Glowbug: a gamma-ray telescope for bursts and other transients


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J. Eric Grove, U.S. Naval Research Laboratory
Glowbug: all-sky 30 keV – 2 MeV band transient monitor optimized for GRBs

Glowbug is funded by NASA APRA for early 2020s launch

- Good sensitivity at low cost
- Large area scintillators with SiPM readout
- Effective area \( \sim 2 \times \) Fermi GBM
- Attached payload Instrument \( \sim 65 \) kg

- High rate of GRB detections
- Modest localization ability
- Rate \( \sim 70 \) short GRBs / year
- Comparable to Fermi GBM

Distribution A. Approved for public release; distribution unlimited.
Tech demonstrator for GAMERA SmallSat mission concept

- Large scintillator array
  - CsI(Tl) + SiPM readout (12 detectors, each 15x15x1 cm$^3$)
    - Good stopping power; not hygroscopic
    - Low size, weight, and power readout
  - CLLB + SiPM readout (6 detectors, each 5 cm diam x 10 cm)
    - Additional effective area above 1 MeV
  - Front end and DAQ from NRL's SIRI-2
    - Low power, space qualified

- Selected by NASA APRA
  - Funding began March 2019

- Launch via DoD Space Test Program (STP)
  - Proposed for STP-H9 to International Space Station (ISS) in early 2023
  - STP provides integration, launch, and 1 year operations costs
Goal: obtain best-possible sensitivity (maximal detector area, minimal background) and degree-scale localization

Design concept: large-area array of SiPM-read CsI(Tl) scintillators

Cesium iodide CsI:Tl
- Better stopping power and photopeak efficiency than NaI
- Minimally hygroscopic, which eliminates need for hermetic enclosures

Silicon photomultipliers (SiPMs)
- High gain, low noise readout of scintillators
- Low size, weight, and power (SWaP); low cost; low operating voltage
  - Heritage from NRL's Strontium Iodide Radiation Instrumentation program

Cs$_2$LiLaBr$_6$:Ce (CLLB)
- Neutron and gamma sensitive scintillator; excellent energy resolution
- Space-qualify new scintillator and improve high energy sensitivity
Aside: SIRI-1 space-qualifies SiPMs, SrI$_2$

**Strontium Iodide Radiation Instrumentation**

- **Purpose:** Space-qualify high-resolution scintillator SrI$_2$ (<3% at 662 keV), SensL SiPMs, with BeagleBone Black Single-Board Computer (SBC)

- SIRI-1 launched 3 December 2018 on STPSat-5

- SensL J-series SiPMs are operating today on orbit

Gamma-ray count rate (E > 30 keV) in SIRI-1 in southern hemisphere during Feb 2019.

Instrument paper:
Total event rate shows elevated background as SIRI transits various trapped particle regions.

- Data from four zones A, B, C and D shown in plot above right
- White area indicates no data (i.e. SAA, where data acquisition is paused)
Design Overview

- **Primary detectors**
  - Seven SrI$_2$(Eu) in hexagonal close-pack design
    - 38.1 mm diameter (19.05 mm per side) x 38.1 mm length
  - SiPM readouts
    - 19 6-mm SensL J-series SiPMs in hexagonal array on PCB

- **Active shield**
  - Six plastic detectors for approx. 4$\pi$ coverage
  - Anticoincidence rejects high-energy cosmic-ray protons

- **Passive shield**
  - Attenuate X-rays during solar events (prevent “swamping” of system)
  - Reduce Bremsstrahlung produced by electrons interacting with enclosure

- **Single CsI detector**
  - External to passive gamma shield
  - Measure hard X-ray component of solar flare

**Aside: SIRI-2 solar gamma-ray spectrometer**

- **Instrument delivered to spacecraft vendor**
- **Awaiting launch Aug 2020 on STPSat-6 to GEO**


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Front end and data acquisition system

- Replicates existing SIRI-2 design
  - Average power 23 W
  - GPS-derived time stamps (<1 us)

Concept of operations

- Rate mode, formed from event list stream
- Autonomous burst detection, switching to event list downlink in ~100 sec pre and post window
- Burst Alert message
- Note: if ISS, entire ~3 GB/day event list dataset will be downlinked
**Detector performance**

- Used SIRI-2 flight unit to shape, digitize largest Glowbug detector
  - CsI(Tl) crystal 15x15x1 cm
  - SiPM array

Measured energy resolution with flood illumination of 15x15x1 cm CsI(Tl) tile, SiPMs, and flight-model SIRI-2 front end and DAQ.

**FWHM = 7.9% at 662 keV**

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Performance estimated from detailed Monte Carlo simulations of scintillator modules, instrument geometry model, and maximum likelihood analyses performed using realistic GBM background

- **~2x Fermi GBM effective area** (total, 12 GBM NaI dets) for typical GRB spectrum
- **CLLB ~ equivalent at 2 MeV to one BGO** detector of Fermi GBM, but with 2x better energy resolution

- Increase in effective area expands horizon for faint sources in local universe by ~1.4
- Estimate ~ 70 sGRB / yr
- EM counterparts of GW binary mergers
Glowbug summary

- Good sensitivity at low cost
- Effective area ~2 x Fermi GBM
- High rate of GRB detections
- Modest localization ability

Larger than CubeSat Instrument ~65 kg
- Funded by NASA
- Launch to be provided by DoD

- Rate ~ 70 short GRBs / year
- Comparable to Fermi GBM

Email me: eric.grove@nrl.navy.mil