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Present and future gamma-ray burst experiments

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Abstract. Gamma-ray burst counterpart studies require small, prompt error boxes. Today, there are several missions which can provide them: BeppoSAX, the Rossi X-ray Timing Explorer, and the 3rd Interplanetary Network. In the near future, HETE-II, a possible extended Interplanetary Network, and INTEGRAL will operate in this capacity. In the longer term future, a dedicated gamma-ray burst MIDEX mission may fly. The capabilities of these missions are reviewed, comparing the number of bursts, the rapidity of the localizations, and the error box sizes.

Key words: instrumentation: detectors — space vehicles — gamma-rays: bursts

1. Introduction

The long-awaited breaktkhrough in our understanding of cosmic gamma-ray bursts (GRBs) has come about because accurate ($<10'$) burst positions have become available quickly (<1 day). Prior to the launch of BeppoSAX, accurate positions were available from the interplanetary networks, but unavoidable delays in the retrieval and processing of data delayed their availability. Similarly, rapidly determined positions were, and still are available from BATSE, but their utility is limited by the fact that their accuracy is in the several-degree range.

The list of things we need to know about bursts is still long. Among the items on it are:

– are burst sources in their host galaxies, or outside them?
– what is the distribution of GRB distances?
– are bursts beamed?
– what is the intrinsic luminosity function for bursts?
– are there different classes of bursts, e.g. long and short, soft-spectrum and hard-spectrum?
– what is the multiwavelength behavior of GRB light curves immediately after the burst?

Given that only $\sim 50\%$ of the GRBs studied to date have optical counterparts, and that only $\sim 50\%$ of the counterparts have measured redshifts, it is clear that answering these questions will require hundreds of GRB detections in the gamma-ray range. But the rate at which rapid, accurate positions become available is still quite small: < 1 burst/month. Thus even minor improvements in the rate can have a major impact on progress in the near-term future. However, major improvements will be needed in the long-term future to make the next big step.

2. Current and future missions

Figure 1 shows the approximate operating dates of the missions which are capable of providing GRB data to answer some of the questions listed above. Each of these missions will be reviewed briefly.

2.1. BeppoSAX

BeppoSAX has now observed 14 GRBs in the Wide Field Camera, with location accuracies in the $< 10'$ range. The resulting detection rate is ~ 10/year. Eleven of these have been followed up with Narrow Field Instrument observations, resulting in many cases in a reduction of the error circle radii to $\sim 1'$ (Costa 1999). There are delays of $\sim$ hours to obtain, analyze, and distribute the data. The approved lifetime of the mission is through 2001.

2.2. BATSE: GCN and locburst

The Global Coordinates Network (GCN: Barthelmy et al. 1999) distributes ~ 300 GRB positions/year with delays of the order of seconds, determined directly onboard the CGRO spacecraft. The error circle radii are $> 4°$. The Locburst procedure (Kippen et al. 1998) distributes ~ 100

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of the stronger bursts/year. As Locburst relies on ground-based processing, the delays are longer, $\sim$ 15 min, but the accuracy is improved: the error circle radii are $> 1.6°$. These data are useful for follow-up searches with rapidly moving telescopes like LOTIS (Park 1999), and with the RXTE Proportional Counter Array, as well as for triangulation with the 3rd Interplanetary Network. BATSE will remain operational at least through 2002; its lifetime is limited by the available funding, and is reviewed every two years in NASA's "Senior Review" process.

2.3. 3rd interplanetary network

The 3rd IPN consists of the Ulysses and Near Earth Asteroid Rendezvous (NEAR) missions in interplanetary space, as well as numerous near-earth missions such as CGRO, RXTE, Wind, and BeppoSAX. The IPN observes and localizes $\sim$ 70 GRBs/year (Hurley 1999a,b). When a burst is observed by just two spacecraft, such as Ulysses and CGRO, the resulting error box is the intersection of the triangulation annulus with the BATSE error circle, with dimensions typically $5'$ by $5°$. When Ulysses, NEAR, and say, BATSE detect the burst, the resulting error box may be as small as $1'$ by $5'$ (Cline 1999). The delays involved are $\sim$ 1 day, imposed by the receipt of data from interplanetary spacecraft through NASA's Deep Space Network. The lifetime of the 3rd IPN will be through 2004, the nominal end of the Ulysses mission.

2.4. The Rossi X-ray timing explorer

The All-Sky Monitor aboard RXTE detects $\sim$ 4 GRBs/year; $\sim$2 of them can be localized to $\sim$ arcminute accuracy with delays of only minutes (Bradt 1999; Smith et al. 1999). In addition, the PCA performs about one target-of-opportunity observation per month of BATSE Locburst positions to search for fading X-ray counterparts (Takeshima et al. 1998). When successful, the counterpart position can be determined to $\sim 10'$ with a delay of hours. Like BATSE, RXTE's lifetime, determined by the Senior Review, will extend through 2002 at least.

3. The next big step

At present we rely on spacecraft instrumentation to provide X-ray positions which are accurate to arcminutes, and on rapid ground-based photometry from small to moderate-sized telescopes to identify optical counterparts to arcsecond accuracy. Only at that point can a large telescope be used to determine the redshift (for example, the spectrometer slits on the Keck Low Resolution Imaging Spectrometer are only $1 - 8''$). The next big step will be to determine GRB positions directly on the spacecraft to arcsecond accuracy, eliminating the delays involved in refining the positions on the ground. Some of the future missions discussed below will be capable of accomplishing this.

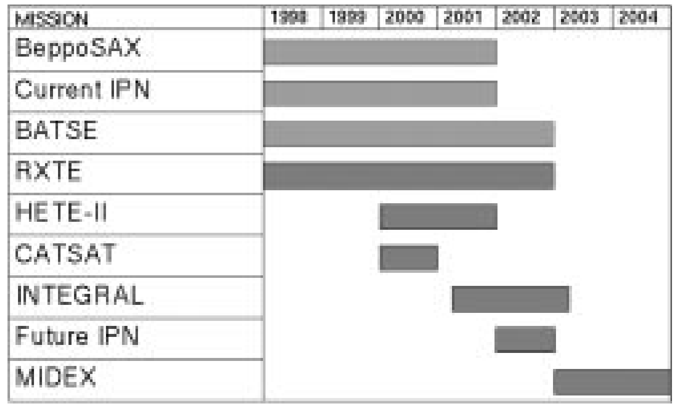

Fig. 1. Approximate dates of current and future GRB missions

3.1. HETE-II

The High Energy Transient Explorer-II combines a Wide Field X-ray Monitor and a Soft X-ray Camera to localize up to $\sim$50 GRBs/y to accuracies of $10''$ to $5'$ (Ricker 1999). Locations will be transmitted to the ground in near real-time. The HETE-II mission is planned for a two year lifetime starting in January 2000.

3.2. CATSAT

The Cooperative Astrophysics and Technology Satellite (Forrest et al. 1995) will contain a soft X-ray spectrometer consisting of 190 cm^2 of Si avalanche photodiodes to measure the $0.5 - 20$ keV spectra of GRBs and their afterglows. From these spectral measurements, the hydrogen column along the line of sight may be determined. CATSAT has only coarse localization capability, but measurements of N_H will help to answer the question of the locations of GRBs with respect to their host galaxies. $\sim$ 12 GRBs/year should be detected, with data available $\sim$ 5 hours after the bursts. A nominal one year mission in 2000 is planned.

3.3. INTEGRAL

The International Gamma-Ray Laboratory can detect bursts with its Ge spectrometer array (the SPI), as well as with IBIS (the Imager on-Board the INTEGRAL Satellite), and with the BGO anticoincidence shield around the spectrometer. IBIS, a CdTe array with a coded mask, provides the most accurate, rapid locations. It can detect $\sim$ 20 GRBs/year and localize them to

Table 1. Capabilities of current and future GRB missions

Mission	Bursts/yr	Accuracy	Delay	Dates
BeppoSAX	10	$1-10'$	hours	through 2001
BATSE (GCN)	300	$8-20°$dia.	seconds	through 2002
BATSE (Locburst)	100	$3-8°$dia.	$15-30$ min	through 2002
Current IPN	70	$5'\times 5° - 1'\times 5'$	$\sim$ day	through 2001
RXTE ASM AND PCA	$2-4$	$3-10'$	min − hours	through 2002
HETE-II	50	$10''-5'$	seconds	$2000-2002$
CATSAT	12	degrees	5 hours	2000
INTEGRAL	20	arcminutes	$5-100$ s	$2001-2003$
Future IPN	70	arcminutes	$\sim$ day	$2002-2003$
MIDEX	300	arcseconds	seconds	$2003-2005$

arcminute accuracy (Kretschmar et al. 1999). These positions can be distributed to observers within $5-100$ s. The nominal INTEGRAL mission is two years long, starting in April 2001.

3.4. Future IPN

A future Interplanetary Network, consisting of Mars Surveyor Orbiter 2001, INTEGRAL, BATSE, and Ulysses, may exist around the year 2002. MSO has two GRB two instruments which will detect GRBs with good sensitivity and time resolution, a Ge spectrometer and a neutron detector. The BGO anticoincidence shield of the INTEGRAL SPI is similarly equipped to detect bursts (Hurley 1999). With such a network, ~ 70 GRBs/year could be localized to arcminute accuracies, with delays of the order of a day. This IPN might remain in place for one or two years, bridging the gap to a possible dedicated GRB MIDEX.

3.5. A dedicated MIDEX

The results of the recent MIDEX competition have just been announced. The SWIFT GRB proposal (N. Gehrels, P.I.) was selected for a 6 month study phase. SWIFT can localize perhaps 300 GRBs/year to arcsecond accuracy on-board the spacecraft, and transmit the locations to the ground in near real-time. The final mission selection will be announced in September 1999. If selected for flight, SWIFT could fly in the years 2003-2005.

4. Conclusions

Table 1 summarizes the essential characteristics of the current and future GRB missions. The emphasis is on the rapid, precise localization of bursts, and this must of course be followed up with in-depth studies. Although we have much to learn about gamma-ray bursts, these missions promise to return the data we need to move forward in this exciting field.

References

Barthelmy S., Butterworth P., Cline T., et al., 1999 (these proceedings)
Bradt H., 1999 (these proceedings)
Cline T., 1999 (these proceedings)
Costa E., 1999 (these proceedings)
Forrest D., Vestrand W., McConnell M., Ryan J., Owens A., 1995, Ap&SS 231 (1/2), 459
Hurley K., Briggs M., Kippen R., et al., 1999a, ApJS 120, 399
Hurley K., Briggs M., Kippen R., et al., 1999b, ApJS 122, 497
Hurley K., 1999, in: Proc. 3rd INTEGRAL Workshop, Astrophys. Lett. & Comm. (in press) (astro-ph 9812052)
Kretschkmar B., Mereghetti S., Robert A., et al., 1999 (these proceedings)
Park H.-S., 1999 (these proceedings)
Kippen R., Connaughton V., Pendleton G., et al., 1998, in: Gamma-Ray Bursts: 4th Huntsville Symposium, Meegan C.A., Preece R.D., Koshut T.M. (eds.). AIP, New York, p. 119
Ricker G., 1999 (these proceedings)
Smith D., et al., 1999, ApJ (in press)
Takeshima T., Marshall F., Corbet R., et al., 1998, in: Gamma-Ray Bursts: 4th Huntsville Symposium, Meegan C.A., Preece R.D., Koshut T.M. (eds.). AIP, New York, p. 414