The influence of cosmic rays on the chemistry in Sagittarius B2(N)

Mélisse Bonfand

A. Belloche, K. M. Menten, R. Garrod

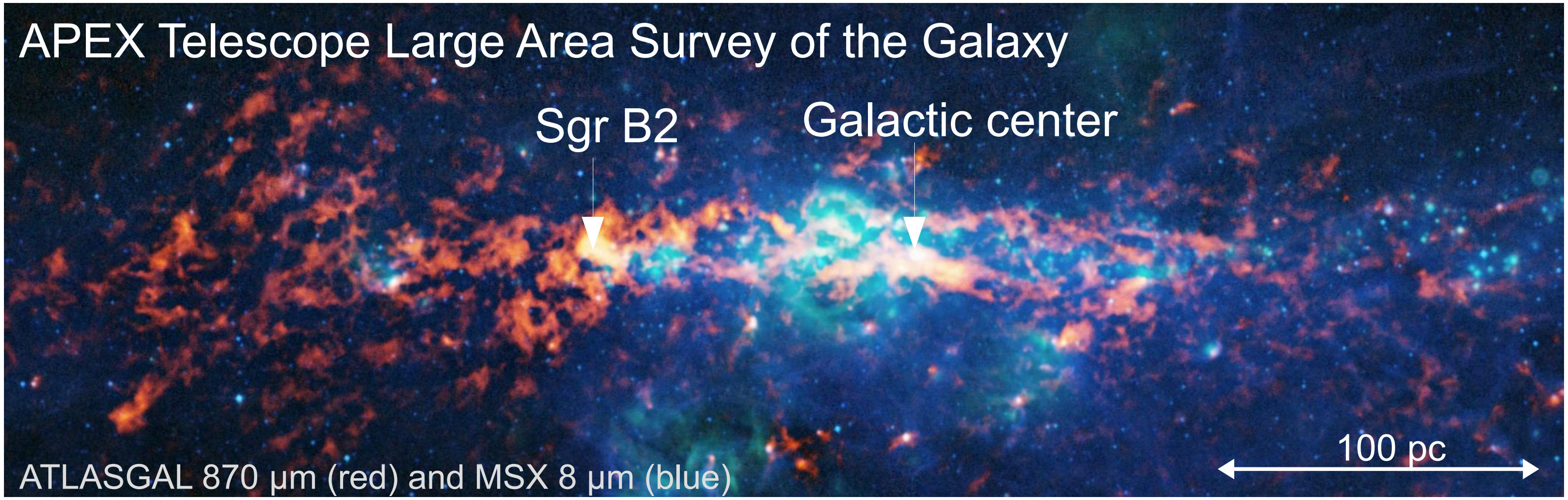
Max-Planck-Institut für Radioastronomie

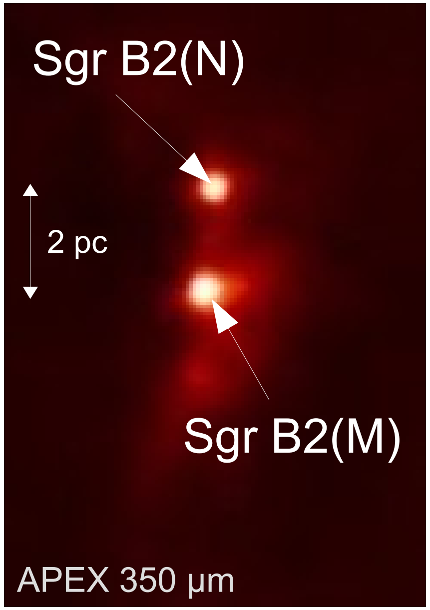
SFB 956 Cologne | Bonn

IMPRS astronomy & astrophysics Bonn and Cologne

University of Virginia 1819

Sagittarius B2



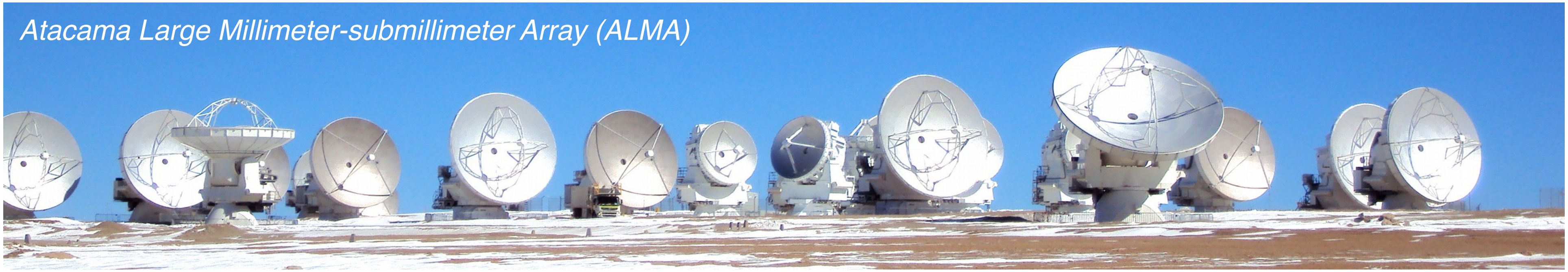


Images credit: ESO

- Located in the CMZ, **close to the galactic center**
- One of the most prominent regions forming high-mass stars in our galaxy
- It contains several active sites of high-mass star formation
- It harbors a great variety of **Complex Organic Molecules (COMs)**

  - expected to form in warm and dense regions
  - expected to form in the ices at the surface of dust grains
  - **formation pathways still poorly understood**

Investigating the complex organic chemistry



Observations

EMoCa (**E**xploring **Mo**lecular **C**omplexity with **A**LMA) survey

- 3 mm (84 – 114 GHz)
- High angular resolution (1.6") and sensitivity (3 mJy/beam)
- Targets Sgr B2(N)

Chemical modeling

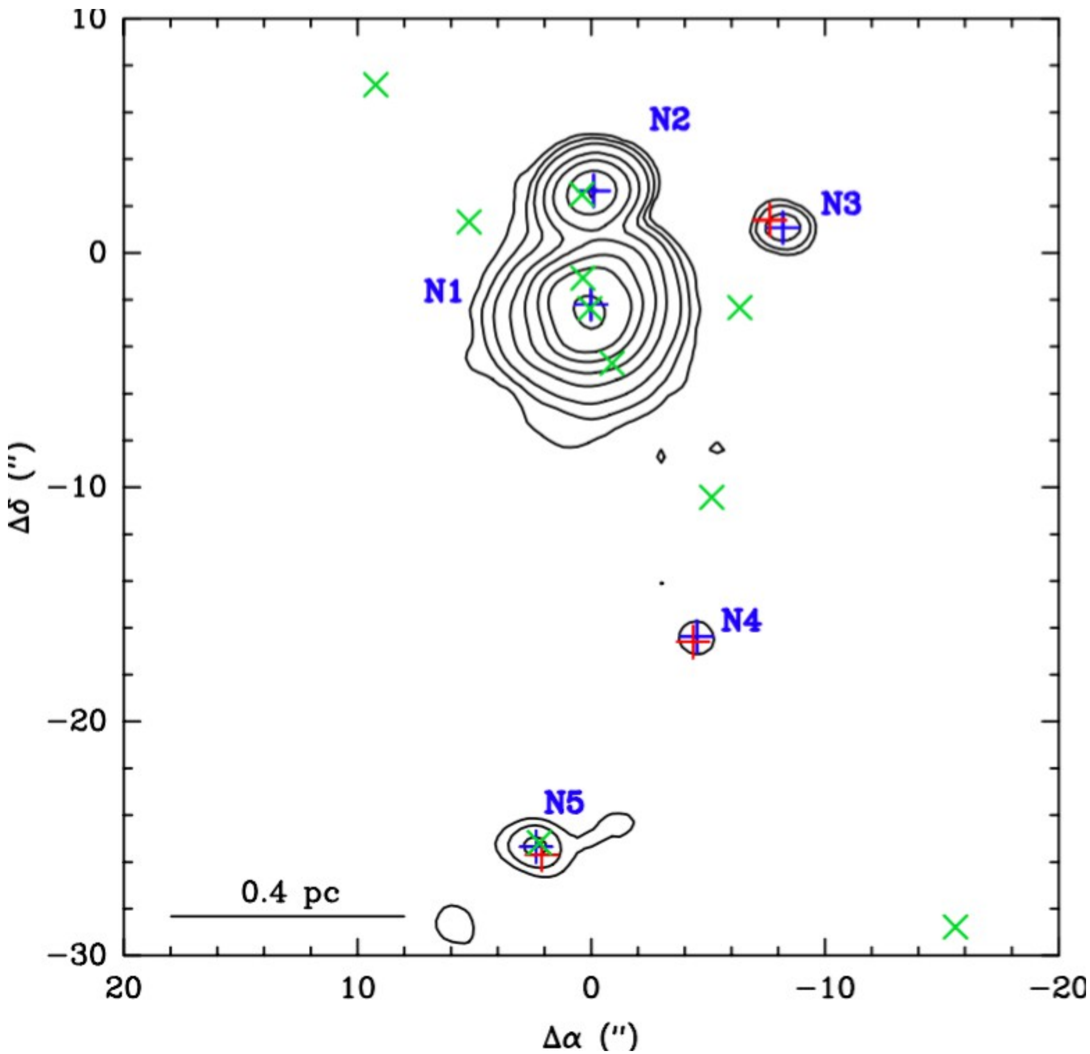
MAGICKAL (**M**odel for **A**strophysical **G**as and **I**ce **C**hemical **K**inetics **A**nd **L**ayering) (Garrod 2013)

Goals

- **Test the predictions of chemical models** (constrain parameters, e.g cosmic rays)
- **Better understand** pathways that lead to the **formation of COMs**

Observations

Hot cores in Sgr B2(N)



Map of spectral line density (Bonfand et al. 2017)

Hot cores

(UC)HII regions

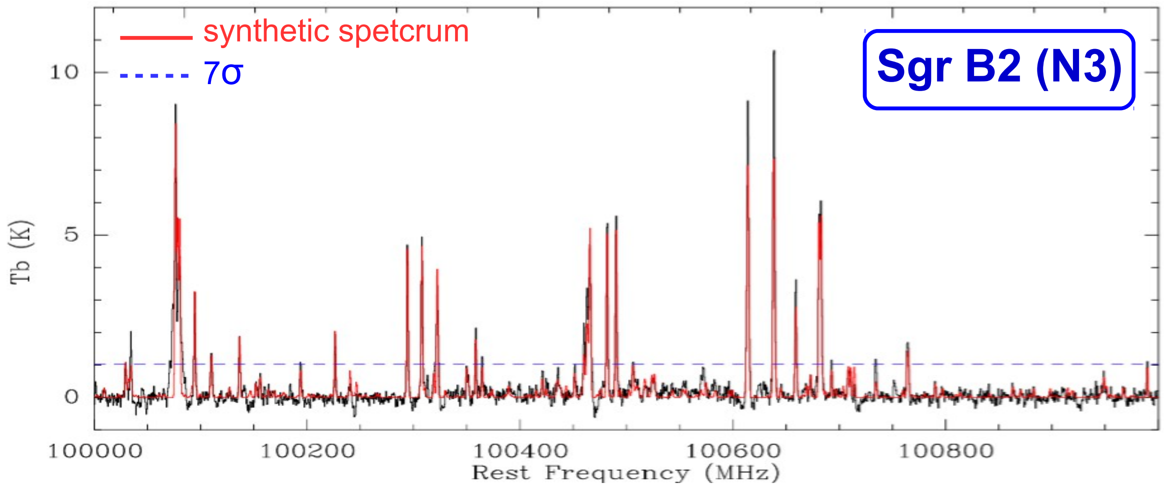
6.7 GHz class II methanol masers

Tracers of high-mass stars

⇨ **5 hot cores**

Chemical composition of the hot cores

- We **derived chemical compositions** by fitting all emission lines assuming LTE

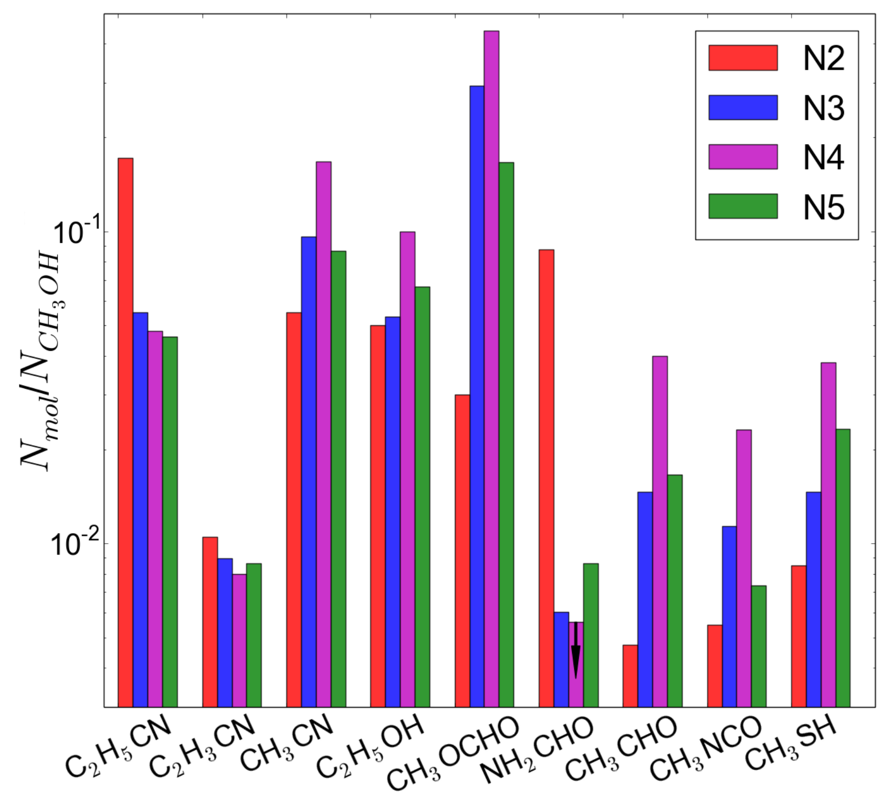


*Part of the **continuum-subtracted** observed spectrum*

Source	#species	#isotopologs	#excited
N2	52	49	70
N3	24	20	16
N4	20	10	5
N5	23	13	7

Chemical composition of the hot cores

⇨ **Results:**



Abundances with respect to methanol

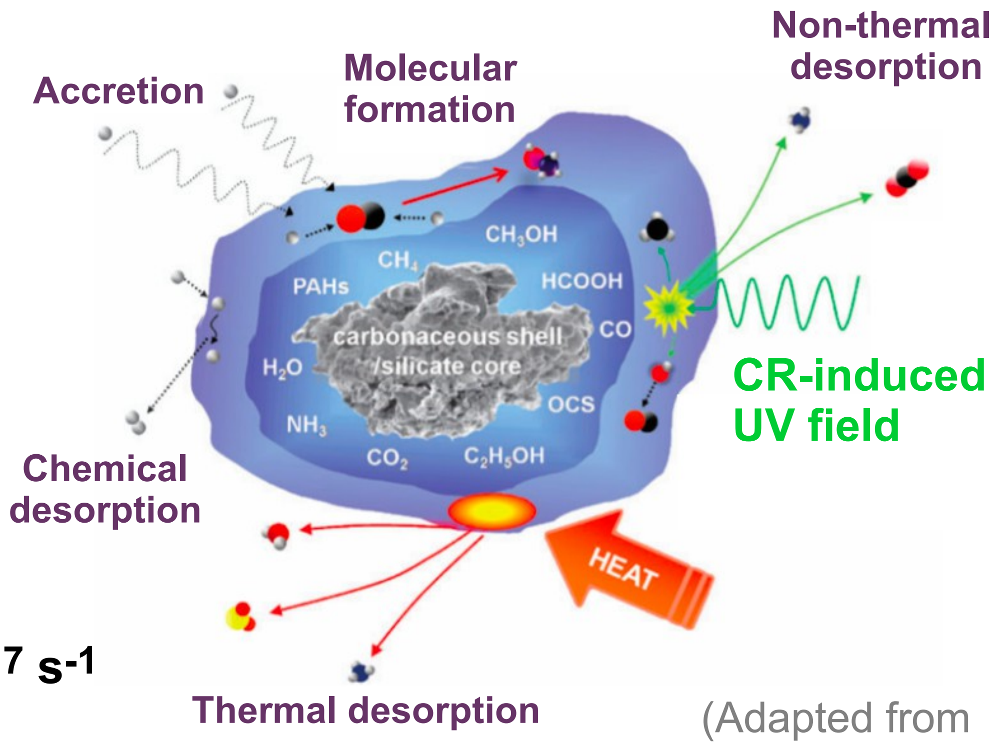
Chemical modeling

MAGICKAL: Chemistry

- Chemical network: 1333 species → 13370 chemical reactions
- **3 phases**: gas-phase , grain/ice-surface, ice mantle
- Modified rate equations (Garrod 2008)

Cosmic rays in the code

- Main source of **ionization**
- **Formation of radicals** at the surface of dust grains by photodissociation
- **Desorption** of surface species



(Adapted from Burke et al. 2010)

Cosmic ray ionization rate (CRIR)

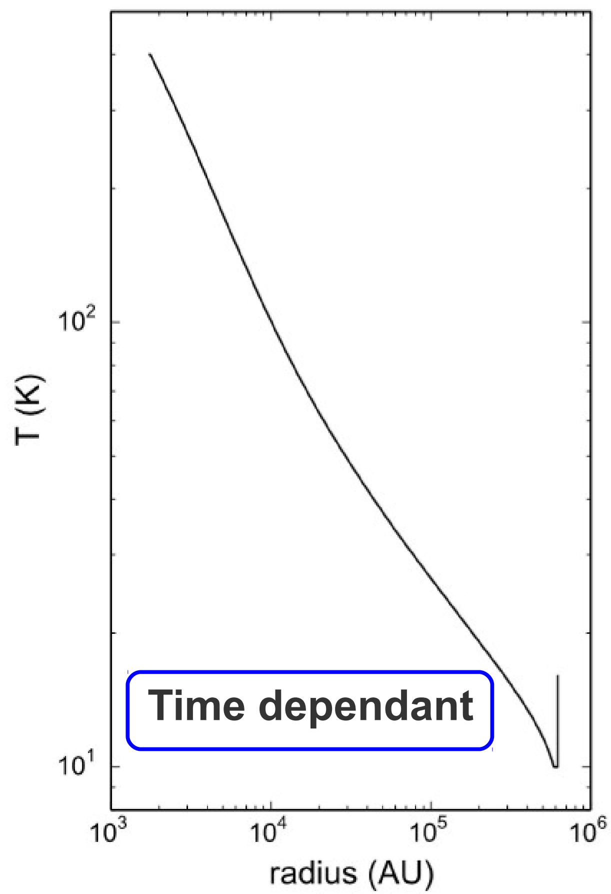
- Our model uses the **standard value 1.3x10^{-17} s^{-1}** (Spitzer & Tomasko1968)
- **Higher CRIR expected towards the galactic center:**
  - **≈ 10^{-15} s^{-1}** in diffuse CMZ gas (Oka et al. 2005)
  - **≈ 10^{-16} s^{-1}** in the Sgr B2 envelope (van der Tak et al. 2006)
  - **≈ 10^{-14} s^{-1}** towards the Brick (Clarke et al. 2013)

MAGICKAL: Physical evolution

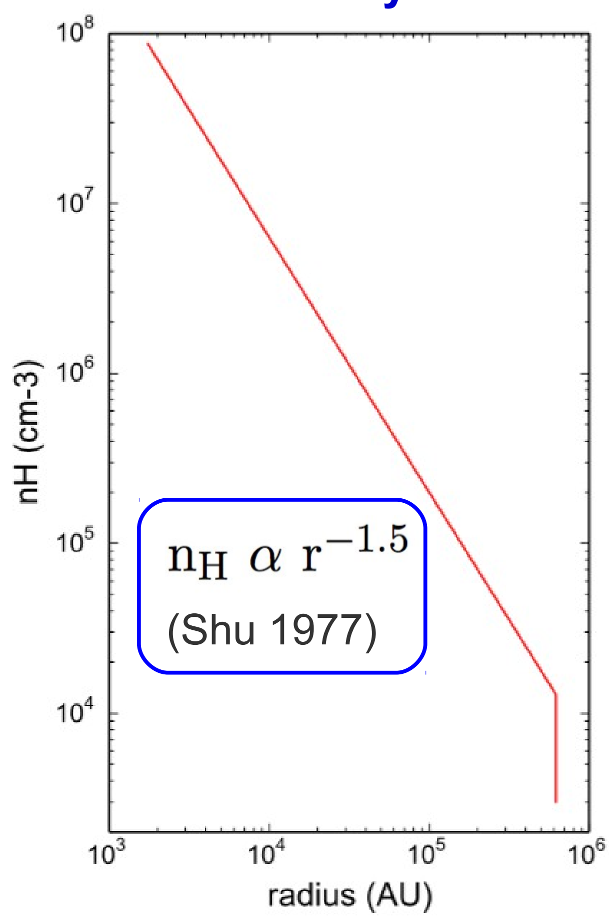
- Physico-chemical evolution: starting from the **cold pre-stellar phase**, followed by the **free-fall collapse** of the cloud, through the **warm-up** of the dense core
- We derived physical profiles based on observational constraints

Sgr B2 (N2)

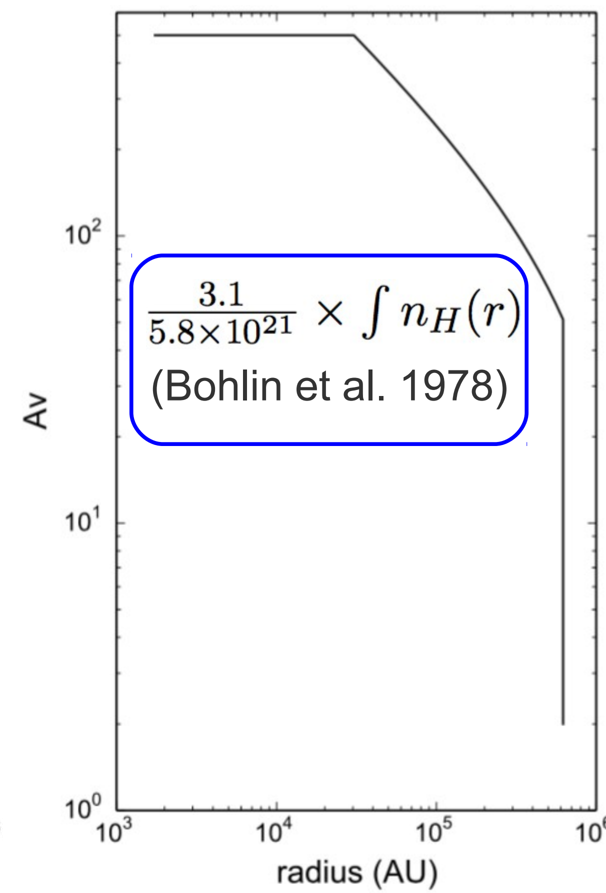
Dust Temperature



Density



Visual exinction



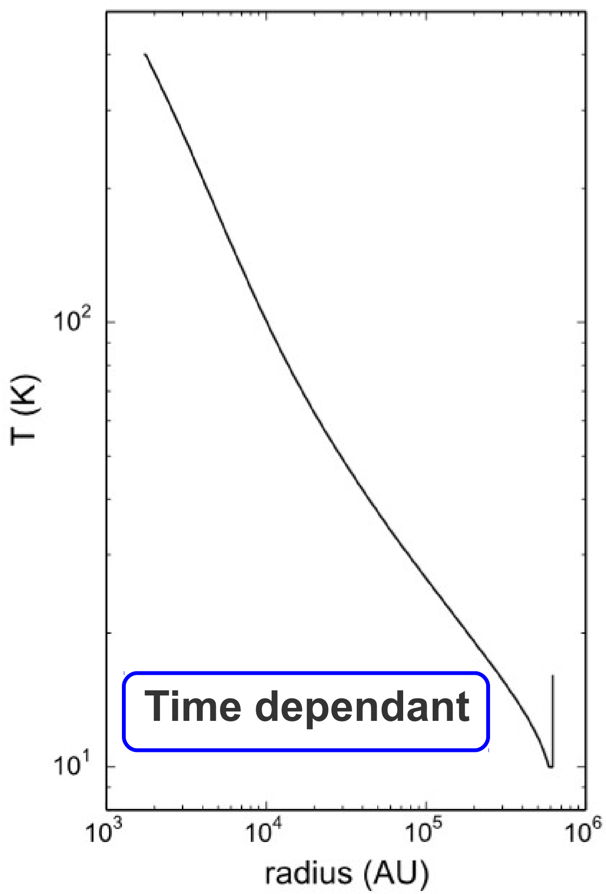
MAGICKAL: Physical evolution

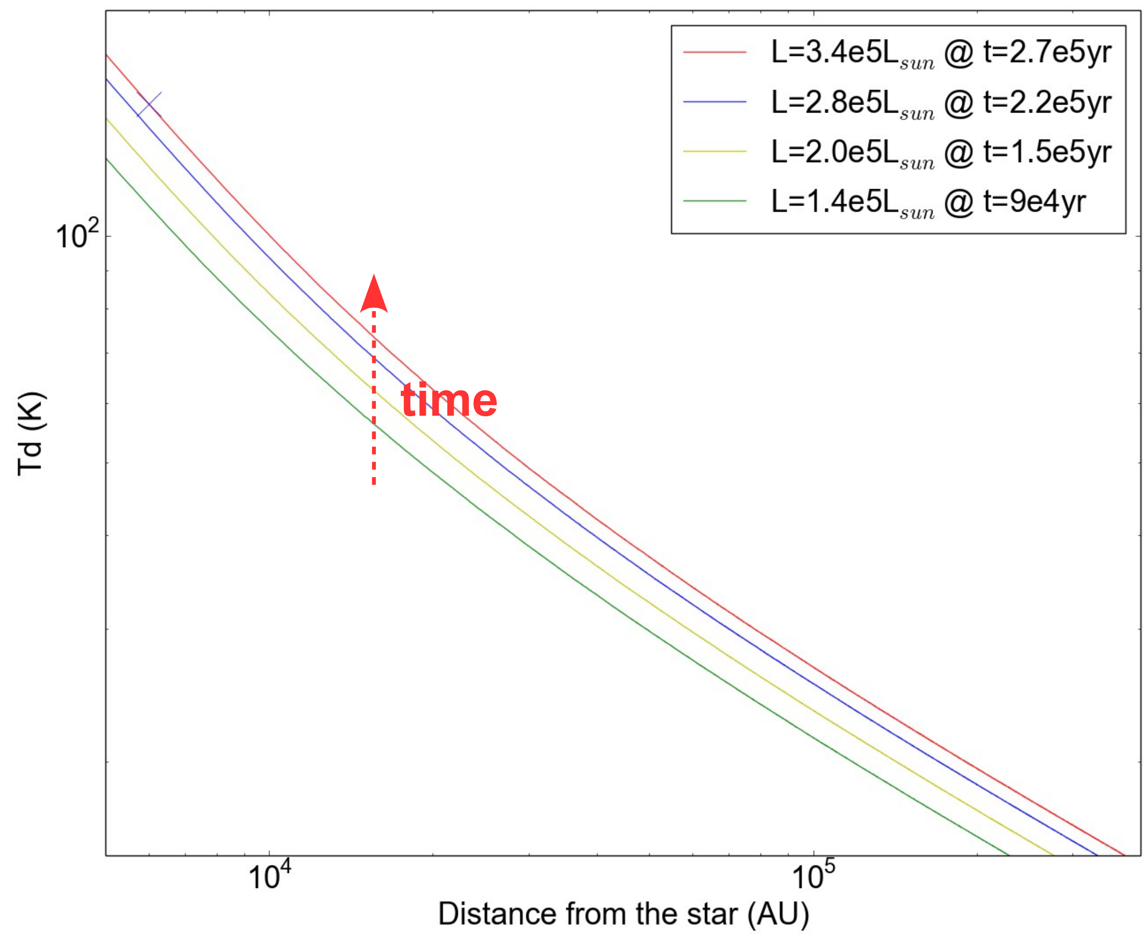
- Physico-chemical evolution: starting from the **cold pre-stellar phase**, followed by the **free-fall collapse** of the cloud, through the **warm-up** of the dense core

- We derived physical profiles based on observational constraints

Sgr B2 (N2)

Dust Temperature



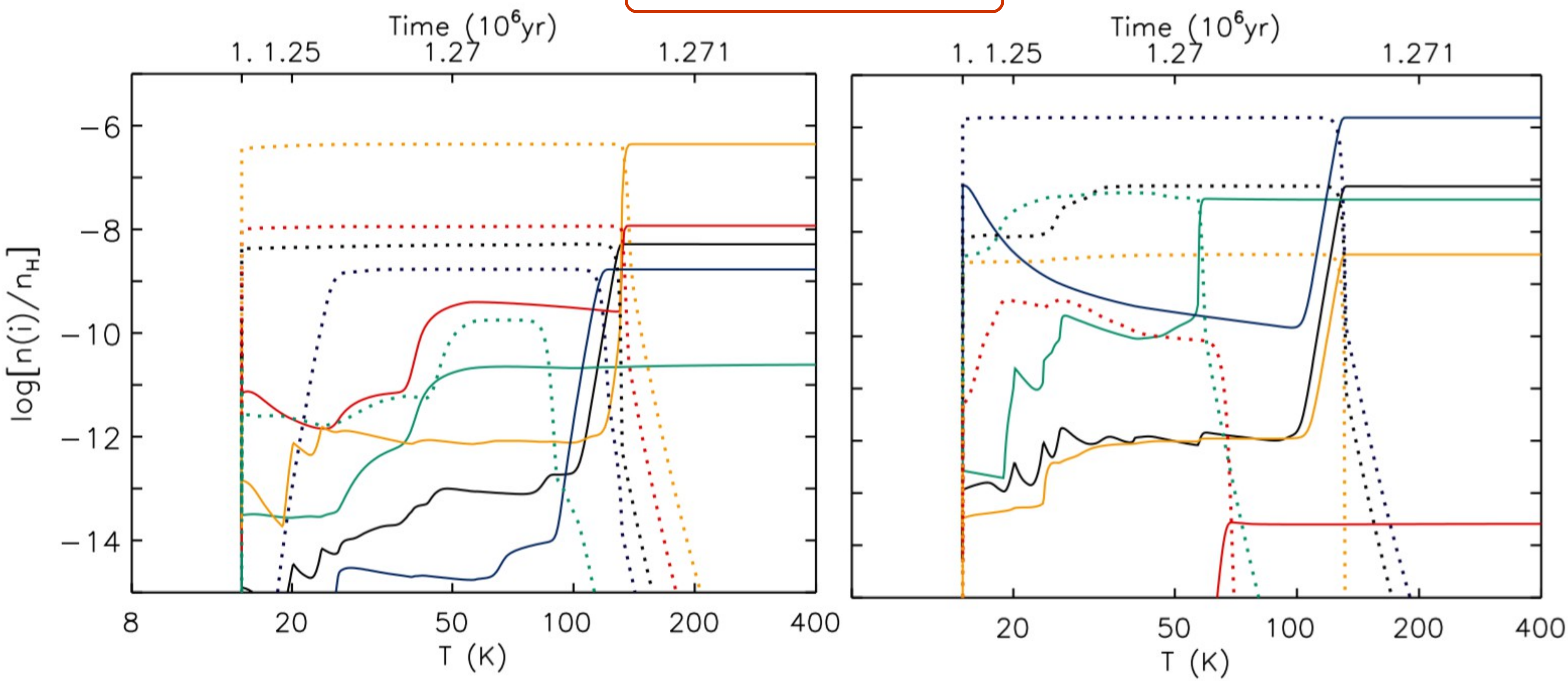


Profiles produced based on radiative transfer calculations

MAGICKAL: Results

Sgr B2 (N2)

CRIR = 1.3×10^{-17} s^{-1}



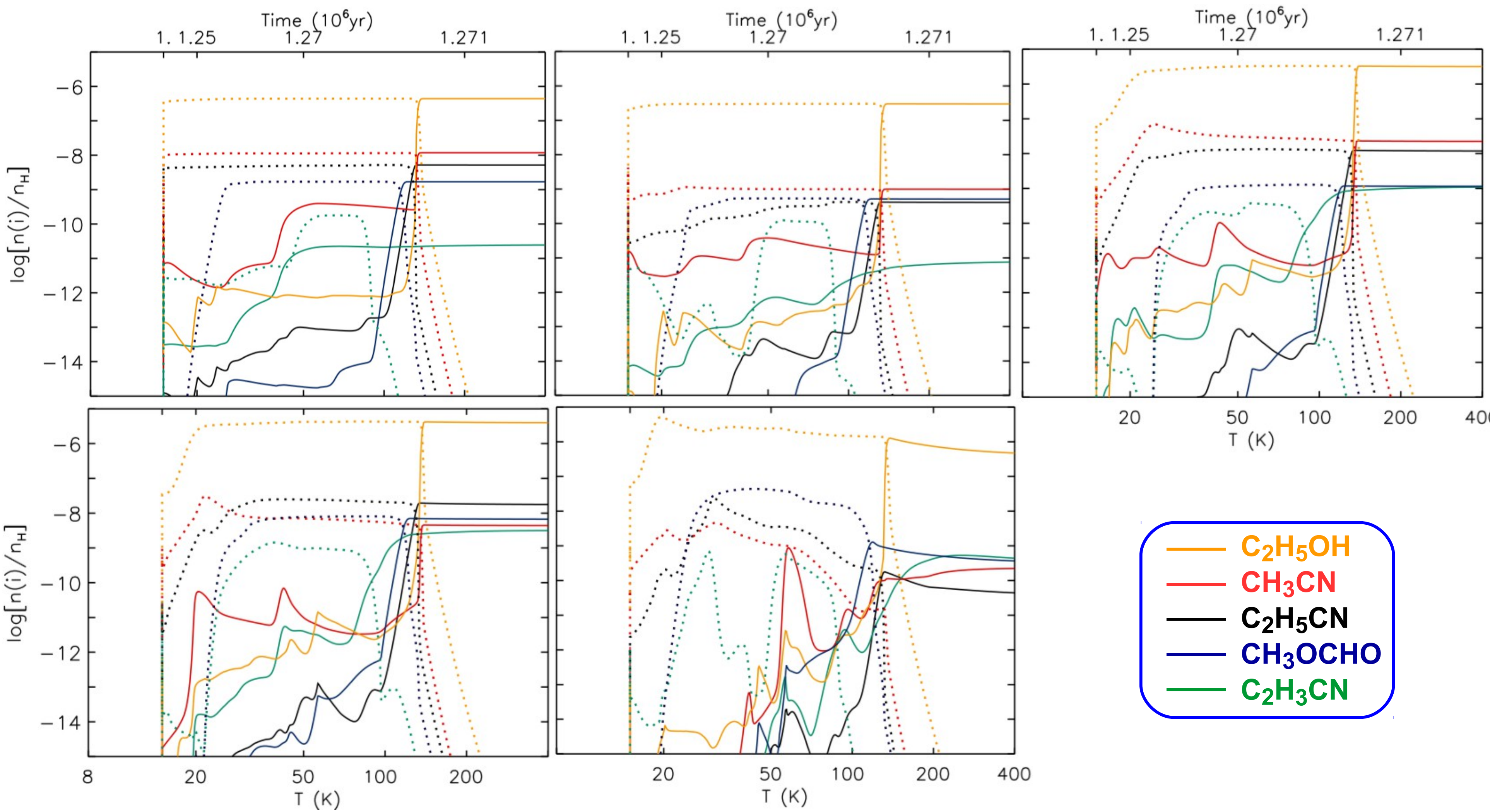
Evolution of fractional abundances (with respect to total hydrogen) in the gas phase (solid lines) and in the ices at the surface of the grains (dotted lines)

- C_2H_5OH
- CH_3CN
- C_2H_5CN
- CH_3OCHO
- C_2H_3CN

- CH_3OH
- NH_2CHO
- CH_3CHO
- CH_3SH
- CH_3NCO

Influence of cosmic rays

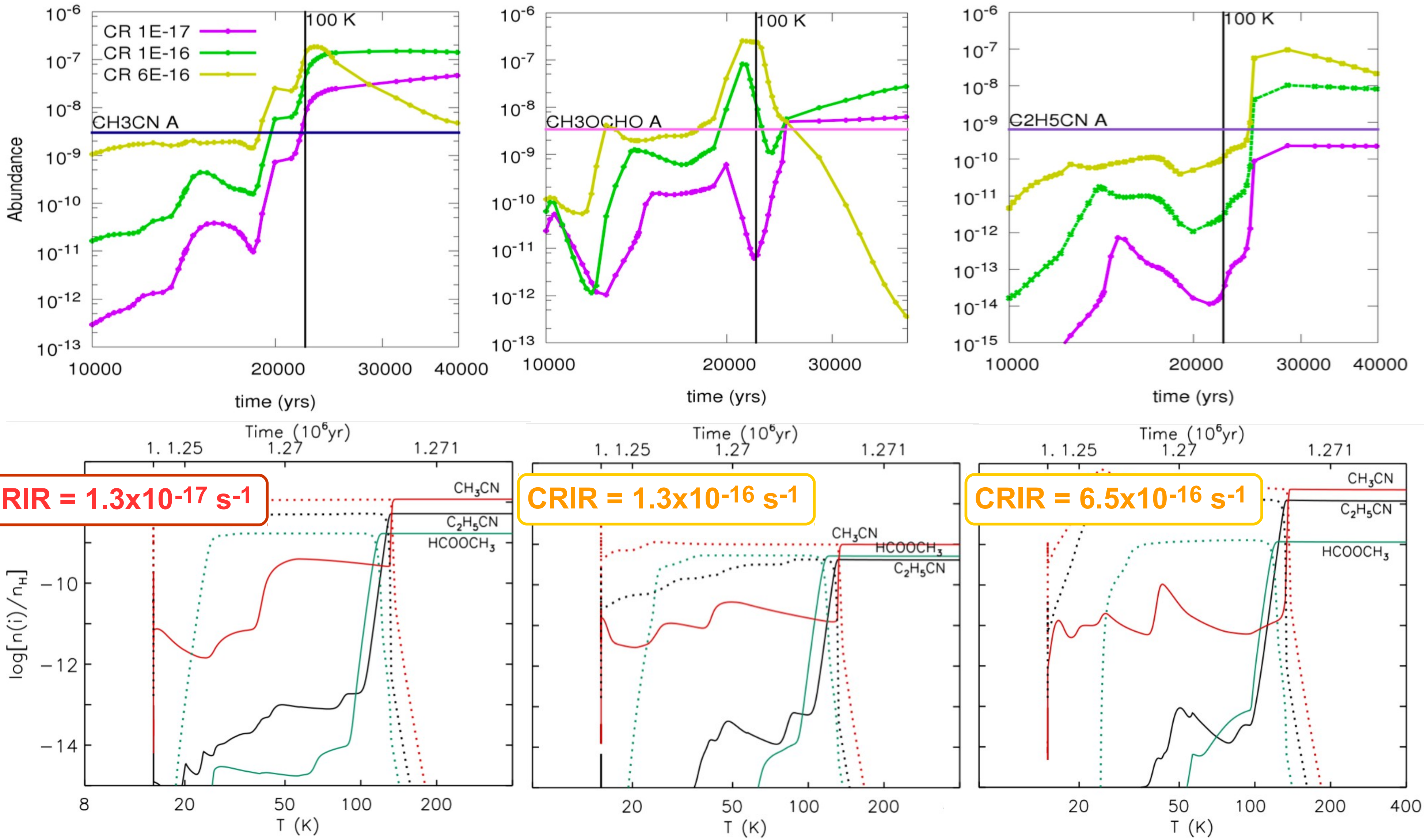
CRIR = 1.3x10^{-17} s^{-1} | CRIR = 1.3x10^{-16} s^{-1} | CRIR = 6.5x10^{-16} s^{-1}



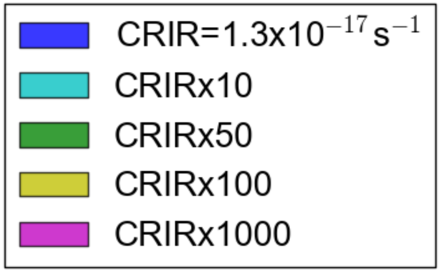
CRIR = 1.3x10^{-15} s^{-1} | CRIR = 1.3x10^{-14} s^{-1}

Comparison with other chemical models

- Allen et al. (2018) used a gas-grain chemical code ($n = 10^7$ cm^{-3}, T =10 → 500 K over 52 kyr) to reproduce abundances observed towards G35.2-0.74 A



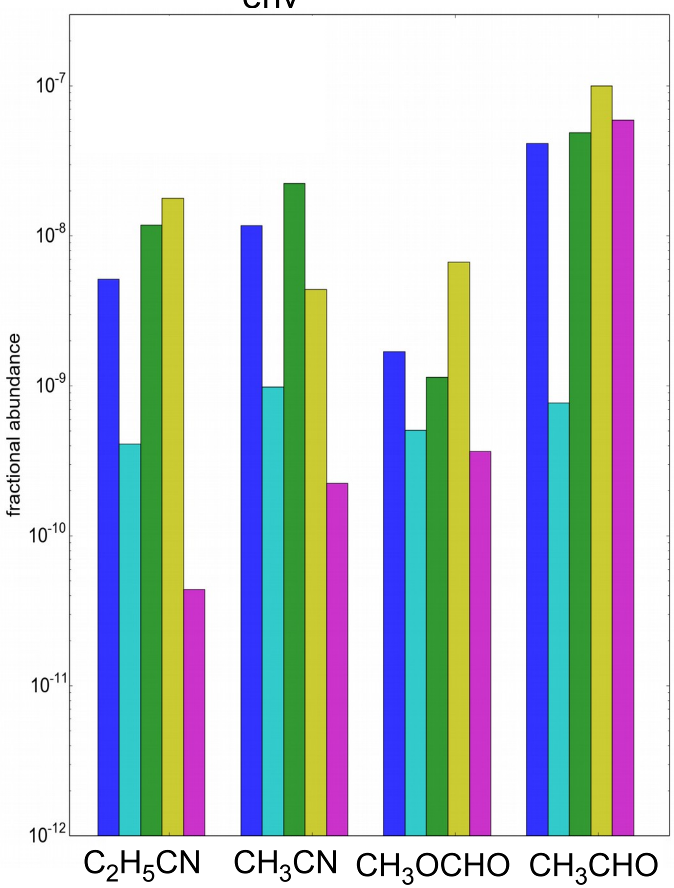
Influence of physical properties



Sgr B2 (N2)

$L_* = 3.4 \times 10^5\ L_\odot$

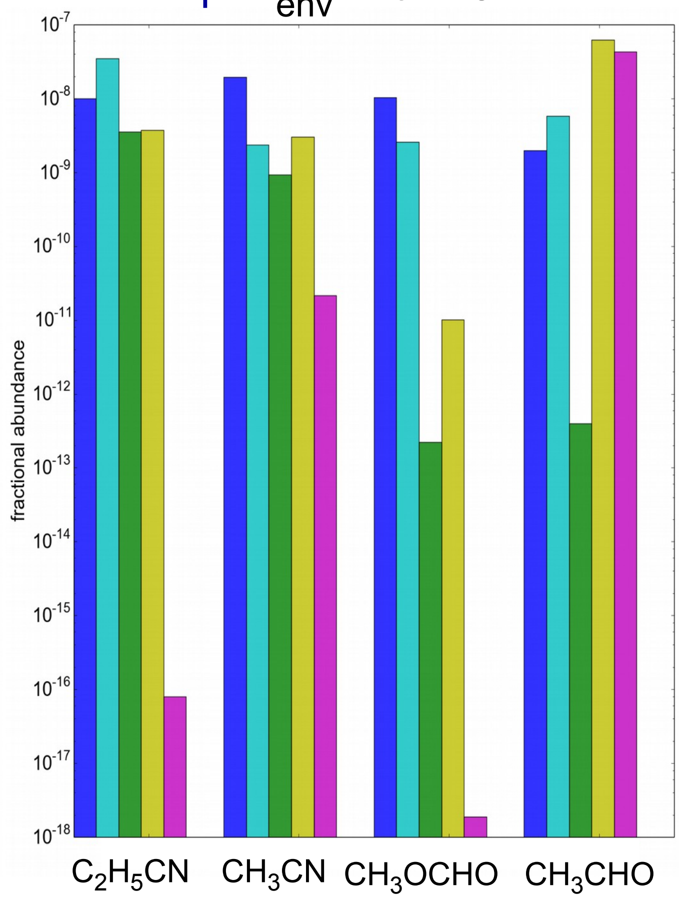
$M_{env} = 170\ M_\odot$



Sgr B2 (N3)

$L_* = 5.5 \times 10^4\ L_\odot$

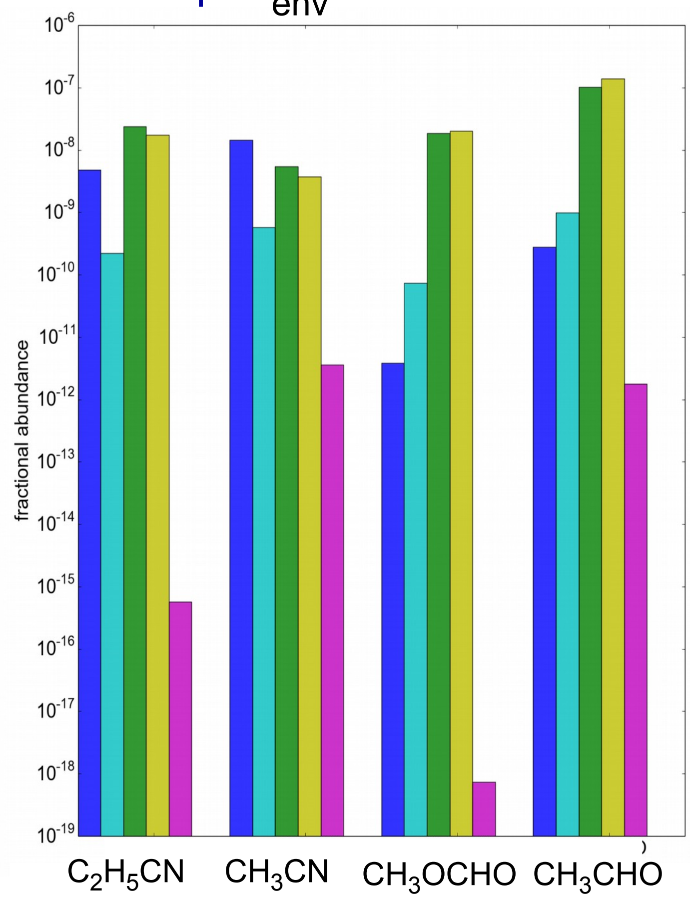
$M_{env} = 6\ M_\odot$



Sgr B2 (N4)

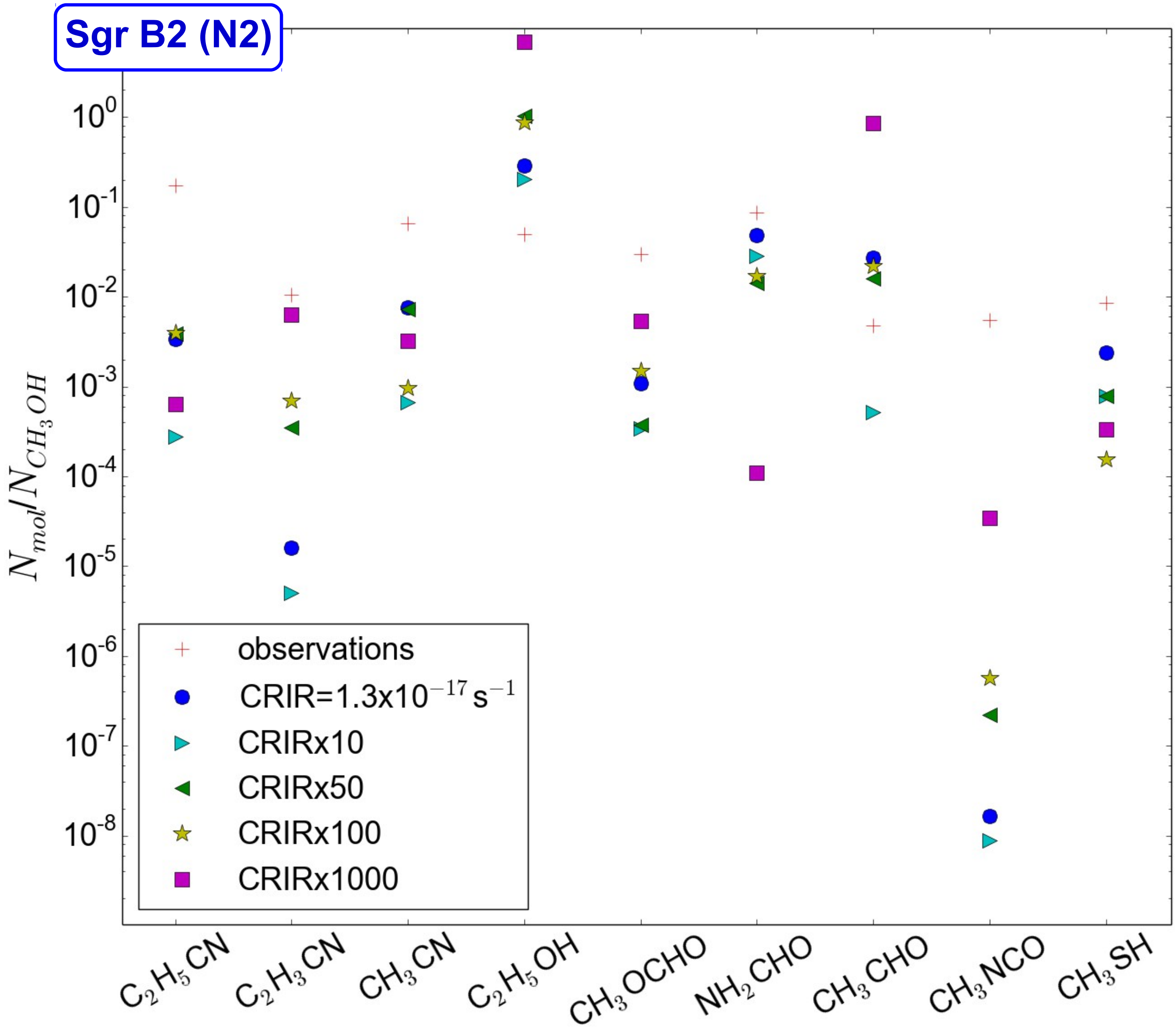
$L_* = 4.6 \times 10^5\ L_\odot$

$M_{env} = 43\ M_\odot$



Fractional abundances (with respect to total hydrogen)

Comparison with observations



Abundances with respect to methanol

Summary

- We characterized the hot cores in Sgr B2(N): physical properties and chemical composition
- We derived physical profiles based on observational constraints
- We studied the **influence of cosmic rays on the gas-phase abundances of COMs** using the chemical kinetics code MAGICKAL

➤ **Work in progress**

- Investigating the **impact of cosmic rays on the chemical reactions involved in the formation/destruction of COMs** using the chemical code MAGICKAL
- Comparing our results with other models
- **Constraining the cosmic ray ionization rate towards Sgr B2(N)** by comparing the predictions of the model with observations

Thank you !