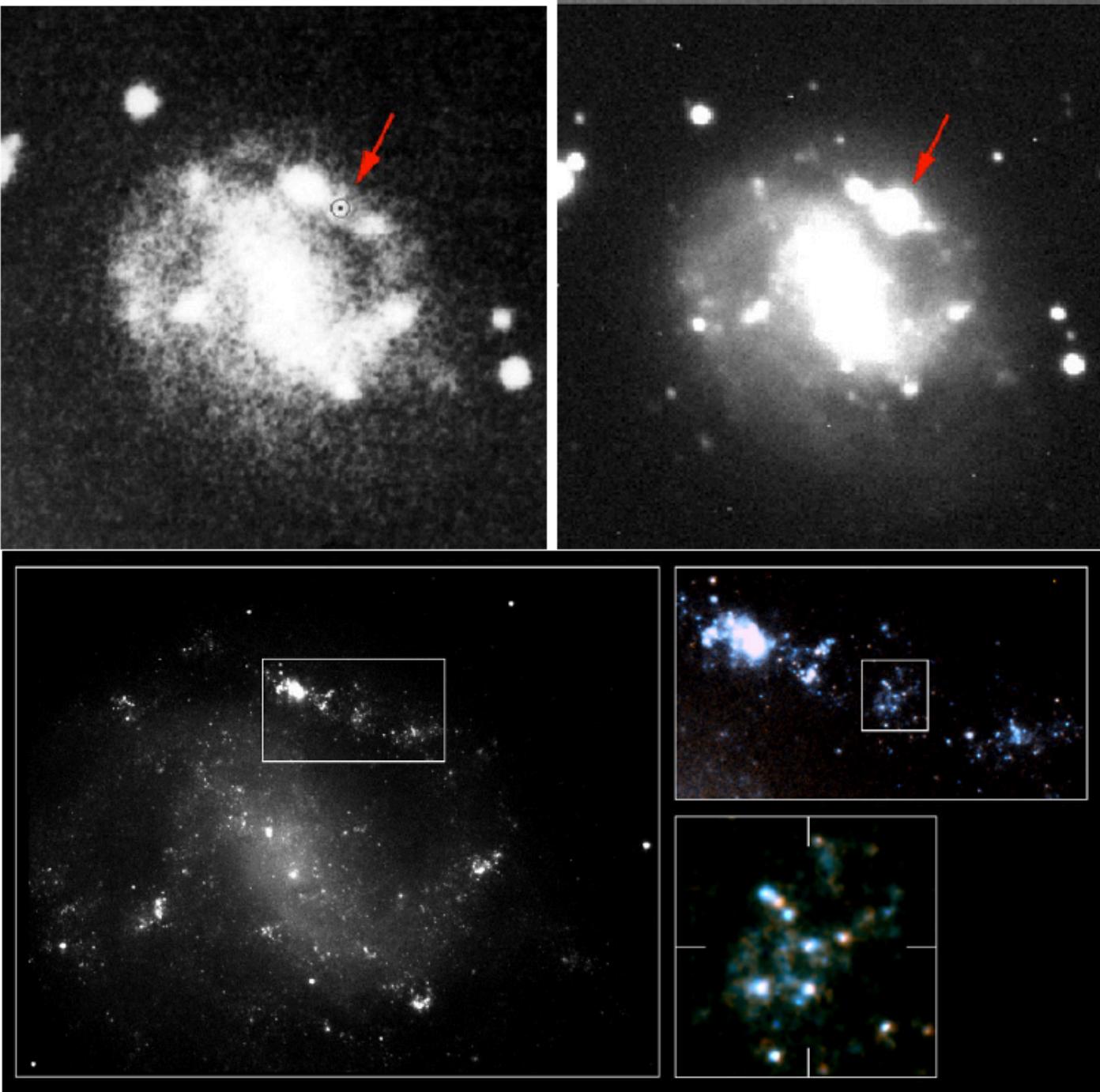


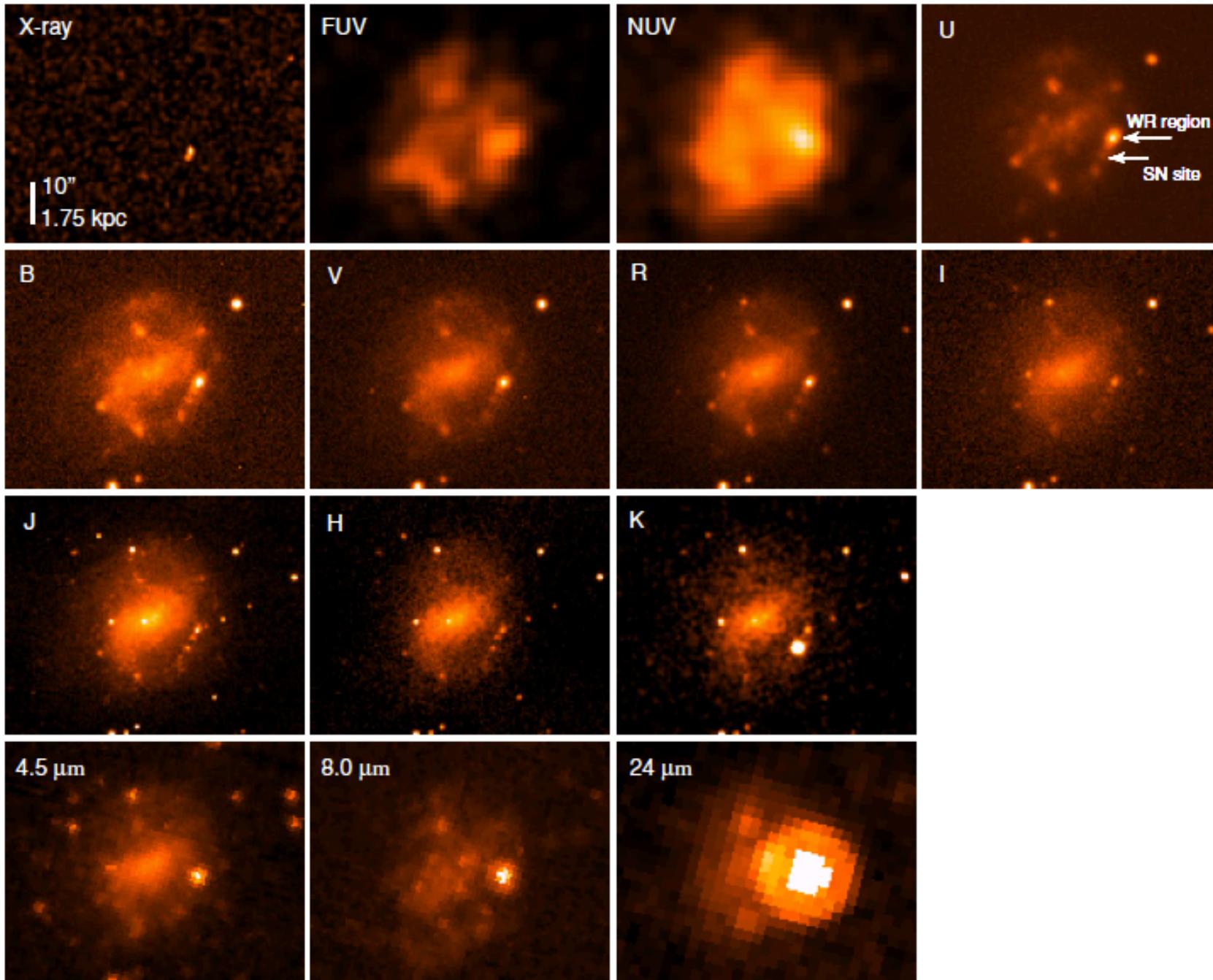
TOUGH: Observational Aspects of Gamma-ray Burst Host Galaxies

Jens Hjorth
Dark Cosmology Centre
Niels Bohr Institute
University of Copenhagen

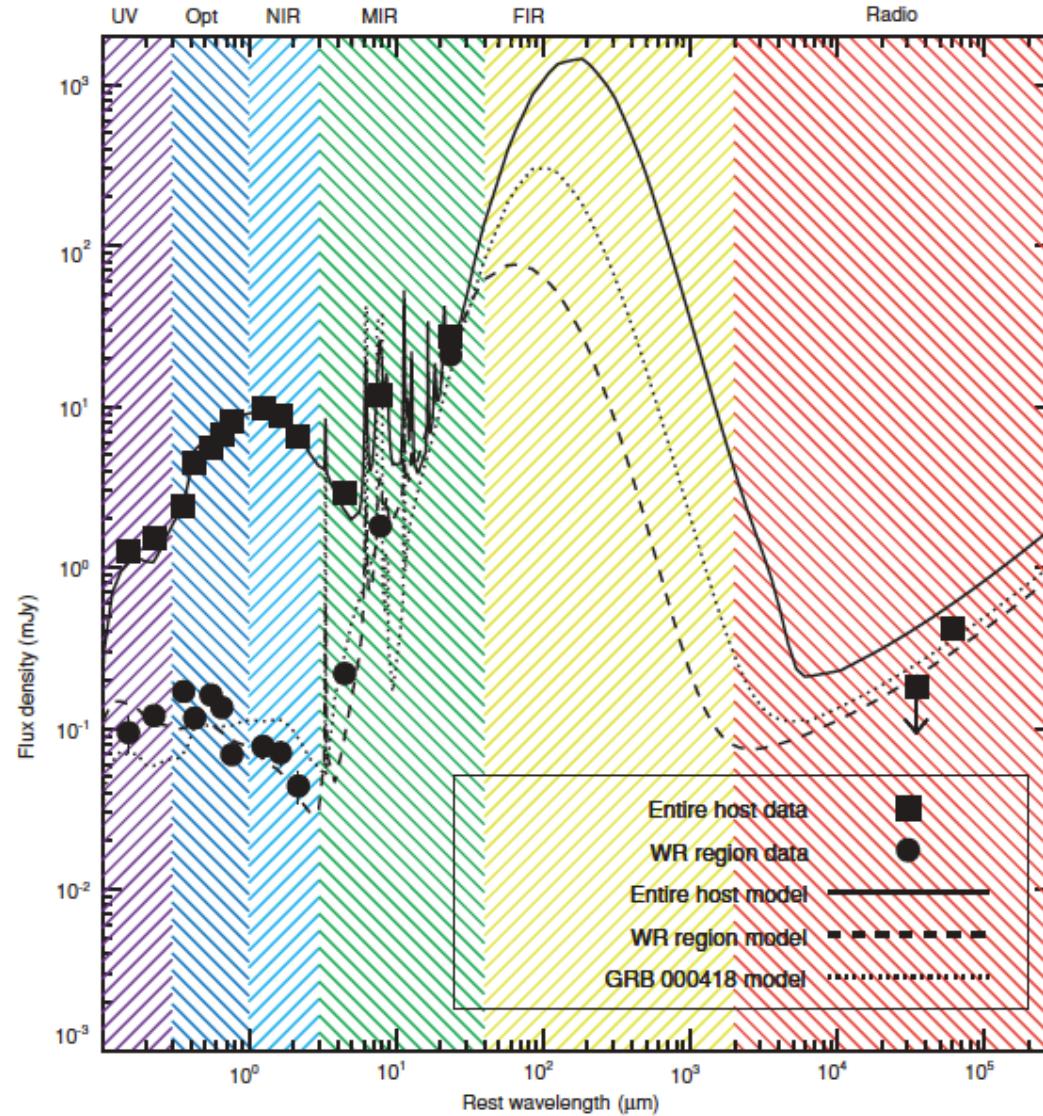
SN 1998bw / GRB 980425



Galama et al. 1998; Fynbo et al. 2000



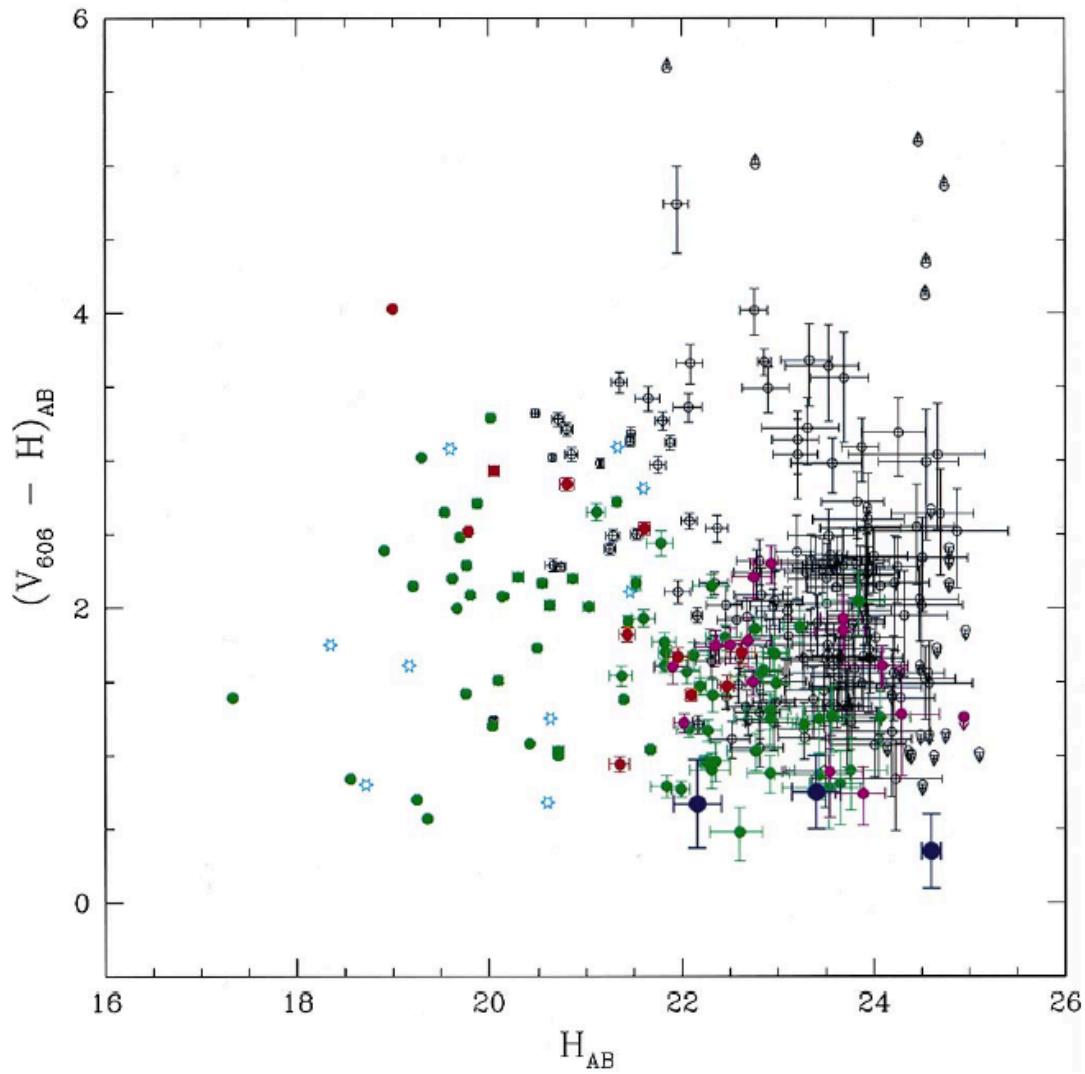
GRB 980425: dwarf galaxy



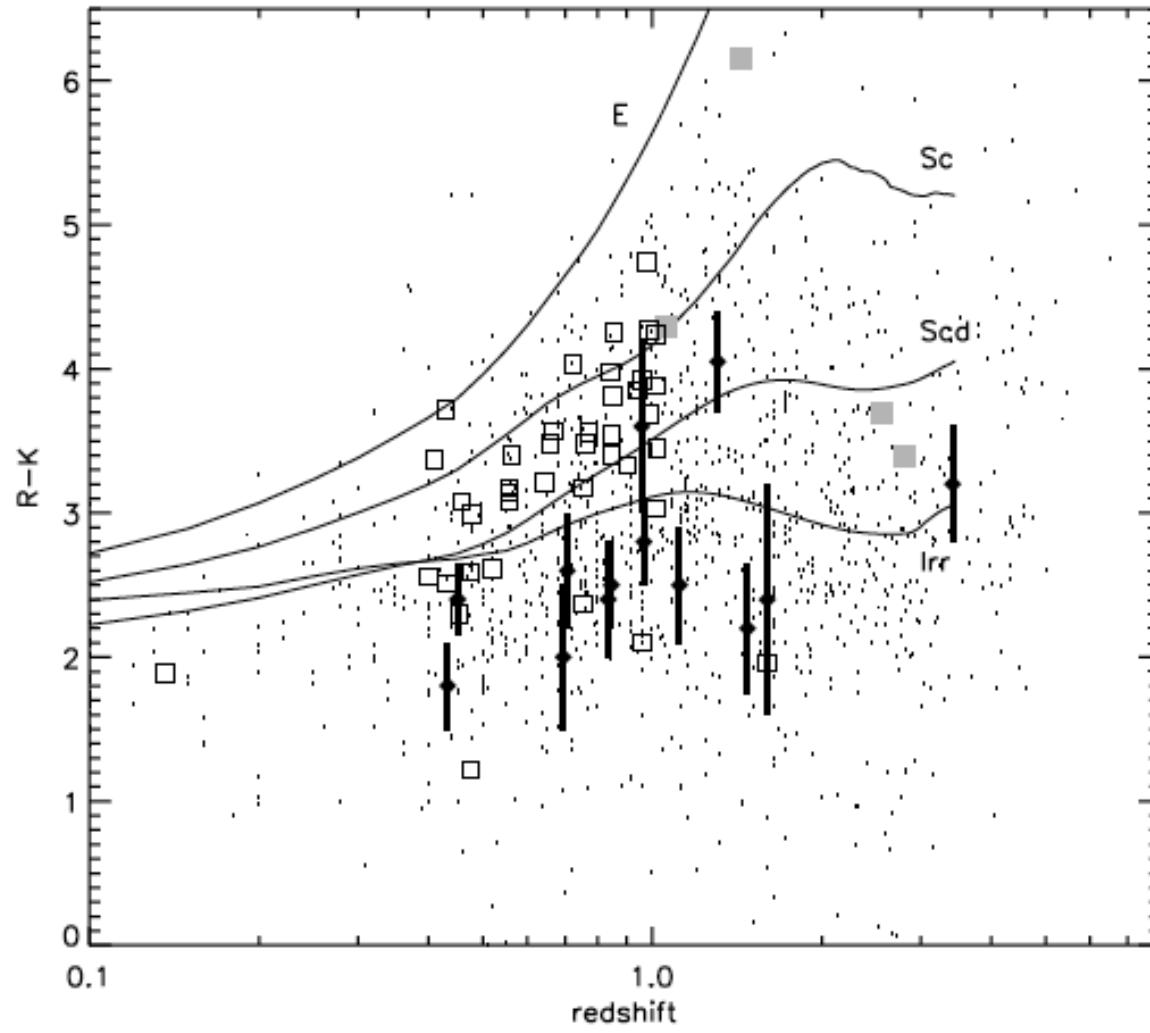
Some star formation

WR region:
high specific SFR
High dust temperature

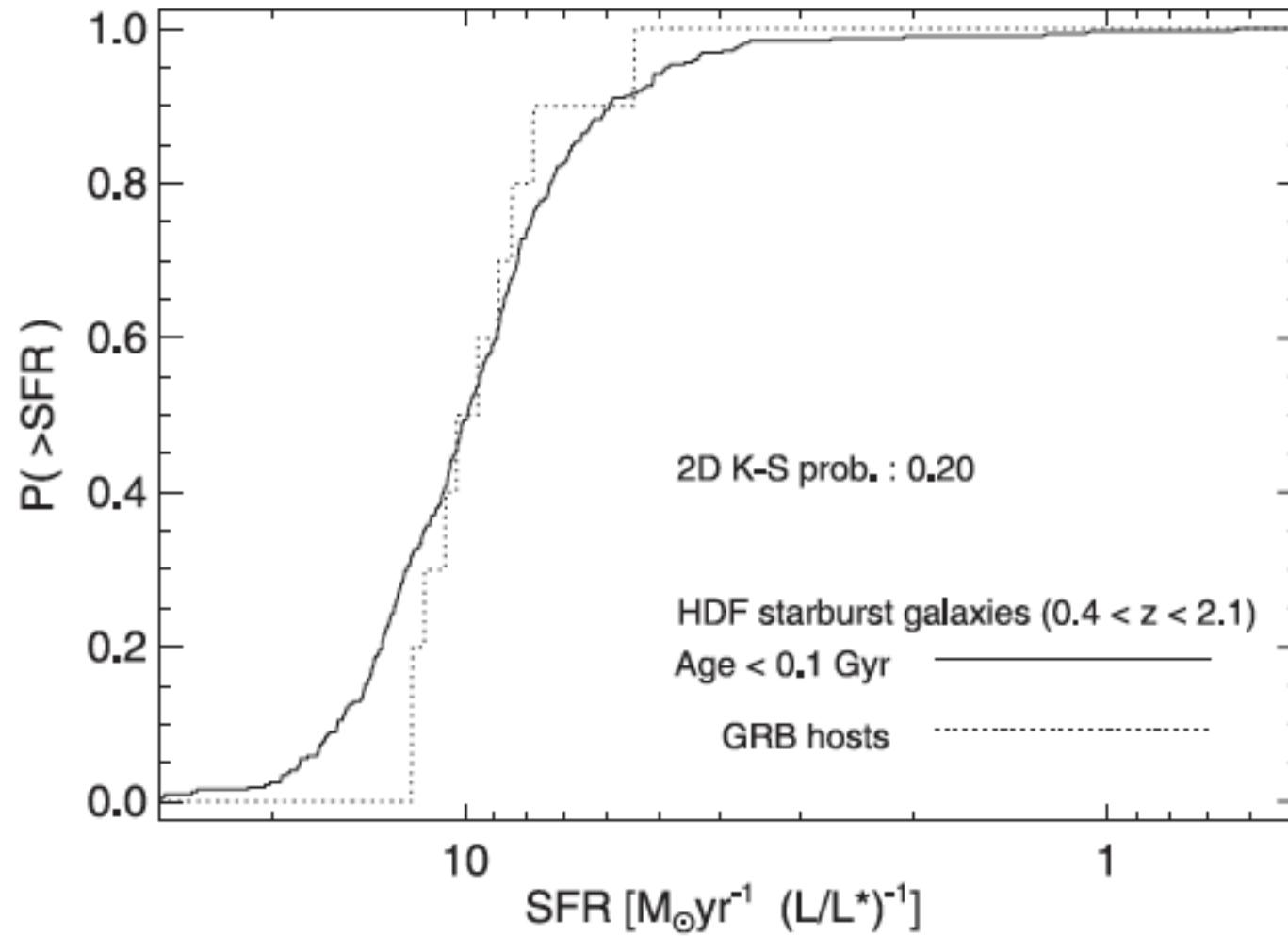
Blue compared to HDF



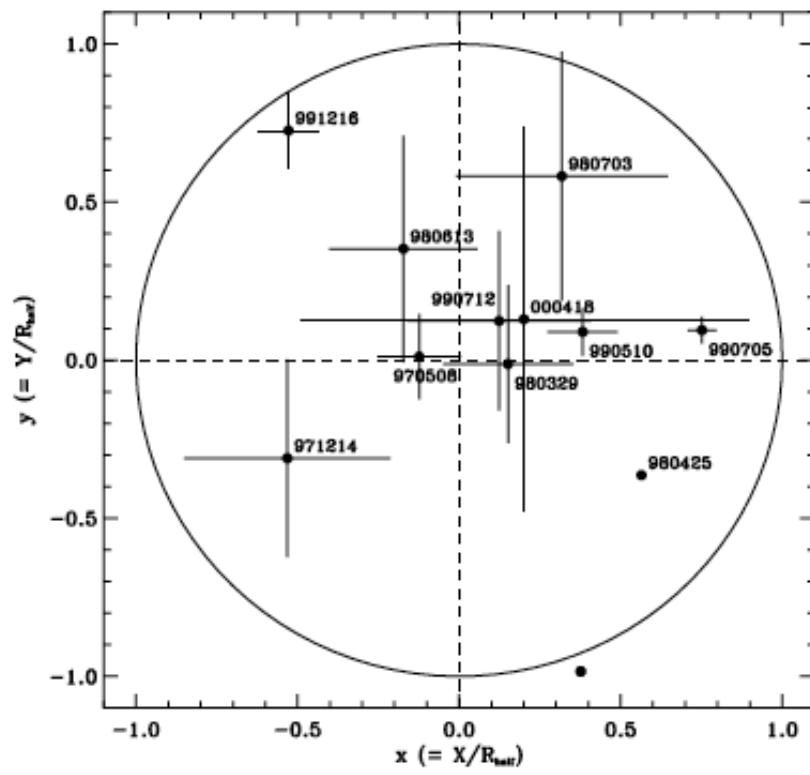
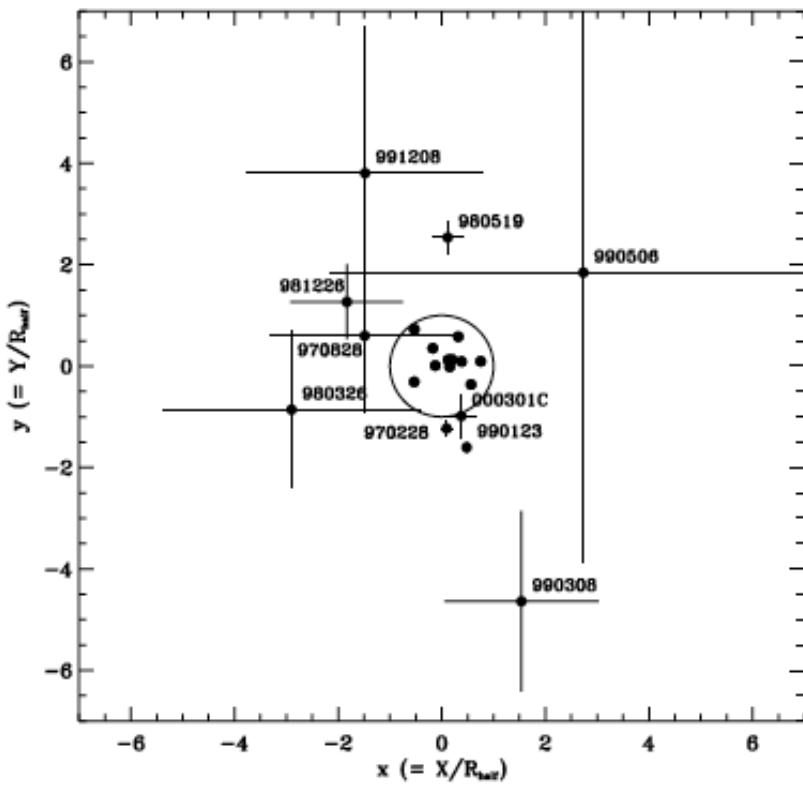
Faint and blue

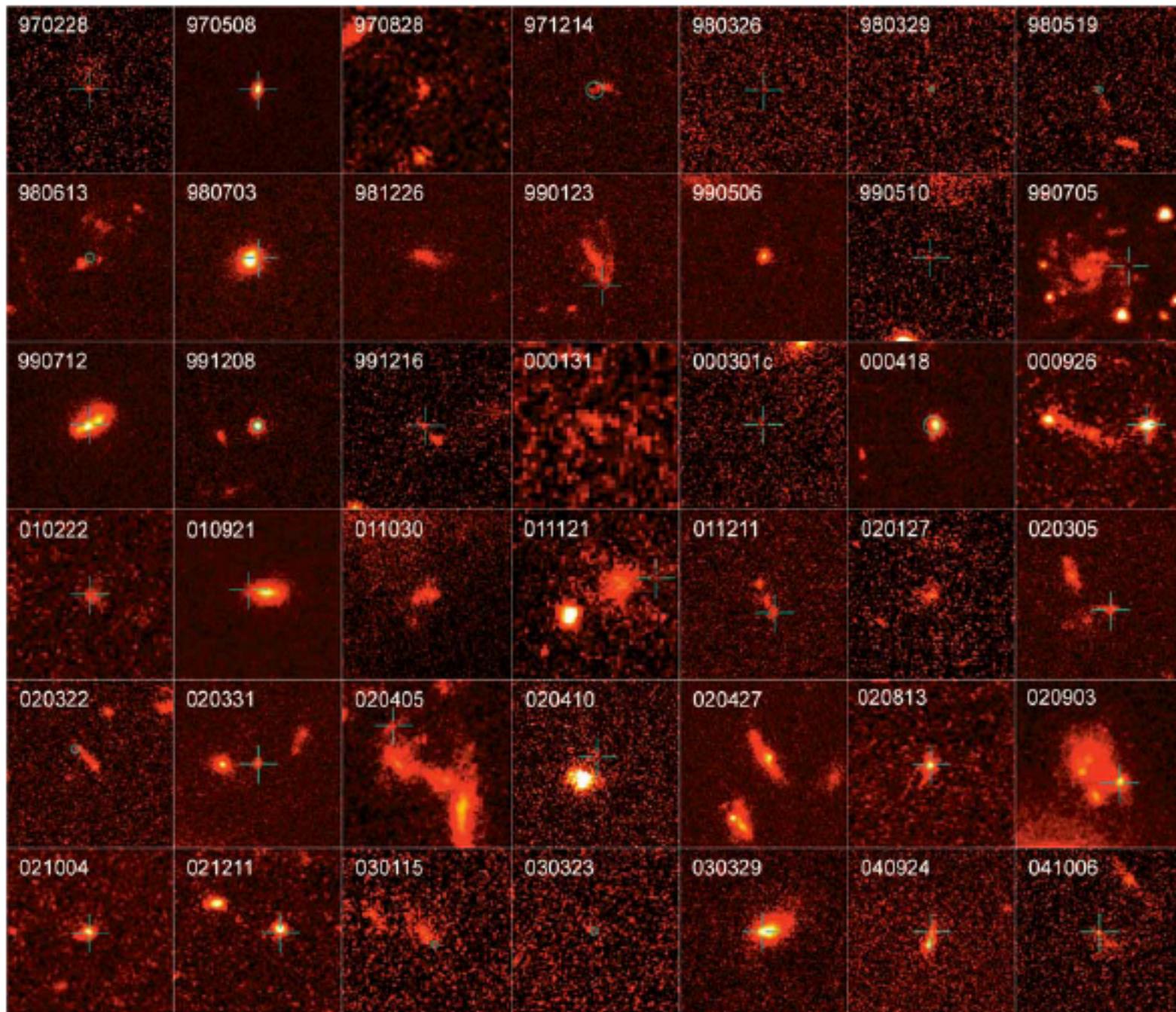


Young and large specific SFR

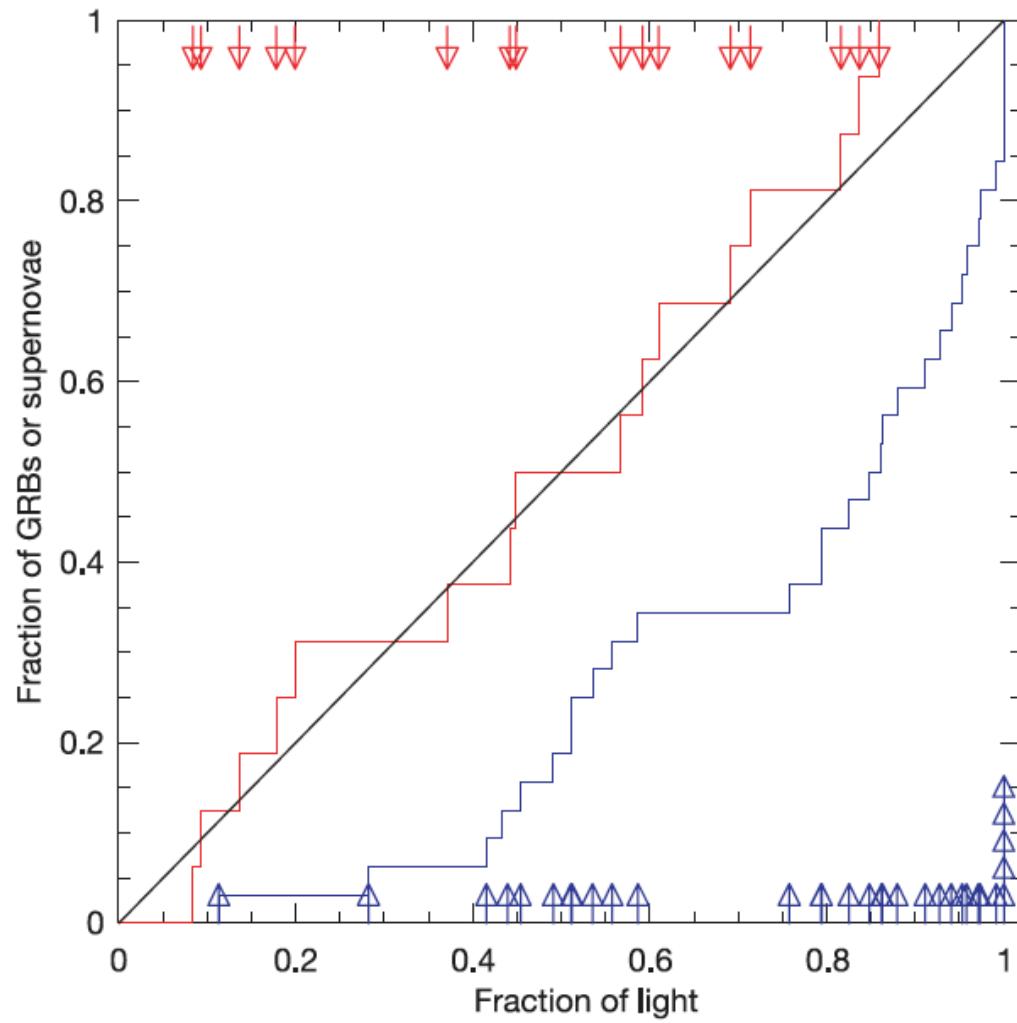


GRBs originate from UV bright region



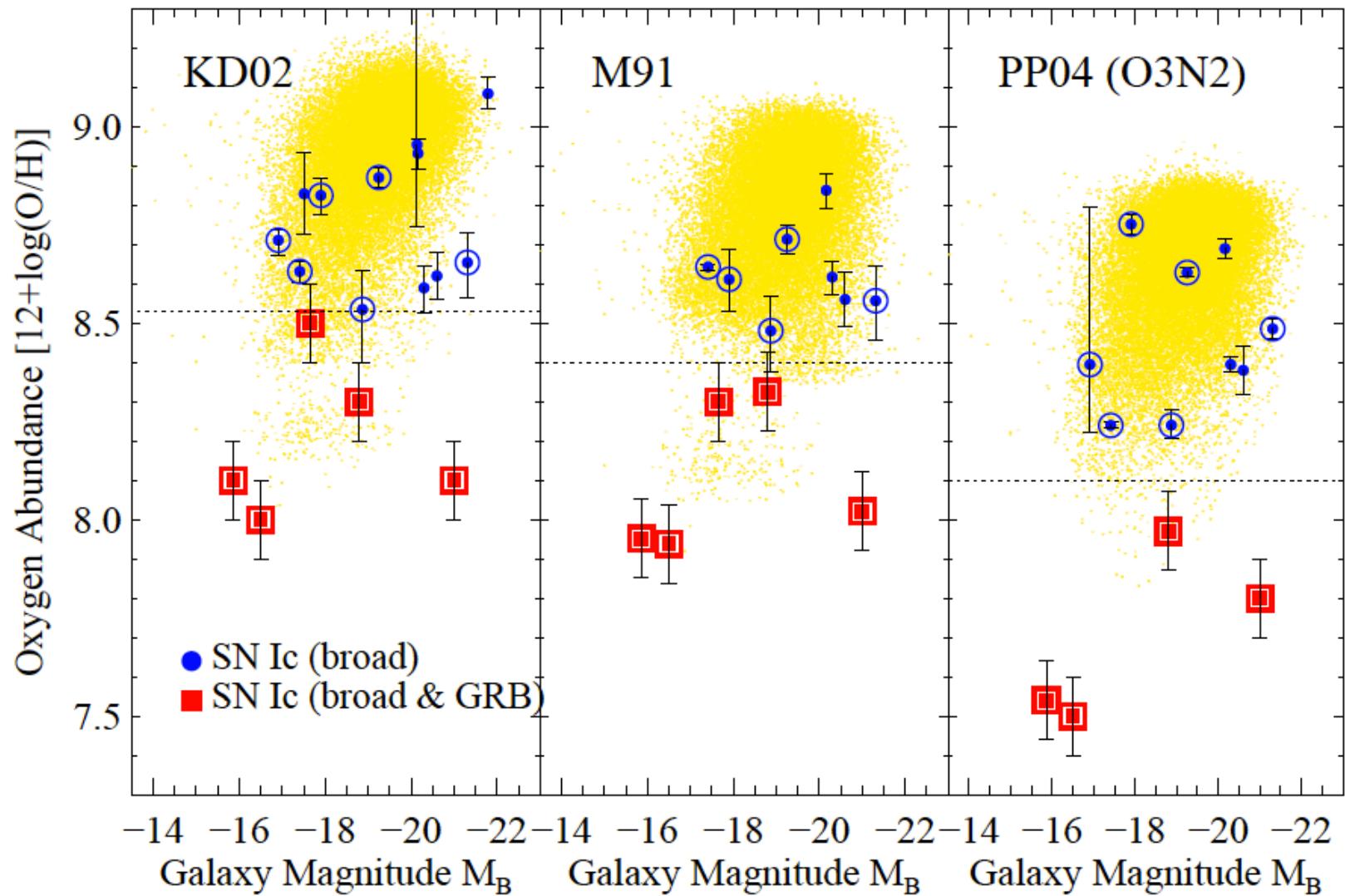


Concentrated to the brightest regions

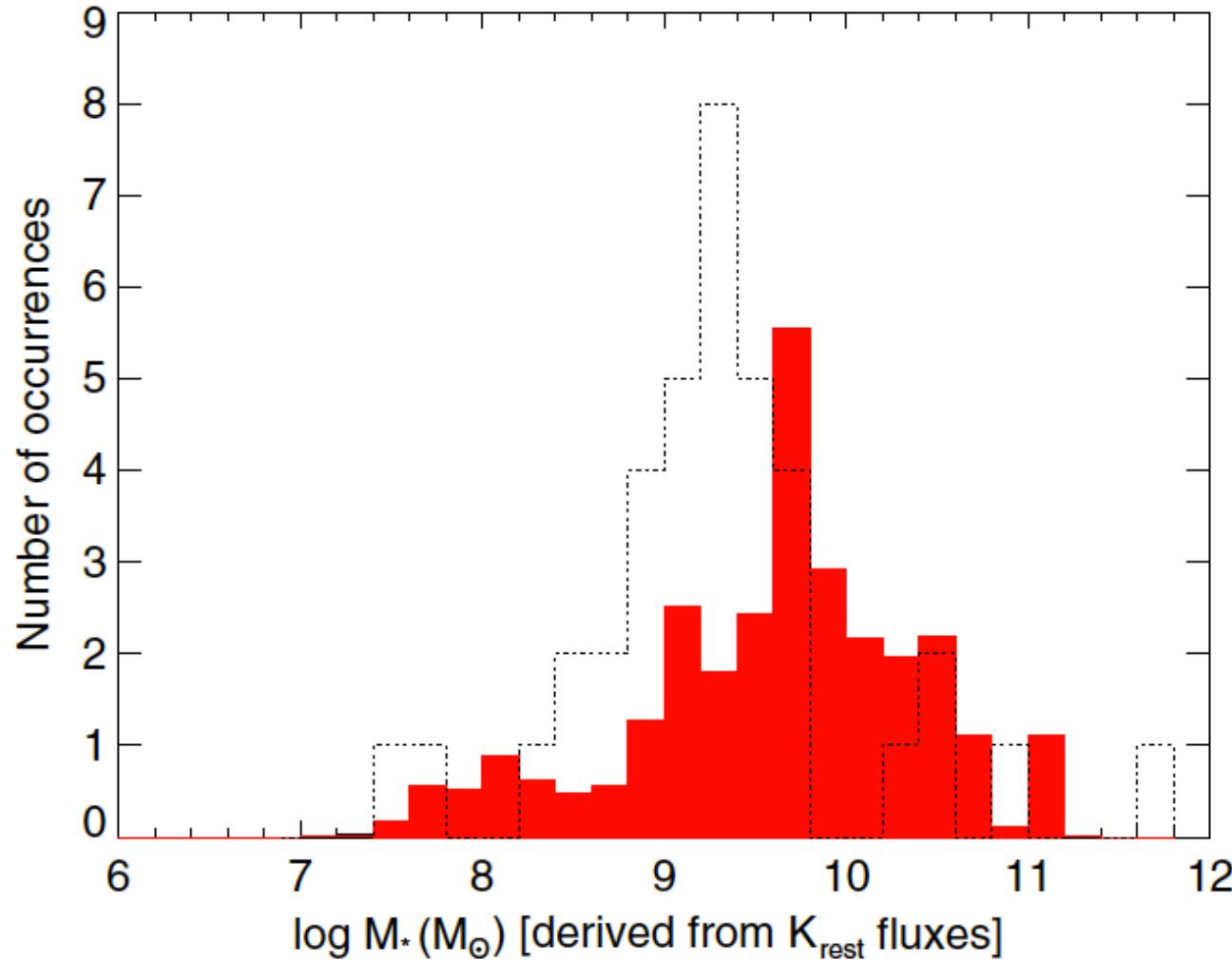


Small + irregular galaxies

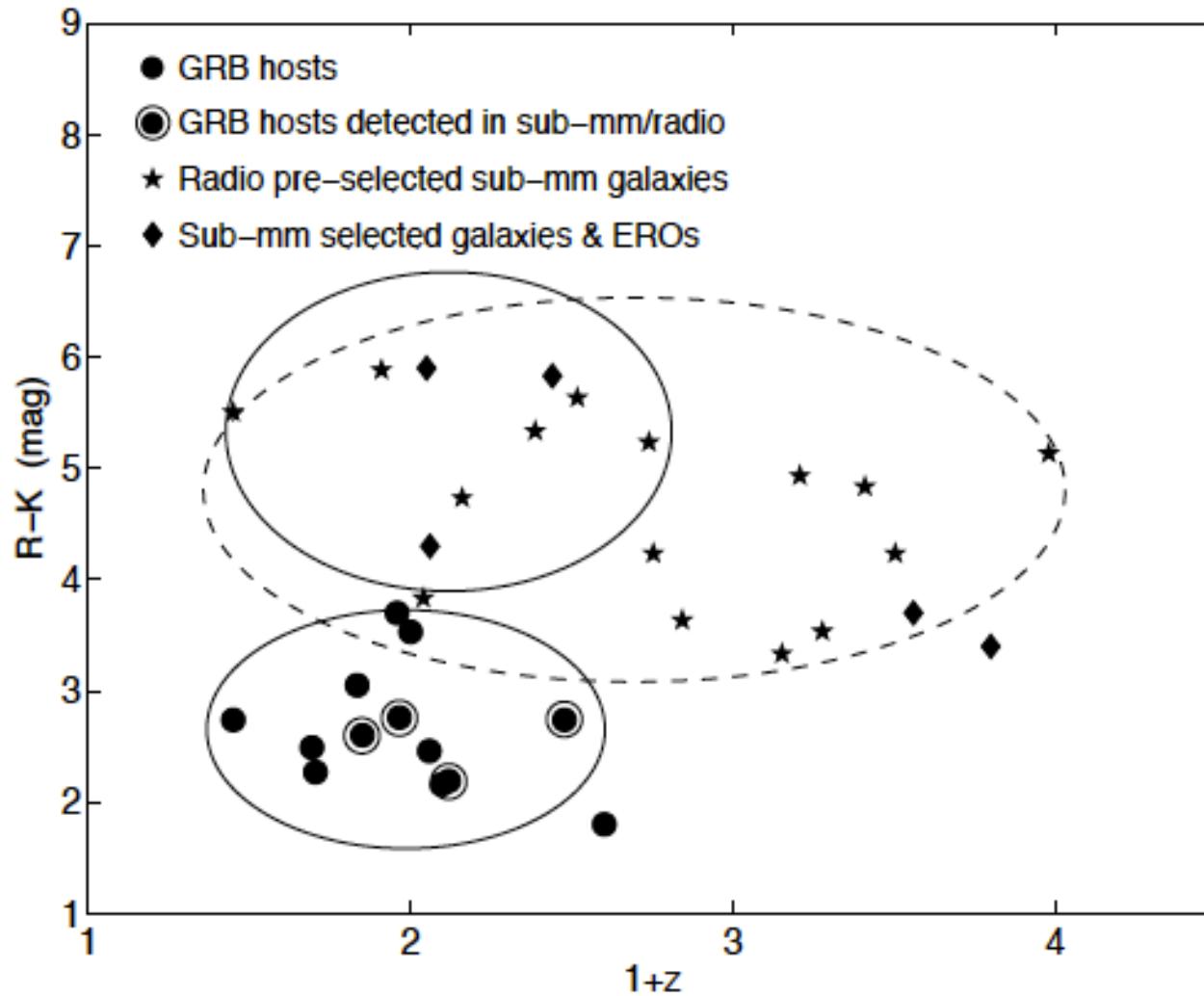
Metallicities



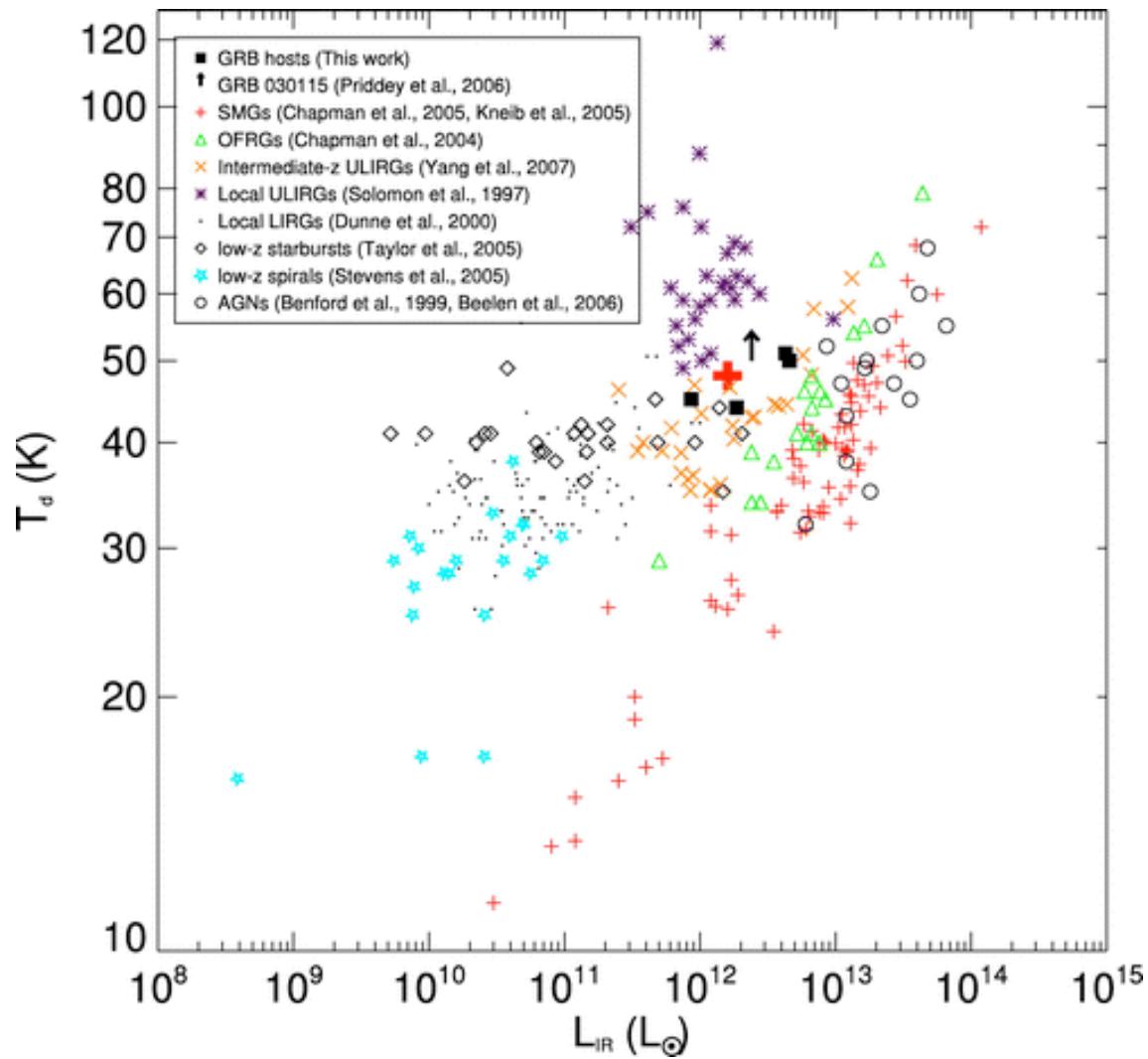
Spitzer/IRAC: Low stellar masses



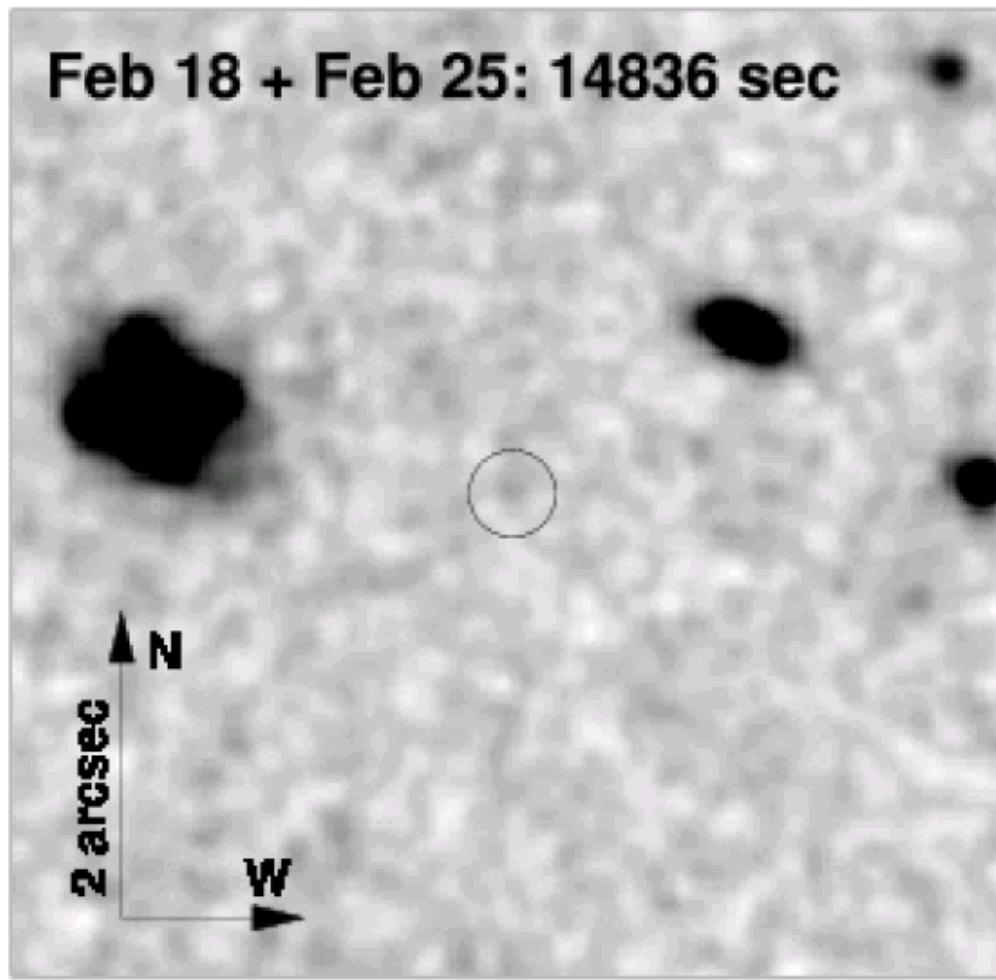
SCUBA GRB hosts: Blue and low z



Fairly high dust temperatures

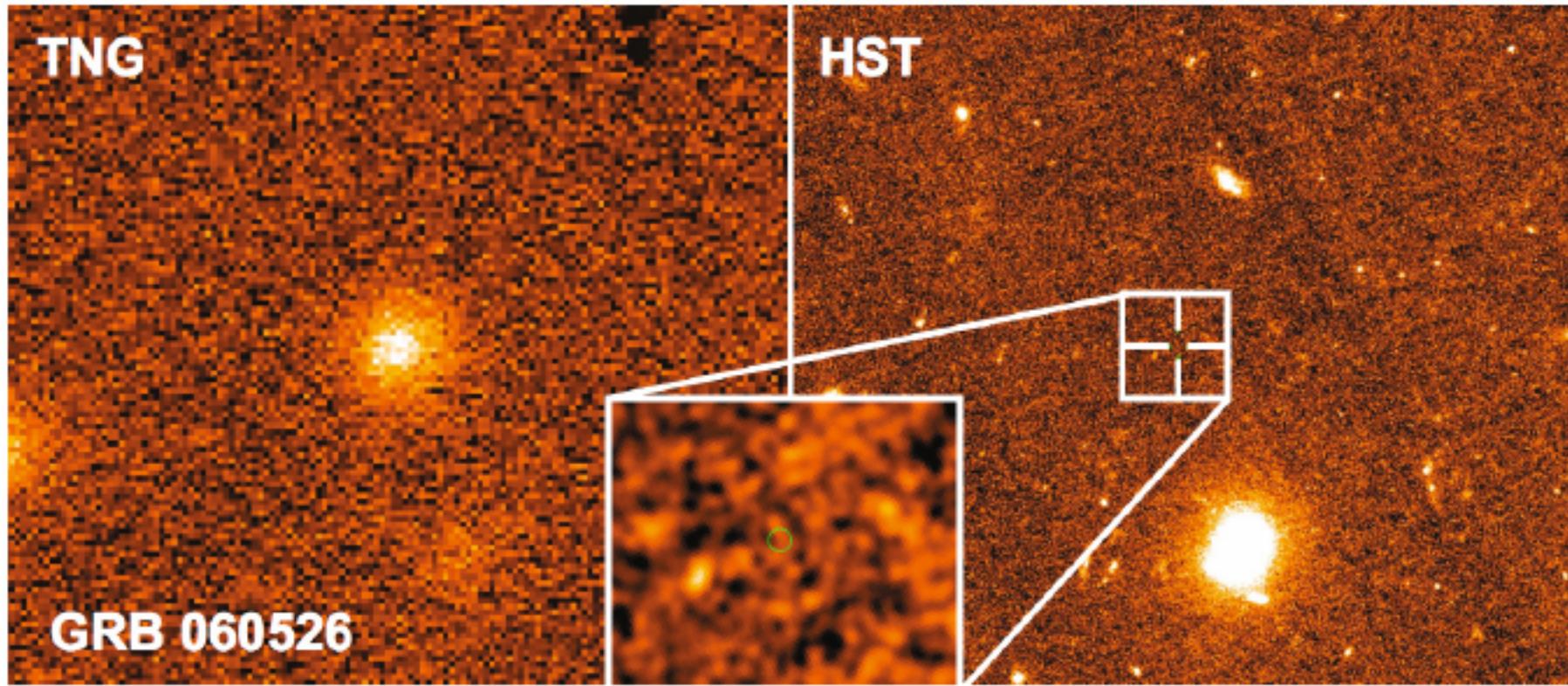


Faint galaxies @ $z=3.2$



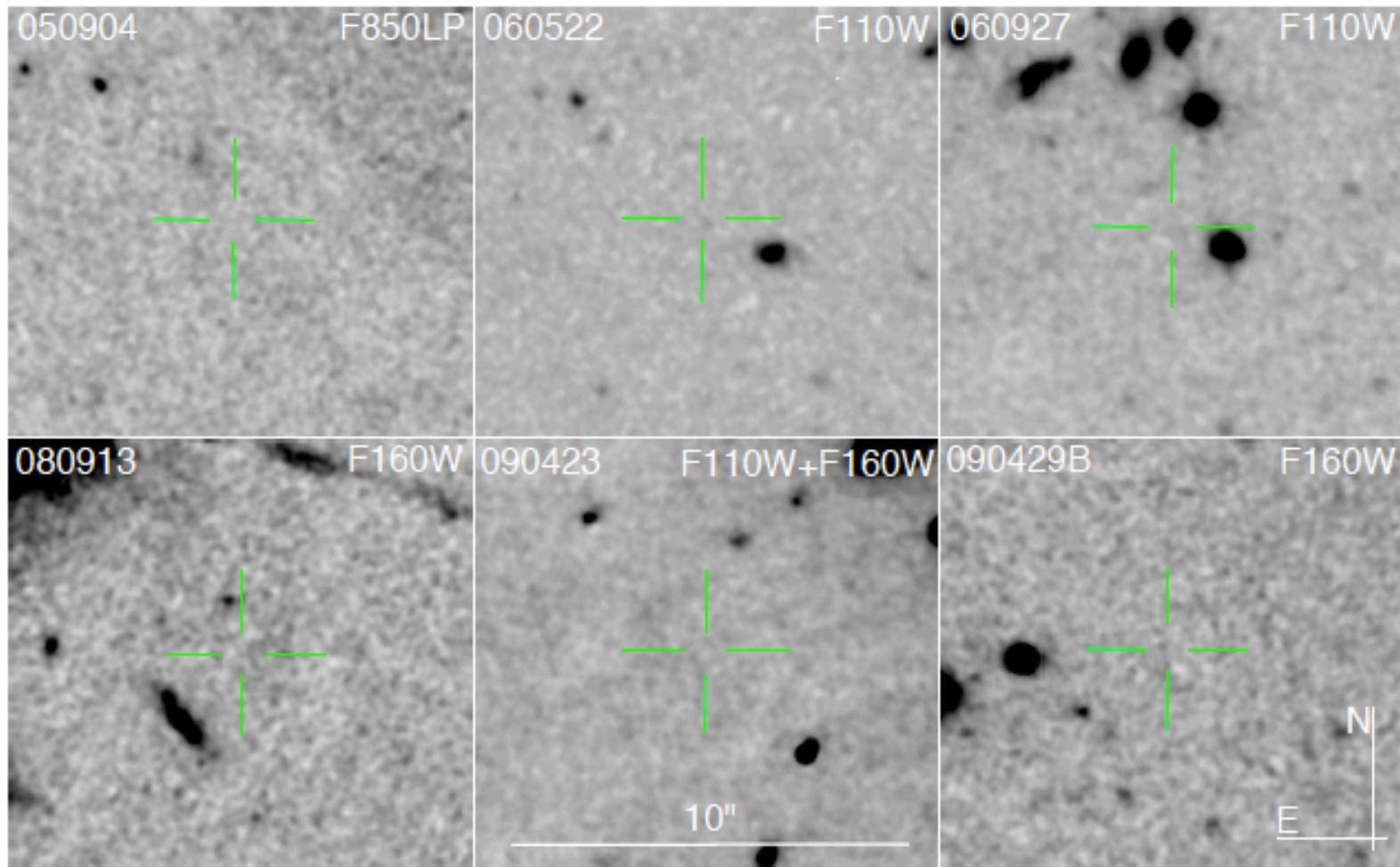
GRB 020124
 $R > 29.5$

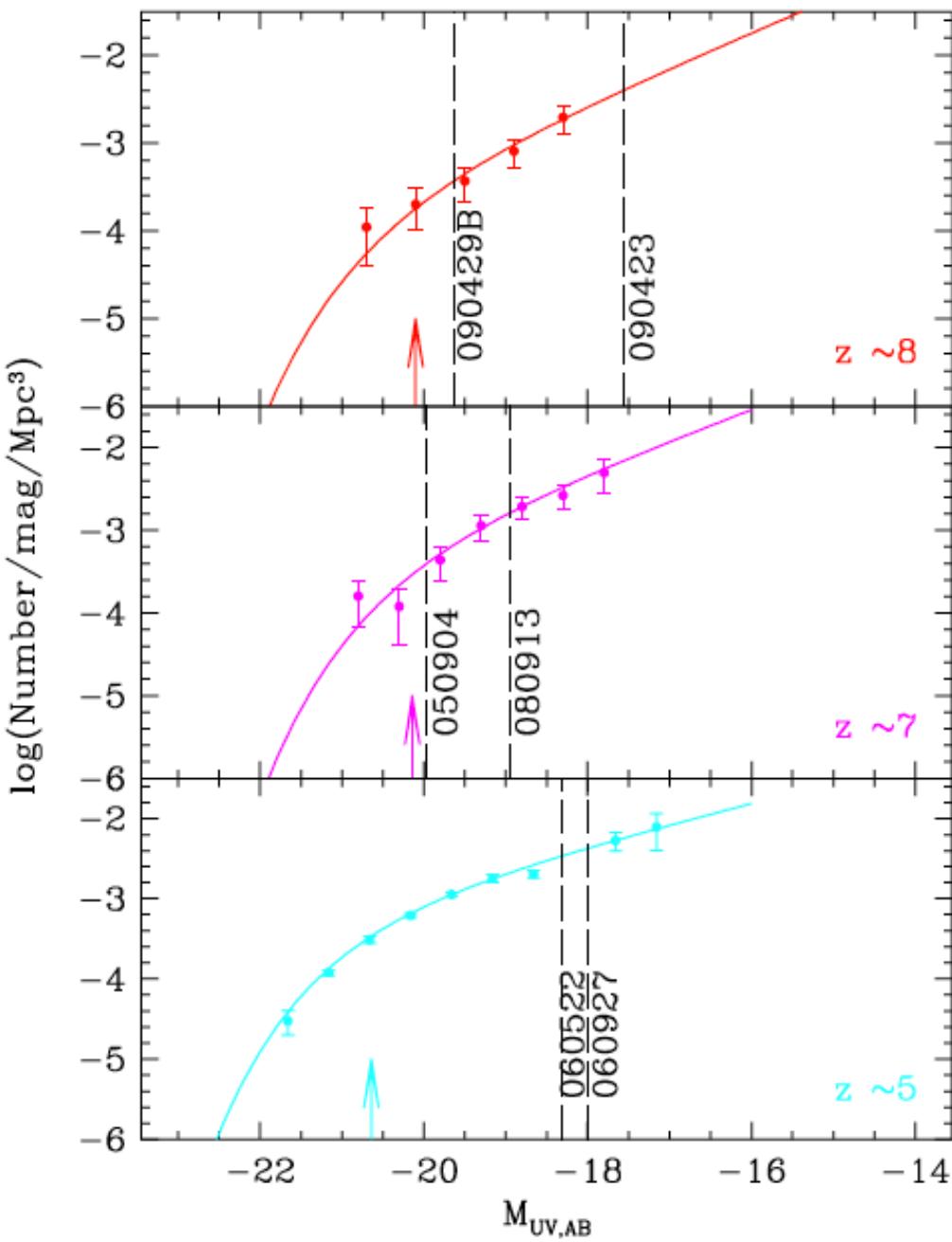
Faint galaxies @ $z=3.2$



GRB 060526
 $R > 28.5$

No $z > 5$ detections!





The Optically Unbiased GRB Host (TOUGH) survey/sample

- *Swift* based
 - Uniform
 - Large
 - Deep limits
- X-selected
 - XRT
 - Eliminate optical bias
 - Well-defined
- Large
 - Many GRBs
 - Comprehensive
- Legacy
 - Statistical
 - Carefully selected

TOUGH: Partners in Crime

Daniele Malesani

Páll Jakobsson

Nial R Tanvir

Johan PU Fynbo

Bob Chapman

Andrew Levan

Bo Milvang-Jensen

Steve Schulze

Michał Michalowski

Darach Watson

Paul M Vreeswijk

Javier Gorosabel

Thomas Krühler

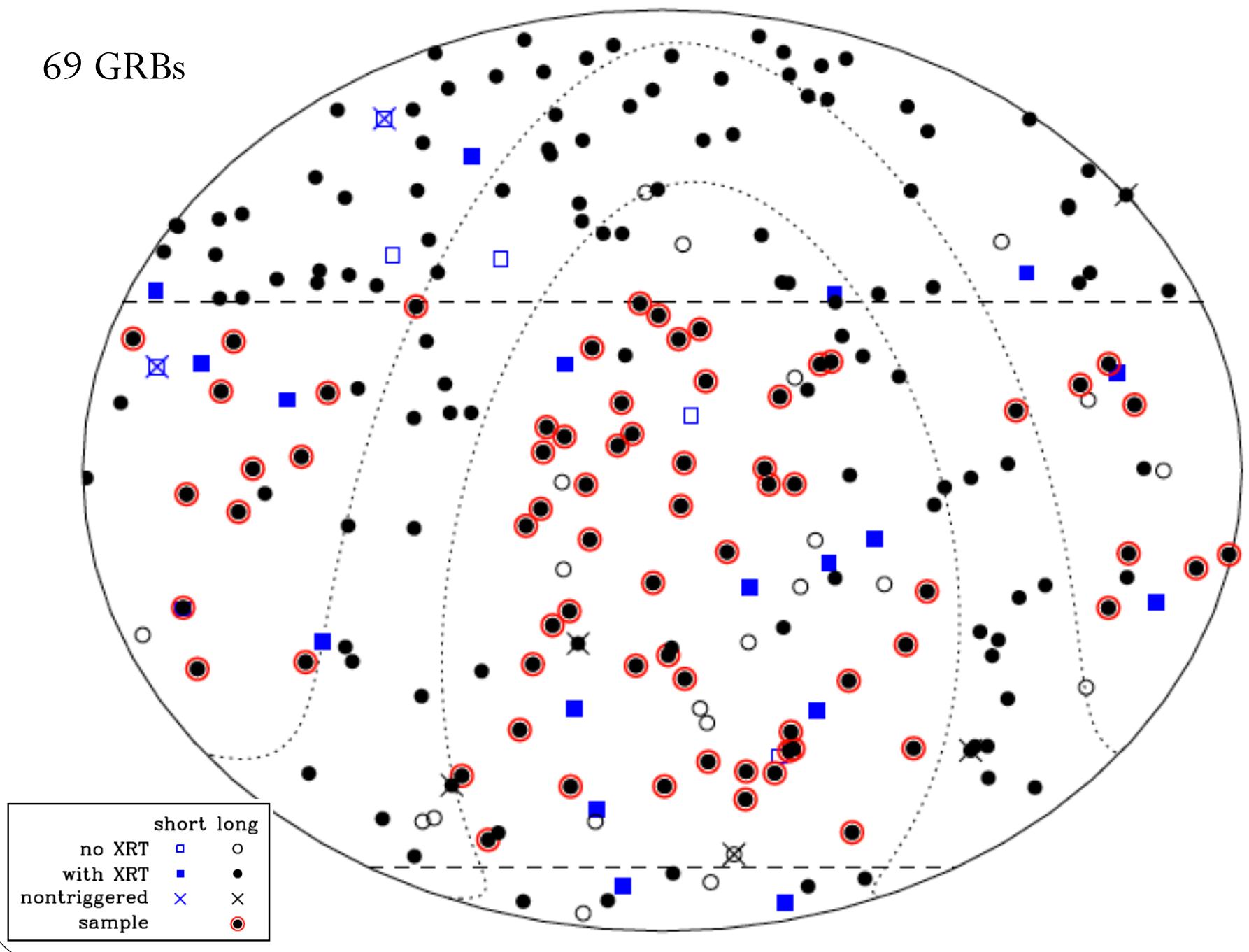
Palle Møller

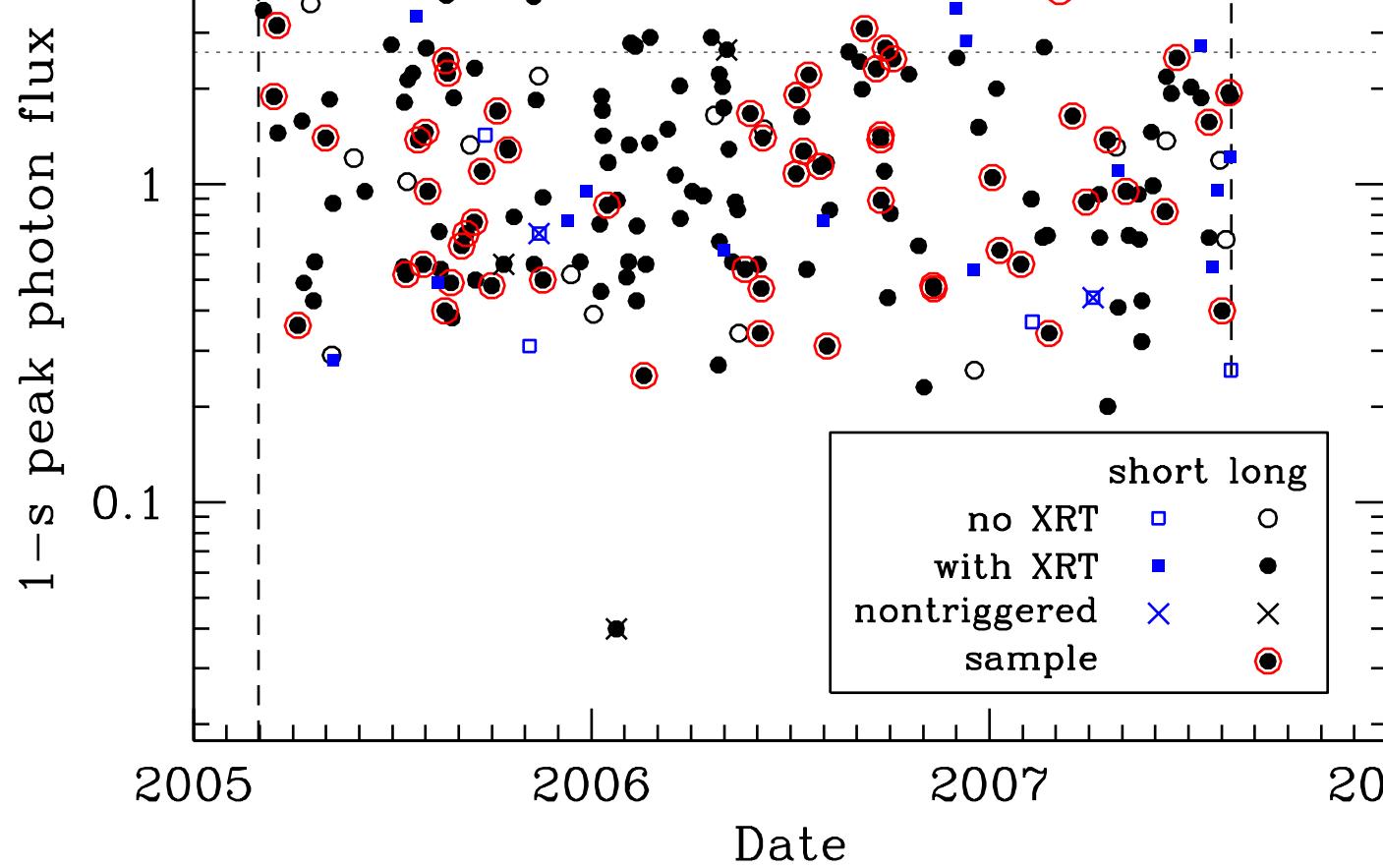
Dan Perley

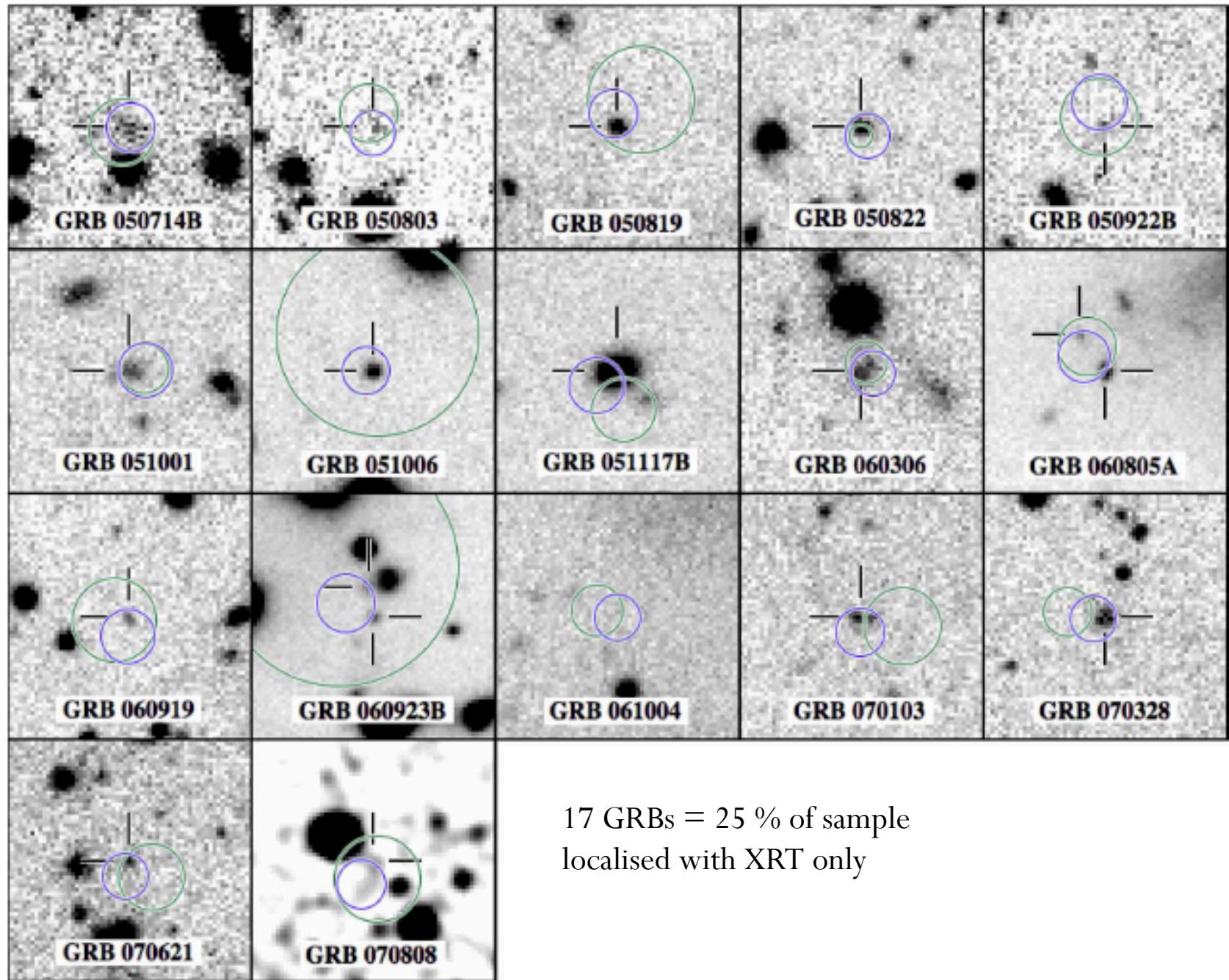
TOUGH selection criteria

1	Onboard <i>Swift</i>/BAT trigger
2	Long GRB: Duration $T_{90} > 2$ s
3	X-ray afterglow position available within 12 h
4	Galactic $A_V < 0.5$ mag
5	Sun distance > 55 deg
6	No nearby bright stars
7	1 March 2005 – 10 August 2007
8	-70 deg $< \delta < +27$ deg (J2000.0)
9	Localisation accuracy better than 2”

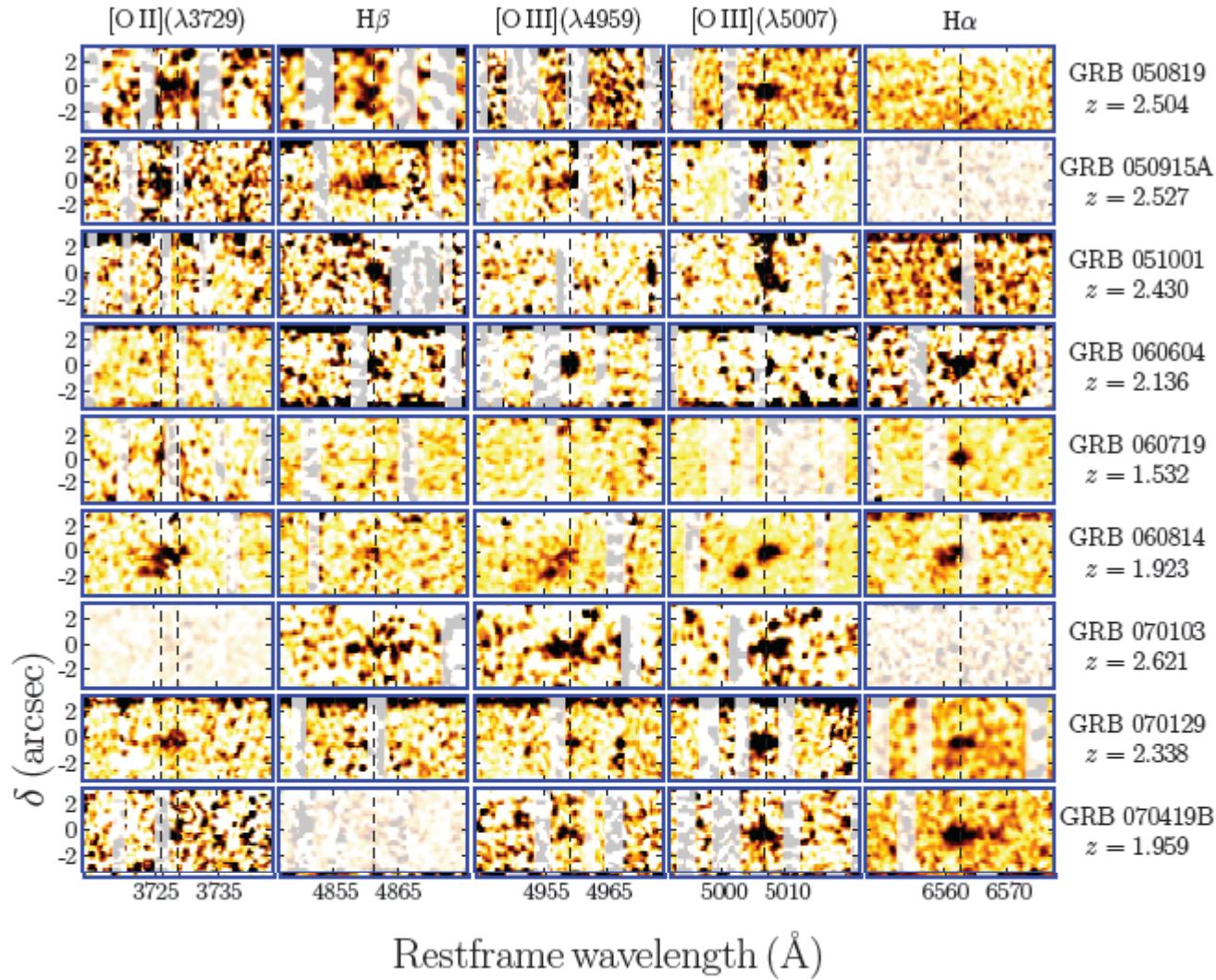
69 GRBs



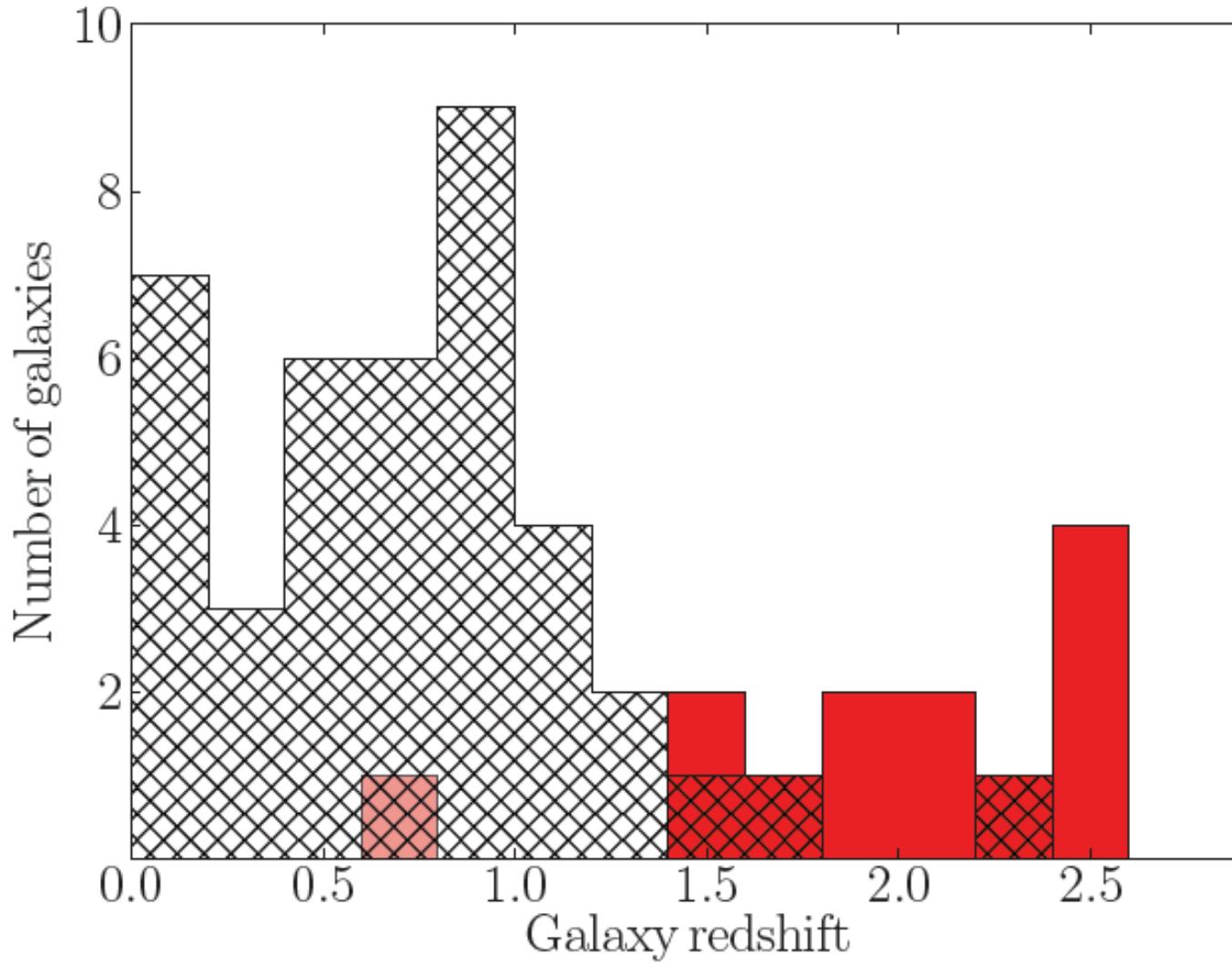




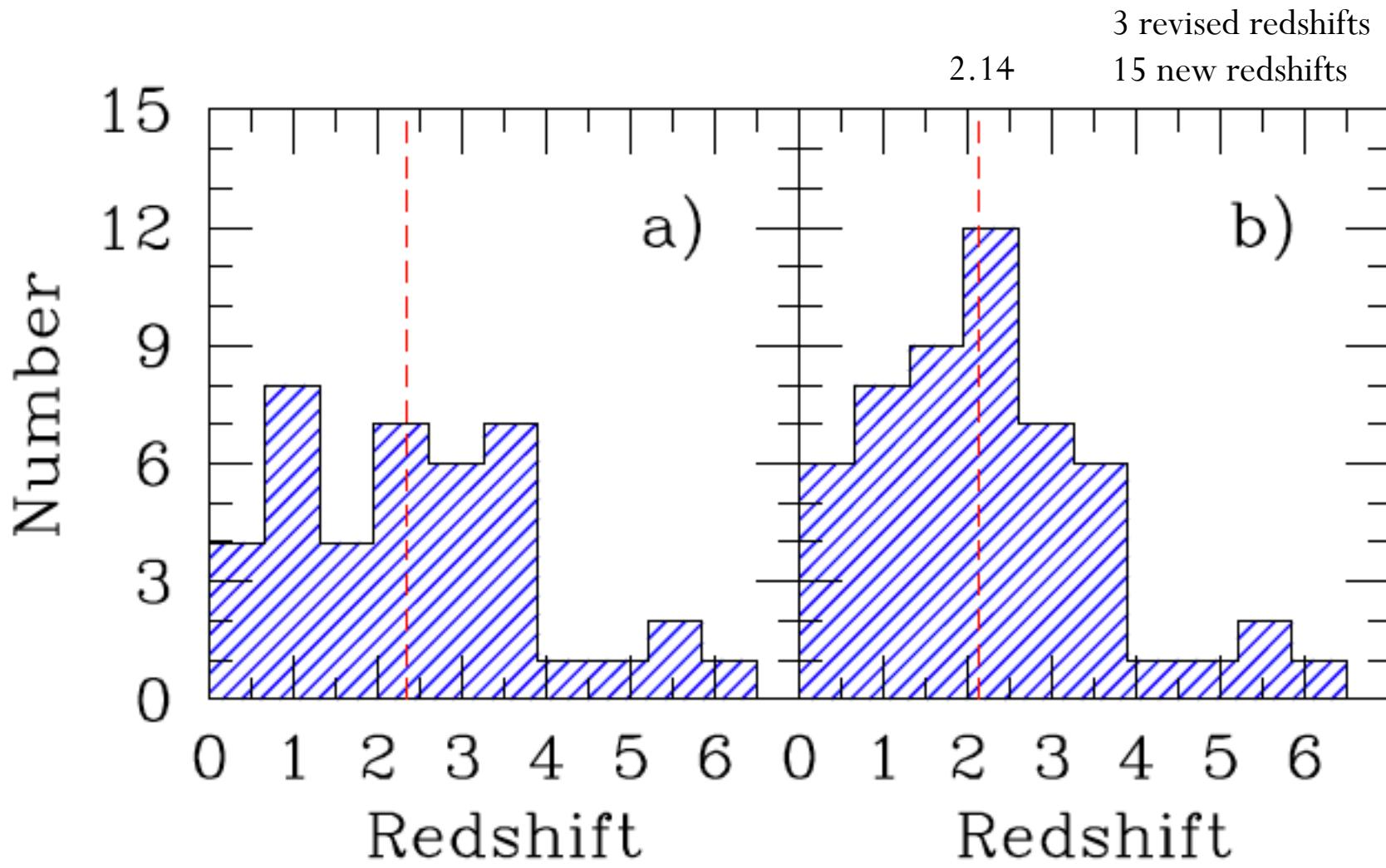
New X-shooter redshifts



X-shooter finds redshifts at $z \sim 2$

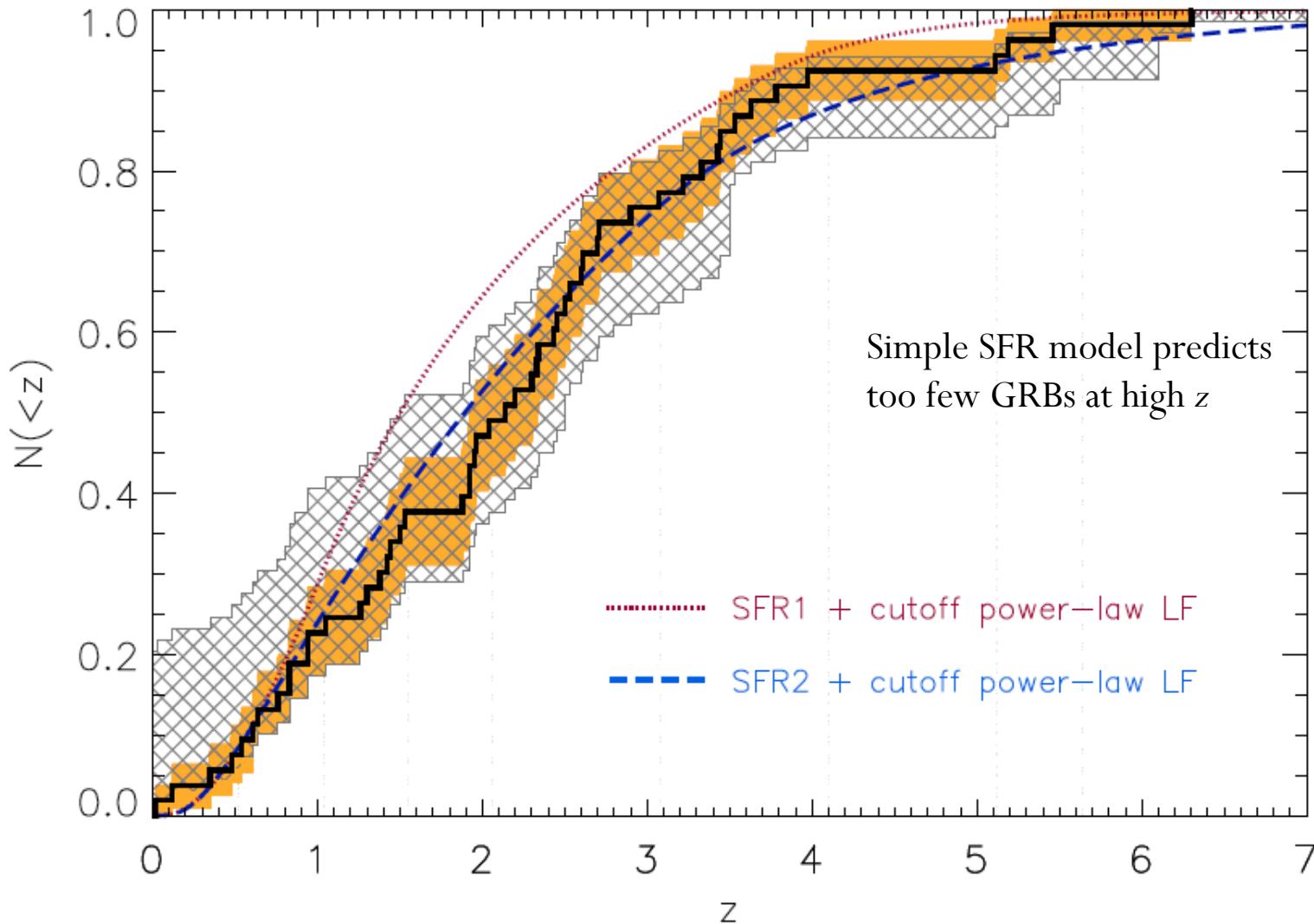


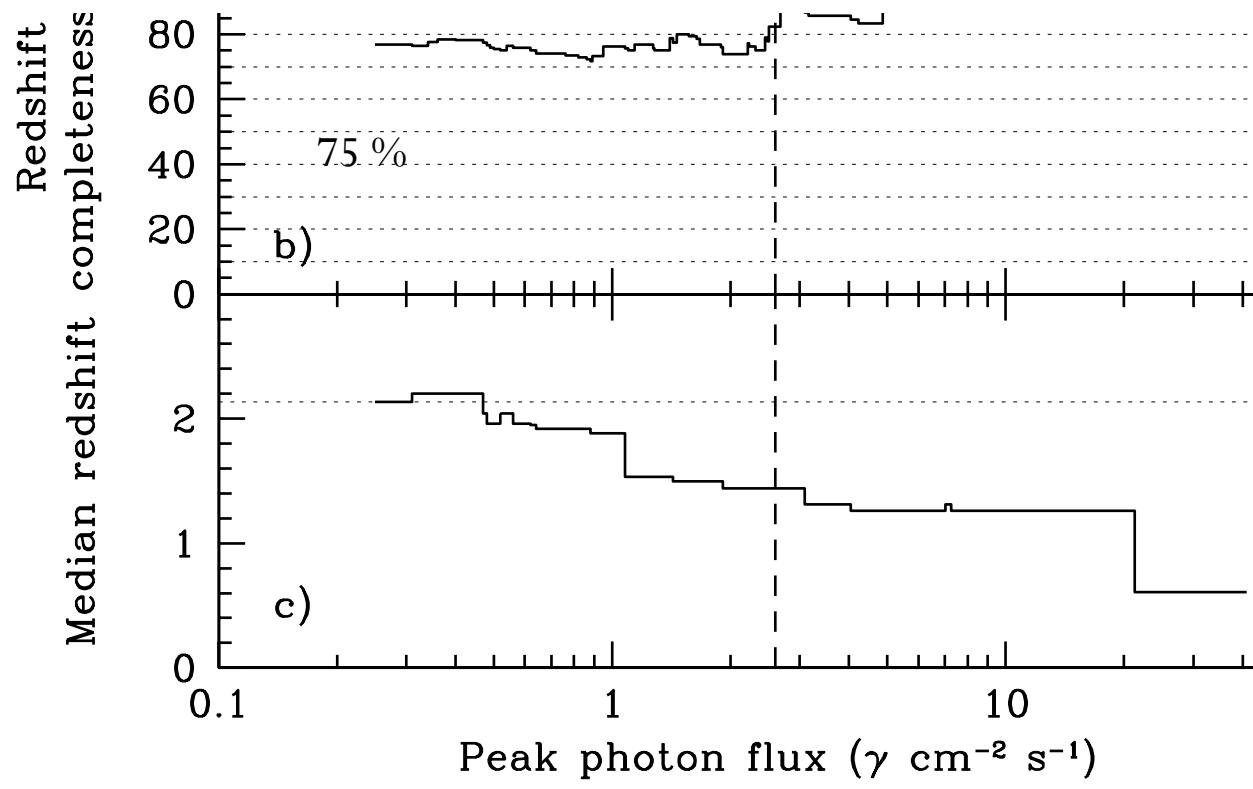
TOUGH redshift distribution



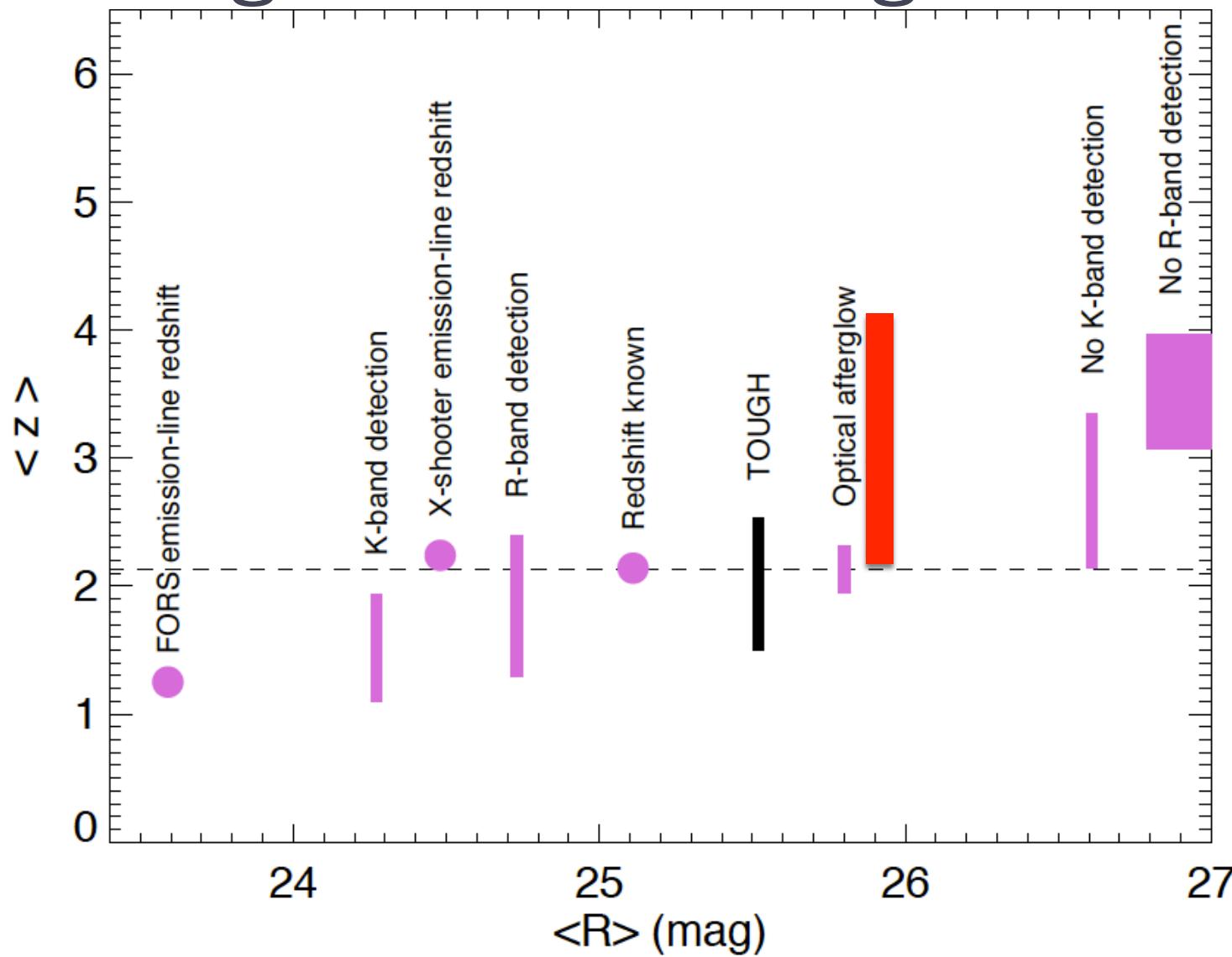


TOUGH redshift distribution

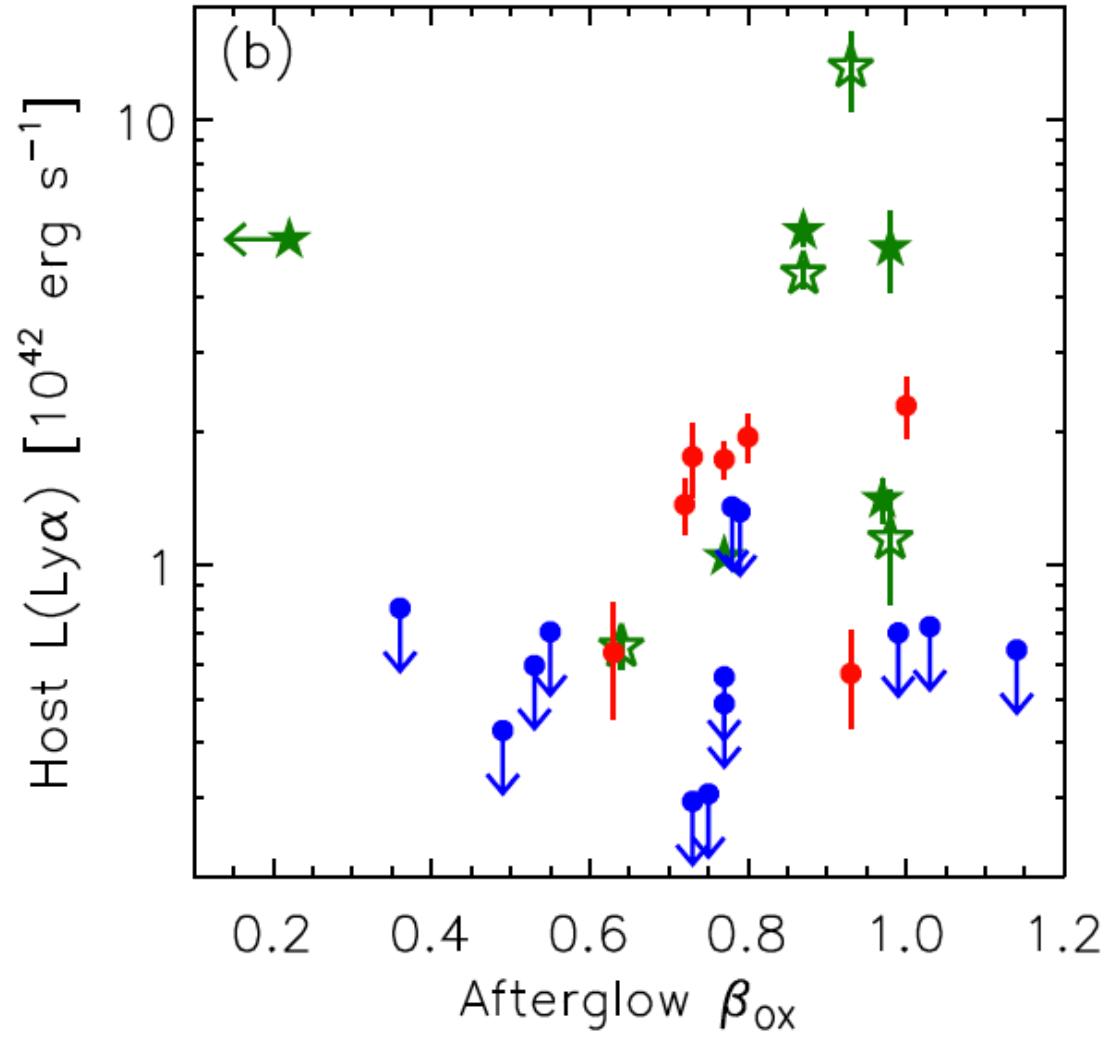


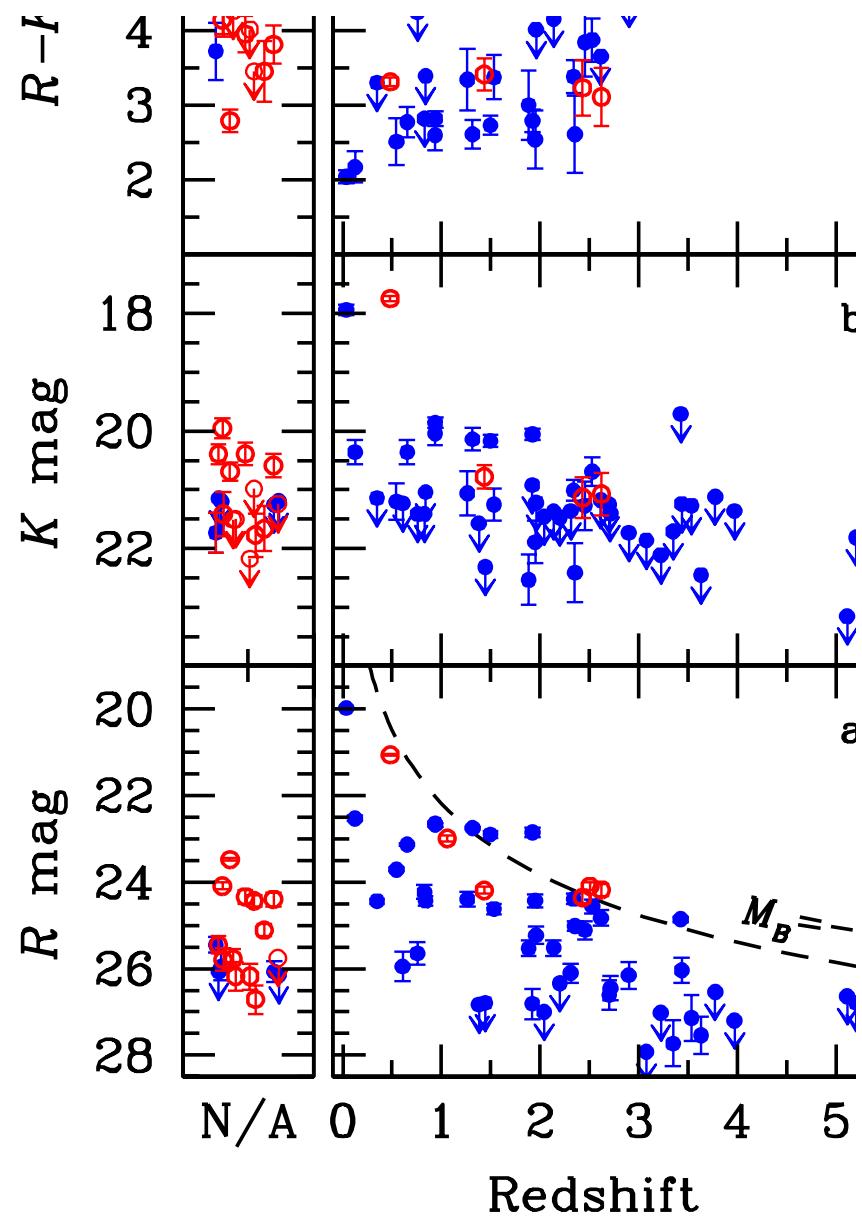


Faint galaxies are at higher redshift



$\text{Ly}\alpha$ host galaxy emission





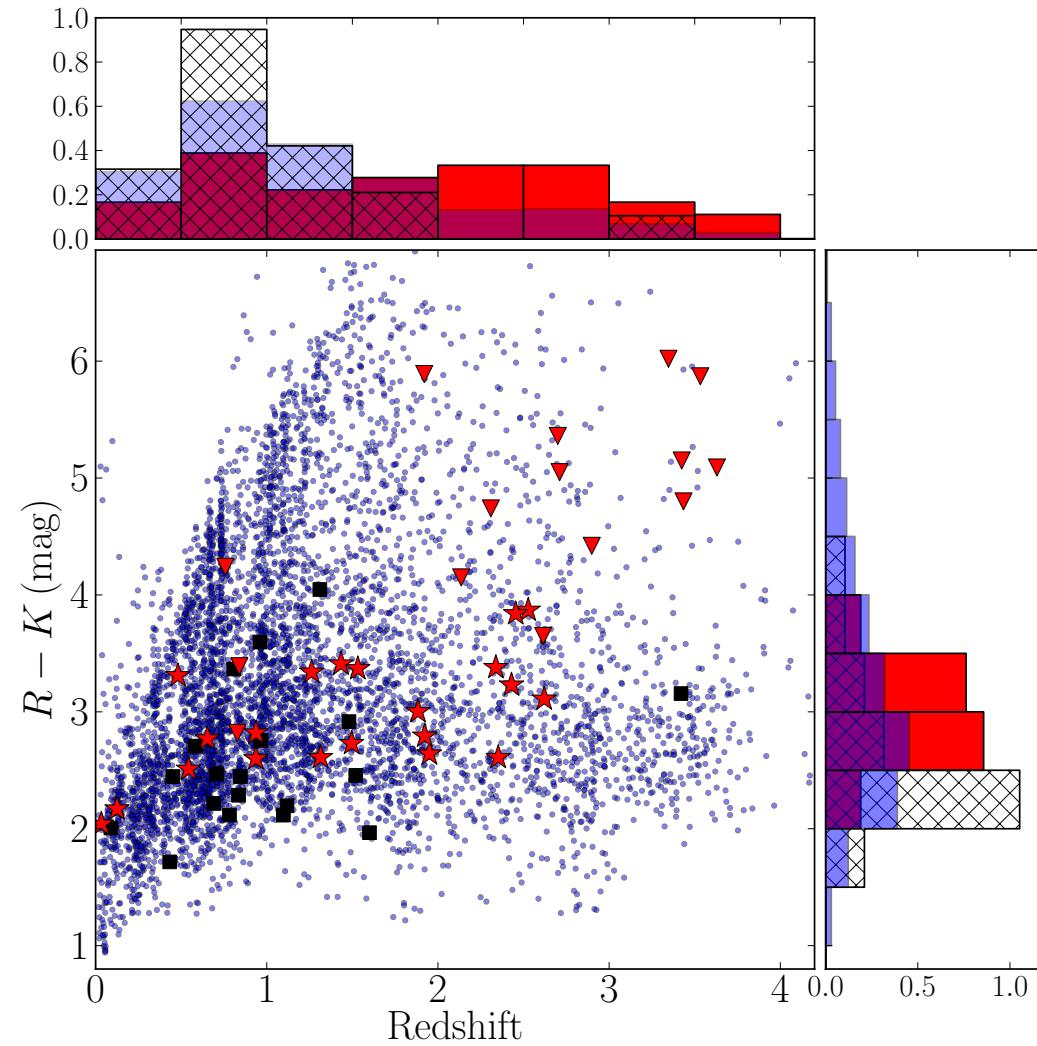
2 EROs

Blue galaxies

Sub-luminous

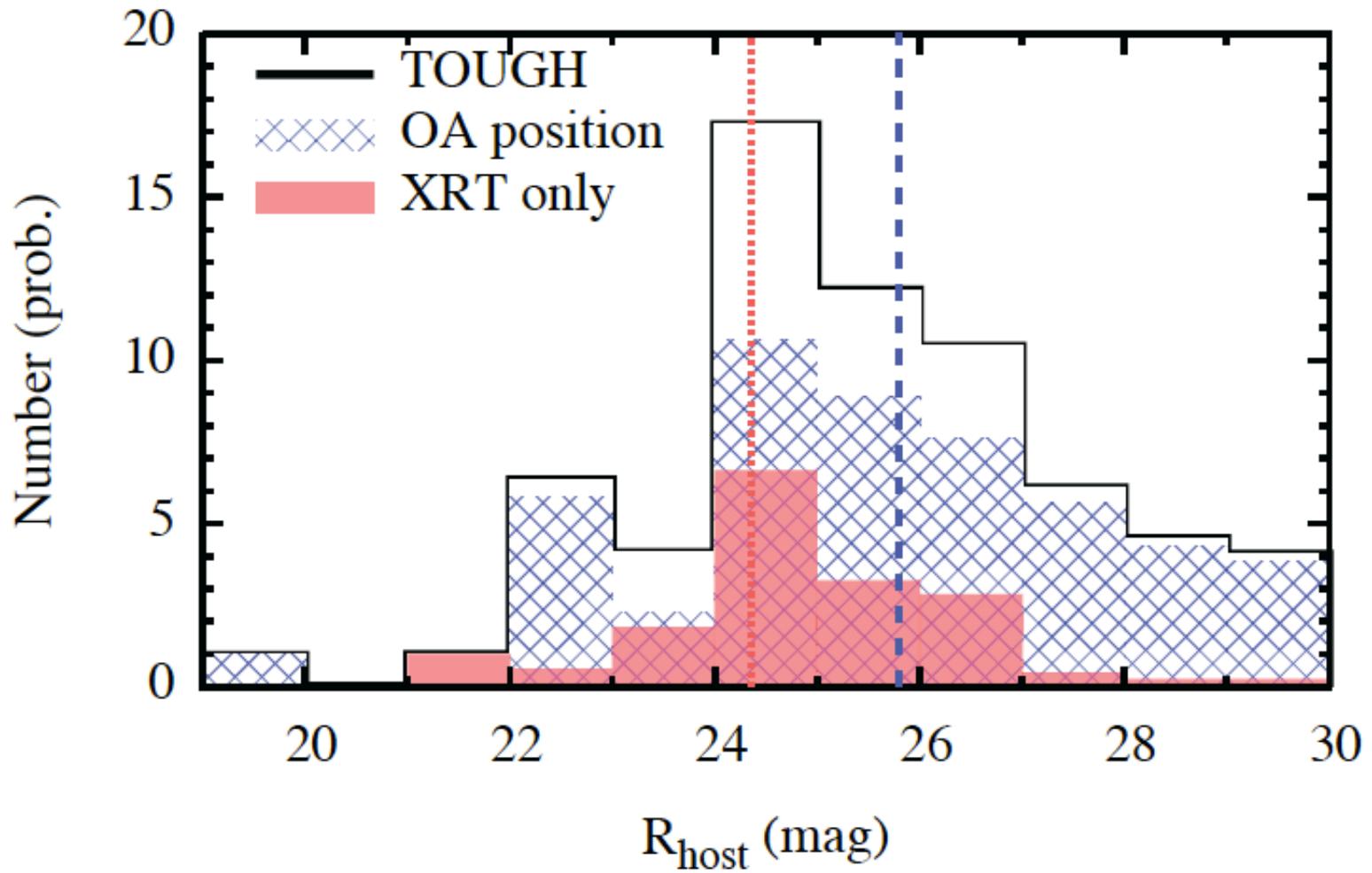
17 $z > 2$ galaxies

TOUGH: higher z and redder

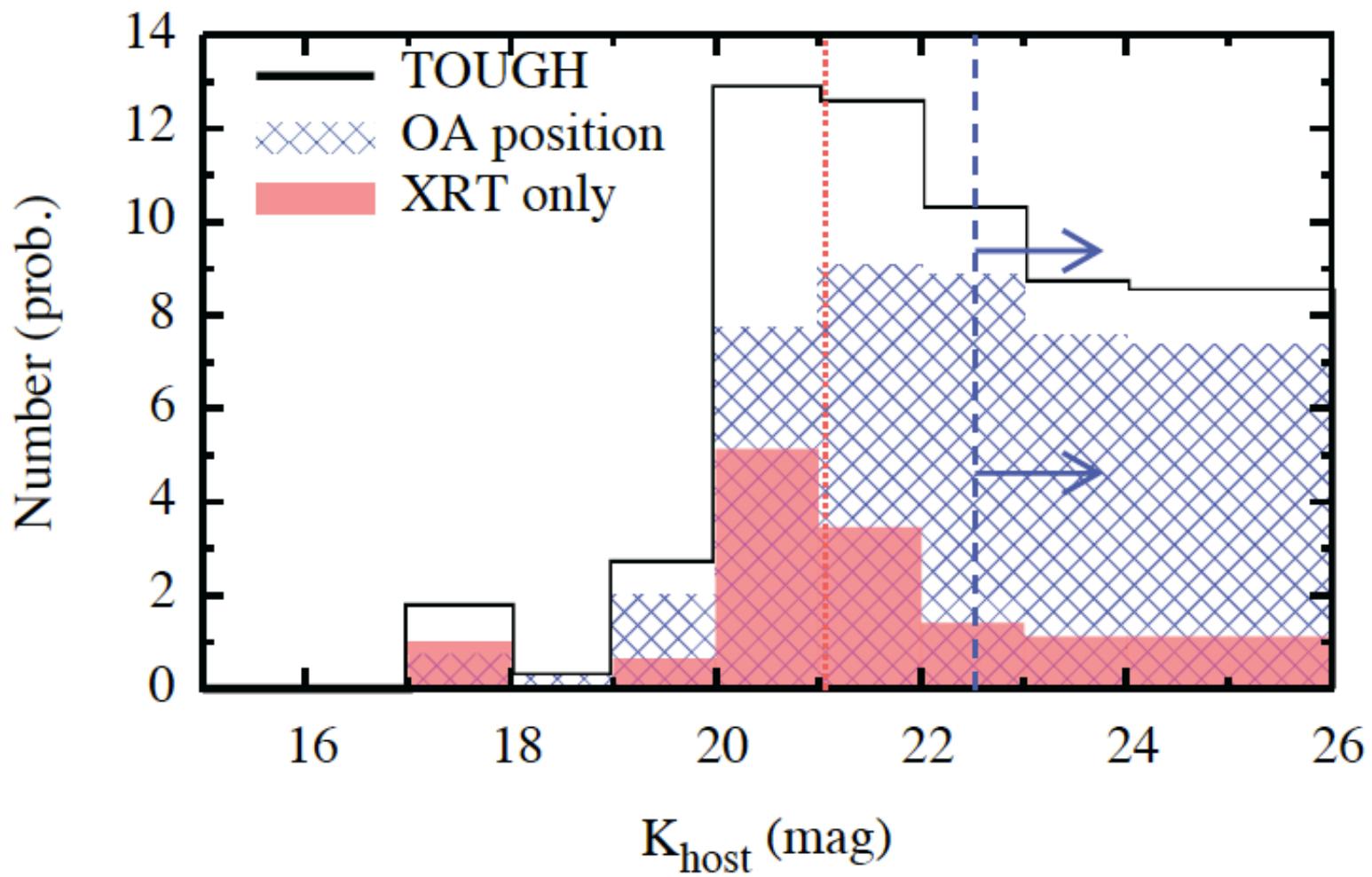


Red: TOUGH
Black: Savaglio et al. 2009
Blue: GOODS

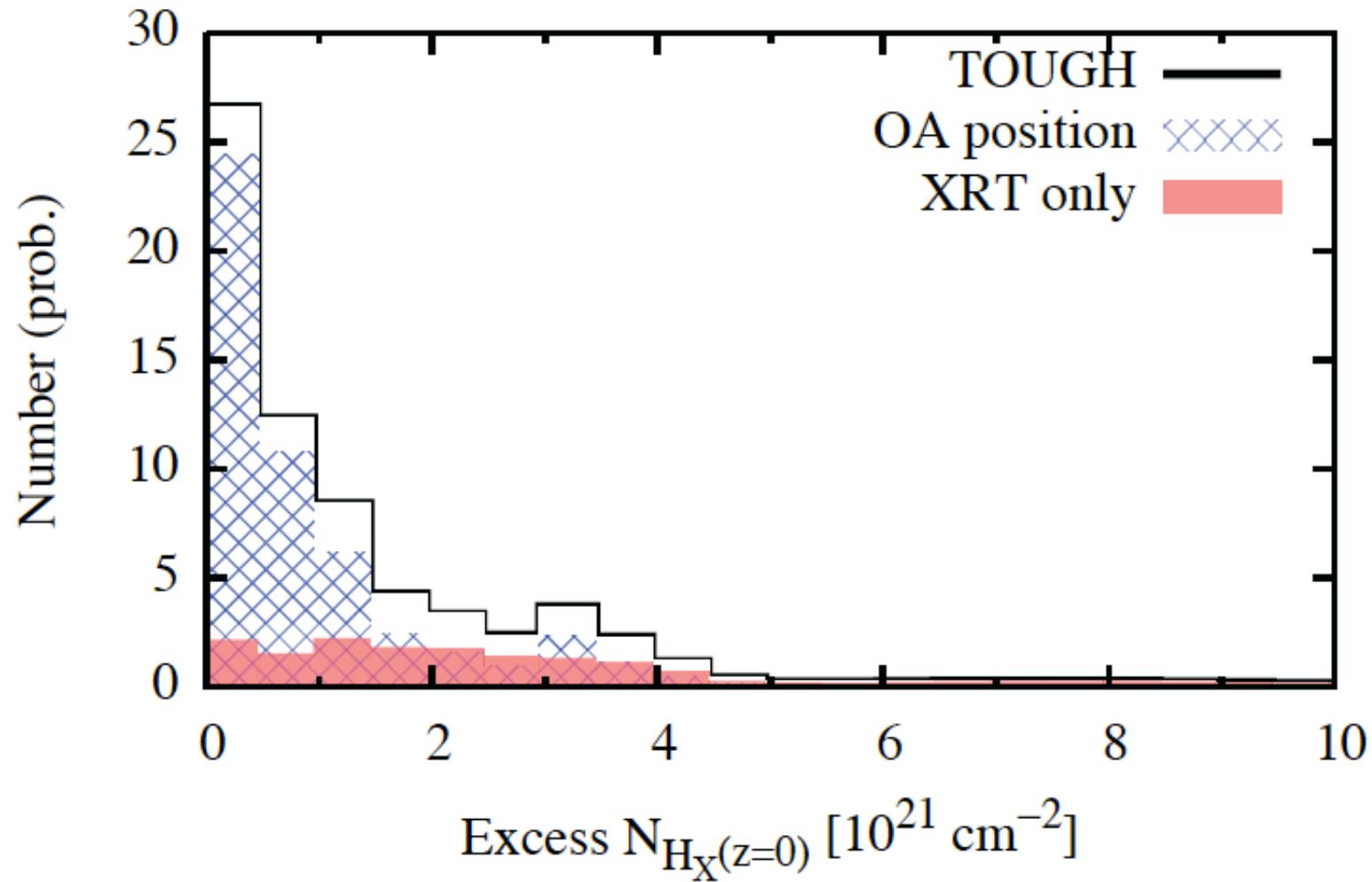
Optical afterglow vs. XRT-localised

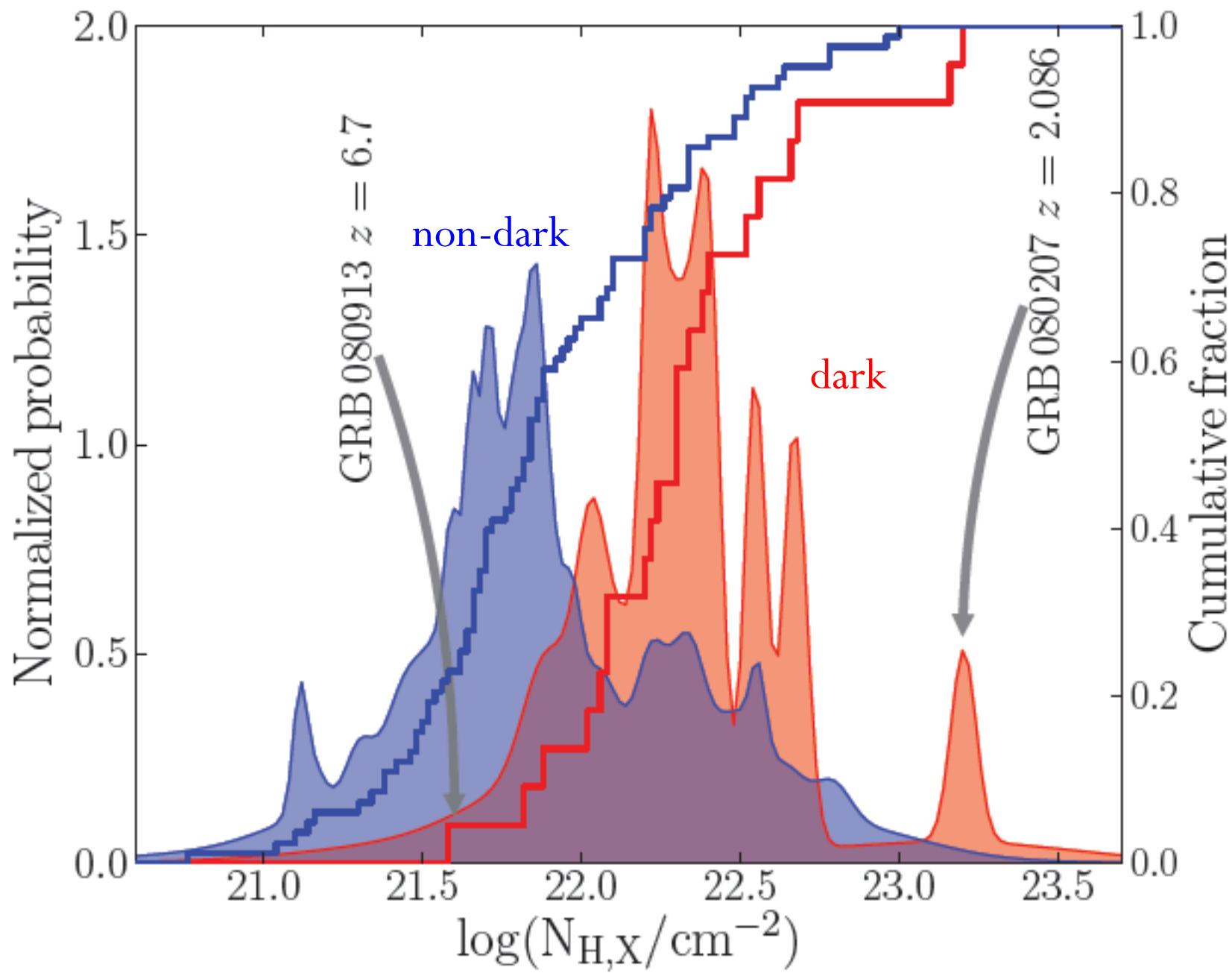


Optical afterglow vs. XRT-localised



Optical afterglow vs. XRT-localised





Summary

- Much of what we know about GRB hosts is based on optically biased, small and incomplete samples
- TOUGH provides a new *Swift* BAT/XRT-selected sample
- Deep $R+K$ imaging of 69 galaxies and 15 new redshifts (53 total, so far)
- 17 detections of $z > 2$ galaxies
- Significant differences between galaxies with or without optical afterglow. Galaxies without optical afterglow are brighter and redder. This is likely due to dust (see also Krühler et al. 2011 + Perley talk later).

The first TOUGH papers

Paper #	Lead author	Subject
1	Hjorth	Overview, sample definition
2	Malesani	R and K photometry, host identification
3	Jakobsson	TOUGH redshift distribution
4	Milvang-Jensen	$\text{Ly } \alpha$ emission survey
5	Kröhler	X-shooter redshifts
6	Michalowski	Radio survey of $z < 1$ TOUGH hosts
7	Schulze	UV host luminosity function
8	Watson	X-ray absorption properties

<http://www.dark-cosmology.dk/TOUGH>

