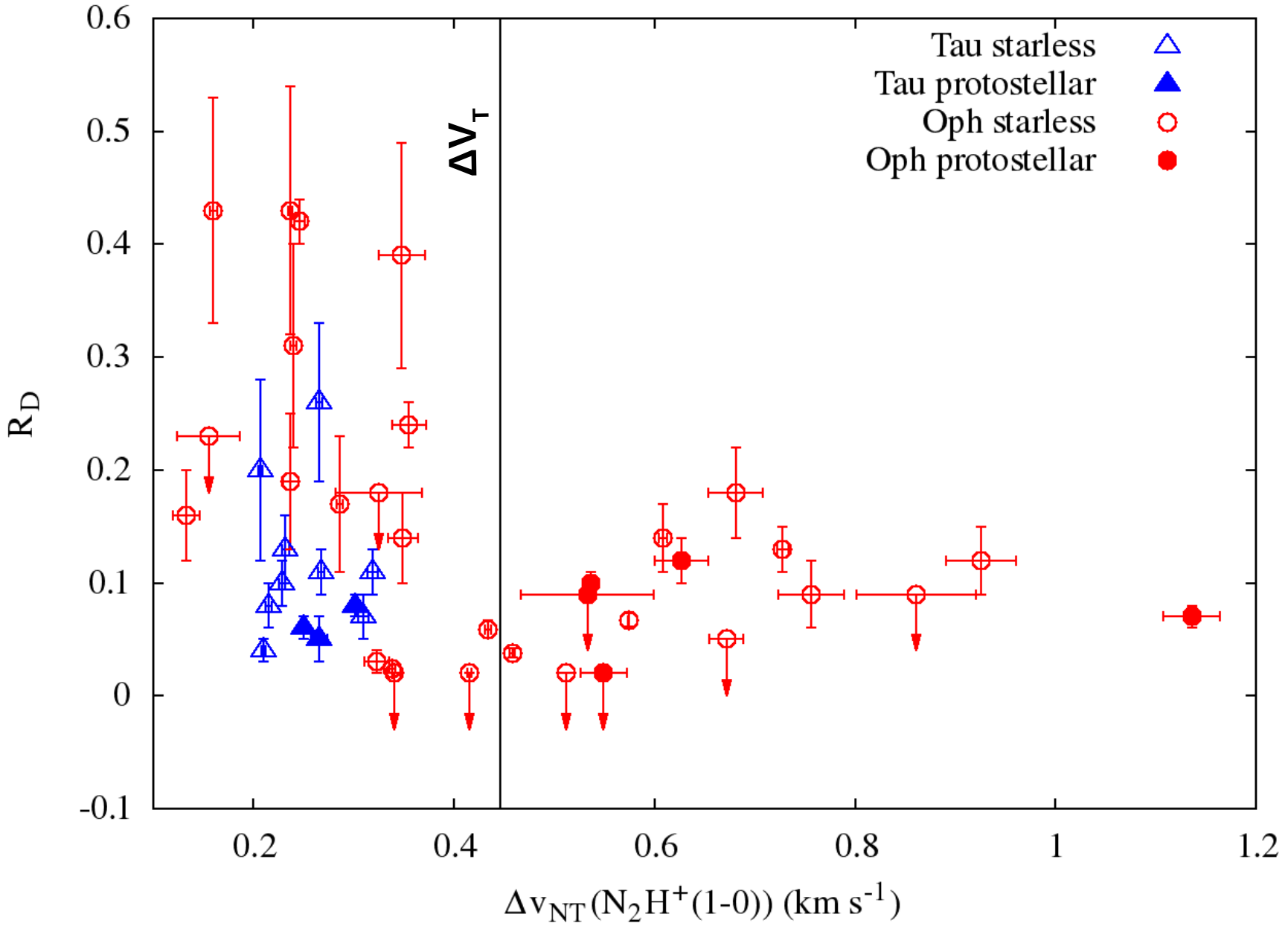

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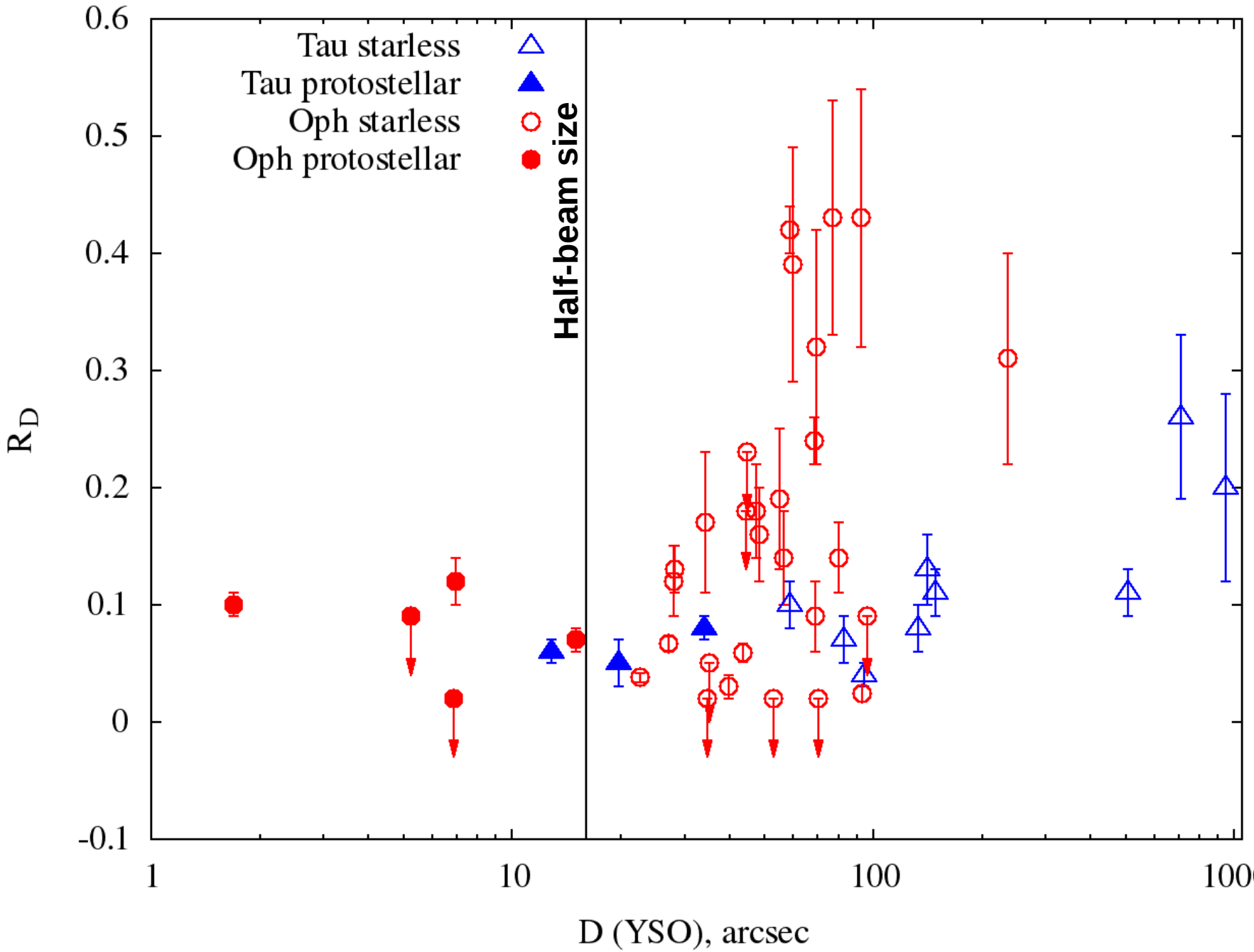
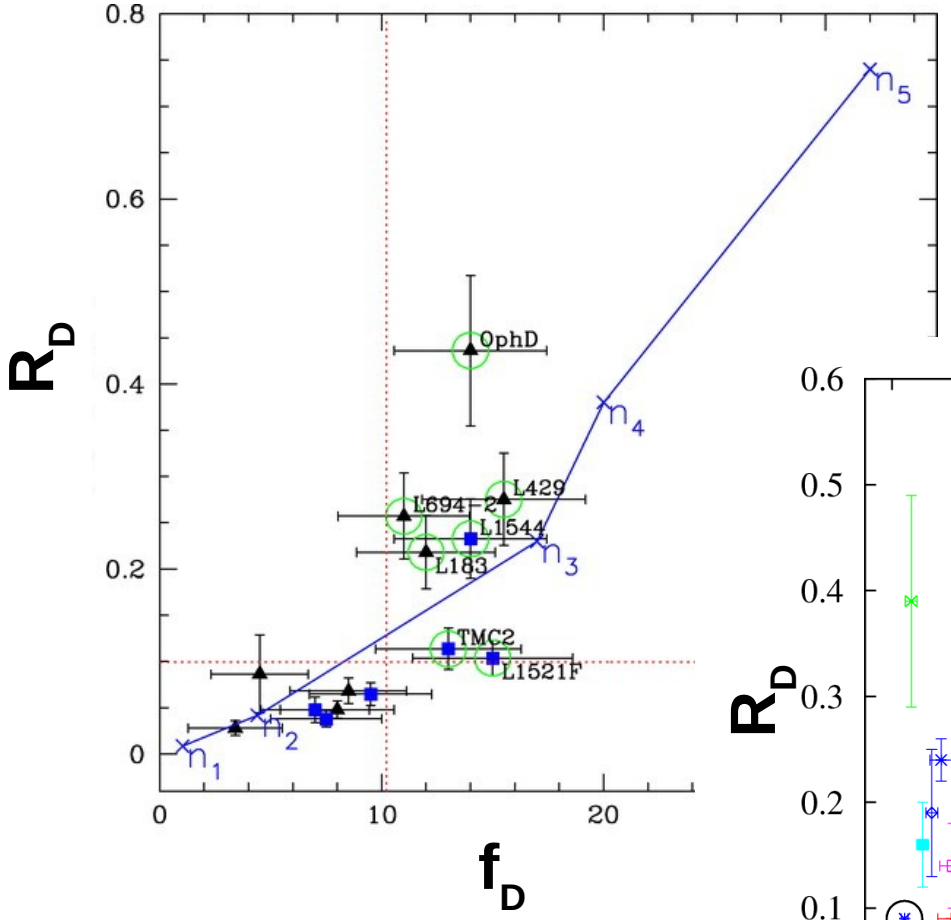
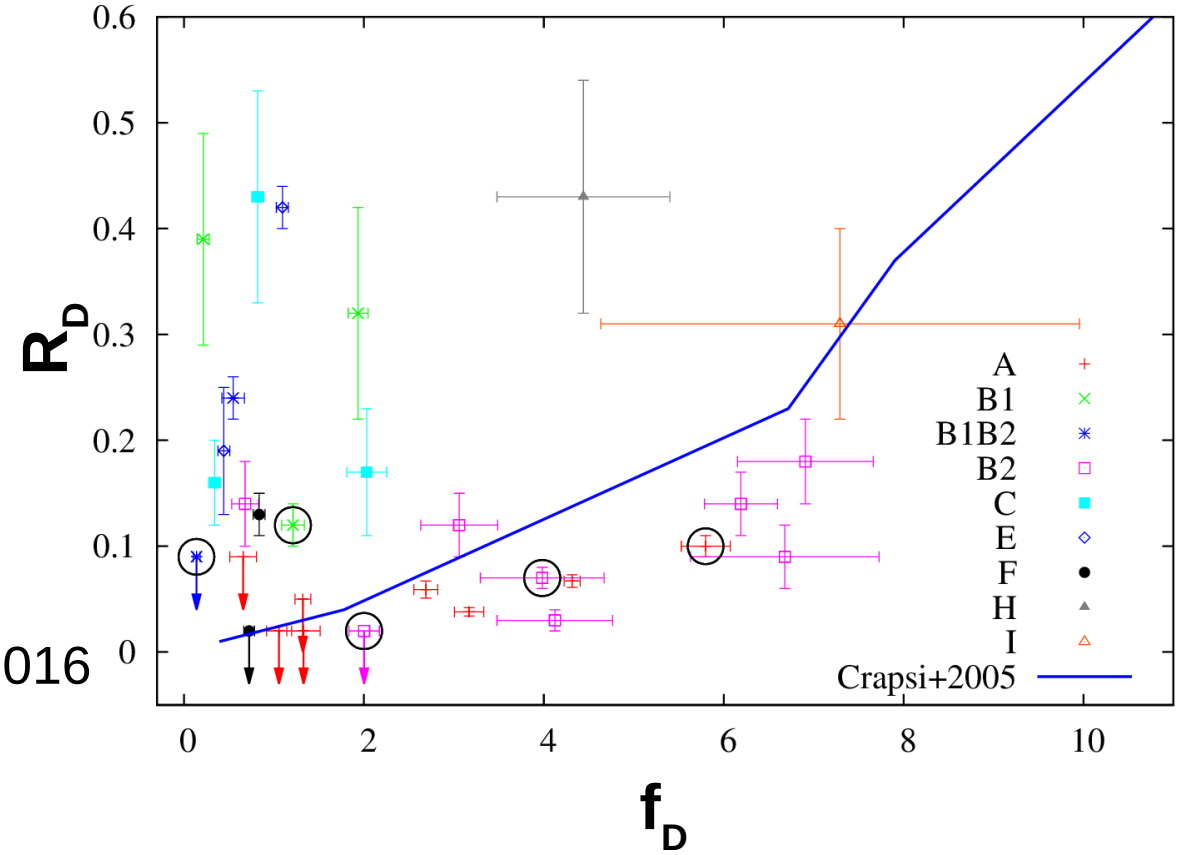


Deuterium fraction and CO depletion

$R_D = N(N_2D^+)/N(N_2H^+)$

$f_D = X(CO)_{ref} / X(CO)_{obs}$





Top: Crapsi et al. 2005
Right: Punanova et al. 2016

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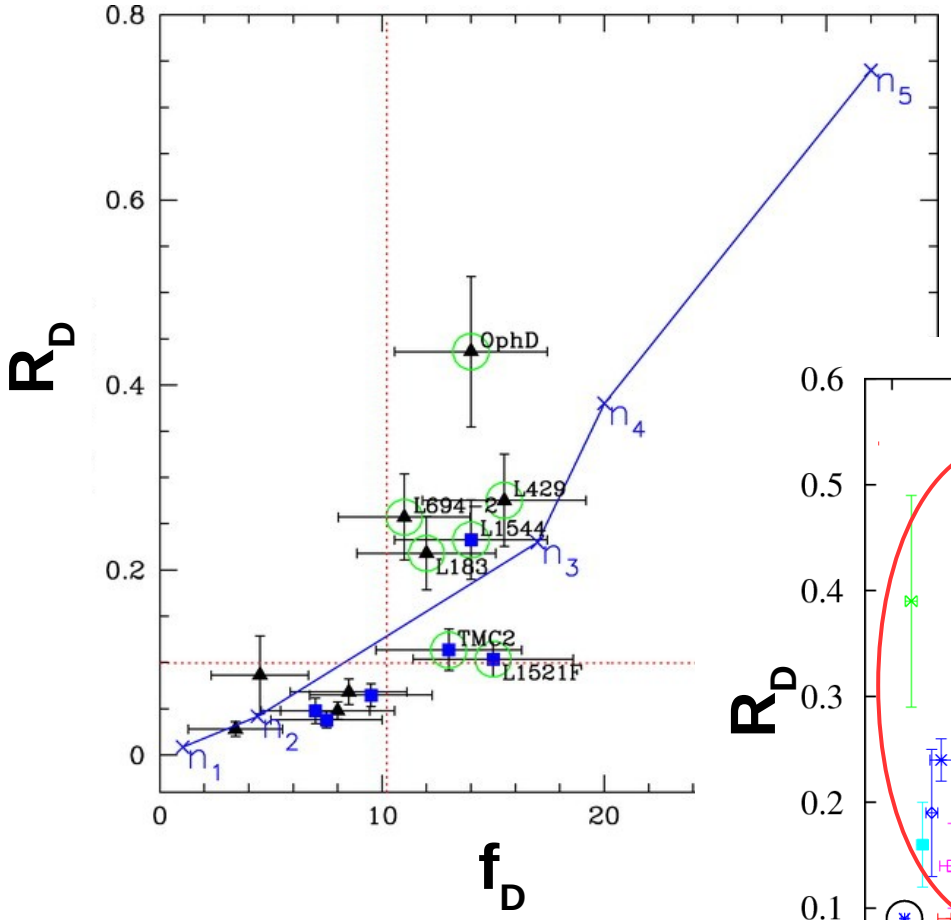

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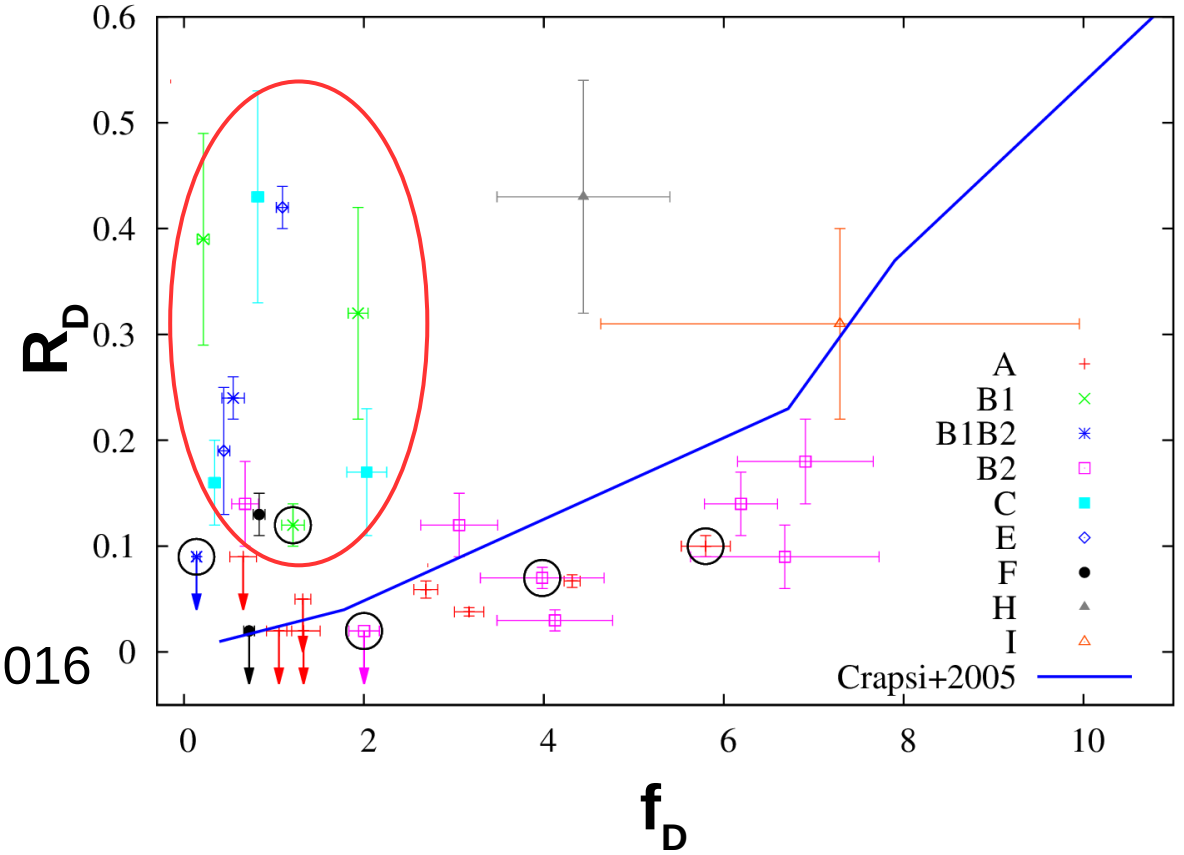

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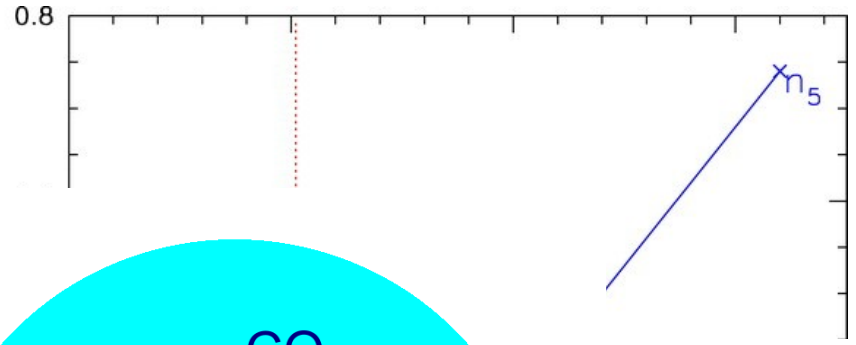

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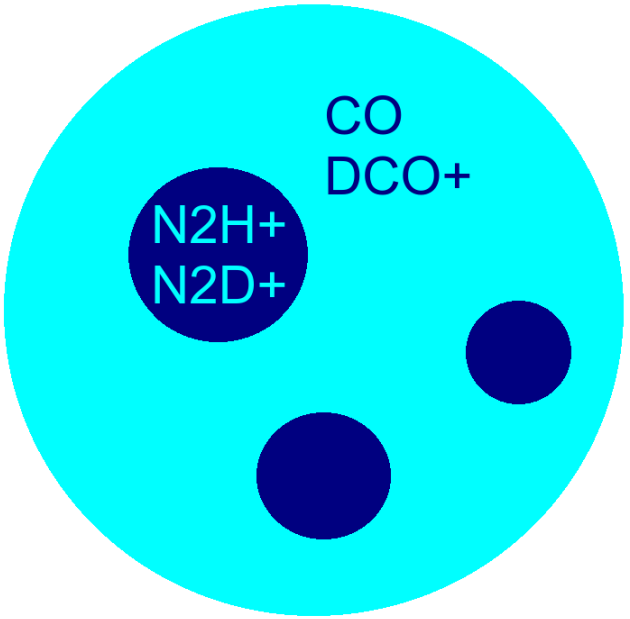
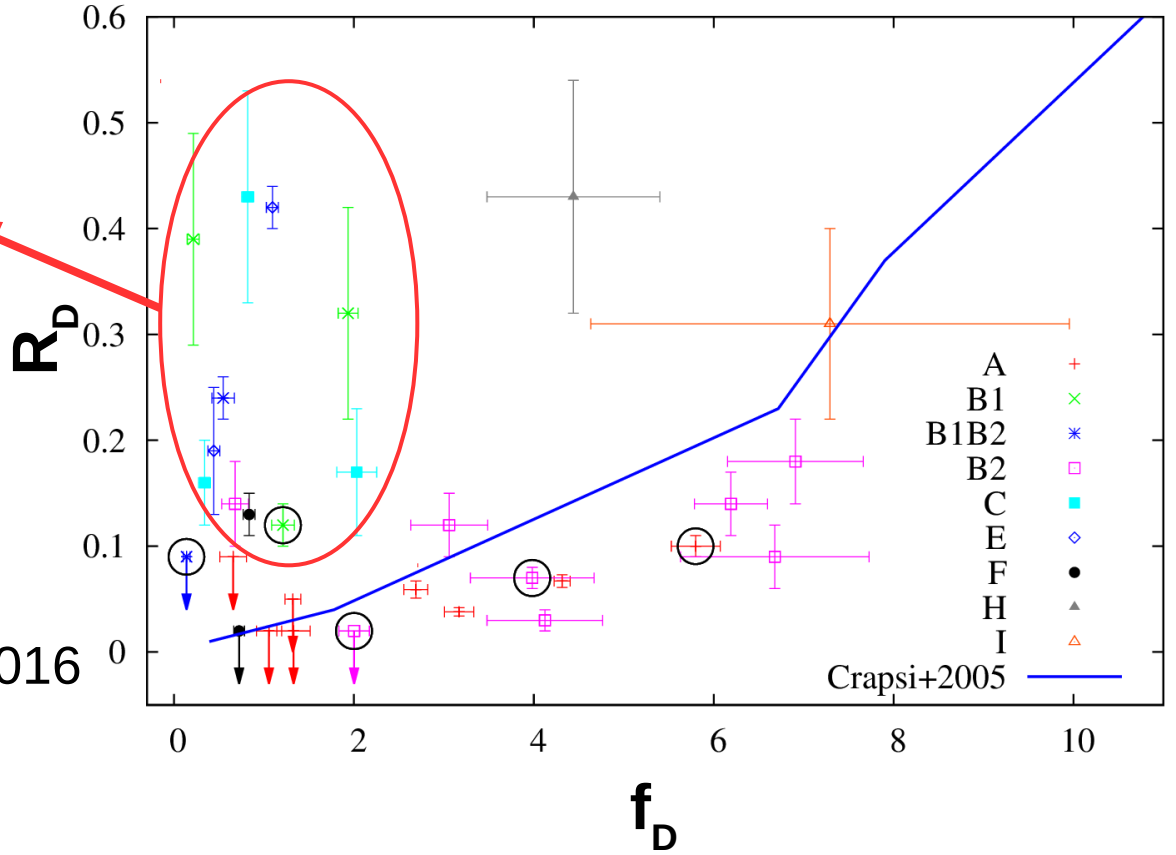


Right: Punanova et al. 2016



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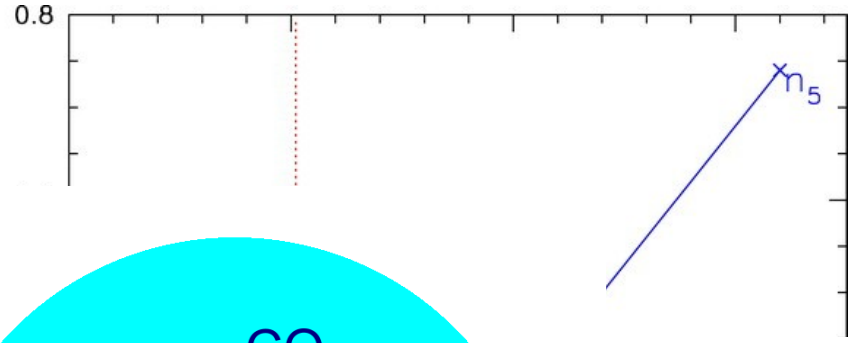

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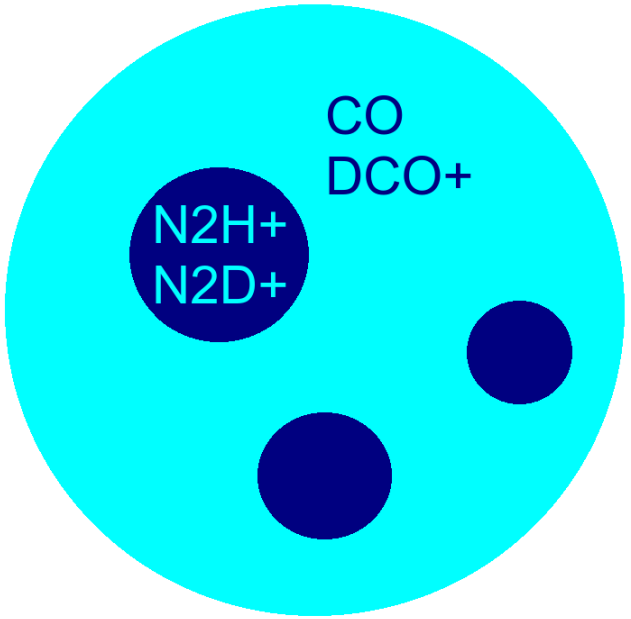

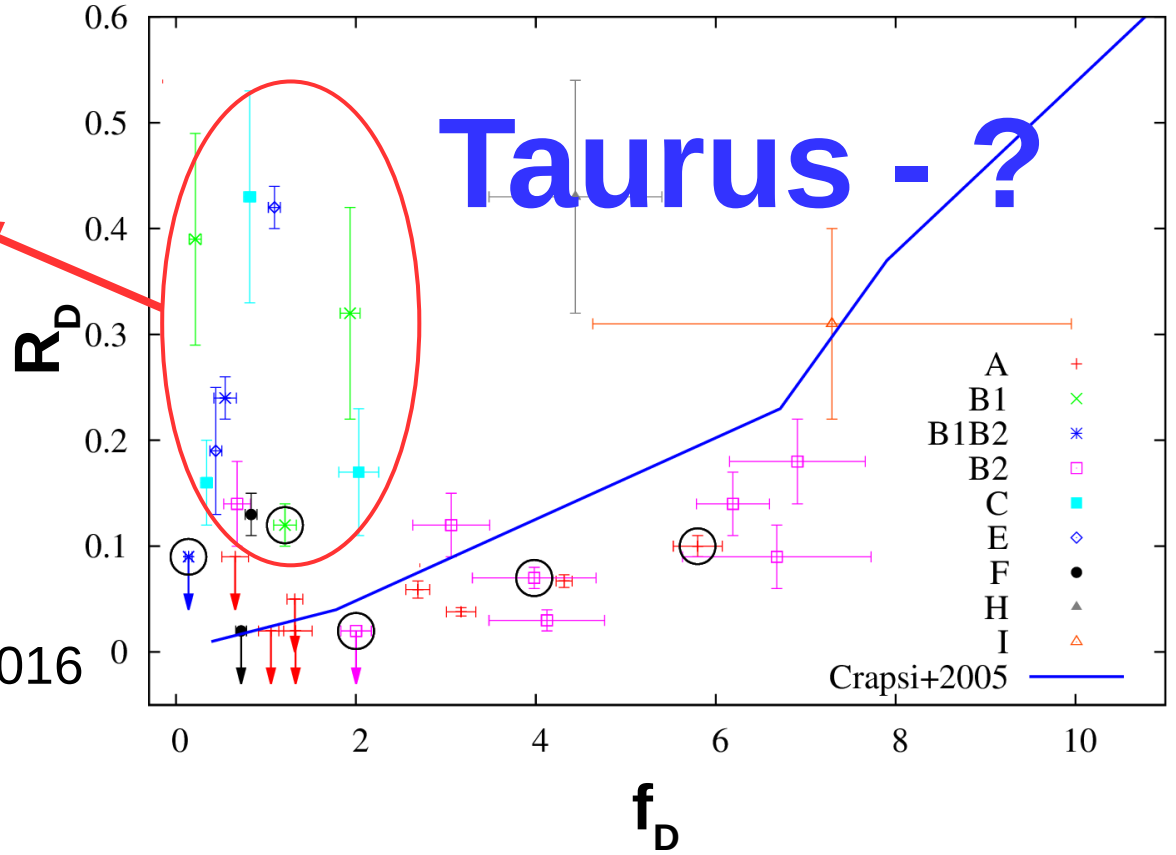

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Summary

- Deuterium fraction in N_2H^+ is higher than in HCO^+
- R_D in Taurus is lower and less spread than in Ophiuchus
- High deuterium fraction (R_D>0.2) is present only in regions dominated by thermal motions
- Cores close to YSOs (within 1.5 beamsize distance) have small deuterium fractions (R_D<0.12)
- Next step: connection core – cloud scale and measure CO depletion towards the cores in L1495

Thank you for your attention!