Observations of Gamma-Ray bursts at High Redshift

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Particular thanks to Andrew Levan (Warwick), Palli Jakobsson (Hertfordshire), Evert Rol, James Duke (Leicester)

GRBs as high redshift probes - in brief

Pros:

- Extremely bright and visible at large luminosity distance.
- Broad SEDs and detectable in gamma-rays through high intervening columns of gas and dust.

• Cons:

- Rare (~2 per day per universe to BATSE and Swift limits).
- Hard to follow up, so samples tend to be inhomogeneous and incomplete.

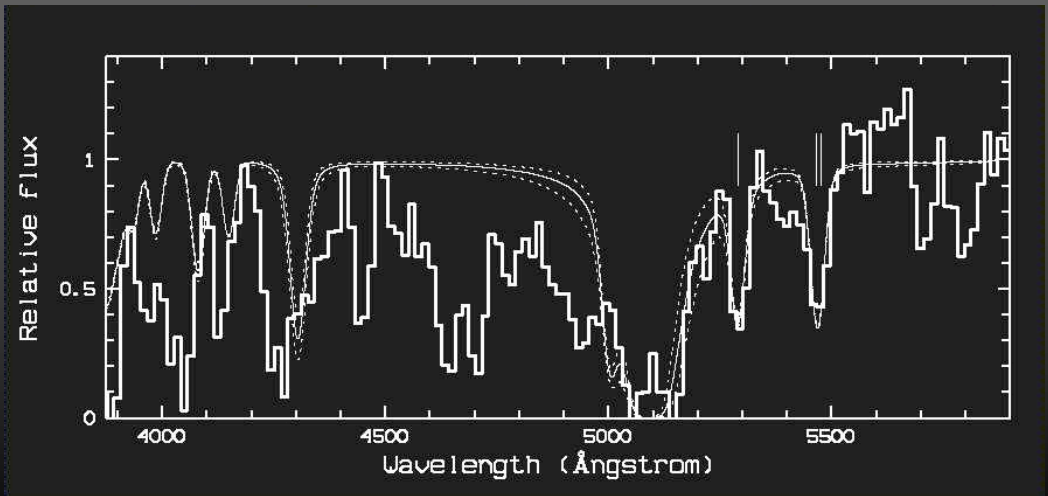
Characterising the early stars and galaxies

Hierarchical growth means small, faint galaxies at early times.

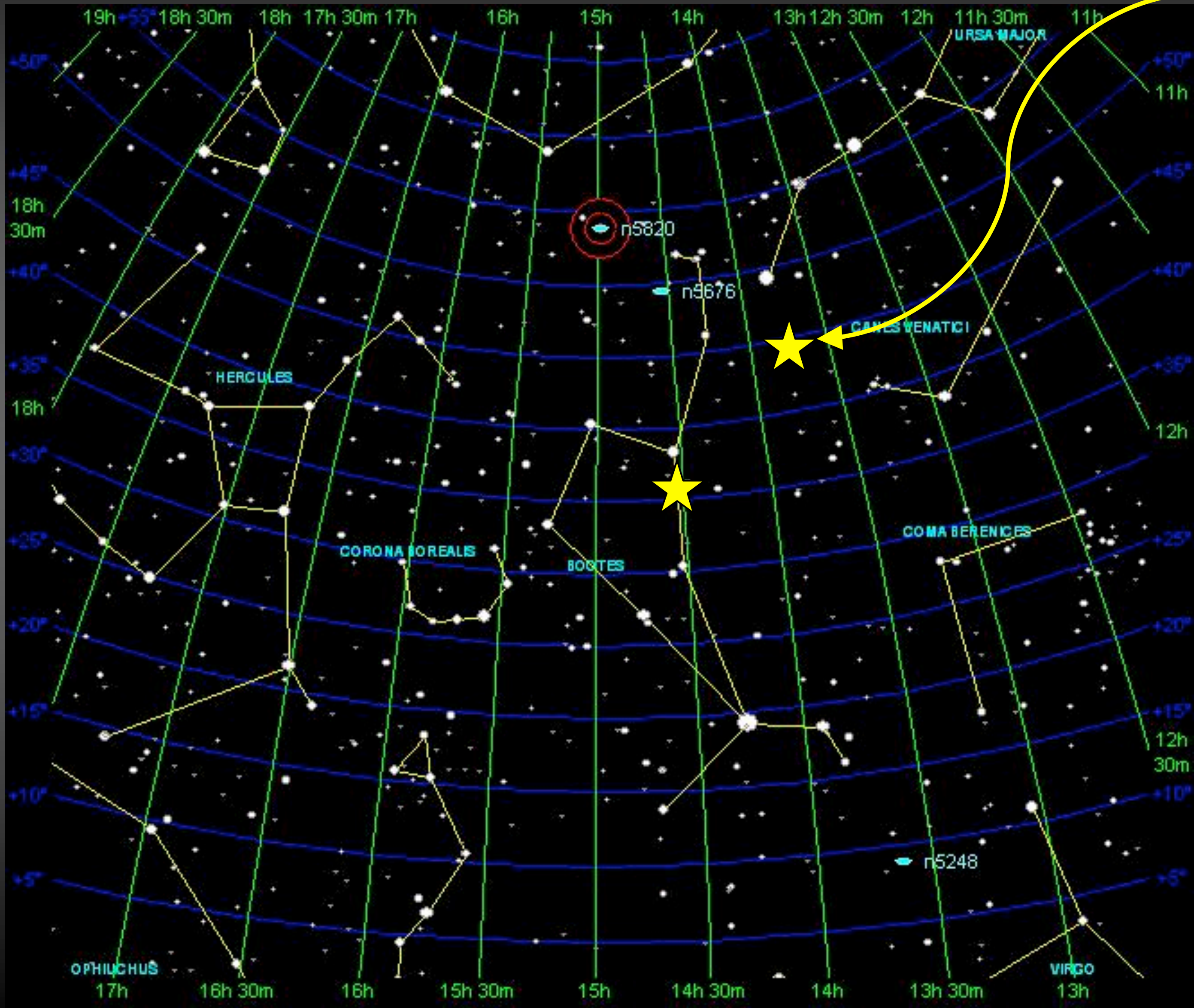
GRBs pinpoint the hosts no matter how faint, allowing deep followup with knowledge of the redshift. GRB hosts may be typical of the galaxies driving reionization.

They also provide information on both the immediate environment of the burst and the global properties of the host ISM through absorption line spectroscopy.

Eg. GRB 020124: Host galaxy found via GRB afterglow at z=3.20 (Hjorth et al. 2003), despite being undetected to R=29.5 by HST! (Berger et al. 2002)



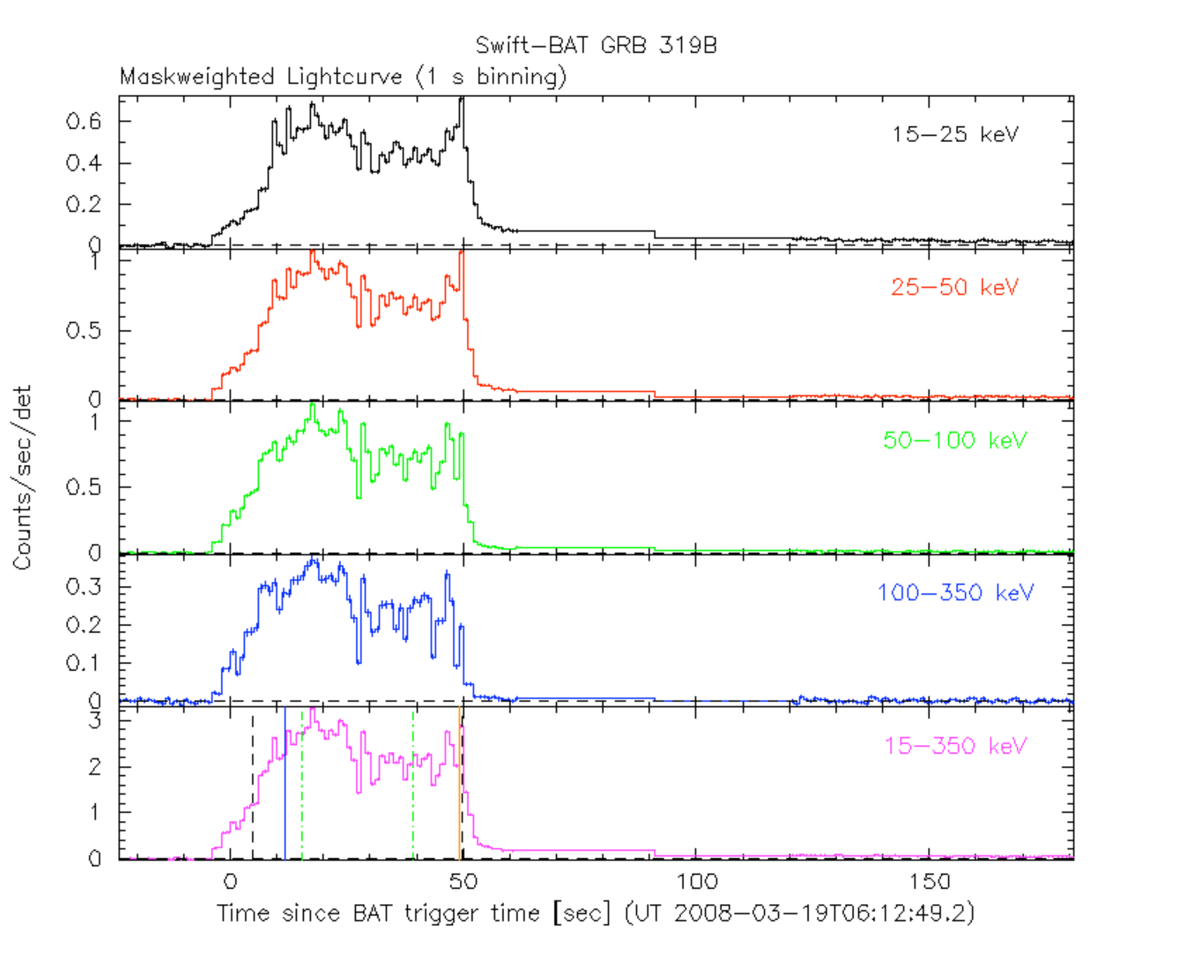
GRB 080319B

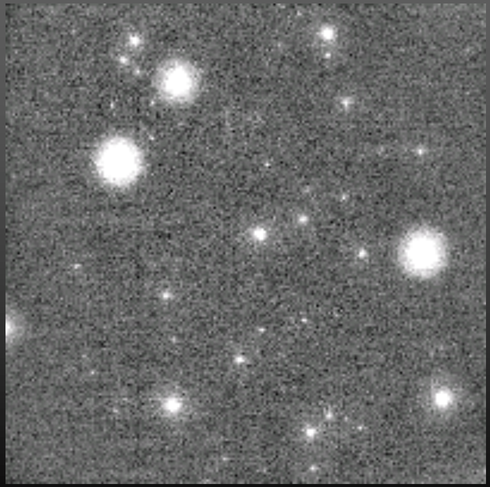


19h +55° 18h 30m 18h 17h 30m 17h 16h 15h 14h 13h 12h 30m 12h 11h 30m 11h
URSA MAJOR
n5820
n5676
CANES VENATICI
HERCULES
CORONA BOREALIS
BOOTES
COMA BERENICES
n5248
OPHIUCHUS
VIRGO
17h 16h 30m 16h 15h 30m 15h 14h 30m 14h 13h 30m 13h

GRB 080319B

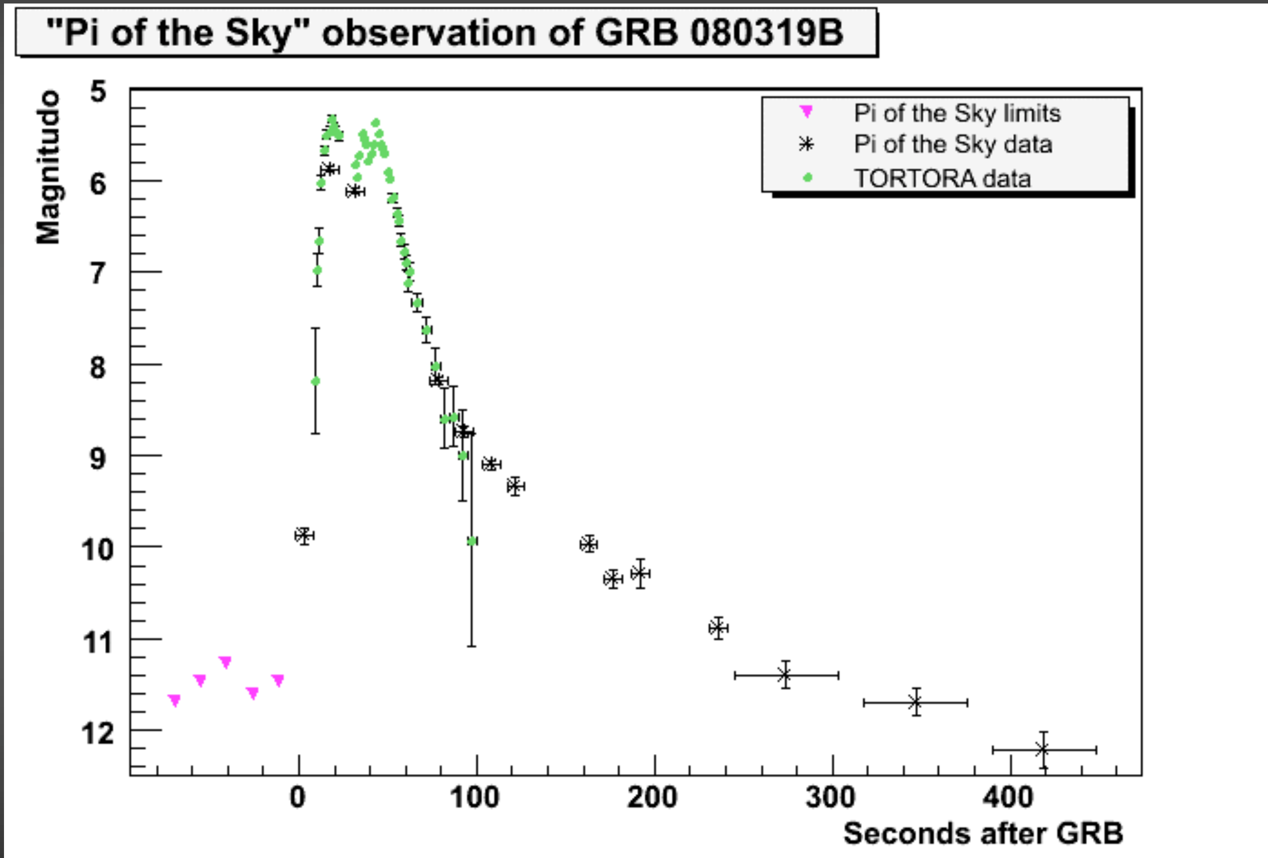
Pi of Sky





Reached visual magnitude 5.3!

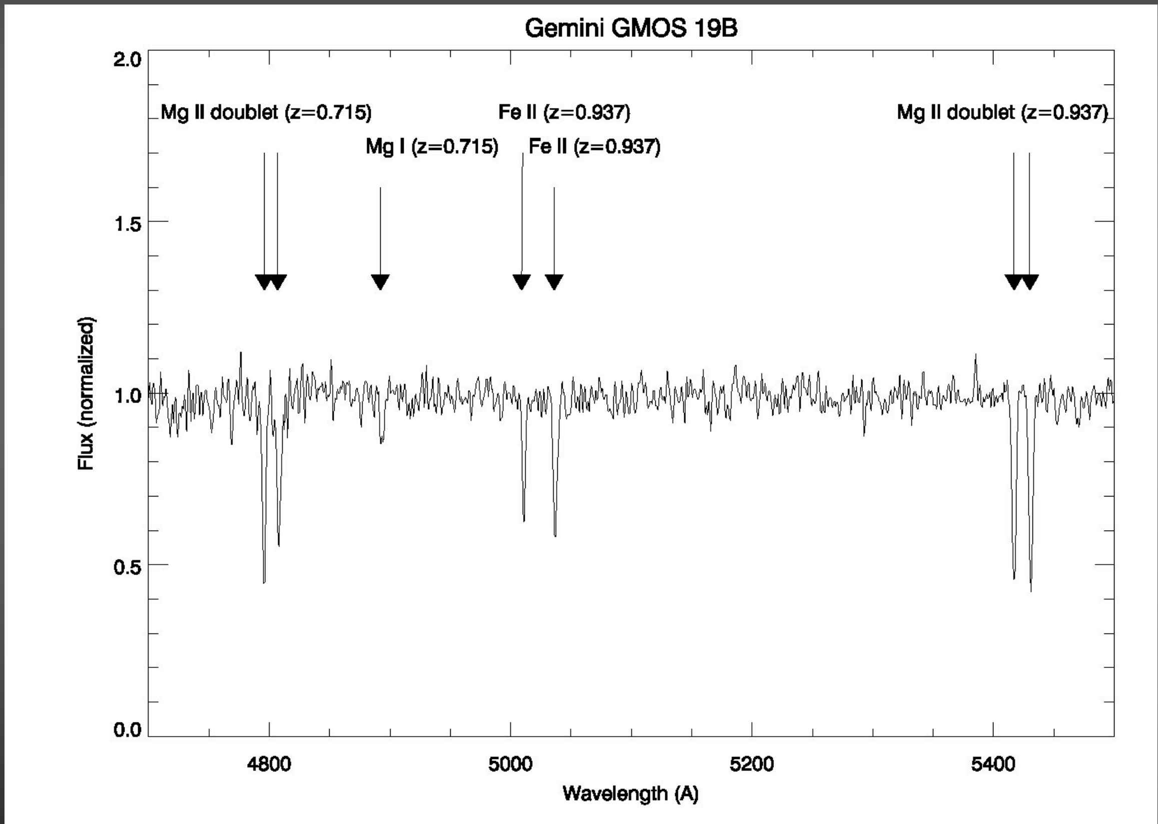
GRB 080319B



REM & Tortora

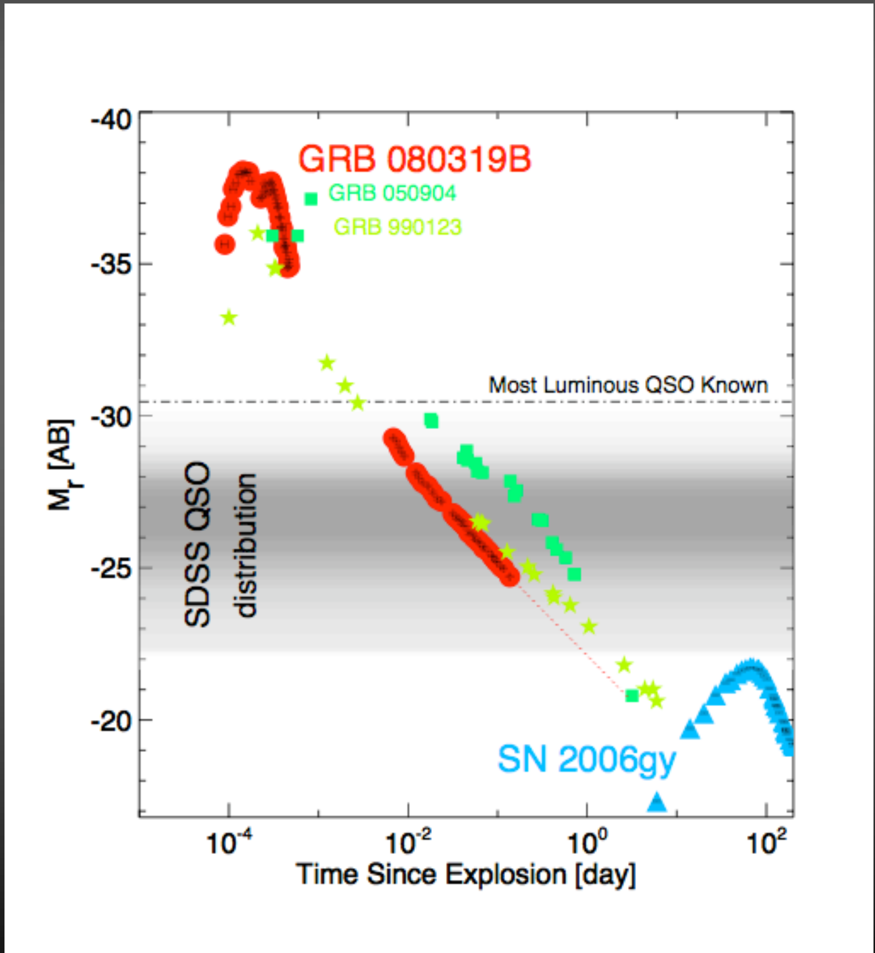
GRB 080319B

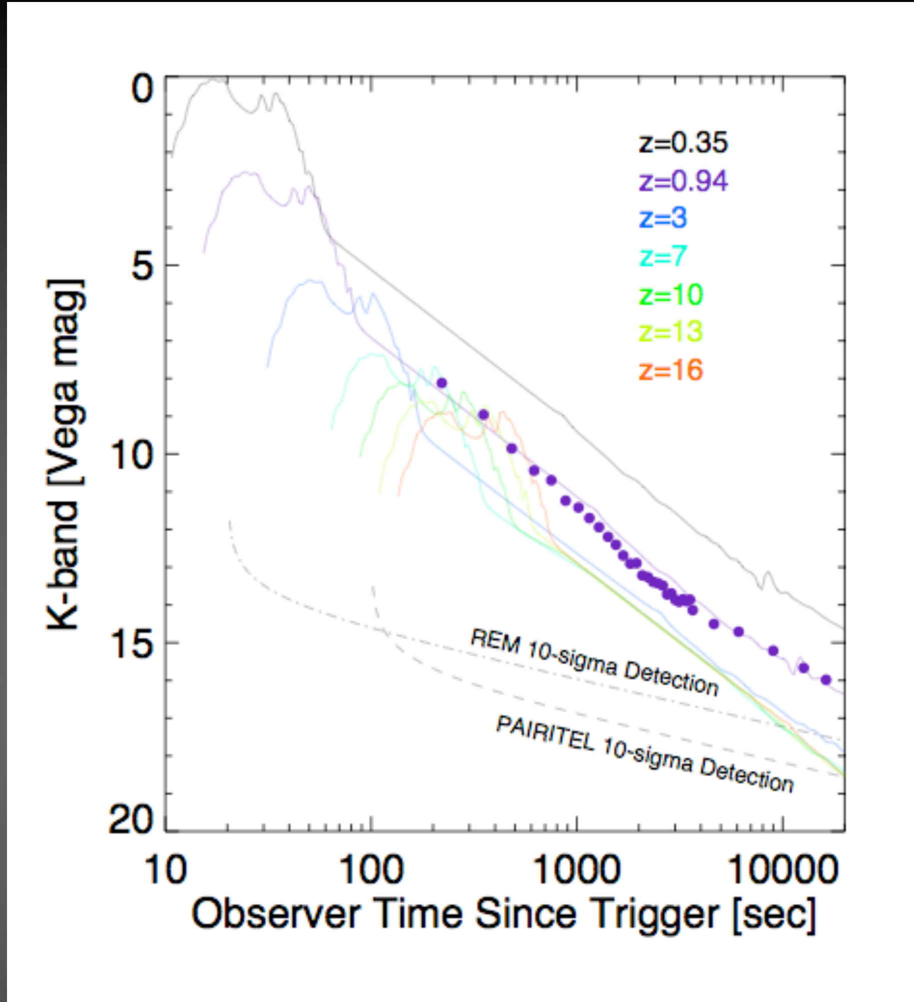
Redshift = 0.937 (Vreeswijk et al. GCN)



GRB 080319B

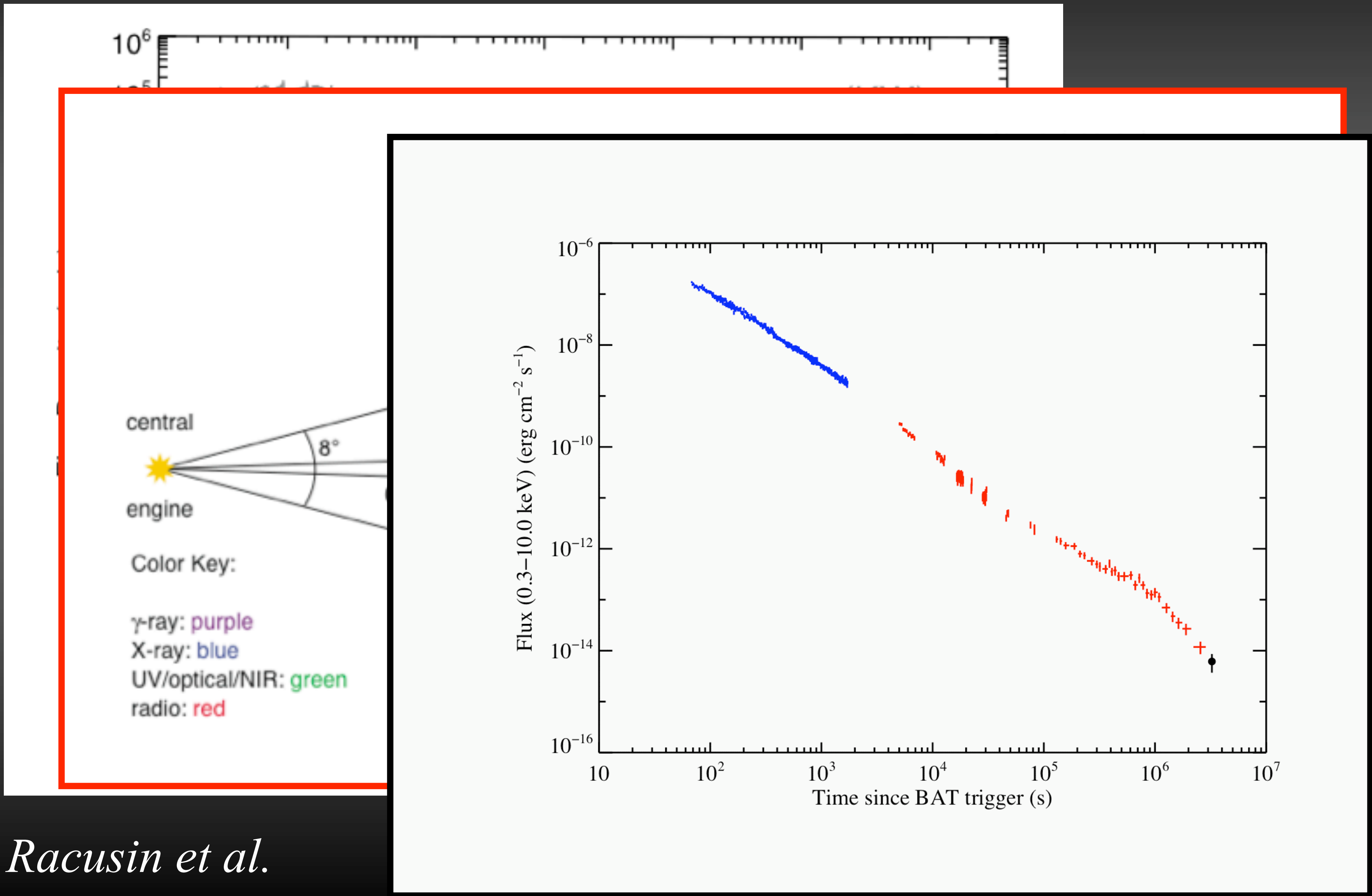
Bloom et al.





At such a luminosity, GRB 080319B would have been easily detectable if it at occurred at only 200 million years after the Big Bang!

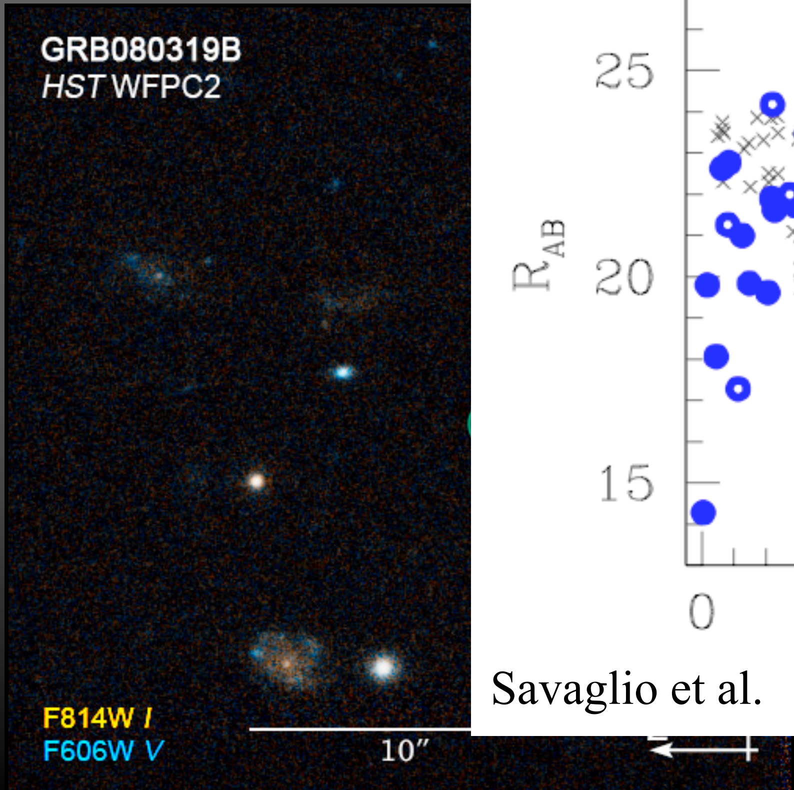
GRB 080319B

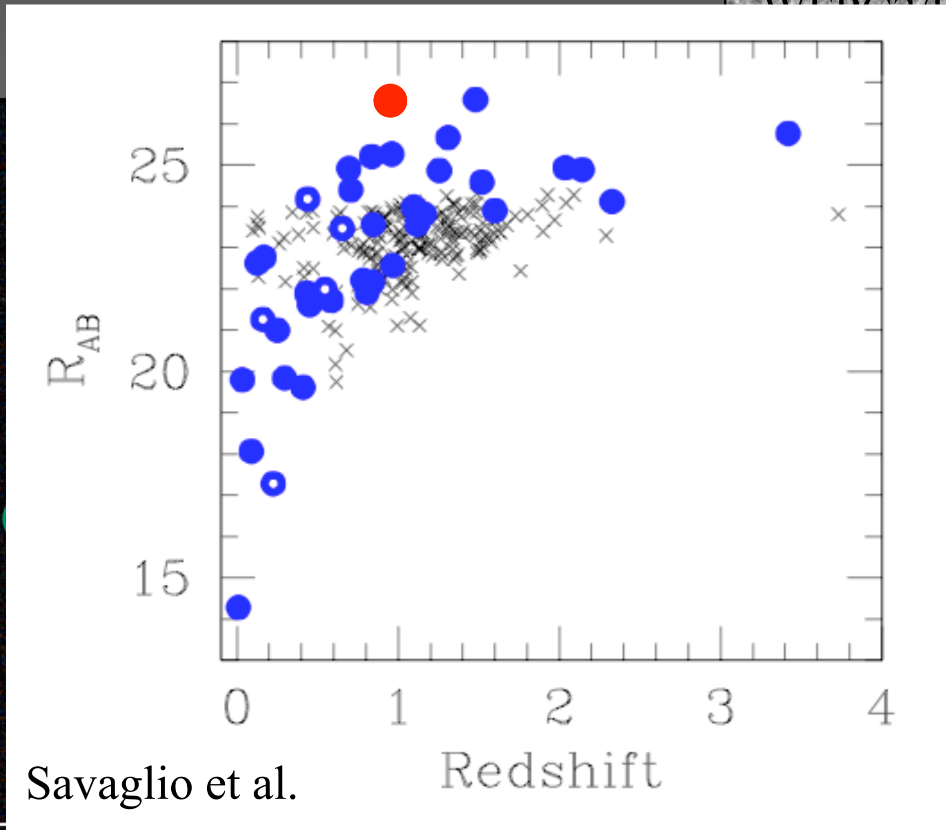


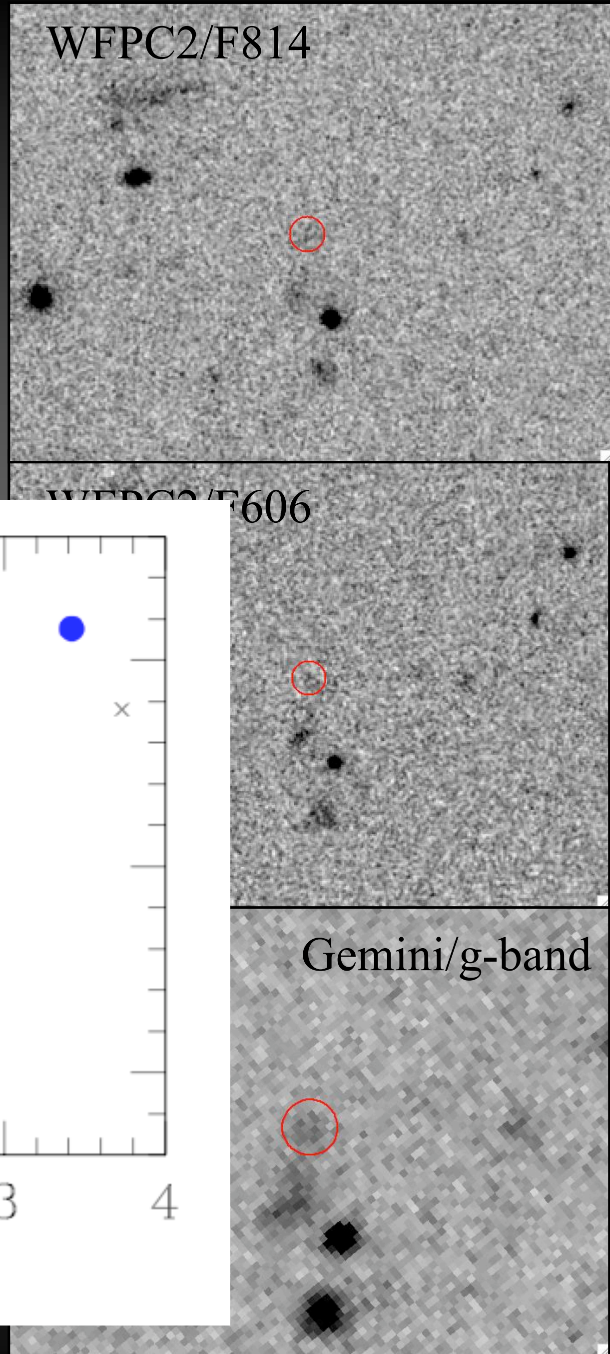
Racusin et al.

GRB 080319B

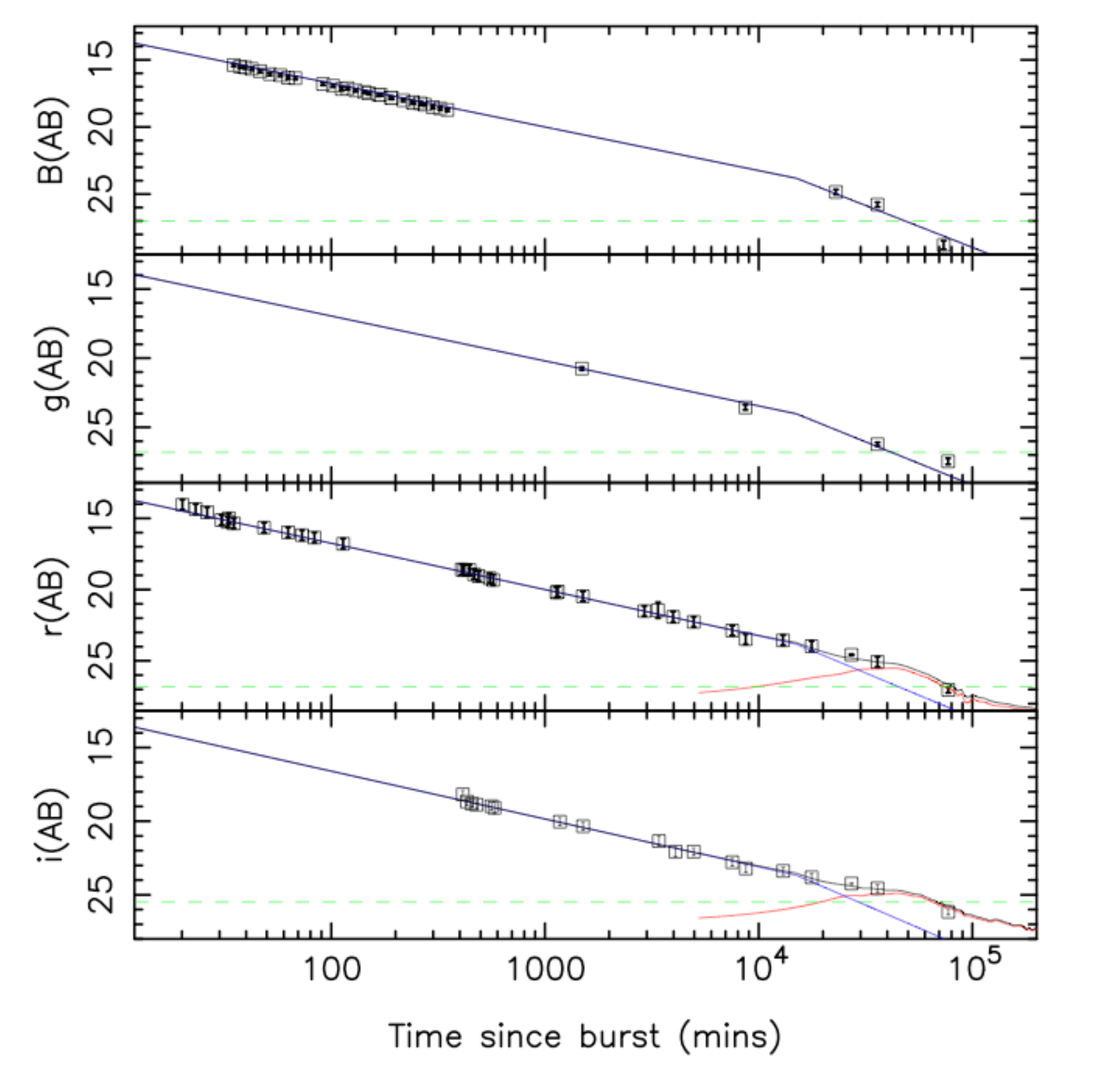
Host very faint, r(AB)~26.8, and would require JWST to see if it were placed at z>6.

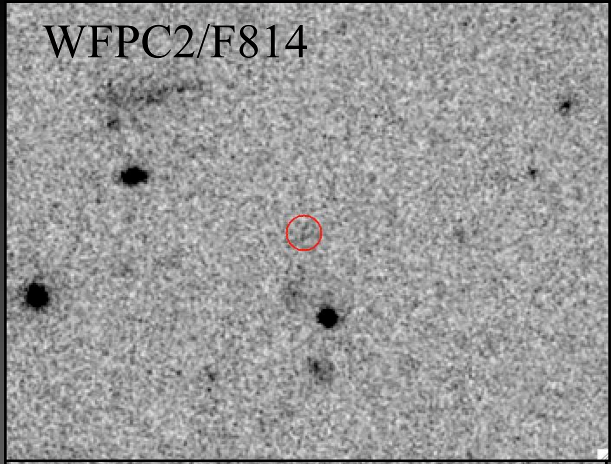


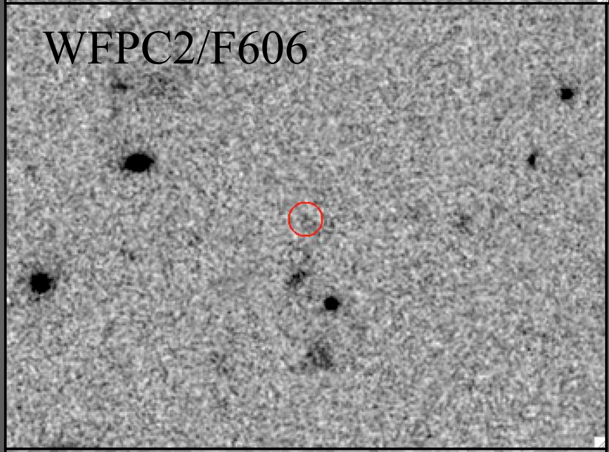


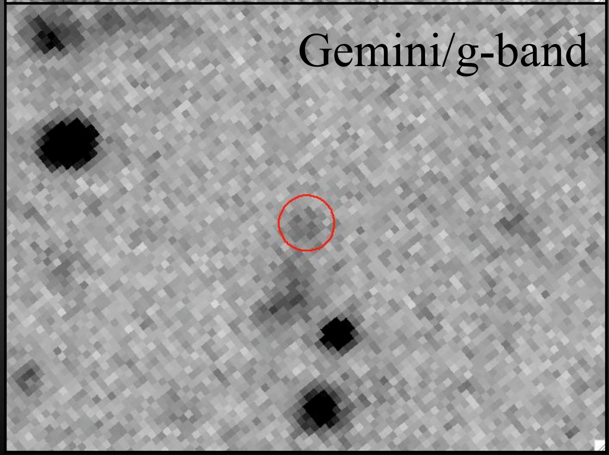


GRB 080319B





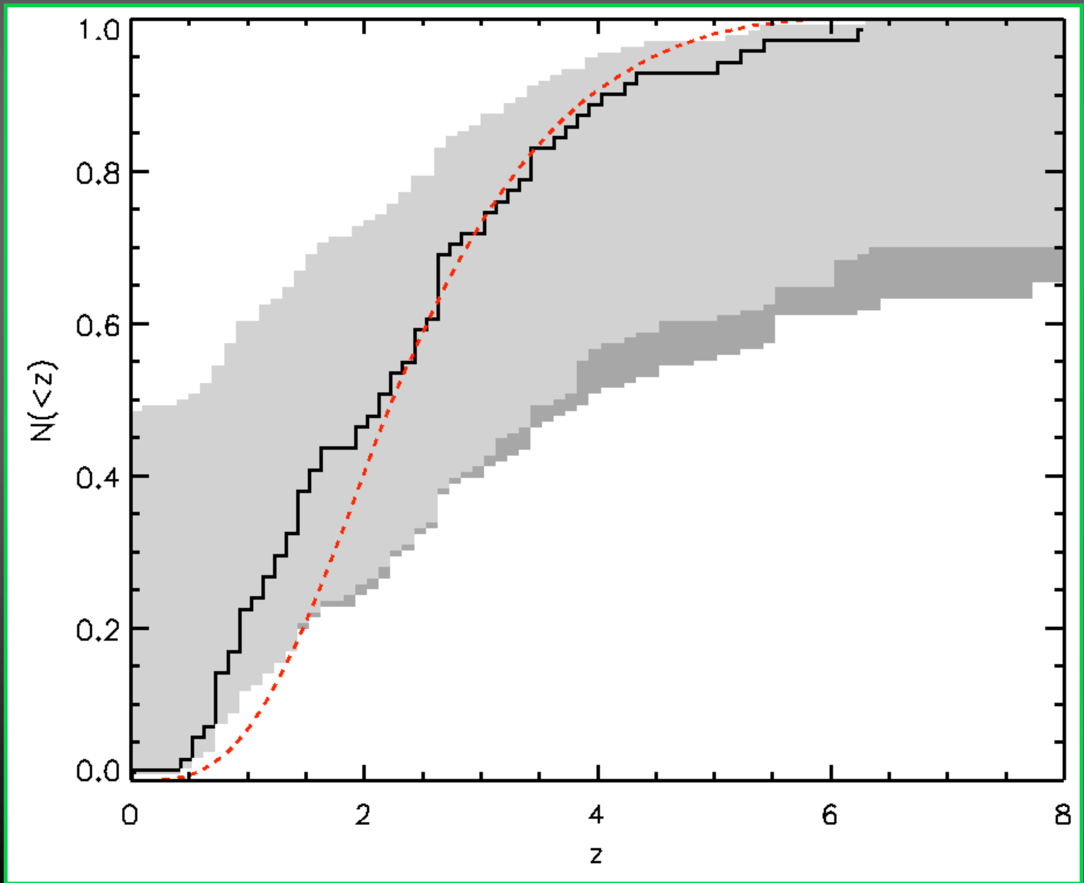




Provisional analysis!

The observed redshift distribution

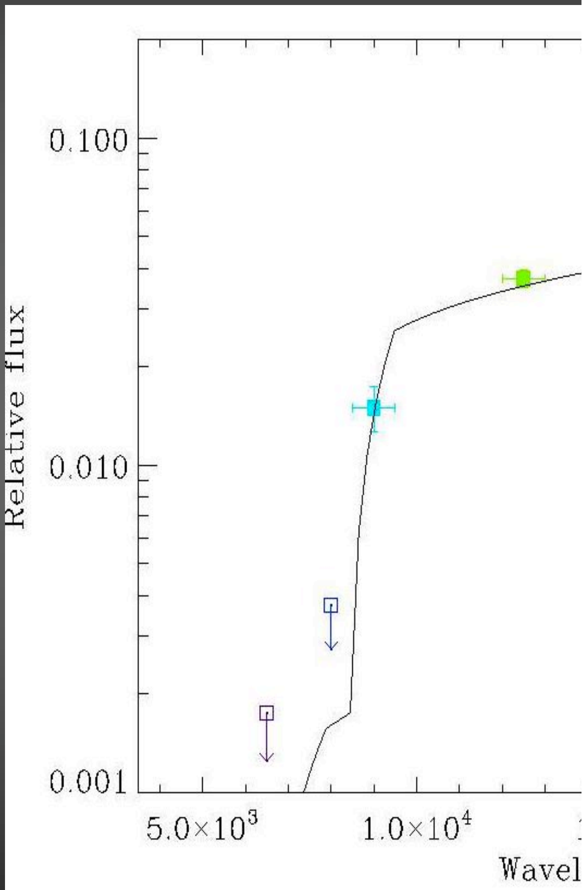
Jakobsson et al. 2006 defined a homogeneous “observable” sample of *Swift* GRBs with rapid (<12 hr) XRT positions, good Sun angle (>55 degs), low foreground extinction (A_V<0.5), non-polar declination (|dec|<70 degs). *Aim is to be optically unbiassed.*

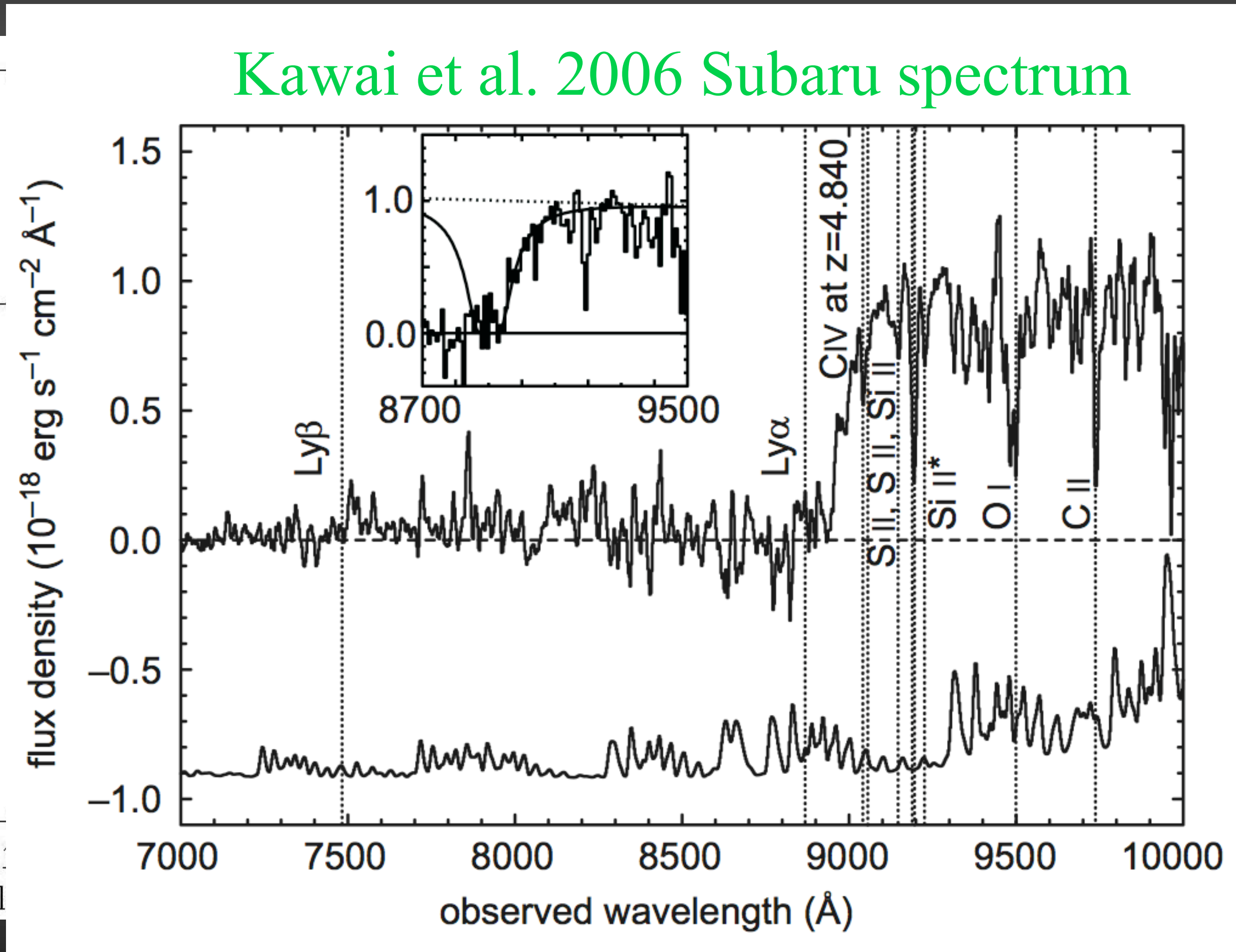


See Jakobsson poster

GRB 050904

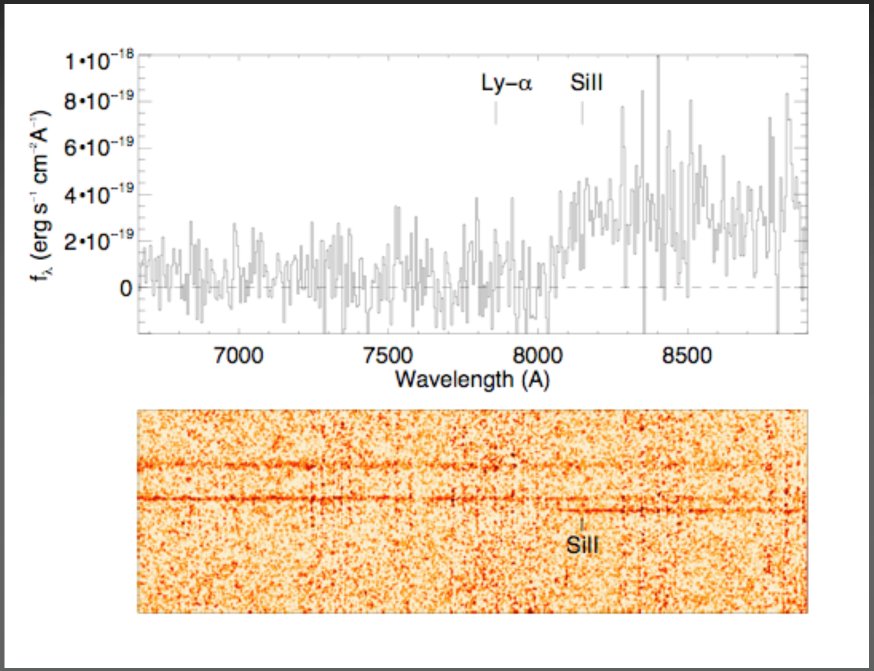
First z>6 GRB (Haislip et al. 2006; Kawai et al. 2006)



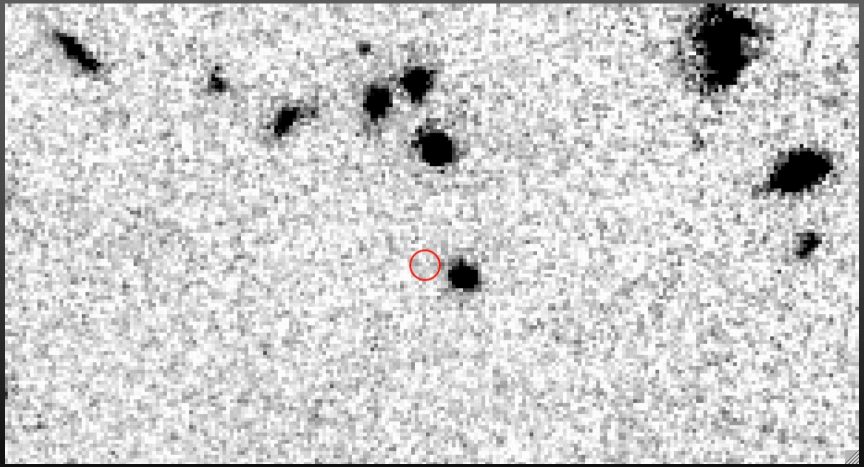


Photometry from SOAR, UKIRT and Gemini-S

GRB060927

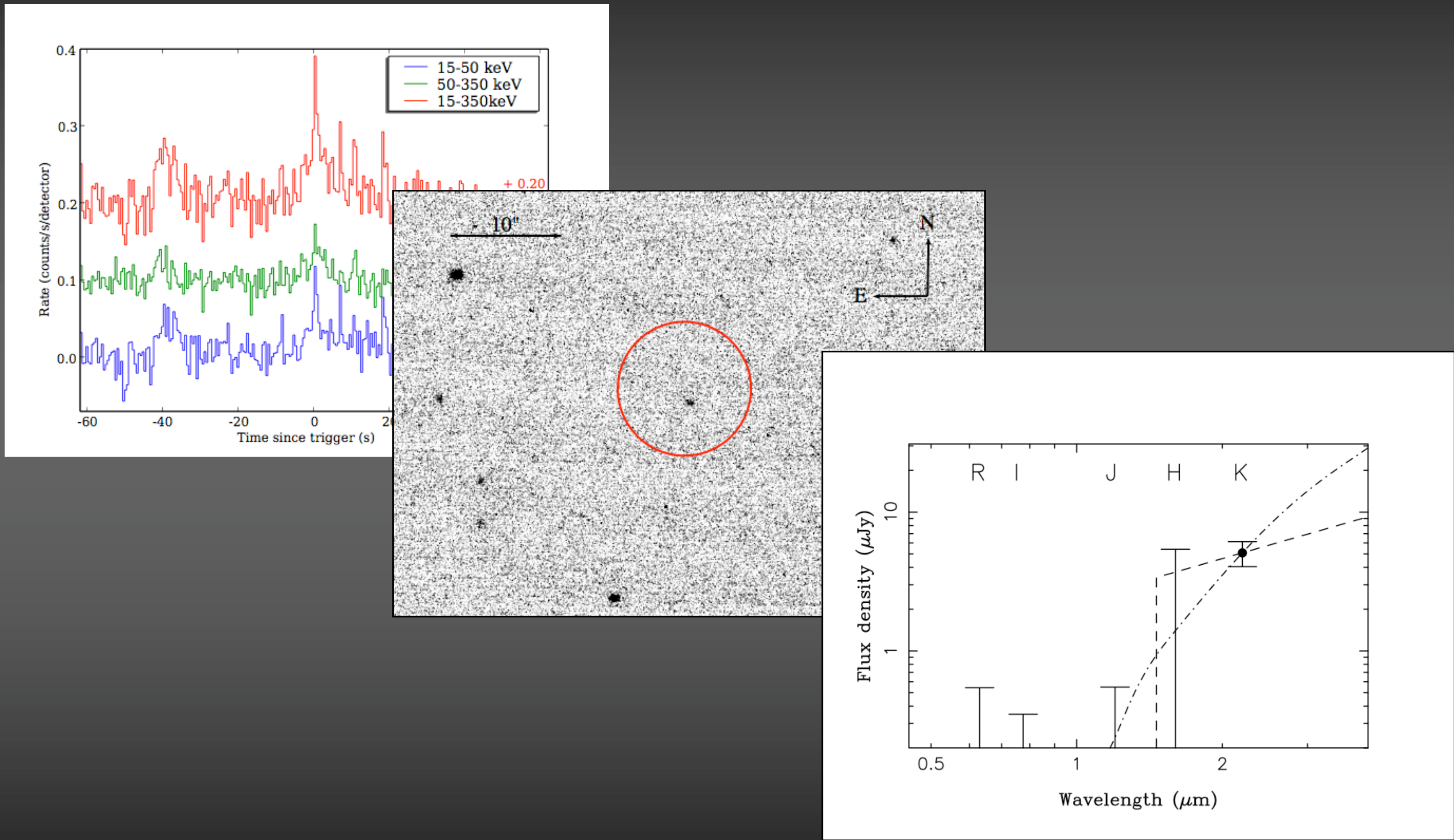


z=5.47, and again a strong host DLA (Ruiz-Velasco et al. 2007)



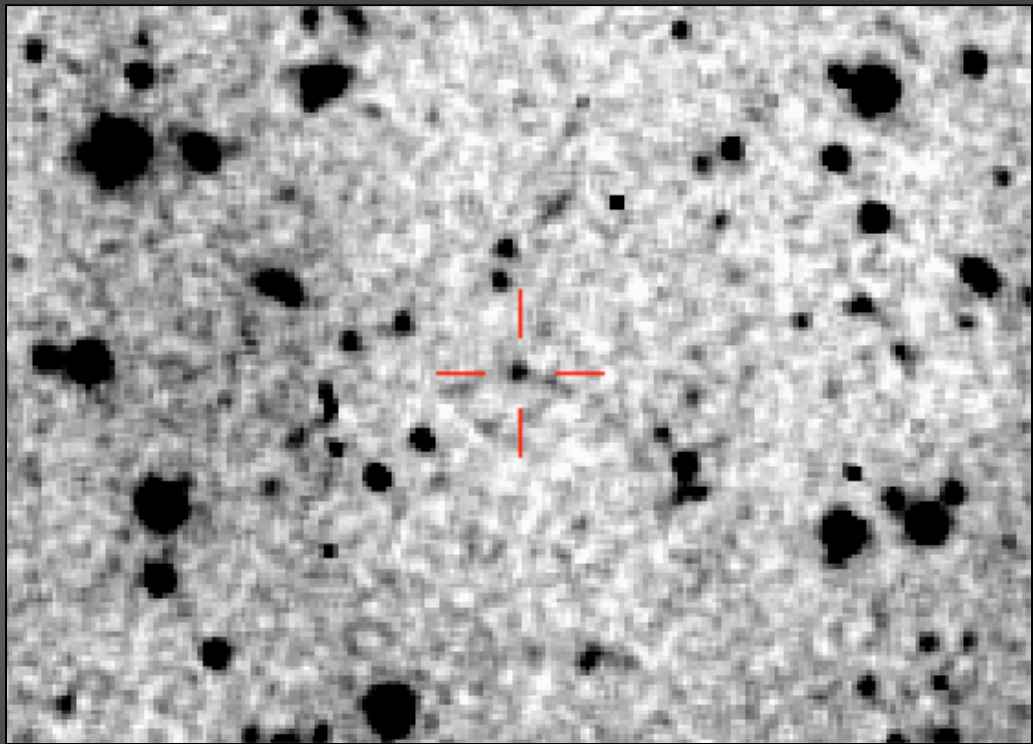
No host seen with NICMOS to H(AB)=27.0 (Duke et al.)

GRB 060923A - high-z?



H-band drop out. Afterglow colours could indicate very high-z

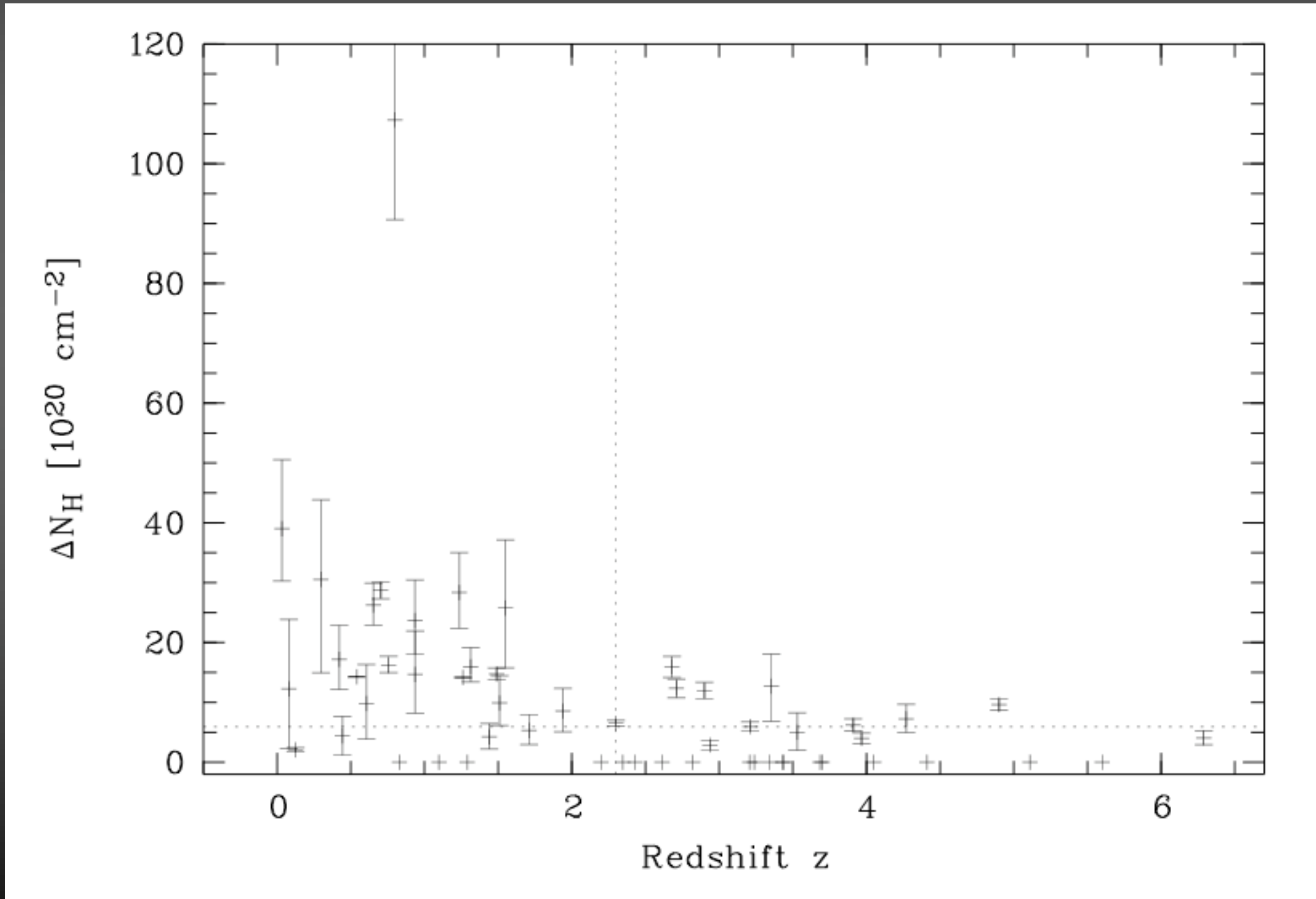
GRB 060923A - high-z?



Our VLT observations show a host in R-band and continuum to about 4500 Angstroms, so z<3 and Av>2.

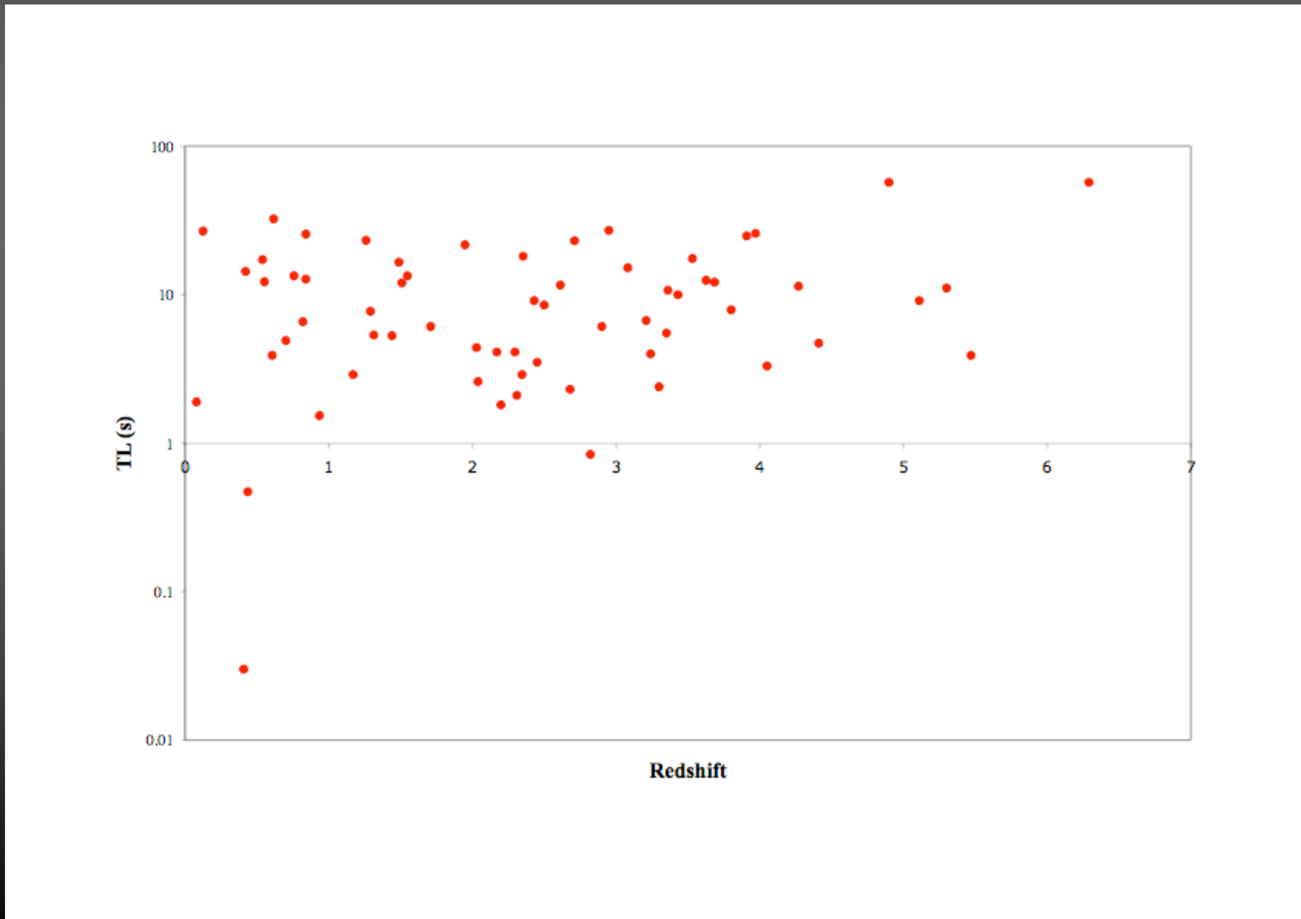
Optimizing high-z searches with Swift:

X-ray determined N(HI) excess is certainly a good pointer (Grupe et al. 2007).



Optimizing high-z searches:

High-z bursts should typically have longer durations, but the intrinsic spread is high, so doesn't allow us to remove many from consideration. Eg. Using Willingale's "luminosity time".



Probe for stars and black holes in the epoch of reionization.

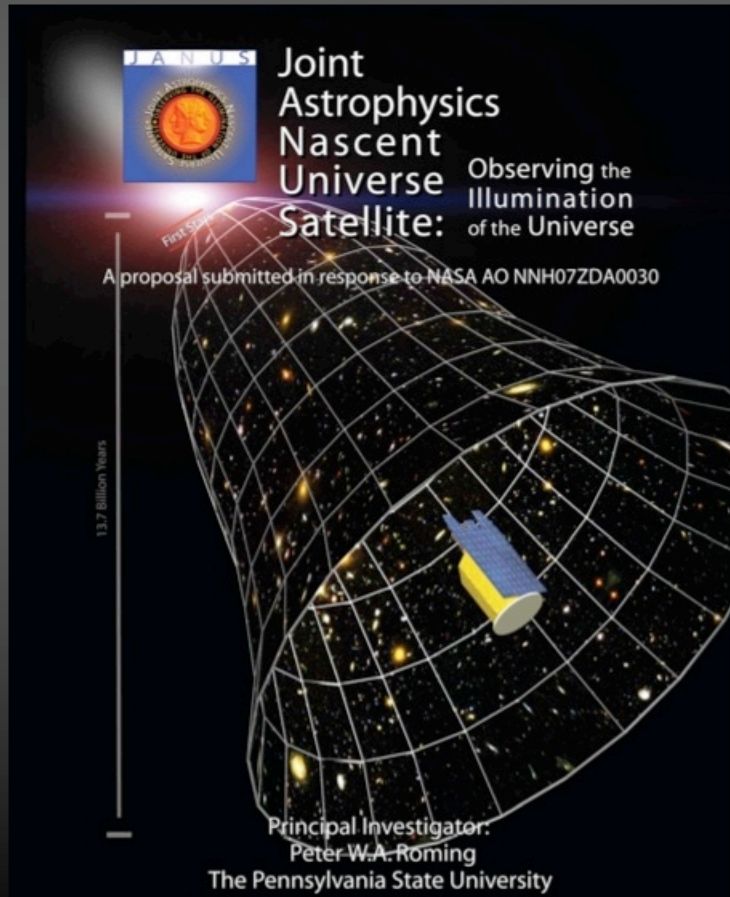
A US/UK/Italian mission proposed in January to the AO for NASA small explorer missions to launch in 2012.

JANUS will:

Hunt the first gamma ray bursts: giant explosions from the deaths of the first massive stars

Hunt the first QSOs: the first massive accreting black holes

JANUS

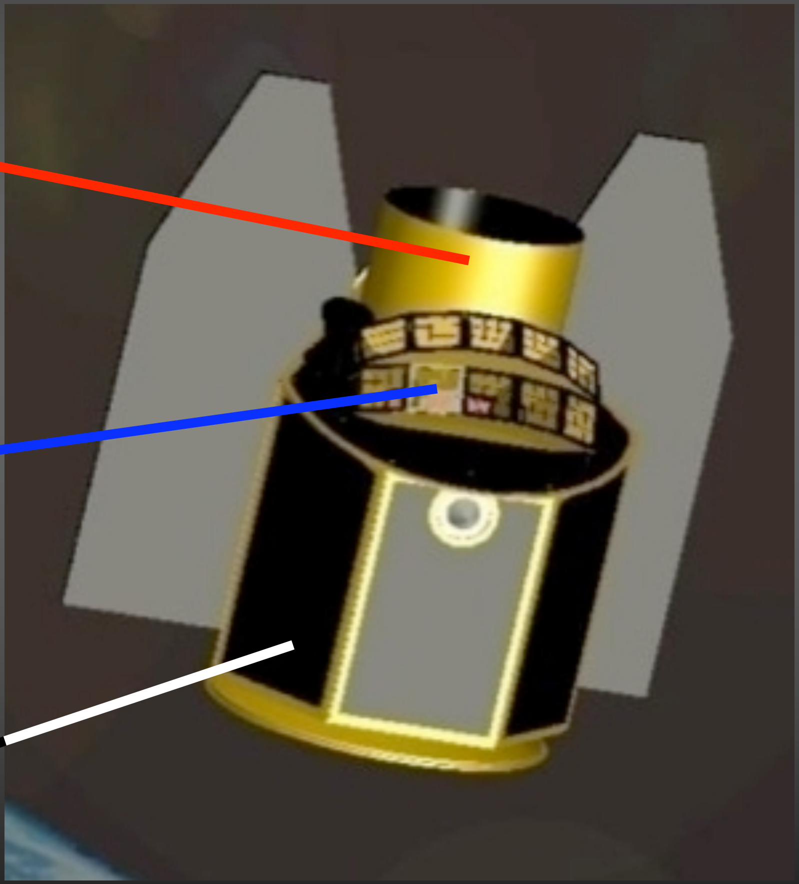


How will JANUS let us explore the epoch of reionization?

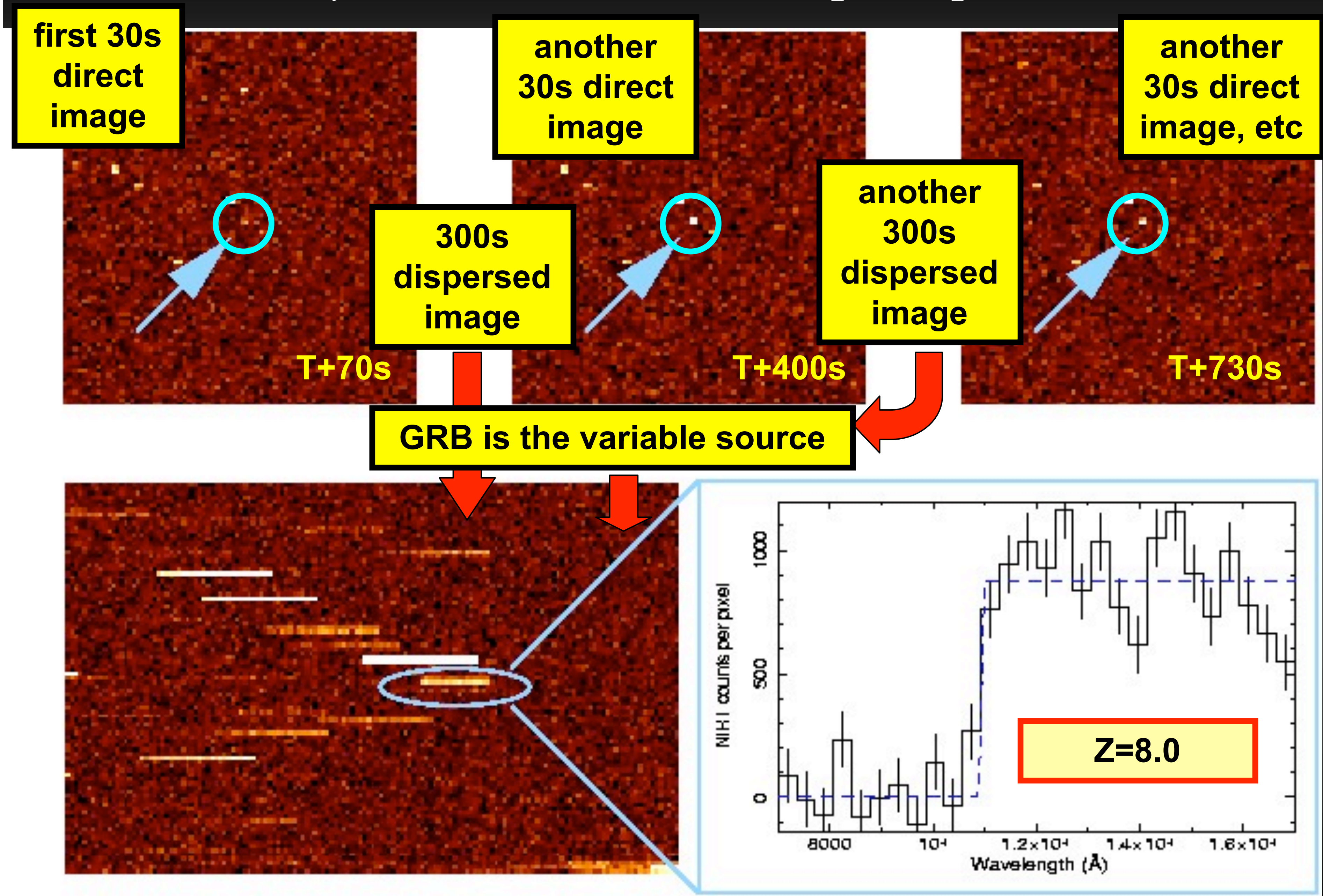
Near InfraRed Telescope (UK) uses slitless spectroscopy to get redshifts of z>5 gamma ray bursts, and surveys the sky for highest redshift quasars

X-ray flash monitor (Penn State) has huge field of view (4 str) to find high-redshift gamma-ray bursts

Ultra-agile satellite bus (SWRI/DRAPER) looks anywhere quickly



Gamma-ray burst Near-IR Telescope sequence



Conclusions and prospects

- High-z GRBs powerful means of locating and studying star formation and galaxy evolution into the era of reionization. GRB 080319B provides an extreme illustration.
- Current rates are low (but broadly consistent with predictions for Swift of ~10% at z>5) despite fairly intensive followup.
- There exist a small but significant population of highly reddened GRBs which can masquerade as high-z.
- Current strategies (rapid 2m - 8m followup) should find at least several z>6 GRBs over lifetime of *Swift*. But campaign of lowering trigger threshold should increase high-z detection rate.
- High S/N spectroscopy key to using GRB afterglows to constrain reionization.
- Any high-z bursts found provide important targets for future facilities, eg. JWST, ALMA etc.
- Future missions (JANUS) may make high-z GRB studies more routine.