Deuteration in Infrared Dark Clouds

Matias Lackington

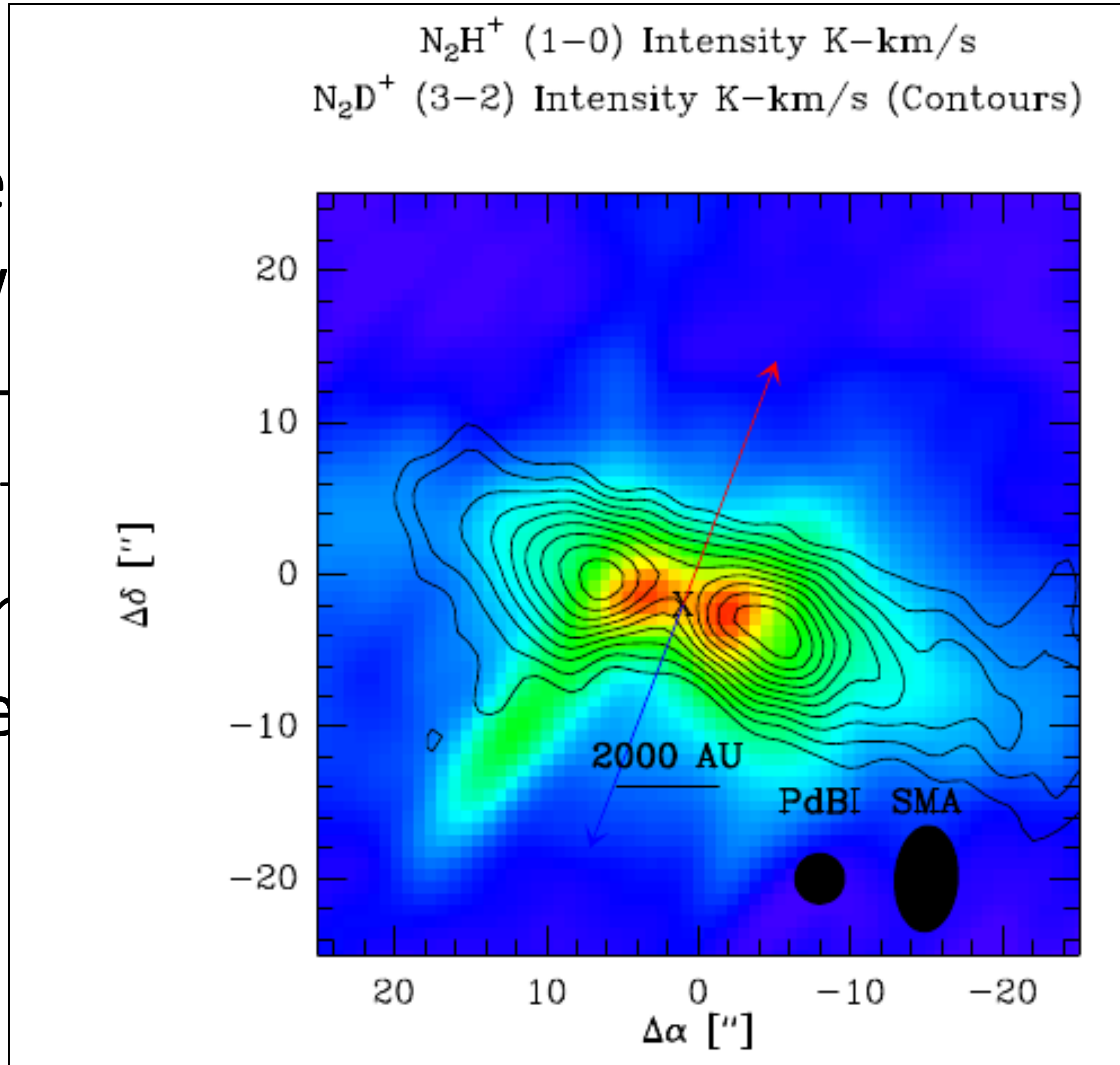
Gary Fuller, Jaime Pineda, Guido Garay,
Nicolas Peretto, Alessio Traficante

Why deuteration?

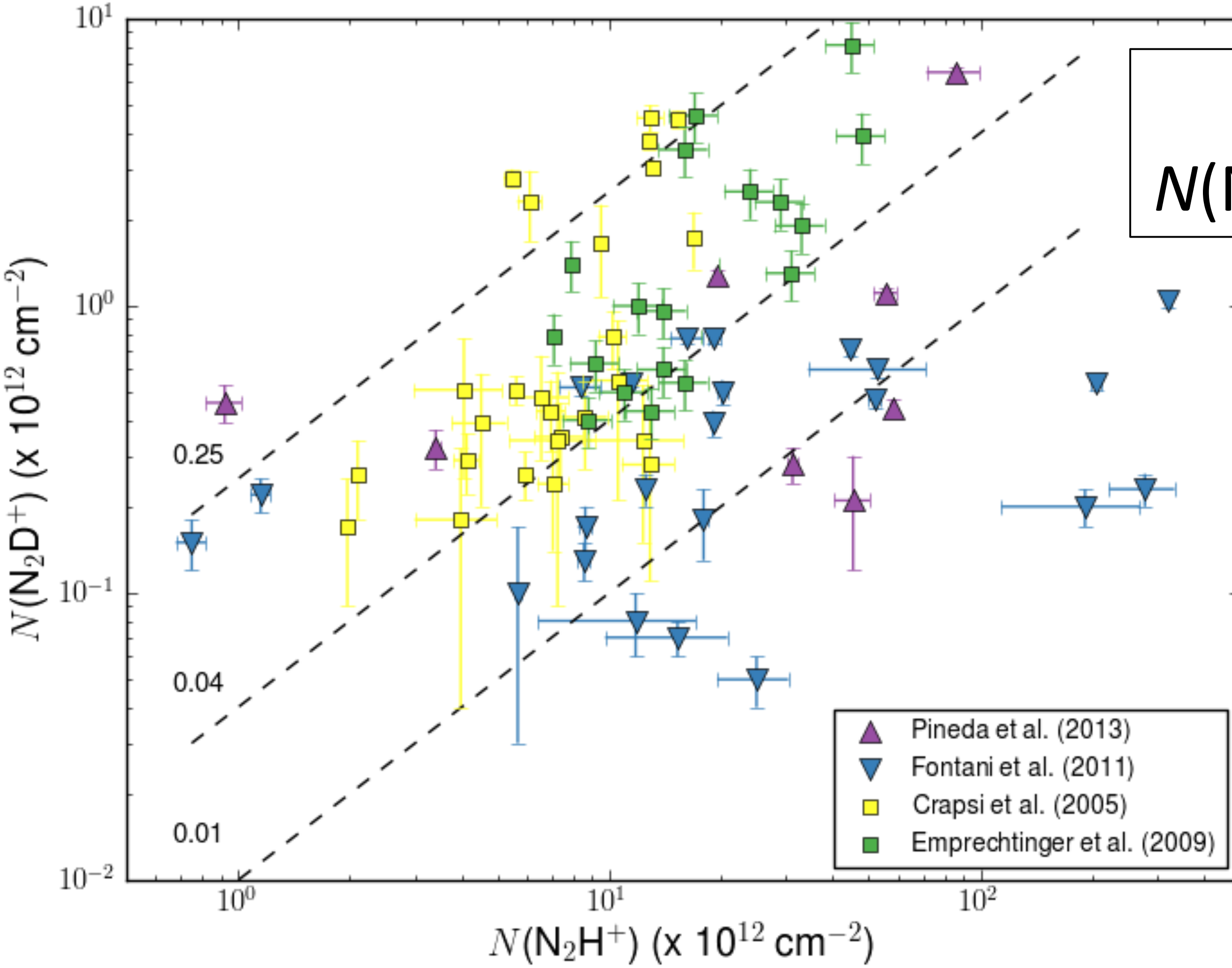
- Deuteration is enhanced at temperatures below 20K as in IRDCs,
  - $H_3^+ + HD \rightarrow H_2D^+ + H_2 + \Delta E$
  - H_2D^+ can cede deuteron to produce N_2D^+ and DCO^+
- YSOs heat up surrounding regions decreasing the deuteration.
- Good results in low mass star forming regions as an evolutionary tracer
  - e.g. Caselli 2002, Bacmann 2003

Why deuteration?

- Deute … es below
  - H_3^+ -
  - H_2D^+ … nd DCO^+
- YSOs h … easing the de
- Good … egions
  - e.g.

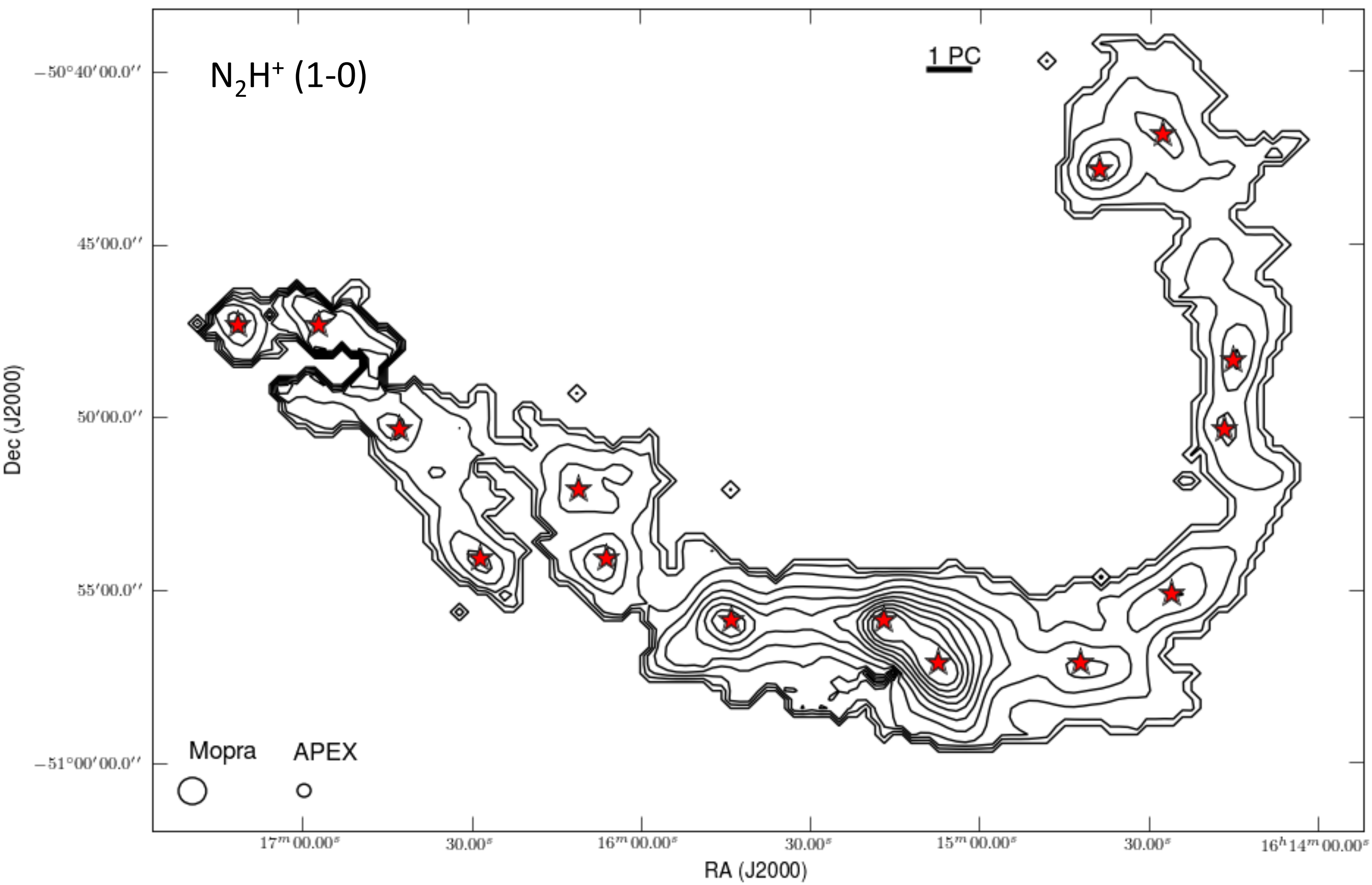


Latest observations using N_2D^+ in middle/high mass regions

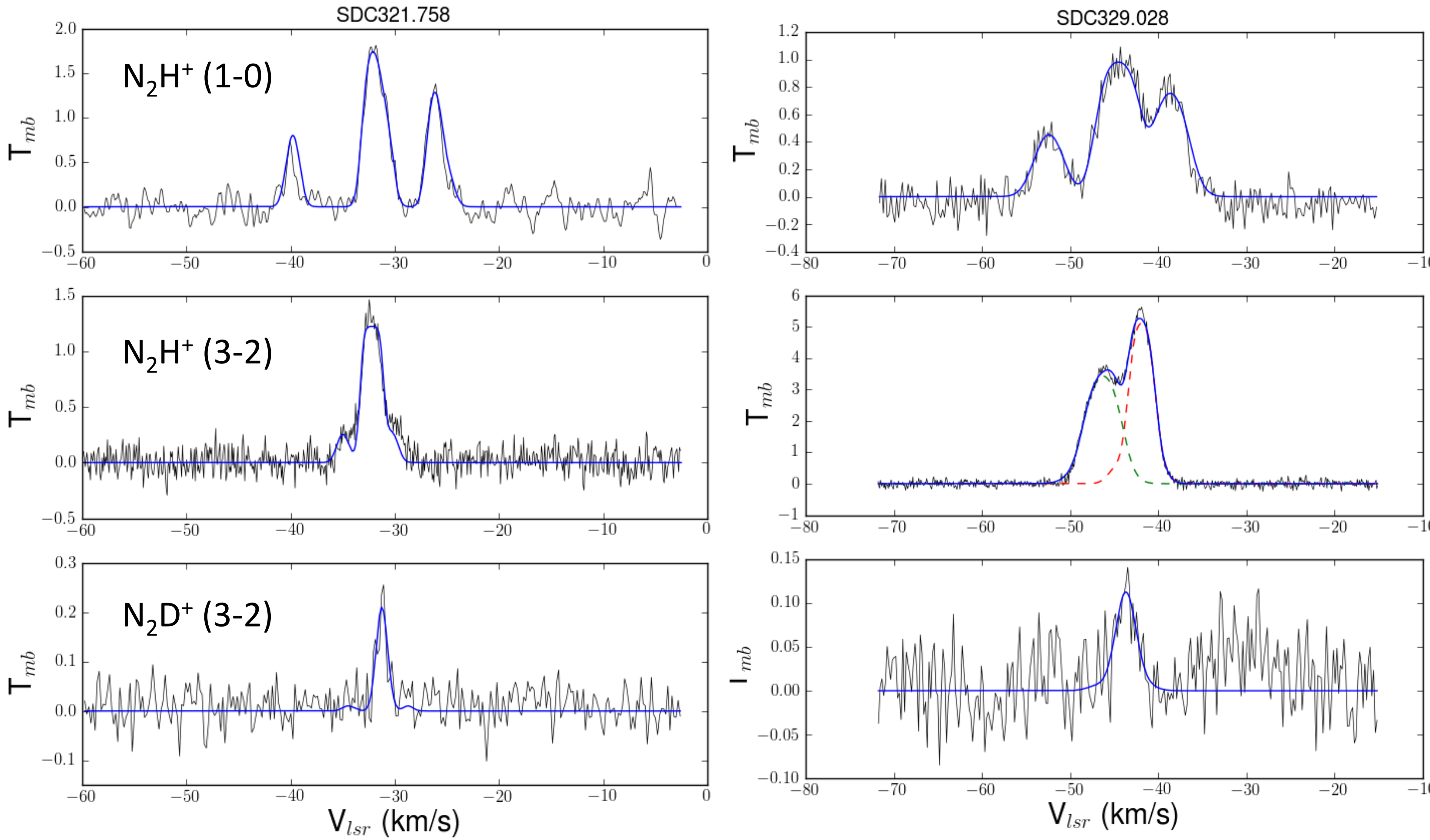


$D_R \equiv N(N_2D^+)/N(N_2H^+)$

Source selection



Mopra: N_2H^+ (1-0) (top)
APEX: N_2H^+ (3-2) (middle), N_2D^+ (3-2) (bottom) spectra



Non LTE line modeling of N_2H^+ using RADEX (van der Tak et al. 2007)

- Grid of models:
  - Density: 10^5 to $2x10^6$ cm^{-3}, T: 5-20...
  - Range of filling factors.
- Model selection: model value equal optical to observed value.
  - N_2H^+ (1-0) optical depth
  - N_2H^+ (1-0) integrated intensity
  - N_2H^+ (3-2) integrated intensity
- Best results with filling factor of 0.4 for N_2H^+ (1-0)

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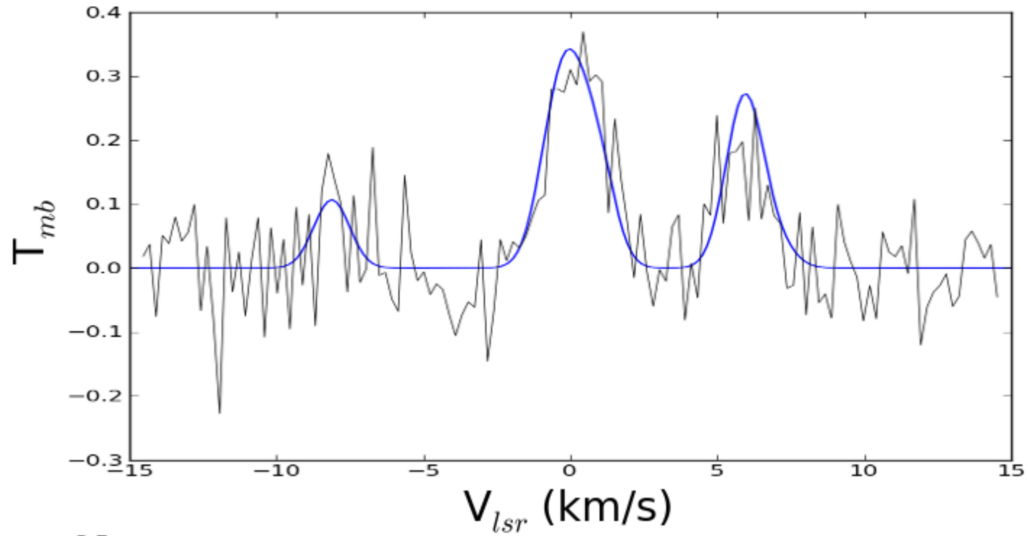
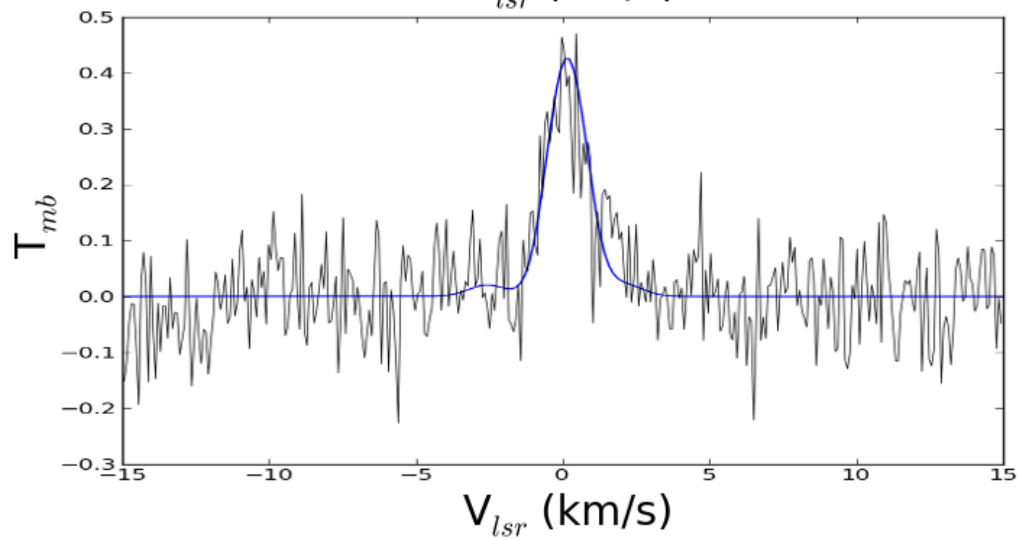
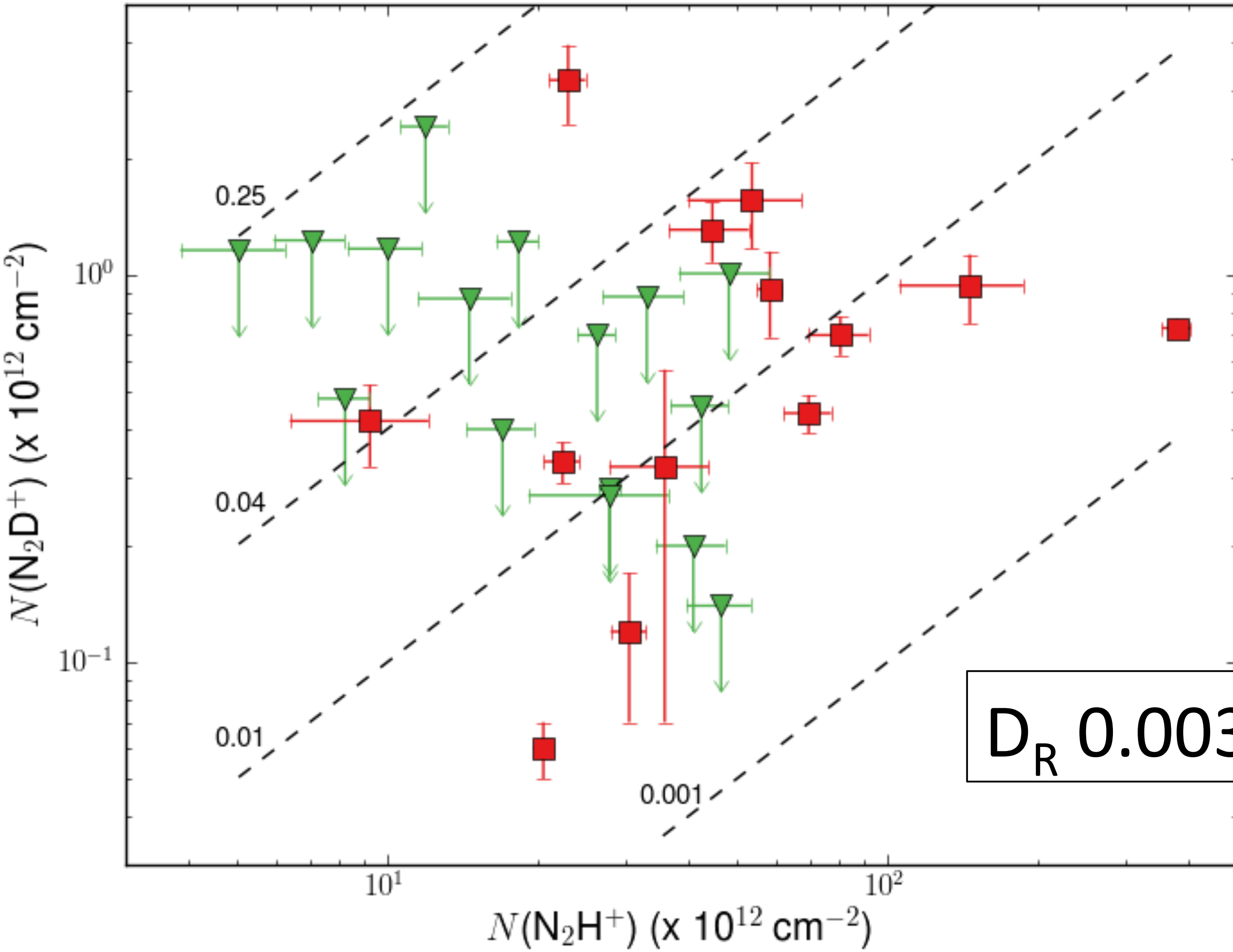


N_2H^+ (1-0)



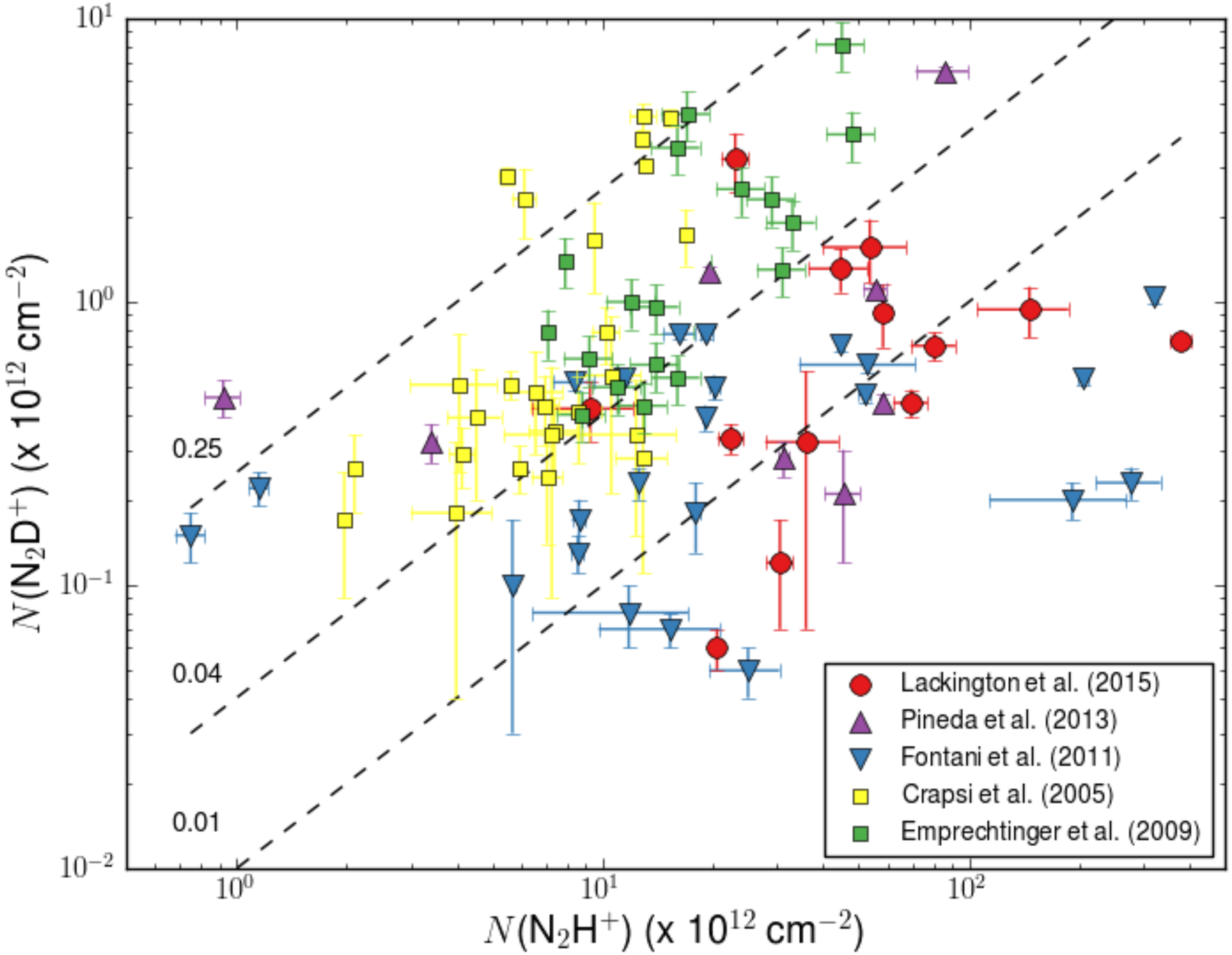
N_2H^+ (3-2)

Deuteration

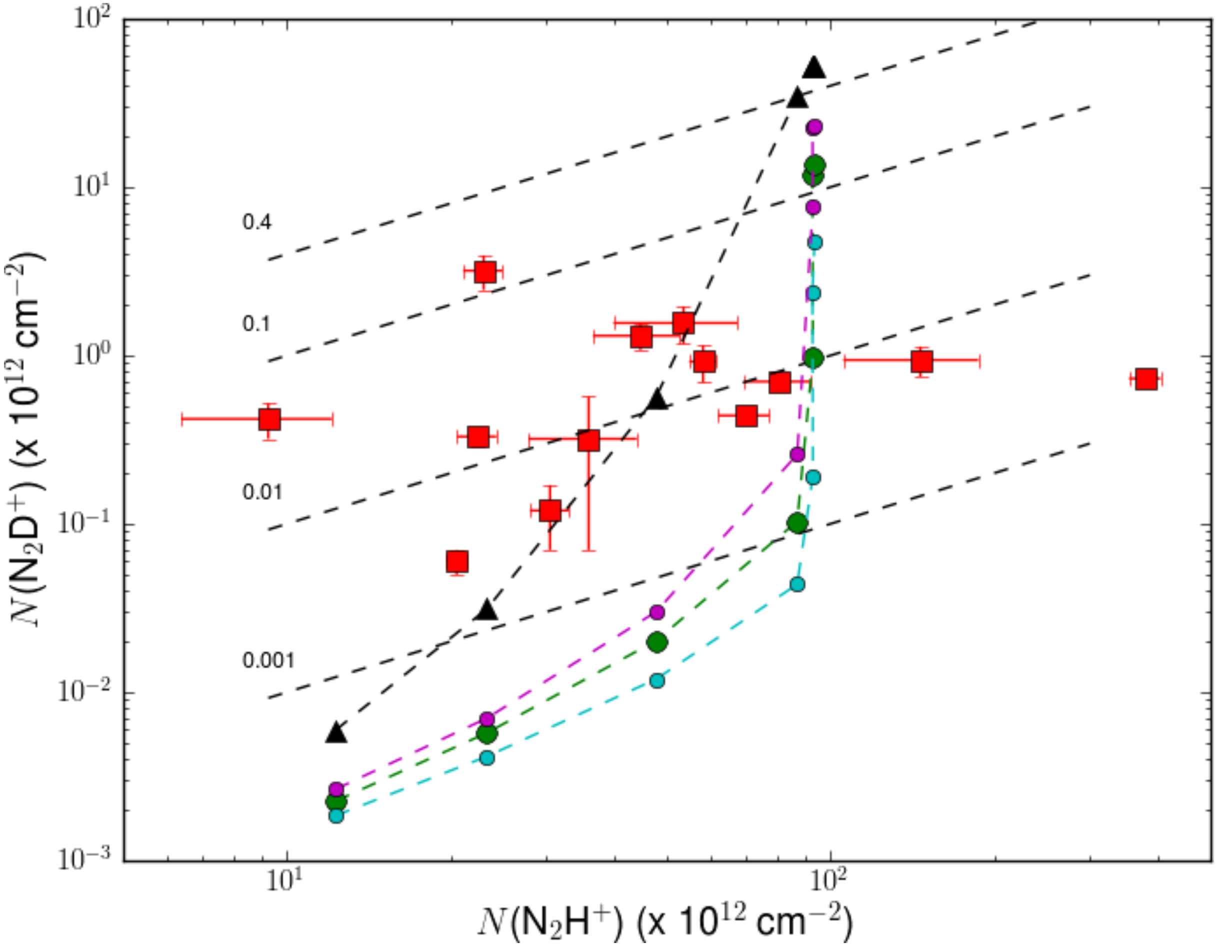


D_R 0.003 to 0.14

Deuteration



Timescales, Kong et al. 2013 models



Kong models:

T = 15 K

Green (main model):

$n_H = 10^5$ cm^{-3} $f_D = 10$

Cyan:

$n_H = 10^4$ cm^{-3} $f_D = 10$

Magenta:

$n_H = 10^6$ cm^{-3} $f_D = 10$

Black:

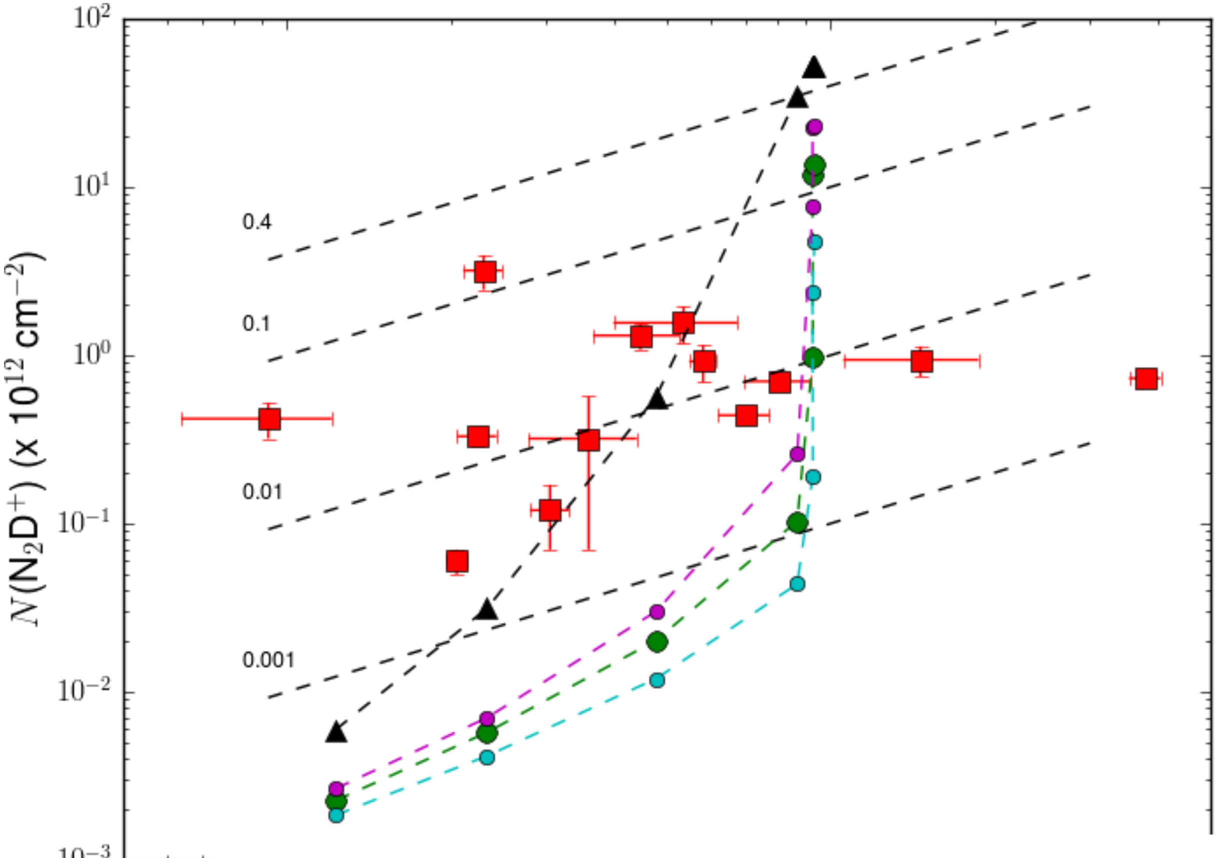
$n_H = 10^5$ cm^{-3} $f_D = 100$

Points:

-5 x 10^4 yr to

3.2 x 10^6 yr

Timescales, Kong et al. 2013 models



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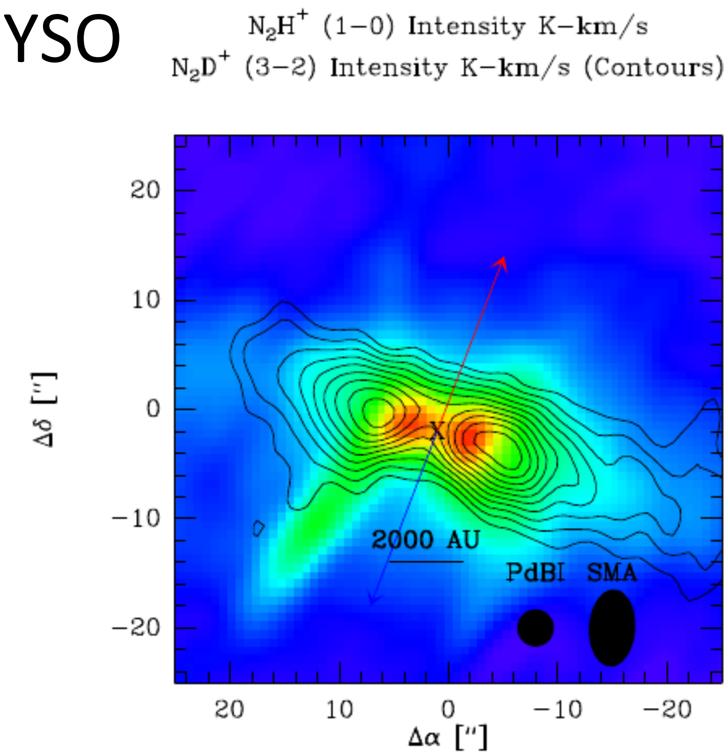
Points:
-5 x 10^4 yr to
3.2 x 10^6 yr

- Main model: Timescales > 0.5 Myr.
- High depletion: timescale > 0.13 Myr

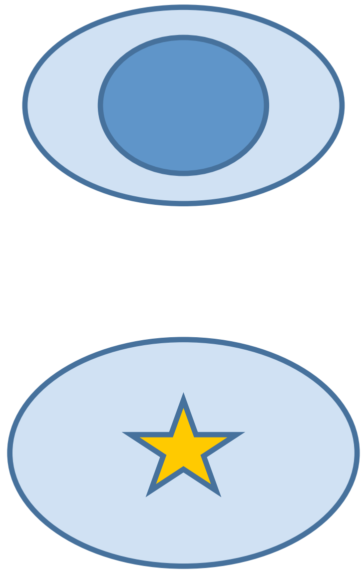
70 μm content

- 16 out of the 51 objects have a HiGal 70 μm source within the APEX beam (30%)
- 6 out of the 13 objects with N_2D^+ (3-2) detections have a 70 μm source. (45%)

Early YSO



Fragmentation



N_2D^+ but no YSO

YSO but no N_2D^+

Conclusions

- 53 objects observed in N_2H^+ (1-0) and (3-2)
- Two velocity components in N_2H^+ (3-2) in 25% of the objects.
- 29 observed in N_2D^+ (3-2)
- N_2D^+ detected towards 13 objects.
- Line modelling: 0.4 filling factor for N_2H^+ (1-0)
- D_R 0.003 to 0.14
- 70 µm source found in 45% of the N_2D^+ detections.
- Derived timescales > 5×10^5 yr (several times T_{ff})