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The SVOM mission

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Abstract. The Space Variable astronomical Object Monitor (SVOM) is a mission dedicated to the detection and characterization of Gamma-Ray Bursts and other high-energy astrophysical transients. SVOM is jointly developed by the Chinese Academy of Science (CAS), the Chinese National Space Administration (CNSA) and the French space agency (CNES) with a launch date foreseen at the end of 2021. SVOM will enable to observe new sources in a large wavelength domain, from the near infrared to gamma rays, thanks to its unique combination of space and ground based instruments. The space borne instruments include two wide field of view monitors, ECLAIRs and GRM, operating in the hard X-ray to gamma-ray energy band, and two narrow field telescopes, MXT and VT, operating in the X-ray and visible domain. On the ground three dedicated robotic telescopes, F-GFT-Colibri, C-GFT, and GWACs will provide complementary coverage in the near infrared and visible bands. SVOM alerts will be distributed publicly to the scientific community in order to enhance the scientific return of the mission.

Key words. Gamma-Ray Bursts; Space Instrumentation

1. Introduction

The Space Variable astronomical Object Monitor (SVOM) mission is being jointly developed by the Chinese Academy of Science (CAS), the Chinese National Space Administration (CNSA) and the French space agency (CNES), and its launch date is foreseen for the end of 2021. The science goals are shared between a Core Programme (CP), a General Programme (GP), and a Target of Opportunity (ToO) Programme. The goals of the CP include the detection and characterization of Gamma-Ray Bursts (GRBs) with a particular emphasis on the detection of high redshift ($z > 5$) events and their use as probes of the early Universe, the broad band coverage of the GRB prompt emission, and the building of a uniform afterglow data sample from the X-rays to the near infrared. The CP will make use of 25% of the SVOM observation time. During the rest of the time SVOM will be operated as an observatory performing pre-planned (GP, 60 % of the SVOM time) and un-anticipated ToO observations (15 % of the time). This sharing applies to the nominal lifetime of the mis-

⋆ includes: CNES Toulouse, CEA Saclay, IRAP Toulouse, APC Paris, LAL Orsay, LAM Marseille, ObAS Strasbourg, LUPM Montpelier, CPPM Marseille, IAP Paris, GEPI Paris, MPE Garching, IAAT Tübingen, University of Leicester, UNAM Mexico, NAOC Beijing, IHEP Beijing, SECM Shanghai, XIOPM Xi'an, Guangxi University Nanning, Nanjing University sion (i.e. the first three years on orbit) and will evolve during the extend mission including a higher fraction of ToO time (up to 40% of the SVOM observation time). The reason for it is that SVOM is also suited to play a role in the upcoming era of multi-messenger astronomy, being able to provide follow-up of triggers related to gravitational wave, neutrino, very high energy gamma-ray or synoptical astronomy.

In order to favour the follow-up of SVOM GRBs by ground based observatories, SVOM will be mainly pointing to the anti-solar direction. In addition, in order to maximize the GRB detection sensitivity, at least during the nominal mission lifetime, the SVOM pointing has been defined as to avoid the Galactic plane (which in turn facilitates the follow-up from ground) and other bright X-ray sources (such as Sco X-1). Thanks to this pointing strategy we expect that about 75% of the SVOM GRBs can be followed promptly from ground, increasing the chances of measuring their redshift through spectroscopy.

For a detailed view of the SVOM science objectives we refer the reader to the SVOM white paper (Wei et al. 2016). In this paper we will mainly review the SVOM space payload and the associated ground segment.

2. The SVOM space segment

SVOM will be launched from Xichang in China by a LM-2C rocket and injected into a circular low Earth orbit with an inclination of about 30° at an altitude of ~625 km. It will carry two wide field monitors and two narrow field telescopes. The wide field monitors are ECLAIRs, a coded mask telescope operating in the 4–250 keV energy range, provided by CNES in collaboration with French laboratories (IRAP, APC, CEA-Irfu), and the GRM, a set of three non-imaging gamma-ray spectrometers, sensitive in the 15 keV–5 MeV energy range, provided by IHEP Beijing. The narrow field telescopes are the MXT, sensitive in the 0.2–10 keV energy range provided by CNES in collaboration with CEA-Irfu, LAL, MPE, and the University of Leicester, and the Visible Telescope (VT), provided by the NAOC in collaboration with XIOPM.

2.1. ECLAIRs

ECLAIRs is composed by a focal plane of 80×80 CdTe pixels of 4×4×1 mm^3 size. A 54×54 cm^2 mask with an open fraction of 40% and a pixel size of about 1.1 cm is placed 46 cm above the detection plane. The mask pattern is random, self supporting. A central cross was introduced for mechanical reinforcement reasons. The system provides a ~2 sr field of view and a point spread function of 52 arc min (FWHM). The ECLAIRs data stream (monitored on time scales from 10 ms to about 20 minutes on 4 energy bands and in 9 detector zones) is analysed in real time on board the satellite by the UGTS electronic box in order to search for new sources appearing in the field on view. Once a new source is detected its coordinates are computed and transmitted to the satellite in order to send the information to ground based observatories and to slew to place the ECLAIRs error box (<12 arc min) into the field of view of the narrow filed telescopes for more accurate localization and physical characterization in the X-rays and in the visible domain. ECLAIRs will be able to detect all kind of GRBs, see Fig. 1, but thanks to its low energy threshold of only 4 keV it will be more sensitive than previous experiments to X-ray rich GRBs which could represent the population of high distance GRBs due to cosmological energy shift(Godet et al. 2014). ECLAIRs is expected to detect about 60 GRBs per year.

2.2. GRM

The Gamma-Ray Monitor (GRM) system is composed by three Gamma-Ray Detectors (GRD) and a particle monitor. Each GRD is made of a NaI(Tl) scintillating crystal, a photomultiplier and its readout electronics, and has a geometrical area of 200 cm^2, thickness of 1.5 cm, FoV of ±60 degrees with respect to its symmetry axis, dead time <8 μs, temporal resolution <20 μs and energy resolution of 16% at 60 keV. A plastic scintillator in front of the NaI(Tl) crystal is used to distinguish low energy electrons from gamma-rays. The 3 GRD-modules point at different directions in order to

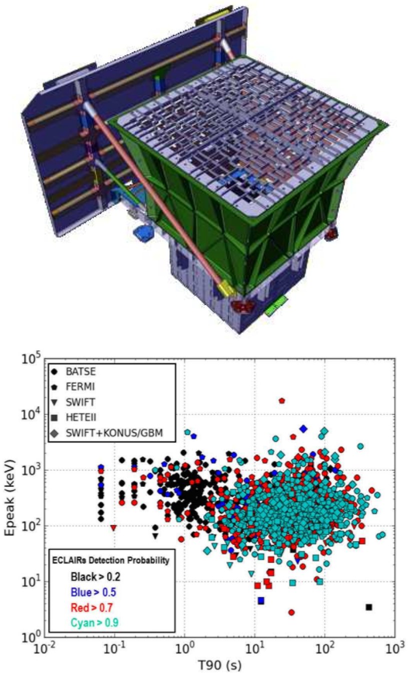

Fig. 1. Upper panel: the ECLAIRs coded mask telescope. Lower panel: the probability of detection by ECLAIRs (color code) of a sample of GRBs observed by previous experiments, plotted as a function of the GRB duration and spectral peak energy.

cover, globally, a field of view which is larger than the ECLAIRs one, see Fig. 2. This will allow to detect a larger number of GRBs (∼90 per year), although most of them will be poorly localized (error box > 10°). For the GRBs detected both in the field of view of ECLAIRs and in the one of one or more GRD a combined spectral analysis will be possible from a few keV to a few MeV, allowing a complete physical description of the SVOM GRBs, as shown in the right panel of Fig. 2.

2.3. MXT

The Microchannel X-ray Telescope (MXT; Götz et al. 2016) is an X-ray focussing telescope with a field of view of 57×57 arc min, whose innovative optical concept is based on the so-called *Lobster Eye* optics (Angel 1979).

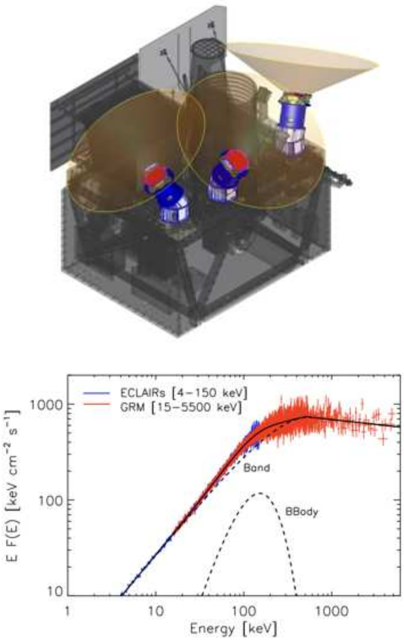

Fig. 2. Upper panel: the GRDs and their individual field of views. Lower panel: a simulation showing a simultaneous spectral fit of GRB 100724B. GRB 100724B was observed by Fermi/GBM and a thermal component (BBody in the figure) has been reported: this component can be detected in the simulated data with the same statistical significance with respect to the GBM data. For more details, see the SVOM white paper (Wei et al. 2016).

This optical concept is realized making use of square pore lead glass micro pore optics (MPOs) plates with 40 μm pore side and 1–2 mm thickness (with inner Ir coating to enhance the reflectivity), produced by Photonis. 25 plates of 40 mm side are used to build the complete MXT optics, which is coupled to a camera sensitive in the 0.2–10 keV energy range, based on a pnCCD (Meidinger et al. 2006) composed of 256×256 pixels of 75 μm side. The pnCCD and is read-out rate every 100 ms and actively cooled to –65°C. A filter wheel allows to put a calibration source or additional optical/UV filters in front of the detector when needed.

The MPO Point Spread Function (PSF) is composed by a central spot and two cross arms: about 50% of the incident X-rays are reflected twice and focused in the central PSF spot, X-rays reflected just once and focused in both PSF arms (2×22%), and the rest produces a diffuse patch. In the *Lobster Eye* geometry the vignetting is very low, reaching 10–15% at the edge of the FoV. Simulations indicate that the PSF of such system could reach 4.5 arc min FWHM at 1.5 keV (central peak). In reality, due to defects in the alignment of the channels, distortions of the channel walls, and misalignment of the plates, such system may finally provide a ∼10 arc min FWHM PSF. The GRB afterglow position is computed on-board in near real-time by the MXT Data Processing Unit. The expected MXT effective area is about 23 cm^2 at 1 keV for the central spot, and expected GRB afterglow localization performance, obtained by folding the entire Swift/XRT afterglow dataset through the MXT response, shows that MXT is well adapted to study GRB afterglows, see Fig. 3. Indeed, 50% of the bursts will be localized to better than 1 arc min (90% c.l. radius; statistical uncertainties only) within 5 min from the MXT stabilization time.

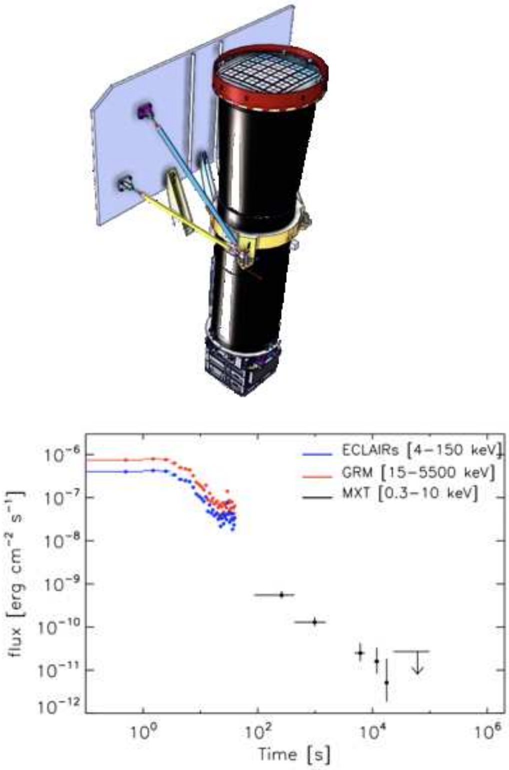

Fig. 3. Upper panel: the MXT telescope. Lower panel: Simulation of the prompt and afterglow emission of GRB 091020 in SVOM instruments. In MXT the afterglow is detected up to ∼10^4 s. For more details, see the SVOM white paper (Wei et al. 2016).

2.4. VT

The Visible Telescope (VT) main purpose is to detect and observe the optical afterglows of GRBs localized by ECLAIRs. It is a Ritchey-Chretien telescope with a 40 cm diameter and its limiting magnitude is about M_V=22.5 for a 300 s integration time. The VT is designed to maximize the detection efficiency of GRB's optical afterglows. A dichroic beam splitter divides the light into two channels, in which the GRB afterglow is observed simultaneously, a blue channel with a wavelength from 0.4 to 0.65 μm and a red channel from 0.65 to 1 μm. Each channel is equipped with a 2K×2K CCD detector. The Quantum Efficiency (QE) of the red-channel CCD is over 50% at 0.9 μm, which gives VT the capability of detecting GRBs with redshifts up to 6.5. The VT FoV is about 26×26 arc min^2, covering the ECLAIRs error box in most cases.

3. The SVOM ground segment

Three optical/infrared instruments compose the ground-based SVOM system. The first unit of the Ground-based Wide Angle Cameras (GWACs), currently located Xinglong (China), and is already operational. Another unit may be installed later at a different site. The GWACs located in China consist of 40 cameras of 180 mm diameter, covering ∼6000 deg^2 in total in the wavelength range 500-850 nm. The GWAC system can reach a magnitude limit of V=16 in 10 s. In addition to the GWACs, whose main goal is to try to catch the prompt optical emission of SVOM GRBs, two robotic 1-m class telescopes are being included in the

SVOM system. The Chinese Ground Follow-up Telescope (C-GFT) has a 1.2 m diameter primary mirror, is located at the Jilin observatory, has a field of view of 21×21 arc min^2 and is sensitive in the 400-950 nm wavelength range. The French Ground Follow-up Telescope (F-GFT/Colibri) will have a 1.3 m diameter primary mirror and will be installed in San Pedro Martir (Mexico). It offers a field of view of 26×26 arc min^2 and operates simultaneously in 3 bands from 400 to 1700 nm.

The SVOM ground segment includes a set of VHF antennas (about 40), which will be deployed on the projected track of the satellite in order to collect in real time the alerts produced by the platform. These VHF ground stations will be connected to the French Science Centre (FSC), which will immediately dispatch the alerts produced by all the SVOM instruments to the scientific community. We expect that 65% of the SVOM alert messages are delivered within less than 30 s, and that 95% of them reach the observers within less than 20 minutes.

4. Conclusions

SVOM will play a key role in the upcoming era of time domain and multi-messenger astronomy. At the time of SVOM launch, new large sky area time domain oriented instruments, like the LSST in the optical or the SKA at radio wavelengths, will deliver an unprecedented number of well localized ToOs that may be worth following up with the space-borne and ground-based SVOM instruments. Gravitational wave detectors (advanced LIGO, VIRGO, LIGO-India, KAGRA, etc.) will provide more alerts than now with improved localisation accuracies. Neutrino detectors IceCube-Gen2, KM3NeT (extension of ANTARES), etc. will also trigger a significant number of alerts. In this respect, the SVOM/MXT grasp appears to be well adapted to the large error boxes delivered by gravitational wave and neutrino detectors.

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