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Dust properties of the faint GRB 080603A

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Abstract. GRB 080603A was an optically faint burst occurred at $z = 1.687$, whose optical afterglow peaked with $R \sim 18$ mag at 26 minutes from the burst onset. The dust extinction toward GRB 080603A within the host galaxy is high, $A_{V,z} = 0.8$ mag, and the well-sampled X-ray-to-near-infrared spectral energy distribution is interesting in requiring an LMC2 extinction profile, in contrast to the majority of GRBs, with possible evidence for the presence of the 2175 Å bump. From the late-time multi-filter photometry obtained with the Keck/LRIS, the host galaxy is typical of long GRBs. Its SED is best fit with that of a starburst galaxy with an age of 130 Myr, $M_B = -20.7$, and a similar dust extinction to that along the GRB sightline. GRB 080603A bridges the gap between the optically missed (either because heavily dust–obscured or because intrinsically faint) and optically bright GRBs. As such, it highlights the importance of prompt and deep ($R \gtrsim 20$ mag) follow-up observations.

Key words. gamma rays: bursts – gamma–ray burst: individual: GRB 080603A – dust, extinction

1. Introduction

The *INTEGRAL*–discovered GRB 080603A had a duration of ∼150 s and was promptly followed up in the optical bands by a number of facilities. In particular, the Faulkes Telescope North (FTN) detected a faint optical flash simultaneous with the last of two γ–ray pulses the prompt emission consisted of. Subsequent multi–filter observations caught the rise of the afterglow onset and monitored the evolution out to four days post burst. We collected one of the richest data sets for an individual GRB yet, spanning from the γ–ray prompt emission, the X–ray afterglow detected with *Swift*–XRT, an optical/NIR ($BVRg'r'i'JHK_s$) data set from as early as 100 s, to the radio-band detections with the Very Large Array (VLA) from 2 to 13 days. In addition, we performed spectroscopic observations of the afterglow at 2.1 hours post bursts, which led to the GRB redshift determination of $z = 1.68742$ through the identification of several absorption features and fine-structure transitions.

GRB 080603A shows several interesting properties, such as the simultaneous detection of prompt optical and γ–ray emission, whose joint analysis rules out an inverse Compton origin for the burst itself. The achromatic evolution of the afterglow is marked by the rise, peak, and decay, followed by a jet break around

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10^5 s which together constrain the physics and energetics. Hereafter, we focus on the dust properties obtained by means of an accurate SED. In particular, we measure the remarkable dust content along the sightline to the GRB, which favours an LMC2 profile, at odds with most GRBs, for which the SMC works better. Full details on all these aspects can be found in the main reference for this work, Guidorzi et al. (2011; hereafter G11).

2. Spectral Energy Distribution (SED)

We built up an SED from fitting the multi-filter light-curve with an achromatic model, based on the observed lack of colour evolution. The SED is best fitted with a single power–law from the observed NIR to the X–rays with a spectral index of $\beta = 1.0$, and a significant amount of dust extinction and soft X–ray absorption due to metals. Figure 1 shows the details of the SED around the NIR/optical frequencies (see G11 for the full broadband SED). The normalisation in Fig. 1 refers to an epoch of 1.5×10^4 s; its shape remains unchanged within uncertainties throughout the sampled time interval, as implied by the achromatic evolution.

We considered three different extinction profiles and adopted the parametrisation of Pei (1992): SMC, LMC2, and MW. We denote with LMC2 the profile originally denoted by Pei with LMC, because from recent estimates (Gordon et al. 2003) this turned out to be representative only of the area around 30 Doradus (the LMC2 supershell). Instead, the typical LMC curve is much more similar to that of the MW. At variance with the majority of GRBs, which prefer an SMC profile (Kann et al. 2010), the SED of GRB 080603A is best fitted with an LMC2 model, with some evidence (at $\sim 3\sigma$ level) for the presence of the 2175 Å bump, while both MW and SMC are ruled out. The amount of dust is remarkable: the rest–frame extinction is $A_{V,z} = 0.80 \pm 0.13$ mag, a value which ranks at the top of the GRBs having observed optical afterglows (Kann et al. 2010). The best-fitting spectral model is a simple power law from NIR to X-rays with an index of $\beta_{o,x} = 1.01 \pm 0.05$. The measured soft X–ray absorption could not be entirely ascribed to our own galaxy, $N_{HI}^{\rm Gal} = 4.7 \times 10^{20}$ cm^{-2} (Kalberla et al. 2005), but required an additional, intrinsic term of $N_{HI,z} = 6.6^{+6.2}_{-4.6} \times 10^{21}$ cm^{-2}. This column density value is expressed in terms of neutral hydrogen assuming solar abundances, but it is actually due to the photoelectric absorption by metals.

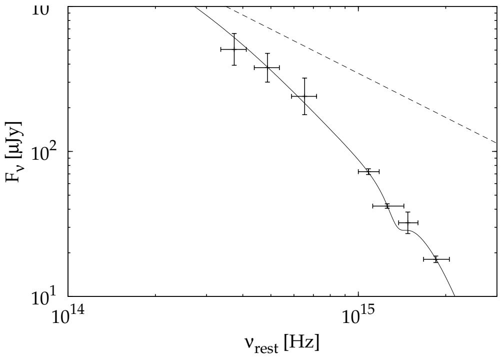

Fig. 1. GRB rest–frame SED in the observed NIR/optical filters at 1.5×10^4 s post burst. The solid line shows the best-fitting model, corresponding to a simple power–law with index 1 extinguished by an LMC2 profile with $A_{V,z} = 0.8$. The dashed line shows the same unextinguished power–law.

The quality of the data available for GRB 080603A propelled us to try to better characterise the dust properties using the general parametrisation of the Local Group extinction laws by Fitzpatrick & Massa (1990, hereafter FM), like with GRB 080607 (Perley et al. 2011). The parameters c_1, c_2, and R_V were all tied to each other. As for the other parameters, we fixed γ to 1 and c_4 to 0.6, respectively. The free parameters were $\beta = 0.98 \pm 0.04$, $A_{V,z} = 0.57 \pm 0.19$, $R_V = 2.14 \pm 0.33$, and $c_3 = 1.76 \pm 0.66$ (strength of the 2175 Å bump) with a total χ^2/d.o.f.= 19.8/18. Indeed, by fitting the FM model we end up with a set of values generally consistent with those of the LMC2 profile (Gordon et al. 2003). Interestingly, fitting the SED of the host galaxy with a LMC model with the HYPERZ code (Bolzonella et al. 2000), one obtains a very similar dust extinction, $A_V = 0.77$ mag (Fig. 2). The SED is that of a typical starburst galaxy with an estimated age of 90 Myr, and an absolute magnitude of

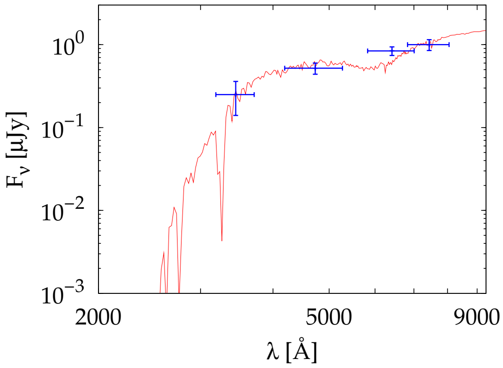

Fig. 2. SED of the host galaxy best fitted with a starburst galaxy with an LMC extinction profile with A_V = 0.77 mag.

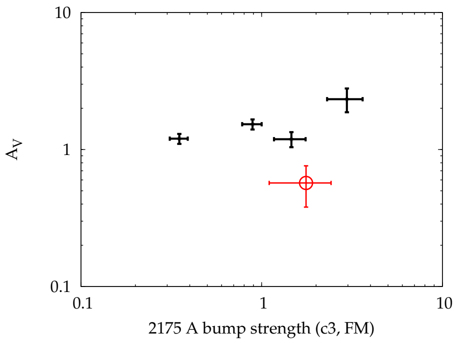

Fig. 3. Dust versus 2175 Å bump strength for a sample of GRBs by Zafar et al. (2011). The circle displays GRB 080603A.

$M_B = -20.7$, typical of host galaxies of other long duration GRBs. Unfortunately, the lack of measurements redward of the Balmer break at 4000 Å in the GRB rest frame prevents us from estimating the total stellar mass.

3. Metals, dust, and a possible 2175 Å bump

The SED of GRB 080603A is one of the few which clearly favours an LMC2 extinction profile. In particular, it shows possible evidence for the presence of the 2175 Å bump, which has been observed in a very few GRB afterglows so far (Krühler et al. 2008; Elíasdóttir et al. 2009; Perley et al. 2011; Zafar et al. 2011). The detection of the 2175 Å bump points toward that a more evolved environment typical of massive hosts, more similar to our Galaxy, providing information on the composition and dust grain size (e.g., Pei 1992).

While this feature has been found in a few ($\lesssim$ 10%) SED of other GRB afterglows, thus supporting the view of the typical GRB host as a blue, star–forming galaxy, only for a fraction of them ($\sim$ 1/4) we can confidently rule out its presence (Zafar et al. 2011). Interestingly, it was noted that all of the few GRBs with clear evidence for the 2175 Å bump are also characterised by a large intrinsic dust extinction, $A_V \gtrsim 1.0$ (Zafar et al. 2011). Given that the sample of observed GRBs with a measured SED is strongly biased against the dust-extinguished events, a large fraction of the dark bursts could show evidence for a 2175 Å bump in the extinction profile of their dust. Since dark GRBs represent the 25–40% of the observed sample of optical afterglows (Fynbo et al. 2009), the fraction of GRB hosts with a 2175 Å bump and a more evolved environment is likely to be correspondingly larger. In this context, GRB 080603A seems to bridge the gap between the few, bright, and highly dust-extinguished GRBs with clear evidence for the 2175 Å bump, and the majority of optically detected GRBs with no evidence for that feature, and whose SED is fitted with an SMC curve. This is suggested by Figure 3, where the dust extinction is shown against the bump strength, expressed by the c_3 coefficient of the FM parametrisation. A significant fraction of GRBs with low extinction that are currently thought to be preferably fitted with an SMC curve, could actually have a 2175 Å bump, and therefore they could populate the lower part of Fig. 3. In this respect, the remarkable quality of the data set collected for GRB 080603A and the prompt discovery of its relatively faint afterglow, allowed us to detect the possible bump and propose it as a possible link between dark, dust–extinguished GRBs and those with a small dust extinction, yet with a 2175 Å bump, which in most cases remains undetected because of the insufficient data quality.

GRBs typically show higher metal-to-dust ratios than what is observed in the Local

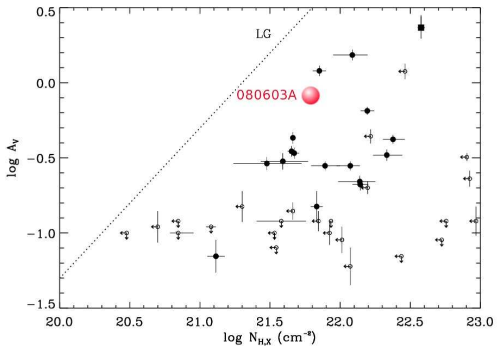

Fig. 4. Dust versus metals. The dashed line shows the ratio typical of the Local Group (adapted from Zafar et al., 2011).

Group, a probable explanation being dust destruction in the GRB surrounding medium by the GRB itself (e.g., Fruchter et al. 2001). In this respect, GRB 080603A has a typical metal column density, while its dust content ranks among the top measured values; as a consequence, its metal-to-dust ratio is closer to the values observed in the Local Group than for other GRBs, as shown in Fig. 4.

4. Conclusions

Among several interesting properties, GRB 080603A went off at $z = 1.687$ and was characterised by a moderate dust content along the sightline through the host galaxy, with $A_{V,z} = 0.80 \pm 0.13$. Thanks to the very accurate SED, we could establish that the dust extinction curve can be fitted only with an LMC2 (Supershell) profile, as seen for a few GRBs, at variance with most afterglows. In particular, we found possible evidence for the 2175 Å bump. Both the remarkable dust extinction and the possible presence of the bump suggest that a large fraction (if not all) dark GRBs, as well as other GRBs with a poorly sampled SED, might exhibit a similar extinction curve. In this sense, GRB 080603A could bridge the gap between the few GRBs so far observed with a large extinction and the 2175 Å bump and those with no evidence for it. The detection of this event highlights the importance of a deep ($R \gtrsim 20$ mag) and prompt follow-up observations.

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