Multi-phase environment of the Centaurus A

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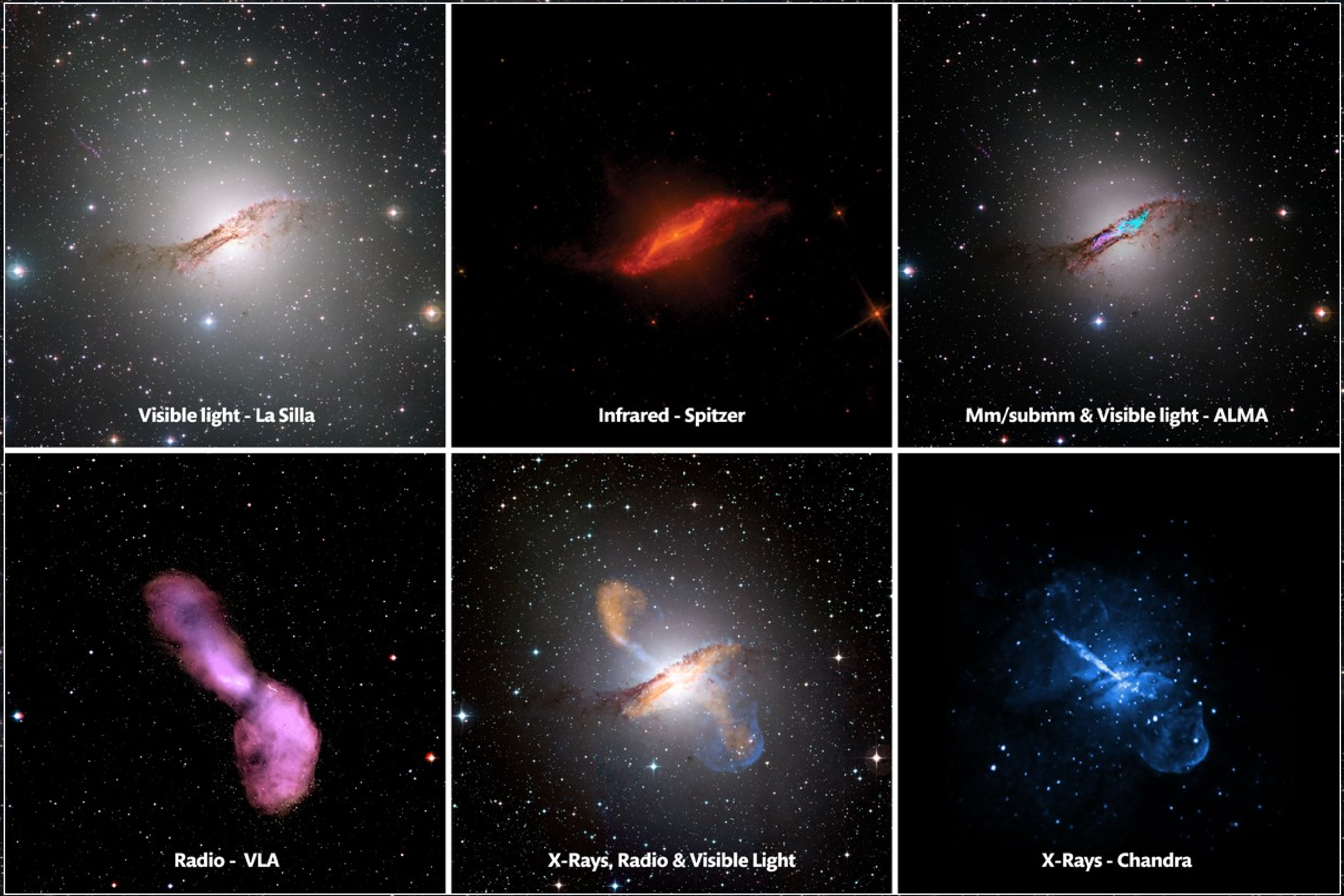
ALMA
EUROPEAN ARC
ALMA Regional Centre || Czech

asu
Astronomical Institute
of the Czech Academy of Sciences

Centaurus A

Fabian Neyer

Image: HST/ESO


Visible light - La Silla
Infrared - Spitzer
Mm/submm & Visible light - ALMA
Radio - VLA
X-Rays, Radio & Visible Light
X-Rays - Chandra

Centaurus A

Nearest Active Radio Galaxy

FR-I low luminosity AGN

Distance: 3.8 Mpc

BH mass: $\sim 6 \times 10^{7}\ M_{sun}$

Luminosity: $L_{bol} = \sim 2 \times 10^{43}$ erg/s

Bondi Accretion: $6.4 \times 10^{-4}\ M_{sun}$/yr

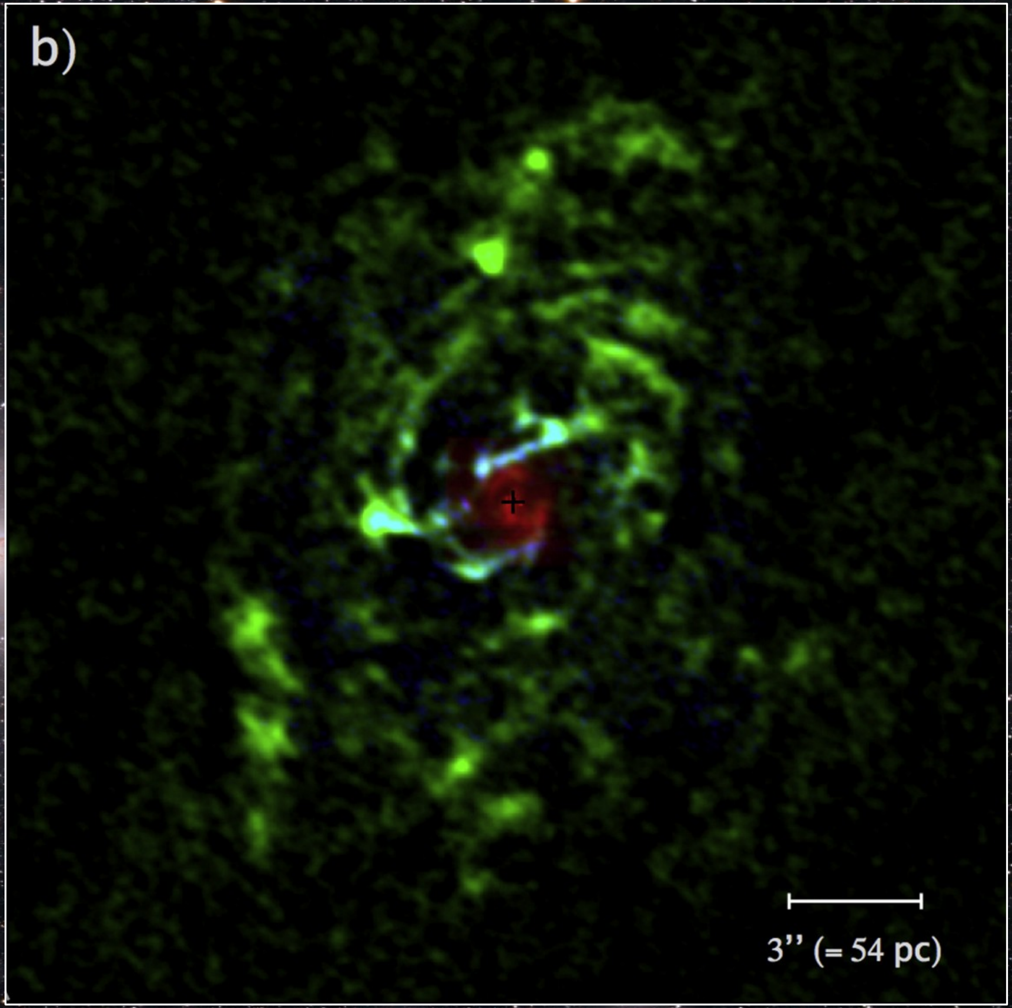
Multiphase environment

The different phases of the gas

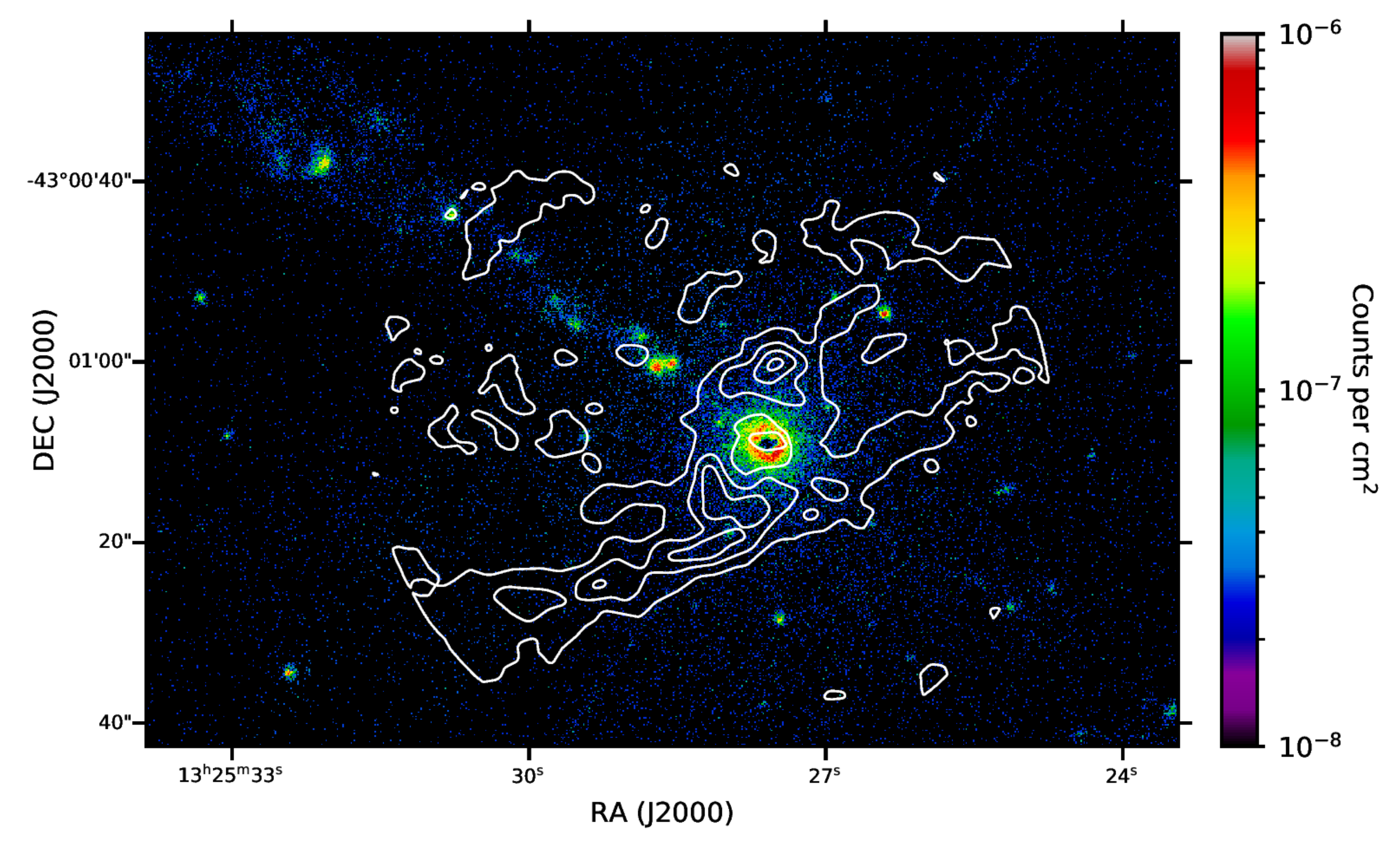
- hot (X-ray),
- warm (ionized)
- cold (H I and molecular)

All detected in Centaurus A

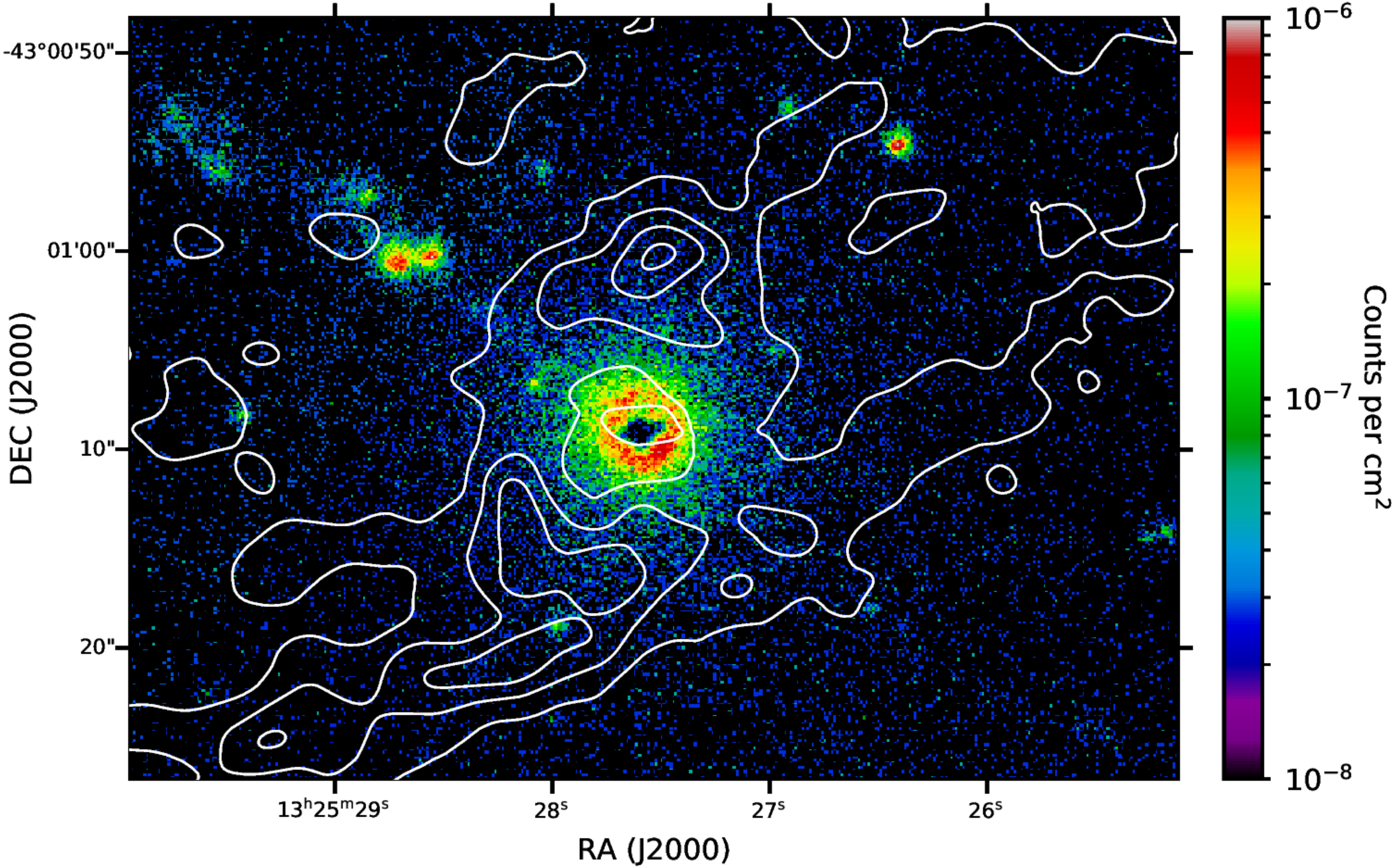
Can be studied at very high spatial resolution, due to its proximity

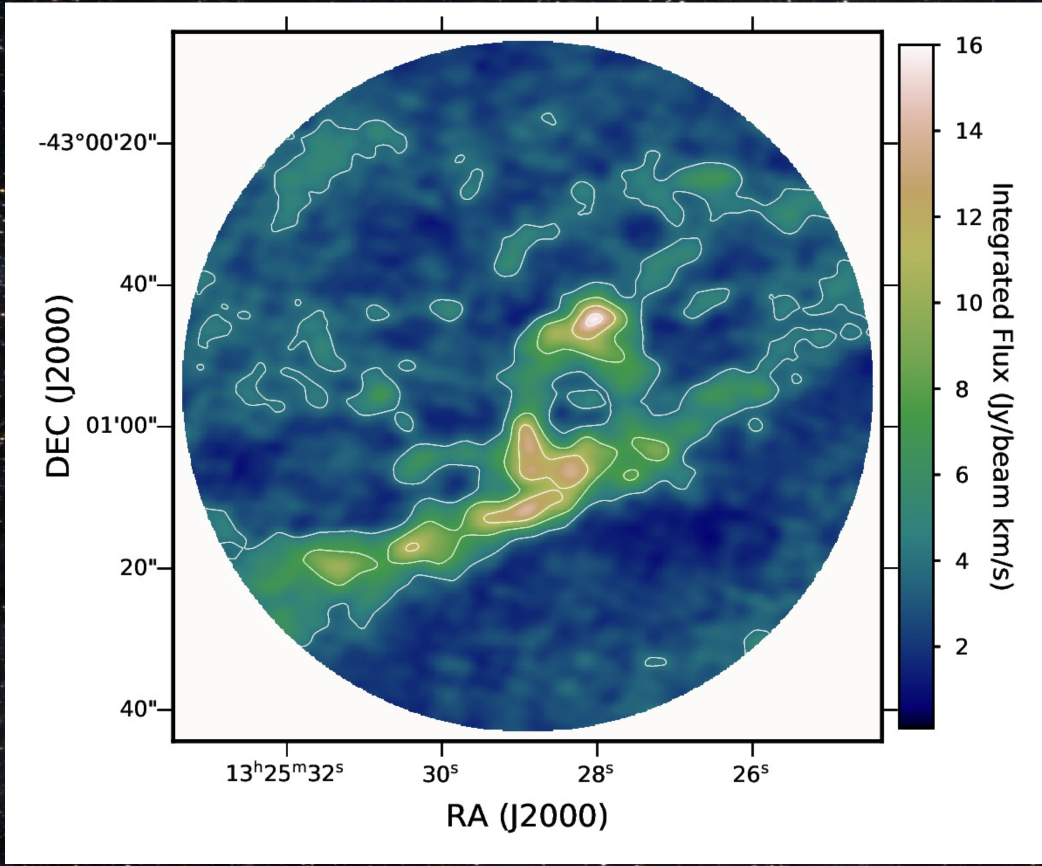


Espada et al. 2017

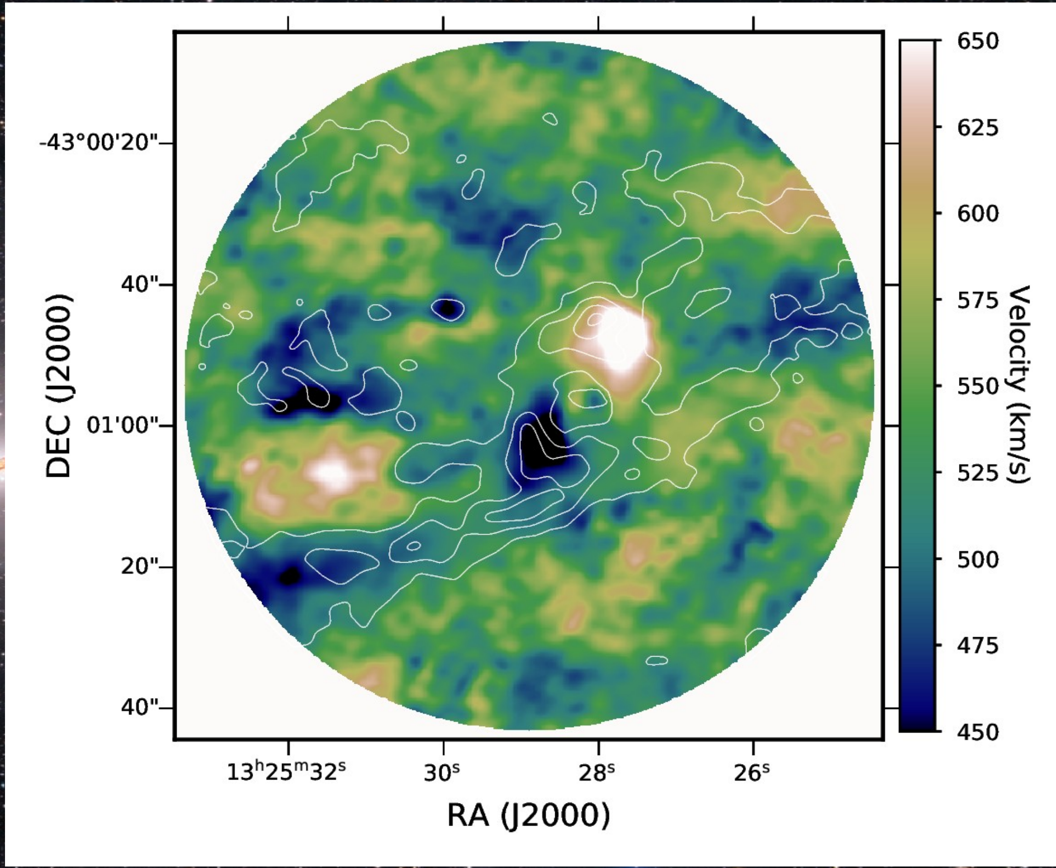


-43°00'40"
01'00"
20"
40"
DEC (J2000)
13h25m33s
30s
27s
24s
RA (J2000)
10^{-6}
10^{-7}
10^{-8}
Counts per cm^2

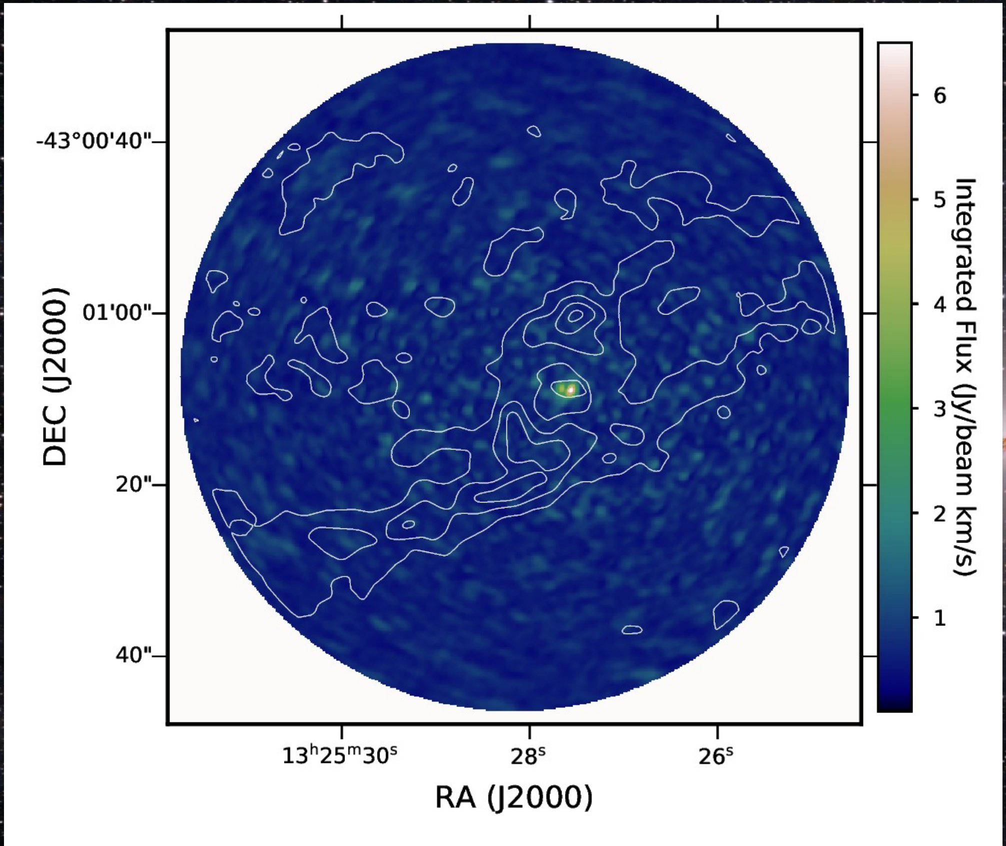

-43°00'50"
01'00"
10"
20"
DEC (J2000)
13h25m29s
28s
27s
26s
RA (J2000)
10−6
10−7
10−8
Counts per cm2



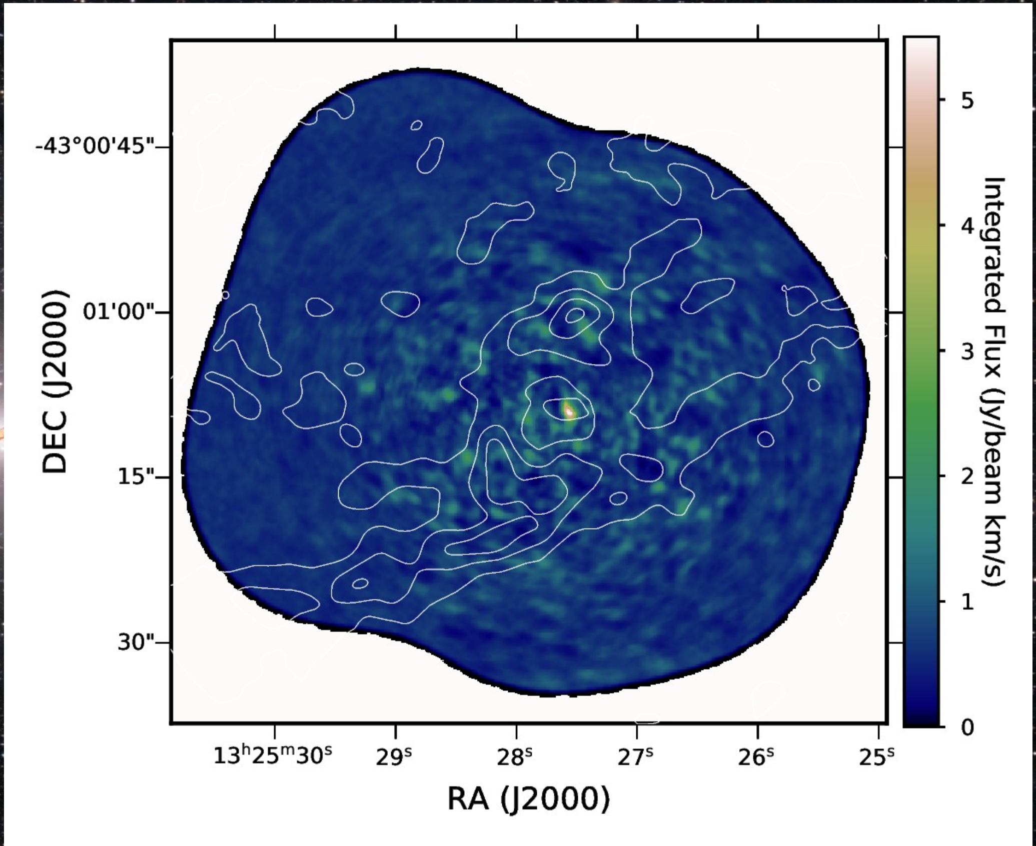
Integrated flux CO (1-0)



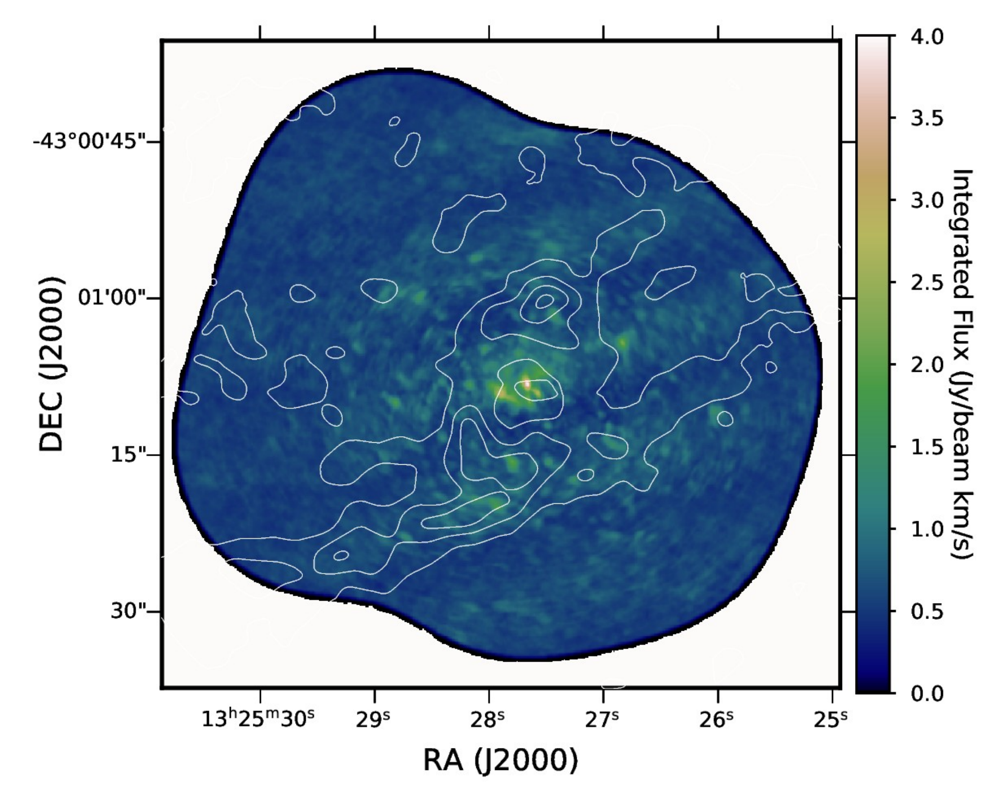
Velocity map CO (1-0)



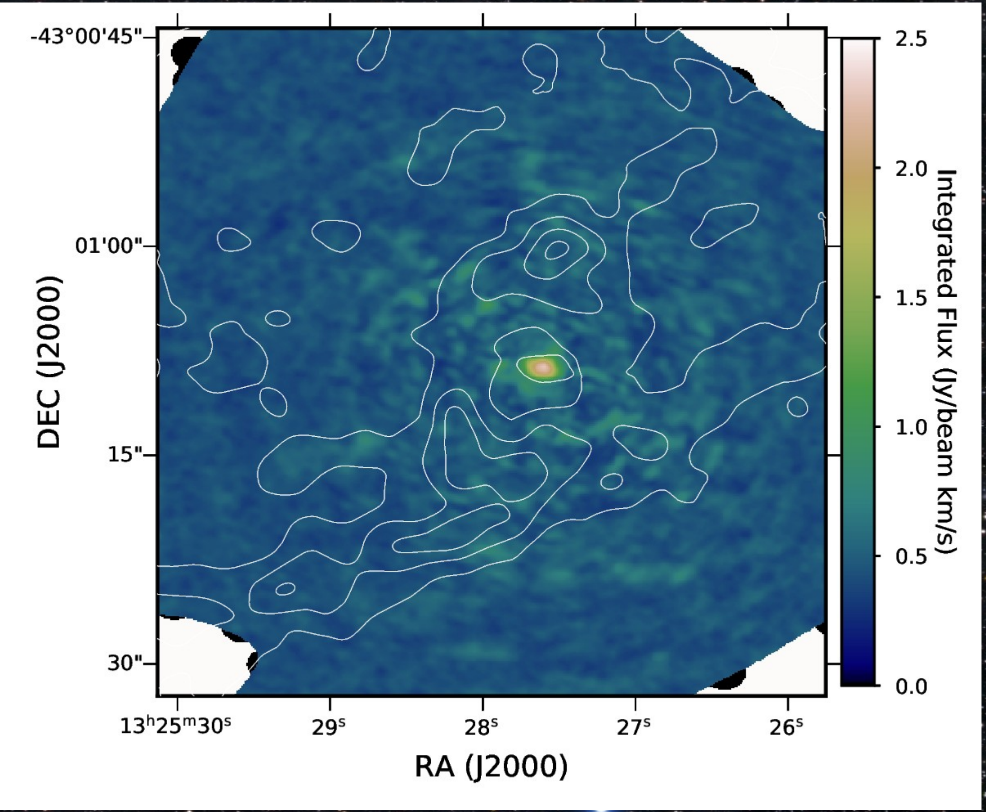
Integrated flux CS



Integrated flux HCN



Integrated flux HCO+



Integrated flux HNC

Model Set-up

- Multi-phase ISM can form spontaneously by the irradiation-induced effects of thermal instabilities.
- Contact between two phases is affected by continuous injection of fresh material.
- Mass & energy input can lead to inflow/outflow or non-stationary accumulation.
- The cooling timescale tcooling depends on the cooling mechanism and corresponding physical parameters: temperature, density, chemical abundances, & dust content.

Model Set-up

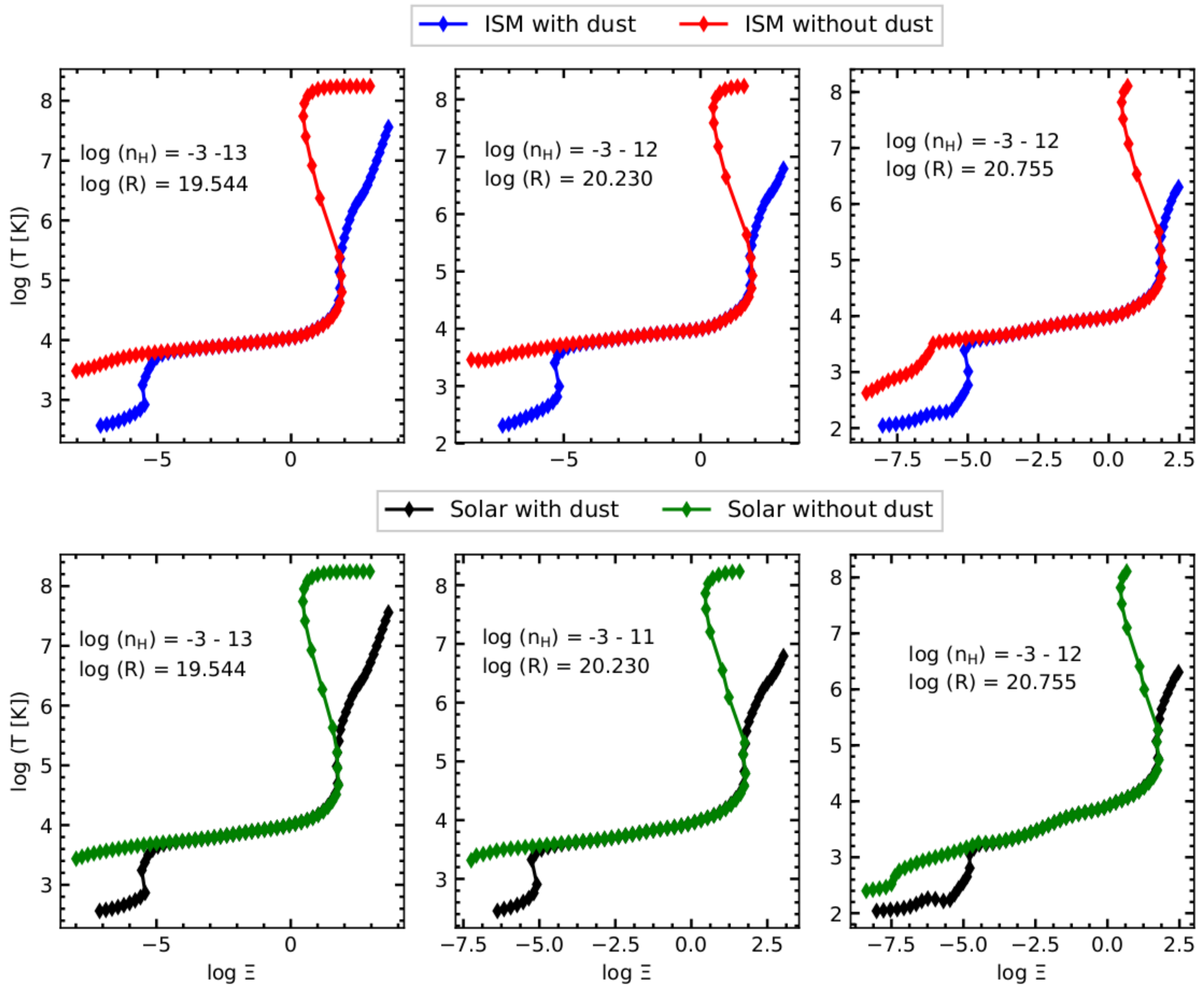
- incident radiation field can both cool and heat the plasma.
- The net effect is determined by plasma density and the spectral shape of the incident radiation.
- we distinguish between two cases:
  - the state of stable plasma in thermal equilibrium
  - the cooling timescales relevant for plasma far from thermal equilibrium

Model Set-up

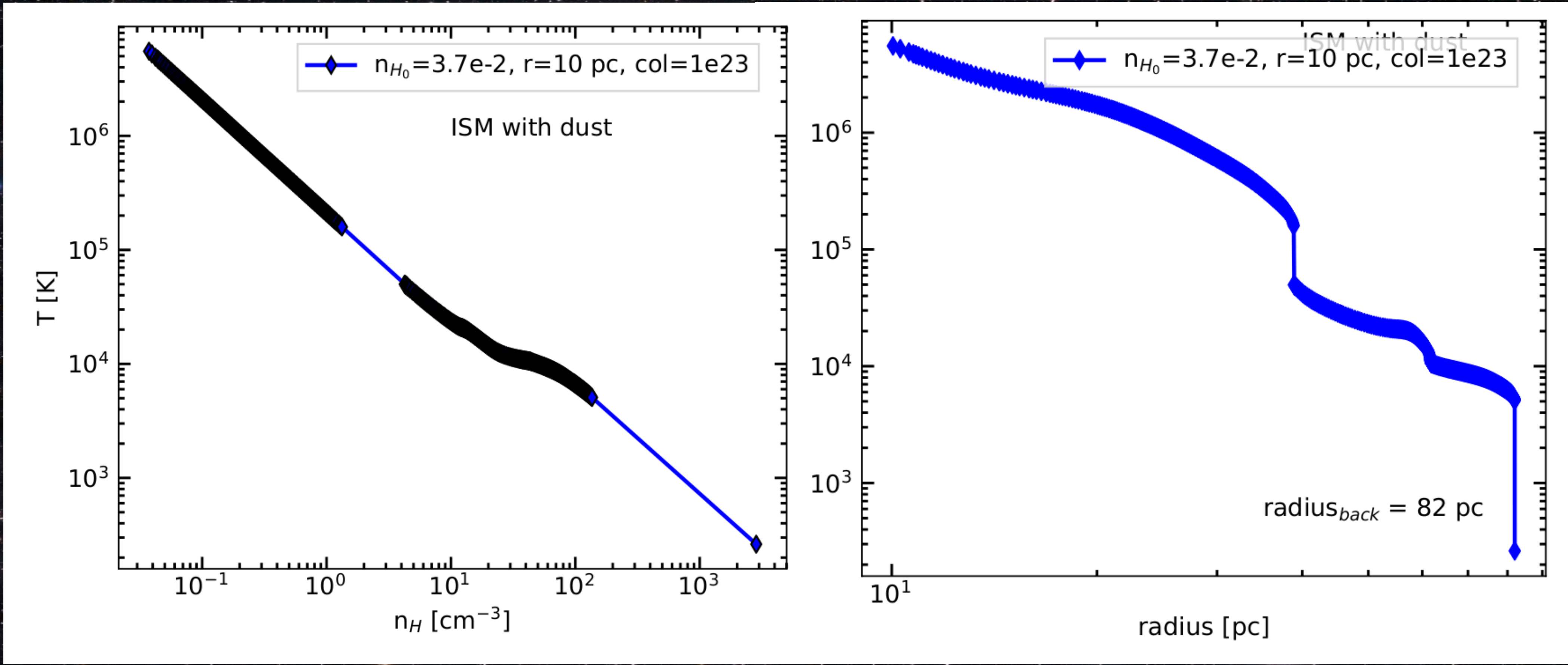
- In the simple model, we analyze the direction of the thermal evolution of the gas.
- Ionization parameter Ξ is given by:

$$\Xi = \frac{L_{\bullet} + L_{\mathrm{stars}}}{4\pi c P_{\mathrm{gas}} R^2},$$

The curve Ξ vs. T indicates the thermal stability


ISM with dust
ISM without dust
log (n_H) = -3 -13
log (R) = 19.544
log (n_H) = -3 - 12
log (R) = 20.230
log (n_H) = -3 - 12
log (R) = 20.755
log (T [K])
Solar with dust
Solar without dust
log (n_H) = -3 - 13
log (R) = 19.544
log (n_H) = -3 - 11
log (R) = 20.230
log (n_H) = -3 - 12
log (R) = 20.755
log (T [K])
log Ξ
log Ξ
log Ξ

Temperature radial structure



Left: upto 10 pc, right 10-82 pc

Results

- Dust can co-exist with X-ray emitting gas.
- Gas emitting Hα and other typical lines can co-exist with X-ray emitting gas at $\log \Xi = 0$
- CO-emitting gas cannot co-exist with X-ray emitting gas, but it could co-exist with warm Hα emitting gas at $\log \Xi = -5$
- Model predicts CO-emitting gas to exist beyond ~80 pc but not inside, as seen in the ALMA data.
- High resolution multifrequency observations are crucial for studying multiphase ISM in galactic centers.