Turbulence in The Halos of Galaxies

By: Ed Buie II

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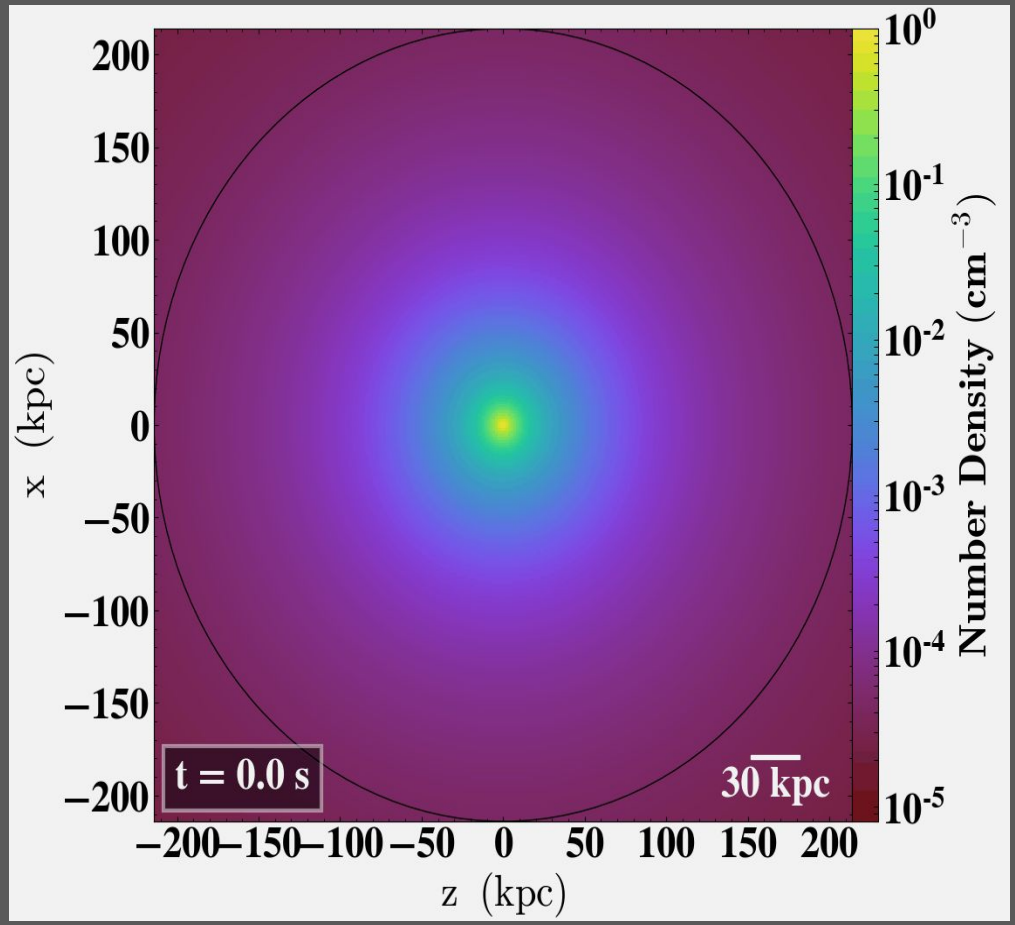
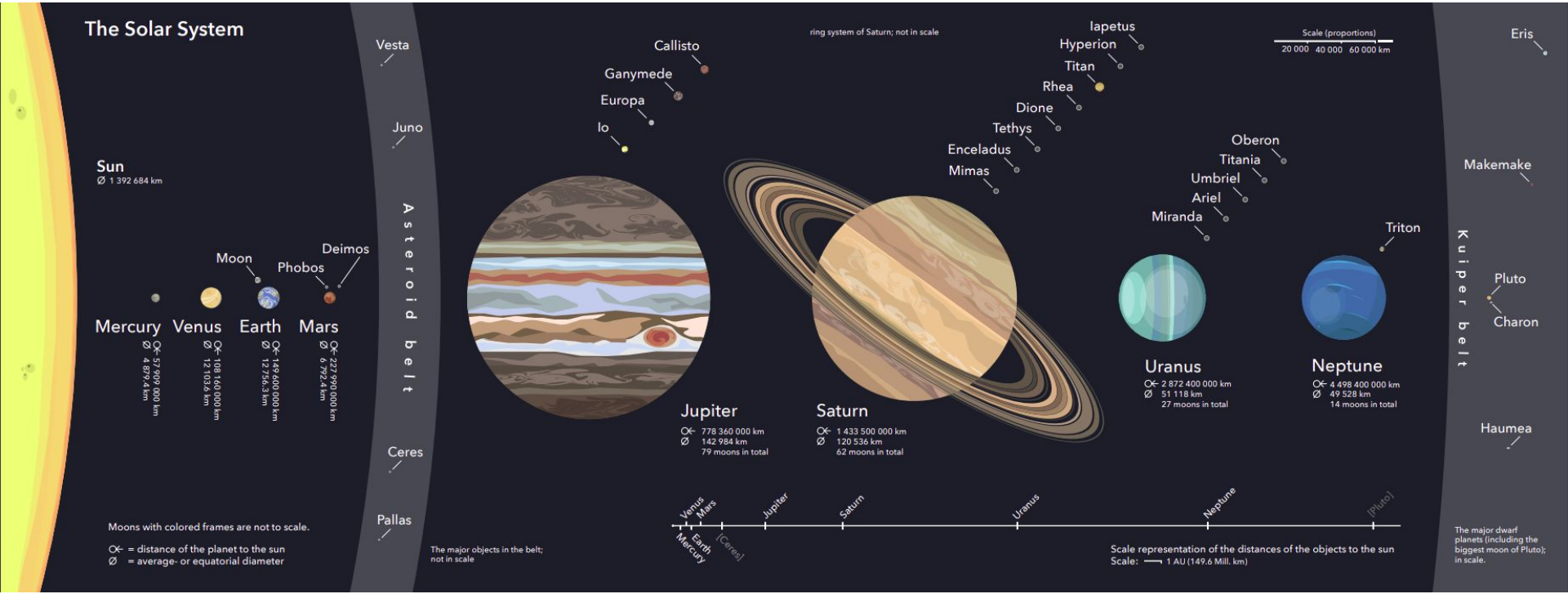


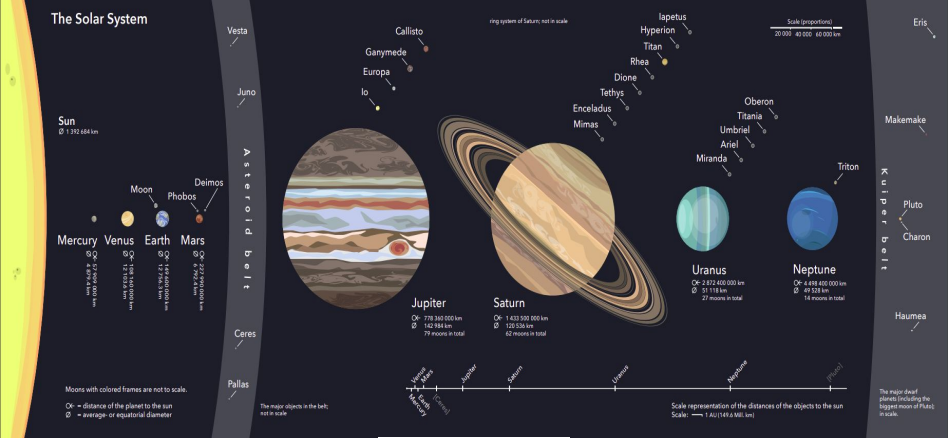
School of Earth and Space Exploration
Arizona State University

First, I want to acknowledge all those who have been negatively impacted by the COVID-19 pandemic. And thank you to all of the essential workers for their efforts. We will get through this.

Credit: Beinahegut

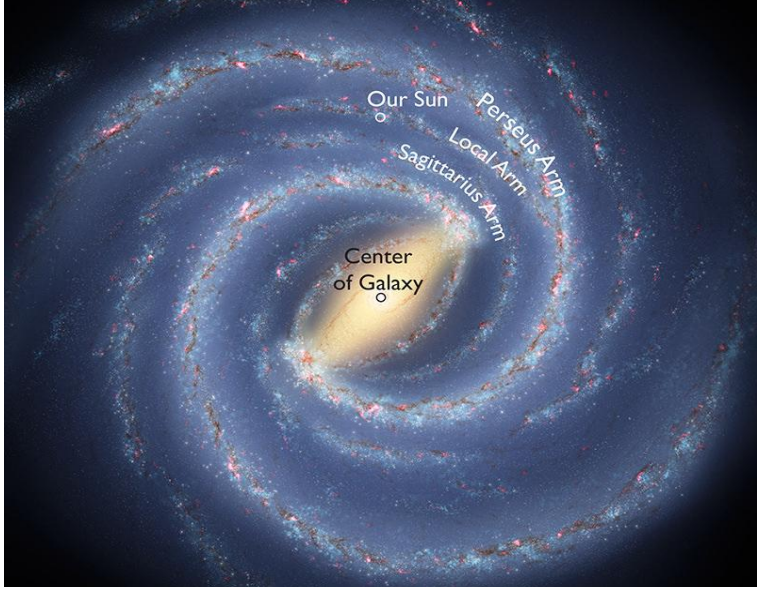


14,500,000,000 mi
or
156 Astronomical Unit or AU



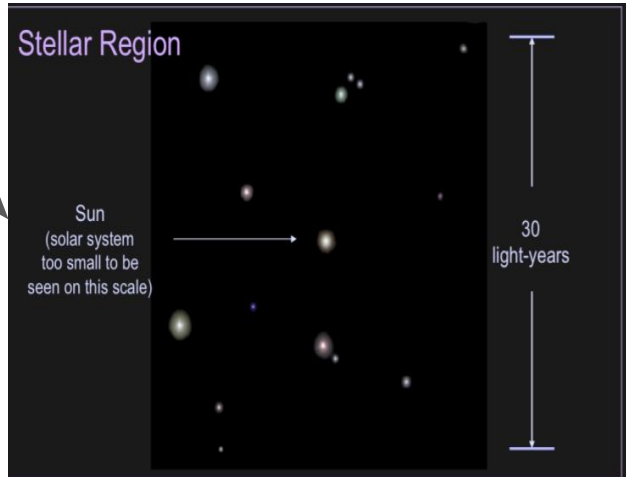
14,500,000,000 mi
or
156 AU

100,000 light-years
or
30 kiloparsecs
(kpc)



Credit: NASA/JPL-Caltech/R.Hurt

15,000 times bigger

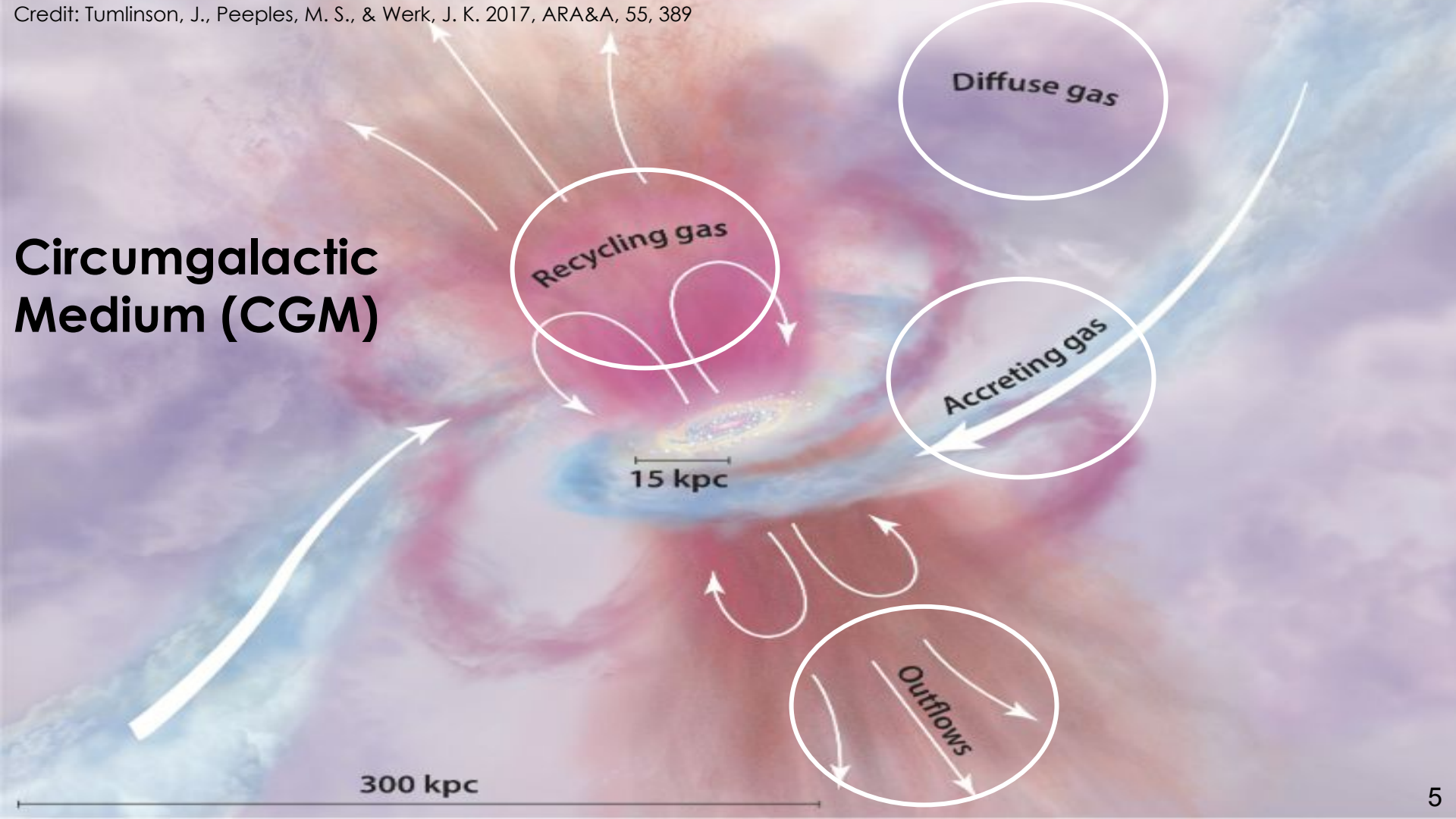


Credit: Edmund Watson

3,500 times bigger

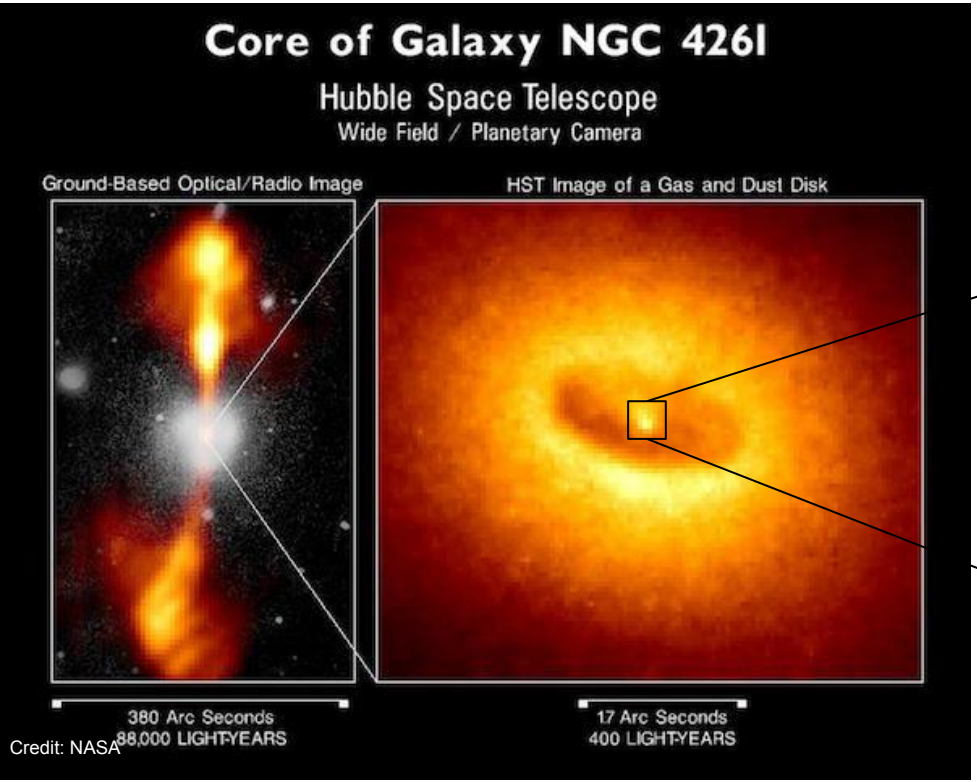
Credit: Tumlinson, J., Peeples, M. S., & Werk, J. K. 2017, ARA&A, 55, 389

Circumgalactic Medium (CGM)

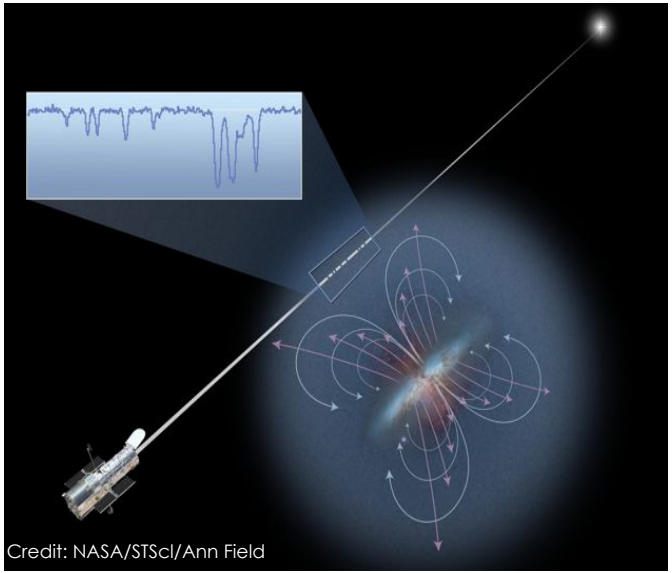


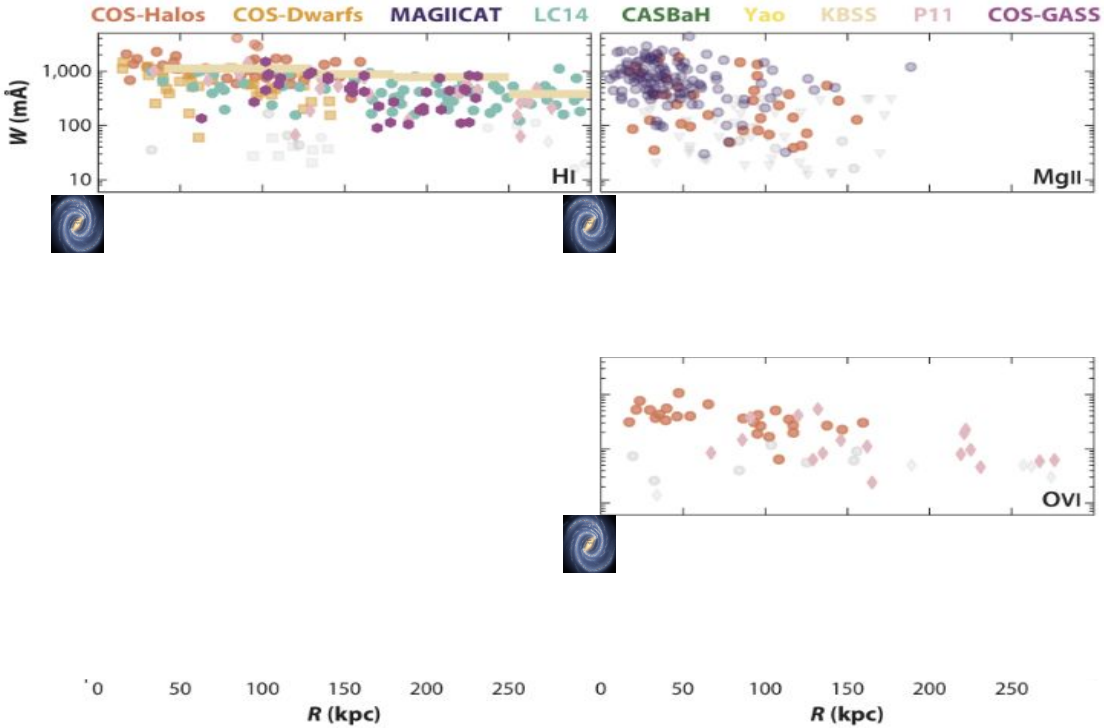
How do we observe the Circumgalactic Medium (CGM)?

Quasars or Active Galactic Nuclei (AGN)!



Halo Surveys

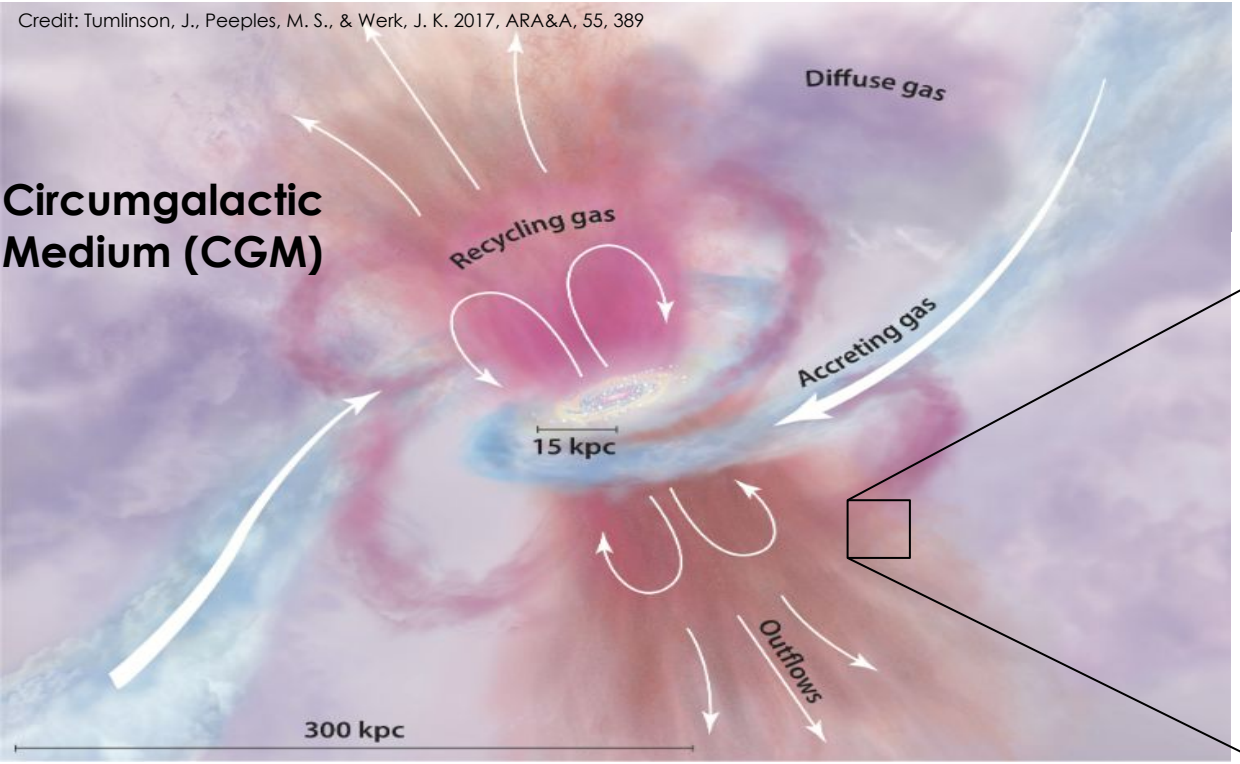




Credit: Tumlinson, J., Peeples, M. S., & Werk, J. K. 2017, ARA&A, 55, 389

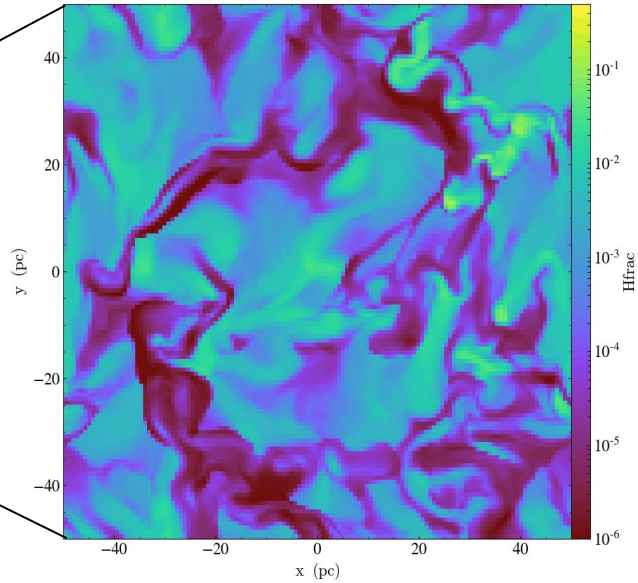
Can turbulence explain observable features of hot halo?

First simulations

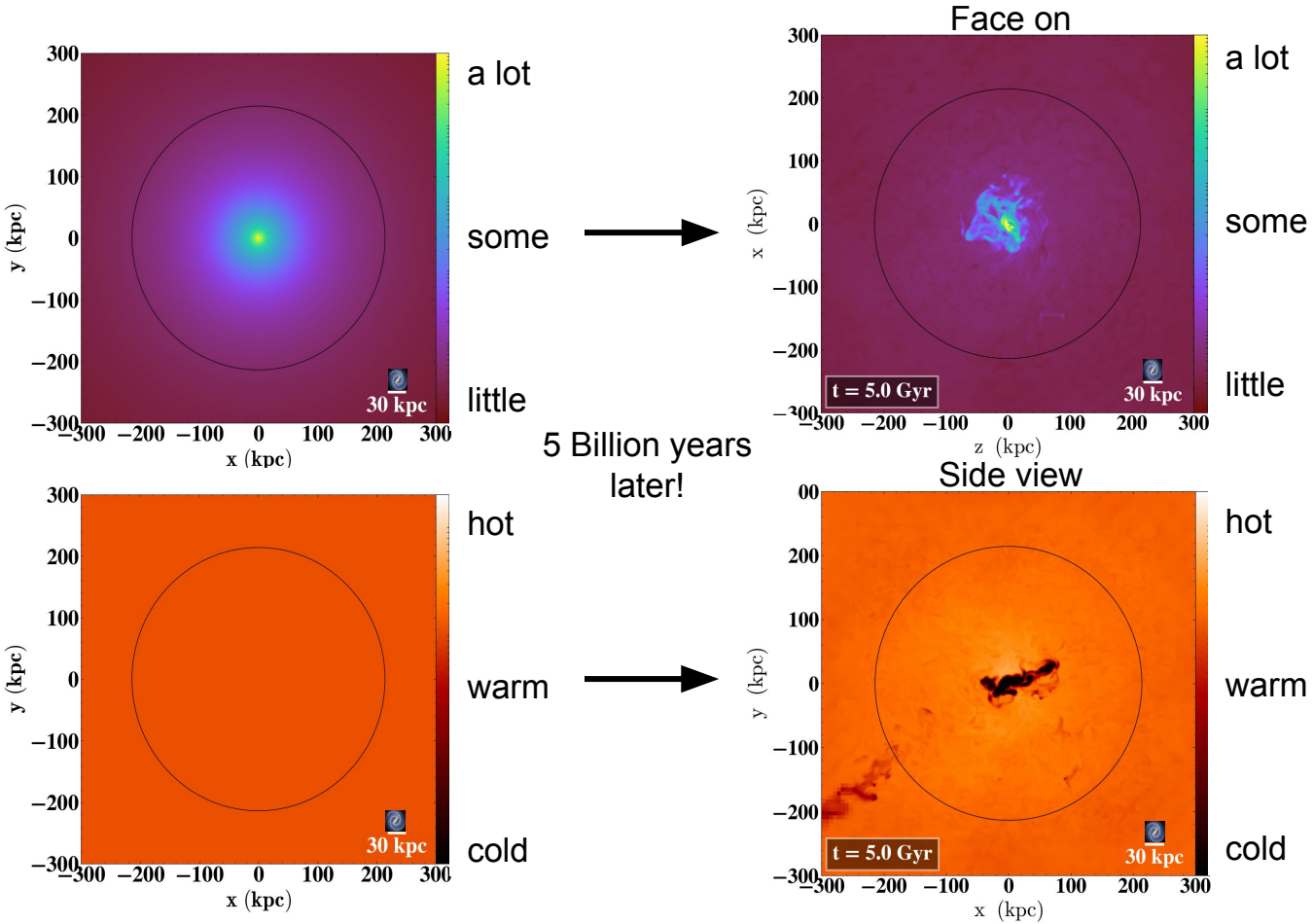


Isotropic stirring + non-equilibrium

Neutral Hydrogen



Halo setup

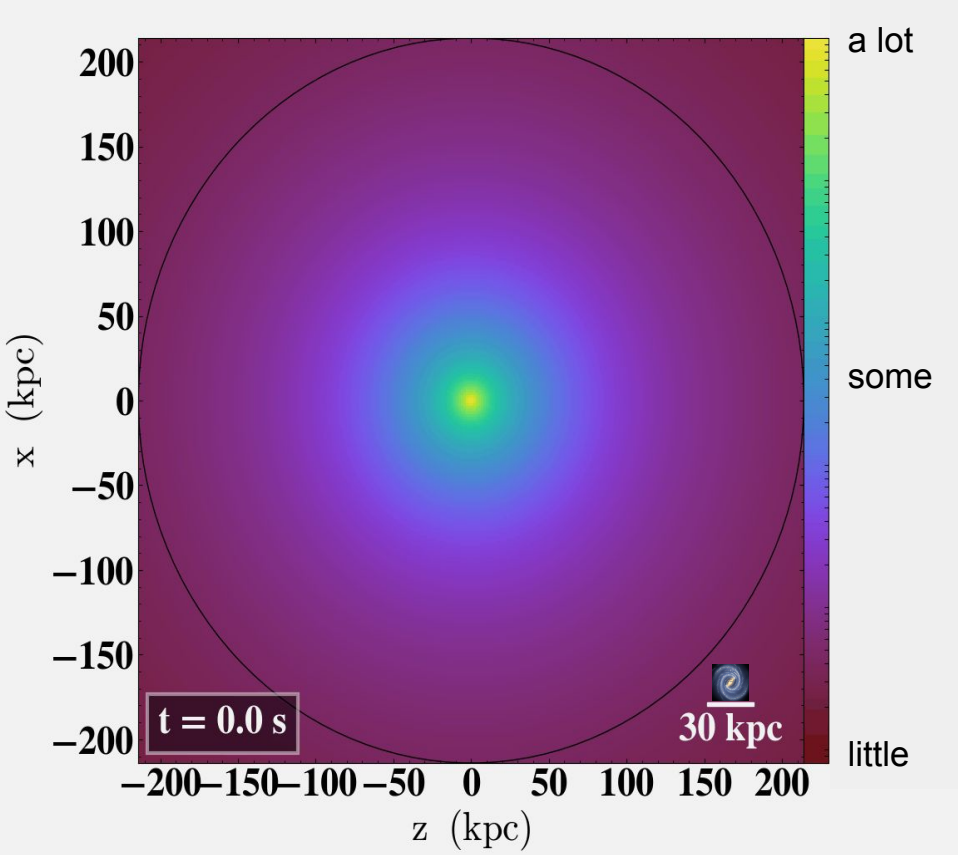


Slices at t = 0 (left) and 3 Gyr (right) along the z-axis showing the number density (top row) and temperature (bottom). A black circle shows the virial radius at r ≈ 220 kpc.

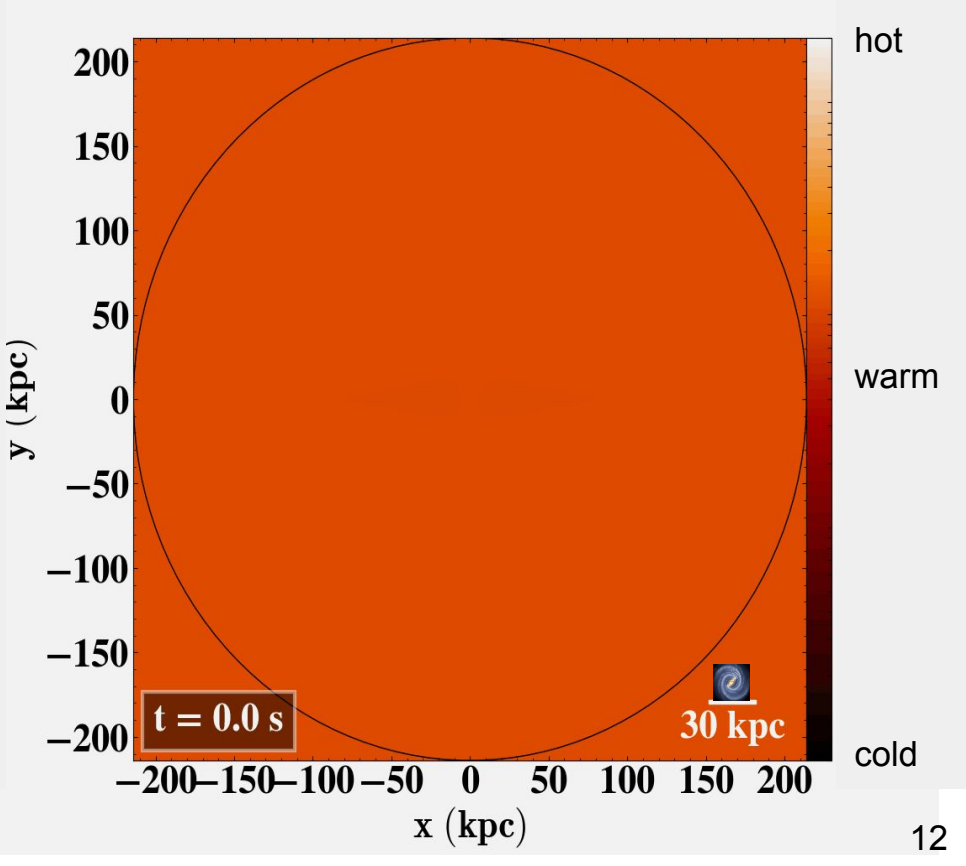
Turbulence sets up a convective flow in the halo. Hot gas moves outward to be replaced by cooler, inflowing material.

Full halo slices

Face-on (density)

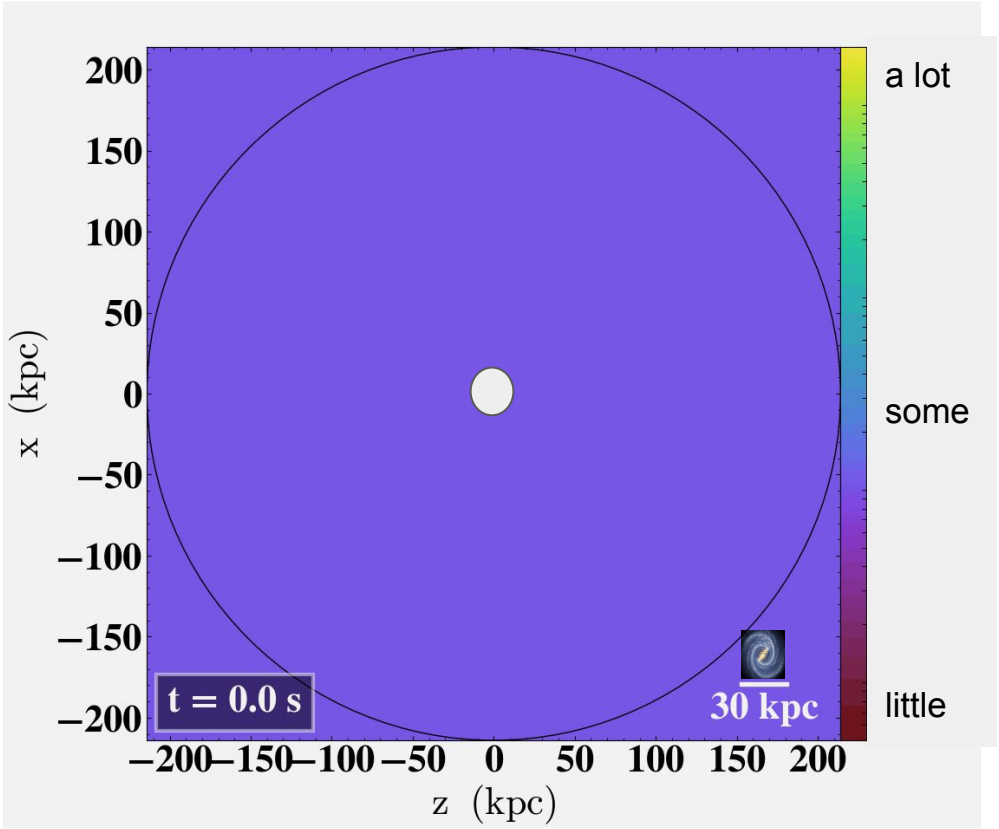


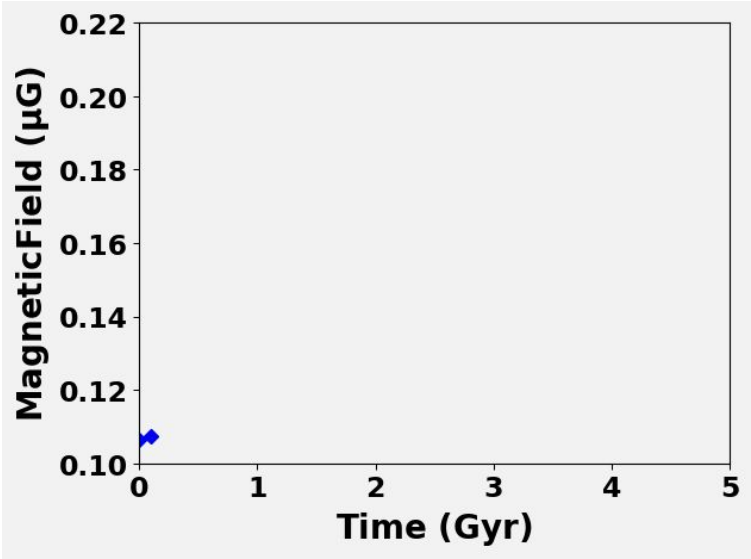
Side-view (temperature)



Magnetic field growth

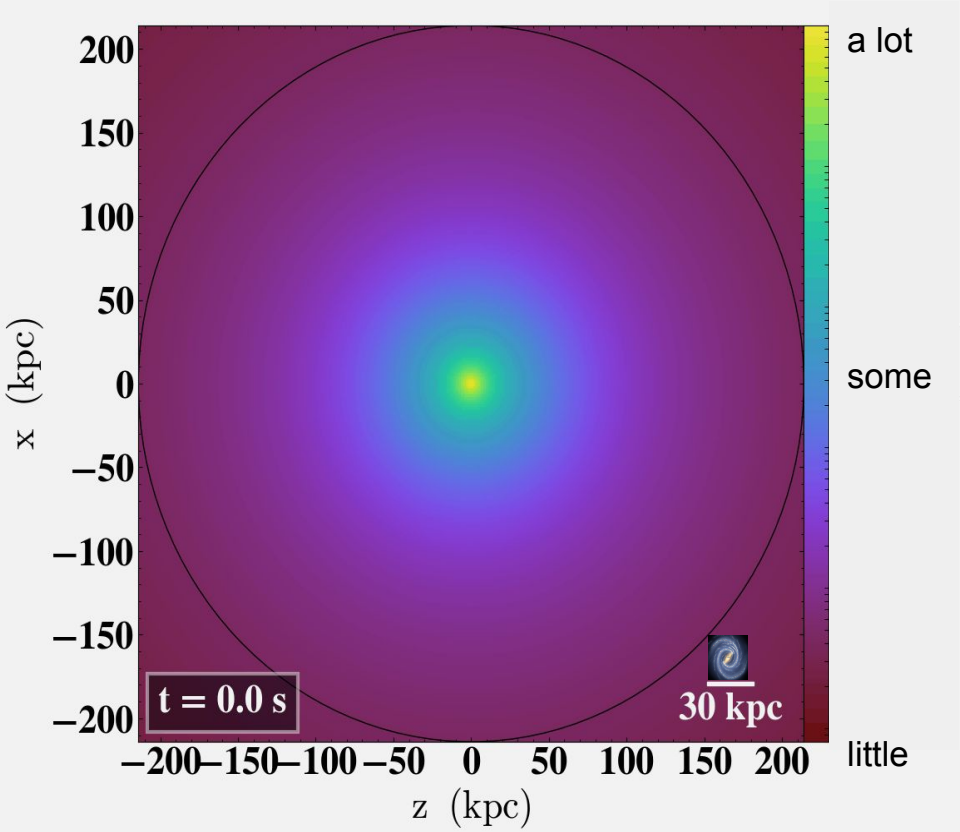
face-on



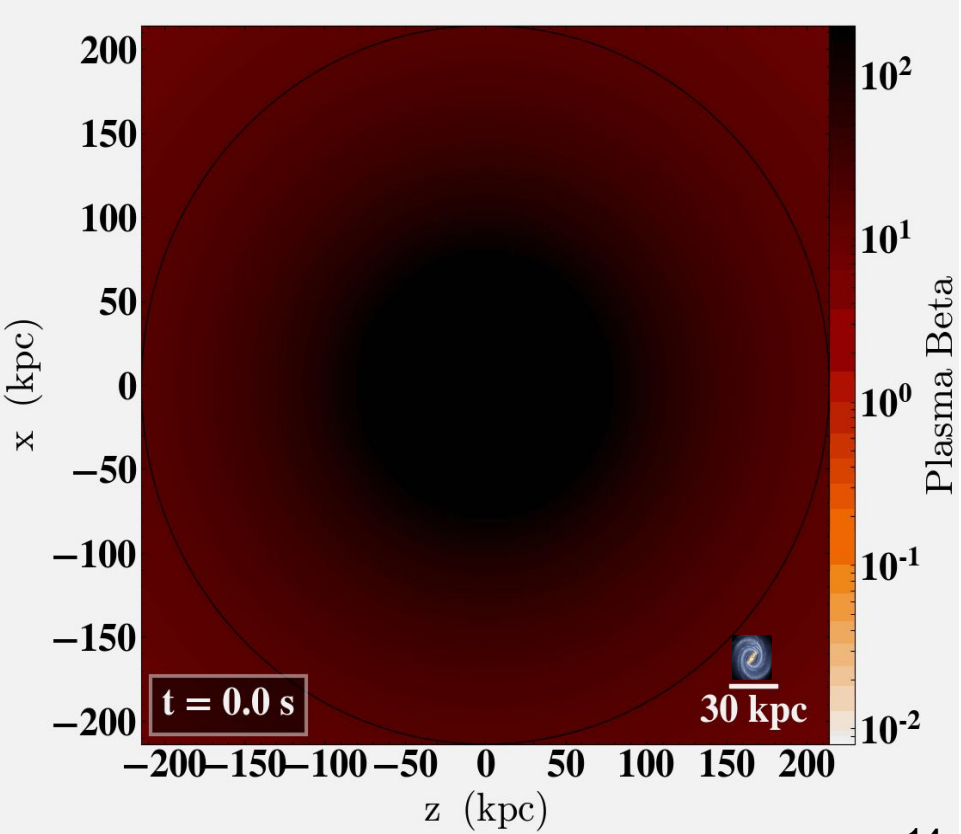


Magnetically supported gas

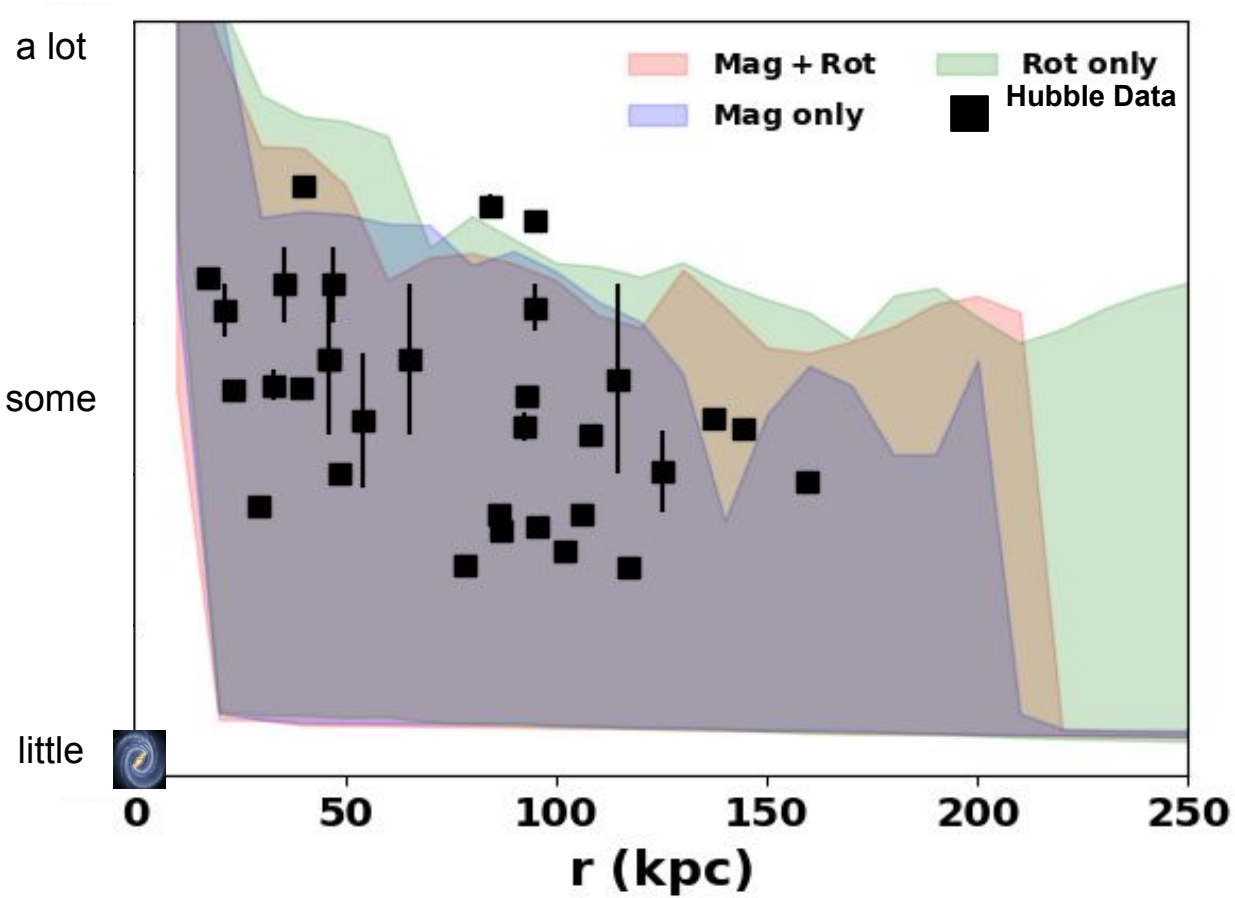
Face-on (density)



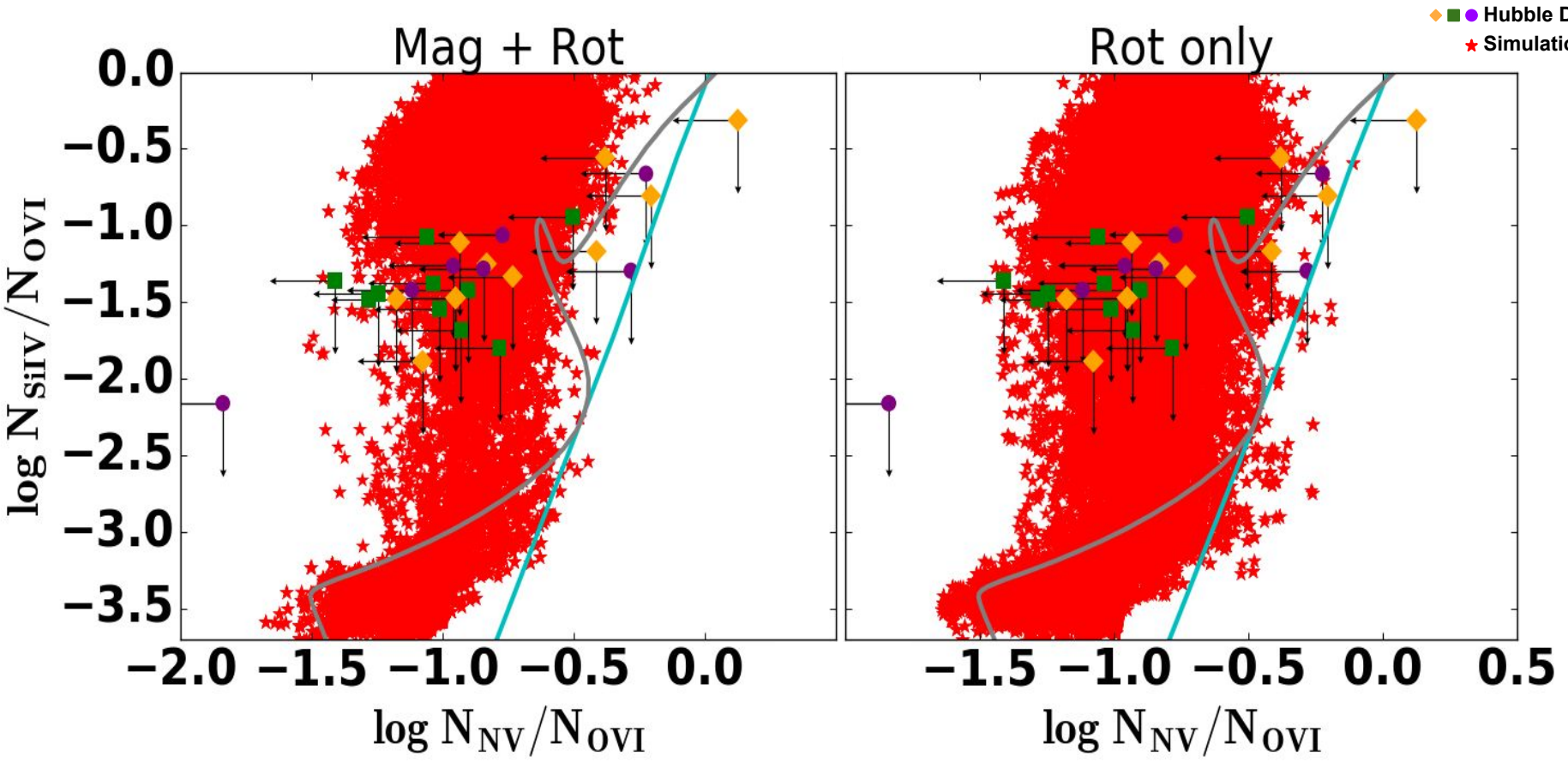
Plasma Beta = thermal pressure/magnetic pressure



How does the neutral Hydrogen (H I) look?



Ion ratios


Hubble Data
Simulation
Mag + Rot
Rot only
log N_{SiIV}/N_{OVI}
log N_{NV}/N_{OVI}
log N_{NV}/N_{OVI}
0.0
−0.5
−1.0
−1.5
−2.0
−2.5
−3.0
−3.5
−2.0 −1.5 −1.0 −0.5 0.0
−1.5 −1.0 −0.5 0.0 0.5

Conclusions

- Galaxies have an “invisible” halo of gas surrounding them called the Circumgalactic Medium.
- This medium is important to the central galaxy evolution.
    - Its where gas is recycled.
    - Gas flows outward and inward.
- Turbulence allows for cycling of hot and cooling gas.
- Magnetic field rises steeply and decreases slowly in the halo over time.
    - May be a consequence of density profile in the halo.
- Extended magnetized co-rotating disk of gas.
- Non-equilibrium chemistry produces neutral hydrogen profile and ion ratios that match Hubble data.