Unveiling the Galaxy Counterparts of Damped Lyman−alpha Absorbers using GRB−DLAs

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Proprietary Period(days): 365

Abstract:
Damped Lyman−alpha systems (DLAs) have primarily been detected along the line of sight to bright quasars (QSOs) through absorption line spectroscopy. They harbor the bulk of the neutral gas in the Universe between redshifts of 0<z<5 and are therefore thought to be the predecessors of star−forming galaxies. It is impossible to measure the stellar mass, star−formation rate and dust in QSO−DLAs at z>2 since the QSO overwhelms the light from the DLA by a factor of 10. The launch of Swift has enabled localization of the optical counterpart of gamma−ray bursts (GRBs) while they are still bright. Prompt, high resolution spectroscopy of these afterglows, which briefly outshine the brightest quasars, reveals a rich forest of absorption features providing an unprecedented window into the star−forming environments of distant galaxies. GRB hosts show higher metallicities, higher neutral gas column densities and depletion onto dust grains compared to QSO−DLAs. This can be attributed to the fact that QSO sight lines are more likely to cross the extended outer regions of intervening systems. GRBs on the other hand, due to their association with massive stars, provide an unbiased tracer of star−forming environments before the molecular cloud is destroyed by feedback. As a result, GRB hosts are the strongest candidates for bridging the evolutionary chasm between Lyman−break galaxies (LBGs) and QSO−DLAs. We propose Spitzer 3.6 and 24 micron imaging of the complete sample of 35 GRB host galaxies with well−characterized absorption line properties and spectroscopic redshifts in the range 2<z<5.6. We will accurately measure the stellar mass, assess the presence of dust which might be responsible for metal depletion and measure the dust−obscured star−formation rate in DLA systems. A comparison between the multiwavelength properties of GRB hosts and LBGs will help define the notion that GRBs can be used as a tracer of the co−moving star−formation rate density of the Universe out to

the epoch of reionization.

1 Scientific Justification

1.1 DLAs: Progenitors of Star-forming Galaxies ?

Damped Lyman alpha absorption (DLAs) systems along quasar (QSO) lines of sight, with HI column densities N(HI)$\geq 2\times10^{20}$ cm^{-2}, are the largest reservoirs of neutral gas in the Universe at $0<z<5$ (Wolfe et al. 2005). The comoving gas density in DLA systems at z~3 corresponds to $\Omega_{gas}\sim10^{-3}$ which is ¼ of the stellar mass density in the local Universe and a factor of 5 larger than the stellar mass density in Lyman-break galaxies (LBGs) at similar redshifts (Storrie-Lombardi & Wolfe 2000, Dickinson et al. 2003, Rudnick et al. 2004, Prochaska et al. 2005). The observational evidence is tentatively in favor of a decrease in neutral gas fraction to $\sim0.5\times10^{-3}$ at z~2, corresponding to the epoch during which star-formation processes are dominating the energetics of the Universe. Since the birthplaces of stars are molecular clouds, which are the direct descendants of neutral gas clouds, DLA systems at z>>2 must harbor the bulk of the baryons that are converted into stars and that are dominating the luminosity density at lower redshifts.

The bright background quasar allows a detailed measure of the metal content of DLAs, which provides a unique window into the chemical evolution of the Universe (Kulkarni et al. 2005, Rao et al. 2005). Firstly, QSO DLAs display a metallicity floor, [M/H] ≥-2.6 out to z~5, indicating that they have been chemically enriched by an early (z>>5) burst of star-formation. Secondly, at z~3, the median metallicity of a DLA is sub-solar while Lyman-break galaxies appear to have solar metallicities, as inferred indirectly from the [NII]/Hα nebular emission line ratios (Shapley et al. 2004). Consequently, the stellar mass in DLAs, which is directly proportional to the amount of chemical enrichment, must be substantially below that of the $\sim10^{10-11}$ $M_{\odot}$ LBGs. Thirdly, measuring the [Zn/Fe] and [Zn/H] ratios in DLAs indicates the depletion of refractory elements such as Fe onto dust grains. Although the presence of dust has been inferred in DLAs, the implied dust mass is far below that of our Galaxy.

Clearly, z>2 DLAs follow star-formation and chemical enrichment histories which are substantially different from that of luminous field galaxies. Yet, at z≤1, observations of ~20 known DLAs suggest that the counterparts are drawn from the population of normal galaxies (Chen & Lanzetta 2003) although the result is ambiguous (Rao et al. 2003). Preliminary results on the LBG-LBG and LBG-DLA correlation functions at z~3, and the similarity of the derived dark matter halo masses of these two populations, argue for a strong connection between the star-forming galaxy population and the DLAs (Cooke et al. 2006). Thus, a dramatic evolution in the stellar mass and metallicity of DLAs must have taken place at z>2.

1.2 GRB-DLAs: Avoiding the Glare

Measuring the dust content and stellar mass of QSO-DLAs is an *impossible* venture. The QSO is >6 mag brighter than an L* galaxy at z~3 with an angular separation of ≤1.5″. A high spatial resolution HST/NICMOS survey in 22 DLA fields at z>1.6, revealed only a single candidate counterpart which remains spectroscopically unconfirmed (Colbert & Malkan 2002) while deeper NICMOS observations have been stymied by source confusion from multiple candidate counterparts (Warren et al. 2001).

Accurate measures of the stellar mass and dust content can only be achieved from observations of rest-frame near- and mid-infrared emission. Spitzer observations with IRAC and

MIPS are the only ones capable of achieving the sensitivity and wavelength coverage required at z>2. However, with a spatial resolution of ~2″ at IRAC wavelengths and ~6″ at 24μm, observations of QSO-DLAs at these wavelengths would be blinded by the QSO light which would exceed that from the DLA by at least an order of magnitude.

With the launch of the Swift satellite nearly three years ago, gamma-ray bursts (GRBs) now routinely reveal DLAs in the spectra of their bright afterglows (e.g. Berger et al. 2006). Unlike in the case of QSO-DLAs, which are intervening systems, GRB-DLA absorption arises within the host galaxy of the bursts due to the association of long duration GRBs with the end states of massive star-formation. As a result, they served as an unbiased tracer of star-forming environments at high redshift. Since GRBs rapidly fade to obscurity within days to weeks, follow-up observations of the GRB host galaxies provides an accurate and unambiguous way to study the stellar population and dust content of DLA systems.

In order to measure the build up of stellar mass in DLAs and compare their properties with the evolutionary history of luminous, star-forming galaxies that are detected in deep imaging surveys such as GOODS, SWIRE and COSMOS, we propose IRAC 3.6μm observations of the *complete* sample of 35 GRB-DLA host galaxies, with spectroscopic redshifts in the range 2<z<5.5. We also propose to observe a subset of 12, 2<z<3 GRB-DLAs at 24μm, with the MIPS instrument (Details in Technical Section). The MIPS 24 μm observations will measure the redshifted PAH and thermal dust emission from star-formation in the hosts. This will provide an accurate measure of the dust obscured star-formation rate in the DLAs and reveal if the unusual metal abundances (e.g. Sulphur/Iron, Iron/Zinc) seen in certain GRB-DLAs is indeed due to the depletion of Fe onto dust grains (Savaglio et al. 2003, Watson et al. 2005).

1.3 Advantages of GRBs

Gamma-ray bursts (GRBs), by virtue of being extremely luminous, briefly outshine the brightest quasars. The launch of the Swift satellite has enabled rapid localization of the optical counterpart of GRBs and spectroscopic follow up of the afterglow when it is still relatively bright (R<20 mag). The rapid spectroscopic follow-up reveals a rich forest of absorption features superposed on the power-law continuum of the GRB similar to the DLA features superposed in quasar spectra (Wolfe et al. 2005). This includes the Lyman-alpha absorption trough, fine structure lines and the detection of low and high ionization species such as SiIV, FeII, CIV etc (Figure 1). The spectra have enabled the neutral gas column density, metallicity of the host environment around the GRB, and depletion of metals onto dust grains to be measured in the *GRB host which is the primary DLA system* in the spectrum (Savaglio et al. 2003, Jakobsson et al. 2004, Vreeswijk et al. 2004, Chen et al. 2005, Berger et al. 2005). Furthermore, due to the rapid decay in the brightness of the GRB, follow up optical imaging has already provided accurate photometry at optical wavelengths, of the host-DLA.

The GRB spectra have not only measured the redshift of the GRBs but also revealed that the hosts have higher metallicities and higher gas column densities that the average QSO-DLAs (Figure 2). This is due to the fact that GRBs occur in gas rich, star-forming regions on a timescale which enables the star-forming environments to be studied before the molecular cloud is disrupted by stellar outflows and SNe. In contrast, the typical quasar-DLA line of sight because of the larger cross section of the outskirts, mostly intersects the outer region of an absorption line system where the gas density is much lower. Furthermore, high spatial resolution observations with HST are already available for a large subset of GRB-DLAs, pinpointing the location of the GRB within the host. Addition of the Spitzer observations will enable a comparison between the global properties of the galaxy and the local properties derived from the high resolution spectroscopy and imaging.

Rather surprisingly, none of the hosts show evidence for strong molecular hydrogen absorption lines. This could be argued as evidence for low dust content and/or photodissociation by a strong ionizing radiation field. However, there is ongoing dust obscured star-formation in at least some of the hosts based on their detection at infrared/submillimeter wavelengths (Le Floch et al. 2005, Berger et al. 2001, Frail et al. 2002). Thus, the low molecular gas content is more likely to be due to a strong ionizing radiation field from a massive starburst that is partially obscured by dust which the 24μm observations are critical for detecting.

1.4 How do Spitzer observations of GRB-DLAs bridge the gap ?

Spitzer observations by Le Floch et al. (2005) claimed a 20% detection rate of GRB hosts at z~1 with both IRAC and MIPS. They targeted all GRBs which had been localized before July 1999 rather than GRB-DLA hosts with high resolution absorption line spectroscopy. Although those observations were rather shallow, typically reaching 4.5 μm sensitivities of ~4 μJy and 24 μm sensitivities of ~90 μJy, they demonstrated that GRB hosts are not the typical massive, infrared luminous galaxies that dominate the star-formation history of the Universe at $0.5<z<2.5$. We estimate, based on the properties of the luminous DLAs at $z<1$ and the field galaxy population in GOODS that the typical hosts must have IRAC fluxes of ≤1 μJy and SFR of ~50 $M_{\odot}$/yr consistent with the upper limit of 100 $M_{\odot}$/yr derived by Le Floch et al. (2005).

The hosts in our sample typically have 1-2 band photometry at rest-frame ultraviolet wavelengths which does not constrain either the stellar mass or the dust obscured component of star-formation. The UV luminosities typically translate to sub-L* values indicating that the star-formation is either obscured or at a low rate. Since the objects are at the metal-rich end of the DLA metallicity spectrum, there has clearly been significant enrichment of the ISM in the hosts by a previous generation of star-formation. This suggests that there must be a significant evolved stellar component which the IRAC observations will be sensitive to. We will undertake 3.6μm (with simultaneous 5.8μm) IRAC observations of all 35 of the hosts, which will place the strongest constraints yet on the existence of a high Mass/Light ratio evolved stellar component, and thereby the contribution of DLAs to the comoving stellar mass density of the Universe.

We will utilize the stellar mass estimates to derive luminosity-metallicity and mass-metallicity relation at z~2-5, for comparison with the field galaxy sample at lower redshifts (Figure 3). Observing these relations in this redshift range, which is currently inaccessible to traditional galaxy studies, is critical for understanding the role of feedback processes from galactic winds and supernovae, in the chemical evolution history of galaxies. For example, at z~0.1, the fact that low mass galaxies are 5 times more depleted than L* galaxies, convincingly demonstrates the ubiquity of galactic winds in such systems and their effectiveness in removing metals from the low mass halos in which they reside (Tremonti et al. 2004). Unlike for Lyman-break galaxy samples, where the metallicity is inferred indirectly using [NII]/Hα line ratios (Shapley et al. 2004), we are able to measure accurately and directly the metallicity of GRB-DLAs, using the abundant wealth of absorption lines (Figure 1).

For the subset of 12 GRB-DLAs which are at $z<3$, have large gas column densities and show unusually low ratios of refractory to non-refractory elements in the absorption line spectrum indicating depletion onto dust grains, we will also undertake MIPS 24 micron imaging. This will measure the dust emission of the host galaxies for comparison with estimates of depletion from the spectral line analysis and will provide an estimate of the gas/dust ratio at z~3.

1.5 Summary of Goals

To summarize, we intend to measure the stellar mass, star-formation rate and dust content of the complete sample of 35 GRB host galaxies which have exquisite measures of metal abundances and gas column densities from high spectral resolution ground based spectroscopy. All the hosts have spectroscopic redshifts of 2<z<5.6. We will be able to derive star-formation histories for the GRB-DLA host galaxies based on stellar population synthesis fits (Figure 4) and compare them to the star-formation histories of z~3 Lyman-break galaxy sample observed in GOODS and other fields (Shapley et al. 2005). Derived parameters include the age of the stellar population, stellar mass and visual extinction. In conjunction with the wealth of information in the absorption line spectra, we will attempt to address if there is anything unique about the star-formation history of GRB hosts that triggers a GRB. In particular, the detection of fine structure lines (FeII*, SiII*; Berger et al. 2006) in GRB-DLA host galaxies seems to indicate that the primary mode of excitation for these lines is radiative pumping by UV or IR photons. The former requires a dense concentration of star-formation while the latter requires large quantities of dust in the neighborhood of the GRB. Since the typical ultraviolet luminosity of the hosts is sub-L*, the Spitzer observations will constrain the presence of dust in the host galaxies, providing vital information on the conditions of star-formation at high redshift. *The brightness of the quasar and the PSF at infrared wavelengths renders an equivalent study of DLAs along quasar lines of sight impossible. This is however not a factor for GRB-DLAs due to the rapid time decay of the optical afterglow associated with the burst.*

Furthermore, by studying a complete sample of GRB-DLAs at z>2, we will be able to apply the powerful technique of stacking, as a function of measure neutral hydrogen column density and metallicity, to constrain ensemble properties of GRB-DLAs, even if the sources are not individually detected. Stacking enables average constraints to be placed on homogeneous galaxy samples at limits fainter than the detection limits of direct observations. Since the noise scales down as the square root of the number of sources, we anticipate that by stacking we will be sensitive to the presence of 0.1L* galaxy stellar masses in the GRB-DLAs, a factor of 5 more sensitive than the direct observations.

Finally, besides bridging the gap between the typical LBG population and the quasar-DLAs, the observations will for the first time, enable a comparison between the multiwavelength properties of GRB hosts with the star-forming field galaxies detected in deep surveys out to z~6-7 (Dickinson et al. 2004; Giavalisco et al. 2004, Bouwens et al. 2004). A confirmation that GRB hosts are predecessors of the LBG population in their evolutionary history, will help define the notion that GRBs can be used to trace the co-moving star-formation rate density of the Universe out to z~10. This is particularly important given that the star-formation rates of detected galaxies at high redshift fall about a factor of 10 short of reionizing the Universe (Bouwens et al. 2006). If high mass star-formation in sub-L* galaxies are the dominant contributor to the reionization process, the only way they can be detected is by either through fluctuations in the near-infrared background light (e.g. Cooray et al. 2004, 2007) or through GRBs and pair-creation SNe.

Deep observations of these GRB fields, with their wealth of data, will leave a lasting Spitzer legacy to address key problems in galaxy evolution while being unbiased by cosmic variance and provide some of the best prospects for future targeted observations with ALMA, JWST and Herschel.

2 Technical Plan

Sample Selection: We selected the complete sample of 35 GRB host galaxies which have *absorption line spectroscopy* available when the GRB afterglow was bright (e.g. Vreeswijk et al., 2004). Of these, one (GRB030429) has Spitzer observations by Le Floch et al. scheduled. The observations resulted in a non-detection. Our observations of the same host do not constitute a duplication since they are more than 4 times longer in integration time. All 35 sources have spectroscopic redshifts between $2<z<5.5$, measured gas column densities, metallicities and rest-frame ultraviolet observations of the host galaxies (Figure 1). Since many of the GRBs in this sample were detected in the last year when the afterglow was still bright, we have either observed or have ongoing late-time (after the afterglow has faded) observations of these host galaxies in the optical and near-infrared with Magellan and Keck. The proposed Spitzer observations will thereby complete the SED of the hosts from the ultraviolet to the far-infrared. About 30% of the host galaxies also have HST observations (e.g. Vreeswijk et al. 2004) which enables a precise localization of the GRB within the host.

Filters: The work of Shapley et al. (2005) has demonstrated that the addition of rest-frame near-infrared data for Lyman-break galaxies at z~2 reduces uncertainties in the stellar mass estimates by factors of ~2 compared to estimates derived from optical through K-band photometry. At the median redshift of our sample, $\langle z\rangle=3.1$, the 3.6 micron passband traces the same rest-frame wavelength as ground-based K-band at $\langle z\rangle=2.0$ enabling the masses of GRB hosts to be determined to the same accuracy as the LBG population. The host galaxies are relatively metal rich compared to the metallicities of QSO-DLA systems. This suggests that a previous burst of star-formation in the hosts must have enriched the ISM in these galaxies. The evolved stellar population from these previous bursts would typically have a spectral energy distribution which peaks in the IRAC bands. We choose to observe with the 3.6μm bandpass since it is slightly more sensitive and has a narrower point spread function than 4.5μm.

We have proposed MIPS 24 observations for only a subset of 12 host galaxies. The subset of 12 objects for which we have proposed MIPS observations are at $2<z<3$, before the 6.2μm PAH feature and warm dust get redshifted out of the 24μm passband. They are also the objects with the highest gas column density, typically $N(HI)>3\times10^{20}$ cm^{-2} and with unusually high S/Fe absorption line ratios that suggest the depletion of Fe onto dust grains. All these factors strongly favor the detection of these galaxies in the MIPS observations. Besides, we have found based on our experience in GOODS that MIPS is insensitive to dust emission from all but the most luminous AGN at $z>3$.

The 24μm observations will detect the redshifted mid-infrared emission from ~300K transiently heated dust grains and polycyclic aromatic hydrocarbon (PAH) emission features, the strongest of which lie between rest-frame 6.2 and 12μm. Our observations are scaled in integration time between to account for the varying luminosity distance at $2<z<3$. Based on our experience among field galaxy samples, neither the 70μm nor 160μm data will be sensitive enough to detect the GRB-DLAs at these redshifts and we do not propose for those.

Flux Estimates/Integration Times: Since there have been no previous Spitzer measurements of the IRAC and MIPS fluxes of either DLAs or GRB hosts at these redshifts besides the constraints from Le Floc'h et al. (2006) discussed earlier, we estimate flux densities and integration times through three different techniques:

1. Extrapolation from the H-band limits and detections of DLAs in Colbert & Malkan (2002) which place limits of <5μJy to the near-infrared flux.
2. Using the z<1 multiwavelengths observations of DLAs by Chen&Lanzetta (2003) and adopting no luminosity evolution from z~1 to 3.
3. The median IRAC and MIPS flux density of 2<z<4 field galaxies in the GOODS fields.

These give broadly consistent results indicating that the average GRB host/DLA system must have an IRAC flux of 0.5-1μJy at z>2. The MIPS fluxes can only be estimated by comparison with the GOODS galaxies. We find that of the red Lyman-break galaxies with spectroscopic redshifts >2 in GOODS, the median 24μm flux density is ~50μJy which we define as our target sensitivity.

Using the SENS-PET and scaling the exposure time to the desired sensitivity, we adopt IRAC integration times of 1 hrs/pix (36×100s) for the z<3 source and 2 hr/pix for the z>3 sources which yields a 5σ sensitivity of 0.4μJy for low background in the 3.6μm channels. This would enable us to detect a 0.5L* galaxy (where L* is measured at z~3 as R=24.54 mag) out to z~4 for a 10-100 Myr old stellar population. The sensitivity is more than 5μJy at 5.8 and 8μm and we do not hope to detect our sources at those wavelengths based on the constraints by Le Floc'h et al. We use medium scale dithers with a random cycling pattern to enable better sky subtraction and flat fielding than the Reuleaux pattern.

For the MIPS 24 observations, we adopt the small scale photometry mode, using the longest possible integration times of 30s. The total exposure time at these wavelengths is 1.3 hrs/pix achieving a 5σ sensitivity of 50μJy. This would enable us to detect a typical 5×10^{11} $L_\odot$ LIRG at z~2 and a hyperluminous (>10^{13} $L_\odot$) infrared galaxy at z~3.

As explained earlier, stacking will enable us to place a factor of 3-6 stronger constraints in the event of non-detections in direct imaging.

Reduction and Analysis: We have extensive experience within the team in the reduction of IRAC and MIPS data since the PI was responsible for many of these aspects as a member of GOODS. The benefits of the tools developed to reduce the GOODS data will be applied towards this program to achieve the maximum possible sensitivity. There is also some danger of the sources being blended with brighter neighboring sources (``confusion") in the MIPS images. We will apply the prior position-based de-blending technique developed for GOODS in the case that source confusion becomes an issue. This technique has proven to be quite robust yielding an 84% completeness rate of 20μJy in the GOODS data, much fainter than the nominal 40 beams/source confusion limit of 80μJy claimed by certain groups.

3 Legacy Data Products Plan

Not a Legacy program.

4 Figures and Tables

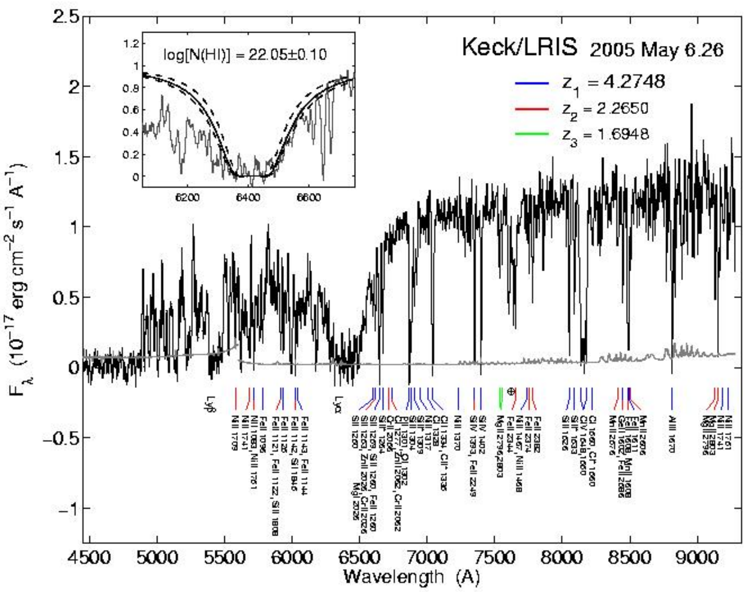

Figure 1: Absorption line spectrum of GRB050505 at z=4.27 (Berger et al. 2006). A wealth of low and high ionization features as well as fine structure transitions are detected which have never been seen in quasar-DLAs, providing an unprecedented view into star-formation environments in the host. *The GRB host is the primary DLA in this spectrum.* The inset shows a zoom in of the Lyman-alpha absorption by the GRB host galaxy and the derived neutral gas column density.

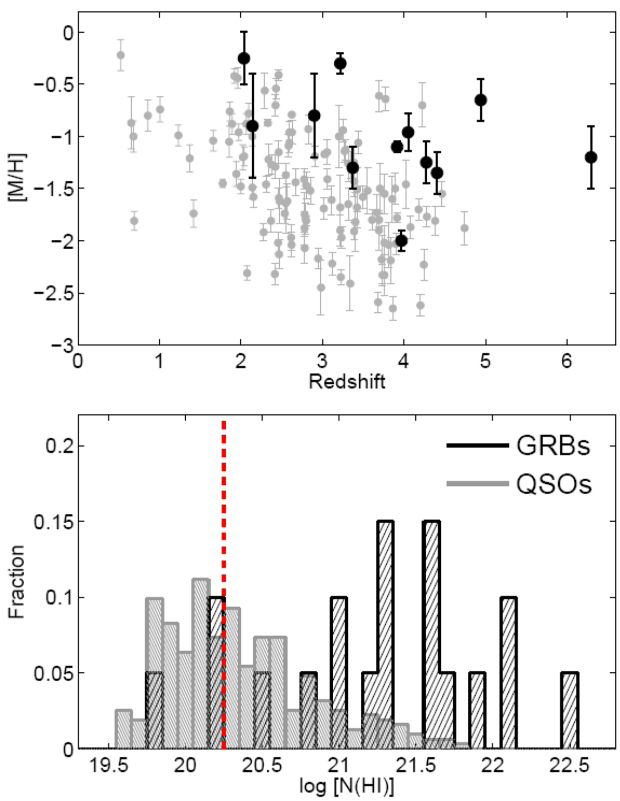

Figure 2: Results from absorption line spectroscopy of GRB hosts. *Top:* Metallicity as a function of redshift for QSO-DLAs (gray; Prochaska et al. 2003) and GRB-DLAs (black; Berger et al. 2005); *Bottom:* Neutral hydrogen column density for the two samples. Clearly, GRB-DLAs have higher gas column densities and metallicities than QSO-DLAs due to the fact that the bursts are embedded within the host galaxies/DLAs. Our proposed measurement of stellar mass and dust will shed light for the first time on the relation between DLAs and star-formation.

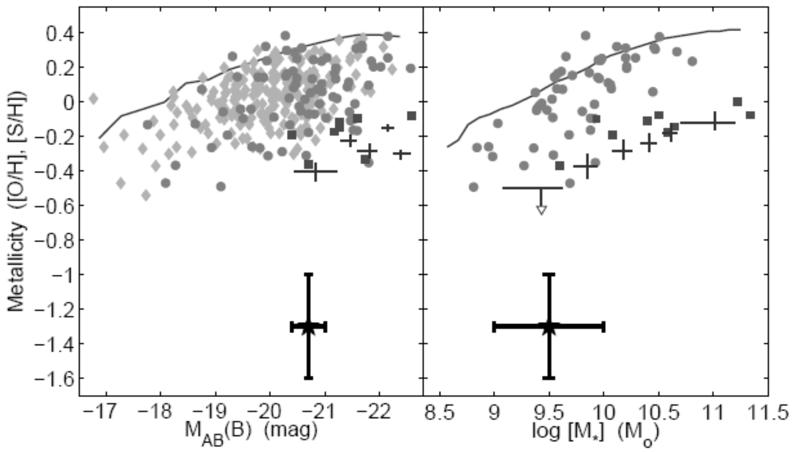

Figure 3: Luminosity-metallicity (left) and mass-metallicity (right) relationships for star-forming galaxies at z~0.1-2. Also shown is the host galaxy/DLA of GRB050904 at z=6.295 (star). The galaxy data are from GDDS and CFRS at z~0.4-1 (circles), TKRS at z~0.3-1 (diamonds), DEEP2 at z~1-1.5 (squares) and LBGs at z~2.3 (error bars). The gray lines represent the relation derived for z~0.1 SDSS galaxies. With the proposed observations we can construct a mass-metallicity relation for GRB-DLAs at z~2-5.5, a redshift range inaccessible to other techniques.

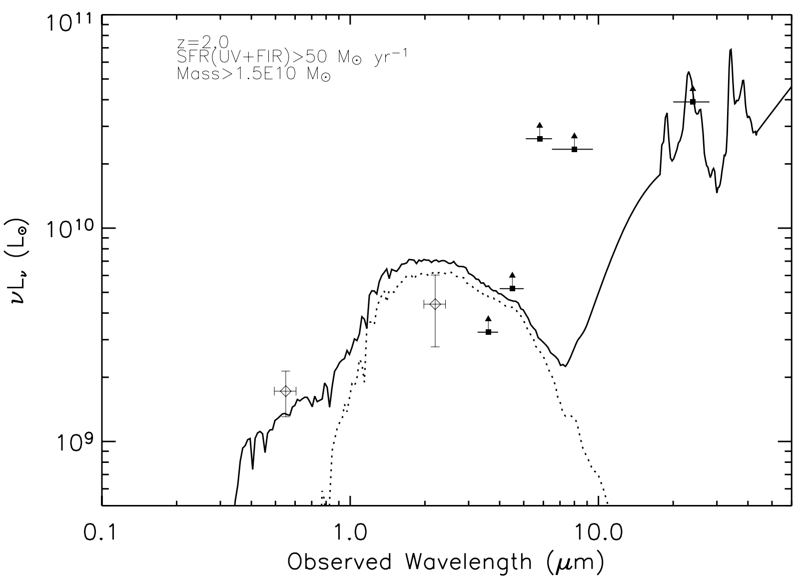

Figure 4: 5σ sensitivity limits of deep ~1 hr observations (solid squares) over-plotted on a template SED which we think will be typical of the GRB DLA/hosts. The dotted line is the maximal M/L ratio stellar component. The 3.6 and 24μm channels are the most sensitive to detecting such objects and so our proposal targets only these wavelengths. We expect to detect stellar masses corresponding to 0.5L* galaxies at z~3 and dusty star-formation rates typical of LIRGs.

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6 Brief Resume/Bibliography

- Ranga-Ram Chary is a Research Scientist at the Spitzer Science Center, Caltech. He is an expert on various aspects of galaxy evolution and cosmology and has extensive experience in all aspects of Spitzer mid-infrared imaging/spectroscopy.
- Edo Berger is a Carnegie-Princeton postdoctoral fellow at OCIW, Pasadena and has been leading various ground-based efforts to obtain high resolution spectroscopy of GRB afterglows.
- Shri Kulkarni and George Djorgovski have led the multiwavelength follow-up of GRBs and their host galaxies since 1997.
- Andrew Blain has been involved in the interpretation of GRBs as tracers of the co-moving star-formation rate density and worked closely with the spectroscopic follow-up and interpretation of infrared luminous submillimeter galaxies

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- Djorgovksi, S. G., et al., 2006, astro-ph/0701155, *'Discovery of a Probable Physical Triple Quasar'*
- Blain, A., et al., 2005, ApJ, 611, 725, *'Clustering of Submillimeter-selected Galaxies'*

7 Observation Summary Table

Rest-frame near-infrared and mid-infrared fluxes of the targeted hosts are unknown and cannot be accurately computed from the rest-frame ultraviolet data that exists. We have estimated the integration times based on the properties of field Lyman-break galaxies at z~3 in the GOODS field and luminous DLAs at z<1 studied by Chen & Lanzetta (2003). We expect to achieve 5σ sensitivities of 0.4μJy with IRAC at 3.6μm and 50μJy with MIPS at 24 μm for the deepest observations listed below. Representative AORs are provided with the proposal.

Target	RA	DEC	z	IRAC	MIPS	IRAC	MIPS
	J2000			micron	micron	AOR Time (sec)	
GRB000926	17:04:09.62	+51:47:11.2	2.04	3.6/5.8	24	4212	2572
GRB000301C	16:20:18.60	+29:26:36.0	2.04	3.6/5.8	24	4212	2572
GRB011211	11:15:17.98	-21:56:56.2	2.14	3.6/5.8	24	4212	2572
GRB050922C	21:09:33.10	-08:45:29.8	2.20	3.6/5.8	24	4212	
GRB060124	05:08:25.50	+69:44:26.0	2.30	3.6/5.8	24	4212	4918
GRB021004	00:26:54.69	+18:55:41.3	2.33	3.6/5.8	24	4212	
GRB051109	22:01:15.30	+40:49:23.3	2.35	3.6/5.8	24	4212	
GRB070110	00:03:39.3	-52:58:26.9	2.35	3.6/5.8	24	4212	4918
GRB060908	2:7:18.3	00:20:31.0	2.43	3.6/5.8	24	4212	4918
GRB050820	22:29:38.11	+19:33:37.1	2.61	3.6/5.8	24	4212	4918
GRB030429	12:13:07.5	-20:54:49.7	2.66	3.6/5.8	24	4212	5814
GRB060604	22:28:54.97	-10:54:59.9	2.68	3.6/5.8	24	4212	4918
GRB060714	15:11:26.5	-6:33:59.3	2.71	3.6/5.8	24	4212	4918
GRB050603	02:39:57.00	-25:10:54.0	2.82	3.6/5.8	24	4212	4918
GRB050401	16:31:28.81	+02:11:14.2	2.90	3.6/5.8	24	4212	4918
GRB060607	21:58:50.4	-22:29:47	3.08	3.6/5.8		8184	
GRB020124	09:32:50.80	-11:31:11.0	3.20	3.6/5.8		8184	
GRB060926	17:35:43.7	13:02:18.6	3.20	3.6/5.8		8184	
GRB060526	15:31:18.3	+00:17:03.7	3.21	3.6/5.8		8184	
GRB050319	10:16:47.9	43:32:54.5	3.24	3.6/5.8		8184	
GRB050908	01:21:50.75	-12:57:17.2	3.34	3.6/5.8		8184	
GRB061222B	7:1:24.8	-25:51:33.9	3.35	3.6/5.8		8184	
GRB030323	11:06:09.38	-21:46:13.3	3.37	3.6/5.8		8184	
GRB060707	23:48:19	-17:54:17	3.43	3.6/5.8		8184	
GRB061110B	21:35:40.4	6:52:34.1	3.44	3.6/5.8		8184	
GRB060115	03:36:08.40	+17:20:43.0	3.53	3.6/5.8		8184	
GRB060906	2:43:00.9	30:21:42.1	3.69	3.6/5.8		8184	
GRB050502	13:29:46.30	+42:40:27.7	3.79	3.6/5.8		8184	
GRB060605	21:28:37.2	-6:3:33.8	3.80	3.6/5.8		8184	
GRB060210	3:50:57.4	27:01:34.4	3.91	3.6/5.8		8184	
GRB050730	14:08:17.09	-03:46:18.9	3.97	3.6/5.8		8184	
GRB060206	13:31:43.44	+35:03:03.6	4.05	3.6/5.8		8184	
GRB050505	09:27:03.30	+30:16:23.7	4.28	3.6/5.8		8184	
GRB050814	17:36:45.39	46:20:21.6	5.31	3.6/5.8		8184	
GRB060927	21:58:11.93	5:21:50.3	5.60	3.6/5.8		8184	

There are 63 hrs total in IRAC AORs, and 14.4 hrs total in MIPS AORs for a grand total of 77.4 hours.

8 Status of Existing Observing Programs

PI R. Chary is also PI of a medium GO-2 program (PID20456) titled “Balancing the Cosmic Energy Budget between AGN and Starbursts in the Great Observatories Origins Deep Survey”. Data were received over the summer of last year and reduced. Early results on the nature of submillimeter galaxies have been presented by Pope et al. astroph/0612105. We are currently in the process of writing up the results of this program.

Co-I Berger is PI of a joint HST-Spitzer program targeting the host galaxies of z>6 GRBs (PID20000). Initial results on the first GRB observed in this program were published in Berger et al. 2006, astro-ph/0603689. Spitzer observations on four other GRB hosts were received in Dec 2006. Data are currently being reduced.

Co-I Blain is PI of 3 GO-1 and GO-2 programs (PID 3473, 20081, 20216). The data sets have received, reduced and the first paper of the series is in press (Menendex-Delmestre et al. 2007, ApJ Letters)

9 Proprietary Period Modification

There are no modifications to the proprietary period.

10 Justification of Duplicate Observations

In our duplication check, we found one GRB host, GRB030439 which has observations scheduled in PID 20370. We note that those observations were too shallow and that our observations are more than x4 longer in integration time at 24μm. At 3.6/5.8 micron, there is no duplication.

11 Justification of Targets of Opportunity

There are no ToO observations.

12 Justification of Scheduling Constraints

There are no constraints on this program.

13 Data Analysis Funding Distribution

PI: R. Chary: 45%; co-I: E. Berger: 25%; co-I: Blain/Djorgovski/Kulkarni: 10%×3=30%

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