Modest Obscured Star-Formation Rates Inferred from EVLA Observations of Dark GRB Host Galaxies

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We present host observations with the full-bandwidth EVLA of a sample of highly dust-obscured ("dark") GRBs previously found to have occurred within significantly dust-obscured galaxies. All systems are quite faint at radio wavelengths, and most are undetected even at the level of the EVLA's sensitivity (RMS ~5 μJy). The implied radio-derived star-formation rates are modest, usually comparable to what is inferred from the dust-corrected optical observations. These results suggest that most dark GRBs occur within dusty regions of relatively ordinary galaxies, and indicate that the most extreme systems rarely produce GRBs.

GRBs and cosmic SFR

Long gamma-ray bursts (GRBs) are produced by the explosions of massive stars at cosmological distances. A significant fraction of cosmic star formation at z~1-3 is believed to occur in extreme star-forming galaxies (SFR > 100-300 $M_\odot$/yr) that are detectable at submillimeter and radio wavelengths[1,2], so one might expect many GRBs to be hosted within these systems. However, few sub-mm/radio host detections have been reported to date[3,4].

Dark GRBs and dark GRB host galaxies

Locating the host galaxy of a GRB requires a precise position, which historically resulted in a host-galaxy sample biased against GRBs occurring along dusty sightlines ("dark" GRBs). Recently, IR photometry of the hosts of dark GRBs has shown them to be much more massive and dusty than the hosts of unobscured GRBs, confirming that the host population studied by earlier radio surveys was not fully representative of all GRB hosts.[5,6,7]

Observations

We selected ten dark GRBs with unambiguously large afterglow dust columns and large host-galaxy stellar masses, properties which separate this group from previous host samples. Seven of these galaxies have known spectroscopic or photometric redshifts. All sources were observed in C-band (4.19-6.24 GHz) using the wide-bandwidth EVLA in A-configuration, for 1.0-1.5 hr integration per target.

1. Smail et al. 1997, ApJL, 490, L5
2. Chapman et al. 2005, ApJ, 622, 772
3. Berger et al. 2003, ApJ, 588, 99
4. Tanvir et al. 2004, MNRAS, 352, 1073
5. Chen et al. 2010, ApJ, 723, L218
6. Krühler et al. 2011, arXiv:1108.0674
7. Perley et al. 2012, in prep.
8. Condon 1992, ARAA, 30, 575
9. Carilli & Yun 1999, ApJL, 513, L13
10. Svensson et al. 2011, arXiv:1109.3167
11. Hunt et al. 2011, ApJ, 736, L36
12. Castro-Tirado et al. 2007, A&A 475:101
13. Rol et al. 2007, ApJ, 669, 1098

Results

Of the ten sources, only one (GRB 080207, right) is clearly detected. For all other sources, a compact nuclear starburst is ruled out to typically <15 μJy (3σ). Constraints on extended flux are less straightforward in A-configuration, but integrating over the optical disk shows no extended radio emission to typically <20-50 μJy. B-configuration observations are scheduled for this summer.

Implications

Using standard radio luminosity/SFR indicators[8,9], our EVLA nondetections indicate relatively modest star-formation rates (<10^{2-3} $M_\odot$/yr). This supports the notion that GRBs tend to avoid the most extreme star-forming galaxies, and (in the prevailing collapsar paradigm) may indicate that these systems are too metal-rich to produce many GRBs. Variations in the IMF in dense starbursts (a "top-light" IMF) could also produce this result.

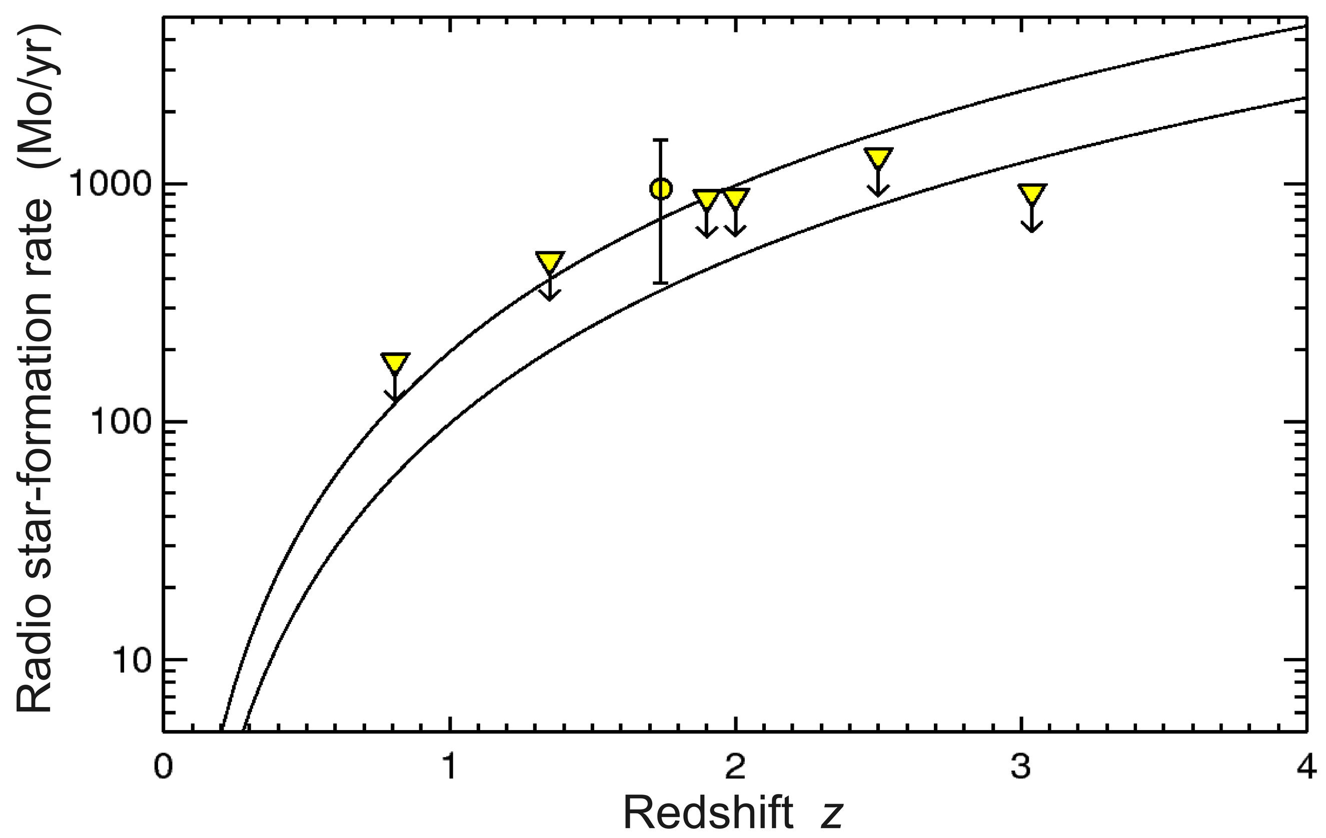
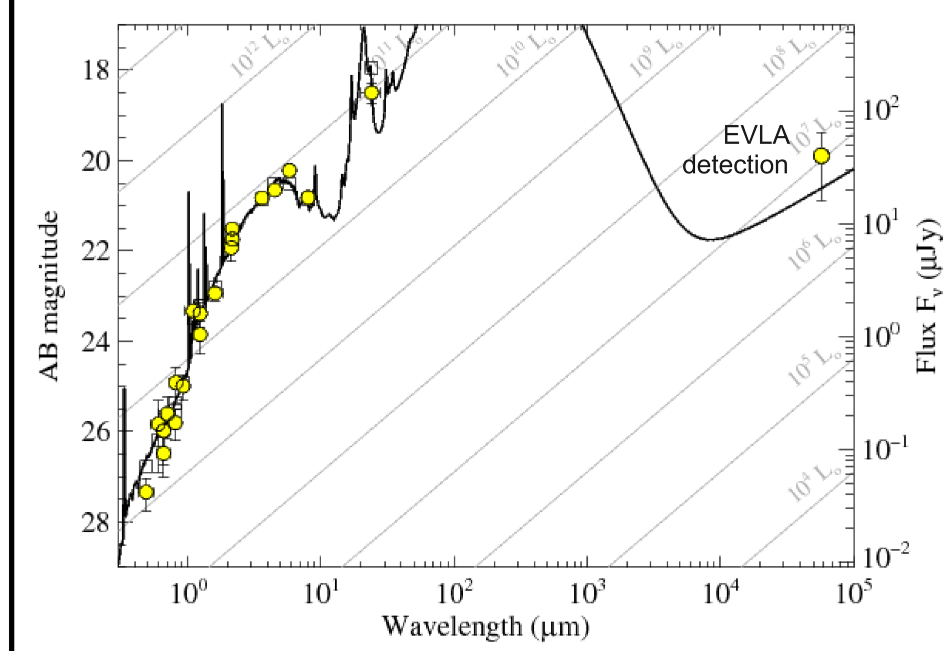


Figure 1: Radio star-formation rates as a function of redshift. Points indicate actual measured fluxes for sources of known redshift, while the curves indicate the limit of a typical observation from our sample for a mildly extended source (upper curve) or a point source (lower curve).

GRB 080207 (z~1.8)

A radio-bright high-z merger



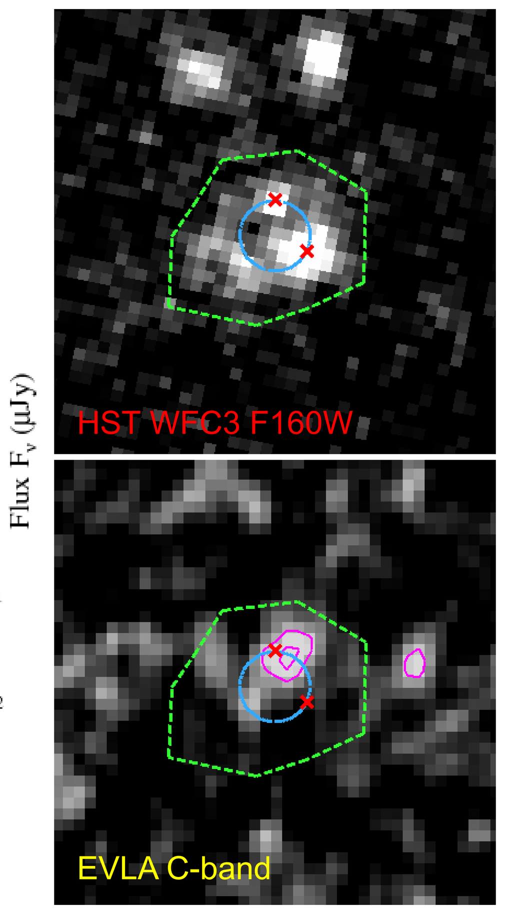
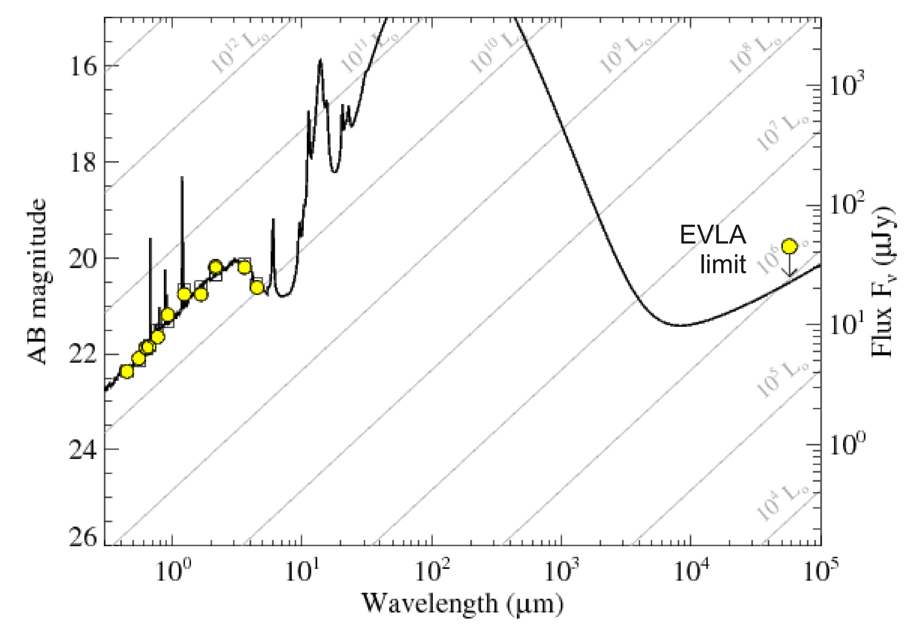


Figure 2a-c: SED (above) and HST+EVLA imaging (right) of the host of GRB 080207. See Figure 4 caption (bottom left) for details.

The most extreme dark GRB host yet known, the host of GRB 080207[10,11] is an extremely red IR-luminous object and one of very few high-z GRB hosts detected at 24μm. It is also the only target detected at >3σ in our EVLA sample: a faint, pointlike source is observed close to the northern optical clump of an apparent merger resolved by HST imaging. This detection is consistent with the large star-formation rate (400 $M_\odot$/yr) inferred for this host by Svensson et al. 2011 based on the Spitzer MIPS detection of this source. This confirms that the host is indeed undergoing a rapid, compact starburst, probably triggered by the merger seen in the HST imaging.

GRB 051022 (z=0.81)

Young merger with no radio starburst



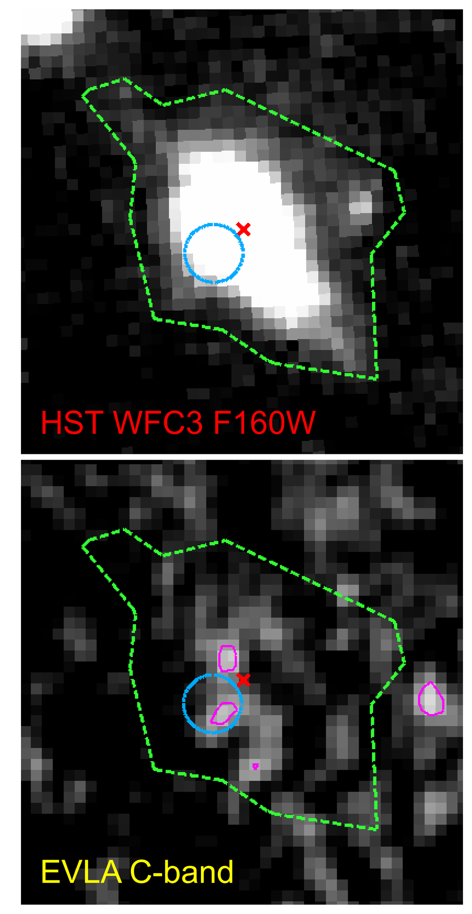


Figure 3a-c: SED (above) and HST+EVLA imaging (right) of the host of GRB 051022. See Figure 4 caption (bottom left) for details.

The host of GRB051022 is among the best-studied dark GRB hosts due to its relatively accessible redshift of z=0.809. The lack of a Balmer break in the SED indicates a very young stellar population and allows a relatively robust measurement of the optical SFR of about 90 $M_\odot$/yr[12,13]. Surprisingly, this system is (at best) only marginally detected by the EVLA, placing a limit on the radio SFR of <180 $M_\odot$/yr and limiting any nuclear starburst component to <60 $M_\odot$/yr. There is very little highly-embedded (τ_{IR}>>1) star-formation in this galaxy.

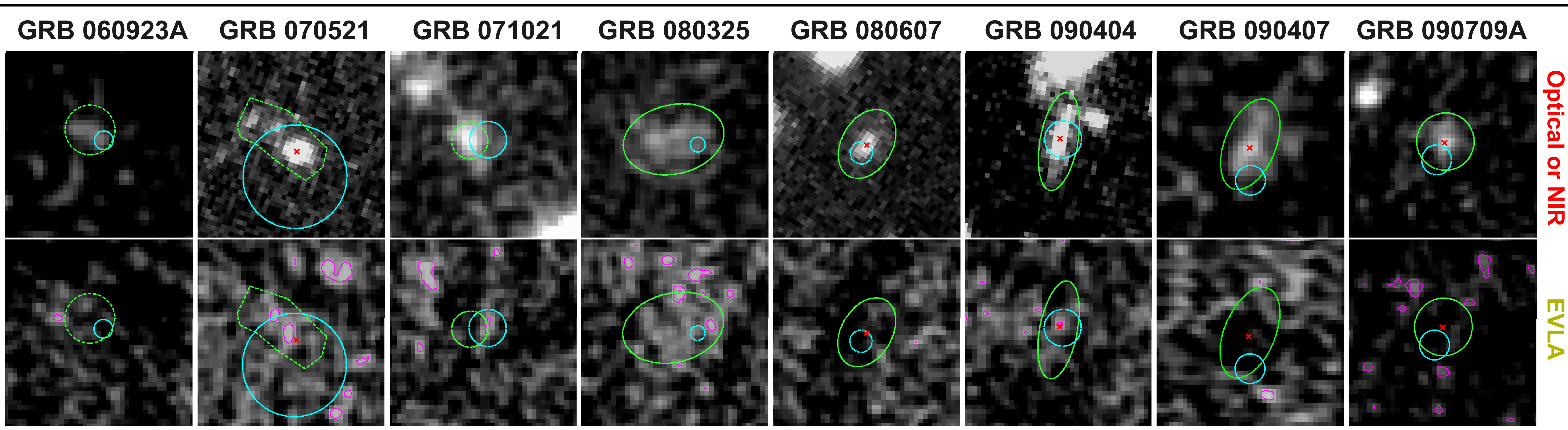


Figure 4a-p: Optical or NIR (top panels) + EVLA (bottom panels) imaging for the remaining eight sources not shown in Figures 2-3. All images are 5" on each side. In each image, the **cyan** circle shows the afterglow position. The **green** circle shows the approximate extent of the optical/NIR disk. A **red** x shows the optical centroid if the host is clearly resolved. The **magenta** contours in the EVLA images show contours of 10 μJy and 15 μJy, roughly corresponding to 2 and 3σ for most images.