Complex organic chemistry around high-mass protostars

Maria Drozdovskaya\textsuperscript{1}

J.C. Tan, Y. Zhang, R. Visser, C. Walsh

E. F. van Dishoeck, K. Furuya, U. Marboeuf, A. Thiabaud, D. Harsono

\textsuperscript{1}Leiden University

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CSH Fellow, University of Bern

From Stars to Massive Stars
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Complex organics (6+ atoms, C-bearing) are prebiotically significant.

How is the chemical complexity of star- and planet-forming regions related to the diversity of exoplanets and the chemical inventory of our Solar System?

When are the ingredients to life implanted into forming planetary systems?
Why is this interesting?

- Complex organics (6+ atoms, C-bearing) are prebiotically significant.
- How is the chemical complexity of star- and planet-forming regions related to the diversity and chemical inventory of our Solar System?
- When are the ingredients to life implanted into forming planetary systems?

What are the chemical properties of high-mass star-forming regions?
Recipes for complex organics

Laboratory experiments
- Methanol & dimethyl ether in hot core G29.96-0.02 by Beuther+ 2007

Observations
- Methanol & dimethyl ether in hot core G29.96-0.02
- glyoxal
- methyl formate
- glycolaldehyde
- ethylene glycol

Theoretical models
- talk F. Fontani

Chuang+ 2016
- Fedoseev+. 2015
- Fuchs+ 2009
- Watanabe+ 2004
- Tielens & Hagen 1982

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“Complex organic chemistry around high-mass protostars”
Grain-surface chemistry

The formation of complex organic molecules on interstellar dust particles

Prof. Ewine F. van Dishoeck

Universiteit Leiden
The Netherlands

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Let’s run some physicochemical models.

any physical model

+ chemical network

2-phase gas-grain; 600+ species; 8000+ reactions

McElroy et al. 2013; Garrod & Herbst et al. 2006; Walsh et al. 2014a, b
Cavity walls of low-mass protostars

Static physical model
power law density distribution
stellar parameters
NGC 1333-IRAS2A as template
Kristensen+ 2010, 2012; Bruderer 2009, 2010; Visser+ 2012

RADMC rad. transfer
Dullemond & Dominik 2004

Run chemistry up to 10^7 yr (after dark core phase)

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Protoplanetary disk midplanes of low-mass protostars

2D, semi-analytic collapse model Visser+ 2009, 2011
+ RADMC-3D* rad. transf.
+ Run chemistry

@ 2.46 \times 10^5 \text{ yr after the onset of collapse}

\[ M_0 = 1 M_\odot; \sim 100+ \text{ traj. per midplane} \]

*http://www.ita.uni-heidelberg.de/~dullemond/software/radmc-3d/

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Hot cores around high-mass protostars

Dynamic protostellar core evolution based on the Turbulent Core Model $M_* = 16 M_\odot; M_c = 60 M_\odot; \Sigma_{cl} = 1 \text{ g cm}^{-2}$


+ Run chemistry @ $1.4 \times 10^4$ yr after the onset of collapse
gaseous complex organics ⇒ hot core recovered on 1000-2000 AU scales

Spatial distribution is species-dependent!

More chemistry: talk S. Kong; posters 30 M. Goodson, 50 S. Doty & 51 B. Bowers

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Low-mass protostars: gaseous complex organics illuminate the cavity walls, while complex organic ices are most abundant in the outer protoplanetary disk midplanes and deeply in the envelopes.

Dynamic infall and the chemistry during transport enhances the abundance of complex organic molecules in the case of low- and high-mass protostars.

High-mass protostars: the hot gaseous complex organics are recovered on the 1000-2000 AU scales in physicochemical models, but the spatial distribution is species-dependent.

Come see my poster #47!

Thank you for your attention!