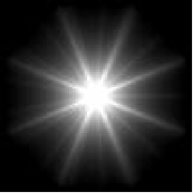


Reionization signatures in QSOs and GRBs absorption spectra

Simona Gallerani

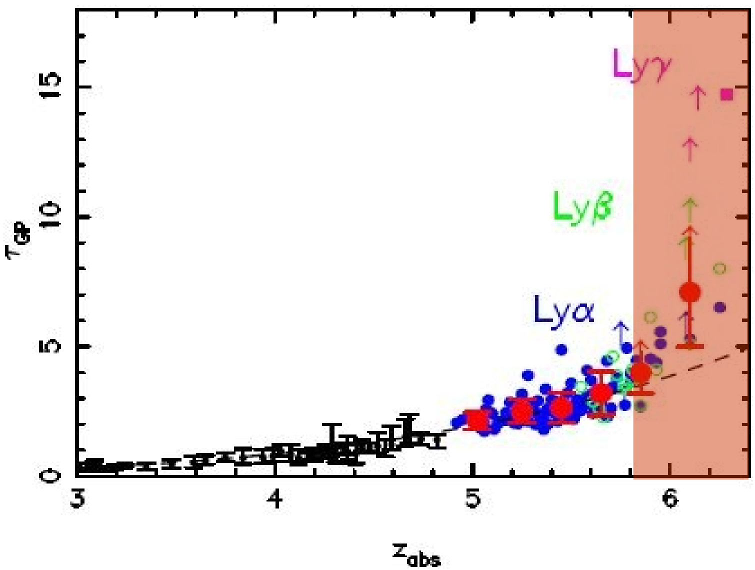
ELTE, Budapest

In collaboration with:

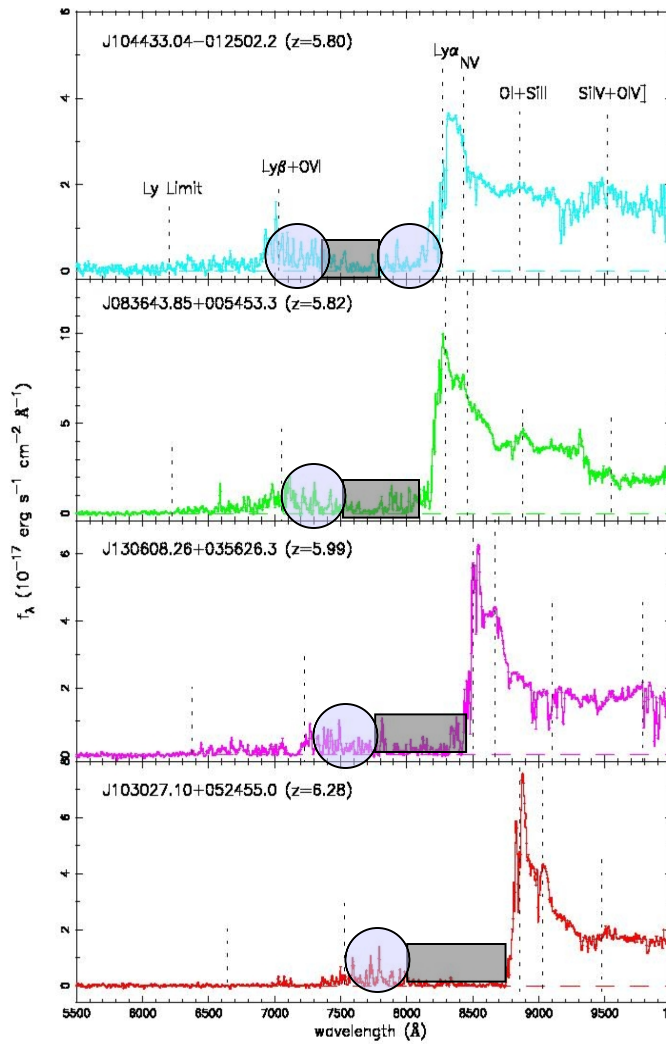
T. Choudhury, X. Fan, A. Ferrara, Z. Haiman, A. Maselli, R. Salvaterra

QSO spectra at high redshift

$$\tau_{GP}(z) = 4.9\times10^{5}\left(\frac{\Omega_m h^2}{0.13}\right)^{-1/2}\left(\frac{\Omega_b h^2}{0.02}\right)x_{HI}\left(\frac{1+z}{7}\right)^{3/2}$$



Fan et al. 2005



Becker et al. 2003

GAPS

PEAKS

What can we learn from these observables?

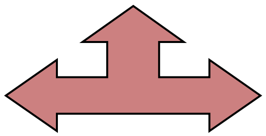
Simulating the Lyα forest

$$F(\nu) = e^{-\tau(\nu)}$$

optical depth
at the Lyα transition

$$\tau(\nu) = \int \sigma_{Ly\alpha} n_{HI} dl$$

Neutral hydrogen distribution



Baryonic density field

IGM ionization state

Log-Normal model

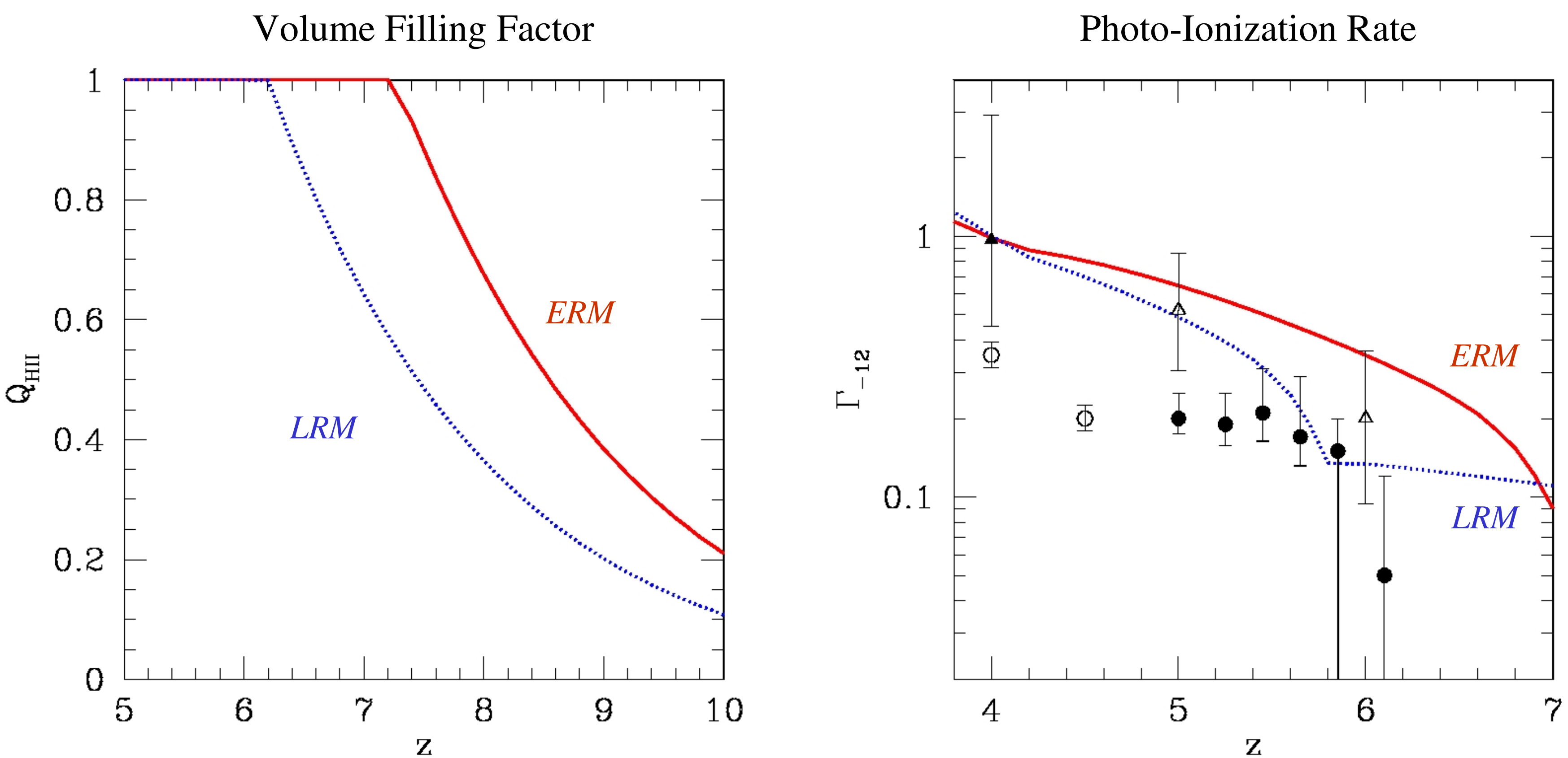
Coles & Jones
(1991)

Reionization model

Choudhury & Ferrara
(2005/2006)

Reionization models

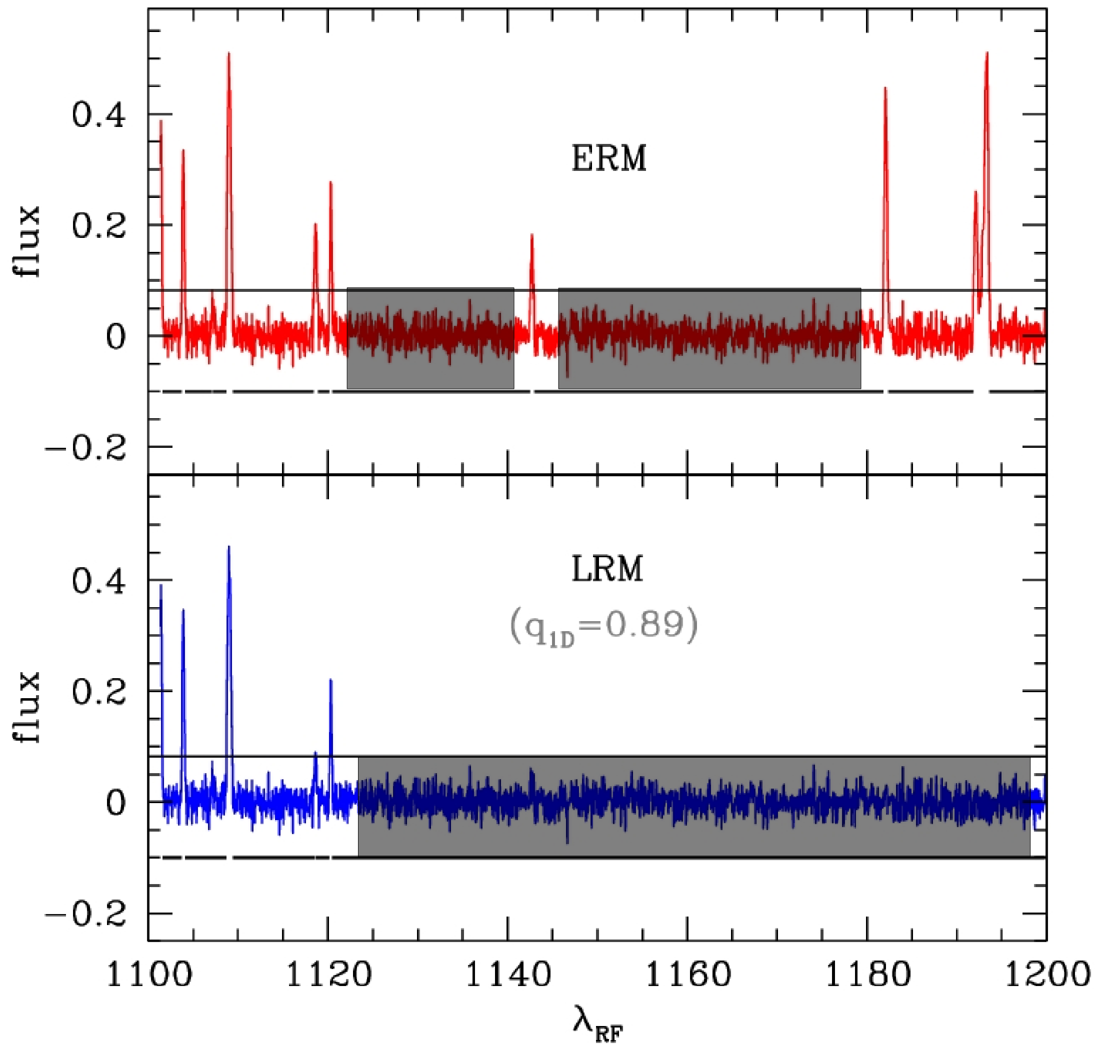
EARLY REIONIZATION ***(ERM)*** *LATE REIONIZATION* ***(LRM)***



Data from McDonald & Miralda-Escude'(2001); Bolton etal. (2005/2007); Fan etal.(2006)

$z = 5.7 - 6.3$

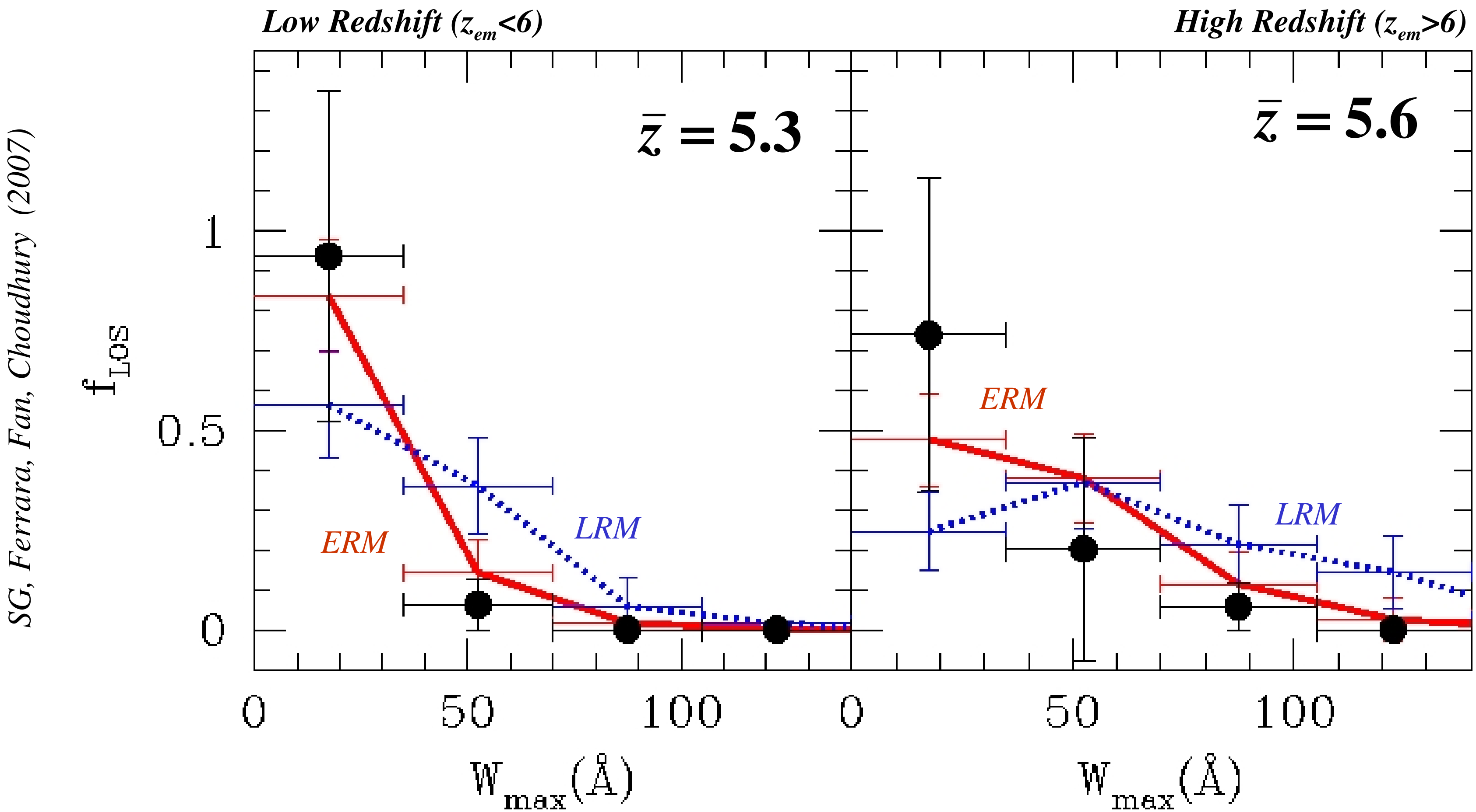
Simulated spectra



GAPS

Largest gap width distribution

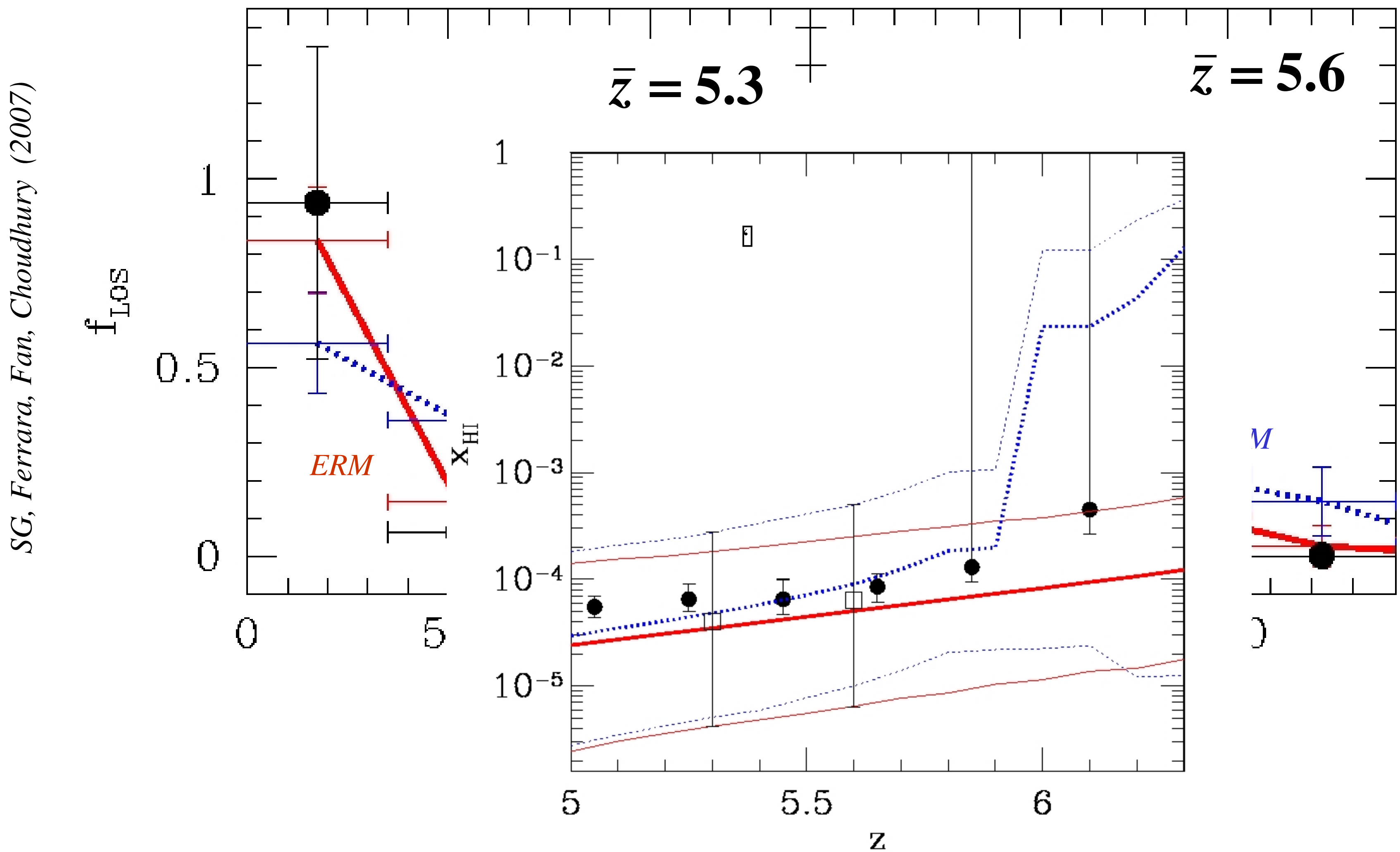
Observations vs Simulations



Largest gap width distribution

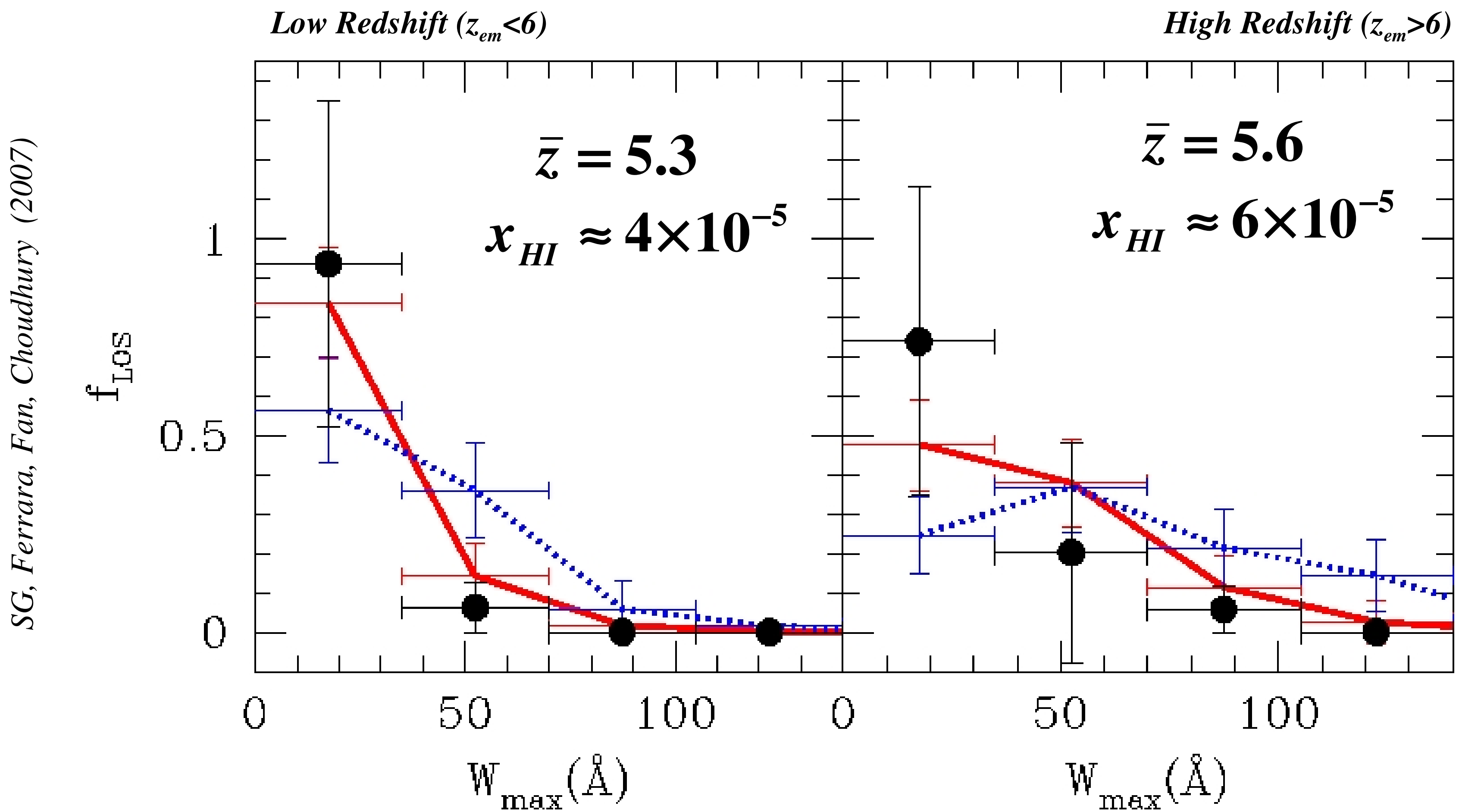
Observations vs Simulations

Low Redshift (z_{em}<6) ***High Redshift (z_{em}>6)***



Largest gap width distribution

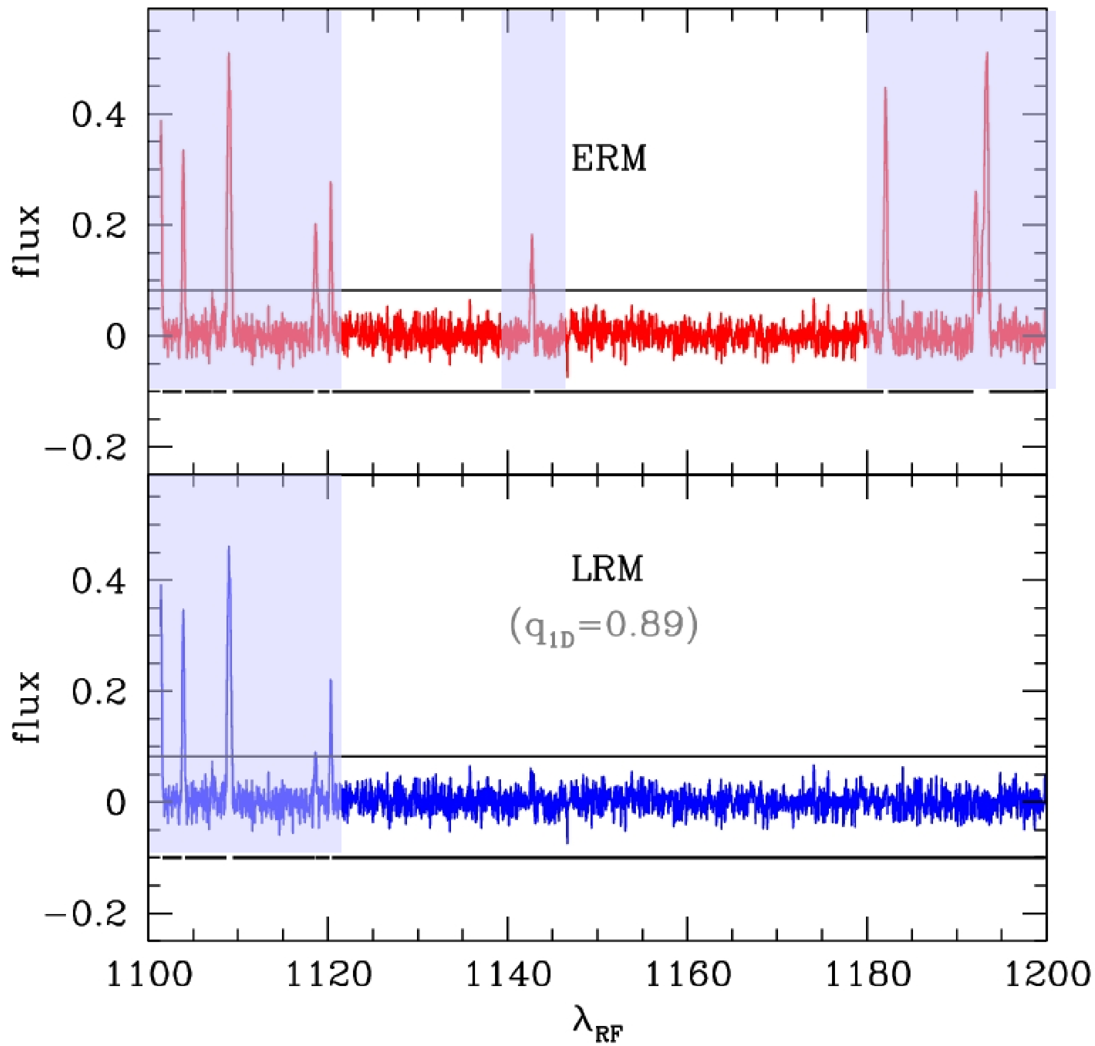
Observations vs Simulations



x_{HI}<0.36 @ z=6.3

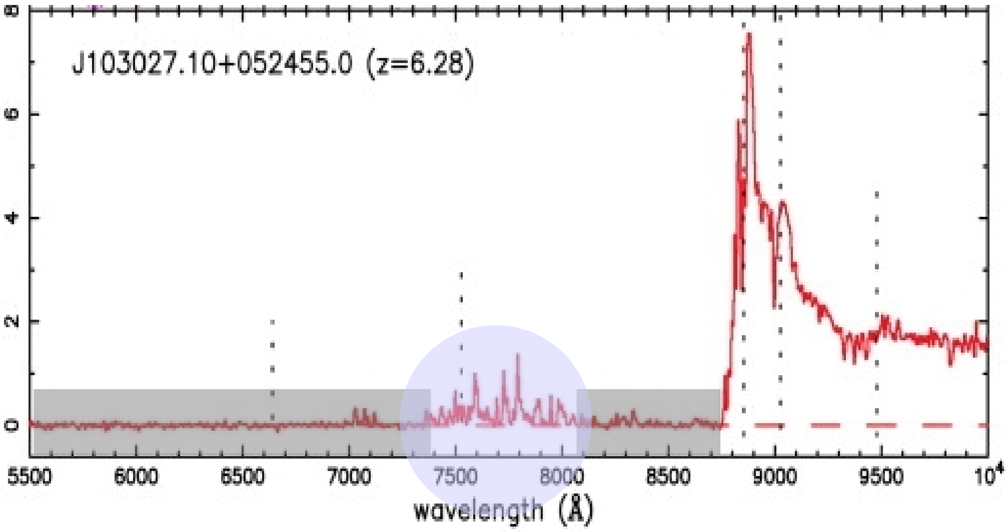
$z = 5.7 \div 6.3$

Simulated spectra



PEAKS

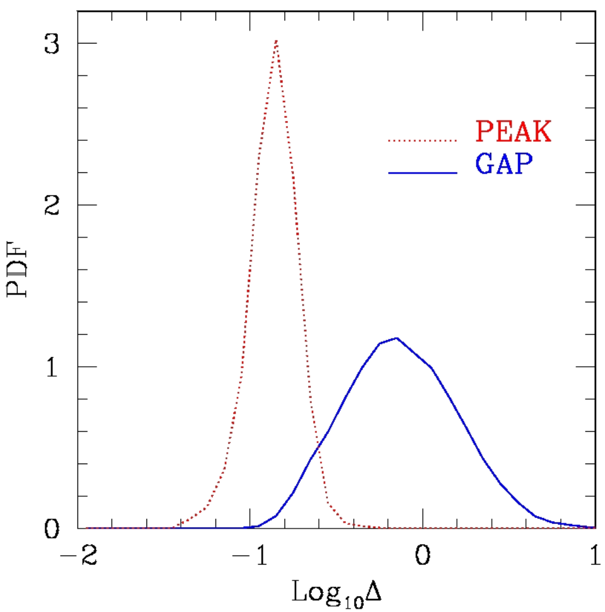
Transmissivity windows



What is the origin of the peaks?

Cosmic underdense regions

$$\Delta \equiv \frac{\rho}{\bar{\rho}}$$



GAP

$\Delta \approx 1$

PEAK

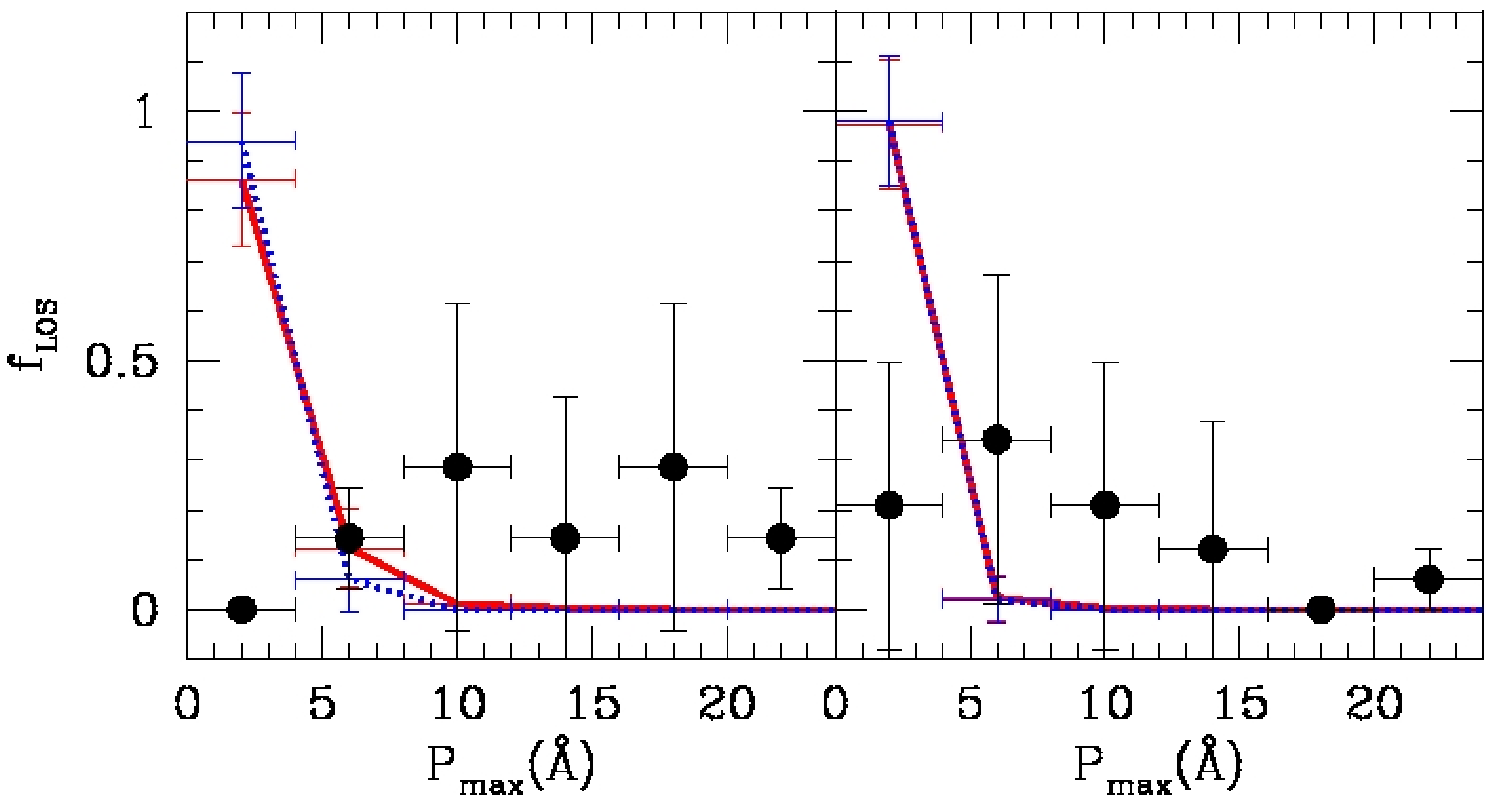
$\Delta \approx 0.1$

Largest peak width distribution

Observations vs Simulations

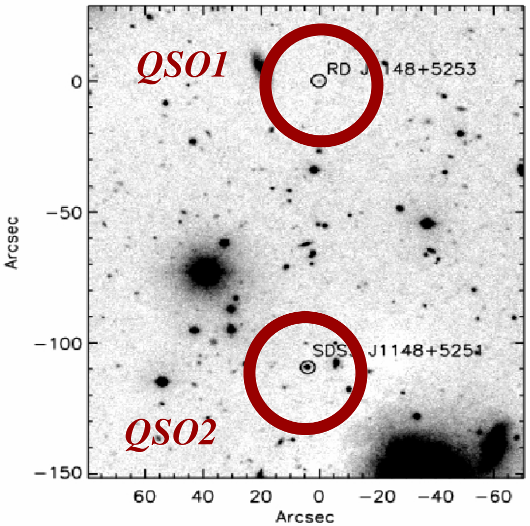
SG, Ferrara, Fan, Choudhury (2007)

Low Redshift (z_{em}<6) **High Redshift (z_{em}>6)**



Transverse proximity effect: *observations*

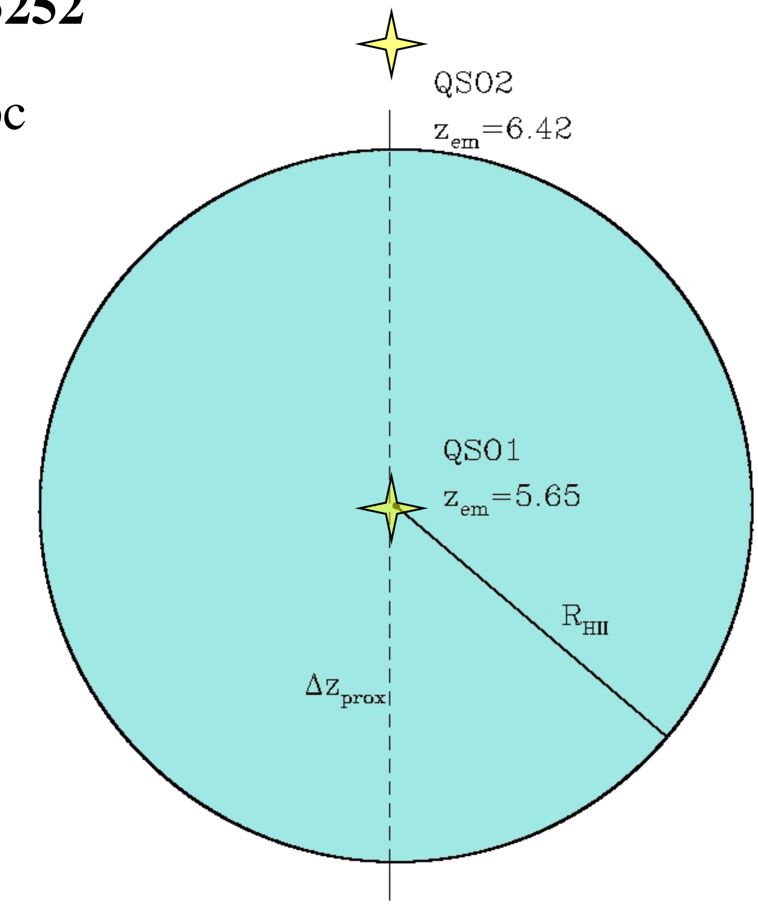
Mahabal et al. (2005)



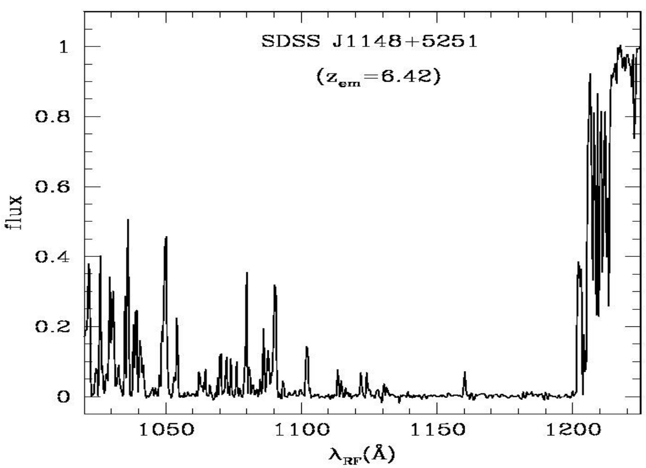
RD J1148+5252

$\boldsymbol{R_{\perp} = 0.7}$ Mpc

$\boldsymbol{M_B = -24.3}$

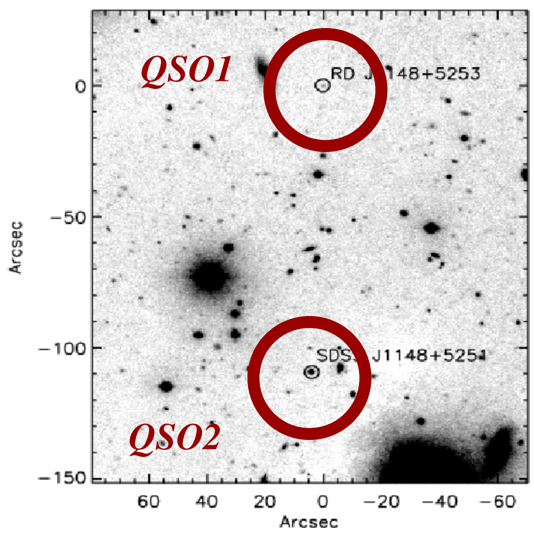


Fan et al. (2006)



Transverse proximity effect: *observations*

Mahabal et al. (2005)



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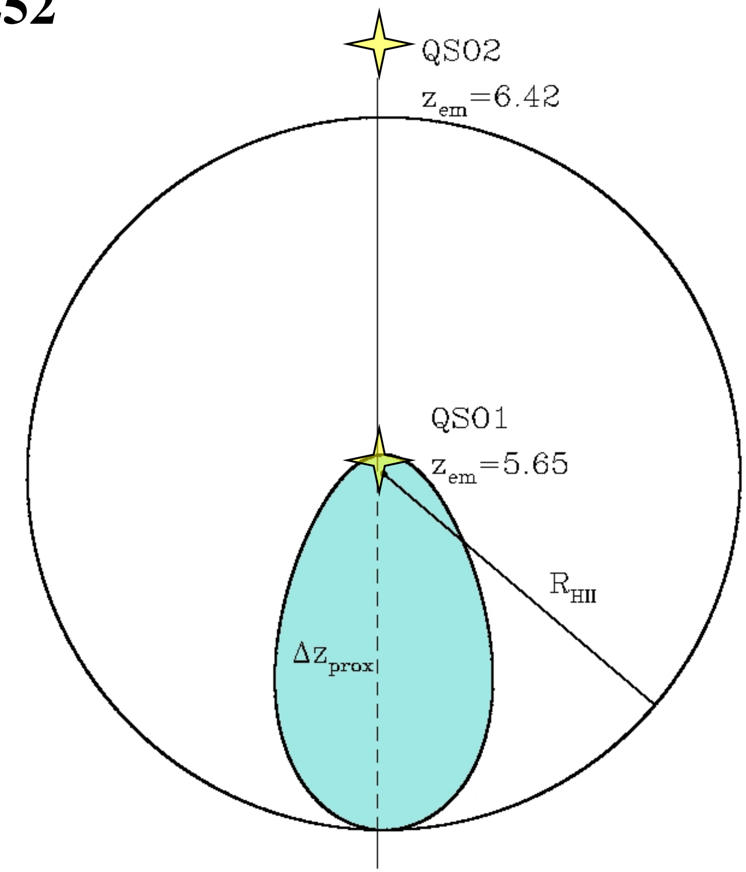
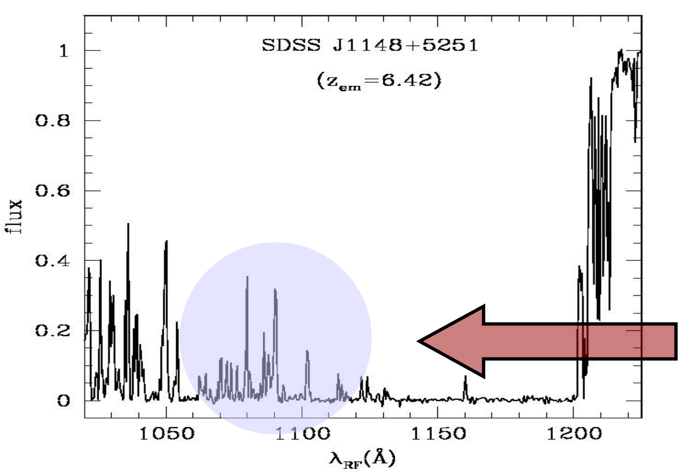


Fan et al. (2006)



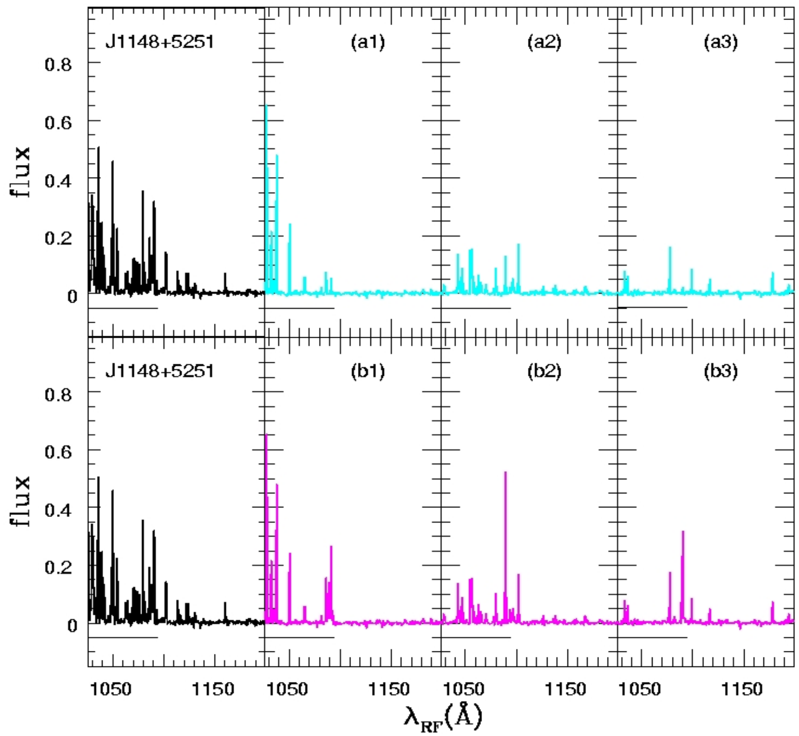
White et al. (2003)
Wyithe et al. (2005)
Yu (2005)
Shapiro et al. (2006)

Transverse proximity effect: simulations

Peaks origin:

Underdense Regions

(case A)



HII Regions

(case B)

$$\Gamma_{TOT} = \Gamma_{bkg} + \Gamma_{QSO}$$

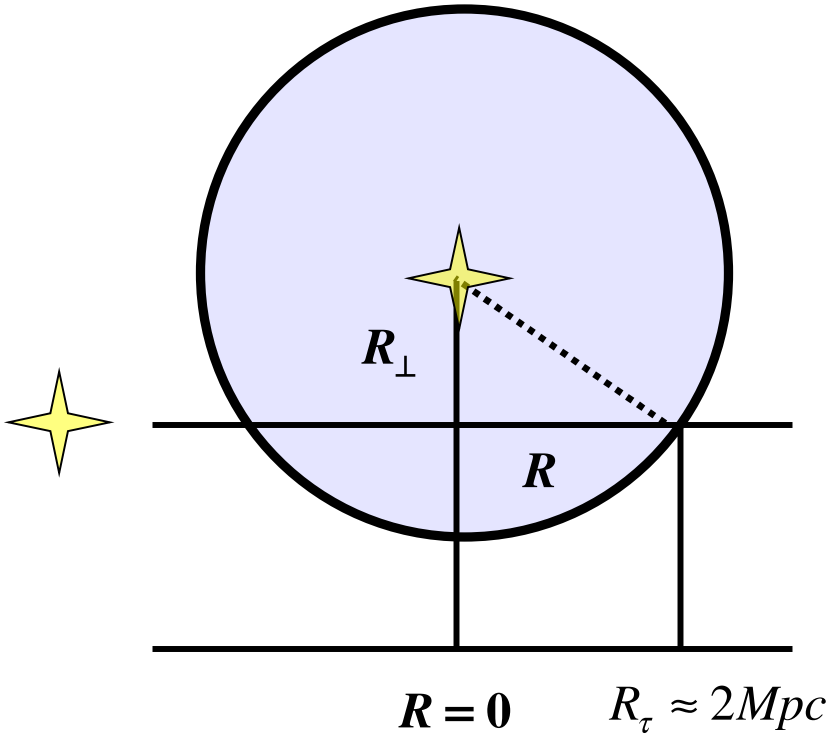
Peak Spectral Density

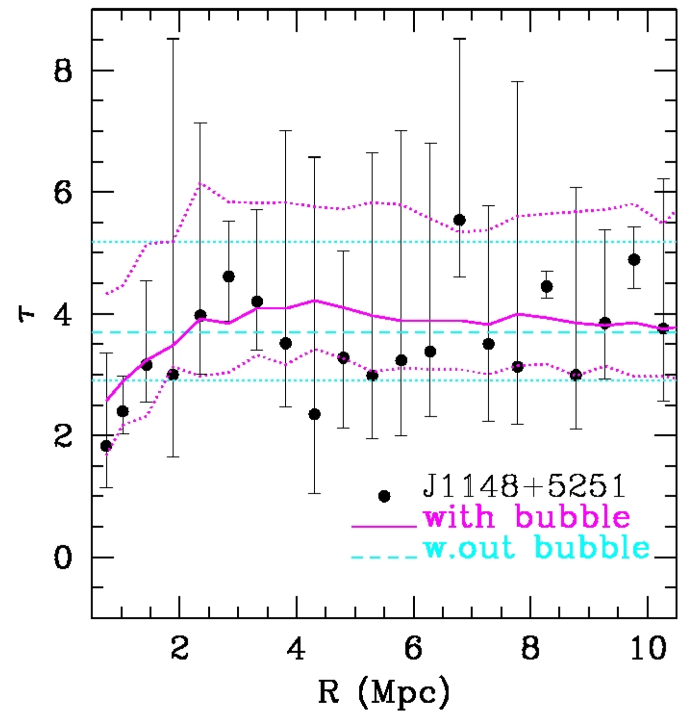
$$PSD = \frac{dN_{peaks}}{d\lambda}$$

$$PSD_{IN} \approx 4 \times PSD_{OUT}$$

SG, Ferrara, Fan, Choudhury (2007)

Transverse proximity effect: *observations vs simulations*





$$t_Q > \frac{R_\tau - R_\perp}{c} \approx 11Myr$$

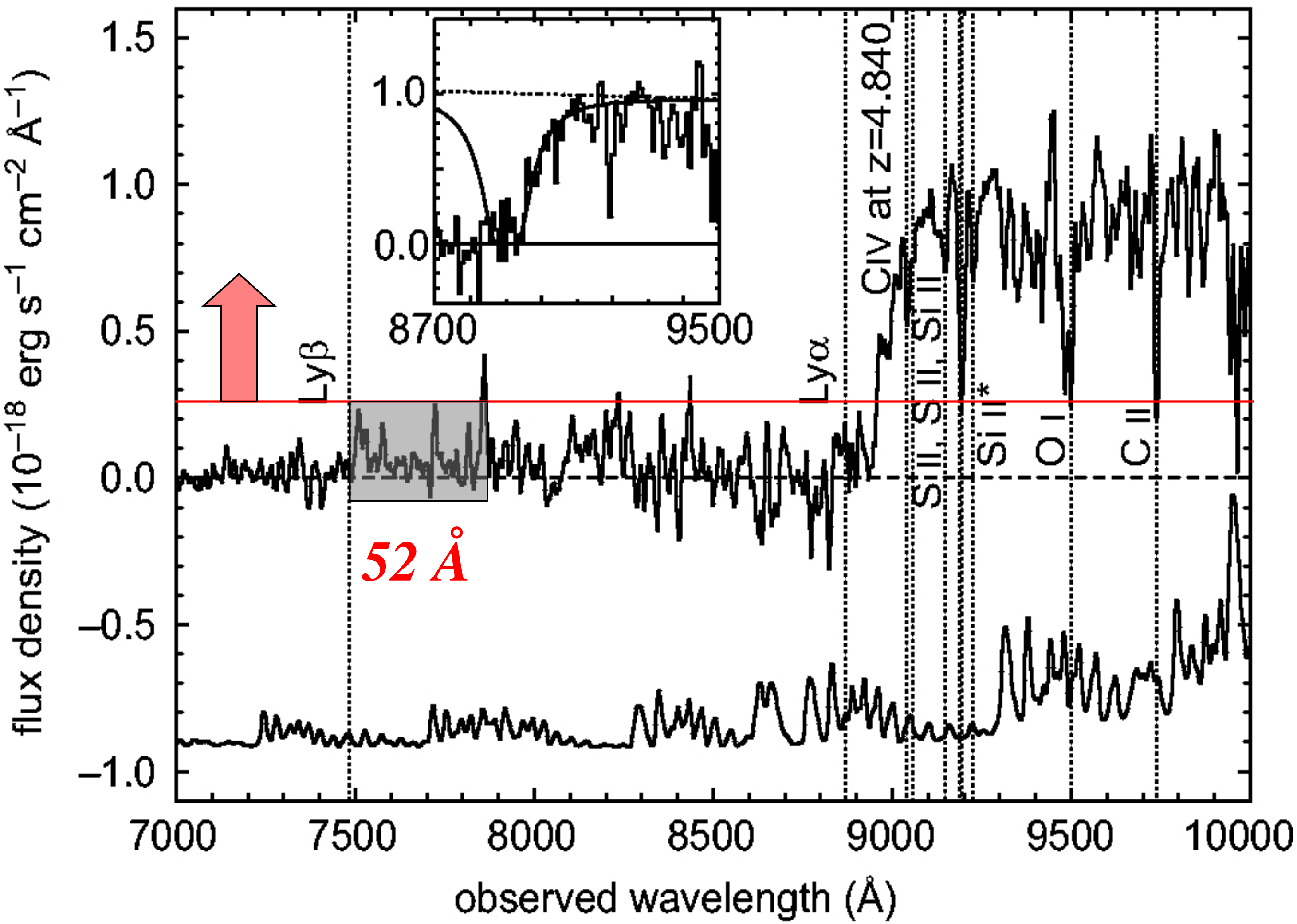
Additional lighthouses: GRBs

* *Afterglow spectra follow a power-law (easier continuum determination).*

* *GRBs are soon expected to be found at redshifts higher than QSOs ones.*

[GRB 050904 @ z=6.29 (Kawai et al. 2006)]

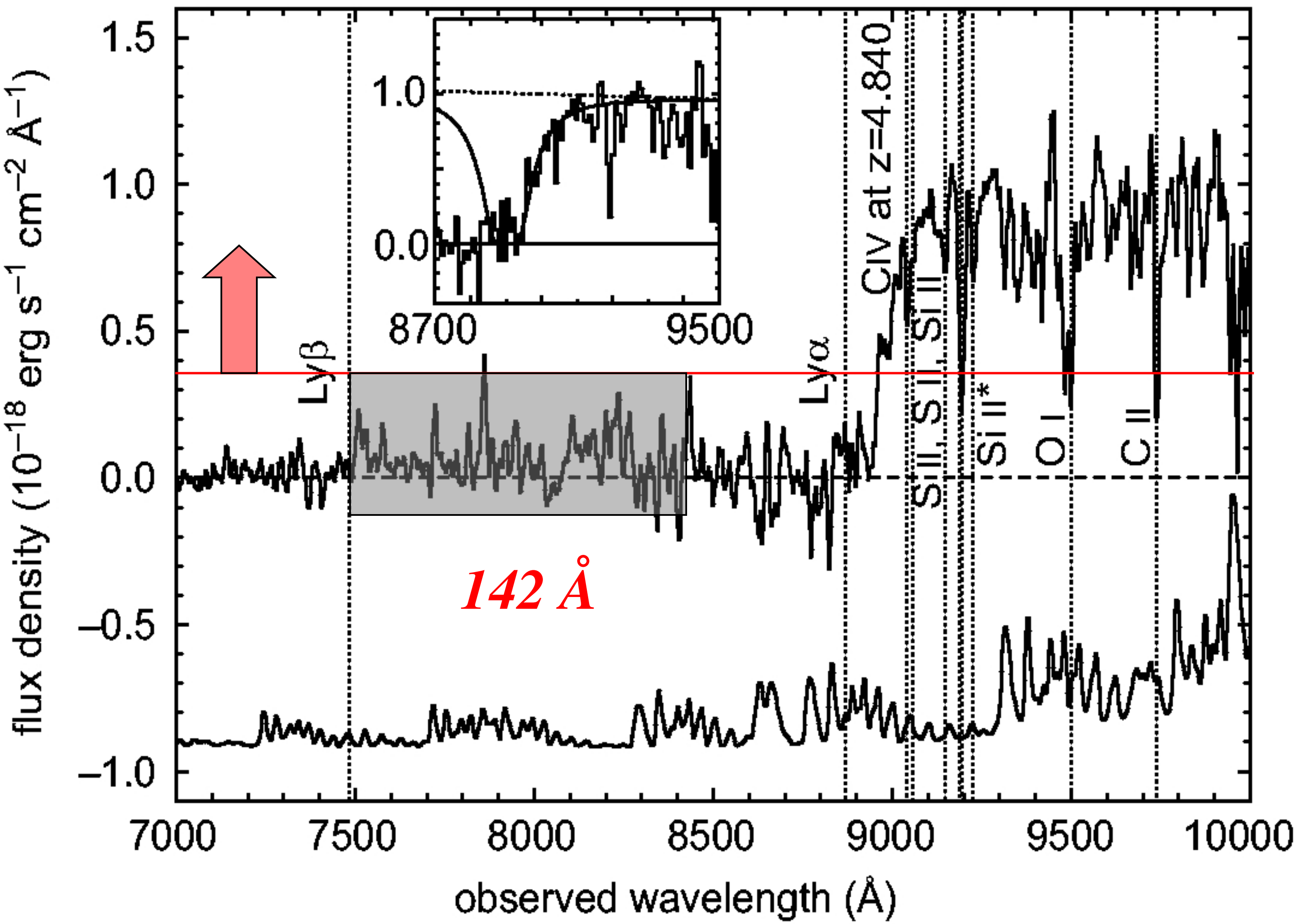
Observed GRBs absorption spectrum: GRB050904



$z_{GRB} = 6.3$

Kawai et al. (2006)

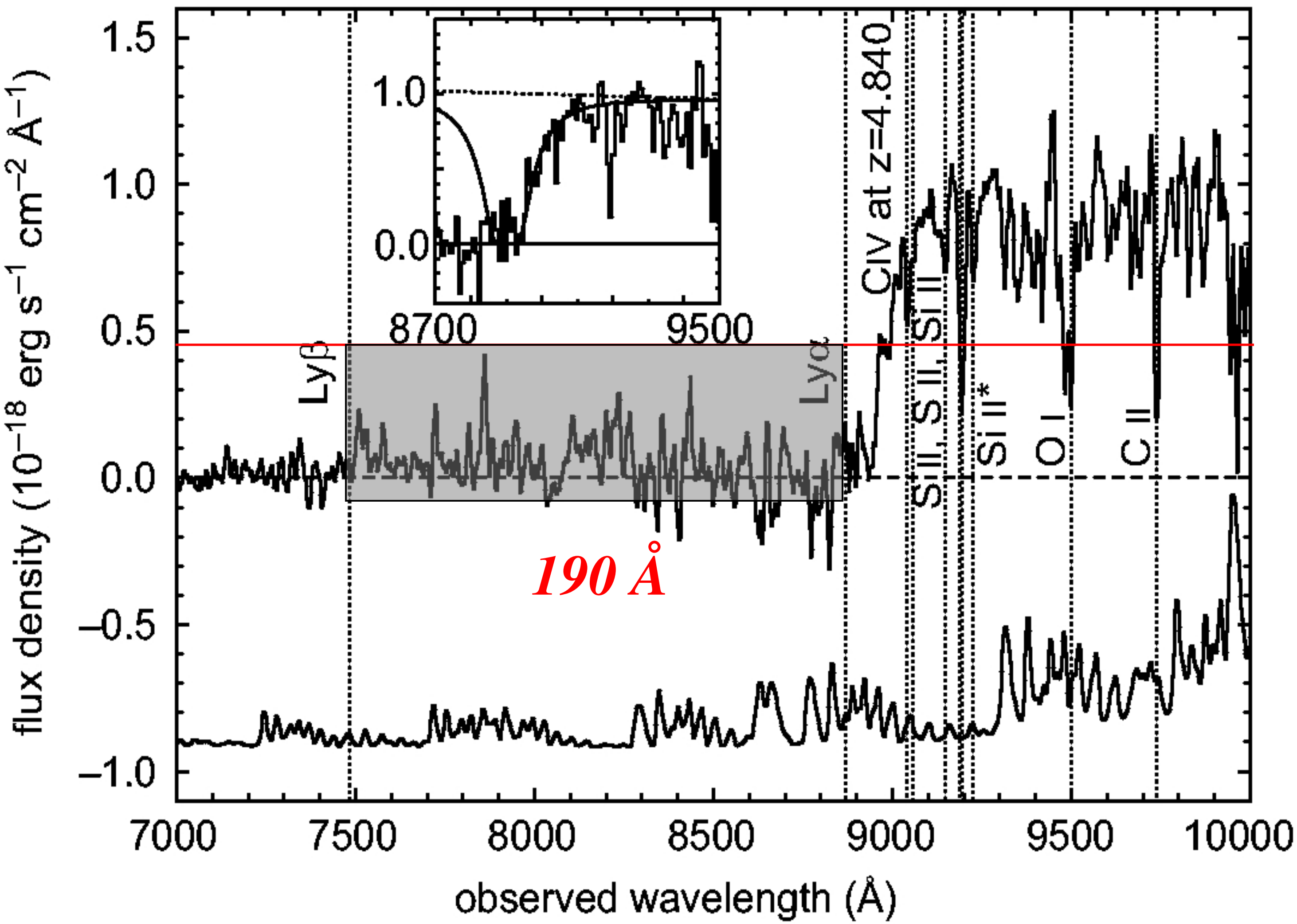
Observed GRBs absorption spectrum: GRB050904



z_{GRB} = 6.3

Kawai et al. (2006)

Observed GRBs absorption spectrum: GRB050904

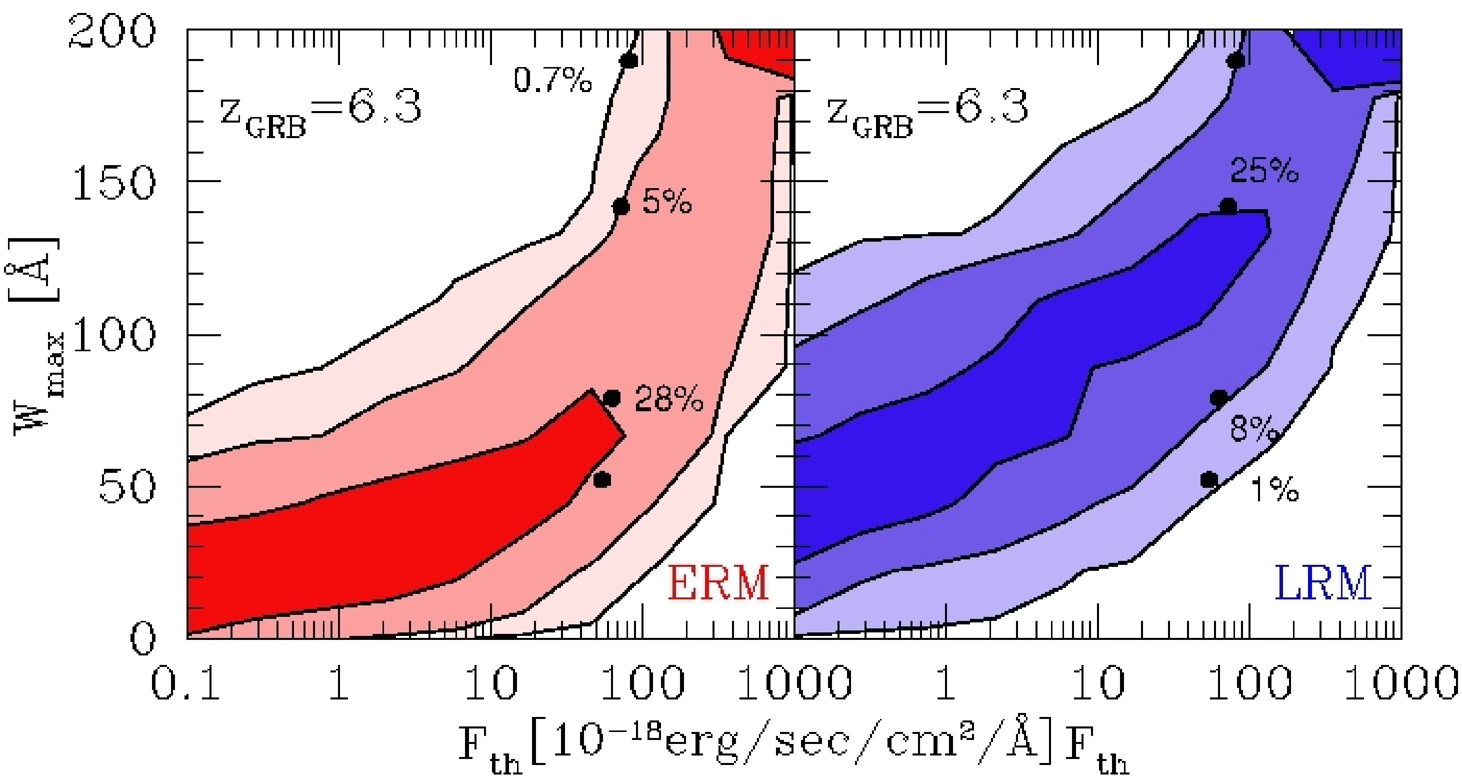


$z_{GRB} = 6.3$

Kawai et al. (2006)

Largest gap probability isocontours: GRBs

SG, Salvaterra, Ferrara, Choudhury (2007)

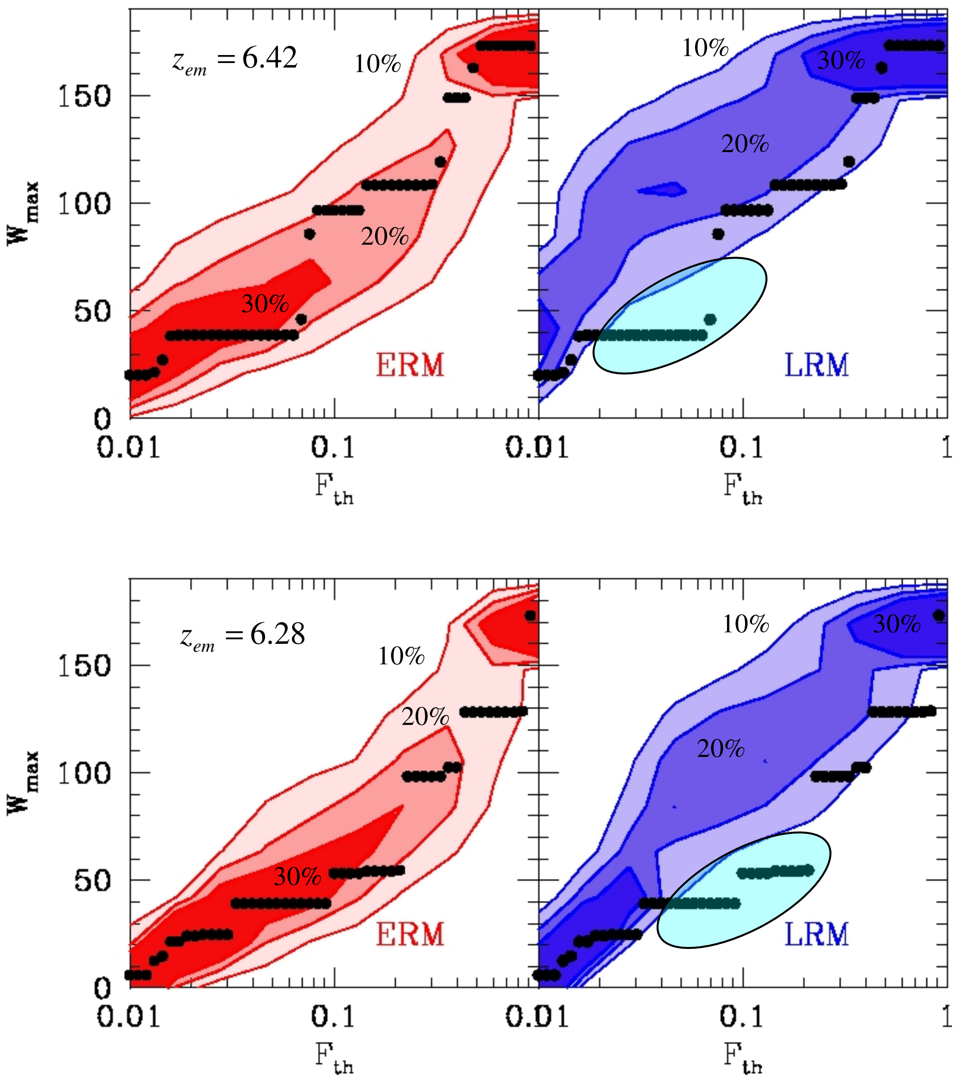


The ***ERM*** *is twice more probable wrt the* ***LRM***

The gap sizes are consistent with $\boldsymbol{x_{HI}=7\times10^{-5}}$.

Largest gap probability isocontours: QSOs

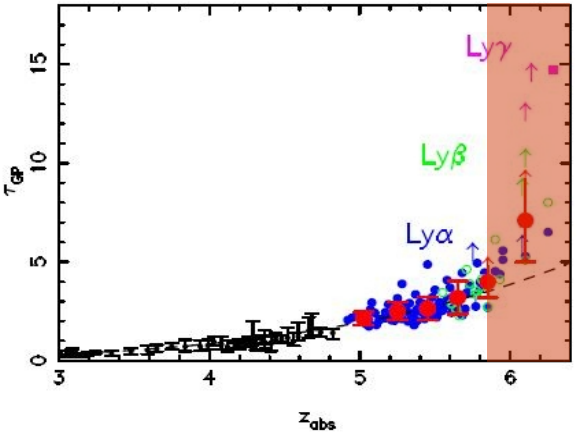
Work in progress

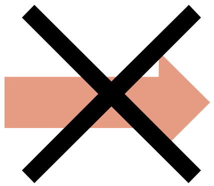


J1148+5251

J1030+0524

<u>*Conclusions*</u>





Epoch of reionization
z~6

(See also Becker et al. 2007)

The analysis of ***QSOs*** *and* ***GRBs*** *absorption spectra favors a* ***highly ionized IGM at z~6****, suggesting an* ***earlier epoch of reionization****.*