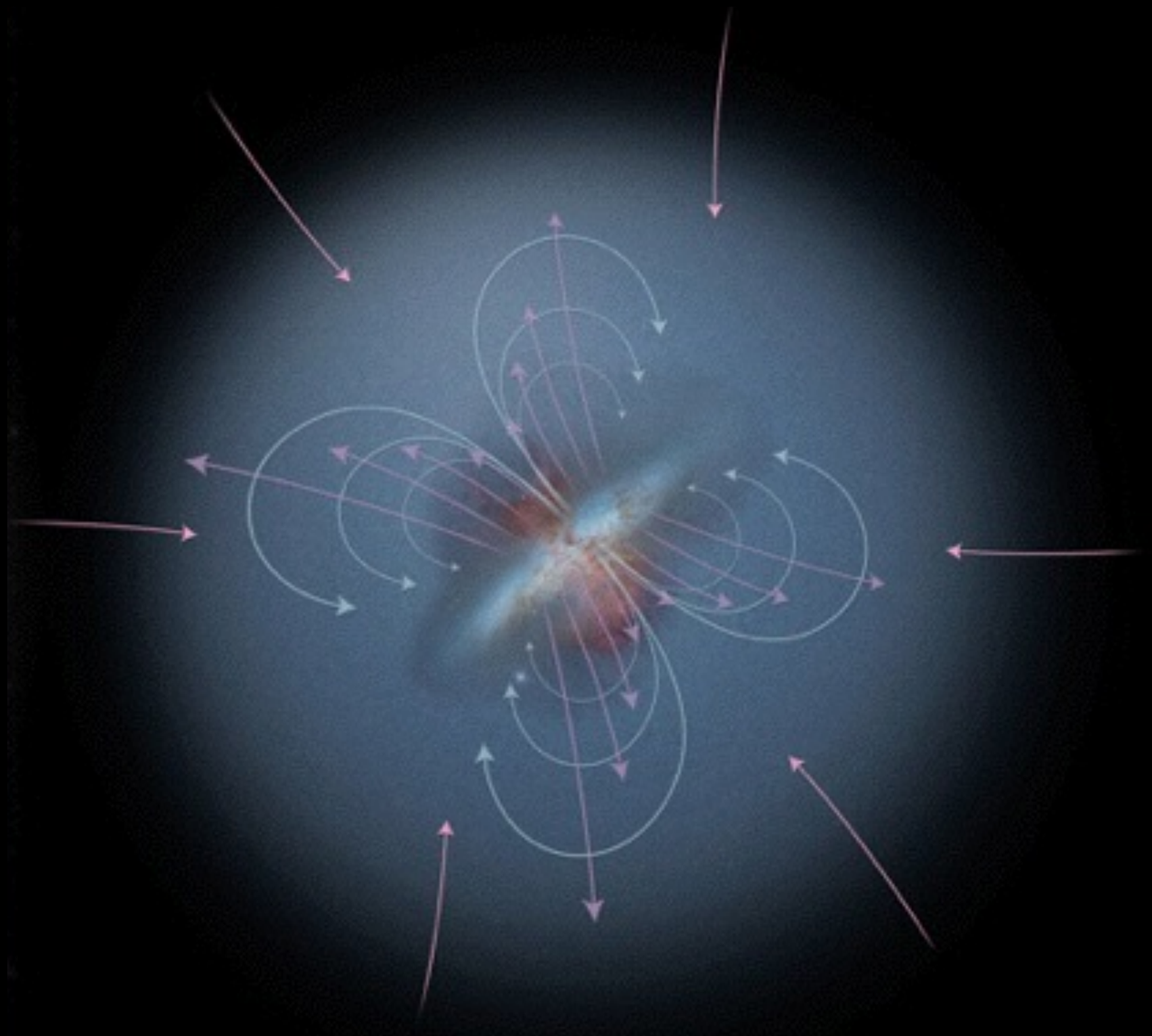
THE CIRCUMGALACTIC MEDIUM

around Dwarf Galaxies

Rongmon Bordoloi

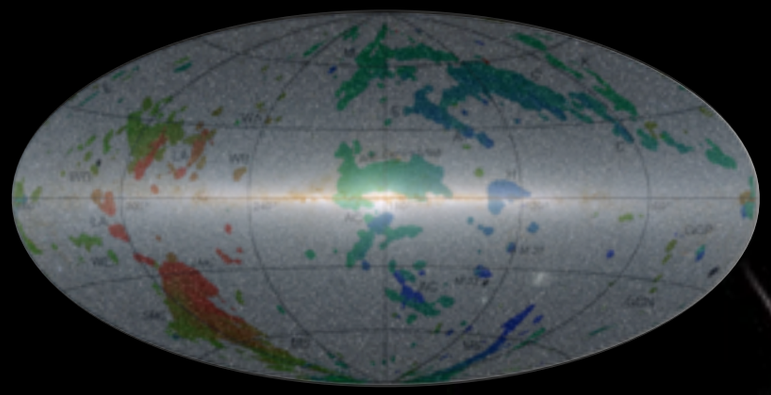
STScI → MIT in Fall

and the
COS-Halos Team

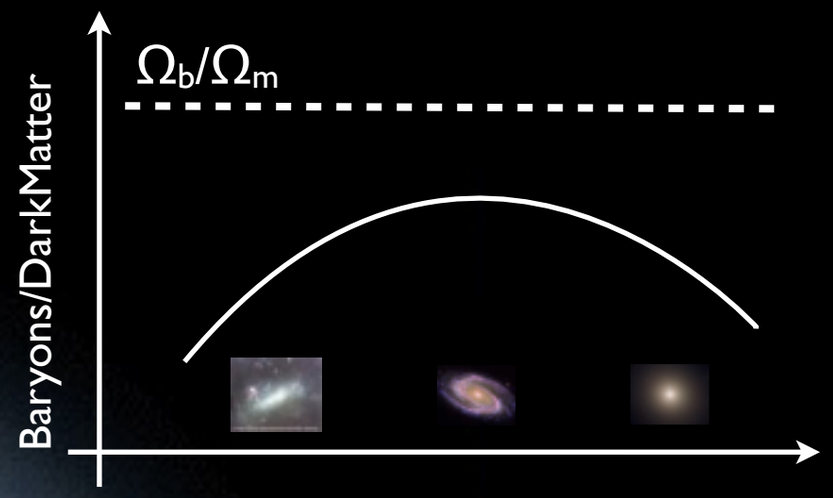


CGM Figure Credit: Ann Feild (STScI)

Gas Flows Drive Galaxy Formation

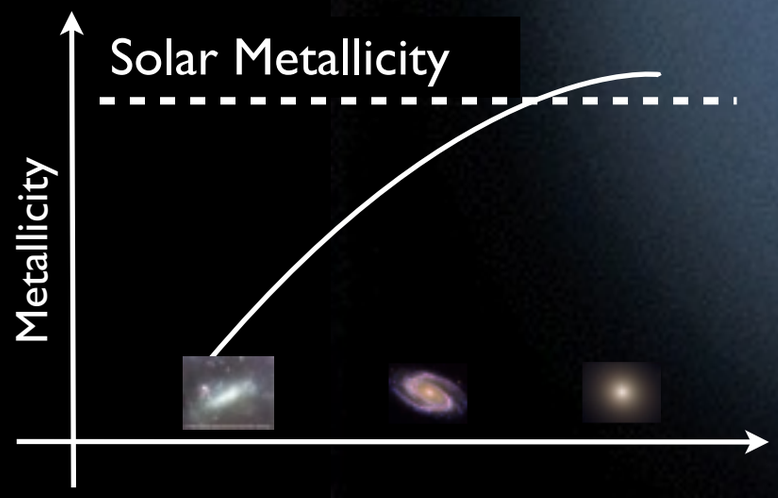


Accretion

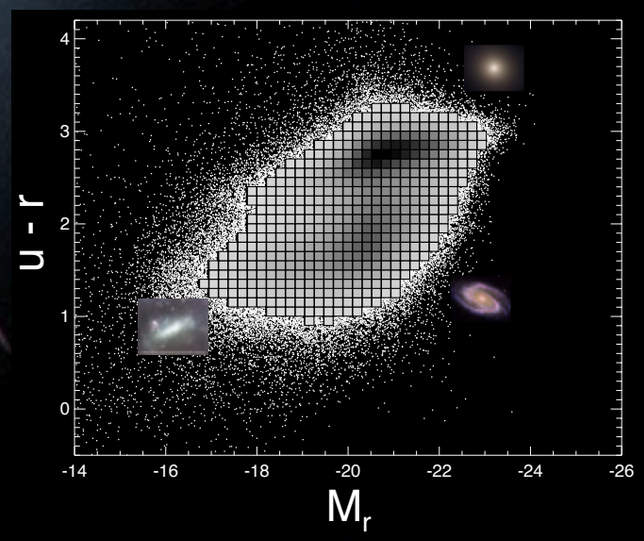


Halo gas

Recycling



Feedback



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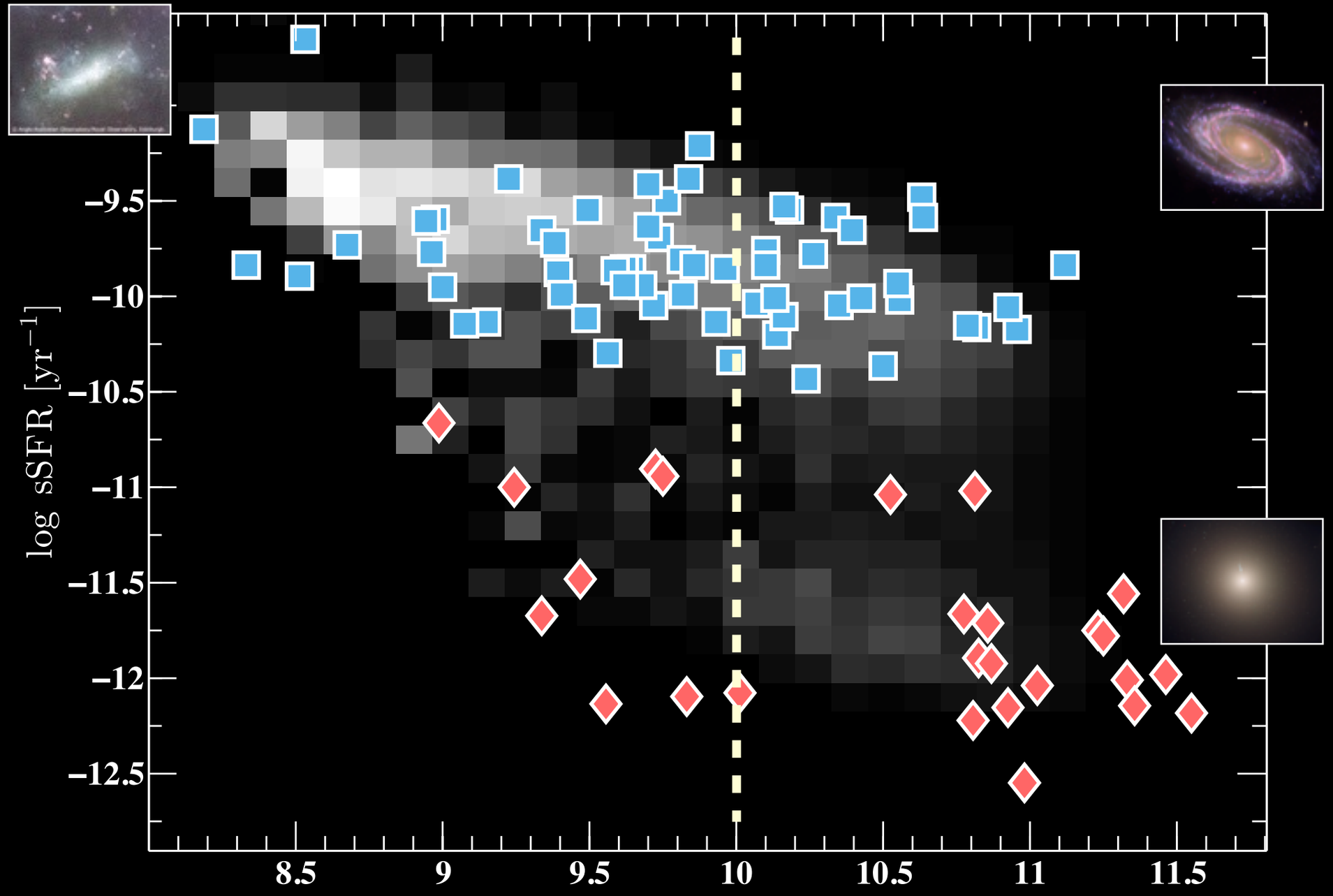


COS-Dwarfs

z = 0.02 - 0.10

logM* = 8 - 10

optimal for CIV

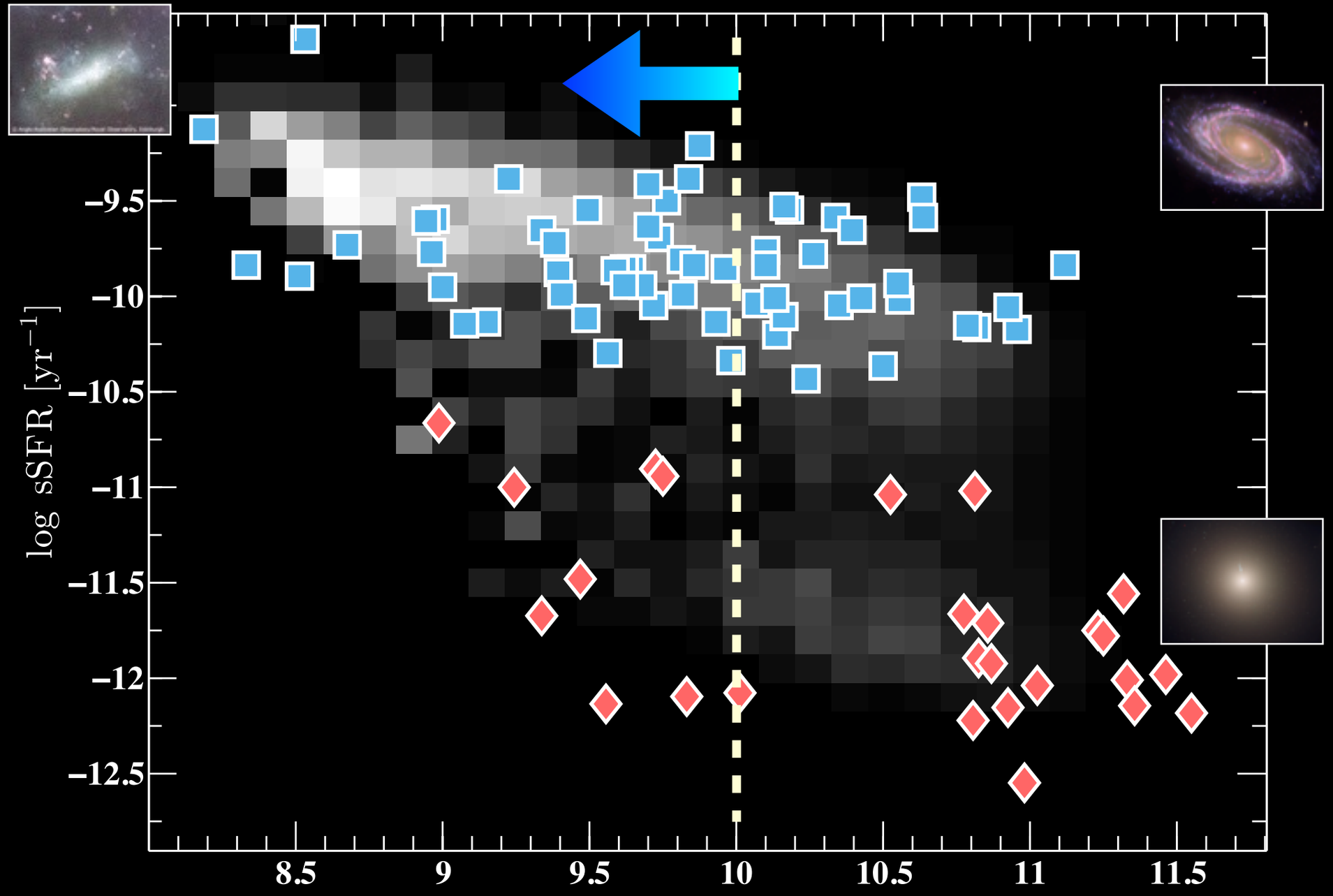
COS-Halos

z = 0.15 - 0.35

logM* = 10 - 11.5

optimal for OVI

ALL GALAXIES SELECTED PRIOR TO ABSORPTION



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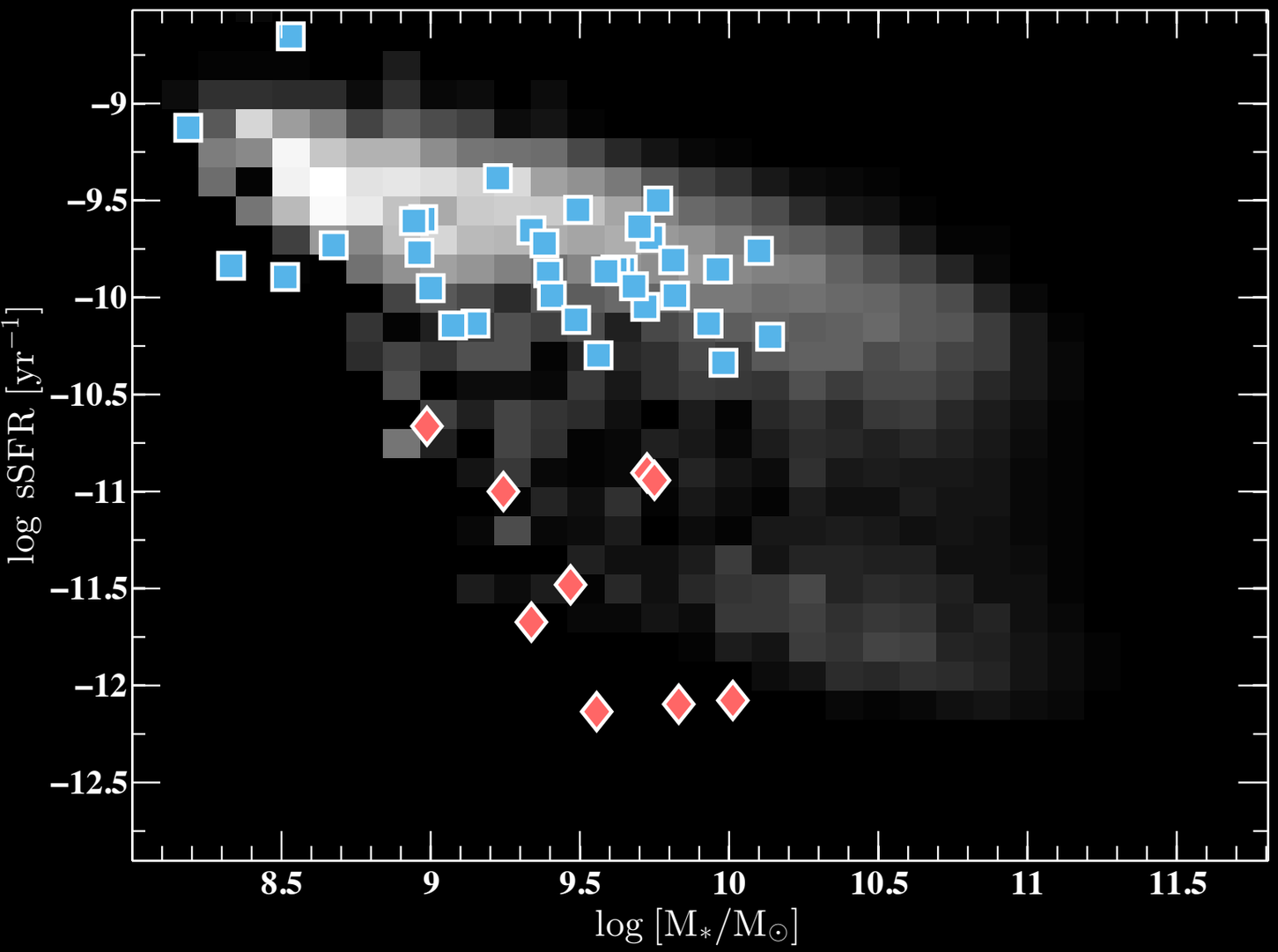
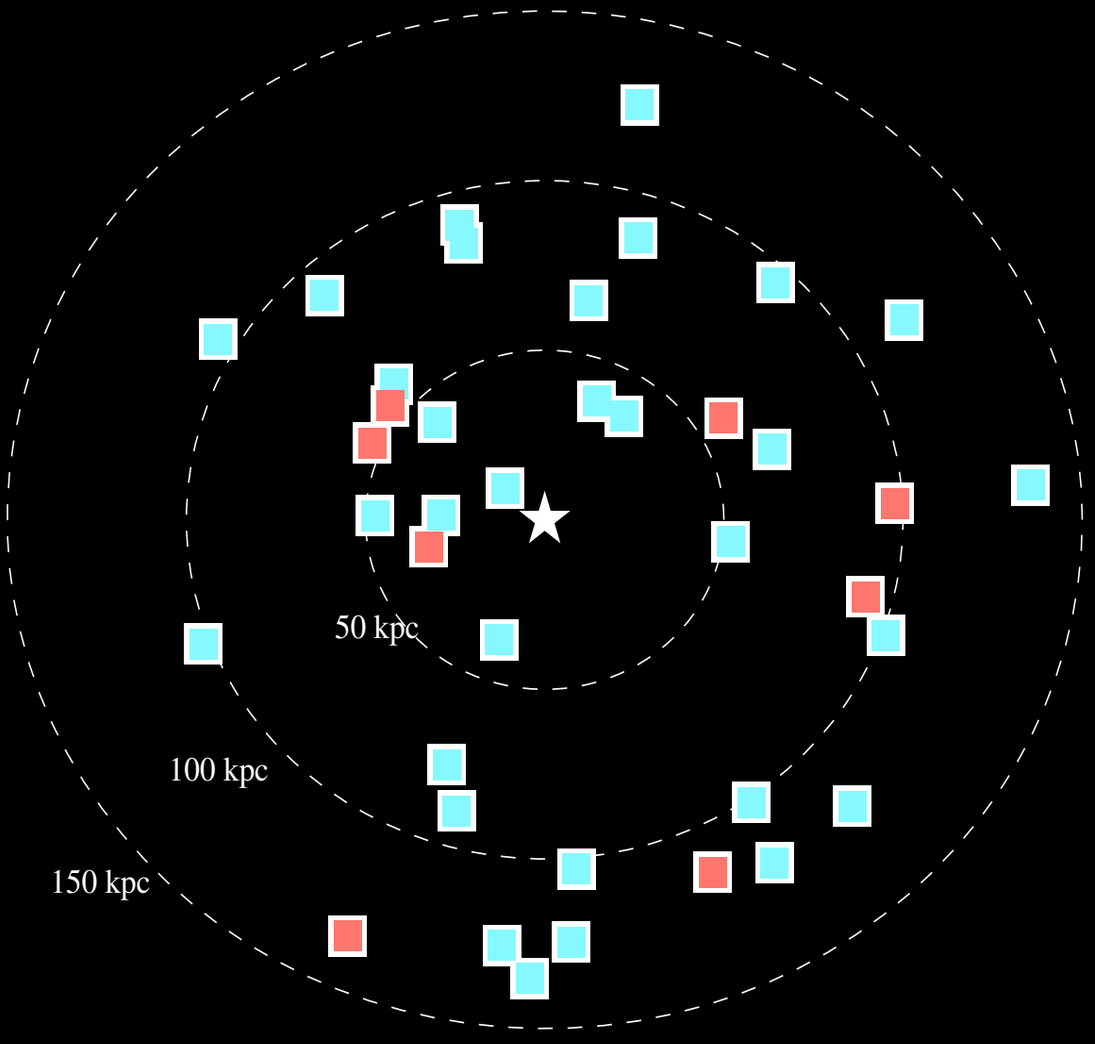
The COS-Dwarfs Survey



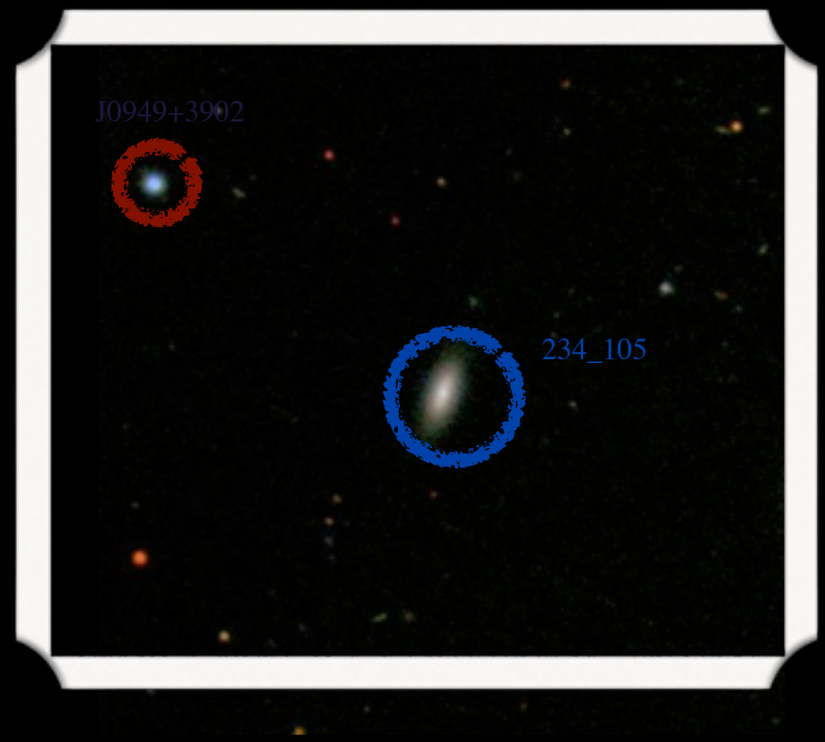


43 galaxies around 41 Quasars

129 HST Orbits

What do we use

◉Morphology of the host galaxies from SDSS



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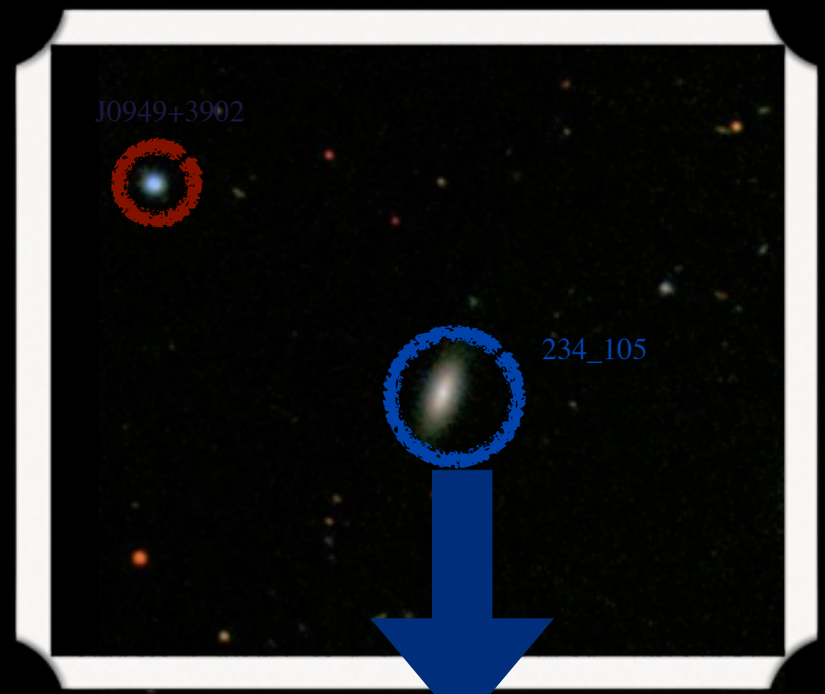
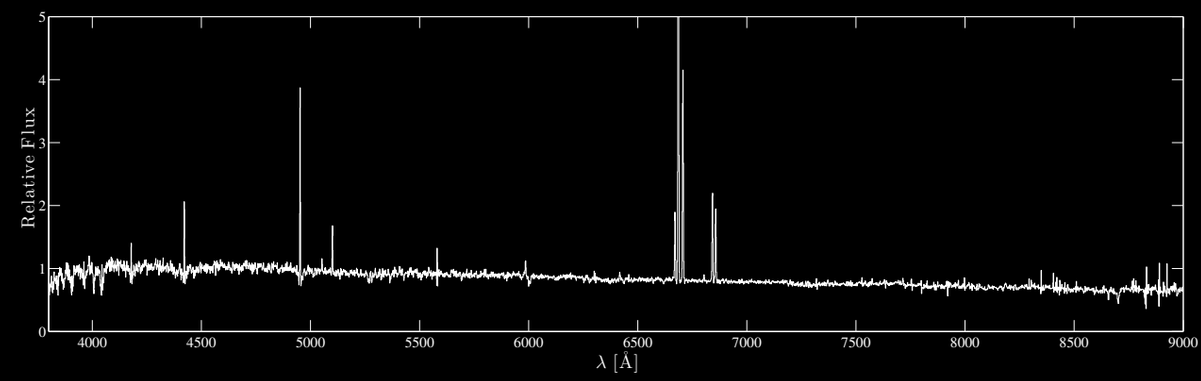


◉SDSS Spectra of the foreground galaxies



log M_* 9.53

ρ = 38 kpc

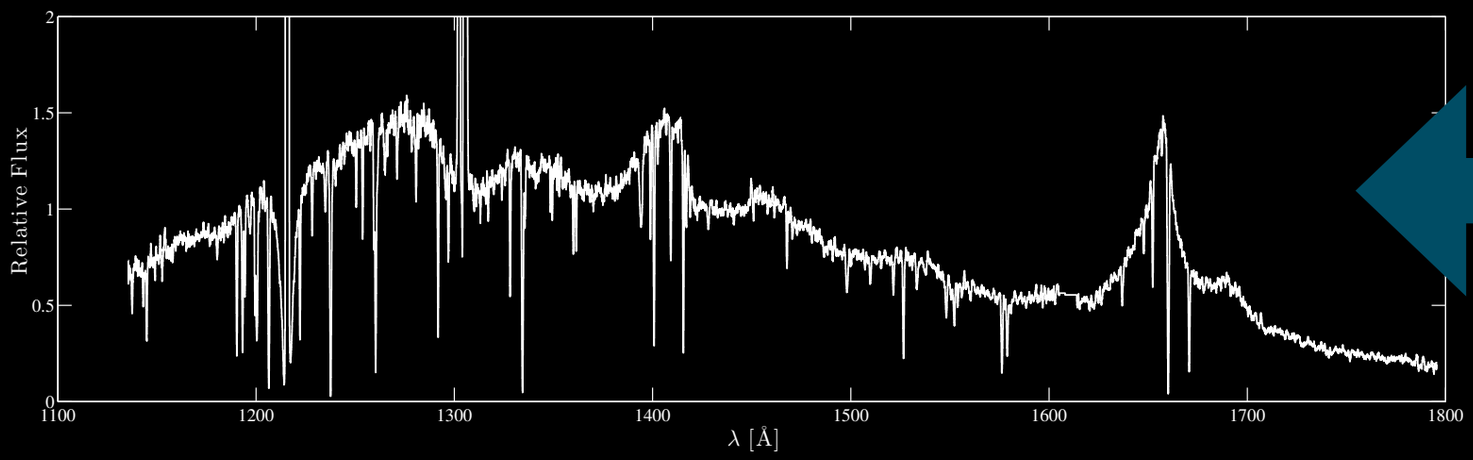
SFR =1.11 $M_\odot$/year

Z_{gal}=0.018145

z_{QSO}=0.3650

What do we use

◉HST-COS spectroscopy of quasars



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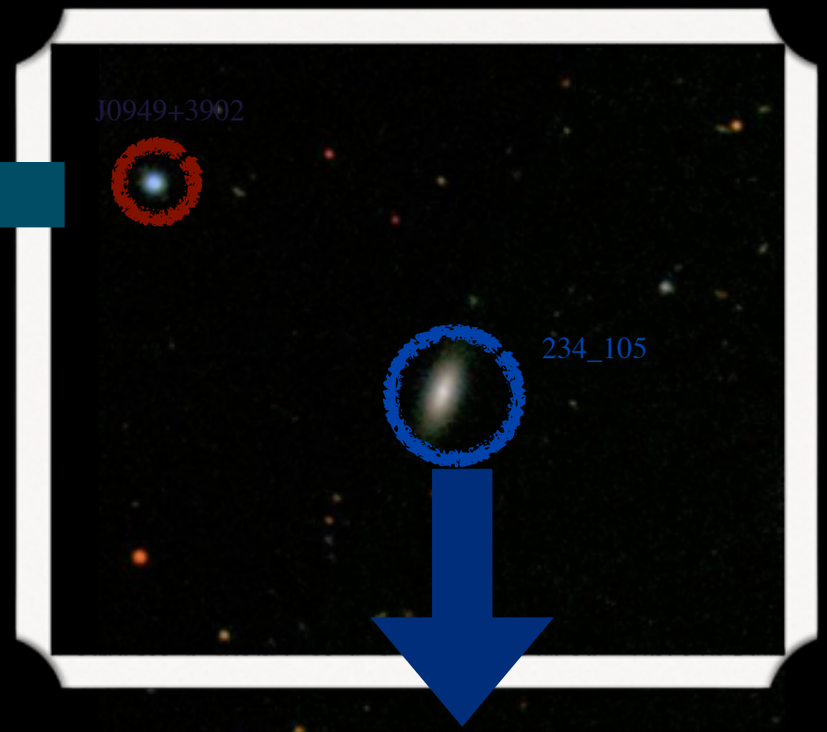

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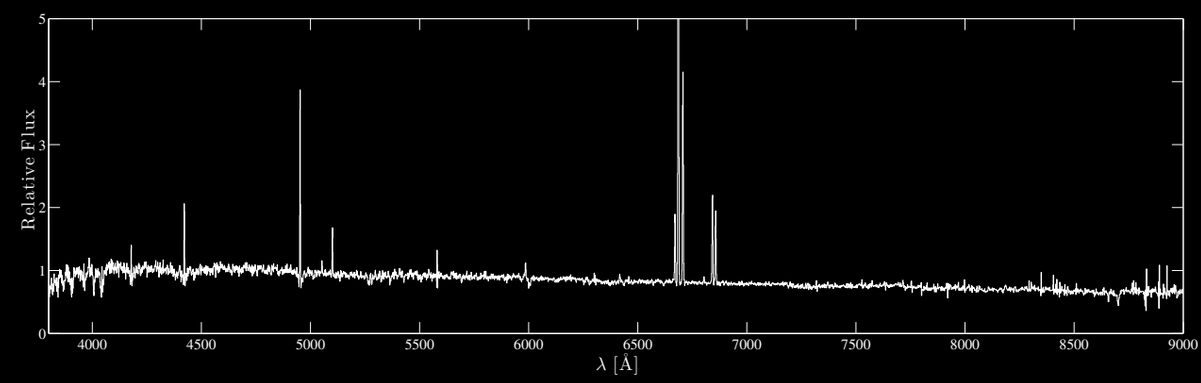

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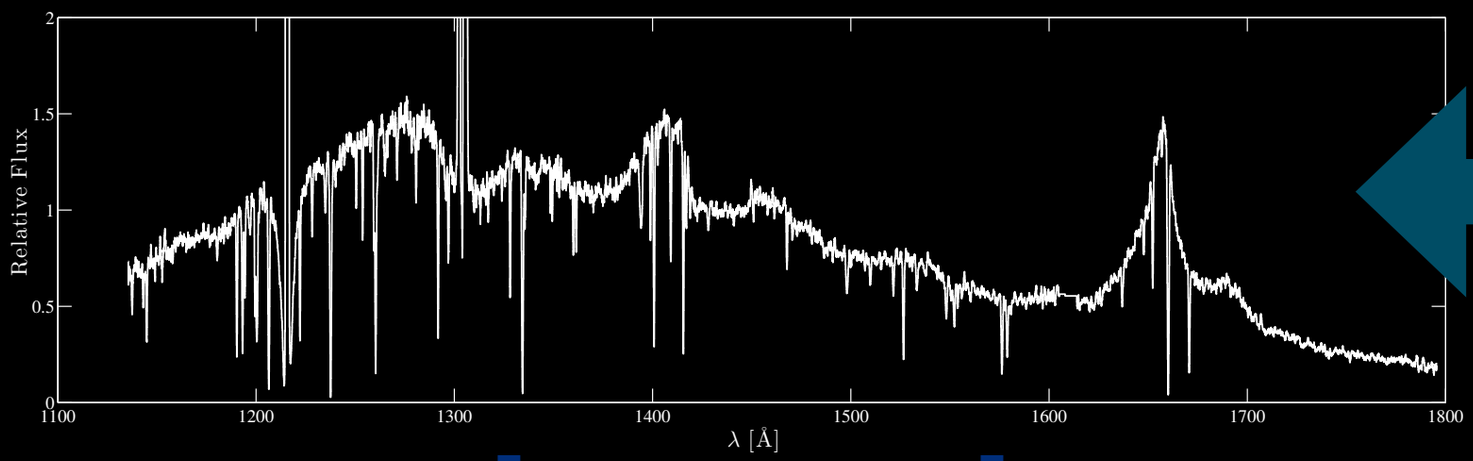

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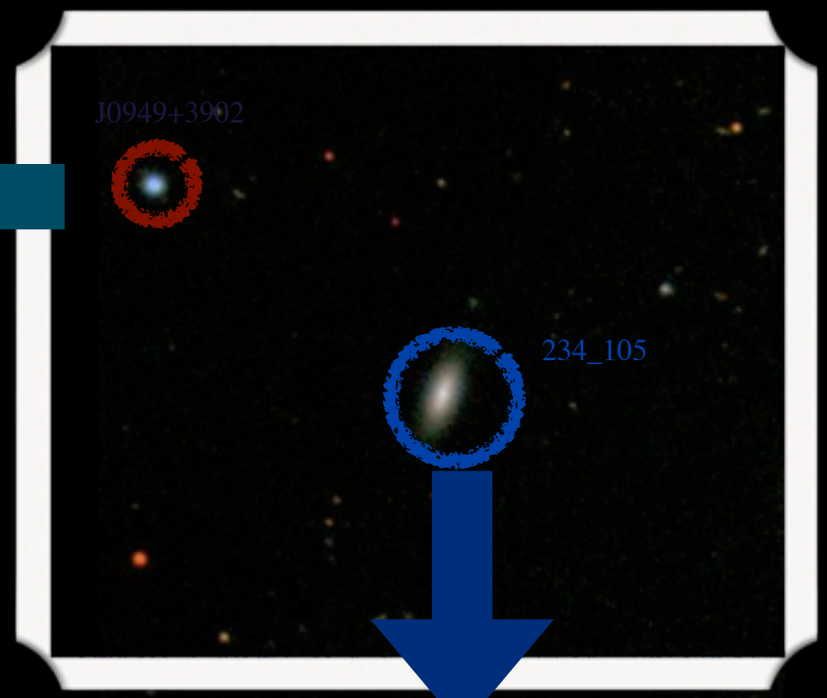

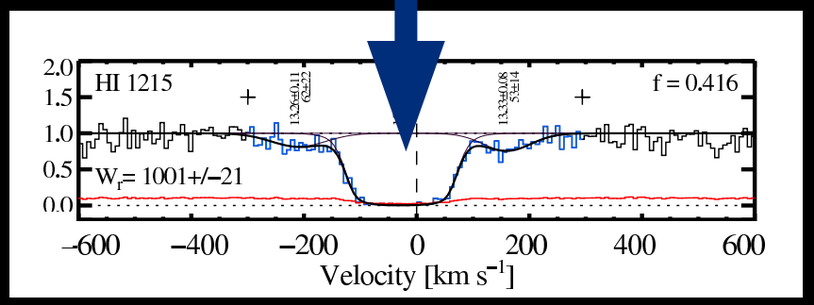

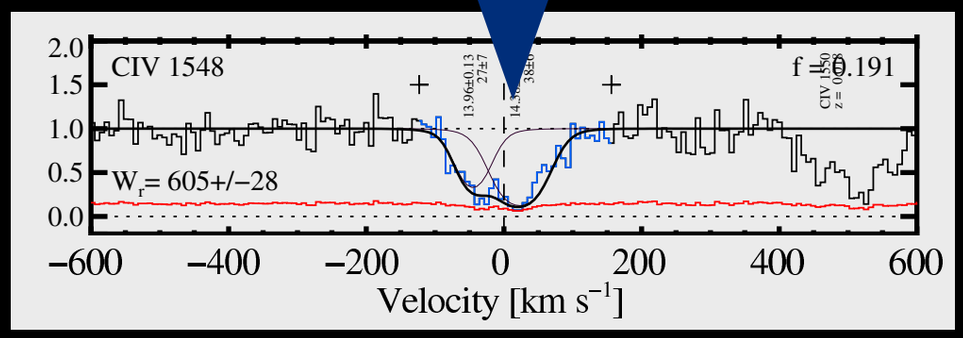

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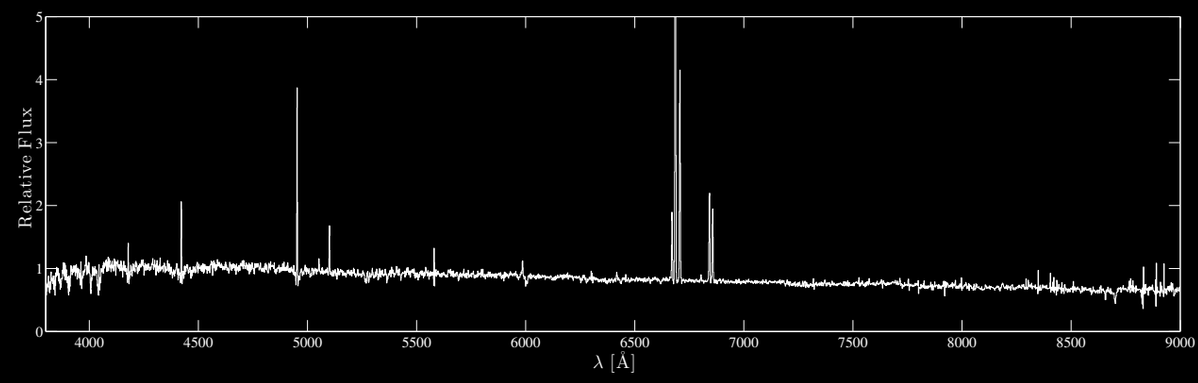

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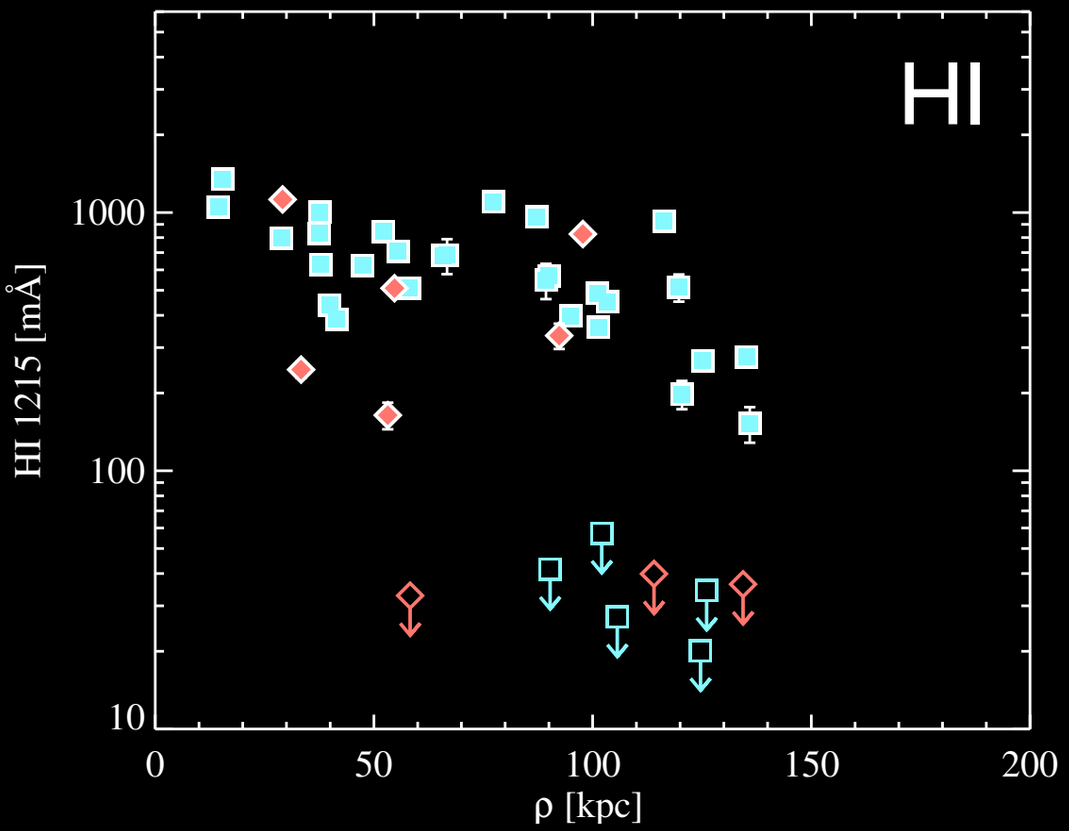
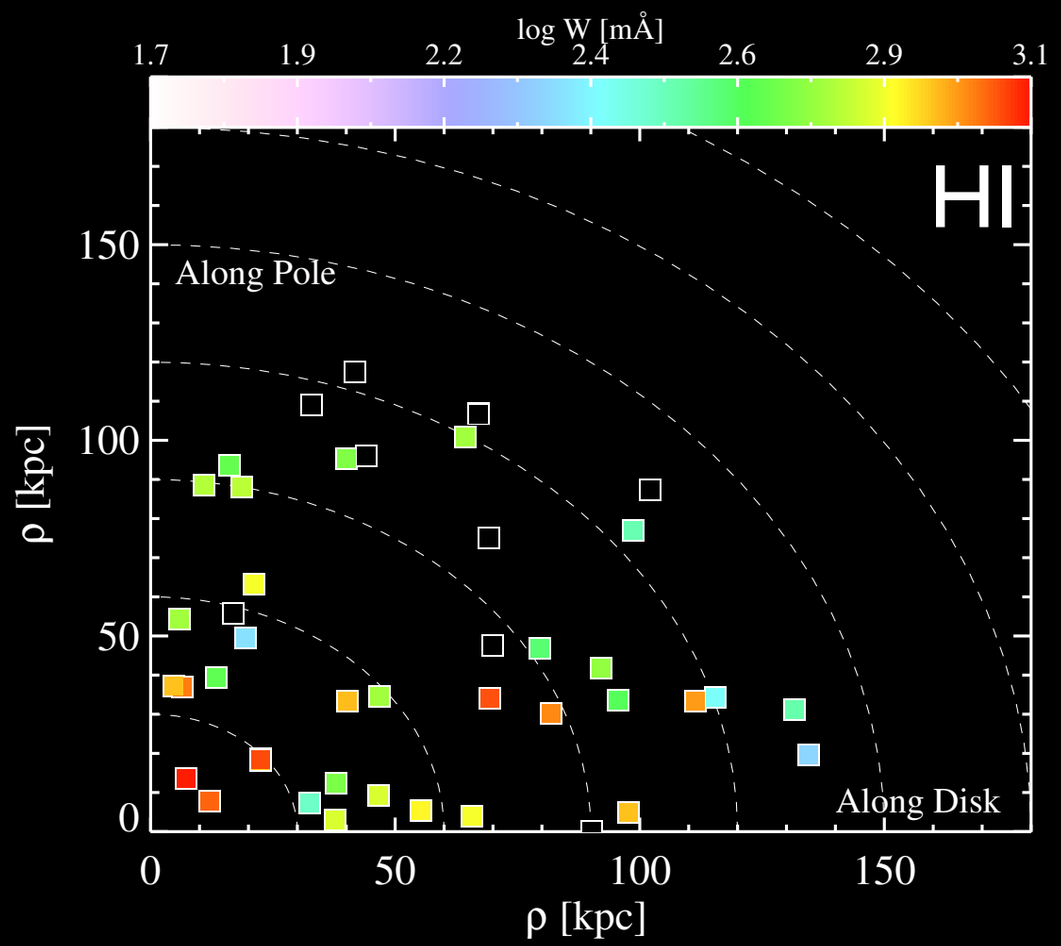
How is gas distributed around galaxies?

← Density Ionization Potential → Temperature →





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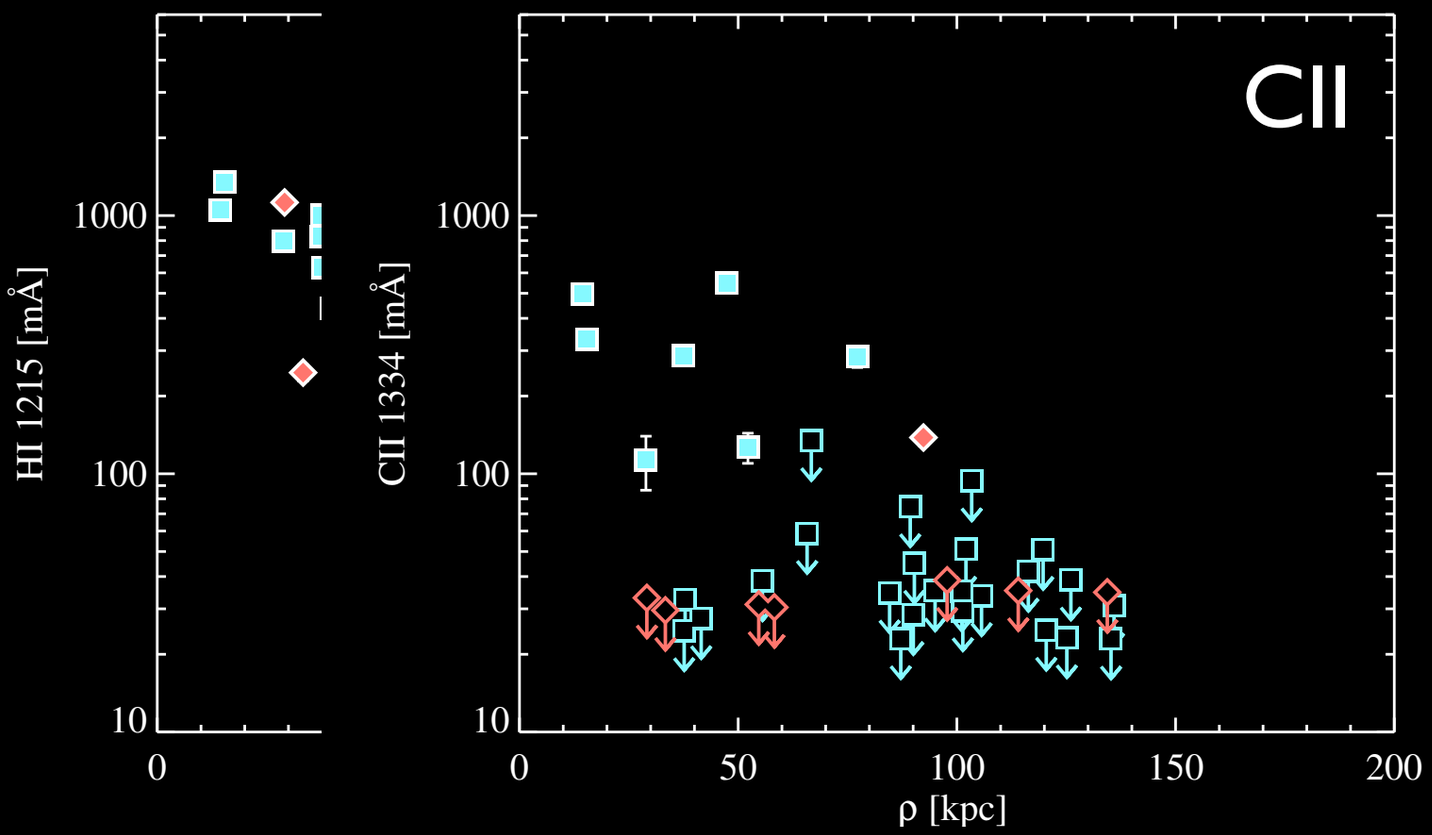

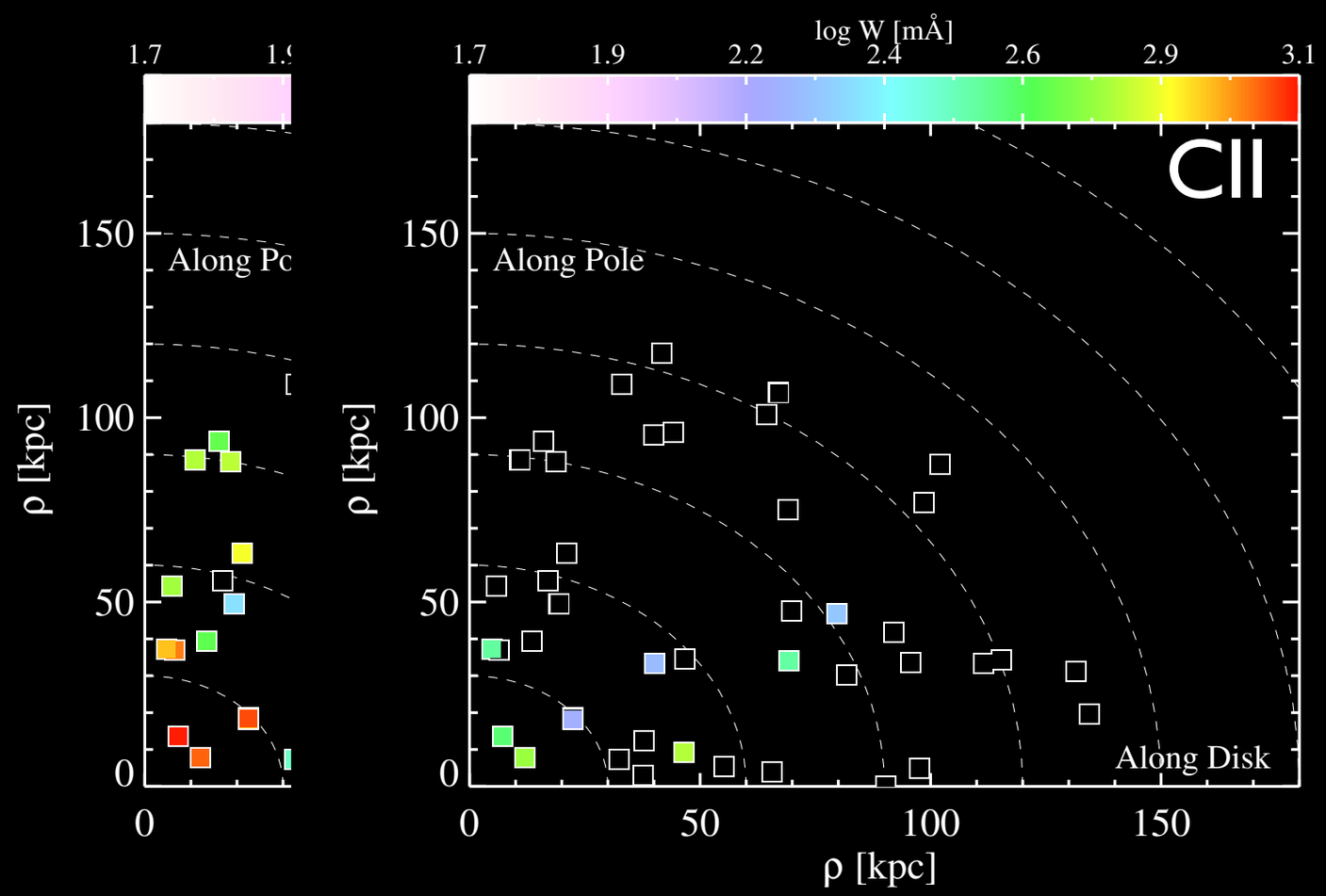

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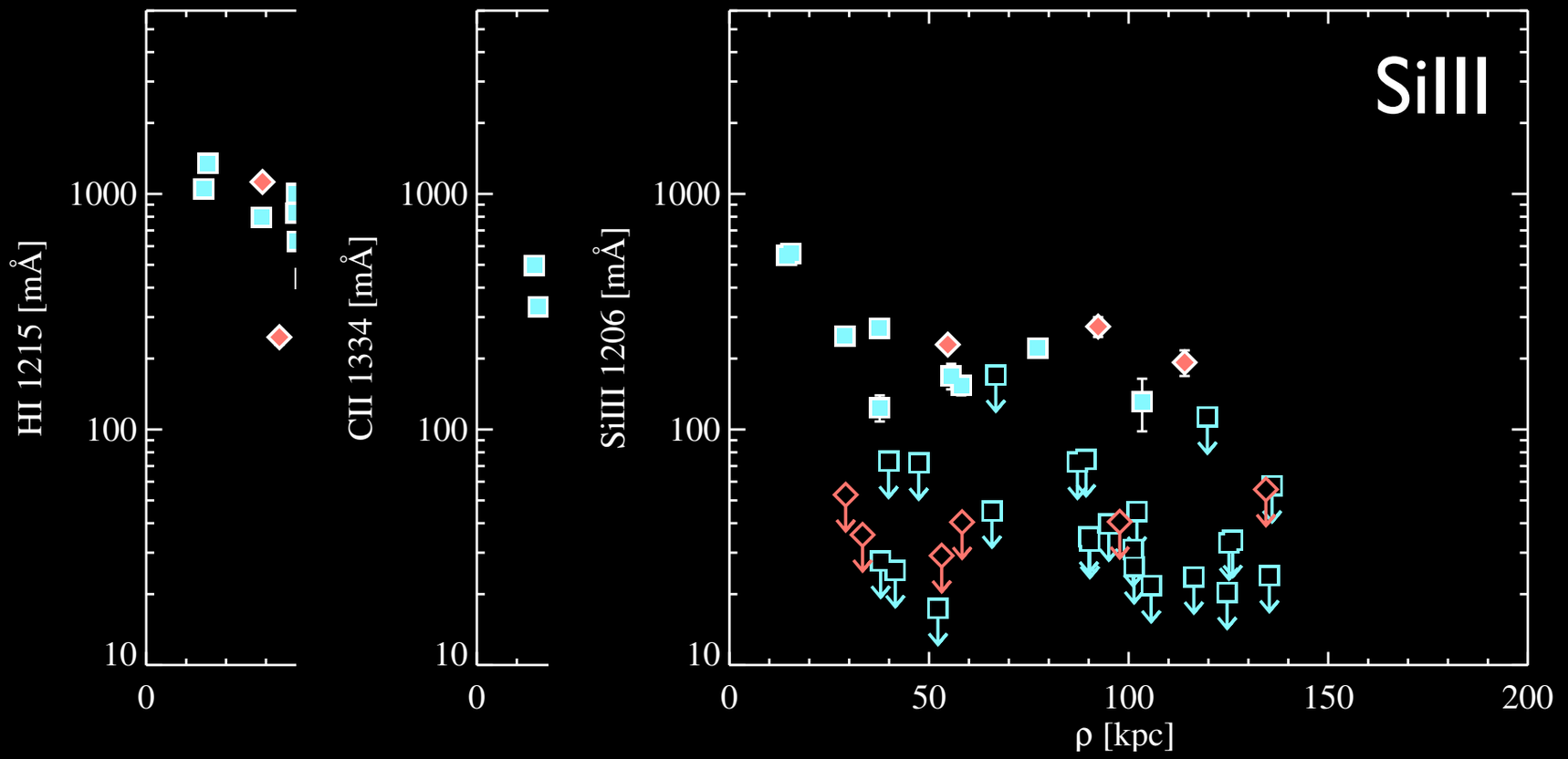
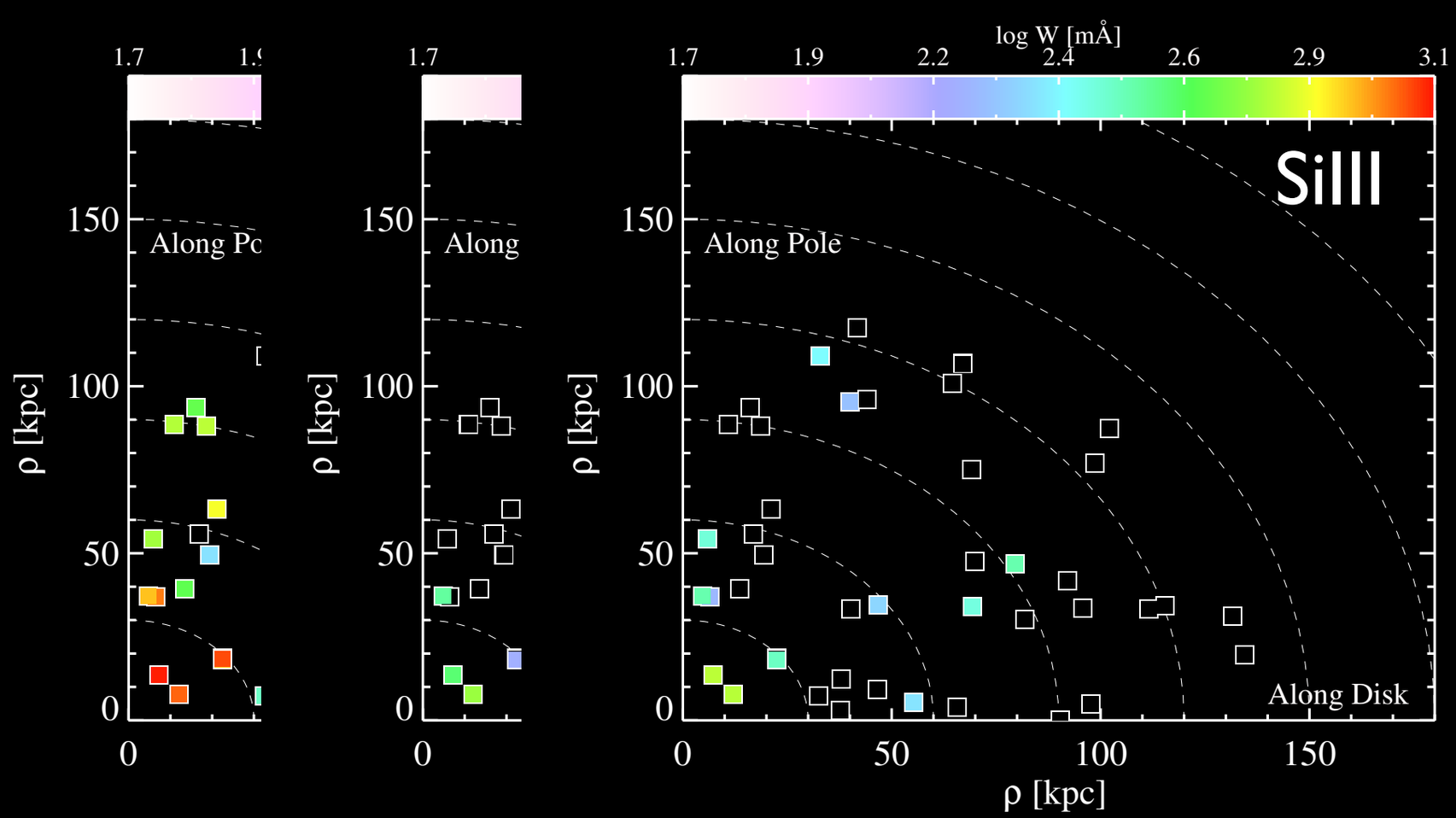
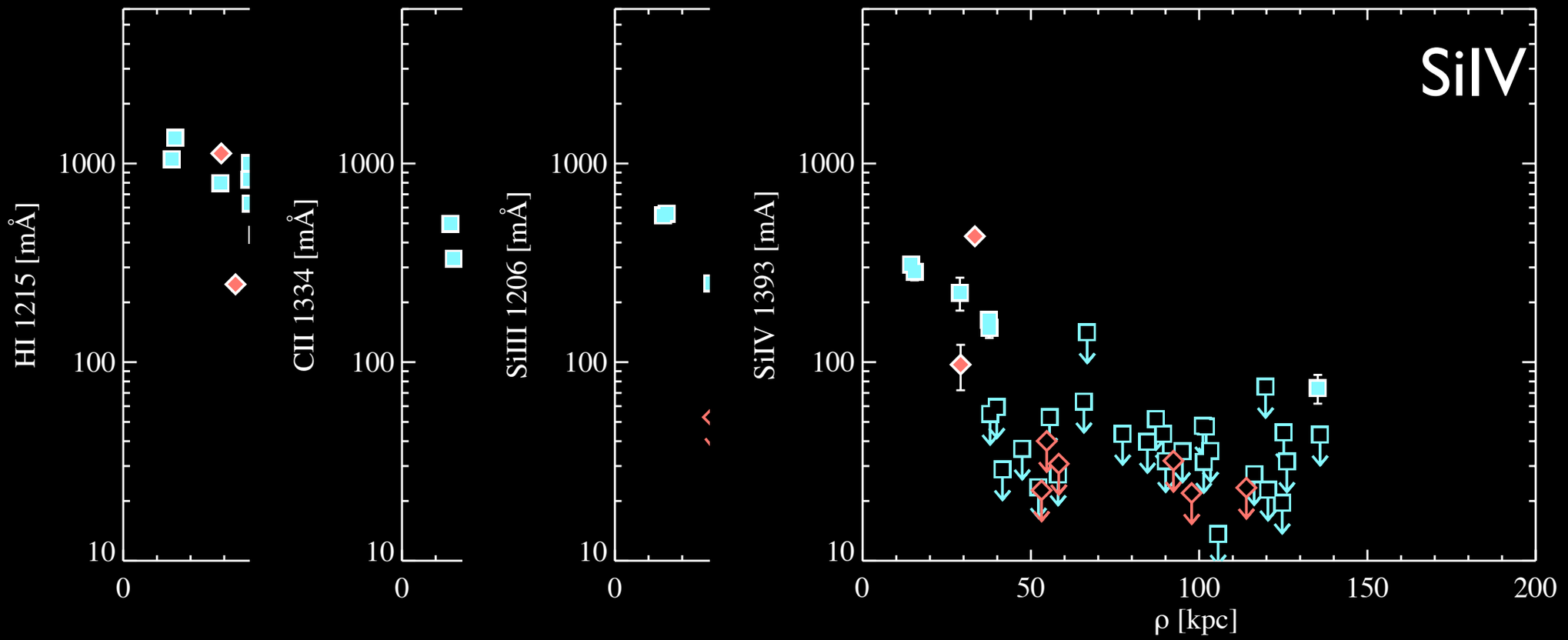
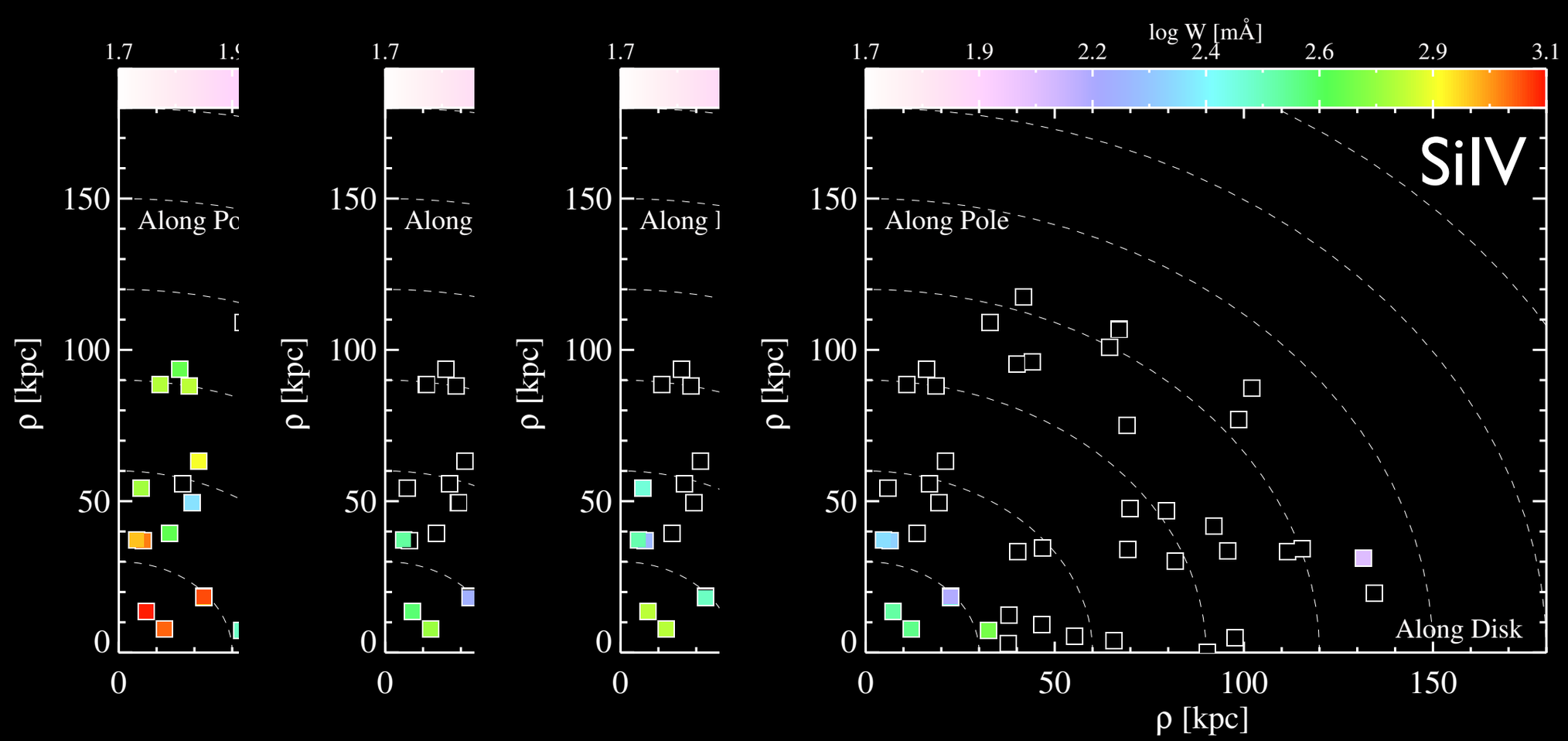




Density ← Ionization Potential → Temperature →





← Density Ionization Potential → Temperature →

HI 1215 [mÅ]

CII 1334 [mÅ]

SiIII 1206 [mÅ]

SiIV 1393 [mA]

CIV 1548 [mÅ]

CIV

ρ [kpc]

log W [mÅ]

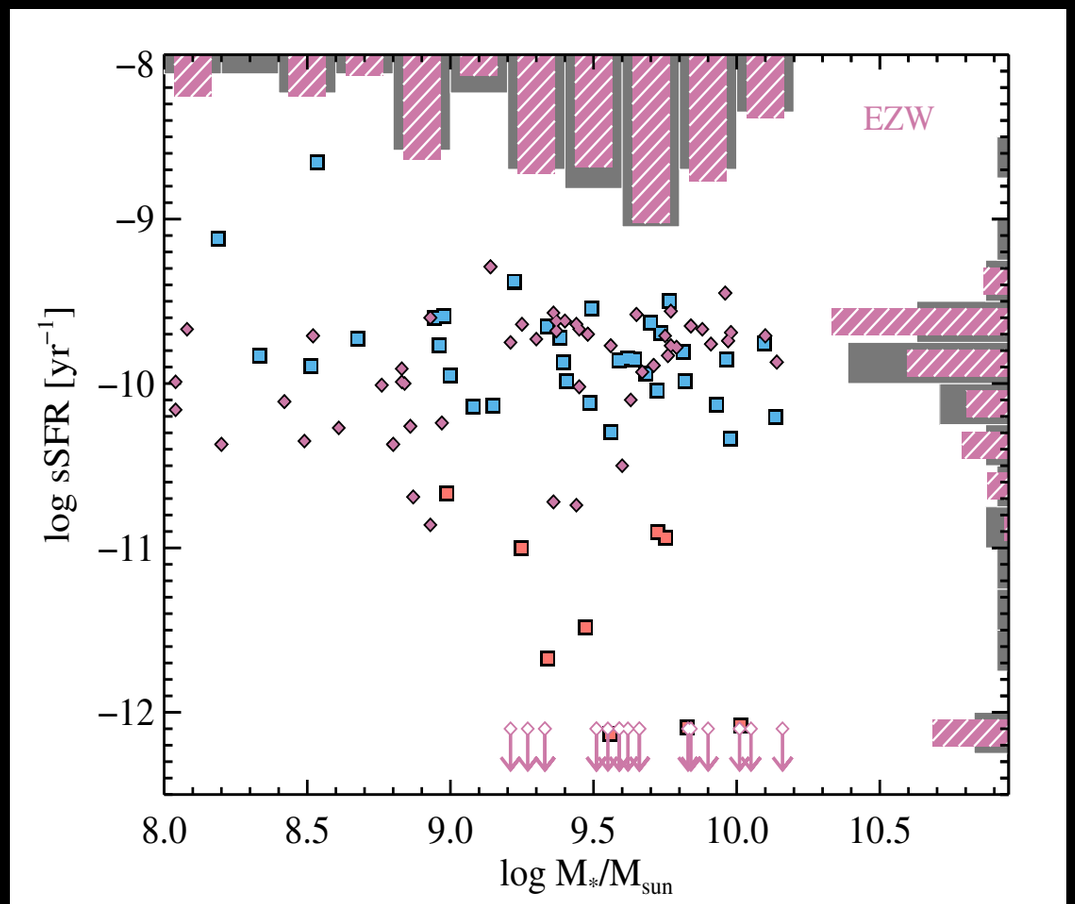
Along Pole

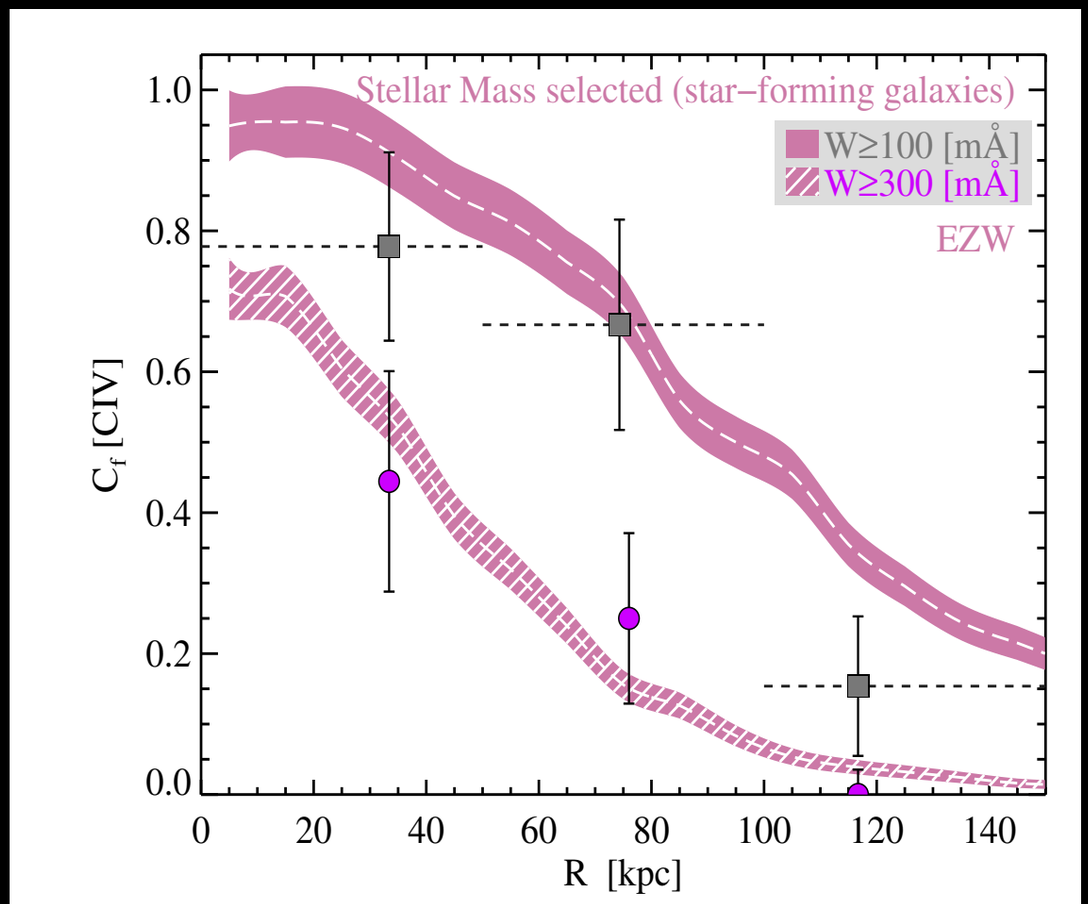
Along Disk

Testing Feedback Models

Wind Model	Wind Velocity	Mass-Loading Factor
Fiducial v2 energy driven scaling for dwarfs (ezw)	V_w	σ_{gal} σ_{gal}
Constant Wind (CW)	V	η=2
No Wind	——	η=0

Testing Feedback Models





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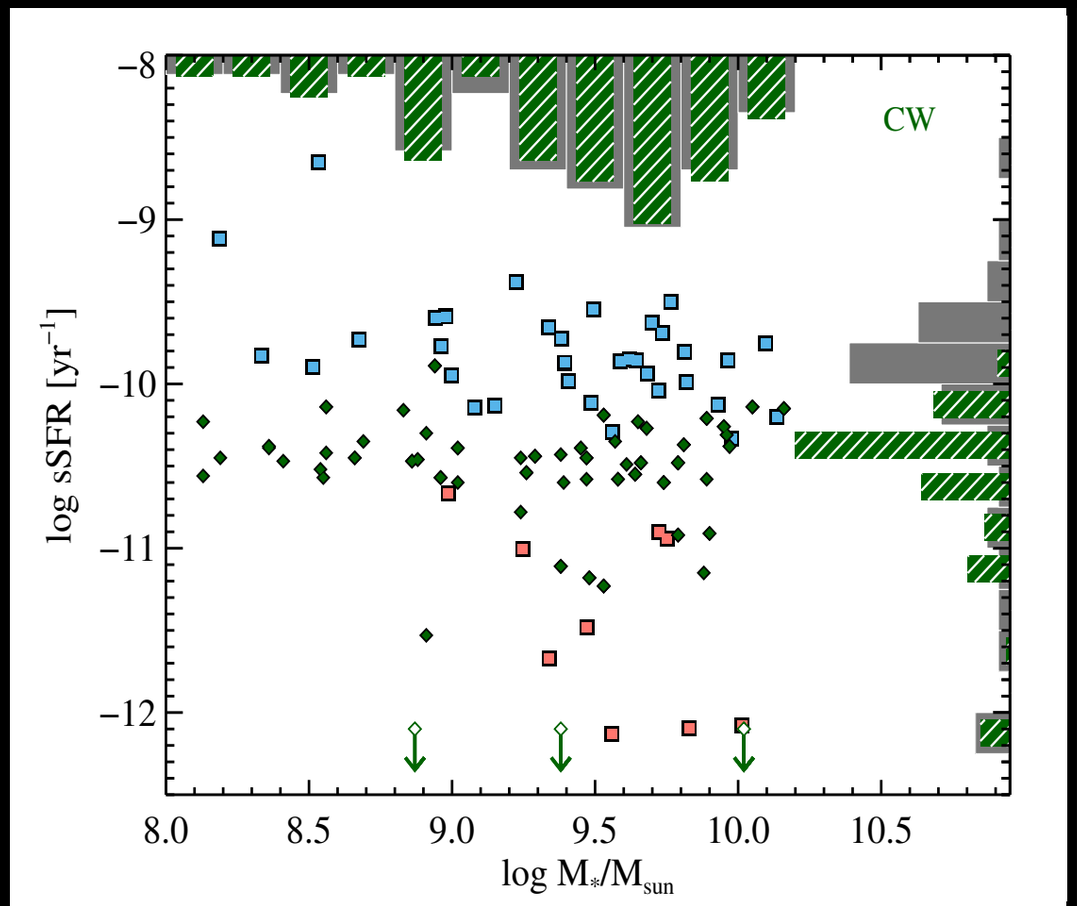
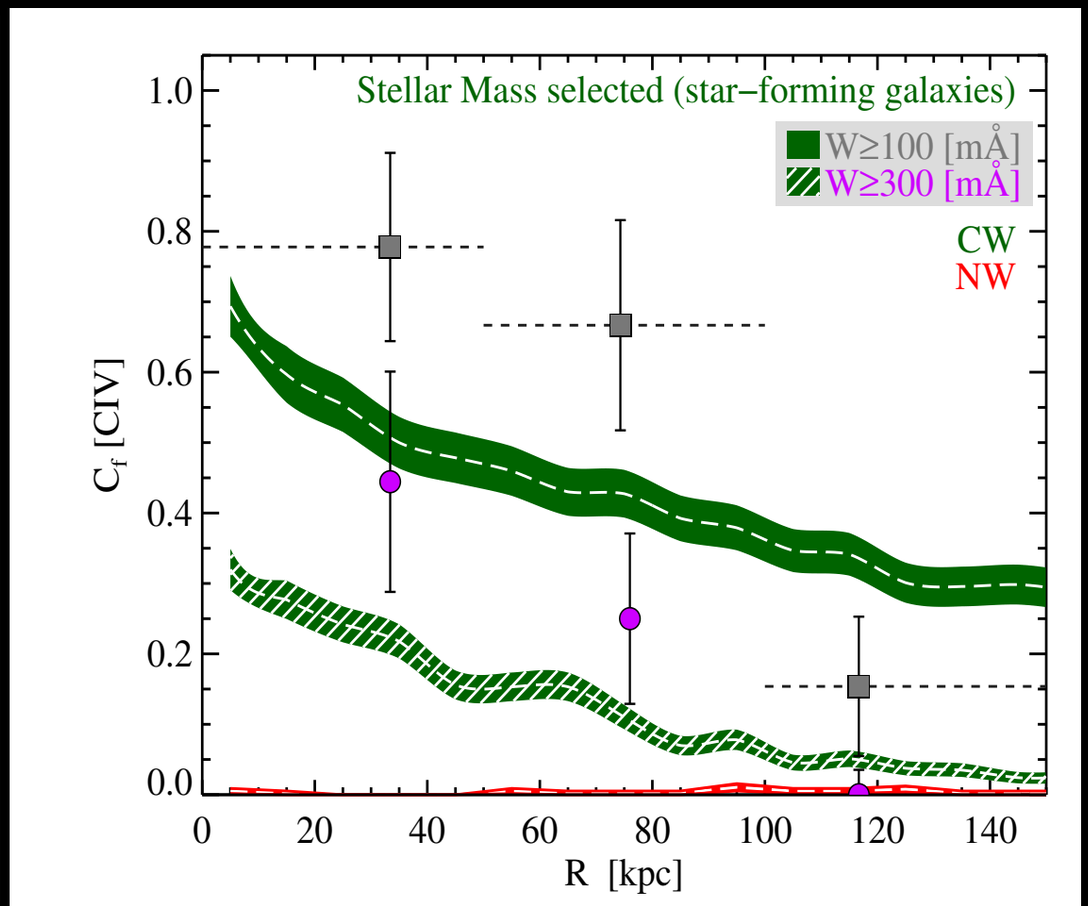
Testing Feedback Models





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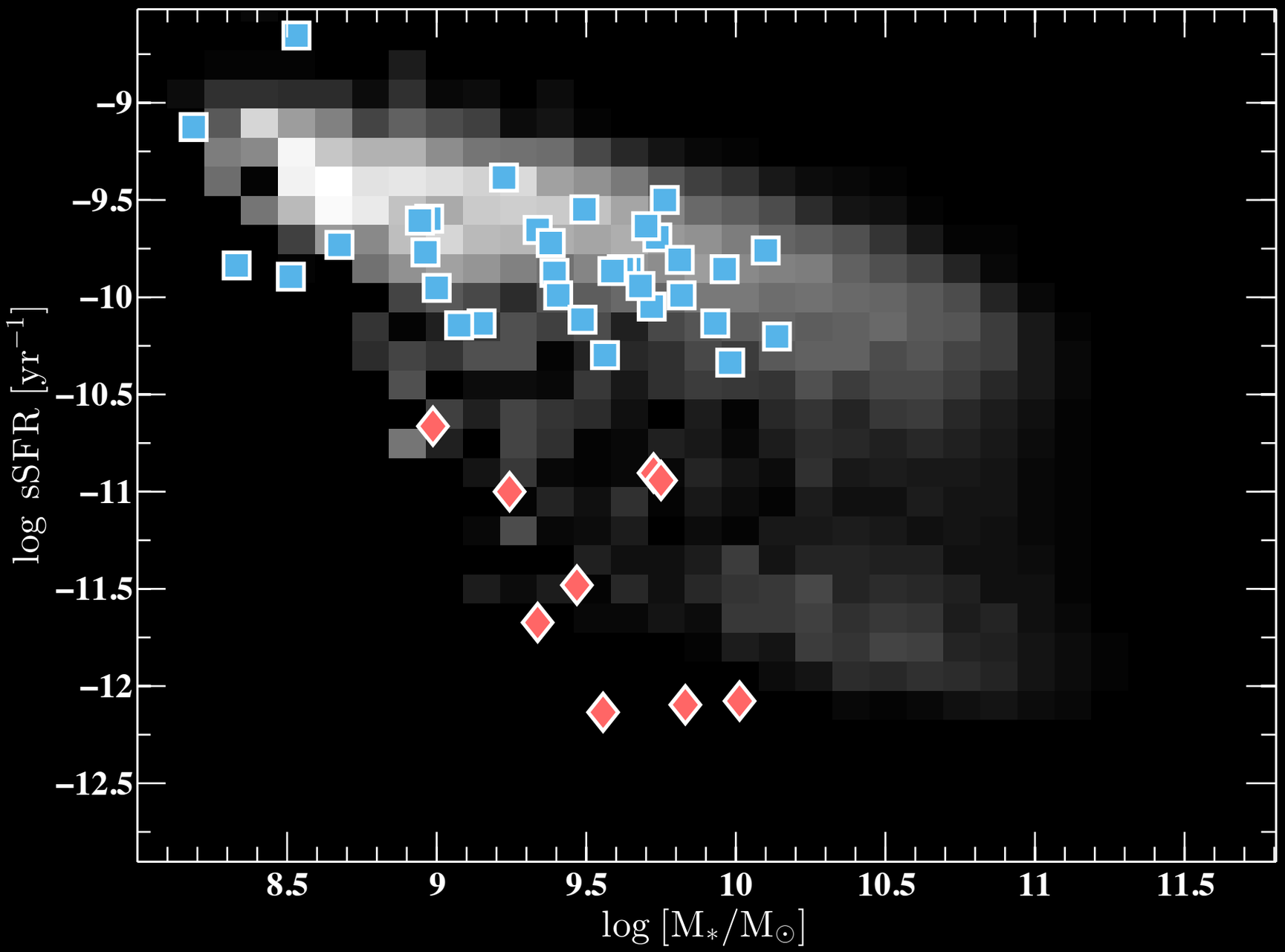
CGM over 3 decades of Stellar Mass



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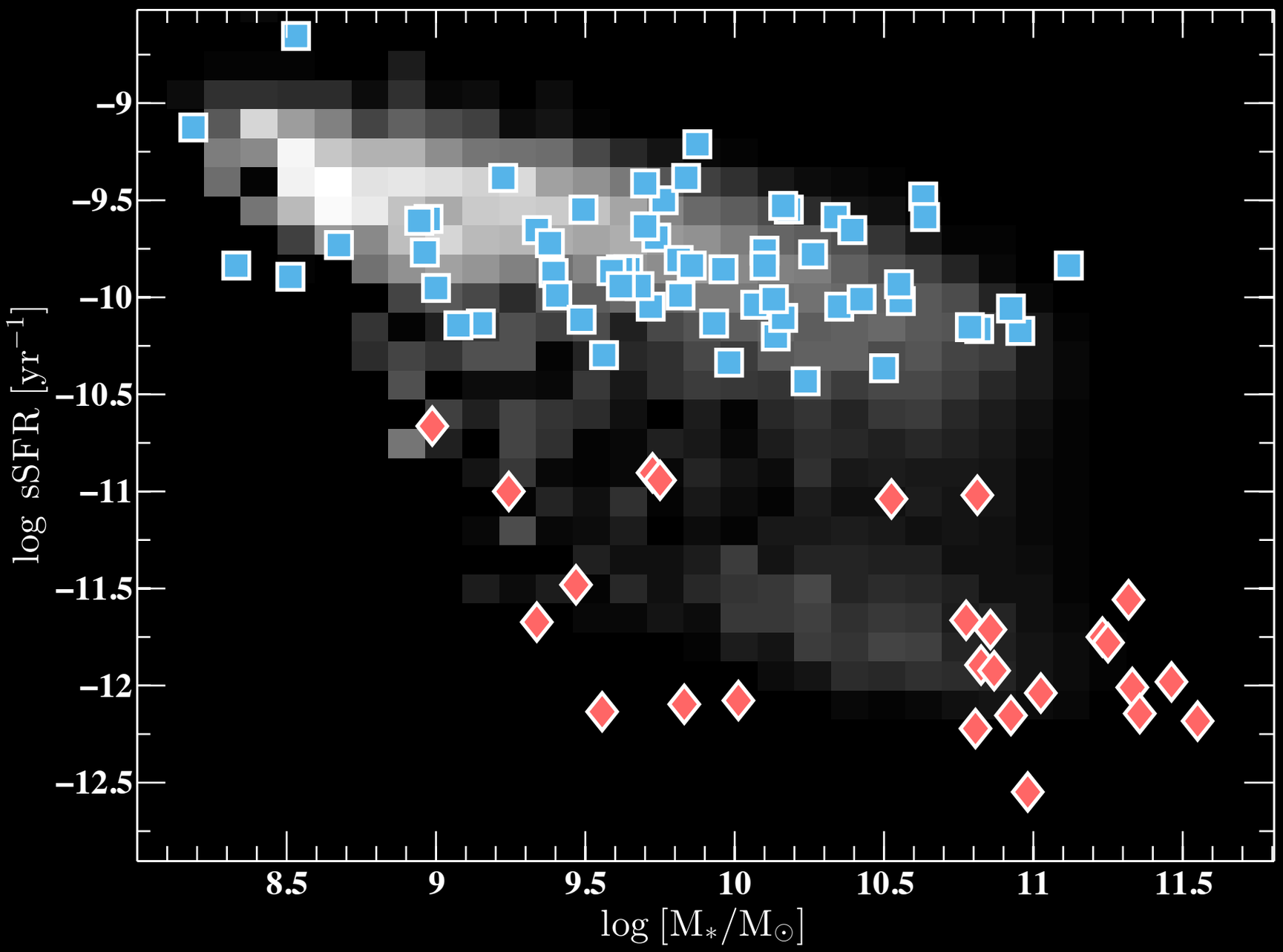
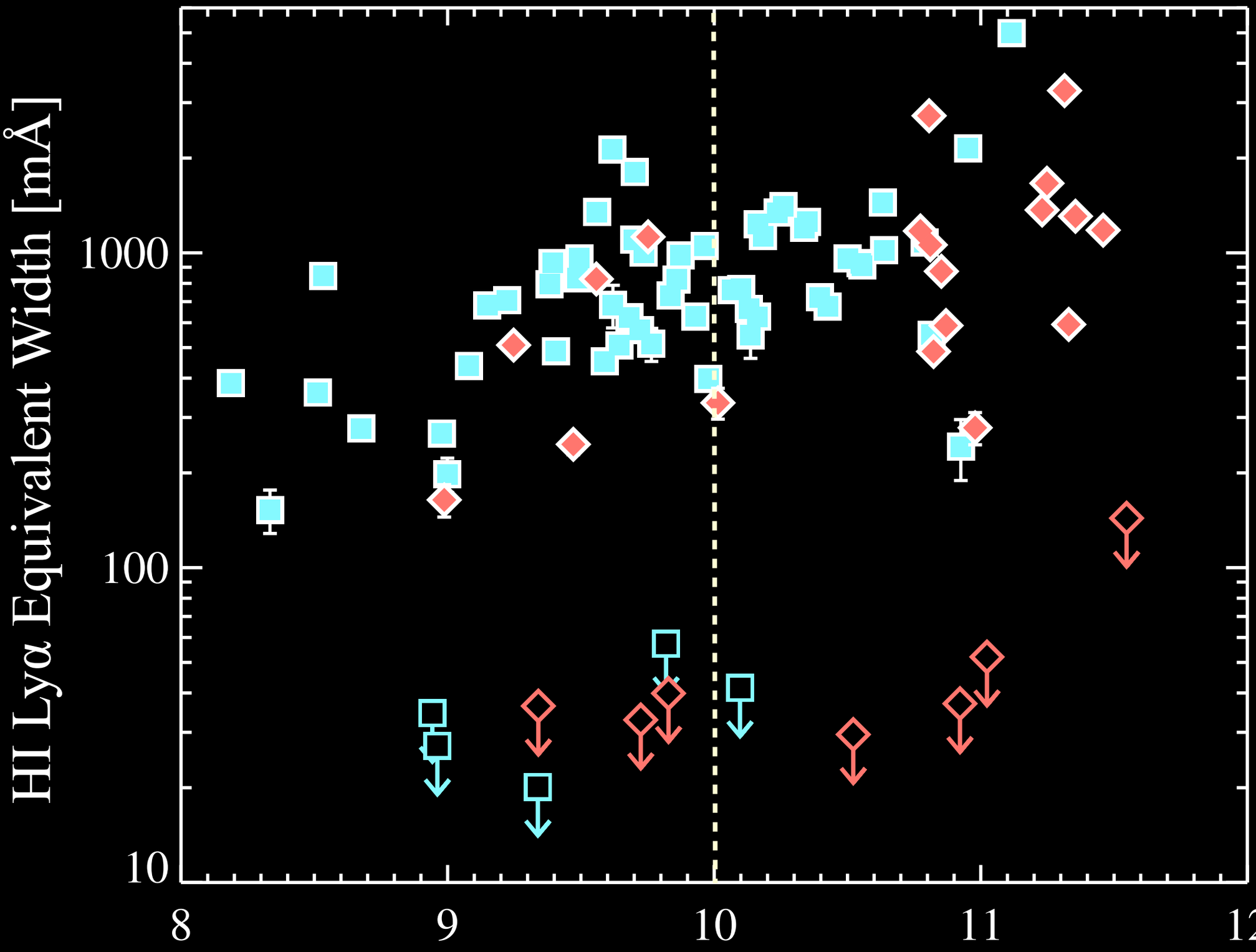


Total of 94 galaxies with 272 HST Orbits

HI (Lyα) over 3 decades of Stellar Mass

COS-Dwarfs

COS-Halos

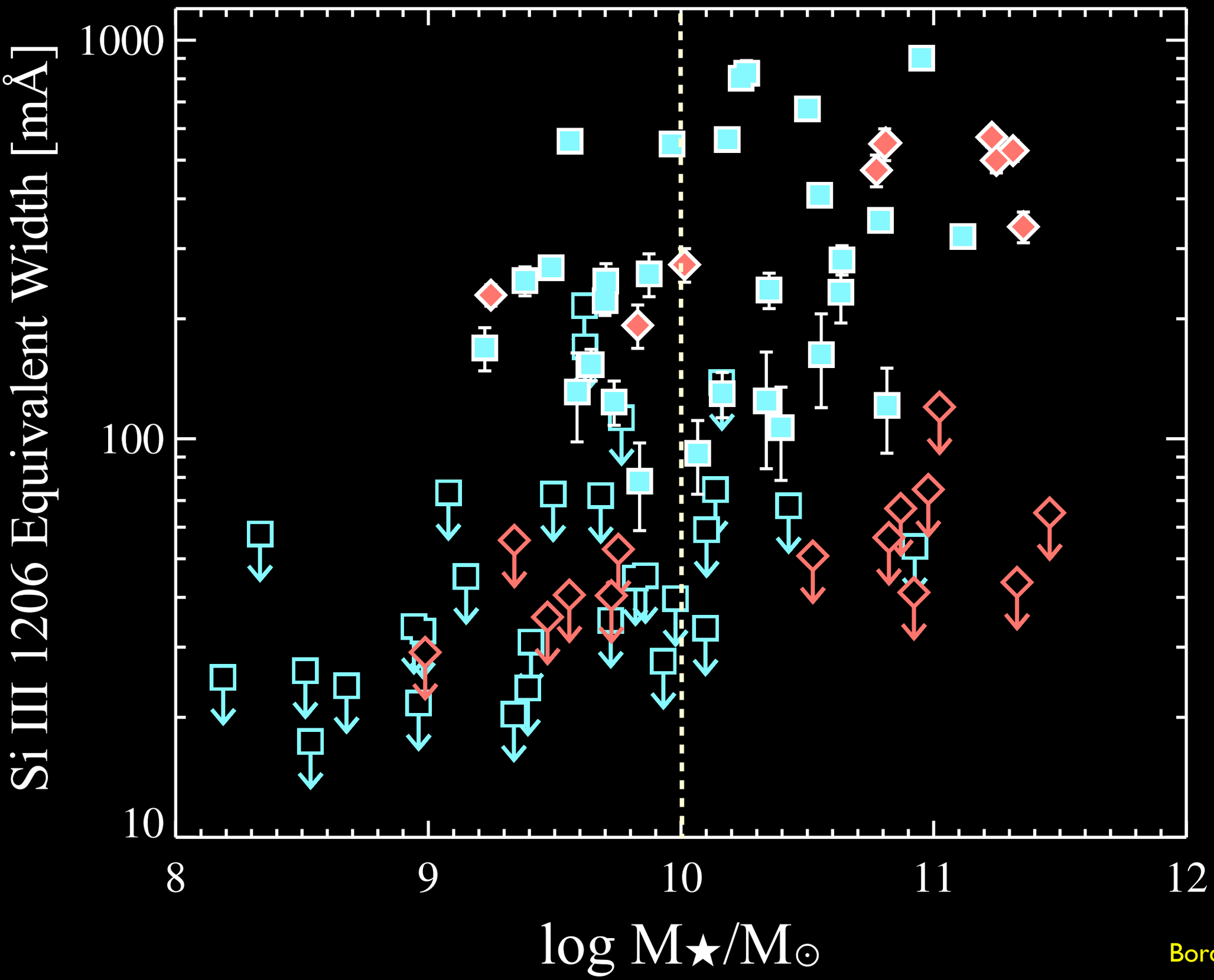


Bordoloi+15 in prep

Si III over 3 decades of Stellar Mass

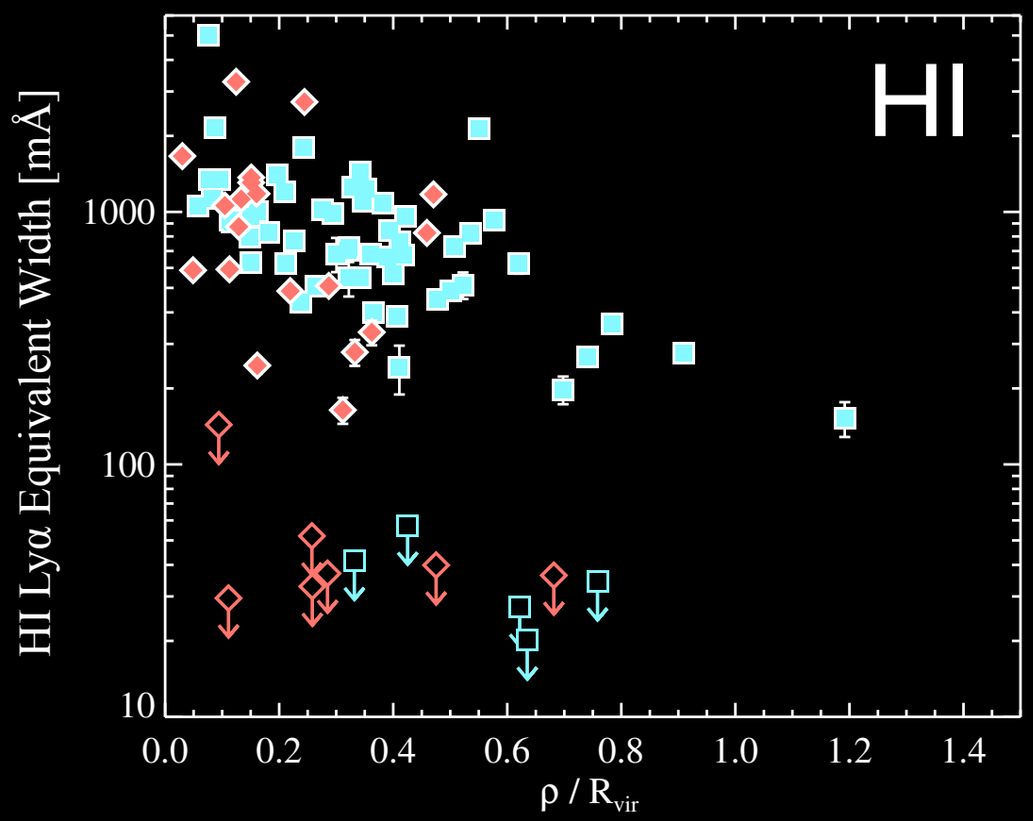
COS-Dwarfs

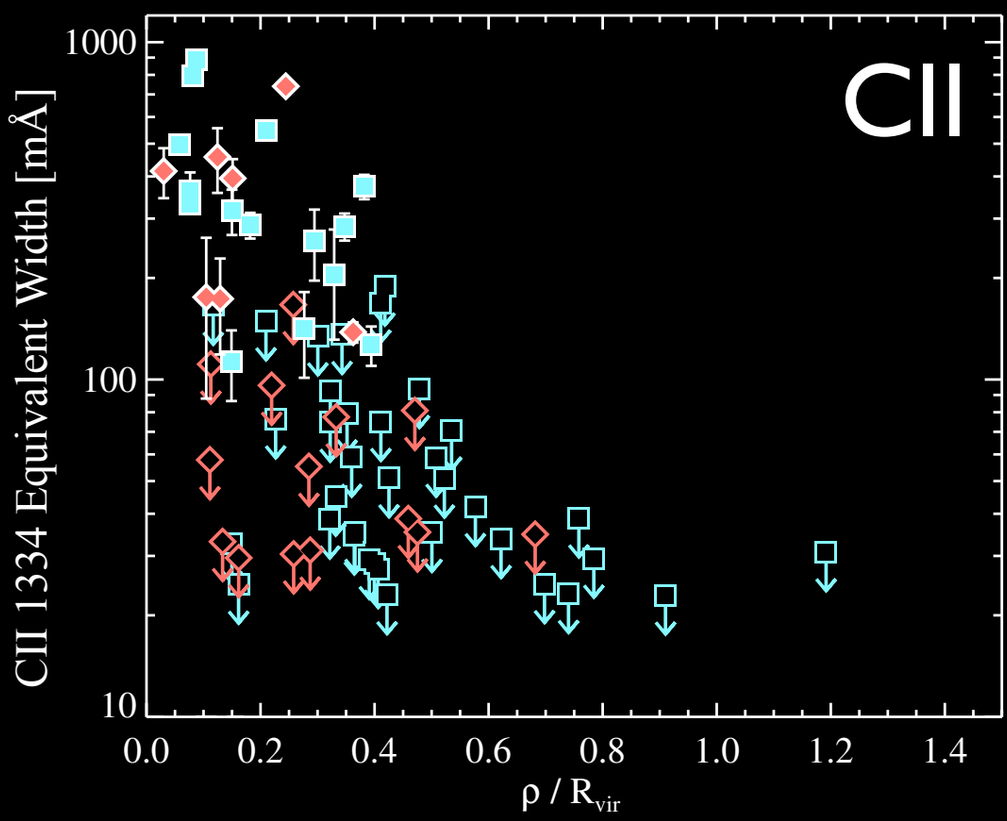
COS-Halos

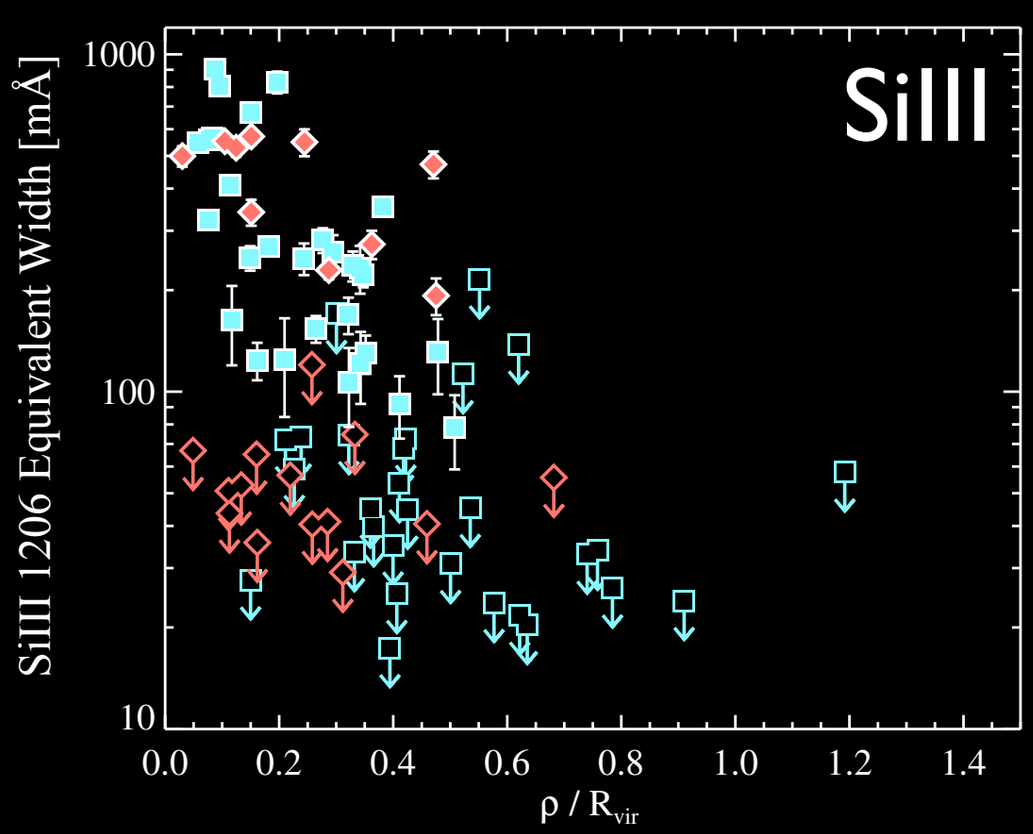


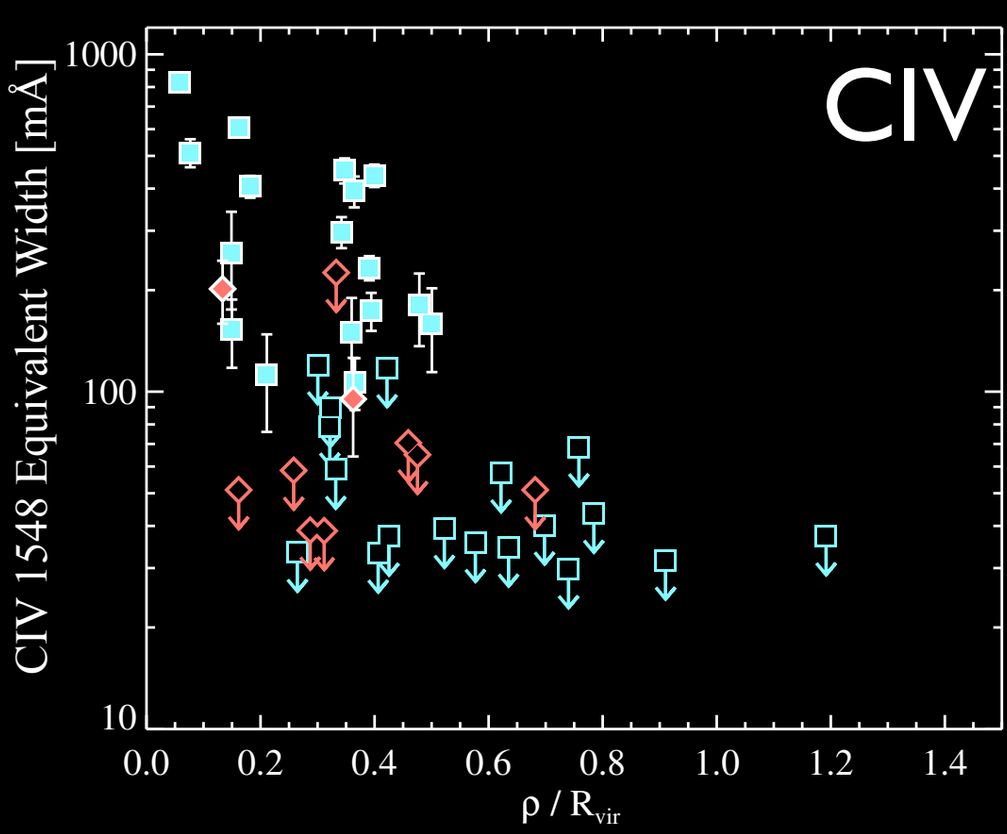
Bordoloi+15 in prep

Metals Census over Three Decades of Stellar Mass





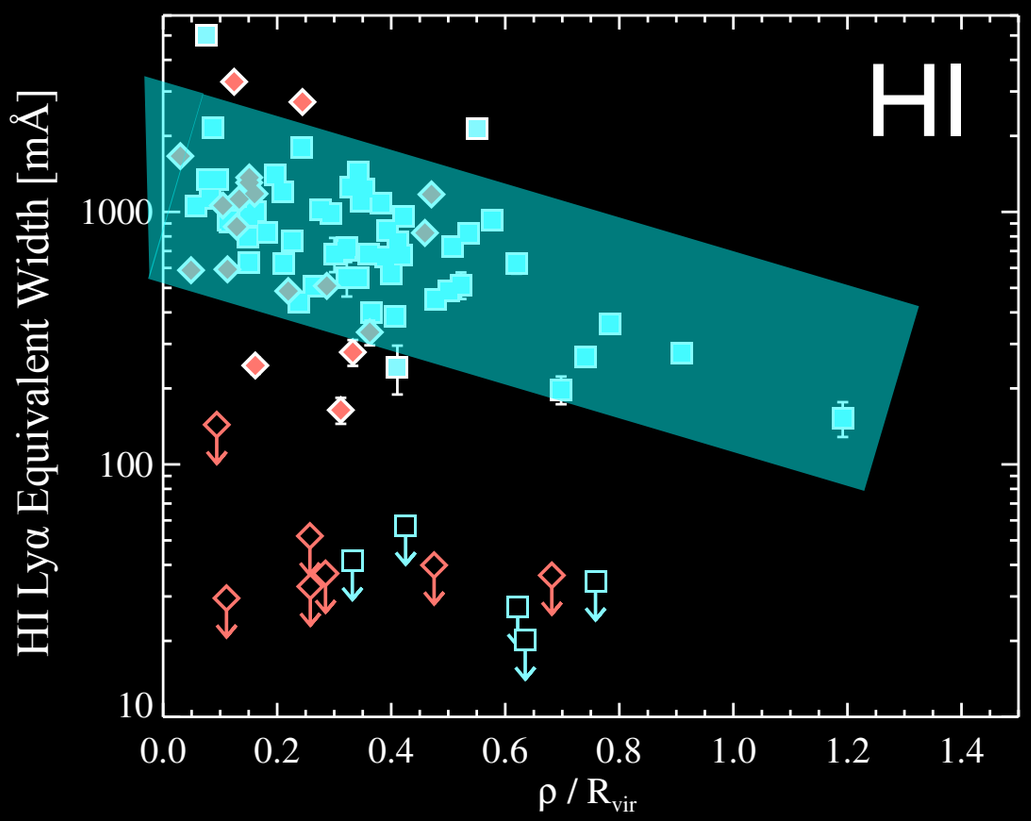


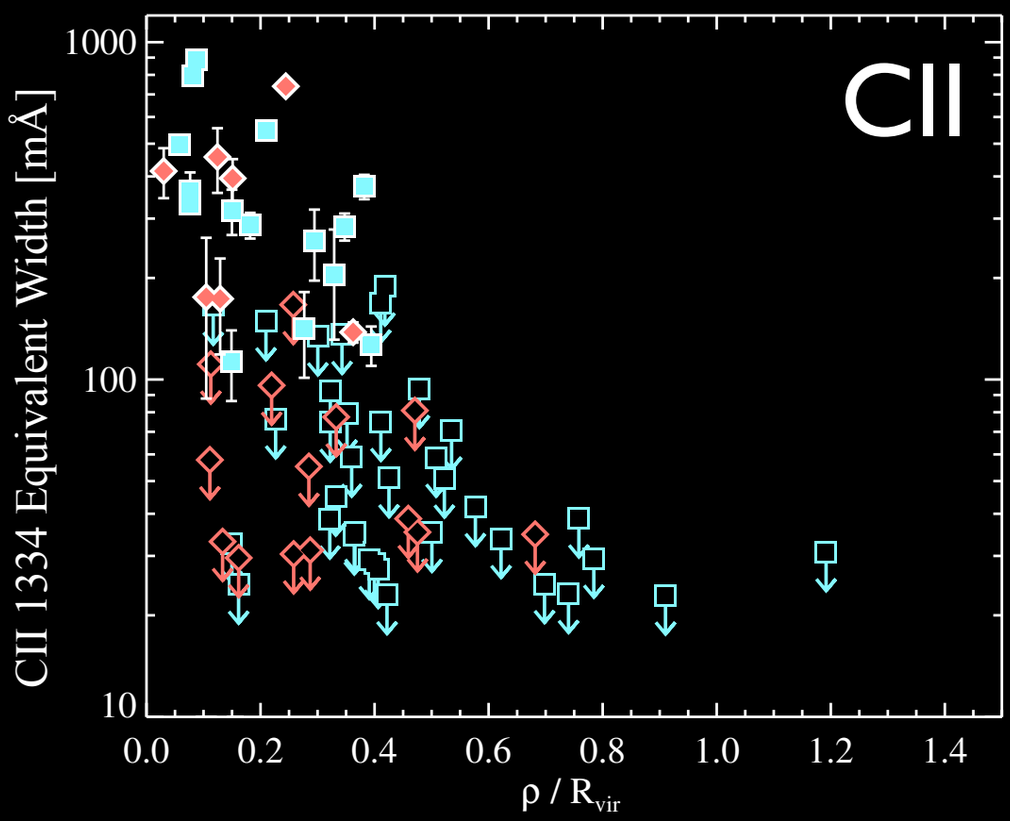


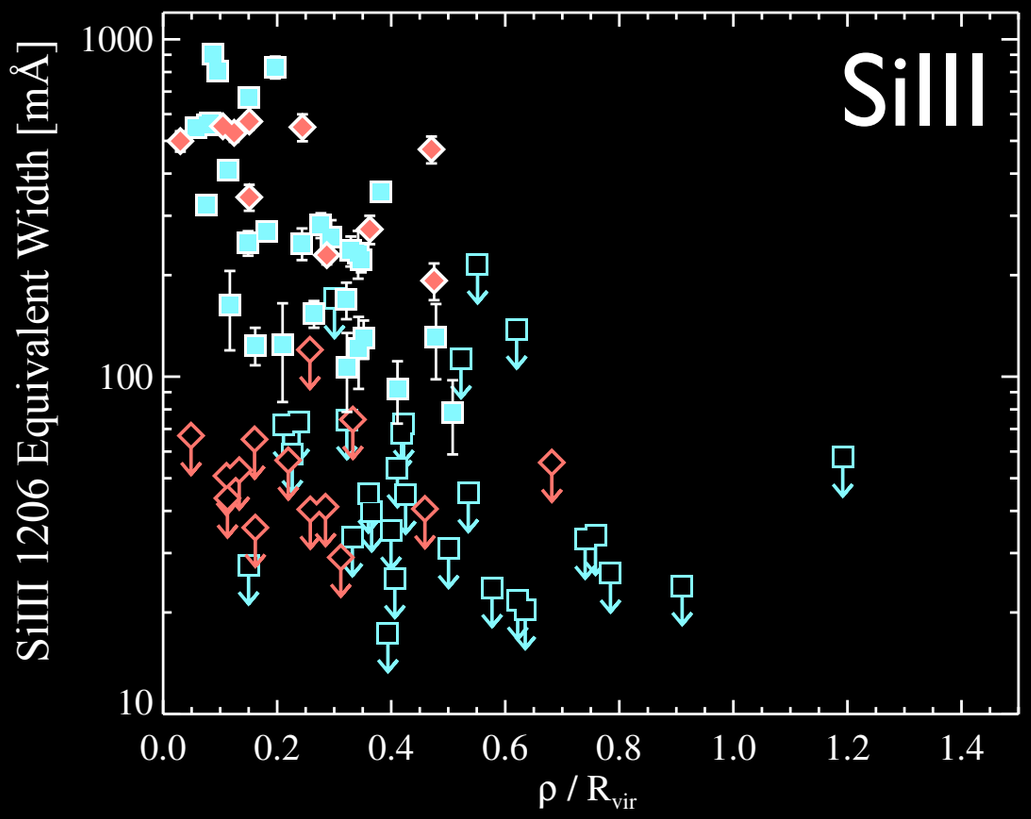
COS-Halos + COS-Dwarfs

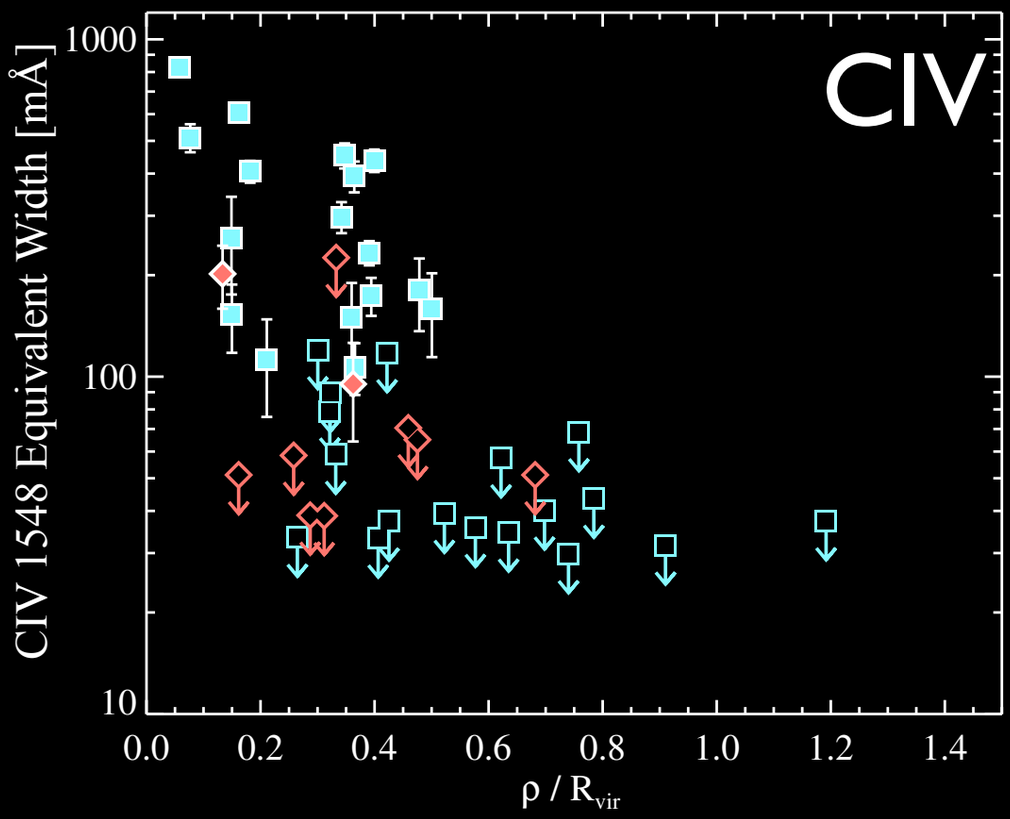
Bordoloi+15 in prep

Metals Census over Three Decades of Stellar Mass









COS-Halos + COS-Dwarfs

Bordoloi+15 in prep

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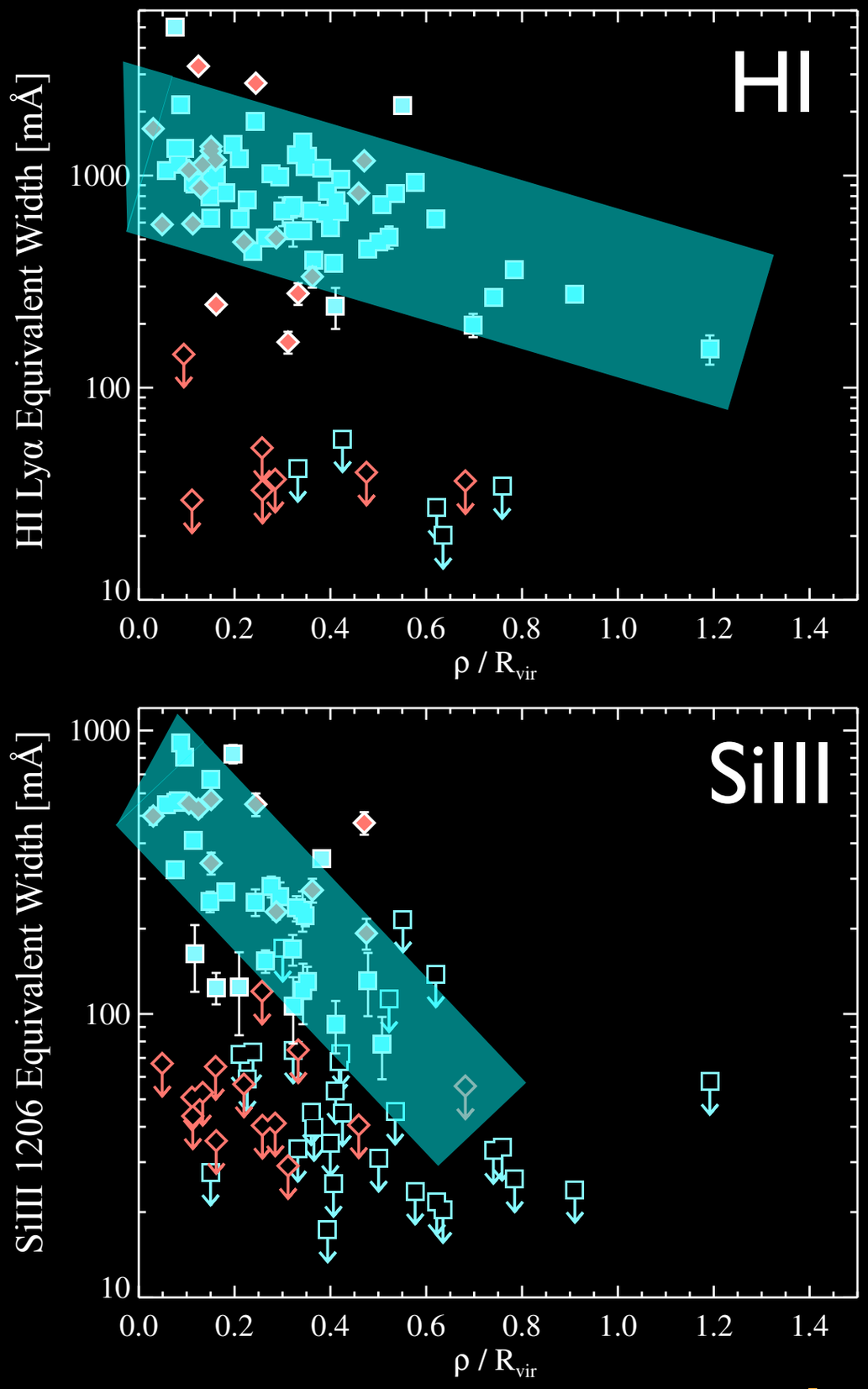
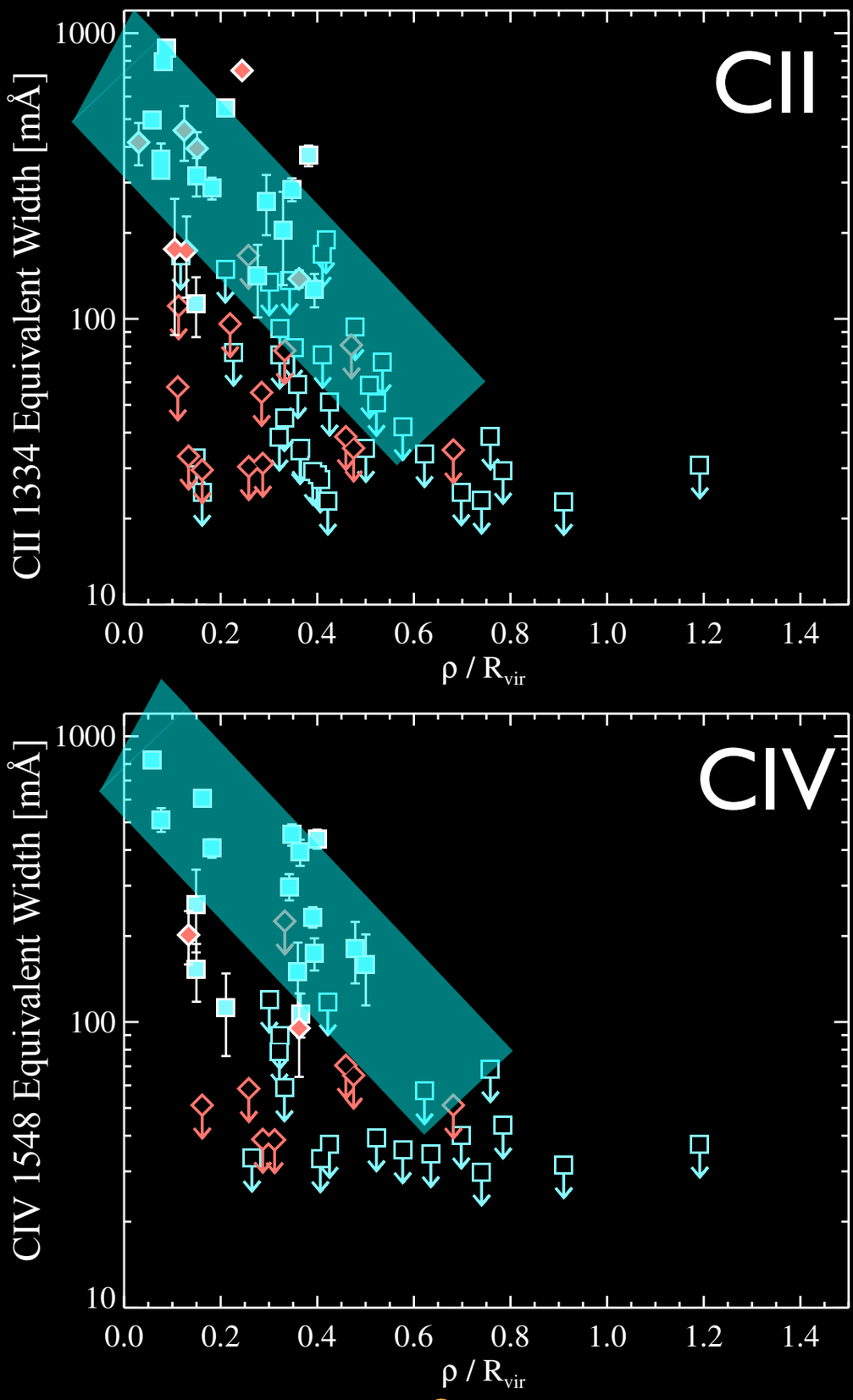


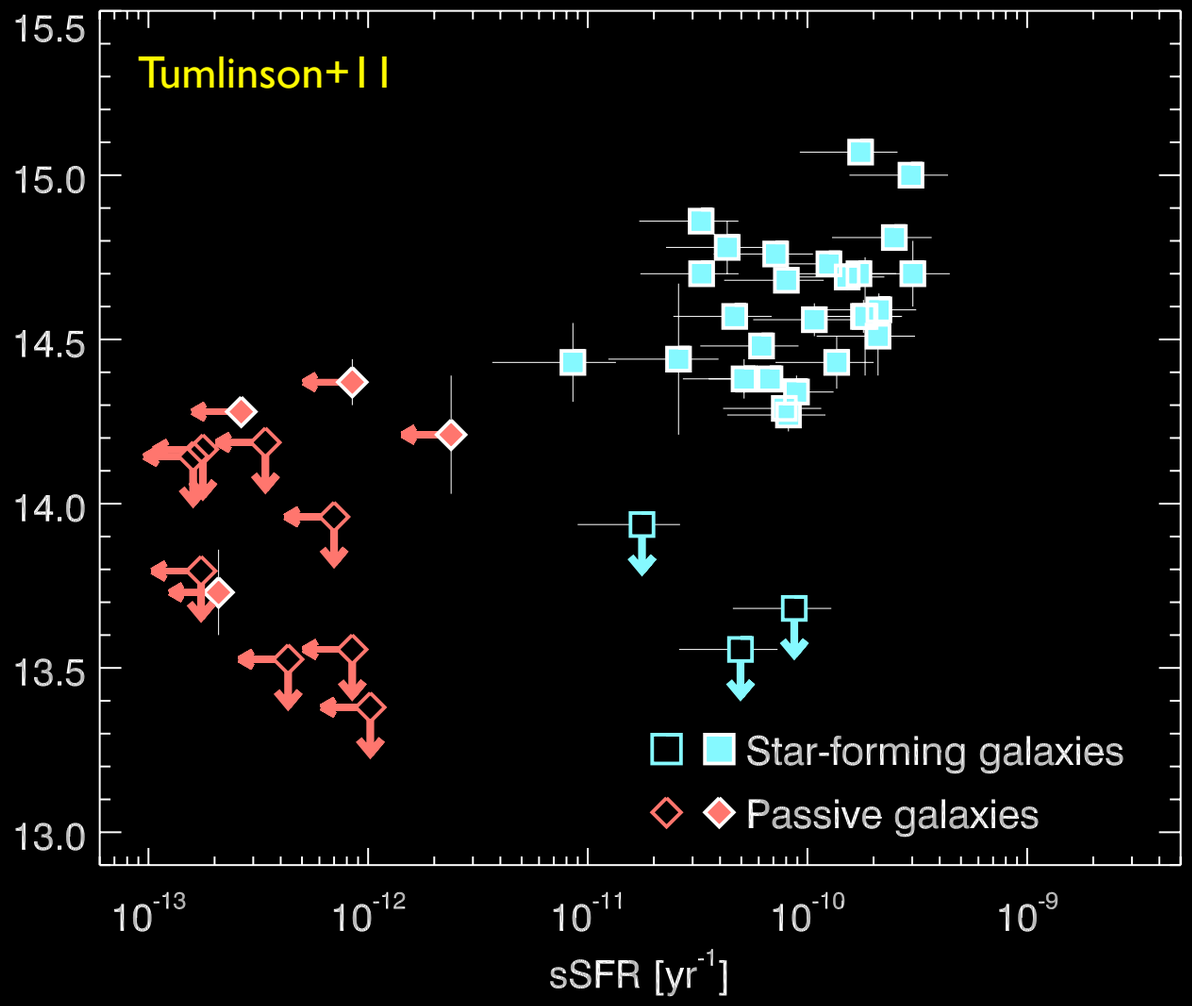


COS-Halos + COS-Dwarfs

Bordoloi+15 in prep

The Metal Content of The CGM

3 Decades of High Ions



The contrast in high-ions seen in OVI for COS-Halos is mirrored in CIV for the <L⋆ galaxies.

Strong C IV is associated predominantly with star-forming galaxies.

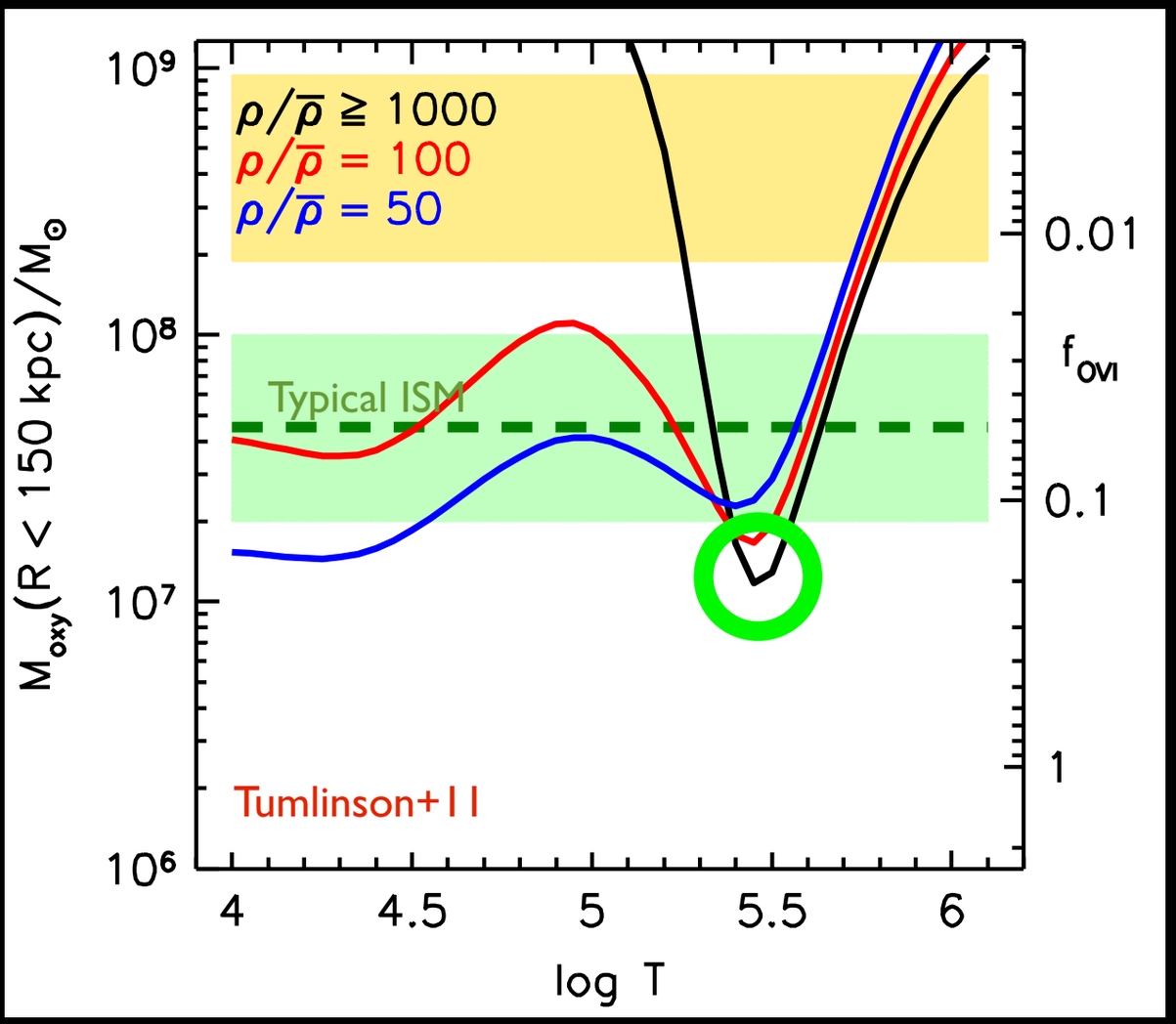
Estimating CGM metal masses

$$M_Z = \pi R^2 N_{ion} A m_H M_\odot$$

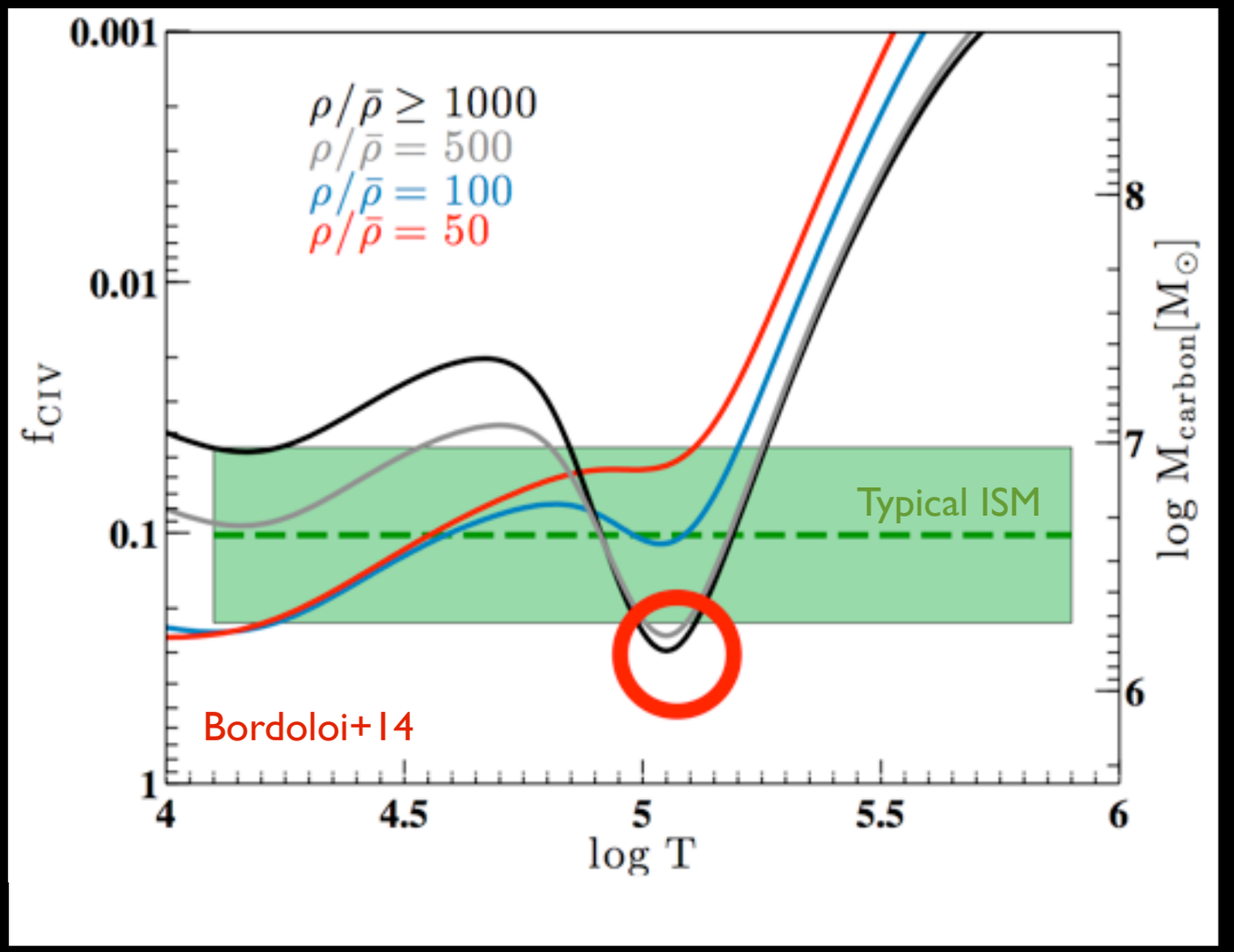
. . . then scale to minimum ionization correction f. . .

$$M_{Oxygen} \gtrsim 1.2 \times 10^7 \, (0.2/f_{OVI}) \, M_\odot$$

$$M_{Carbon} \gtrsim 1.2 \times 10^6 \, (0.3/f_{CIV}) \, M_\odot$$



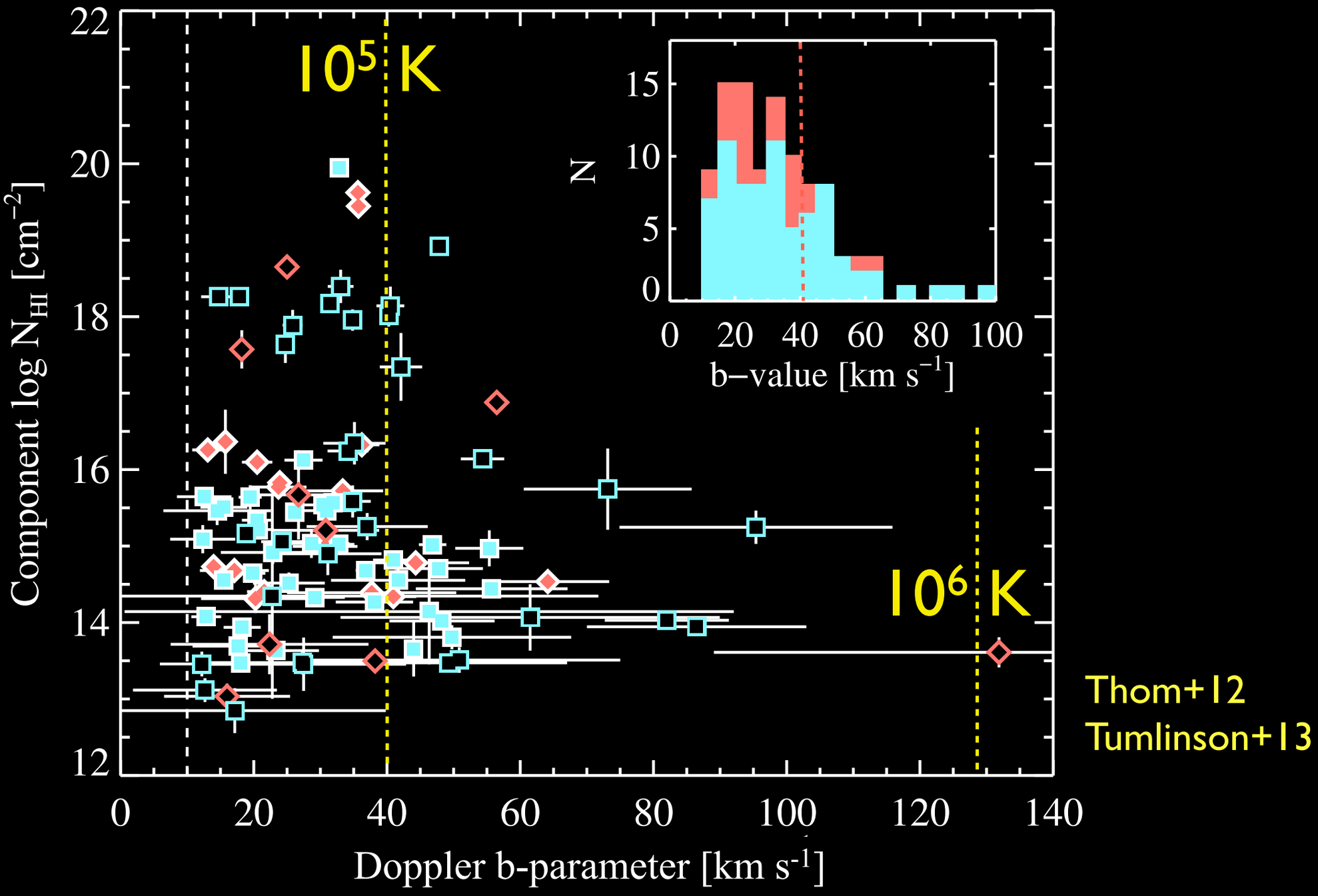
COS-Halos
log $M_\star$ = 9.6-11.2



COS-Dwarfs
log $M_\star$ = 8.5-10

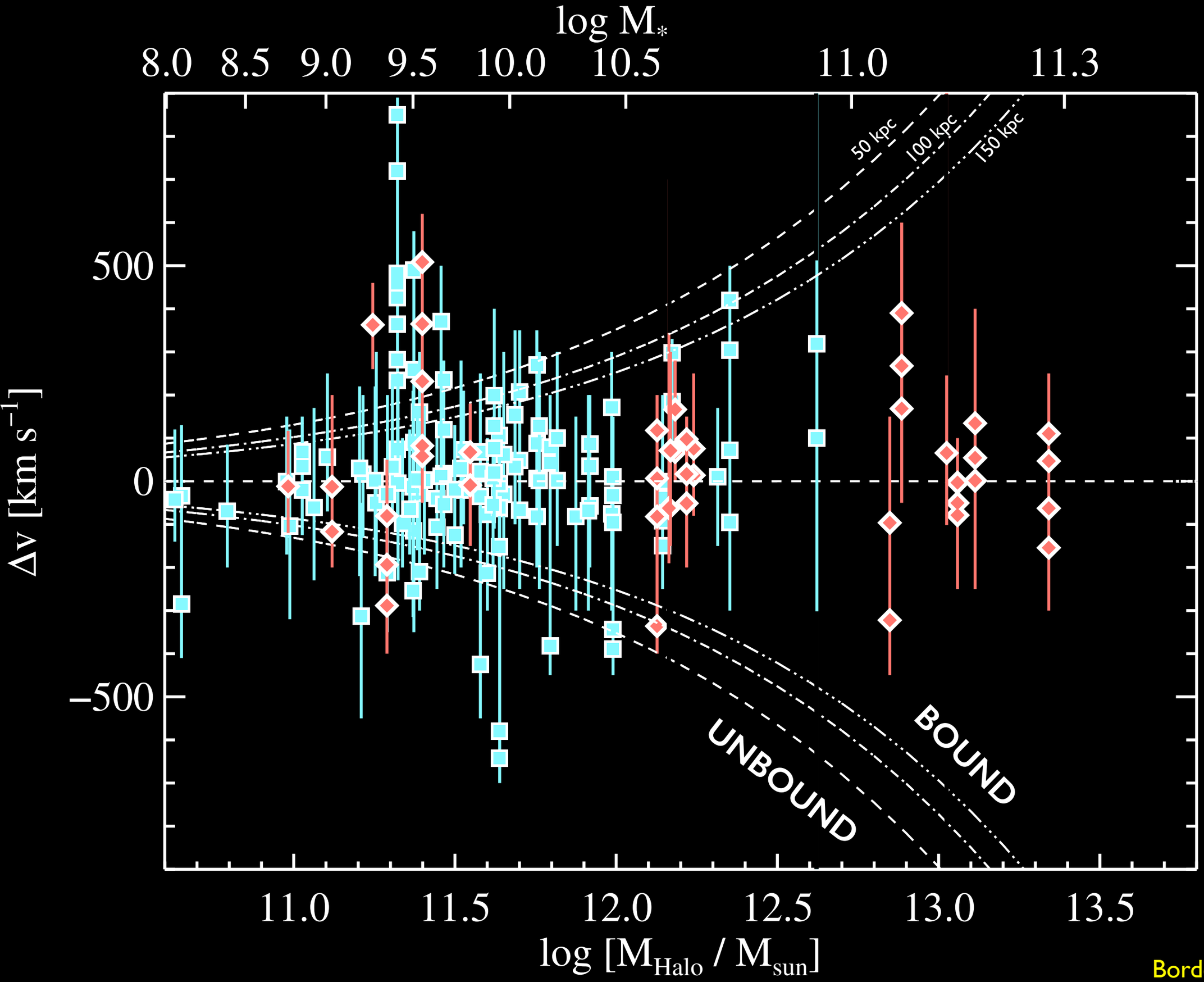
Gas and Metal Recycling of the CGM

Nearly all the mass traced by HI is COOL



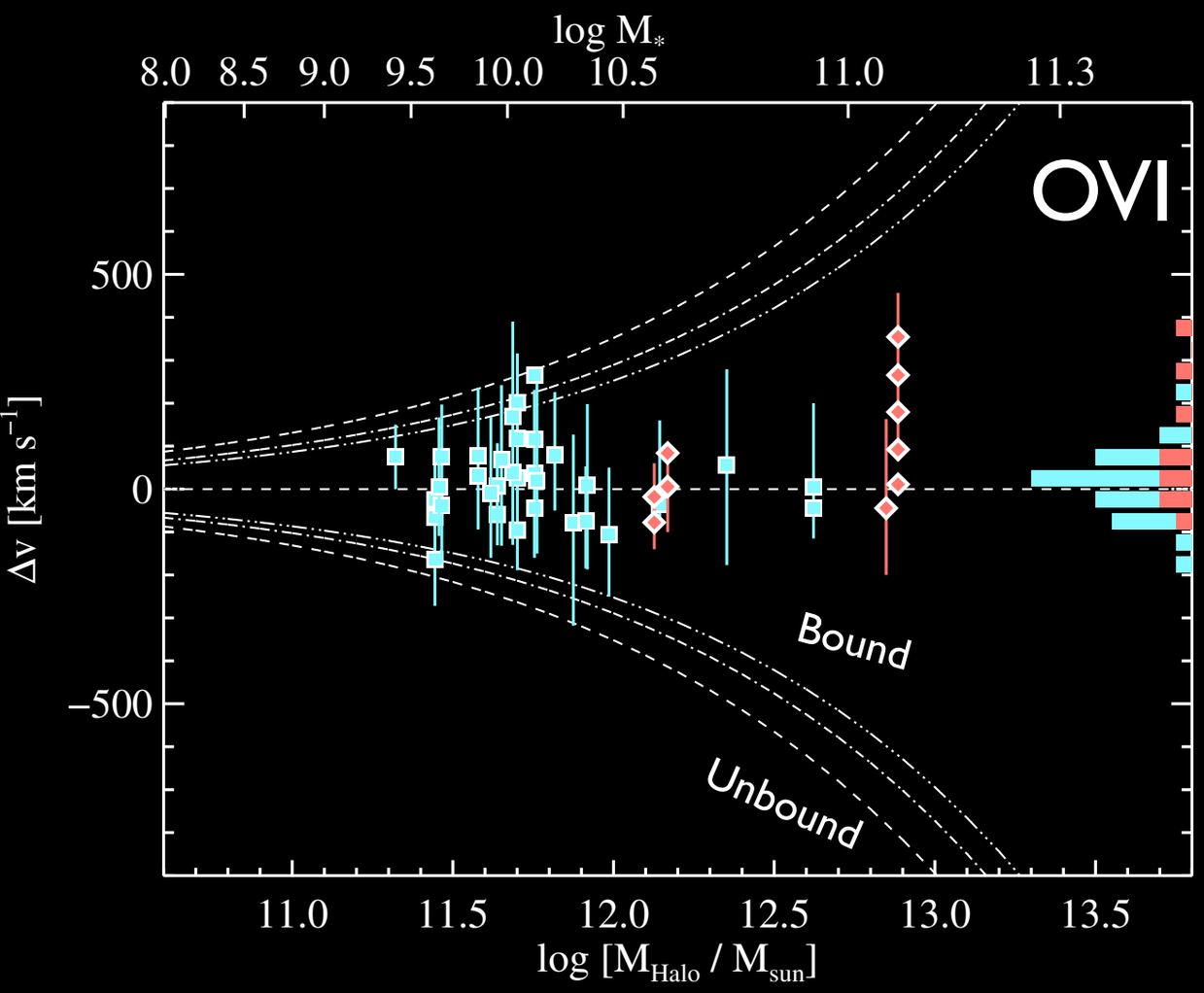
This is well below the expected ~ 10^6 K virial temperatures.

Nearly all the mass traced by HI is **BOUND**

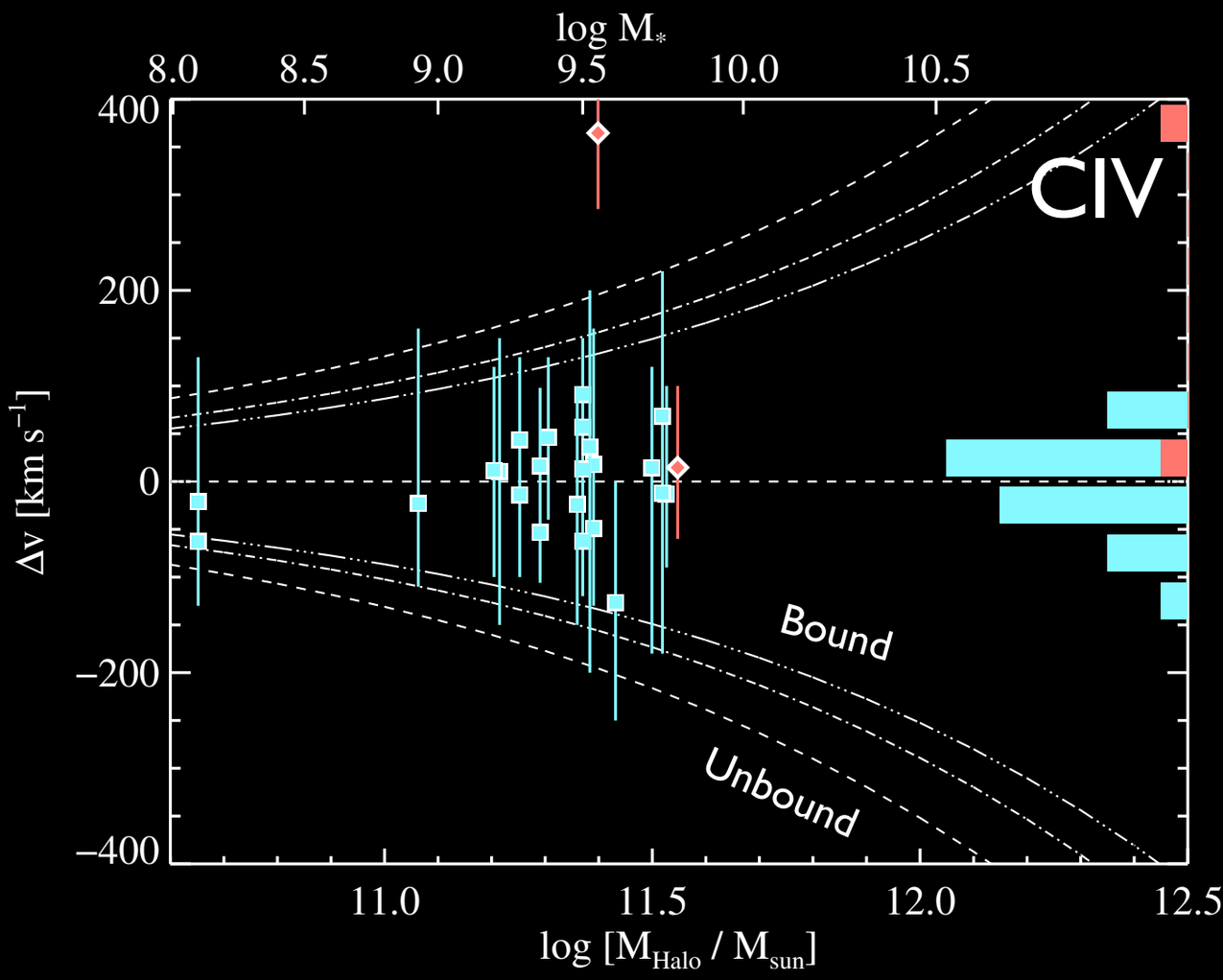


Bordoloi+15 in prep

High Ion Kinematics



Tumlinson+11



Bordoloi+14

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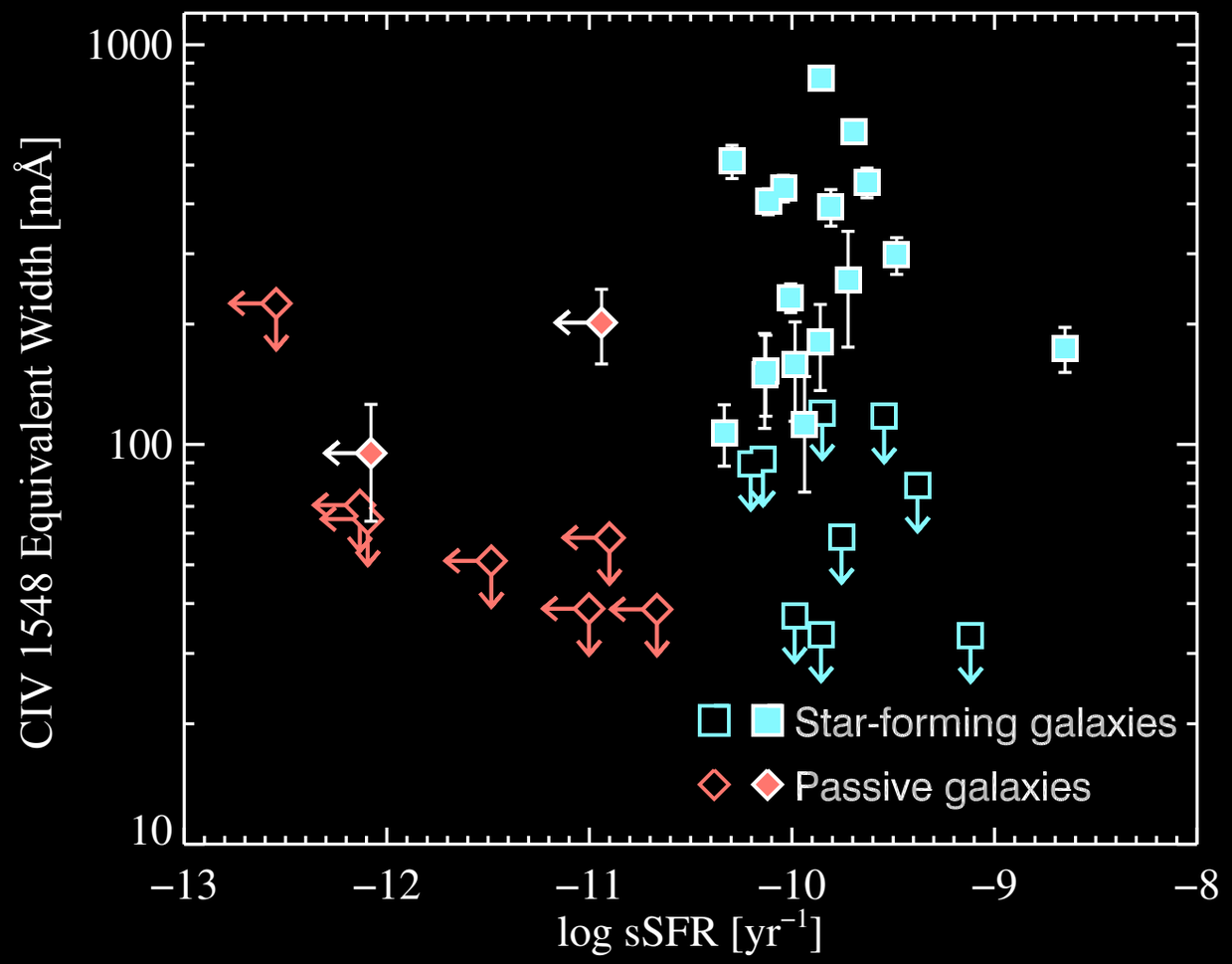
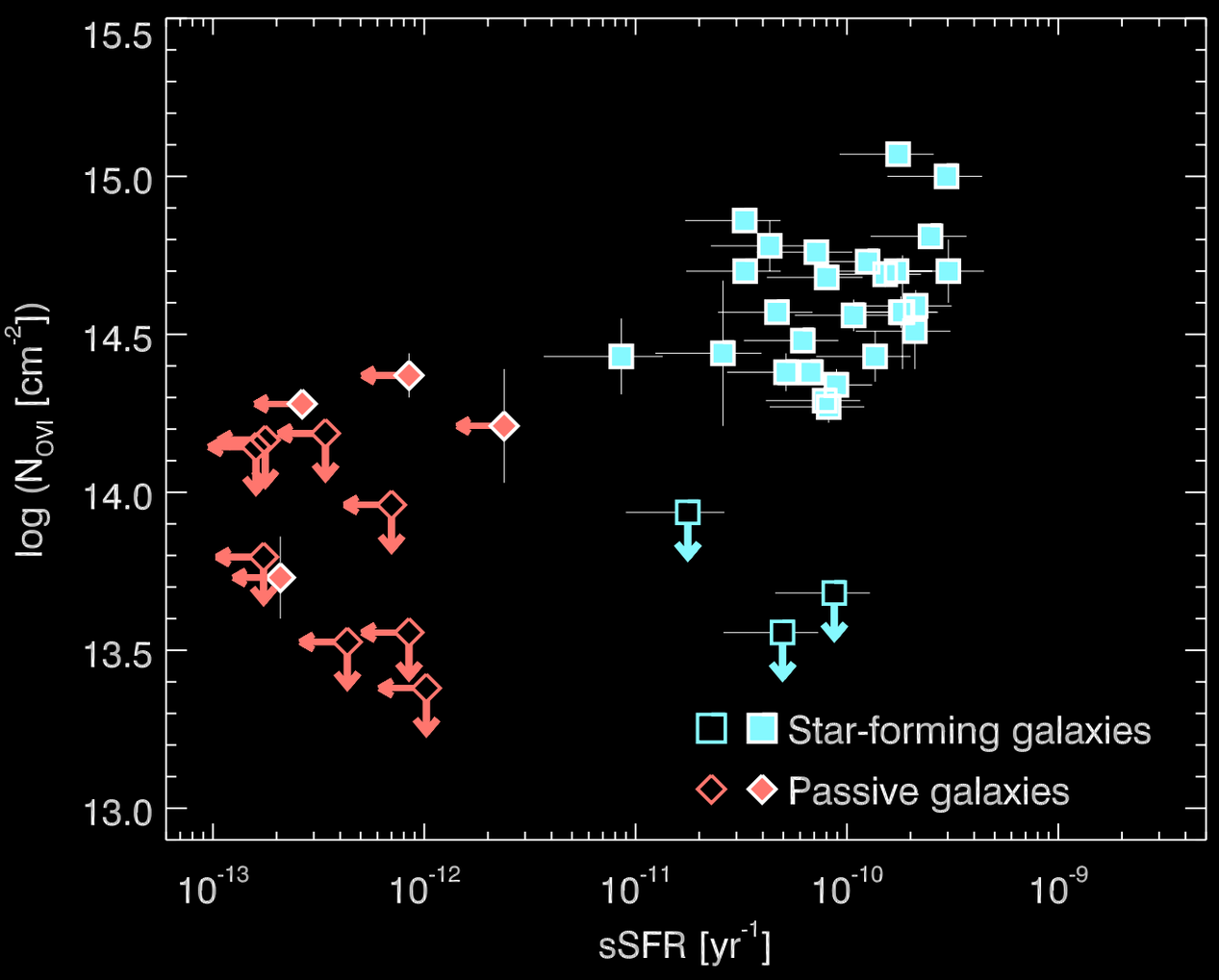
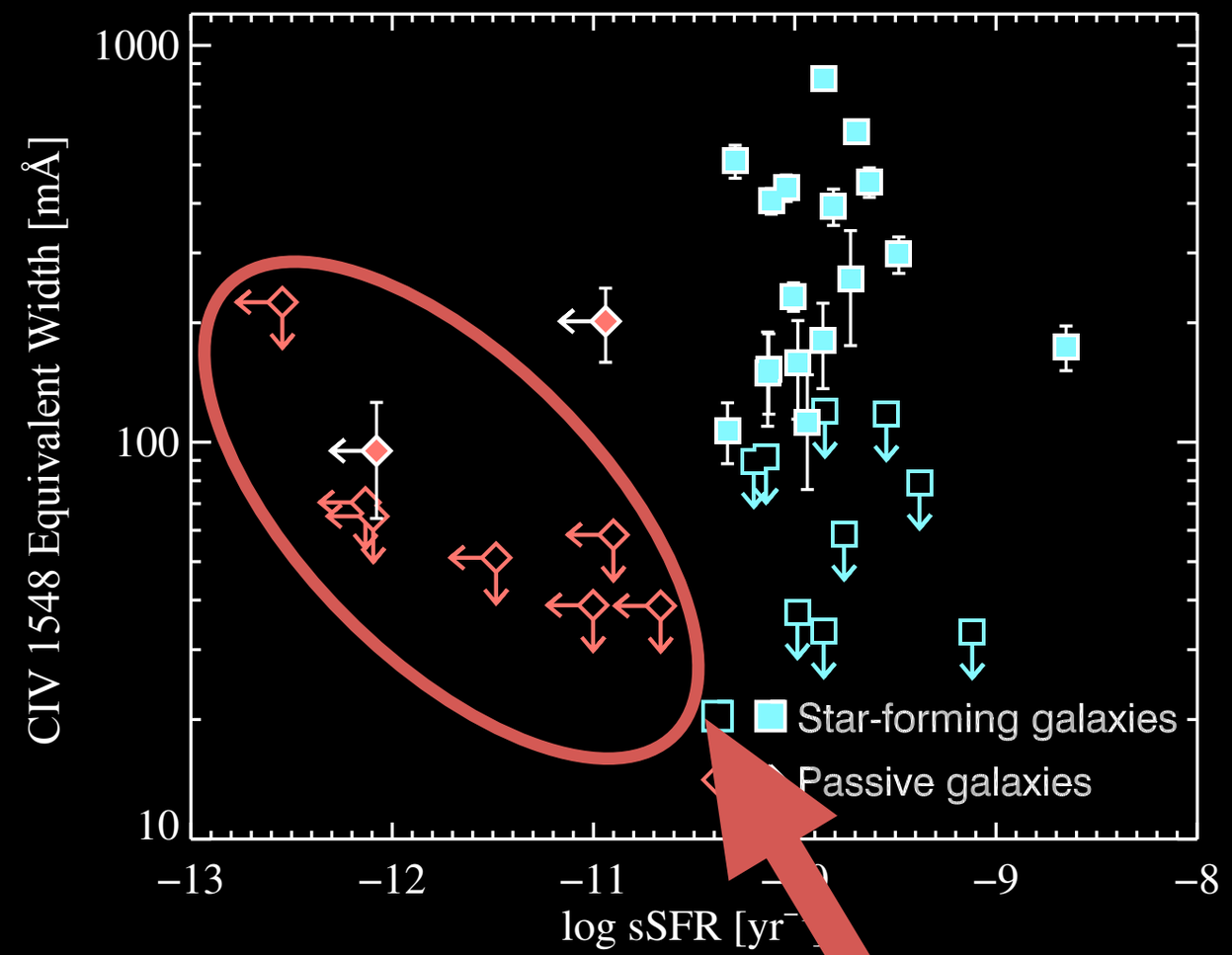


Bordoloi+14

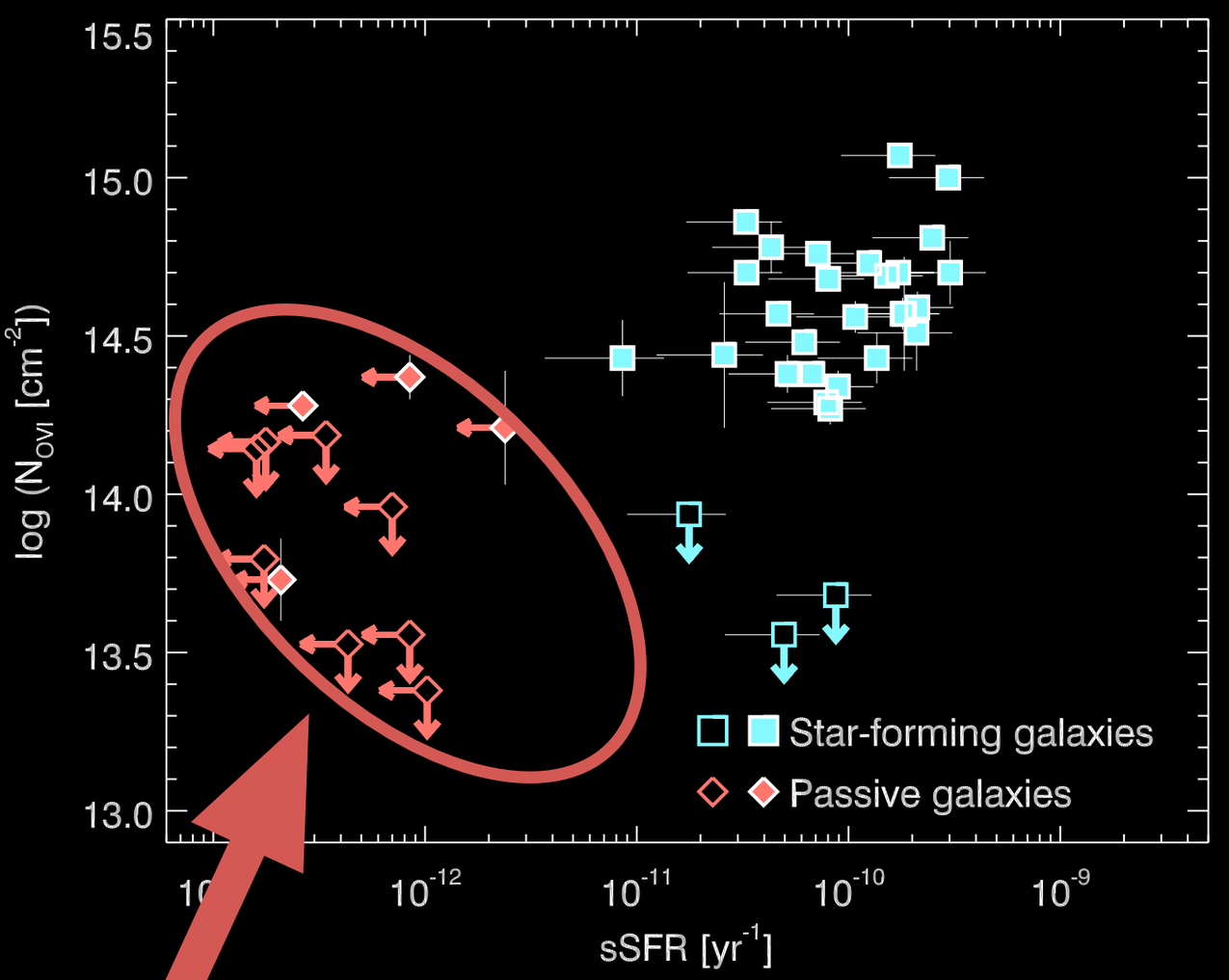


Tumlinson+11

3 Decades of High Ions



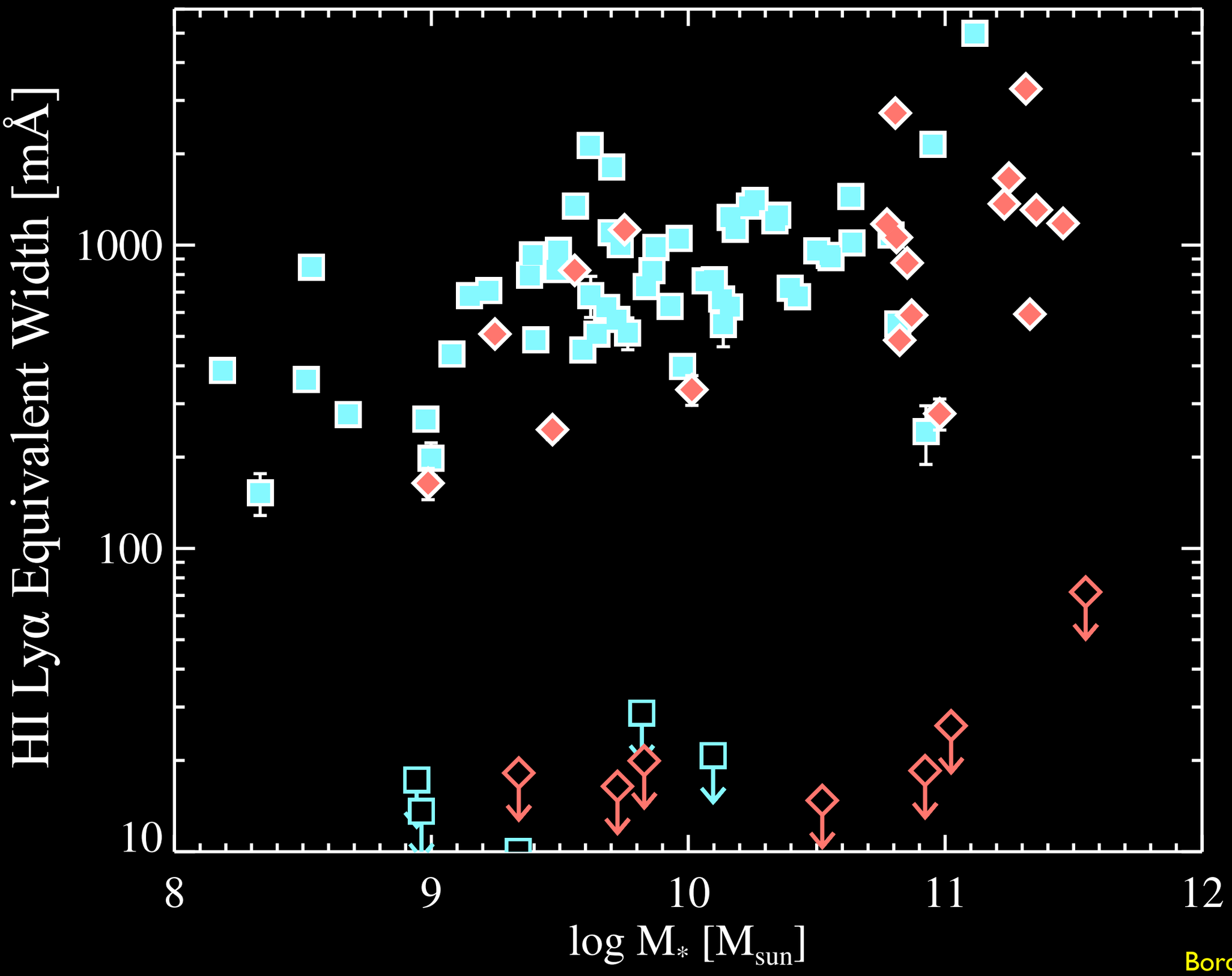
Bordoloi+14



Tumlinson+11

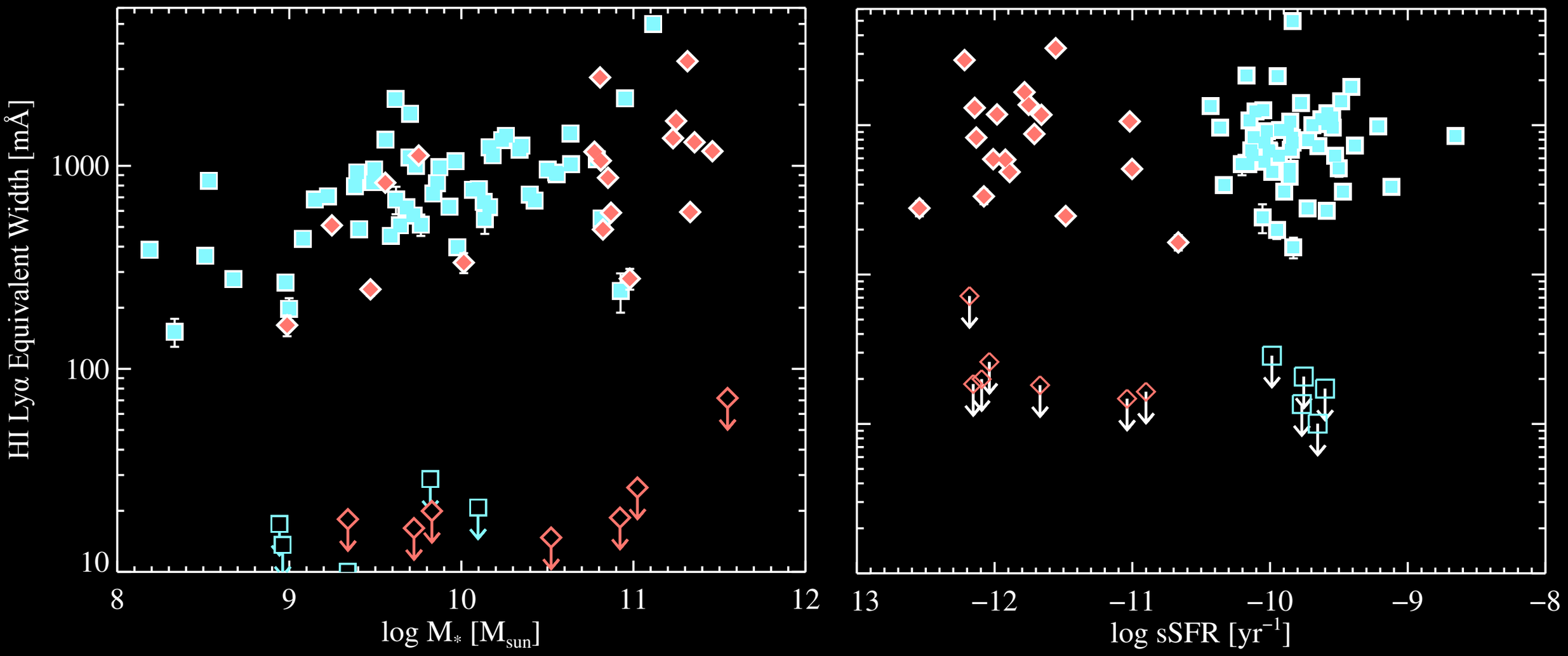
Is this Quenching?

So What Actually Happened: Quenching?



Bordoloi+15 in prep

Not Exactly!!!

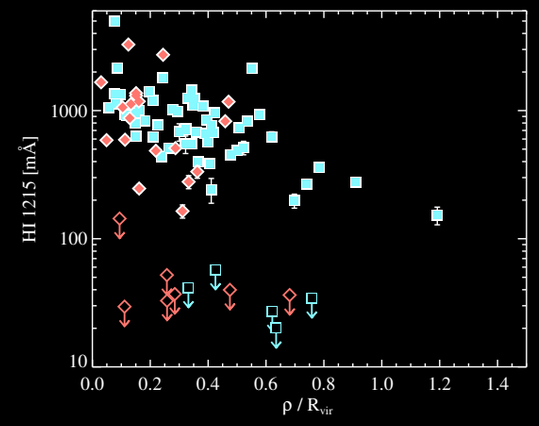


Thom+12

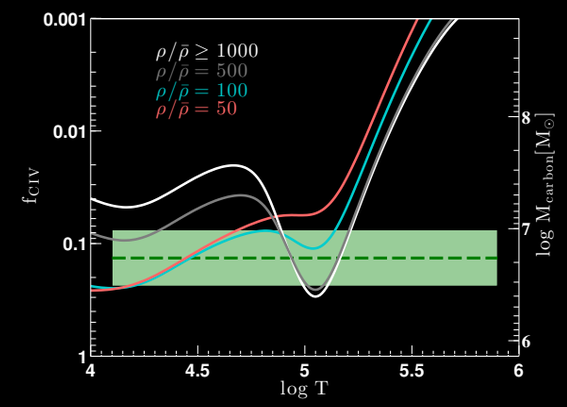
Bordoloi+15 in prep

Conclusions

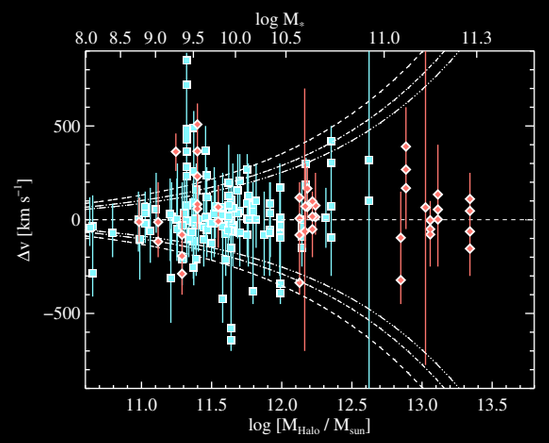
- HI is ubiquitous—— Uniformly distributed for all galaxies!



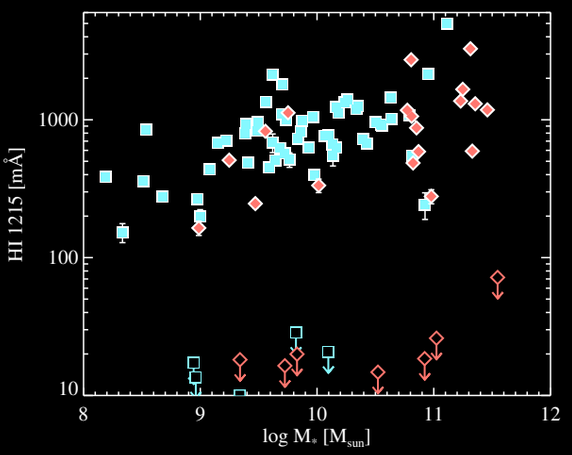
- The CGM harbors at least as much metal as is in the ISM of the galaxies (or more).



- Most of the CGM gas is bound and will be recycled for future star formation.



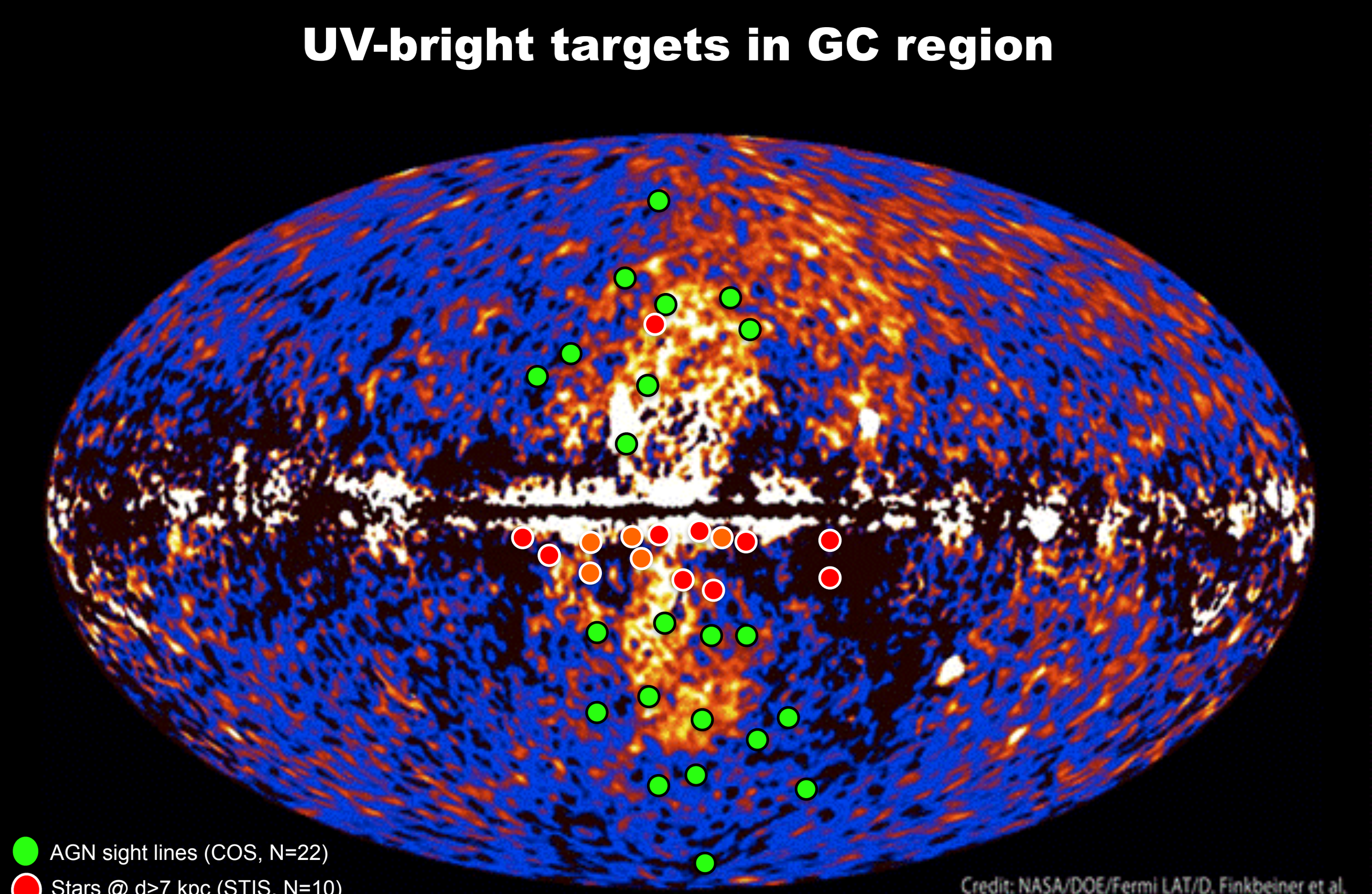
- Quenching suppresses, but does not completely destroy the CGM of their host galaxies.



A Front Row Seat to Study Outflows...

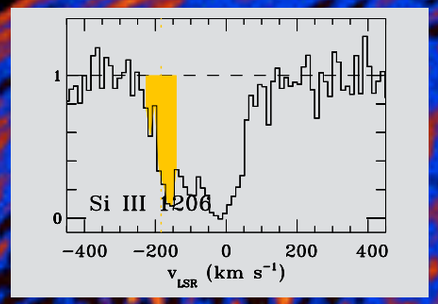
The Milky Way

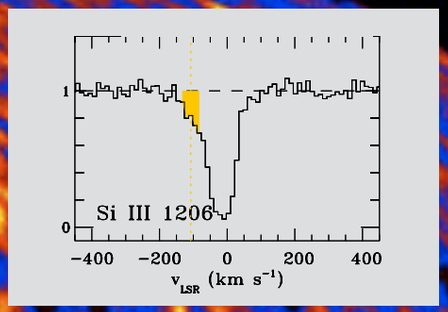
UV-bright targets in GC region

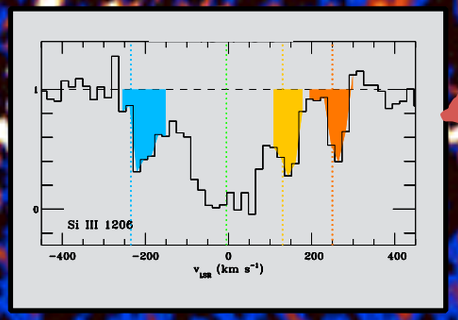


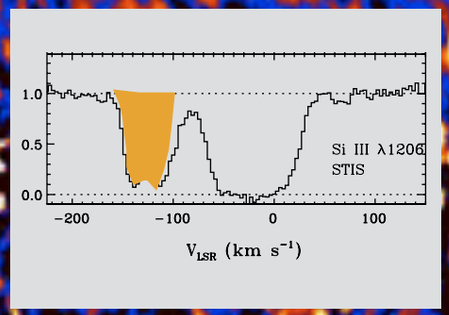
PI Fox, 49 Orbits

Kinematically Mapping the Northern Fermi Bubble









AGN sight lines (COS, N=22)

Stars @ d>7 kpc (STIS, N=10)

Stars @ d<7 kpc (STIS, N=5)

Credit: NASA/DOE/Fermi LAT/D. Finkbeiner et al.

Bordoloi+15b in prep

Stay Tuned...