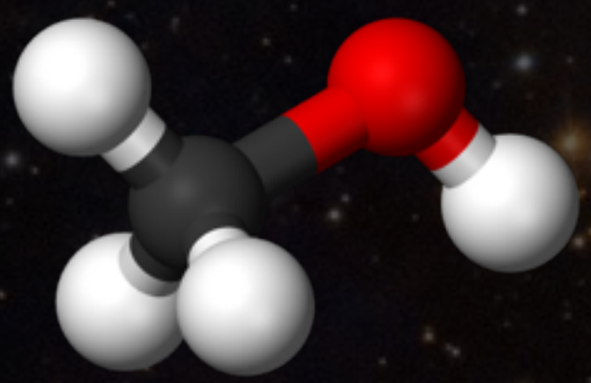
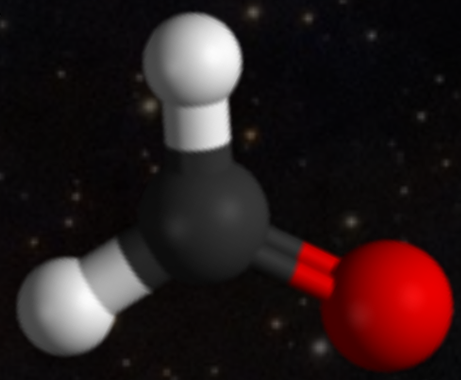
DECREASE OF THE ORGANICS DEUTERATION DURING THE FORMATION OF SUN-LIKE STARS

The case of SVS13-A

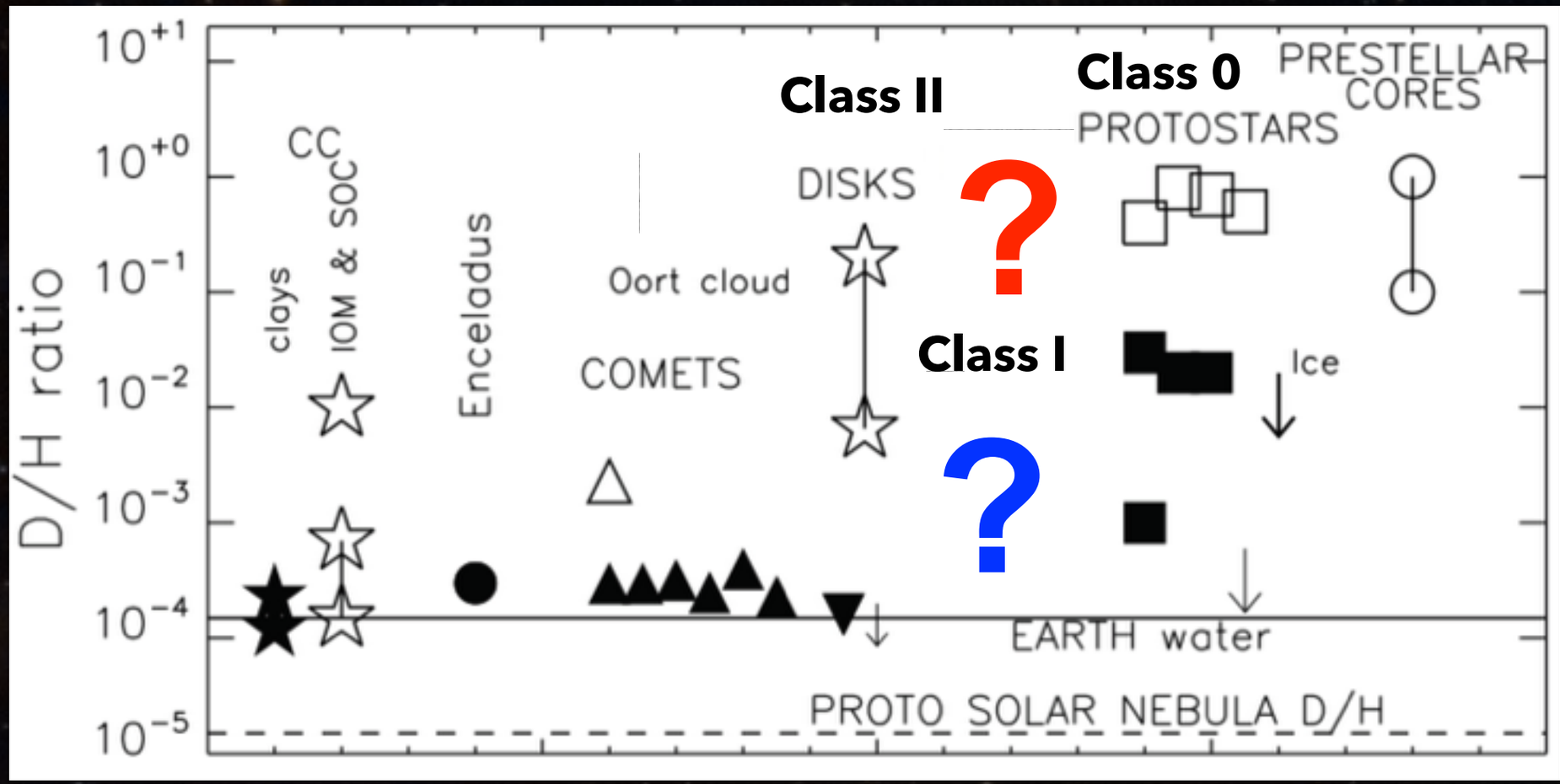




Eleonora Bianchi

on behalf of: C. Codella (Arcetri), C. Ceccarelli (IPAG), F. Fontani (Arcetri), L. Testi (ESO/ Arcetri), R. Bachiller (OAN), B. Lefloch (IPAG), L. Podio (Arcetri) , V. Taquet (Leiden)

D/H: WHAT HAPPENS BETWEEN CLASS 0 AND CLASS II?



Adapted from Ceccarelli et al. 2014, PPVI

In the Local ISM

D/H ~ 1.5 10^{-5}
(Oliveira+03; Linsky+06)

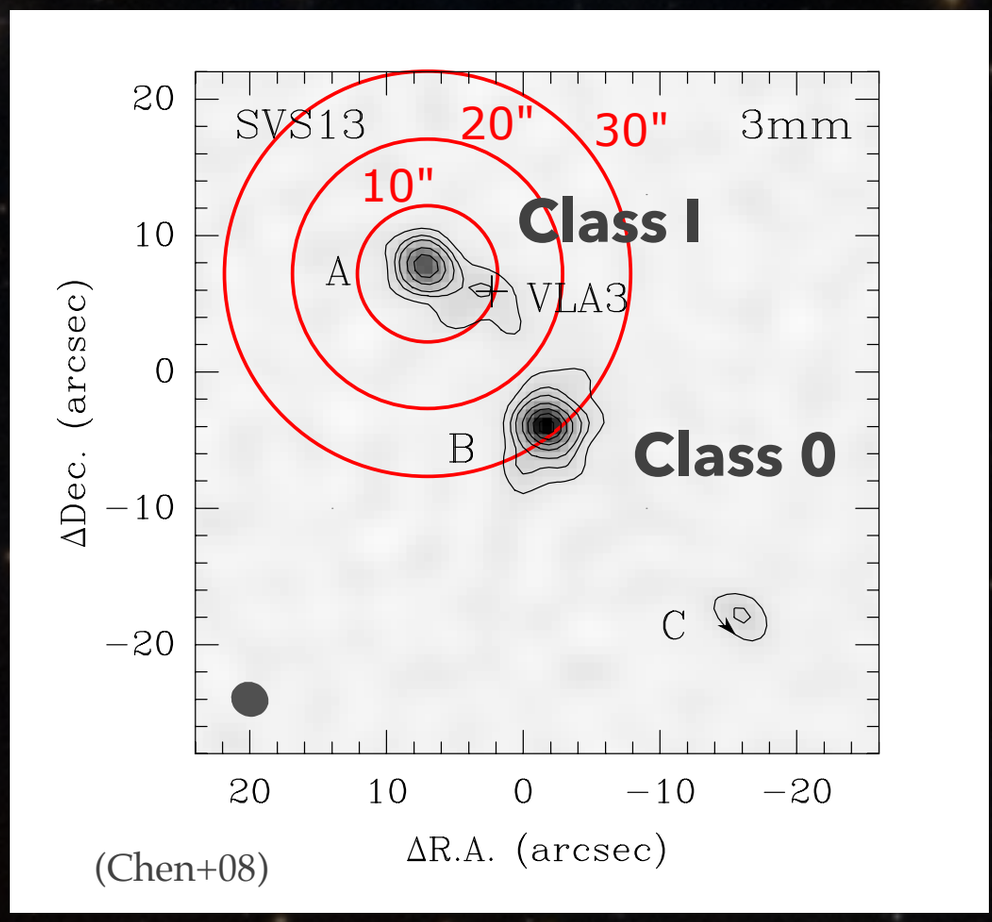
Different from Terrestrial Standards by a factor 10!

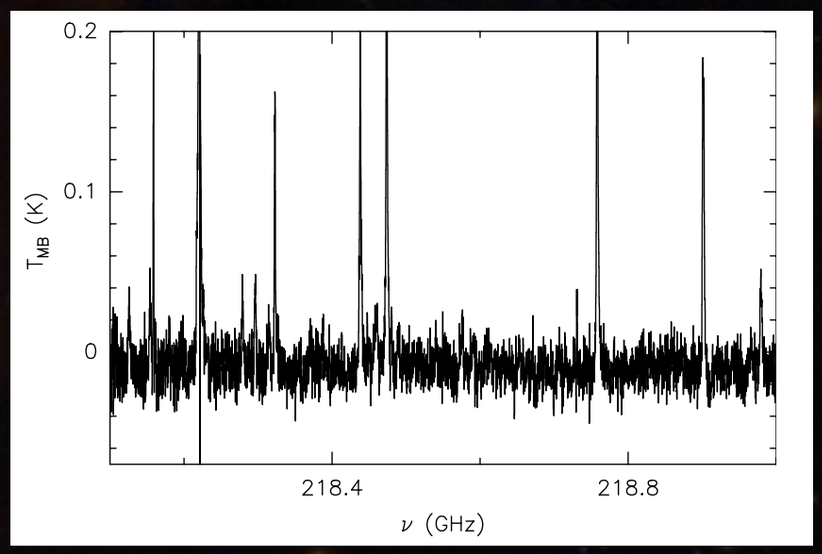
TIME

SVS 13-A
Astrochemical Surveys At IRAM 30m

IRAM 30-m Large Program
(PI B. Lefloch & R. Bachiller)

Unbiased spectral surveys
(80-280 GHz)
sensitivity : 1.5-5 mK
HPBW = 10 - 30 arcsec





Forest of lines!
~ 15 lines in 1 GHz

SVS 13-A

$L_{bol} = 32.5\ L_{\odot}$

$L_{submm}/L_{bol} = 0.8\ \%$

Perseus d = 235 pc

LINE PROFILES OF DEUTERATED SPECIES

$H_2{}^{13}CO$:

7 lines E_u=10-45 K

HDCO:

5 lines E_u=18-40 K

D_2CO:

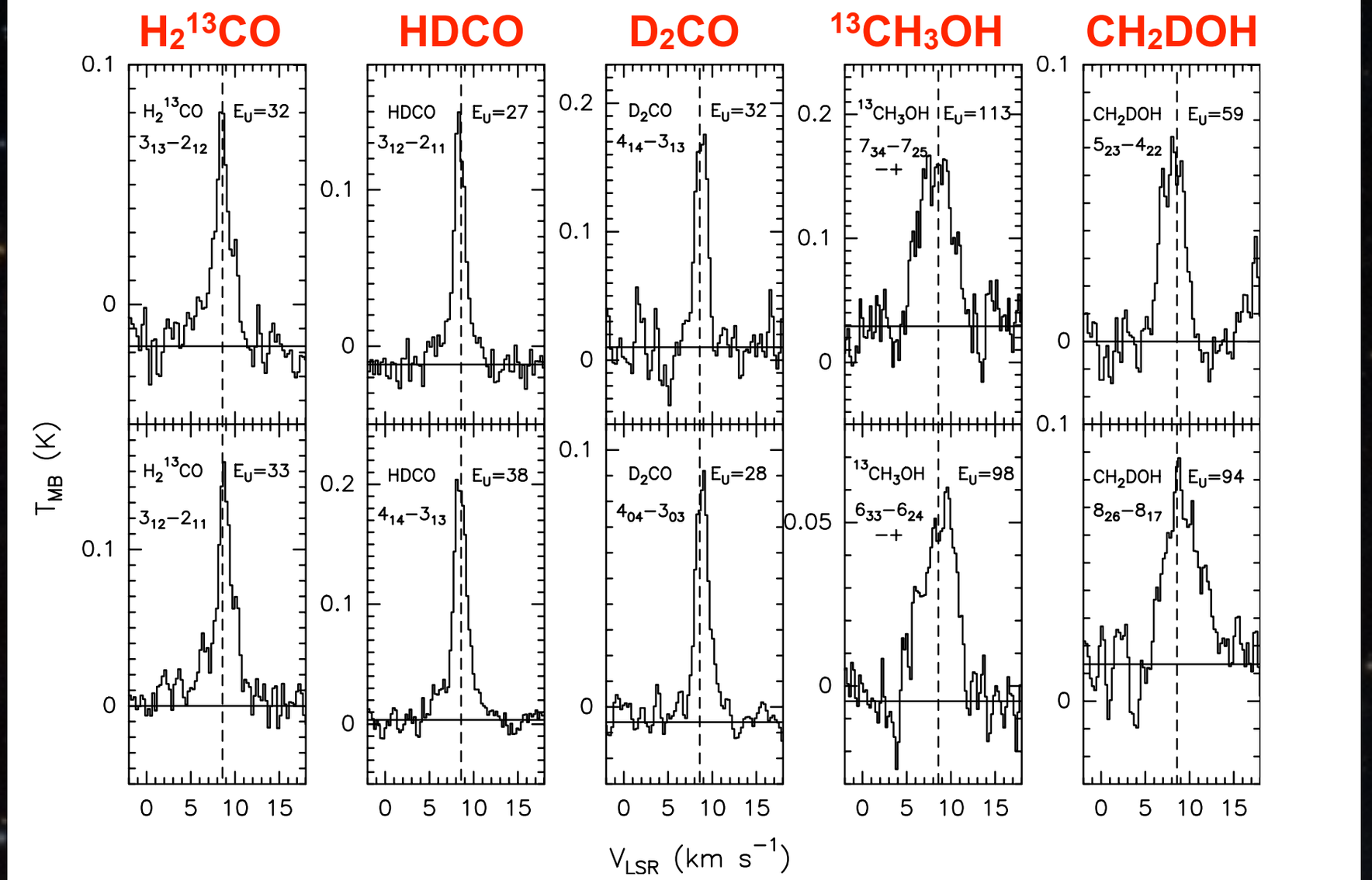
5 lines E_u=21-50 K

$^{13}CH_3OH$:

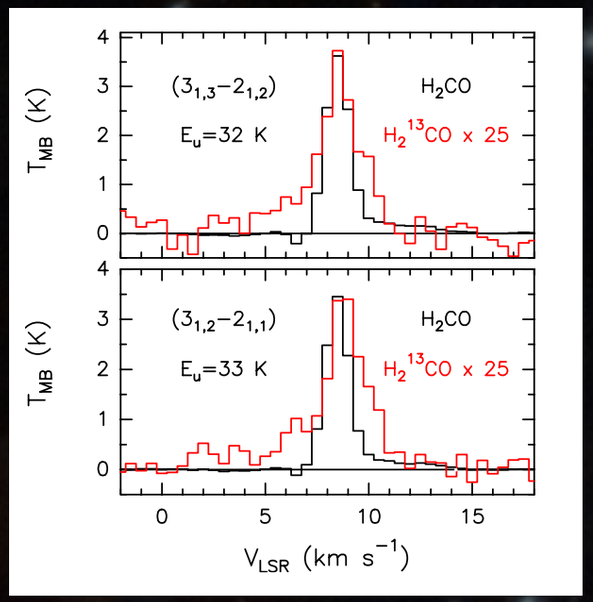
19 lines E_u=20-175 K

CH_2DOH:

27 lines E_u=20-194 K



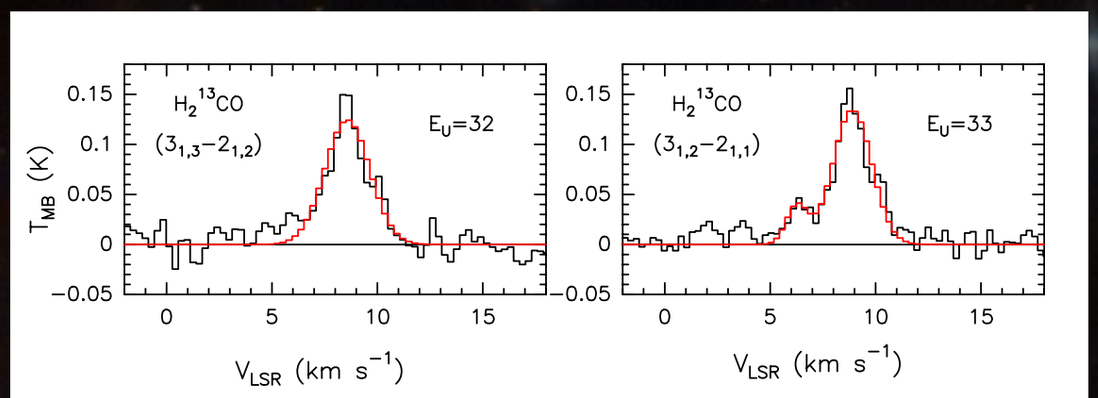
WHICH H_2CO ISOTOPOLOGUE?



$$\frac{H_2CO}{H_2{}^{13}CO} \approx 25$$

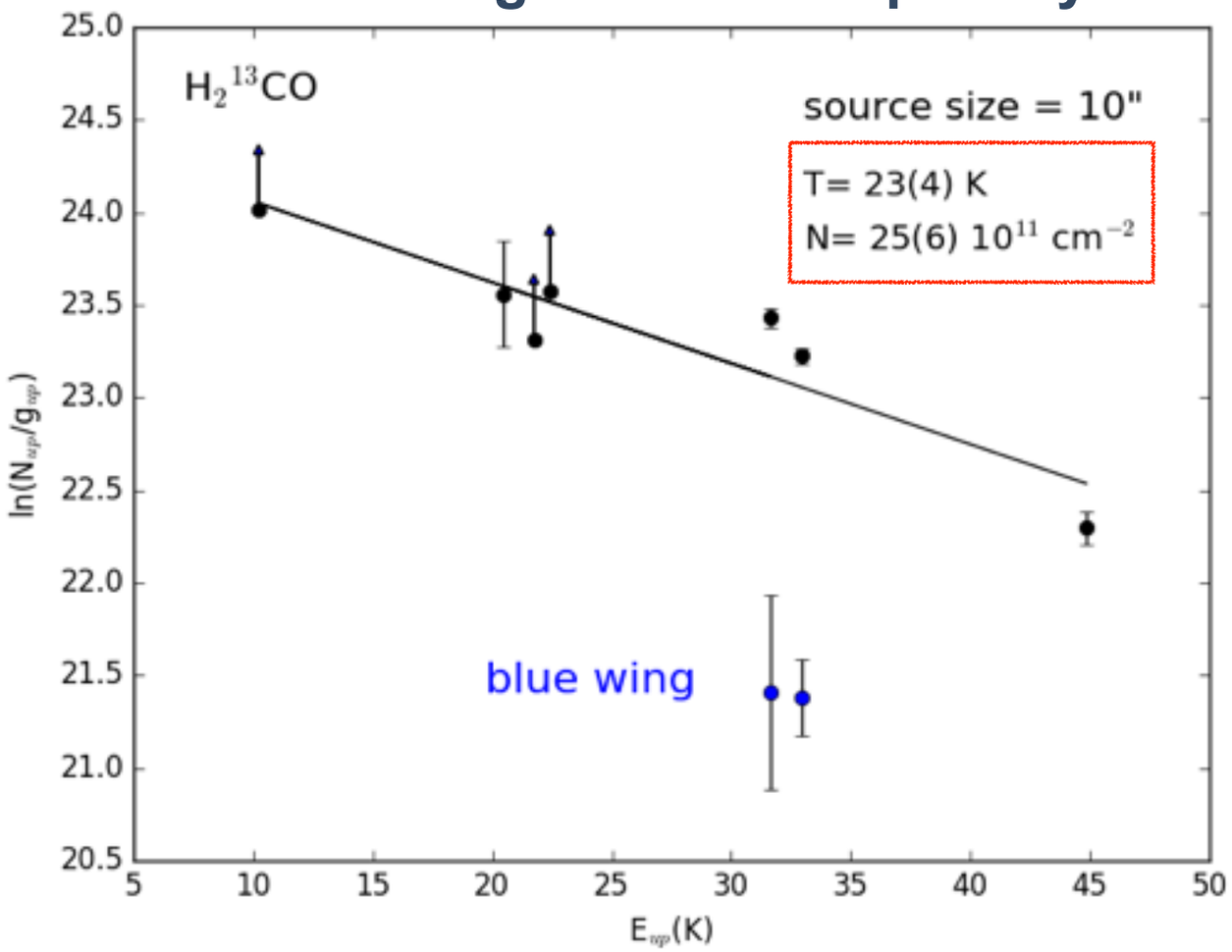
$$v \approx +8.5 km/s$$

H_2CO optically thick → **$H_2{}^{13}CO$**



Low T_{rot}, indipendent from size assumption!

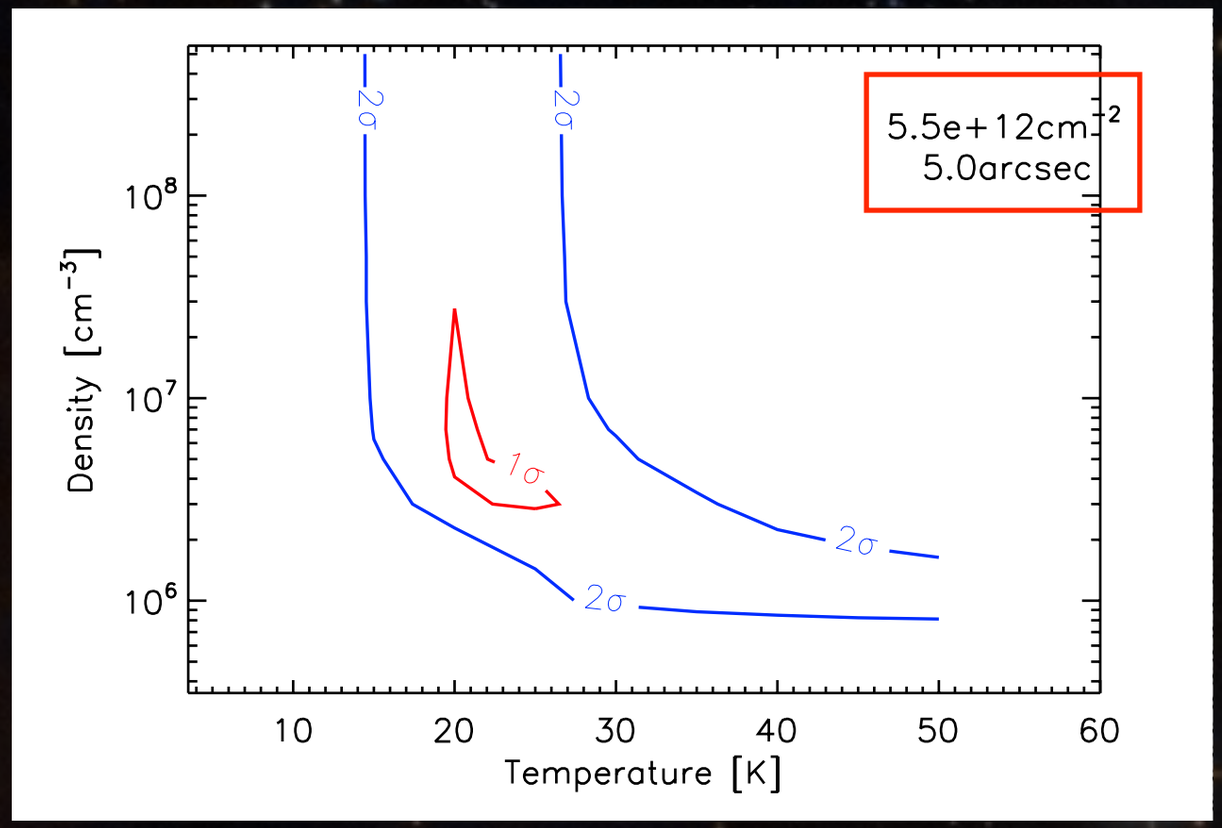
Rotation diagram: LTE + optically thin

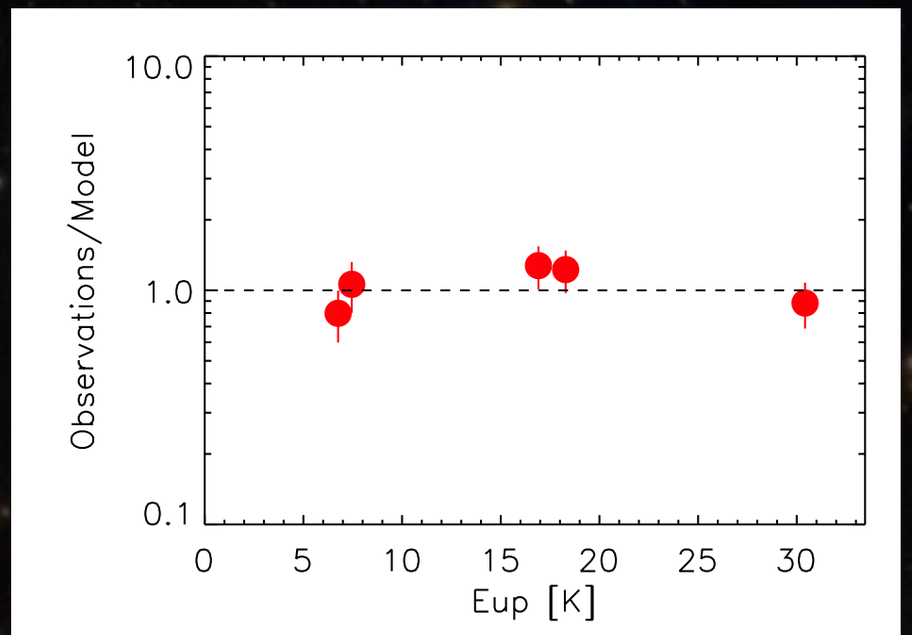


FORMALDEHYDE: LVG ANALYSIS

$H_2{}^{13}CO$

$$\frac{H_2CO}{H_2{}^{13}CO} \approx 25$$

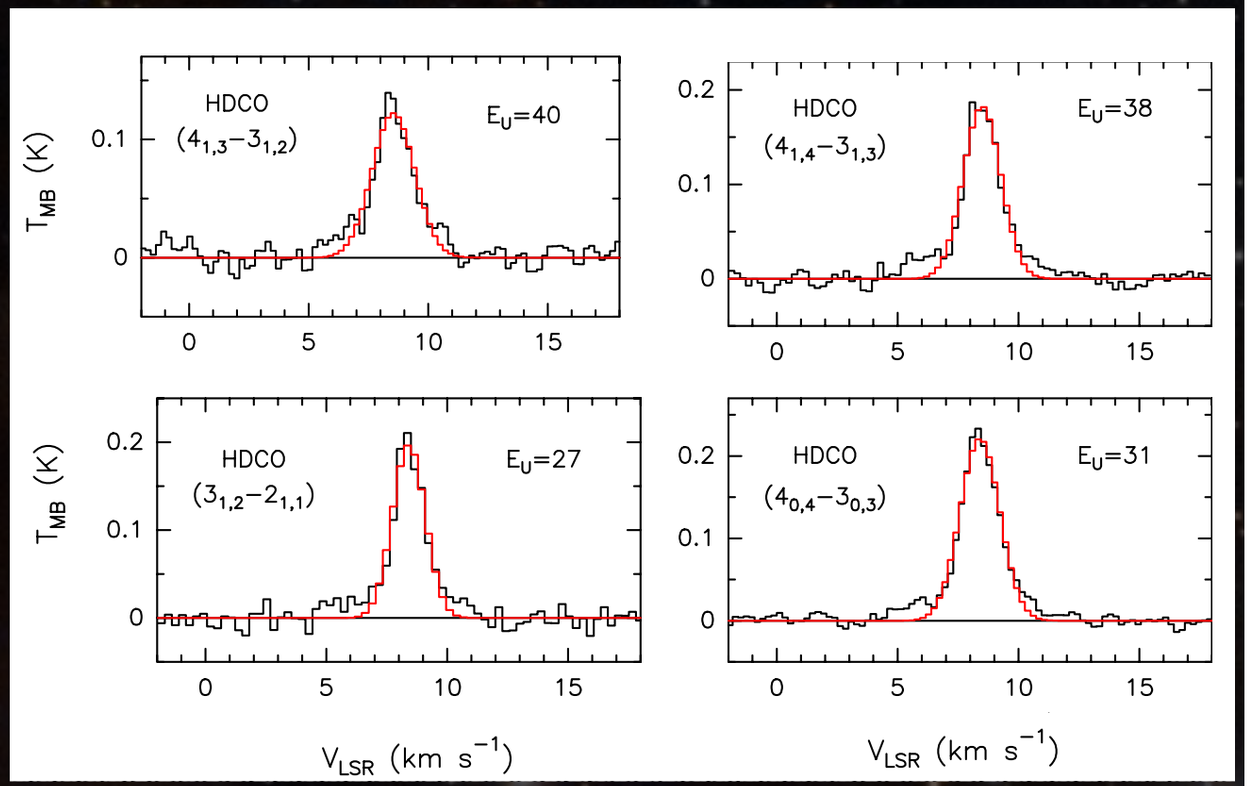


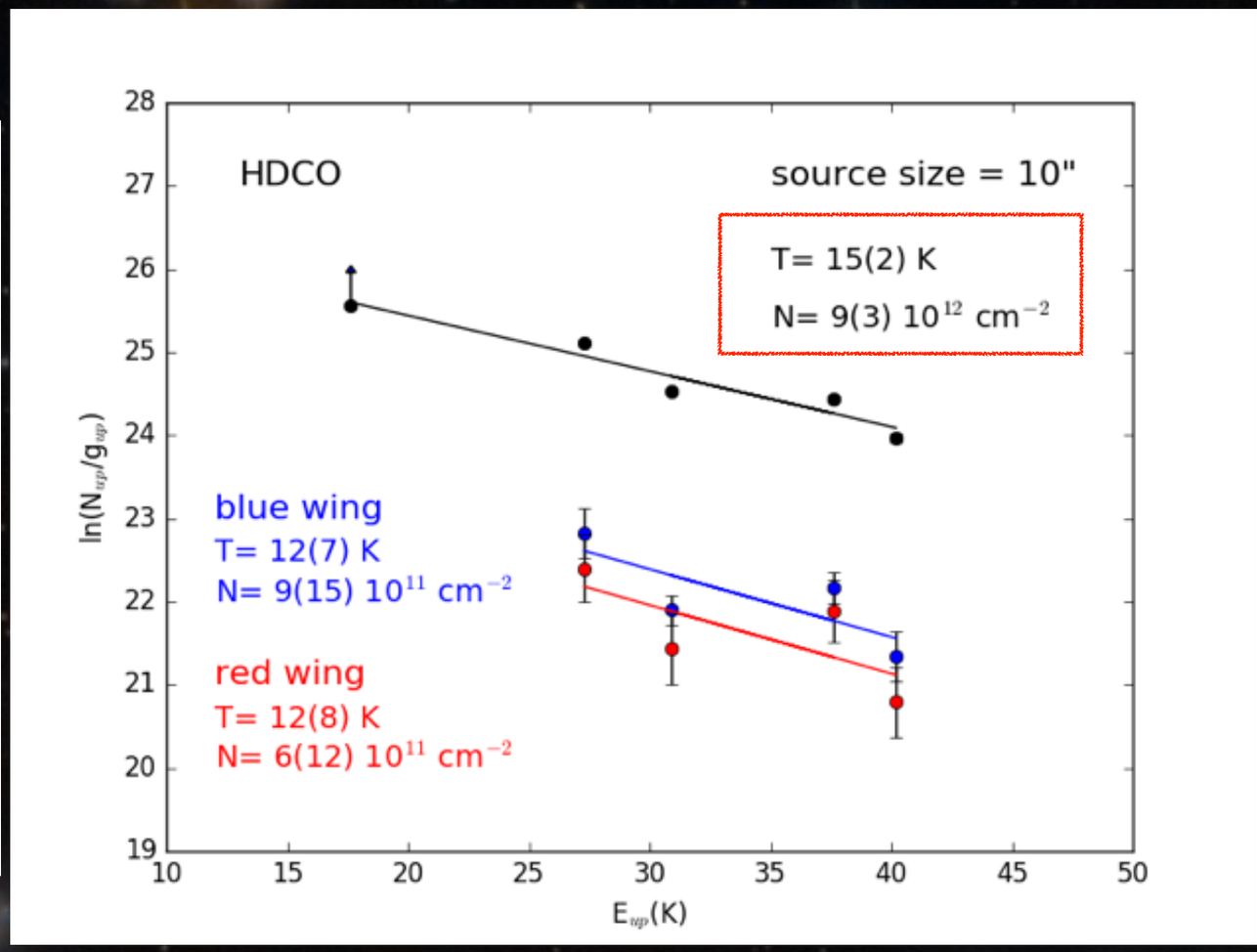


LVG analysis confirms T around 20 K and indicates densities close to 10^7 cm^{-3} (supporting LTE conditions)

SINGLE DEUTERATED FORMALDEHYDE

HDCO

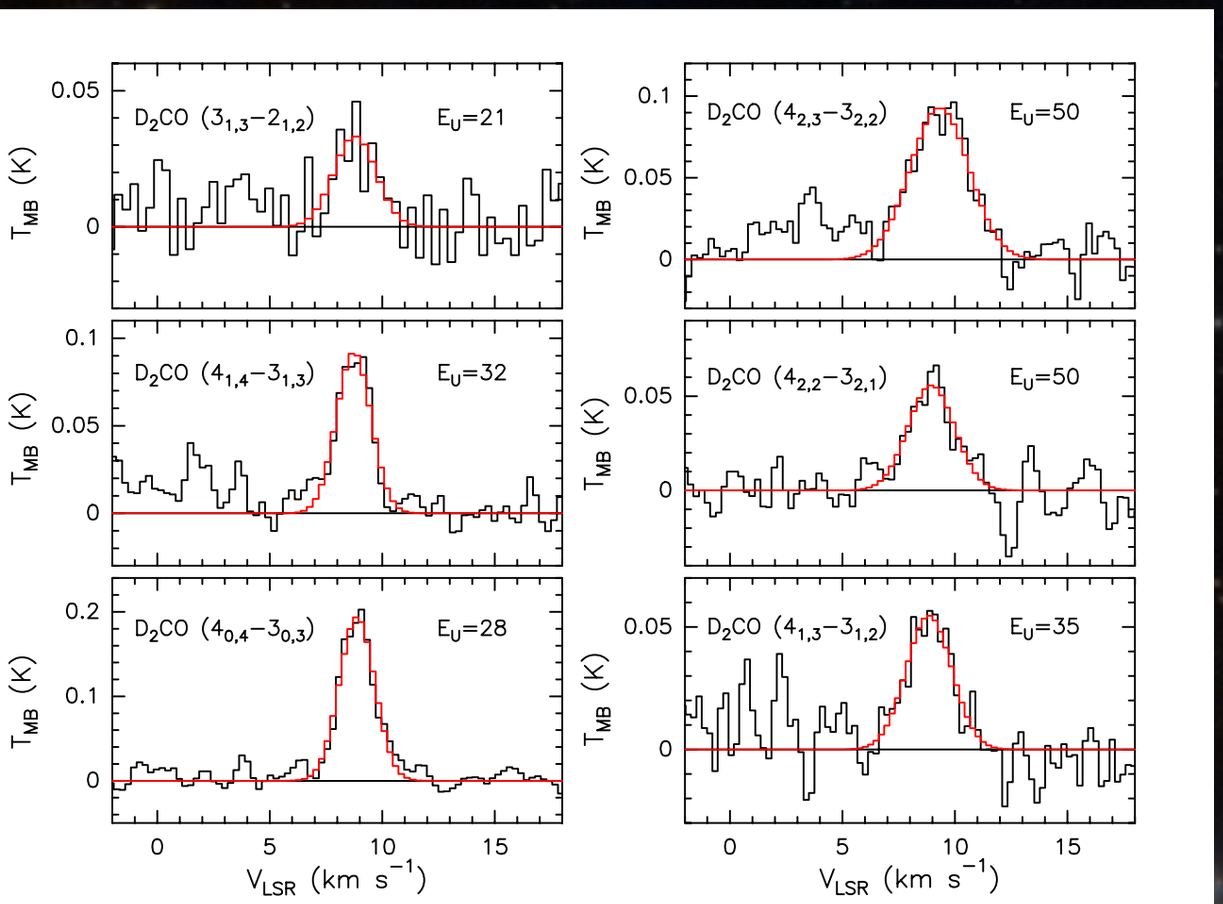


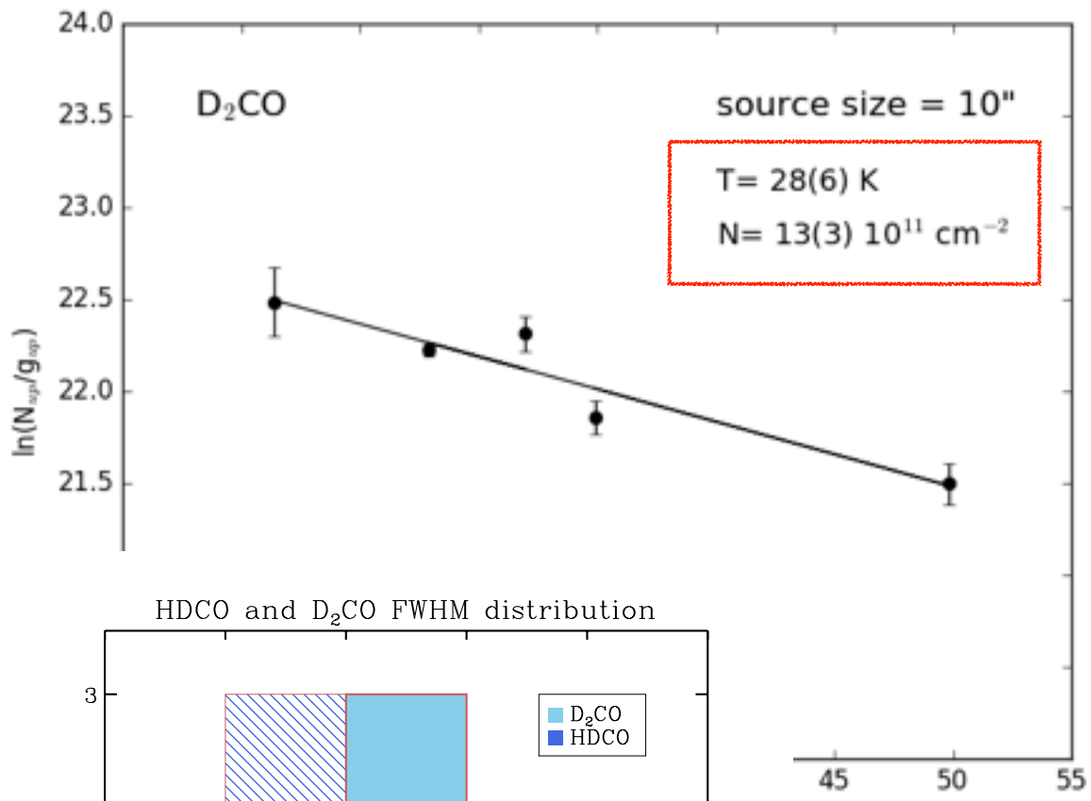


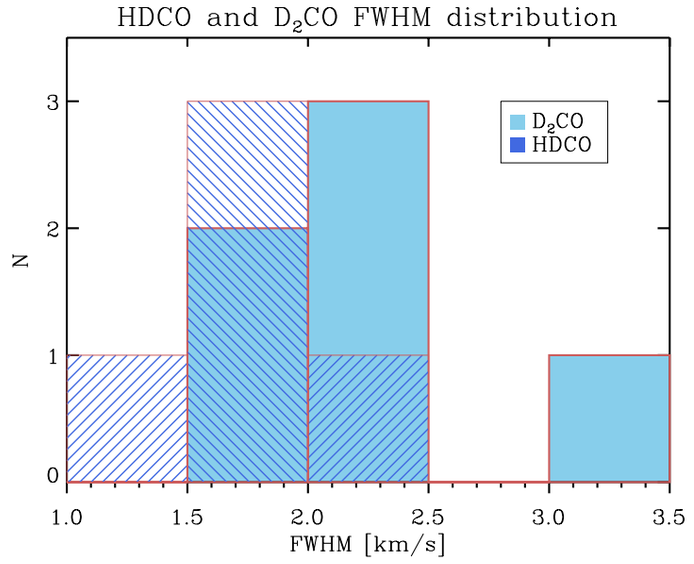
Low T$_{rot}$ ➡ **This suggests an extended emission! Envelope/outflow components**

DOUBLE DEUTERATED FORMALDEHYDE

D_2CO



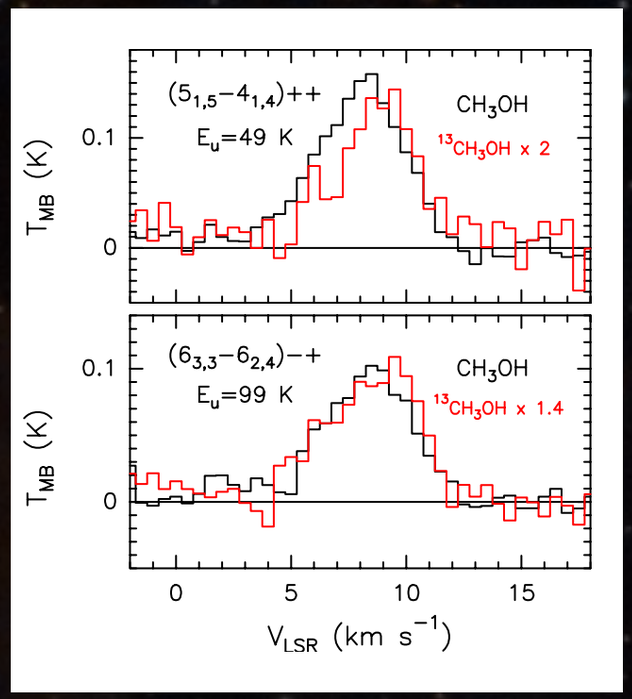




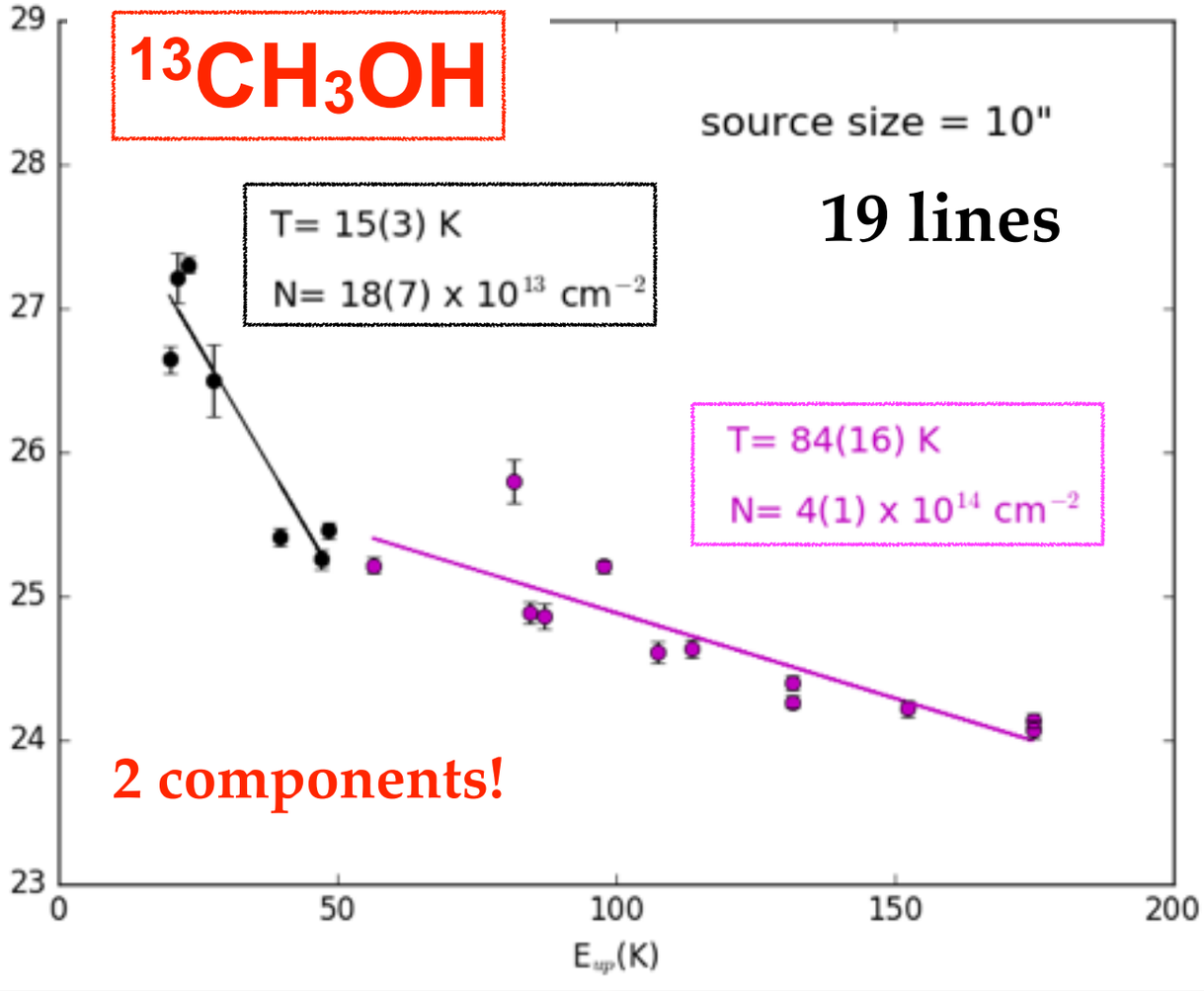
T_{rot} and FWHMs seem to be higher.. different origin??

WHICH CH_3OH ISOTOPOLOGUE?

CH_3OH optically thick



- E_u > 50 K high temperatures; hot corino ?
- E_u < 50 K colder gas



METHANOL: LVG ANALYSIS

Work in progress…

Preliminary results: $^{13}CH_3OH$: 2 components!

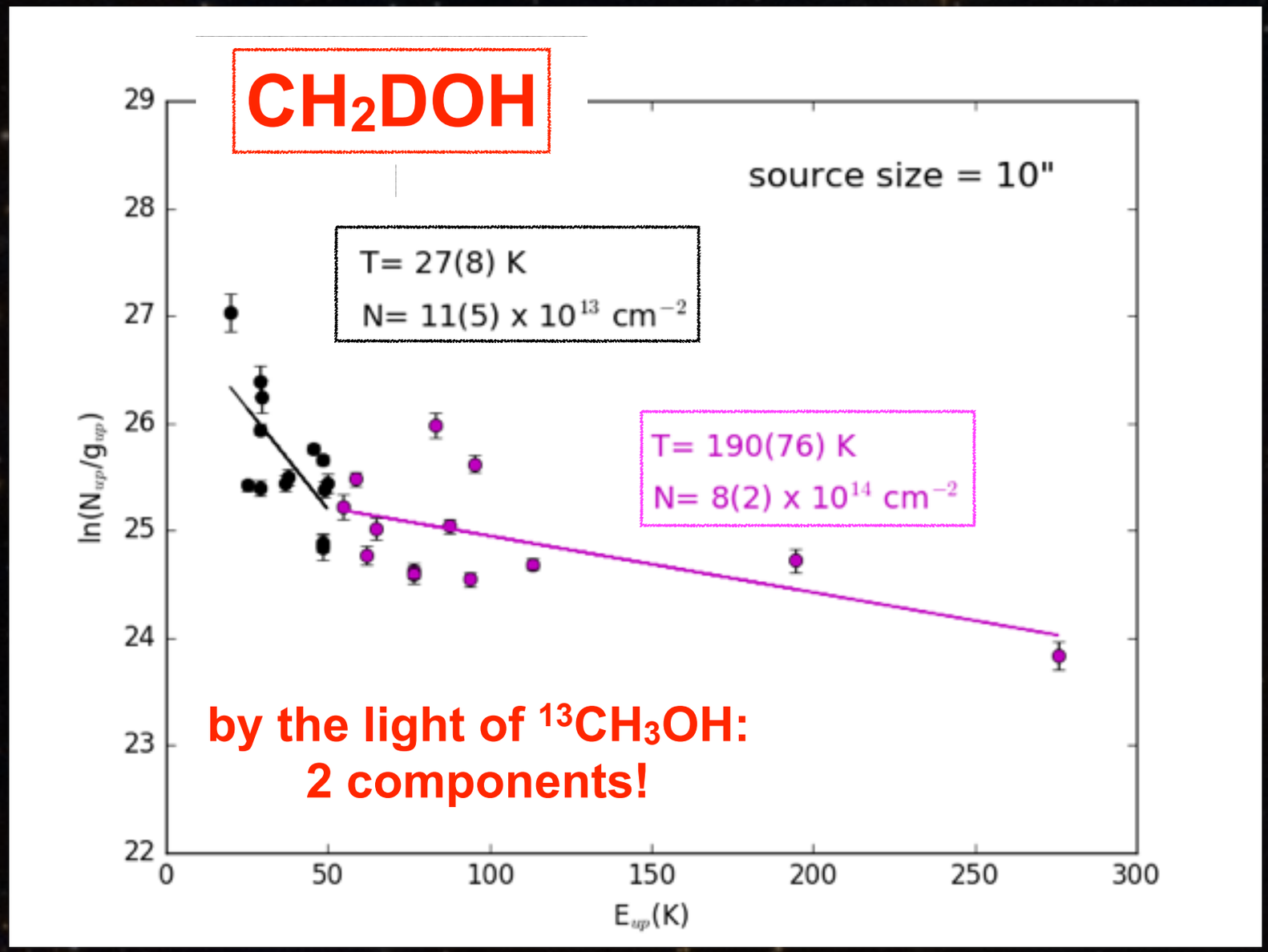
LVG analysis suggests:

1. a very small (~ 0.3”), dense (> 10^8 cm^{-3}), and hot (~ 80 K): the hot corino

2. a colder (~ 40 K), less dense (≥ 10^6 cm^{-3}), and still quite compact (≥ 1”-2”): which is the origin?

3. we need interferometric maps

SINGLE DEUTERATED METHANOL



29 lines!

Same as for $^{13}CH_3OH$:

- E_u > 50 K high temperatures; hot corino ?
- E_u < 50 K colder gas

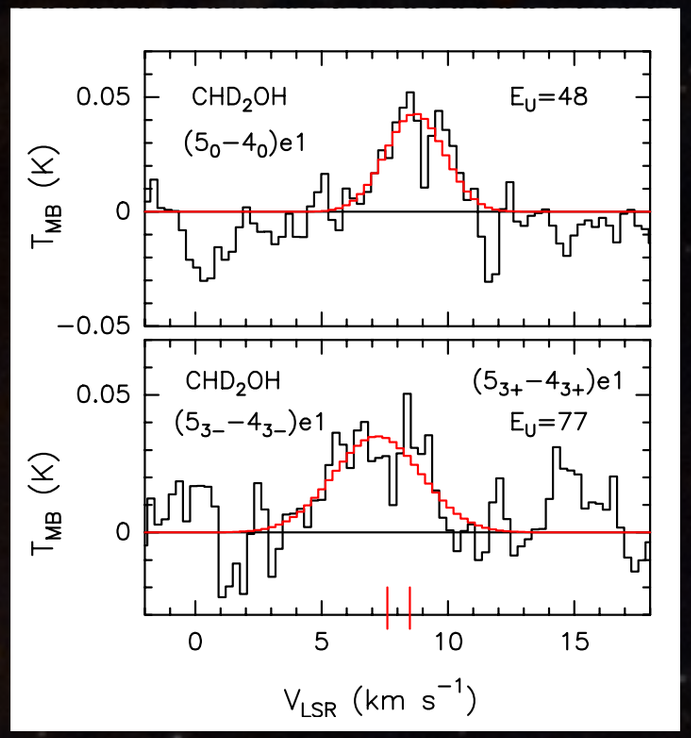
SINGLE AND DOUBLE DEUTERATED METHANOL

Tentative detections (only two lines…)

$[CH_2DOH]/[CH_3OD] \geq 2$

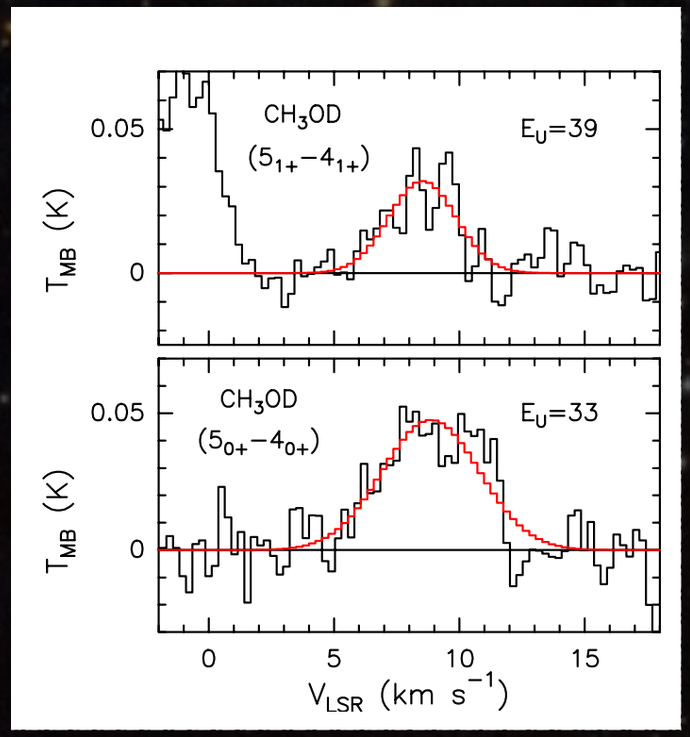
not so far from the grain chemistry statistical value ? (Charnley et al. 1997, Osamura et al. 2004).

CHD_2OH

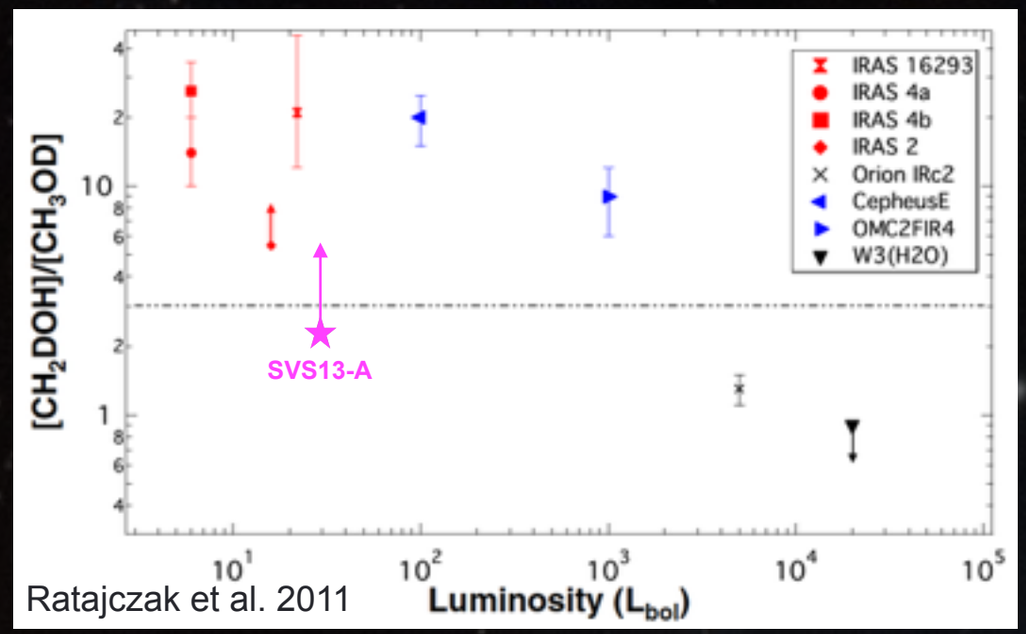


$N \leq 2 \times 10^{14}$ cm^{-2}

CH_3OD

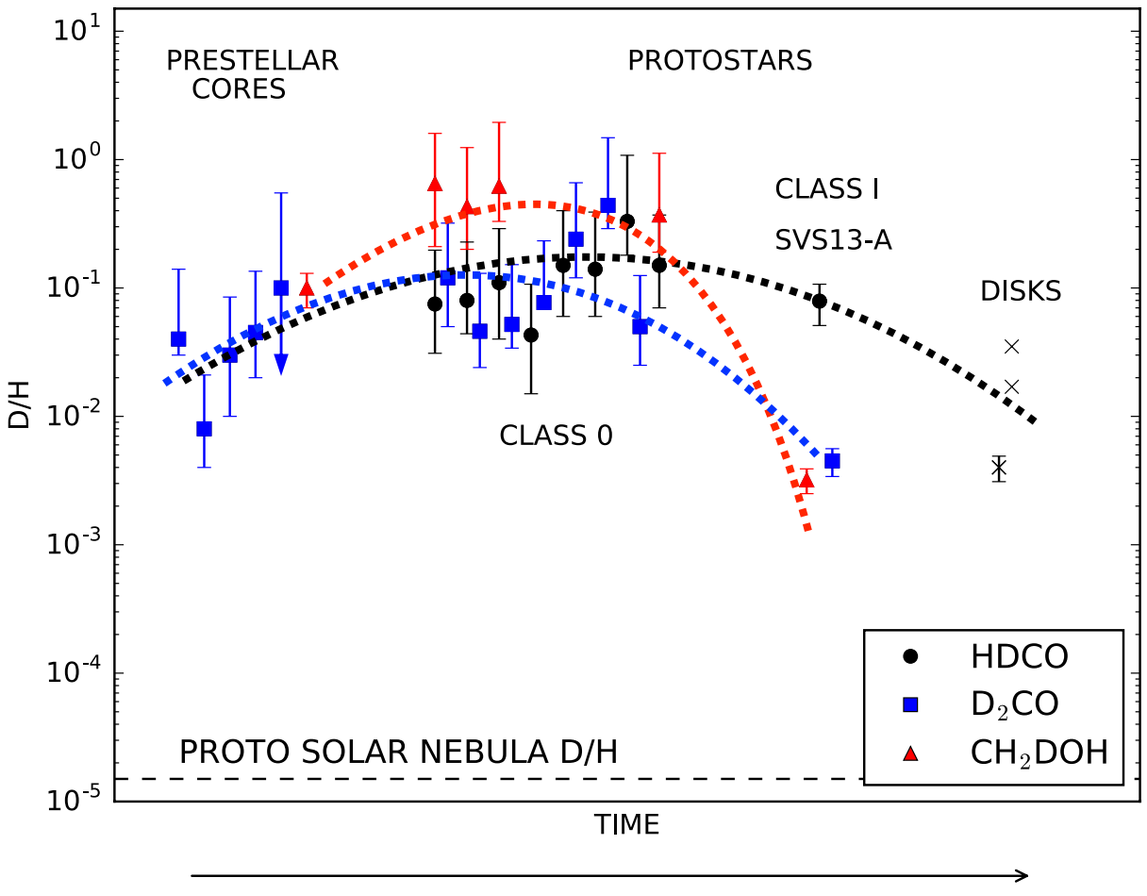


$N \leq 5 \times 10^{13}$ cm^{-2}



Ratajczak et al. 2011

DECREASE OF THE ORGANICS DEUTERATION



- **[HDCO]/[H_2CO] ~ (7.9 ± 0.80) 10^{-2}**
  HDCO: a lower D/H ?
  (Outflow: D/H ~ 4 10^{-3}; consistent with L1157-B1)

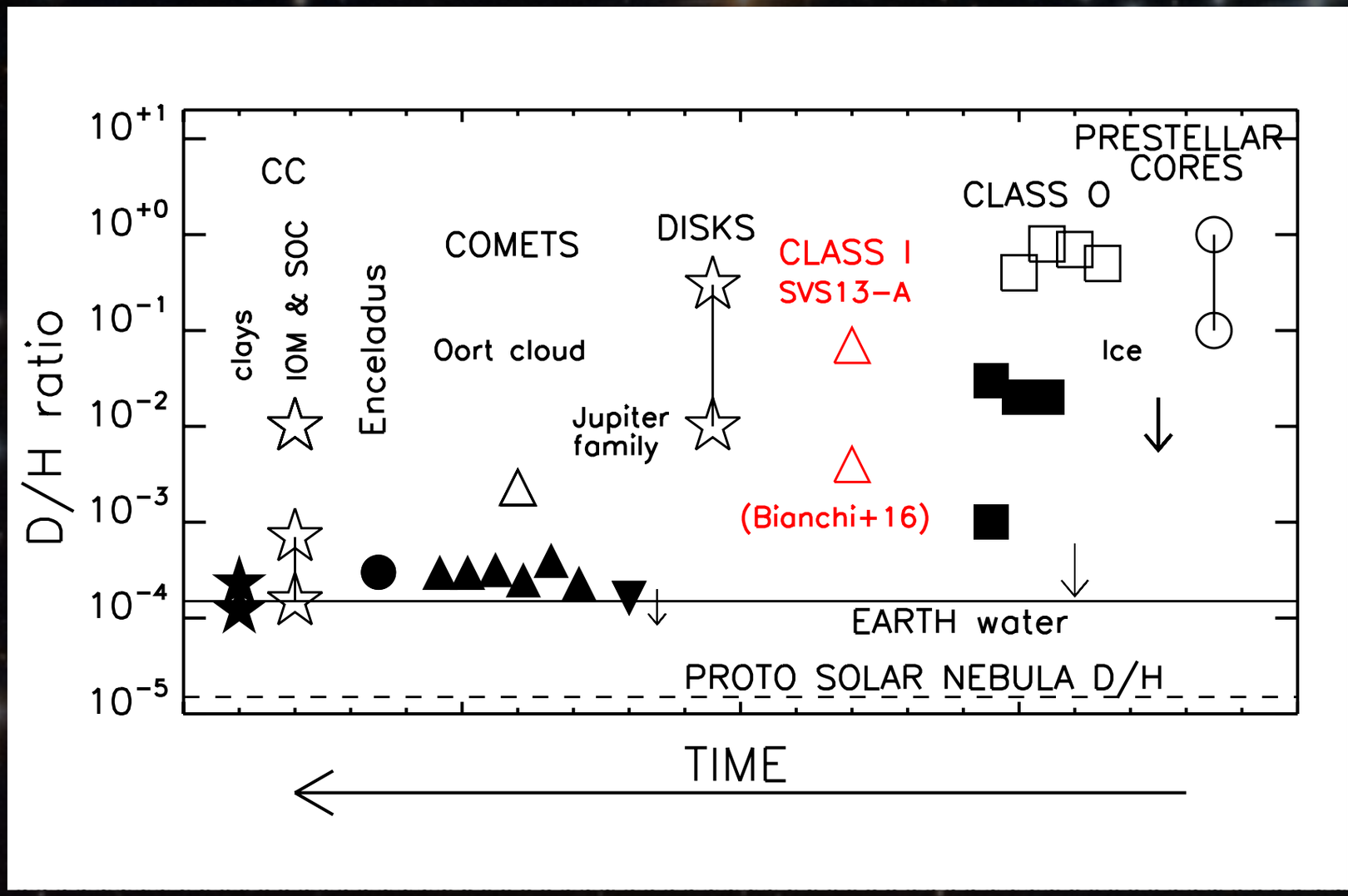
- **[D_2CO]/[H_2CO] ~ (4.5 ± 1.1) 10^{-3}**
  D_2CO deuteration decreases of about 1 order of magnitude for Class I

- **[CH_2DOH]/[CH_3OH] ~ (3.2 ± 0.7) 10^{-3}**
  CH_3OH deuteration decreases from Class 0 to Class I by 2 orders of magnitude!

These results call for further observations of Class I objects (more statistics!!)

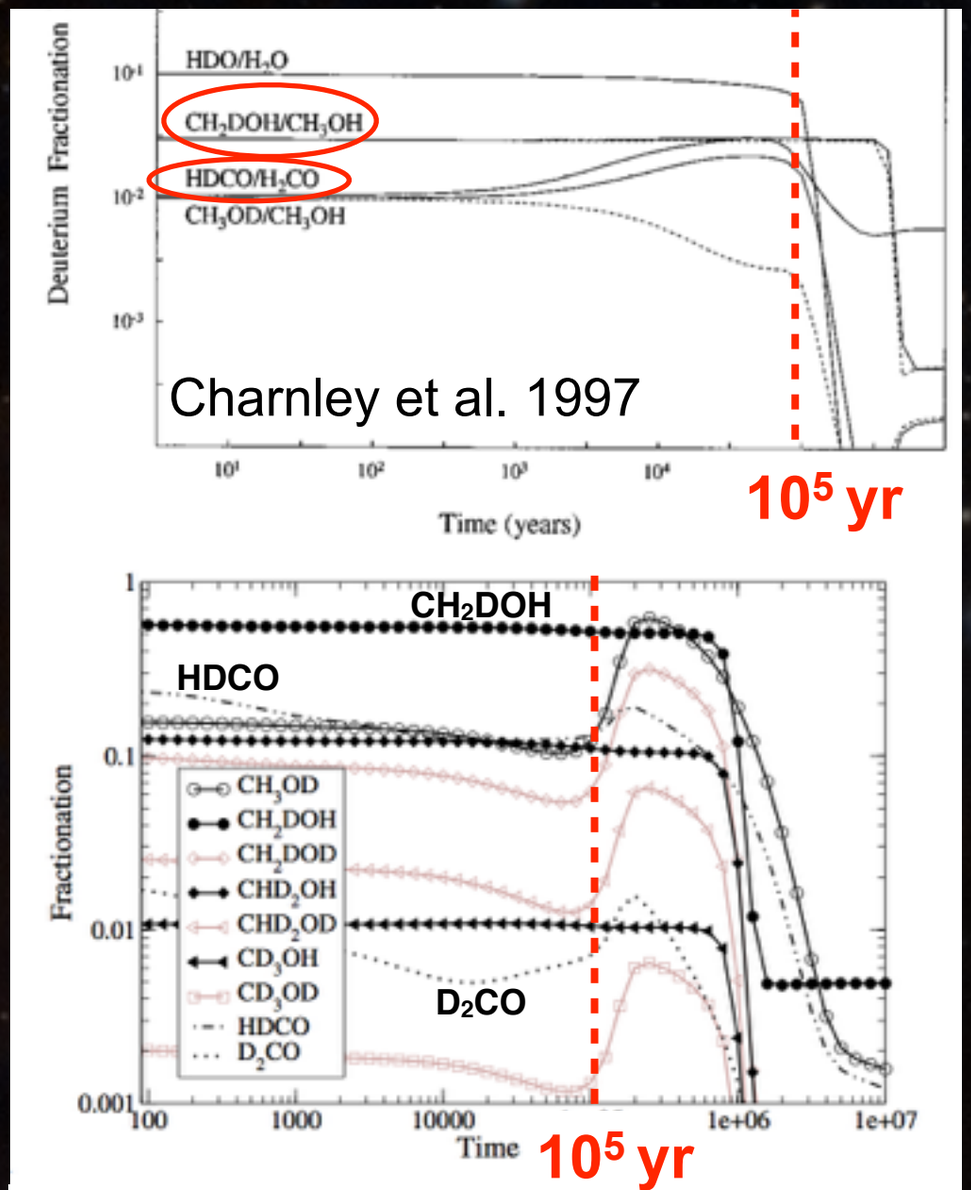
DECREASE OF THE ORGANICS DEUTERATION

Ceccarelli et al. 2014 (PPVI)



These results call for further observations of Class I objects (more statistics!!)

COMPARISON WITH GRAIN-GAS MODELS



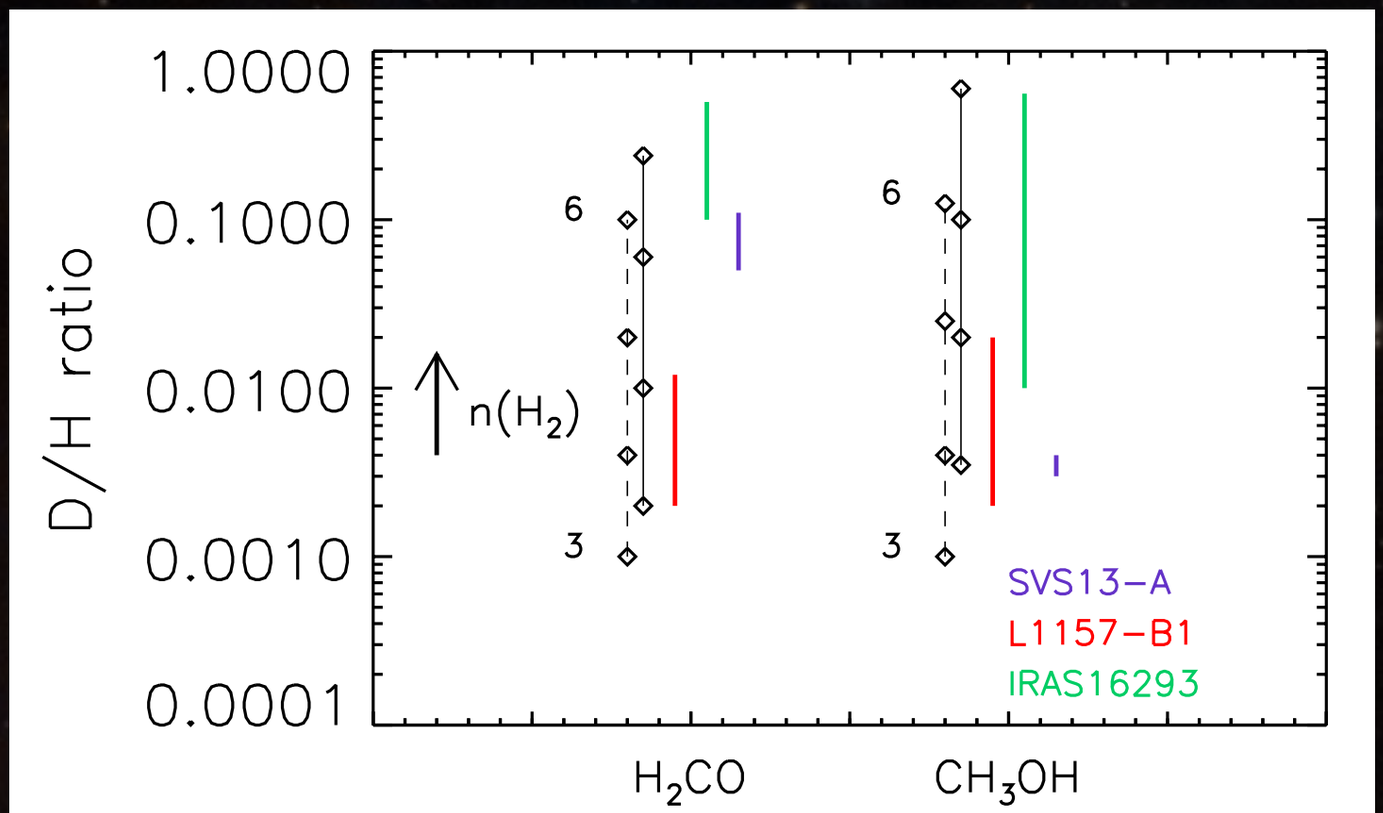
Osamura et al. 2004

- **Gas-phase chemistry kills the deuteration as time goes by**
- **Is this occurring on timescales of 10^5 yr, i.e. a typical Class I age ? Possibly not…..**

Caution: dynamical timescale could be shorter…. (Visser et al. 2009)

COMPARISON WITH GRAIN-GAS MODELS

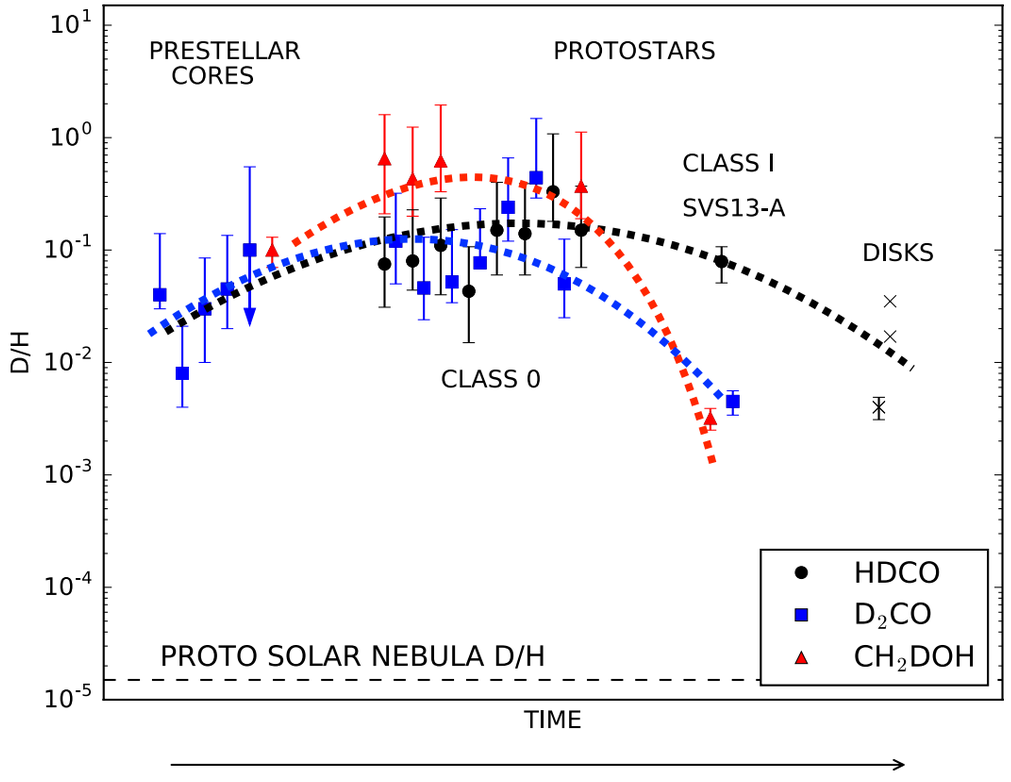
L1157-B1 (shock, off from the protostar)
Codella et al. 2012 IRAM 30 m
Fontani et al. 2014 PdBI



Taquet et al. 2012

- **A Class I hot corino could provide a signature of less dense gas collapsed around the protostar**
- **In other words as time proceeds the protostar accumulates external portion of its natal cloud reasonably associated with lower densities (Taquet et al. 2014)**

CONCLUSIONS



- **[HDCO]/[H_2CO] slightly decrease ?**
- **[D_2CO]/[H_2CO] decreases of about 1 order of magnitude for Class I**
- **[CH_2DOH]/[CH_3OH] decreases from Class 0 to Class I by 2 orders of magnitude!**
- **Gas-phase chemistry or gradual collapse of the core with a lower deuteration in outer shells ?**

FUTURE:

- more statistics (Class I observations)
- interferometry (high angular resolution images of the emitting regions)