

Overview of GECAM Observations from 2024 to 2026*

XIONG Shaolin

(State Key Laboratory of Particle Astrophysics, Institute of High Energy Physics,
Chinese Academy of Sciences, Beijing 100049)

Abstract During the past two years, the Gravitational-wave high-energy Electromagnetic Counterpart All-sky Monitor (GECAM) has developed into a multi-instrument constellation, including GECAM-A/B, GECAM-C, and GECAM-D, for monitoring high-energy transients over a broad energy range from about 10 keV to 5 MeV. GECAM observations have produced important results on gamma-ray bursts, compact binary mergers, magnetar X-ray bursts, high-energy counterparts of fast X-ray transients, and terrestrial high-energy events. This review summarizes highlight of GECAM results published from 2024 to 2026, emphasizing observations of GRB 221009A, GRB 230307A, and the prolific Galactic magnetar SGR J1935+2154. These observations demonstrate the important role of GECAM as a high-time-resolution, all-sky gamma-ray monitor in time-domain multi-messenger astronomy and space science.

Key words GECAM, Gamma-ray bursts, Magnetars, Fast radio bursts, High-energy transients

Classified index V474

1 Introduction

Gamma-ray transients are sudden enhancements of high-energy emission that may originate from astrophysical or near-Earth sources. They include cosmological Gamma-Ray Bursts (GRBs), GRBs associated with Gravitational Waves (GWs), Soft Gamma-ray Repeaters (SGRs), bursts associated with Fast Radio Bursts (FRBs), Solar Flares (SFLs), Terrestrial Gamma-ray Flashes (TGFs), Terrestrial Electron Beams (TEBs), particle precipitation events, and related phenomena. The joint detection of GW170817 and GRB 170817 A established compact-object mergers as a central topic of multi-messenger astronomy^[1,2]. GECAM was primarily designed to provide all-sky, wide-band, high-time-resolution monitoring for these critical events and other gamma-ray transients.

GECAM-A and GECAM-B were launched on

10 December 2020 (Beijing Time). GECAM-C, carried by the SATech-01 satellite, was launched on 27 July 2022, and deorbited in February 2025, and GECAM-D, carried by the DRO-A spacecraft, was launched on 13 March 2024. The GECAM series now provides multi-platform monitoring with gamma-ray detectors and charged-particle detectors, covering roughly 10 keV to 5 MeV for various high-energy transients.

The main science targets of GECAM remain on high-energy counterparts of GWs and FRBs, GRBs, and SGRs. In addition, GECAM has become useful for studies of solar flares, TGFs/TEBs, particle precipitation, and high-energy cosmic rays in low Earth orbit.

2 GRBs

GRBs are among the most luminous explosive phenomena in the universe. The underlying physics and mecha-

* Supported by the National Natural Science Foundation of China (12273042)

Received June 30, 2026

©The Author(s) 2026. This is an open access article under the CC-BY 4.0 License (<https://creativecommons.org/licenses/by/4.0/>)

nisms of GRBs remain uncertain. Bright GRBs provide an important opportunity to probe these questions. GECAM is particularly valuable for these studies because its detectors can record very bright events with high time resolution and reduced saturation effects.

2.1 GRB 221009A

GRB 221009A, the brightest gamma-ray burst of all time, remains one of the most important bursts. GECAM-C recorded the prompt emission without the severe saturation that affected several other instruments, allowing precise measurements of the prompt burst, early afterglow, flare component, and high-energy spectral evolution^[3–7]. Additional results based on GECAM observations of this burst have been reported during the past two years.

A major result reported in 2024 was the identification of time-evolving spectral-line features in GRB 221009A (see Figure 1). The line centroid was reported to reach up to 37 MeV and to decrease approximately as a power law with time, while the line energy flux also decayed as a power law^[6]. Subsequent theoretical work discussed the production mechanism of the high-energy emission line, including an interpretation based on electron-positron pair annihilation followed by down-Comptonization in an evolving GRB outflow^[7]. These studies suggest that line features could become a direct diagnostic of the bulk Lorentz factor and radiation region in GRB jets.

GECAM observations also help connect flare activ-

ity with prompt emission in extremely bright GRBs. A recent analysis reported the brightest GRB flare observed in GRB 221009A and argued that the flare occupies the parameter space between classical X-ray flares and prompt-emission pulses, helping to bridge the gap between late internal activity and the prompt phase^[8].

2.2 GRB 230307A

GRB 230307A is the second-brightest GRB and the brightest merger-origin GRB reported so far. Although its duration is long, its prompt properties measured by GECAM, host-galaxy environment, and kilonova association indicate a compact-object-merger origin^[9,10]. This event therefore strengthens the view that the physical classification of GRBs cannot rely only on the duration of prompt emission.

Broadband GECAM and LEIA observations revealed a transition from gamma-ray emission to an extended X-ray component, interpreted as evidence for a long-lived central engine. An achromatic temporal break in the GECAM-detected hard X-ray light curve during the prompt phase was interpreted as a jet edge effect, providing a new way to constrain jet geometry directly during prompt emission^[9].

Modeling of the rapidly variable components in the saturation-free light curve of GRB 230307A measured by GECAM supports a minijet-emission interpretation in a large emission region within a magnetically dominated jet^[10]. Further work on GRB 230307A and related long merger-origin bursts identified distinctive prompt-

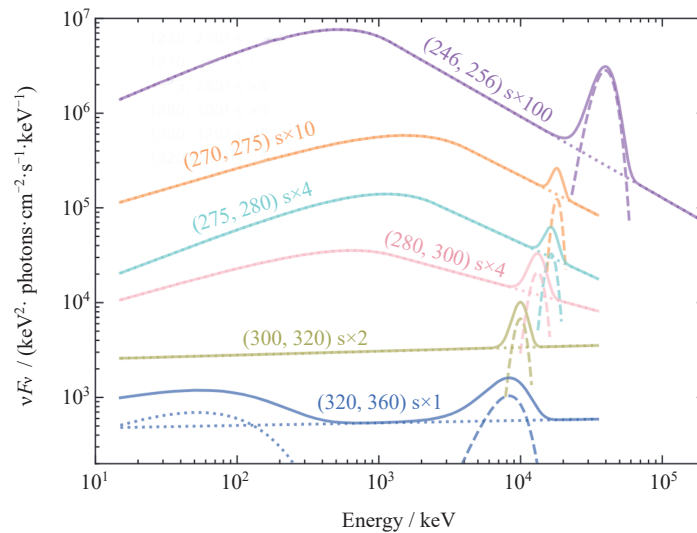


Fig. 1 MeV emission lines found in GRB 221009A by jointly analyzing the GECAM-C and Fermi/GBM data^[6]

emission properties, including exponential evolution of pulse intensities, waiting times, pulse widths, and spectral peak energy^[11]. Remarkably, a brief 909 Hz gamma-ray periodic signal has been revealed in the GECAM accurate light curve of GRB 230307A, providing strong evidence for a millisecond-magnetar central engine in this burst^[12].

2.3 Other GRBs

The operation of Einstein Probe (EP) has increased the need for high-energy monitoring of Fast X-ray Transients (FXTs). A systematic search for gamma-ray counterparts of EP fast X-ray transients using GECAM together with Insight-HXMT and Fermi/GBM found that about 22% of FXTs have gamma-ray counterparts^[13]. Another systematic search of Fermi/GBM subthreshold triggers in GECAM data extended the short-GRB population, improving the statistical context for weak compact-merger candidates^[14]. GECAM also detected early emission from the very important ultralong GRB 250702B/EP250702a. A targeted ETJASMIN search over a 30-day window using GECAM, Insight-HXMT, and Fermi/GBM data revealed multi-episode main emission lasting several hours, making it one of the longest GRBs ever detected^[15].

3 SGRs and FRB-associated Bursts

SGRs are recurrent X-ray and soft gamma-ray bursts from magnetars, a class of neutron stars with extremely strong magnetic fields. SGR J1935+2154 is the most important GECAM magnetar target because it produced FRB 200428 and later radio-burst-associated X-ray bursts. GECAM observations from the 2021 and 2022 active episodes have enabled catalogue-level studies of burst timing, spectra, and morphology^[16–19]. Together with Fermi/GBM and Insight-HXMT data, the GECAM sample supports studies of burst waiting times, duration, spectral hardness, and correlations among temporal and spectral parameters.

Several studies used this sample to examine magnetar-burst phenomenology. Spectral lag and minimum variation timescale studies indicate millisecond-scale structures and energy-dependent timing behavior, pointing to compact emission regions in the magnetosphere^[17,18]. Power density spectrum and self-organized

criticality analyses further suggest that some timing properties are scale invariant across the burst population^[19,20].

Remarkably, GECAM detected rare Magnetar X-ray Bursts (MXBs) associated with radio bursts from SGR J1935+2154, including MXB 221014 and the peculiar MXB 221120^[21,22]. These observations strengthen the empirical connection between magnetar X-ray bursts and FRB-like radio emission, while showing that radio association is not a simple function of X-ray fluence alone.

GECAM observations have also revealed more detailed light-curve morphology in magnetar bursts. Recent studies of GECAM observations of SGR J1935+2154 revealed a peculiar burst pattern called ER-COD^[23] and eclipse features in X-ray bursts that can be used to probe trapped fireballs and magnetospheric geometry^[24].

Overall, the magnetar results from 2024 to 2026 indicate that GECAM is useful both for event discovery and for population studies. The same data set supports burst catalogues, FRB-association searches, timing analyses, and physical modeling of magnetar fireballs.

4 High-energy Transients around the Earth

GECAM's configuration of both gamma-ray detectors and charged-particle detectors provides a way to study near-Earth particle phenomena as well as gamma-ray transients. Building on earlier TGF and TEB observations^[25], recent work reported peculiar oscillating particle-precipitation events discovered by GECAM^[26]. These events indicate that GECAM data can probe the coupling between magnetospheric particles and the near-Earth environment.

A related methodological advance is the pitch-angle measurement method based on detector-count distributions of GECAM^[27]. By using the relative count rates of multiple detectors, the method aims to infer the incident direction and pitch-angle information of charged particles. This expands the scientific use of GECAM from transient detection to quantitative studies of particle anisotropy and precipitation geometry.

Finally, a systematic study of simultaneous events

detected by GECAM suggests a novel way to monitor and characterize high-energy cosmic rays in low Earth orbit^[28].

5 Summary

From 2024 to 2026, GECAM research has moved from mission demonstration to systematic exploitation of the transient universe. For GRBs, GECAM provided key unsaturated observations of the brightest events, including GRB 221009A and GRB 230307A, and contributed to studies of jet structure, spectral-line features, prompt emission and flare connections, and merger-origin long GRBs. For magnetars, GECAM observations of SGR J1935+2154 enabled burst catalogues, timing analyses, FRB-association burst studies, and constraints on magnetar and fireball geometry. Additionally, GECAM has contributed to a broader transient science program, including particle-precipitation and cosmic-ray events in low Earth orbit. These results confirm GECAM's role as an important Chinese high-energy transient monitor in the era of time-domain multi-messenger astronomy and space science.

Conflict of Interests The authors declare that there is no conflict of interests

References

- [1] ABBOTT B P, ABBOTT R, ABBOTT T D, *et al.* Gravitational waves and gamma-rays from a binary neutron star merger: GW170817 and GRB 170817A[J]. *The Astrophysical Journal Letters*, 2017, **848**(2): L13
- [2] GOLDSTEIN A, VERES P, BURNS E, *et al.* An ordinary short gamma-ray burst with extraordinary implications: *Fermi*-GBM Detection of GRB 170817A[J]. *The Astrophysical Journal Letters*, 2017, **848**(2): L14
- [3] LIU J C, ZHANG Y Q, XIONG S L, *et al.* GRB 221009A: HEBS detection[J/OL]. *GRB Coordinates Network*, (2022-10-14). <https://ui.adsabs.harvard.edu/abs/2022GCN.32751....1L/abstract>
- [4] AN Z H, ANTIER S, BI X Z, *et al.* Insight-HXMT and GECAM-C observations of the brightest-of-all-time GRB 221009A[OL]. arXiv preprint, arXiv: 2303.01203, 2023
- [5] ZHENG C, ZHANG Y Q, XIONG S L, *et al.* Observation of GRB 221009A early afterglow in X-ray/gamma-ray energy bands[J]. *The Astrophysical Journal Letters*, 2024, **962**(1): L2
- [6] ZHANG Y Q, XIONG S L, MAO J R, *et al.* Observation of spectral lines in the exceptional GRB 221009A[J]. *Science China Physics, Mechanics & Astronomy*, 2024, **67**(8): 289511
- [7] LIU J Y, MAO J R, XIONG S L, *et al.* The production mechanism of the high-energy emission line in the brightest cosmic burst[OL]. arXiv preprint arXiv: 2509.14715, 2025
- [8] YU Z H, WANG C W, XIONG S L, *et al.* Brightest gamma-ray-burst flare observed in GRB 221009A: bridging the last gap between the prompt emission and flare in gamma-ray bursts[J]. *The Astrophysical Journal Letters*, 2026, **998**(1): L21
- [9] SUN H, WANG C W, YANG J, *et al.* Magnetar emergence in a peculiar gamma-ray burst from a compact star merger[J]. *National Science Review*, 2025, **12**(3): nwae401
- [10] YI S X, WANG C W, SHAO X, *et al.* Evidence of minijet emission in a large emission zone from a magnetically dominated gamma-ray burst jet[J]. *The Astrophysical Journal*, 2025, **985**(2): 239
- [11] MACCARY R, GUIDORZI C, MAISTRELLO M, *et al.* A set of distinctive properties ruling the prompt emission of GRB 230307A and other long γ -ray bursts from compact object mergers[J]. *Journal of High Energy Astrophysics*, 2026, **49**: 100456
- [12] CHEN R C, ZHANG B B, WANG C W, *et al.* Evidence for a brief appearance of gamma-ray periodicity after a compact star merger[J]. *Nature Astronomy*, 2025, **9**(11): 1701-1713
- [13] ZHANG Y Q, XUE W C, ZHANG J P, *et al.* Multi-instrument search for gamma-ray counterpart of X-ray transients detected by EP/WXT[J]. *The Astrophysical Journal Letters*, 2025, **987**(2): L38
- [14] CAI C, XIONG S L, ZHANG Y Q, *et al.* Extending the short gamma-ray burst population from subthreshold triggers in *Fermi*/GBM and GECAM data and its implications[J]. *The Astrophysical Journal Letters*, 2025, **989**(2): L21
- [15] ZHANG J P, WANG C W, YU Z H, *et al.* On the ultralong gamma-ray transient GRB 250702B/EP 250702a[J]. *The Astrophysical Journal Letters*, 2026, **997**(2): L45
- [16] XIE S L, CAI C, YU Y W, *et al.* GECAM observations of the galactic magnetar SGR J1935+2154 during the 2021 and 2022 burst active episodes. I. burst catalog[J]. *The Astrophysical Journal Supplement Series*, 2025, **277**(1): 5
- [17] XIAO S, TUO Y L, ZHANG S N, *et al.* Discovery of the linear energy dependence of the spectral lag of X-ray bursts from SGR J1935+2154[J]. *Monthly Notices of the Royal Astronomical Society*, 2023, **521**(4): 5308-5333
- [18] XIAO S, YANG J J, LUO X H, *et al.* The minimum variation timescales of X-ray bursts from SGR J1935+2154[J]. *The Astrophysical Journal Supplement Series*, 2023, **268**(1): 5
- [19] XIAO S, LI X B, XUE W C, *et al.* Individual and averaged power density spectra of X-ray bursts from SGR J1935+2154: quasi-periodic oscillation search and slopes[J]. *Monthly Notices of the Royal Astronomical Society*, 2024, **527**(4): 11915-11924
- [20] XIAO S, ZHANG S N, XIONG S L, *et al.* The self-organized criticality behaviours of two new parameters in SGR J1935+2154[J]. *Monthly Notices of the Royal Astronomical Society*, 2024, **528**(2): 1388-1392
- [21] WANG C W, XIONG S L, WANG Y, *et al.* GECAM discovery of the second FRB-associated magnetar X-ray burst from SGR

- J1935+2154[J]. *Monthly Notices of the Royal Astronomical Society*, 2026, **546**(4): stag312
- [22] TAN W J, WANG Y, WANG C W, *et al.* GECAM discovery of a peculiar magnetar X-ray burst (MXB 221120) from SGR J1935+2154 associated with a fast radio burst[J]. *Astronomy & Astrophysics*, 2026, **707**: A289
- [23] WANG Y, WANG C W, XIONG S L, *et al.* Unveil a peculiar light-curve pattern of magnetar burst with GECAM observations of SGR J1935+2154[J]. *The Astrophysical Journal*, 2025, **993**(1): 24
- [24] XIE S L, CHEN A M, YU Y W, *et al.* Eclipsed X-ray bursts from magnetar SGR J1935+2154 and the fireball measurements[J]. *The Astrophysical Journal*, 2026, **999**(2): 159
- [25] ZHAO Y, LIU J C, XIONG S L, *et al.* The first GECAM observation results on terrestrial gamma-ray flashes and terrestrial electron beams[J]. *Geophysical Research Letters*, 2023, **50**(14): e2022GL102325
- [26] WANG C W, XIONG S L, ZHAO Y, *et al.* GECAM discovery of peculiar oscillating particle precipitation events[J]. *Science China Physics, Mechanics & Astronomy*, 2026, **69**(2): 229513
- [27] WANG C W, XIONG S L, XUE H B, *et al.* Pitch angle measurement method based on detector counts distribution. -I. Basic conception[J]. *Experimental Astronomy*, 2025, **60**(3): 25
- [28] REN Y Z, ZHU F R, XIONG S L, *et al.* Systematic study of the simultaneous events detected by GECAM[J]. *Astronomy & Astrophysics*, 2026, **707**: A318

Author Biography



XIONG ShaoLin Male, born in Feb. 1983 in Fengcheng city of Jiangxi Province, China. Currently working in the Institute of High Energy Physics, Chinese Academy of Sciences as researcher (professor). Proposed the GECAM mission as the Principal Investigator. Participated in other high-energy space telescopes including Insight-HXMT, POLAR, SVOM, POLAR2, eXTP, *etc.* Research interests include high energy astrophysics (*e.g.*, GRB, GW, SGR, FRB) and high energy phenomena of from the Sun to the Earth (*e.g.*, SFL, TGF, TEB), in terms of instrumentation, observation, data analysis and physical interpretation.
E-mail: xiongsli@ihep.ac.cn