3D Modelling of HCO^+ in The Low-mass Proto-star IRAS16293–2422

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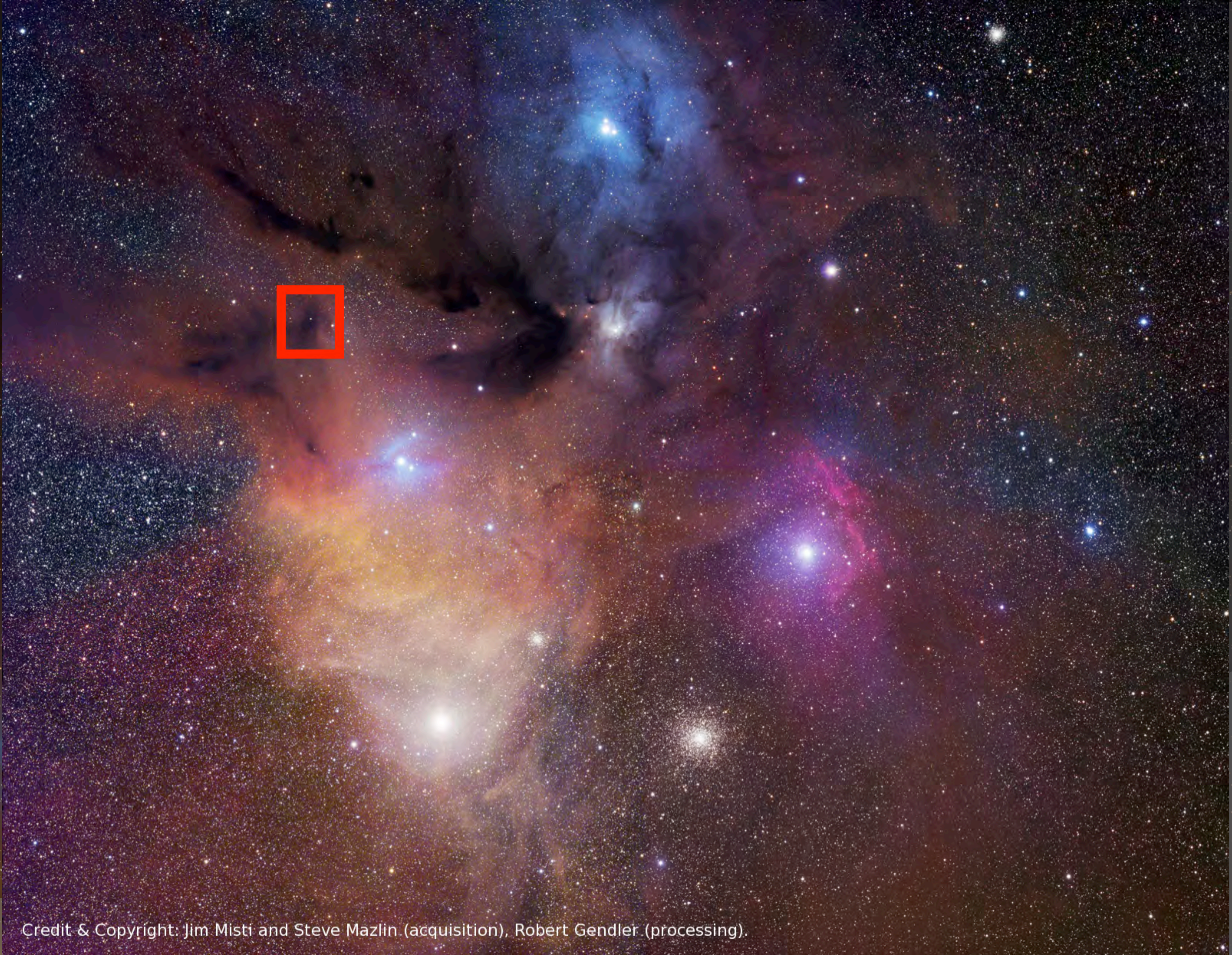
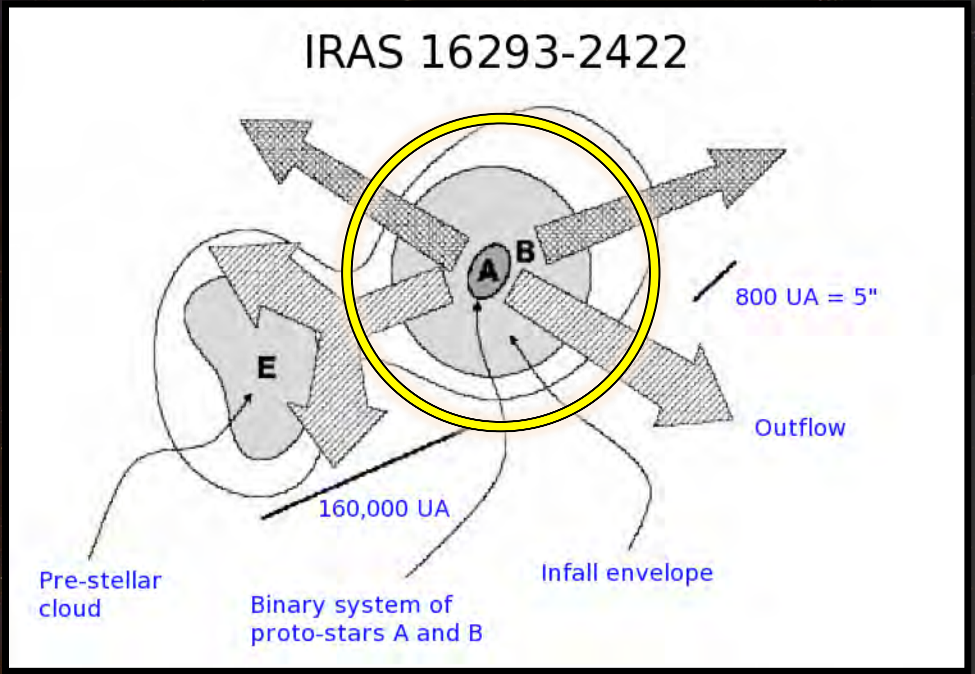


Overview of the source

Goal: study the formation mecanism in a low-mass proto-star such as IRAS16293

➔ Better understanding of the different formation stages of future Sun-like stars.

- Located at 120 pc from the Sun (ρ Ophiuchus complex)
- Mass similar to the Sun (~1 $M_{\odot}$)
- Luminous (22 $L_{\odot}$)
- Binary system : 2 sources (Wootten et al. 1989; Pech et al. 2010)
  - A (1 $M_{\odot}$) and B (< 0.1 $M_{\odot}$)
  - distant by 5''



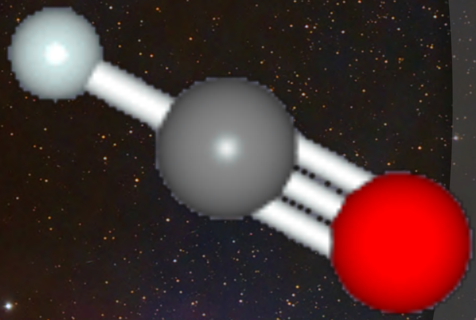
Why studying HCO^+ ?

- Tracers of the ionisation rate in the proto-stellar environment.

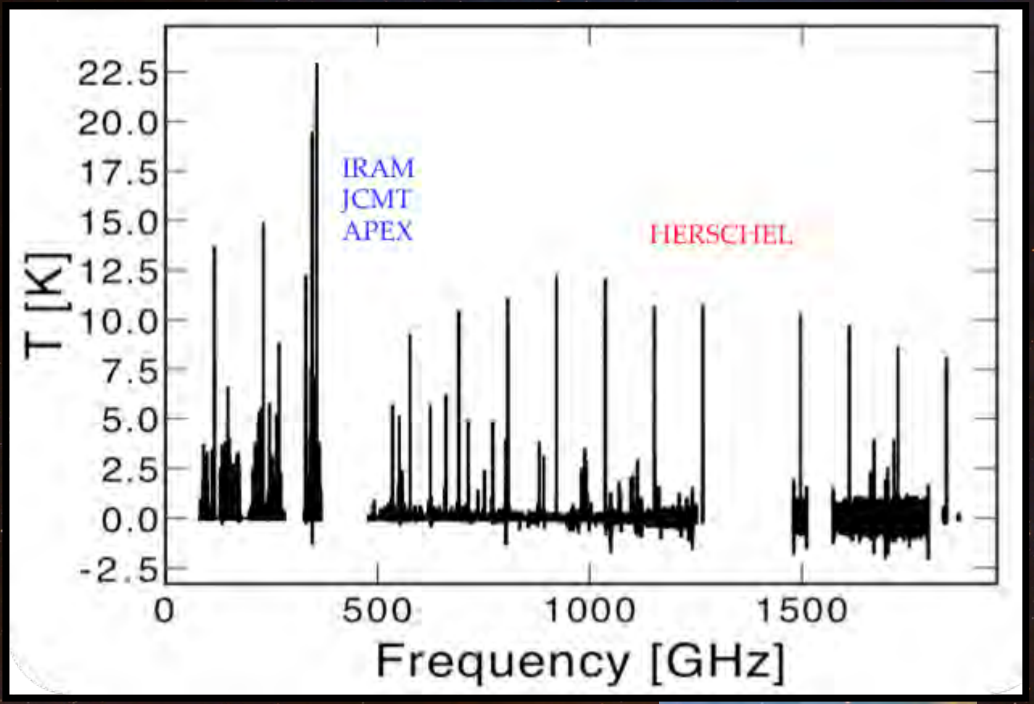
- Gravitational collapse slowed down by collisions between neutral species and ions + electrons linked to the magnetic field.

- Ionisation allows to create and destroy more complex molecules (up to COMs).

HCO^+



How studying HCO^+ ?



- Spectral surveys CHESS (*Herschel*/HIFI) and TIMASSS (IRAM 30m and JCMT + APEX) towards IRAS16293: 80-1000 GHz (E_{up} ≤ 850 K)

- HCO^+ : 11 transitions
- $H^{13}CO^+$: 7 transitions
- $HC^{18}O^+$: 5 transitions
- DCO^+ : 5 transitions
- $D^{13}CO^+$: 3 transitions

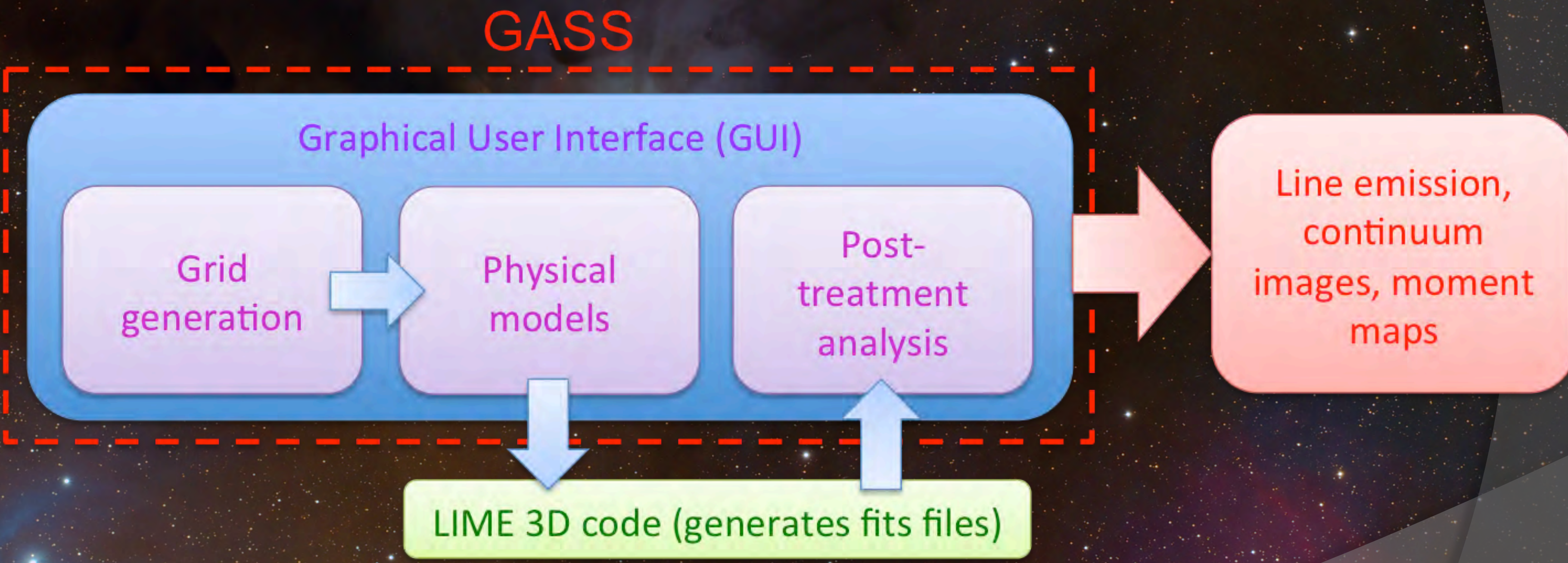
31 transitions

3D modelling of the source

- 2 steps: generation of the 3D physical model + radiative transfer solution
- GASS code: Generator of Astrophysical Sources Structures (Quénard et al., in prep.)
- Radiative transfer code LIME (Brinch et al. 2010): 3D, non-LTE, Monte-Carlo/ALI method

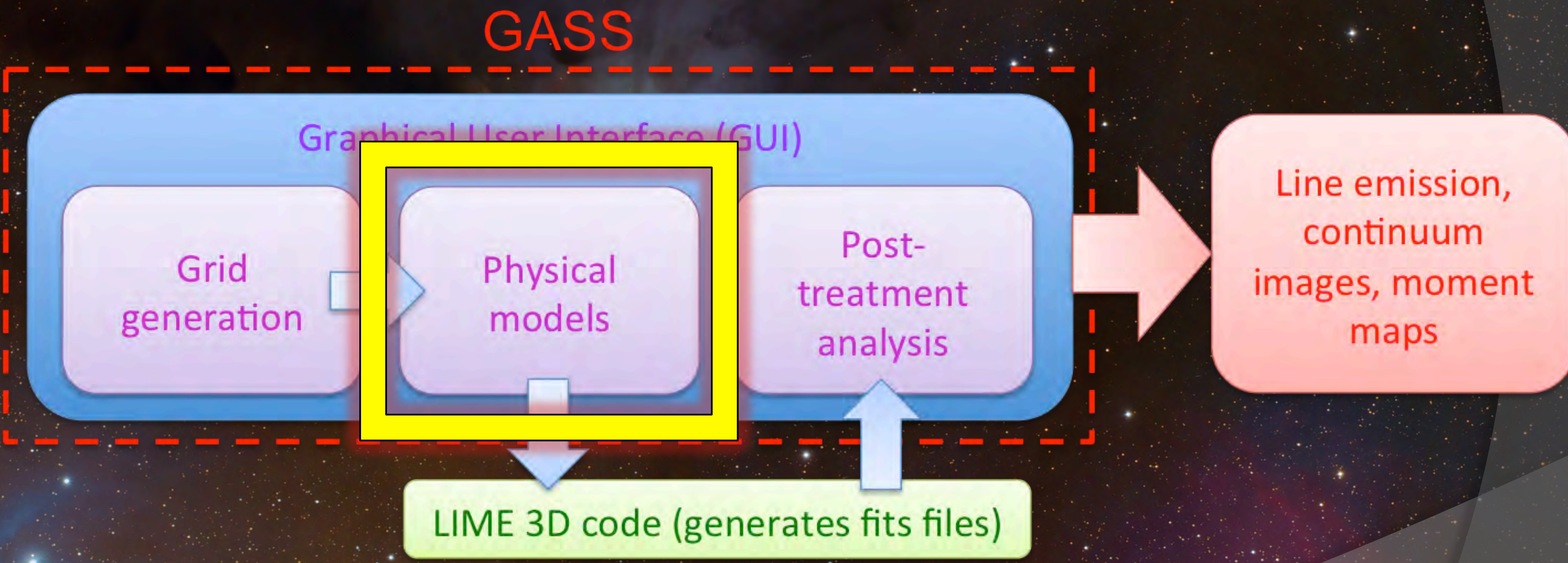
➔ GASS is coupled to LIME thanks to its interface (GUI)

GASS code
Generator of Astrophysical Sources Structures



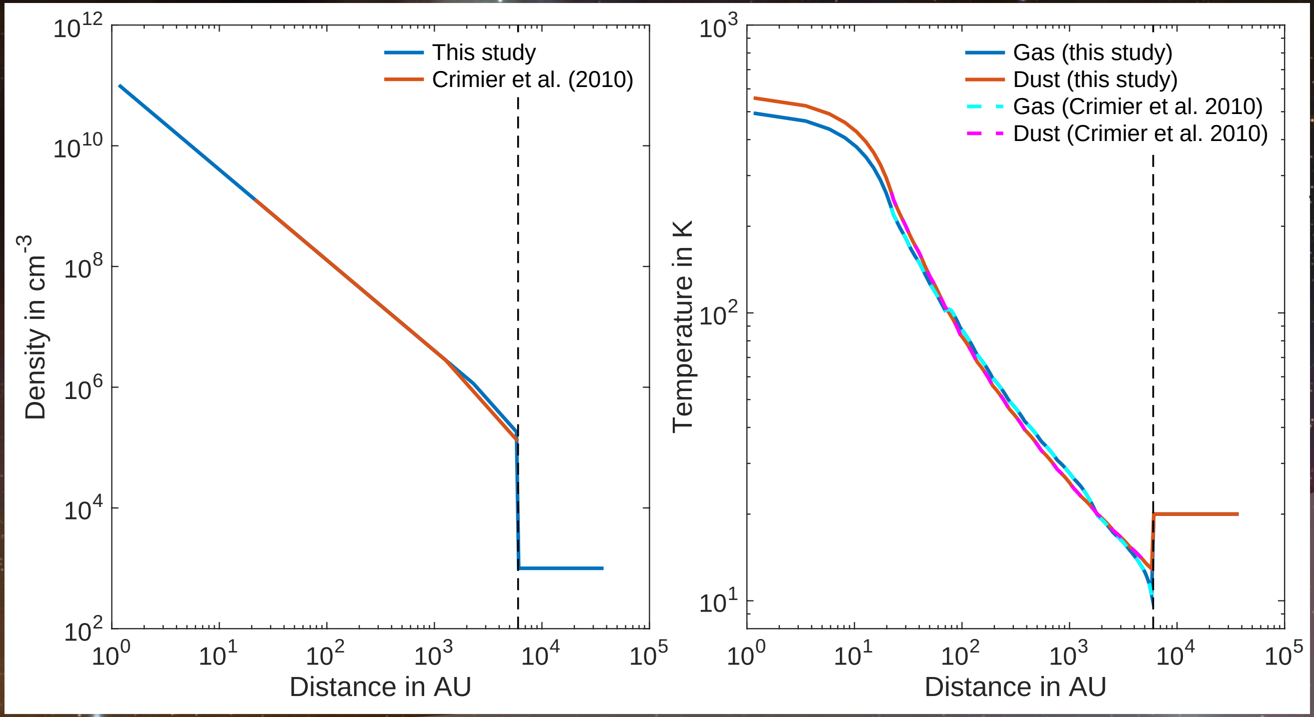
GASS code

Generator of Astrophysical Sources Structures



Envelope model

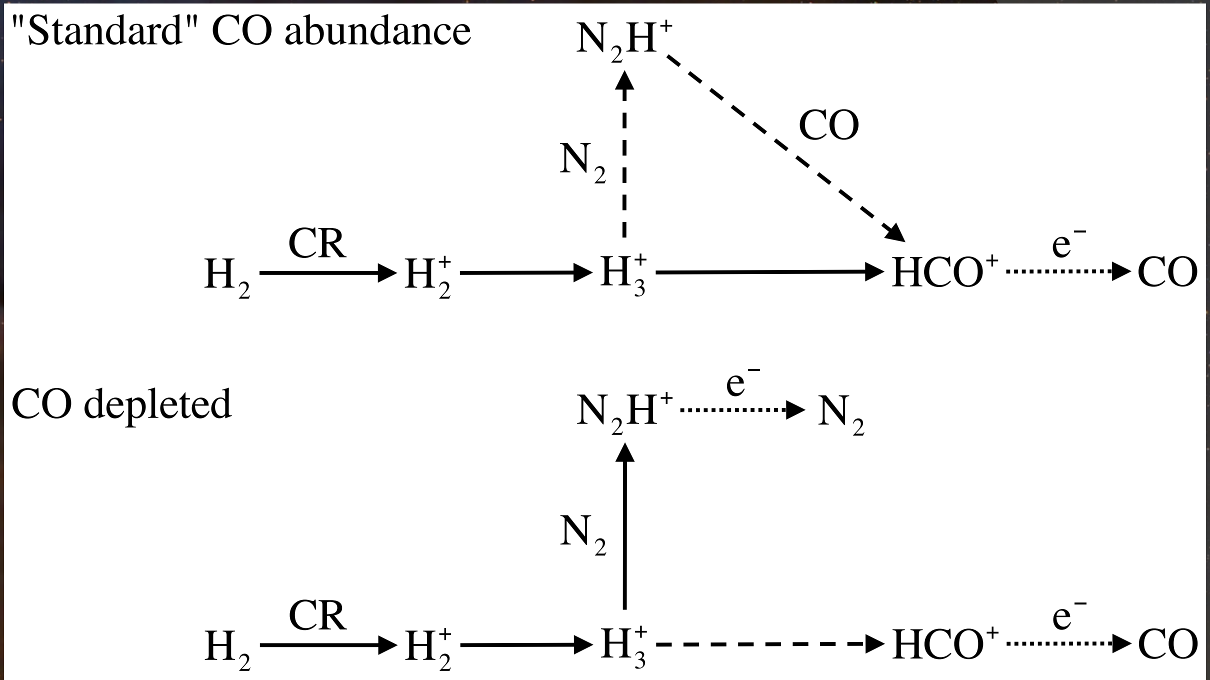
- Physical structure (H_2 density, température) determined by Crimier et al. (2010).
- To fit line profiles, the infall radius (r_{inf}) is taken to be 2400 AU instead of 1280 AU.
- No need to consider the multiplicity of the source to study the emission of HCO^+.
- Source A dominating → we suppose that only one envelope is centred on it.



Formation and destruction

Good recipe to form and/or destroy HCO^+ :

- CO abundance
- Ionisation by cosmic rays (ζ)
- H_2 density



Other important reactions: fractionation and deuteration!

Estimation of isotopologues abundances ($H^{13}CO^+$, DCO^+, $D^{13}CO^+$,…)

New theoretical study made by Mladenović et al. (2014)

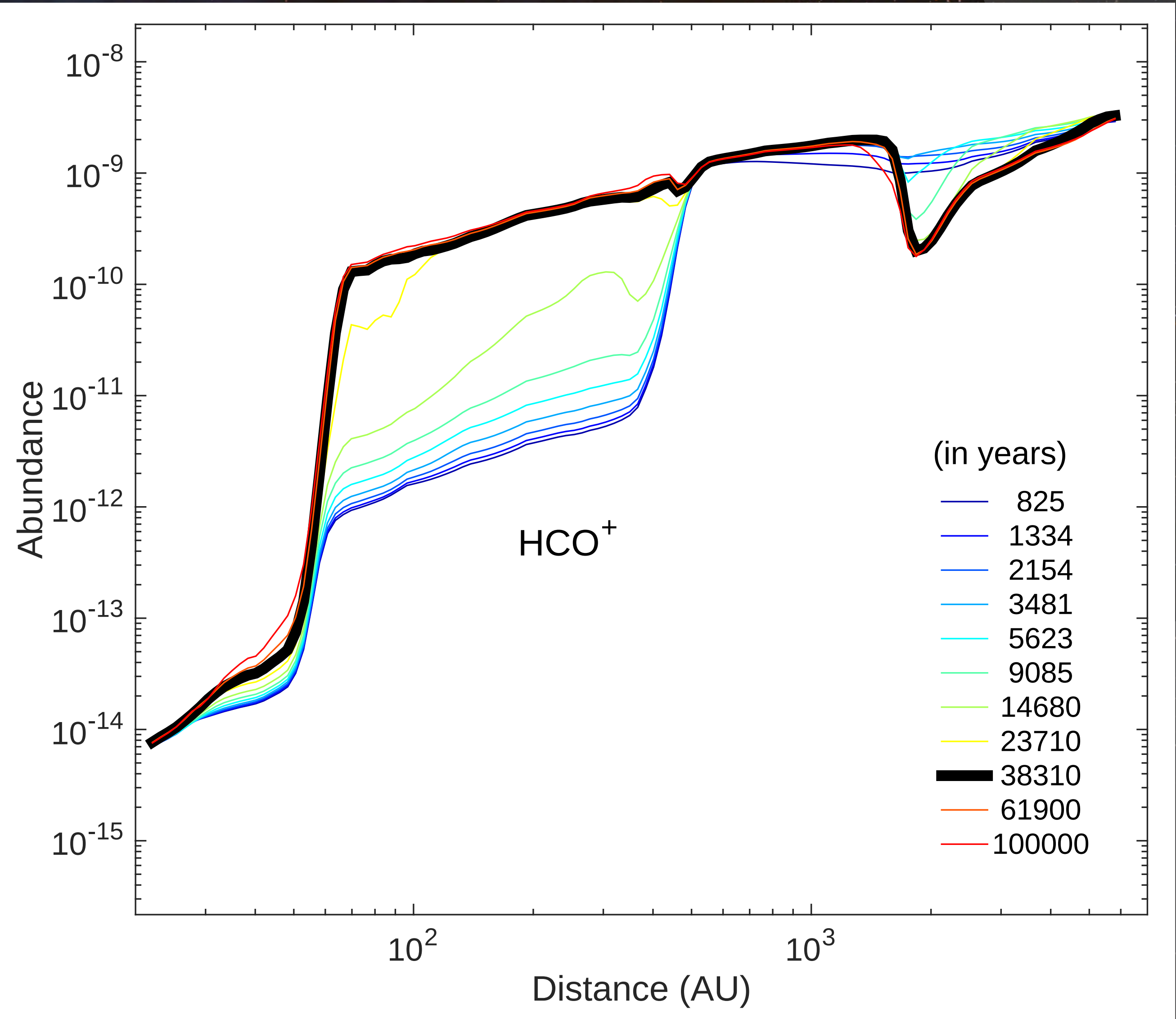
Chemical code Nautilus (gas + grain)
(Using the physical structure shown previously)

Abundance profile for the envelope only

- Different parameters are varied:

- Cosmic rays ionisation rate ζ
- Evolution of the initial parental cloud (age, density, temperature)
- Age of the proto-star

→ Trend of the parameters on the abundance profile



- Rao et al. (2009) & Girart et al. (2013):

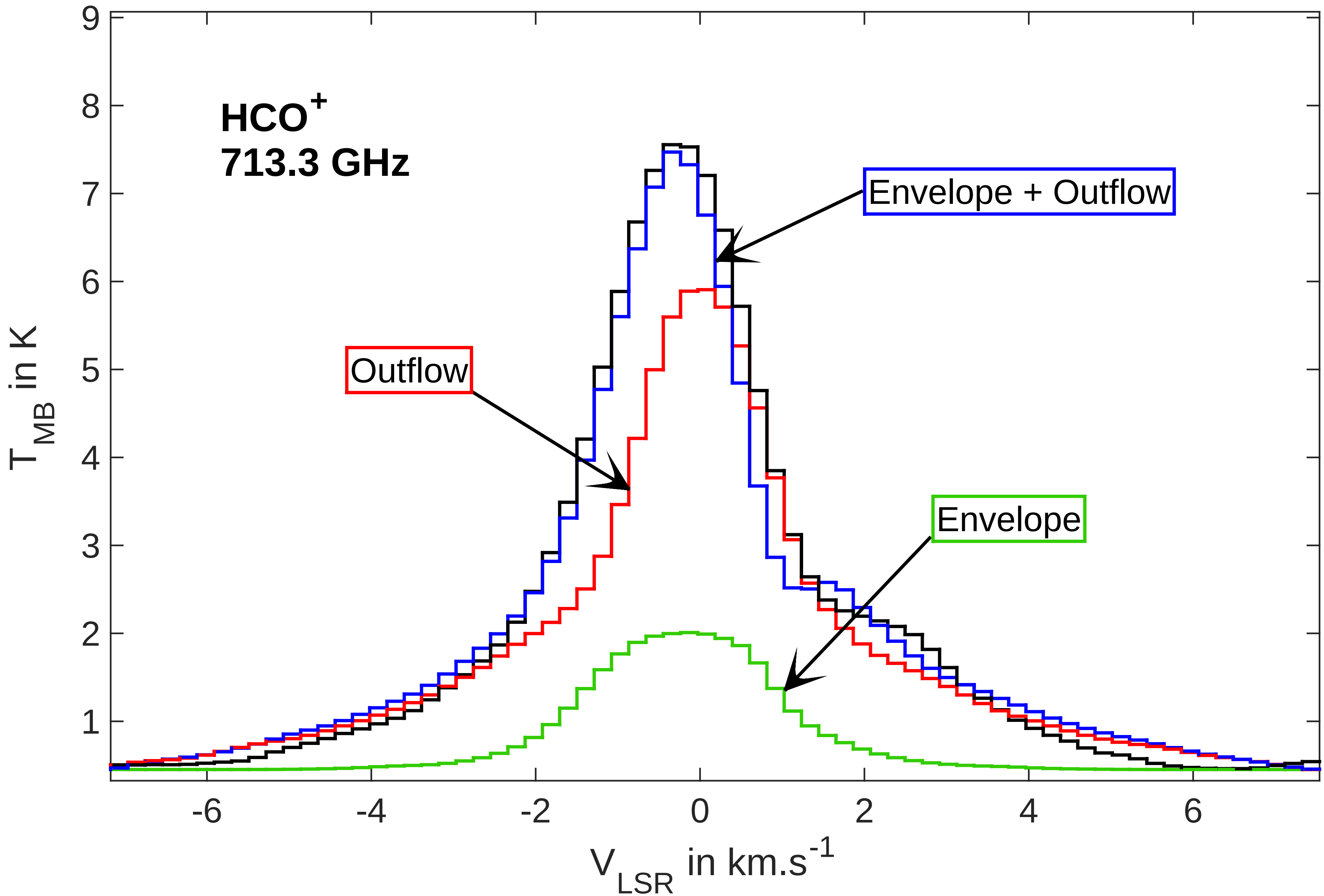
  Young outflow detected (~ 400 yrs) in IRAS16293, seen with $H^{13}CO^+$!

- Rollins et al. (2014) and Rawlings et al. (2000, 2004):

  HCO^+ abundant in young outflows ➔ Chemistry destroys HCO^+ in older outflows

- Different parameters (supposed to be constant through the outflow) are varied:

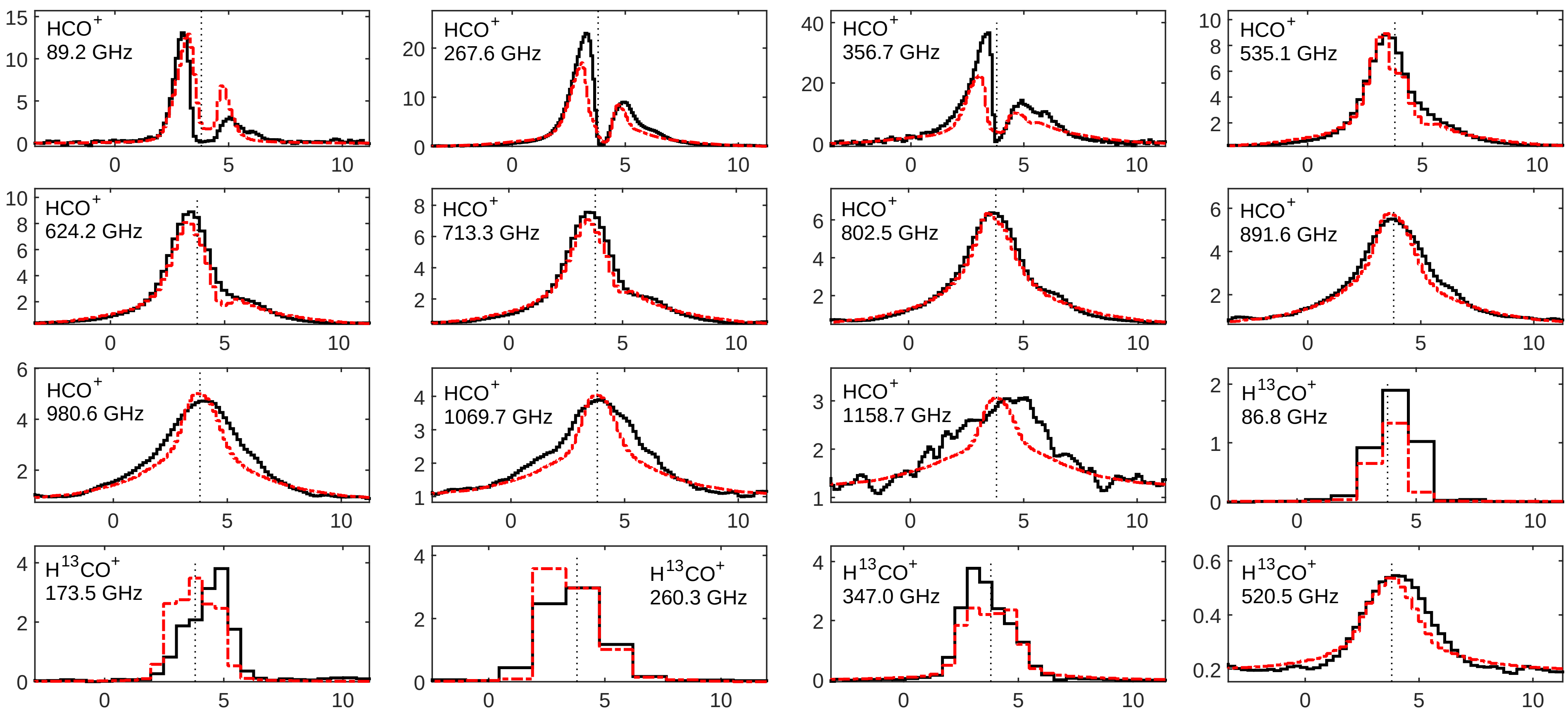
  - Kinetic temperature
  - H_2 density
  - HCO^+ abundance



HCO+
713.3 GHz
Envelope + Outflow
Outflow
Envelope
T_MB in K
V_LSR in km.s-1
9
8
7
6
5
4
3
2
1
-6
-4
-2
0
2
4
6

Line profiles

- Line fitting with both envelope + outflow (for HCO^+ and its isotopologues)
  - Foreground cloud in front of the source (Coutens et al. 2012)



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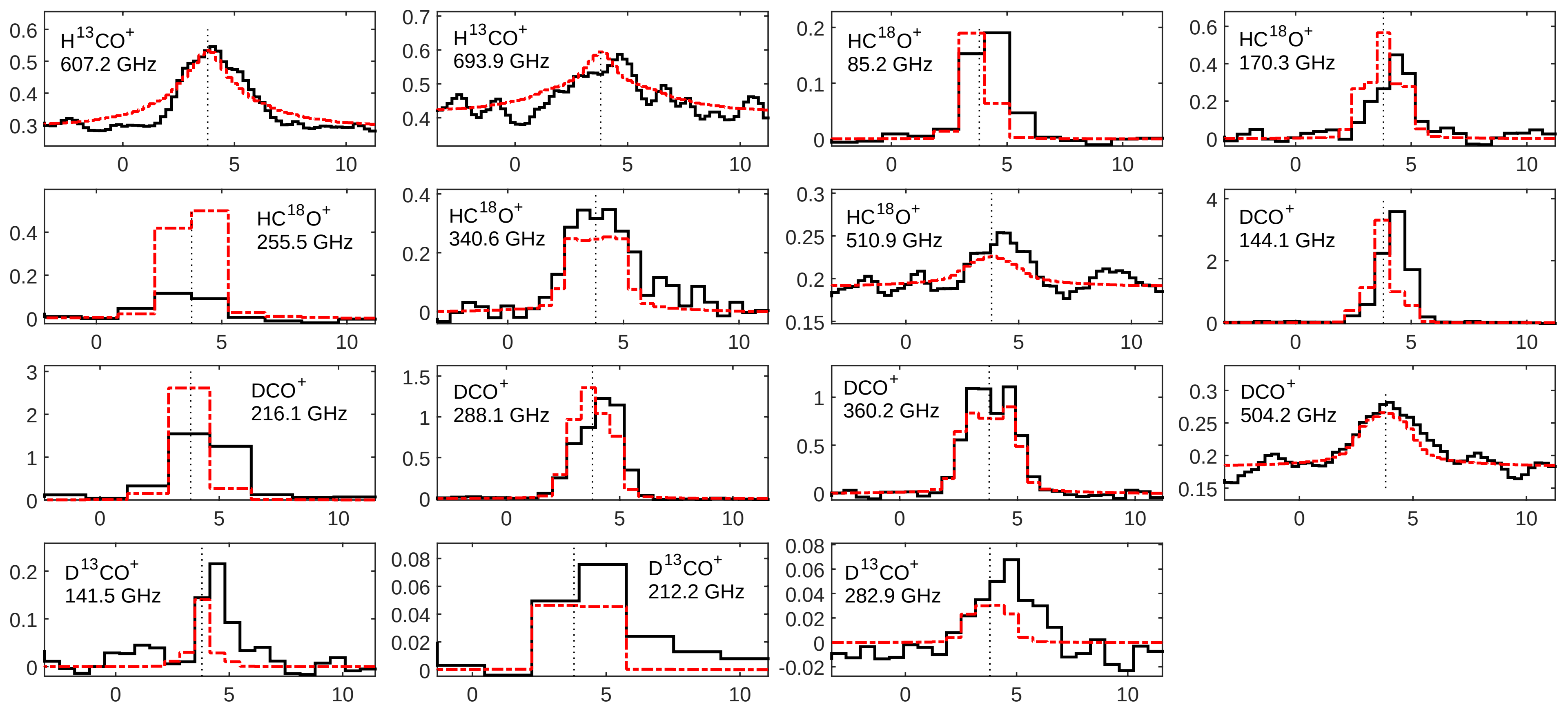

Conclusions

- HCO^+ emission coming from both the envelope AND the outflow.
- Modellings done with the combination of GASS and LIME.
- 31 transitions of HCO^+ and its isotopologues used simultaneously.
- Envelope abundance consistent with astrochemical modellings.