The Host Galaxies of Dark Gamma-Ray Bursts: Insights from *Chandra* and *HST*

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1. Abstract

Ever since the first gamma-ray burst (GRB) afterglow detections, it has been known that some bursts have their optical emission supressed, based on extrapolation of the X-ray spectral slope [1]. Explanations include intrinsic faintness, dust extinction within the host, and HI absorption at high redshift [2]. We present *Chandra* and *Hubble Space Telescope* (*HST*) imaging of 21 dark (long-duration) GRB afterglows and burst locations. We compare the dark GRB host properties with host samples in the literature, attempt to measure the burst offset distribution, and discuss the implications of the observed galaxy colours.

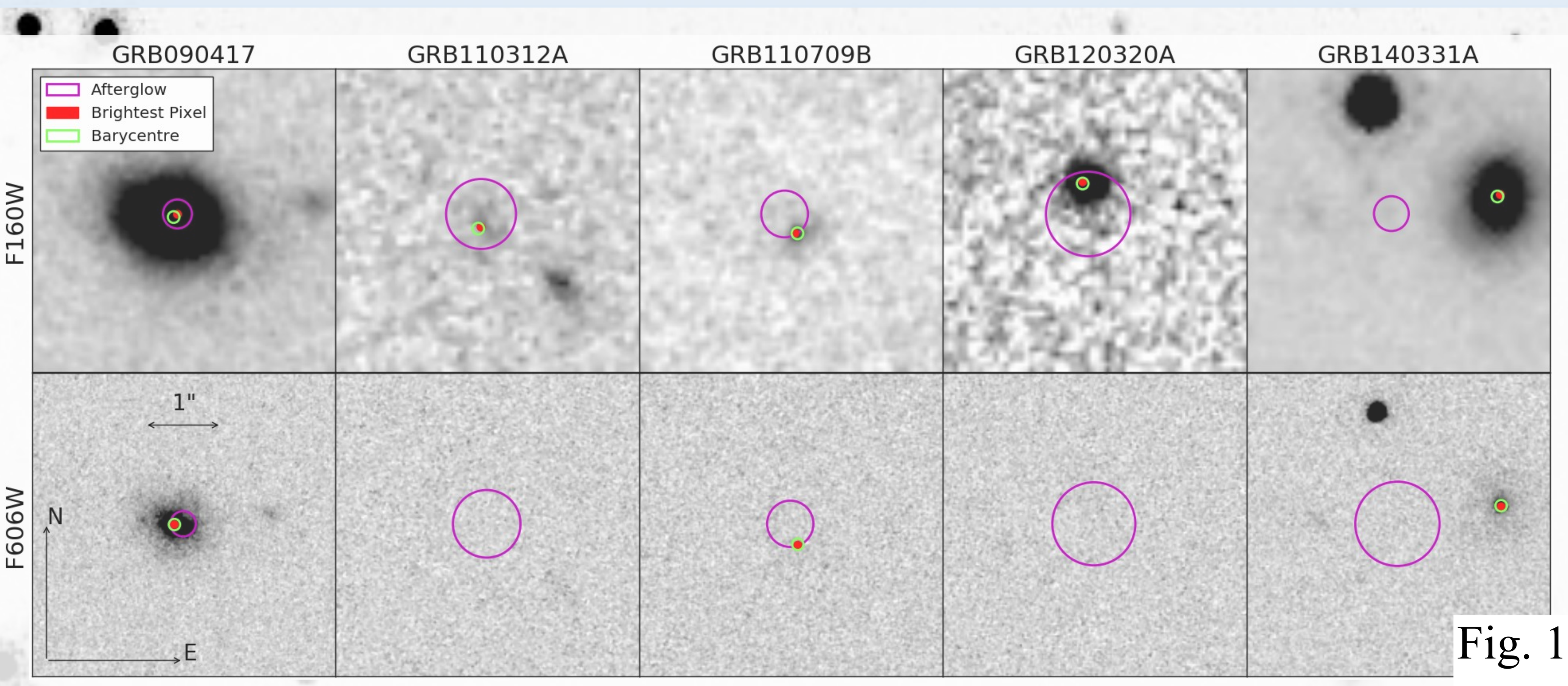
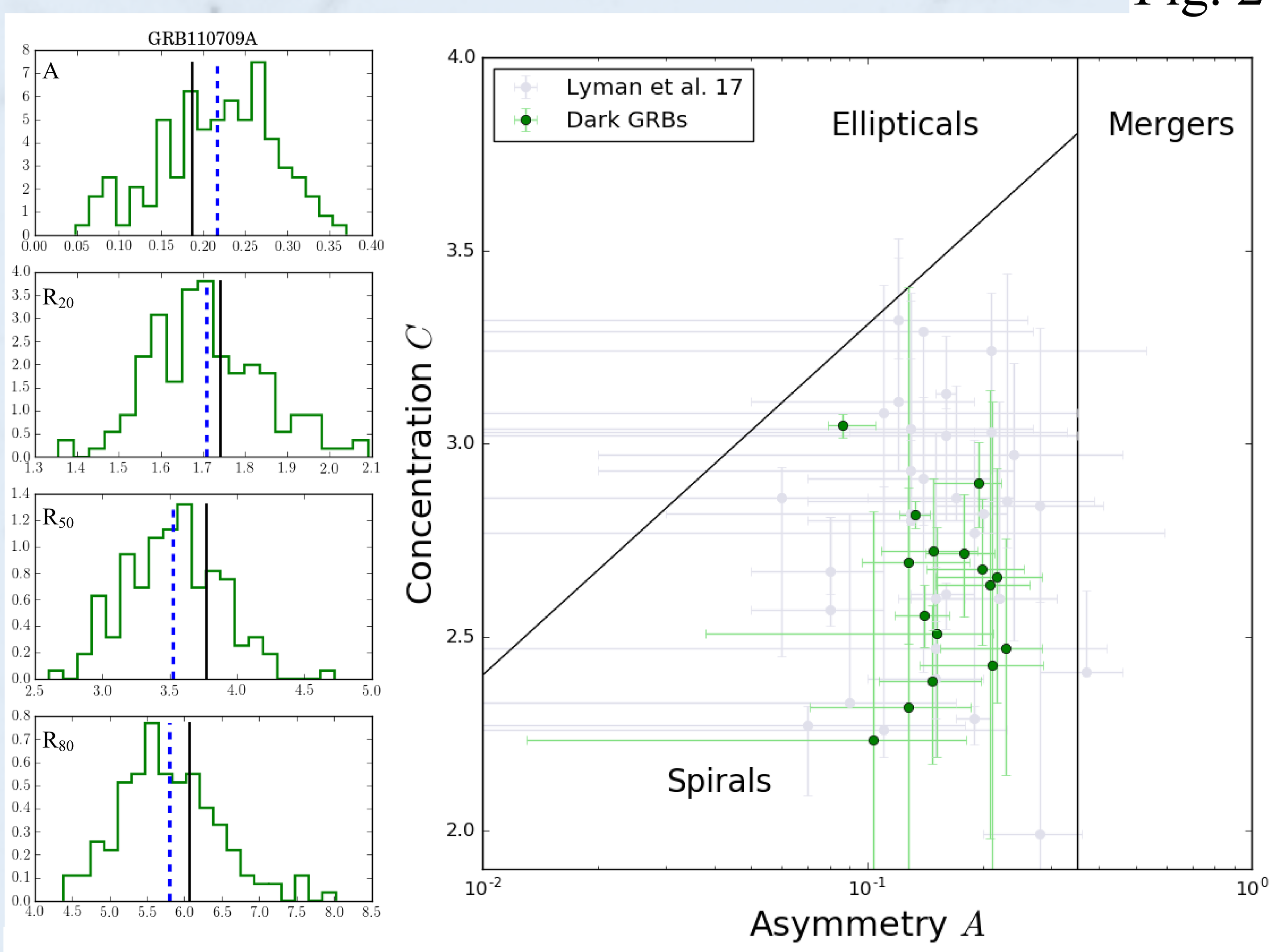


Fig. 1

2. Background and Rationale

Early host studies omitted dark bursts, since they lack the bright optical afterglow often required for precise localisation. More recent studies have found that dark GRB hosts are typically brighter and dustier than the rest of the population [3], raising questions about the inferred metallicity aversion of GRBs. While *Swift* X-ray localisations can reach ~arcsec accuracy, this is often insufficient to uniquely identify a host (or rule a candidate out). The sub arcsec precision of *Chandra*, combined with the depth and resolution of *HST* imaging, allows us to identify and resolve the hosts of dark GRBs down to around 27th mag.

Fig. 2



3. Methodology

Following reduction of the *Chandra* and *HST* data, the methodology is as follows:

Astrometry: The burst locations on their hosts were calculated via relative astrometry between the *Chandra* and *HST* images. If there were insufficient sources in common, Pan-STARRS images were used as an intermediary. Some examples of the final X-ray afterglow positioning on the *HST* images are given in fig 1.

Host Measurement: Apparent magnitudes and enclosed flux radii were measured. The concentration (log ratio of 20 to 80% light radius) and asymmetry (residual of 180 degree rotation and subtraction) were calculated. See [4] and references therein.

Uncertainties: The concentration and asymmetry (CA) parameters [5] had their uncertainties estimated by pixel resampling of the input images, following by re-drizzling and repeated measurement. Example output distributions, and the positioning of the dark burst population in CA parameter space, are shown in fig 2.

4. Results and Discussion

Morphologies: In F160W, the dark hosts are similar to those of the wider population. No galaxies fall into the merger region of parameter space. However, this result is for the observed F160W band. It appears that higher asymmetries and mergers can be seen in the optical, where the spatial resolution is higher, and galaxies tend to be intrinsically clumpier.

Absolute Magnitudes and Colours: Where redshifts are available, we calculate absolute magnitudes, physical offsets and physical R_{80} sizes. Fig 3 shows that the dark hosts are typically brighter than the general long GRB population, in agreement with other works. We also find very red F606W-F160W colours (fig 4), implying high dust extinction, or redshifts of at least ~4 if the Lyman break is invoked.

Fig. 3

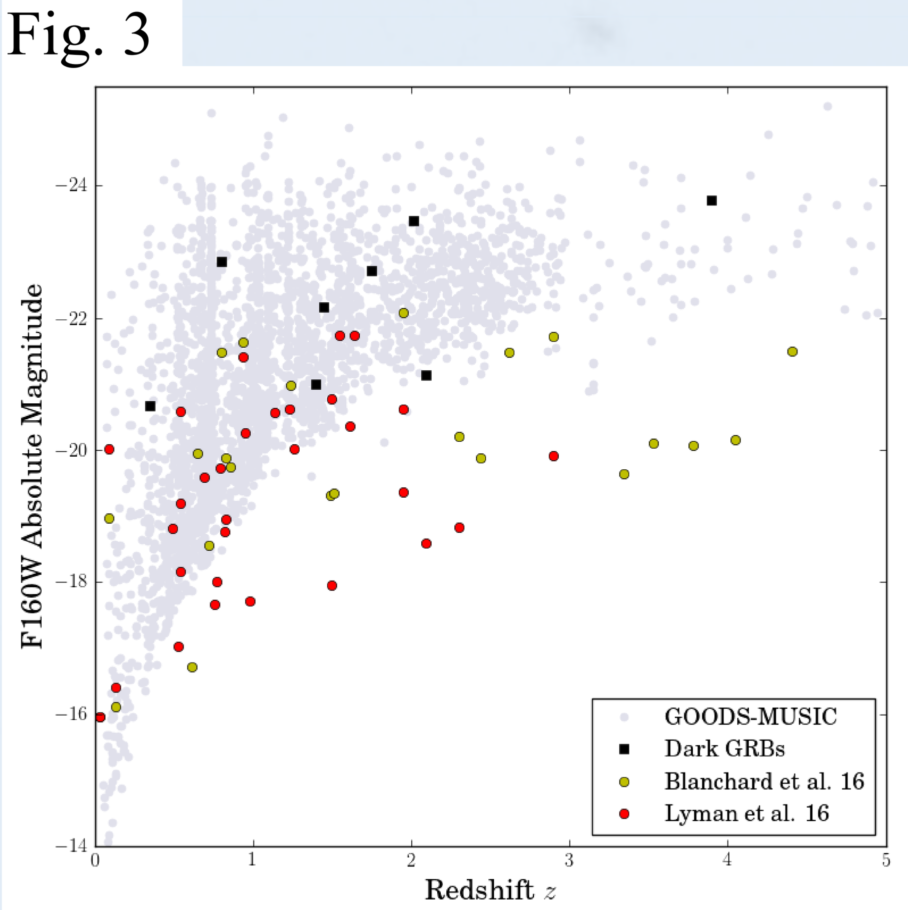
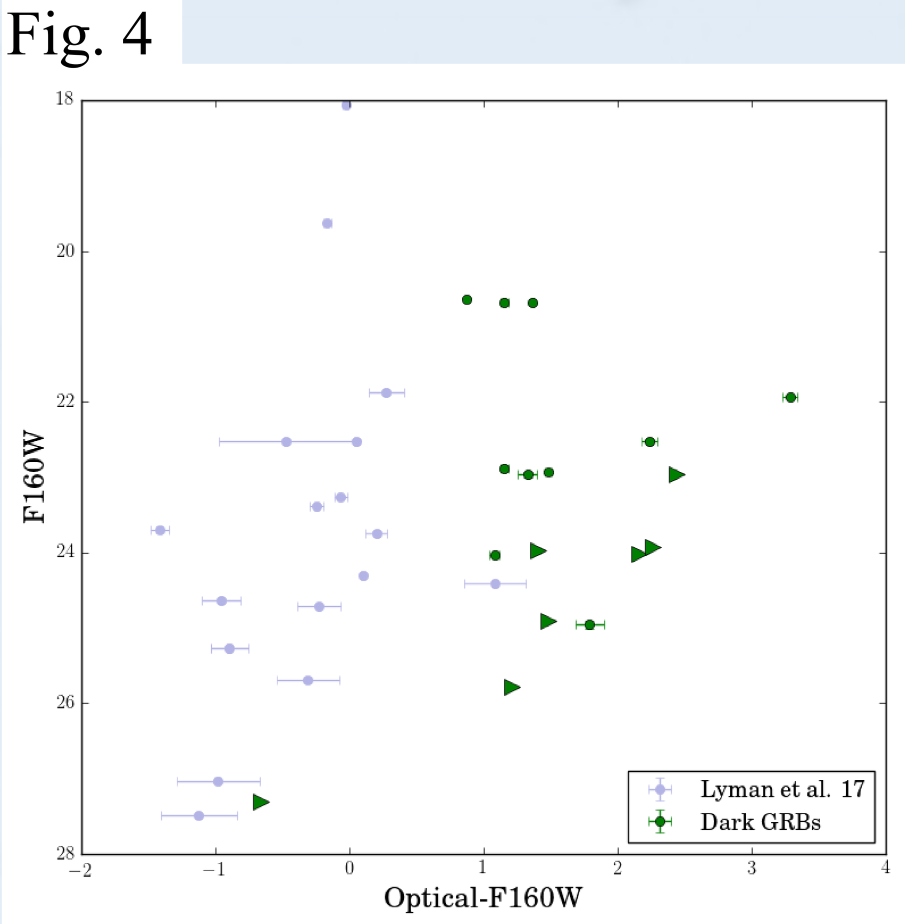
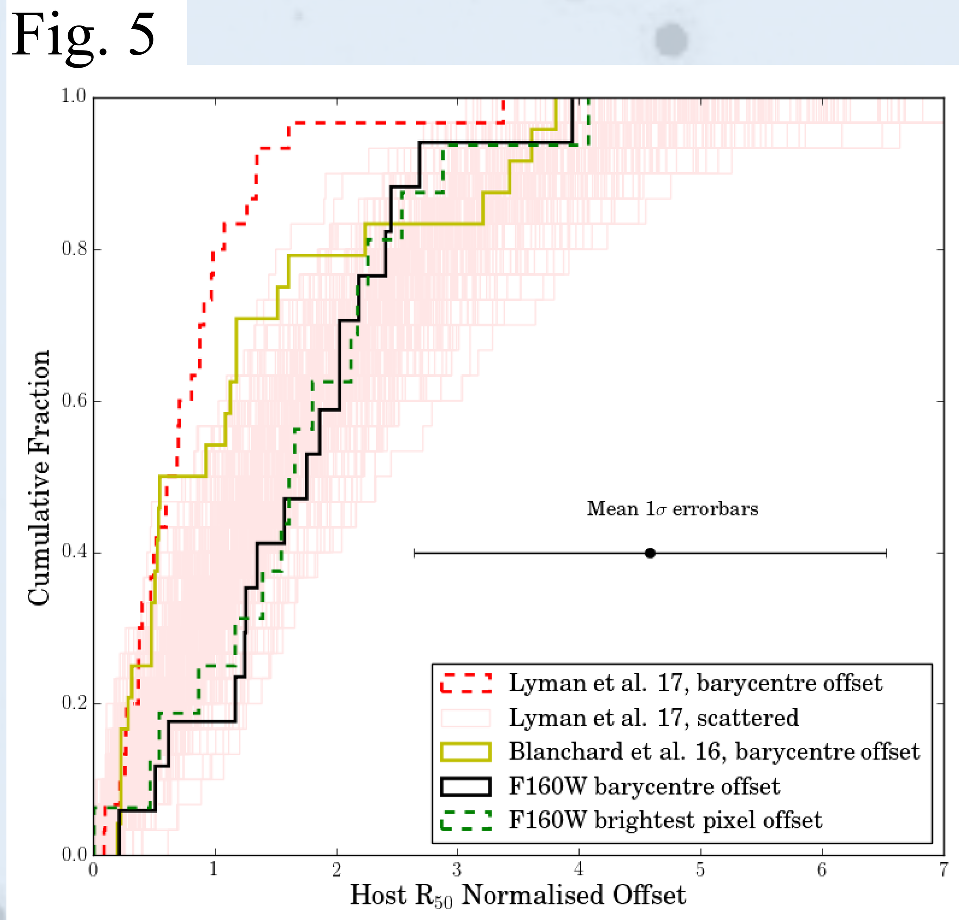


Fig. 4



Burst Offsets: Barycentre and brightest pixel burst offsets are measured. These are expressed in terms of R_{50} in fig 5. Scattering the Lyman et al. (2017) results by the mean dark errorbar shows that the higher offsets arise from larger relative uncertainties, which disfavour the measurement of small offsets [5,6].

Fig. 5



5. Conclusions

We have shown that dark GRB hosts are typically redder and more intrinsically luminous than the average host. There are signs that galaxy interactions may be prevalent amongst this population, despite more typical *H*-band CA values. Dark GRBs occur in unusual hosts, challenging theories of how long GRBs are produced, and their further study will help constrain the progenitor systems behind these extraordinary events.

Acknowledgements & References

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[1] Rol et al. (2005), [2] Schady et al. (2017) , [3] Perley et al. (2016) , [4] Conselice et al. (2005), [5] Lyman et al. (2017), [6] Blanchard et al. (2016)