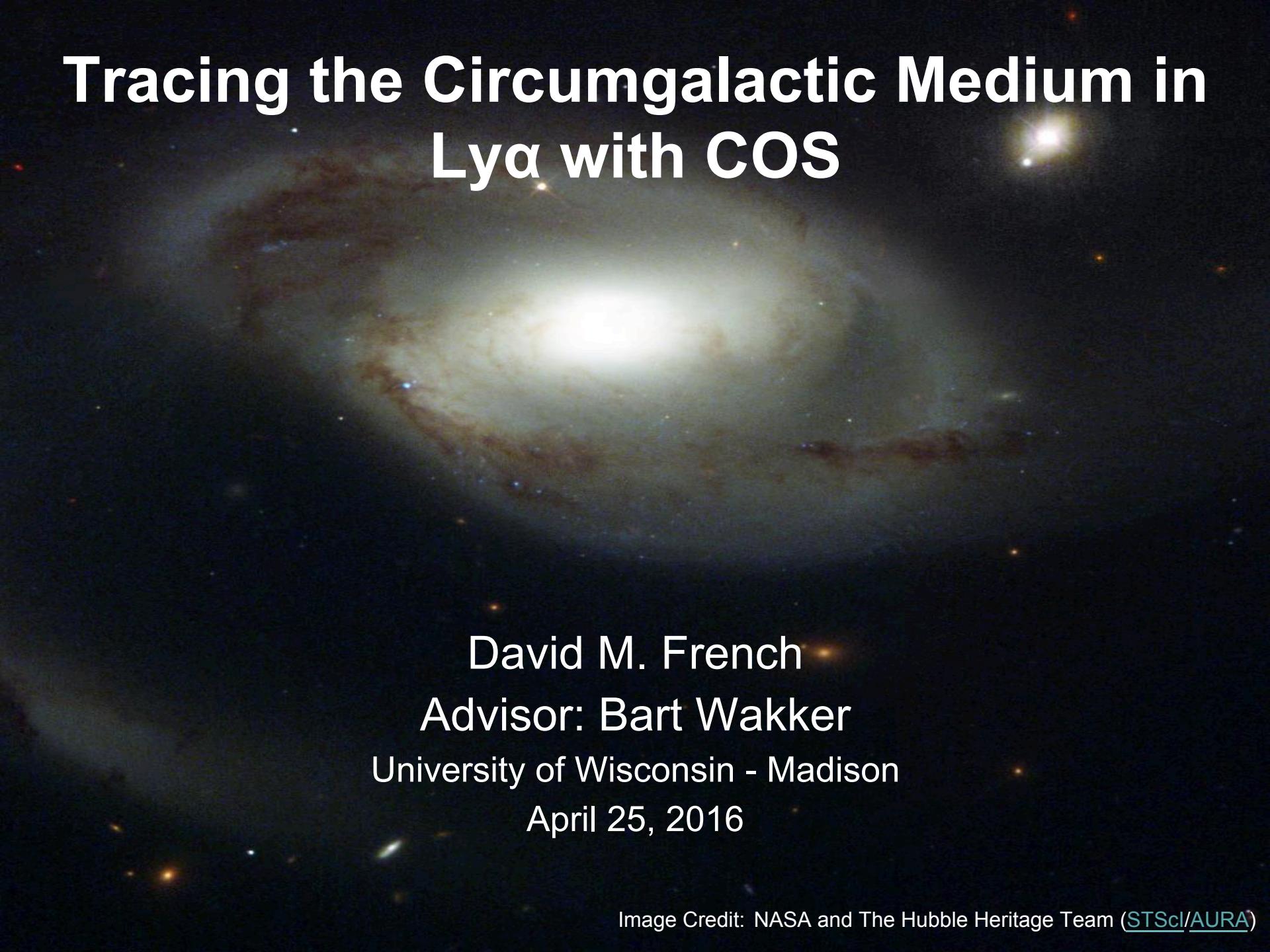


Tracing the Circumgalactic Medium in Ly α with COS



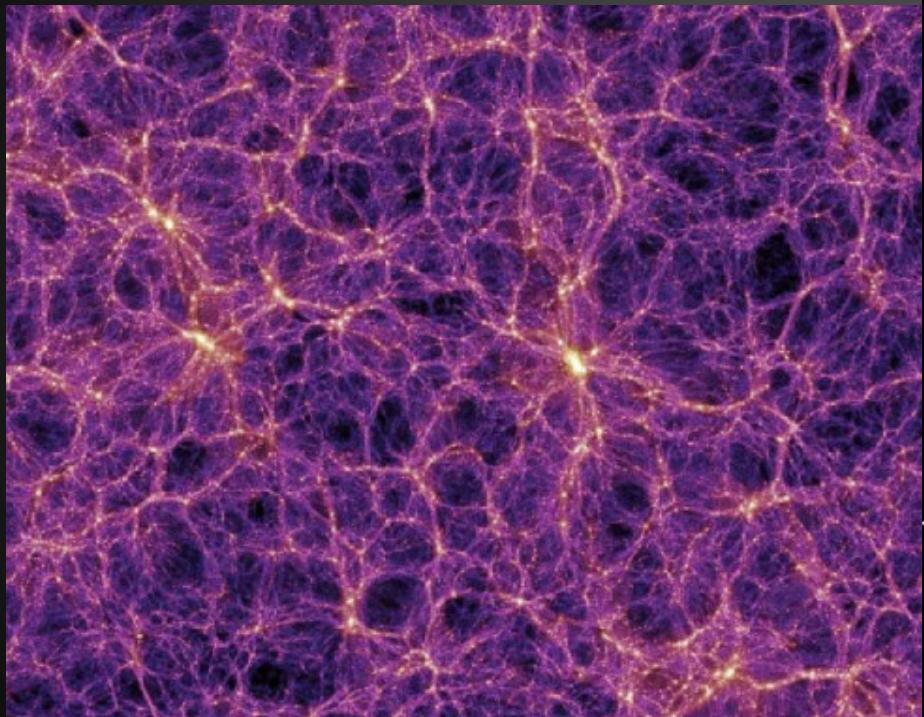
David M. French

Advisor: Bart Wakker

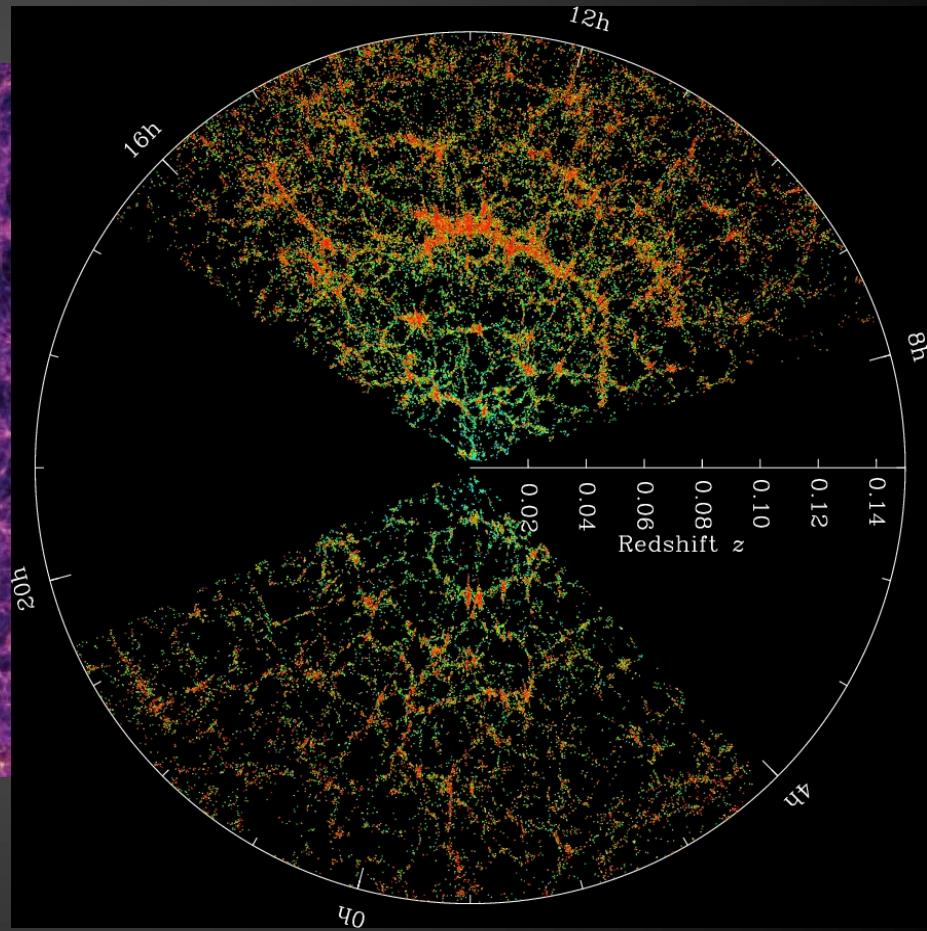
University of Wisconsin - Madison

April 25, 2016

Gas in the Universe



The Millenium Simulation



SDSS Collaboration

Understanding the CGM

- Gas and galaxies follow the same DM potential
 - Galaxies need to continue accreting gas over cosmic time to match observations
- 
- Feedback kicks gas out of galaxies

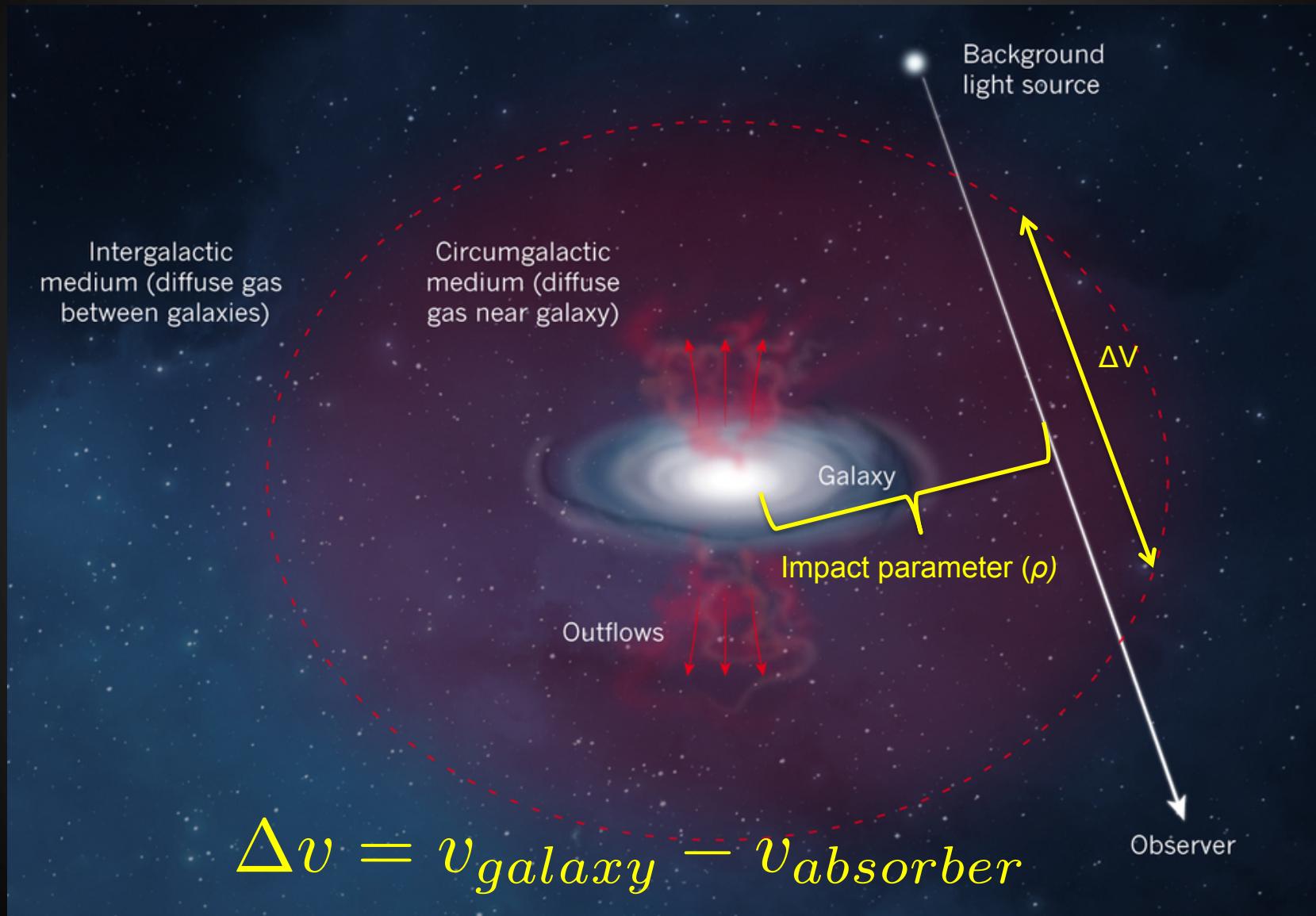


How do the properties of gas correlate with associated galaxy properties?

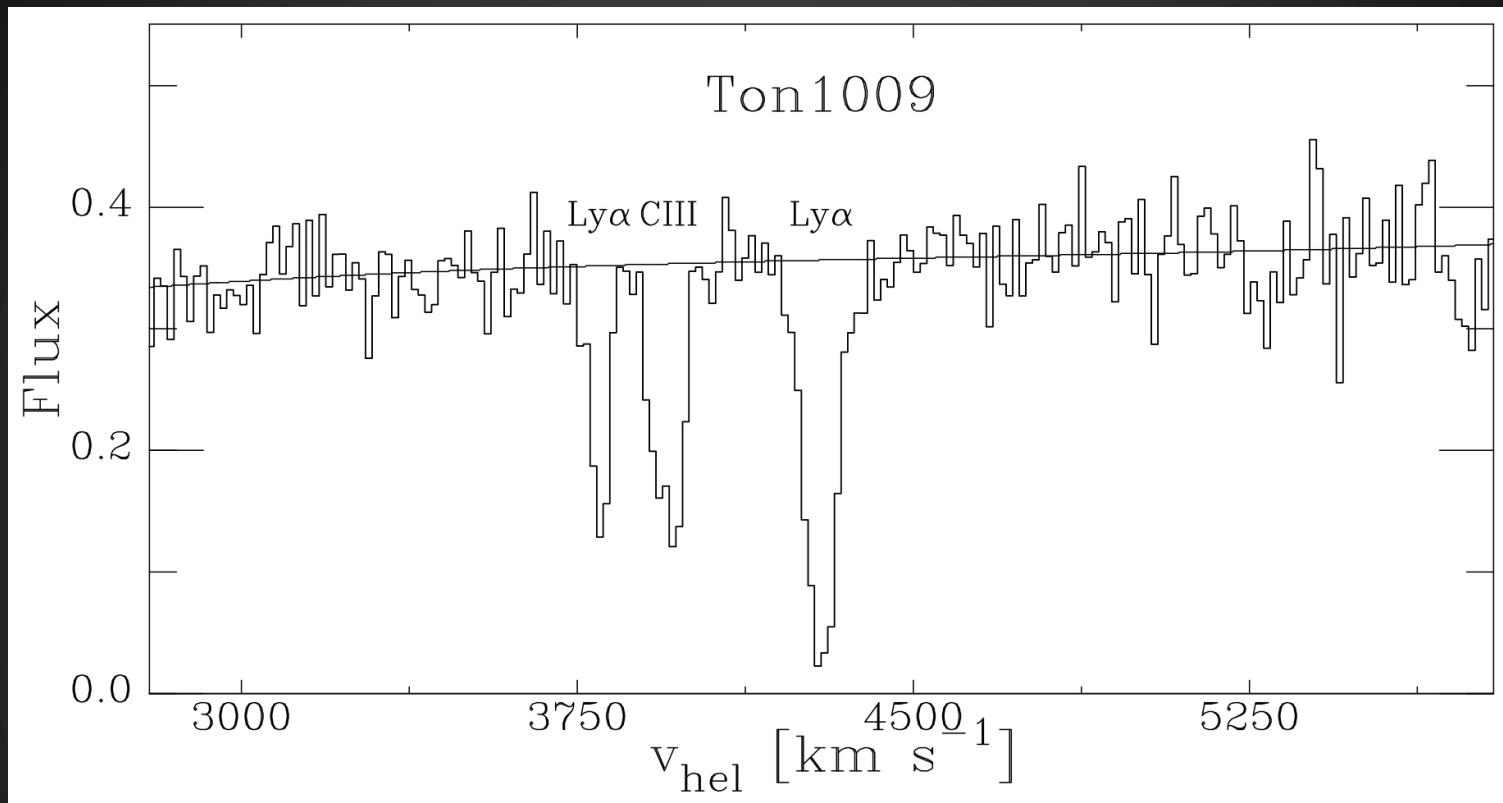
Science Outline

- Use archival COS sightlines (~300)
 - *Find Ly α , associate with galaxy environment*
- Stay close ($z < 0.034$, $cz < 10,000$ km/s)
 - *Available galaxy data complete to $\sim 0.1 L^*$*
- Automate associating galaxies – absorbers
- Ask:
 - absorber (EW, velocity)
as a function of
 - galaxy (impact parameter, size, orientation)

Defining the CGM



Associating galaxies with absorbers



Is this Ly α absorber associated with a galaxy?

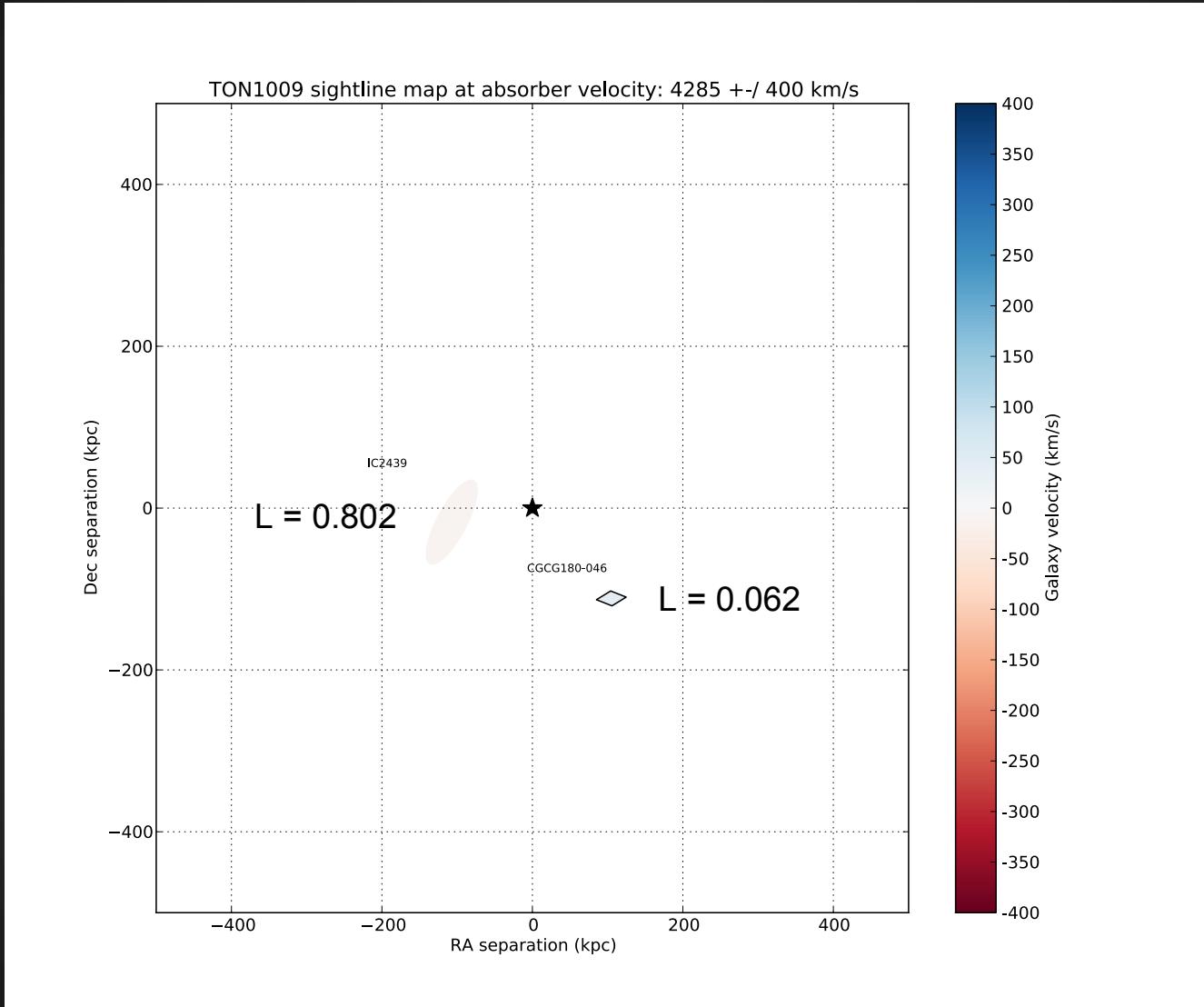
Associating galaxies with absorbers

- 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 $\mathcal{L} \geq 0.001$

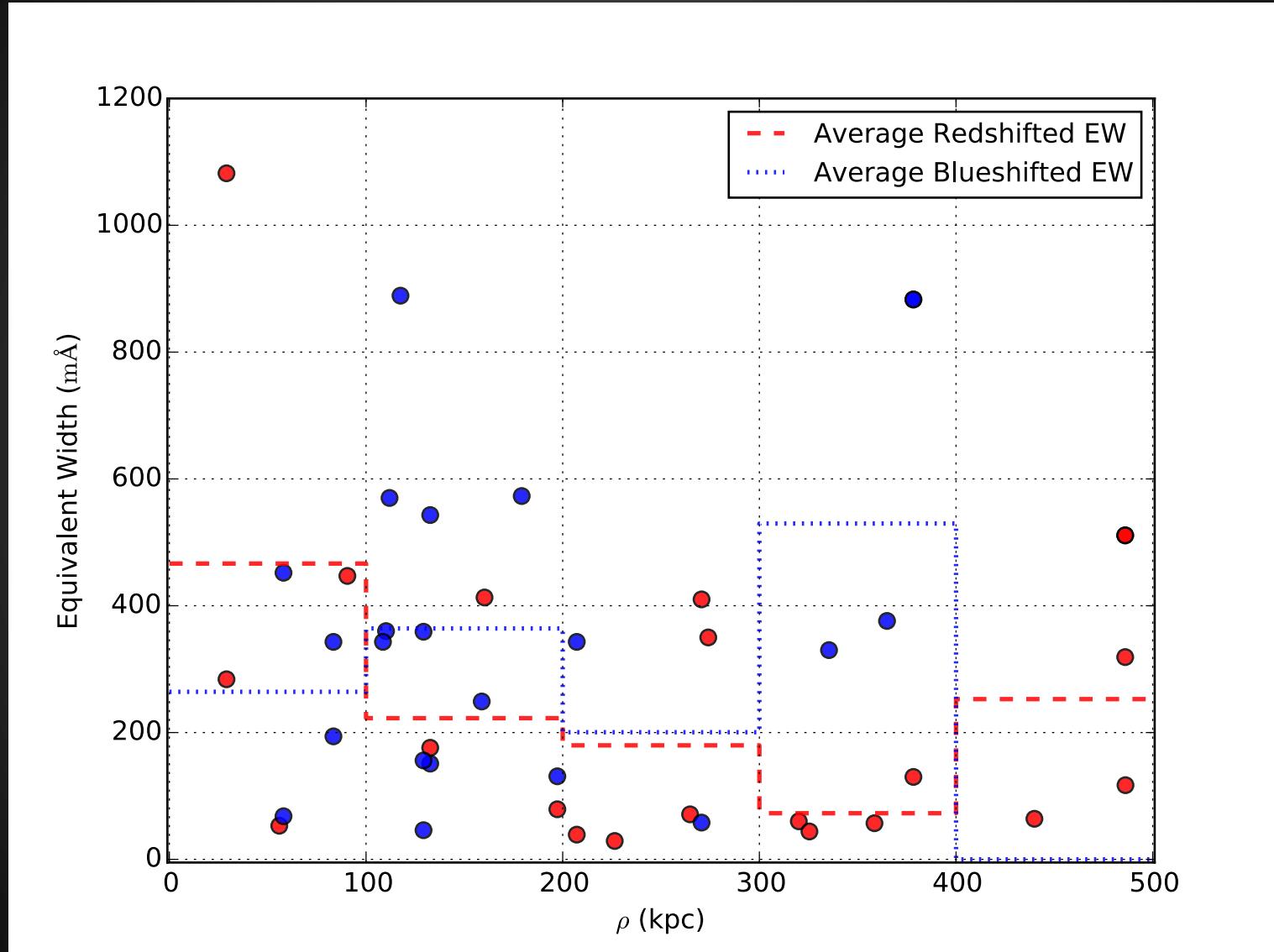
Associating galaxies with absorbers



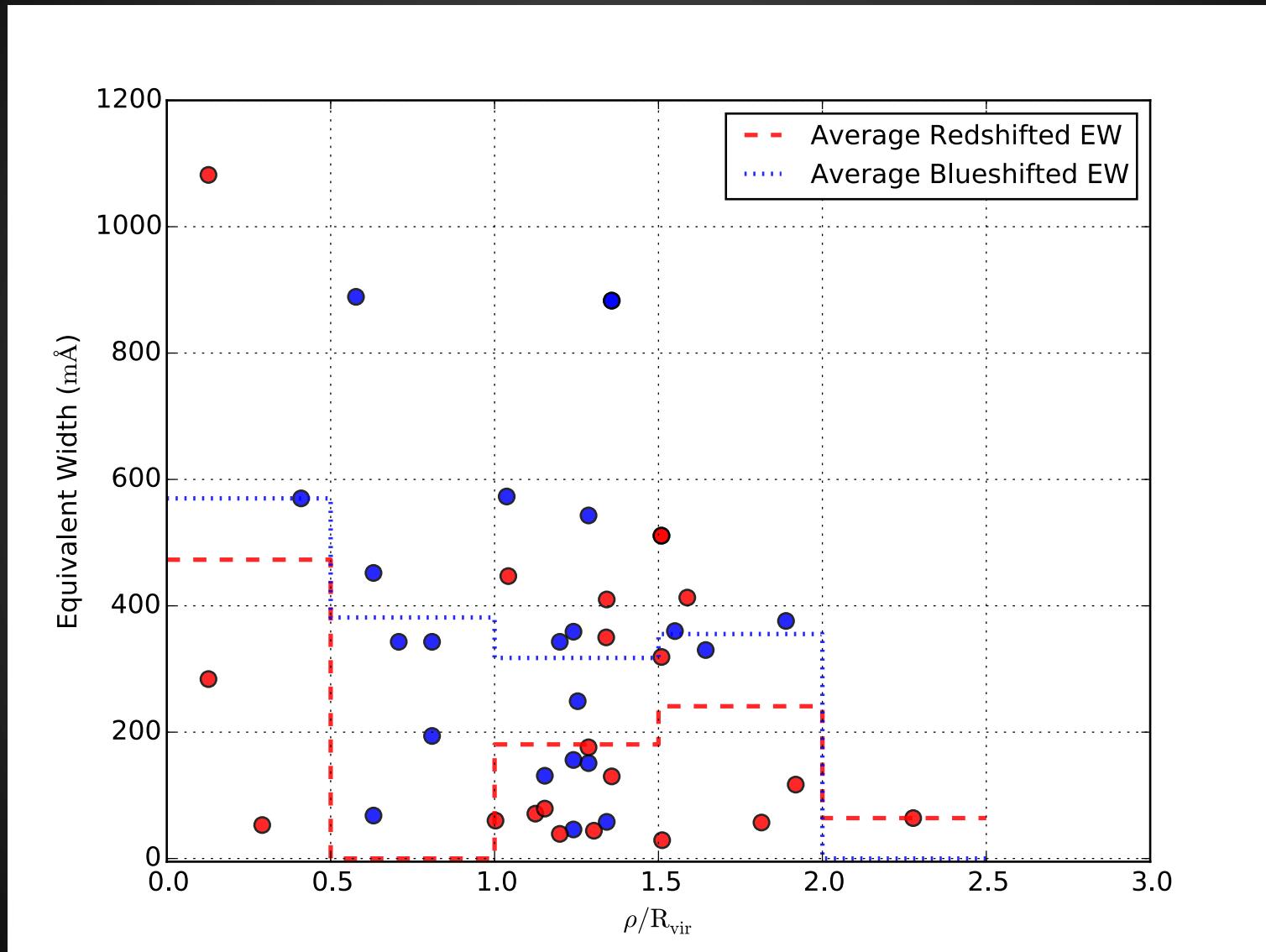
Results so far...

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

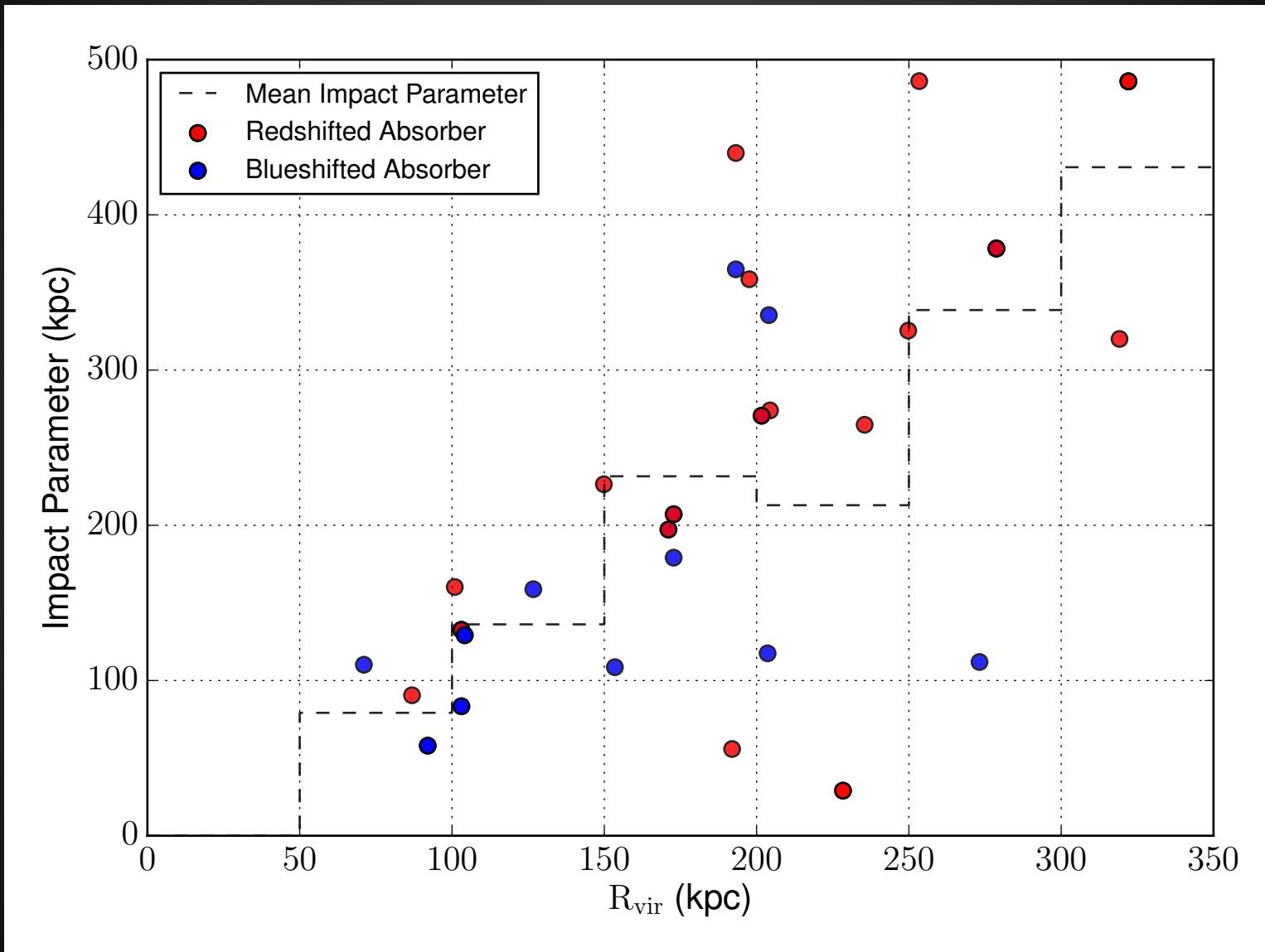
Impact parameter



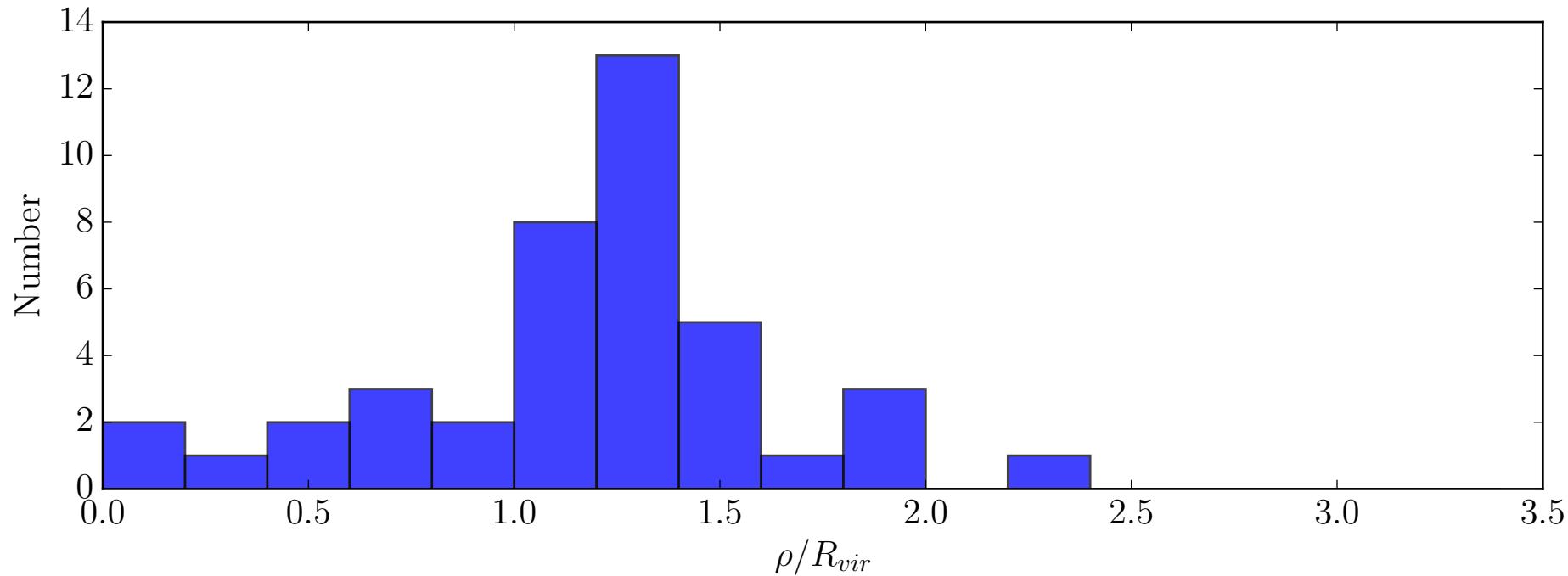
Impact parameter / R_{vir}



Impact parameter vs R_{vir}

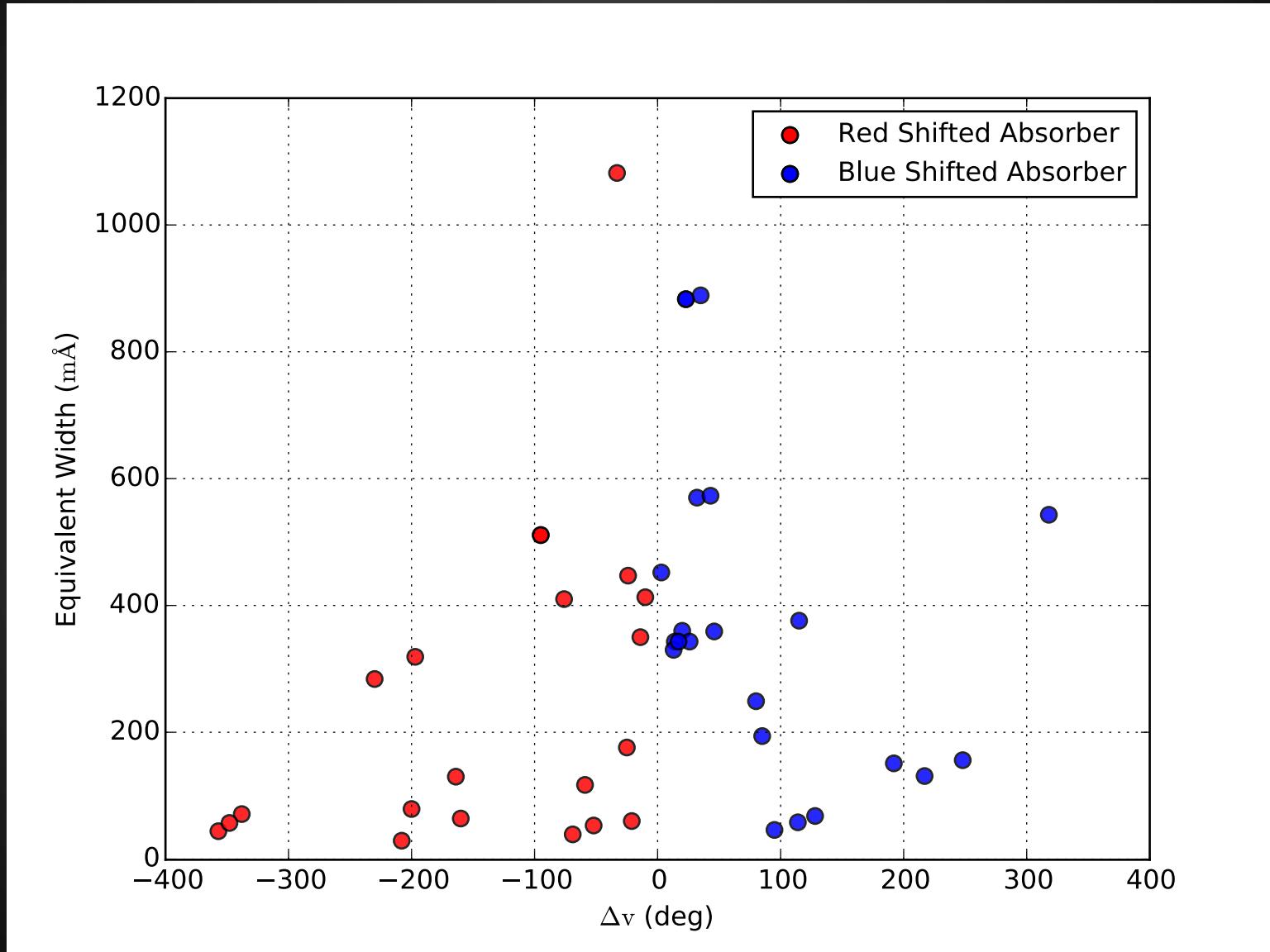


Impact parameter / R_{vir}



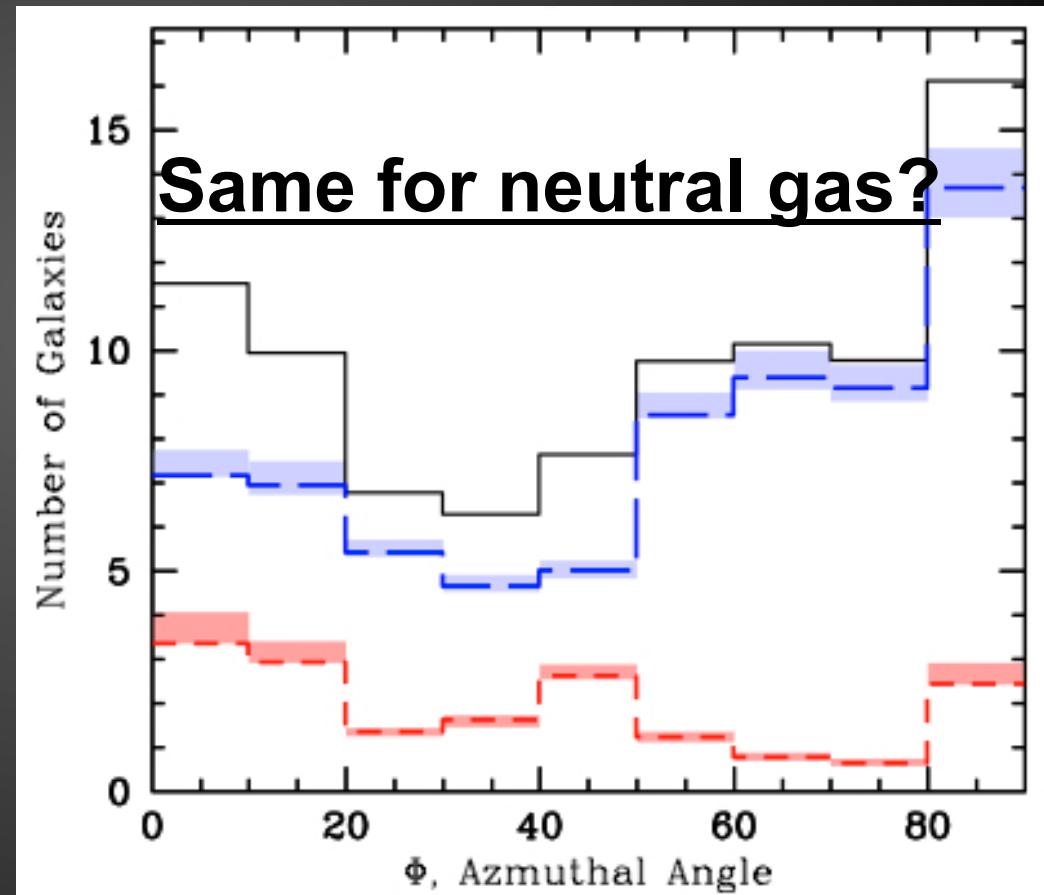
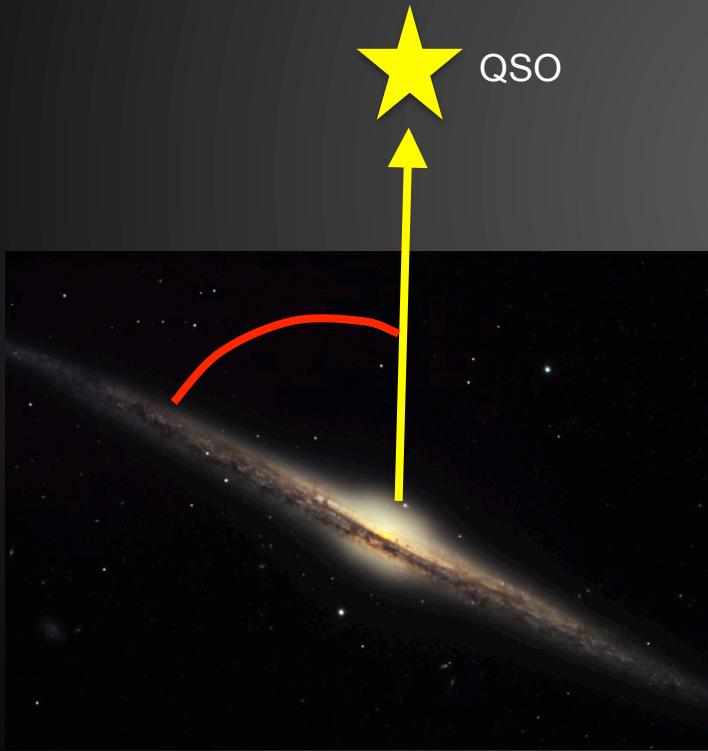
Most absorbers are found around $\frac{\rho}{R_{vir}} = 1.2$

EW vs Δv



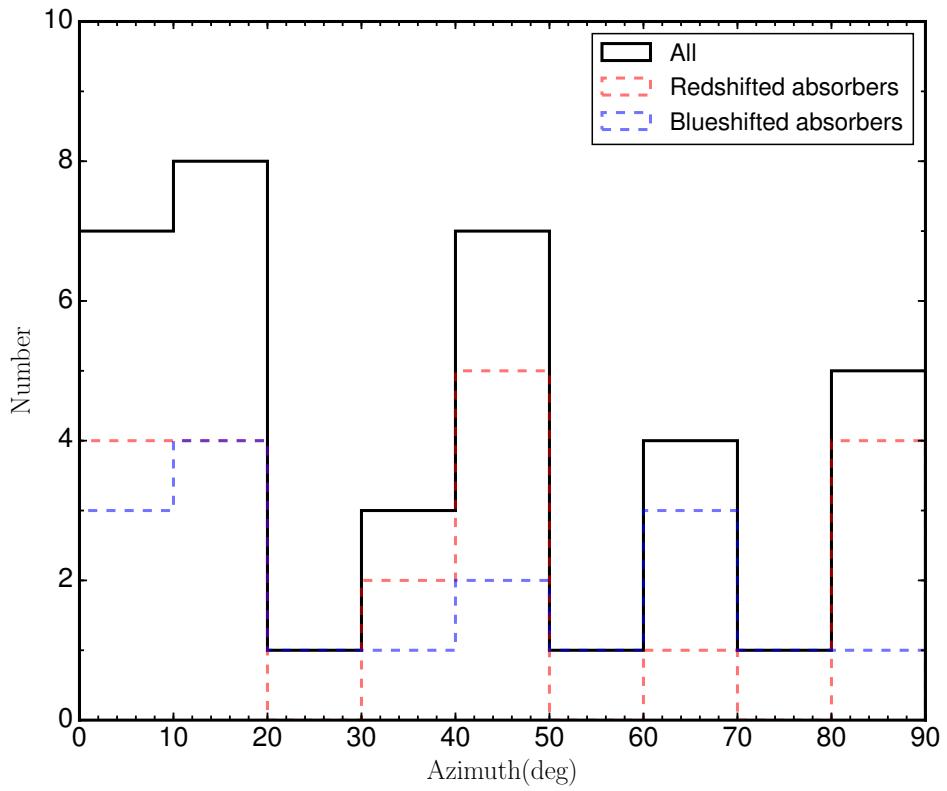
How do CGM absorber properties depend on galaxy orientation?

- *Major vs minor?*

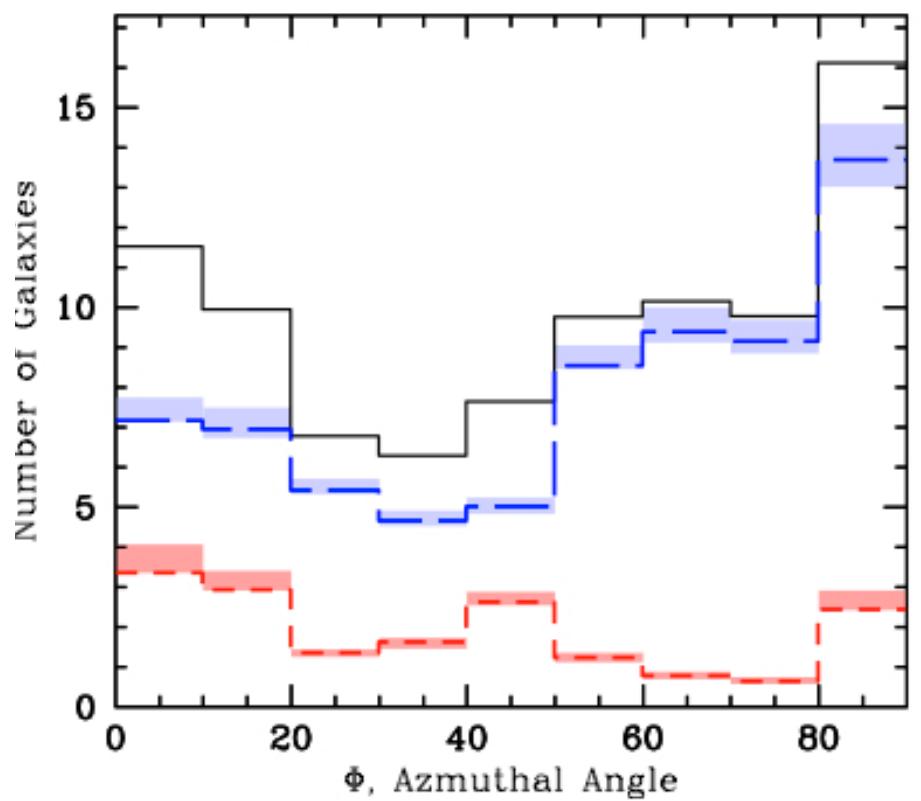


How do CGM absorber properties depend on galaxy orientation?

Lya

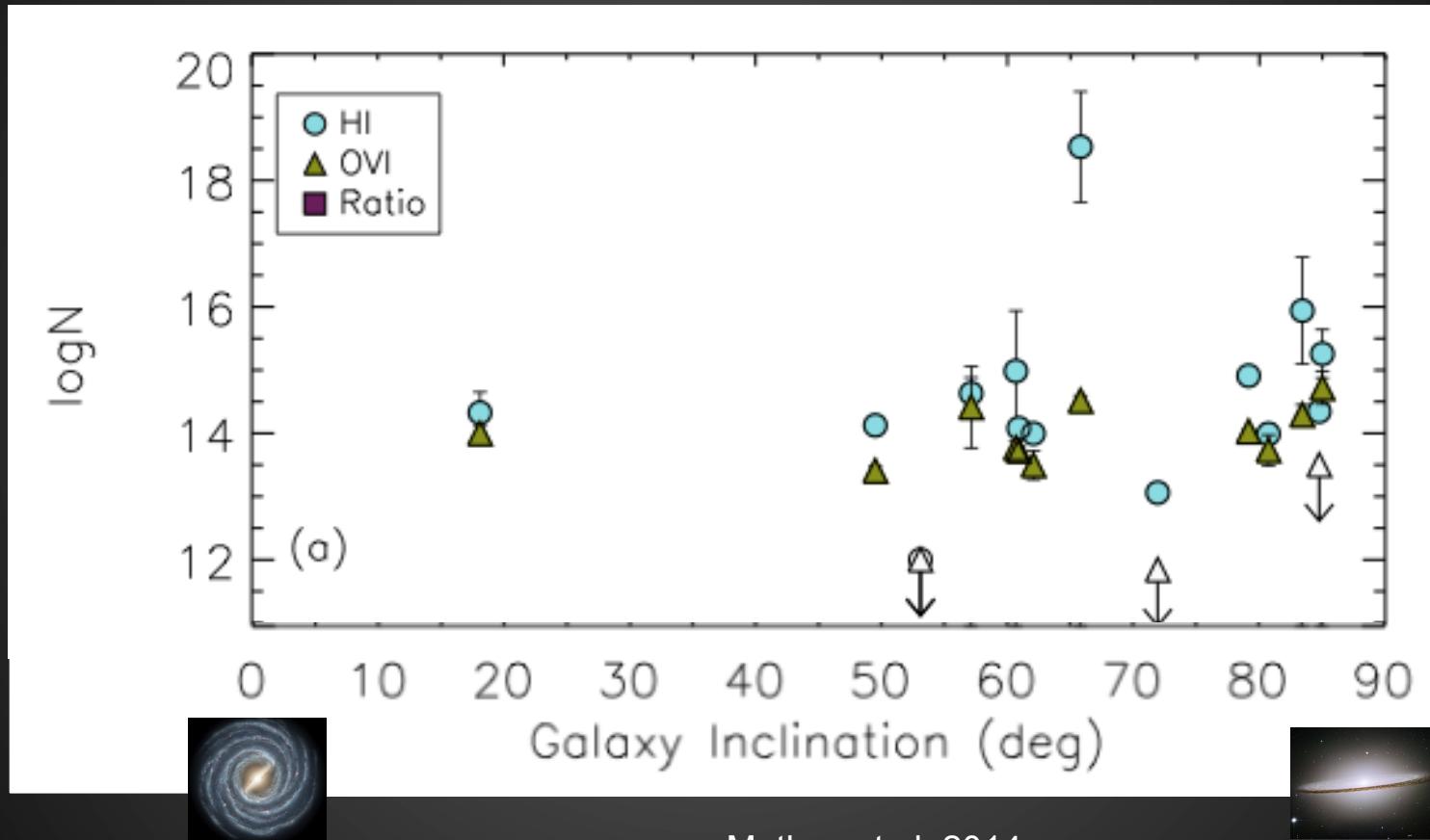


MgII



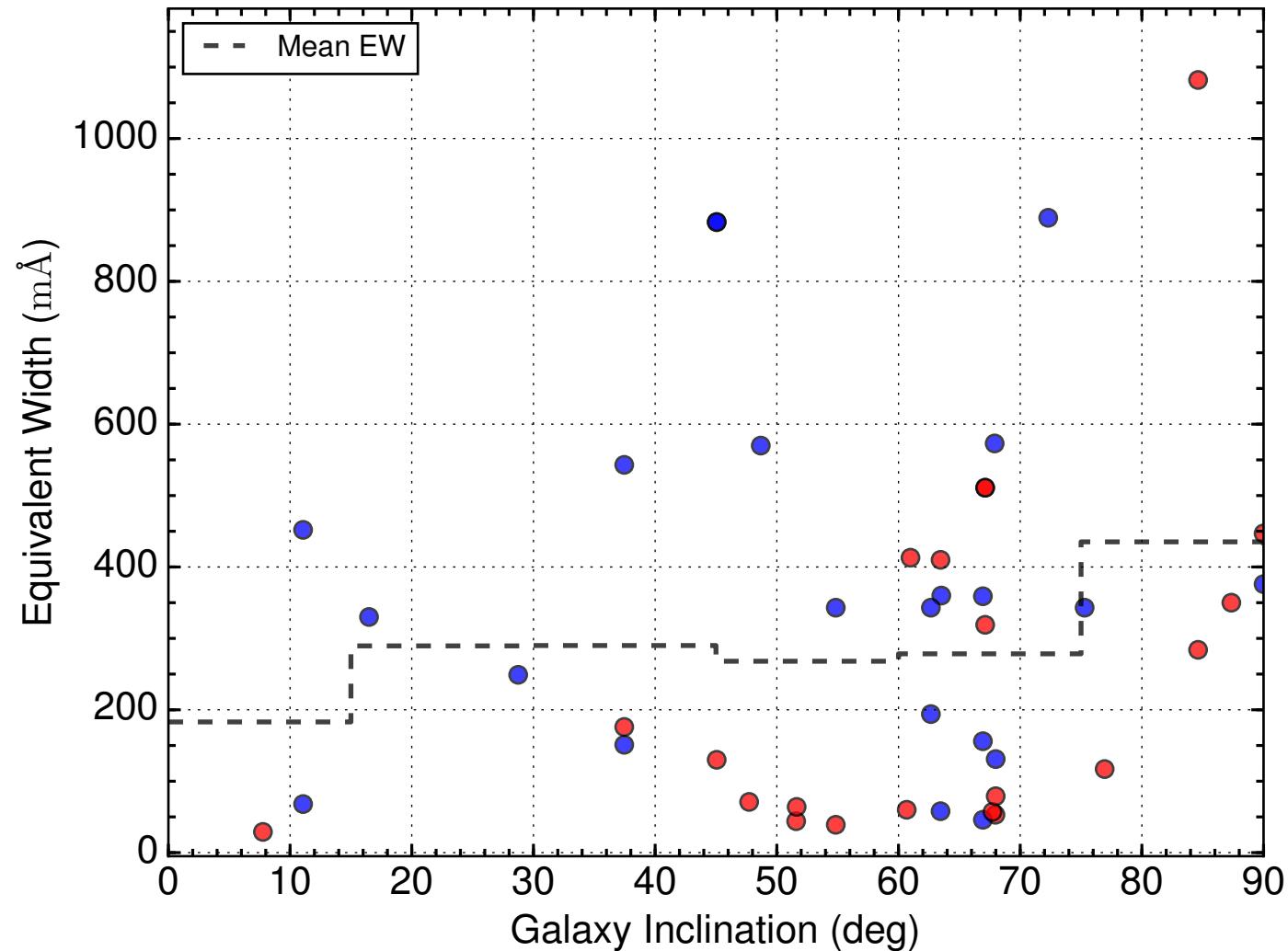
Galaxy Inclination

No?

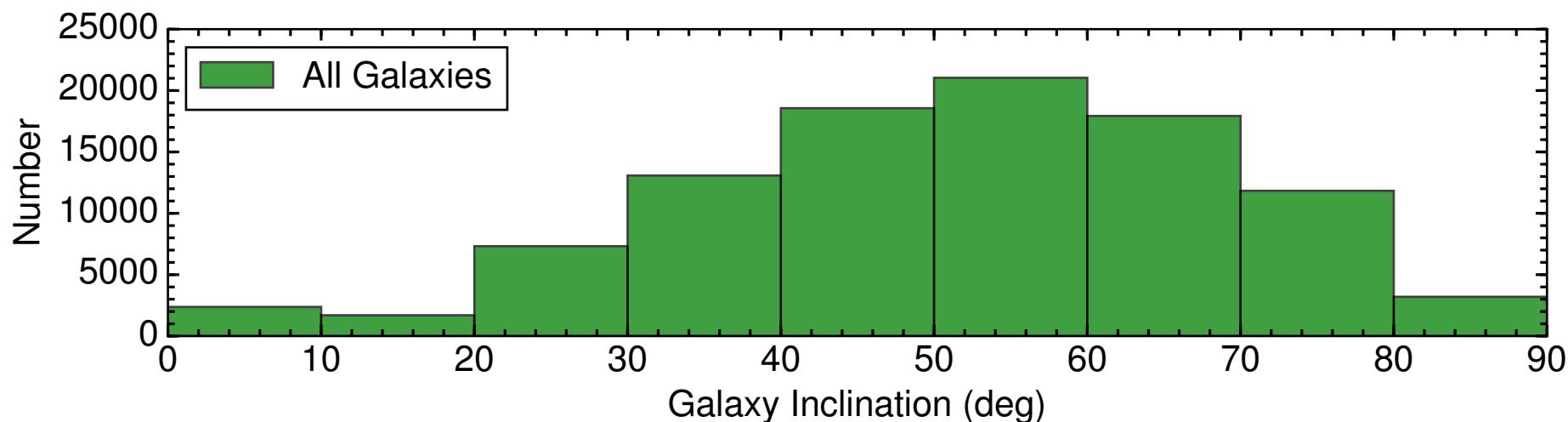
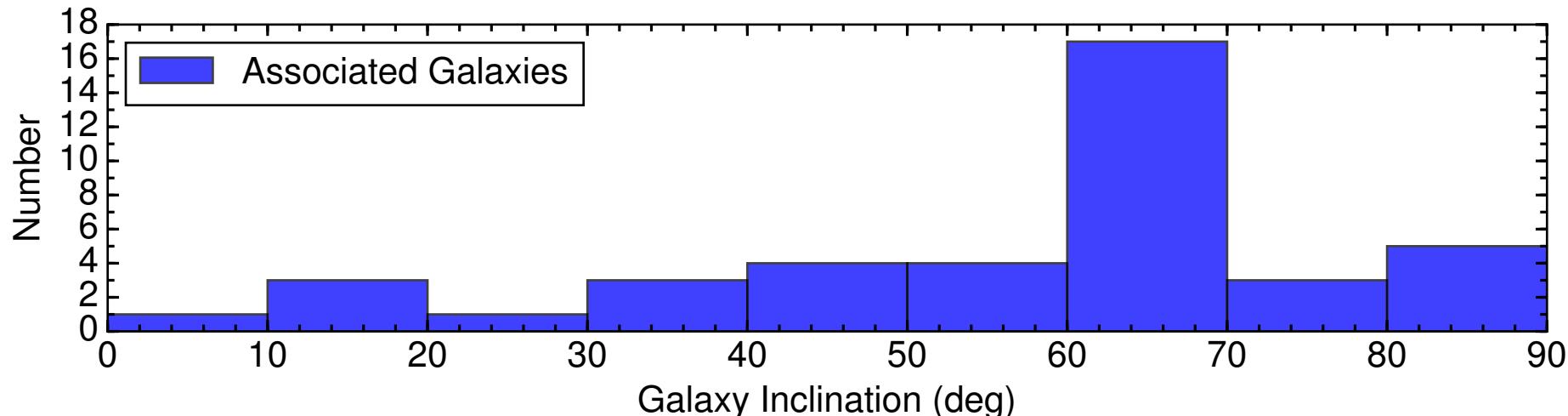


Galaxy Inclination

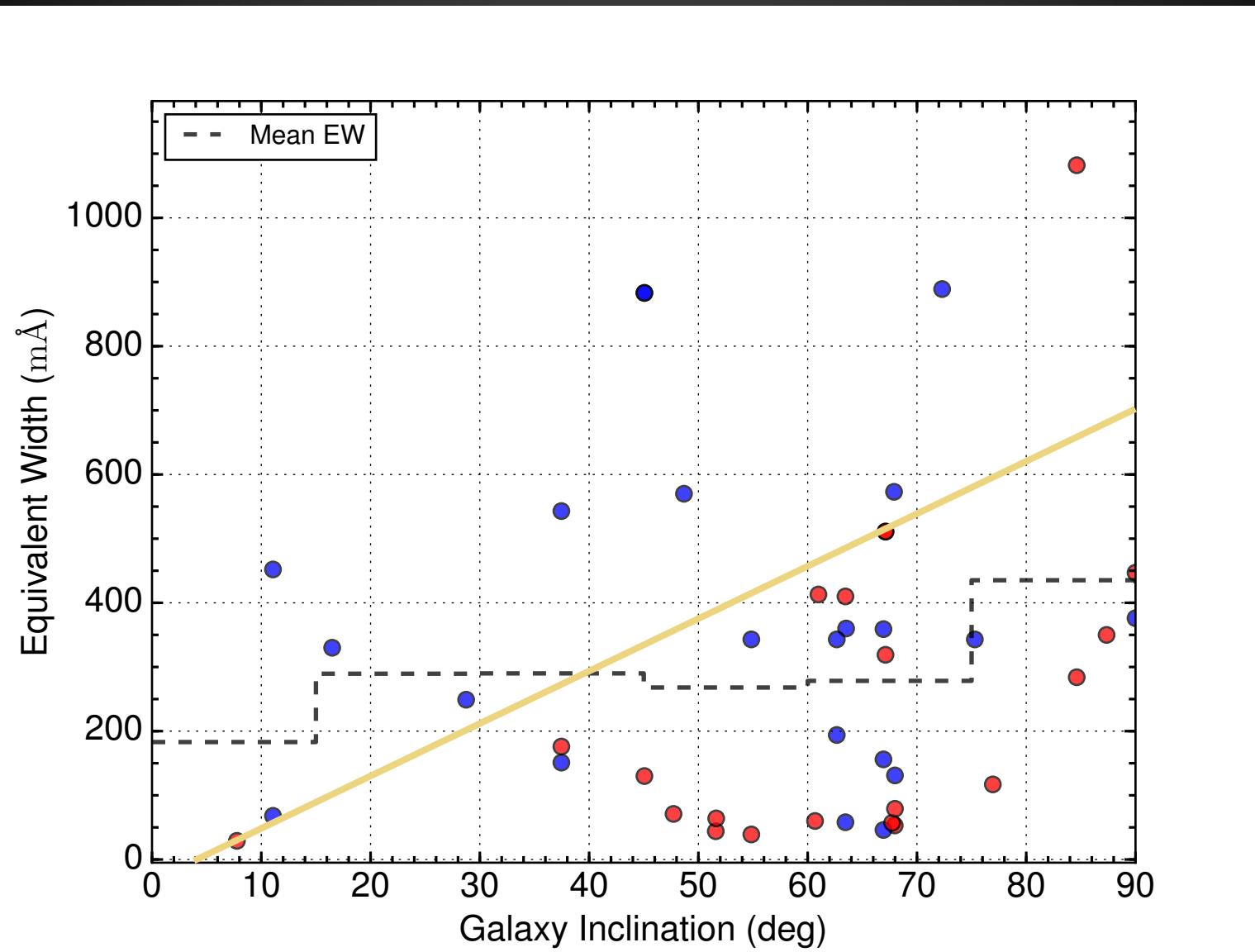
Maybe?



Galaxy Inclination



EW dichotomy



EW dichotomy

- Median EW(blueshifted) = $343 \pm 10 \text{ m}\text{\AA}$
- Average = $353 \pm 12 \text{ m}\text{\AA}$
- Median EW(redshifted) = $124 \pm 9 \text{ m}\text{\AA}$
- Average = $236 \pm 16 \text{ m}\text{\AA}$
- The difference: KS p-value = 0.04
- Why?
 - Inflows/outflows?
 - Rotation?

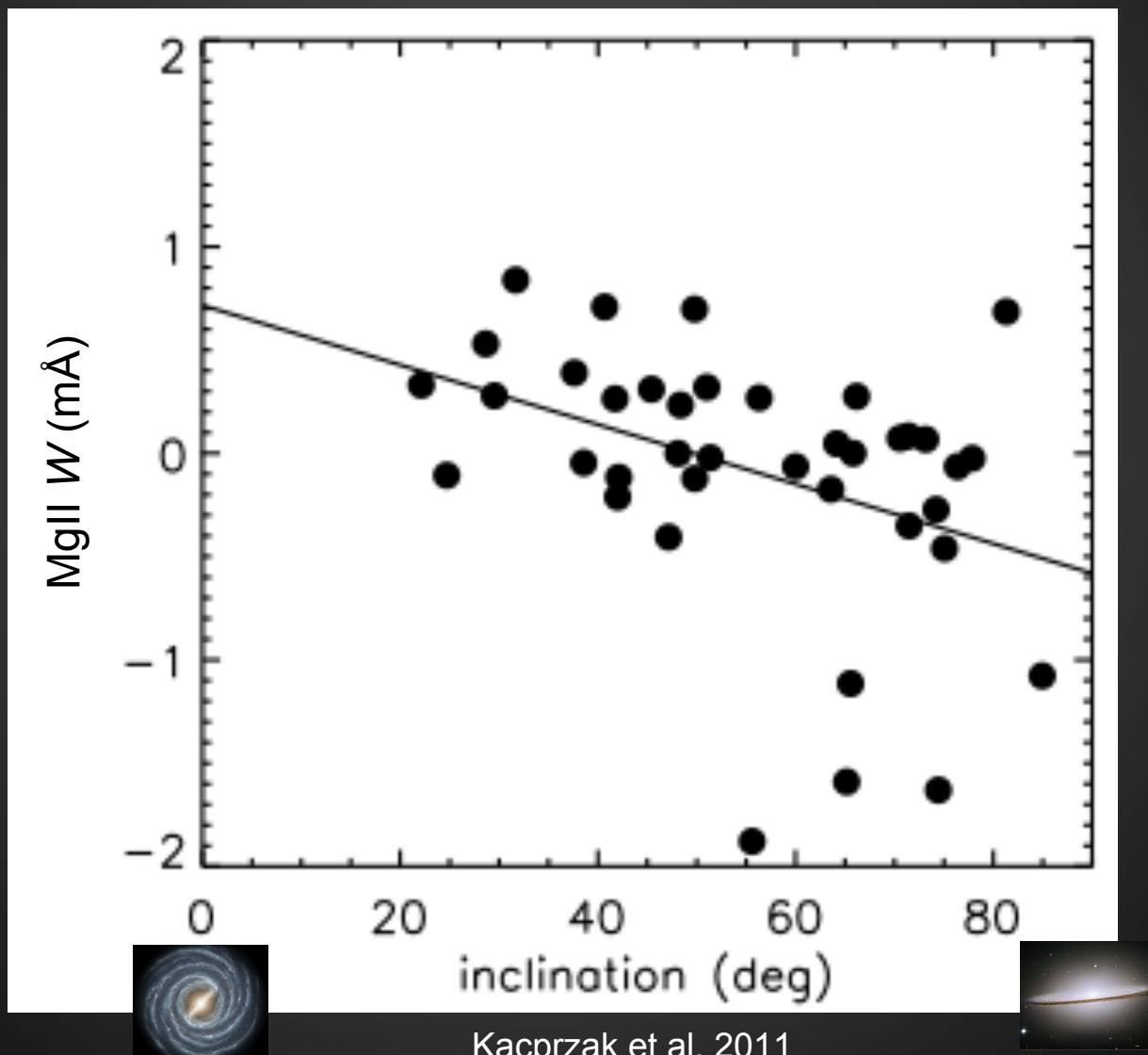
Summary:

- Define likelihood – a reproducible method for associating absorption with nearby galaxies
- EW – Impact parameter anti-correlation with R_{vir}
- Absorbers most commonly found near $p \sim 1.2 R_{vir}$
- Median EW increases with decreasing Δv
- Azimuth, inclination dependence is unclear
- Absorbers are more common near highly inclined galaxies
- Redshifted absorption weaker than blueshifted?

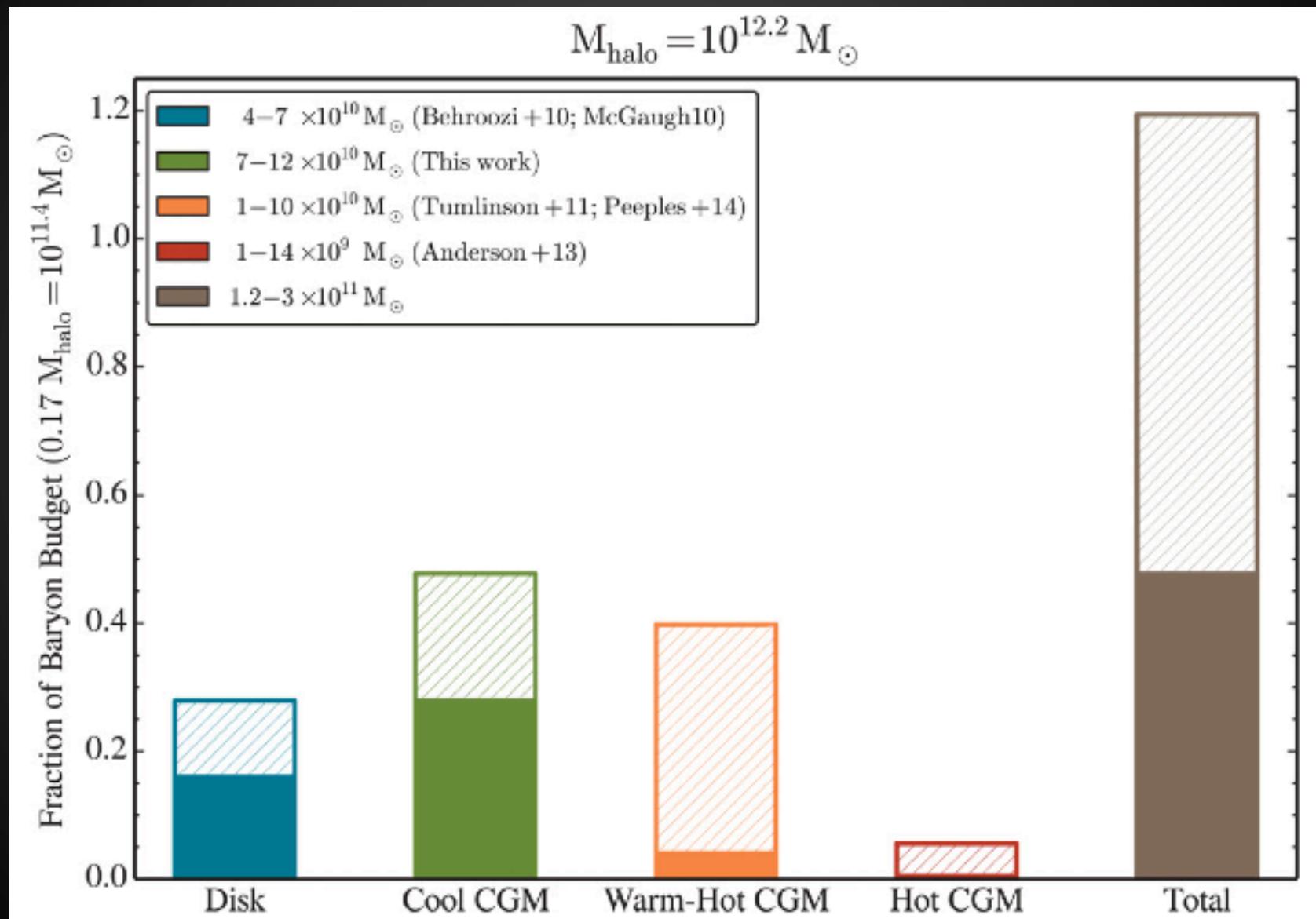
Questions?

How do CGM gas properties depend on galaxy inclination?

Maybe?

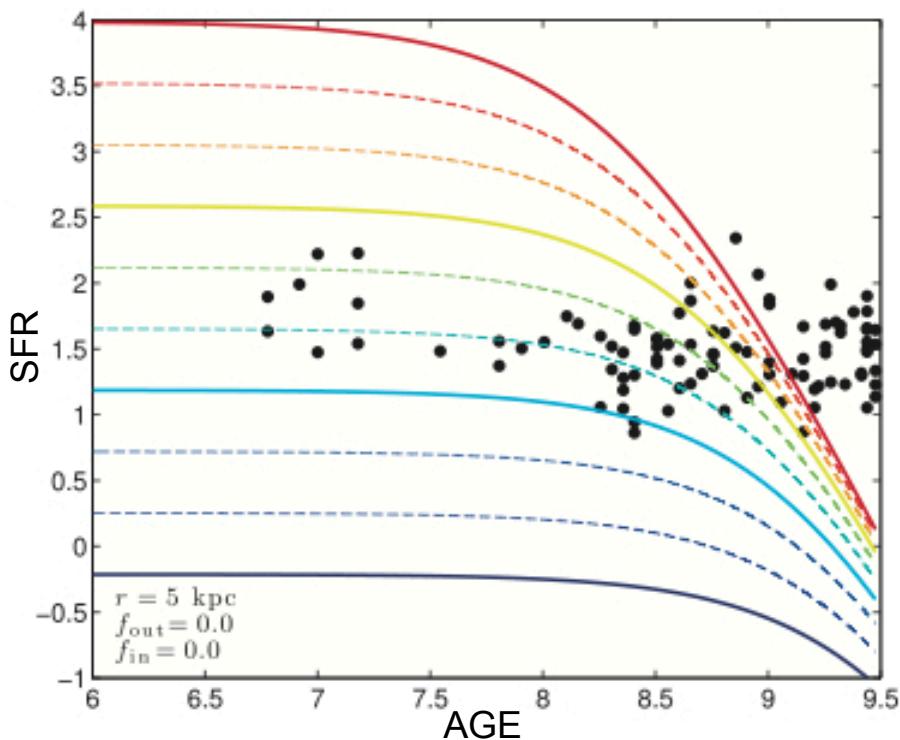


Baryon Budget

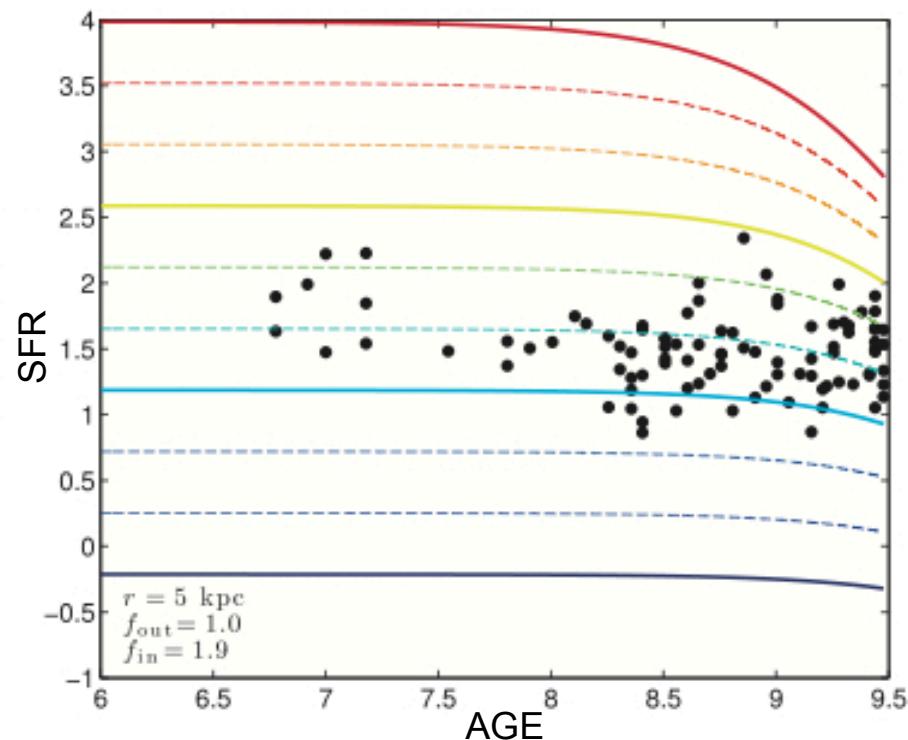


Accretion required

With no accretion



With accretion



Erb 2008

Associating galaxies with absorbers

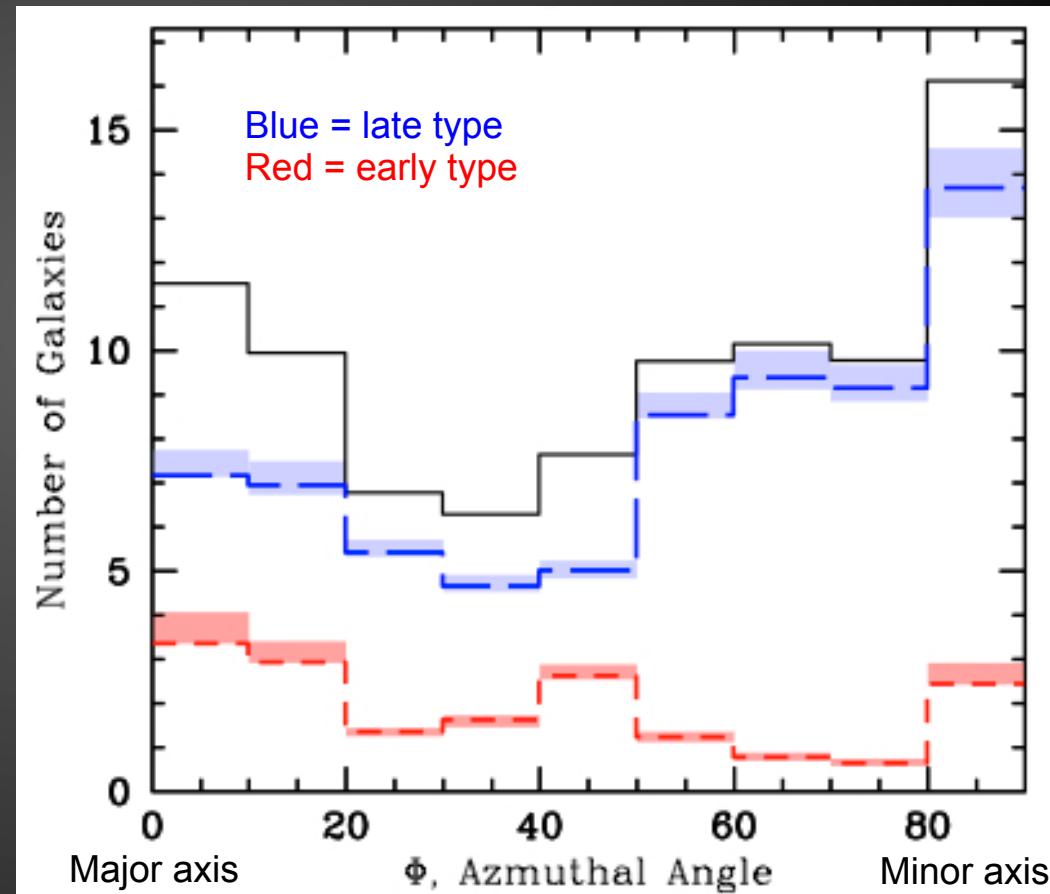
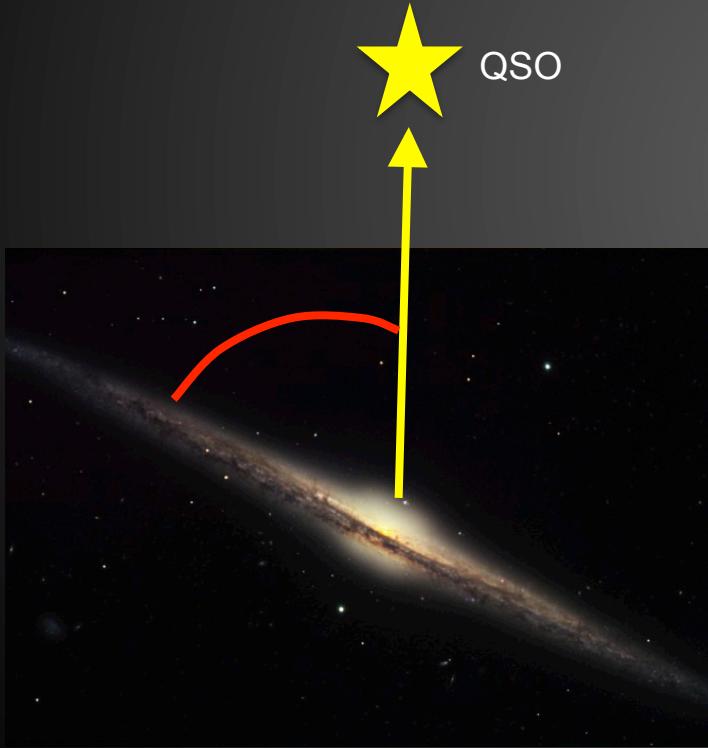
- Define a likelihood:

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

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

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

The gas nearby galaxies

- Gas and galaxies both follow DM potential
- Do they “know” about each other?
 - i.e. Do gas properties depend on galaxies?