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Molecule formation in AGN-driven galactic winds

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CIERA, Northwestern University

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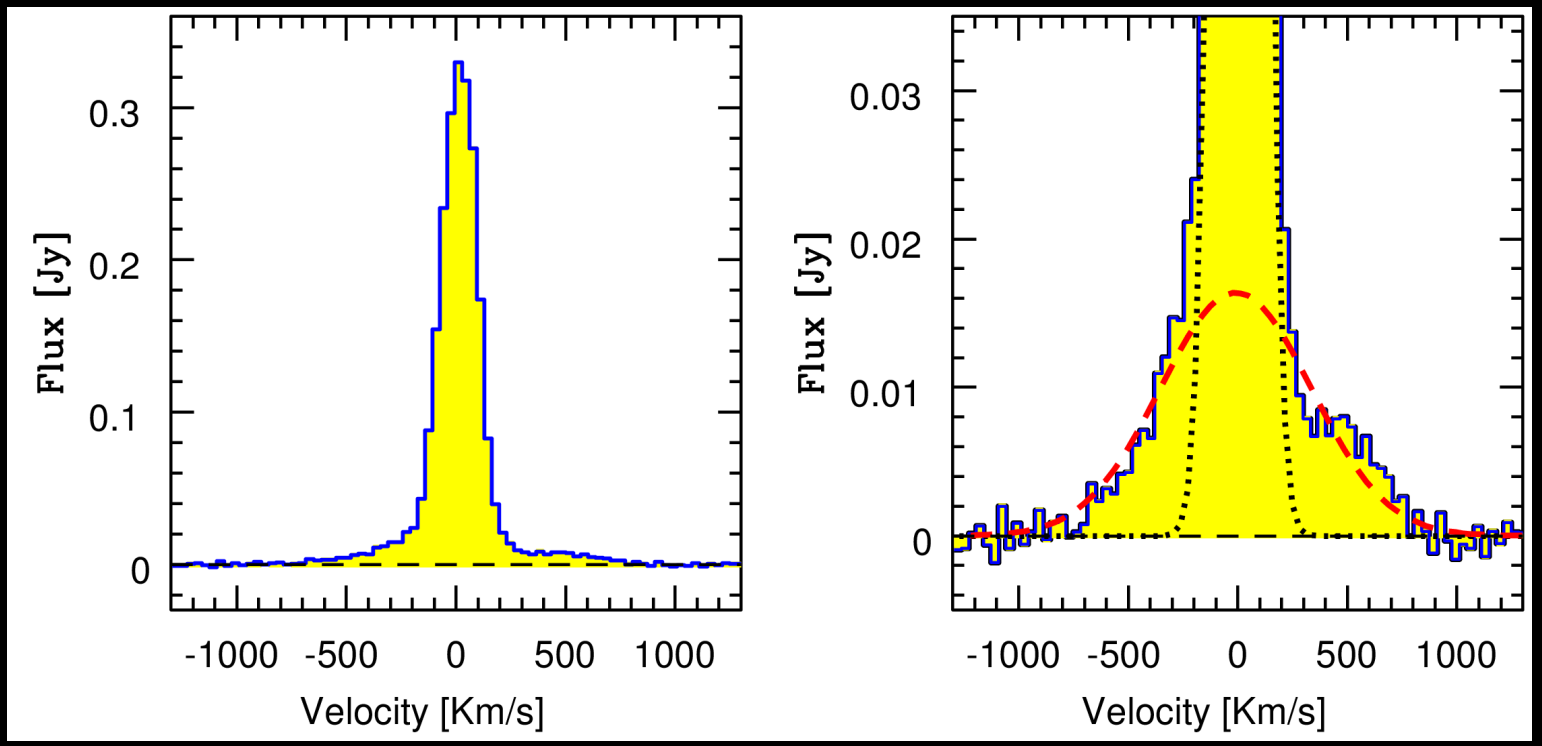
Introduction

Observations of fast molecular outflows

CO 1-0 line in Mrk 231



Feruglio et al. (2010)

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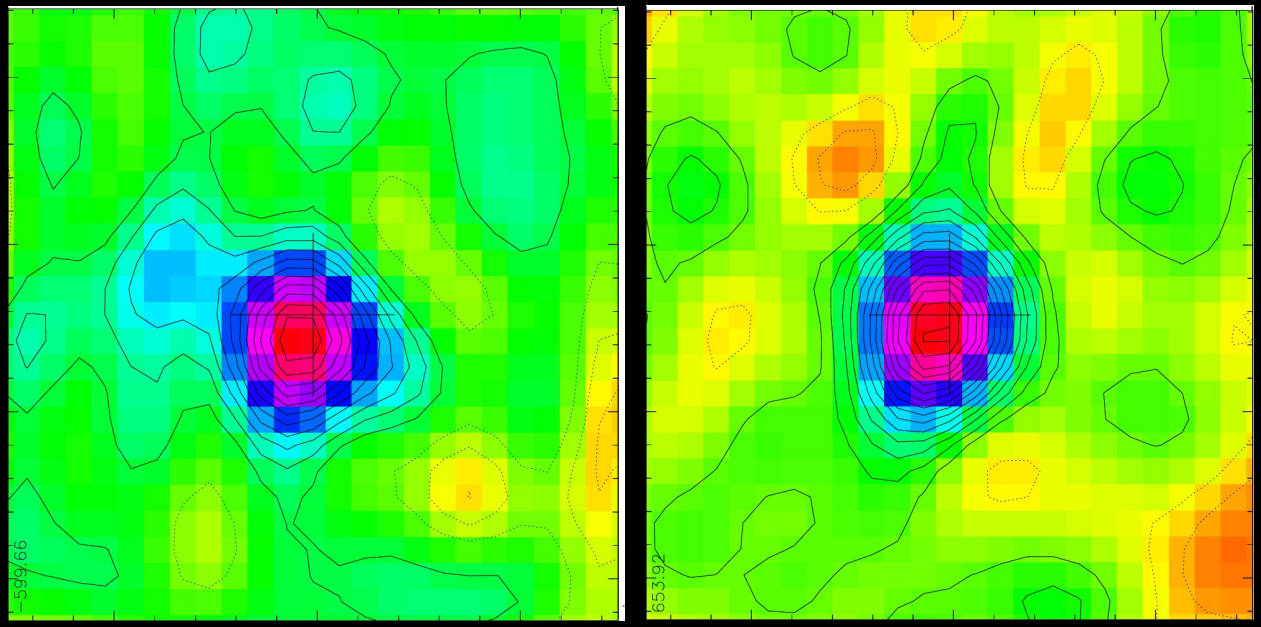
Introduction

Observations of fast molecular outflows

CO 1-0 maps in Mrk 231

-500 to -700 km s^{-1} +500 to +800 km s^{-1}

12.7 kpc



Feruglio et al. (2010)

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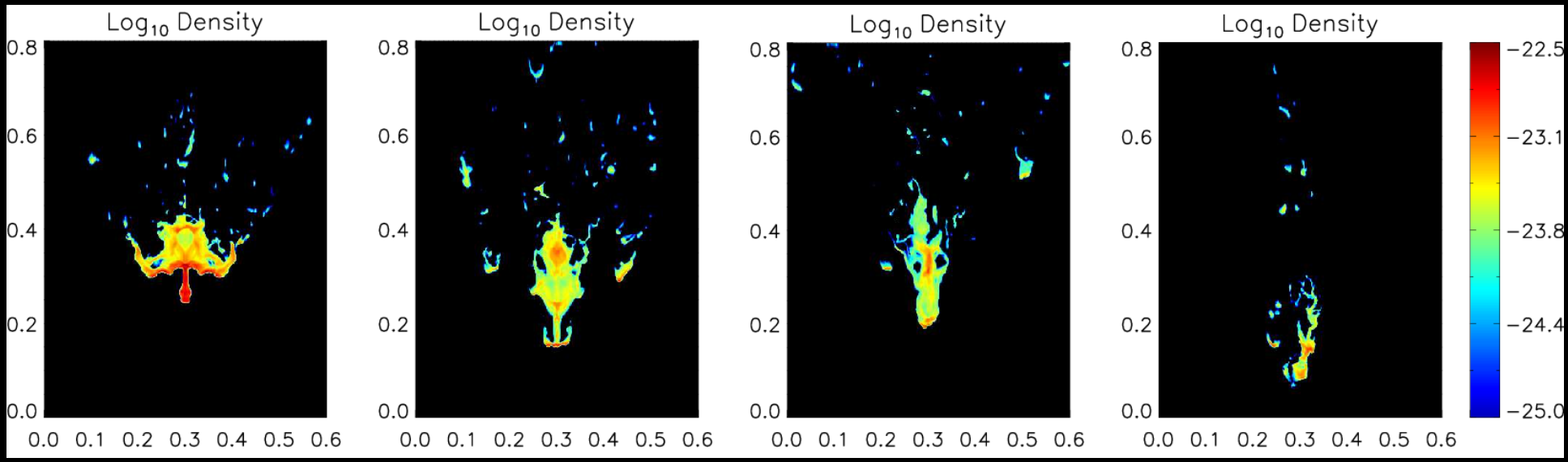
Introduction

Acceleration of cold clouds



Scannapieco & Brüggen (2015)

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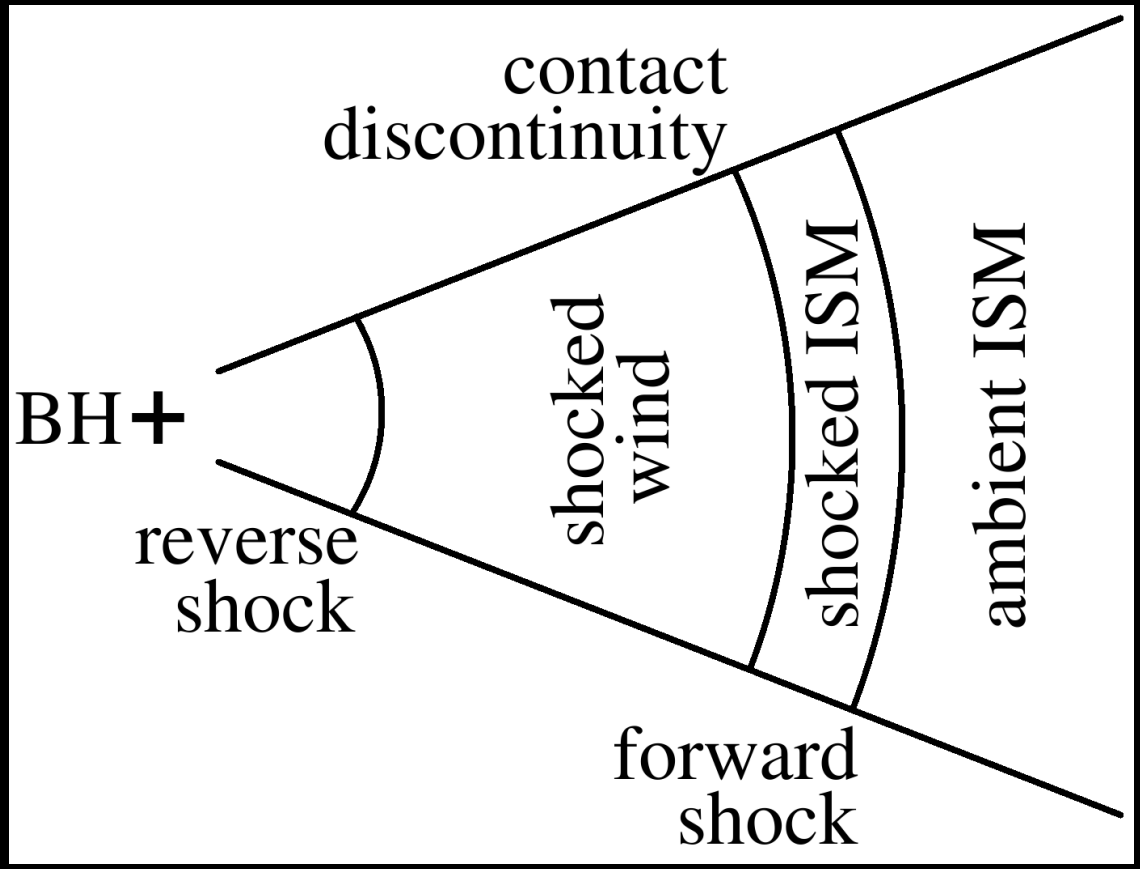
Introduction

In-situ molecule formation

An energy-driven AGN wind



Simulation Setup

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- 3D simulations of an isotropic AGN wind.
- 1.6-5.0 kpc box, periodic boundary conditions.
- Inject wind particles, initial $v = 30{,}000$ km s^{-1}, $\mathrm{d}P/\mathrm{d}t = L_{\mathrm{AGN}}/c$.

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Chemistry

- Evolve time-dependent chemistry of 157 species, including 20 molecules.
- Most importantly: H_2, CO, OH and HCO^+.
- We assume a Milky Way dust-to-metals ratio.

Simulation Setup

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Parameters

n_H (cm^{-3})	L_{AGN} (erg s^{-1})	Z / Z_{sol}
10	10^{46}	1.0
1	10^{46}	1.0
10	10^{45}	1.0
10	10^{46}	0.1

Simulation Results

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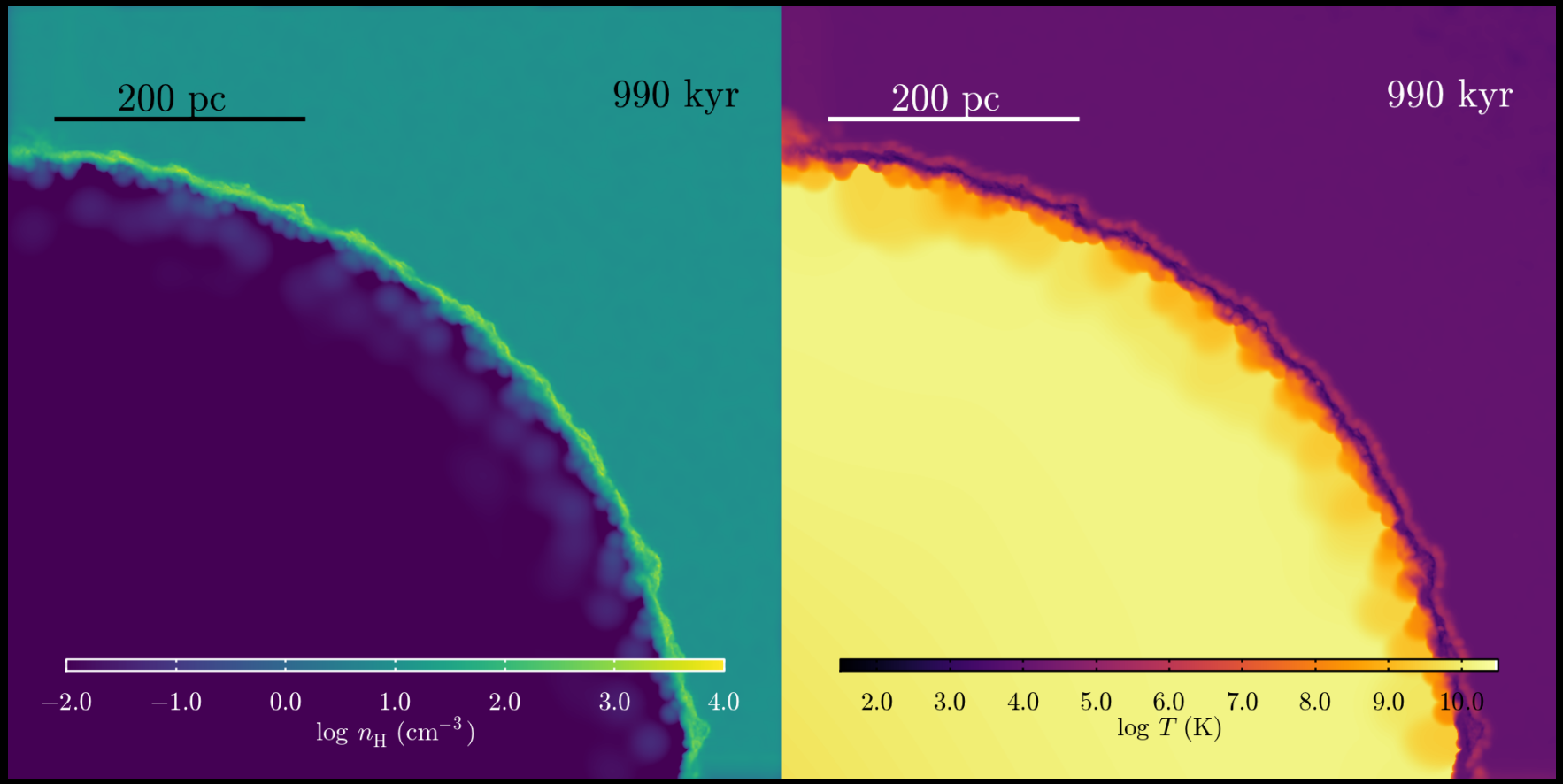
nH10_L45_Z1



Simulation Results

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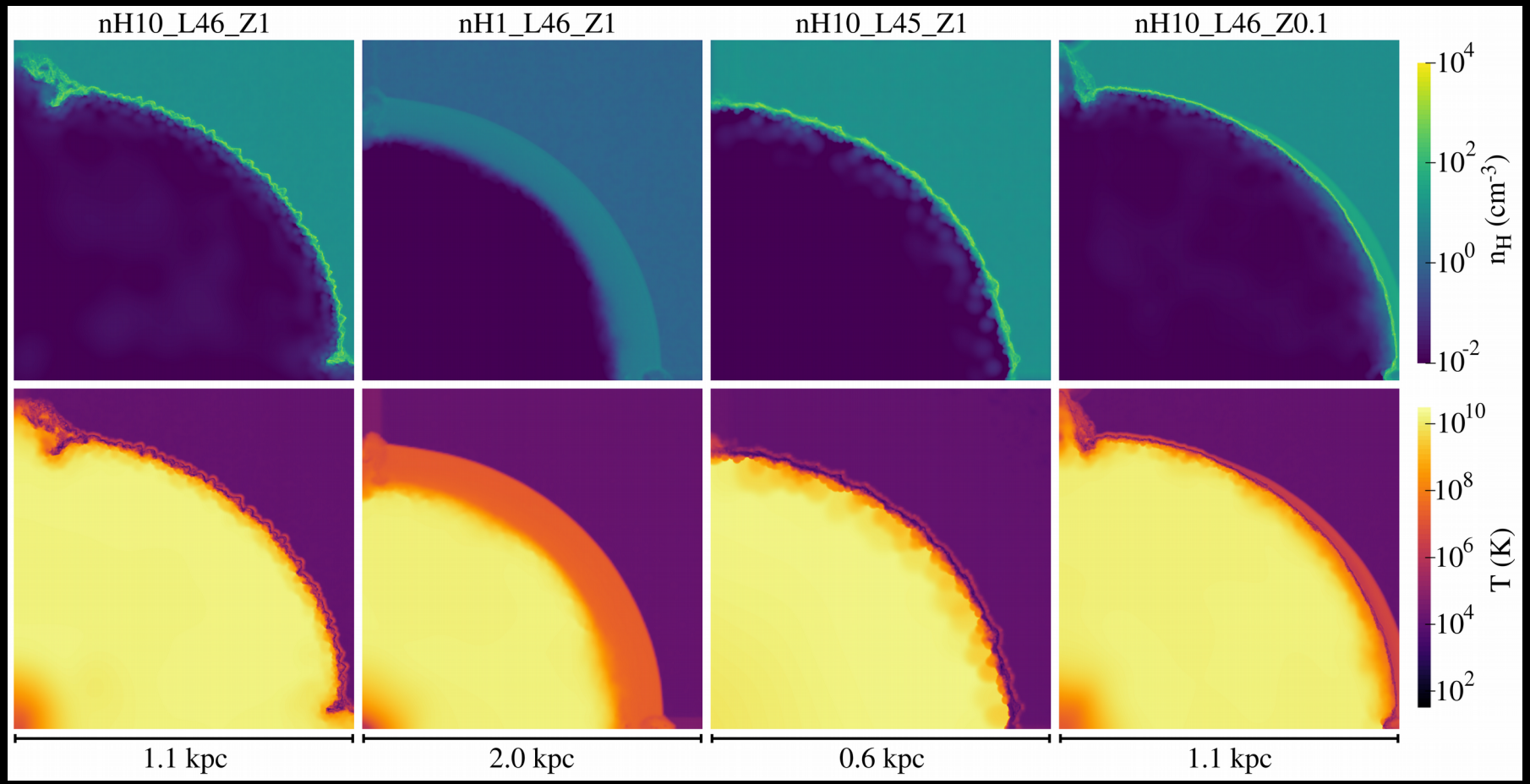
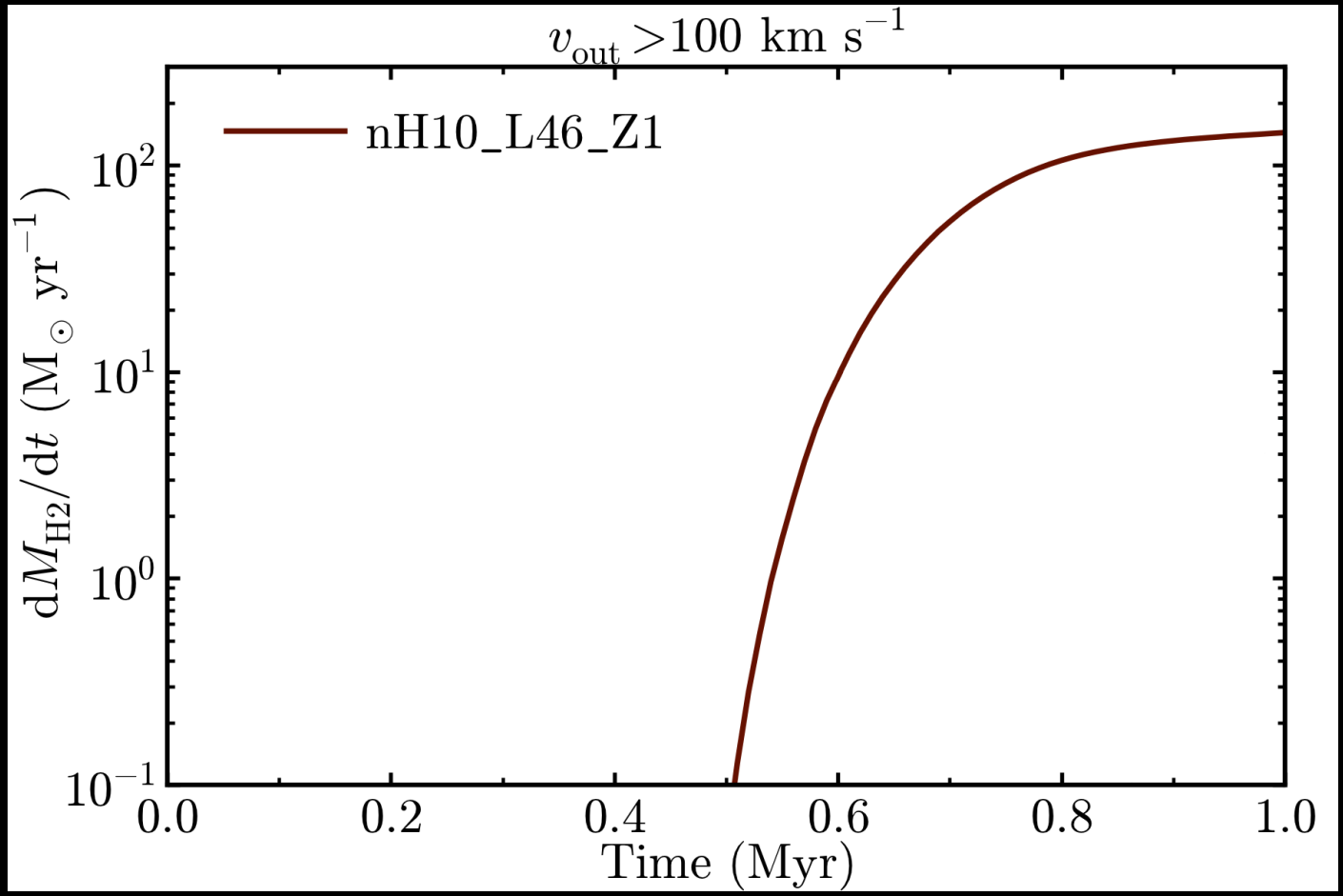


Richings & Faucher-Giguère (2017)

Simulation Results

H_2 outflow rates



Richings & Faucher-Giguère (2017)

Simulation Results

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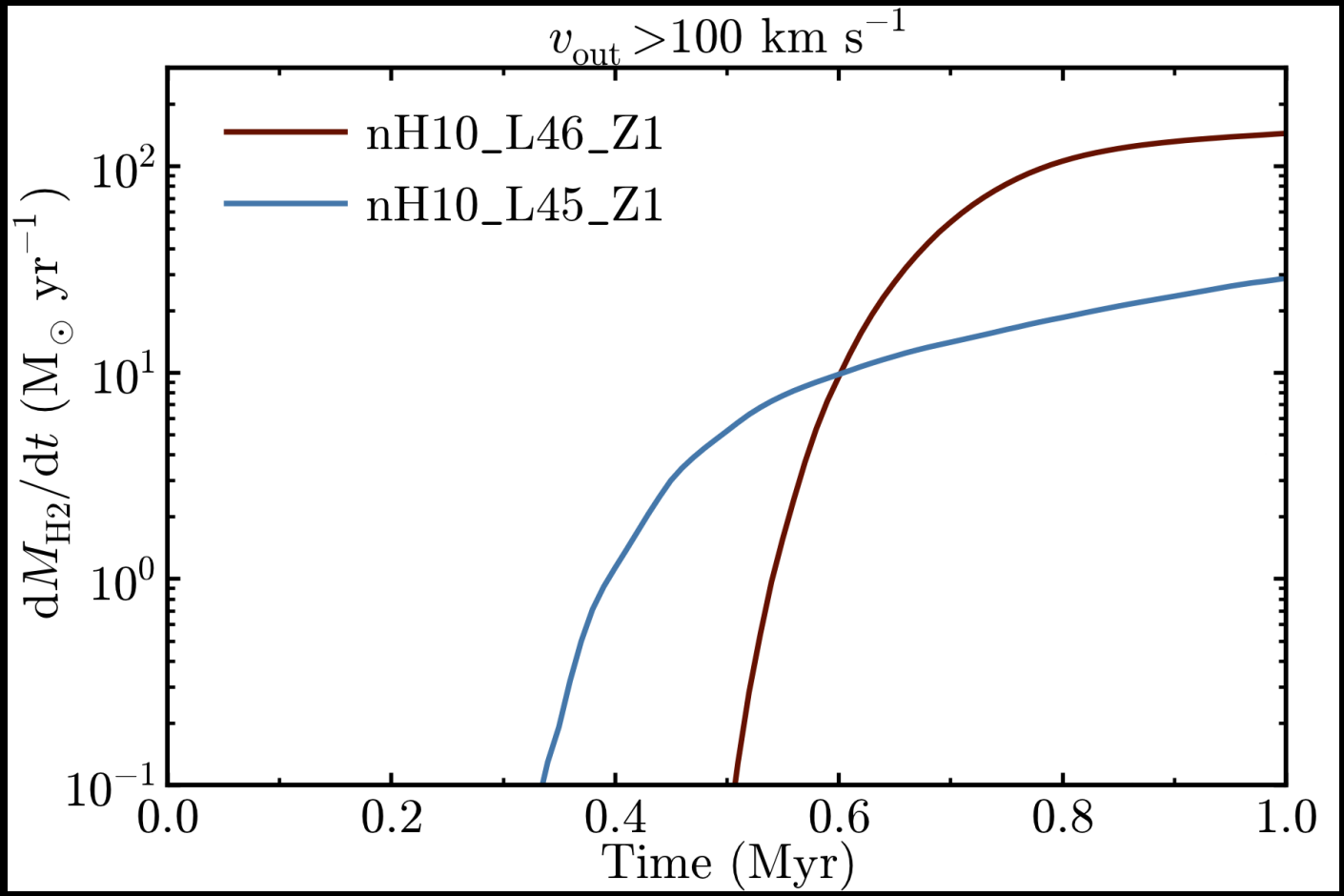
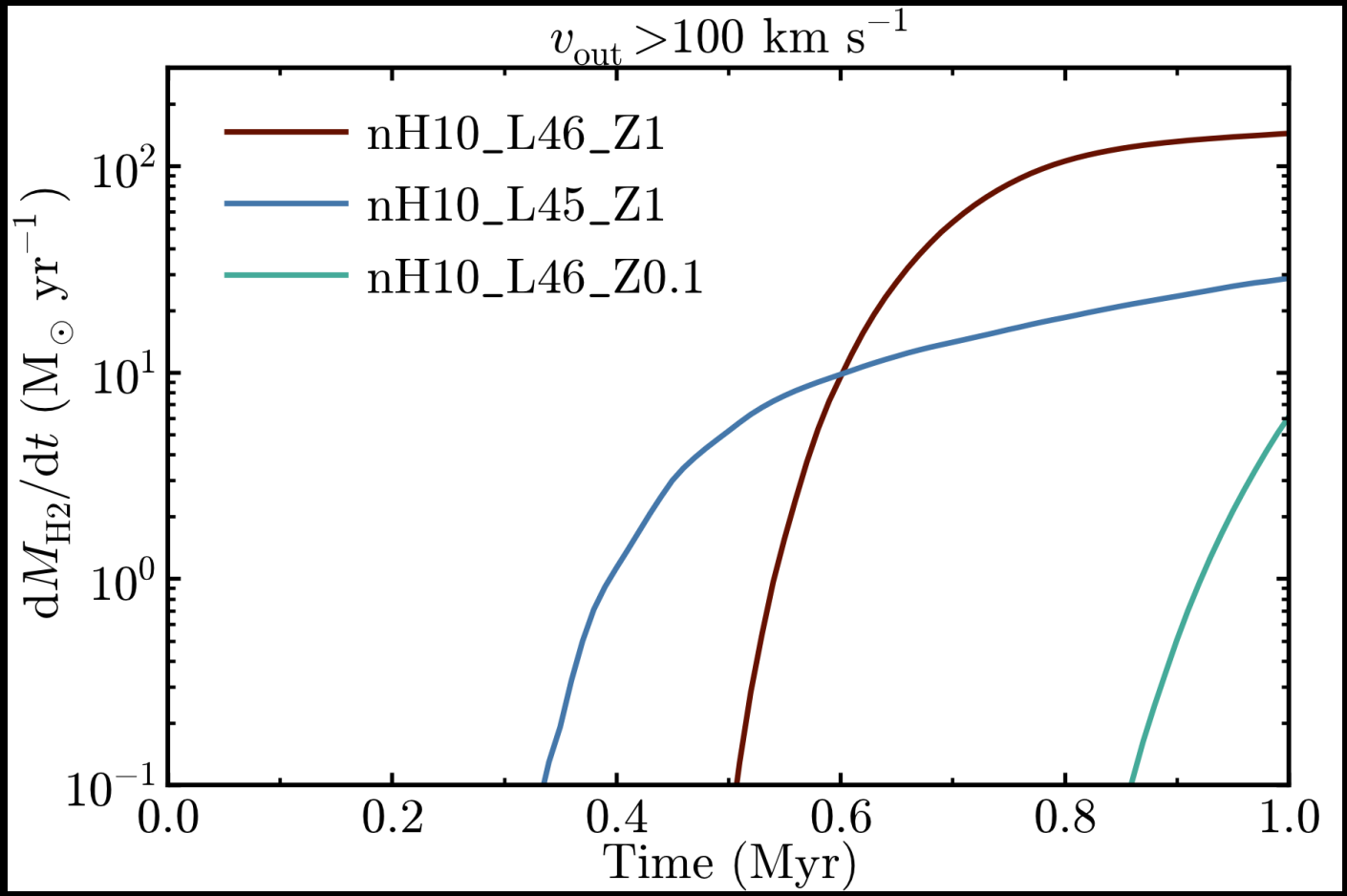


Richings & Faucher-Giguère (2017)

Simulation Results

H_2 outflow rates

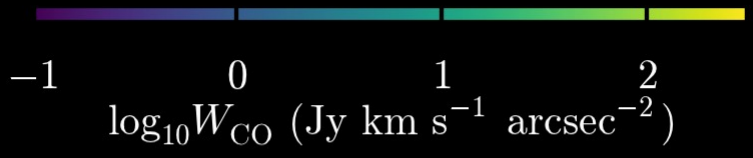


Richings & Faucher-Giguère (2017)

Simulation Results

CO 1-0 line emission

nH10_L45_Z1



Richings &
Faucher-Giguère (2017)

Simulation Results

CO to H_2 conversion factors

Simulation	$\alpha_{CO} = M_{H2} / L_{CO}$*		
	(1-0)	(2-1)	(3-2)
nH10_L46_Z1	0.15	0.08	0.06
nH10_L45_Z1	0.15	0.09	0.07
nH10_L46_Z0.1	1.88	0.88	0.88

*Units: M_{sol} (K km s^{-1} pc^2)$^{-1}$

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➢ Observations typically assume:

$$\alpha_{CO\ (1\text{-}0)} = \mathbf{0.8}\ M_{sol}\ (\text{K km s}^{-1}\ \text{pc}^2)^{-1}.$$

Summary

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- Molecular outflow rates up to 140 M_{sol} yr^{-1} formed within the AGN wind after 1 Myr.
- Molecule formation sensitive to n_H, L_{AGN} and Z.
- CO to H_2 conversion factor at solar metallicity: $\alpha_{CO\ (1\text{-}0)} = 0.15\ M_{sol}\ (K\ km\ s^{-1}\ pc^2)^{-1}$.
- **arXiv:1706.03784**

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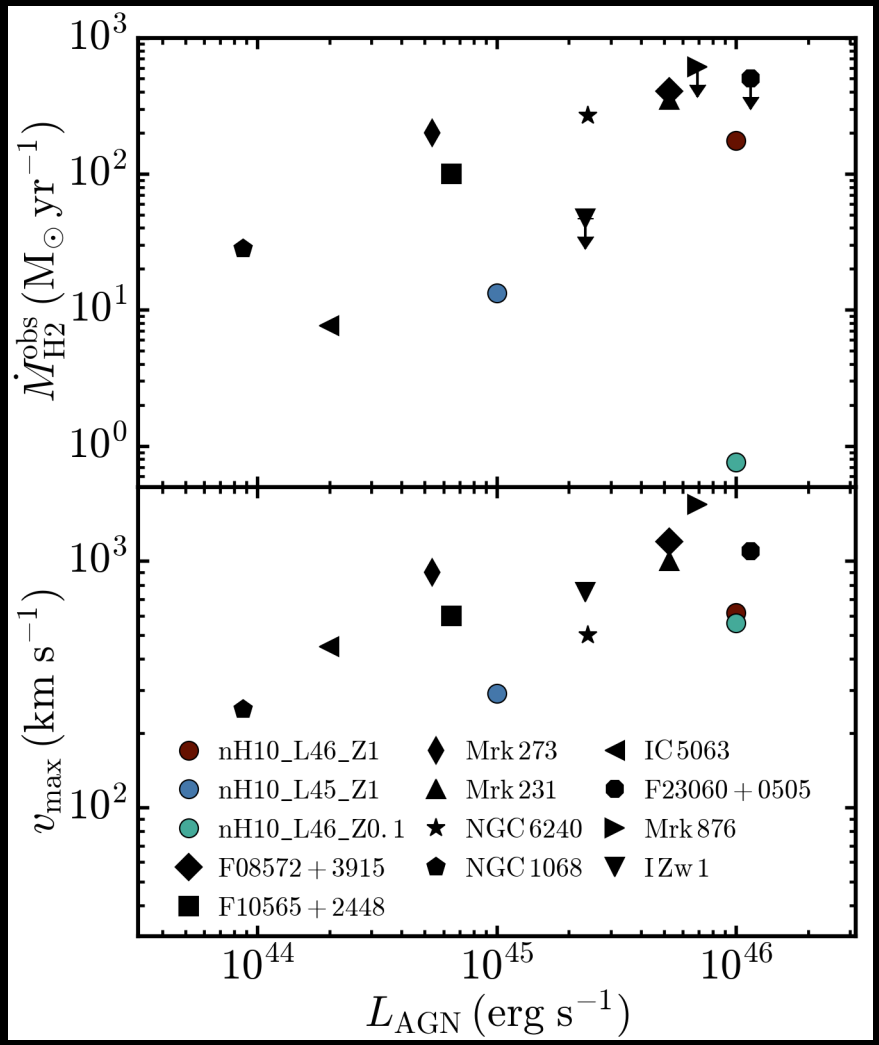
Extra Slides

Simulation Results

Comparison with CO-based observations



Observations:
Wiklind et al. (1995)
Maiolino et al. (1997)
Cicone et al. (2012, 2014)
Feruglio et al. (2013a, b)

Simulation Results

Warm H_2 Emission

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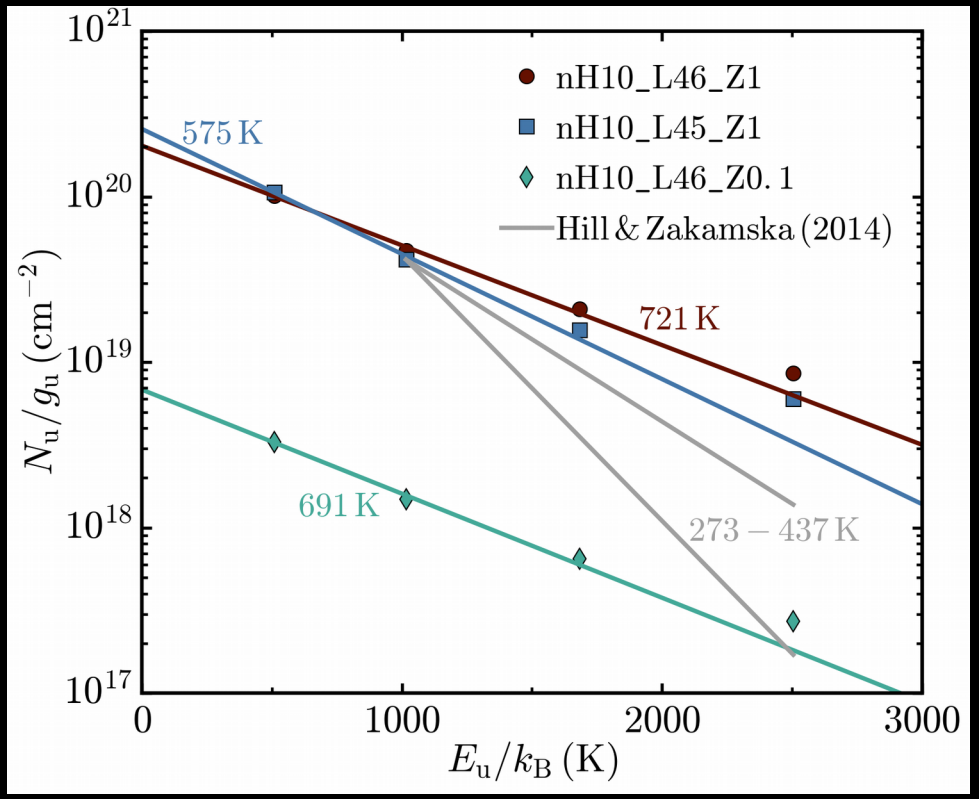
- H_2 infrared lines from warm (100s – 1000s K) molecular gas.
- Traces ~70% of the total H_2 mass in our simulations.
- T_{exc} ~ 575 – 721 K.



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Temperature-Density Plots

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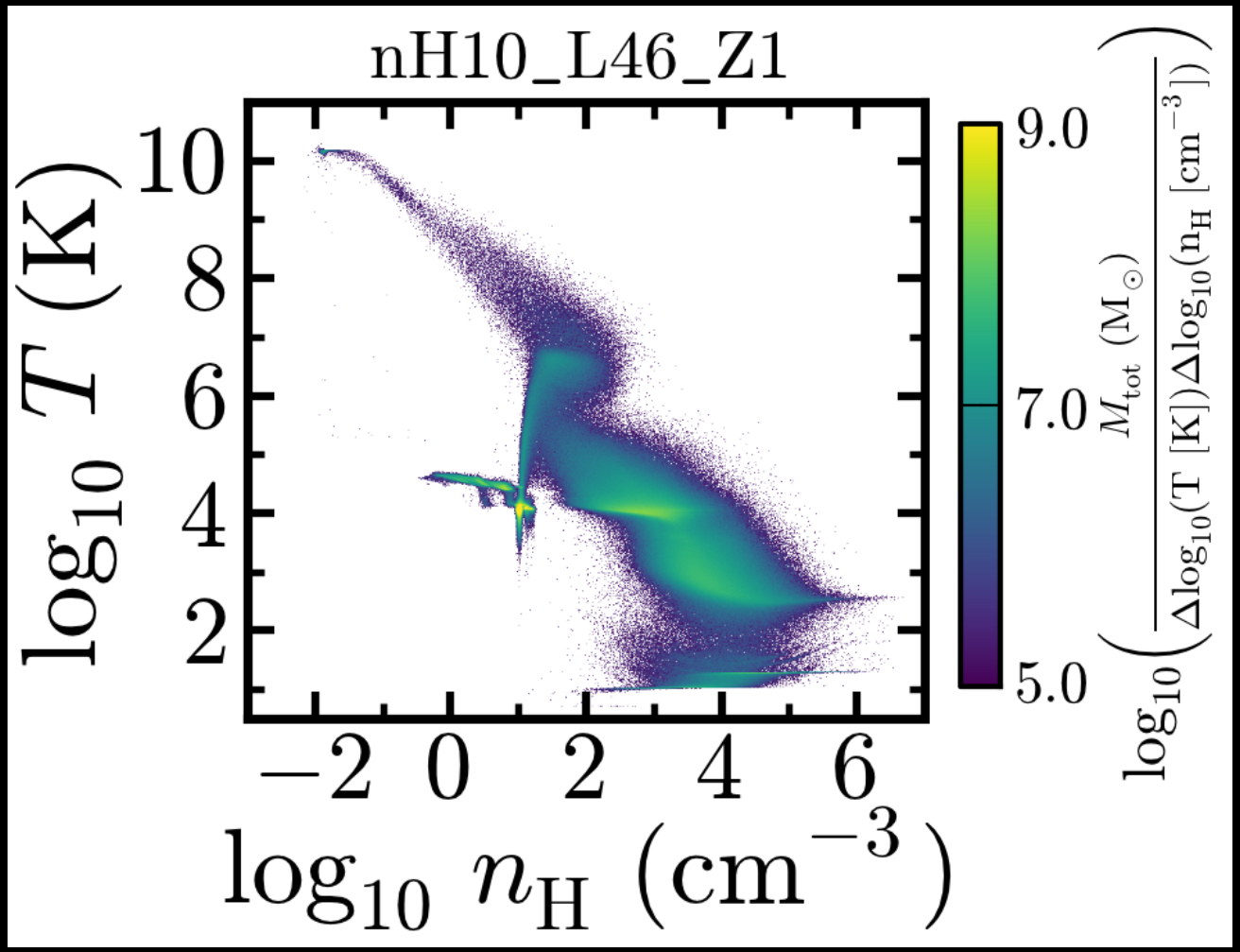

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Temperature-Density Plots

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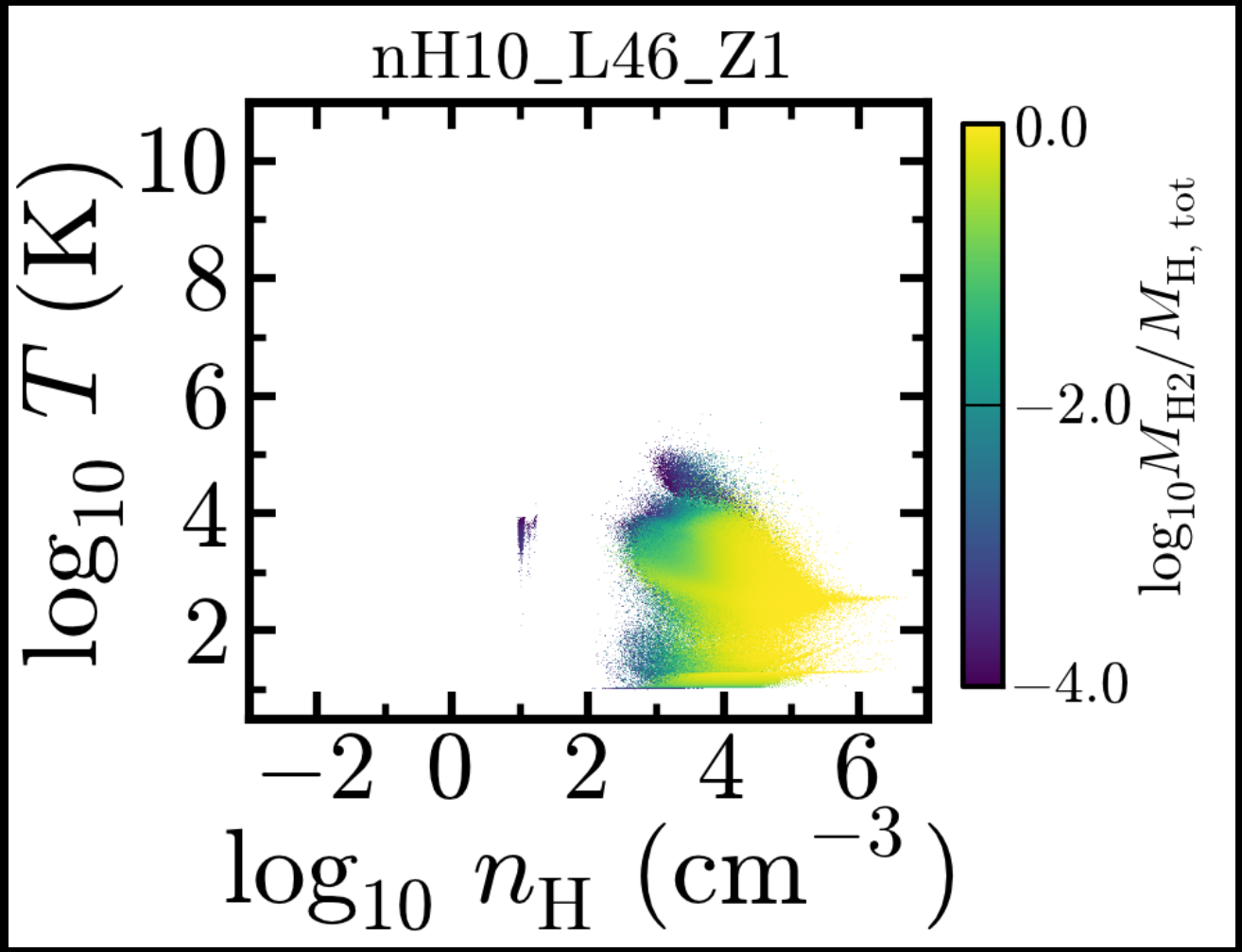

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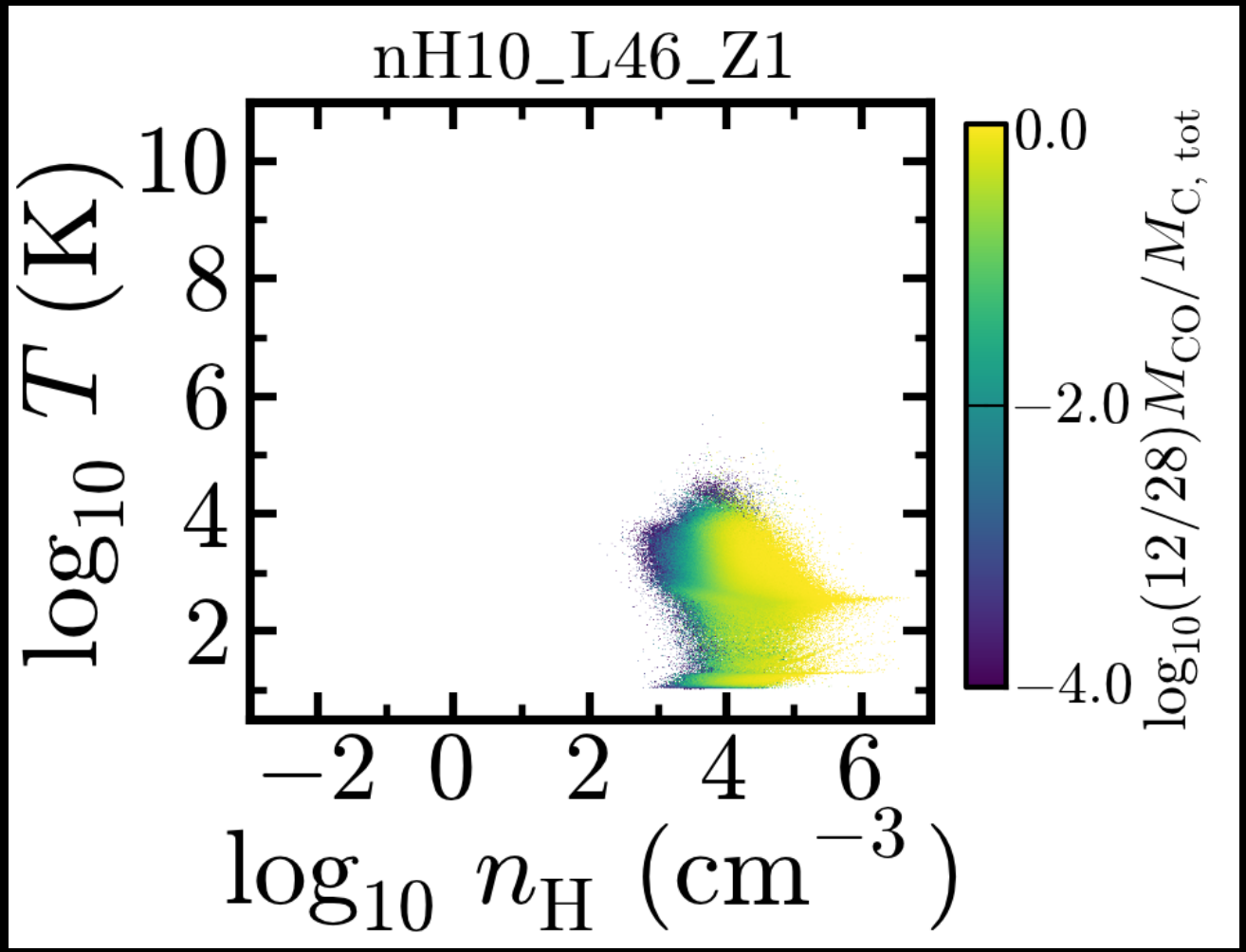

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