Introducing the *SVOM* mission for Gamma-Ray Bursts Studies

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We present the *SVOM* (Space-based multi-band astronomical Variable Object Monitor) mission, that is being developed in cooperation between the Chinese National Space Agency (CNSA), the Chinese Academy of Science (CAS) and the French Space Agency (CNES), and is expected to be launched in 2014. Its scientific objectives include the study of the GRB phenomenon (diversity and unity), GRB physics (particle acceleration, radiation mechanisms), GRB progenitors, cosmology (host galaxies, intervening medium, star formation history, re-ionization, cosmological parameters), and fundamental physics (origin of cosmic rays, Lorentz invariance, gravitational waves sources). *SVOM* is designed to detect all known types of Gamma-Ray Bursts (GRBs), to provide fast and reliable GRB positions, to measure the broadband spectral characteristics and temporal properties of the GRB prompt emission. Four space borne instruments have been selected for phase A study: a wide field (∼2 sr) coded mask telescope (ECLAIRs), operating in the 4–250 keV energy range, will provide the triggers and localizations, while a gamma-ray non-imaging spectrometer (GRM), sensitive in the 50 keV-5 MeV domain, will extend the prompt emission energy coverage. After a satellite slew, in order to place the GRB direction within field of view of the two narrow field instruments - a soft X-ray (XIAO), and a visible telescope (VT) - the GRB position will be refined and the study of the early phases of the GRB afterglow will be possible. A set of three ground based dedicated instruments, two robotic telescopes (GFTs) and a wide angle optical monitor (GWAC), will complement the space borne instruments. Thanks to the low energy trigger threshold (∼4 keV) of the ECLAIRs, *SVOM* is ideally suited for the detection of soft, hence potentially most distant, GRBs. Its observing strategy is optimized to facilitate follow-up observations from the largest ground based facilities.

1 Introduction

Despite recent observational progress, the 40 years old Gamma-Ray Bursts (GRBs) mystery is far from being completely solved (see e.g. Mészáros (2006)[1] for a review). There is general consensus on the cosmological nature of these transient sources of gamma-ray radiation, and, at least for the long burst category, the association with the explosion of massive stars (>30 $M_{\odot}$) is a scenario that reproduces most observed features. Whatever the exact progenitors of long GRBs are, they have been detected up to redshift 6.7 [2], making them powerful tools to investigate the early Universe (star formation history, re-ionization, etc.), and to possibly derive cosmological parameters. For short bursts, on the other hand, the situation is less clear, mainly because of the lack of a statistically compelling number of good quality observations of their afterglows. Many questions concerning GRBs are still open, such as the physical processes at work during the prompt phase, in terms of particle acceleration and radiation processes, the GRBs classification, a better characterization of GRB host galaxies and progenitors, as well as some fundamental physics issues like Lorentz invariance, the origin of cosmic rays and gravitational waves.

In order to contribute to address the above questions, the French Space Agency (CNES), the Chinese Academy of Sciences (CAS) and the Chinese Space Agency (CNSA) are developing the *SVOM* mission (Space-based multi-band astronomical Variable Object Monitor). *SVOM* has successfully reached the end of its phase A design study, and is planned to be launched in 2014 in a circular orbit with an inclination of $\sim 30°$ and altitude of $\sim$600 km. For Phase A study four instruments have been selected: ECLAIRs, a coded mask wide field telescope that will provide real time localizations of GRB to arcminute level, two GRMs units, non-imaging gamma-ray spectrometers, and two narrow-field instruments, XIAO and VT, for arcsecond localizations, and for the study of the early afterglow phases in the X-ray and optical bands. Indeed, once a GRB is detected within field of view of ECLAIRs, the satellite will autonomously perform a slew towards the GRB direction, in order to allow the observations of the afterglow by the XIAO and VT telescopes. The *SVOM* pointing strategy derives from a combination of two main constraints: the avoidance of bright X-ray galactic sources and an anti-solar pointing, to have the GRBs always detected on the night side of the Earth. Even if the latter choice induces some dead time at mission level, due to the Earth passages occulting ECLAIRs field of view once per orbit, it will enhance the possibility of successful follow-up with large ground based facilities, with a goal of 75% of *SVOM* GRBs easily observable during their early afterglow phase.

Besides the space flown instruments, the *SVOM* mission includes a set of ground based instruments, in order to broaden the wavelength coverage of the prompt and of the afterglow phase: GWACs are a set of wide field optical cameras that cover a large fraction of ECLAIRs field of view. They will be based in China and will follow ECLAIRs pointings, in order to catch the prompt optical emission associated with GRBs. Two robotic telescopes (GFTs), one based in China, and one provided by CNES, complete the ground based instrumentation. Their goal is to measure the photometric properties of the early GRB error region from the near infra-red to the optical band, and to refine the afterglow position provided by the on-board instruments. In the following sections the instruments and the mission are described in some detail.

2 ECLAIRs

ECLAIRs[3] is made of a coded mask telescope working in the 4–250 keV energy range (CXG), and a real-time data-processing electronic system, UTS[4], which is in charge of analyzing ECLAIRs data stream in real-time and of detecting and localizing the GRBs occurring within its field of view. The CXG has a wide field of view ($\sim$ 2 sr), and a fair localization accuracy ($\sim$10 arcmin error radius (90% c.l.) for the faintest sources, down to a couple of arcmin for the brightest ones). Its detector plane is made of 80×80 CdTe pixels yielding a geometrical area of 1024 cm^2. The telescope is passively shielded, and a new generation electronics allows to lower the detection threshold with respect to former CdTe detectors by about 10 keV, reaching $\sim$4 keV. The CXG, in spite of its rather small geometrical surface, is thus more sensitive to GRBs with soft spectra, potentially the most distant ones, than currently flying telescopes, see Fig. 1.

The ECLAIRs/CXG telescope is expected to localize about 70 GRBs per year. This estimate takes into account the dead time induced by the passages over the Southern Atlantic Anomaly, that increase significantly the instrumental particle induced background, and by the passage of the Earth in the CXG field of view.

3 GRM

The Gamma-Ray Monitor (GRM) on board *SVOM* is composed of two identical units each made of a phoswich (NaI/CsI) detector of 280 cm^2, read by a photomultiplier. In front of each detector there is a collimator in order to reduce the background and to match the CXG and GRM fields of view. The GRM does not have imaging capabilities, however as can be seen from Fig. 1, the GRM extends the spectral coverage of the *SVOM* satellite to the MeV range. This is an important point, since the current detectors like BAT on board *Swift*[5] or IBIS/ISGRI on board *INTEGRAL*[6] have a comparable or better localization accuracy with respect to the CXG, but they lack a broad band coverage, hampering a correct spectral characterization of the prompt high-energy emission of GRBs, which is a key input of any sensible modeling of GRBs' radiative processes. The recent successful launch of *Fermi*, and the availability of the GBM detectors (non-imaging spectrometers with a 2π field of view) used in synergy with BAT and ISGRI will partially fill this need before the launch of *SVOM*, but the different orbits, pointing constrains, and sensitivities of the three instruments imply a low rate of simultaneous detections. On the other hand, for every *SVOM* GRB a good localization and good spectral information will be available at the same time.

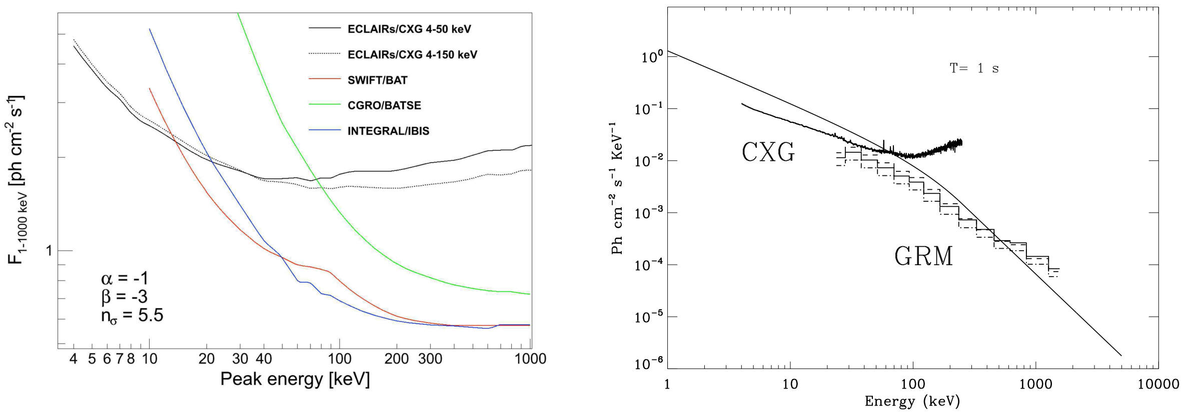

Figure 1: Left: ECLAIRs/CXG sensitivity compared to previous and current instrumentation. The curves have been computed as a function of the GRB peak energy for a 5.5 σ detection assuming a Band spectrum (Band et al. 1993) with the other spectral as parameters reported in the plot. Right: Combined GRM (two units) ECLAIRs on axis sensitivity for a 1 s integration time and a 5 σ detection. A Band spectrum with α=–1, β=–2.5, E_0=100 keV, and $F_{50-300keV}$=1 photon cm^{-2} s^{-1} is overplotted for comparison.

4 XIAO

The X-ray Imager for Afterglow Observations (XIAO[8]) has been proposed by an Italian consortium, lead by the INAF-IASF institute in Milan. It is a focusing X-ray telescope, based on the grazing incidence (Wolter-1) technique. It has a short focal length of $\sim$0.8 m, and a field of view (25 arcmin diameter) adequate to cover the whole error region provided by the CXG telescope, so that after the satellite slew the GRB position should always be inside the XIAO field of view. XIAO has an effective area of about 120 cm^2 and the mirrors are coupled to a very compact, low noise, fast read out CCD camera, sensitive in the 0.5–2 keV energy range.

5 VT

The space-borne Visible Telescope will be able to improve the GRB localizations obtained by the CXG and XIAO to sub-arcsecond precision through the observation of the optical afterglow. In addition it will provide a deep and uniform light-curve sample of the detected optical afterglows, and allow to do primary selection of optically dark GRBs and high-redshift GRB candidates (z>4). The field of view of the telescope will be 21×21 arcmin, sufficient to cover the error box of the CXG. The detecting area of the CCD has 2048 × 2048 pixels to ensure the sub-arcsecond localization of detected sources. The aperture of the telescope should guarantee a limiting magnitude of $M_V = 23$ (5σ) for a 300 s exposure time. Such a sensitivity is a significant improvement over the UVOT on board the *Swift* satellite and over existing ground-based robotic GRB follow-up telescopes. The VT is expected to detect nearly 70% of SVOM GRBs for which a slew is performed. The telescope will have at least two bands in order to select high-redshift GRB candidates. They are separated at 650 nm, which corresponds to a redshift of z∼4-4.5 using Lyα absorption as the redshift indicator.

6 Ground segment

The ground segment of the mission will be composed of X- and S-band antennas (for data and housekeeping telemetry download), a mission operation center, based in China, two science centers (based in China (CSC) and France (FSC) and in charge of operations and monitoring of the scientific payload), and a VHF alert network. The latter will be composed of a series of receivers distributed over the globe in order to guarantee continuous coverage for the alerts dispatched by the platform. The alerts will contain the information about the GRB positions, that will be sent to the ground as soon as more accurate information is derived on board, followed by complementary quality indicators (light curves, images, etc.) produced on board. The VHF network is directly connected to the FSC, which is in charge of formatting and dispatching the alerts to the scientific community through the Internet (GCNs, VO Events, SVOM web page, etc.). The first alerts corresponding to the initial localization by the CXG are expected to reach the recipients one minute after the position has been derived on board. Then the following alerts, containing the refined positions derived on-board, will reach the scientific community within 10 minutes from the first notice. In case of a refined (sub-arcsec) position is available from the prompt data analysis of the GFTs or GWACS, this information will immediately reach the the FSC, and dispatched to the scientific community through the channels mentioned above. For more details on the alert distribution strategy, see Claret (2008)[9]. In addition the FSC will be on charge of publishing the CXG pointing direction in order to facilitate ground based robotic telescopes to quickly react, minimizing the slew time.

Acknowledgments

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Dark Matter