

# Probing the Signatures of Feedback in the Circumgalactic Medium

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with

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Brice Ménard

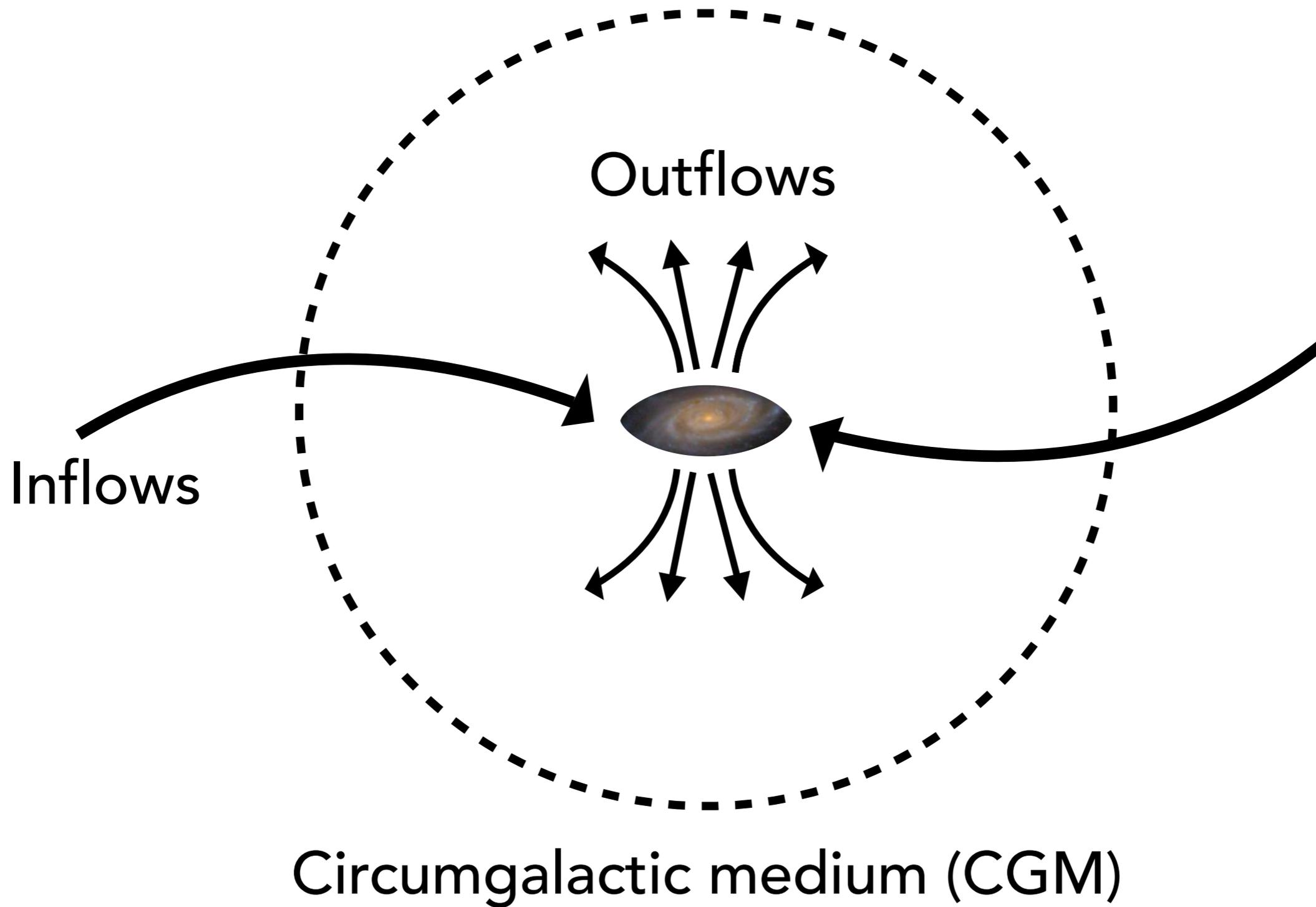


Houjun Mo

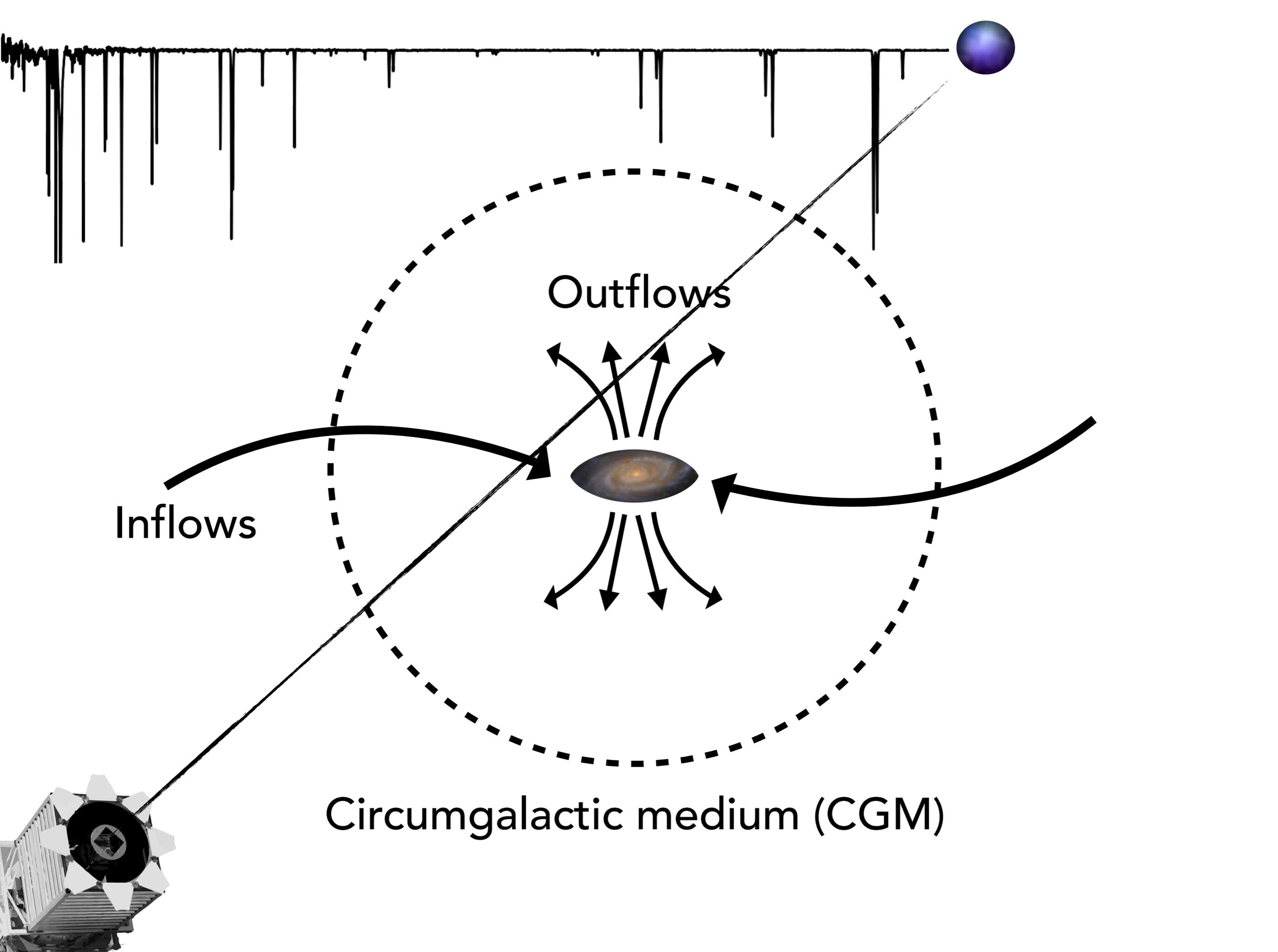


Guangtun Zhu





All feedback mechanisms require interaction with the CGM!



Outflows

Inflows

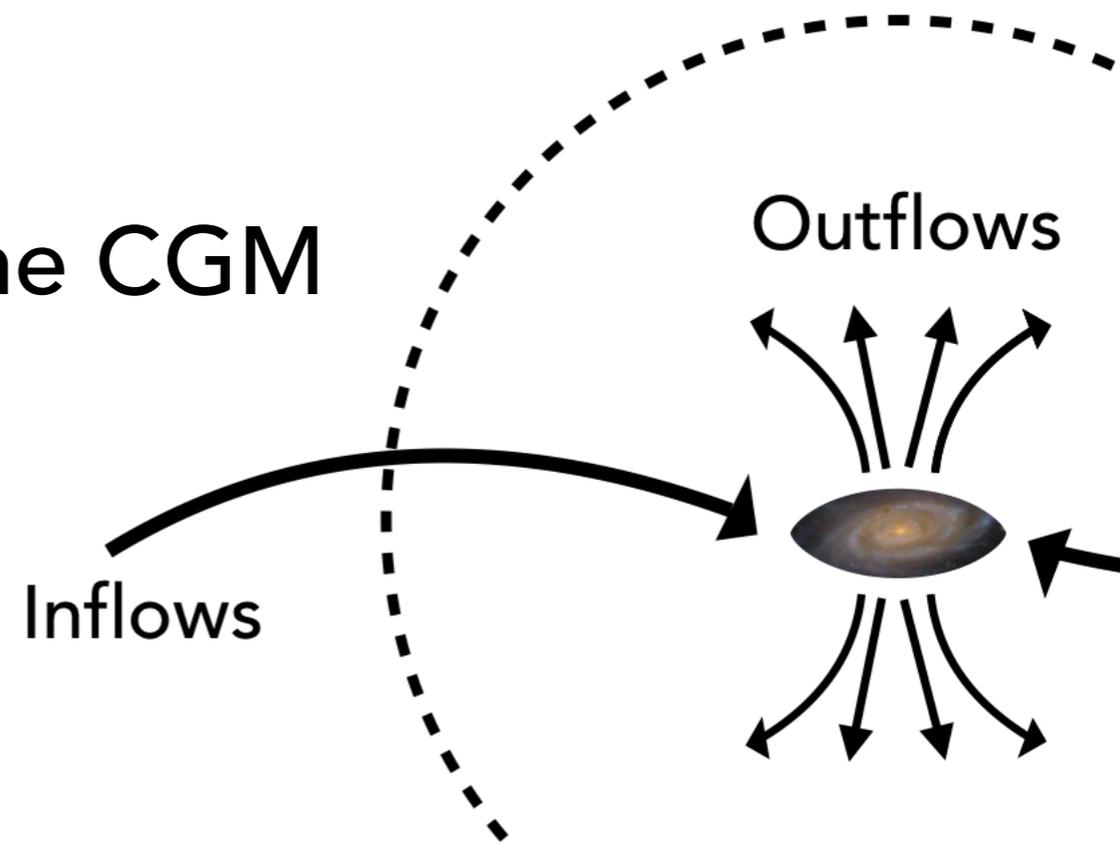
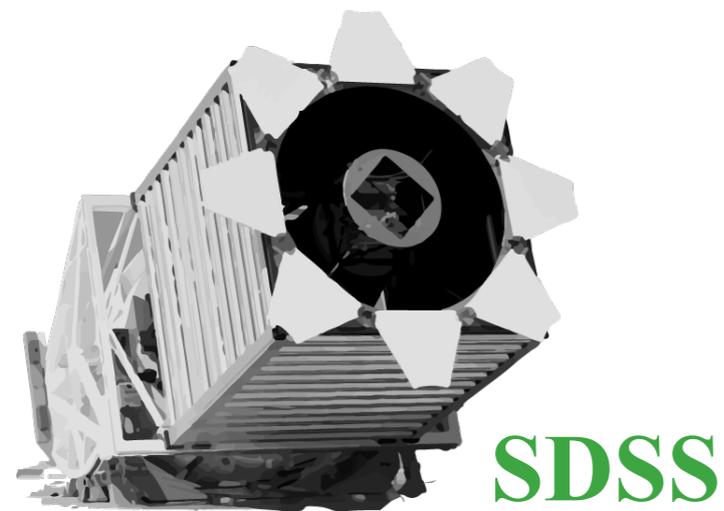
Circumgalactic medium (CGM)

# Three signatures of Feedback in the CGM

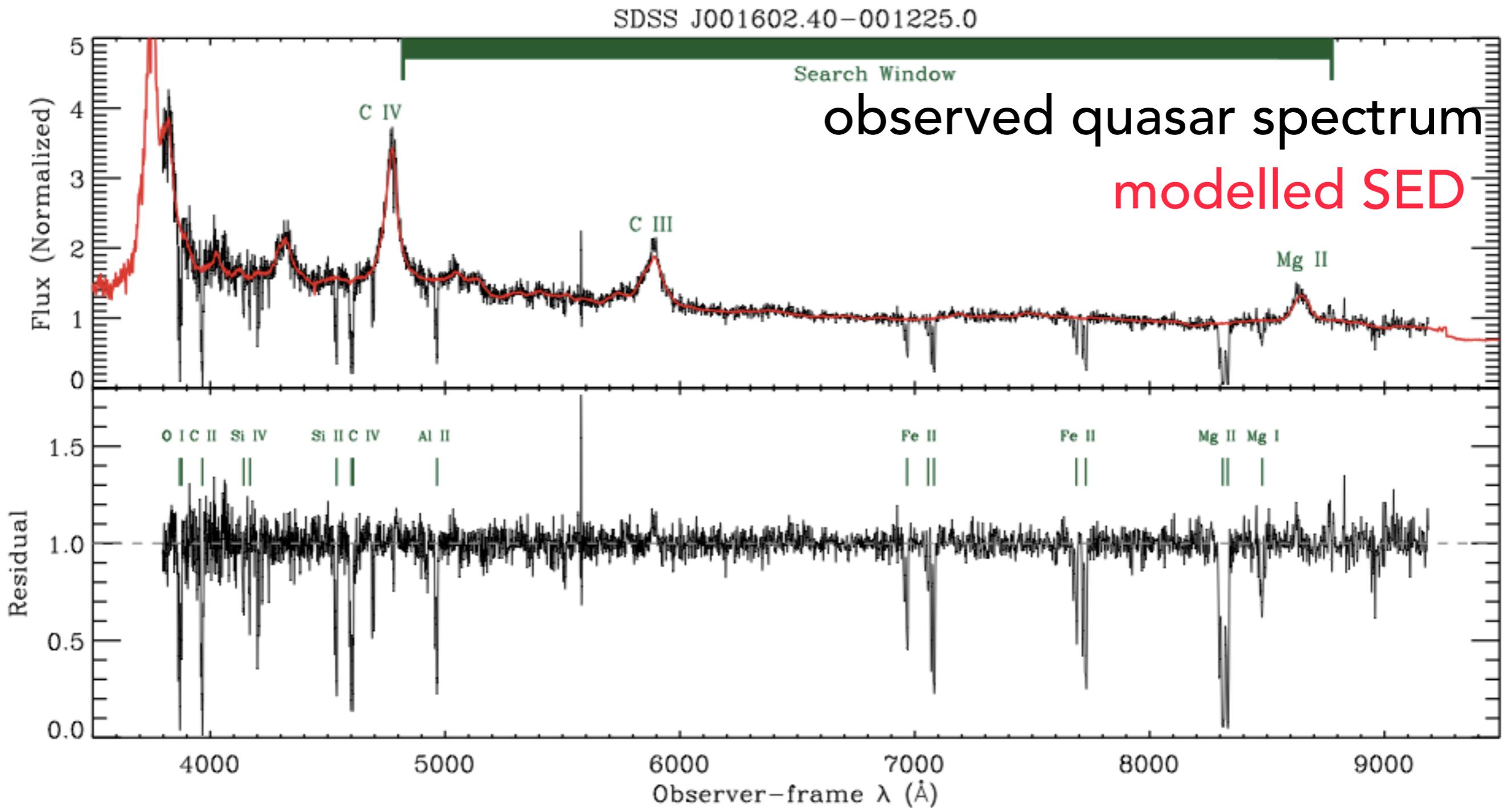
Correlations between  
the properties of galaxies and the CGM

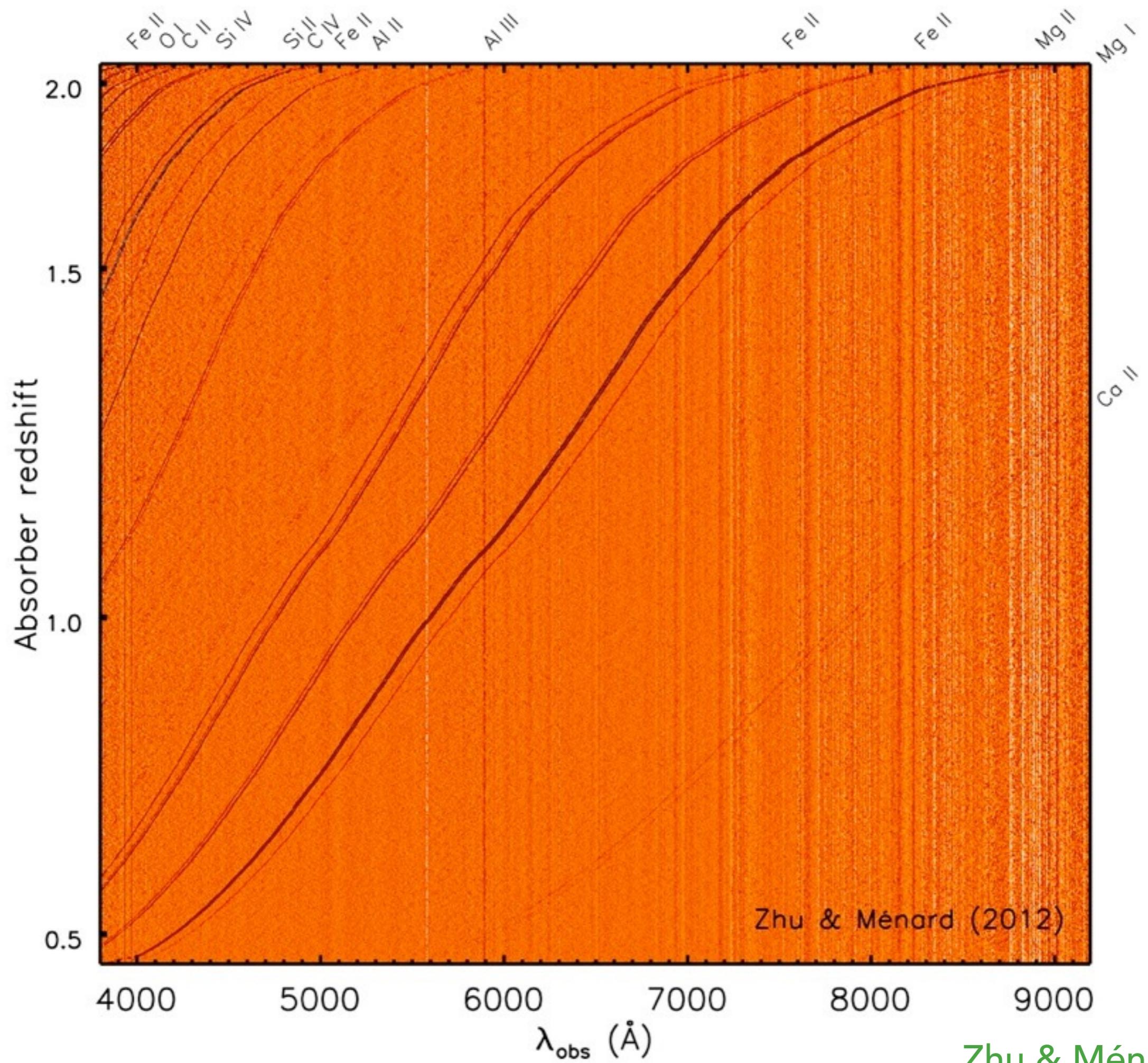
Spatial distribution of the CGM

Metal content of the CGM



# Detecting metal absorbers in SDSS quasar spectra



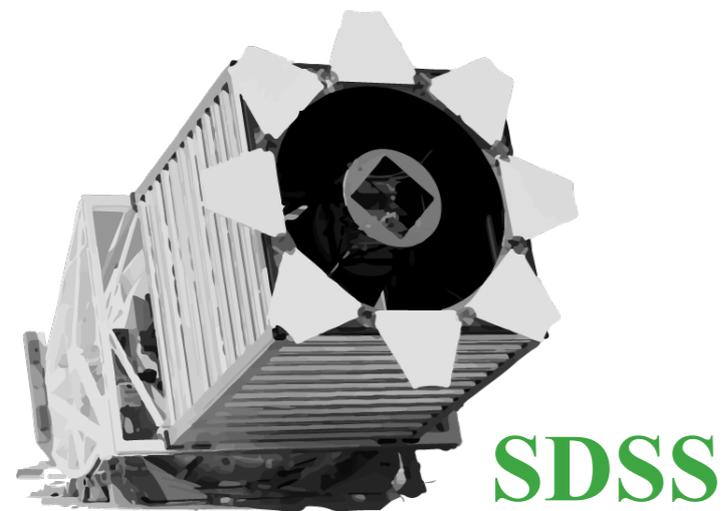


# Three signatures of Feedback in the CGM

Correlations between  
the properties of galaxies and the CGM

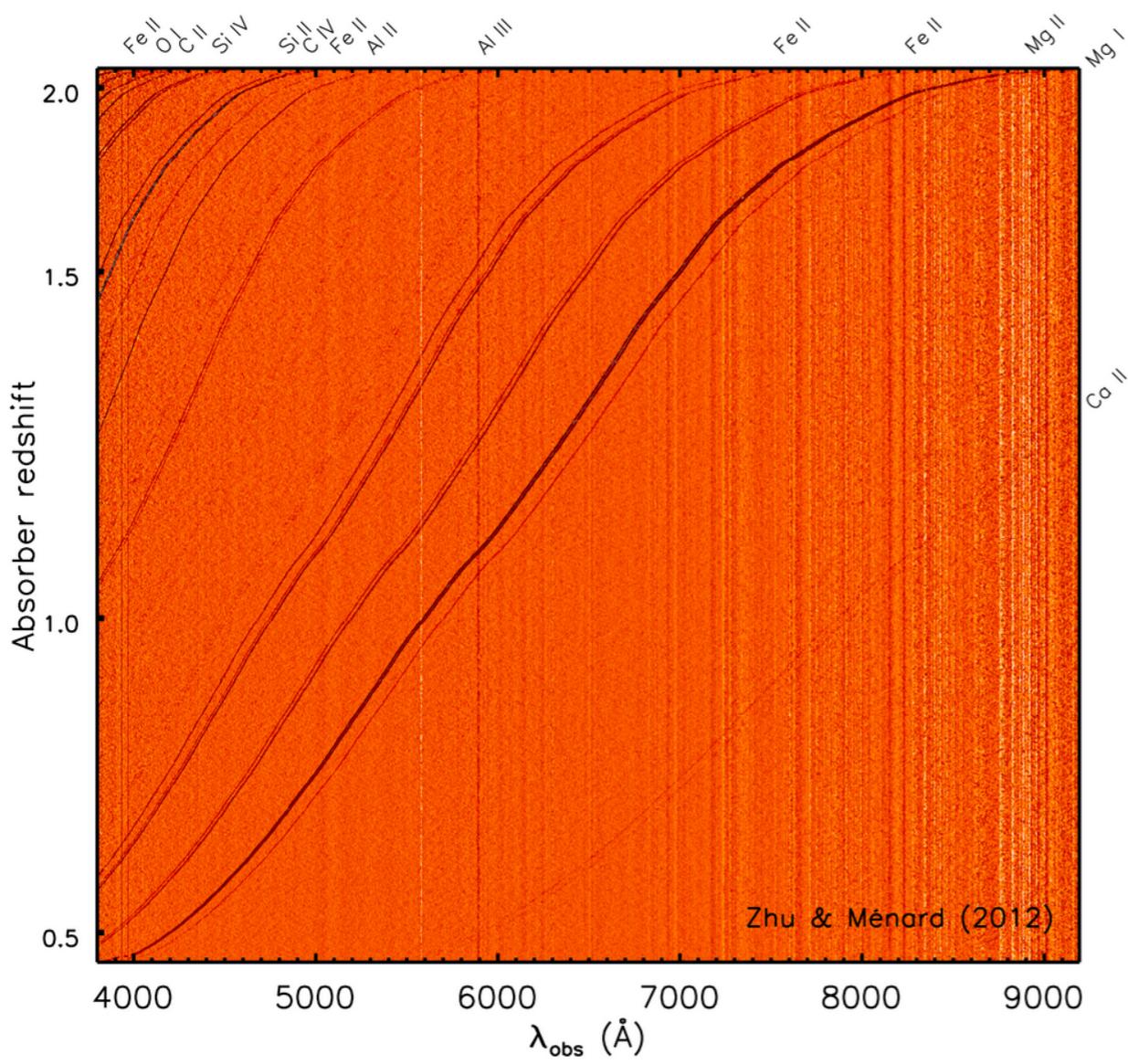
Spatial distribution of the CGM

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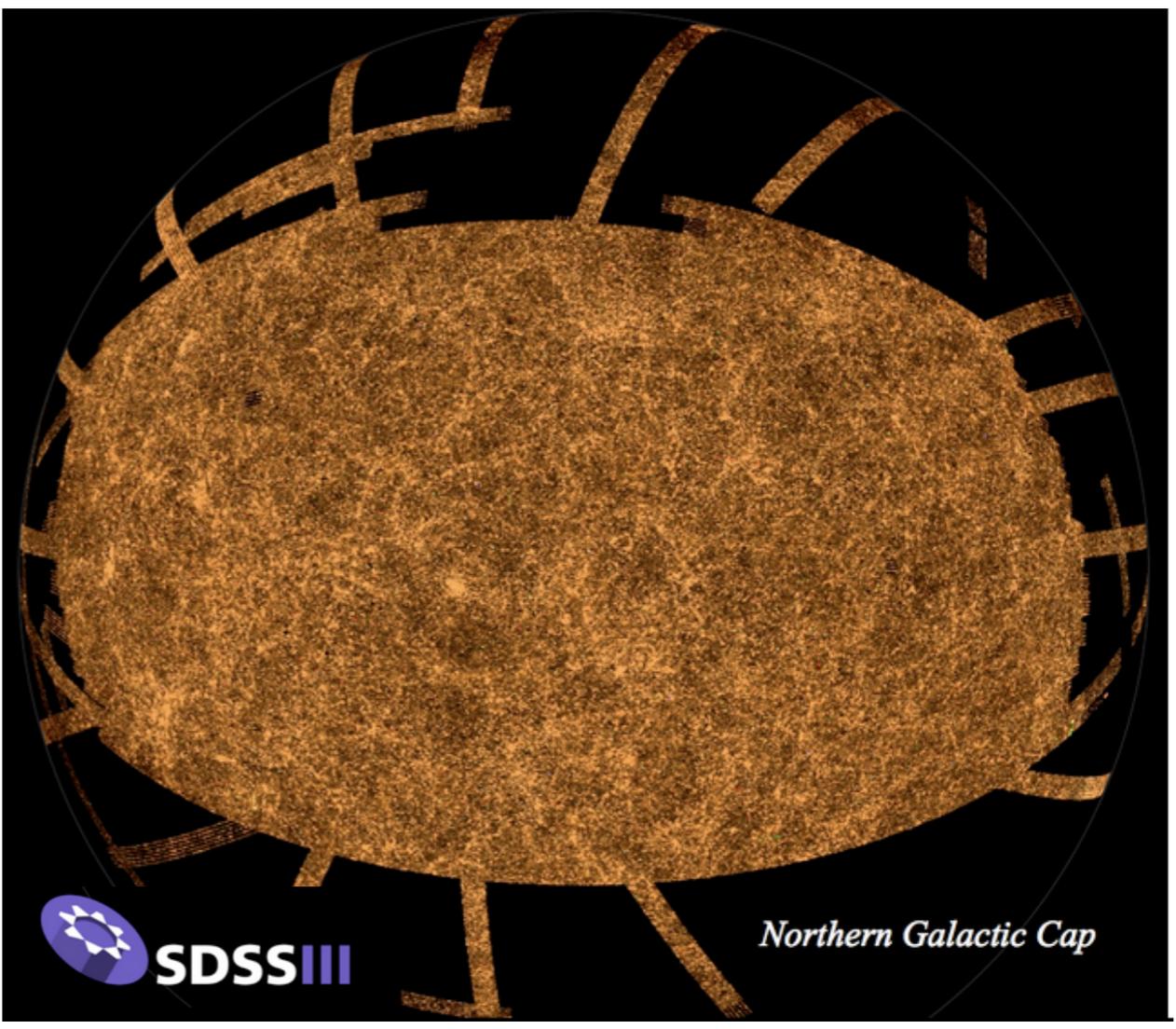


# Probing the associated galaxies with a statistical approach

## Metal absorbers



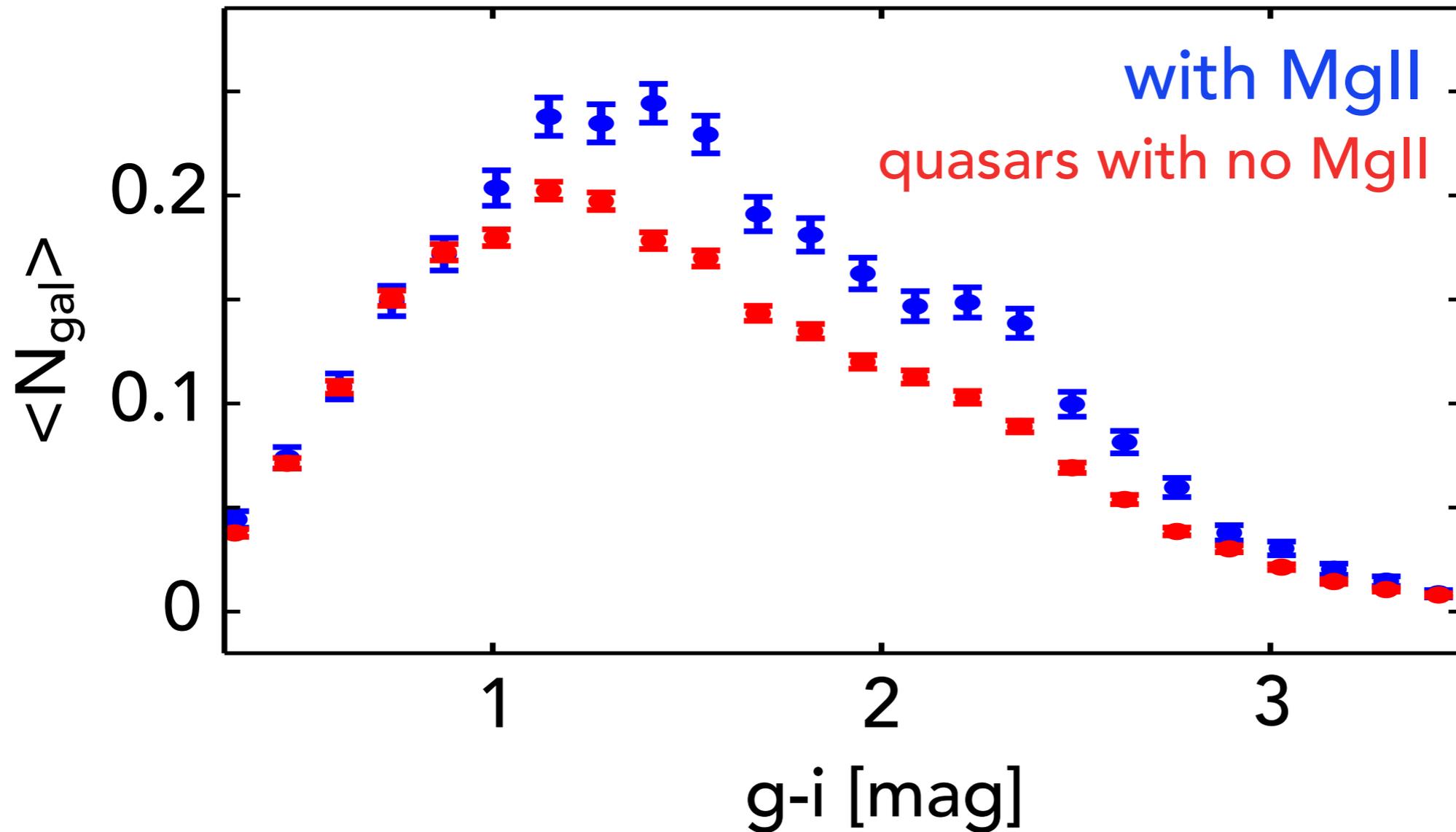
## millions of photometric galaxies



$$\langle \delta_{\text{MgII}} \cdot \delta N_{\text{gal}} \rangle$$

# Probing the associated galaxies with a statistical approach

SDSS galaxies (<200 kpc) around 3,000 absorbers at  $z \sim 0.5$



randomly-distributed  
background galaxies

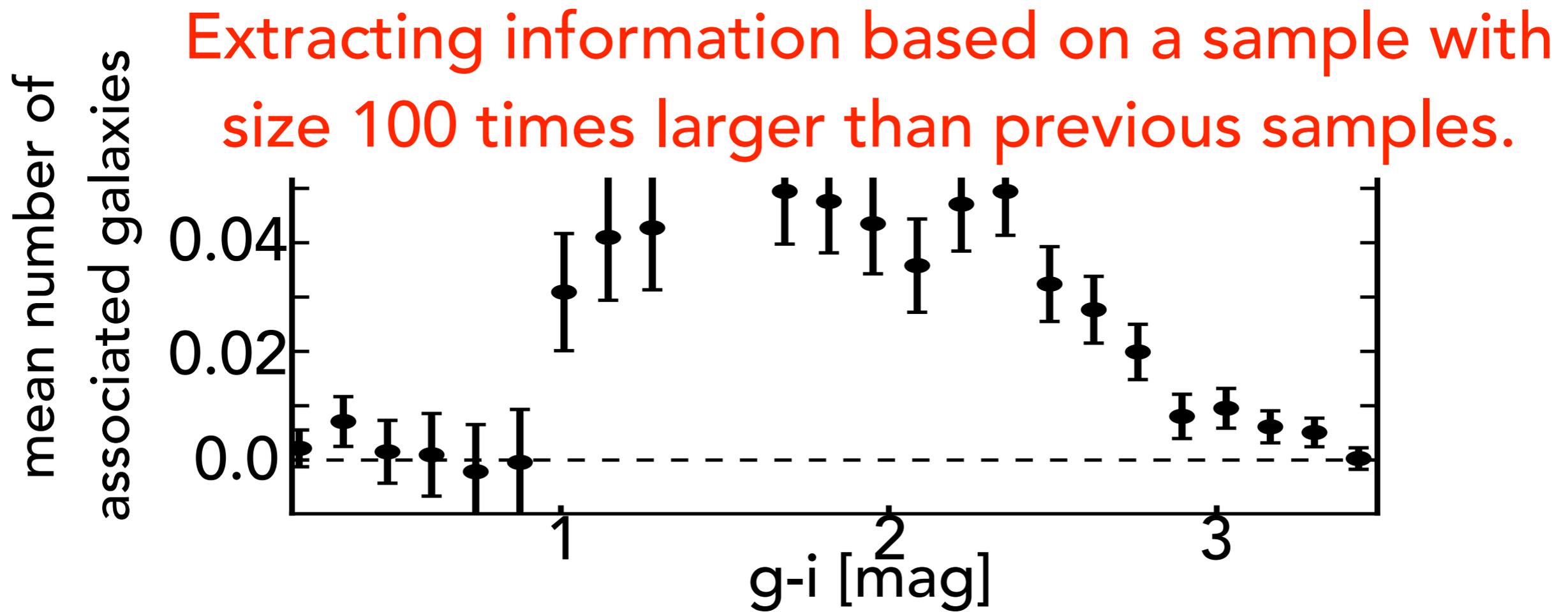
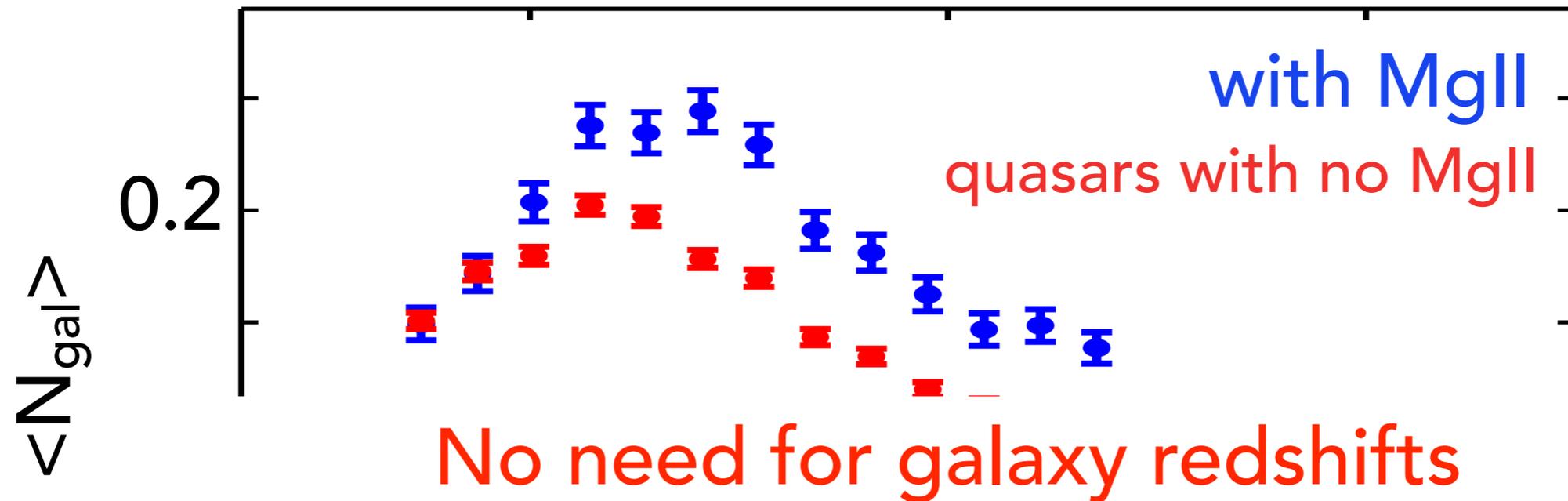
+

galaxies associated with MgII

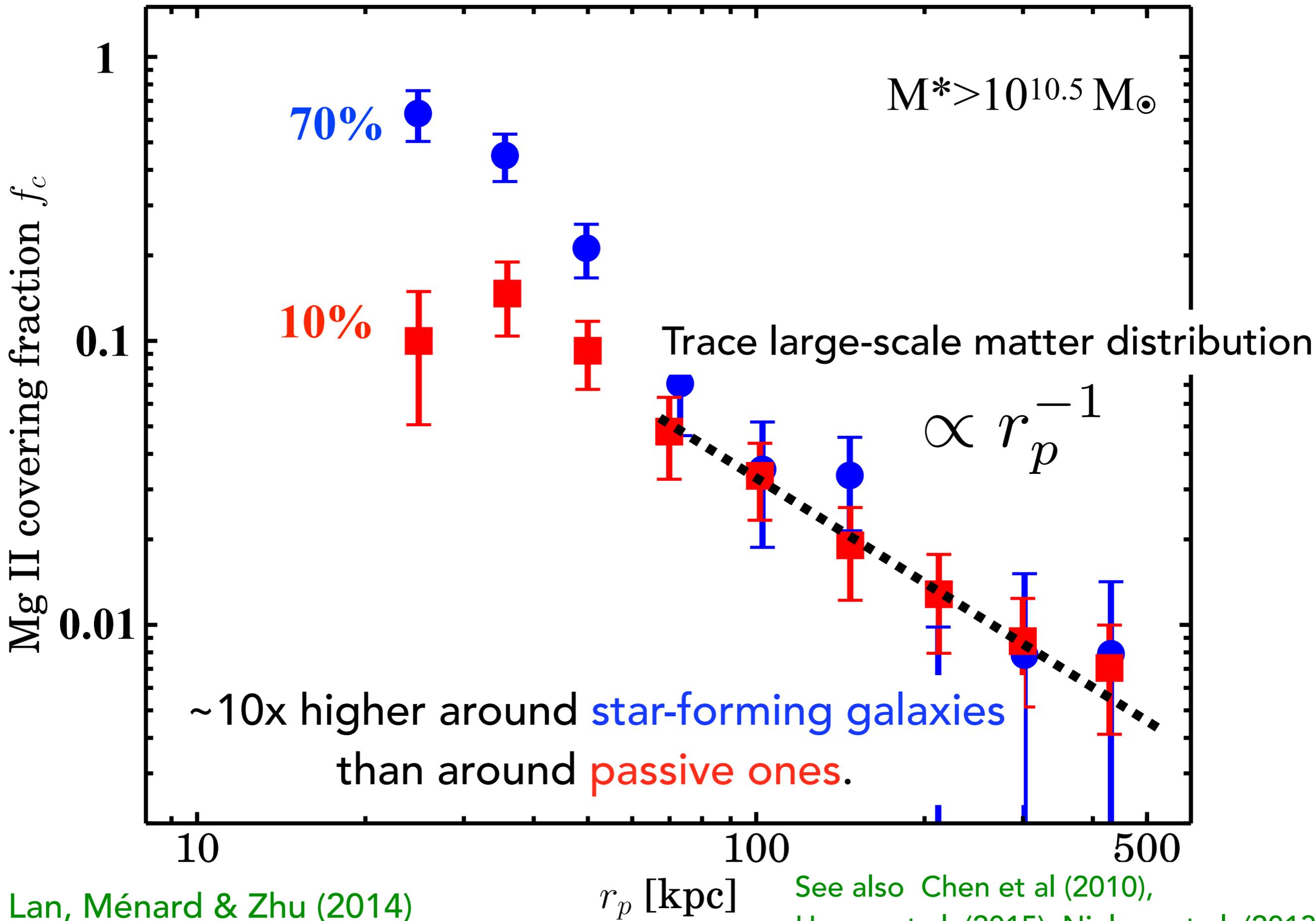
randomly-distributed  
background galaxies

# Probing the associated galaxies with a statistical approach

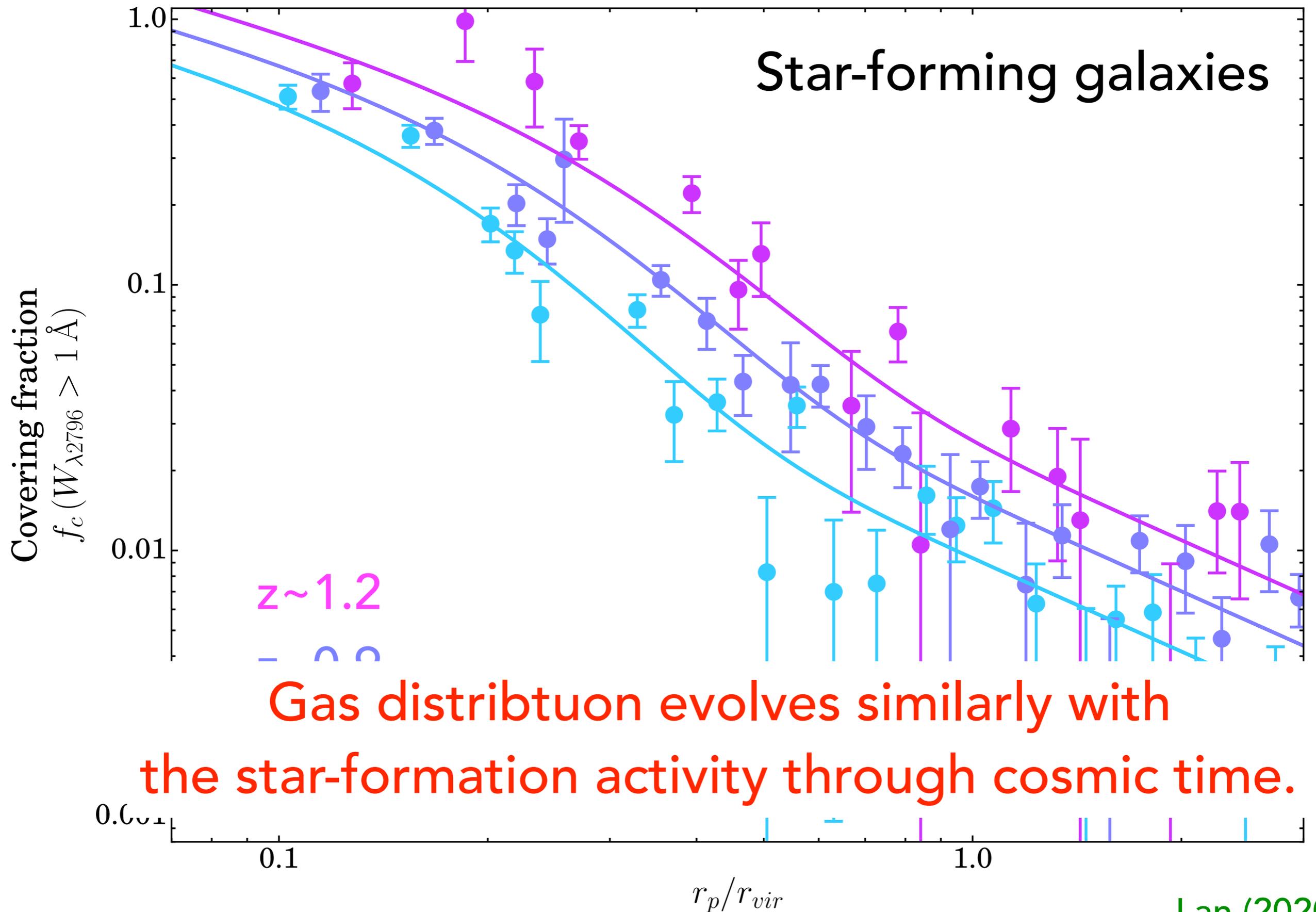
SDSS galaxies (<200 kpc) around 3,000 absorbers at  $z \sim 0.5$



# Mg II covering fraction

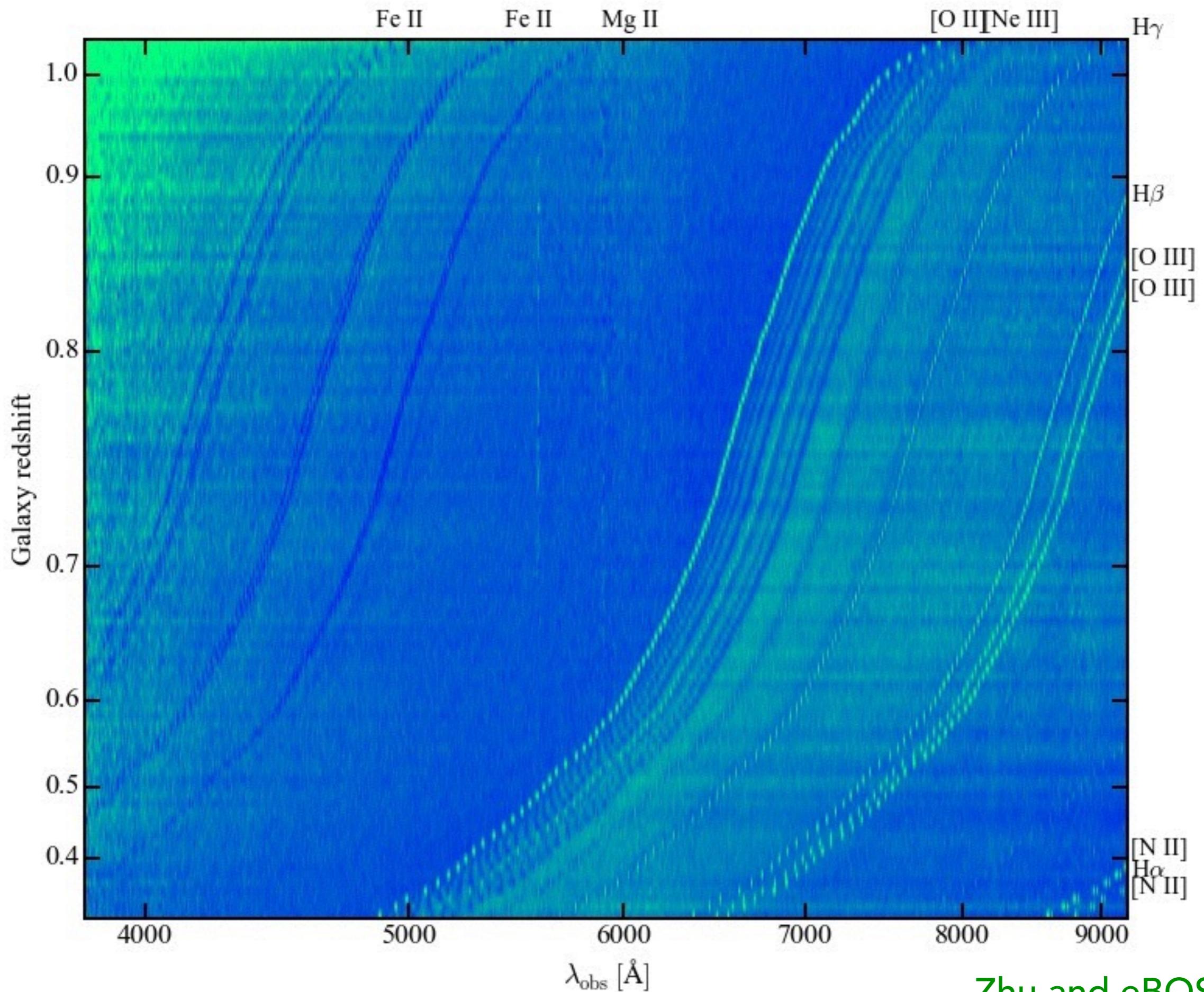


# Redshift evolution of gas profiles

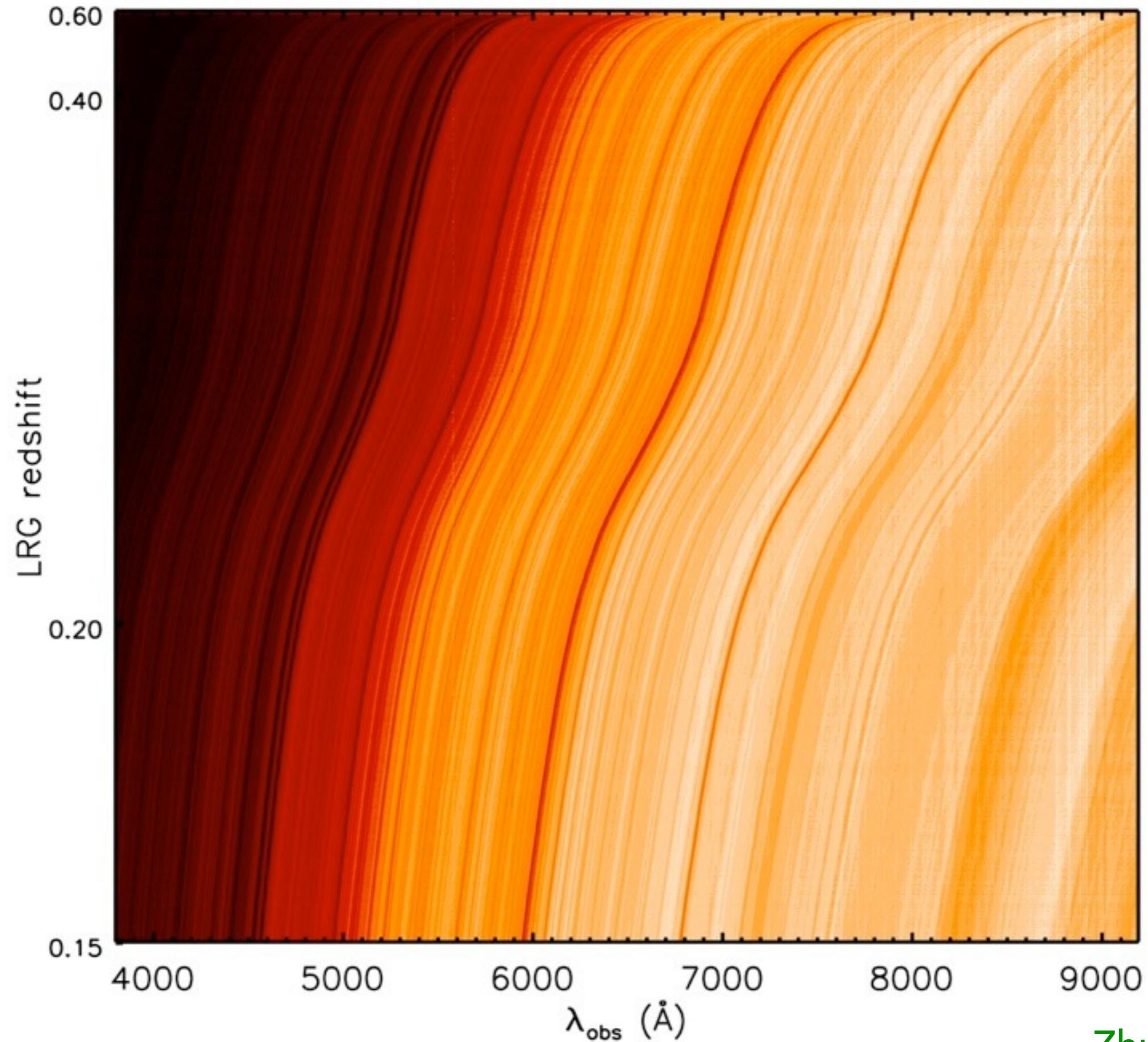




# ~200,000 emission line galaxies



~1,000,000 luminous red galaxies



Absorption  
Strength

$$\langle \delta_{\text{gal}} \cdot \delta F(\lambda) \rangle$$

$r_p$

$10^{-1}$

25 kpc

50 kpc

100 kpc

$10^{-2}$

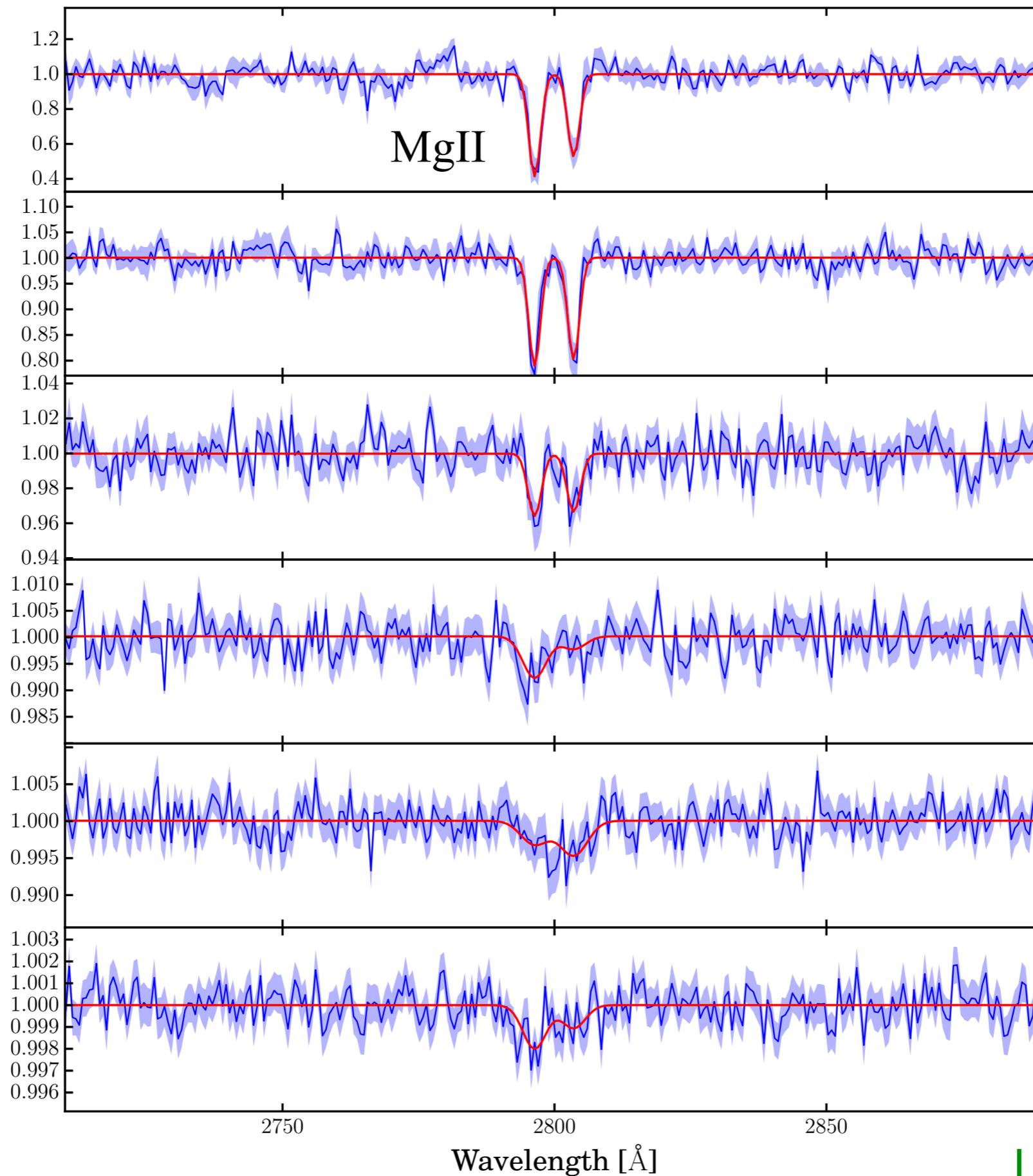
250 kpc

500 kpc

$10^{-3}$

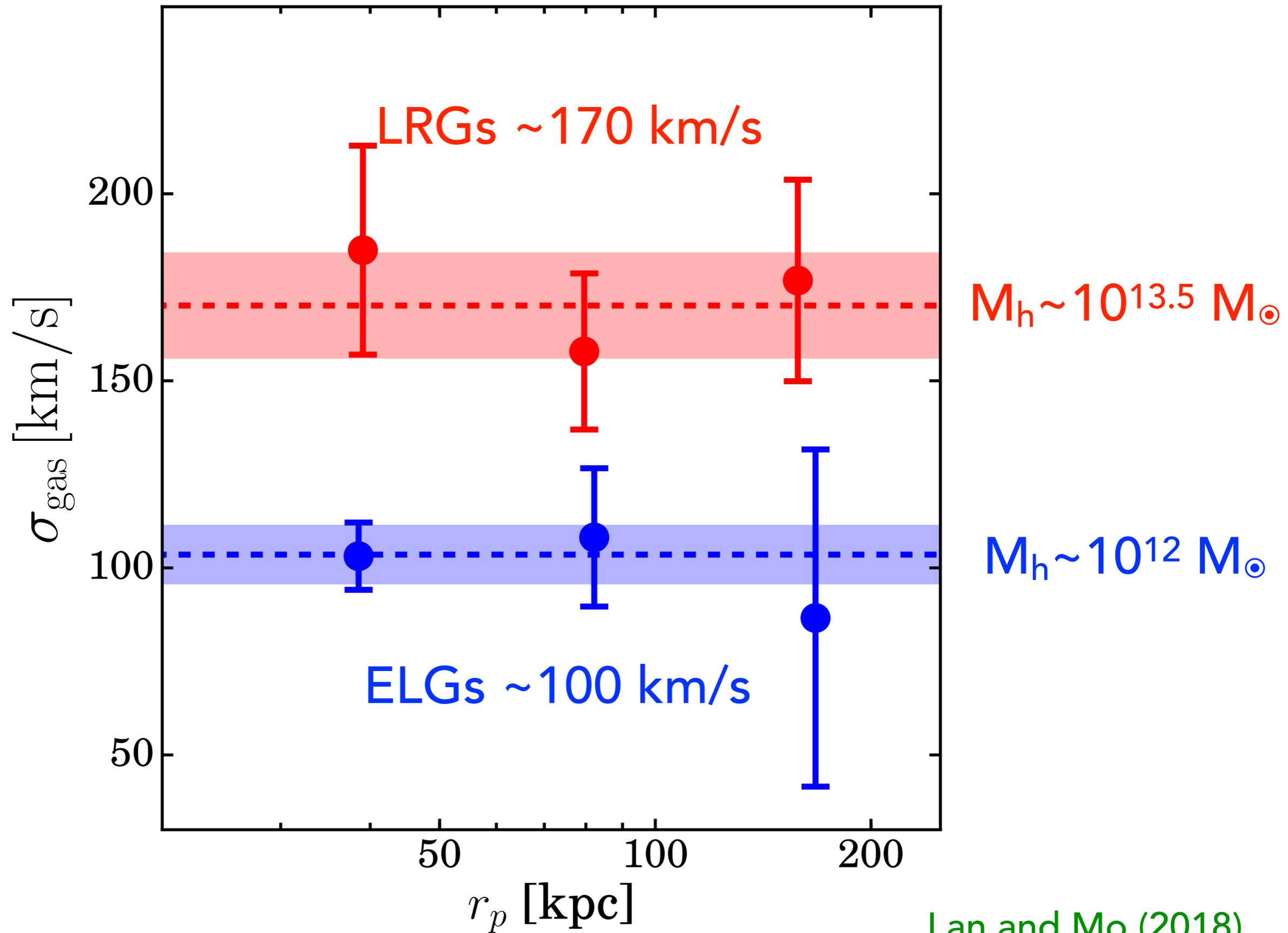
1 Mpc

Normalized Flux

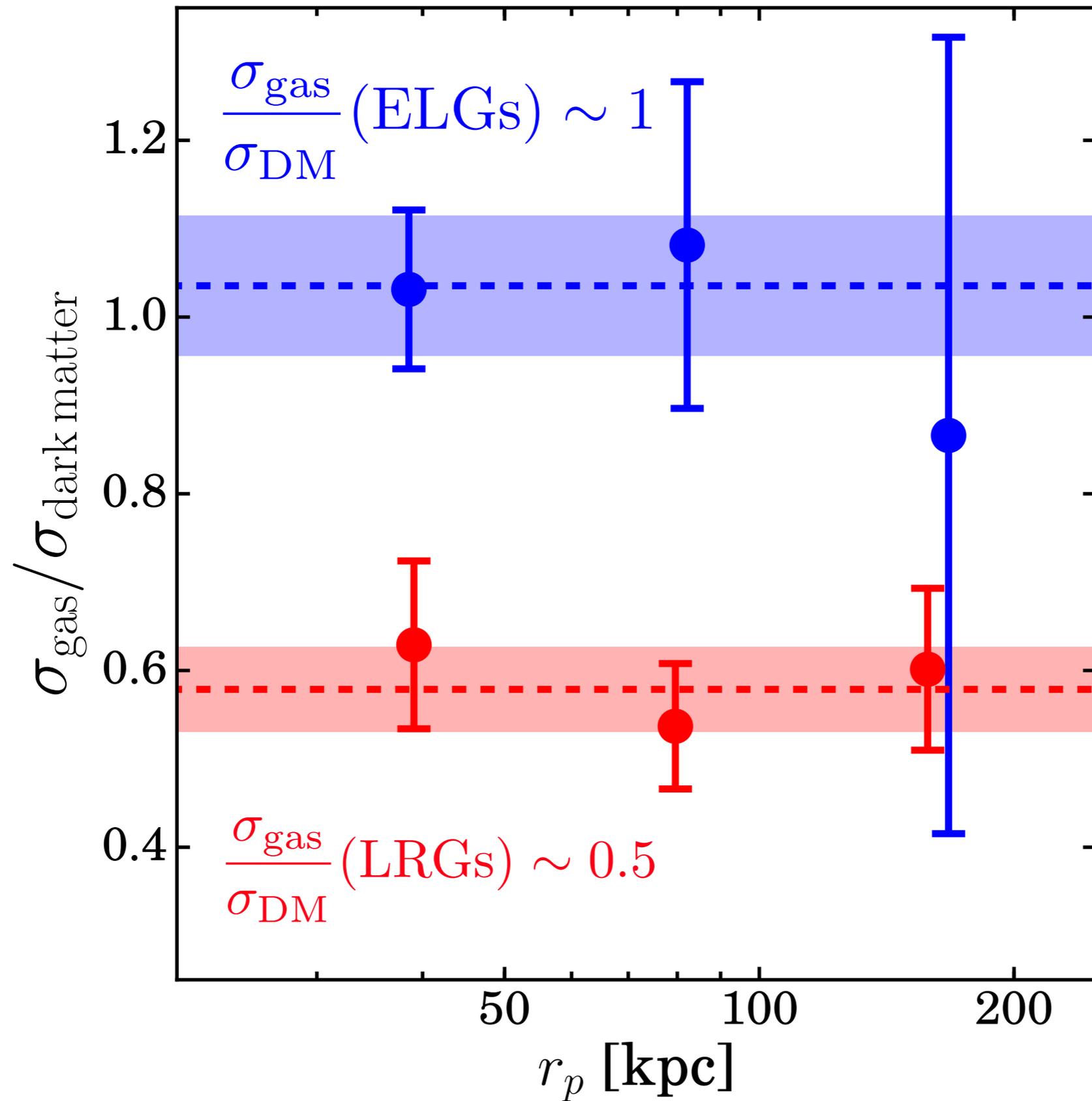


Lan and Mo (2018)

# Gas kinematics



# Gas kinematics



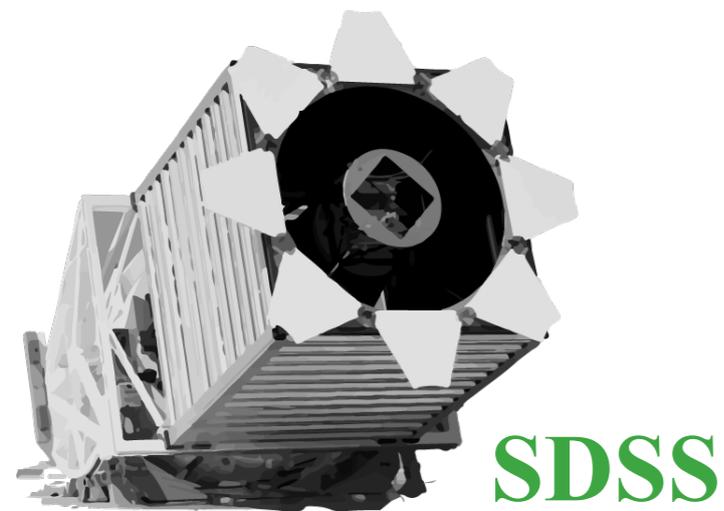
# Three signatures of Feedback in the CGM

Correlations between  
the properties of galaxies and the CGM

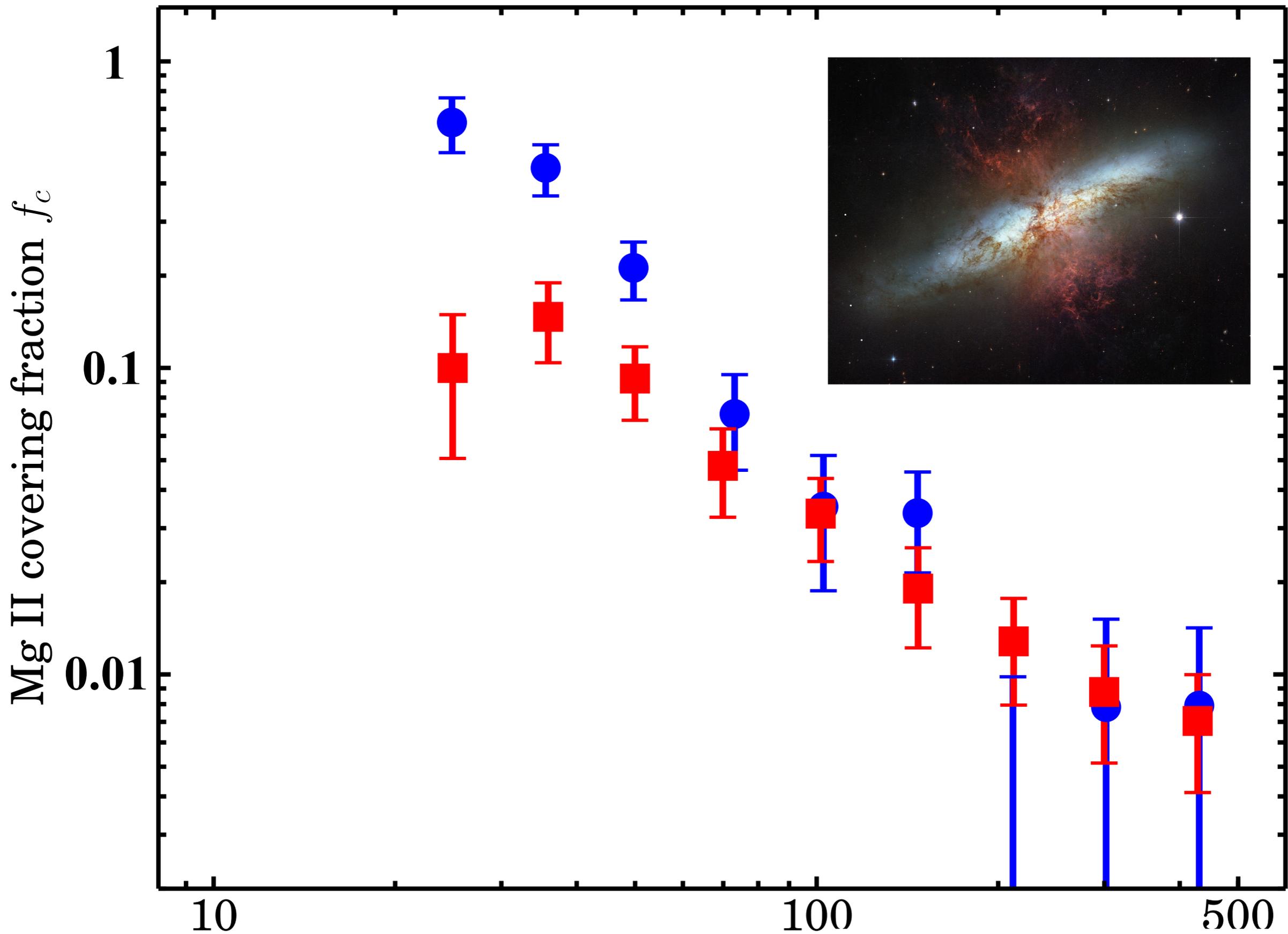
Gas distribution and kinematics correlate with star-formation

Spatial distribution of the CGM

Metal content of the CGM



# Mg II covering fraction

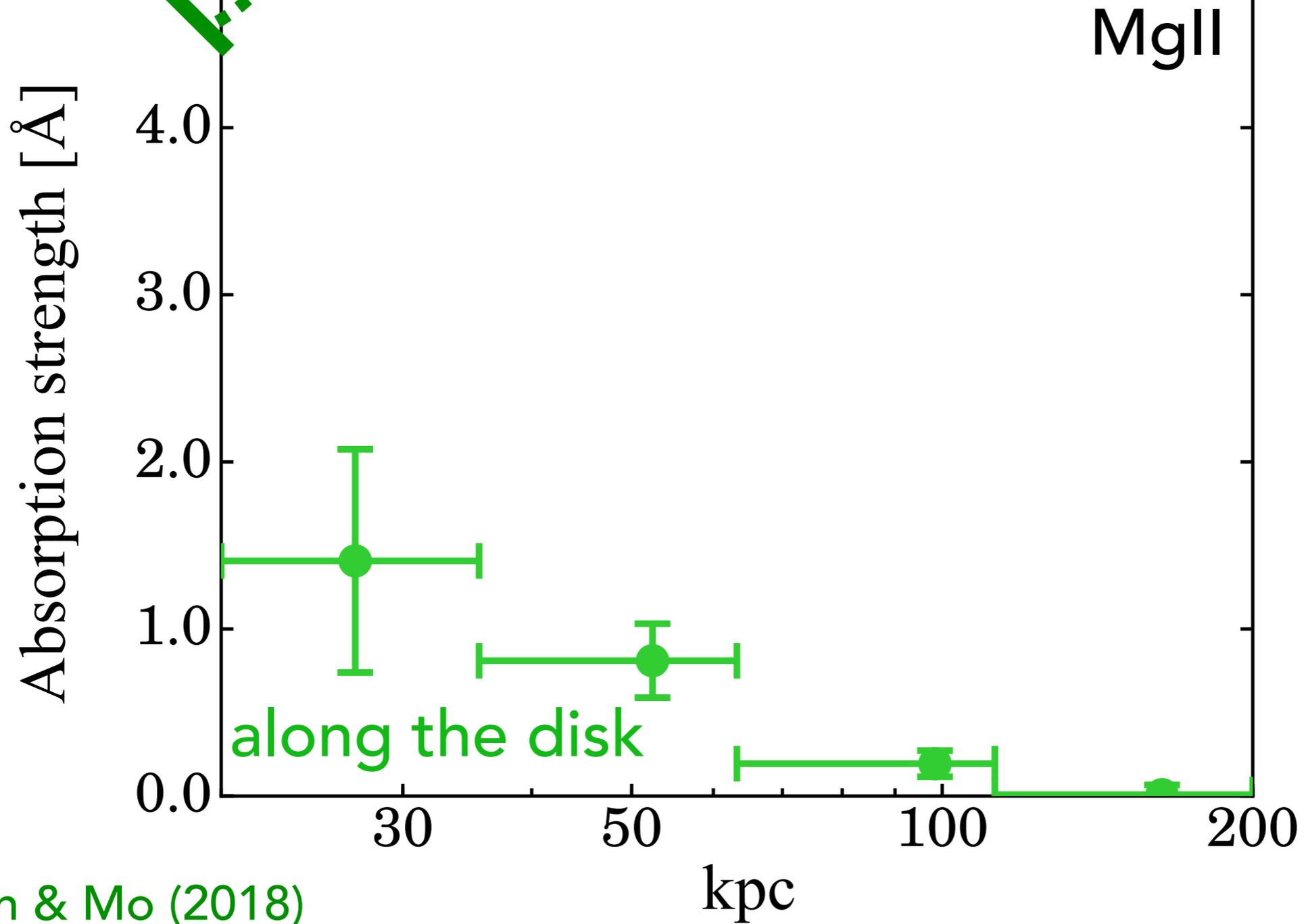
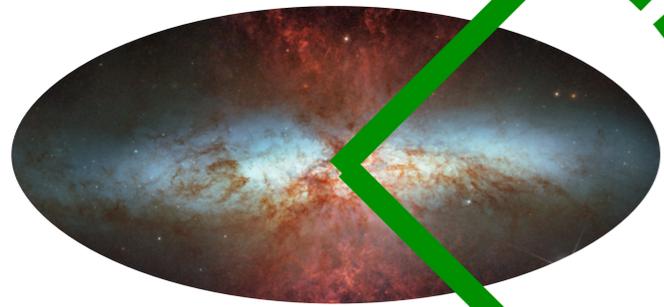


Lan, Ménard & Zhu (2014)

$r_p$  [kpc]

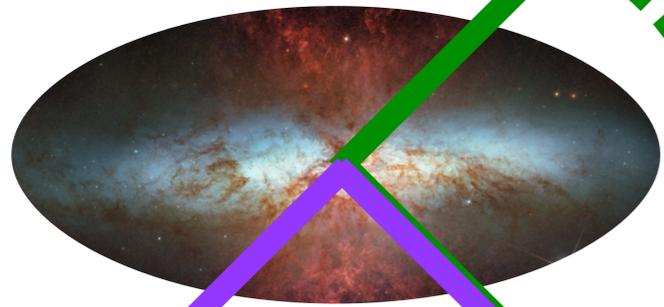
See also Chen et al (2010),  
Huang et al. (2015), Nielsen et al. (2013)

# Azimuthal dependence



See also Bordoloi et al. 2011, Kacprak et al. 2011,  
Bouche et al. 2012, Lan et al. 2014

# Azimuthal dependence

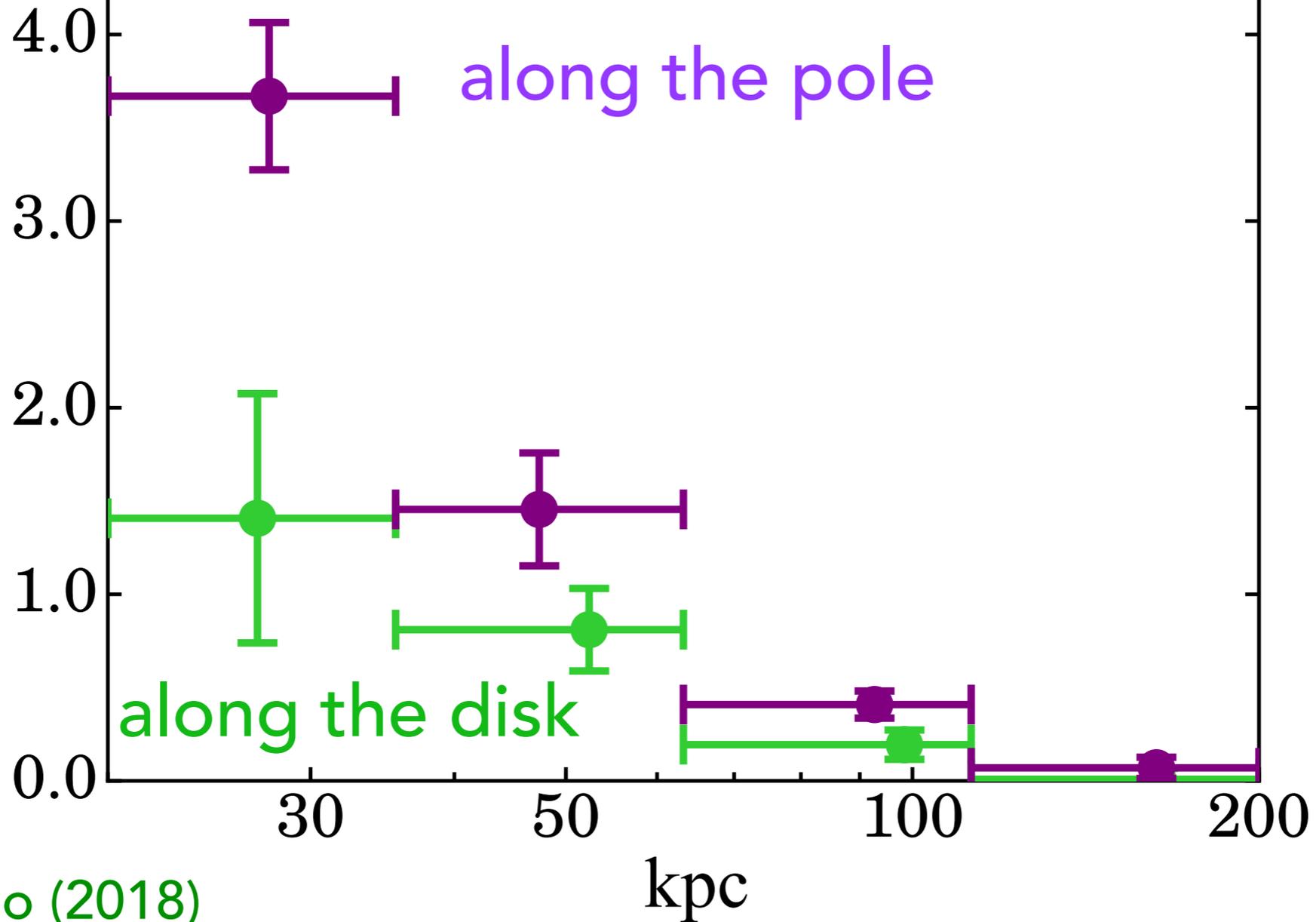


Absorption strength [ $\text{\AA}$ ]

MgII

along the pole

along the disk



Lan & Mo (2018)

See also Bordoloi et al. 2011, Kacprak et al. 2011,  
Bouche et al. 2012, Lan et al. 2014

# Three signatures of Feedback in the CGM

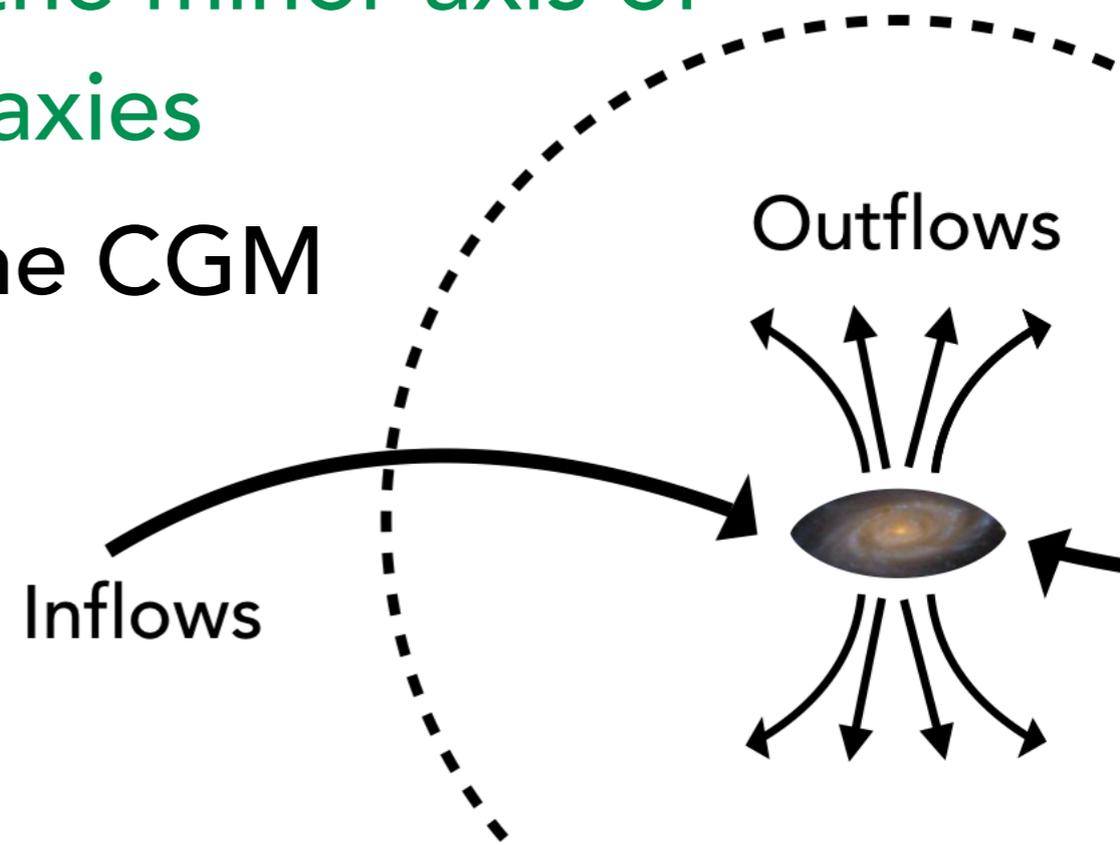
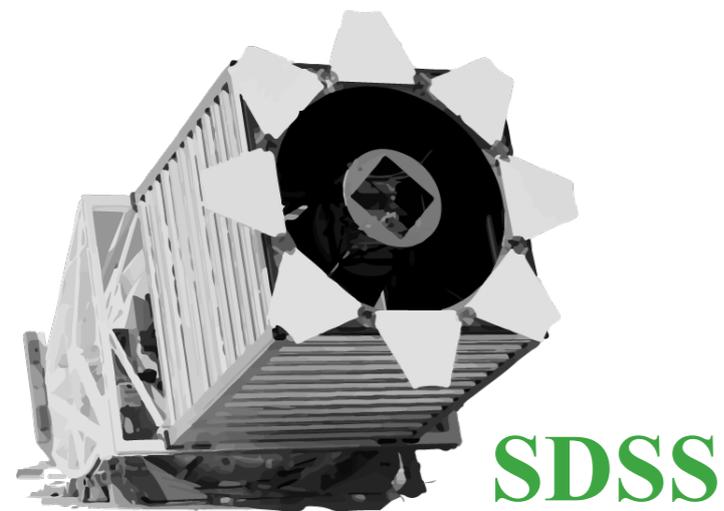
Correlations between  
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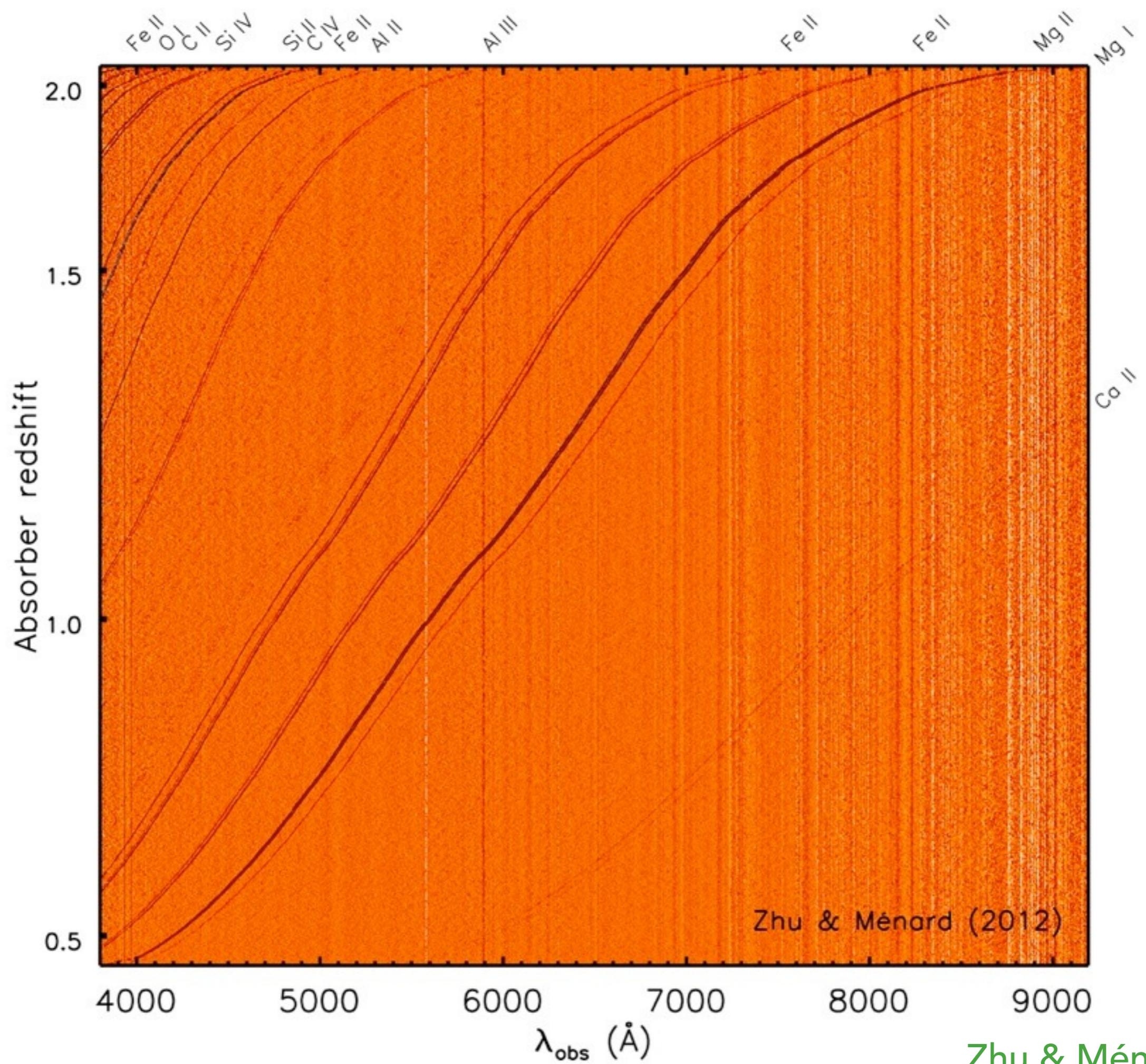
Gas distribution and kinematics correlate with star-formation

Spatial distribution of the CGM

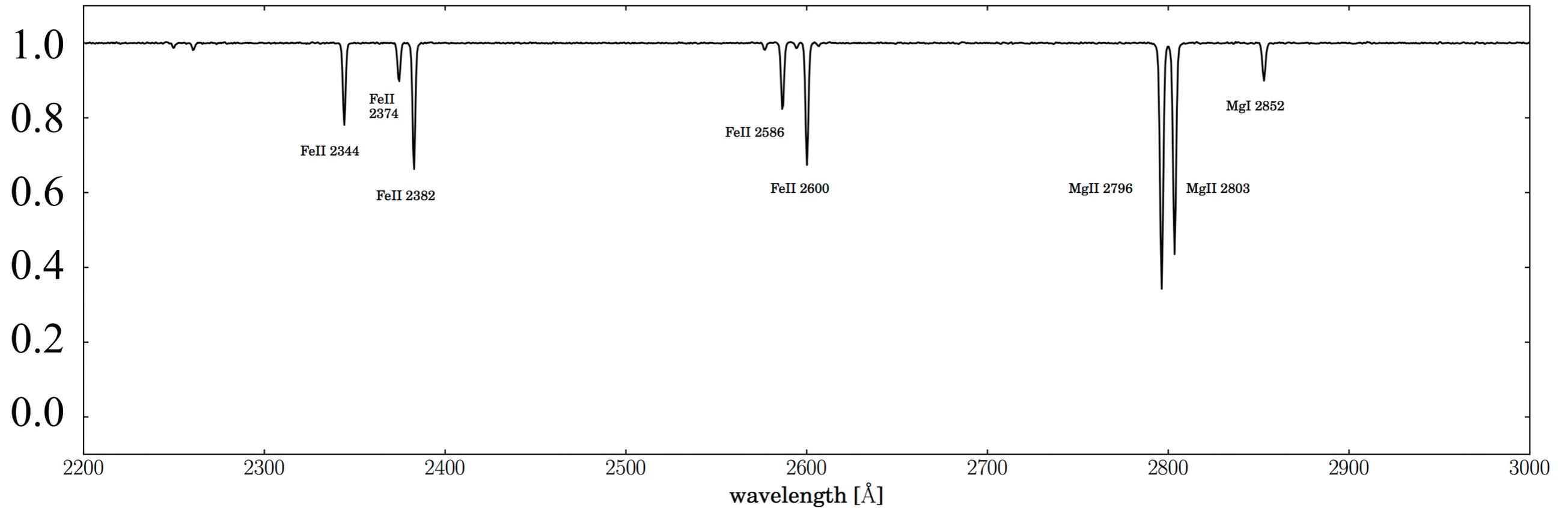
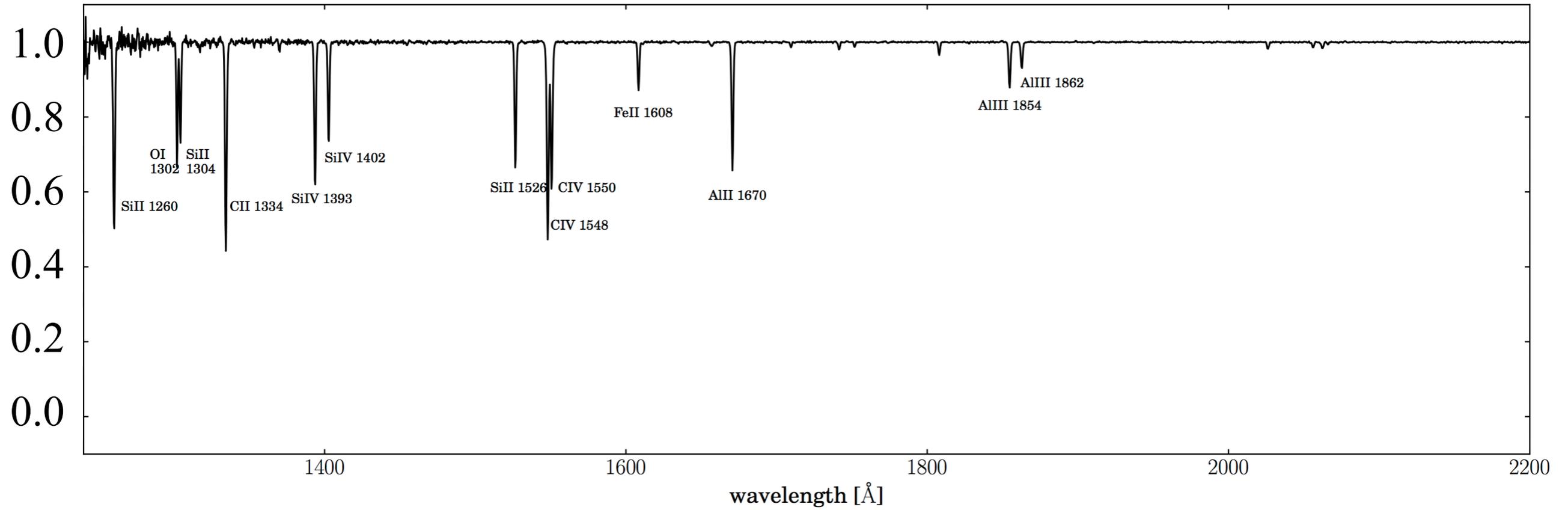
Stronger absorption along the minor axis of  
star-forming galaxies

Metal content of the CGM

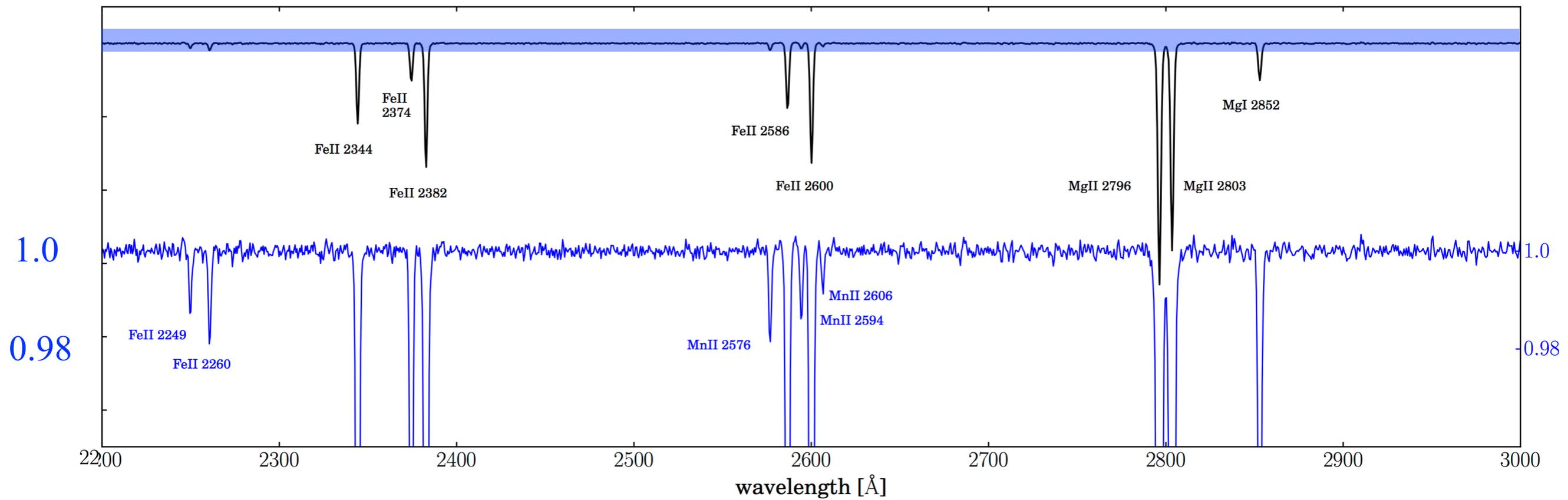
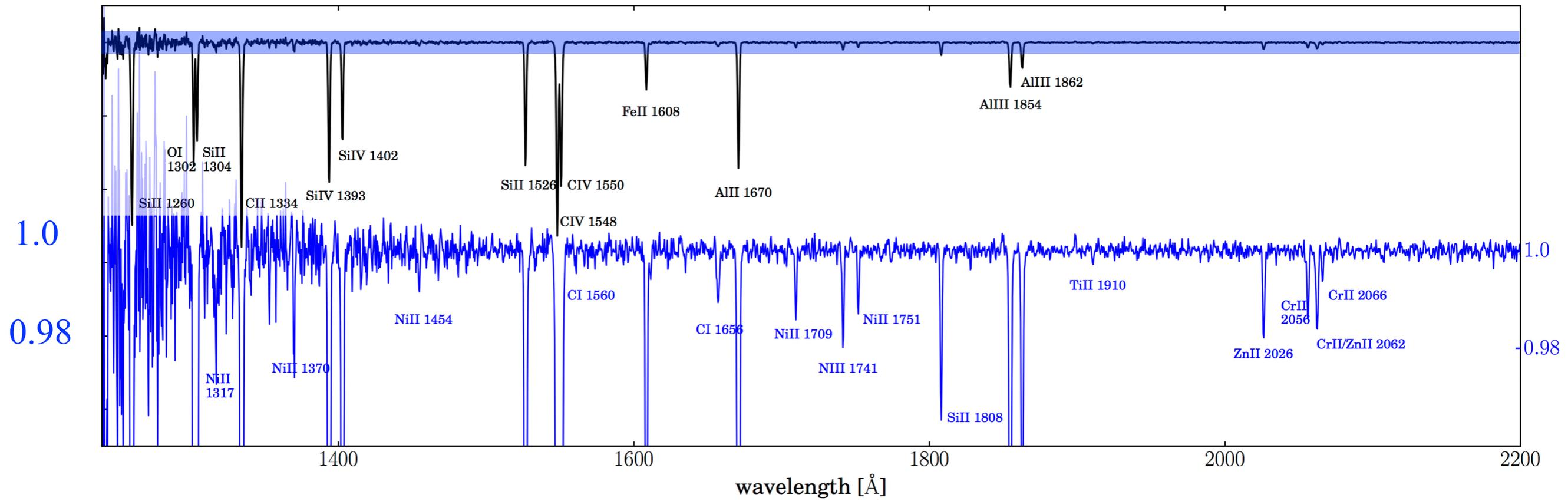




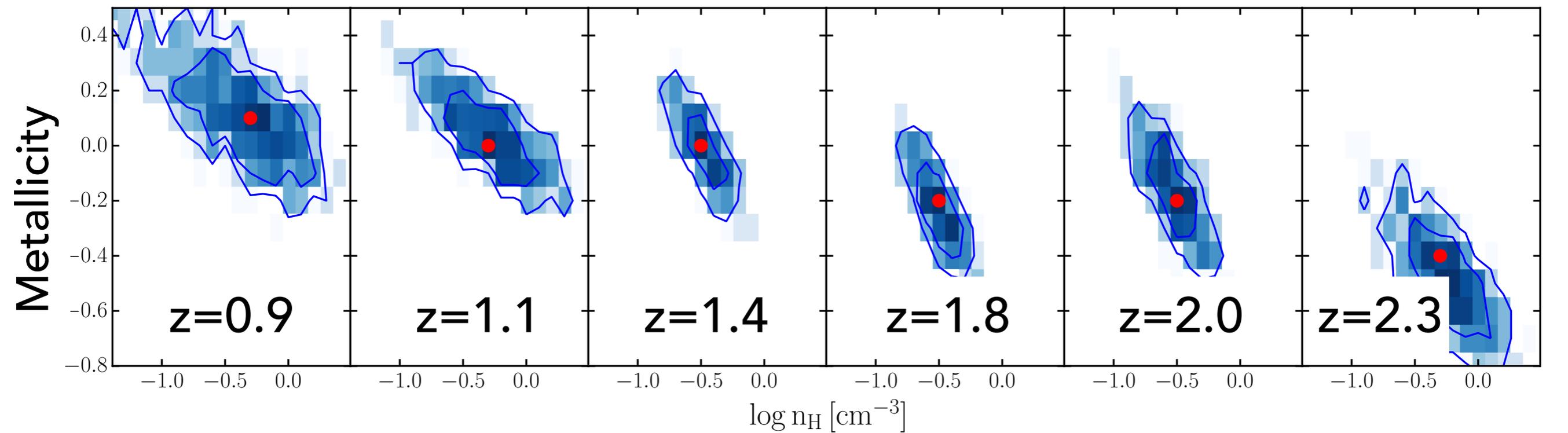
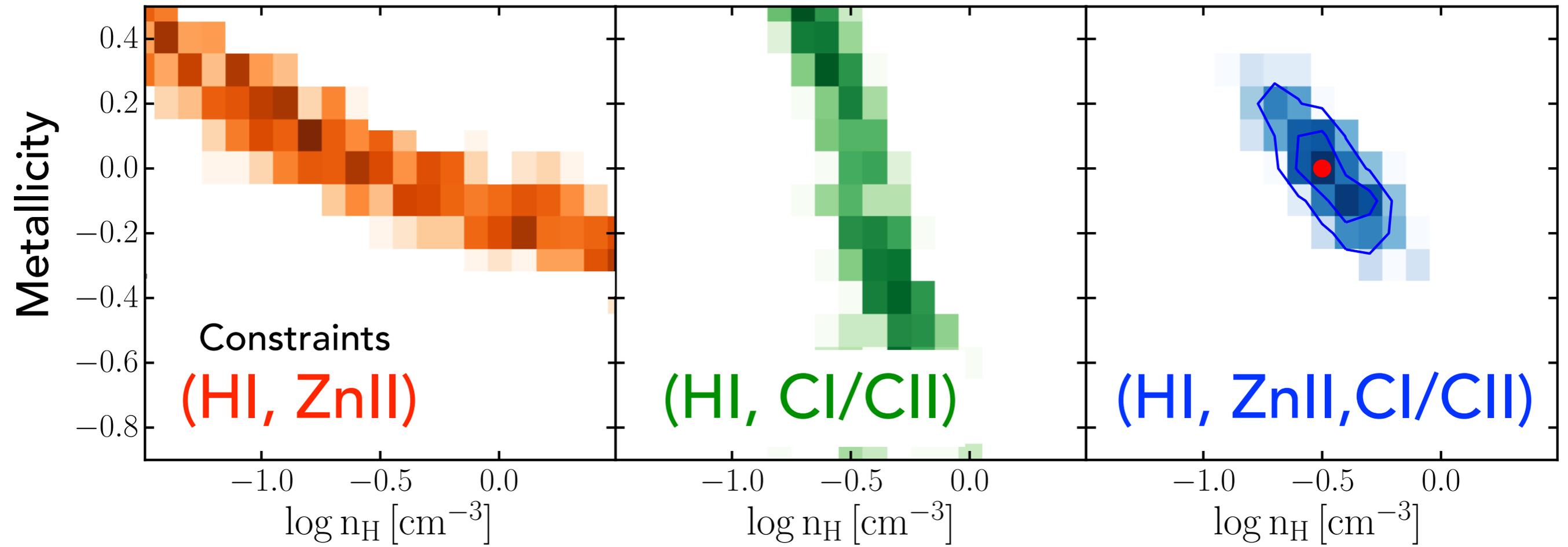
# Metal composite spectrum



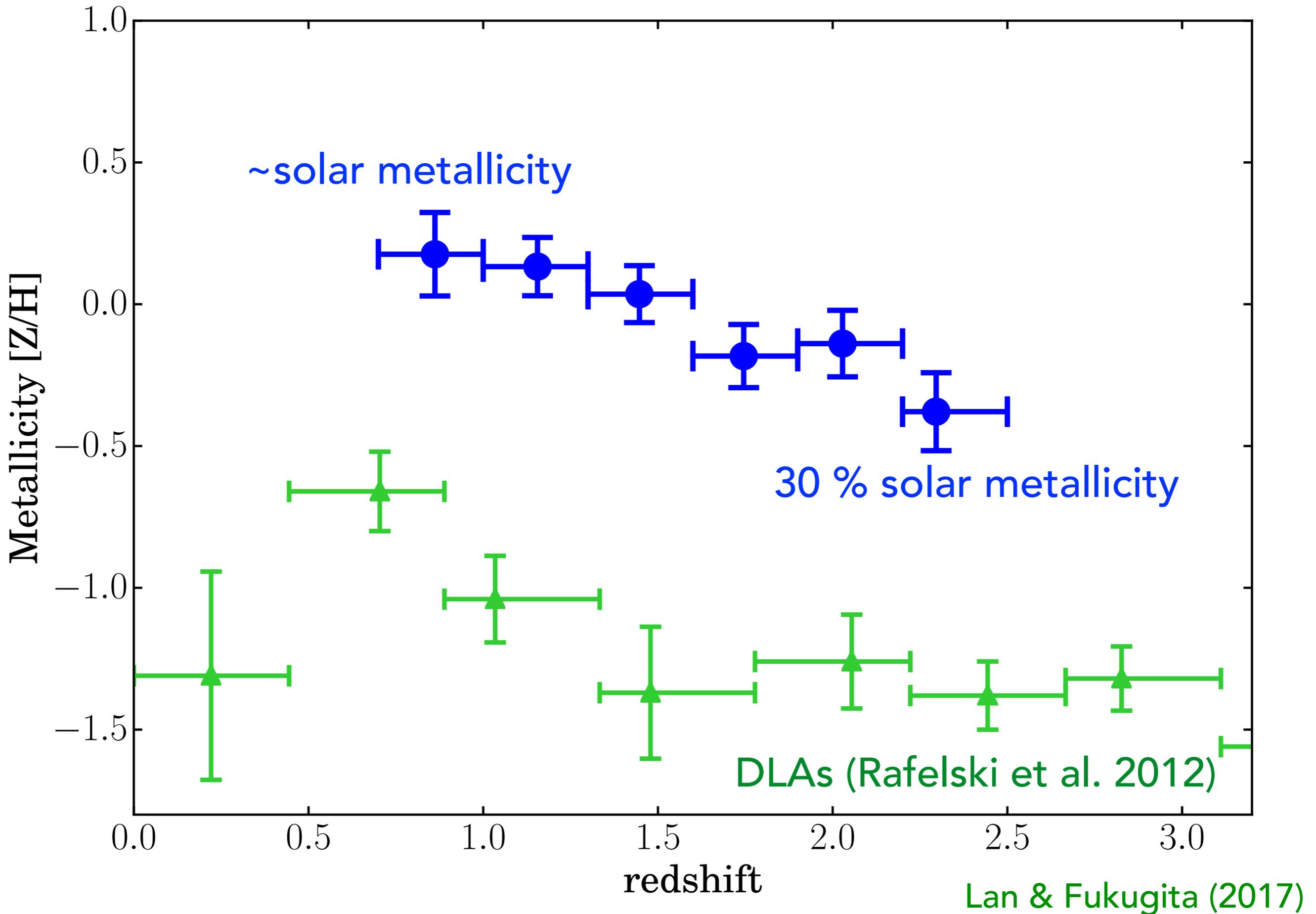
# Metal composite spectrum



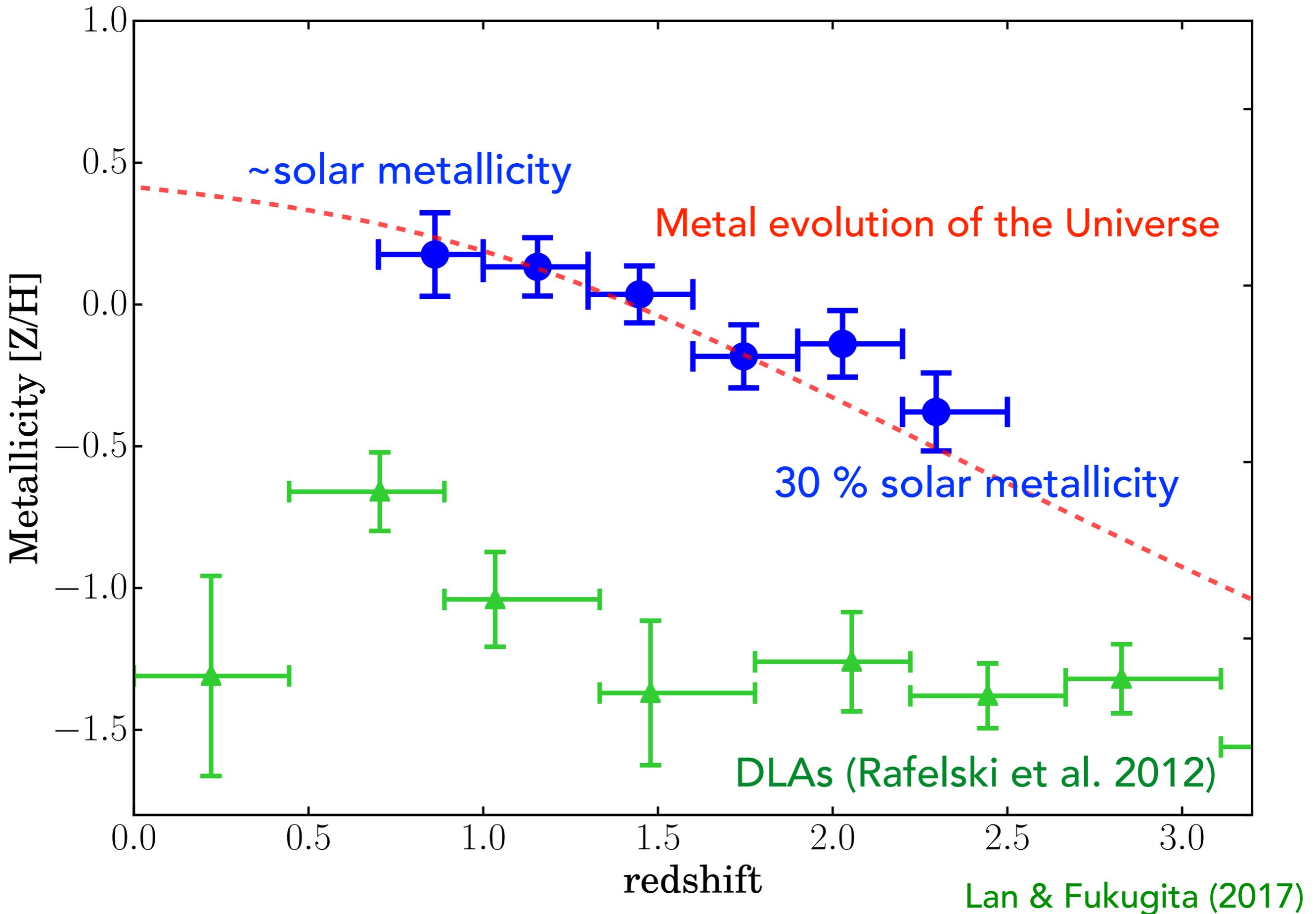
# Constraining the physical properties of gas with CLOUDY



# Metallicity evolution

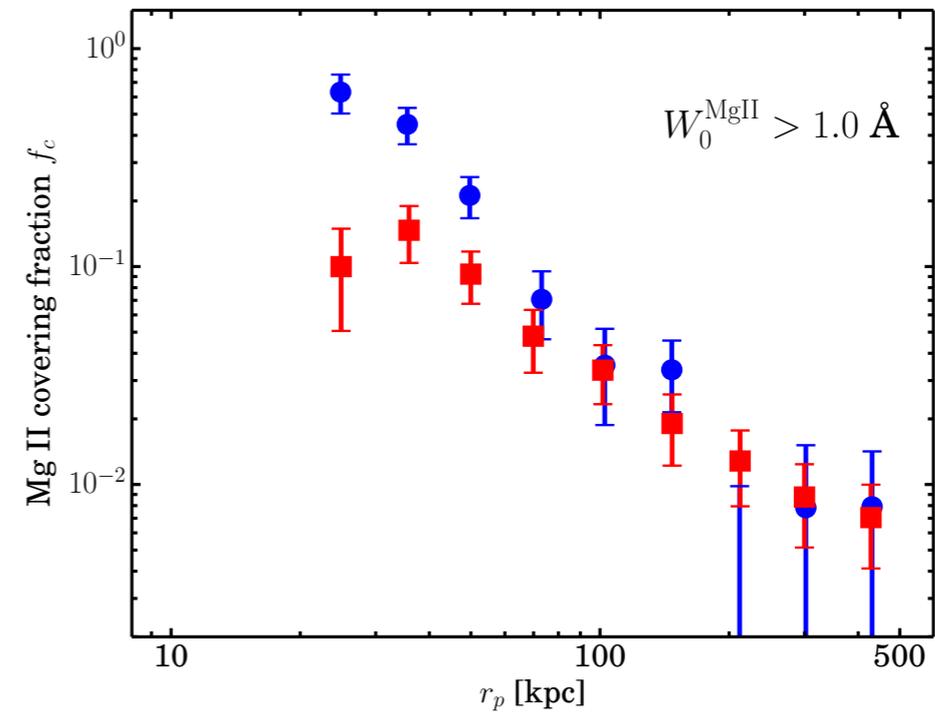
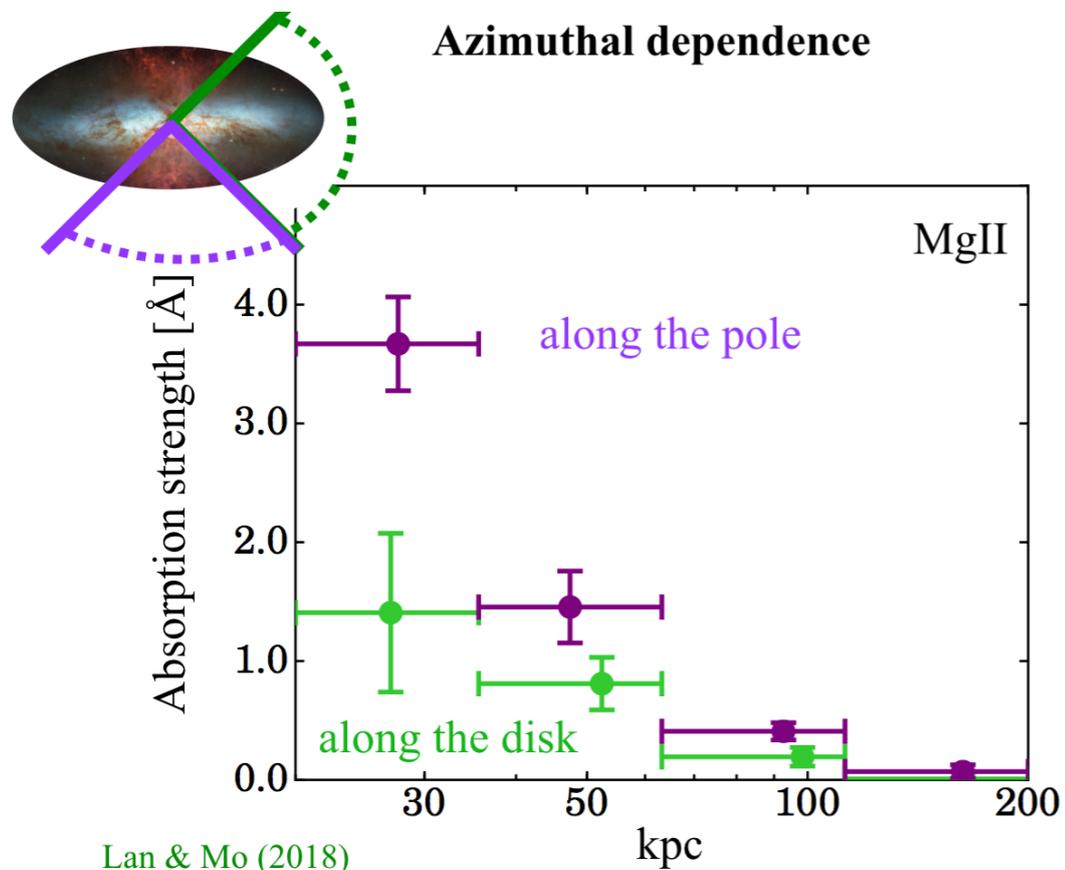


# Metallicity evolution

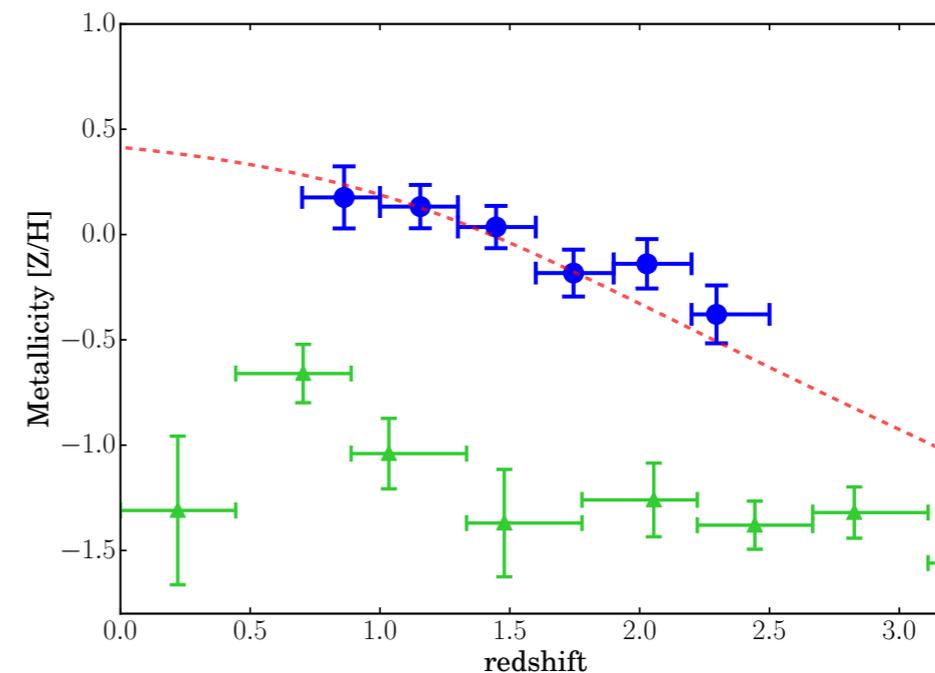


# Three signatures of Feedback in the CGM

## Correlations between the properties of galaxies and the CGM



## Spatial distribution of the CGM



## Metal content of the CGM