Nitrogen fractionation in dark clouds

P. Hily-Blant

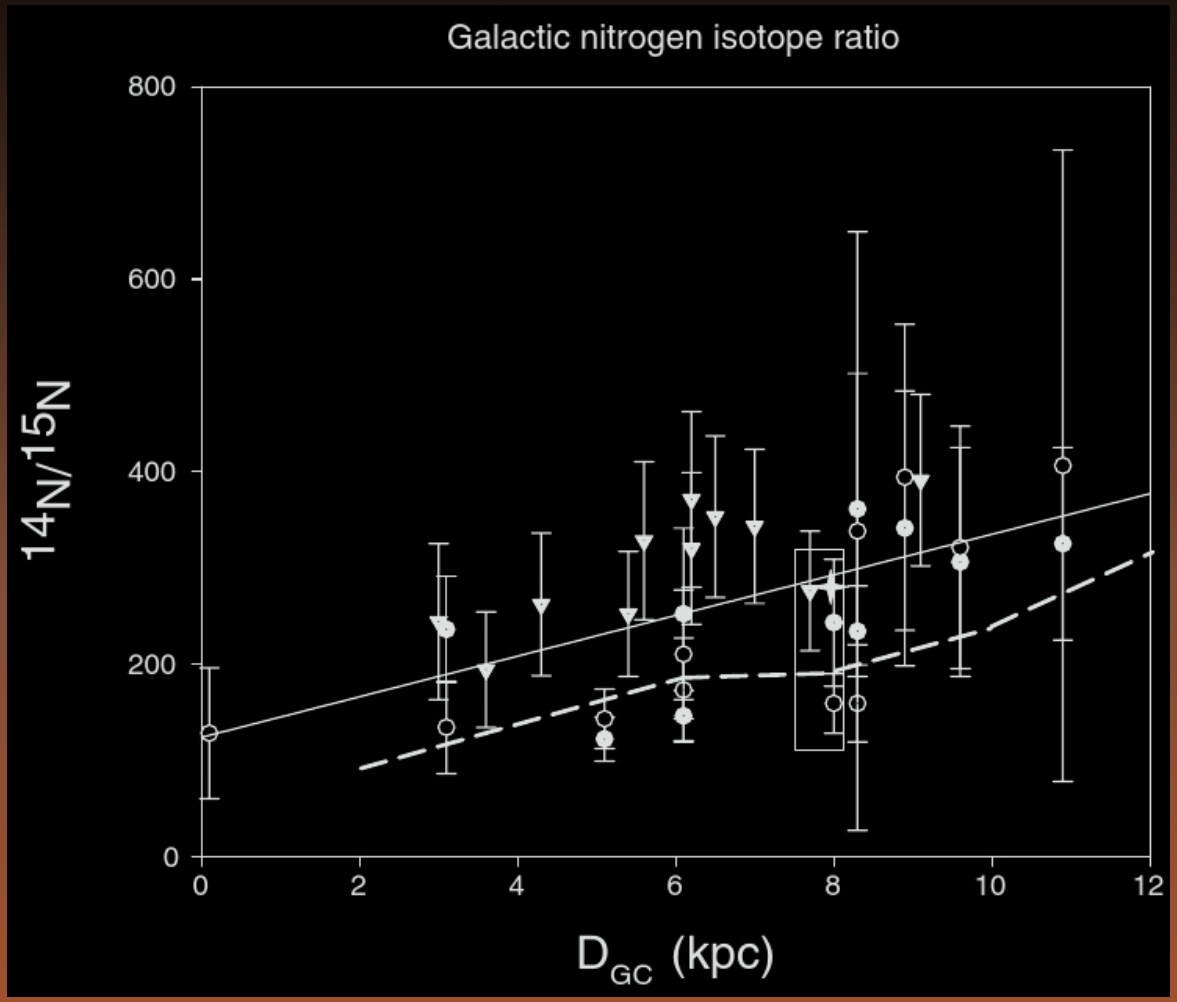
R. Le Gal (PhD),
A. Faure, G. Pineau des Forêts, C. Rist, M. Padovani

PCMI Colloque, November 19-21, 2012

Isotopic ratios

- tools to understand the chemical evolution of galaxies (nucleosynthesis theoretical predictions)
- tools to link the composition of the presolar nebula – the primitive solar system – with the composition of the dense ISM – the place where stars form.
- *Dark cloud models: not as well developped as nucleosynthesis however.*

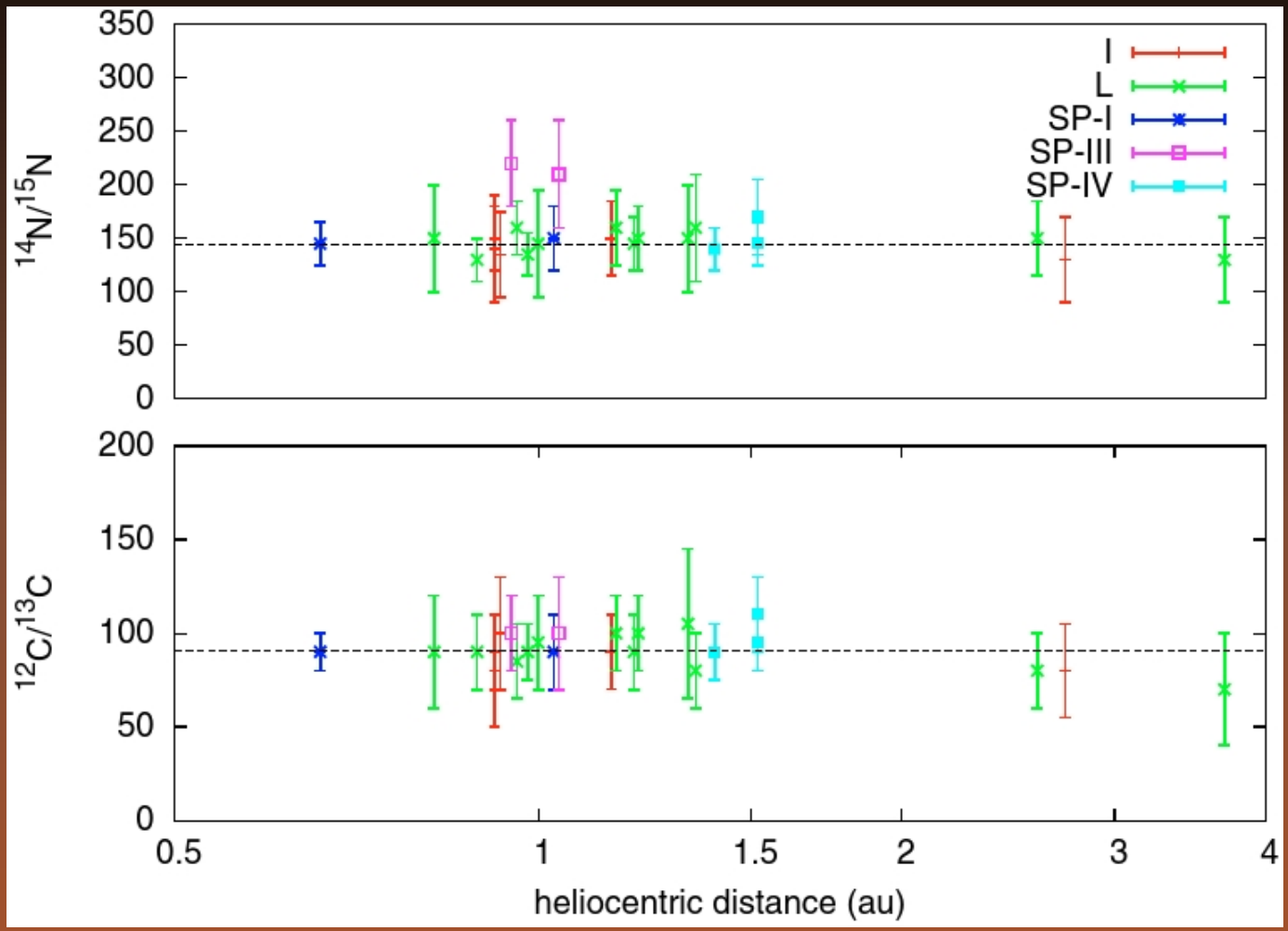
^{14}N:^{15}N accross the Milky Way



Adande et al 2012

At $R = 7.9$ kpc, $^{14}\mathrm{N} : {}^{15}\mathrm{N} = 290 \pm 40$, whereas ^{14}N:^{15}N=440 in the presolar nebula (Marty et al 2011)

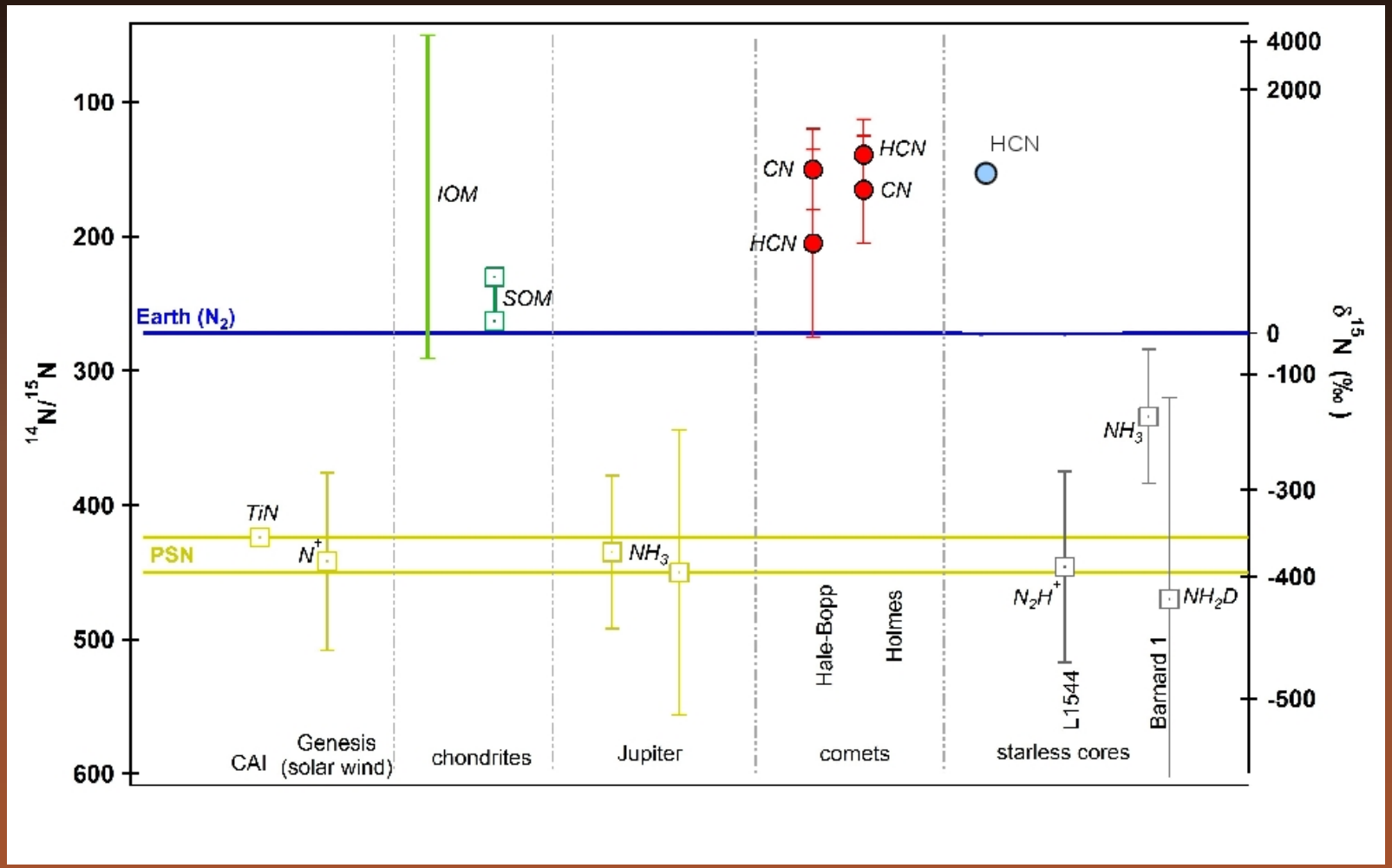
^{14}N:^{15}N in comets



Manfroid et al 2009

Cosmic abundance ratio for C, but not for N: $150 < 440$

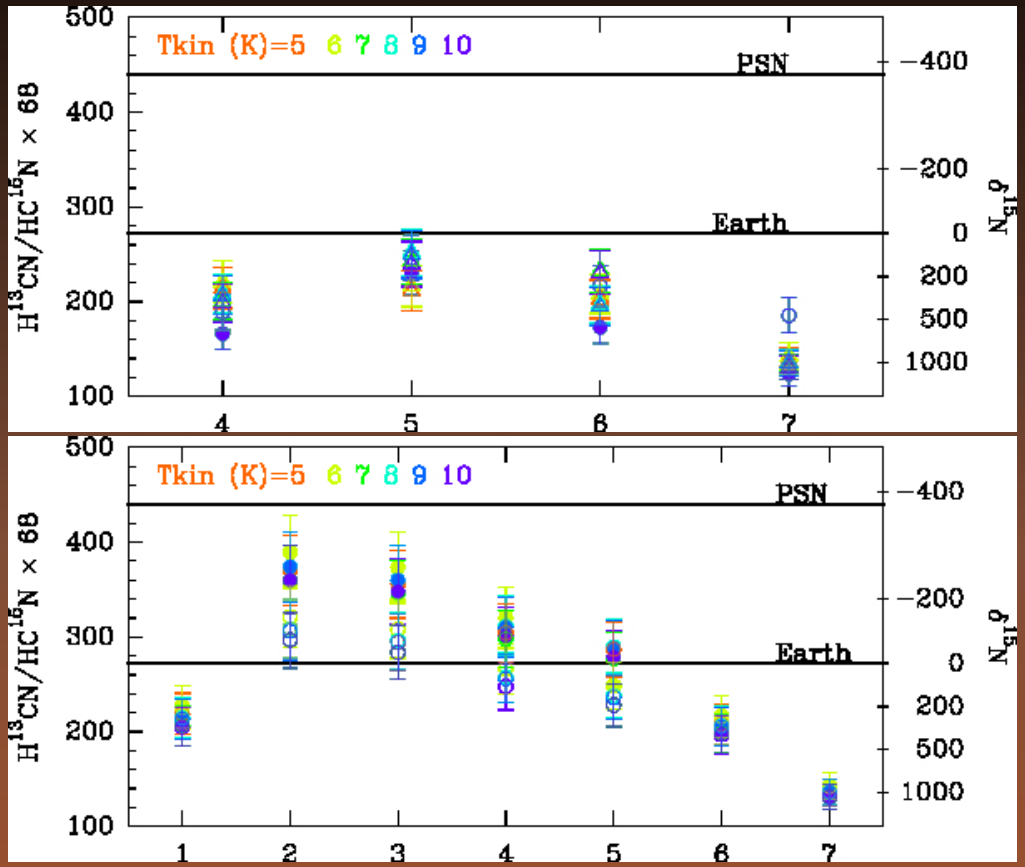
Overview



Ikeda+02, Fouchet+06, Manfroid+09, Bockelée-Morvan+08, Gerin+09, Bonal+09, Lis+10, Bizzocchi+11, Marty+11

To which extent, did the presolar nebula inherit its chemical composition from the dark cloud ?

Dark clouds: ^{14}N:^{15}N from HCN

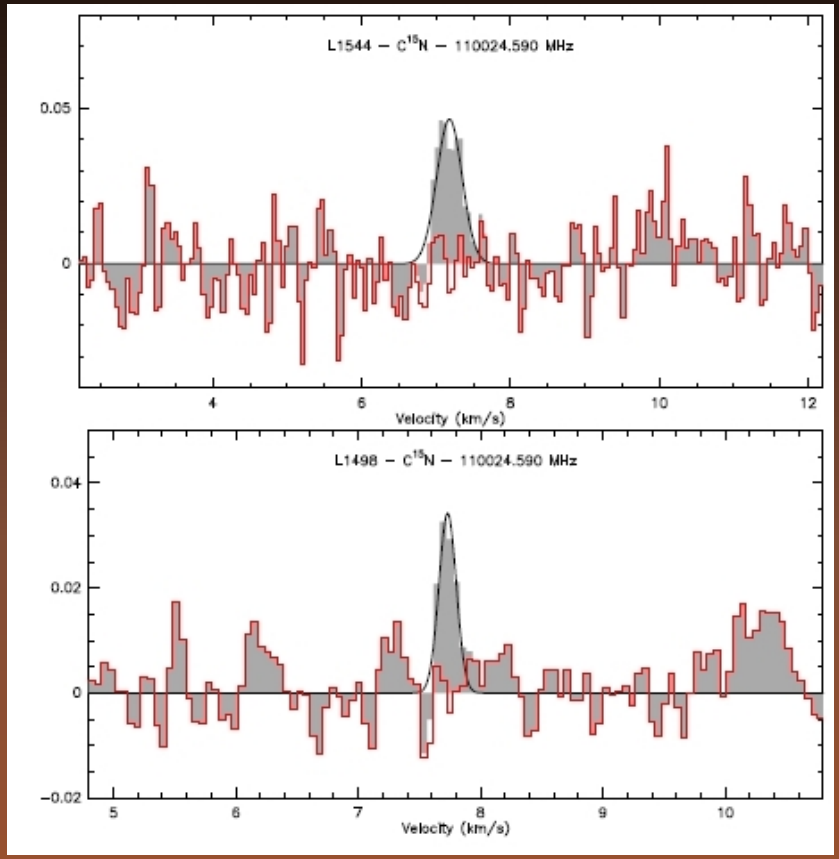


Hily-Blant, Bonal, Faure, Quirico, to appear in Icarus

Derived ^{14}N/^{15}N assuming ^{12}C/^{13}C=70:

- L183: $140 \leq {}^{14}\mathrm{N}/{}^{15}\mathrm{N} \leq 250$
- L1544: $140 \leq {}^{14}\mathrm{N}/{}^{15}\mathrm{N} \leq 360$

Dark clouds: ^{14}N:^{15}N from CN

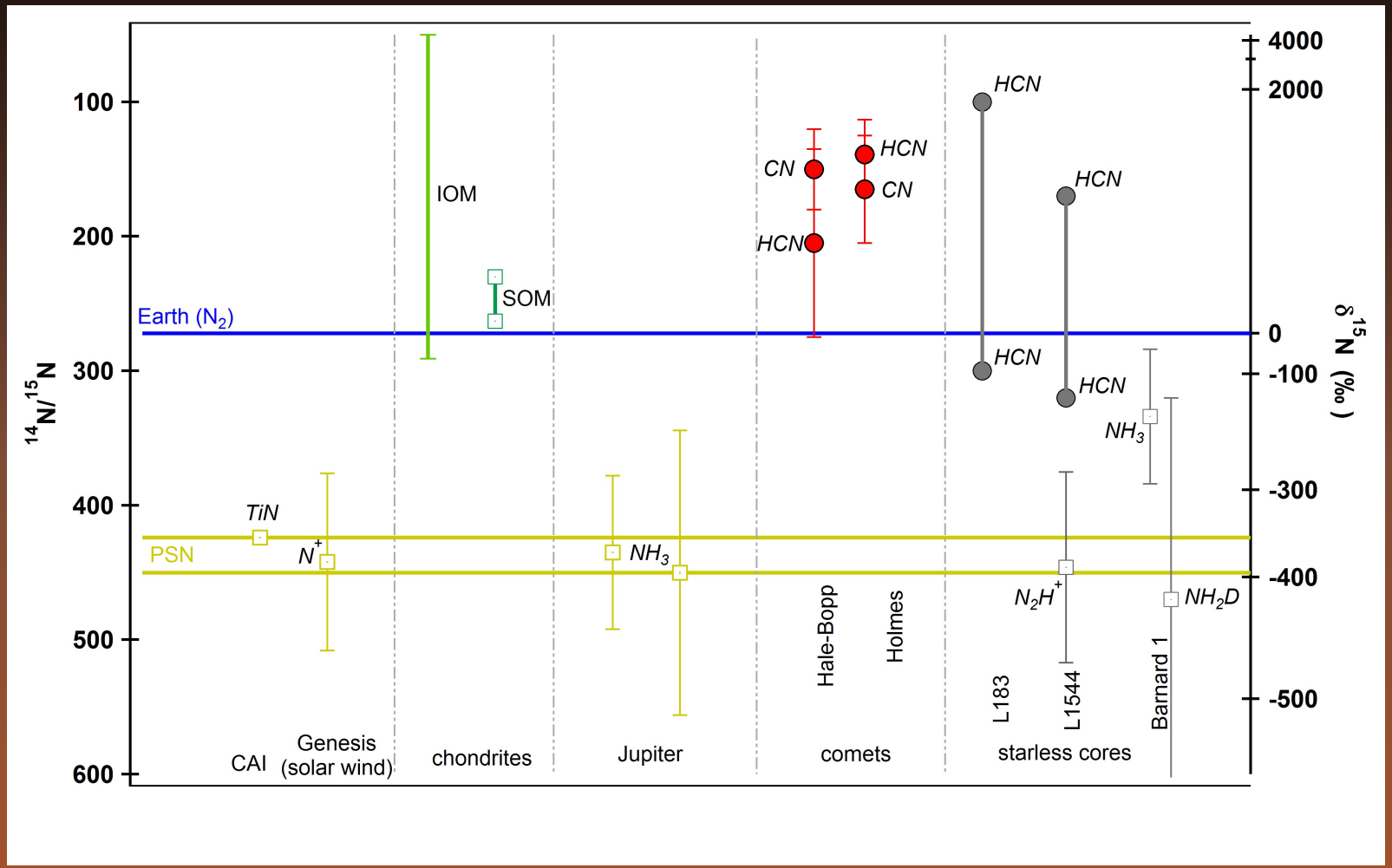


Hily-Blant, Padovani, Le Gal, Pineau des Forêts, Faure, to be submitted

Derived ^{14}N/^{15}N assuming Tex=4 K and ^{12}C/^{13}C=70:

- L1498: 600±90
- L1544: 530±70

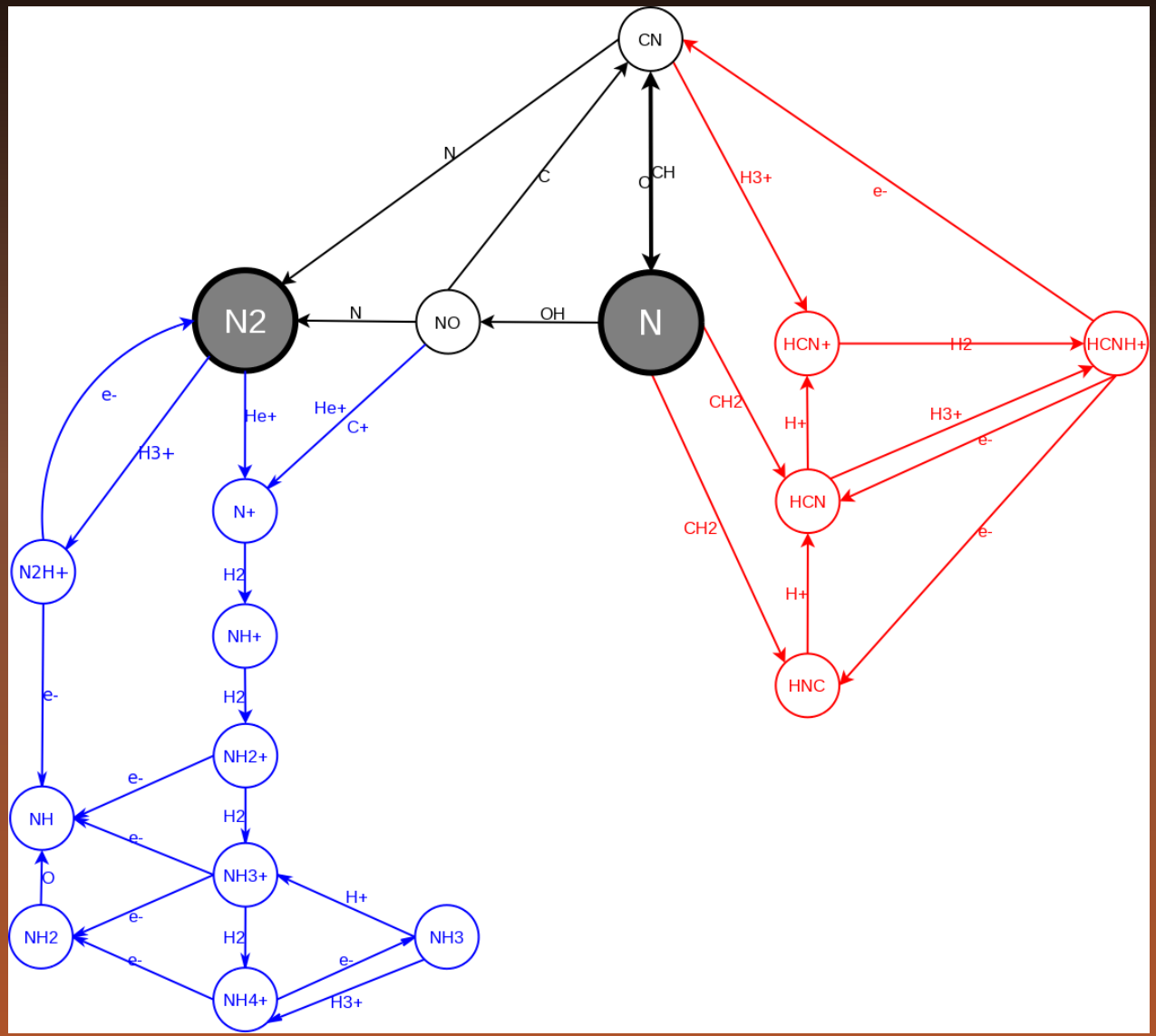
Differential fractionation



Hily-Blant, Bonal, Faure, Quirico, to appear in Icarus

Two fractionation families: hydrides and nitriles. But CN ?

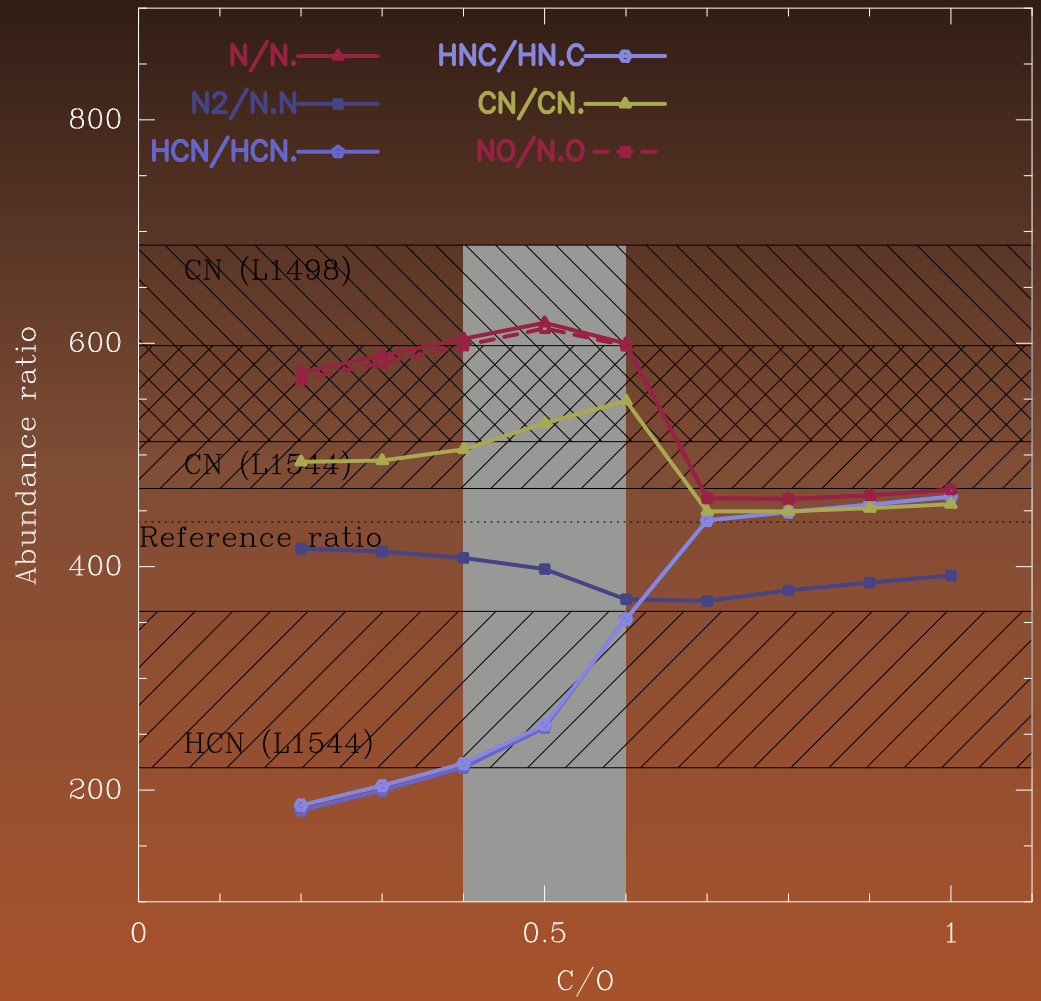
Gas-phase nitrogen chemistry



Model calculations

- Updated chemical network (see posters of Le Gal et al and Rist et al)
- Includes new neutral-neutral reaction rates (Bergeat et al, Daranlot et al 2012)
- Fractionation:
  - only ion-neutral fractionation reactions
  - ZPE from Terzieva & Herbst 2000

Model calculations



Conclusions

- Fractionation measured in HCN towards dark clouds: interstellar origin for the measurements in IOM and SOM (see also Aléon 2010)
- Modelling: influence of the elemental abundances;
- Carrier-dependence of fractionation: amine-group or nitrile-group

Open questions

- Observations: repeat measurements towards other sources using various carriers (F. Daniel et al private comm.)
- Amino acids in Soluble Organic Material: what is the source of $^{15}\mathrm{N}$? (see poster by Noble #50)
- Modelling:
  - identify the key reactions
  - include surface chemistry (Taquet's talk, see also posters by Zins #35, Berné #3)
- Move towards the diffuse medium: use of $^{15}\mathrm{NH}$ (Bailleux et al 2011, Herschel OT2)
- Detection of isotopologues in protoplanetary disks
- Measurements of isotopologues of complex molecules in star forming regions

Dislaire, V., Hily-Blant, P., Faure, A., et al. 2012, A&A, 537, A20

Gerlich, D. 2008, in Low temperatures and cold molecules, ed. I. Smith (Imperial College Press), 121–174

Herbst, E. & Klemperer, W. 1973, ApJ, 185, 505

McKellar, A. 1940, PASP, 52, 187

Persson, C. M., De Luca, M., Mookerjea, B., et al. 2012, A&A, 543, A145