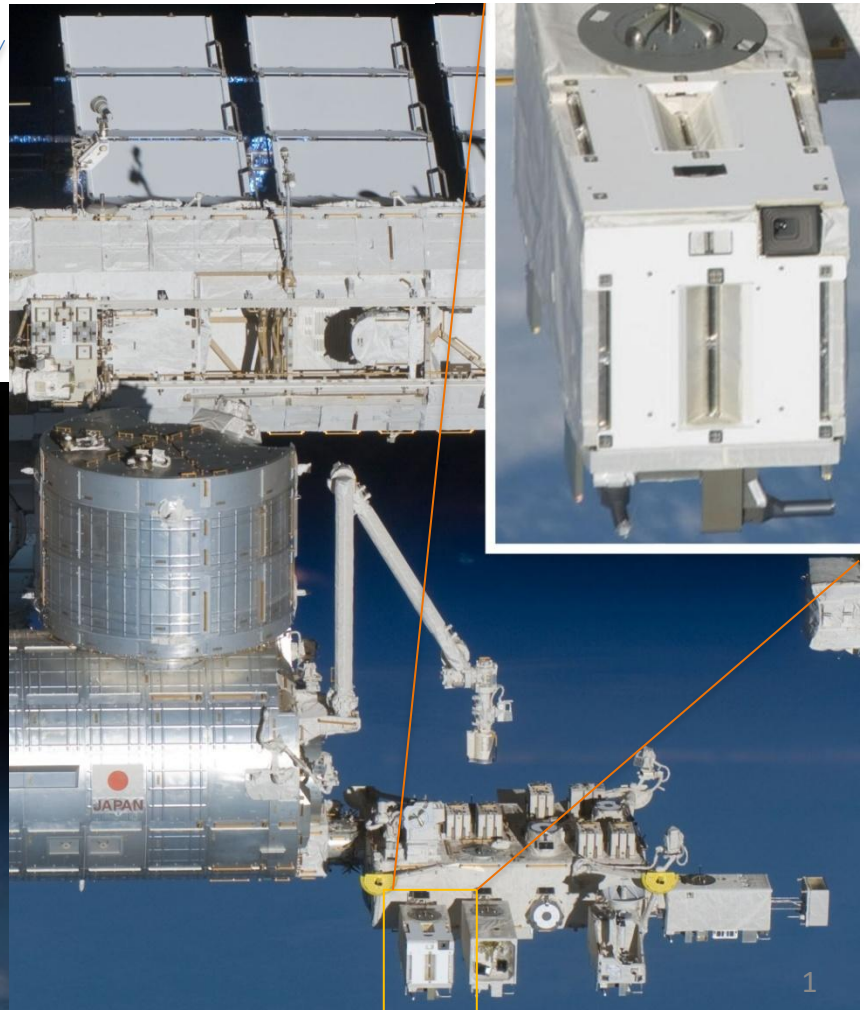
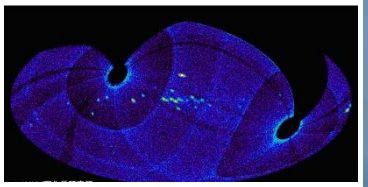
MAXI status and recent results

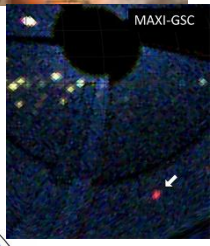
Tatehiro MIHARA and MAXI team

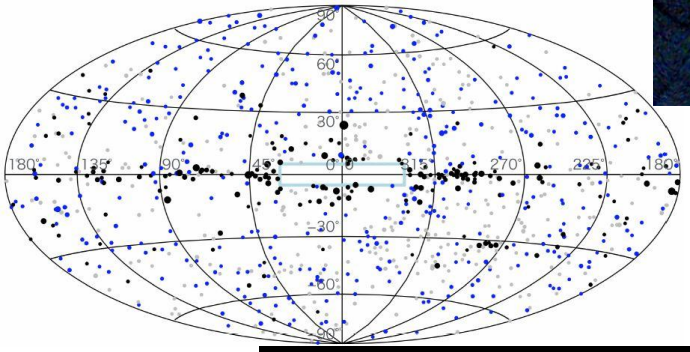


MAXI (Monitor of All-sky X-ray Image)



- First astronomical mission on ISS mounted in 2009
  - Proposed from RIKEN (PI : Matsuoka)
  - Scans all-sky every 92 minutes with ISS rotation
  - **Watching for X-ray novae,**
  - **Monitoring hundreds of X-ray sources**,
  - with Gas Slit Camera (GSC) in 2-20 keV
  - Public data **http://maxi.riken.jp/**





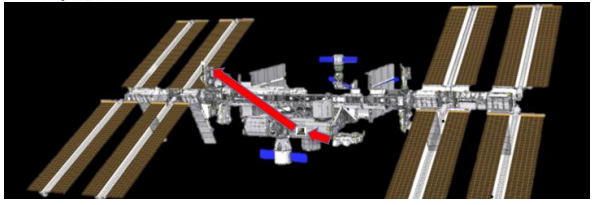
- **3MAXI Catalog** (7yr data, confusion limit)
- **Real time alert**

Automatic search for X-ray nova
Send out by MAXI ML 294 subscribers

- Triggering roll in Time-domain astronomy
- Operation is accepted until 2030 December.

with new value added by OHMAN, and

GW, VHE neutrino, new astronomical satellites.



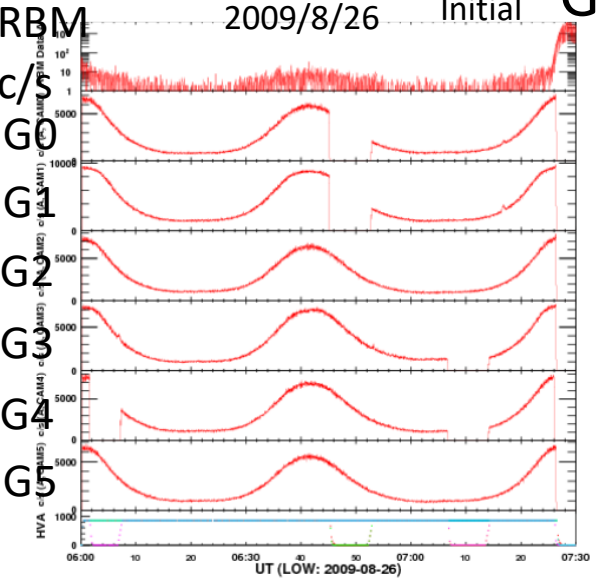
contents

- MAXI status
  - GSC gain
  - SSC degrade
  - DP radiation damage. one RLG was down.
- Recent 8 years (after 7yr workshop)
  - GW 170817 NS-NS merger
  - Big transients
  - Moon reflection
- OHMAN
- 2024 with New satellites
- Internet and robotic telescope, GRB very quick follow-up framework
- towards 2030

GSC status

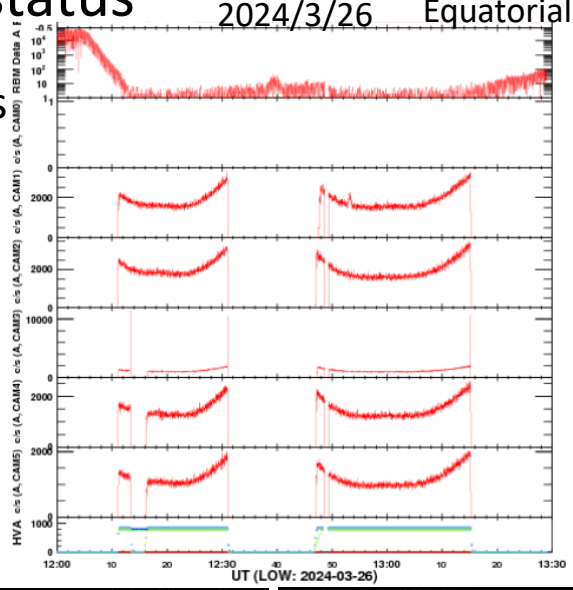
RBM c/s

2009/8/26 Initial



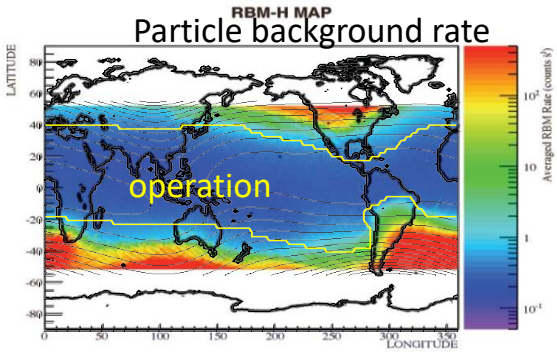
c/s

2024/3/26 Equatorial operation



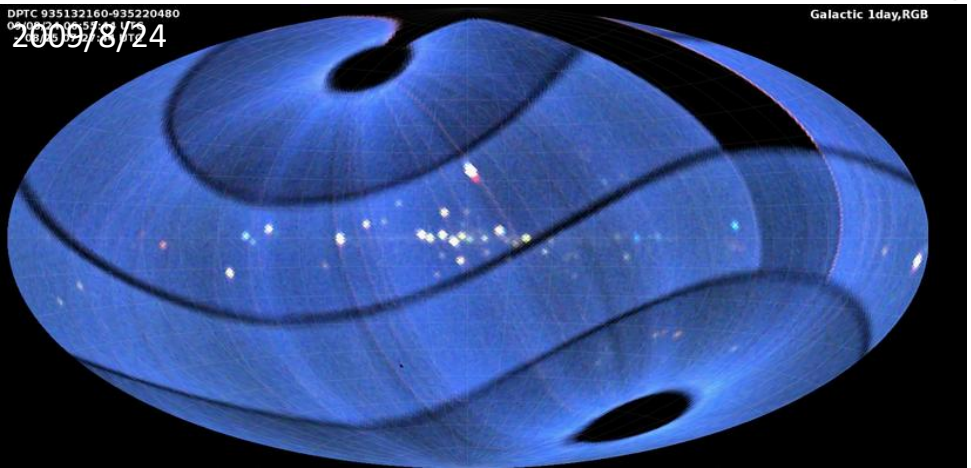
MAXI RBM

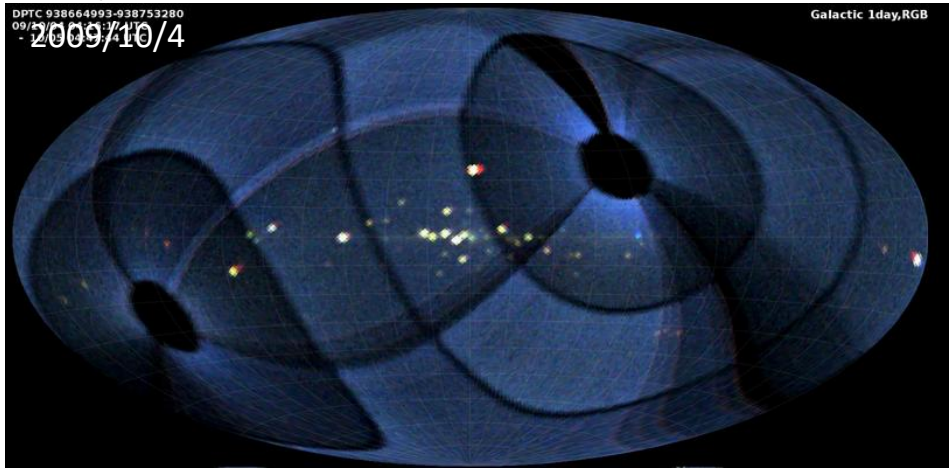
Particle background rate



Operating in equatorial region

Carbon wires of 3 cameras were broken.





GSC status

Working time (HV on time) of 12 GSC cameras in 2009 and 2023.

blue : normal HV of 1650V 2 cam.

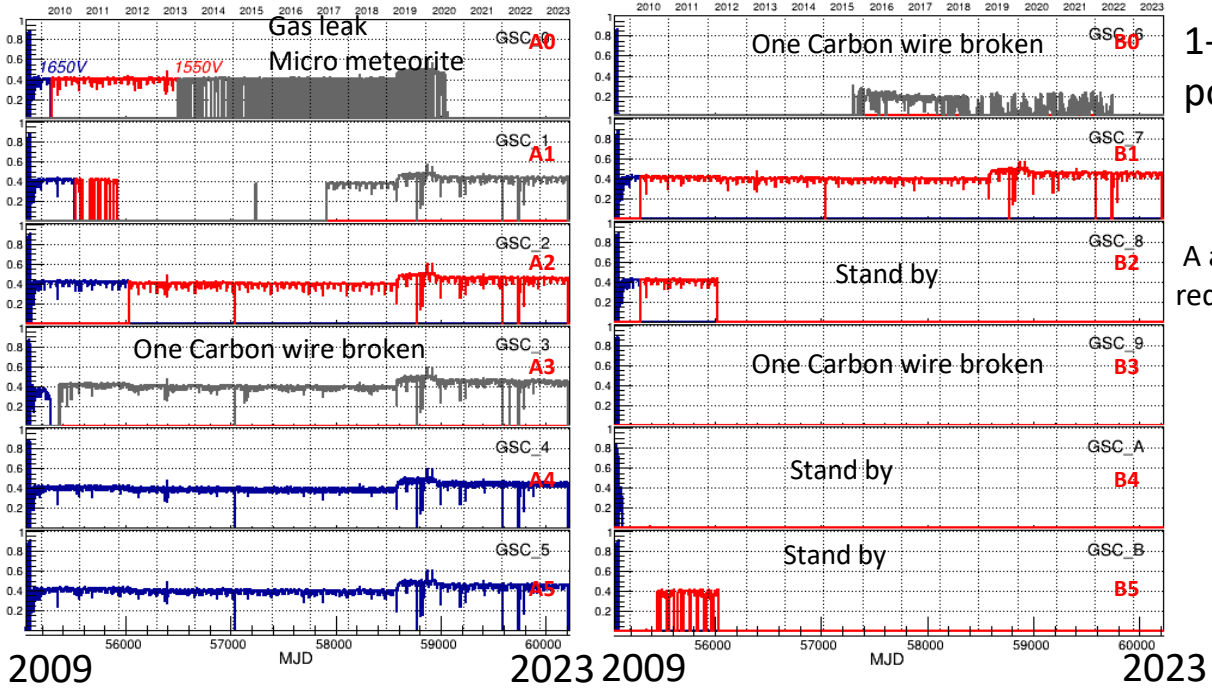
red : acceptable HV of 1550 V 2 cam.

gray : low position resol. HV 1500V 1 cam.

GSC 3 is a degraded camera working, (half area, without veto function).

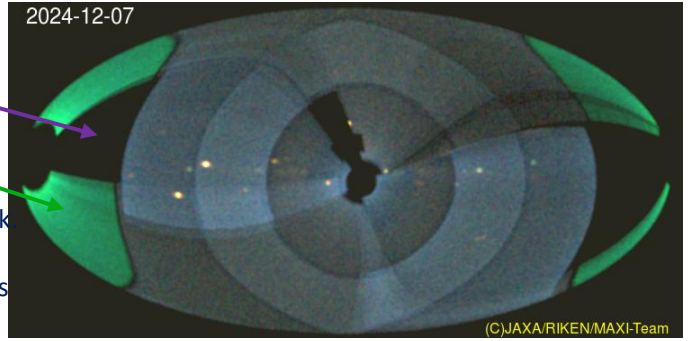
GSC 0 and GSC 6 are stopped.

The average working time is 40 %, because GSC are operated only in low latitude regions, where the particle background is low.



1-day points

A and B redundant



Region covered with GSC 0 and 6 are blank. That with the degraded camera GSC 3 appears in green because the count-rate is higher than the normal cameras.

89% of the sky, one day

Recent 1-day observation

red: 2-4 keV

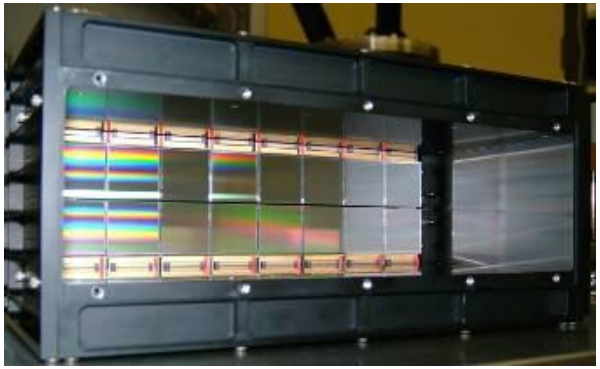
green: 4-10 keV

blue: 10-20 keV

http://maxi.riken.jp/pubdata/v7.6l/

SSC status

Solid-state Slit Camera



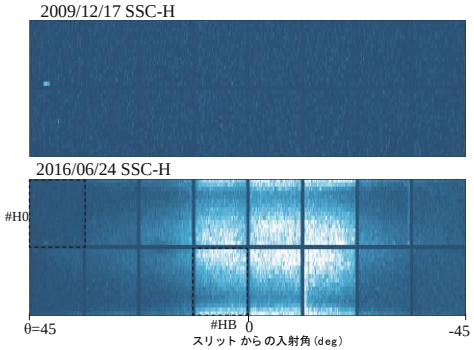
SSC is off after 2022 June 21
to reduce the power load.

CCD degradation : Charge transfer efficiency is decreasing, and dark current is increasing. The degradation is most evident in the central chips where the incident angle from the slit is small, that is, penetrating length of the window is thinnest for particles to get in the CCD. Therefore the cause would be the low-energy particles from the slit.

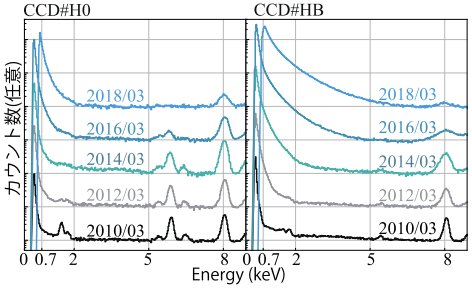
Low energy noise depends on the location of CCD chips. The CCD #H0 (horizontal camera ,number 0) locating at the edge has small noise, while CCD #HB locating at the center has large noise.

As of 2020, SSC could still detect bright sources in the lower energy than GSC. Sensitivity was 1 Crab in 1 scan. Some hundreds of mCrab in 1 day.

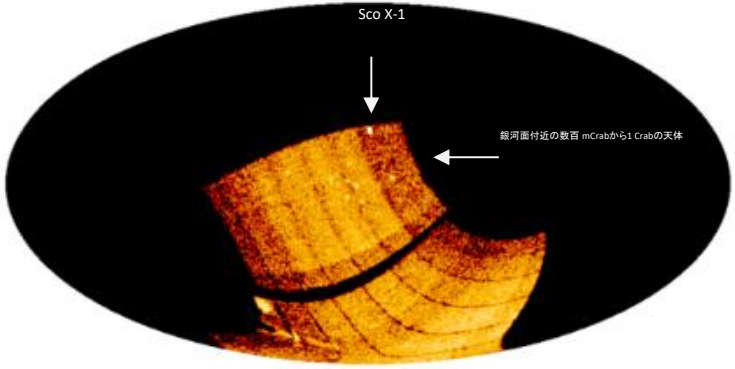
CCD background rate



Energy spectra with time



SSC 1.5-3 keV 2020/8/7 1day



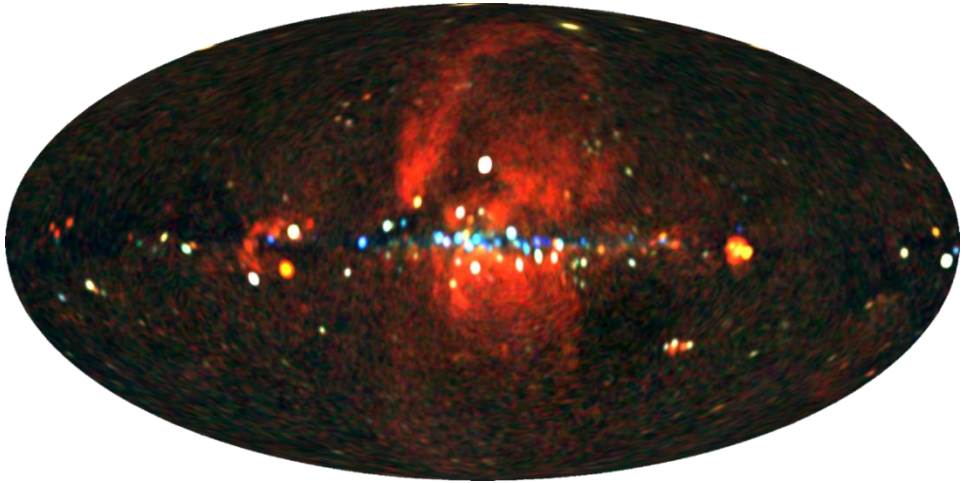
MAXI mission in Handbook of X-ray and Gamma-ray Astrophysics Mihara, Tsunemi, Negoro (2023)

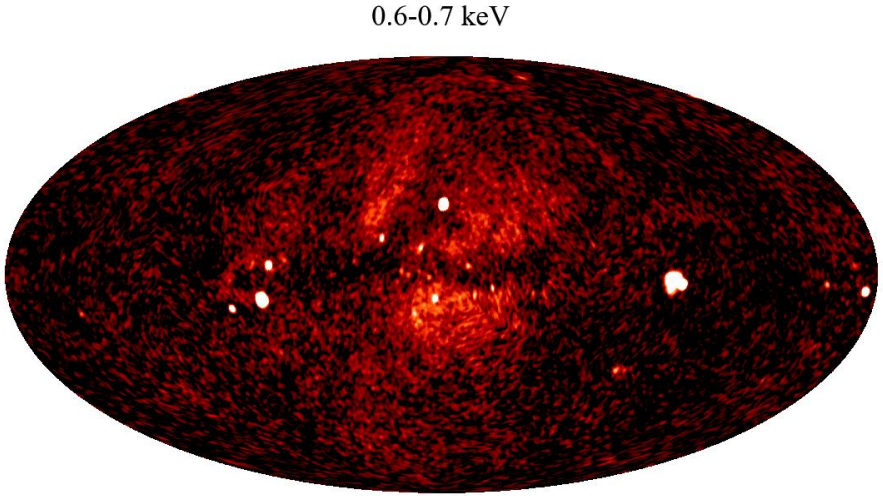
2020

Nakahira 2020

SSC diffuse X-ray map

MAXI/SSC all-sky image (2009/08/15 -2011/8/27)



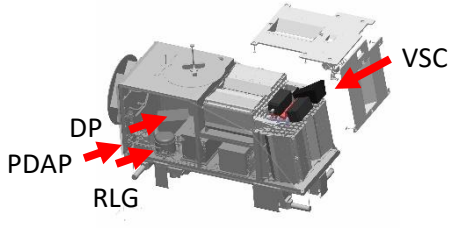


World’s first soft-X-ray all-sky map with X-ray CCD. (just before eROSITA)

MAXI System status -problems-

Data Processor

Abrupt shutdown in 2022 June 4 and 21
After June 23 in "Power saving" mode
(SSC off, degraded camera B-camera 0 off).
Continuing operation till now (2024.12)



- NEC reported the cause would be CPU radiation degradation.
  - ✓ Radiation tolerant of CPU and Ethernet controller is 7.15 krad.
  - ✓ Total dose in 13 years is 8.7 krad.
  - ✓ Not completely broken, but almost? sometimes? broken.

Visual Star Camera

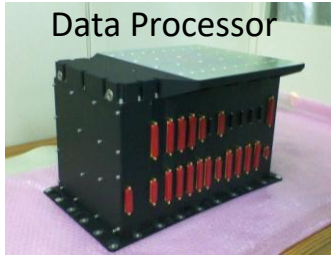
Since 2016 the attitude has not been determined due to VSC/CCD radiation damage.

In 2018 we raised the hot pixel threshold, but again in 2020 the attitude has not been often determined. ⇒ We use ISS attitude

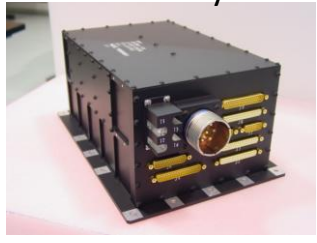
Ring Laser Gyro

2018/12.Y-axis was broken due to life.(10 years) ⇒ We use ISS attitude.

Data Processor



Power Distributor of Attached Payload



Visual star camera

Ring Laser Gyro

2018
GW 170817

Sugita 2018

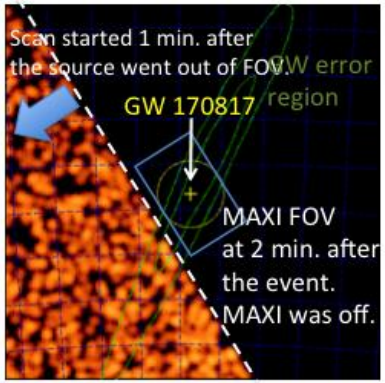
- **NS-NS merger** at 40 Mpc exhibited electromagnetic (EM) emission: prompt short gamma-ray burst (SGRB), delayed UV-optical-IR “kilonova”, and late-time faint X-ray/radio afterglow.
  - Implications on r-process elements, neutron star EoS, and jets
- MAXI set the earliest X-ray upper limit at 4.6 hours after the GW event.
  - MAXI was not able to observe GW170817 for 4.6 hours after the GW trigger due to operational radiation-zone constraints.

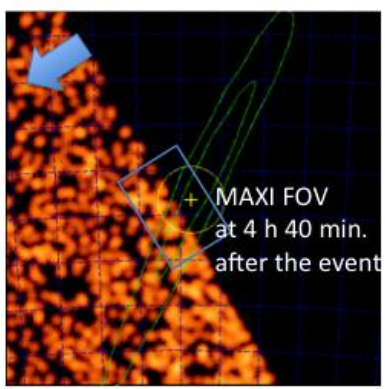
MAXI observation

The last observation was 18 min. before the event.

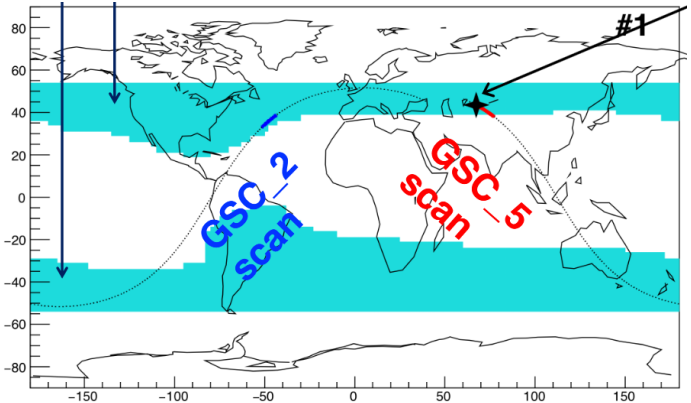
12:41 GW 170817 occurred.

Since 6th orbit MAXI scanned the GW position every orbit.





12:41:06UT

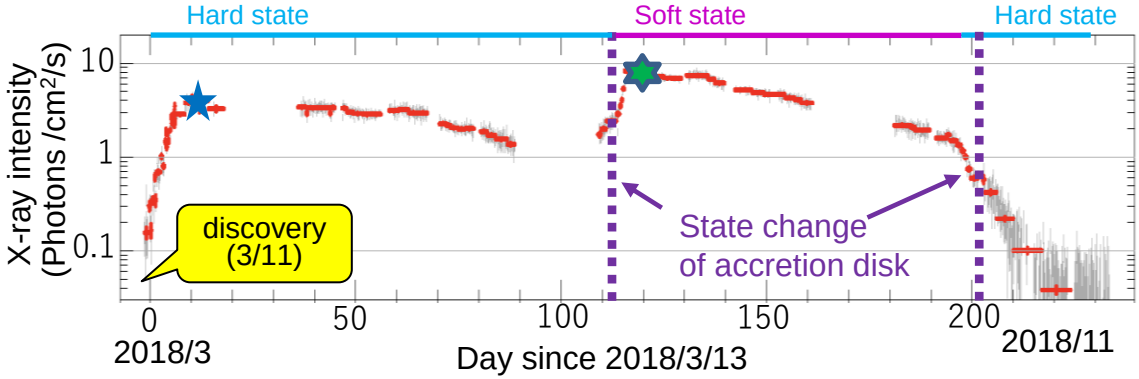


Bright and variable MAXI J1820+070

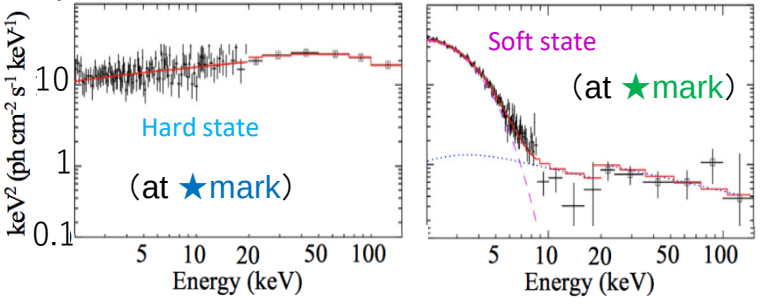
The second “late state transition BH”

【(Credit: Aurore Simonnet and NASA GSFC)】

MAXI J1820+070 X-ray light curve (2-10 keV)

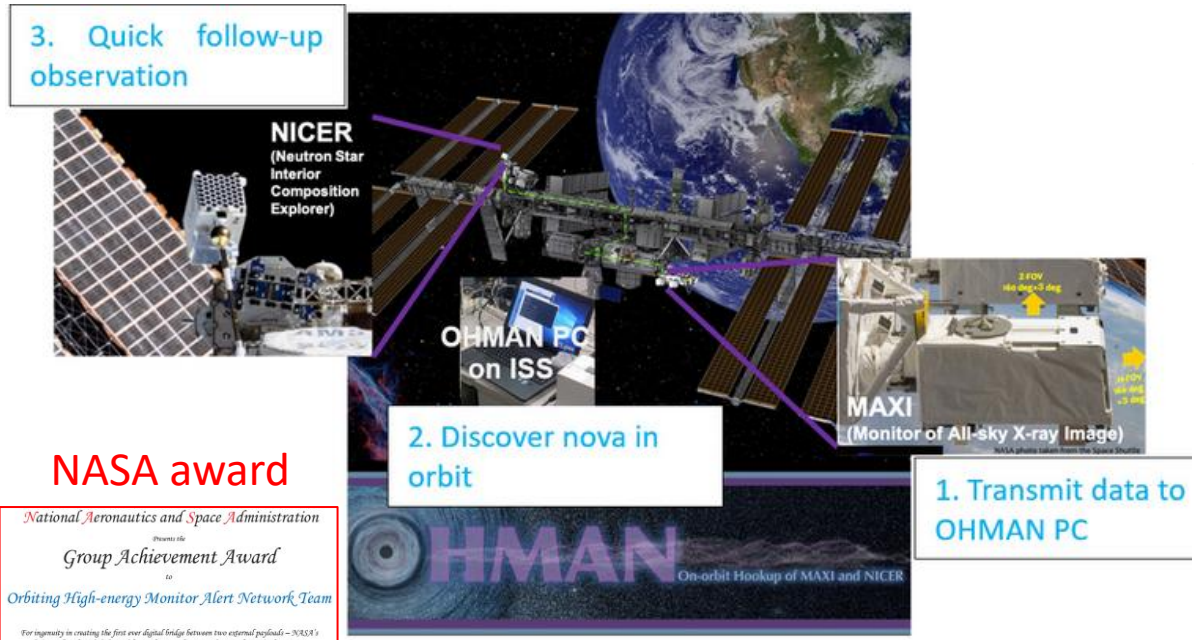


Spectra of hard and soft states with MAXI and Swift/BAT



2022

OHMAN started. M15 X-ray burst.



drawing of the MAXI-NICER orbital coordination per OHMAN© NASA/JAXA

NASA award

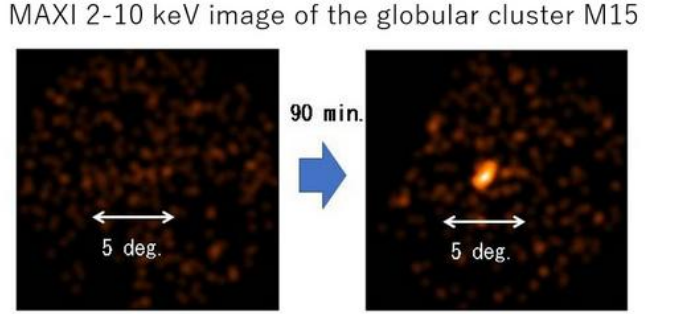
National Aeronautics and Space Administration

Group Achievement Award

to

Orbiting High-energy Monitor Alert Network Team

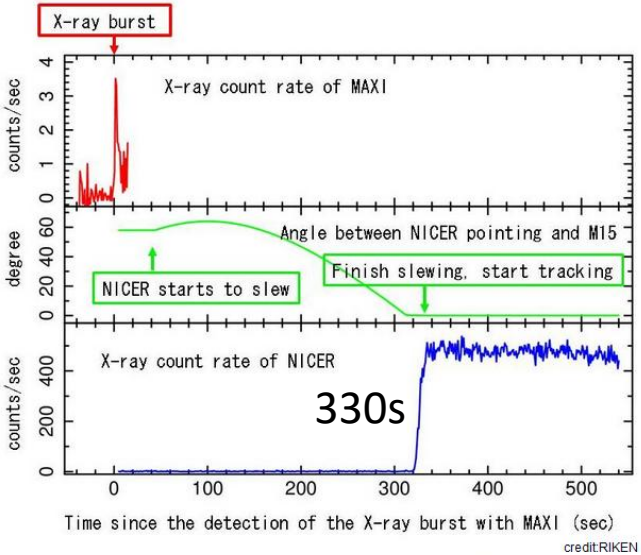
Tatehiro Mihara



the last ISS orbit before the X-ray burst. At the burst detection.

credit:RIKEN

2: MAXI images of M15 before the X-ray burst and at the burst detection.



credit:RIKEN

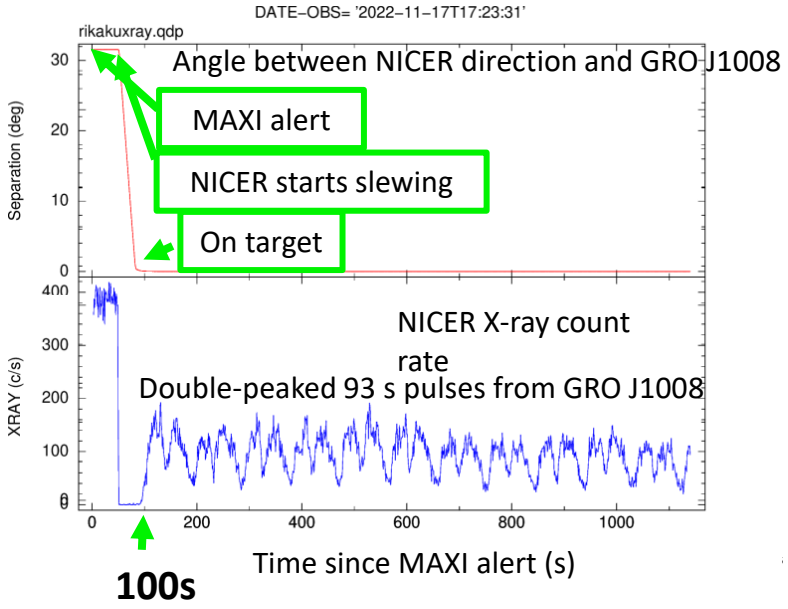
Figure. 3: Time flow from the detection of the X-ray burst to the NICER observation.

https://global.jaxa.jp/press/2022/10/20221017-2_e.html

OHMAN（On-orbit Hook-up of MAXI and NICER）

Quick response to GRO J1008-57 pulses

2022/11/17



2022/9/13　X-ray burst from M15　5m 30s

2022/10/9 GRB 221009A afterglow.　No　NICER visibility
2022/10/17 GRB 221017A　No NICER visibility

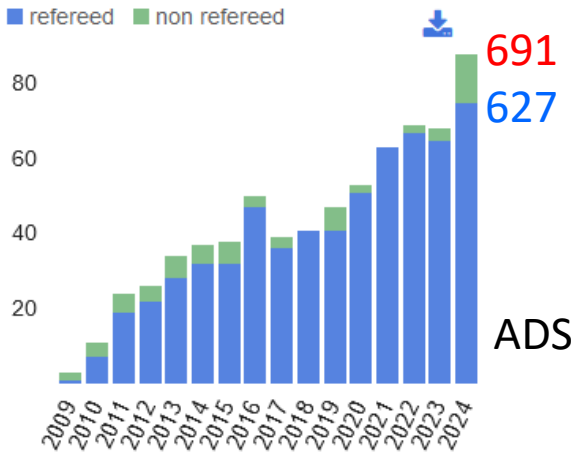
2022/11/17　Quick response to GRO J1008-57 pulses　1m 40s

2023/8/1　X-ray burst from H 1636-536　2min 2s
2023/8/15 intermediate burst from 4U 1850-086　10min 31s
Lu et al. 2024

2024/4/24　4U1850-086　intermediate long burst

But,
Fake events by Solar flares
PC troubles (hang up, PC replacement)
Network problem (HUB mis-setting, cable pull-off)

Awards



- Refereed paper using MAXI data
  691 (2024.12.8) Matsuoka et al. 2009
- 2013 Paper Award by Publ. Astron. Soc. Japan
- 2016 ISS R&D award on innovation in earth and space science, at ISS R&D conf. 2016 by CASIS (Center for Advance. of Science In Space), American Astronautical Society, NASA

Time domain astronomy --- Real time astronomy
Multi-messenger astronomy

2024

ISS R&D 2024 award

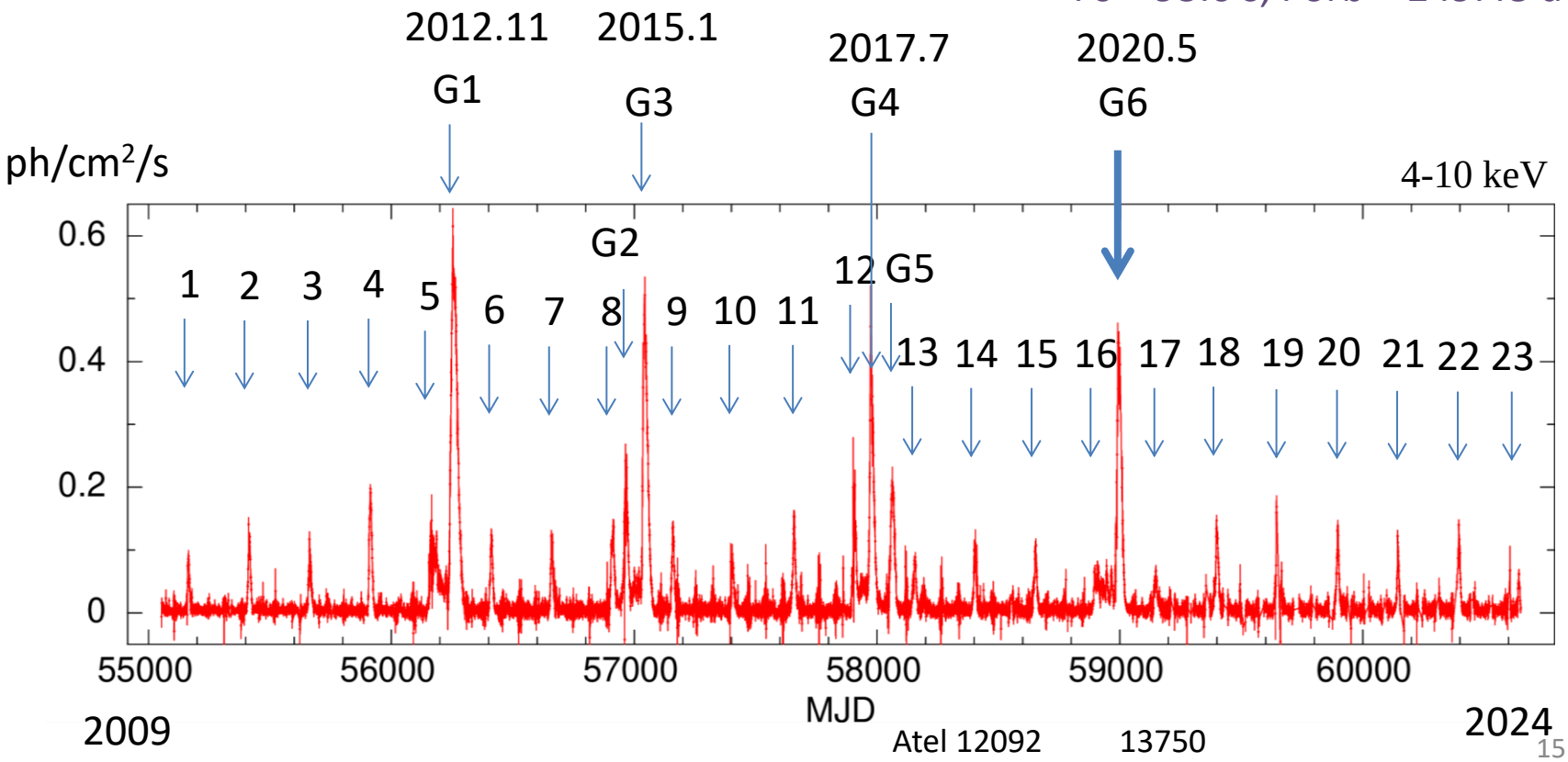
ISSRDC2024(ボストン) DAY2/ アワード受賞式の様子 (MAXIチーム受賞)

Displayed in poster room

GRO J1008-57 Giant OB 2020 May 22 ATel #13750

Regular normal OB, Giant OB ~3 y (4 or 5 Porb)

Ps = 93.6 s, Porb = 249.48 d



M, R, B estimation of X Persei

Sugizaki talk

Yatabe 2018

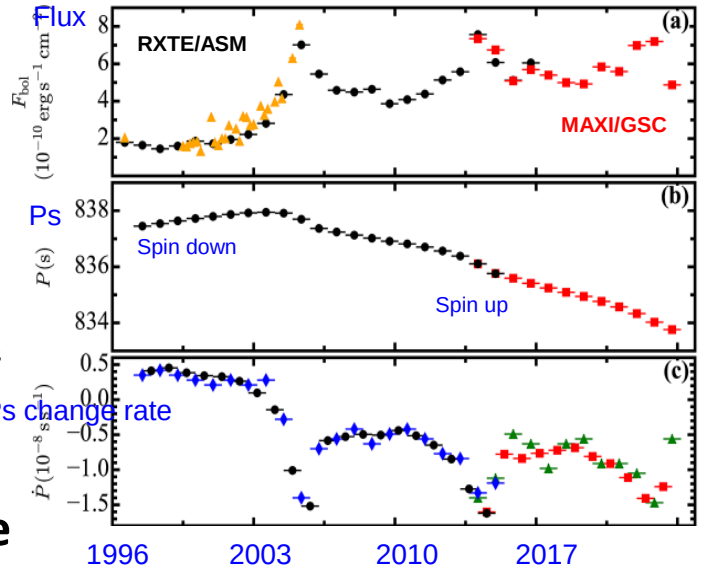
Ps = 835 s, Porb = 251.0 d

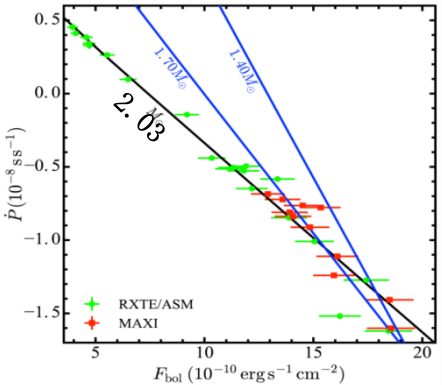
- RXTE/ASM – MAXI 22 yrs
- GL79 gives B = (5- 23) x 10^{13} G

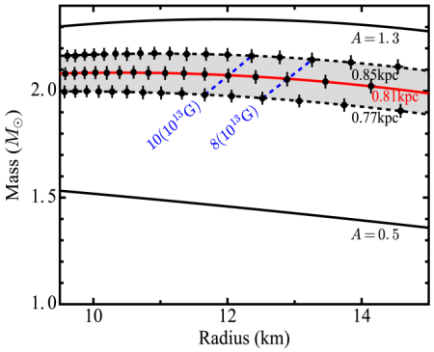
(cyclotron 3x10^{12}G report contradicts. It could be interpreted as a dip between two components as seen in SGR)

- GAIA Distance 0.81±0.04 kpc
- → M = 2.03 ±0.17$M_\odot$

High magnetic fields and massive







Similar analysis for 4U 1626−67 was done by Takagi et al. (2016)

Long-term flux variation of NS-LMXB

8 NS-LMXB with Ginga/ASM, RXTE/ASM, MAXI/GSC : 33 years Asai 2022

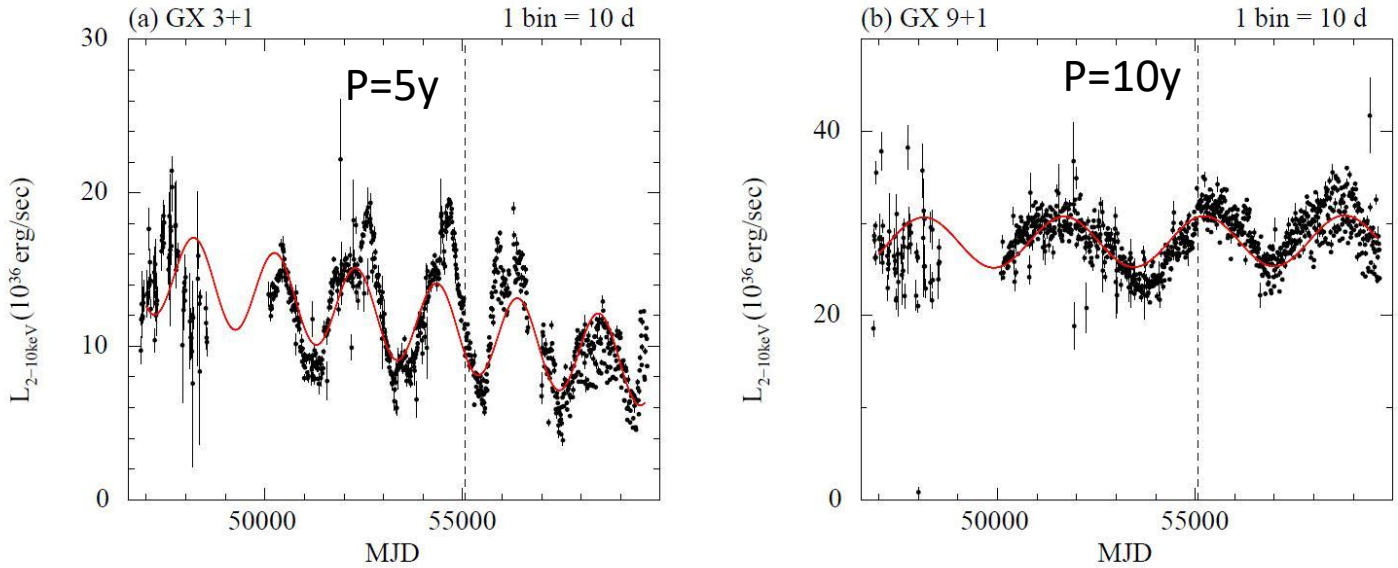
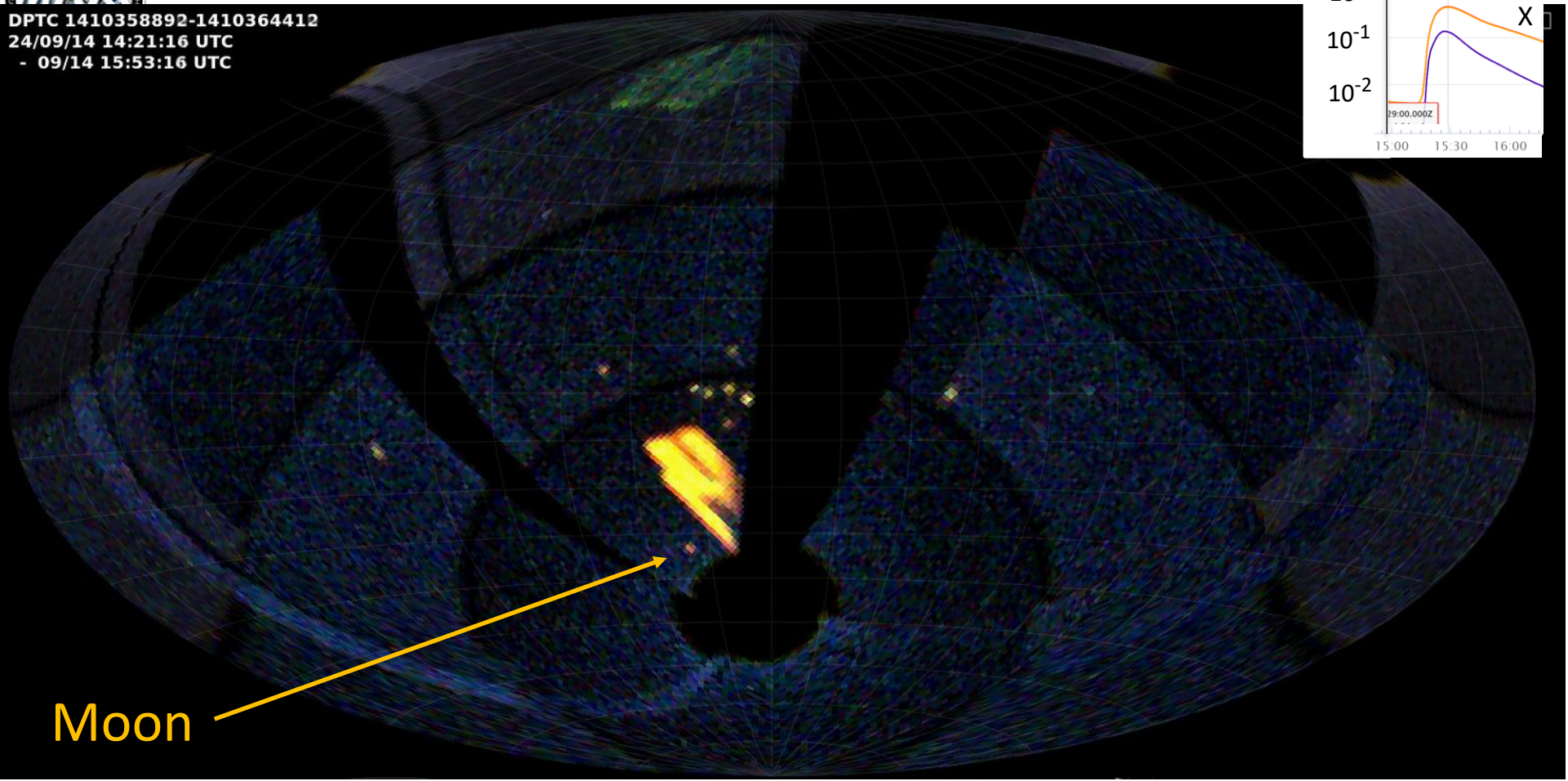


Fig. 2. Light curves observed by Ginga/ASM, RXTE/ASM, and MAXI/GSC. For GX 3+1 and GX 9+1, we show the fitted sinusoidal curves in red (Color online). The model function and parameters are shown in table 2. The data of GX 9+1 has a discrepancy between ASM and GSC fluxes. MAXI data are processed in a regular way as for other sources. There is no contamination source nor background uncertainty by the ridge emission. So we plotted the data as they are.

Reason unknown

2nd observation of the reflected X-ray from the Moon

2024/9/14 15:26(UT)



Reflected X-ray by the Moon

Sugawara poster 02

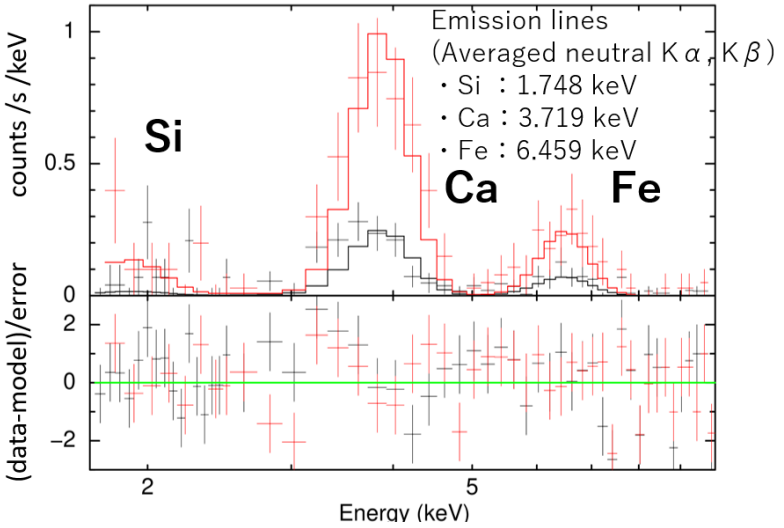
	First	Second
Time(UT) in 2024	Feb. 22 22:34	Sep. 14 15:26
Solar flare intensity	X6.3 (at observation)	X4.2 (at observation)
Moon age (area)	13.0 (96.7% full moon)	11.5 (88.5% full moon)
flux(2-10 keV) [erg/cm²/s]	9.15×10^{-9}	2.57×10^{-9}

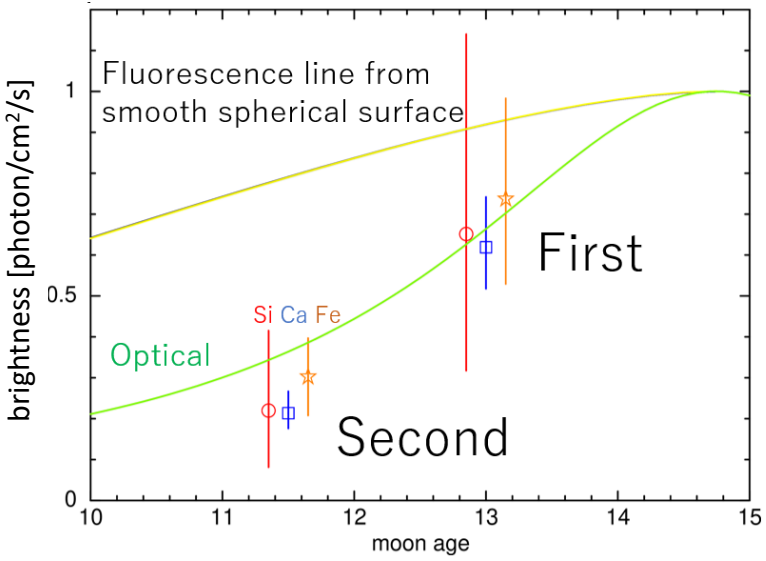
strong X-class solar flare
almost full moon

Moon/Sun ratio = 3e-8

1 Crab

200 mCrab





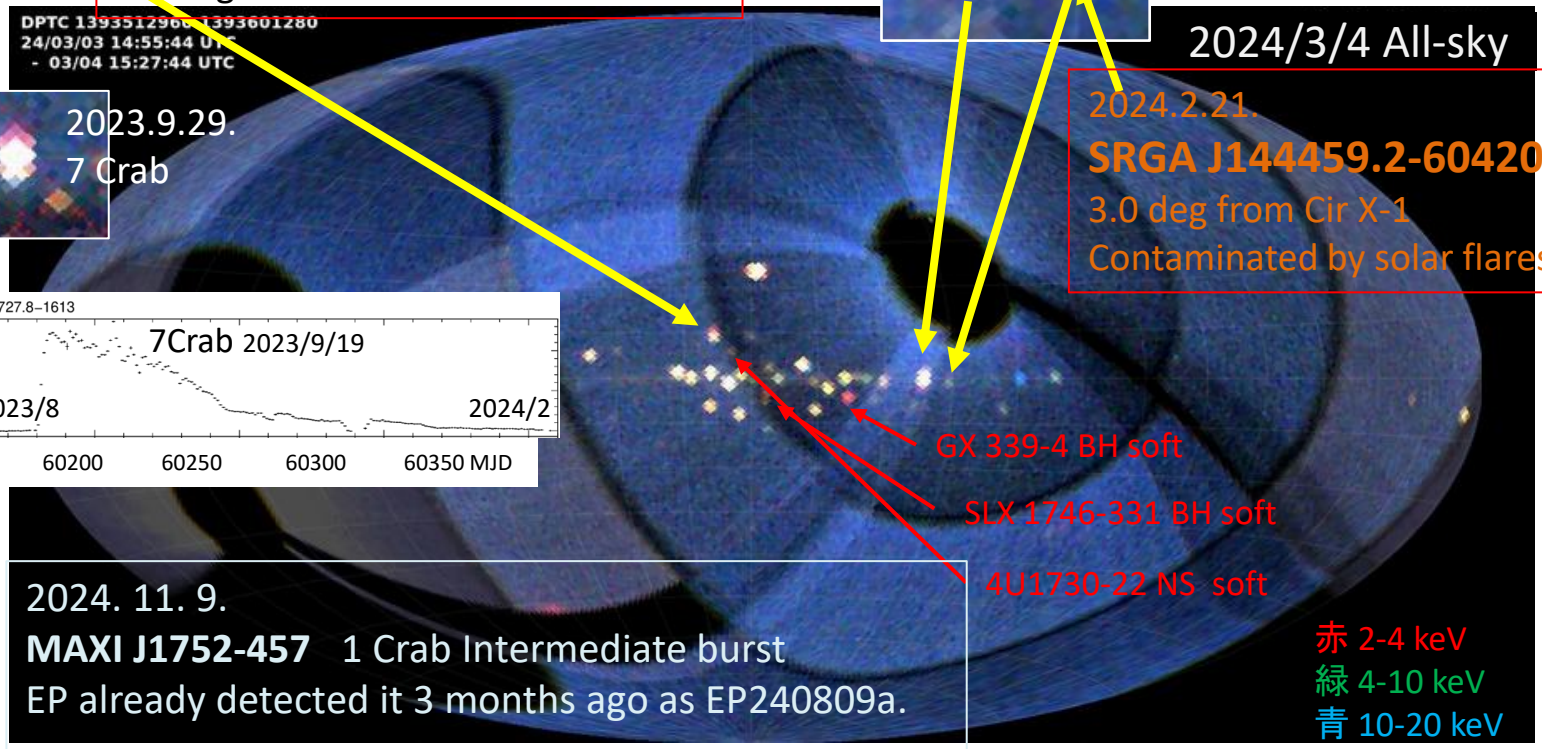
MAXI detected reflected fluorescent X-rays from the moon, which Giaconni intended in 1962.

2024 trials for MAXI

Repeating solar flares disturb OHMAN.

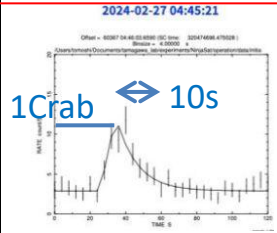
2023.8.24. decayed to 50 mCrab
Swift J1727.8-1613 BH soft state
1.2 deg from GX 9+9

2024.3.3. 1.2 Crab
Swift J151857.0-572147 hard state
0.3 deg from Cir X-1



2023.9.29.
7 Crab

2024.2.21.
SRGA J144459.2-604207 NS hard state
3.0 deg from Cir X-1
Contaminated by solar flares on 2/14



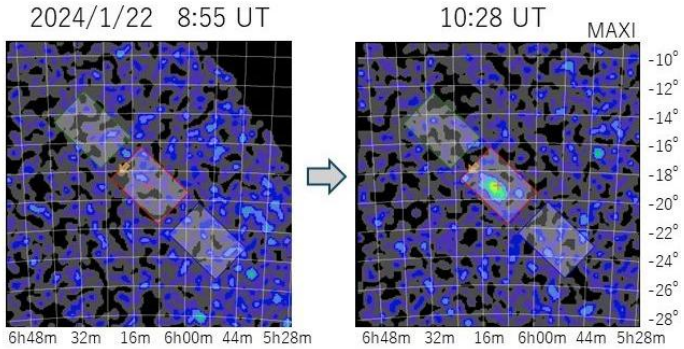
NinjaSat
X-ray burst

2024. 11. 9.
MAXI J1752-457 1 Crab Intermediate burst
EP already detected it 3 months ago as EP240809a.

赤 2-4 keV
緑 4-10 keV
青 10-20 keV

Distant and ancient GRB 240122A

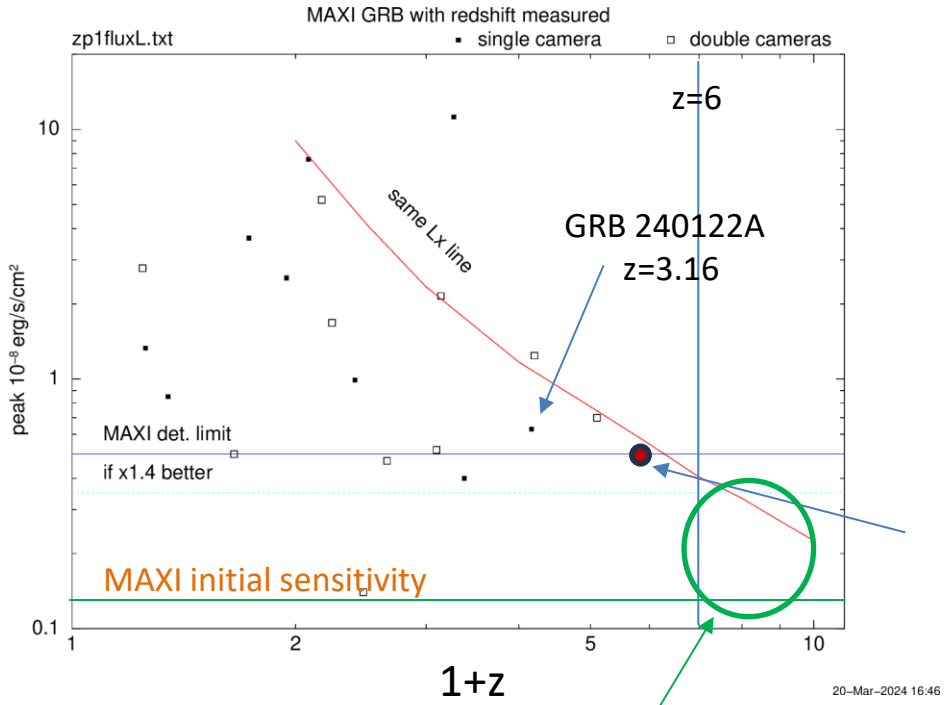
- MAXI detected GRB 240122A at 10:28:03 UT on Jan. 22 (GCN #35593). The X-ray intensity was 150 mCrab.
- GOTO (Gravitational-wave Optical Transient Observer) caught the GRB by chance at 44 min later (GCN #35596 The optical afterglow was 17th magnitude. It decayed to 20th magnitude at 13 h later . (GCN #35611).



- Swift follow-up detected an X-ray afterglow of 1 mCrab at 8 h later (GCN #35600).
- The 10m diameter GTC/ORISIS+ (Gran Telescopio Canarias) telescope took an optical spectrum at 13 h later and determined the redshift of z=3.162 (GCN #35598).
- The 8m telescope VLT/X-shooter in Chile also observed it at 16 h later and confirmed the redshift (GCN #35599).
- The distance to the GRB is 11.7 billion lt-yr. This is the second farthest GRB ever detected with MAXI among 18 GRBs with observed redshifts.

MAXI GRB

Redshift was measured from 19 GRBs
from MAXI 161 GRBs in 14 years



So-called "High z" GRB

090423	z=8.26	
120923A	7.8	
240218A	6.782	<-- 2024
080913	6.7	
140515A	6.32	
210905A	6.318	
050904	6.3	Kawai GRB
130606A	5.9	

over z = 6

Launched
2024 Jan 9

Shock of GRB 240315C = EP short object EP240315a

5e-10 erg/s/cm^2(0.5-4 keV) lasted for 1600s

[5e-9 erg/s/cm^2 (2-20 keV)]

detection with Konus, Swift/BAT → GRB

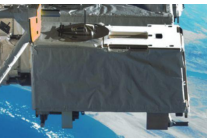
VLT X-shooter z=4.859

Initial sensitivity of MAXI might have detected high-z GRBs.

The 2 – 4 times more sensitivity was essential for MAXI GRB.

From the beginning,
EP GRB exceeded MAXI GRB.

MAXI in 2024 - 2030



Now

2024.12

2030.12

Late phase Ope (4)

Late phase operation (5)

FY 2024 | FY 2025 | FY 2026 | FY 2027 | FY 2028 | FY 2029 | FY 2030

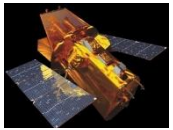
GSC

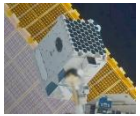
Continue All-sky monitoring, Alerts, public data

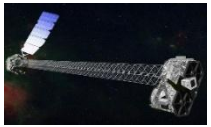
OHMAN

Transients with NICER in 10 minutes (2 min.)

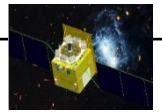
Follow up observations with Swift, NICER, NuSTAR





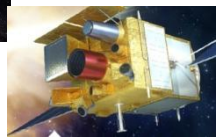


HXMT, Chandra, XMM-Newton, SRG

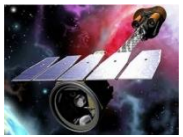


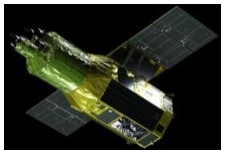
EP, XPolSat

SVOM



Detailed observation of bright sources IXPE, XRISM



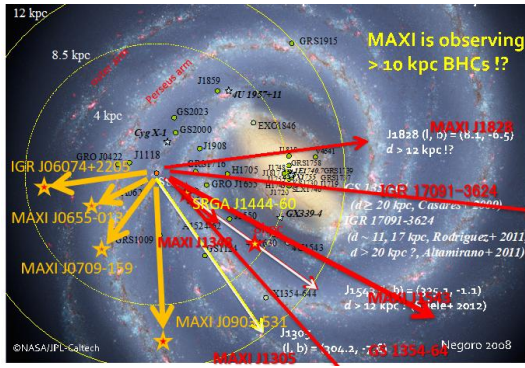


GW O4 2023.5 - 2025.6

O5 2027.8 – 2030.

VHE neutrino IceCube

summary



MAXI will keep watching the sky till 2030.

MAXI watches through our Galaxy.

Follow up is very fruitful and getting more rapidly.

OHMAN (MAXI – NICER) has started.

New satellites joined with surpassing performance.

Let’s search for the discovery space in

time-domain astronomy and

multi-messenger astronomy