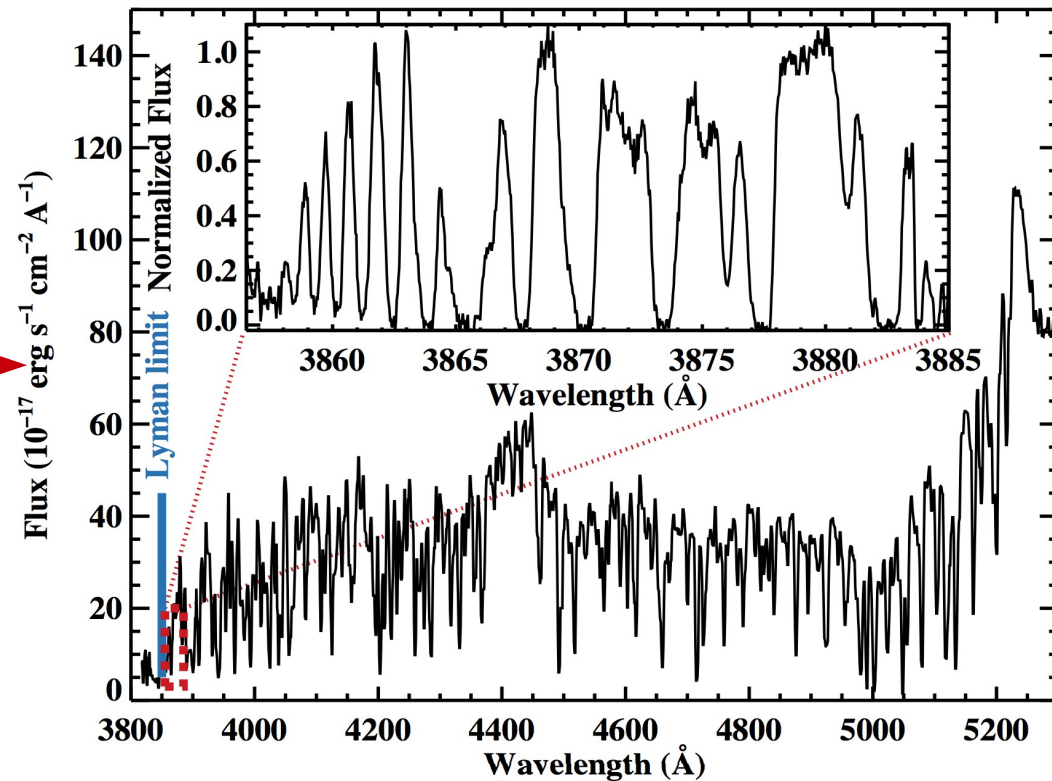
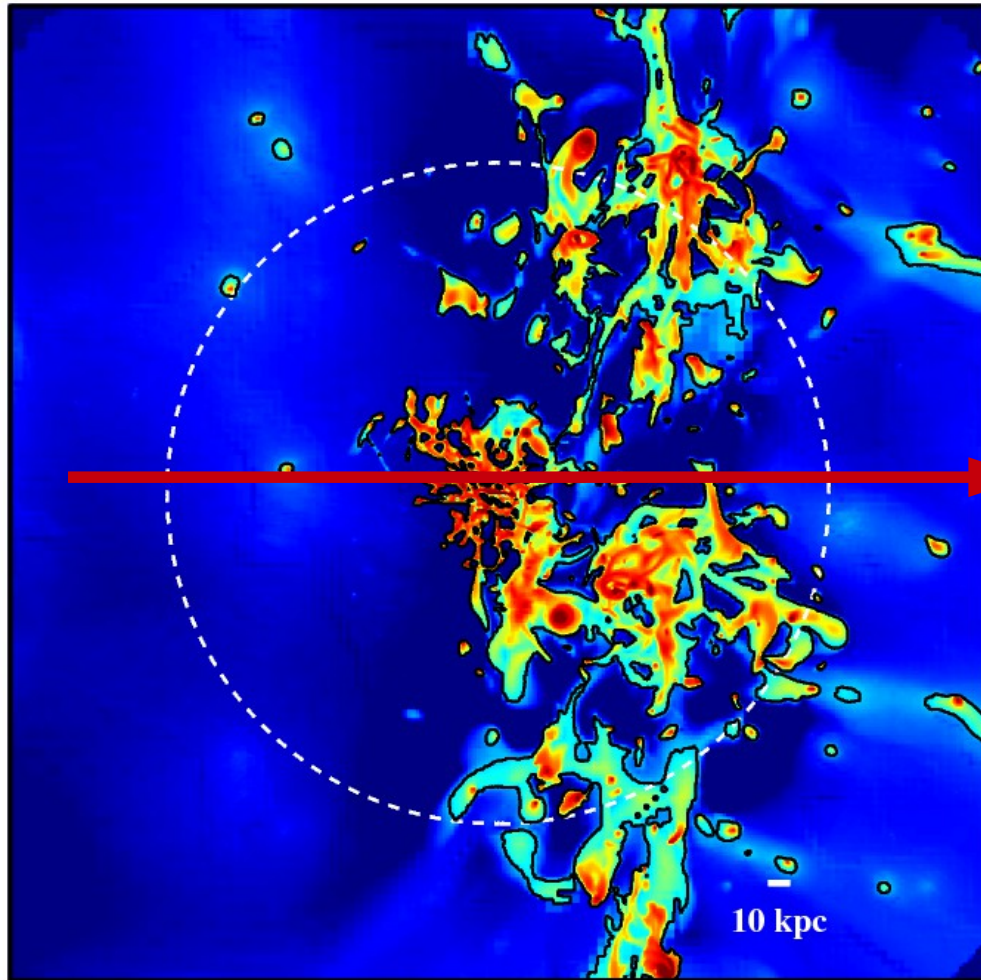


Lyman limit systems and the circumgalactic medium at $z \sim 2-3$



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Hubble Fellow

Carnegie Observatories
Princeton University

June 2013

Outline

Lyman limit systems and the circumgalactic medium

A prediction of simulations

Optically-thick hydrogen in massive galaxies

Comparing simulations and observations

Moving forward: the LLS auto-correlation function

A new experiment to rapidly advance our knowledge on the CGM

...if there is time...

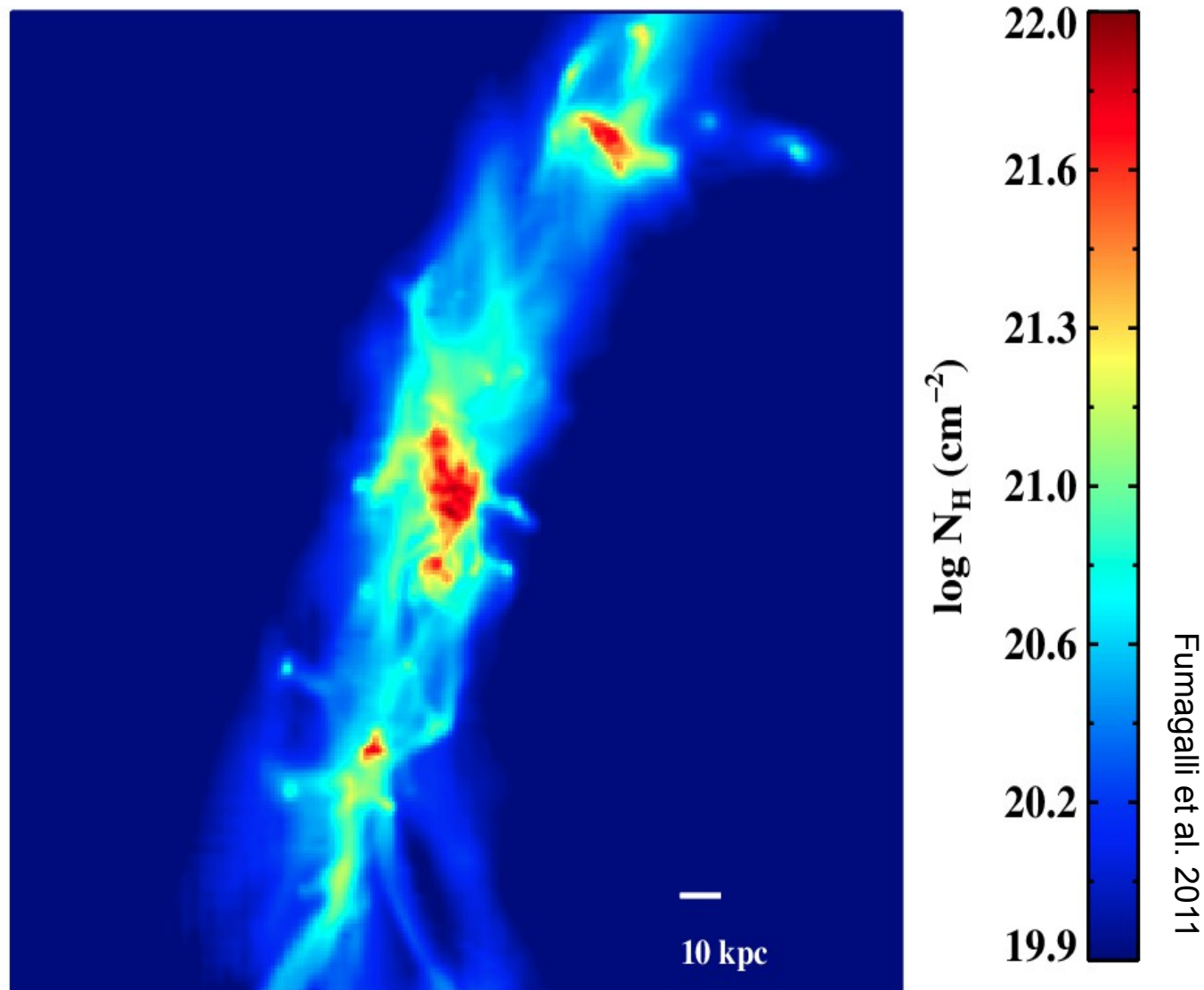
Learning from Lyman limit system surveys

Probing the CGM in a more statistical fashion

Lyman limit systems and the circumgalactic medium

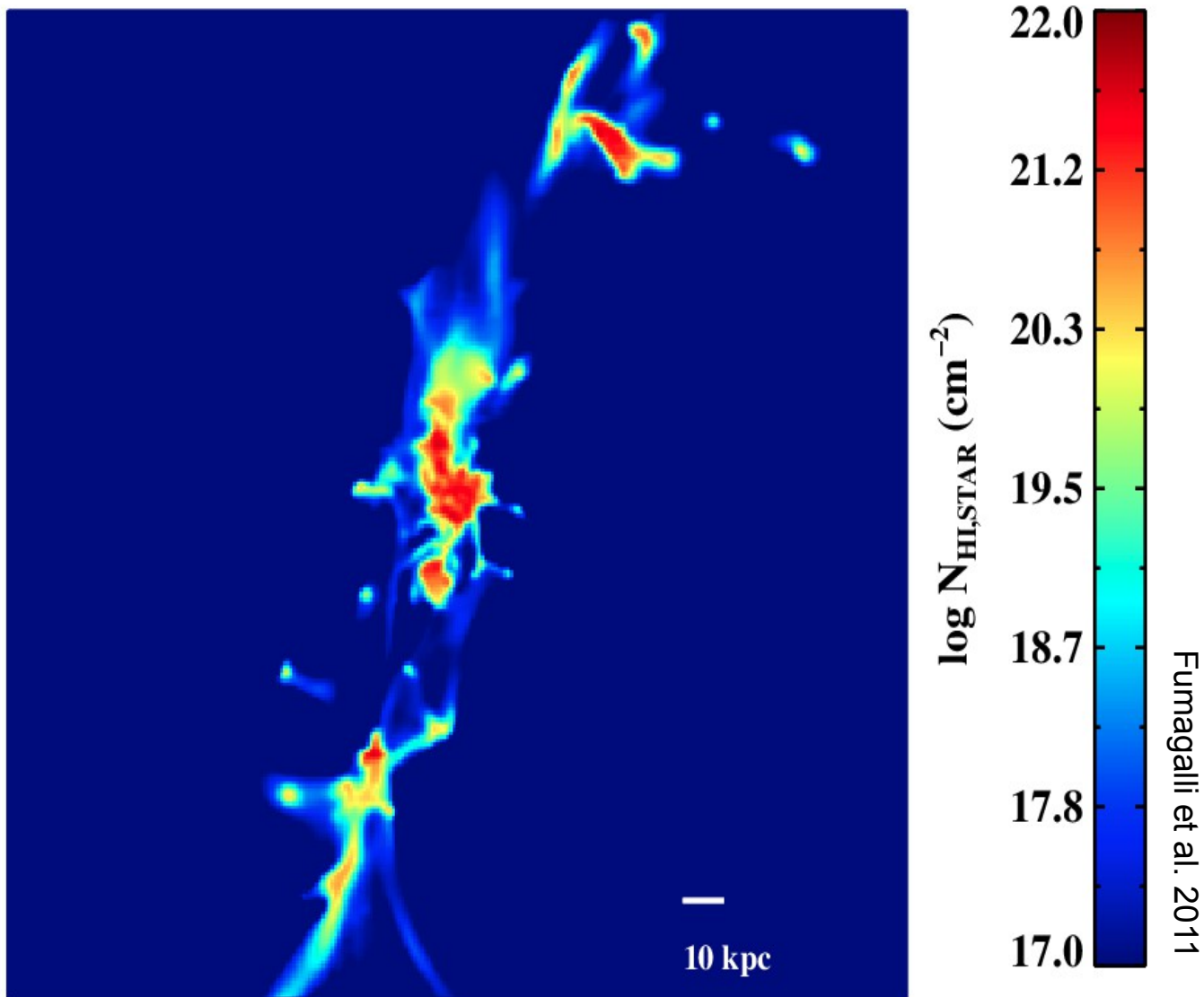
The link between LLSs and the CGM

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



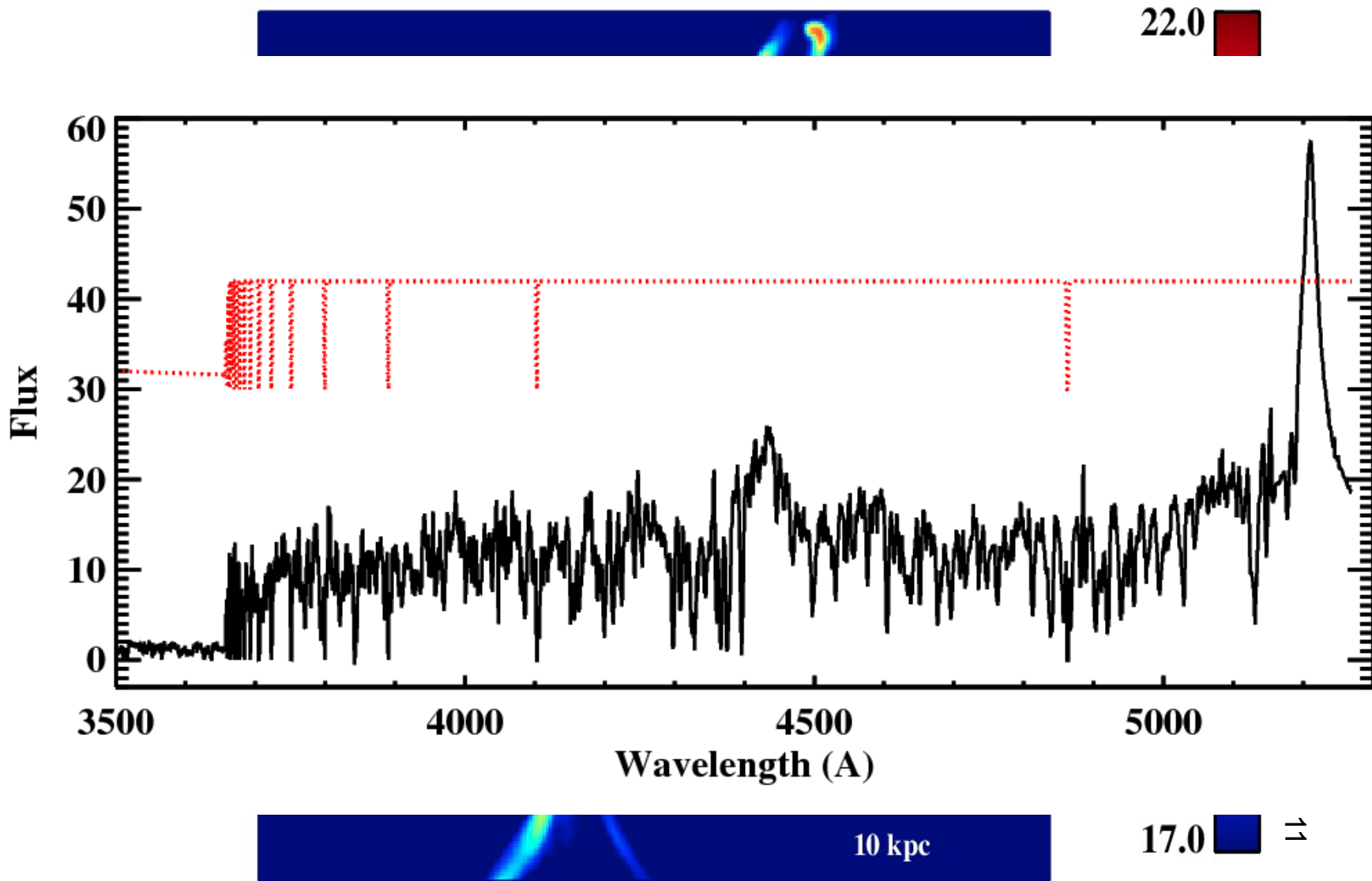
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The link between LLSs and the CGM

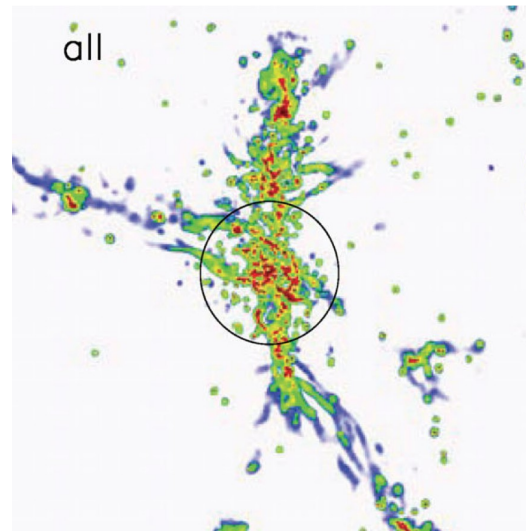
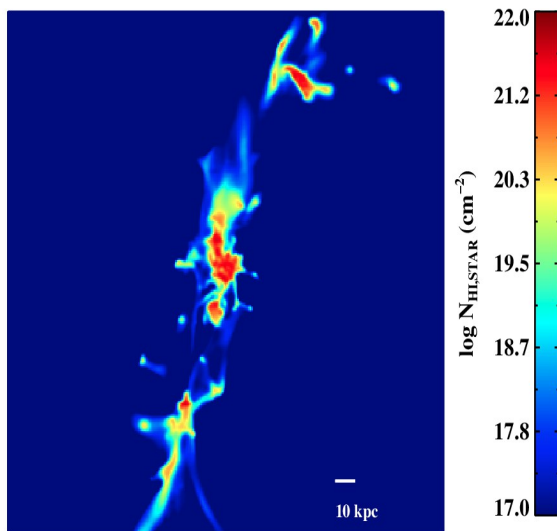
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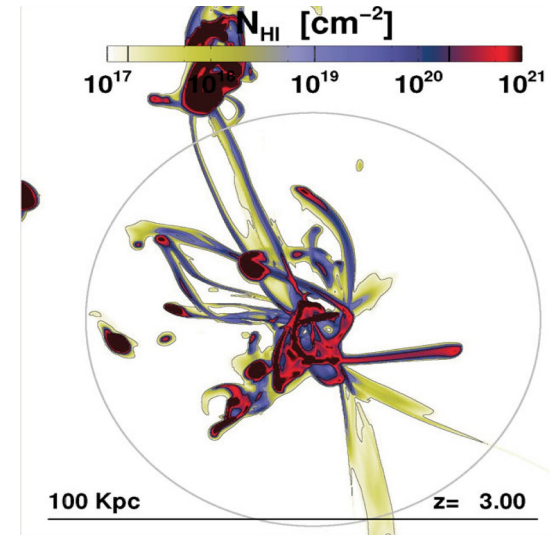
The link between LLSs and the CGM

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

Fumagalli et al. 2011

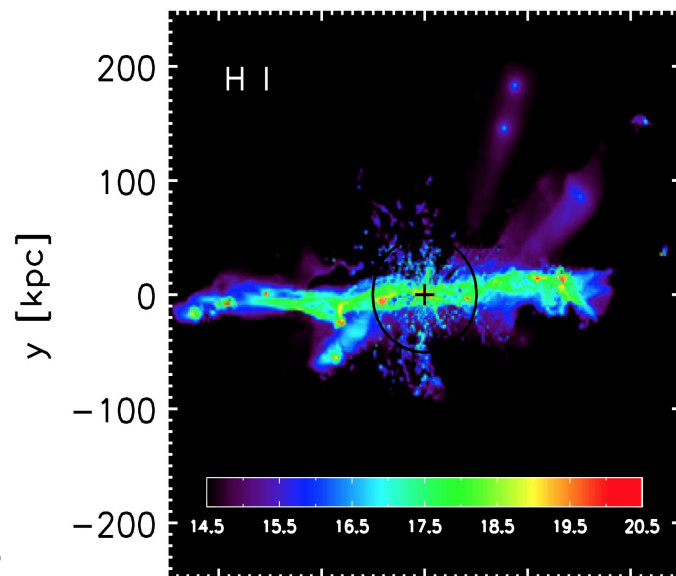
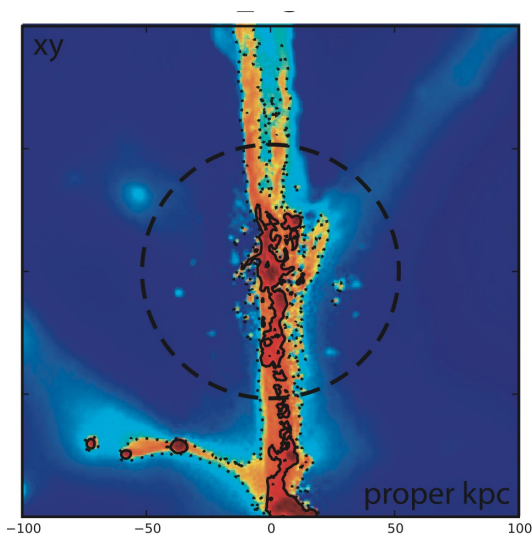


van de Voort et al. 2012

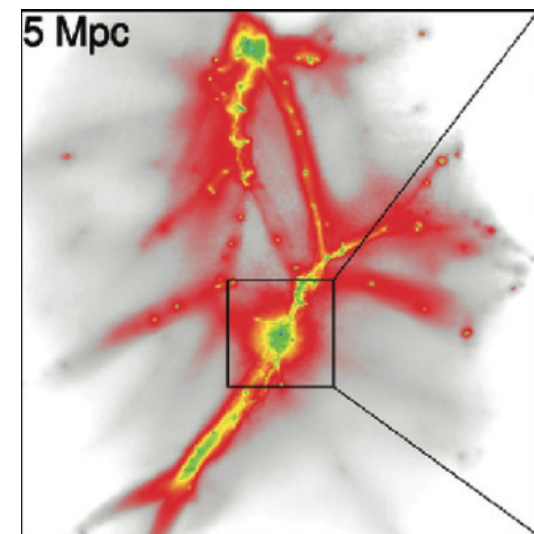


Rosdahl et al. 2012

Faucher-Giguère et al. 2011



Shen et al. 2013

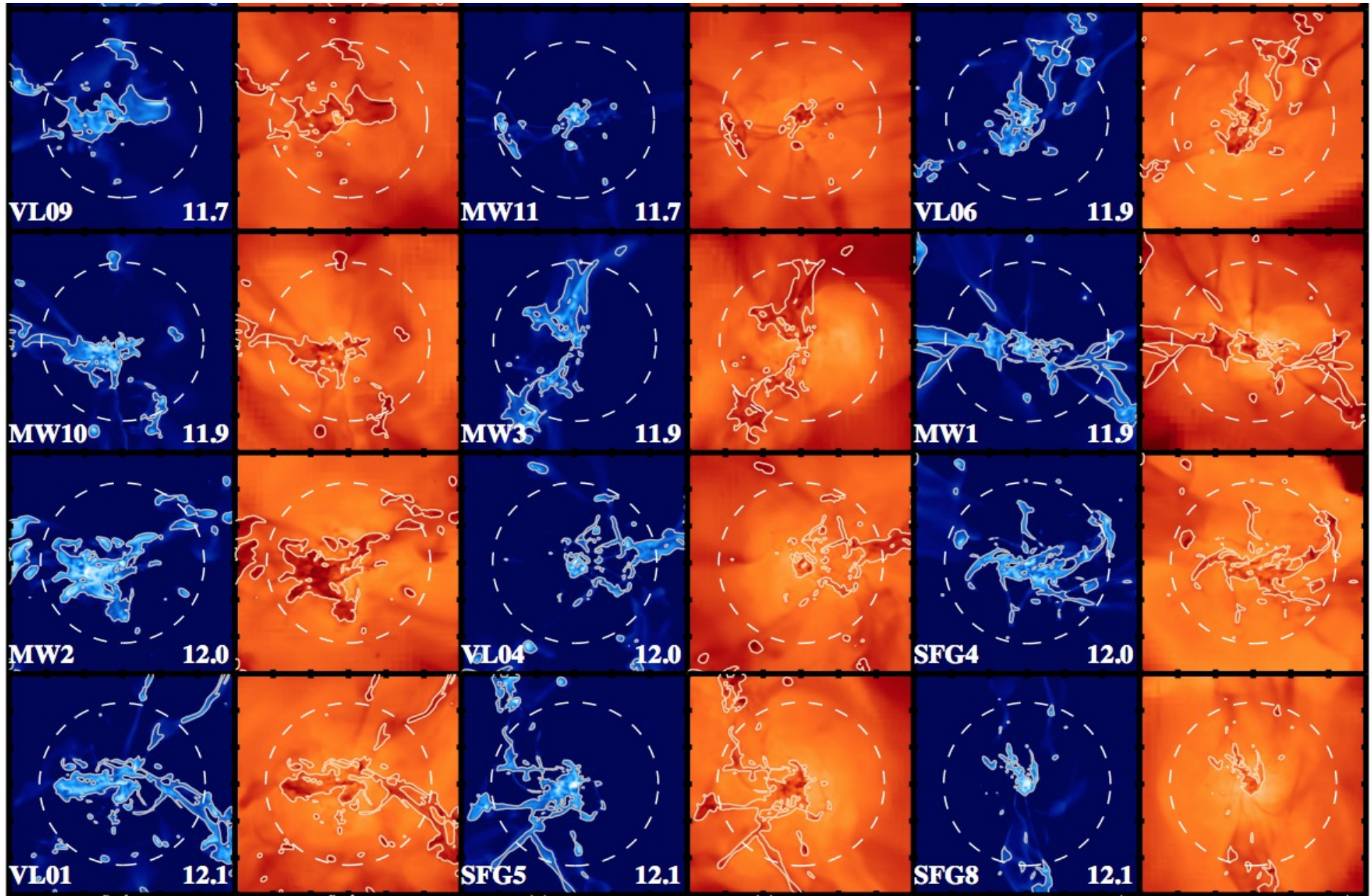


Stewart et al. 2011

Optically-thick hydrogen in massive galaxies

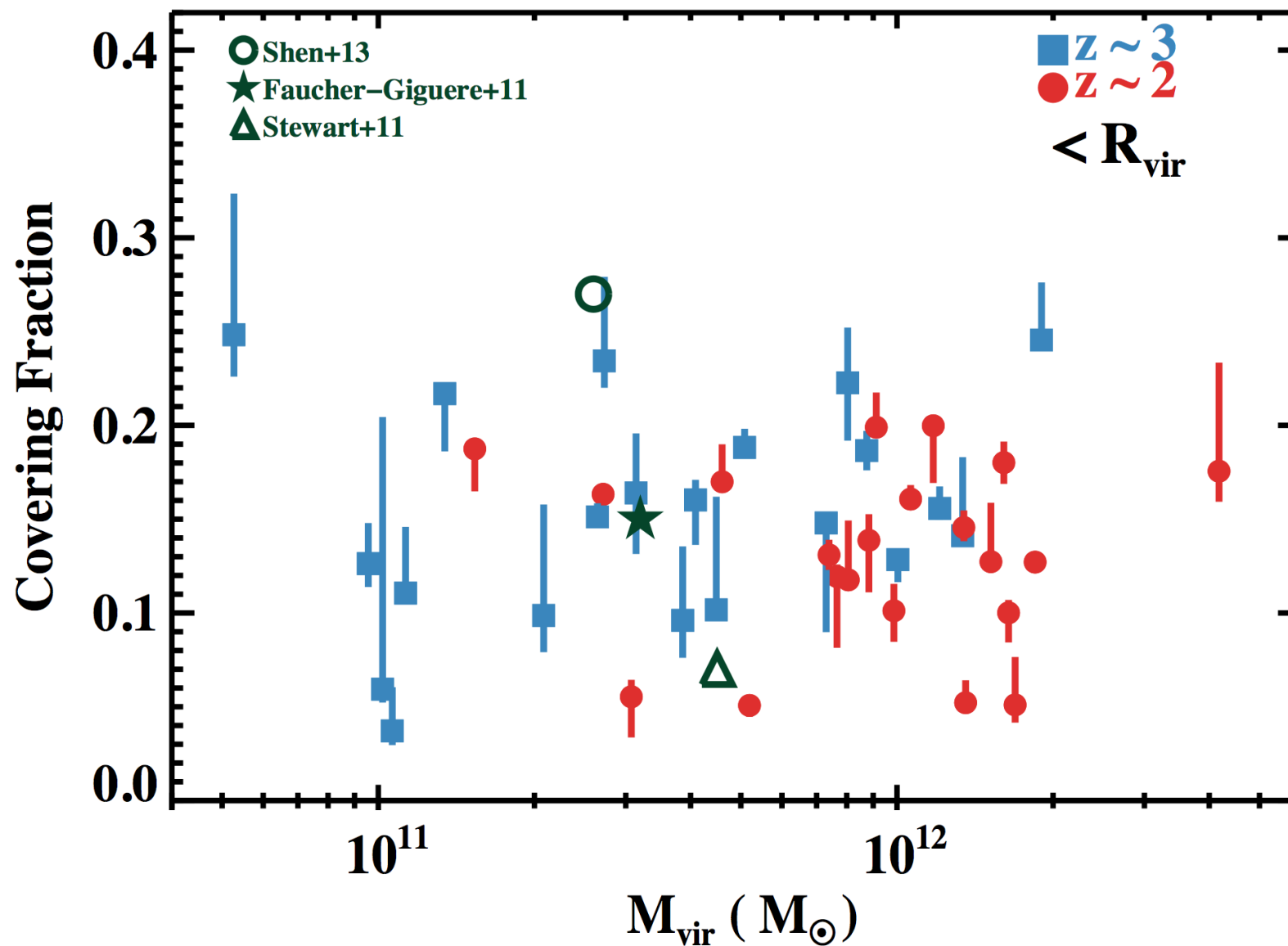
The covering fraction of optically thick gas

We investigate the hydrogen distribution in 21 simulations at $z \sim 2$ and $z \sim 3$



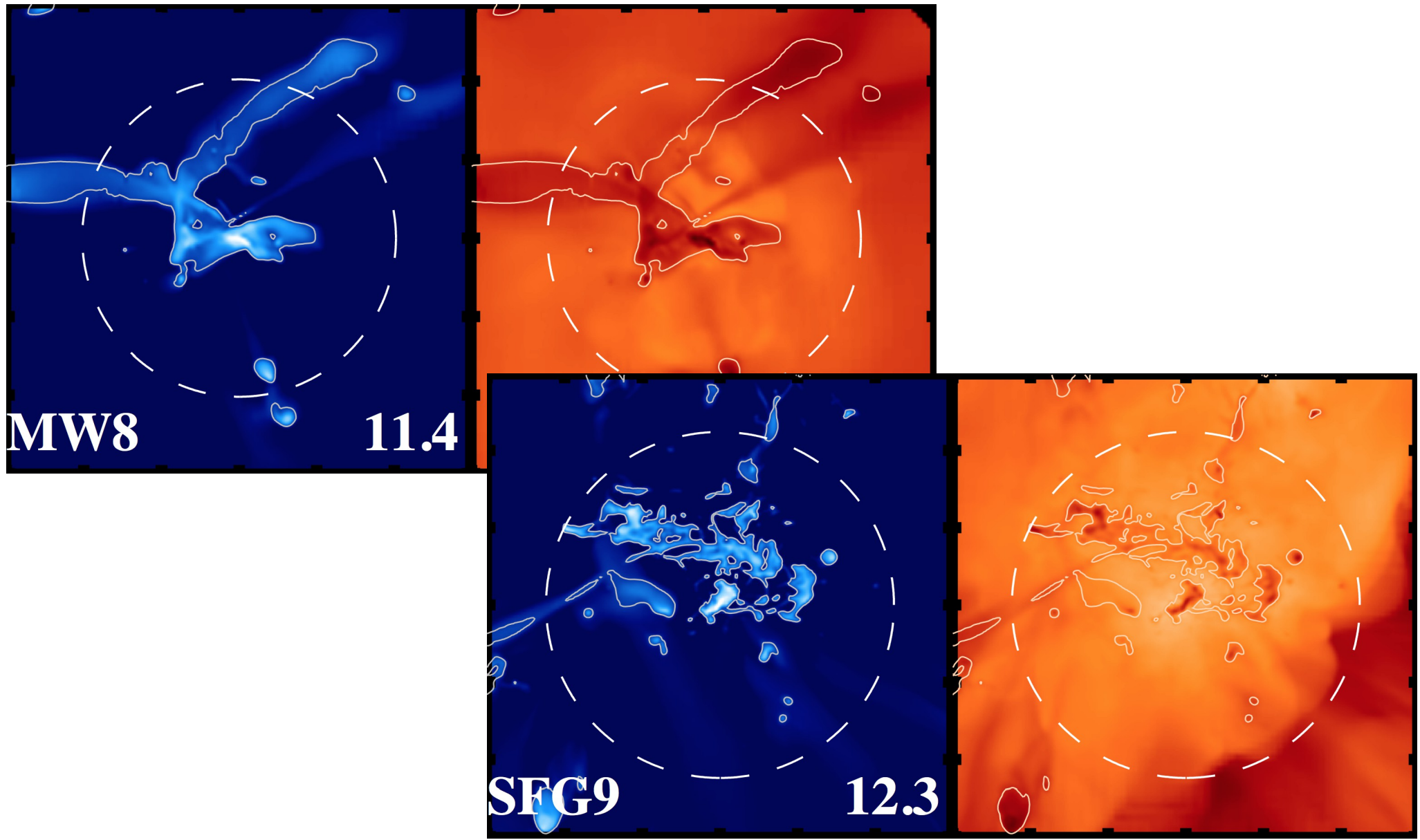
The covering fraction of optically thick gas

Simulations predict a low, mass-independent covering fraction of optically thick gas between $z \sim 2-3$



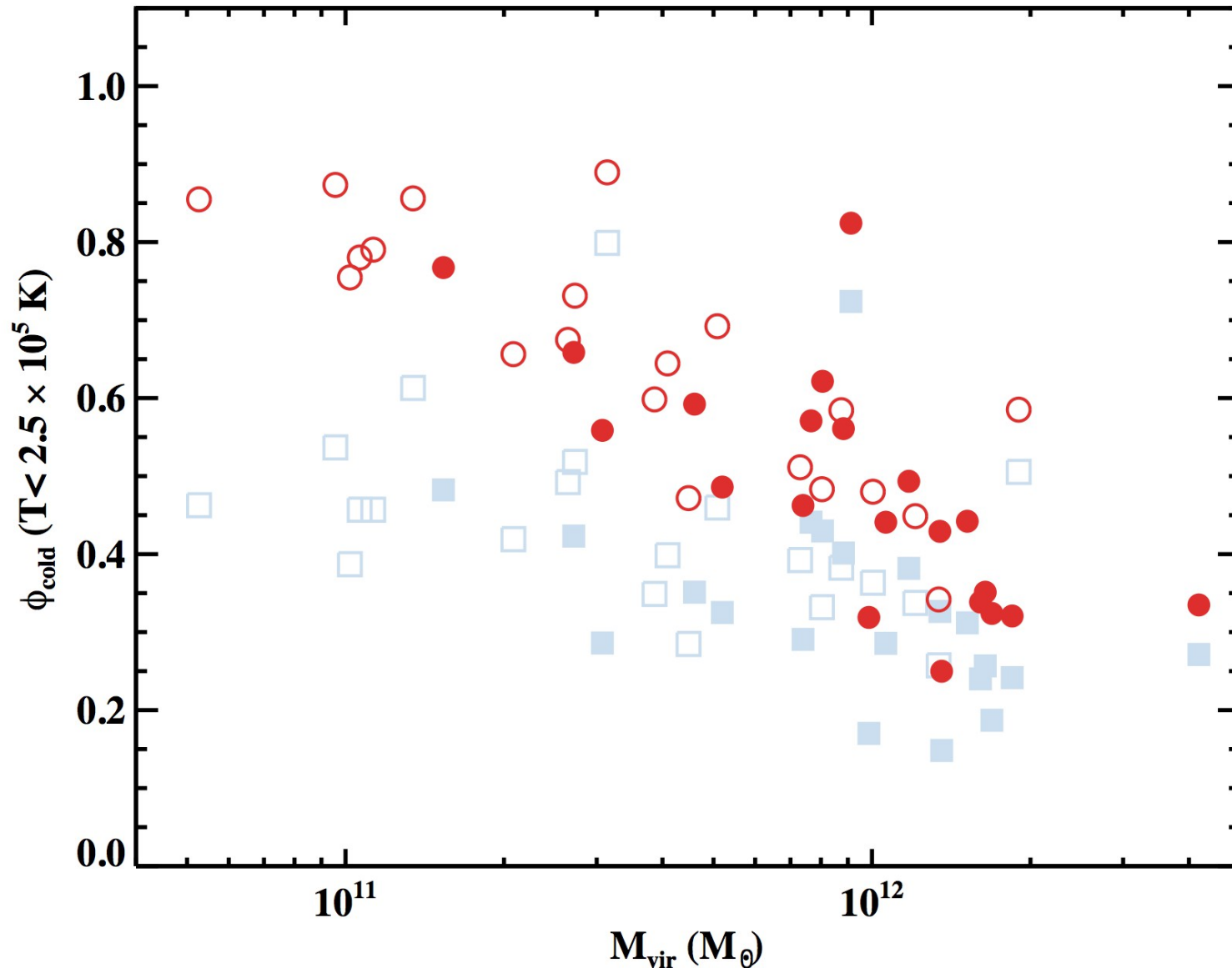
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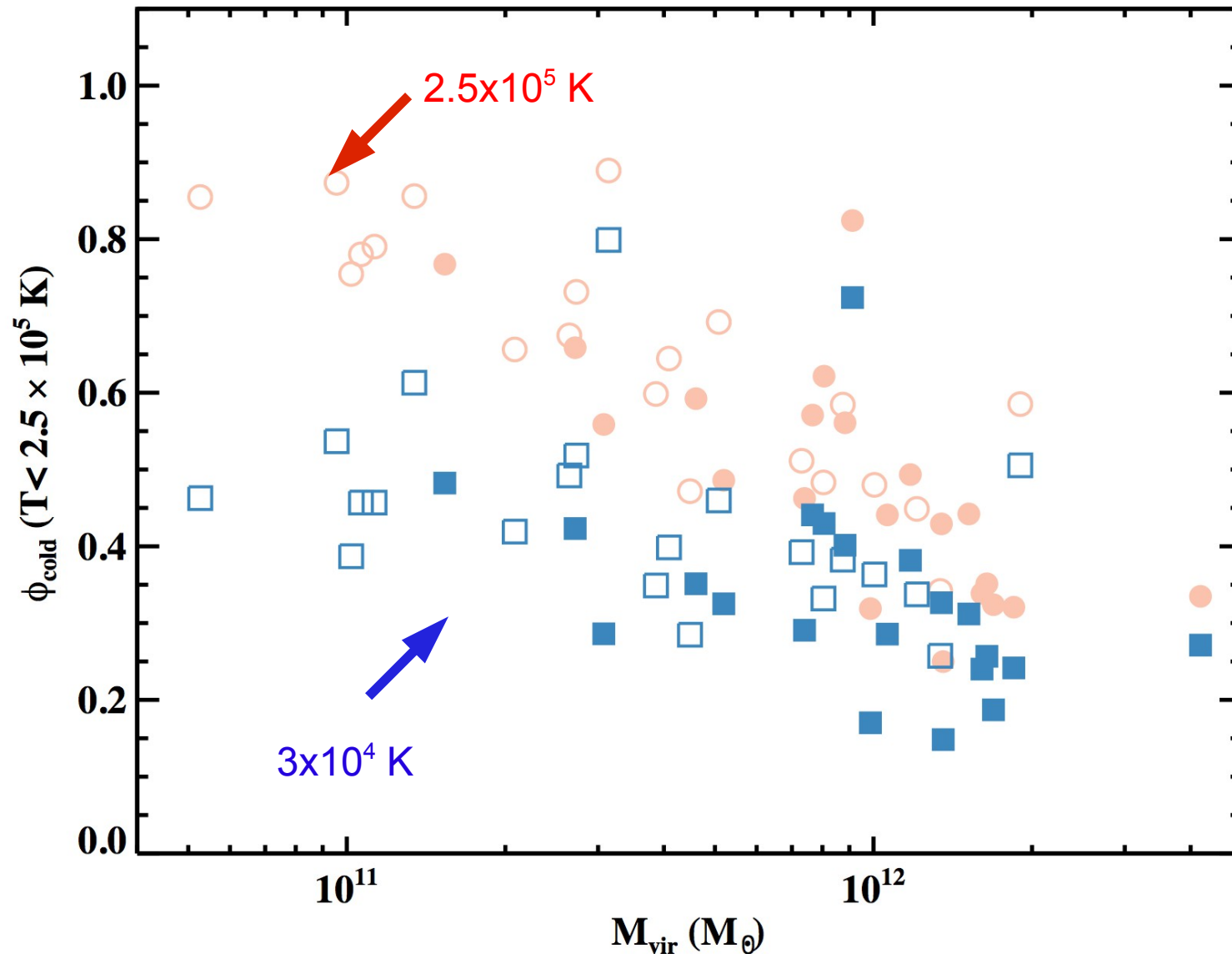
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Fumagalli et al. 2013b

The covering fraction of optically thick gas

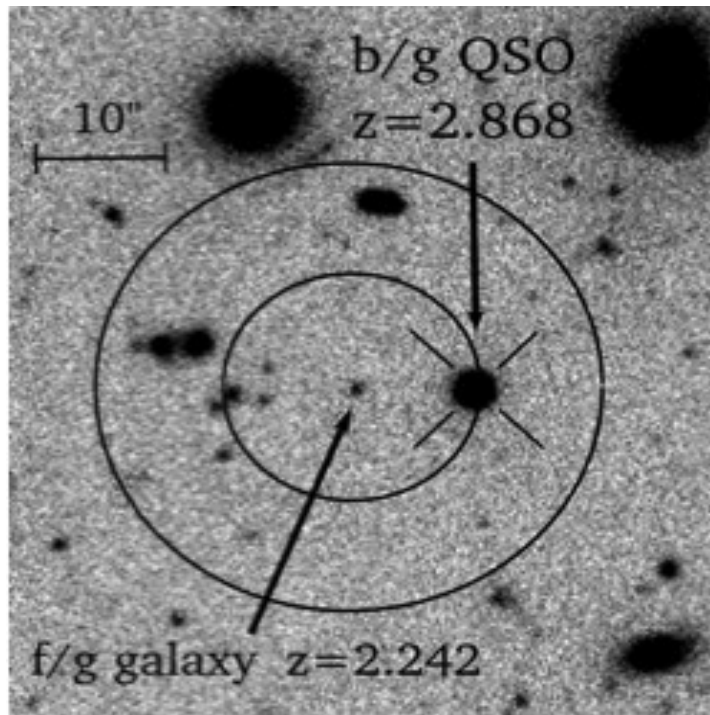
Simulations predict a low, mass-independent covering fraction of optically thick gas between $z \sim 2-3$



Samples of galaxy-quasar pairs

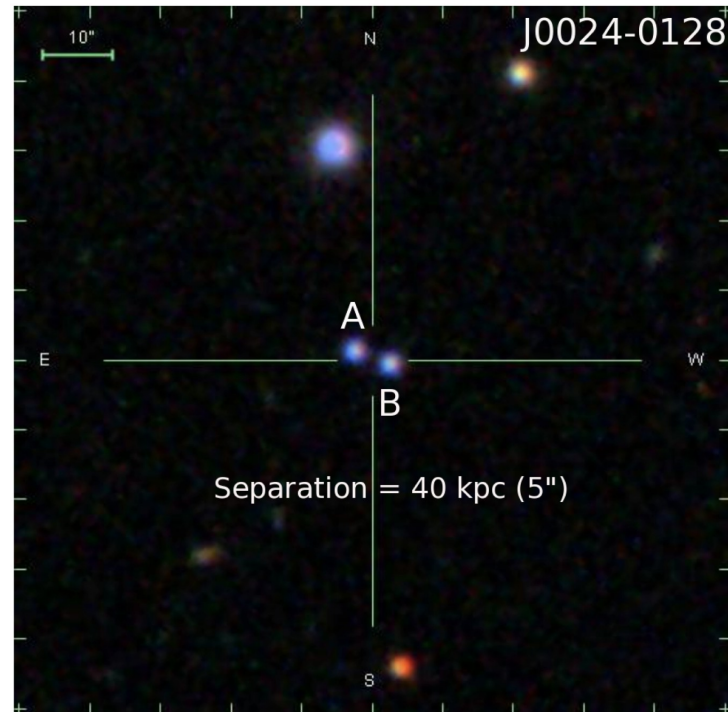
Observations of galaxy-quasar pairs offer a perfect experimental setup to test some of these predictions

LBG – quasar pairs



Crighton+2013

quasar host galaxy – quasar pairs

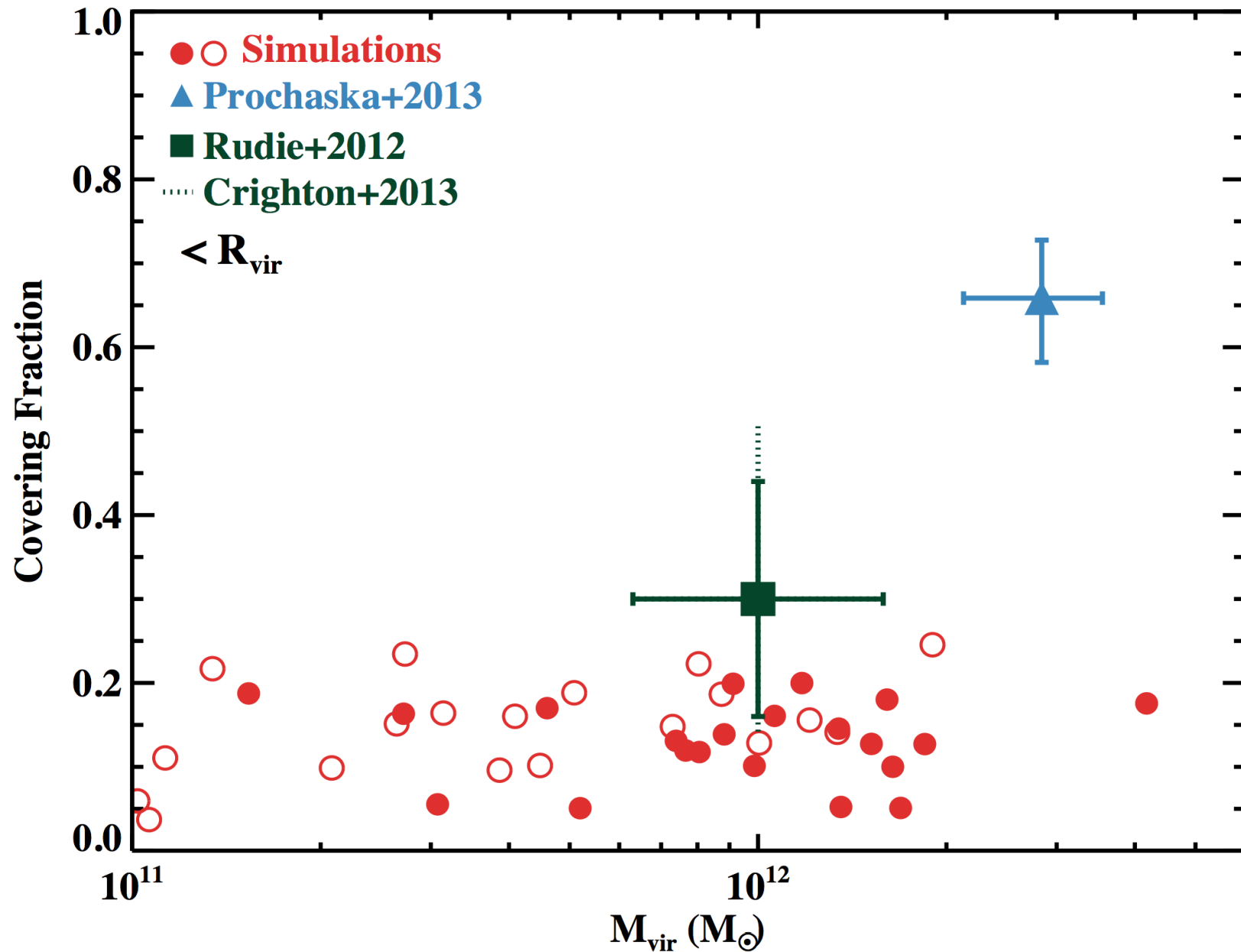


Rudie+ 2012:
Keck Baryonic Structure Survey
Crighton+; Bielby+:
VLT-LBG survey

Hennawi&Prochaska et al.:
Quasars Probing Quasars I. - VI.

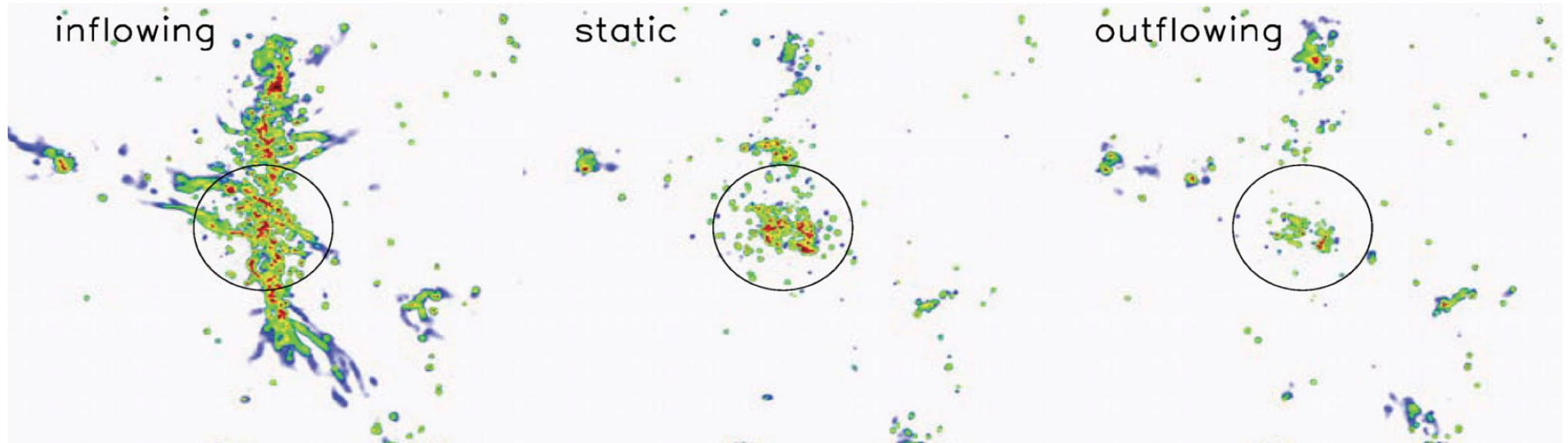
The covering fraction of optically thick gas

Simulations underestimate the covering fraction around massive halos

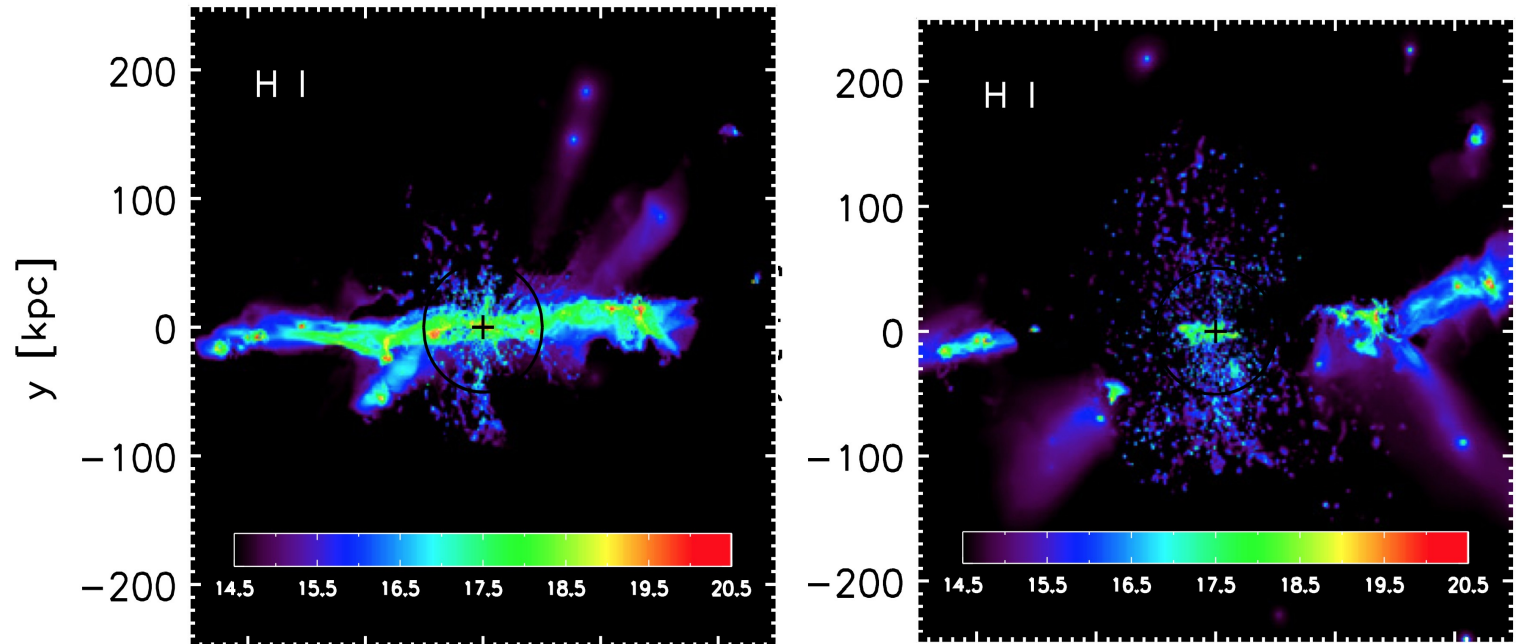


Does feedback matter?

The majority of the cross section is in inflowing gas. So, maybe not.



van de Voort et al. 2012

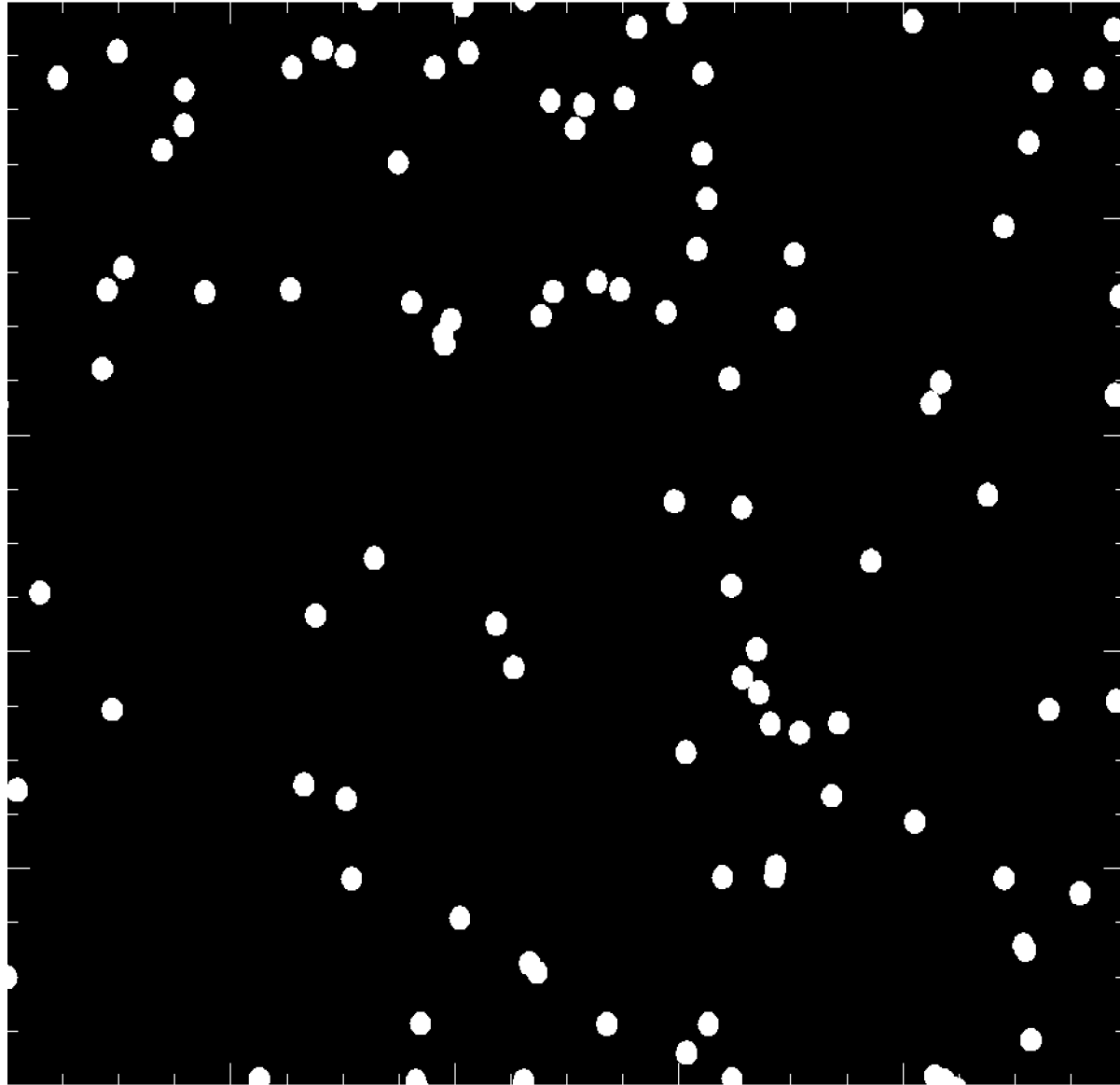


Shen et al. 2013

Moving forward:
The LLS auto-correlation function

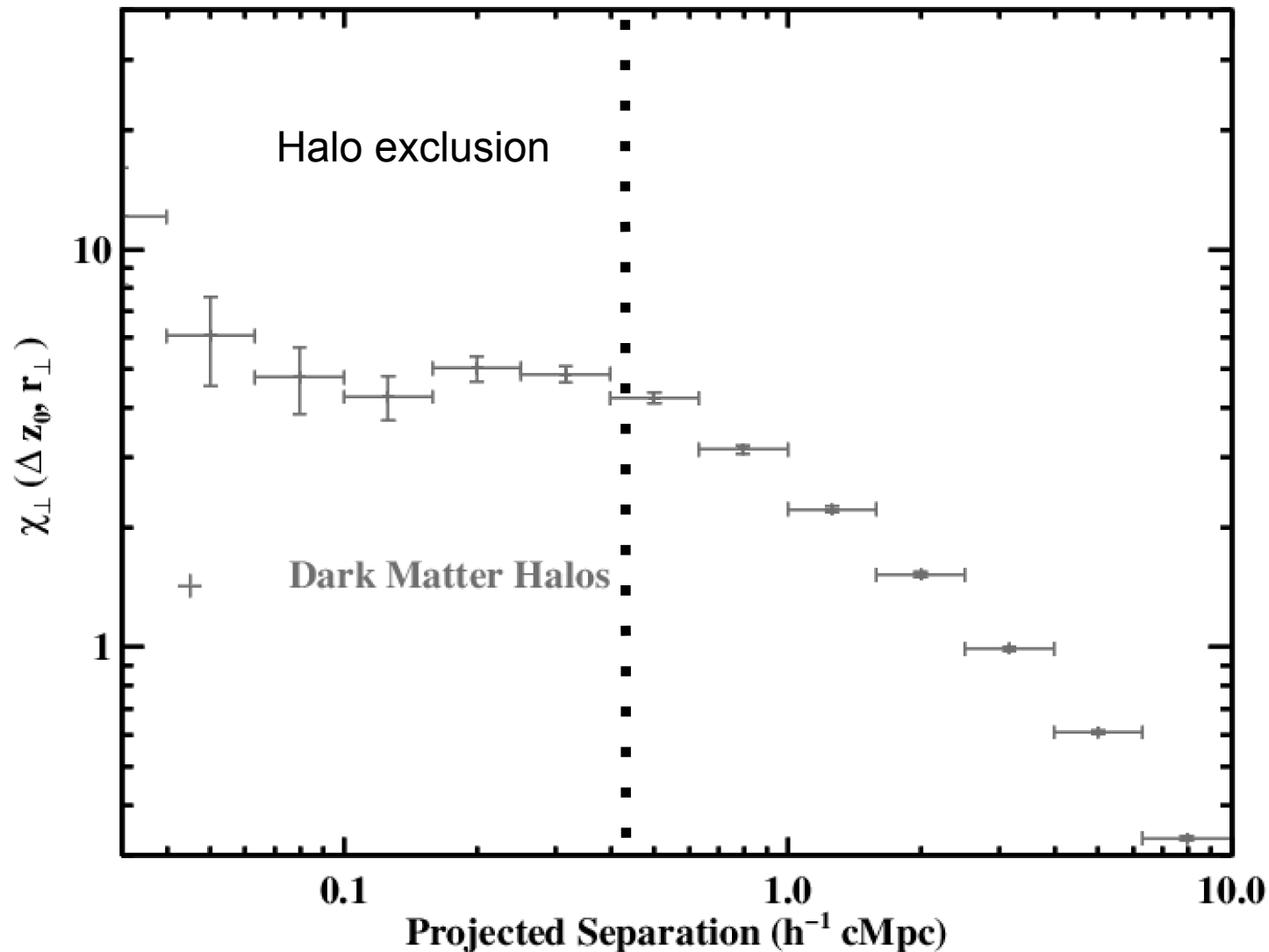
Galaxy – LLS correlation function

The covering fraction of optically-thick gas can be recast in terms of the galaxy-LLS cross-correlation function



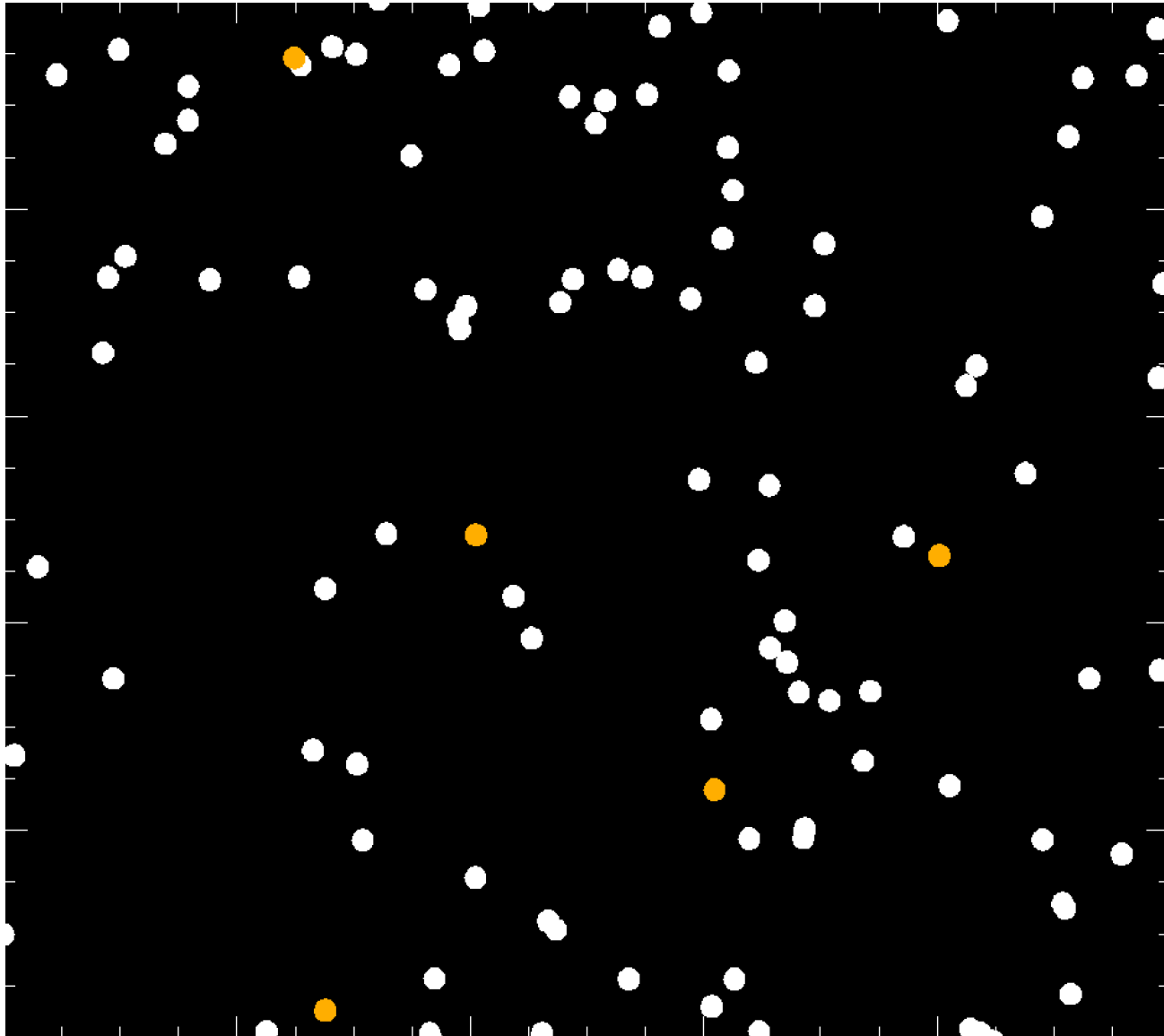
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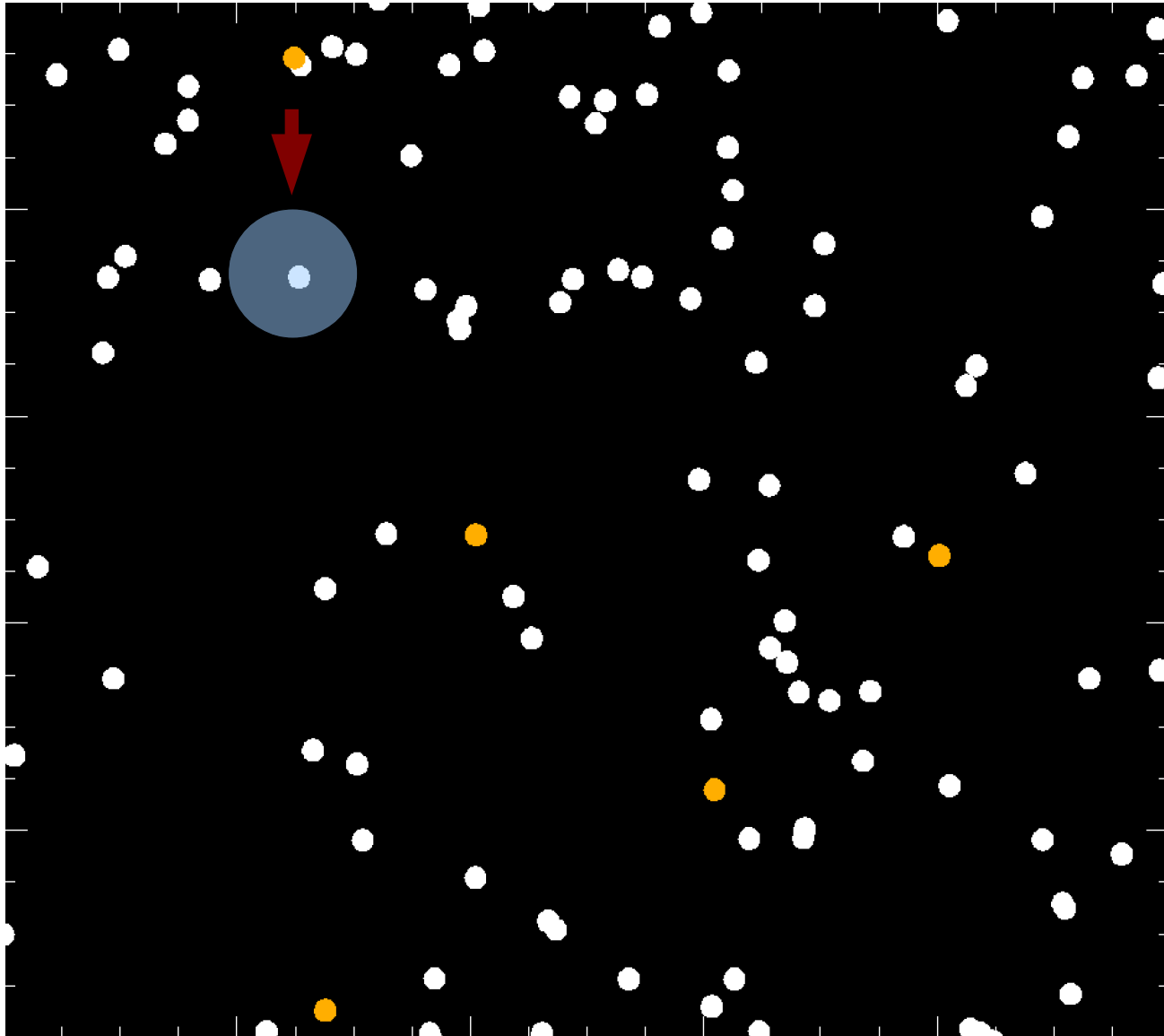
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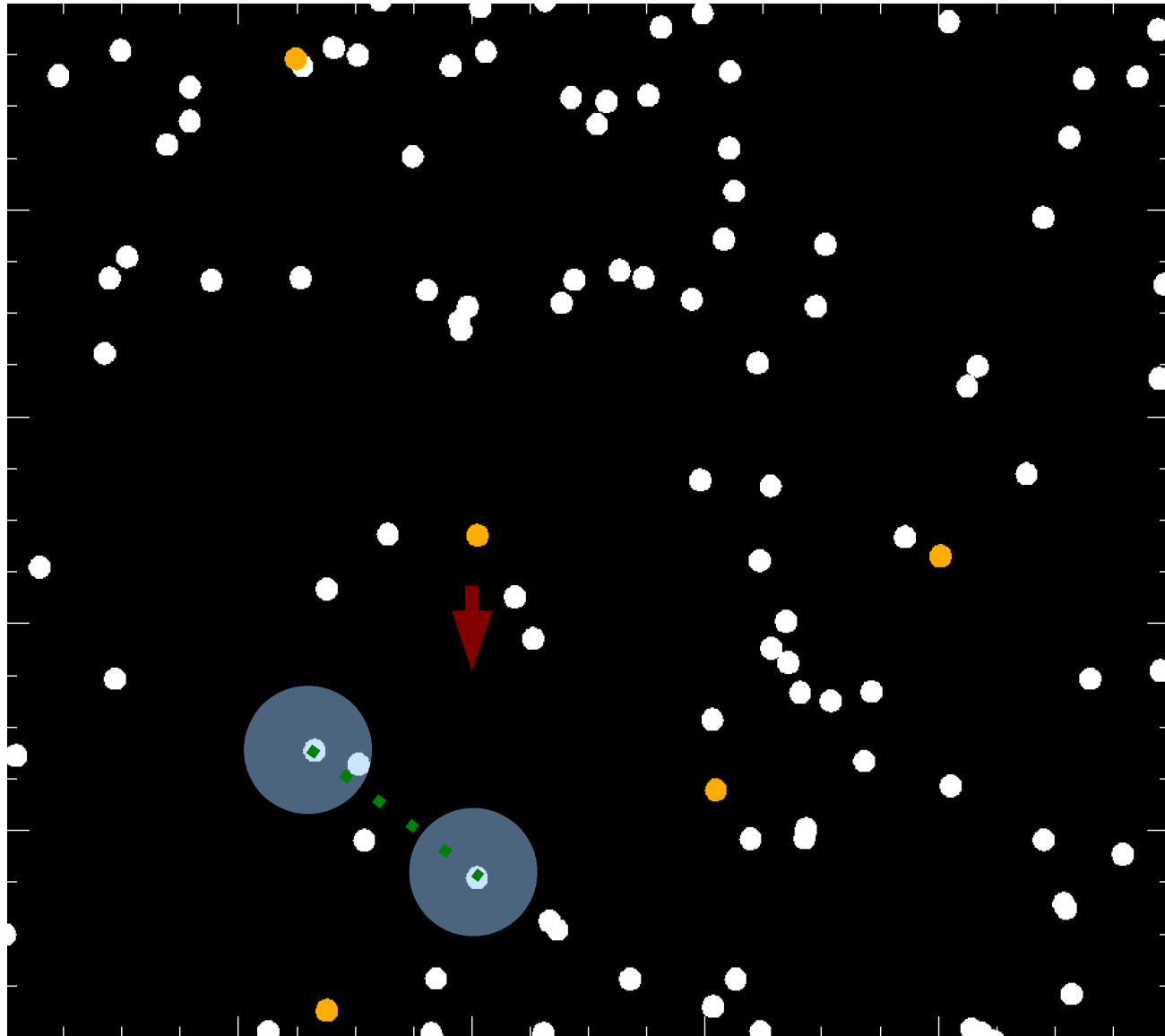
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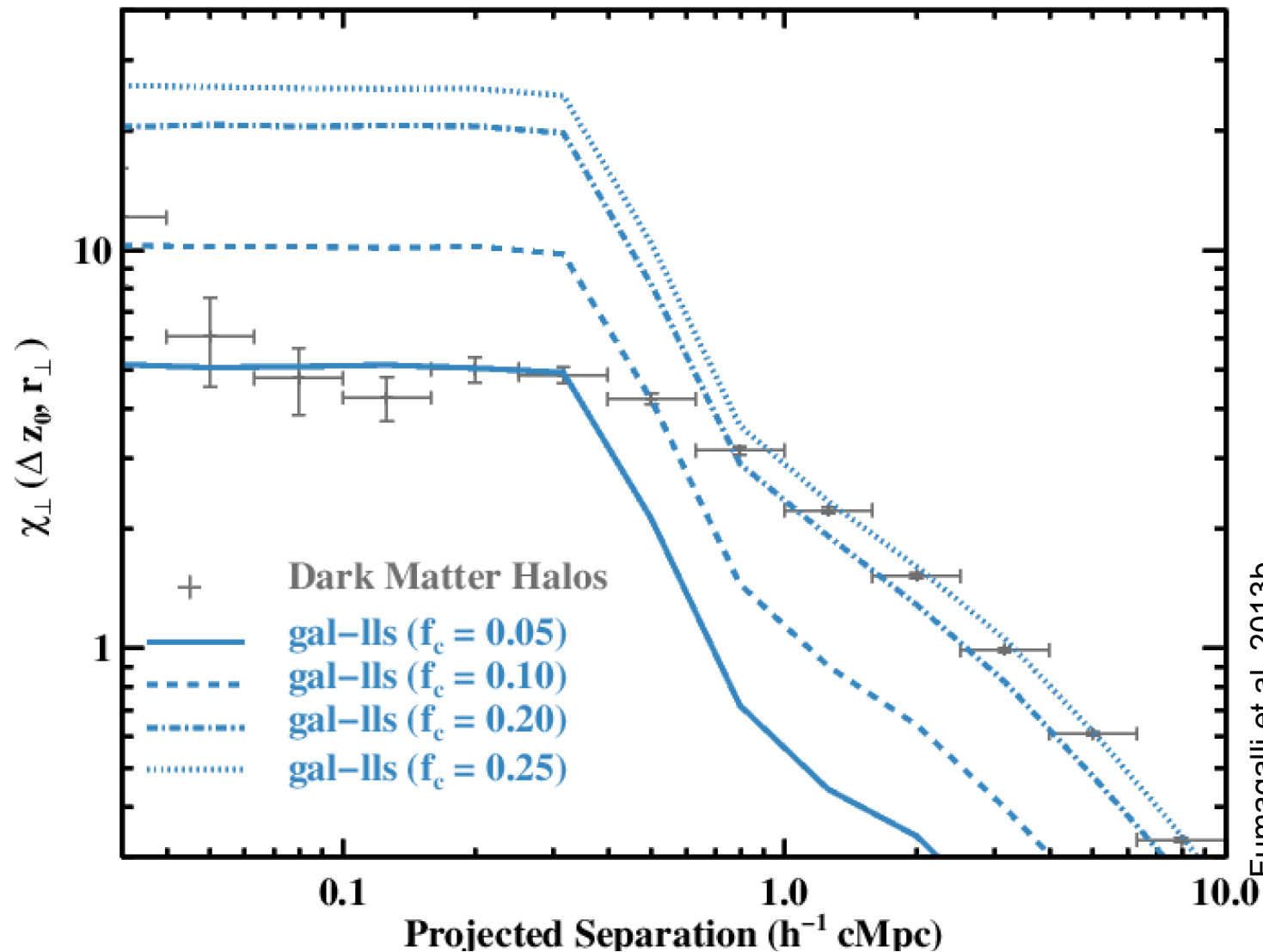
Galaxy – quasar correlation function

The covering fraction of optically-thick gas can be recast in terms of the galaxy-quasar cross-correlation function



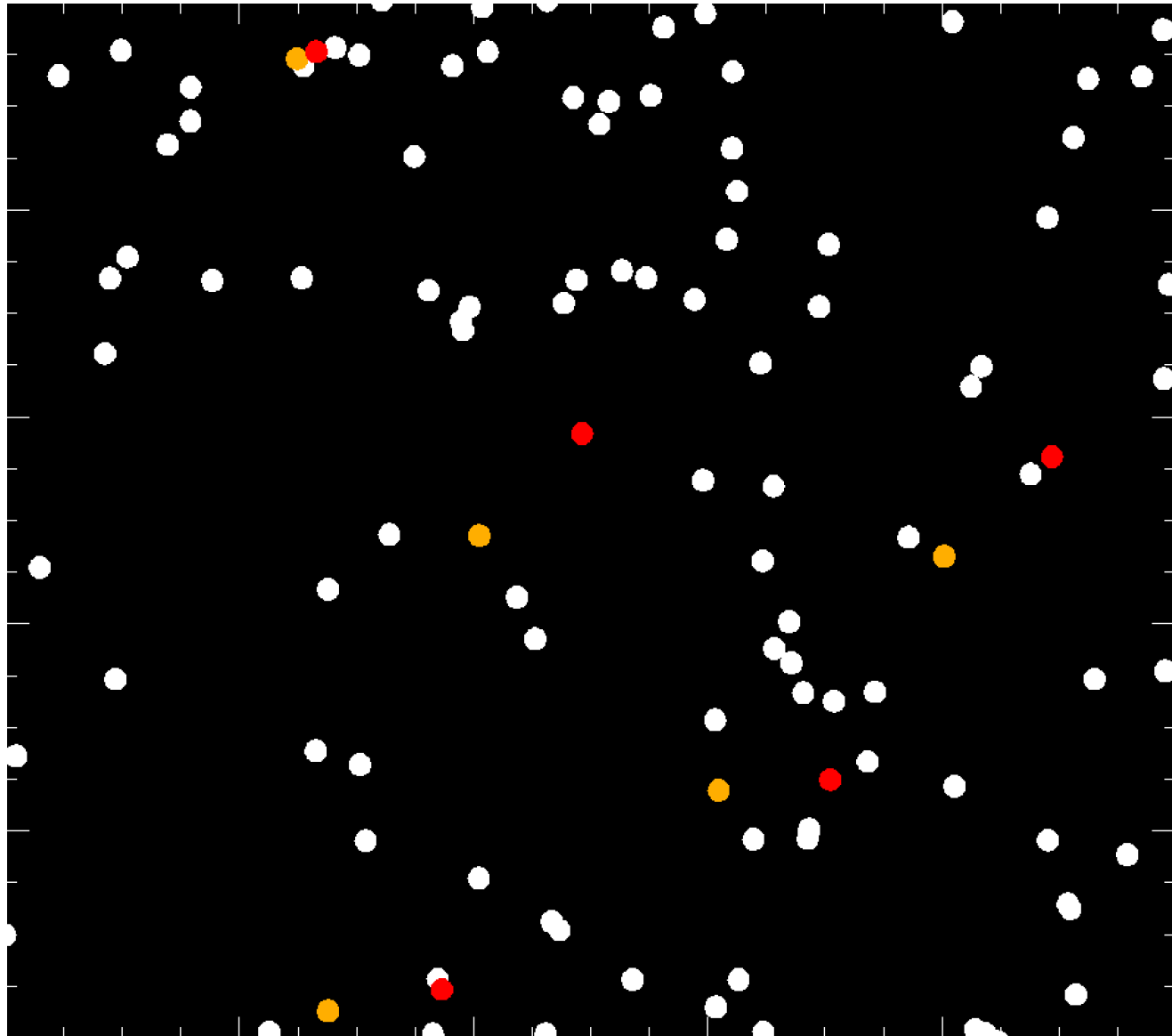
Galaxy – LLS correlation function

The covering fraction of optically-thick gas can be recast in terms of the galaxy-LLS cross-correlation function



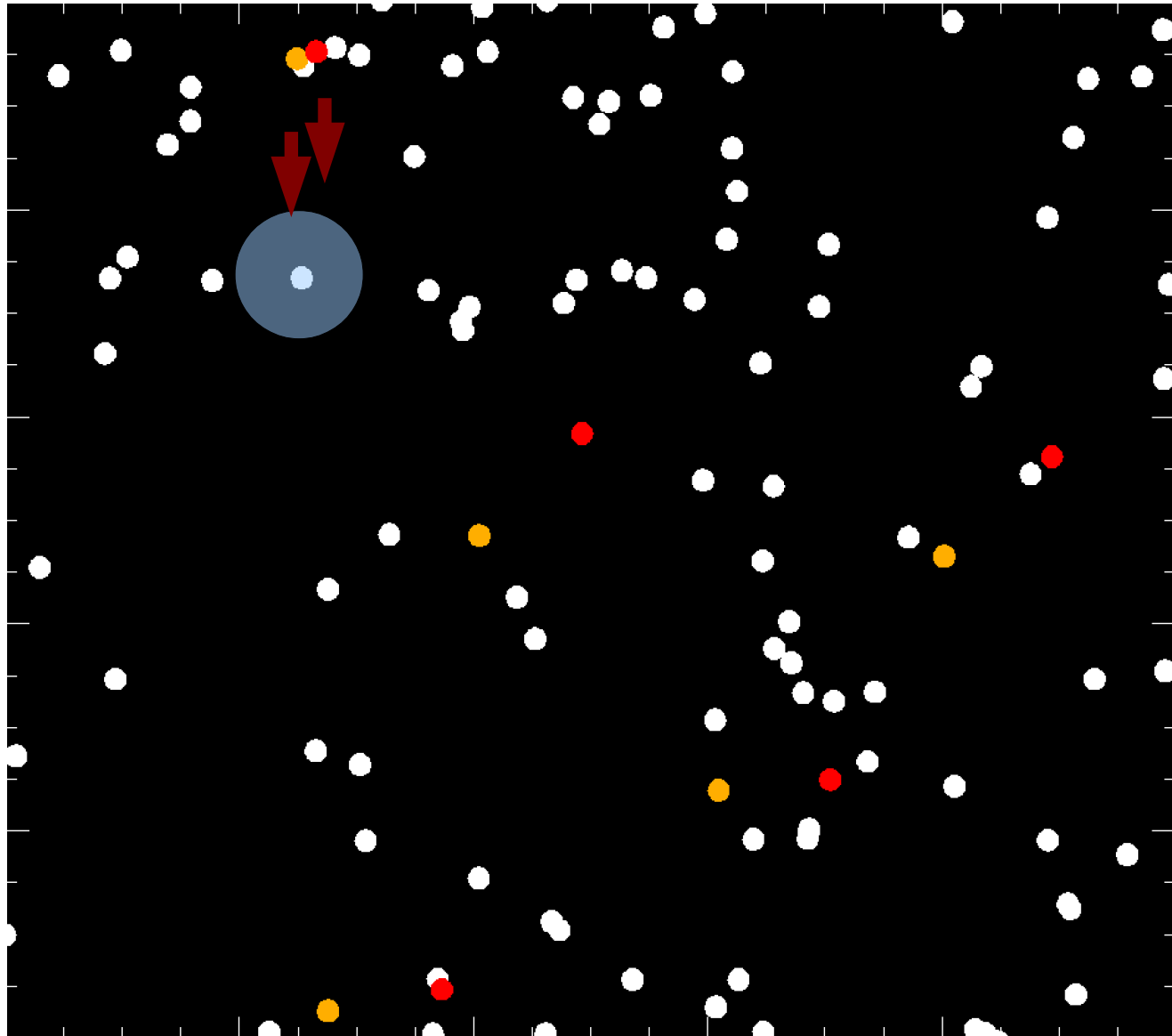
LLS auto-correlation function

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



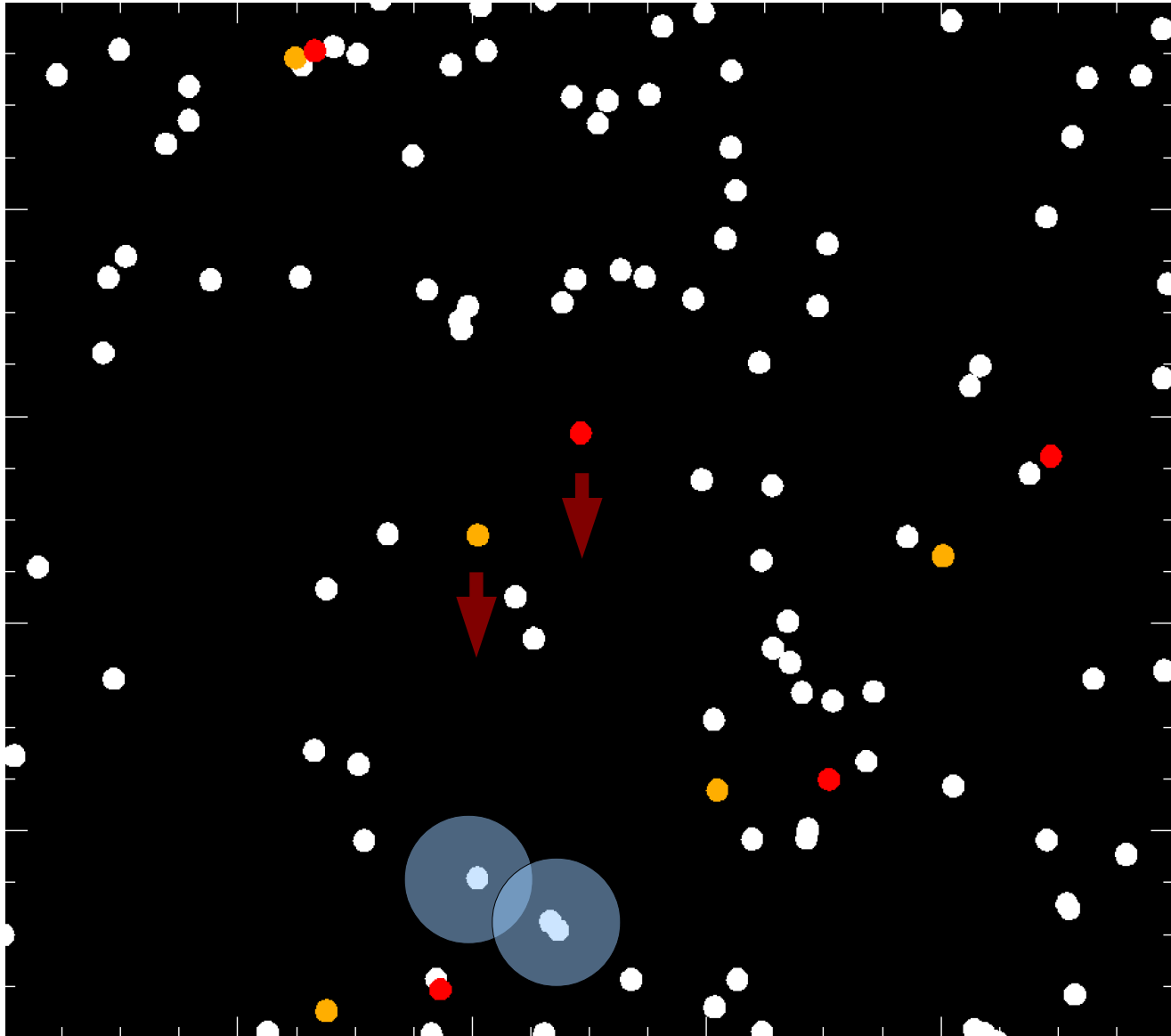
LLS auto-correlation function

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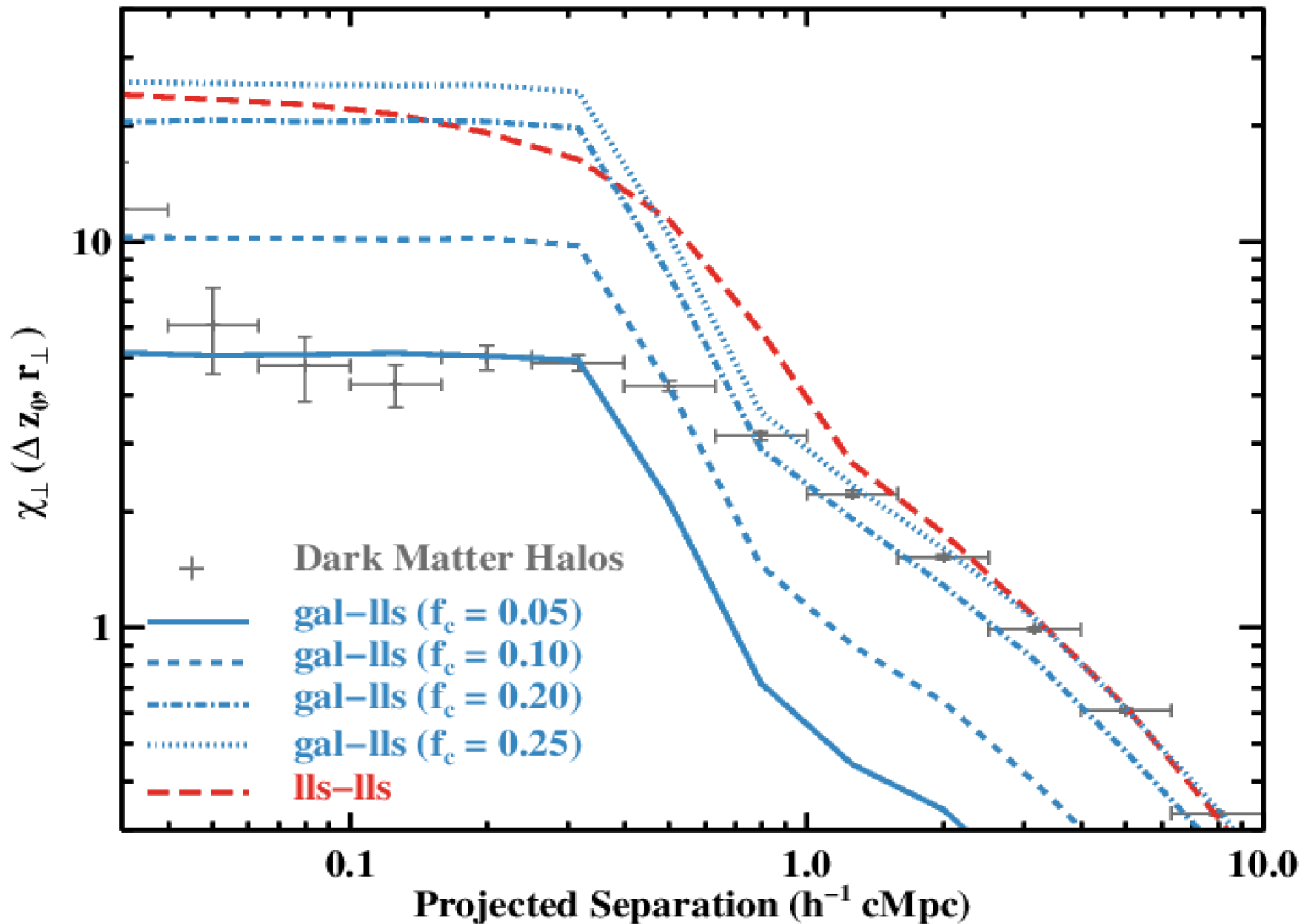
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Summary I

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Comparing simulations and observations

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A new experiment to rapidly advance our knowledge on the CGM