

First Detections of Ethyl Formate and n-Propyl Cyanide*

Dust-grain chemistry strikes again

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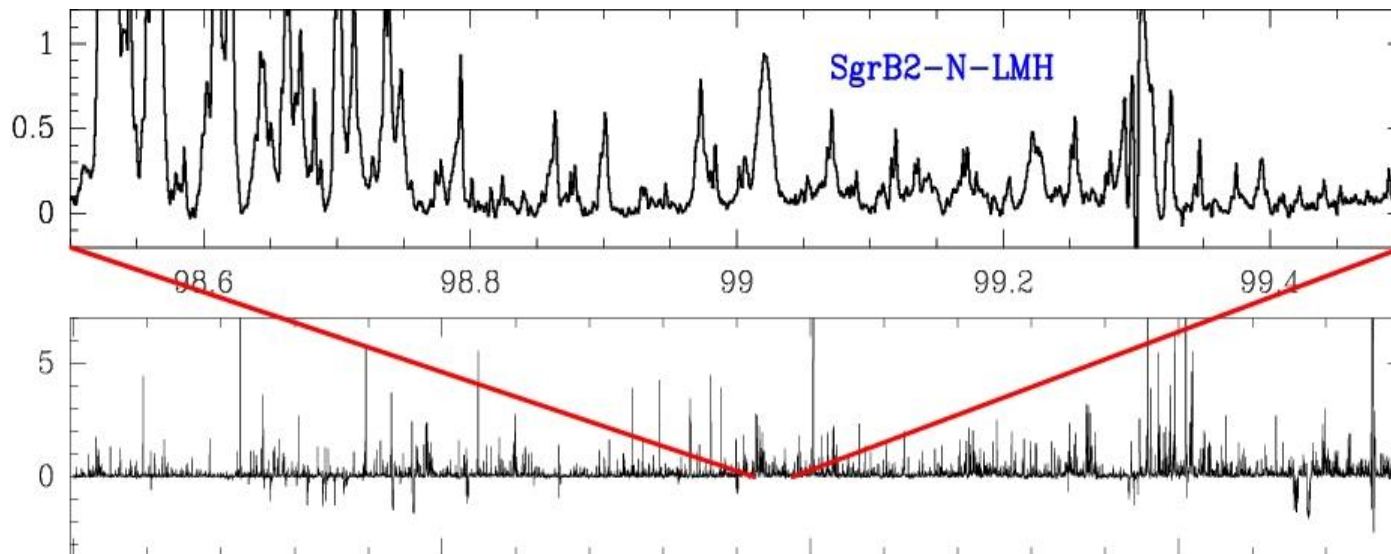


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*Belloche, A., Garrod, R. T., Müller, H. S. P.,
Menten, K. M., Comito, C. & Schilke, P.
2009, *A&A*, *in press*, *ArXiv: 0902.4694*

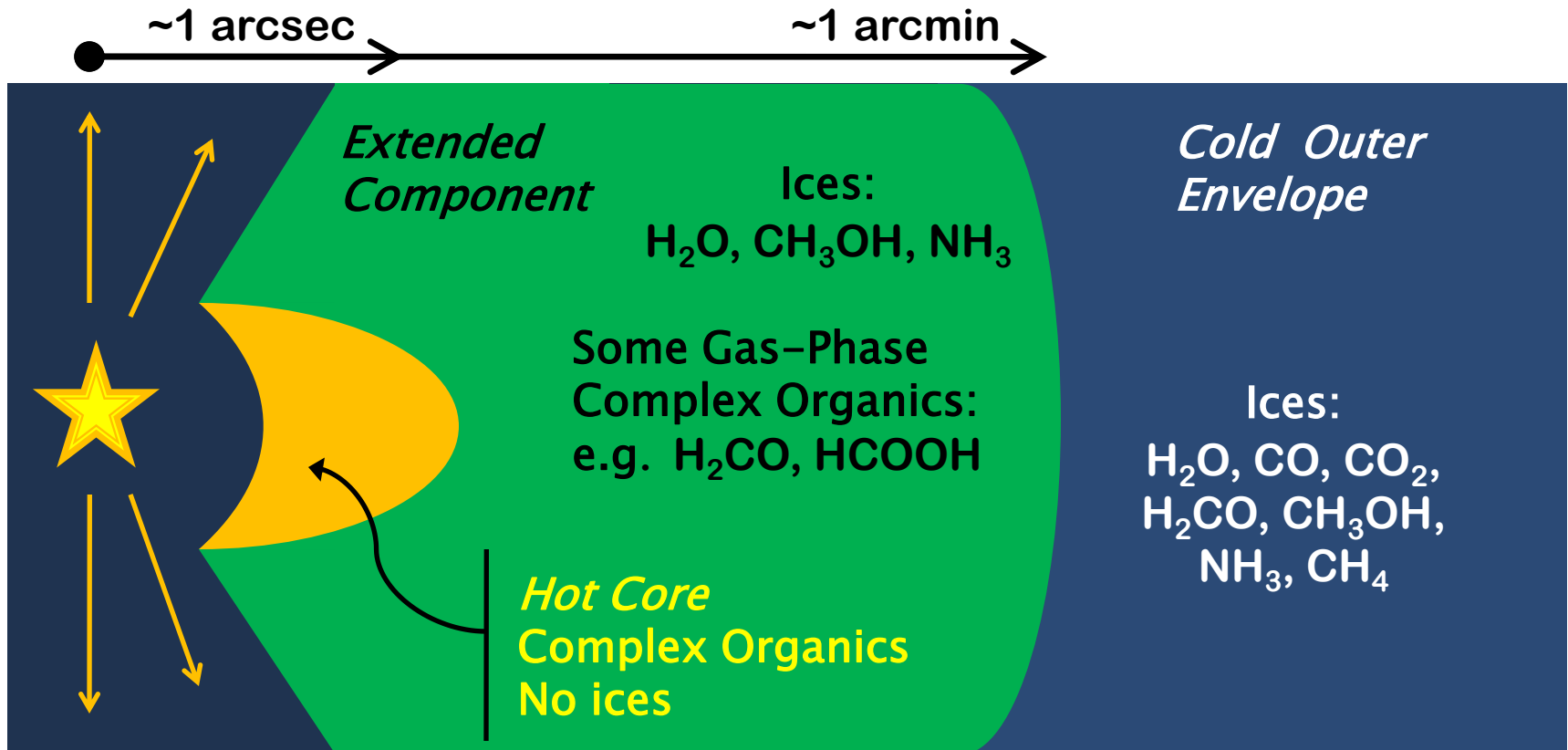
Hot Cores

- ▶ Star-forming regions (typically high-mass)
- ▶ Hot (>100 K), dense gas ($\sim 10^7$ cm $^{-3}$)
- ▶ Rich mm, sub-mm spectra



Belloche et al. 2008

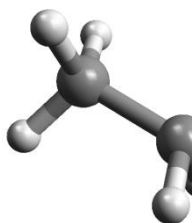
Hot Core Structure



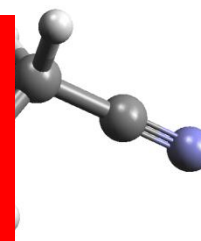
Detection and spectral analysis

- ▶ IRAM 30m telescope \Rightarrow Sgr B2N (LMH)
- ▶ 3mm, 1.3mm surveys + some 2mm spectra
- ▶ ~ 3600 lines detected
- ▶ Spectra modelled using XCLASS software:
 - Produce synthetic spectrum for all known interstellar species (assume LTE, non-interacting)
 - Subtract out spectra \Rightarrow FIND WEAKER LINES

Ethyl Formate
 $\text{CH}_3\text{CH}_2\text{OCHO}$



n-Propyl Cyanide
 $\text{CH}_3\text{CH}_2\text{CH}_2\text{CN}$



Next stage of
complexity in each
class of molecule

- ▶ Ester
- ▶ *Anti*-conformer found
- ▶ 24 lines (80–116 GHz)
- ▶ *No missing lines*

▶ Already detected:
 CH_3OCHO

- ▶ Alkyl cyanide / Nitrile
- ▶ *Anti*-conformer found
- ▶ 12 lines (80–116 GHz)
- ▶ *No missing lines*

▶ Already detected:
 CH_3CN
 $\text{CH}_3\text{CH}_2\text{CN}$
(CH_2CHCN)

Spectral fitting parameters

(main velocity component)

	Name	Size (arcsec)	T _{rot} (K)	N (cm ⁻²)	Abundance Ratio (scaled to 3")
C ₂ H ₅ OCHO	ethyl formate	3	100	5.4e+16	1
CH ₃ OCHO	methyl formate	4	80	4.5e+17	15
t-HCOOH	formic acid	5	70	1.5e+16	0.8
C ₃ H ₇ CN	n-propyl cyanide	3	150	1.5e+16	1
C ₂ H ₅ CN	ethyl cyanide	3	170	1.2e+18	80
CH ₃ CN	methyl cyanide	2.7	200	2.0e+18	108

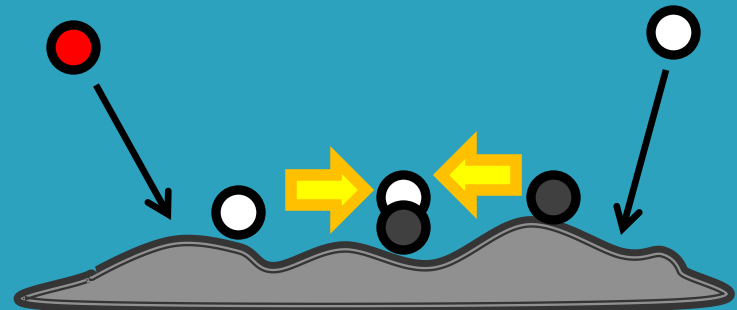
How are **complex** molecules formed?

1) Gas-phase only

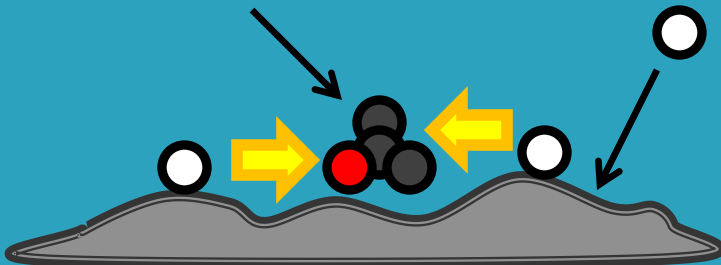
E.g. Horn et al.
(2004)

A diagram showing a grey, wavy surface representing a grain. Above it, a red 'X' is drawn over a small molecular structure. The text 'E.g. Horn et al. (2004)' is written in red over the 'X'.

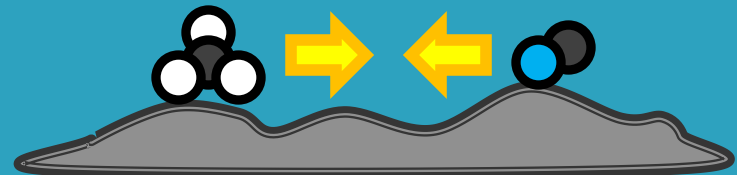
2) Grains: Atom-by-atom



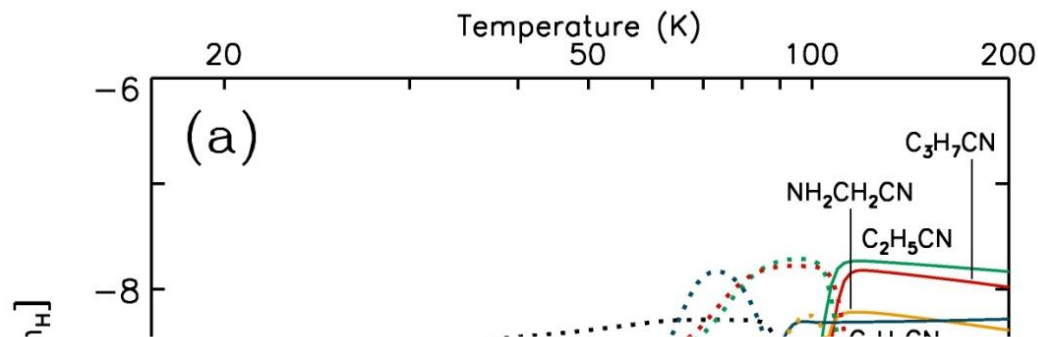
3) Gas-phase backbone
+ hydrogenation on grains



4) Grains: Radical addition
(radicals from ices)



Garrod & Herbst (2006)
Garrod et al. (2008)

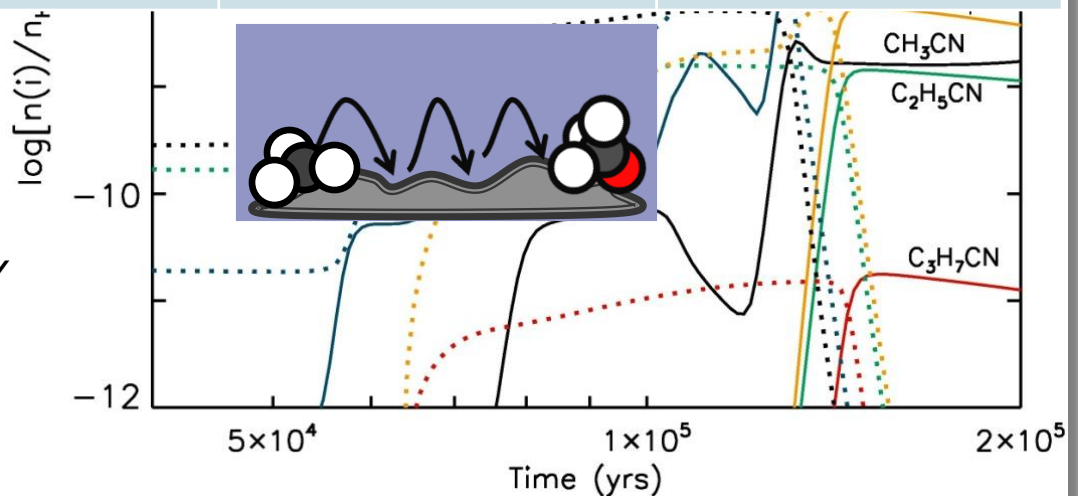


All surface mechanisms

Molecular Ratios	All surface mechanisms	Simple-radical addition <i>only</i>	Observed
n-propyl cyanide	1	1	1
ethyl cyanide	1.3	82	80
methyl cyanide	0.18	171	108

*Fully-coupled gas-grain
Chemical models*

Simple-radical addition *only*



Chemical model results

- ▶ Dust–grain chemistry is *sufficient!*
- ▶ Reproduce ratios with smaller relatives
- ▶ Sequential formation: *one (methyl) group at a time*
- ▶ Hydrogenation of gas–phase backbone does not fit
- ▶ Atom–by–atom formation does not fit
- ▶ Amino acetonitrile ($\text{NH}_2\text{CH}_2\text{CN}$) also well reproduced

Implications

- ▶ No apparent size limit for organic molecules
- ▶ Expect many more very complex molecules to be present, if they can be detected
- ▶ Complexity of 2 new molecules
 \approx complexity of Glycine ($\text{NH}_2\text{CH}_2\text{COOH}$)
- ▶ Amino acids... other pre-biotics/biotics

ALMA!



Thanks



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Stiftung / Foundation

IRAM

Ethyl formate spectroscopy:
The Ohio State University
(Medvedev et al., 2009, ApJ, 181, 433)

Molecule diagrams:
Oliver Baum (University of Cologne)