

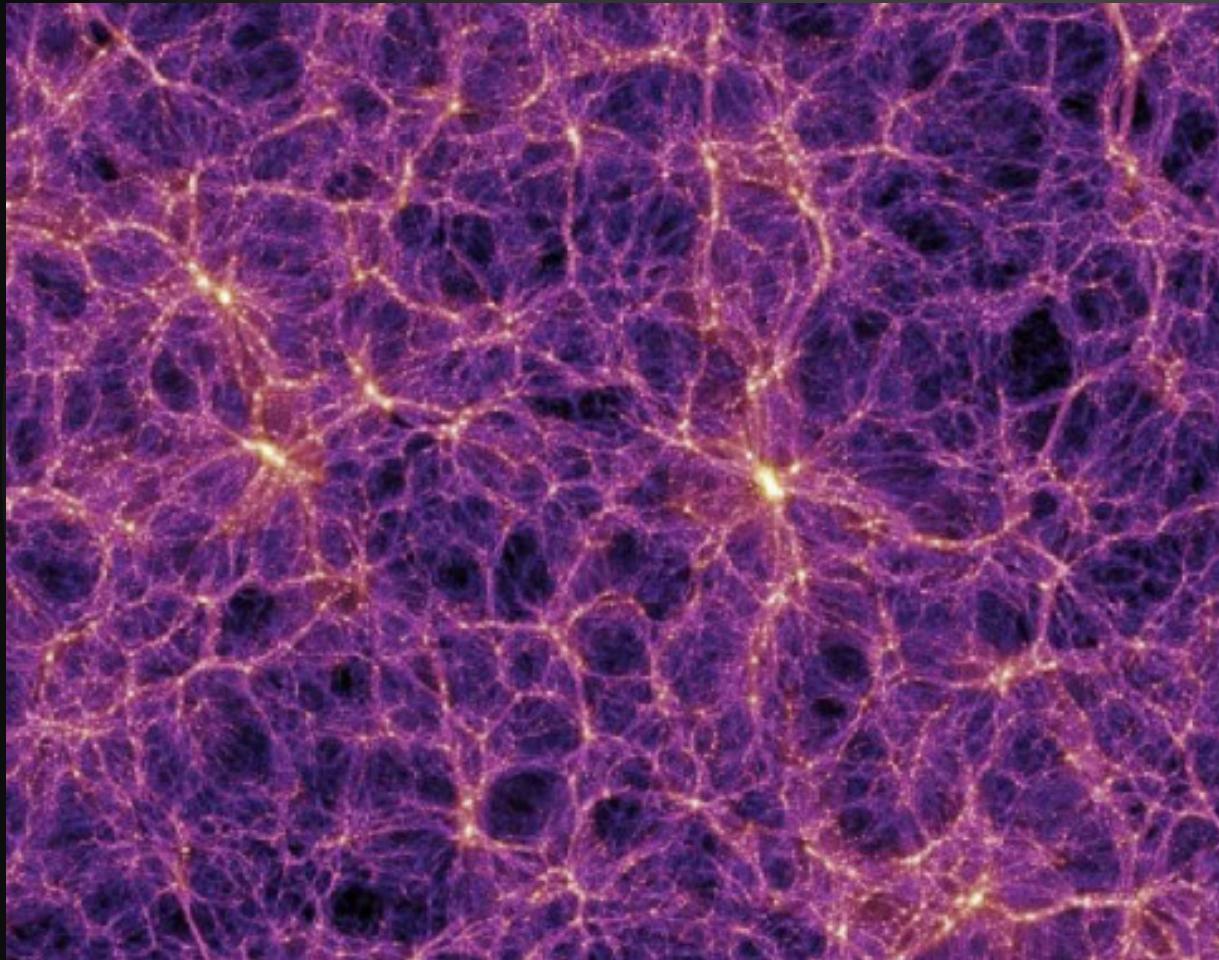
# Does the gas in the IGM care about galaxies?

*Tracing the Circumgalactic Medium in Ly $\alpha$  with COS*

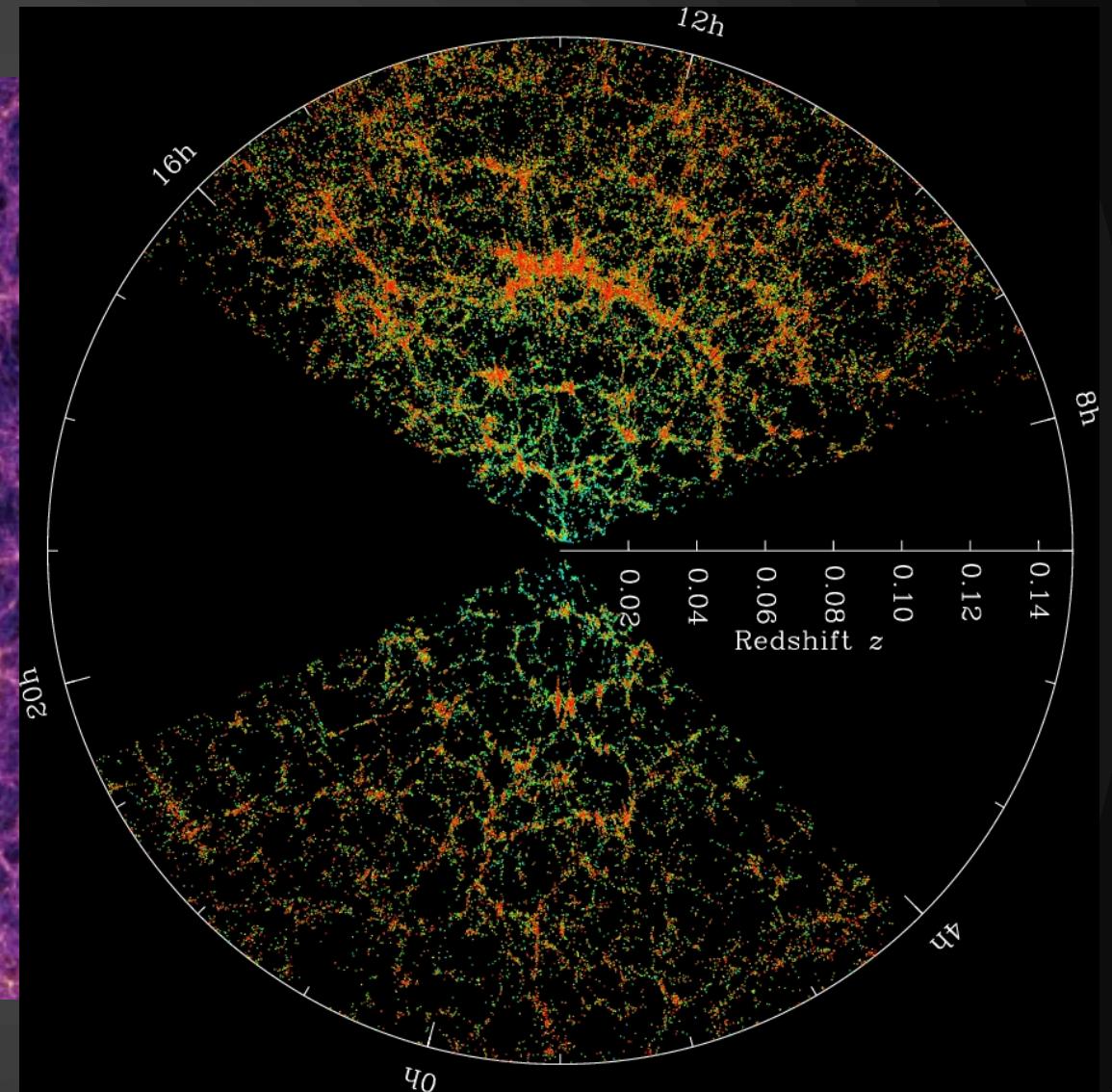
David M. French

Thesis Advisor: Bart Wakker  
University of Wisconsin - Madison  
Jan 11, 2018

# Gas + galaxies trace the same potential



The Millenium Simulation



SDSS Collaboration

# Does the gas care about the galaxies?

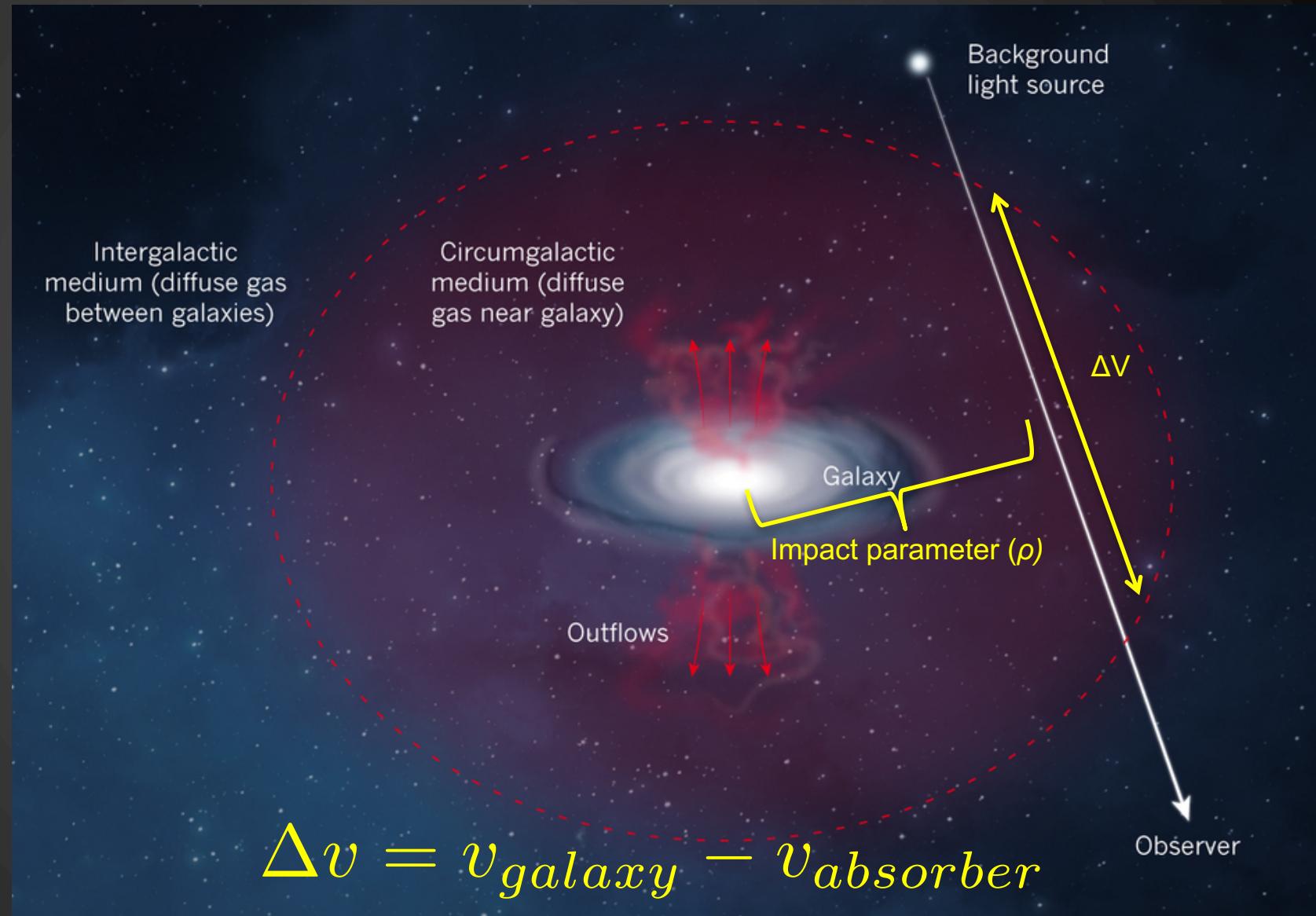
- Gas and galaxies follow the same DM potential
- Galaxies need to continue accreting gas over cosmic time to match observations
- Feedback kicks gas out of galaxies



★ How do the properties of halo gas correlate with nearby galaxy properties?

# Probing the CGM with QSO absorption

- Relying on serendipitous QSO locations
- Build a sample of single galaxy-QSO pairs
- Impact parameter and  $\Delta V$  give absorber position



# Science Outline

- Stay close ( $z < 0.034$ ,  $cz < 10,000$  km/s)
  - *Available galaxy data complete to  $\sim 0.2 L^*$*
- Use archival COS sightlines ( $\sim 700$ )
  - *Find Ly $\alpha$ , associate with galaxy environment*
- Automate associating galaxies – absorbers
- Ask:
  - absorber (EW, N(HI), velocity)  
as a function of
  - galaxy (impact parameter, size, orientation)

# Science Outline

- Use archival COS sightlines (~700)
  - Concentrating on Ly-alpha lines
- Correlate with galaxy environment
  - Limit search to  $cz < 10,000 \text{ km/s}$
- Ask
  - absorber(EW, velocity) vs galaxy properties (size, proximity, orientation)

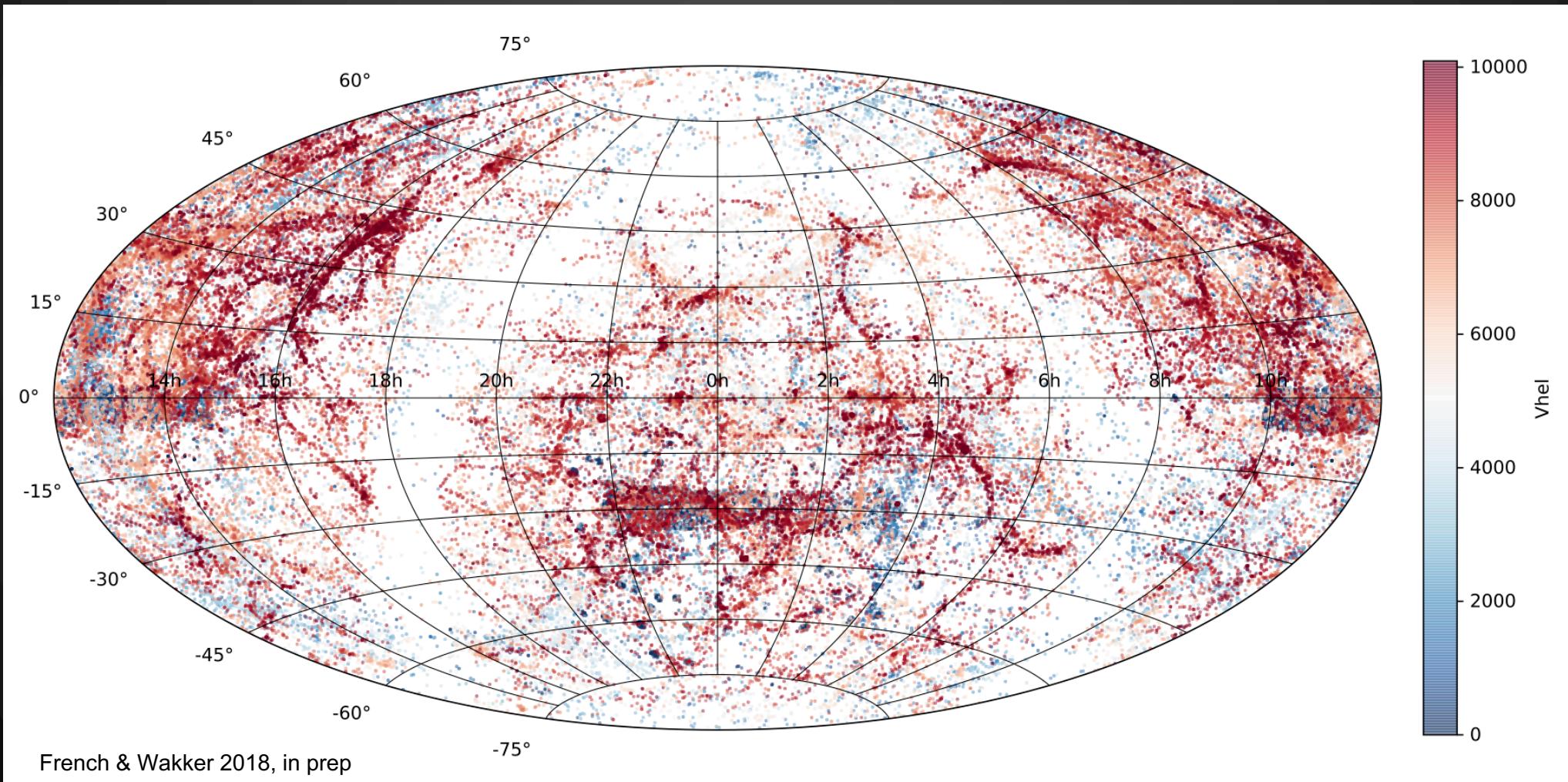
# Science Outline

- Use archival COS sightlines (~700)
- Find Ly $\alpha$ , associate with galaxy environment
- Ask:
  - absorber properties (EW, N(HI), velocity)  
as a function of  
galaxy properties (impact parameter, size, orientation)

# First – New Nearby Galaxy Catalog

Gather and homogenize existing galaxy data

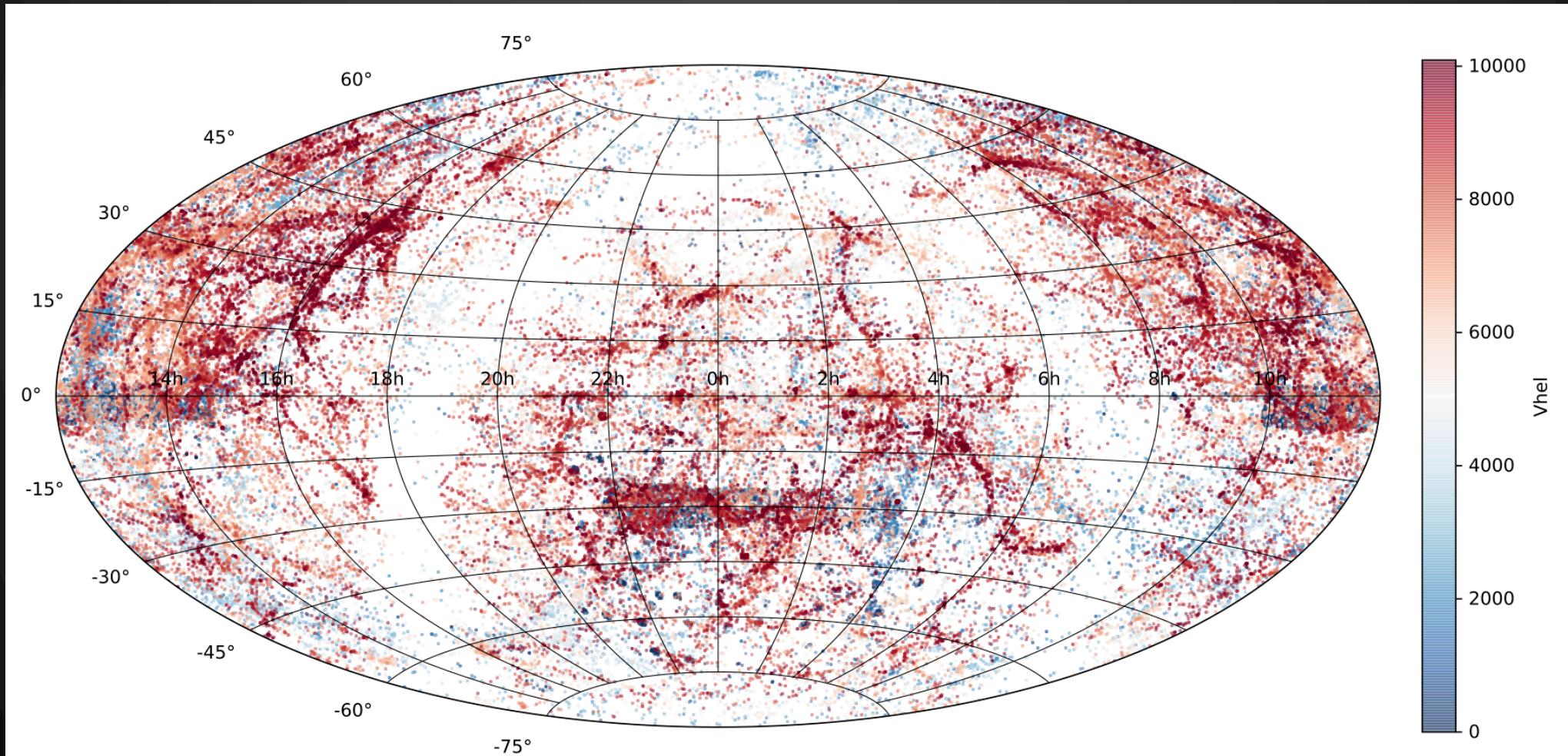
- NED + IRSA
- 130,000+ galaxies with  $cz < 10,000$  km/s



# New Nearby Galaxy Catalog

## Homogenize existing data

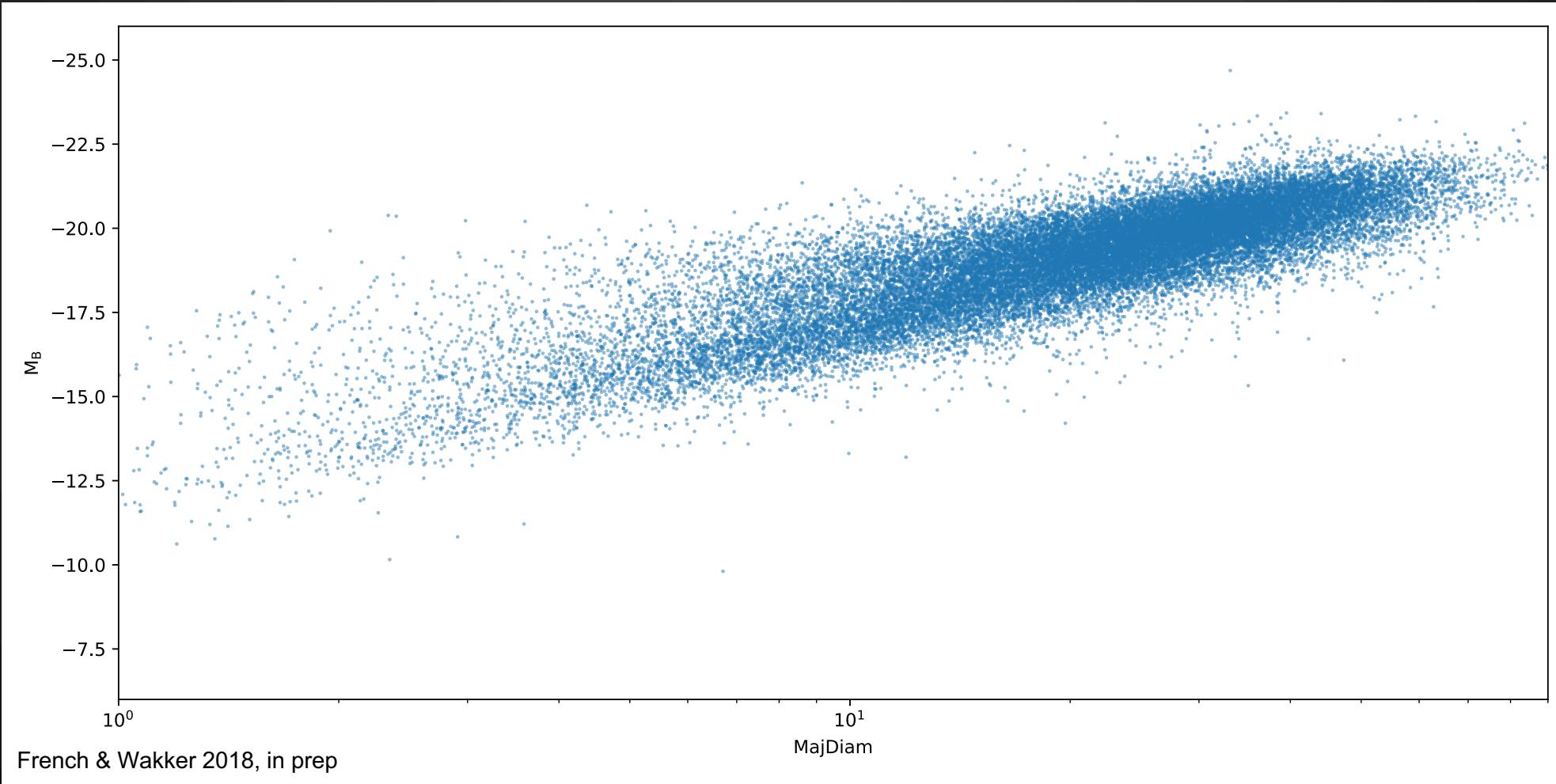
- Normalize diameters, inclination, PA to 2MASS values
- Choose magnitudes, calculate ( $L^*$ ,  $R_{vir}$ )



# New Nearby Galaxy Catalog

## Homogenize existing data

- Normalize diameters, inclination, PA to 2MASS values
- Choose magnitudes, calculate ( $L^*$ ,  $R_{vir}$ )

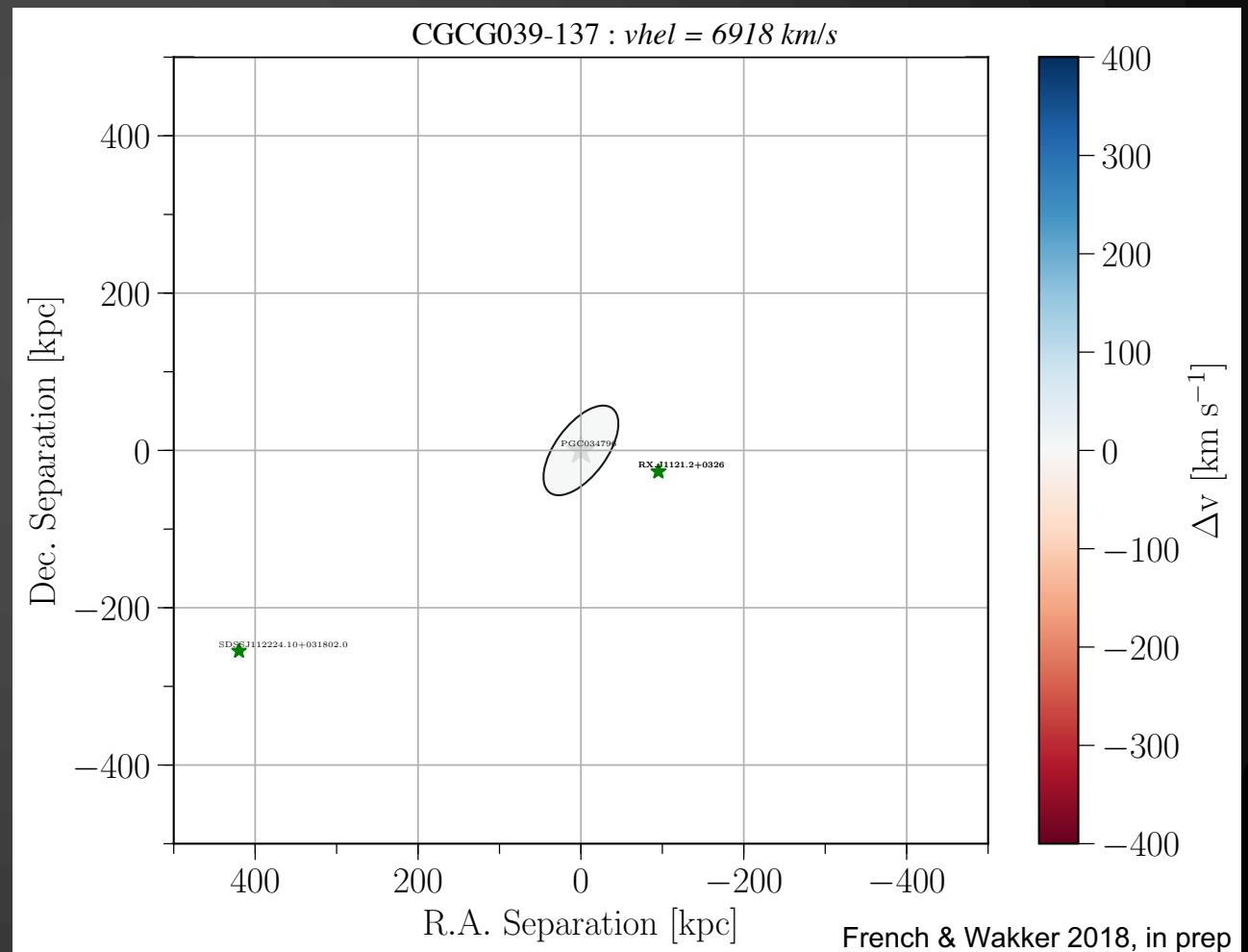


# Step 2

**Model the velocity structure probed by a QSO sightline**

# Model sightline velocity structure

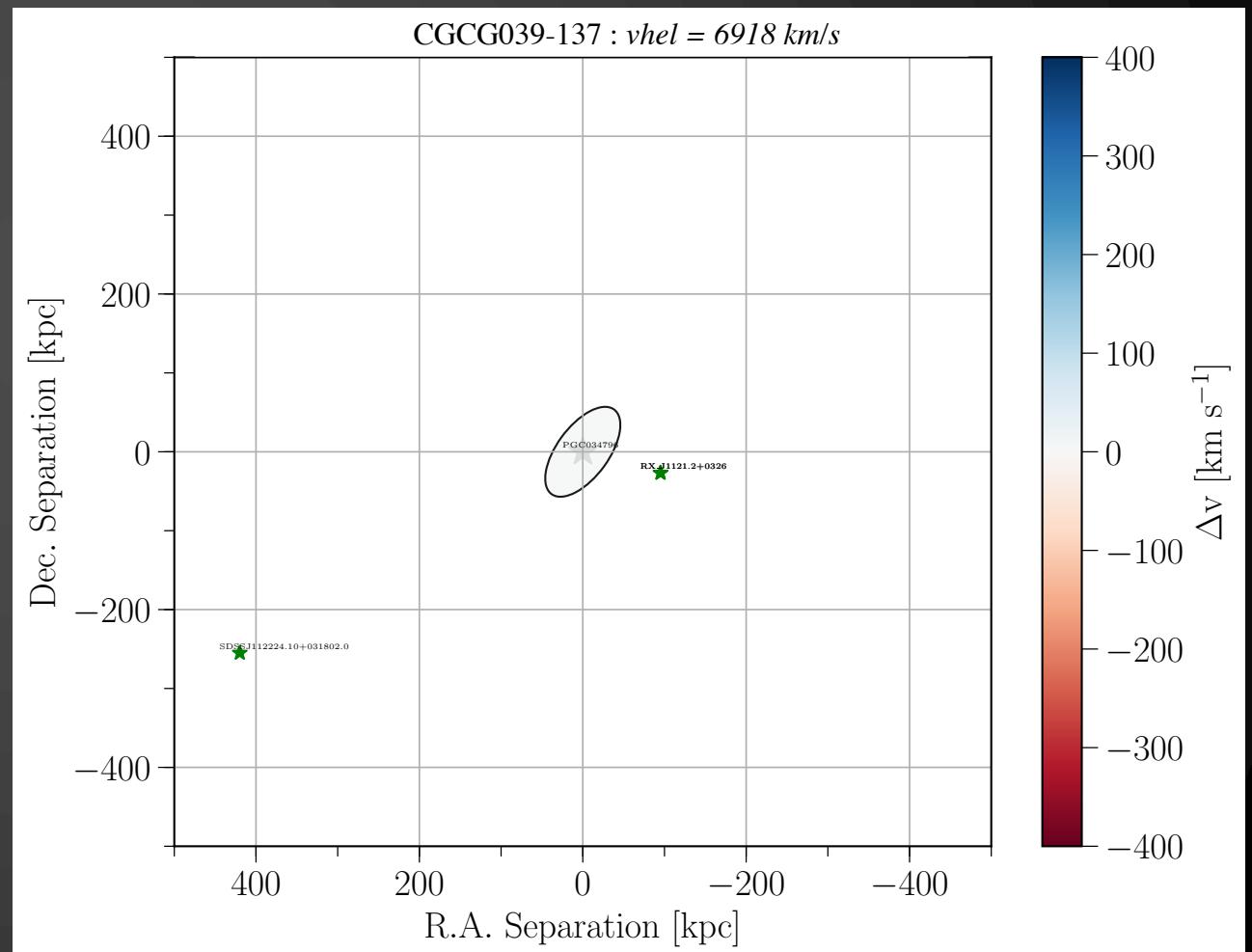
- Is there Halo – disk kinematic connection?



# Step 2

## The halo – disk kinematic connection

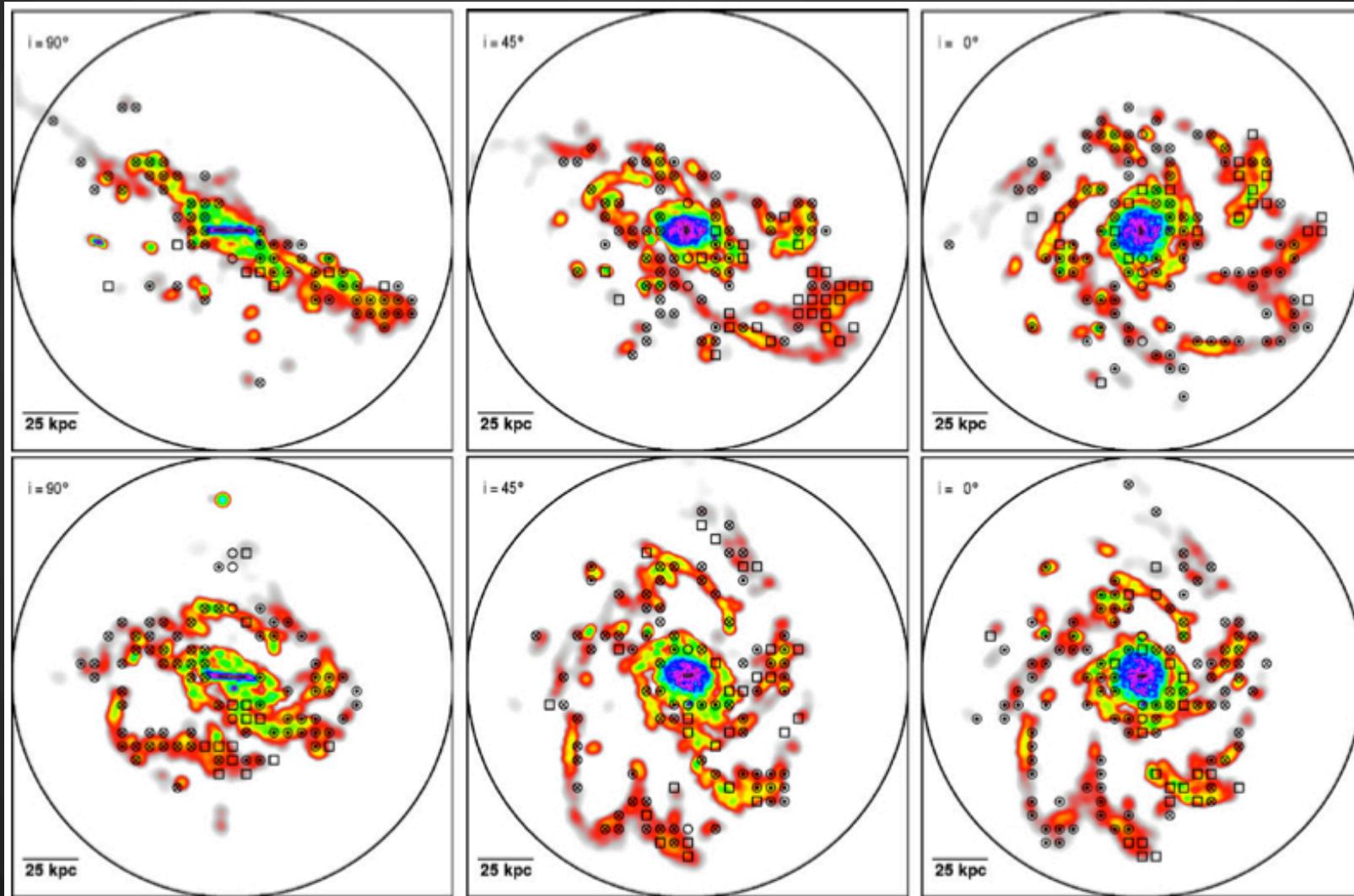
- Model the sightline velocity



# Step 2

## The halo – disk kinematic connection

- Is there one?

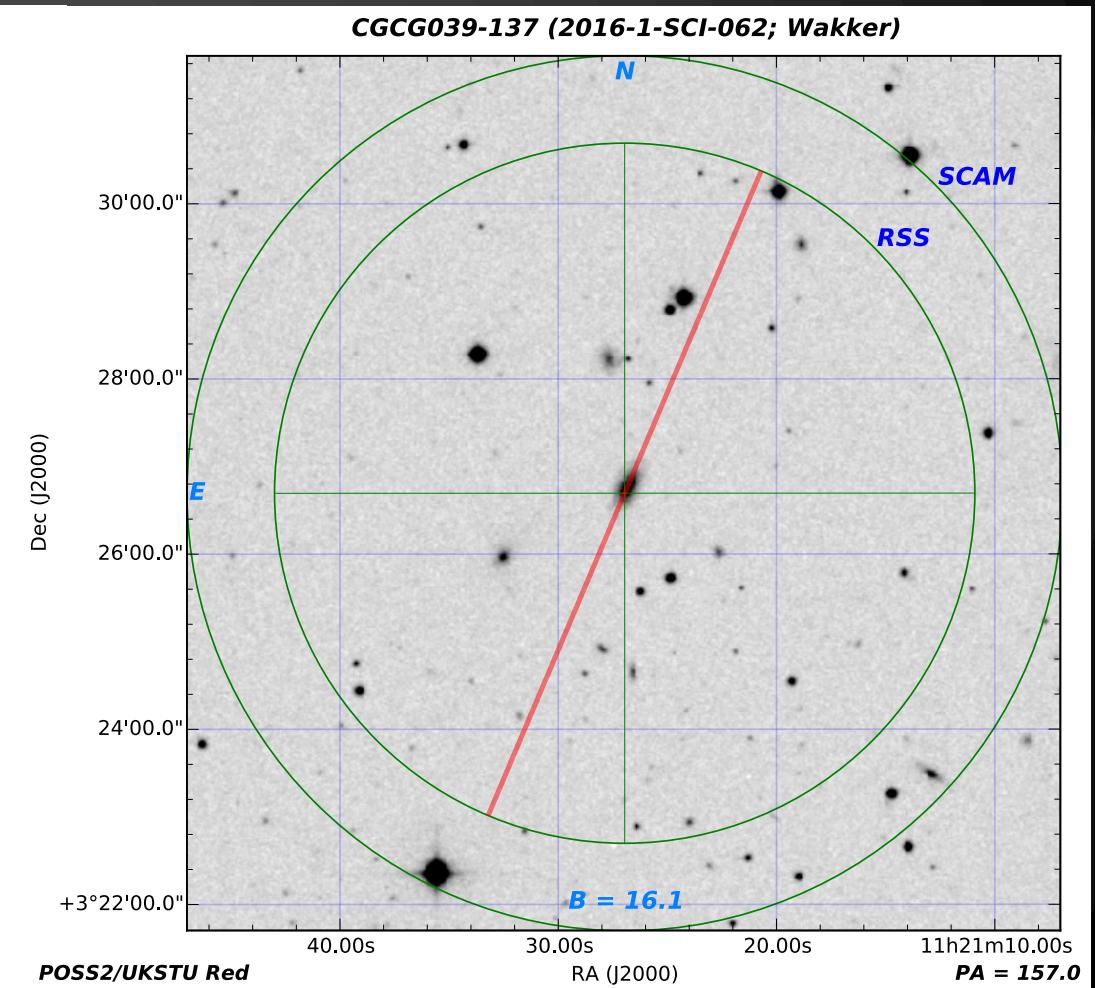
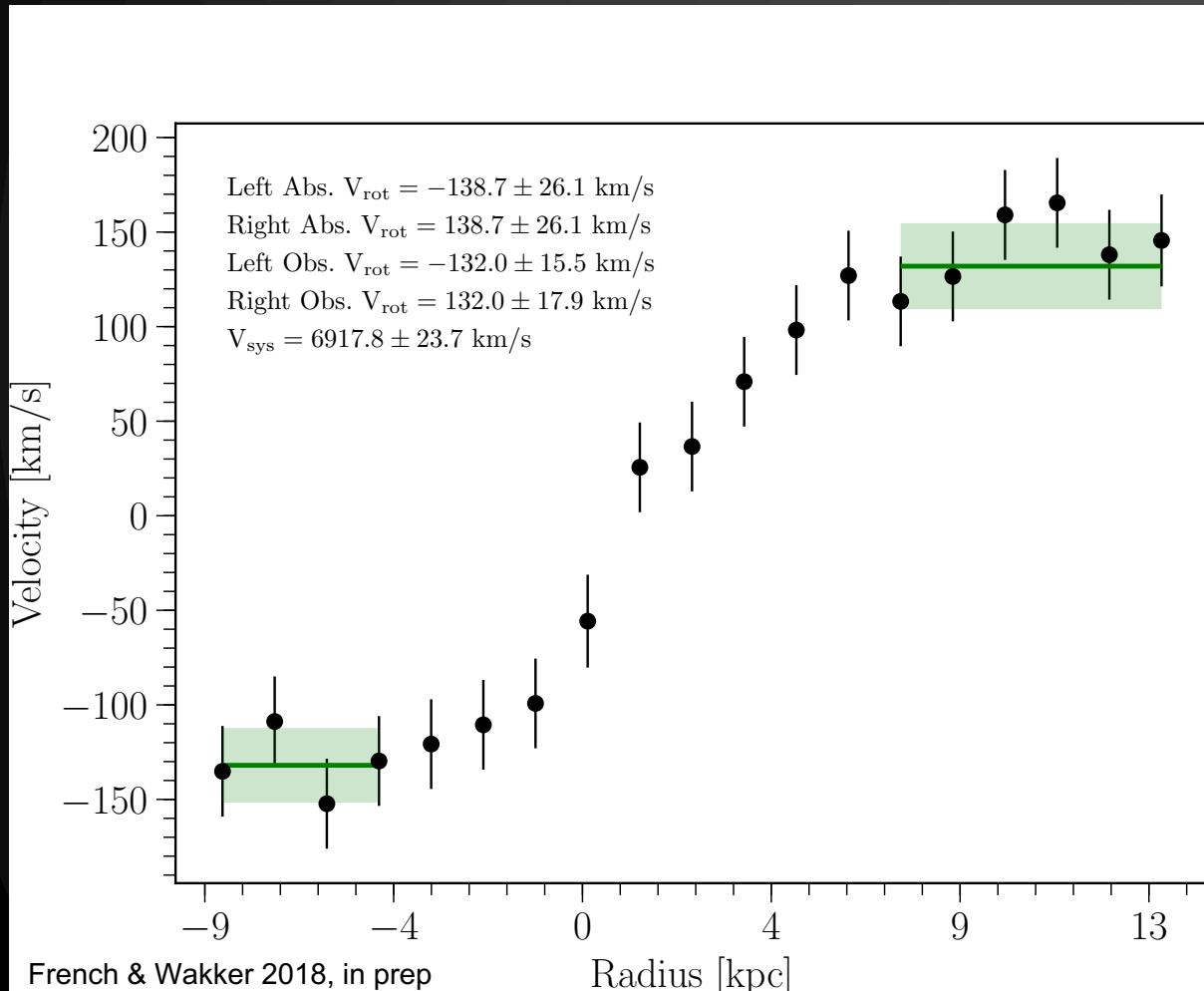


Stewart+ 2011

# Model sightline velocity structure

## The halo – disk kinematic connection

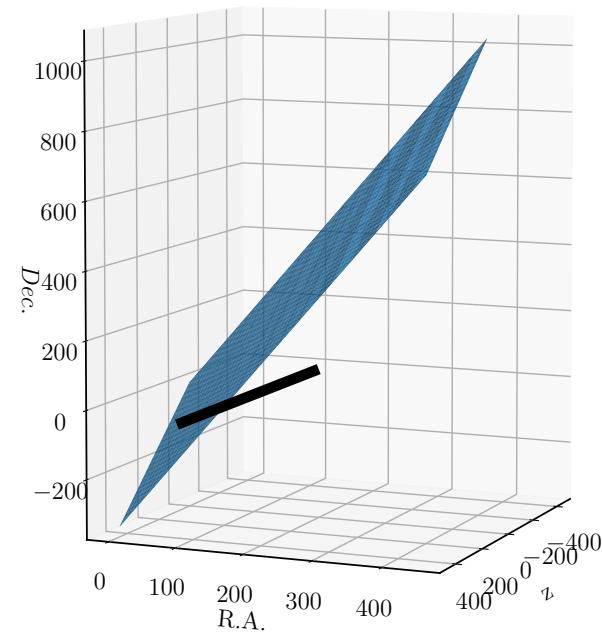
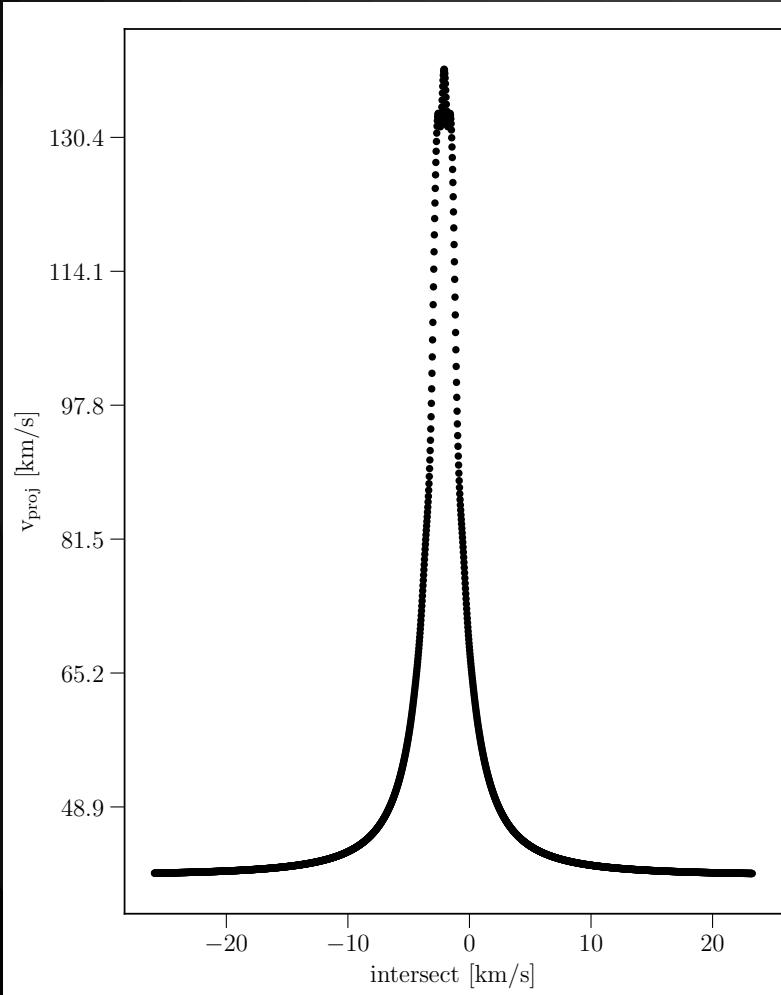
- Rotation curves from SALT



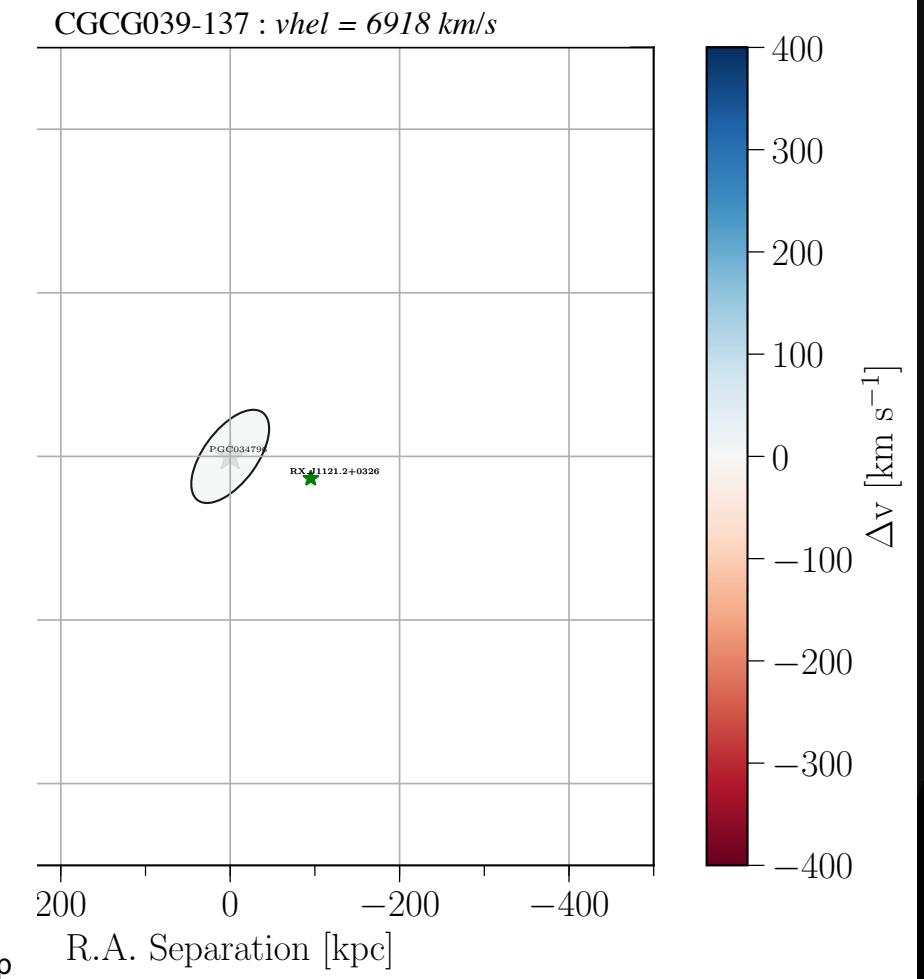
# Model sightline velocity structure

## The halo – disk kinematic connection

- Model the sightline velocity



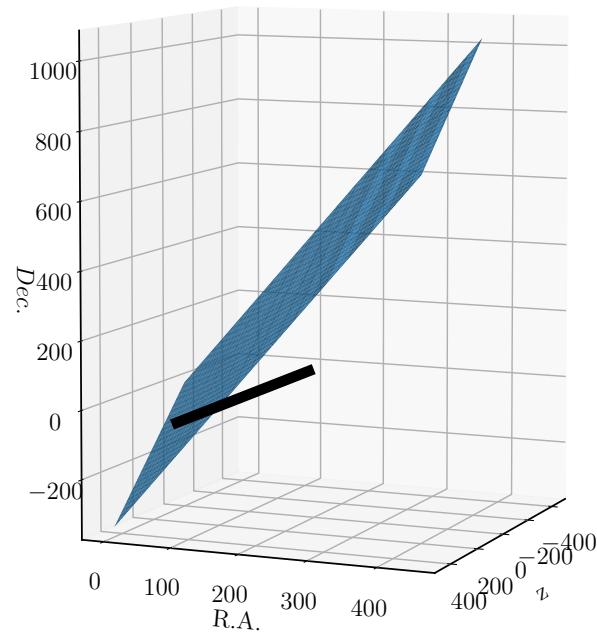
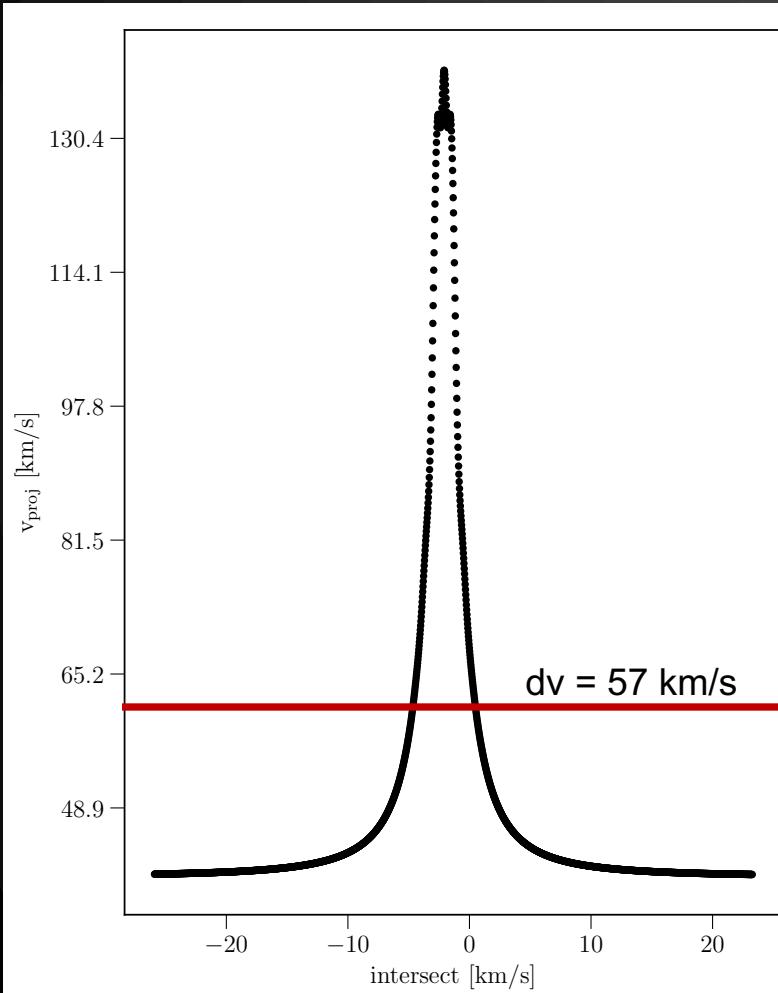
French & Wakker 2018, in prep



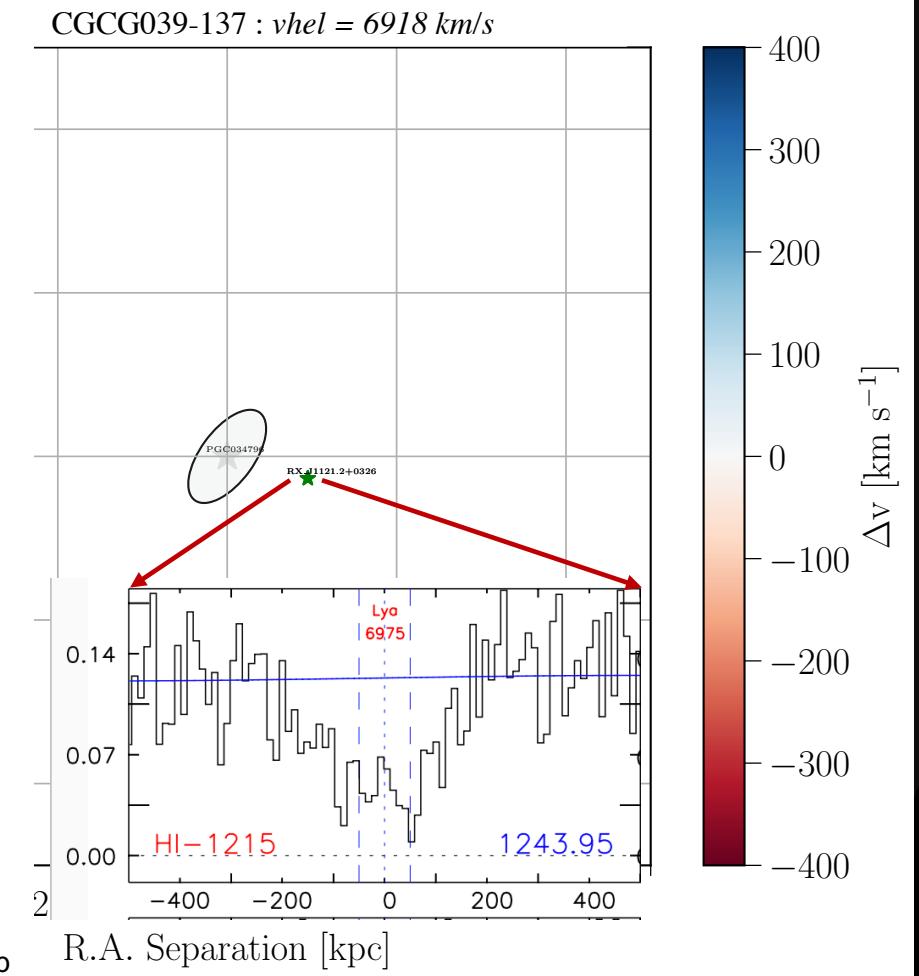
# Model sightline velocity structure

## The halo – disk kinematic connection

- Model the sightline velocity

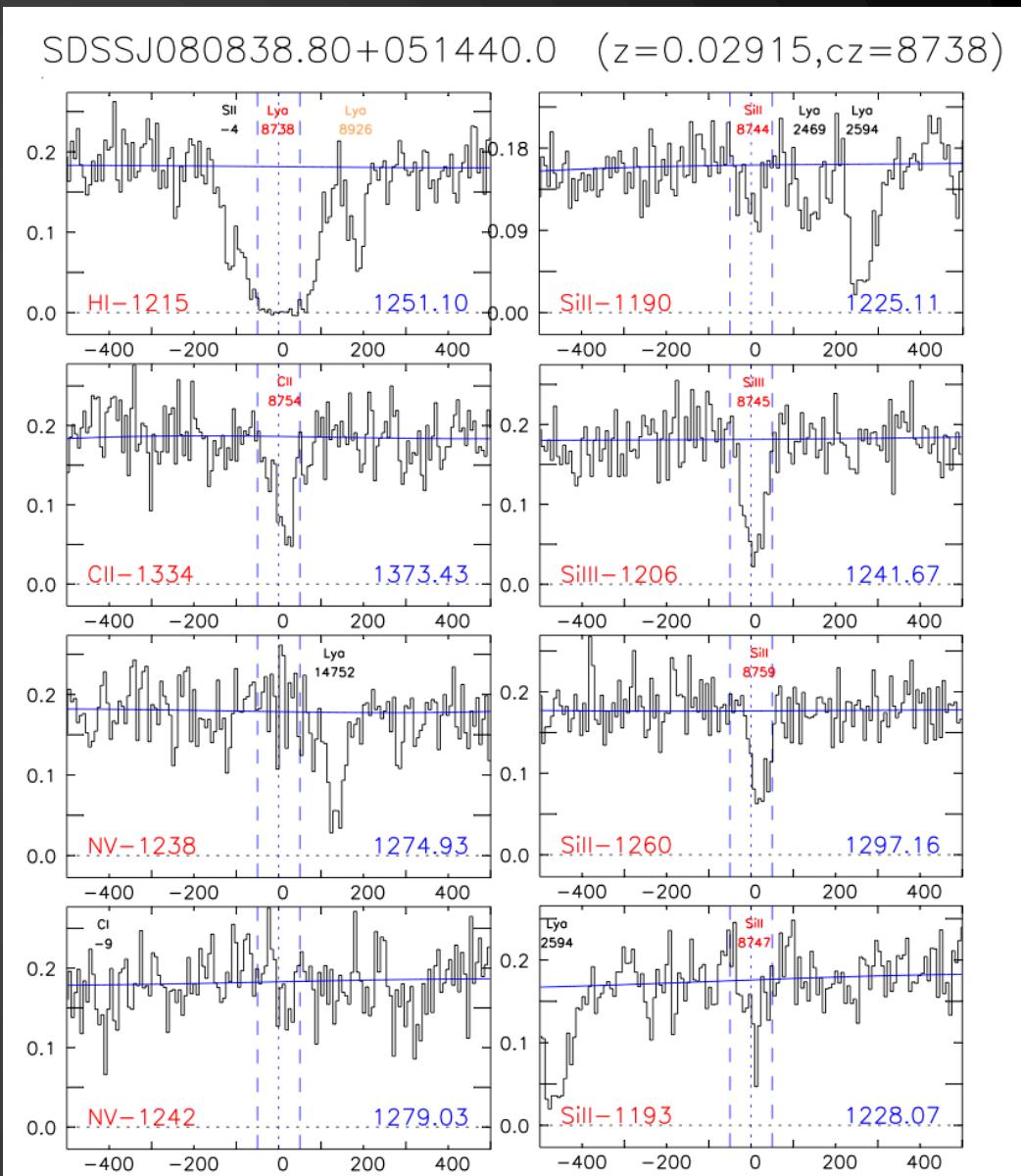


French & Wakker 2018, in prep



# Catalog the absorbers

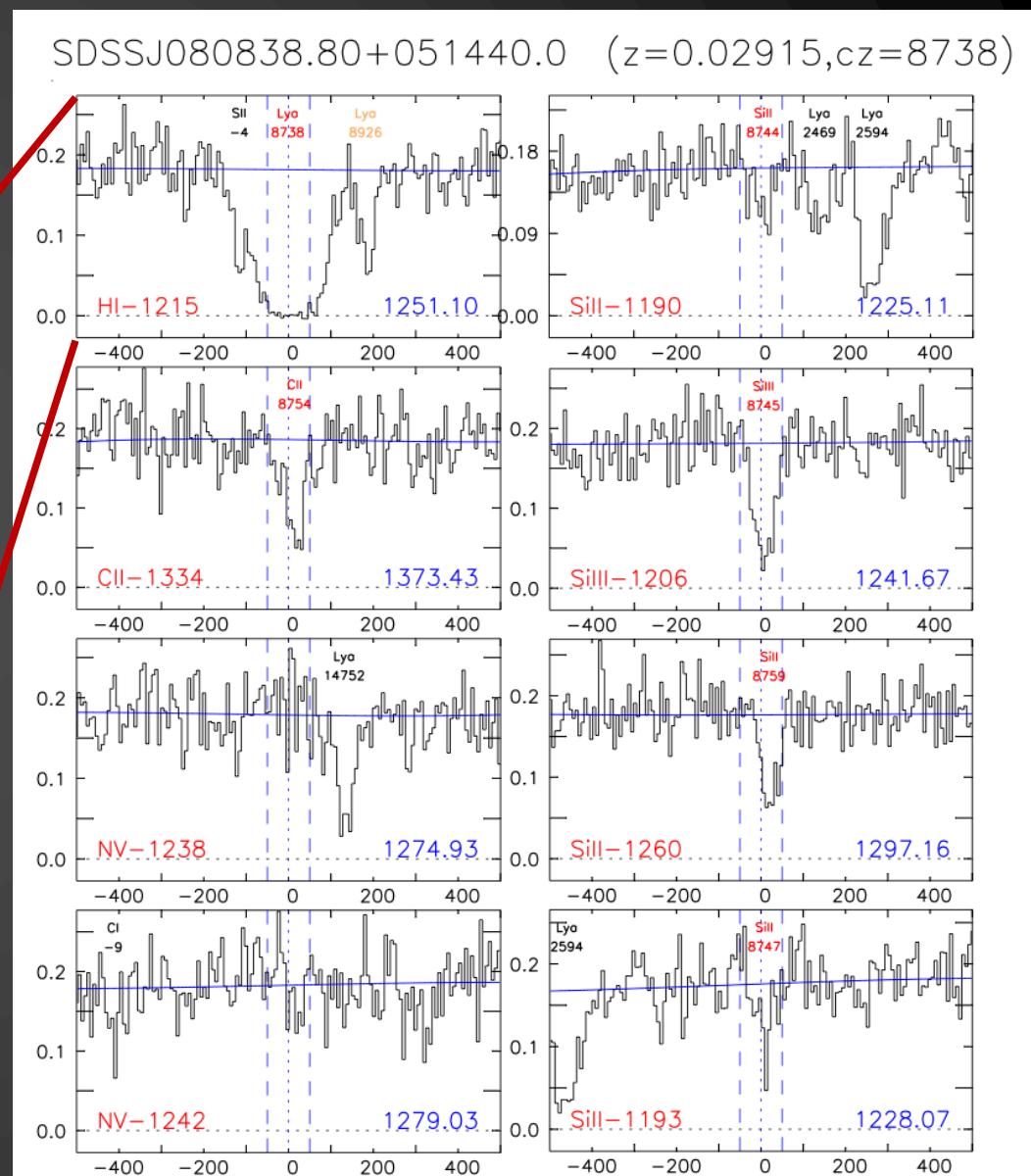
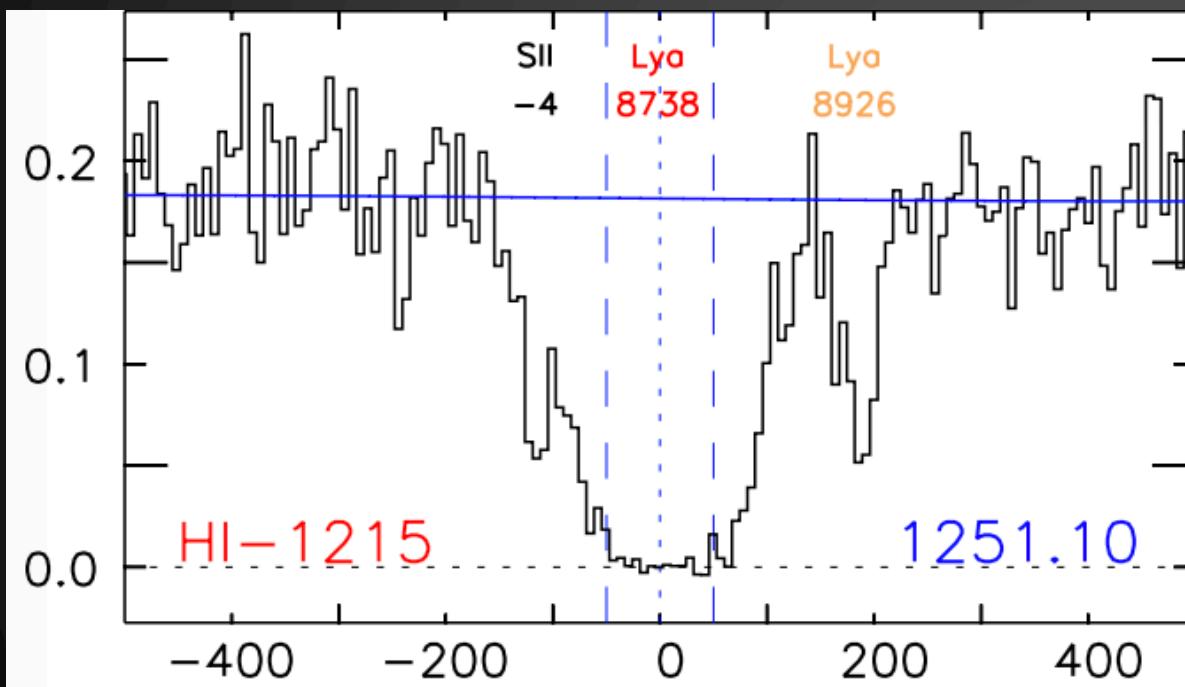
- 700+ G130M COS targets
  - Align, identify and measure all lines



# Catalog the absorbers

- Connecting with galaxies

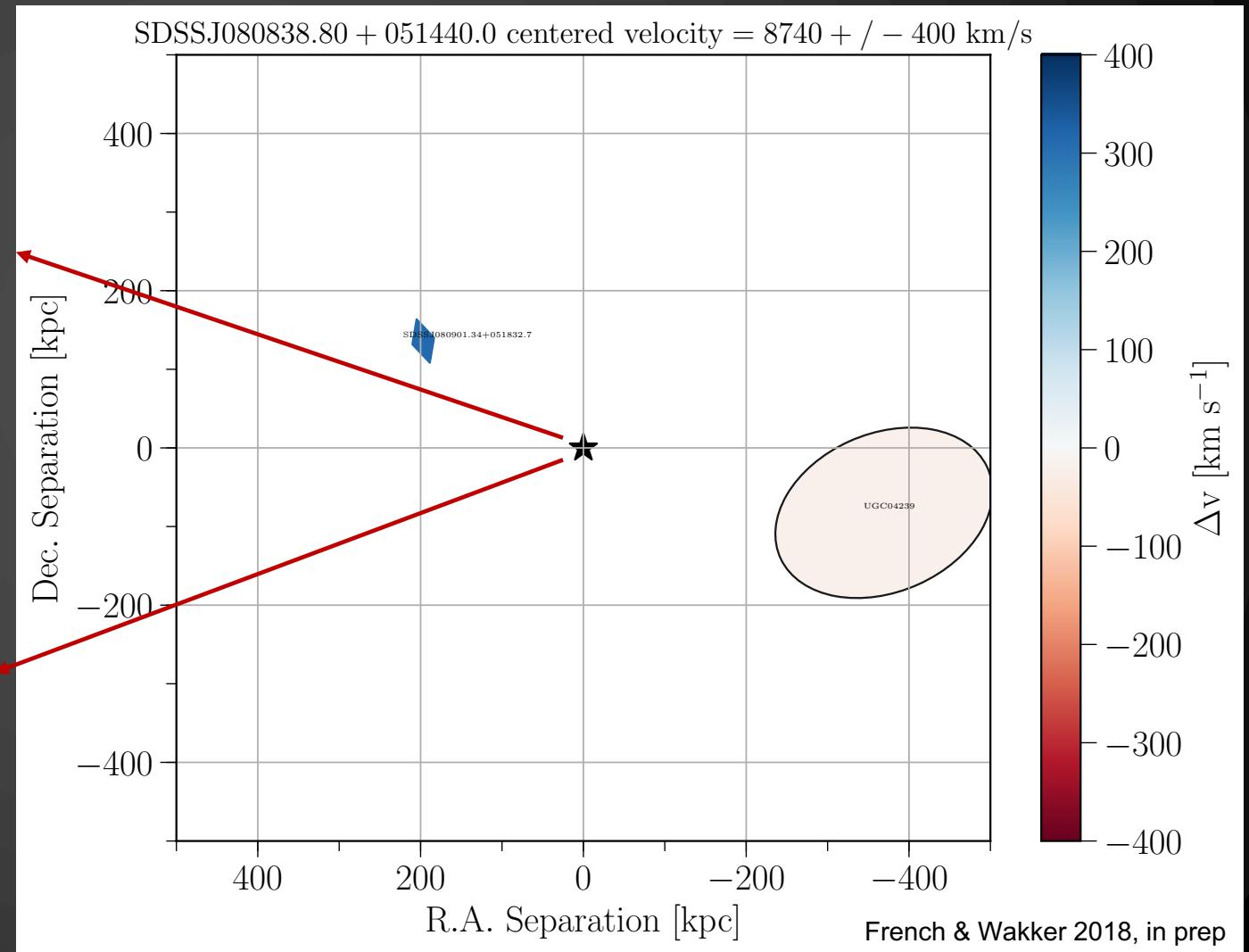
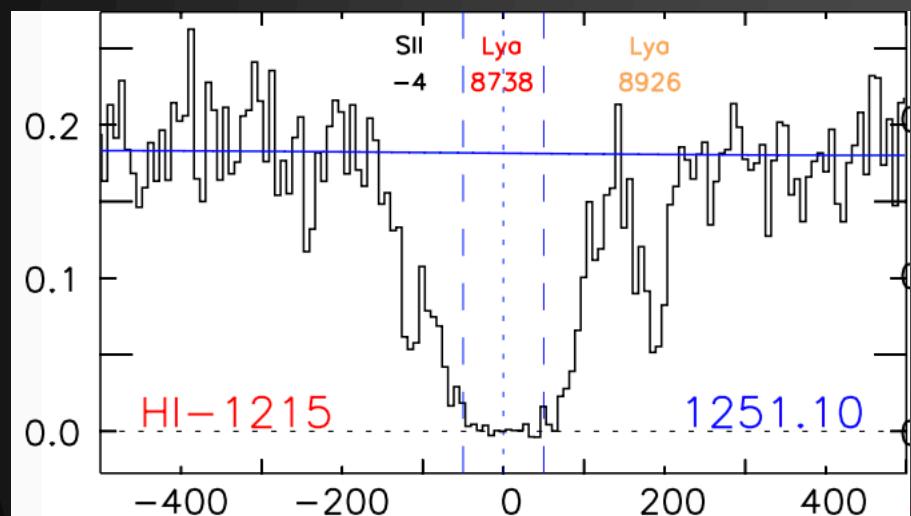
- How?



# Catalog the absorbers

Connecting with galaxies – using our galaxy catalog

- Which one?



# Matching absorbers with galaxies

Define an objective likelihood parameter

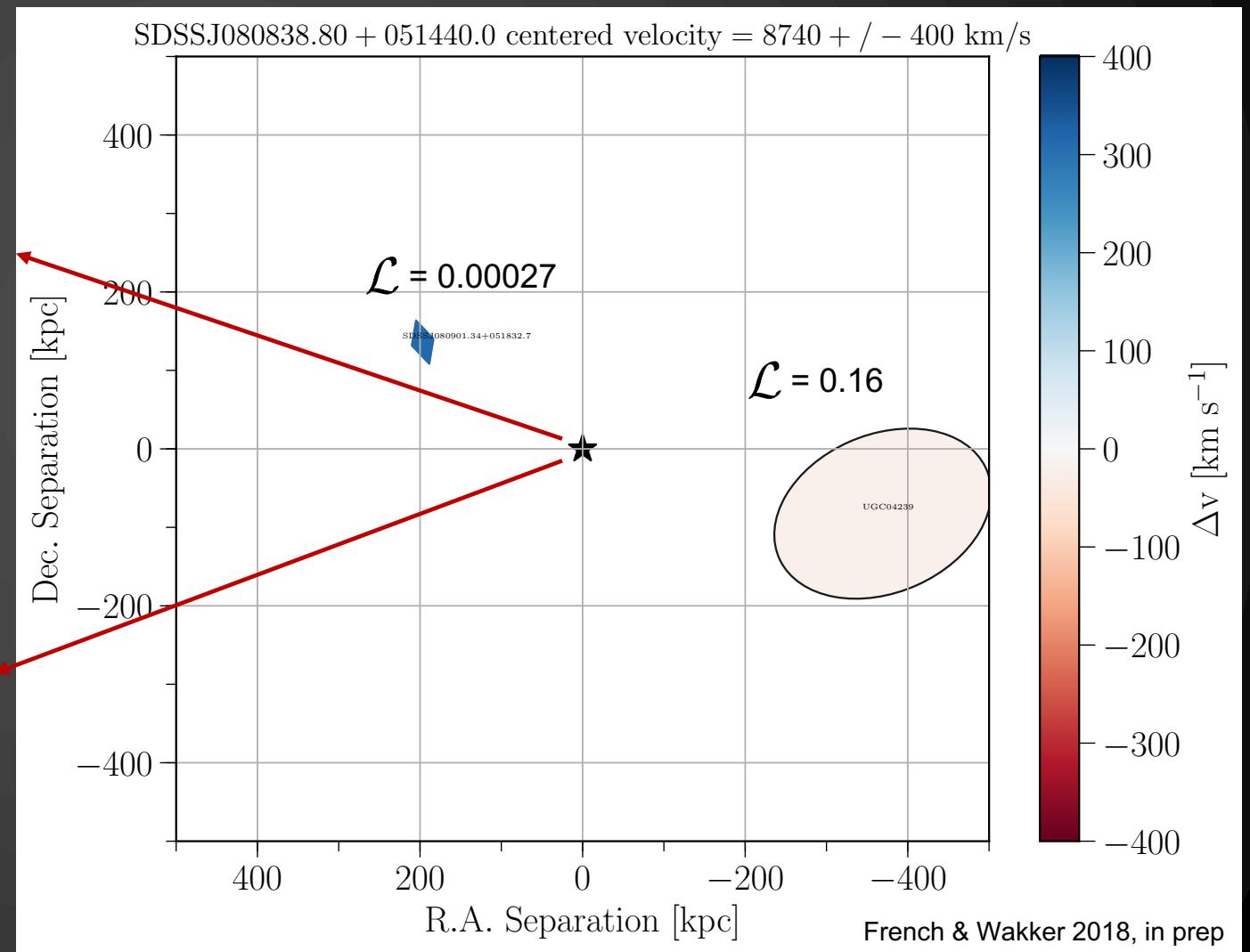
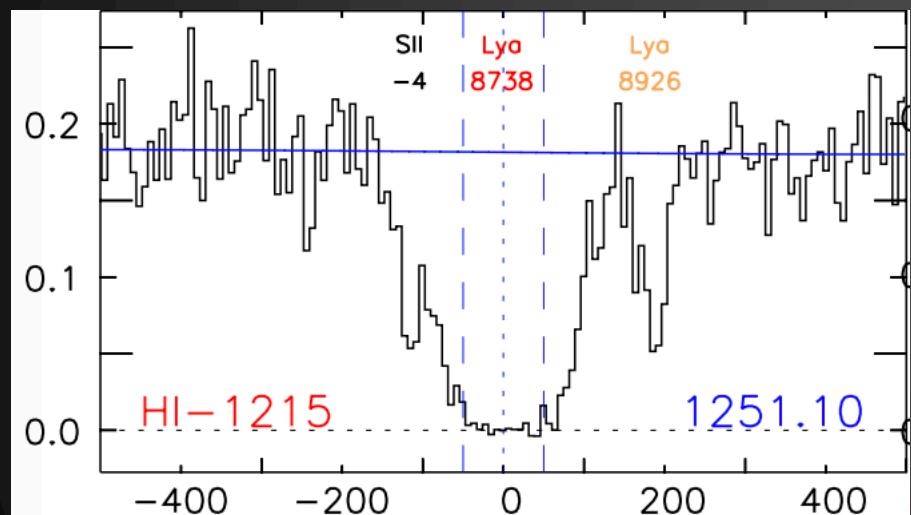
- Define a likelihood:

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

- $\rho$  = impact parameter
- $\Delta v = v_{galaxy} - v_{absorber}$
- $R_{vir}$  = viral radius of the galaxy

# Matching absorbers with galaxies

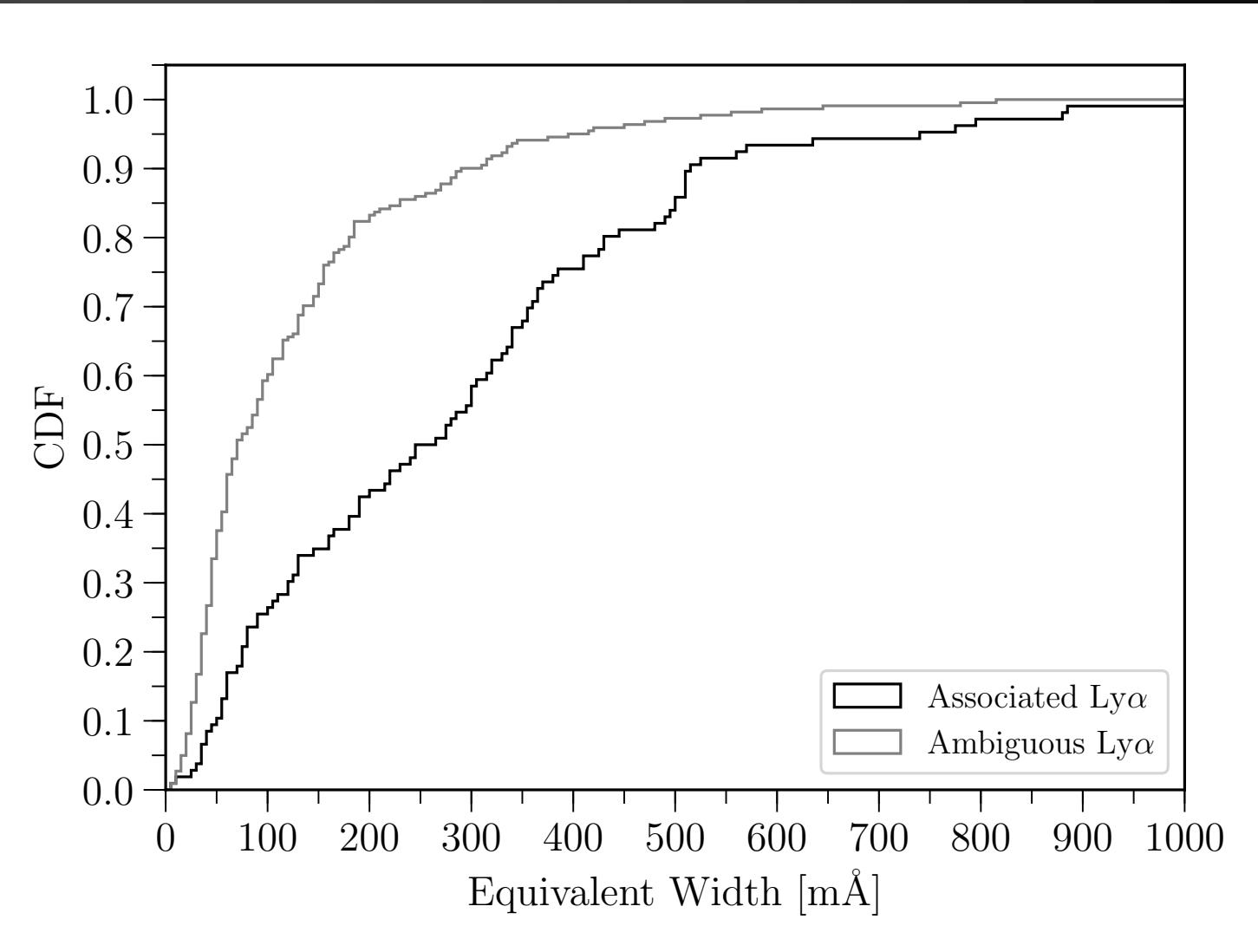
## Applying the likelihood method



# Preliminary Results

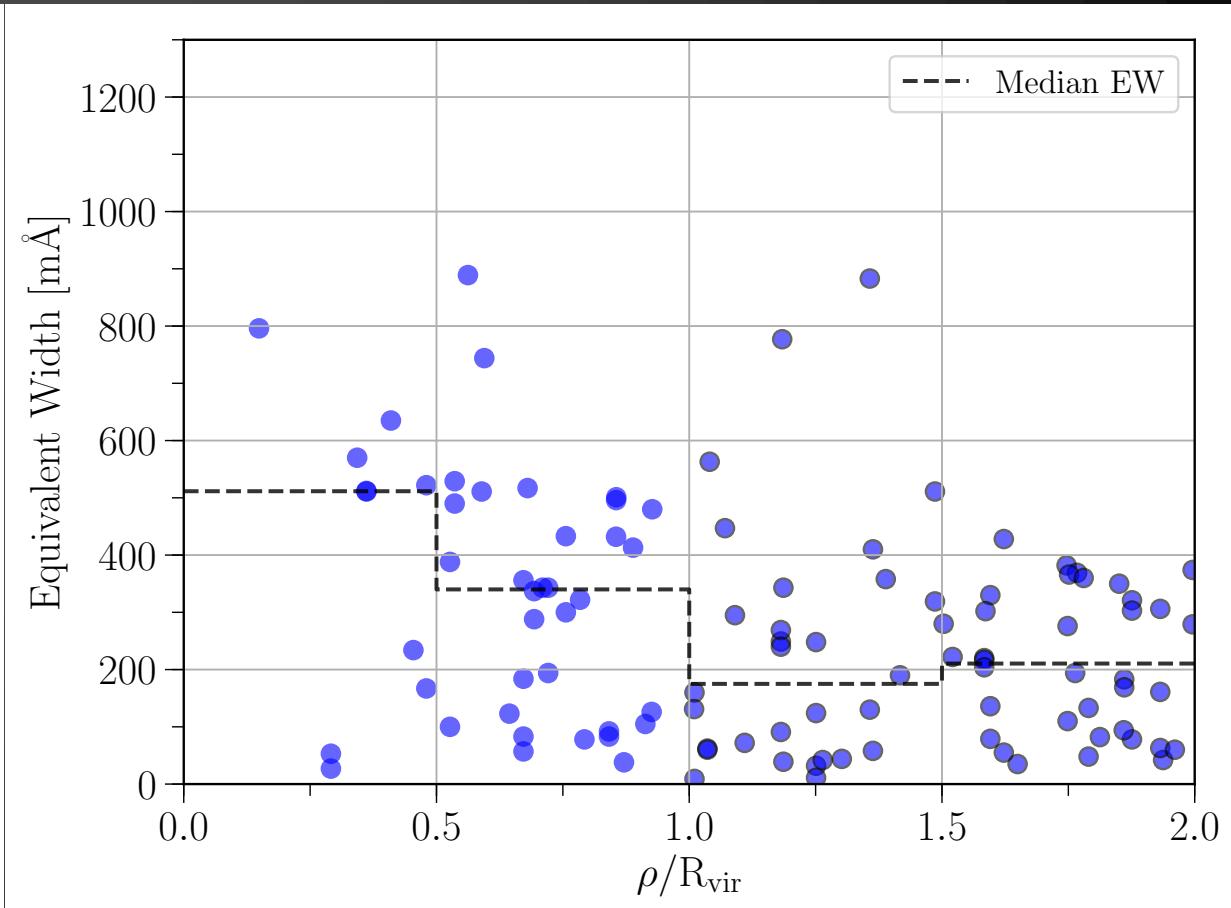
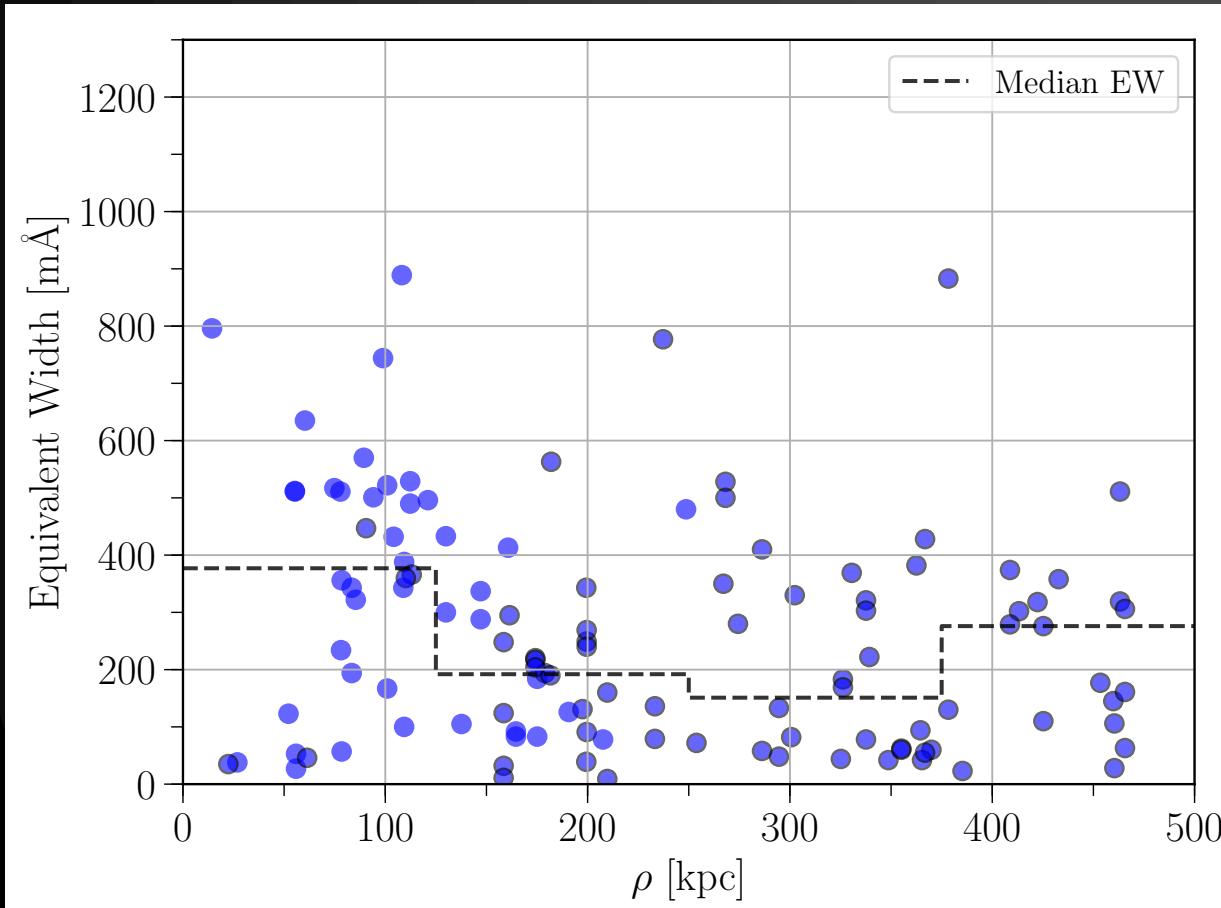
## Status:

- **237 spectra aligned and identified**
  - 1067 Ly-alpha absorbers
  - 331 measured
  - 116 "associated" with a single galaxy



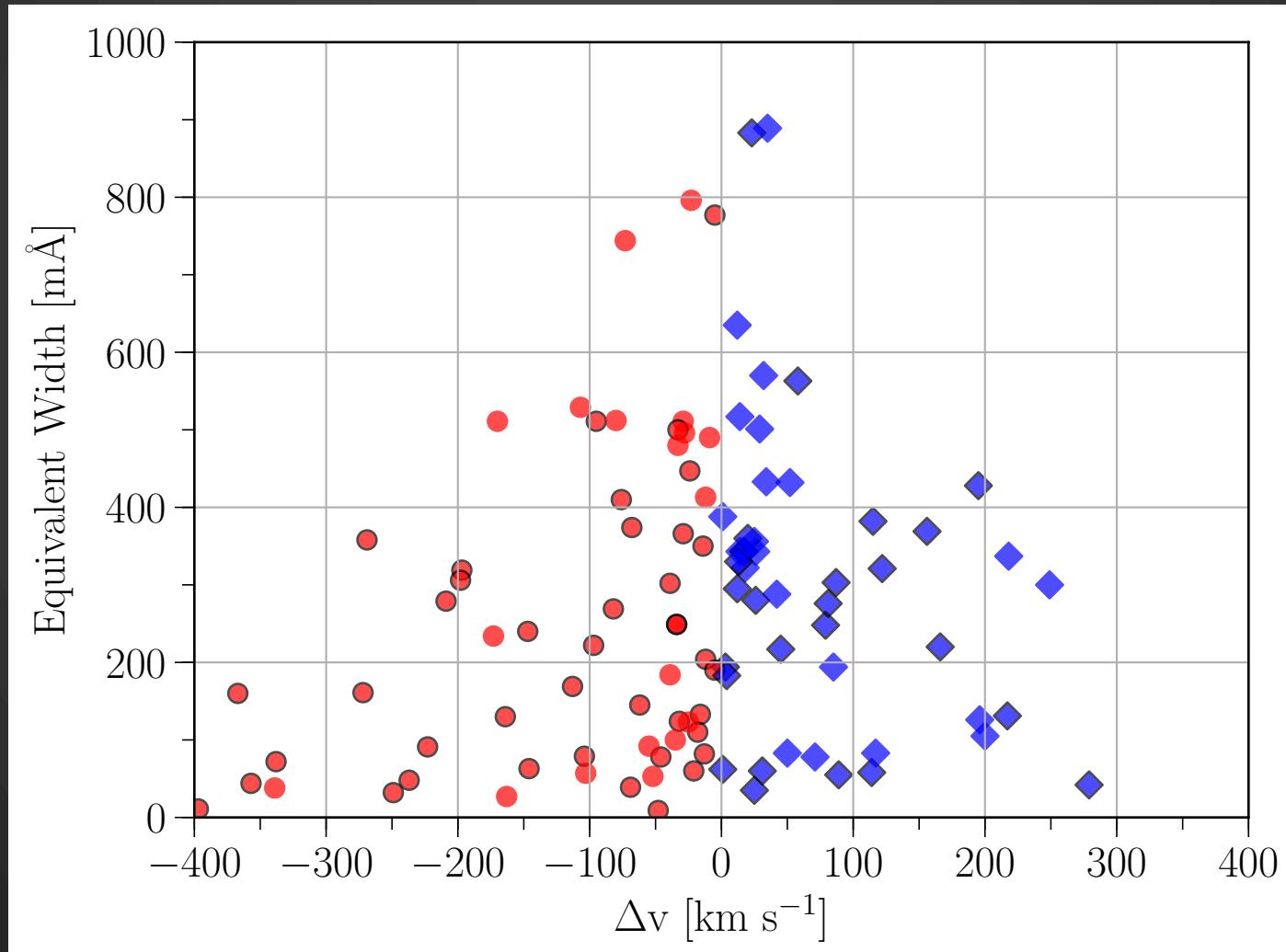
# Preliminary Results

EW vs impact parameter:



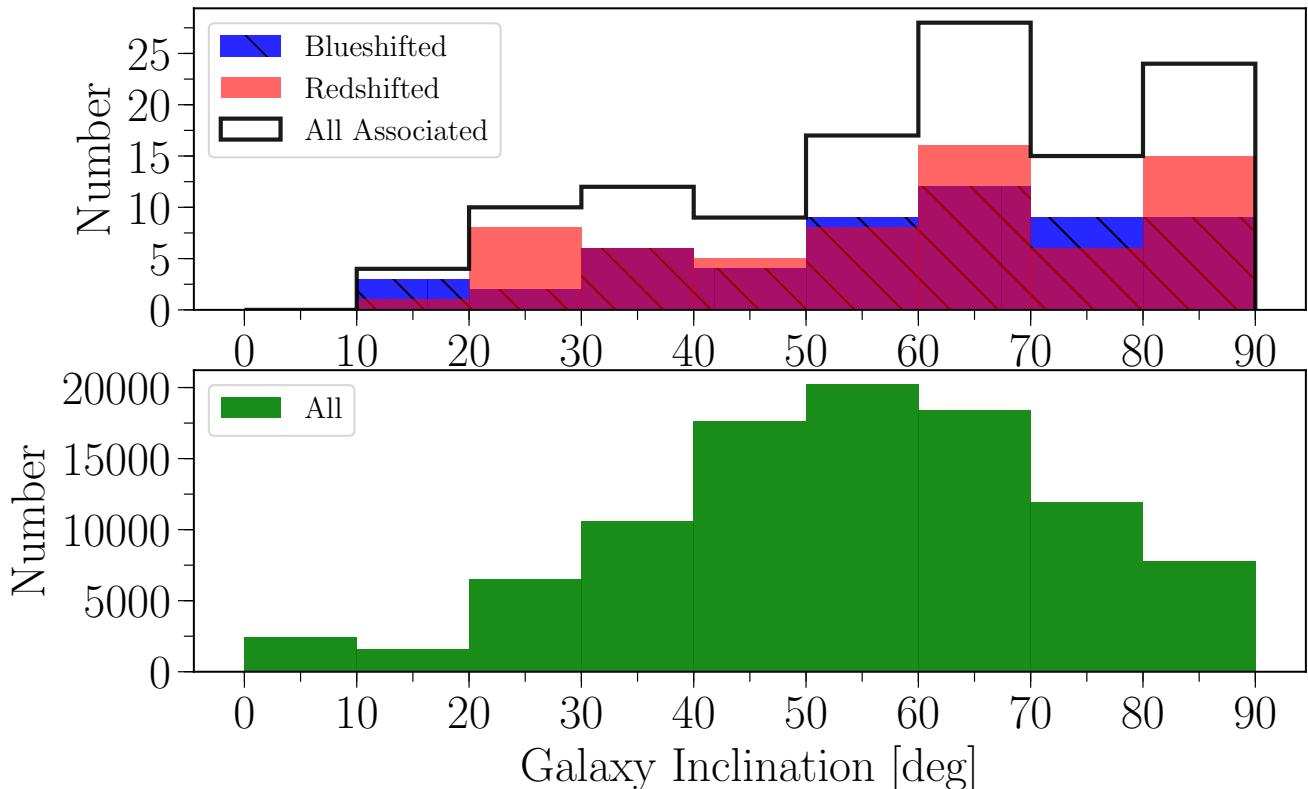
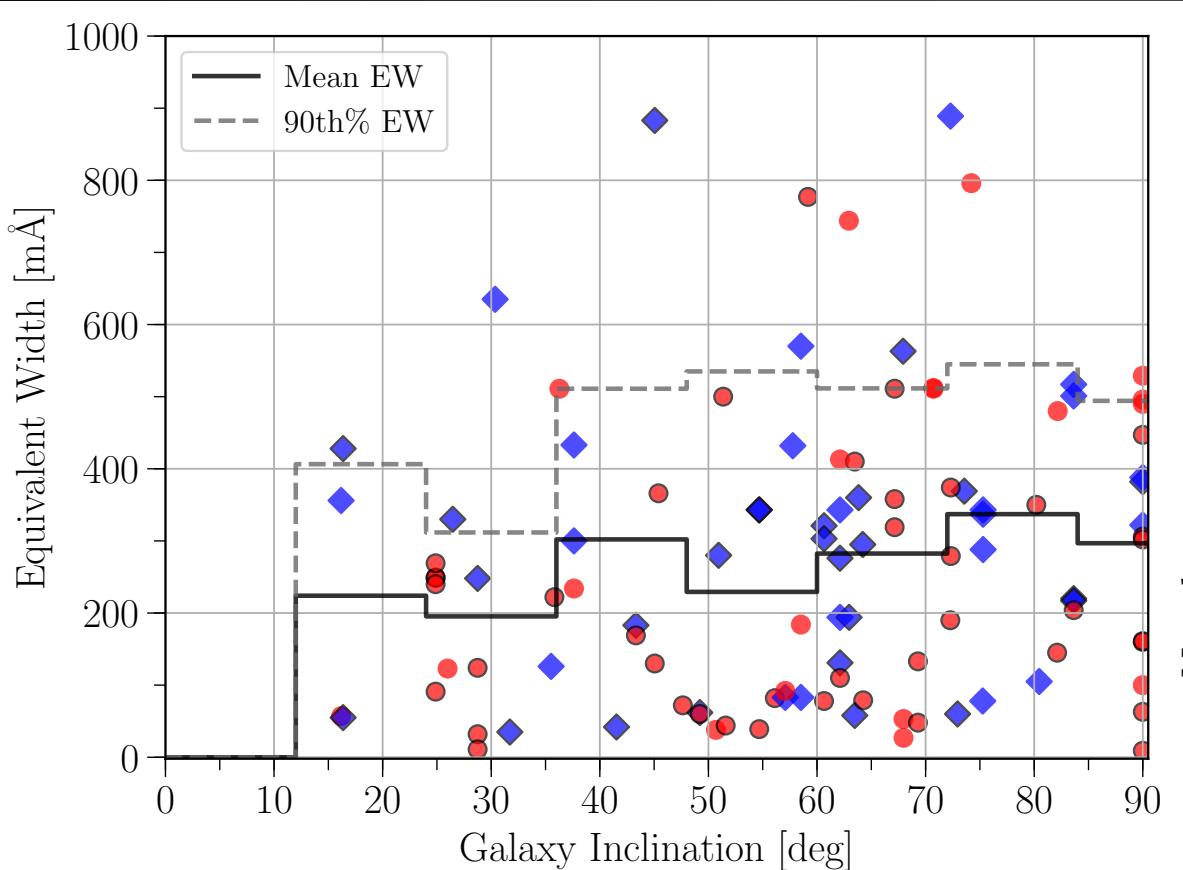
# Preliminary Results

**EW vs velocity separation:**



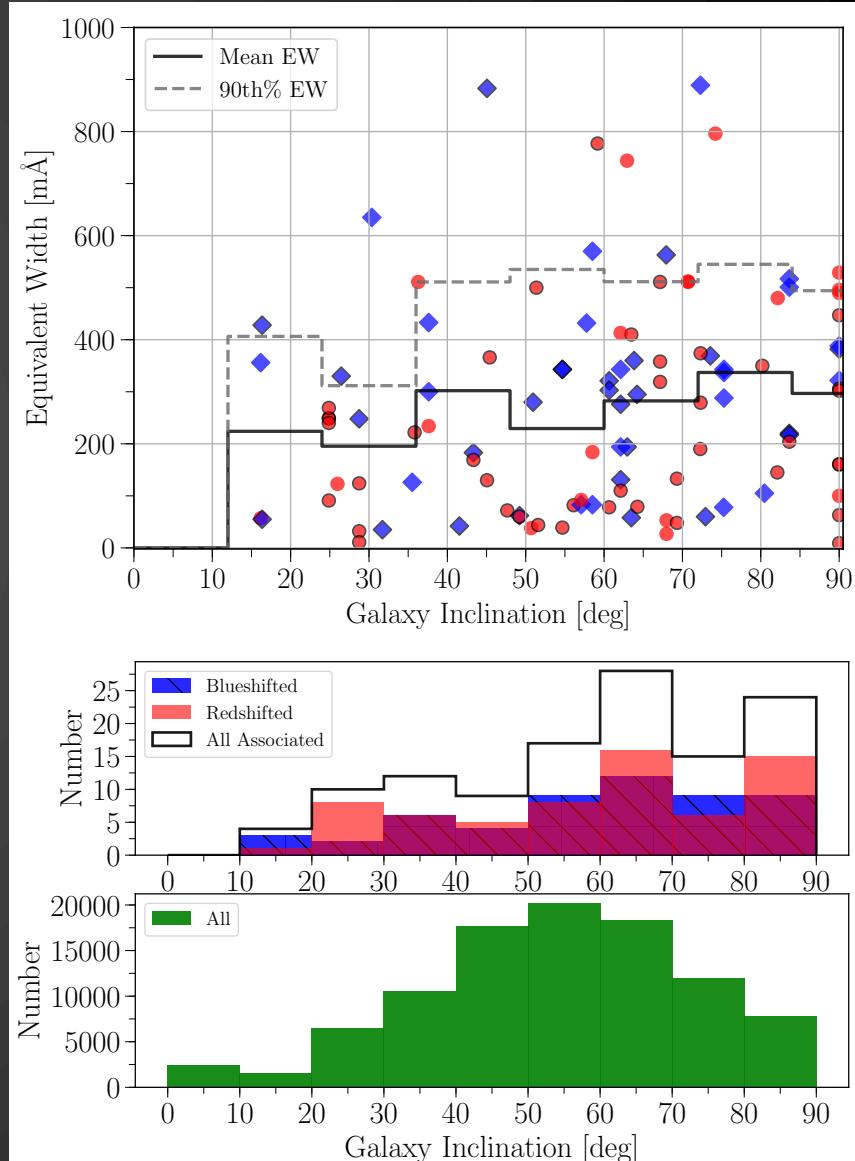
# Preliminary Results

## Inclinations:



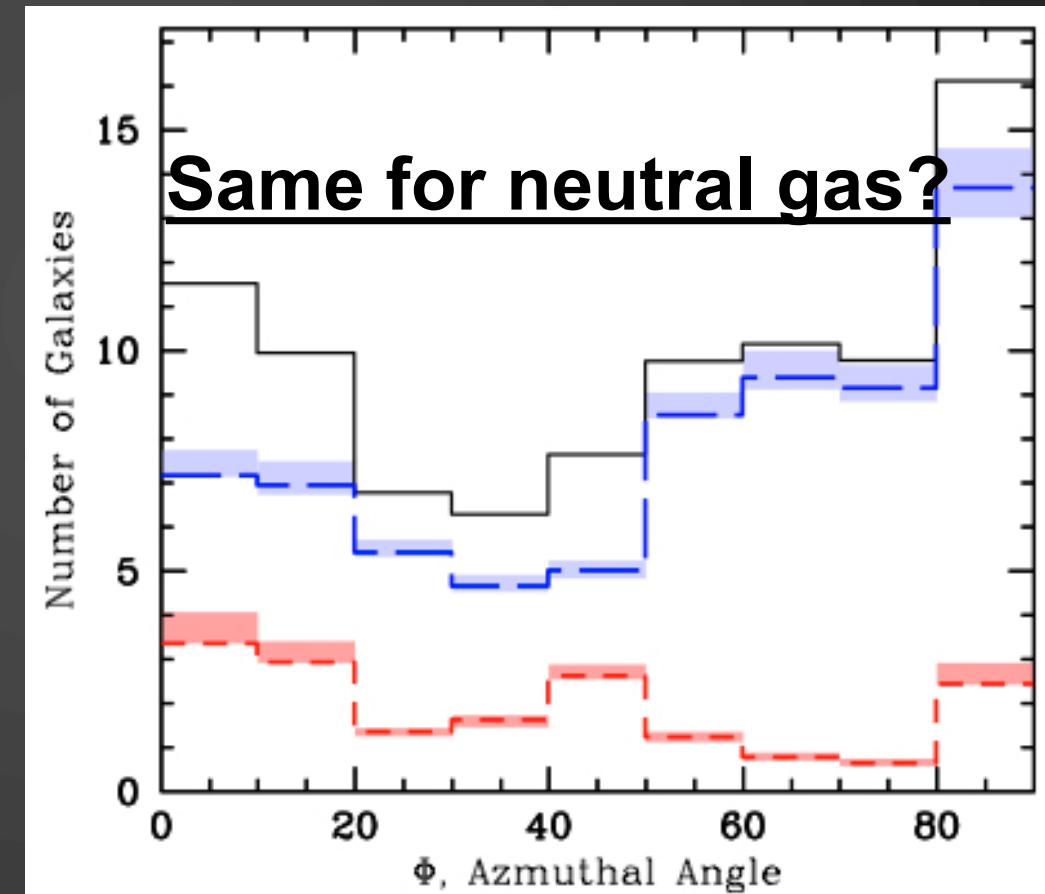
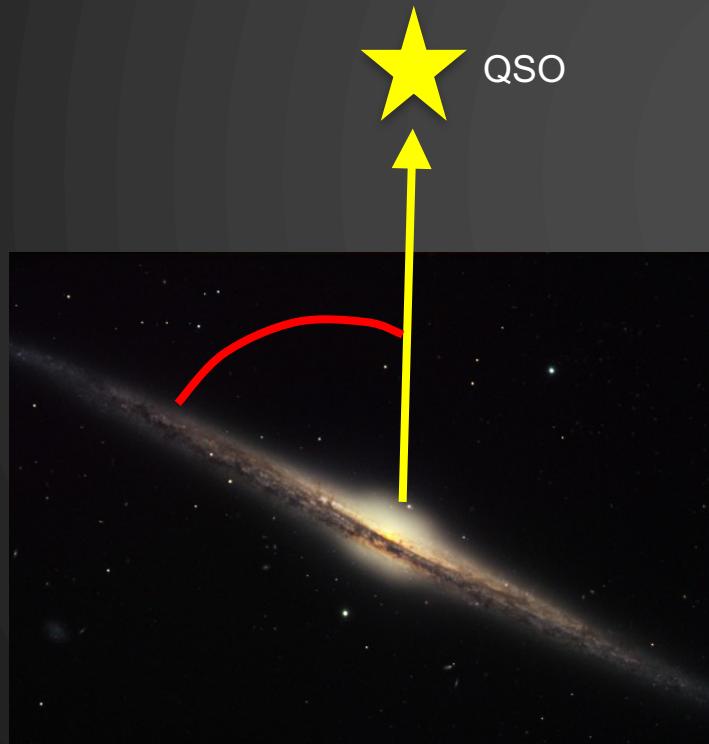
# Summary:

- **700+ COS spectra correlated with 130,000+ galaxies**
  - Expect ~3000 Ly-alpha absorbers
  - ~1000 absorber-galaxy pairs using likelihood method
  - Strong EW –  $\Delta V$  correlation
  - Overabundance around highly inclined galaxies
- **Disk-halo kinematic connection?**
  - Probably not very far reaching
- **Does CGM gas care about galaxies?**
  - It seems like it might! Stay tuned.



# *How do CGM absorber properties depend on galaxy orientation?*

- Major vs minor?

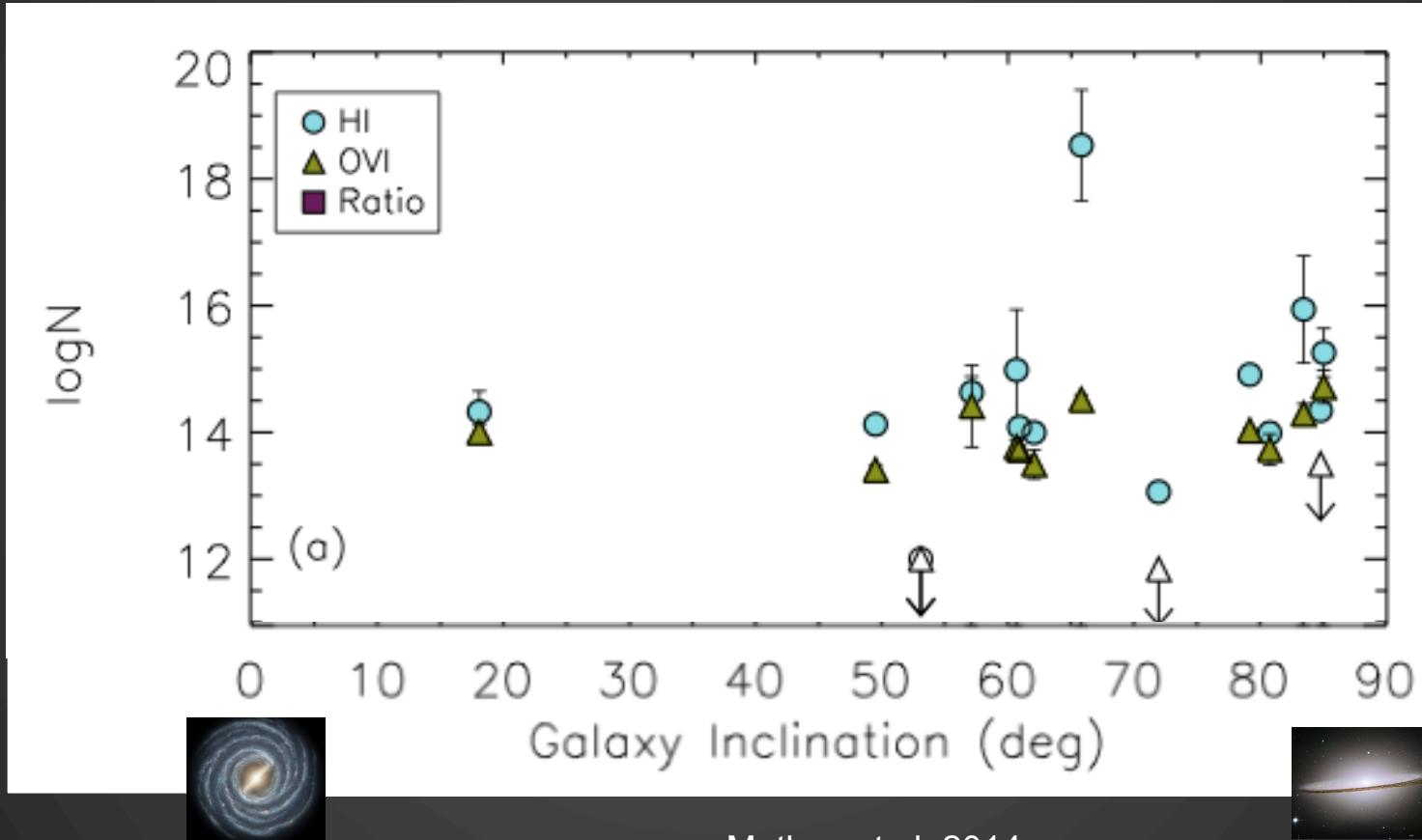


Credit: Bruce Hugo & Leslie Gaul, Adam Block, NOAO, AURA, NSF

Kacprzak et al. 2012

# *Galaxy Inclination*

No?



Mathes et al. 2014

# Baryon Budget

