Can the virial parameter reliably trace the dynamical state of molecular clouds?

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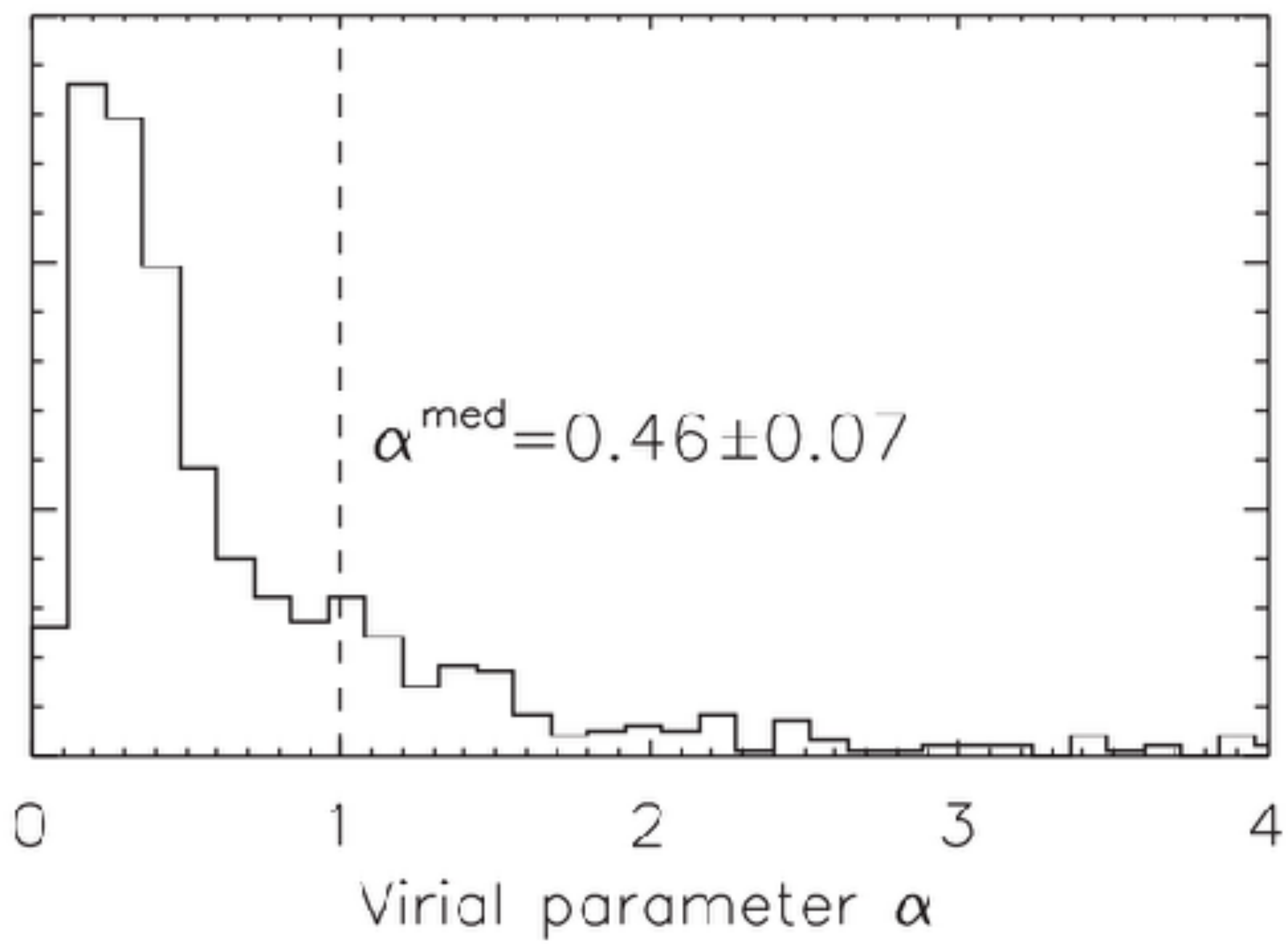
Are clouds bound?



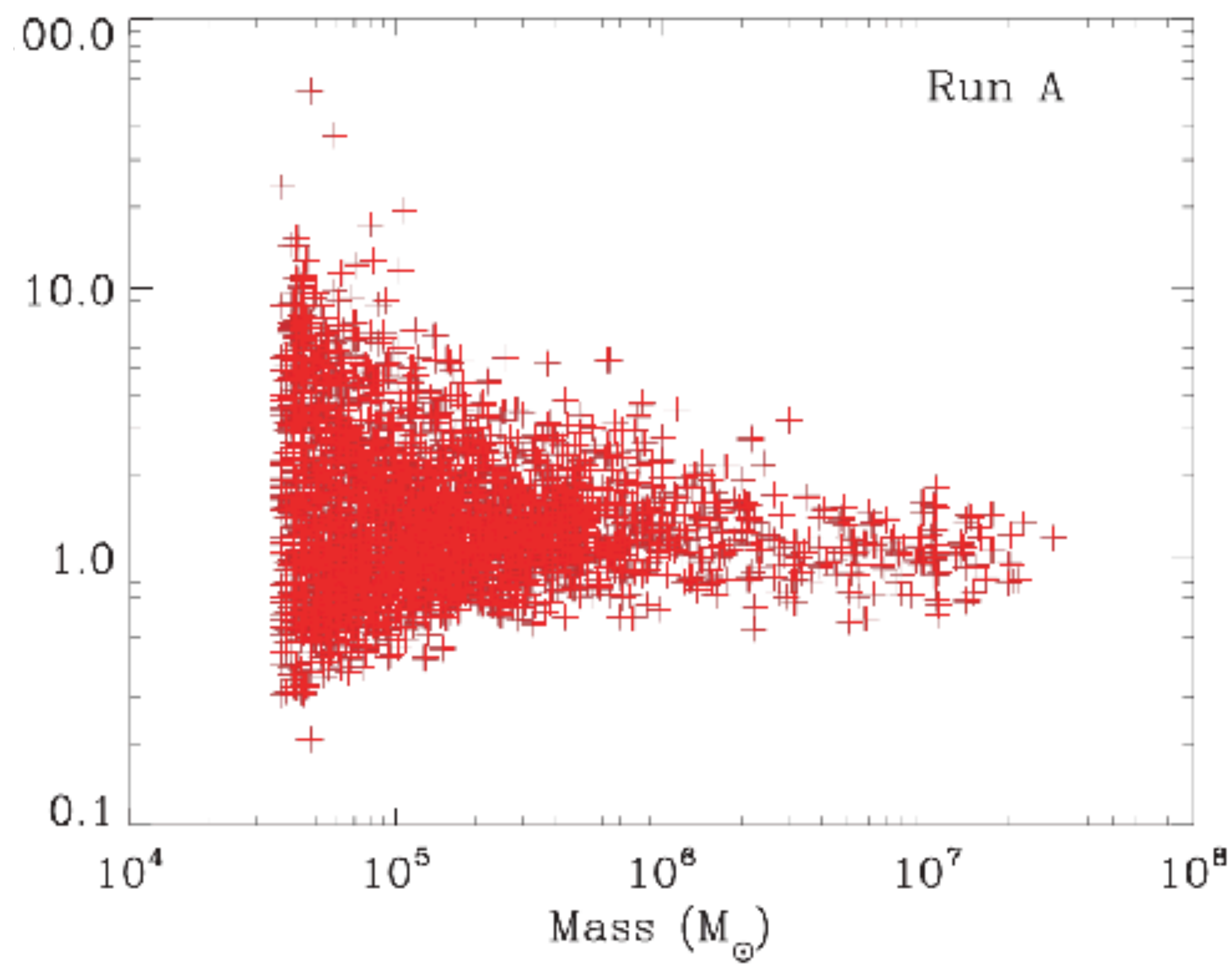
Roman-Duval et al. 2010

$$\alpha = \frac{2E_{\rm kin}}{E_{\rm pot}}$$

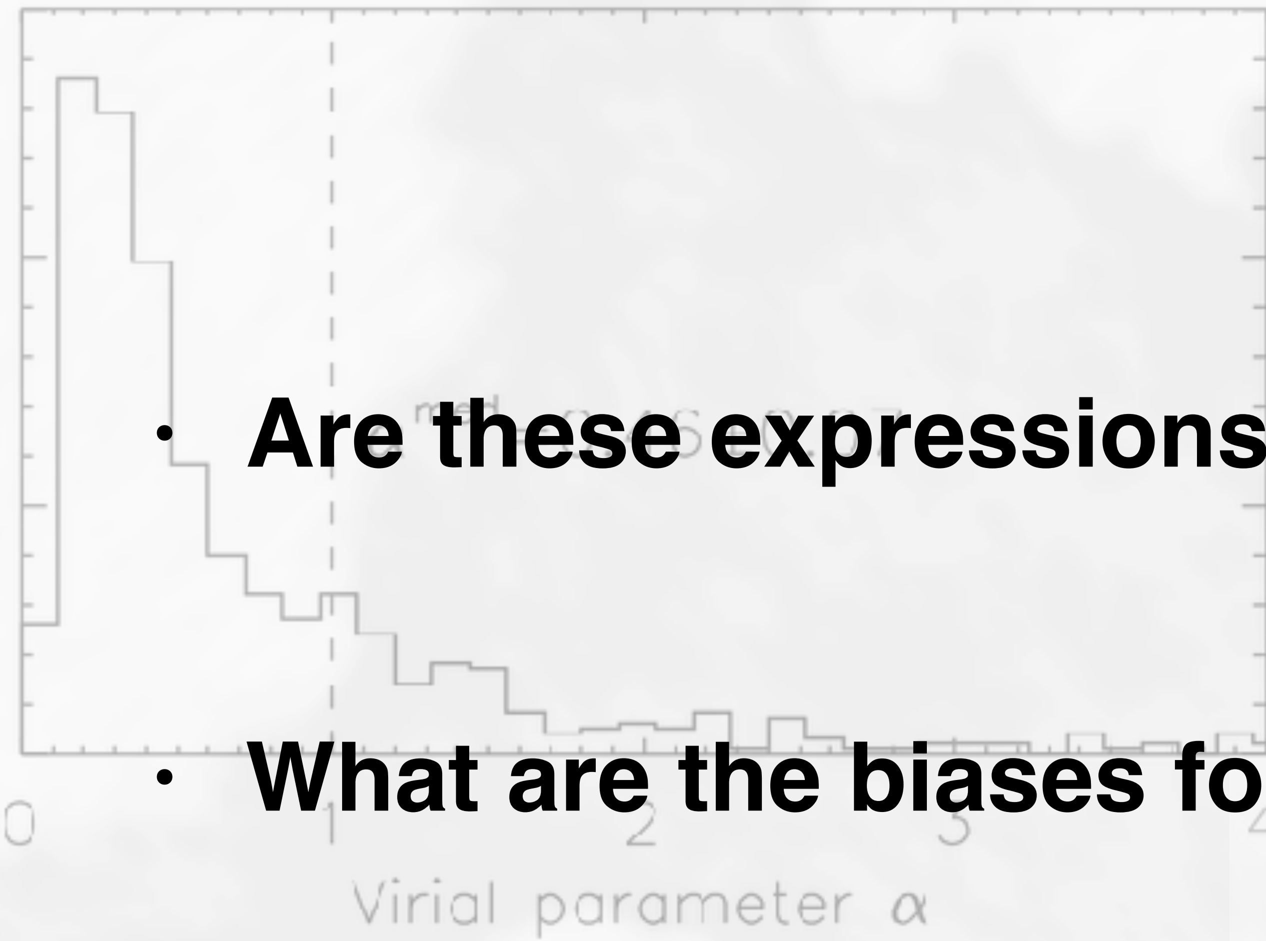
$$\alpha = \frac{5\sigma^2 R}{GM}$$

Bertoldi & McKee 1992

Dobbs et al. 2011



Are clouds bound?



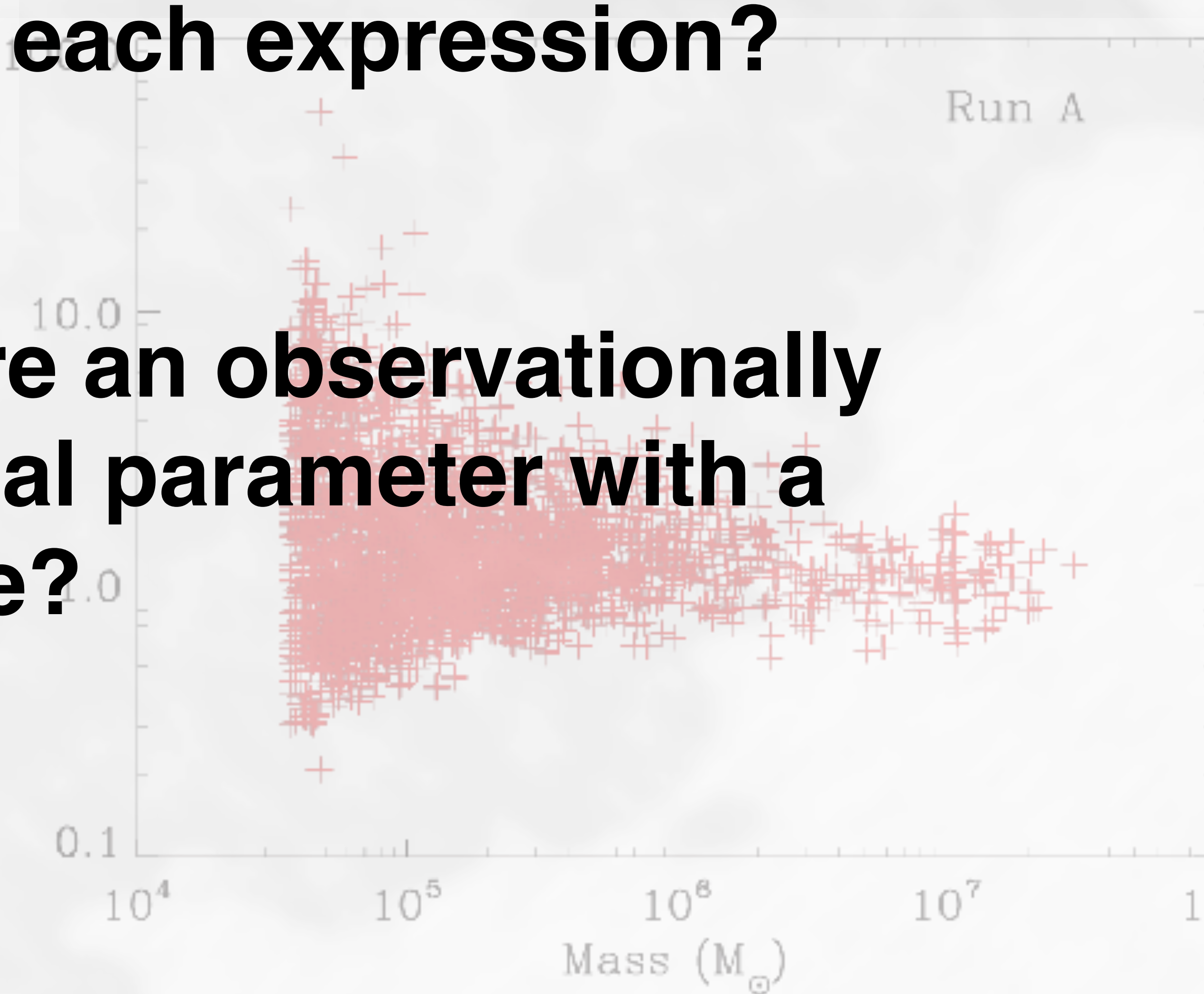
Roman-Duval et al. 2010

$$\alpha = \frac{5\sigma^2 R}{GM}$$

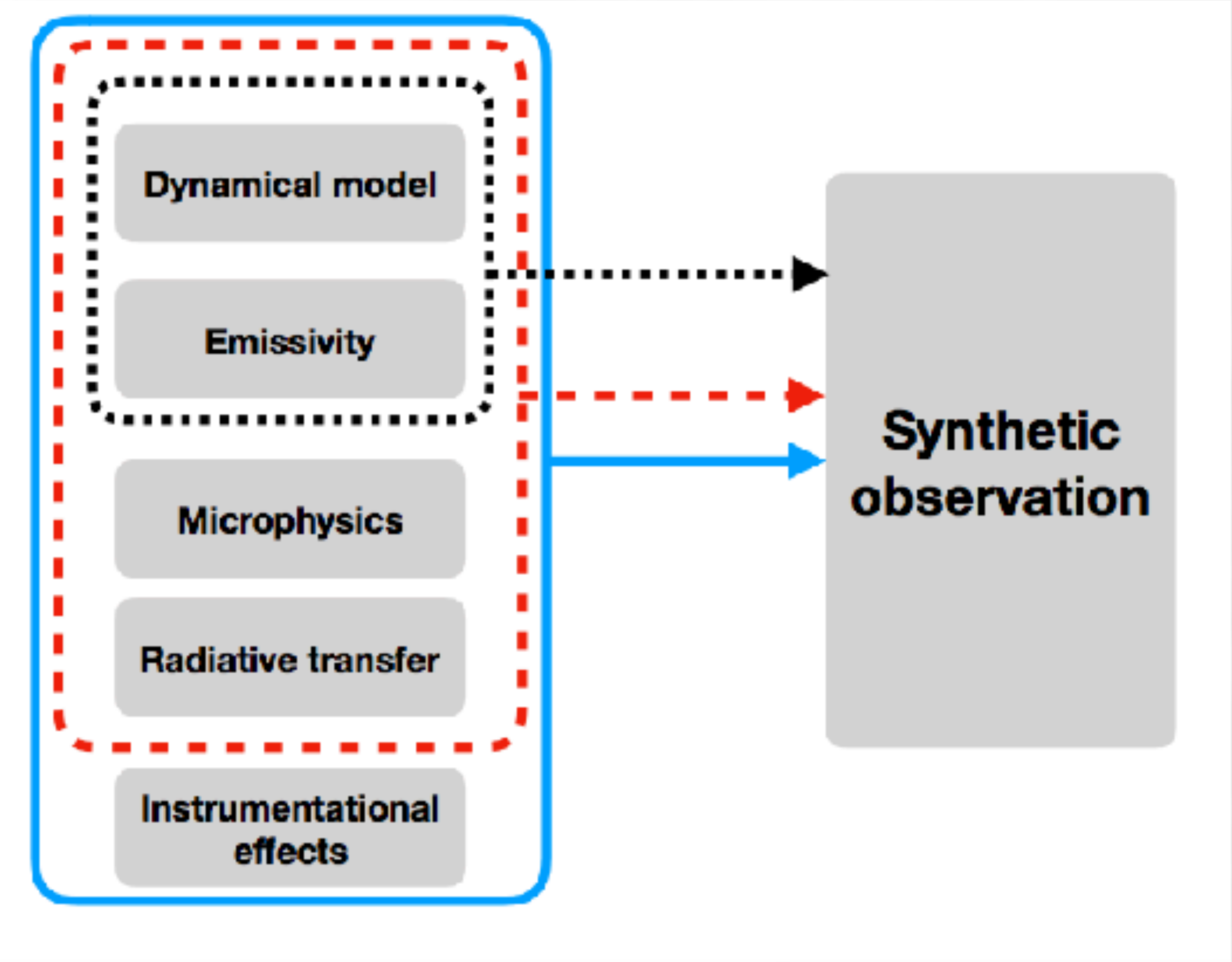
$$\alpha = \frac{2E_{\rm kin}}{E_{\rm pot}}$$

- **Are these expressions equivalent?**
- **What are the biases for each expression?**
- **Can we directly compare an observationally derived value of the virial parameter with a numerically derived one?**

Dobbs et al. 2011



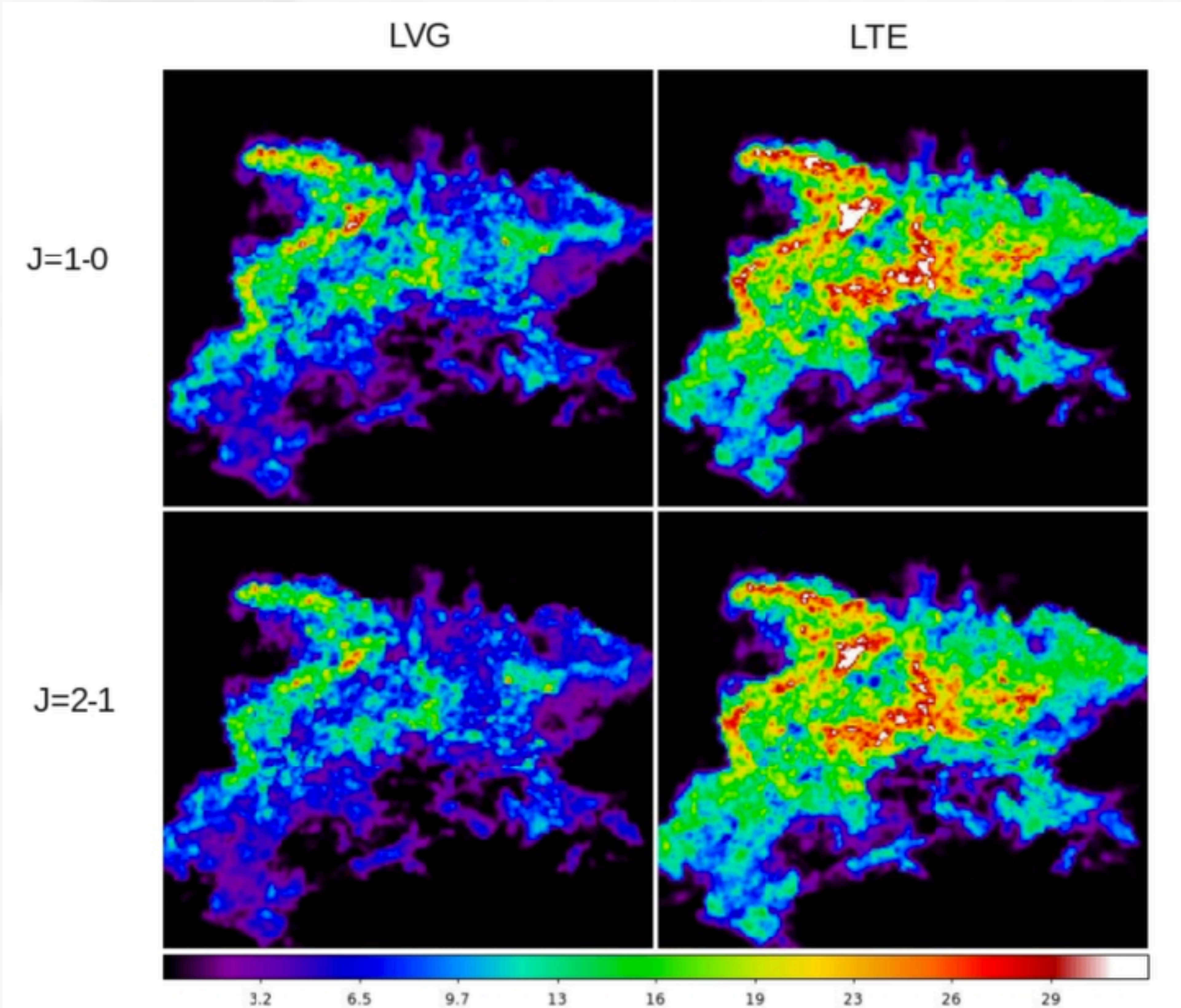
Numerical Simulations



Haworth et al. 2017

- Hydrodynamics:
  - Modified version of GADGET-2, (Springel 2005)
  - Time dependant chemistry
  - Attenuation of the ISRF
  - Stop before SF
  - No magnetic fields
  - No feedback
- Radiative Transfer:
  - RADMC-3D (Dullemond 2012)
  - AMR-grid (Accounts for all SPH particles)
  - Sobolev-Gnedin Approximation(LVG+)
  - CO's first two rotational transition lines

LTE vs Non-LTE



Numerical Simulations

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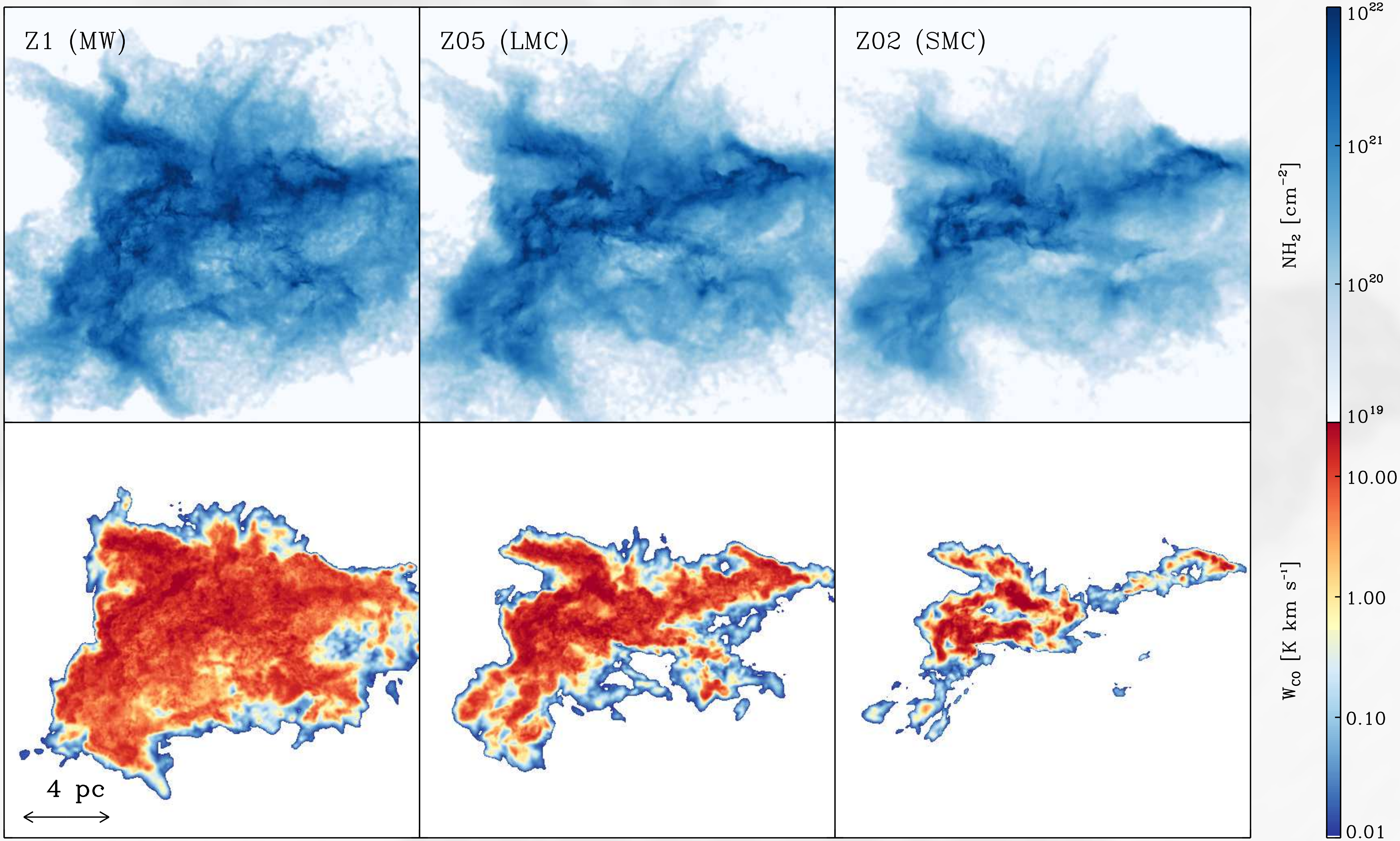
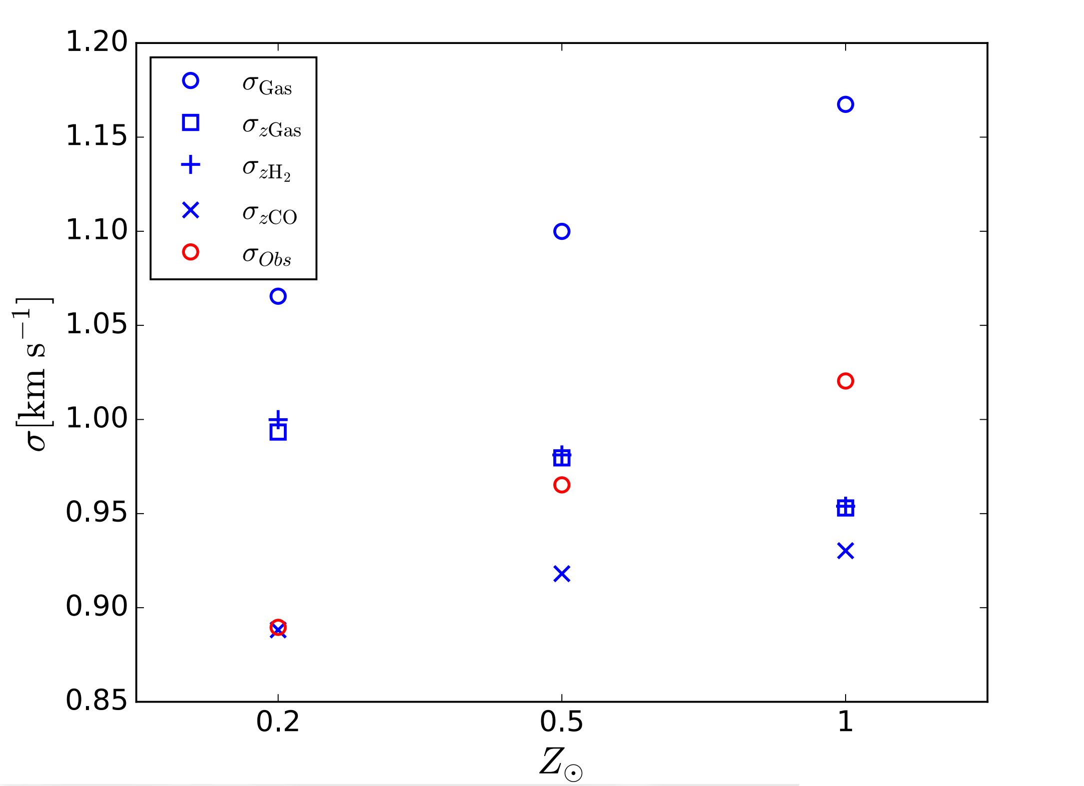
- Initial Conditions:
  - $10^4 M_\odot$ uniform sphere
  - $n = 276 \text{ cm}^{-3}$
  - $\nabla \cdot \mathbf{u} = 0$
  - $G_0 = 1.7 \text{ in Habing(1968)}$
  - $Z = Z_\odot \ / \ 0.5 \ Z_\odot \ / \ 0.2 \ Z_\odot$

Observations vs Simulations

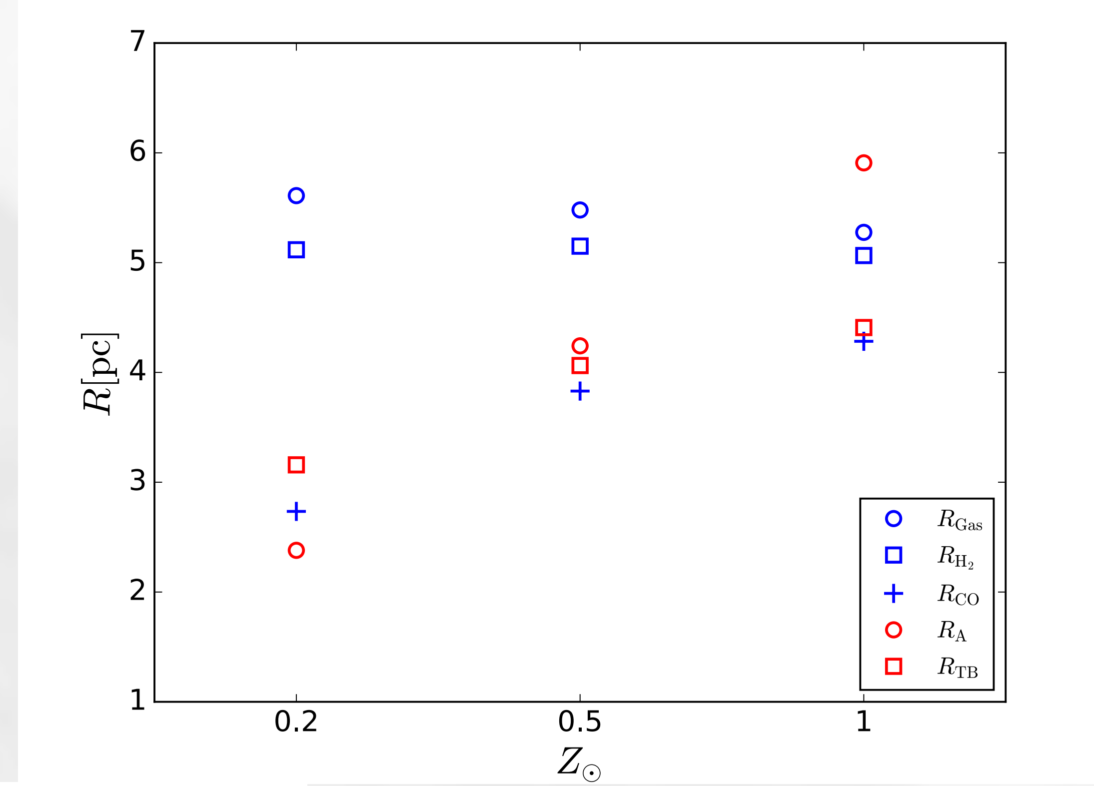


The components of the virial parameter

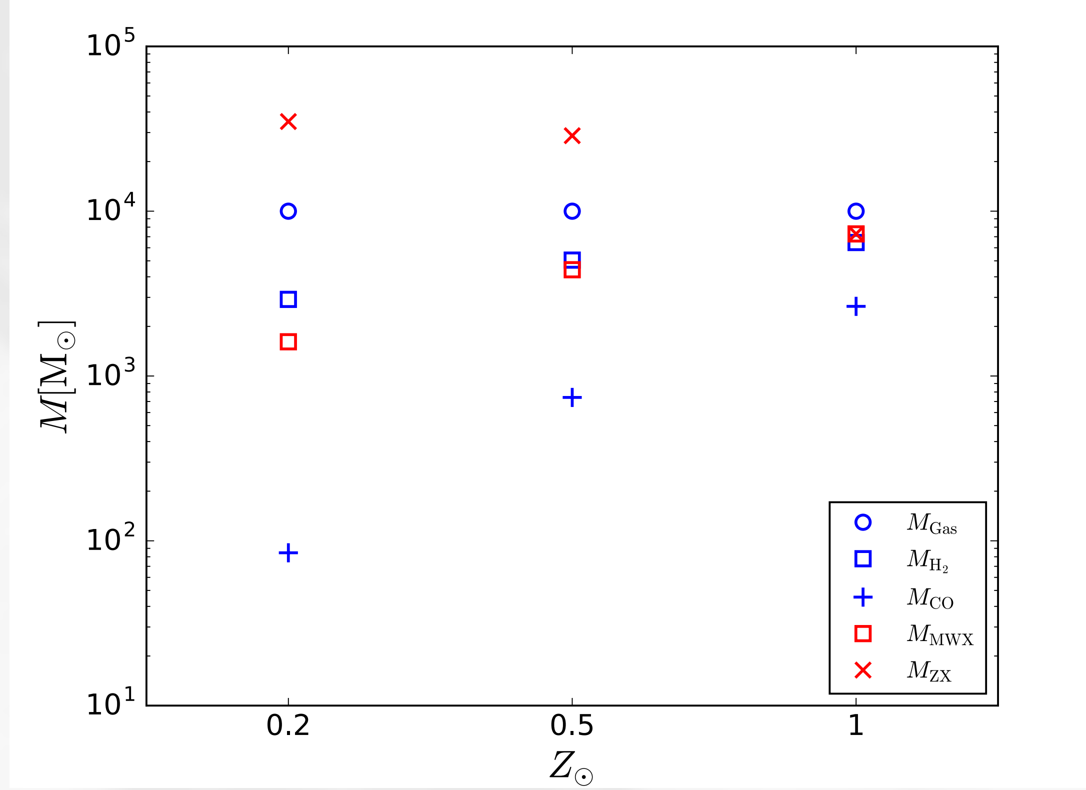
Velocity Dispersion



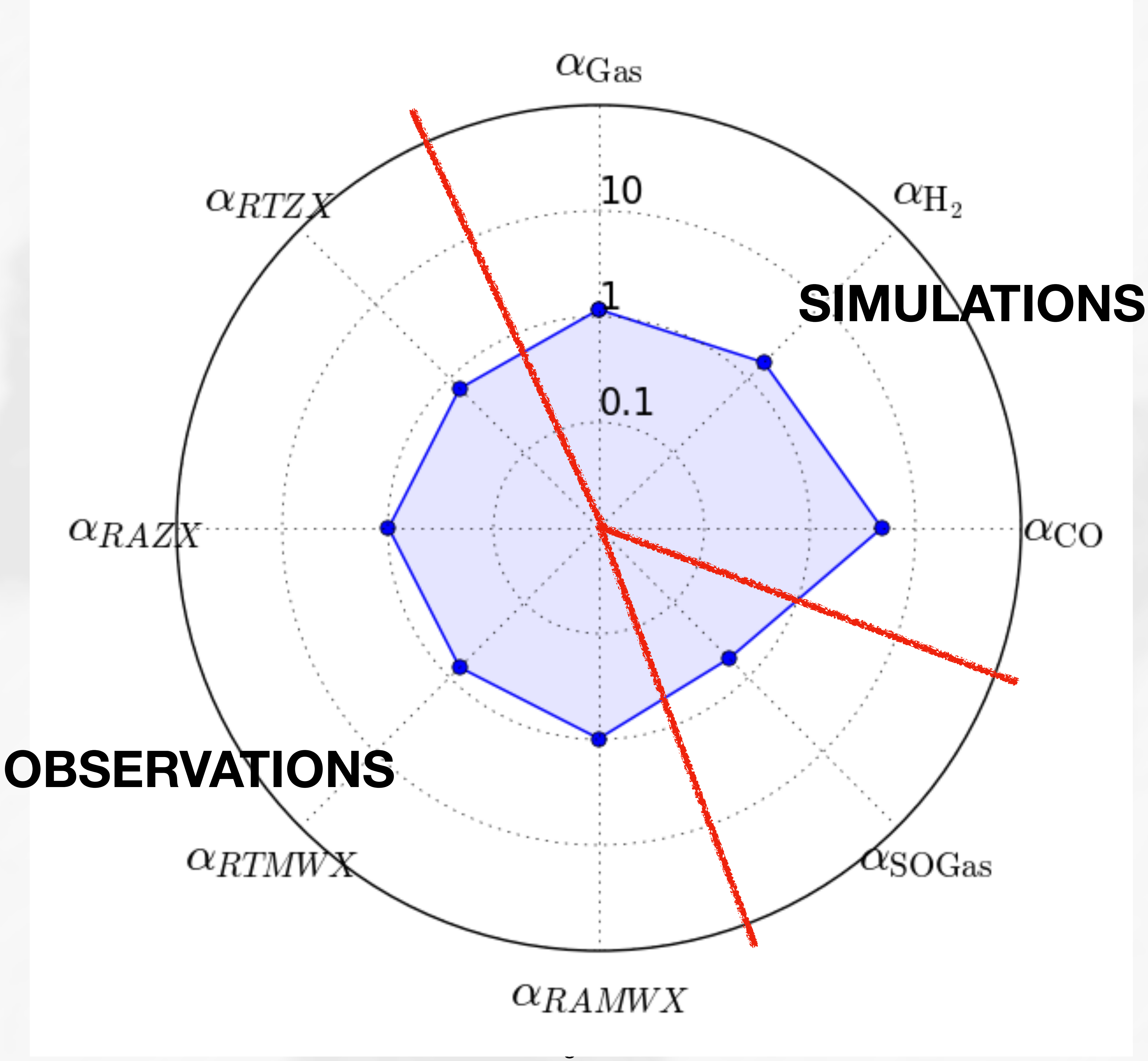
Radius



Mass



The virial parameter (Z1)



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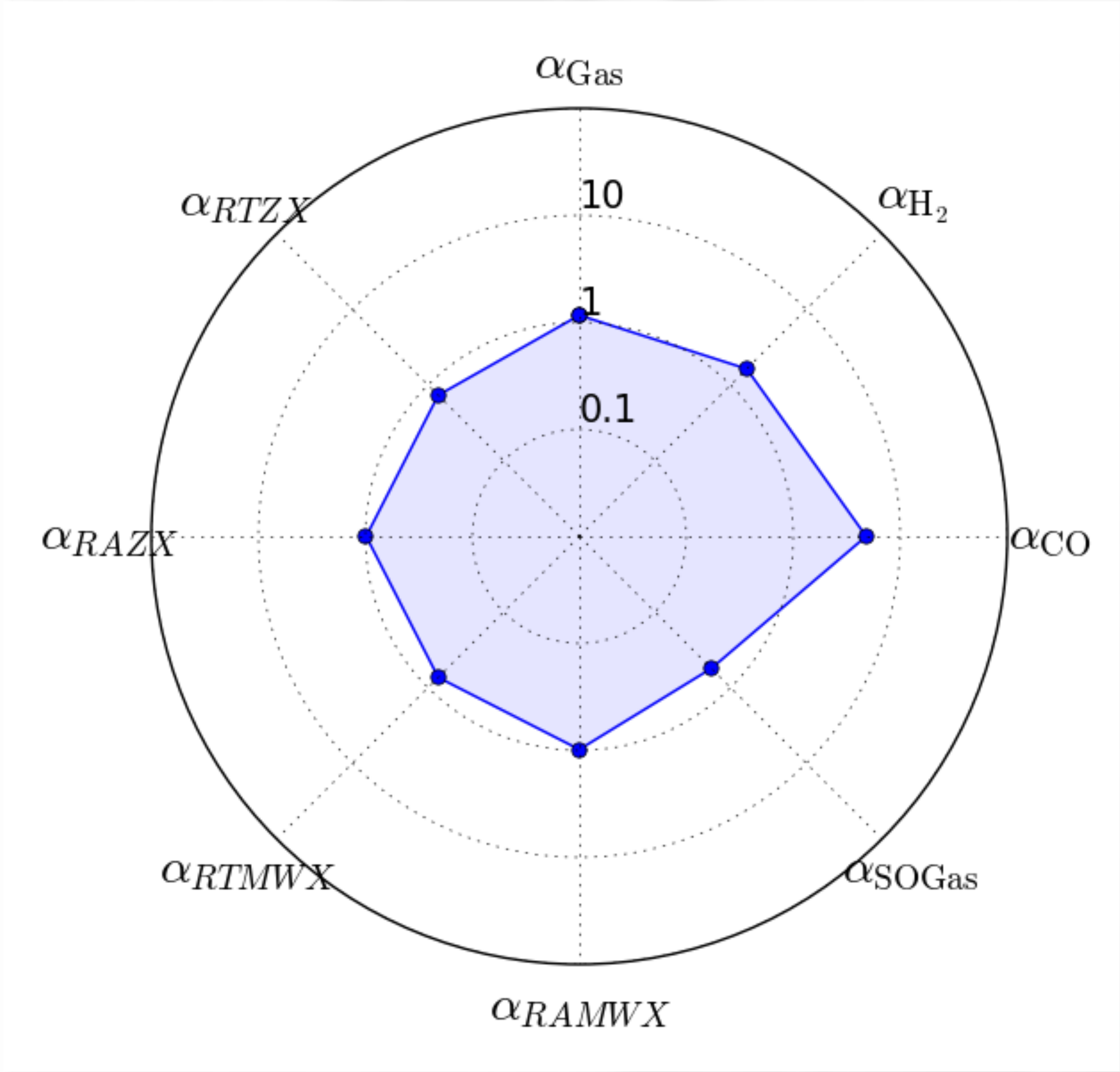
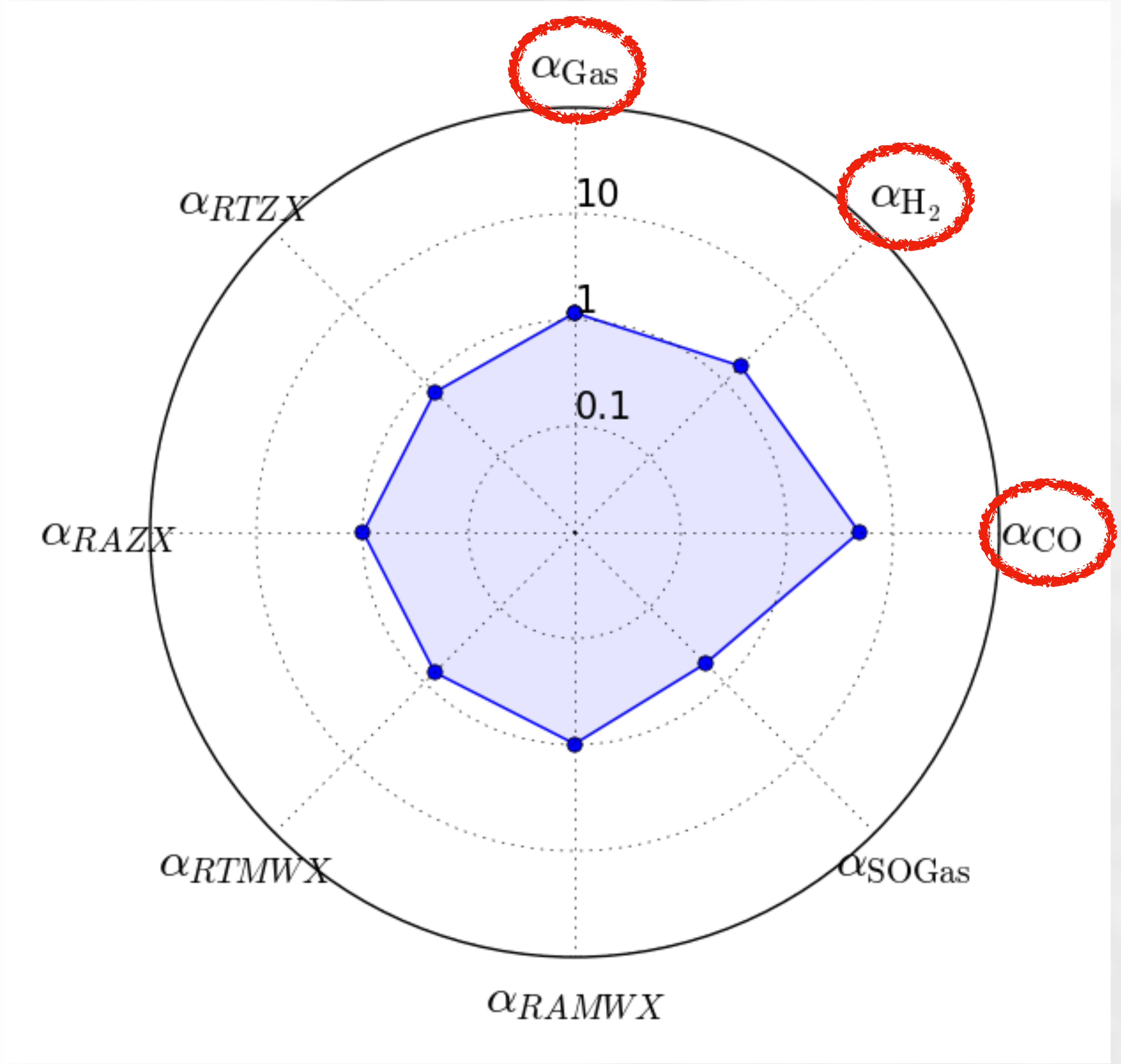


The virial parameter (Simulations)

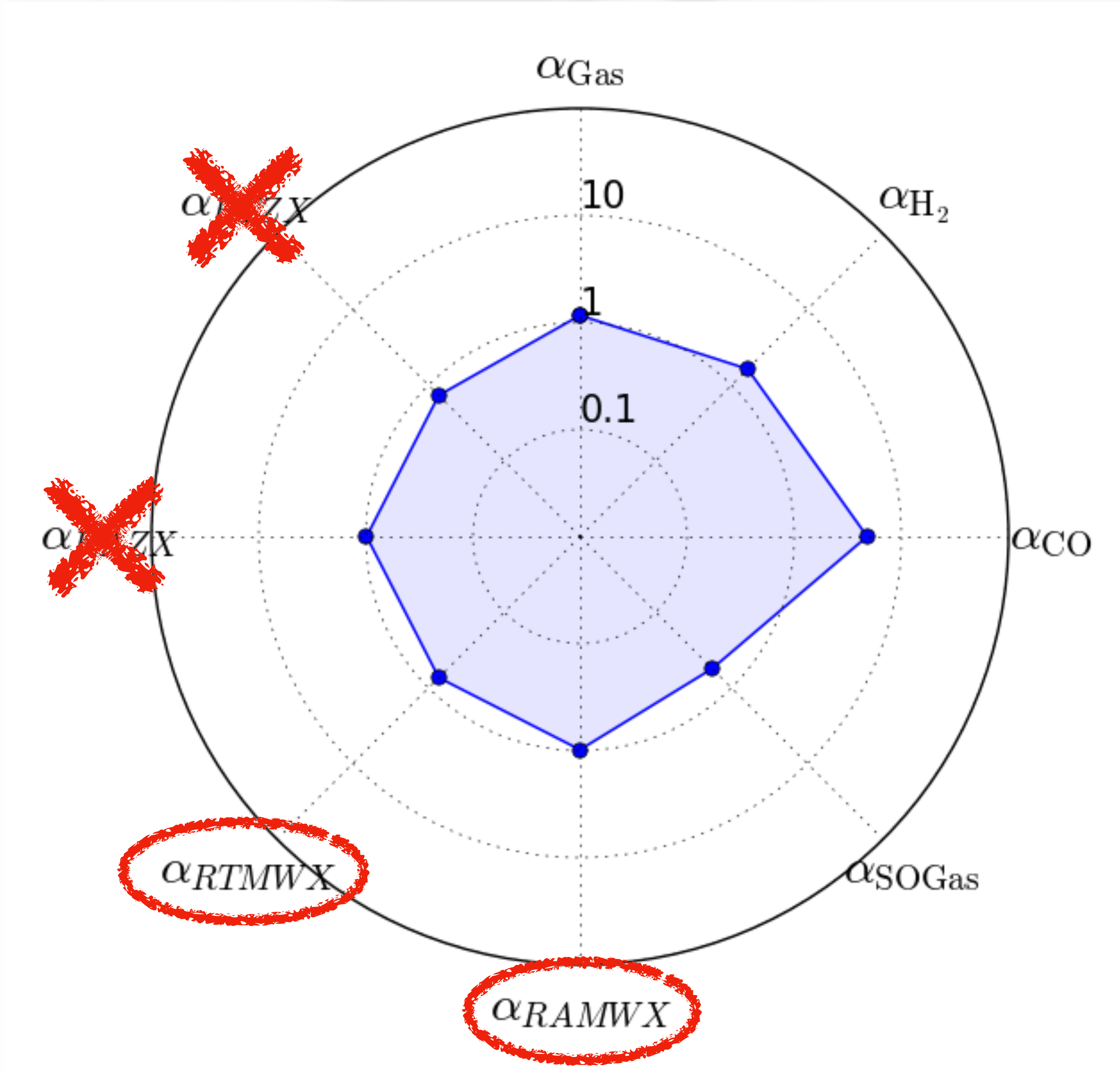


$$\alpha_{\mathrm{gas}} = \frac{2E_g}{E_k}$$

$$\alpha_{\mathrm{gas}} = \frac{\sum 5GM_n/3R_n}{\sum m_i v_i^2/2t}$$

$$n = \mathrm{gas}, \mathrm{H_2}, \mathrm{CO}$$

The virial parameter (Observations)

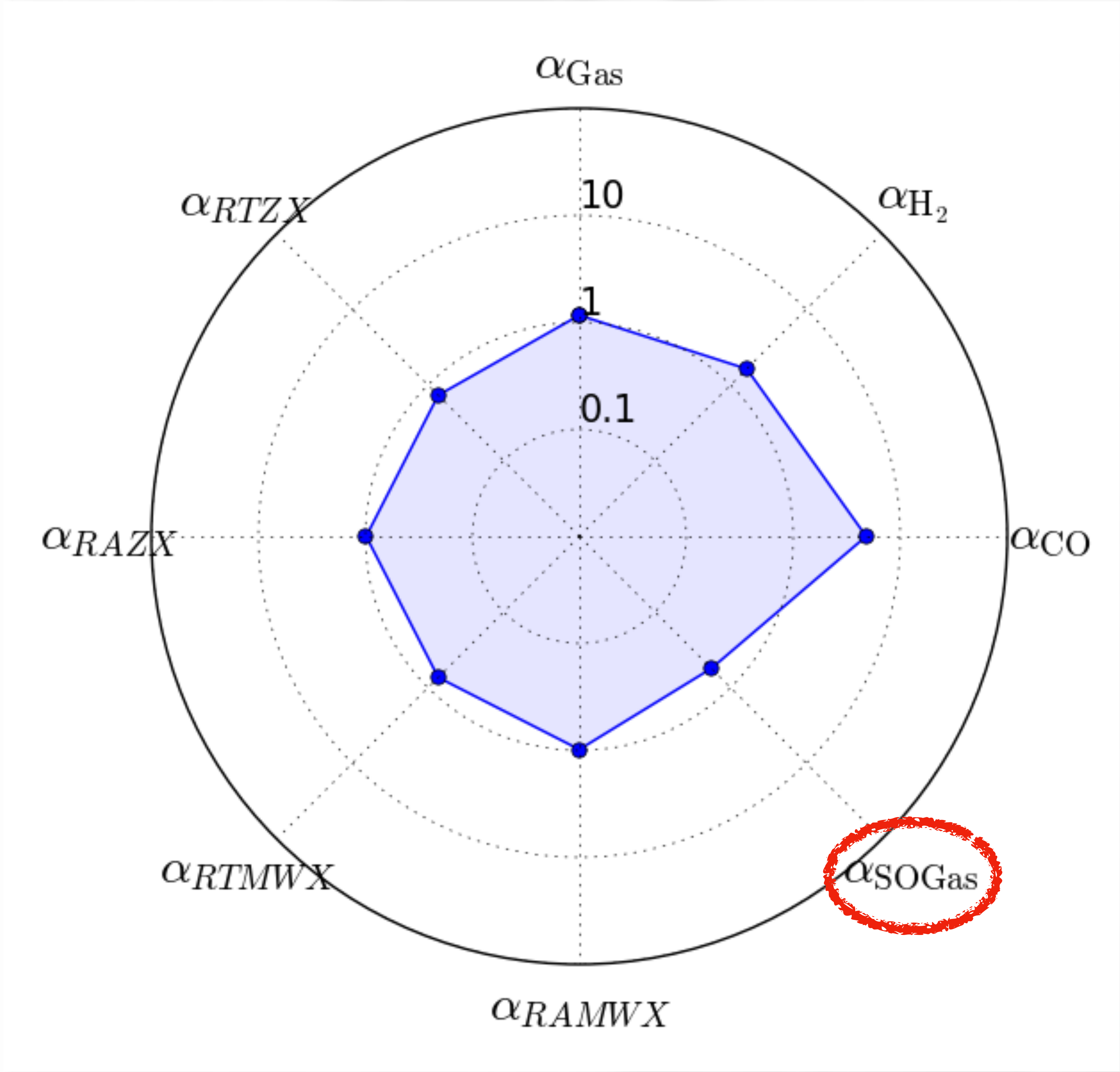


$$\alpha = \frac{5\sigma^2 R}{GM}$$

$$R_A = \sqrt{\frac{A}{\pi}}$$

$$R_{T_B} = \sqrt{\frac{\sum_i^N T_{\mathrm{B},i}(R_{ij} - \langle R_j \rangle)^2}{\sum_i^N T_{\mathrm{B},i}}}$$

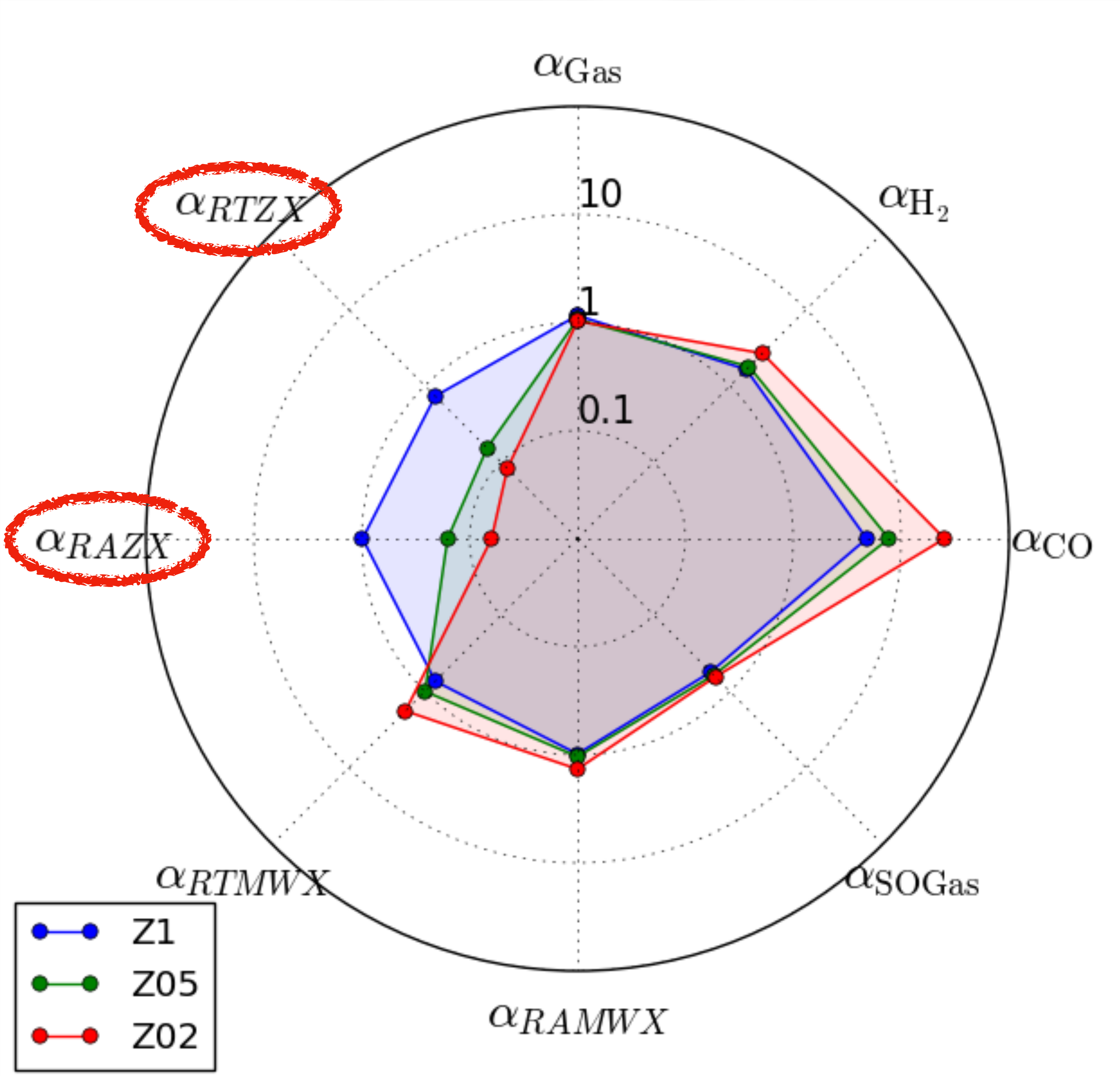
The virial parameter



$$\alpha = \frac{5\sigma^2 R}{GM}$$

R, M and σ^2 are all calculated from simulations

The virial parameter



$$\alpha = \frac{5\sigma^2 R}{GM}$$

$$M = \alpha_{\rm CO,MW} L_{\rm CO}$$

$$M = \alpha_{\rm CO,Z} L_{\rm CO}$$

Summary

- The observationally derived virial parameter is highly dependent on how the velocity dispersion, size and mass are calculated.
- Our results show that the same cloud can appear unbound in simulations and bound through synthetic observations.
- When comparing observations to simulations its important to consider what techniques are used and how different quantities are calculated. Synthetic observations can really help!

THANKS :)