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Energetics–spectral correlations versus the BATSE gamma-ray bursts population

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ABSTRACT

The proposed correlations between the energetics of gamma-ray bursts (GRBs) and their spectral properties, namely the peak energy of their prompt emission, can broadly account for the observed fluence distribution of all 'bright' BATSE GRBs, under the hypothesis that the GRB rate is proportional to the star formation rate and that the observed distribution in peak energy is independent of redshift. The correlations can also be broadly consistent with the properties of the whole BATSE long GRB population for a peak energy distribution smoothly extending towards lower energies, and in agreement with the properties of a sample at 'intermediate' fluences and with the luminosity functions inferred from the GRB number counts. We discuss the constraints that this analysis imposes on the shape of such peak energy distribution, the opening angle distribution and the tightness of the proposed correlations.

Key words: gamma-rays: bursts.

1 INTRODUCTION

The proposed correlations between energetics and spectral properties are among the most interesting clues to the physical processes taking place in gamma-ray bursts (GRBs). More precisely it has been suggested (Lloyd-Ronning, Petrosian & Mallozzi 2000; Amati et al. 2002, hereafter A02; Atteia et al. 2004; Lamb, Donaghy & Graziani 2004; Sakamoto et al. 2005) that the apparent isotropic energy of the prompt phase, $E_{\rm iso}$, correlates with the intrinsic peak energy of the integrated emission $E_{\rm peak}$ [in a $\nu f(\nu)$ representation], with a dependence $E_{\rm peak} \propto E_{\rm iso}^{0.5}$. A similar correlation has been claimed between $E_{\rm peak}$ and the peak luminosity (Yonetoku et al. 2004). More recently, (Ghirlanda, Ghisellini & Lazzati 2004, hereafter GGL04) by correcting for the putative fireball opening angle – estimated from the (achromatic) break time in the afterglow lightcurve (Sari, Piran & Halpern 1999; Frail et al. 2001; Bloom, Frail & Kulkarni 2003) – argued that an even tighter correlation holds between the actual prompt energetics, E_γ and $E_{\rm peak}$, namely $E_{\rm peak} \propto E_\gamma^{0.7}$. Such correlations have been determined from and calibrated using a limited number of GRBs, i.e. at most the ∼40 long GRBs for which redshift information was available. No unique and robust interpretation of such results has been found so far (Zhang & Meszaros 2002; Schaefer 2003; Eichler & Levinson 2004; Liang, Dai & Wu 2004; Yamazaki, Ioka & Nakamura 2004; Rees & Meszaros 2005). However, it is clear that if these correlations were to hold for the whole GRB population (see Nakar & Piran 2005; Band & Preece 2005; Friedman & Bloom 2005, for dissenting views), they could provide powerful clues to the physical origin of the prompt emission and have important repercussions on the potential cosmological use of GRBs.

We aimed at assessing whether these correlations are statistically consistent with the observed peak energy versus fluence distributions of a large sample of long (BATSE) GRBs, until redshifts can be determined for a significantly larger number of events. The only assumptions are that these events follow the cosmological star formation rate redshift distribution and that the observed peak energy distribution is not significantly affected by the GRB redshifts. Although a statistical consistency – given the above hypothesis – is not a proof of the reality of such correlations, it would support the view that they might indeed represent intrinsic properties of long GRBs.

The outline of this paper is the following. We detail our assumptions and procedure in Section 2, present our results in Section 3 and discuss them in Section 4. Preliminary results of this work can be found in Bosnjak et al. (2004). While finishing writing this paper, we received the manuscript by Ghirlanda, Ghisellini & Firmani (2005), who – through a complementary and independent analysis – reach conclusions remarkably similar to those reported here.

2 METHOD AND ASSUMPTIONS

In order to test whether the observed peak energy and fluence distributions are consistent with the correlations proposed by A02 and GGL04, we considered the sample of BATSE GRBs analysed by Preece et al. (2000) (referred to as the 'bright' BATSE sample

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hereafter), consisting of 154 events for which $E_{\rm peak}$ has been estimated. We then simulated – via a Monte Carlo – the fluence distribution for a population of GRBs characterized by the corresponding $E_{\rm peak}$ distribution. The procedure we adopted is the following.

(i) We assumed that the GRB rate follows the star formation rate distribution in redshift (as estimated by Madau & Pozzetti 2000), namely $R_{\rm GRB}(z) = 0.3\ \exp(3.4z)[\exp(3.8z) + 45]^{-1}\ {\rm M}_{\odot}\ {\rm yr}^{-1}\ {\rm Mpc}^{-3}$.

(ii) We adopted the observed $E_{\rm peak}$ distribution of the bright BATSE GRBs, as obtained by averaging the results of the time-resolved spectral analysis by Preece et al. (2000).

(iii) We randomly assigned a redshift and a characteristic intrinsic peak energy $(1 + z)\ E_{\rm peak}$ to each event, where $E_{\rm peak}$ is randomly extracted from the observed distribution.

(iv) We adopted the A02 correlation (with its spread) to estimate the corresponding energetics.

(v) By applying the cosmological corrections[1] estimated the corresponding fluence in the 50–300 keV energy range (for a typical Band's spectral representation with $\alpha = -1$ and $\beta = -2.25$, see Preece et al. 2000).

(vi) We compared the simulated fluence distribution with that of bright BATSE GRBs. The comparison of fluences clearly avoids, with respect to fluxes, any further assumption about GRB durations.

It is clear that any agreement found under the above assumptions does not exclude that different hypothesis on the intrinsic $E_{\rm peak}$ distribution, and the relation (or lack of) between $E_{\rm peak}$ and energetics and their dependence on redshift might reproduce the observed fluence distributions. We, however, tested some simple alternative hypothesis on our assumptions, as described below, without finding satisfactory results.

The consistency between the simulated and the observed distributions has been quantitatively assessed by estimating the maximum difference D in the cumulative distributions as in the two-sample Kolmogorov–Smirnoff (KS) test. The parameter D has been used to compare the degree of agreement of the different models with data (i.e. for different assumptions/parameters). We adopted as a limit for a qualitatively satisfactory agreement a value $D < 0.14$, although formally the corresponding associated probability of two distributions being drawn from the same parent one would be only $P_{\rm KS} = 0.01$. Because of this, our claims of agreement have to be considered in a 'broad', rather than statistical, sense. The consistency of the distributions has also been tested with a χ^2 test for the most important results (see below).

As mentioned above, the observed $E_{\rm peak}$ distribution is considered at $z = 0$, i.e. it is implicitly assumed to evolve with redshift. Although this might not be necessarily true, it provides the simplest (and only possible) self-consistent hypothesis for the intrinsic distribution. In other words, as it is not possible to a priori assess the biases which might lead to a dependence of the observed $E_{\rm peak}$ distribution with redshift the only viable assumption on it is that it does not depend on z (see also below). It should pointed out that Mallozzi et al. (1995) found a trend between GRB brightness and spectral peak energy, which could be interpreted, assuming that GRBs properties are independent of distance, as due to cosmological redshift. Our assumptions imply instead that the observed properties are consistent with being dominated by a spread in the intrinsic GRBs properties.

An analogous test for the GGL04 relation is clearly less straightforward, as it requires information on the GRB opening angle distribution. The latter is, however, constrained only by 16 (8) BATSE GRBs for which an estimate (limit) on the opening angle can been determined from the break time of the afterglow lightcurve (see GGL04). We approximated such a distribution as a lognormal function and constrained it by requiring that the observed fluence distribution can be reproduced. We can then only verify its qualitative consistency with the values inferred for those 16 GRBs and treat it as a prediction to be tested when more estimates of opening angles will be available.

3 RESULTS

The robust finding of this analysis is that the assumption that the A02 correlation holds for bright BATSE GRBs leads to a fluence distribution in agreement with the observed one. The comparison of the predicted and observed distributions is shown in Fig. 1 (top panel) and their formal consistency is confirmed by a KS test (probability $P_{\rm KS} = 0.35$). The figure shows the result relative to the simulation of a set of events at least 100 times larger than the bright BATSE sample (∼1500). A further statistical test was performed (being this the chief result of the paper) on the binned fluence distributions and a χ^2 test returned a probability of 0.04.

As alternative possibilities we explored the cases where the intrinsic $E_{\rm peak}$ is constant (set at value of 500 keV) and where the observed $E_{\rm peak}$ is constant (250 keV). Clearly, as the GRB rate peaks at redshift ∼1, both scenarios mimic the case considered above, and lead to fluence distributions which are qualitatively similar to what shown in Fig. 1. This indicates that our assumption on the $E_{\rm peak}$ is not by itself a crucial reason for the found agreement.

Furthermore, we tested scenarios in which the GRB energetic is not set via the A02 correlation. To this aim we assumed that the intrinsic 'luminosity function' of GRB is described by a Gaussian

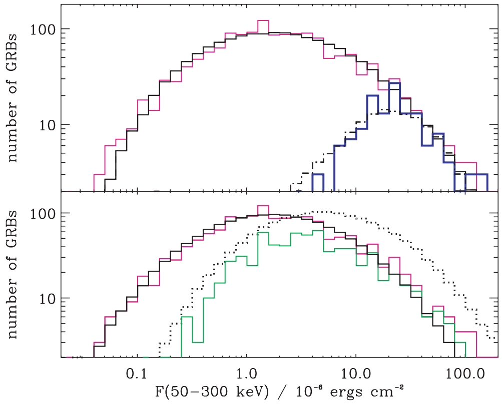

Figure 1. Fluence distributions. Observed ones: 'bright' BATSE GRBs (Preece et al. 2000) (blue line, top panel); the whole BATSE long GRB population (red line, top and bottom panels); the observed distribution of the sample by Yonetoku et al. (2004) (green line, bottom panel). Simulated ones, under different assumptions: the A02 relation + the 'bright' BATSE $E_{\rm peak}$ distribution (dash–dotted line, top panel); the A02 relation + the extrapolated $E_{\rm peak}$ distribution shown in Fig. 3 peaking around 70 keV (black solid line, top panel); the GGL04 relation + the extrapolated $E_{\rm peak}$ distribution shown in Fig. 3 + the opening angle distribution for the 'bright' GRBs shown in Fig. 2 (dotted line, bottom panel); the GGL04 relation + the extrapolated $E_{\rm peak}$ distribution + the opening angle distribution peaking around 7° shown in Fig. 2 (black solid line, bottom panel).

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[1] Throughout this work, we adopt a 'concordance' cosmology $\Omega_\Lambda = 0.7$, $\Omega_{\rm M} = 0.3$ and $H_0 = 65$ km s^{-1} Mpc^{-1} ($H_0 = 70$ km s^{-1} Mpc^{-1} for the GGL04 case).

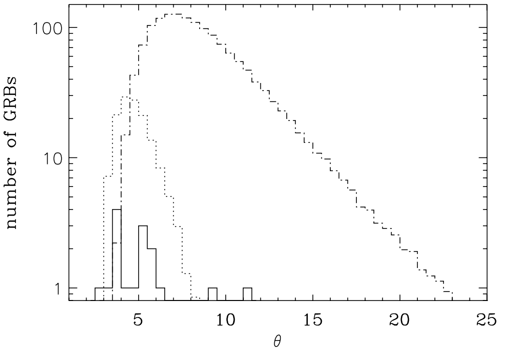

Figure 2. Opening angle distributions as constrained by the request that the GGL04 correlation is representative of bright BATSE GRBs (dashed line) and the whole of the BATSE GRB population (dot–dashed). Reported are also the values inferred from the break time of the afterglow lightcurves in a small number of GRBs (solid histogram, data from GGL04).

distribution (peaked at 10^{52} erg and with a logarithmic spread of 0.7), and for each GRB we randomly and independently selected an $E_{\rm peak}$ and energy. The $E_{\rm peak}$ distribution has been assumed both to be that of bright BATSE GRBs (Preece et al. 2000) and to be flat (probability independent of $E_{\rm peak}$). No reasonable agreement has been found in these cases, basically because of the lack of connection between $E_{\rm iso}$ and $E_{\rm peak}$ (i.e. the fluence-observed $E_{\rm peak}$ plane tends to be more uniformly covered with respect to the observed case).

The observed fluences can be satisfactorily reproduced ($P_{\rm KS} = 0.18$) also by adopting the GGL04 relation for an lognormal opening angle distribution peaking around ∼4–5°. Indeed this appears to mimic the distribution of the (few) estimated opening angles (see Fig. 2). The χ^2 test confirmed the consistency of the observed and the simulated distributions.

3.1 The BATSE long GRB population

The above results would be greatly strengthened if it were possible to extend them to the whole BATSE long GRB population. However, this is hampered by the fact that the corresponding $E_{\rm peak}$ distribution is not determined.

However, the interesting consideration in this respect is that the fluence distribution of all BATSE GRBs extends down in fluence more than two orders of magnitudes with respect to the bright BATSE sample. If the GRB rate does follow the star formation rate redshift distribution, this implies that the bulk of GRBs has much lower E_γ than the bright ones. In other words, *if* the Amati et al. relation holds, the cosmological distance cannot be responsible for such a spread in fluences, as the cosmological effect is largely compensated by the higher GRB luminosity at high redshifts. It is clearly possible that effects such orientation with respect to the line of sight play a major role. In any case observationally this corresponds to the existence of a significant population of (apparently) less powerful events. Indeed High Energy Transient Explorer (HETE)-2 observations show direct evidence for a trend of decreasing peak energy with decreasing GRB fluence (Lamb, Donaghy & Graziani 2005; Sakamoto et al. 2005).

Given the above results at this stage it is meaningful to determine the $E_{\rm peak}$ distribution which allows us to reproduce the fluence distribution of all BATSE GRBs if the A02 correlation were to hold for all events. The point here is that – if tightly constrained – the inferred $E_{\rm peak}$ distribution provides a prediction to be tested against observations without requiring the determination of the redshift for a consistent number of GRBs.

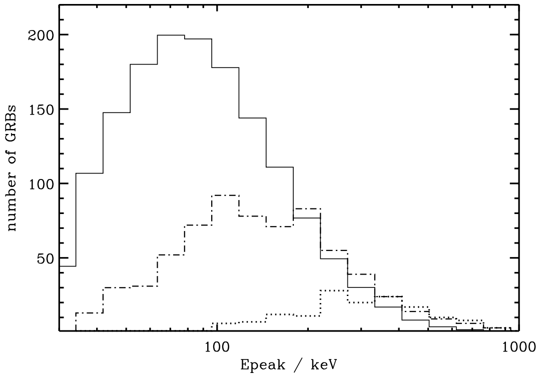

Figure 3. $E_{\rm peak}$ distributions for the bright BATSE GRBs (dotted line; Preece et al. 2000), for the sample examined by Yonetoku et al. (2004) (dot–dashed line) and that constrained by this work for the whole BATSE long GRB sample (solid line).

To this aim, we considered the fluences of the whole BATSE GRB population[2] comprising $\sim 1.5 \times 10^3$ events and repeated the above procedure for different extrapolations of the $E_{\rm peak}$ distribution of bright GRBs (simulating 100 times more events than the observed ones). In Fig. 3, we report the $E_{\rm peak}$ distribution which – assuming the A02 relation – allows us to satisfactorily reproduce the overall fluence distribution (as shown in Fig. 1, top panel). This broadly peaks around ∼70 keV.

Whether this ‘exercise’ has any meaning depends on how tightly such an extrapolation is constrained. We considered other smooth extrapolations of the bright GRB $E_{\rm peak}$ distributions, and for illustration we mention a couple of them, namely a distribution extending even further down in energy, peaking around ∼60 keV and one peaking around 100–200 keV. These alternatives resulted in inconsistent fluence distributions, over and under estimating the dimmest GRBs, respectively. We conclude that this analysis is quite sensitive to the shape and extent of such an extrapolation.

Interestingly, we realized a posteriori that information on GRBs with intermediate fluences (between the bright and whole BATSE samples) is available. Yonetoku et al. (2004) considered BATSE GRBs at fluence levels lower than the ‘bright’ BATSE sample and performed a spectral analysis on them. Thus, the properties of such sample are ideal to provide an independent cross-check on the predicted $E_{\rm peak}$ distribution. Indeed, the $E_{\rm peak}$ and fluence distributions for the Yonetoku et al. (2004) sample are consistent with our extrapolated $E_{\rm peak}$ distribution (see Fig. 3).

Finally, we considered the GGL04 correlation. In this case, the extrapolation to lower $E_{\rm peak}$ shown in Fig. 3 cannot account by itself for the fluence distribution if the (narrow) distribution of angles inferred for bright GRBs is adopted. As shown in Fig. 1 (bottom panel), the corresponding fluence distribution in such case results to be a factor of ∼5 higher and narrower than the observed one. Within this scenario such discrepancy can be accounted for if all BATSE GRBs include a large fraction of bursts with wider opening angles: Fig. 2 reports the inferred (lognormal) opening angle distribution which yields a satisfactory agreement for the fluences. This peaks around 6–8° and extends to about 20–25°.[3] It should also be stressed

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[2] http://cossc.gsfc.nasa.gov/batse/BATSE_Ctlg/flux.html.

[3] The larger central value of the angles has to be considered as a representative parameter, which could, in principle, mimic other effects, like possible absorption.

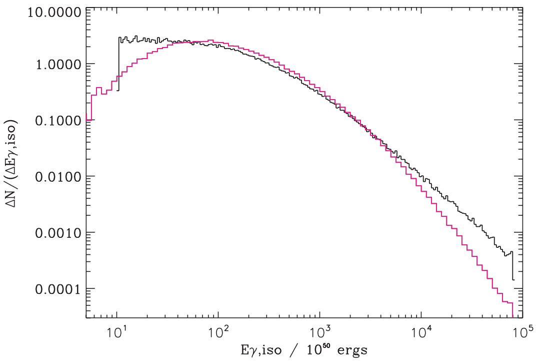

Figure 4. 'Luminosity' (E_γ) function of the BATSE GRBs simulated in this work (red line). Also reported are the results of simulations by Daigne et al. (2006) (black line) as detailed in the text.

that such opening angle distribution is quite constrained both in shape and extension.

3.2 Inferred properties of BATSE GRBs

Under the above assumptions, the redshift distribution and luminosity function of (BATSE) GRBs can be inferred.

Given that the cosmological distance (up to $z \sim 5$) is not the primary driver for the spread in fluences, the GRB rate basically follows the assumed star formation rate redshift distribution. For the very same reason, the results are basically insensitive (within a factor of 2 in fluences) to a star formation rate approximately constant above $z \sim 2$ (case 2 in Porciani & Madau 2001). Indeed, we tested the results against the assumption that the star formation rate is approximately constant or increasing above the apparent maximum in redshift (SFR2 and SFR3 in the above paper), and found no statistically different result.

The inferred 'luminosity' function expressed in terms of E_γ (i.e. as the distribution in intrinsic energy integrated over all redshifts) is reported in Fig. 4. It clearly reflects the $E_{\rm peak}$ distribution. For comparison, the observed luminosity function resulting from Monte Carlo simulations by Daigne, Rossi & Mochkovitch (2006) is also reported. The latter authors generated a sample of GRBs according to the specific intrinsic distributions (intrinsic luminosity function, comoving rate and spectral parameters); the free parameters of the model were constrained by the observation properties (observed peak energy and peak flux). Their assumptions are the same we adopt, namely the star formation rate SFR1 from Porciani & Madau (2001) an Amati-like relation and a detection efficiency for BATSE. In Fig. 4, the energetics of bursts from their simulations reported in Fig. 4 are estimated assuming a typical duration for long bursts of ~20 s. Interestingly, Daigne et al. (2006) also found that the observed peak energy distribution of the subsample of bright BATSE GRBs (Preece et al. 2000) is not representative of the whole GRB population – which results to be largely dominated by low $E_{\rm peak}$ events. The comparison of the two luminosity functions provides a self-consistency check on the assumptions and an independent support to the validity of the extrapolation in $E_{\rm peak}$ constrained above. It should be stressed that the decline at low E_γ might be simply due to incompleteness near the BATSE fluence sensitivity limit.

3.3 Spread of the correlations

While the above results do support the existence of a connection between energetics and $E_{\rm peak}$, it is of great relevance to quantitatively determine any intrinsic spread of such relations, both for understanding the robustness of the physical process behind these correlations and for the possible use of GRBs for cosmological studies.

Indeed, Nakar & Piran (2005) have recently argued that the A02 correlation might be the result of selection effects, as a large number of GRBs (at least 50 per cent in the sample they considered) do not appear to follow it. Similar findings have been reported by Band & Preece (2005) who performed a more refined analysis and concluded that 88 per cent of BATSE bursts are not consistent with the A02 relation, and only at most 18 per cent could be consistent with it. Whether these findings imply that the correlations are totally spurious – contrary to our indications – or that they are significantly broader than estimated so far, has to be determined.

To this aim, we simply considered a variable spread (σ) around the A02 correlation, whose shape was approximated as a Gaussian in logarithmic energy. The comparison of the simulated and observed fluence distributions constrains such spread to be centred at $E_0 \simeq E_{\rm A02}$ [$\log(E_0/E_{\rm A02}) = 0.05$ for the bright GRB subsample] with $\sigma = 0.17$. This value of σ is fully compatible with the actual spread in the A02 correlation (see GGL04). While a smaller spread is acceptable, a very strong upper limit $\sigma < 0.3$ is imposed in order not to exceed the fluence distribution both at high and low values. This result argues against the possibility that the A02 correlation is in fact just the result of selection effects (see Nakar & Piran 2005; Band & Preece 2005).

4 DISCUSSION AND CONCLUSIONS

The main result of this work is that the properties of the whole 'bright' BATSE GRBs sample (Preece et al. 2000) can be broadly accounted for under the assumptions that (i) there is a link between the energetics and the typical spectral peak energy of the prompt phase, as described by the correlations proposed by A02 and GGL04, (ii) GRBs follow the star formation rate redshift distribution and (iii) the observed $E_{\rm peak}$ distribution is not affected by a redshift-dependent bias. We stress, as reported in Section 3, that the findings are not critically affected by the assumed $E_{\rm peak}$ and redshift distributions.

The fluences of dim GRBs cannot be ascribed to their cosmological distribution, and our hypothesis is that they are due to an extension of the $E_{\rm peak}$ distribution towards lower energies (and thus the results are rather insensitive to the actual GRB redshift distribution at high z). In this respect, it is expected that the average fluence dependence on redshift corresponds to about a $\Delta z \sim 0.5$ between bright and dim BATSE GRBs.

The condition that under the above assumptions the fluence distribution of the whole of the BATSE population (long GRBs) can be reproduced, tightly constraints the extrapolation of the $E_{\rm peak}$ distribution to low energies.

The inferred extrapolation, partly overlapping with the range of definition of X-ray rich bursts, predicts a rising number of events at decreasing $E_{\rm peak}$, slowly declining below ~70 keV. This turned out to be in agreement with the $E_{\rm peak}$ and fluence distributions of the GRBs at intermediate fluences analysed by Yonetoku et al. (2004), and implies a luminosity function in agreement with those constrained from the GRB number counts.

The bright GRB fluence distribution can be broadly reproduced also adopting the GGL04 relation, for an opening angle (lognormal) distribution peaking around 4–5° and extending to $\sim 8°$, consistent with the ~15 estimated angles. Consistency with the whole BATSE sample does instead require a broader opening angle distribution,

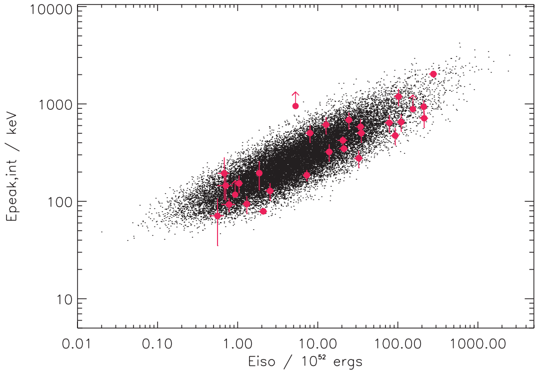

Figure 5. Distribution of the simulated GRBs in the intrinsic peak energy versus $E_{\rm iso}$ plane, including the spread around the A02 correlation. The red circles indicate the GRBs considered by GGL04.

peaking around ∼6–8° and extending to ∼ 25°. This reflects the fact that the A02 and GGL04 distributions have a different slopes, i.e. the indication of a connection between the average GRB opening angle and energetics E_γ (and/or $E_{\rm peak}$). However, our analysis does not allow to exclude an A02 correlation with slope similar to the GGL04 one, i.e. an opening angle distribution independent of energy.

While the found broad consistencies cannot prove the reality of an intrinsic tight link between GRB energetics and spectral properties, they significantly corroborate such possibility. The scenario tested appears to be in agreement with the observed properties. The spread in the above correlations has to be similar to the observed one. This provides an indication of the strength of a physical connection in the prompt emission and constrains the statistics required for the use of GRBs as cosmological distance indicators.

It should be stressed that the above inferences only refer to GRBs observable and observed by the fluence and energy range sensitivity of BATSE. Selection effects even within the BATSE sample (related to the determination of redshift and opening angle) have being claimed to be responsible for the A02 (and GGL04) correlations by Nakar & Piran (2005) and Band & Preece (2005), on the basis of events inconsistent with them.[4] Well-known 'outliers' of such correlations include two of the GRBs with evidence of an associated Supernova (see also Bosnjak et al. 2006, for more cases) as well as short GRBs (Ghirlanda, Ghisellini & Celotti 2004). Nakar & Piran (2005) and Band & Preece (2005) argued that a large fraction of the whole GRB population does violate the above relations.

We cannot identify the reason for the discrepant results. Clearly, it is possible that the agreement we find with the BATSE fluence distributions is fortuitous.

Alternatively, one could ascribe the discrepancy to a significant spread in the above correlations. However, an estimate of the distribution of the parameter '$d_{\rm k}$' (i.e. the 'distance' of a GRB from the A02 correlation in the $E_\gamma - E_{\rm peak}$ plane) as defined by Nakar & Piran (2005) for our simulated sample is inconsistent with their findings within the spread 'allowed' by our analysis. We find proportionally more GRBs with low '$d_{\rm k}$'.

In Fig. 5, we report the simulated GRBs in the $E_{\rm peak}$ versus $E_{\rm iso}$ plane together with the GRBs considered by GGL04 (red points). Fig. 6 shows the analogous information in the fluence versus $E_{\rm peak,obs}$ plane together with the GRBs in the Yonetoku et al. (2004) sample (red points), selected by lowering the fluence threshold with respect to the Preece et al. (2000) sample (the fluences are estimated in the same energy range as for the simulated GRBs). The simulated samples appear to have properties in satisfactory agreement with observed GRBs.

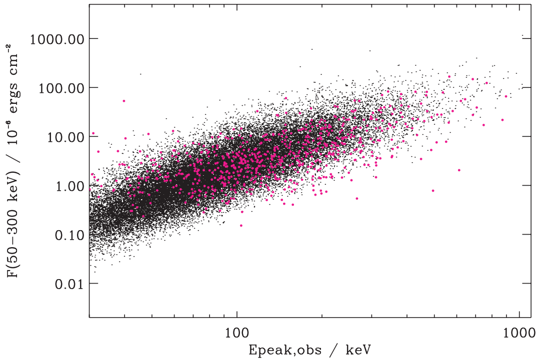

Figure 6. Fluence versus $E_{\rm peak}$ distributions as inferred from the model. The red points refer to the GRBs in the Yonetoku et al. (2004) sample.

With respect to the possibility that the 'outliers' found by the above authors might represent the tail of a distribution, it is worth noting the large fraction of high $E_{\rm peak}$ GRBs found by Nakar & Piran (2005). They estimated $E_{\rm peak} > 250$ keV for about 50 per cent of their events (i.e. corresponding to about 25 per cent of the whole BATSE long GRB sample). This fraction is inconsistent with the findings by Yonetoku et al. (2004) whose lower fluence GRBs are typically characterized by softer spectra, supporting our results. We stress that our analysis does not suffer from the constraints on the fluence (and z) imposed by the signal-to-noise ratio requirement to estimate $E_{\rm peak}$. Unfortunately, the lack of detailed information on the GRBs considered by Nakar & Piran (2005) and Band & Preece (2005) does not allow a deeper investigation on the discrepancy at this stage.

The direct testing of the A02 and GGL04 correlations based on individual events requires the determination of redshift (and break time in the afterglow lightcurves) for a significant number of GRBs. Indirect support to their reality can, however, come from the determination of the $E_{\rm peak}$ distribution at lower energies, i.e. for X-ray rich GRB and X-ray flashes, as is going to be provided by HETE-2 and Swift.

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REFERENCES

Amati L. et al., 2002, A&A, 390, 81
Atteia J.-L., Ricker G. R., Lamb D. Q., Sakamoto T., Graziani C., Donaghy T., Barraud C., The Hete-2 Science Team, 2004, in Fenimore E. E., Galassi M., eds, AIP Conf. Proc. Vol. 727, Gamma-Ray Bursts: 30 Years of Discovery. Am. Inst. Phys., New York, p. 37

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[4] Although it might be difficult to pinpoint a reason why the GGL04 correlation would be tighter than the A02 one.

Band D. L., Preece R. D., 2005, ApJ, 627, 319
Bloom J. S., Frail D. A., Kulkarni S. R., 2003, ApJ, 594, 674
Bosnjak Z., Celotti A., Barbiellini G., Longo F., 2004, in Chen P., Bloom E., Madejski G., Petrosian V., eds, Proc. XXII Texas Symp. on Relativistic Astrophys. at Stanford University, (http://www.slac.stanford.edu/econf/C041213/)
Bosnjak Z., Celotti A., Ghirlanda G., M. Della Valle, Pian E., 2006, A&A, 447, 121
Daigne F., Rossi M. E., Mochkovitch R., 2006, MNRAS, 372, 1034
Eichler D., Levinson A., 2004, ApJ, 614, L13
Frail D. A. et al., 2001, ApJ, 562, L55
Friedman A. S., Bloom J. S., 2005, ApJ, 627, 1
Ghirlanda G., Ghisellini G., Celotti A., 2004, A&A, 422, L55
Ghirlanda G., Ghisellini G., Lazzati D., 2004, ApJ, 616, 331
Ghirlanda G., Ghisellini G., Firmani C., 2005, MNRAS, 361, L10
Lamb D. Q., Donaghy T. Q., Graziani C., 2004, New Astron. Rev., 48, 459464
Lamb D. Q., Donaghy T. Q., Graziani C., 2005, in Piro L., Amati L., Covino S., Gendre B. eds, 4th Workshop 'Gamma-Ray Bursts in the Afterglow Era'. Il Nuovo Cimento, C, 28, 365
Liang E. W., Dai Z. G., Wu X. F., 2004, ApJ, 606, L29
Lloyd-Ronning N. M., Petrosian V., Mallozzi R. S., 2000, ApJ, 534, 227
Madau P., Pozzetti L., 2000, MNRAS, 312, L9
Mallozzi R., Paciesas W. S., Pendleton G. N., Briggs M. S., Preece R. D., Meegan C. A., Fishman G. J., 1995, ApJ, 454, 597
Nakar E., Piran T., 2005, MNRAS, 360, 73
Porciani C., Madau P., 2001, ApJ, 548, 522
Preece R. D., Briggs M. S., Mallozzi R. S., Pendleton G. N., Paciesas W. S., Band D. L., 2000, ApJS, 126, 19
Rees M. J., Meszaros P., 2005, ApJ, 628, 847
Sakamoto T. et al., 2005, ApJ, 629, 311
Sari R., Piran T., Halpern J. P., 1999, ApJ, 519, L17
Schaefer B. E., 2003, ApJ, 583, L71
Yamazaki R., Ioka K., Nakamura T., 2004, ApJ, 606, L33
Yonetoku D., Murakami T., Nakamura T., Yamazaki R., Inoue A. K., Ioka K., 2004, ApJ, 609, 935
Zhang B., Meszaros P., 2002, ApJ, 581, 1236

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