Dating a prestellar core: L1512

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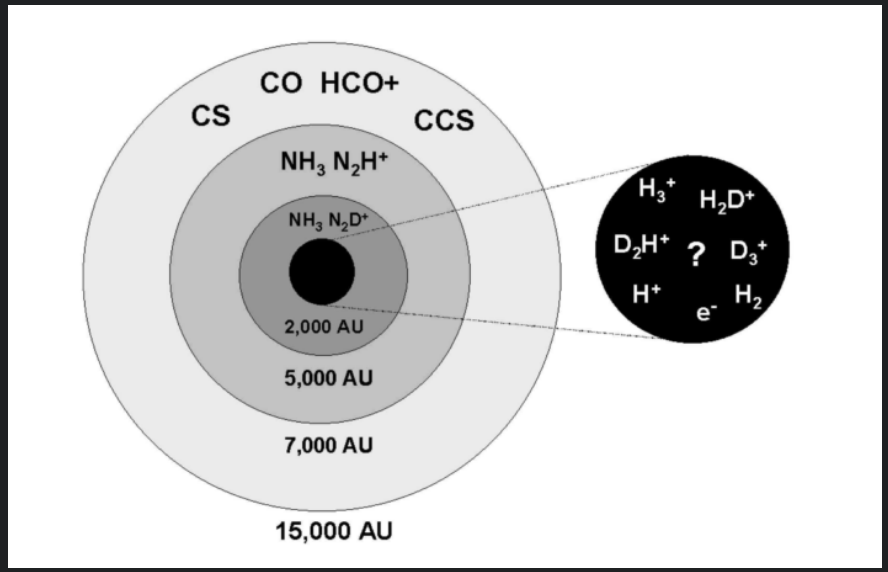
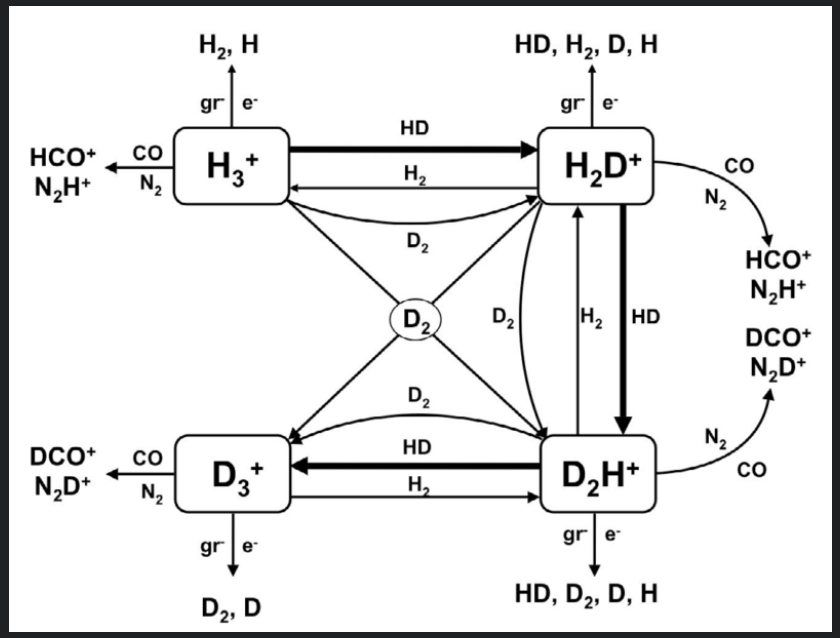
Prestellar Core

- Very few observable species are not depleted
  - e.g. o-H_2D^+, N_2H^+, NH_3
- High deuterium fraction appears in cold environment due to deuterium fractionation.



Deuterium chemistry

- Low temperature environment enhance deuterium fractionation.



(Pagani et al., 2009)

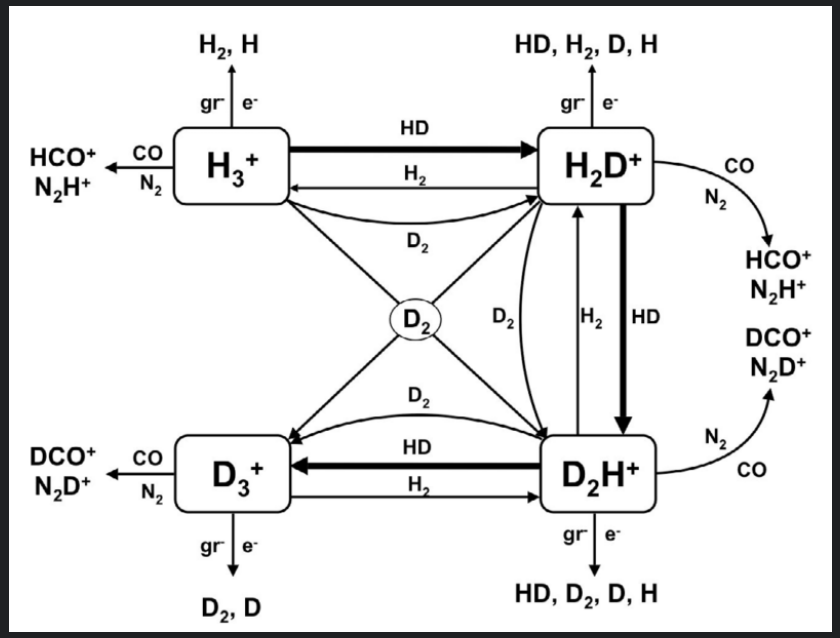
$$H_3^+ + HD \longleftrightarrow H_2D^+ + H_2 + 232\,K$$

$$H_2D^+ + HD \longleftrightarrow D_2H^+ + H_2 + 187\,K$$

$$D_2H^+ + HD \longleftrightarrow D_3^+ + H_2 + 234\,K.$$

Deuterium chemistry

- Low temperature environment enhance deuterium fractionation.



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$$H_3^+ + HD \longleftrightarrow H_2D^+ + H_2 + 232\,K$$

p-H_3^+ + HD ⟶ p-H_2D^+ + p-H_2 + 232K

p-H_3^+ + HD ⟶ **o-H_2D^+** + p-H_2 + 145K

p-H_3^+ + HD ⟶ p-H_2D^+ + o-H_2 + 62K

p-H_3^+ + HD ⟶ **o-H_2D^+** + o-H_2 - 25K

p-H_2D^+ + o-H_2 ⟶ **o-H_2D^+** + p-H_2 + 83K

Deuterium chemistry

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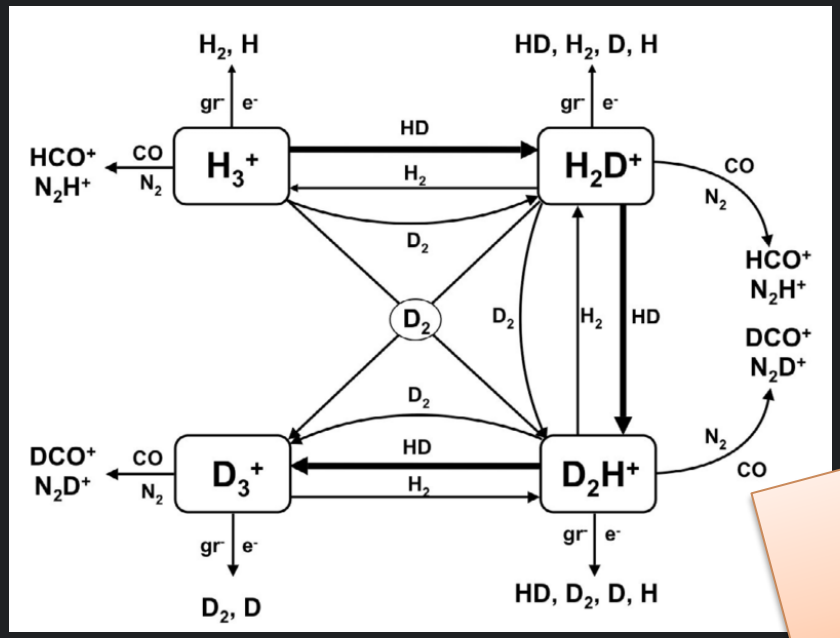

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$H_3^+ + HD \longleftrightarrow H_2D^+ + H_2 + 232\,K$

$p\text{-}H_3^+ + HD \longrightarrow p\text{-}H_2D^+ + p\text{-}H_2 + 232K$

$p\text{-}H_3^+ + HD \longrightarrow \mathbf{o\text{-}H_2D^+} + \ldots$

$p\text{-}H_3^+ + HD \ldots$

$\ldots \longrightarrow \mathbf{o\text{-}H_2D^+} + p\text{-}H_2 + 83K$

$o\text{-}H_2$ control the deuterium process !

Deuterium chemistry

- OPR (ortho/para ratio) indicates the evolutionary stage.

Initial OPR=3

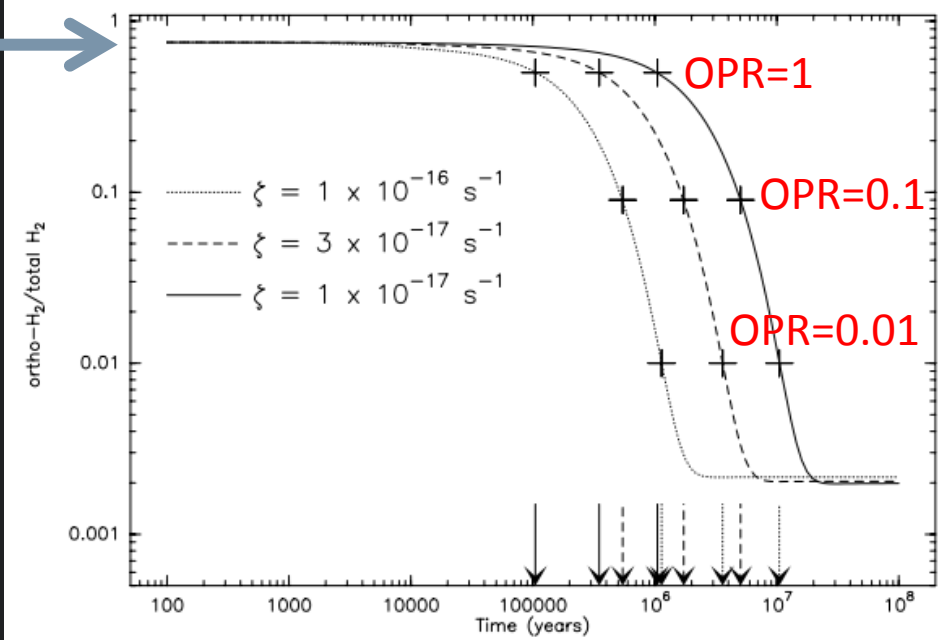

Fig. 1. Ortho-H_2 abundance variation with time for 3 different values of ζ, the cosmic ray ionization rate. Crosses and arrows indicate the time it takes to reach an OPR of 1 (full arrows), 0.1 (dashed arrows), and 0.01 (dotted arrows) for a starting value of 3. The calculations are done for a temperature of 10 K and a density of $n(\mathrm{H} + 2\mathrm{H_2}) = 2 \times 10^4\ \mathrm{cm^{-3}}$.

(Pagani et al., 2013)

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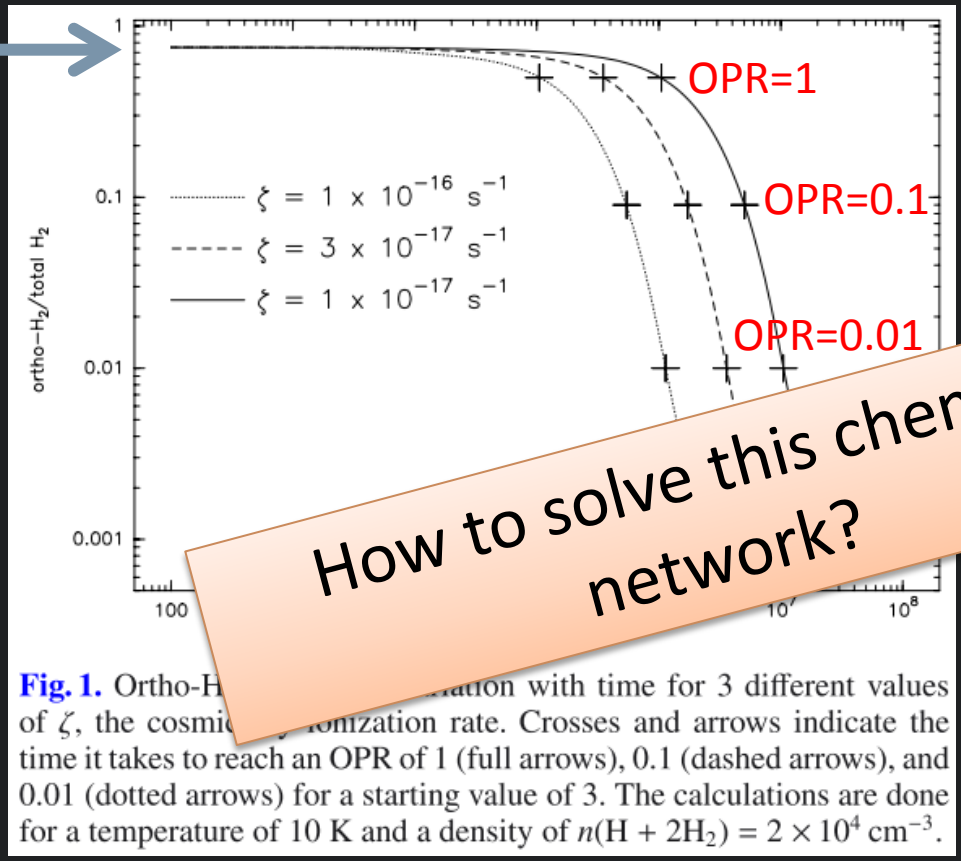

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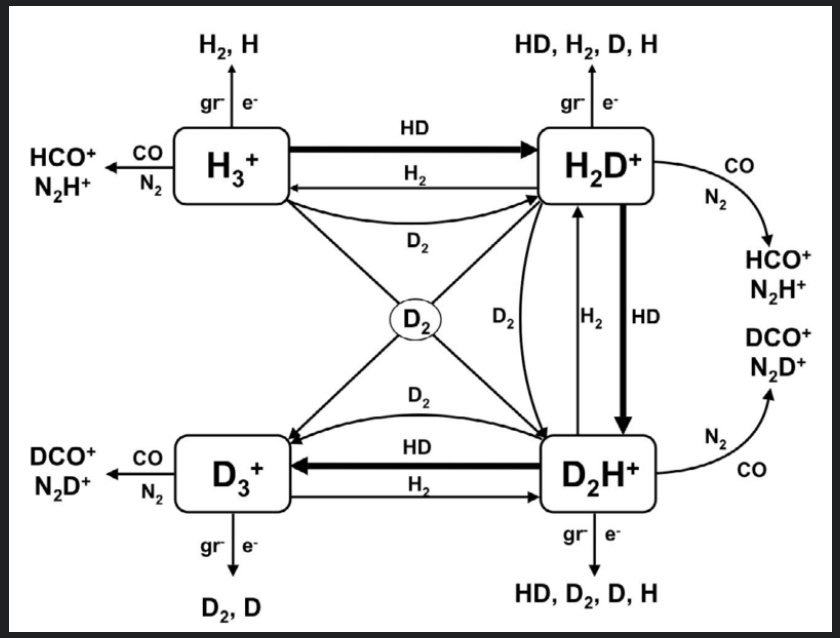
How to solve this chemical network?

(Pagani et al., 2013)

Deuterium chemistry

- Back to deuterium fractionation.



(Pagani et al., 2009)

Species related to N_2

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

$H_2D^+ + N_2 \rightarrow N_2D^+ + H_2$ (for 1/3)

$\rightarrow N_2H^+ + HD$ (for 2/3)

$D_2H^+ + N_2 \rightarrow N_2D^+ + HD$ (for 2/3)

$\rightarrow N_2H^+ + D_2$ (for 1/3)

$D_3^+ + N_2 \rightarrow N_2D^+ + D_2$

Species related to CO

$H_3^+ + CO \rightarrow HCO^+ + H_2$

$H_2D^+ + CO \rightarrow DCO^+ + H_2$ (for 1/3)

$\rightarrow HCO^+ + HD$ (for 2/3)

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Deuterium chemistry

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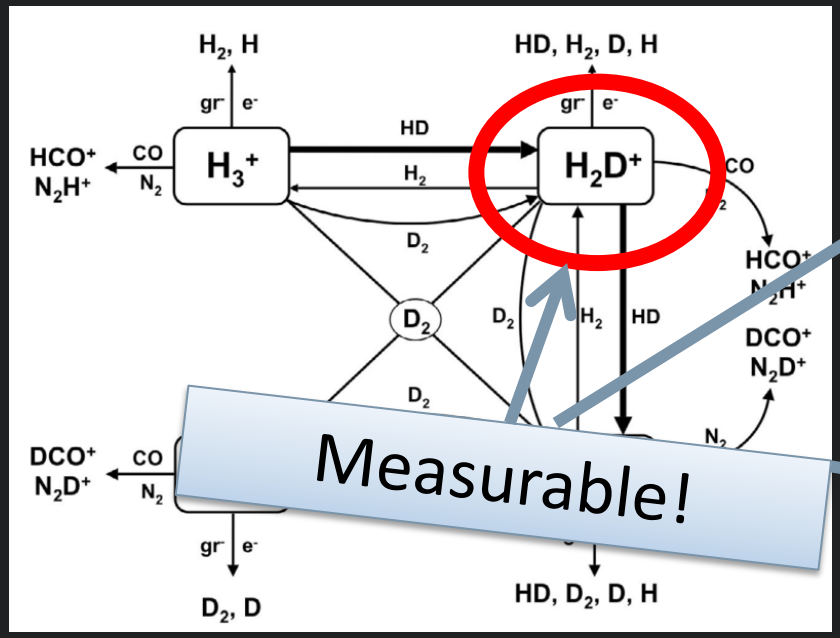

(Pagani et al., 2009)

Measurable!

Species related to N_2

$H_3^+ + N_2 \rightarrow \mathbf{N_2H^+} + H_2$

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$D_3^+ + CO \rightarrow \mathbf{DCO^+} + D_2$

Method

Density Profile

Temperature Profile

N_2H^+, N_2D^+, DCO^+, and H_2D^+ Line Observations

Non-LTE Radiative Transfer Model (Pagani+07)

Abundance Profiles

Solve deuterium chemical network (Pagani+13)

Estimate the age of the prestellar core

CO/N_2 Depletion Profile

Data

Density Profile

Temperature Profile

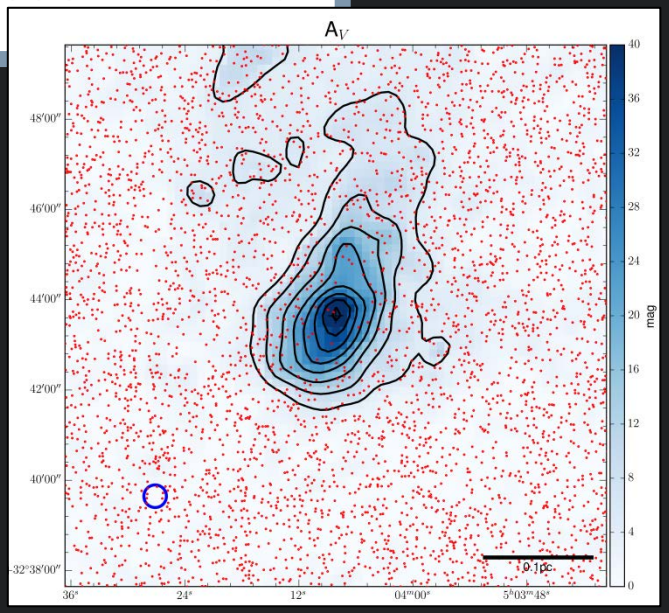
N_2H^+, N_2D^+, DCO^+, and H_2D^+ Line Observations

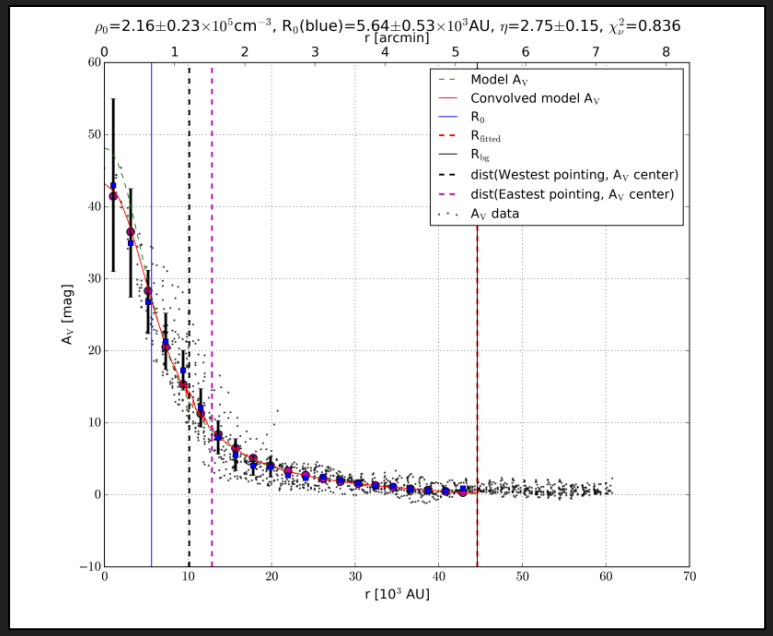
Fitting the extinction profile with the plummer-like profile density,

$$\rho(r) = \frac{\rho_0}{1+(\frac{r}{R_0})^{\eta}}.$$

$$\rightarrow \rho_0 = 2.16 \times 10^5 \text{cm}^{-3},$$

$$R_0 = 5640 \text{ AU}, \eta = 2.75$$





Data

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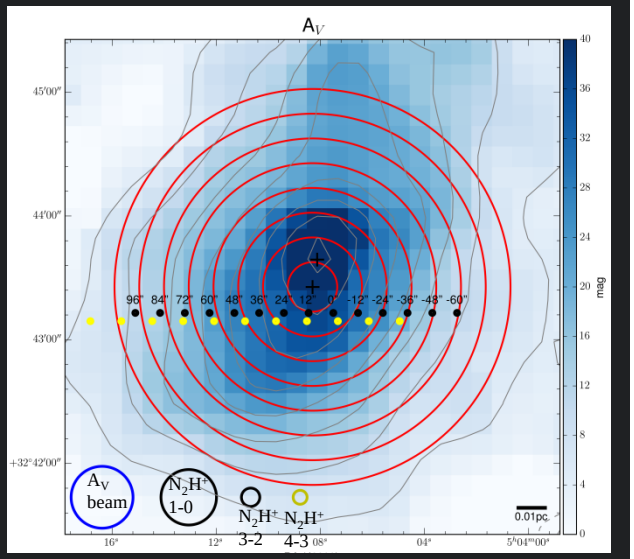
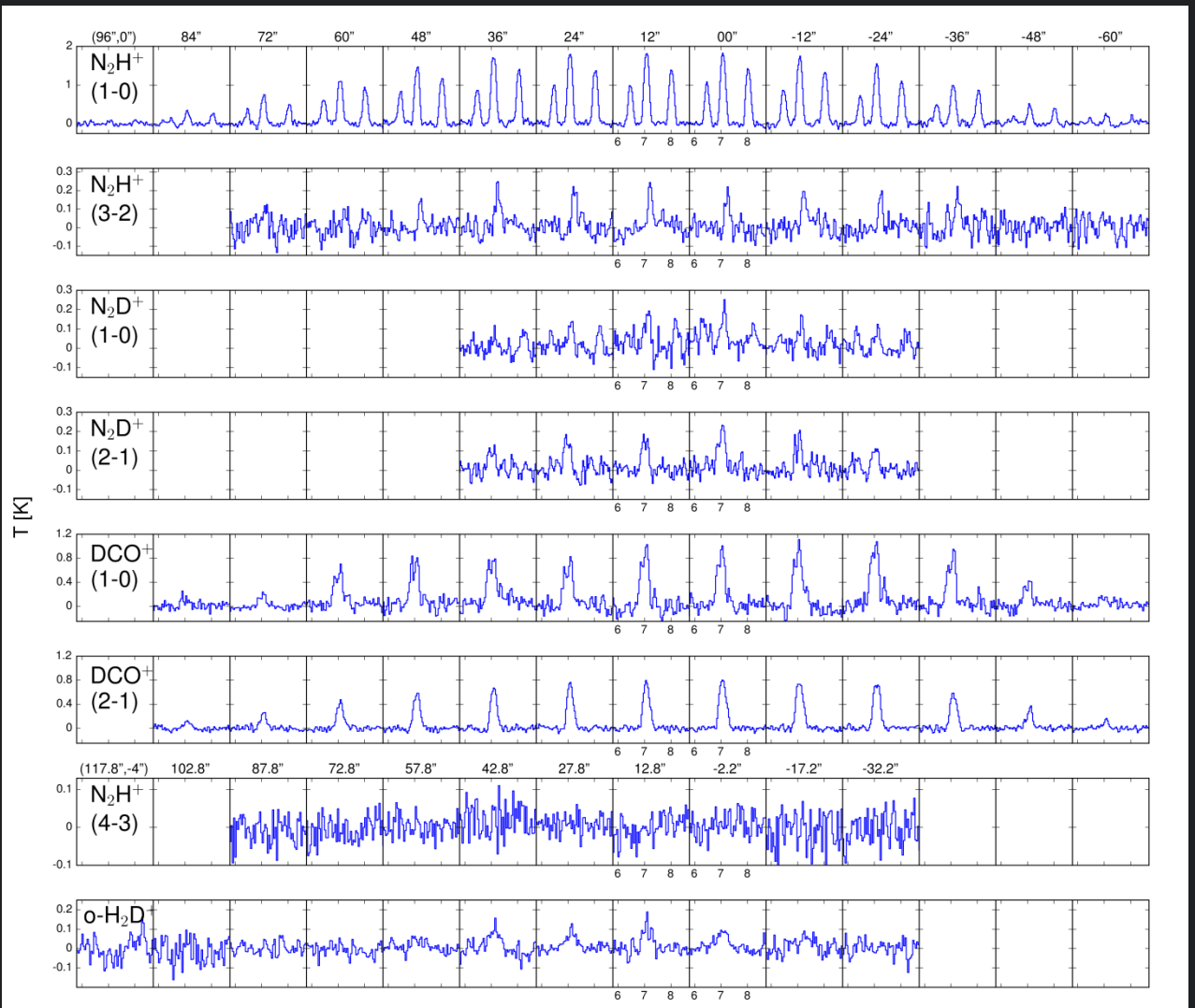
N_2H^+, N_2D^+, DCO^+, and H_2D^+ Line Observations



Spectra along the horizontal cut



Idea of determining abundance profile

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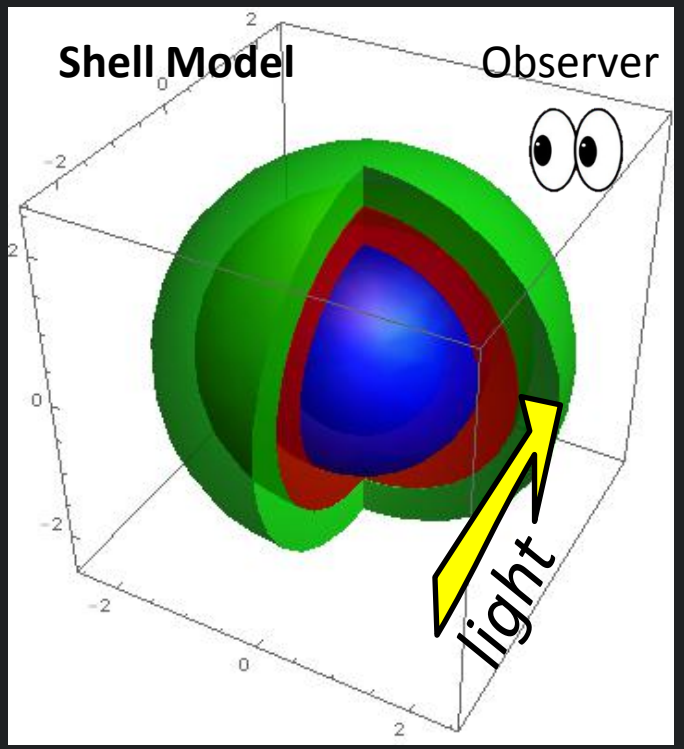
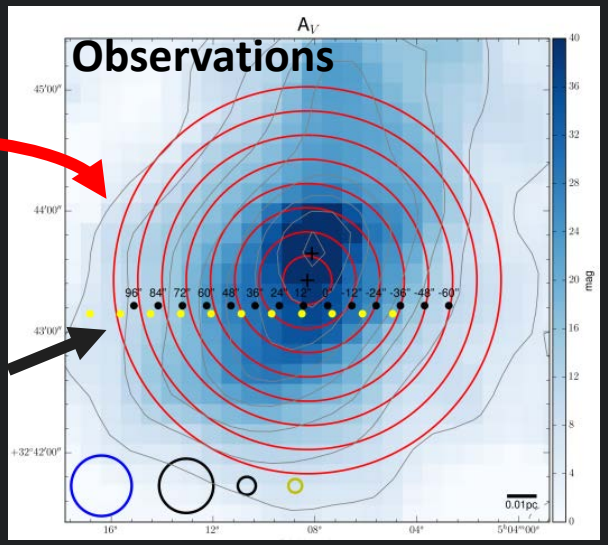


Assume multiple spherical layers

Conduct pointing observations along a cut



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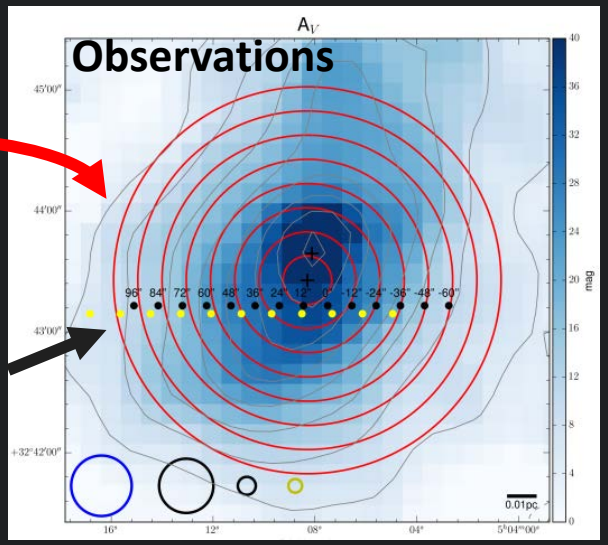

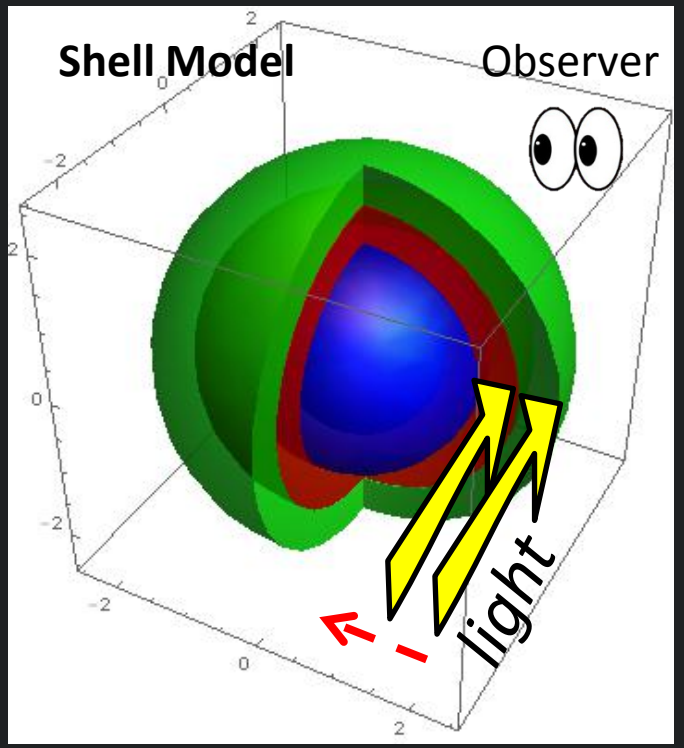

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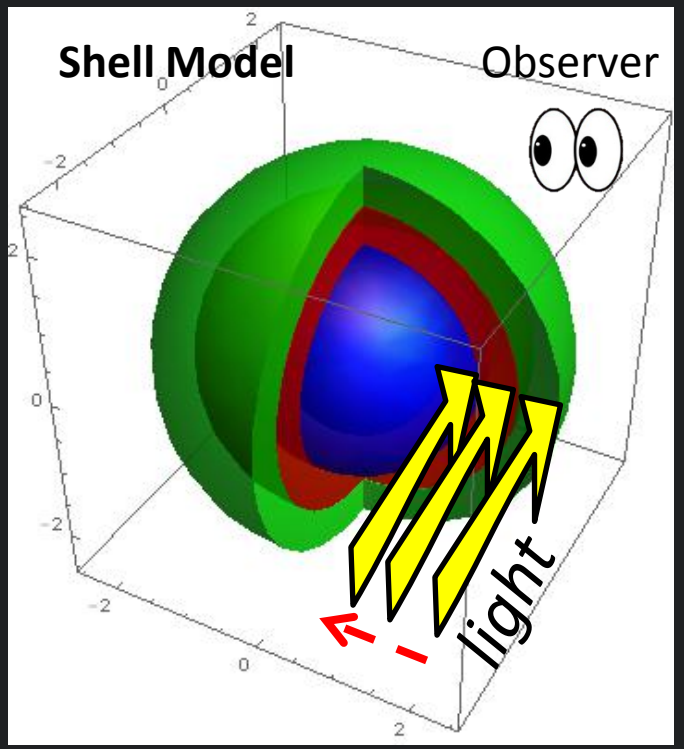

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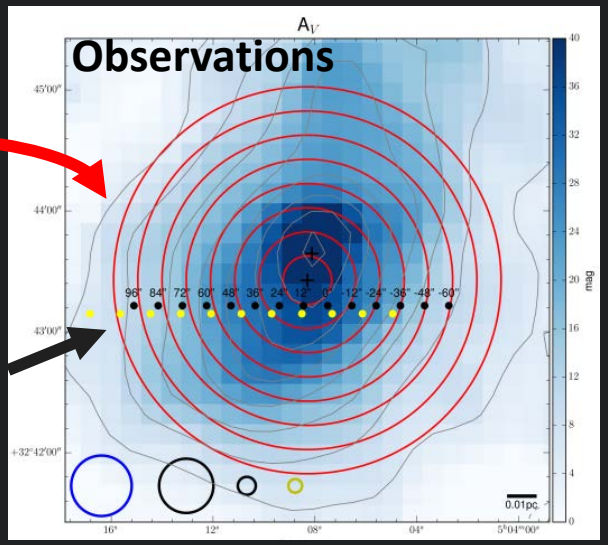
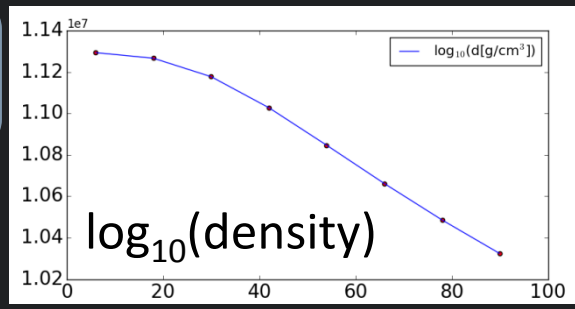


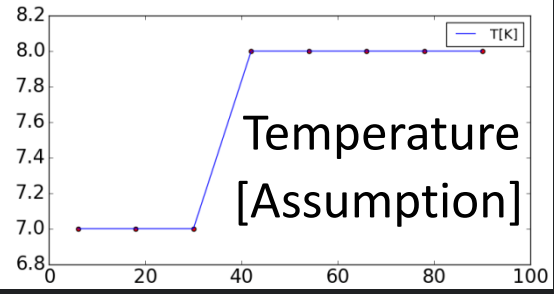
Fitting for N_2H^+ transitions

Density Profile

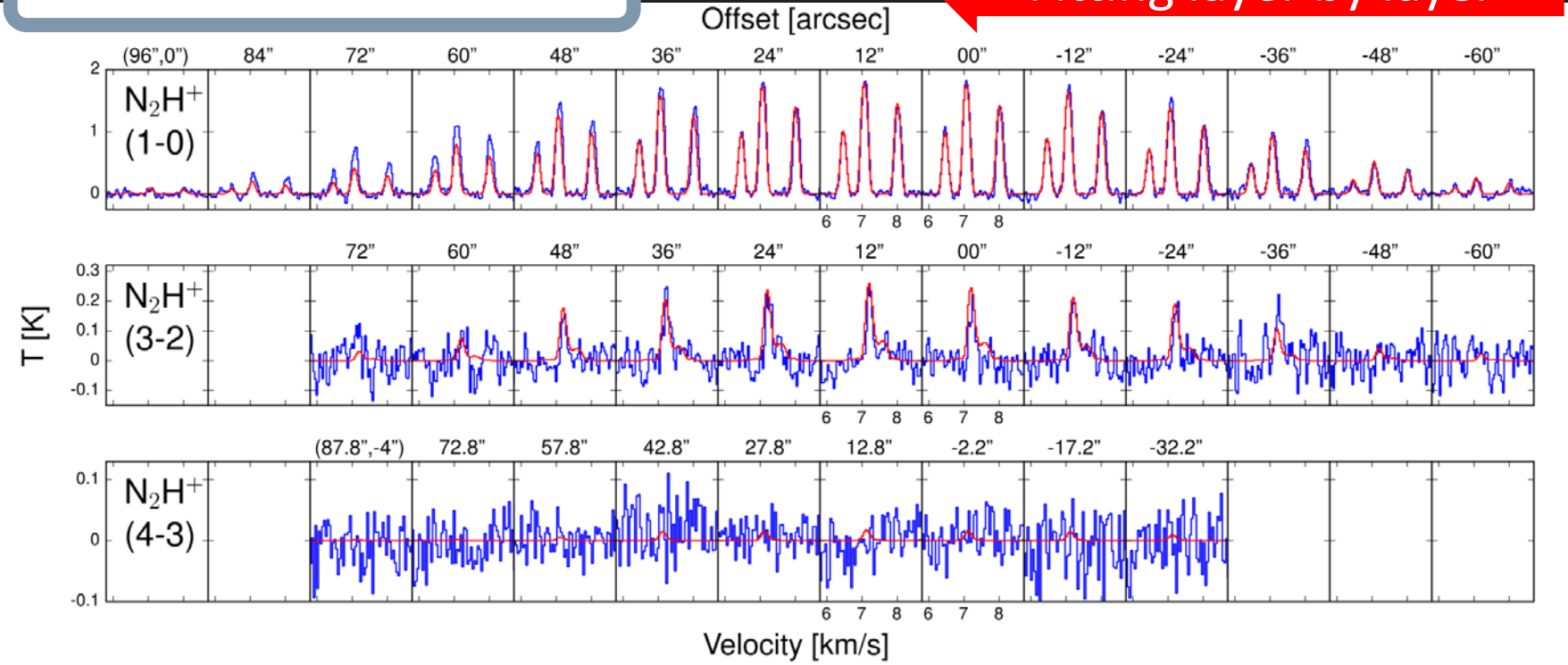
Temperature Profile

Line Observations





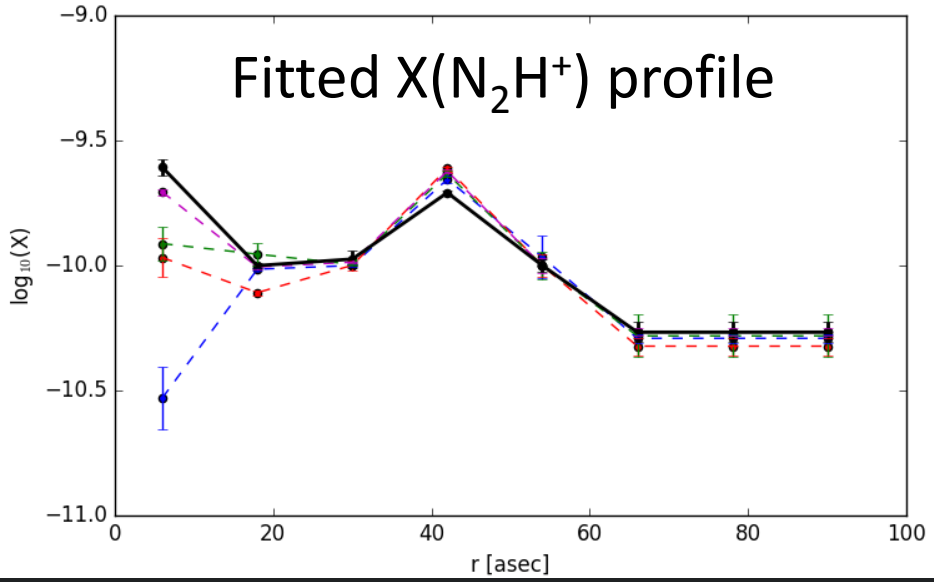
Fitting layer by layer

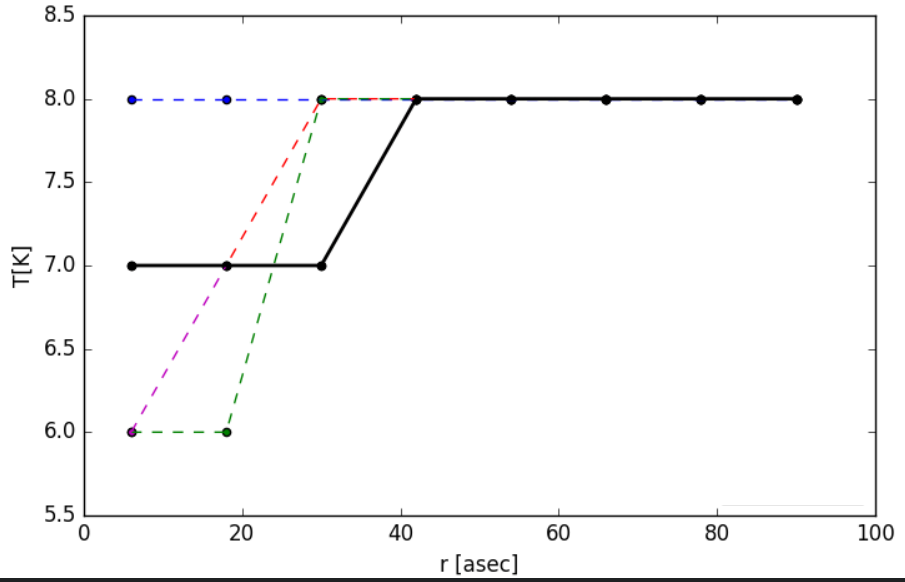


Abundance results

Abundance Profiles

assumed Temperature Profile





Summary

- The maximum of N_2H^+ abundance is ~2e-10 which is similar to L1498, L1517 (Tafalla+04) and L183 (Pagani+09).
- We found a N_2H^+ ***diminution factor*** of ~2 at the inner region of L1512.

Future work

- Apply the fitting of other spectra to constrain their abundance profiles to estimate the age of L1512.
- Apply the same method to other prestellar cores to compare.

Thank you for your attention!