Observational Tracers of Hot and Cold Gas in Isolated Galaxy Simulations

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Simulation vs. Observation: Modeling quasar absorption line studies

- The circumgalactic medium (CGM) is the gas surrounding galaxies outside their disks and inside their virial radii
- Quasars are the centers of active, very luminous galaxies, and their spectra are well-modeled
- Accordingly, quasar absorption line spectra help us determine the gas composition of galaxies spatially coincident on the sky

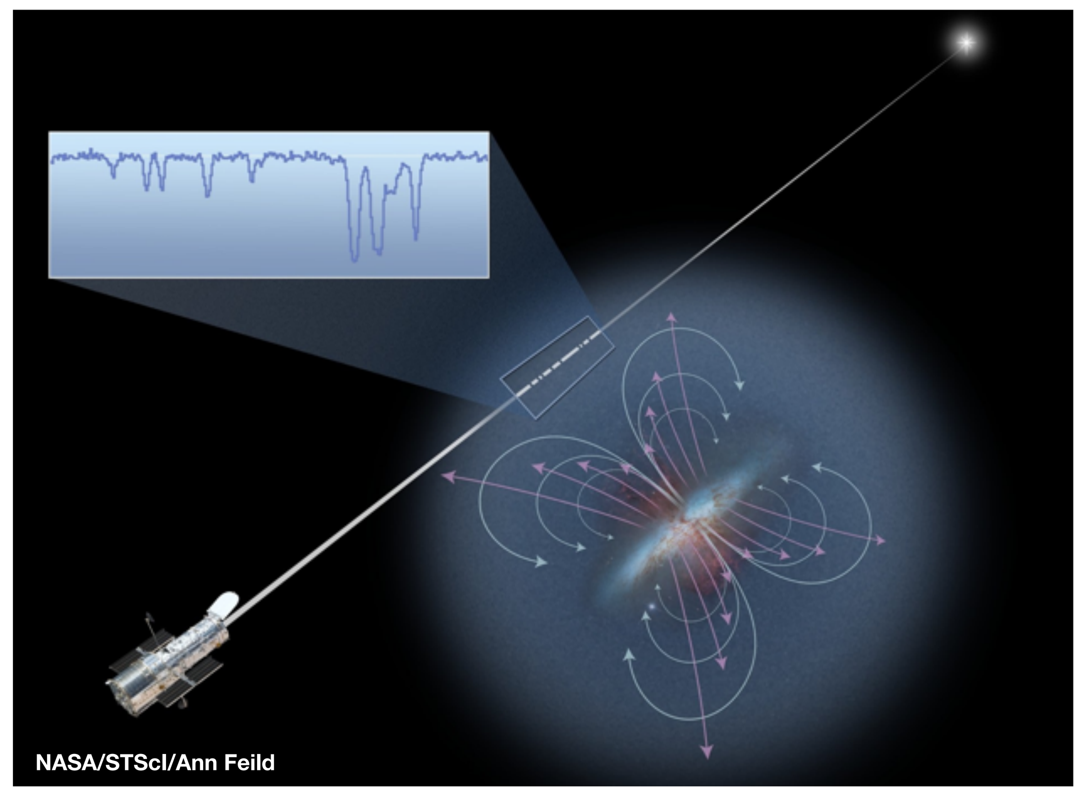

Figure 1. Schematic of quasar absorption line spectra. The sightline between the telescope and the quasar (in the top right) passes through the CGM of a galaxy, which alters the quasar spectra.

- We estimate gas column densities in the CGM from absorption lines in these quasar spectra
- However, quasar sightlines from observations are **essentially random** by nature, and **statistically select for larger impact parameters**
- Using hydrodynamic simulations*, we can simulate the randomness in sightline orientation and directly compare with observations, or analyze the CGM structure at smaller impact parameters

Calculating radial gas column density distributions using synthetic sightlines

- We **generate uniformly random synthetic sightlines** through a simulated galaxy in order to compare with the quasar sightline method
- We bin synthetic sightlines to make radial profiles of column densities (a proxy for equivalent width) for different observable ion species
- To compare with observational sightlines, we select for larger impact parameters by generating more sightlines at higher radial bins

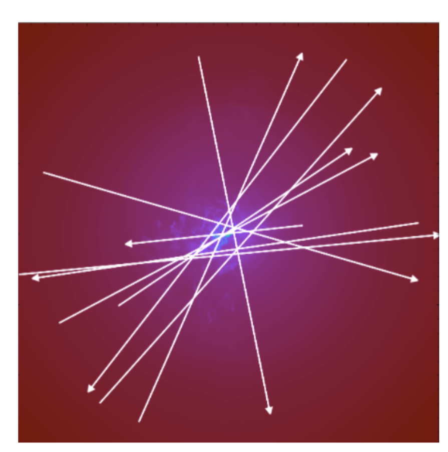

Figure 2. A sample of 10 random sightlines passing through the CGM.

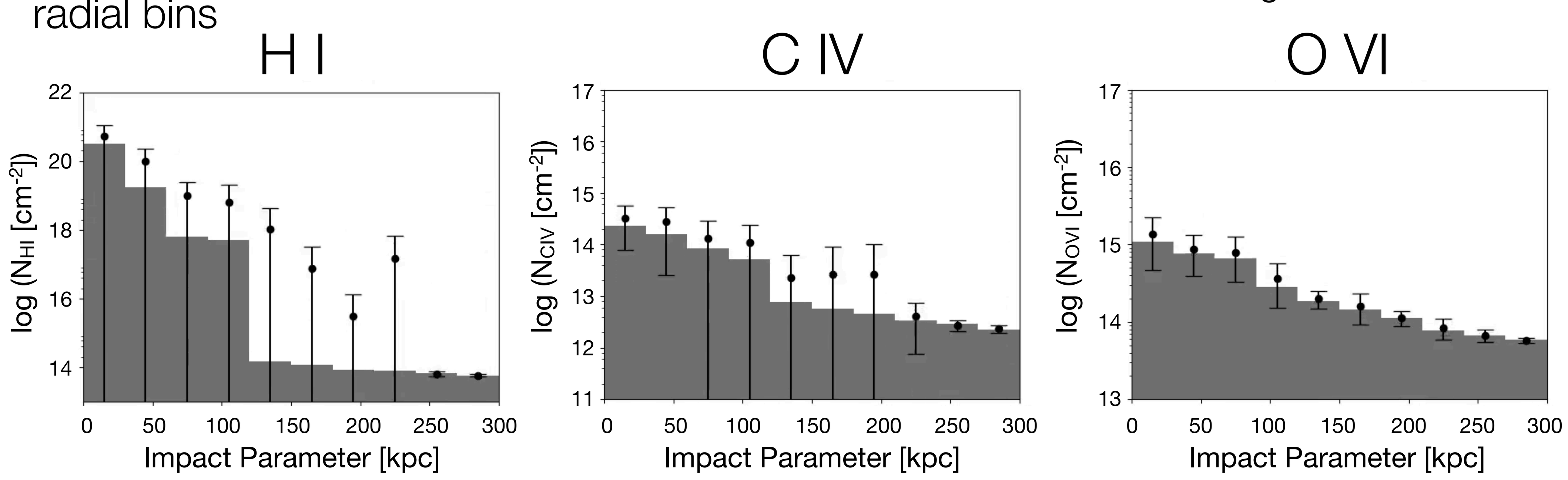

Figure 3. Radial profiles of column densities in H I, C IV, and O VI at 8.0 Gyr into the simulation. Grey bars represent medians, while points represent means (with error bars given by standard deviations), per bin.

- Comparing our radial profiles with observations, **we find that column densities are consistent within ~150 kpc, but find a slight disparity in the fall-off farther out into the CGM, especially in O VI**
- Generally, we find an **order-of-magnitude agreement in H I and C IV.** However, for O VI, while we find an order-of-magnitude agreement near the disk, our simulations yield **too quick of a fall-off farther out in the CGM.**

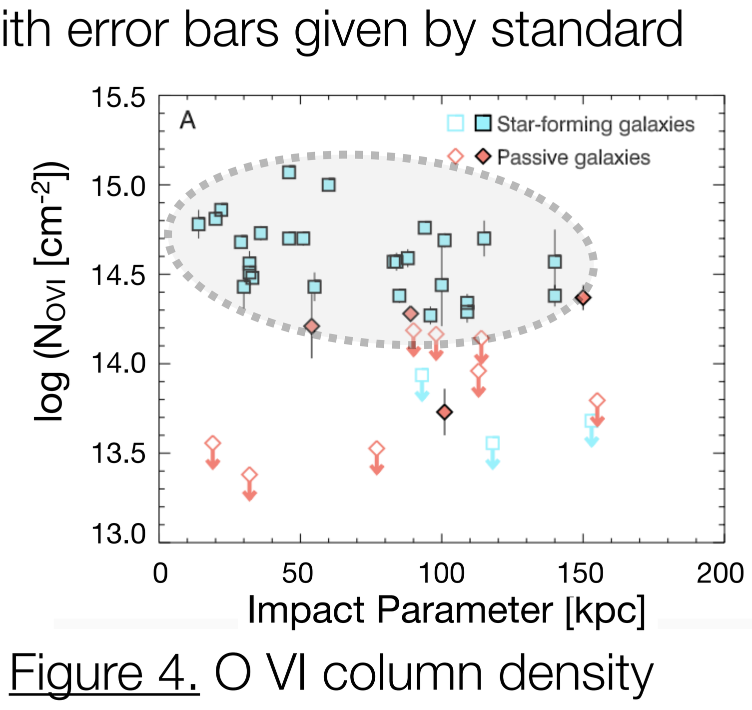

Figure 4. O VI column density detections as a function of impact parameter (Tumlinson et al. 2011).

An anomaly? Stable precipitating gas in the CGM

- In one of our simulations, we **observe hot gas cooling and condensing, or precipitating, in a stable manner**
- Begins about 5.0 Gyr into the simulation and remains in this state until 11.4 Gyr, the final timestep of our simulation data

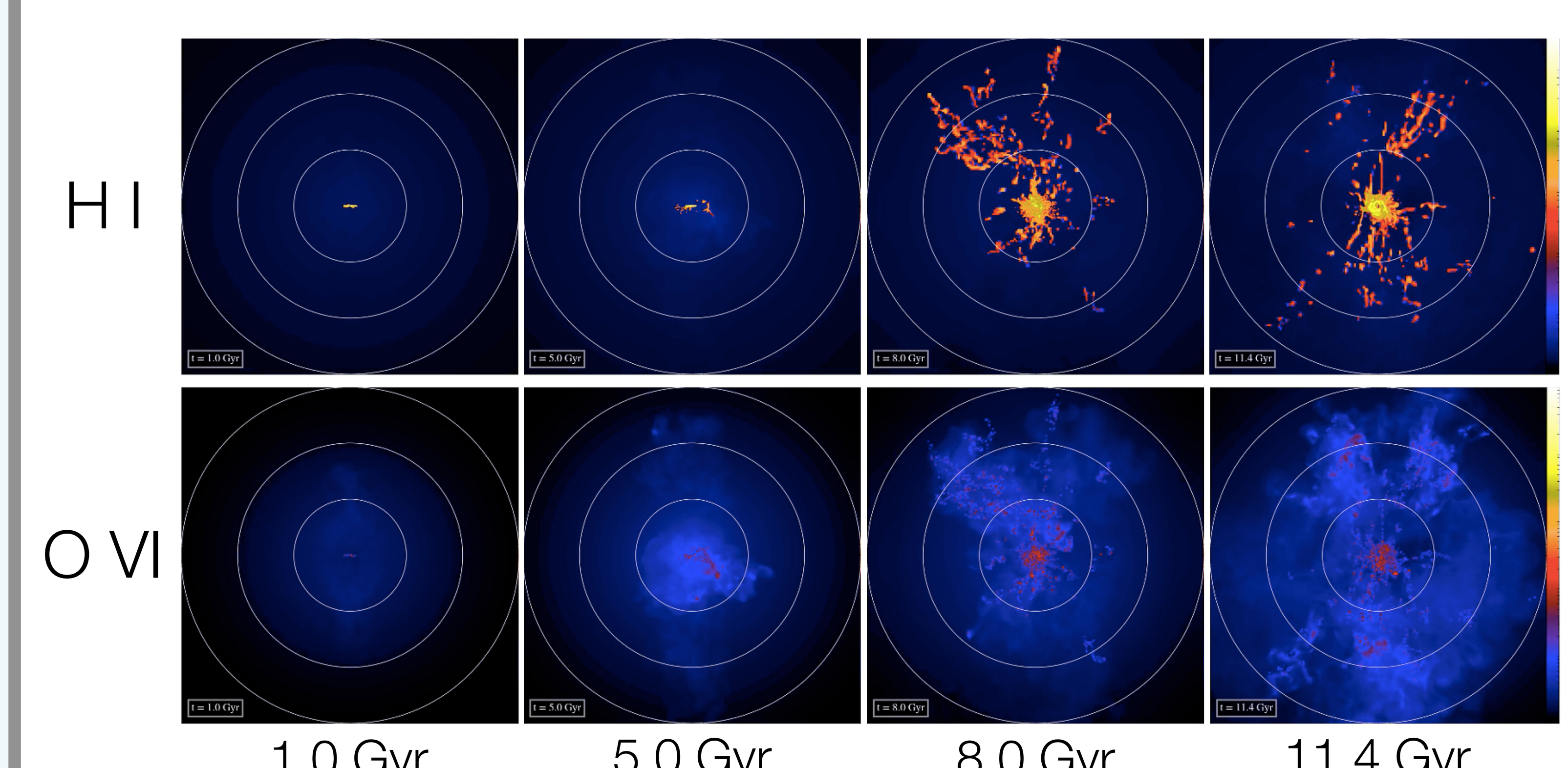

Figure 5. Evolution of H I and O VI column density from 1.0 to 11.4 Gyr. Edge-on view of spiral galaxy, with annuli of radii 100, 200, and 300 kpc. The logarithmic colorbar ranges from 10^{13}–10^{24} cm^{-2} for H I and 10^{13}–10^{18} cm^{-2} for O VI.

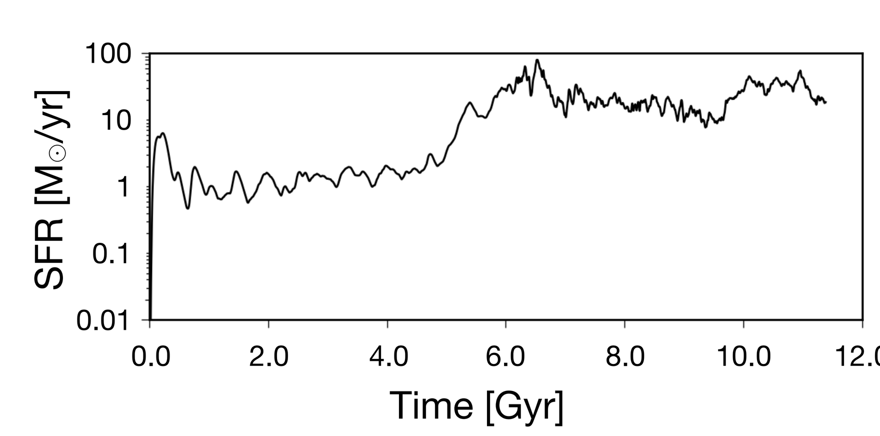

Figure 6. Star formation rate (SFR) over time. Sustained precipitation leads to increased star formation rates, about 10^2 M$_\odot$/yr.

- As these SFRs are unphysical **for low-redshift galaxies**, the **initial quantity of gas in the CGM was likely too high**
- However, **high-redshift galaxies can have higher CGM gas masses, so this kind of precipitation may not be unusual for such galaxies!**

*Used Enzo to produce isolated galaxy simulations. A goal is to see if we can generate stable spiral galaxies, such as our Milky Way, without using AGN feedback.

References:

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Liang, C. & Chen, H. 2014, MNRAS
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Acknowledgments:

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