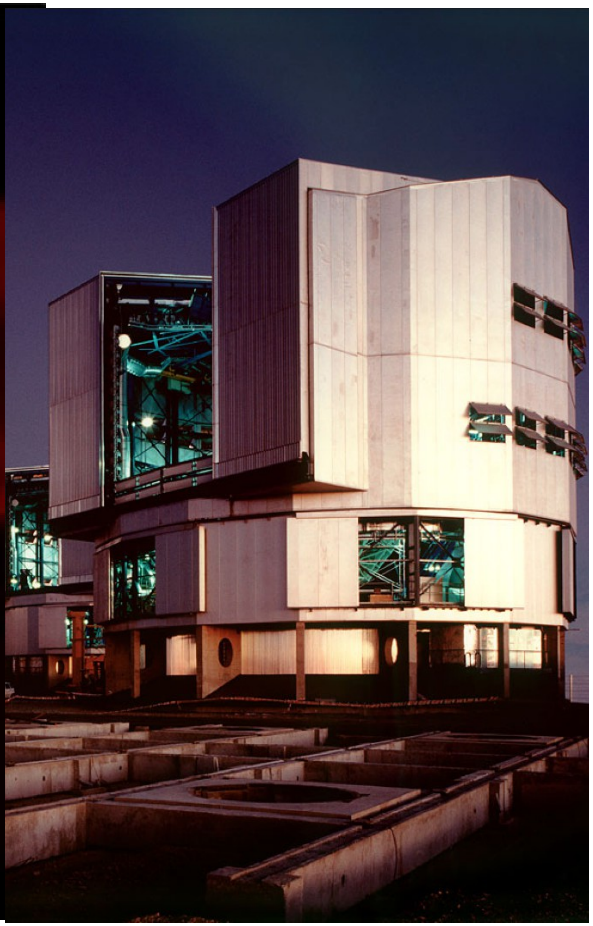
Durham University

Probing gas flows near galaxies: a spotlight on Lyman Limit Systems



Durham Centre for Extragalactic Astronomy

ICC Institute for Computational Cosmology

Michele Fumagalli

With Xavier Prochaska, John O'Meara, Joe Hennawi, Tom Theuns, Avishai Dekel, and many others...

Why Lyman Limit Systems (a.k.a LLSs)?

In this talk

The clustering of LLSs in “statistical” samples provides solid empirical evidence of the association between LLSs and galaxies

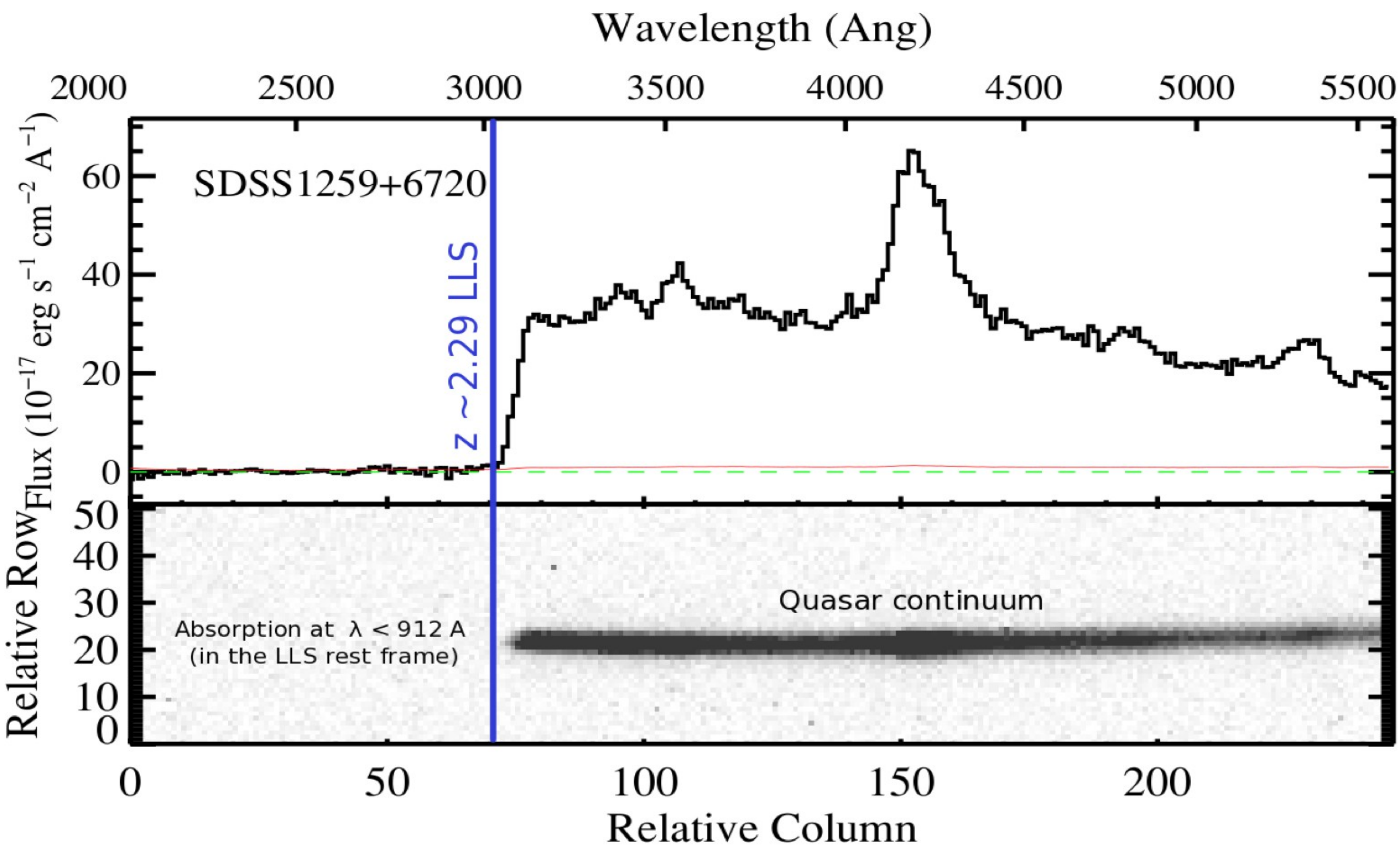
LLSs appear to be generally metal poor, i.e. $\log Z/Z_{o} \sim -2$
(but more work on the robustness of ionisation correction is ongoing)

In summary, the study of LLSs provides interesting new metrics to constrain models for feedback and accretion in simulations

So far, there is no empirical evidence against the association between LLSs and cold accretion as put forward by theory

Halo gas, Absorption Lines, and LLS

Absorption lines, and particularly LLSs, offer a powerful tool to investigate the properties of gas around galaxies

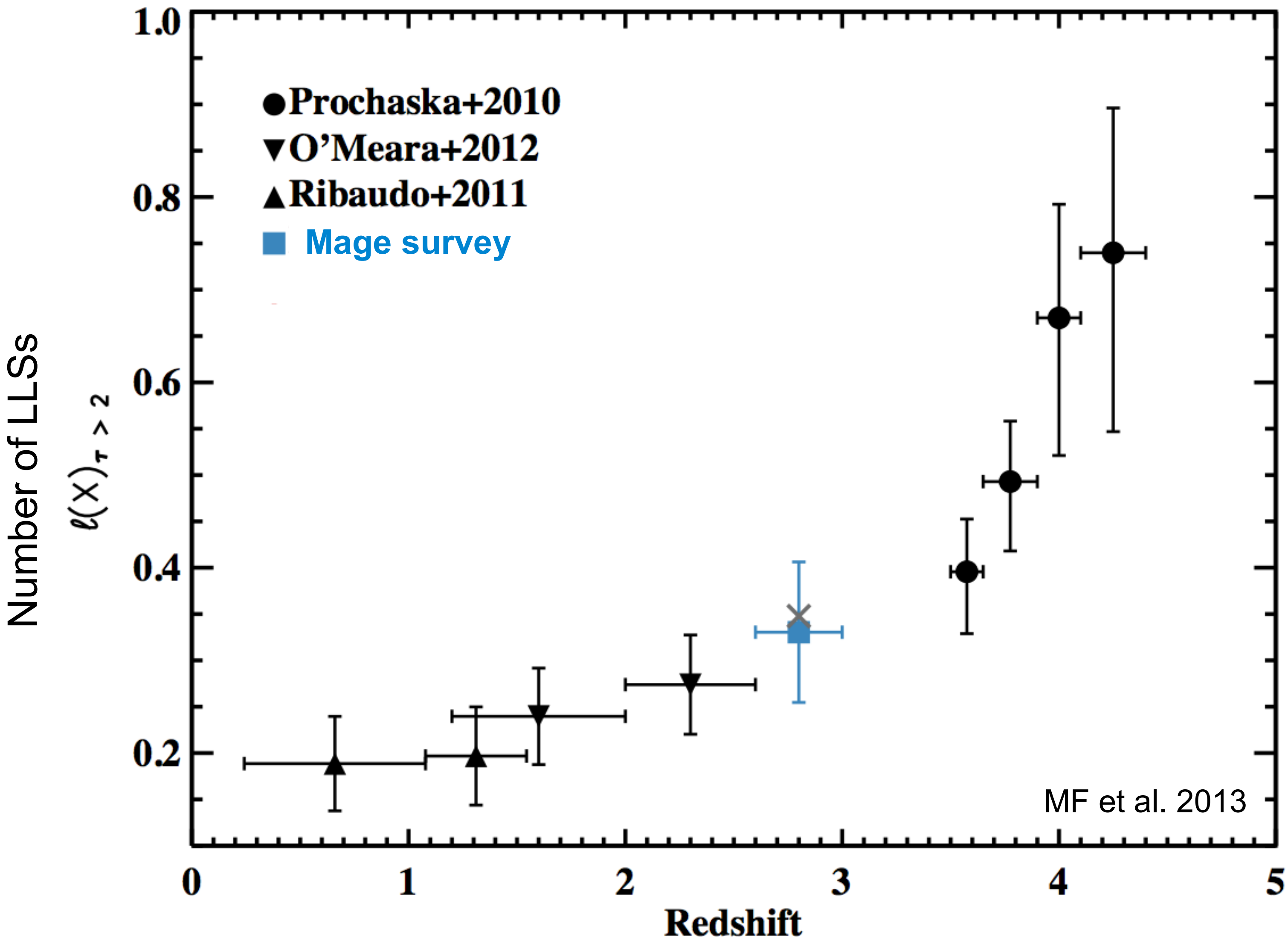


O'Meara et al. 2012

Halo gas, Absorption Lines, and LLS

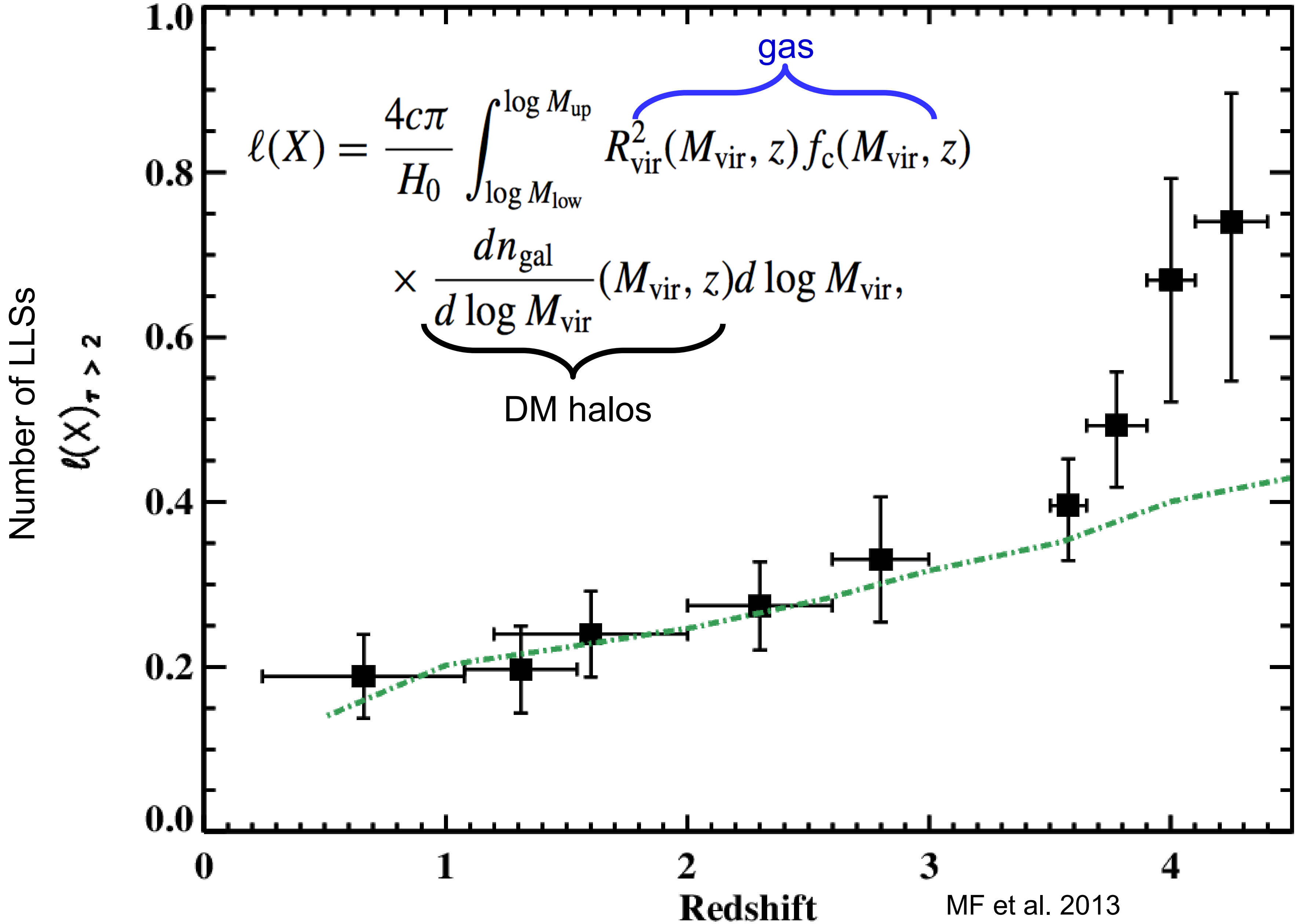
Already from the first LLS surveys, it became evident that LLSs are distinct from the IGM and trace the galaxy population

Sargent et al. 1989: “we believe that most of the LLSs are produced by galaxies”



Halo gas, Absorption Lines, and LLS

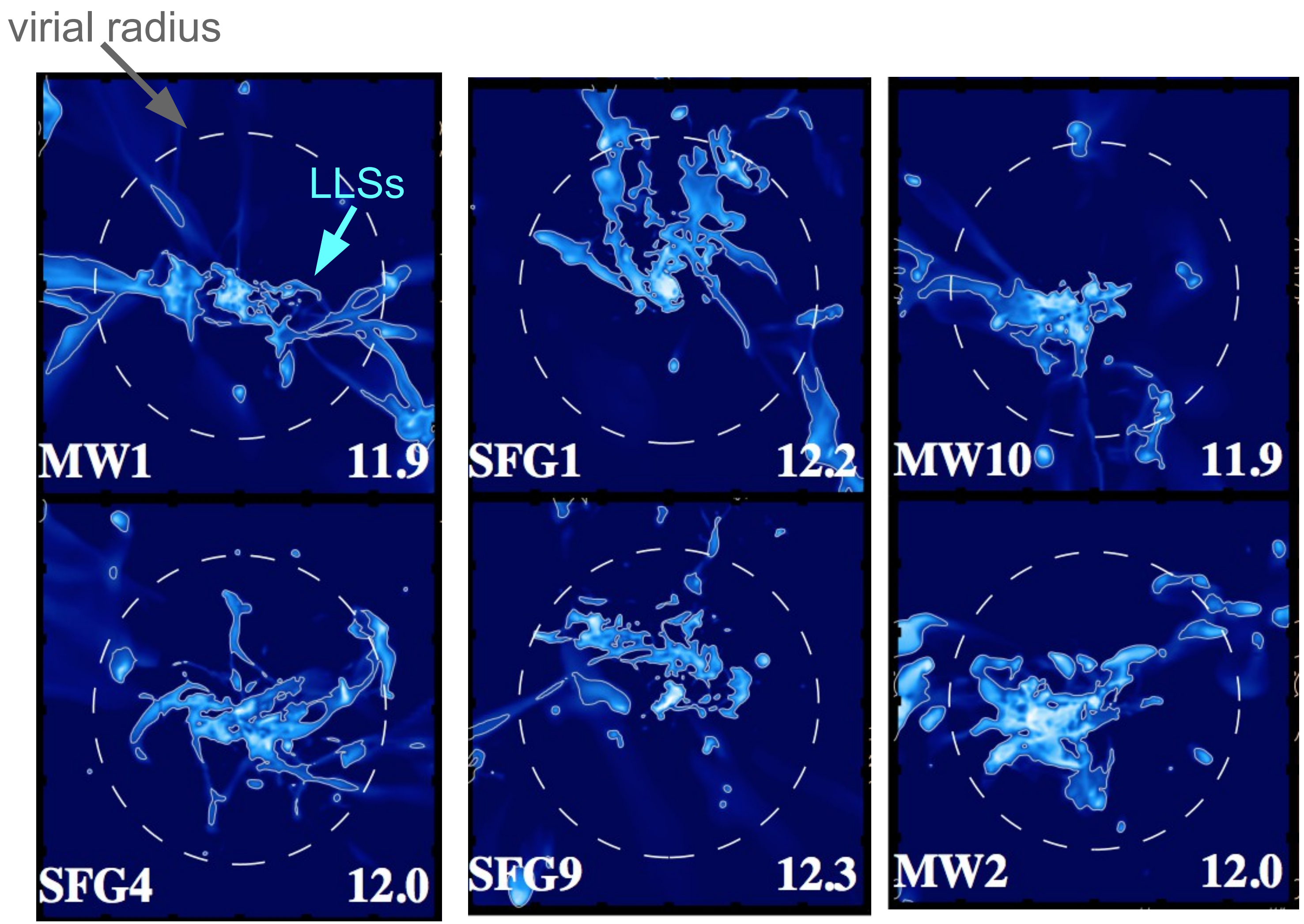
Toy models can account for redshift evolution of LLSs up to z~3.5



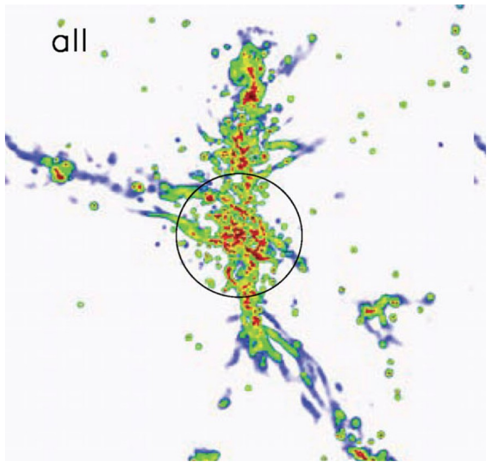
MF et al. 2013

Predictions from simulations

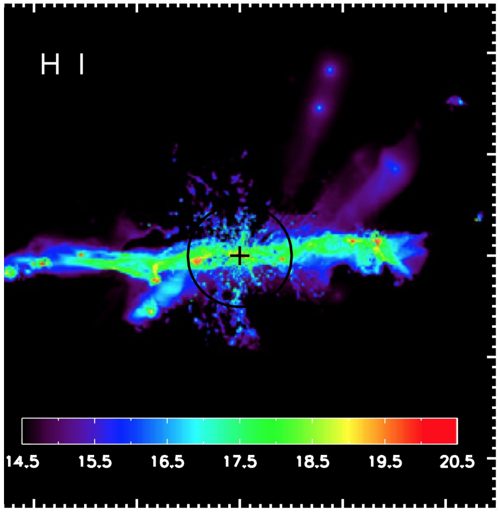
Modern hydrodynamic simulations make quantitative predictions of the distribution of LLSs around galaxies



MF et al. 2011,2014



van de Voort et al. 2012

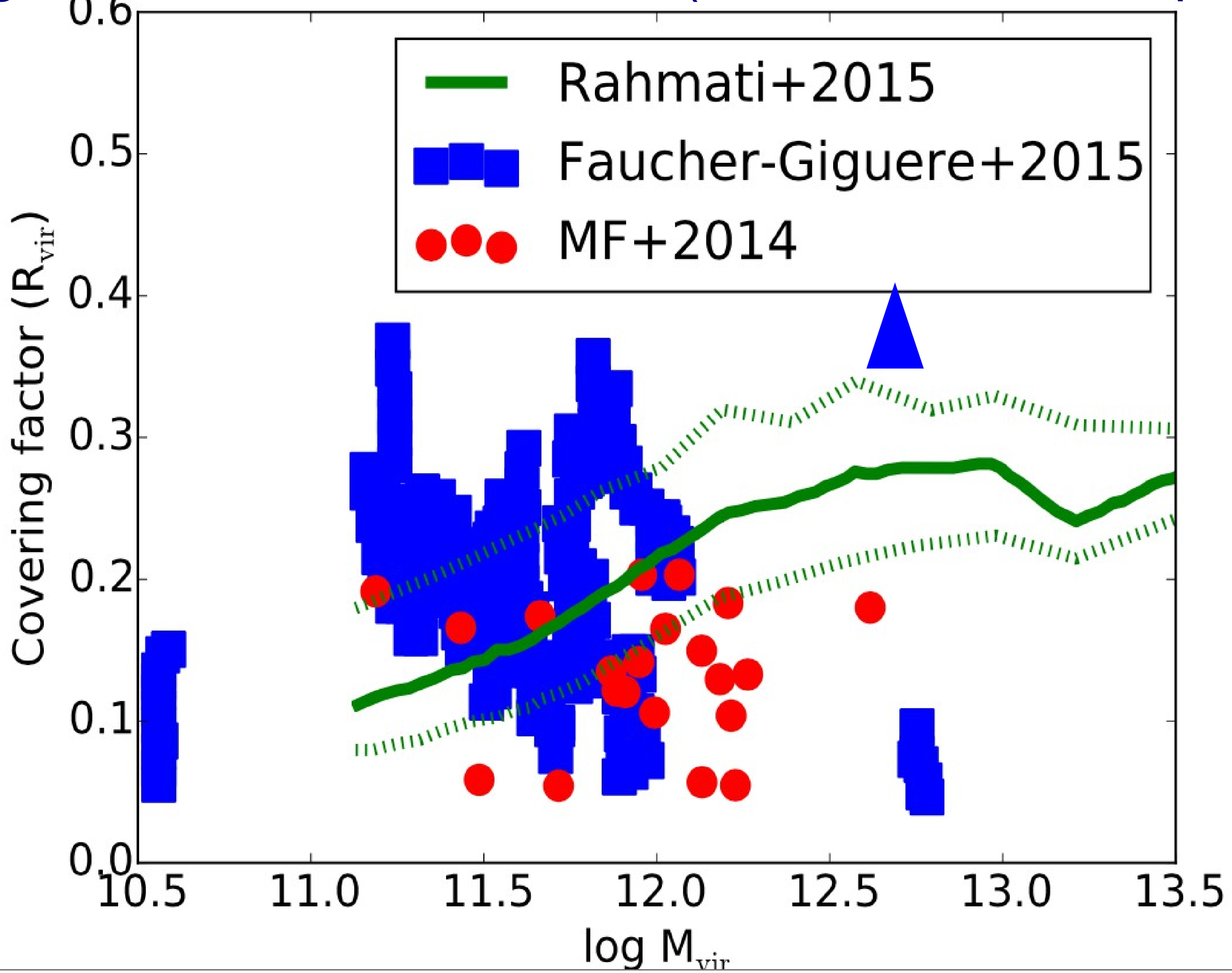


Shen et al. 2013

See also Faucher-Giguere et al. 2011,2015...

Predictions from simulations

To zeroth order, the bulk of LLSs is associated with accretion with covering fractions between 0.1-0.3 (with weak mass dependence)

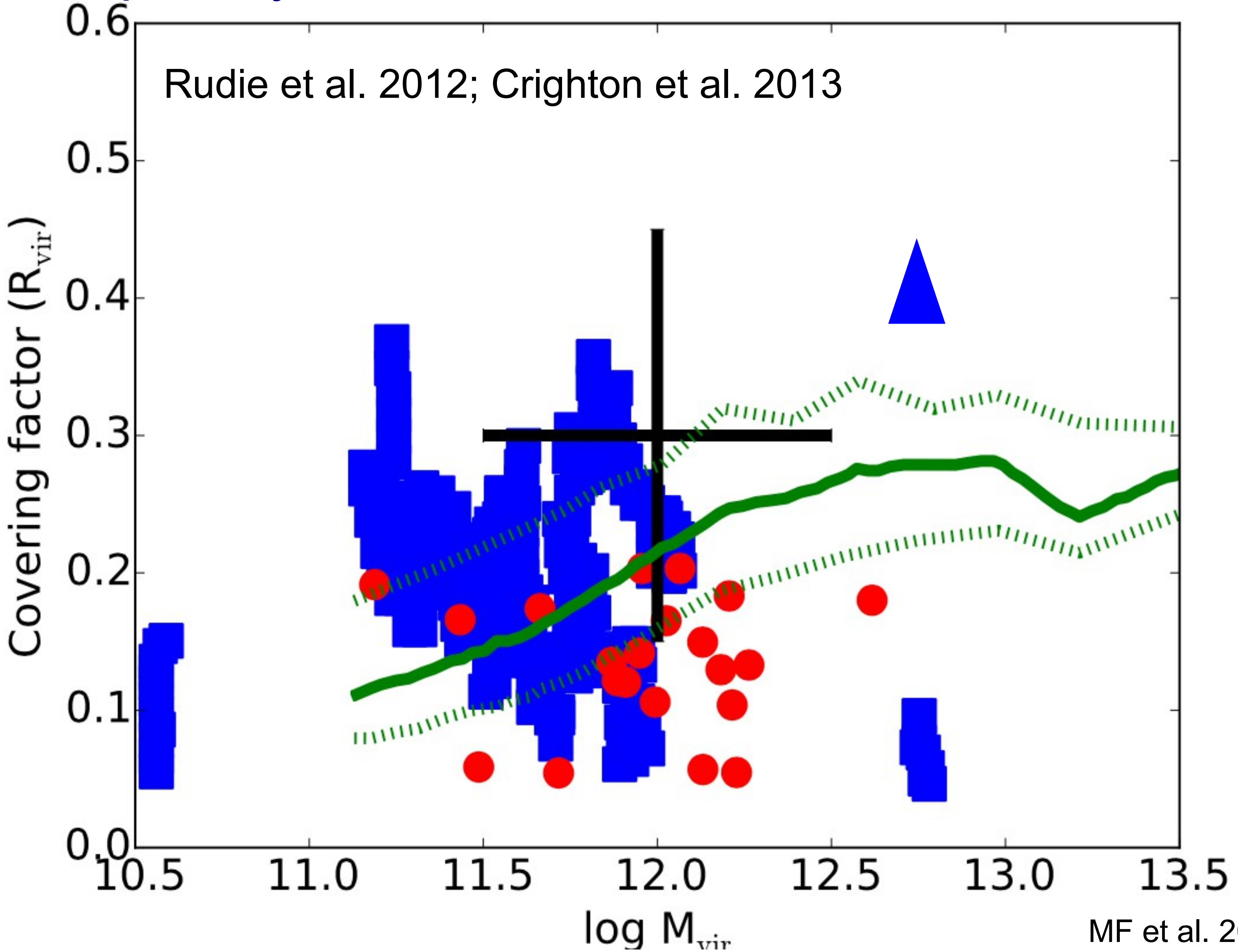


What's next (observationally)?

… besides tightening theoretical predictions...

1) Establish a solid connection between galaxies and LLSs

2) Define/quantify metrics that can be used to constrain models



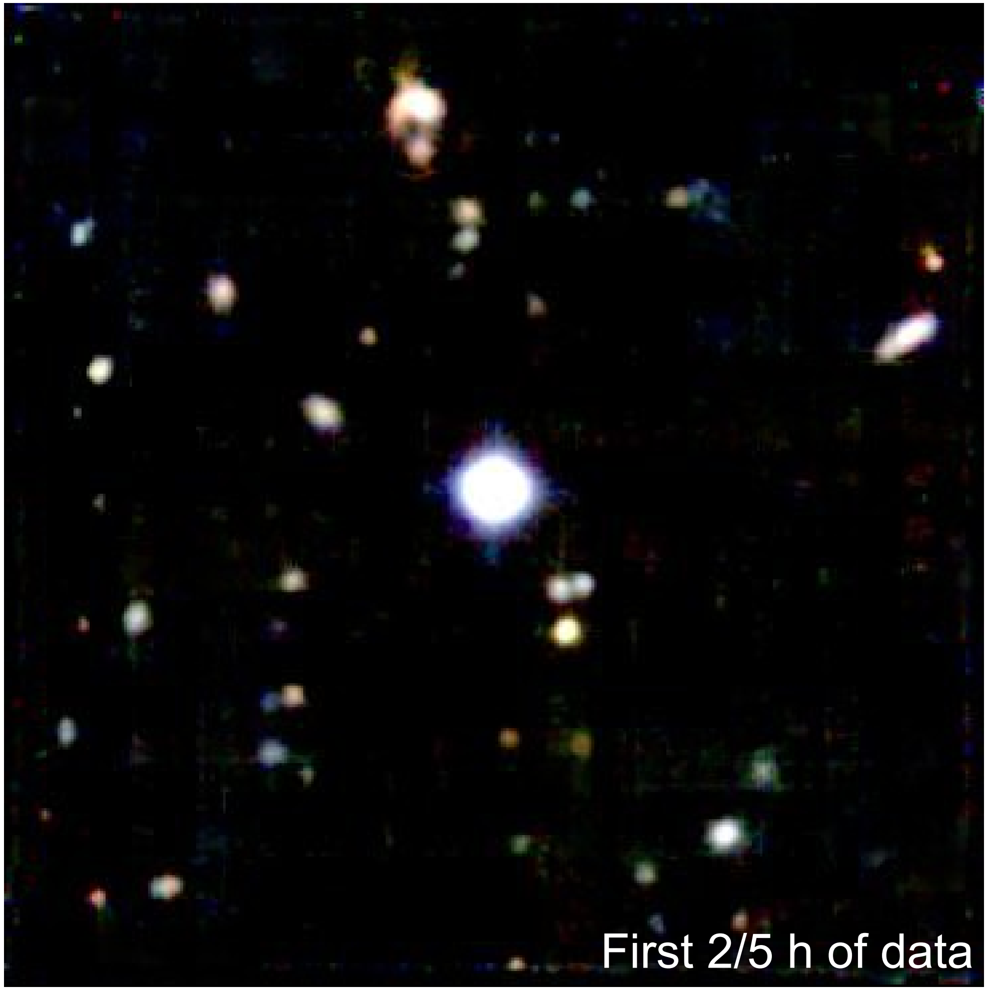
MF et al. 2011,2014

Method #1: galaxy/LLSs pairs

MUSE/KCWI will soon help shrink the error bars

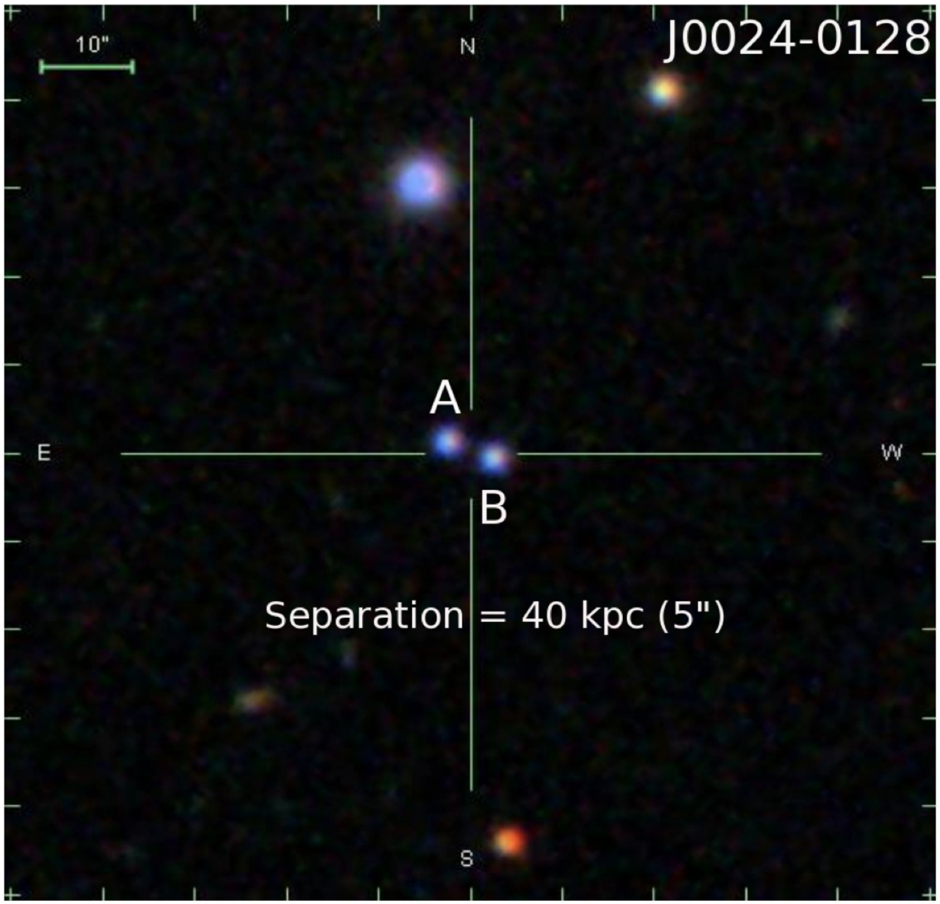
(PI programmes + GTO)

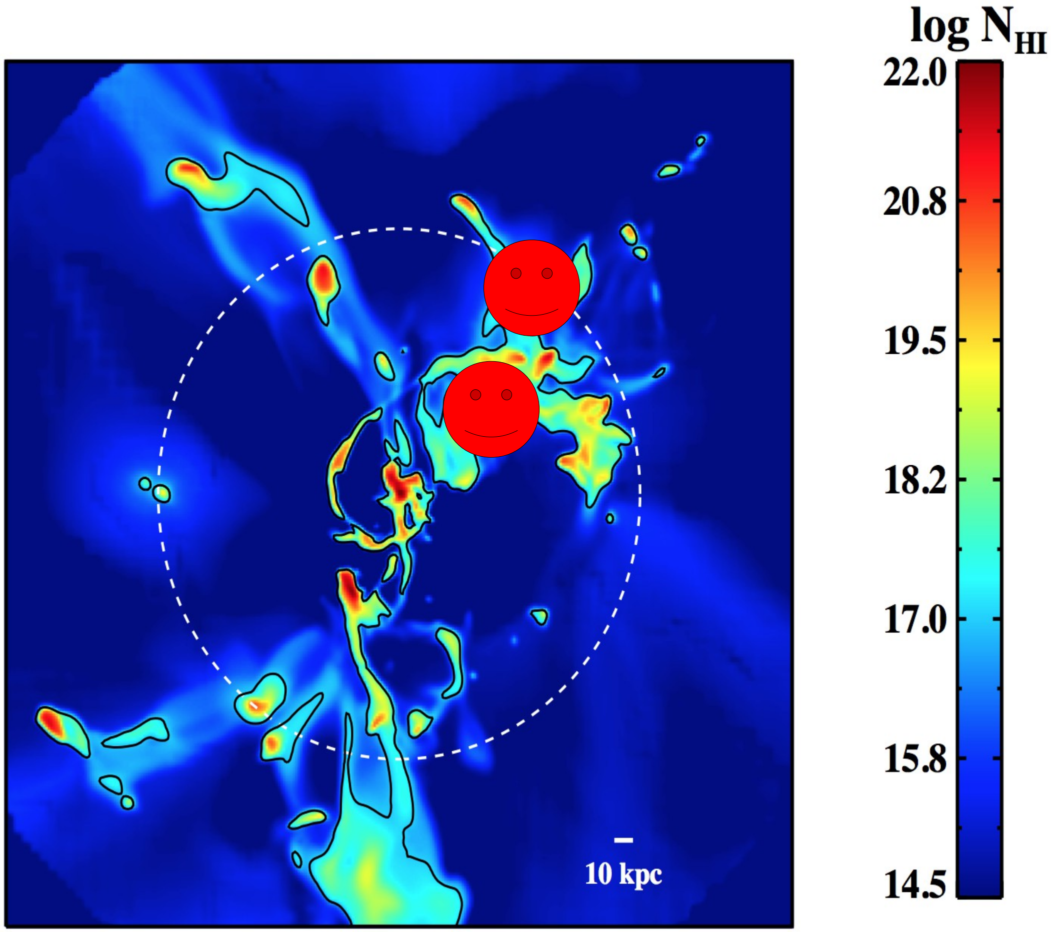
Quasar Q0956+122 with "pristine" LLS at z = 3.09 in queue for MUSE observations



Method #2: LLS autocorrelation

We can leverage quasar pairs to map the neutral hydrogen distribution around high-redshift galaxies

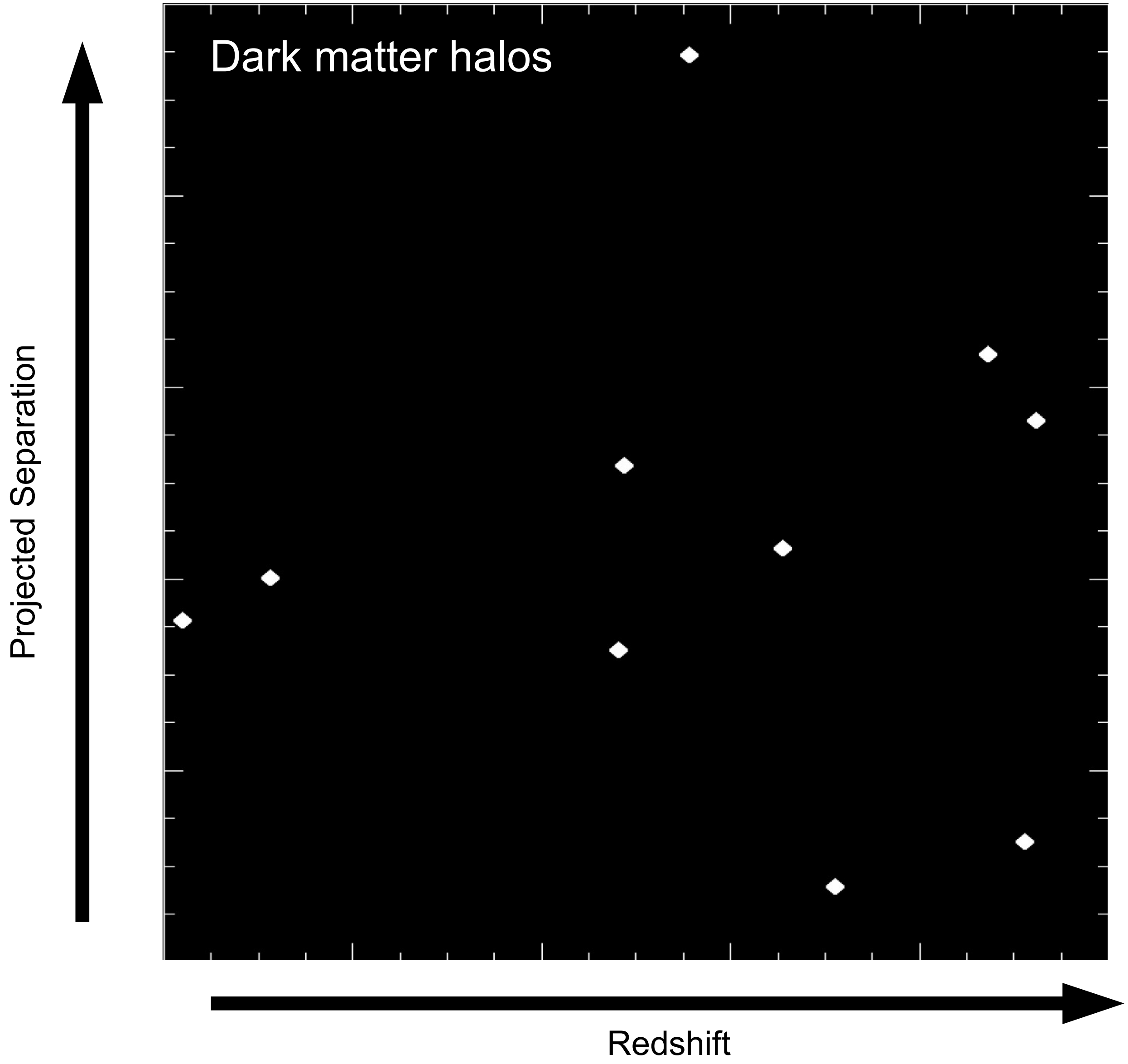




MF et al. 2014; MF et al. 2015 in prep

Method #2: LLS autocorrelation

The basic idea behind the experiment is to probe the correlation length of LLSs, which should correspond to the size of halos



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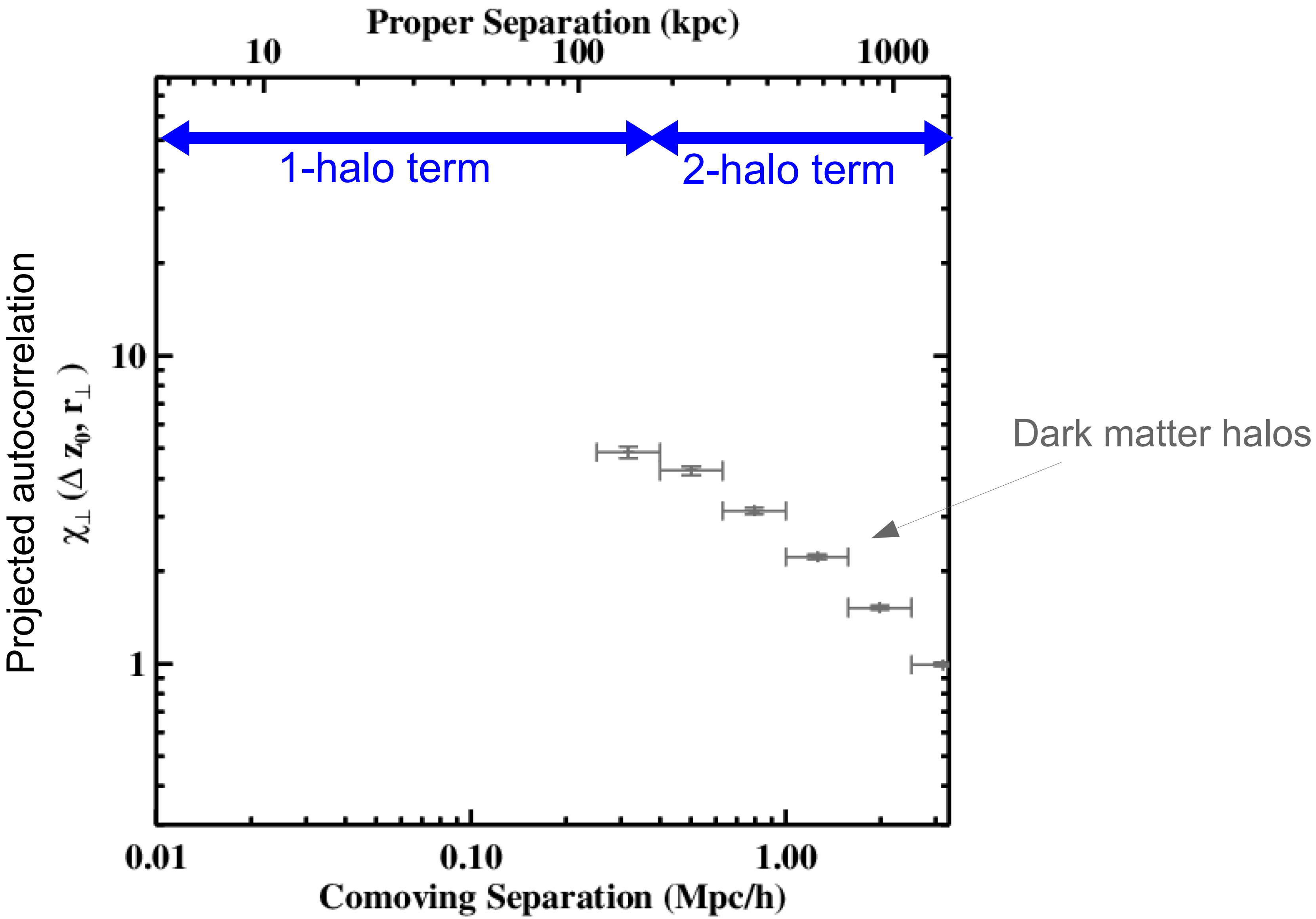

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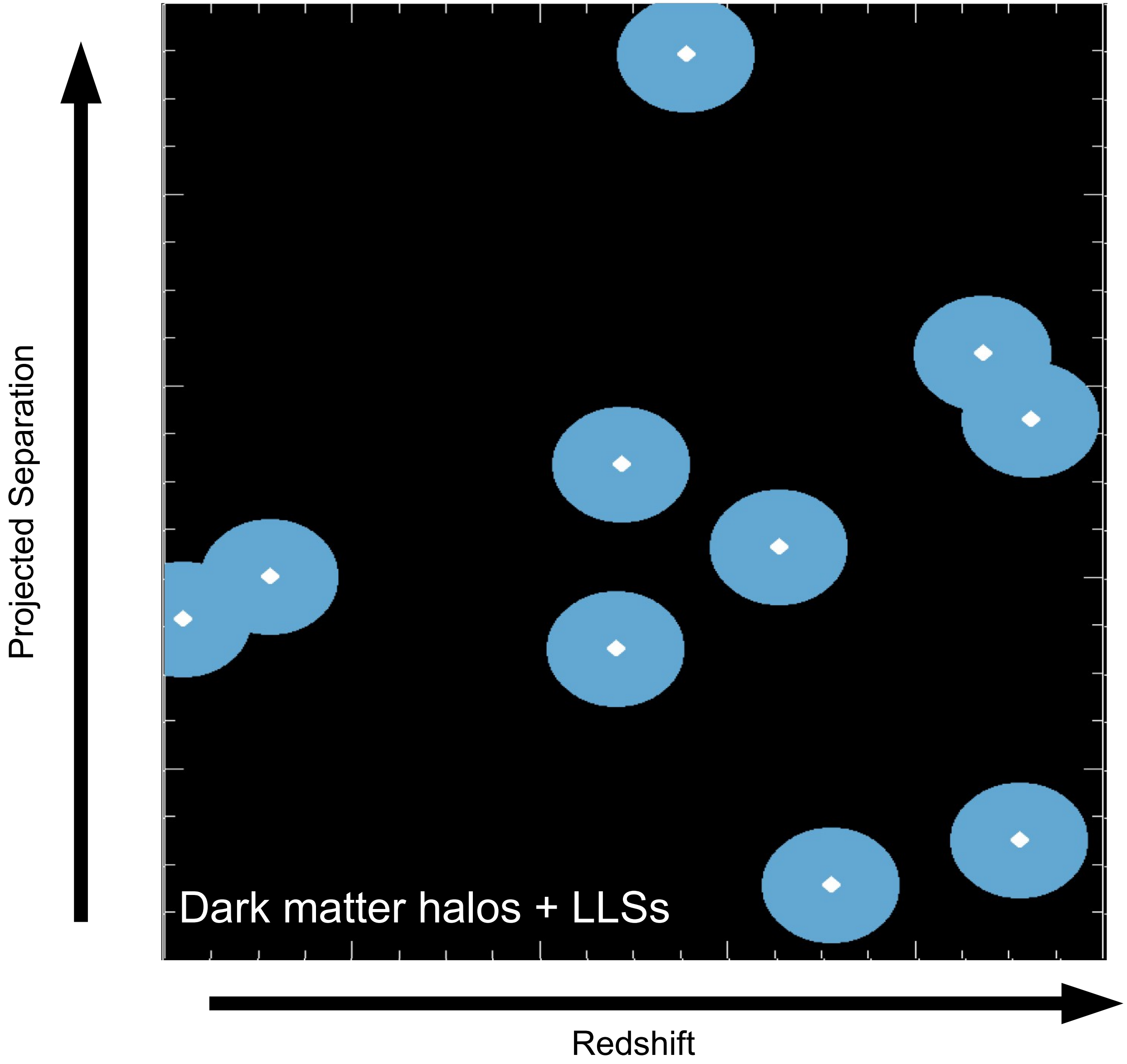

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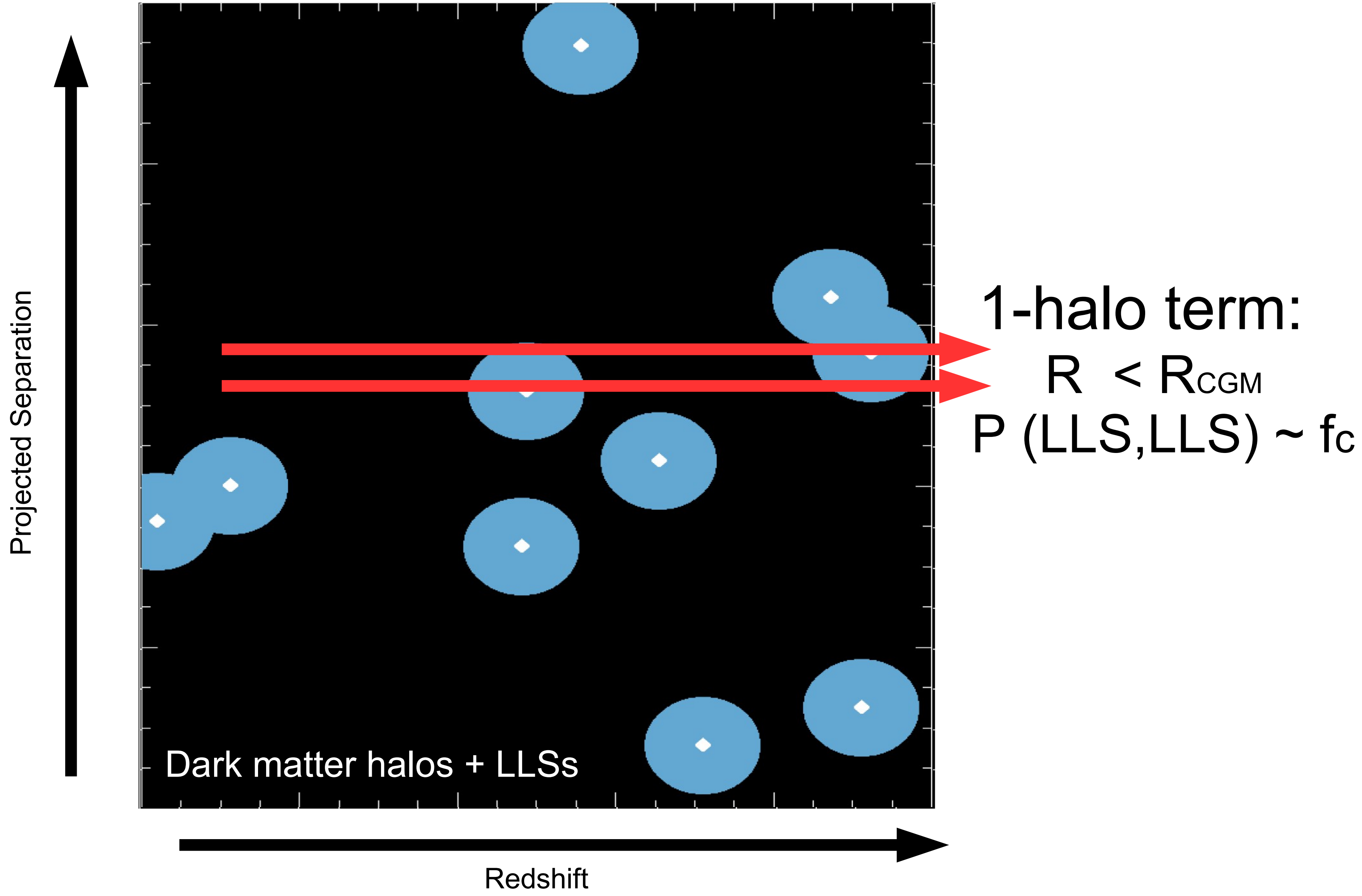

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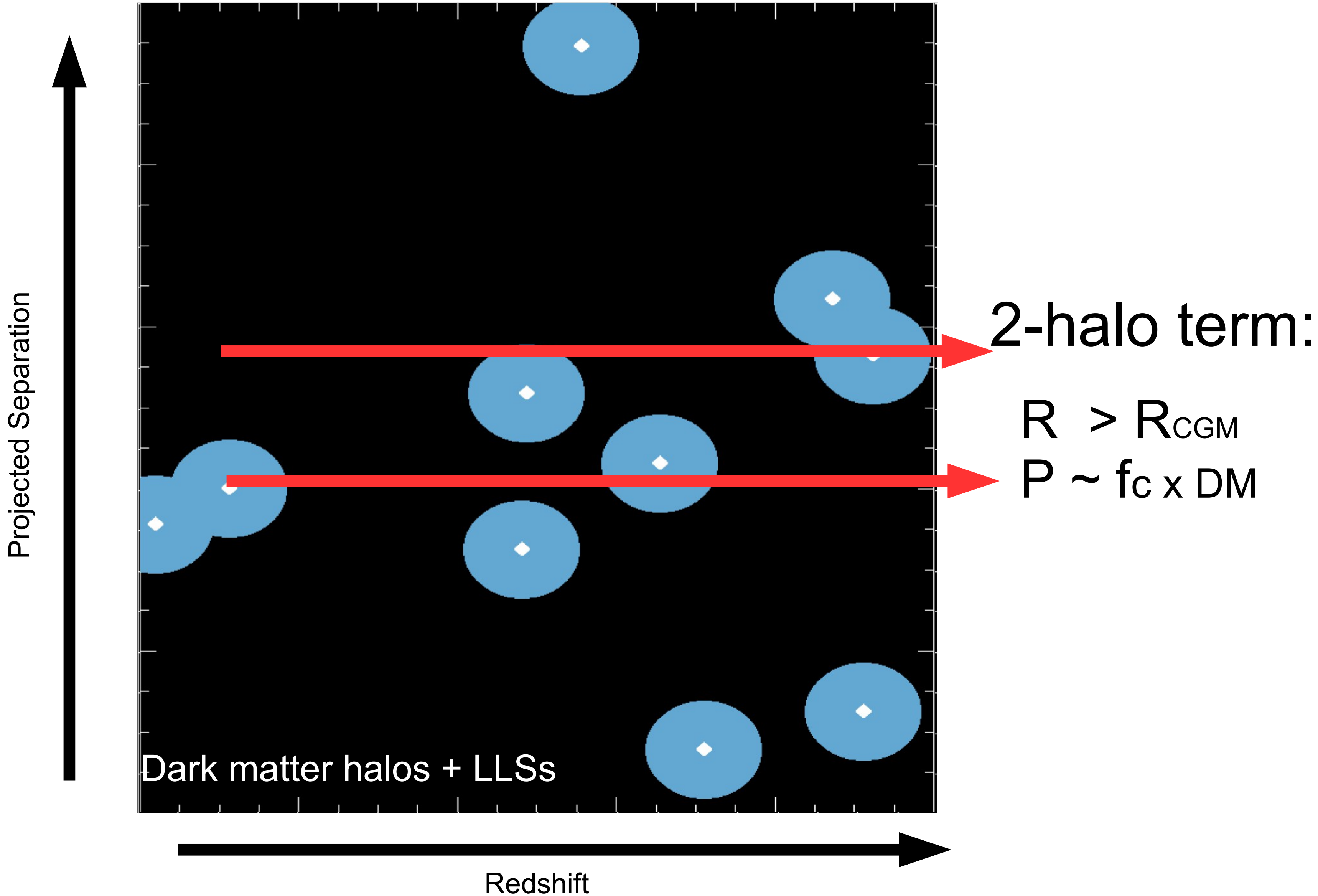

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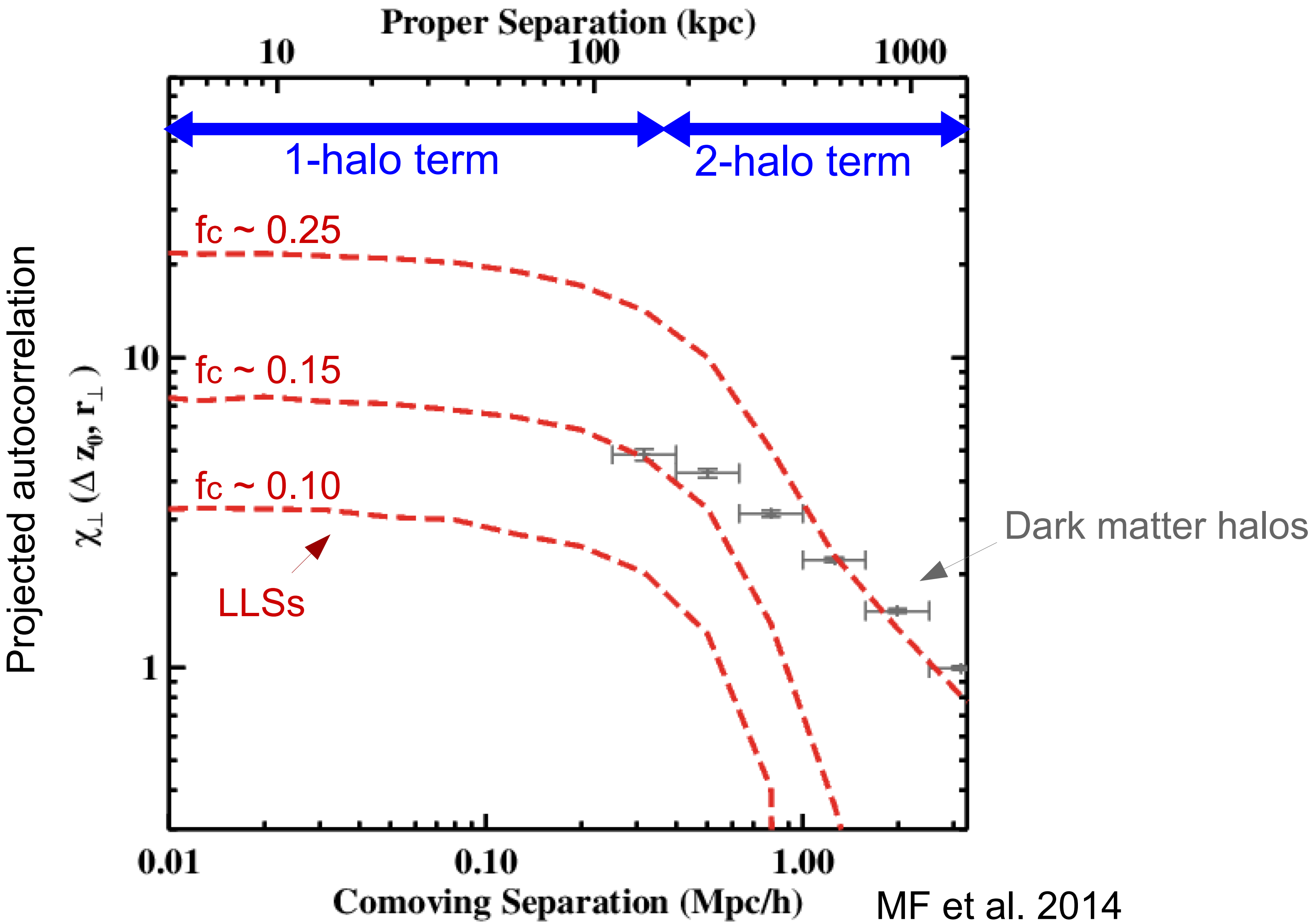


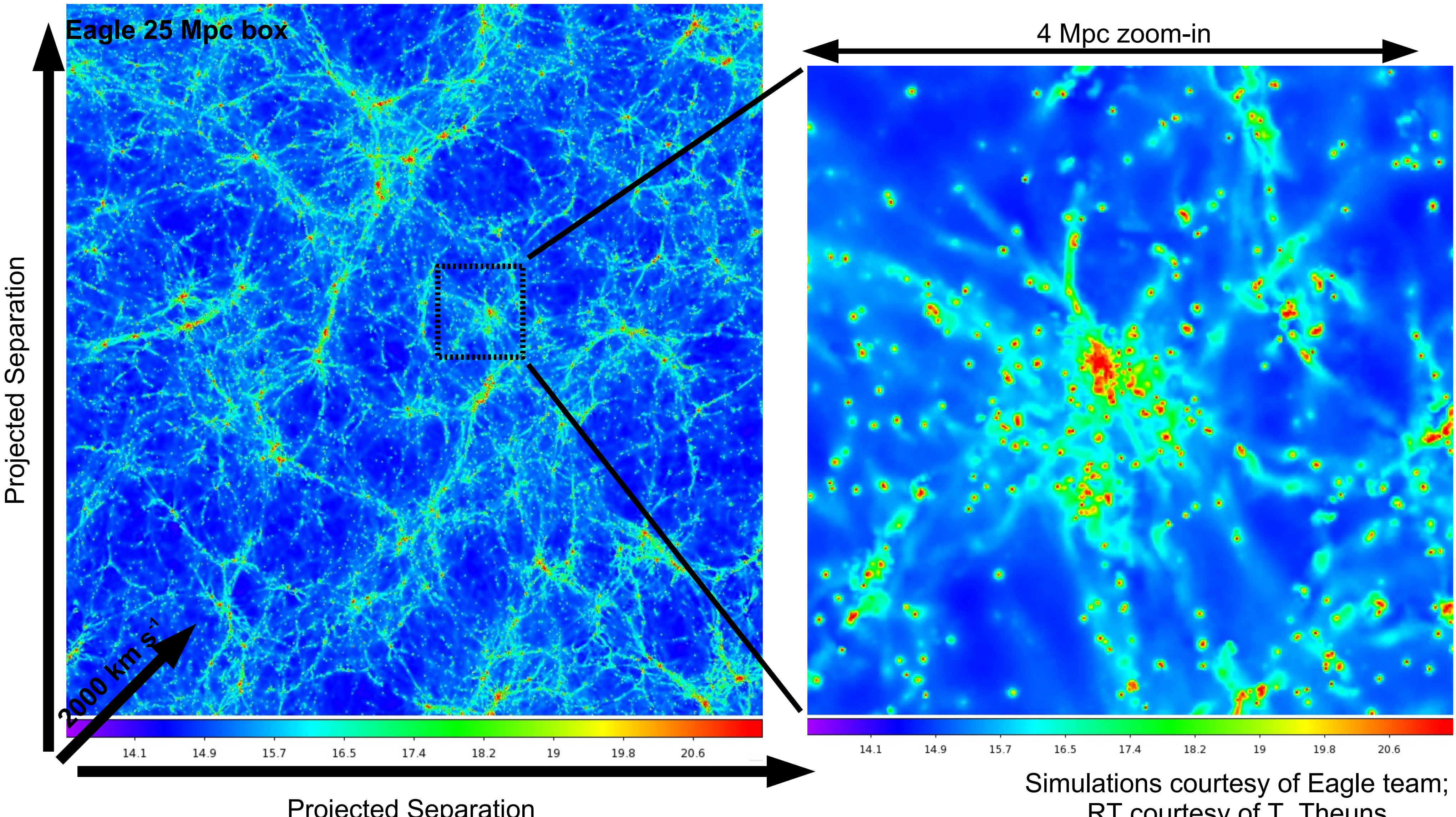
MF et al. 2014

Method #2: LLS autocorrelation

A **preliminary** measurement against 50 quasar pairs at z~3 reveals that LLSs are clustered, in line with theoretical expectations

Method #2: LLS autocorrelation

We can construct more advanced models with simulations including radiative transfer post-processing



Simulations courtesy of Eagle team;
RT courtesy of T. Theuns

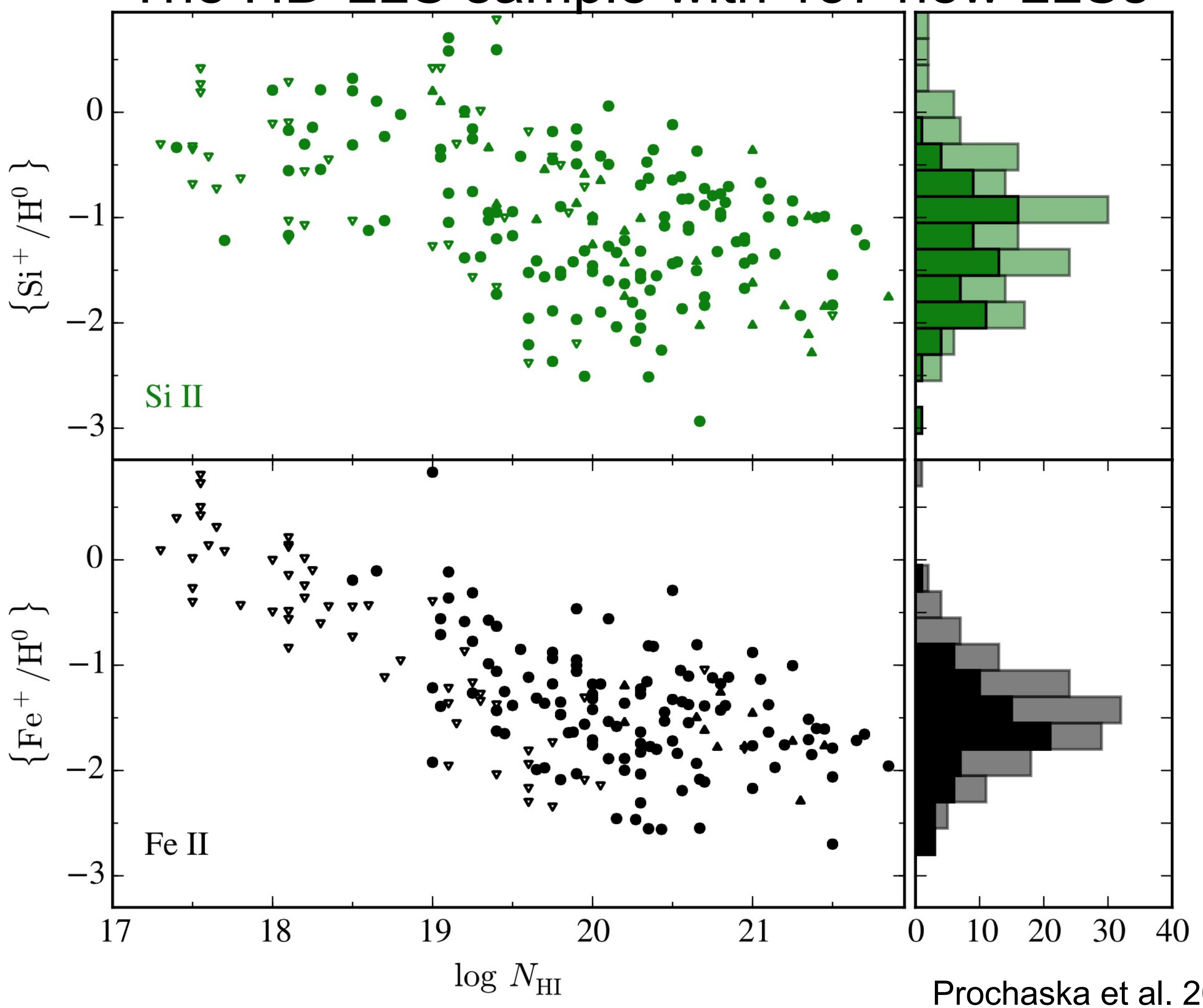
Method #2: LLS autocorrelation

We can construct more advanced models with simulations

Method #3: LLS metallicity distribution

We can exploit large samples of LLSs to map the imprint of feedback (or lack thereof) onto halo gas.

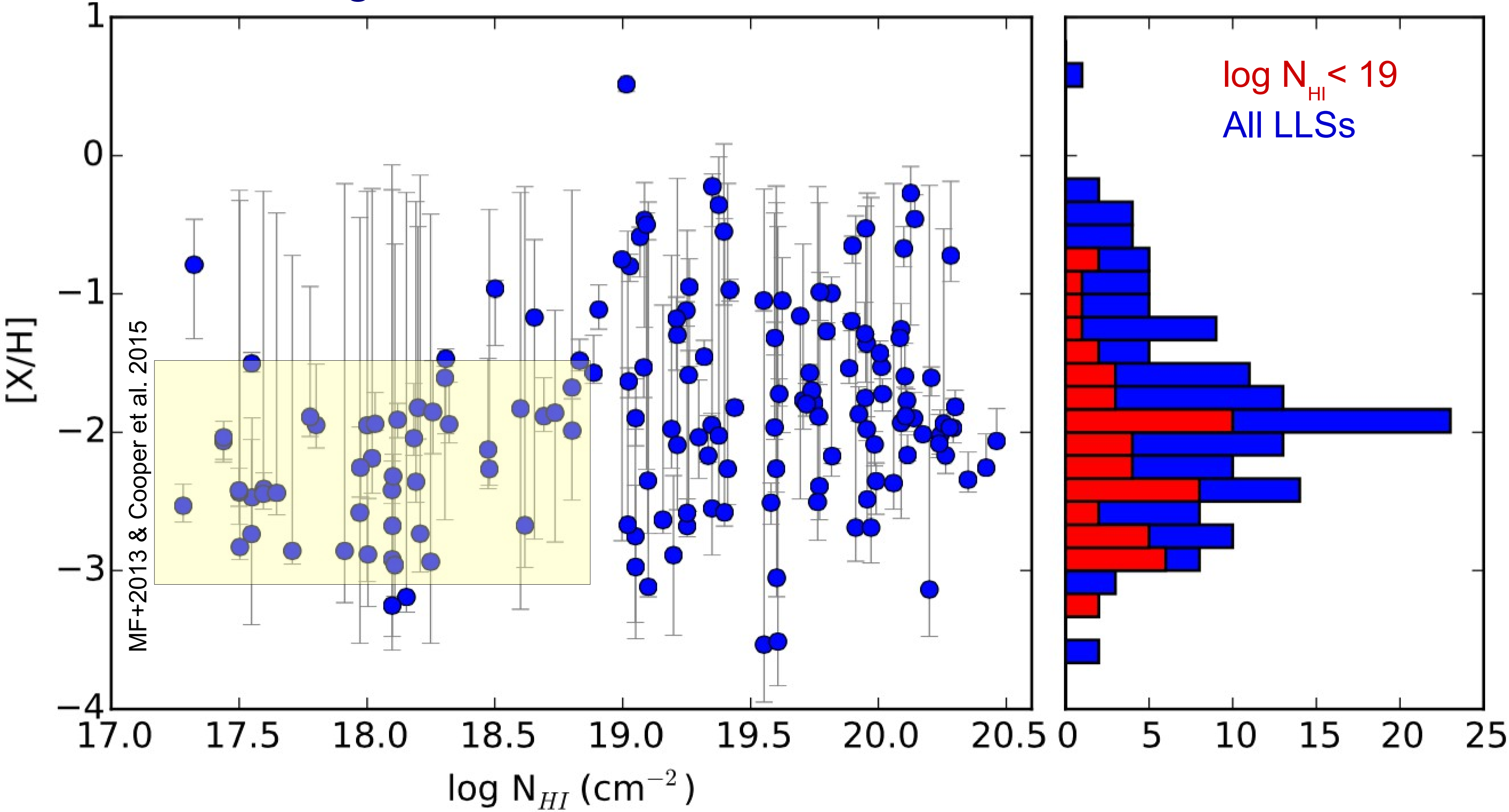
The HD-LLS sample with 157 new LLSs



Prochaska et al. 2015

Method #3: LLS metallicity distribution

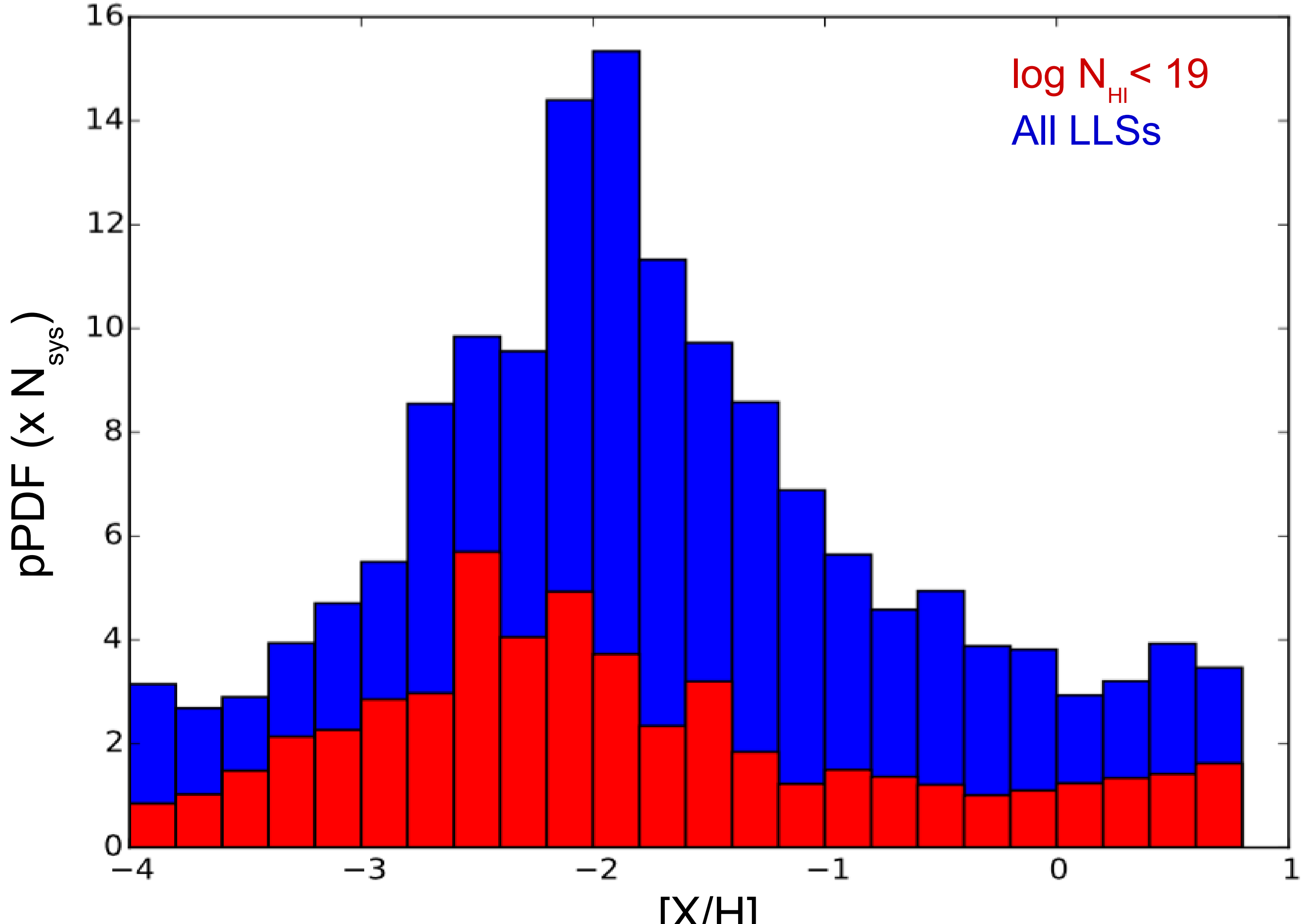
Ions are only tracers of the underlying metallicity.
We are working on the delicate business of ionisation corrections.



MF et al. 2013; MF et al. 2015 (in prep)
See also recent work by Lehner et al. 2013; Cooper et al. 2015

Method #3: LLS metallicity distribution

Metallicity distributions may become an interesting constraint for feedback models (maybe with some surprises?)



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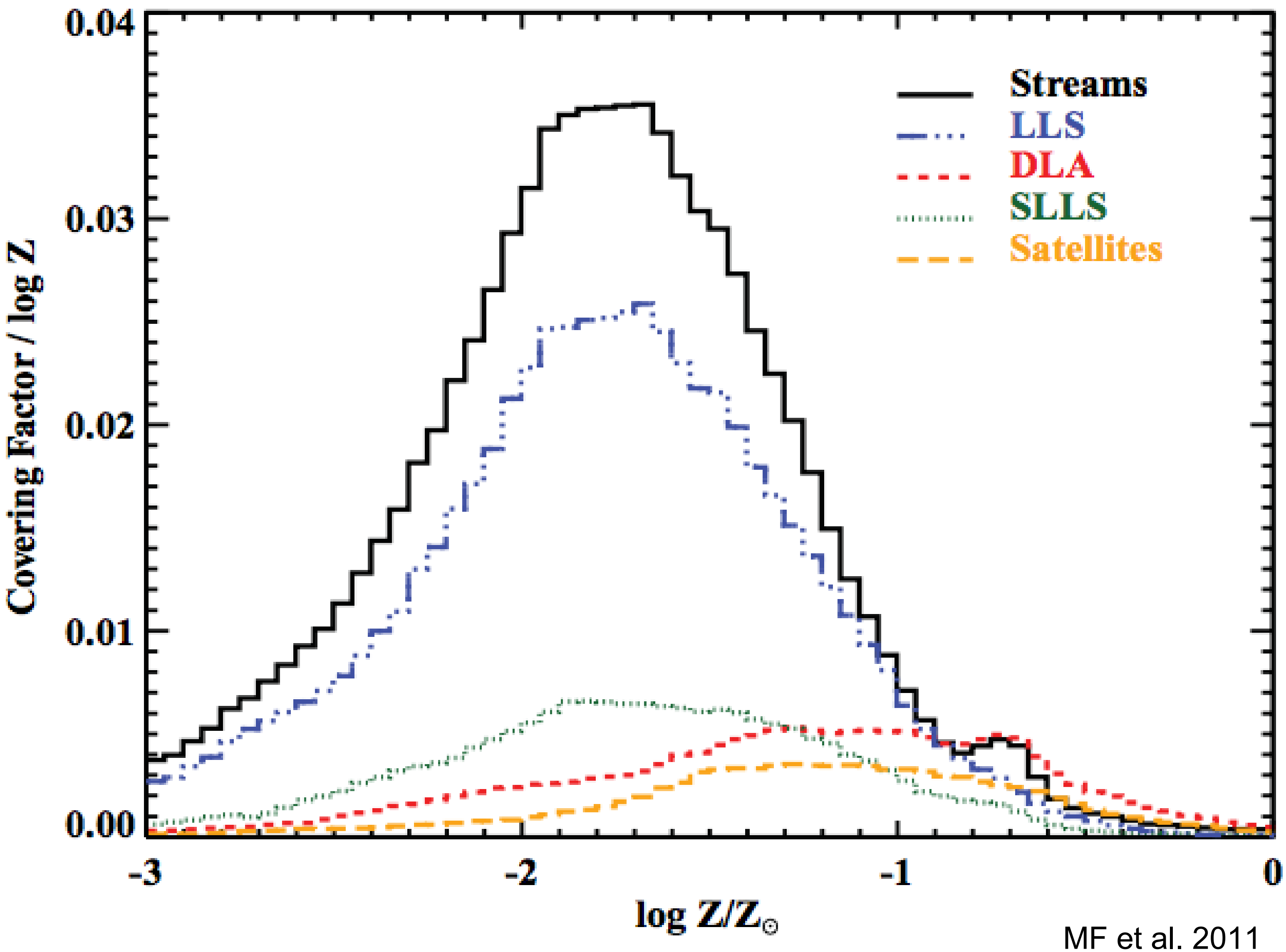

MF et al. 2011

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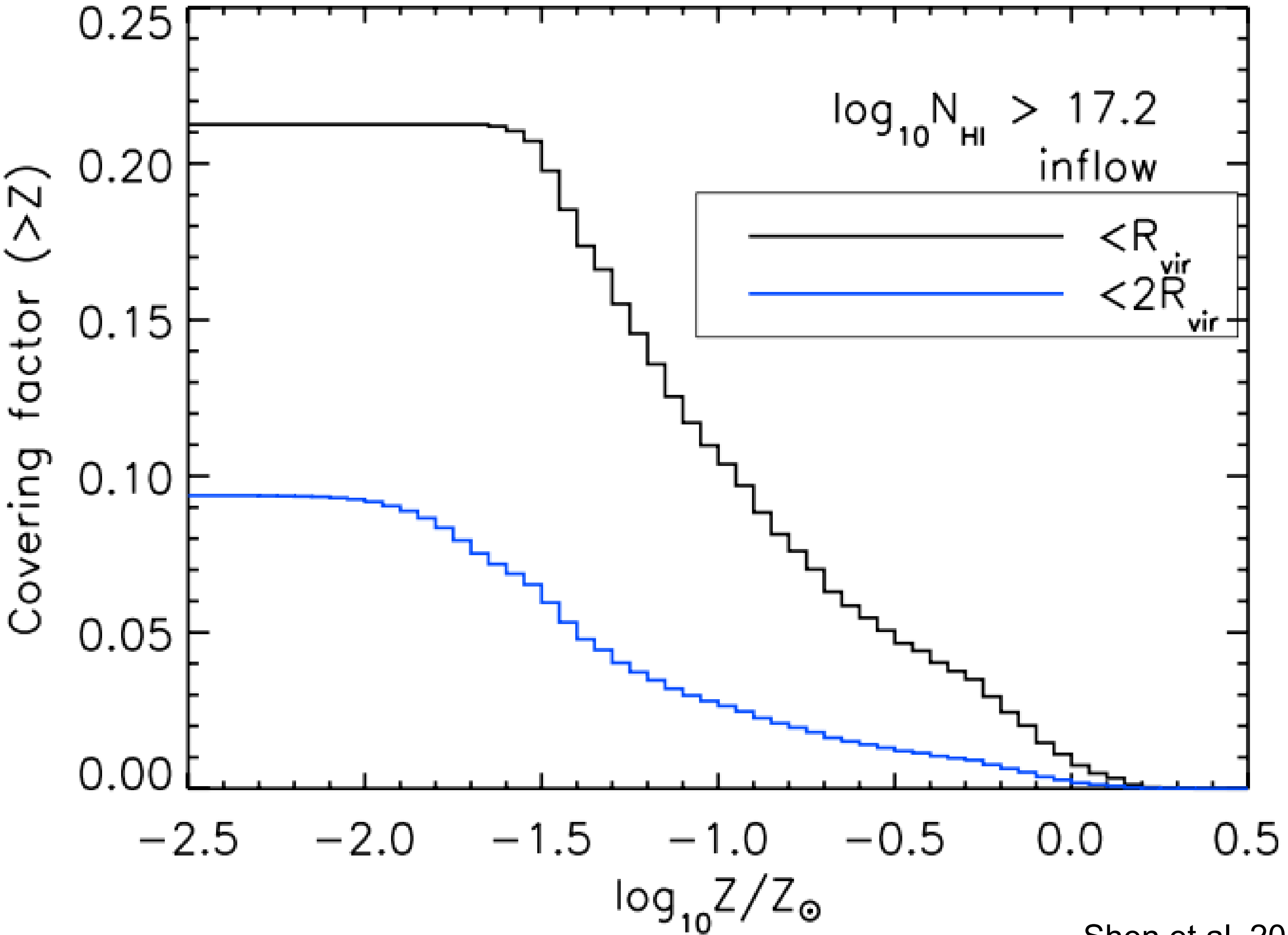

Shen et al. 2012

Summary

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