A new study of the chemical structure of the Horsehead nebula: the influence of grain-surface chemistry

Romane Le Gal
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in Karin Oberg's group

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E. Herbst (UVa), G. Dufour (NASA Goddard),
P. Gratier (LAB), M. Ruaud (NASA Ames),
T. H. G. Vidal (LAB), and V. Wakelam (LAB)

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A&A 605, A88 (2017)
DOI: 10.1051/0004-6361/201730980

Astronomy & Astrophysics

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CfA

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Outline

- **Context**
  - Detection of a wide variety of molecules in the Horsehead nebula
- **Our study**
  - Model developed: gas-grain chemistry
  - Results: comparison with observations

The Horsehead nebula

Credit: ESO

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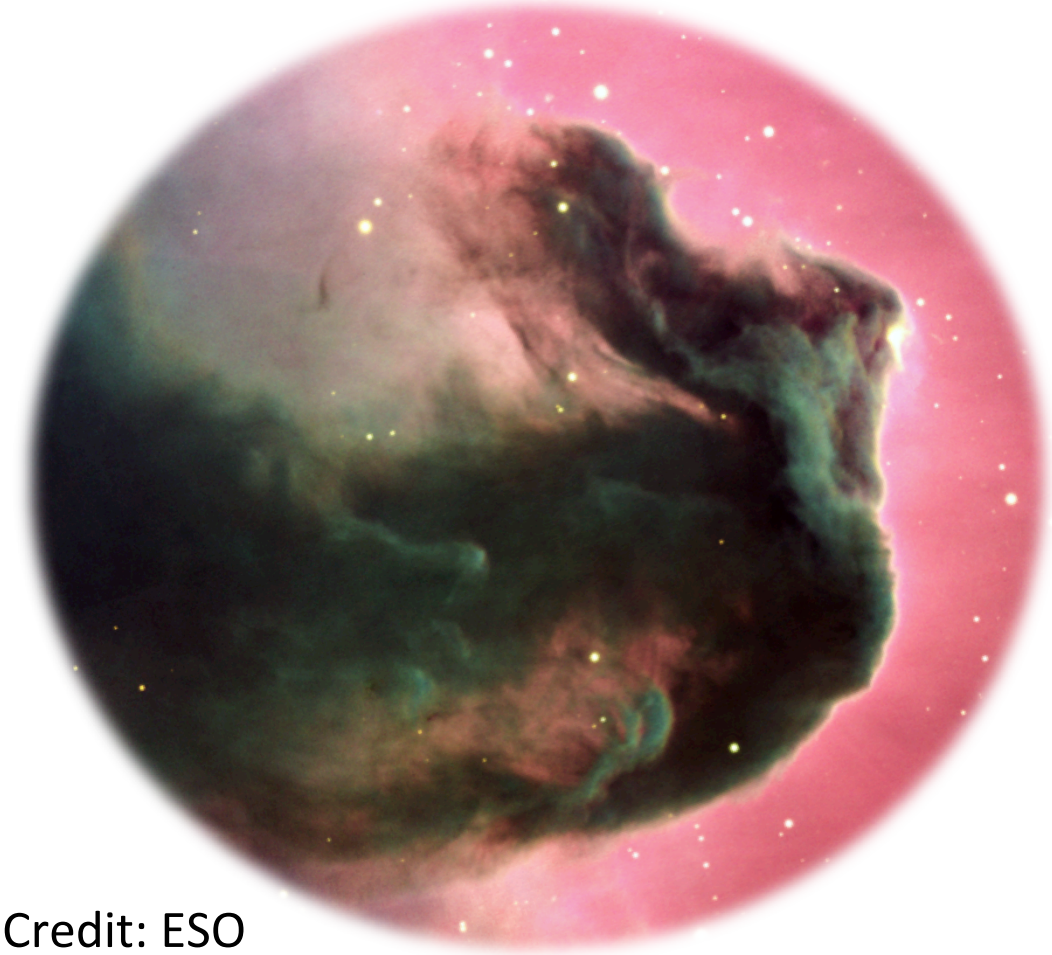

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Nearby ≈ 400 pc (Anthony-Twarog 1982)

Nearly edge-on (Abergel et al. 2003)

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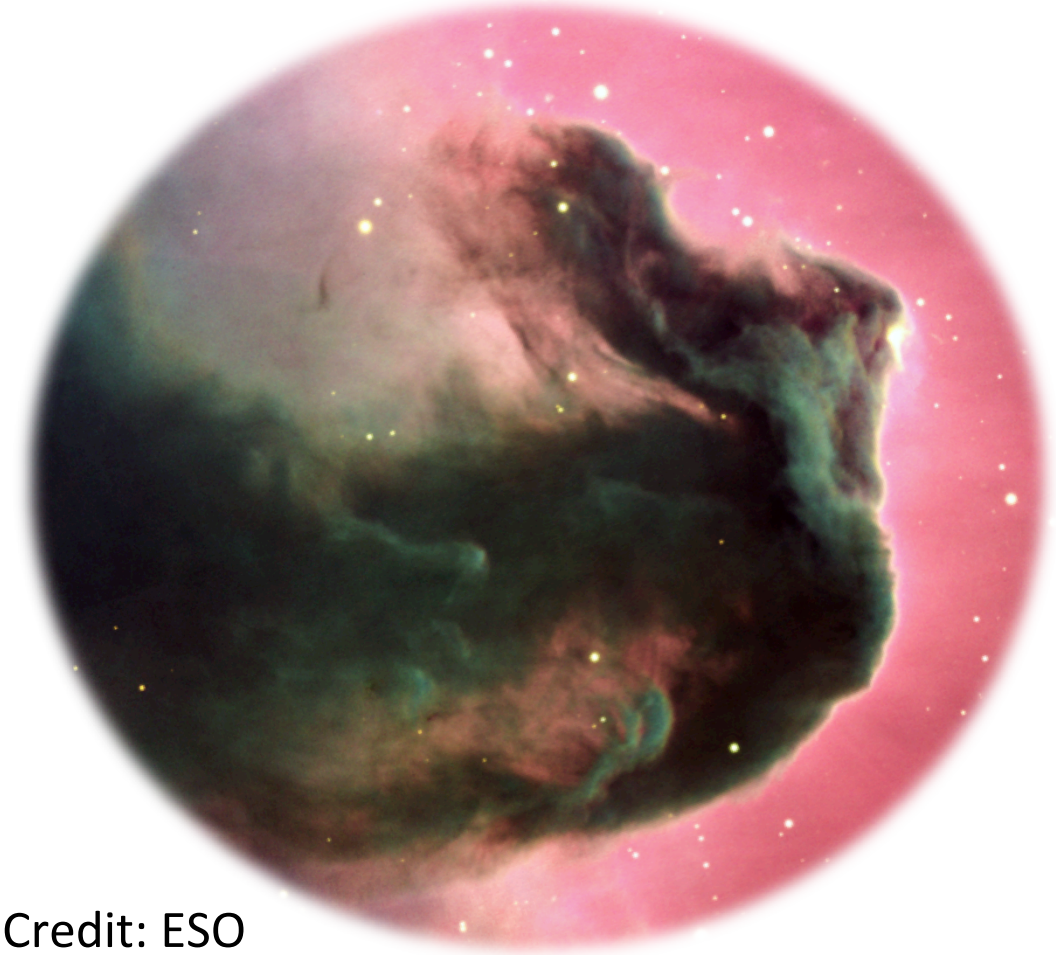

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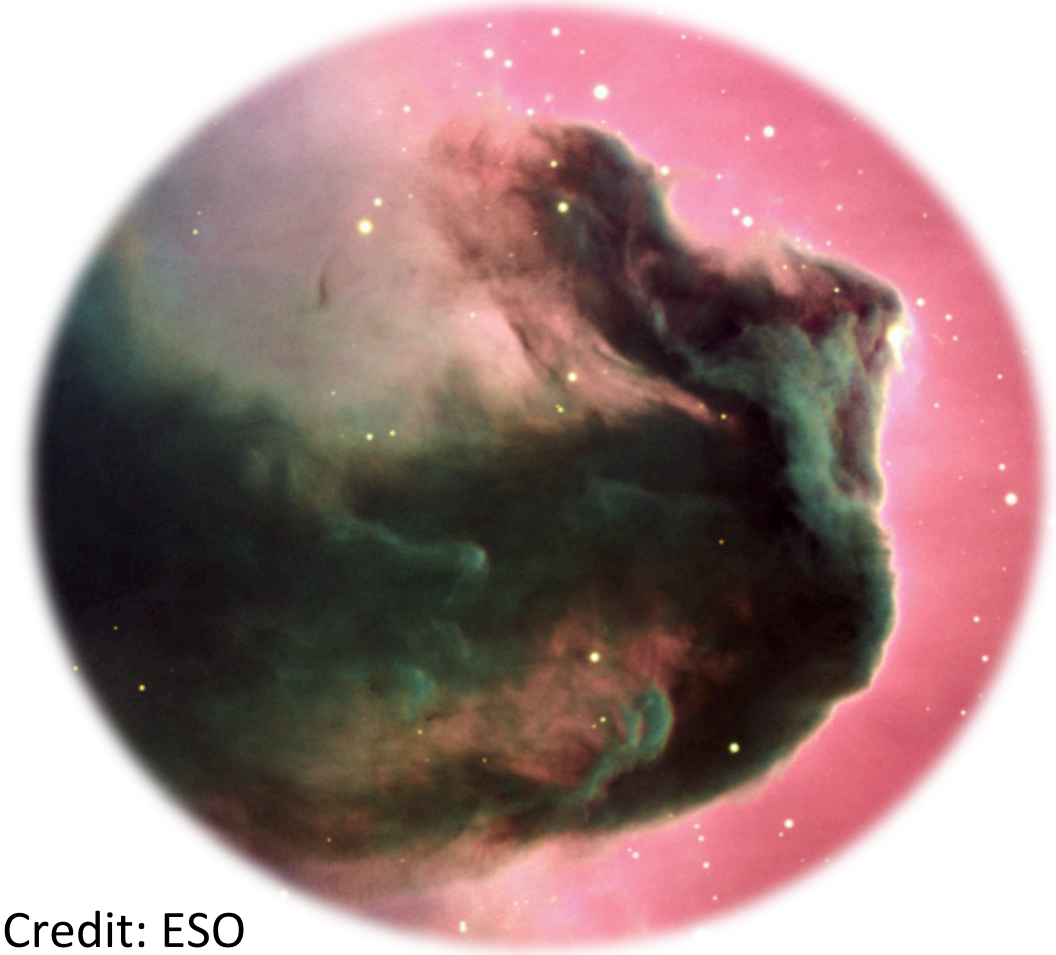

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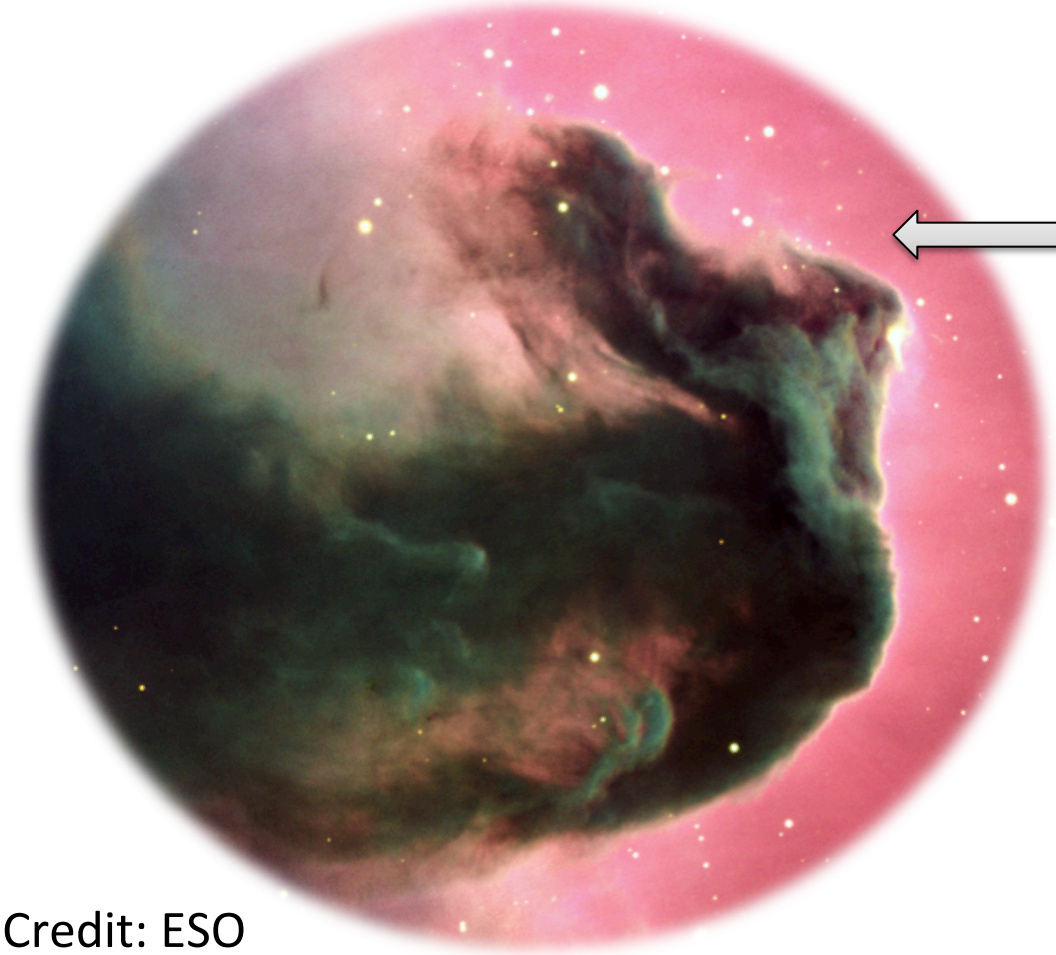

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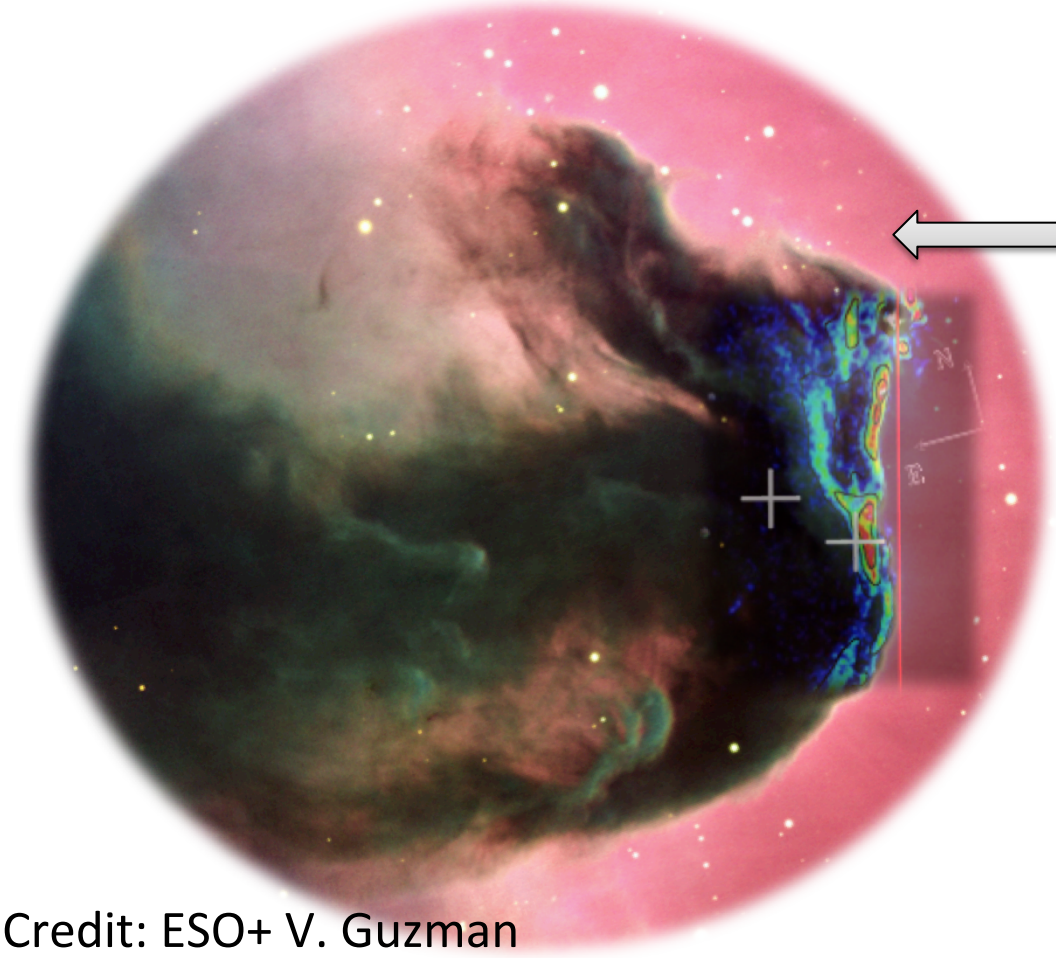

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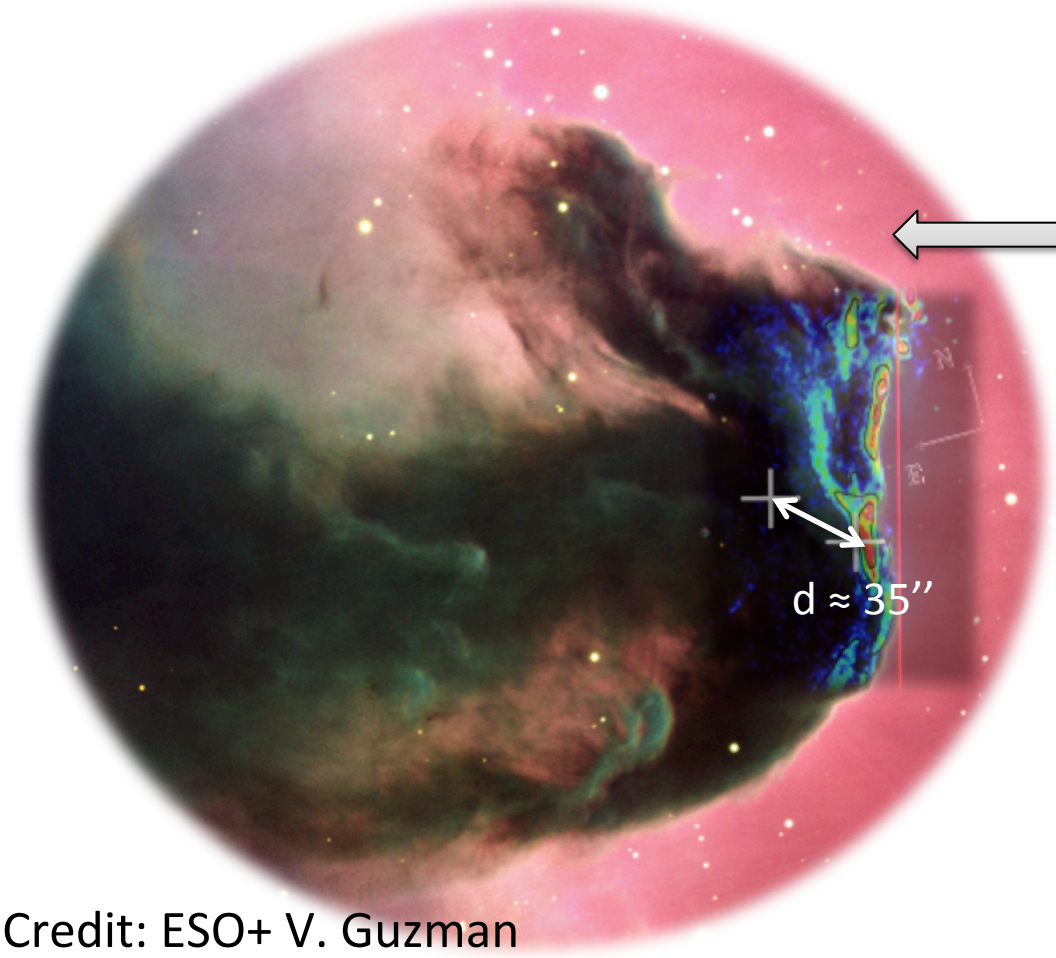

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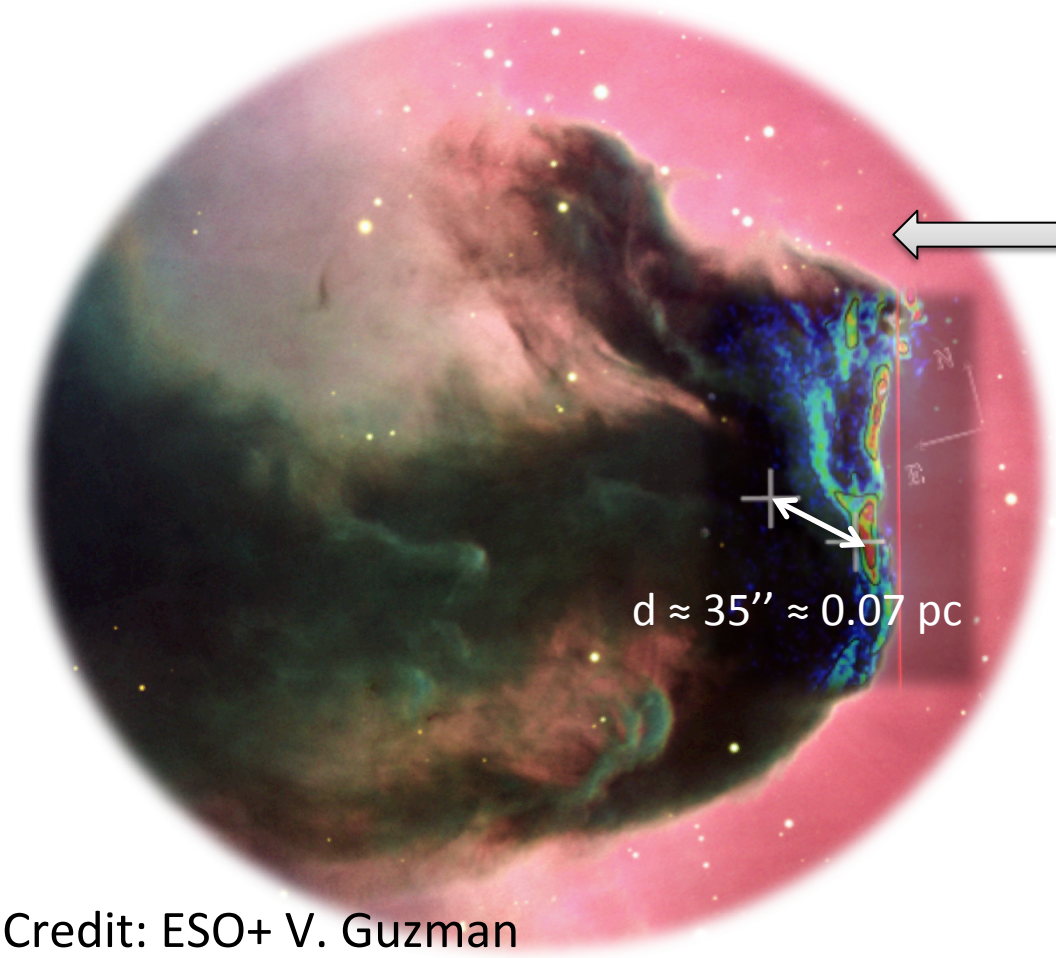

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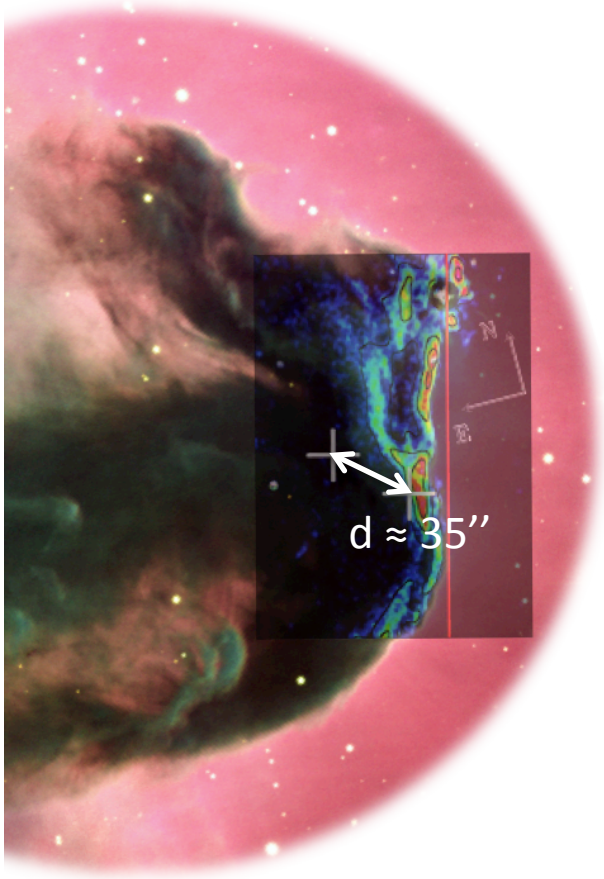
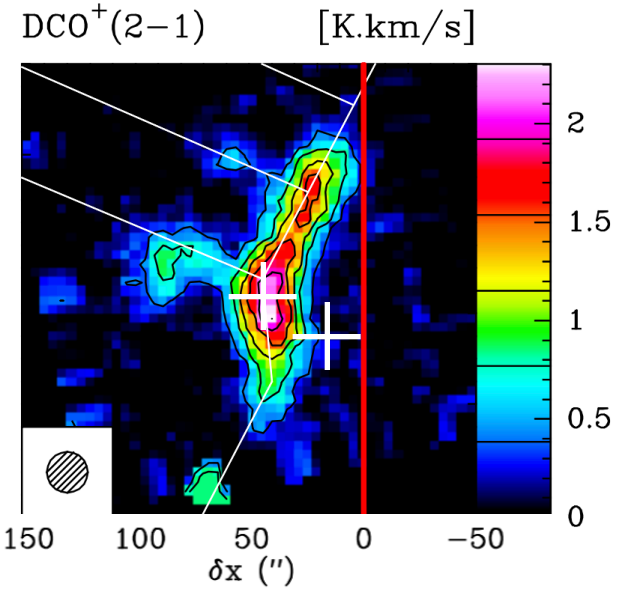
Two distinguishable environments





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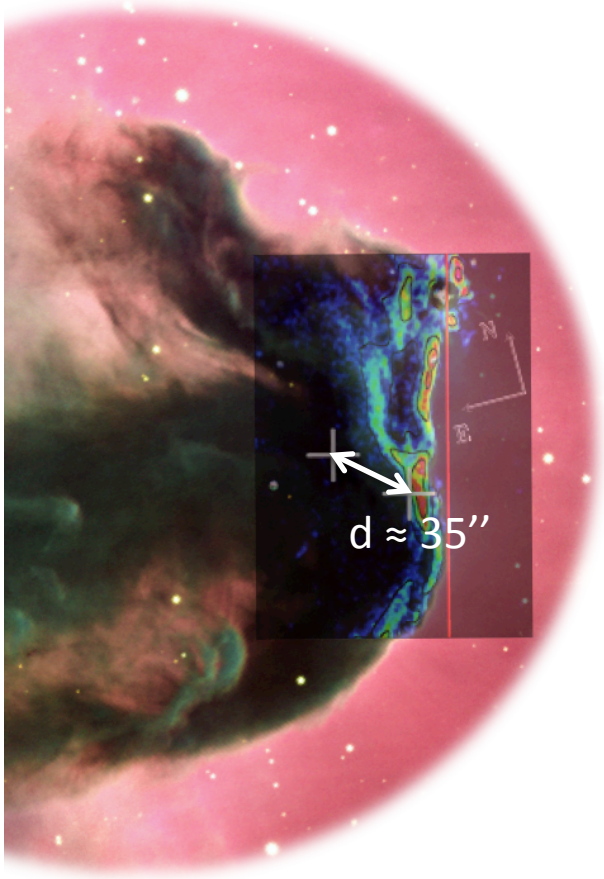

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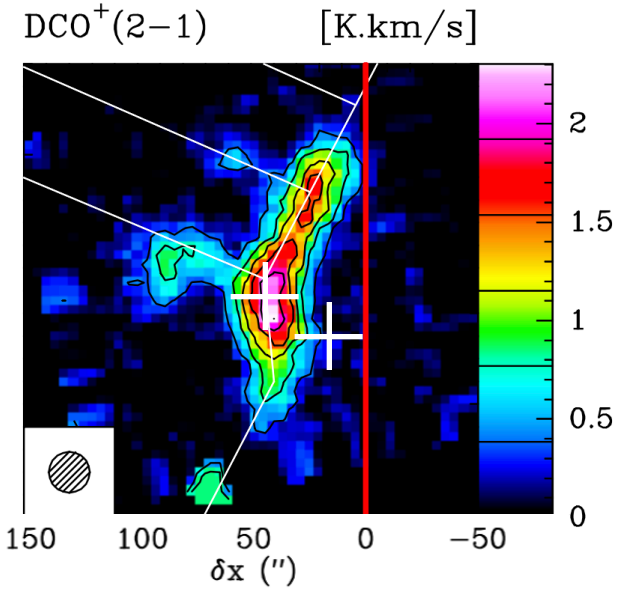

A shielded, dense core (Pety+ 2007)
$T \approx 20$ K

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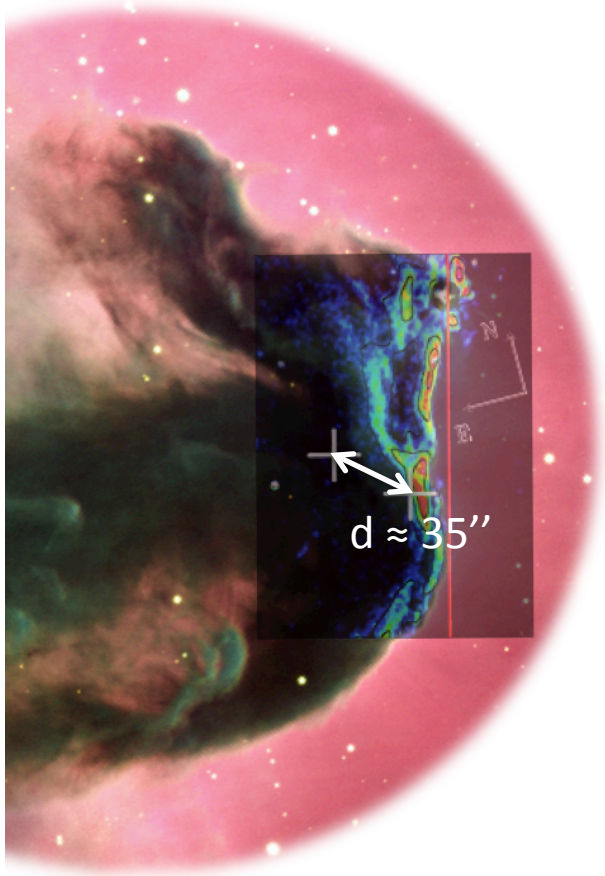

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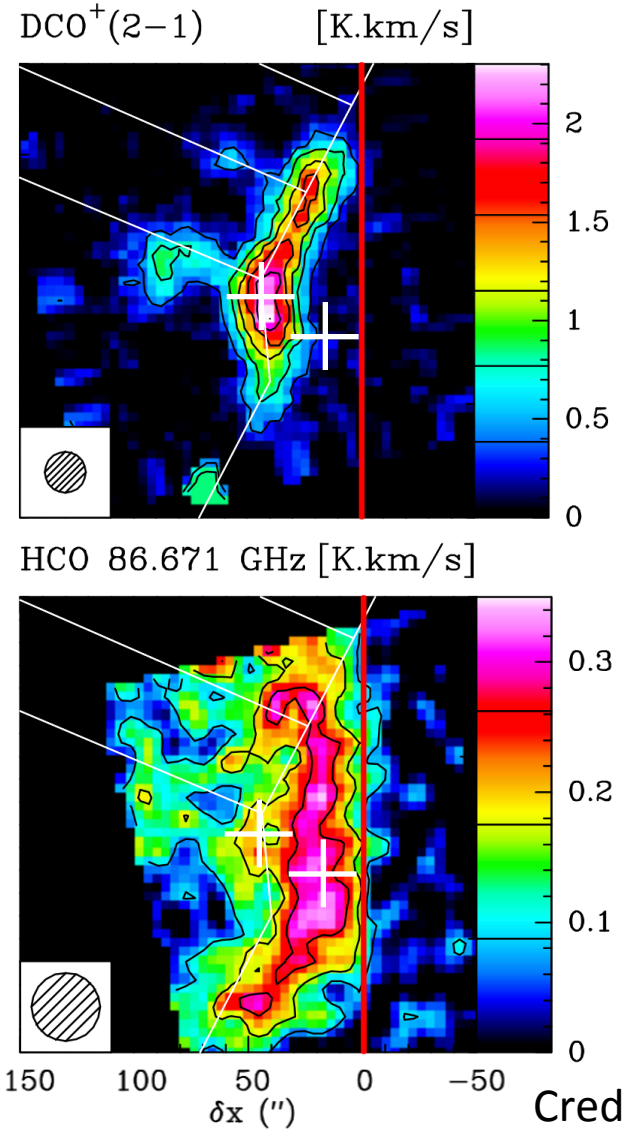

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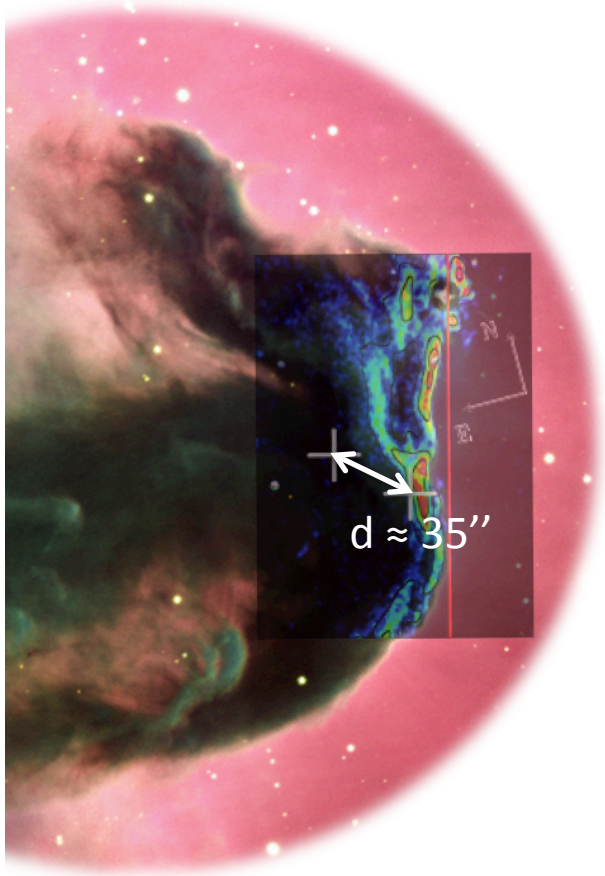

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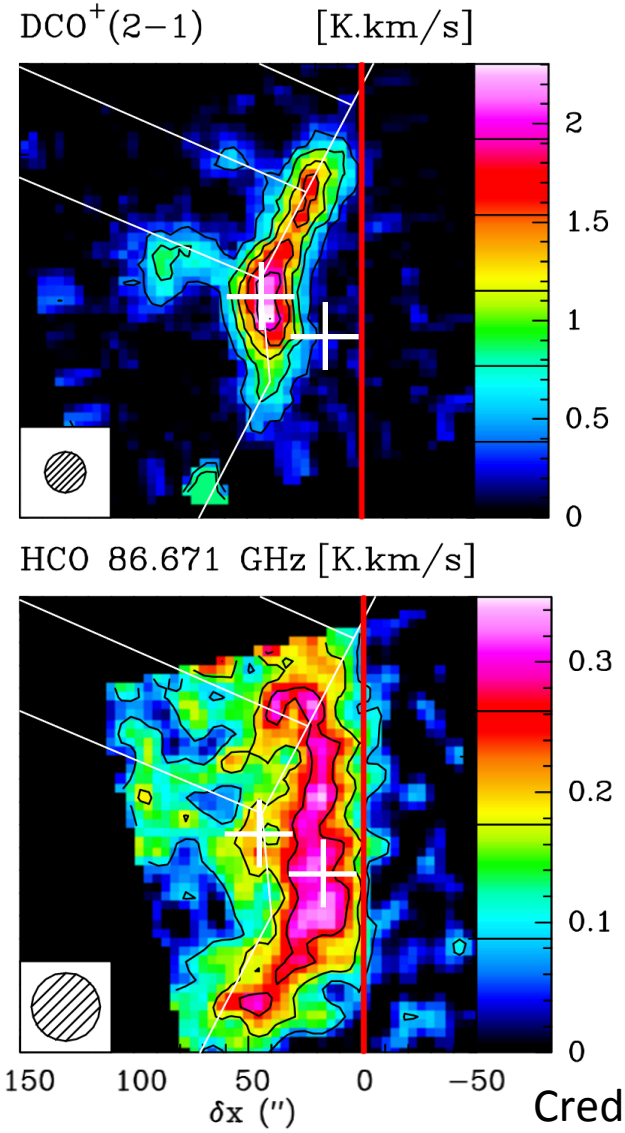

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A far-UV illuminated PDR (Gerin+ 2009)
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- Two positions observed with the IRAM 30 m telescope

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Organic molecules and precursors	Nitriles	Small hydrocarbons	F-bearing molecules
HCO	CH_3CN	CCH	CF^+
H_2CO	HC_3N	$l-C_3H$	
CH_3OH	C_3N	$c-C_3H$	
HCOOH		$l-C_3H_2$	
CH_2CO		$c-C_3H_2$	
CH_3CHO		$l-C_3H^+$	
CH_3CCH			

A new astrochemical model

- **Context**
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chemical evolution during 1e6 yr of a starless dense cloud with Nautilus (Ruaud+2016)

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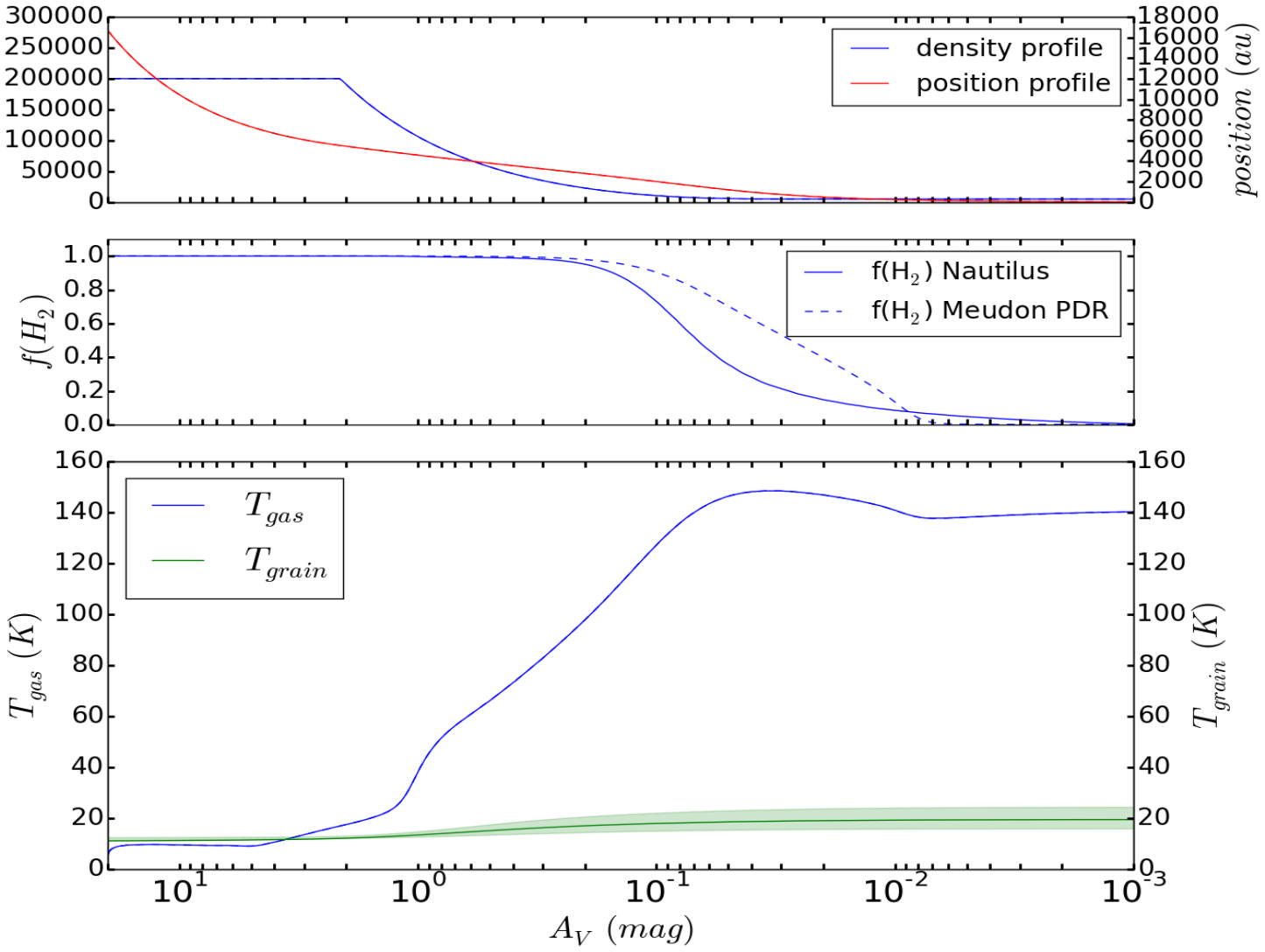
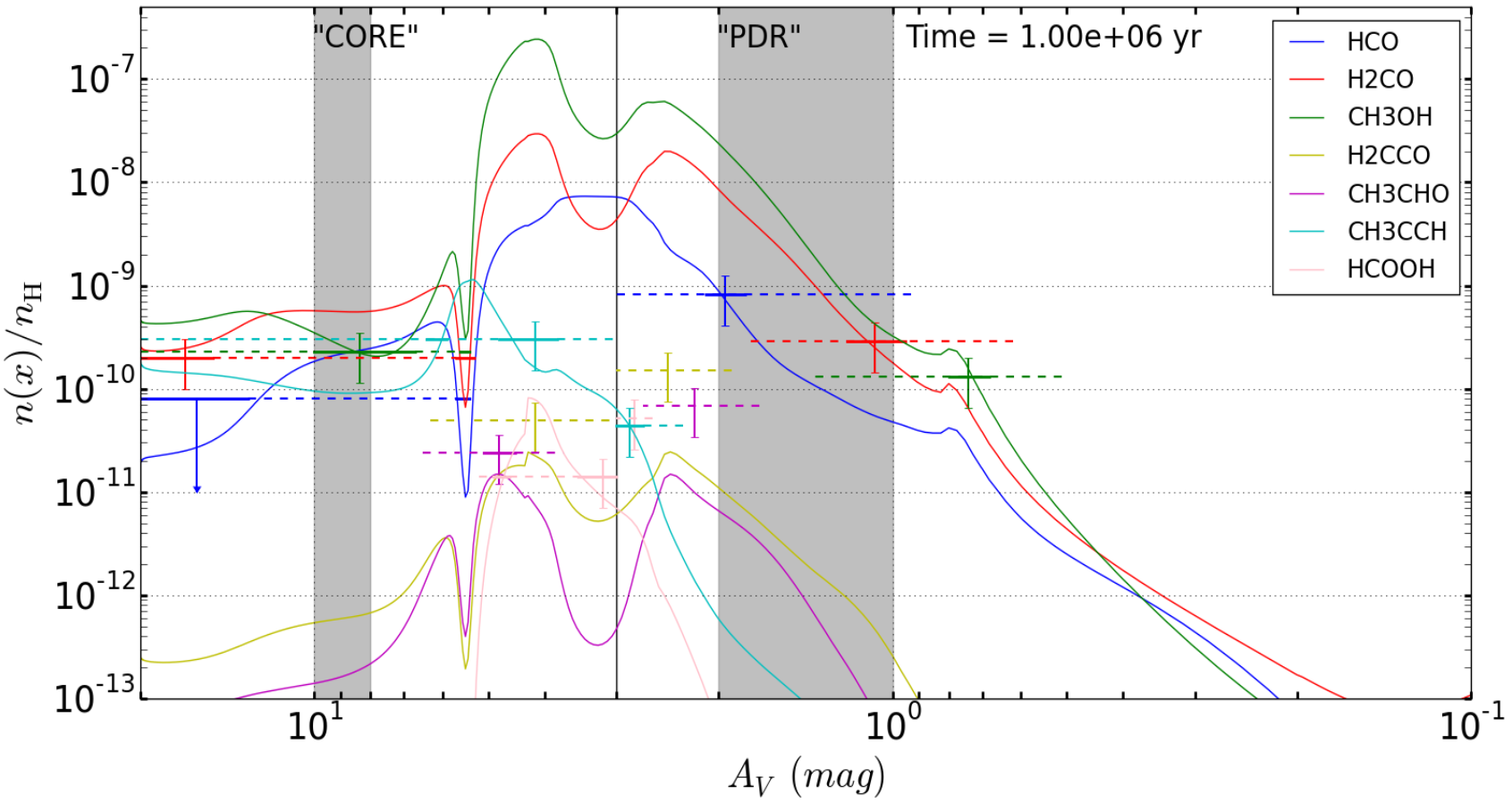


Le Gal et al., A&A 605, A88 (2017)

Results: modeled abundances *vs* observations (I)



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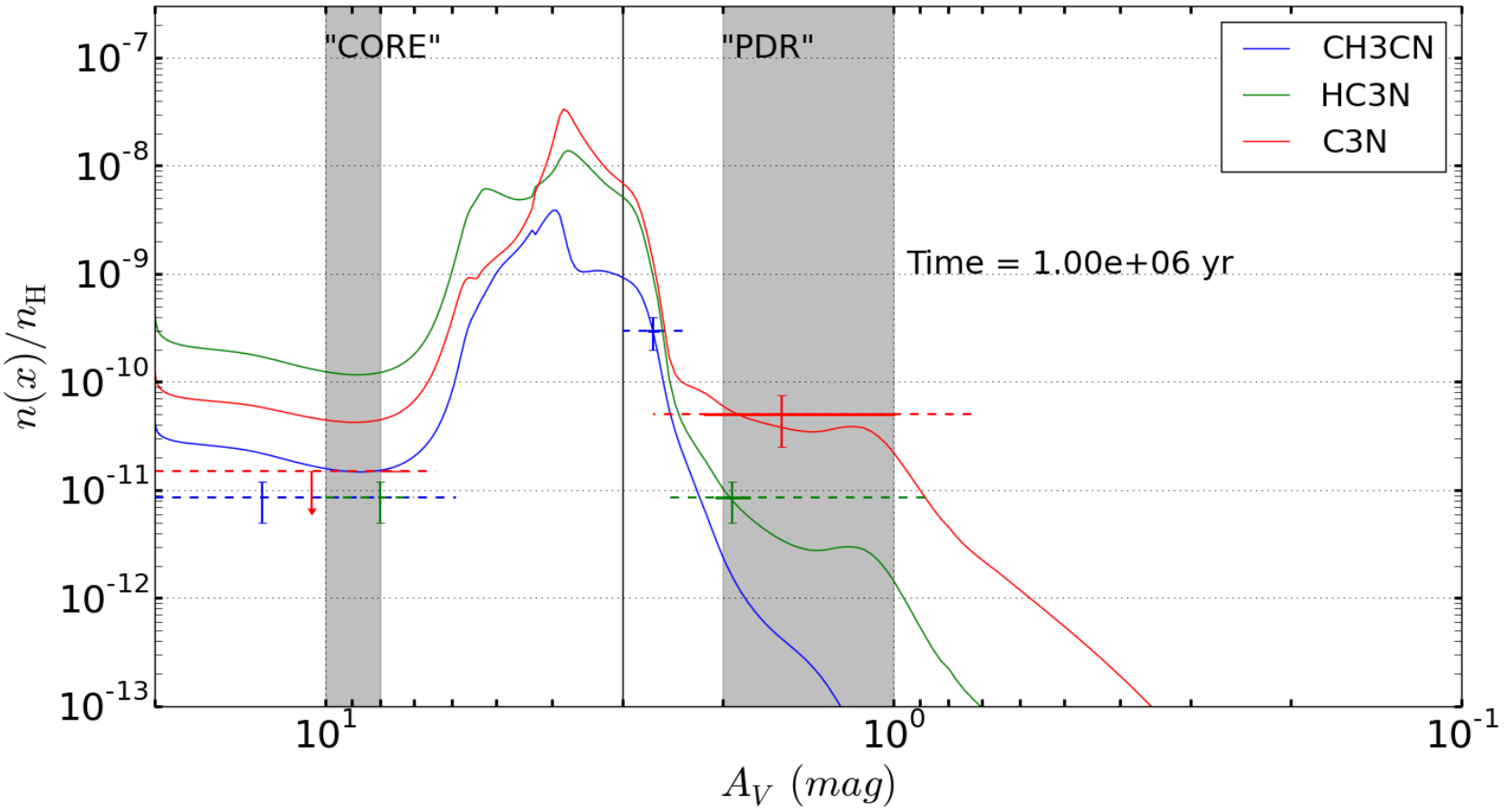

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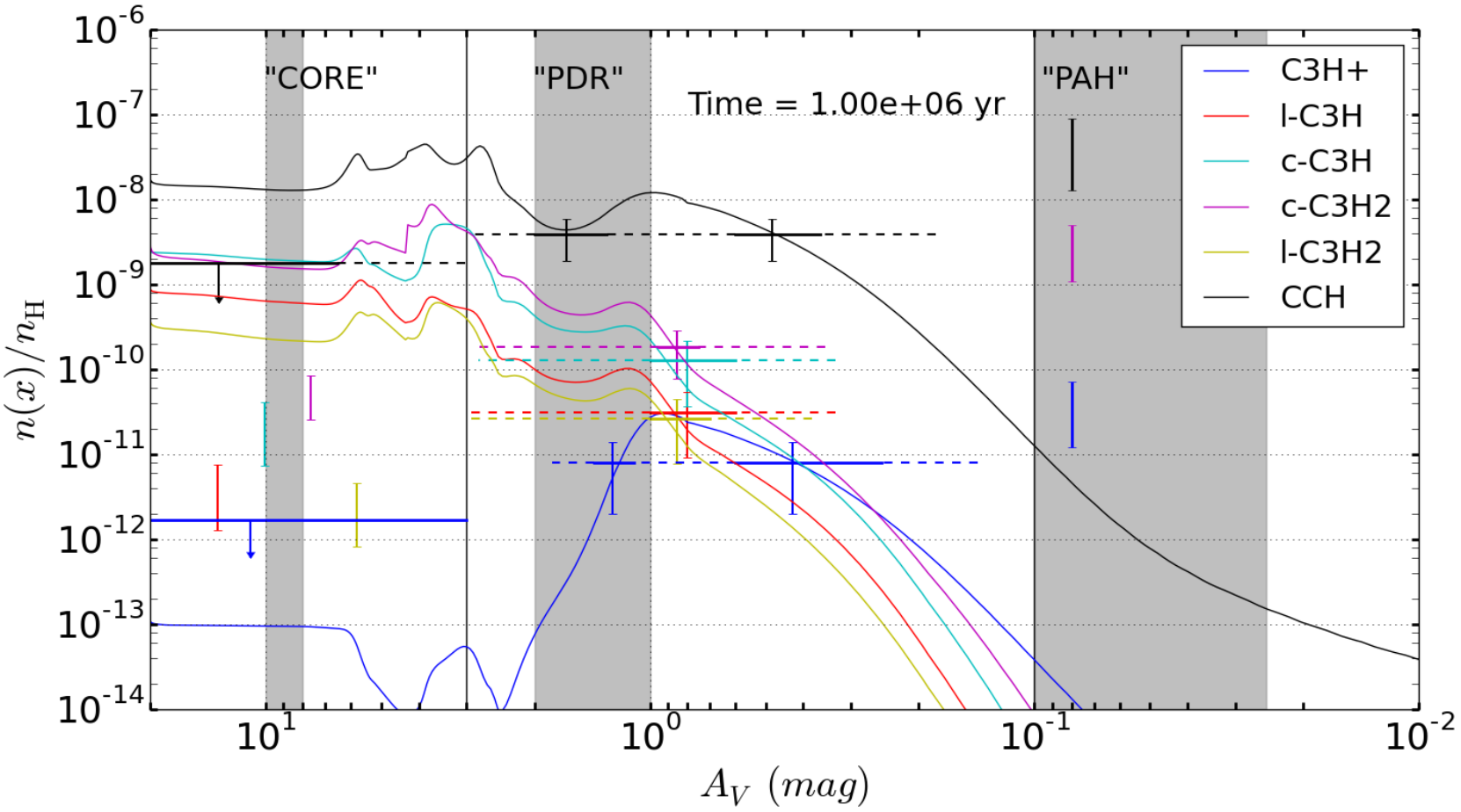

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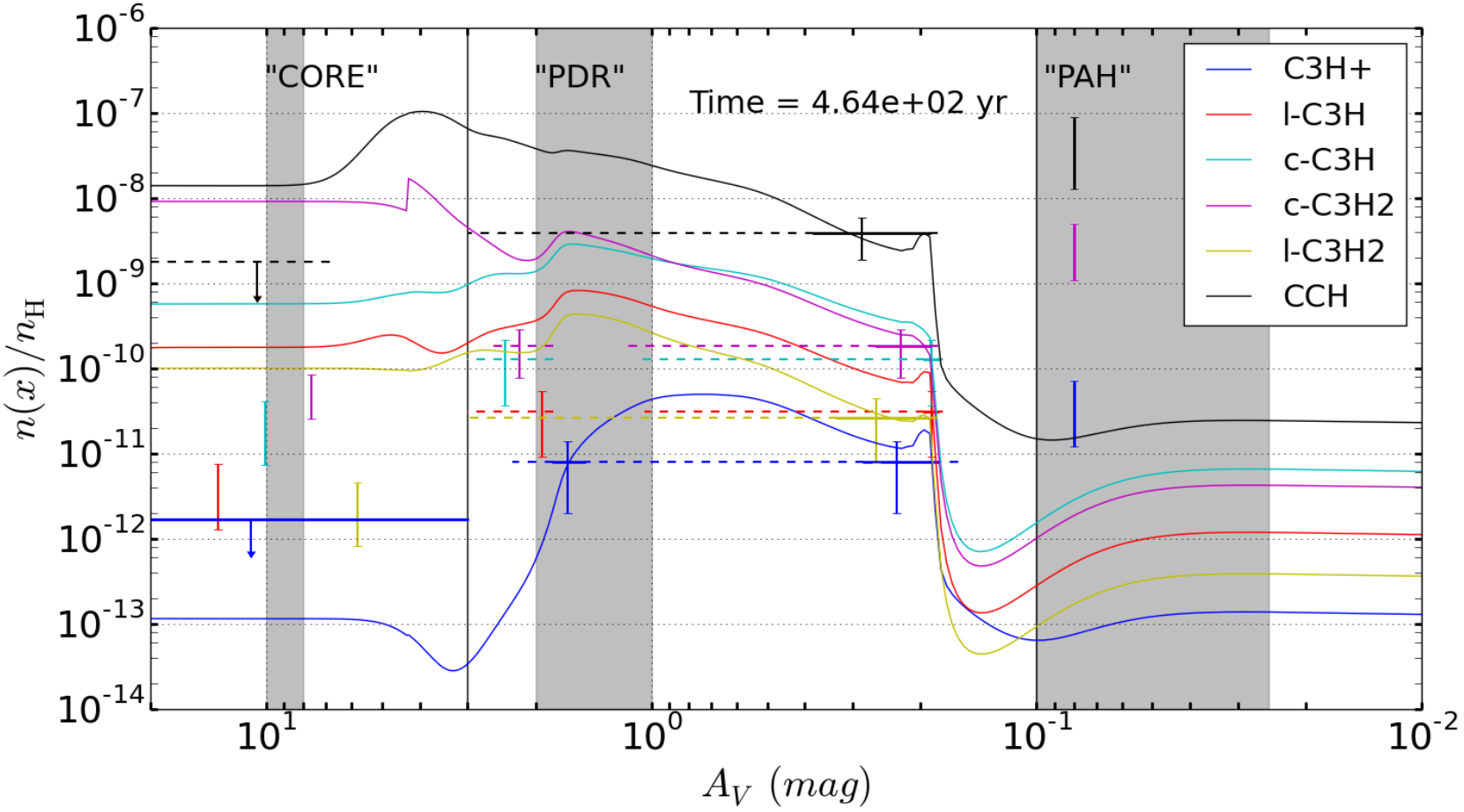

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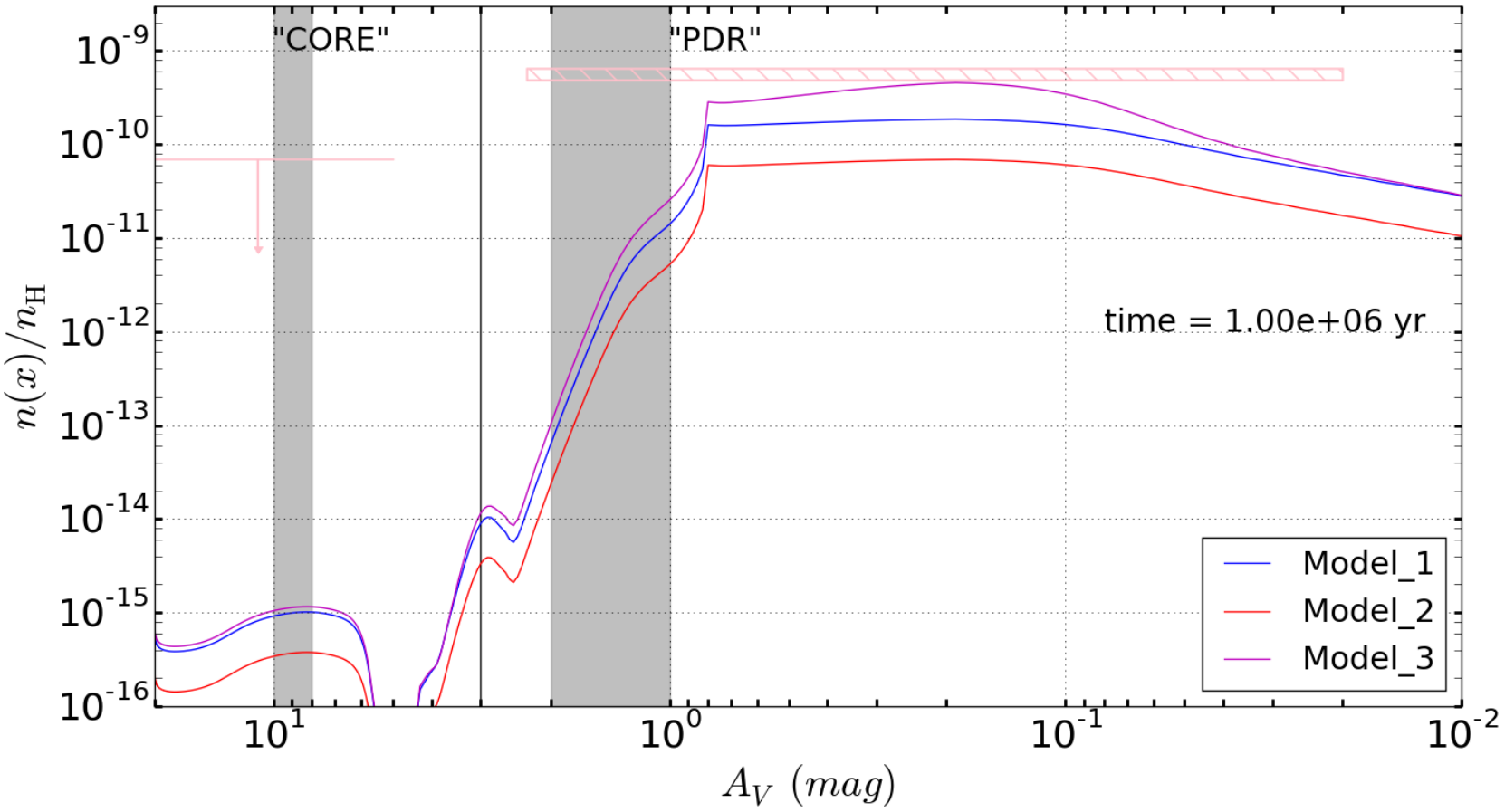

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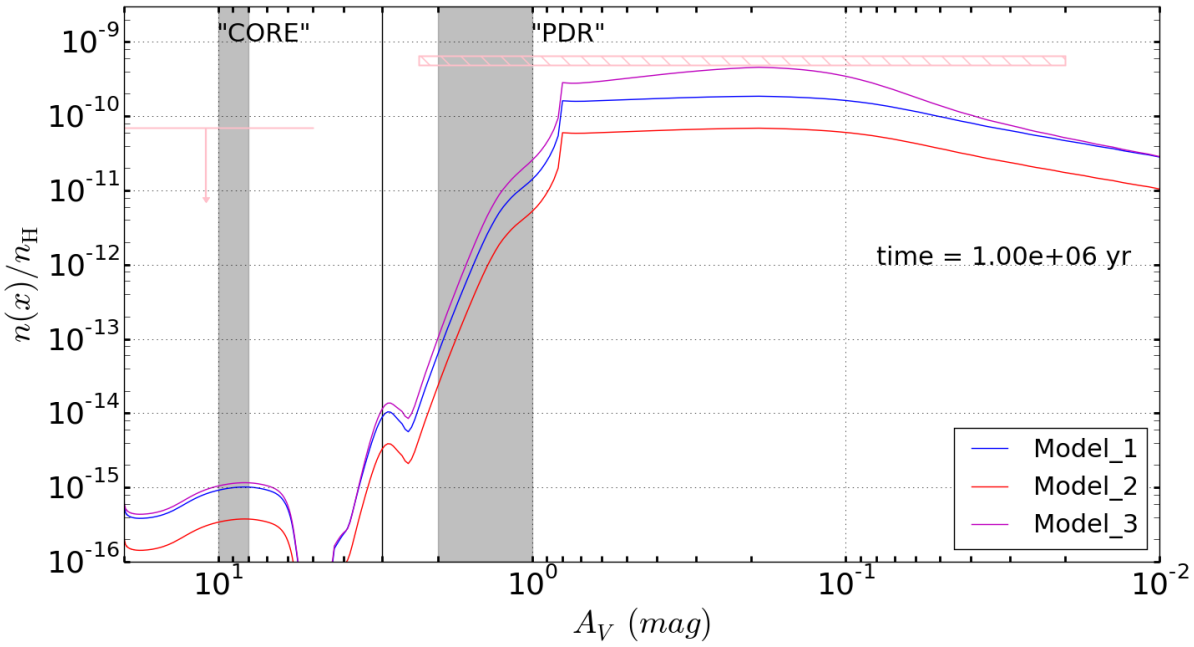

- $CF^+ + Photon \longrightarrow F + C^+$ (Guzman et al. 2012),
- $HF + C^+ \longrightarrow H + CF^+$ (Neufeld et al. 2005; Guzman et al. 2012),
- $CF^+ + e^- \longrightarrow C + F$ (Novotny et al. 2005; Neufeld & Wolfire 2009; Guzman et al. 2012),
- $F + H_2 \longrightarrow HF + H$ (Tizniti et al. 2014).

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Summary & future works

Summary:

- **Our time-dependent gas-grain chemistry model**:
  - 0D model => initial starless molecular cloud = birth place of the σ Ori star, with Nautilus
  - 1D model => takes into account the FUV-flux from the star impinging the Horsehead and the physical structure
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  - Grain-chemistry needed
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