The High-Redshift Universe

Bologna, June 5-6

Why a workshop on the High-redshift Universe?

- To report on the state of the art in the high-redshift Universe field
- To combine expertise in high-redshift AGN and galaxies at different wavelengths
- To possibly plan for future observations with major space- and ground-based facilities and jointed projects

It is not a review, and it is not meant to be exhaustive

Biased towards AGN science…

Some open and debated issues

- What were the properties of the first stars, galaxies, and AGN?

- How did interactions between galaxies, AGN and the IGM at the end of the "Dark Age" shape the Universe we observe at later times?

- Are current theoretical models and simulations able to explain the accretion and star-formation history of high-z objects? What is the role of feedback? Can we estimate the AGN vs. SF duty cycles? (see talk by Shankar)

- How do AGN and galaxies populate dark matter halos? How do they trace proto-clusters at high redshift? (see talk by Pentericci)

- What are the seeds of first super-massive black holes in the Universe? (see constraints in Cappelluti's talk)

- What re-ionized the Universe? (see talk by Giallongo)

What are the physical limitations in our understanding of the z>5 Universe?

What are plans and prospects for the incoming years (on the path to JWST)?

Wide and shallow vs. pencil-beam and deep surveys

• Large surveys are able to pick up bright objects. Over the last decade, SDSS provided significant improvements in our understanding of cosmology and AGN and galaxy evolution. Euclid will open a new observational window in the future (see talk by Zamorani)

• For the highest redshifts, deep fields are needed, HST mandatory (e.g., HUDF, CANDELS, …), deep near-IR coverage fundamental to push the redshift frontier close to the dawn of the Universe (many talks in this workshop)

What is the margin for improvement in these approaches?

AGN vs. Galaxies vs. GRBs: redshift records

z~5 “barrier” breached in 1998

[see Dunlop 2012 review]

Mostly adopted techniques:

Lyman-break Galaxies, LBGs – Drop-out technique

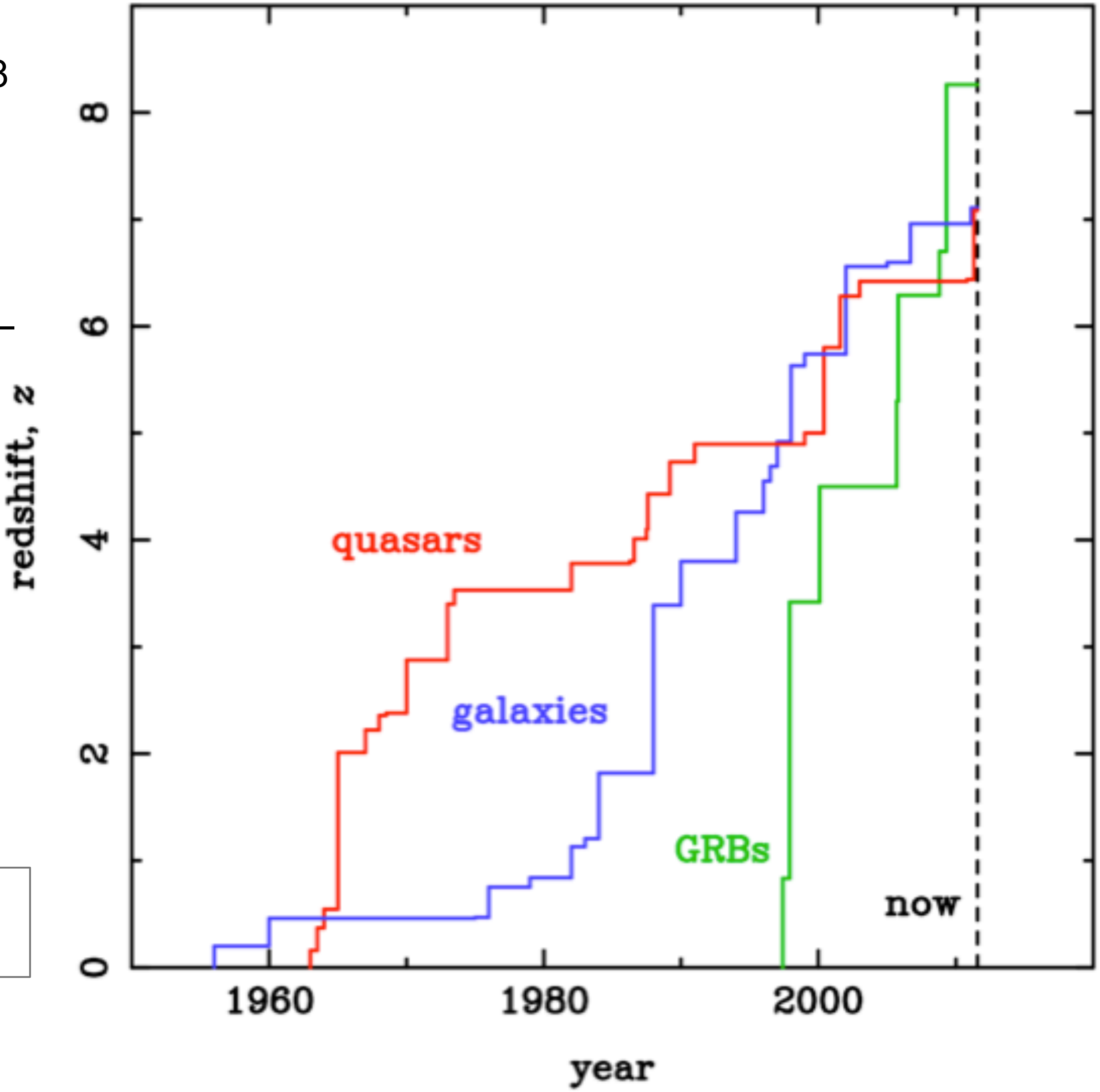
Lyman-α emitters, LAEs

Drop-out technique

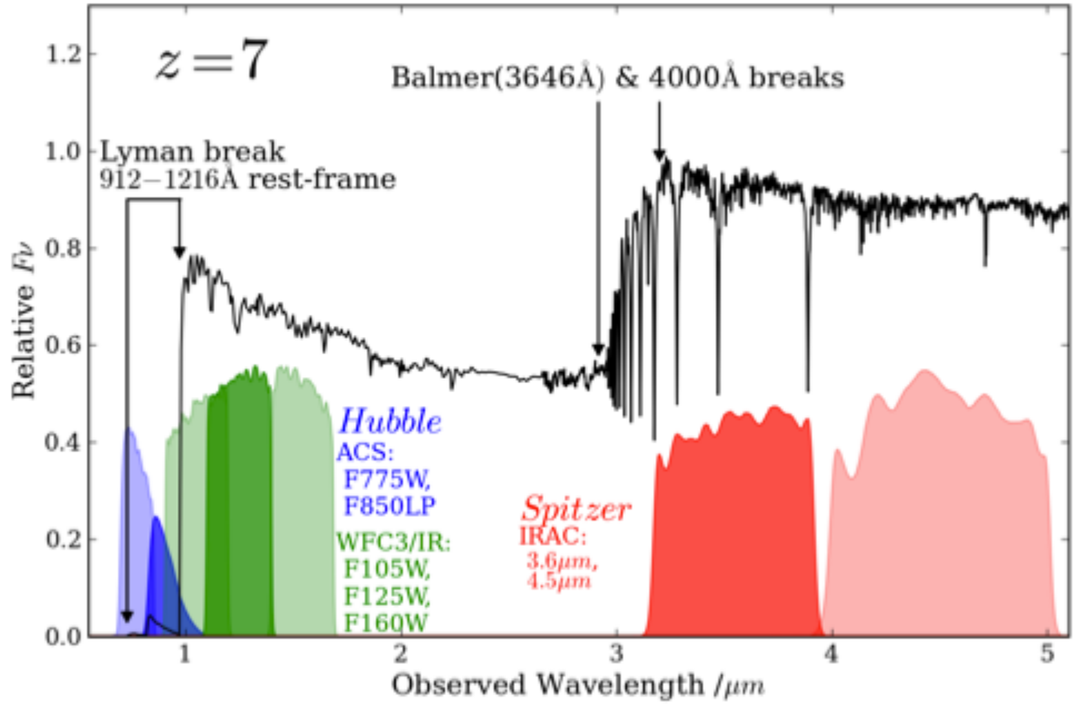
Sub-mm/mm emission (cold dust)

Radio/X-ray selection (still limited)

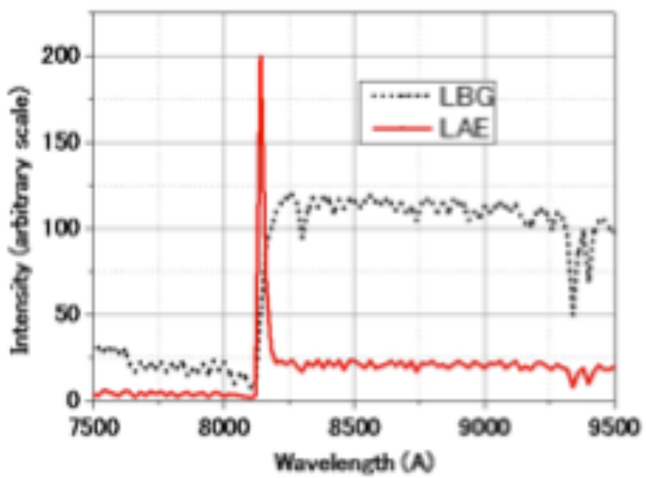
Role of photometry + follow-up spectroscopy

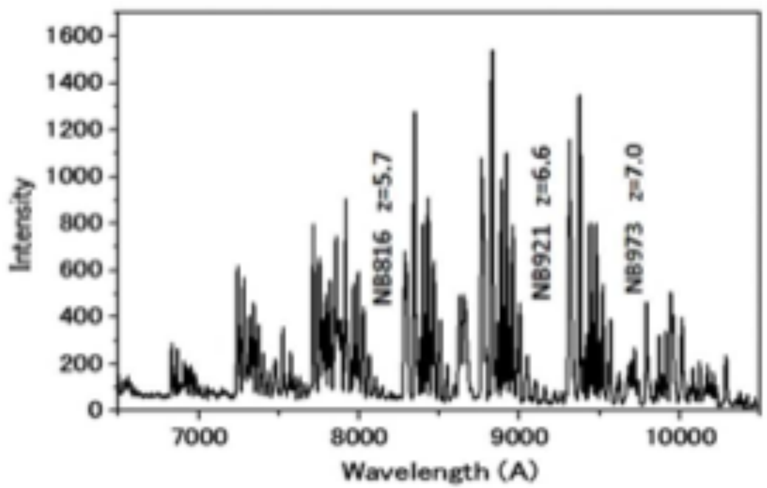


LBG and LAE, and the role of narrow-band filters

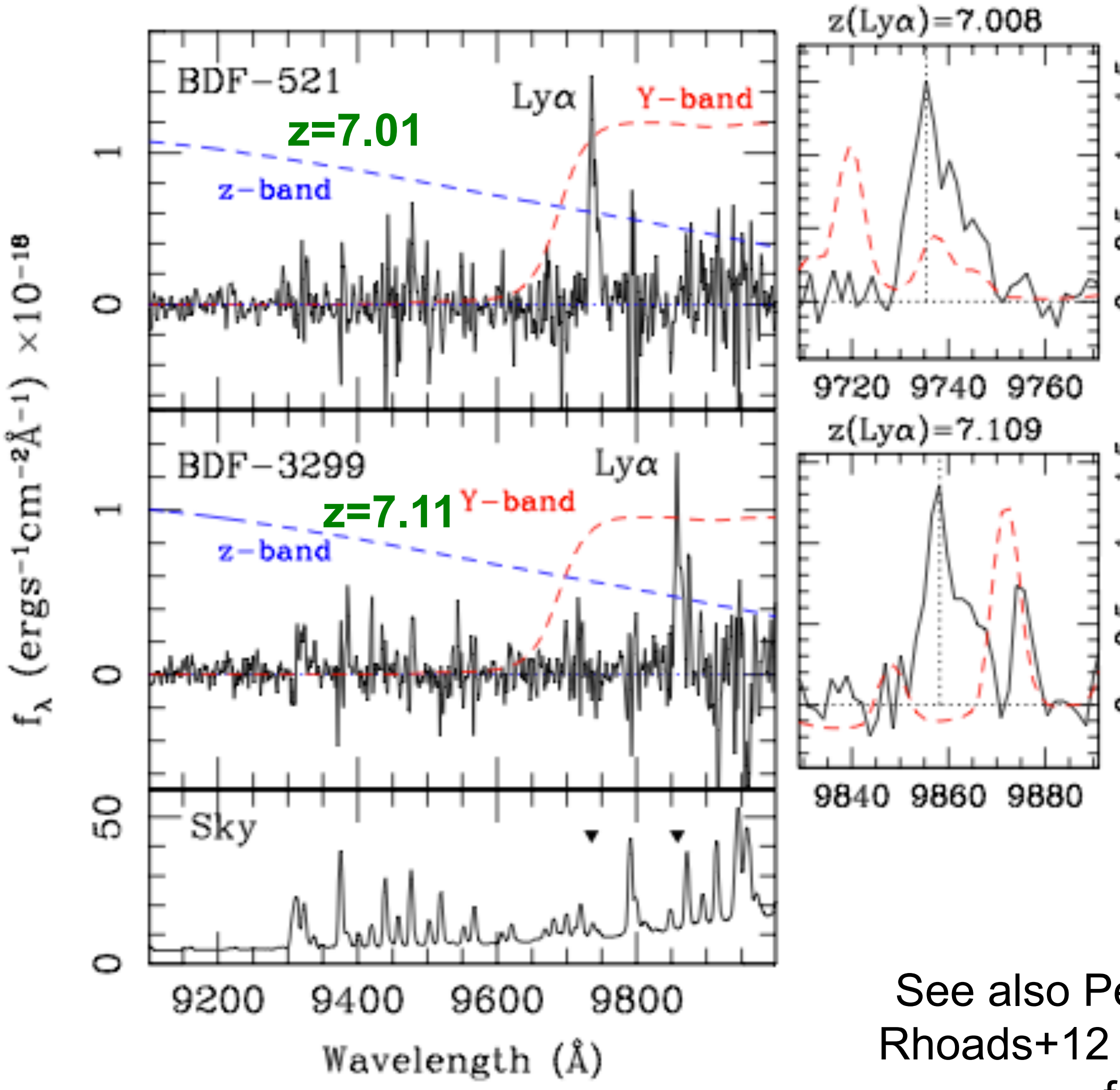


Talks by Nonino, Grazian, Fontana,

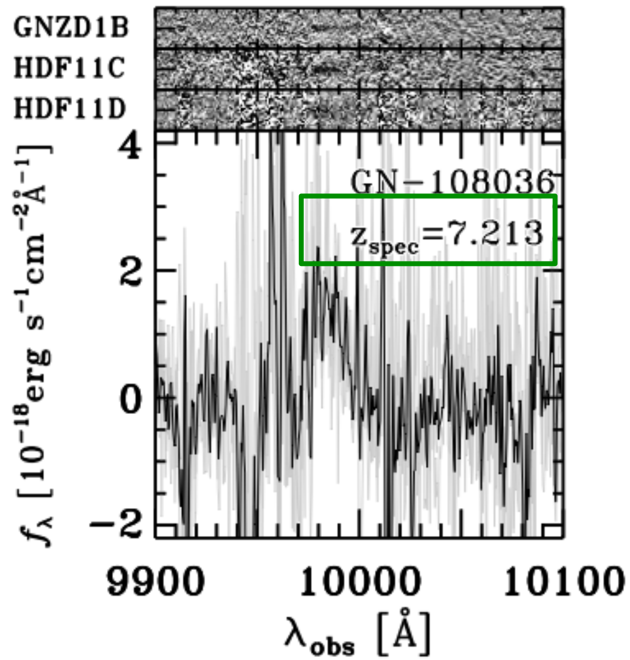




LBGs at high z: breaking the z=7 spectroscopic barrier



Vanzella et al. 2011, FORS2



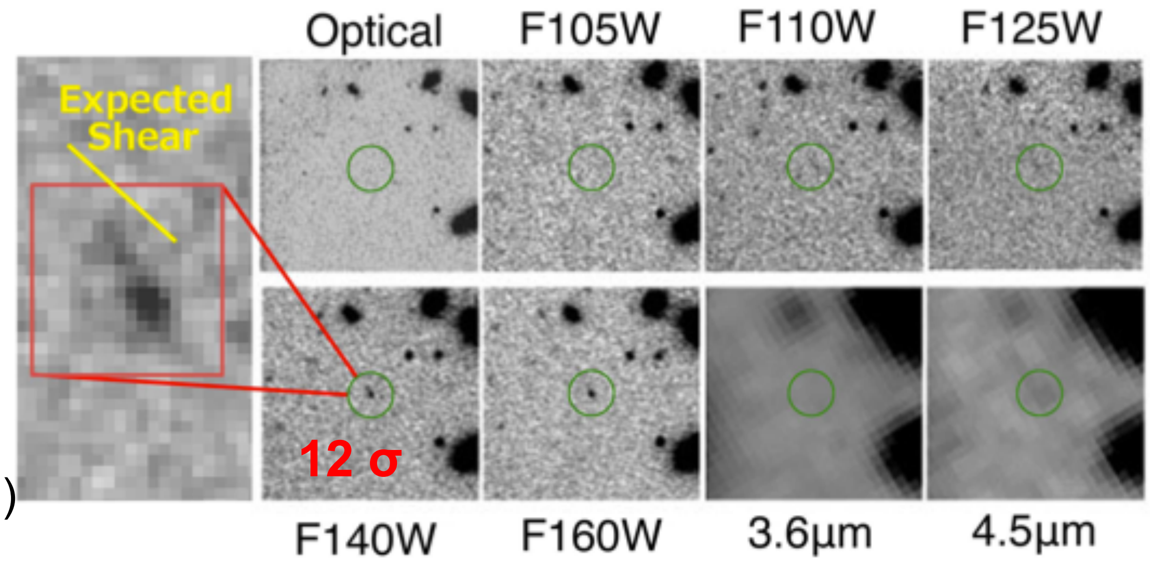
Ono et al. 2012, DEIMOS

See also Pentericci's, Castellano's works, …
Rhoads+12 and Capak+11 (z=7.69 candidate)
for studies in COSMOS
Schenker et al. z=7.05

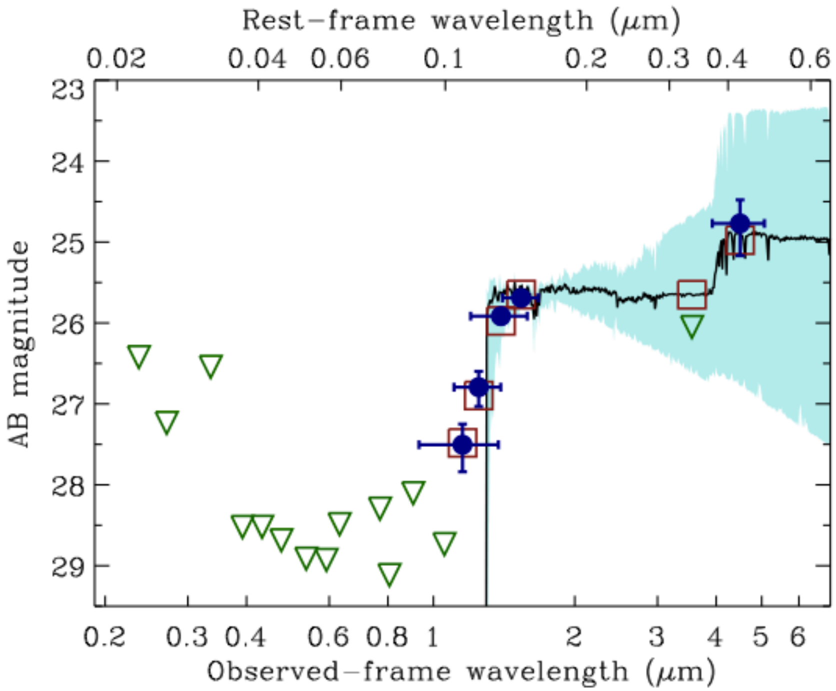
Using lensing to probe the high-z Universe

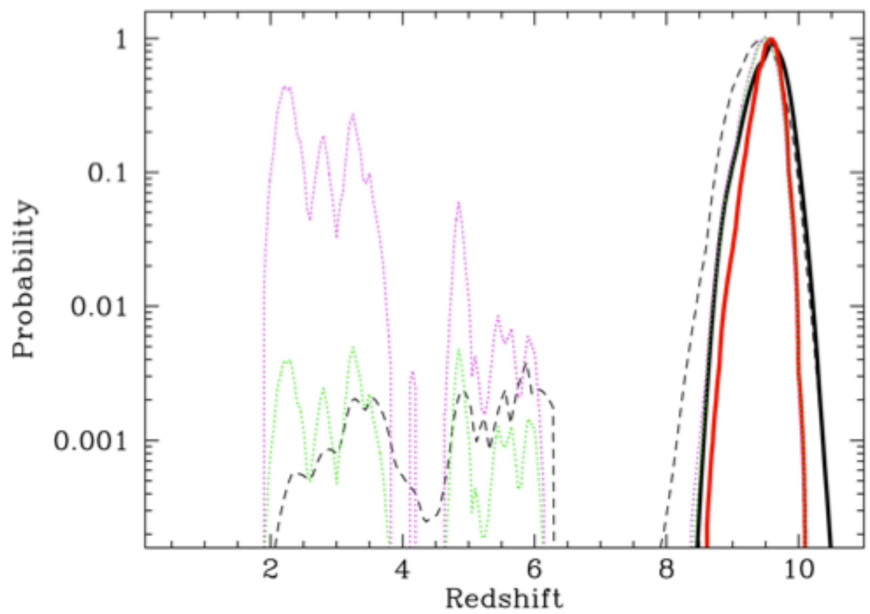
WFPC3 detection
z=9.6±0.2
<500 Myr (3.6% age Univ.)

Zheng et al. 2012, Nature
See also Ota et al. 2012 for
a similar program (no detected LAEs)

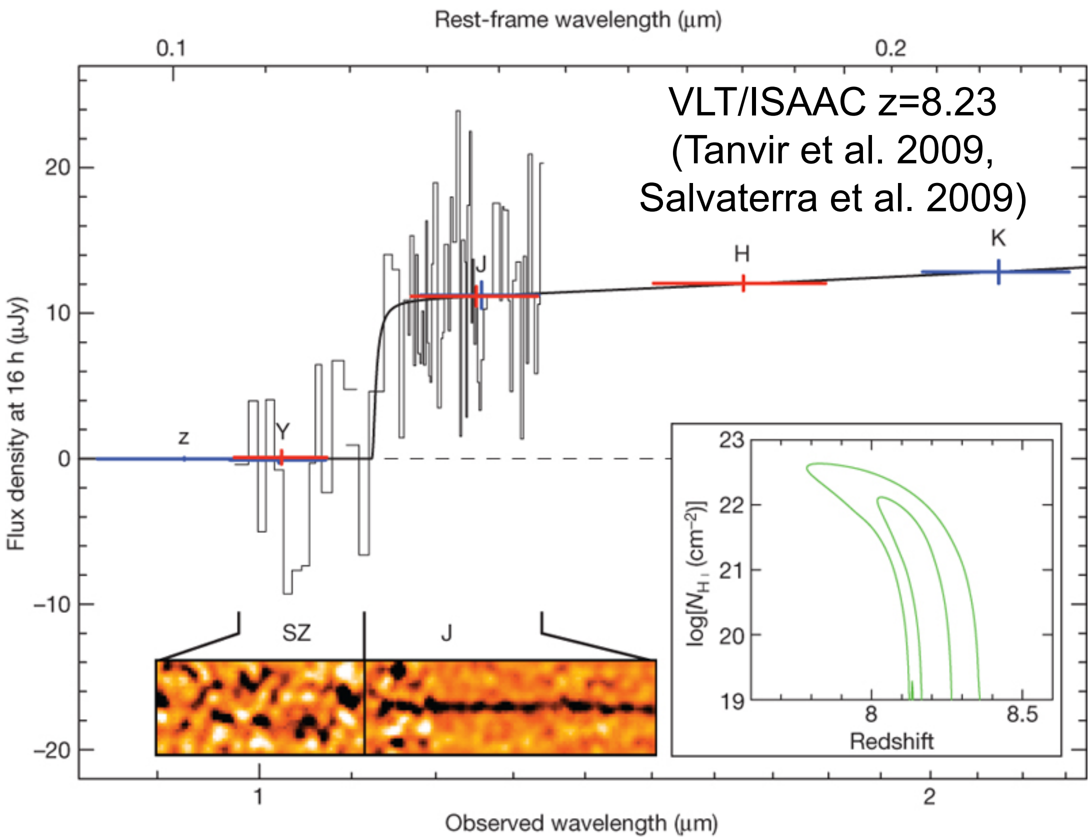


see Rosati's talk

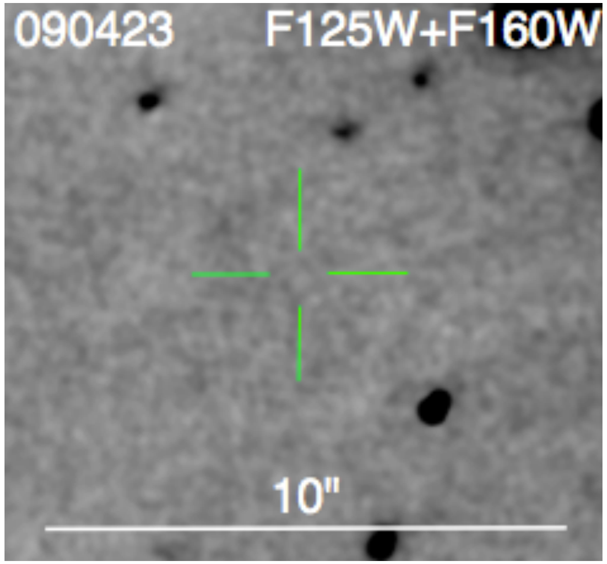




Gamma-ray bursts: the cases of GRB 090423 and 090429B

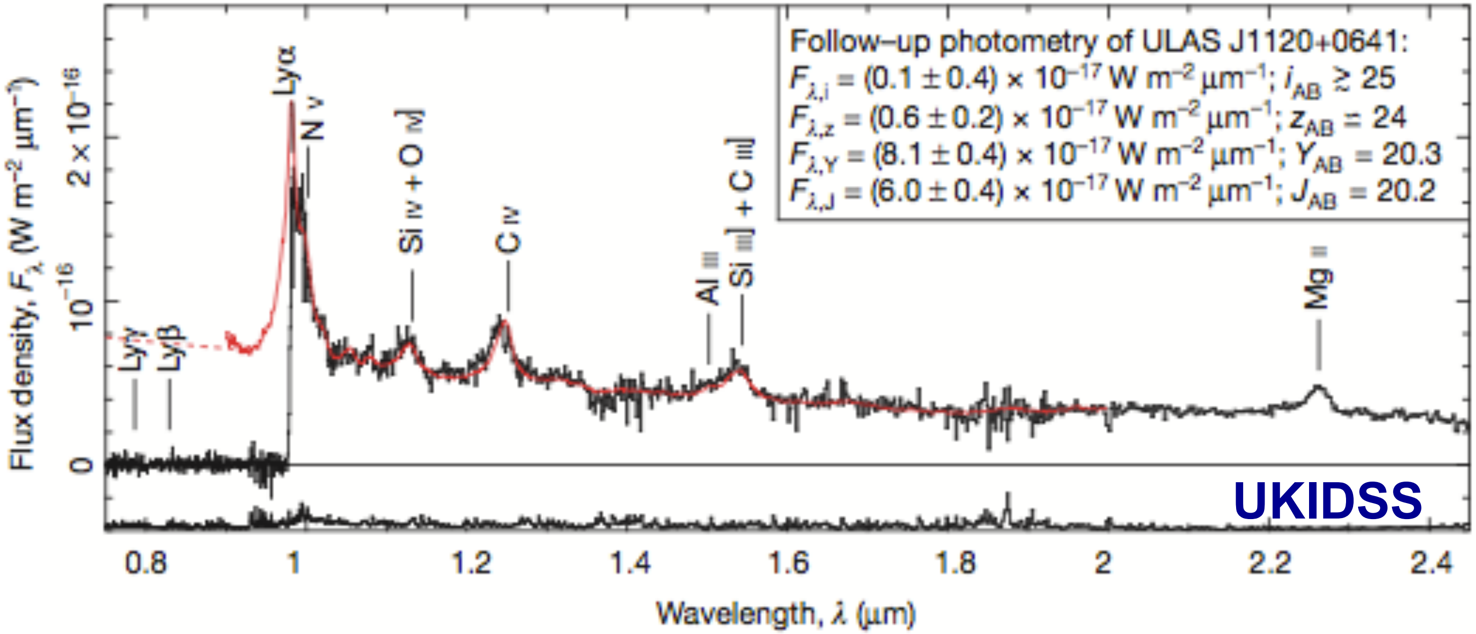


See also **GRB090429B** (Cucchiara et al. 2011, z=9.1−9.5 90% c.l.)

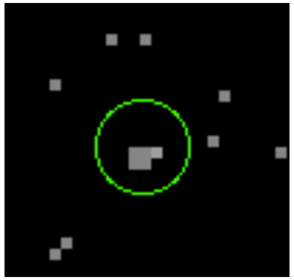


Host gals not visible in deep images
Bulk of the SF at high redshifts arises in galaxies below the detection limit of deep fields (Tanvir+12)
➔ One science case for 30-m class telescopes

z~7 quasars: beyond CFHQS and SDSS

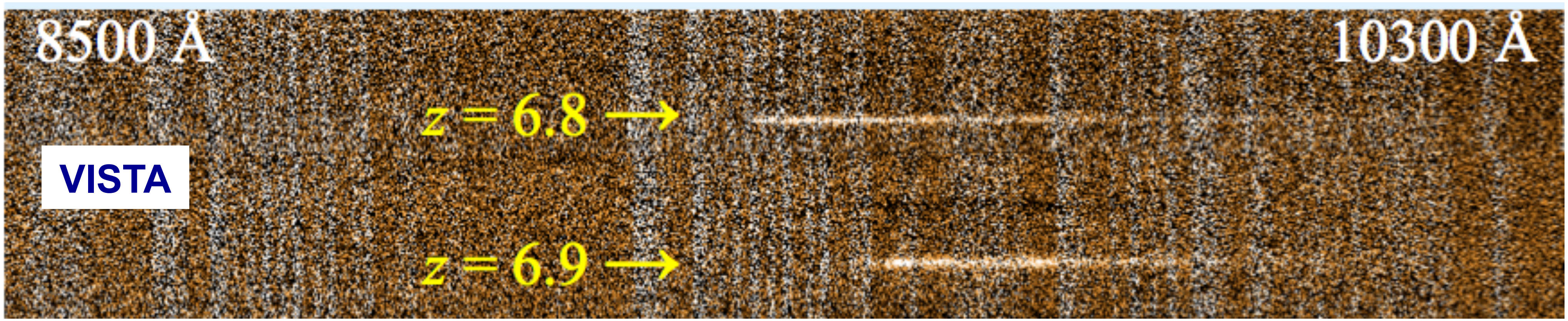


Mortlock et al. 2011, GNIRS+FORS2, compared to average z~2.5 SDSS QSOs

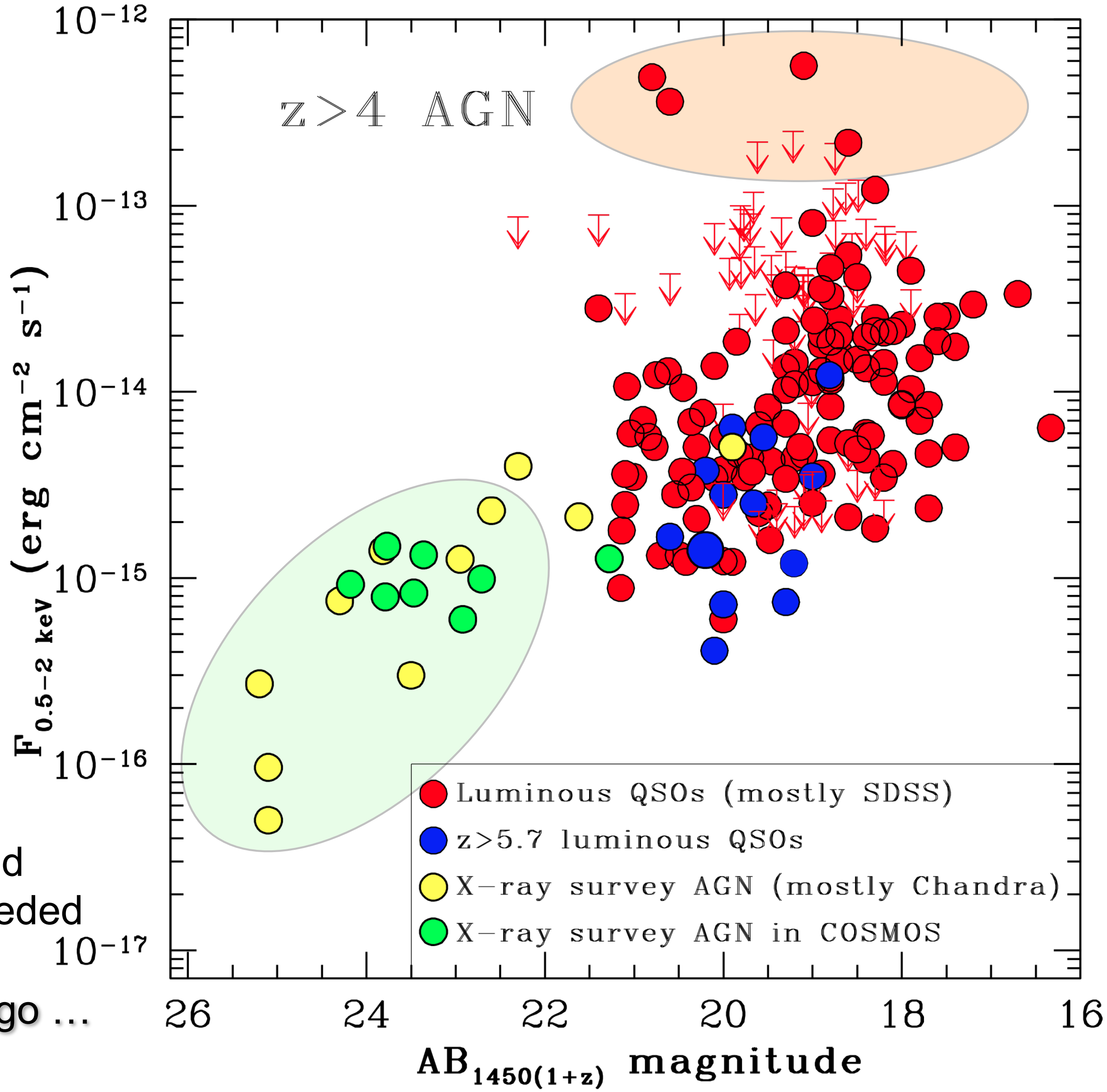


Chandra detection
F_x~(1-2) ×10^{-15} cgs
"standard" QSO

Venemans, FORS2



AGN at high-redshift: Where do we stand? I.

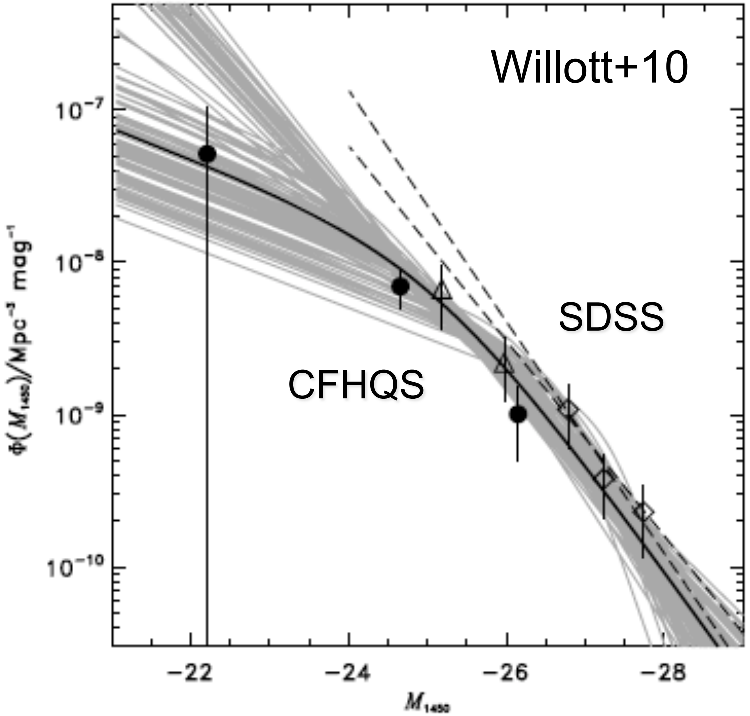


Kaspi et al. 2000

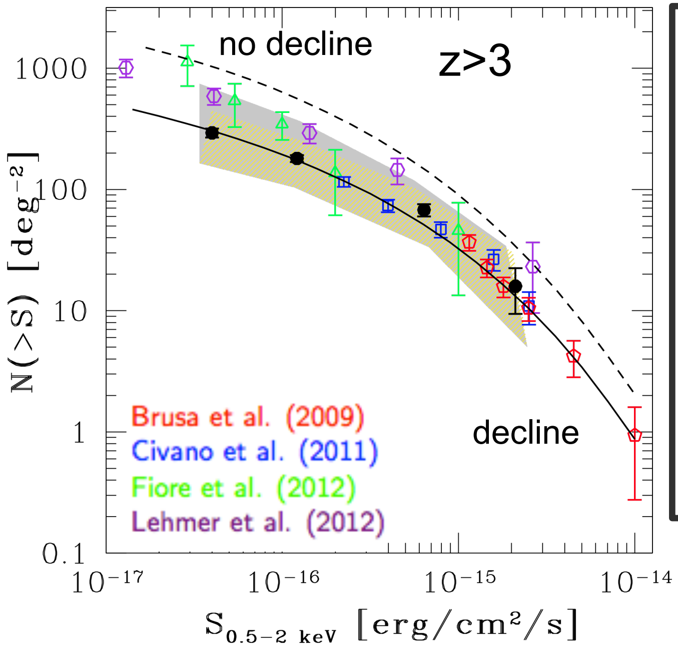
Deep optical and
X-ray coverage needed

Where we need to go …

AGN at high-redshift: Where do we stand? II.



Steep bright-end slope
LF break at M_{1450}≈−25?



XMM/*Chandra*-COSMOS + CDF-S data consistent with the decline scenario

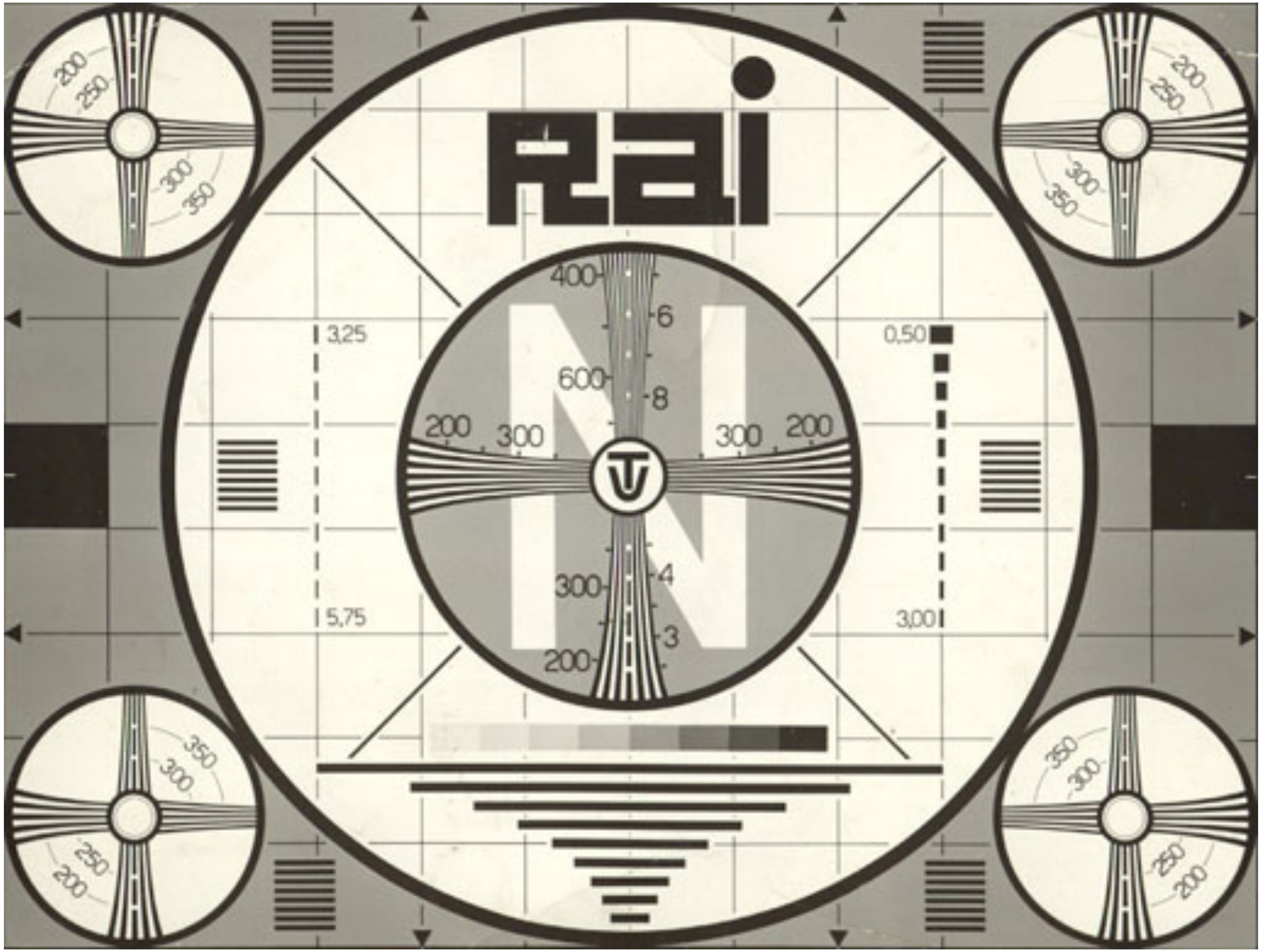
Approx 2/3 of the z>3 AGN in the CDF-S are likely highly obscured

Vito et al., in preparation

see talks by Brusa, Vito, Gilli, Fiore, Mignoli

X-ray surveys start probing very high redshifts, down to ~Sey-like X-ray luminosities, including obscured AGN

Intervallo


RAI
400
6
600
8
200 300
300 200
3,25
0,50
5,75
3,00
300
4
200
3
200
250
300
350

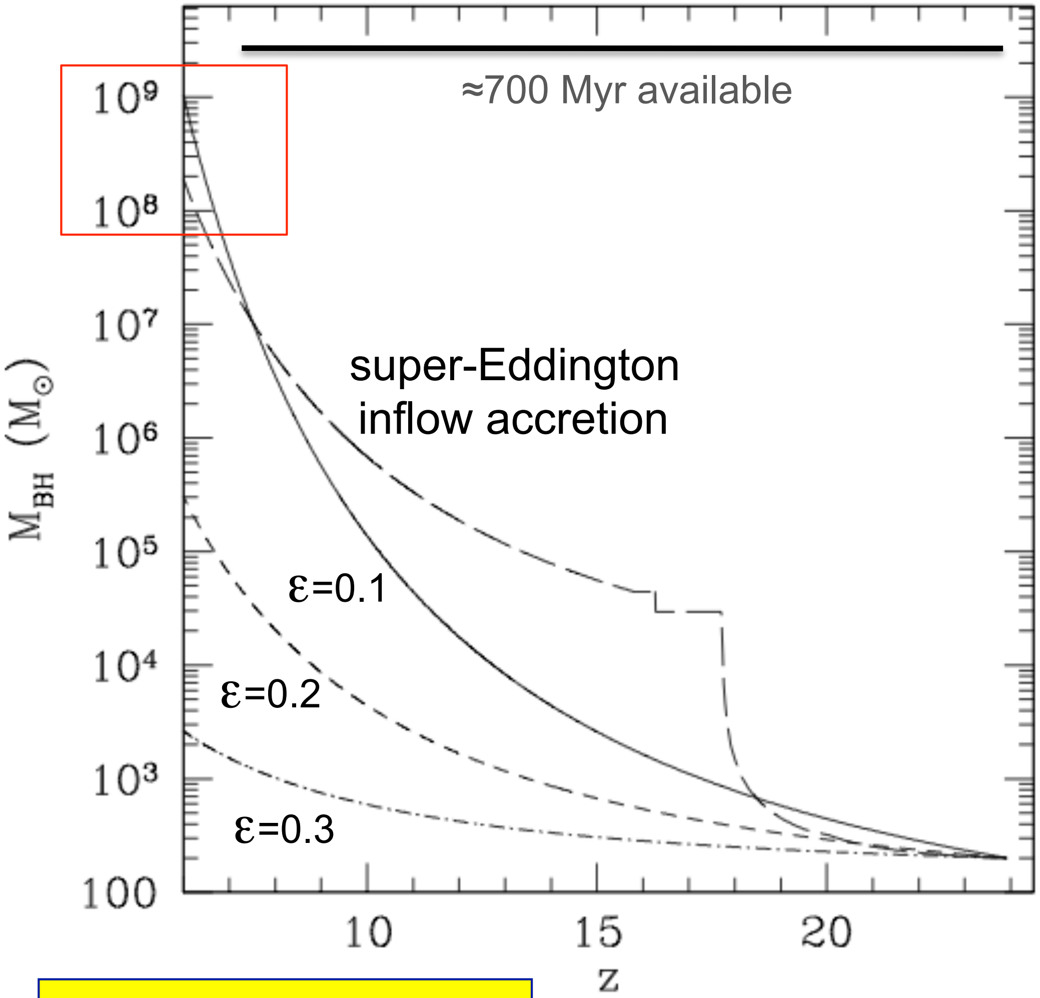
Q1: Is there enough time for BH growth at z≈6?

$$M(t) = M_0\, e^{\left(\frac{1-\varepsilon}{\varepsilon}\,\frac{t}{t_{\mathrm{Edd}}}\right)}$$

Larger radiation efficiency ε means longer times to achieve a given mass
[t_{Edd}=0.45 Gyr for ε=0.1]

Rapidly spinning BHs might have problems because of a larger ε

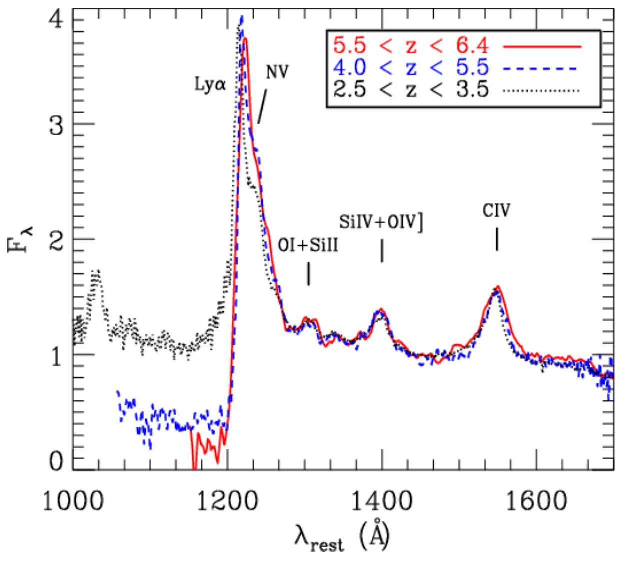
Highest-redshift quasar so far spectroscopically identified: ULASJ1120+0641, z=7.08, $M_{BH} \approx 2\times10^9\ M_\odot$ (Mortlock et al. 2011)



see talk by Shankar

Volonteri & Rees 2006

Q2: Is fast metal enrichment at z≈6 fully understood?



(Juarez+09; see also Dietrich+, …)

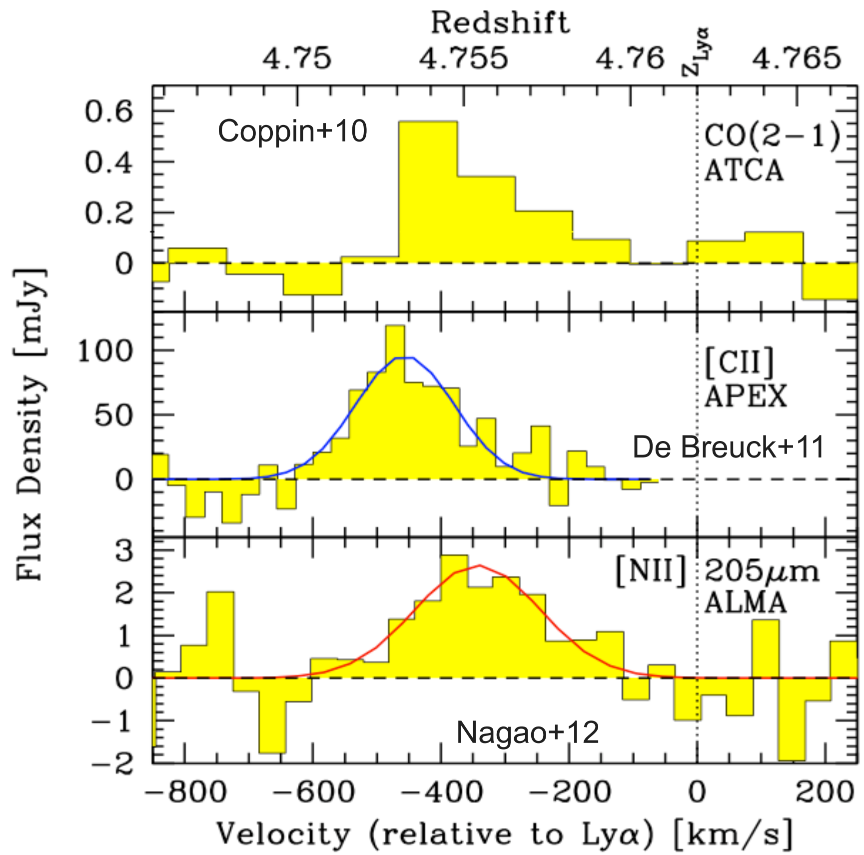
High metallicities at very high redshift

➔ early chemical enrichment: the host galaxy has undergone a vigorous star formation

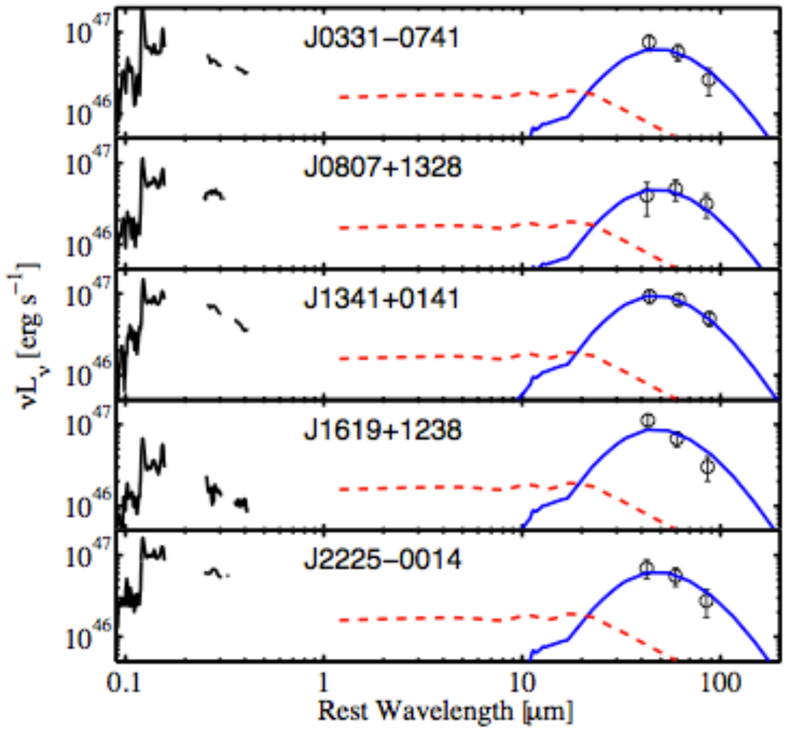
BUT BH-to-galaxy mass ratio at least one order of magnitude larger than observed locally
The ISM has already reached super-solar metallicities but >90% of the final stellar mass has still to be formed to reach the local $M_{BH}/M_\star$ relation
(BHs grows 'faster' than their host galaxies)

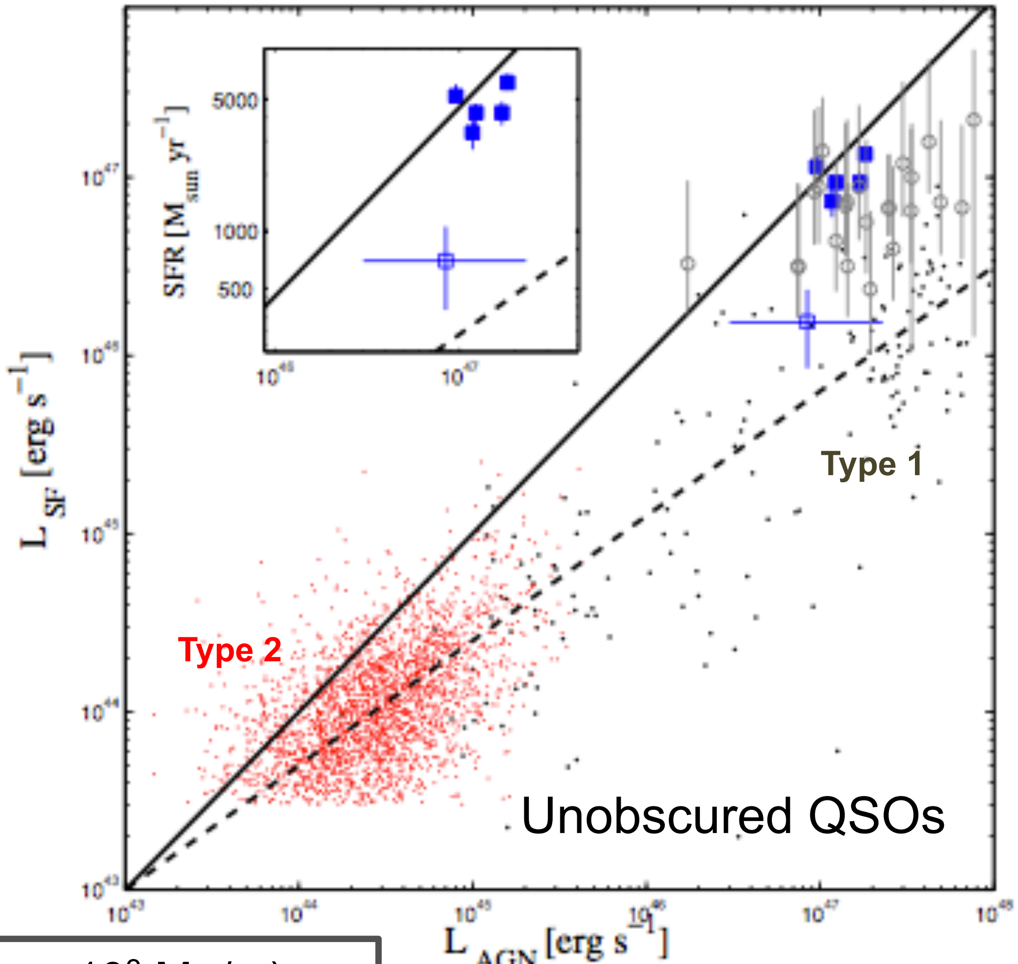
First galaxy with both $[CII]_{158\mu m}$ and $[NII]_{205\mu m}$ detections at very high redshift
➔ physical properties of the gas (e.g., metallicity) in a dusty environment

A
L
M
A



Q3: How common are systems with significant accretion and star formation?





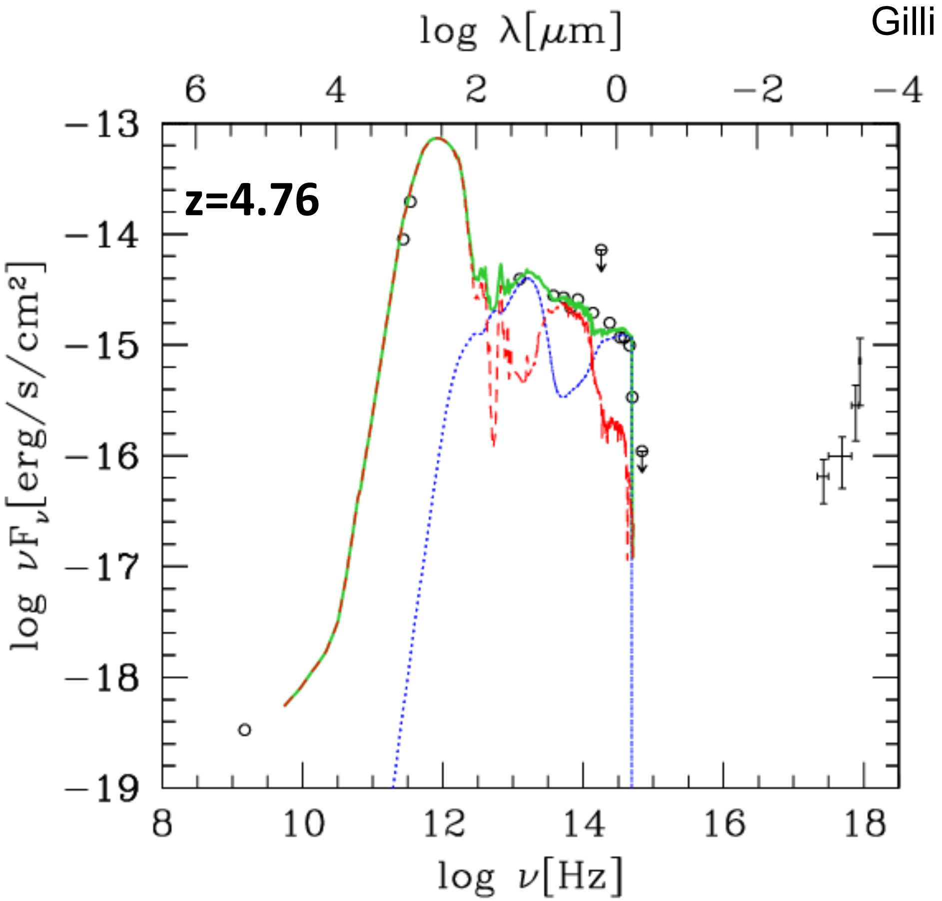
SDSS QSOs at z~4.6−4.9
Mor et al. 2012

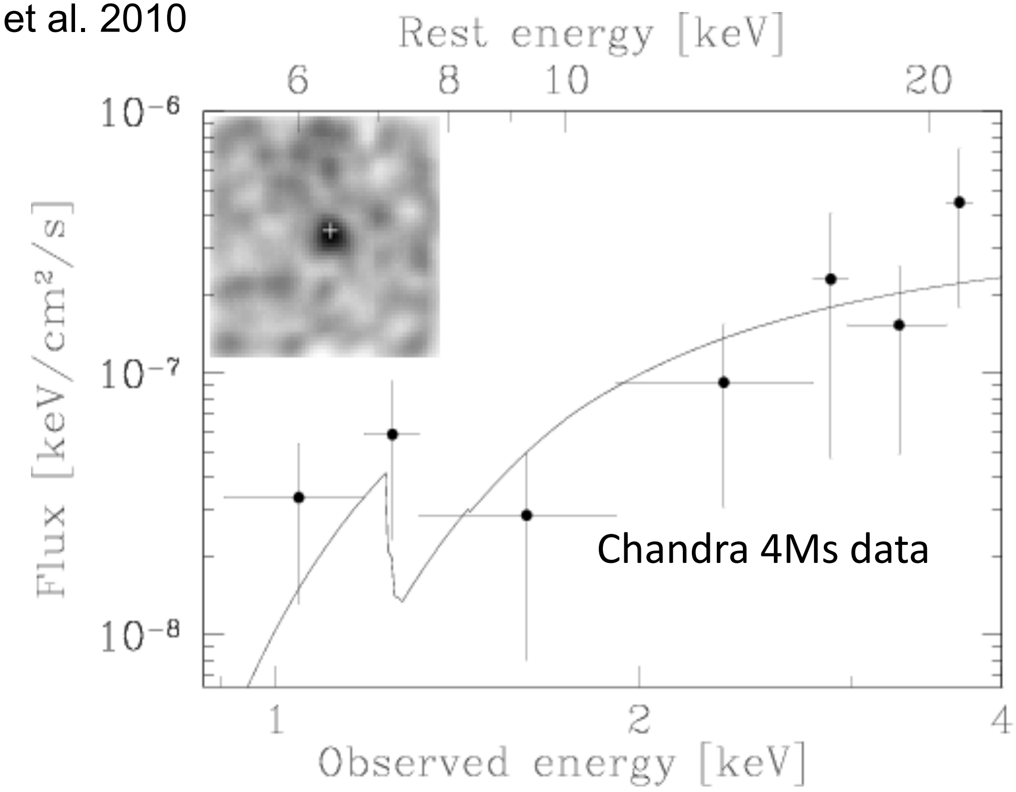
Strong star formation at high redshift (a few ×10^3 $M_\odot$/yr)
Major mergers to explain extreme systems, secular evolution for the others?
Was SF already quenched? Timescale of ~100Myr for this process

And how common is to find heavily obscured accretion in star-forming systems?

Xue 403: a SMG hosting a Compton-thick AGN

Gilli et al. 2010





L_X=2.5×10^{44} erg/s , N_H=1.4×10^{24} cm^{-2}

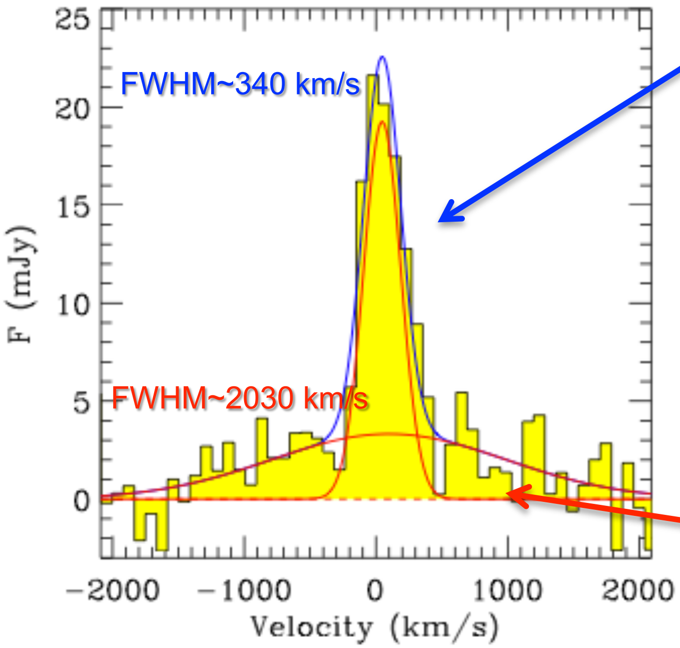
SED decomposition: SFR = 1000 M_{sun}/yr ; L_{SB}=6x10^{12} L_{sun} ; L_{AGN} = L_{SB}/3

R_{SB} ~ 3.3 kpc ; Σ_{IR} = 3.5x10^{11} L_{sun}/Kpc^2 ➔ compact SB

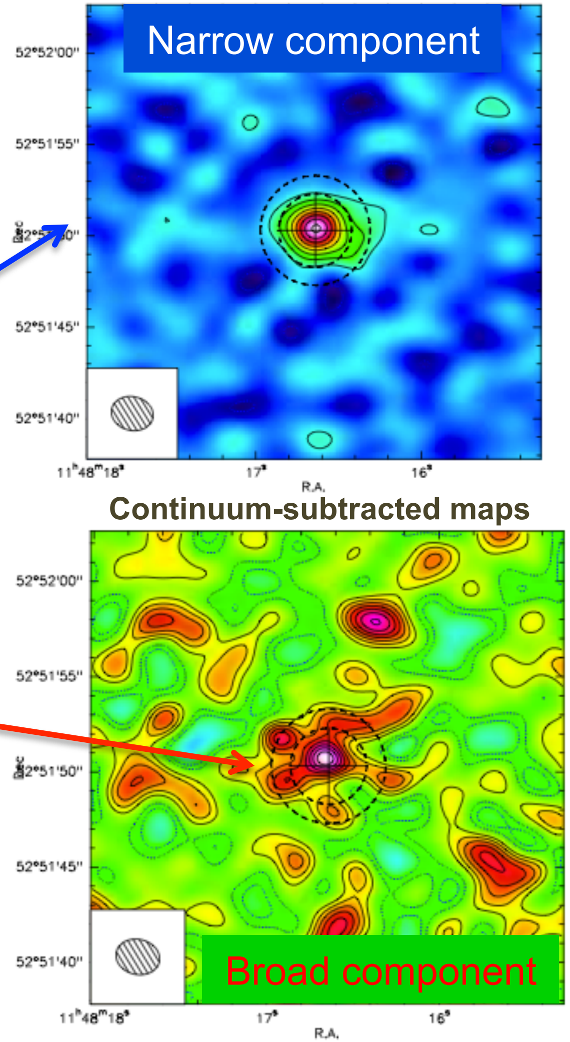
Q4: What is the role of the feedback at very high redshift?

SDSS J1148+5251: z=6.43

see talk by Cappi



Maiolino et al. 2012



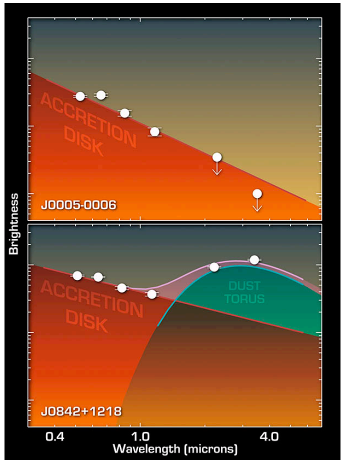
Evidence of feedback at low and intermediate redshifts from neutral/ionized gas (e.g., Feruglio+10, Alexander+10)

Capable of quench SF? (e.g., Page +12, Cano-Diaz+12)

Massive outflow of $[CII]_{158\mu m}$ line, of Mdot>3500 $M_{\odot}$/yr (Maiolino +12, Valiante+12), ~SFR in the host galaxy

$P_K > 1.9\times10^{45}$ erg/s ≈0.6% L_{bol} (QSO) OK with AGN Prad, barely consistent with STB-driven winds

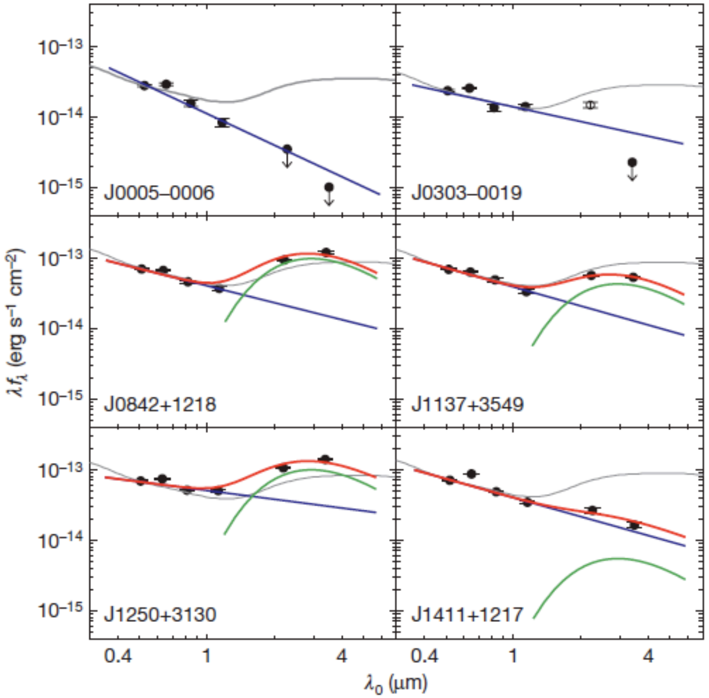
Q5: Is the dust ubiquitous in z~6 QSOs?

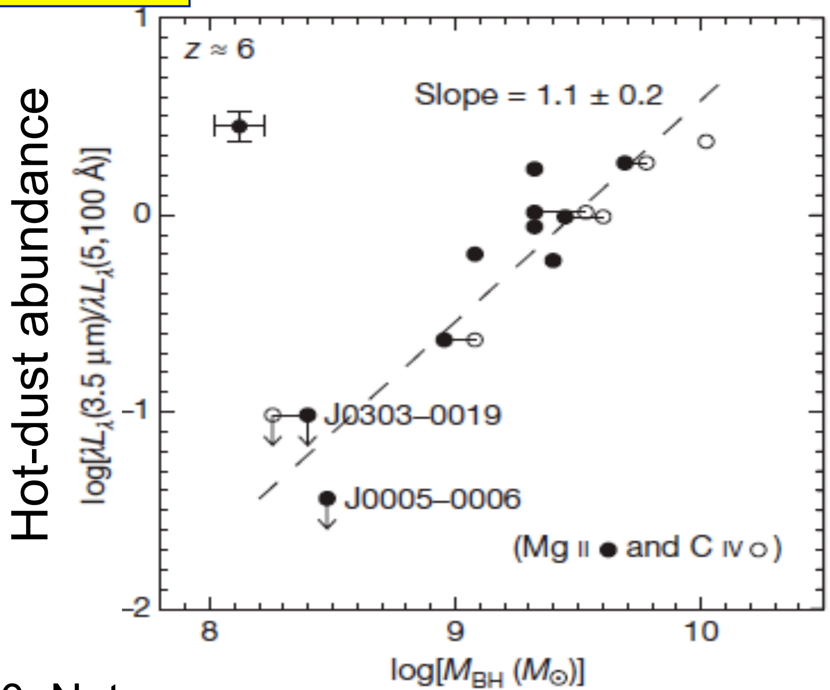


✓ 2/21 z>6 QSOs without hot dust: QSOs born in dust-free environments or not enough time to produce dust? High Eddington ratios, early stage of QSO evolution?

✓ Similar findings recently found for Type 1 AGN in the C-COSMOS survey (Hao et al. 2010) – from 6% at z<2 to 20% at z=2−3.5

see talk by Gallerani

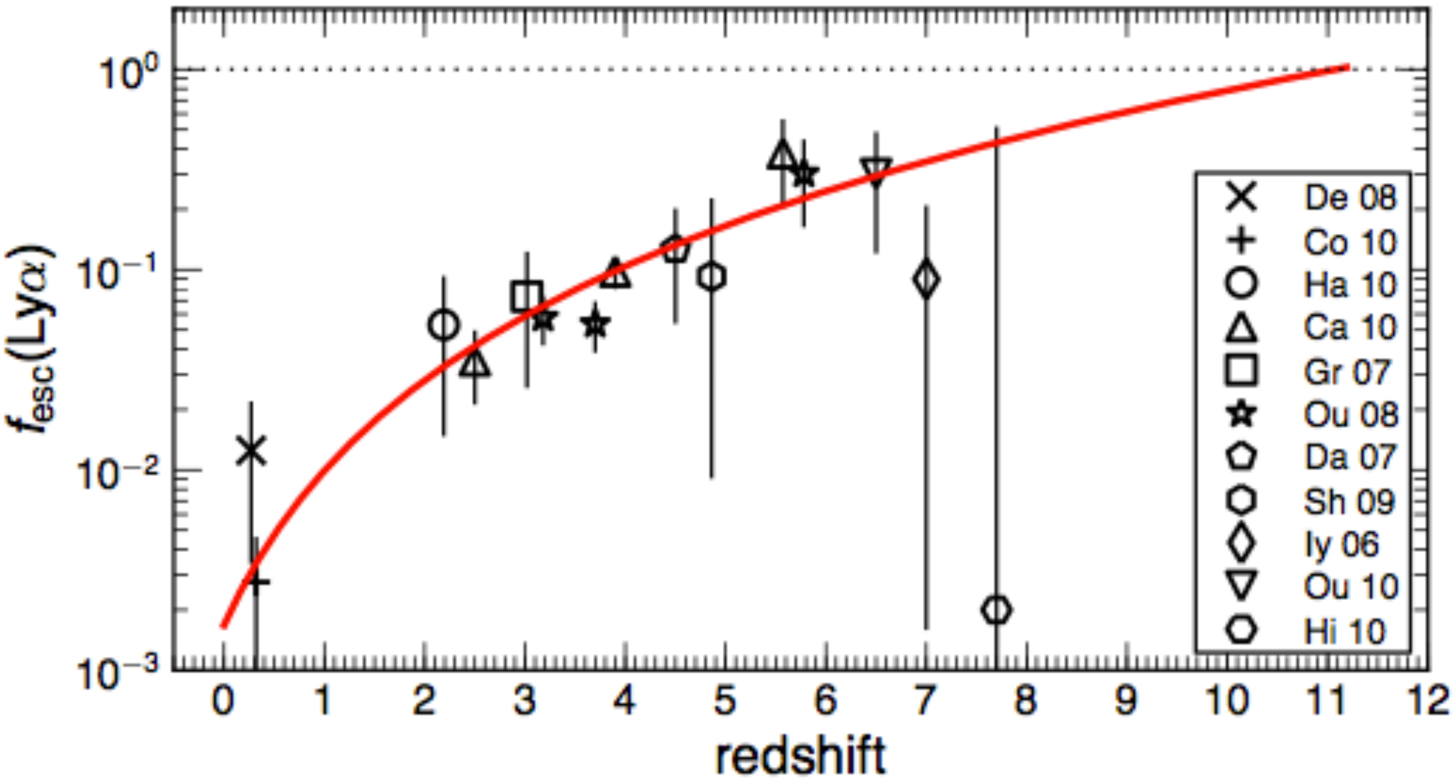




Jiang+10, Nature

Q6: What are the implications for the Lyman-α escape fraction evolution?

Hayes+11: Volume-average Lyman-α escape fraction normalized to 5% at z~2 (through a comparison of Ly-α vs. Hα LFs)

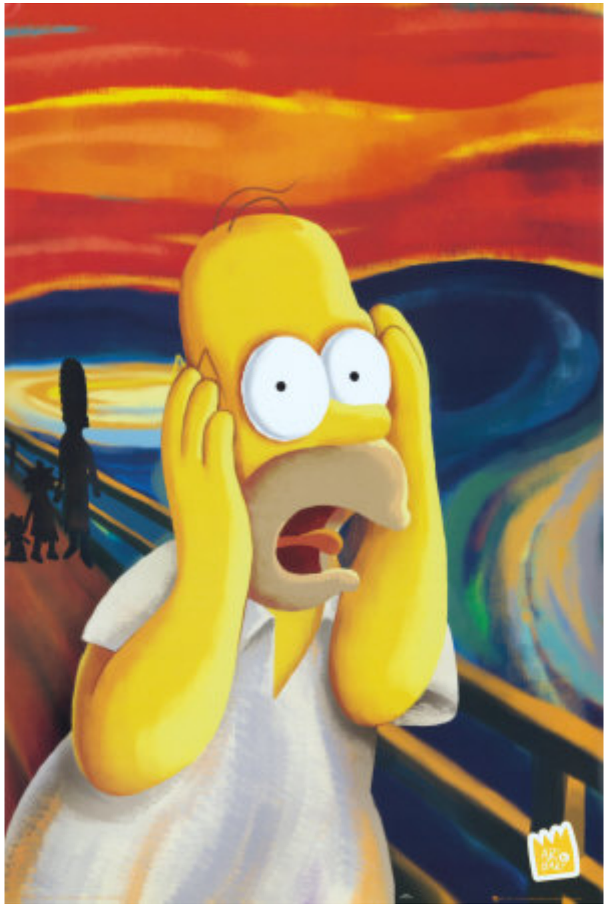


Conclusions

The study of the high-redshift Universe is related to quite outstanding issues and questions because of the strong implications for today' structures

Something to think deeply on

Something to be worried about



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