AGNs as main contributors to the UVB

Giallongo,Menci,Fiore,Castellano,Fontana,Grazian,Pentericci ApJ subm.

Reionization : when and how

When: Current constraints suggest z=6-11

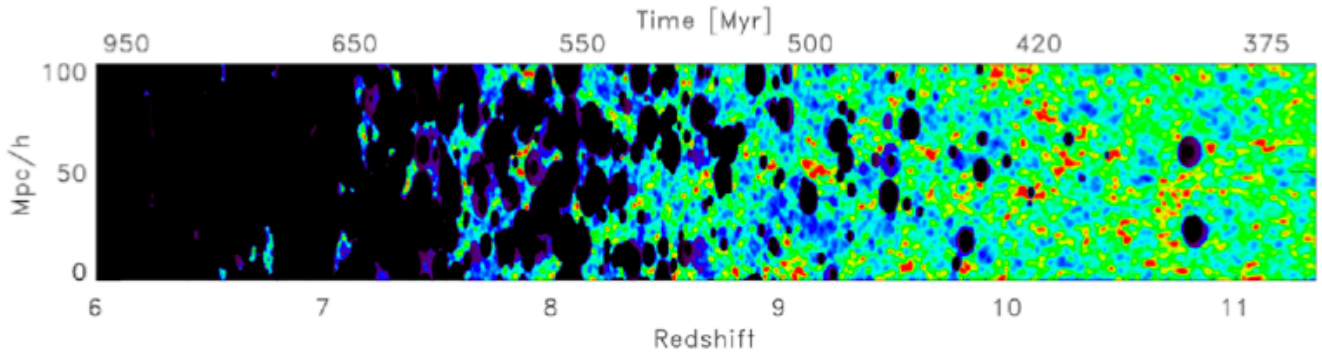
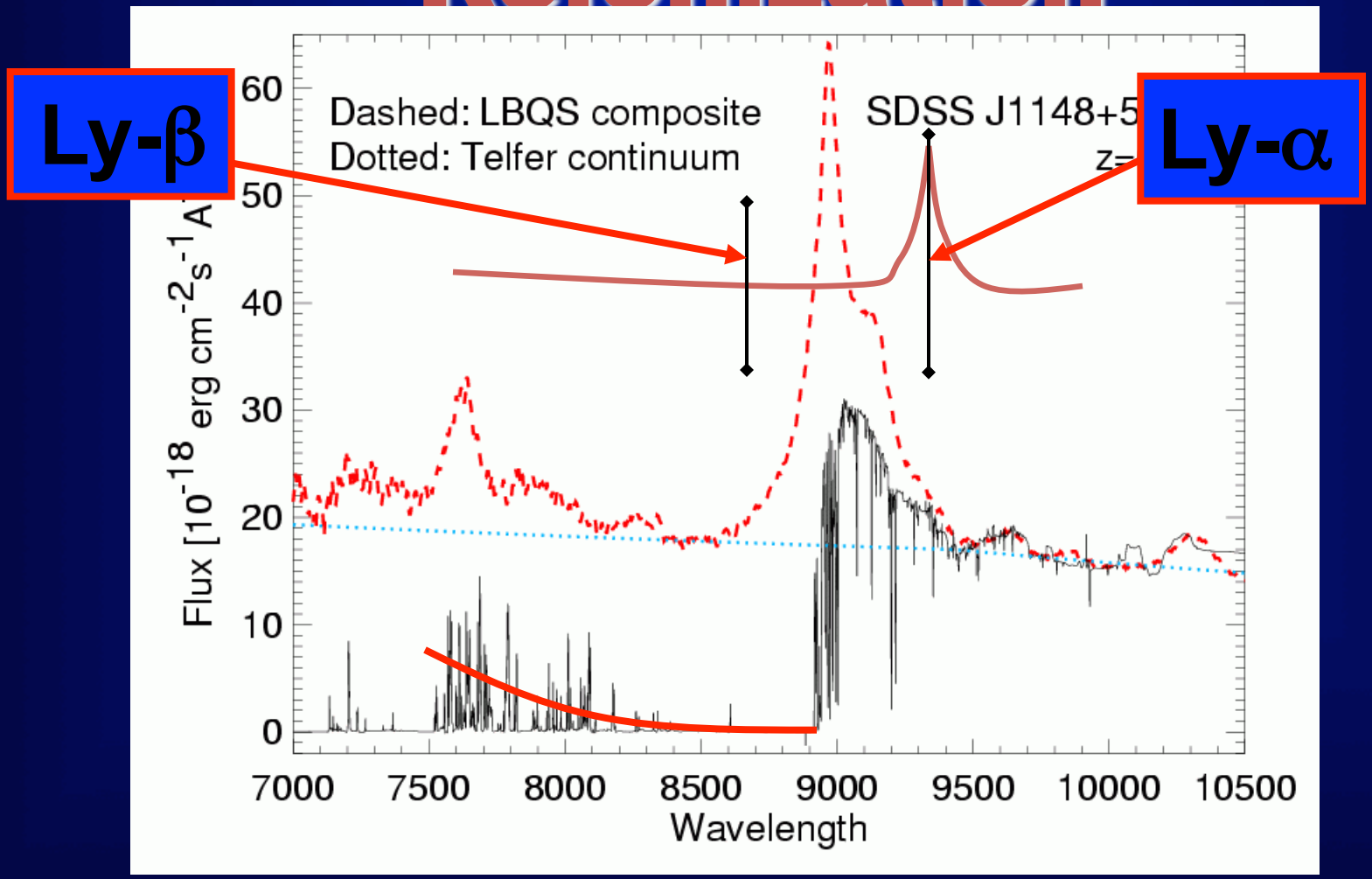


Fig. 1 This figure shows a slice through redshift of the 21 cm radiation in which the reionization process progresses through the volume of a cosmological simulation with radiative transfer [206].

What We Know About Reionization



How: what ionizes IGM

- Bright sources (LBGs, QSOs)
- Faint sources (dwarfs, AGNs, low-mass objects)

Bright galaxies are observed up to z≈7 but their ionizing contribution is questioned (Nestor et al. 2011, Vanzella et al. 2010, Boutsia et al. 2011, Grazian et al. in preparation)

Estimating fesc: Method

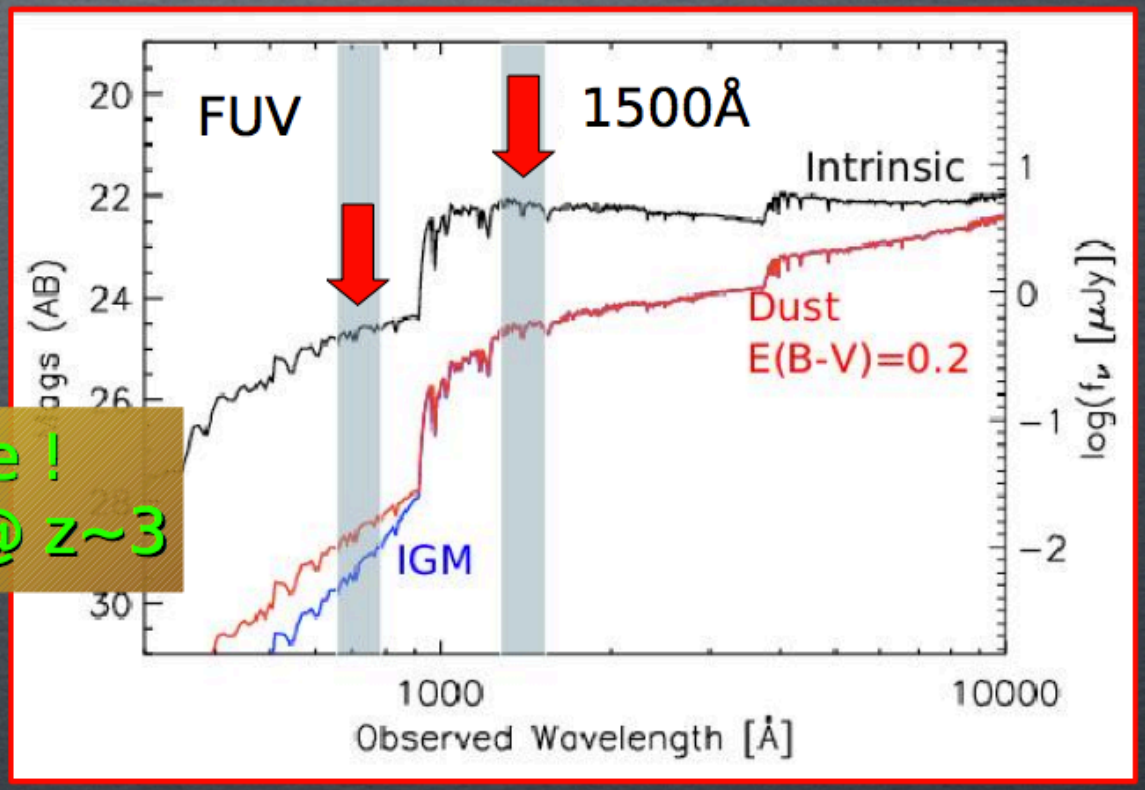
From Grazian

$$f_{\rm esc,rel} \equiv \frac{(L1500/L900)_{\rm int}}{(F1500/F900)_{\rm obs}} \exp\left(\tau_{900}^{\rm IGM}\right)$$

$$f_{\rm esc} = 10^{-0.4A_{1500}} f_{\rm esc,rel}$$

(Steidel et al. 2001, Shapley et al. 2006)

Intrinsic ionizing photons unknown:
commonly adopted strategy is to compare the observed flux at LyC to the observed Flux at a frequency where the intrinsic emissivity can be inferred.

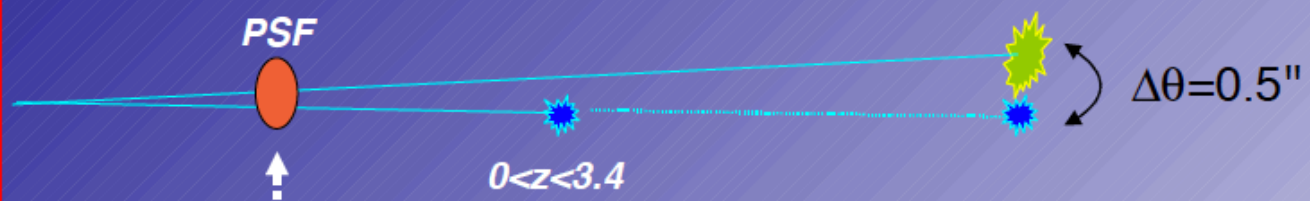


Difficult measure !
Δm~5 → fesc~8% @ z~3

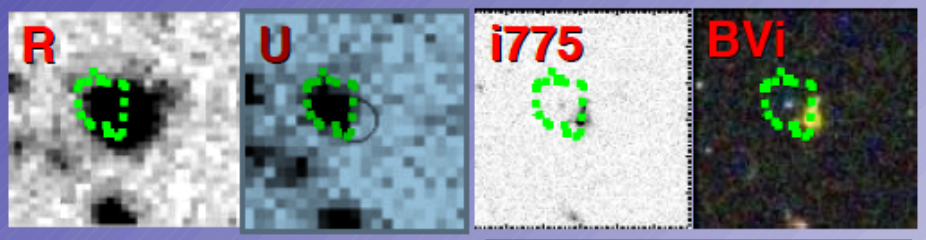
Grazian et al
in preparation

fesc from z>~3 galaxies: contamination from low-z

From E. Vanzella



Example in GOODS z=3.41



(L1500/L900)int=3, A1500=0.7, Tigm=1

~~Ground based:~~
~~fesc > 17%~~
~~fesc,rel > 33%~~

From U and HST:
fesc > 230%
fesc,rel > 433%

Spatially resolved U-emission allow us to check:

(1) fesc measured properly $(F1500/FLyC)_{obs}$ → all have fesc,rel > 1

(2) zphot (prob(zphot)>3.4) → all have prob < 0.3%

(3) $\Delta(B-V) = (B-V)_{lbg} - (B-V)_{blob}$ → all have $\Delta(B-V)>1$ (transverse 20 kpc)

median $(B-V)_{blob} = 0.24^{+0.40}_{-0.22}$; $(B-V)_{lbg} = 1.85^{+0.95}_{-0.58}$

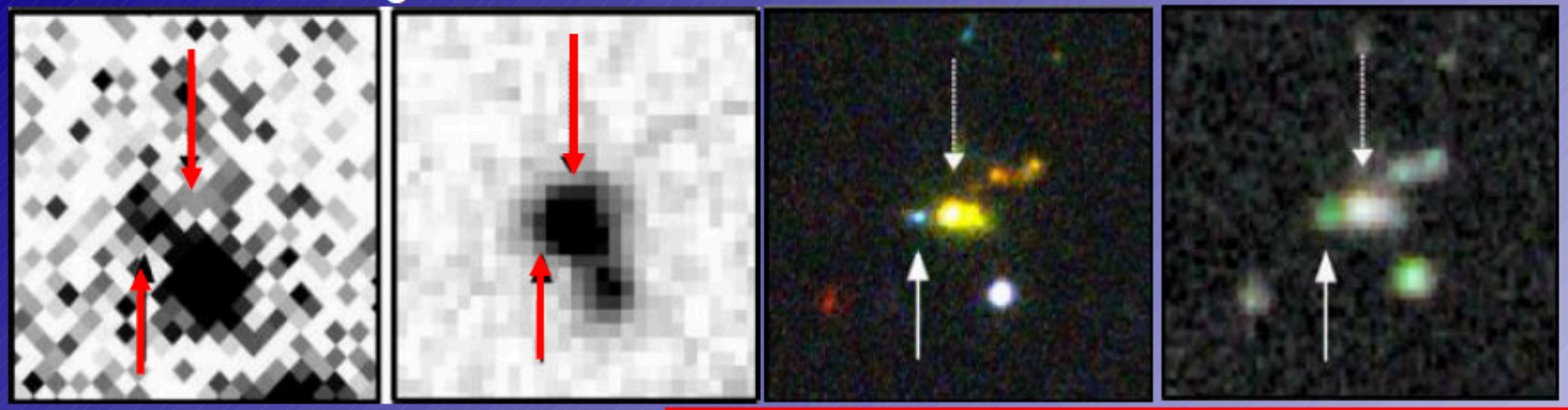
(4) λ<<700A , WFC3 UV channels (F225, F275, F336), future.

LyC emission from a LBG at z=3.8 ? No.

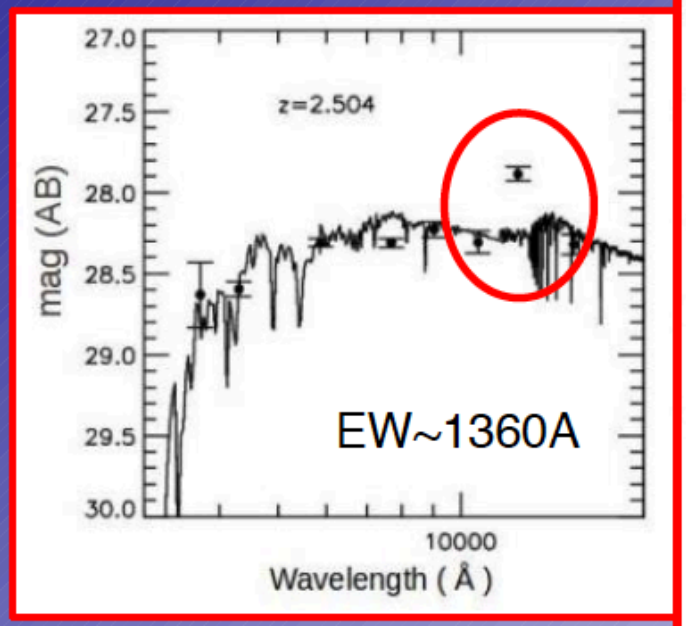
(an extreme example U(AB)~28.63)

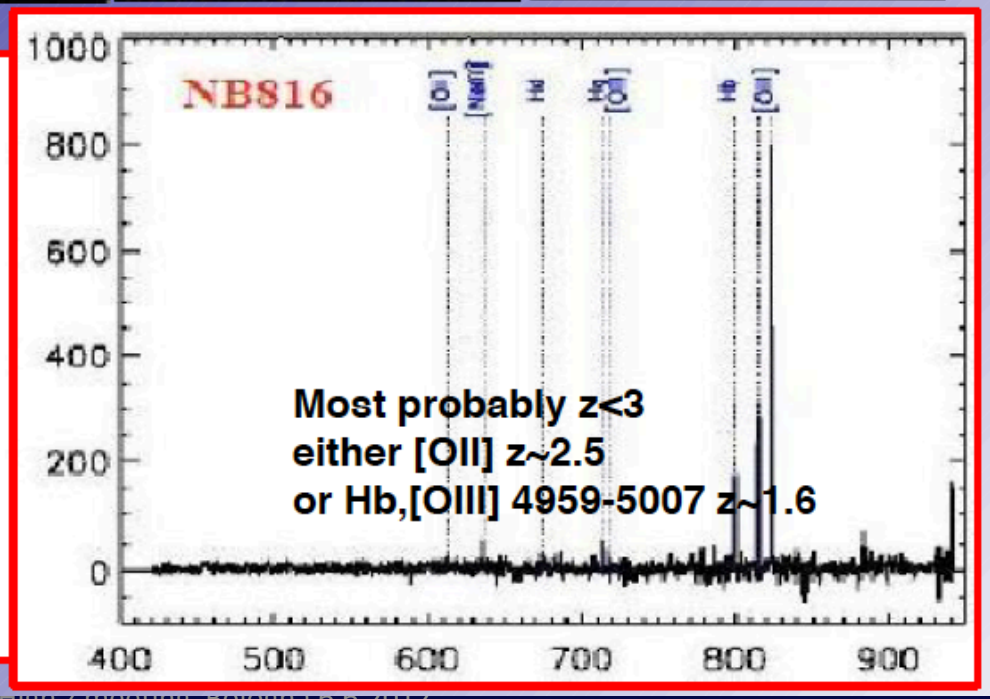
U-band → seeing~0.8" → R-band ACS/BVi WFC3/YJH

← 4.5" →

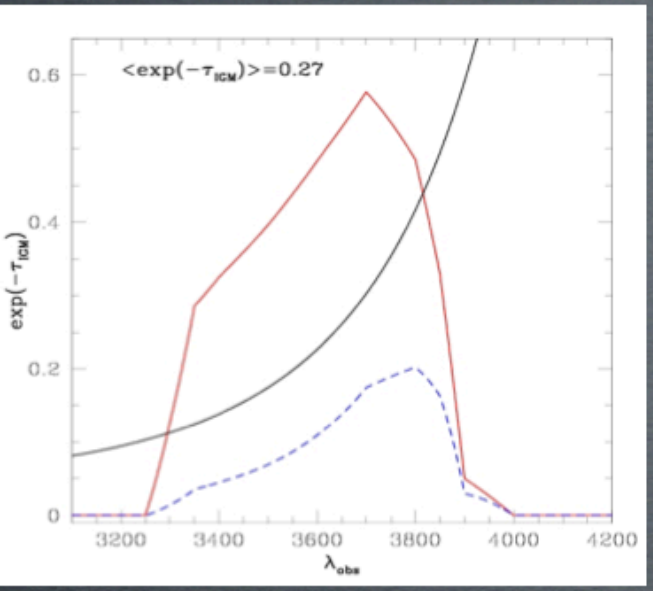


Y → B
J → G
H → R





LBGs at z~3.3



- Selected 28 LBGs with zspec 3.27<z<3.40
- z>3.27 U-LBC filter in the Lyman Continuum region (<912A rest frame)
- IGM extinction by Prochaska et al. (2009)
- Effective wavelength=860A rest frame

Image Stacking

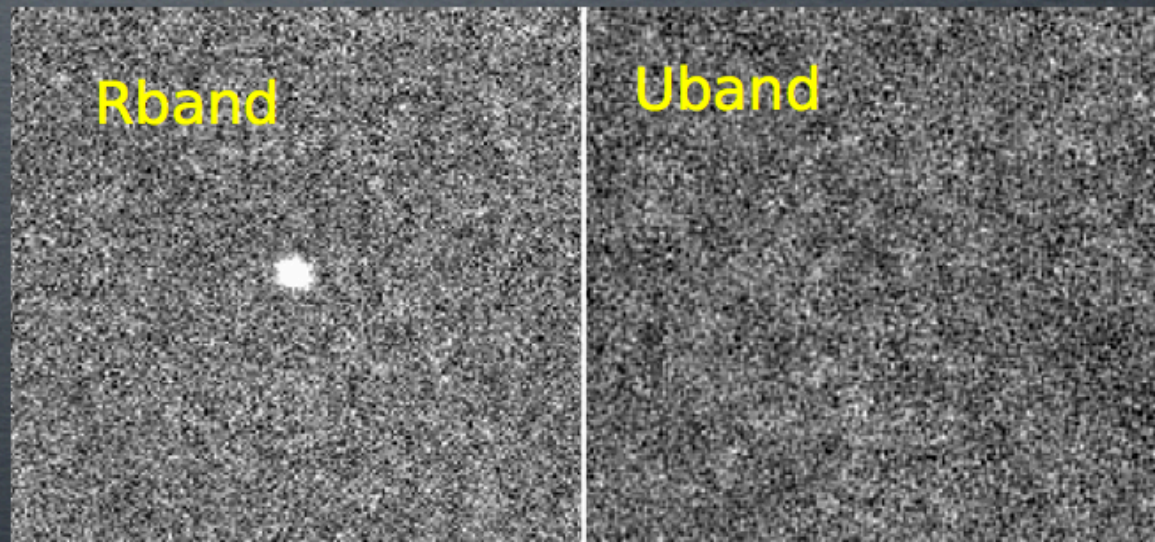
No detection at U=30.7(AB) at S/N=1

f1500/f900obs>403

fesc_rel<2.8% (1 sigma) at z=3.3

Haardt & Madau 2011

fesc=2.7% at z=3.3



Way out: Contribution by dwarf galaxies

This requires: Escape fraction ≈ 1 and Gal. LF very steep at the faint end

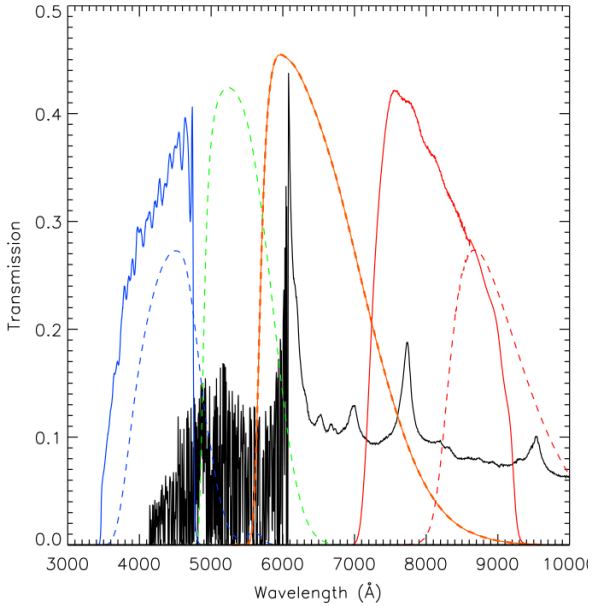
No indication of very steep LF (see Grazian).

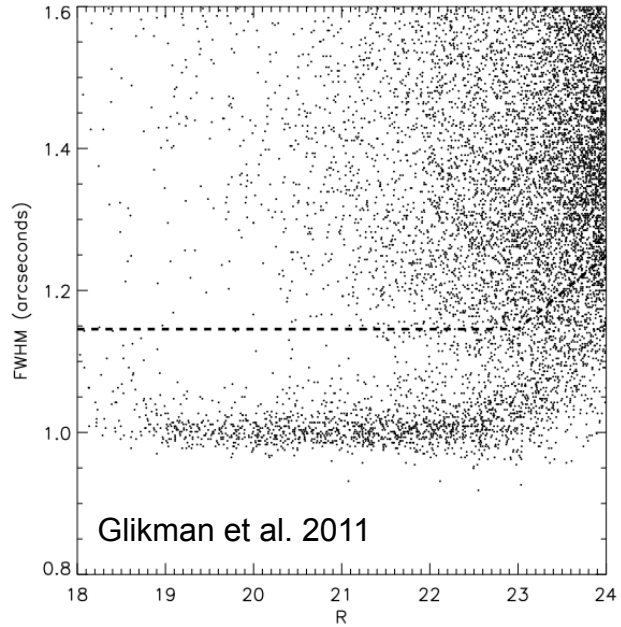
Measuring escape fraction in fainter galaxies (use of gravitational lensed gal.? Vanzella et al. 2012).

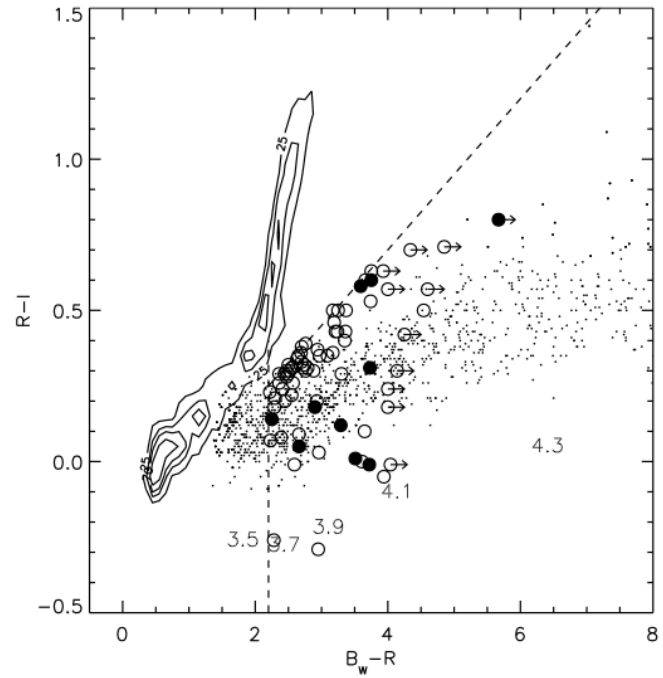
Alternatively :

Bright QSOs are observed up to z≈6.5, they are able to ionize the IGM but are too few (Haardt & Madau 1996,2012)

Look for faint AGNs

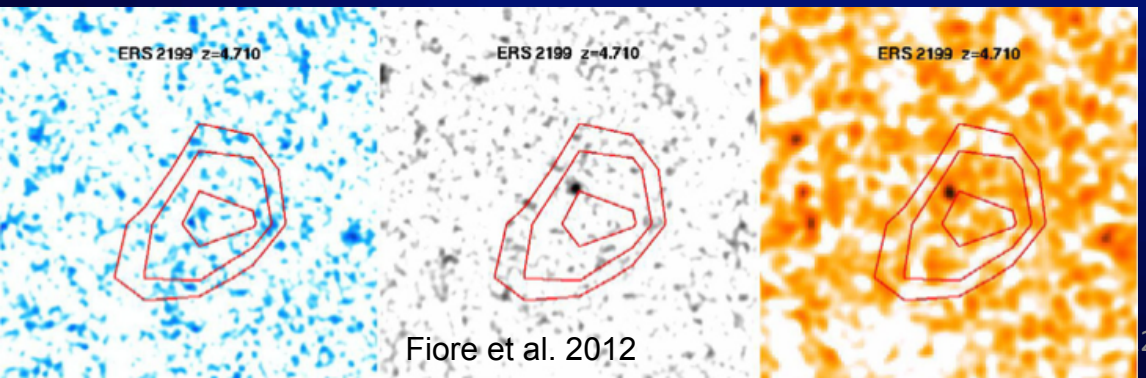






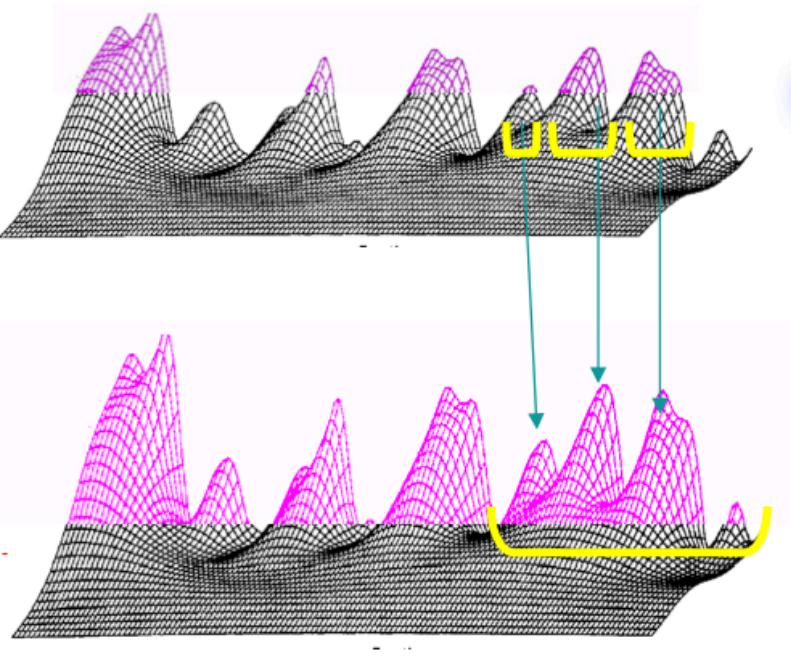
Search for high z AGNs. Three main uncertainties:

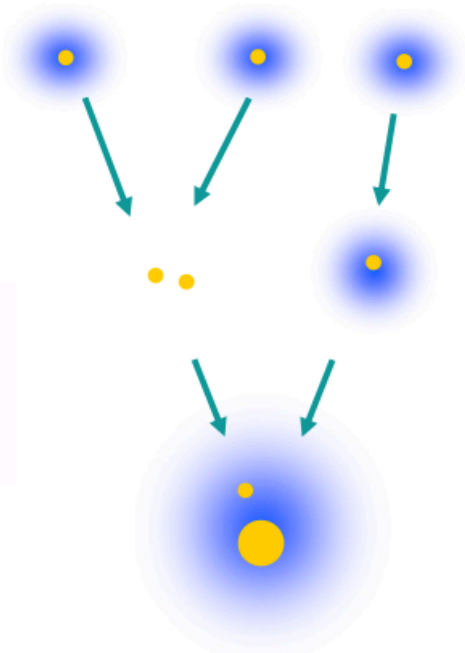
- Morphological threshold (increasing incompleteness at low L)
- Dropout threshold (IGM absorption adopted so far should be revised)
- X-ray association (Deep Chandra images)
- Photometric redshifts (Spectroscopic confirmation or more accurate photometry)

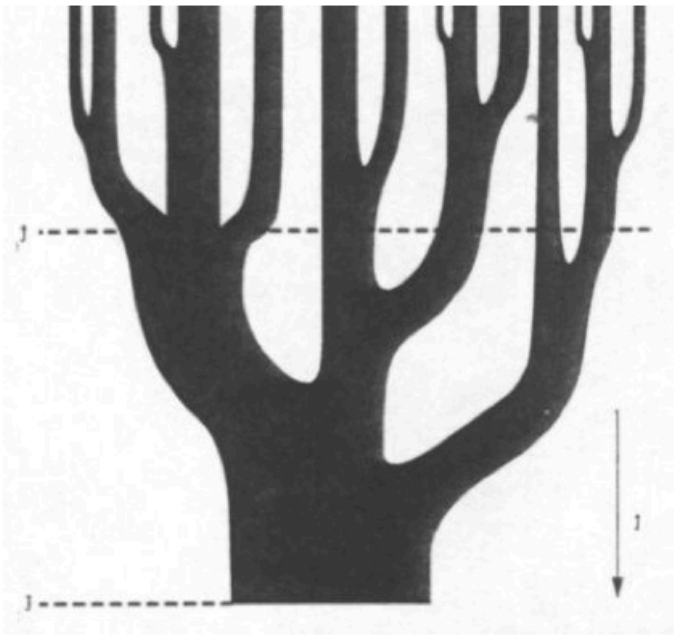


Given the possible biases and uncertainties, an insight into the origin of the ionizing flux can be gained by models

Rome-SAM (R-SAM; Menci et al. 2003-2011)







Standard SAM with three main implementations:

- Additional channel for star formation by interaction-driven starbursts (merging and fly-by events) which facilitate early formation of stars in massive galaxies. (Galaxy MF, colour bimodality)
- SMBHs growing at the center of galaxies by interaction-triggered inflow of cold gas (Feedback effects on Galaxy LF, MF and QSO LF)
- Blast wave expansion in ISM from Cavaliere & Lapi model (AGN feedback, X-ray absorption)

AGN evolution driven by galaxy encounters
(R-SAM, Menci et al. 2003/04)
(Cavaliere & Vittorini 2000)

Cold gas accretion triggered by galaxy encounters (fly-by or merging)

$$f_{\rm acc} \approx 10^{-1} \left| \frac{\Delta j}{j} \right|$$

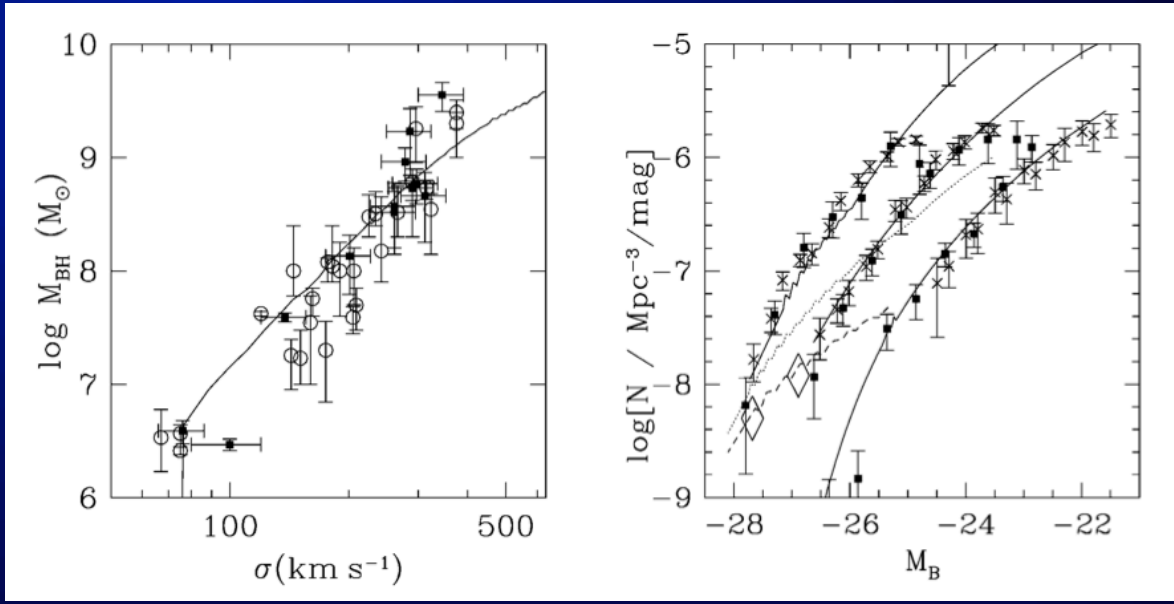
destabilize part of cold gas by inducing loss of angular momentum

$$\Delta m_{\rm acc} = f_{\rm acc}\, m_{\rm c}$$

$$10^{-3} \lesssim f_{\rm acc} \lesssim 10^{-2}$$

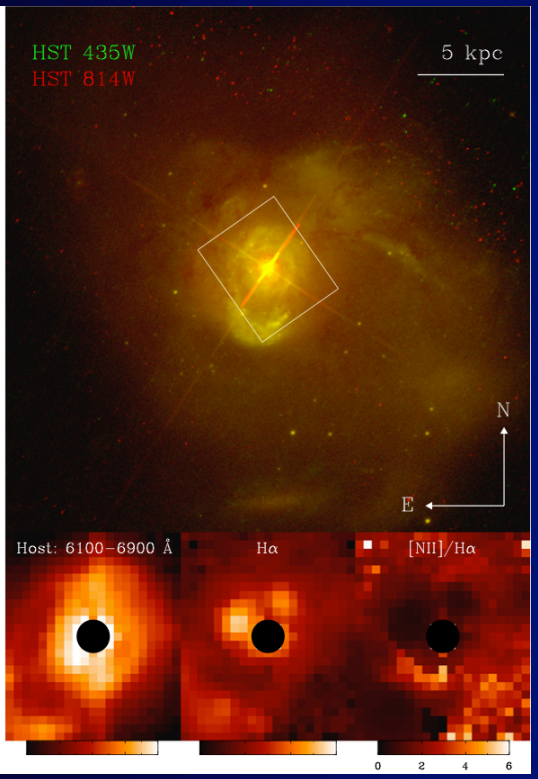
$$L = \frac{\eta\, c^2 \Delta m_{acc}}{\tau}$$

Where τ is the crossing time



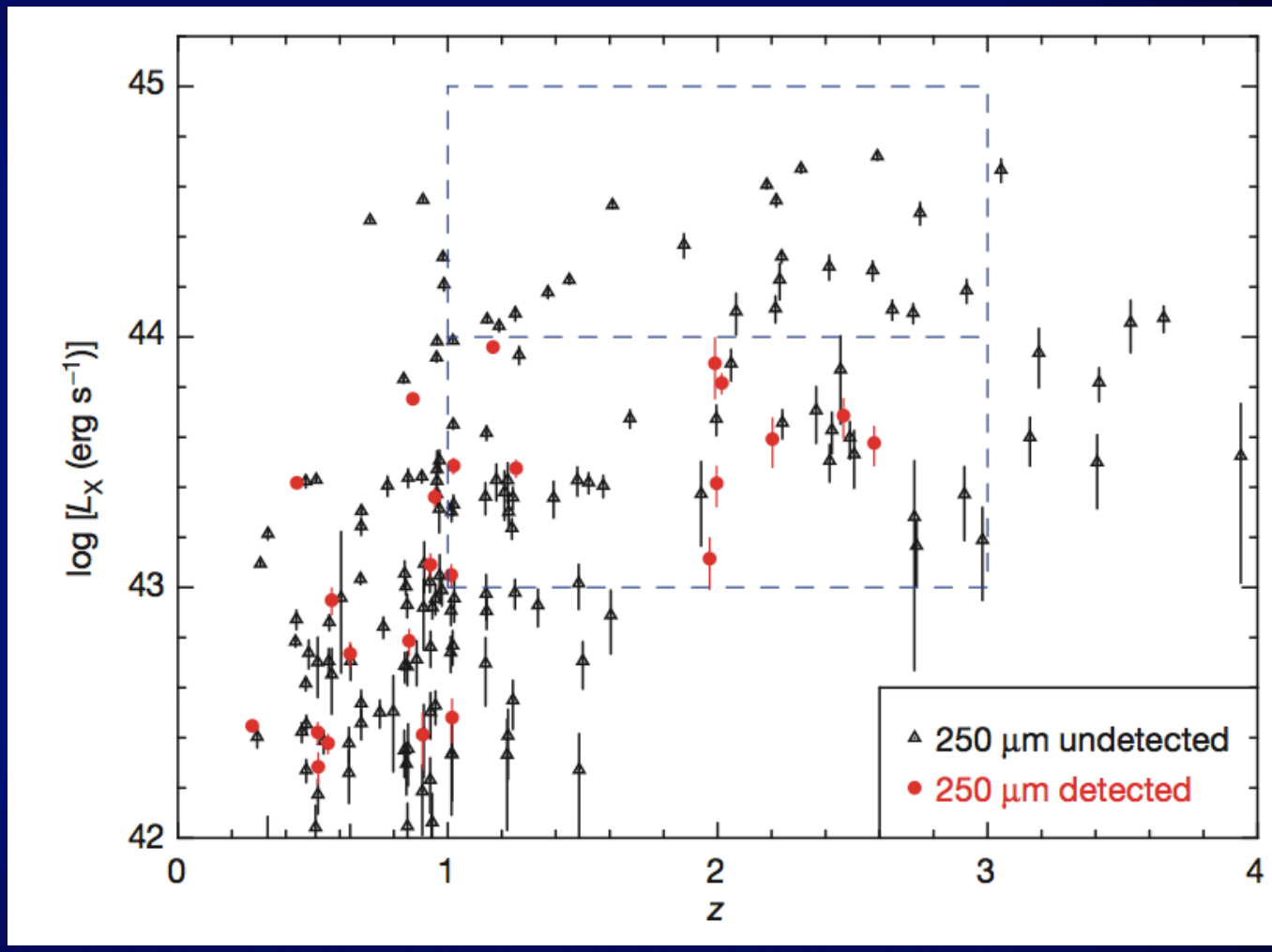
AGN feedback: radio-mode vs quasar mode

Outflows observed e.g. in Mrk 231,573



Feruglio et al. 2010
Rupke & Veilleux 2011

Page et al. 2012 Nature



Data inconsistent with radio-mode feedback which would imply correlation between SFR and Accretion R.

Blast-wave model for AGN feedback and the escape fraction of UV photons

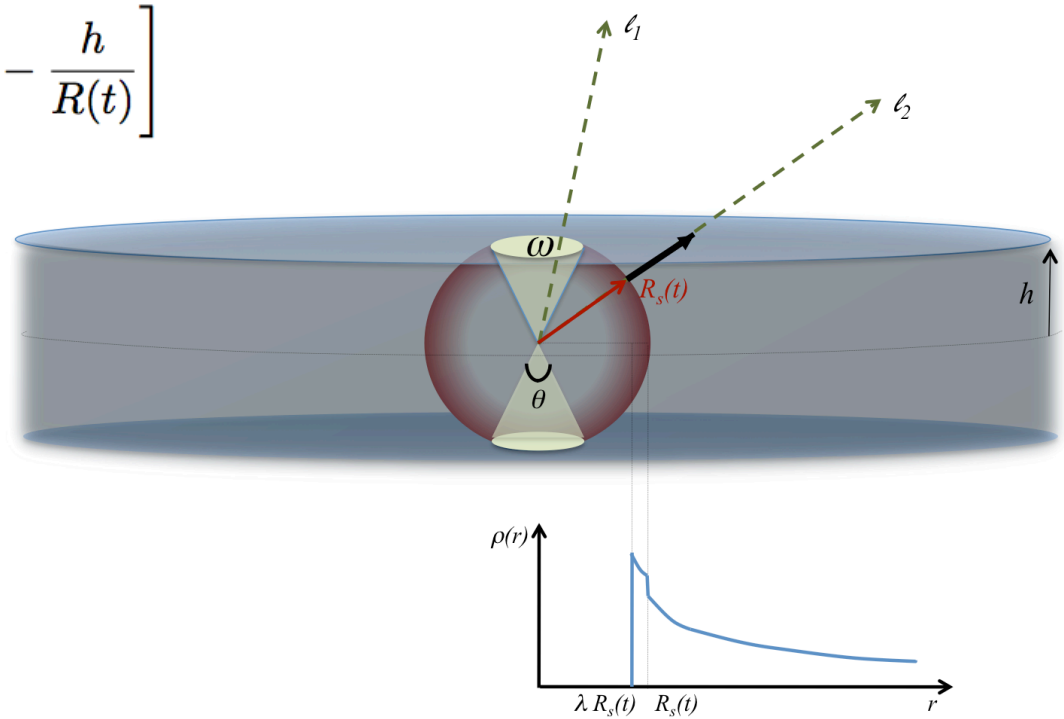
A BLAST-WAVE model for the transport of energy has been developed by Lapi, Cavaliere, Menci 2005
The key quantity is

$$\Delta E = \epsilon_{AGN} \eta c^2 \Delta m_{acc} = \epsilon_{AGN} L \tau$$

$$R_s(t) \approx r_d \mathcal{M} t/t_d \text{ where } \mathcal{M}^2 = 1 + \Delta E/E$$

We have computed

$$\langle f(L) \rangle = \frac{1}{\tau} \int_{t_S}^{\tau} dt \left[\frac{\omega(t)}{2\pi} \right] = \frac{1}{\tau} \int_{t_S}^{\tau} dt \left[1 - \frac{h}{R(t)} \right]$$

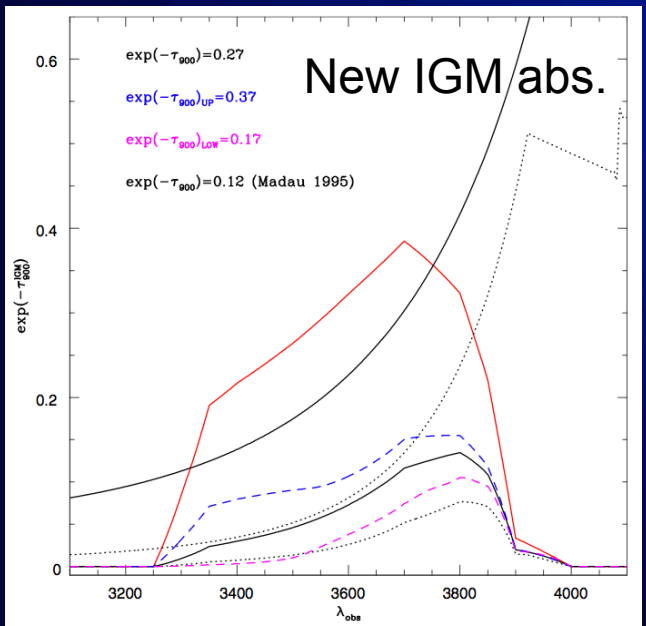


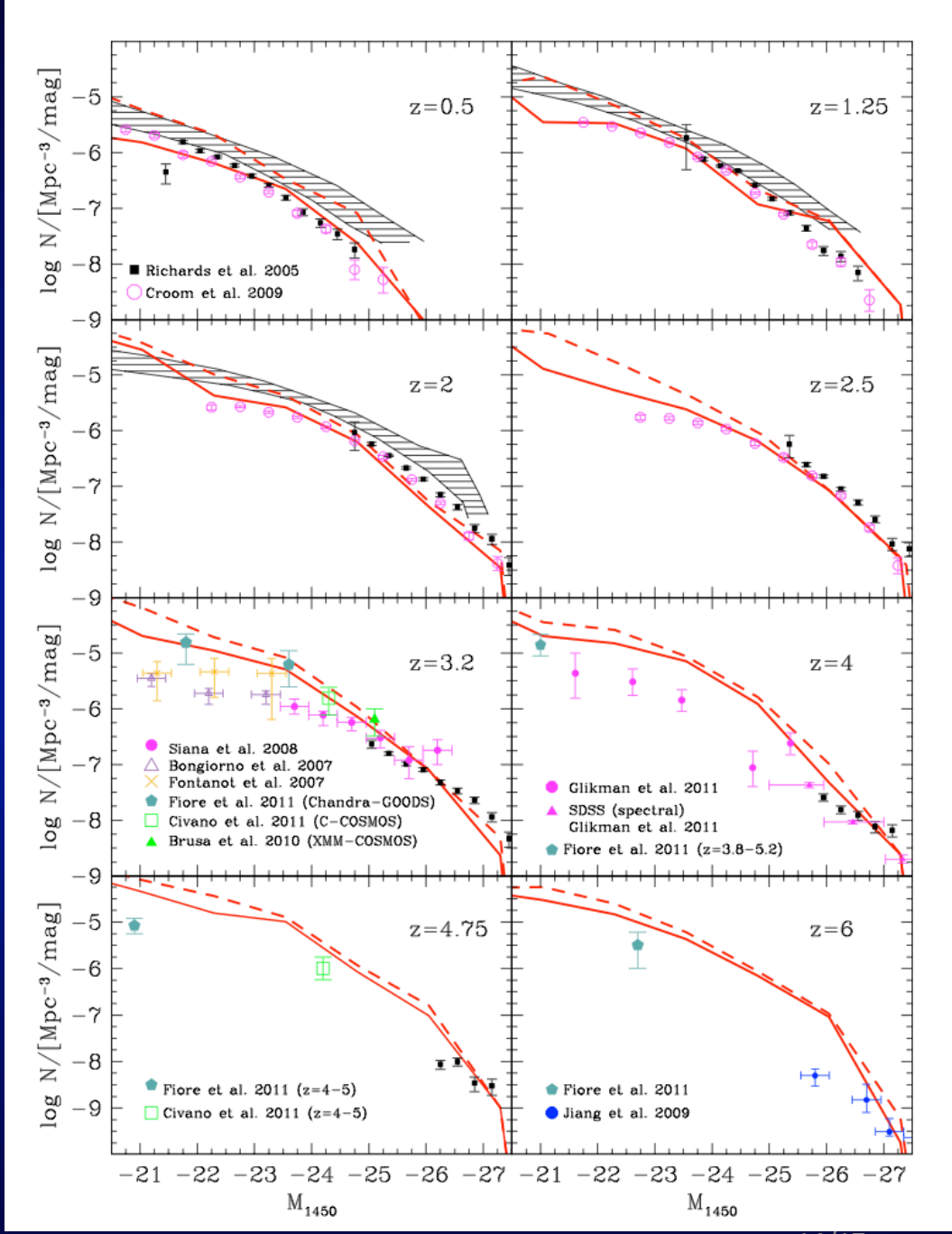
Low escape fraction in M≈-22 low-luminosity AGNs

f≈0.1 @ z=0.5
f≈0.3 @ z=4

Escape fraction increases with z at fixed L

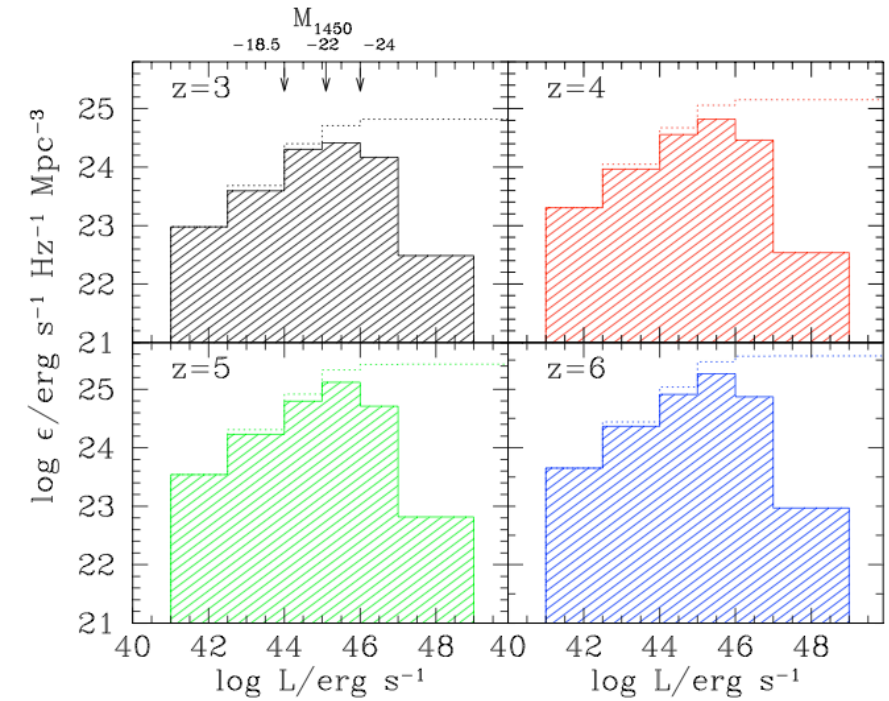
X-ray surveys
NIR survey with X-ray check are the most complete and approach the model predictions

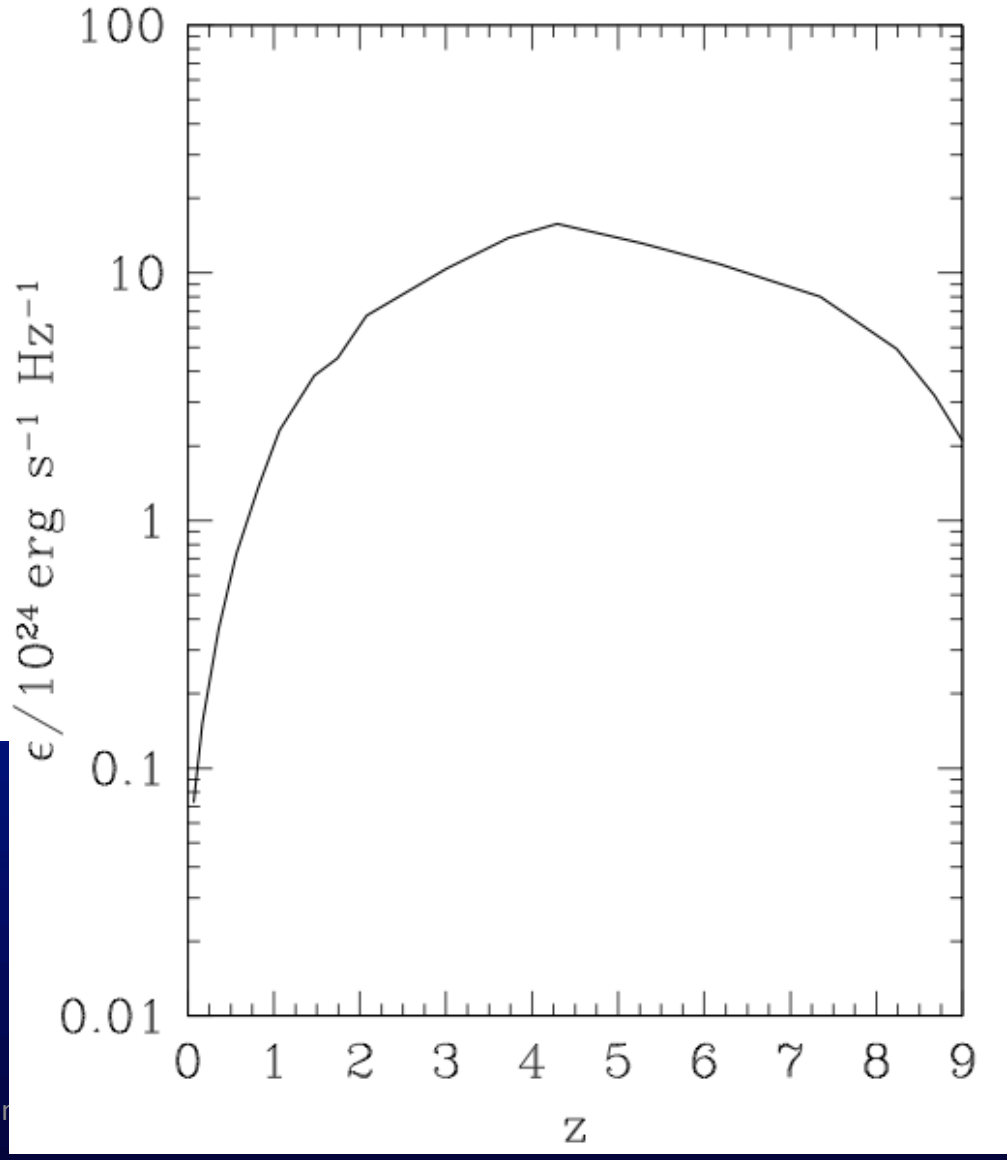




Predicted AGNs Emissivity

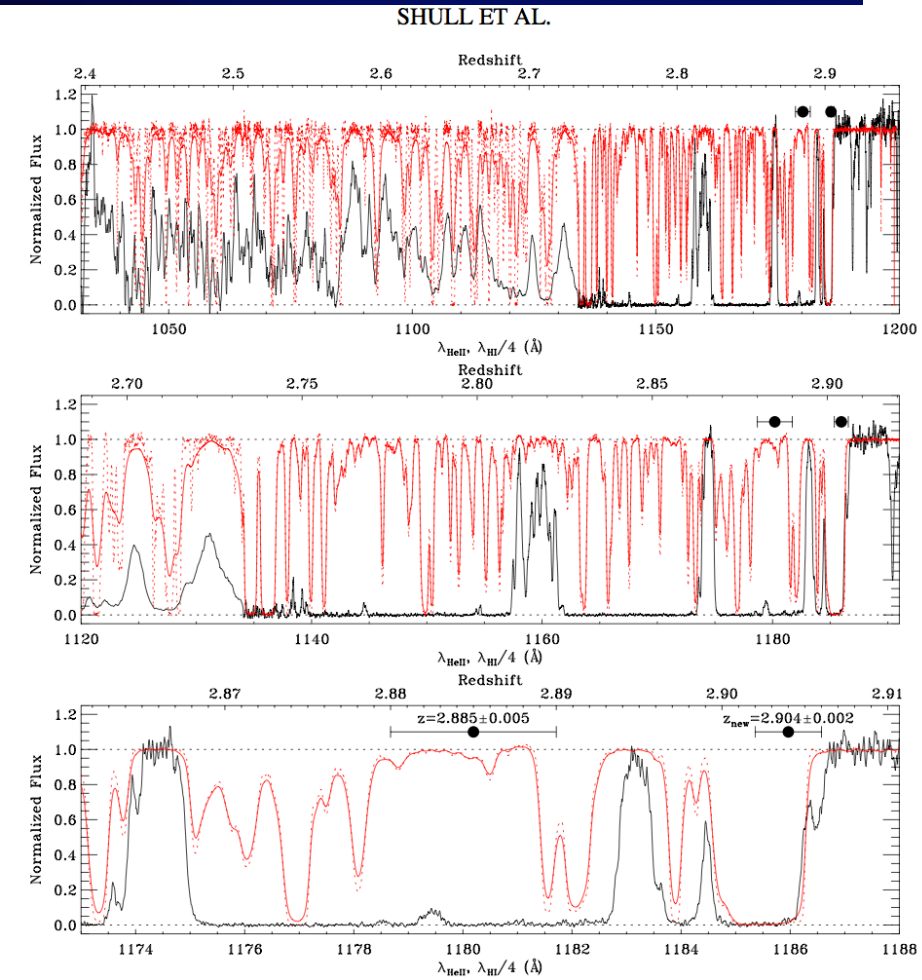
$$\epsilon = \int \langle f(L) \rangle N(L)\, L\, \frac{E_{912}}{E}\, dL$$

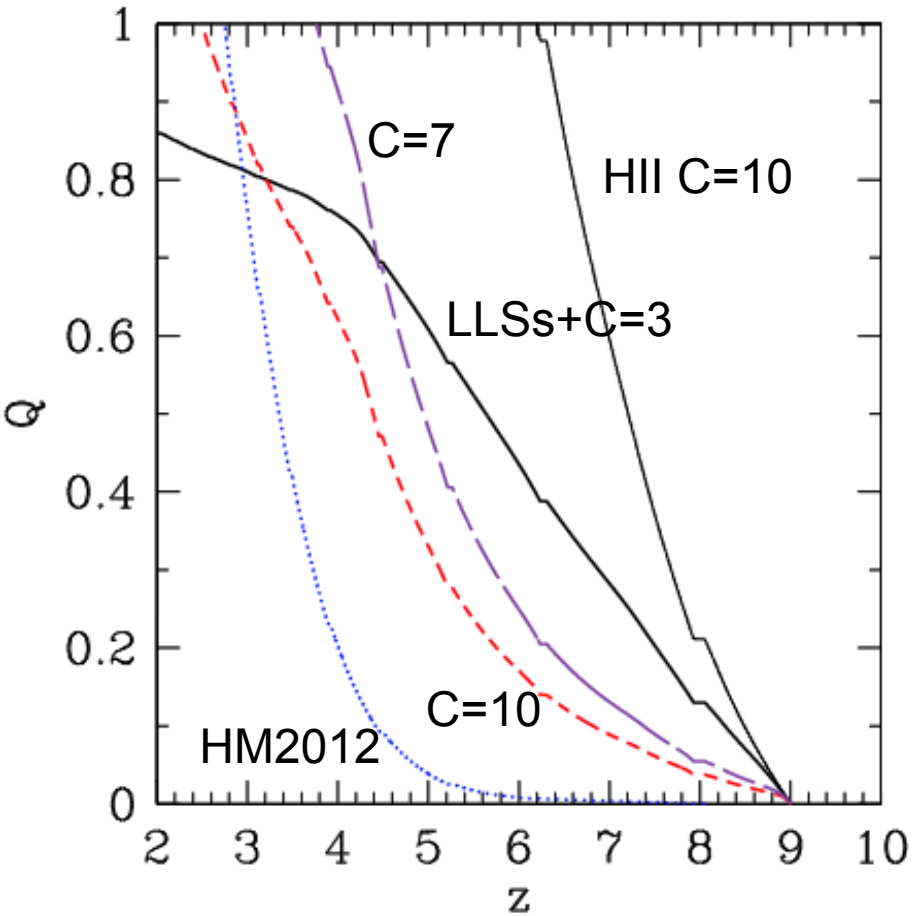




HeIII volume filling factor

HE 2347-4342 z=2.9

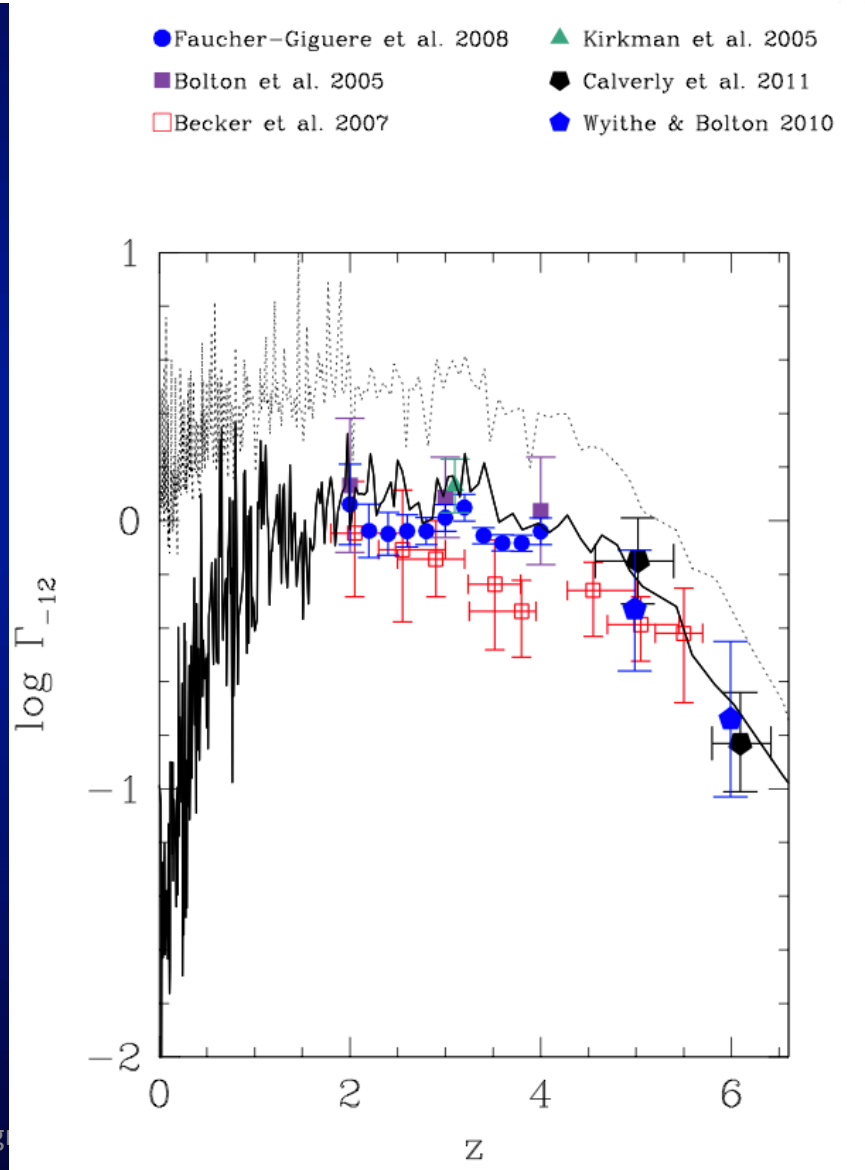




Predicted Photoionization Rate

$$\Gamma_{-12}(z) \simeq 0.46 \frac{\epsilon_{24}(z)}{3+\mid \alpha_{UV} \mid} \left(\frac{\Delta l}{50 Mpc}\right) \left(\frac{1+z}{4.5}\right)^{3-(2.5+\gamma)}$$

A value $\Gamma_{-12} \approx 1$ is reached at z=1 which remains const. up to z≈4

Only gradual decline by a factor 4 up to z=6
Mainly due to the strong decrease of the mfp

It's time
to reconsider the role of AGNs as main driver of the ionization history of the Universe