Searching for Lyα emission in GRB host galaxies

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GRB basics

GRB = Gamma Ray Burst

- γ–ray burst, localised to a few arcmin (Swift satellite)
- X–ray afterglow usually seen, localised to a few arcsec (Swift)
- Optical afterglow — not always seen
- Spectroscopy of the optical afterglow can provide a redshift
- A *host galaxy* may be found, typically in deep observations at later times

Do GRB host galaxies have Lyα emission?

In the pre-Swift era, Fynbo et al. (2003) noted:
5 detections of Lyα emission from GRB host galaxies out of 5 possible:

- GRB 011211, $z = 2.14$, EW $= 21 \pm 10$ Å (Fynbo et al. 2003)
- GRB 000926, $z = 2.04$, EW $= 71 \pm 18$ Å (Fynbo et al. 2002)
- GRB 971214, $z = 3.42$ (Kulkarni et al. 1998; Ahn 2000)
- GRB 021004, $z = 2.33$ (e.g. Møller et al. 2002 and refs. therein)
- GRB 030323, $z = 3.37$ (Vreeswijk et al. 2004)

This result needed to be verified using a large, well defined and complete sample of *Swift* bursts

The GRB host ESO Large Programme by Hjorth et al.

Fundamental properties of GRB-selected galaxies:
A Swift/VLT legacy survey

- GRBs as tracers of star-forming galaxies (long GRBs are associated with the deaths of massive stars, Stanek et al. 2003; Hjorth et al. 2003)
- GRB-selection complementary to other galaxy selection methods: LAE, LBG, DLA, DRG, SMG
- Special attention devoted to making the sample useful for statistical studies through simple and well-determined selection criteria
- Sample important for future complementary HST, Spitzer, X-shooter/VLT, Herschel, ALMA and JWST observations

Large Programme VLT observations

For all GRBs in the sample:

- FORS2 *R*–band imaging to identify the host galaxies
- ISAAC *K*–band imaging to identify the host galaxies

For subsets of the GRBs in the sample:

- FORS1/2 spectroscopy to secure missing redshifts
- FORS1 spectroscopy targeting Lyα (Milvang-Jensen et al., in prep.)
- FORS1/2 spectroscopy to determine properties (e.g. metallicities) of particularly interesting host galaxies

In total 270 hours (all service mode), with 70 hours for Lyα.

Observations just completed (spring 2006 – summer 2008).

All observations are performed at least 60 days after the GRB explosion in order to avoid possible contamination from afterglow or associated supernova.

GRB selection criteria for the host Large Programme

1. Detected automatically by the γ–ray imager BAT onboard Swift
2. Detected in the period 2005 March 1 to 2007 August 10 (Swift fully operational, and automatic slews routinely enabled)
3. Swift repointed to observe the burst with the X–ray telescope XRT within 12 hours from the trigger
4. An X–ray afterglow should be detected
5. The localization of the burst (from X–ray, optical or NIR afterglow) should be better than $2.0''$ (90% error radius)
6. Only long-duration bursts
7. Milky Way extinction $A_V \leq 0.5\,\mathrm{mag}$
8. Declination in the range -70° to $+27^\circ$ (suited for VLT observations)
9. No nearby bright stars (would make host galaxy observations difficult)

This gives a sample of 71 bursts.

Redshift status (will improve): 45 bursts have a redshift, $z = 0.03$–6.30. Additionally, a number of bursts have redshift limits.

Selection criteria for the Lyα spectroscopy

Apply the following single criterion to the sample of 71 GRBs:

- Redshift should be known and be in the range $1.95 \leq z \leq 4.5$
  - lower cut (Lyα at $\approx$3600 Å): atmospheric+instrumental cut-off
  - upper cut (Lyα at $\approx$6700 Å): FORS1 fringing from $\sim$6500 Å (new CCDs only)

This gave a sample of 23 bursts, with $1.95 \leq z \leq 4.41$.
Spectroscopy targeting Lyα has now been obtained for all of these.

All 23 bursts have a detected optical afterglow. This was not required, but a consequence of the requirement of a known redshift.

There was no requirement that the host should be detected in the deep R–band imaging(!) The statistics are

- detected : 14 hosts, with R in the range 24.6 to 27.6
- maybe detected: 2 hosts
- not detected : 7 hosts, with R fainter than typically 27

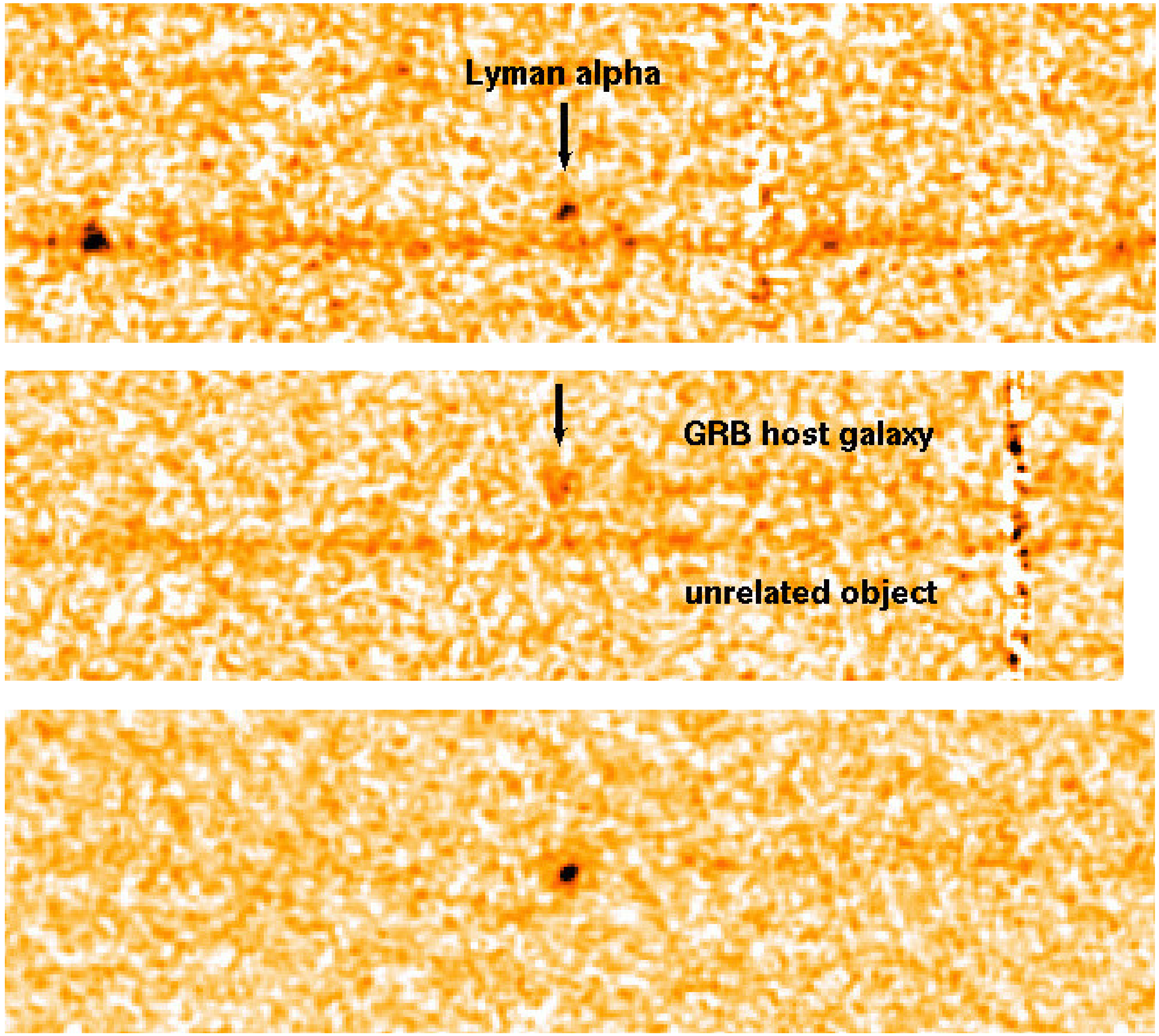
The Lyα spectroscopy sample of 23 systems

R–band host?	*R* [mag]
yes	
yes	
yes	
yes	
yes	
yes	
yes	
yes	R $=$ 24.6–27.6
yes	
yes	
yes	
yes	
yes	
yes	
maybe	R $\approx$ 26
maybe	
no	
no	
no	
no	R $\gtrsim$ 27
no	
no	
no	

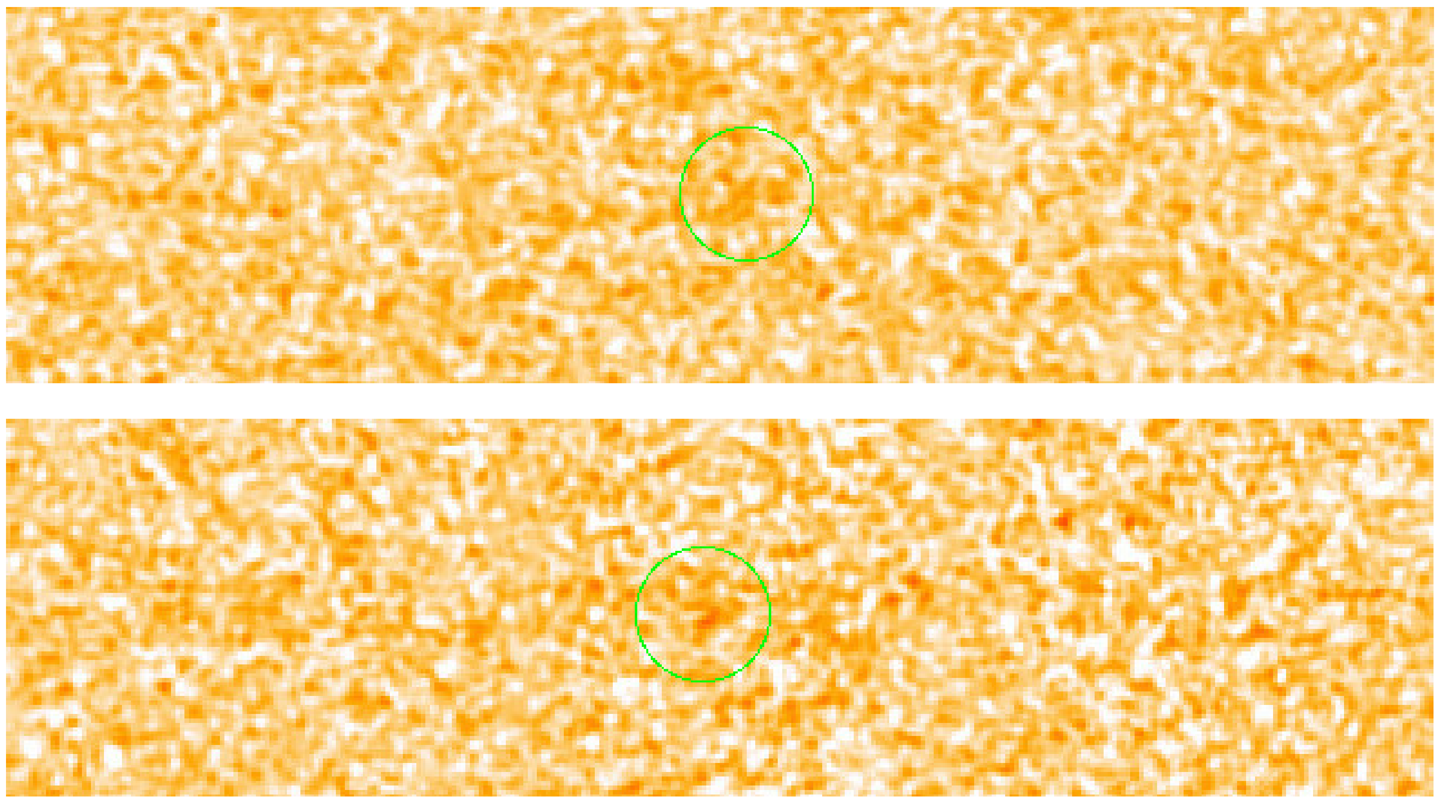
Lyα observations

- VLT/FORS1, old or new CCDs
- Target acquisition (i.e. how to get the "*invisible*" target into the slit): a nearby acquisition star is always used. Two options:
  1. First go to the acquisition star, and then do a "blind offset"
  2. Choose the position angle (rotation) of the slit such that it goes through both the acquisition star and the target
- Grisms: 600B, 600V, 600R, 300V
- $1.3''$ longslit
- Total net exposure time: 1.4–3.8 hours, split into 4–8 exposures, dithered along the slit

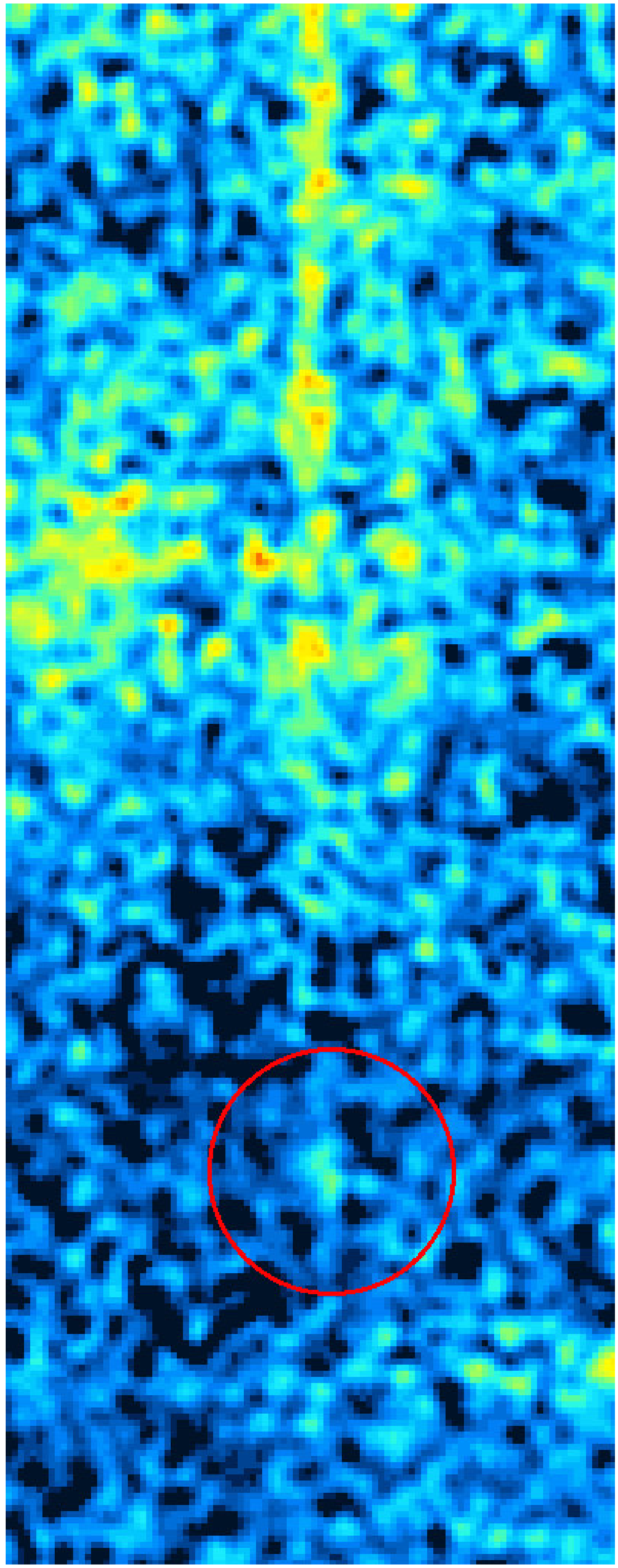
Lyα detected



Lyα detected???



Lyα detected



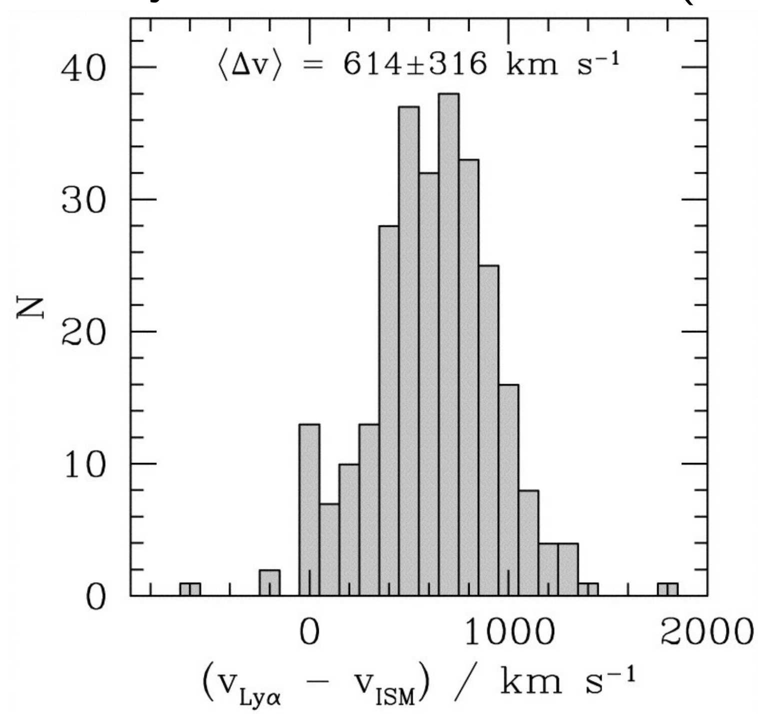
Results from Lyα spectroscopy of 23 GRB hosts

Host?	R [mag]	Contin.	Lyα em.	Comments
yes		**yes**	**yes**	
yes		**yes**	**yes**?	
yes		**yes**	**yes**	
yes		**yes**	no	
yes		**yes**	no	
yes		**yes**	no	
yes		**yes**	no	
yes	24.6–27.6	**yes**	no	
yes		maybe	maybe	
yes		**yes**	**yes**	
yes		**yes**	no	
yes		no	no	
yes		maybe	**yes**	
yes		**yes**	**yes**	
maybe	≈ 26	no	no	
maybe		...	...	Lyα @ z=1.89
no		no	no	
no		no	no	
no		no	no	
no	$\gtrsim 27$	no	no	
no		**yes**	no	
no		no	no	
no		no	no	

Lyα redshifts vs absorption redshifts

For the 5 secure Lyα detections from this work (Milvang-Jensen et al., in prep.), and for 2 systems from the literature (Vreeswijk et al. 2004; Møller et al. 2002) the difference between z(host,Lyα,em.) and z(aftergl.,abs.) gives a rest-frame velocity difference $v(\text{Ly}\alpha) - v(\text{abs.})$ in the range 100–600 km/s.

This shift is also seen for Lyman Break Galaxies (Adelberger et al. 2003):



Summary

- A well defined sample of 71 GRBs has been constructed and followed up using 270 hours of VLT time — observations just finished
- All 23 systems with $z = 1.95$–4.5 have been observed spectroscopically targeting Lyα (FORS1, $t_{exp} \sim 2$ hours)
- 5 hosts have secure detections of Lyα emission. This is out of:
  - 14 hosts detected in the R–band ($R = 24.6$–27.6)
  - 23 GRBs in total
- For non-detections, upper limits on Lyα flux (and EW) should be computed
- Velocity shift $v(\mathrm{Ly}\alpha) - v(\mathrm{abs.})$ found to be 100–600 km/s
- Analysis ongoing (Milvang-Jensen et al., in prep.)