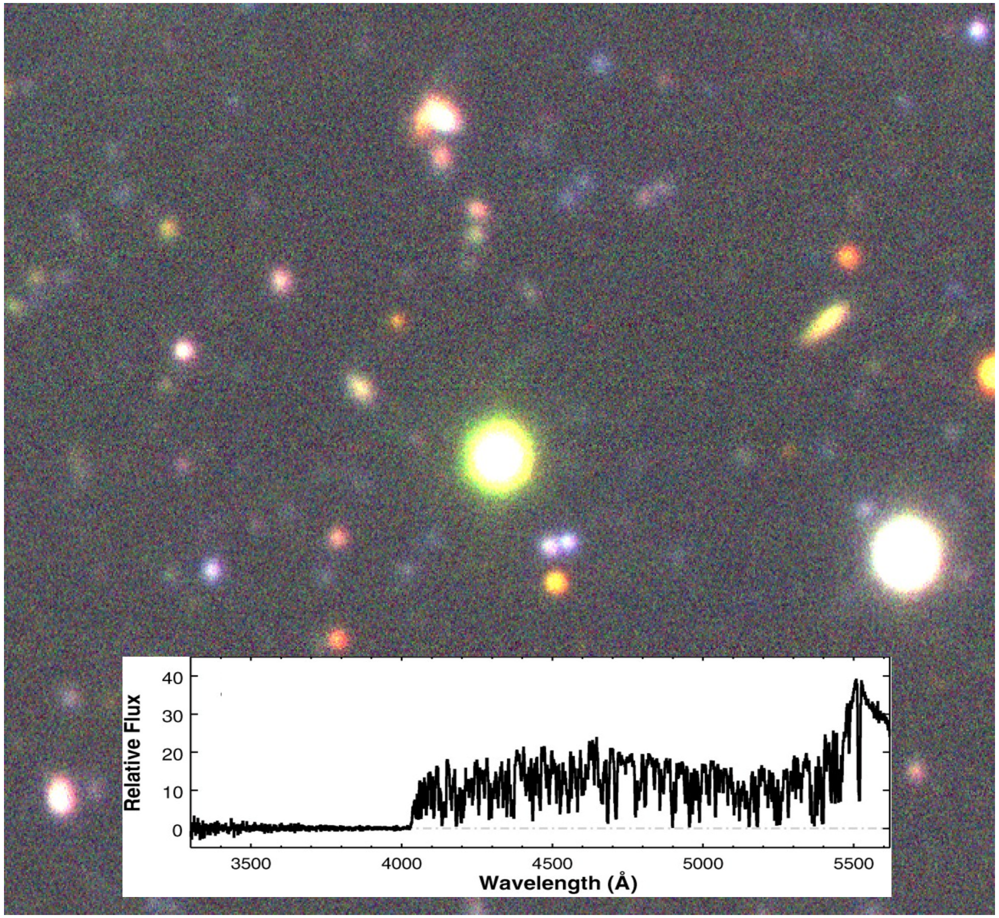
Investigations on the gaseous environment of distant galaxies

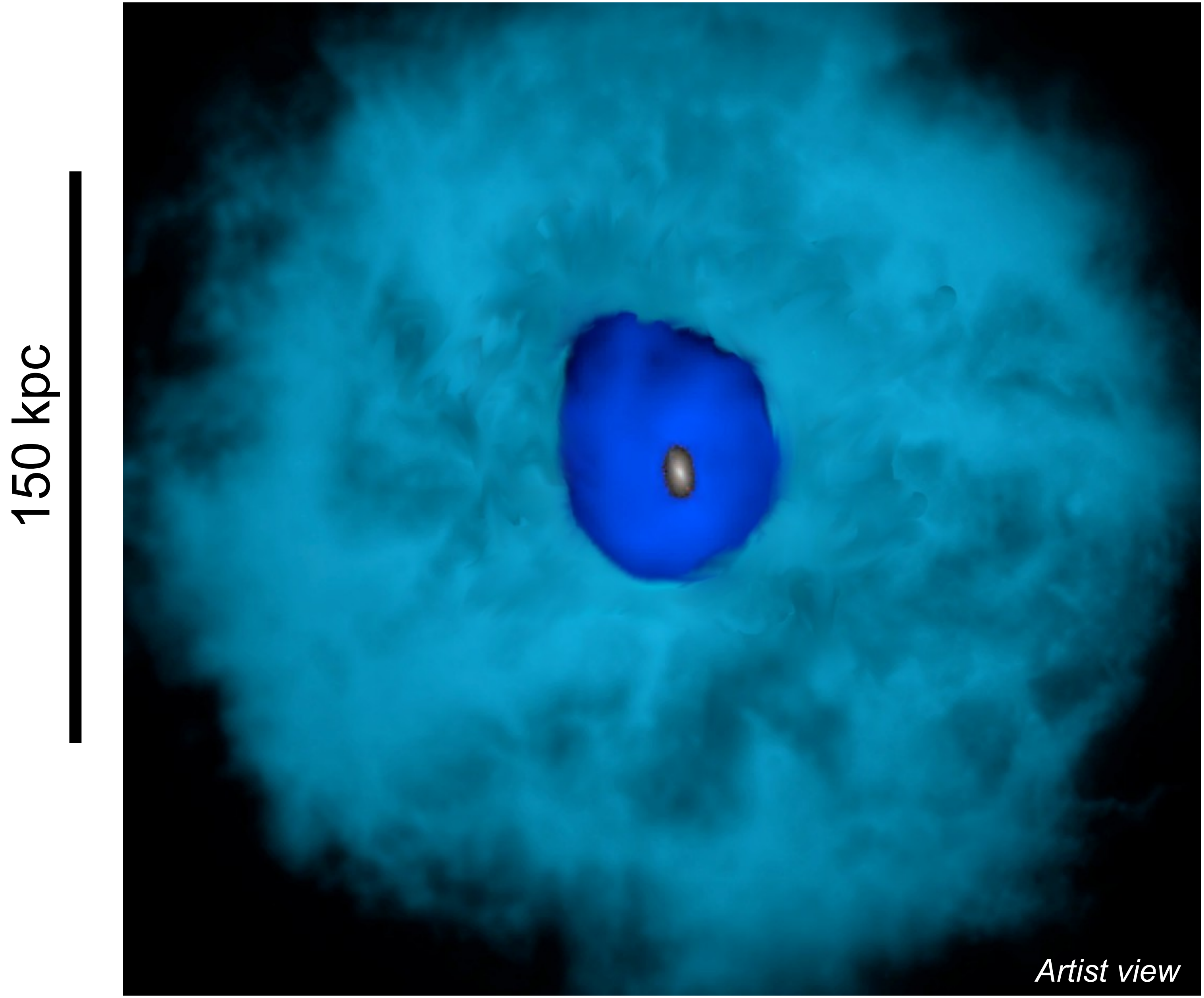


Michele Fumagalli
Durham University
Carnegie Observatories

Durham - January 2014

The gaseous environment of galaxies

Baryons in and around disks determine the fate of galaxies

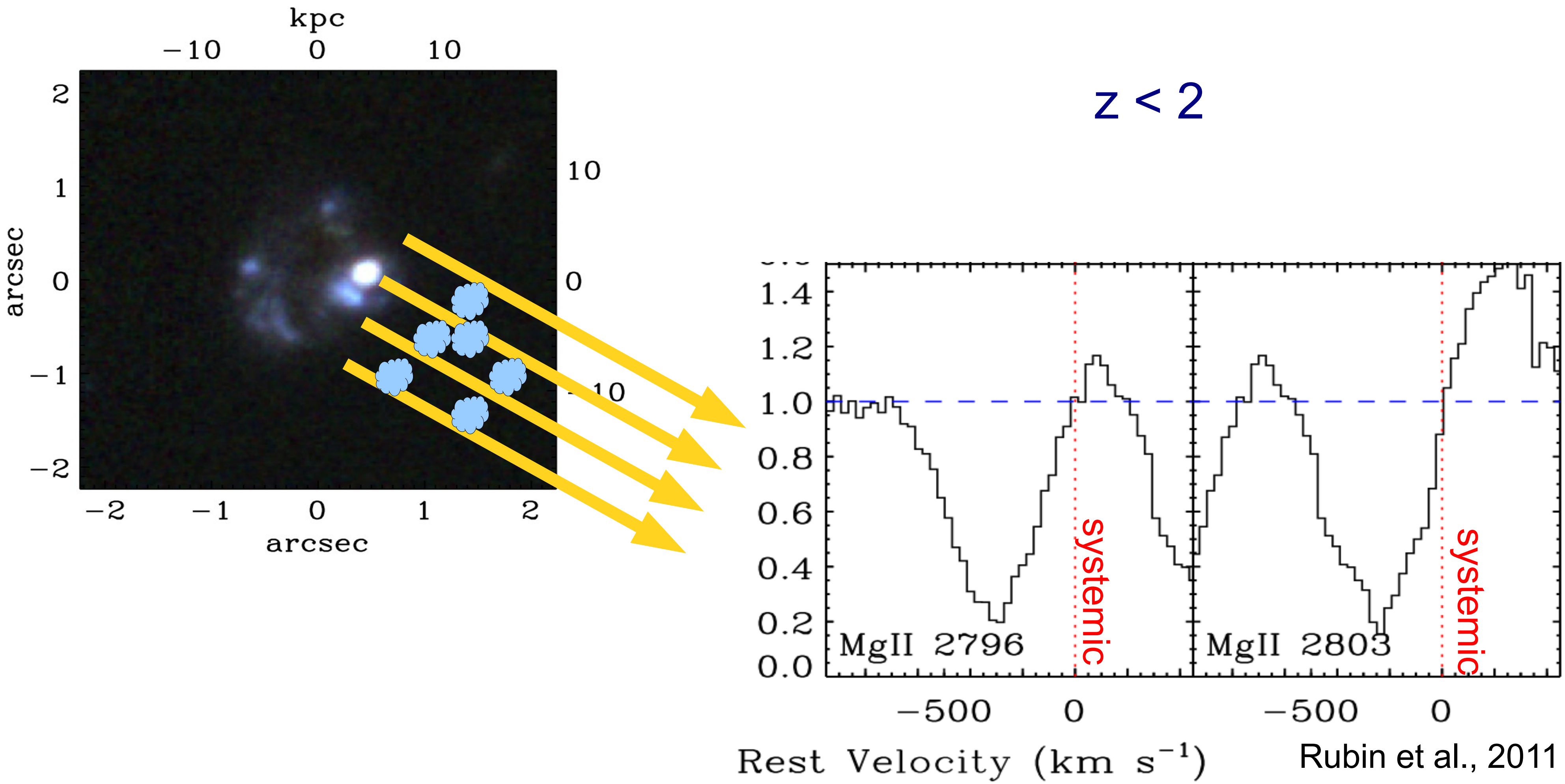


Winds from star forming galaxies

Galactic outflows are ubiquitous in star-forming galaxies at all redshifts

(e.g. Weiner et al., 2009; Rubin et al., 2011; Martin et al., 2009; Menard et al., 2009; Steidel et al., 2010)

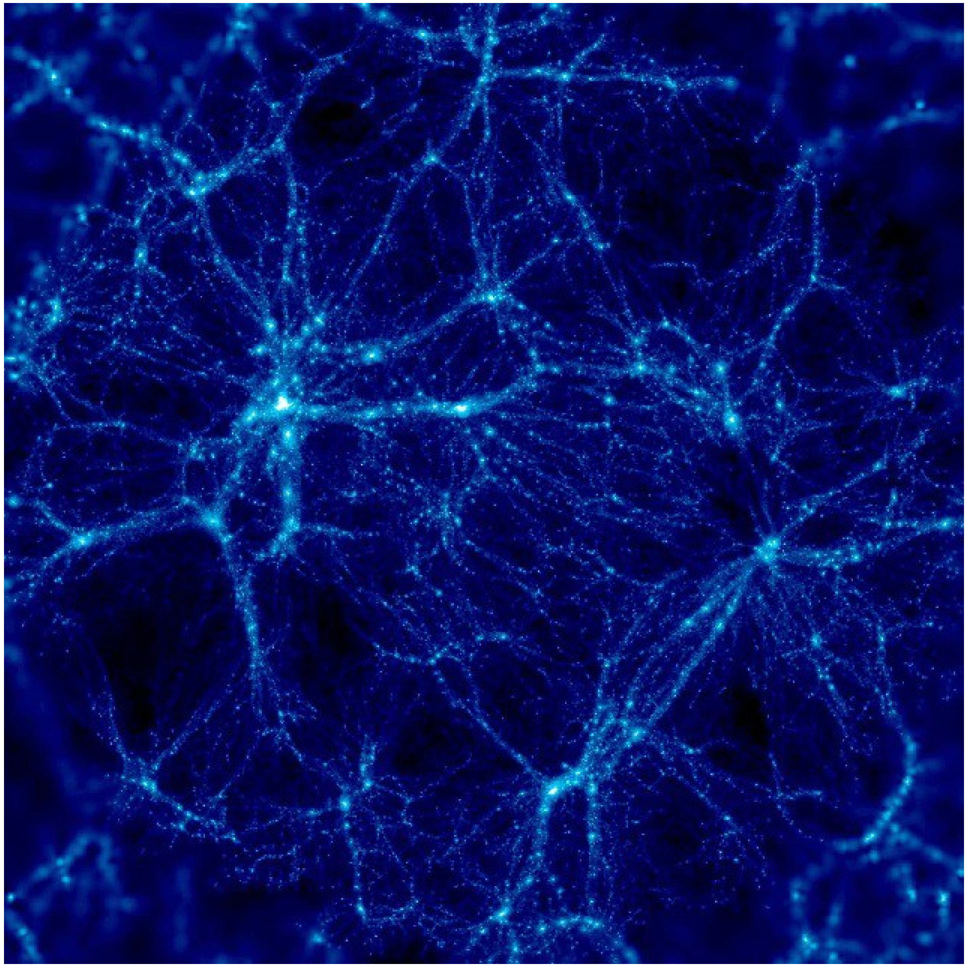
z < 2

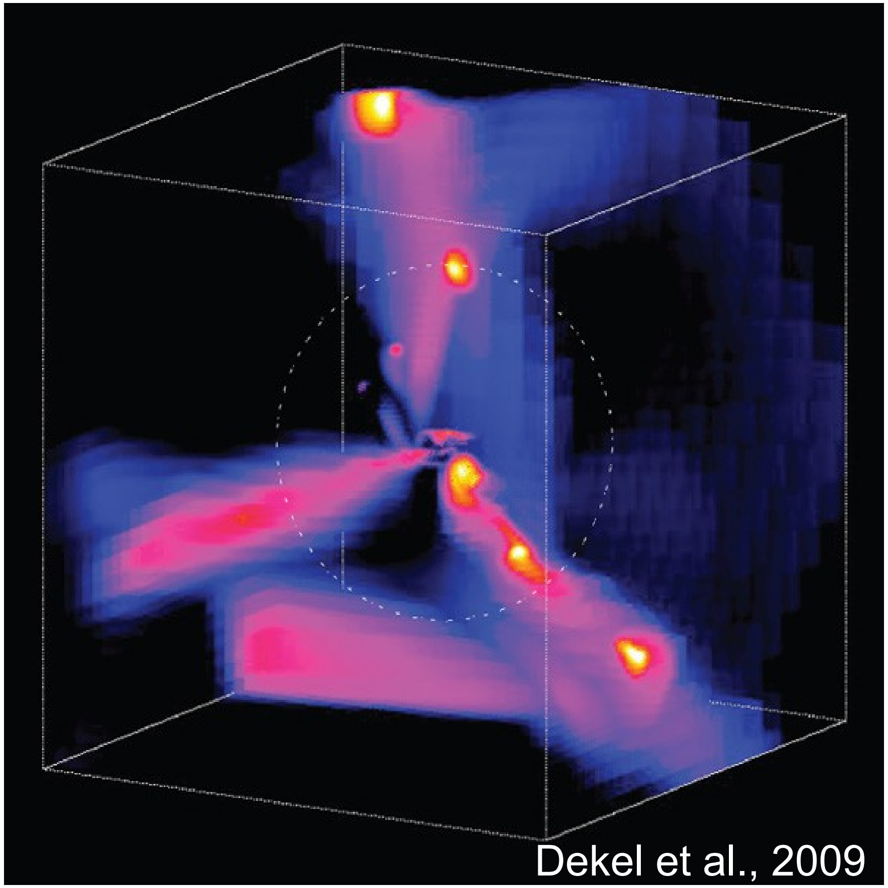


Rubin et al., 2011

Inflow of fresh fuel for star formation

Accretion at high redshift is predicted to occur along narrow and dense filaments: the cold streams or cold flows



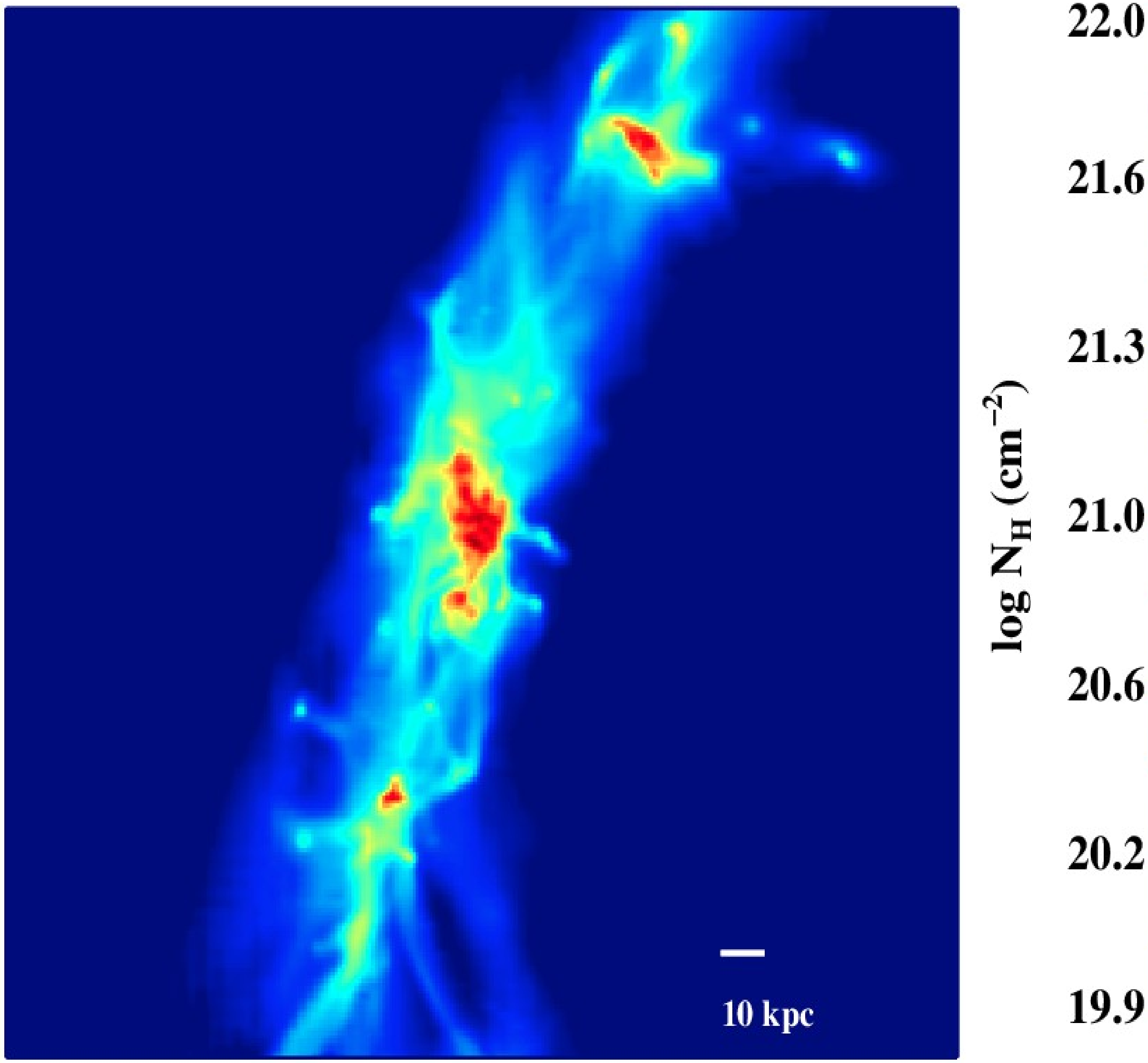


Dekel et al., 2009

Cold accretion in numerical simulations

The phenomenology of accreting streams

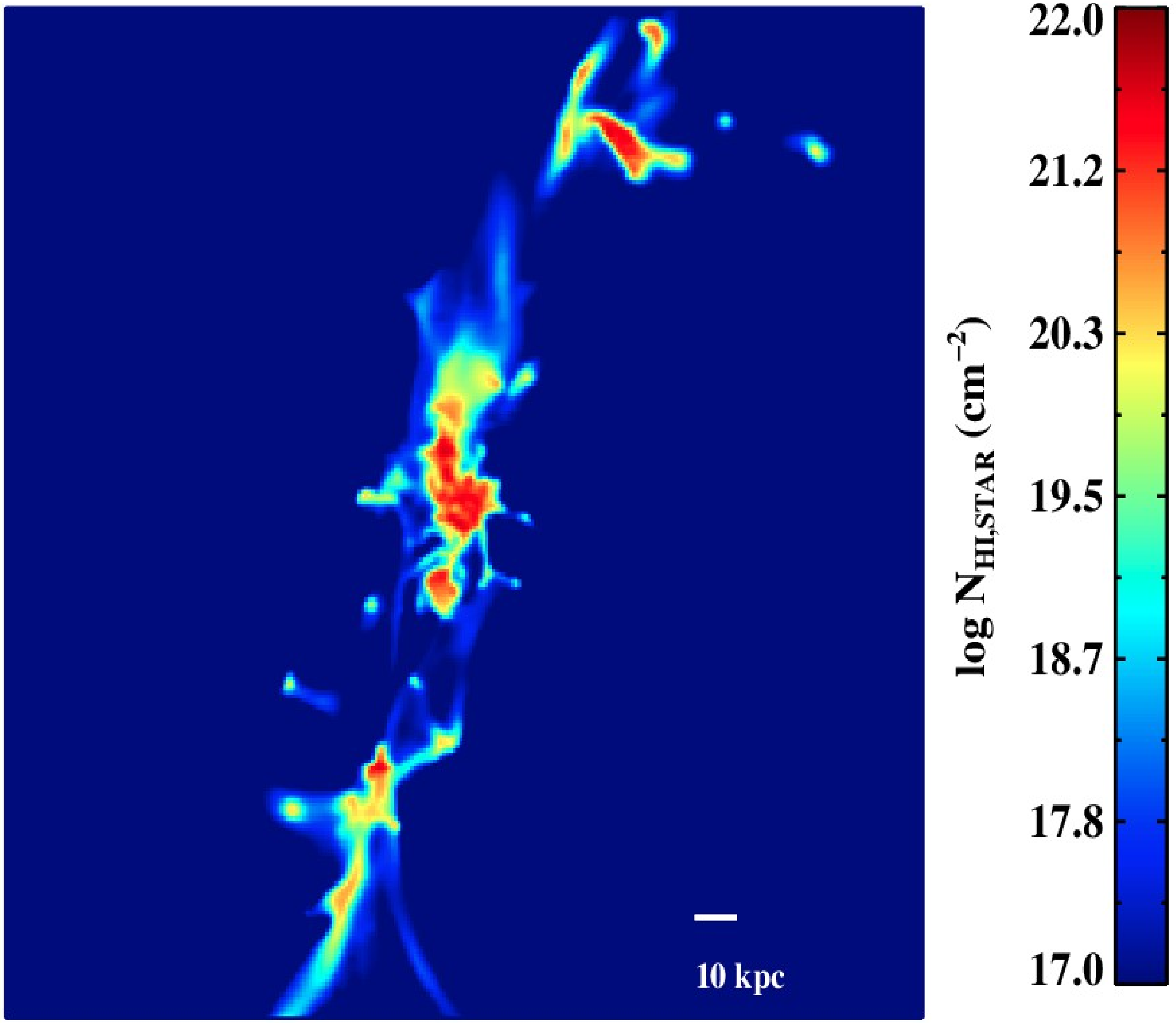
Simulations consistently predict the presence of optically thick hydrogen in the surroundings of high-redshift galaxies



Fumagalli et al. 2011a

The phenomenology of accreting streams

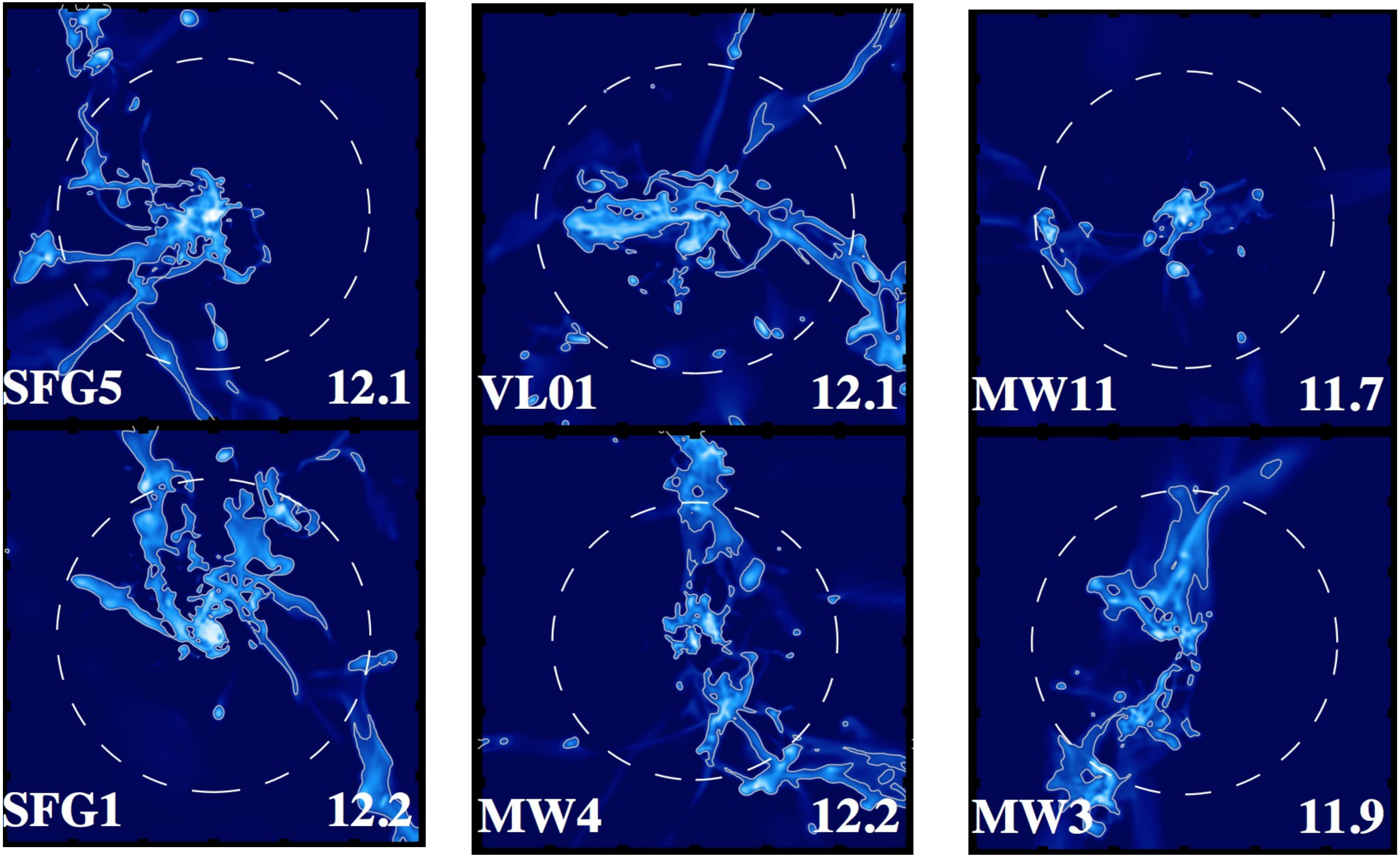
Simulations consistently predict the presence of optically thick hydrogen in the surroundings of high-redshift galaxies



Fumagalli et al. 2011a

The phenomenology of accreting streams

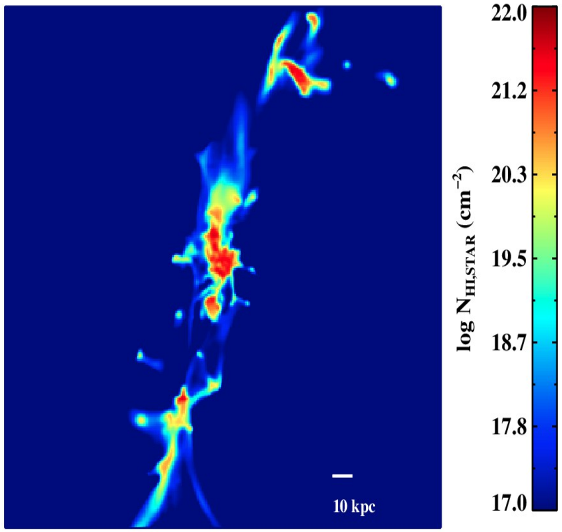
Simulations consistently predict the presence of optically thick hydrogen in the surroundings of high-redshift galaxies



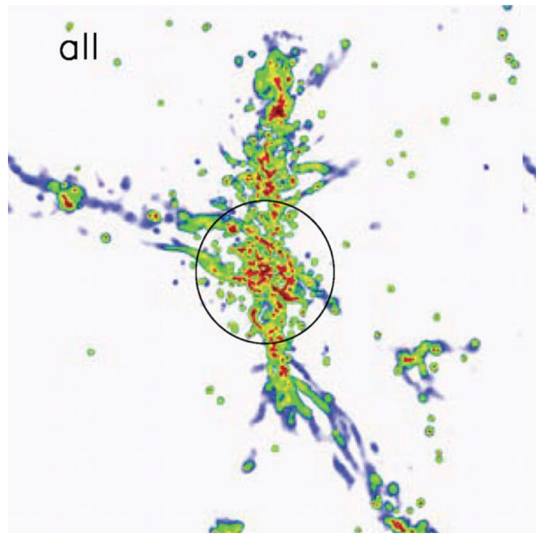
Fumagalli et al. 2013b

The phenomenology of accreting streams

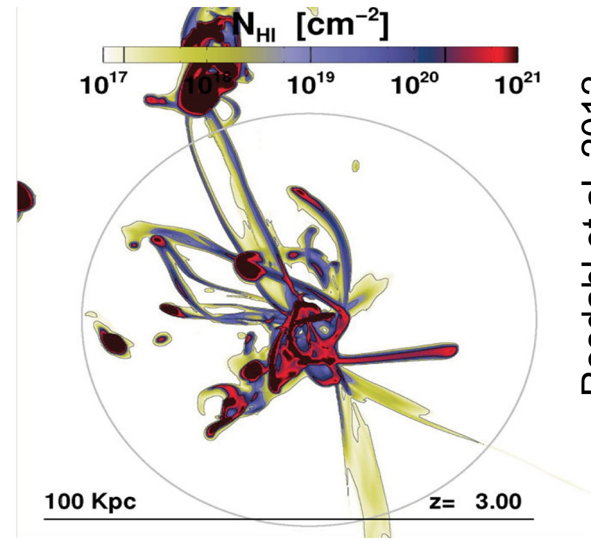
Narrow and elongated streams of dense and cold gas are a ubiquitous prediction of current cosmological simulations



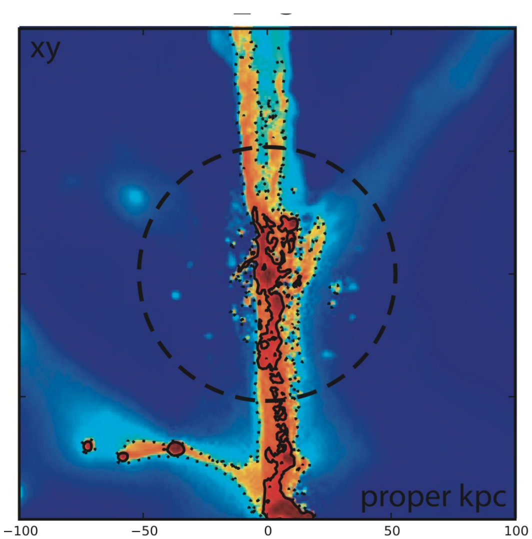
Fumagalli et al. 2011a



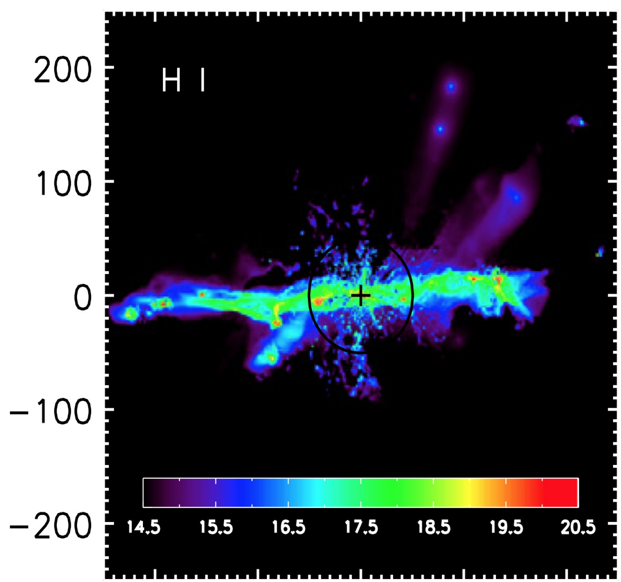
van de Voort et al. 2012



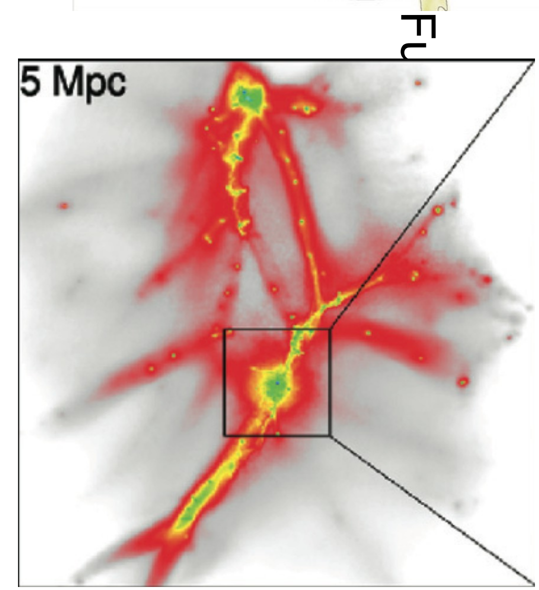
Rosdahl et al. 2012



Faucher-Giguère et al. 2011



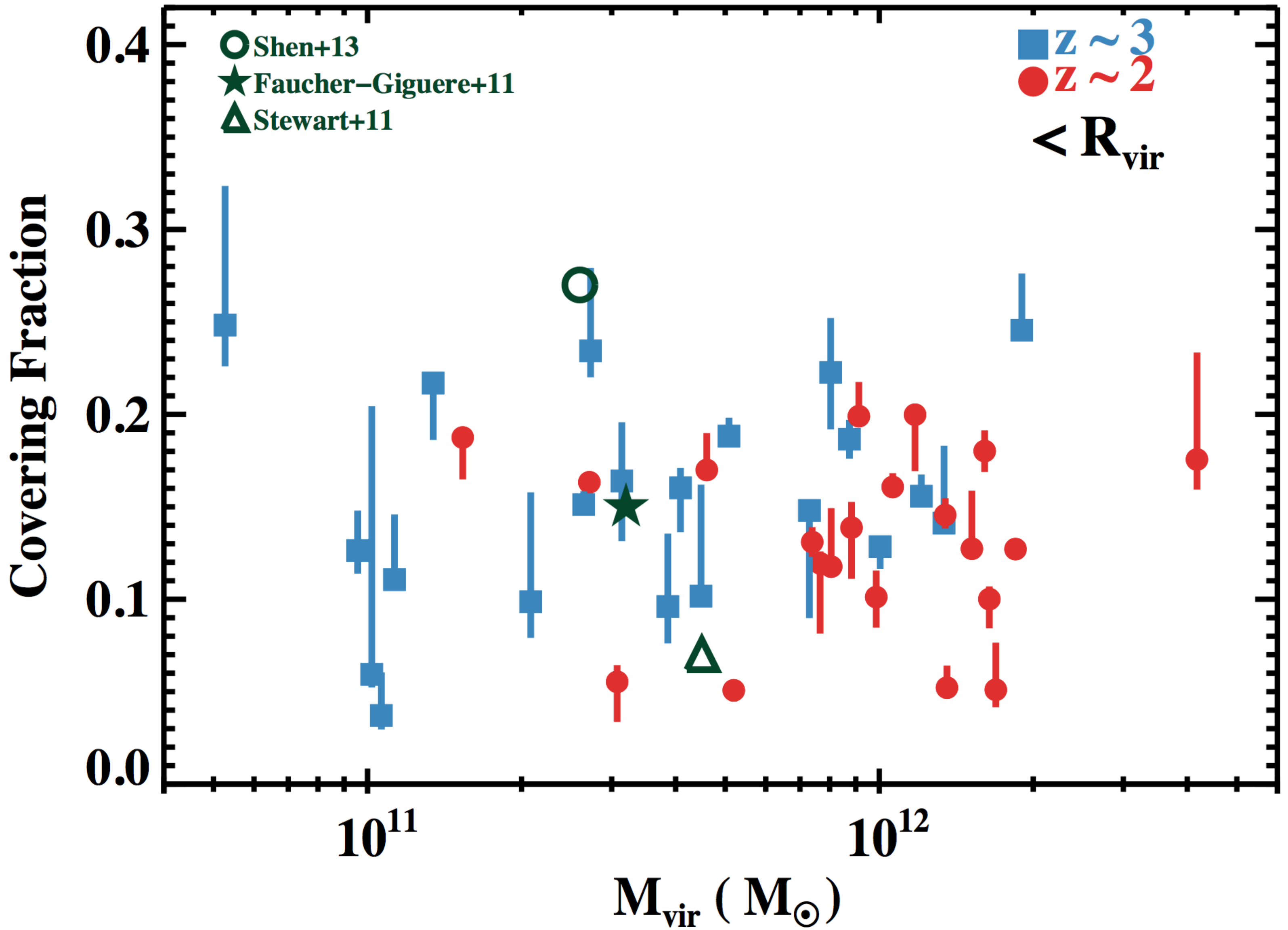
Shen et al. 2013



Stewart et al. 2011

The phenomenology of accreting streams

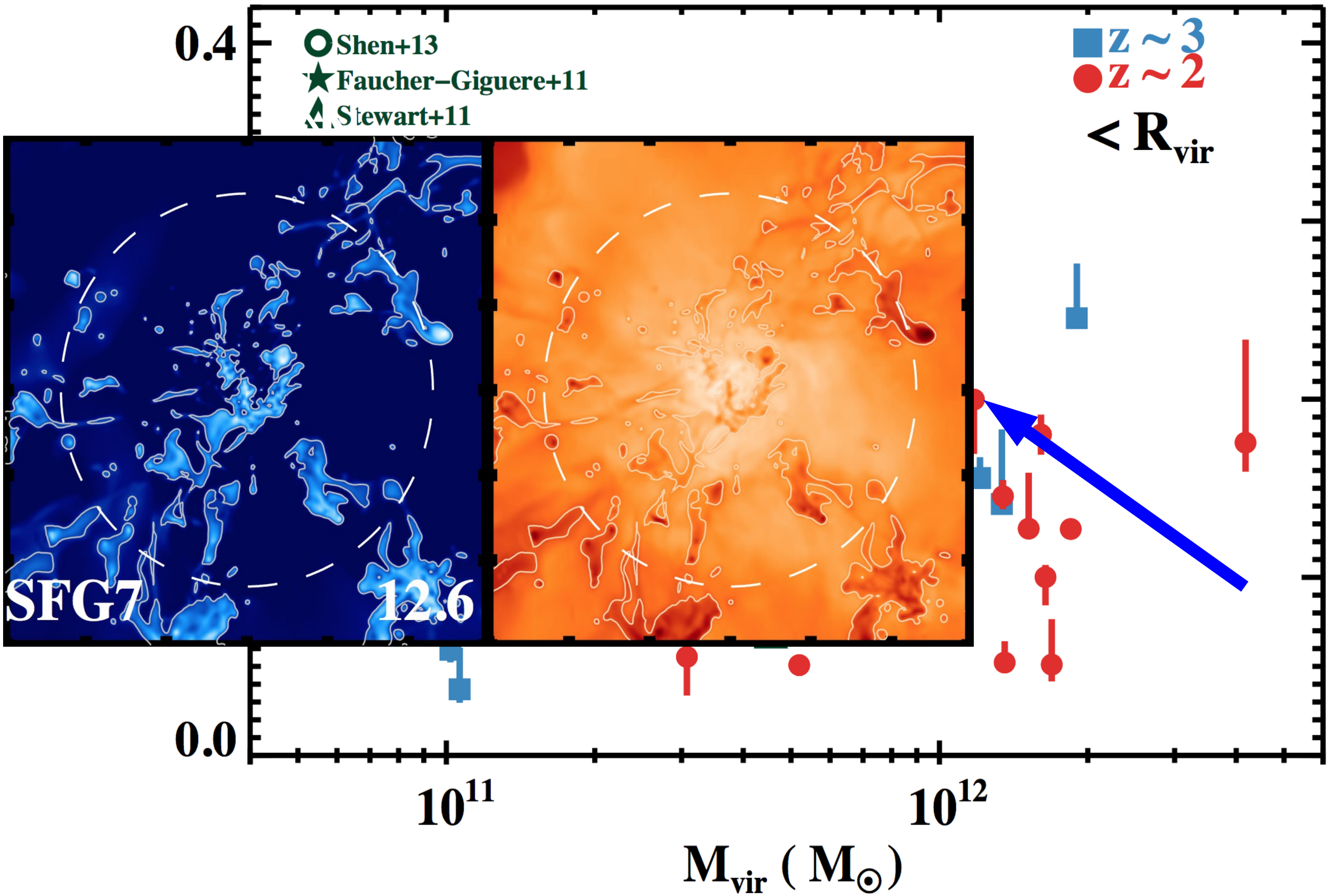
A basic property to characterize cold accretion is the covering fraction, which varies as a function of mass and redshift



Fumagalli et al. 2013b

The phenomenology of accreting streams

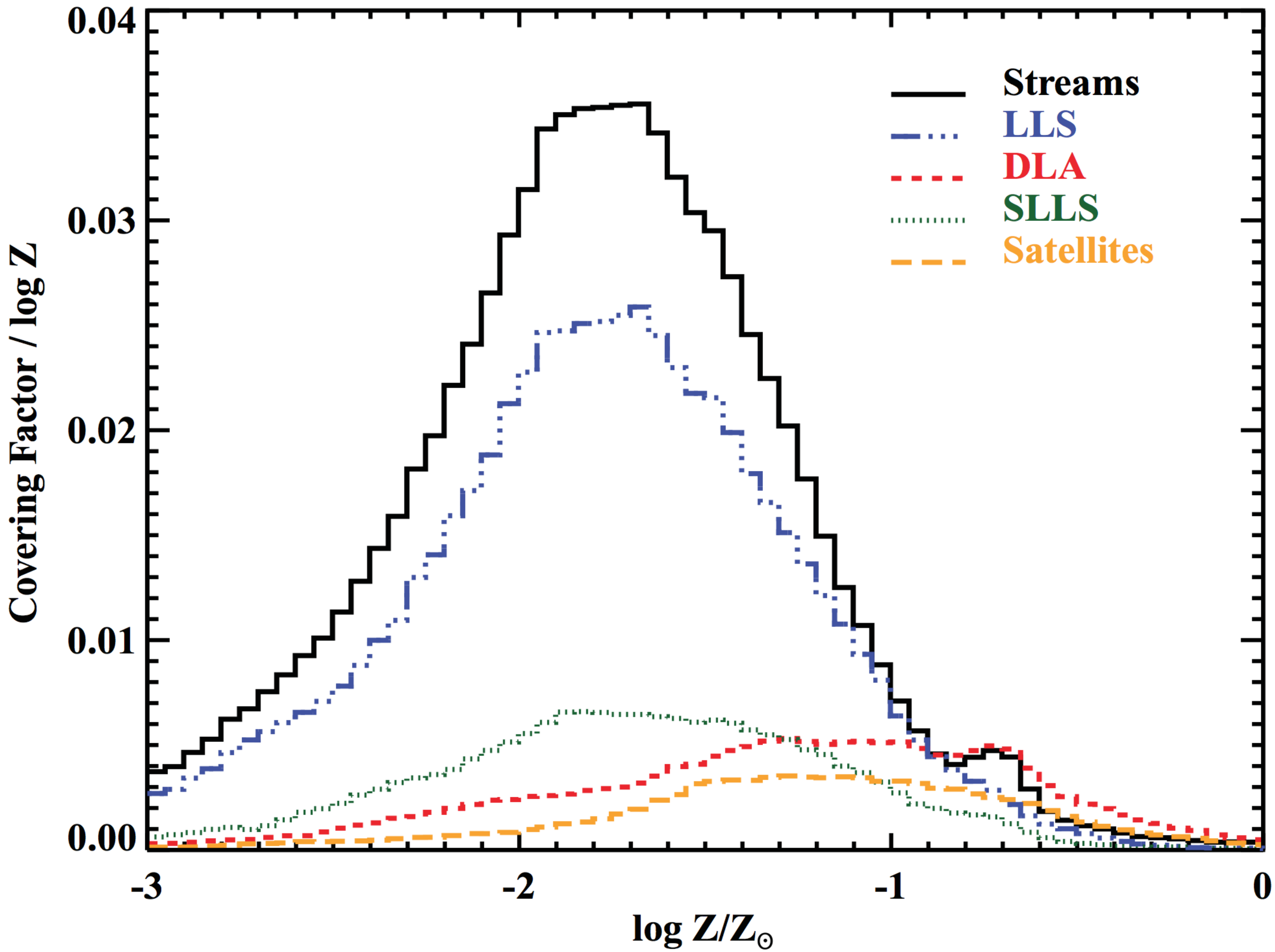
A basic property to characterize cold accretion is the covering fraction, which varies as a function of mass and redshift



Fumagalli et al. 2013b

The phenomenology of accreting streams

Inflowing gas in on average more metal-poor than outflowing/recycled gas

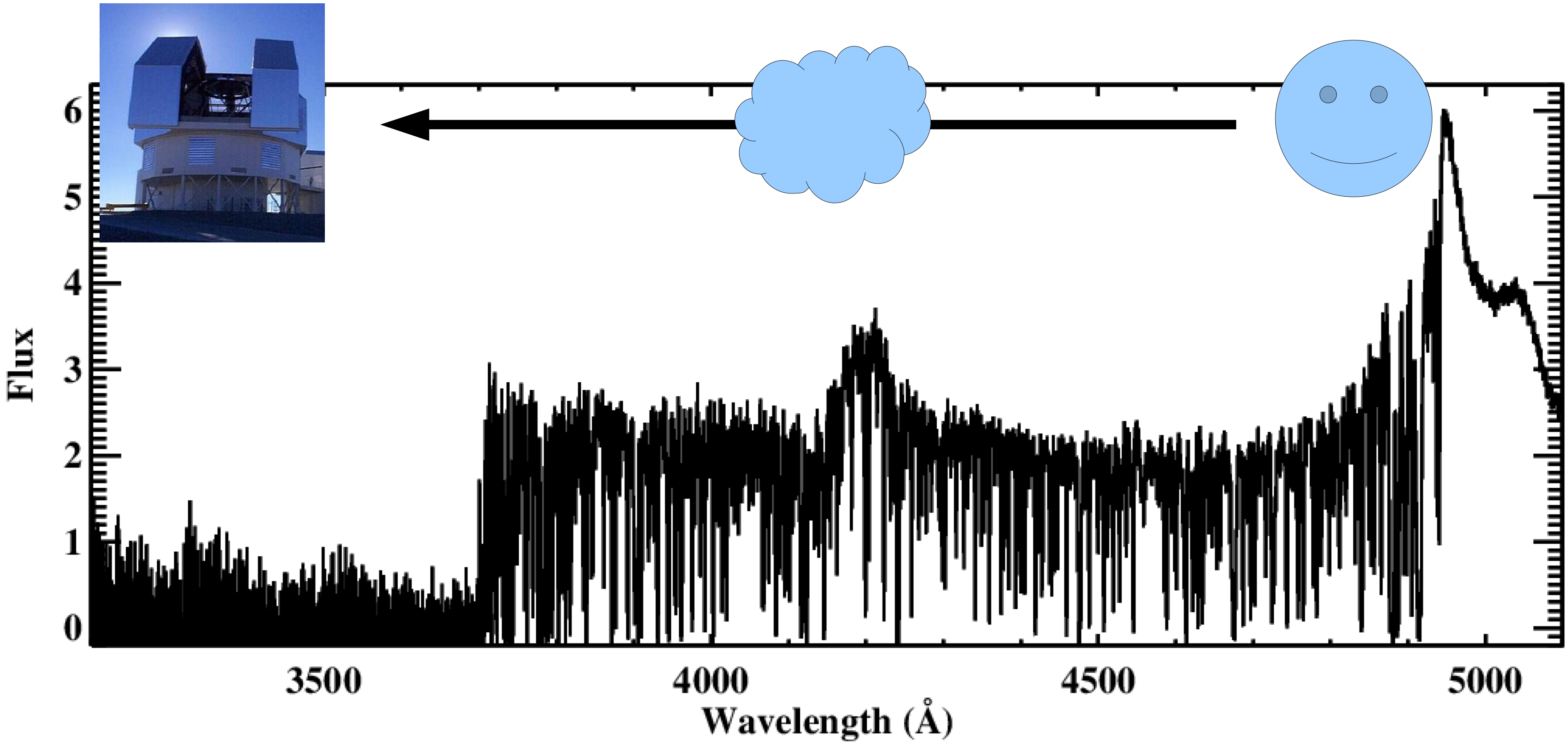


Fumagalli et al. 2011a

Tracing gas inflows with absorption lines

Testing theoretical predictions

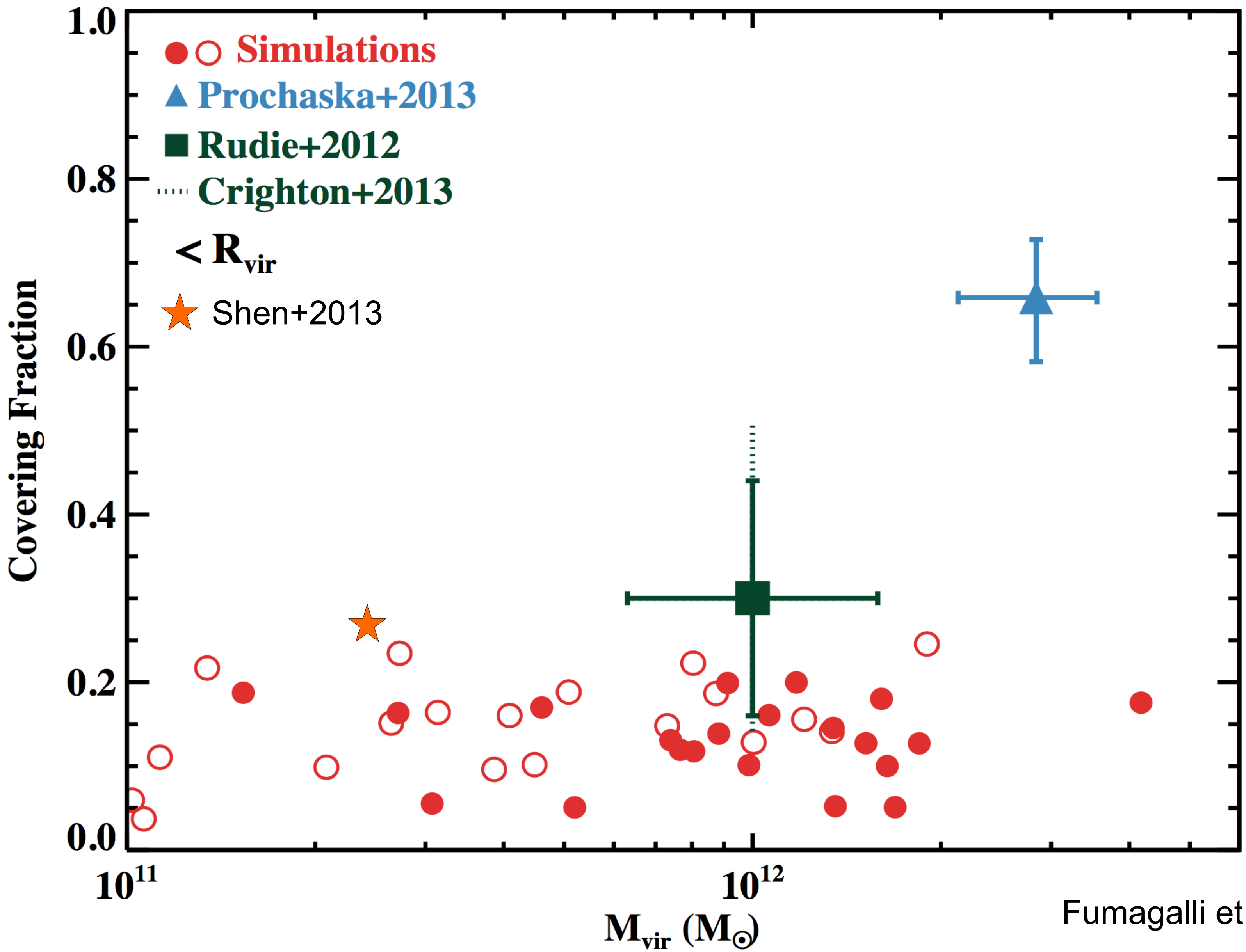
Currently, we can gather evidence via absorption line systems and in particular LLSs



Testing theoretical predictions

We can use LLSs as probes of the halo gas in z~2.8 galaxies

(Fauchere-Giguere+2011; Fumagalli+2011;van de Voort+2012; Rudie+2012; Prochaska+2013)

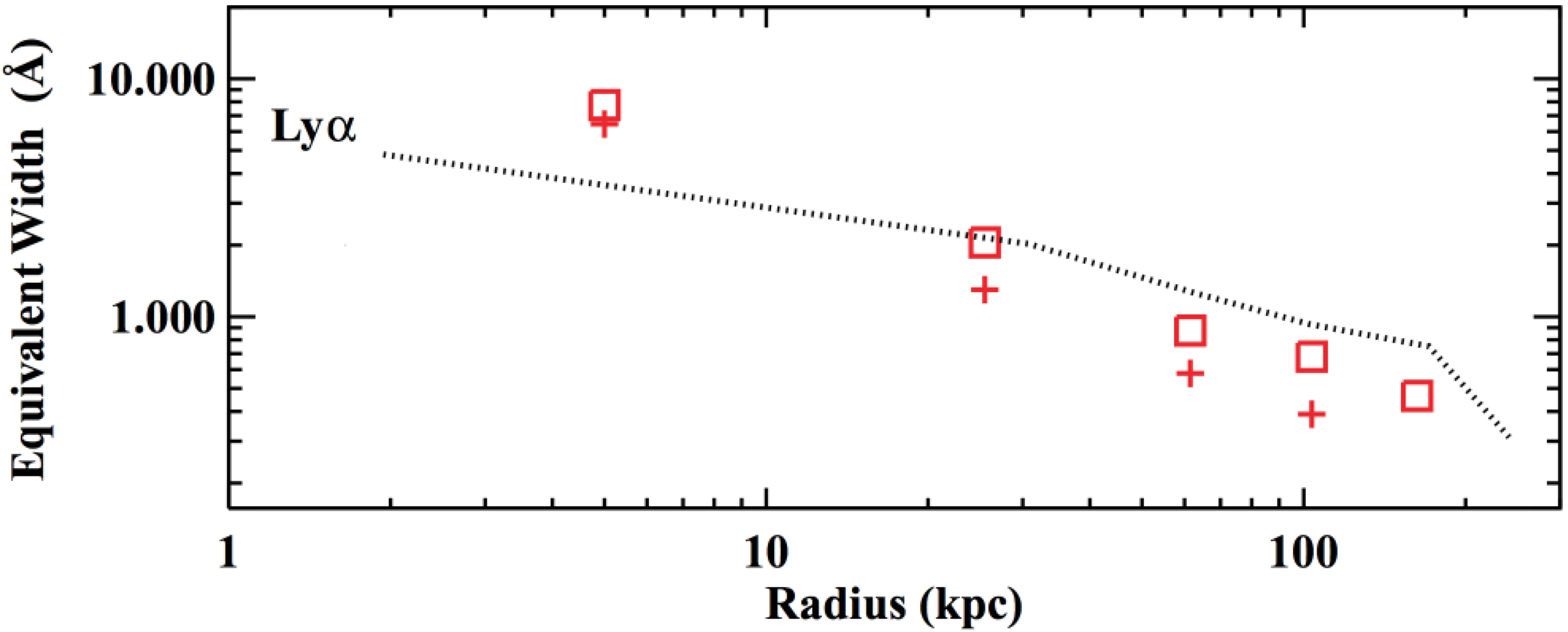


Fumagalli et al., 2013b

Testing theoretical predictions

We can use LLSs as probes of the halo gas in z~2.8 galaxies

(Fauchere-Giguere+2011; Fumagalli+2011;van de Voort+2012; Rudie+2012; Prochaska+2013)

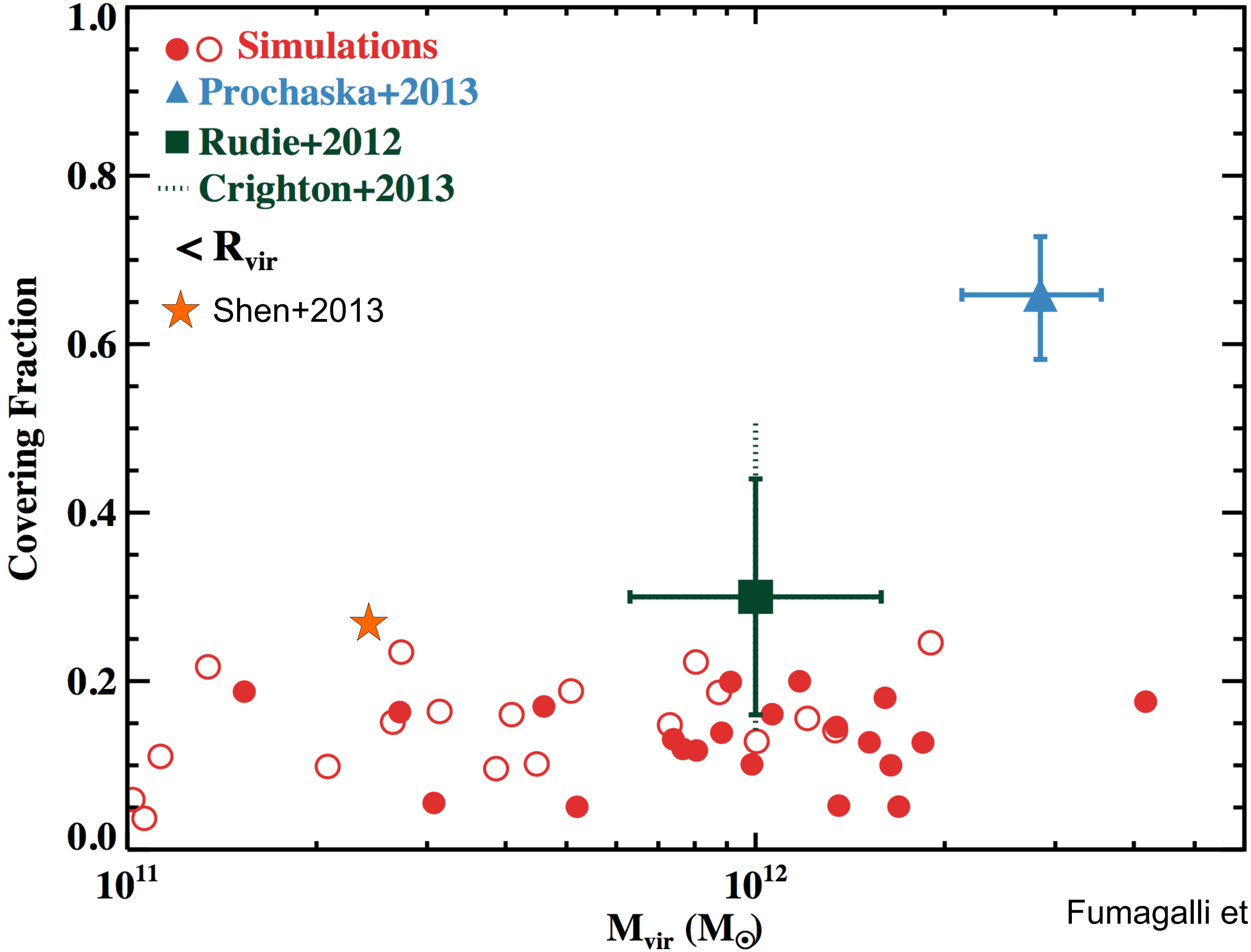


Fumagalli et al., 2011a

Testing theoretical predictions

We can use LLSs as probes of the halo gas in z~2.8 galaxies

(Fauchere-Giguere+2011; Fumagalli+2011;van de Voort+2012; Rudie+2012; Prochaska+2013)

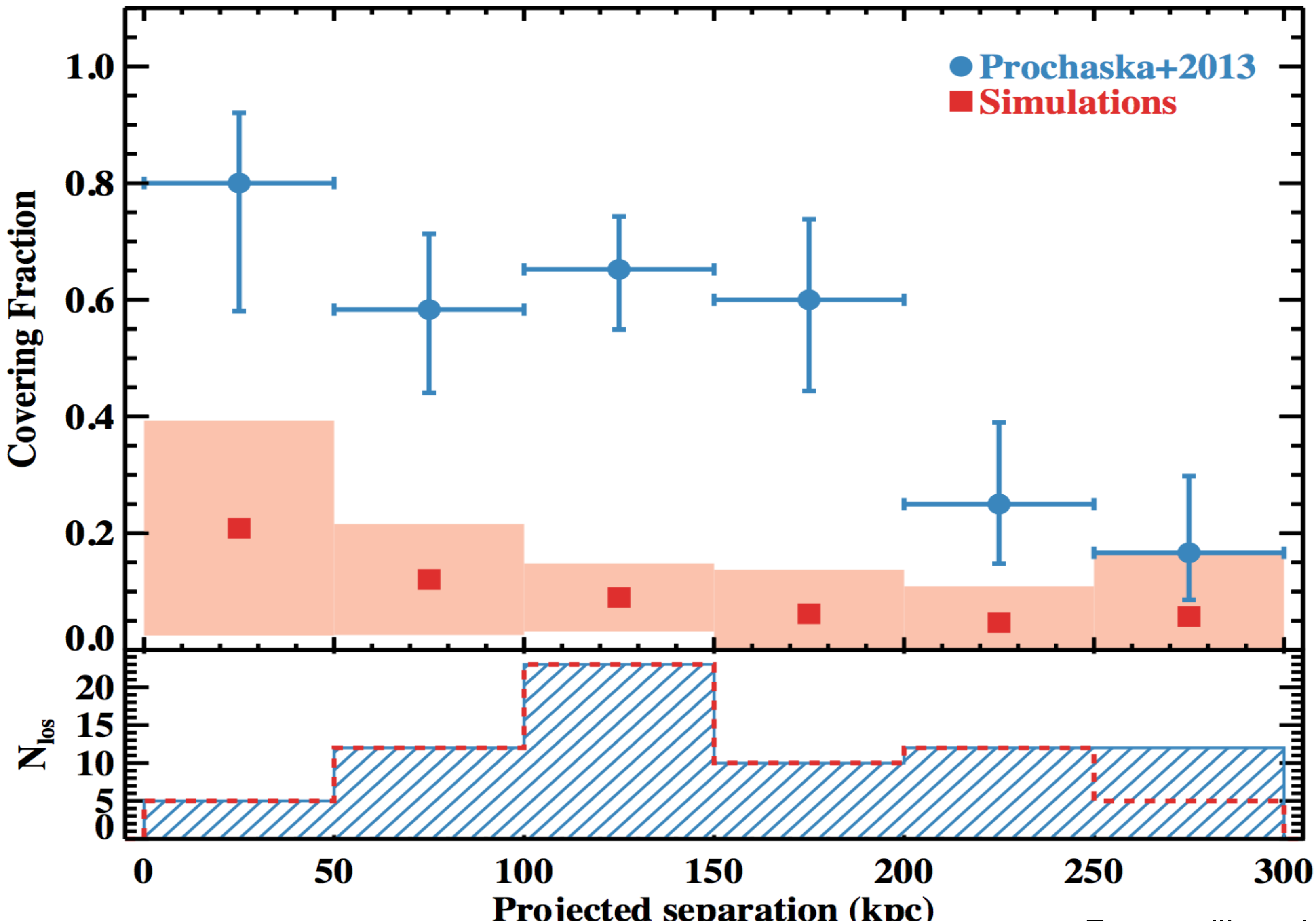


Fumagalli et al., 2013b

Testing theoretical predictions

We can use LLSs as probes of the halo gas in z~2.8 galaxies

(Fauchere-Giguere+2011; Fumagalli+2011;van de Voort+2012; Rudie+2012; Prochaska+2013)

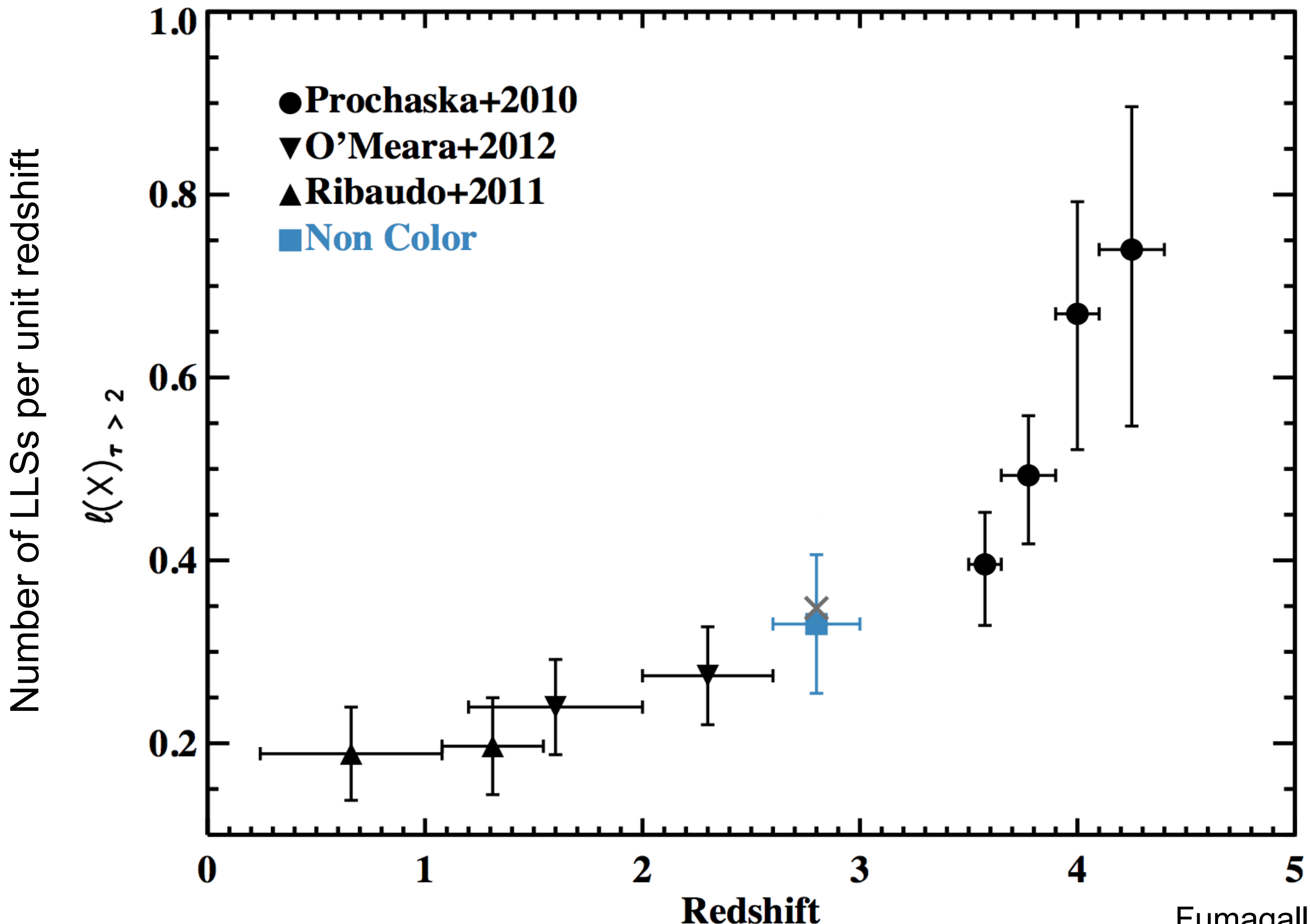


Fumagalli et al., 2013b

Using LLSs as cosmic tools

LLSs are easy to find, even in moderate S/N spectra

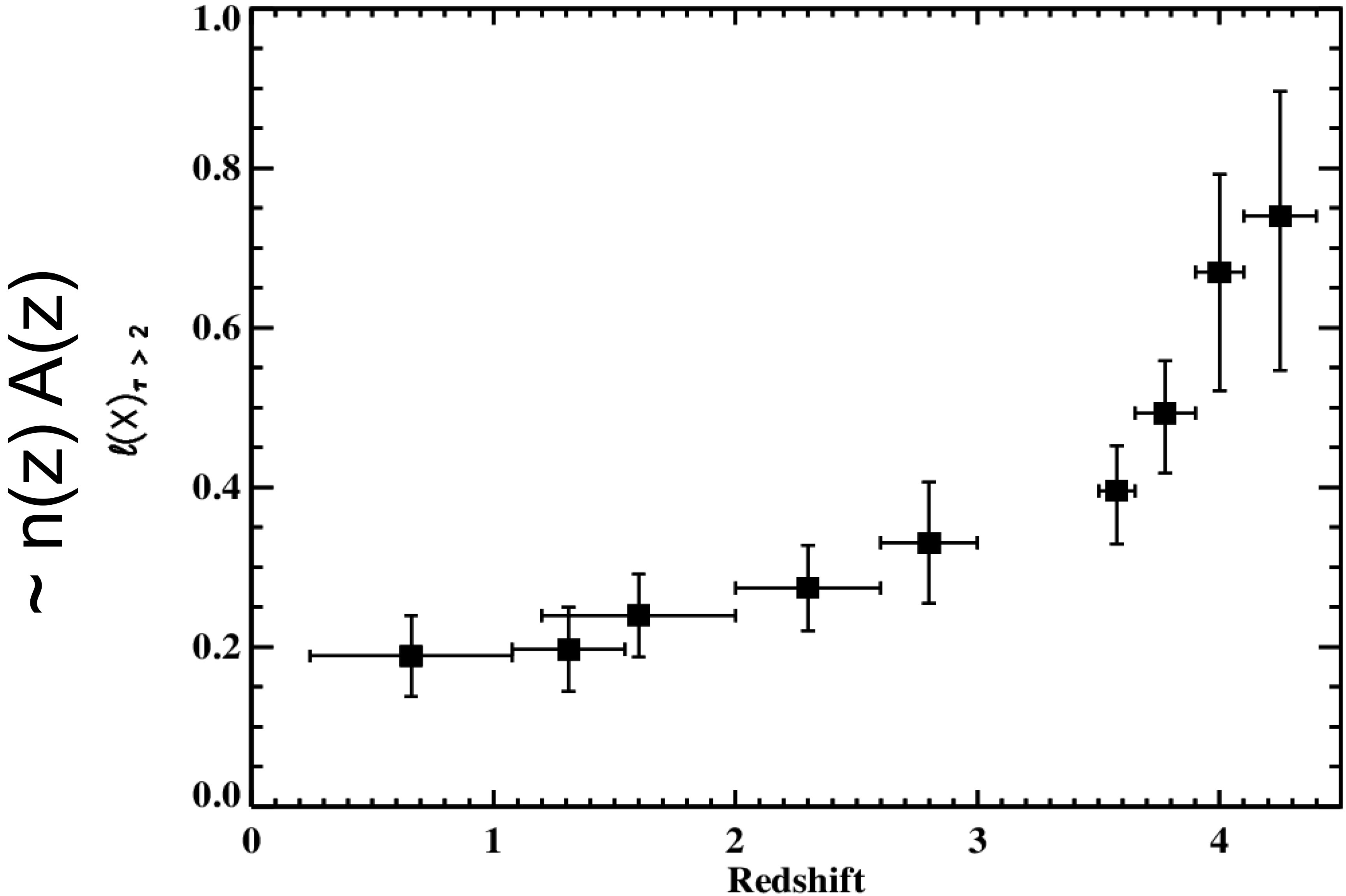
(Tytler 1982; Sargent et al. 1989; Lanzetta 1991; Storrie-Lombardi et al. 1994; Stengler-Larrea et al. 1995; Songaila & Cowie 2010)



Fumagalli+2013a

Using LLSs as cosmic tools

Is there enough optically thick gas in halos to account for all LLSs?



Fumagalli+2013a

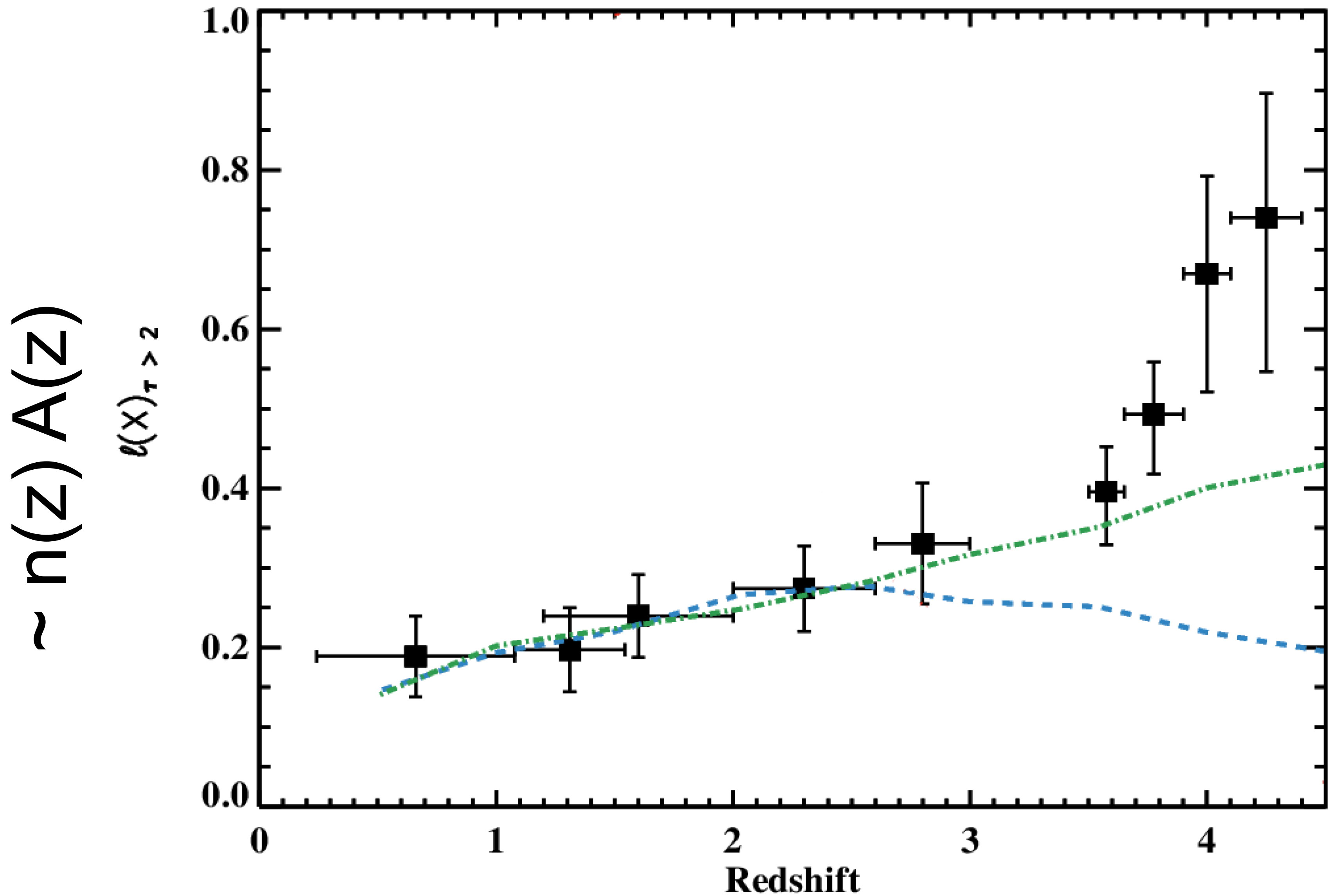
Using LLSs as cosmic tools

Is there enough optically thick gas in halos to account for all LLSs?

$$\ell(X) = \frac{4c\pi}{H_0} \int_{\log M_{\rm low}}^{\log M_{\rm up}} R^2_{\rm vir}(M_{\rm vir}, z) f_{\rm c}(M_{\rm vir}, z) \frac{dn_{\rm gal}}{d\log M_{\rm vir}}(M_{\rm vir}, z) d\log M_{\rm vir}$$

Using LLSs as cosmic tools

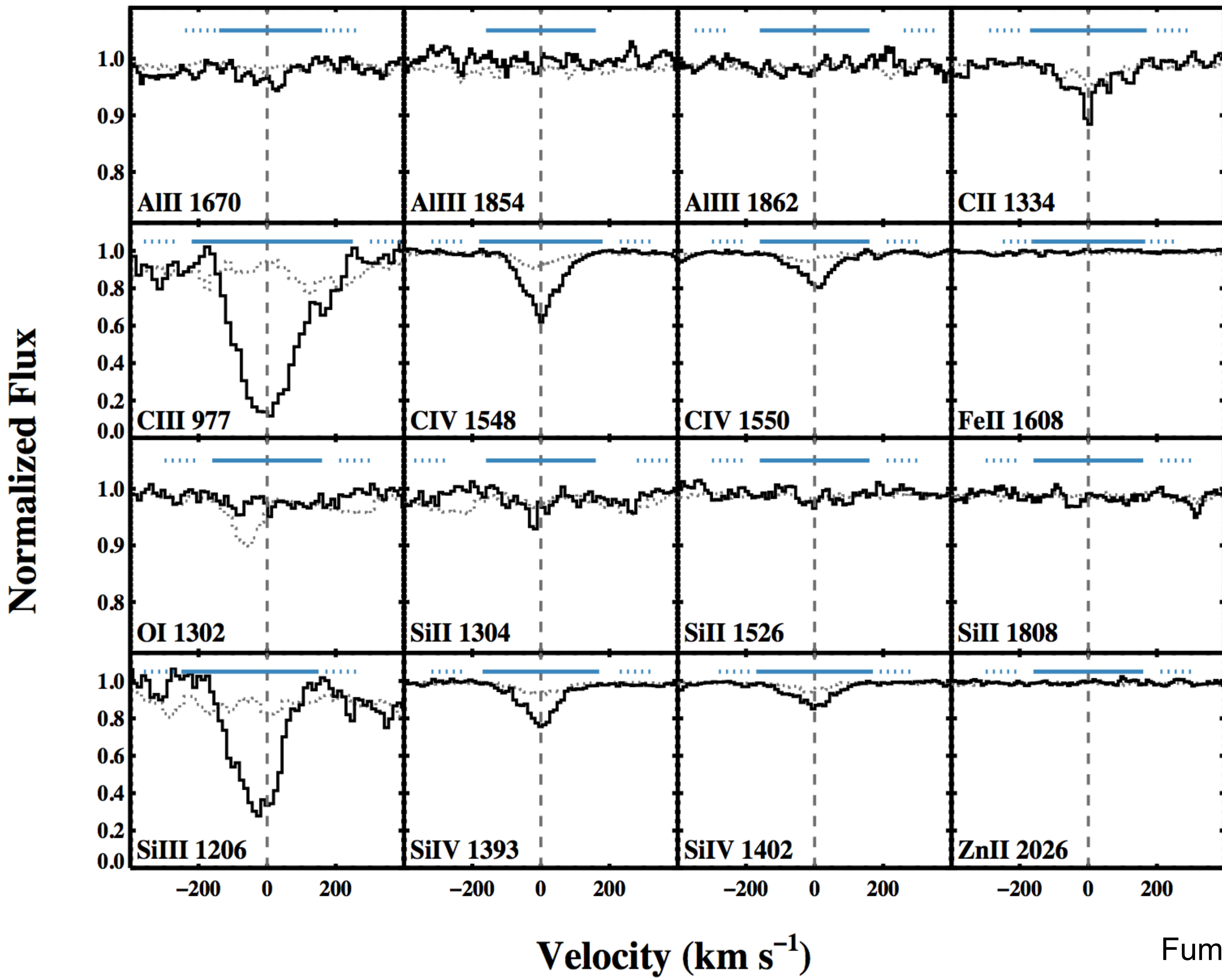
Is there enough optically thick gas in halos to account for all LLSs?



Fumagalli+2013a

Using LLSs as cosmic tools

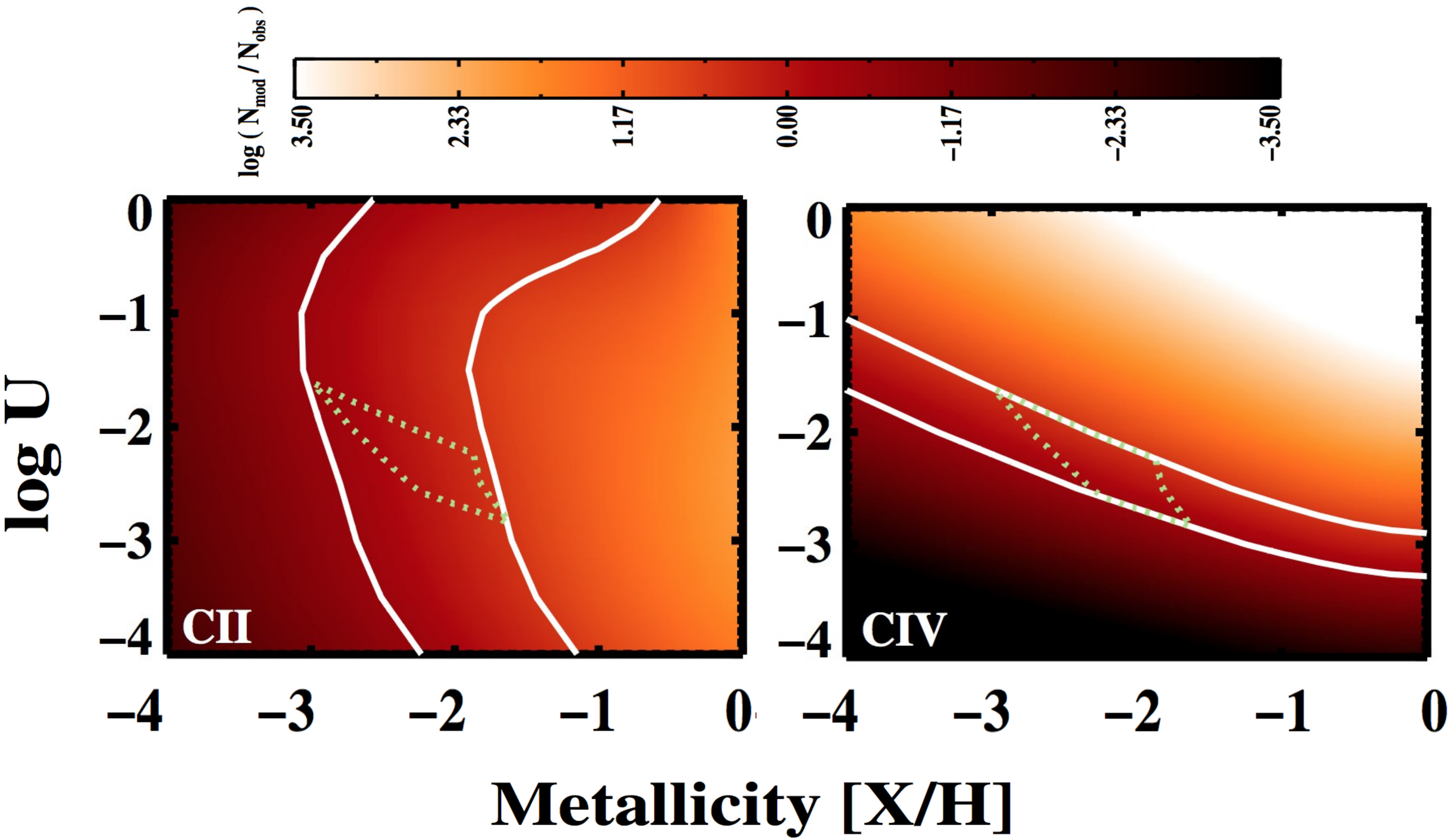
Compare the distribution of metals in LLSs with model predictions



Fumagalli+2013a

Using LLSs as cosmic tools

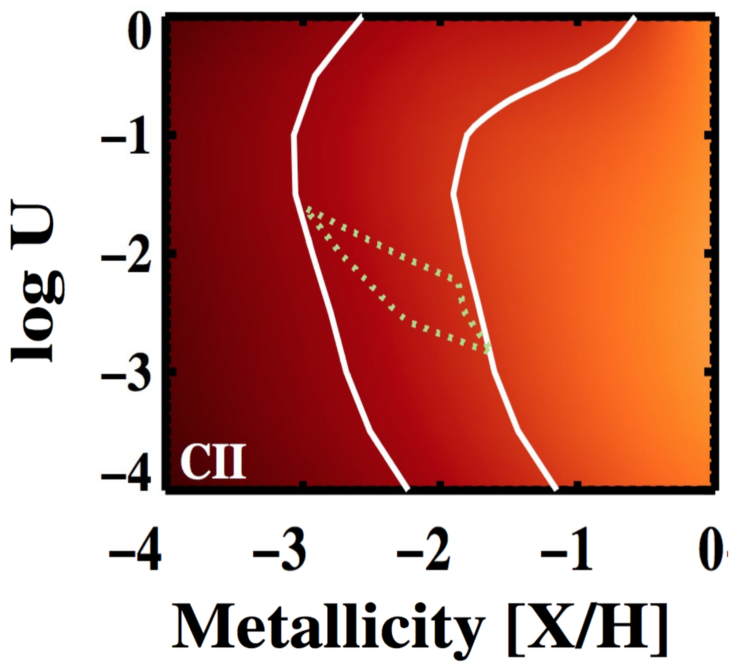
Compare the distribution of metals in LLSs with model predictions



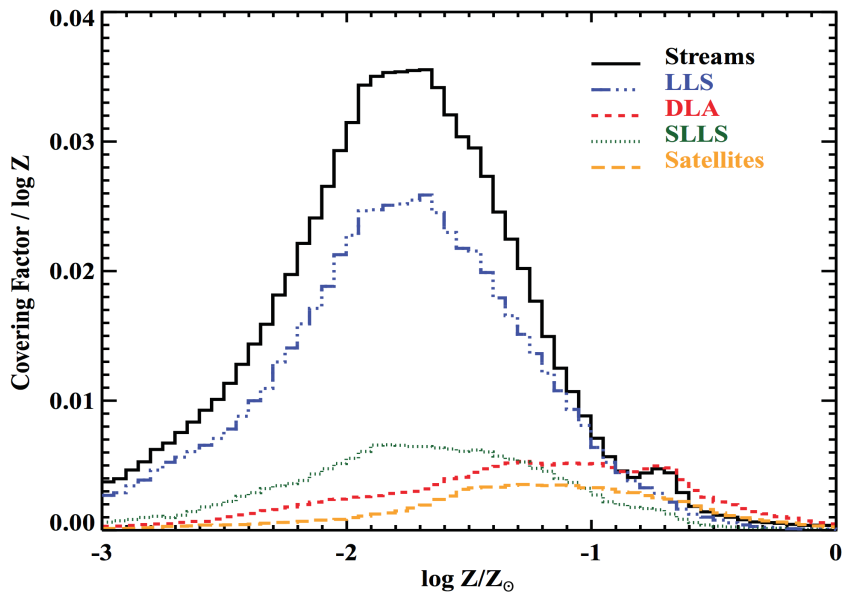
Fumagalli+2013a

Using LLSs as cosmic tools

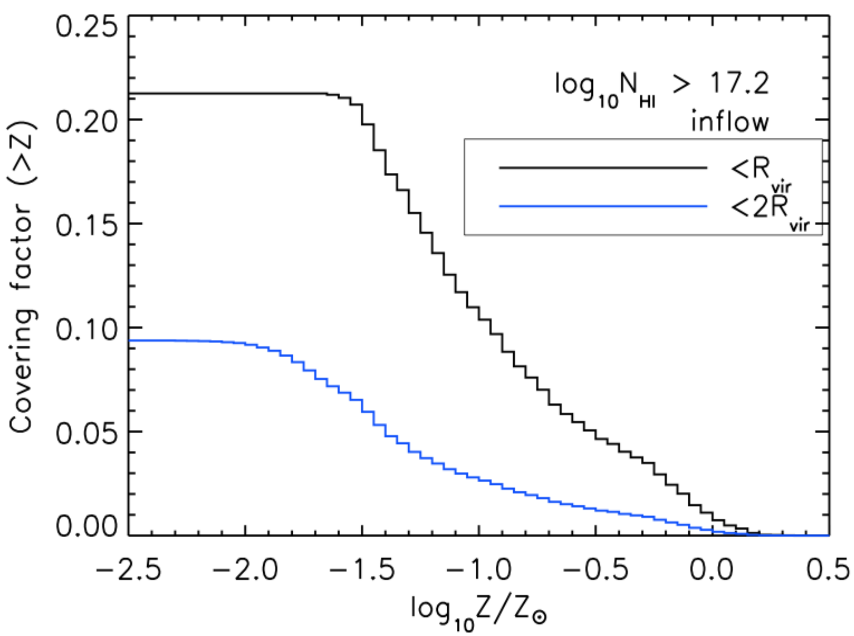
Compare the distribution of metals in LLSs with model predictions



Fumagalli+2013a



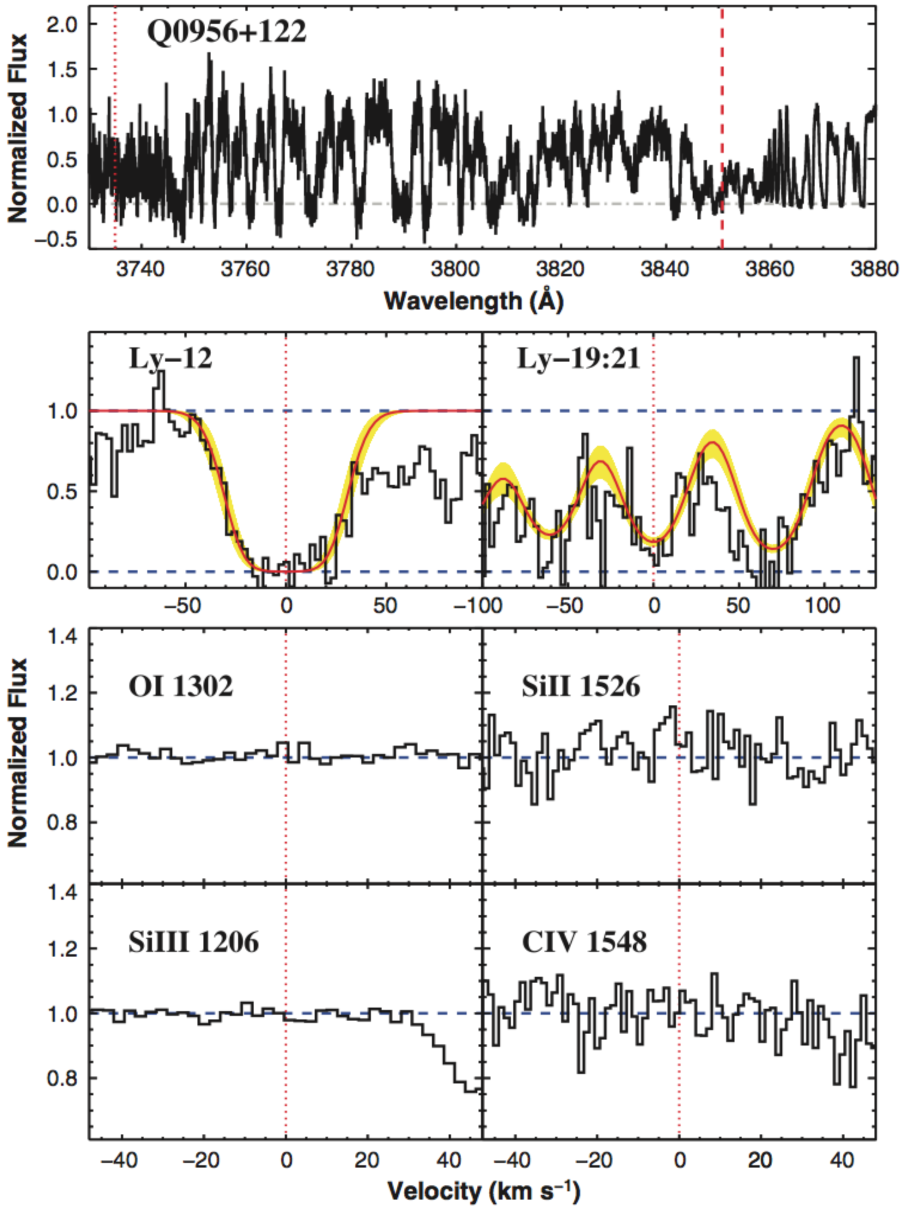
Fumagalli+2011a



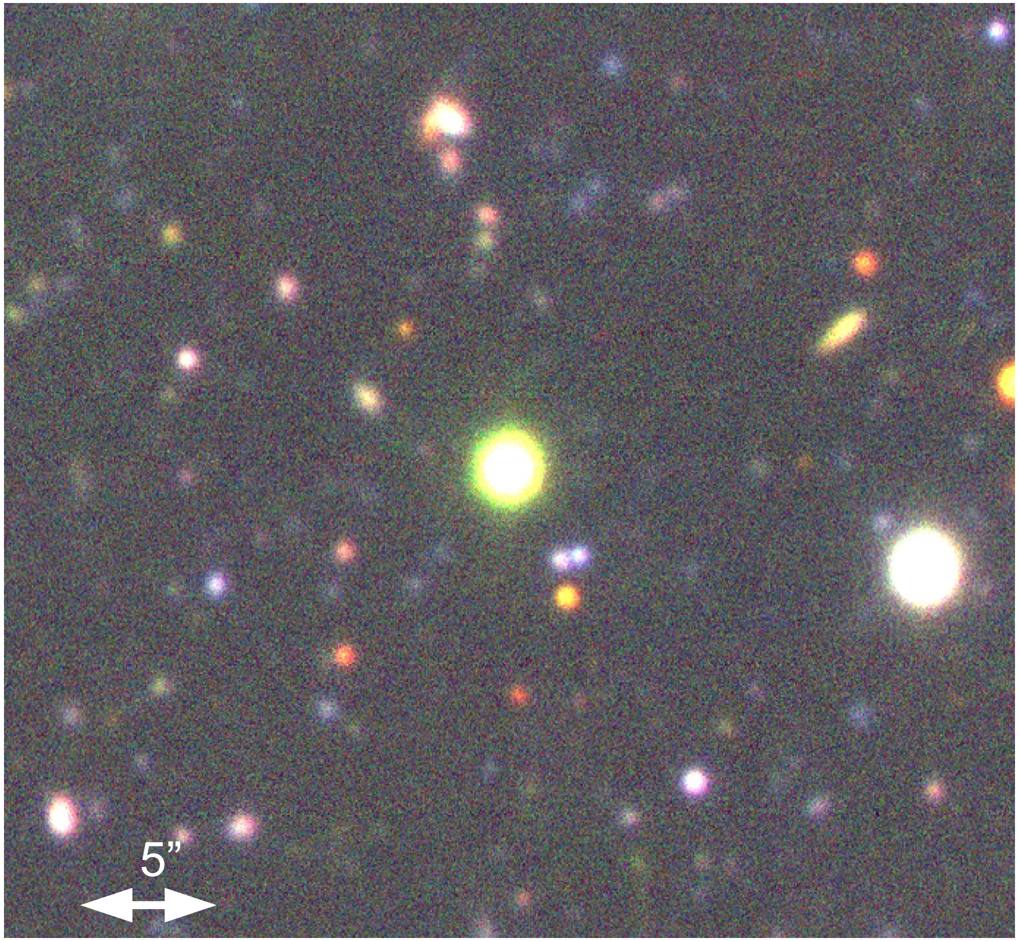
Shen+2013

Using LLSs as cosmic tools

Two extreme outliers in the LLS population, maybe associated to galaxies...



Fumagalli+2011b

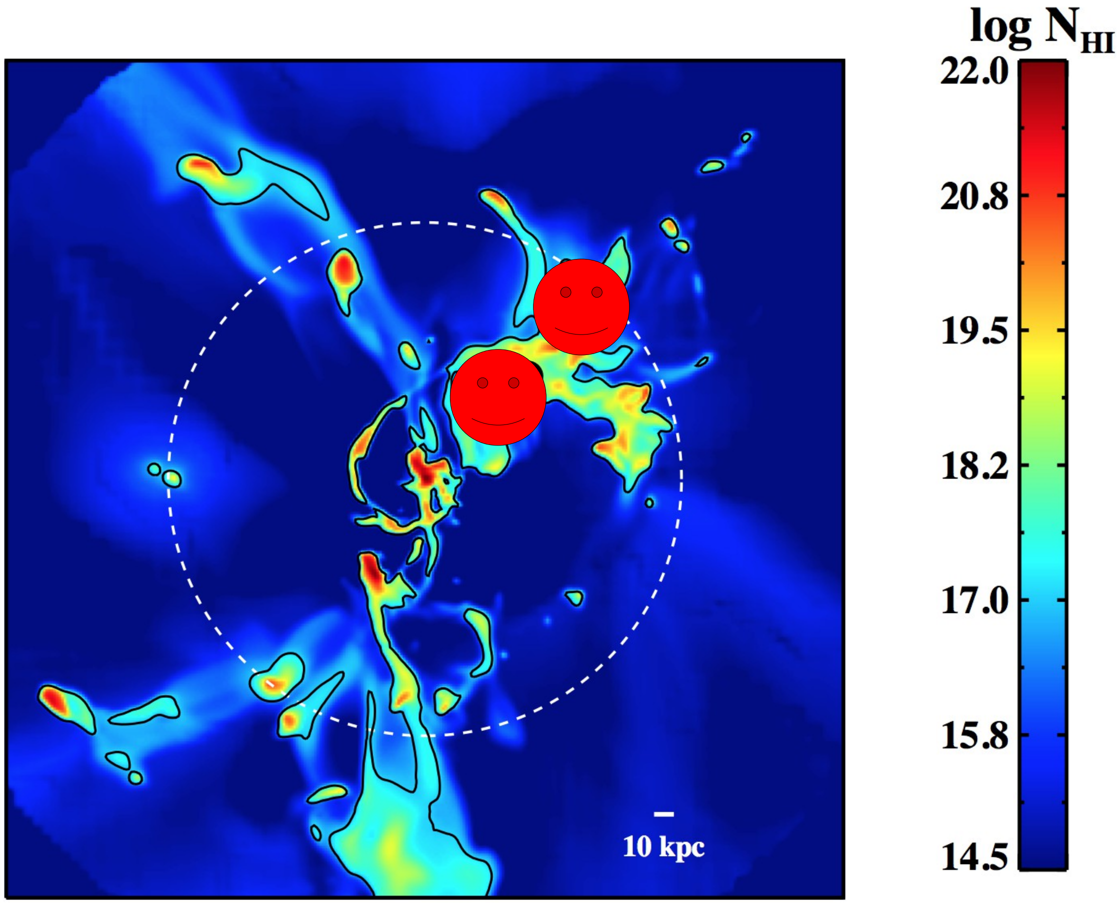


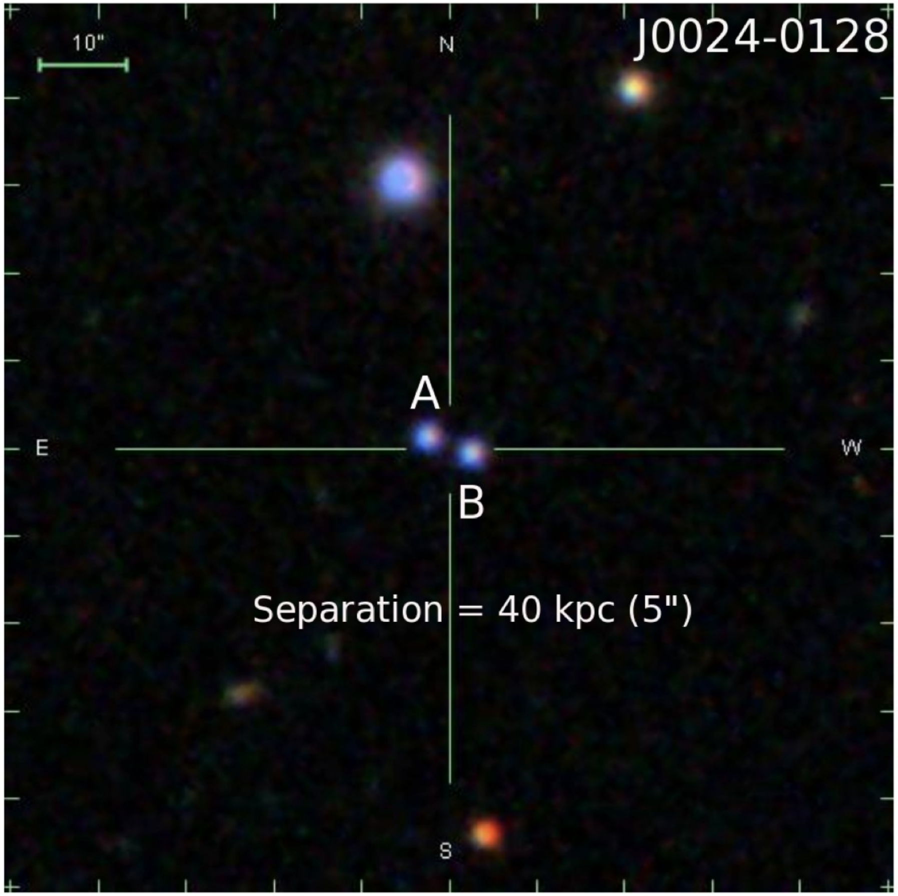
Fumagalli+in prep

Moving forward...

The LLS-LLS correlation function

The LLS autocorrelation function maps the LLS distribution around galaxies

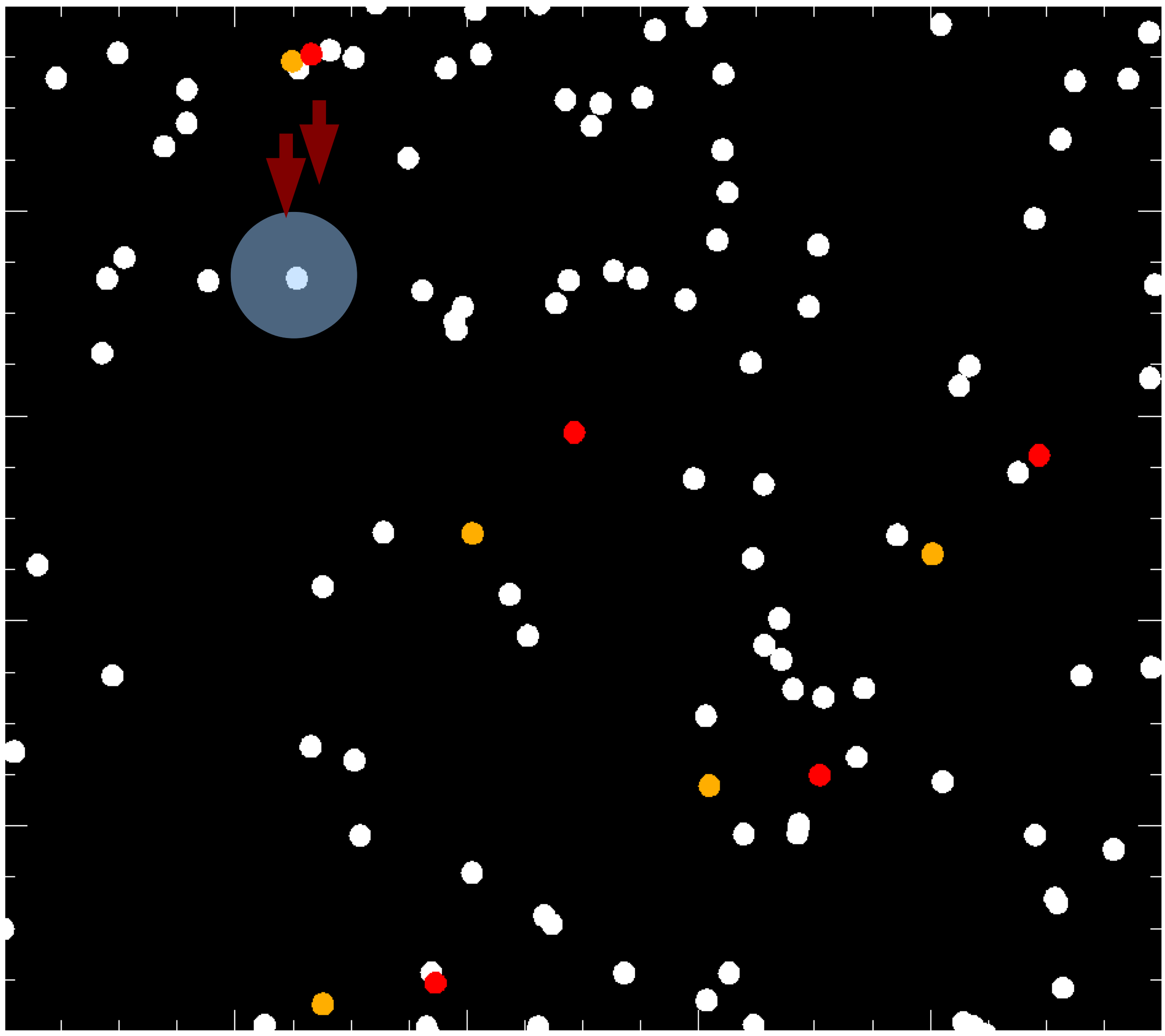




Fumagalli+2013b

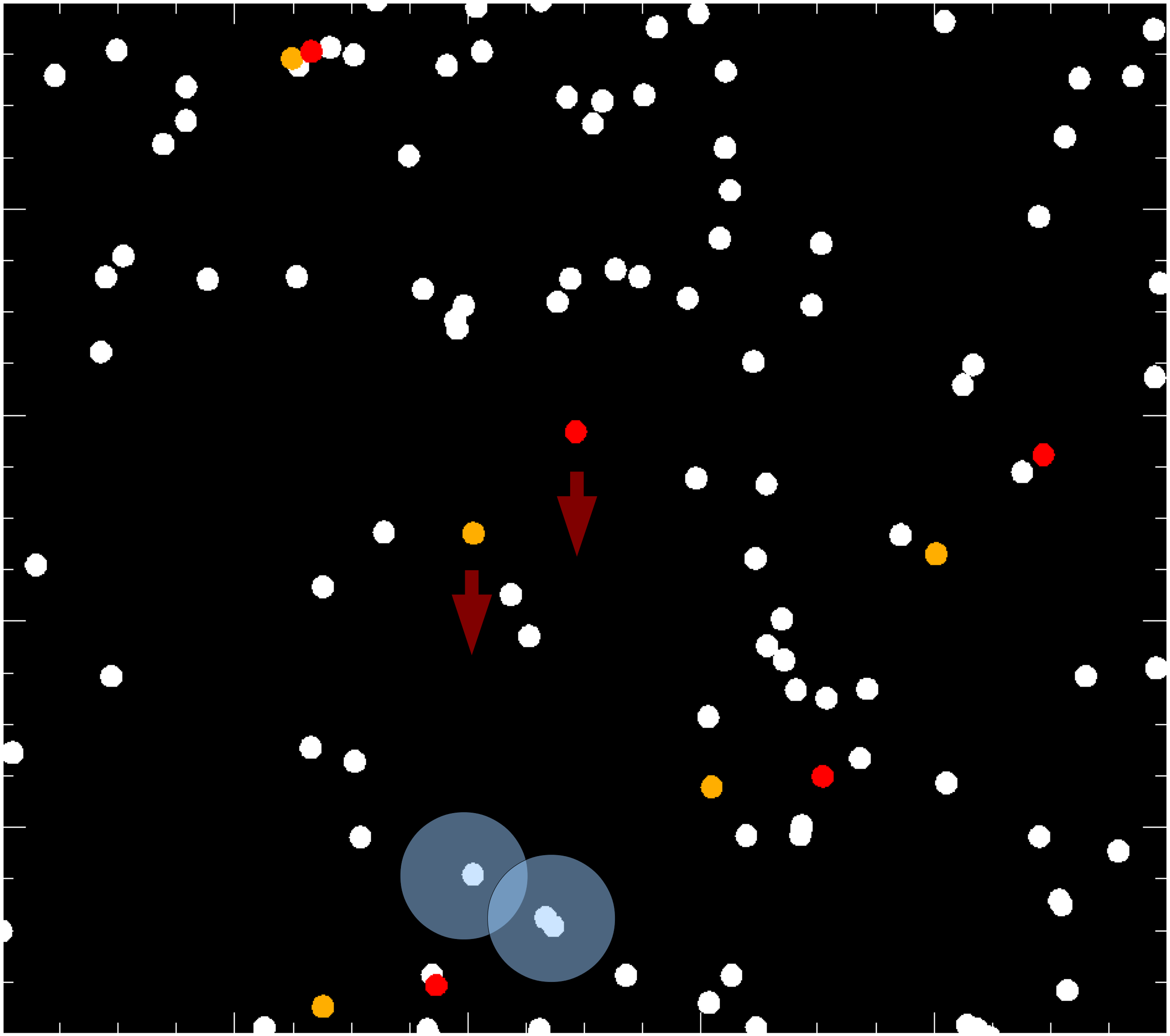
The LLS-LLS correlation function

If LLSs arise from galaxies, the LLS autocorrelation function is equivalent to the galaxy-LLS correlation function



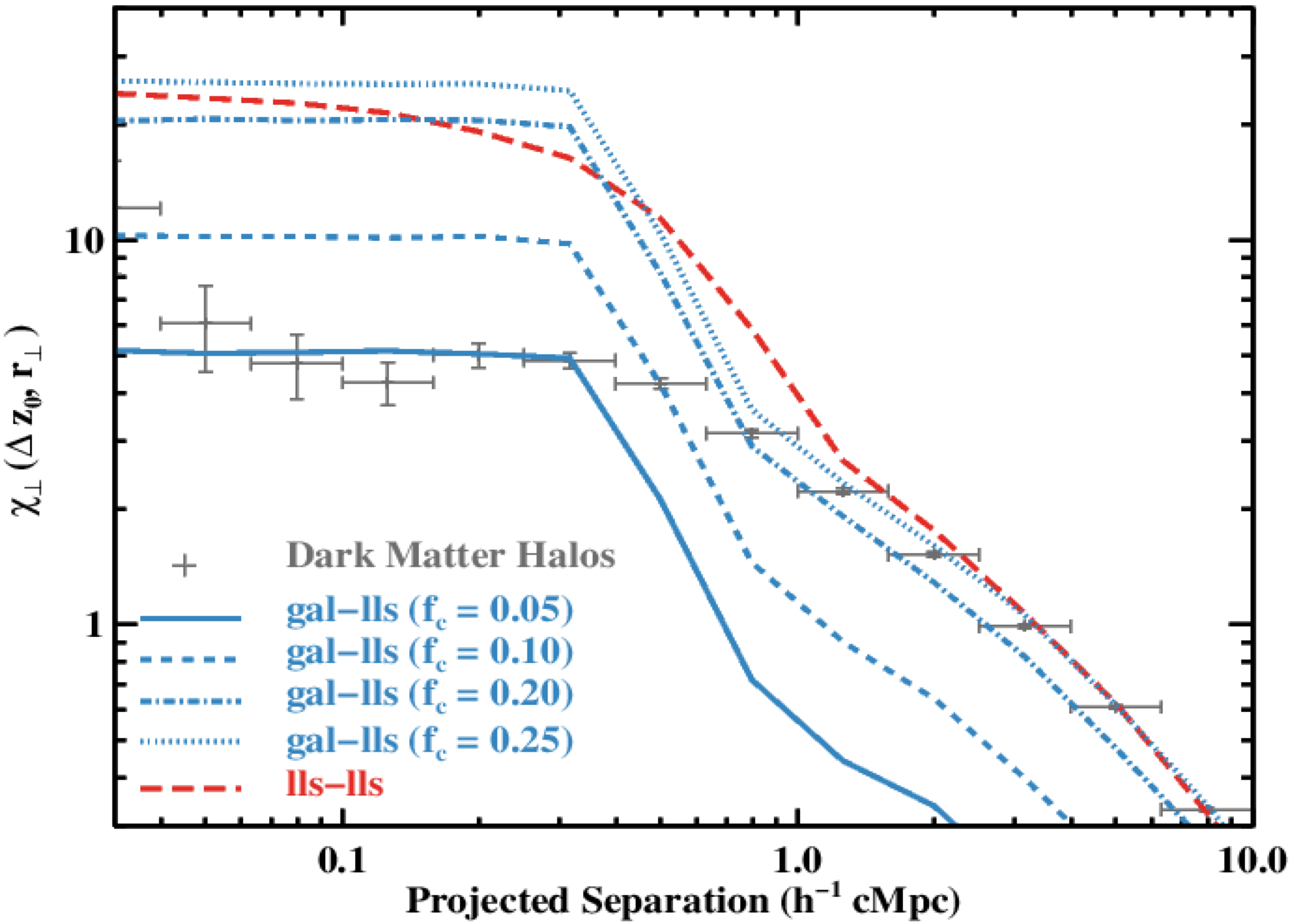
The LLS-LLS correlation function

If LLSs arise from galaxies, the LLS autocorrelation function is equivalent to the galaxy-LLS correlation function



The LLS-LLS correlation function

If LLSs arise from galaxies, the LLS autocorrelation function is equivalent to the galaxy-LLS correlation function



Fumagalli+2013b

Summary

Cold accretion in numerical simulations

An optically-thick gas phase is ubiquitously found in accreting streams

These streams are likely to be metal poor(er)

Tracing gas inflows with absorption lines

Comparisons between LBGs and simulations are at the moment inconclusive

Quasar host galaxies have a high covering factor (why?)

It is possible to account for a substantial fraction of LLSs with halo gas

These LLSs appear on average metal poor

Moving forward

Galaxy surveys near LLSs and the LLS autocorrelation function are promising way to add more information to this picture