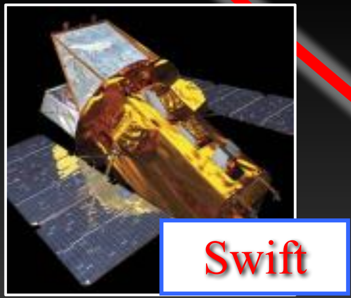
THESEUS W/S 2017 – Napoli

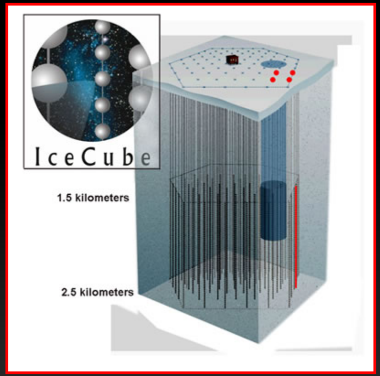
Exploring the early universe with GRBs
– overview –

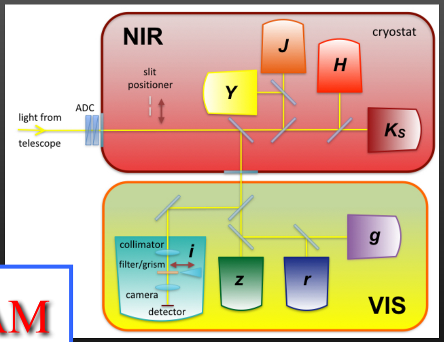
Nial Tanvir
University of Leicester

The developing landscape

Now







OCTOCAM

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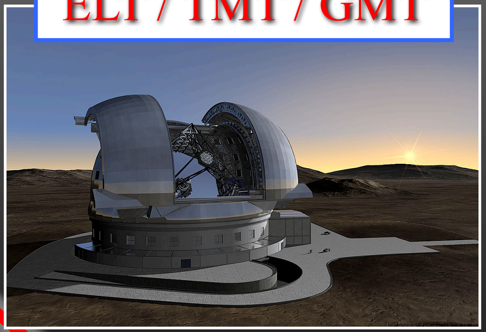
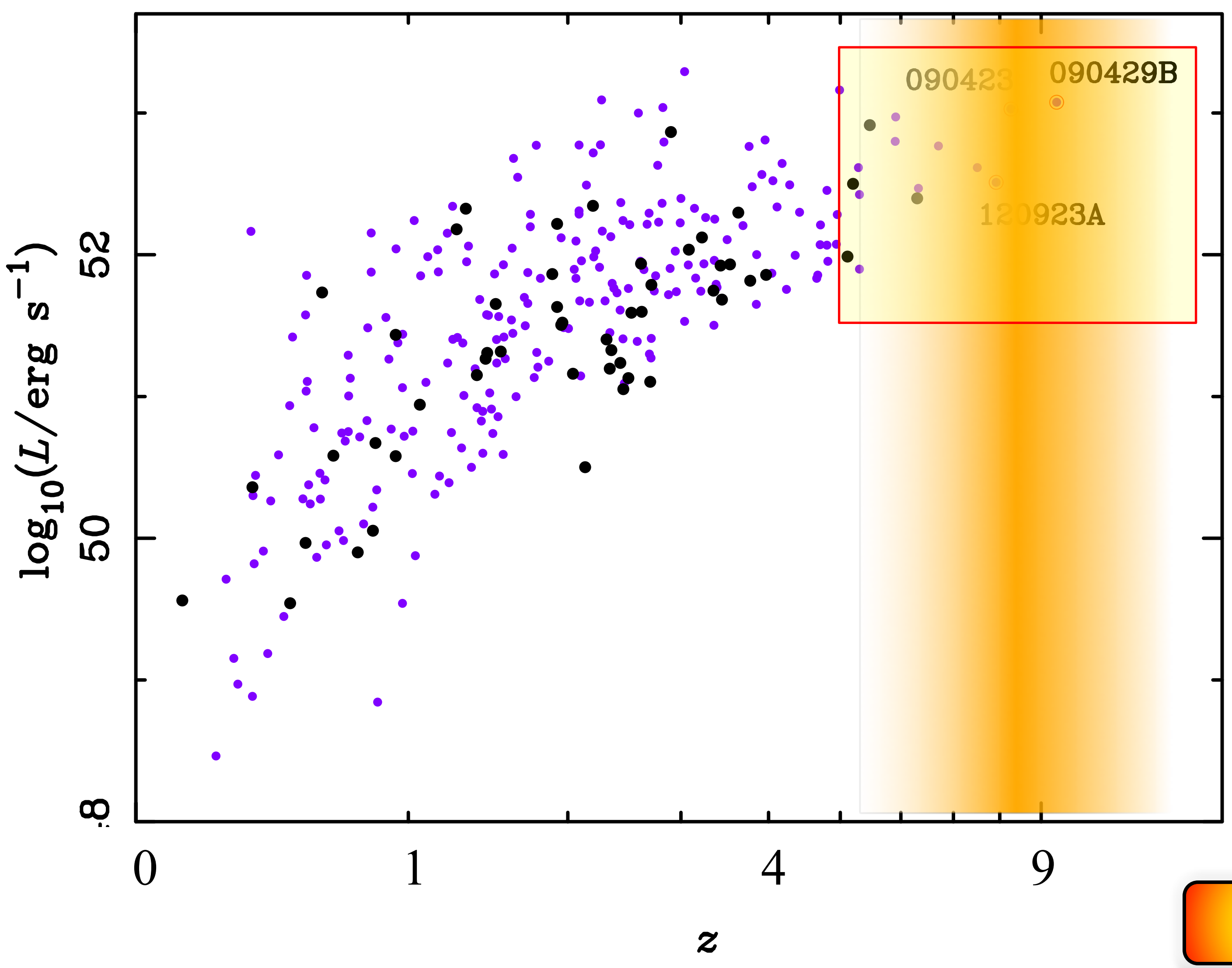


2030

Swift GRBs span most of cosmic history

Planck2016
arXiv:1605.03507



BAT

GRBs @ high-z

Thanks to their extreme brightness, the broad spectral energy distributions of their afterglows and association with massive star formation, provide powerful complementary probe of star formation and galaxy evolution in the era of reionization (and potentially beyond).

Some key issues now (and likely still in THESEUS era):

- Star formation rate density at high redshifts
- Nature of primordial galaxies
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- Timeline and topology of reionization
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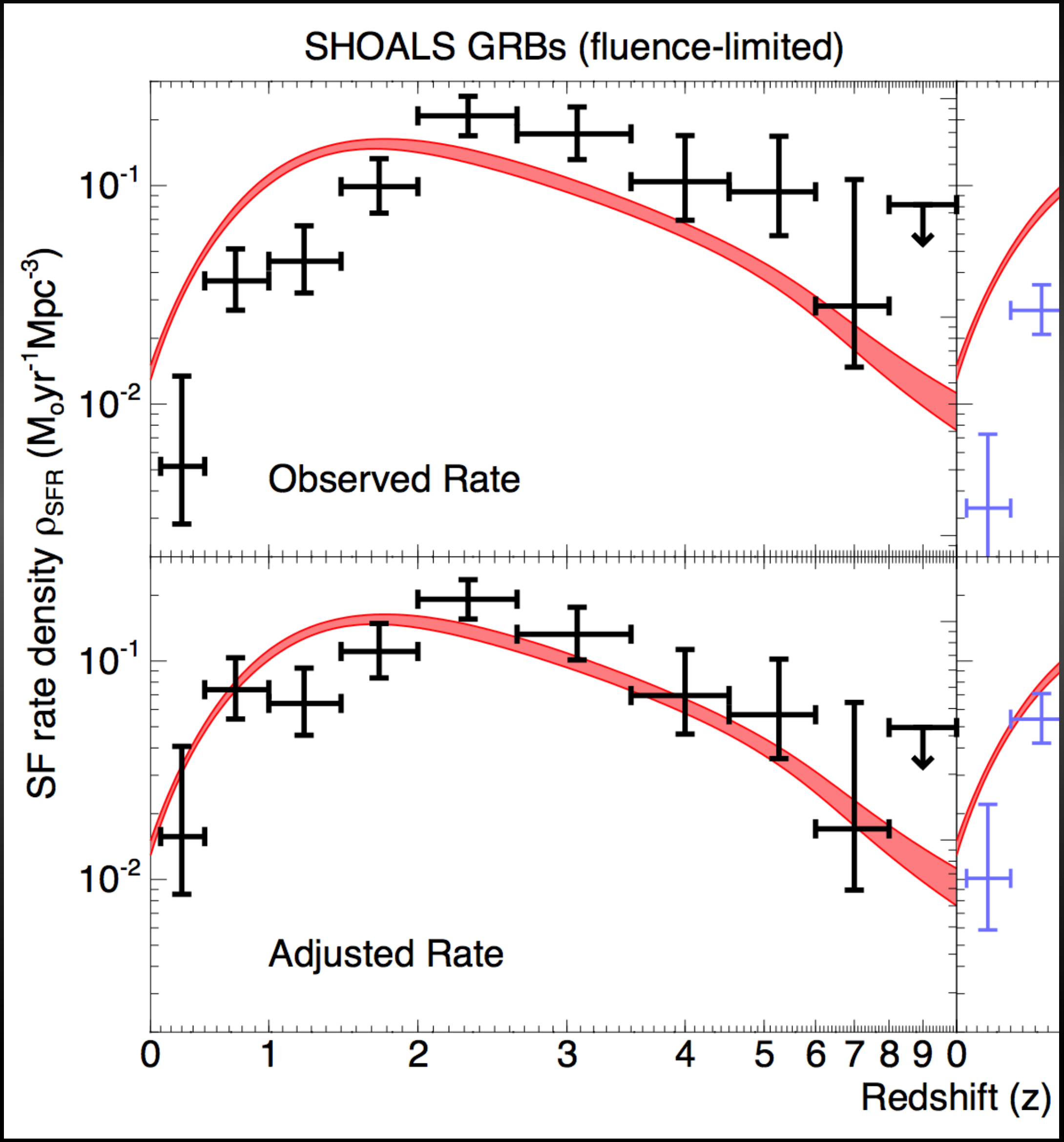
- Population III …

Star formation history from GRBs

Perley et al. 2016

Long-standing problem – "too many GRBs at high-z" compared to naïve predictions based on galaxy SFR estimates.

Better accounting for evolving GRB:SFR (i.e. metallicity effects) and faint end of galaxy LF ~ tension reduced.



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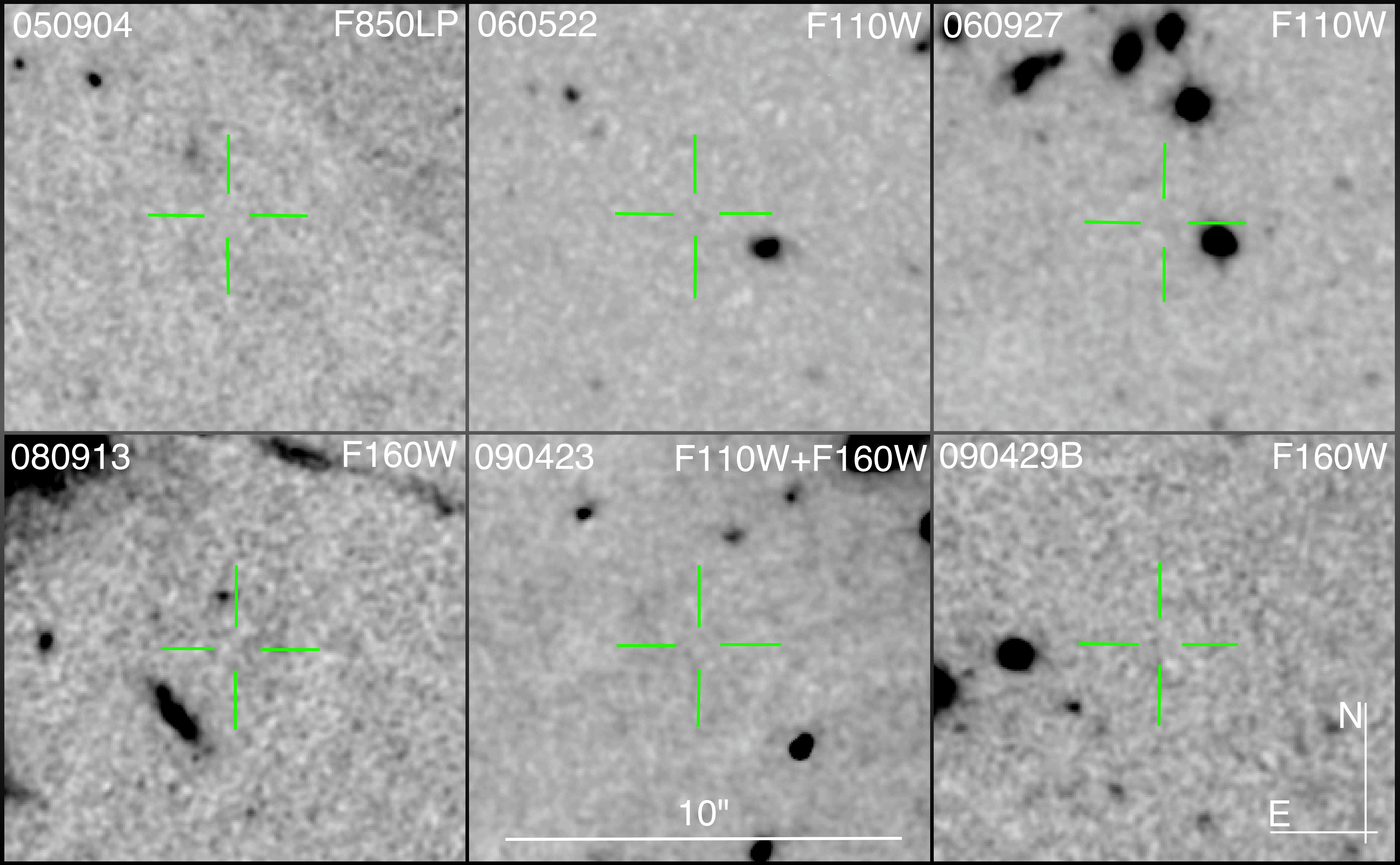
Detecting undetectable galaxies

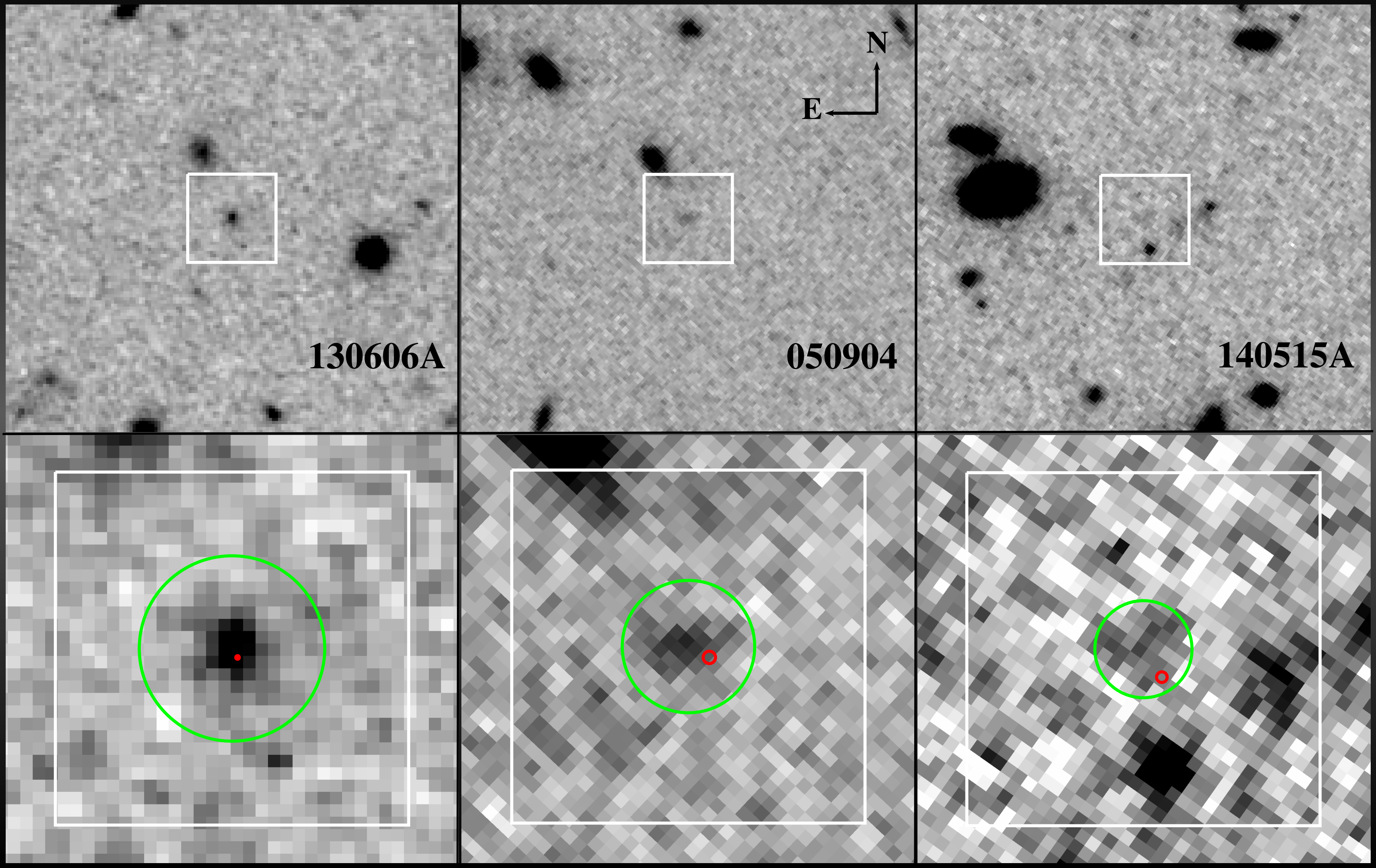
HST



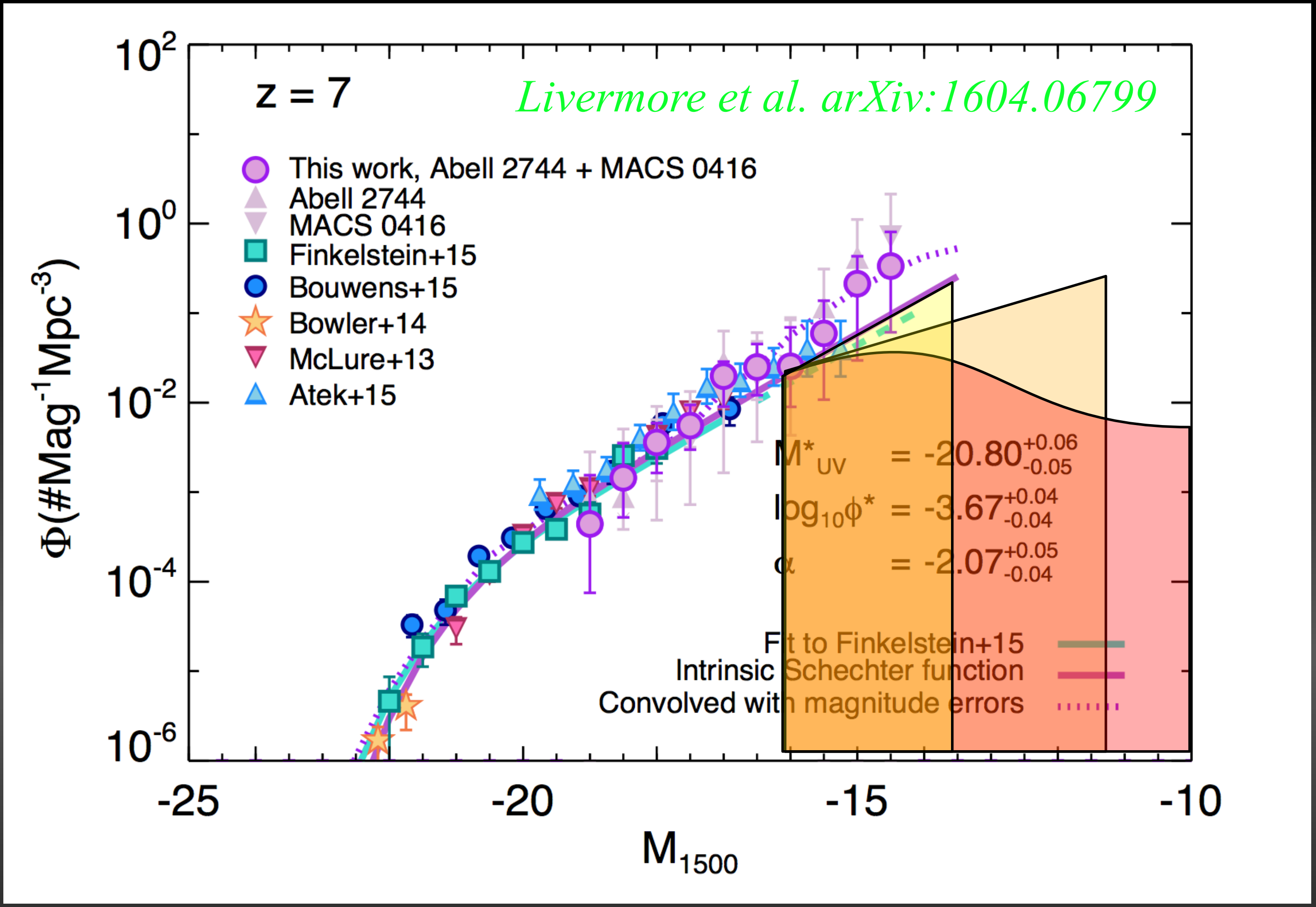
Tanvir et al. 2012

First GRB hosts at z~6

HST



McGuire et al. 2016 ApJ



Ultimately seeking to quantify amount of star formation in unseen galaxies.

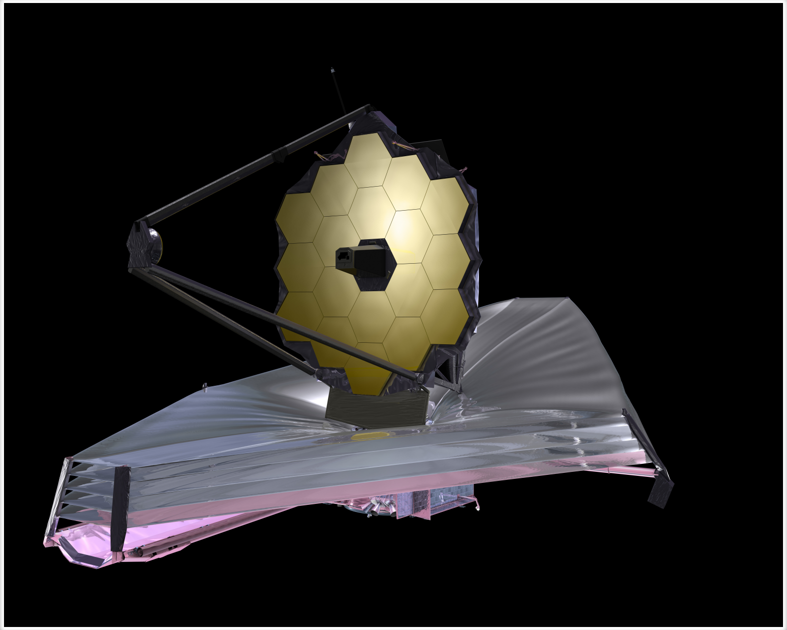
GRB host limits can be very deep since knowledge of position allows us to look for low-significance detections (and we don't need deep veto filters).

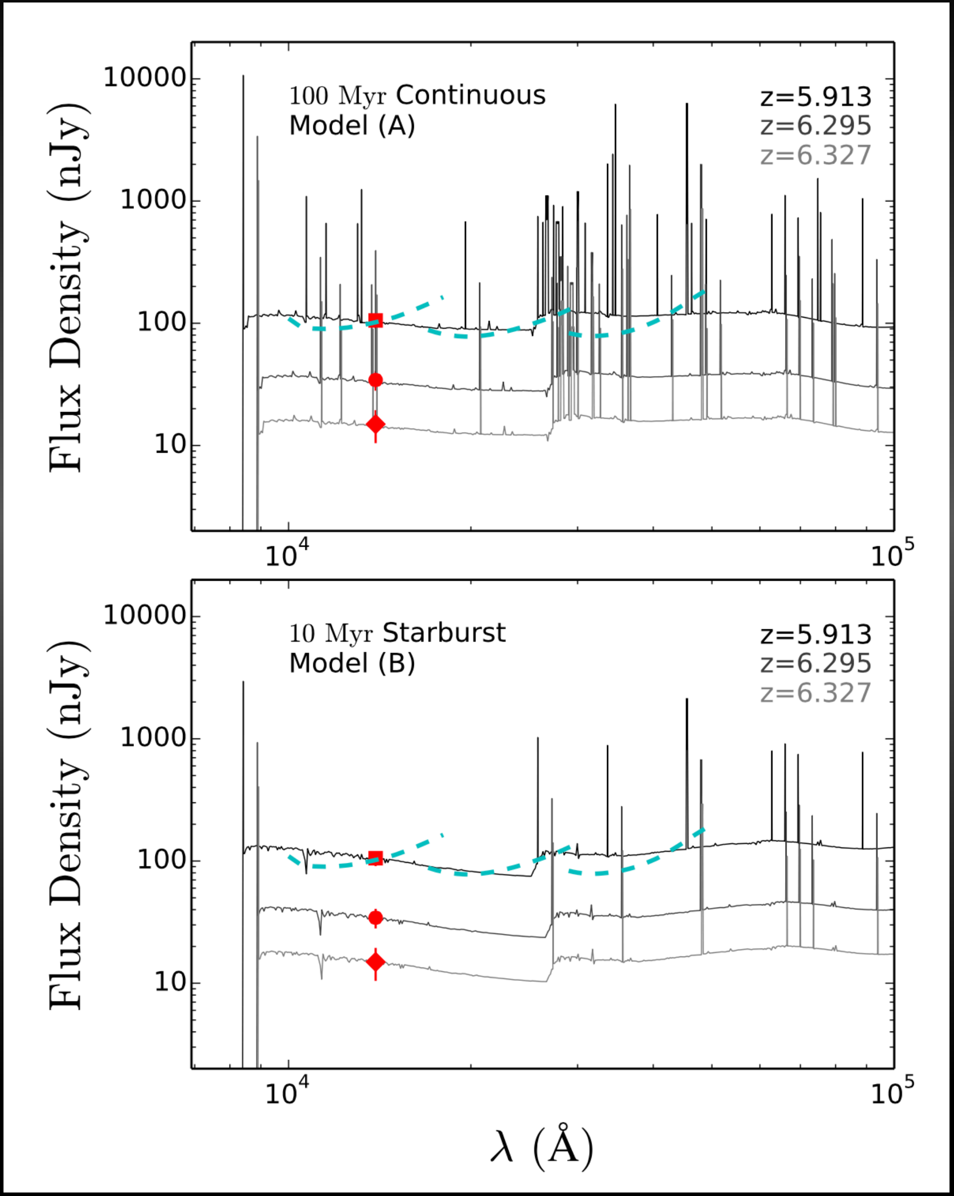
Assume

GRB rate ~ SFR ~ UV

First GRB hosts at z~6

Potential for JWST spectroscopy – unique targets with absorption spectroscopy.





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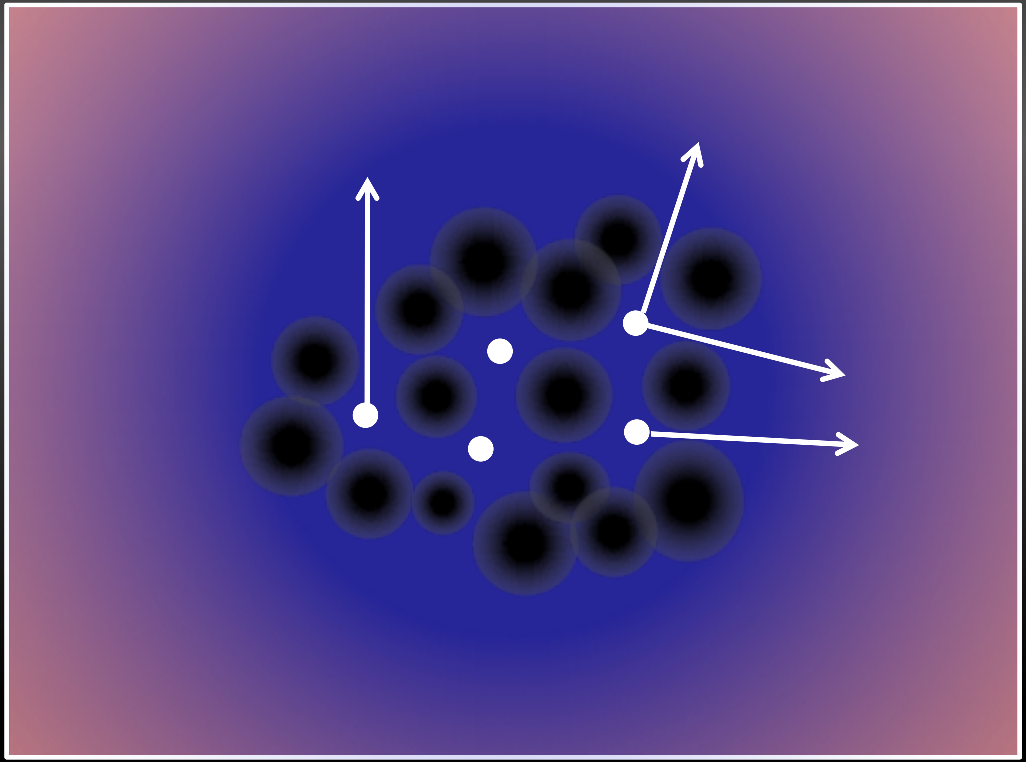
Reionization of the intergalactic medium

The intergalactic medium went from being completely neutral to completely ionized, in the era between z=10 and z=7.

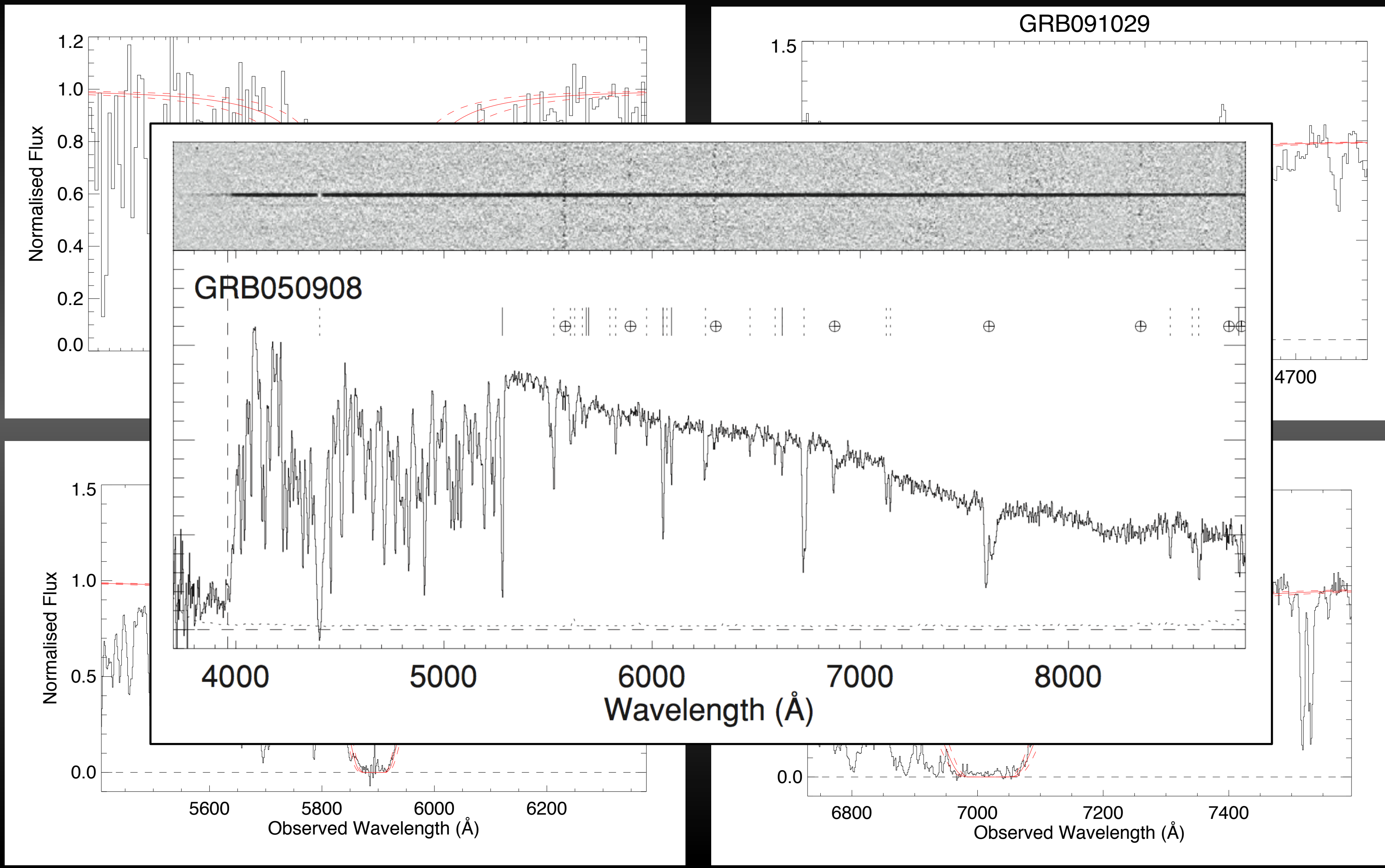
Ionizing escape fraction

Generally assumed some fraction of ionizing radiation from stars escapes their host galaxies.

If this is not reasonably high (>10%) at $z>6$ then becomes hard to envisage reionization being driven primarily by stars.

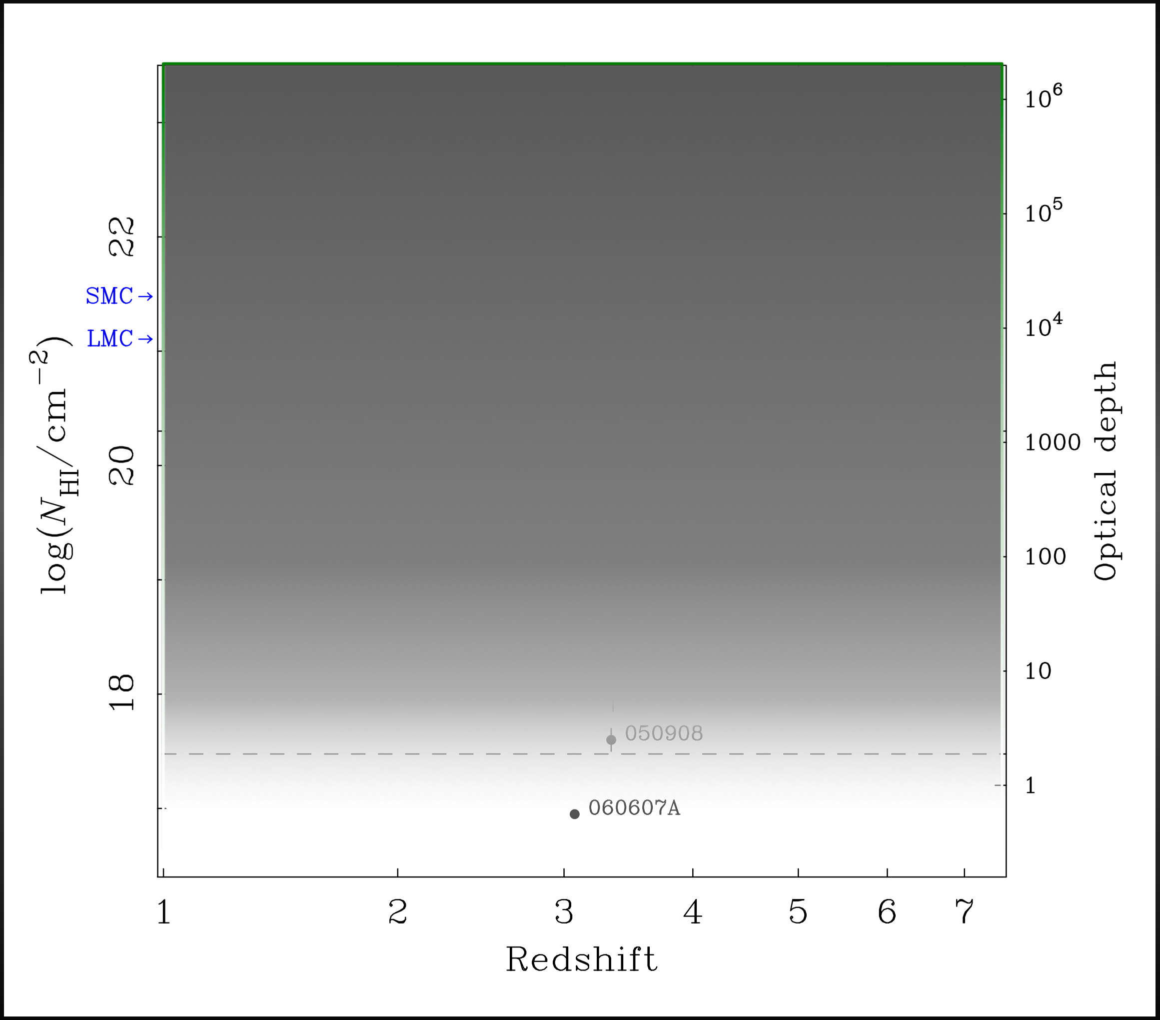


HI column density from Ly-a absorption in afterglow spectra



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

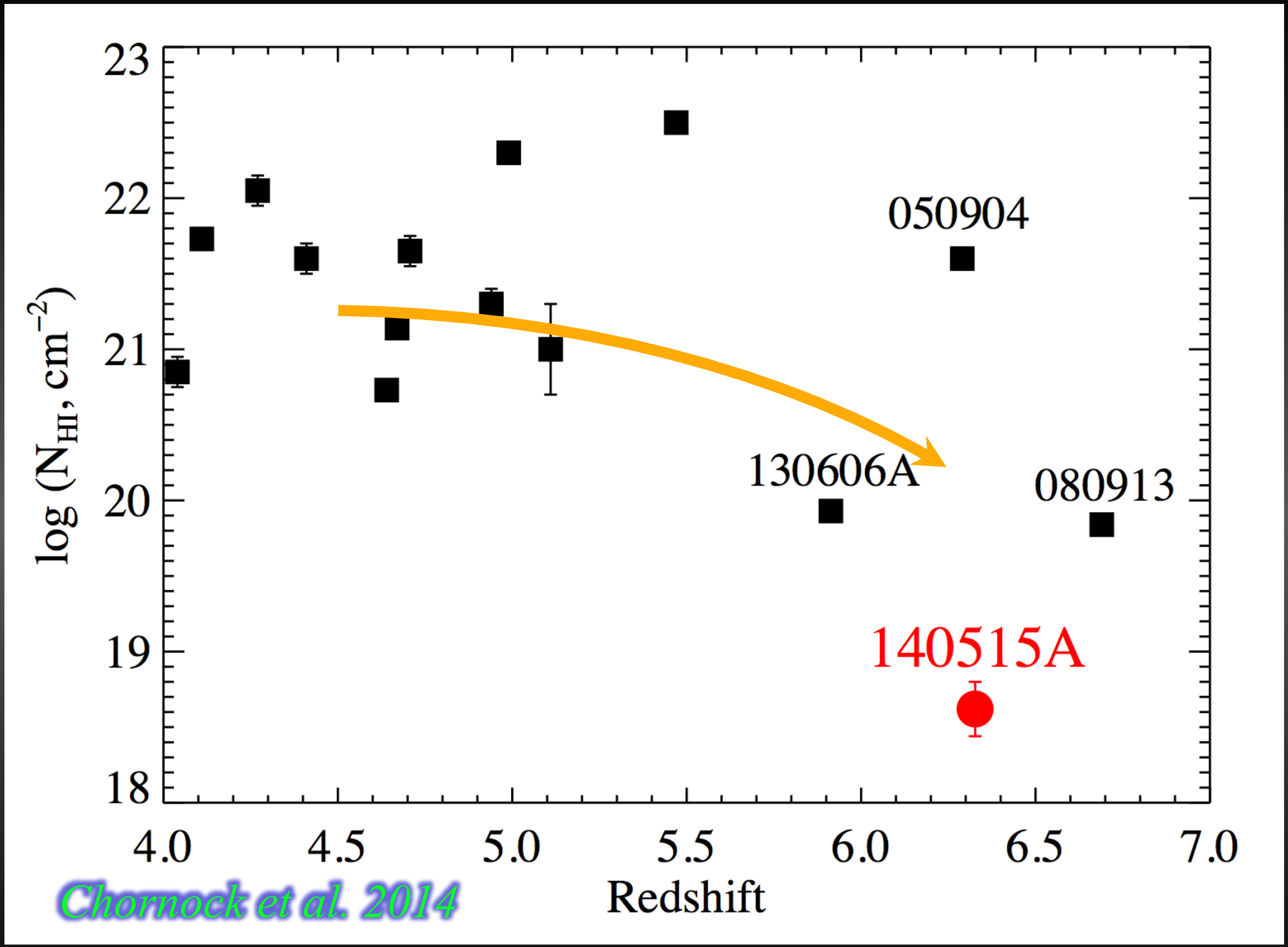
HI column density evolution



High column densities seen in optical spectra of most 2<z<4 GRBs suggest escape fractions for these stellar pops of <~1 %.

NT et al. (subm.)

Escape fraction of ionizing radiation



Marginal evidence for reducing opacity at high redshift, but from four GRBs at 6<z<7, inferred escape fraction remains zero ! (2-sigma limit is ~50%)

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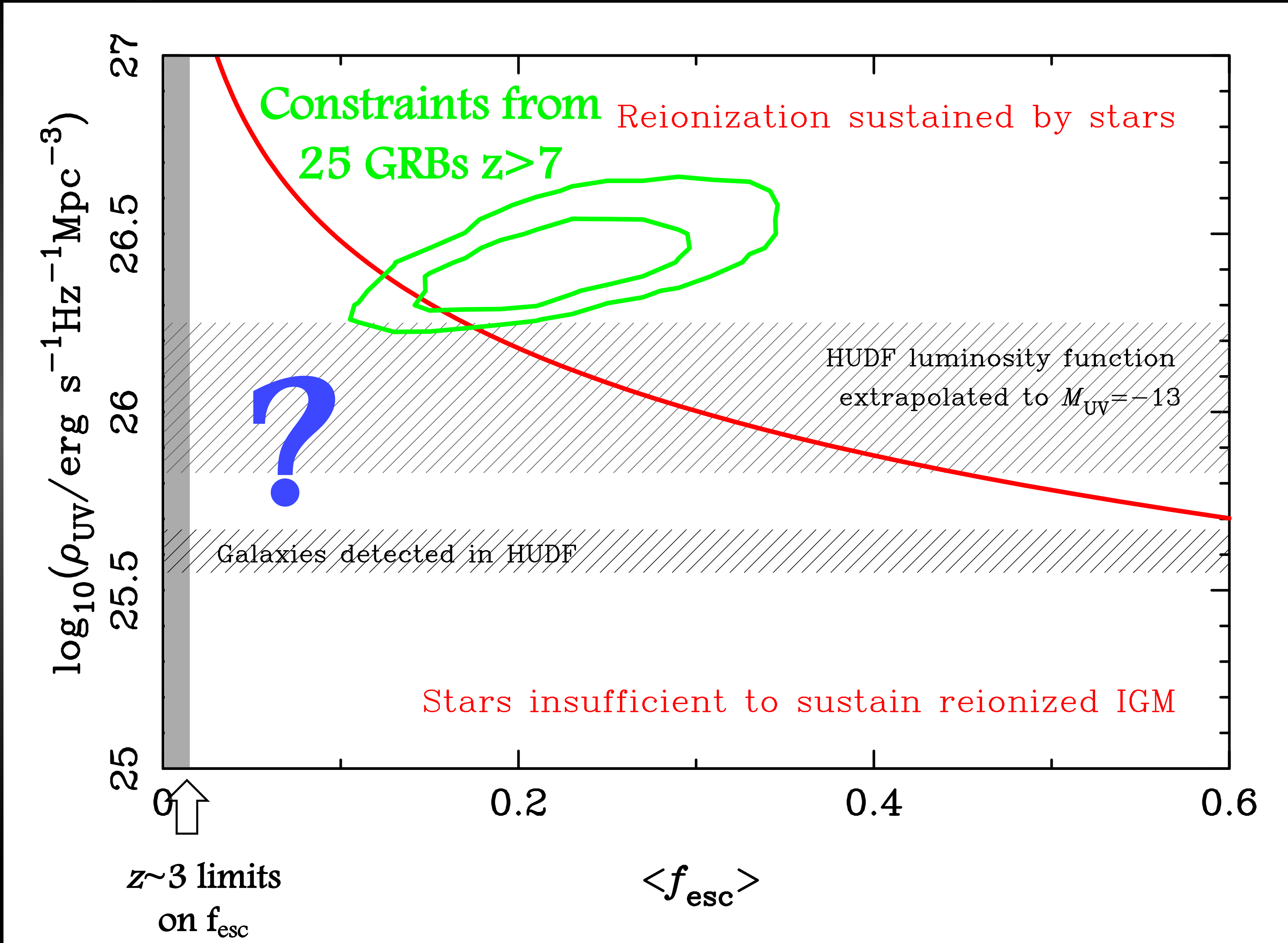
Prospects for the future – 25 GRBs at z>7



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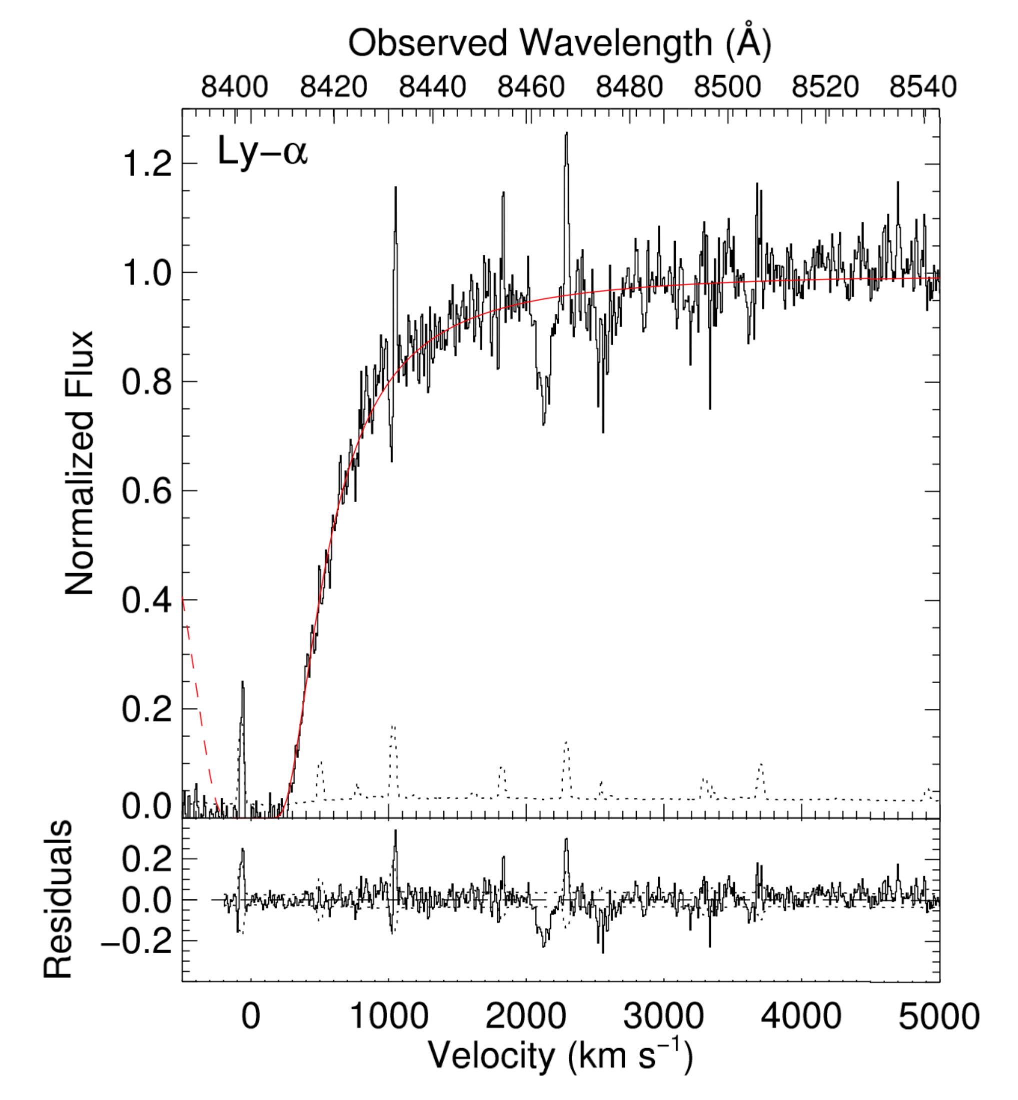
Probing the neutral IGM

Decomposition of Ly-alpha red-wing into IGM and ISM components.

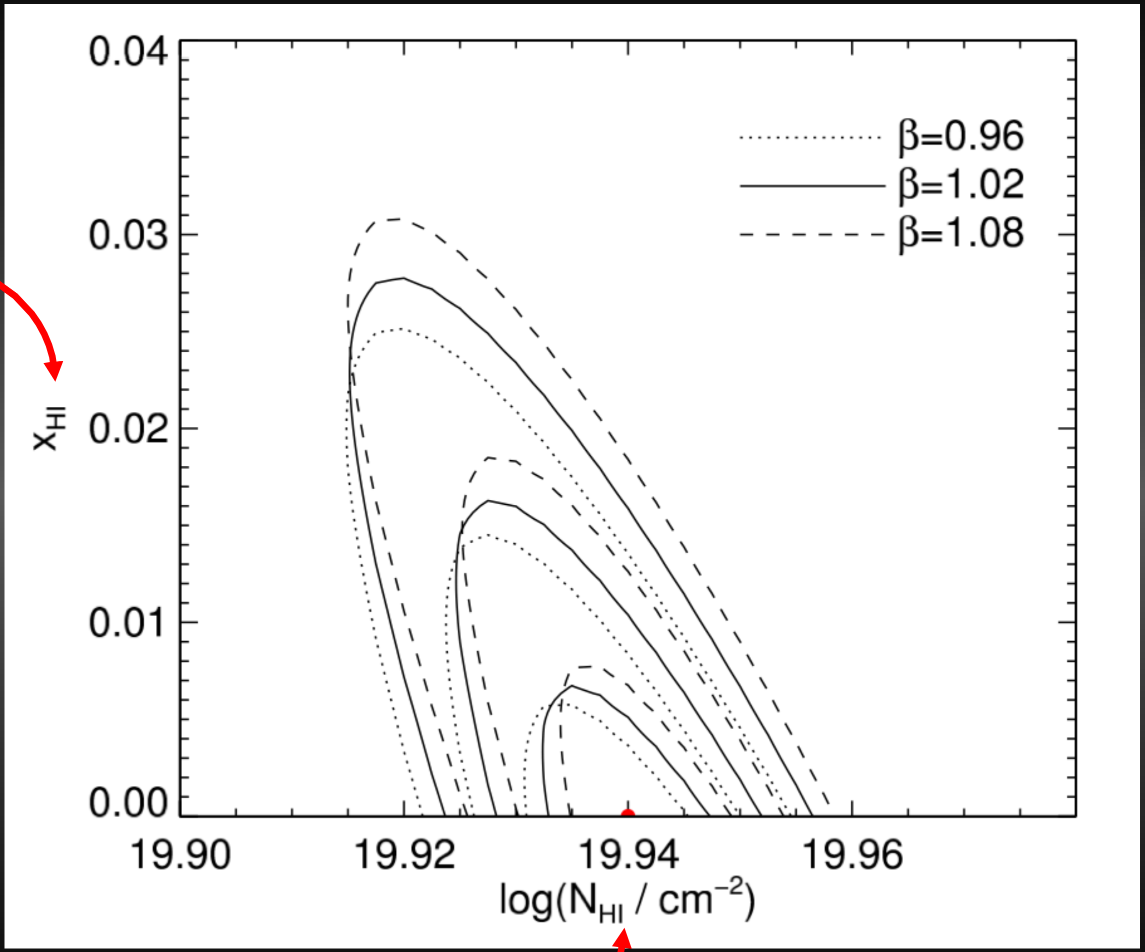
Hence quantify neutral fraction of IGM at location of GRB *(Barkana & Loeb 2004).*



Hartoog et al. 2015

e.g. GRB 130606A at $z = 5.91$

IGM predominantly ionized by z~6



Host NH relatively low, but still opaque to ionizing photons.

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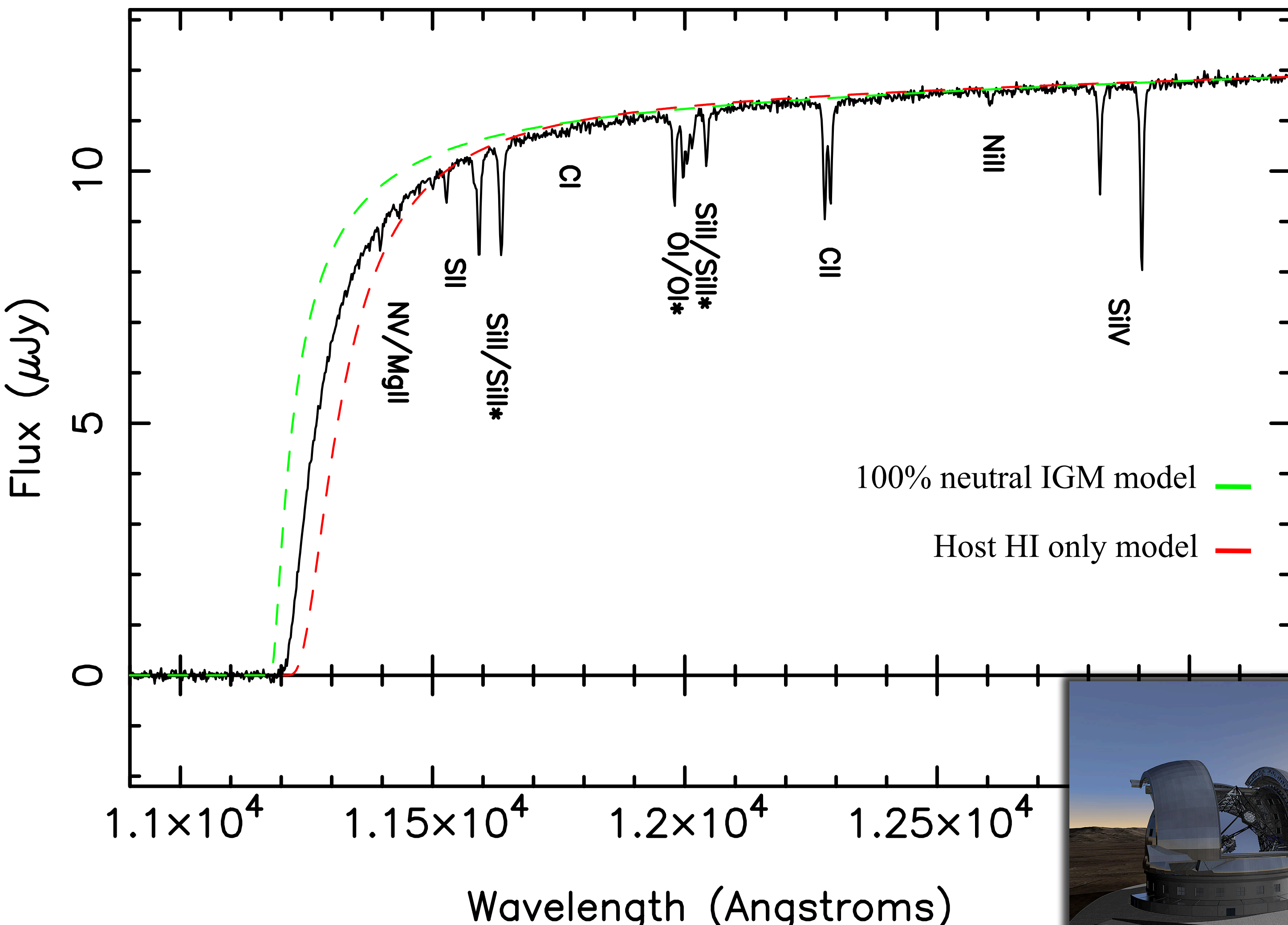
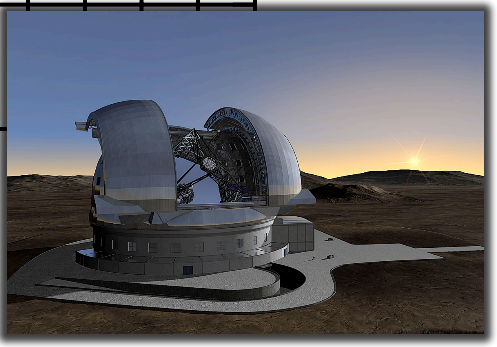
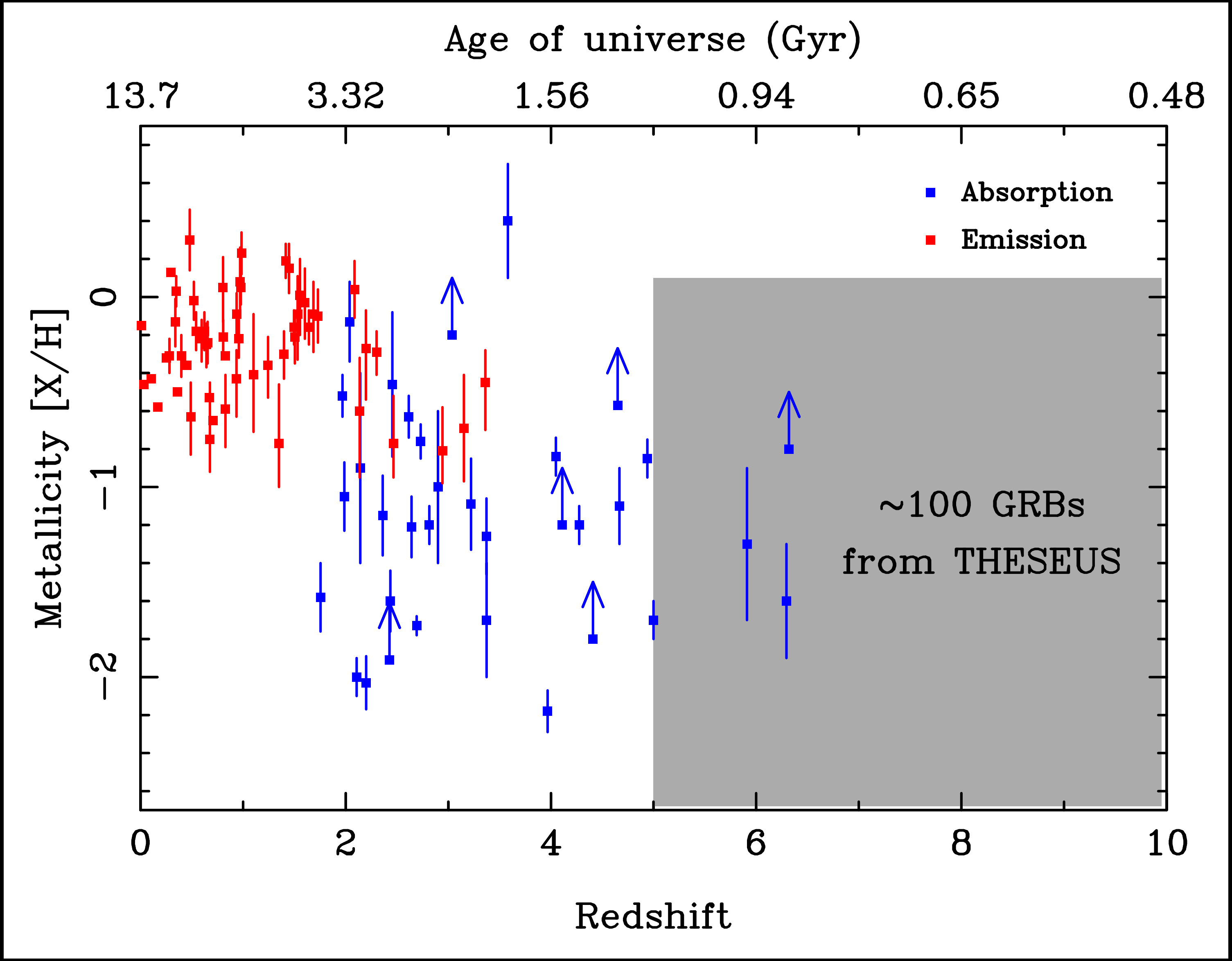
z=8.2 simulated ELT afterglow spectrum





The environments

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



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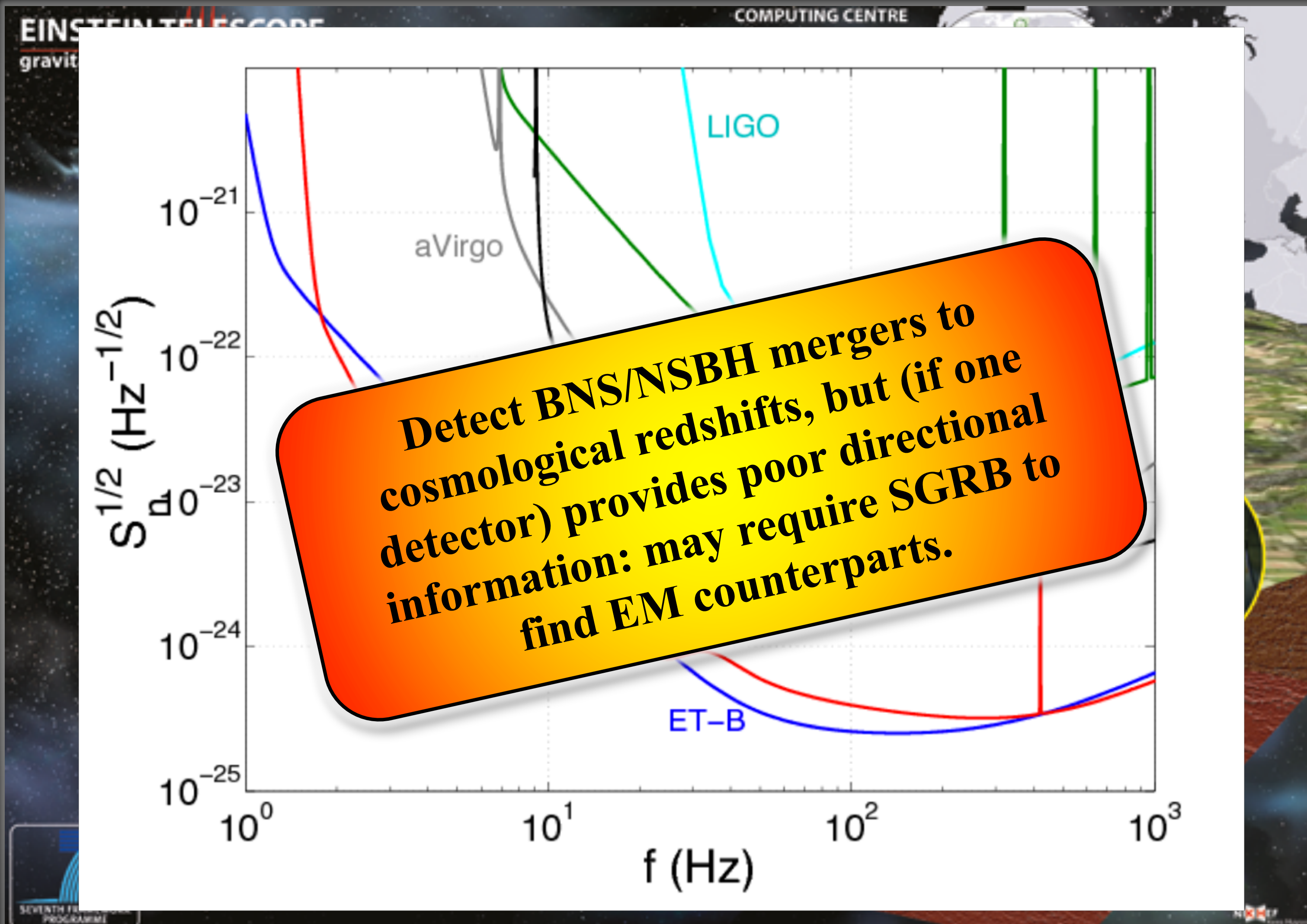
Final thought: THESEUS in era of Einstein Telescope



Detect BNS/NSBH mergers to cosmological redshifts, but (if one detector) provides poor directional information: may require SGRB to find EM counterparts.