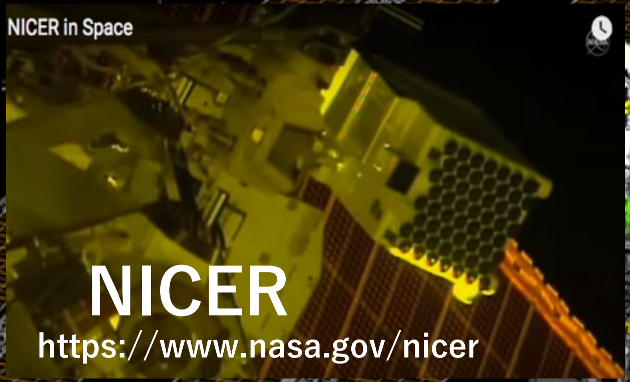
MAXI and NICER collaboration for soft X-ray transients



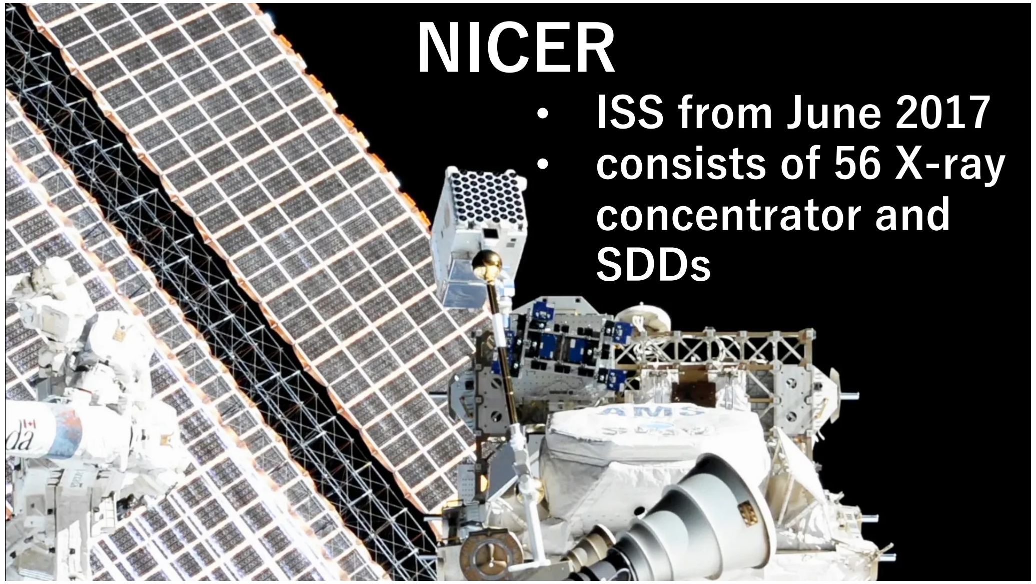
Wataru Buz Iwakiri (ICEHAP Chiba Univ.),
Keith Gendreau, Zaven Arzoumanian (NASA/GSFC),
Tatehiro Mihara (RIKEN)
on behalf of MAXI and NICER operation

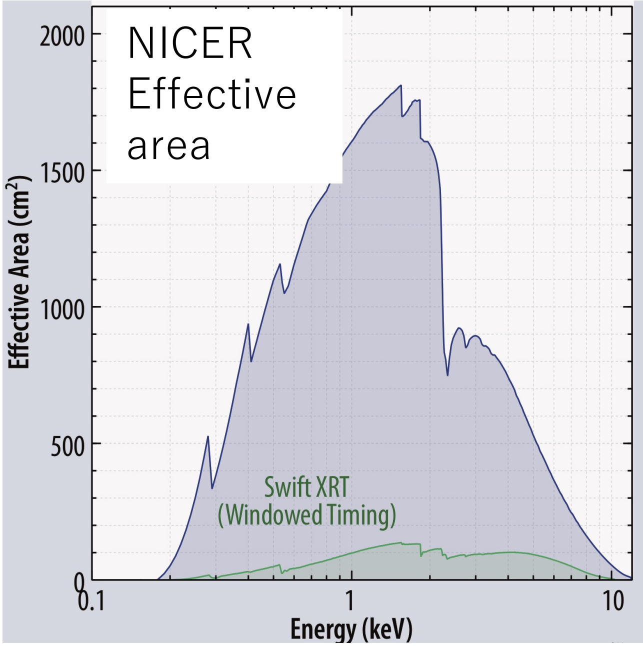
Soft X-ray transients observed by MAXI

- Huge stellar flares
- Long X-ray bursts
- Outbursts from galactic X-ray binaries
- MAXI GRBs, MUSST (MAXI Unidentified Short Soft Transient)

MAXI can detect these rare soft X-ray transients (several events per year). However, detailed spectral and timing information cannot be obtained.

crave follow-up observations





Objective : to constrain the NS EOS from detailed observations of isolated neutron star pulse profiles

large effective area (~1900 cm@1.5 keV)
High time resolution (<300 nsec)
Higher energy resolution than MAXI (137 eV@6 keV)

→ important for MAXI transients follow-up

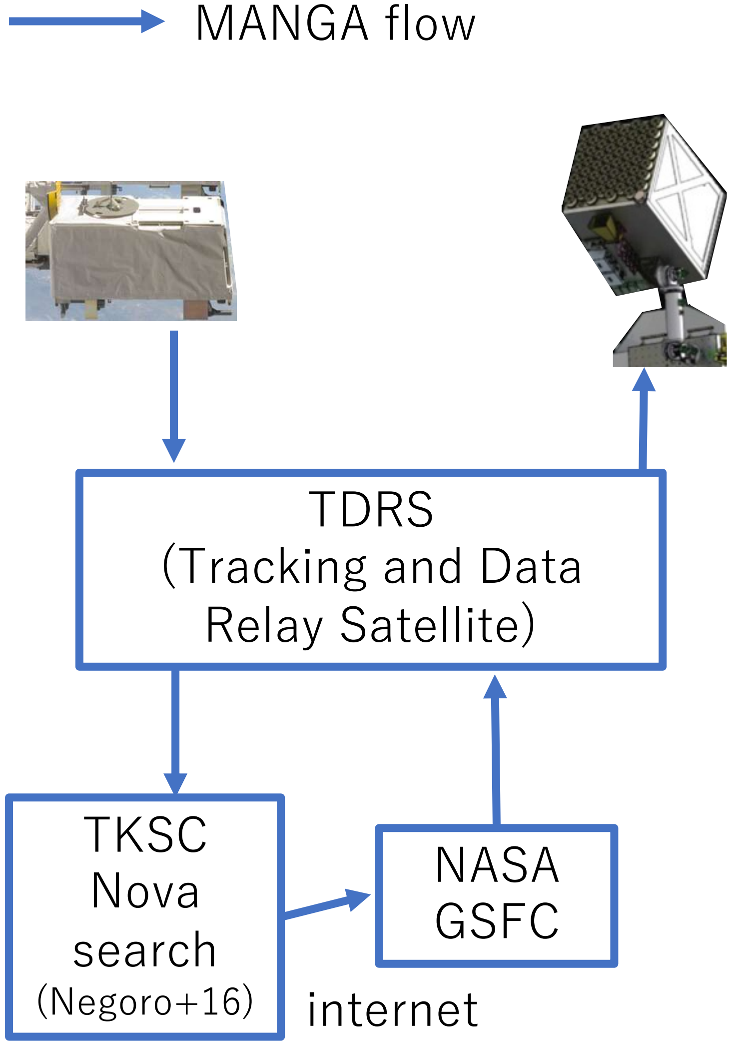
MAXI team discussed collaboration before NICER was launched.

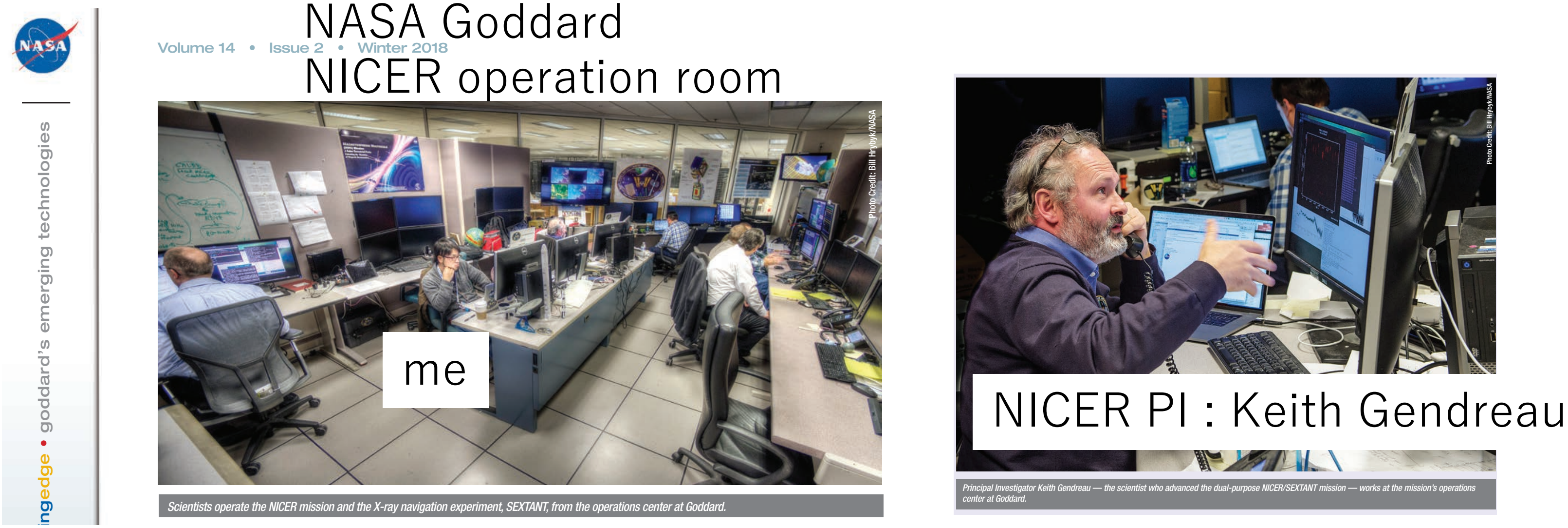
Our collaboration strategy is quite simple : NICER follow-up MAXI transients ASAP

MANGA (MAXI And NICER Ground Alert)

There are two possible flows of how MAXI's trigger information is sent to NICER :

1. MANGA : Sent MAXI trigger information from Japan to NICER (US) via internets
2. OHMAN (explain later)

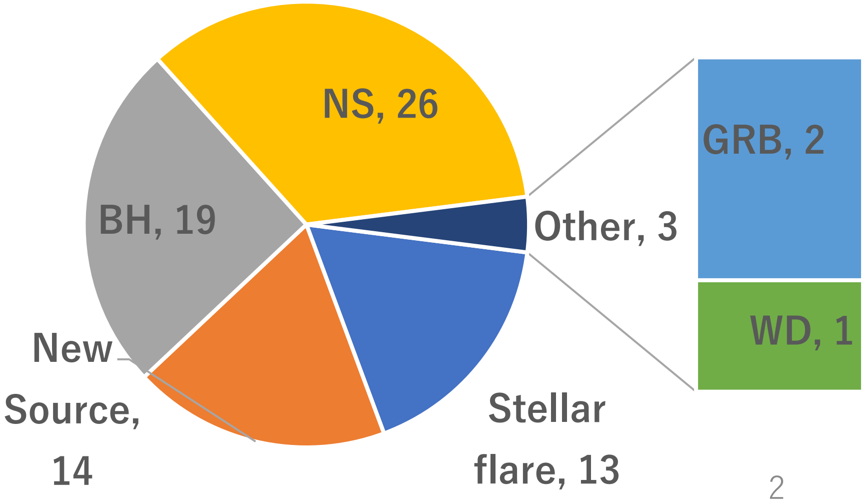




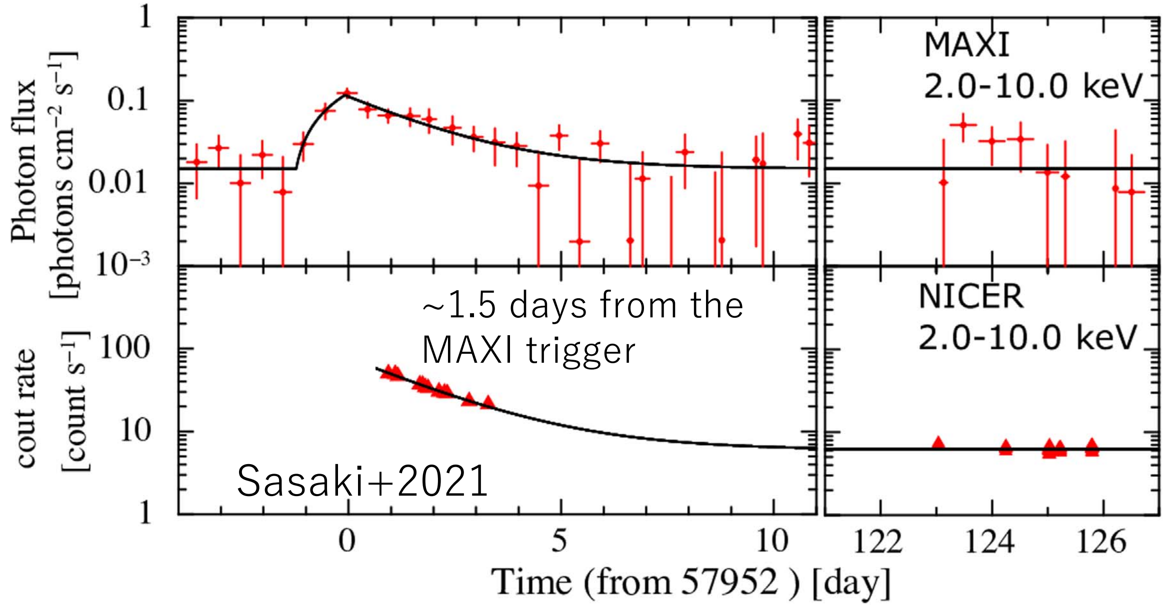
Scenes from MANGA observation testing and training

~75 MANGA observation have done in 7 years

In most cases, NICER observations are made <u>within 12 hours</u>
(Earliest follow-up was 75 min)



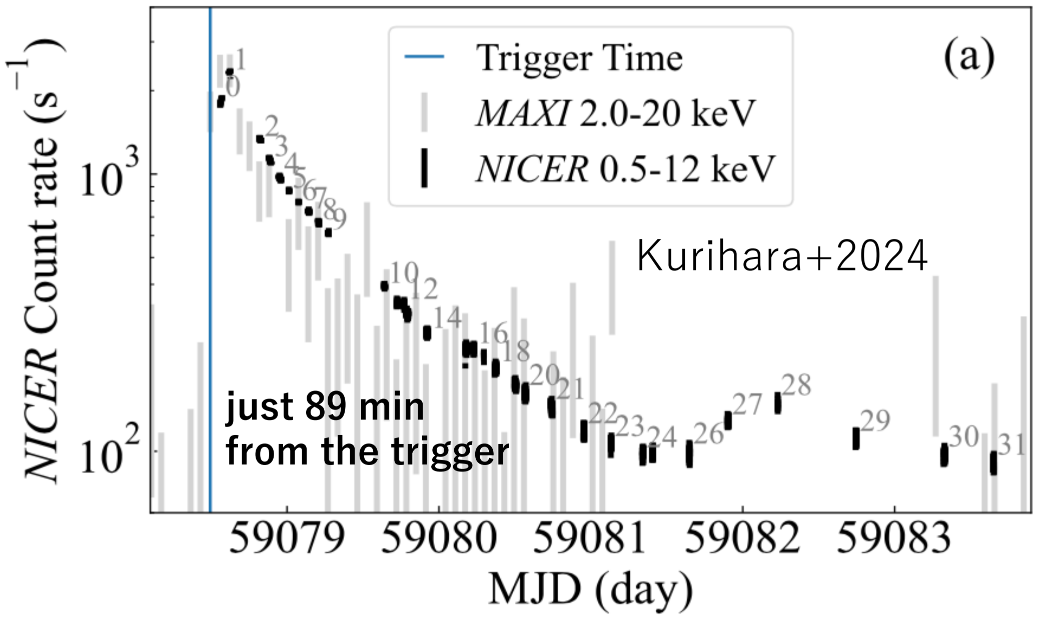
Stellar flare



GT Mus flare July 17 2017 (Sasaki et al., 2021) :

- First MANGA observation (only a month after the launch) -> took ~1.5 days
- On the basis of a quasi-static cooling model, the flare loop size is estimated to be $4.2 \pm 0.2 \times 10^{12}$ cm (2–3 orders of magnitude larger than that of typical solar flare)

After various improvement of the system, follow-up observations can now be made within half a day



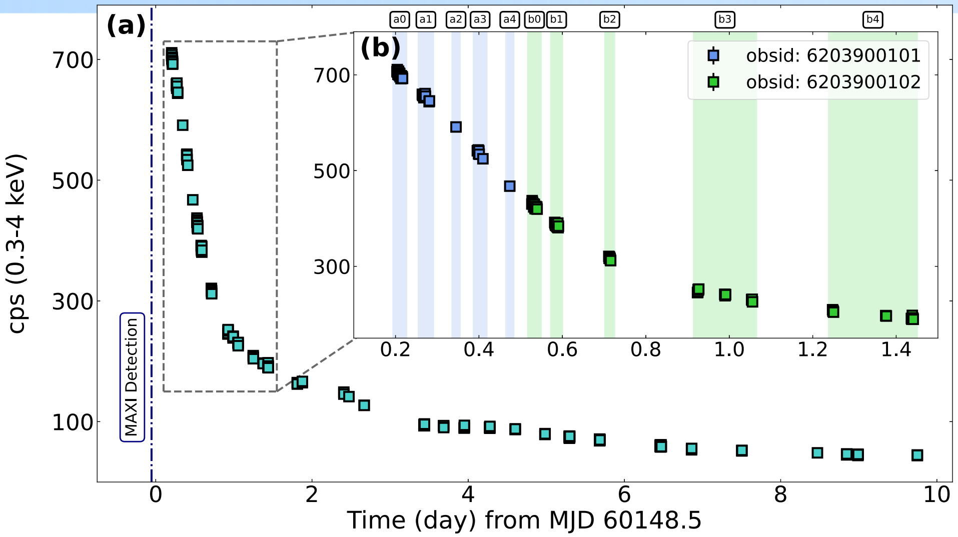
UX Ari flare Aug 17 2020 (Kurihara et al., 2024)

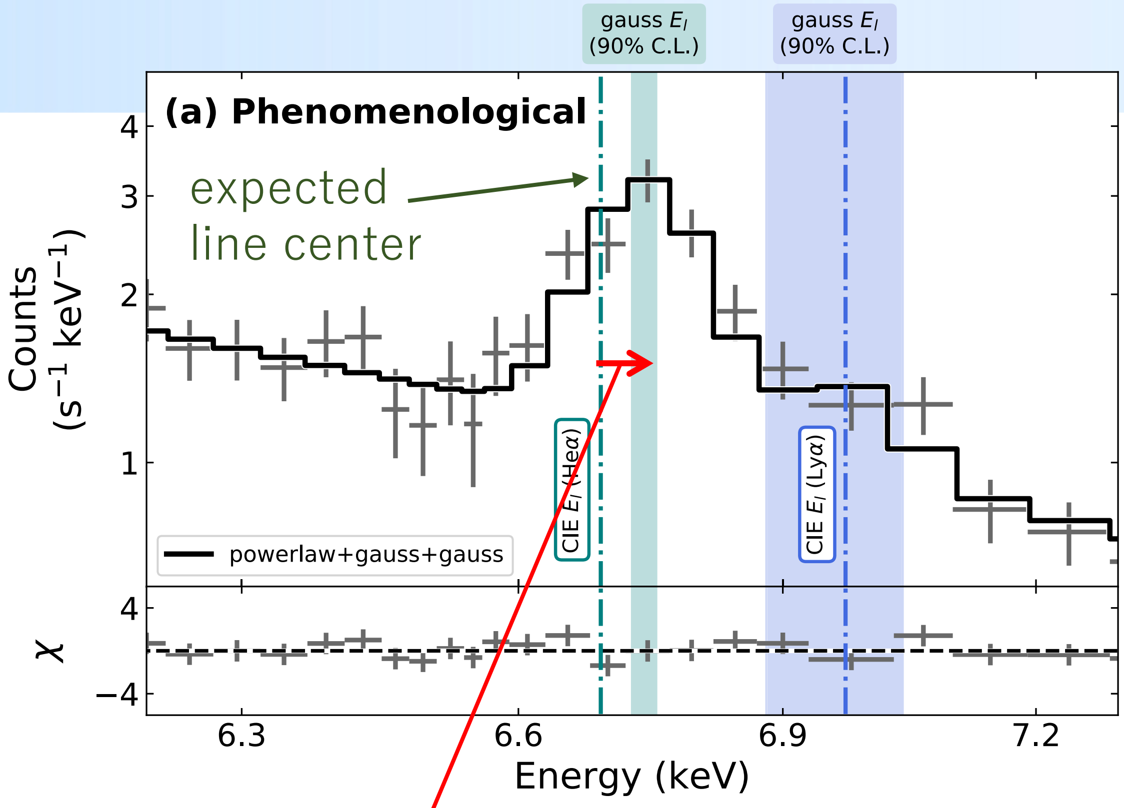
- was observed after just 89 minutes.
- H-like and He-like Fe emission lines were detected and their time variability was observed.

=> plasma diagnostics and good connection to XRISM science (See Miki Kurihara's talk)

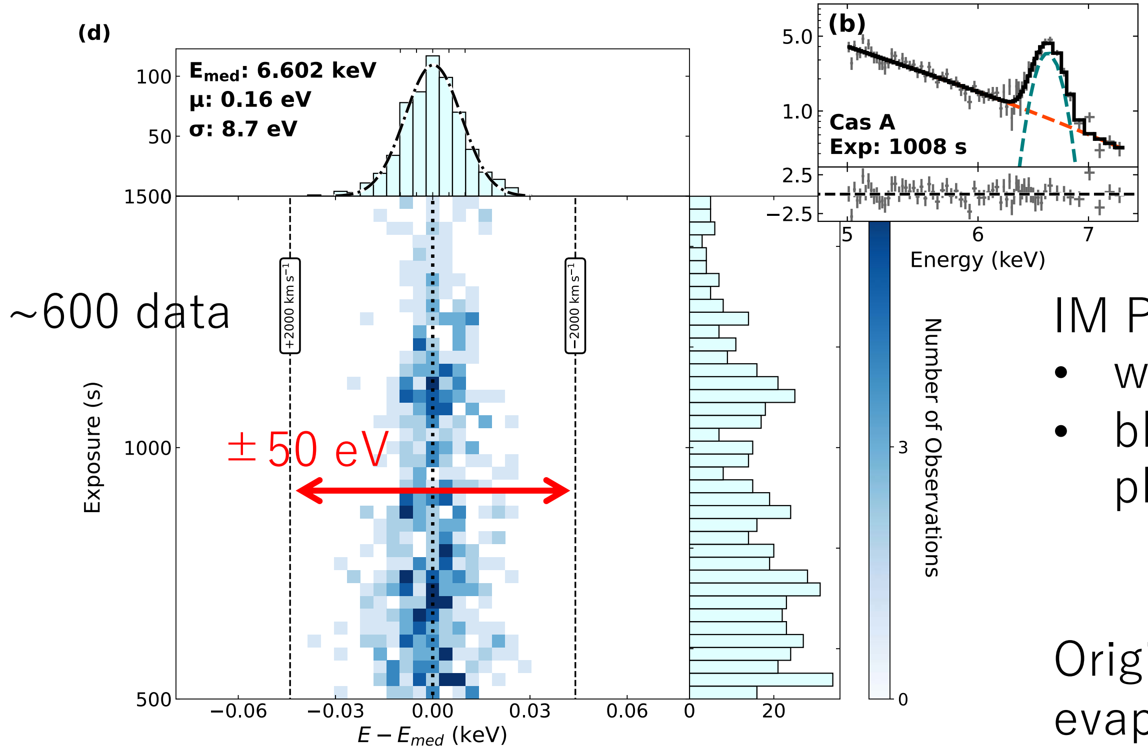
Stellar flare – Blue shifted ionized Fe line

Inoue et al., 2024





He-like Fe line 50 eV blue-shifted? (2200 km/s?)



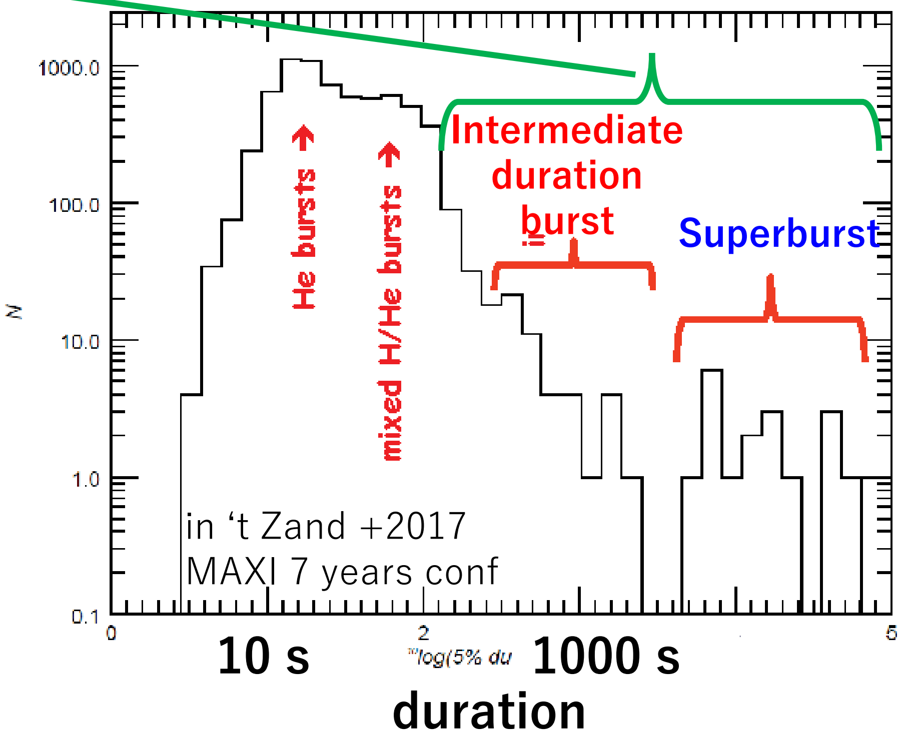
IM Peg flare July 23 2023:

- was observed after ~6 hours -> keep monitoring ~10 days
- blue-shifted Fe XXV line was detected during the decay phase
  - significantly shifted from the uncertainty estimated by the calibration analysis using SNR (Cas A) Fe line

Origins : Coronal Mass Ejection?? Chromospheric evaporation??

Long X-ray burst

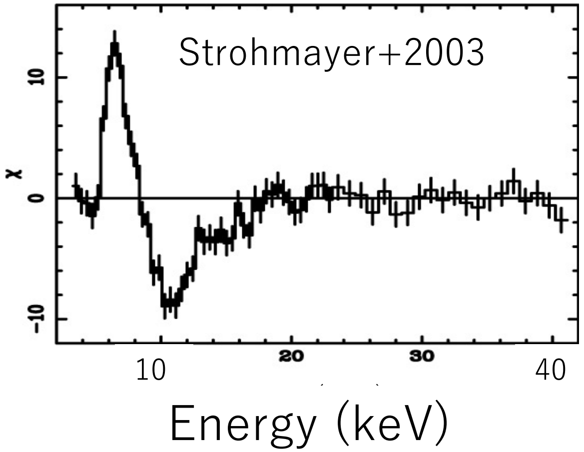
X-ray bursters are considered to be the production factories of heavy elements.
However, no direct evidence of heavy elements produced in bursts has been observed.
→detailed study of long X-ray bursts is the key.

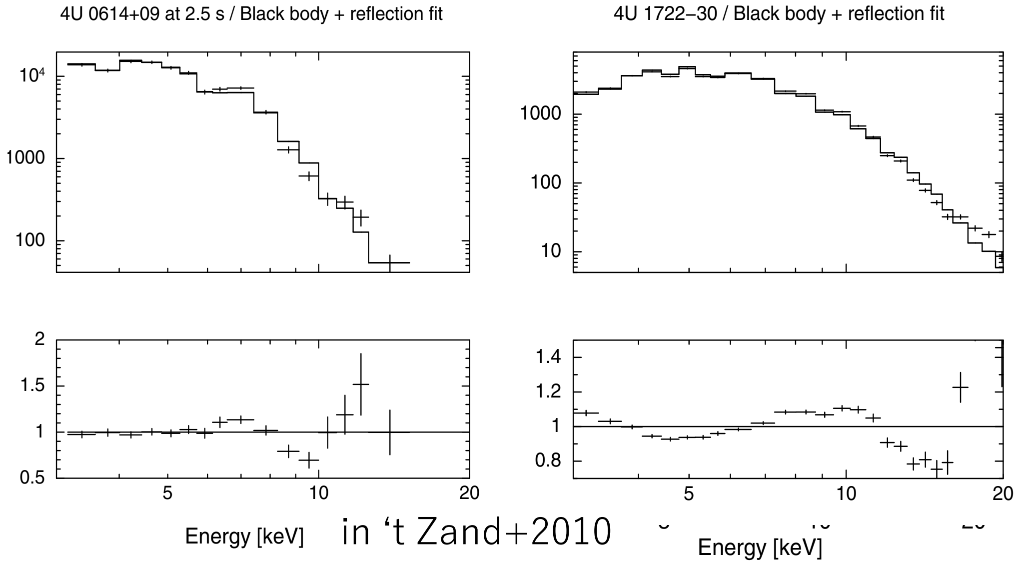


- thermonuclear bursts which duration exceeds several hundred seconds
➔ ignited deeper layer
➔ a larger amount of heavy elements under the surface of NS could be ejected or exposed ??

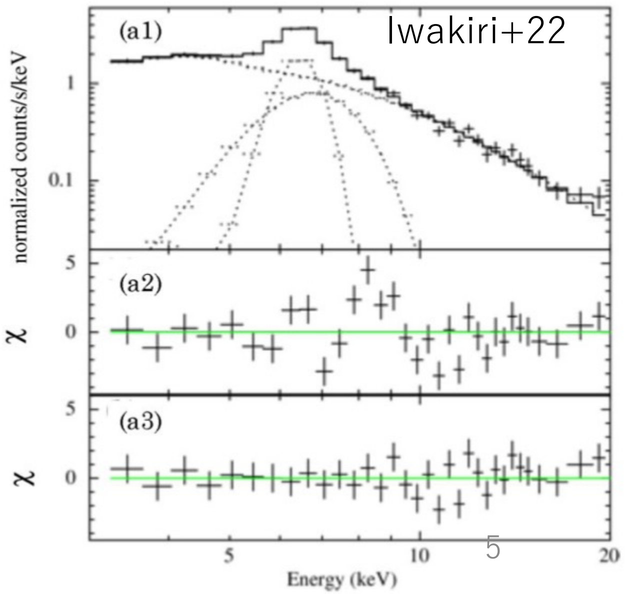
So far, discussion of long burst spectral lines has been done mainly with RXTE/PCA data.
→MANGA

RXTE/PCA observational results :





in 't Zand+2010

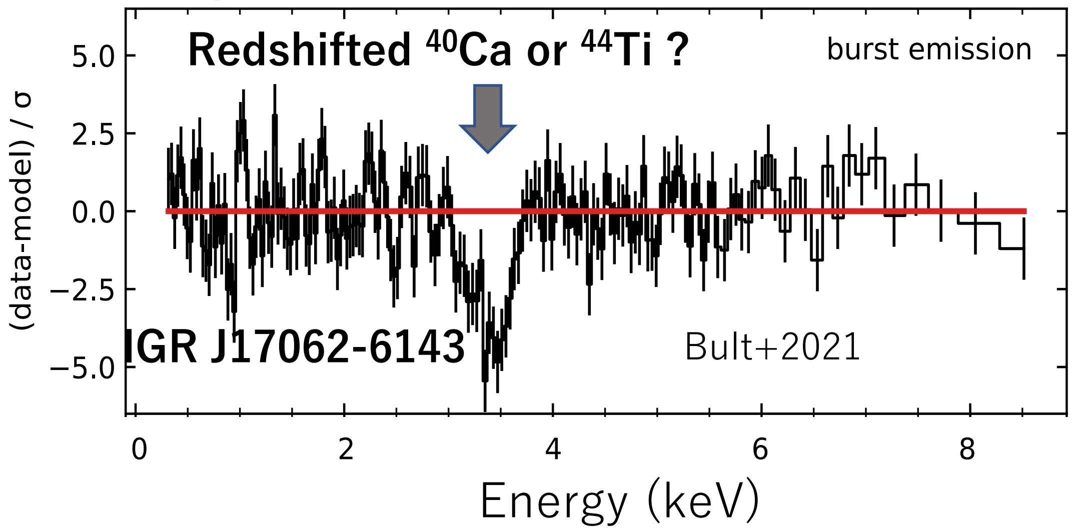


Long X-ray burst

MAXI detection of the long X-ray burst from IGR J17062-6143 and 4U 1820+30

Successful NICER observation in 3 hours after detection.

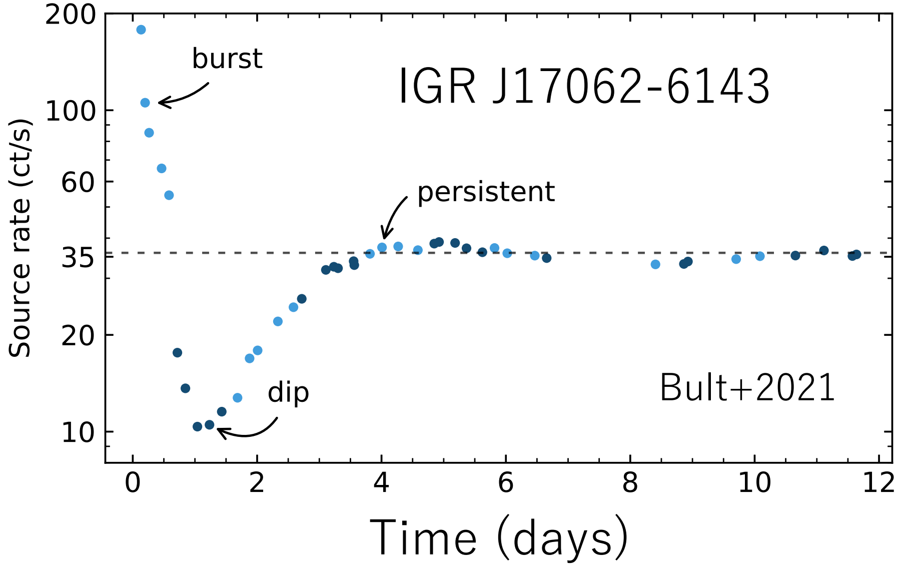
Spectral feature

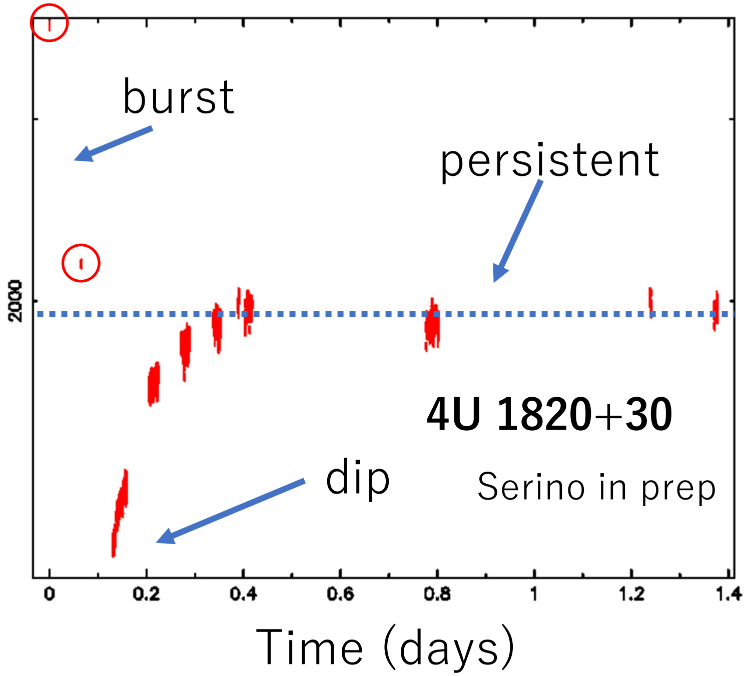


MANGA detected an unknown absorption line during the burst.

Gravitationally redshifted burning ashes??

Mysterious dip after the burst





MANGA detected an strange dip from several long bursts

Is the inner accretion disk gradually restoring itself after being perturbed by the burst irradiation ?

Identification of new X-ray sources by MANGA

MAXI J1957+032 : the huge effective area and high timing resolution were key factors

MAXI/GSC detection of a faint X-ray transient MAXI J1957+032

ATel #7504; *H. Negoro (Nihon U.), M. Serino, T. Mihara (RIKEN), S. Nakahira (JAXA), S. Ueno, H. Tomida, M. Kimura, M. Ishikawa, Y. E. Nakagawa (JAXA), M. Sugizaki, M. Shidatsu, J. Sugimoto, T. Takagi, M. Matsuoka (RIKEN), N. Kawai, T. Yoshii, Y. Tachibana (Tokyo Tech), A. Yoshida, T. Sakamoto, Y. Kawakubo, H. Ohtsuki (AGU), H. Tsunemi, R. Imatani (Osaka U.), M. Nakajima, T. Masumitsu, K. Tanaka (Nihon U.), Y. Ueda, T. Kawamuro, T. Hori (Kyoto U.), Y. Tsuboi, S. Kanetou (Chuo U.), M. Yamauchi, D. Itoh (Miyazaki U.), K. Yamaoka (Nagoya U.), M. Morii (ISM)*

on **14 May 2015; 05:48 UT**

First observed in May 2015. After that, four outbursts were detected (#8143,#8529, #9565), and follow-up observations were made in Swift, Chandra and optical telescopes, but the origin was unknown due to their short duration.

MAXI/GSC detection of the X-ray transient MAXI J1957+032 (J1956+035)

ATel #15440; *H. Negoro (Nihon U.), W. Iwakiri (Chuo U.), Y. Kawakubo (LSU), M. Nakajima, K. Kobayashi, M. Tanaka, Y. Soejima (Nihon U.), T. Mihara, T. Kawamuro, S. Yamada, T. Tamagawa, M. Matsuoka (RIKEN), T. Sakamoto, M. Serino, S. Sugita, H. Hiramatsu, A. Yoshida (AGU), Y. Tsuboi, J. Kohara (Chuo U.), M. Shidatsu, M. Iwasaki (Ehime U.), N. Kawai, M. Niwano, R. Hosokawa, Y. Imai, N. Ito, Y. Takamatsu (Tokyo Tech), S. Nakahira, S. Ueno, H. Tomida, M. Ishikawa, M. Tominaga, T. Nagatsuka, T. Kurihara (JAXA), Y. Ueda, S. Ogawa, K. Setoguchi, T. Yoshitake, K. Inaba (Kyoto U.), H. Tsunemi (Osaka U.), M. Yamauchi, T. Sato, R. Hatsuda, R. Fukuoka, Y. hagiwara, Y. Umeki (Miyazaki U.), K. Yamaoka (Nagoya U.), and M. Sugizaki (NAOC)*

on **19 Jun 2022; 02:15 UT**

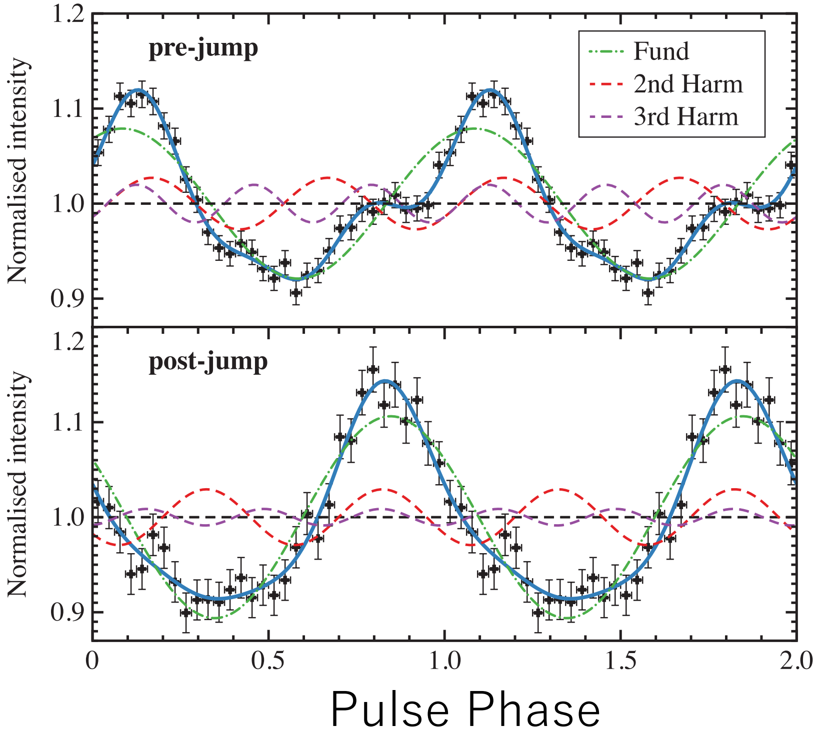
In June 2022, MAXI detected the fifth outburst.
→ MANGA
→ ms pulse detection and confirmed accretion mili-second pulsar within a day

NICER discovers 314 Hz pulsations from MAXI J1957+032

ATel #15444; *M. Ng (MIT), P. M. Bult, K. C. Gendreau, Z. Arzoumanian (NASA/GSFC), A. Sanna (University of Cagliari), W. C.G. Ho (Haverford), S. Guillot (IRAP/CNRS), G. K. Jaisawal (DTU Space), T. Guver (Istanbul Univ.), D. Chakrabarty (MIT), on behalf of the NICER team*

on **19 Jun 2022; 20:19 UT**

Credential Certification: Mason Ng (masonng@mit.edu)



Sanna+2022

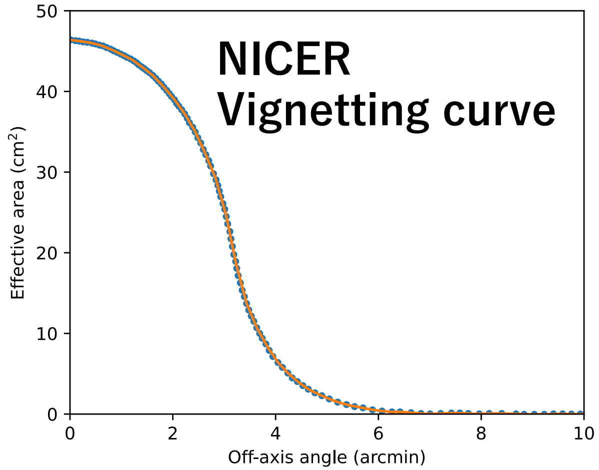
Doppler modulation of the X-ray pulsation revealed the ultra-compact nature of the binary system characterized by an orbital period of ~1 hour (Sanna+22)

MAXI J1816-195 was also identified as AMXP about a day after its discovery at MAXI by MANGA (Bult+2022)

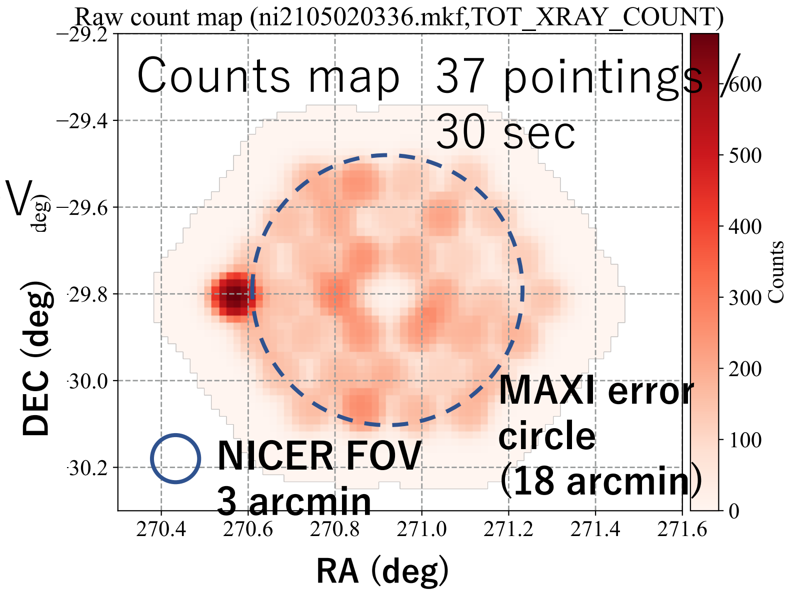
NICER multiple pointing system for New MAXI sources

Known source :
→ point NICER directly
New source → typical MAXI position accuracy is ~18 arcmin, but NICER FOV is 3 arcmin

To localize, need to search the error region.
→ **developed automatic multiple pointing system**



Non-imaging detector
→ reconstruct images by taking into account the vignetting effect and determine the position.



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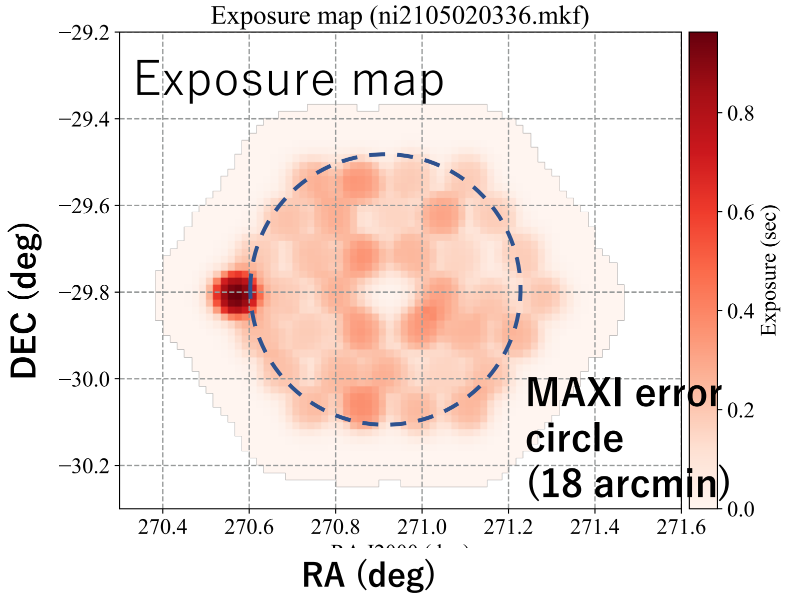

Case of New MAXI source
MAXI J1803-298
ATel #14587, 14588

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To localize, need to search the error region.
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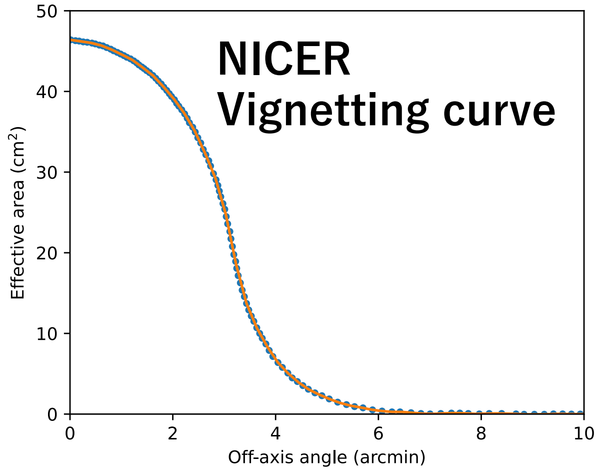

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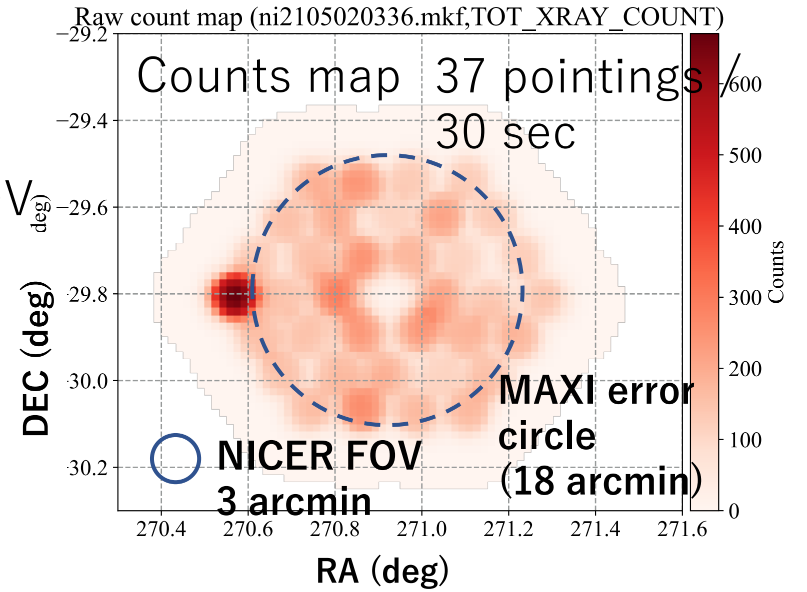

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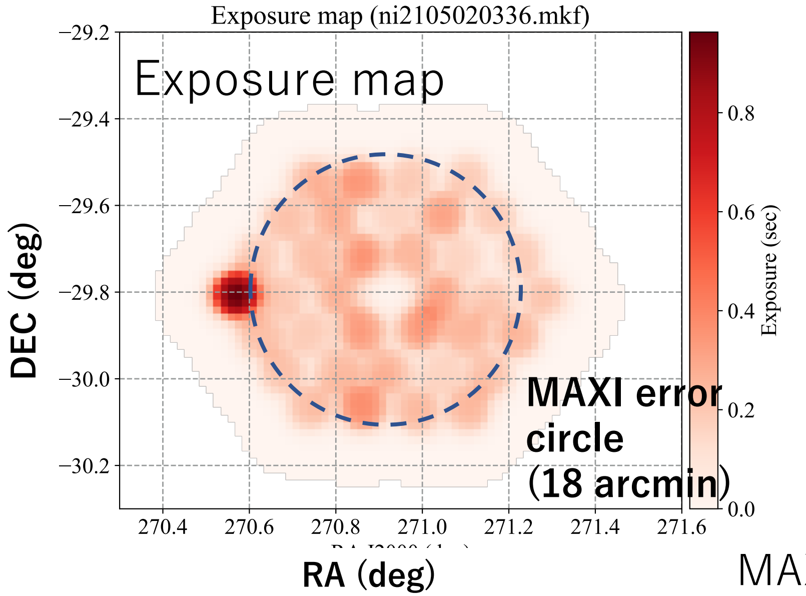

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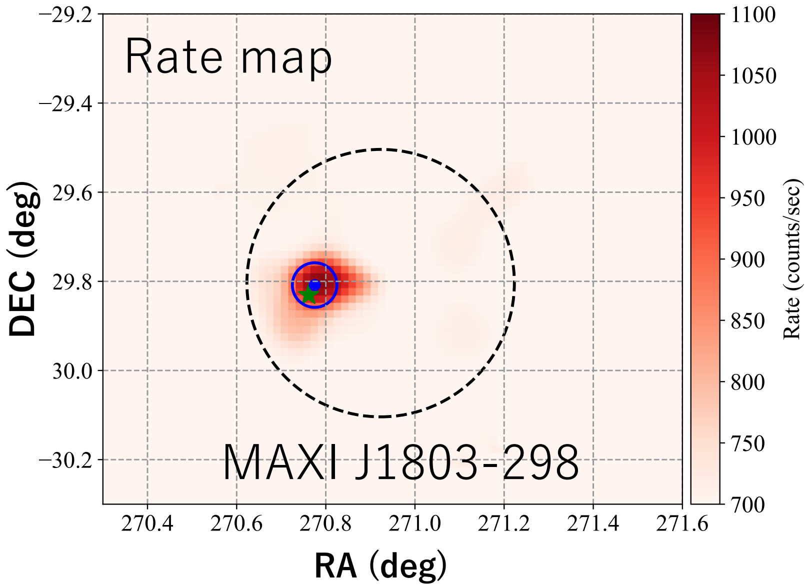
ATel #14587, 14588



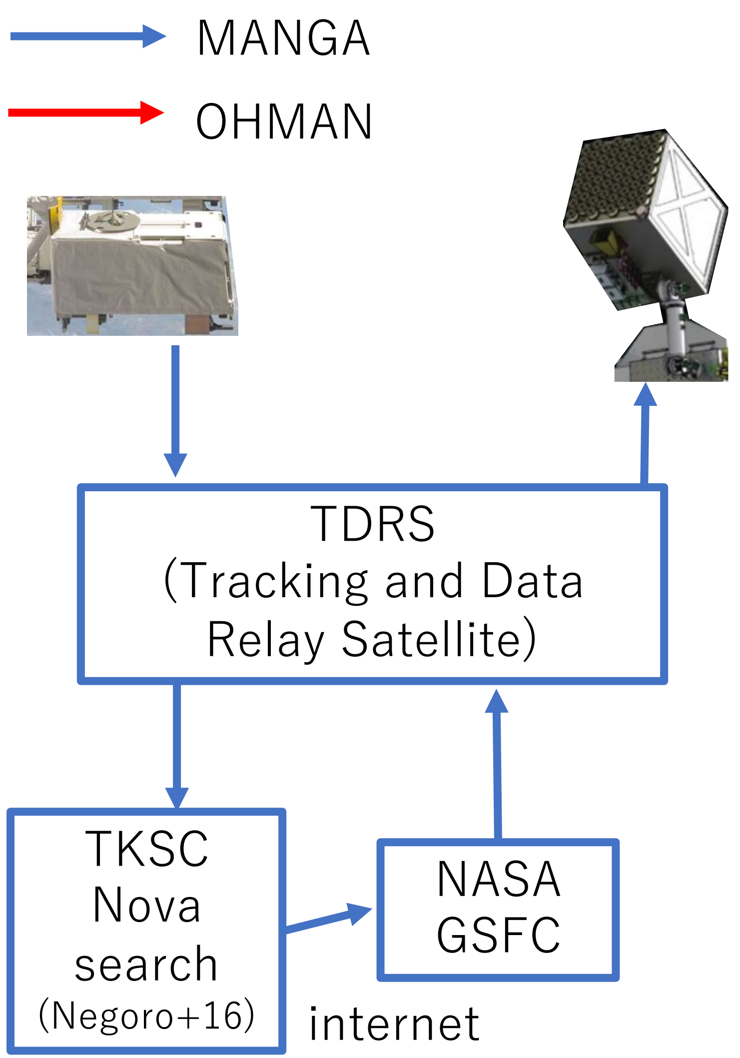
successfully localized new MAXI sources by NICER with an accuracy of 3 arcmin within half a day of discovery

MAXI J1803-298 (Shidatsu et al.,2021)
MAXI J0709-159/LY CMa (Sugizaki at al.,2022)

OHMAN (On-orbit Hookup of MAXI and NICER)

There are two possible flows of how MAXI's trigger information is sent to NICER :

1. MANGA : Sent MAXI trigger information from Japan to NICER (US) via internets
2. OHMAN: Install MAXI novasearch system on ISS laptop and sent the info to NICER directly via ISS network



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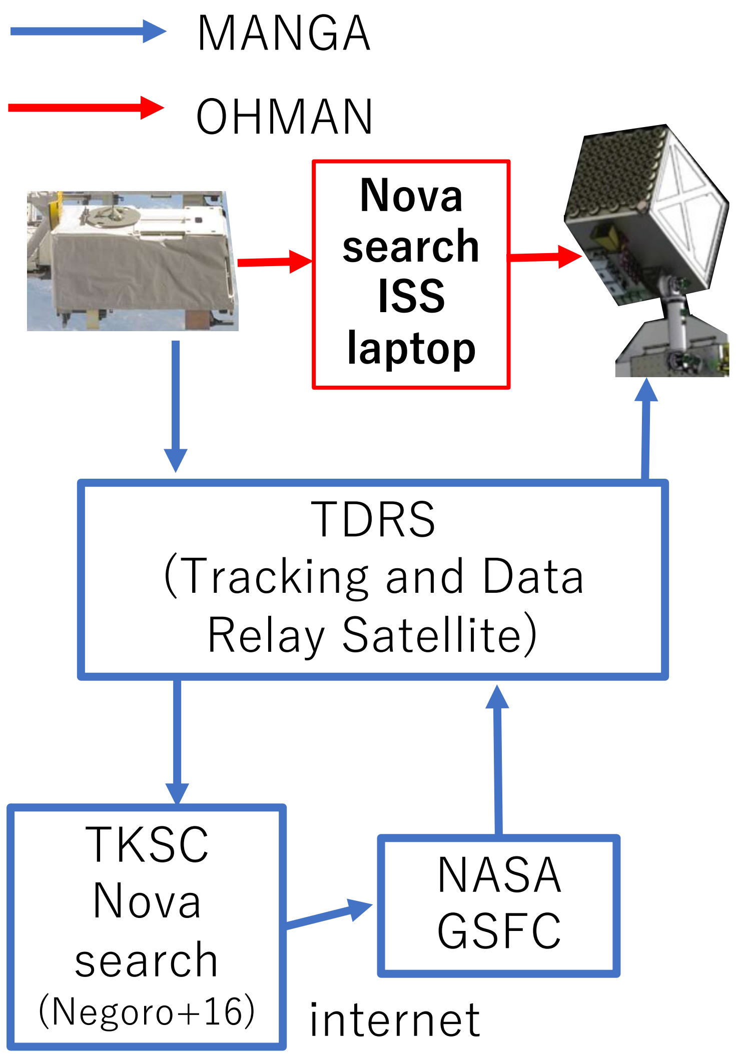

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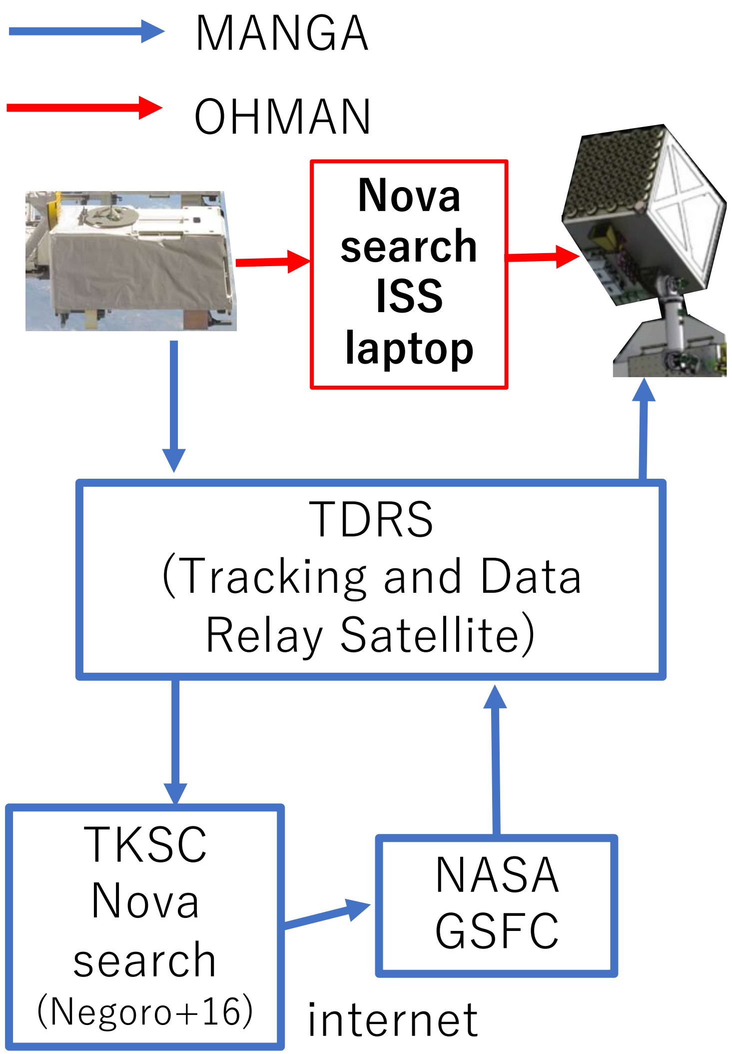
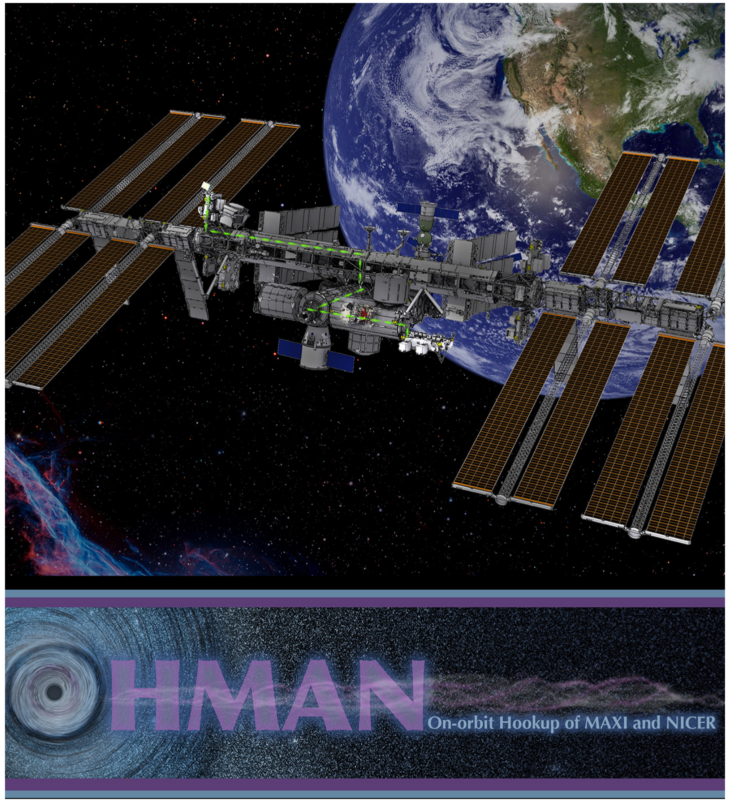




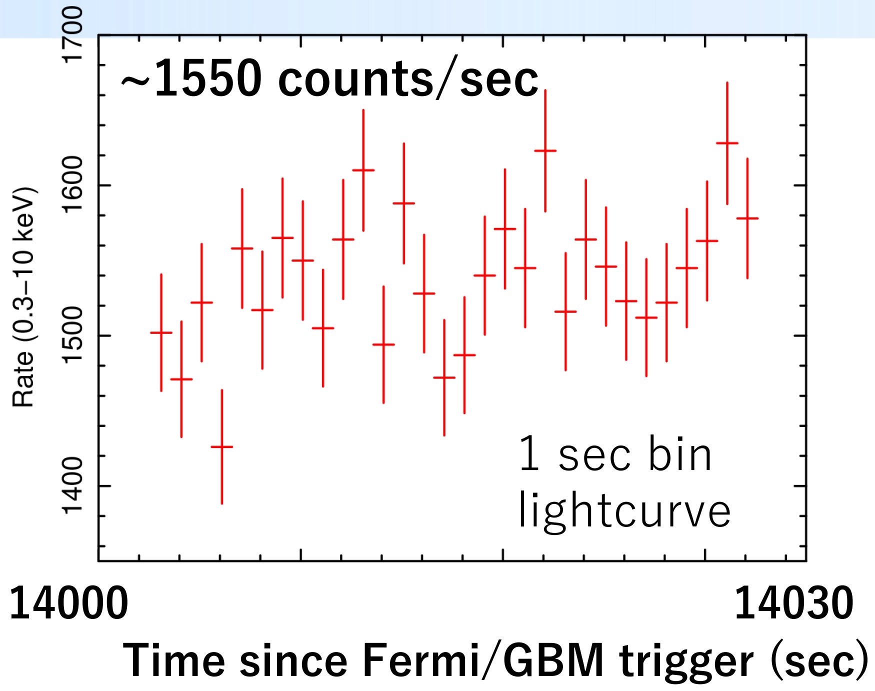
In 2020, based on the science results of the MANGA collaboration and other effort, an MOU was signed between NASA and JAXA to promote OHMAN as part of the U.S.-Japan Program OP 3.

In 2021 we did a lot of work (software testing, reconnection of the network HUB by Astronaut Hoshide-san, etc.) and OHMAN started in June 2022.

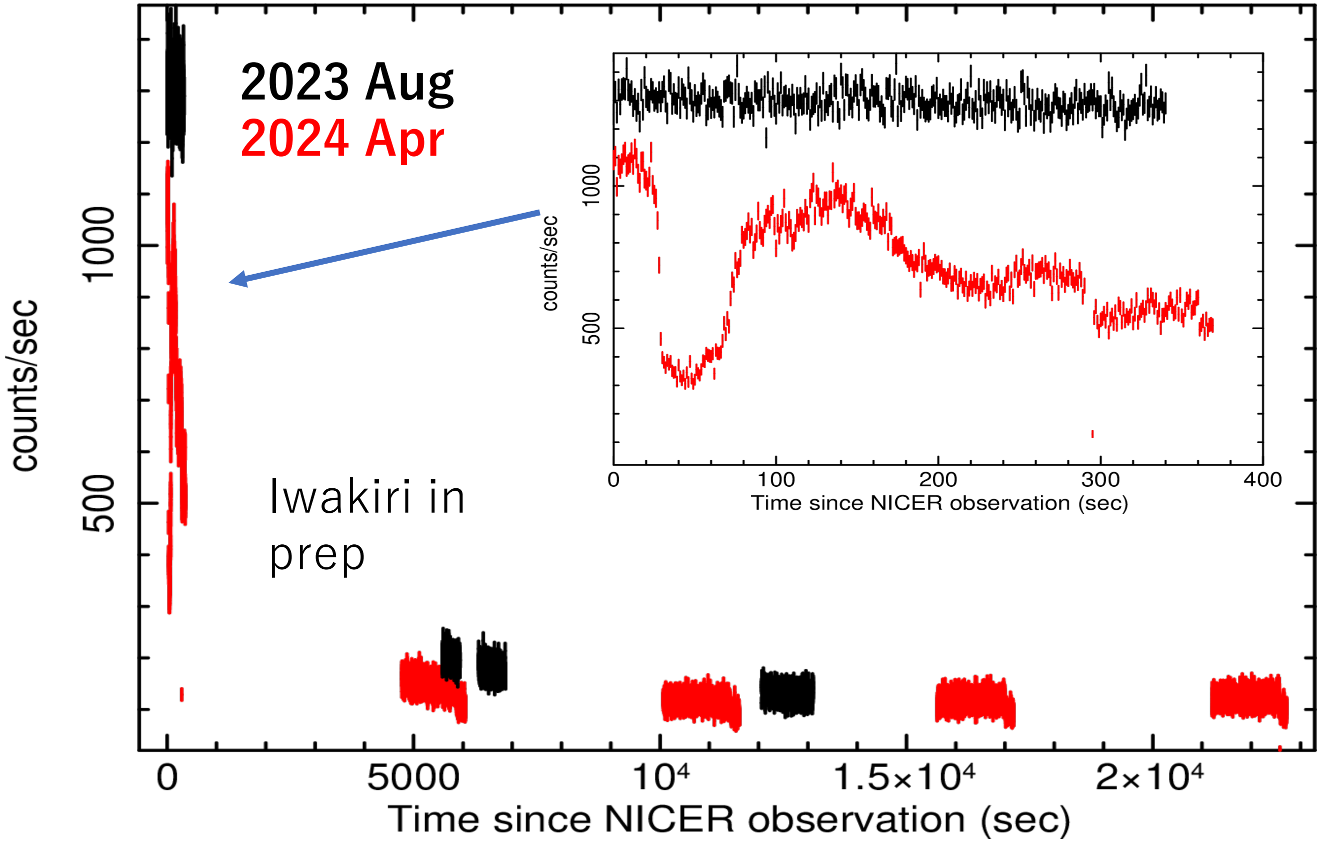
Known source →NICER direct maneuver to catalog coordinates
New source → automatic multiple scan started

OHMAN

GRB 221009A (BOAT) 😢 :
The OHMAN trigger was issued ~1000 seconds after the occurrence, but unfortunately there was no NICER visibility .
→ was able to start observations after 14,000 seconds, and from there it continued for two weeks, acquiring GRB afterglow data with very good statistics (ATel #15664, Williams+23).



Long X-ray burst from 4U 1850-086 😊 :



Two OHMAN observation succeeded for long X-ray bursts from UCXB 4U 1850-086

NICER observation started after :
1st : 631 sec MAXI trigger
2nd : 187 sec (!) MAXI trigger

The lightcurves of the two bursts are totally different.

Summary

- The collaborative observation between MAXI and NICER, which combines MAXI's ability to find soft X-ray transients with NICER's ability to acquire detailed X-ray data, has continued from NICER's launch to the present.
- ~75 MANGA observation was succeeded in ~7 years so far
- For stellar flare observations, the data provides information on plasma diagnostics, plasma kinetic velocity, and flare loop size.
- For observations of long X-ray bursts, information on heavy elements produced by the X-ray bursts and on the relationship between the burst radiation and the surrounding accretion disk and corona is provided.
- For the discovery of new AMXPs, NICER's high-statistical time information has been very useful.
- For new objects with unknown positions, an automatic multiple pointing system has been implemented to automatically cover the MAXI error regions.
- OHMAN has been started and two long X-ray burst observations were succeeded. The earliest response time was just ~3 min