Cosmic Rays: The Hidden Architects of the Circumgalactic Medium

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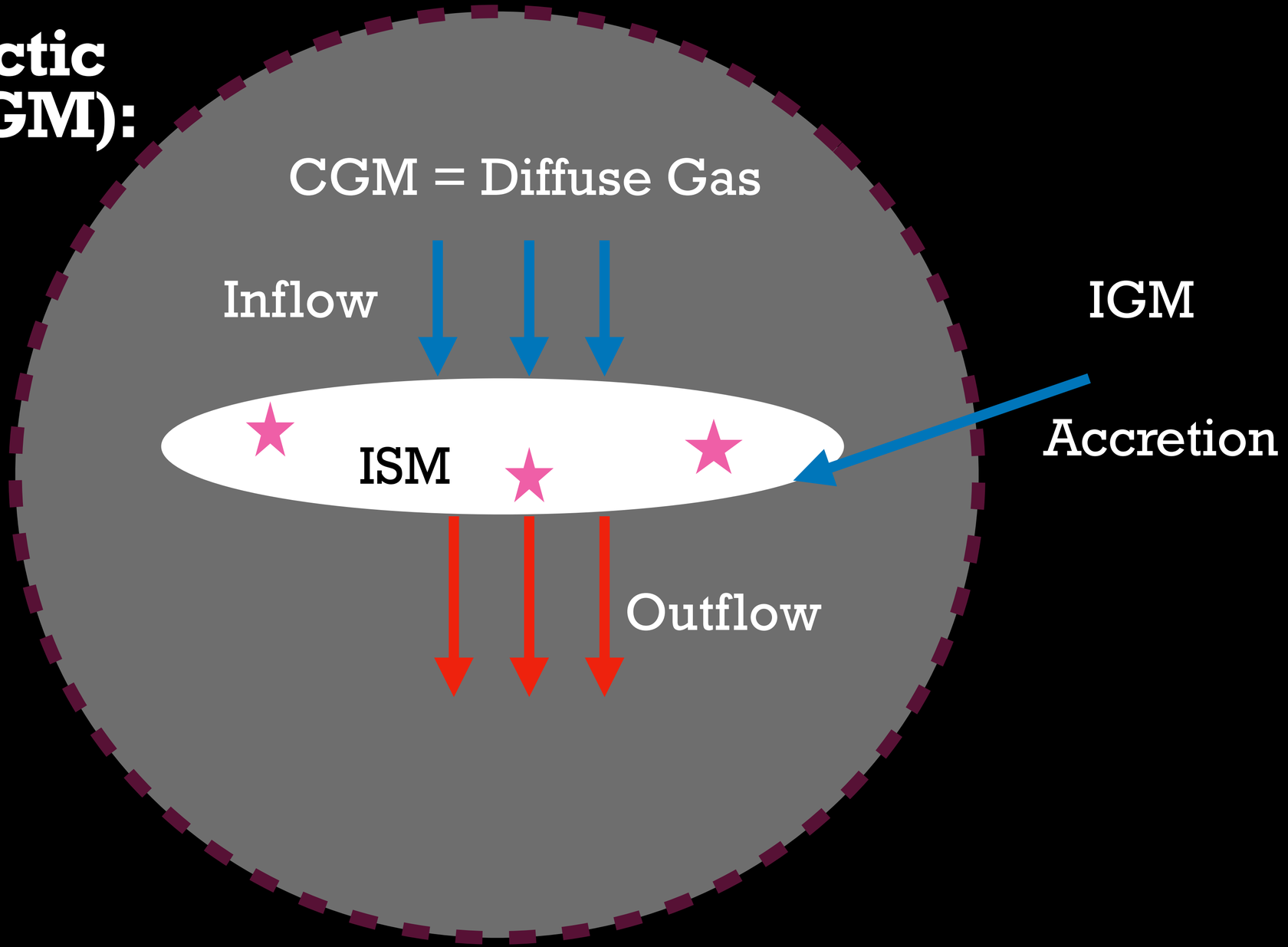
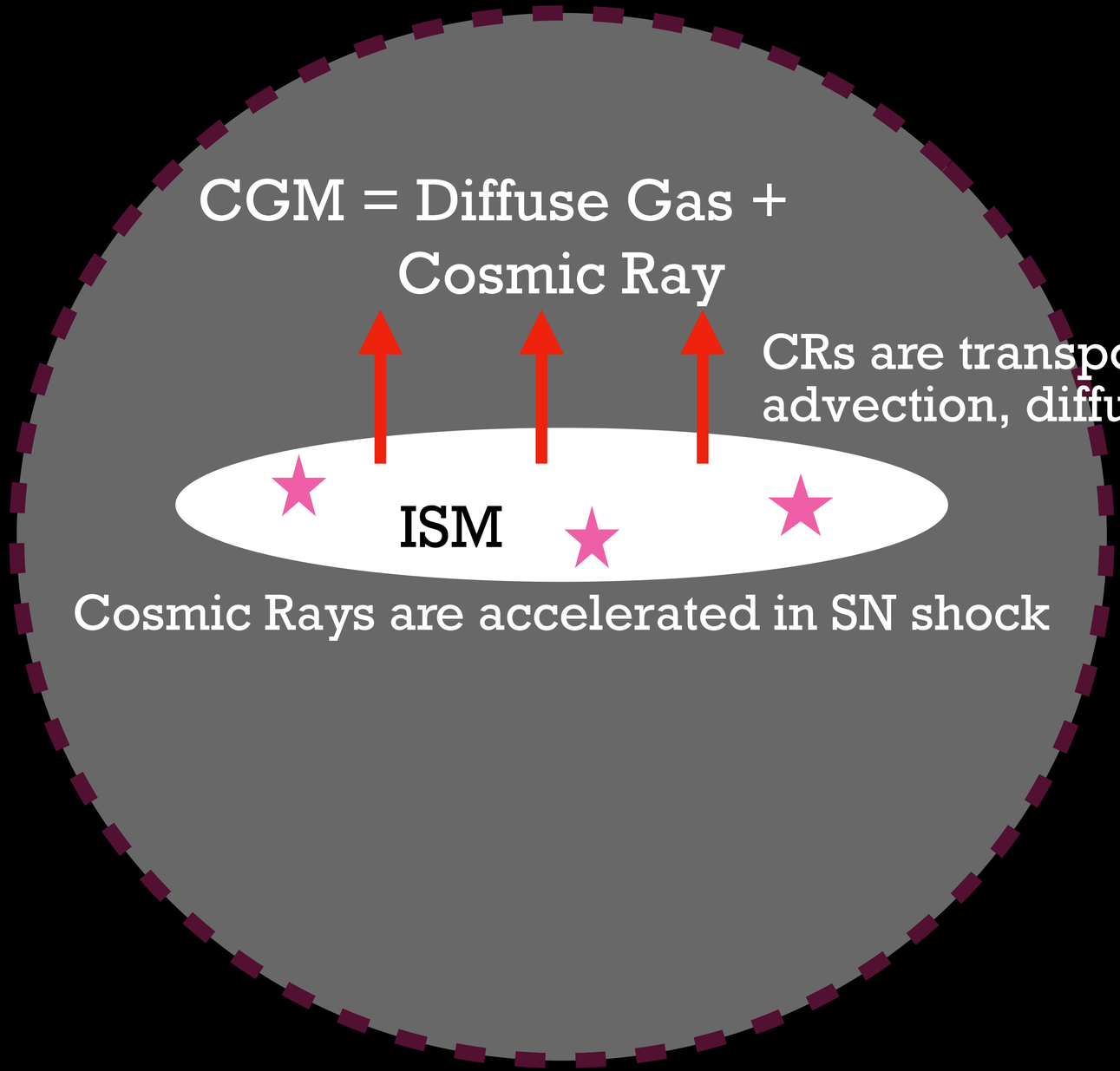
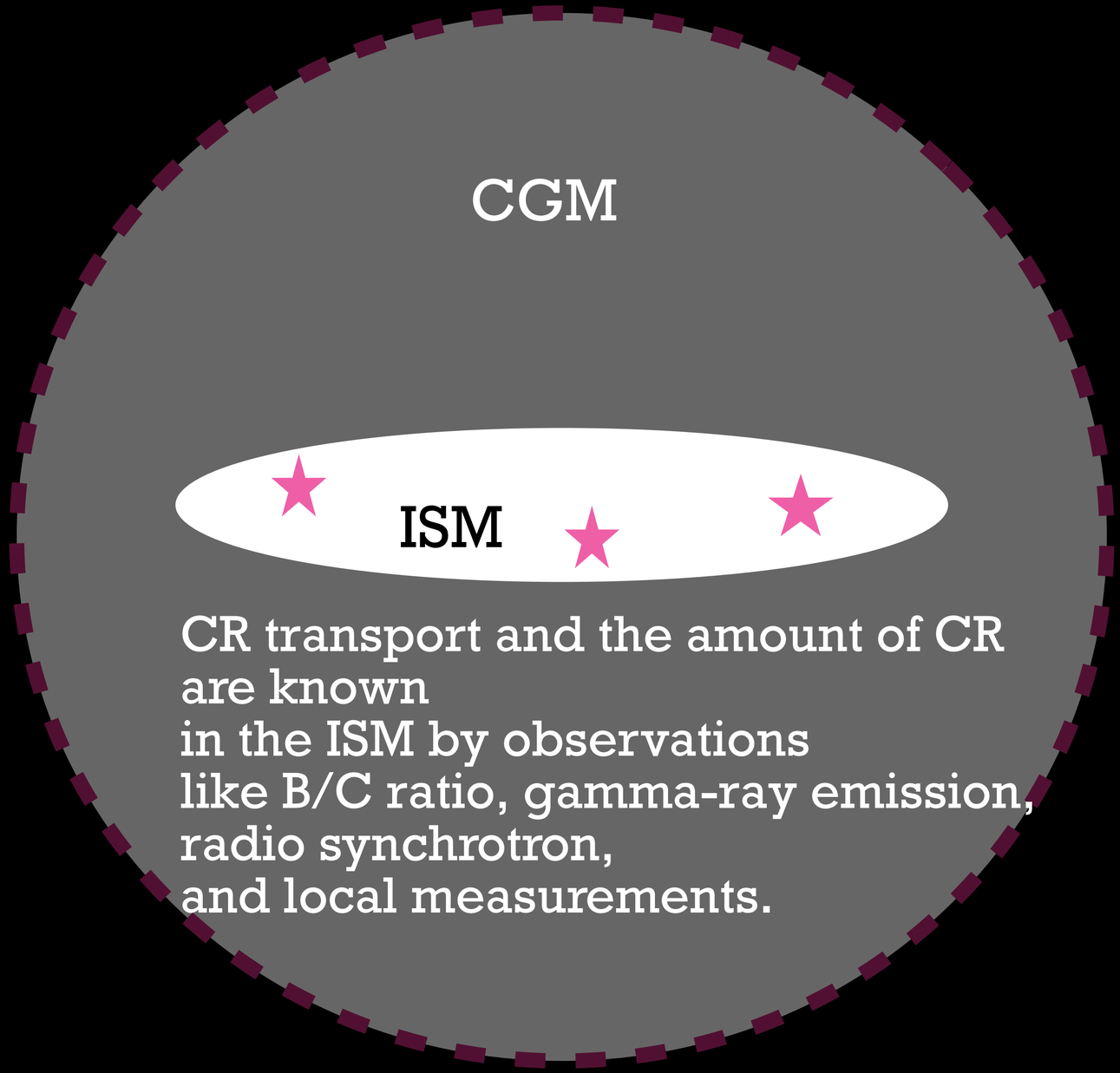
Circumgalactic Medium (CGM):



CGM is important for galaxy evolution


CGM = Diffuse Gas +
Cosmic Ray
CRs are transported to CGM by
advection, diffusion, and streaming
ISM
Cosmic Rays are accelerated in SN shock



CR transport and the amount of CR are known
in the ISM by observations
like B/C ratio, gamma-ray emission,
radio synchrotron,
and local measurements.

On the contrary, CR transport in CGM is an open question due to a lack of observations.

Main Questions:

1. How to constrain CR transport in CGM?

2. What are the effects of CR in the CGM?

How to constrain Cosmic rays in the CGM?

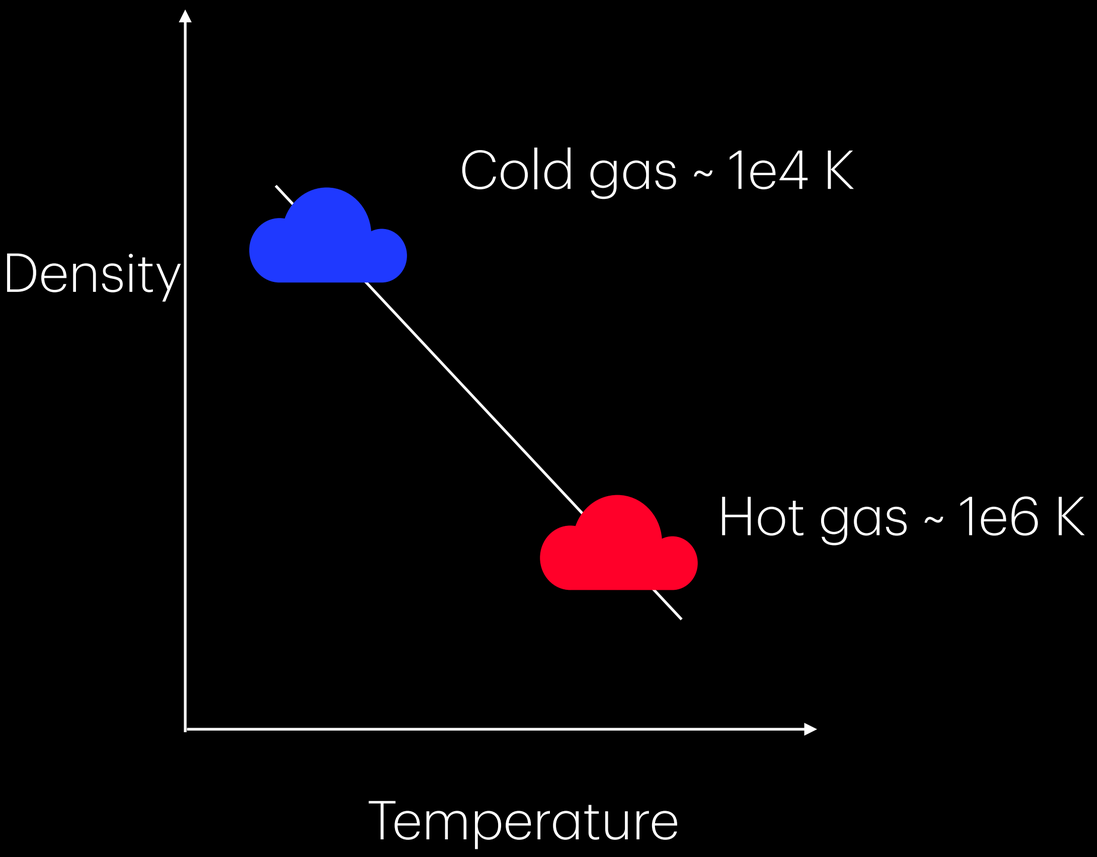
CR MODELS in Simulation → Produce different galaxy/ CGM observables → Match with observations

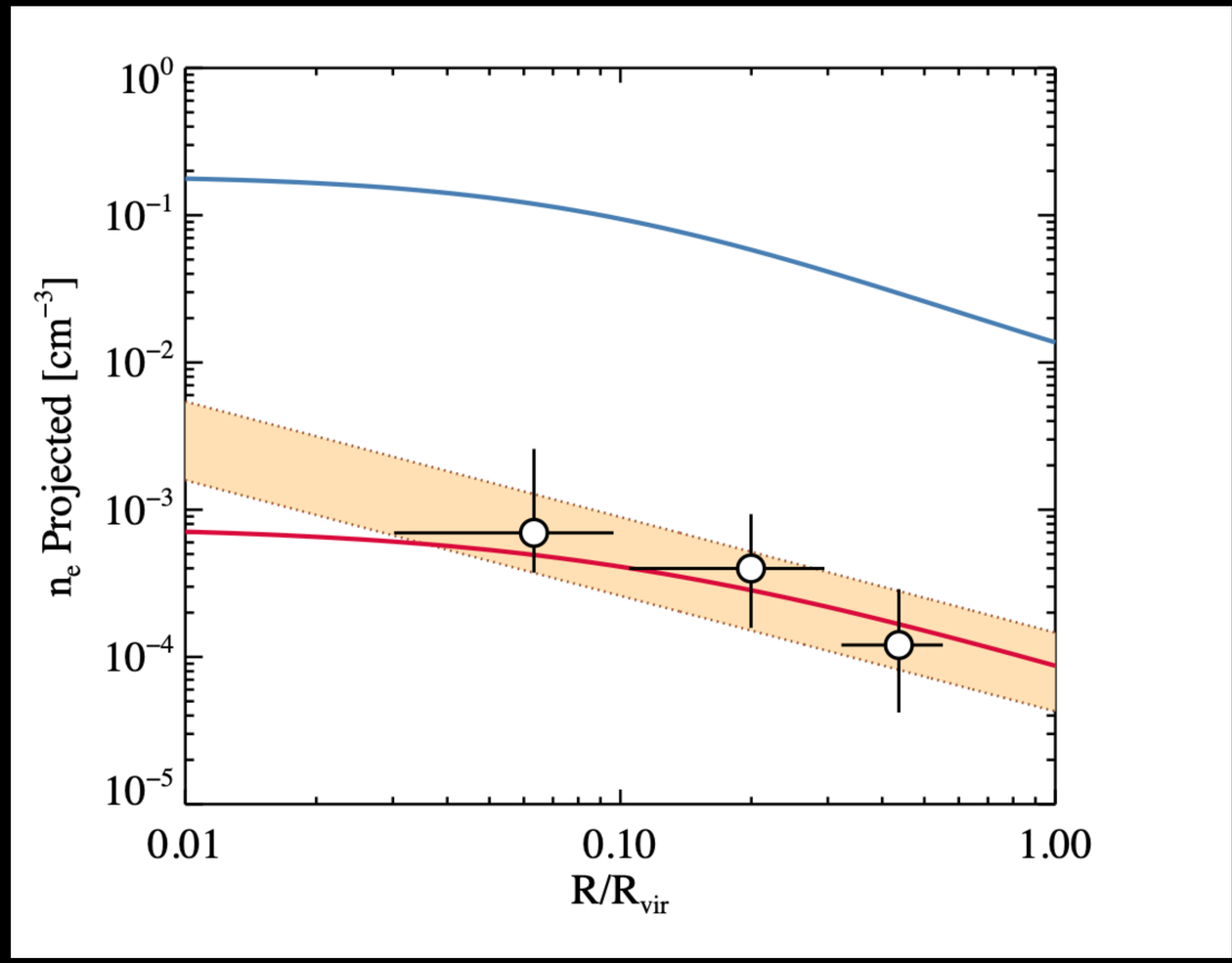
1. Constant Diffusion
2. Extrinsinc Turbulence
3. Self Confinement

And so on…

1. Galaxy morphology
2. Different ion column
3. Thermal Pressure
4. Covering Fraction

Cold gas in the CGM



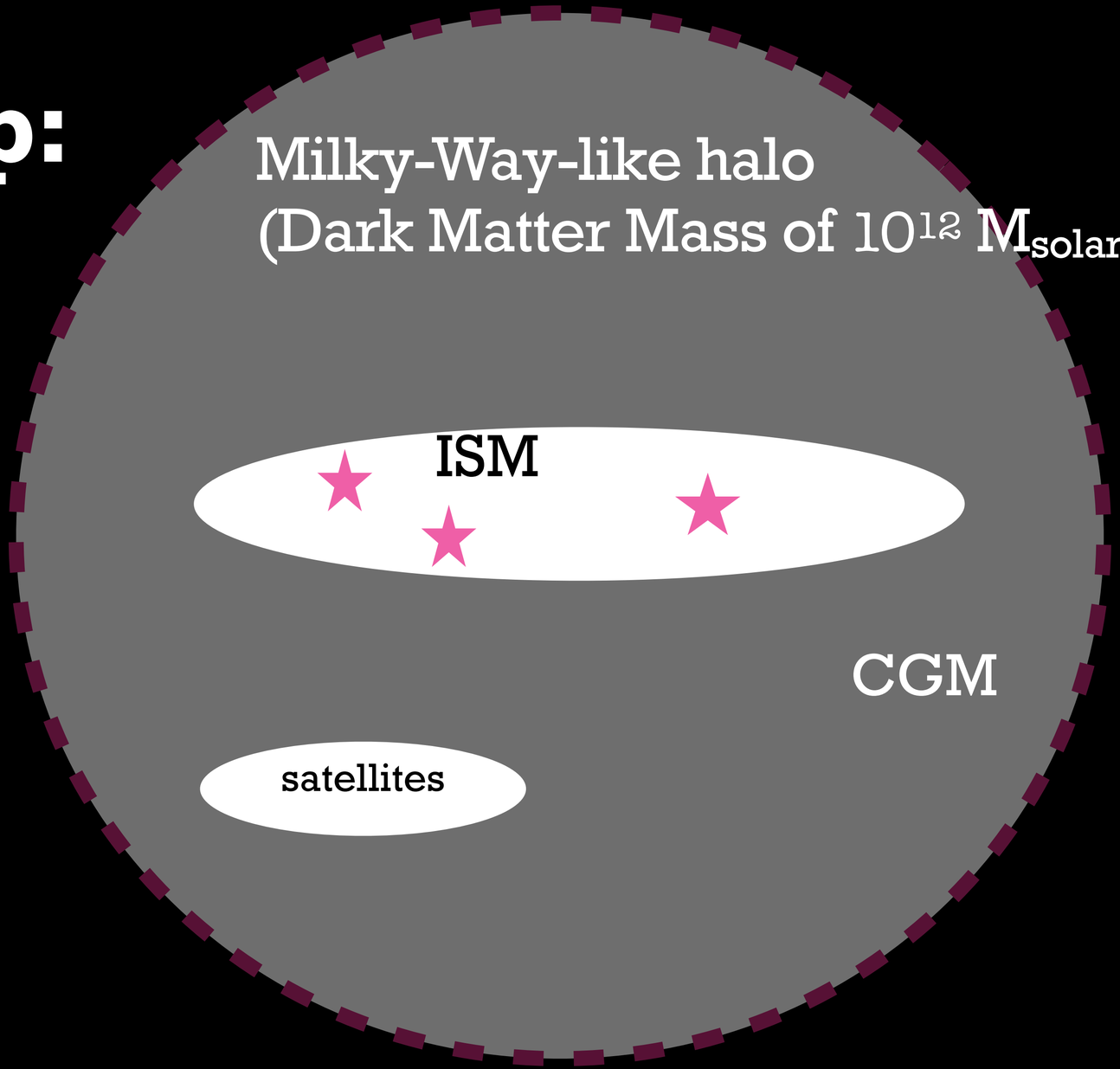


Werk+2014

Simulation Setup:

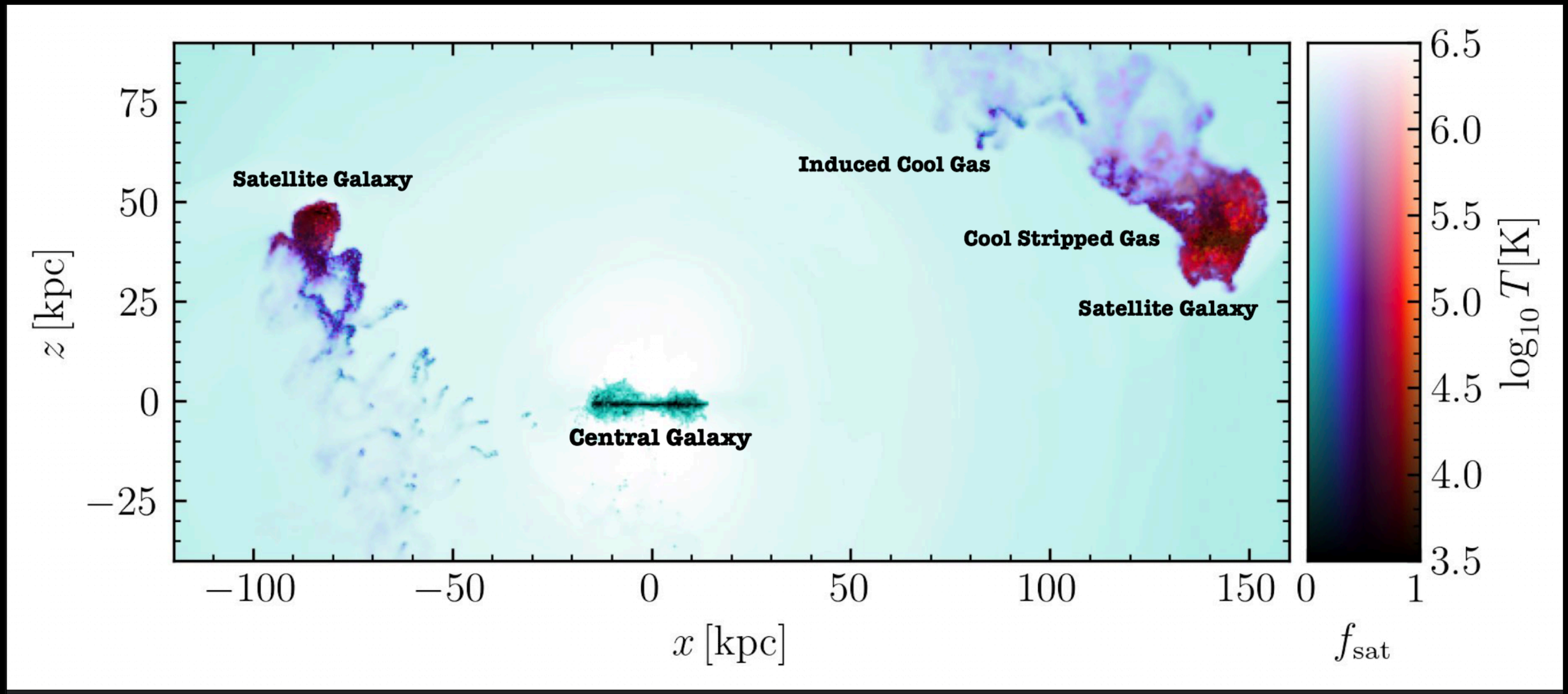
1. Injection of CR by SN in the host and satellite

2. Constant Diffusion + Advection + Streaming



GIZMO, FIRE-2 Feedback

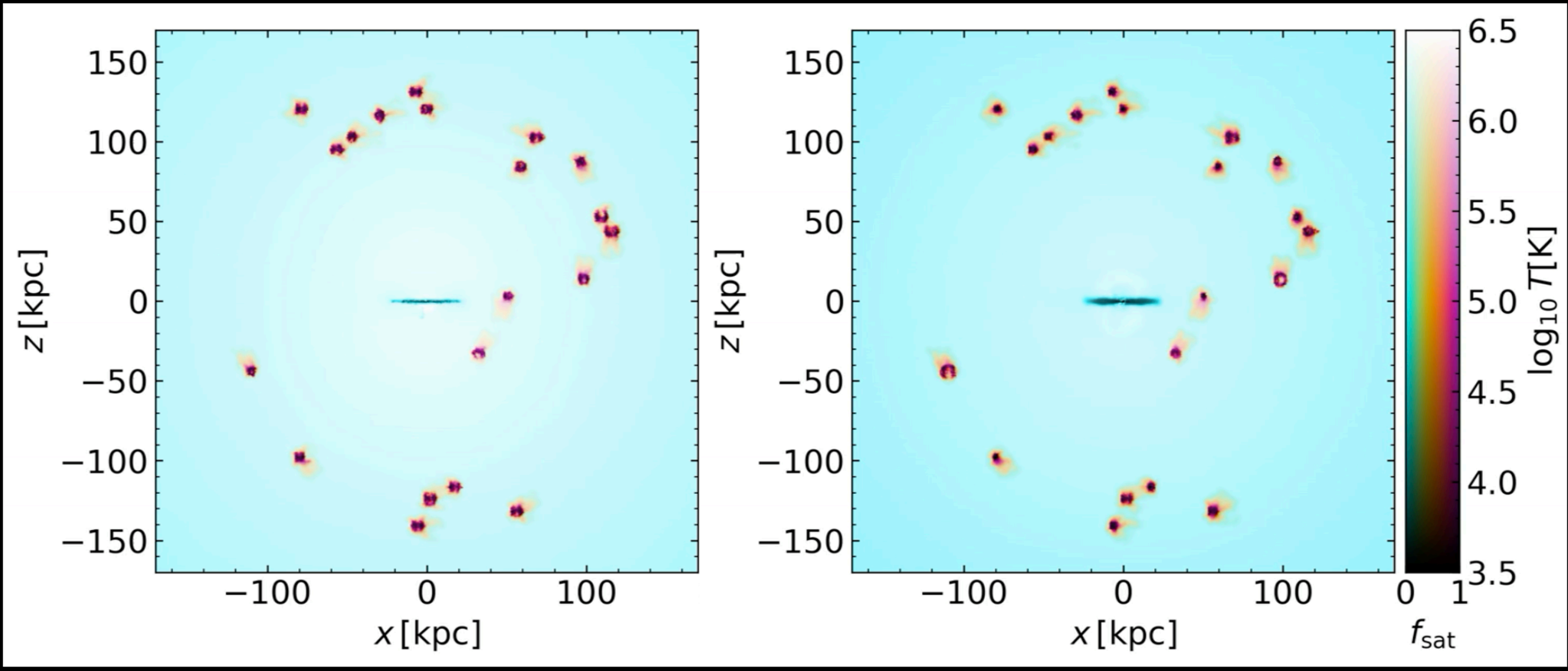
Roy +2025 Submitted in ApJ



Roy +2024

https://doi.org/10.1093/mnras/stad3142

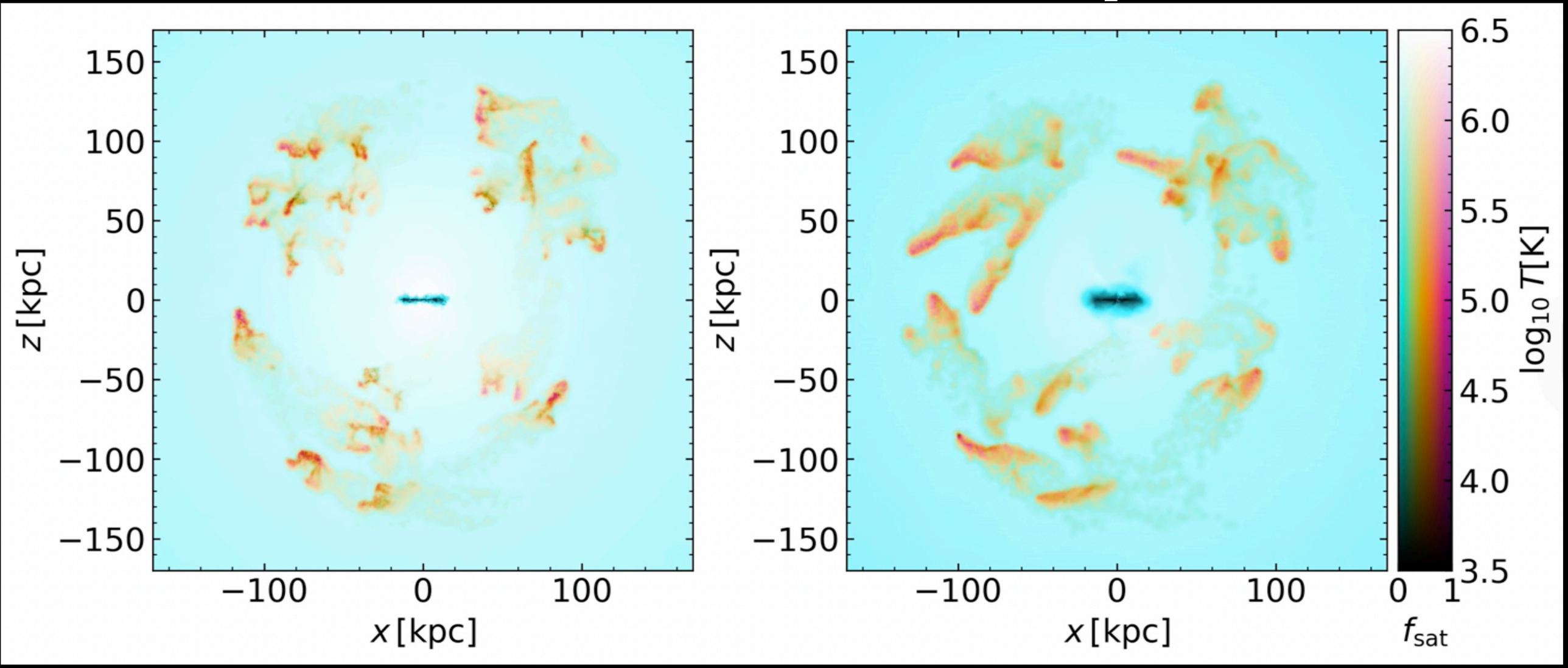
t = 0 Gyr



No CR

With CR

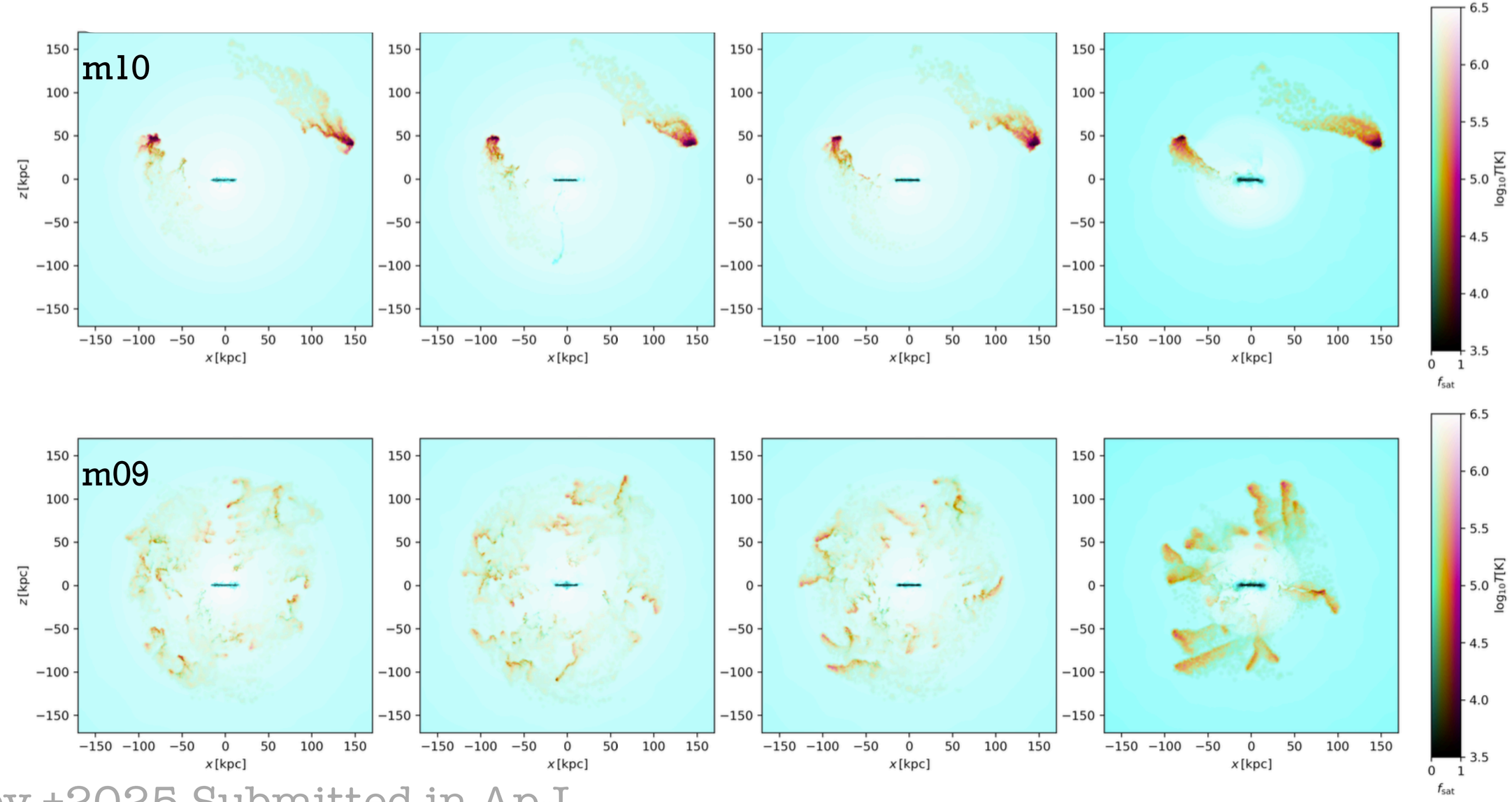
Later Time: t ~1 Gyr



No CR

With CR

No CR Low CR Mid CR High CR



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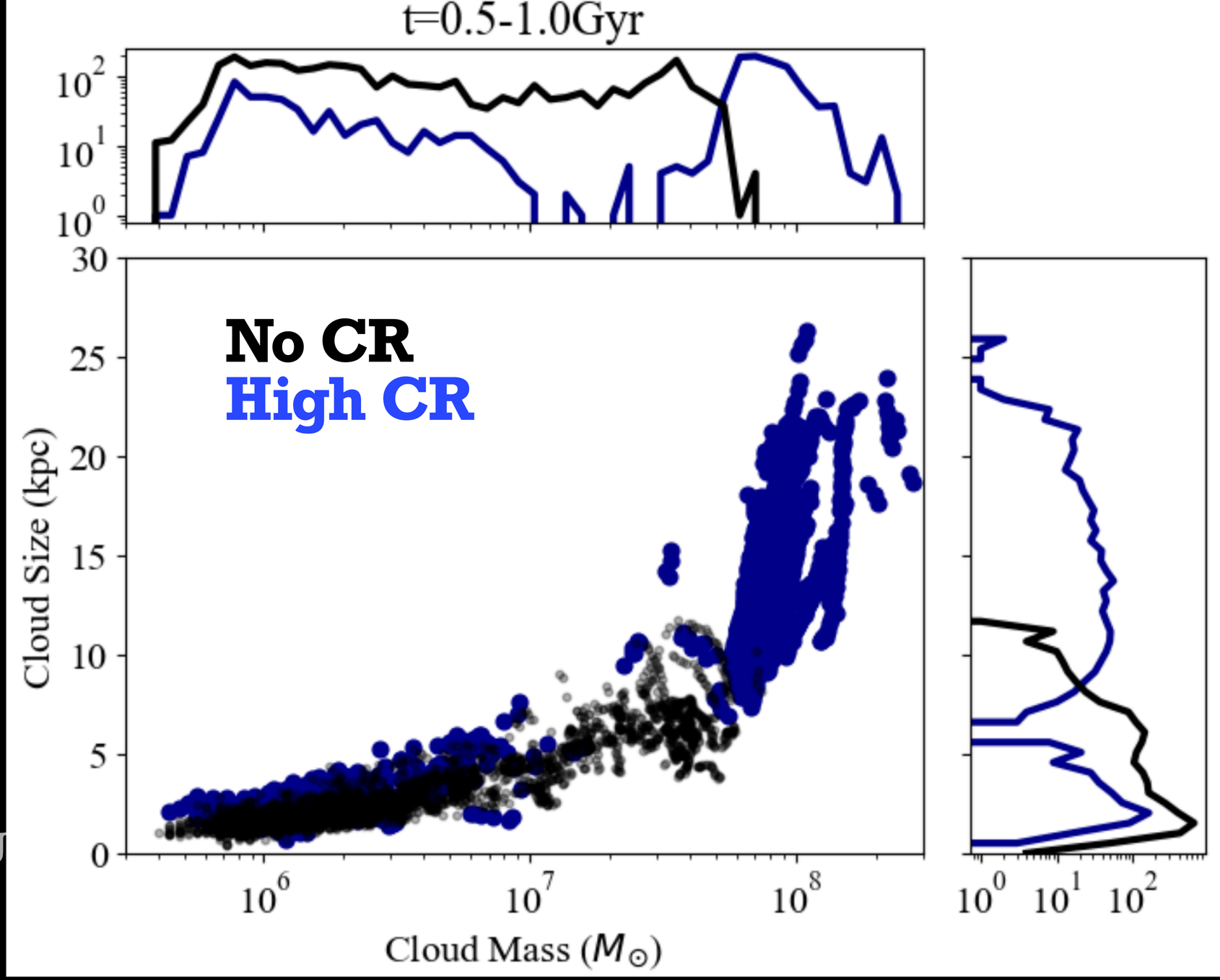
Increasing Cosmic Rays > Increase size of the cloud

Size vs mass:

Larger clouds with an increase in CR



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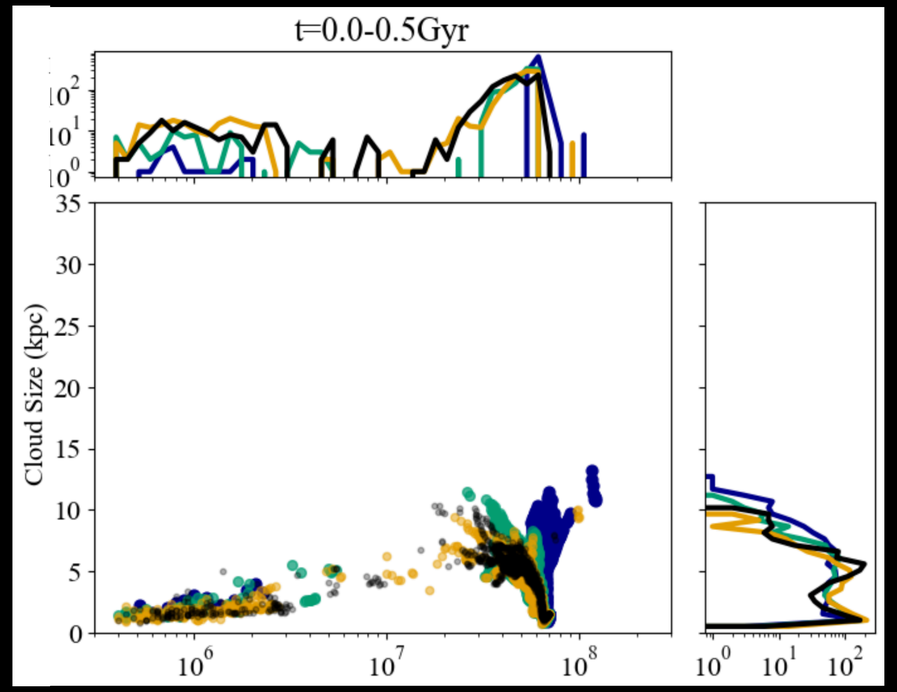
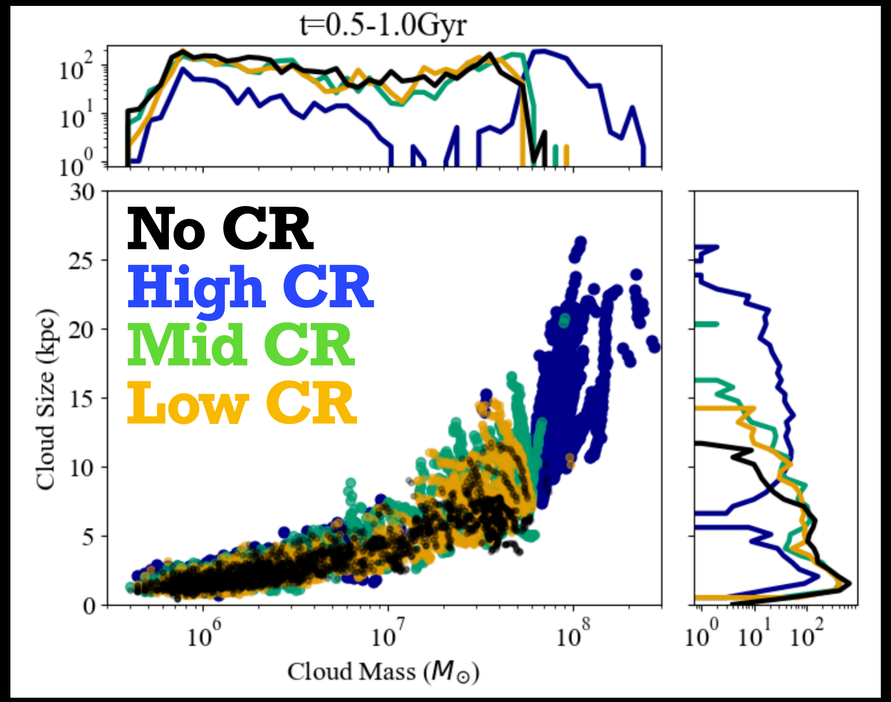
Size vs mass:

Earlier Time

Larger clouds and cloud mass growth with an increase in CR



Later Time



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Covering Fraction:

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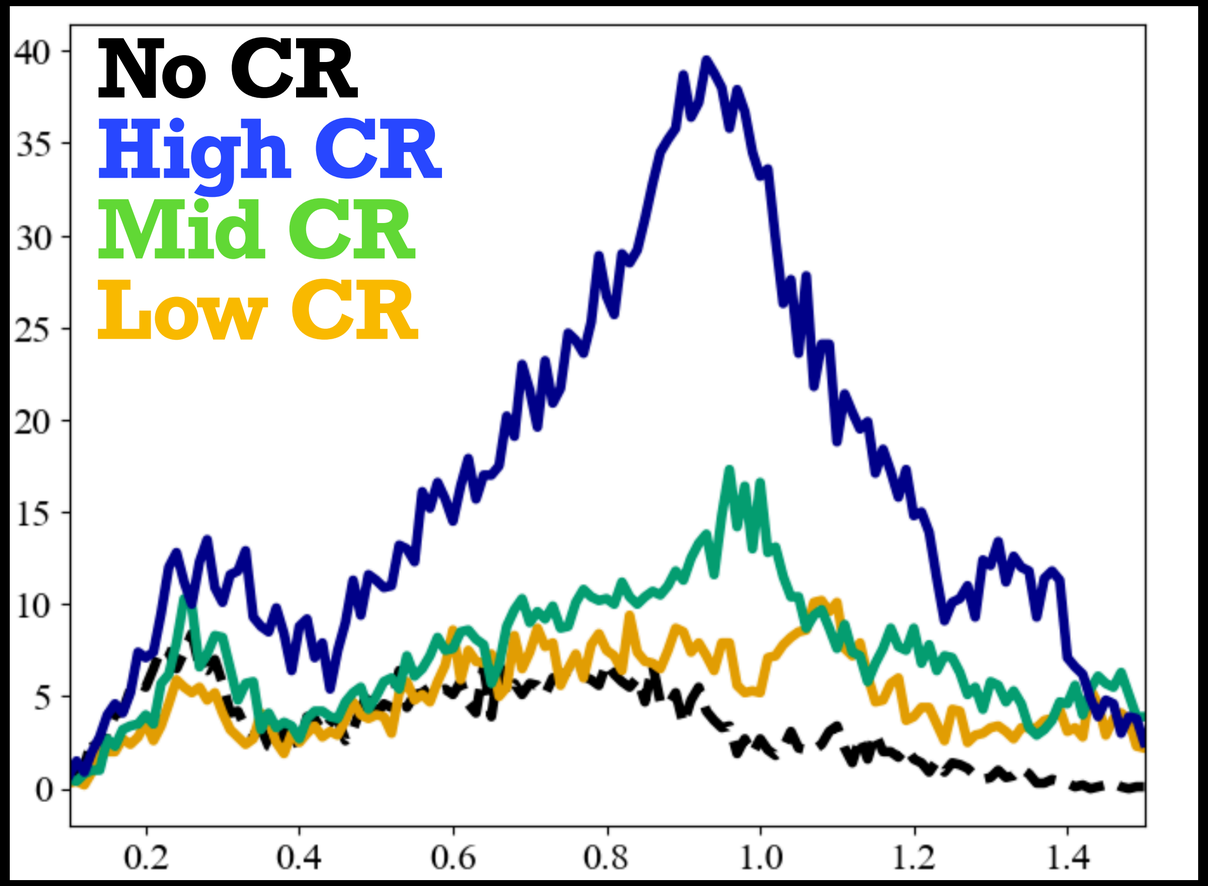
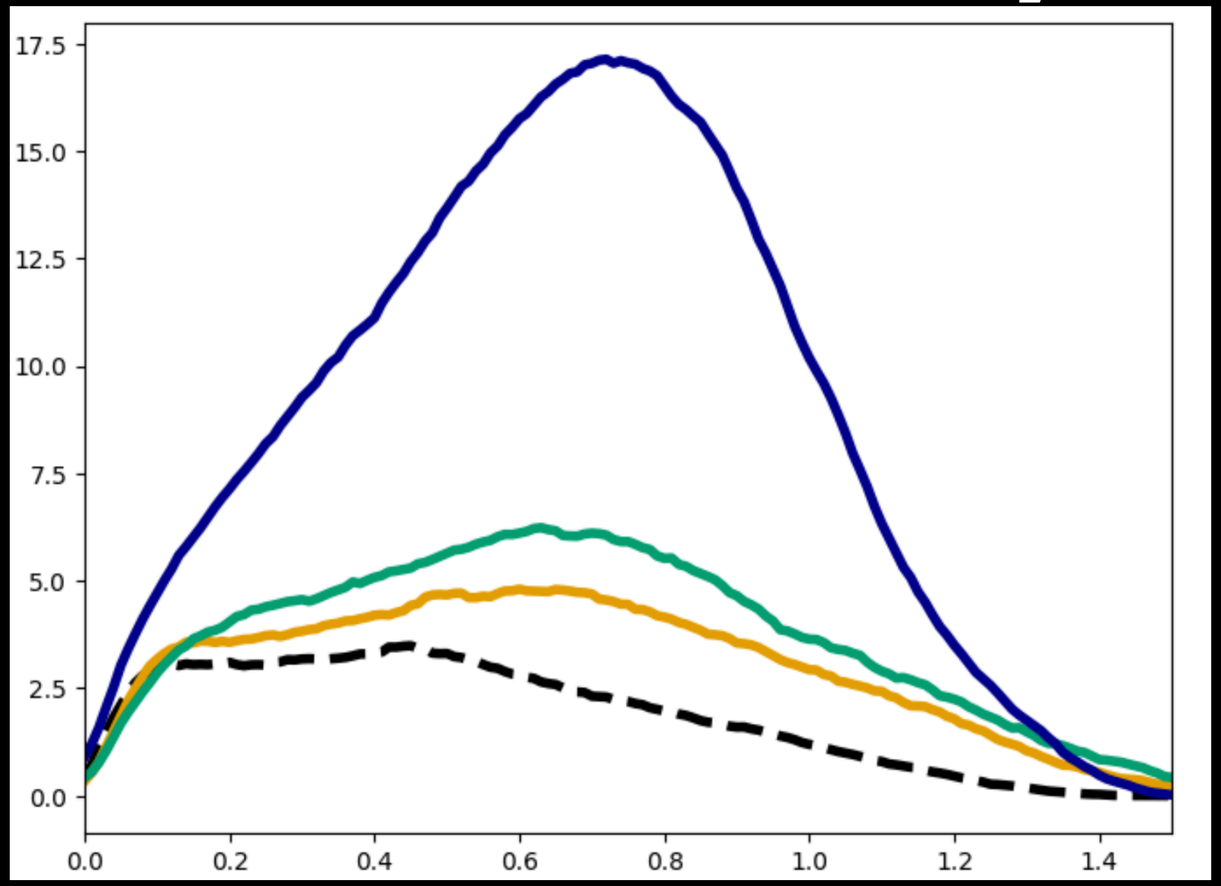
MW

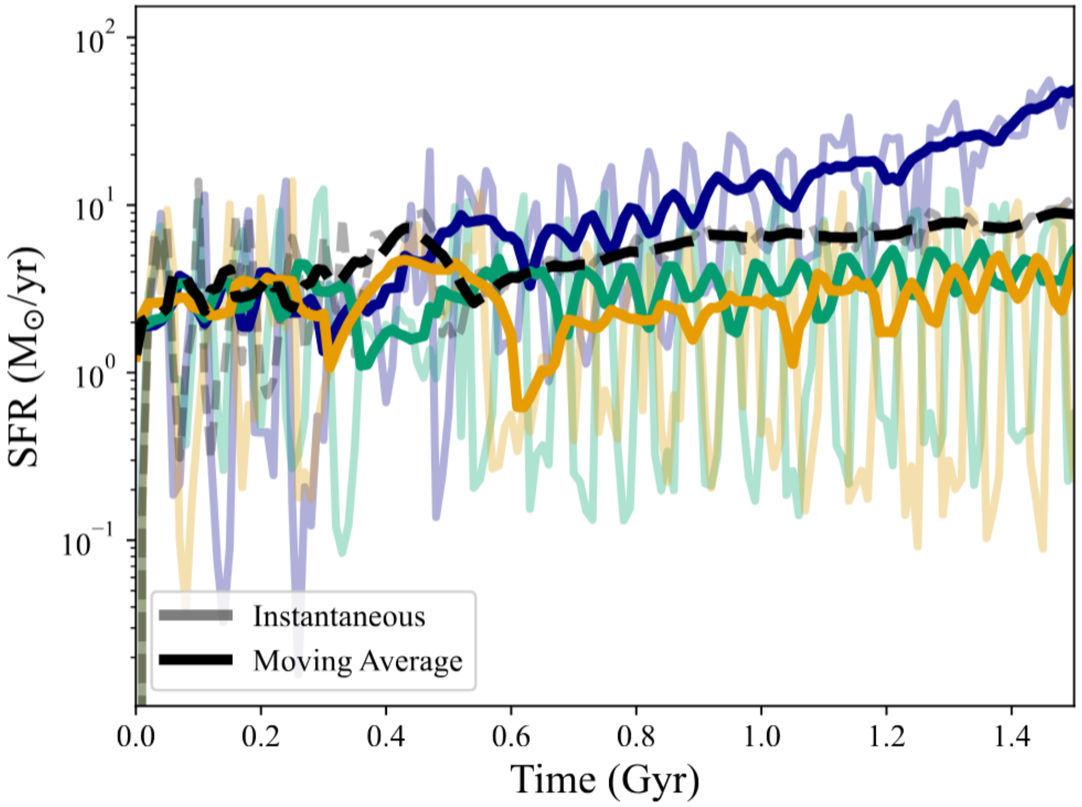


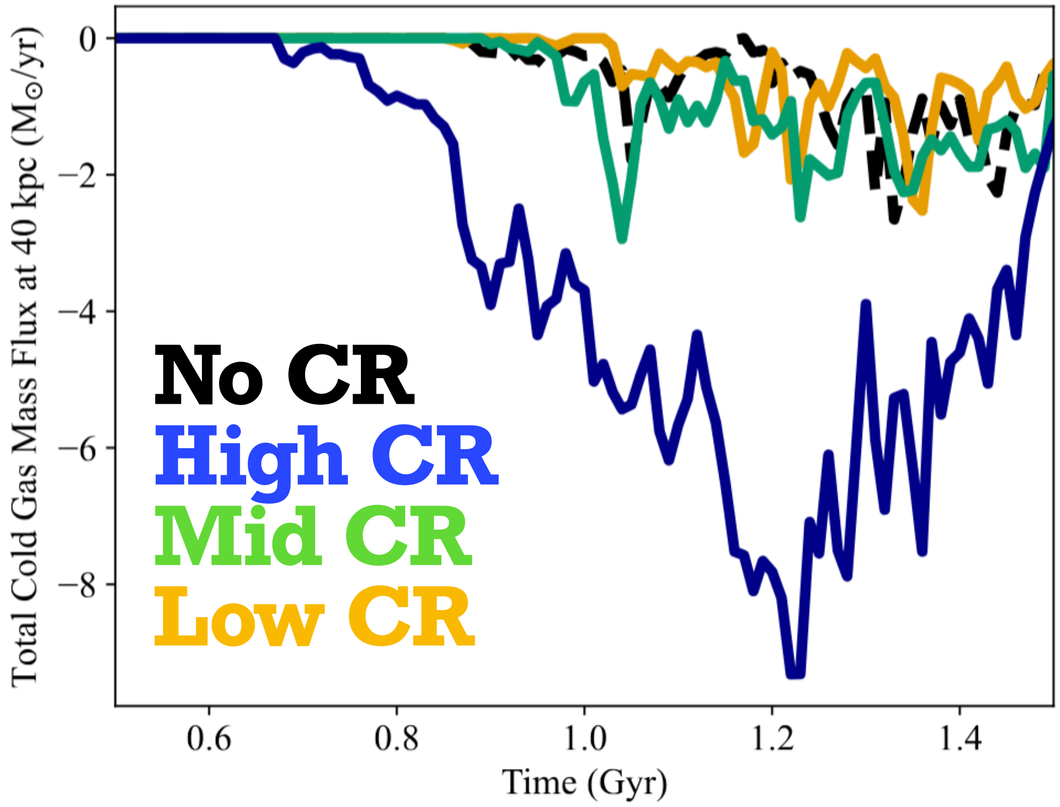
External Galaxy



Cosmic rays significantly enhance the covering fraction of cold gas in CGM, particularly in the MW view. It is also true for external galaxies, but in satellite-rich environments like the m09 run

Feeding the galaxy:





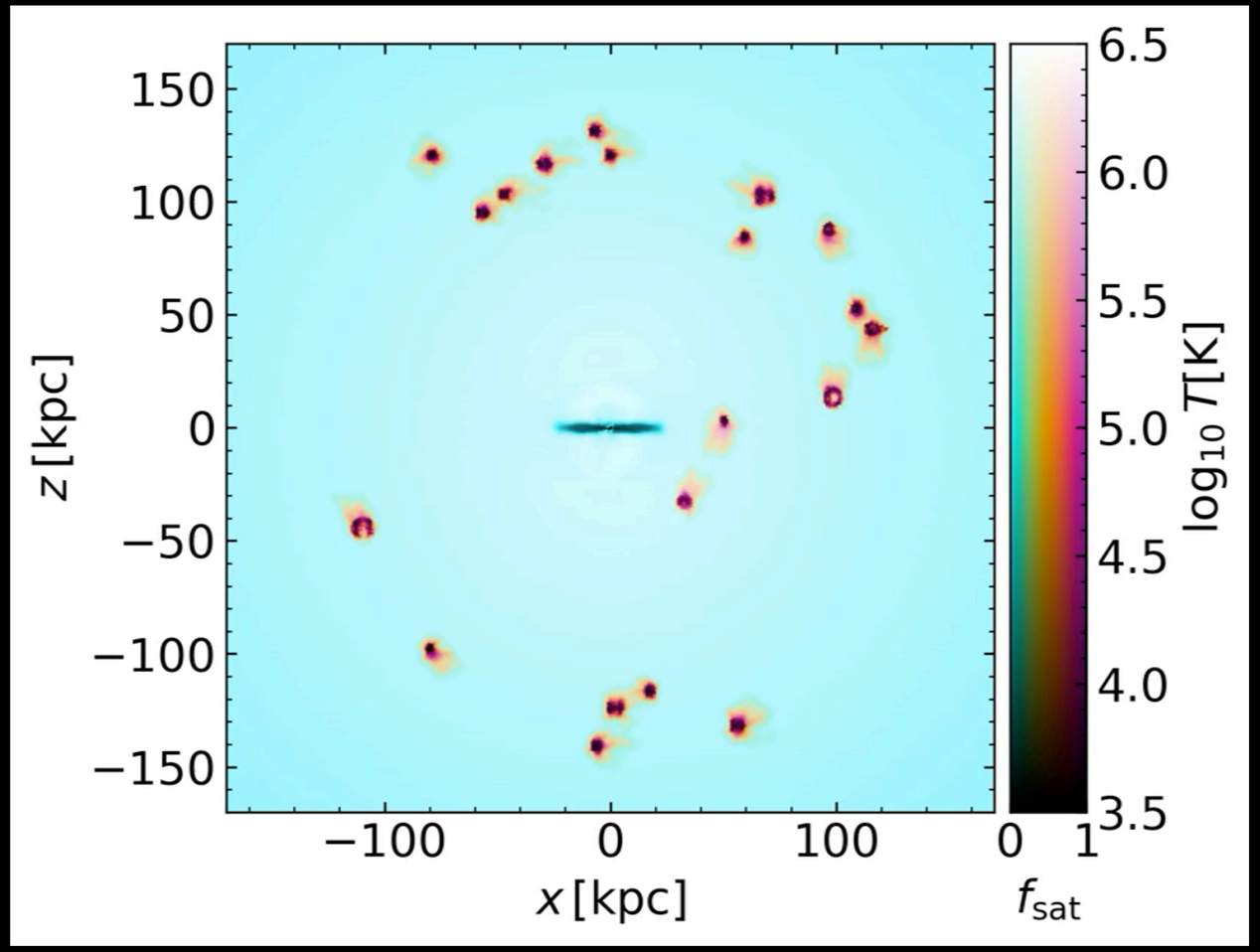
Inflow is 3-4 times higher, and SFR is also 2 times higher in the high-CR run than in the no-CR run

Roy +2025 Submitted in ApJ

Take Home

Paper I (Roy+2024)
Paper II (Roy+2025 to be Submitted to ApJ)

- ***CR makes the clouds bigger in size which them grow more by mixing layer cooling***
- ***Covering Fraction of the cold gas increases***
- ***Inflow of the cold gas into the central galaxy increases***
- ***SFR of the host galaxy can be boosted at a later time***



Effect of CR transport: