Morphology and Metallicity Evolution of the Circumgalactic Medium

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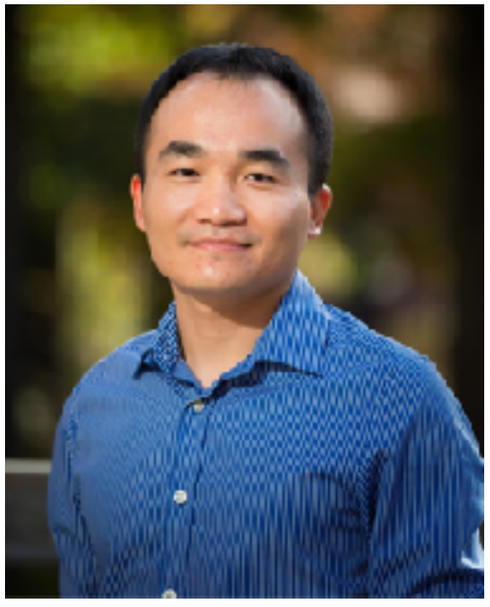
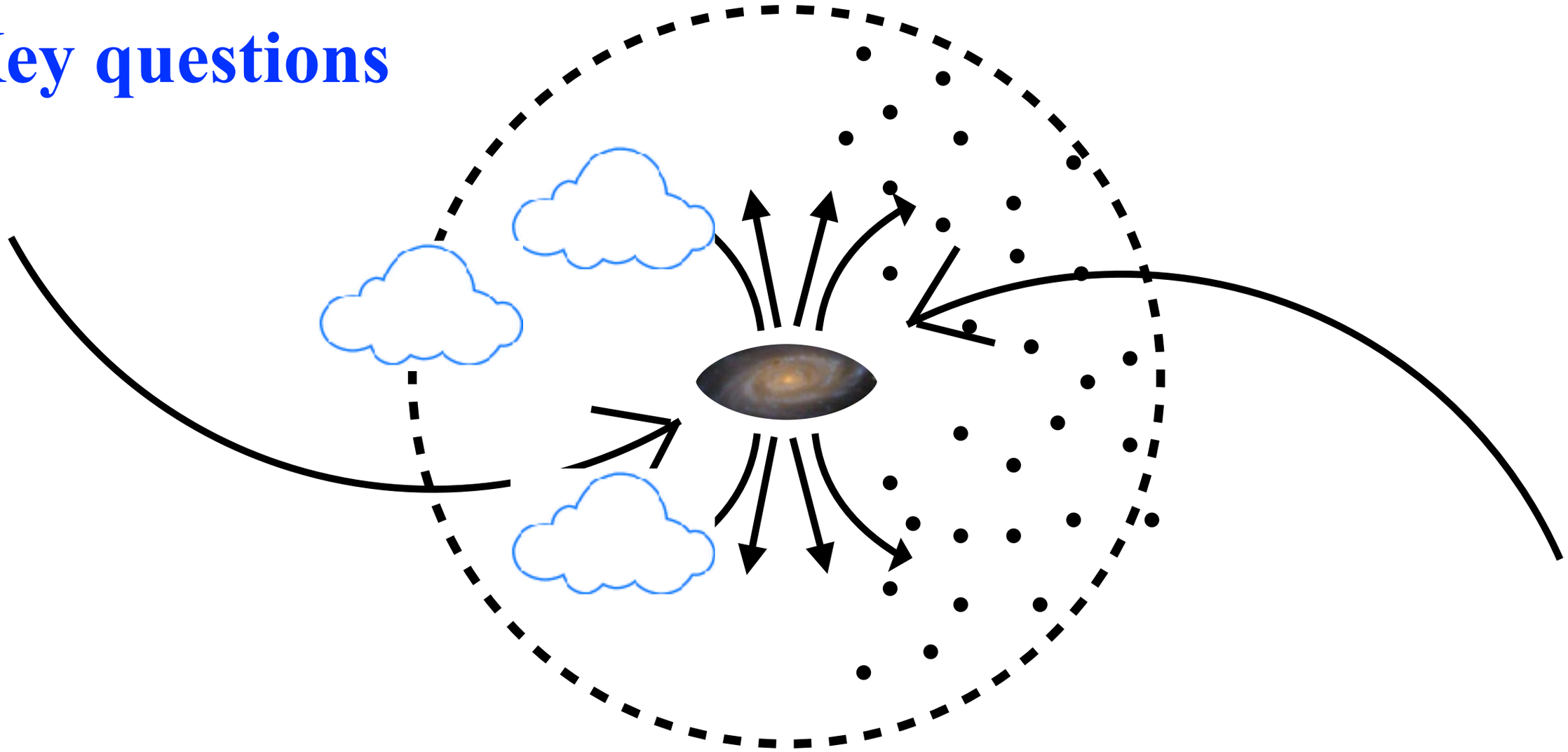
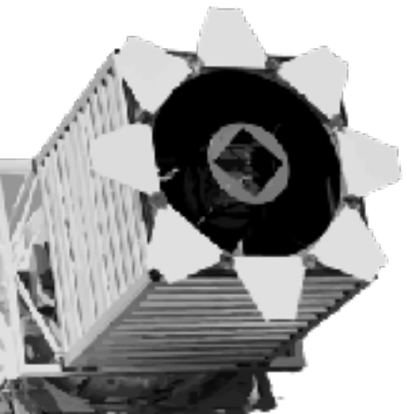

JHU

Key questions

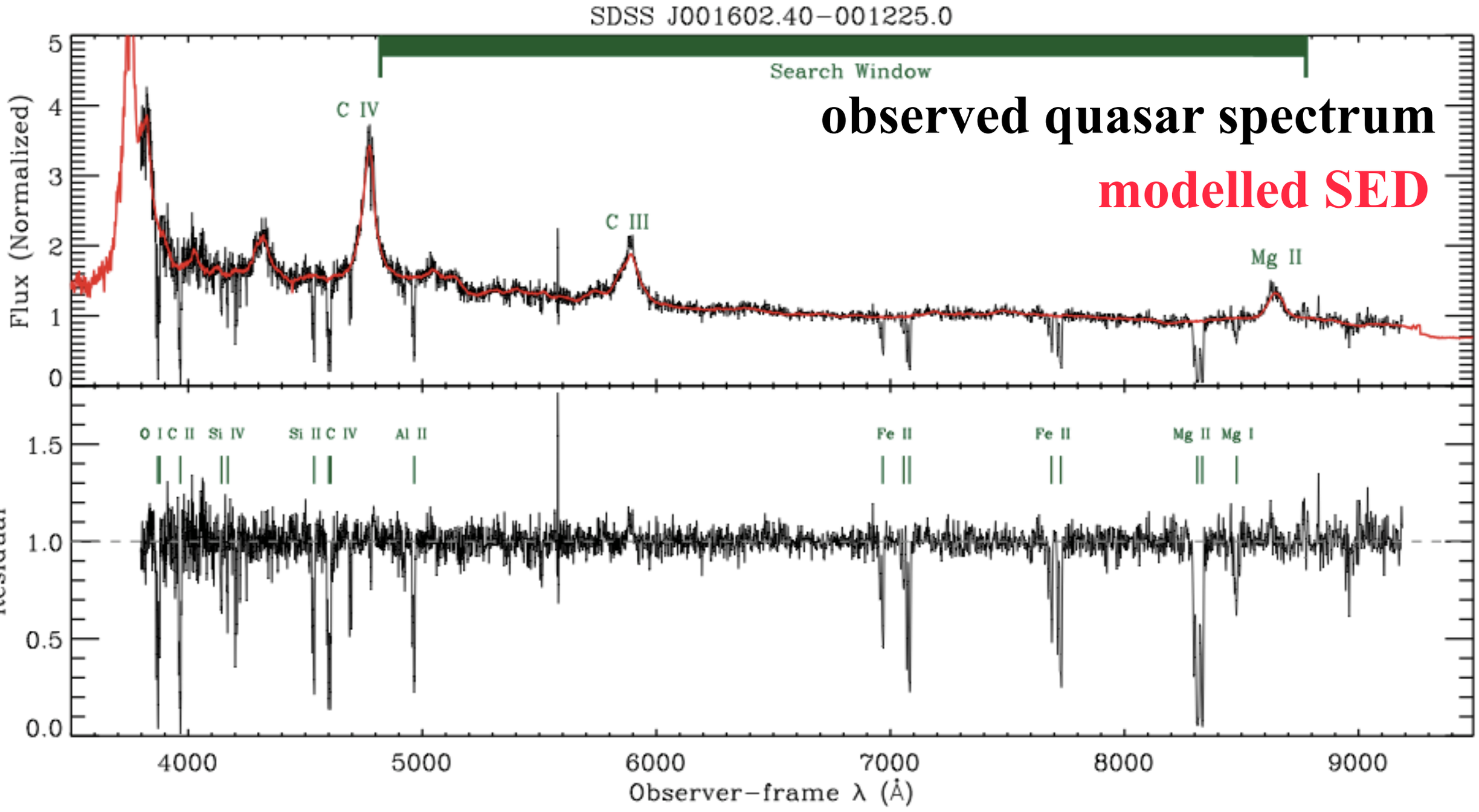


How does the metallicity of the CGM evolve?

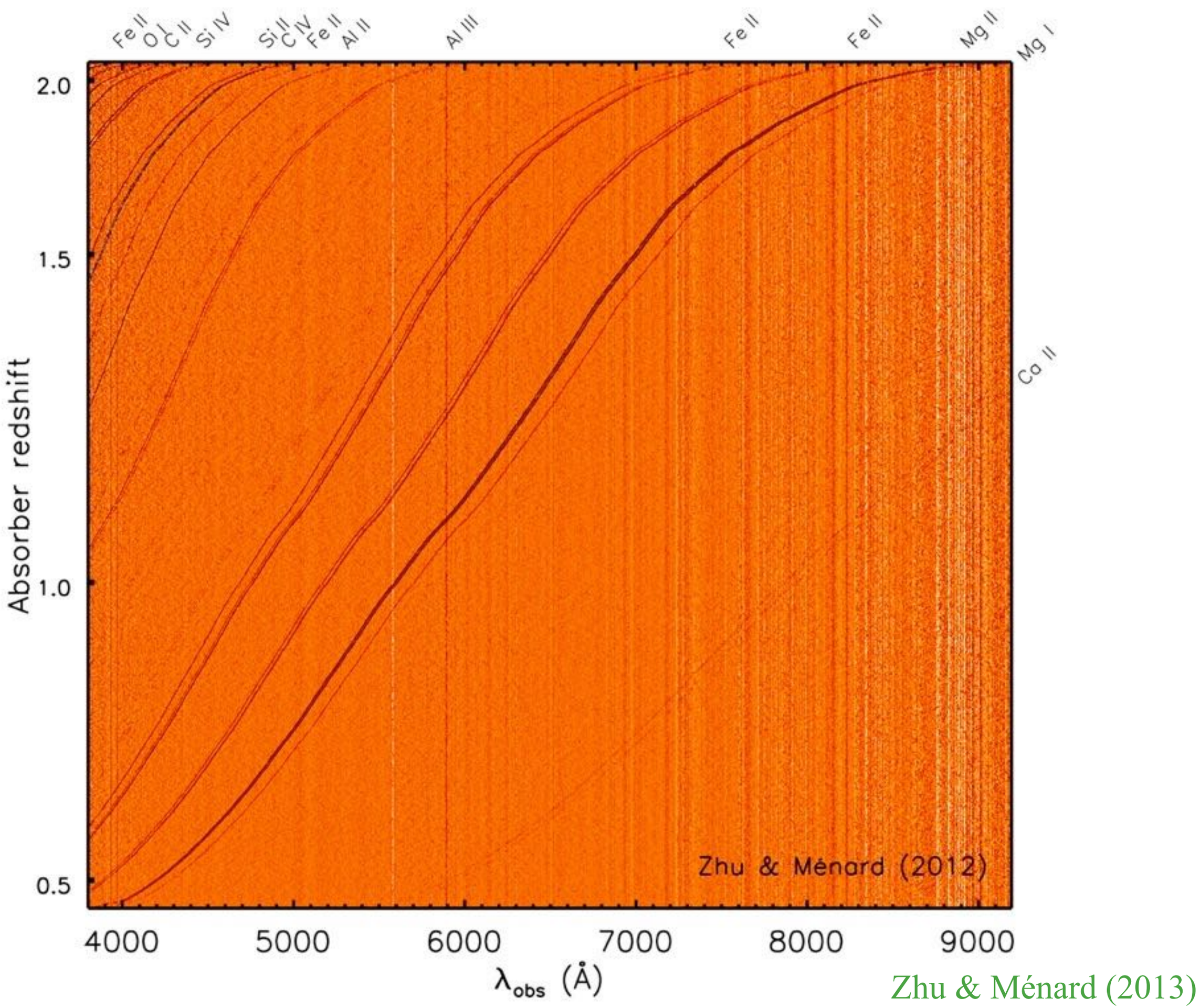


What is the morphology of the CGM?

Detecting MgII absorbers in SDSS quasar spectra

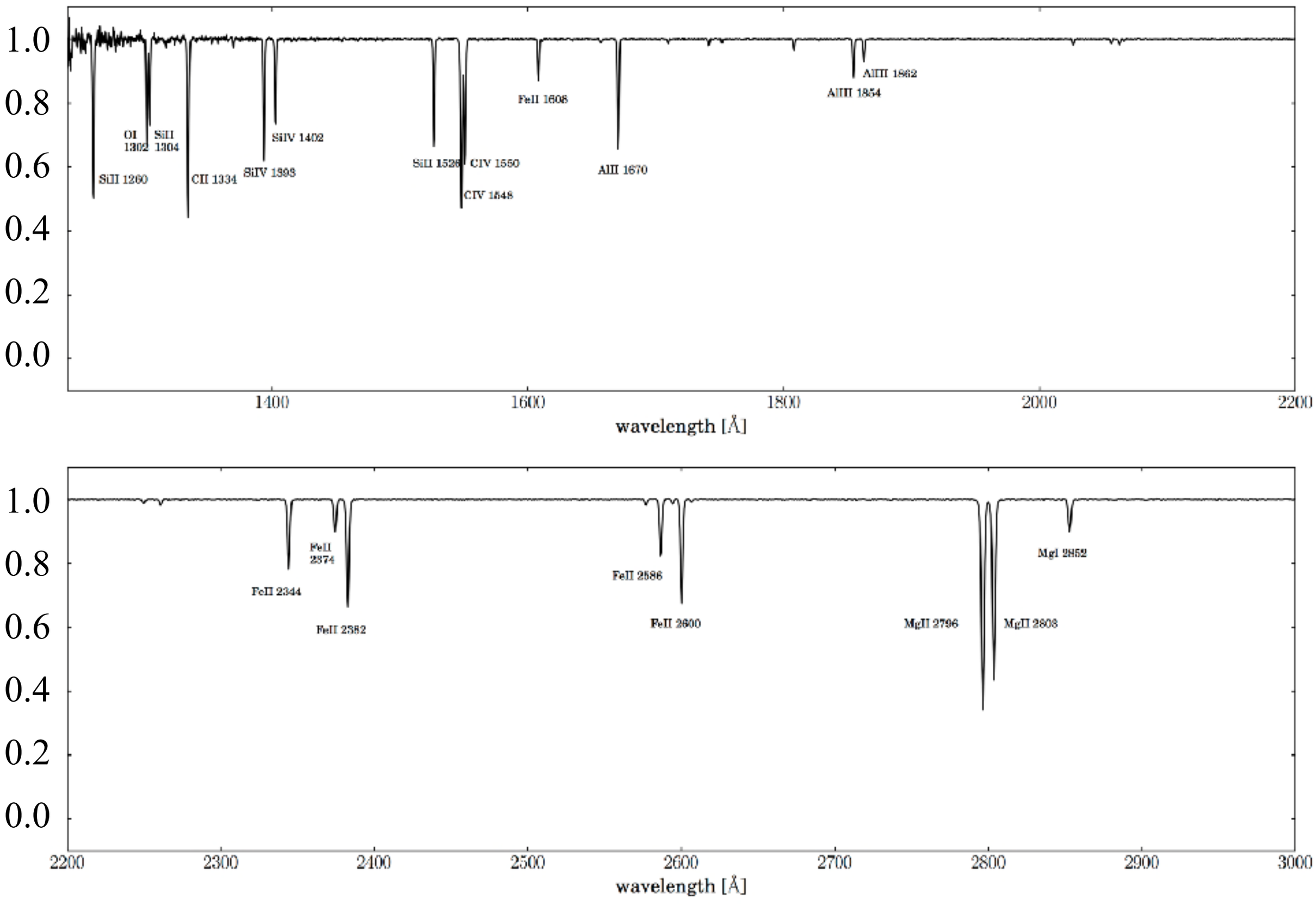


Zhu & Ménard 2013



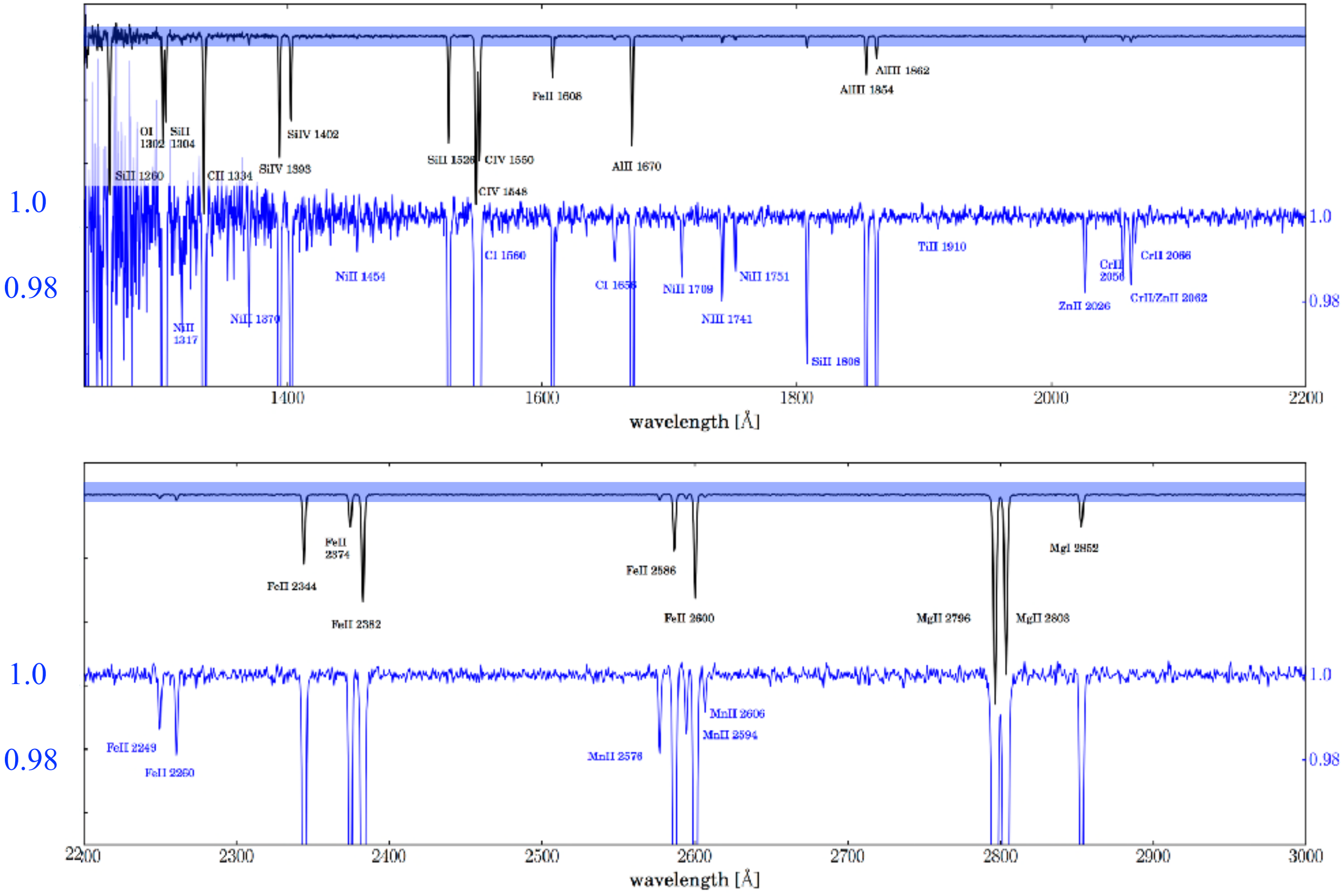
Zhu & Ménard (2013)

Metal composite spectrum



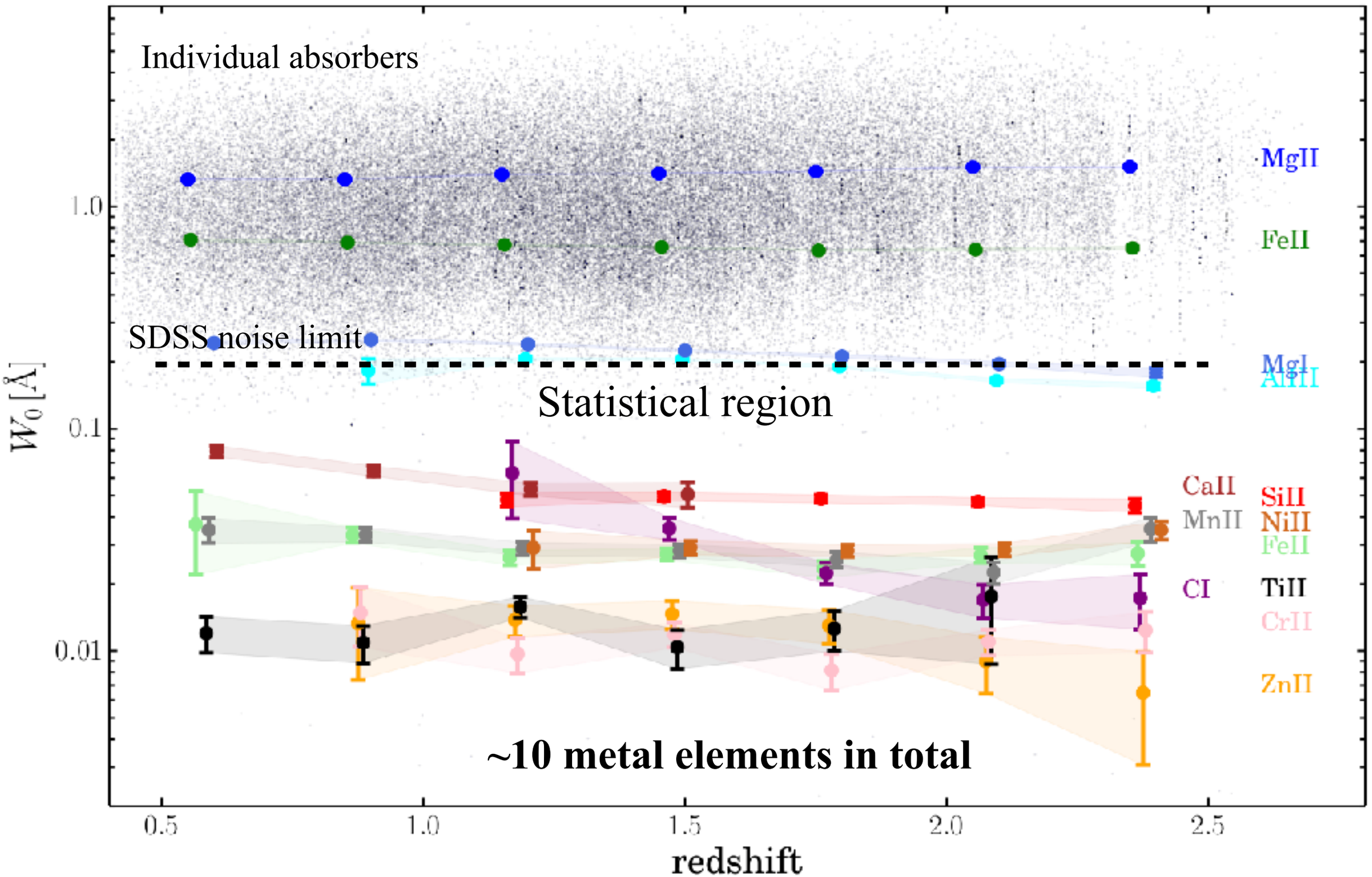
Lan & Fukugita (2017)

Metal composite spectrum



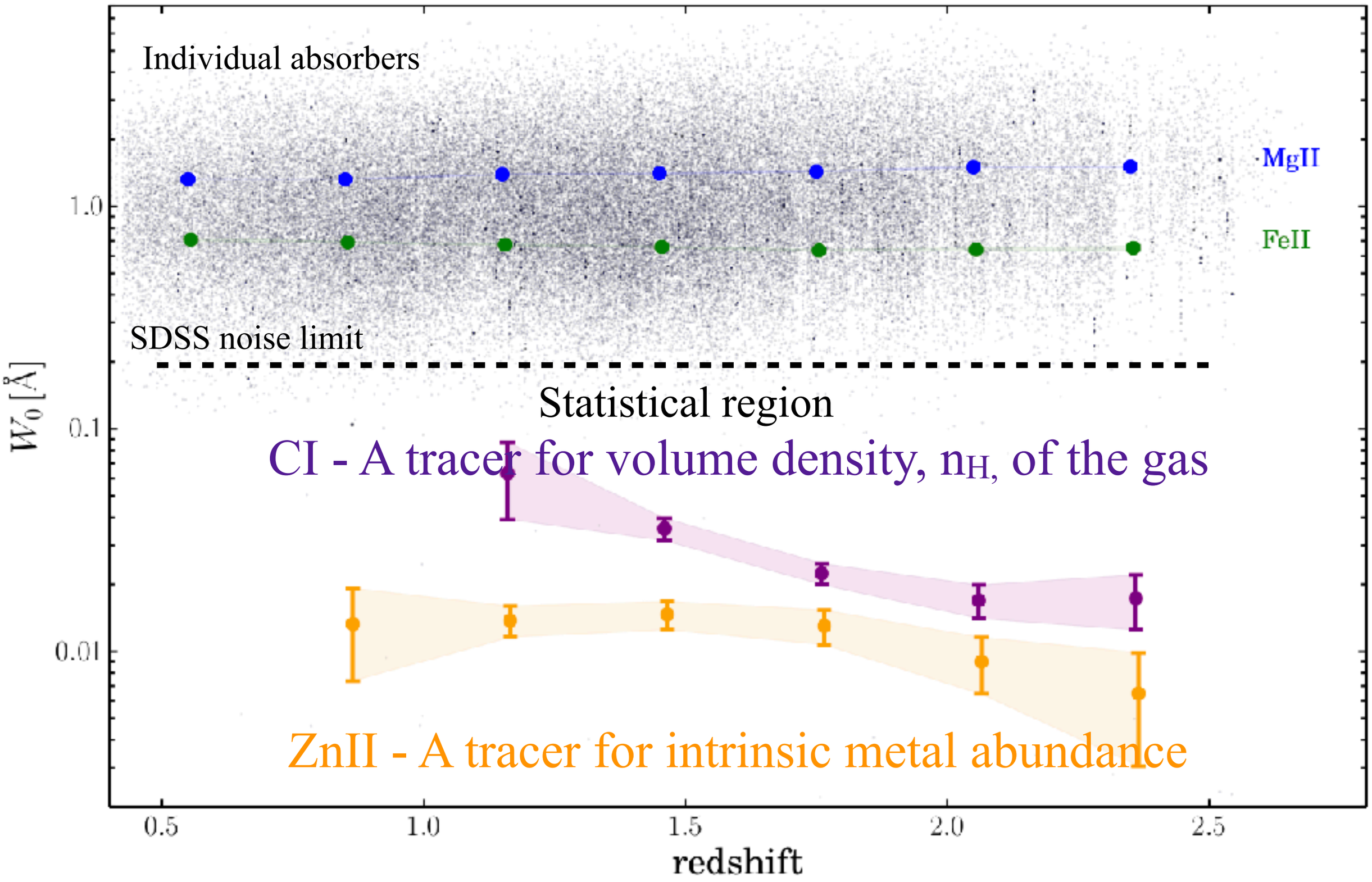
Lan & Fukugita (2017)

Probing weak absorption lines with SDSS

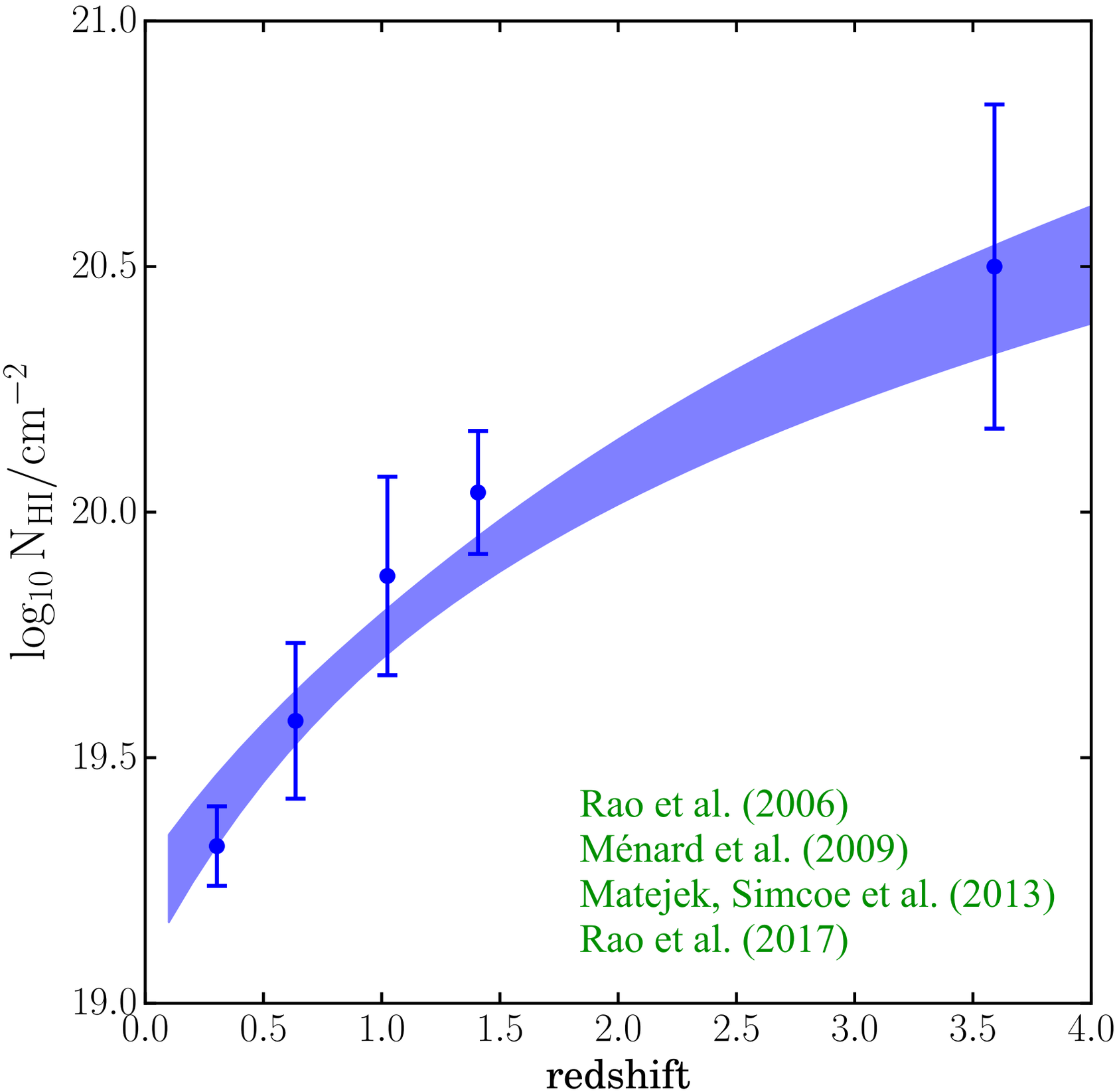


Lan & Fukugita (2017)

Probing weak absorption lines with SDSS

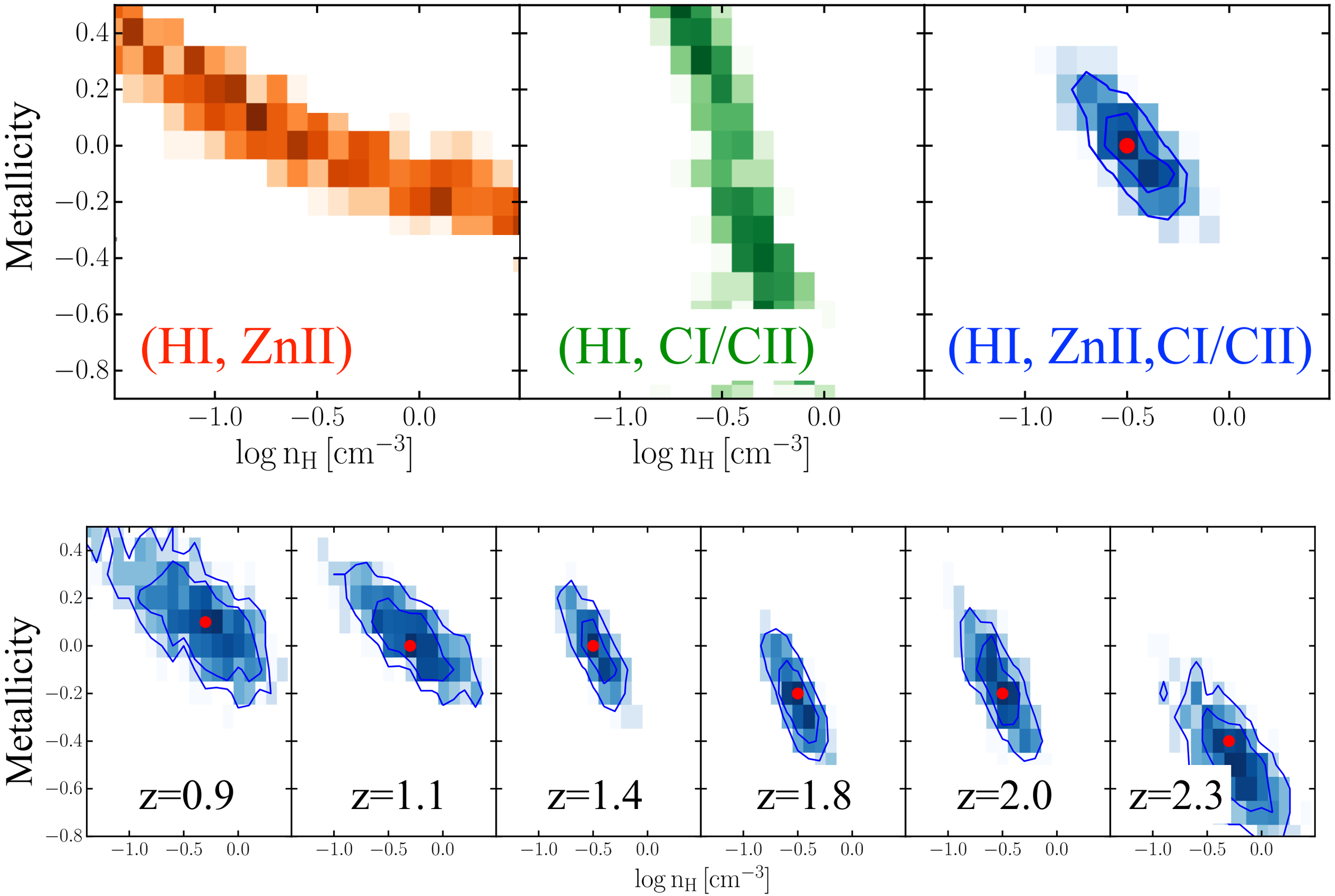


Neutral hydrogen column densities as a function of redshift

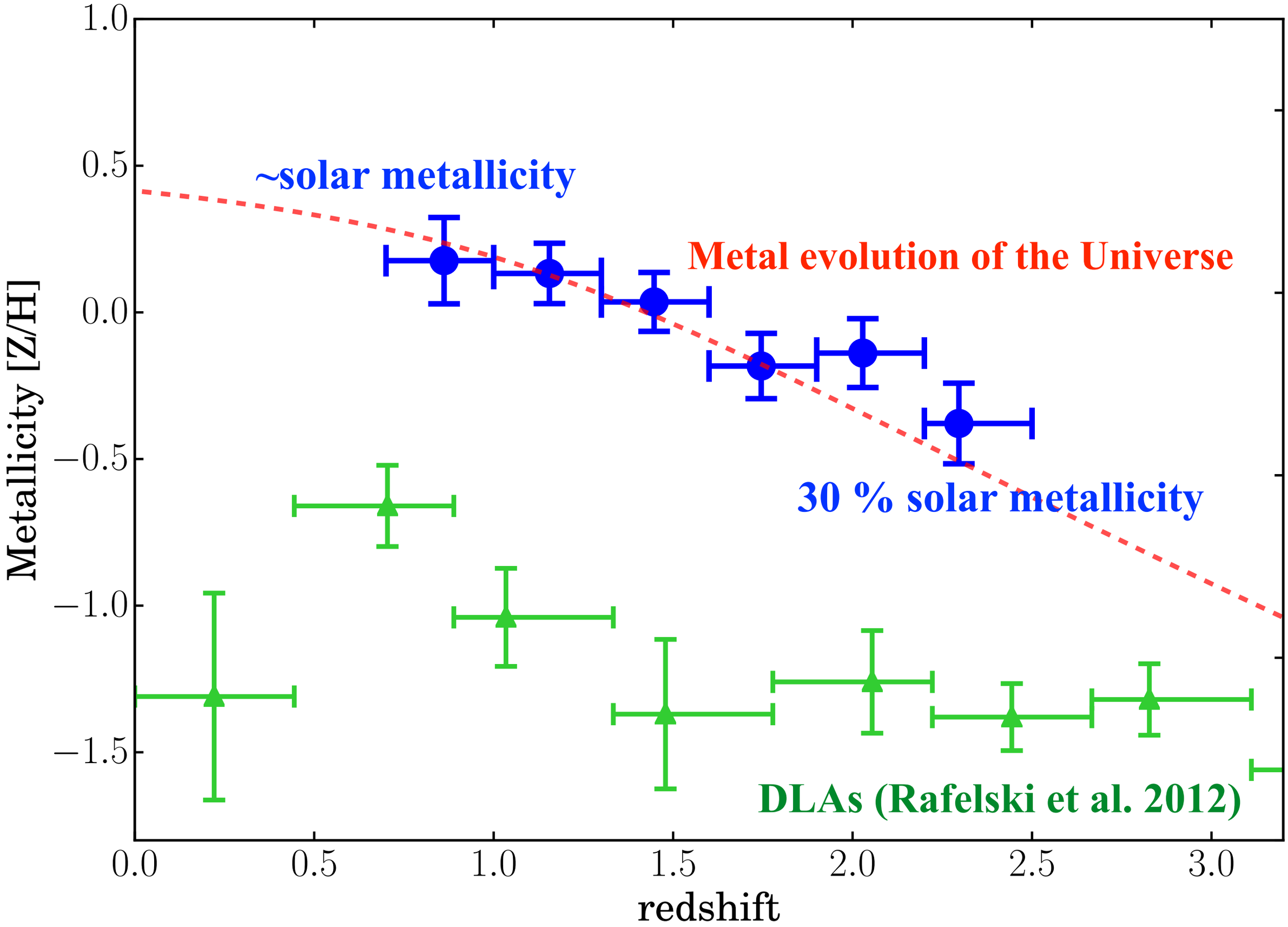


See also Matejek, Simcoe et al. (2013)

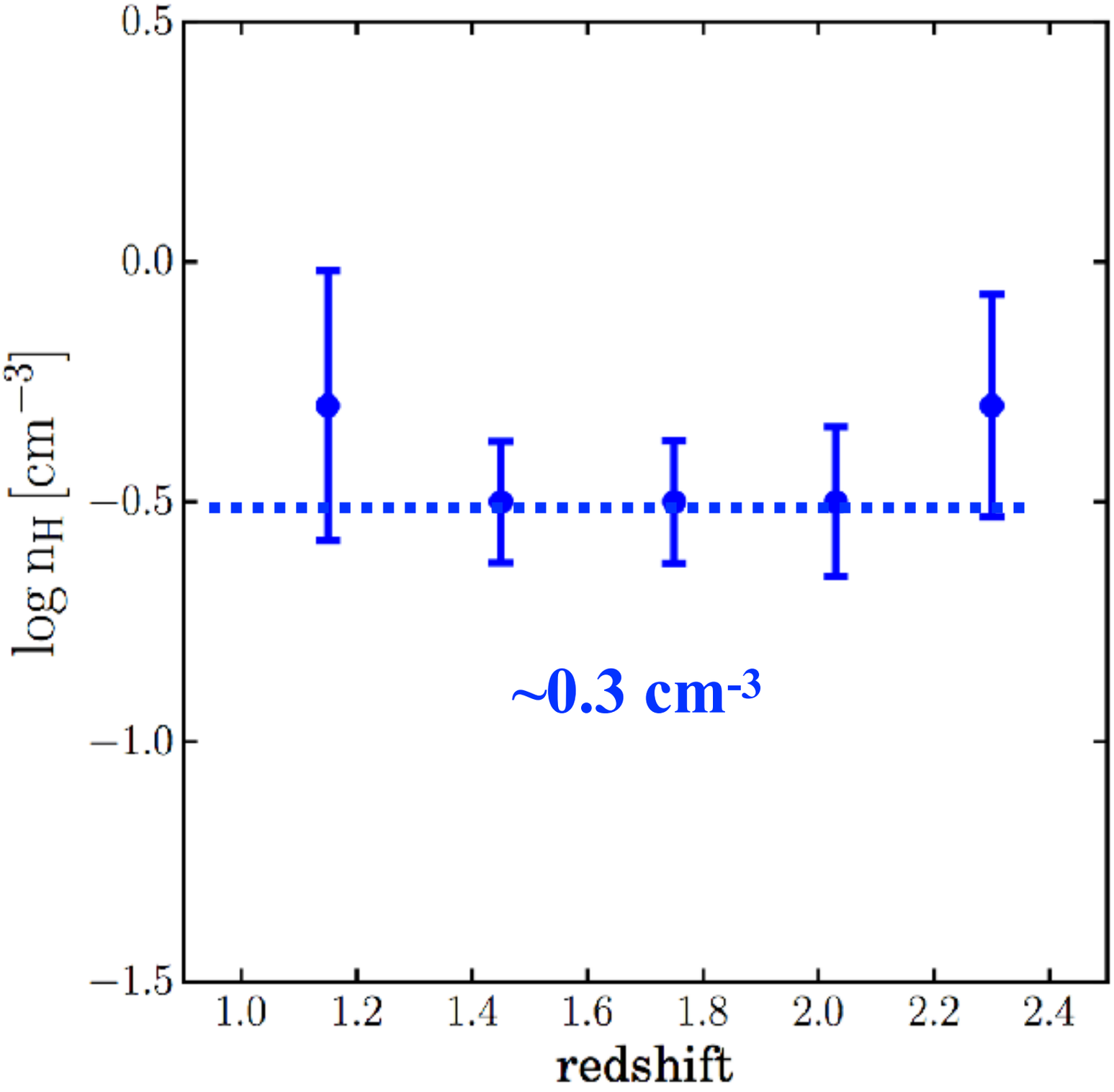
Constraining the physical properties of gas with CLOUDY



Metallicity evolution

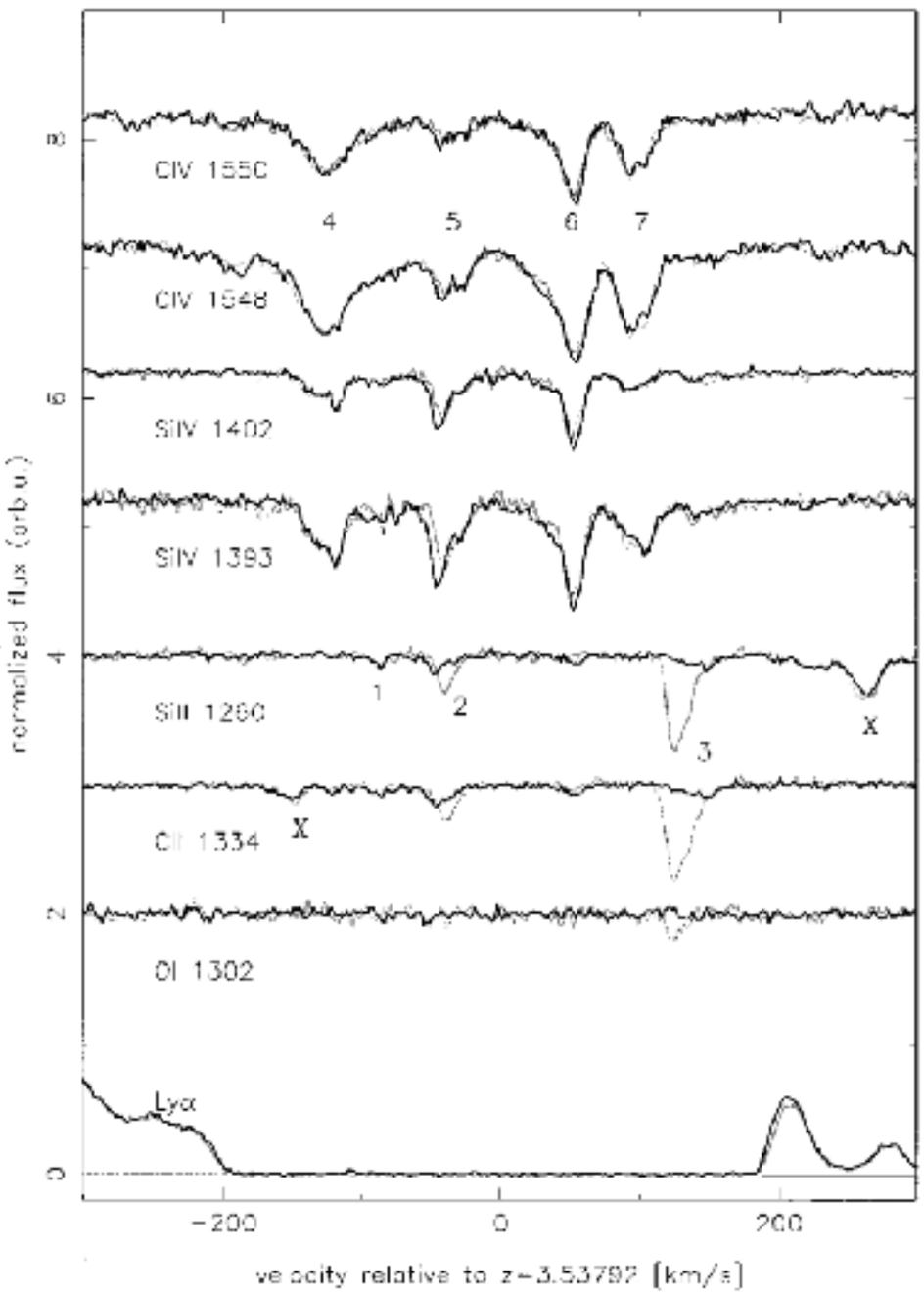


Gas cloud volume density



size of clouds ~ N_H / n_H ~ 30 pc

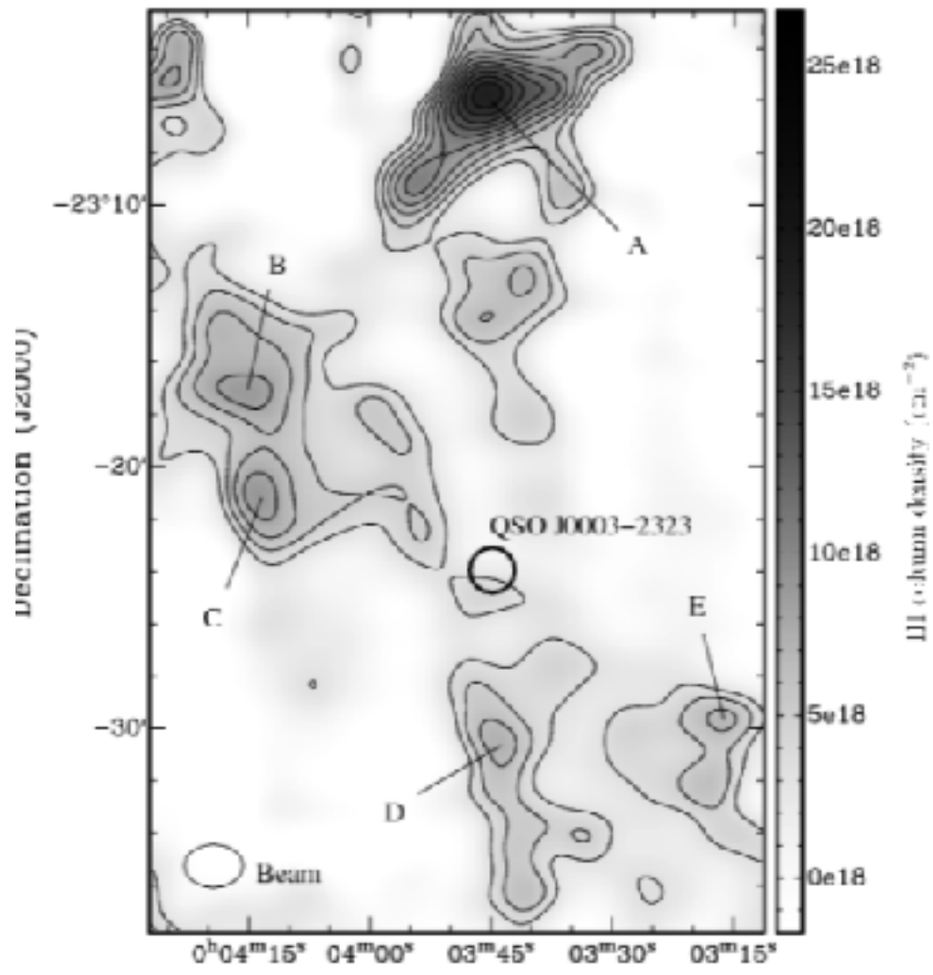
Size constrained by lensed background quasars



size ≤ 30 pc

Rauch et al. 1999

HVCs

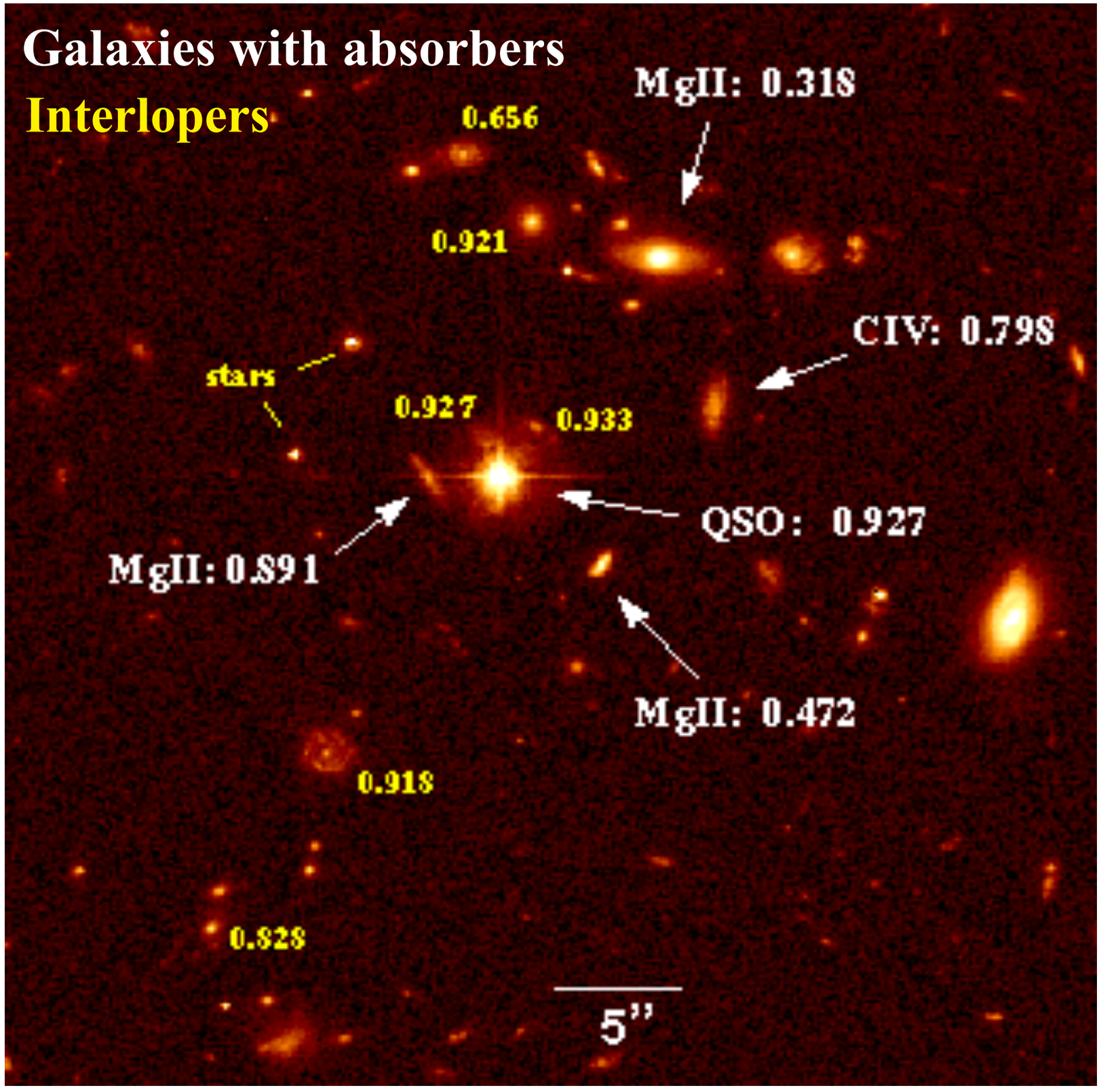


clump	r	$M_{\rm HI}$	$n_{\rm HI}$
	[pc]	[$M_\odot$]	[cm^{-3}]
A	45	470	0.14
B	45	280	0.06
C	49	160	0.06
D	36	150	0.06
E	32	160	0.07

size ~ 50 pc

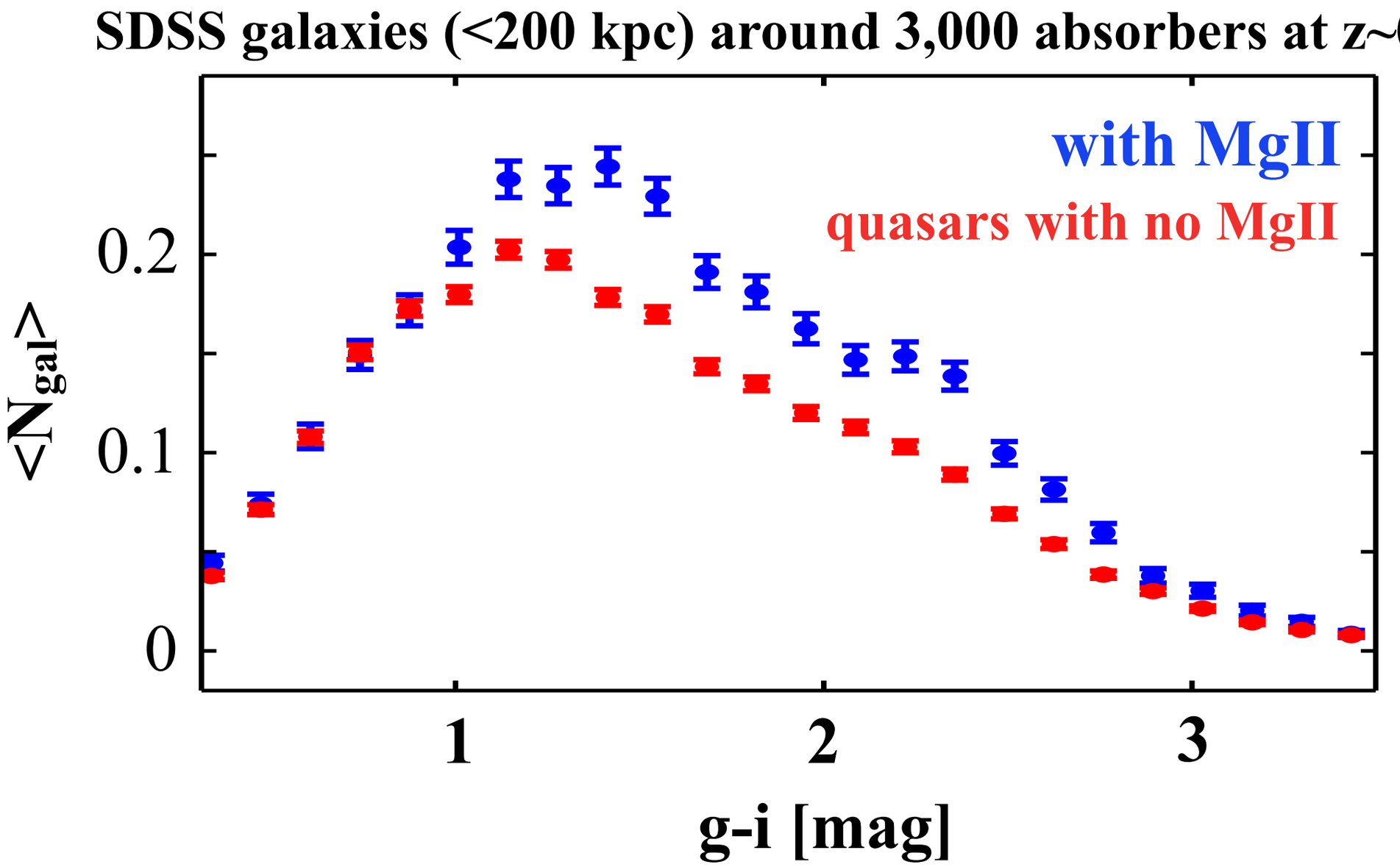
Ben Bekhti et al. 2009

Searching for galaxy - absorber pairs



Steidel et al. (1997)

Probing the associated galaxies with a statistical approach



randomly-distributed background galaxies

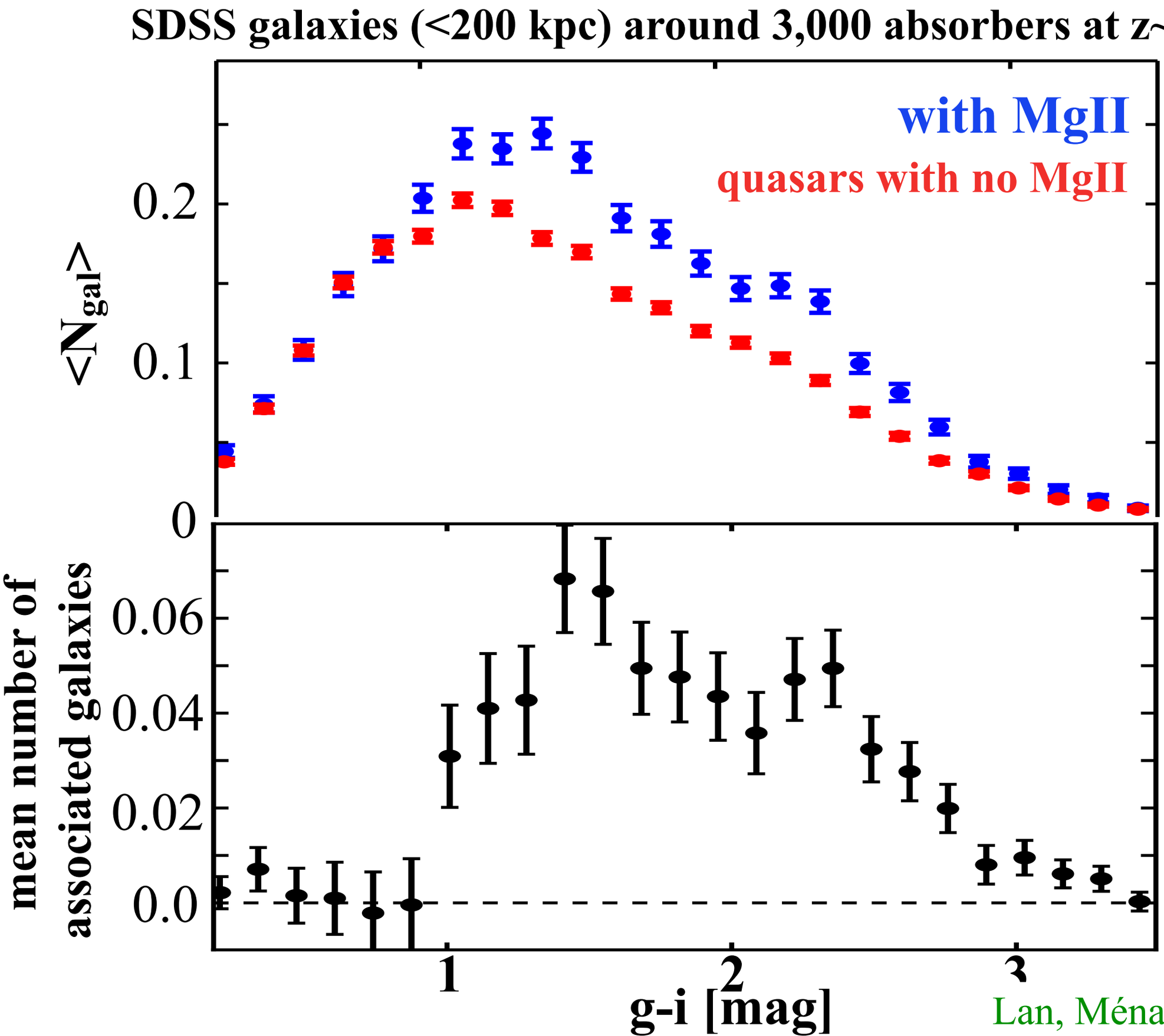
+

galaxies associated with MgII

randomly-distributed background galaxies

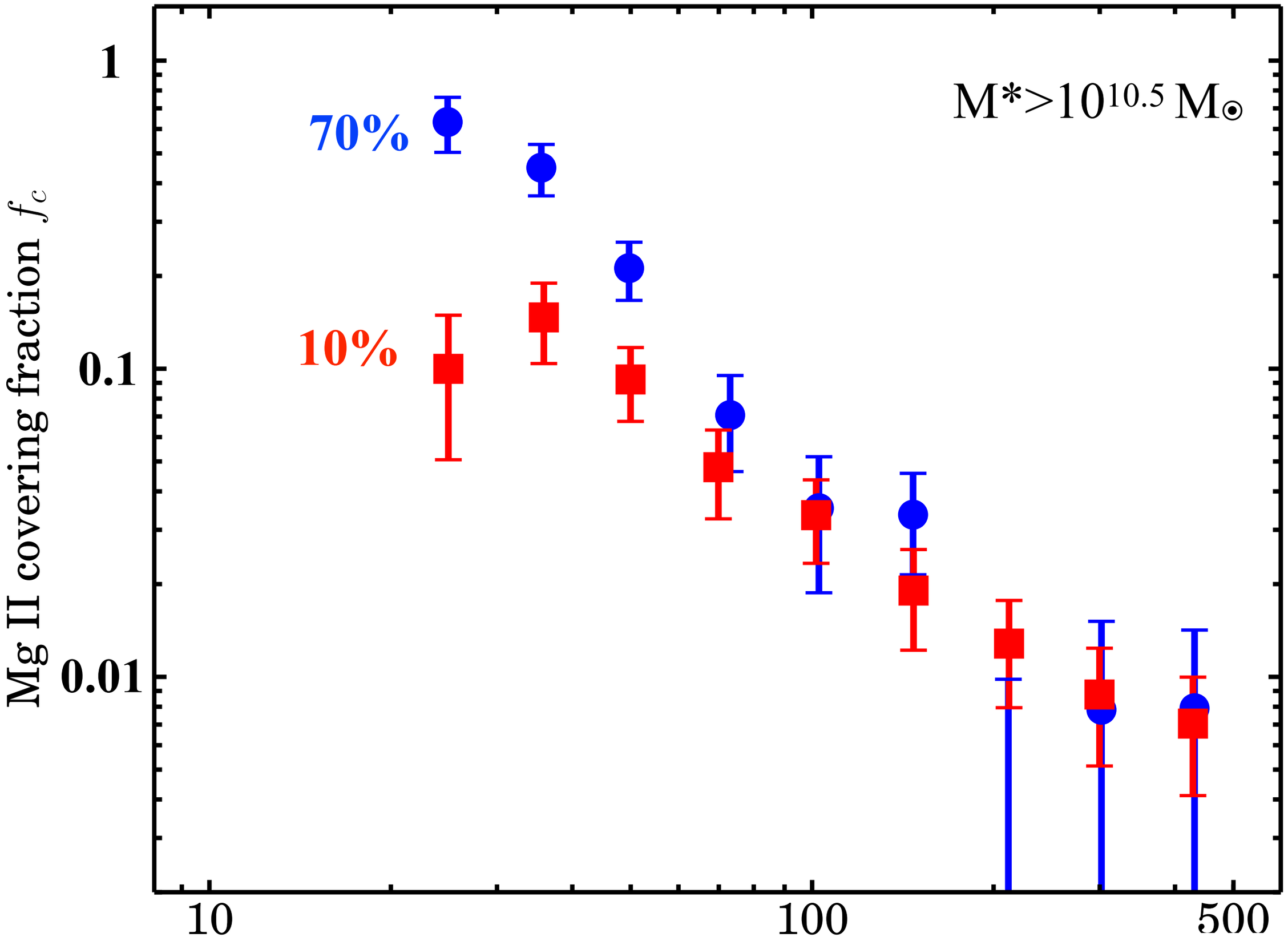
Lan, Ménard & Zhu (2014)

Probing the associated galaxies with a statistical approach



Lan, Ménard & Zhu (2014)

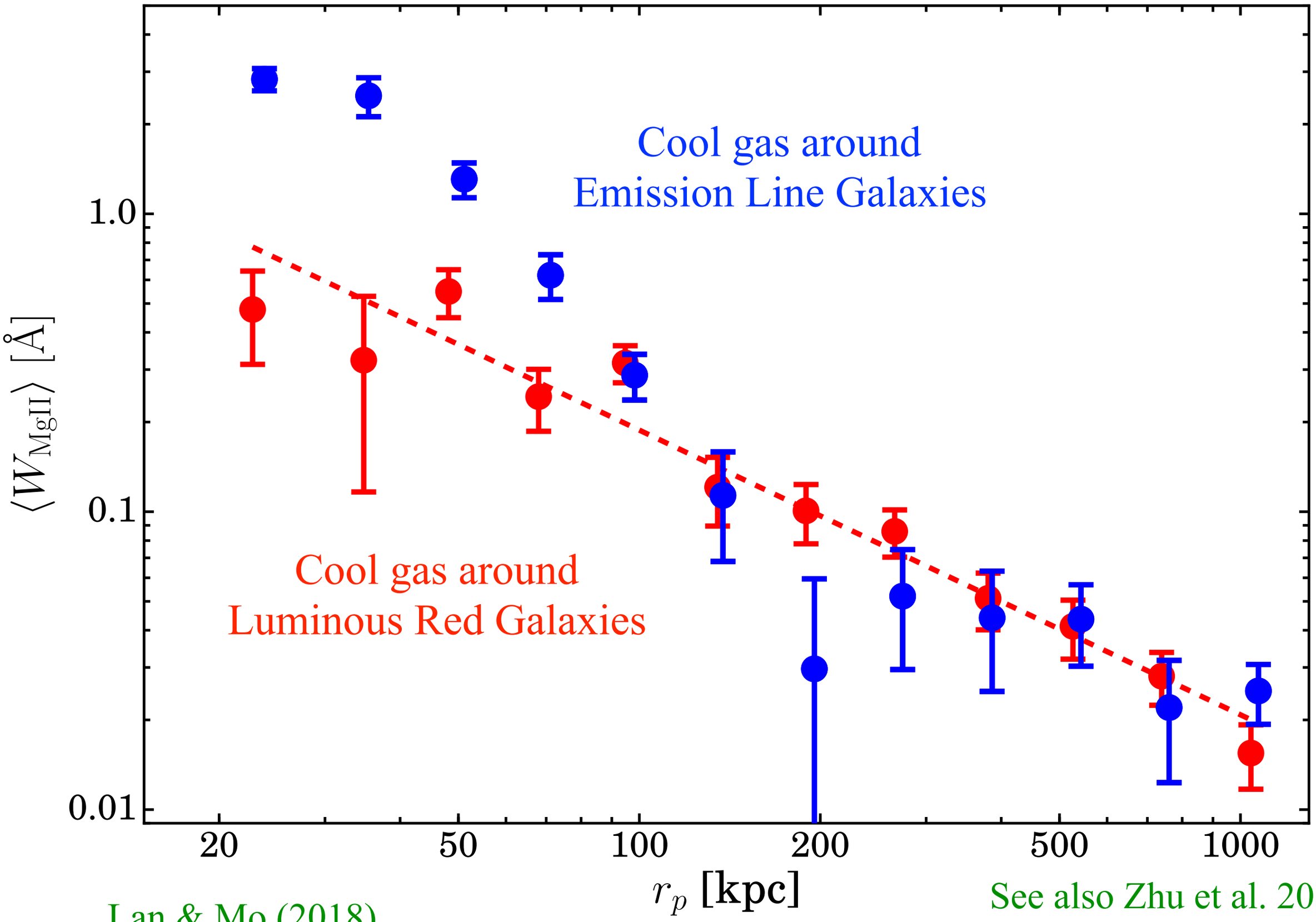
Mg II covering fraction



Lan, Ménard & Zhu (2014)

See also Chen et al, Bordoloi et al. Huang et al., Zhu et al. Nielsen et al.

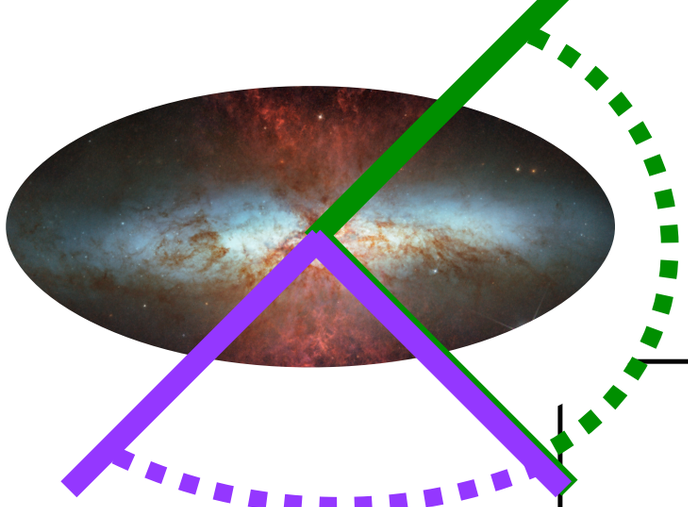
Gas distribution

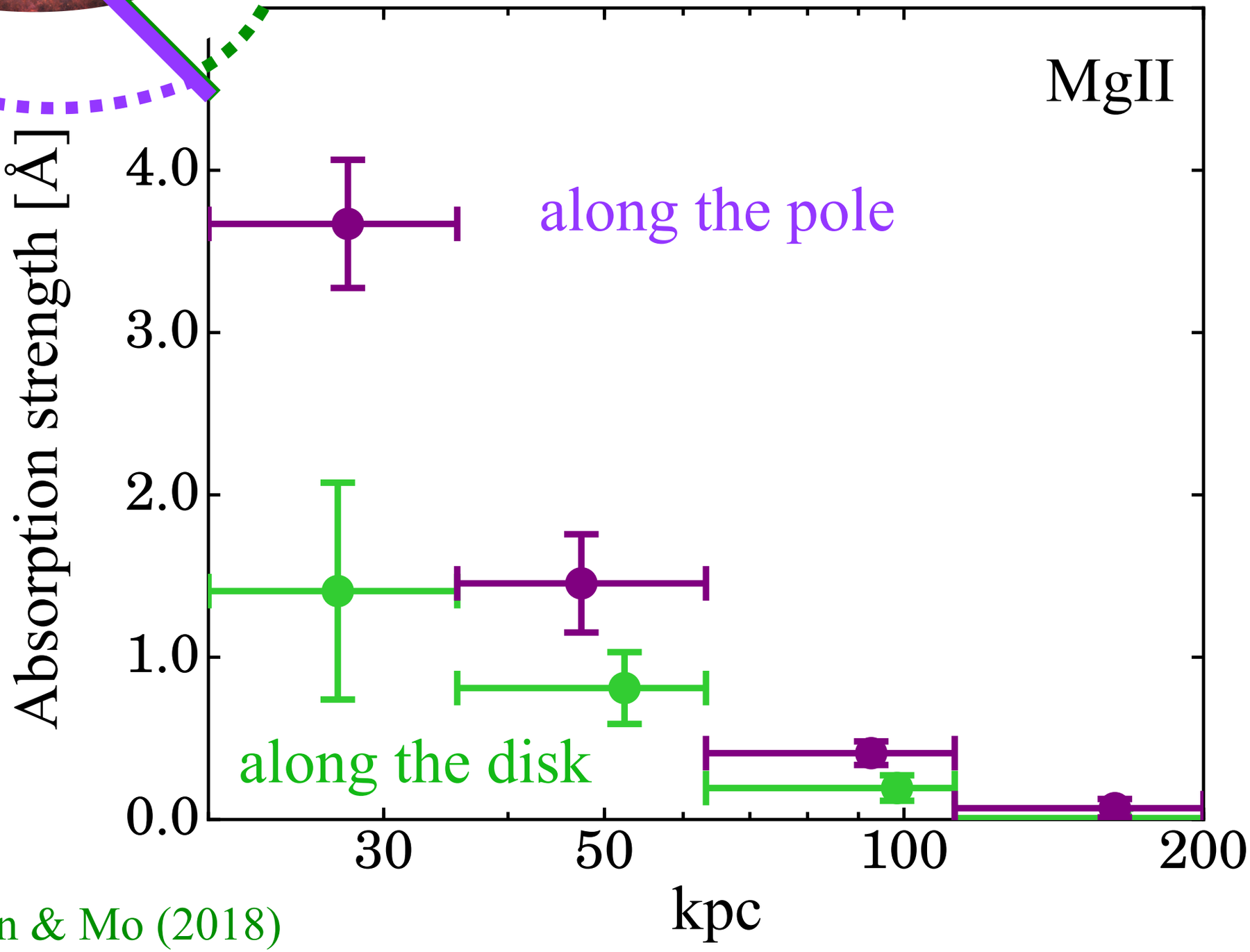


Lan & Mo (2018)

See also Zhu et al. 2014,
Pérez-Ràfols et al. 2015

Azimuthal dependence

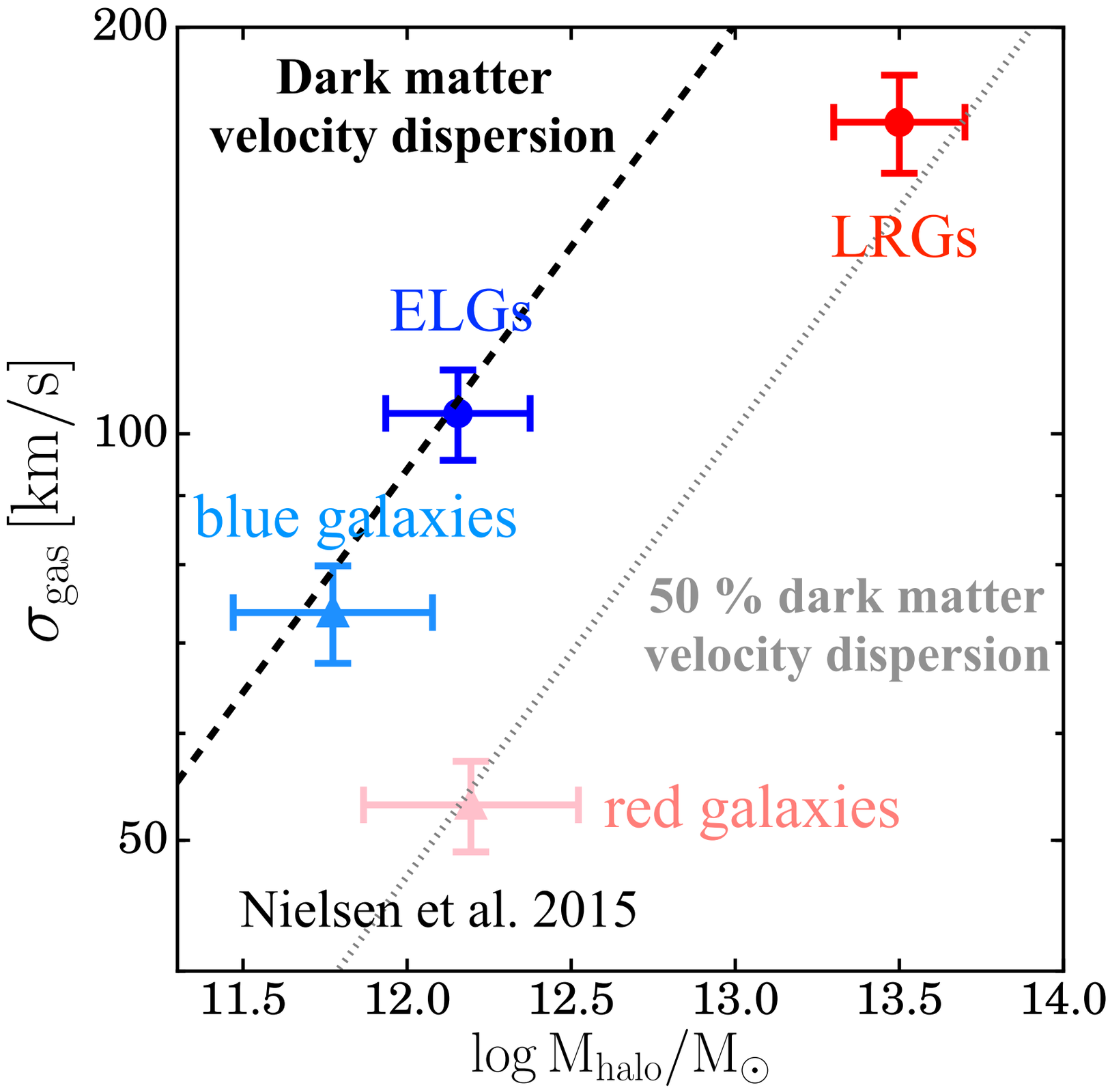




Lan & Mo (2018)

See also Bordoloi et al. 2011, Kacprak et al. 2011,
Bouche et al. 2012, Lan et al. 2014, Kacprak et al. 2015, Lundgren et al. 2018

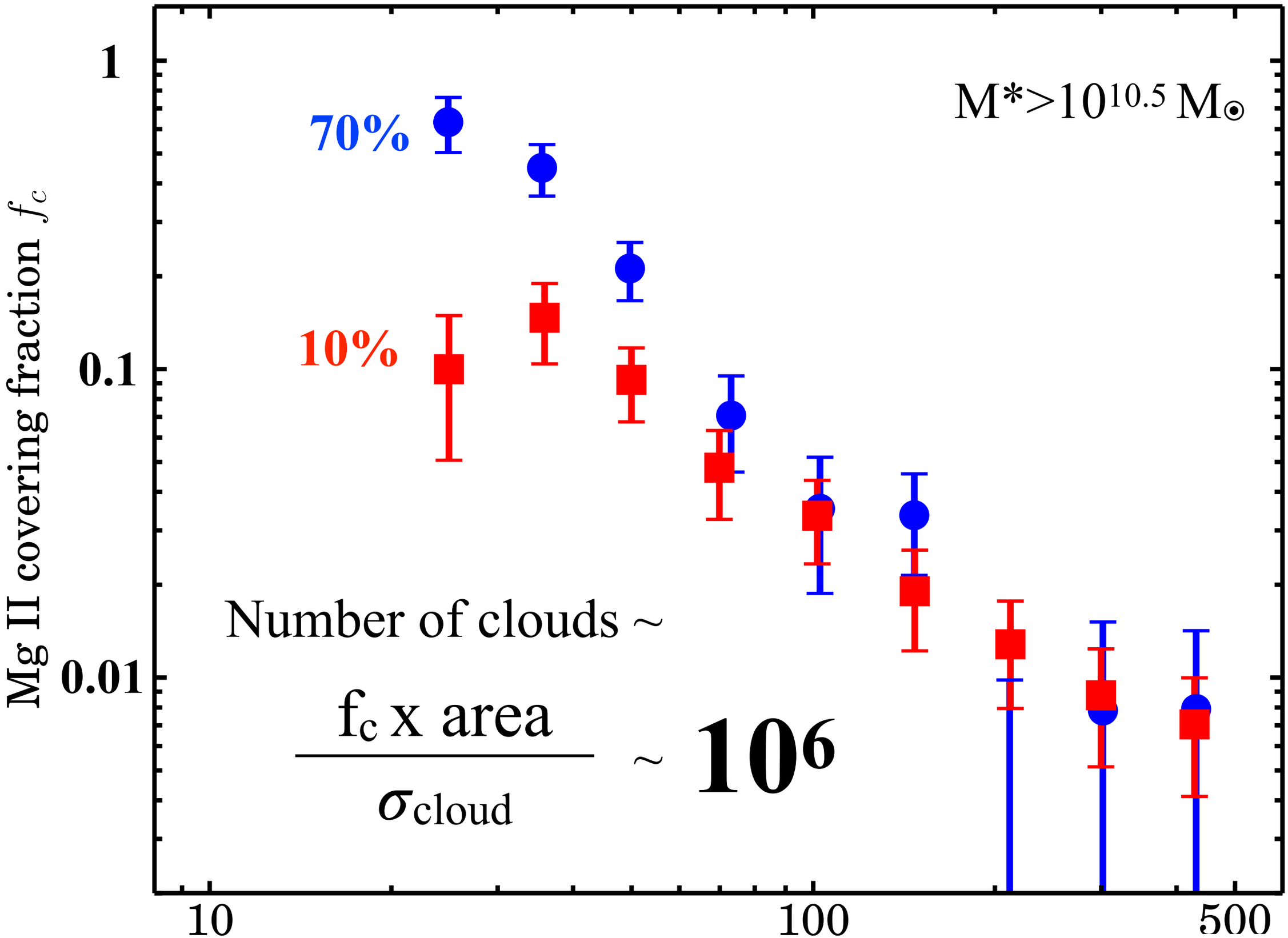
Gas kinematics



Lan & Mo (2018)

See also Nielsen et al. 2015, 2016

Mg II covering fraction



Lan, Ménard & Zhu (2014)

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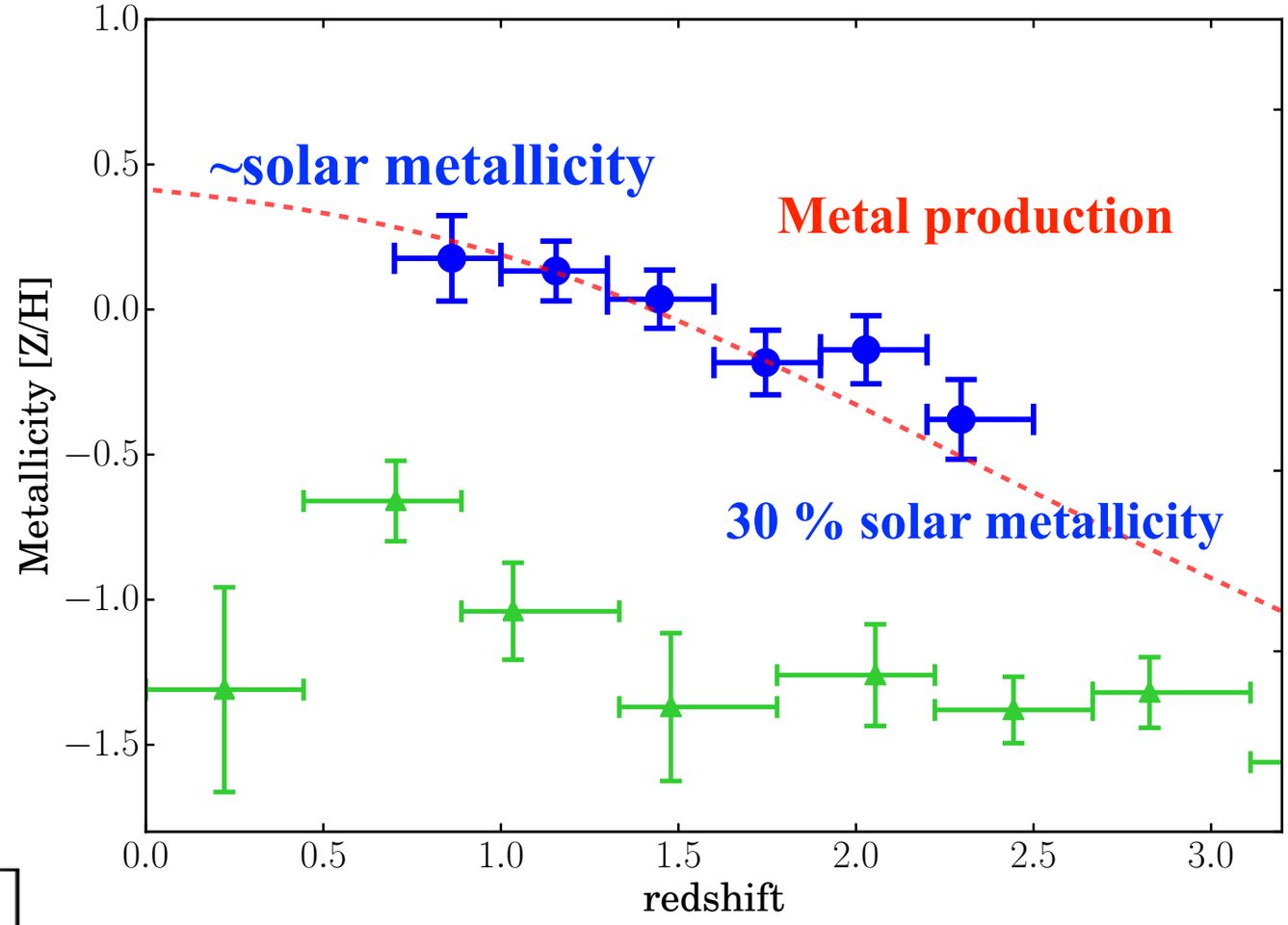
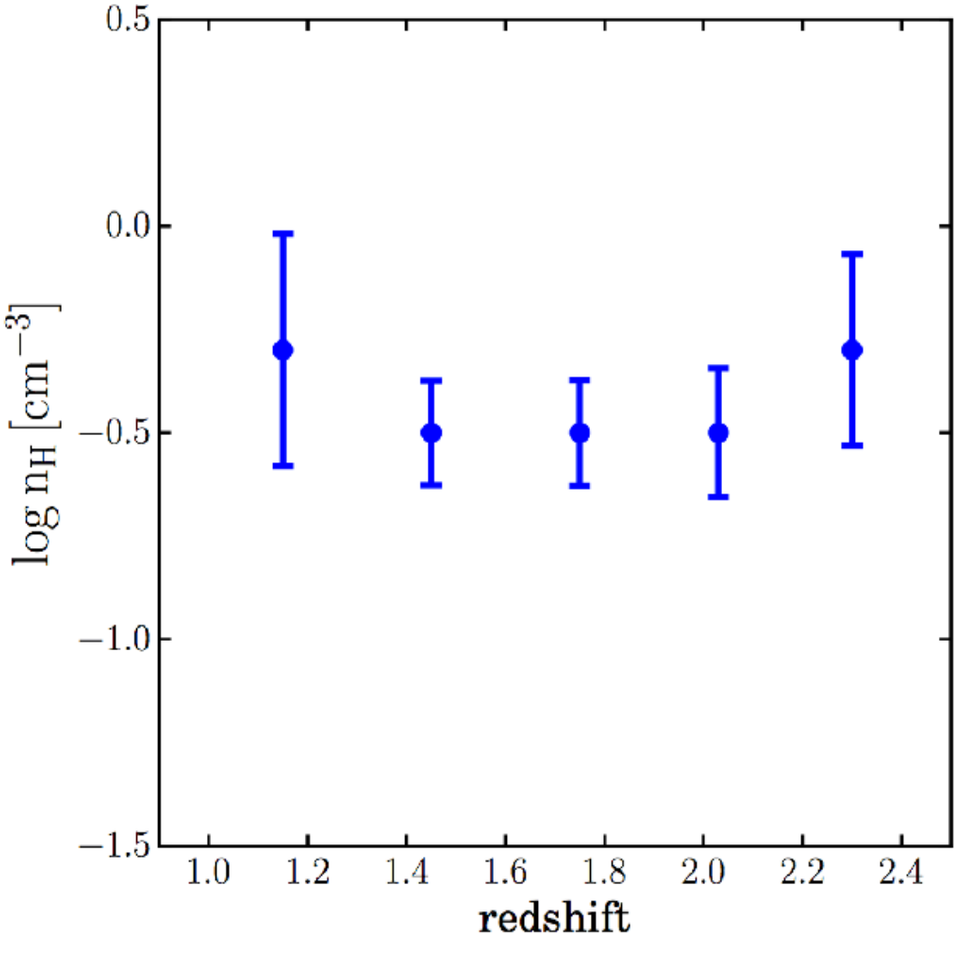
Summary

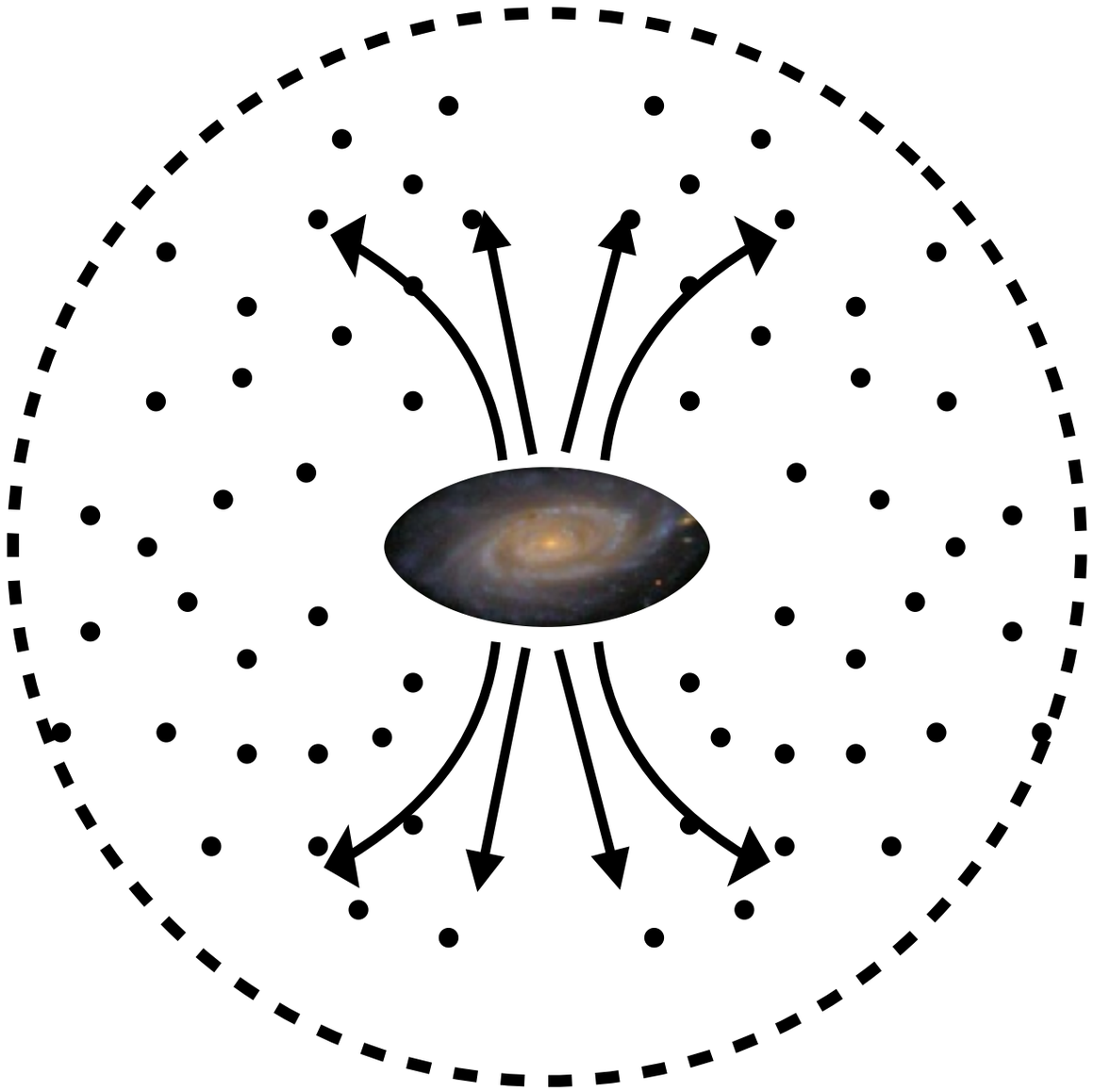
Metallicity evolution





volume density ~ 0.3 cm^{-3}

cloud size ~ 30 pc



The CGM is clumpy,

consisting of ~10^6 metal-rich clouds.