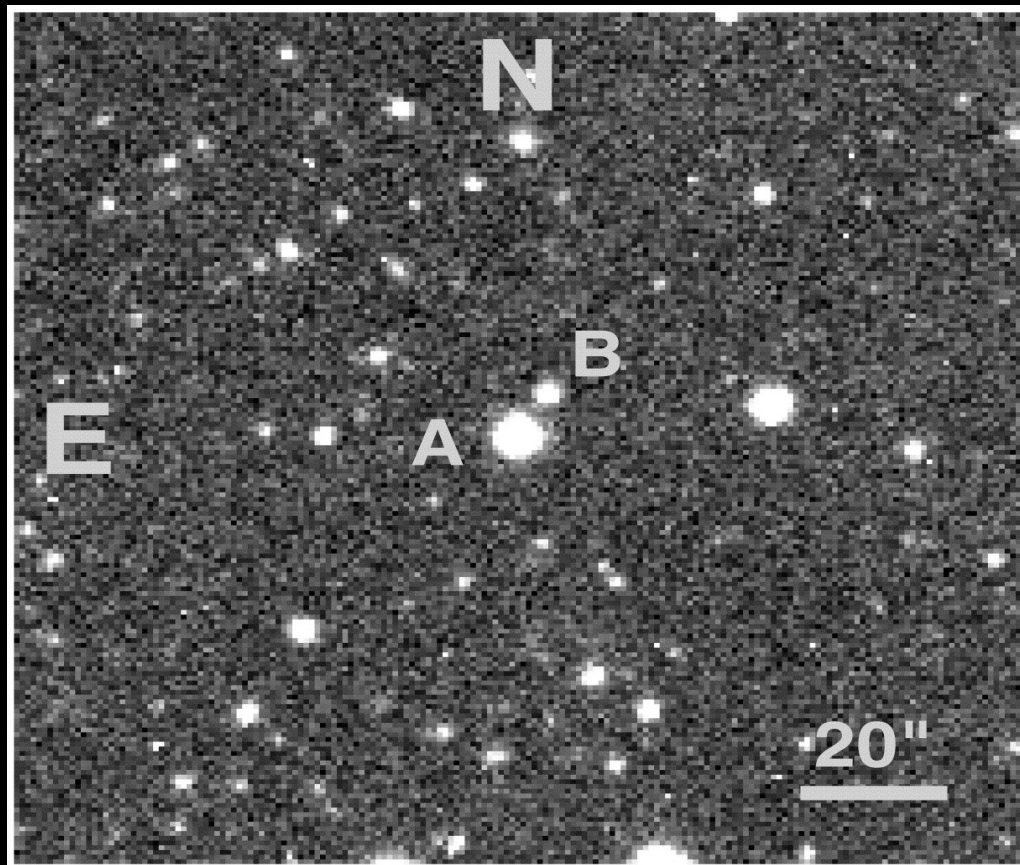


The proximity effect in quasar and its applications



Michele Fumagalli
Ay 230 Dec, 10

Outline

The proximity effect:

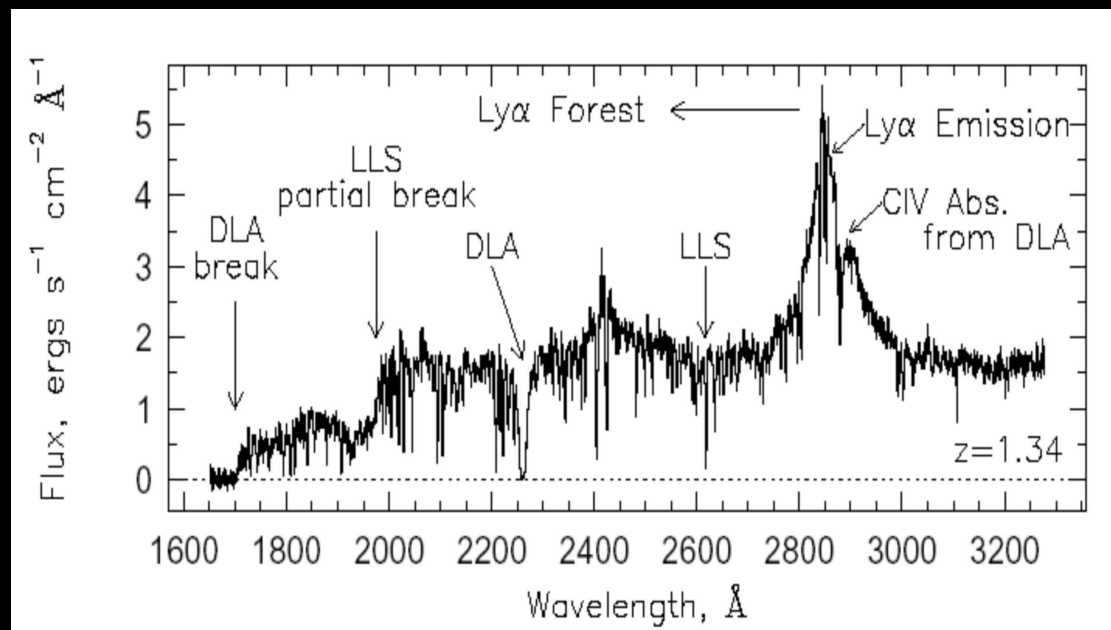
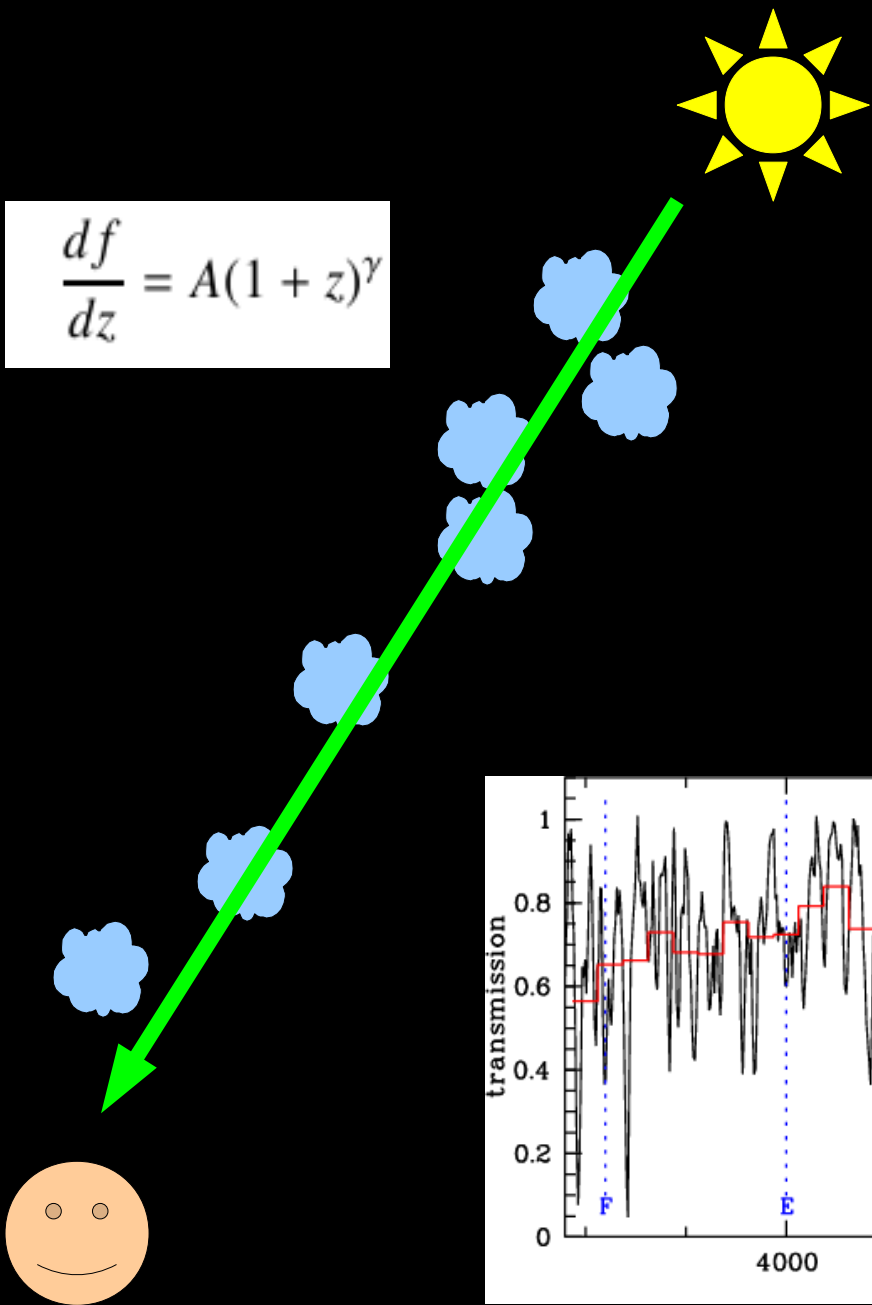
Discovery and model

Applications:

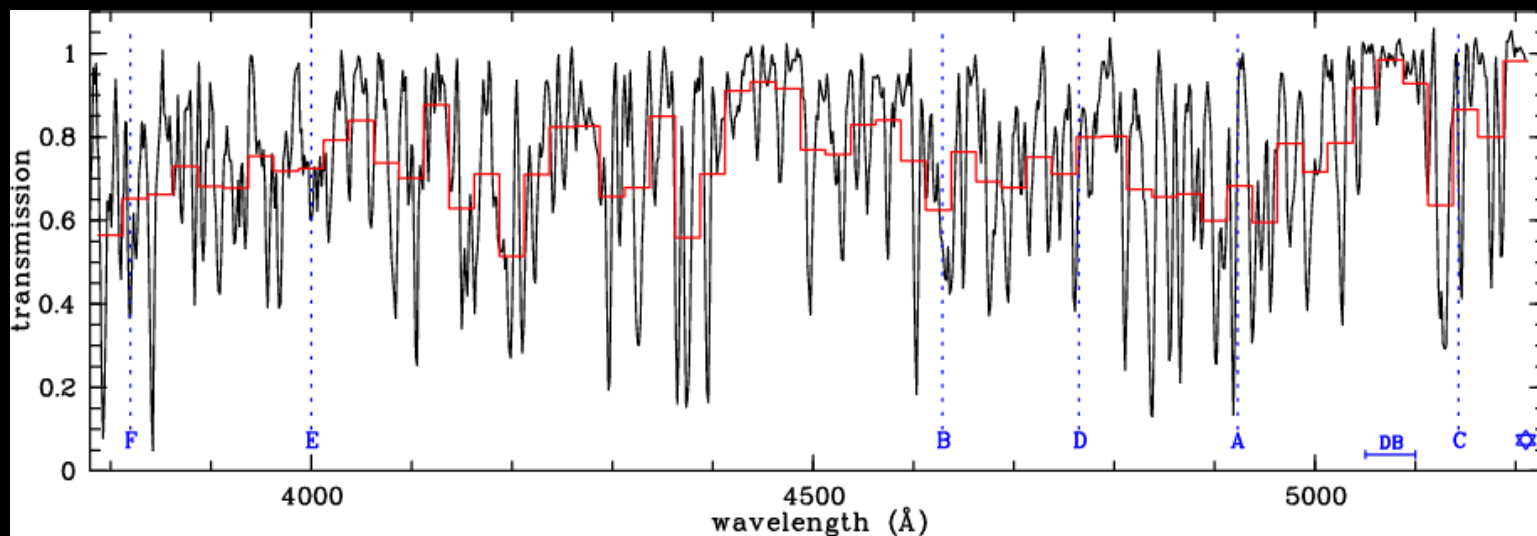
- 1) The ionization background
- 2) Quasar probing quasar
- 3) Quasar host galaxies

The proximity effect

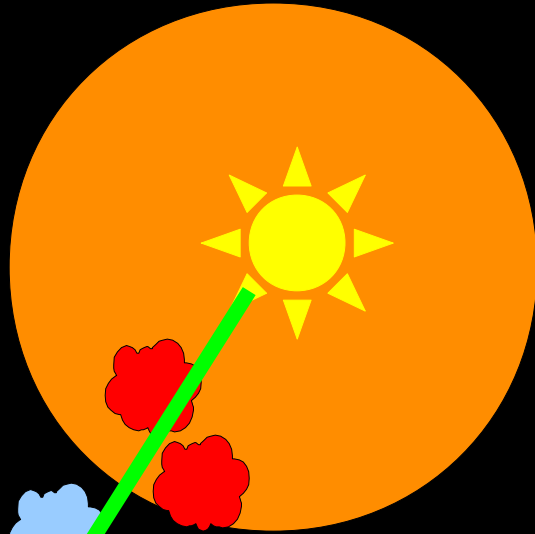
$$\frac{df}{dz} = A(1+z)^\gamma$$



The inverse effect (Carswell et al., 1982)



The proximity effect



The photoionization model
(Bajtlick et al., 1988)

$$\frac{df}{dz} = A(1+z)^\gamma$$

Due to the QSO radiation

$$N = N_0(1 + \omega)$$

with

$$\omega = \frac{F_\nu^Q}{4\pi J_\nu}$$

Finally

$$\frac{df}{dz} = A(1+z)^\gamma (1+\omega)^{1-\beta}$$

The proximity effect

Compare model with observation.

The UV background is
(Ikeuchi & Ostriker (1986))

$$J_\nu(z) = \frac{h\nu c}{4\pi} (1+z)^{3-\mu} \int_z^{z_0^n} dz \frac{S_\nu(z)}{H(1+z)^{1-\mu}}.$$

with

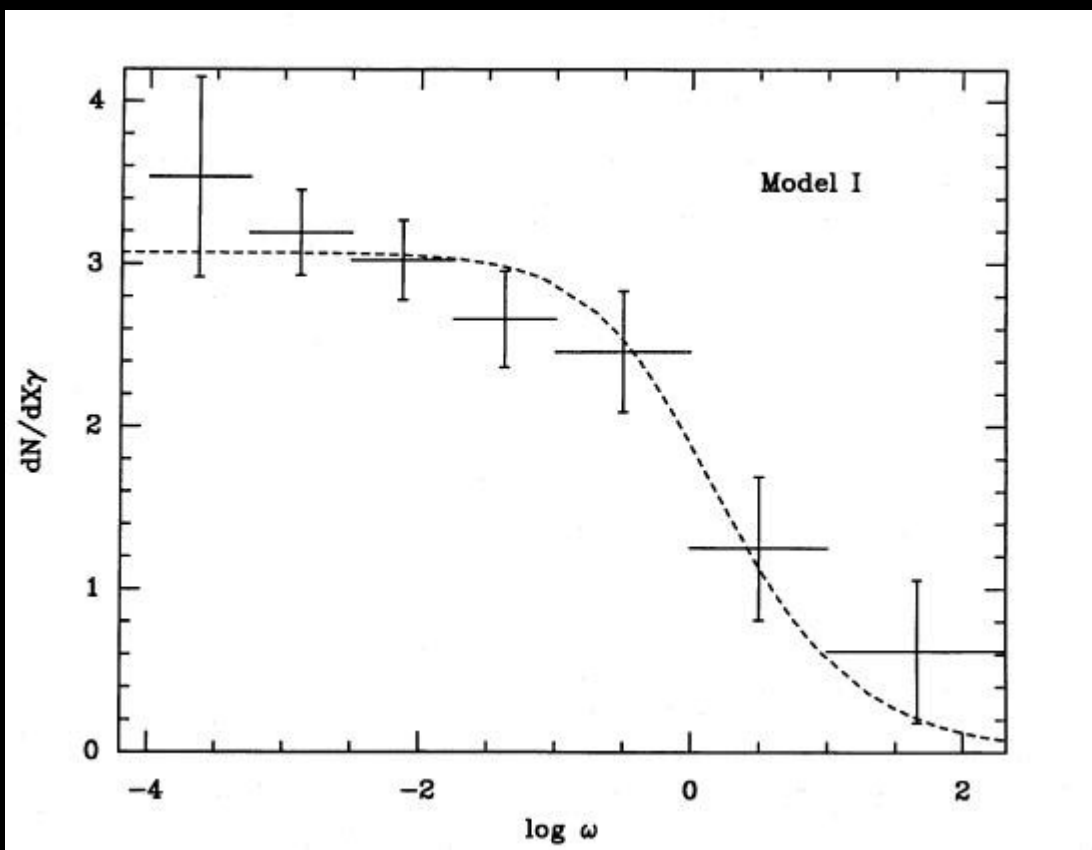
$$S_\nu(z) = \frac{L_*}{h\nu} \left(\frac{\nu}{\nu_r}\right)^\mu \int_{L_{\min}}^{\infty} dL \rho(z, L) \left(\frac{L}{L_*}\right)$$

and

$$\rho(z, L) = \frac{\rho_0}{L_*} g(z)^{\alpha-1} \left(\frac{L}{L_*}\right)^{-\alpha}$$

Fitting the QSO continuum and counting the mean absorber per coevolving redshift unit, one can compare data/model

$$\frac{df}{dX_\gamma} = A(1 + \omega(z))^{1-\beta}$$

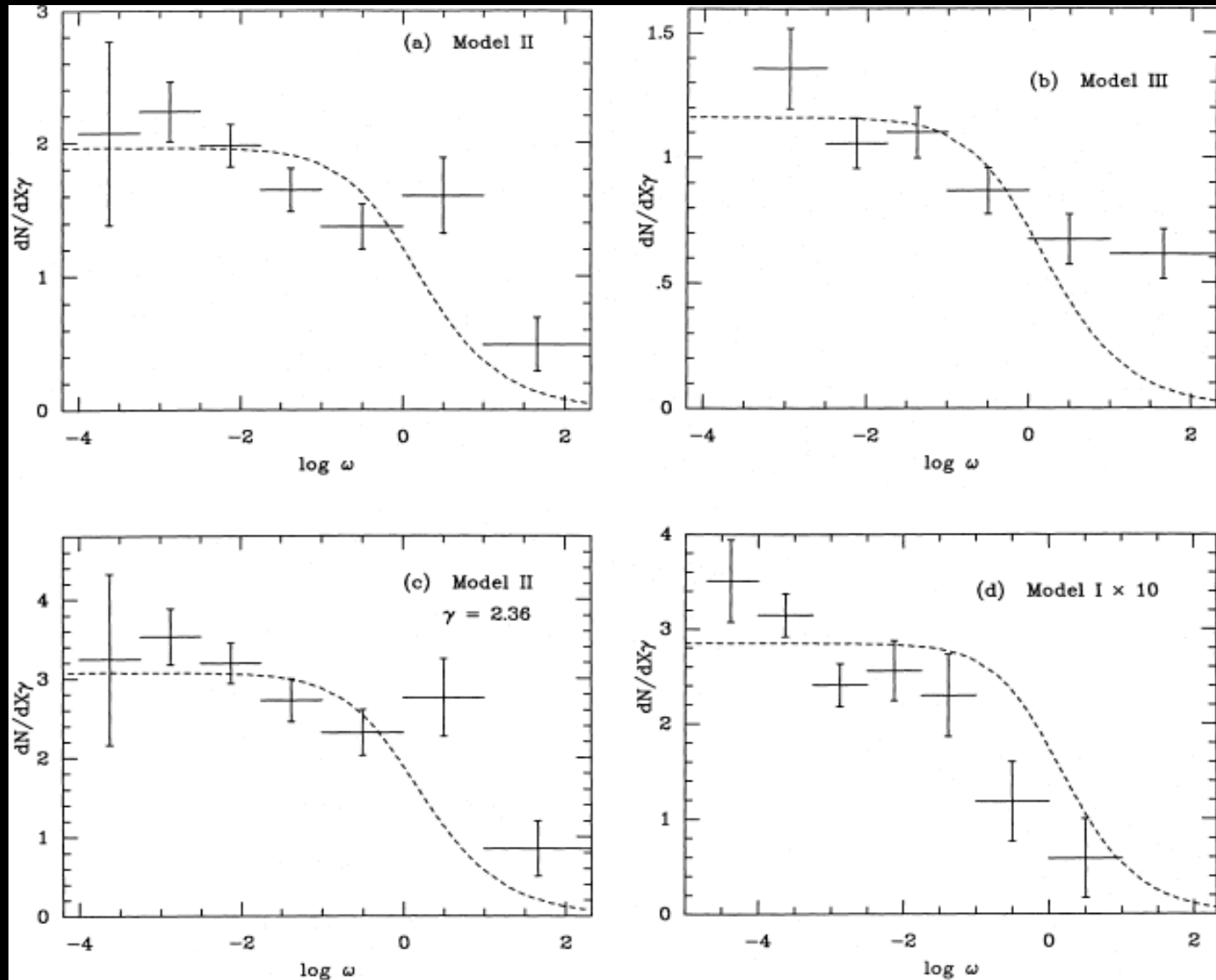


The UV background

Studying the proximity effect allows the determination of the UV background.

The idea is to find J that fits the data.

By changing the parameters in the previous equations:



The UV background

Nowadays, high resolution spectra! (Dell'aglio, 2008)

In terms of optical depth

$$\tau_{eff} = -\ln\langle e^{-\tau_{HI}} \rangle$$

and

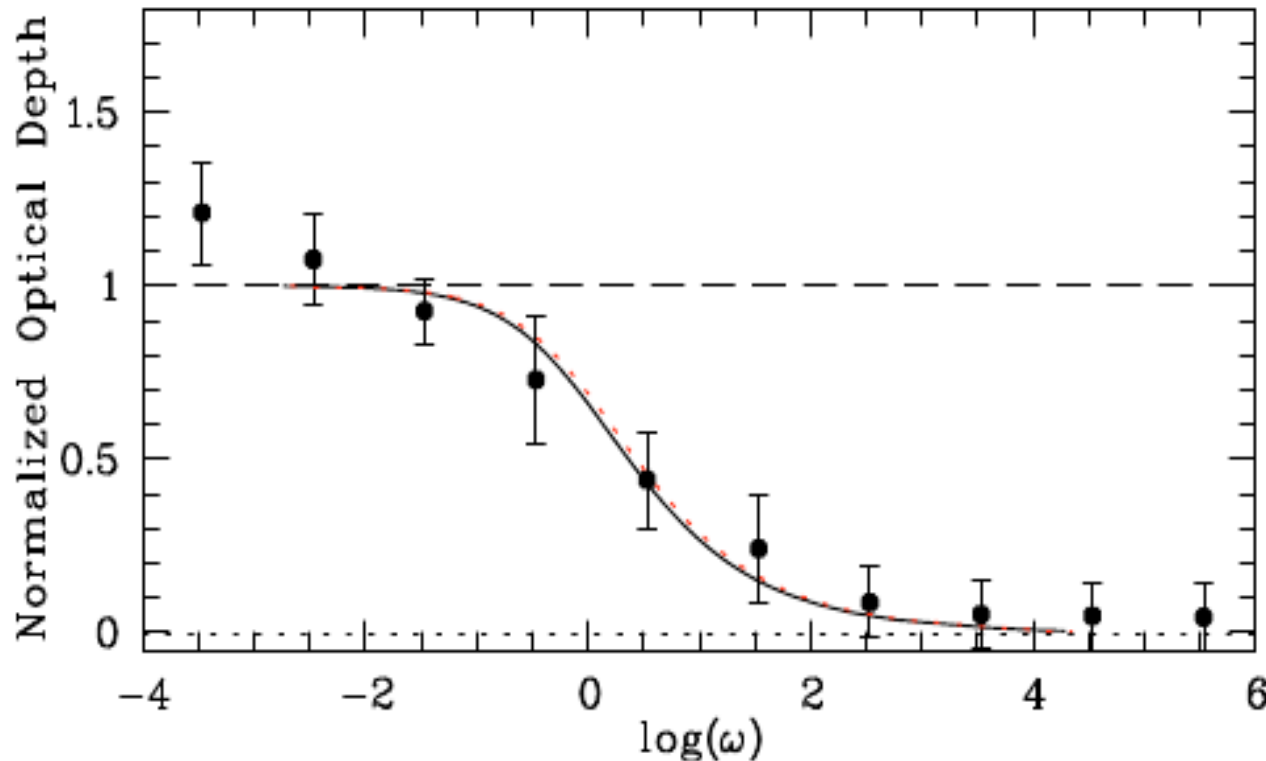
$$\tau_{eff} = \tau_0(1+z)^{\gamma+1}$$

The proximity effects becomes

$$\xi = \frac{\tau_{eff}}{\tau_0(1+z)^{\gamma+1}} = (1+\omega)^{1-\beta}$$

with

$$F(\omega) = \left(1 + \frac{\omega}{a}\right)^{1-\beta}$$

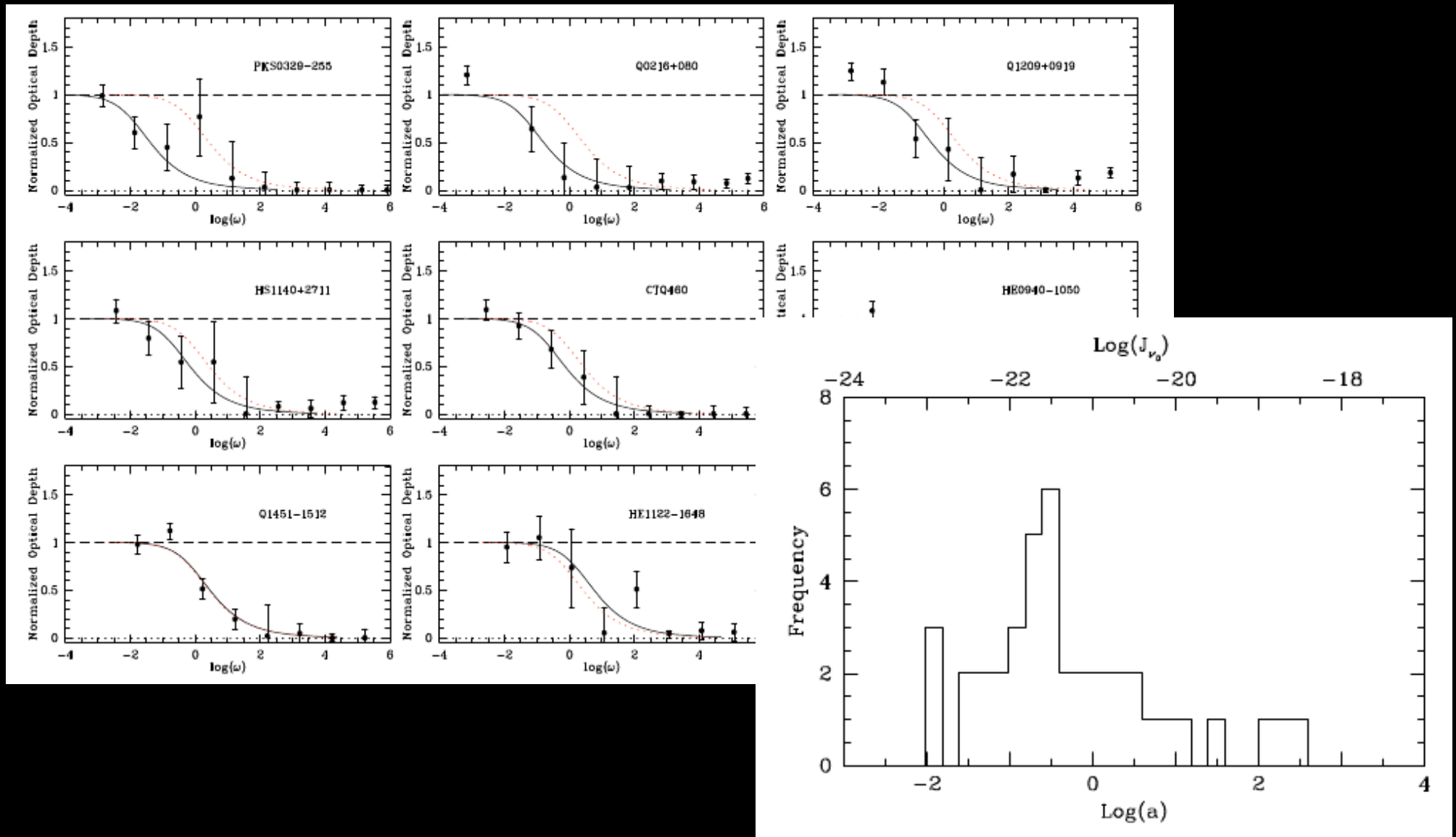


The best fit $J = a J^*$
gives $\log J = -21.10$

The UV background

Life is not simple (Dell'aglio, 2008)

The proximity effects for each line of sight is



The UV background

Life is not simple (Dell'aglio, 2008)

Bias due to skewness and tail in the distribution:
we need a simulation

The procedure used to generate synthetic spectra is based on the assumption that the Ly α forest is well represented by three observed distributions:

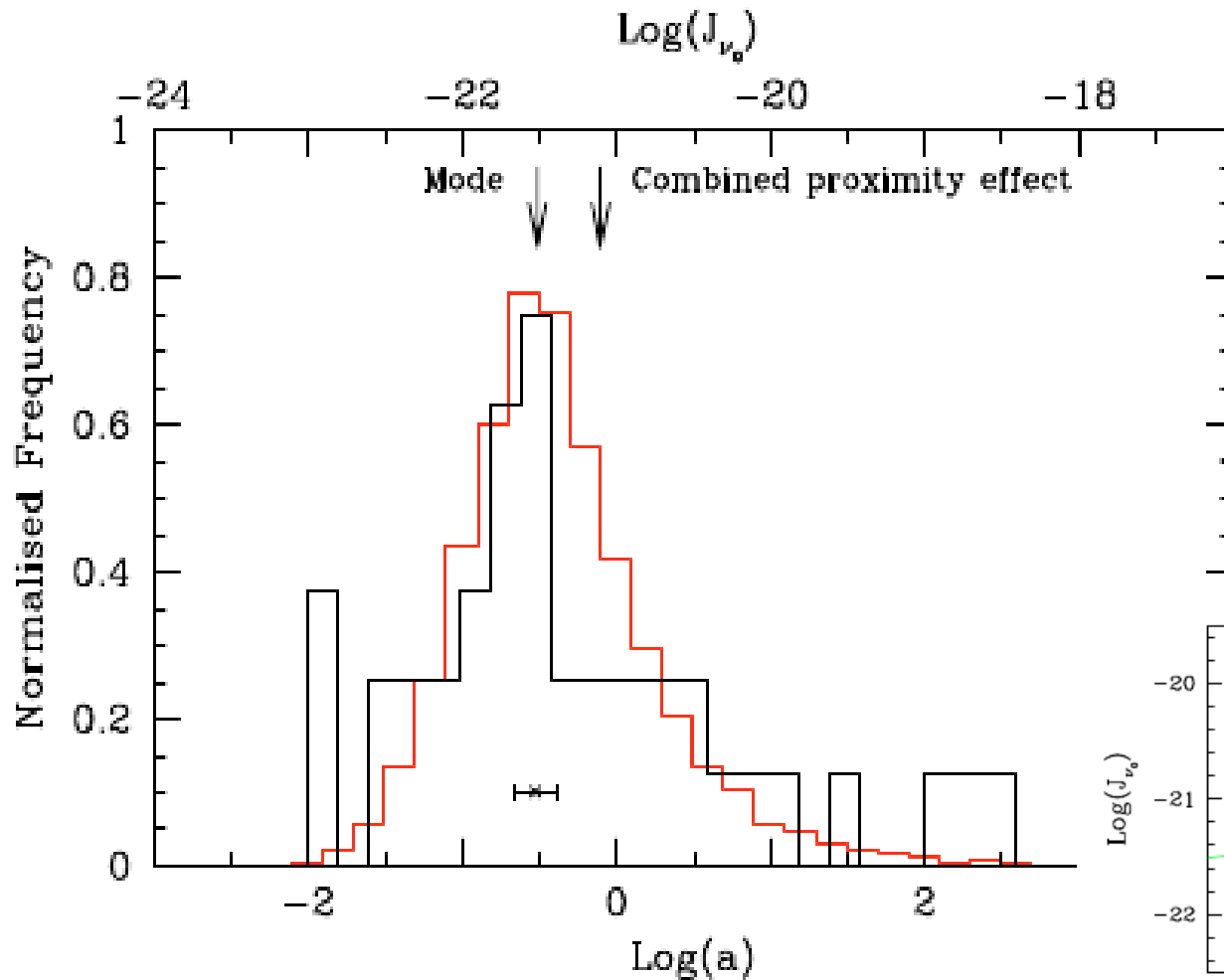
1. The line number density distribution, approximated by a power law of the form $dn/dz \propto (1+z)^\gamma$ where γ will be measured in Sect. 4.
2. The column density distribution, given by $f(N_{\text{HI}}) \propto N_{\text{HI}}^{-\beta}$ where the slope is $\beta \simeq 1.5$ (Kim et al. 2001).
3. The Doppler parameter distribution, given by $dn/db \propto b^{-5} \exp[-b^4/b_\sigma^4]$ where $b_\sigma \simeq 24 \text{ km s}^{-1}$ (Kim et al. 2001).

The simulated absorbers have column densities within the range $10^{12} < N_{\text{HI}} < 10^{18} \text{ cm}^{-2}$ and Doppler parameters between $10 < b < 100 \text{ km s}^{-1}$. The slope of the column density distribution was fixed to $\beta = 1.5$.

The UV background

Life is not simple (Dell'aglio, 2008)

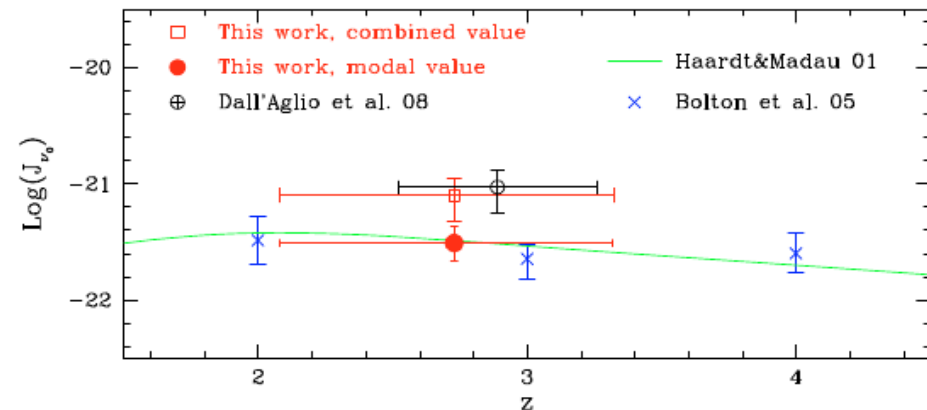
Bias due to skewness and tail in the distribution:
we need a simulation



Distribution is driven by
statistical fluctuations

The mode is unbiased!

$\text{Log } J = -21.51$

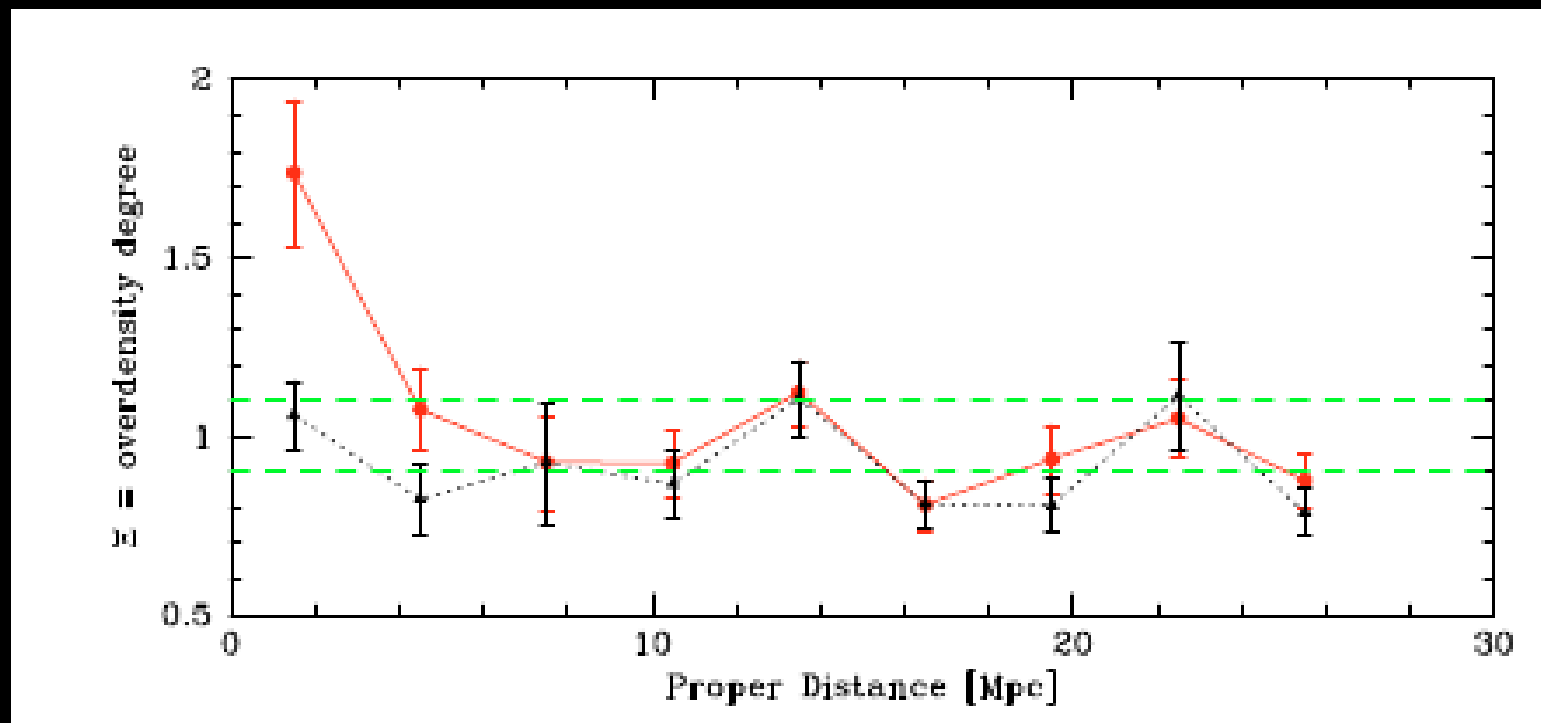


The UV background

Done? Not yet! Bias due to clustering (Dell'aglio, 2008)

Iterative procedure:

- 1) Correct for proximity effect
- 2) Study deviation from the model to probe the overdensity
- 3) Compare with random noise in the absence of overdensity

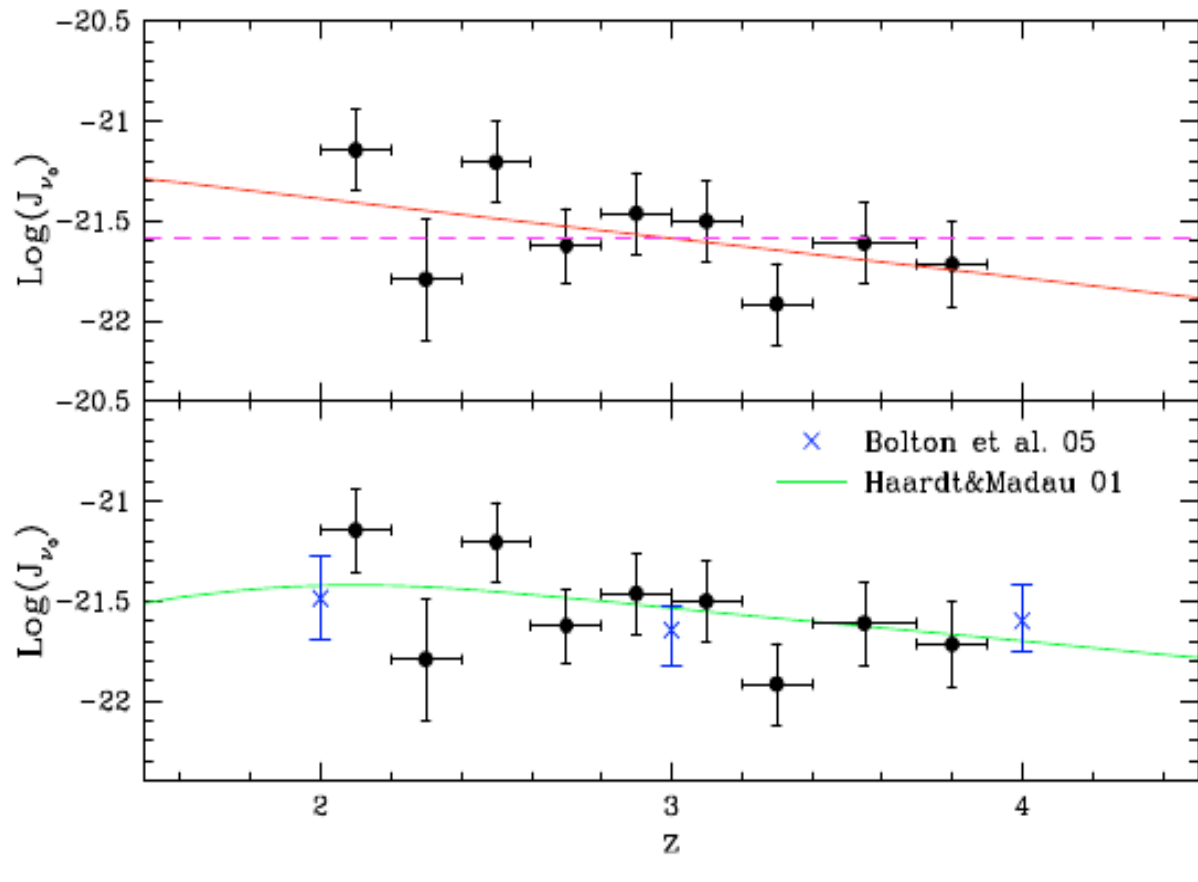


The UV background

Best way for UV background determination (Dell'aglio, 2008)

- 1) Study each line of sight
- 2) Identify the outliers in the clustering distribution
- 3) Stack data and fit for a
- 4) Correct the mode with a rigid shift

$$\log J_\nu = -21.49^{+0.14}_{-0.21}$$



In bin of redshift:

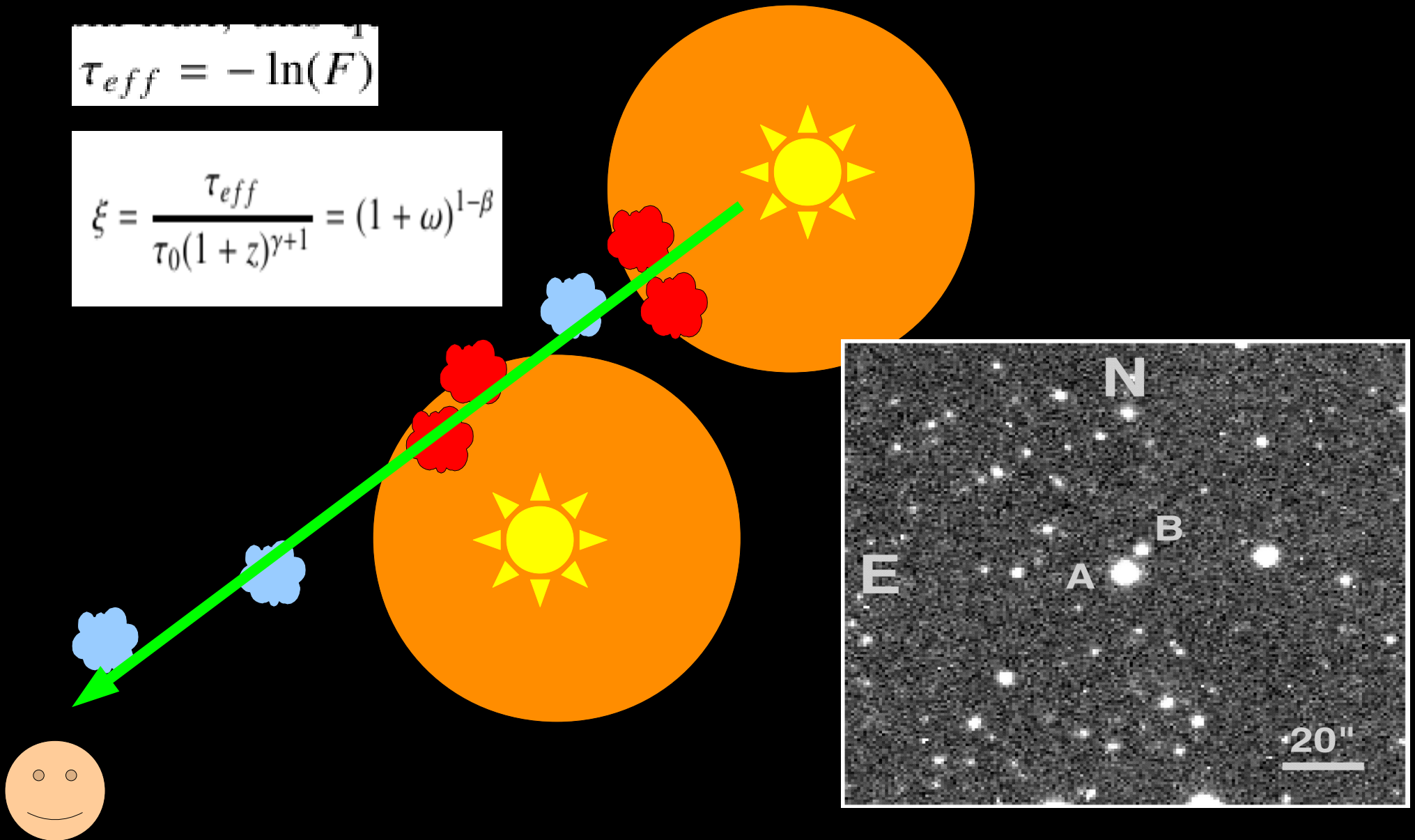
$$\log J_\nu(z) = (-0.20 \pm 0.14)z + (-21.0 \pm 0.4)$$

Quasar probing quasar

The transverse proximity effect:
now for the foreground quasar

$$\tau_{eff} = -\ln(F)$$

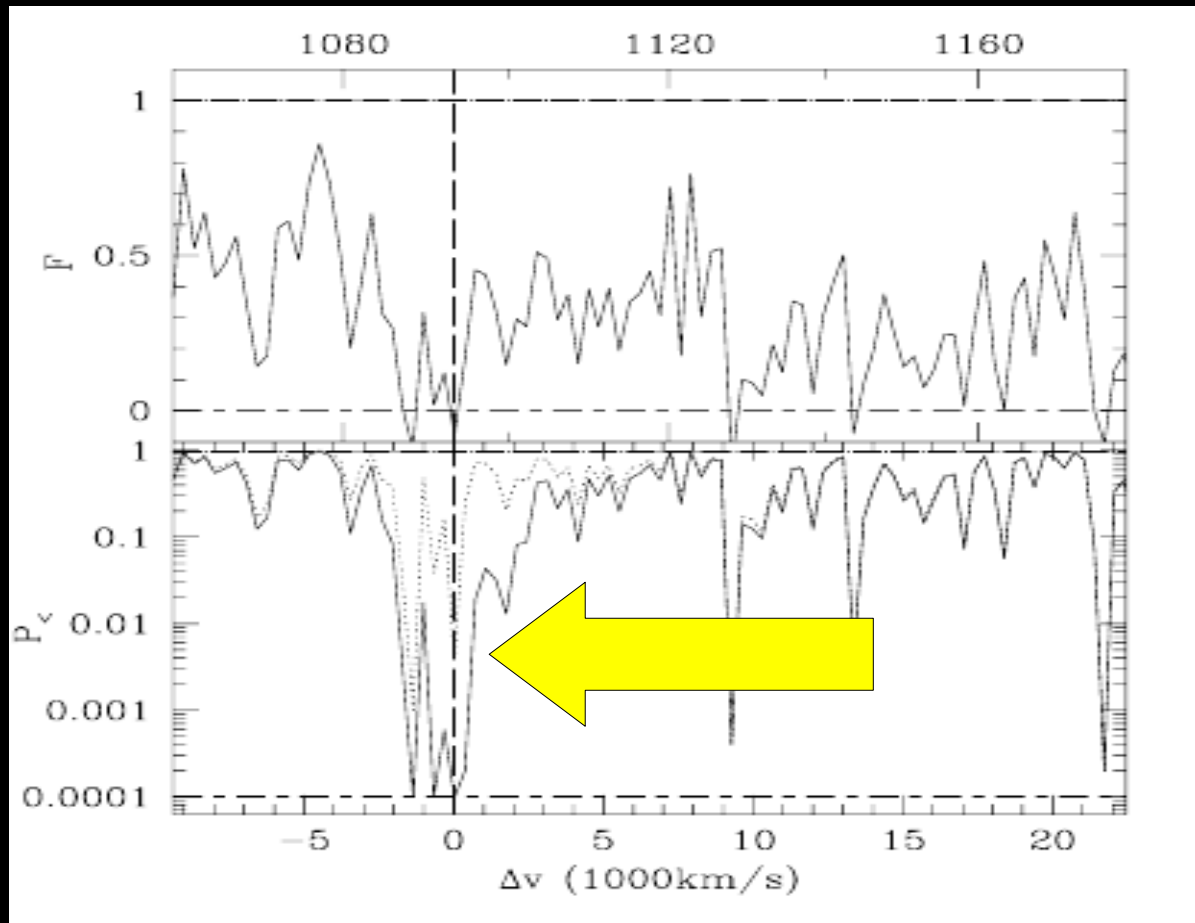
$$\xi = \frac{\tau_{eff}}{\tau_0(1+z)^{\gamma+1}} = (1+\omega)^{1-\beta}$$



Quasar probing quasar

Compare real with simulated spectra in three QSO pairs (Schirber, 2004)

- 1) Generate population of absorbers via CDM (bias, power spectrum)
- 2) Generate synthetic spectra assuming photoionisation model (Γ bgk, qso)
- 3) Compare Monte Carlo simulation with observation

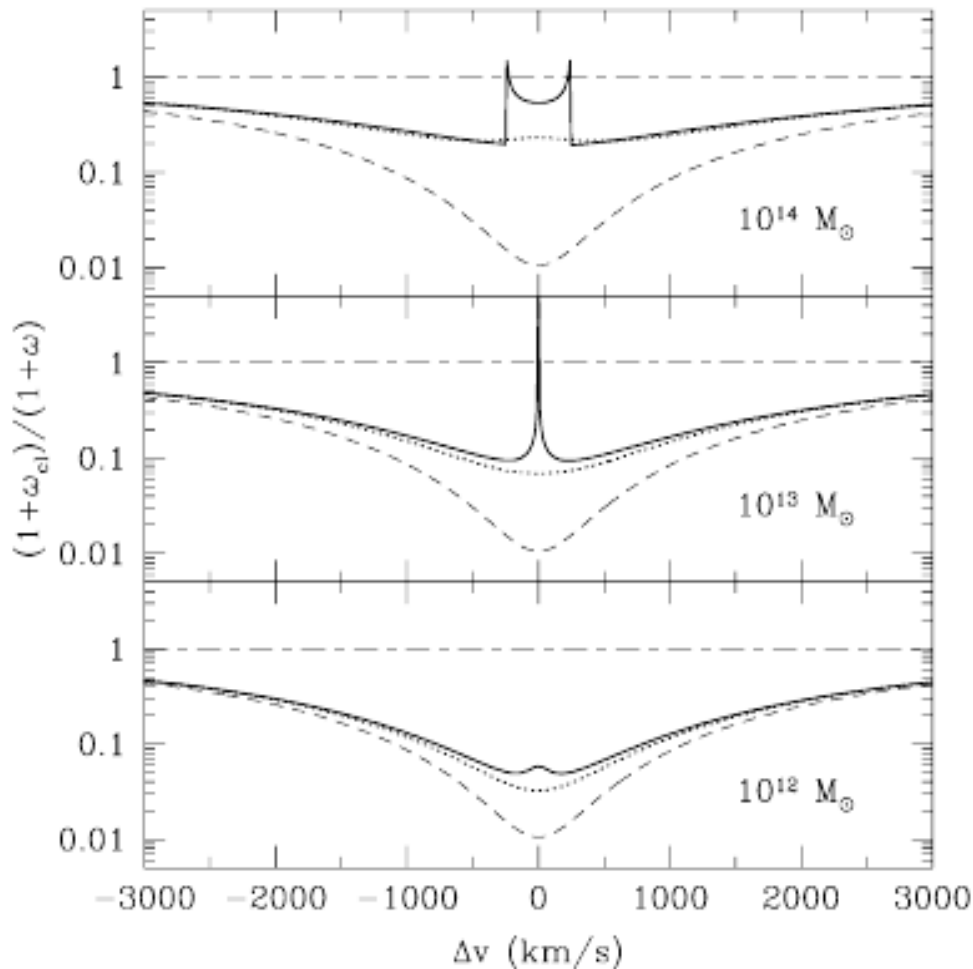


All the generated spectra have higher transmissivity F

No detection of transverse proximity effect

Quasar probing quasar

- What we learn about quasar? (Schirber, 2004)
- 1) There is a density enhancement around QSO



A Gaussian overdensity Δ increases the opacity by

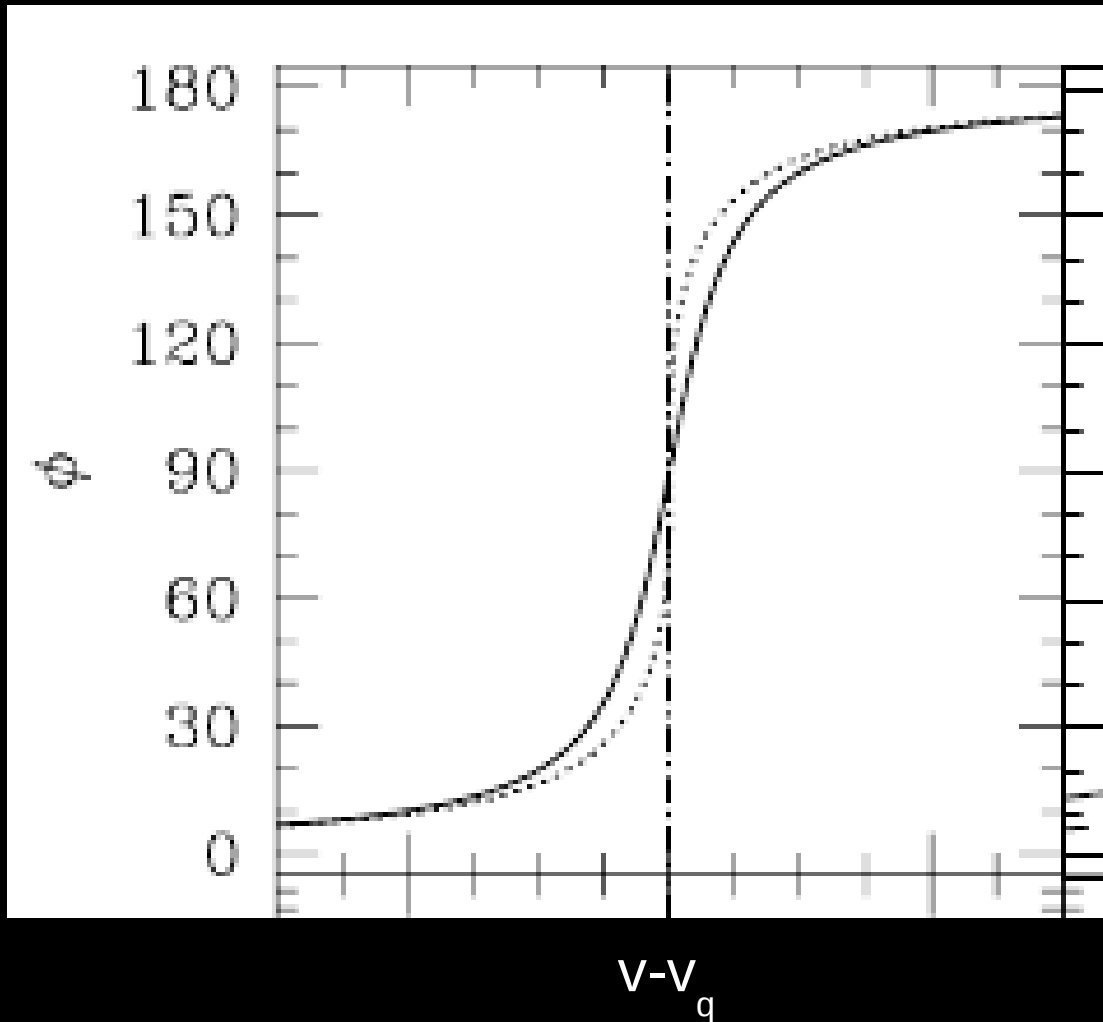
$$1 + \omega_{\text{cl}} = \Delta_1^{1.79} \left| \left(1 + \frac{dv_{\text{pec}}}{H dt} \right)^{-1} \right|,$$

Nice, but not enough!

Quasar probing quasar

What we learn about quasar? (Schirber, 2004)

2) QSO emission is anisotropic



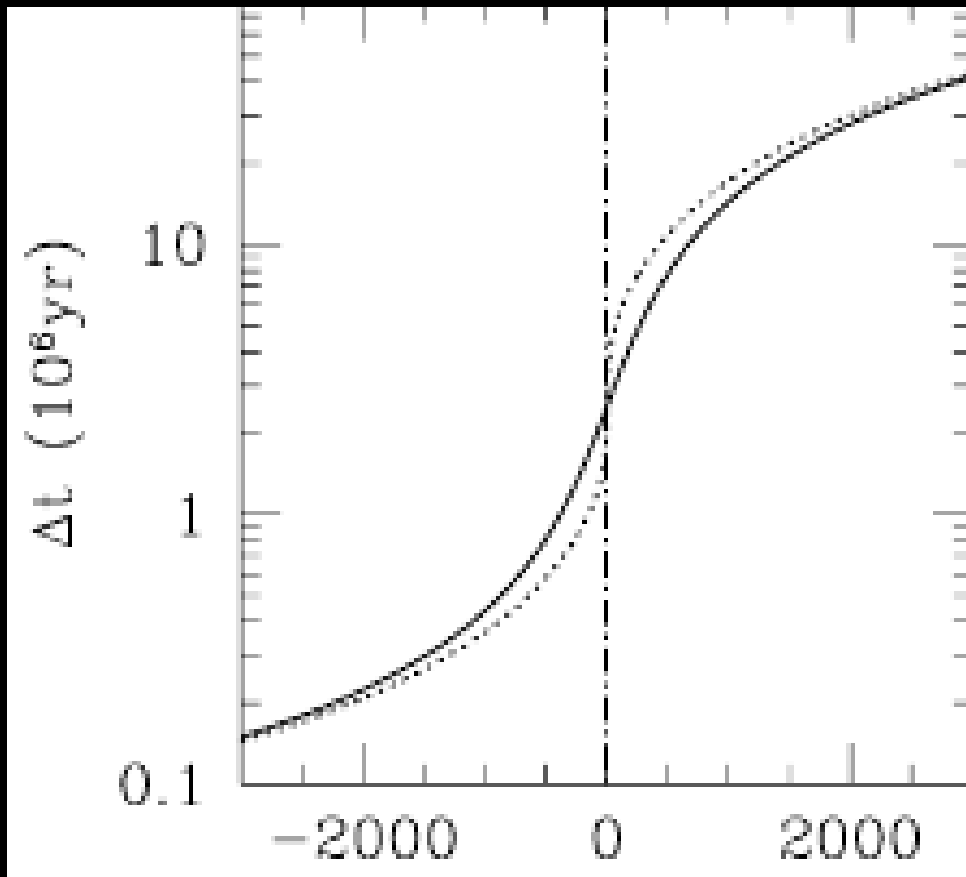
Selection bias towards line of sight

If the only effect, beams are too collimated

Quasar probing quasar

What we learn about quasar? (Schirber, 2004)

3) QSO variability



$v - v_q$

Relativistic delay:

$$\Delta t = \frac{c^{-1}}{R_f + R_p}$$

$$R_f = \sqrt{R_{\perp}^2 + R_{\parallel}^2}, \quad (2)$$

where R_{\perp} is the impact parameter from Table 1 and

$$R_{\parallel} \equiv \frac{c}{H(z_f)} \frac{z - z_f}{1 + z_f} \equiv \frac{\Delta v}{H(z_f)}. \quad (3)$$

Once again, not enough alone

Quasar probing galaxies

What we learn about quasar host galaxy? (Prochaska et al., 2008)

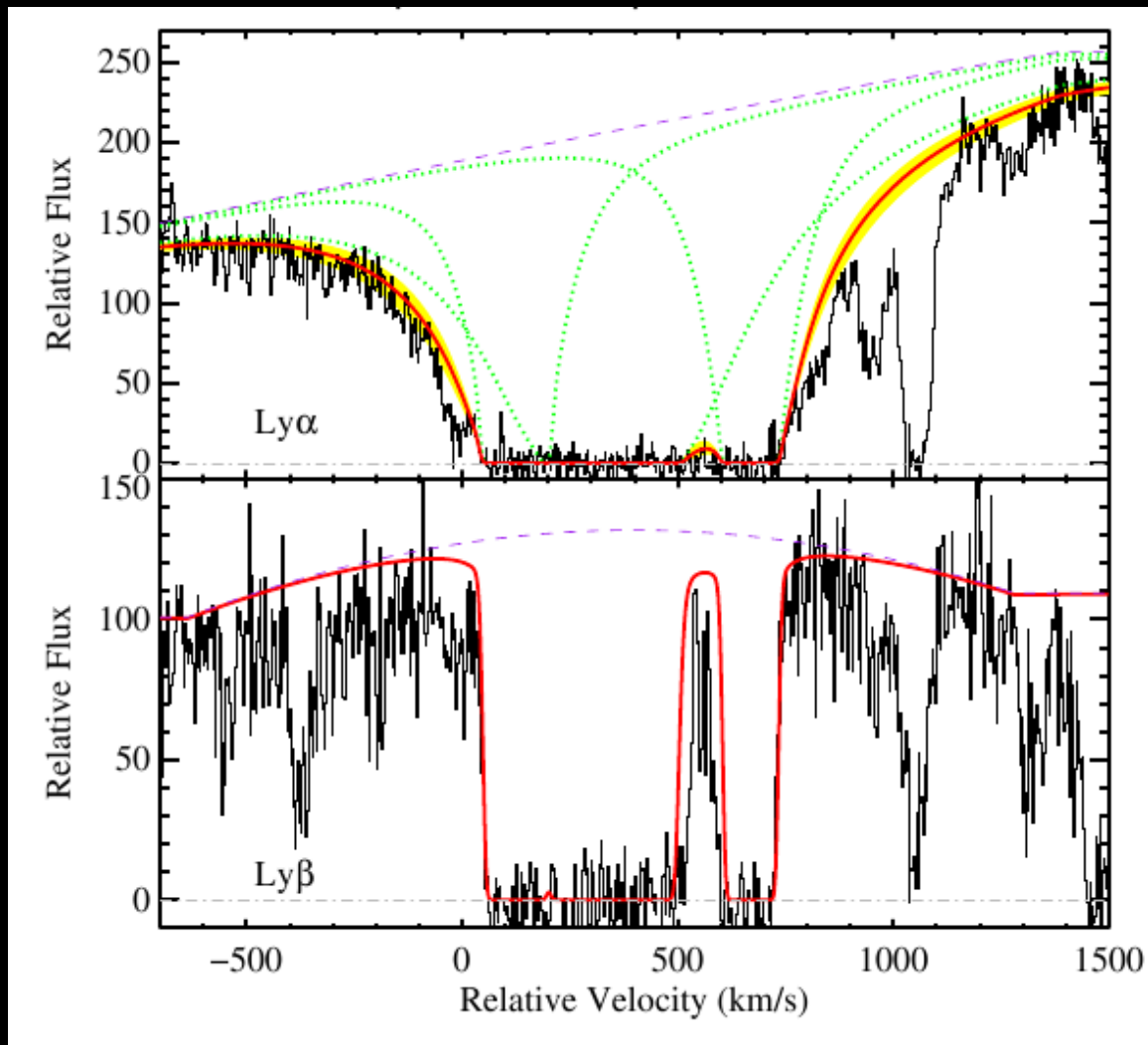
Several cosmological scenarios for massive quiescent galaxies:

- 1) Feedback from black hole accretion can quench the star formation
- 2) Gas collapsing in the DM halo can be shock-heated up to the virial temperature
- 3) Cosmological gravitational energy can be liberated during the halo contraction

Quasar pairs are useful to study the gas in the halo of the foreground quasar through a background quasar

Quasar probing galaxies

SDSSJ1204+0221, $\Theta = 13.3''$, $R_p = 108$ kpc, $z_{fg} = 2.4360$



1) Best fit profile implies 3 clouds

$N_{\text{HI}} \sim 10^{19} \text{ cm}^{-2}$ SLLS

2) From metal lines, $\Delta v \sim 600$ km/s and $\Delta v > 0$:

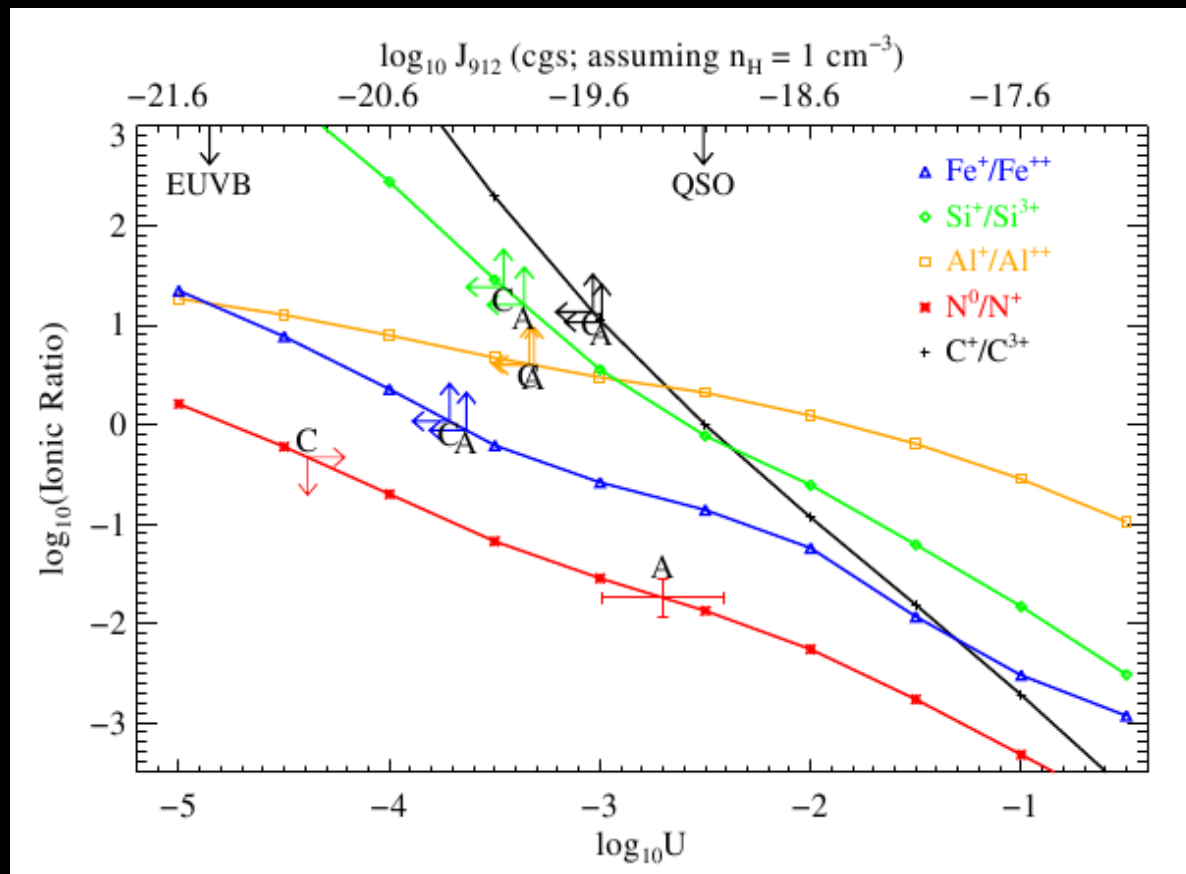
extreme kinematic
coherent motion

Quasar probing galaxies

The population of the low-ions and the absence of high-ions suggests partial ionization with $4 < \log T < 5$ (K)

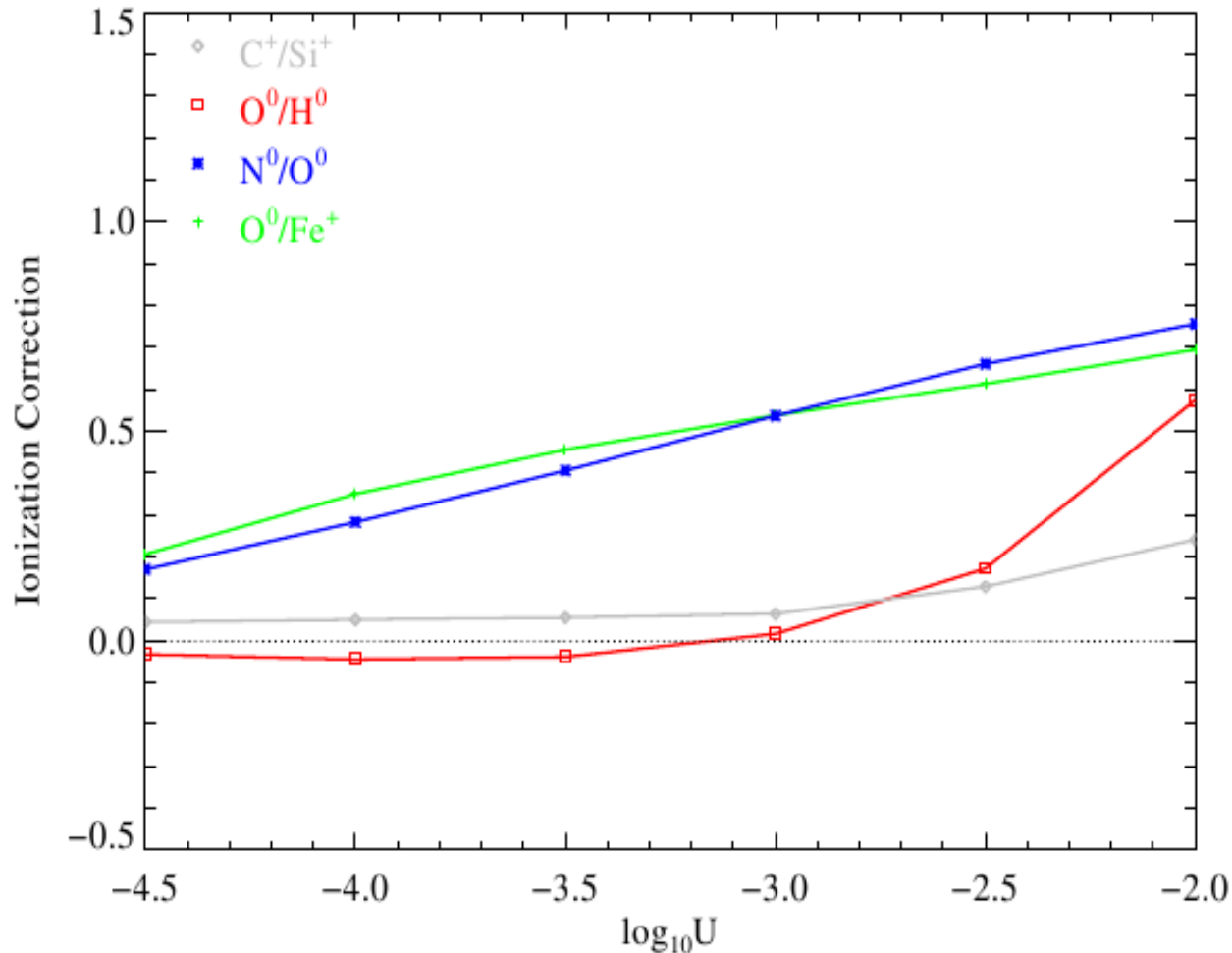
Assuming b-parameter as pure thermal motion $T_e \sim 20000$ K

Photoionization dominates over collisional excitation. From a photoionisation model, $\log U \sim -3$ dex, $x \sim 0.96$ and $N_H \sim 10^{20.6} \text{ cm}^{-2}$



Quasar probing galaxies

At low U , $O^0/H^0 \sim O/H$, N^0/O^0 and O^0/Fe^+ need corrections



Gas metal rich

$[M/H] > -1$

Gas metal enriched,

$[O/Fe] > +0.5$

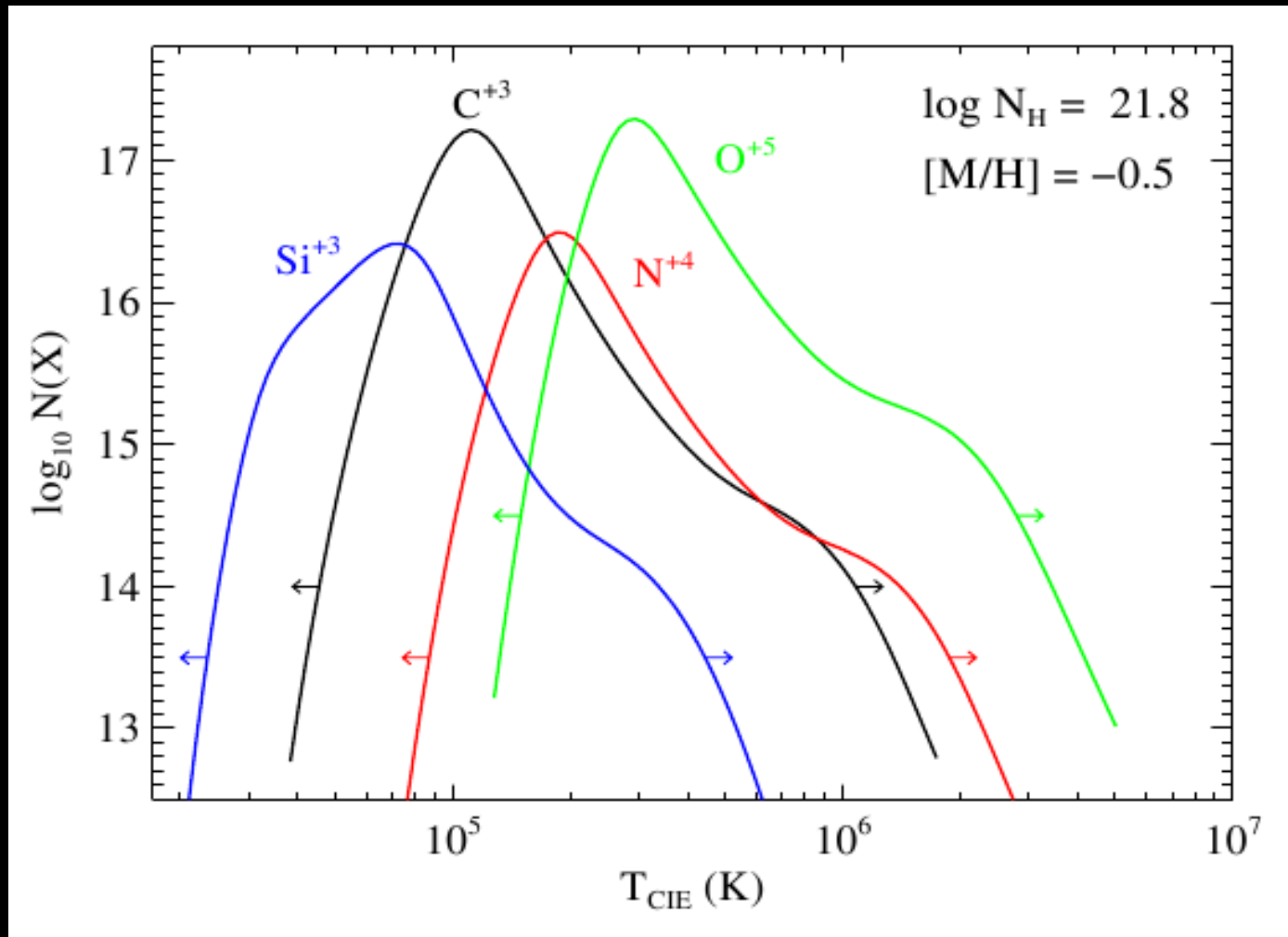
$[N/O] > -0.5$

This gas is associated with episode of SF $t > 100\text{Myr}$

Quasar probing galaxies

The absence of high ions transitions Si^{+3} , C^{+3} , N^{+4} , O^{+5} implies there is no warm phase $T \sim 10^5 - 10^6$ K.

Assuming a collisional ionization model, a diffuse medium must have $T > 10^6$ K, similar to the temperature of shock-heating



Quasar probing galaxies

The gas is not illuminated by the QSO that emits anisotropically.

Assuming Te, from the fine structure of C⁺ or Si⁺ which are collisionally excited one predicts n_e, thus n_H

Adopting $\log U < -3$ and $n_{\text{H}} < 5 \text{ cm}^{-3}$, we infer an upper limit to the ionizing photon flux,

$$\Phi_{\text{obs}} = U n_{\text{H}} c < 1.5 \times 10^8 \text{ photons s}^{-1} \text{ cm}^{-2} \quad . \quad (6)$$

We may compare this value with the ionizing flux of SDSSJ1204+0221FG under the assumptions that the gas lies at a distance equal to the impact parameter and that the quasar emits isotropically. Combining the SDSS optical photometry of SDSSJ1204+0221FG with an assumed power-law spectral shape ($f_{\nu} \propto \nu^{-1.57}$), we derive an AB magnitude $m_{912} = 21.42$ at 1 Ryd. At $z_{\text{fg}} = 2.436$, this gives a specific luminosity $L_{912} = 1.16 \times 10^{30} \text{ erg s}^{-1} \text{ cm}^{-2} \text{ Hz}^{-1}$ and we estimate an ionizing photon flux at $r = R_{\perp} = 108 \text{ kpc}$ of

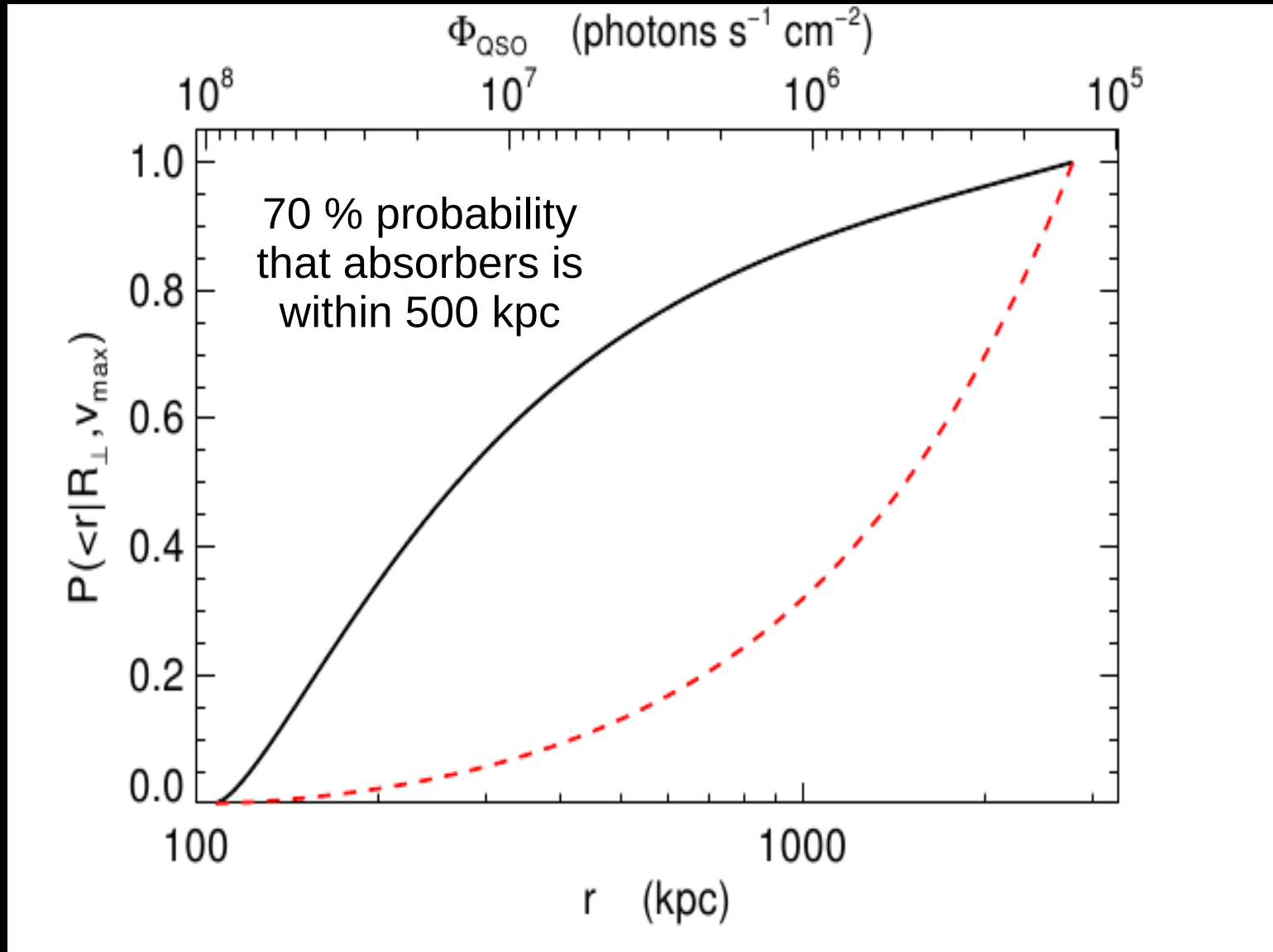
$$\Phi_{\text{QSO}} = 9 \times 10^7 \text{ photons s}^{-1} \text{ cm}^{-2} \quad , \quad (7)$$

assuming the quasar emits isotropically. Therefore, the conservative upper limit to Φ_{obs} roughly matches the predicted photon flux from SDSSJ1204+0221FG at the observed impact parameter. In this conservative observational limit, we do not have strong evidence for anisotropic emission.

If we adopt less conservative but more realistic constraints on the ionization parameter and volume density ($\log U < -4; n_{\text{H}} < 1 \text{ cm}^{-3}$), we set an upper limit to the observed photon flux $\Phi'_{\text{obs}} < 3 \times 10^6 \text{ photons s}^{-1} \text{ cm}^{-2}$.

Quasar probing galaxies

From the clustering it's most likely that the gas is close to the impact parameter



Quasar probing galaxies

All together, the physics of the gas can constrain the halo assembly

Cold gas/diffuse hot, extreme kinematics, metal rich at $R=108$ kpc

Not SF wind nor radiation pressure from QSO luminosity

Maybe feedback black hole accretion

Why lack of warm medium?

Shock-heated gas infalling or virialized in the DM halo.

Why high metallicity?

Conclusion

The study of the proximity effect real goldmine:

Accurate determination of the UV background

Study of the quasar physics:

Variability

Anisotropy

Clustering

Study of halo assembling and comparison
with cosmological model