# Detectability of cold streams into high-z galaxies in absorption



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### Outline

- Metal line observations
- The AMR simulations
- Central geometry
- Computing line profiles
- Comparisons to observations
- Background geometry

#### Steidel et al. 2010:

- Observes "Circum Galactic Medium"
- Absorption line profiles
- Central geometry / background geometry
- Stacks more than 100 spectra
- Detects massive outflows
- But: no sign of inflows
- Claim: Proof of absence of cold streams

#### The AMR simulations

- Ceverino, Dekel & Bournaud
  - Art by Andrey Kravtsov
  - UV background, Haardt & Madau 1996
  - mimics self-shielding
  - Gas can cool down to 100K
  - 3 re-simulated galaxies
  - High resolution (70 pc physical)

#### **Central geometry**

 Observes central galaxy through its own circum galactic medium



### Sky covering fraction

- Very low sky covering fraction
- Low metallicity in streams



### **Computing line profiles**

#### Doppler broadening

$$b = \sqrt{\frac{2 k T}{m_{\rm Y}}},$$

Optical depth т

$$\begin{aligned} \tau_{\nu}(\phi, \theta, \Delta w) &= \frac{\sqrt{\pi} \ e^2 \ f_{\lambda} \ \lambda_0}{m_{\rm e} \ c} \int_{\rm r_i}^{R_{\rm v}} \frac{n_{\rm Y}(\vec{r}) \ X_{\rm XX}(\vec{r})}{b(\vec{r})} \\ &\times H\left[\frac{\gamma_{\lambda} \ \lambda_0}{4 \ \pi \ b(\vec{r})} \ , \frac{\Delta w - v(\vec{r})}{b(\vec{r})}\right] \ dr, \end{aligned}$$

• Intensity  $I(\Delta w) = exp(-\tau)$ 

#### **Example line profiles**

#### Lyα

- Gaussian point spread function with 4kpc beam-size applied
- Velocity resolution degraded to 50 km s<sup>-1</sup>
- Observer convention: inflow positive (right)



#### Stacked line profile:

 Averaging over all available example line profiles (3 galaxies, all directions)



## Stacking?

- Stacking washes out the cold filament absorption signal
- Cold filament absorption signal might still be visible in non stacked data

#### **Statistics**

 Mg II: inflow > 150 km s<sup>-1</sup> with an EW > 0.2 Å in 1.3 % of all observations



## **Background geometry**

- Observes background galaxy through circum galactic medium of galaxy in question
- Additional parameter: Impact parameter b



## Column density vs impact parameter

- All lines decreasing
- Ly alpha considerably higher than metals



#### Stacked line profile

 Averaging over all available example line profiles (3 galaxies, 6 principal directions, all points in radiusrange)



#### Summary

- Observational features from cold streams
  extremely difficult to detect.
- Outflows are dominant.
- No falsification done.



#### Equivalent width

$$EW = \frac{\lambda^2}{c} \int_0^\infty \left[1 - \exp(-\tau_\nu)\right] \,\mathrm{d}\nu = \frac{\lambda^2}{c} \int_0^\infty g(\nu) \,\mathrm{d}\nu,$$



#### covering fraction vs impact parameter vs column density



## Equivalent width

