

Tracing the Circumgalactic Medium with the Cosmic Origins Spectrograph

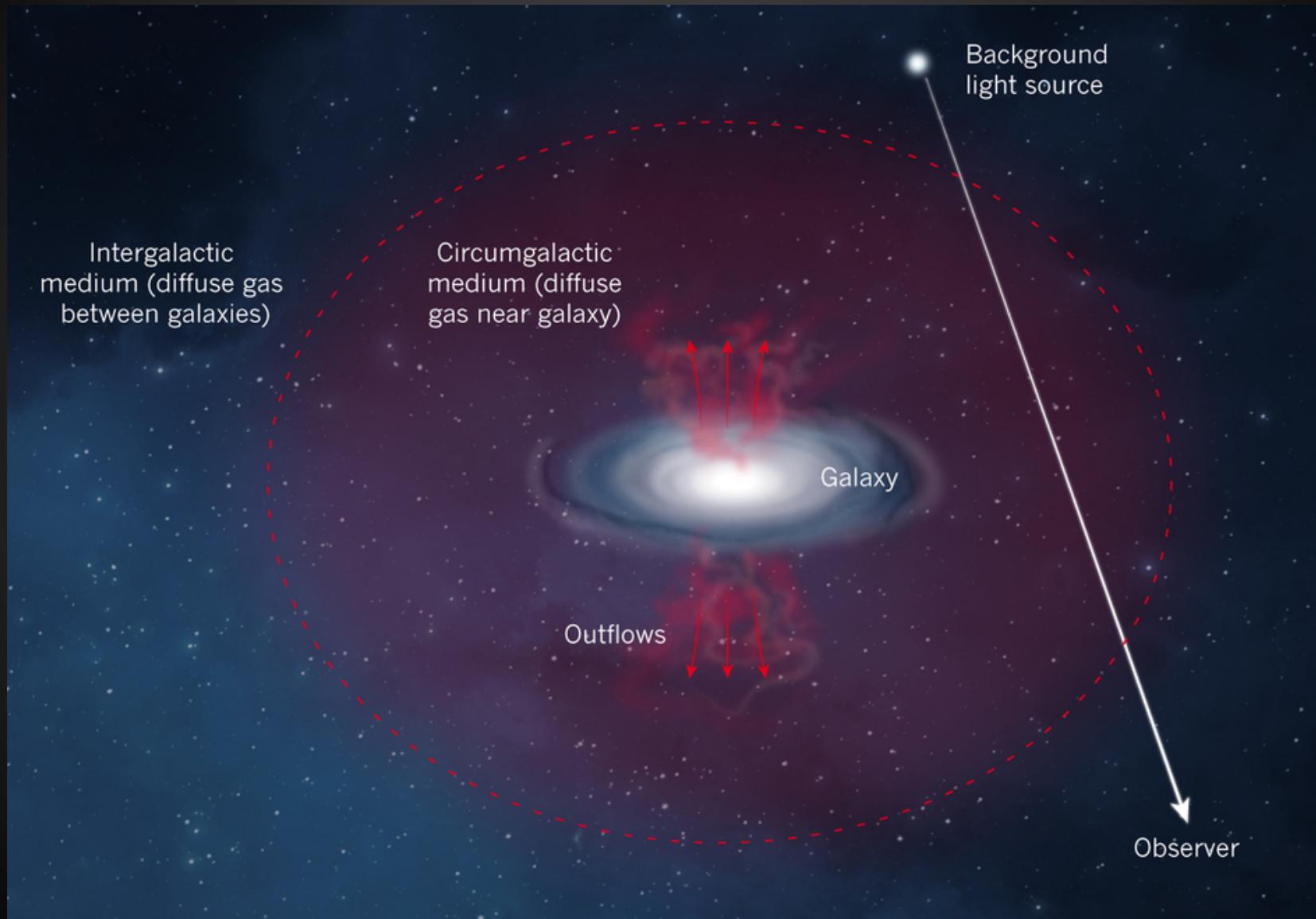
David M. French

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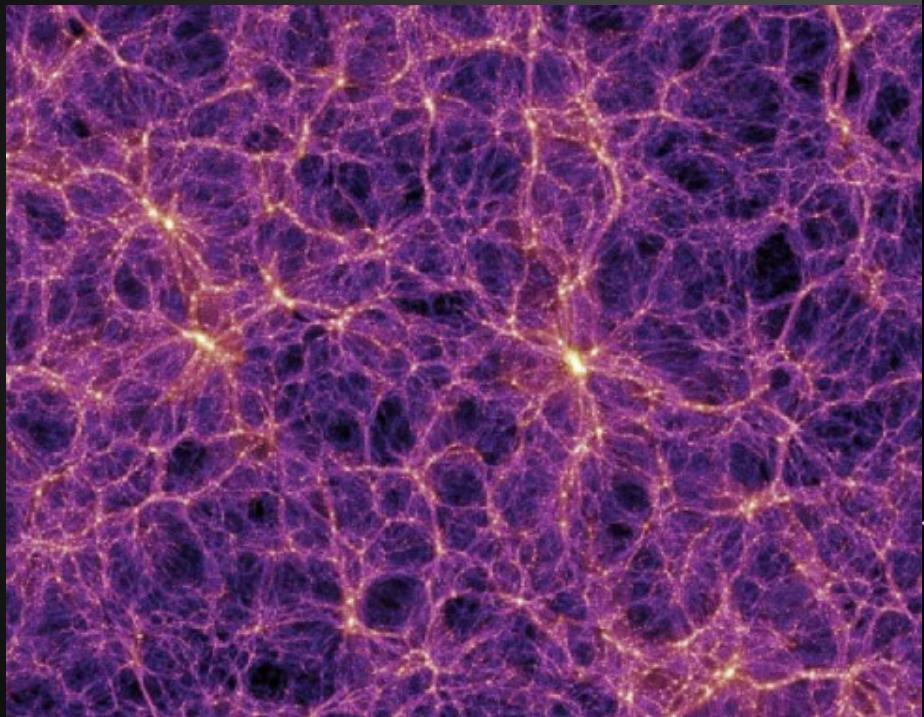
University of Wisconsin - Madison

April 25, 2016

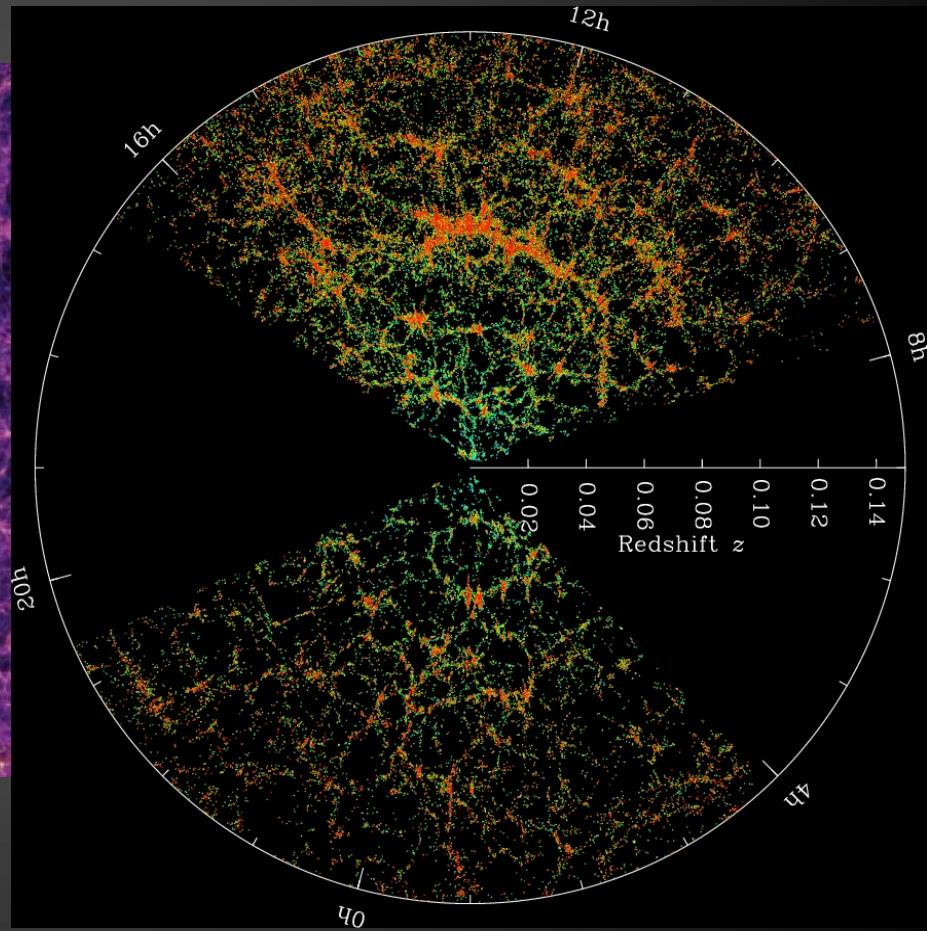
Defining the CGM



Gas in the Universe



The Millenium Simulation



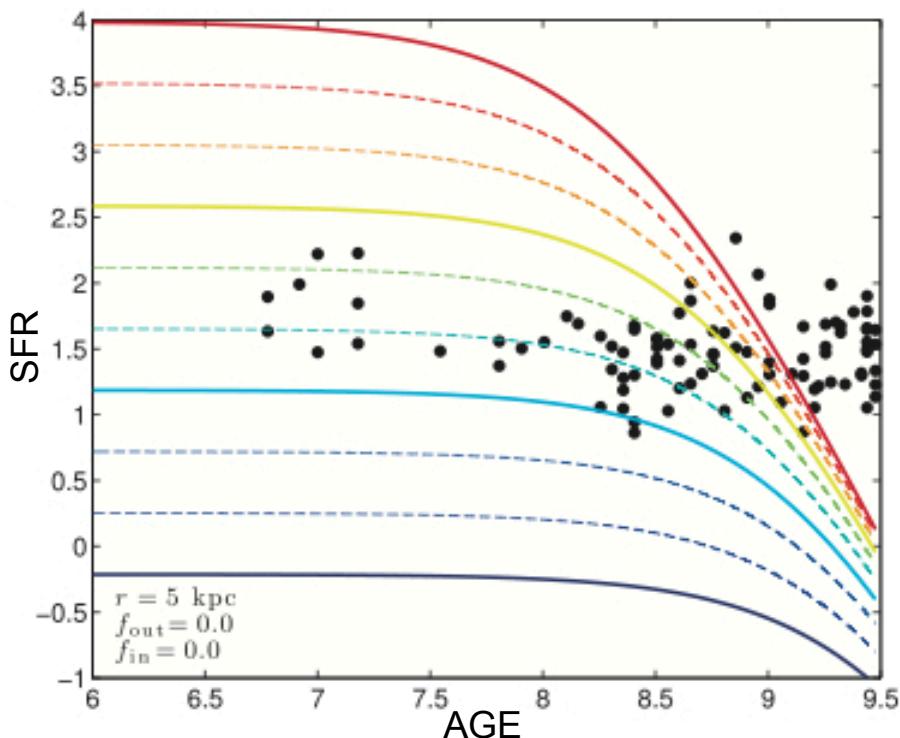
SDSS Collaboration

The gas nearby galaxies

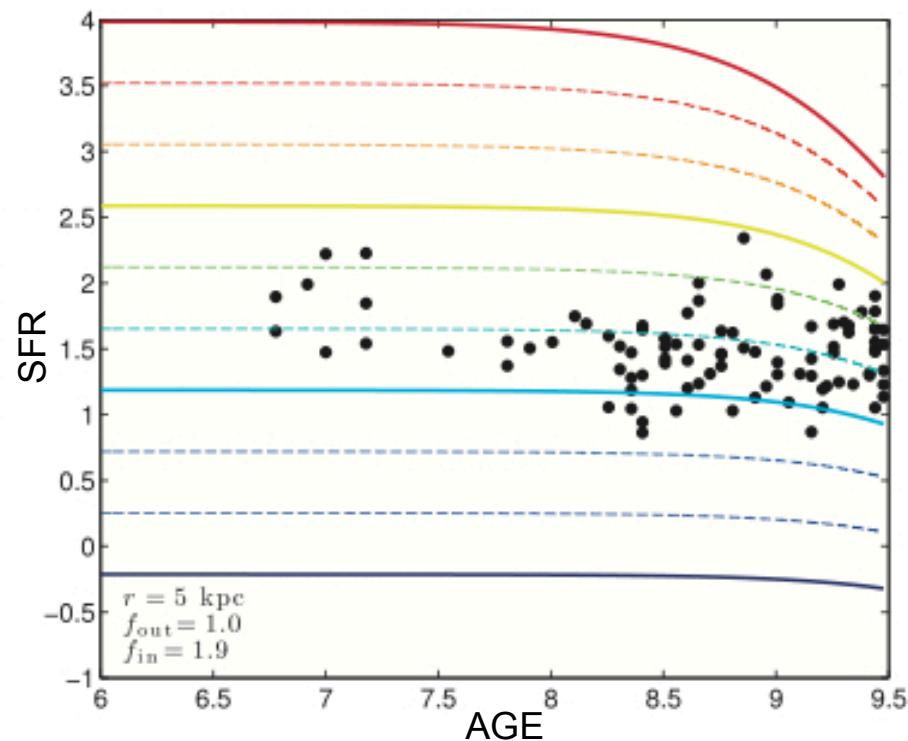
- Gas and galaxies both follow DM potential
- Do they “know” about each other?

Accretion required

With no accretion

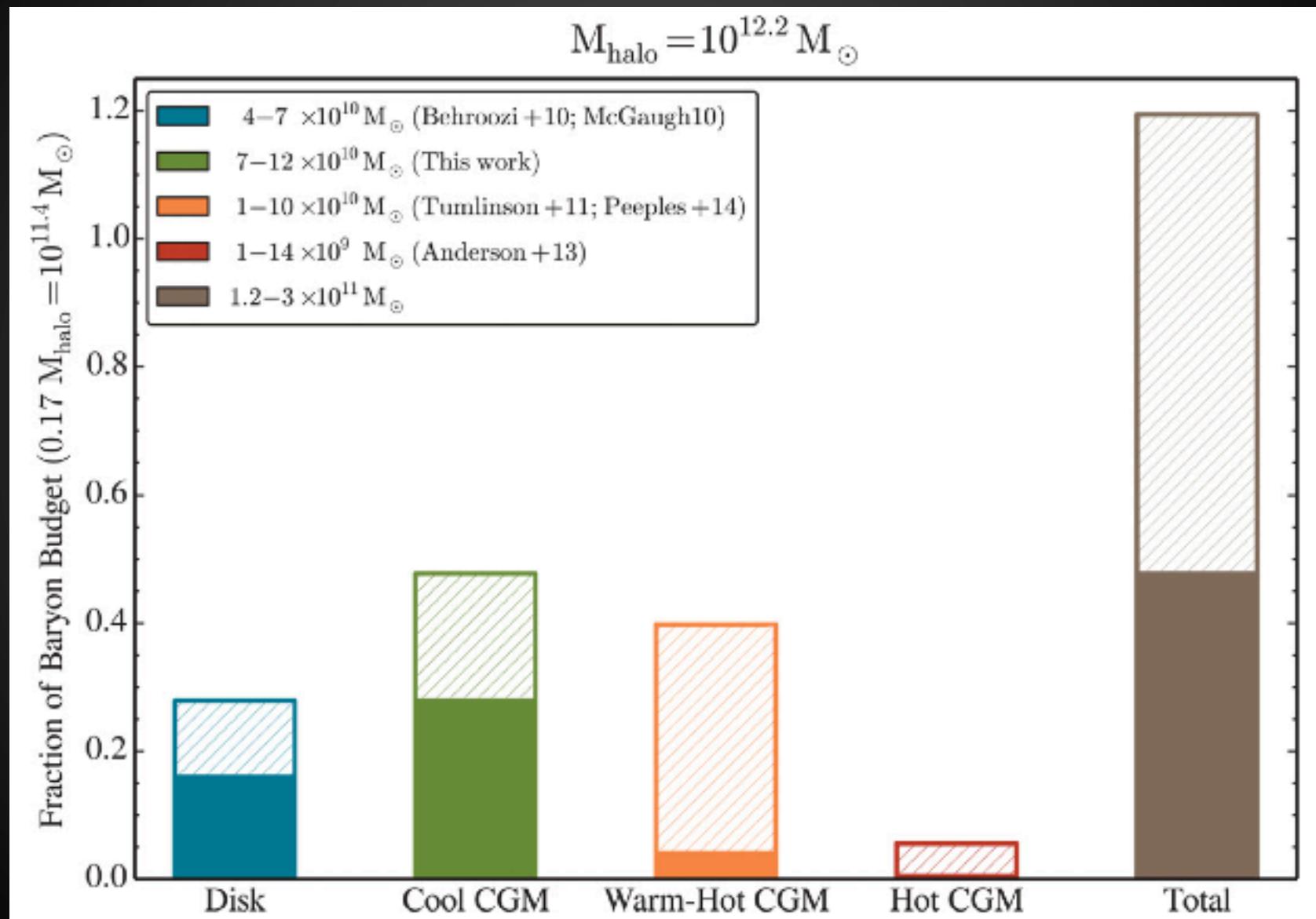


With accretion



Erb 2008

Baryon Budget



Understanding the CGM

- Galaxies need to continue accreting gas over cosmic time to match observations



- Feedback kicks gas out of galaxies

Understanding the CGM

- Galaxies need to continue accreting gas over cosmic time to match observations



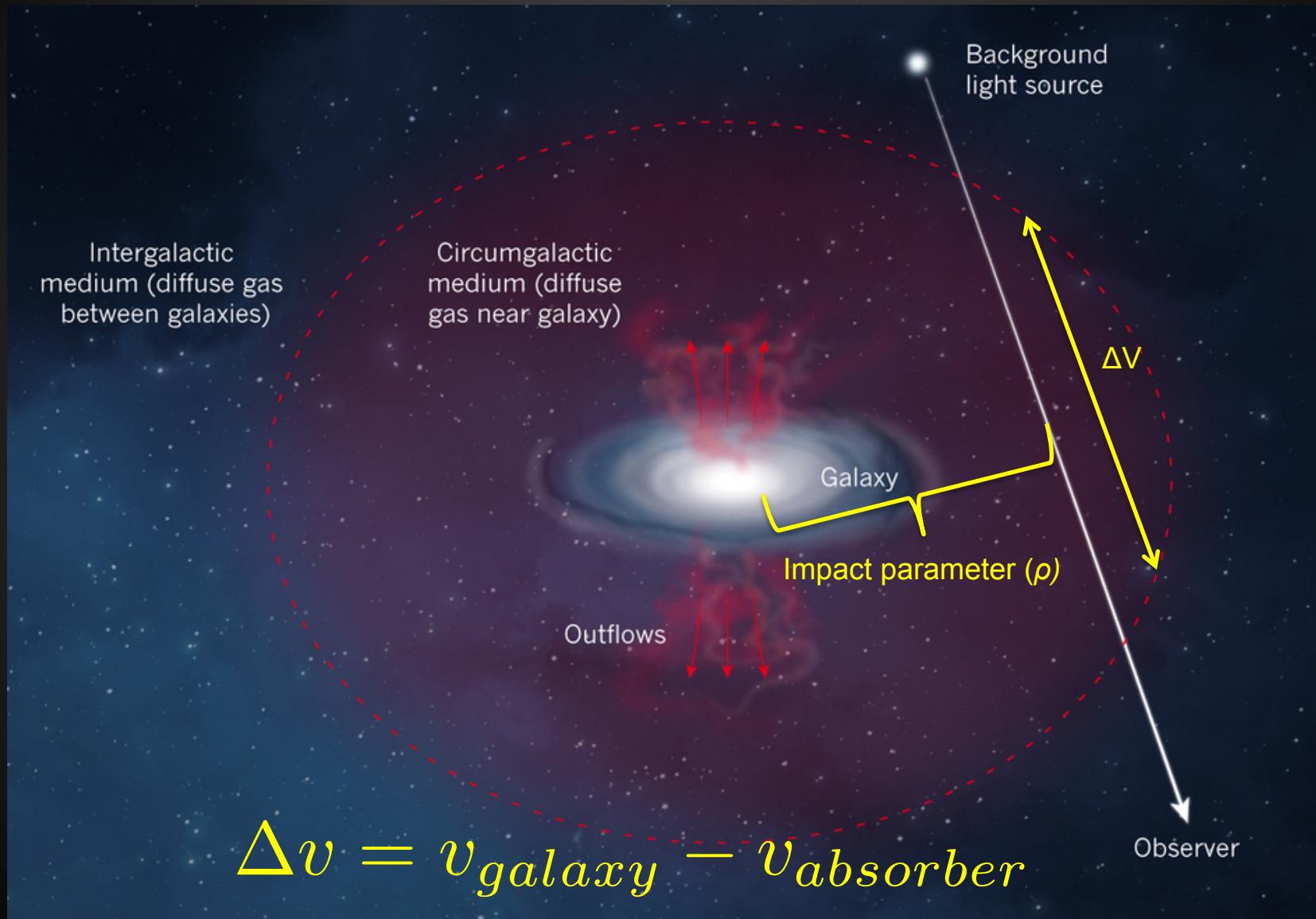
- Feedback kicks gas out of galaxies

★ How do the properties of gas correlate with associated galaxy properties?

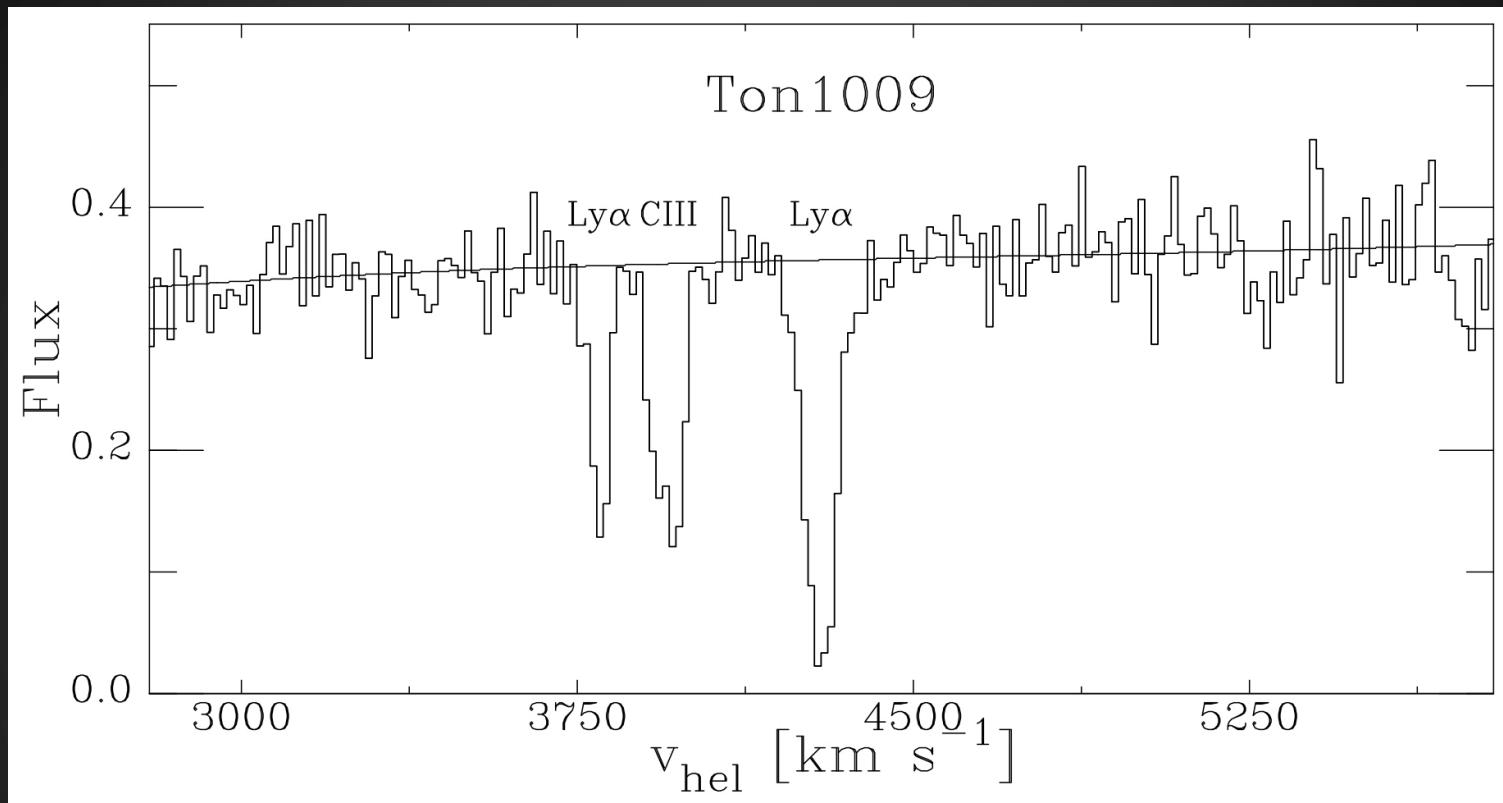
Science Outline

- *Use archival COS sightlines (~ 300)*
- *Stay close ($cz < 10,000$ km/s)*
 - *Available galaxy data complete to $\sim 0.1 L^*$*
- *Automate associating galaxies – absorbers*
- *Ask: (absorber velocity, EW, frequency)
as a function of
(Galaxy size, inclination, position)*

Defining the CGM



Associating galaxies with absorbers



Is this Ly α absorber associated with a galaxy?

Associating galaxies with absorbers

- Define a likelihood:

$$\mathcal{L} = e^{-\left(\frac{\rho}{R_{vir}}\right)^2} e^{-\left(\frac{\Delta v}{200}\right)^2}$$

- ρ = impact parameter
- $\Delta v = v_{galaxy} - v_{absorber}$
- R_{vir} = viral radius of the galaxy
- Require $\mathcal{L}_1 \geq 5 * \mathcal{L}_2$ and $\mathcal{L} \geq 0.001$

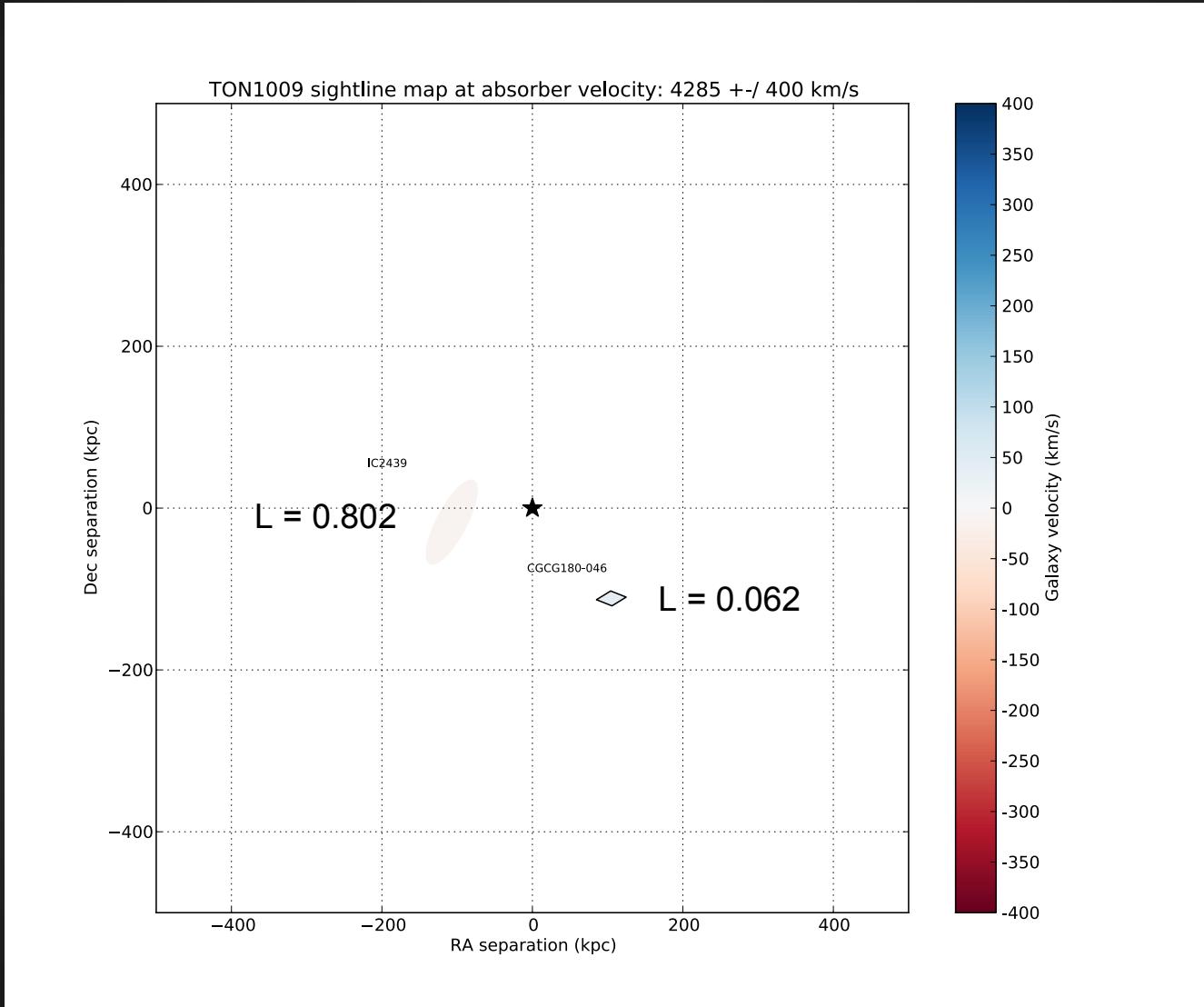
Associating galaxies with absorbers

- Define a likelihood:

$$\mathcal{L} = e^{-\left(\frac{\rho}{R_{vir}}\right)^2} e^{-\left(\frac{\Delta v}{200}\right)^2}$$

$$\mathcal{L} = 0.27 \text{ for } \Delta v = 200 \text{ km/s}, \rho = 1 R_{vir}$$

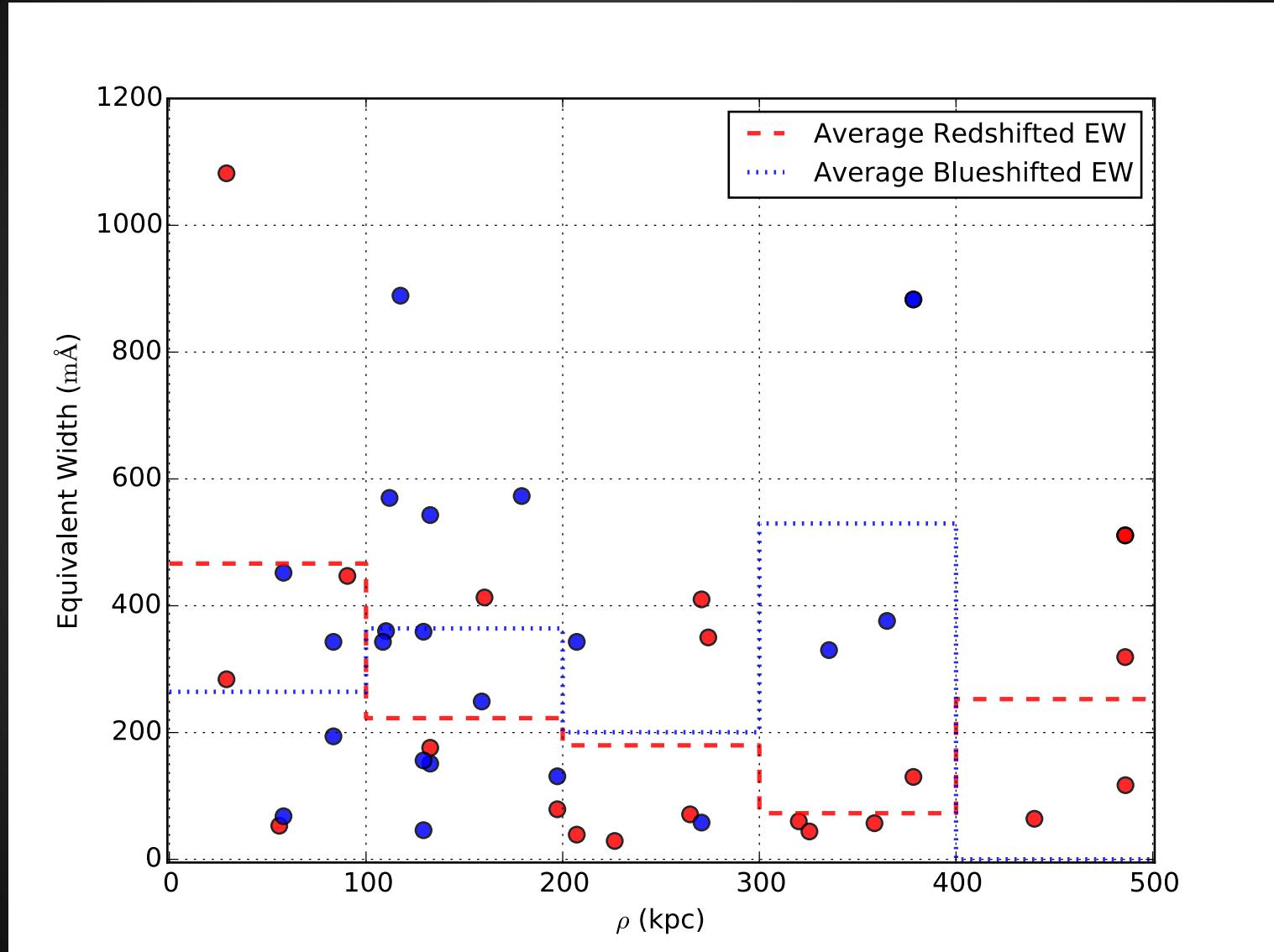
Associating galaxies with absorbers



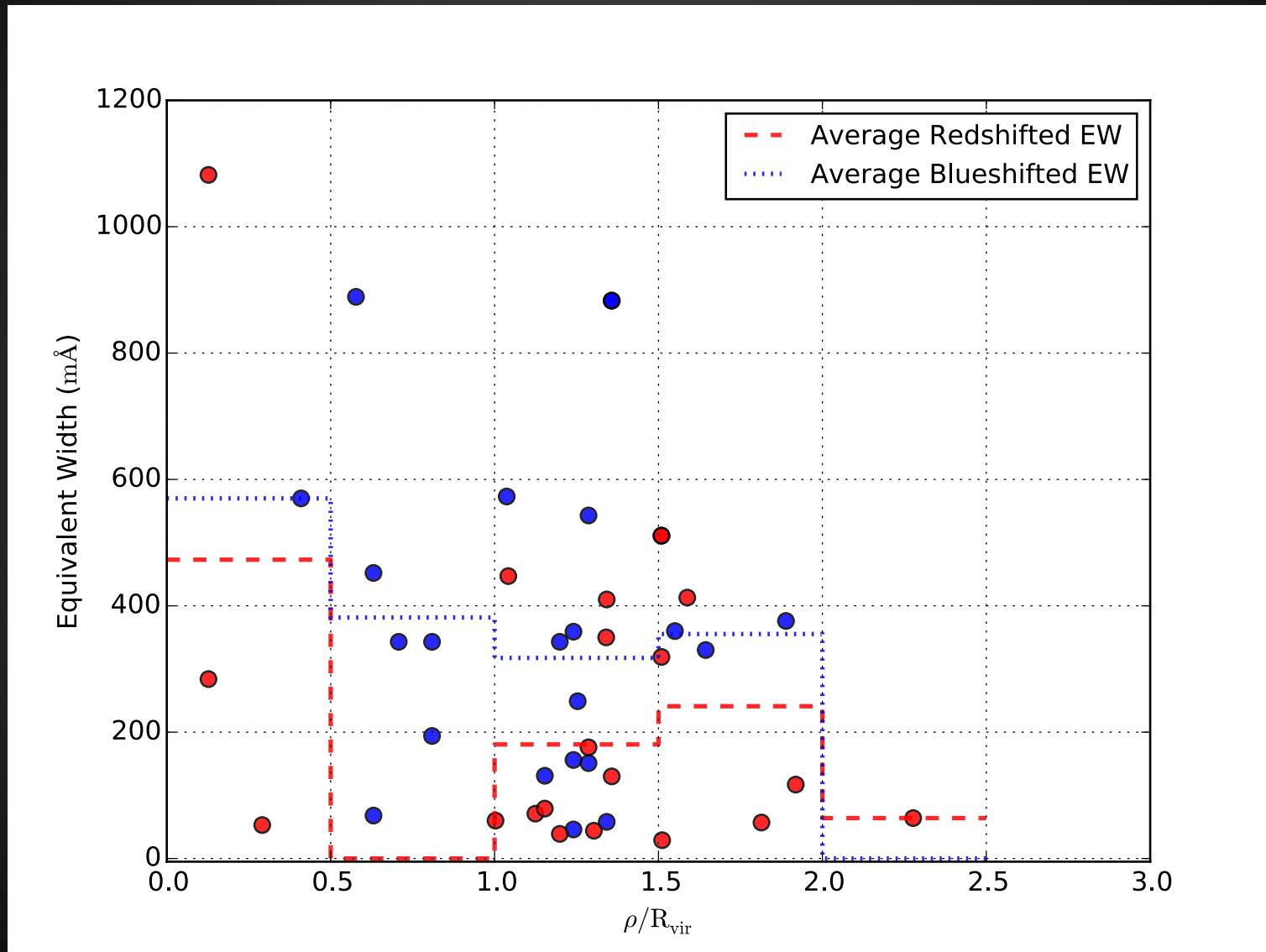
Results so far...

- 35 COS sightlines analyzed
- 175 Ly α lines
 - 41 associated
 - 44 ambiguous (no best match)
 - 88 IGM (no galaxies nearby)

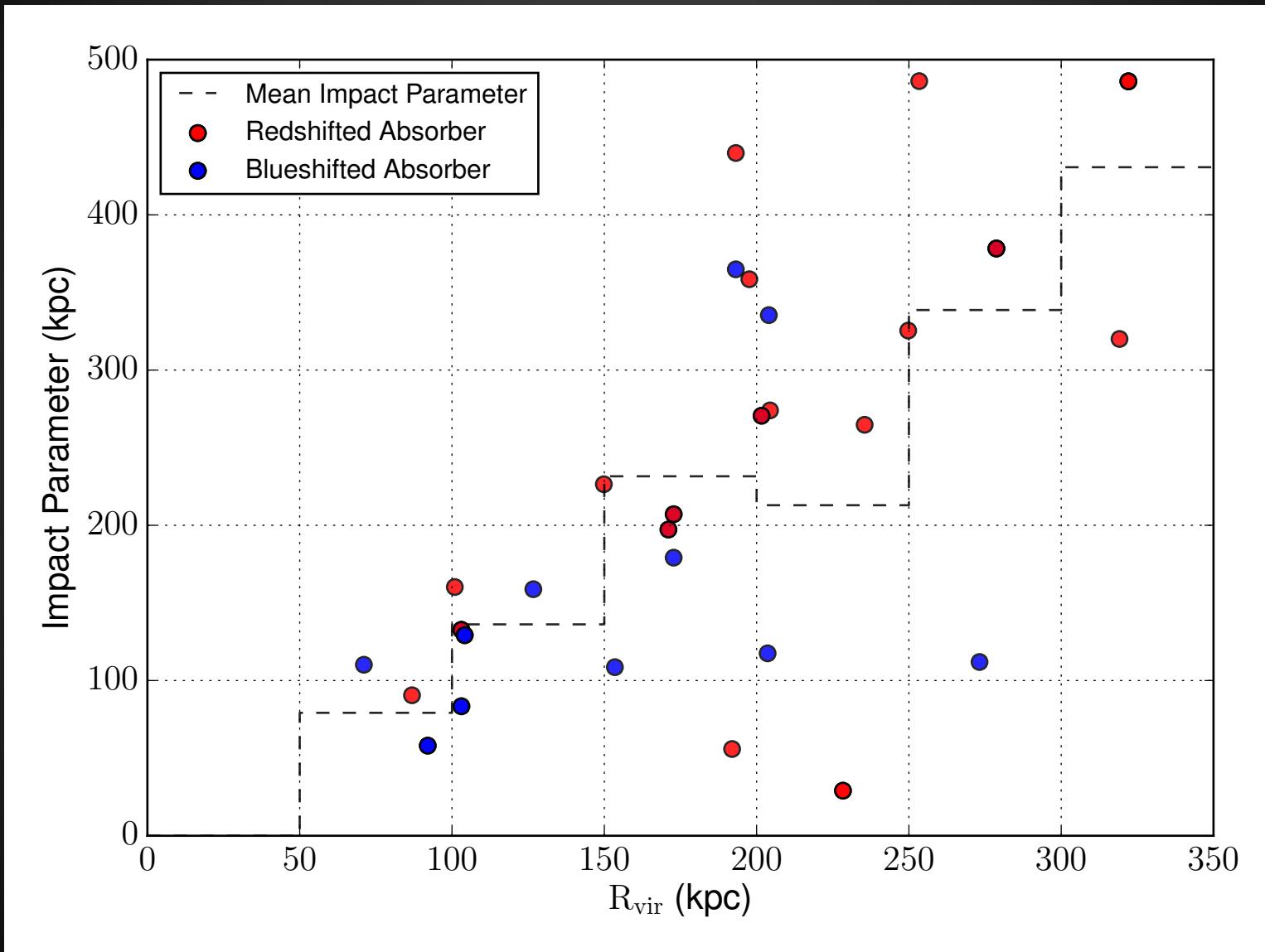
Impact parameter



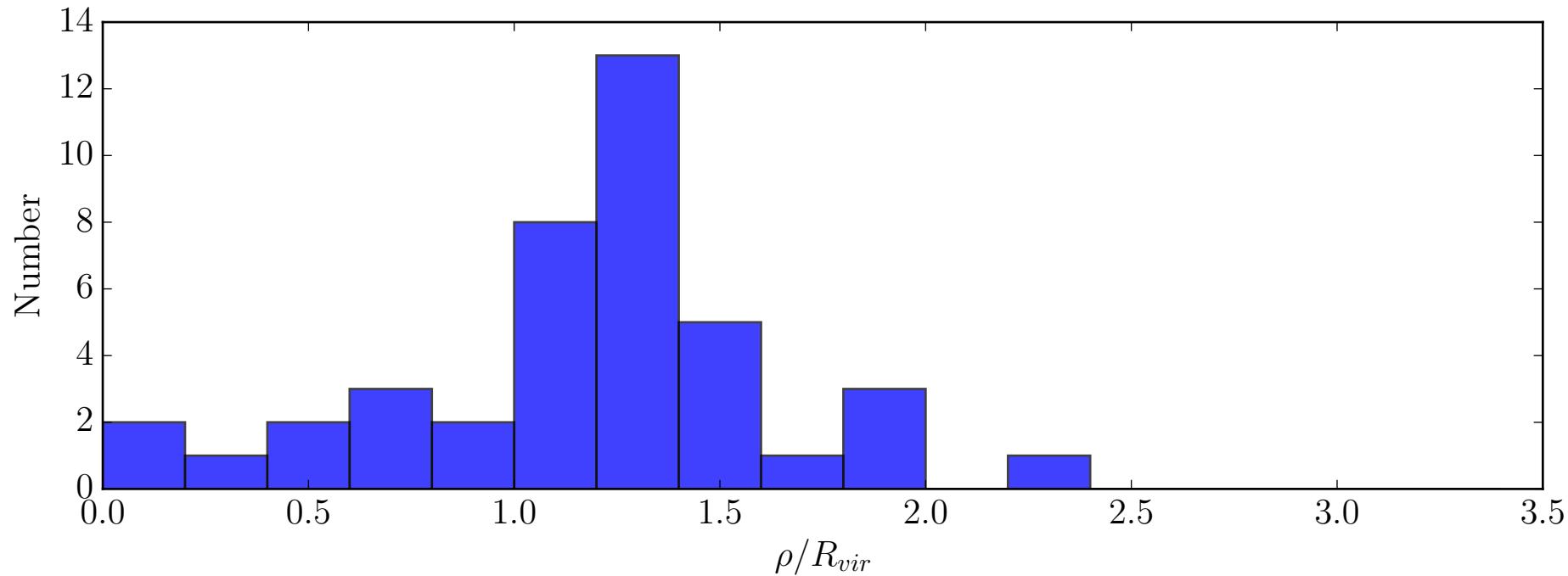
Impact parameter / R_{vir}



Impact parameter vs R_{vir}



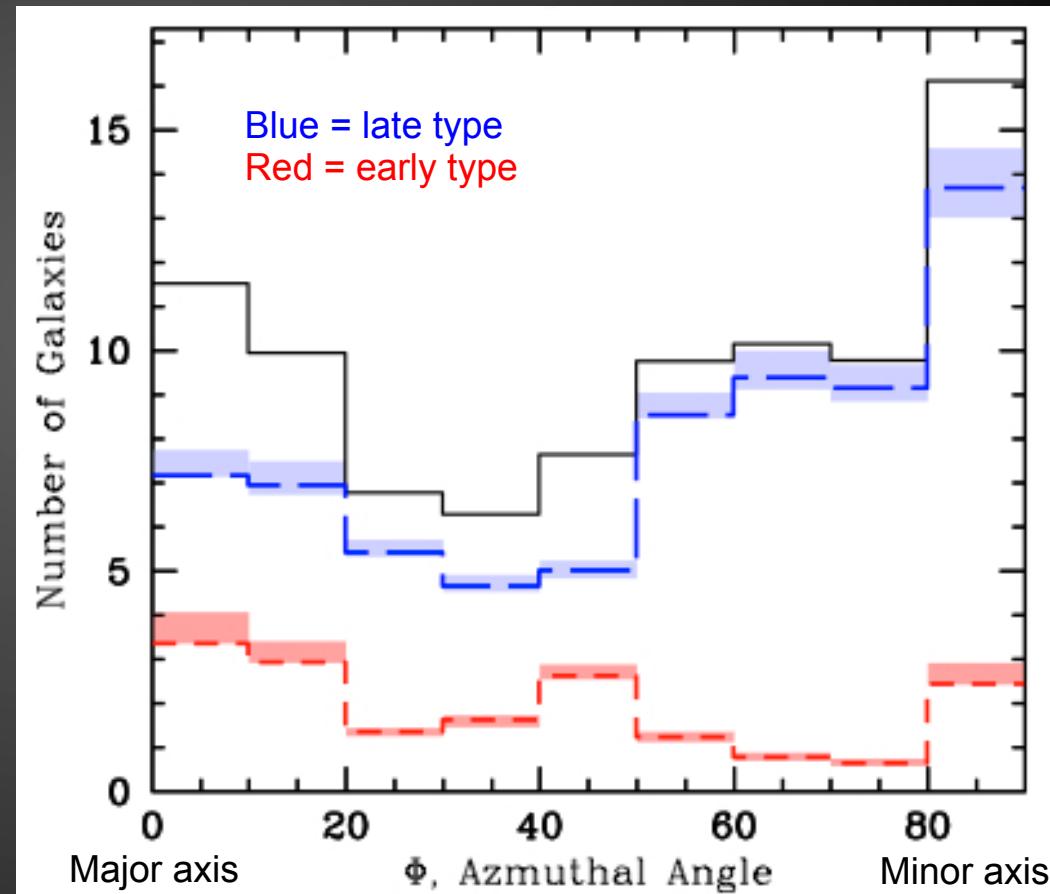
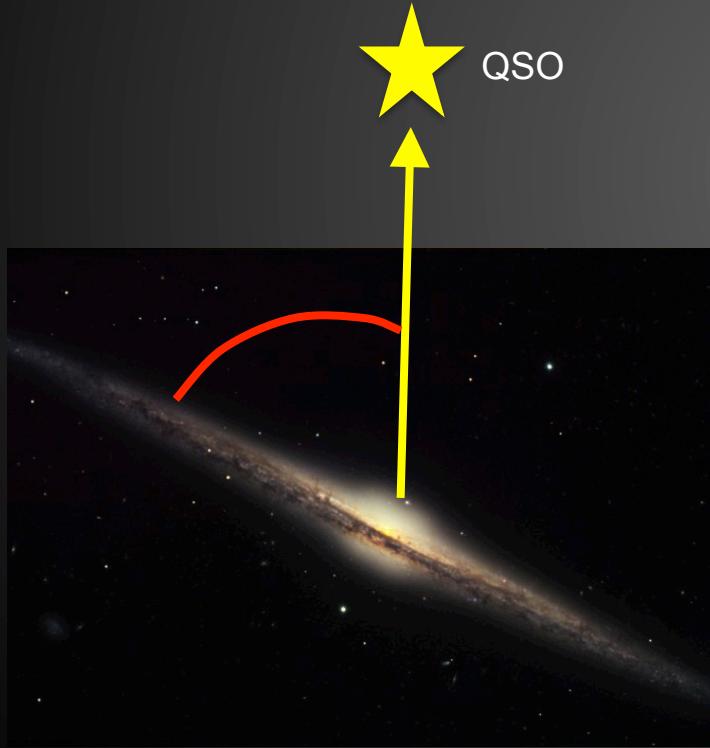
Impact parameter / R_{vir}



Most absorbers are found around $\frac{\rho}{R_{vir}} = 1.24$

How do CGM gas properties depend on galaxy orientation?

- Kacprzak et al 2012 find bimodal MgII absorption

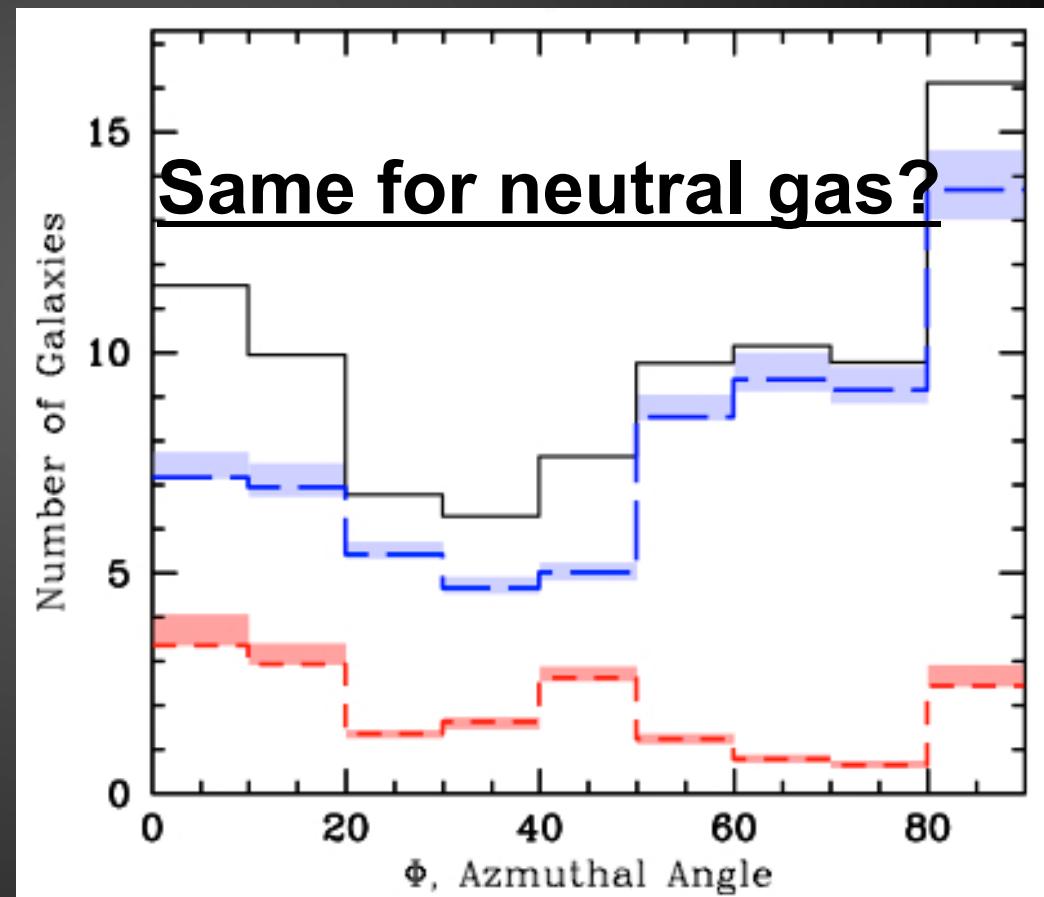
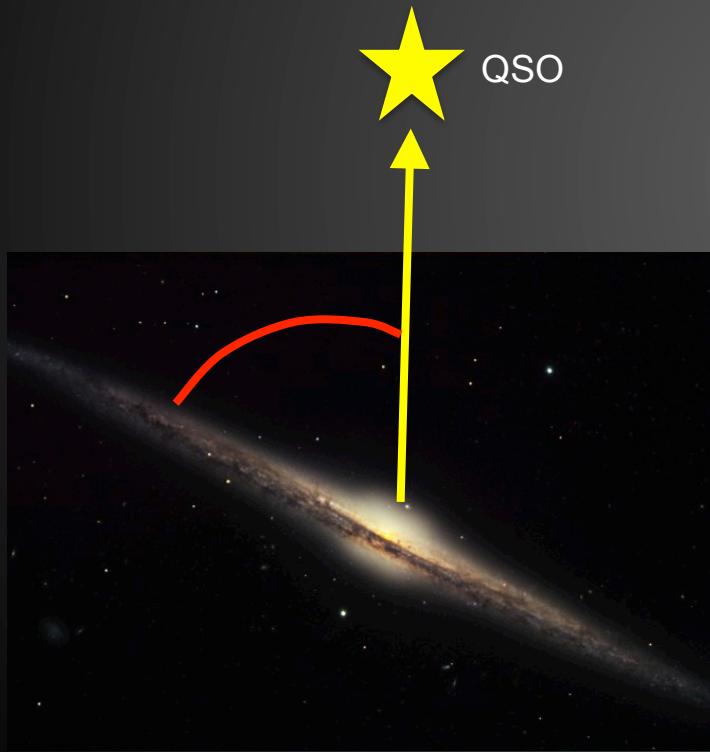


Credit: Bruce Hugo & Leslie Gaul, Adam Block, NOAO, AURA, NSF

Kacprzak et al. 2012

How do CGM gas properties depend on galaxy orientation?

- *Major vs minor?*

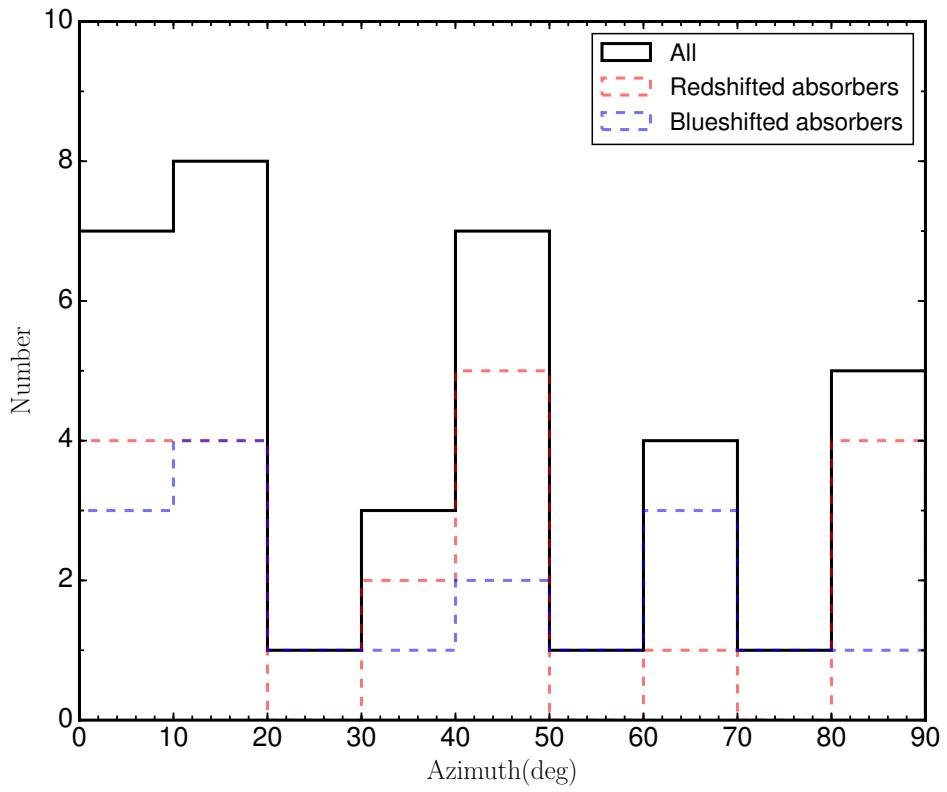


Credit: Bruce Hugo & Leslie Gaul, Adam Block, NOAO, AURA, NSF

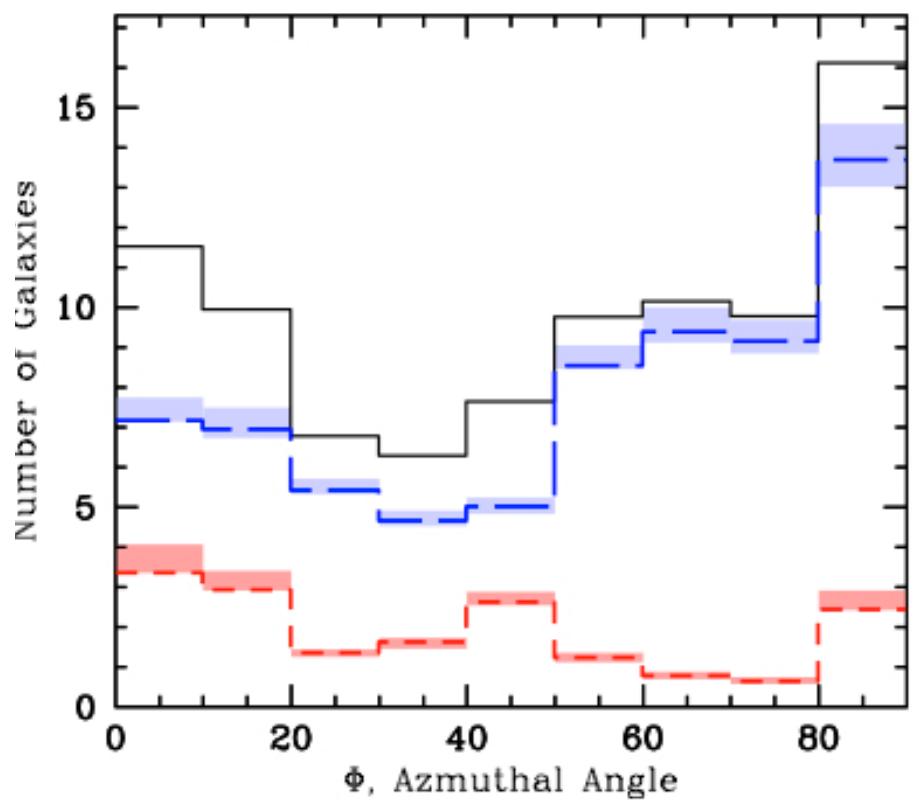
Kacprzak et al. 2012

How do CGM gas properties depend on galaxy orientation?

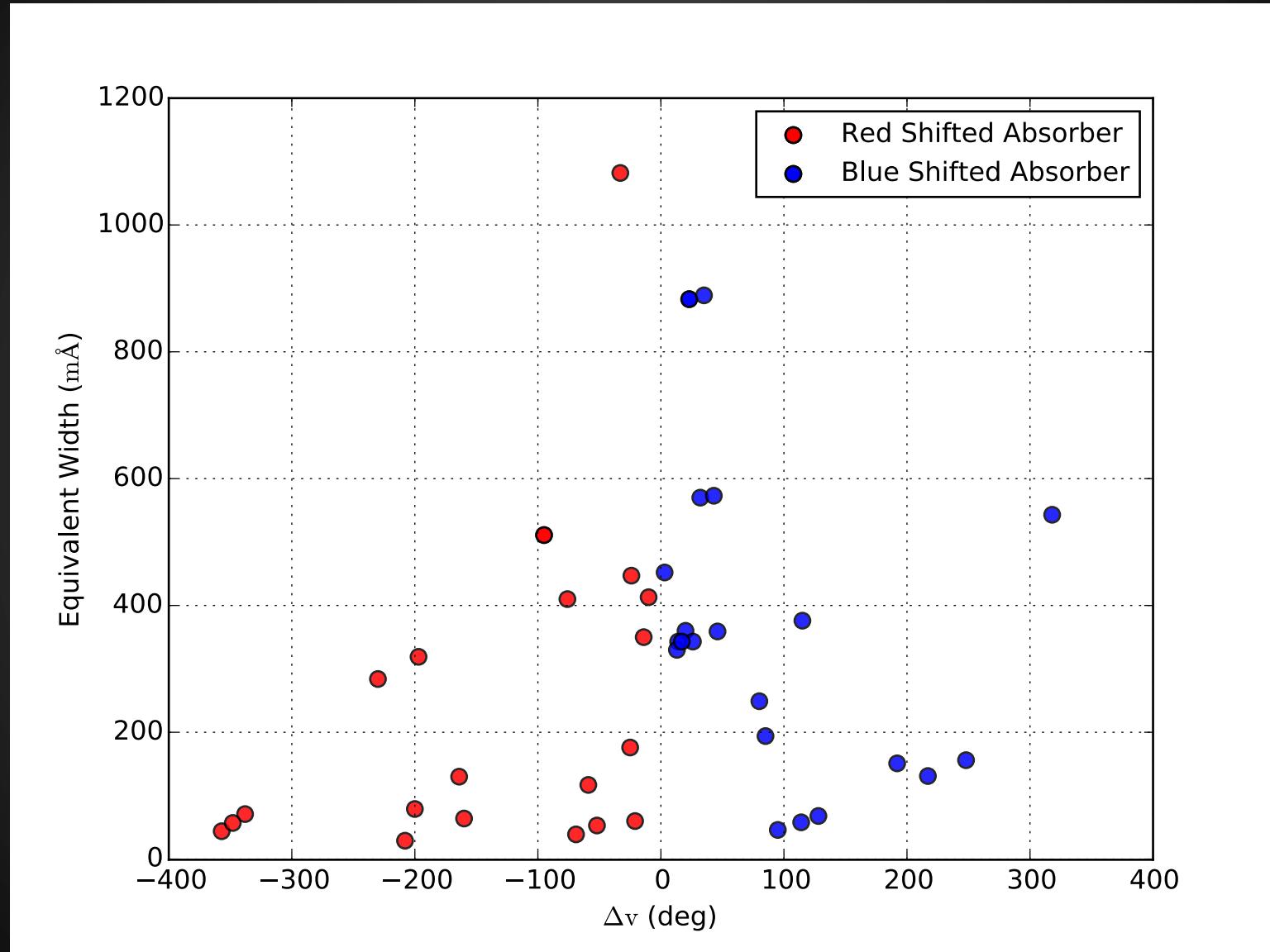
Lya



MgII

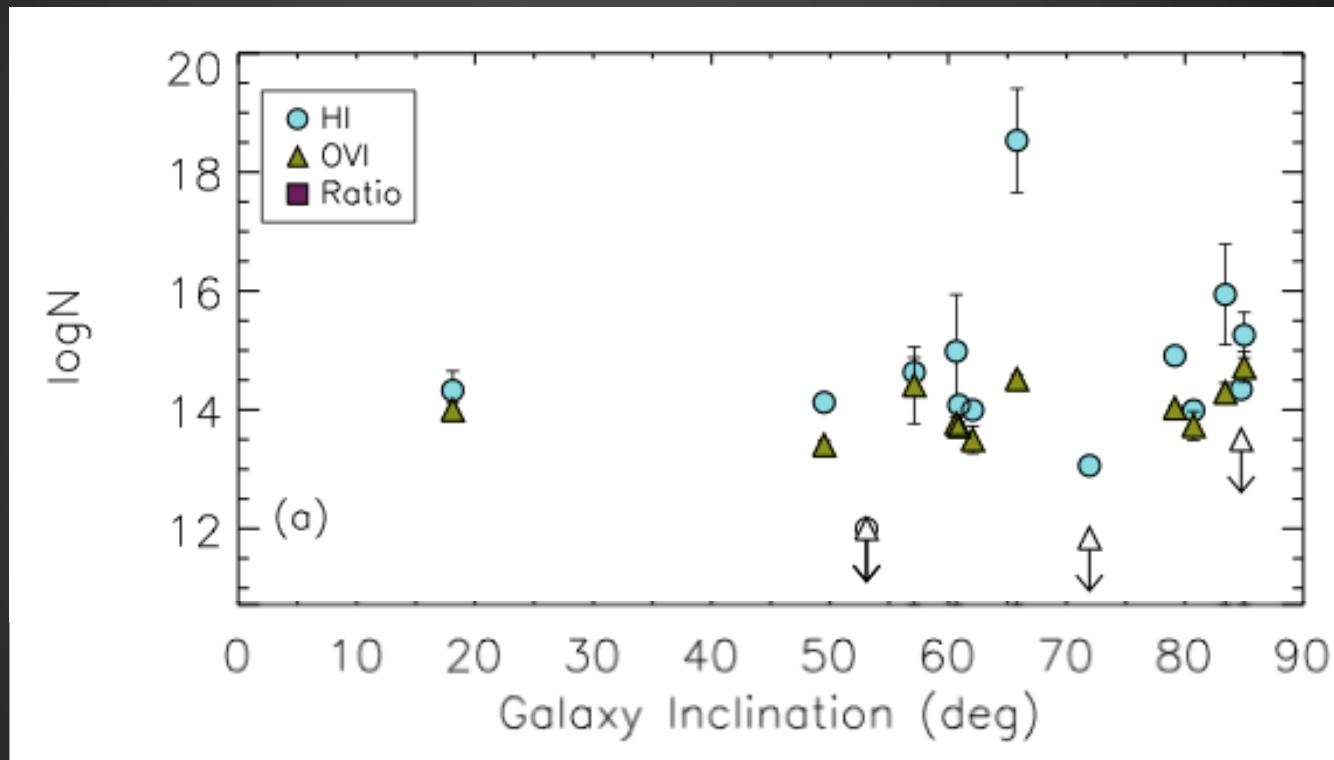


EW vs Δv



How do CGM gas properties depend on galaxy inclination?

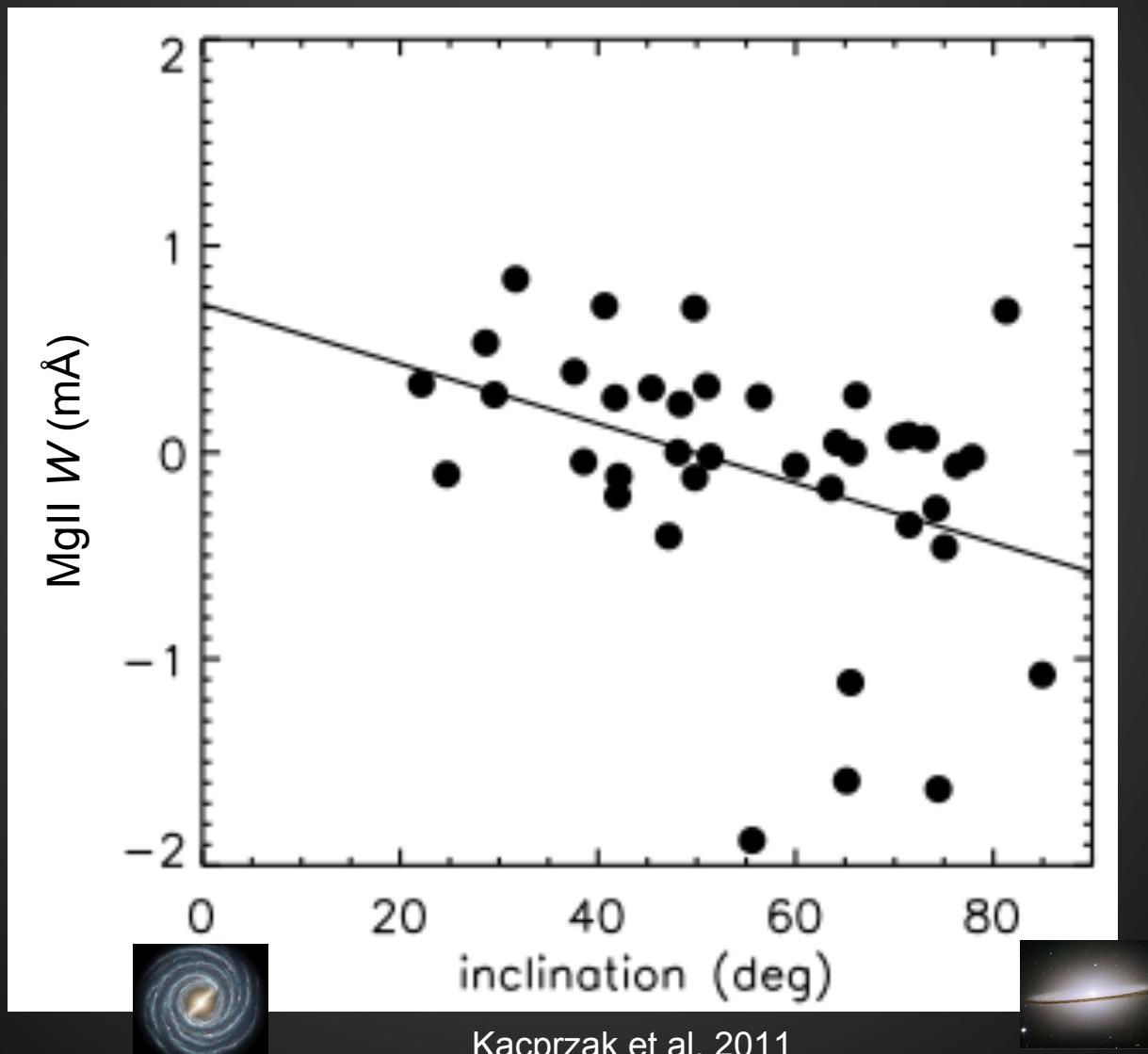
No?



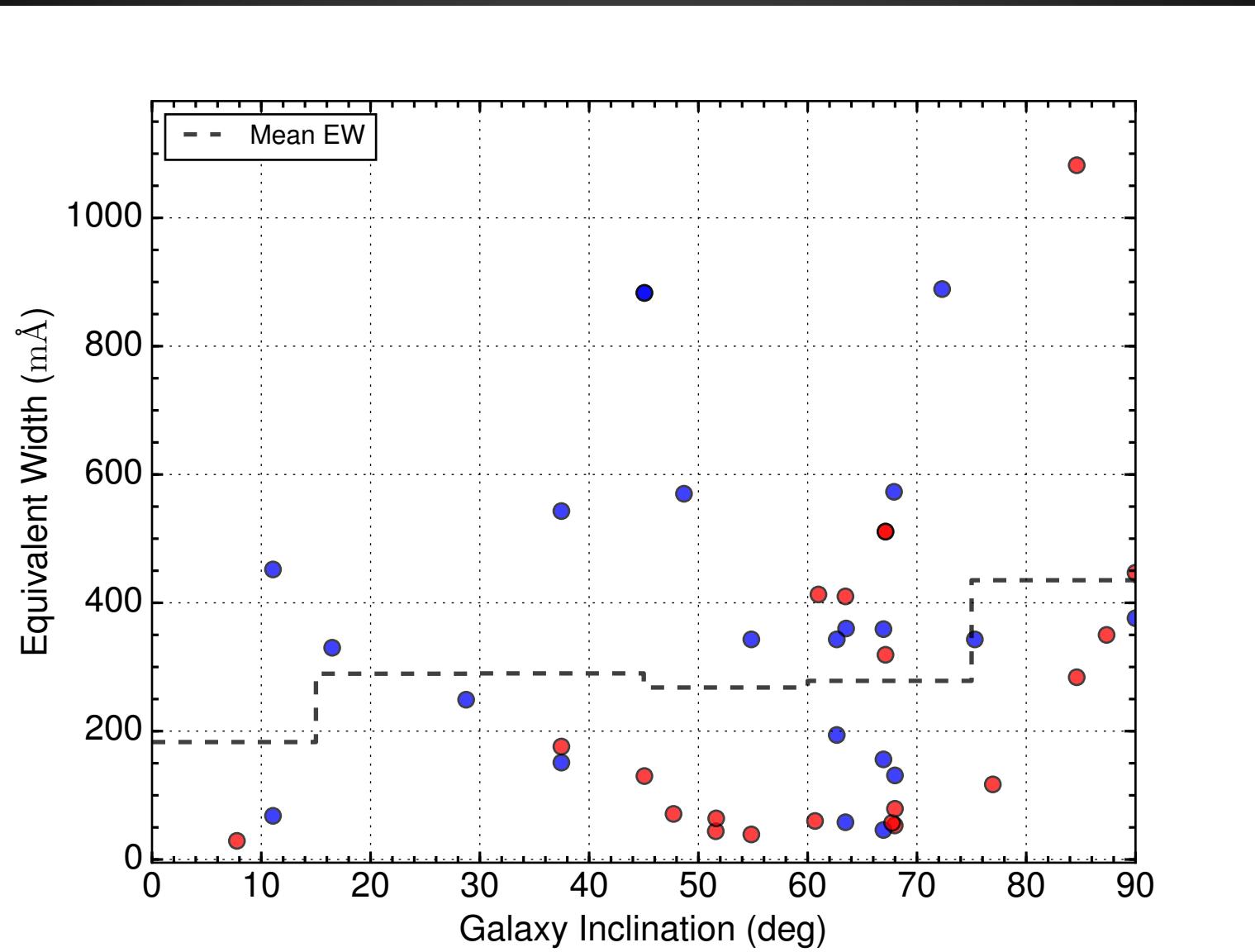
Mathes et al. 2014

How do CGM gas properties depend on galaxy inclination?

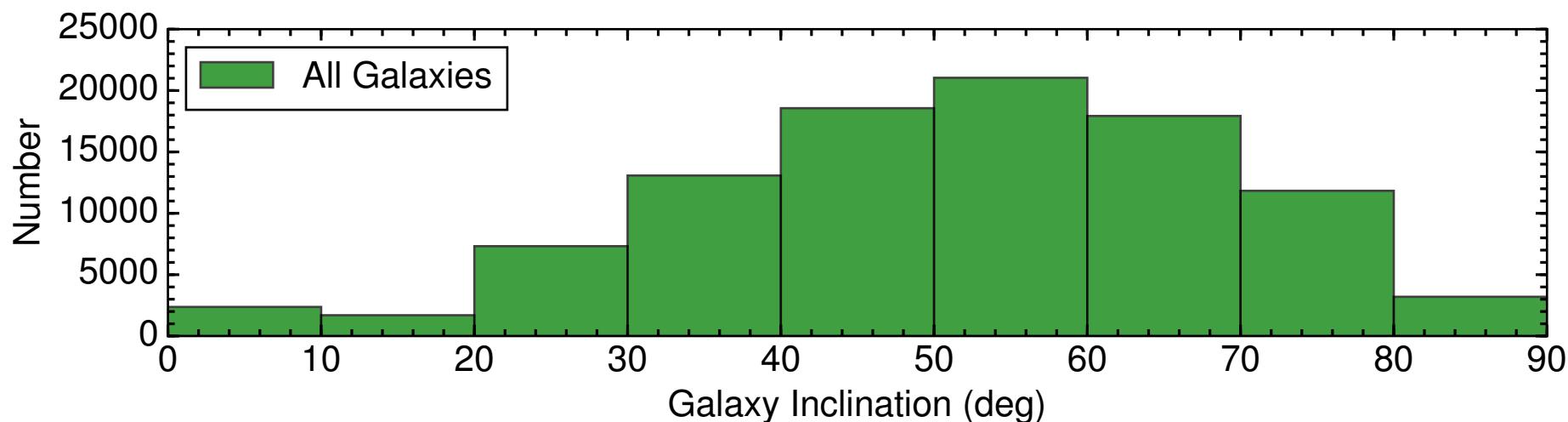
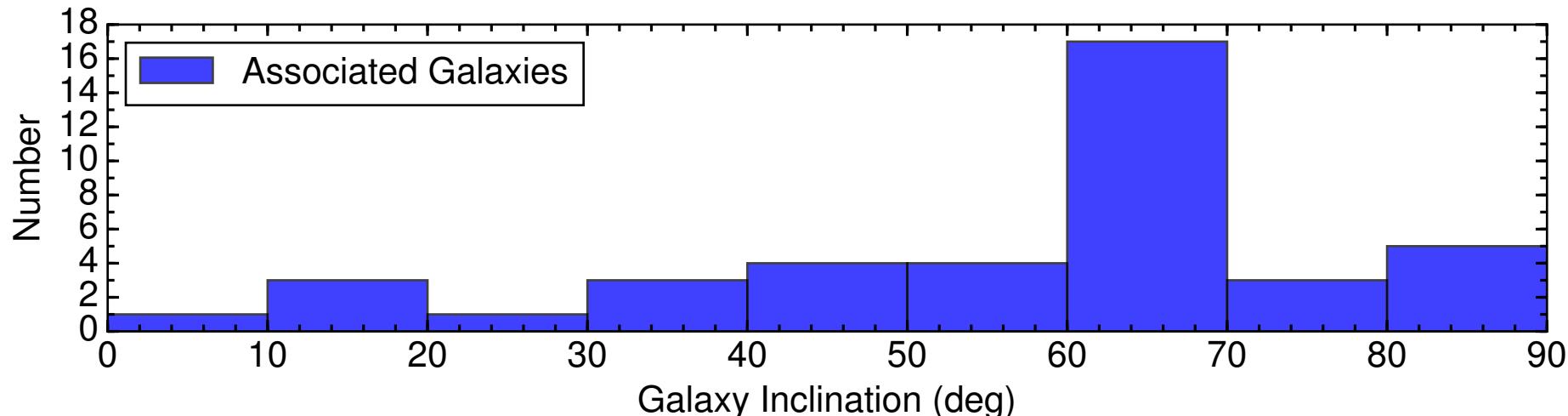
Maybe?



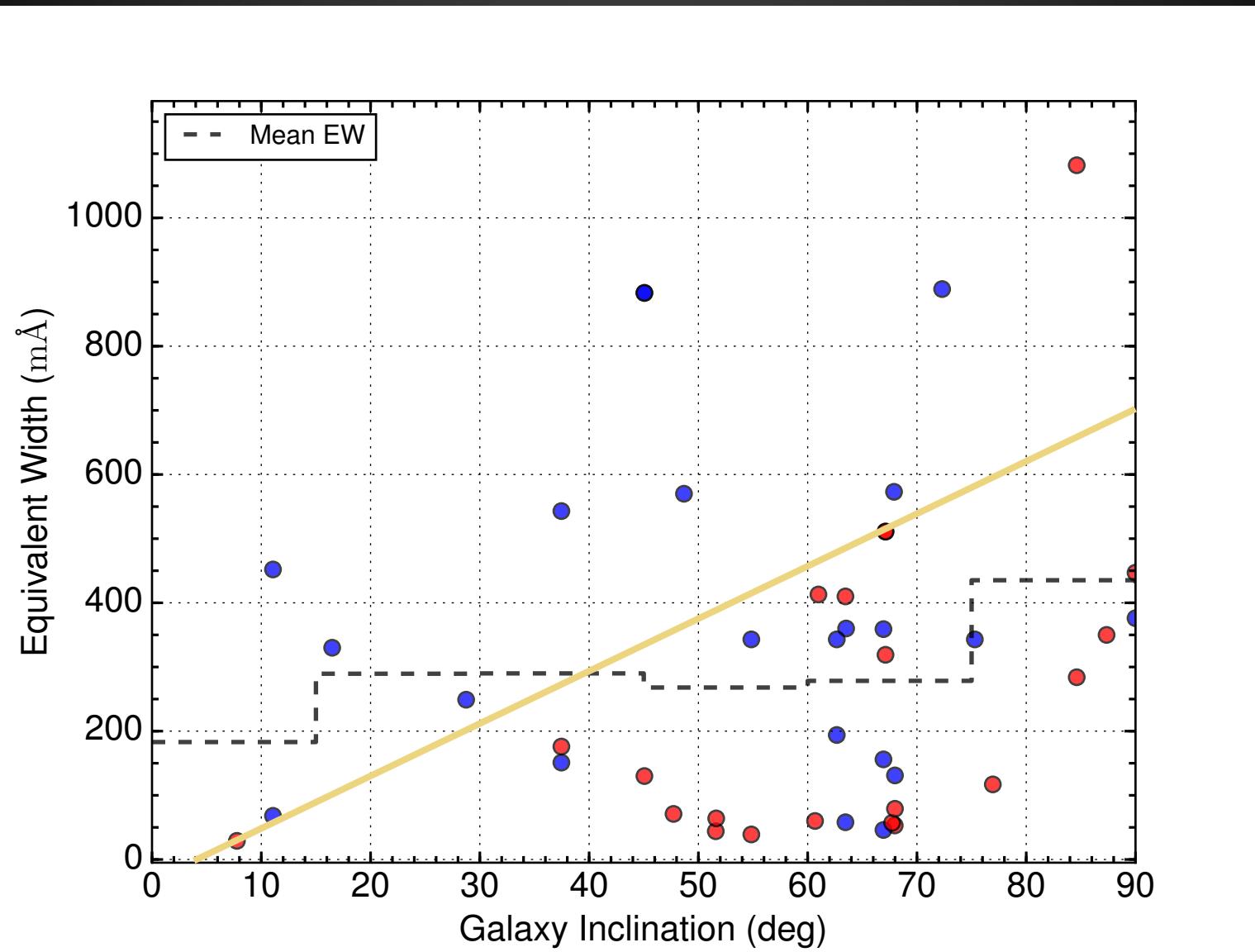
Galaxy Inclination



Galaxy Inclination



EW dichotomy



EW dichotomy

- Median EW(blueshifted) = $343 \pm 10 \text{ m}\text{\AA}$
- Median EW(redshifted) = $124 \pm 9 \text{ m}\text{\AA}$
- The difference: KS p-value = 0.04

Summary:

- Define likelihood – a reproducible method for associating absorption with nearby galaxies
- EW – Impact parameter anti-correlation with R_{vir}
- Absorbers are more common near highly inclined galaxies
- Absorbers most commonly found near $R \sim 1.25 R_{vir}$
- Azimuth dependence is unclear
- Median EW increases with decreasing Δv
- Redshifted absorption weaker than blueshifted?