FRANCESCO FONTANI
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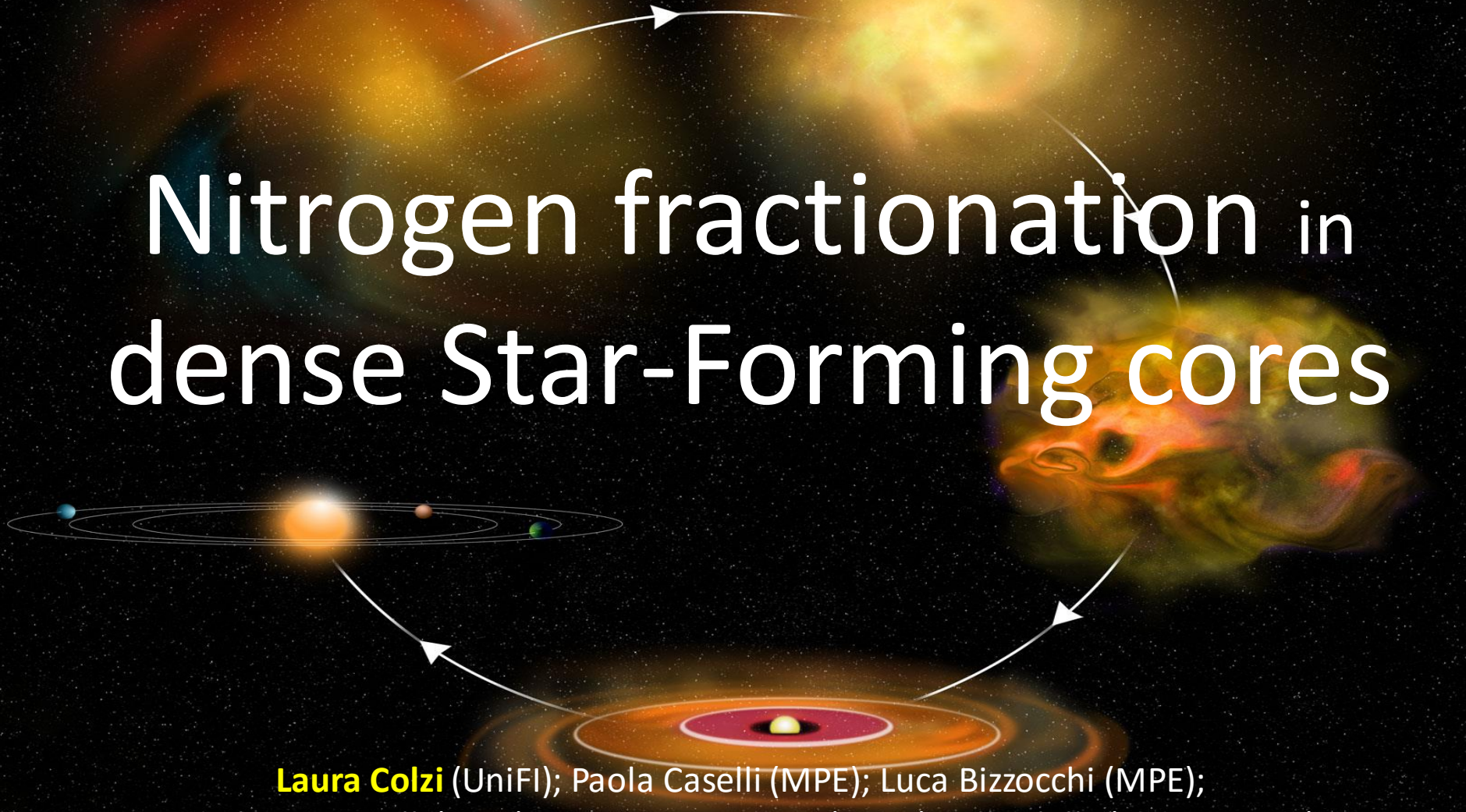
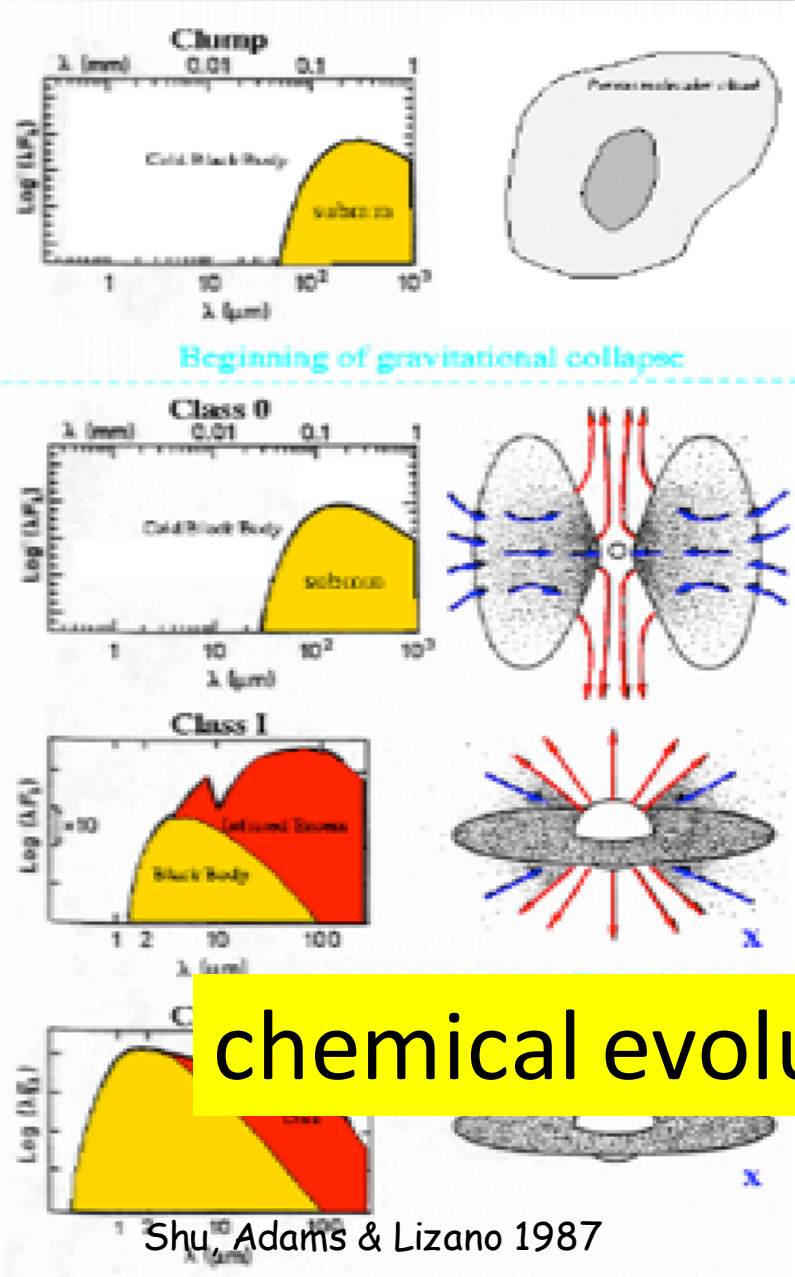
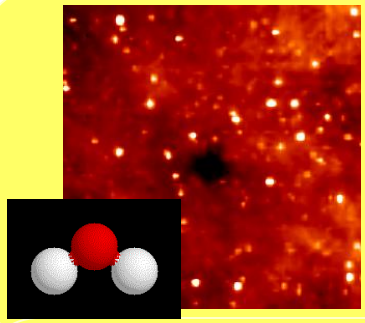
Nitrogen fractionation in dense Star-Forming cores



Laura Colzi (UniFI); Paola Caselli (MPE); Luca Bizzocchi (MPE);
Cecilia Ceccarelli (IPAG); **Marta De Simone** (UniFI); C. Codella (INAF-Arcetri)
…and many others !

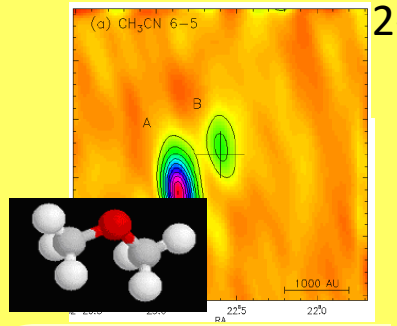
Low-mass star formation





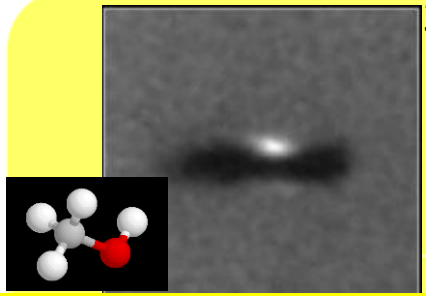
1- PRE-STELLAR PHASE:
SIMPLE MOLECULES

10^6 yr



2- PROTOSTELLAR PHASE:
COMPLEX MOLECULES

10^4-10^5 yr



3- PROPLYDS PHASE:
SIMPLE + COMPLEX

10^6 yr

chemical evolutionary sequence!

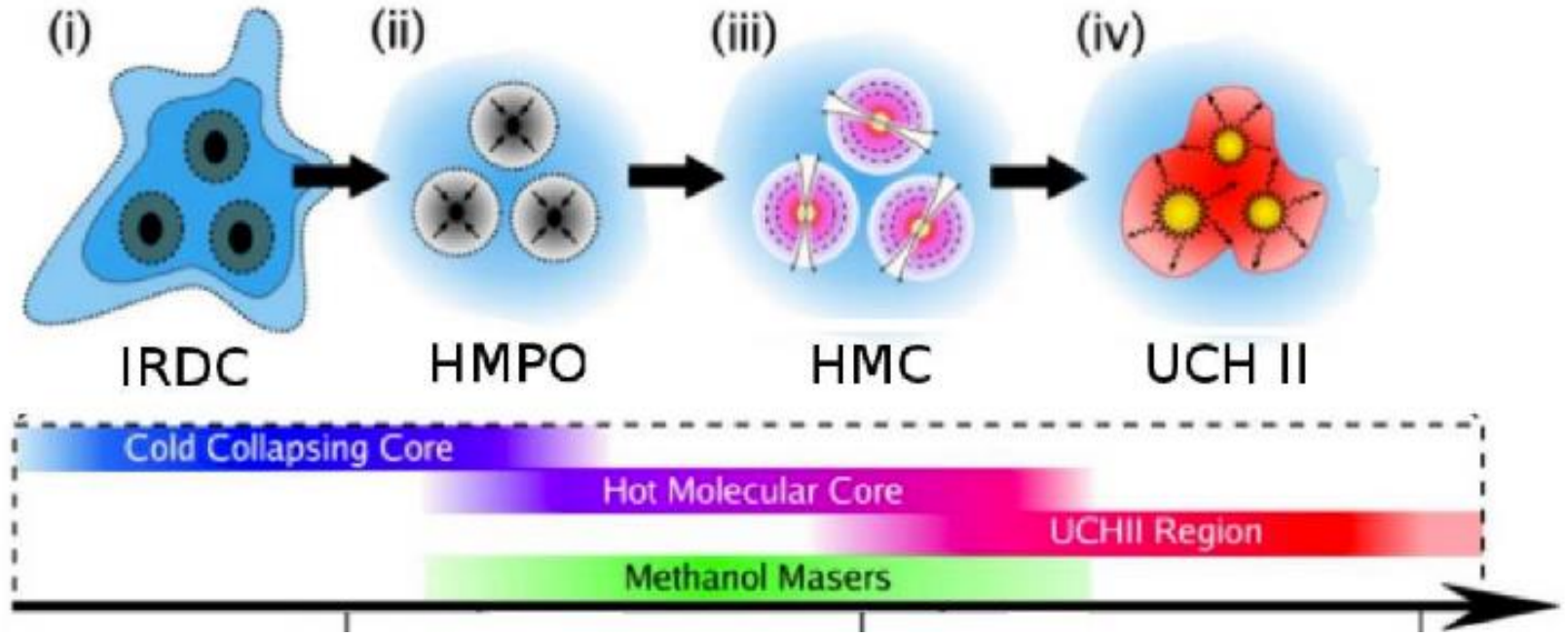
ORMATION
ON +
DELIVERY: LIFE (?)

Caselli & Ceccarelli 2012

High-mass star formation

Tentative evolutionary sequence

(adapted from Purcell (2006) and Gerner (2015) PhD thesis; recommended reviews: Beuther+2007, Tan+2014)



T ~ 10 – 20 K T ~ 20 – 100 K T ≥ 100 K

✓Huge distances (d>1 kpc)

chemical evolutionary sequence?

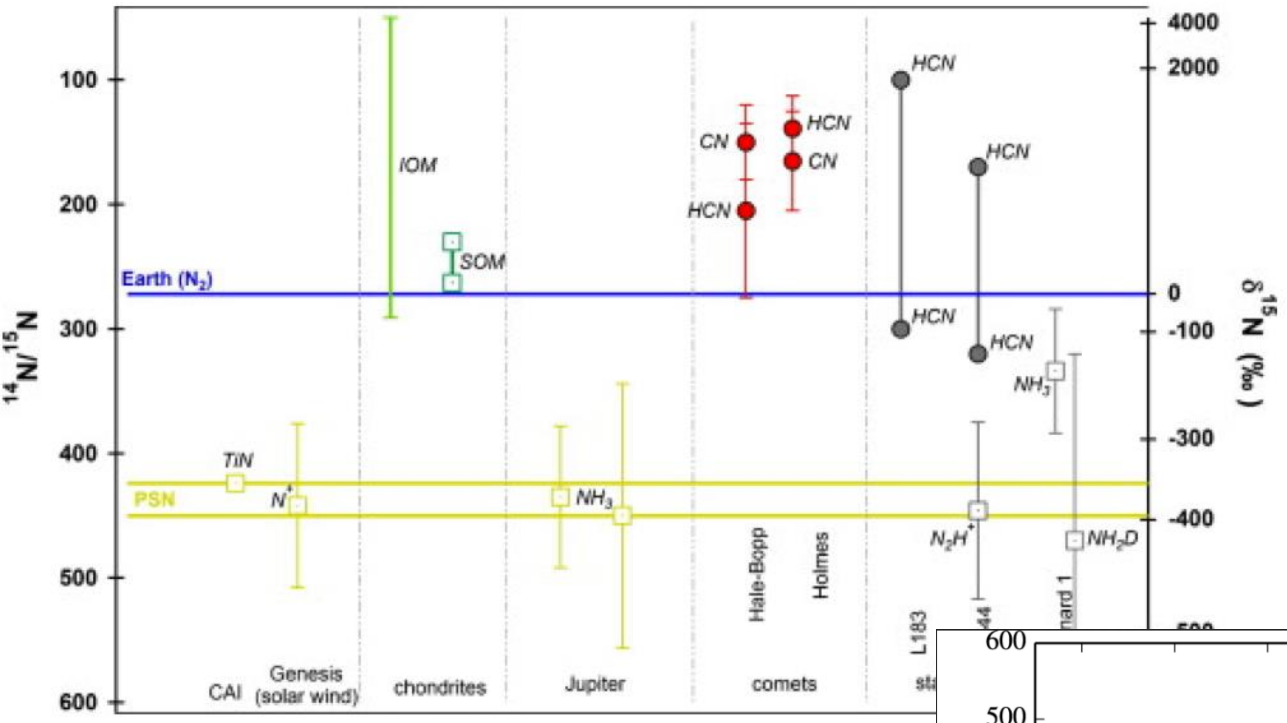
✓ T and n variations in a shorter time

✓strong **feedback**

Presentation outline

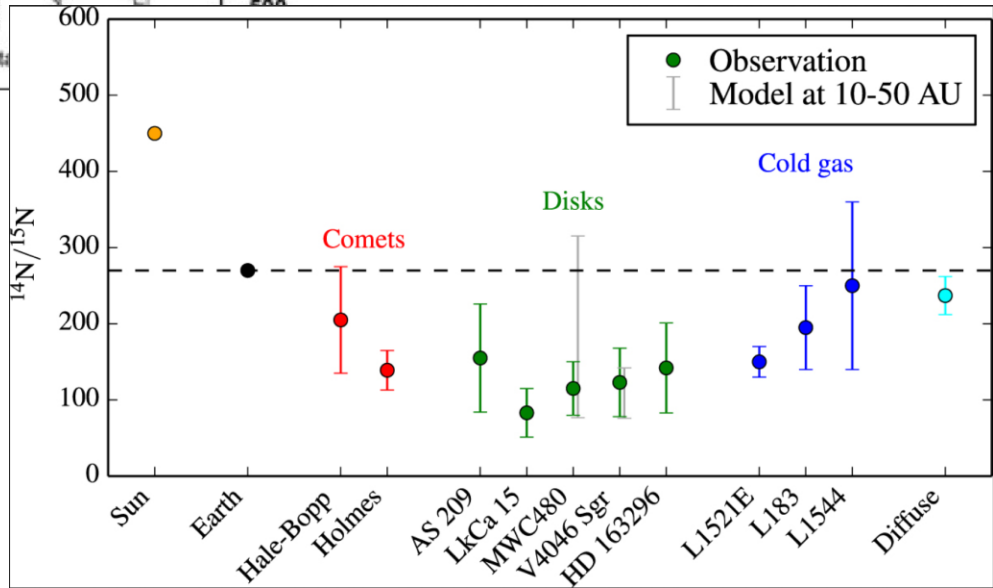
1. Observations of ^{15}N-molecules: until a few years ago
2. ^{15}N-molecules: new observations in high-mass SF cores
3. ^{15}N-molecules: new observations in low-mass SF cores
4. ^{15}N-fractionation vs D-fractionation: relation?

$^{14}N/^{15}N$: observations (low-mass)



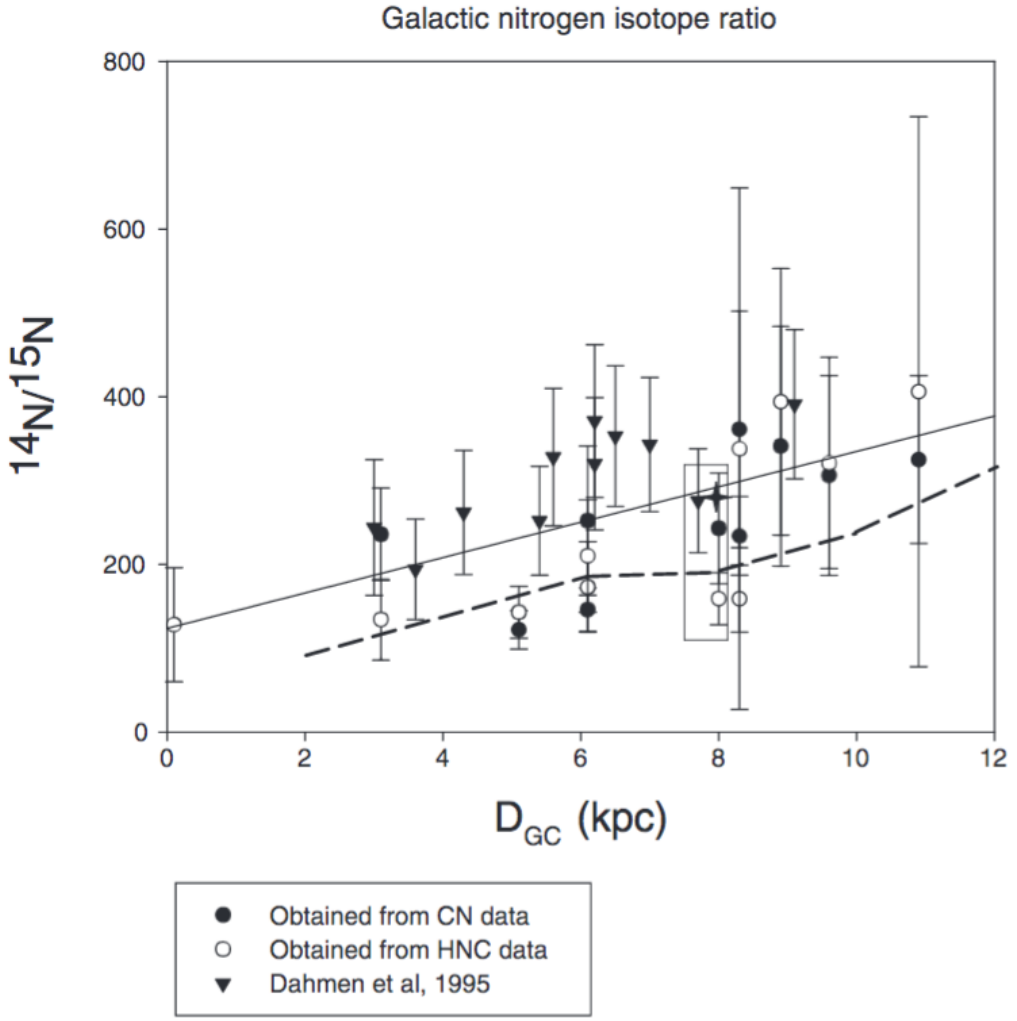
Guzman+2013

Hily-Blant+2013



$^{14}N/^{15}N$: observations (high-mass)

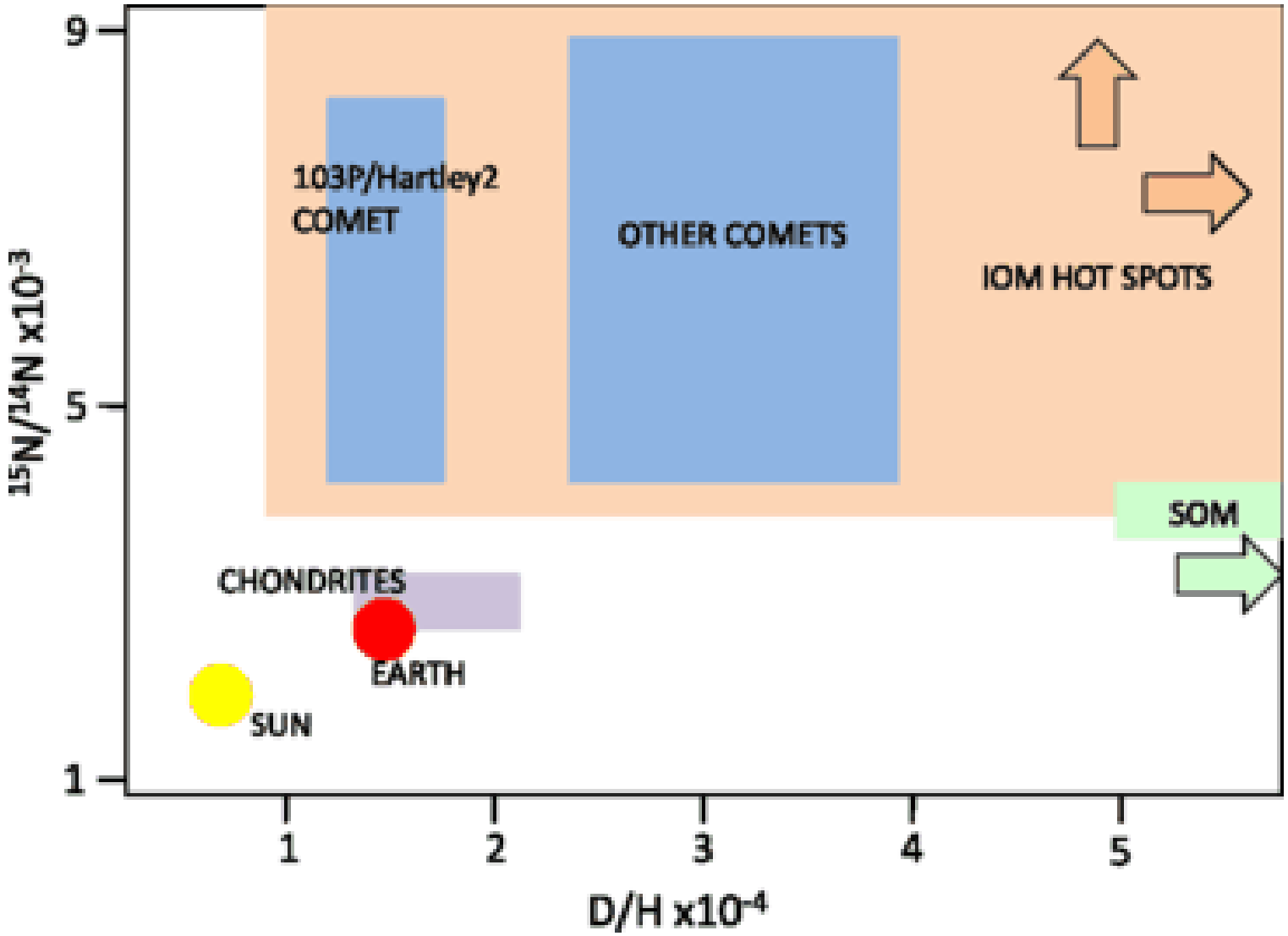
Adande & Ziurys 2012



$$14N/15N = 21.1(5.2)\,kpc^{-1} \times DGC + 123.8\,(37.1)$$

H and N isotopic anomalies

Caselli & Ceccarelli 2012, A&ARv (and references therein)



$^{14}N/^{15}N$ and H/D: common behaviour?

e.g. Terzieva & Herbst 2000; Charnley & Rodgers 2002; Rodgers & Charnley 2008; Hily-Blant et al. 2013; Roueff et al. 2015

If T is low

$$^{15}N + N_2H^+ \longrightarrow {}^{15}NNH^+ + N + 36K$$
$$N^{15}NH^+ + N + 28K$$

$$^{15}N + HCNH^+ \longrightarrow HC^{15}NH^+ + N + 36K$$

If *T* is low

$$H_3^+ + HD \longrightarrow H_2D^+ + H_2 + 230K$$

From Wirstroem et al. 2012

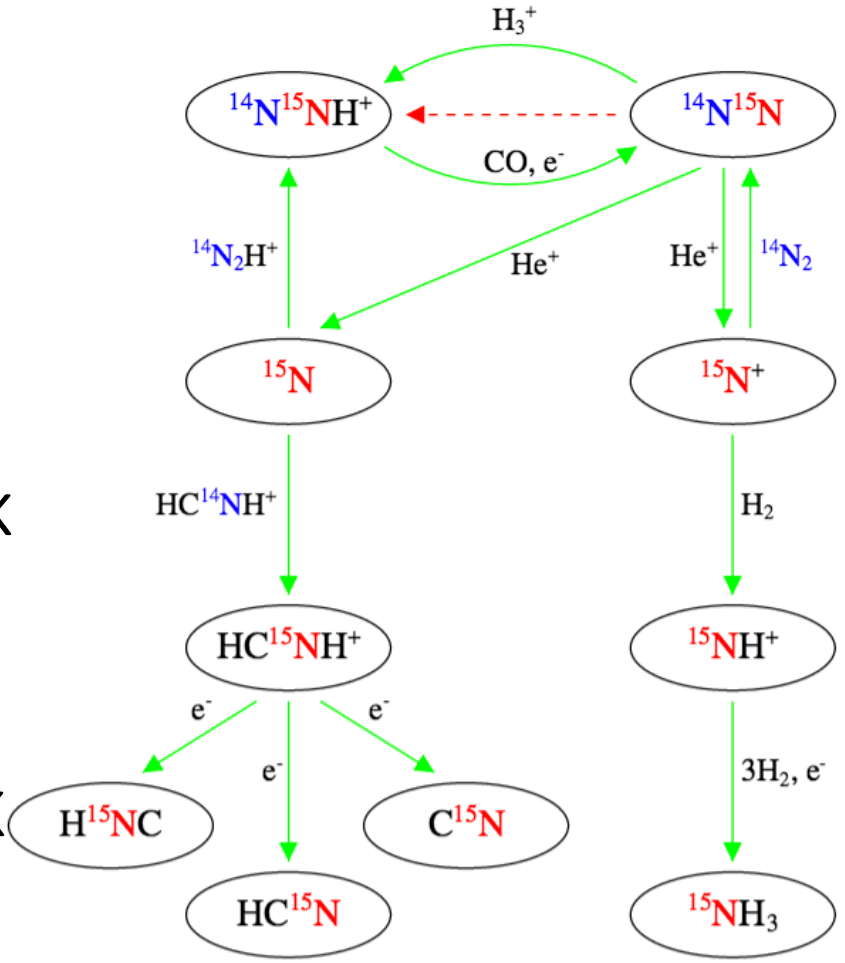


Figure 1. Chemical network showing the main reactions responsible for ^{15}N enhancement in nitriles and ammonia.

New observations in MASSIVE SF cores

Fontani et al. 2011, A&A, 529, L7; Fontani et al. 2014, MNRAS, 440,448; Fontani et al. 2015, A&A, 575, 87

27 Cores associated with high-density gas

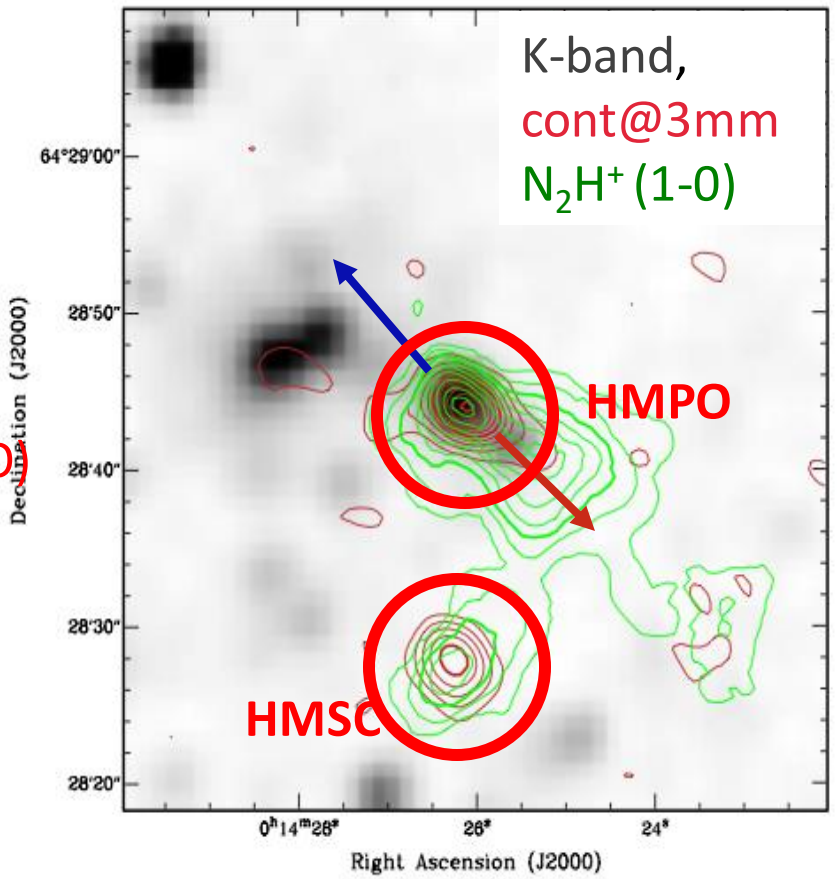
different evolutionary stages

i. NO infrared; NO outflows; NO 3.6cm
→ High-Mass Starless Core (HMSC)

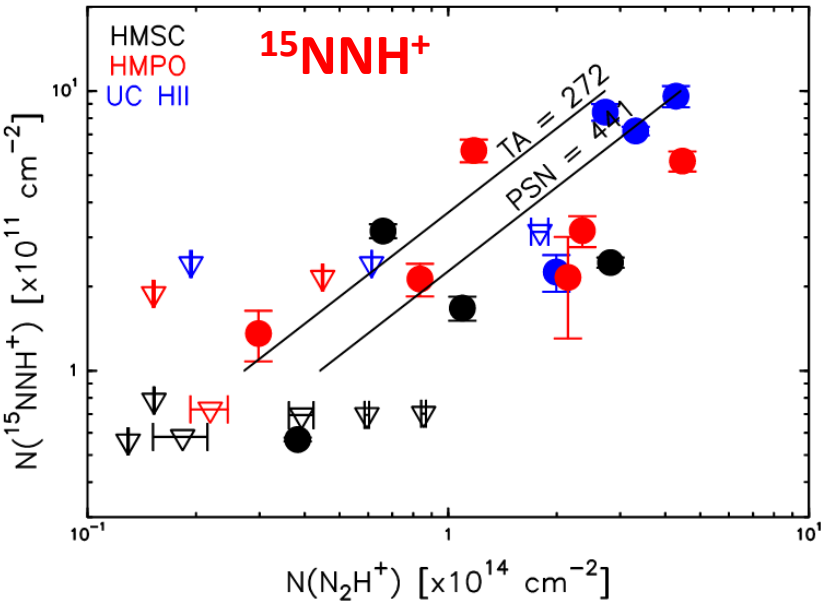
ii. YES infrared; YES outflows; NO 3.6cm
→ High-mass Protostellar Object (HMPO)

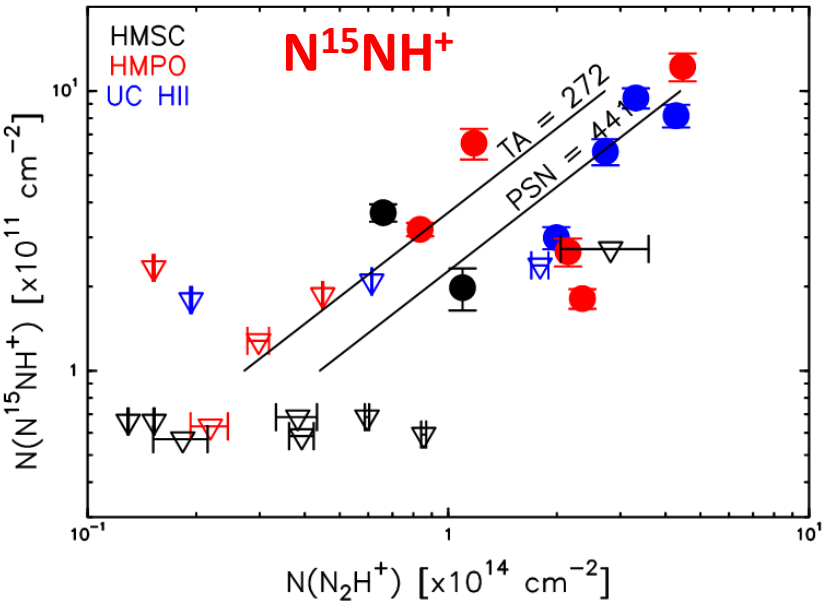
iii. YES infrared; YES/NO outflows; YES 3.6cm
→ UltraCompact HII region (UCHII)

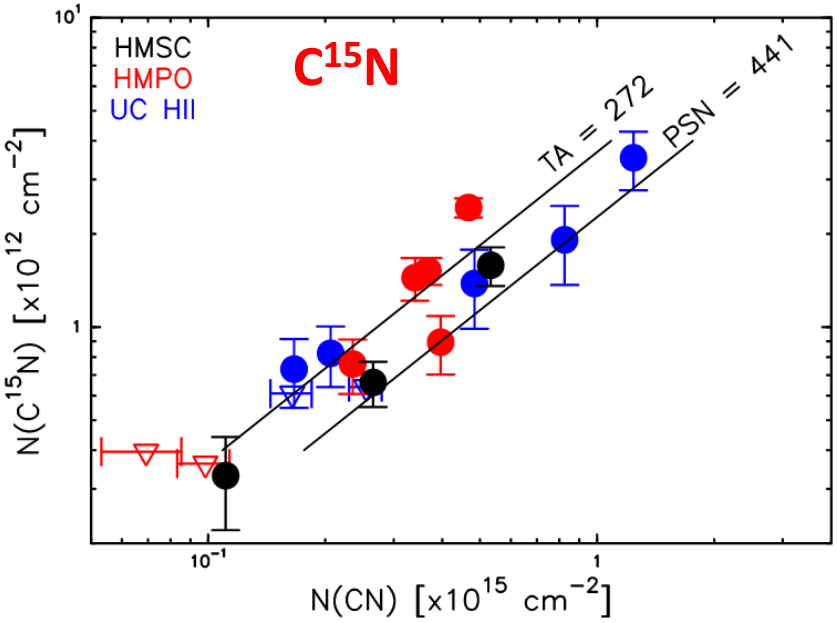
Palau et al. 2010



^{15}N fractionation in massive cores: N_2H^+ and CN







Fontani et al., ApJL, 808, 46

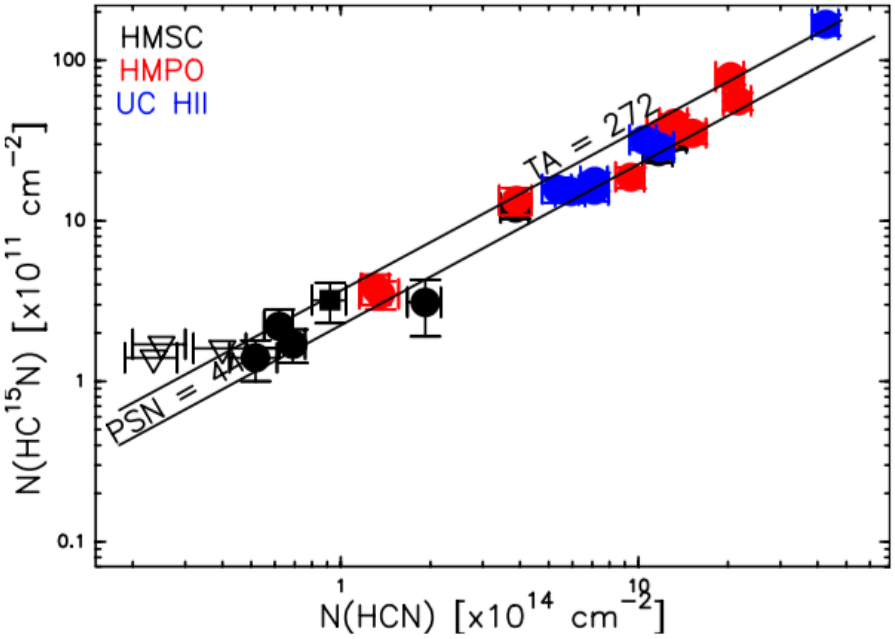
Main results:

1) ***Huge range of $^{14}N/^{15}N$ in N_2H^+***

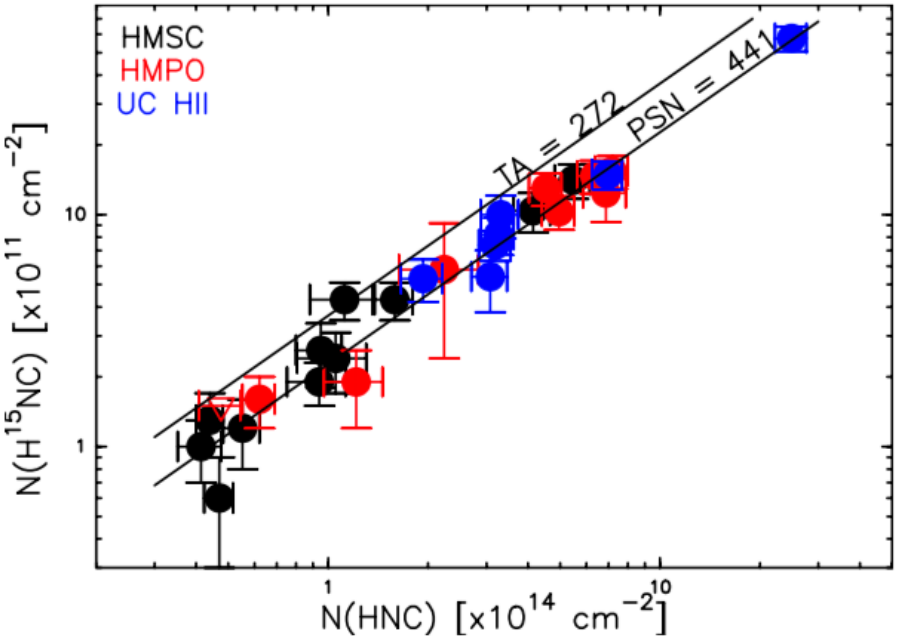
2) NO statistical separation between the evolutionary groups
   → ***time does not seem to play a role in 15N fractionation***

^{15}N fractionation in massive cores: HN^{13}C and H^{13}CN

H^{15}NC



HC^{15}N



Colzi et al., A&A in press, arXiv:170904237

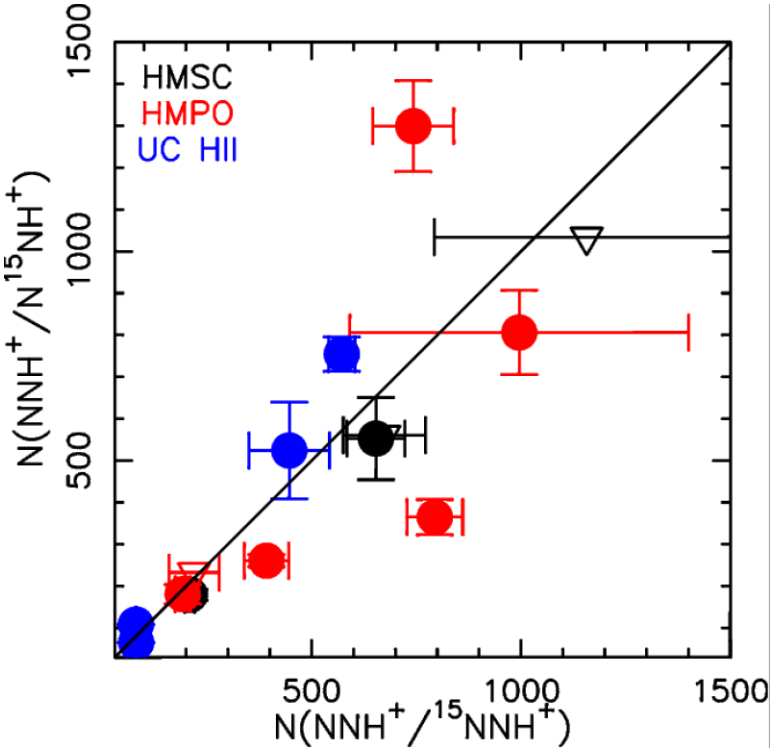
1) ***Smaller spread of ^{14}N/^{15}N in HCN***

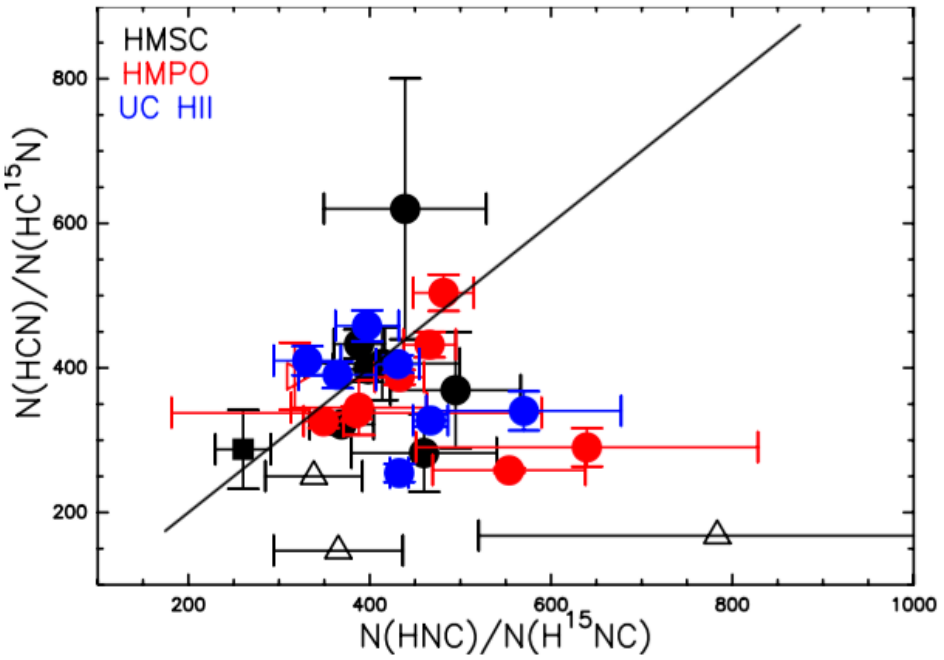
2) NO statistical separation between the evolutionary groups
   → ***time does not seem to play a role in 15N fractionation even in HCN and HNC***

$^{15}NNH^+$ vs $N^{15}NH^+$

$H^{15}NC$ vs $HC^{15}N$

Colzi et al. 2017, A&A in press





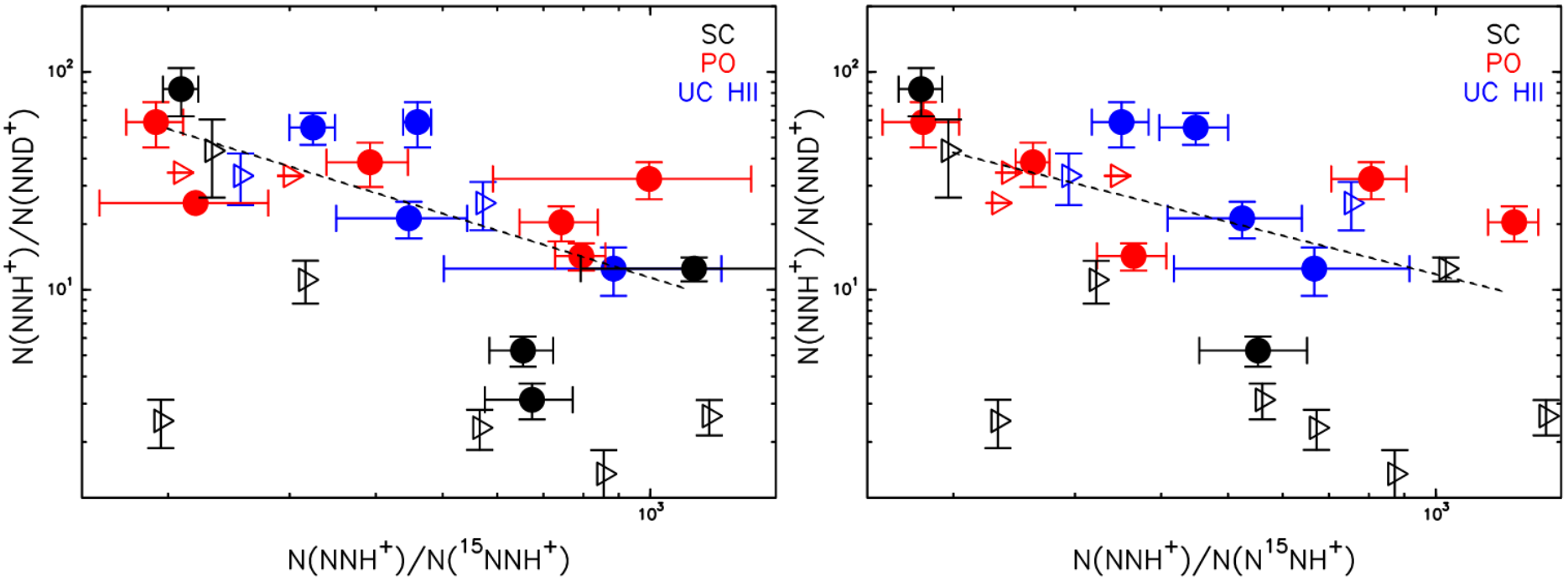
1) ***$^{14}N/^{15}N$ are not the same in all objects in N_2H^+***

2) ***$^{14}N/^{15}N$ are not the same in all objects in HCN and HNC***

→ ***different fractionation pathways (even for N_2H^+ !?)***

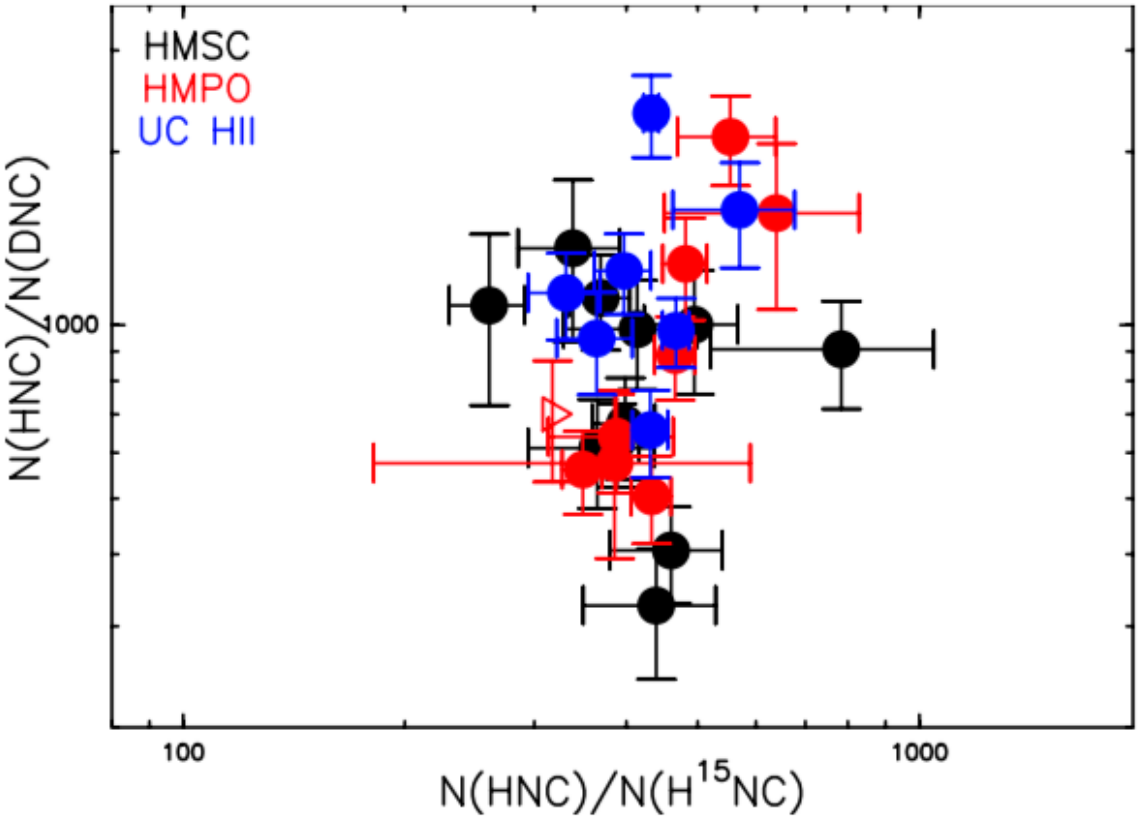
H/D vs $^{14}N/^{15}N$ fractionation in N_2H^+

Fontani et al., ApJL, 808, 46



NO statistical separation between HMSCs / HMPOs / UCHIIs,
But overall **faint anti-correlation (similar to L1544!!)**:
Spearman's ρ ~ -0.5
Kendall's τ ~ -0.6

H/D vs $^{14}N/^{15}N$ fractionation in HNC



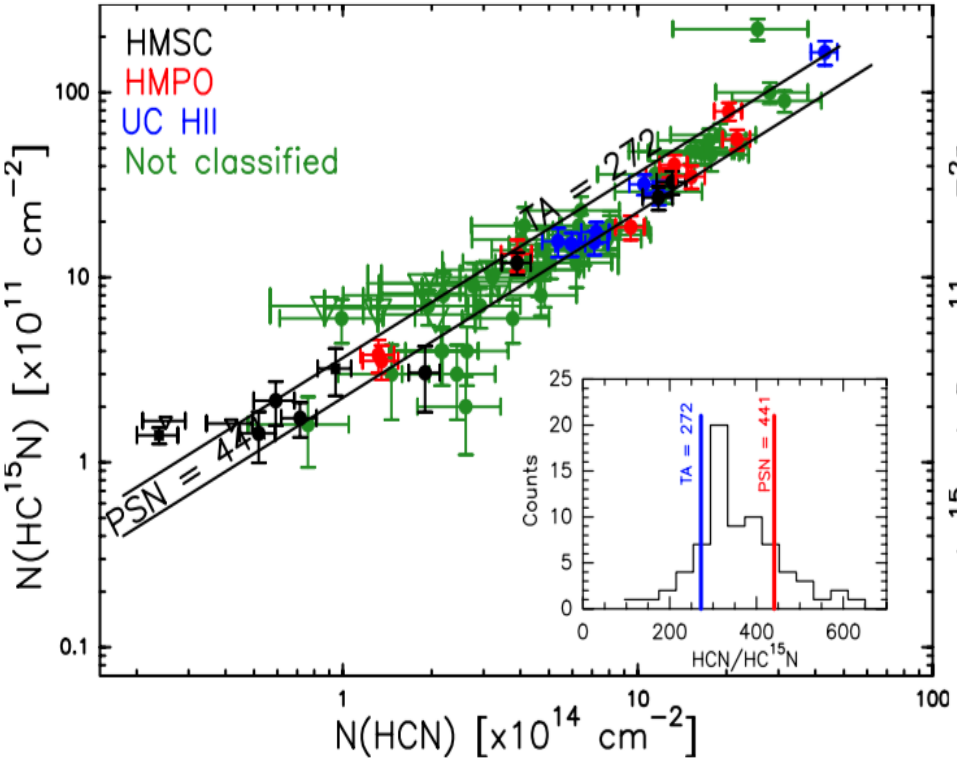
Colzi et al., A&A in press

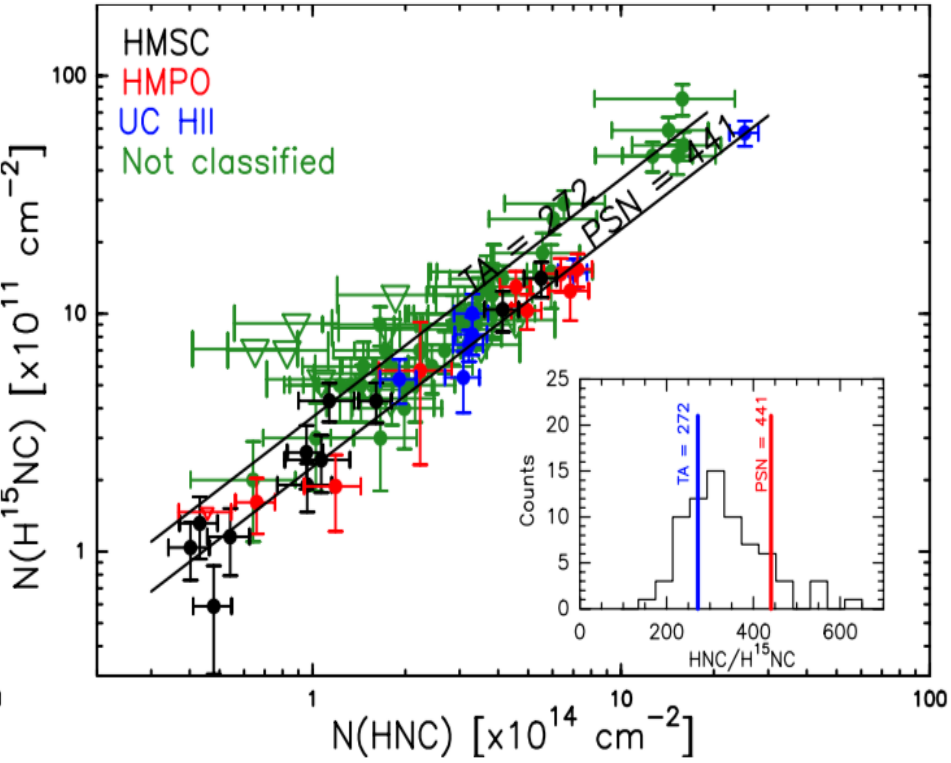
NO statistical separation between HMSCs / HMPOs / UCHIIs,
And **NO (anti-)correlation**:

^{15}N fractionation in massive cores: The extended sample

60 new massive dense cores (not classified yet…)

Colzi, Fontani, et al. In prep.



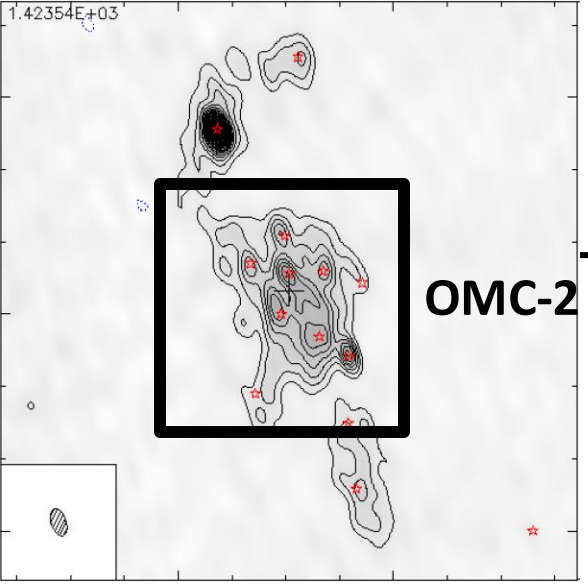


1) ^{14}N/^{15}N ~ 180 – 555 from HNC

2) ^{14}N/^{15}N ~ 115 – 810 from HCN

3) Asymmetric distribution, with peak close to the TA value…

$^{14}N/^{15}N$ in OMC-2 FIR4:
An environment analog to that in which the Solar system was born….

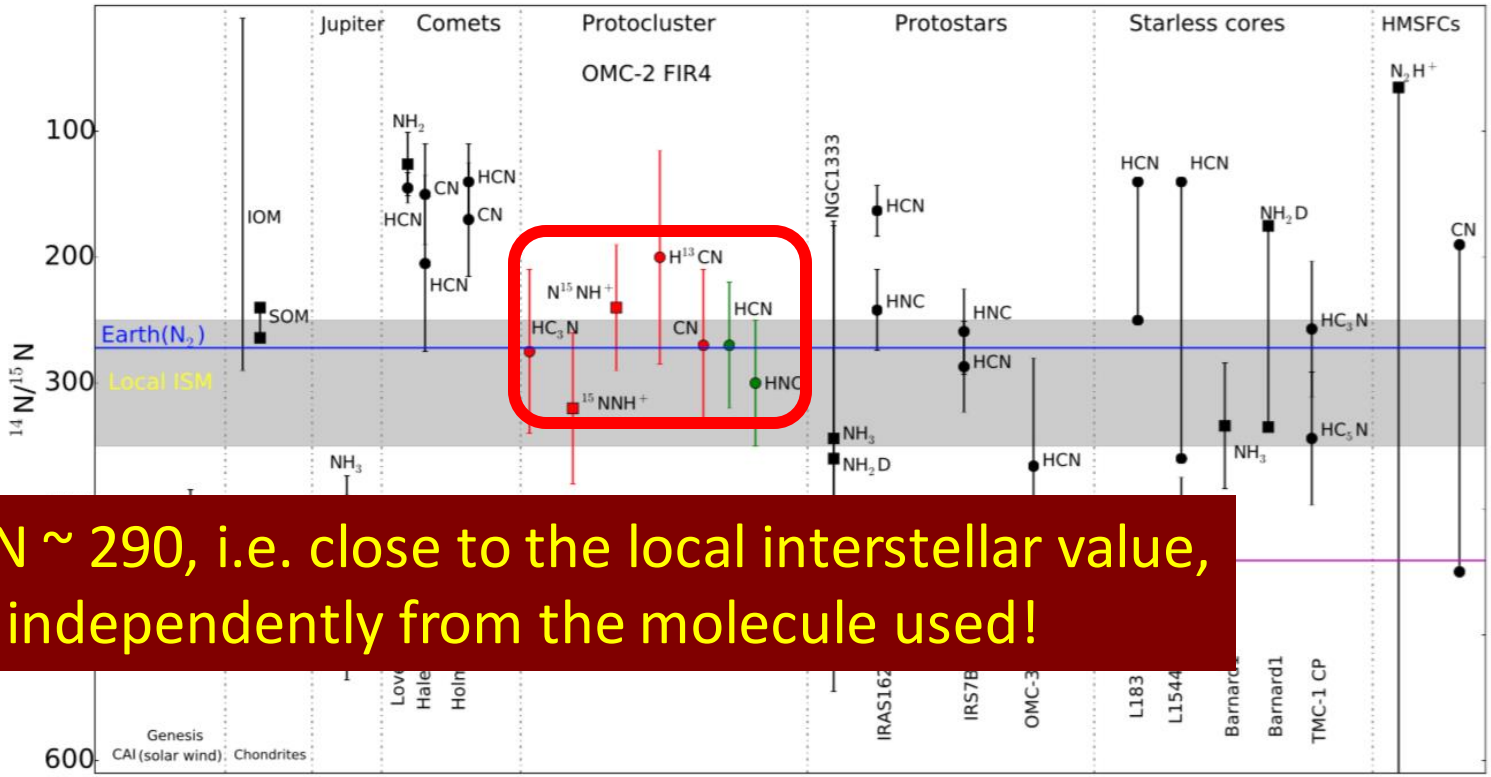


OMC-2 FIR4

Kahane et al., submitted to ApJ
(adapted from Hily-Blant+2013)

Neri+, in prep.

THE $^{14}N/^{15}N$ RATIO IN OMC-2 FIR4



$^{14}N/^{15}N$ ~ 290, i.e. close to the local interstellar value, independently from the molecule used!

Summary and conclusions

1) ^{15}N clearly not enriched at the dense core stage → is enrichment in comets and disks a "local" process?

1) No (clear) relation between H/D and $^{14}N/^{15}N$

2) Huge range in $^{14}N/^{15}N$ (100-1000), and differences in isomers: still mysterious…

4) A new galactic gradient (based on a huge statistics!) points to differences with nucleosynthesis models