Empirical Constraints on the Cool Gas Content of Dark Matter Halos

Jean-René Gauthier
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Great Lakes Cosmology Workshop
Chicago, 16 June 2010

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For lower-mass halos at low z, see poster by *Jennifer Helsby*

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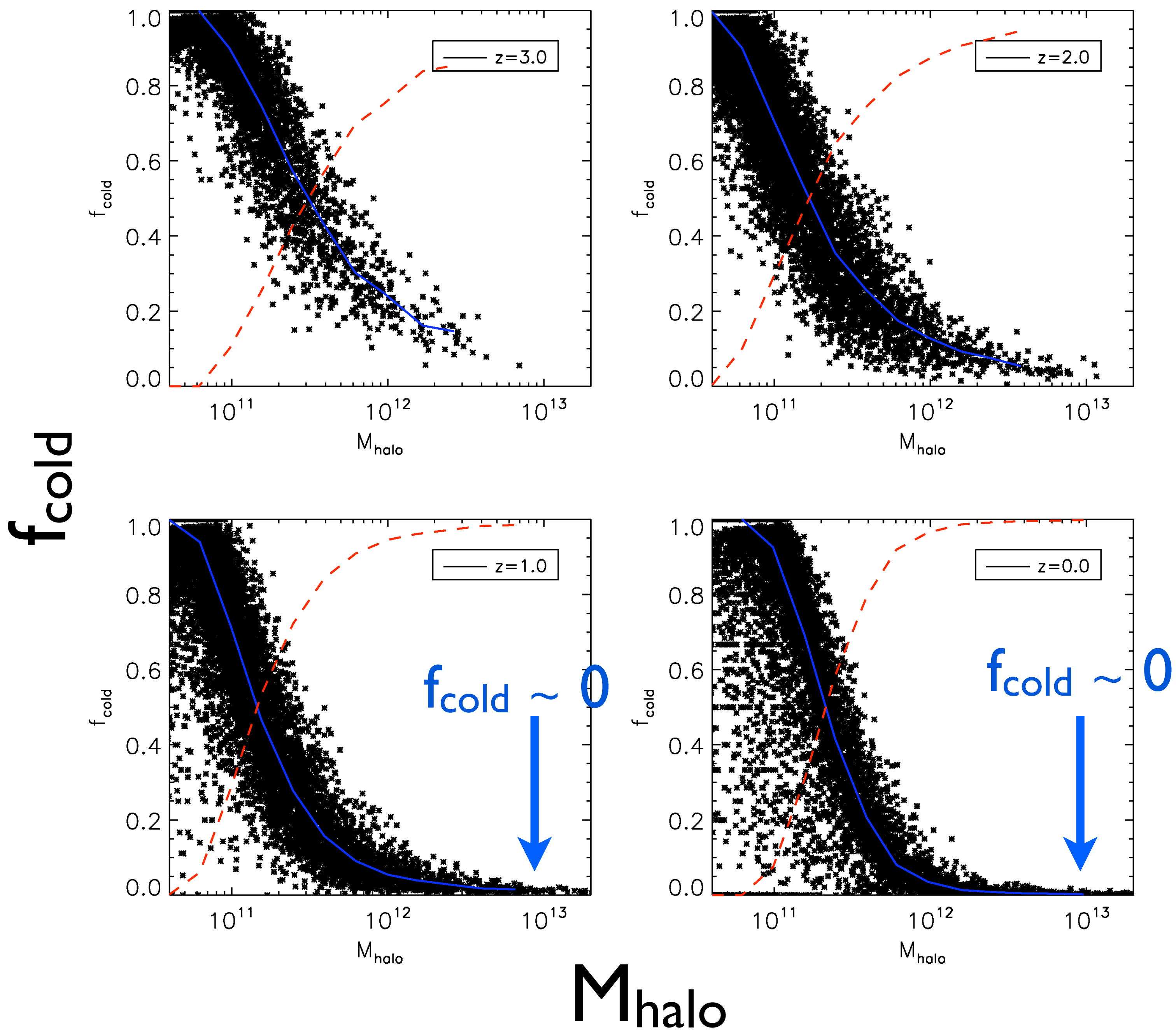
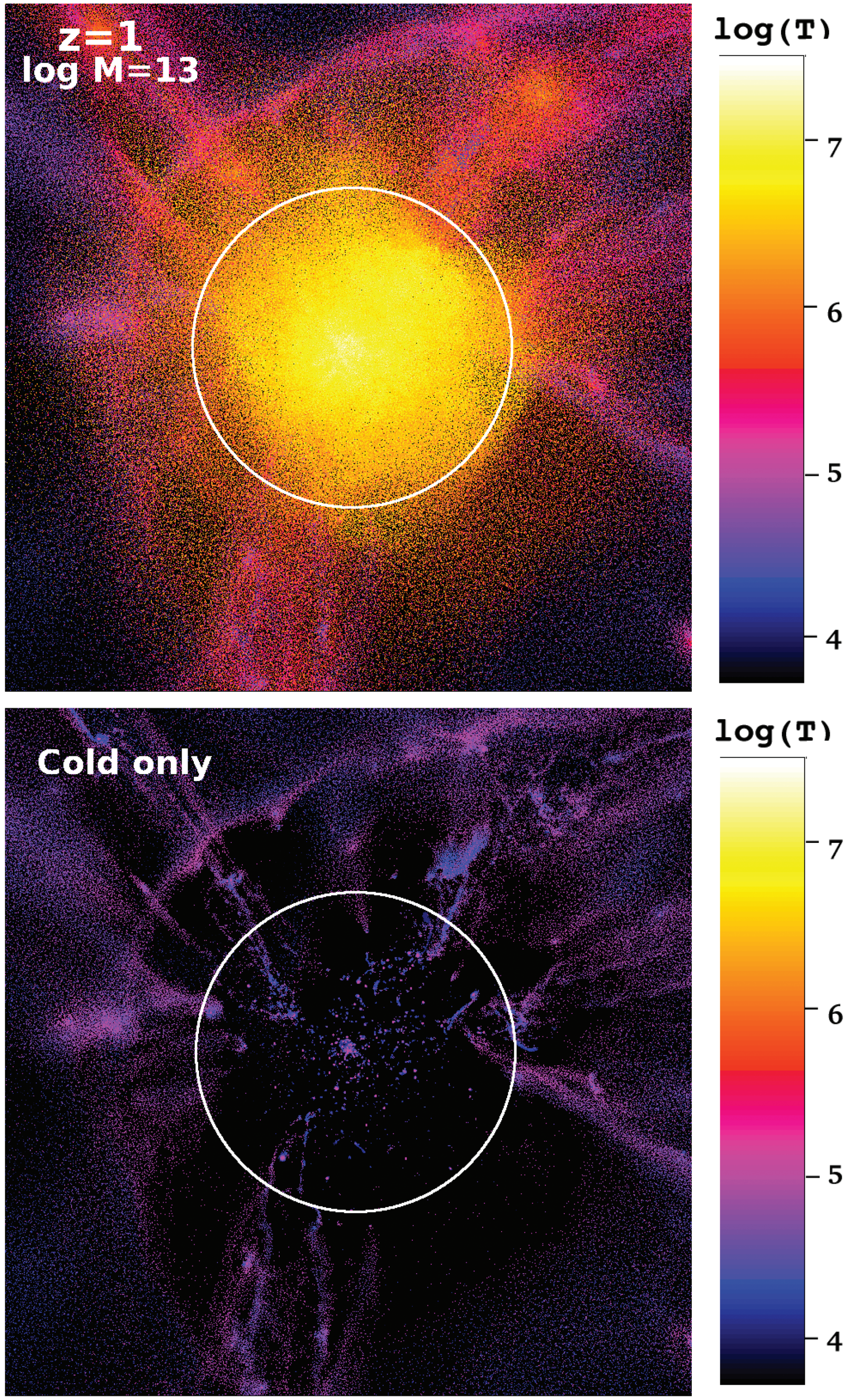
Cold Gas Accretion on Dark Matter halos

e.g. Keres et al. 2009





Accretion of cool, T~10^4 K gas, is inefficient in massive halo

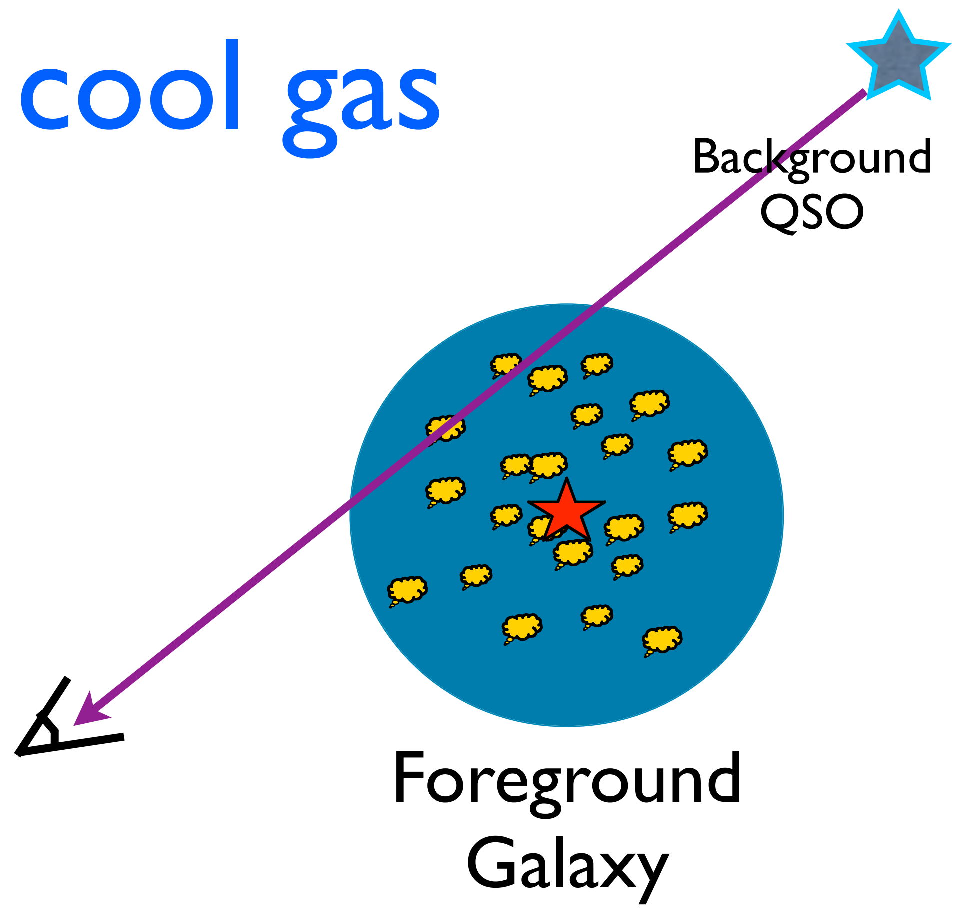
Exploring the cool gas content of dark matter halos

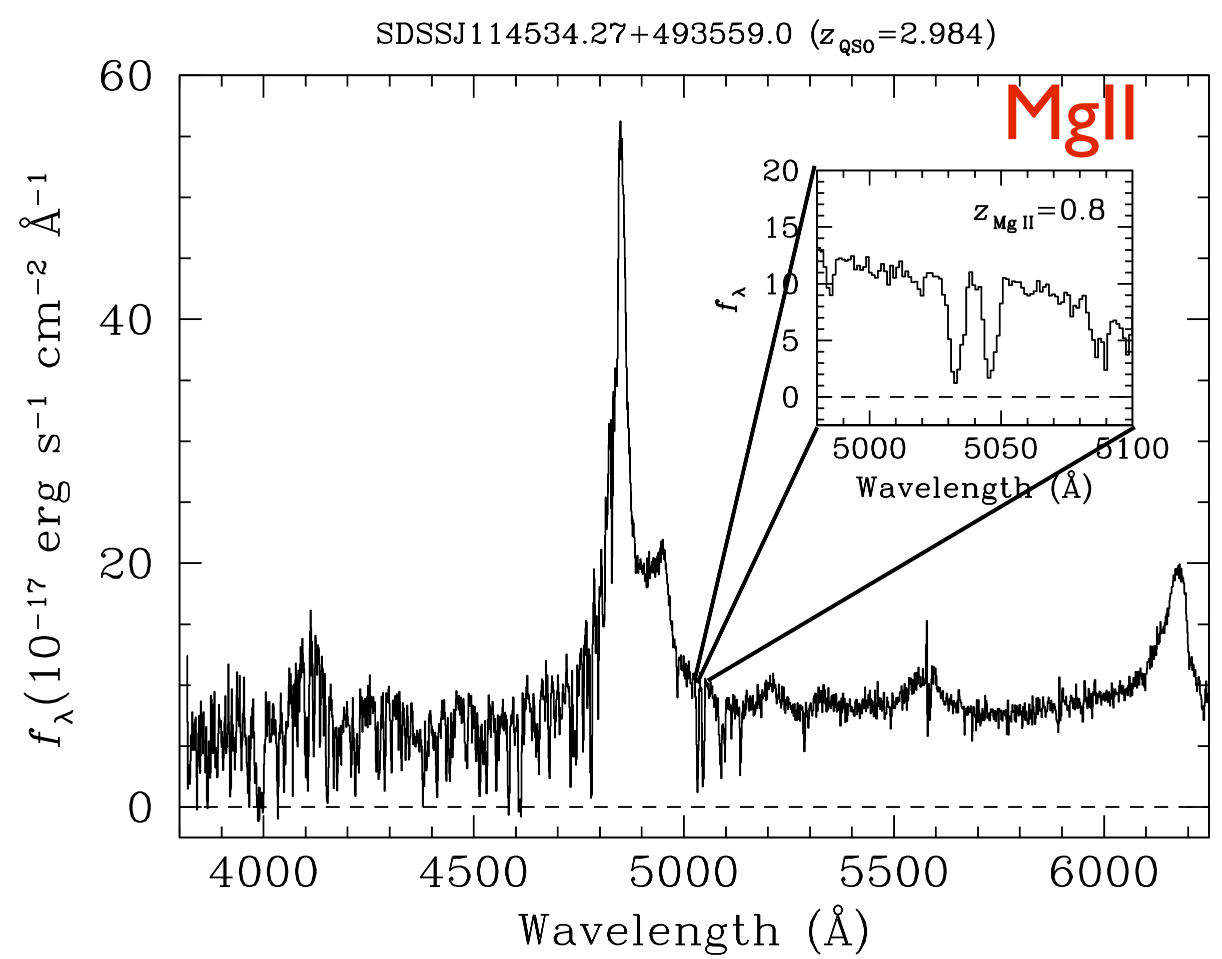
(using QSO absorption line clustering)

- Taking advantage of the large data sample of SDSS
- Need a tracer/indicator of cool gas in halos : MgII absorbers in background QSO spectra
- Need a tracer of dark matter density field : Luminous Red Galaxies

MgII absorbers as a tracer of cool gas

- MgII λλ 2796, 2803 absorption doublet is commonly seen in QSO spectra
- Absorbers arise in photo-ionized gas of T ~ 10^4 K and trace high-column density HI clouds with N(HI) ≈ 10^{18} - 10^{22} (Bergeron & Stasínska 1986; Rao et al. 2006)
- Large HI column density suggests that MgII absorbers originate in halo gas around individual galaxies (Doyle et al. 2005).
- Many luminous galaxies have been found at projected distances ρ = 50 - 100 h^{-1} kpc from *known* MgII absorbers. (Bergeron 1986; Lanzetta & Bowen 1990, 1992; Steidel et al. 1994; Zibetti et al. 2005,2007; Nestor et al. 2007; Kacprzak et al. 2007).

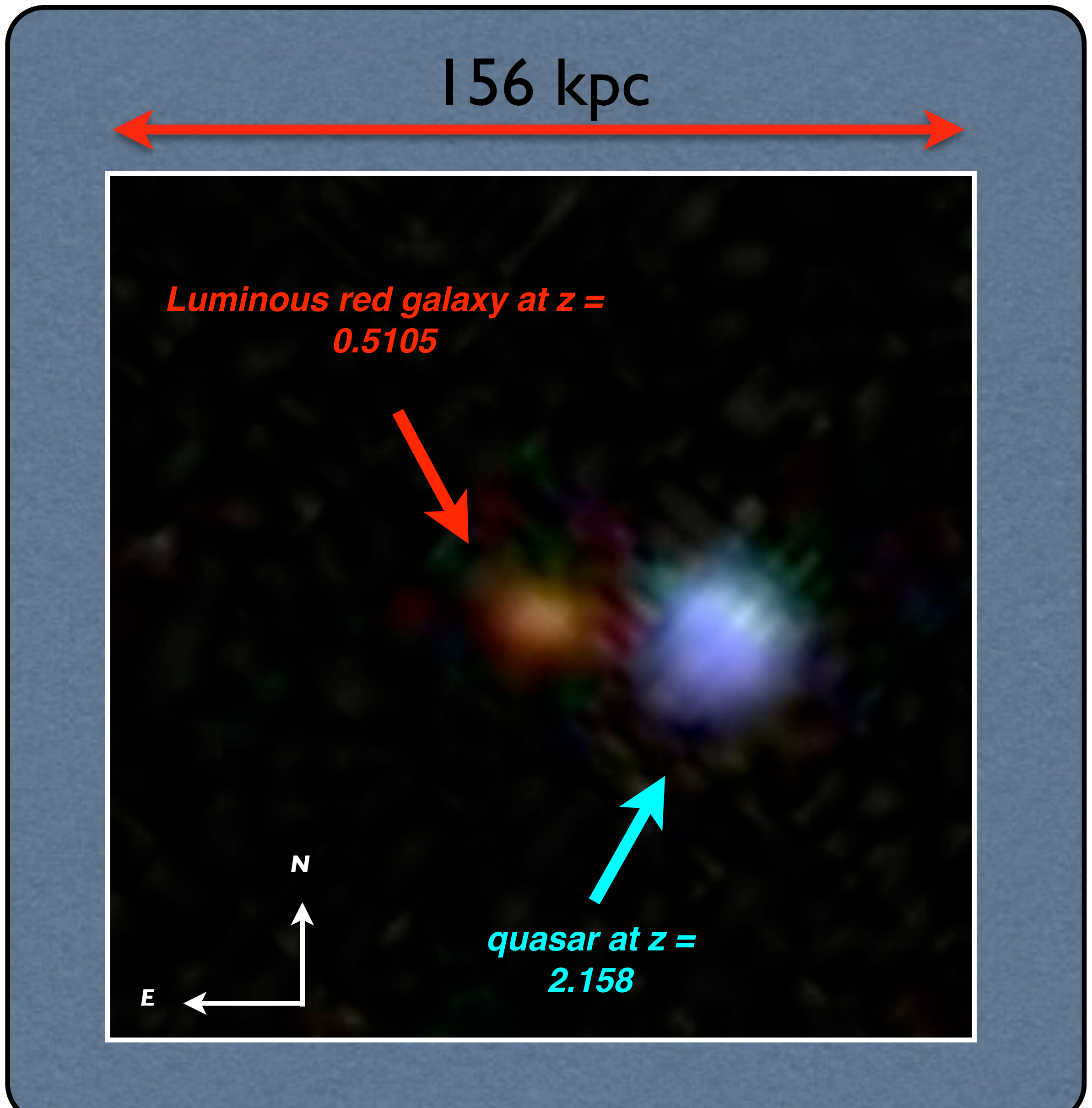




Cool gas in massive halos

Probing the cool gas of LRGs halos

Gauthier et al. 2009,2010



- LRGs are "red and dead" early-type massive galaxies. They constitute a homogeneous non-evolving population of galaxies. Luminous -> can be detected to high z.

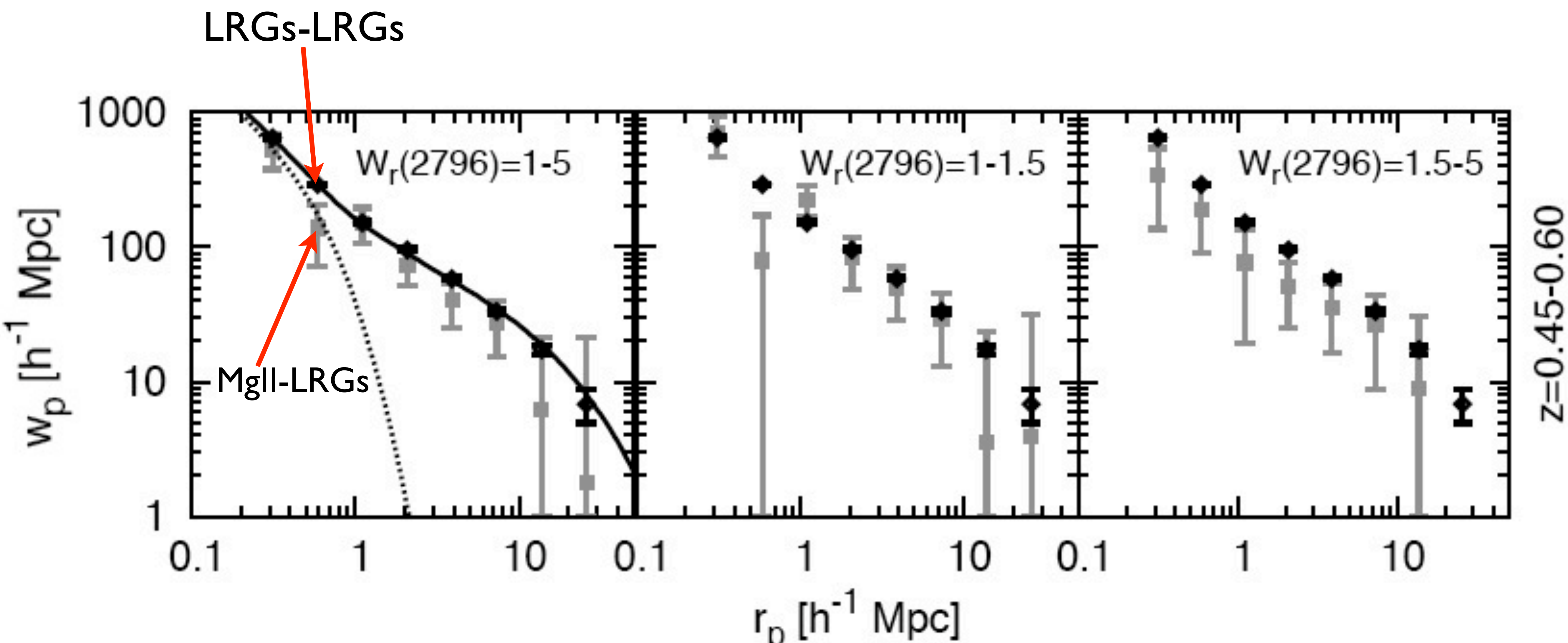
- known to inhabit massive halos and are good tracers of the large-scale cosmic structures.

- Their strong 4000Å break allows for reliable photometric redshift estimates.

Cool gas in massive halos : the clustering of MgII absorbers

Gauthier et al. (2009)

Cross-correlation MgII - LRGs at z ~ 0.5



projected separation

see also Bouché et al. (2006)
and Lundgren et al. (2009)

From the bias of LRGs to the bias of the absorbers hosts

- 1) compute the relative bias of your absorber hosts by computing the ratio between correlation functions on large scales

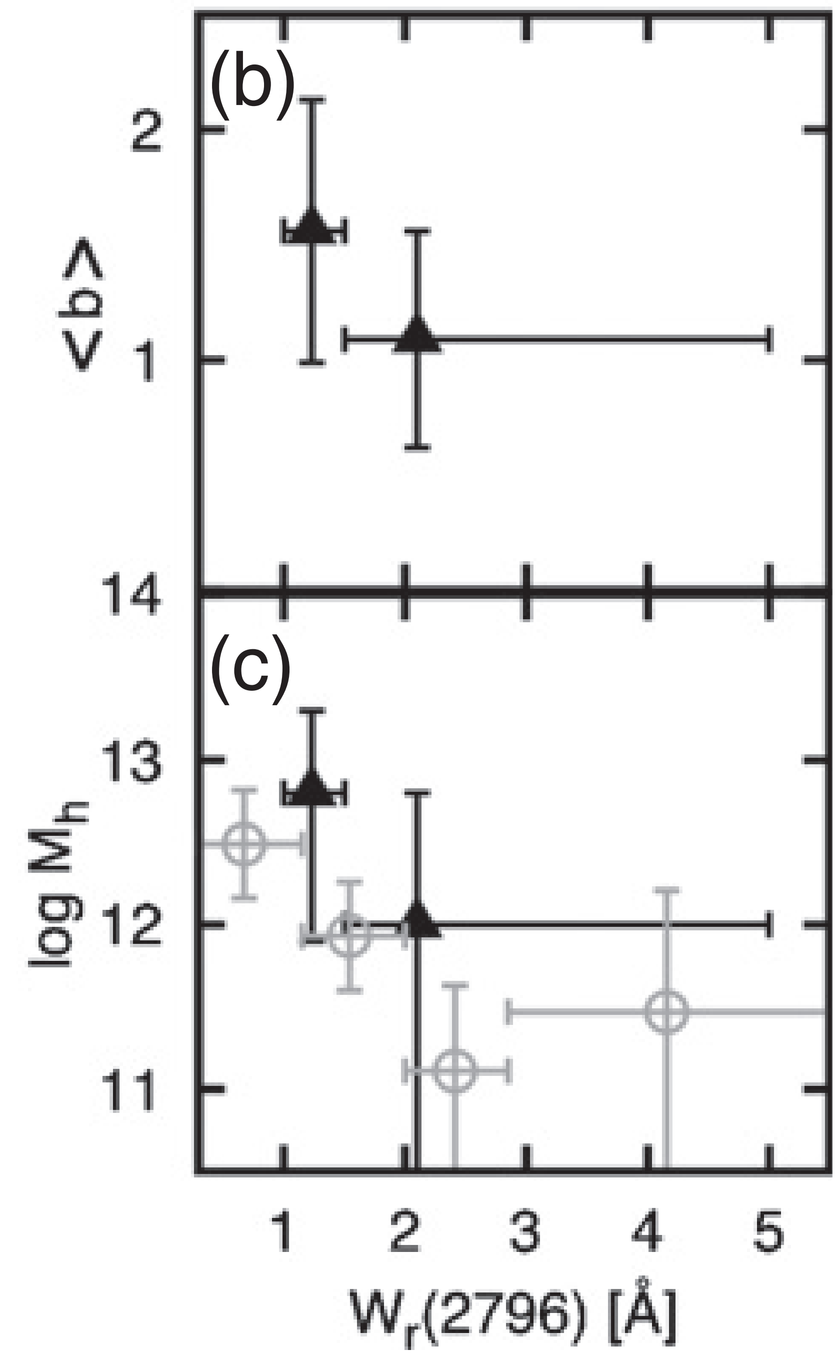
$$\hat{b} \equiv \frac{b_a}{b_g} = \frac{w_{ag}}{w_{gg}},$$

2) you know bias of LRGs from the HOD fit. You can obtain bias of absorbers hosts.

Clustering of MgII absorbers at z~0.5

The main results of the clustering analysis

EW	log M_h
W_r(1-1.5)	$13.0^{+0.4}_{-0.6}$
W_r(1.5-5)	$11.9^{+0.8}$
All	$12.6^{+0.4}_{-0.6}$



On average, stronger absorbers are unbiased. Weaker ones are preferentially found in more massive halos

THE INCIDENCE OF COOL GAS IN $\sim 10^{13}$ $M_{\odot}$ HALOS[1]

Jean-René Gauthier[2,3], Hsiao-Wen Chen[2] and Jeremy L. Tinker[4]

Accepted for publication in the Astrophysical Journal

ApJ, 716

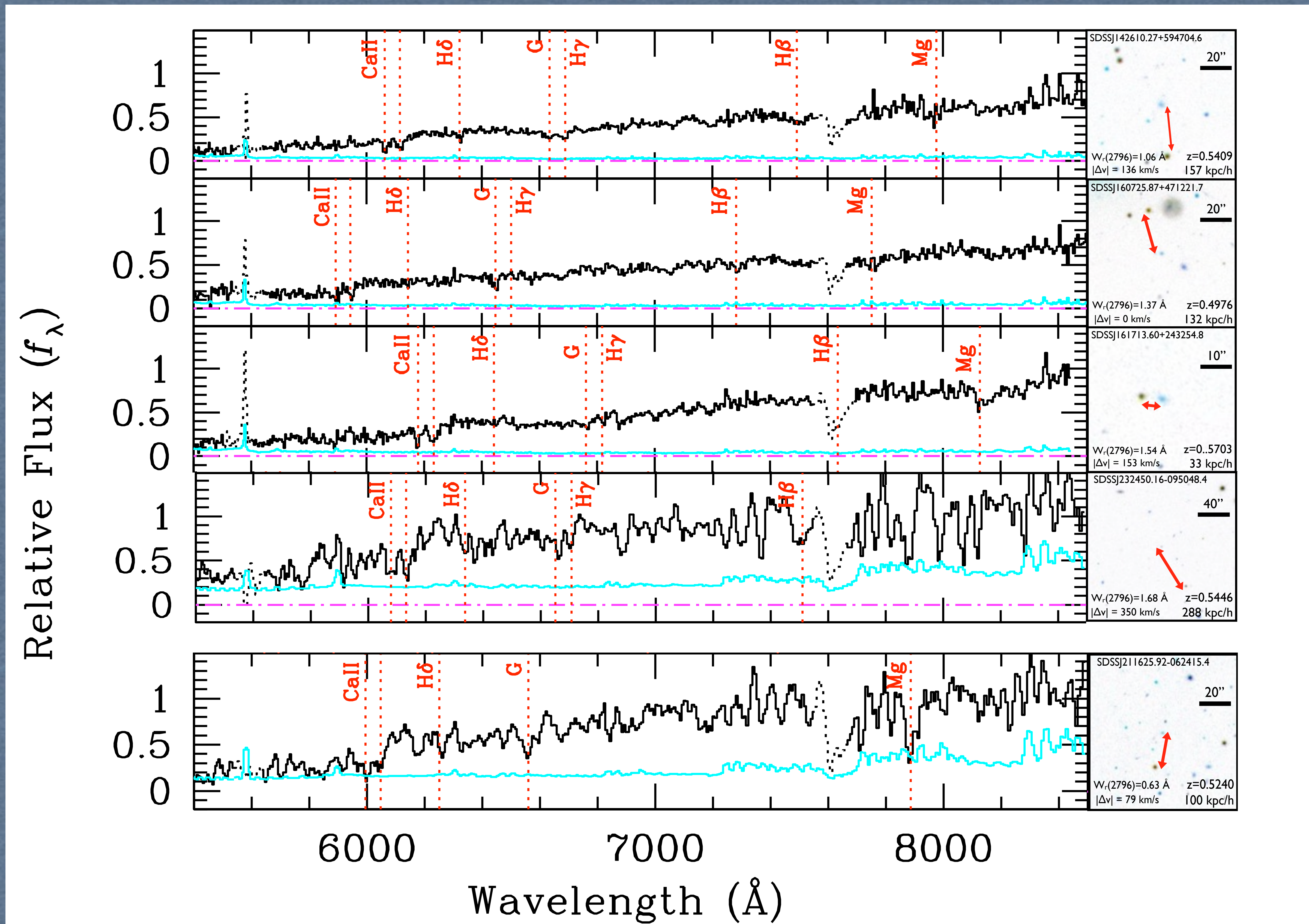
Spectroscopic follow-up of LRGs around QSO sightlines

- 15 LRG spectra
- Isolated LRGs
- 5 physical MgII-LRG pairs
  (ρ< 300 kpc/h, |Δv| < 350 km/s)
- Wr(2796) > 0.6 Å

The incidence of cool gas in ~ 10^{13} M_{sun}/h

Gauthier et al. (2010)

The 5 physical pairs

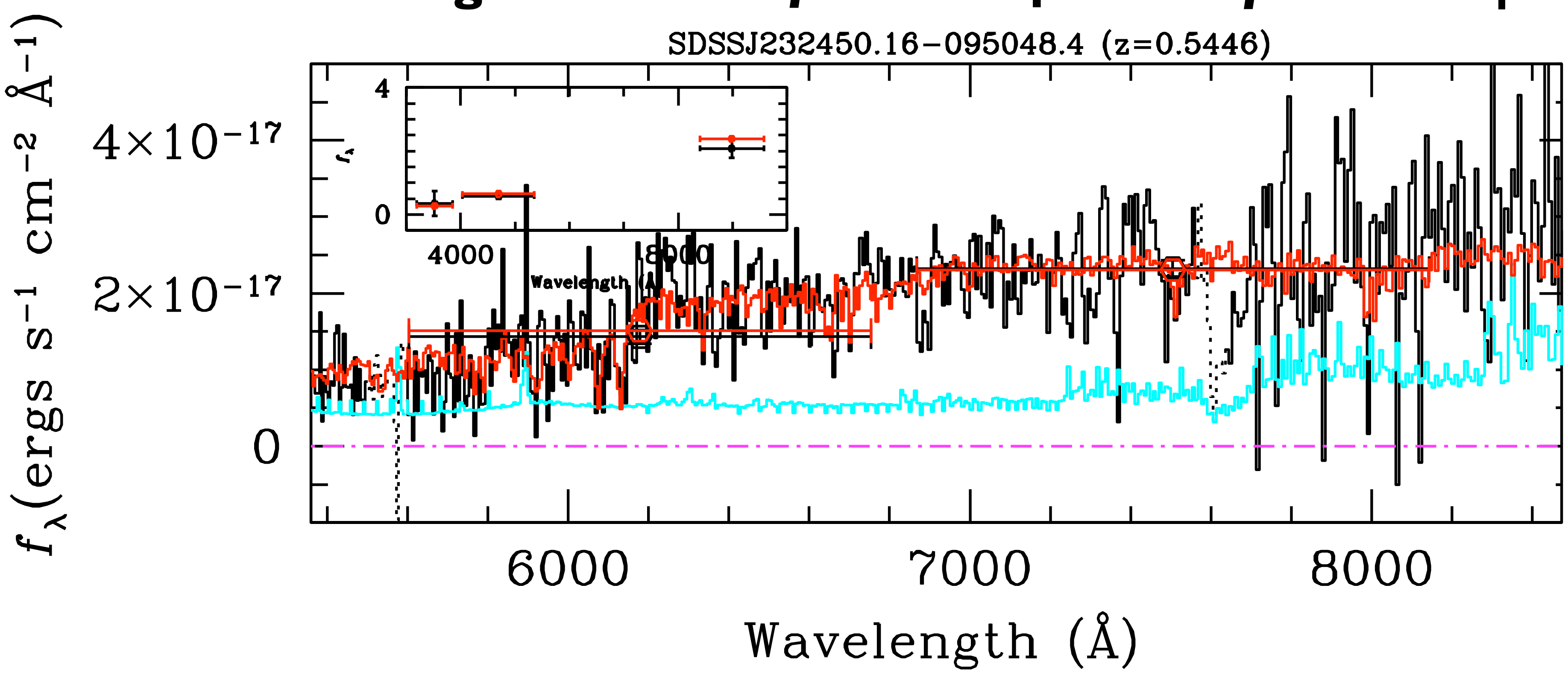


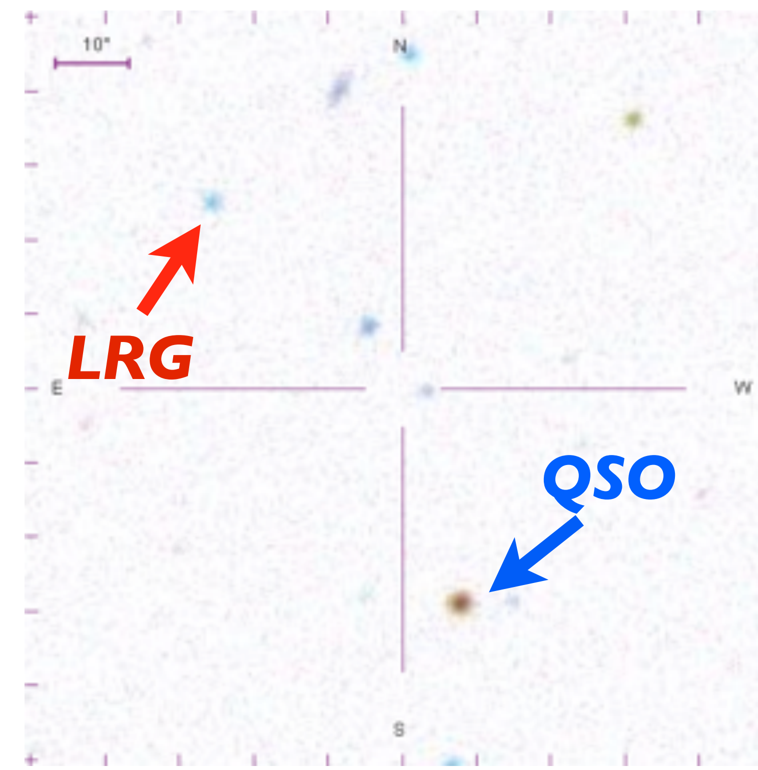
The origin of cool gas in ~ $10^{13}\ M_{sun}/h$

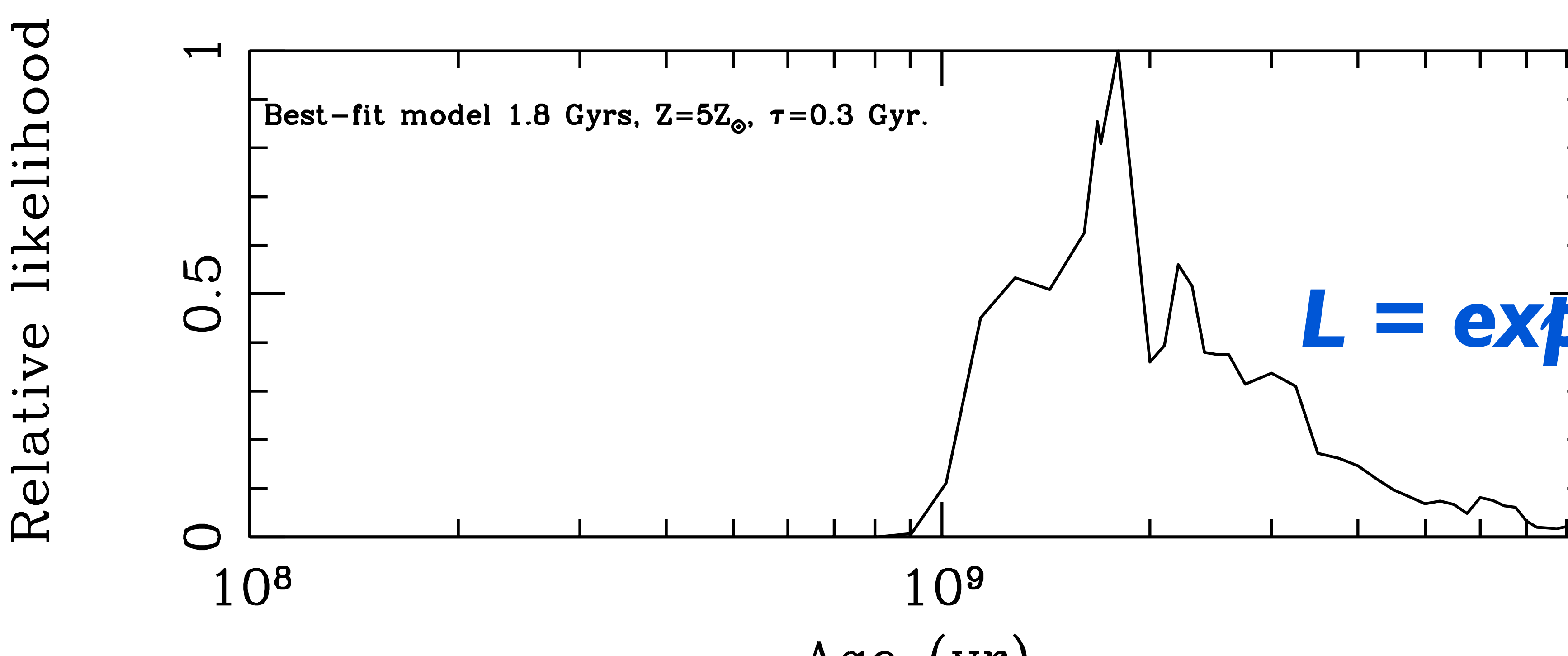
Gauthier, Chen, Rauch & Tinker (2010) In prep.

A stellar population synthesis of the LRGs

MgII absorber found at ρ=287 kpc/h and |Δv|=350 km/s







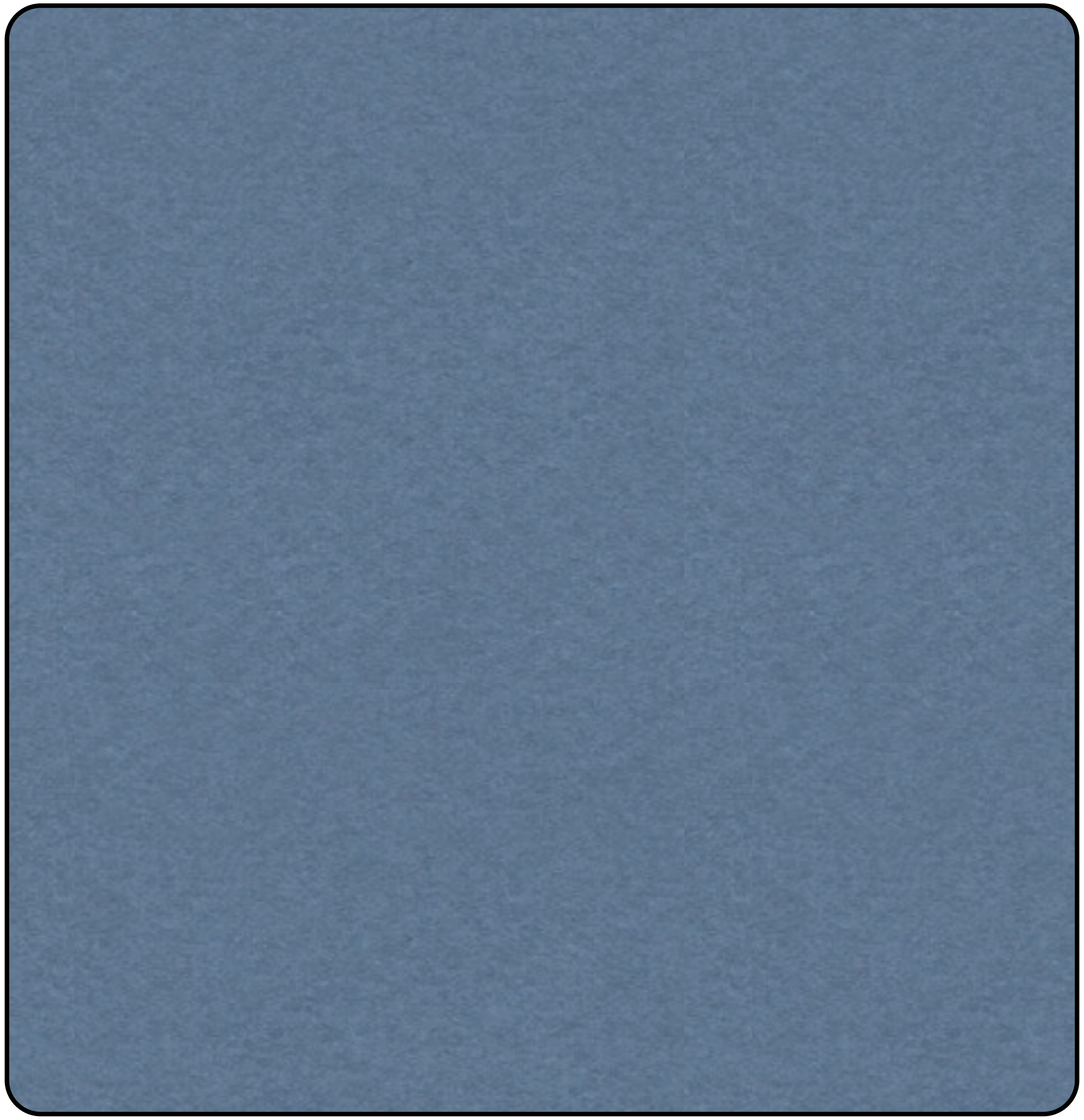
$$L = \exp[-(\chi^2_i - \chi^2_{min})/2]$$

Thank You !

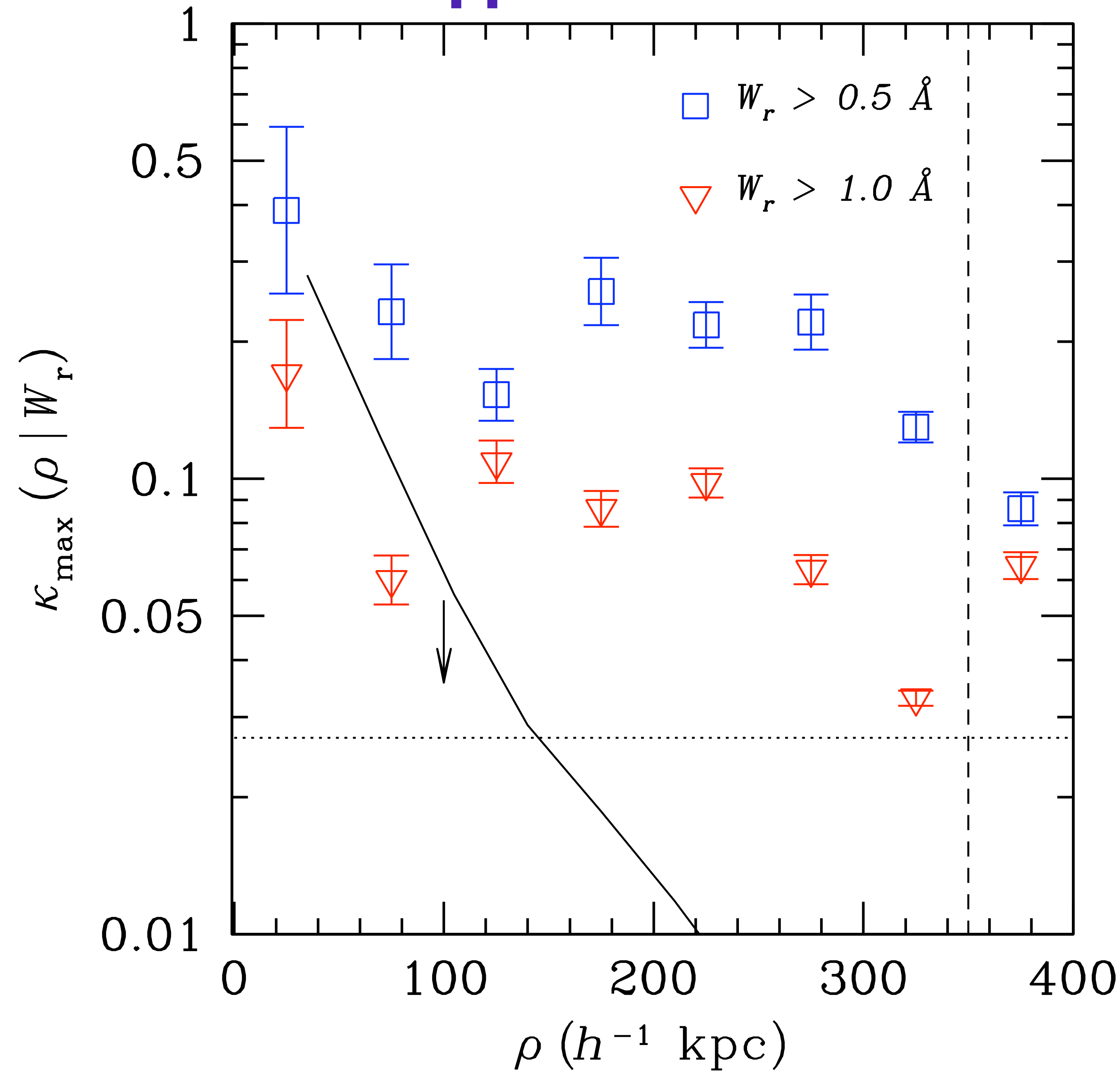
The incidence of cool gas in ~ 10^{13} M_{sun}/h

Gauthier et al. (2010)

A search for MgII absorbers (within +/- $3\sigma_{Zph}$) in the QSO spectra



Upper limits on κ



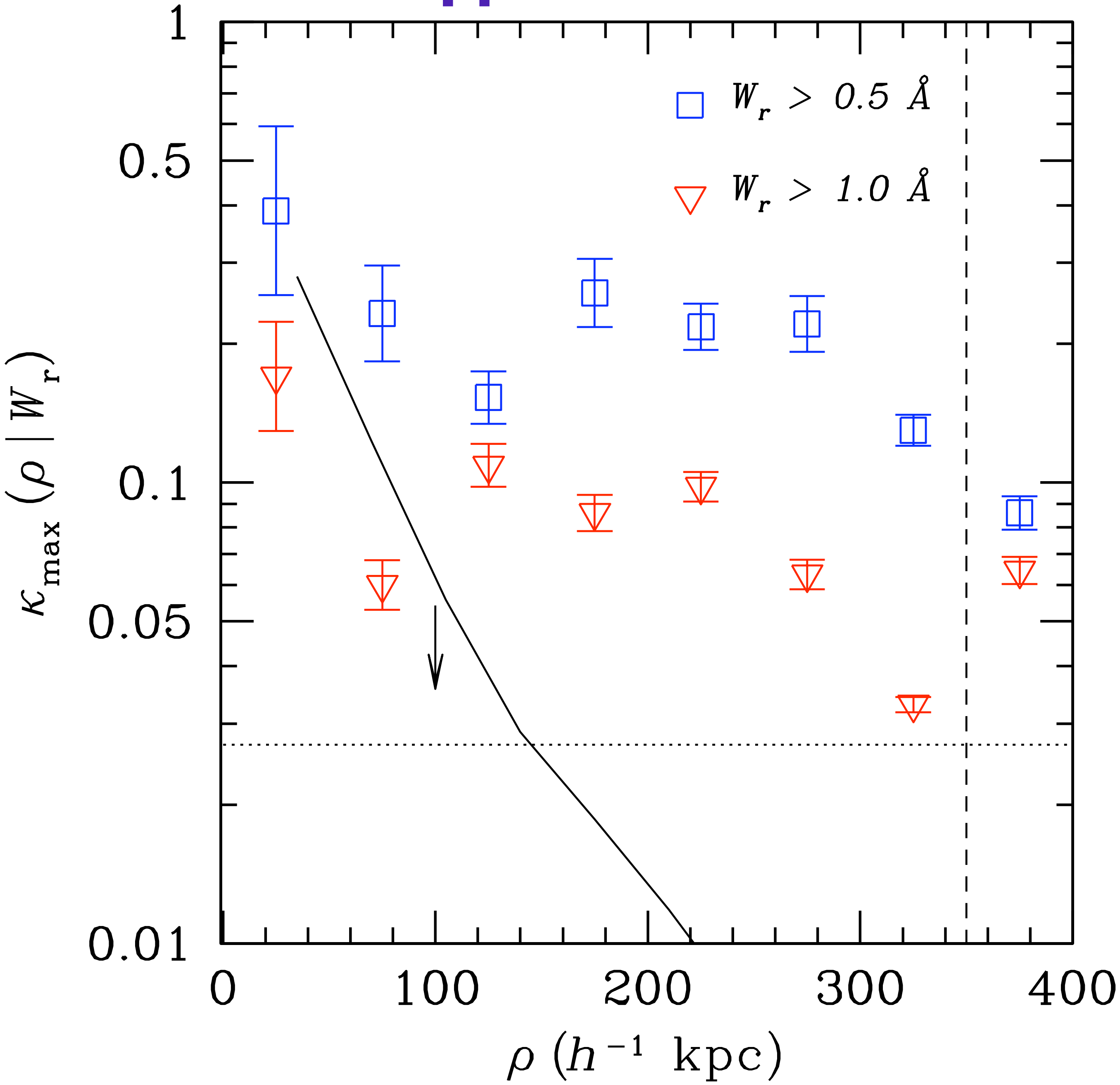
The incidence of cool gas in ~ 10^{13} M_{sun}/h

Gauthier et al. (2010)

A search for MgII absorbers (within +/- $3\sigma_{Zph}$) in the QSO spectra

- $\kappa \leqq 7\%$ for $W_r(2796) > 1.0$ Å
  $\kappa \leqq 18\%$ for $W_r > 0.5$ Å
- Cool gas cross-section from satellite galaxies seem to be insufficient
- Correlated structures (other galaxies in the surveyed volume) contribute ~ 3%
- Where does the cool gas come from?

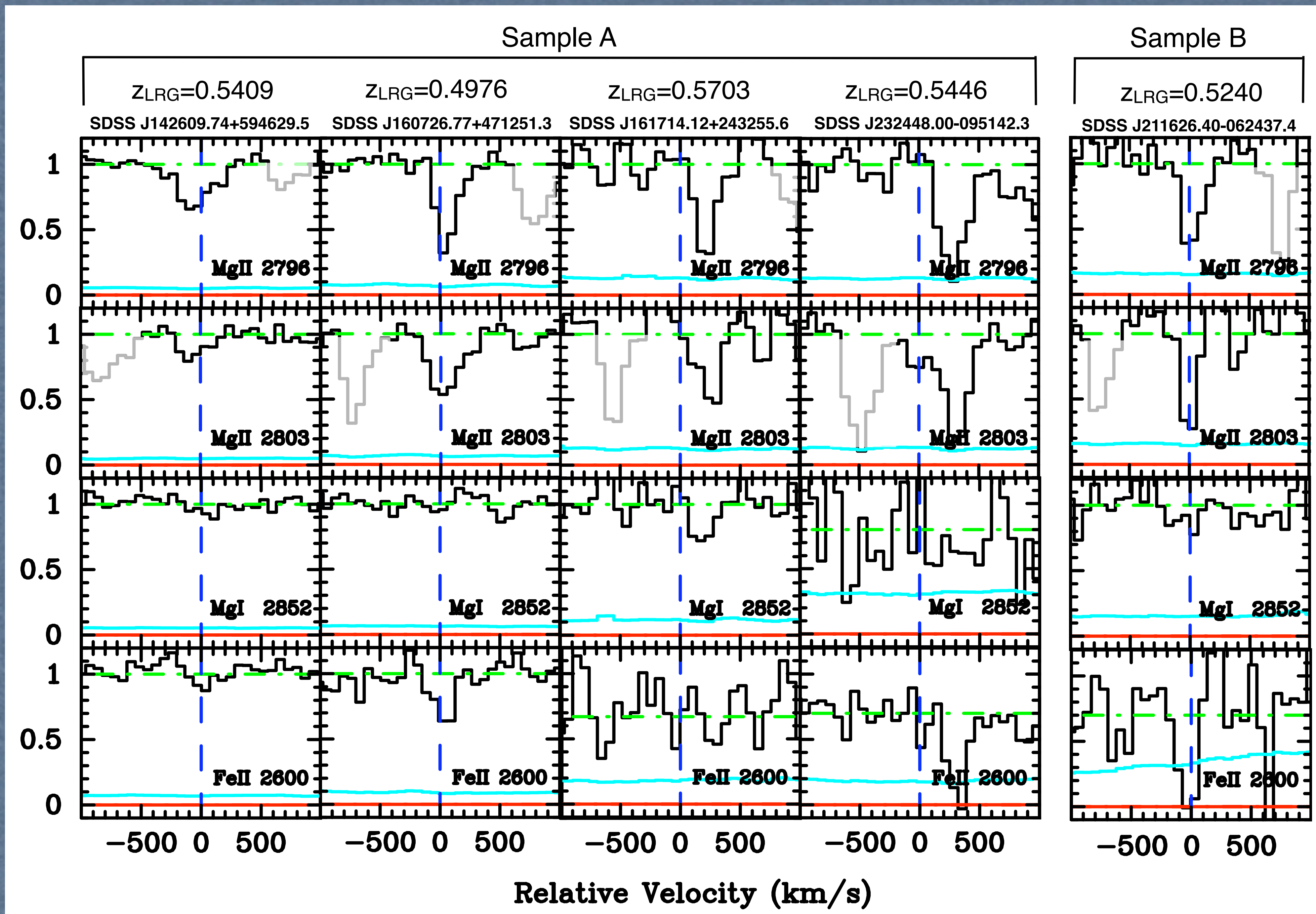
Upper limits on κ



The incidence of cool gas in ~ 10^{13} M_{sun}/h

Gauthier et al. (2010)

Absorption profiles



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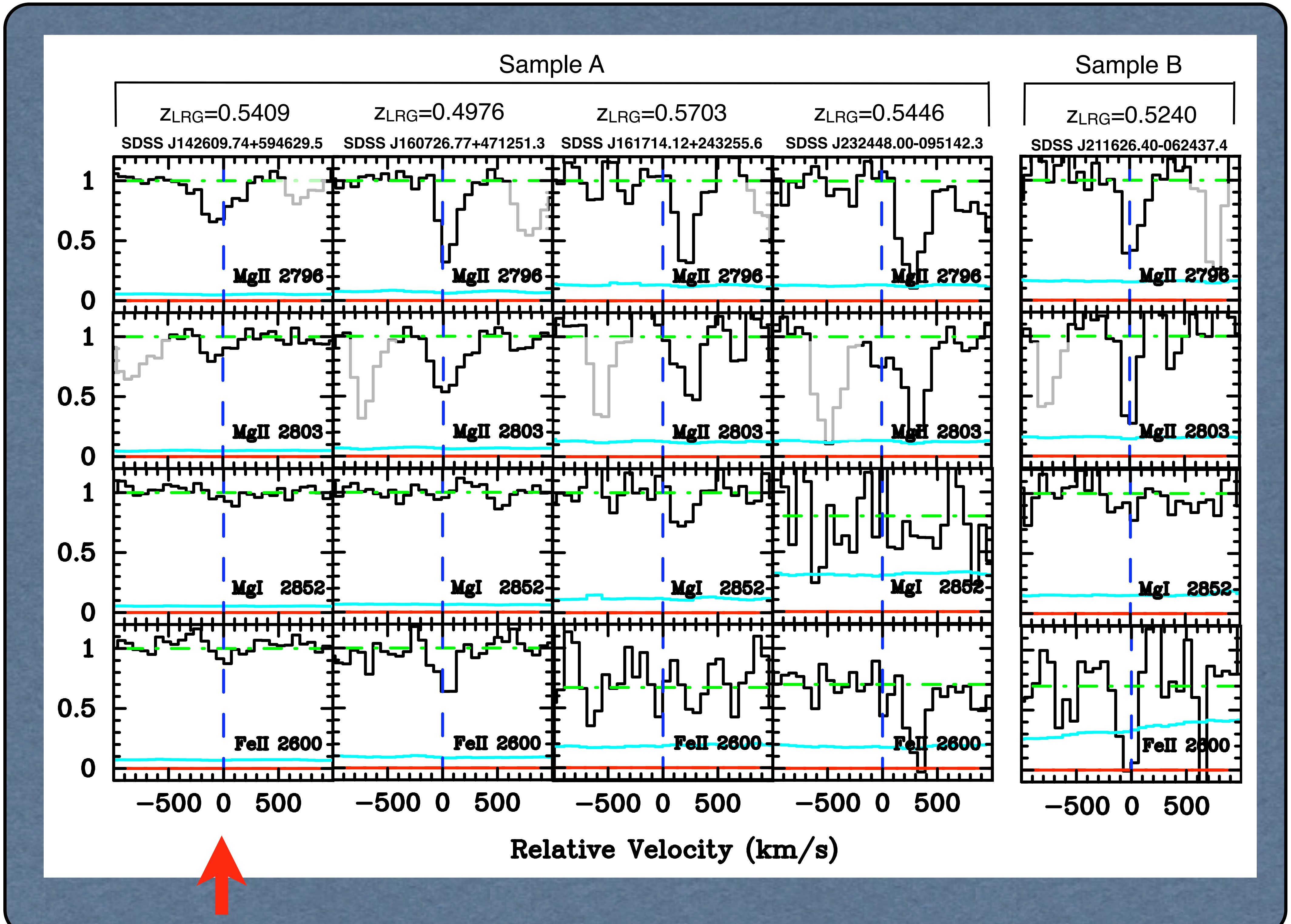

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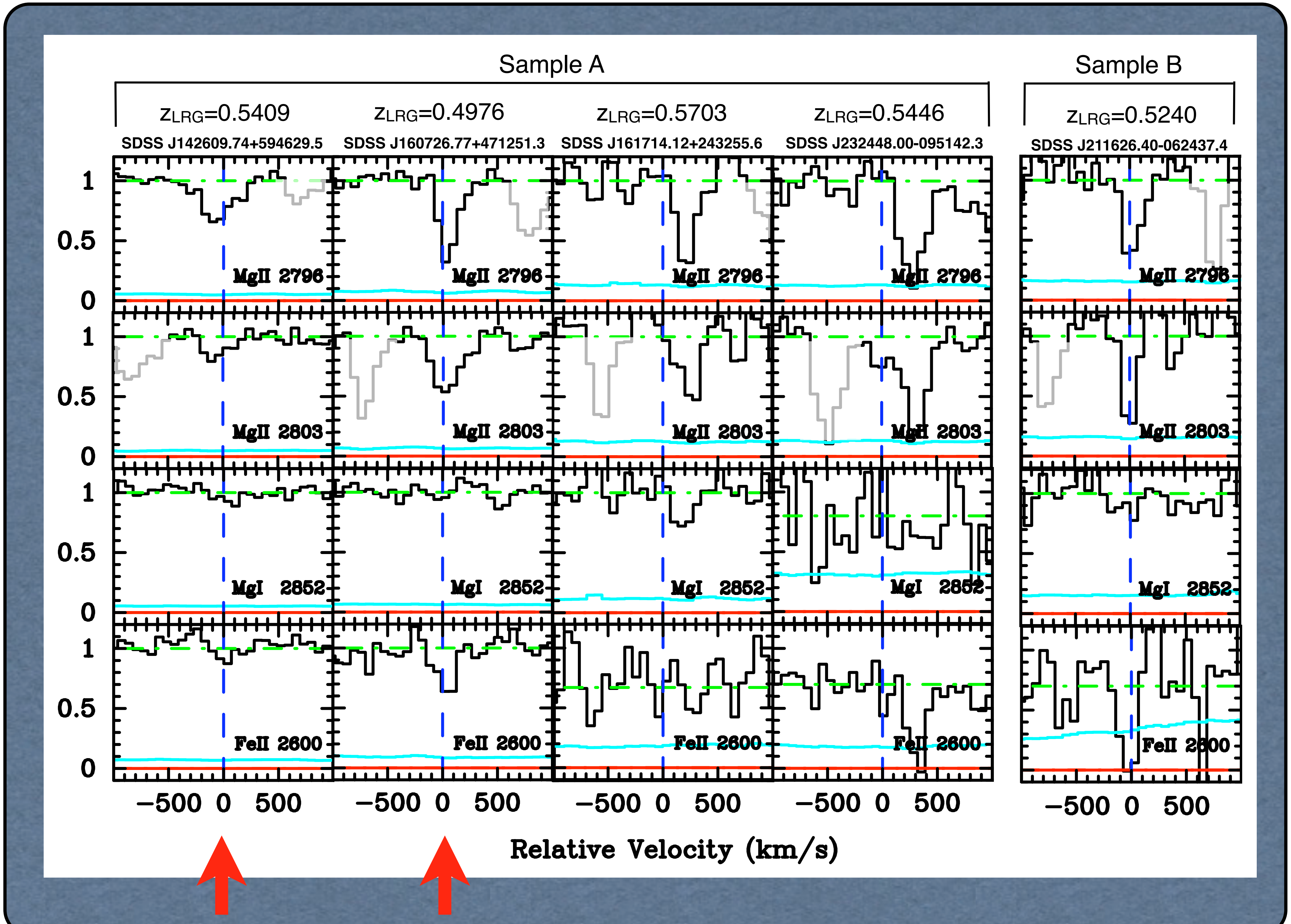

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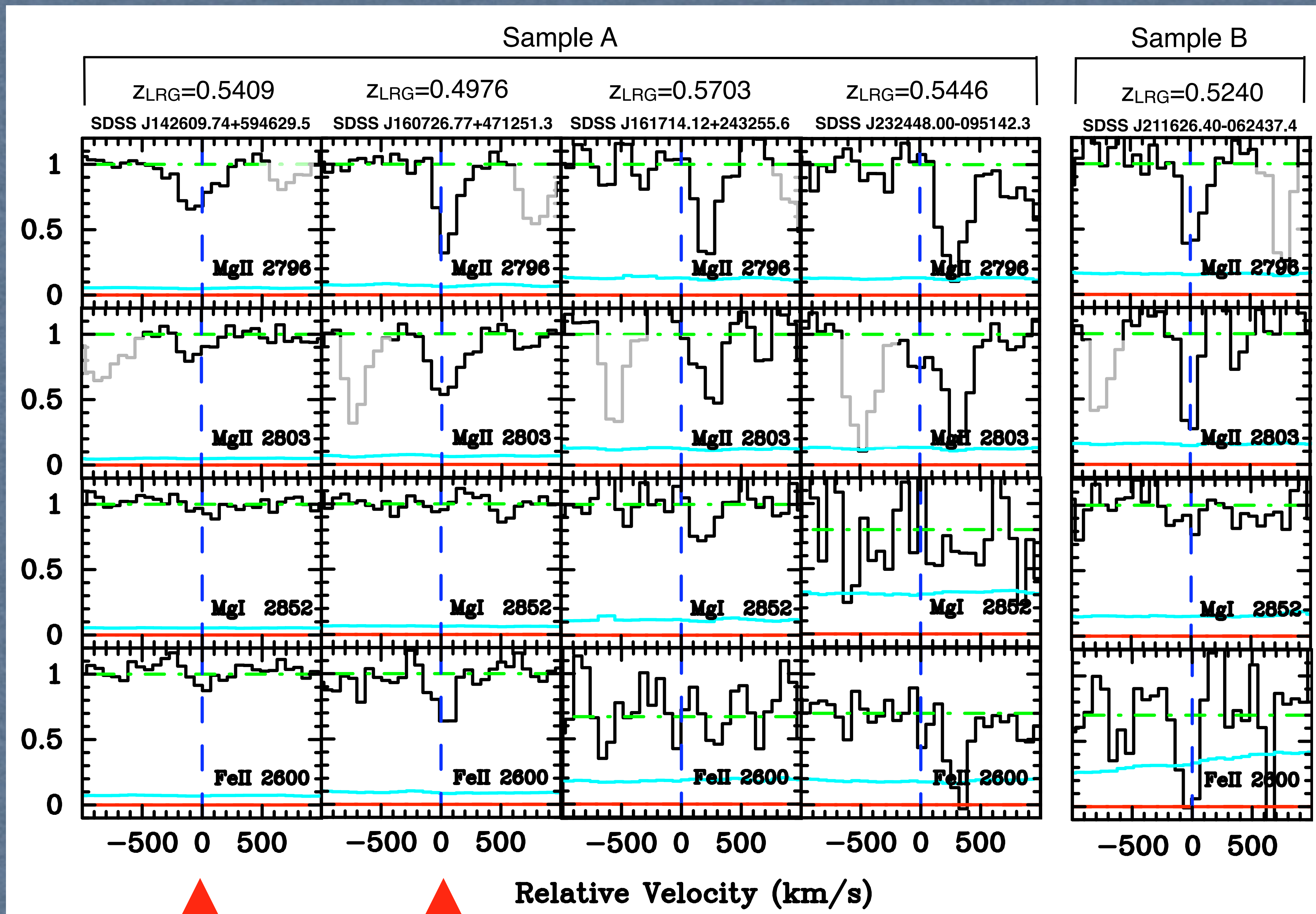
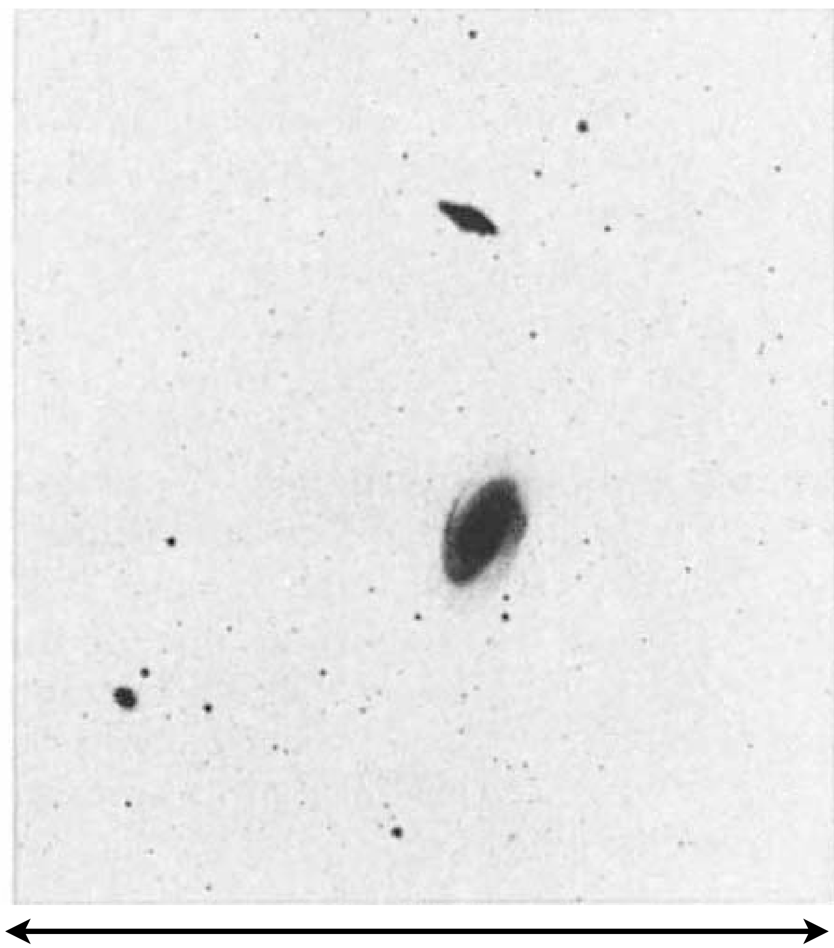


DLAs? *(Rao, Turnshek & Nestor 2006)*

Origin of cool baryons in dark matter halos

Galactic interactions - stripping and tidal structures



150 kpc

See also Yun et al. (1994)

See also Stephan's Quintet

Credit: Chynoweth et al., NRAO/AUI/NSF, Digital Sky Survey.

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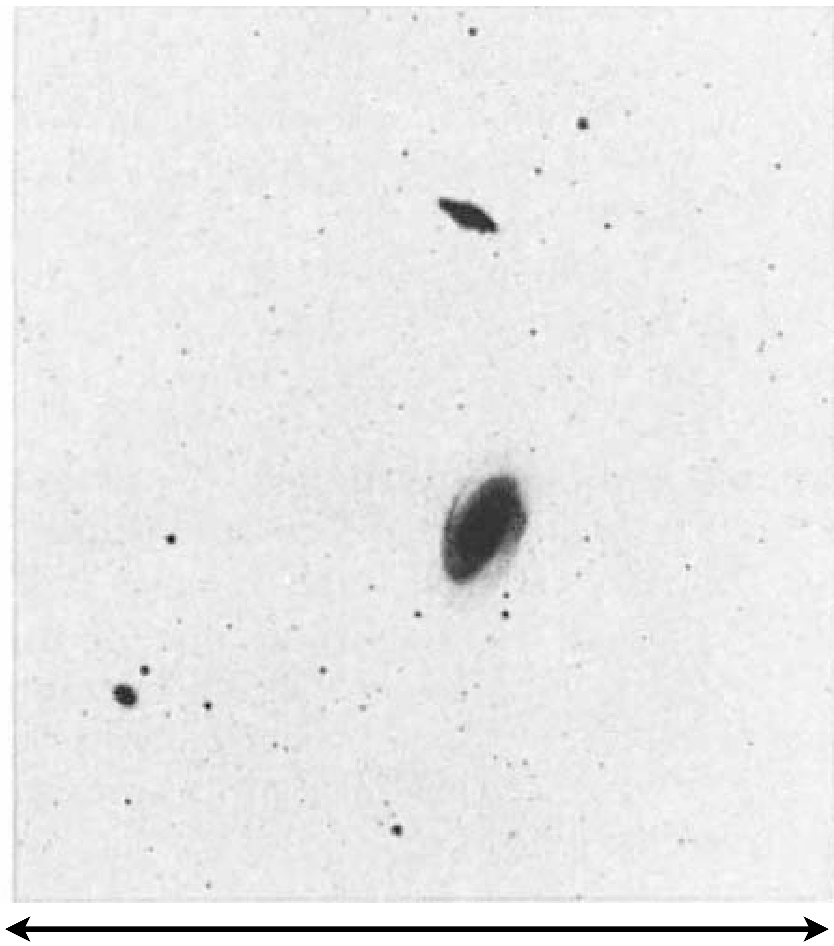

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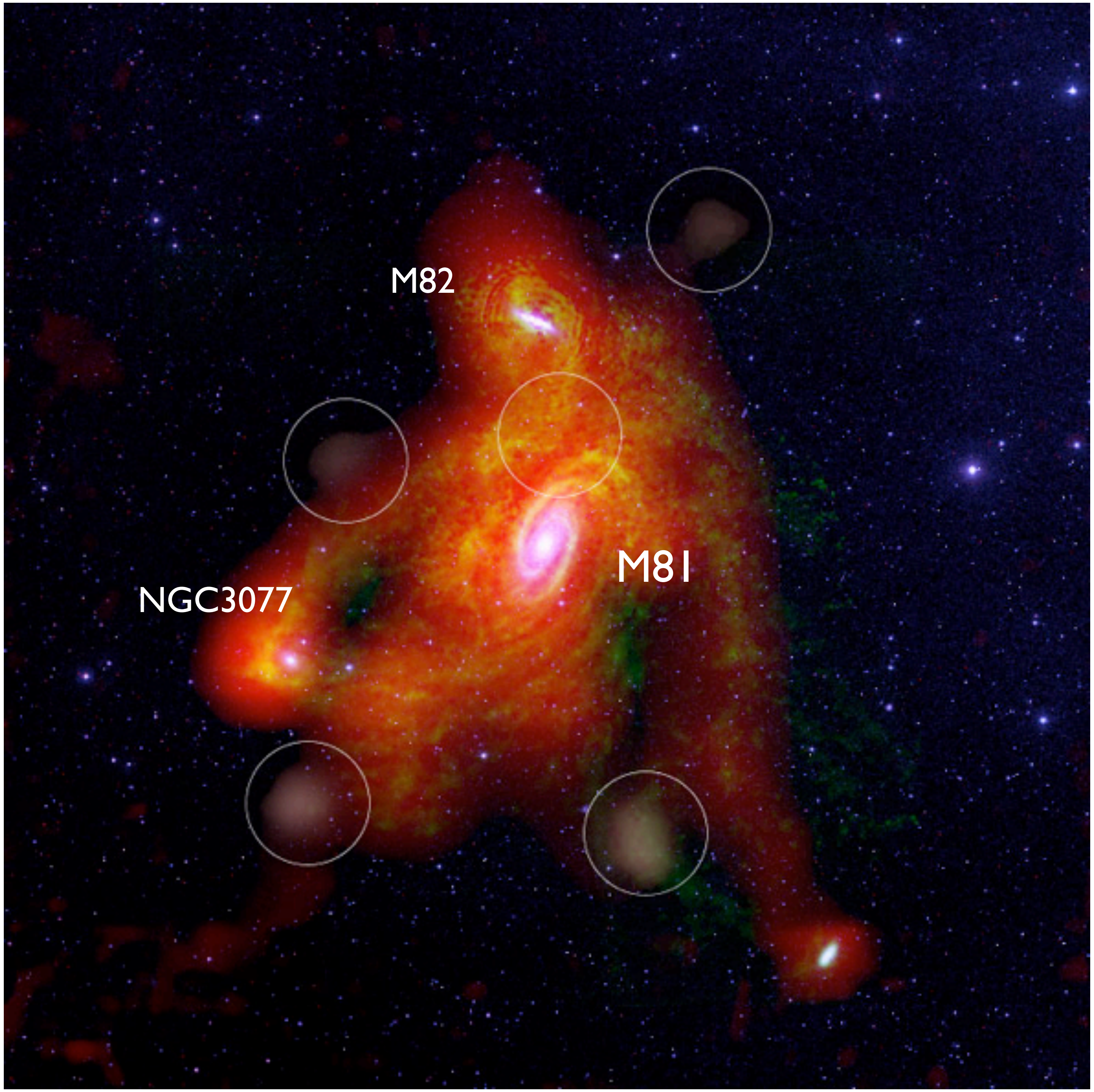

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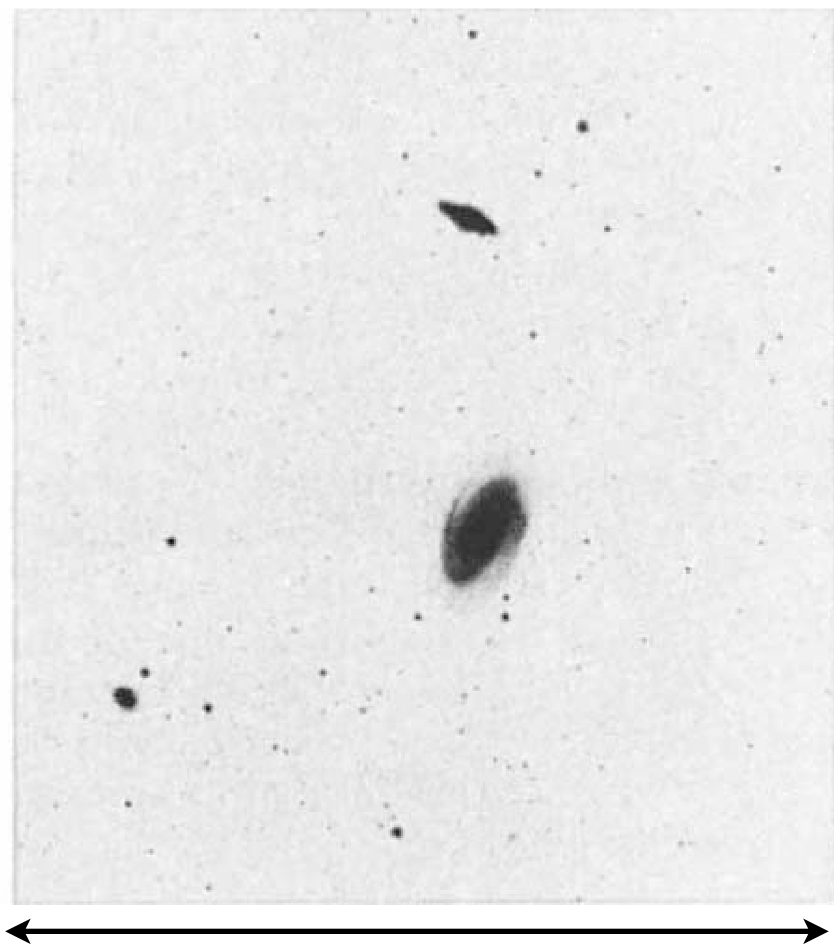

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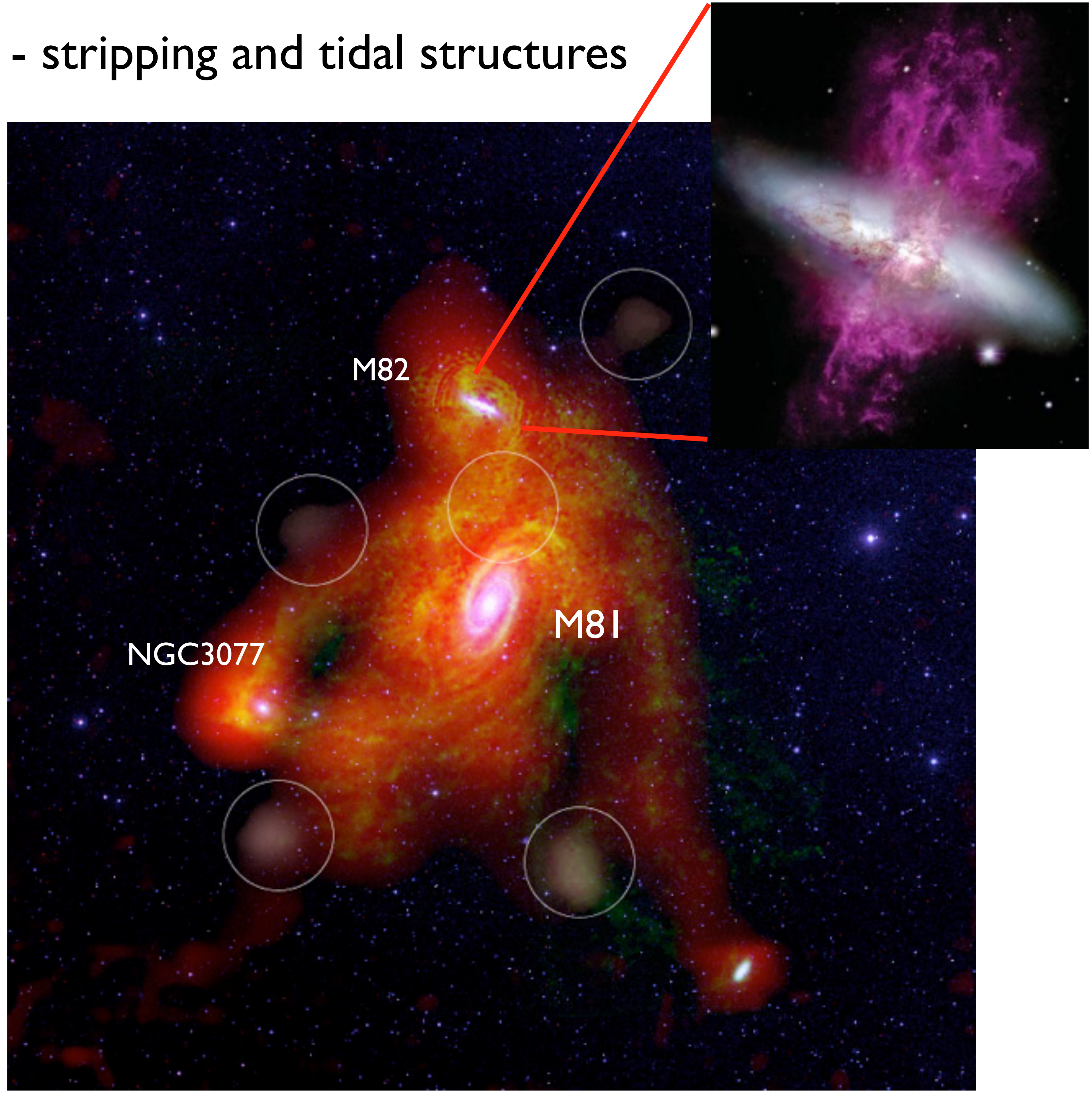

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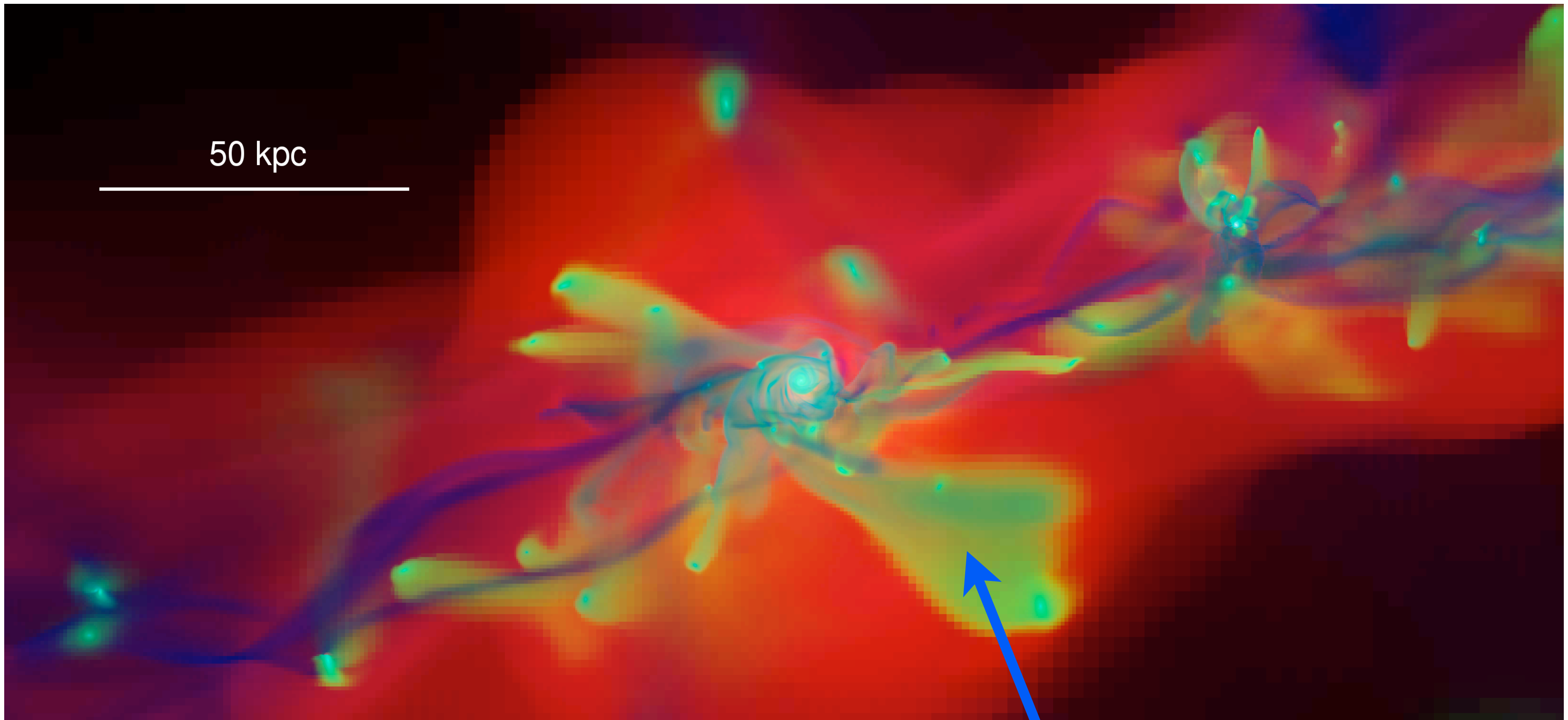
Origin of cool baryons in dark matter halos

Formation of a 10^{11} M_{sun} halo at $z \sim 3$



temperature

metals

density

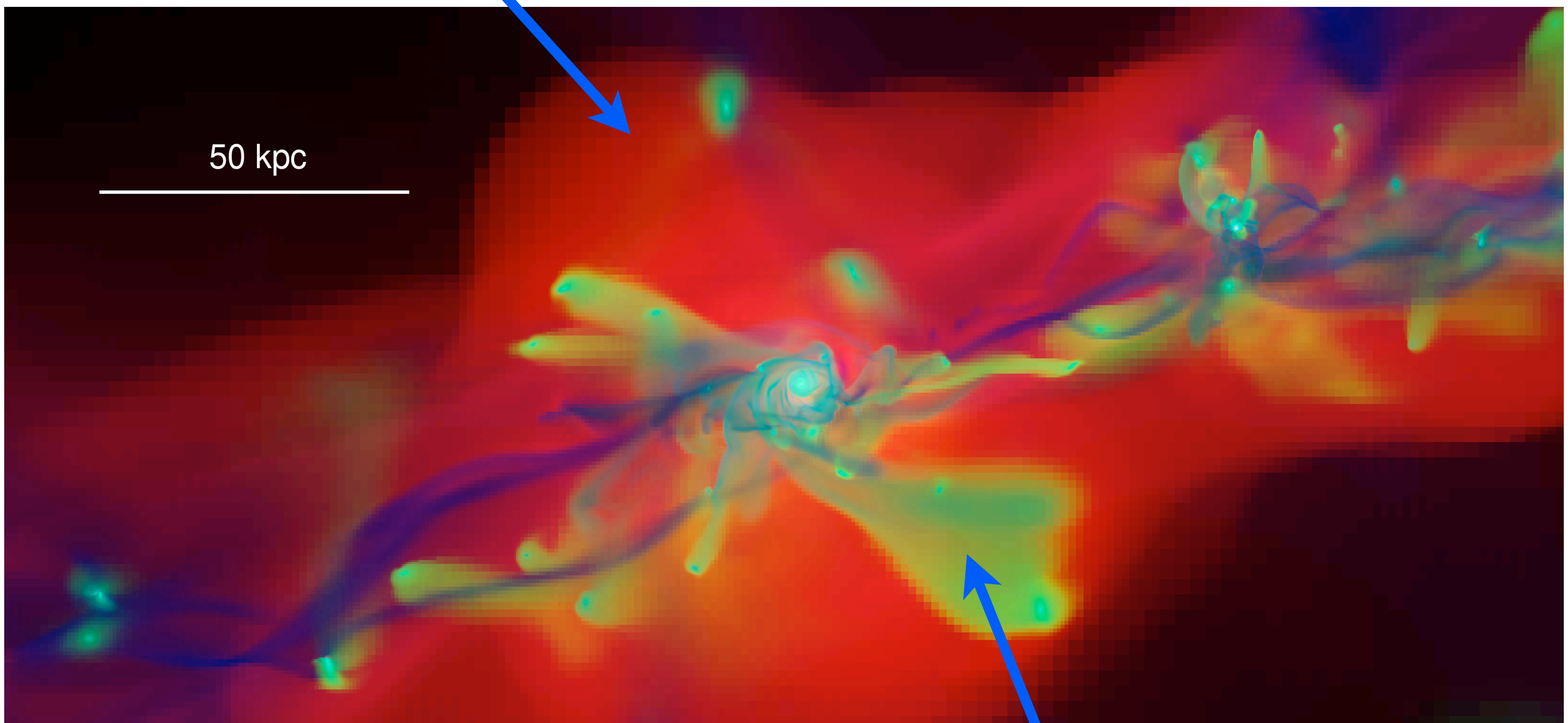
Agertz, Teyssier & Moore (2009)

Stripped satellite material

Origin of cool baryons in dark matter halos

Shock-heated halo gas

Formation of a 10^{11} M_{sun} halo at $z \sim 3$



temperature

metals

density

Agertz, Teyssier & Moore (2009)

Stripped satellite material

Origin of cool baryons in dark matter halos

Shock-heated halo gas

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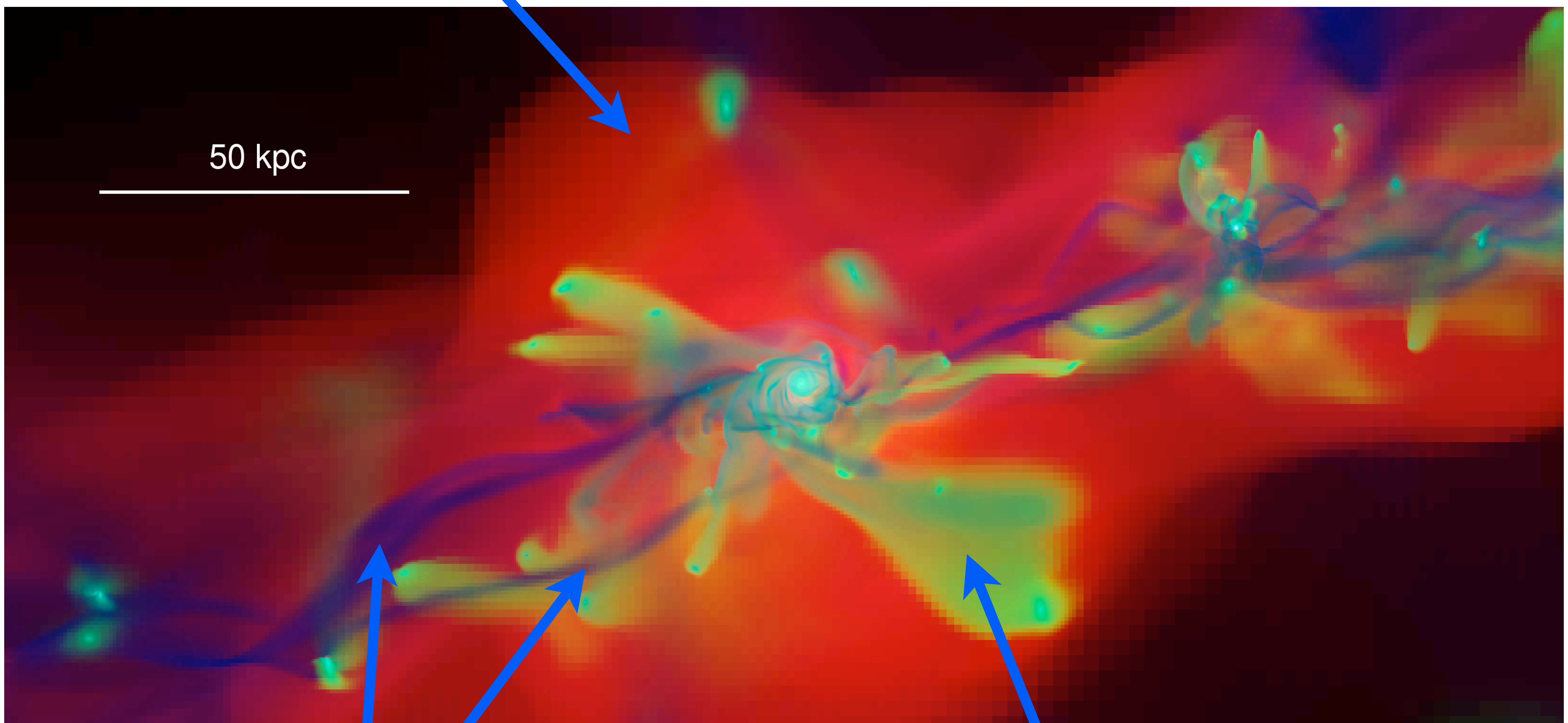

temperature

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Cold Streams

Stripped satellite material