Dust-Obscured Gamma-Ray Bursts and the Cosmic Star-Formation Rate

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How the GRB rate relates to SFR is still controversial: GRBs offer, in principle, a powerful alternative tool for characterizing the evolution of the star-formation rate as a function of environment and redshift, but this is only possible if the relation between the GRB rate and star-formation rate is understood in the first place. Known GRB hosts are bluer, more metal-poor, lower-luminosity and lower-mass than wide-field survey-selected galaxy populations, which could indicate a strong dependence on metallicity[1,2] –but the details of this relation have not been quantitatively explored, and some argue that the trend can be explained as a reflection of the fact that their selection is weighted by star-formation with no metallicity bias[3]. At higher redshifts, GRB hosts also appear much less luminous than field-selected galaxies–but this could be a reflection of the difficulty in locating the host galaxies of events whose afterglows were obscured by dust. (Before *Swift* launched, most GRB hosts were found via optical afterglow emission alone.)

A significant minority of GRBs are heavily obscured[4,5,6] and inclusion of this population is essential to correctly address whether GRBs follow SFR uniformly or not. Motivated by this goal, we have carried out a large campaign combining observations from Keck, Gemini, VLT, HST, and Spitzer to locate and characterize the hosts of the most dust-obscured *Swift* GRBs and compare them to unobscured-GRB hosts. Keck observations are the mainstay of the program and have been vital in obtaining redshifts for many systems, as well as in providing rest-frame UV photometry to determine their star-formation rate and mean extinctions.

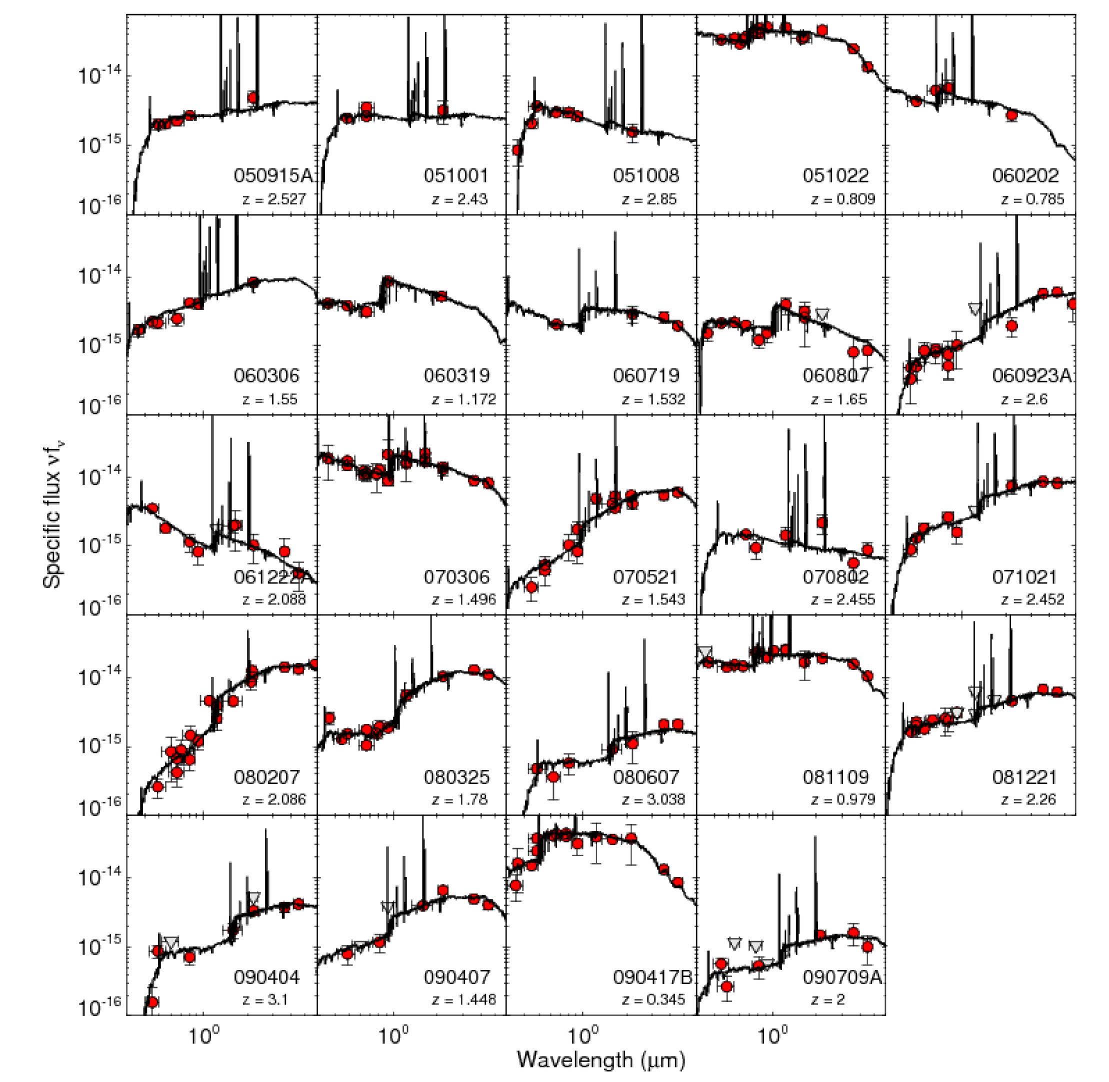
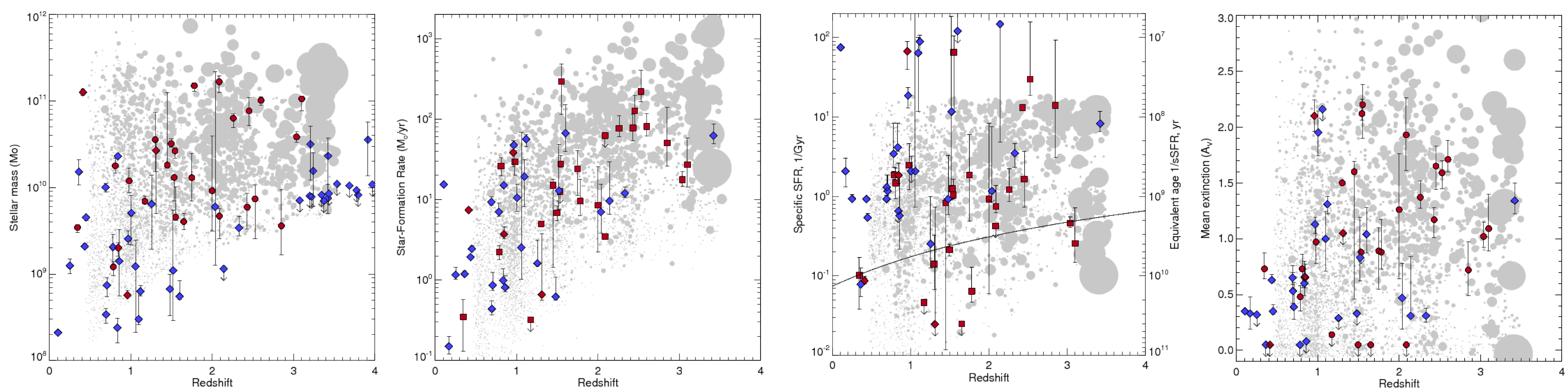
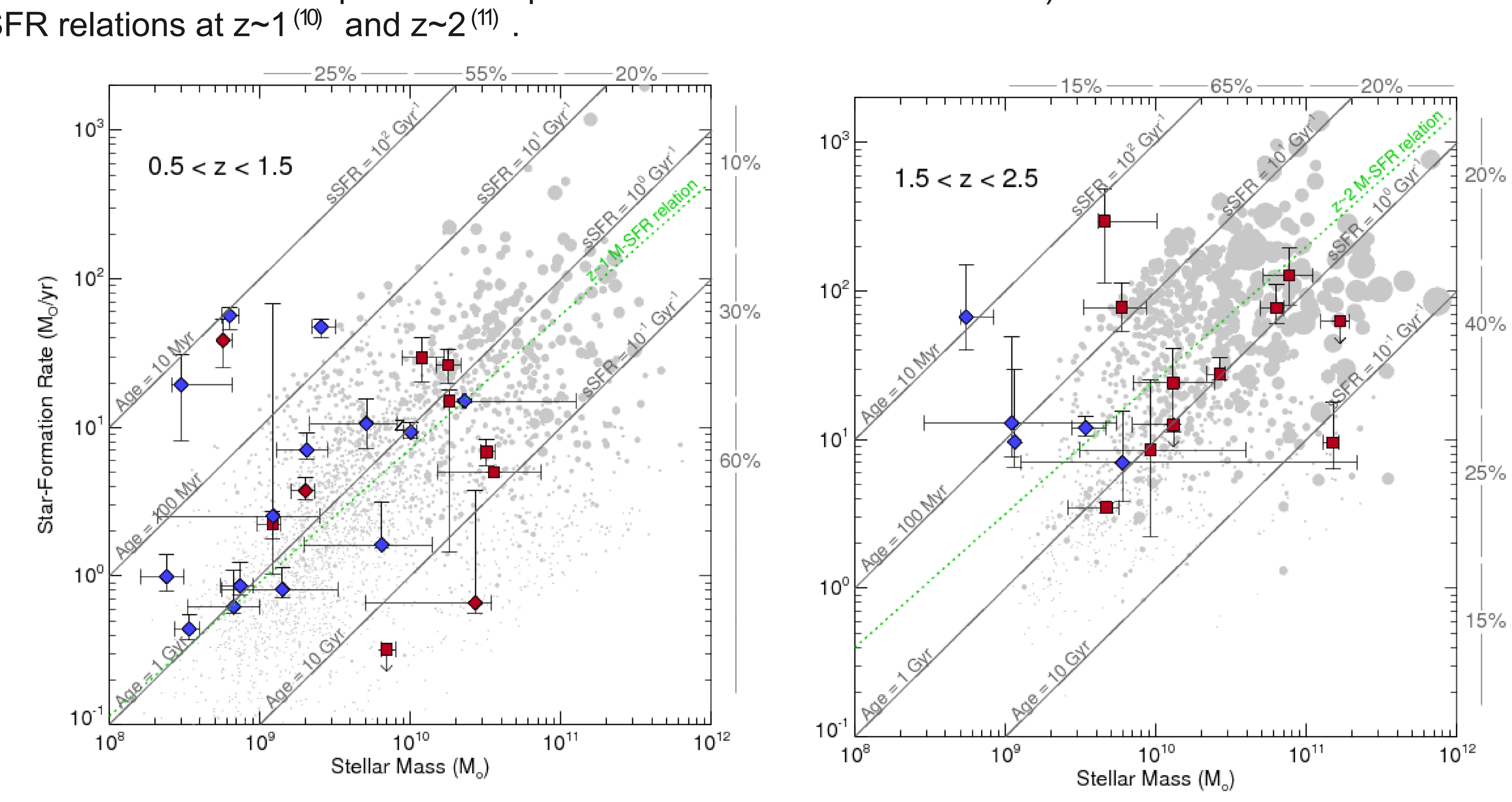


Figure 1 (top) – Broadband SEDs of 24 dust-obscured GRB hosts observed as part of our program, fit with a custom population-synthesis fitting routine.



Figures 2-6 (above) – Intrinsic properties of GRB host galaxies as determined by our fitting to the broadband photometry. Unobscured-GRB hosts[7] are shown in blue; obscured-GRB hosts are shown in red. While both populations are fairly diverse, dark GRB hosts are significantly more massive, luminous, and dust-attenuated. In gray we show a comparison sample of field-selected galaxies from the Subaru MOIRCS Deep Survey[8]; symbol size is proportional to UV+IR SFR.

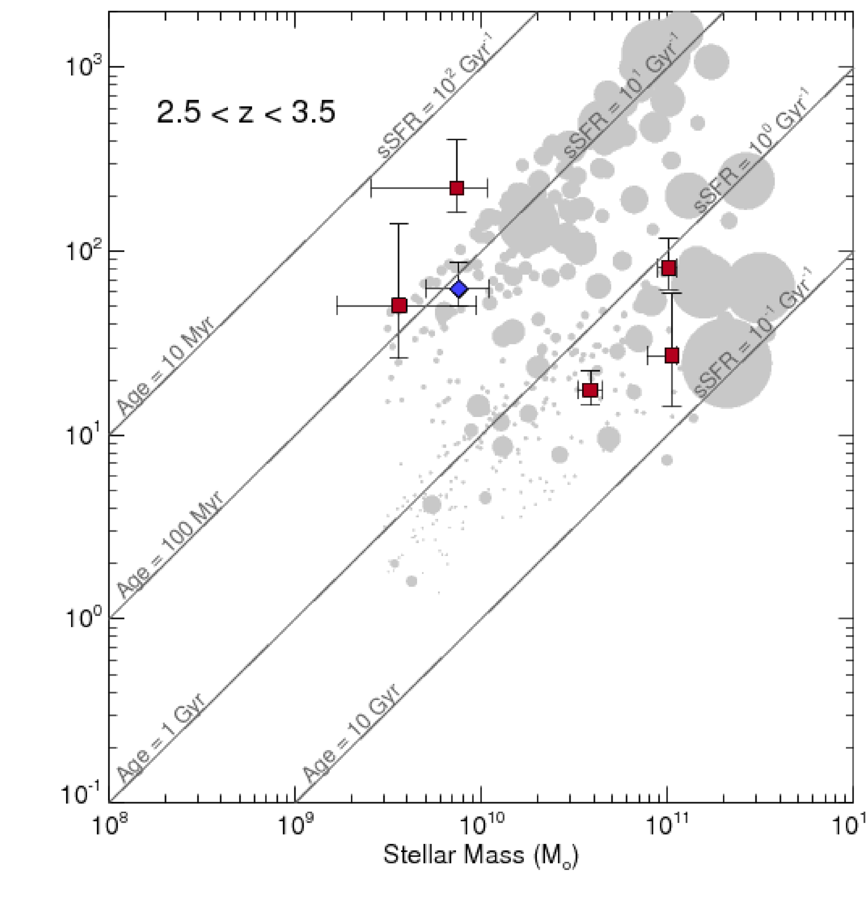
Figures 7-9 (below) – Stellar mass versus UV star-formation rate for unobscured-GRB hosts, obscured-GRB hosts, and field galaxies; symbol conventions are the same as in Fig. 2-6. The plots are divided into three redshift ranges. Percentages indicate the expected number of events in each range (based on results from [8,9]); these do not appear to be met in reality (at least at z~1, where a sufficient literature comparison sample of non-dark hosts is available). Green lines indicate mass-SFR relations at z~1 [10] and z~2 [11].



Dark GRB hosts are dustier, more luminous, and more massive than the hosts of their optically-bright counterparts (Figures 2-6). This clearly indicates that samples based mostly on events localized via optical afterglow positions cannot be used as a fully representative sample. At comparable redshifts, dark GRB hosts are about a factor of 10x more massive, a factor of 5x more rapidly star-forming (UV/IR luminous), and extinguished by an additional ~1 mag (in V-band, about 2-3 additional mag in the UV), although there is significant scatter in both populations in all cases. There is no clear difference in average specific SFR, although obscured GRBs are found in low-sSFR systems while optically-bright GRBs are not.

GRBs can happen in any star-forming galaxy, including quite luminous and massive ones with no obvious evidence on an upper limit on any single parameter. This is in agreement with recent results identifying a few cases of low-redshift (z<0.5) GRBs showing events occurring in galaxies with metallicities above previous suggestions of a maximum metallicity cutoff. Among dust-obscured GRBs, most occur in LIRGs and a few originate in ULIRGs or in sub-LIRGs.

However, GRBs in massive galaxies are still rarer than expected if they were to follow star-formation in a strictly uniform sense: the median GRB mass at z~1 is about 10^9 M☉, about an order of magnitude lower than predicted from (for example) the results of the deep K-band survey of MDS[8]. These differences seem to become less important at z~2, but at these higher redshifts we are limited by the lack of detailed studies of the hosts of optically-bright bursts (which still do represent the majority of GRBs) in the literature.



The GRB rate is probably a gradual function of environment, slowly declining towards higher metallicity. This would explain both the apparent preponderance towards very subluminous galaxies as well as the small (but nonzero) abundance of GRBs in very massive and luminous systems. Further convergence between different (field-survey-based) estimates of the cosmic SFR as will help confirm this conclusion, and larger samples of higher-z hosts will be needed to extend it beyond z>1.5.

References: [1] Le Floc'h et al. 2006 (ApJ, 642, 636) [2] Modjaz et al. 2008 (ApJ, 135, 1136) [3] Mannucci et al. 2011 (MNRAS 413, 1263) [4] Perley et al. 2009 (AJ, 138, 1690) [5] Cenko et al. 2009 (ApJ, 693, 1484) [6] Greiner et al. 2011 (A&A, 526, 30) [7] Savaglio et al. 2009 (ApJ 691, 182) [8] Kajisawa et al. 2009 (ApJ 723, 129) [9] Reddy & Steidel 2009 (ApJ, 692, 778) [10] Elbaz et al. 2007 (A&A 468, 33) [11] Daddi et al. 2007 (ApJ 670, 156)