Lyα emission from GRB host galaxies

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The Lyman alpha universe, IAP, Paris, 7 July 2009

GRB basics

GRB = Gamma-Ray Burst

- γ–ray burst, localised to a few arcmin (e.g. Swift satellite)
- X–ray afterglow usually seen, localised to a few arcsec (e.g. Swift)
- Optical afterglow — not always seen
- Spectroscopy of the optical afterglow can provide a redshift (from interstellar absorption lines such as Si II, C IV, Fe II, Mg II)
- 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.

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, Hjorth et al. 2003; Stanek 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, X-shooter/VLT, Herschel, ALMA and JWST observations

Large Programme VLT observations

The survey has several imaging and spectroscopy components.
Lyα spectroscopy presented here (Milvang-Jensen et al., in prep.)

GRB selection criteria for the host Large Programme

1. Detected *automatically* by the γ–ray imager onboard Swift
2. Detected in the period 2005 March 1 to 2007 August 10
(Swift fully operational, and automatic slews routinely enabled)
3. Swift X–ray observation available 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. Sun distance $> 55^\circ$
9. Declination in the range -70° to $+27^\circ$ (suited for VLT observations)
10. No nearby bright stars (would complicate host galaxy observations)

This gives a sample of 68 bursts.

Redshift status (will improve): 42 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 68 GRBs:

- Redshift should be known and be in the range $z = 1.8$–4.5

This gave a sample of 20 bursts, with $z = 1.9$–4.0.
All were observed targeting Lyα.

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

- detected : 15 hosts, with *R* in the range 24.6 to 27.6
- maybe detected: 1 host
- not detected : 4 hosts, with *R* fainter than typically 27

Lyα observations

- VLT/FORS1
- Grisms: 600B, 600V, 600R, and 300V
- 1.3$''$ longslit
- Spectral resolution FWHM rest-frame: typically 500 km/s, but generally 350–900 km/s
- Total net exposure time: $\sim$1.5–4 hours

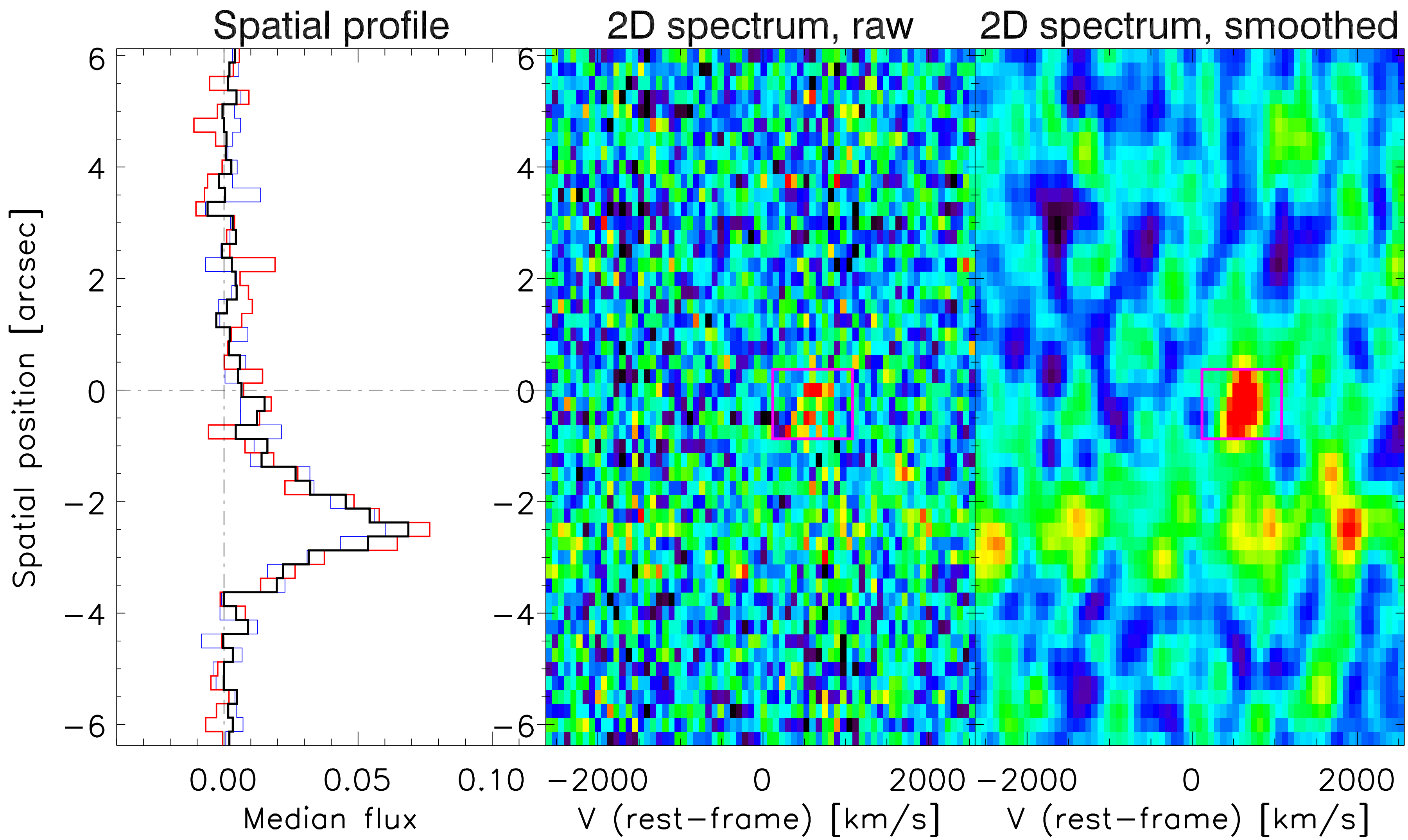
Measurement of Lyα in the spectra

Lyα measured in the 2D spectra using the following default aperture:

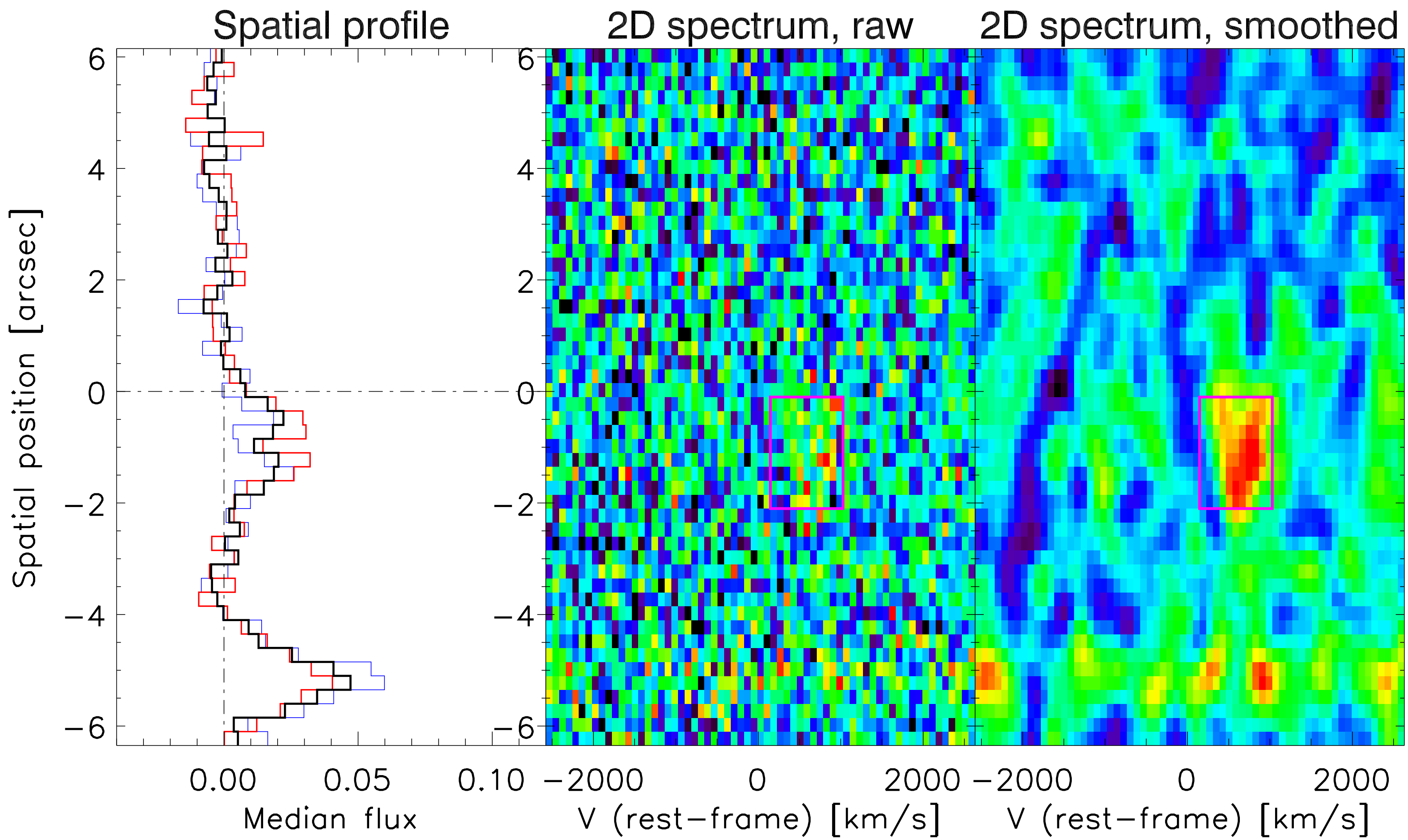
- Centre: rest-frame velocity $= +300$ km/s,
  spatial position $= 0.0$ arcsec
- Width: 900 km/s $\times$ 1.2 arcsec

The following slides will show some example spectra.

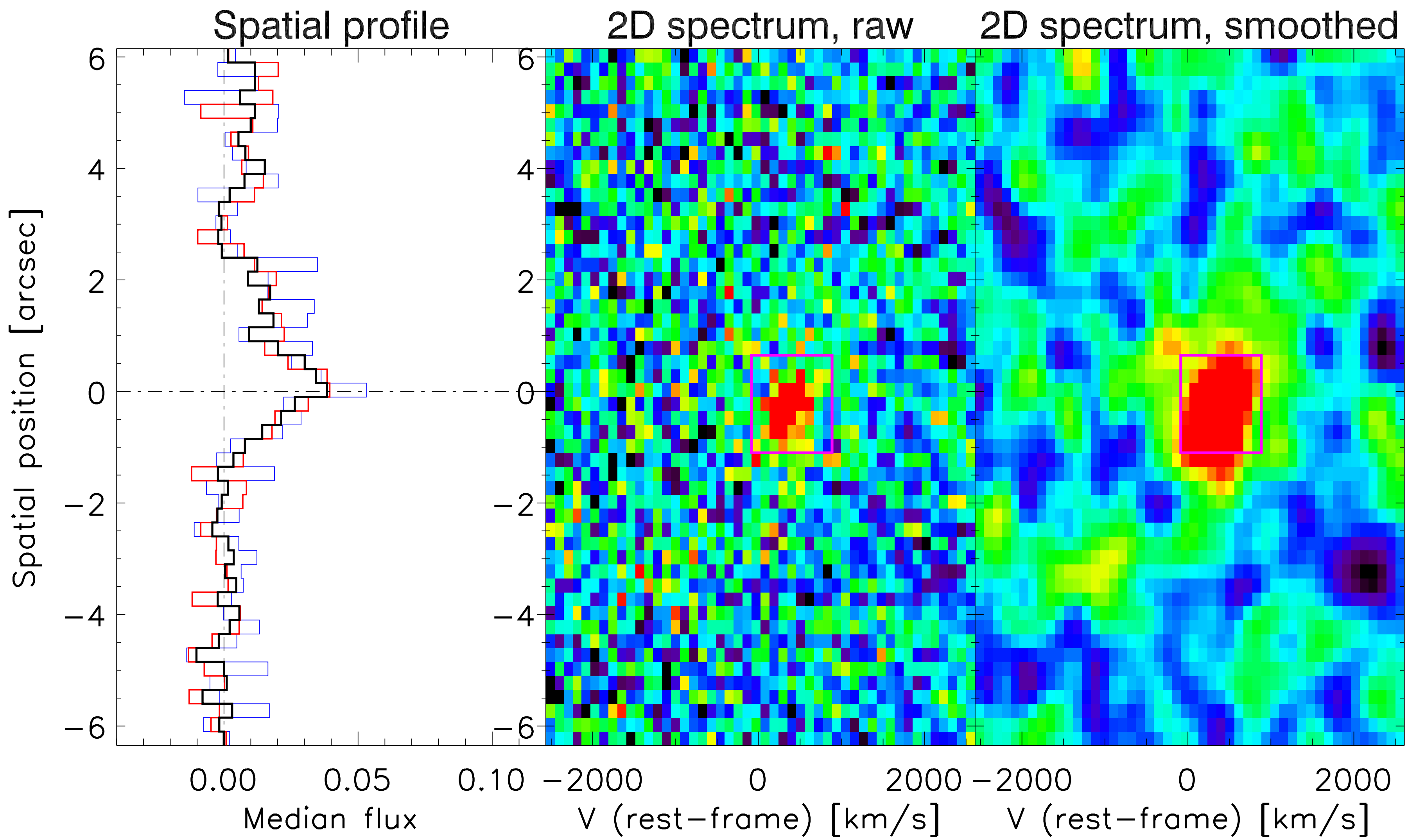
Example: continuum detected, Lyα detected



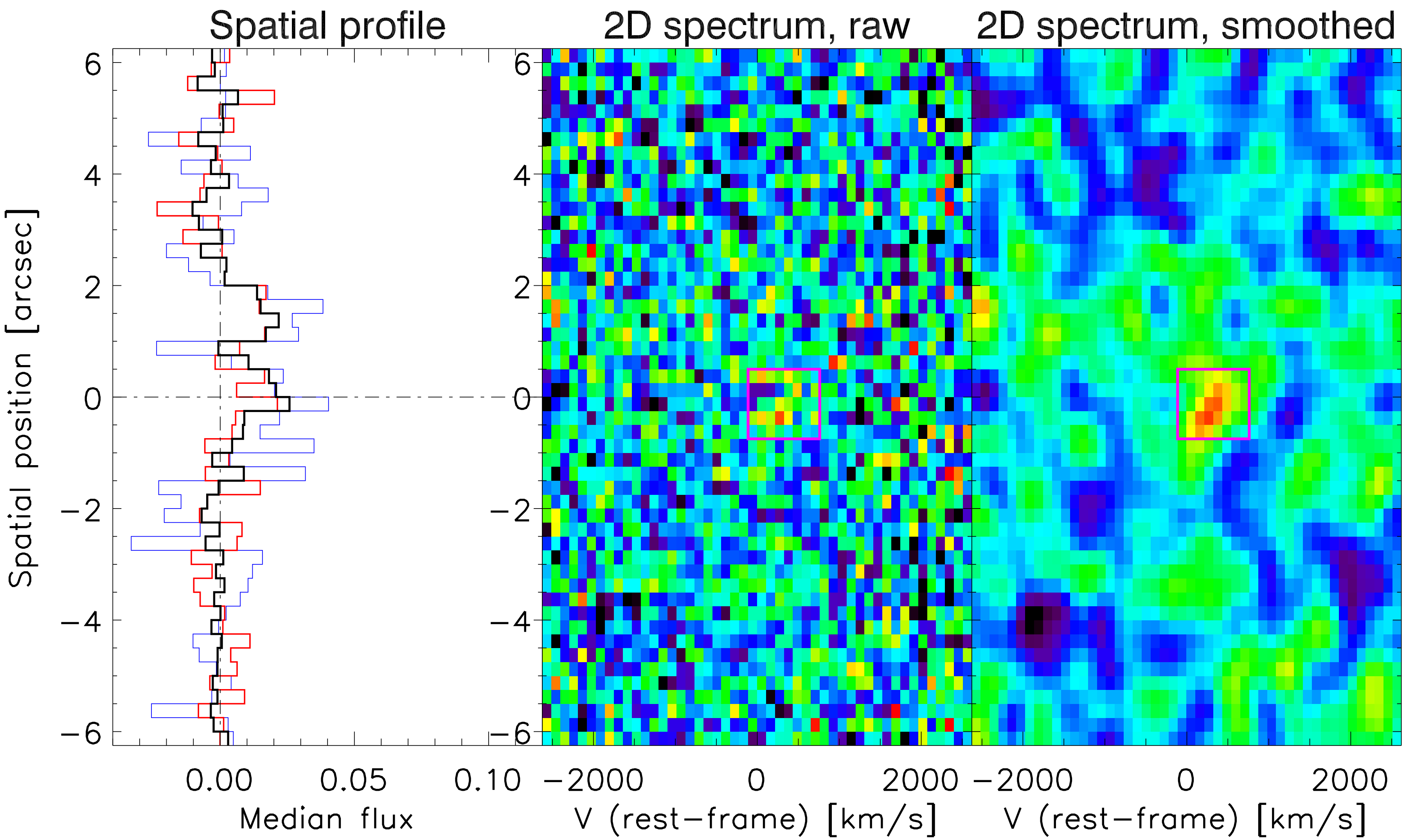
Example: continuum detected, Lyα detected



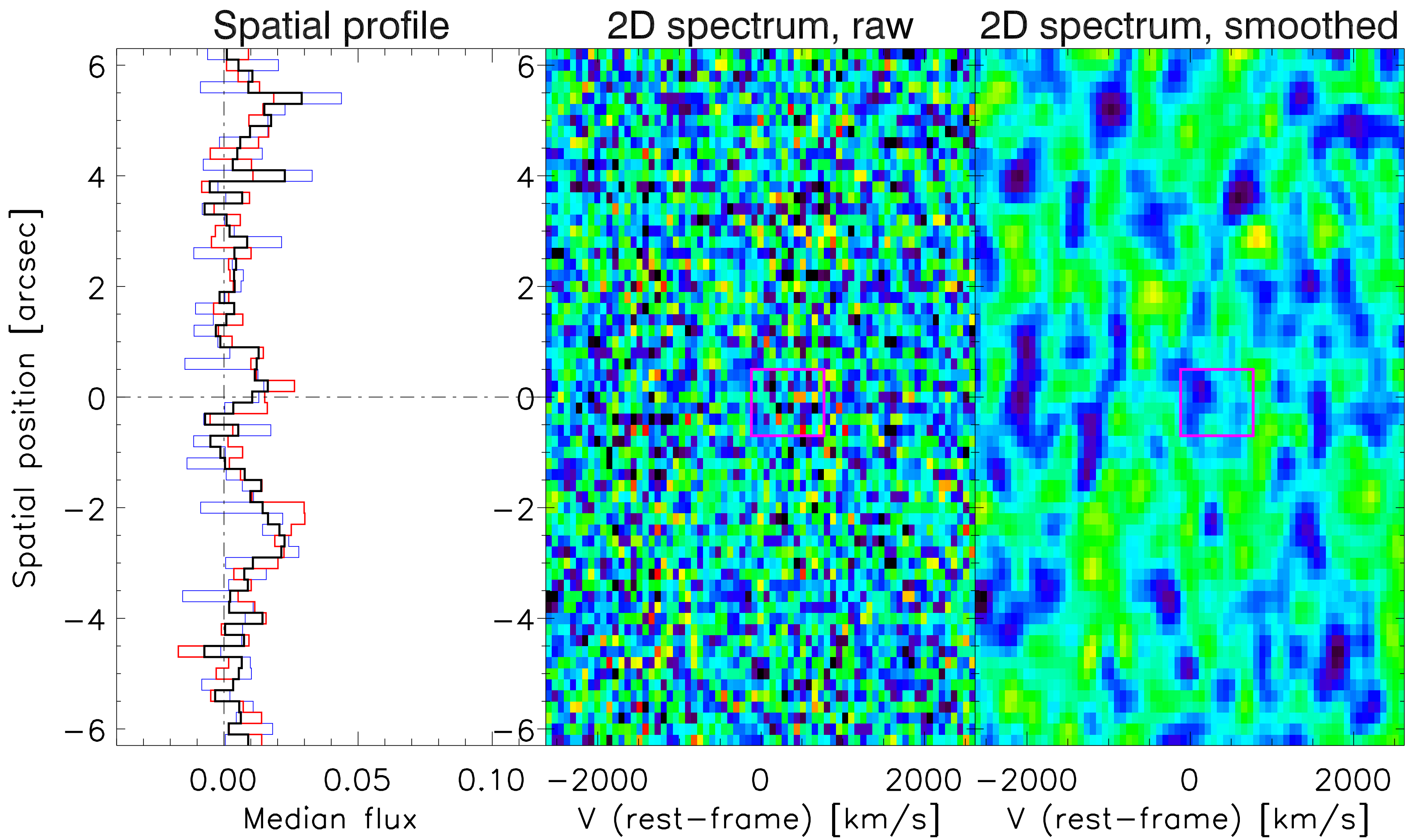
Example: continuum detected, Lyα detected



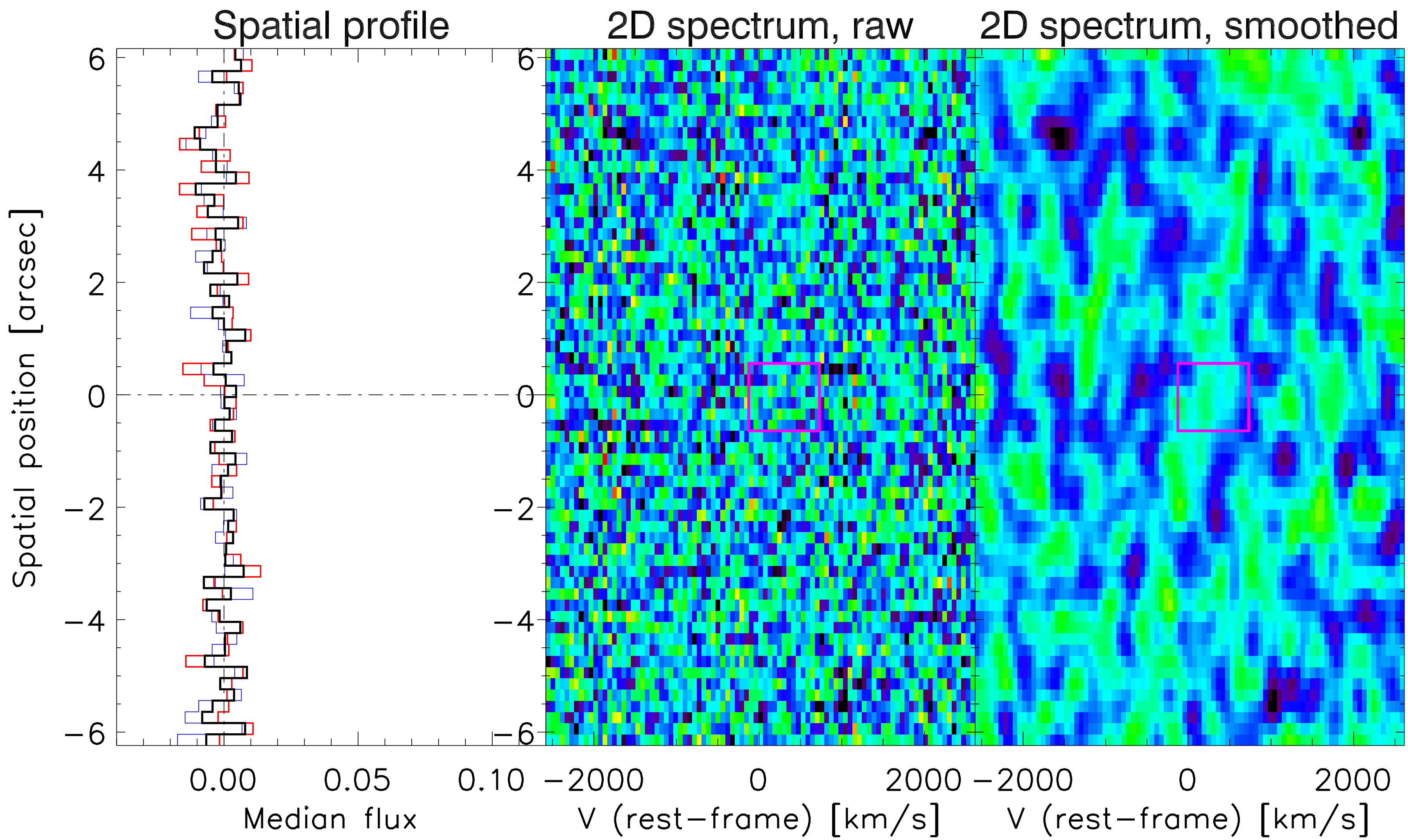
Example: continuum detected, Lyα detected



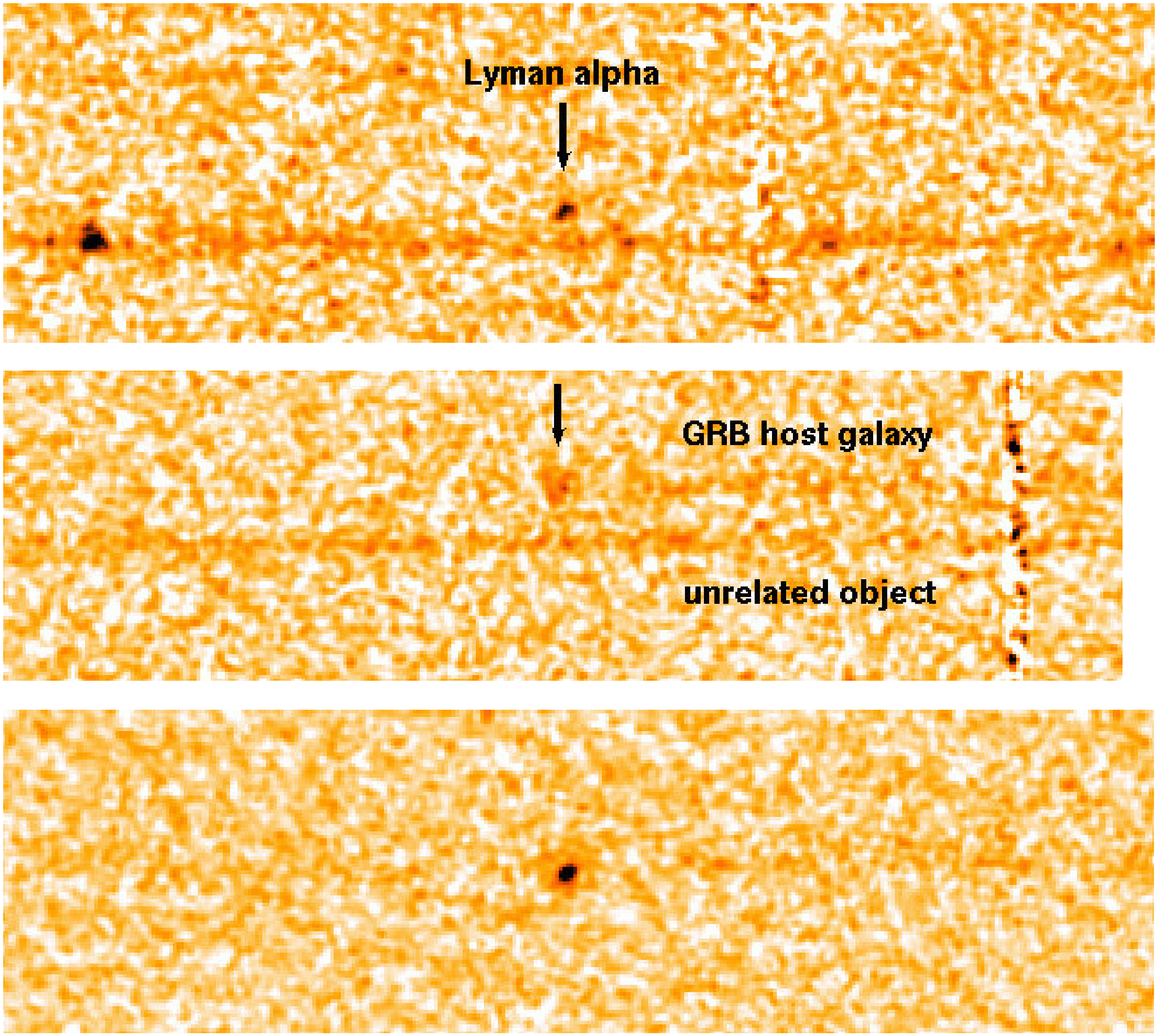
Example: continuum detected, Lyα *not* detected



Example: continuum *not* detected, Lyα *not* detected

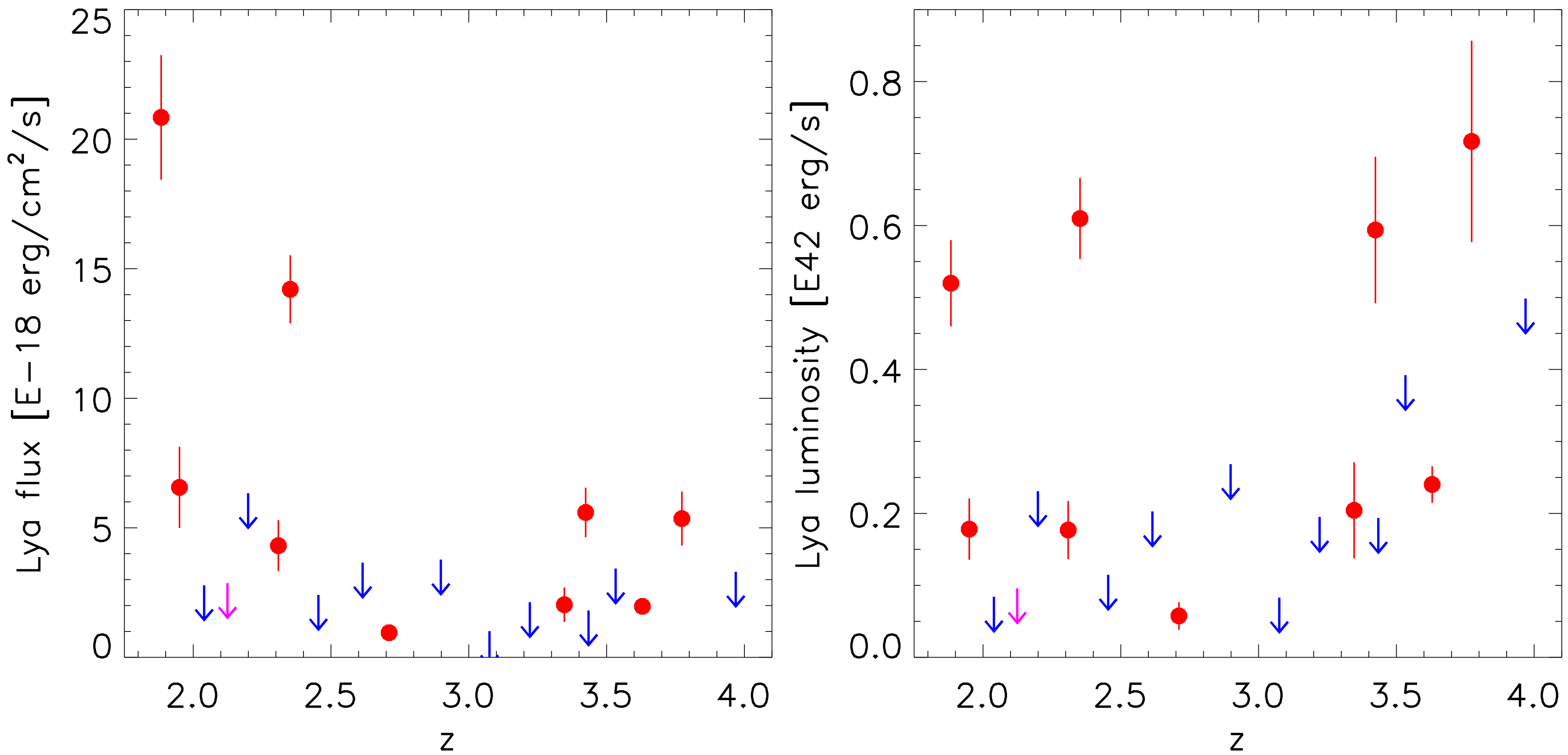


Alternative spectral plots: Lyα detected



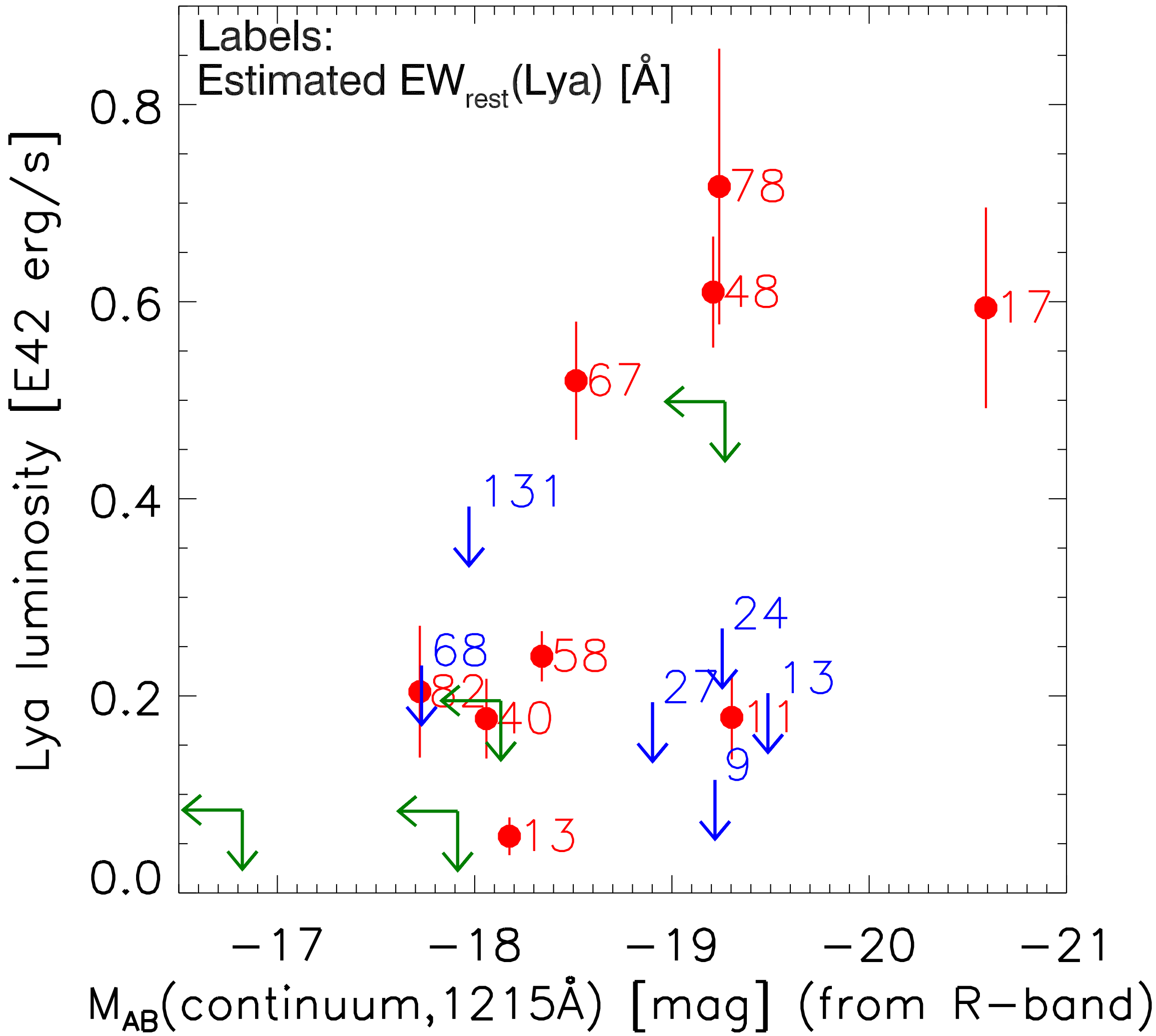
Result: Lyα fluxes and luminosities

- 9 Lyα detections, at 3σ confidence
- 11 non-detections (3σ upper limits plotted)



($H_0 = 70\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$, $\Omega_m = 0.3$, $\Omega_\Lambda = 0.7$)

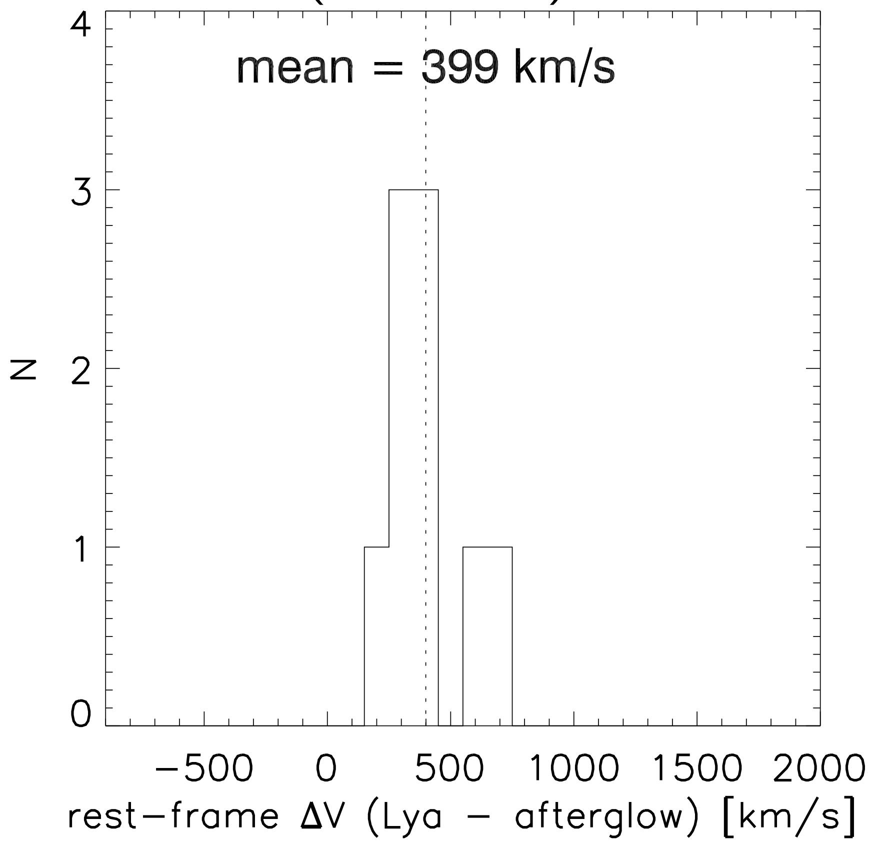
Toy plot: Lyα luminosity vs M_{AB}(continuum,1215 Å)



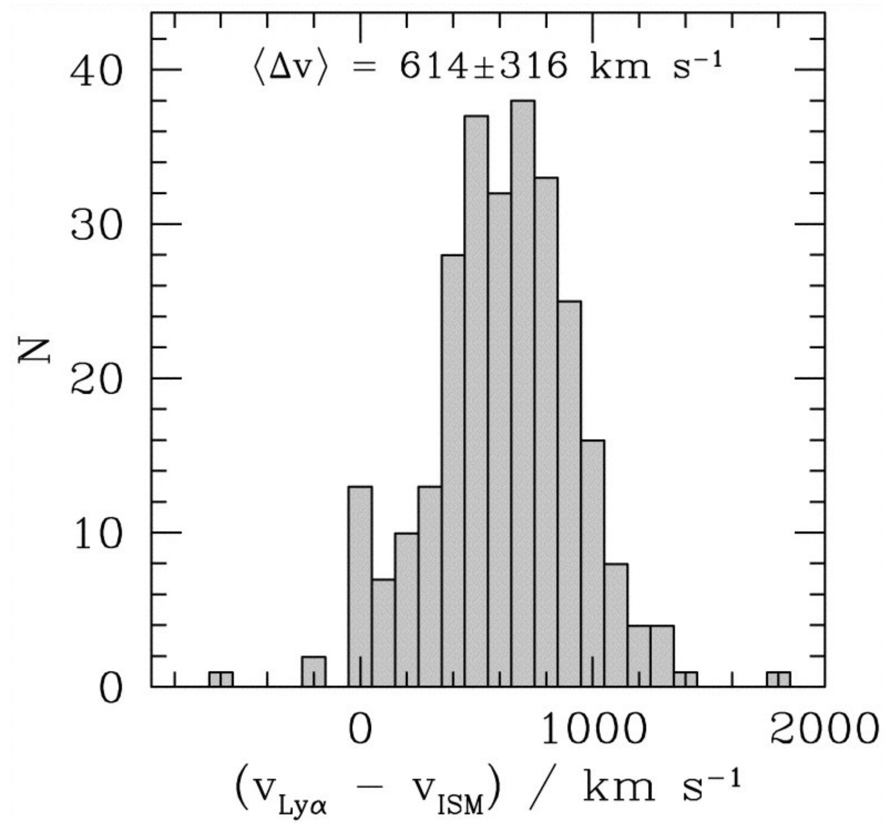
- Lyα luminosities from the spectra
- Continuum absolute magnitudes from the R–band images, assuming an $F_\nu \propto \nu^{-1}$ spectrum

Lyα velocity offset

GRB host galaxies
(this work)



Lyman break galaxies
(Adelberger et al. 2003)



- Lyα: emission line in the host spectrum
  (note: Lyα velocity measured simply as the centroid of the line)
- Afterglow: interstellar absorption lines (e.g. Si II, C IV, Fe II, Mg II)

Summary

- 9 of the GRB hosts have detections of Lyα emission (at 3σ). This is out of:
  - 15 hosts detected in the R–band (R $=$ 24.6–27.6)
  - 20 GRBs observed in total
- For the 9 detections
  - Lyα flux in the range (1 to 20) $\times 10^{-18}\,\mathrm{erg\,cm^{-2}\,s^{-1}}$
  - Lyα luminosity in the range (0.1 to 0.7) $\times 10^{42}\,\mathrm{erg\,s^{-1}}$
  - Lyα EW in the range $\sim$ 10 to 80 Å
- For the non-detections, 4 systems have 3σ upper limits on EW of $\sim$ 10–25 Å
- Velocity shift $v(\mathrm{Ly}\alpha) - v(\mathrm{interstellar})$ found to be 200–600 km/s
- Analysis ongoing (Milvang-Jensen et al., in prep.)