GECAM: a SiPM-based Gamma-ray All-Sky Monitor

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Chinese Academy of Sciences (CAS)

GECAM (Huairou-1)

Gravitational wave high-energy Electromagnetic Counterpart All-sky Monitor

Detectors:
25 GRD (gamma-ray)
8 CPD (e-, proton)

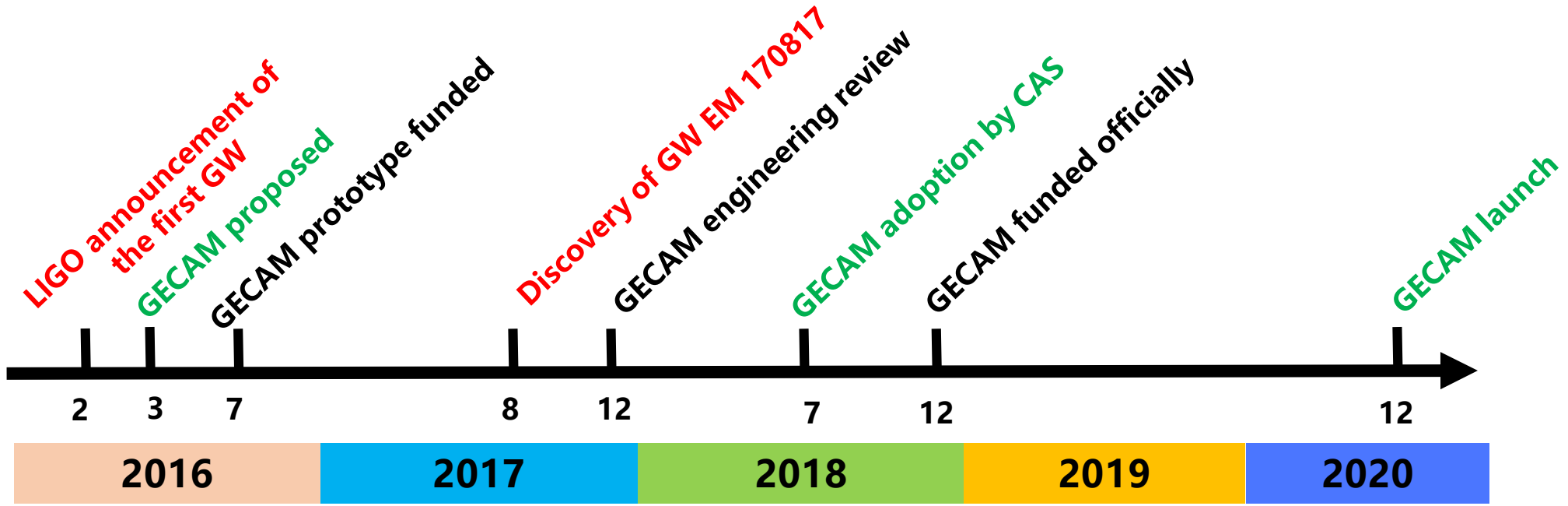
GECAM satellite

- **Composed of two identical microsatellites (GECAM-A/B)**
  - Launched on Dec. 10, 2020
  - **GECAM-B** works for ~11 hours/day since **Jan. 14, 2021**
- **Monitor gamma-ray transients in all-sky**
  - GRBs, especially associated with GW, FRB, HEN, etc.
  - Magnetars, XRBs, Pulsars,
  - Solar Flares, Terrestrial Gamma-ray Flashes
- **Characteristics of GECAM-B**
  - **FOV:** **~60**% all-sky
  - **Energy band:** **15** keV – 5 MeV
  - **Sensitivity:** **~1**E-8 erg/cm^2/s
  - **Localization:** **~2** deg (1-σ stat., 1E-5 erg/cm^2)
- **Near Real-time alerts**
  - **Time latency: ~1 minute**
  - Content: Trigger time, localization, duration, spectrum, etc.

GECAM science cases

Launched on Dec 10, 2020

GECAM Timeline

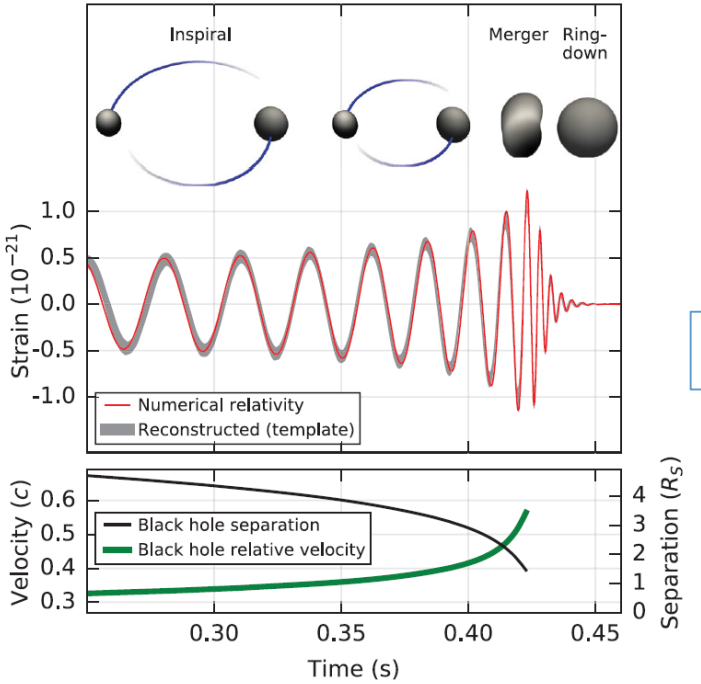


The first *Mission of Opportunity* in the Strategic Priority Program on Space Science (SPPSS-II), Chinese Academy of Sciences (CAS)

Direct Detection of Gravitational Wave (2015-2016)

LIGO

(Laser Interferometer Gravitational Wave Observatory)



GW150914

Photo: Bryce Vickmark
Rainer Weiss
Prize share: 1/2

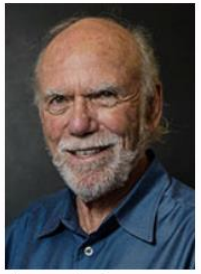


Photo: Caltech
Barry C. Barish
Prize share: 1/4

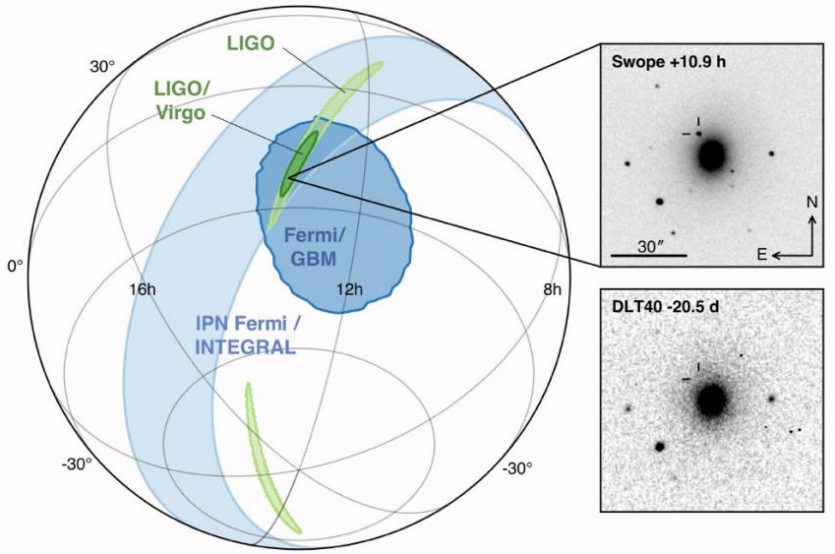
Photo: Caltech Alumni Association
Kip S. Thorne
Prize share: 1/4

2017 Nobel Prize

"for decisive contributions to the LIGO detector and the observation of gravitational waves"

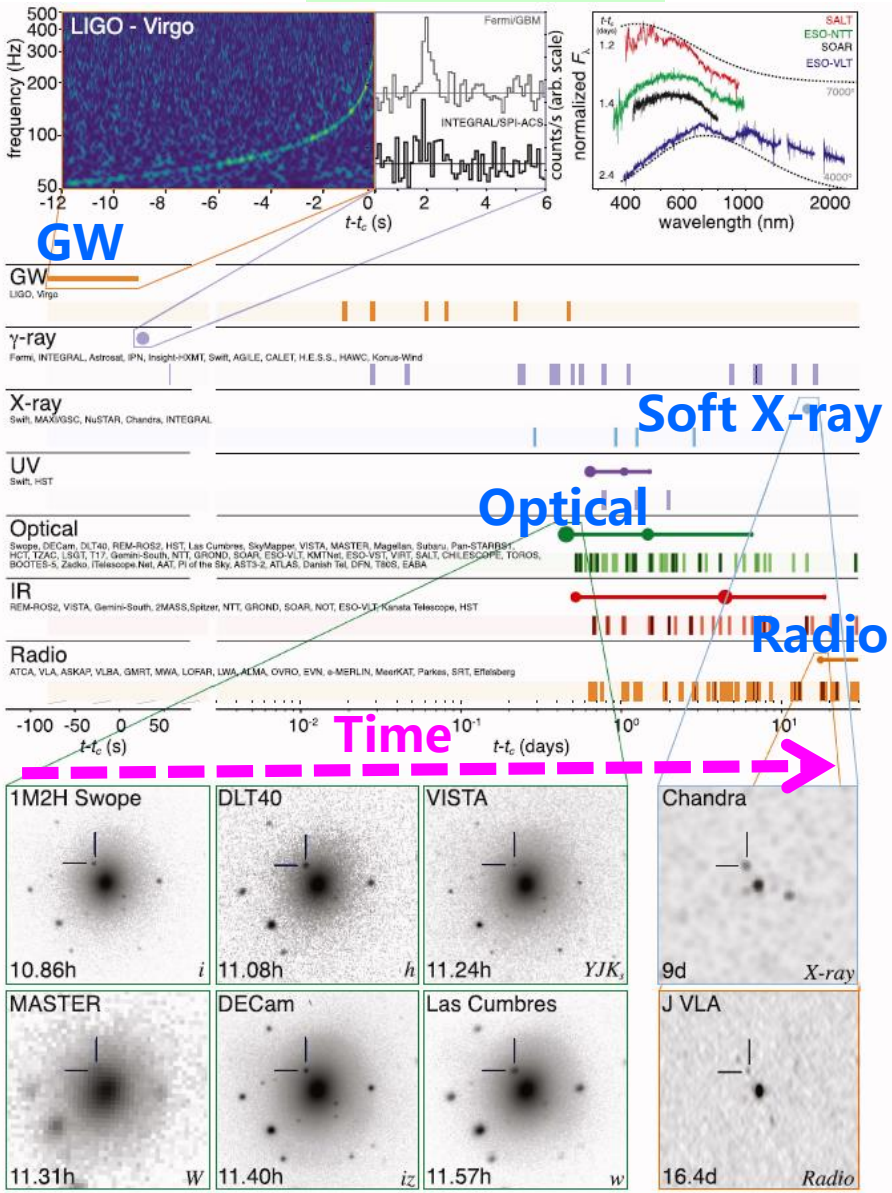
GWGRB played an important role in the MM/MW obs.

- **Early alert, even earlier than GW**
- Independent confirmation
- Reduced localization area facilitating follow-up observations
- Provide important astrophysics context



Localization is crucial for follow-up

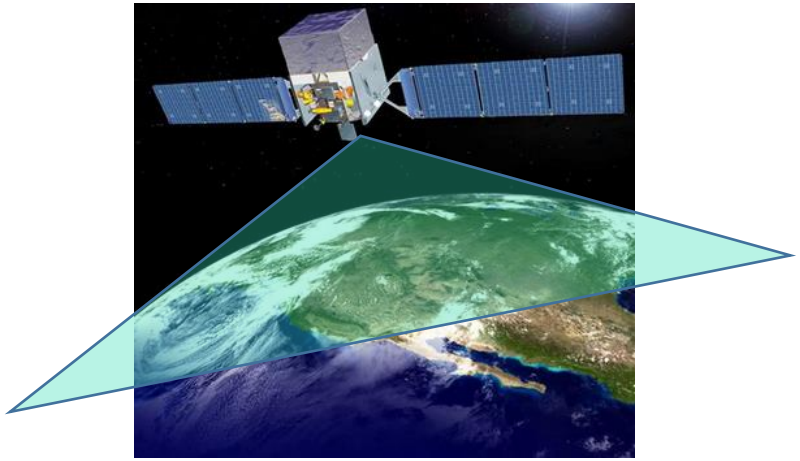
GRB170817A

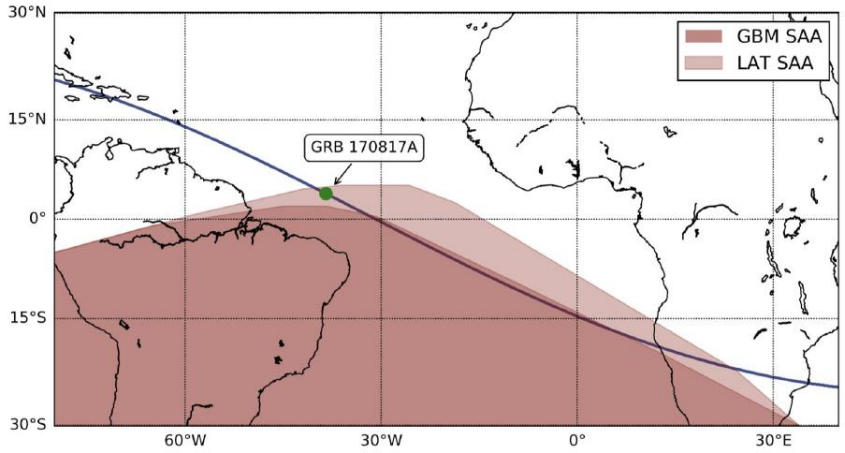


GWGRB: very rare, short & weak, difficult to catch

- Fermi/GBM+LVC @2020
  - 2018-2019： 0.1-1.4/year
  - **2020： 0.3-1.7/year**

LVC, Fermi GBM, INTEGRAL, 2017, ApJL, 848, L13





TITLE: GCN CIRCULAR
NUMBER: 24185
SUBJECT: LIGO/Virgo S190425z: Fermi GBM Observations
DATE: 19/04/25 15:35:23 GMT
FROM: Cori Fletcher at USRA/NASA <corinne.l.fletcher@nasa.gov>

C. Fletcher (USRA) reports on behalf of the Fermi-GBM Team and the GBM-LIGO/Virgo group:

For S190425z and using the initial BAYESTAR skymap, Fermi-GBM was observing 55.6% of the probability region at event time.

TITLE: GCN CIRCULAR
NUMBER: 24065
SUBJECT: LIGO/Virgo S190408an: Fermi GBM Observation
DATE: 19/04/08 21:00:15 GMT
FROM: C. Michelle Hui at MSFC/Fermi-GBM <c.m.hui@nasa.gov>

C. M. Hui (NASA/MSFC)

reports on behalf of the Fermi-GBM Team and the GBM+LIGO/Virgo Working Group:

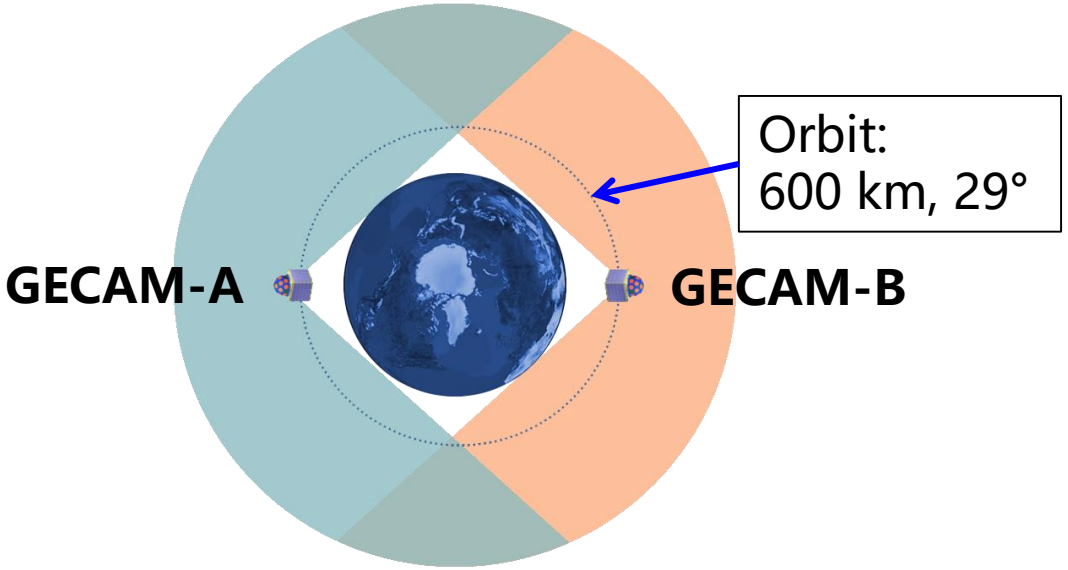
At the time of S190408an, Fermi was passing through

the South Atlantic Anomaly from 14 minutes prior to 15 minutes after

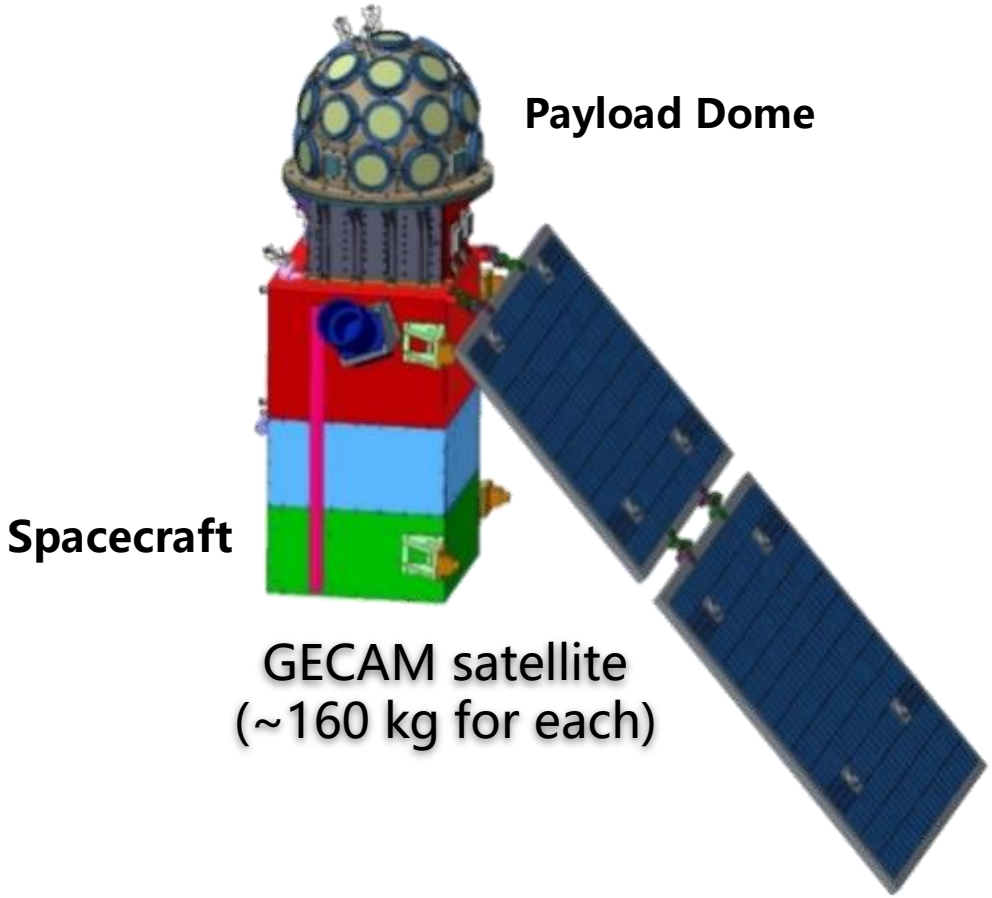
the trigger time; therefore the GBM detectors were disabled.

GECAM

Gravitational wave high-energy Electromagnetic Counterpart All-sky Monitor

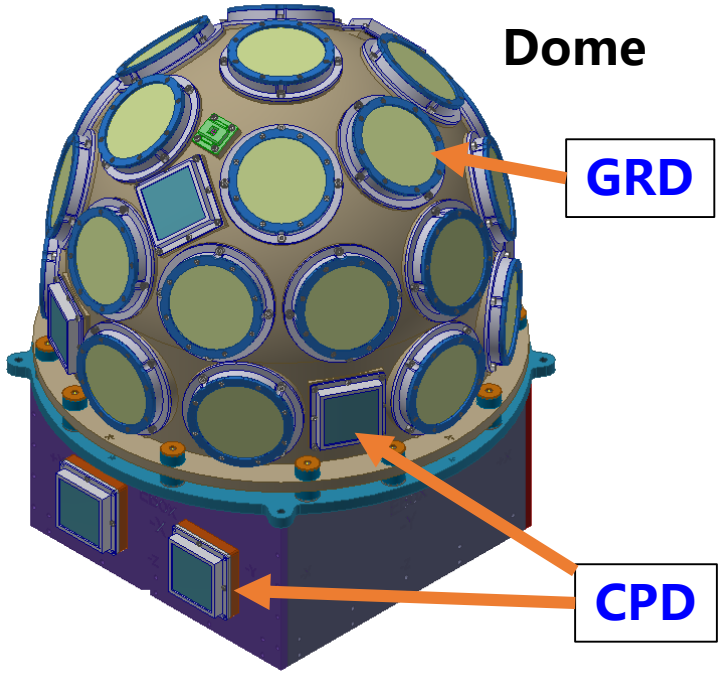


- **Characteristics**
  - **FOV:** 100% all-sky
  - **Energy band:** 6 keV – 5 MeV
  - **Sensitivity:** <2E-8 erg/cm^2/s
  - **Localization:** <1 deg (1-σ stat., 1E-5 erg/cm^2)
- **Real-time alerts**
  - Trigger time, localization, duration, spectrum, etc.
  - Latency: ~ minutes



GECAM satellite
(~160 kg for each)

GECAM Payload



- **Detectors for each GECAM satellite**
  - **25 Gamma-ray Detectors (GRD, circle)**
  - **8 Charged Particle Detectors (CPD, square)**

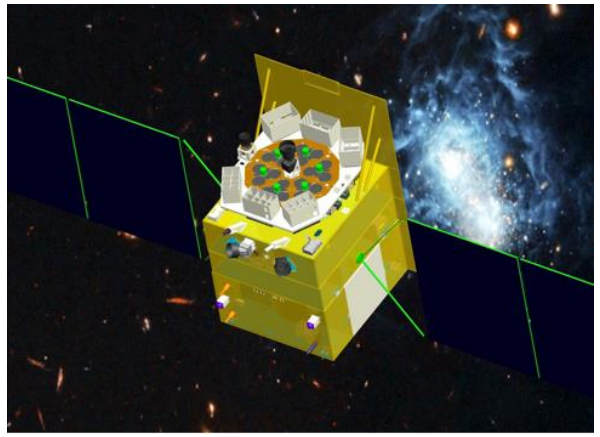
- **Low energy threshold**
- **Wide energy range**
- **Light weight**
- **Without high voltage**
- **Insensitive to magnetic field**
- **Low power consumption**

- **GRD (LaBr$_3$+SiPM)**
  - Monitor x/gamma-ray from all-sky
  - Temporal, spectral, localization measurement for GRB
- **CPD (Plastic scintillator + SiPM)**
  - Monitor charged particles (e, p)
  - Identify the bursts in GRD produced by charged particles in the Earth orbit (i.e. distinguish GRB and particle burst)

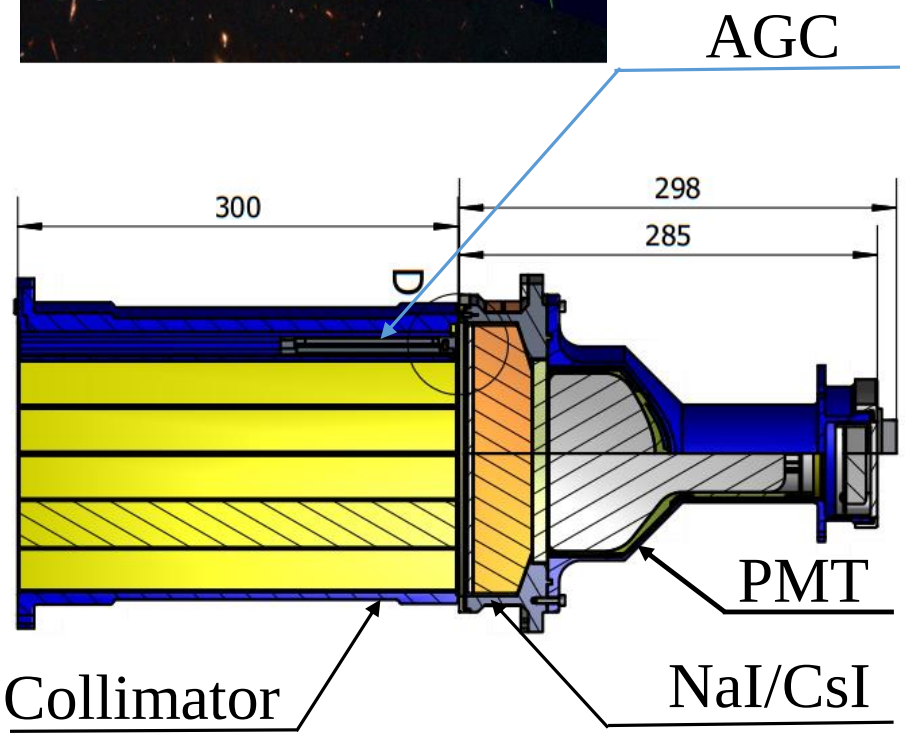
See more details in Dali Zhang talk

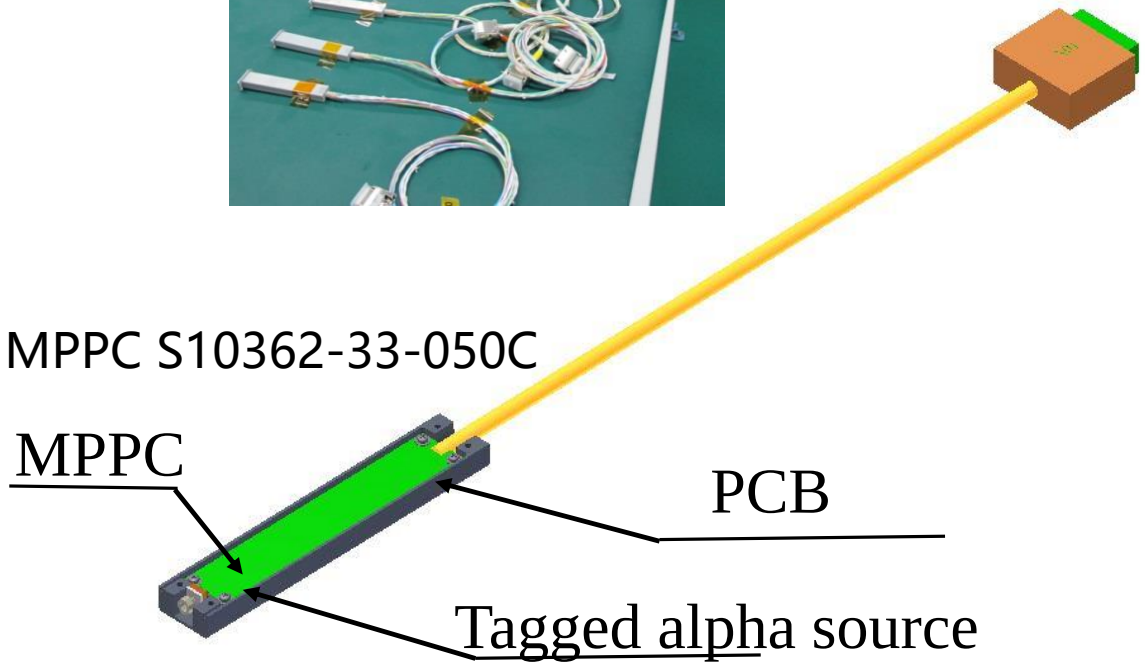
SiPM firstly used in the *Insight*-HXMT mission

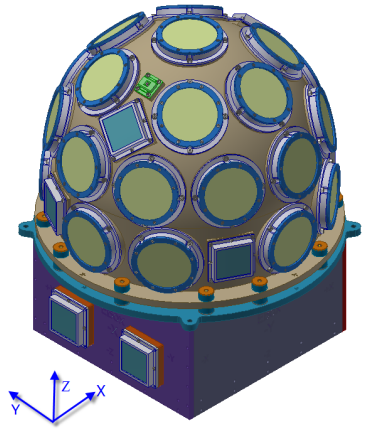
(Launched on 2017.6.15)



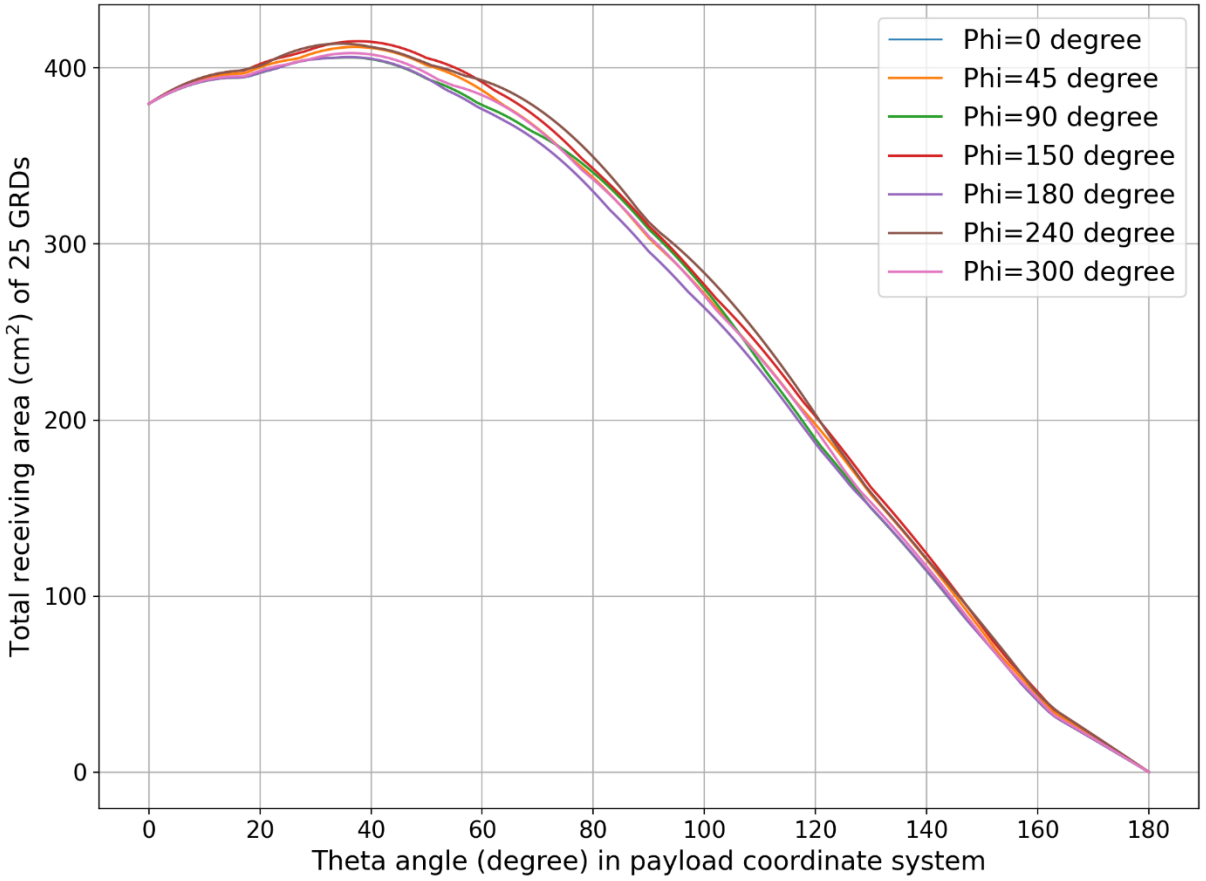
AGC (Automatic Gain Calibration detector)

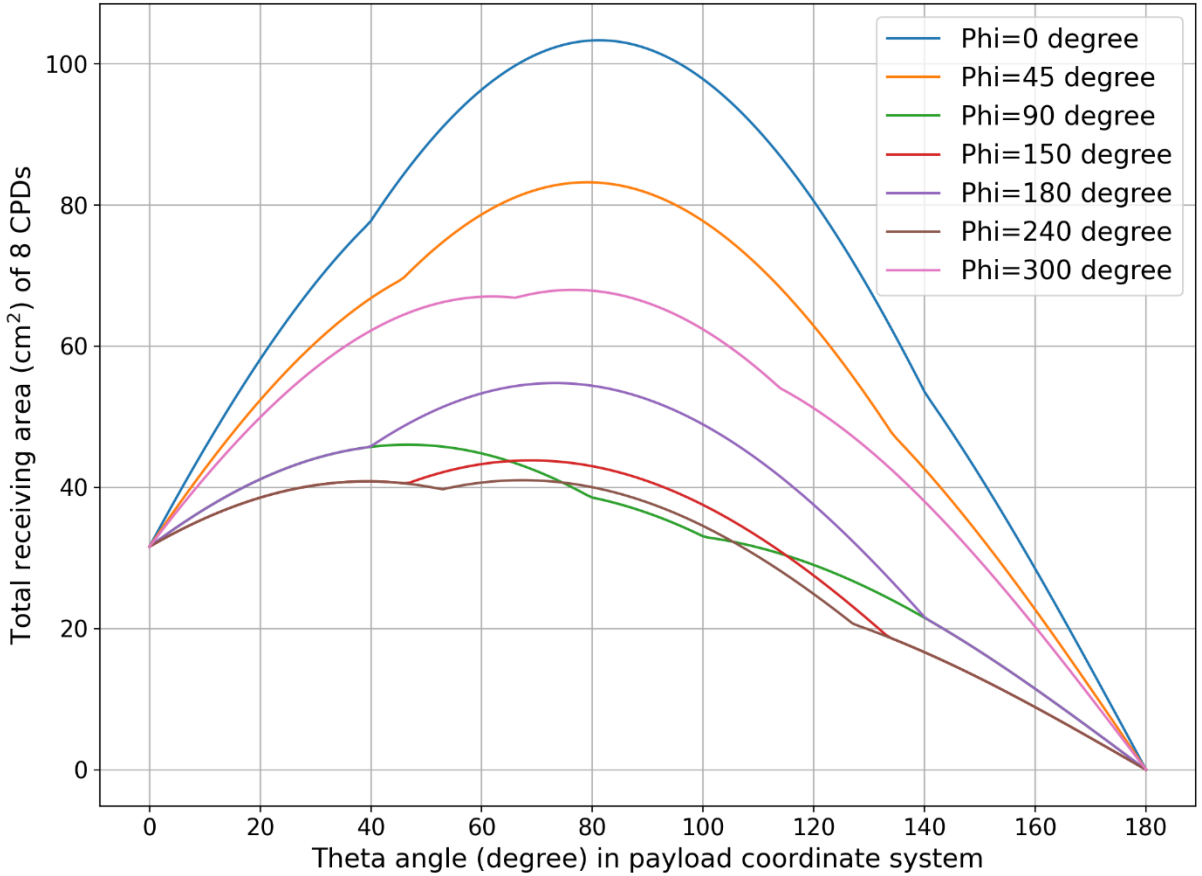




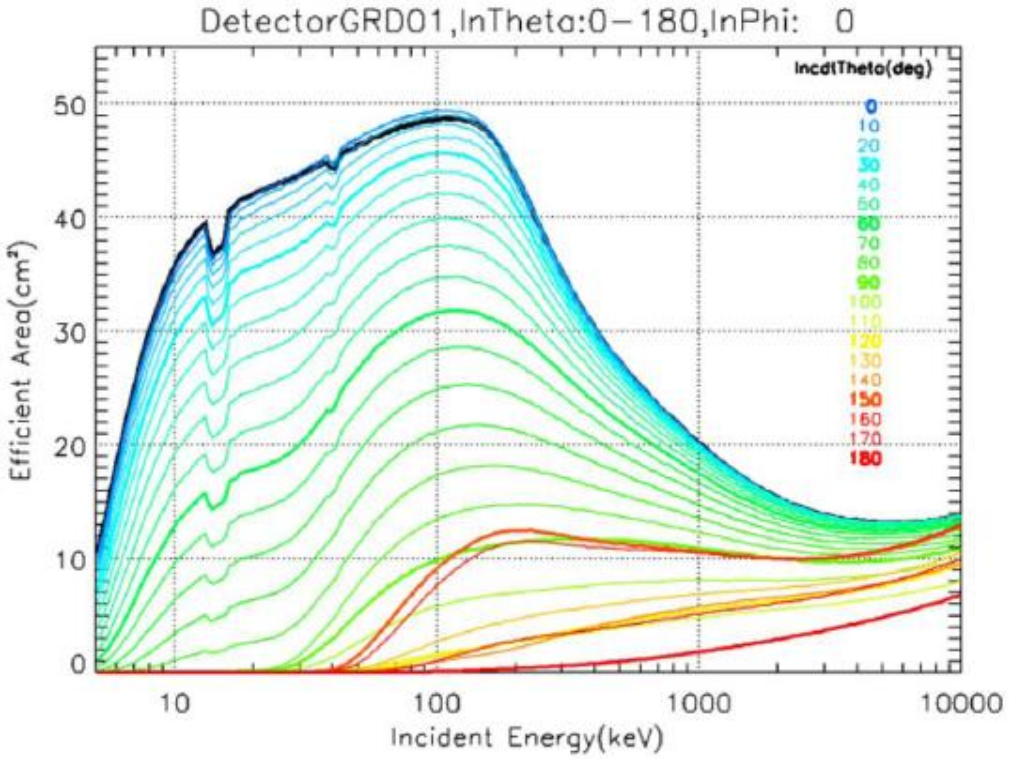


Total receiving area of GRDs and CPDs



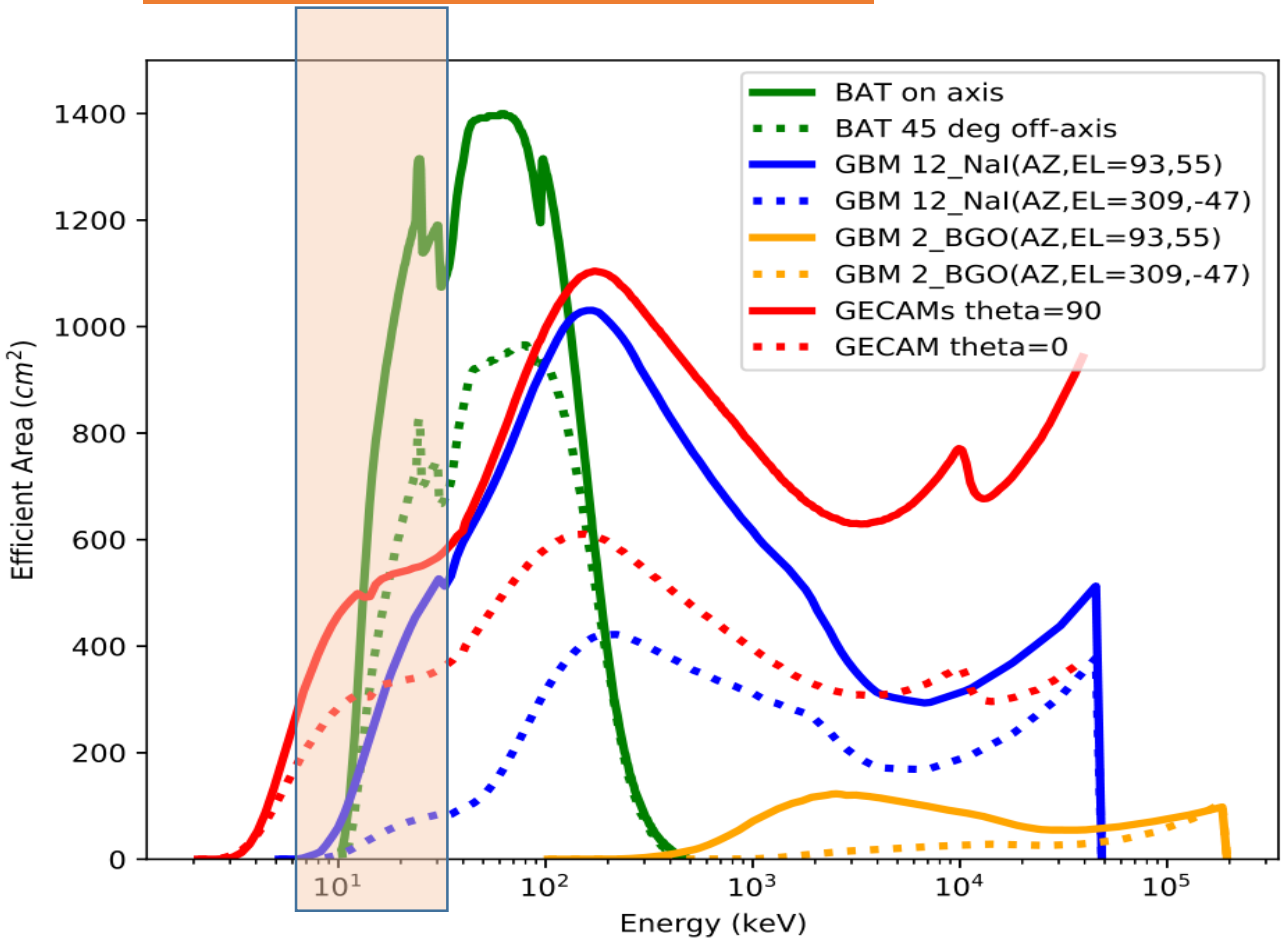


Effective Area



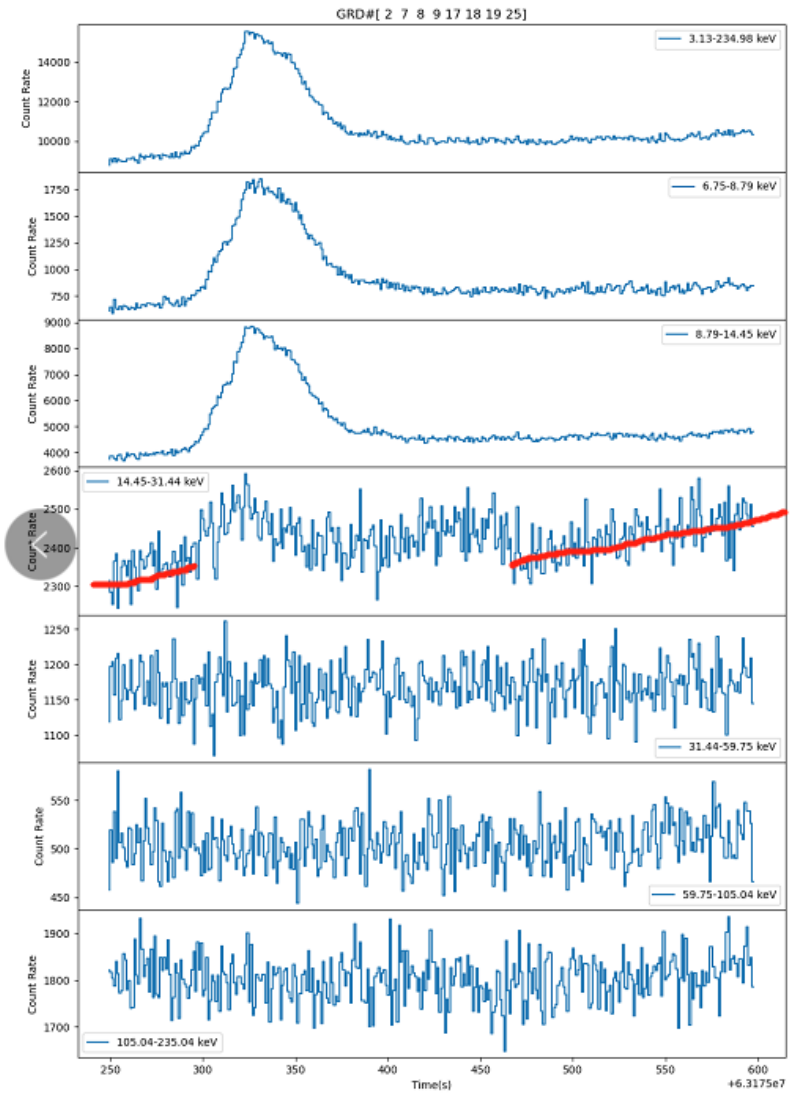
Effective area vs. Energy and incident angle

Advantages in Low energy band

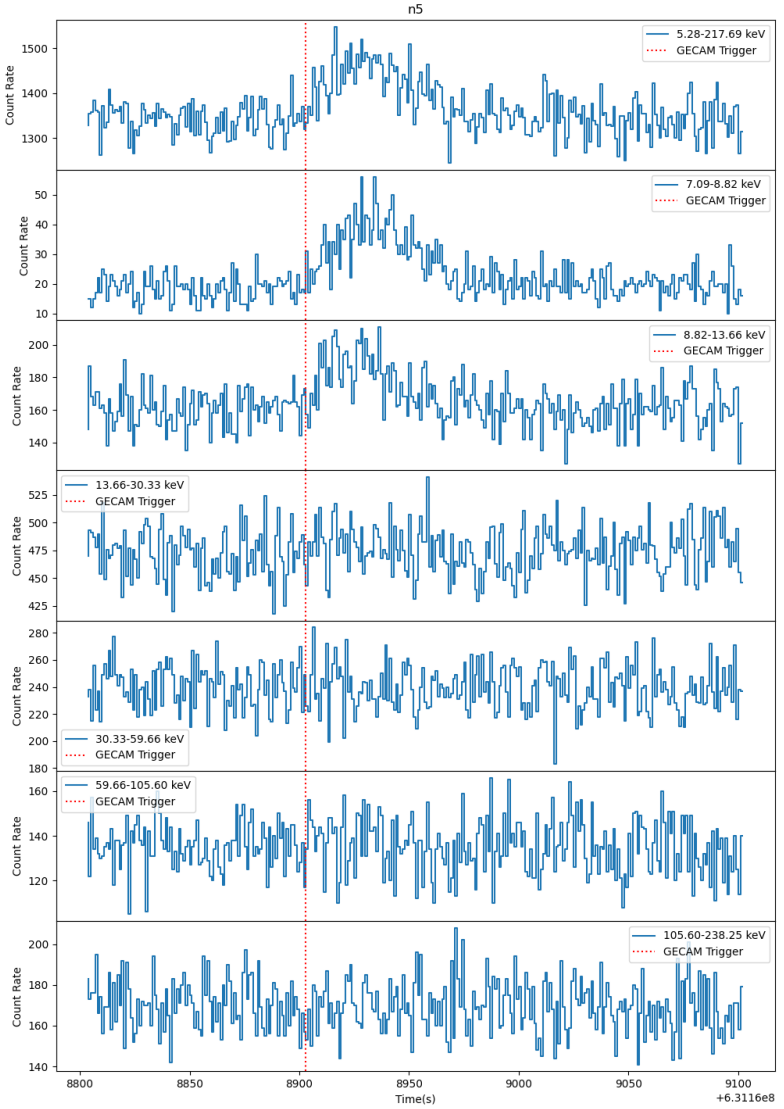


GECAM vs. Fermi/GBM, Swift/BAT

Advantages in low energy band

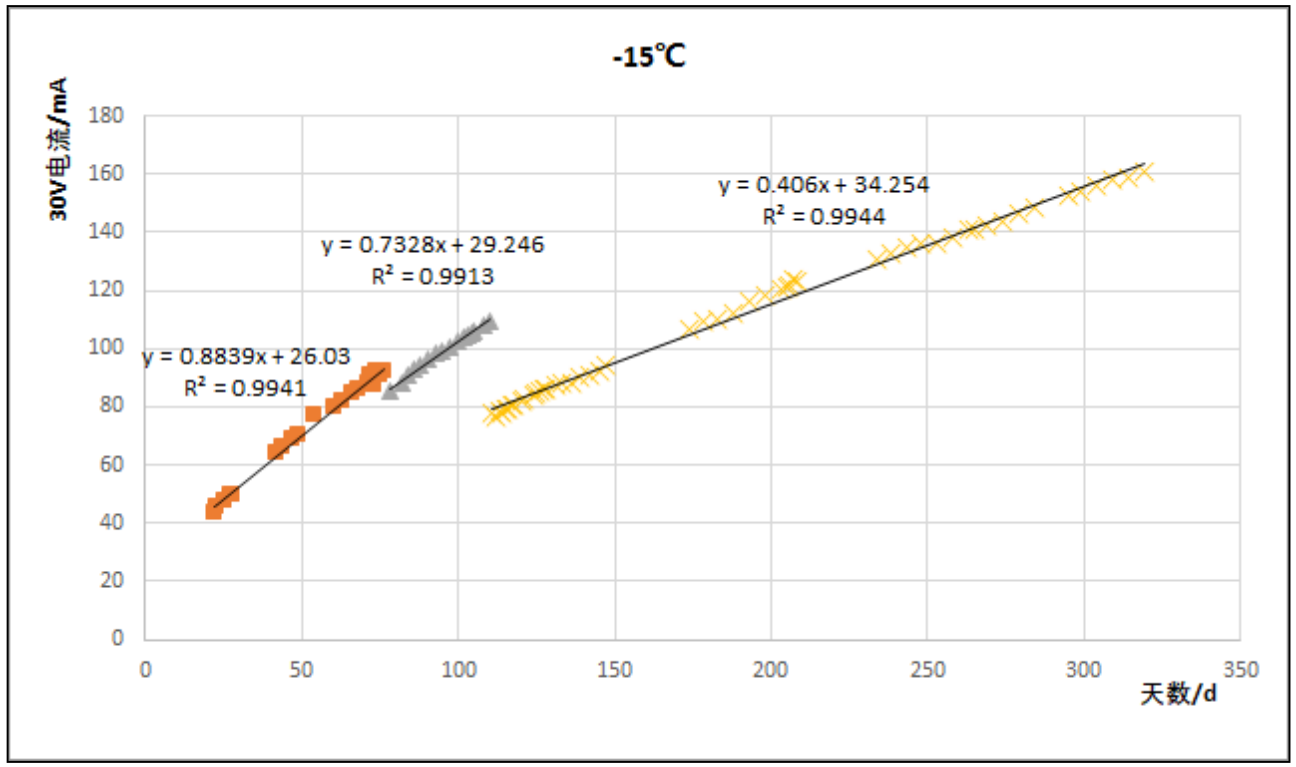


GECAM In-flight trigger

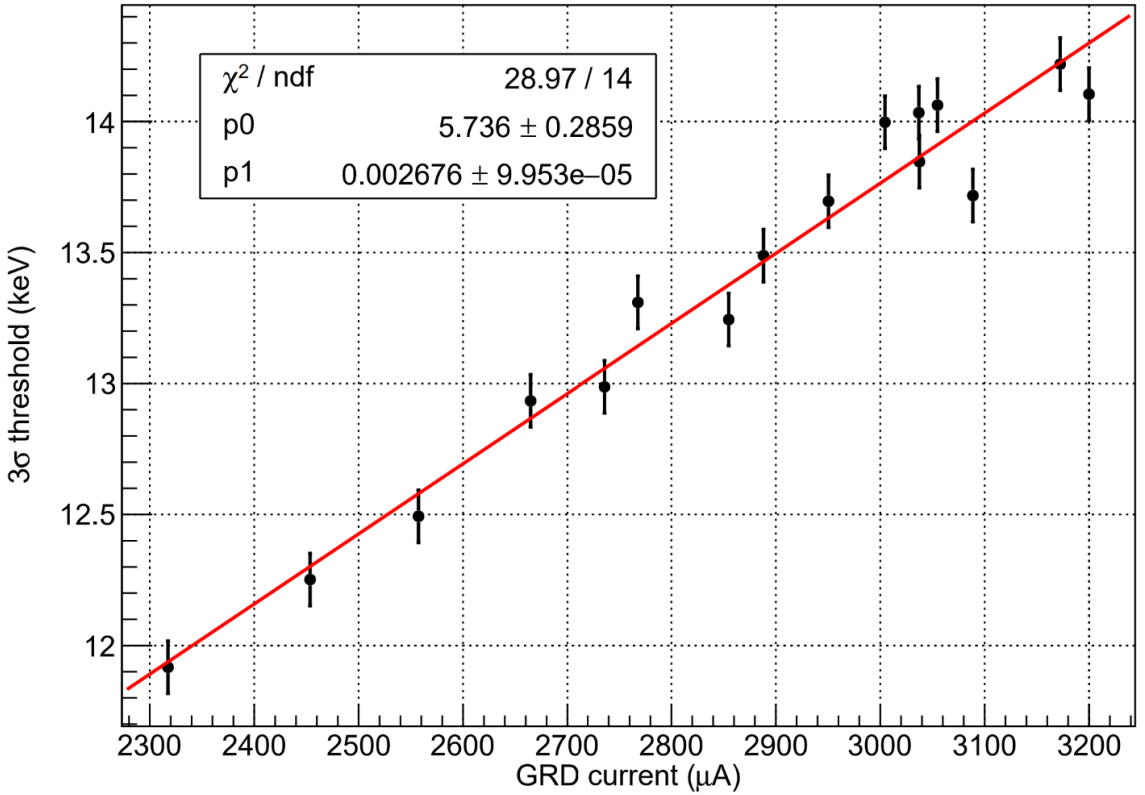


Fermi/GBM (no in-flight trigger)

Energy threshold goes up as SiPM dark current increases



SiPM current increasement (-15℃/low count rate)



GRD threshold vs SiPM array dark current

Dali Zhang et al. RDTM volume 6, pages 35–42 (2022)

See more details in Dali Zhang talk

Main Characteristics of GECAM-B

Items	Value	Comments
Orbit	600 km, 29 deg	-
Launch and lifetime	Dec 2020， 3yrs	5 yrs (goal)
Gamma-ray energy range	15 keV – 5 MeV	-
Gamma-ray FOV	~60% all-sky	GECAM-B
Burst sensitivity	~ 1E-8 erg/cm^2/s (20 s, 10-1000 keV)	Band medium spectrum
Burst location error	~ 2 deg (1-σ, stat. error)	1E-6 erg/cm2/s, 10s
Electron energy range	300 keV - 5 MeV	CPD
Dead time	4 μs (normal event)	GRD and CPD
Absolute time accuracy	< 10 μs	GNSS system
Relative time accuracy	**~ 0.1 μs**	GRD and CPD detectors
In-flight alert time latency	**~1 minute (BeiDou Navigation System)**	In-flight performance

GECAM observations

- **Sources**
  - GRB (>70 bursts)
    - GRB 210126A，GRB 210121A，GRB 210120A
  - SGR (>100 bursts)
    - SGR 1935+2154, SGR 1555.2, SGR 1830
  - X-ray Binary
    - 4U 0614+09
  - X-ray sources by Earth occultation
    - Sco X-1, Crab
  - X-ray pulsars
    - Crab
  - Solar Flares
    - >80 bursts
- **Joint observations**
  - *Swift*, *Fermi*, *Insight*-HXMT, FAST, LHAASO, MASTER, GWFUNC, etc.
  - Routinely report observation results through GCNs

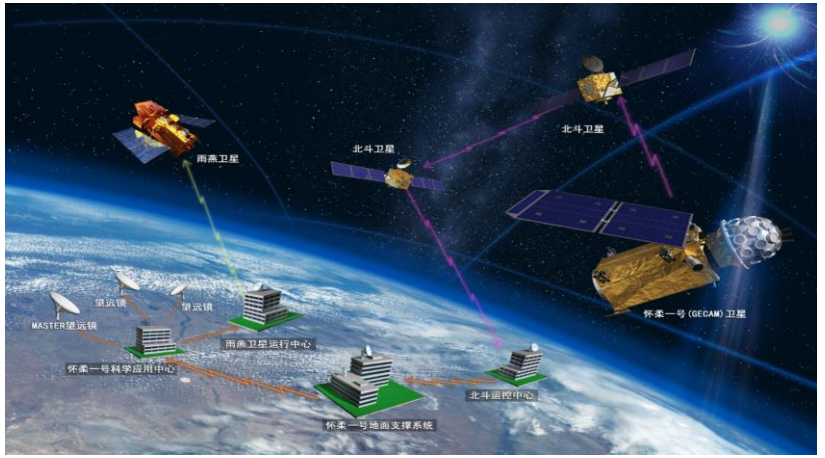
- 29363 GECAM detection of a short burst probably from SGR 1935+2154
- 29362 GRB 210127A: Fermi GBM Final Real-time Localization
- 29361 GRB 210120A: Fermi GBM detection
- 29360 Fermi trigger No 633348010: Global MASTER-Net observations report
- 29359 HAWC Transient event on 2021/01/25
- 29358 Konus-Wind detection of GRB 210121A
- 29357 Konus-Wind detection of GRB 210124B
- 29356 GRB 210126A: GECAM detection
- 29355 IPN triangulation of GRB 210124B (short)
- 29354 GRB 210126A: BALROG localization (Fermi Trigger / GRB 210126417)
- 29353 GRB 210124B: Insight-HXMT/HE detection
- 29352 Fermi trigger No 633257525: Global MASTER-Net observations report
- 29351 GRB 210123A: Fermi GBM Final Localization
- 29350 GECAM detection of a burst possibly from the X-ray burster 4U 0614+09 or GRB 210124A
- 29349 GRB 210123A: Insight-HXMT/HE detection
- 29348 IPN triangulation of GRB 210121A
- 29347 GRB 210121A: GECAM detection
- 29346 GRB 210121A: Insight-HXMT/HE detection
- 29345 GRB 210120A : 1.3m DFOT optical observations
- 29344 ZTF21aaeyldq: GROND and CAHA jet break confirmation
- 29343 ZTF20aaeyldq: VLA radio detection
- 29342 GRB 210116A: AstroSat CZTI detection
- 29341 GRB 210120A(MASTER OT J105242.66+152355.0 / AT2021axc): Mondy optical observations
- 29340 GRB 210116: AstroSat LAXPC detection
- 29339 GRB 210120A: MASTER OT (possibly) discovery
- 29338 GECAM In-Flight Trigger of GRB 210120A
- 29337 GRB 210104A: 3.6m DOT optical upper limit
- 29336 Fermi GRB 210120A: Global MASTER-Net observations report
- 29335 GRB 210120A: BALROG localization (Fermi Trigger 632819449 / GRB 210120299)
- 29334 GRB 210120A: Fermi GBM Final Real-time Localization
- 29333 GRB 210112A: 3.6m DOT optical detection
- 29332 GRB 210119A (Swift J1851.2-6148): Swift-BAT refined analysis
- 29331 GECAM detection of a short GRB 210119A or a new SGR candidate Swift J1851.2-6148

GECAM GCNs

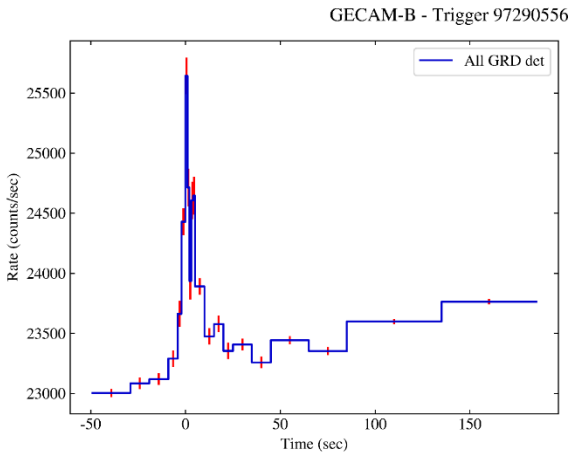
GECAM Alerts

- **In-flight alerts**
  - Content: Trigger time, location, duration, spectrum, etc
  - Latency: **~1 minutes**
- **Ground automatic alerts**
  - Content: refined location, duration, refined trigger classification, etc.
  - Latency: **~10 minutes**
- **Final alerts**
  - Content: final results of GECAM
  - Latency: **~hours**

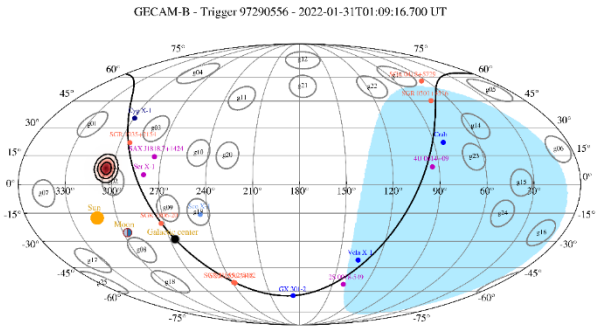
GECAM alerts have been sent to collaborators, Working on the connection to GCN server of GSFC



BeiDou Navigation System (BDS) short message service

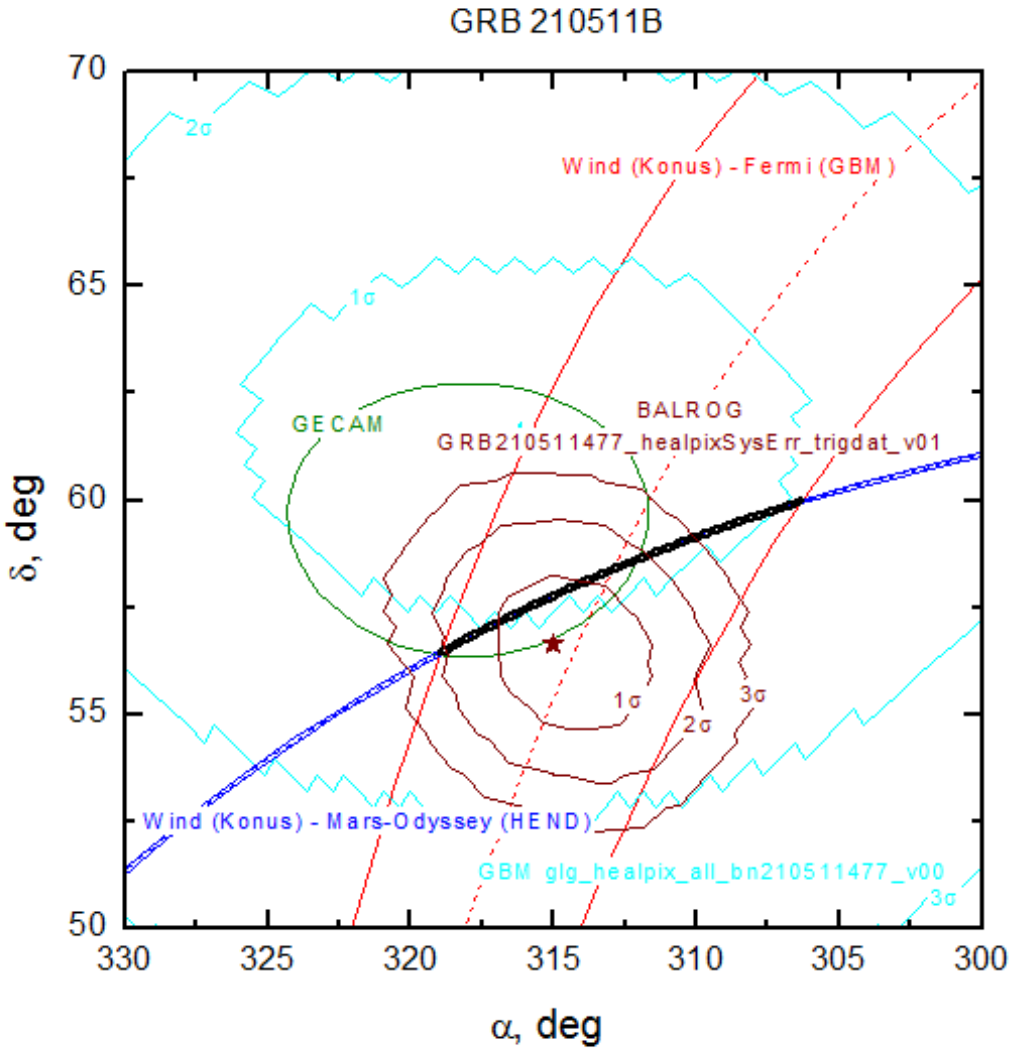


In-flight light curve

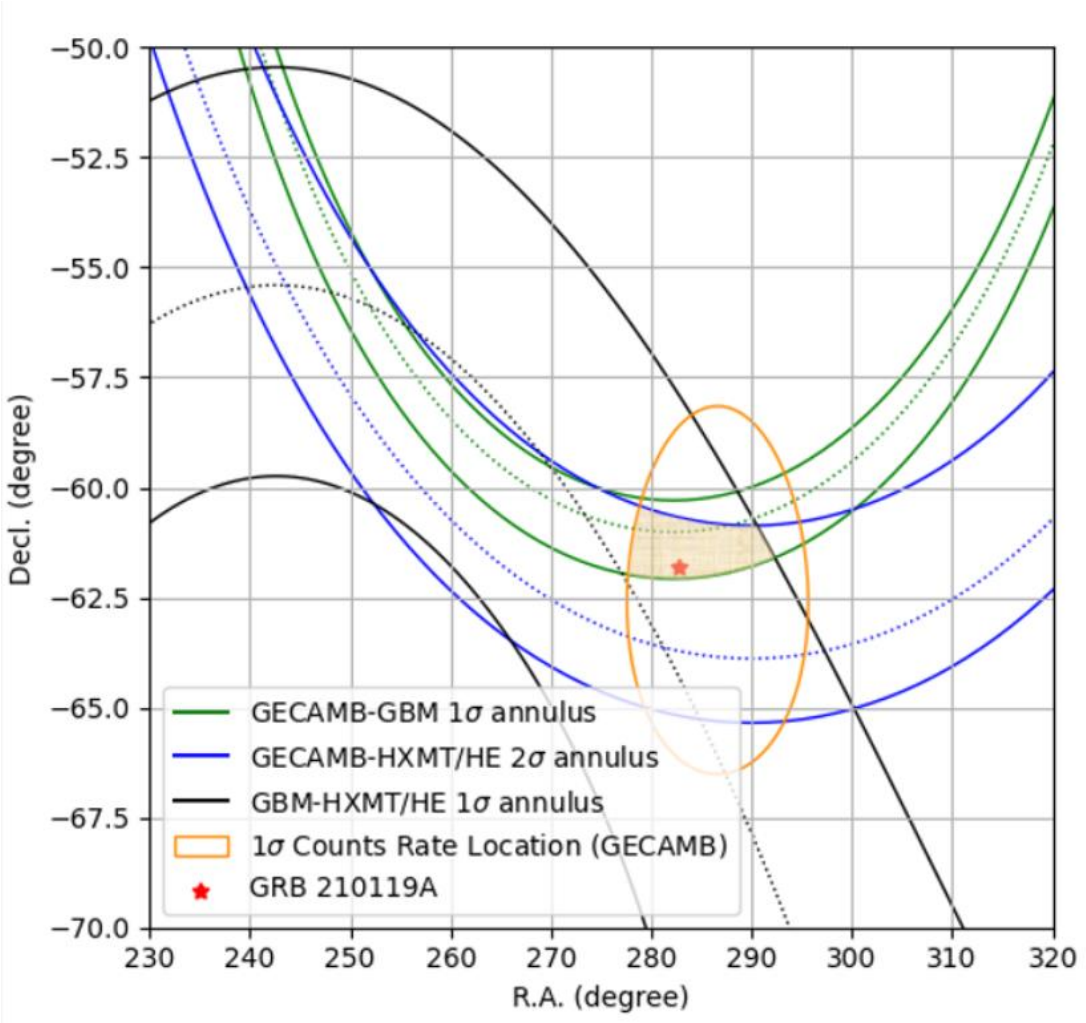


Automatic localization

GECAM localization of bursts



http://www.ioffe.ru/LEA/GRBs/GRB210511_T41201/IPN/

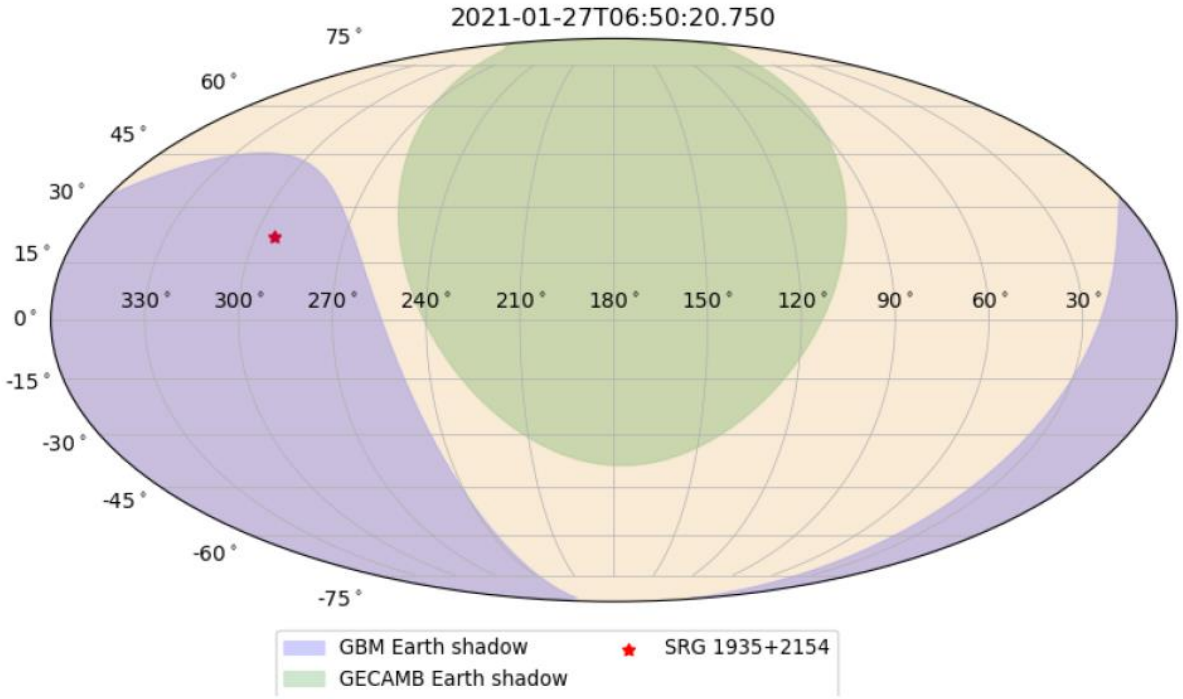


Joint localization with multiple missions

GRB Name	Fermi/GBM detection
GRB 210119A	Yes
GRB 210120A	Yes
GRB 210121A	Yes
GRB 210126A	Yes
GRB 210131A	No
GRB 210204A	Yes
GRB 210207B	No
GRB 210228A	Yes
GRB 210307A	No
GRB 210307B	No
GRB 210317A	Yes
GRB 210328A	Yes
GRB 210330A	No
GRB 210401A	Yes
GRB 210409A	No
GRB 210413A	No
GRB 210421B	Yes
GRB 210421A	No
GRB 210425A	No

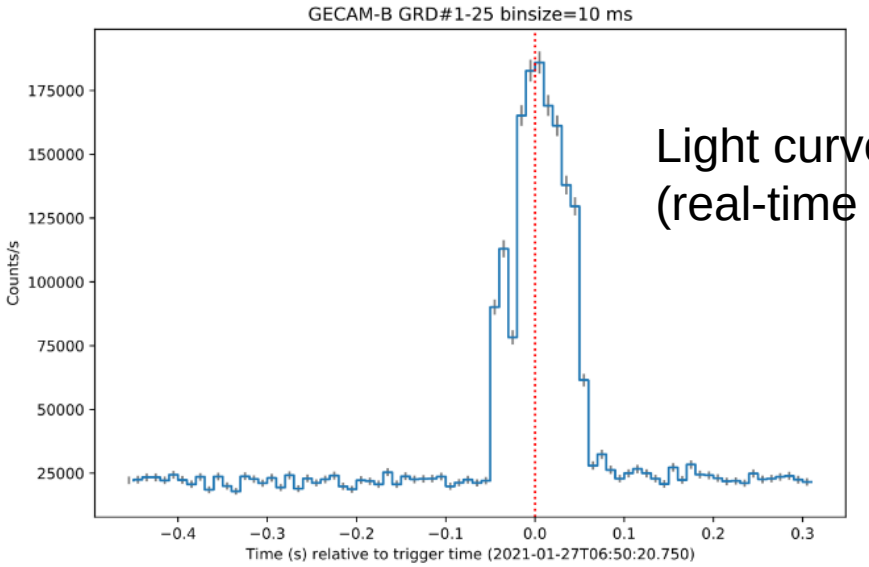
GRB Name	Fermi/GBM detection
GRB 210511B	Yes
GRB 210520A	Yes
GRB 210522A	No
GRB 210529A	Yes

GECAM GRB rate: ~70/year



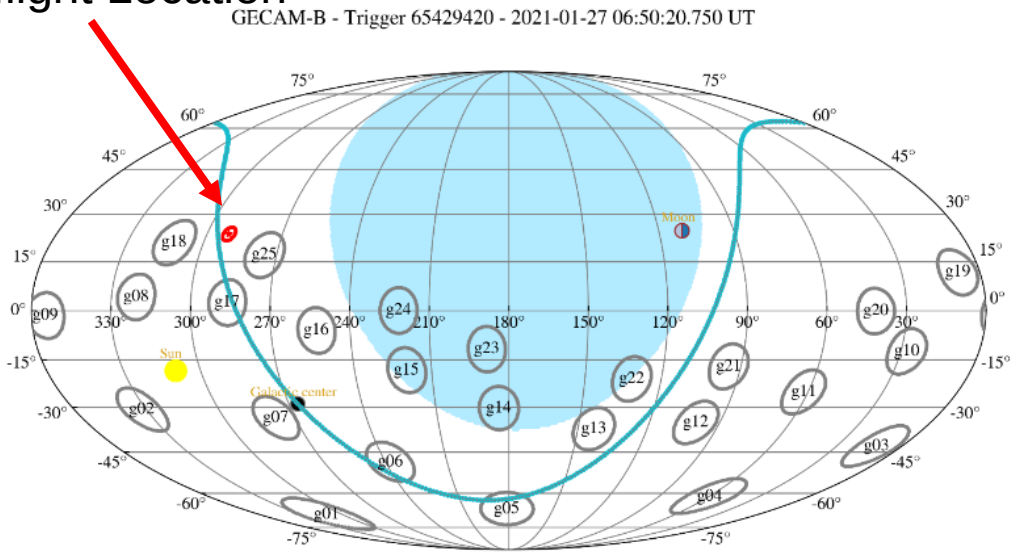
GECAM and Fermi/GBM complementary to each other

GECAM detection of SGR J1935+2134



Light curve
(real-time alerts)

In-flight Location



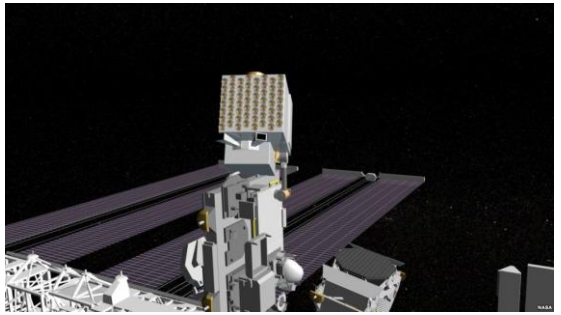
The bright, short-duration, soft burst
(GECAM detection: Huang et al., GCN Circ. 29363)
was detected by GECAM, Konus-Wind, and Swift (BAT)
at about 24617 s UT (06:50:17) on January 27.
The burst was outside the coded field of view of the BAT.

We have triangulated it to a Konus-BAT annulus centered at
RA(2000)=315.213 deg (21h 00m 51s) Dec(2000)=-14.116 deg (-14d 06' 56"),
whose radius is 41.658 +/- 0.174 deg (3 sigma).

The position of SGR 1935+2154 lies inside the annulus at 3.5 arcmin
from its center line.

Given the positional coincidence (initially suggested in GCN 29363) of
this burst with SGR 1935+2154, its time history, and softness of its
spectrum (as observed by Konus-Wind), we conclude this burst is
likely originated from SGR 1935+2154.

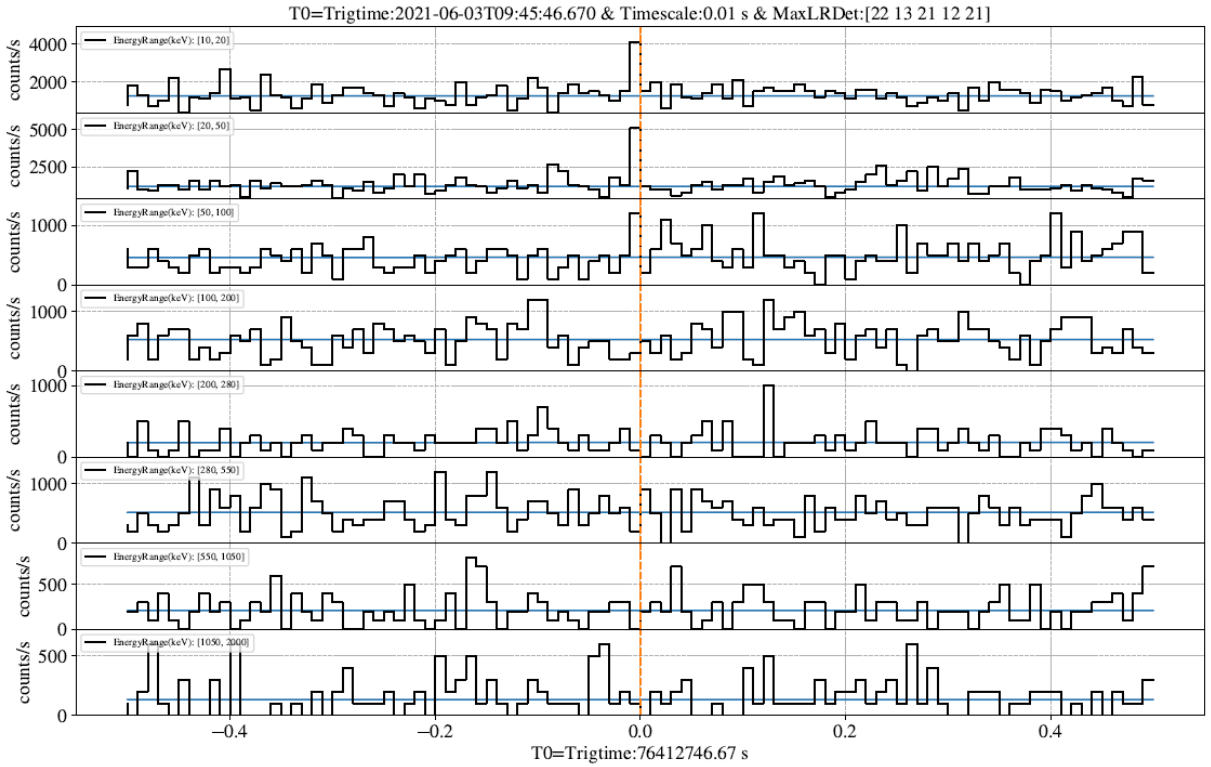
A triangulation map is posted at
http://www.ioffe.ru/LEA/SGRs/210127_T24616/IPN/

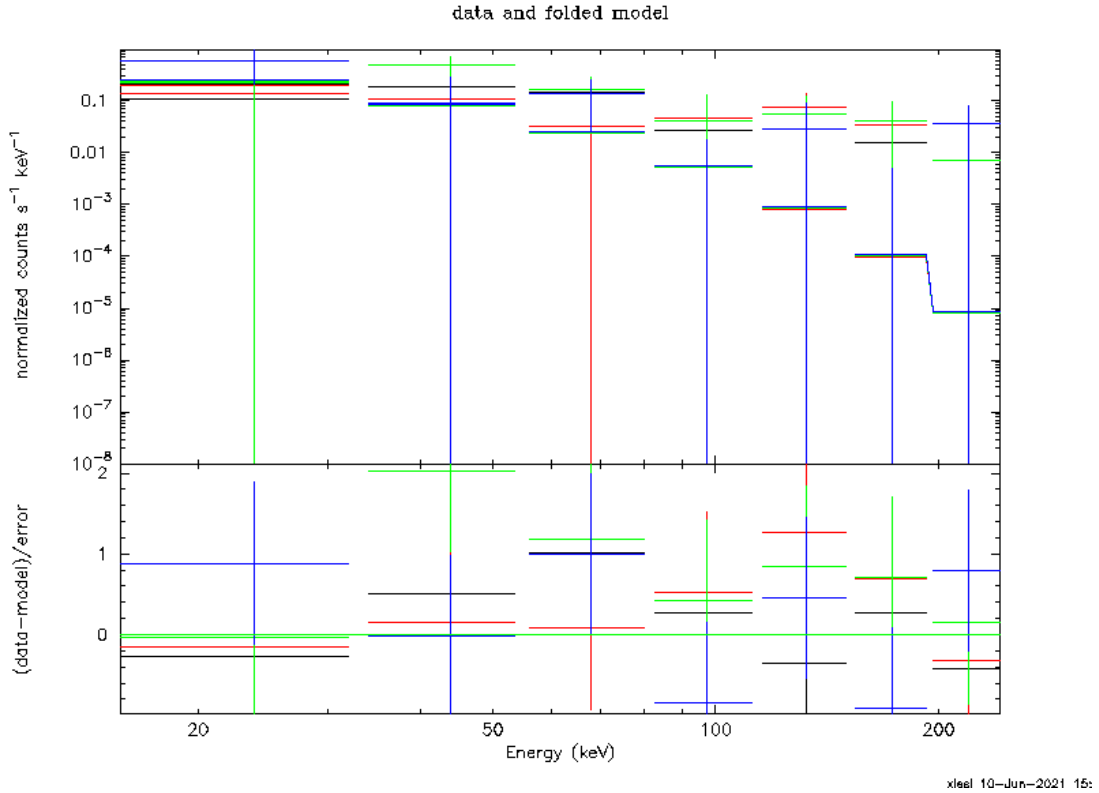


Co-ordinate observation with FAST, etc.

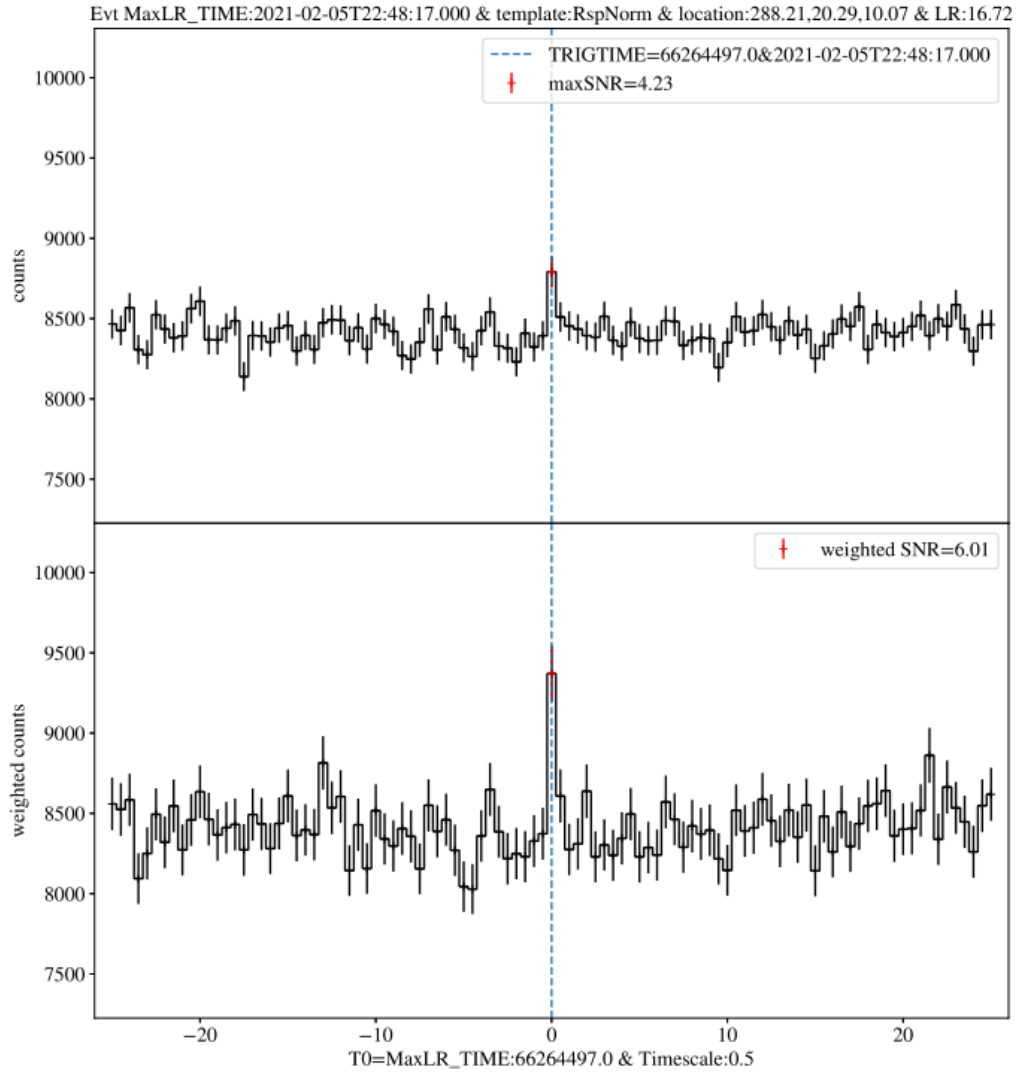
Detection of the new magnetar Swift SGR J1555.2-5402

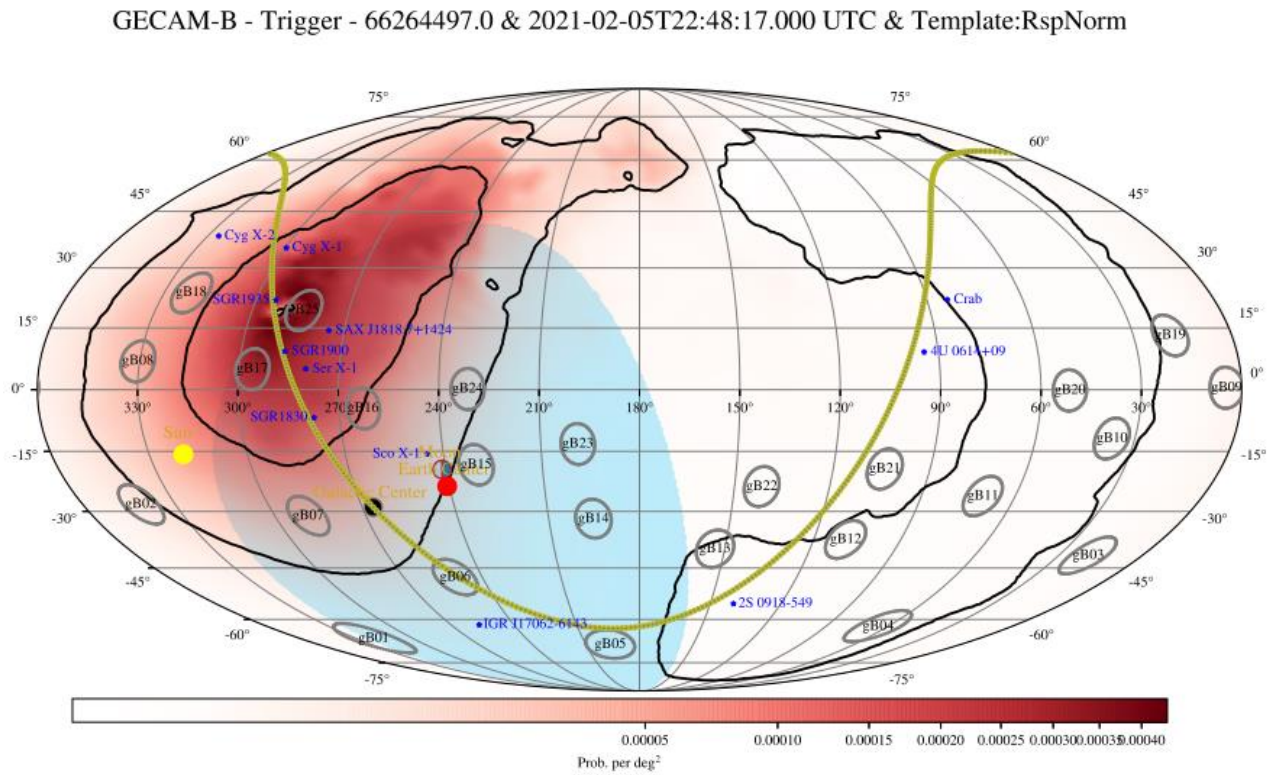
- **Sub-threshold detection by on-ground targeted search**
- **Spectrum is generally consistent with Swift/BAT**





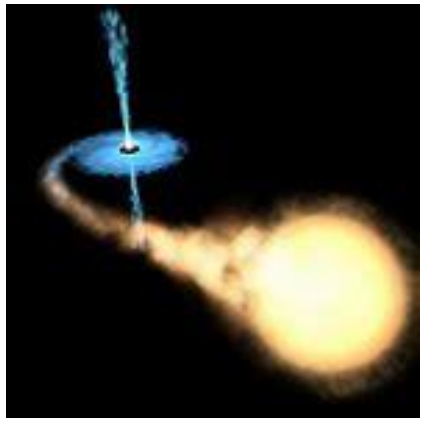
More weak bursts found by ground search

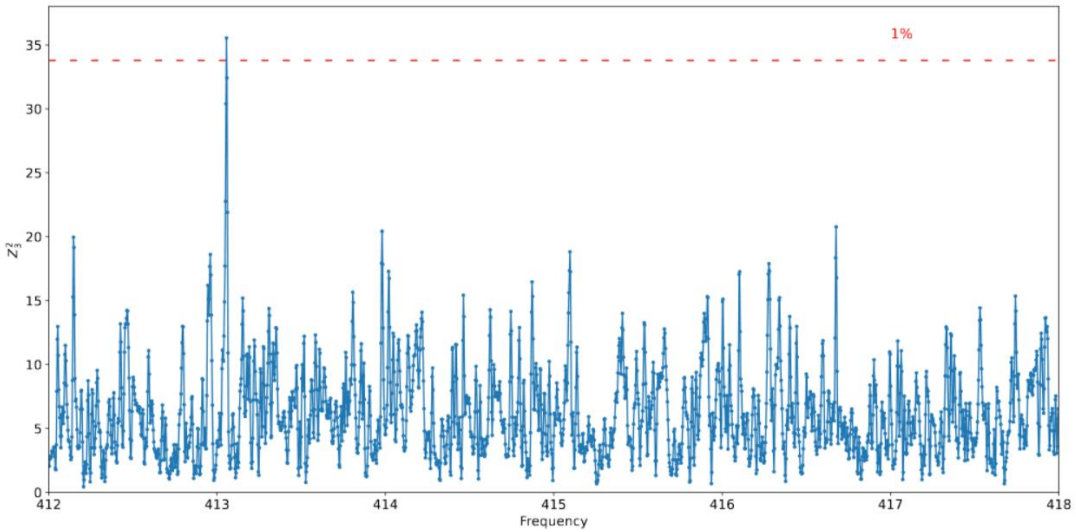




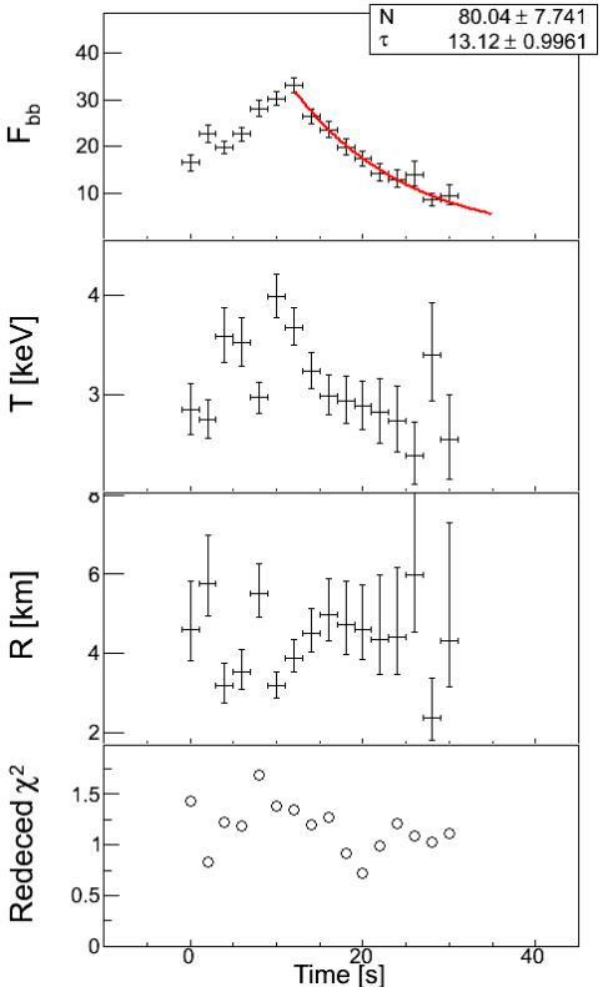
Location is generally consistent with SGR J1935

GECAM detection of Type I burst from NS X-ray Binaries





PSD confirmation of 4U 0614+09



GECAM detection of a bright thermonuclear burst from 4U 0614+091

ATel #14363; *Y. P. Chen (IHEP), J. Li (USTC), S. L. Xiong (IHEP), L. Ji (SYSU), S. Zhang (IHEP), W. X. Peng (IHEP), R. Qiao, X. Y. Zhao, Y. Huang, F. J. Lu, S. N. Zhang, L. M. Song, S. Xiao, C. Cai, B. X. Zhang, Z. H. An, C. Chen, G. Chen, W. Chen, M. Gao, K. Gong, D. Y. Guo, J. J. He, B. Li, C. Li, C. Y. Li, J. H. Li, Q. X. Li, X. B. Li, X. Q. Li, Y. G. Li, X. H. Liang, J. Y. Liao, J. C. Liu, X. J. Liu, Y. Q. Liu, Q. Luo, X. Ma, G. Ou, D. L. Shi, J. Y. Shi, X. Y. Song, G. X. Sun, X. L. Sun, Y. L. Tuo, C. W. Wang, J. Z. Wang, P. Wang, X. Y. Wen, Y. B. Xu, Y. P. Xu, W. C. Xue, S. Yang, M. Yao, Q. B. Yi, C. Y. Zhang, D. L. Zhang, Fan Zhang, Fei Zhang, H. M. Zhang, K. Zhang, P. Zhang, Y. Q. Zhang, Z. Zhang, S. Y. Zhao, Y. Zhao, C. Zheng, S. J. Zheng, X. Zhou (IHEP), report on behalf of GECAM team:*
on 1 Feb 2021; 05:06 UT
Credential Certification: Yu-Peng Chen (chenyp@ihep.ac.cn)

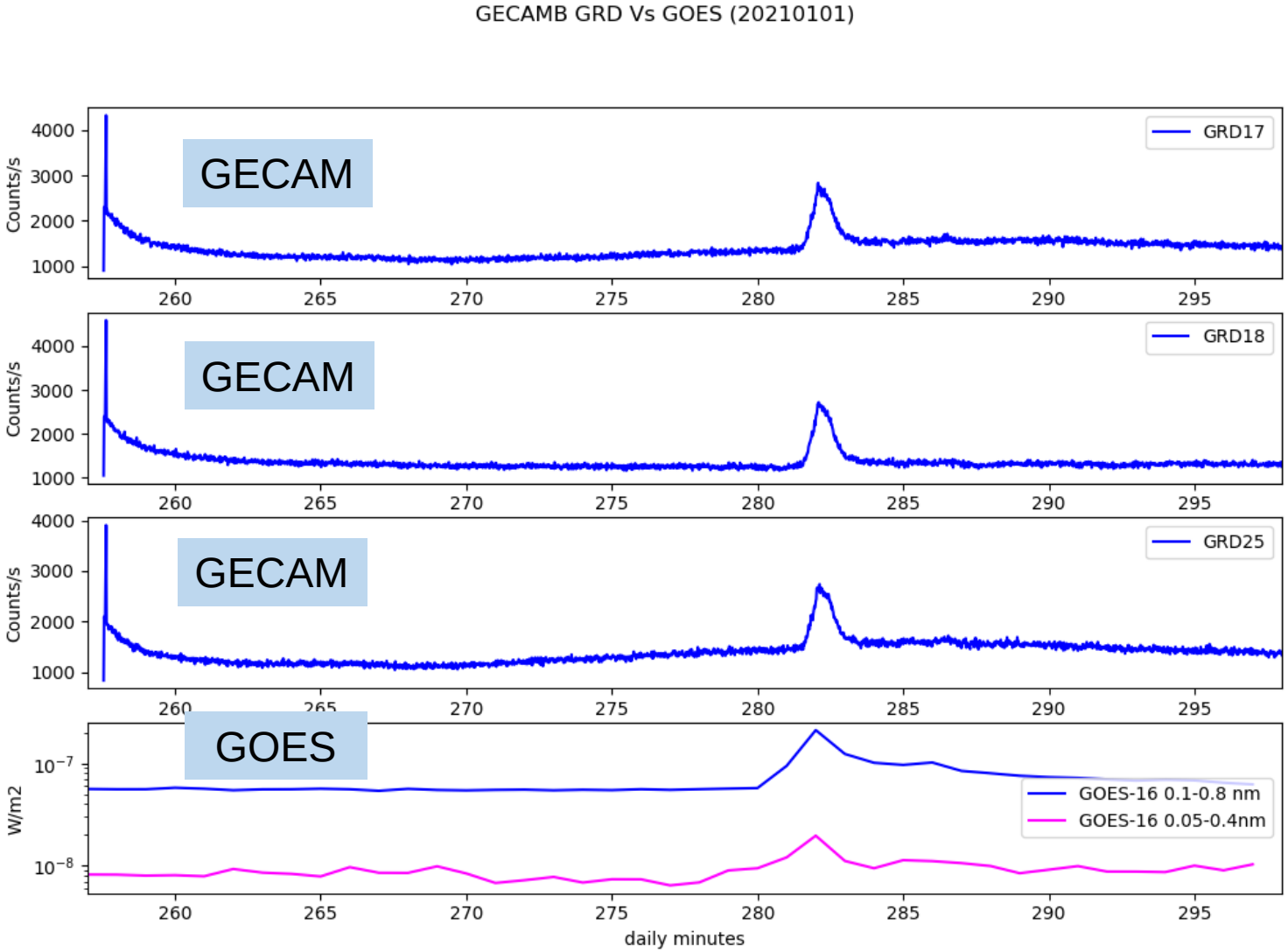
Subjects: X-ray, Binary, Neutron Star

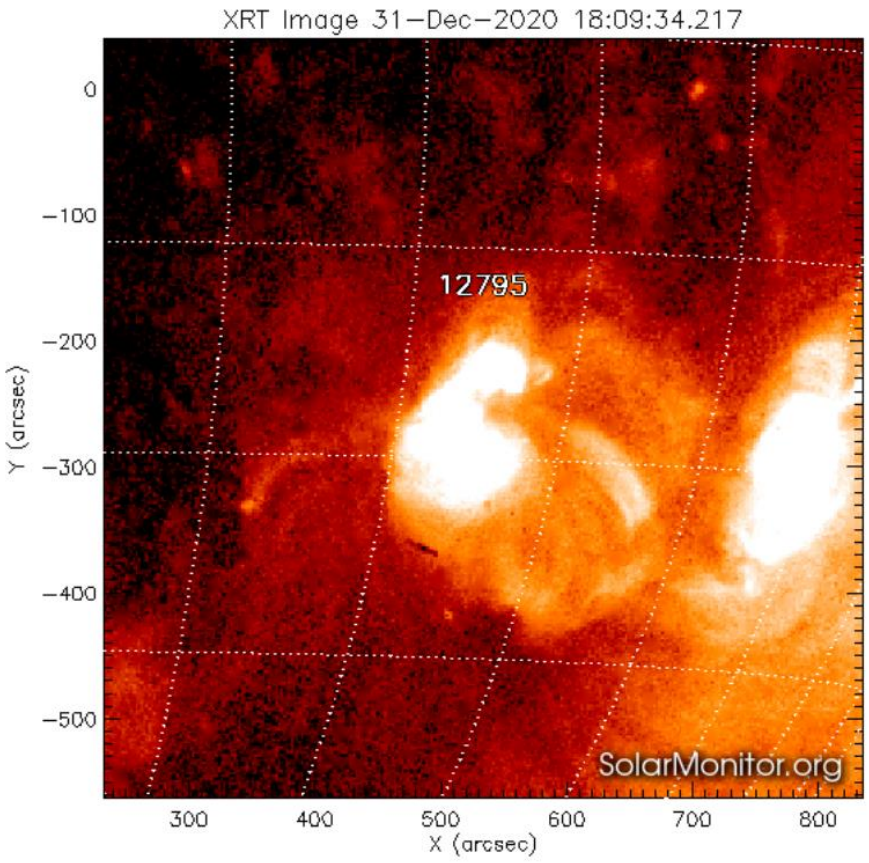
Tweet

During the commissioning phase, GECAM-B detected a very bright X-ray burst at 2021-01-24T11:50:03.600 UTC (denoted as T0, GCN 29350) from a direction centered on Ra: 94.9 degree, Dec: 6.6 degree with an error circle 2.7 degree (1-sigma, statistical only). The burst has a fast rise of 10 s, an exponential fashion decay and a duration of ~60 s. With 4 detectors out of 25, the peaks flux is ~700 cts/s above the pre-burst emission.
A pulsation at 413 Hz is detected with ~4 sigma. The 2-second time bin burst spectra are well represented by a blackbody, with a temperature peaking at 4.0+/-0.2 keV and a peak flux (3.3+/-0.2) x 10^-7 erg/cm2/s. The spectrum softens with the temperatures from ~4 keV to ~2 keV during the decay. Assuming the source at a distance 3 kpc, the unabsorbed bolometric peak luminosity is (3.6+/-0.2) x 10^38 erg/s, which is well consistent with the Eddington limit with a stellar mass of 1.4 solar mass for hydrogen-poor matter.
This analysis shows convincingly the burst is a genuine thermonuclear X-ray burst from 4U 0614+09, a faint and persistently accreting neutron star X-ray binary lying within the location error, from which the 415 Hz burst oscillation was first reported with data from Swift/BAT (Strohmayer et al. 2008). Since 4U 0614+091 has a burst recurrence time ~12 day (Linares et al. 2012), thanks to the very wide field of view (more than a half sky) of GECAM-B, more bursts should be detected during future observations of GECAM-B.

Gravitational wave high-energy Electromagnetic Counterpart All-sky Monitor (GECAM) mission consists of two small satellites (GECAM-A and GECAM-B) in Low Earth Orbit (600 km, 29 deg), launched on Dec 10, 2020 (Beijing Time), which was funded by the Chinese Academy of Sciences (CAS).

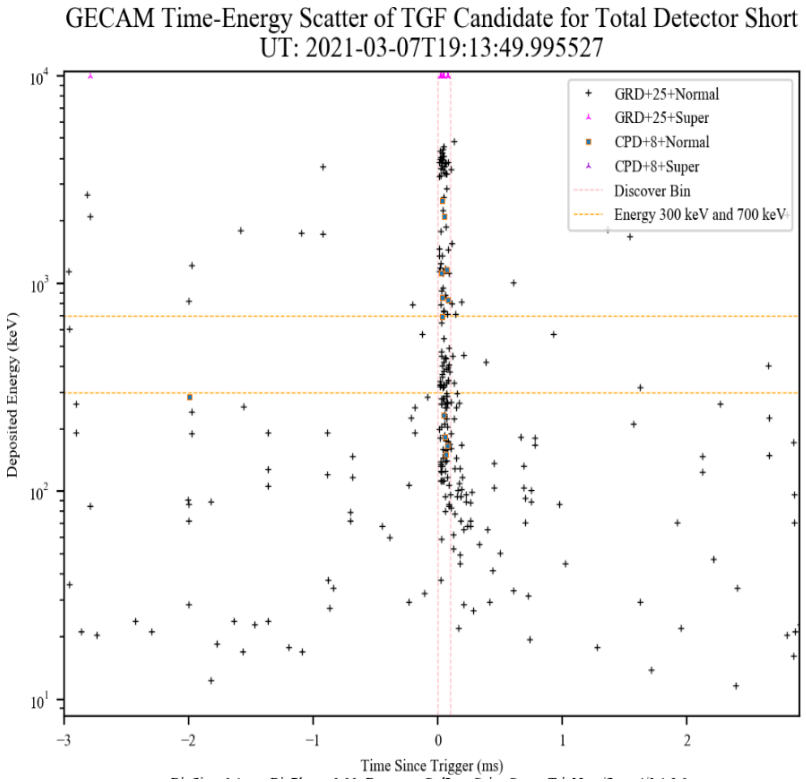
GECAM detection of Solar Flares

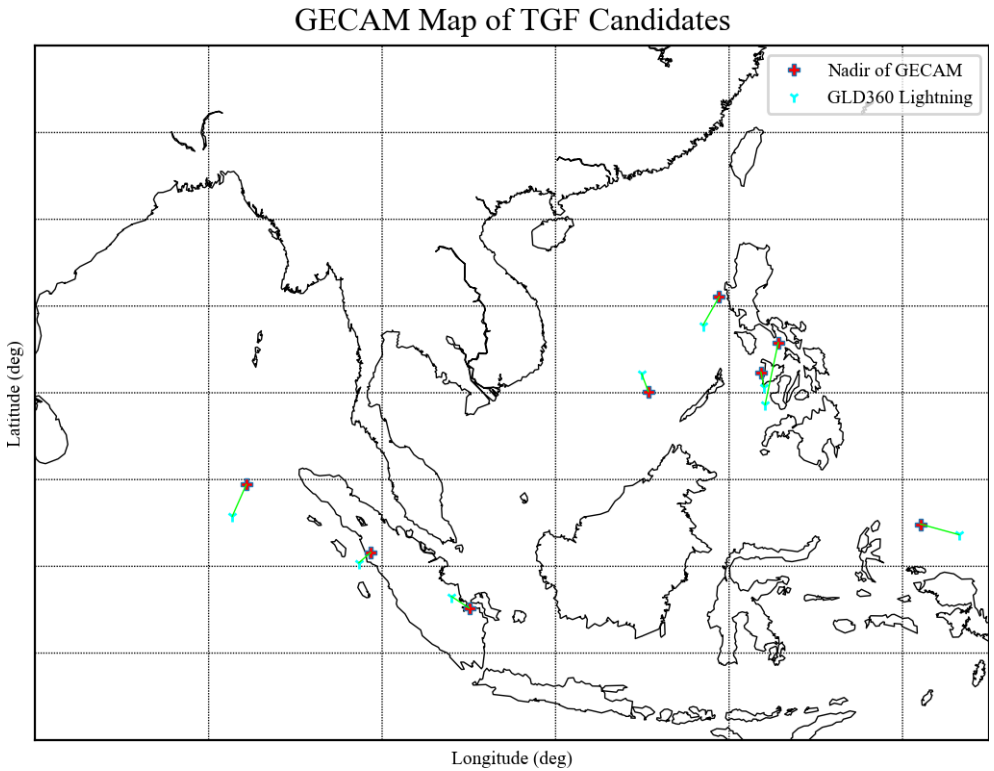


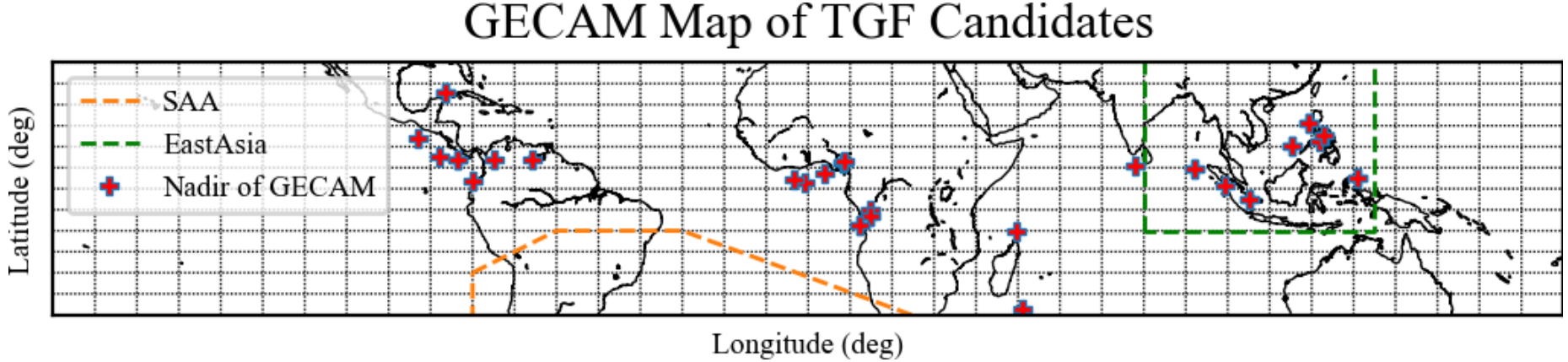


B2.1 class flare

GECAM detection of Terrestrial Gamma-ray Flash (TGF)







Summary

- GECAM dedicated for GWGRB, launched on Dec 10, 2020 (during COVID-19)
  - Two microsatellites: **GECAM-A**, **GECAM-B** (~11 hours/day)
- Detectors performance good while SiPMs showed complicated behaviors
  - GRD (LaBr3 + SiPM) and CPD (PS + SiPM)
- Many detections of GRBs, SGRs, XRBs, SFLs, TGFs…
  - Data and software will be released when the commissioning is finished
- Near real-time alert system based on BeiDou Navigation System (BDS)
  - Latency ~ 1 minute, testing GCN notices pipeline (working with GCN server)

Collaboration is OPNE!

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