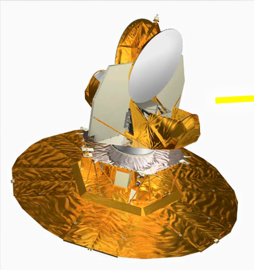
Nial Tanvir
University of Leicester

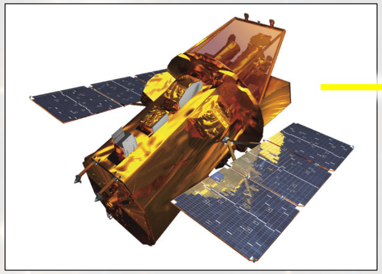
High redshift gamma-ray bursts

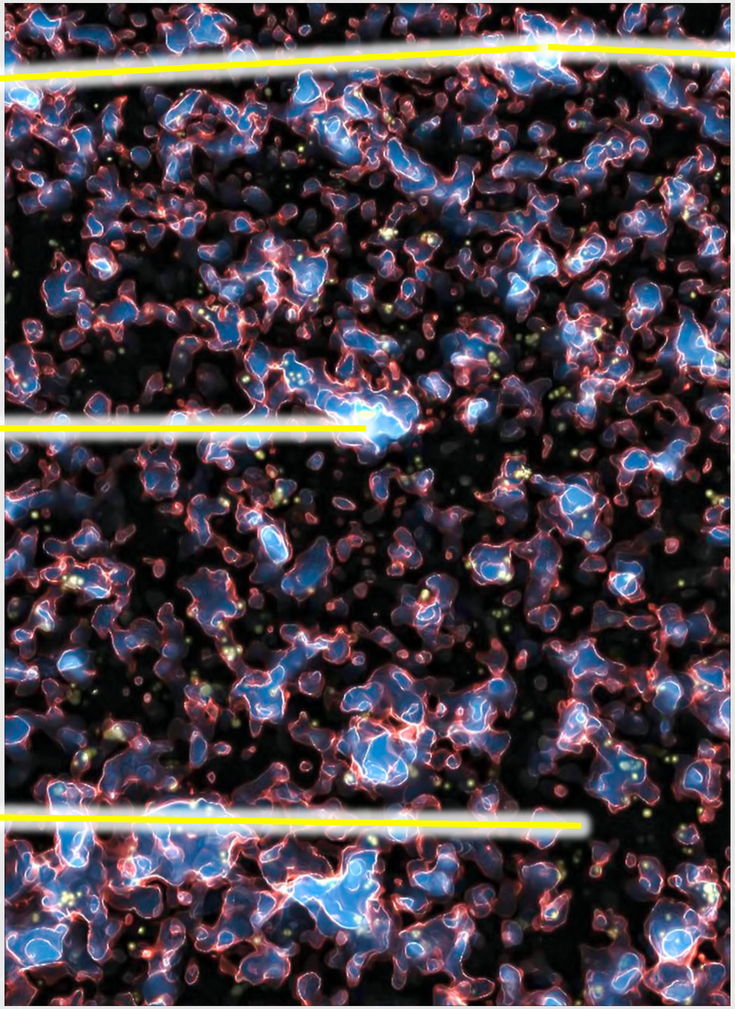
Annapolis November 2010


z=12.8

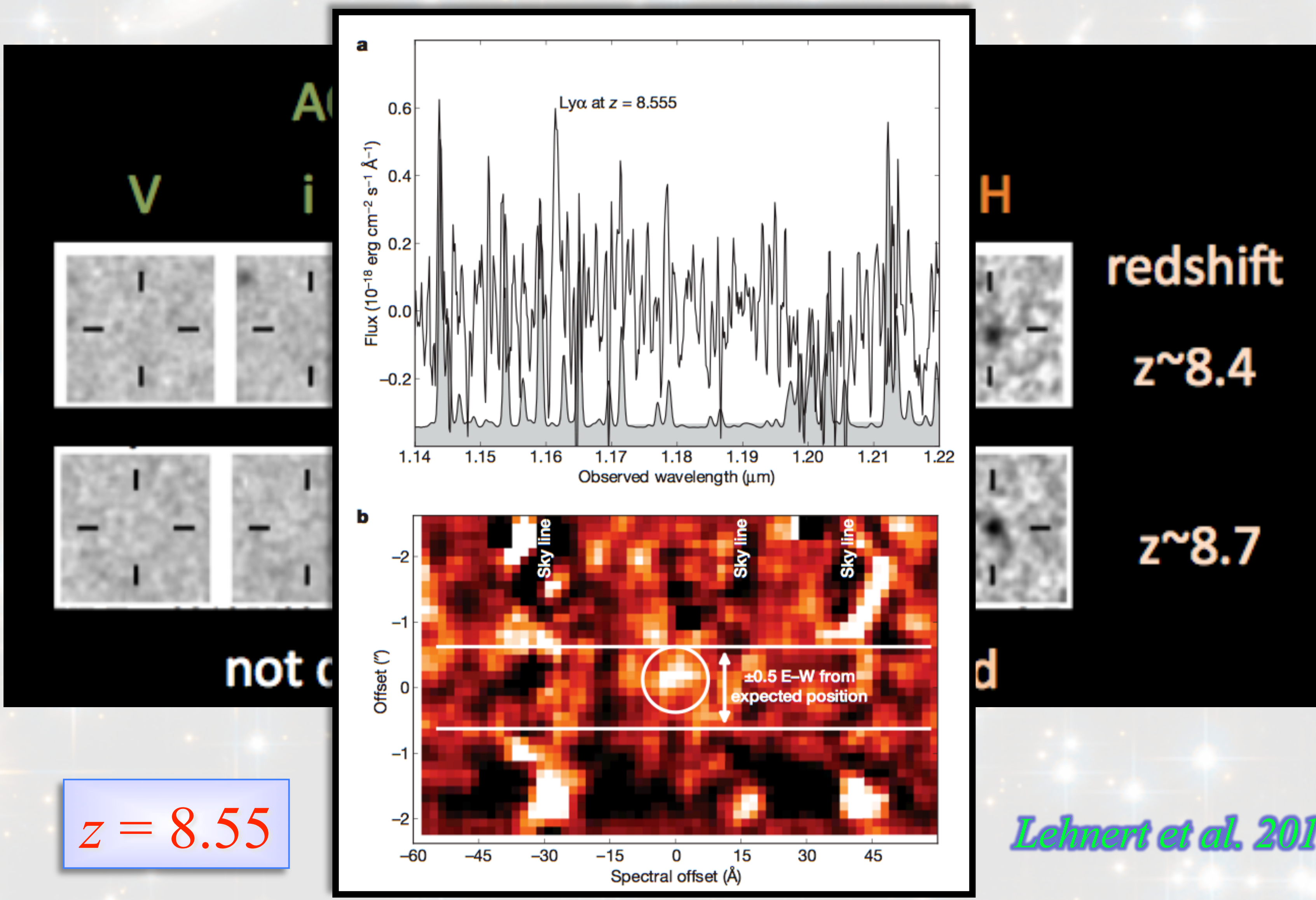
Reionization era – what's all the fuss about?







Direct detection of stars and galaxies at z>7 is tough!



$z = 8.55$

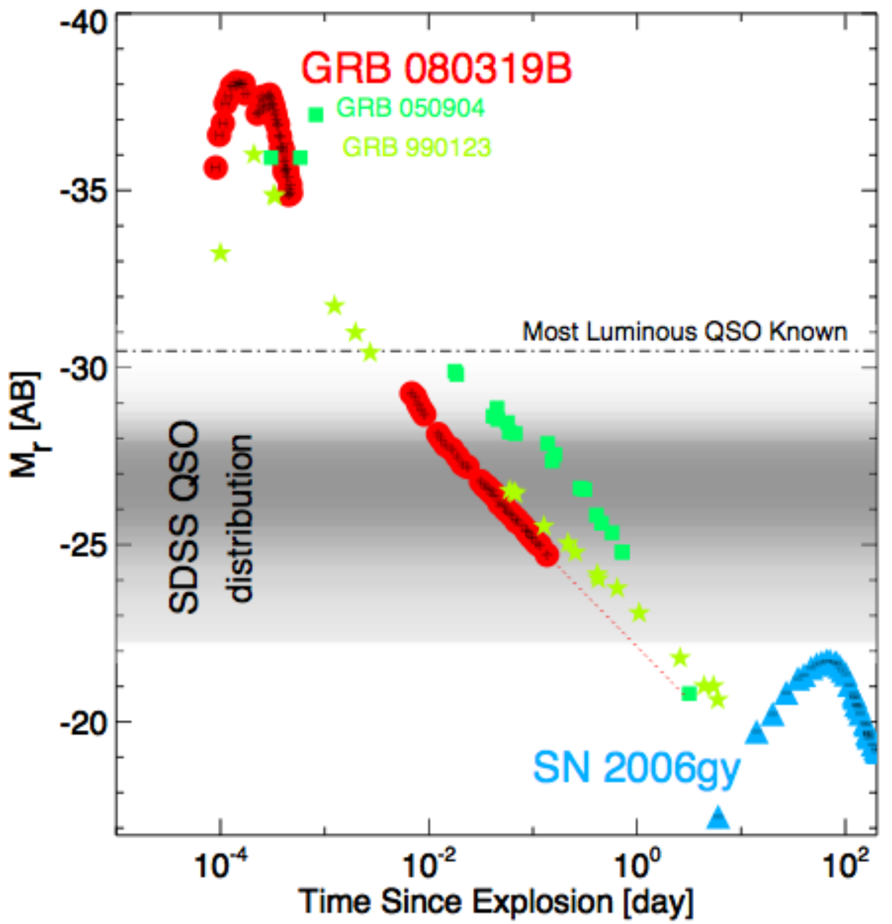
Lehnert et al. 2010

GRBs as probes of the high-z Universe

- Extremely bright and visible into the era of reionization.
- Afterglows pinpoint their hosts - may provide redshifts from Lyman-alpha break and other absorption lines, chemical enrichment, dust, molecules etc. irrespective of galaxy luminosity.
- Provide backlight for measuring neutral fraction in IGM.
- Trace (pop I/II/III ?) massive star formation.

All the above are difficult to achieve with other methods of exploring high-z galaxies and the IGM.

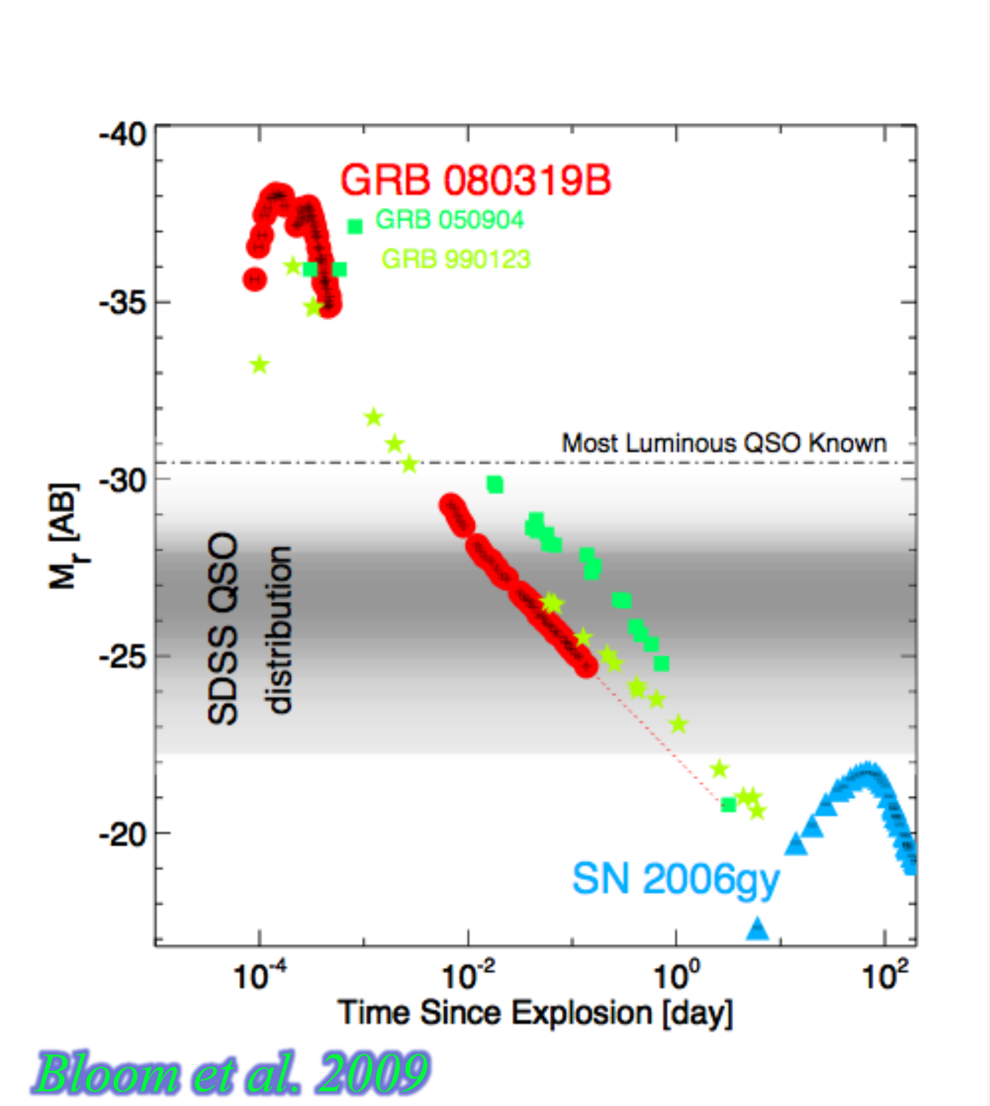
GRBs: can be very bright!



Bloom et al. 2009

Reached visual magnitude 5.3, at redshift 0.94! (Racusin et al. 2008)

GRBs: can be very bright!



Bloom et al. 2009

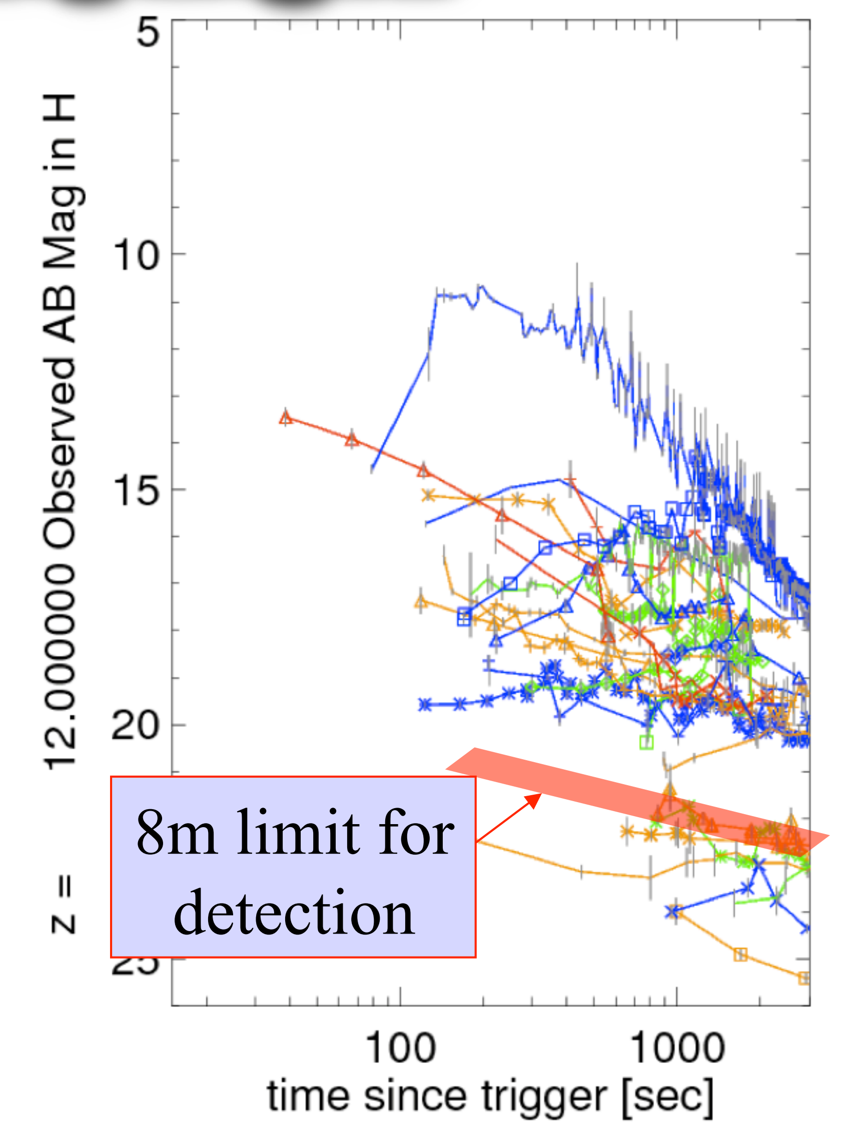


Figure from Grindlay et al. 2010

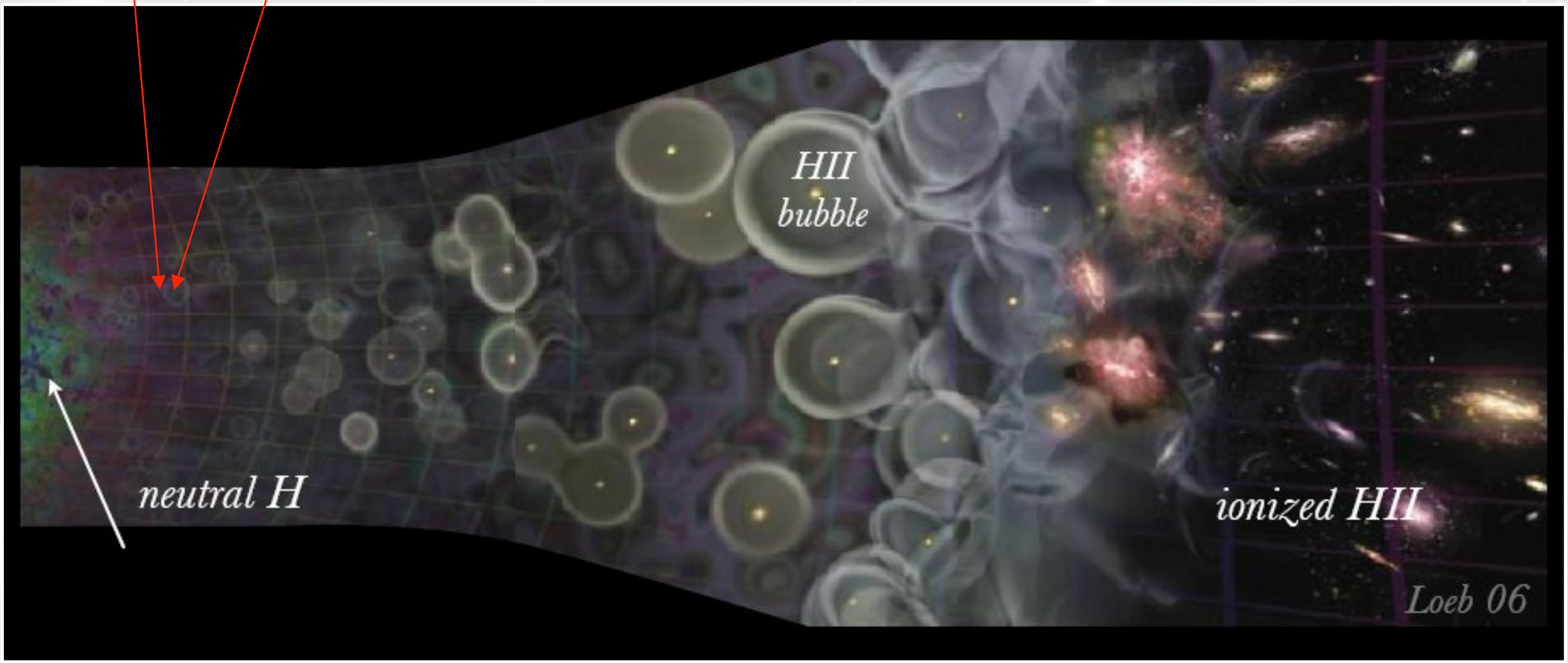
GRBs: occurred early

See later talk by Yudai Suwa

Pop III collapsars?

Pop II GRBs

We know GRBs can be formed at low metallicities, so much of the early star formation very likely gave rise to GRBs (just as bright as those we see at low redshift).



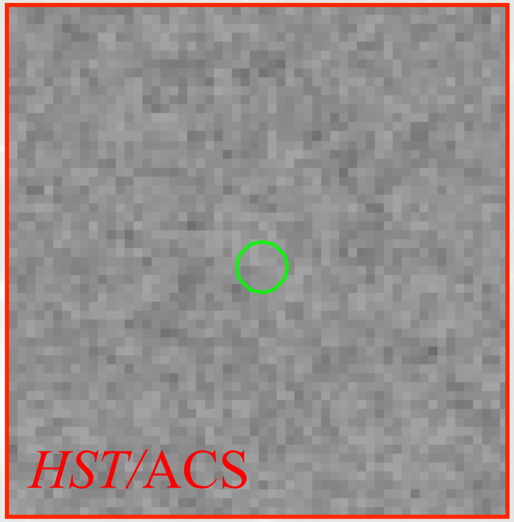
GRBs: powerful probes of host galaxies

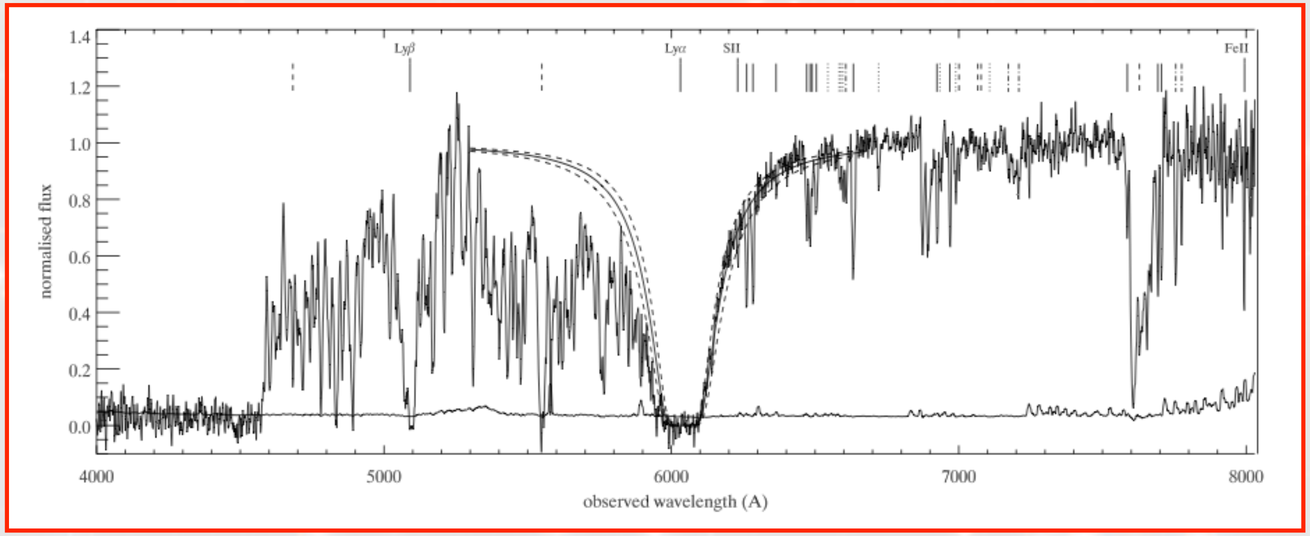
GRBs select high-z galaxies *independently of host galaxy luminosity*.

Afterglow spectroscopy can give *redshift, chemical abundances, dust, molecular content, dynamics*.

See also talk by Dieter Hartmann

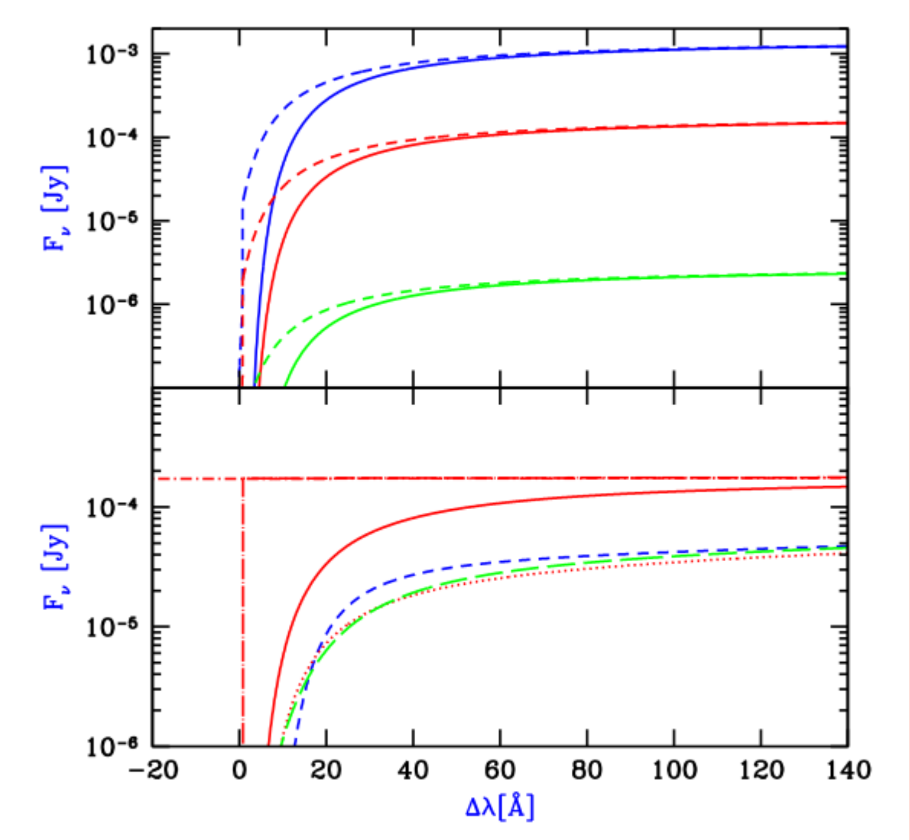
E.g. GRB 050730: faint host (R>28.5; Levan et al. in prep.), h
z=3.97, [Fe/H]=-2 and low dust, from afterglow spectrum (Chen et al. 2005; Starling et al. 2005).





GRBs: powerful probes of IGM

Red damping wing of Ly-alpha measures IGM neutral fraction.



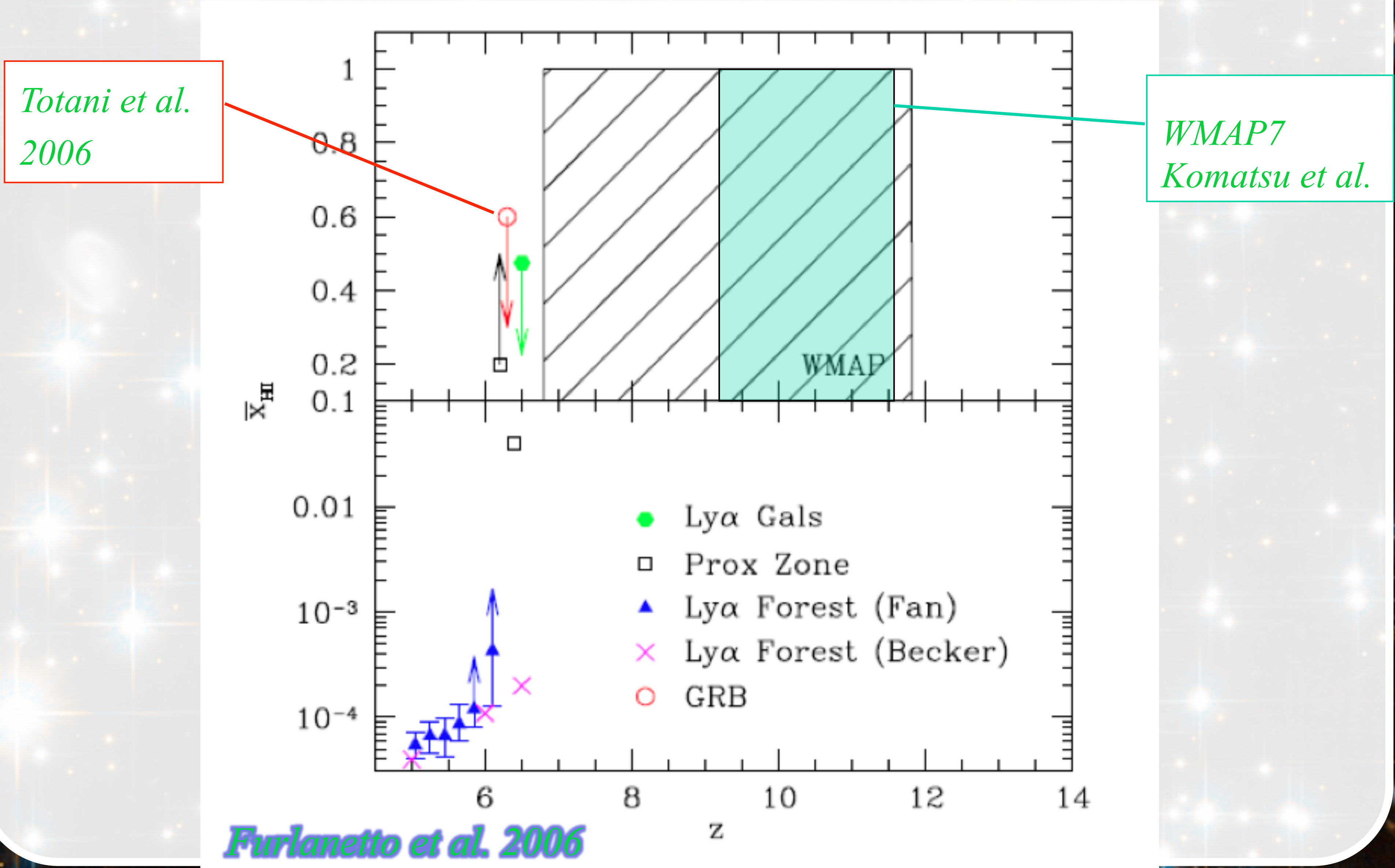
In practice very good S/N required to disentangle host absorption and effects of local ionized bubble.

Also many sight-lines required to map environment-dependent progress of reionization.

Barkana & Loeb 2004, see also McQuinn et al. 2008.

GRB 050904

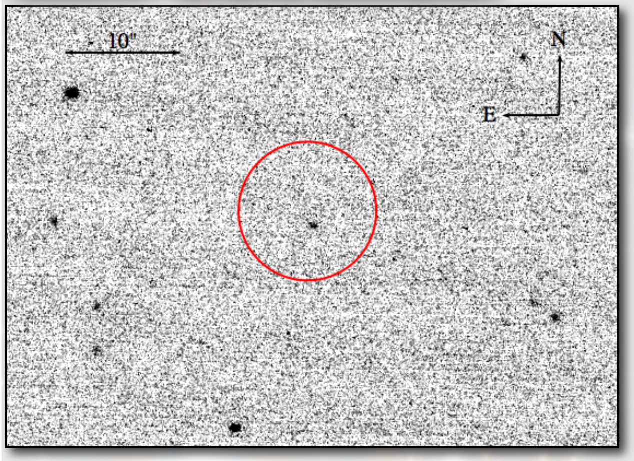
First z>6 GRB (Haislip et al. 2006; Kawai et al. 2006)



GRBs: but it ain't easy!

- You need to be prepared to do rapid optical/IR followup a lot of bursts with big glass.
- Red afterglows could be Lyman-alpha break, or could be dust.

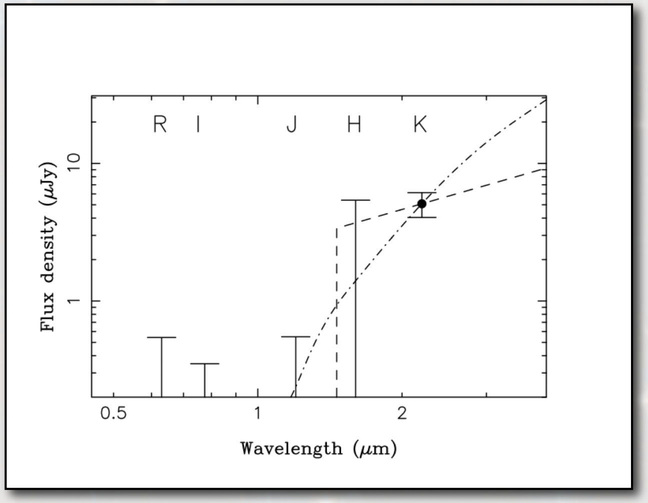
GRB 060923A



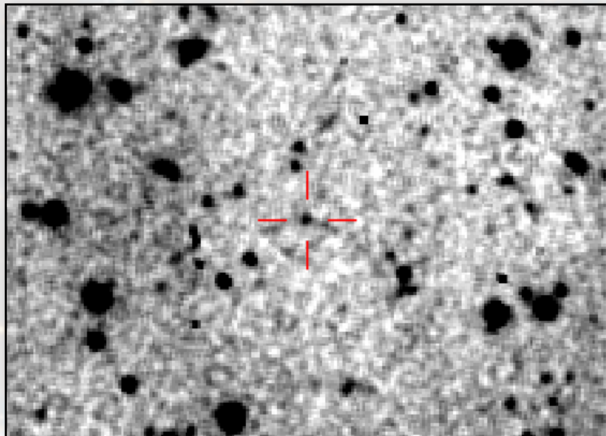
Only seen in K-band at UKIRT (T+

See talk Thursday by Dan Perley

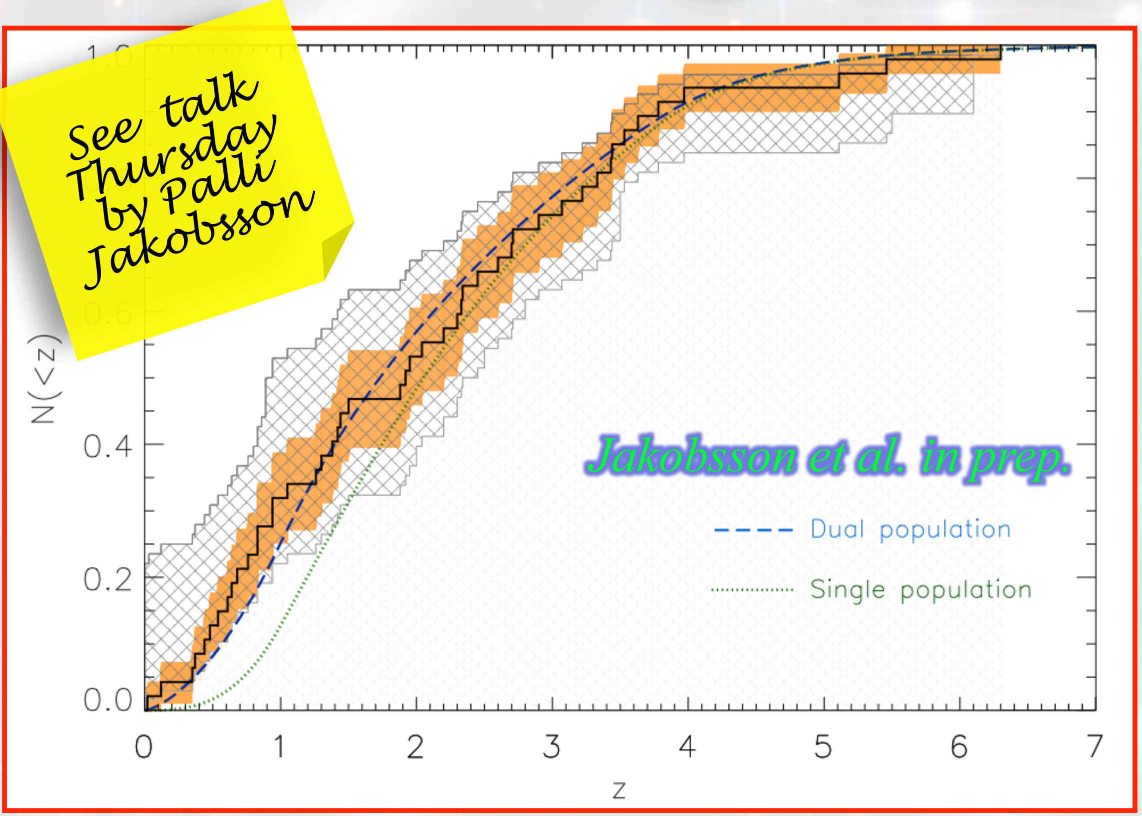
H-band dropout.
Very high-z?



Host seen in deep R-band image

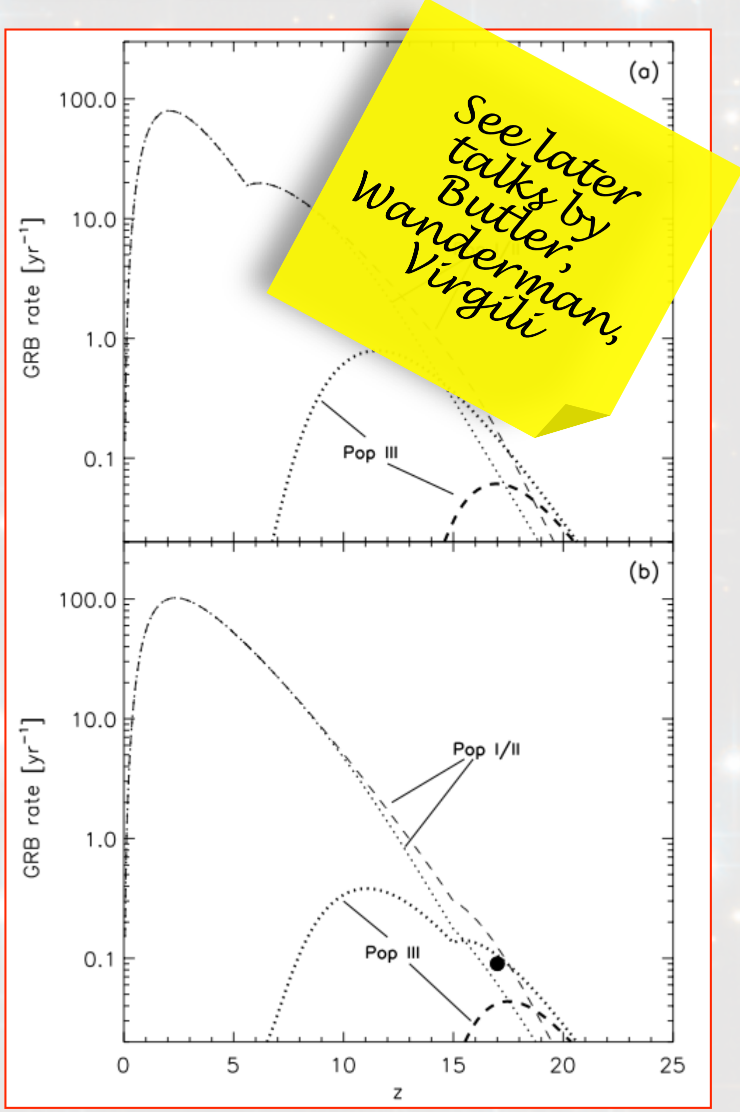


GRBs: High-z GRBs are rare



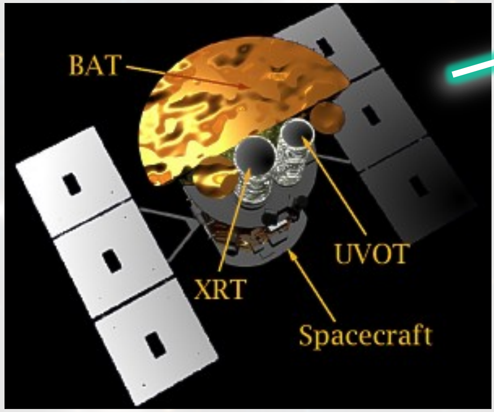
< 3% of Swift bursts are at z >7.

Most optically "dark" bursts are dusty.

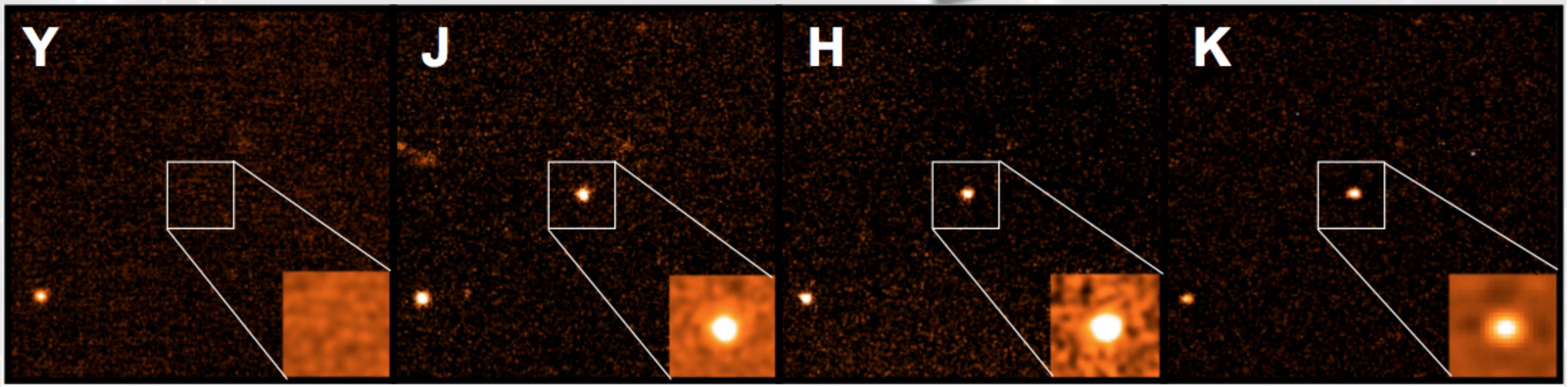


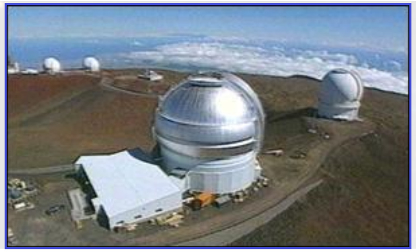
Bromm & Loeb 2006

GRB 090423



NB. We don't get much clue from early Swift data which are going to be the high redshift bursts!

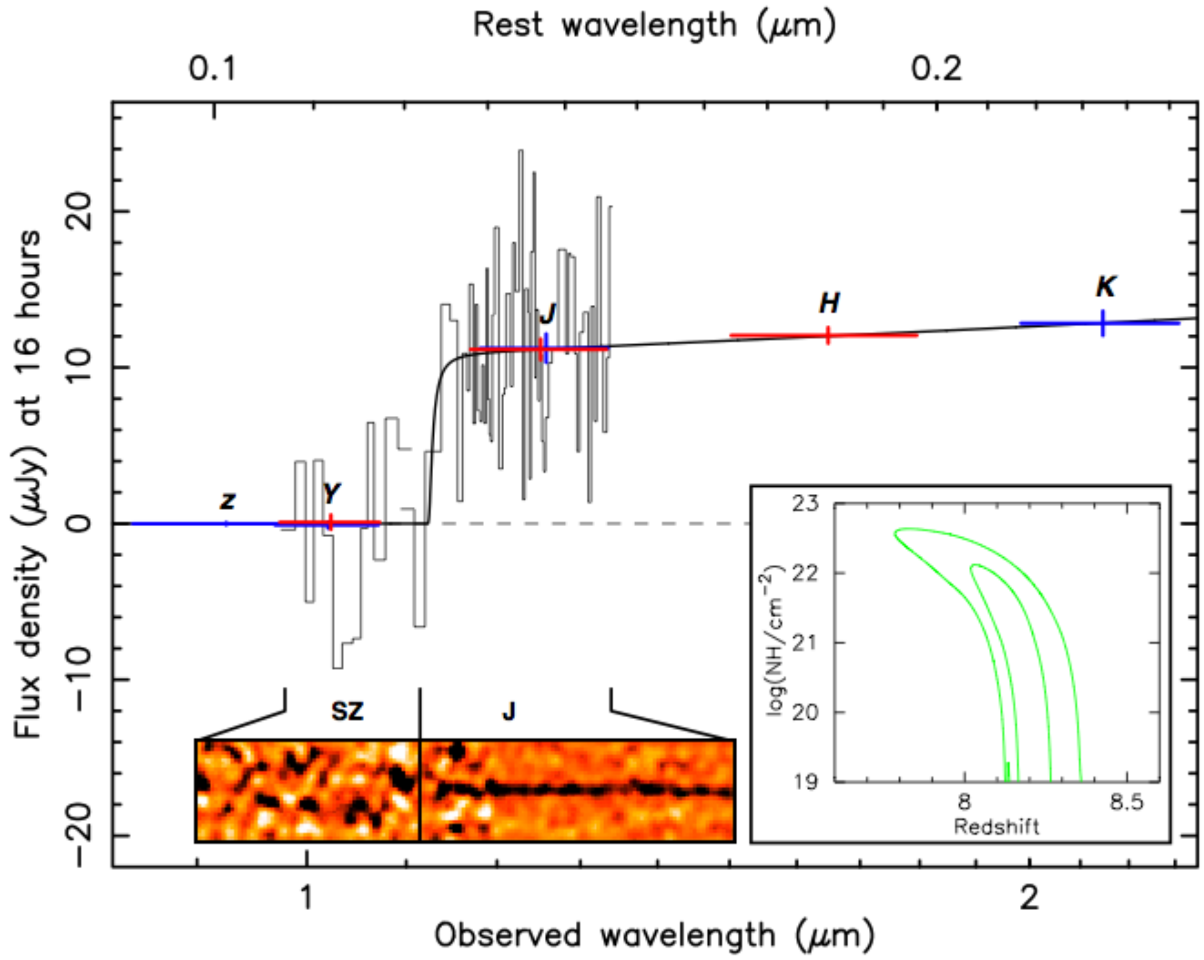




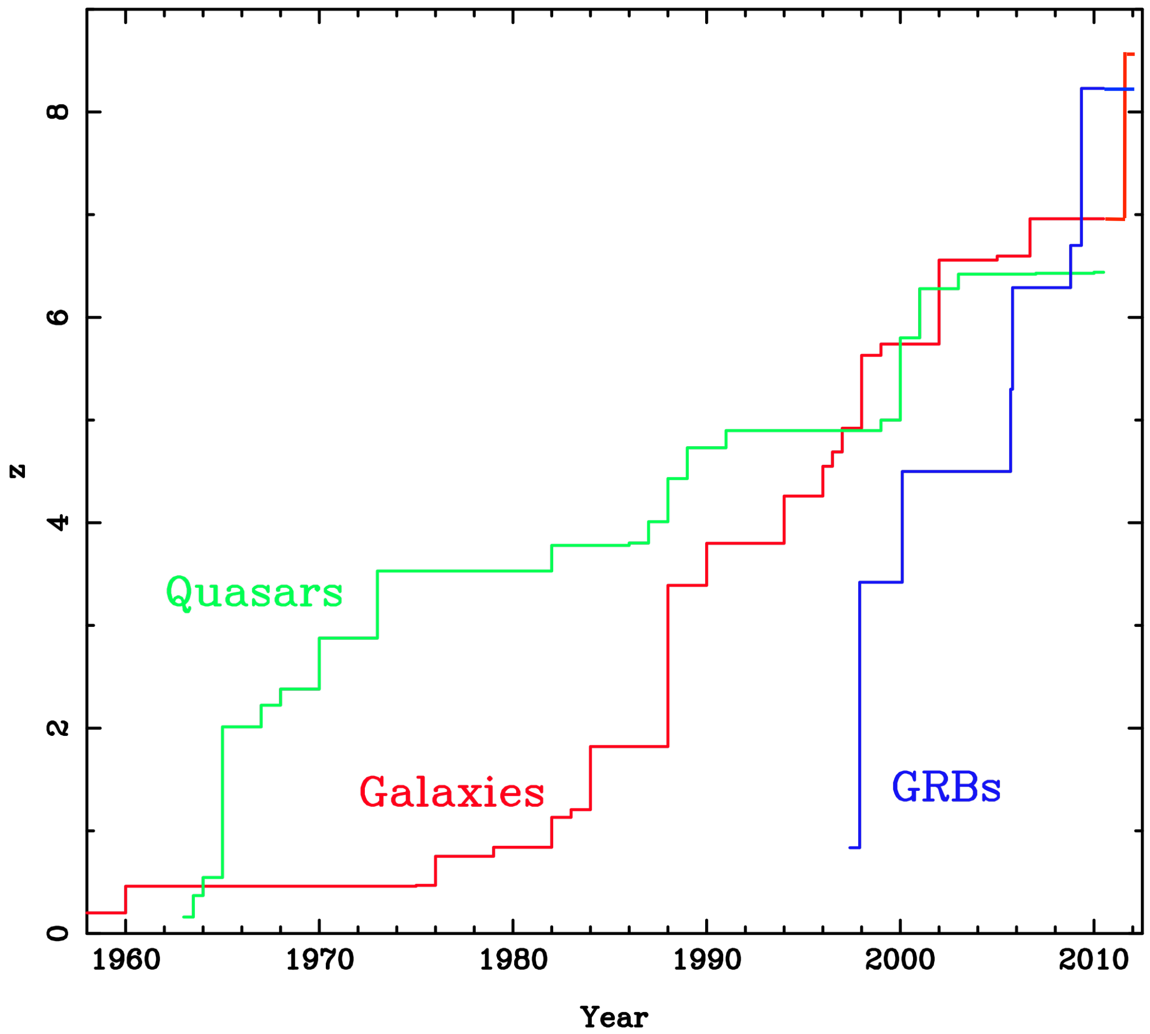
GRB 090423

$z = 8.23 \pm 0.08$

Power law continuum ⇒ photo-z robust

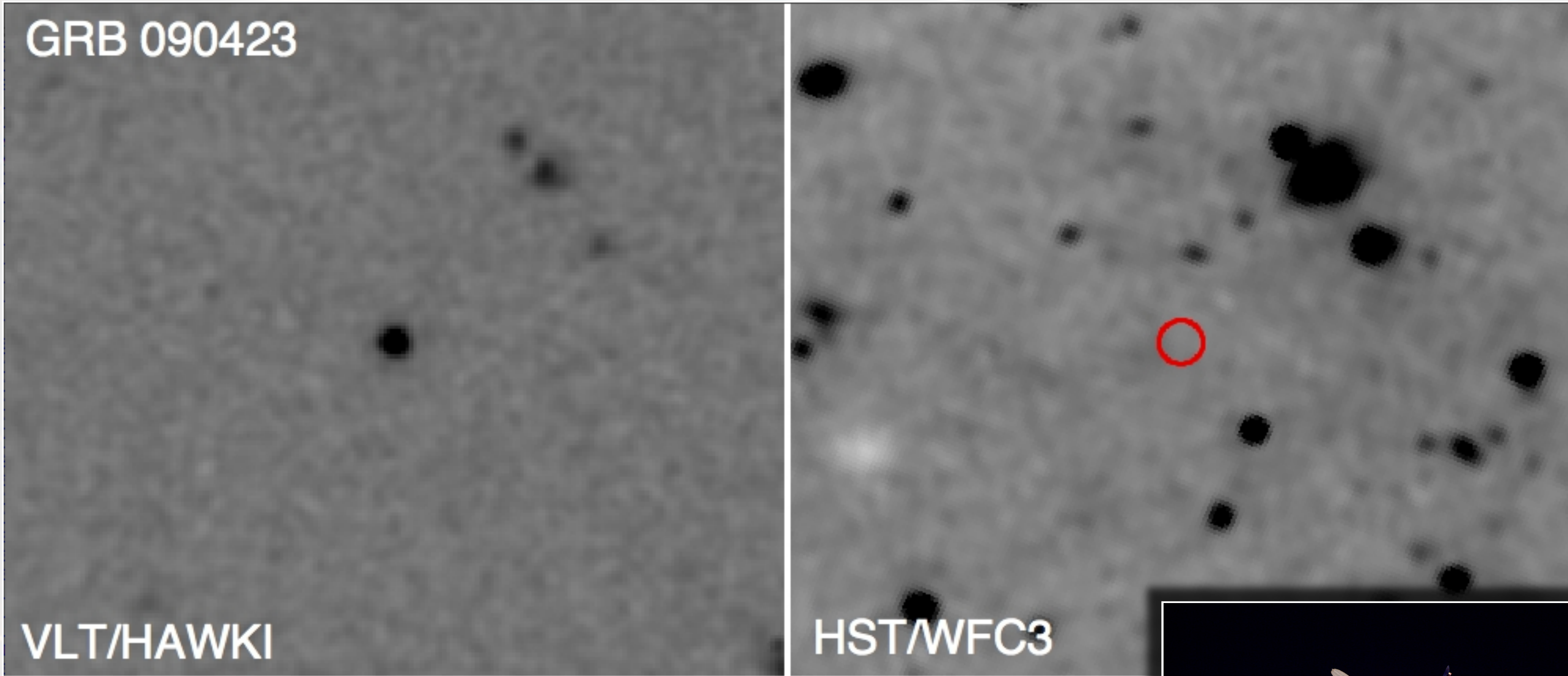


NT et al. 2009, see also Salvaterra et al. 2009.



Quasars
Galaxies
GRBs
z
0
2
4
6
8
1960
1970
1980
1990
2000
2010
Year

GRB 090423: host and environment

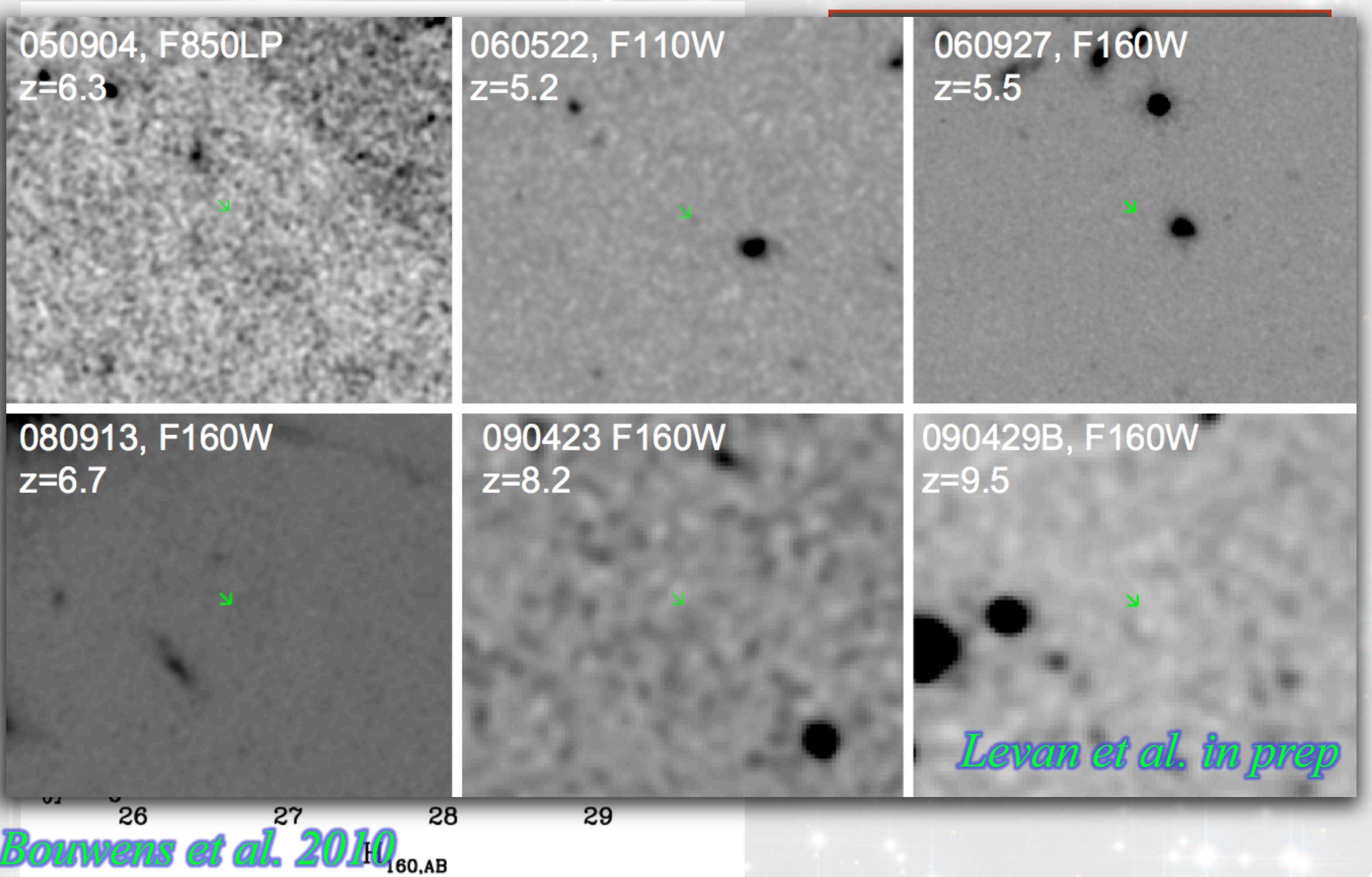


20 orbits of HST WFC3/IR imaging

Limiting magnitudes J(AB) > 28.2; H(AB) > 28.3

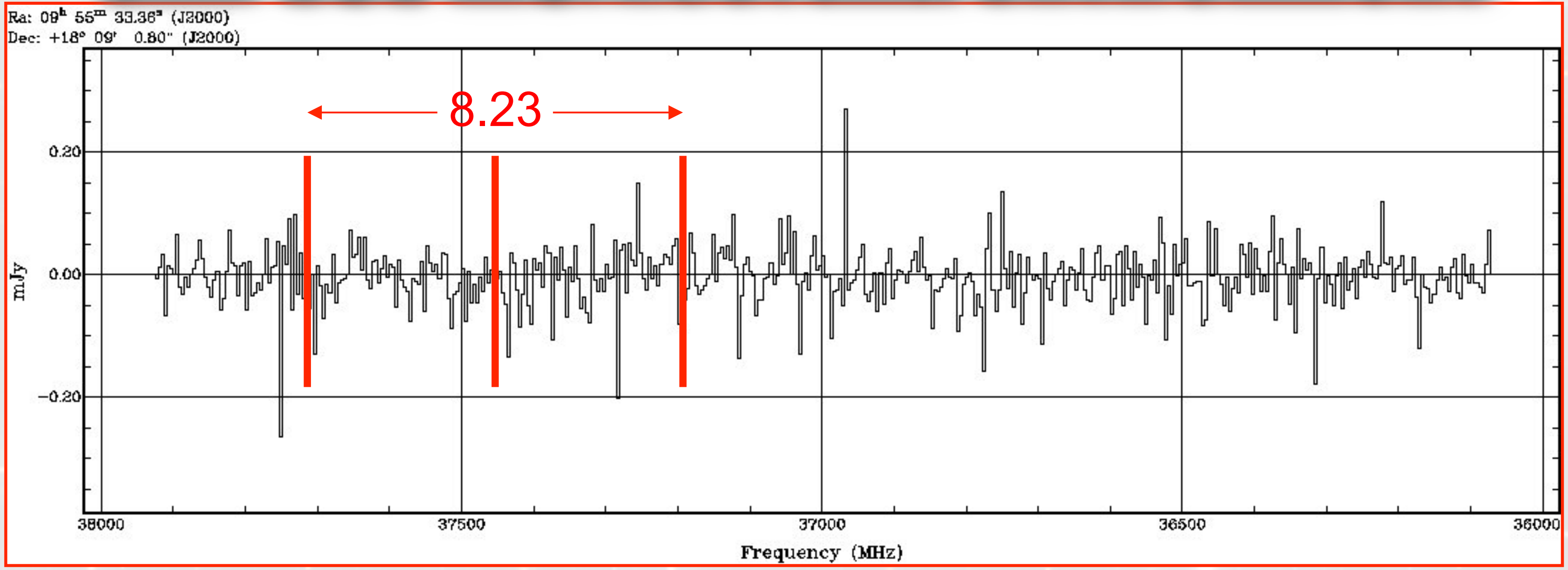
Levan et al. in prep.

Comparison to other populations



Bouwens et al. 2010

GRB 090423: host and environment



ATCA observations

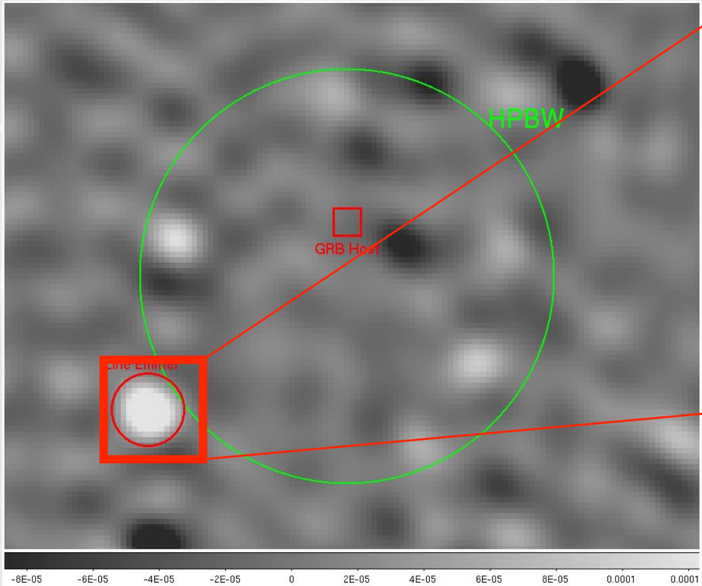
- Sensitive to the CO(3-2) transition at 38 GHz
- 35 hours of observations (25hrs on source)
- 55 μJy RMS in 30 km/s channels, 4 GHz bandwidth

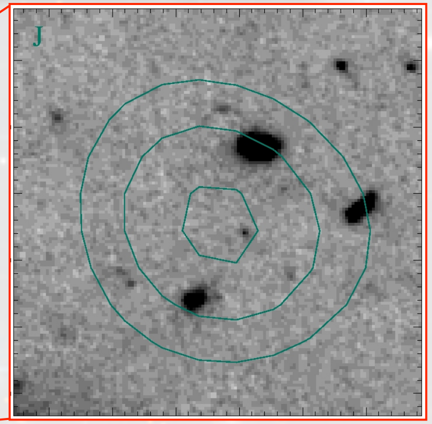
⇒ No line detection -- $M(H_2) < 4.3 \times 10^9\ M_{sun}$

Stanway et al. in press.

GRB 090423: host and environment

- One line emitting source found in data cube.
- 45 arcsec from GRB (~2 Mpc co-moving at z=8)
- Interpretation unclear - low-z contaminant? (~1/20 random chance)





Several galaxies in HST image.

Could be:

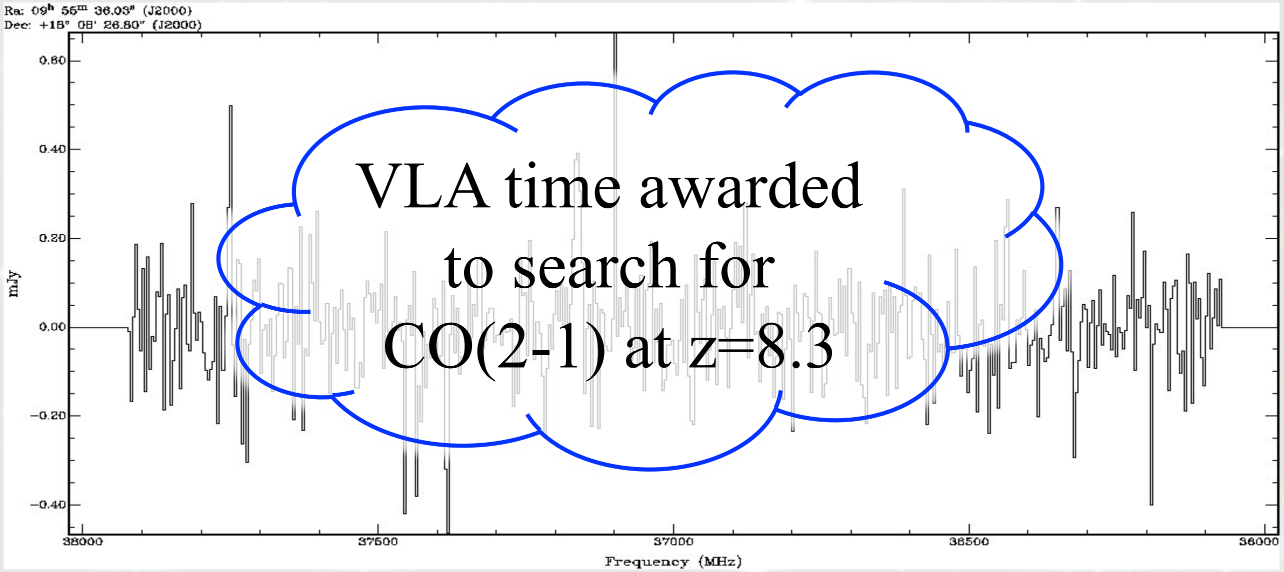
CO(1-0) at z=2.1

or

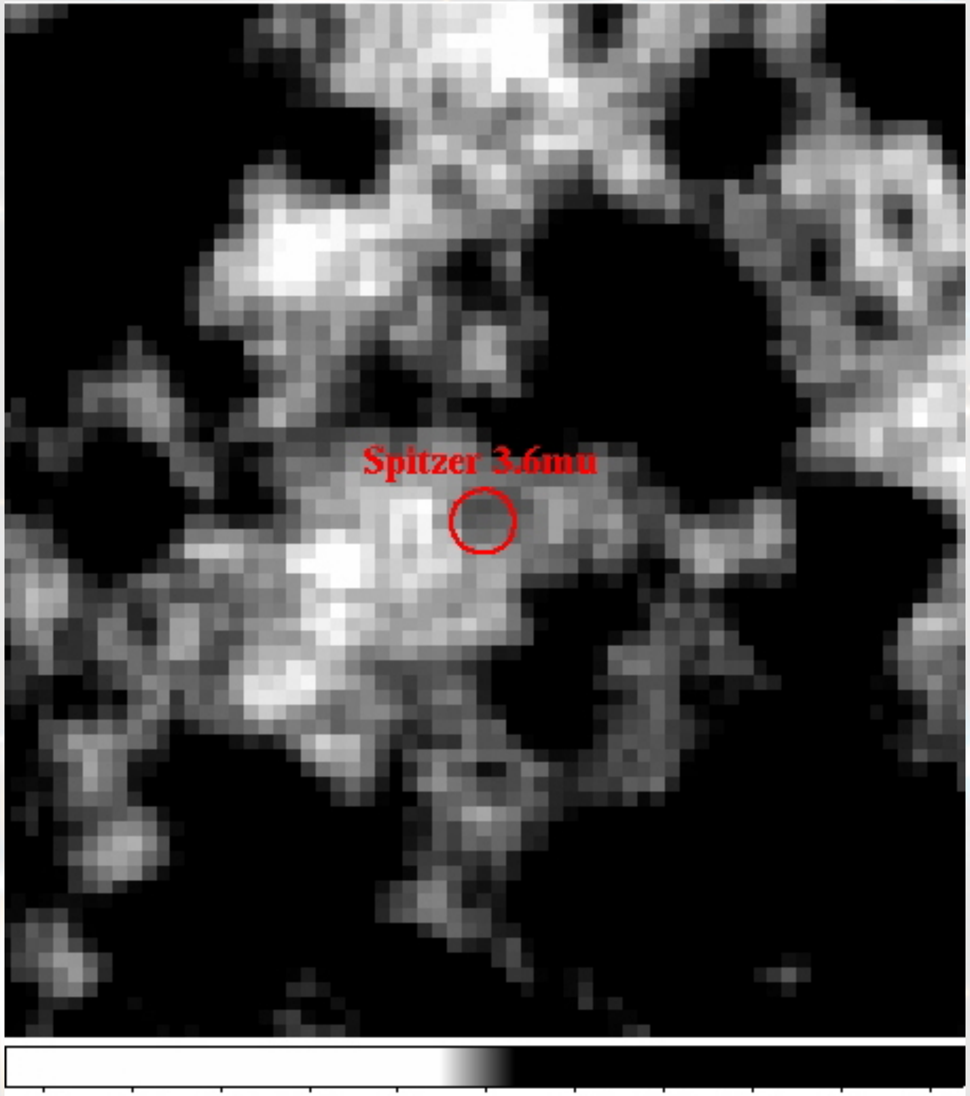
CO(2-1) at z=5.2

or

CO(3-2) at z=8.3



GRB 090423: host and environment



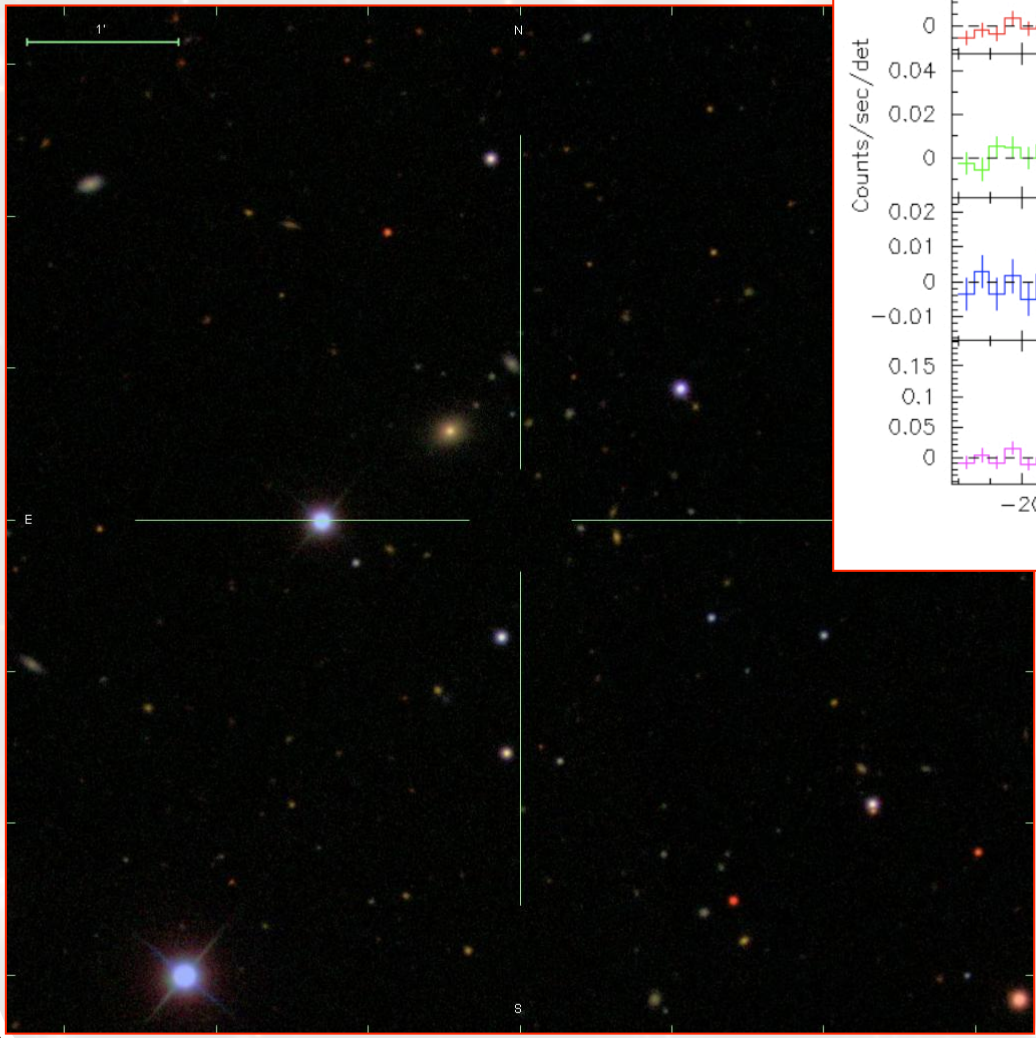
Chary, Berger, et al. 2009, 2010

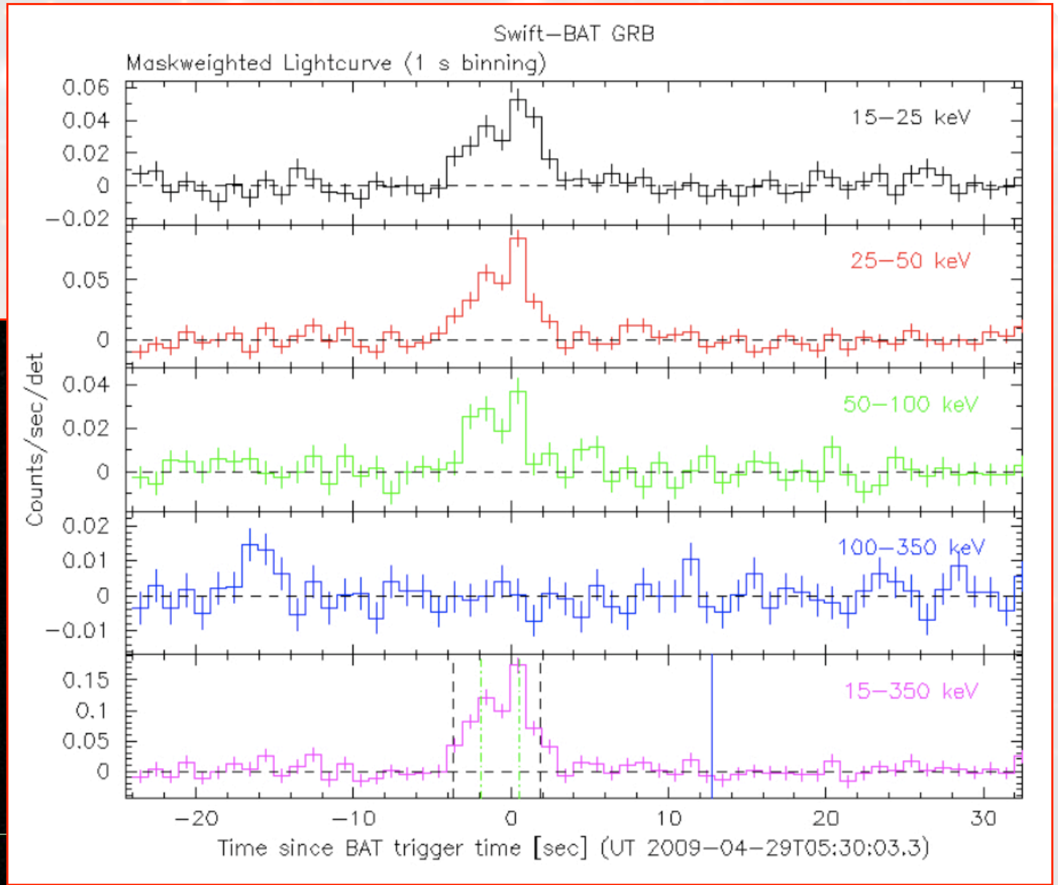
Detection at 3.6 μm 46 days after the burst (5 days in the rest-frame):

72 hr exposure: 27.2 AB mag = 48 nJy

2nd epoch in Feb 2010: no detection of the underlying host galaxy => L < 0.1 L*

GRB 090429B


1'
N
E
S


Swift–BAT GRB
Maskweighted Lightcurve (1 s binning)
15–25 keV
25–50 keV
50–100 keV
100–350 keV
15–350 keV
Counts/sec/det
Time since BAT trigger time [sec] (UT 2009–04–29T05:30:03.3)

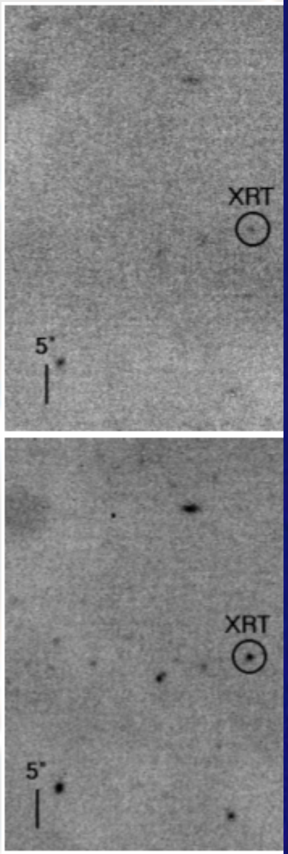
GRB 090429B

Optically dark

z > 21.8 at 13

z > 23.5 at ~1

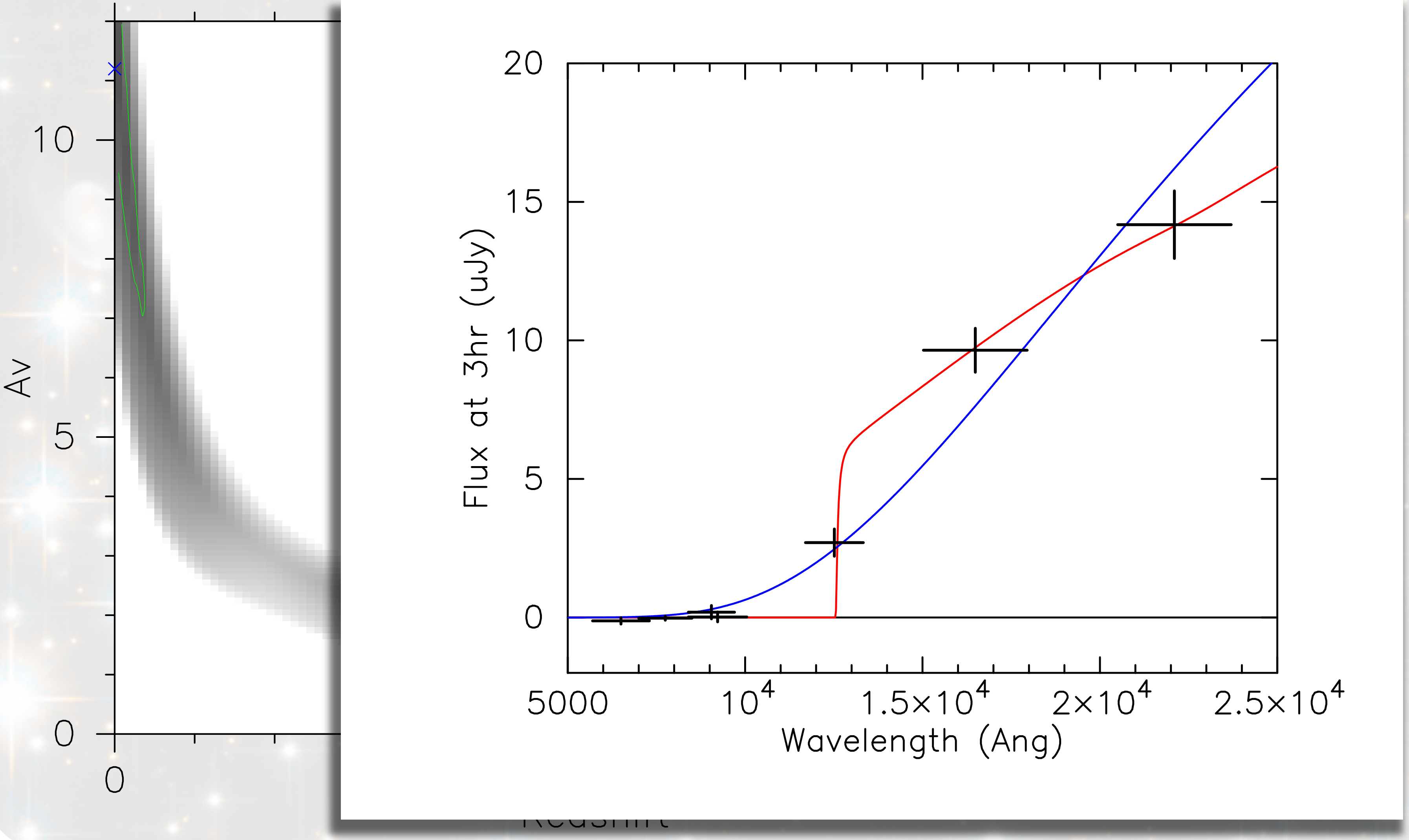
z > 24.1 at ~3



hours)

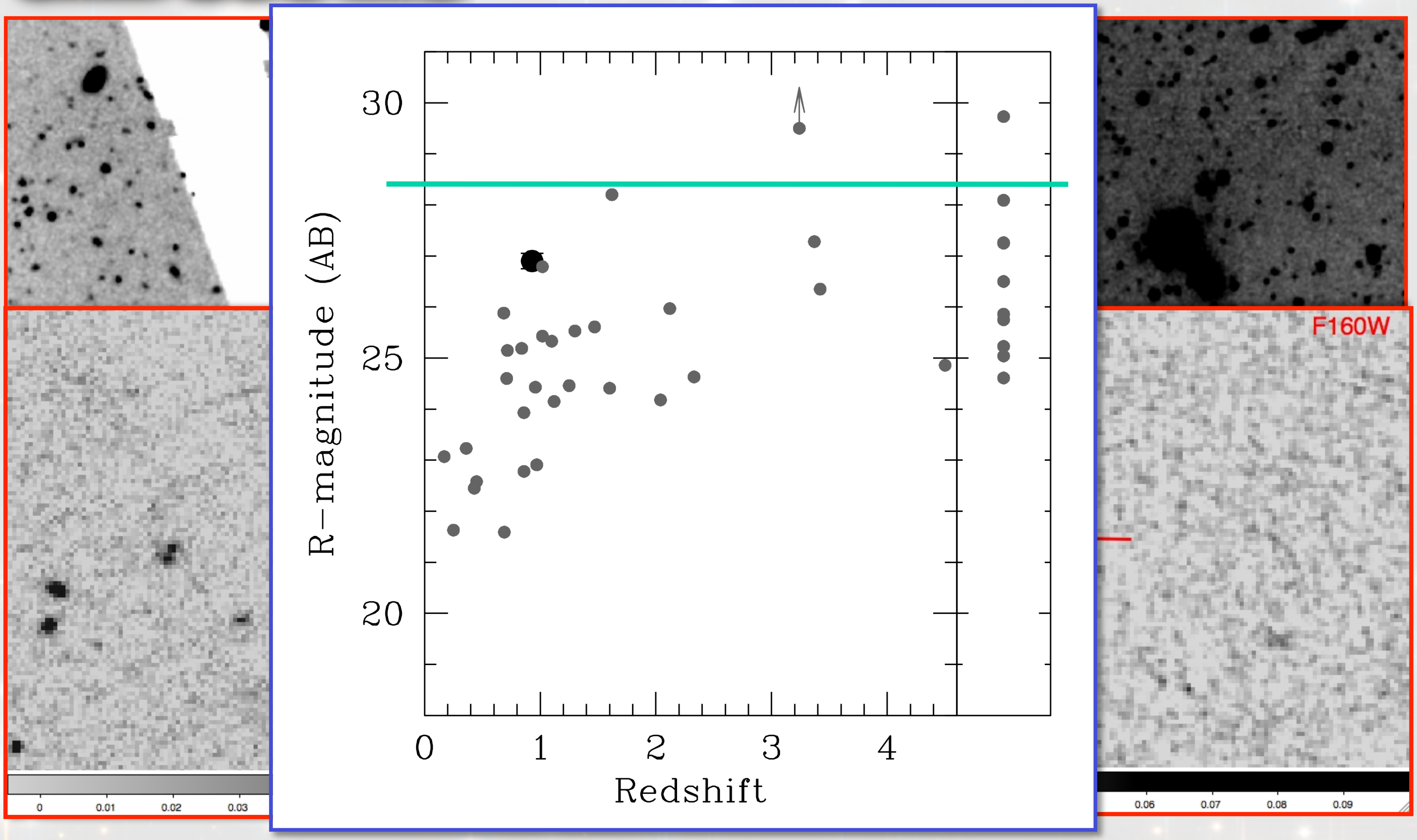
GRB 090429B

Another high-redshift candidate (z~9.3; *Cuchiarra et al. in prep*).



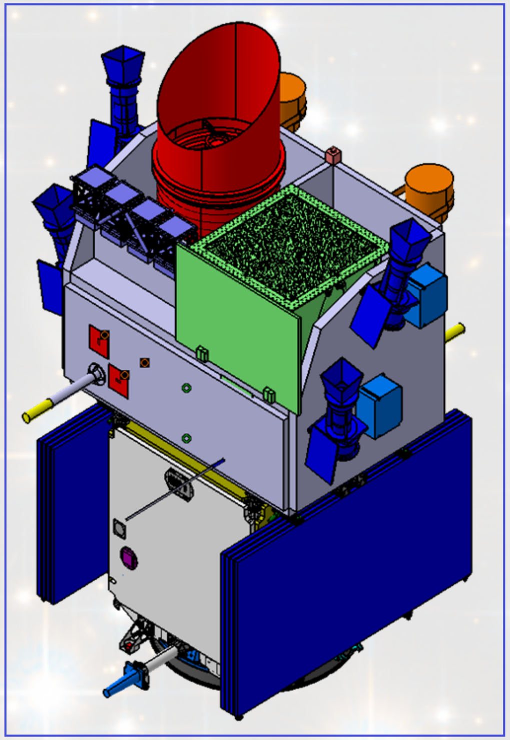
GRB 090429

Other evidence...



Provisional limits 606W(AB)>28.5, 160W(AB)>27.5

Future (there's no such thing as a free launch!)



SVOM - 2015

SVOM: Similar to Swift but enhanced optical imaging capability (50 cm VT sensitive to 1 micron). Hence more rapid identification of candidate high redshift bursts.

Several other new mission concepts are also being proposed.

BUT, it's a great shame that GRBs were only a footnote in the 2010 decadal review! As a field, do we need to work harder at long-term (10-20 year) future planning?