TMT Observations of GRBs & SNe as Early Universe Probes

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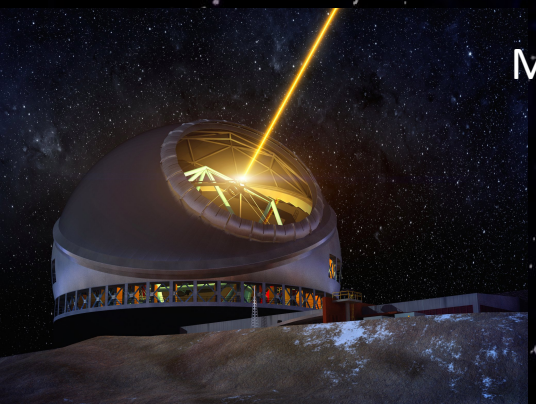
(with acknowledgements to Antonino Cucchiara, Koji Kawabata, Bruno Leibundgut, Bahram Mobasher, Masaomi Tanaka, and Nial Tanvir)



Understanding GRBs & SNe with TMT

- GRBs
  - Universality of GRB-SN connection?
  - Characterize environments (circumburst and galactic)
- SNe (Core Collapse and Type Ia)
  - Map local stellar population (progenitors and companions)
  - Characterize environments (circumburst and galactic)
  - Observe cooling phase of CCSNe shock breakout
  - Origin of Type Ia diversity
  - Fill z>1 with Type Ia and IIP

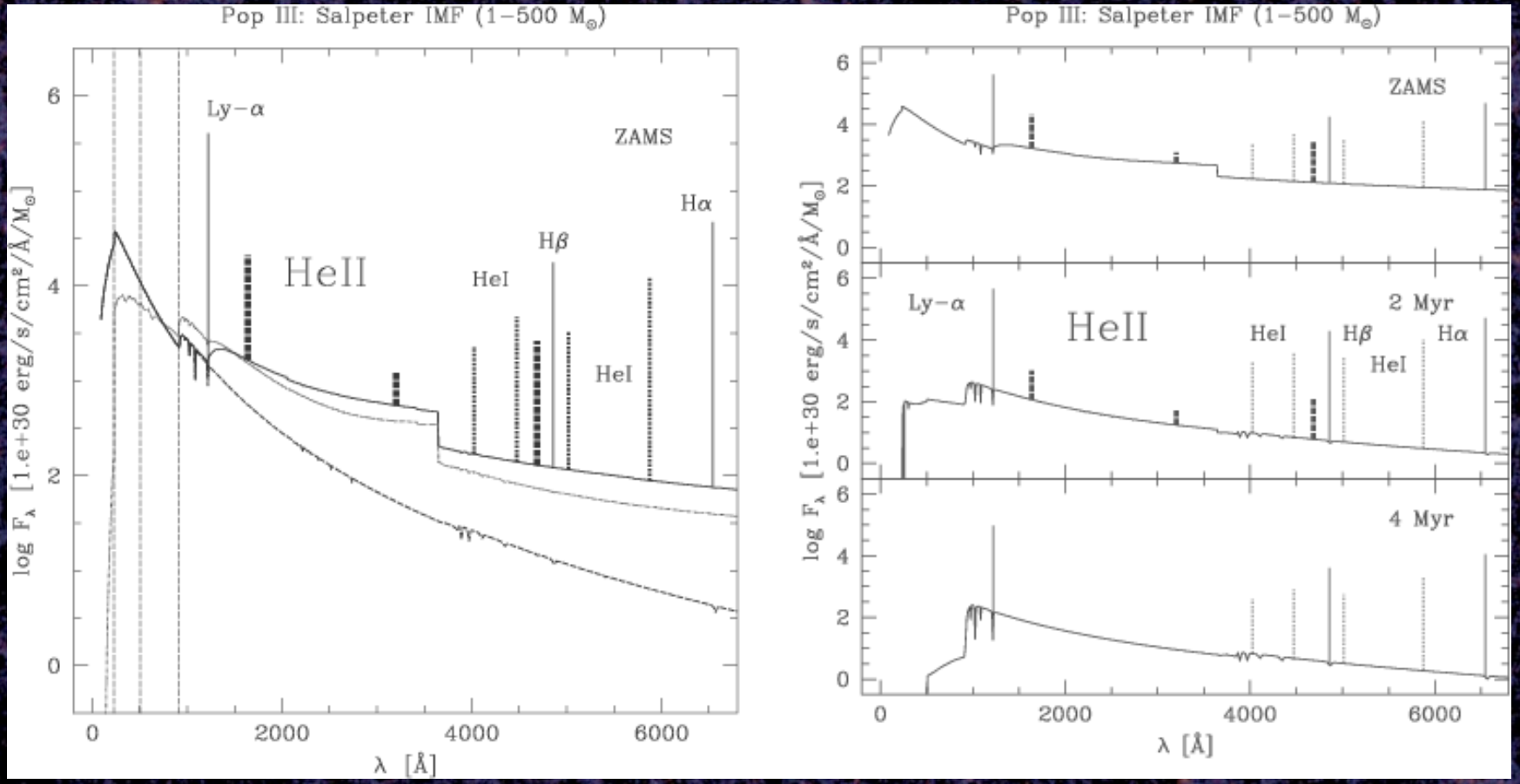
See also Xiaofeng Wang's talk for a more detailed discussion for low redshift use of GRBs and SNe

Probing the Early Universe

- First Stars (Pop III) and the Transition to Pop II
  - When did they occur and over what period of time?
  - What environment do they reside in?
- Massive Star Formation Rate at $z > 6$
- Environments of Massive Stars
  - What is the chemical abundance and how does it change?
  - How much dust and how does it change over time?
- Reionization
  - When did it begin and end?
    - Is it consistent with other (WMAP, quasars, etc.) results?
  - Is it patchy or smooth?

Observations can be done with IRIS

Identifying Pop III Stars in Galaxy Surveys

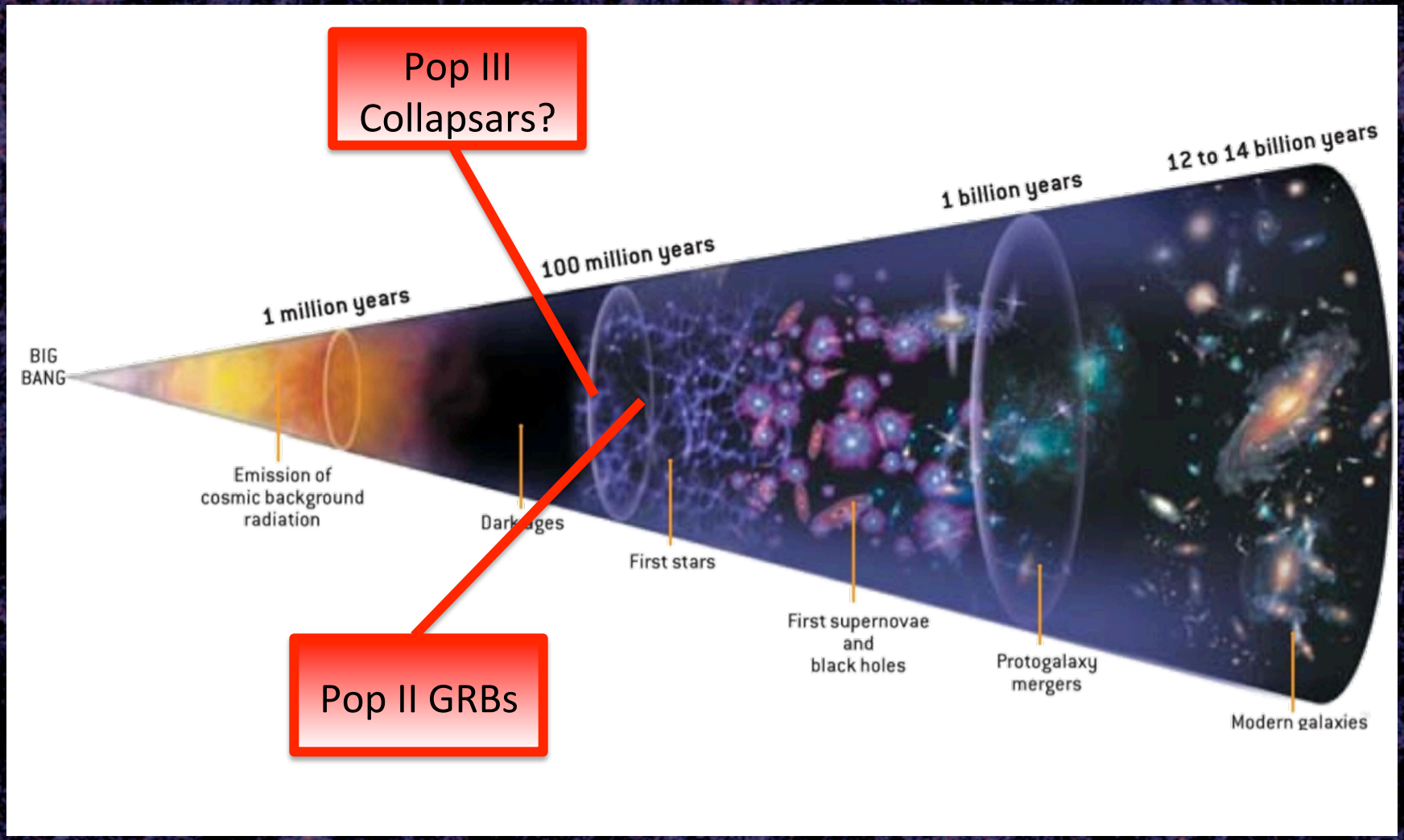


Using IRIS, could possibly detect out to z ~15 depending on true strength of signal. Depending on bluest band, might be able to use MICHI.

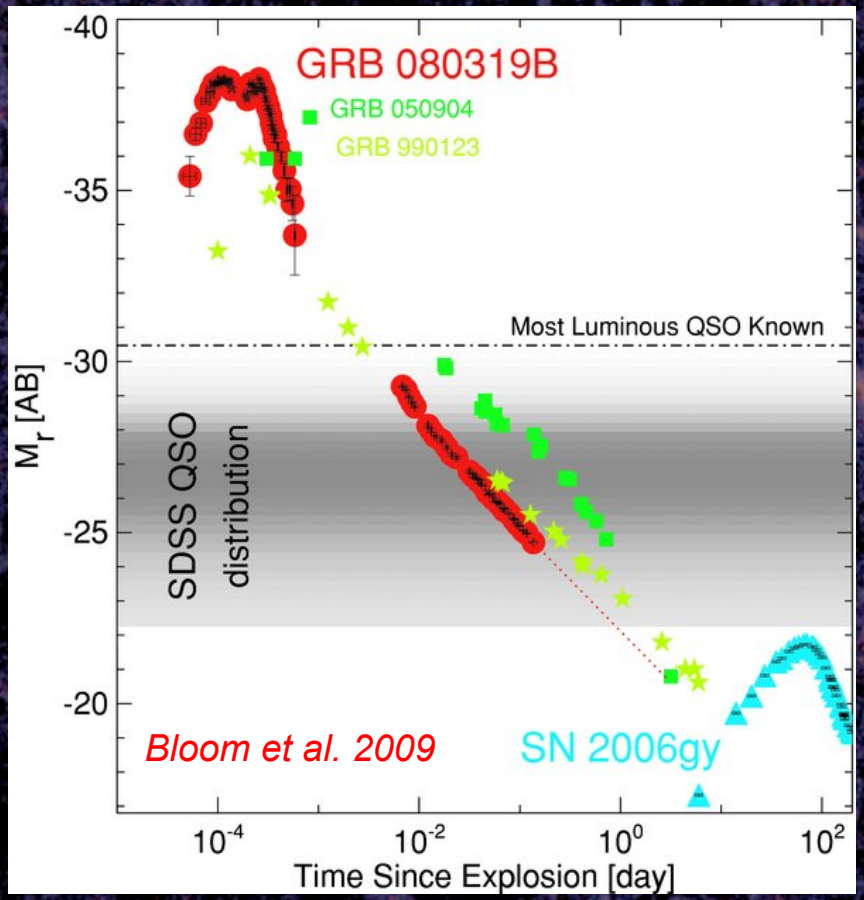
Using GRBs to Find the First Stars

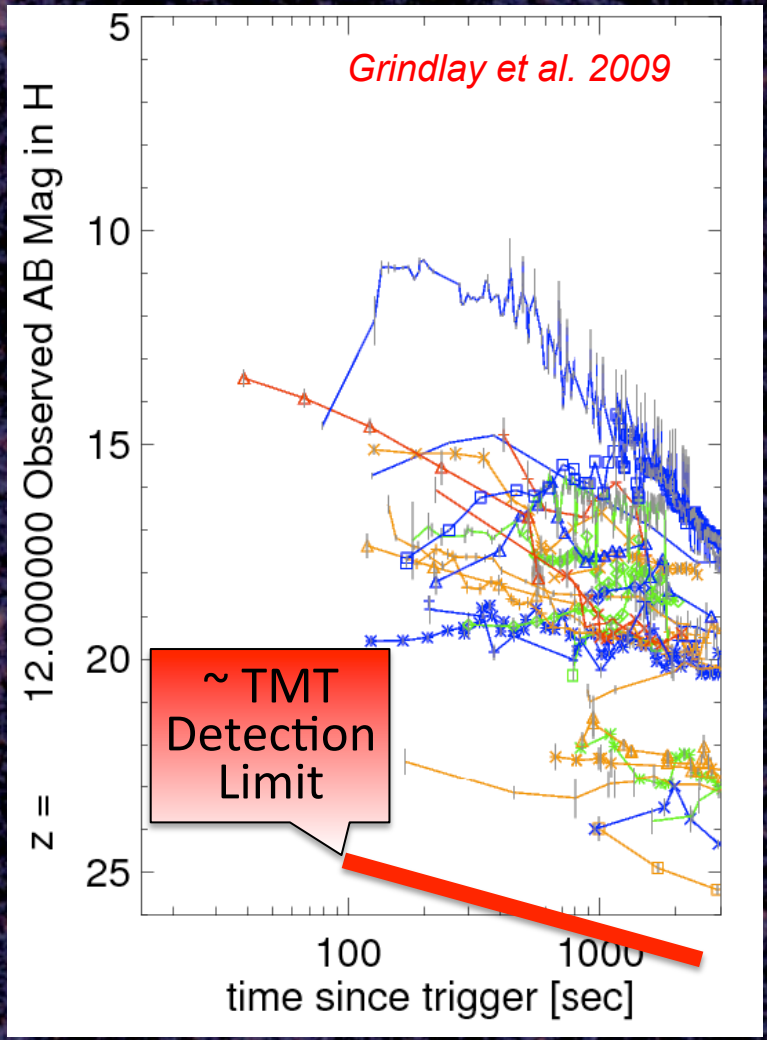
- GRBs may be the only way to observe these distant objects directly
  - JWST won't know where to look
  - Probability of finding one by chance extremely low
- Caveat: unclear that Pop III stars explode as GRBs
- If not, we will still see some of the earliest stars (Pop II)
  - GRB 090423 (z = 8.2)

GRBs are in the Early Universe



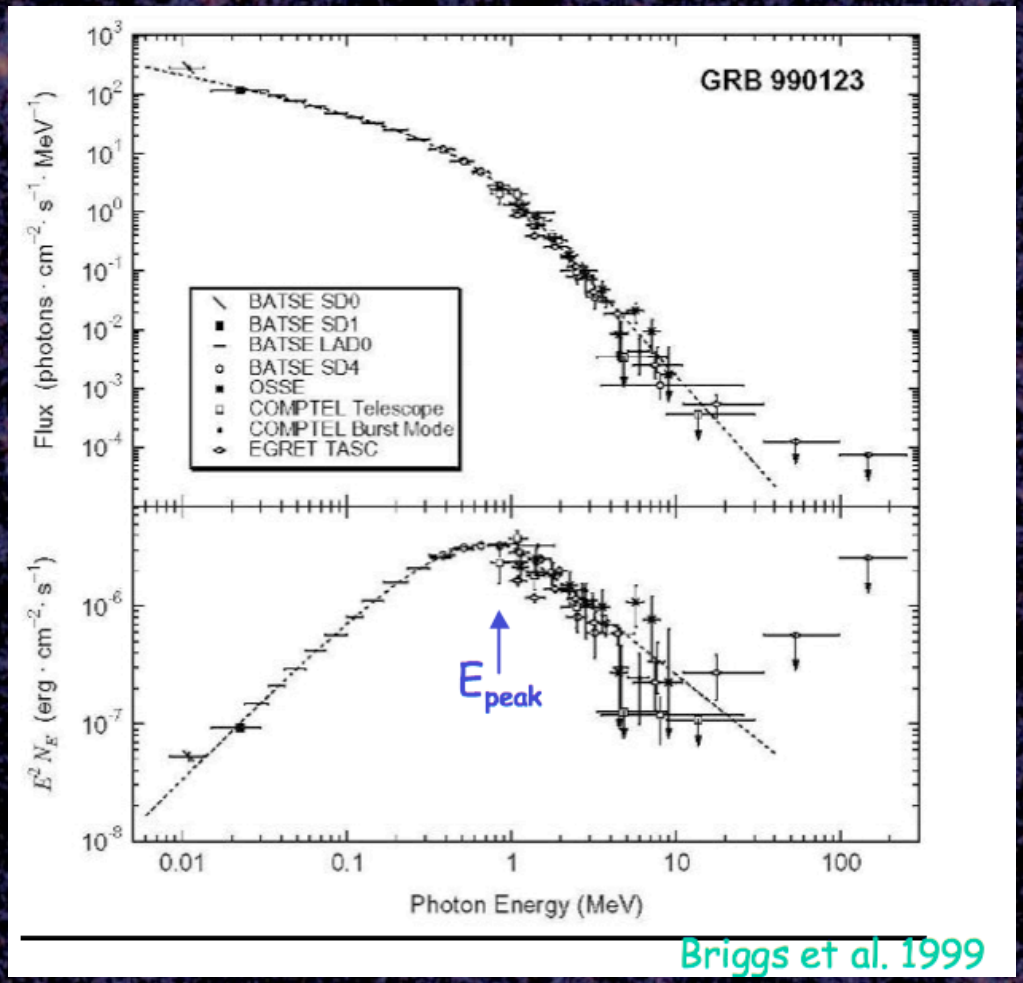
GRBs are Bright!



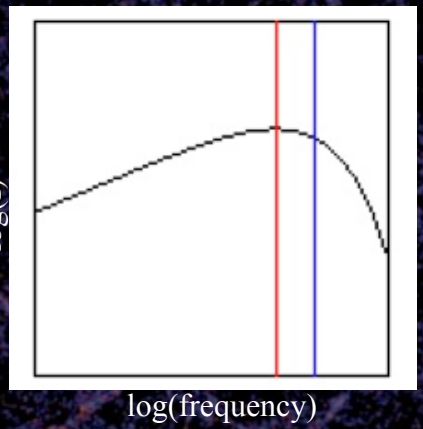


Ideal GRB Spectral Properties for Probing

Non-thermal, smoothly joint broken power-law spectrum



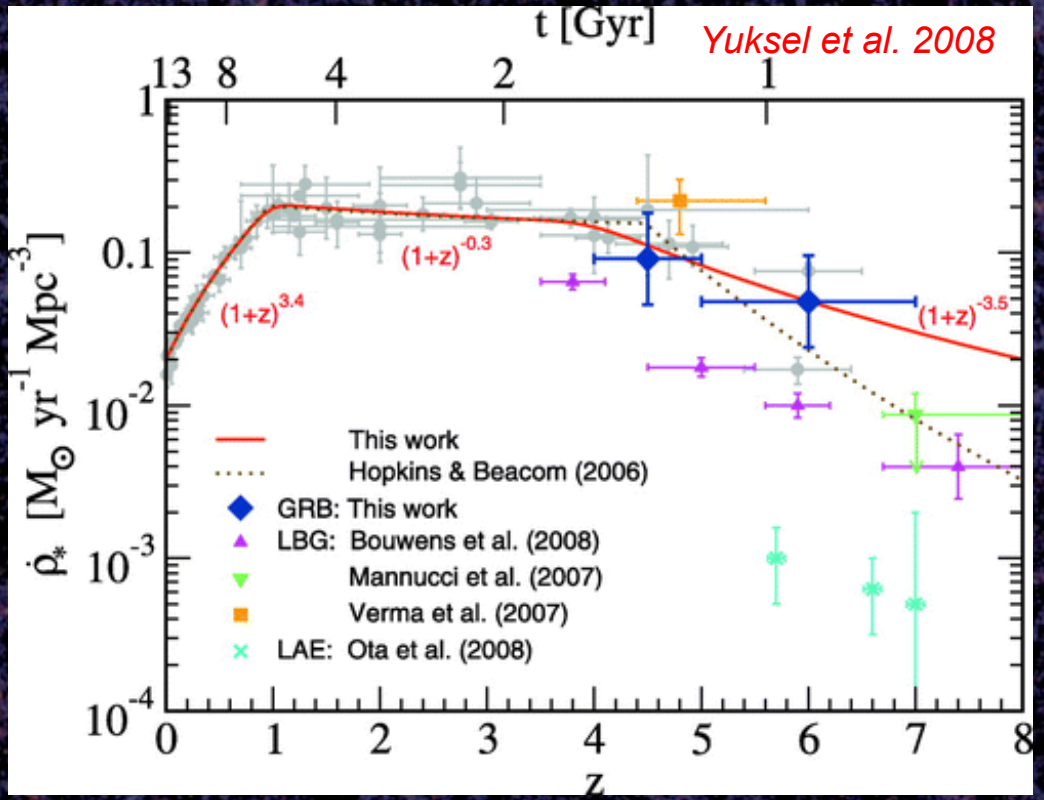
Briggs et al. 1999



GRBs are not powered by a hot gas in equilibrium, but are powered by accelerated relativistic electrons not in thermal equilibrium.

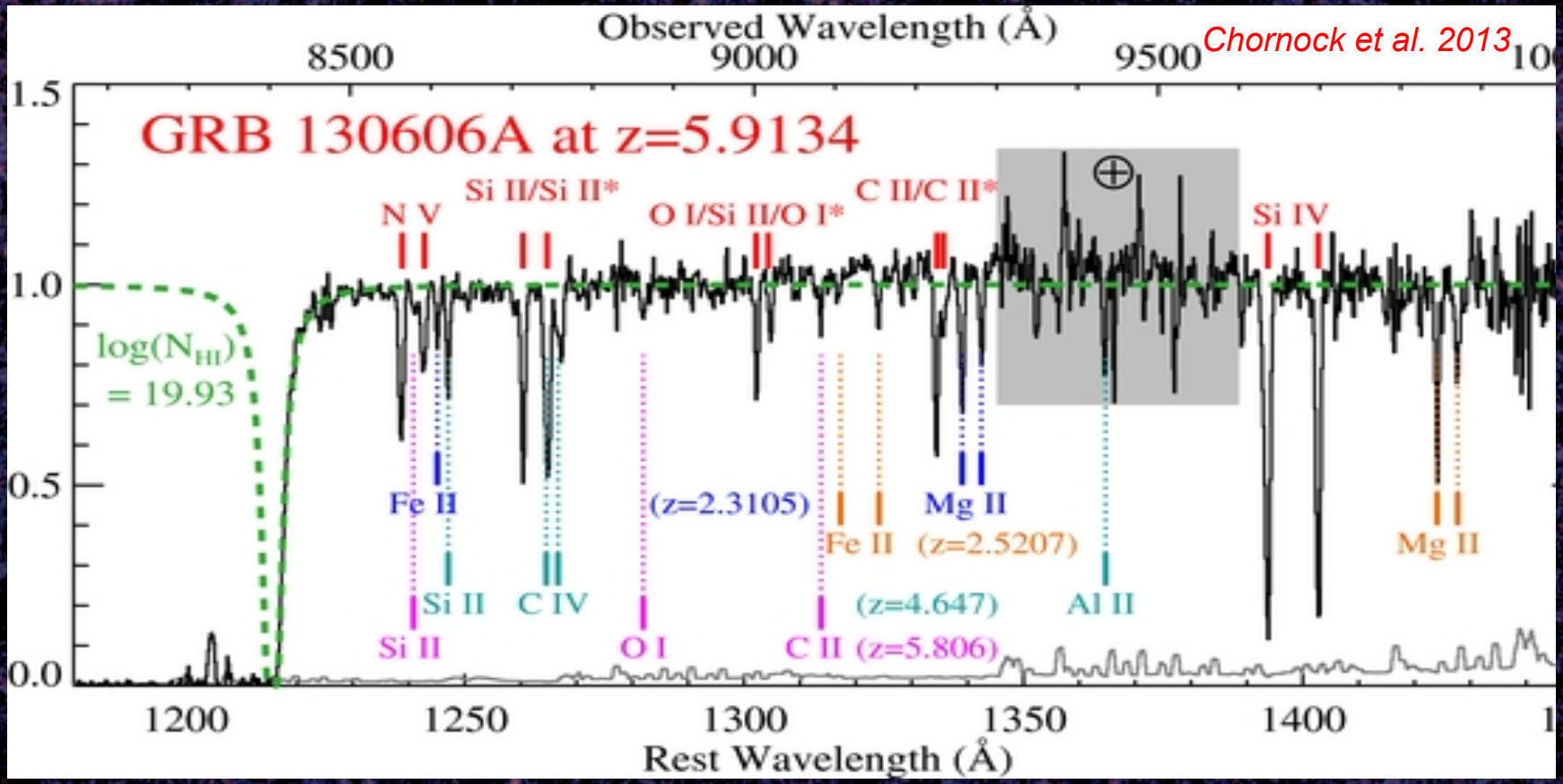
Determining Massive SFR with GRBs

- Most star formation at z>10 is in galaxies fainter than 1nJy
  - This is fainter that what the JWST can see
- GRBs select high-z galaxies independent of host galaxy luminosity



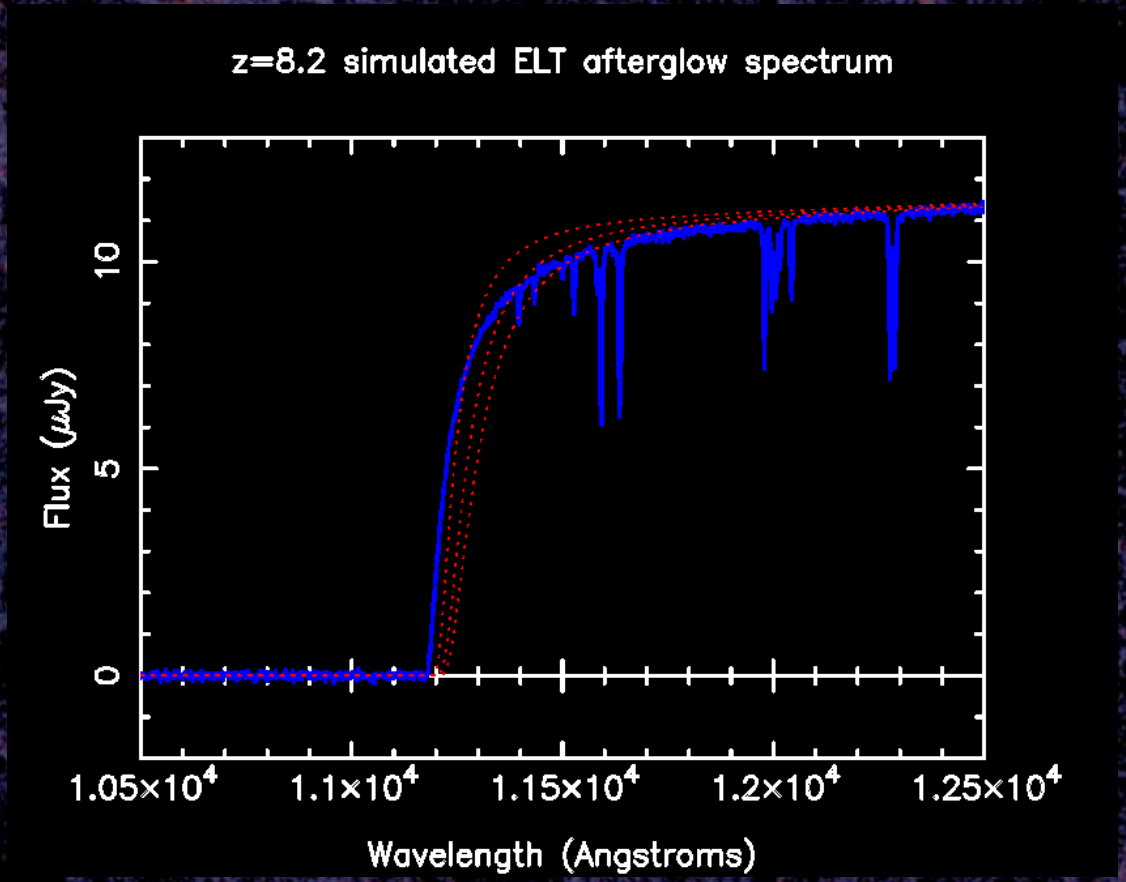
See also Ranga-Ram Chary's Talk

Determining Environments with GRBs



Afterglow spectroscopy with IRIS can provide *z*, HI column density of host, chemical abundances, dust, & info on intervening systems

ELT Simulated Afterglow Spectrum



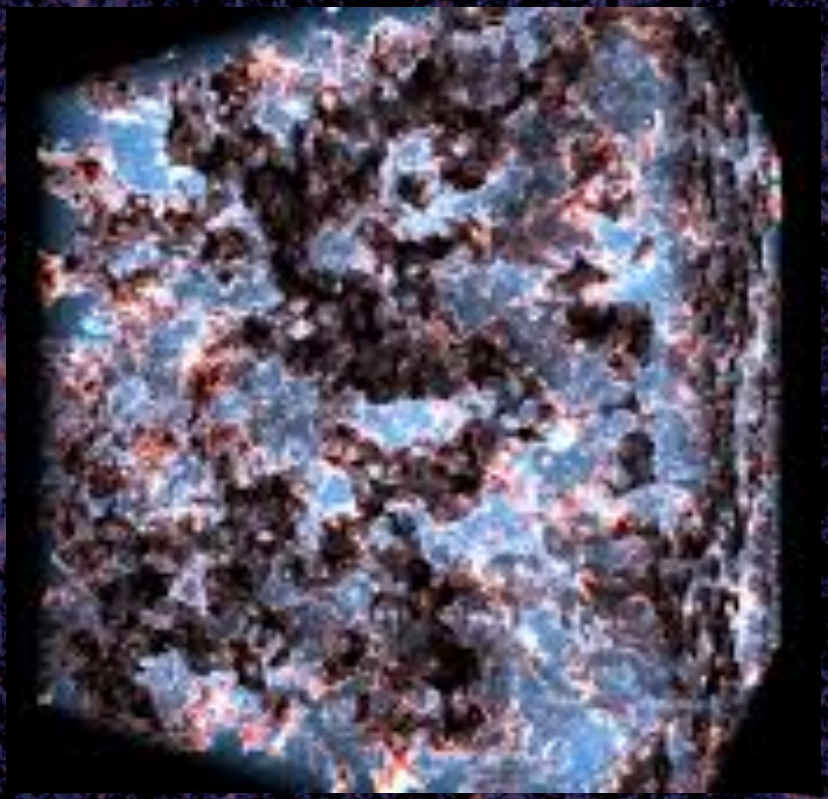
Little gas in host ⇒ good characterization of IGM.

Much gas in host ⇒ superb metallicity determinations.

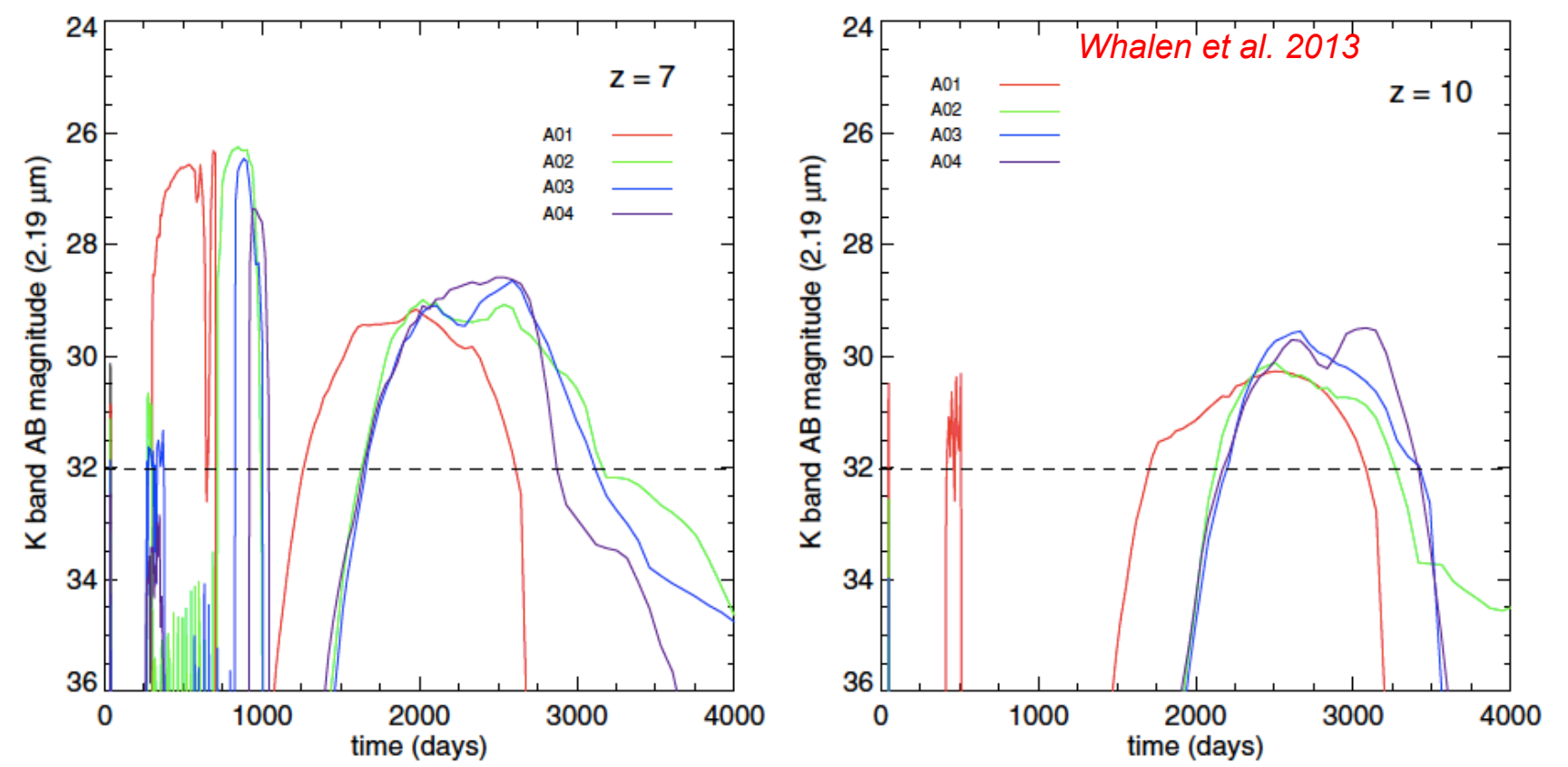
Simulated GRB090423 spectrum taken by ELT rather than VLT (remember this was a faint afterglow!)

Probing Reionization with GRBs

- Multiple GRB Sight Lines Addresses:
  - When reionization began
  - When it ended
  - Is it cnsistent with other sources?
    - If not, why?
  - Is it smooth or patchy?



Using IIn SNe to Find the First Stars



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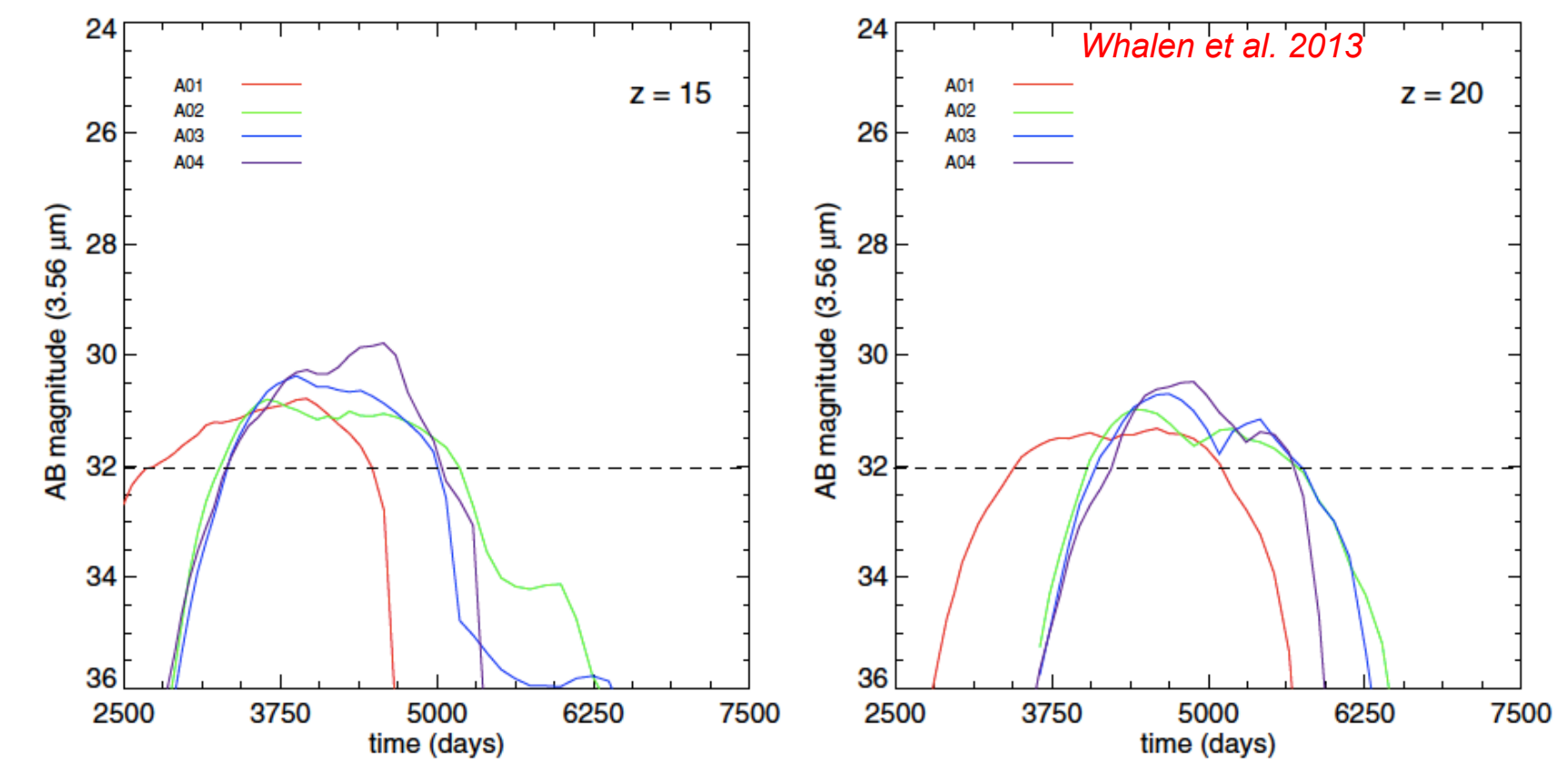
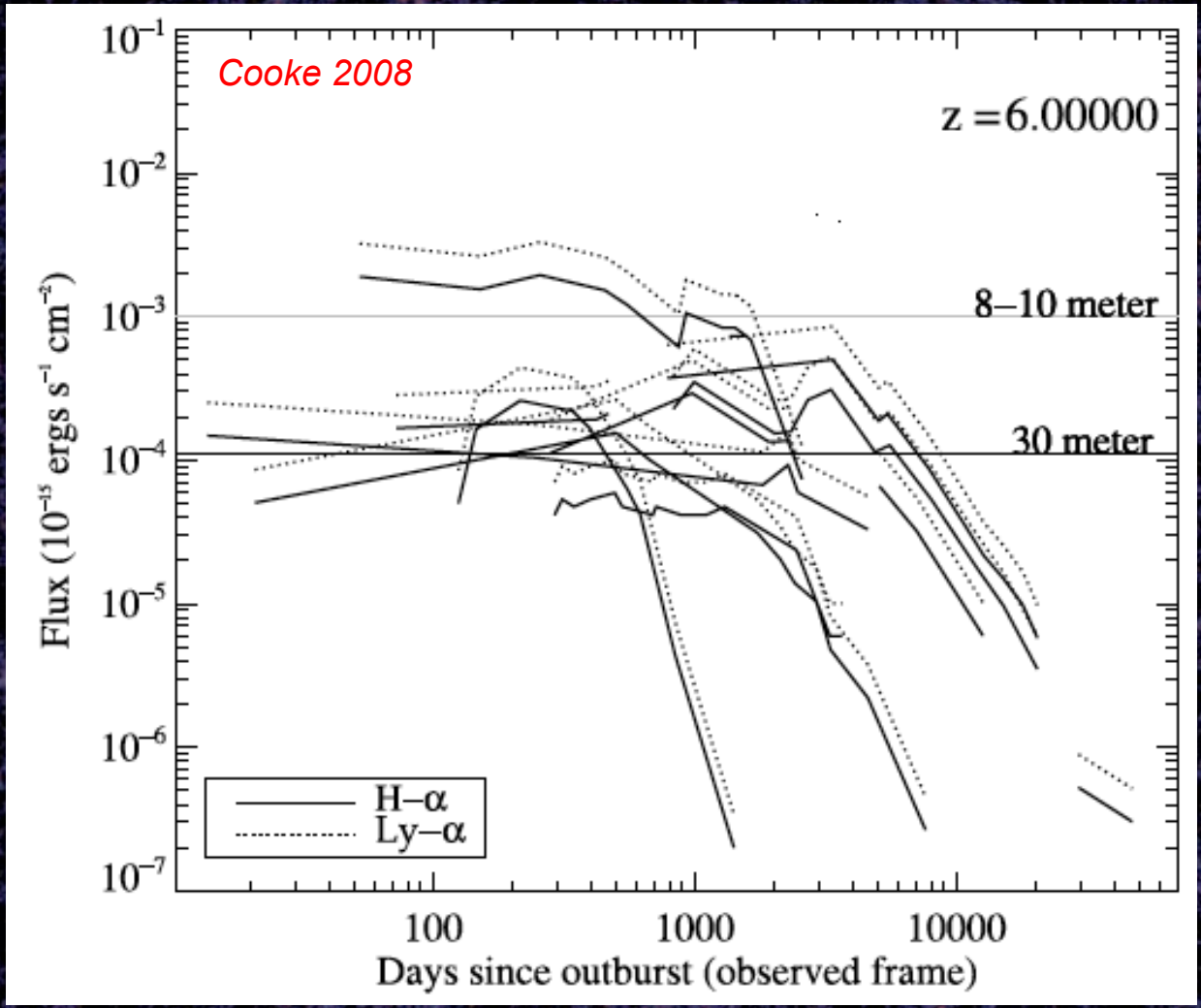


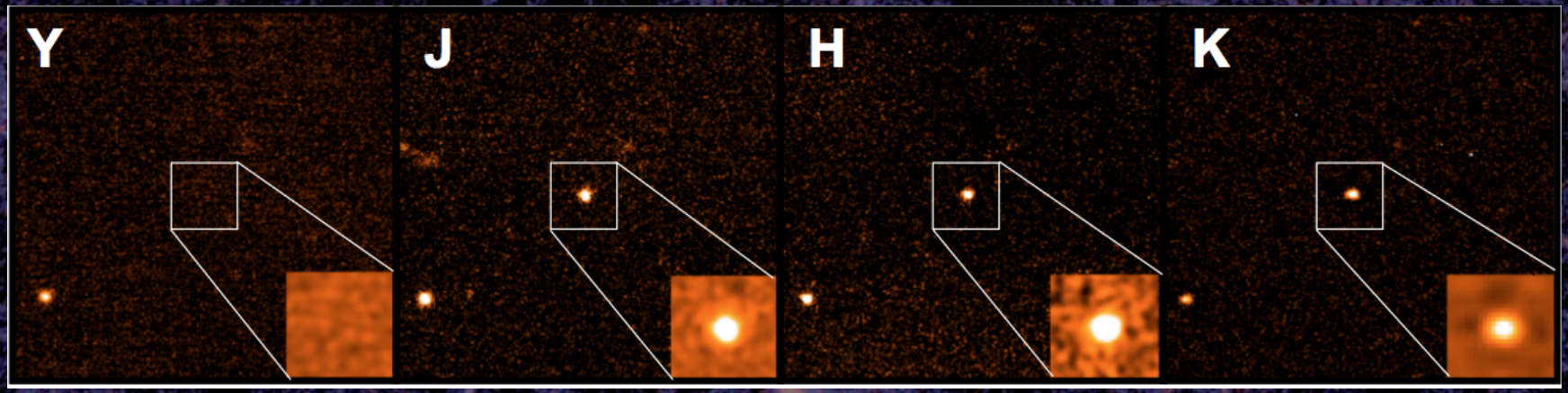
Using IIn & SLSNe to Probe Environments

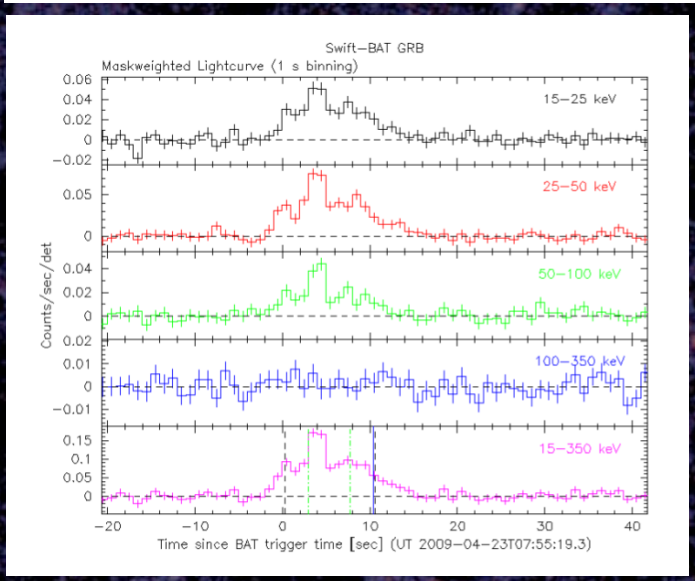
- Finding shock break outs at high-*z* will aid in probing the progenitors
  - Helped by time dilation



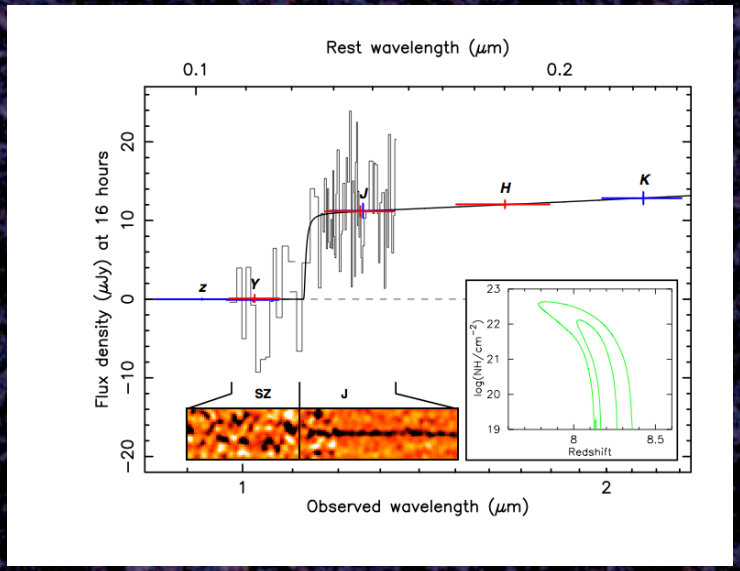
Is It a High-z GRB?

Tanvir et al. 2009

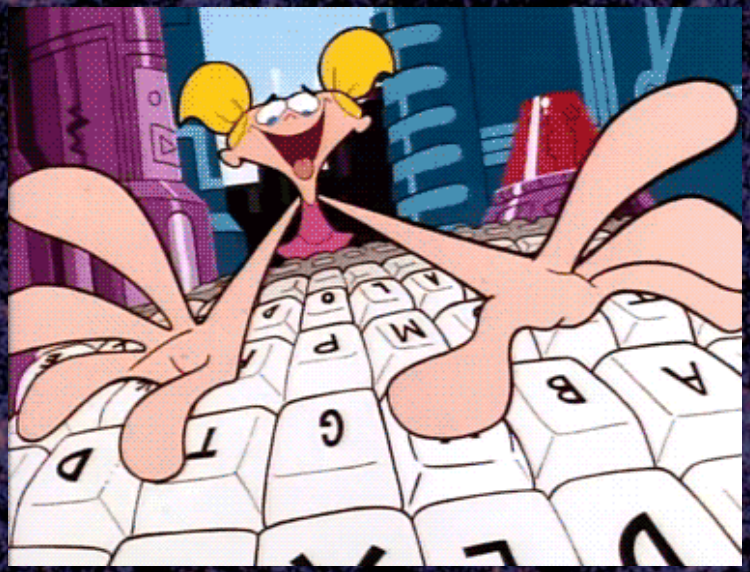




Current missions don't tell us anything about the redshift



Problem with No "*A Priori*" Redshifts



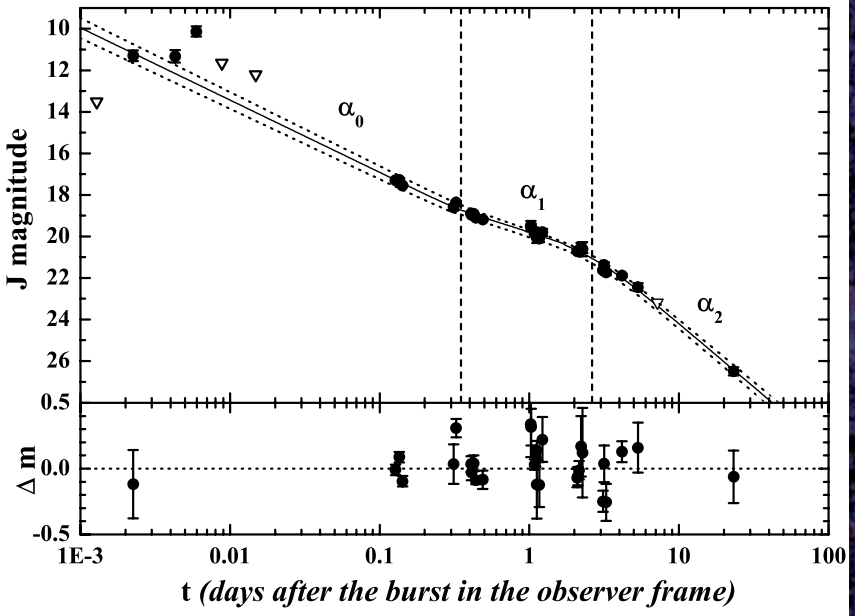
First few GRB alerts

100th GRB alert

You want to interrupt my telescope time?!?

Problem with No *A Priori* Redshifts

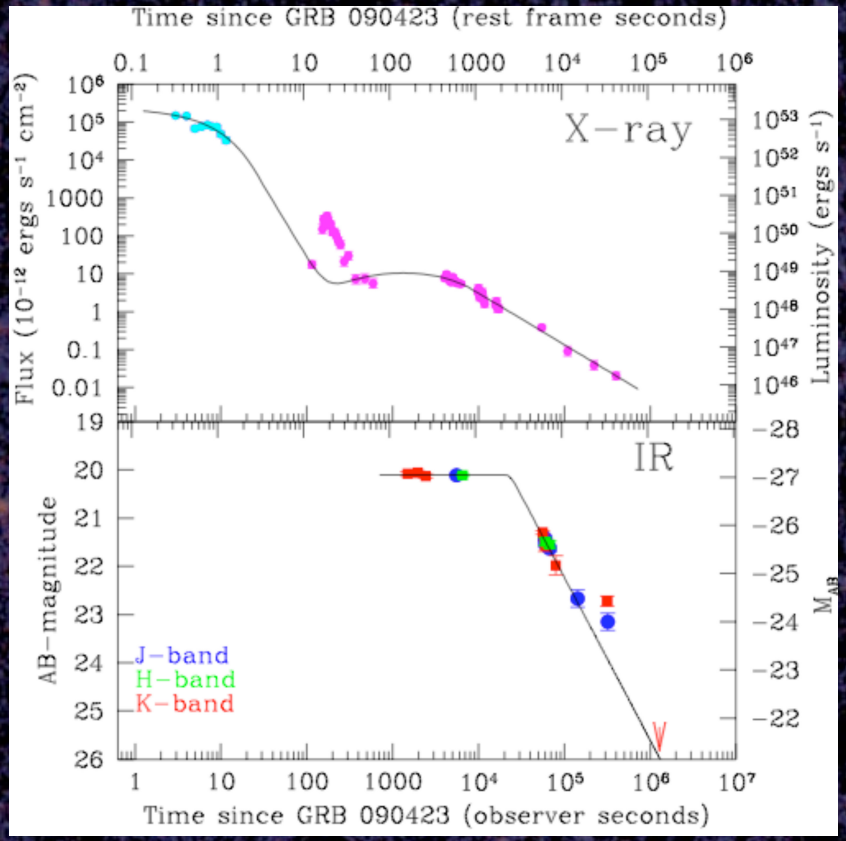
GRB 050904



Kann et al. 2007

GRB	$t_{Photo-z}$	$t_{Spectra-z}$	z
050904	10 hrs	3.5 dys	6.3
080913	10 hrs	11 hrs	6.7
090423	7 hrs	24 hrs	8.2

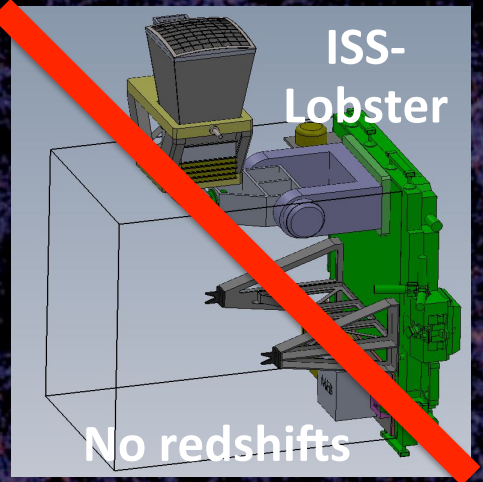
GRB 090423

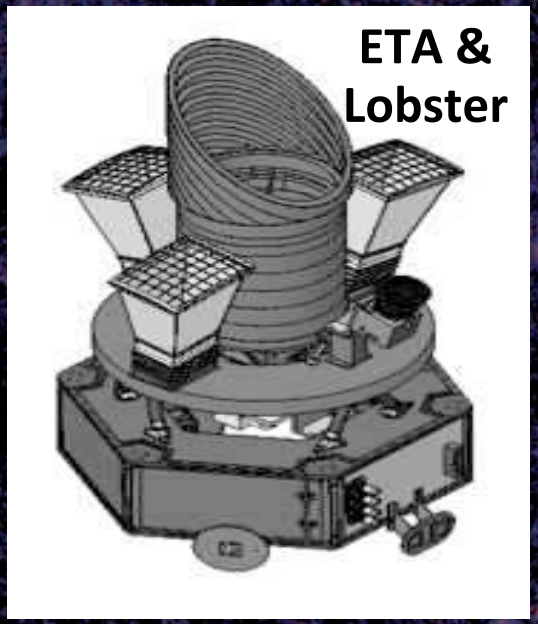


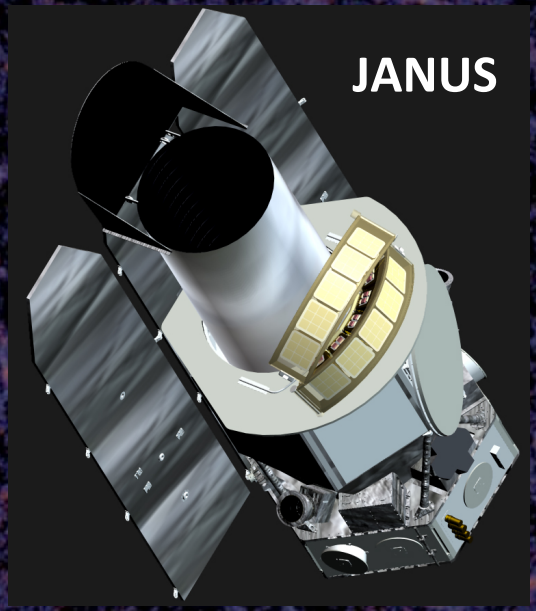
Tanvir et al. 2009

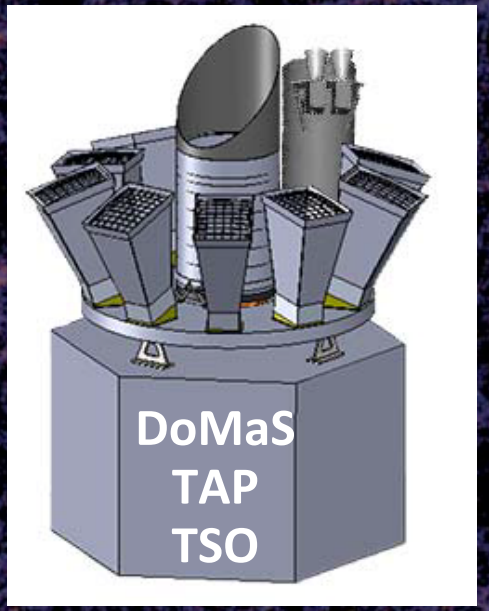
~30 min

Future GRB Missions During TMT?









TMT Observations of GRBs & SNe Crucial

- We must have GRB triggering capability, coupled with *a priori* redshift determinations, during the era of TMT!
- LSST will provide thousands of SNe per year. Sifting thru those that TMT should observe is currently a challenge.
  - We are developing the Supernova Analysis Application (SNAP) which will quickly type the SNe based on light curve and model comparisons
  - Future should include redshift estimation
  - http://snap.space.swri.edu