Status of MAXI observations of EM counterparts of GW events

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MAXI 15 Year Workshop for the Time Domain Astronomy, 10-12 Dec 2024, Nihon University

MAXI observations of gravitational wave events

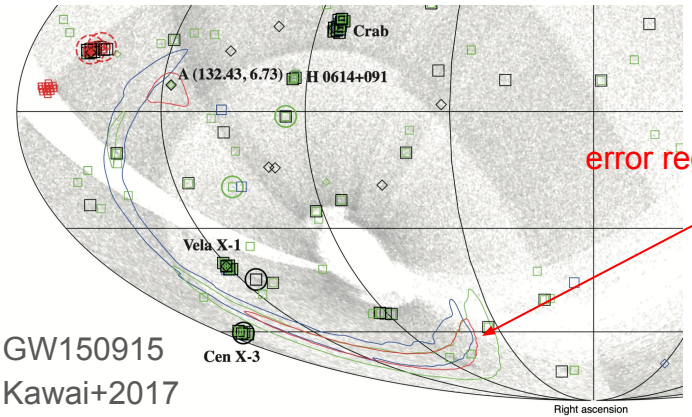
All-sky monitoring in one orbit (92 min)

- can cover large error area of GW events: ~85% of whole sky in one-orbit, ~95% in one-day
- can search the emissions of the same position before GW trigger

MAXI team has been part of LIGO/Virgo collaborations since 2014

We have reported the observation results (only upper limits at present) of X-ray flux at 2-10 keV in one-orbit and one-day

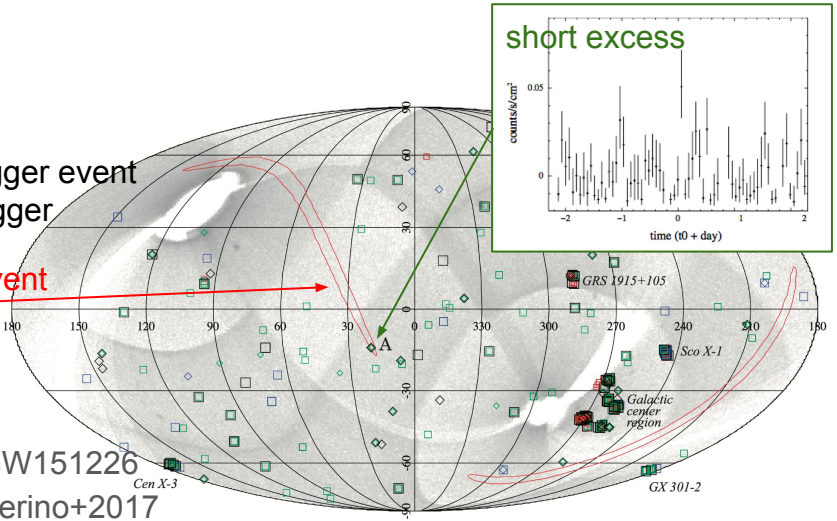
All-sky image in one-day



GW150915
Kawai+2017

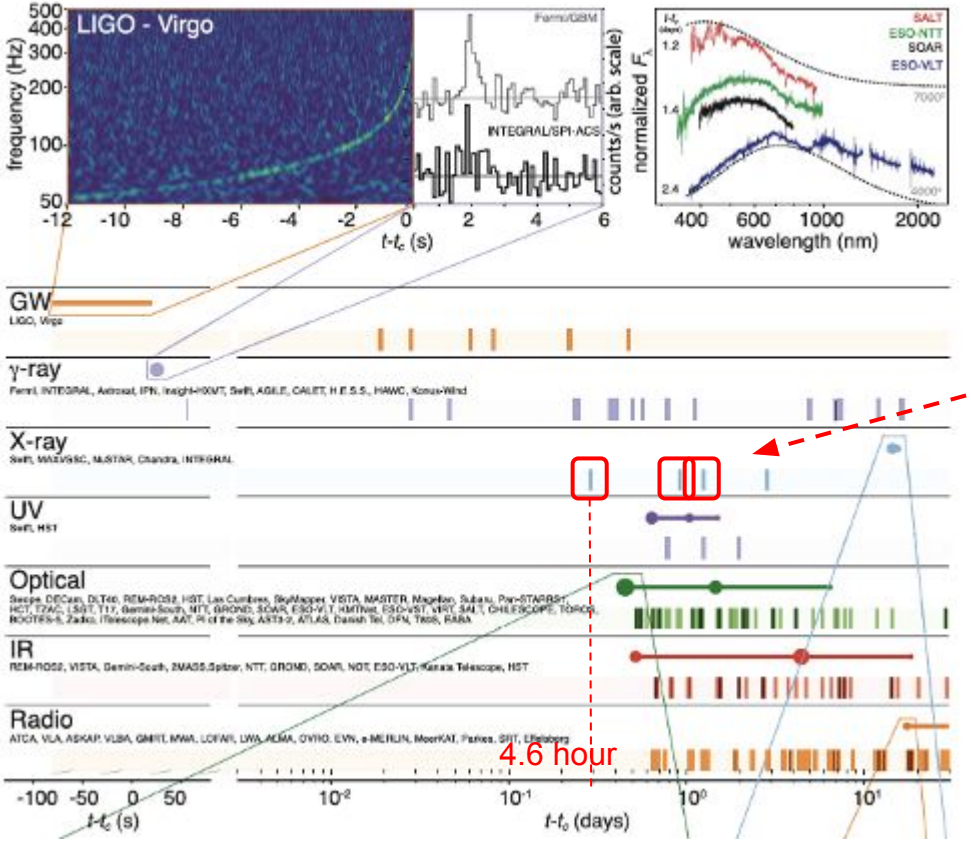
Nova-search
◇ 1-orbit trigger event
□ 4-orbits trigger

error region of GW event



GW151226
Serino+2017

Multimessenger observations of GW170817



abbott+2017

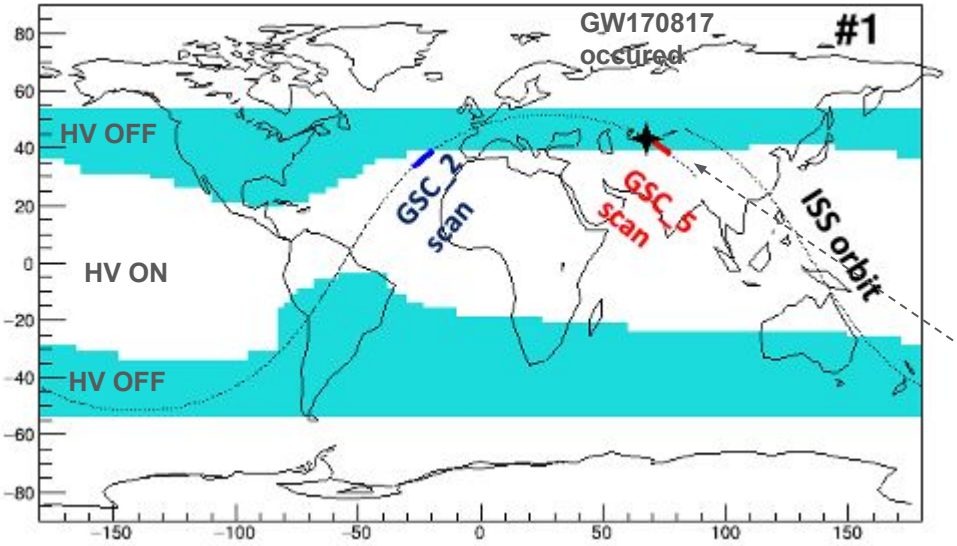
GW170817 is the first and the currently only GW event of electromagnetic counterpart detection.

MAXI/GSC upper limits of X-ray flux at 2-10 keV

The GSC observation was the first X-ray observation of GW170817 (GRB 170817A) but took 4.6 hour despite of 1.5 hour in one-orbit.

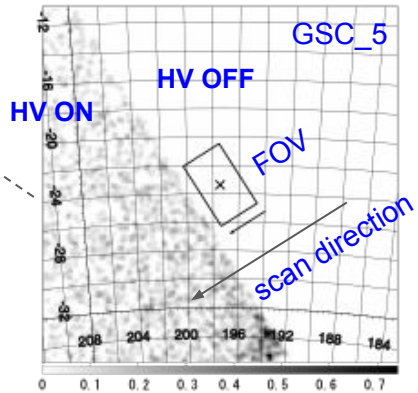
MAXI observations of GW170817 (GRB170817A)

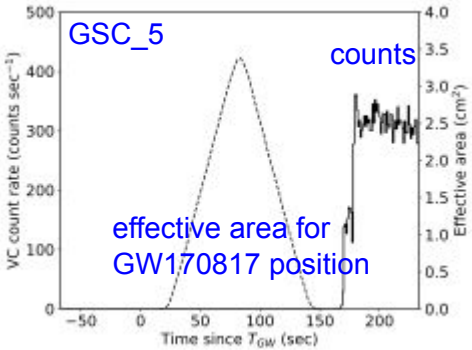
The FOV of MAXI/GSC entered to the position of GW170817 30 sec after the trigger, but in this time MAXI was in high particle background region where GSCs were turned off.



ISS orbit on earth when GW170817 occurred

GSC started observation 173 sec after the trigger but it was already passing through the position of GW170817

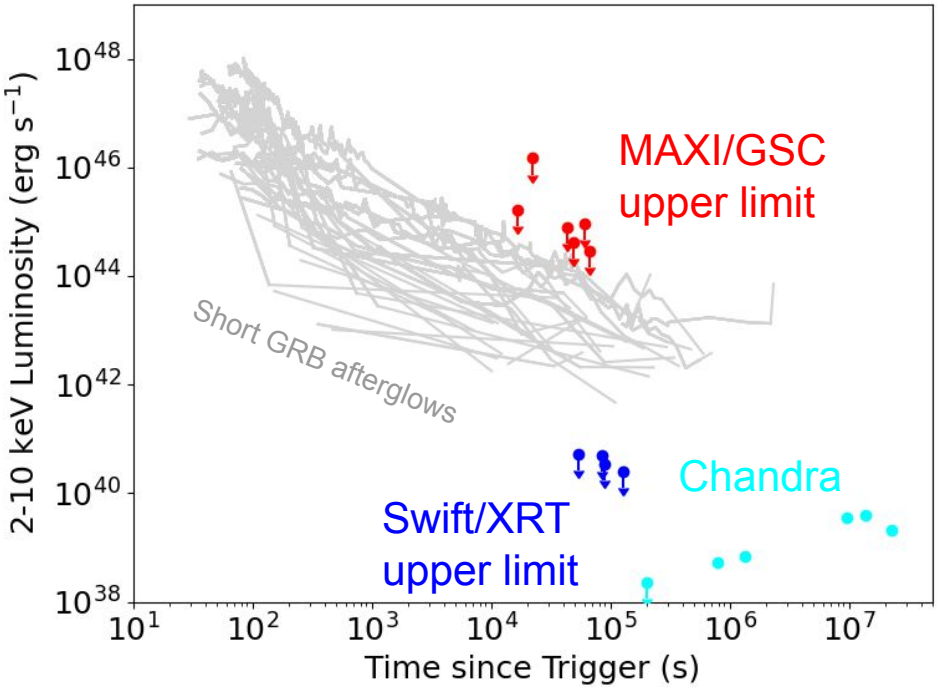




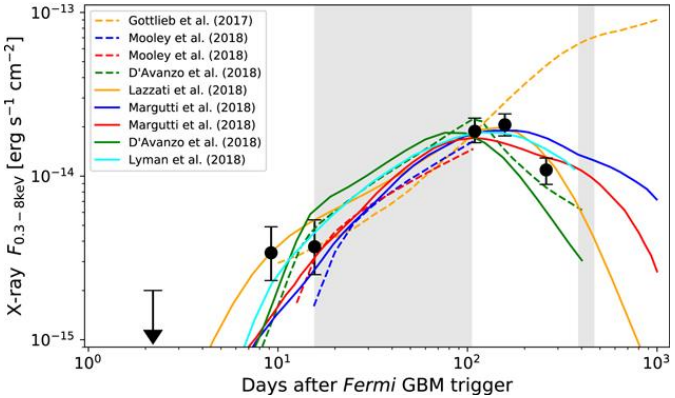
Sugita+2018

MAXI observations of GW170817 (GRB170817A)

X-ray emission of GRB 170817A was not detected by MAXI/GSC, Swift/BAT and also Chandra at first, but continued to slowly brighten over Chandra's sensitivity



Large angle off-axis and structured jet model is consistent with the X-ray afterglow of GRB 170817A

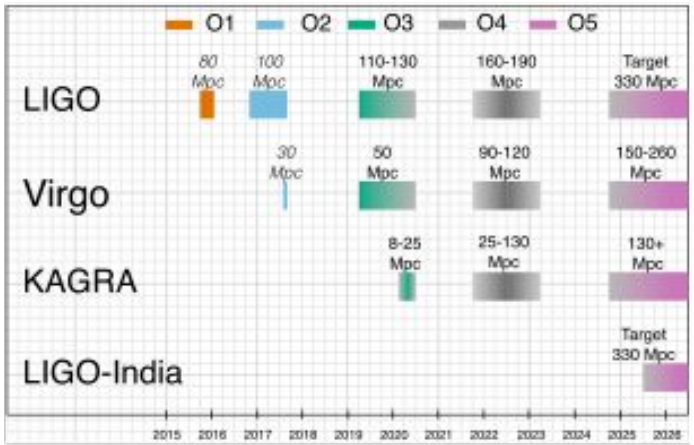


nynka+2018

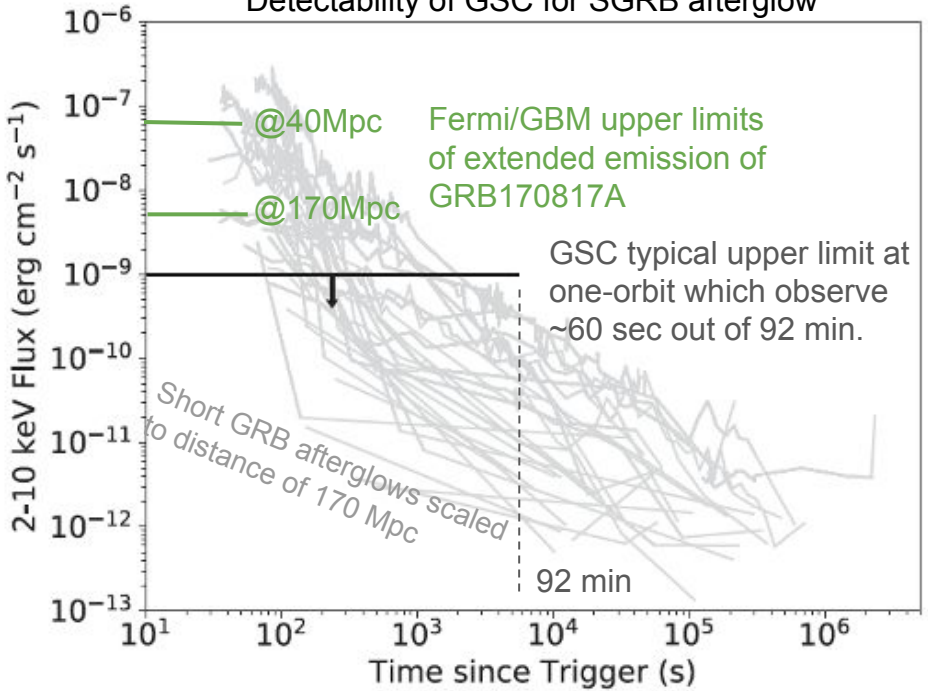
Expected sensitivity of GSC for short GRB from BNS

MAXI/GSC can observe the early afterglow of the canonical (on-axis) short GRB at 170 Mpc
If BNS merger have an extended emission (GRB170817A had soft extended emission), GSC is able to detect the extended emission

The horizon distance of the GW detectors for BNS events



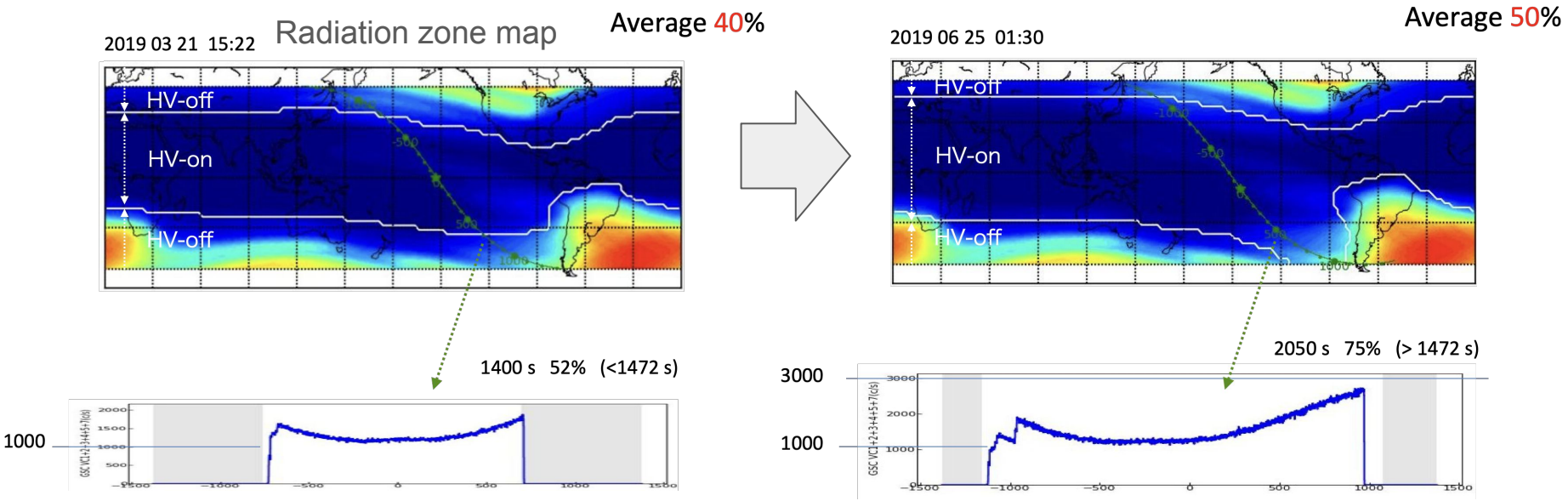
Detectability of GSC for SGRB afterglow



Operation update from Observing run 3 (O3)

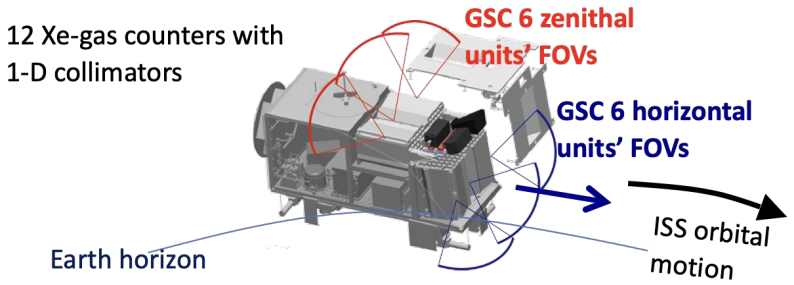
Carefully expanding HV-on area so that all-sky coverage is achieved

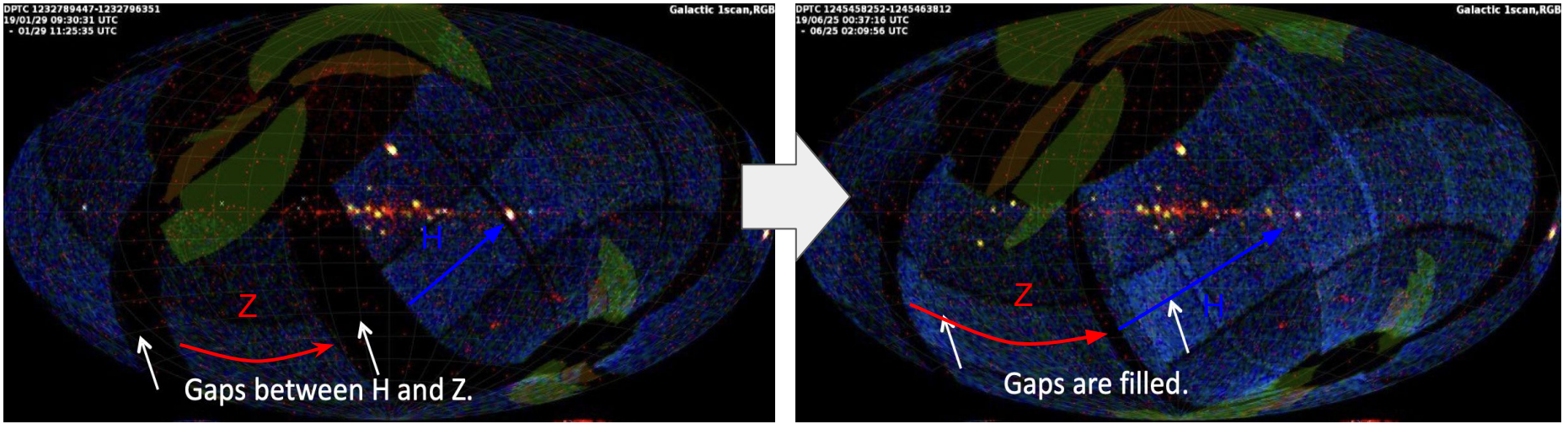
- Connecting sky coverage from Z camera to H needs to observe for 96 deg
  - → 96/360*92min = 24.5 min = 1472 s
- Increased counts by particle events are acceptable up to 3000 counts/sec



Operation update from Observing run 3 (O3)

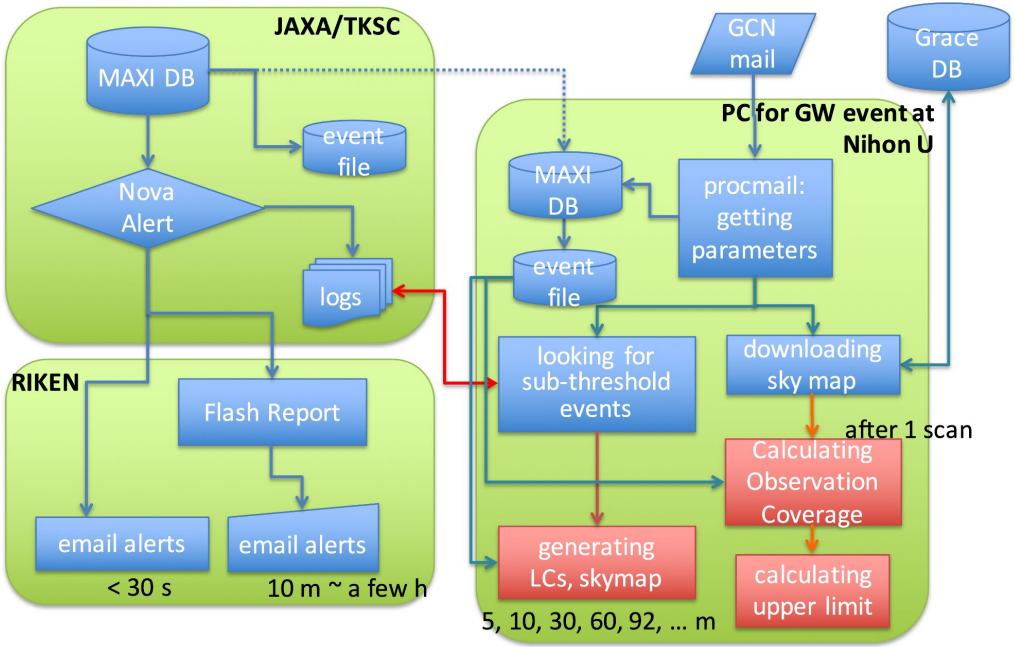
Expanding HV-on area made gaps between camera H and Z filled and then sky coverage is improved

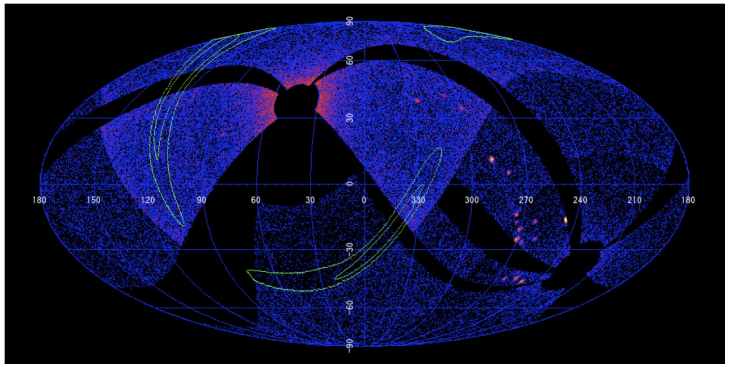




MAXI GW alert system

New pipeline for GW events to make event data immediately and automatically after GW trigger from data base MAXI DB





- All-sky map with GW error region
- HV on/off at trigger
- Observation coverage of the error region in one-orbit
- search sub-threshold events in the region

To GCN

Policy of submission to GCN from O4

In O4, detection candidates are extremely increasing (O4: 167 significant candidates, 2867 low significant) which are too large to report completely to GCN.

We have criteria for the candidates to or not to report to GCN

Classification of importance according to False Alert Rate (FAR)

High importance (rank A,B) events report the observation result to GCN

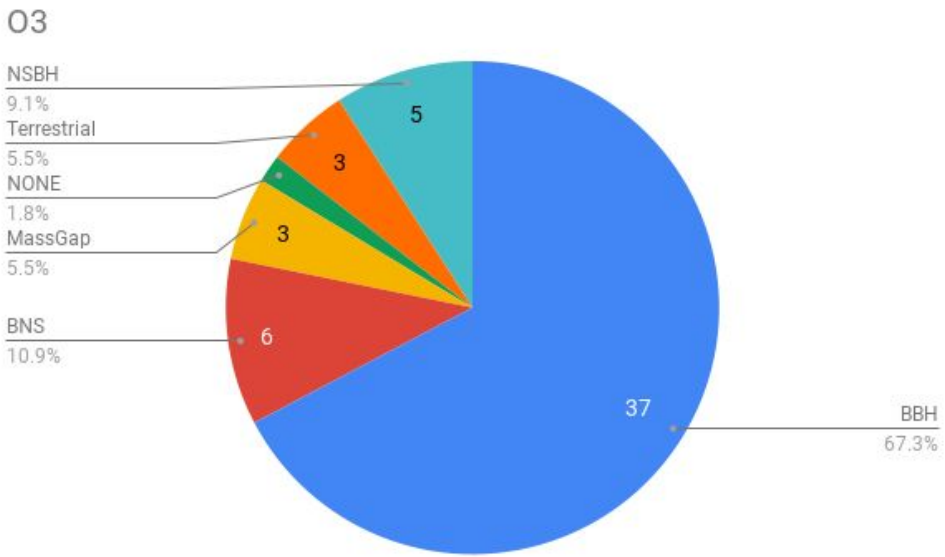
If any significant observations by MAXI occurred in the error region of even low importance events, we investigate and report the results

rank	FAR (per 1 year)	Probability
A	> 10	BNS or NSBH > 5%
B	> 20	BNS or NSBH > 5%
C	otherwise	otherwise

BNS: Binary Neutron Star
NSBH: Neutron Star - Black Hole

Summary of observations of GW events: GCN reports

We have reported to GCN for all candidates until O3, only candidates with rank A or B from O4

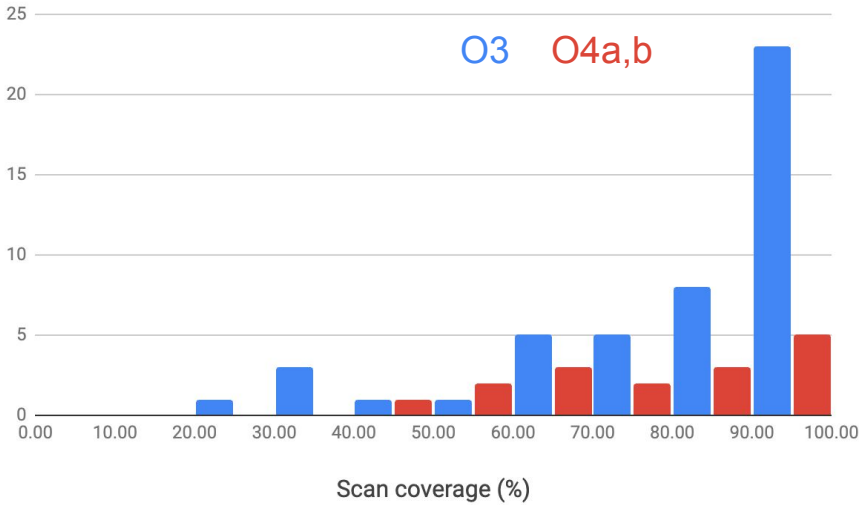


LIGO run	type	rank	Num of GCN
O4a	NSBH	A	7
	NSBH	B	4
		C	1
O4b	NSBH	A	7
	NSBH	B	2

rank	FAR (per 1 year)	Probability
A	> 10	BNS or NSBH > 5%
B	> 20	BNS or NSBH > 5%
C	otherwise	otherwise

Summary of observations of GW events: GCN reports

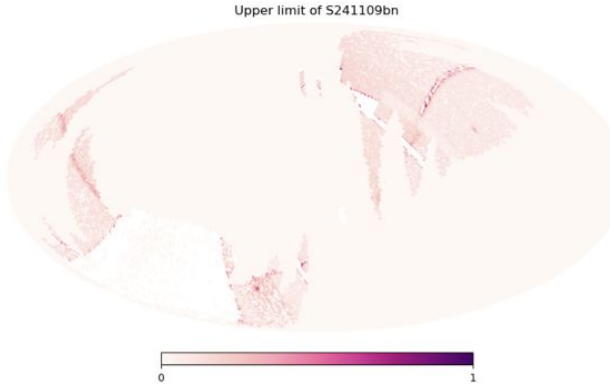
Coverage of the error region at one-orbit



Coverage distribution in O4 is lower than in O3. The GCN reports of O4 are only BNS and NSBH which have typically large error region because of weaker signal than that of BBH

Poster #34 Yuta Kondo

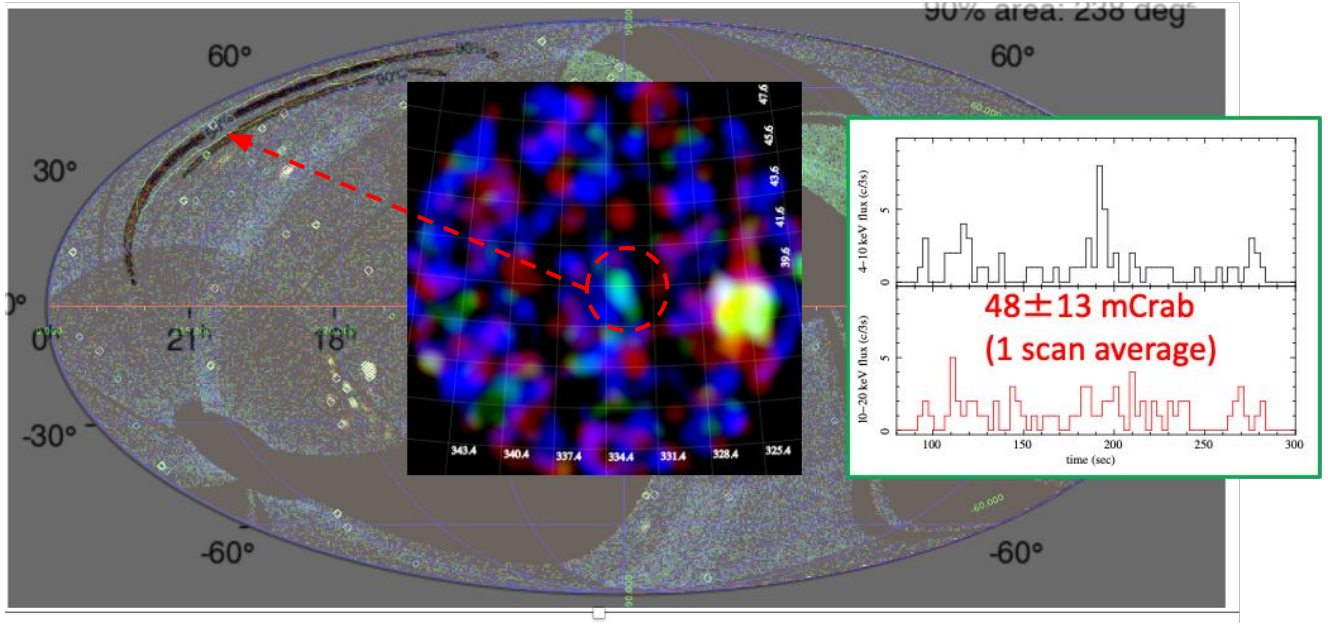
“Upper limit estimation of X-ray flux for gravitational wave counterparts with MAXI”



Investigation of the upper limit in each pixels with the error region of 21 GW events with rank A,B in O4a,b

Summary of observations of GW events: GCN reports

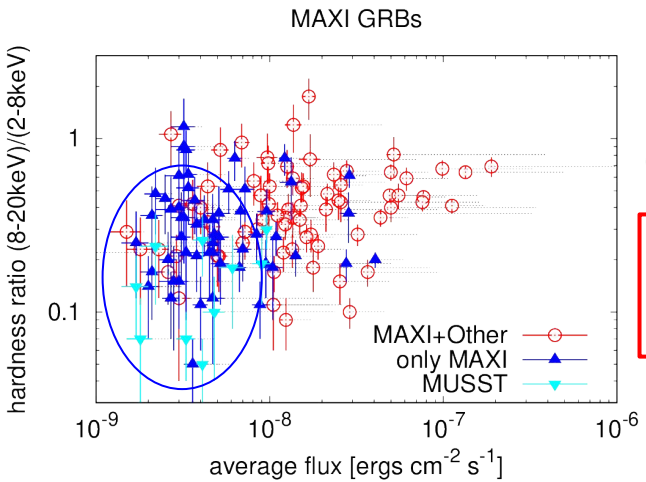
MAXI detected subthreshold event in the error region of low significant candidate S230917af (46 min after the trigger).
Swift/XRT performed follow-up observation 29 hours after the trigger but there were no significant candidates.



GRB observations by MAXI in the GW era

Redshift decided GRBs detected by MAXI have recently increased
← For GW EM counterparts detection, follow-up observations by ground telescopes were enhanced and wide-field telescopes were operational.
Chance of follow-up observation of MAXI detected GRBs might be increased.

GRB	Redshift z
240225B	0.946
240122A	3.162
230204B	2.142
221006A	0.731
150518A	0.256
110213B	1.083



updated Serino+2014

MAXI detected GRBs may be unique soft/dark sample in comparison with other GRB detectors sample.

Hiramatsu san's talk in 12-3 session

MUSST: MAXI Unidentified Short Soft Transient

Poster #40 Motoko Serino

Summary

- MAXI team has been part of LIGO/Virgo collaborations since 2014
- We have reported the observation results (only upper limits at present) of X-ray flux at 2-10 keV in one-orbit and one-day
  - The results of GW150915, GW151226, GW170817 were published
- MAXI/GSC can observe the early afterglow of the canonical (on-axis) short GRB at 170 Mpc
- If BNS merger have an extended emission (GRB170817A had soft extended emission), GSC is able to detect the extended emission
- We updated operation to increase chance to detect GW EM counterparts
  - carefully expanding HV-on area so that all-sky coverage is achieved
- We have reported to GCN for all candidates until O3, only candidates with importance events from O4