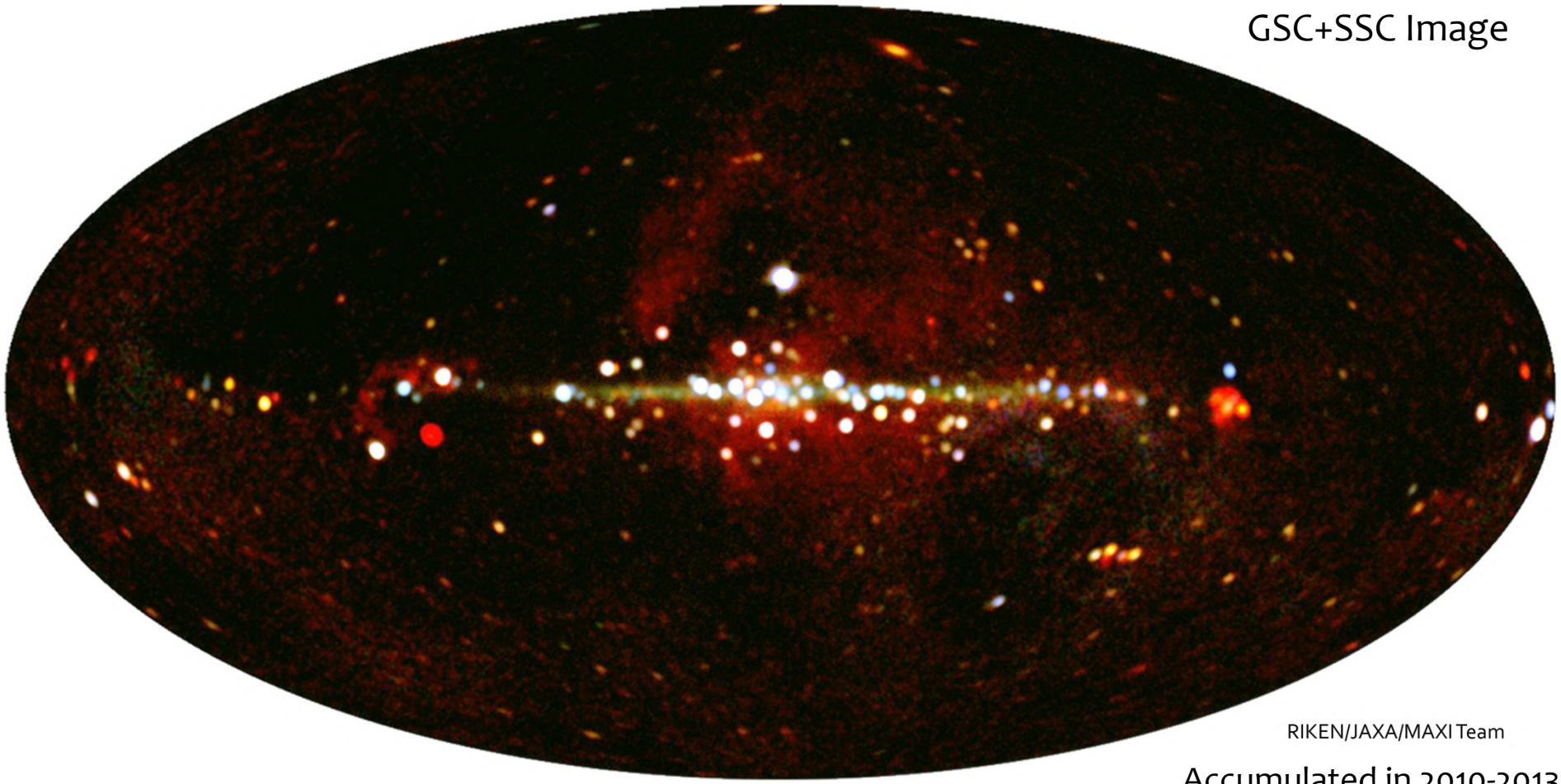
Monitor of All-sky X-ray Image (MAXI) :
Watching stars in X-Rays from ISS

Tatehiro Mihara (RIKEN), and the MAXI team

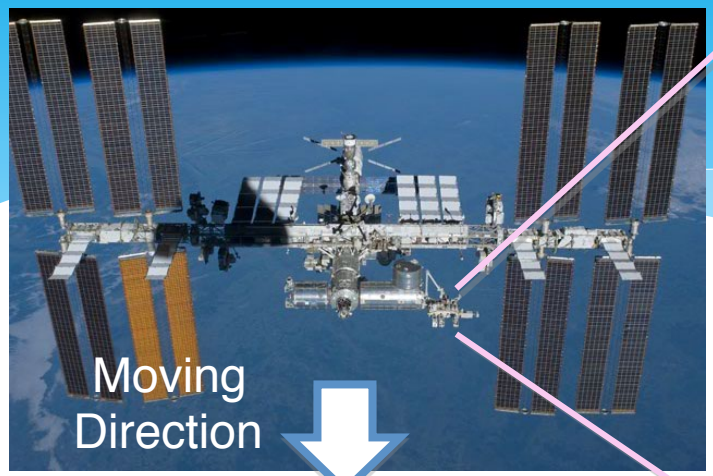
GSC+SSC Image

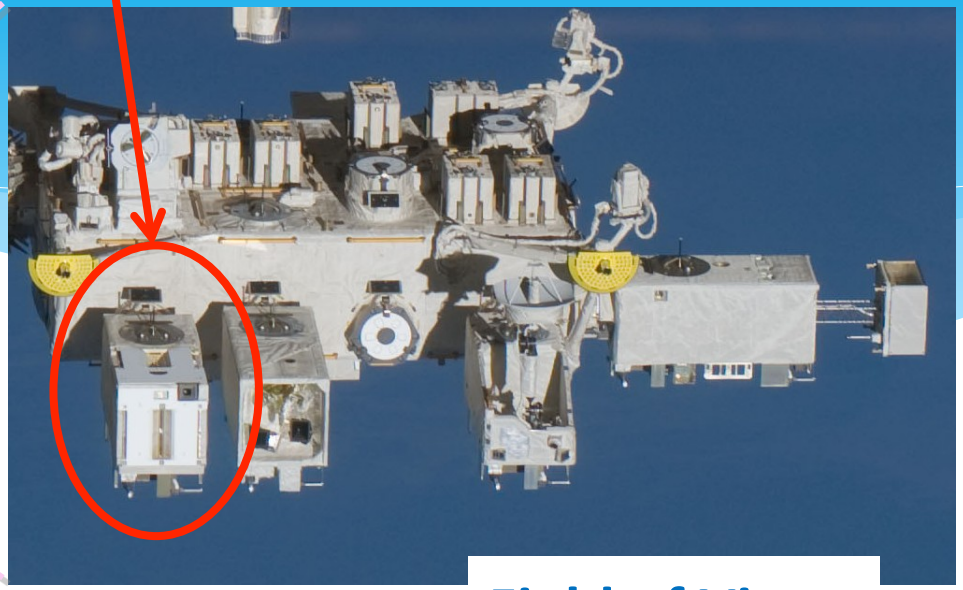


RIKEN/JAXA/MAXI Team

Accumulated in 2010-2013

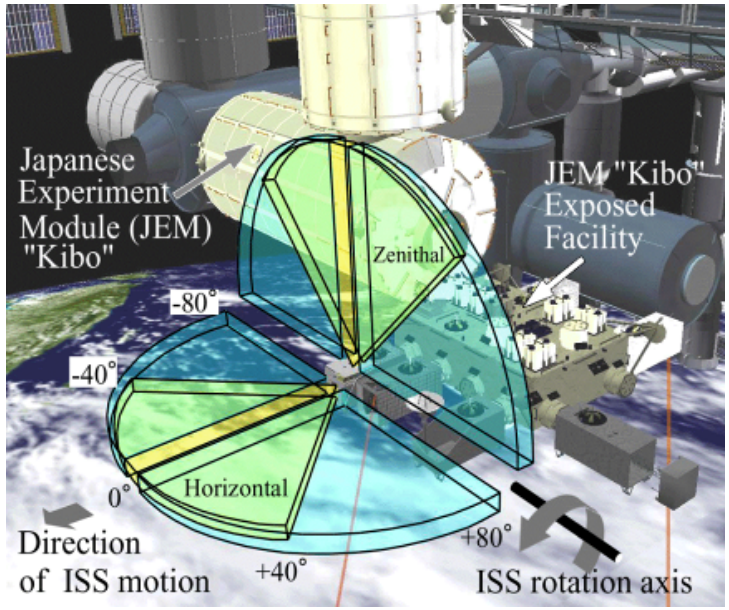
MAXI (Monitor of All-sky X-ray Image)



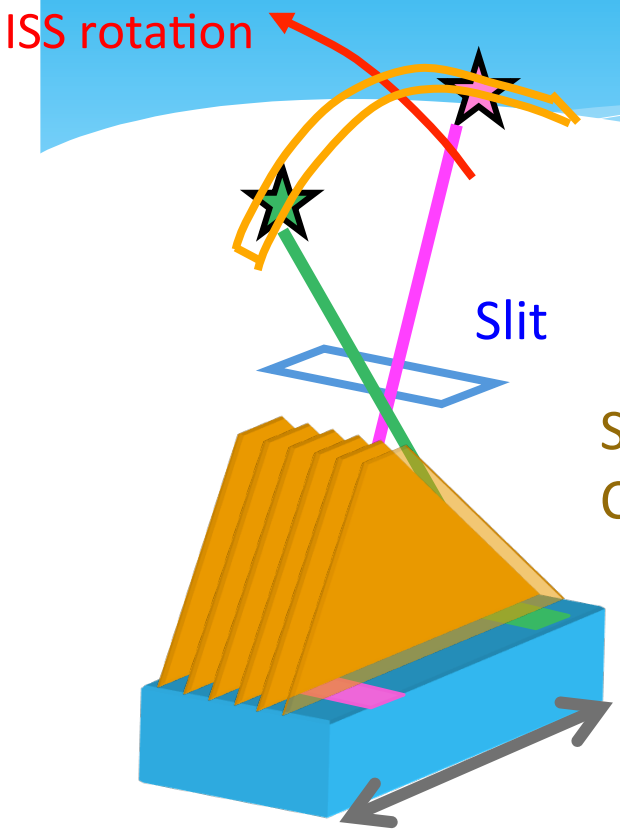


- **First astronomical** mission on ISS
- Infrastructure (**power** and **realtime-link**)
- First light was on **August 15 2009**
- Scans every **92 min.** with ISS rotation
- Observing for **7 yrs,** till **2018.3.** and **more**
- Data available at http://maxi.riken.jp

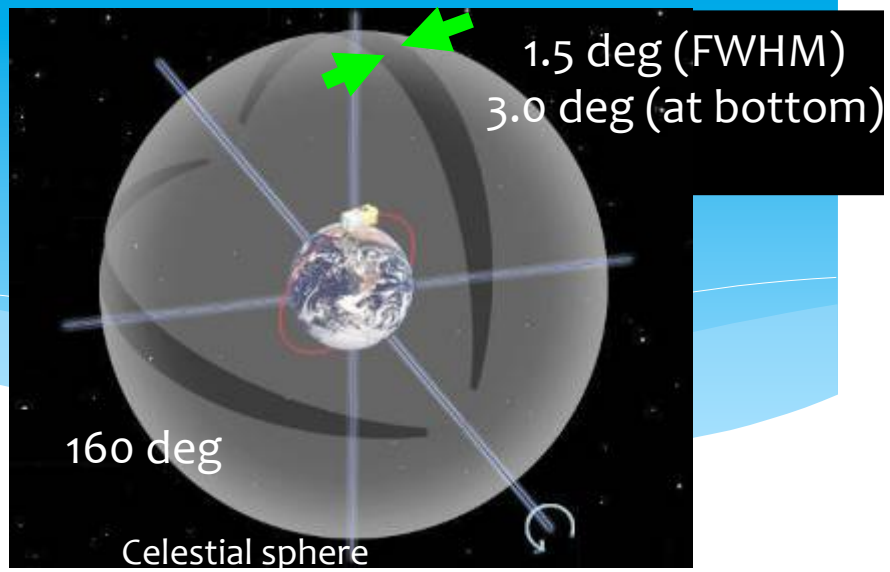
Field of Views

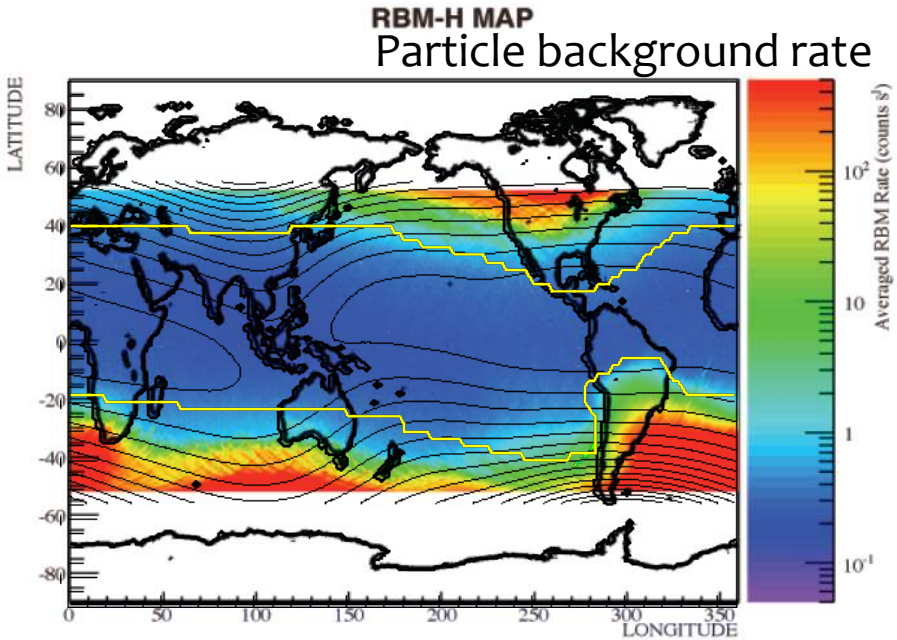


Scans with Slit + Slats collimator



1-dimensional position sensitive detector



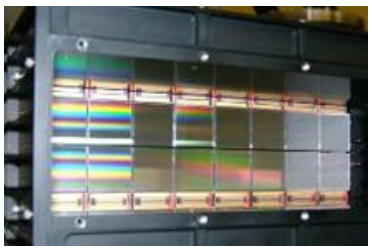


Particle background rate

Operating in equatorial region

proportional counter

X-ray CCD

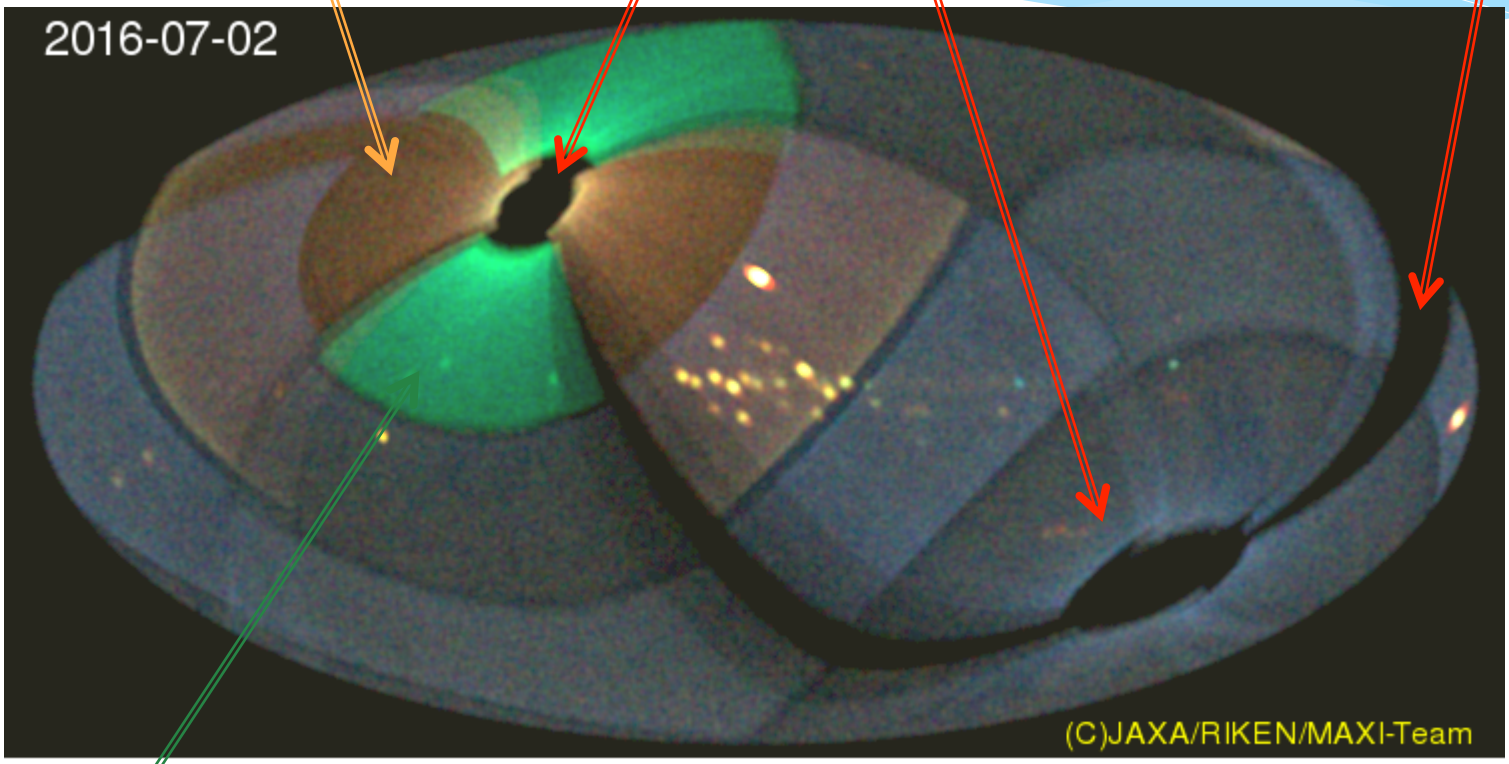


Today's All-Sky Coverage (GSC, one-day)

Scan poles (blind, r = 10 deg.) moves with the orbital precession period of 70 days.

GSC 0 (slow gas leak)

Sun avoidance (5 deg.)



GSC 3 (degraded sensitivity with a damaged anode)

Galactic coordinates

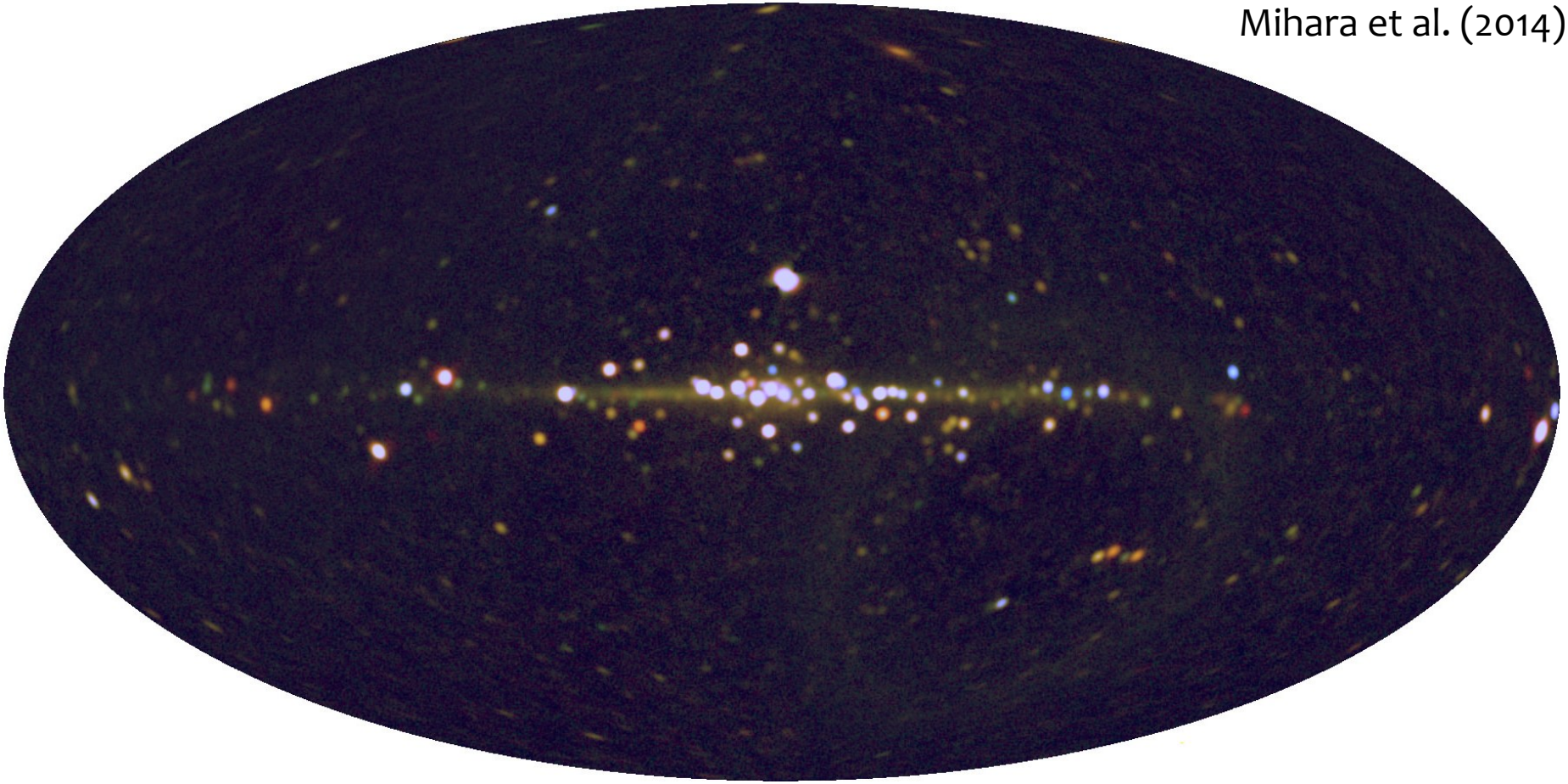
http://maxi.riken.jp/

Outline

1. MAXI instruments
2. **Results**
    1. All-sky map
    2. Cygnus super bubble
    3. Variable X-ray sources
    4. Nova Alerts
    5. New blackholes
    6. Nova ignition
    7. Tidal disruption
    8. GW 150914

GSC all-sky map (4.1 years)

Mihara et al. (2014)

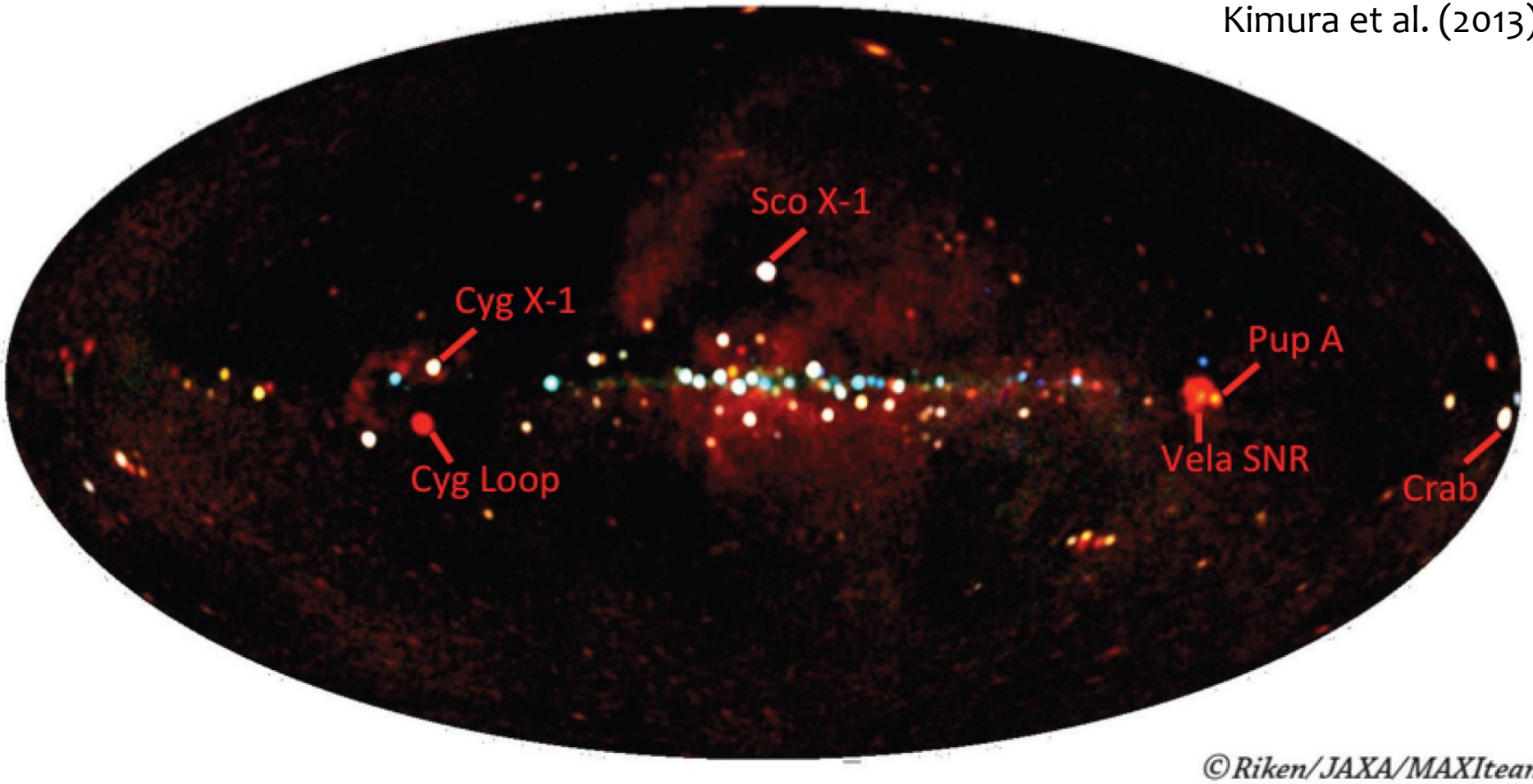


Red: **2-4** keV, Green: **4-10** keV, and Blue: 10-20 keV.
X-ray binary pulsars appear in blue, supernova remnants appear in red,
low-mass X-ray binaries appear in yellow.
More than 500 sources are detected. Members of bright AGN have changed in 30 years. A new catalog in the early 21st century.

Hiroi et al. (2013)

GSC+SSC all-sky map

Kimura et al. (2013)



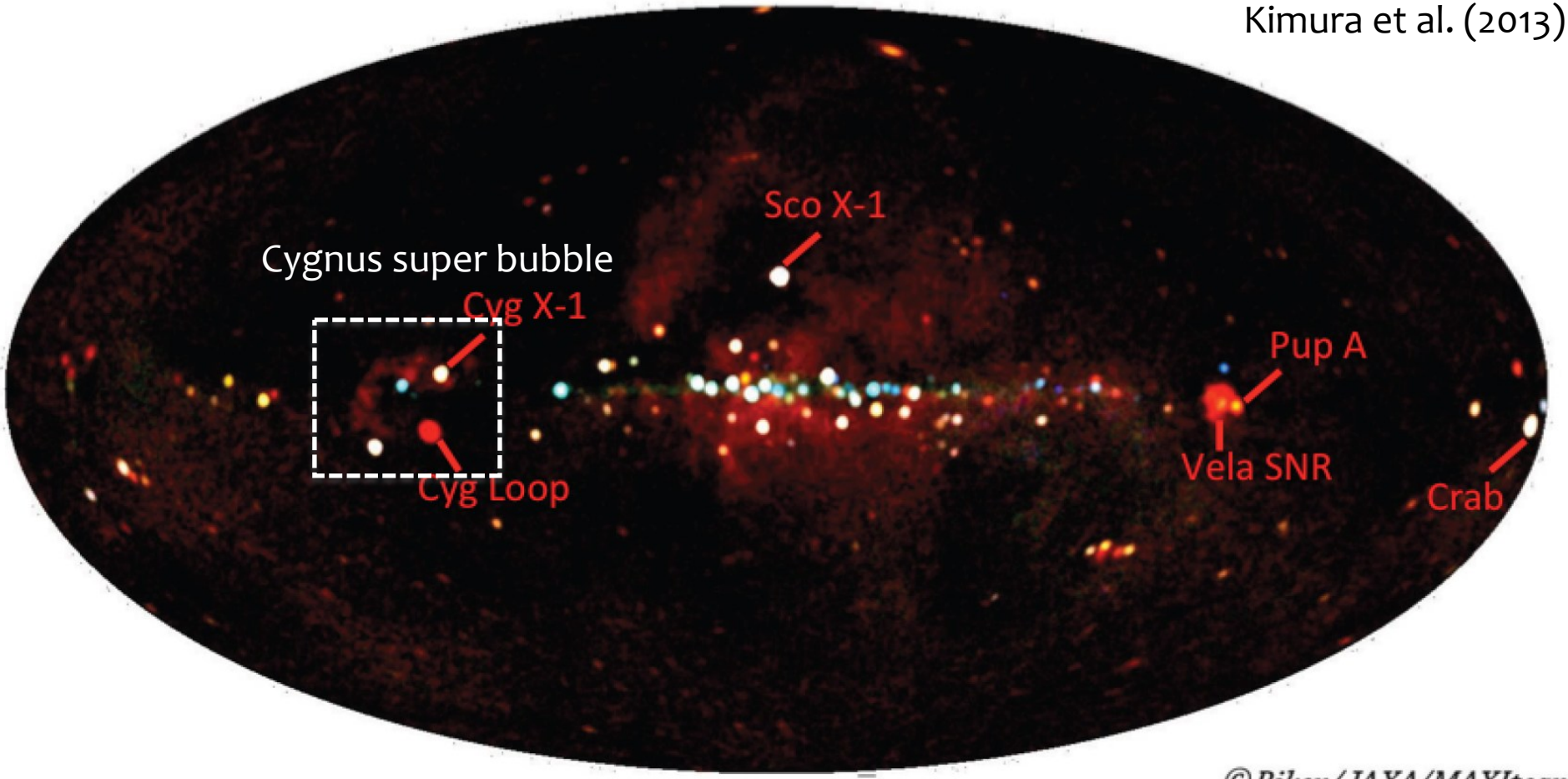
Red: **0.7-2** keV, Green: **2-4** keV, and Blue: **4-7** keV.

Supernova remnants appear in red.

Large structures (North polar spur, Cygnus super bubble) are recognized.

Large scale diffuse structure

Kimura et al. (2013)

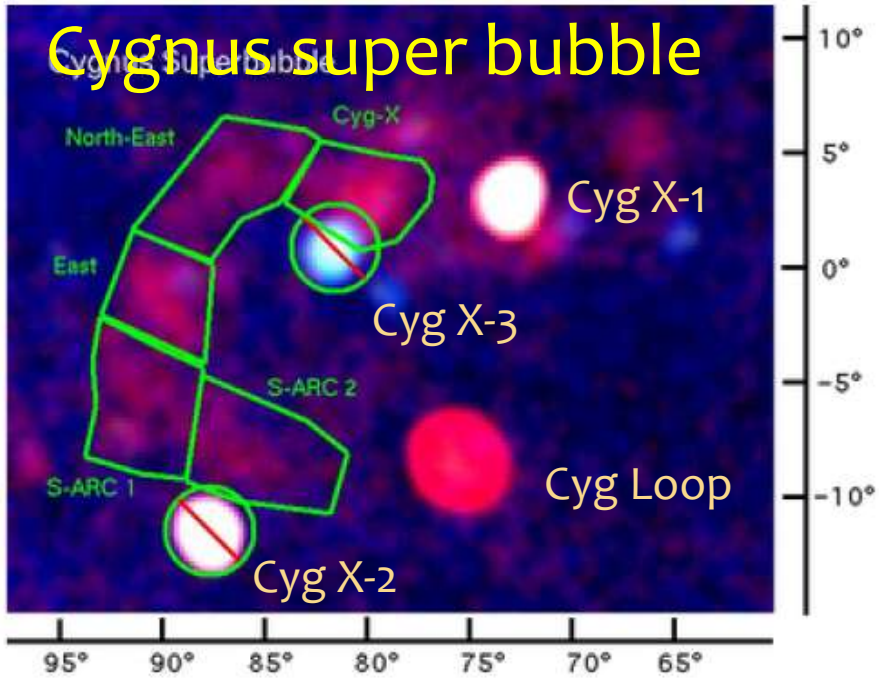


Red: **0.7-2** keV, Green: **2-4** keV, and Blue: **4-7** keV.

Supernova remnants appear in red.

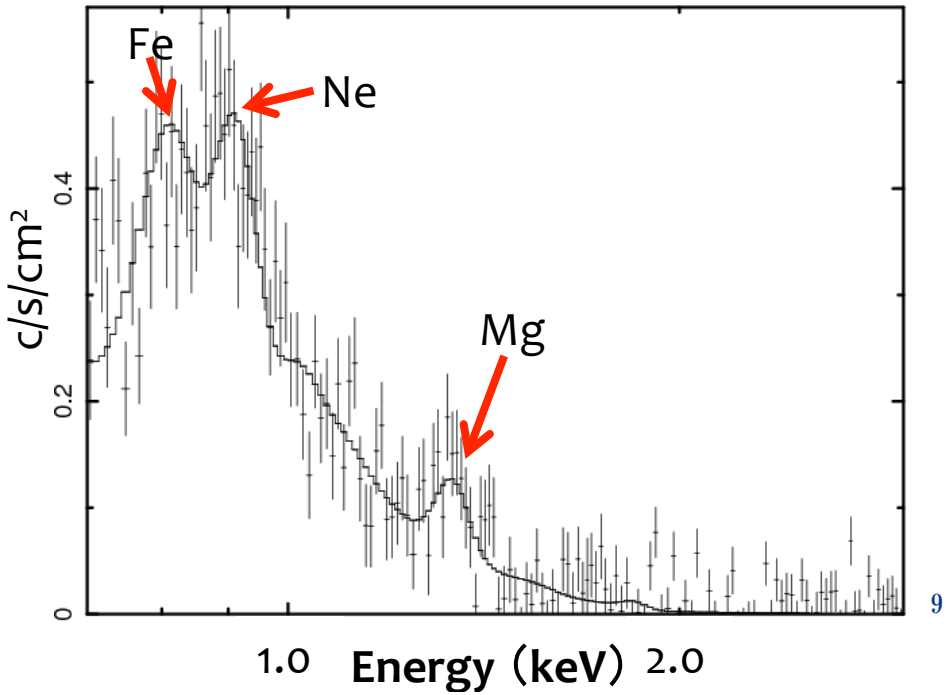
Large structures (North polar spur, cygnus super bubble) are recognized.

MAXI CCD achived an imaging spectroscopy for diffuse emission for the first time.



Region name	N_H (10^{22}cm^{-2})	kT (keV)	Abundance Relative to solar
All	$0.30^{+0.01}_{-0.01}$	$0.228^{+0.007}_{-0.007}$	$0.26^{+0.1}_{-0.1}$
Cyg-X	$0.27^{+0.04}_{-0.04}$	$0.21^{+0.03}_{-0.03}$	0.26 (fixed)
East	$0.28^{+0.03}_{-0.03}$	$0.23^{+0.03}_{-0.03}$	0.26 (fixed)
North-East	$0.33^{+0.03}_{-0.03}$	$0.20^{+0.02}_{-0.02}$	0.26 (fixed)
S-ARC1	$0.23^{+0.03}_{-0.03}$	$0.22^{+0.02}_{-0.02}$	0.26 (fixed)
S-ARC2	$0.22^{+0.03}_{-0.03}$	$0.22^{+0.02}_{-0.02}$	0.26 (fixed)

Kimura et al. (2013)



- Emission lines like SNR.
- Similar NH and kT in 5 regions.
- Suggesting
  the same distance and age.
- $E_{total} = 9 \times 10^{51}$ergs
  ~ 1000 $E_{SuperNova}$
- ⇒ Hyper nova remnant
- First HNR in the Galaxy

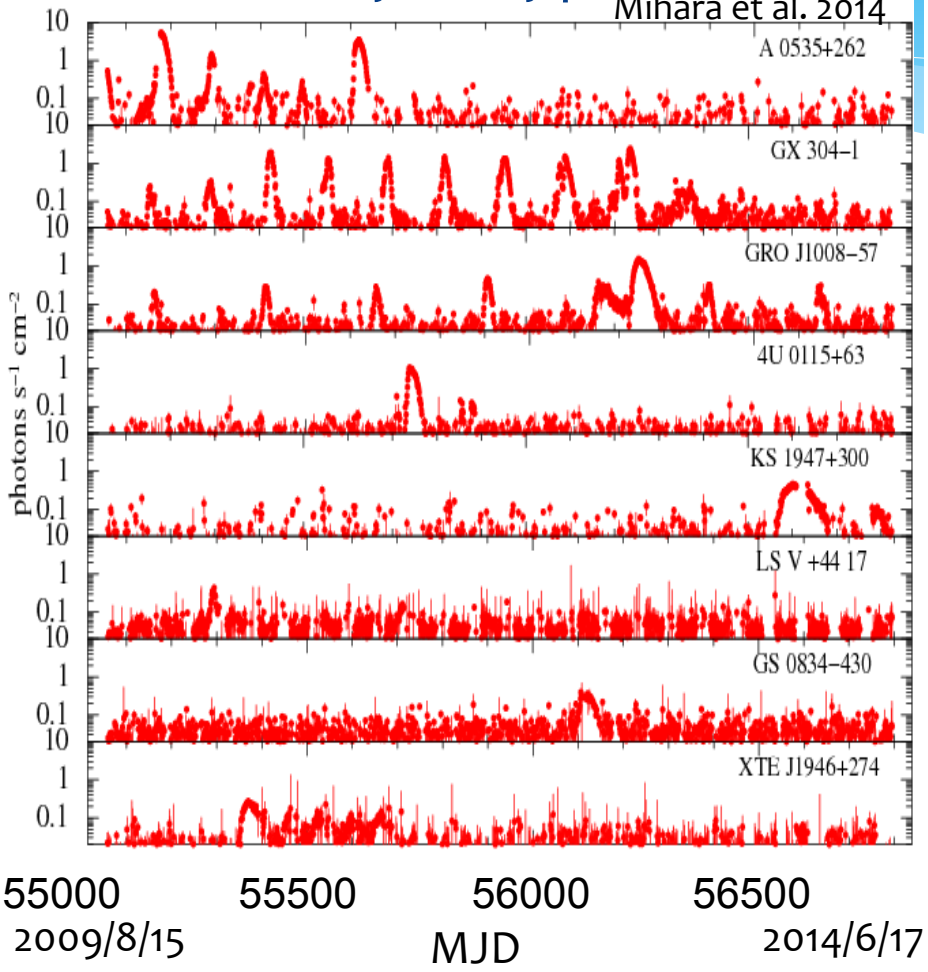
Outline

1. MAXI instruments
2. Results
    1. All-sky map
    2. Cygnus super bubble
    3. **Variable X-ray sky**
    4. Nova Alerts
    5. New blackholes
    6. Nova ignition
    7. Tidal disruption
    8. GW 150914

X-ray sources are variable

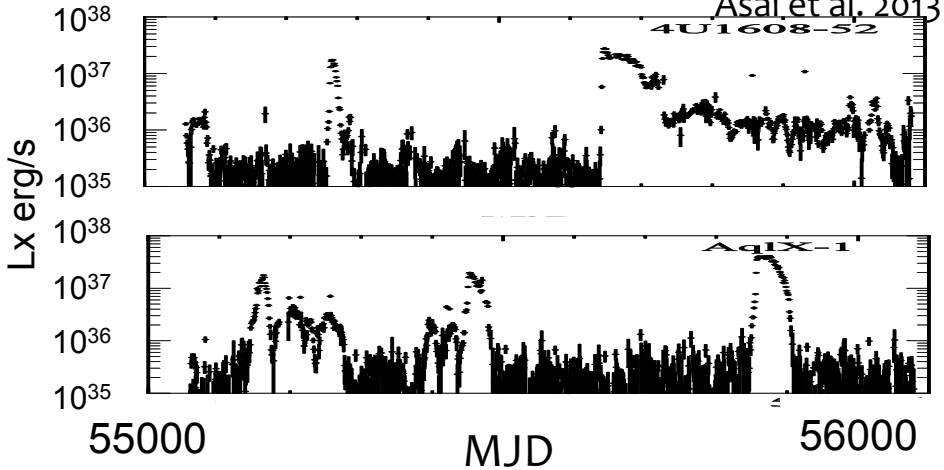
Be X-ray binary pulsars

Mihara et al. 2014

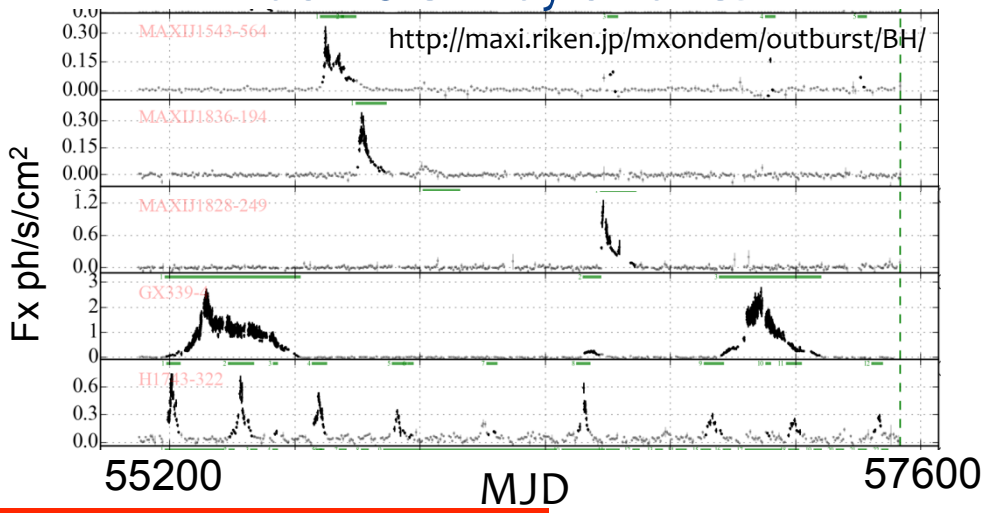


Neutron star Low-mass X-ray binaries

Asai et al. 2013



Blackhole X-ray binaries



We need to watch every day and every seconds.

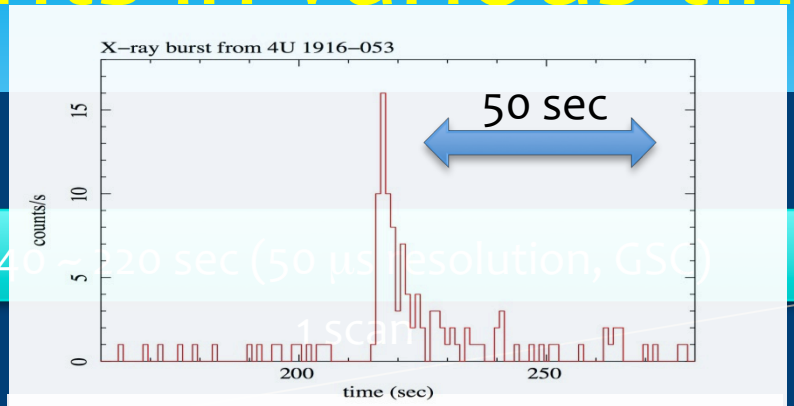
Transients in various time scales

X, γ-ray bursts

Superburst
SFXT
Star Flares

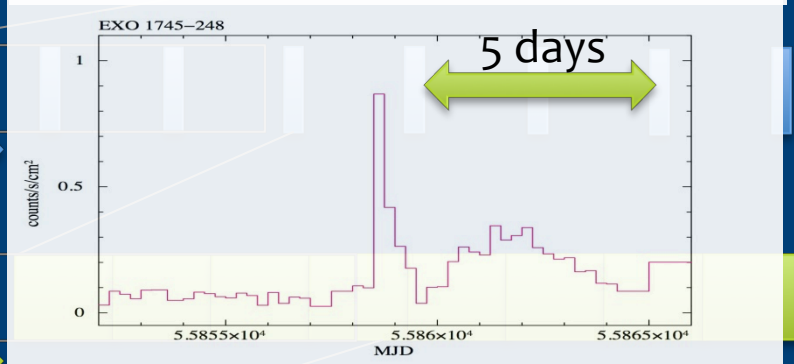
X-ray novae

AGN Flares



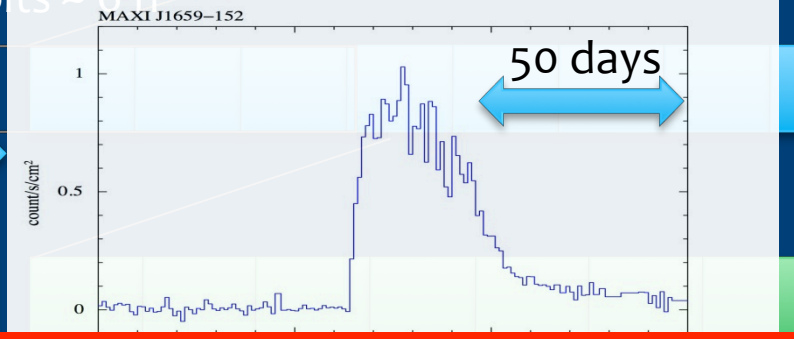
40 ~ 20 sec (50 μs resolution, GSC)

1 scan



92 m

4 orbits ~ 6 h



1 day

X-ray burst
From 4U 1916-053

Superburst + Outburst
From EXO 1745-248
Serino+ 2012

BH Outburst
MAXI J1659-152
Negoro+ 2010,
Yamaoka+ 2011

MAXI opened the time-domain astronomy

V404 Cyg on 2015.6.15.

By MICHAEL CASEY / CBS NEWS / June 25, 2015, 4:25 PM

Massive black hole wakes up after 26 years

Scientists had all but given up on the system known as V404 Cygni, which includes a monster black hole that was fond of devouring material from its stellar companions.

Part of the Milky Way galaxy, the system had been silent for a quarter century. But that all changed earlier this month, when a number of telescopes and the European Space Agency's (ESA) Integral satellite observed a burst of high energy light coming from almost 8,000 light-years away in the constellation Cygnus, the Swan.

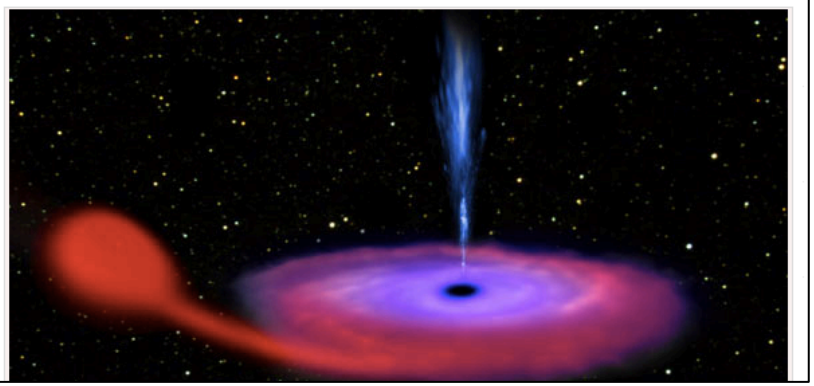
The first inklings the system may be active came from the Burst Alert Telescope on NASA's Swift satellite, which detected a sudden burst of gamma rays. Soon after, MAXI (Monitor of All-sky X-ray Image), part of the Japanese Experiment Module on the International Space Station, observed an X-ray flare from the same patch of the sky.

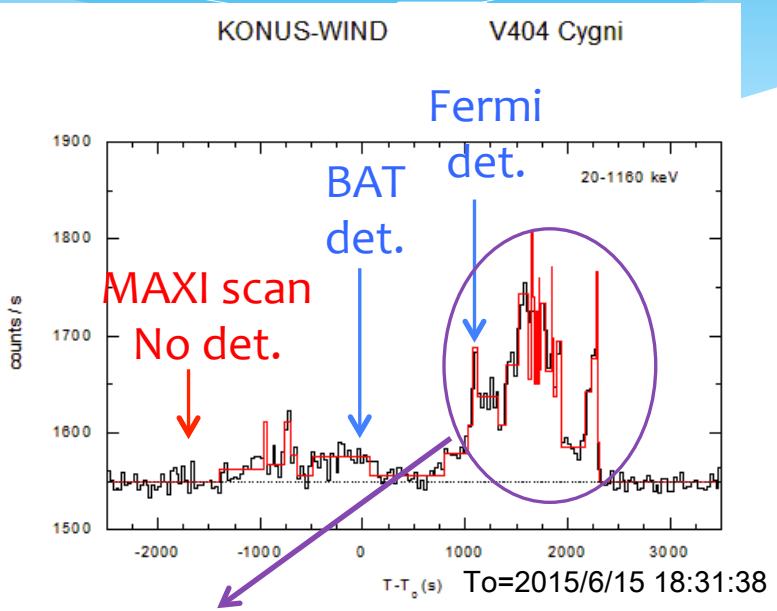
Published in
Astronomy

Tagged as
Binary star
Black hole
ESA
Gamma rays
Integral
MAXI
NASA
Swift spacecraft
V404 Cygni
X-rays

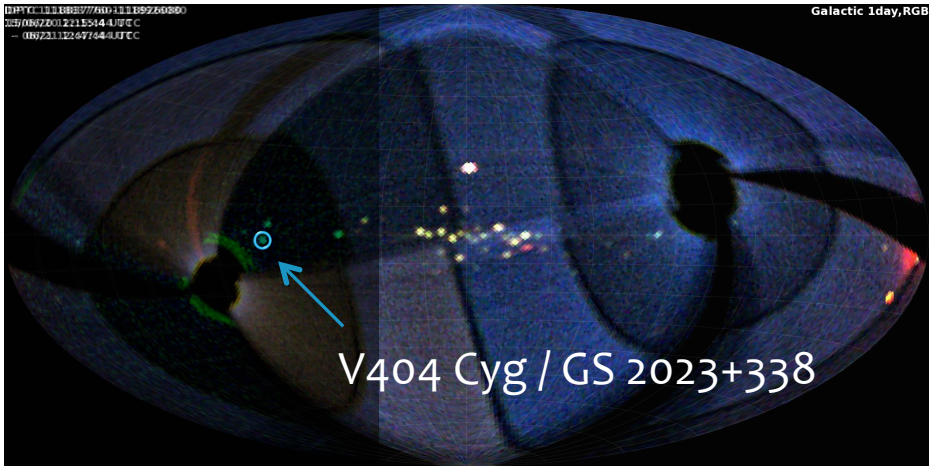
Follow
いいね！ 1.7万
Share
Tweet 28
いいね！ 73

Astronomers using a fleet of orbiting telescopes, including ESA's Integral satellite, NASA's Swift satellite and the Japanese MAXI telescope, have observed a strong outburst of gamma rays and X-rays produced by a low-mass black hole in a binary system called V404 Cygni.





Quick follow-up optical observation
Discovery of rapid variability (Kimura et al. Nature 2016)

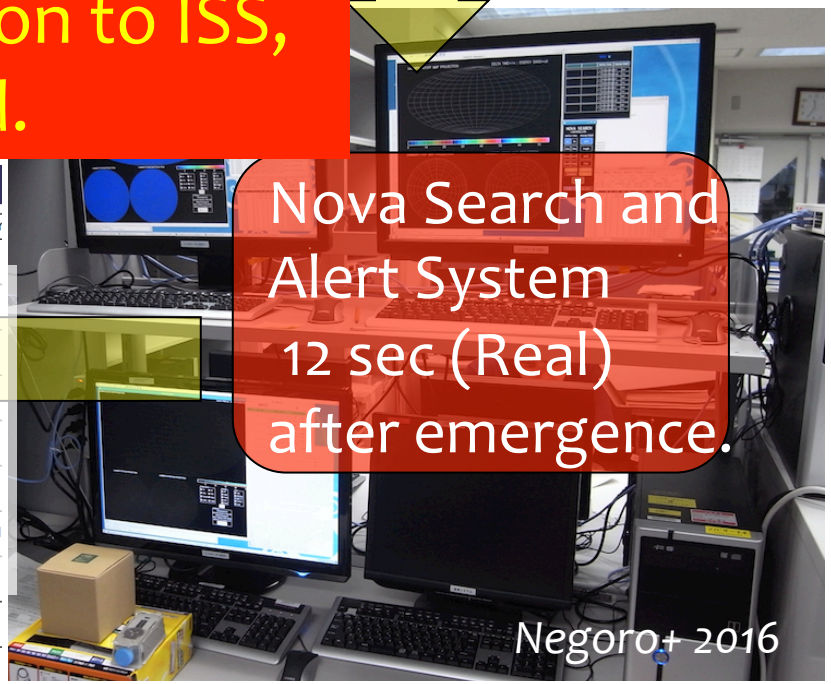


Outline

1. MAXI instruments
2. Results
    1. All-sky map
    2. Cygnus super bubble
    3. Variable X-ray sky
    4. **Nova Alerts**
    5. New blackholes
    6. Nova ignition
    7. Tidal disruption
    8. GW 150914

Nova-Alert System

Thanks to the real-time connection to ISS,
a prompt alert has been realized.



Nova Search and
Alert System
12 sec (Real)
after emergence.

Negoro+ 2016

Astronomers
all over the world.

Alert
MAXI mail list
Astr. telegram / GCN
from RIKEN

Novae -- list --

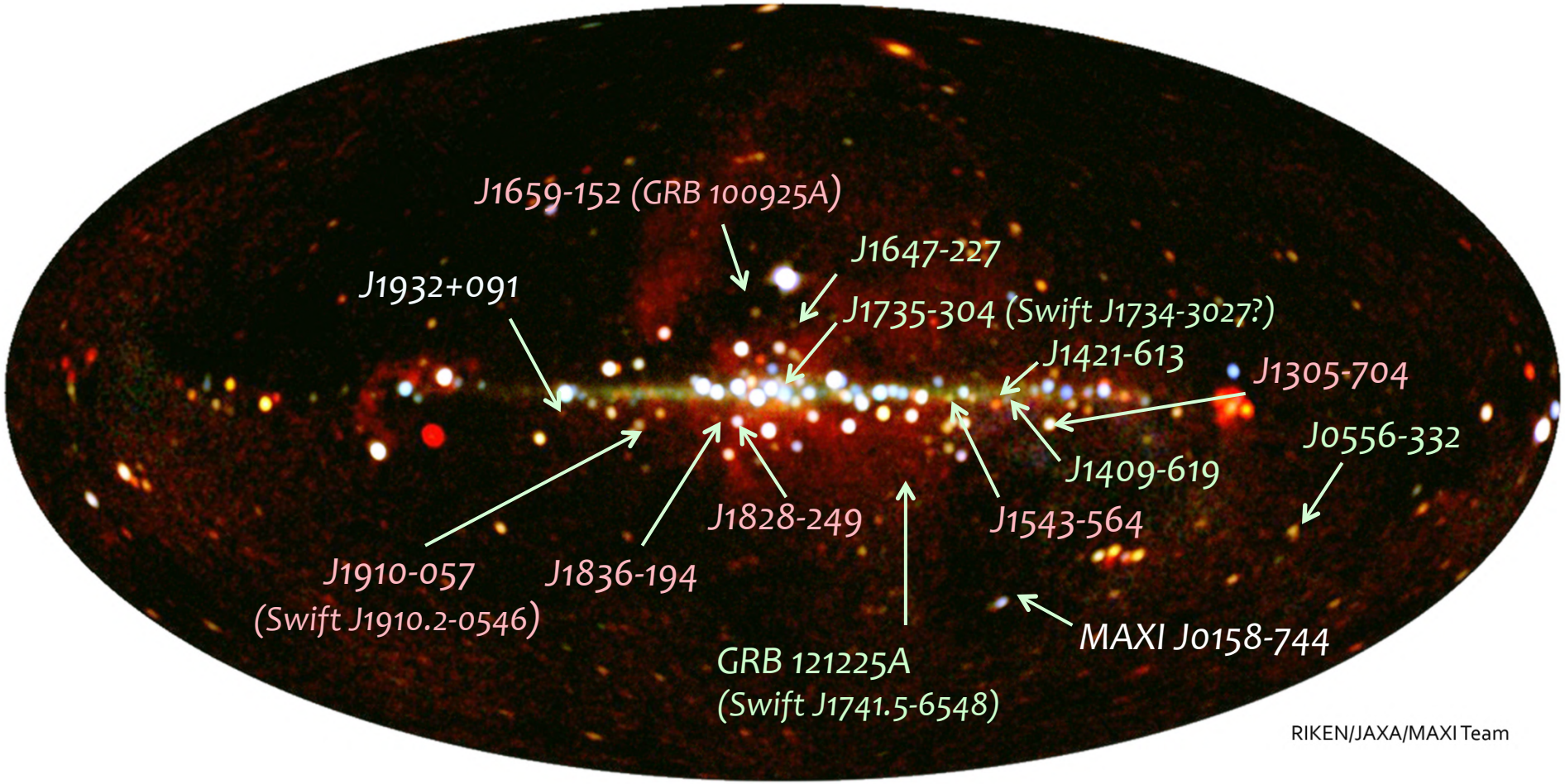
ID	Image	Date	RA, Dec	com
5337375271 958473409 (Warning)		2010-05-21T10:36:34	(308.764, 37.464)	EXO 2030+375
53520 95973		2010-06-05T00:20:14	(82.544, -66.334)	LMC X-4
53 960424195 (Warning)		2010-06-13T00:29:40	(230.060, -57.227)	Cir X-1
53 96			(24.044)	GS 1826-238
5360774677 960 5 (Alert)		2010-06-13T23:23:30	(230.037, -57.016)	Cir X-1
53 96 0687741 (Warning)			778)	
5365027798 96			(289.188, -5.447)	X-ray burst of 4U 1
537 961659391 (Warning)		2010-06-27T07:36:16	(84.738, 26.065)	A 0535+262
5378212885 962002493 (Warning)		2010-07-01T06:54:38	(189.997, -34.181)	likely to be an XRF

228 Atels and 98 GCNs
>150 original papers

Outline

1. MAXI instruments
2. Results
    1. All-sky map
    2. Cygnus super bubble
    3. Variable X-ray sky
    4. Nova Alerts
    5. **New blackholes**
    6. Nova ignition
    7. Tidal disruption
    8. GW 150914

MAXI discovered 17 X-ray Transients in 6 years

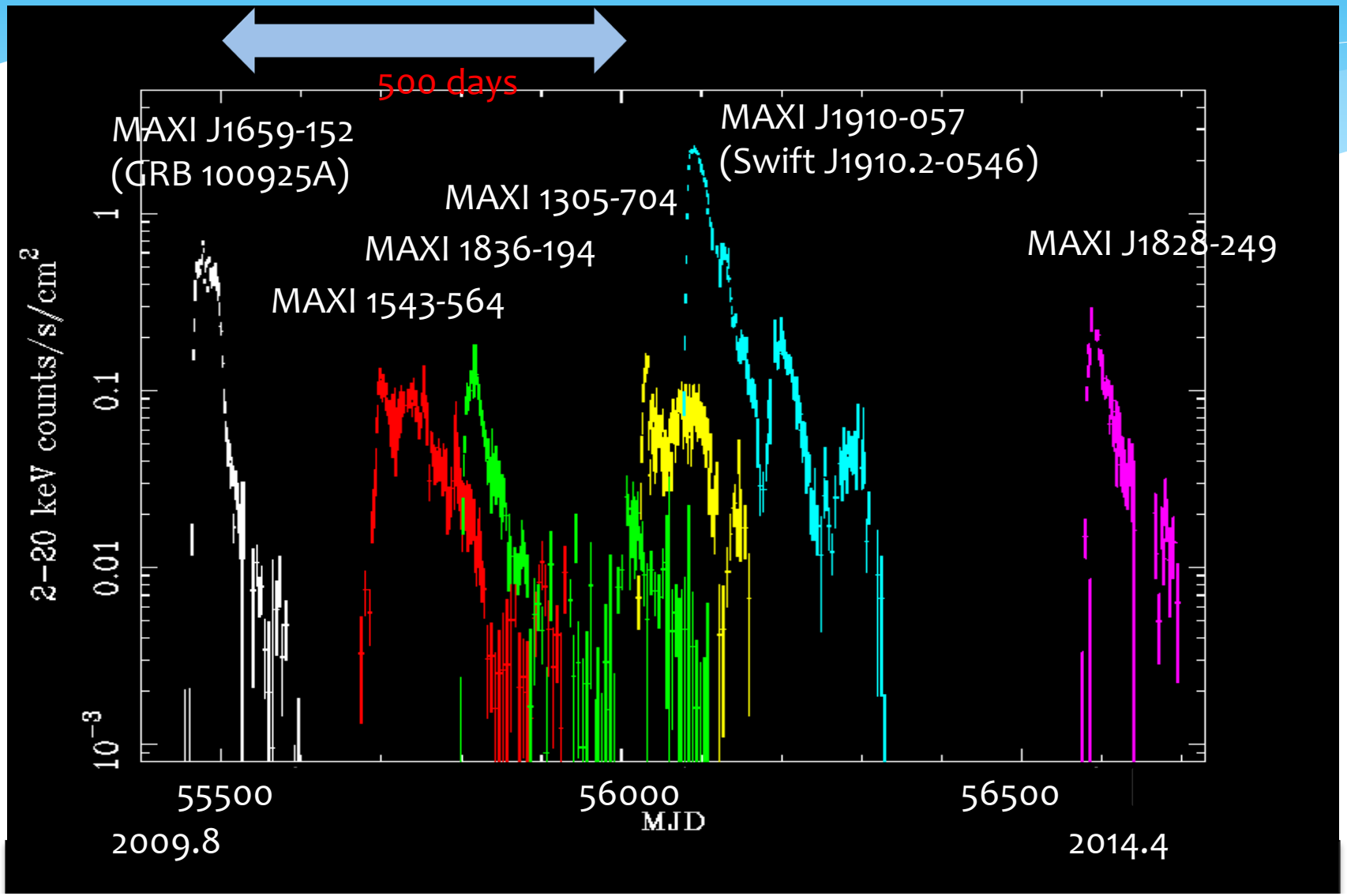


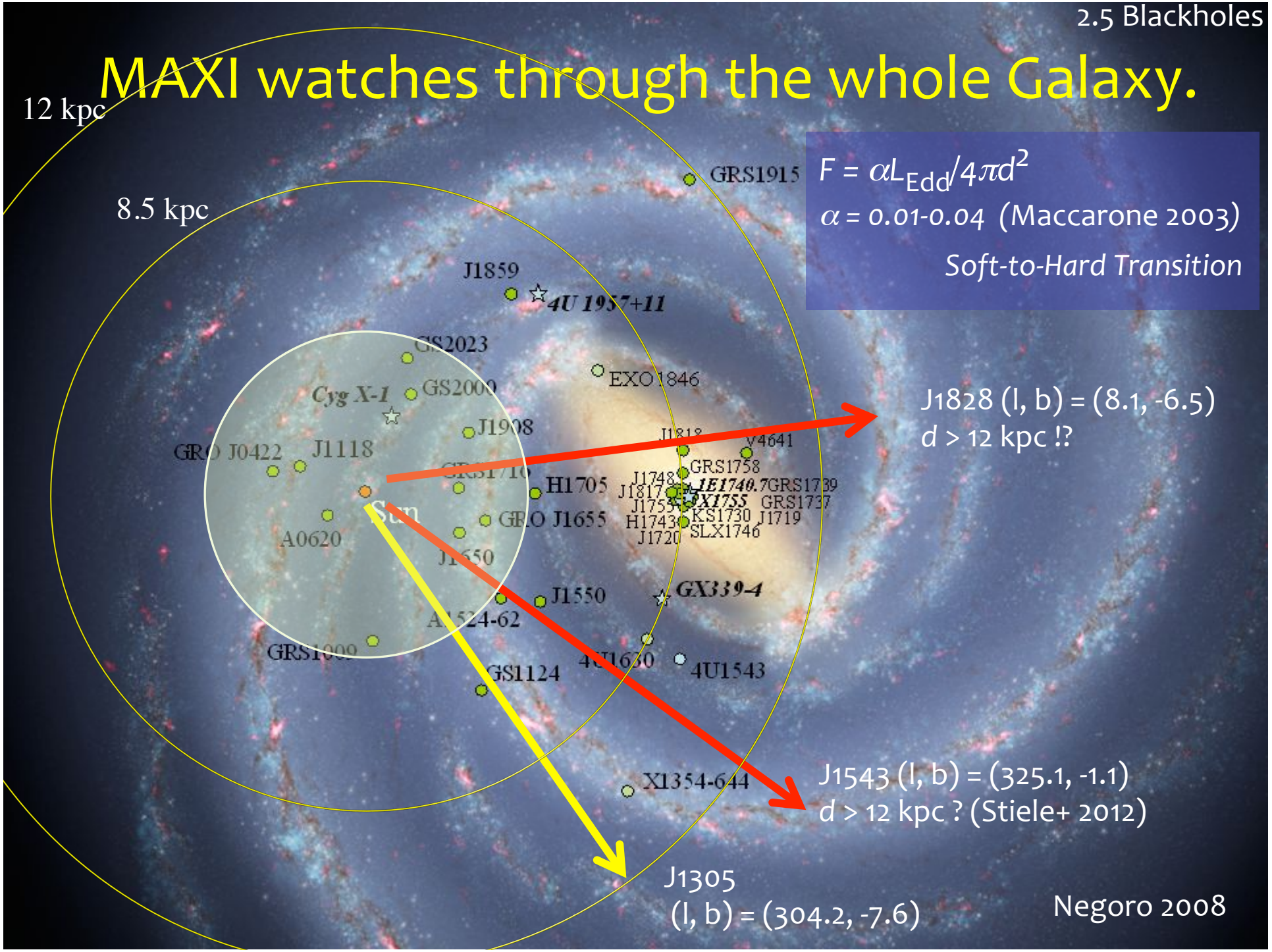
1 White Dwarf 6 Neutron Stars 6 Black Hole Candidates, and 1 unknown

6 Blackholes discovered by MAXI

- Since 2009 August, 12 BHCs were discovered.
  6 out of them were discovered by MAXI.

Negoro et al. (2014)

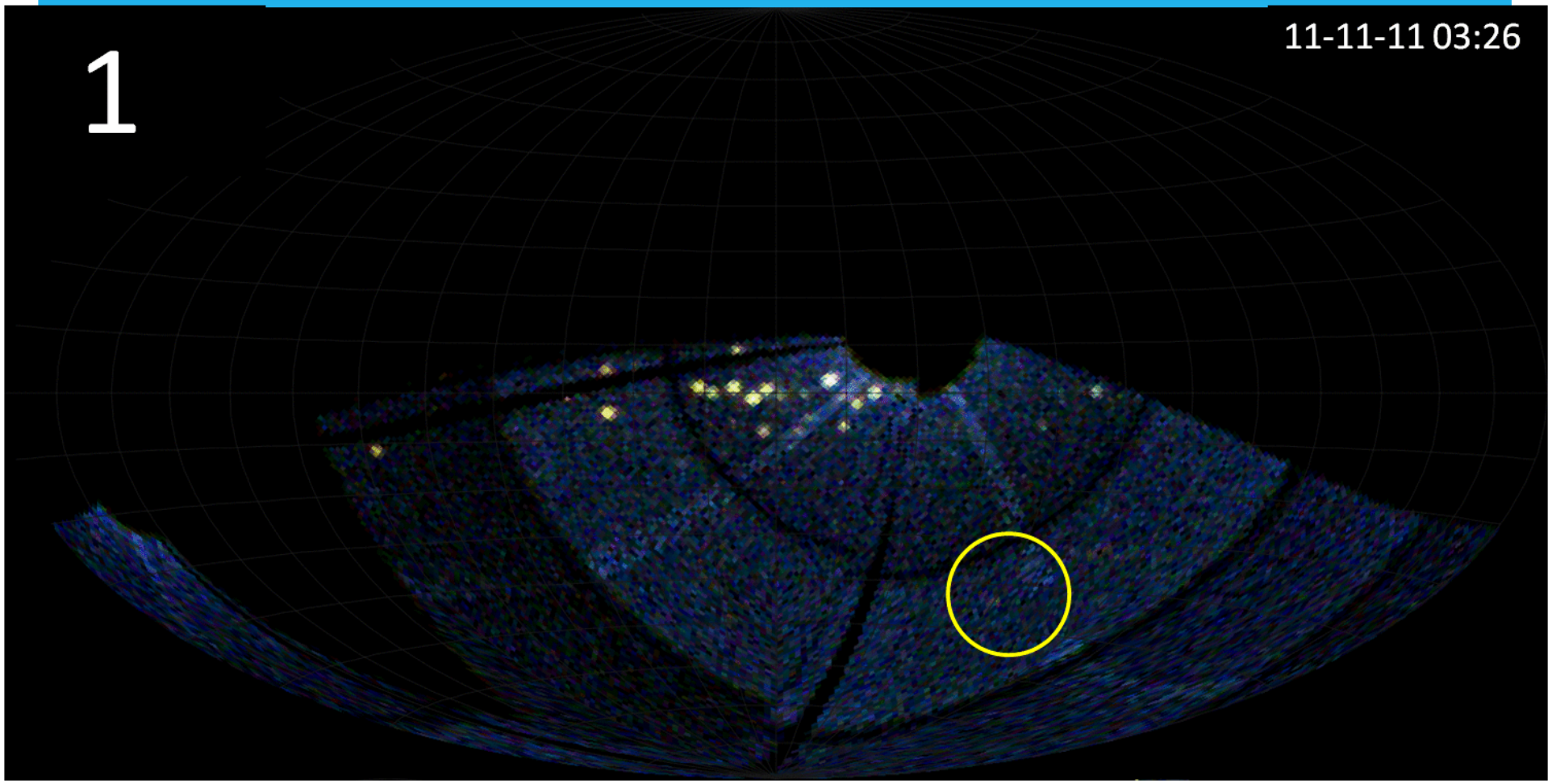



2.5 Blackholes
MAXI watches through the whole Galaxy.
12 kpc
8.5 kpc
$F = \alpha L_{Edd}/4\pi d^2$
α = 0.01-0.04 (Maccarone 2003)
Soft-to-Hard Transition
GRS1915
J1859
4U 1957+11
GS2023
EXO1846
Cyg X-1
GS2000
J1908
GRO J0422
J1118
V4641
GRS1758
H1705
J1748
1E1740.7
GRS1739
J1817
GX1755
GRS1737
J1755
KS1730
J1719
GRO J1655
H1743
SLX1746
J1720
A0620
J1650
J1550
GX339-4
A1524-62
GRS1009
4U1630
4U1543
GS1124
X1354-644
J1828 (l, b) = (8.1, -6.5)
d > 12 kpc !?
J1543 (l, b) = (325.1, -1.1)
d > 12 kpc ? (Stiele+ 2012)
J1305
(l, b) = (304.2, -7.6)
Negoro 2008

Outline

1. MAXI instruments
2. Results
    1. All-sky map
    2. Cygnus super bubble
    3. Variable X-ray sky
    4. Nova Alerts
    5. New blackholes
    6. **Nova ignition**
    7. Tidal disruption
    8. GW 150914

Discovery of MAXI J0158-744

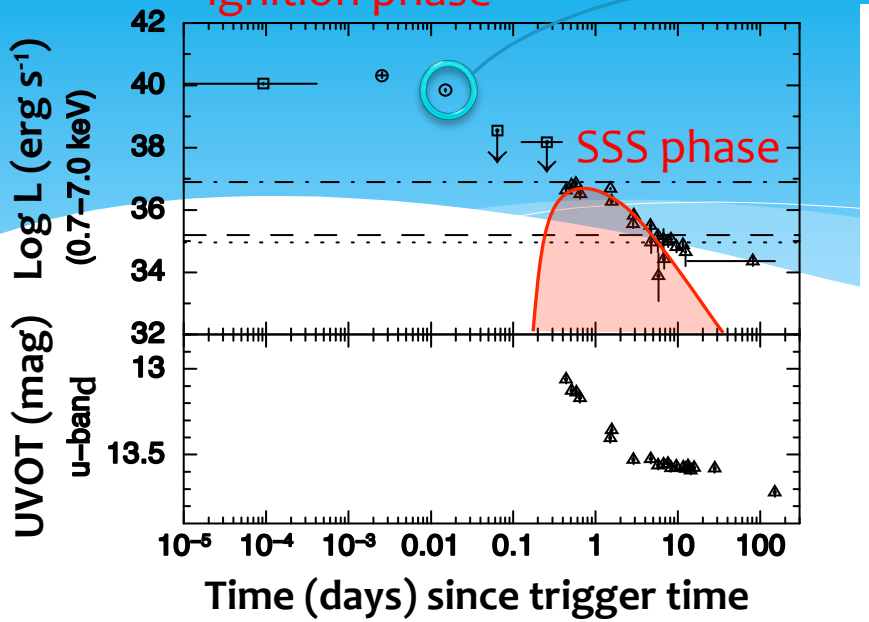


- MAXI GSC All-sky Image
- Every 90 min.
- 2011-11-11 05:05:59 (UT)

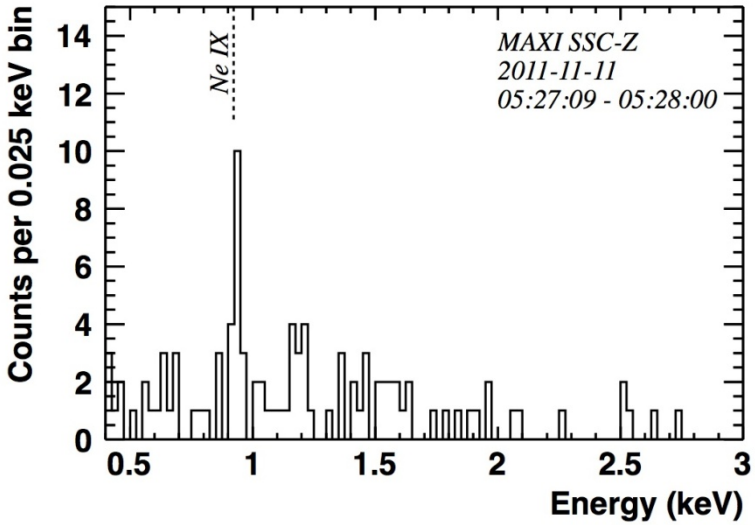
- Soft X-ray short Transient (< 5 keV)

None of GRBs, X-ray burst on neutron stars, Flare of magnetars, Super-giant Fast X-ray Transient, and supernova shock breakout

MAXI J0158-744



Ionized Ne line



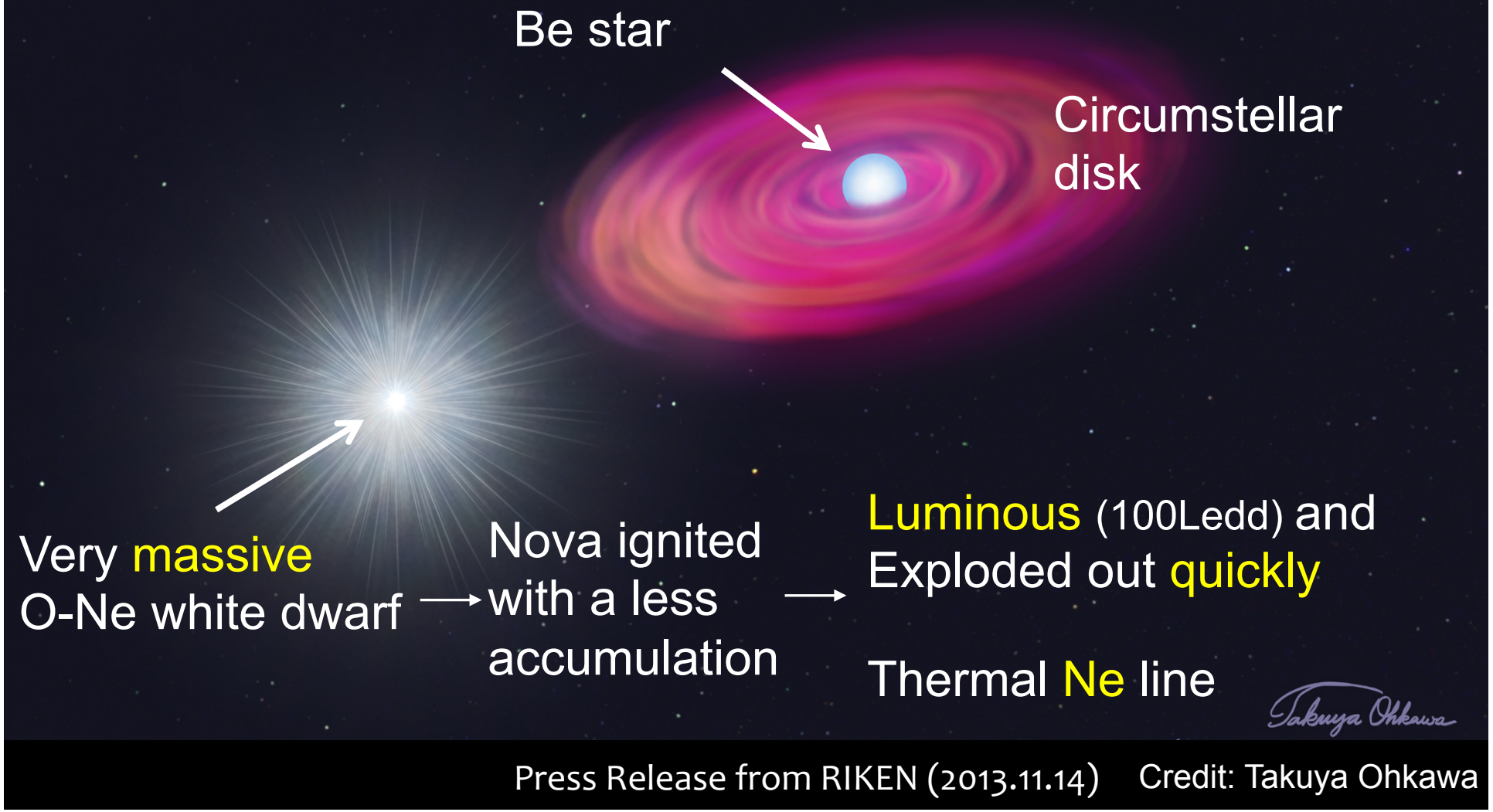
* Near the edge of Small Magellanic Clouds (SMC)
  - Optical spectrum: Be star at SMC distance (= 60 kpc) (B1-2 IIIe)
  - Luminosity = 10^{40} erg/s (Ignition phase)
  - Ionized Ne line was detected.
* Energy spectrum (0.5 → 30 days) :
  * Blackbody (radius = 10^4 → 10^2 km, Temperature= 60 → 110 eV)
  * Similar to soft X-ray emission after nova explosions.
  * Super Soft X-ray Source phase (SSS phase)

Nova (nuclear fusion) explosion

Morii et al. (2013)

rare

WD-Be binary system (MAXI J0158-744)



Press Release from RIKEN (2013.11.14) Credit: Takuya Ohkawa

Outline

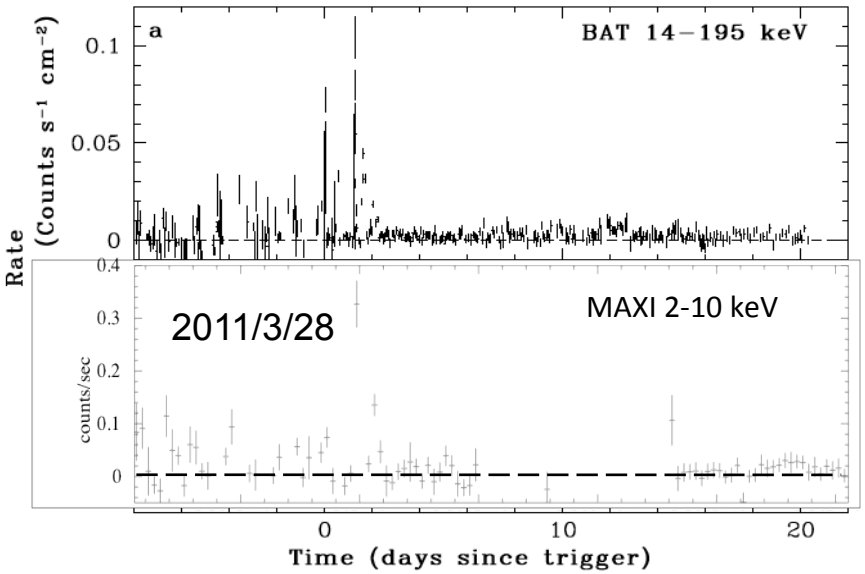
1. MAXI instruments
2. Results
    1. All-sky map
    2. Cygnus super bubble
    3. Variable X-ray sky
    4. Nova Alerts
    5. New blackholes
    6. Nova ignition
    7. **Tidal disruption**
    8. GW 150914

Tidal Disruption Event with MAXI

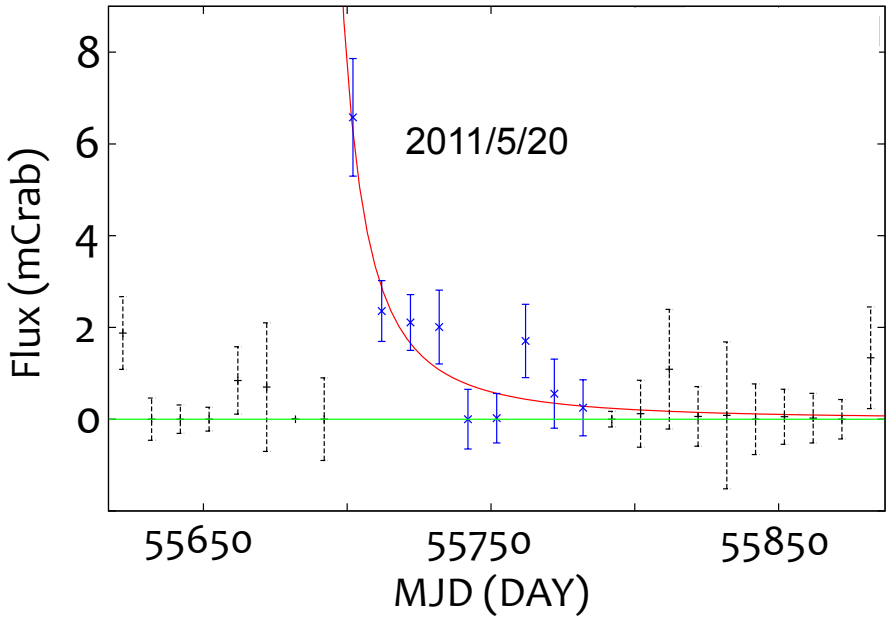
- A star approaching to a giant blackhole in the center of a galaxy is torn into pieces by the tidal force. The debris accretes to the blackhole.
- Long time monitoring of MAXI guarantees a single event, not one of the AGN activities.
- MAXI detected three TDE during 2009-2012.

Burrows et al. Nature 2011

Swift J1644+57 with Swift/BAT and MAXI/GSC



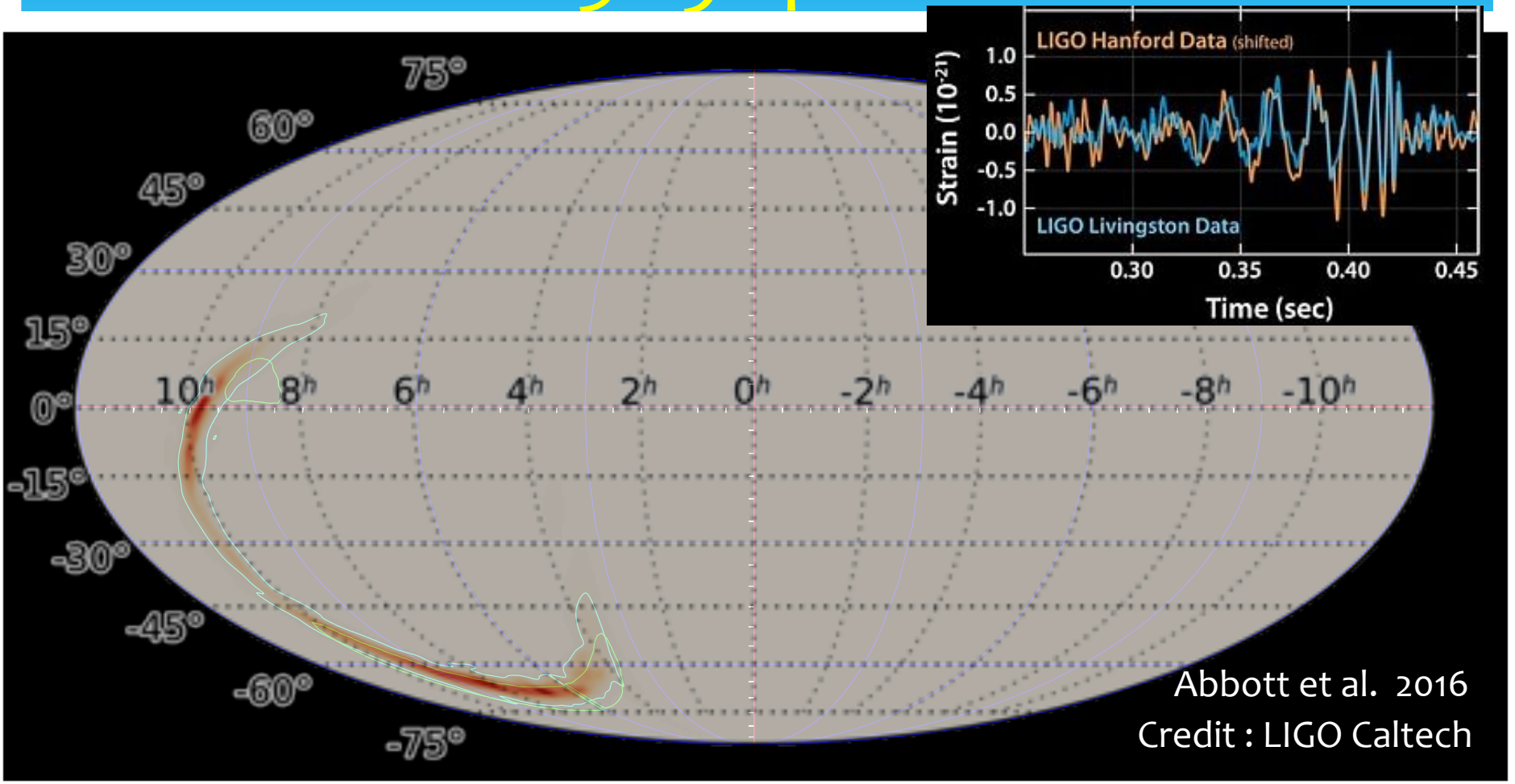
Swift J2058+05 with MAXI/GSC



Outline

1. MAXI instruments
2. Results
    1. All-sky map
    2. Cygnus super bubble
    3. Variable X-ray sky
    4. Nova Alerts
    5. New blackholes
    6. Nova ignition
    7. Tidal disruption
    8. GW 150914

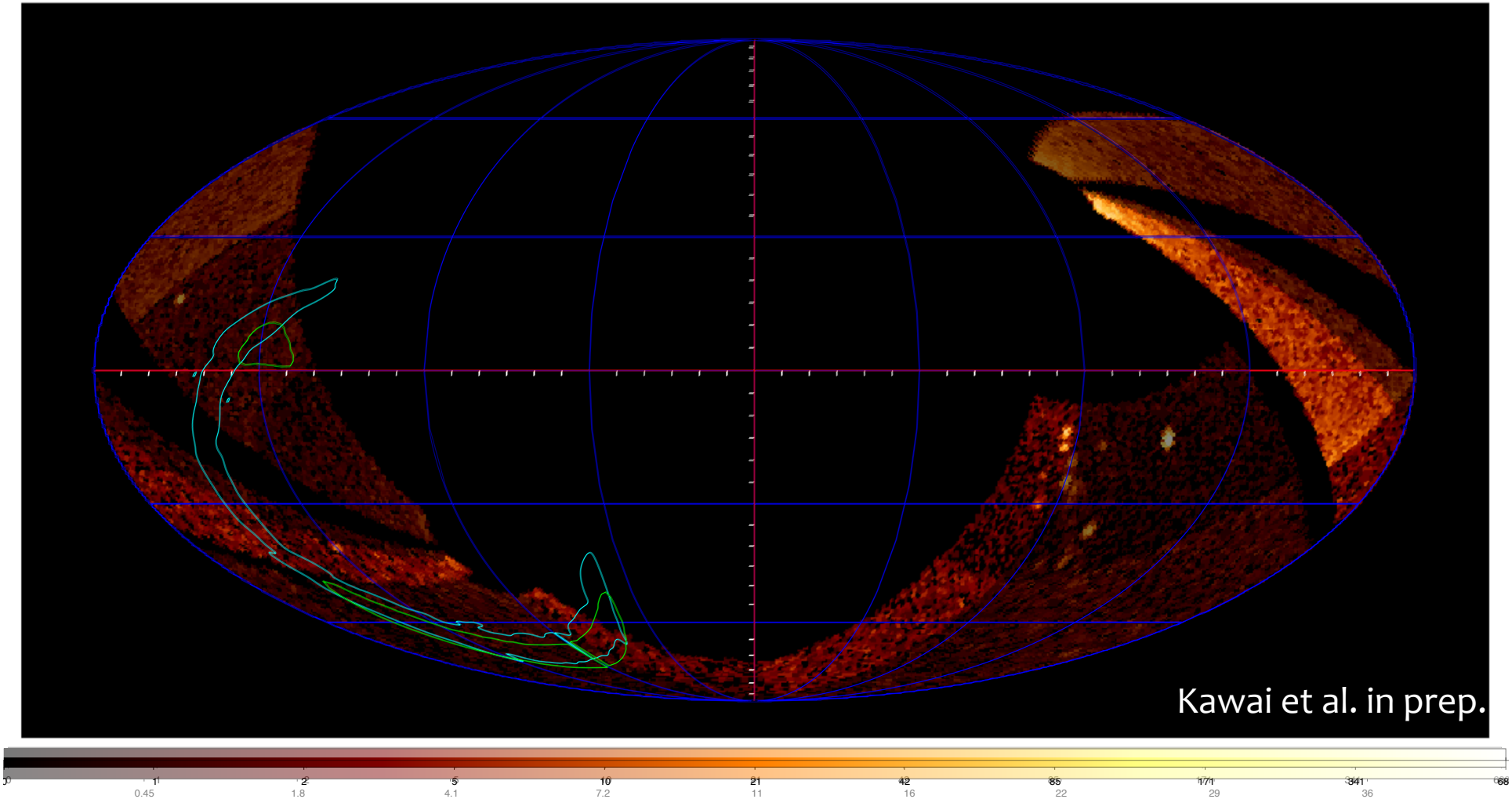
GW 150914 Event



Sky Blue Contour: ROUGHLY 90% credible level

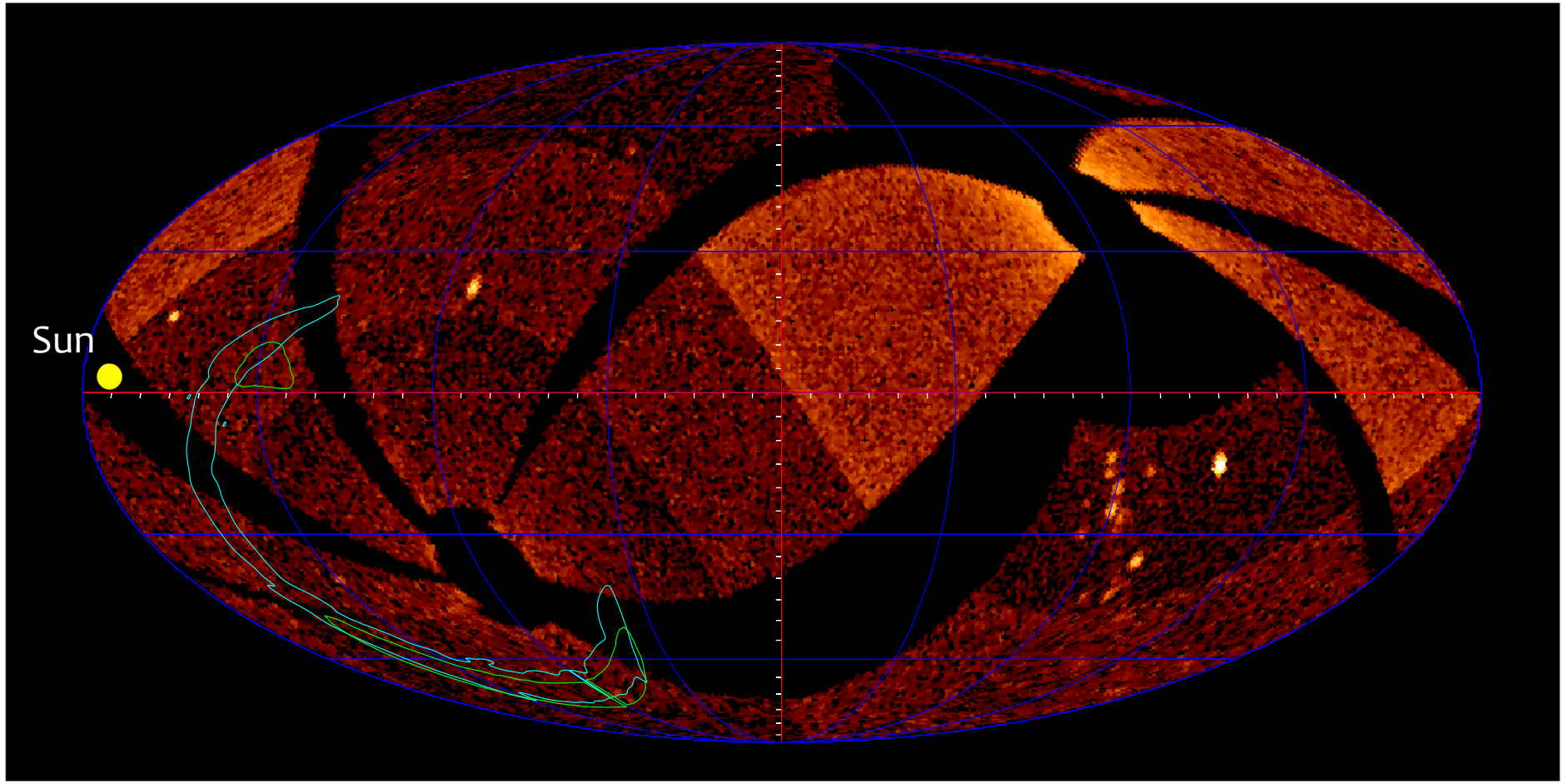
MAXI was not operating at the GW time 2015.9.14. 9:50:45 UT.

4-30 min after the detection



Scans on the GW region started in 4 minutes later.
About 90% of the error region was observed in less than 30 min.

1 orbit (~92 min)



3 σ upper limit (2-20 keV) : 0.1 c/s/cm^2 ~ 30 mCrab ~ 10^{-9} erg/s/cm^2 (Serino et al. 2015)

Although MAXI was off at the GW time, it put upper limit in flux in just after the event, long before and long after the event.

Summary

- Continuous monitoring of MAXI on ISS provides basic information on variability of X-ray sources, which is distributed freely to the world.
- A real-time alert triggers many follow-up observations of ground observatories and satellites in orbit.
- New phenomena (as an ignition of a nova) and six blackholes were discovered.
- MAXI has opened a new era of time-domain astronomy and of multi-messenger astronomy with the highly-sensitive X-ray all-sky monitor and the real-time alert.
- Together with new instruments (gravitational wave detectors, the X-ray detector NICER on ISS), MAXI will be on the cutting edge of the X-ray astronomy.

End