Space Multi-band Variable Objects Monitor

-----A Chinese-French Mission for GRBs

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On behalf of the joint SVOM team

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Open Questions in GRB Physics

- **Classification** (how many physically distinct types?)
- **Progenitors** (massive stars vs. compact stars; others?)
- **Central engine** (black hole, magnetar, quark star?)
- **Ejecta composition** (baryonic vs. magnetic)
- **Energy dissipation mechanism** (shock vs. magnetic reconnection)
- **Particle acceleration & radiation mechanisms** (synchrotron, inverse Compton, quasi-thermal)
- **Afterglow physics** (medium interaction vs. long-term engine activity)

From Bing Zhang, 2010
The first stars and the baby Universe

~13.8Byrs

Evolution after the big bang

Re-Iron.

Pop III

Dark Age

last diffusion limit

GRB 090429B z=9.4

Evolution after the big bang

Now

Sun

Big Bang

3
10
100
1000
3000

10^10
10^9
10^8
10^7
10^6
10^5

1 + z

10
100
300
1000
Multi-Messenger Astronomy in 2020’s

- **Big telescopes:** JWST, ELT, ALMA, SKA…
- **Opt. Survey:** PanSTARRs, ZTF, LSST…
- **Advanced GW detectors:** A-LIGO, A-Virgo, KAGRA…..
- **Neutrino detectors:** IceCube, KM3, ANTARES…
- **Ultra high energy cosmic rays:** LHAASO, AUGER, CTA….
- **GRB missions:** Swift?, Fermi?
Scientific rationale of a new GRB mission

GRB phenomenon • Diversity and unity of GRBs

GRB physics • Acceleration and nature of the relativistic jet
• Radiation processes
• The early afterglow and the reverse shock

GRB progenitors • The GRB-supernova connection
• Short GRB progenitors

Cosmology • Cosmological lighthouses (absorption systems)
• Host galaxies
• Tracing star formation
• Re-ionization of the universe
• Cosmological parameters

Fundamental physics • Origin of high-energy cosmic rays
• Probing Lorentz invariance
• Short GRBs and gravitational waves
Scientific requirements on SVOM

- Permit the detection of all known types of GRBs (>200), with a special care on high-z GRBs and low-z sub-luminous GRBs

- Provide fast, reliable and accurate GRB positions

- Measure the broadband spectral shape of the prompt emission (from visible to MeV)

- Measure the temporal properties of the prompt emission

- Quickly identify the afterglows of detected GRBs, including those which are highly redshifted (z>6)

- Quickly provide (sub-) arcsec positions of detected afterglows

- Quickly provide redshift indicators of detected GRBs
Proposed scientific instruments

- **ECLAIRs**, the X-ray and soft gamma-ray trigger camera
  - Energy range: 4-250 KeV
  - Solid angle: 2sr (90*90 deg)

- **GRM**, the gamma-ray spectro-photometer
  - Energy range: 30 KeV-5 MeV
  - Solid angle: ~2π

- **MXT**, the micro-channel soft X-ray telescope
  - Energy range: 0.3-5 KeV
  - Field of View: 65’×65’

- **VT**, the visible telescope
  - Wavelength range: 400-650 nm, 650-950 nm
  - Field of View: 26’×26’

- **GWAC**, an array of ground wide angle cameras
  - Wavelength range: 450-900 nm
  - Solid angle: 2sr

- **C-GFT**, the Chinese ground follow-up telescope
  - Wavelength range: 400-1700 nm
  - Field of View: 25’×25’

- **F-GFT**, the French ground follow-up telescope
  - Wavelength range: 400-1700 nm
  - Field of View: 30’×30’
Eclairs: the trigger

- 2-D coded mask (30% transparency)
- Passive shield to block X-ray background
- 200 modules of 32 CdTe detectors (4 mm × 4 mm)
  - Useful area: 1024 cm²

Field of view: 2 sr
Spectral domain: 4 keV to 250 keV
ECLAIRs: the trigger camera

Main design objective

A low energy threshold in the X-ray domain

Simulated sensitivity

ECLAIRs expected to be more sensitive than SWIFT (BAT) for GRBs whose peak energy is < 20 keV

![Energy spectrum graph]

- **Counts**
  - 0
  - 100
  - 200
  - 300

- **Energy (keV)**
  - 0
  - 10
  - 20
  - 30
  - 40
  - 50
  - 60

- **3.5 keV**
Simulated redshift distribution of long GRBs to be detected by ECLAIRs

Nearly 10-20% of ECLAIRs GRBs could be situated at high redshift (z > 6)
GRM: the Gamma-Ray Monitor

Scintillation (phoswich) detector

NaI (D~160 mm)

FoV: ~2 π

Spectral Domain: 30 keV to 5 MeV

Measurement of $E_{\text{peak}}$ (up to ~ 500 keV)
GRM: 3 Modules

Localization error ~10 degrees
MXT: to provide the accurate positioning

Micro-Channel optics

Effective area

PN detector from MPE

Field of view: 65 arc min × 65 arc min
Spectral domain: 0.3 keV to 5 keV
Useful area: 52 cm² at 1 keV

Detected GRBs to be localized with an error ~ 20 arc sec
MXT can detect \(~90\%) of the afterglows
VT: the Visible Telescope

Modified R-C optical design

Aperture size: 400 mm
Focal length: 3600 mm
Field of View: 26 arc min × 26 arc min
Bands: 400-650 nm & 650-950 nm

Afterglow emission detection down to $M_V \sim 22.5$ (300 s exposure)
The intrinsic cumulative GRB apparent optical afterglow distribution

To detect ~ 80% of the observed GRBs

VT: the visible telescope

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Spectral band</th>
<th>Field of View</th>
<th>Allocation Accuracy</th>
<th>GRBs/yr (Detect. Rate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GRM</td>
<td>30keV-5MeV</td>
<td>2 sr</td>
<td>Not applicable</td>
<td>~100</td>
</tr>
<tr>
<td>ECLAIRs</td>
<td>4-250 keV</td>
<td>2 sr</td>
<td>10 arcmin</td>
<td>~80</td>
</tr>
<tr>
<td>MXT</td>
<td>0.3-5 keV</td>
<td>65×65 arcmin</td>
<td>30 arcsec</td>
<td>~90%</td>
</tr>
<tr>
<td>VT</td>
<td>400-650 nm</td>
<td>26×26 arcsec</td>
<td>1 arcsec</td>
<td>~80%</td>
</tr>
<tr>
<td></td>
<td>650-950 nm</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Parameters of GWAC

- **Cameras:** 72
- **Diameter:** 180mm
- **Focal Length:** 213mm
- **Wavelength:** 450–900nm
- **Total FoV:** 9000Sq.deg
- **Limiting Mag:** 16.0V (5σ, 10sec)

Prompt optical emission detection down to \( M_V \sim 16.0 \) (10 s exposure)
Provide new window to understand GRBs.

Extend 3-4 order!
Two 60cm multi-color telescope
-----A contribution to GWAC from GXU

- Diameter: 60cm
- FoV: 10arcmin
- Colors: g,r,i (z)
- CCDs: 1k×1k EMCCD

- Confirming GWAC OT:
  ✓ Sub-arcsecond localization
  ✓ Multi-color diagram

- One-second time resolution light curves
  ✓ Time resolution is very important to understand about prompt emissions
SVOM: Combined optical light curve

Kann et al 2010

GWAC

GFT

VT

T-t0=30 sec
GWAC: a new era for opt. transients

Wozniak et al. 2009
About 75% of the GRBs detected by SVOM to be well above the horizon of large ground based telescopes all located at tropical latitudes.
Red-shift measurement: Swift (and before)

- 238 GRBs with redshift
- Only 4 with z > 6, < 2%!
Prompt dissemination of the GRB parameters

VHF Network
GRB observation strategy

**Space**
- GRB trigger provided by ECLAIRs at time $T_0$

**Ground**
- $T_0 + 1$ min
  - GWAC
  - GFTs (g, r, i, J, H)

- $T_0 + 5$ min
  - VT (V & R band photometry)
  - MXT (Soft X-ray photometry)

- 1-2 m robotic telescopes

**Multi messenger follow-up**
Multi-wavelength capabilities of SVOM
SVOM compared to Swift

- **Prompt emission measurement**
  - More sensitive below 20keV (to 4keV)
  - Better Epeak measurement capability
  - Prompt optical emission

- **Afterglow emission measurement**
  - 10 times more sensitive in the visible, additional 650-950 nm band

- **Ground follow-up observation**
  - Two dedicated 1 meter telescopes with NIR detector
  - GRBs much easily scrutinized by the largest telescopes
Hunting for high-z GRBs

- SVOM is going to provide redshift indicators to GCN
  - Eclairs + GRM: pseudo redshift
  - VT: redshift indicator: $z<4.2$, $4<z<6.0$, $z>6.0$ or “dark”
  - GFTs: photometric redshift

- Ground near Infrared telescopes are encouraged to point promptly to the GRBs which are detected by MXT in X-ray, but not by VT! (~10 per year)
Status of the SVOM mission

2005  Sino-French discussions (CNES-CNSA) on a mini satellite mission
      Scientific discussions on the SVOM mission for GRB studies

2006  SVOM Phase 0 kick-off meeting (March, Toulouse)
      SVOM phase 0 review (Sept., Shanghai) – No critical issue
      CNSA/CNES MoU signed during the President visit (Oct., Beijing)

2007  SVOM Phase A kick-off meeting (March, Xi’an)
      SVOM mission approved by CNES SPC (April, Paris)

2008  SVOM Phase A review meeting (Oct., Beijing)

2009  SVOM proved by CNES France

2010  SVOM funded by CNSA China

2017/18  SVOM launch at Xichang (西昌), China
谢谢！