GRBs with the Swift satellite

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Abstract

I touch upon some of the discoveries made by the Swift Team during the first 18 months of operation focusing on a few critical points. In addition to the early afterglows and complete coverage of the light curves, we mention the discovery of the location of Short bursts, the statistics on flares that is under completion and refer to their explanation as due to late internal shocks. The full understanding of the connection with supernovae and the study of high z flares will ultimately lead to the detailed understanding of the mechanism of explosion both for GRBs and for Supernovae.

1 Introduction

Following the launch of the Swift satellite, Gehrels et al. (2005) the Swift Team, and the community at large, witnessed an unprecedented collection of data. The instrument performed excellently and more than anything else many of us felt that the key advantage consisted in the rapidity by which the spacecraft was able to point the target on the axis of the Narrow Field Instruments (NFI) and in a perfect worldwide organization that allowed the real time data analysis and follow up both from the ground and from space. In addition the performance of the spacecraft, the ASI (Agenzia Spaziale Italiana) ground station was far beyond specifications thanks to the Malindi staff so that all the data were, and are being, received quickly and without losses. Now, at about 18 months from launch, we have a reasonable
understanding of the data and we can tackle the statistical studies since the sample is large enough (we detect about 102 bursts per year) to allow it. It is also time to improve theory and interpretation. The data are now good enough that in spite of the fact that the fireball model (Rees & Meszaros, 1992) has been confirmed in its more general features, many details are lacking and such details, once they are related to the observations, are fundamental to understand the physics at work. The work carried out with Swift has been, so far, a Team work where everybody participated to the research we carried out in different roles and capabilities. The input of the theoretician has been extremely useful since thanks to them the team was greatly facilitated in the understanding of the models and of the observations and move swiftly since the very beginning.

It is an impossible task to evidence in a few pages the richness of the data we obtained in this period, data that relate to a large number of bursts and involve other satellites and the largest ground based facilities of the world. In addition very many review articles and excellent journal articles are being published in the field. We will simply try to touch upon the most important issues and briefly illustrate some of the data we obtained. In the following we will discuss some of the highlights of the Swift observations and discoveries.

In the second section we describe the theoretical framework. In the third section we will discuss the morphology of the light curves. To give a broader understanding of the capability of the Swift mission and to illustrate the power of combining observations by different satellites, in Section 4 we briefly discuss the burst GRB060124. In the Section 5 we will deal with flares. One of the major discoveries carried out by Swift has been the location of the short GRBs. This will be discussed in Section 6. Finally we will touch upon two fundamental issues again related to discoveries made by Swift, the connection between GRBs and SNe, Section 7, and the detection of high z objects, Section 8. We conclude with the host galaxies and progenitors with the conclusion that the real research work and deep understanding of what is going on just started.

2 Generalities on the model

The framework of the discussion in this paper is that of the collapsar (Woosley 1993, MacFadyen & Woosley 1999, Zhang & Woosley, 2003) while for the emission we refer to the fireball model by Rees & Meszaros (1992) and following modifications. In the collapse of the iron core of a massive rotating star we likely end up with a black hole and an accreting disk. In
the process a large amount of energy is produced that finds its way out the
star as a well collimated jet, ∼10 degrees, and later impact in the inter-
stellar medium. The decrease of the external pressure after the break out
causes the front of the jet to expand. The central engine, black hole and
accretion disk, has a scale length of about $10^6$ cm and the energy released
is of the order of $10^{50} - 10^{52}$ erg. The emission is turbulent and relativis-
tic pellets move at different Lorentz factors causing an internal shock when
a faster pellet (shell) catches up with a slower pellet. The physics of the
encounter between two pellets, conversion of kinetic energy in internal en-
ergy and emission of electromagnetic waves, is rather straightforward (see
for instance Kobayashi et al., 1997). The scenario becomes now somewhat
more complex. In the immediate vicinities of the progenitor we certainly
have a small ionized region of the interstellar medium or a cocoon formed
by highly absorbing material. Wind, as observed in massive stars and Wolf
Rayet stars, may be present. It is important to disentangle the various com-
ponents of the environment in order to better understand the physics, the
characteristics of the environment and of the progenitor. A high Lorentz
factor ($\gamma$) pellet may be expelled first and this could interact with the ISM
before the internal shock occurs. While detailed work and simulations are
going on in order to fully clarify the evolution of the ejected material, it
suffices to remind now that in addition to the clashing pellets (shells) caus-
ing the so called internal shock we have an external shock as soon as the
material encounters the interstellar medium. Shocks, as it is well known, are
characterized by a forward and reverse shock with Synchrotron and Inverse
Compton emission. It is striking that such a complex set of phenomena
will originate, as we will see in the following, a quite simple observed out-
put with rather standard characteristics. As we know, and we will describe
later, Swift located also the short bursts. The short duration of the prompt
emission rules out immediately the collapse of a massive star for which the
free fall time is too long, $t_{ff} \propto M^{-1/2}R^{-3/2}$. These seem to be due to the
merging of a NS-NS or NS-BH binary and the events show characteristics
in the light curve that are very similar to those observed in the long bursts.
The basic physical phenomena must be simple and similar.

3 Morphology of the light curves and steep early
decay

The basic features of the X-ray light curve were discussed in Chincarini et
al. (2005) and later by Nousek et al. (2006), O’Brien et al. (2006). It just
Figure 1: Light curves of GRBs non presenting Flares in the source rest frame. The filled squares refer to the mean BAT Luminosity. The dashed dotted line is the mean curve. Note the mild decay of GRB050401. In the inset we plotted both the BAT (transformed to the XRT pass-band) and XRT data in order to evidence the continuity between the BAT observations and the XRT observations.
Figure 2: This composite light curve, without the flares however, reflects a possible fitting of the light decay of GRB050814. The curve is fit by a triple broken light curve with different slopes. In this case the second mild slope is slightly increasing in brightness as it happens in various cases. There is somewhat of a degeneracy between this model and that of a broad bright flare of low intensity. In both cases we need injection of energy.

happened that the first set of light curves observed by XRT and for which we had an estimate of the redshift did not show any flare, see Section 5. These curves, however showed the whole story. We had continuity between the BAT light curve and the XRT light curve (see the inset in Fig. 1 from Chincarini et al. 2005). They showed a steep decay at the very beginning of the XRT light curve, Fig. 1 and Tagliaferri et al. (2005), except in some cases, as GRB 050401, where the initial decay is rather smooth, and showed the presence of 1 to 4 breaks. The morphology of the light curves in other words is not the same for all the long (T90 > 2s) GRBs. The cartoon, Fig. 2 shows the various morphologies we might have. The steep early decay, starting at the onset of the XRT observations, may be due in most cases to the tail of the prompt emission and related flare activity. Such model would easily explain the steep decay since by measuring it from the beginning of the flare (see next section) and eventually normalizing it to the rising time of the flare prompt emission it would be within the limits posed by the curvature effect where $\alpha = 2+\beta$ with $\text{Flux} \propto t^{-\alpha} \nu^{-\beta}$ (Kumar & Painatescu 2000).
The continuity between the BAT prompt emission and the XRT emission supports the model. More problematic is the modeling of the second phase of the light curve where we observe a mild decline $< \alpha > \sim 0.7$. To stop the steep decay of the light curve we need to inject energy. What is striking is that not only we need energy injection but in most cases this needs to be done smoothly since the light curves do not generally show, during this phase, strong oscillations. Oscillations or fluctuations are observed in some cases however. Panaitescu (2006) discusses the energy injection model following the steep decay, on the other hand it seems to us we really need too finely-tuned injection to have such smooth light curves. Finally we have a series of breaks. Late breaks with steepening of the light curve decay have been interpreted as mark of the time when the relativistic beaming angle of the eject equals the jet opening angle. Such a break should be achromatic since it is simply due to geometrical factors. Here our knowledge is rather confused. The number of achromatic breaks that have been observed is rather small. Often we did not observe a break when expected and in many cases the break observed in the X-ray band does not match the break observed in the optical, Fig. 3 (Panaitescu 2006b). The latter lack of coincidence may be due to a different origin of the breaks in the two bands and in any case these uncertainties put a shadow on the use of the break to estimate the jet opening angle and emitted energy. This and the lack of an accurate control on the bias of the samples used, generally flux limited samples, make very uncertain, even if obviously promising due to their detection at large cosmological distances, the use of GRB sample to estimate the cosmological parameters (Ghirlanda et al. 2004). The energy, or Fluence, involved in the XRT light curves is likely a mixture of late prompt emission and afterglow, in some cases it is similar to the energy observed during the prompt emission.

4 GRB060124. Precursor and Multi-wavelenght observations

GRB060124 (Romano et al. 2006b and references therein) is a beautiful example of multi-wavelength observations and of a complete temporal coverage on a very broad range of frequencies. BAT was triggered on the precursor so that the narrow field instruments were already on the source at the time the main burst occurred. It is located at a distance $z = 2.297$. While we refer the reader to the paper above for a full discussion, here we will only touch upon a few details. The precursor precedes the GRB by about 500 s, it is rather soft and in about 20 s emits a few percent of the prompt emission.
Figure 3: Some of the cases in which the X-ray break is not observed at optical frequencies (Courtesy of Panaitescu).

Figure 4: The precursor of the GRB060124. The total fluence of the precursor is $1.24 \times 10^{-6}$ erg cm$^{-2}$ while the fluence of the prompt emission is $2 \times 10^{-5}$ for the prompt emission at $t = 550$ s and $2.93 \times 10^{-6}$ for the BAT emission at $t = 700$ s (for the shape of the prompt emission see Figure 1 in Romano et al. (2006b). The precursor is about 4.1% of the prompt emission (for uniformity to other GRBs we did not add the emission in the band 0.2-10 keV, XRT).
Figure 5: This is one of the brightest and cleanest (no blends) flares observed. The slope of the decay is larger than the limit imposed by the naked burst unless the slope of the power law is computed with T0 set at the maximum of the flare. It also fit the normalized profile suggested by Kobayashi for the prompt emission.

energy, that is an energy of the order of $10^{49} - 10^{50}$. The emission starts off rising in a similar way in all channels and however it dies off after a few seconds in the 100-350 keV channel while it lasts for about 20 seconds in the softer BAT channels, Fig. 4. What is a precursor telling us? We must take into account this time scale in the modeling. This needs to be looked upon carefully since not only it is the messenger of the GRB but may also carry information on how the event is going to perform. The burst is very energetic and the prompt emission in 510 s emits $E_{iso}(1 - 10^4 \, \text{keV}) = 4.2 \times 10^{53}$ erg. The prompt emission has been observed both from the BAT and XRT instrument. It is noisy and presents a morphology slightly different from normal flares (see next section) but the XRT curve has similarities albeit very high luminosity (compare to the flare in GRB050502B however). The hardness ratio of the prompt emission follows almost in phase the flaring of the prompt emission and the spectral index soften passing from the first flare to the second. A behavior that we will also find in the flares we are dealing with in the next section.
Figure 6: Distribution of the decay slopes computed using as $T_0$ the point where the flux 1% of the peak ($T_{99}$). This procedure is self consistent but overestimates somewhat the slope due to the early $T_0$. For the largest slopes see GRB050502B, Figure 5.

5 Flares

Early in the mission we observed two unusual events GRB050406 (Romano et al. 2006a) and GRB050502B (Falcone et al. 2006a), Fig. 5. Similar events were also detected in some of the GRBs observed by Beppo SAX and analyzed only later (Piro et al. 2005). The XRT light curve gives right away the impression it consists of two components: a standard component whose morphology follows the shape and details discussed in section 2, with superimposed a more or less large and intense bump that we call flare. Such morphology has implications on the physical model. The two curves are unrelated and generated by different collisions. The running of time for the flare, therefore, is not related to the running of time dictated by the beginning of the prompt emission. In other words the flare has its own clock. Indeed an interesting analysis carried out by Liang et al. (2006) shows that, assuming that the decay of the flare can not violate the curvature slope, $\alpha = 2+\beta$, the origin of time $T_0$ from which to compute the evolution of the event is near the beginning of the flare itself.

The morphology of flares should reflect the characteristics of the shock
generating them. To isolate them from the composite light curve, in Chincarini et al. (2006a) we subtracted from the observations the standard light curve after fitting it with a broken power law. The flares are characterized by various morphologies. The cleanest shape is that suggested by the flare in GRB050502B. This fits very well the Kobayashi profile or, equally well, an exponential profile of the form \( f_{\text{rising}} = a(1 - e^{-b(x-c)}) \), followed by a power law decay, see also Dermer (2004, 2006).

In some of the flares the rising part is better fit by a simple power law. On the other hand, flares are very complex and are not isolated events (see, for instance GRB051117A). In other words they are due to the collision of a set of pellets, very similar to the activity we have during the prompt emission. Quite often, therefore, as it may be the case for the simple power law fit of the rising part of the curve, the true profile may be masked by multiple flares, low count rate and sampling. The decay, as stated above, is generally well fit by a power law, Fig. 6. The spectrum and the hardness ratio variations during the flares show some resemblance with the behavior of the spectrum characteristics of the prompt emission (Falcone et al. 2006a). In the case of GRB050502B, for instance, a Band function or cut–off power law fits better than a simple power law and spectral evolution is evident. In some cases the use of a black body + power law is requested (Falcone et al. 2006). The hardness ratio shows quite clearly that the spectral evolution is almost in phase with the flare light curve hardening during the rise to the peak to soften again in the decaying phase, Fig. 7 (compare also with GRB060124). A sample of 61 Flares has been analyzed by Chincarini et al. (2006b), Falcone et al. (2006) to measure statistical parameters as \( \Delta t/t \) (flare duration versus time of occurrence), decay slope, decay to rise ratio, flare energetic, flare to burst fluence and spectral parameters. In addition simulation were carried out to understand the selection effects and biases introduced by the mode of observation and sampling characteristics especially at later times and low fluxes. Here we show only the \( \Delta t/t \) and refer to Chincarini 2006a, or to Chincarini 2006b, for further details. To have a robust and unbiased statistics we plotted the results shown in Fig. 8 where the estimate of the flare duration is given by the sigma of the Gaussian (\( T_{\text{sigma}} \) used in the fit of the composite light curve). This is a robust indicator and simulations show that it is not much affected by the morphological model of the flare. On the other hand we must keep in mind that the Gaussian fit has neither physical meaning nor we can transform the \( T_{\text{sigma}} \) in \( T_{90} \) easily. The statistics tell us that the Half Peak Width (HPW) distribution of the flare peaks at about 3/10 of the time of occurrence. On the other hand it is customary to estimate the parameter \( \Delta t/t \), especially in the theoretical modeling, with \( \Delta t = T_{90} \).
Figure 7: GRB060607: this is one of those GRBs that tell the whole story. We notice continuity between the BAT and XRT light curve. The early flare, related to the prompt emission, are detected both with BAT and with XRT. The hardness ratio follows the light curve of the flare almost in phase hardening in its rise to the maximum and softening afterwards see inset.
To use this parameter we must perform a more detailed fit and use only the flares for which we have a reasonable good statistics. The distribution of $T_{90}/t$ (where $T_{90}$ has been derived in this way) is given in Fig. 9 with the peak of the distribution at about 5/10. These figures are in agreement both with the internal shock model as given by a continuously active engine or by internal shocks due to the lazy shells model (refreshing), see discussion below.

6 Short Bursts

One of the big discoveries made by Swift is the location of the short bursts and in particular the location of GRB050509 next to an Elliptical galaxy (Gehrels et al. 2005). This was the observation that immediately guided to the NS-NS, NS-BH model. In one case, GRB050709 (Hjorth et al 2005, Covino et al. 2005), we observed a host galaxy of irregular morphology that however showed a EA (Emission-Absorption) line spectrum. That is we recognized the presence of dominant type A stellar population indicating the existence, in addition to the gas and HII regions, of an old population, old enough to let binaries evolve and form relativistic binaries. We have
detected so far (updated to GRB060801 and including HETE detections) 18 shorts. For 6 of these we also have an optical detection and six redshifts, two of which rather uncertain however. GRB050724, Fig. is one of the most significant light curves we have so far. The X-ray light curve has all the characteristics presented by long bursts showing continuity between the BAT emission and the XRT emission, early mini-flares and late large flare. The presence of flares is indeed a fundamental point since it would indicate that such phenomenon is completely independent from the environment since it occurs both in star forming galaxies and in old population galaxies where we have little gas and dust. This would call immediately for an internal shock origin of the flares, late activity of the central engine or lazy shells (refreshing). The inconvenient is that this burst is on the border line of the distribution and we may doubt somewhat that it is really a short (or do we have different types of short bursts?). The initial spike lasted 250 ms followed after about 30 s, as in GRB050709, by a soft bump that lasted 120 s. The observed spectrum index was $\beta = 0.7$ and the source was detected in the radio, optical and near-IR. The other open question is whether the emission in this case is spherical or, as expected due to the preferential axis defined by the BH-accretion disk model, confined to a jet. In this case we need to
Figure 10: The continuous lines illustrate the approximation by which the flare profile is isolated from the standard underlying light curve. It also evidences the composite nature (blend) of the late flare. Finally the inset evidences an early flare after subtraction of the main curve and the excellent fit of the decay with a power law.
estimate the opening angle. Do we observe an achromatic break in any of the observed light curves? A break in the X-ray light curve, with XRT and Chandra, has been observed in GRB051221, (Burrows et al. 2006). The estimated jet opening angle is $4^\circ - 8^\circ$. We do not have any way to know whether the break is achromatic. Except for a very few uncertain cases all the detected shorts are at low $z$. The energy $E_{\text{iso}}$ is about $10^{48} - 10^{49}$ erg, about a factor 100–1000 lower that the energy involved in long GRBs. In conclusion, while in the field we reached fundamental knowledge, we are far from having a complete data set to carefully guide the interpretation and the theory. The space-based observations and ground-based observations are hard to come and shorts remain, and may remain, rather elusive. Finally are short burst giant magnetar? Energy, spectrum and duration would be in good agreement; magnetars, furthermore, manifest themselves more than once so that monitoring (but the task is close to impossible) may pay off eventually.

7 GRBs and Supernovae

We observed 5 golden cases demonstrating the connection of Supernovae with GRBs. GRB980425, Galama et al. (1998), GRB 030329, Hjorth et al. (2003), Stanek et al. (2003), GRB031203, Malesani et al. (2004), Thomsen et al.(2004), GRB050525A, Della Valle et al.(2006), GRB060218, Campana et al.(2006). The clear indication of the possible presence of the Supernova, when the source is bright enough to be detectable over the decaying curve of the GRB, is the presence of a bump, as shown in Fig. for GRB050525A, that occur generally 10 to 20 days from the GRB trigger. The spectrum of the Supernova is obtained by subtraction of the galaxy and it has been shown that, in all the cases, we are dealing with SNe - Ibc Supernovae, rather luminous, $M_V \sim -19$ and expansion velocities of the ejecta up to $v \sim 30000$ km/s. GRB-SNe are comparable at optical frequencies to locally observed SNe. Radio emission is observed at later time when the jet, impacting the interstellar medium, decelerates to sub-relativistic speed and its emission becomes nearly isotropic. The radio luminosities of the local events are about 104 times fainter than those of typical GRB-SNe. There is, therefore, a clear distinction in the radio between the two types likely due to the large amount of energy that the GRB ejecta deposit in the interstellar medium, Soderberg (2006). The observations of GRB060218, Campana et al. (2006), gave us the unique opportunity to observe the evolution of the phenomenon in all of its details since the very onset of the SN phenomenon with the
Figure 11: The figure shows the light curve of GRB050525A where the classical bump indicates the presence of a Supernova.
Figure 12: The XRT light curve (upper panel) and optical light curve (lower panel) of GRB060218. Top: The open circles refer to the contribution to the light curve of the thermal component. Bottom: The light curve as derived from UVOT. From top to bottom the following filters: V, B, U, UW1, UM1, UW2 (from Campana et al. 2006).
detection of a thermal component in its X-ray spectrum. We are catching a SN in the act of exploding. We witness the break out of a shock driven by a mildly relativistic shell into the dense wind of the progenitor. The long lasting prompt emission, $T_{90} = 2100$ s, shows a rather smooth behavior at all frequencies (XRT and UVOT observed simultaneously most of the prompt emission since the NFI were pointing the target after 150 seconds). The peak emission moved from high to low energies ($\nu^{\text{Peak}} \approx 10^{-0.58 \nu}$) roughly as $T_{\text{Peak}} = k 10^{-0.58 \nu}$ with an optical re-brightening at about 800 ks from the trigger. The XRT spectrum shows a blackbody component, $kT \sim 0.17$ keV, visible for about 10000 s. The peaks observed with UVOT allow following the evolution of the thermal spectrum component and deriving from the Luminosity the radius of the emitting shell. The resulting model is that of a shock propagating into the wind of the Wolf Rayet star progenitor.

We have discovered that the death of massive stars leads to the collapse and explosions that manifest themselves either as GRBs or SNe. In a few cases it has been possible however to observe both events in the same source as in the cases listed above. The rate of GRB-SNe is likely about 0.003 the rate of all massive star deaths, (Woosley & Heger, 2006), and observations should finally tell us whether we have a SN (spanning however a large range of Luminosities) in each GRB or whether the collapse of a massive star evolves following different paths according to the value of parameters as mass, angular momentum and metallicity. Whatever the answer may be the fundamental point of the connection is that GRBs may serve as a guideline to better understand the mechanism, and possibly solve the long standing problem of the SN explosion, since we have additional information related to the core collapse. For a detailed review on the connection between GRBs and SNe see Woosley & Bloom (2006).

8 High z GRB, Host Galaxies and Cosmology

It is well known that the redshift distribution of the bursts detected by Swift is skewed toward high redshifts when compared to previous detections. This means that we have the possibility, once we have a reasonably large sample, to study under a new point of view the intergalactic medium and host galaxy interstellar medium as a function of redshift. The radiation we observe carries information on the environment surrounding the progenitor (Berger et al, 2005, detect absorption lines generating in the wind of the proto-star), on the interstellar medium of the Host Galaxies (HG) and on the IGM. The estimate of the abundance may allow the tracking of the metal production
Figure 13: GRB050904 and other high z GRBs observed by Swift. The early points are the BAT data converted to XRT. Note the very high flare activity and how the early flares are visible with both instruments. Flare activity is spread over most of the light curve.
up to the re-ionization epoch. The large amount of information we are getting and will get are easily understood since we move to some extent along a track already sketched by the studies of the AGN and we will complement that work adding new capabilities especially thanks to the lack of the proximity effect. The highlight of the Swift high z detection is GRB050904 at a redshift of z=6.29, Cusumano et al. (2005), Tagliaferri et.al (2005), Kawai et al.(2005). The composite picture we show in Fig. 13 is aimed to evidence, among other things, the high frequency of bright flares in high z objects. The frequency of activity, and of GRBs as a function of the metal abundance, will be fundamental to the understanding of the mechanism of the core collapse, whether the choice to collapse into a GRB-SN or into a SN is dictated by rotation influenced by the metal abundance of the progenitor and how much governed by the laws of chaos. Following Woosley & Janka (2006) if the star preserves high rotation velocity during its evolution (essentially bypassing the red giant phase or losing the envelope to a companion) the resulting Wolf-Rayet star will preserve angular momentum assuming the metal abundance is low. Otherwise the rather large winds (mass loss) will carry away also angular momentum and compromise the progenitor in its path toward a GRB. Indeed rotation and lack of symmetry are essential to produce a GRB (Zhang et al., 2005). GRB050904 is obviously very luminous and may have involved in the process a very massive star. The flare activity is very high, larger at late time than in other bursts, and distributed practically over the whole light curve so that Luminosity and metal abundance may also be two parameters related to the flare activity and decreasing opacity. The problem is now detection, one case is not enough for statistics. Swift should insist on searching for these very rare targets. Furthermore for those GRBs without optical counterpart we need to know accurate position in order to track down the host galaxy. A step forward in this direction has been done by Moretti et al. (2006), improving the typical XRT error circle from 6.5'' to 3.5''. A team effort lead by M.Goad is underway to further improve the XRT astrometry. Here we may get fundamental knowledge in evolution and cosmology. On the other hand we are far from a good knowledge of the luminosity function that is the base for statistical studies and the basic for the use of the GRBs as cosmological probes. The most dangerous thing, as always in astronomy, is the presence of unknown bias. The least known statistical bias is related to the probability of detecting an object of a given Energy at a distance z. Assuming, for simplicity (easy integration) and in order to clarify the concept, a Schechter Luminosity Function in a survey limited in flux by the sensitivity of the detector, (for simplicity we disregard pass-band and spectral distribution of the source and assume for the
selection function a step function) the counts as a function of \( z \) are given by:

\[
N(> f) = \phi \Gamma[\alpha + 1, (E = D_L^2 A\pi / E^* Vol \Delta \Omega)]
\]

It is possible therefore to estimate in the plane redshift - Energy the number of objects we expect, the minimum energy boundary for the flux limited sample and the maximum energy boundary as determined by the equation \( N(E, z) = 1 \), that is the probability to find an object at the Energy to be determined. With the present rate of detection and redshift estimate we may be able to have soon a statistical significant sample and attack some classical problems in Cosmology having full control of the data.

9 Conclusions

There is no doubt that with the observations we obtained with the Swift satellite we made, and are making, a fundamental step forward in understanding observationally the evolution of the event and in collecting data for statistical studies. At the same time it has been possible to test theories and at least have an indication of what is acceptable and what needs to be revised. Indications that came earlier from observations from GRBs detected by Beppo SAX or other satellites, were confirmed, as the GRBs-SNe connection, or denied, as the simple power law decaying light curve, and the theory has now a more solid ground on which to proceed. So far the interpretation of the data has been done, by a large extent, on the existing theory that, in their basic features, hold. We showed that the field touches almost in all branches of astronomy and is very demanding for the state of the art instrumentation. Knowledge of the performance of the central engine and of the progenitors is intimately related to the complex physics of the death of massive stars and to all those phenomena accompanying the evolution of relativistic stars. The evolution, and physics of the collapse, is intimately connected to the GRBs - SNe connection and to the abundance of the progenitors and of the host galaxies. This open the field to evolution in relation to cosmology and at the end the high luminosity and the possibility to be detected at very large reshifts make them a fantastic beacon to probe the high \( z \) Universe and the interstellar medium. The most important observations seem to be those capable of detecting high \( z \) GRBs that could be immediately followed up by ground based observations with large and robotic telescopes. Robotic telescopes are essential to ease such search. We may need to think about designing a few two meters aperture robotic telescopes. While all the data tend to suggest we might have more long bursts
at high redshifts either because of the characteristics of the progenitors and host galaxies or because of statistics based on what we observed so far or simply because the phenomenon seems to prefer low abundances galaxies it remain a puzzle why so far we detected only one GRB at 6.29 (the detection of a possible object at higher redshift, GRB060116 remains uncertain). How many did we loose because of limitations related to the zone of the sky in which the bursts have been detected and the difficulty of a proper and immediate follows up?

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