SIRI-2 Detection of the Gamma-ray Burst 221009A

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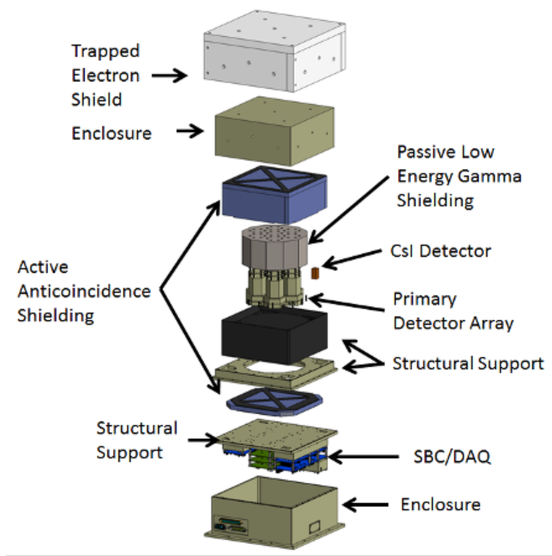
Abstract: SIRI-2 is a collection of Strontium Iodide gamma-ray detectors sensitive at approximately 400 keV to 10 MeV, launched on the Department of Defense's STPSat-6 to geosynchronous orbit. SIRI-2 detected the gamma-ray burst (GRB) 221009A and, unlike most GRB detectors, was not saturated and did not require any pulse pile-up corrections. We present observations of this GRB by SIRI-2, including spectral fits and comparison with other detectors.

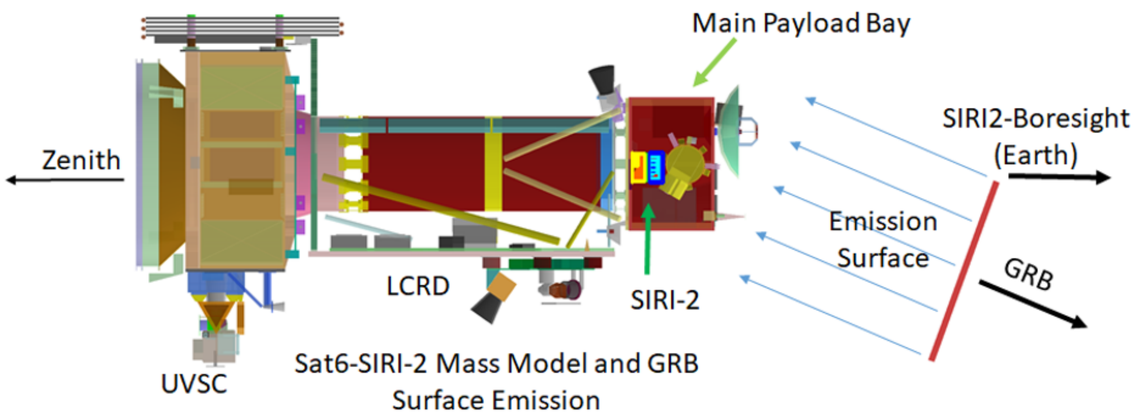
I. GRB 221009A

The Gamma-ray Burst 221009A was the brightest of all time (BOAT; Burns et al. 2023). It was detected by almost every astrophysical gamma-ray detector that existed at the time of its explosion. The burst was so bright that most gamma-ray detectors were saturated. One exception was the Strontium Iodide Radiation Instrument II (SIRI-2; Mitchell et al. 2022).

II. SIRI-2 Instrument



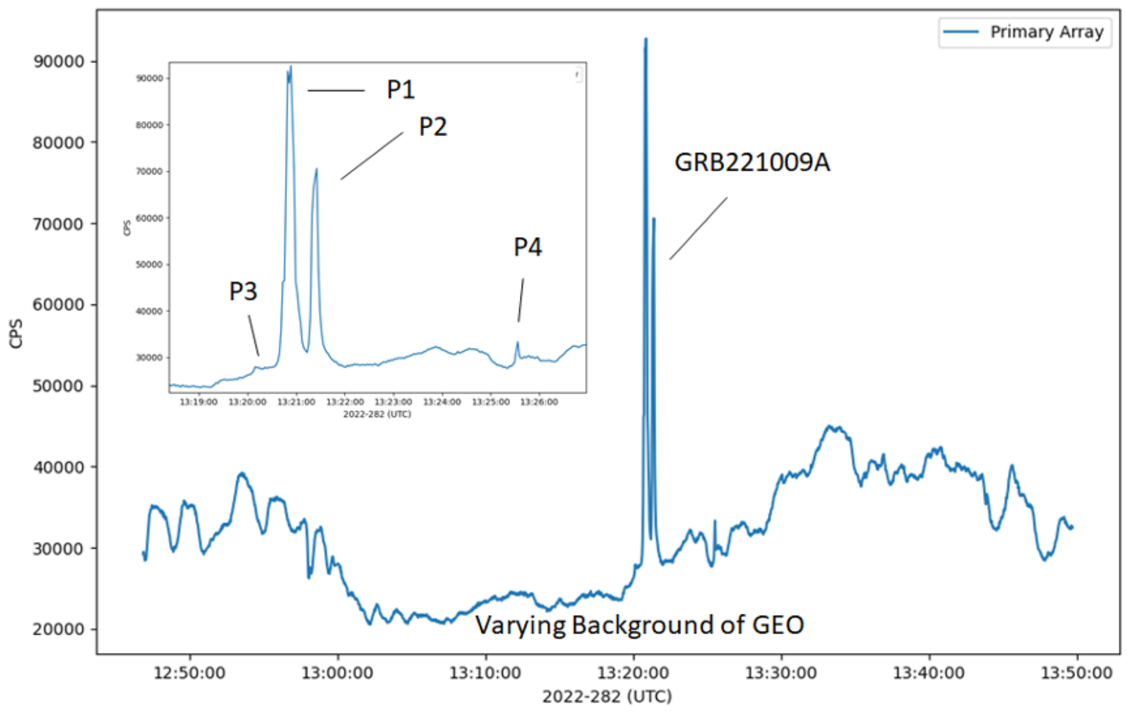
Two SIRI instruments have been launched as part of the Department of Defense Space Test Program (STP). The original instrument was launched in 2017. SIRI-2 was launched in 2021 to geosynchronous (GEO) orbit onboard STPSat-6. SIRI-2 consists of 7 hexagonal shaped SrI_2:Eu detectors with a frontal area of 66 cm^2, and an anti-coincidence detector. The SrI_2 scintillator has greater energy resolution than most room-temperature detectors (4% at 662 keV) and does not have cryogen requirements like, e.g., Germanium used by COSI (Tomsick et al. 2023). It is sensitive in the energy range 400-7000 keV. ***Left***: Exploded view showing major components of the SIRI-2 Instrument. ***Below***: Mass model for STPSat-6 and SIRI-2, along with simulated direction of GRB 221009A and the Earth.



Sat6-SIRI-2 Mass Model and GRB Surface Emission

III. SIRI-2 Light Curve of 221009A

Below: Light curve of 221009A with SIRI-2. The rapidly varying background at GEO is shown. Several peaks of the GRB are shown in the inset.



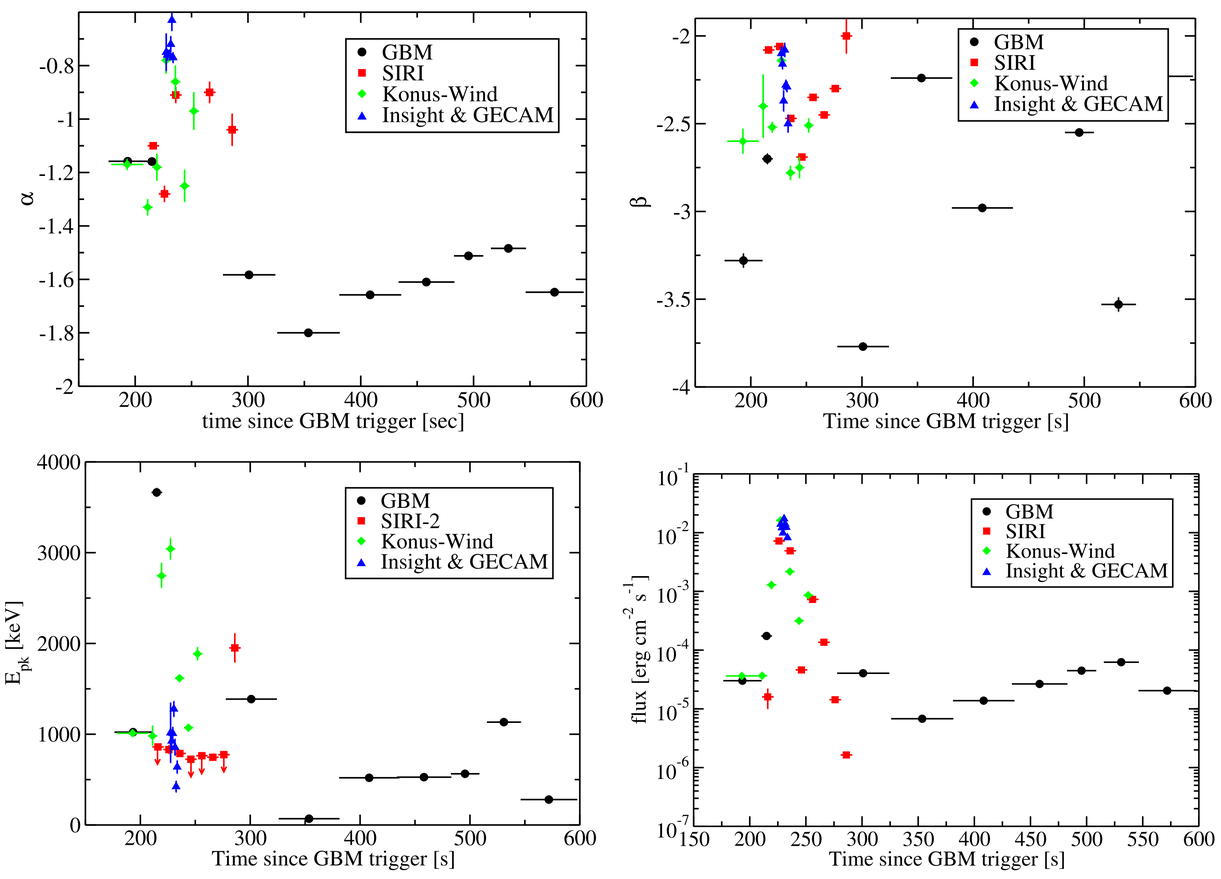
IV. Spectral fits

Table 1. Result of Band Function fits

Time since GBM trigger [s]	α	β	E_{pk} [keV]	20 keV - 10 MeV flux [erg cm^{-2} s^{-1}]
$211-221$	-1.1^{*}	-2.08 ± 0.02	<860	$(1.6\pm0.6)\times10^{-5}$
$221-231$	-1.28 ± 0.03	-2.06 ± 0.01	831 ± 46	$(7.2\pm0.2)\times10^{-3}$
$231-241$	-0.91 ± 0.03	-2.47 ± 0.01	788 ± 22	$(4.9\pm0.1)\times10^{-3}$
$241-251$	-1.1^{*}	-2.69 ± 0.01	<724	$(4.60\pm0.07)\times10^{-5}$
$251-261$	-1.1^{*}	-2.35 ± 0.01	<763	$(7.3\pm0.1)\times10^{-4}$
$261-271$	-0.90 ± 0.014	-2.45 ± 0.02	746 ± 29	$(1.36\pm0.04)\times10^{-4}$
$271-281$	-1.1^{*}	-2.30 ± 0.01	<775	$(1.43\pm0.03)\times10^{-5}$
$281-291$	-1.04 ± 0.06	-2.00 ± 0.10	1951 ± 160	$(1.64\pm0.05)\times10^{-6}$

*Fixed in fit.

We fit the spectrum of GRB 221009A with a Band function (Band et al. 1993). SIRI-2 was designed to qualify these new scintillators in the space environment, not necessarily for science operations. Consequently, there are no response functions for SIRI-2. In order to fit the spectra, we simulated the instrument's response to several Band function spectra using SWORD (Duvall et al. 2019) and Geant4. Fits were performed in the 600-7000 keV band. Results were extrapolated to the 20 keV – 10 MeV bandpass for comparison with other instruments. ***Above***: Band function parameters from this fit. ***Below***: Band function parameters as a function of time for SIRI and several other instruments, taken from the literature (GBM, Lesage et al. 2023; Konus-Wind, Frederiks et al. 2023; Insight and GECAM, An et al. 2023).



The SIRI-2 spectral results are generally consistent with other instruments. The value E_{pk} with SIRI-2 is softer than instruments that were saturated (Fermi-GBM and Konus-Wind), but roughly consistent with GECAM, which was not saturated. Lesage et al. (2023) did not attempt to correct the instrument for saturation during the bad time intervals. Frederiks et al. (2023) did try estimate spectral parameters with Wind while the instrument was saturated, by correcting for pulse pile-up. For this instrument, many lower-energy photons may have been recorded as higher energy photons, leading to a harder spectrum determined by the instrument than the actual GRB spectrum.

References:
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