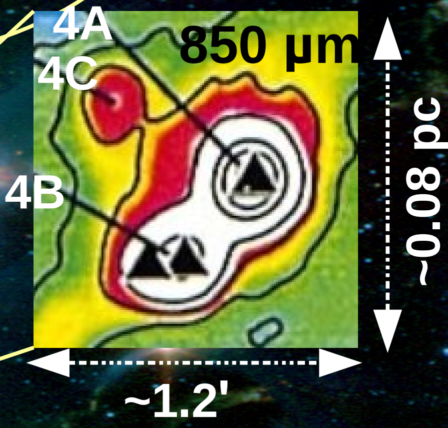
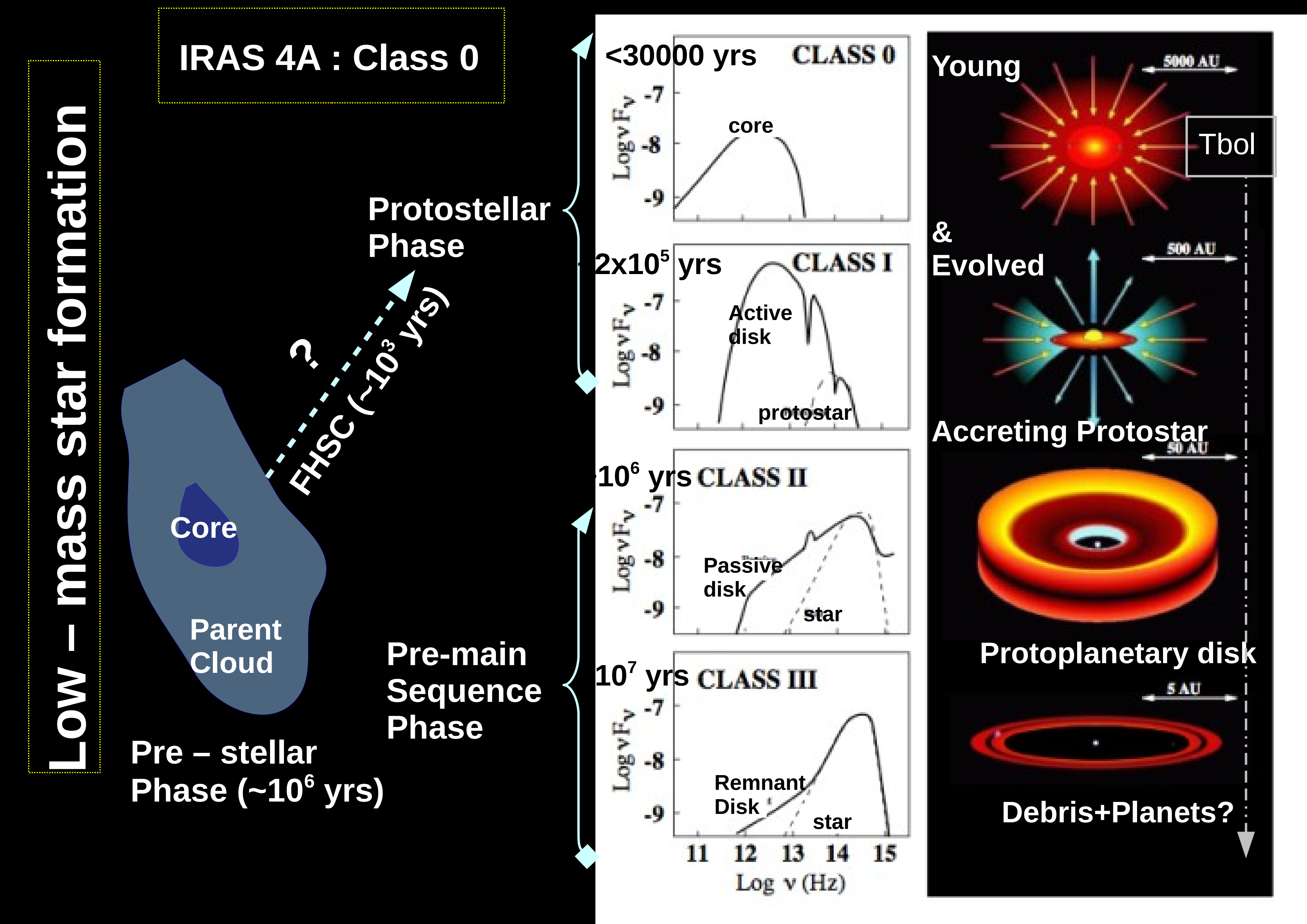
The chemical structure of the Class 0 protostellar envelope NGC 1333 IRAS 4A



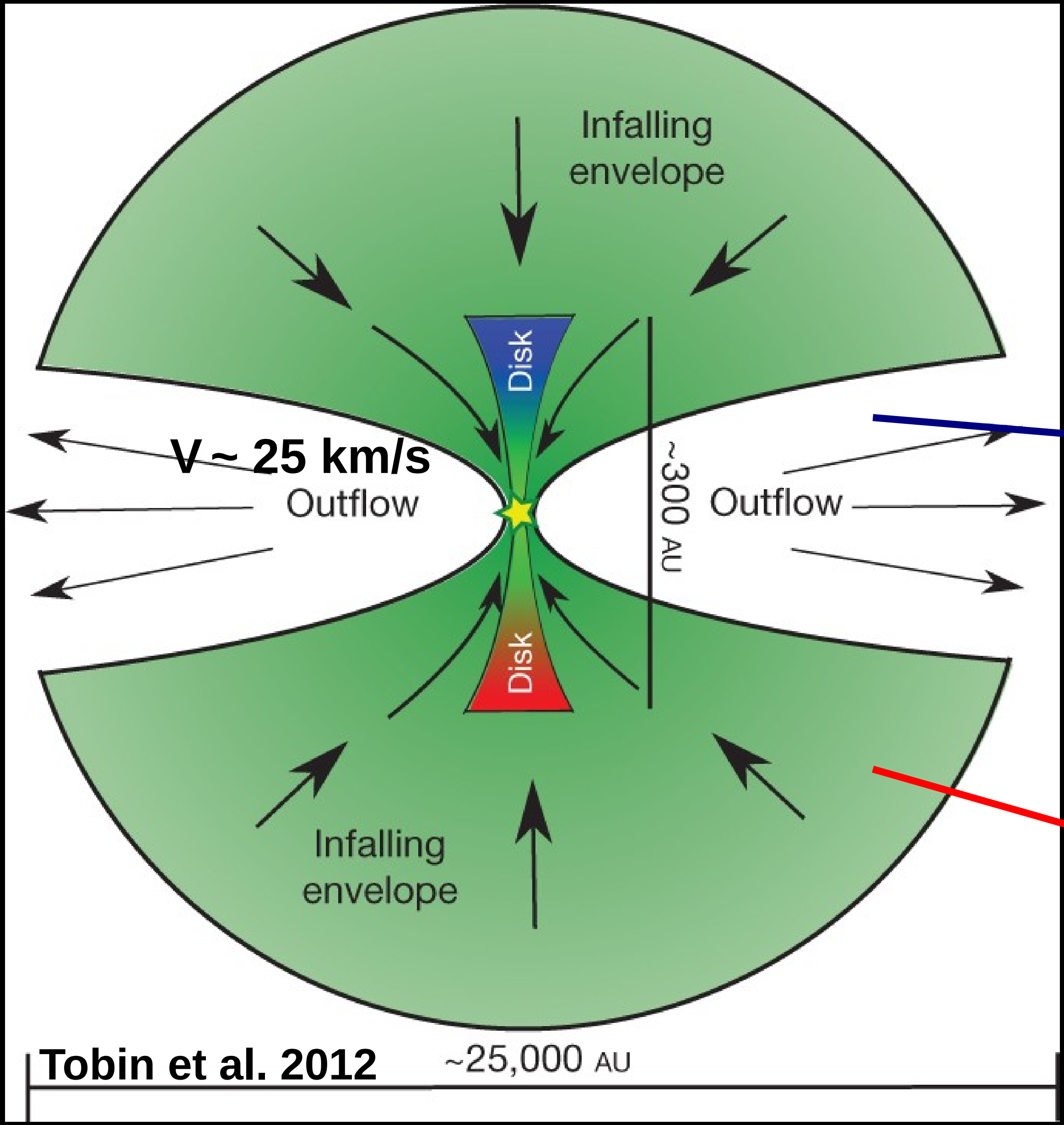
Evgenia Koumpia, D. Semenov,
F. van der Tak, A. Boogert, E. Caux (A&A, 2017)

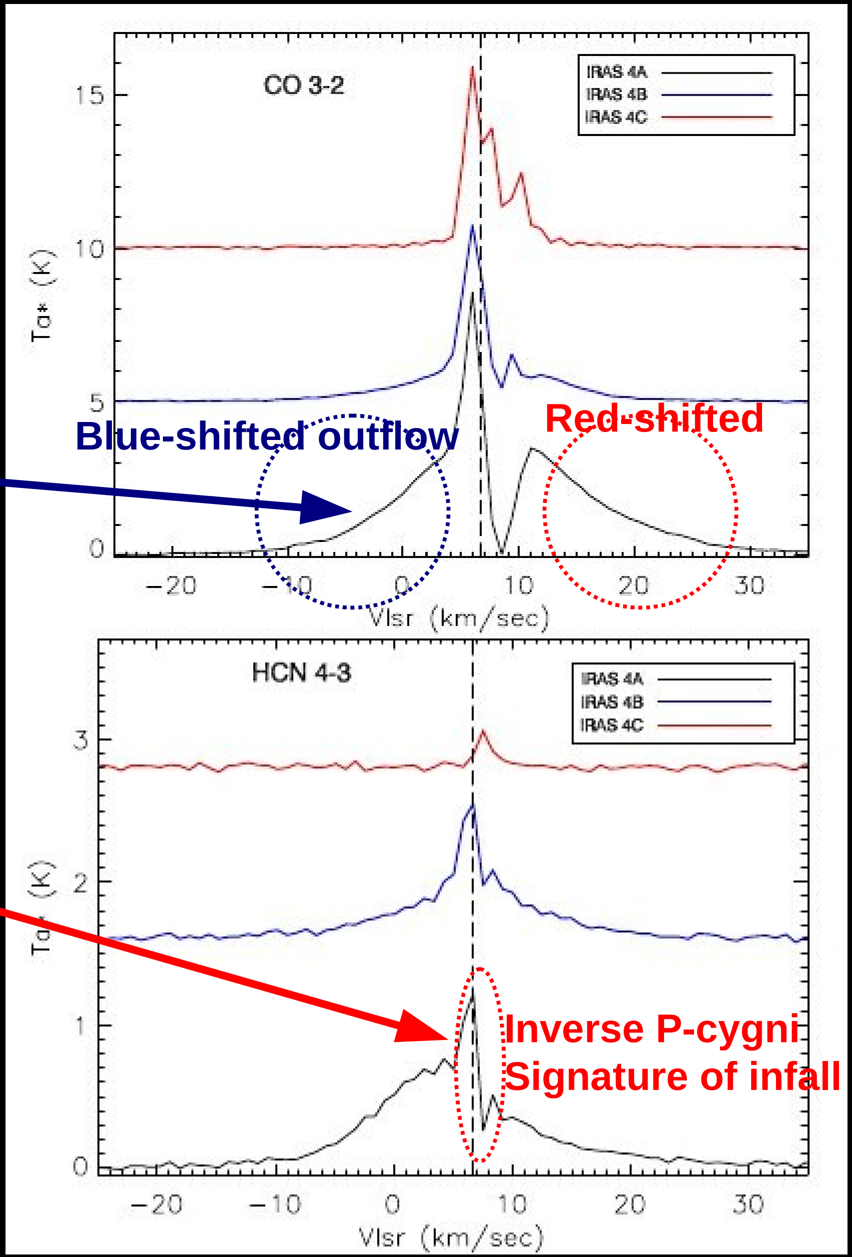
Background image: Spitzer IRAC 3.6-8 μm



Low – mass star formation
IRAS 4A : Class 0
Core
Parent Cloud
Pre – stellar Phase (~10^6 yrs)
?
FHSC (~10^3 yrs)
Protostellar Phase
Pre-main Sequence Phase
<30000 yrs
CLASS 0
core
2x10^5 yrs
CLASS I
Active disk
protostar
10^6 yrs
CLASS II
Passive disk
star
10^7 yrs
CLASS III
Remnant Disk
star
Log νFν
-7
-8
-9
11
12
13
14
15
Log ν (Hz)
Young
&
Evolved
5000 AU
500 AU
50 AU
5 AU
Tbol
Accreting Protostar
Protoplanetary disk
Debris+Planets?

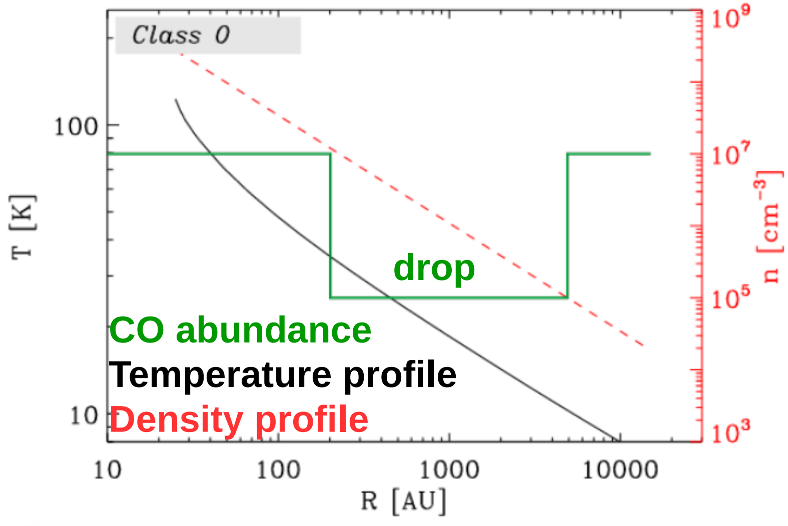
How does a Class 0 protostar look like?

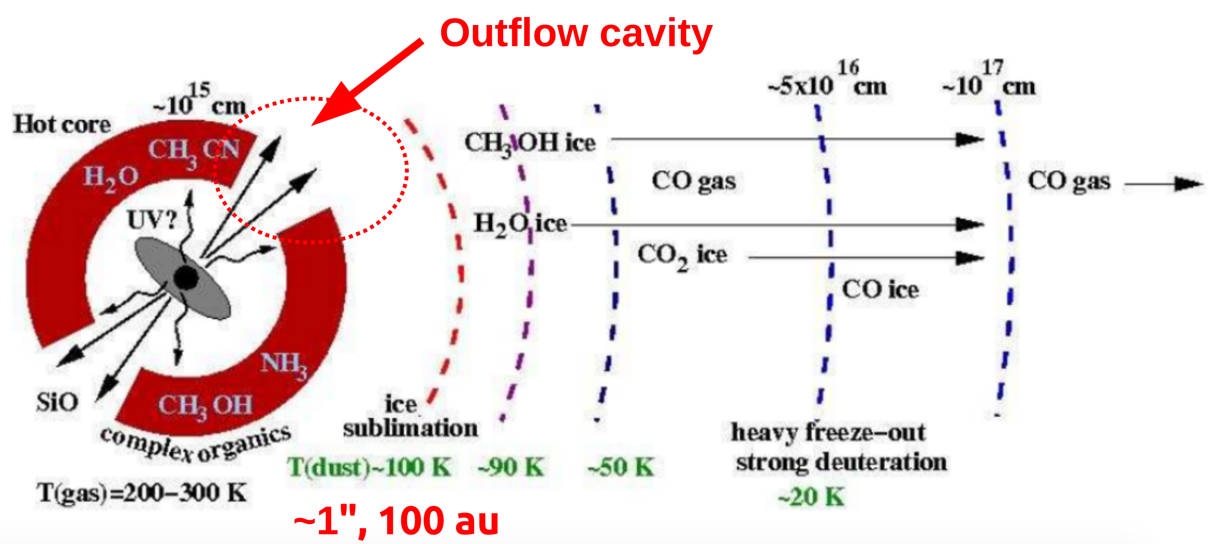




Physical & chemical structure of a Class 0 protostar

Hot corino chemistry vs shock enhancement? → resolution limitations → diluted emission





Timescale for freeze-out: ~ 2 × 10^9/n yr

van Dishoeck 2007

Importance of outflow cavities ?

Chemical structure of IRAS 4A

Goal #1

Investigate the importance of the outflow cavities

Goal #2

Compare this low mass case with a high mass counterpart (AFGL 2591)

Observations

IRAS 4A

Herschel

HIFI-Band 2 Spectral Scans

bands 2a-2b: 479-375µm, 626-800 GHz

ϑ (band 2) ~ 30”

RMS noise ~ 30 mK

Detected Species

CO, ^{13}CO, $C^{18}O$, CS, HCN,

HCO^+, N_2H^+, H_2CO, CH_3OH,

H_2O

IRAS 4

JCMT

HARP-B/ACSIS

325-375 GHz, Field of view (2'x2')

ϑ ~ 15”

RMS noise ~ 15mK

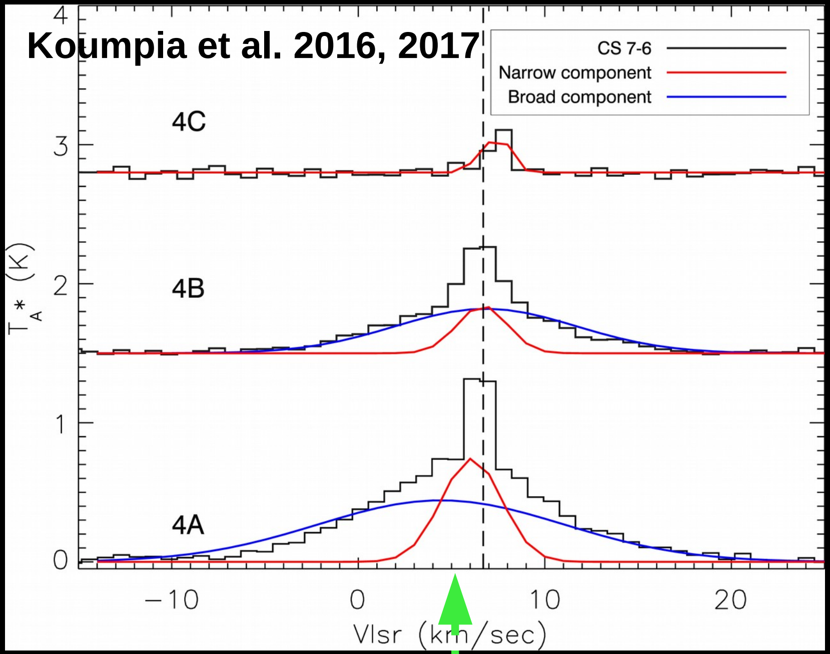
Detected Species

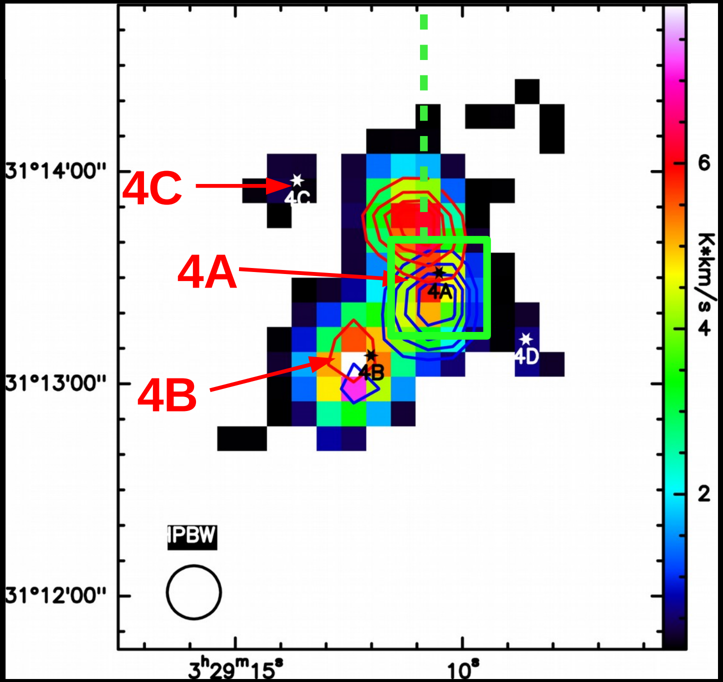
HCN (4-3), $H^{13}CO^+$, H_2D^+, N_2H^+, ^{13}CO, CH_3OH, $C^{17}O$, SO, SiO, H_2CO, HCO^+, DCO^+, HNC

Searched but not found in HIFI range

Observed and modeled abundances of 17 species

Method



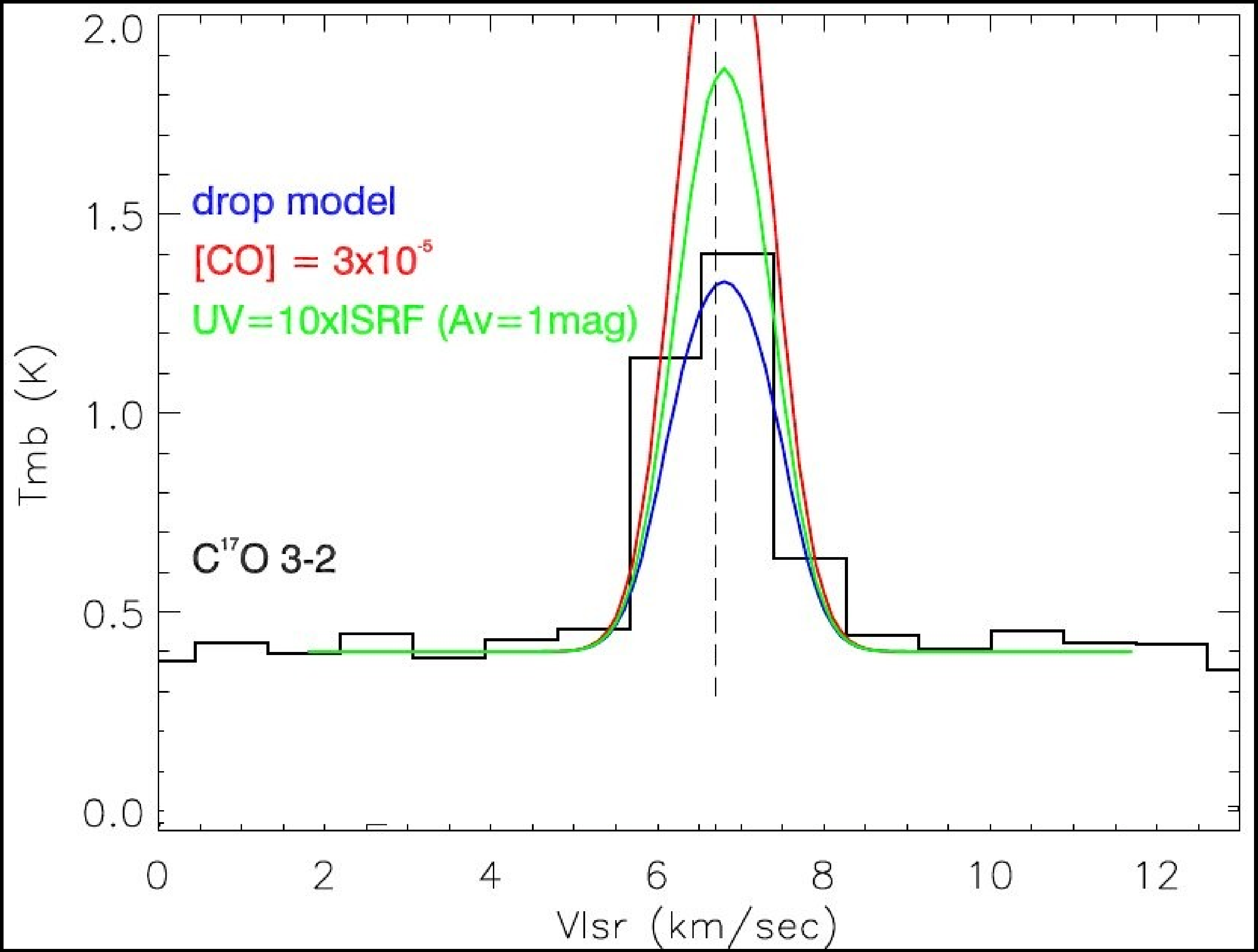


narrow component → Integrated intensity → Abundance

RATRAN (Hogerheijde & van der Tak 2000)

- Empirical abundances → compare with a high mass of similar chemical age (AFGL 2591; Kaźmierczak-Barthel et al 2015)
- Time dependent gas grain chemical code (ALCHEMIC; Semenov et al. 2010) → Theoretical abundances → compare with the empirical abundances

Modeling the emission



RATRAN:

Density/temperature profile (Kristensen et al. 2012)

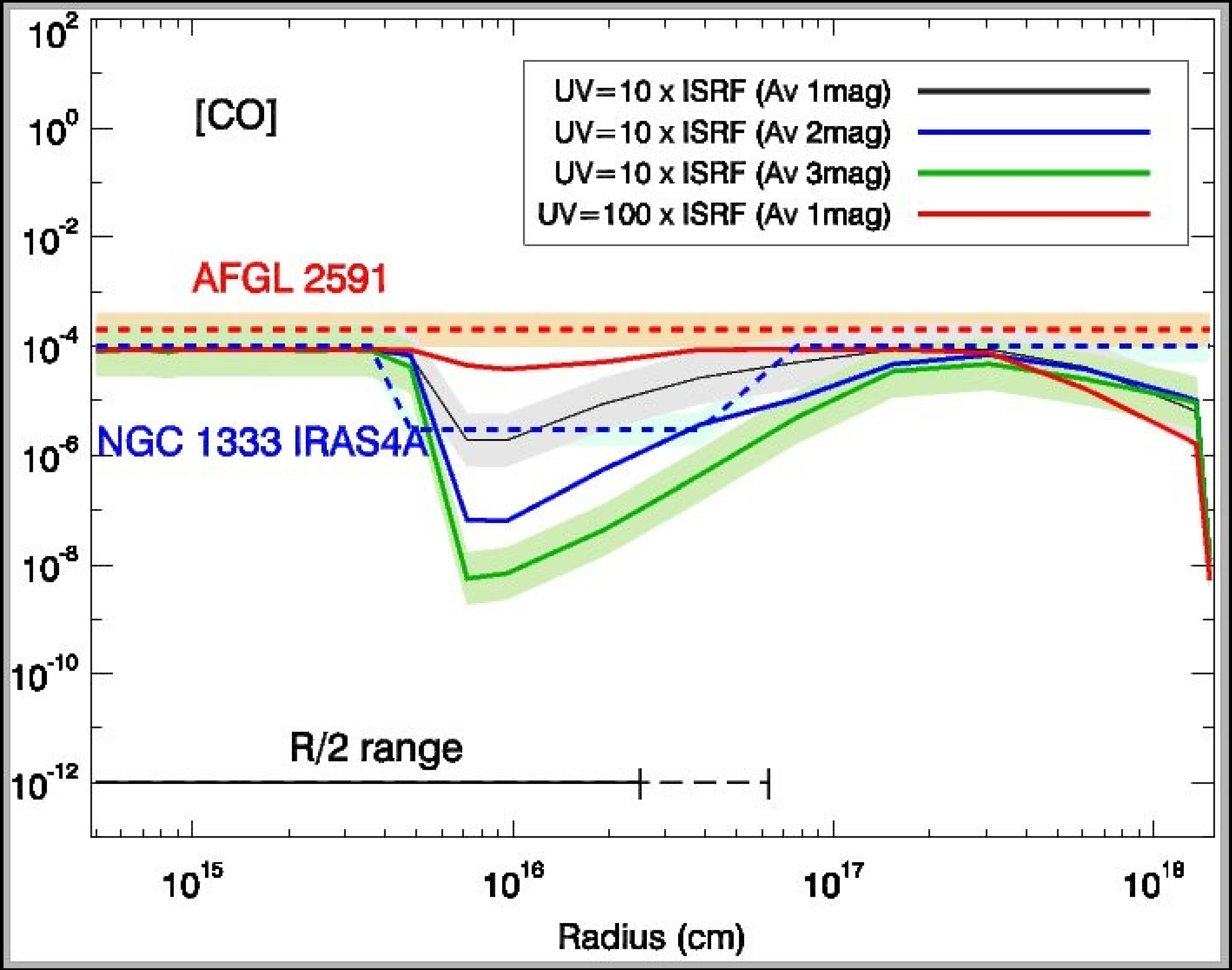
a) **constant** abundance profiles (e.g HCN, HNC, CS)

b) abundance profiles with **jumps/drops** at two radii:

i) T~100 K; H_2CO,CH_3OH
ii) T~25 K; CO)

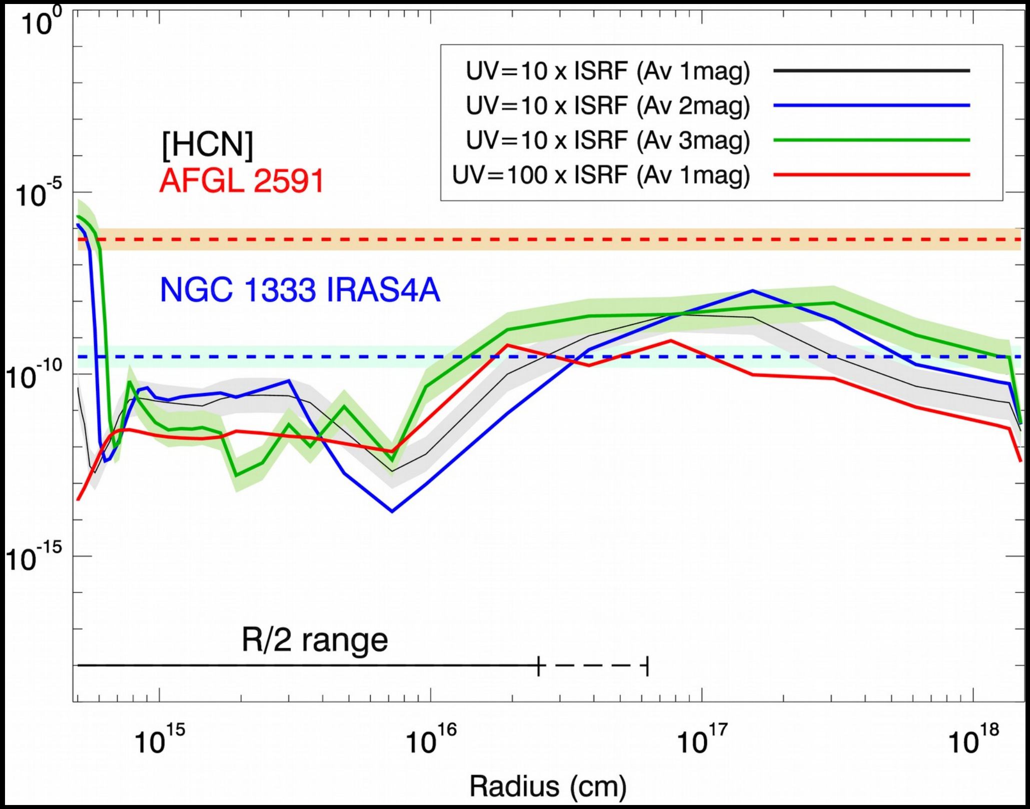
Freeze out zone is important

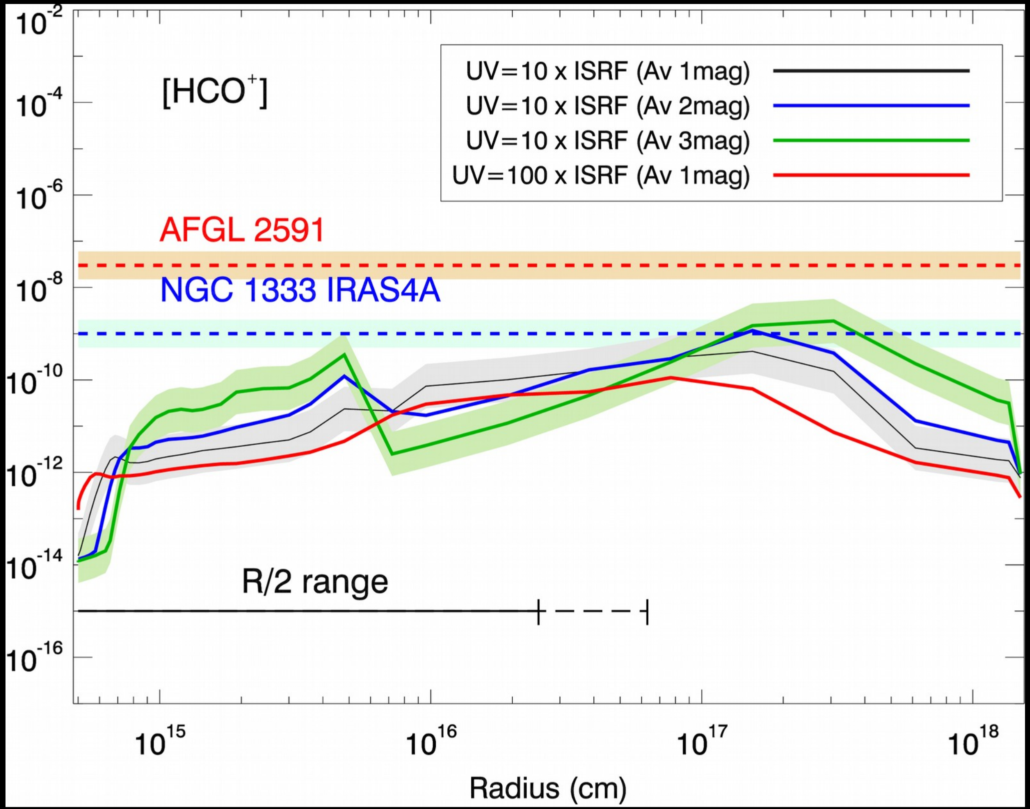
Simulating an outflow cavity



Outflow cavities are important (e.g. CO, HCO^+, DCO^+)

Comparison with a high mass protostar

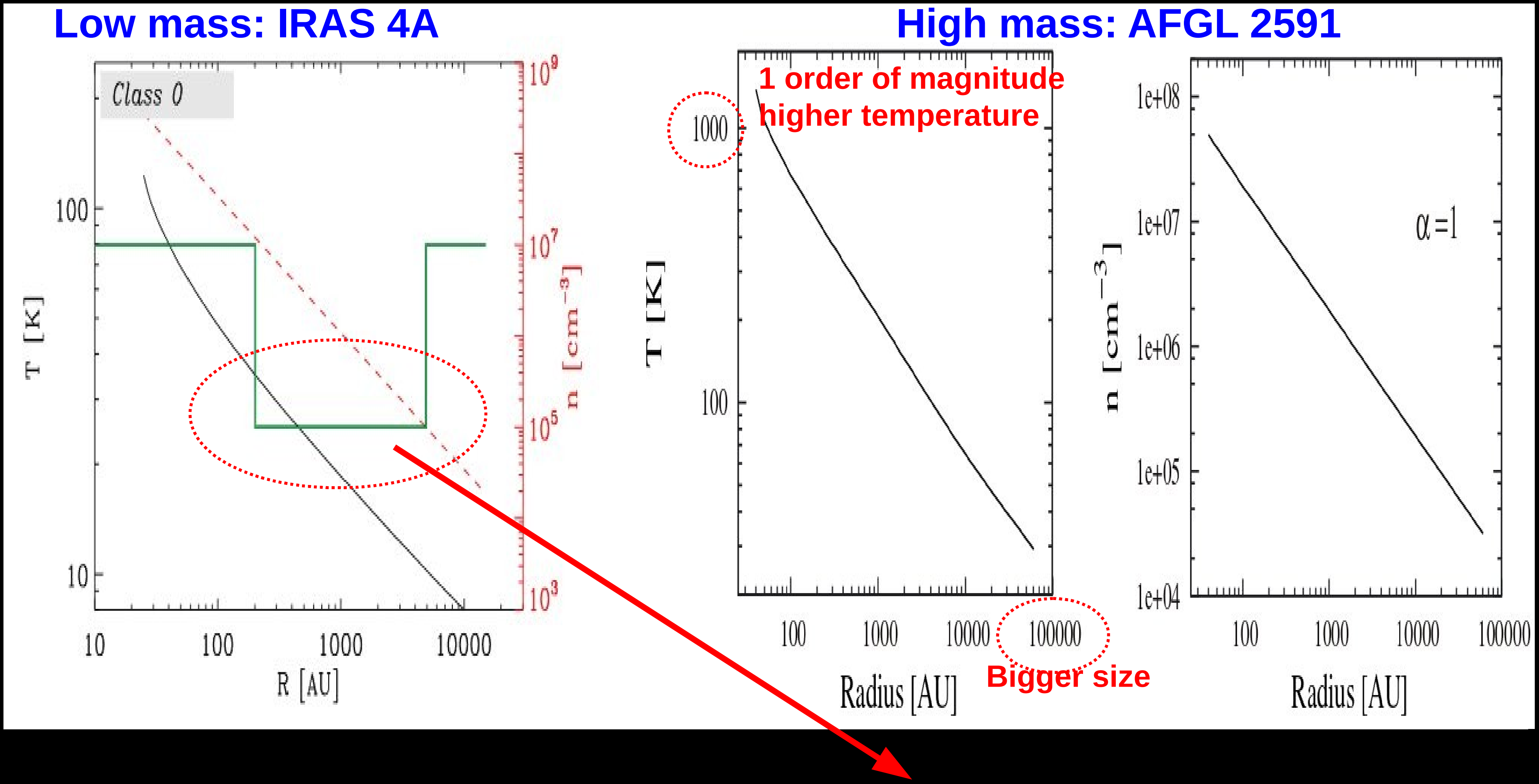




High vs low mass protostar:

- 1-2 orders of magnitude higher abundances (wrt H_2) but similar wrt CO
- No need for UV cavities
- Absence of freeze out zones (e.g. CO)

Possible explanation



Absence of freeze out zone

Secondary Results

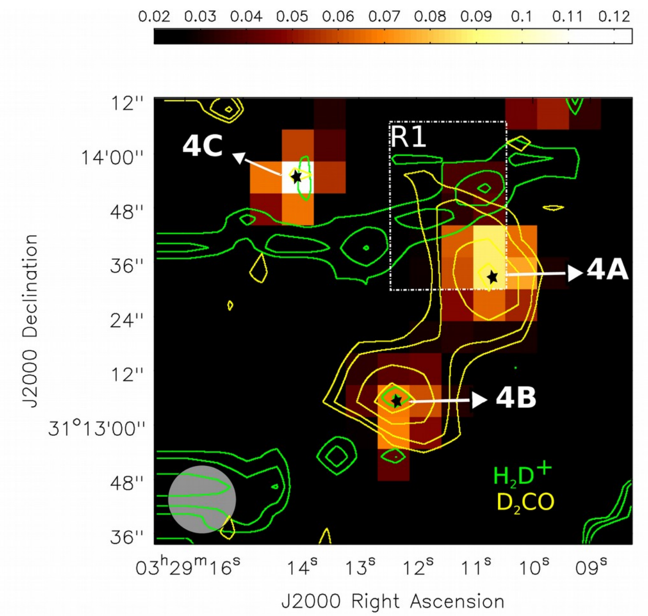
Koumpia et al. 2017 (A&A, 603A, 88K)

a) The CH_3OH modeled abundance profile points towards an age of ≥ 4×10^4 yrs for IRAS 4A

b) The spatial distribution of H_2D^+ differs from other deuterated species (i.e. DCO^+, HDCO and D_2CO) → colder layer (<20 K) in the foreground?

Not seen in any other tracer !

c) Enhanced deuterated species towards the outflow

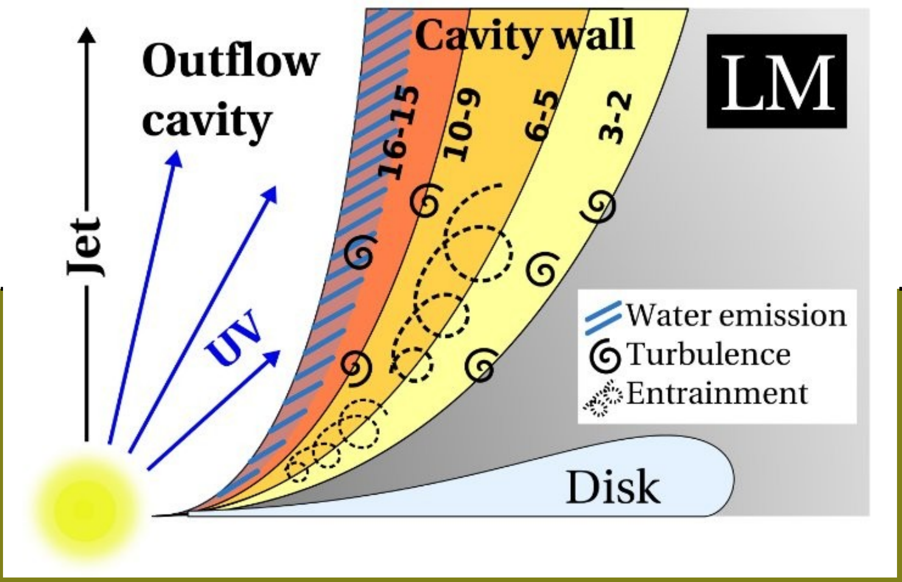


Conclusions

The observed abundances can be explained by different mechanisms:

a) high mass → *passive* heating

b) low mass → *UV cavity* channels



Future direction

2D and 3D Models which include disk structure and outflow activity

Studies of a bigger sample

Gas-phase CO/H_2 measurements

High resolution observations (e.g. ALMA)

The presence/absence of *freeze out zone* influences the absolute values of the abundances (higher towards AFG 2591).