IL NUOVO CIMENTO Vol. 28 C, N. 4-5 Luglio-Ottobre 2005
DOI 10.1393/ncc/i2005-10172-7

ESTREMO: Extreme phySics in the TRansient and Evolving COsmos(*)

E. Costa and L. Piro (**)

Istituto Astrofisica Spaziale e Fisica Cosmica, INAF - Rome, Italy

(ricevuto il 23 Maggio 2005; pubblicato online il 2 Novembre 2005)

Summary. — We present a mission designed for the study of transient phenomena in the high-energy sky, through a wide field X-ray/hard X-ray monitor, and fast (< 1 min) follow-up observations with Narrow Field Instrumentation. This is based on an X-ray telescope with an area of $1000\,\mathrm{cm}^2$, equipped with highresolution spectroscopy microcalorimeters and X-ray polarimeter. The performances of the mission on the physics of GRB and their use as cosmological probes are presented and discussed.

PACS 95.85.Nv – X-rays.
PACS 98.70.Rz – γ-ray sources, γ-ray bursts.
PACS 01.30.Cc – Conference proceedings.

1. – Scientific goals

The ESTREMO mission is devoted to address, through a smart, focussed approach, two main themes of Astrophysics and Cosmology:

– The study of extreme objects in our Universe, in particular those characterized by very large energy release over short time scale (minutes-hours) such as Gamma-ray Bursts, massive and star-size black holes, neutron stars, Supernovae explosions, flaring sources.

– The study of the evolution of the Universe by using the brightest and most distant explosions, the Gamma-Ray Bursts, as distant beacons.

(*) Paper presented at the "4th Workshop on Gamma-Ray Burst in the Afterglow Era", Rome, October 18-22, 2004.
(**) On behalf of the ESTREMO Collaboration.

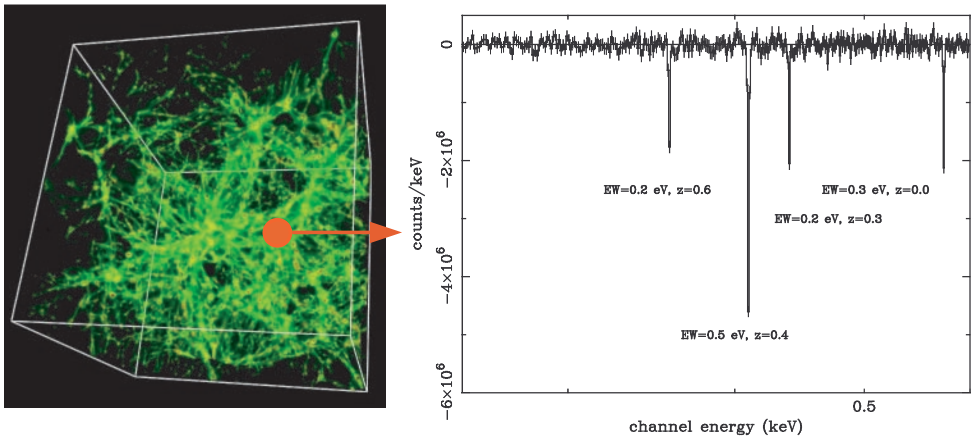

Fig. 1. – GRB as cosmological probes of the WHIM structures. The simulation refers to an observation by ESTREMO with a microcalorimeter with 2 eV resolution below 1 keV of a bright afterglow with a fluence of 10^{-5} erg cm^{-2} from 60 s to 60 ks after the burst.

2. – Mission profile

The mission is designed to localize transient sources in outburst and to observe them while they are still in outburst phase. Catching a source during large and fast flare activity gives access to the study of very large energy release under extreme conditions. In addition, in this phase the flux can be orders of magnitude greater than in quiescent state, thus allowing very sensitive observations with relatively small effective area. The mission comprises:

1. a wide field instrument, to localize X-ray transient phenomena in the sky in the X-ray and hard X-ray range (2–300 keV): as a baseline an array of CdZnTe with coded mask;
2. an autonomously fast pointing (1 min) satellite for follow-up observations by narrow-field instruments with an X-ray telescope of 1000 cm^2;

to perform:

- high-resolution X-ray spectroscopy with TES (Transition Edge Sensor) microcalorimeters (Resolution $\approx$ 2–4 eV in the 0.1–10 keV range);
- high-sensitivity X-ray polarimetry.

Auxiliary instrumentation should extend the spectral coverage of prompt emission to soft X-rays and to the MeV region. To underline the mission capabilities with regard to GRB, we present two examples, one based on high-resolution spectroscopy, the other on polarimetry.

3. – X-ray spectroscopy and GRB as cosmological probes

GRB are the brightest and most distant sources in the Universe. The radiation intensity of GRB's is so high that they can be detectable out to much larger distances than those of the most luminous quasars or galaxies observed so far. In addition, long bursts are now unquestionably associated with explosions of massive stars, taking place in star formation regions. Taking advantage of these GRBs properties, with ESTREMO we can address three key themes of modern Cosmology and Astrophysics:

– *Discover and study the first "X-ray light" from primordial gravitationally bounded object in the Universe at* $z = 10$–30. Our observational window on the Universe extends in distance up to $z = 6$–7, the reshift of the most distant object discovered so far, and then recovers at $z = 1000$, the epoch of primordial fluctuations measured by BOOMERANG and WMAP. The formation of the first objects, stars, and protogalaxies, should have taken place at epochs corresponding to $z = 10$–30, certainly beyond $z = 5$. These first gravitationally bound proto-systems are the result of the evolution of the primordial fluctuations observed at $z = 1000$, this evolution depending on cosmological models and dark-matter properties. The large observational gap in between these epochs is then particularly serious. These objects are obscure in the optical due to the dusty environment (and Ly α forest absorption at $z > 5$). On the other hand, X-rays and gamma-ray photons produced by a GRB will easily pierce through this environment, pin-pointing the location of the host galaxy and allowing to measure its distance in X-rays by measuring the redshift of X-ray features (X-ray redshift).

– *Trace the cosmic dark matter web at* $z < 2$ *in X-rays*. In the local ($z < 1$) Universe the evolution of large-scale structures dominated by dark matter is challenging the observers. The sudden decrease of the baryon density in the local Universe is one of the unresolved issues of Cosmology. The most intriguing solution is that most of the baryon are in a hot phase, that can be detected primarily through X-ray measurements. Numerical simulations predict that, at $z < 1$, most of the baryons fall onto the cosmic web pattern of the dark matter, and are heated at $T \approx 10^6$ K by shock mechanisms, forming filamentary and sheet-like structures [1]. Such gas is called Warm-Hot Intergalactic Medium (WHIM). One of the most promising methods to detect and study this component is by searching for the narrow absorption features— the strongest of which is OVII (at 0.574 keV in the rest frame)— imprinted by the WHIM on the X-ray spectrum of a bright background object. Using bright GRB afterglows as background sources gives the big advantage, with respect to AGN [2], to reach out much larger distances, increasing the number of filaments through the line of sight. For a burst at $z \gtrsim 0.5$ at least one system with an equivalent width $\gtrsim 0.4$ eV is expected along a random line of sight, while many more (8) are expected for just twice weaker systems [3]. In fig. 1 we show one expected absorption spectrum where, for clarity, we have limited the number of weaker absorption lines to 3 plus one stronger line.

– *Study the history of metal enrichment in the Universe from early epoch to the local Universe*. X-ray "light" emitted from distant GRB will be selectively absorbed at specific frequencies by metals at the source, thus allowing to build up a "map" of metal abundances and hence star formation rate as function of the redshift.

4. – X-ray polarimetry and GRB engine

Magnetic fields play a major role in current theories of Gamma-Ray Bursts. While energetics can be directly probed through multi-band evolution of spectra, our knowl-

Table I. – *Minimum polarization detectable with ESTREMO at* 3σ *confidence for two bright GRBs and for two representative bursting episodes of a Soft Gamma Repeater.*

Source	$T_{Start} - T_{End}(s)$	MDP(%)	Exposure (s)
GRB970228	35–100	13	65
GRB970228	100–300	13	200
GRB990123	35–100	4	65
GRB990123	100–300	4	200
SGR1900+14(normal burst)	35–1000	20	965
SGR1900+14(giant burst)	35–1000	1	965

edge of the structure of the magnetic field and its genesis are totally committed to very indirect evidences. Polarization would give a straightforward evidence of the structure of the magnetic field and of its evolution, enlightening the shock mechanism. Polarizations of the order of 1% have been detected in the optical band, in the afterglow phase on timescales of 1 day. A polarization of $\gtrsim 60$ % was claimed [4] in the prompt emission of a burst (GRB021206). While this result is still to be confirmed, it generated theoretical predictions on the role of a highly oriented magnetic field, to suport the theory of magnetic fireballs [5]. The study of how the polarization evolves (in degree and angle) from the main burst to the afterglow phase in the first minutes/hours can give a deep insight on the nature and structure of the magnetic field and, possibly give important constraints on the progenitor models. Gruzinov and Waxman [6], by assuming the fireball to be composed of large, mutually not ordered fragments of internally well ordered field had predicted a high polarization level in the early phase, quickly decreasing with the decrease of the Lorentz Factor. Other authors [7,8] have explored the hypothesis that in a GRB jet the magnetic fields are compensating to produce a reduced polarization. When the relativistic beaming cone crosses the jet cone (namely close to the breaking of the light curve) the symmetry is broken and a strong polarization would appear for a limited time. In table I we show the performances of the ESTREMO mission, based on the X-ray Micro Pattern Gas Chamber polarimeter [9]. We choose a prudent configuration for the detector so that meaningful measurements can be performed only on bright bursts. From development studies we expect a significant improvement of this figure. The polarimeter is operated in alternative to the microcalorimeter. Nevertheless, it provides a good imaging and timing of the source, and energy-resolved polarimetry.

* * *

REFERENCES

[1] Cen R. and Ostriker J. P., *Ap.J.*, **514** (1999) 1.
[2] Nicastro F. *et al.*, *Nature*, **433** (2005) 495.
[3] Hellsten U., Gnedin N. Y. and Miralda-Escude J., *Ap.J.*, **505** (1998) 56.
[4] Coburn W. and Boggs S. L., *Nature*, **423** (2003) 415.
[5] Lyutikov M., Pariev V. I. and Blandford R. D., *Ap.J.*, **597** (2003) 998.
[6] Gruzinov A. and Waxman E., *Ap.J.*, **511** (1999) 852.
[7] Rossi E., Lazzati D., Salmonson J. D. and Ghisellini G., *MNRAS*, **354** (2004) 86.
[8] Sari R., *Ap. J. Lett.*, **524** (1999) L43.
[9] Costa E. *et al.*, *Nature*, **411** (2002) 662.