Nitrogen: Dark Clouds Chemistry and Fractionation

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Isotopic Ratios in the Solar System

Mumma & Charnley 2011 ARAA
Manfroid et al. 2009

- $^{12}\text{C}/^{13}\text{C}$: $91 \pm 4 \approx \text{Cosmic abundance ratio for C}$
- $^{14}\text{N}/^{15}\text{N}$: $148 \pm 6 \neq 440$
The ISM-SS connection

Charnley & Rodgers 2002

C & O-bearing species depletion
Measurements in dark clouds

Ikeda+02, Fouchet+06, Bockelée-Morvan+08, Gerin+09, Bonal+09, Manfroid+09, Lis+10, Bizzocchi+11, Marty+11
1. Does fractionation take place in dark clouds?

2. How does it relate with isotopic ratios in cosmomaterials?

3. To which extent, did the presolar nebula inherit its chemical composition from the dark cloud?
Cold (10K), dense ($10^4 \text{ cm}^{-3}$), UV-shielded
Observations of Nitrogen Fractionation

Observations of dark clouds

Tafalla et al. 2004
Observations of Nitrogen Fractionation

Observations of HCN/HC\textsuperscript{15}N

\[ 140 \leq \text{HCN}/\text{HC}\textsuperscript{15}N \leq 360 \]
Observations of Nitrogen Fractionation

$\frac{\text{CN}}{\text{C}^{15}\text{N}} = 500 \pm 75$

Hily-Blant+13, submitted to A&A
Comparisons to gas-phase models

- Updated/Upgraded nitrogen chemical network from Flower & Pineau des Forêts
  *Rist et al 2013, Le Gal’s poster*

- Time-dependent; no depletion; pure gas-phase

- Constant density ($10^{14}$ cm$^{-3}$) and temperature ($T_{\text{kin}}=10$K)

- Fractionation (ion-neutral) reactions from Terzieva & Herbst 2000
Comparisons to gas-phase models

enriched HCN and depleted CN simultaneously
Comparisons to Solar System ratios

Fractionation of nitriles in comets $\approx$ dark clouds

Hily-Blant+13, Icarus
Modelling

Two distinct families

Herbst & Klemperer 1973, Pineau des Forêts et al 90
Hily-Blant et al 2013, Icarus

N-hydrides (unaffected) & Nitriles ($^{15}\text{N}$-enriched)
Summary

- Similar HCN fractionation in dark clouds and comets
- Non-fractionated CN in dark clouds:
  - Gas-phase models reproduce both facts

Perspectives

- Nitrogen isotopic ratio in other nitriles (e.g. HC$_n$N)
- N$_2$H$^+$ fractionation issue
- CN daughter molecule of HCN in comets?
- Measurements of NH$_3$ in dark clouds, and comets
- Isotopic ratio in protoplanetary disks
Thank you
$^{14}\text{N} : ^{15}\text{N}$ accross the Milky Way

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