SVOM workshop - May 2018

Optical Spectroscopy of Cosmic Transients

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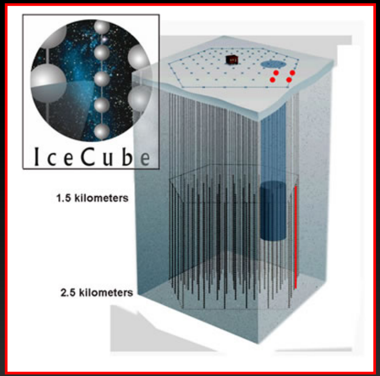
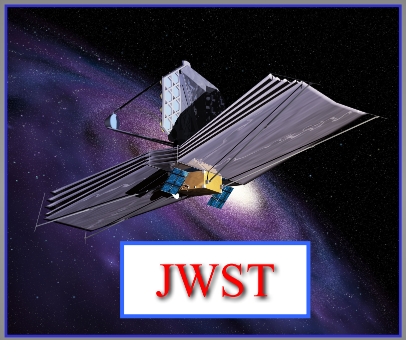
Probes of universe

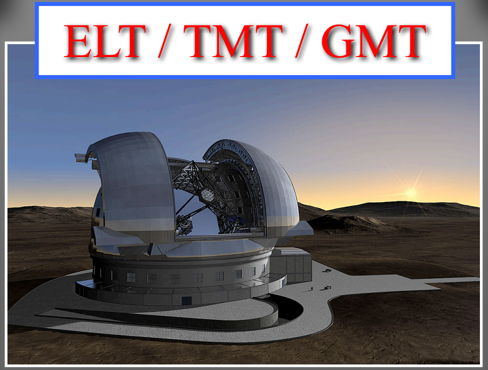
Physics of the explosion itself

The galactic environments

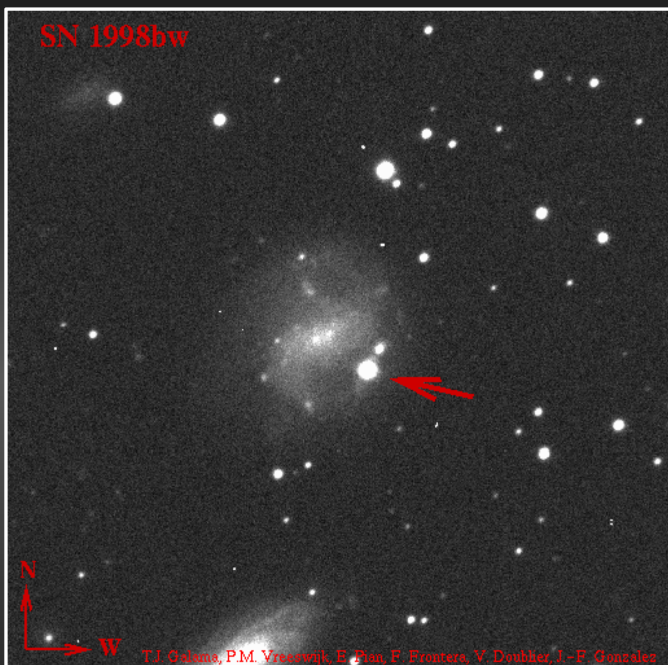
The developing landscape

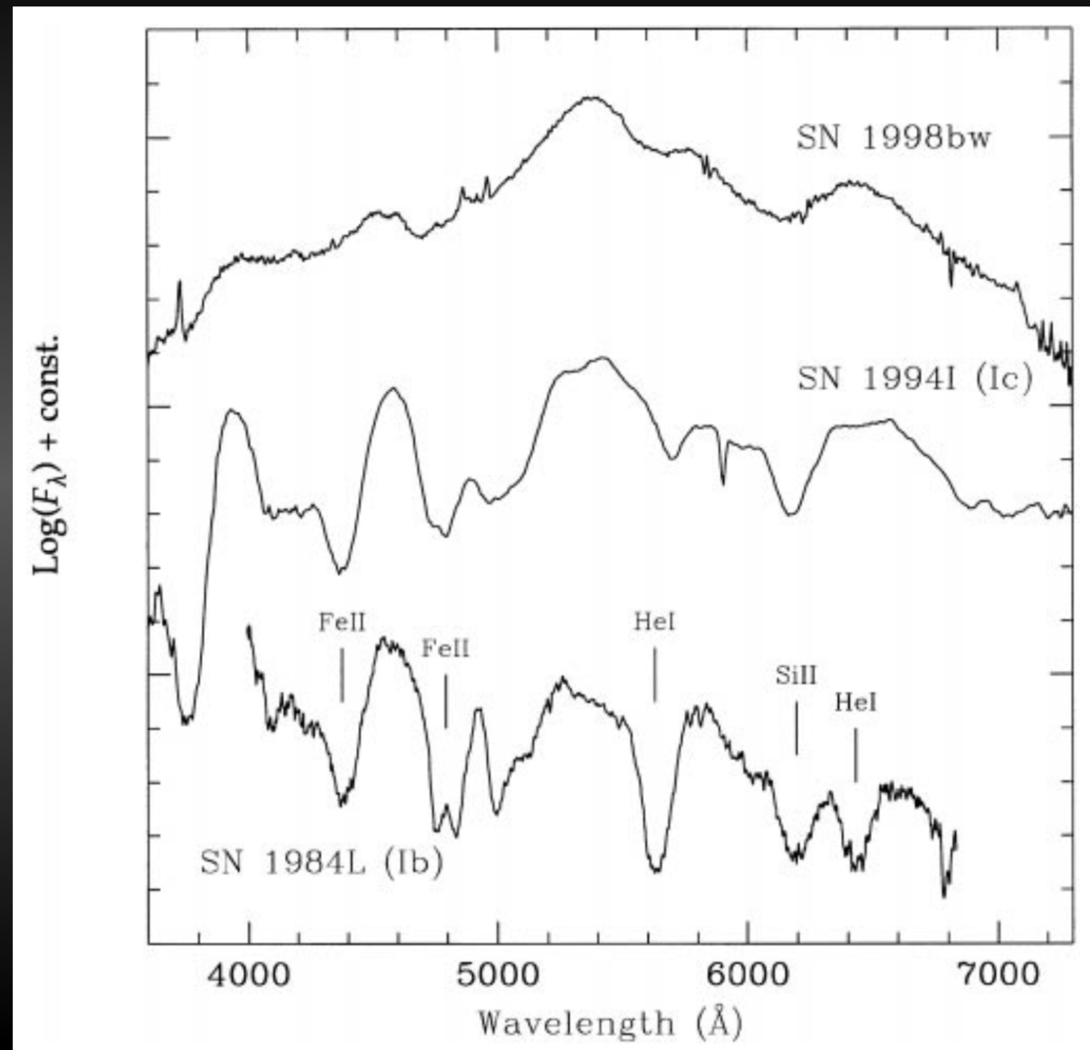






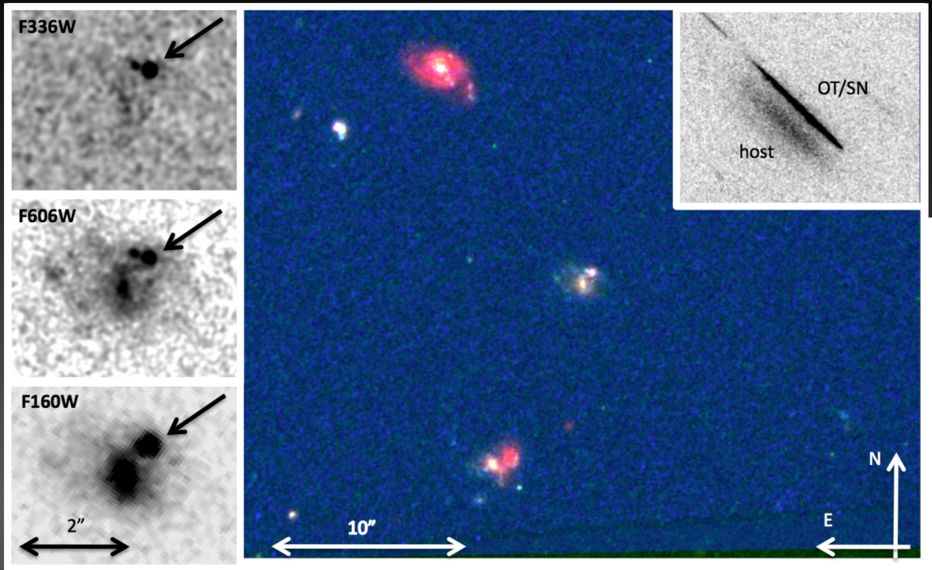
GRB 980425/SN1998bw





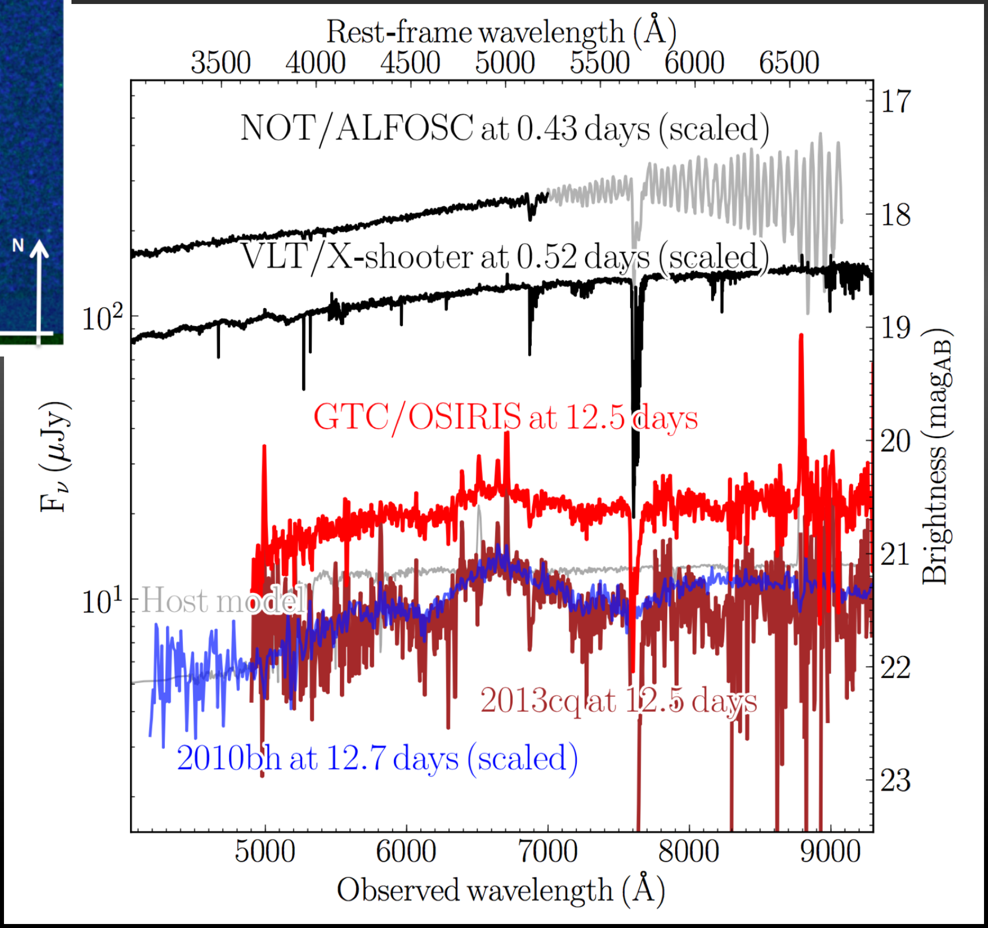
Galama et al. 1998

GRB 130427A/SN2013cq



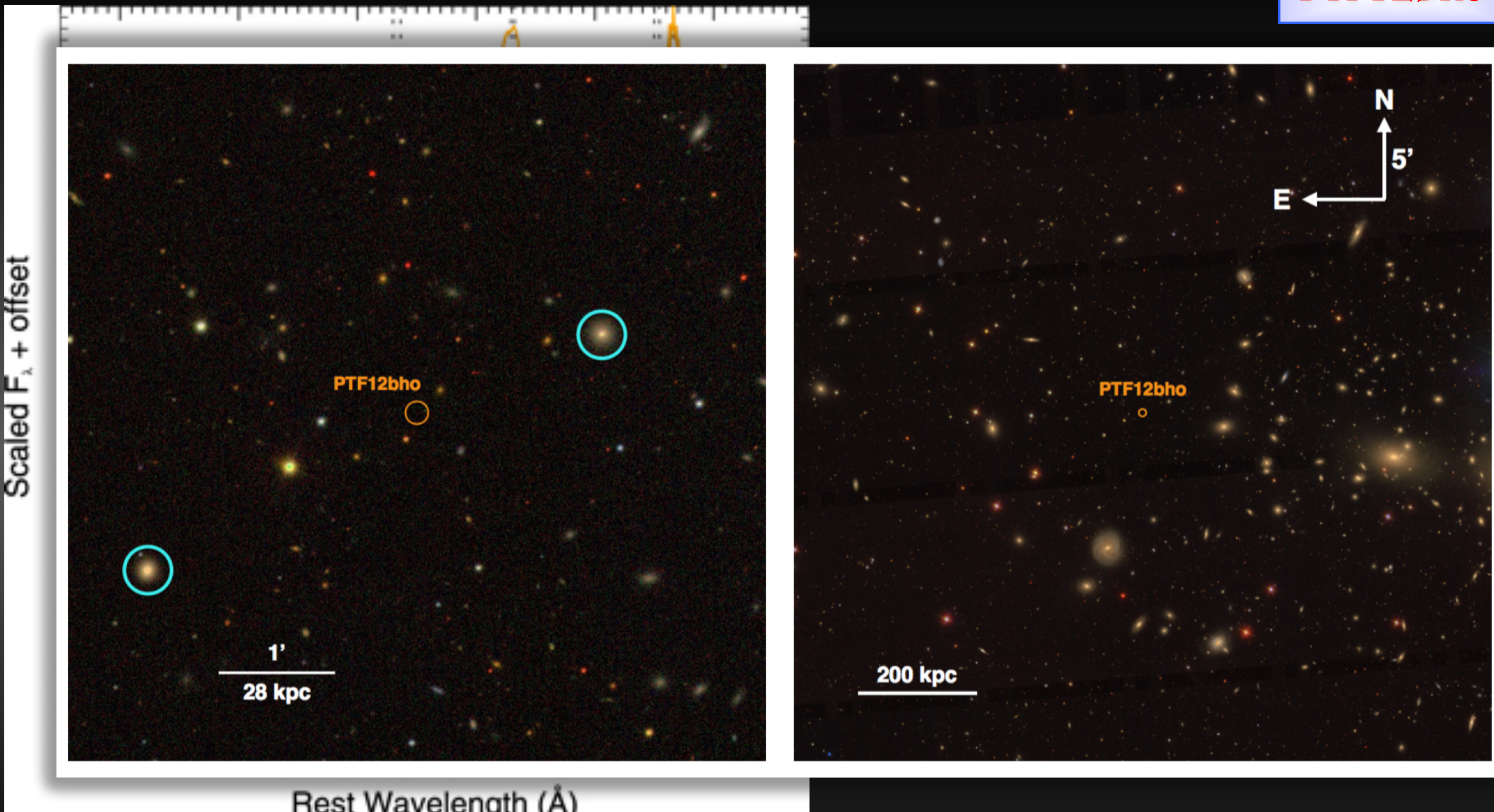
Levan et al. 2014

Xu et al. 2013



Ca-rich supernovae

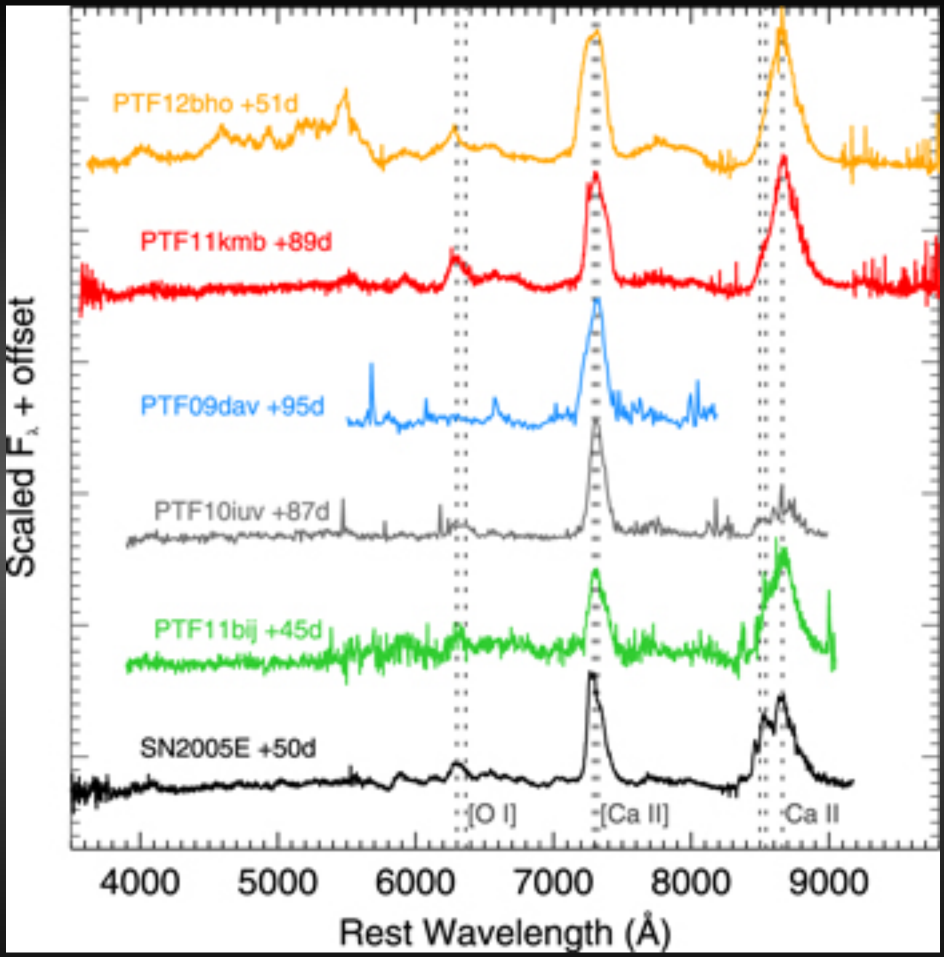
PTF12bho



Faint; fairly high volume density; early spectra indicate stripped envelope.

Lunnan et al. 2017

Ca-rich "gap" transients

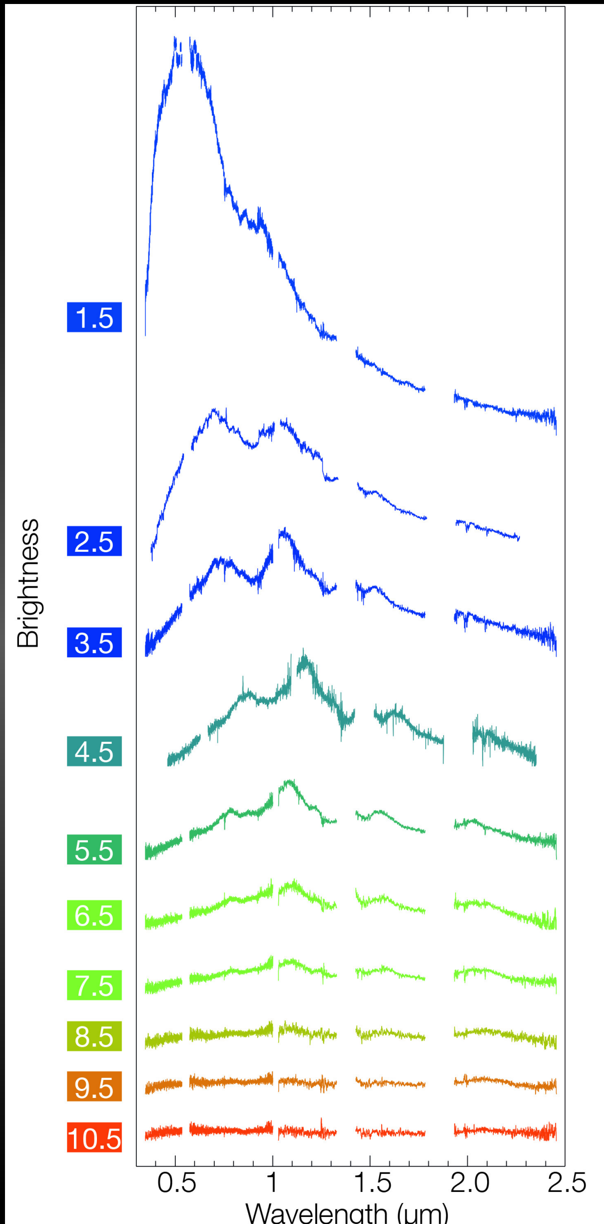


Remote cases may be He-CO WD binaries kicked by interaction with central SMBH.

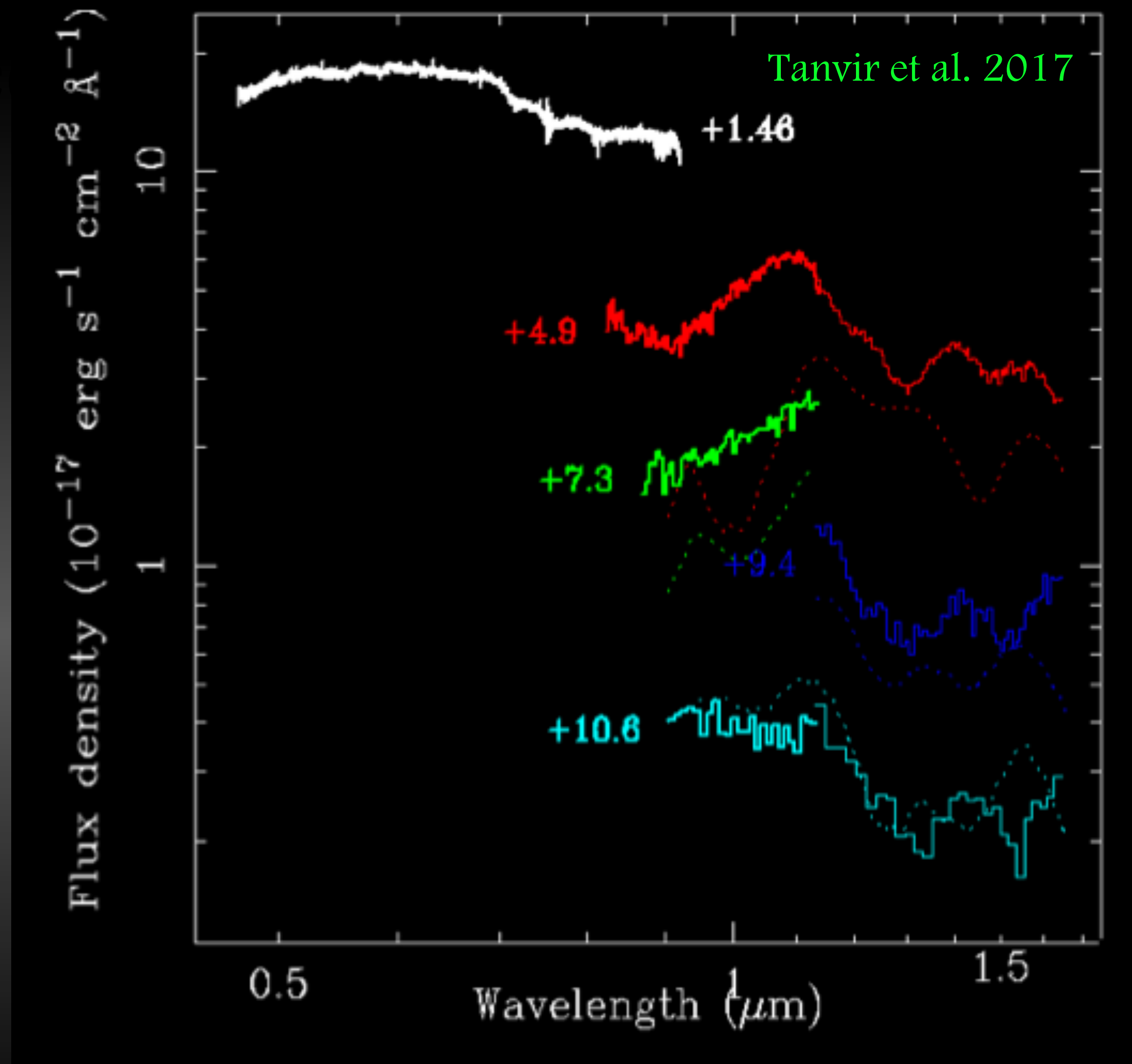
Moriya et al. 2017 suggest some could be ultra-stripped cores in binaries with compact object. After explosion left with NSNS binary.

Faint; fairly high volume density; early spectra indicate stripped envelope.

Lunnan et al. 2017



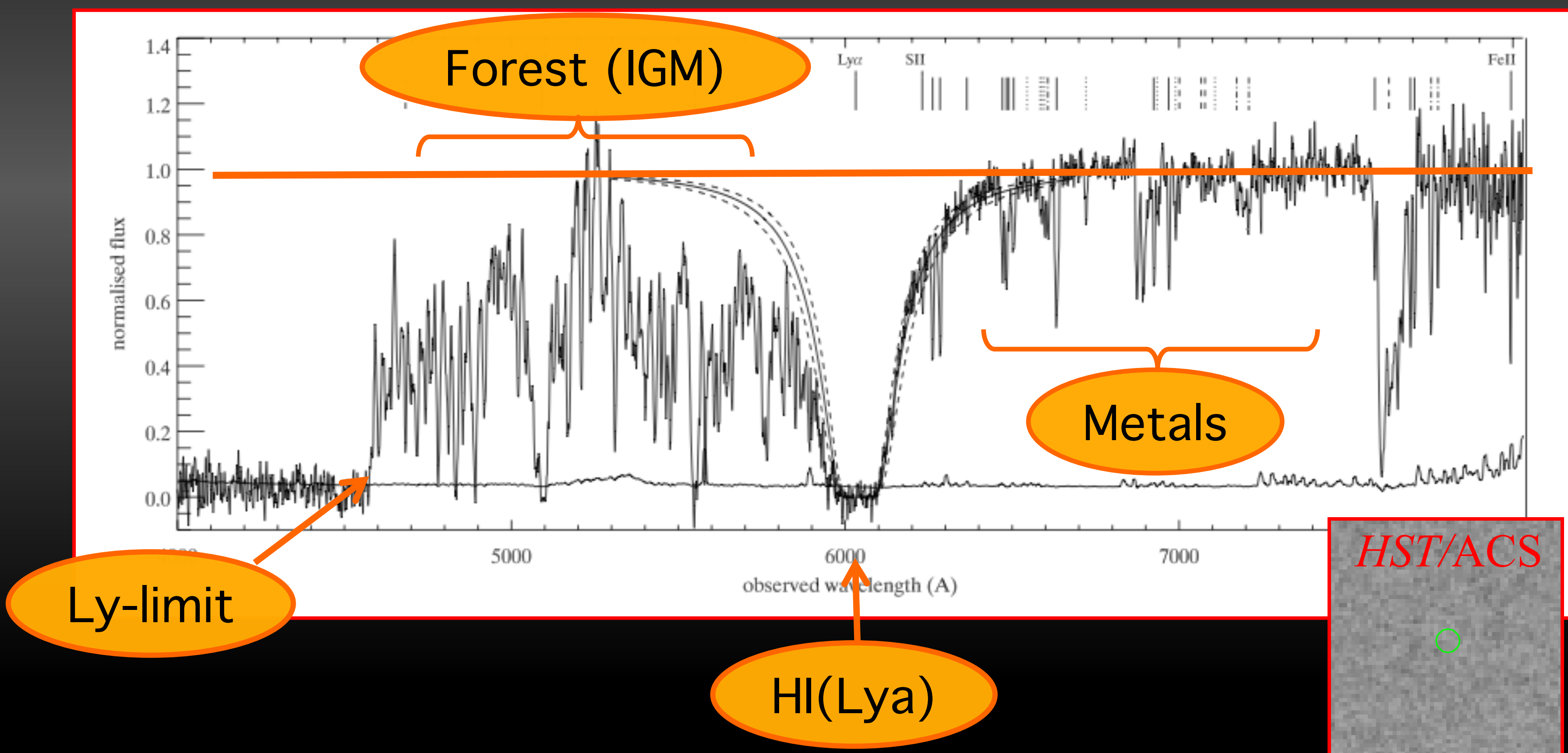
Pian et al. 2017; Smartt et al. 2017



Broad features indicate v>~0.1c, and roughly match neodymium models of Kasen et al. 2013.

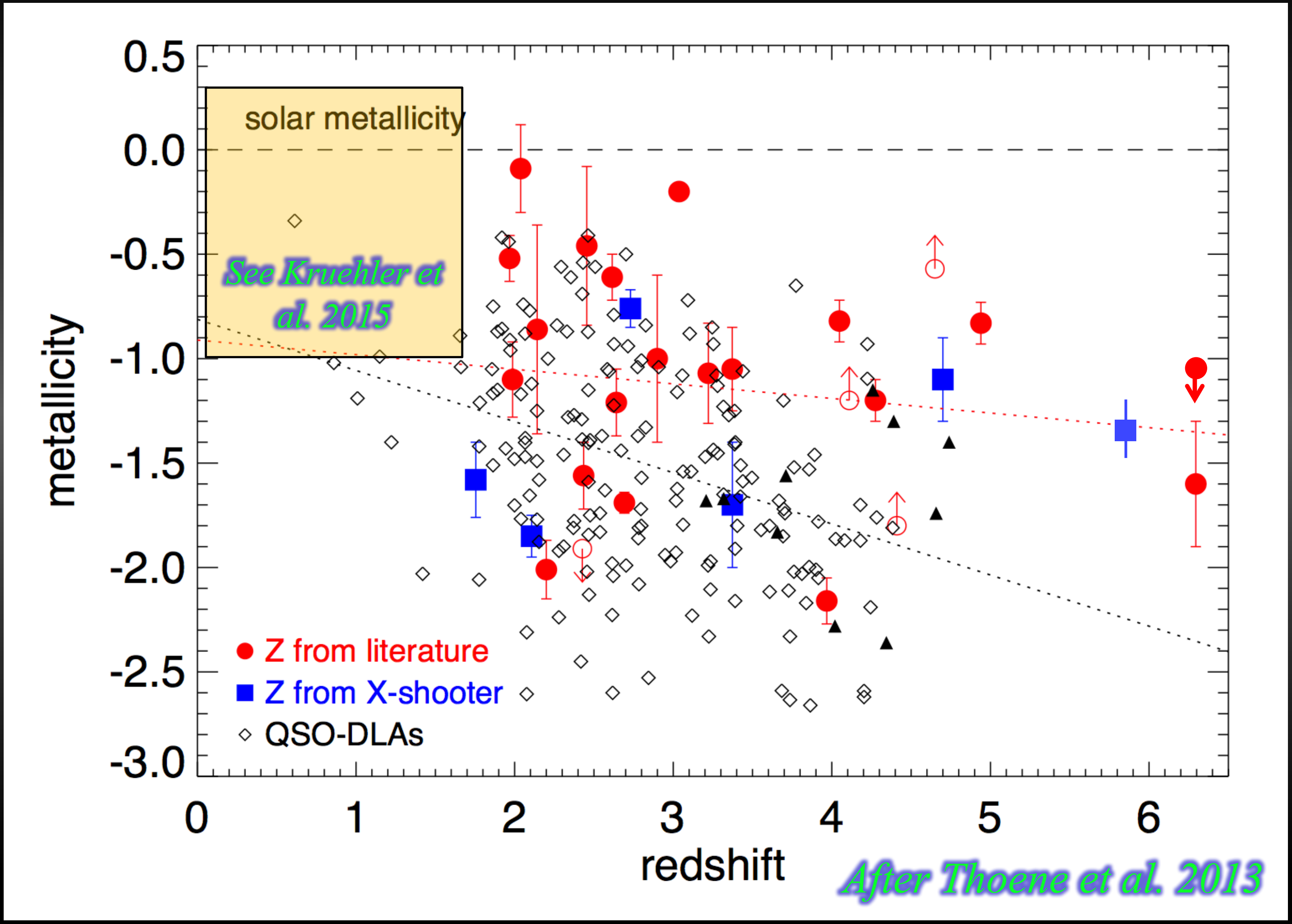
Afterglow spectra contain much information

Abundances, HI, dust, dynamics etc. even for very faint hosts. E.g. GRB 050730: faint host (R>28.5), but z=3.97, [Fe/H]=~2 and low dust, from afterglow spectrum (Chen et al. 2005; Starling et al. 2005).

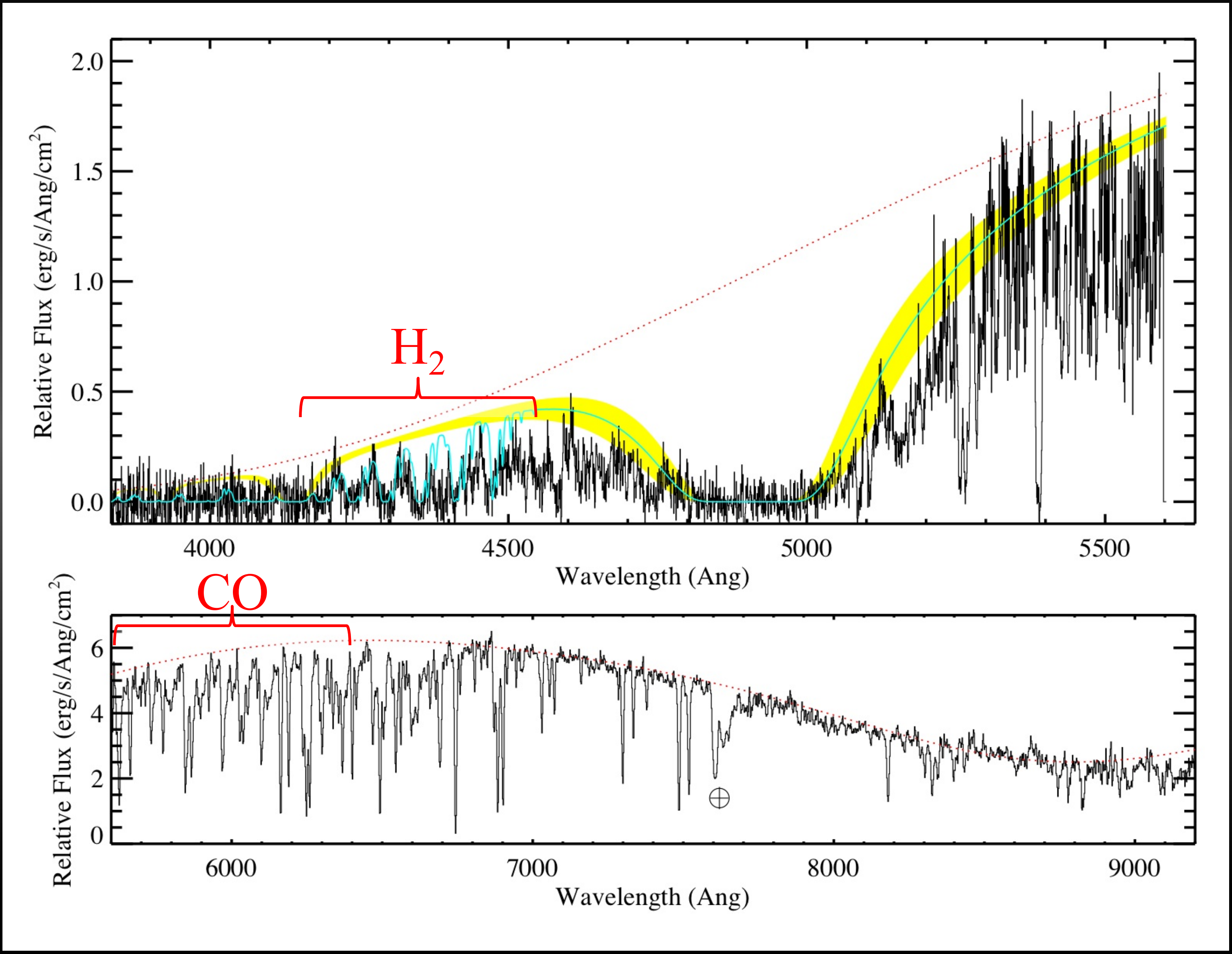


Metalicity

From hosts and afterglow spectroscopy, mostly low (at least ~sub-solar) metallicity.

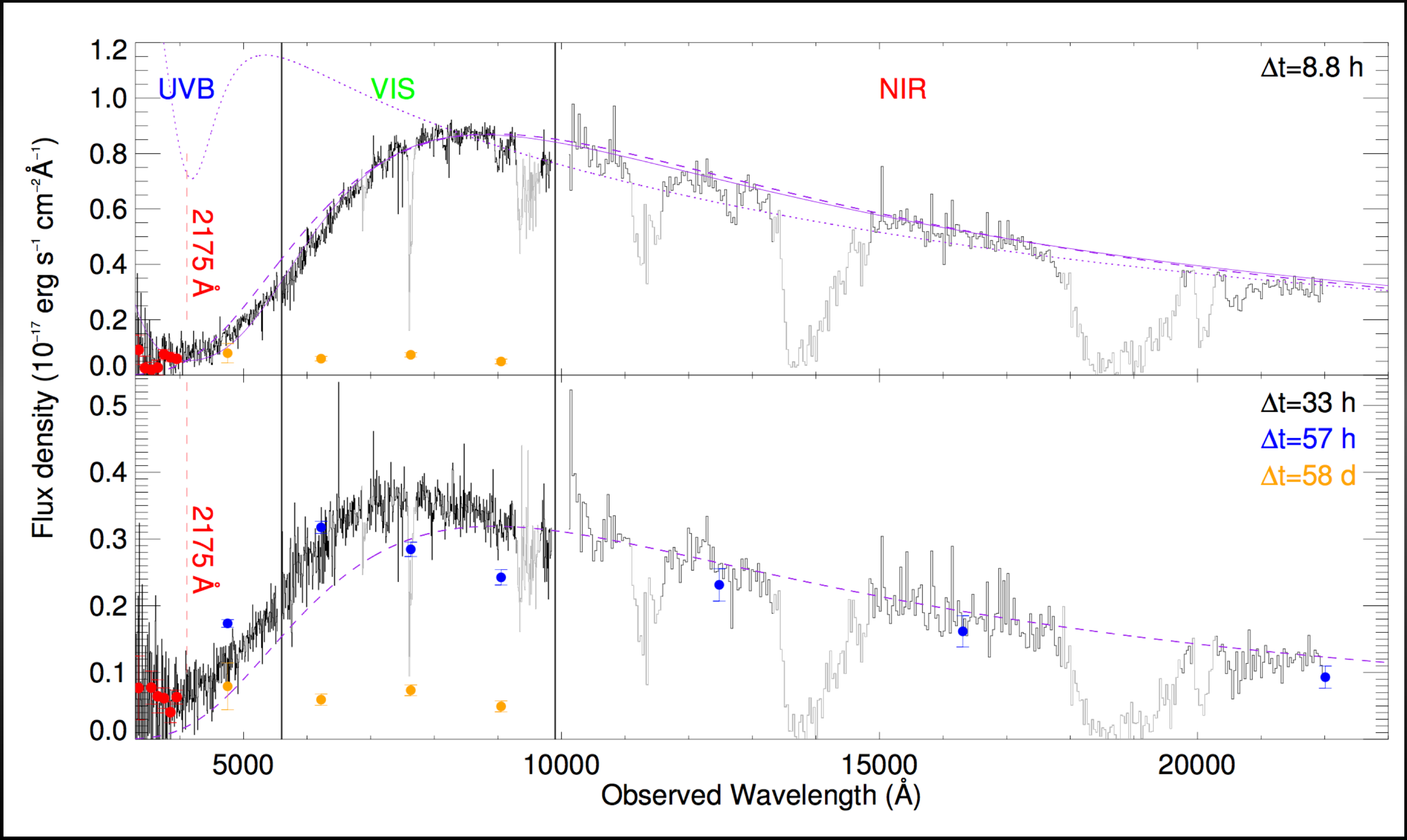


Molecules



Prochaska et al. 2009

GRB 140506A



Fynbo et al. 2015, Heintz et al. 2017

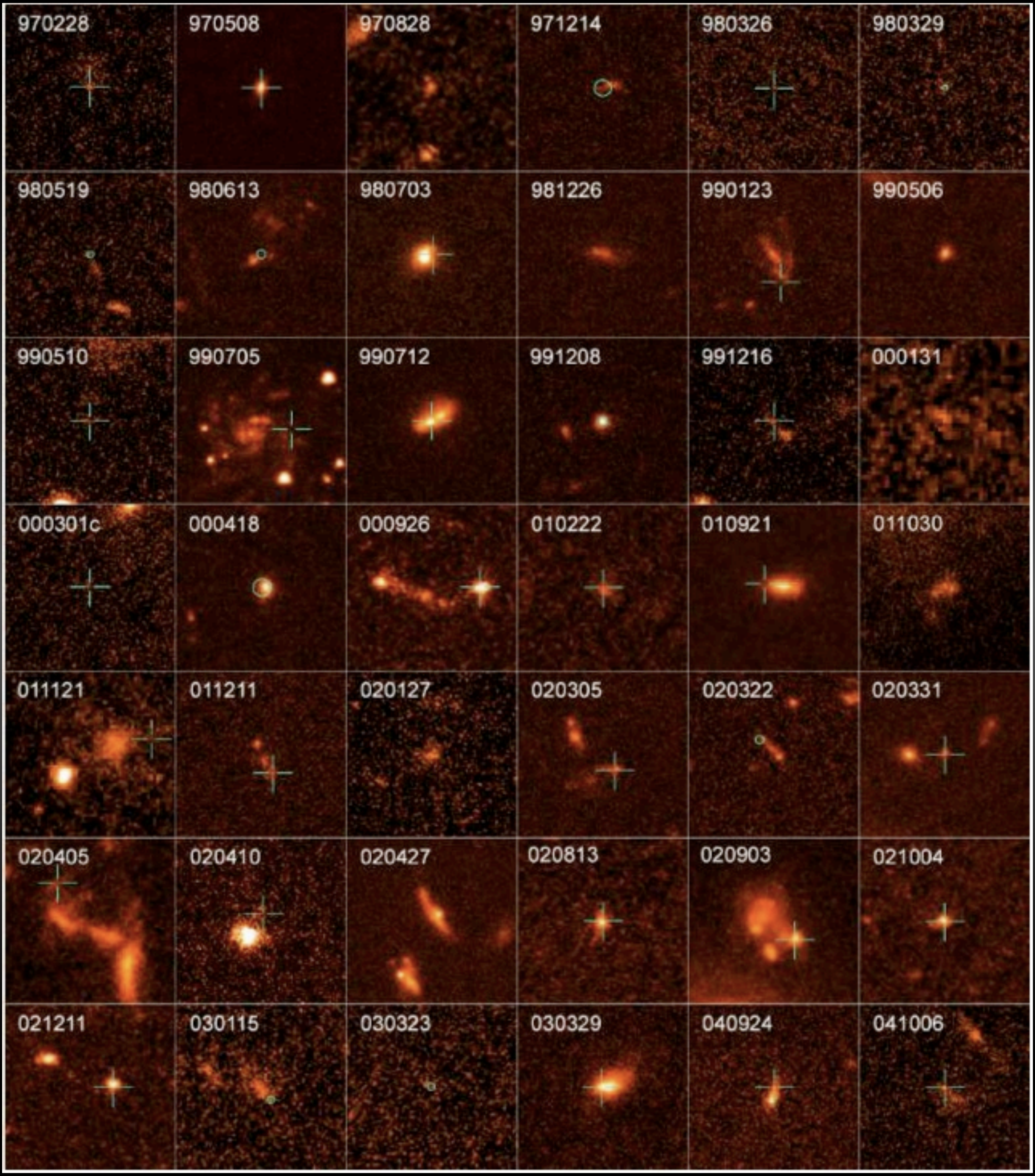
$z = 0.89$

Hosts

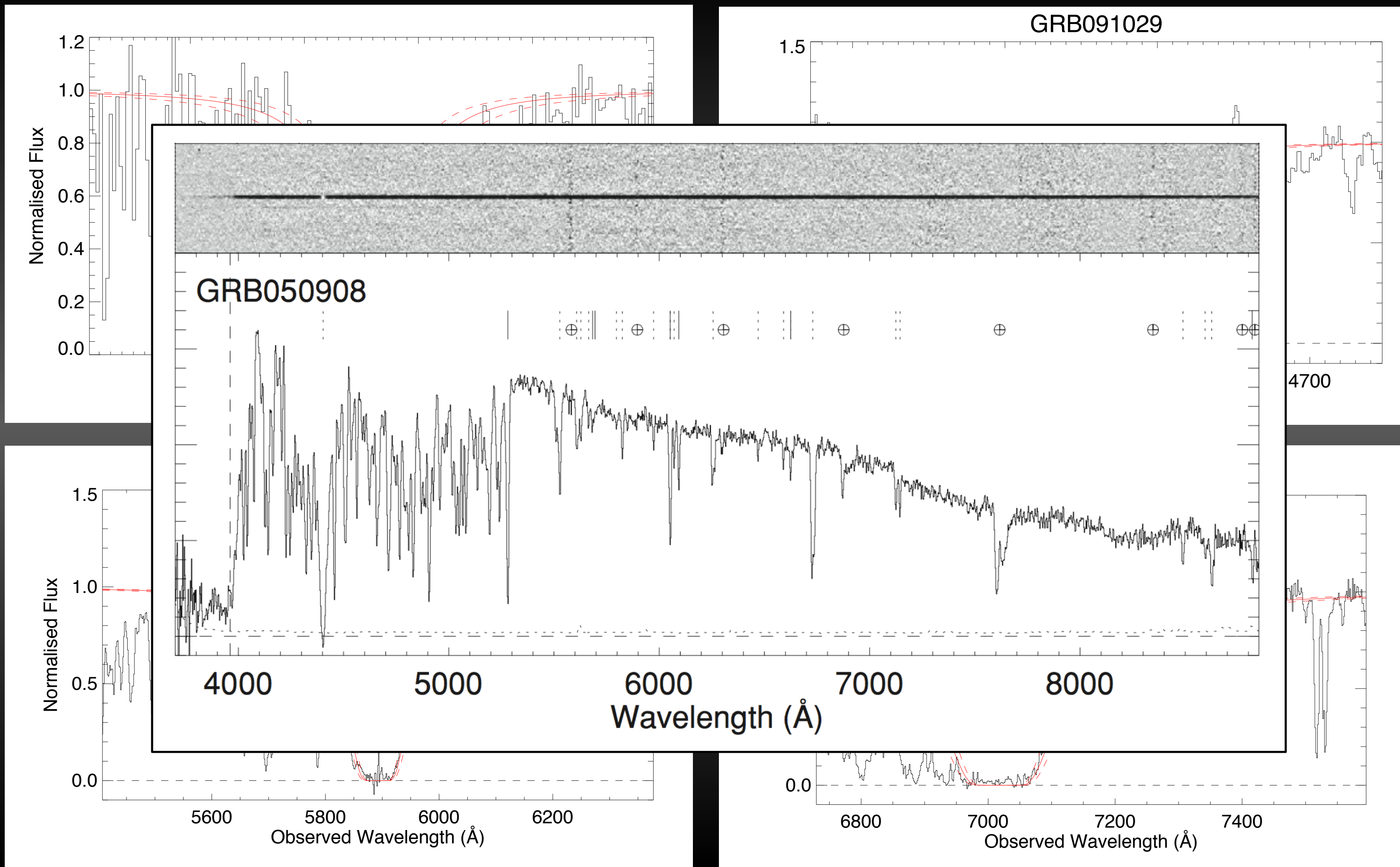
Actively star forming, typically low luminosity, irregular, low(ish) metallicity.

Generally trace brightest regions of star formation, suggestive of short-lived (<~10 Myr) massive star progenitor.

Fruchter et al. 2006



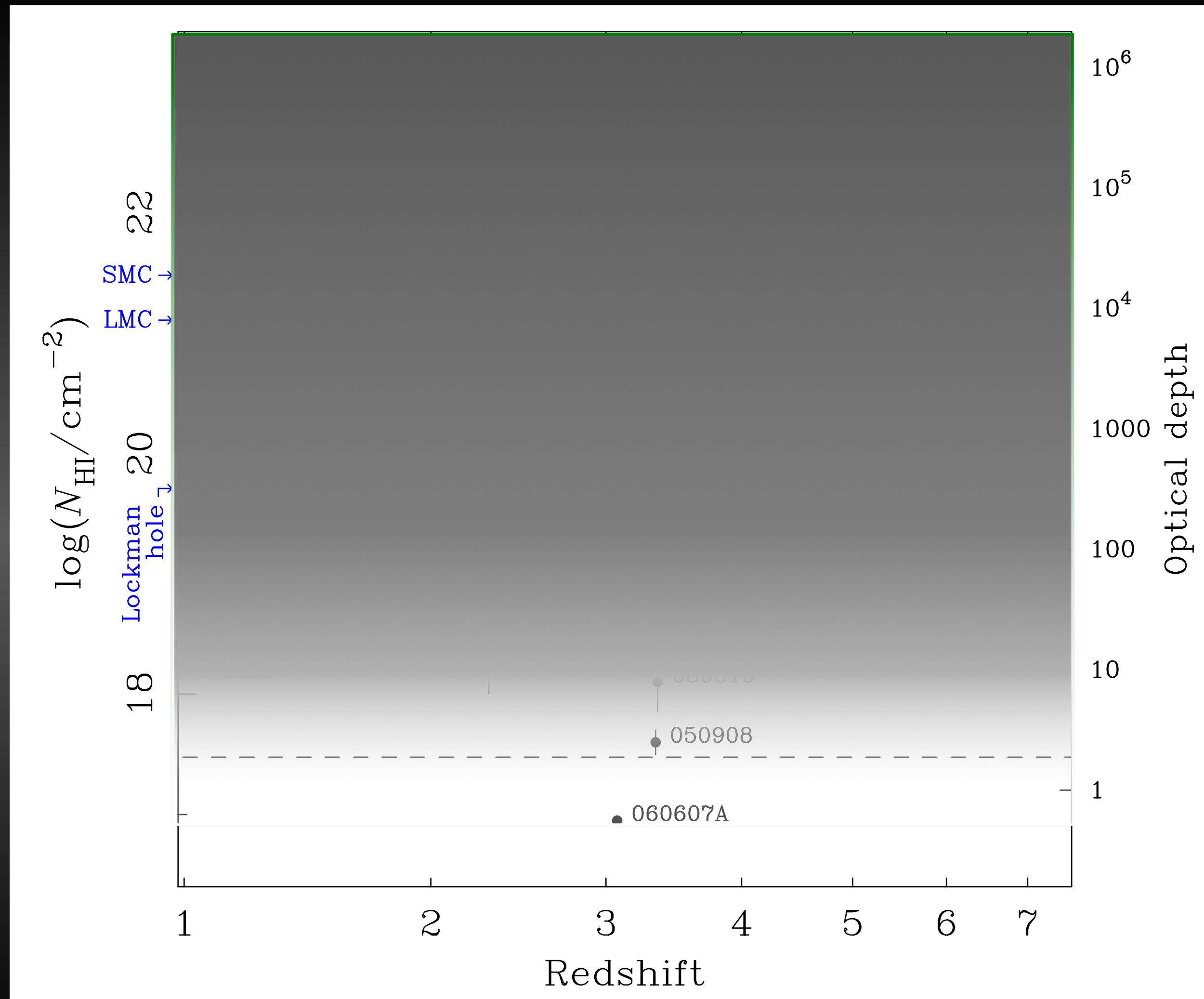
HI column density from Ly-a absorption in afterglow spectra



Provides direct upper limit on escape fraction on each line of sight.

HI column density evolution

Reionization requires escape fraction ~20%



High column densities seen in optical spectra of most 2<z<5 GRBs suggest escape fractions for these stellar pops of <1.5 %.

NT et al. (subm.)

HI column density evolution

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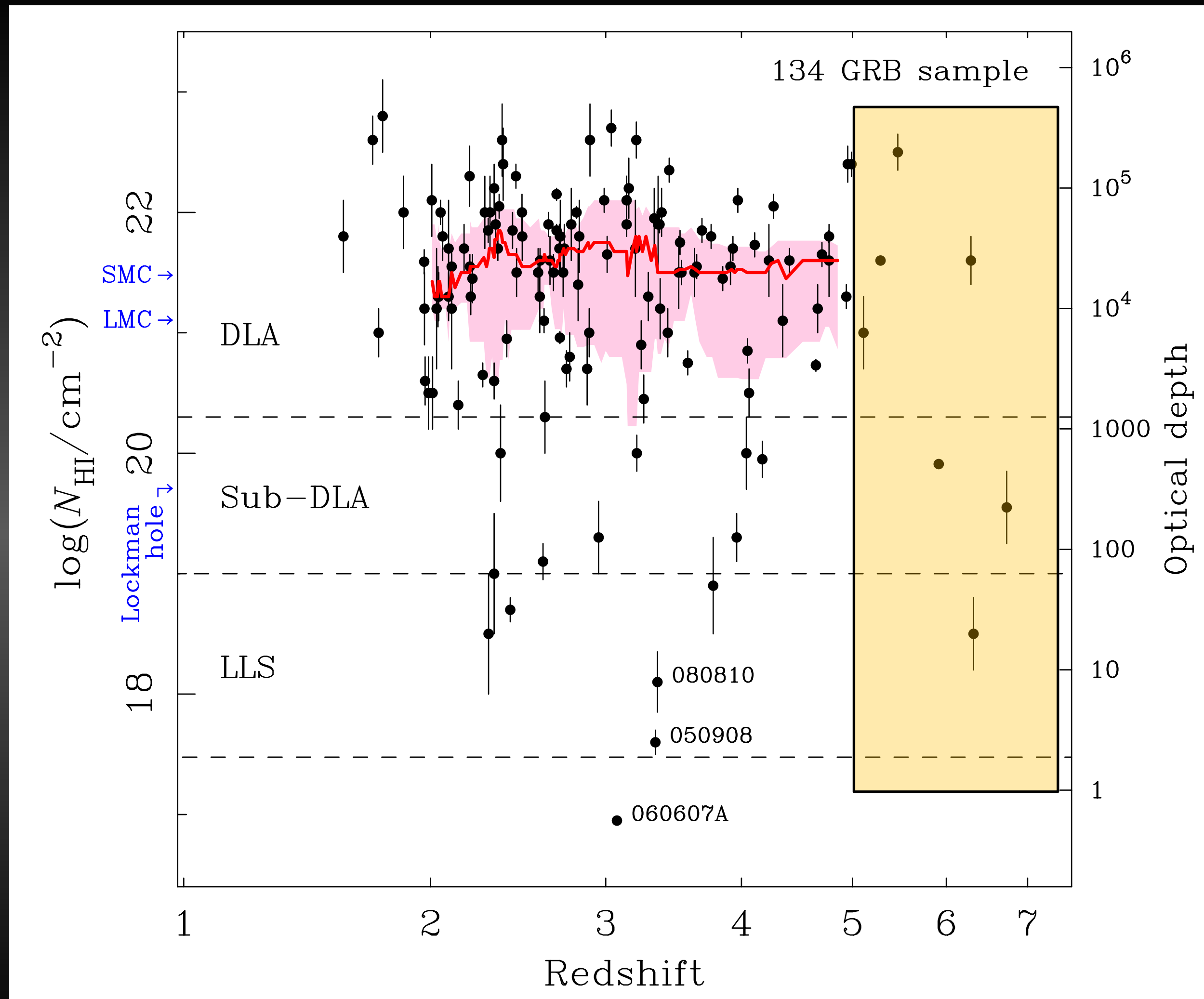

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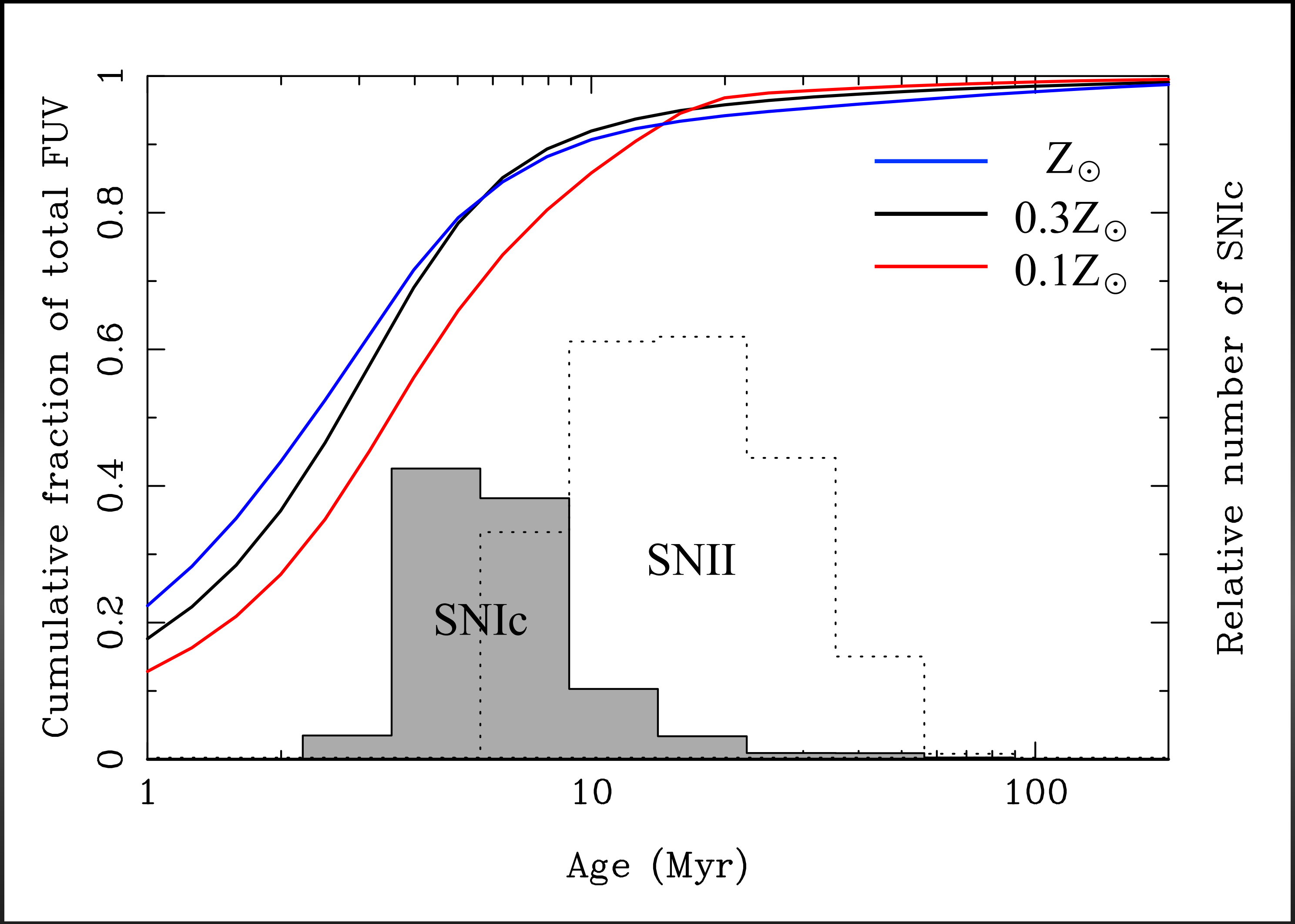


Single burst stellar population synthesis, based on binary evolution BPASS-2 models (Stanway & Eldridge 2016) – most production is $t < 10$ Myr, consistent with typical GRB progenitor lifetimes (and SNIc).

Factors making this upper limit stronger

1. There is a bias against locating and measuring redshifts for the high NH (dusty) systems (especially at higher redshifts). Also the low NH systems may also have dust absorption.

2. GRBs typically select small, lower metallicity systems that might be expected to have relatively high f_{esc}.

3. Neutral gas proximate to the progenitor is likely to be ionized by the GRB and early afterglow, so we may underestimate the the column in some cases.

z

Possible "get-outs"

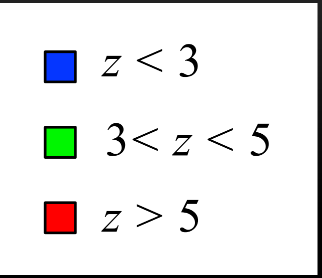
1. GRBs in low density environments produce faint afterglows and weak absorption features – could we miss them? Would only need to miss a few to make a difference. At z>3 should reliably see the Ly-a forest turn on, so likely not missed.

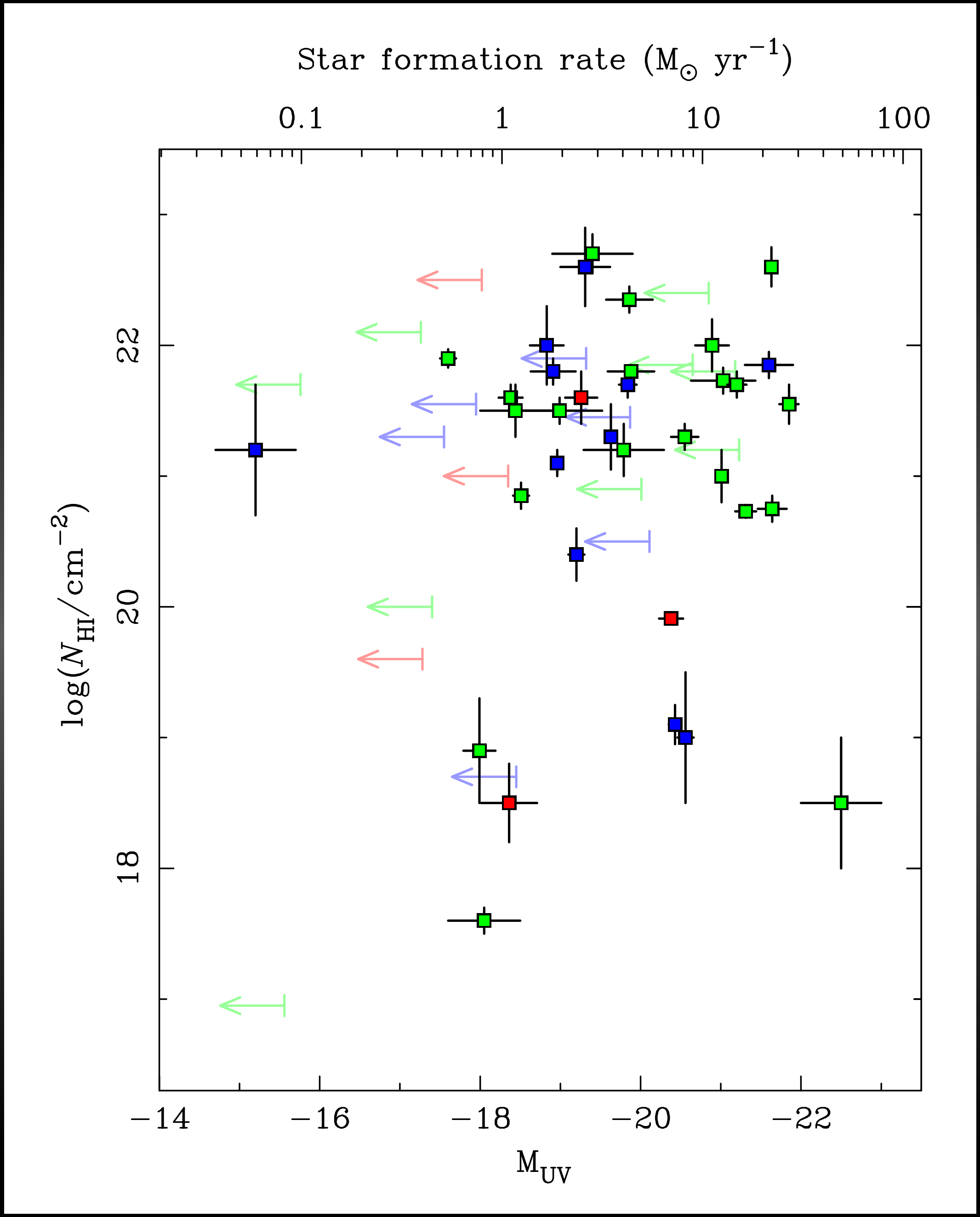
2. Do GRBs select dense environments? Maybe – but much absorption is from galactic scale gas.

3. Could it be that the massive stars giving rise to GRBs are different from the ones dominating the UV production? (ANS: probably not!)

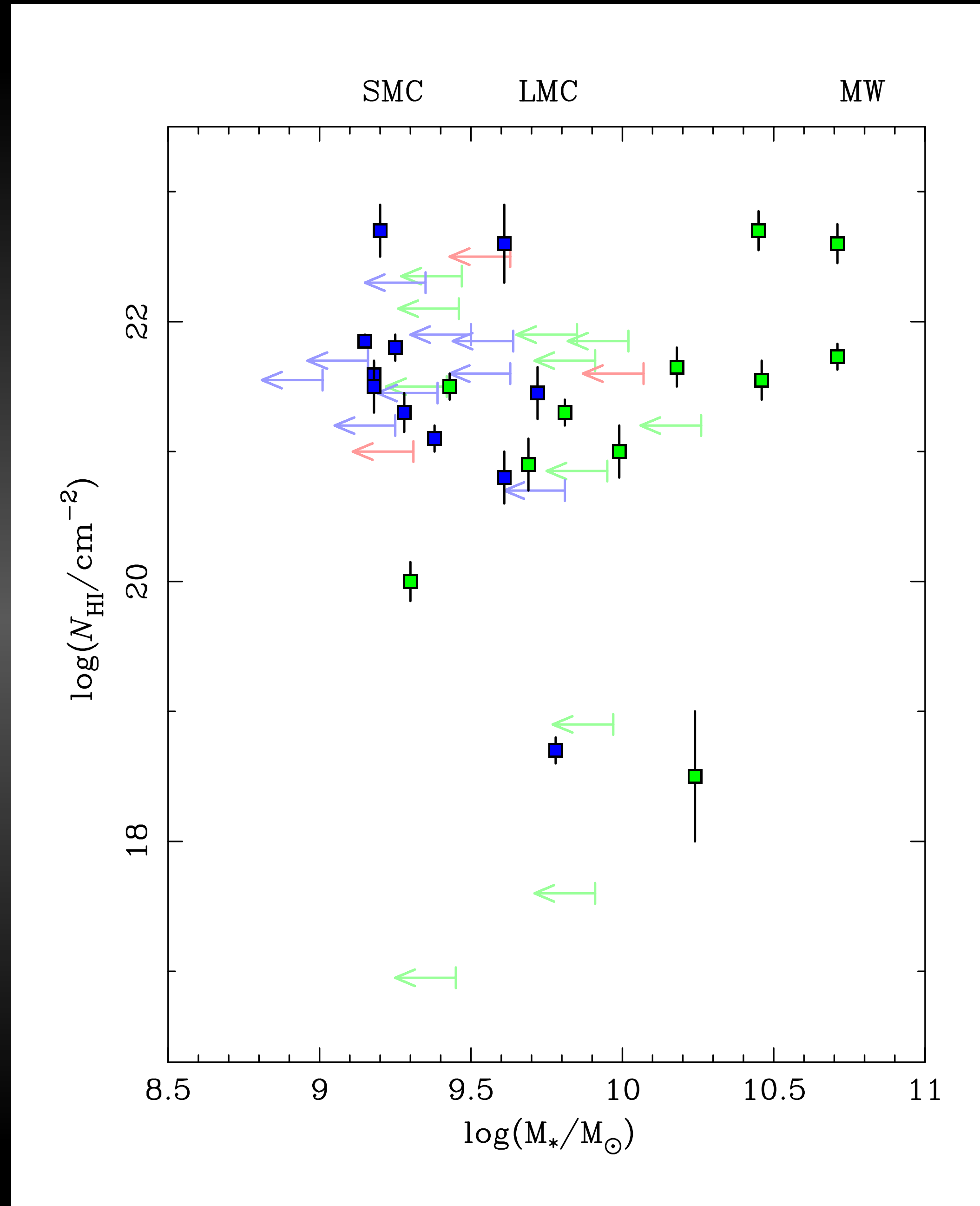
4. May it still be that at z>5 the escape fraction increases by ~an order of magnitude? Little evidence for that so far.

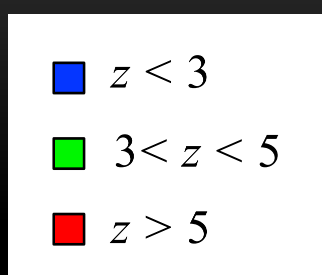
No clear trend with host UV magnitude (proxy for star formation rate).



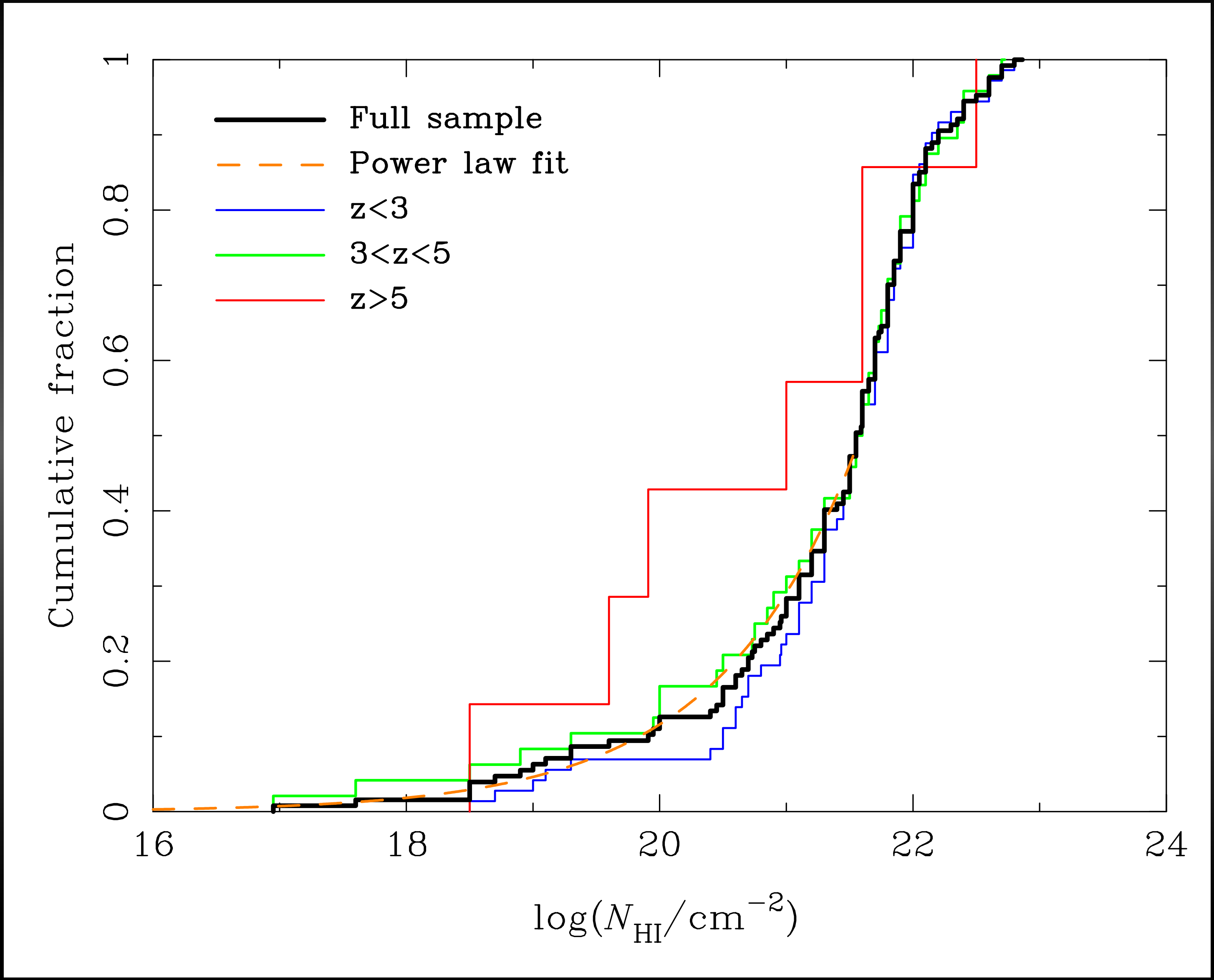


Nor with stellar mass





Trend with redshift



Conclusions

- Spectroscopy provides information about explosions, their environments and the universe.
- A particular problem is how to reconcile the observed low escape fraction of ionizing radiation from GRB locations with the requirement to reionize the intergalactic medium.
- SVOM may benefit from powerful new spectroscopic facilities e.g. *JWST*, ELT