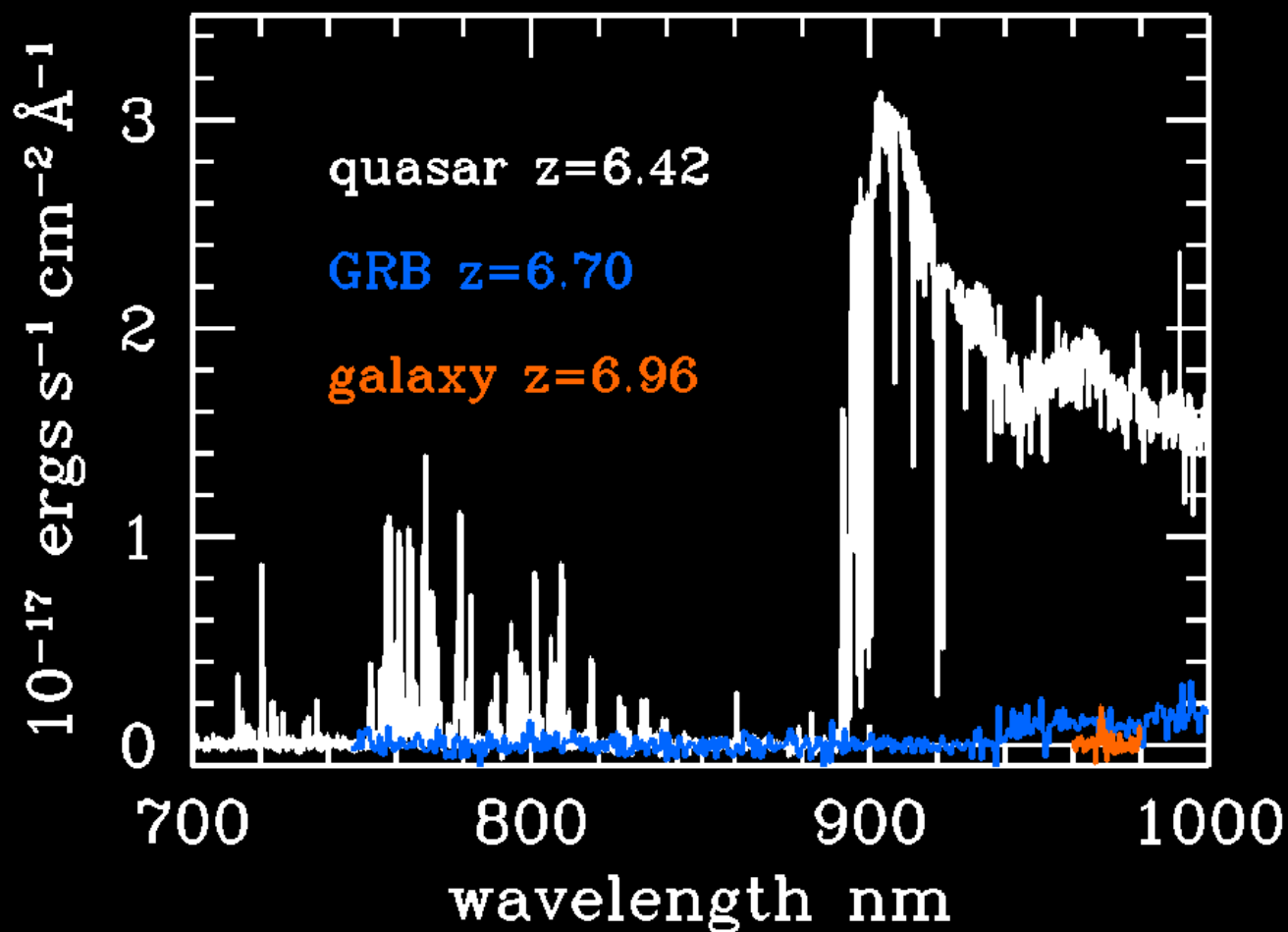


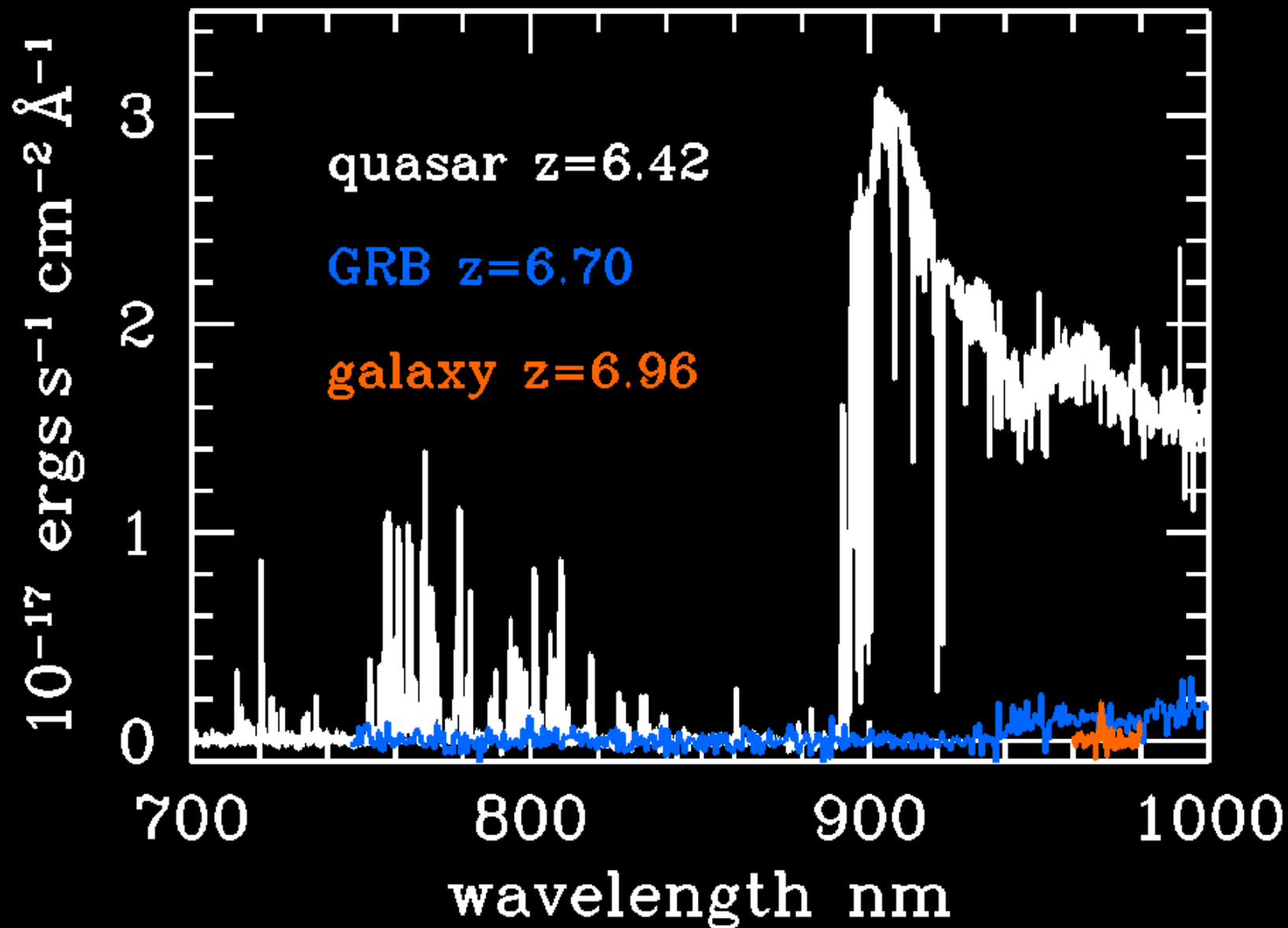
Searches for AGN at $z > 5$ from X-ray to radio

Steve Warren Imperial College London

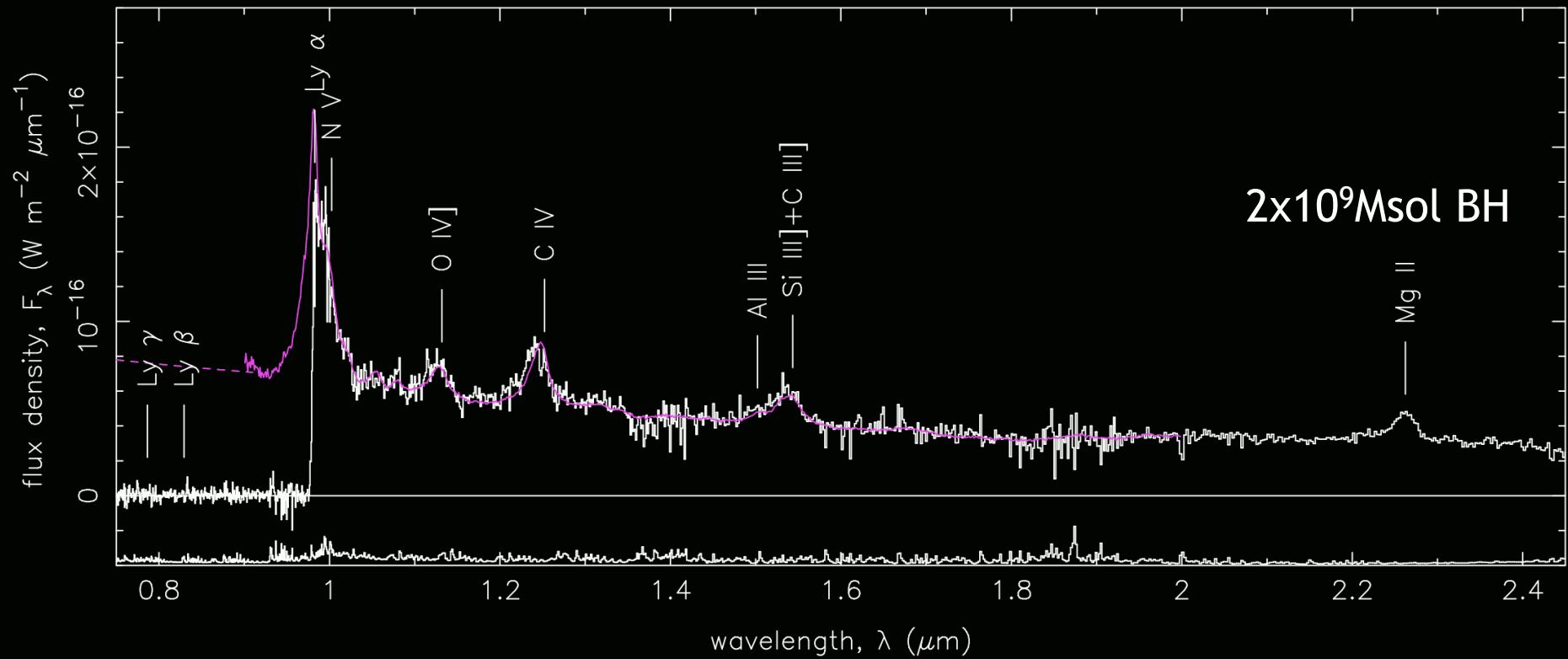


Motivation

- Finding bright sources as beacons to study reionisation
- Following the history of black-hole accretion activity
 - Black hole mass function
 - Relation between black hole growth and star formation
 - Contribution to reionisation



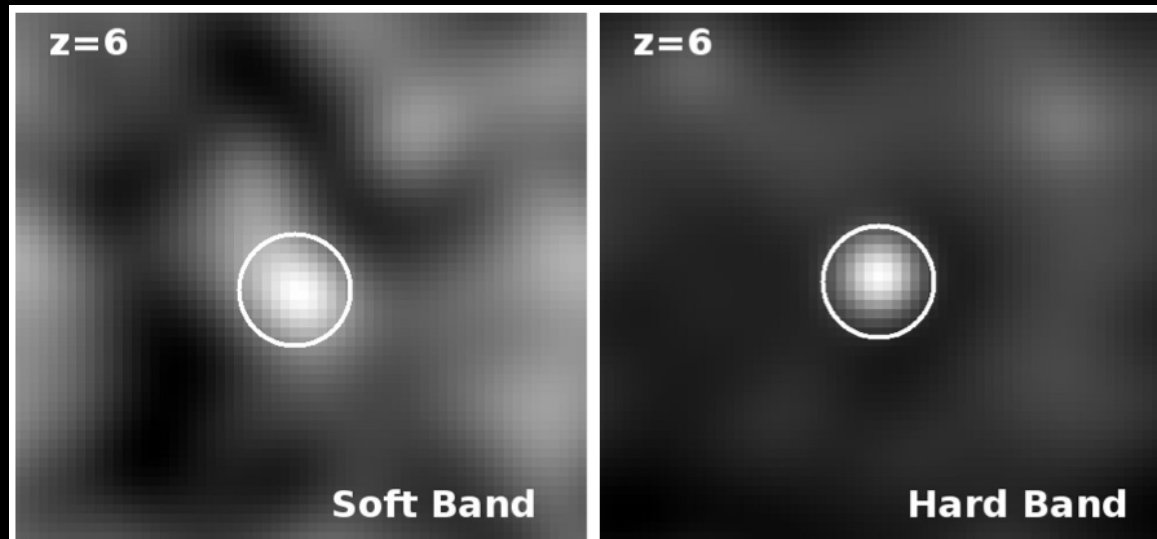
$z=7.085$ quasar Mortlock et al, 2011



Treister et al. 2011

Detection of obscured $z > 6$ AGN from X-ray stacking analysis of photo-z redshifts

- Substantial black-hole growth at $z > 6$ in star-forming galaxies
- Most high- z black-hole growth is obscured
- But see counterclaims by Fiore et al (2011), Barger et al (2011)



Searches for AGN at $z > 5$

1. Current status and next few years at
 - X ray
 - Mid-ir
 - Radio (radio quasars, radio galaxies)
2. Current status in the optical / near-ir
 - Reionisation
 - Decline in space density
3. Prospects with Euclid

X rays: current status

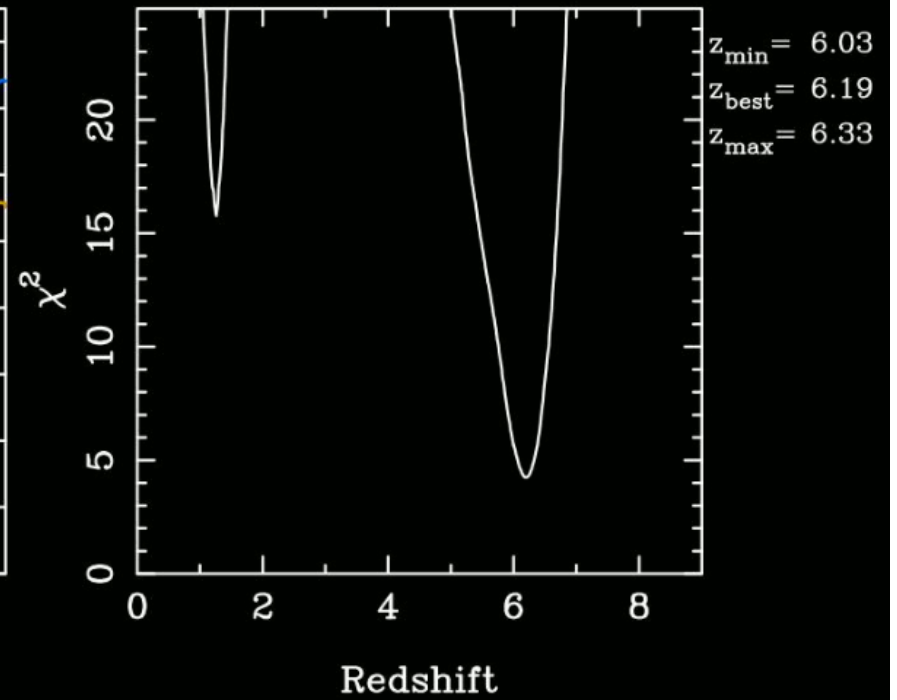
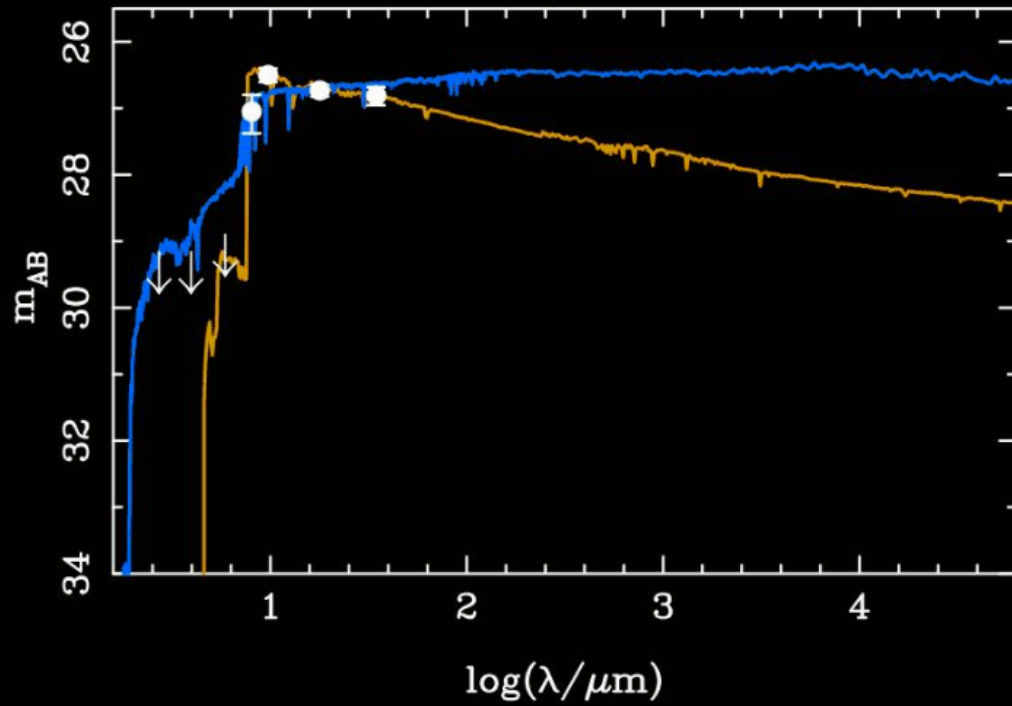
- **Motivation**

- A census of SMBH accretion activity, including obscured AGN

- **Results**

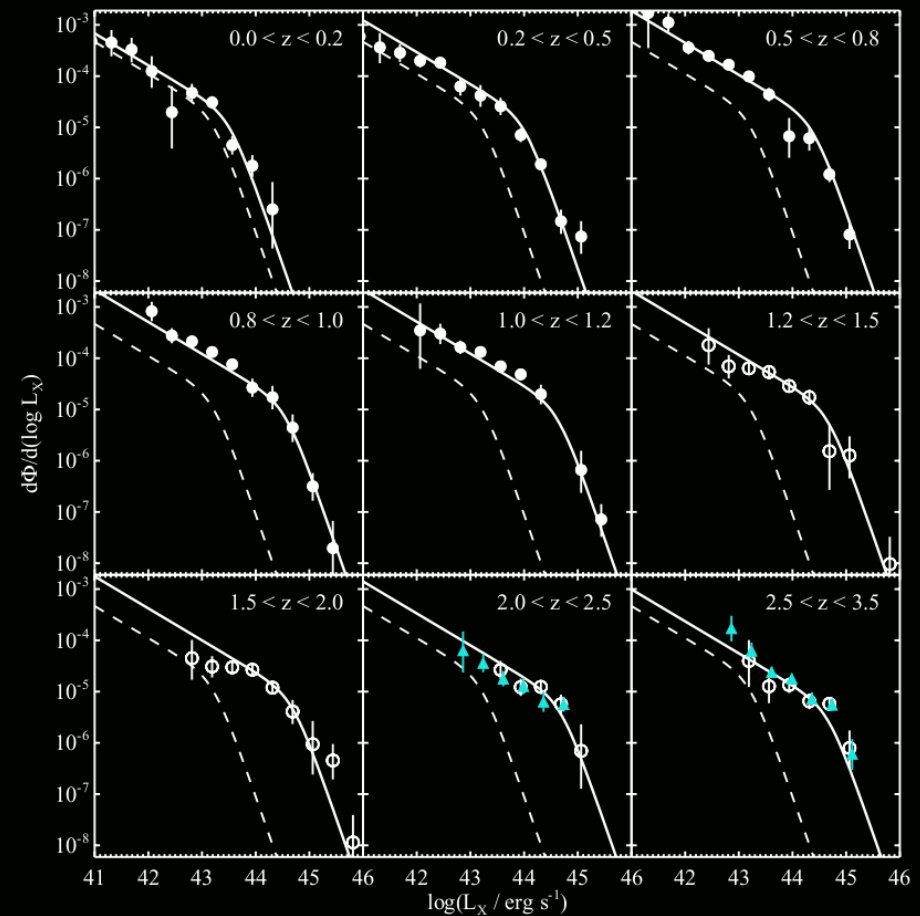
- $z=5.19$ (Barger et al 2002)
- $z=5.40$ (Steffen et al 2004)
- $z=6.19$ candidate CDF-S

X rays: current status

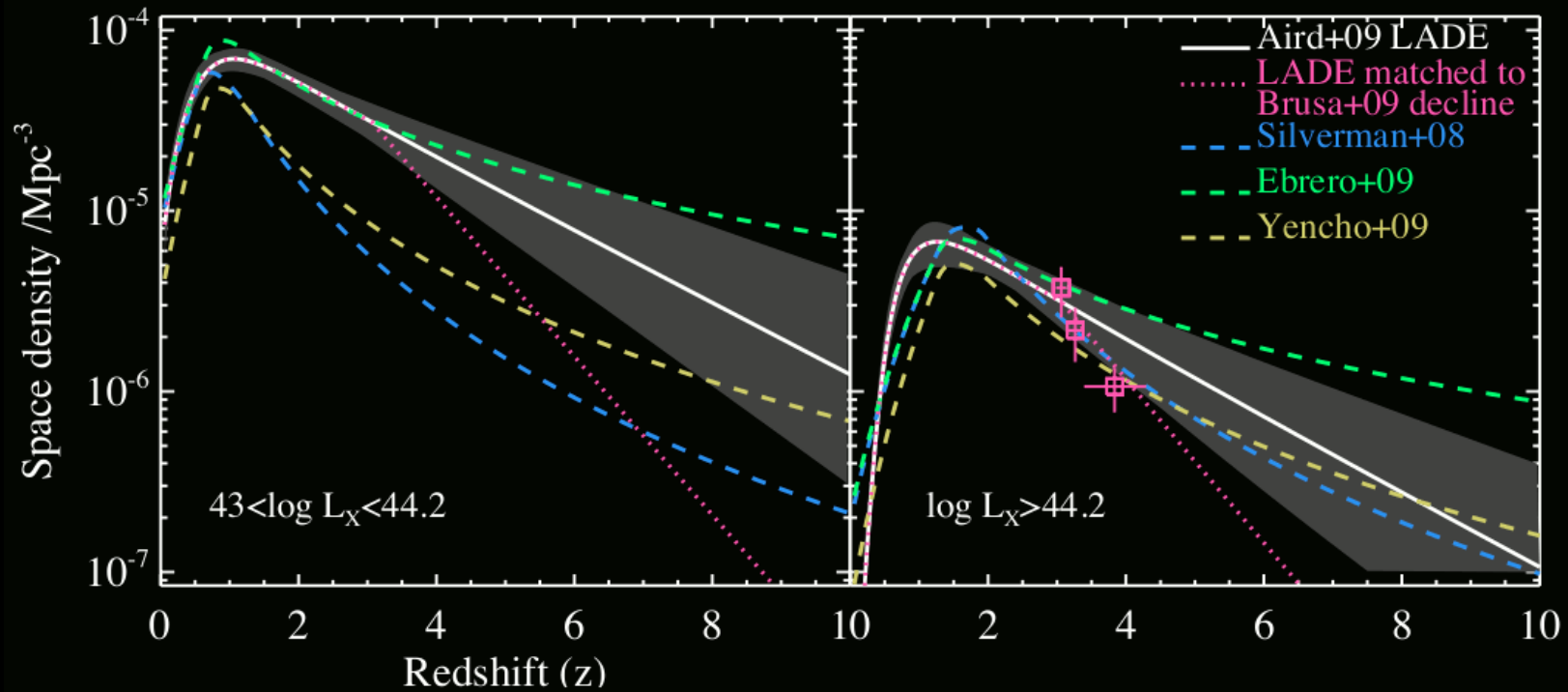


X rays: the near future

Predictions using the hard
X-ray luminosity function of
Aird et al. (2010)



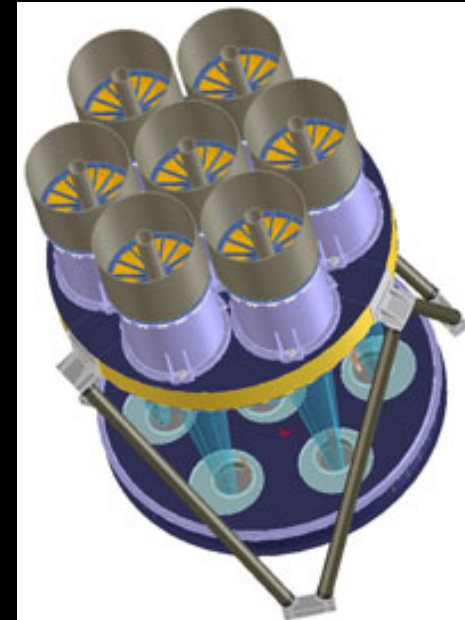
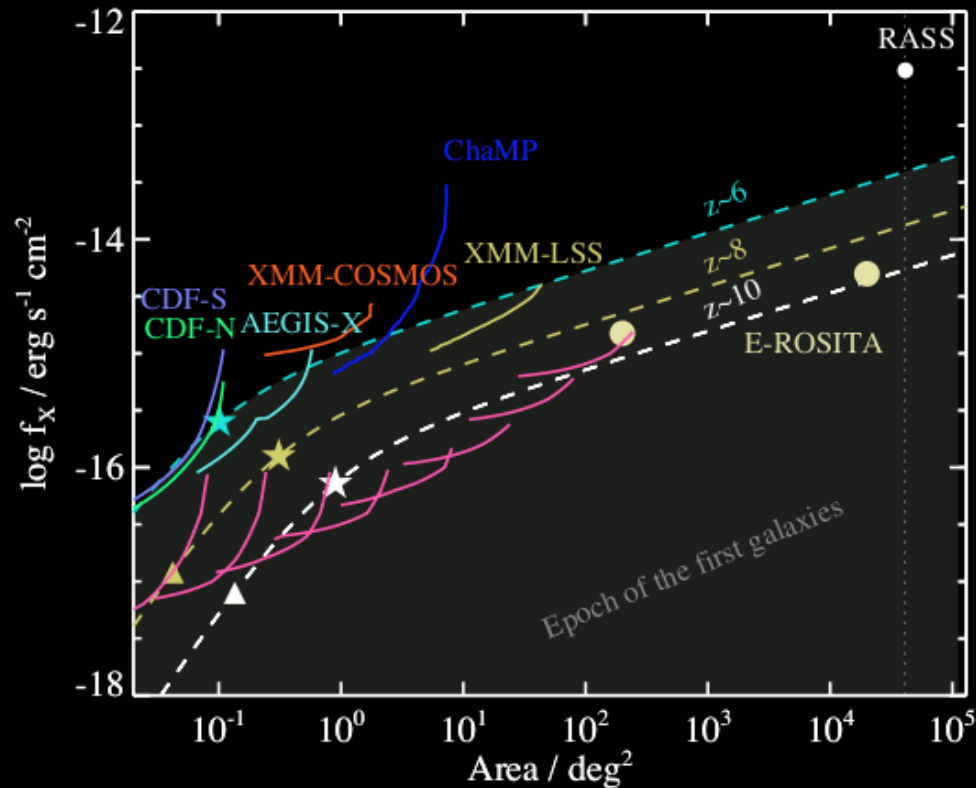
X rays: the near future



X rays: the near future

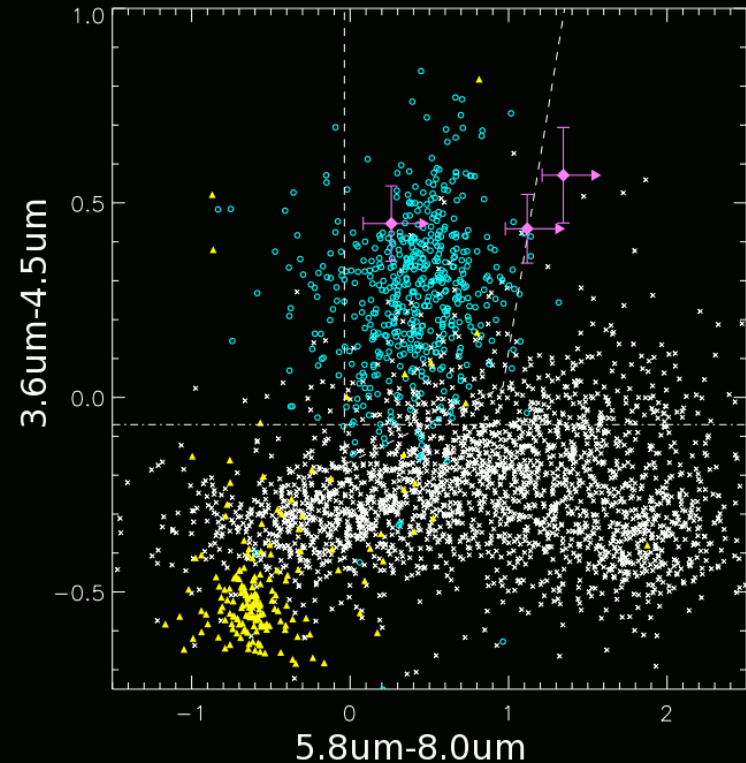
eROSITA all-sky survey could find a number of $z > 6$ AGN, but

- numbers uncertain
- very substantial follow-up required



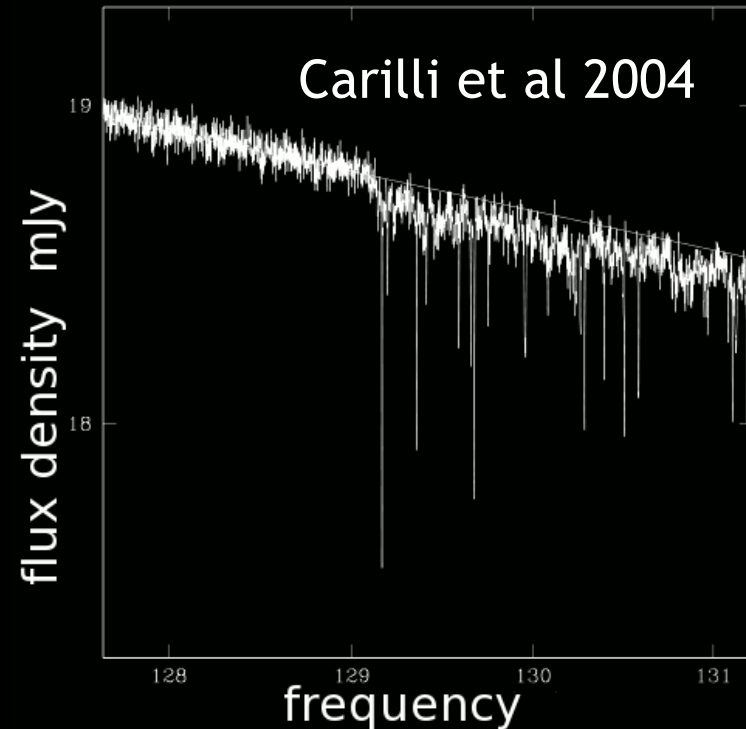
Mid-ir: current status

- **Motivation**
 - Avoiding selection biases
- **Results**
 - $z=5.39, 5.53, 5.85$ (Cool et al 2006)
 - $z=6.12$ (Stern et al 2007)
- **Drawback $z>6.4$**
 - Near-ir data needed
 - Brown dwarf contamination
 - WISE too faint



Radio: current status

- **Motivation**
 - Targets for 21cm forest
- **Results - quasars**
 - $z=5.19$ (McGreer et al 2009)
 - $z=5.47$ (Romani et al 2004)
 - $Z=5.95$ (Ziemann et al 2011)
 - $z=6.12$ (McGreer et al 2006)
- **Results - galaxies**
 - $z=5.19$ (Van Breugel et al 1999)

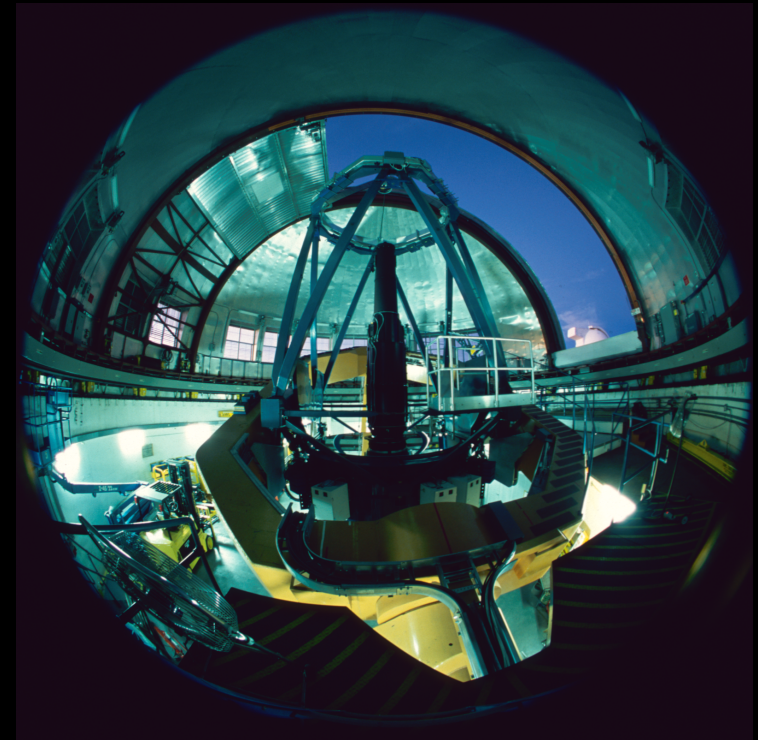


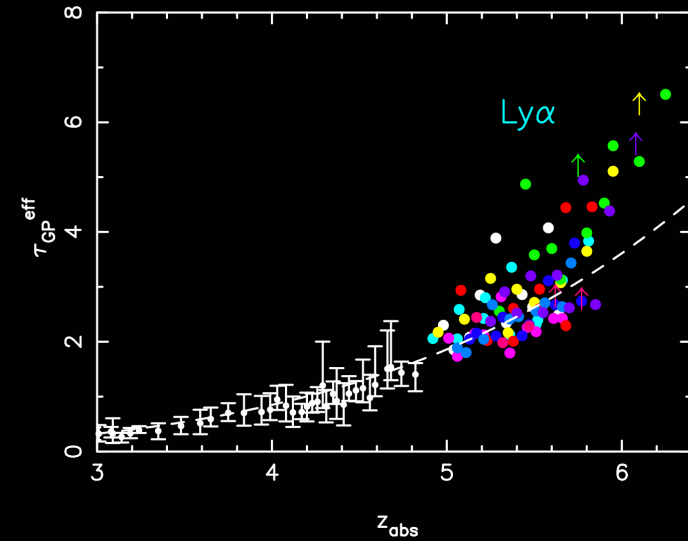
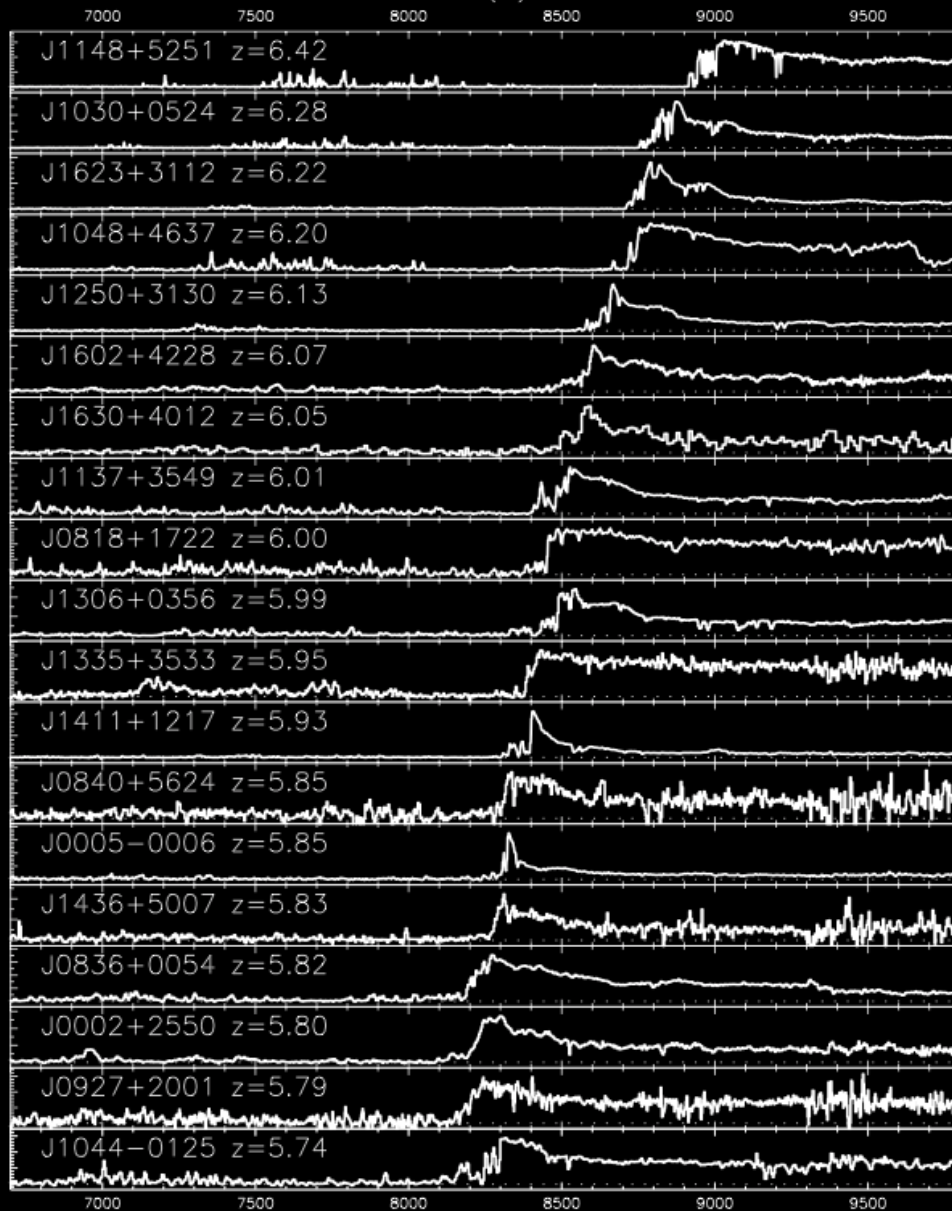
Radio: the near future

- LOFAR wide survey (2012)
 - Radio quasars - flat spectrum, Pan-STARRS blank
 - Radio galaxies - PanSTARRS, WISE blank, very faint in K
 - Predicted numbers very uncertain
 - Very extensive follow-up needed

Current status in the optical / near-ir

- Over 50 quasars $z > 5.8$ so far discovered
- First $z > 6.5$ quasar discovered by UKIDSS $z = 7.08$ (Mortlock et al. 2011)
- Two further $z > 6.5$ quasars discovered by VISTA $z = 6.8, 6.8$ (Venemans et al. in prep.)
- First $z > 5.7$ quasar discovered by PanSTARRs (Morganson et al. 2011)

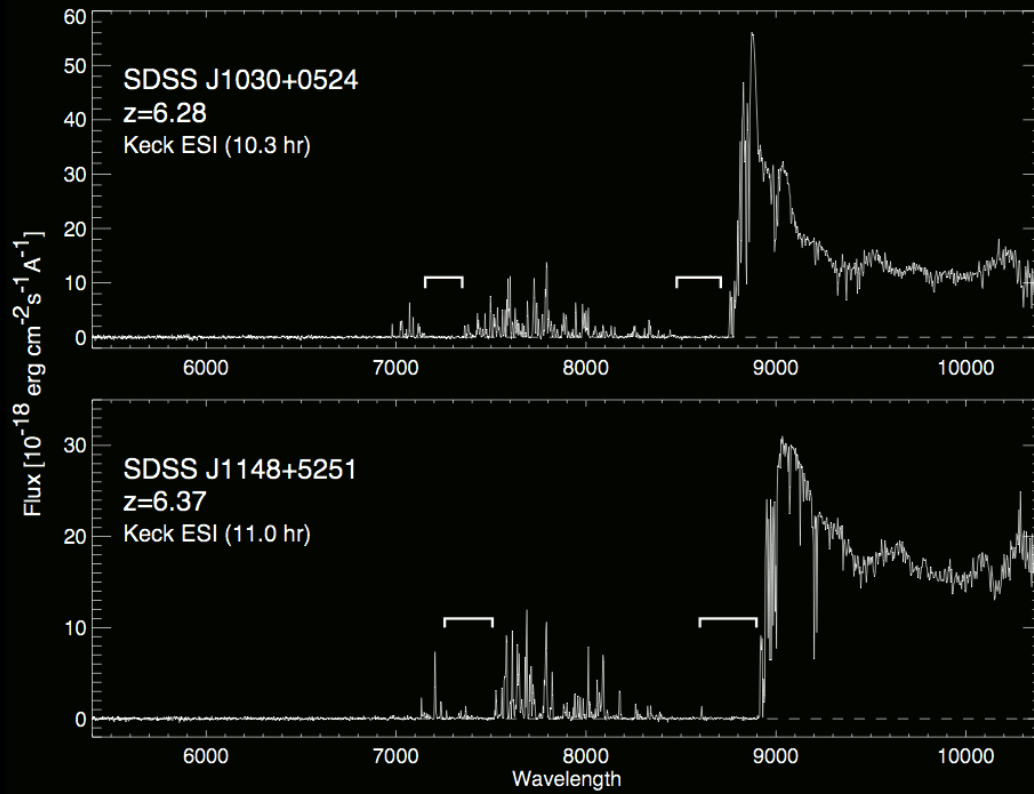




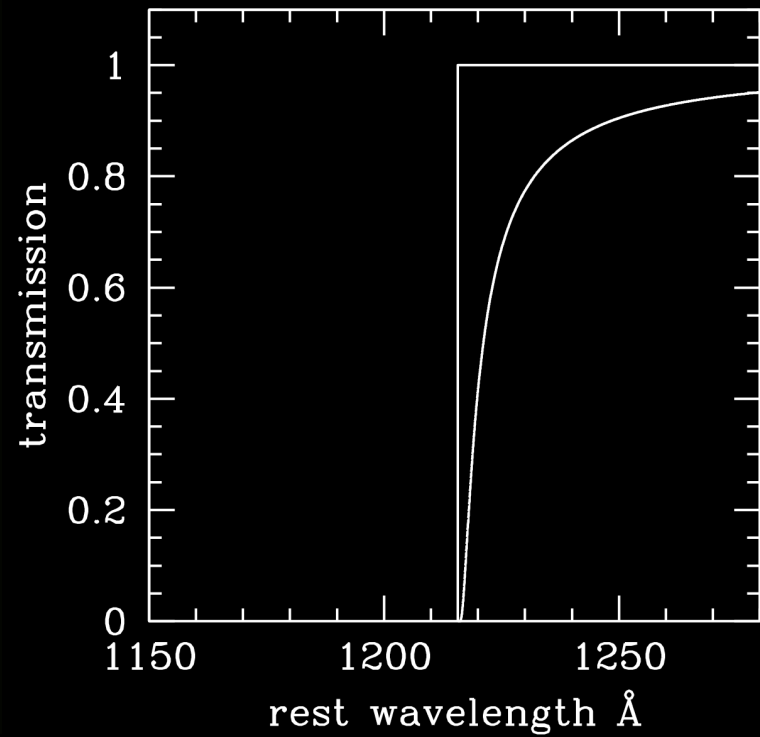
From SDSS at $z=6.2$:
 $f_{HI}=10^{-3}$

From WMAP:
 $z(\text{reion})=10.5 \pm 1.2$

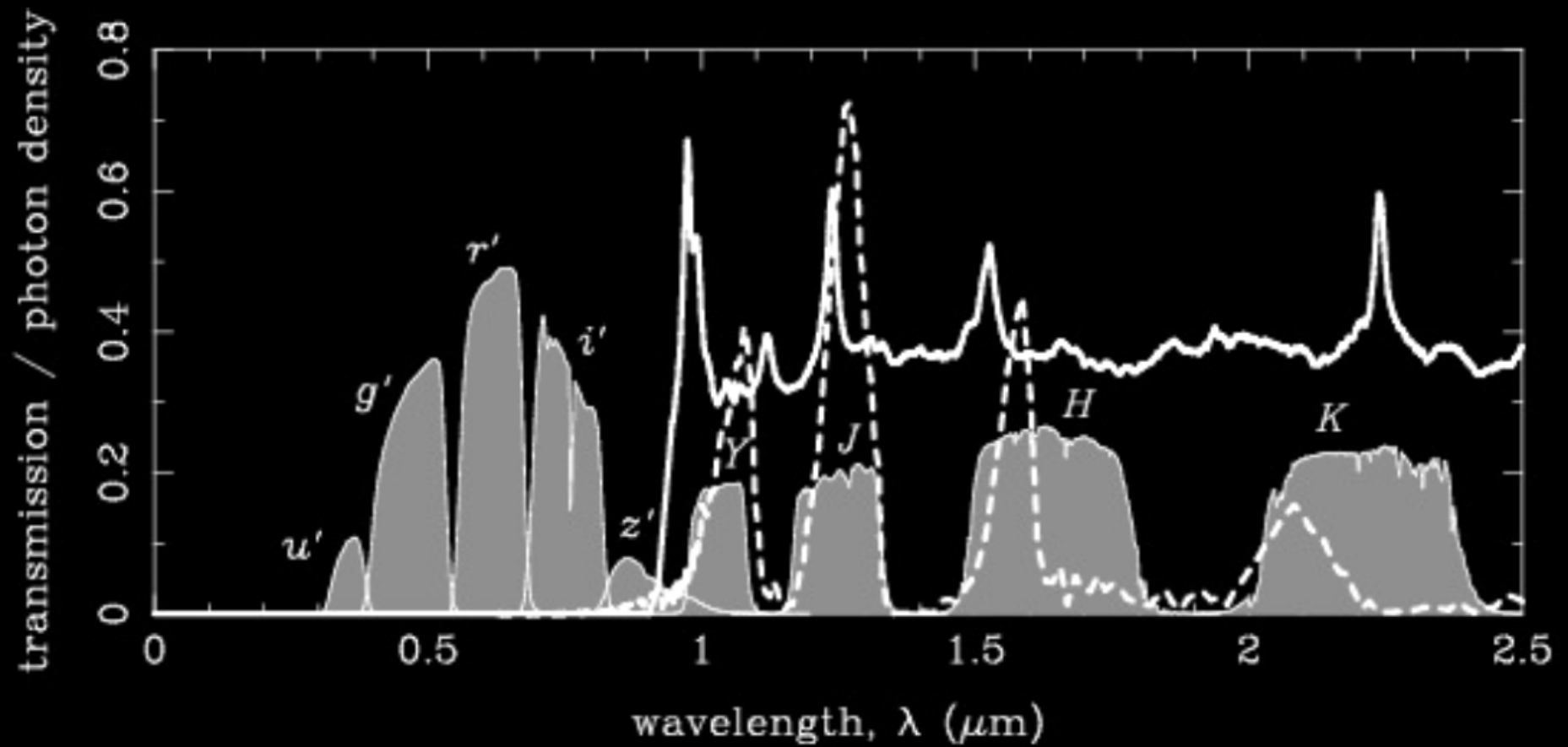
$z=6.5$ is SDSS limit



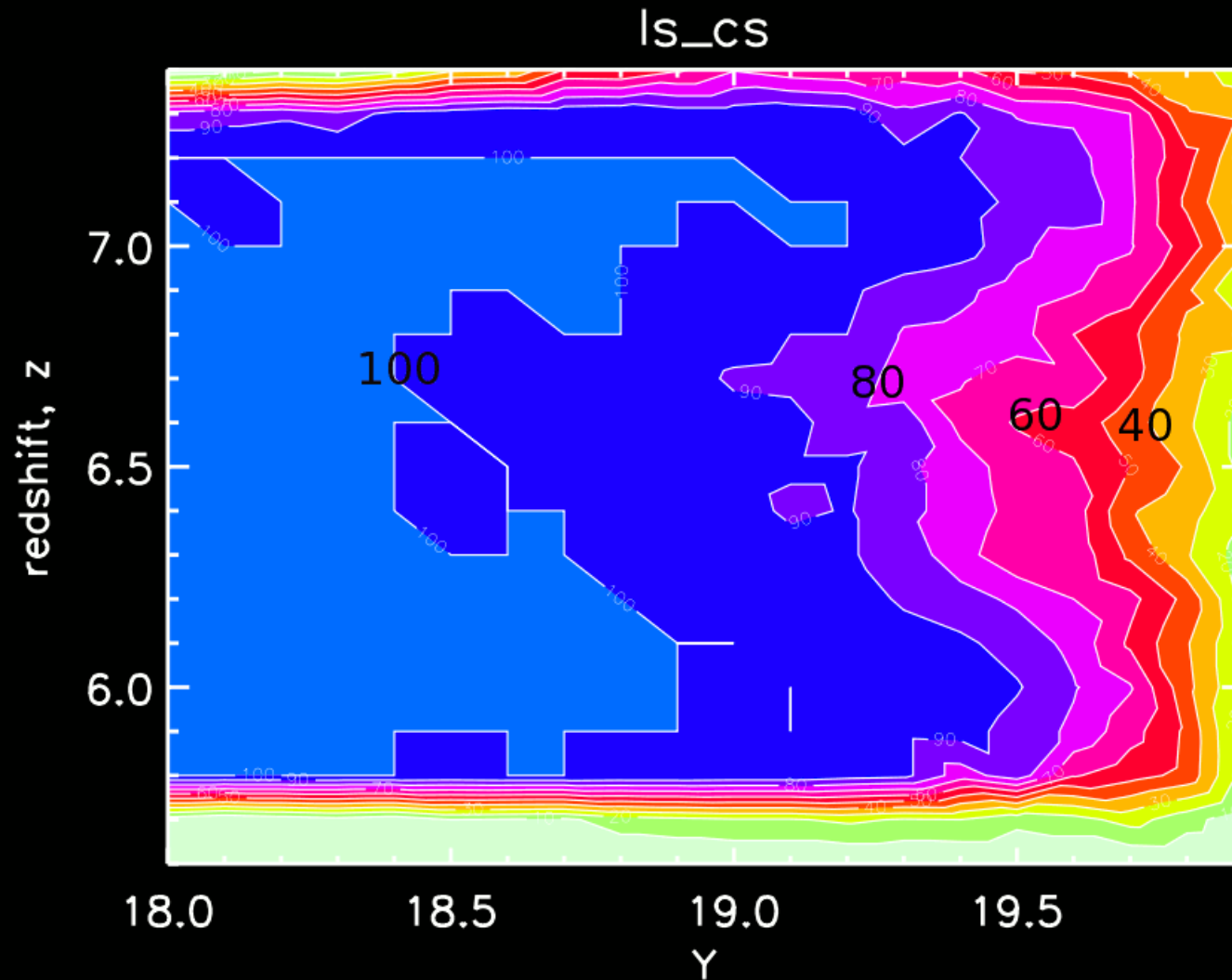
Predicted IGM red damping wing Miralda Escude 1998

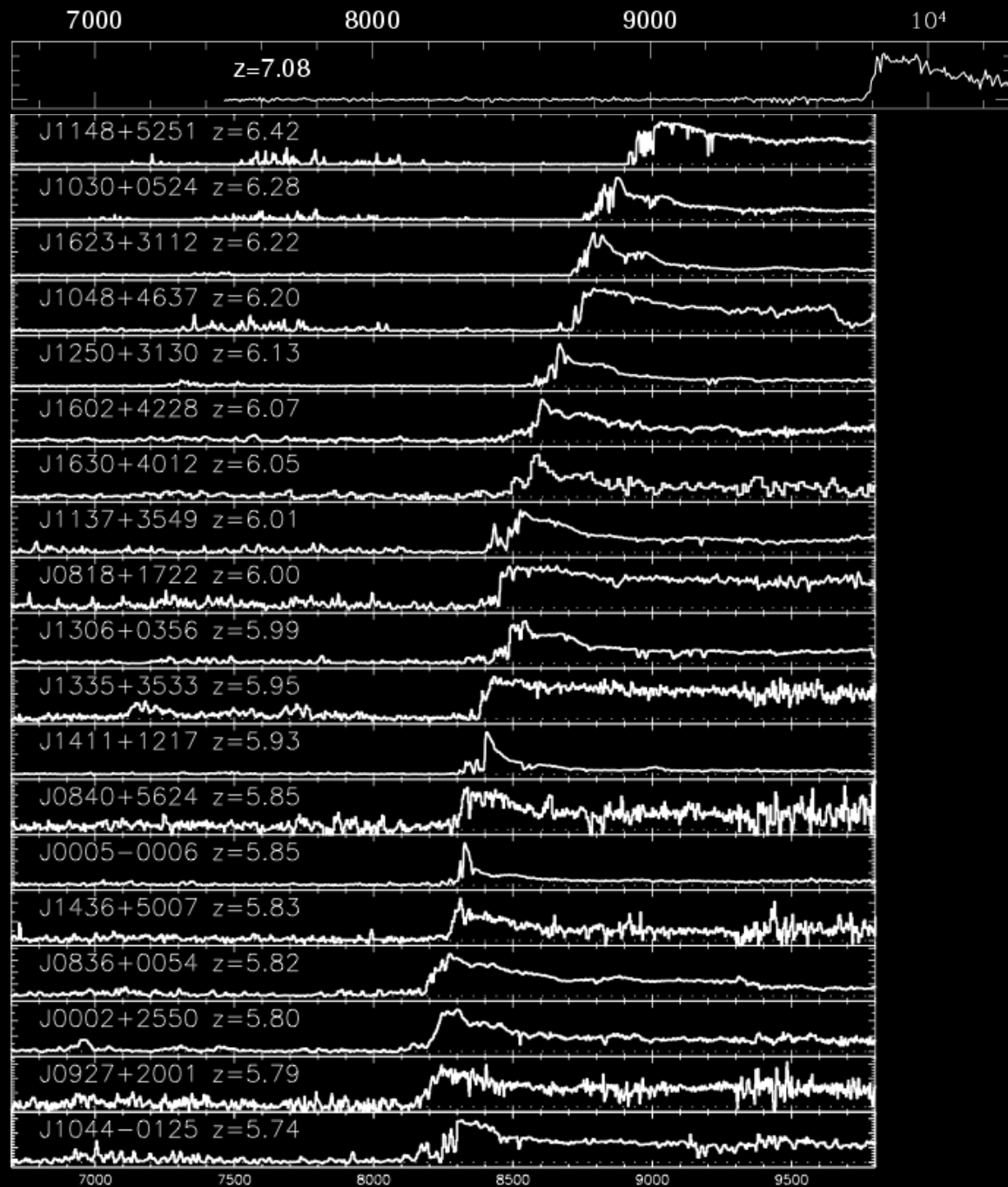


Methods



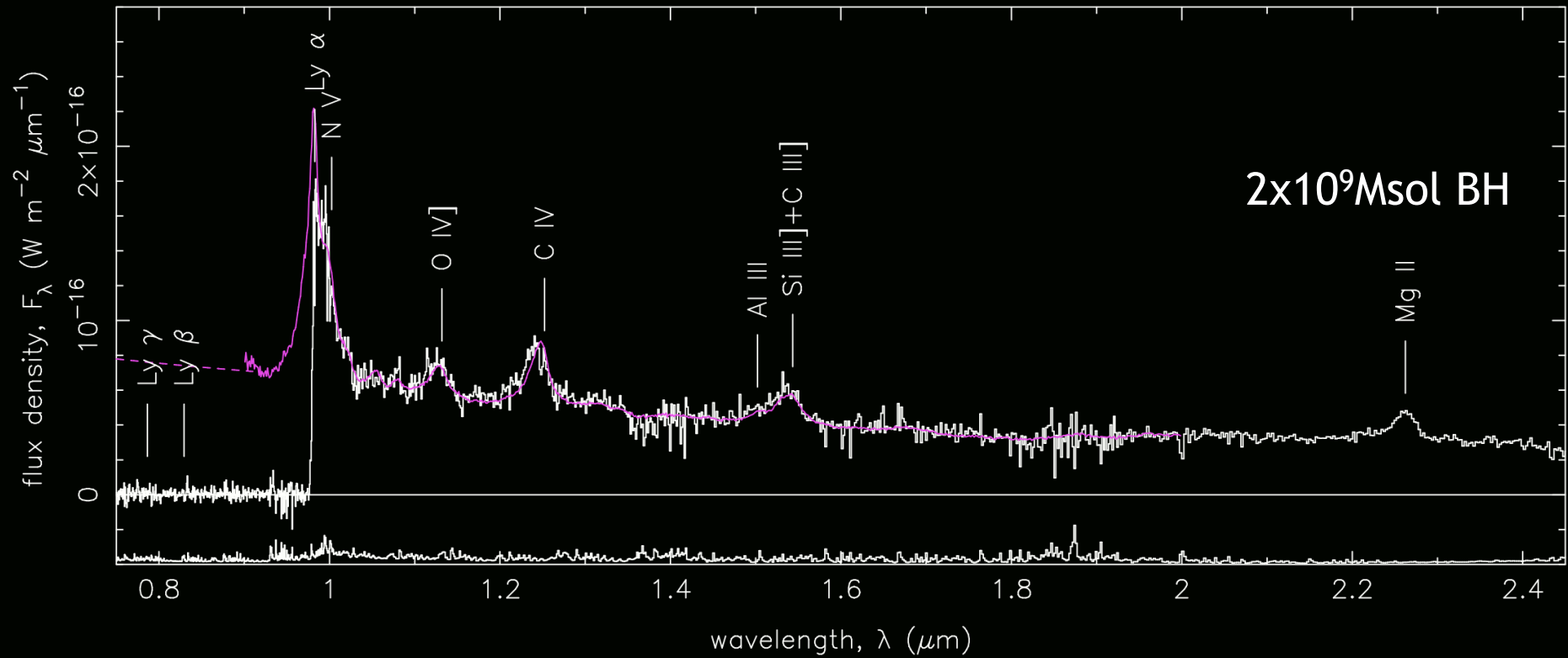
Completeness calculation





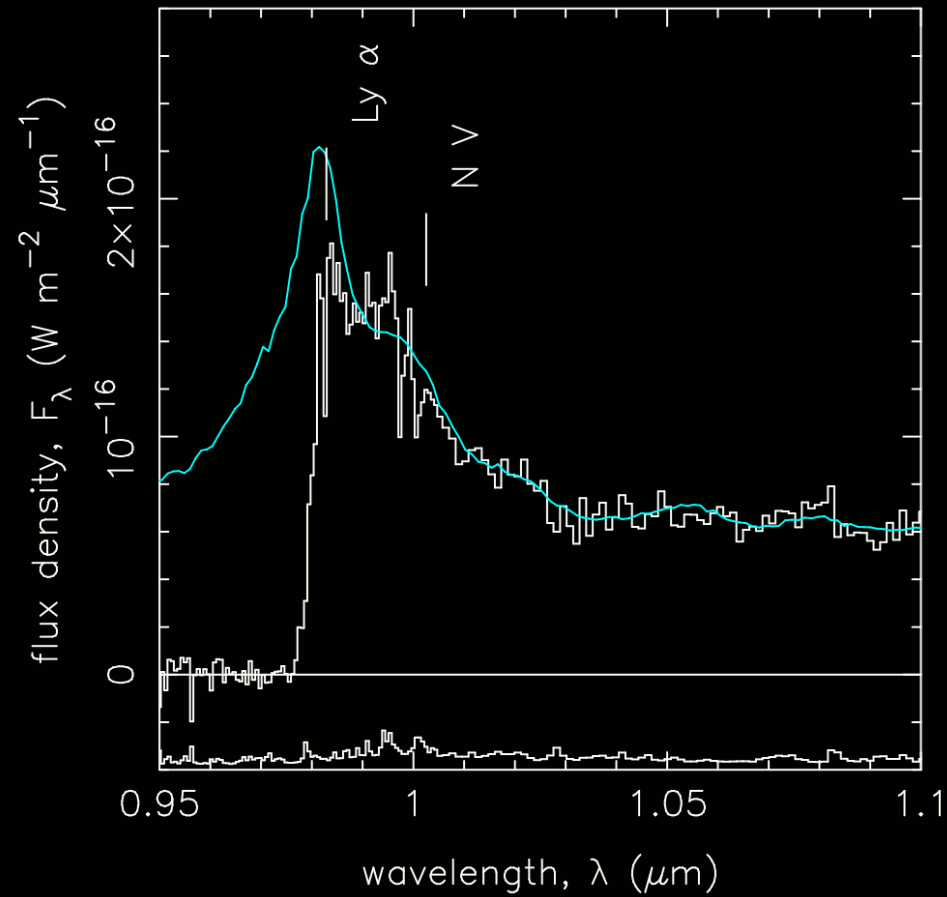
$z=7.085$ from MgII

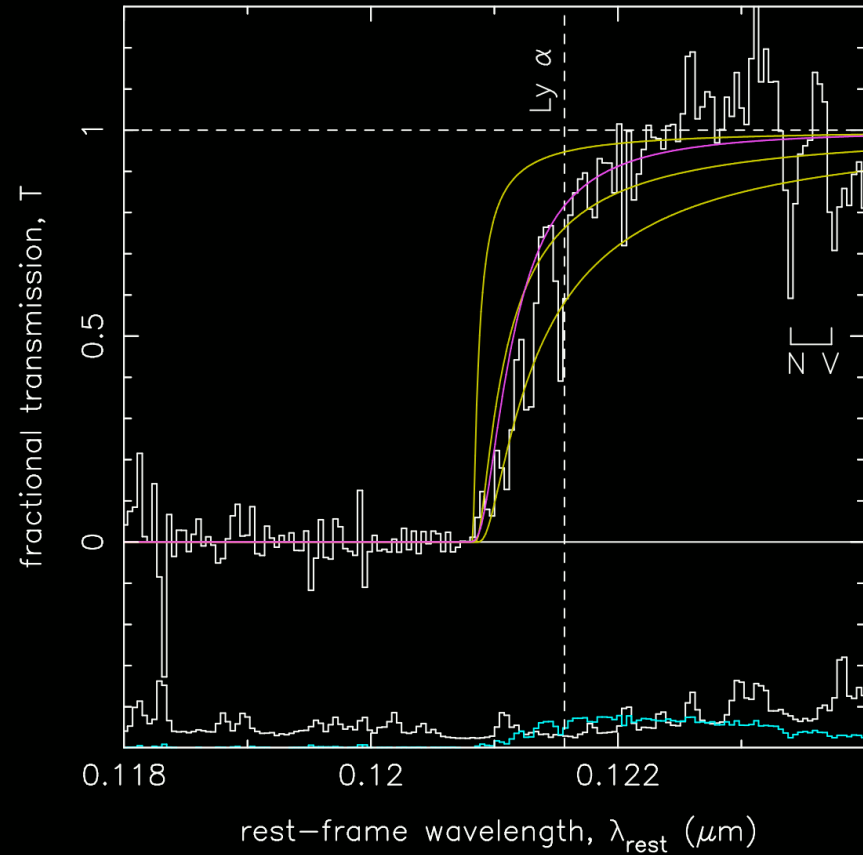
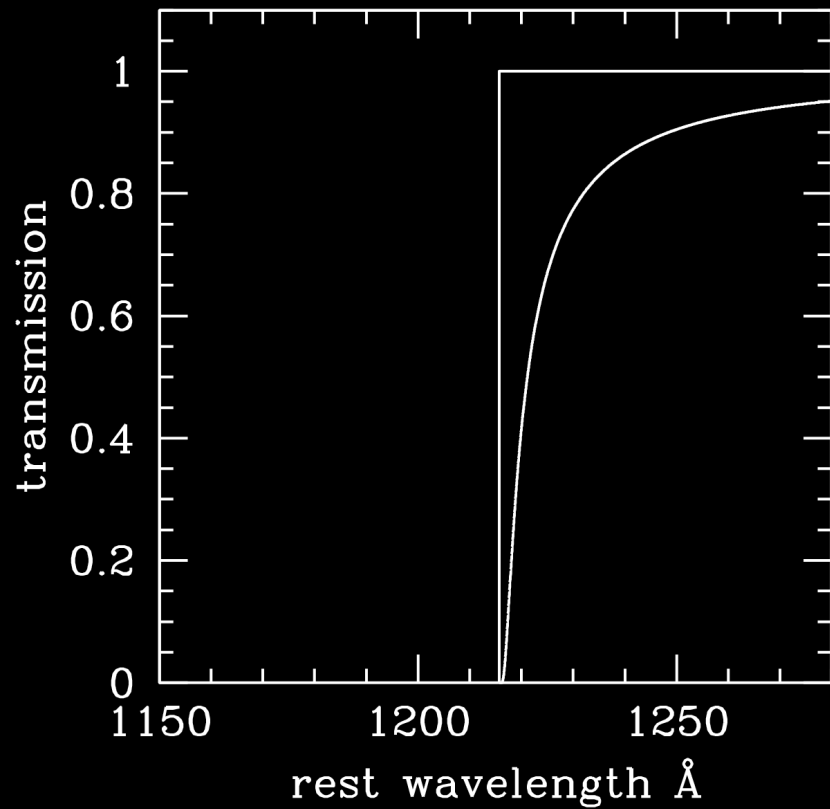
Mortlock et al, 2011 Nature



$z=7.085$ from MgII

Mortlock et al, 2011 Nature





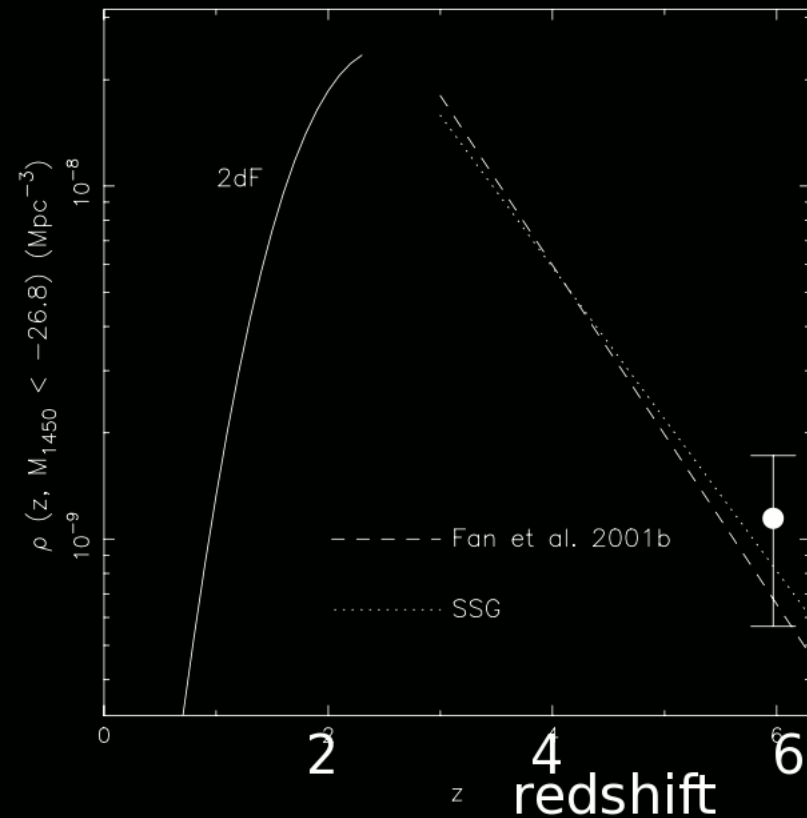
Transmission profile resembles damping wing of the IGM
with neutral fraction $f > 0.1$

Decline in space density $z > 6.4$ from UKIDSS

For Willott et al (2010) LF at $z=6$, $Y < 19.88$, 2200deg^2

Fan et al (2001) decline extrapolated to $z > 6$

$5.8 < z < 6.4$ predict 12.3 quasars, compared to 11 found

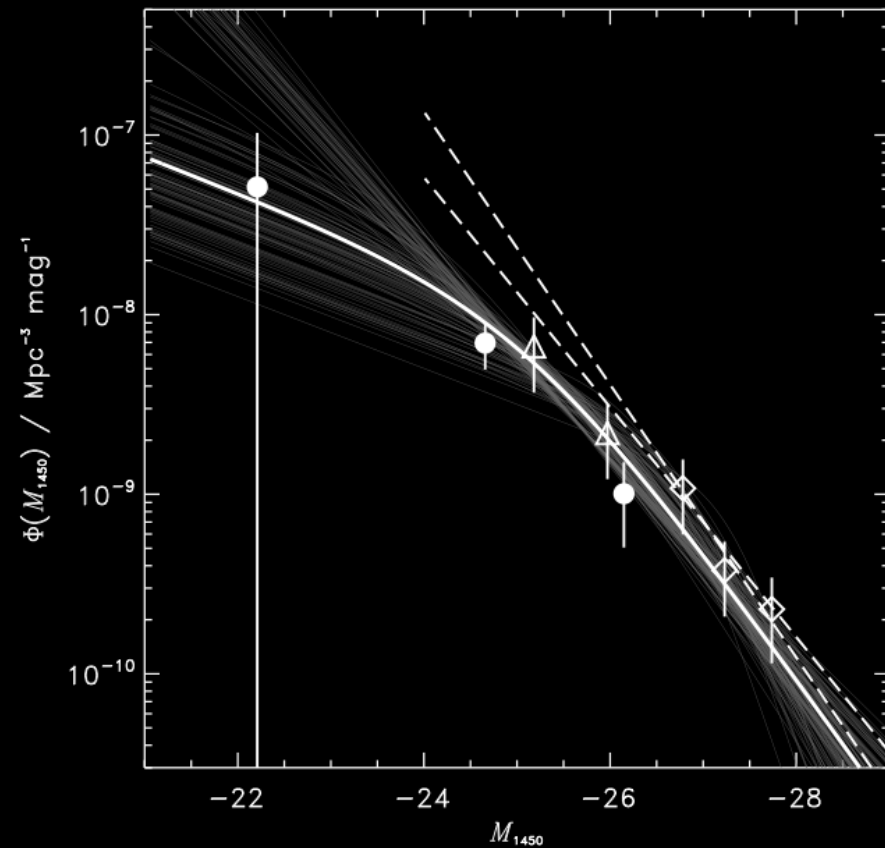


Decline in space density $z > 6.4$ from UKIDSS

For Willott et al (2010) LF at $z=6$, $Y < 19.88$, 2200deg^2

Fan et al (2001) decline extrapolated to $z > 6$

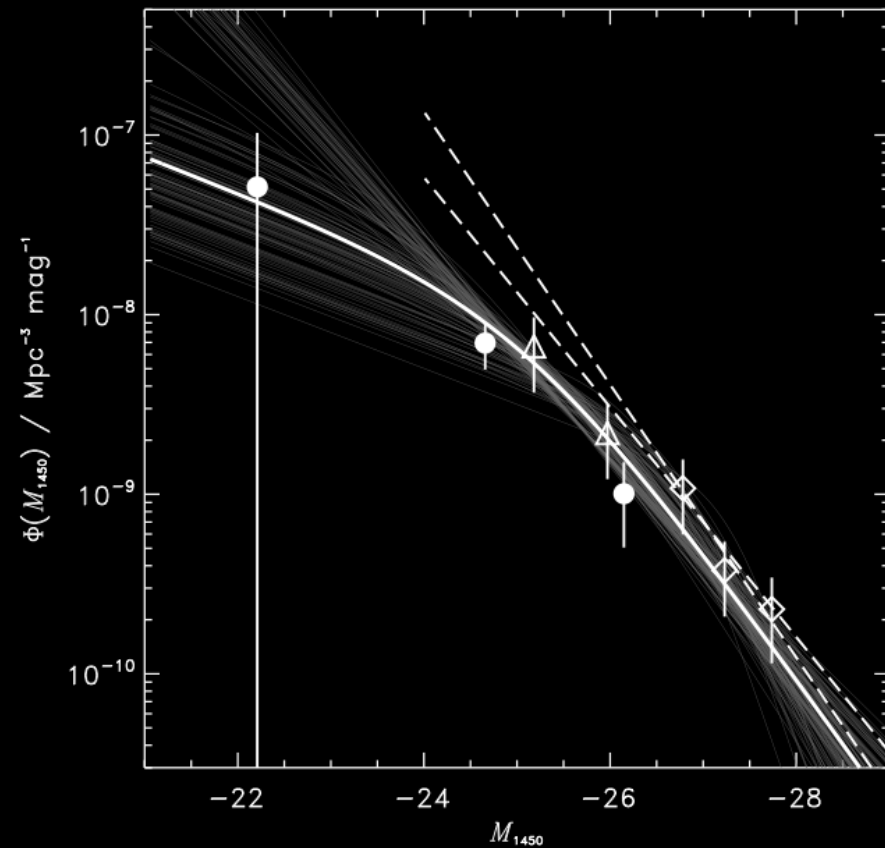
$5.8 < z < 6.4$ predict 12.3 quasars, compared to 11 found



Decline in space density $z > 6.4$ from UKIDSS

$6.4 < z < 7.2$ predict 3.2 quasars compared to 1 found.

For predicted 3.2 quasars probability of detecting 0 or 1 is 16% i.e. no evidence for accelerating decline beyond $z = 6.4$.



Predictions for future surveys $z > 6.4$

Survey	Area	Depth Y (Vega)	Number	complete
UKIDSS	3800	19.6	6	2012
VIKING	1000	20.8	9	2015
PanSTARRS 10 sigma	20000	19.6	33	2015

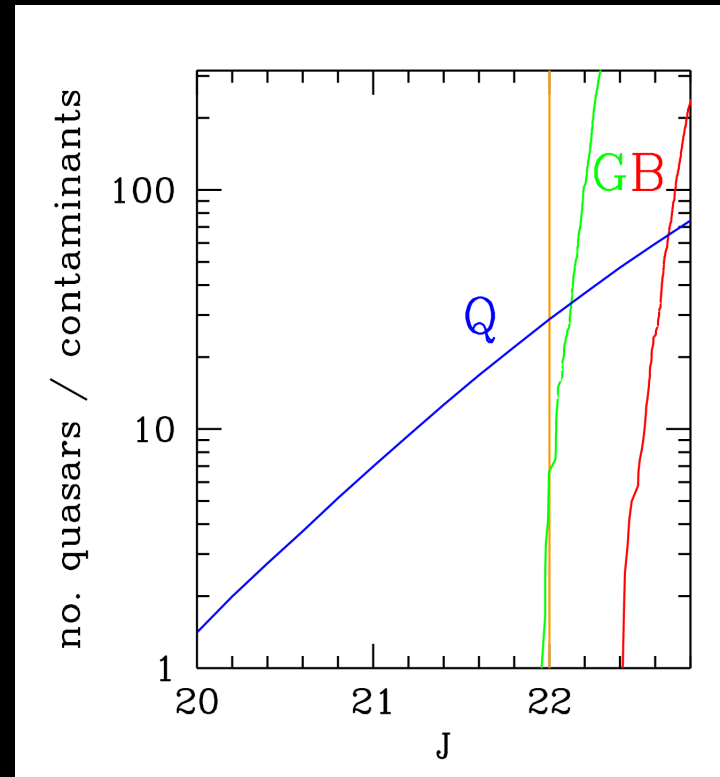
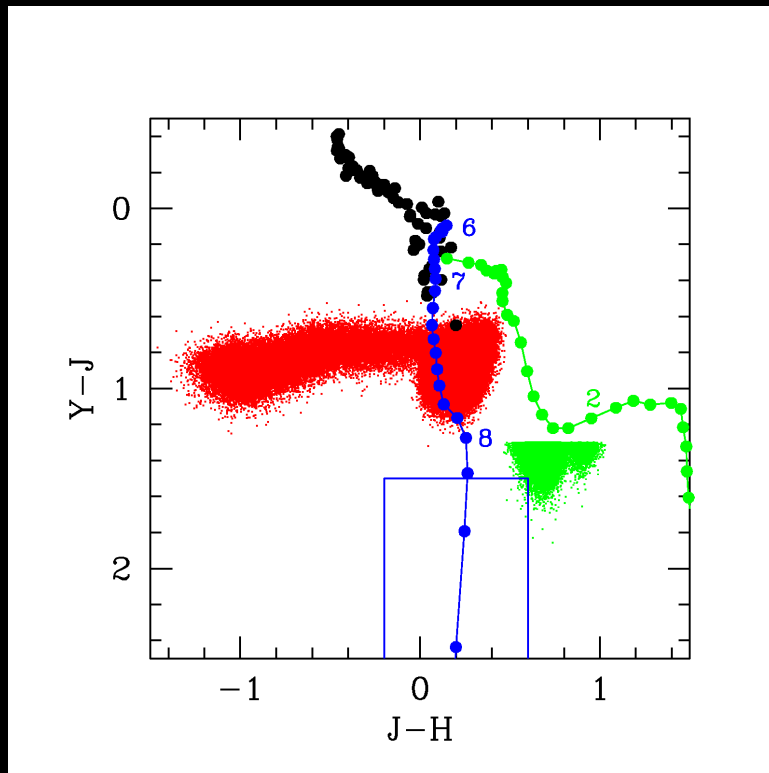
Summary of UKIDSS results

- Probable detection of the red damping wing of the IGM in $z=7.08$ quasar: the first quasar in the epoch of reionisation. But note that reionisation is predicted to be very inhomogeneous
- Detection of $2 \times 10^9 M_{\text{sol}}$ BH at $z=7.08$: problem of formation
- Decline in space density of quasars $3 < z < 6$ continues to $z=7$, with no strong evidence yet of acceleration

The scope of the Euclid surveys

- Wide survey $15,000 \text{ deg}^2$ $YJH_{AB}=24$ would take 680 years with VISTA or 66 years with SASIR (2017)
- Deep survey 40 deg^2 $YJH_{AB}=26$ would take 72 years with VISTA or 7 years with SASIR
- The Euclid surveys are >100 times more ambitious than anything underway and at least >10 times more ambitious than anything else currently conceived

Bright quasars $z > 8$ $J < 22$ from Euclid imaging



Euclid will find 30 $z > 8.1$ quasars $J < 22$ and 55 quasars $J < 22.5$