GRBs have remained a puzzle for many high–energy astrophysicists since their discovery in 1967. With the advent of the X–ray satellites BeppoSAX and RossiXTE, it has been possible to carry out deep multi-wavelength observations of the counterparts associated with the long GRBs class just within a few hours of occurrence, thanks to the observation of the fading X-ray emission that follows the more energetic gamma-ray photons once the GRB event has ended. The fact that this emission (the afterglow) extends at longer wavelengths, has led to the discovery optical/IR/radio counterparts in 1997-2000, greatly improving our understanding of these sources. Now it is widely accepted that GRBs originate at cosmological distances with energy releases of $10^{51}$–$10^{53}$ ergs. About 25 host galaxies have been detected so far for long-duration GRBs. The observed afterglow satisfies the predictions of the "standard" relativistic fireball model, and the central engines that power these extraordinary events are thought to be the collapse of massive stars rather than the merging of compact objects as previously also suggested. Short GRBs still remain a mystery as no counterparts have been detected.

Key words: gamma-ray bursts; galaxies; stellar evolution.

1. INTRODUCTION

In 1967-73, the four VELA spacecraft (named after the spanish verb velar, to keep watch), that where originally designed for verifying whether the former Soviet Union abided by the Limited Nuclear Test Ban Treaty of 1963, observed 16 peculiarly strong events (Klebesadel, Strong and Olson 1973, Bonnell and Klebesadel 1996). On the basis of arrival time differences, it was determined that they were related neither to the Earth nor to the Sun, but they were of cosmic origin. Therefore they were named Cosmic Gamma-Ray Bursts (GRBs hereafter). Nearly 4000 events have been detected to date.

2. OBSERVATIONAL FACTS AND IMPLICATIONS

2.1. GRBs in the gamma-ray domain

GRBs appear as brief flashes of cosmic high energy photons, carrying the bulk of their energy above $\approx 0.1$ MeV. The KONUS instrument on Venera 11 and 12 gave the first indication that GRB sources were isotropically distributed in the sky (Mazets et al. 1981, Atteia et al. 1987). Based on a much larger sample, this result was nicely confirmed by BATSE on board the CGRO satellite (Meegan et al. 1992). In general, there was no evidence of periodicity in the time histories of GRBs. However there was indication of a bimodal distribution of burst durations, with $\sim 25\%$ of bursts having durations around 0.2 s and $\sim 75\%$ with durations around 30 s. A deficiency of weak events was noticed in the log $N$-log $S$ diagram, as the GRB distribution deviates from the $-3/2$ slope of the straight line expected for a homogeneous distribution of sources assuming an Euclidean geometry. However, the GRB distance scale had to remain unknown for 30 years. A comprehensive review of these observational characteristics can be seen in Fishman and Meegan (1995).

2.2. GRBs in the whole electromagnetic spectrum: eight selected bursts

It was well known that an important clue for solving the GRB puzzle was going to be the detection of transient emission -at longer wavelengths- associated with the bursts. A review on the unsuccessful search for counterparts prior to 1997 can be seen in Castro-Tirado (1998) and references therein. Here I will present some results concerning eight selected bursts detected by the BeppoSAX (BSAX) and RossiXTE (RXTE) satellites in 1996-2000 and their impact on the current understanding on the physics of GRBs.
2.2.1. GRB 970228: the first X-ray and optical counterpart

Thanks to BSAX, it was possible on 28 Feb 1997 to detect the first clear evidence of a long X-ray tail-the X-ray afterglow-following GRB 970228. A previously unknown X-ray source was seen to vary by a factor of 20 on a 3 days timescale. The X-ray fluence was ~ 40% of the gamma-ray fluence, as reported by Costa et al. (1997), implying that the X-ray afterglow was not only the low-energy tail of the GRB, but also a significant channel of energy dissipation of the event on a completely different timescale. Another important result was the non-thermal origin of the burst radiation and of the X-ray afterglow (Frontera et al. 1998). The precise X-ray position (1') led to the discovery of the first optical transient (or optical afterglow, OA) associated to a GRB, 20 hr after the event with V ∼ 21.3 (Groot et al. 1997, van Paradijs et al. 1997). The OA was afterwards found on earlier images taken by Pedichini et al. (1998) and Guarnieri et al. (1997). The optical flux decayed following a power-law decay F ∝ t−1.2 (Galama et al. 1997, Bartolini et al. 1998). An extended source was seen at the OA position since the very beginning by ground-based and HST observations (van Paradijs et al. 1997, Sahu et al. 1997). New HST observations taken 6 months after the event were reported by Fruchter et al. (1997) and both the OA (at V = 28) and the extended source (V = 25.6) were seen. The latter object was interpreted as a galaxy, according to the similarities (apparent size, magnitude) with objects in the HST Deep Field. Finally, after two years, the redshift of this object has been determined as z = 0.695 (Djorgovski et al. 1999a), confining its extragalactic nature and implying a star-forming rate comparable to other galaxies at similar redshifts.

2.2.2. GRB 970508: the clue to the distance

The second OA associated to a GRB was discovered by Bond (1997) within the GRB 970508 error box, and observed 3 hr after the burst in unfiltered images (Pedersen et al. 1998). The optical light curve reached a peak in two days (R = 19.7, Castro-Tirado et al. 1998a, Djorgovski et al. 1997, Galama et al. 1998a) and was followed by a power-law decay F ∝ t−1.2. Optical spectroscopy obtained during the maximum allowed a direct determination of a lower limit for the redshift of GRB 970805 (z ≥ 0.835), implying E ≥ 7 × 1051 erg and was the first proof that GRB sources lie at cosmological distances (Metzger et al. 1997). The flattening of the decay in late August 1997 (Pedersen et al. 1998, Sokolov et al. 1998) revealed the contribution of a constant brightness source-the host galaxy- that was revealed in late-time imaging obtained in 1998 (Bloom et al. 1998, Castro-Tirado et al. 1998b, Zharikov et al. 1998). The maximum observed 1-day after the burst has not been detected in other GRBs and it was interpreted by a delayed energy injection or by an axially symmetric jet surrounded by a less energetic outflow (Panaitescu et al. 1998). The luminosity of the galaxy is well below the knee of the galaxy luminosity function, L ∼ 0.12 L*, and the detection of deep Mg I absorption (during the bursting episode) and strong [O II] 3727 Å emission (the latter mainly arising in H II regions within the host galaxy) confirmed z = 0.835 and suggested that the host could be a normal dwarf galaxy (Pian et al. 1998), with a star formation rate (SFR) of ∼ 1.0 M⊙ year−1 (Bloom et al. 1998). Prompt VLA observations of the GRB 970508 error box allowed detection of a variable radio source at 1.4, 4.8 and 8.4 GHz, the first radio counterpart ever found for a GRB (Frail et al. 1997). The fluctuations could be the result of strong scattering by the irregularities in the ionized Galactic interstellar gas, with the damping of the fluctuations with time indicating that the source expanded to a significantly larger size. However VLBI observations did not resolve the object (Taylor et al. 1997). The transient was also detected at 15 GHz (Pooley and Green 1997) and as a continuum point source at 86 GHz with the IRAM PdBI on 19-21 May 1997 (Bremer et al. 1998). A Fe Kα line redshifted at z = 0.835 in the X-ray afterglow spectrum (Piro et al. 1999) was attributed to a thick torus surrounding the central engine (Mészáros and Rees 1998). GRB 970508 is the best observed afterglow so far. The broad band spectrum (see Fig. 1) is nicely explained by the standard relativistic blast wave model (Wijers and Galama 1999).

2.2.3. GRB 970828: the first dark GRB

This burst was detected by RXTE (Remillard et al. 1997) and was followed up by ASCA and ROSAT (Murakami et al. 1997, Greiner et al. 1997). The fact that no optical counterpart down to R = 23.8 was detected between 4 hr and 8 days after the event, could support the idea that the non-detection was due to photoelectric absorption (Groot et al. 1998). The X-ray spectrum as seen by ASCA is strongly absorbed, suggesting that the event occurred in a dense medium. An excess at 6.7 keV was found by ASCA and the steep spectrum, with an electron temperature of 2.3 keV and a power law index of 4.2, was ascribed to a thin absorber (Iwasawa et al. 1998). The redshift was also determined using the UV afterglow (Castro-Tirado et al. 1998a, Zharikov et al. 1998). After two years, the redshift of this object has been determined as z = 0.835 (Djorgovski et al. 1999a), confirming its extragalactic nature and implying a star-forming rate comparable to other galaxies at similar redshifts.
in the X-ray afterglow spectrum. If this is due to highly ionized Fe, then $z \sim 0.33$ (Yoshida et al. 1999) and the host would be another dwarf galaxy (Gorosabel 1999). However, if the transient radiosource detected with the VLA is indeed associated to the event, the galaxy would be at $z = 0.96$ (Djorgovski et al. 2001), although there is some concern (Murakami et al. 2001) regarding the proposed association as the rest frame energy of the line (9.79 keV) will be even larger than the energy of the FeXXVII recombination edge at 9.28 keV (Weth et al. 2000).

And least in another three cases (GRB 981226, GRB 990506 and GRB 001109), radiotransients were detected without accompanying optical/IR transients. For GRB 000210, the CHANDRA position is consistent with a $R = 23.5$ constant brightness object (Gorosabel et al. 2000).

2.2.4. GRB 980425: a GRB-SN connection?

A peculiar Type Ic supernova (SN 1998bw) was found in the error box for this soft GRB (Galama et al. 1998b). The SN lies in the galaxy ESO 184-G82, an actively star forming SBC sub-luminous galaxy at $z = 0.0085$. The fact that the SN event occurred within $\pm 1$ day of the GRB event, together with the relativistic expansion speed derived from the radio observation (Kulkarni et al. 1998a) strengthens such a relationship. In that case, the total energy released would be $8 \times 10^{57}$ erg which is about $\sim 10^3$ smaller than for "classical" GRBs. Follow-up HST observations of ESO 184-G82 2.1 yr after the event, revealed an object consistent with being a point source within the astrometric uncertainty of 0.018 arcseconds of the SN position. The object is located inside a star-forming region and is at least one magnitude brighter than expected for the SN based on a simple radioactive decay model, implying either a significant flattening of the light curve or a contribution from an underlying star cluster (Fynbo et al. 2000a).

Reichart (1999) proposed a type Ib/c supernova lies "behind" another GRB (GRB 970228), overtaking the light curve two weeks after. This fact seems to be confirmed by the work of Galama et al. (2000). Castro-Tirado and Gorosabel (1999) and Bloom et al. (1999) also suggested the presence of an underlying SN in GRB 980326 and recently in GRB 991208 (Castro-Tirado et al. 2001).

2.2.5. GRB 990123: the existence of a jet

This is the first for which contemporaneous optical emission was found simultaneous to the gamma-ray burst, reaching $V \sim 9$ (Akerloff et al. 1999). This optical flash did not track the gamma-rays and did not fit the extrapolation of the SAX and BATSE spectra towards longer wavelengths. This optical emission was interpreted as the signature of a reverse shock moving into the ejecta (Sari and Piran 1999). A brief radiotransient was also detected (Frail et al. 1999a) coincident with the optical counterpart (Odewahn et al. 1999) and spectroscopy indicated a redshift $z = 1.599$ (Kulkarni et al. 1999, Andersen et al. 1999). A break observed in the light curve $\sim 1.5$ days after the high energy event suggested the presence of a beamed outflow (Castro-Tirado et al. 1999, Fruchter et al. 1999, Kulkarni et al. 1999). See Fig. 2. A weak magnetic field in the forward shock region could account for the observed multiwavelength spectrum in contrast to the high-field for GRB 970508 and it seems that the emission from the three regions was first seen in this event (Galama et al. 1999a): the internal, reverse and forward shocks.

2.2.6. GRB 990510: first detection of linear polarization

This burst belongs to the top 10% of all GRBs detected by BATSE. Following the BSAX/WFC detection, an optical counterpart was reported by Vreeswijk et al. (1999a) and $z = 1.619$ was determined. The acromatic break seen in the light curve was also interpreted as a jet, with a model yielding an opening angle of 0.08 and a beaming factor of 300 (Harrison et al. 1999). This is the first burst for which polarized optical emission was detected ($\Pi = 1.7 \pm 0.2 \%$), by means of an observation performed $\sim 18.5$ hr after the event (Covino et al. 1999) and later on (Wijers et al. 1999). This confirms the synchrotron origin of the blast wave itself and represents

![Figure 2. The R-band light-curve of the GRB 990123 OA. Based on our observations (filled circles) and other data reported elsewhere (empty circles). The doted line is the contribution of the underlying galaxy, with $R \sim 23.77$. The three dashed lines are the contribution of the OA, following $F \propto t^\delta$ with $\delta = -2.12$ up to $\sim 10$ min, $\delta = -1.13$ up to $\sim 1.5$ d, and $\delta = -1.75$ after that time. The solid line, only drawn after 1.5 d for clarity is the total observed flux (OA + galaxy). From Castro-Tirado et al. (1999).](image_url)
Table 1. GRBs detected by BeppoSAX/WFC or RXTE in 1996-2000

| GRB   | X-rays | opt-IR | radio | GRB   | X-rays | opt-IR | radio |
|-------|--------|--------|-------|-------|--------|--------|-------|
| 960720| yes    | no     | no    | 990627| yes    | no     |       |
| 970111| yes    | no     | ?     | 990704| yes    | no     |       |
| 970228| yes    | yes    | no    | 990705| yes    | yes    |       |
| 970402| yes    | no     | ?     | 990712| yes    | yes    |       |
| 970508| yes    | yes    | yes   | 990806| yes    | no     |       |
| 970616| yes    | no     | no    | 990907| yes    | ?      | no    |
| 970815| yes    | no     | no    | 990908| yes    | ?      | no    |
| 970828| yes    | ?      | no    | 991014| no     | no     |       |
| 971214| yes    | yes    | no    | 991105| yes    | no     |       |
| 971227| yes    | no     | ?     | 991106| yes    | no     |       |
| 980109| yes    | yes    | no    | 991216| yes    | yes    |       |
| 980326| yes    | yes    | yes   | 991217| yes    | no     |       |
| 980329| yes    | yes    | yes   | 991217| yes    | no     |       |
| 980425| yes    | yes    | yes   | 991217| yes    | no     |       |
| 980515| yes    | yes    | yes   | 991217| yes    | no     |       |
| 980519| yes    | yes    | yes   | 991217| yes    | no     |       |
| 980613| yes    | yes    | no    | 991217| yes    | no     |       |
| 980703| yes    | yes    | no    | 991217| yes    | no     |       |
| 980706| yes    | no     | no    | 991217| yes    | no     |       |
| 981220| yes    | yes    | no    | 991217| yes    | no     |       |
| 981226| yes    | yes    | yes   | 991217| yes    | no     |       |
| 990123| yes    | yes    | yes   | 991217| yes    | no     |       |
| 990217| yes    | yes    | yes   | 991217| yes    | no     |       |
| 990308| yes    | yes    | yes   | 991217| yes    | no     |       |
| 990506| yes    | yes    | no    | 991217| yes    | no     |       |
| 990510| yes    | yes    | no    | 991217| yes    | no     |       |
| 990520| yes    | no     | no    | 991217| yes    | no     |       |
| 990625| yes    | yes    | yes   | 991217| yes    | no     |       |

the second case for a jet-like outflow (Stanek et al. 1999). Further polarization measurements were carried out in GRB 990712 during one-day time interval. The polarization angle did not vary significantly but the degree of polarization was not constant. No current model can account for this (Rol et al. 2001).

2.2.7. GRB 991216: a jewel for X-ray spectroscopy

This GRB was detected by BATSE (Kippen et al. 1999) and subsequently scanned by RXTE detecting a bright X-ray afterglow about 1 and 4-hr after the occurrence of the event (Takeshima et al. 1999, Corbet and Smith 1999). The optical and radio counterparts were identified by Ugesich et al. (1999) and Taylor et al. (1999) respectively. Three absorption systems at redshifts z = 0.77, 0.80 and 1.02 were found by Vreeswijk et al. (1999c) in the OA spectra. A follow-up X-ray observation by CHANDRA has revealed the presence of a redshifted K-α line from H-like Fe (at rest energy of 6.97 keV). See Fig. 3. The line width and intensity imply that the progenitor of the GRB was a massive star system that ejected, shortly before the GRB event, about a ∼ 0.1 M⊙ of Fe at 0.1c, probably by a SN explosion (Piro et al. 2000), at distances less than a light-hour (Rees and Mészáros 2000) thus giving support to the “supranova” model discussed in section 4.2 (Vietri et al. 2001).

2.2.8. GRB 000301c: a very peculiar afterglow

It was detected by RXTE, Ulysses and Near; and following IPN coordinates (Hurley et al. 2000), a very blue optical counterpart was found (Fynbo et al. 2000b, Jensen et al. 2001). The R- and K'-bands show significant differences, especially in the early time decay slope and break time. This is contrary to the expectation of achromatic light curve breaks (Rhoads and Fruchter 2001). Therefore jet collimation is not the responsible mechanism for the sharp break. Refreshed shock effects can account to the high variability observed at optical wavelengths (Masetti et al. 2000, Sagar et al. 2000), but also an ultra-relativistic shock in a dense medium rapidly evolving to a non-relativistic phase (Dai and Lu 2001). An UV spectrum with HST (+ NUV-MAMA) allowed to detect the H I Lyman-break at z = 2.03 (Smette et al. 2000, 2001). A gravitational microlens has been also proposed to explain the short-time scale variability (Garnavich, Loeb and Stanek 2000).

Further X-ray afterglows were observed by BSAX and RXTE in 1997-2000, with exponents for the power-law decay in the X-rays and in the optical are
Table 2. GRB host galaxies

| GRB   | R<sub>host</sub> | z      | References                                      |
|-------|-----------------|--------|------------------------------------------------|
| 970228 | 24.6            | 0.695  | Djorgovski et al. (1999a)                      |
| 970508 | 25.0            | 0.835  | Bloom et al. (1998)                            |
| 970828 | 24.2 ?          | 0.33 ? | Yoshida et al. (1999), Djorgovski et al. (2001a) |
| 971214 | 25.6            | 3.418  | Kulkarni et al. (1999b)                        |
| 980326 | ≥27.3           | 1 ?    | Bloom et al. (1999)                            |
| 980329 | 28.2            |        | Holland et al. (2000a)                         |
| 980425 | ~15             | 0.0085 | Galama et al. (1998), Fynbo et al. (2000a)      |
| 980519 | ~26             |        | Hjorth et al. (1999)                           |
| 980613 | 23.7            | 1.069  | Djorgovski et al. (2001b)                      |
| 980703 | 22.4            | 0.966  | Djorgovski et al. (1998)                       |
| 981226 | 24.9            |        | Frail et al. (1999b)                           |
| 990123 | 24.6            | 1.599  | Kulkarni et al. (1999), Andersen et al. (1999)  |
| 990506 | 24.8            |        | Frail et al. (2000)                            |
| 990510 | 28              | 1.619  | Vreeswijk et al. (1999b), Bloom et al. (2001)   |
| 990705 | 23              | 0.85   | Holland et al. (2000b), Amati et al. (2000)     |
| 990712 | 21.8            | 0.430  | Galama et al. (1999b)                          |
| 991208 | 24.3            | 0.707  | Dodonov et al. (1999), Castro-Tirado et al. (2001) |
| 991216 | 26.9            | 1.02   | Vreeswijk et al. (1999c,2000)                   |
| 000131 | ≥25.7           | 4.50   | Andersen et al. (2000)                         |
| 000210 | 23.5            |        | Garmire et al. (2000), Gorosabel et al. (2000)  |
| 000214 | 23.5            |        | Antonelli et al. (2000)                        |
| 000301c| ≥28.5           | 2.03   | Smette et al. (2000,2001), Jensen et al. (2001) |
| 000418 | 24.0            | 1.118  | Bloom et al. (2000)                            |
| 000926 | 23.9            | 2.066  | Fynbo et al. (2000c,2001), Price et al. (2001)  |
| 001109 | 20.7            |        | Taylor et al. (2000), Greiner et al. (2000)     |

in the range $\alpha = 0.75$-2.25 for a dozen of bursts. Energies releases are of the order of $5 \times 10^{51} - 2 \times 10^{54}$ erg. These results are given on Table 1. See also Greiner (2001) for an updated information.

3. GRB HOST GALAXIES

About 50% of the GRBs with X-ray counterparts are not detected in the optical, and this could be due to intrinsic faintness because of a low density medium, high absorption in a dusty environement, or Lyman limit absorption in high redshift galaxies ($z > 7$). If GRBs are tightly related to star-formation, a substantial fraction of them should occur in highly obscured regions. For instance, most of star formation in the Hubble Deep Field is so enshrouded by dust that starlight from the galaxies detected by SCUBA is attenuated by a factor of $\sim 10^2$ (Hughes and Dunlop 1999). About 25 host galaxies have been detected so far, in the range $0.430 \leq z \leq 4.50$ if ESO 184-G82 is excluded. None of the hosts are brighter than the knee of the luminosity function $L^*$ at their redshift, but the GRB hosts are noticeable bluer than typical galaxies of similar magnitude (Fruchter et al. 1999). Table 2 summarizes the properties of the host galaxies found so far. See also Sokolov et al. (2001).

4. THEORETICAL MODELS

4.1. The standard model of GRB afterglows

The observational characteristics of the GRB counterparts can be accommodated in the framework of the relativistic fireball models, first proposed by Goodman (1986) and Paczyński (1986), in which a compact source releases $10^{53}$ ergs of energy within dozens of seconds in a region smaller than 10 km. The opaque radiation-electron-positron plasma accelerates to relativistic velocities (the fireball) with Lorentz factors of $\Gamma \sim 10^2$-$10^3$. The GRB itself is thought to be produced by a series of "internal shocks", at large radii probably within the fireball due to collisions amongst layers expelled with different $\Gamma$ that are being caught up to each other (Rees and Mészáros 1994, Daigne and Mochkovitch 1998).

When the fireball runs into the surrounding medium, a "forward shock" ploughs into the medium, and sweeps up the interstellar matter, decelerating and producing an afterglow at frequencies gradually declining from X-rays to radio wavelengths (Mészáros and Rees 1997). A "reverse shock" impinges on the ejecta. An extensive review is given by Piran (1999). See Fig. 4. Further collisions amongst faster shells and outer layers that have been decelerated are expected in the refreshed shock scenario where the ejecta is reenergized. This can be done either continuously or in discrete episodes (Sari and Mészáros 2000).

The properties of the blast wave can be derived from the classical synchrotron spectrum (Ginzburg and Schramm 1966, 1976).
Syrovatskii (1965) produced by a population of electrons with the addition of self absorption and a cooling break (Sari, Piran and Narayan 1998). The determination for every GRB of the six observables: the synchrotron, break and self-absorption frequencies, the maximum flux and the power-law decay exponent (all from the multiwavelength spectrum) and $z$ (from optical or X-ray spectroscopy) allows to obtain the total energy per solid angle, the fraction of the shock energy in electrons and post-grb magnetic fields, and the density of the ambient medium.

4.2. What are the progenitors?

The most popular models fall into two broad categories: the explosion of a massive star and the coalescence of a compact binary system.

The “collapsar” model (Bodenhaimer and Woosley 1983, Woosley 1993, 2001) deals with a rotating massive star with a Fe core that collapses forming a Kerr black hole (BH) and a 0.1-1 $M_{\odot}$ torus. The matter is accreted at a very high rate and the energy can be extracted in two manners: i) from the accretion of disk material by the BH; ii) from the rotational energy of the BH via the Blandford-Znajek process (Blandford and Znajek 1977), within the framework of a force-free magnetosphere with a strong magnetic field and a magnetically dominated MHD flow (Brown et al. 2000, Spruit, Daigne and Drenkhahn 2001). The energy released in this process is $\sim 10^{54}$ erg. A “dirty fireball”, is produced reaching a luminosity $\sim 300$ times larger than that of a normal SN. This would happen every $\sim 10^9$ yr. In this scenario, GRBs would be produced in dense environments near star forming regions (see also MacFadyen and Woosley 1999) and GRBs might be used for deriving the SFR in the Universe (Krumholz et al. 1998, Totani et al. 1999).

Within this category, the “supranova” model (Vietri and Stella 1998) involves a supra-massive neutron star imploding to a black hole and during the SN explosion the medium surrounding the remnant is swept-up, leading to a baryon-clean environment. A torus of $\sim 0.1 M_{\odot}$ is also expected and energy extraction is via the conversion of the Poynting flux into a magnetized relativistic wind.

The coalescence of neutron stars in a binary system has been also proposed (Narayan et al. 1992): lifetimes of such systems are of the order of $\sim 10^9$ years, and large escape velocities are usual, putting them far away from the regions where their progenitors were born. The likely result is a Kerr BH, and the energy released energy during the merger process is $\sim 10^{54}$ erg. It is also possible that a $\sim 0.1 M_{\odot}$ accretion disk forms around the black hole and is accreted within a few dozen seconds, then producing internal shocks leading to the GRB (Katz 1997). In this scenario, GRBs would be produced far away from their host galaxies, and this could account for the $\sim 40\%$ of bursts not located in the optical window.

There are variations of this latter model where one or two components are substituted for black holes (Paczynski 1991), white dwarfs (Fryer and Woosley 1998) or He stars (Zhang and Fryer 2001).

A statistical study of the offsets of 20 long-duration GRBs from their apparent host galaxies centers (see Fig. 5) favours the explosion of a massive star rather than the binary merger model (Bloom et al. 2000). It has been suggested that the short duration ($< 1\text{ s}$) bursts could be due to compact star mergers, whereas the longer ones are caused by the collapse of massive stars.

5. SUMMARY

The existence of X-ray afterglow in most bursts is confirmed. Out of 27 BSAX pointings, 18 revealed a clear afterglow, leading to the detection of several
optical/IR/radio counterparts in 1997-2000. However, only the population of bursts with durations of few seconds has been explored. Short bursts lasting less than 1 s, like GRB 980706, that follow the -3/2 slope in the log $N$-log $S$ diagram (in contrast to the longer bursts) remain to be detected at longer wavelengths. In any case, it is clear today that GRBs might provide an important clue for the study of the early Universe (Lamb & Reichart 2000).

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