

Status of MAXI Instrument Calibration

(Current status of operation, calibration,
software works *in progress*)

Mutsumi Sugizaki (RIKEN)
on behalf of MAXI Team



MAXI Team

JAXA: M. Matsuoka, K. Kawasaki, S. Ueno, H. Tomida, M. Kohama, M. Ishikawa, K. Ebisawa, H. Katayama

RIKEN: T. Mihara, M. Sugizaki, M. Suzuki, Y. Nakagawa, T. Yamamoto

Tokyo Tech. Univ.: N. Kawai, M. Morii, K. Sugimori

Aoyama Gakuin Univ.: A. Yoshida, K. Yamaoka, T. Kotani, S. Nakahira

Osaka Univ.: H. Tsunemi, M. Kimura

Nihon Univ.: H. Negoro, M. Nakajima, R. Ishiwata, S. Miyoshi

Kyoto Univ.: Y. Ueda, N. Isobe, S. Eguchi, K. Hiroi

Miyazaki Univ.: M. Yamauchi, A. Daikyuji

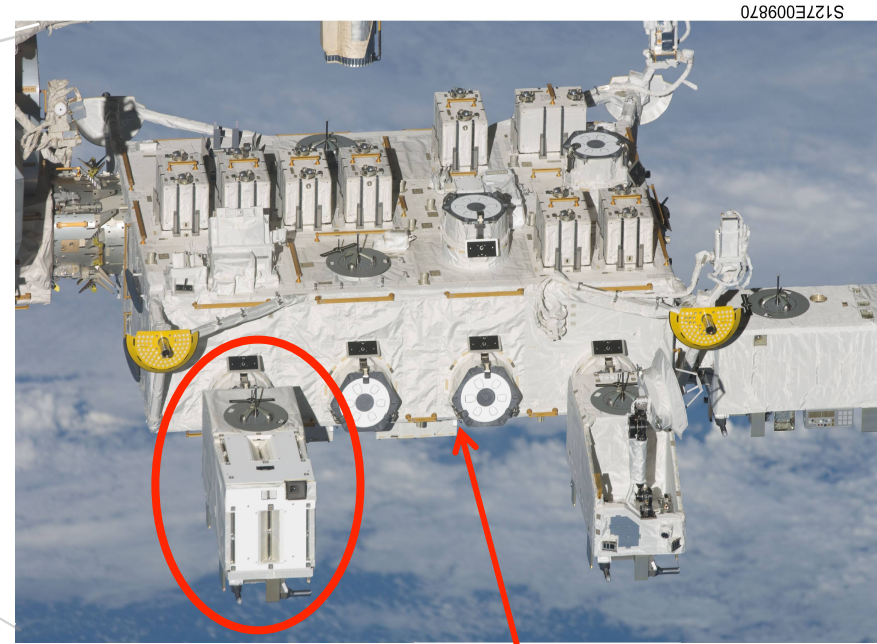
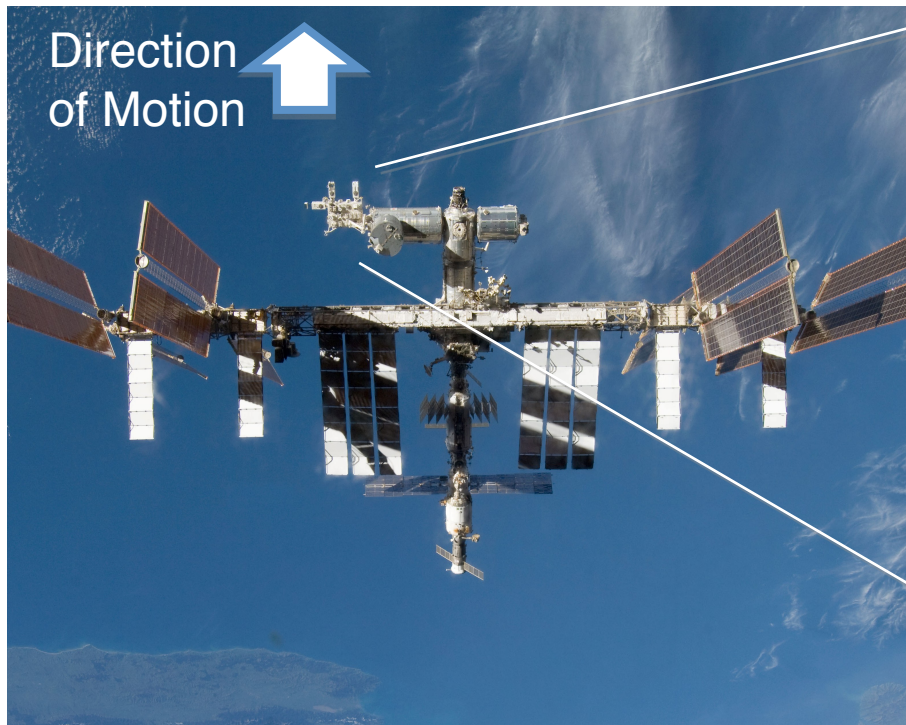
Chuo Univ.: Y. Tsuboi



Outline

- MAXI (Monitor of All-sky X-ray Image) Overview
- GSC (Gas Slit Camera)
 - Operation
 - Calibration
 - Alignment and position accuracy
 - Effective area
 - Energy response
 - Timing
- SSC (Solid-state Slit Camera)
 - Operation
 - Calibration
- Data Archive and Analysis Software
- Summary

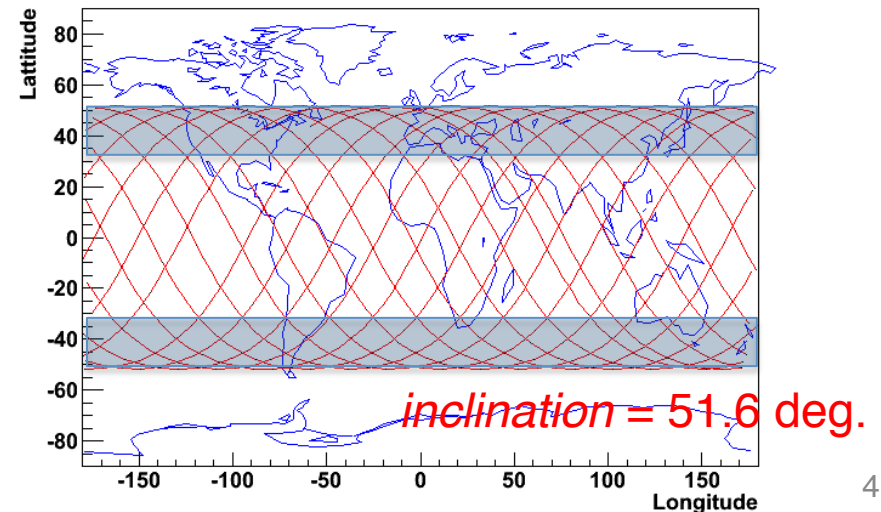
MAXI (Monitor of All-sky X-ray Image) on ISS



MAXI

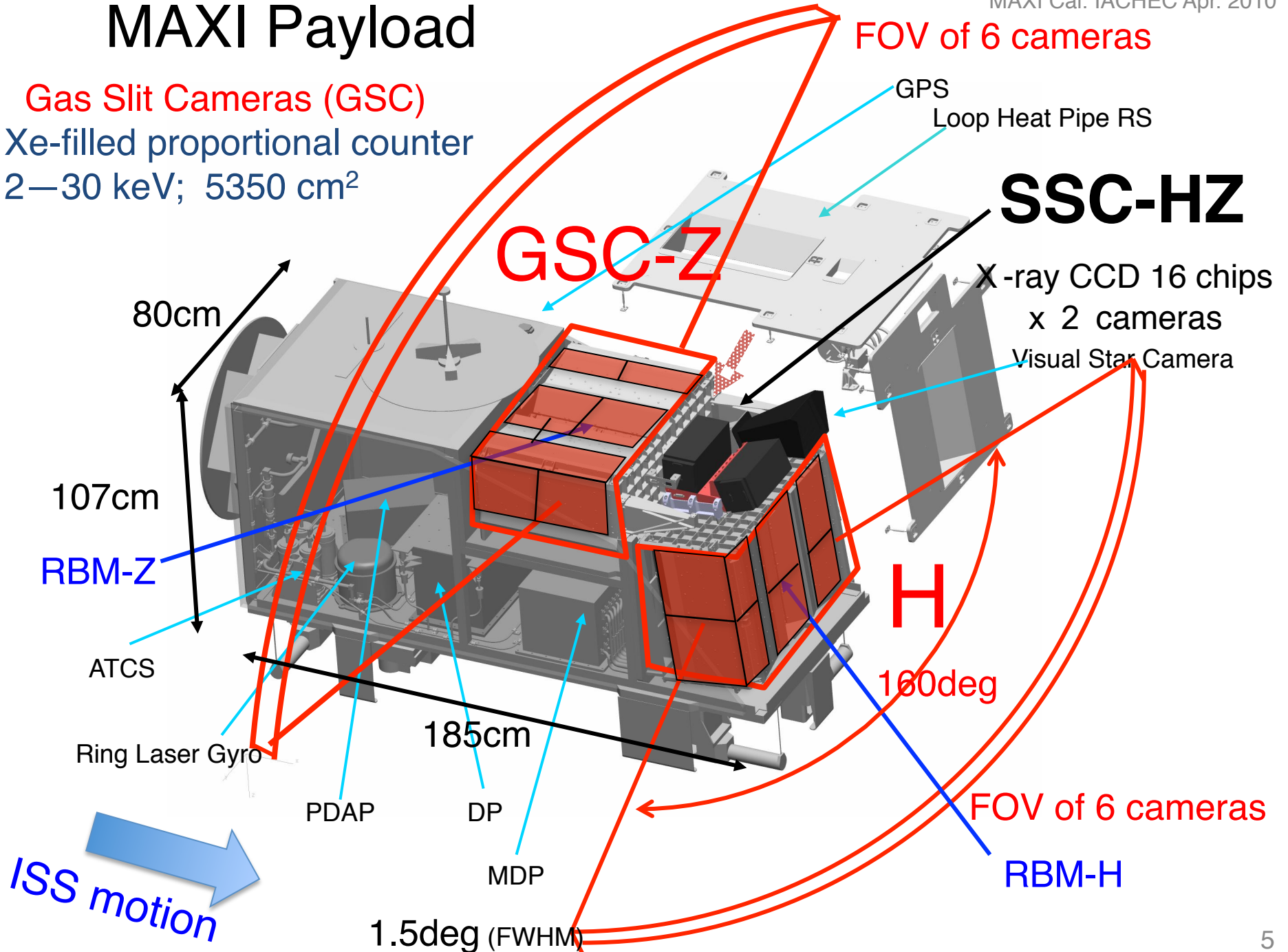
JEM EF

- The first astronomical mission on ISS
- Transported by Space Shuttle (Endeavour) on **July 16, 2009**
- Installed on JEM (Japanese Experiment Module, KIBO) EF (Exposed Facility) on **July 23**.
- First Light on **August 15**.



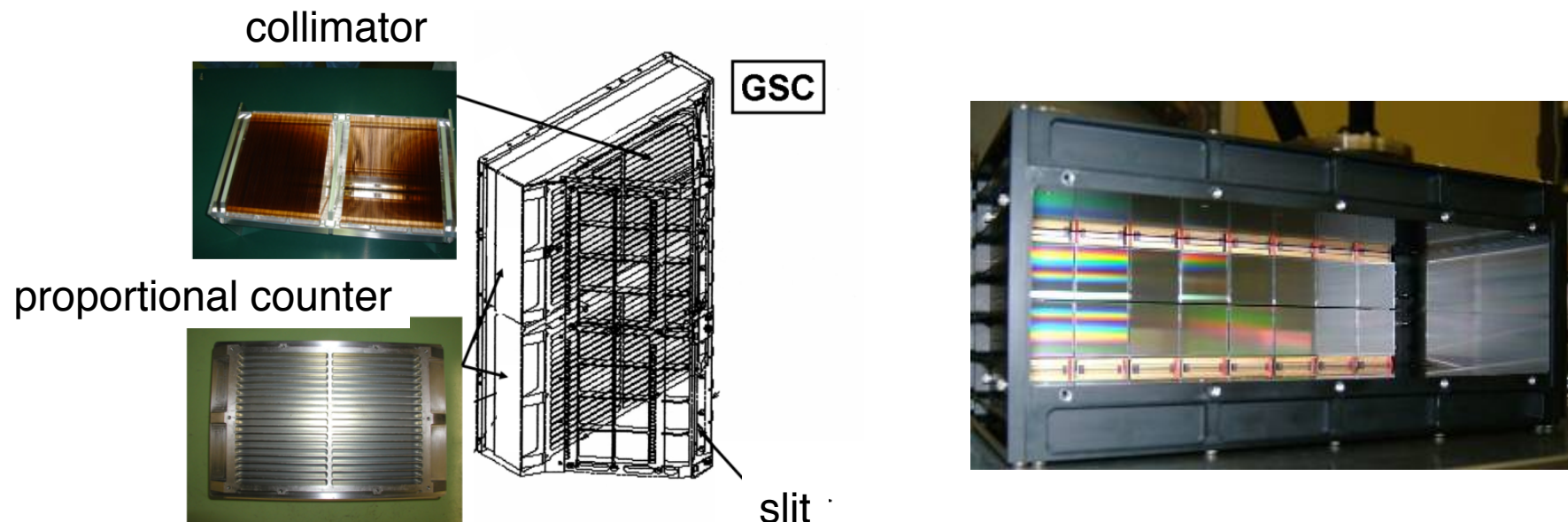
MAXI Payload

Gas Slit Cameras (GSC)
Xe-filled proportional counter
2—30 keV; 5350 cm²



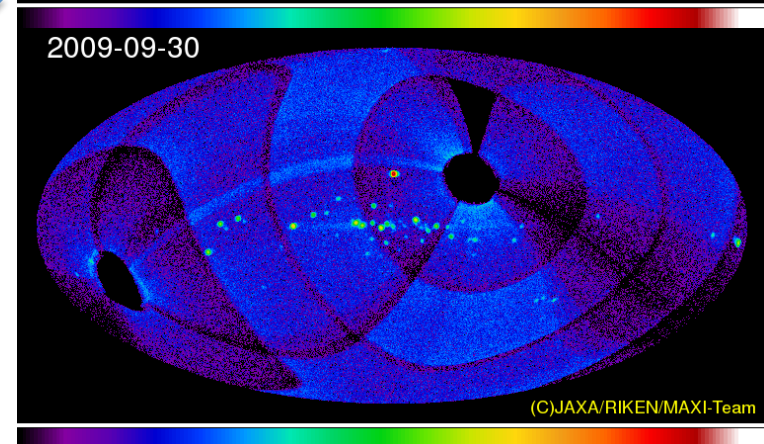
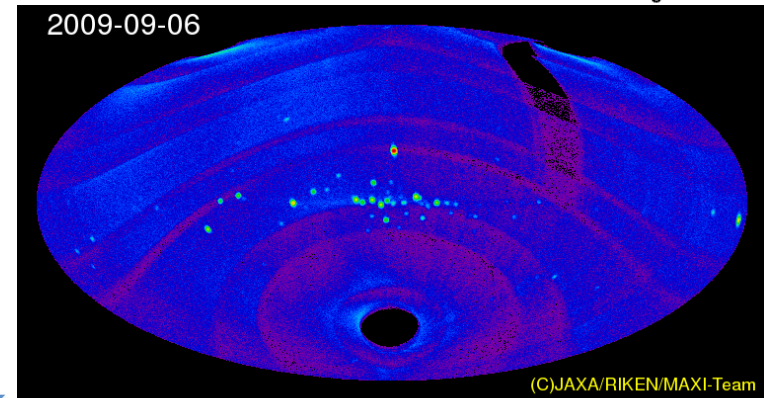
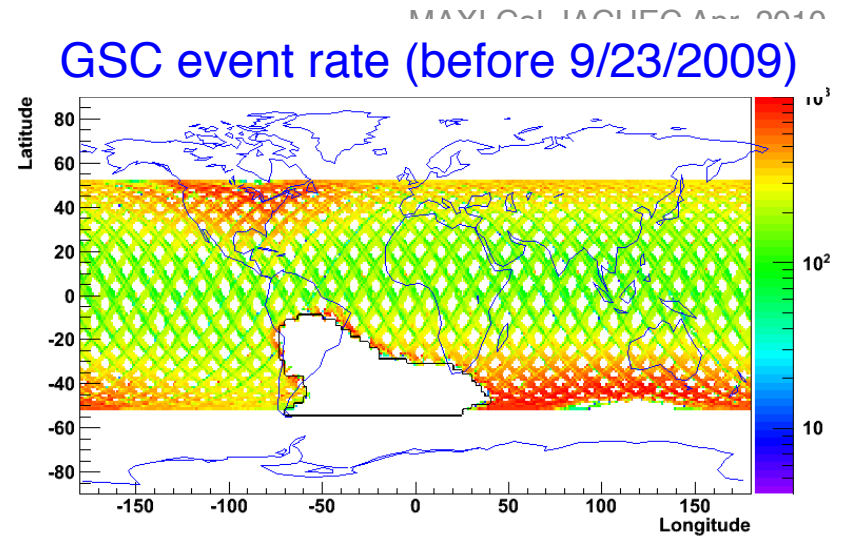
Detectors

	GSC (X-ray Gas Camera)	SSC (X-ray CCD Camera)
Detector	Gas(Xe) prop. counter x12	CCD 16 chips x 2 camera
Energy range (Q.E.>10%)	2–30 keV	0.5–12 keV
Energy resolution (FWHM)	15.7%(at 8.0keV)	< 2.5%(150eV) (at 5.9keV)
Time resolution & accuracy	<200 μ sec	~6 sec
Instantaneous sky coverage	2.4 % of the whole sky (160 deg x 3 deg x 2 sets)	1.4% of whole sky (90 deg x 3 deg x 2 sets)
Point Spread Function	1.5 degree	1.5 degree
sensitivity	2 mCrab (week)	5 mCrab (week)

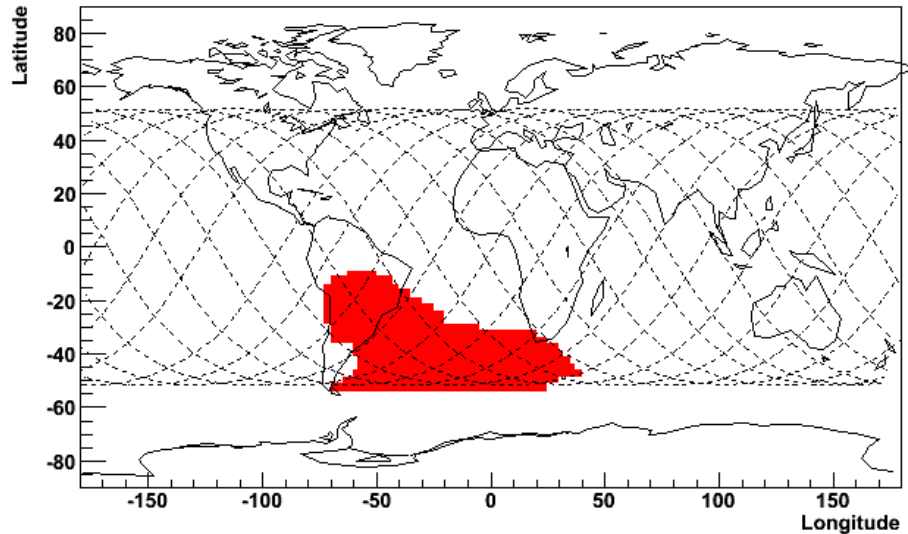


GSC operation issues

- Due to heavy particle irradiations at the high latitude area, 4 out of 12 cameras were stopped since 9/23/2009.
- One another camera stopped on 3/23/2010. We are now re-tuning the HV level.
- 8(→7) cameras are operated in the low latitudes
 - Effective area $8/12=2/3$
 - Effective exposure time → 50%
 - BGD is higher than Ginga/LAC.
- Sensitivity (5 sigma) in the current process
 - 10-20 mCrab/day (2-10 keV)
- 1-day sky coverage remains 96%.

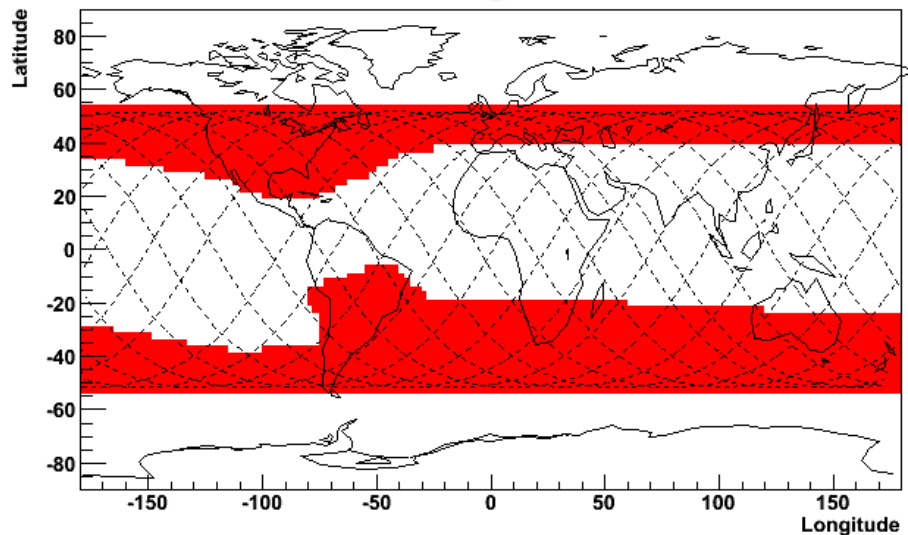


GSC operation-down area



- SAA

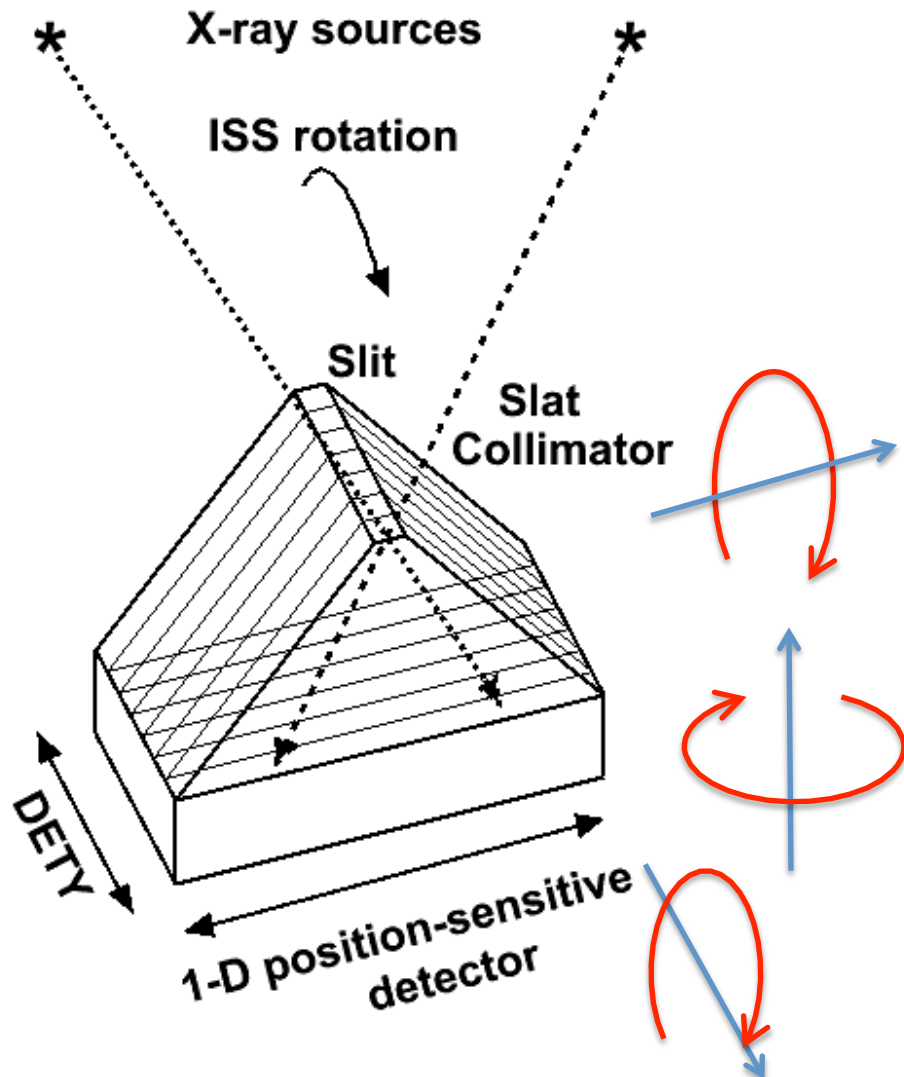
2009
8/15-9/23



- SAA
- COR < 6-7

2009
9/23-

Camera alignment and position accuracy

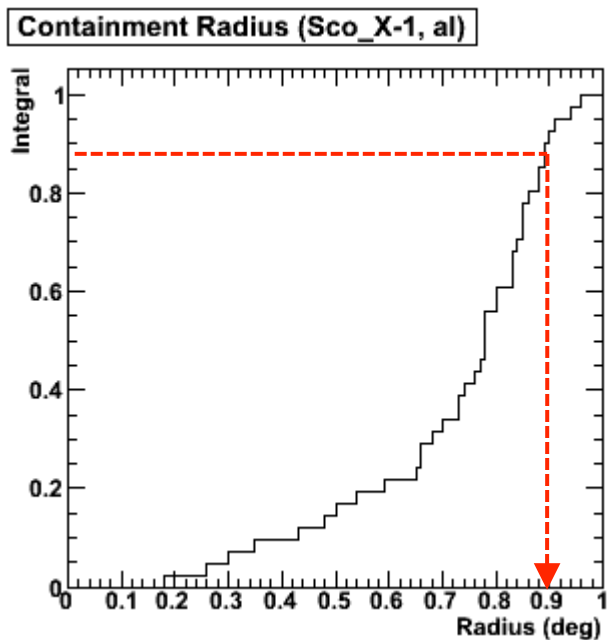


- Attitude of MAXI payload module is always monitored by ADS (Attitude Determination System) using Visual Star Camera and Ring Laser Gyro. Its accuracy should be \sim arcseconds (calibration is in progress).
- Source position of incident X-ray is determined from the attitude and alignments of collimator and detector.
- These alignments can be calibrated using a few standard X-ray sources whose positions and intensities are well-known.

Progress of calibration

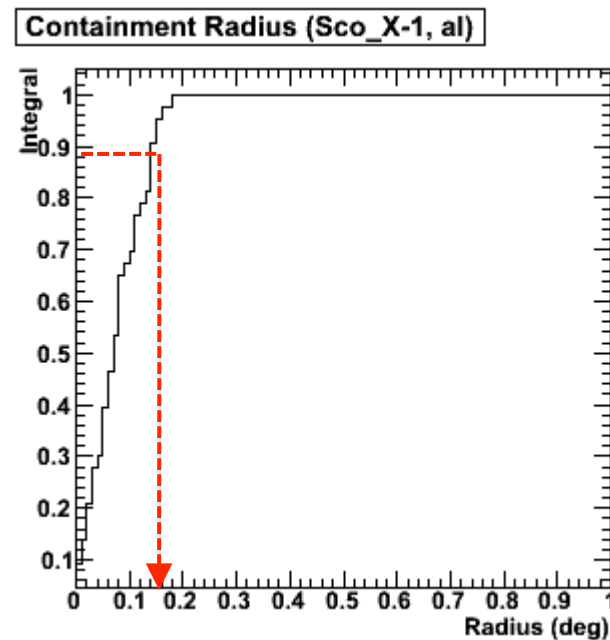
- Sco X-1 90% containment radius (Sugimori et al.)

August 2009



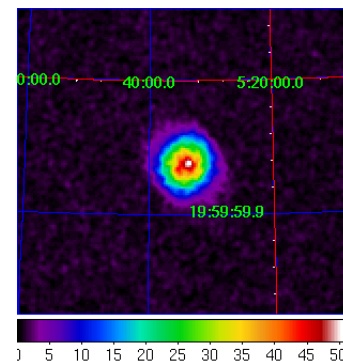
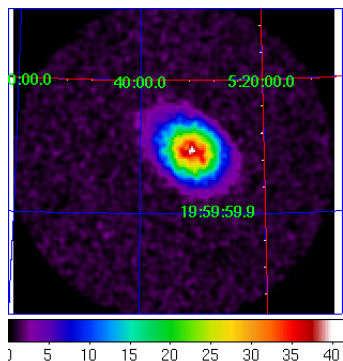
0.9 deg

January 2010



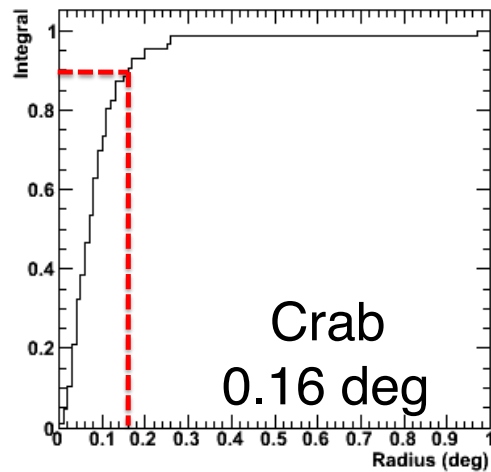
0.14 deg

PSF

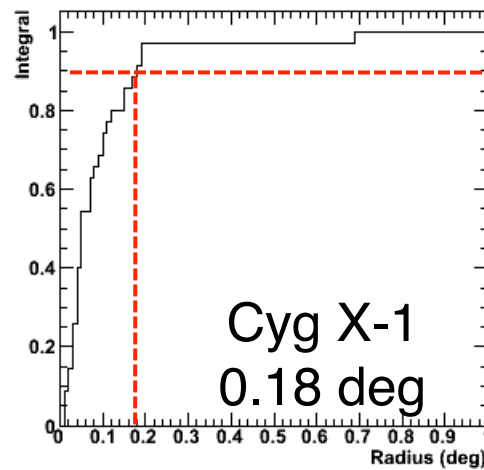


90% containment (other sources)

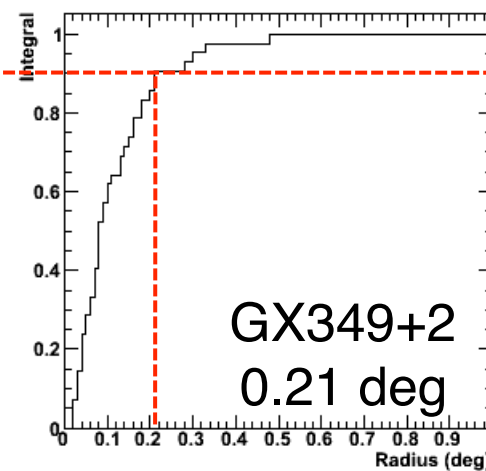
Containment Radius (Crab, al)



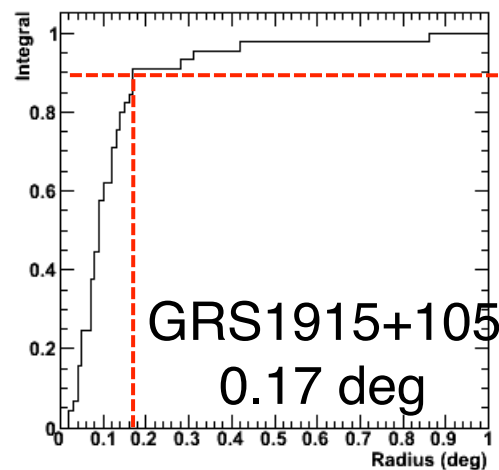
Containment Radius (Cyg_X-1, al)



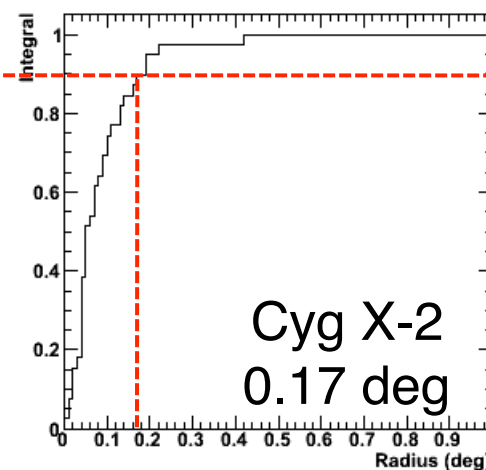
Containment Radius (GX_349+2, al)



Containment Radius (GRS_1915+105, al)



Containment Radius (Cyg_X-2, al)

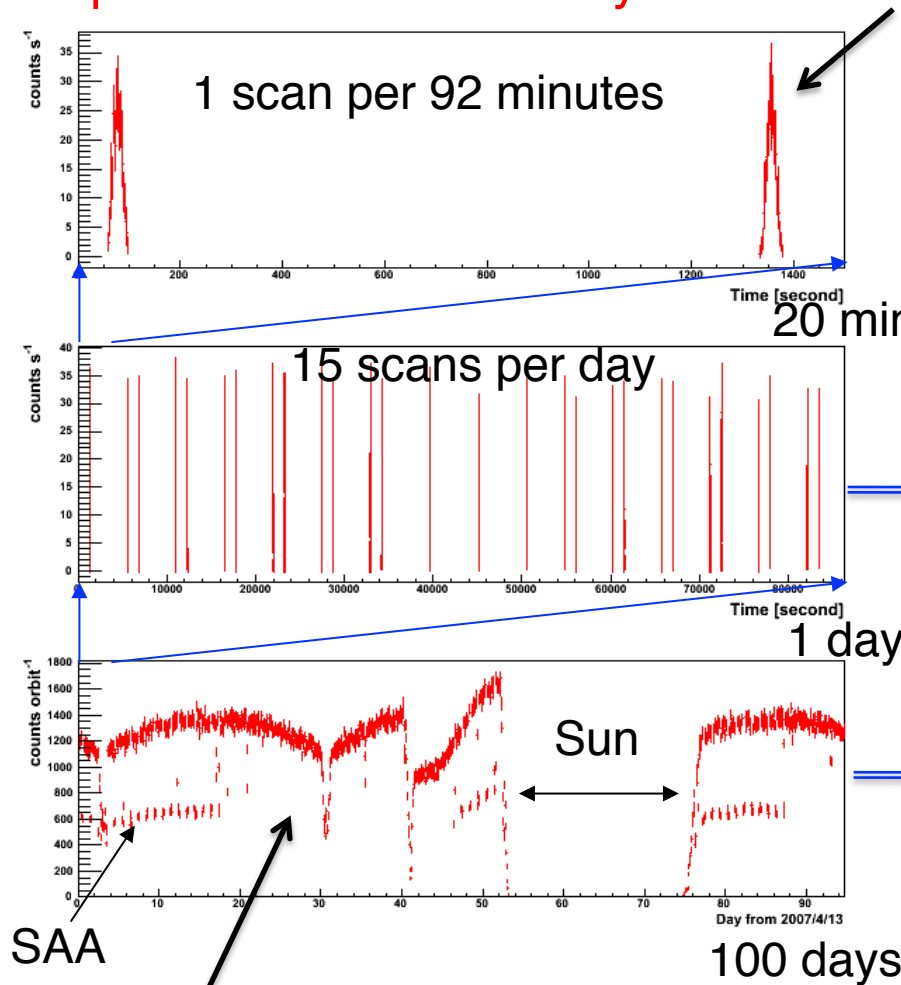


Current position error (systematic) ~ 0.15 deg.

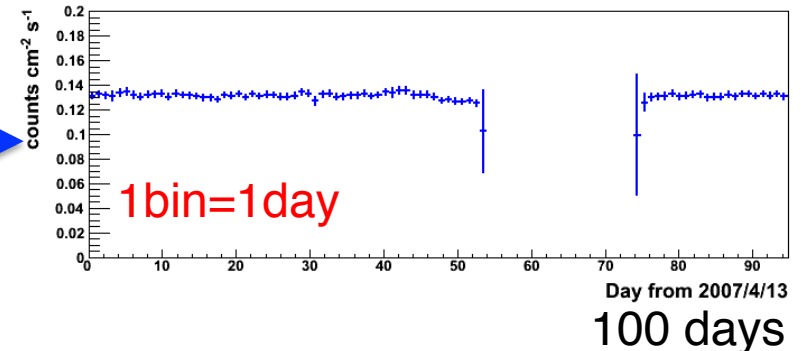
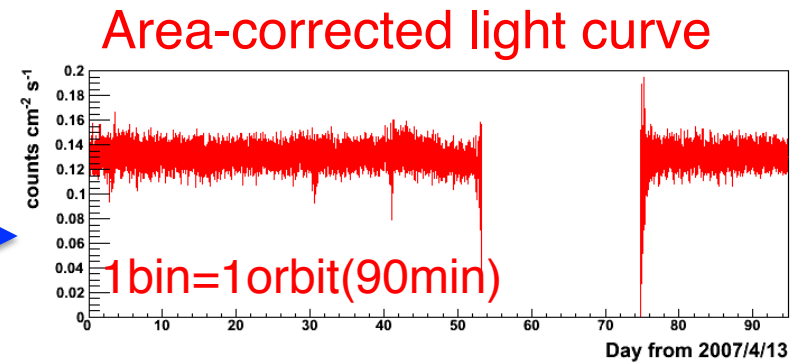
Effective area and light curve (*simulation data*)

Expected event rate for stable point source on the sky

Triangular transmission function of slat collimator



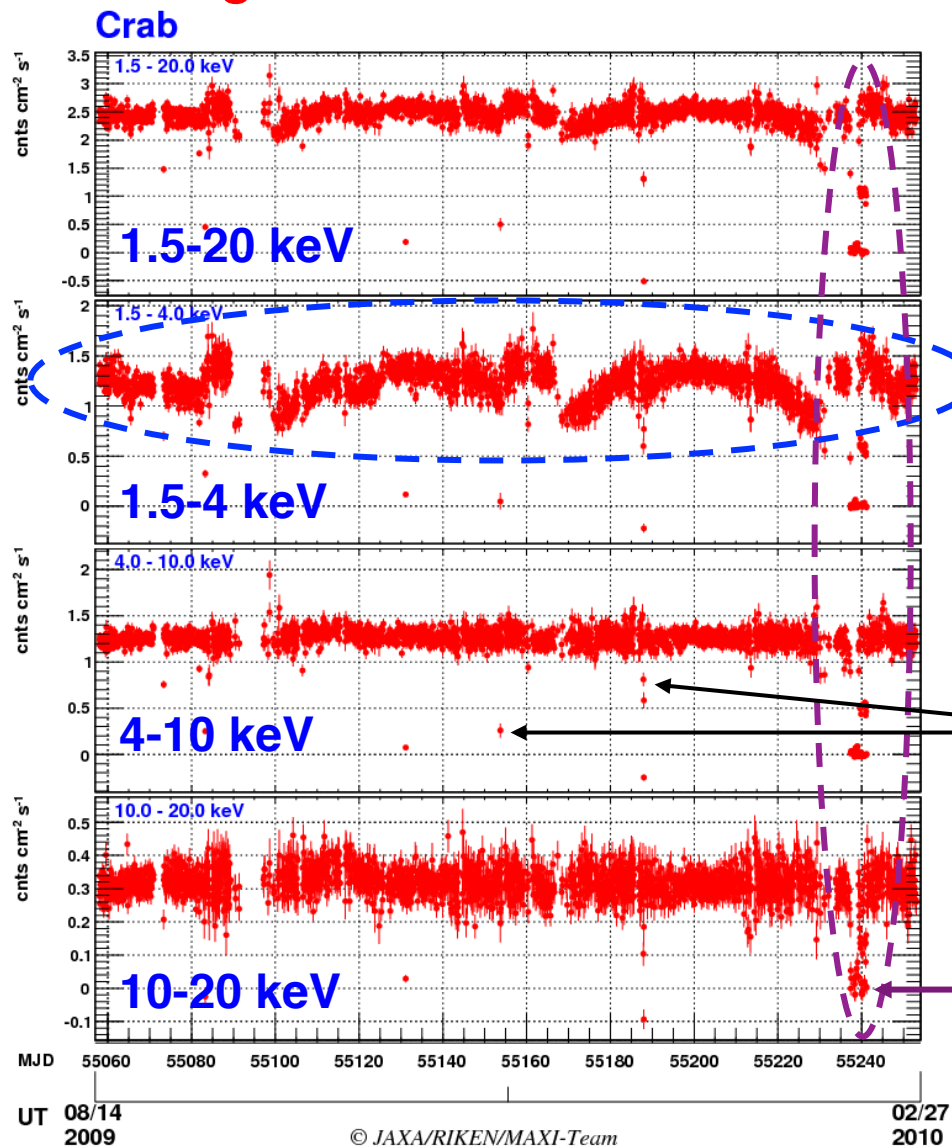
Effective-area correction



Ideal case !

Effective area correction of **real data**

- **Light curve of Crab Nebula** (on the MAXI public web page)



- 1.5-20 / 1.5-4 / 4-10 / 10-20 keV energy bands

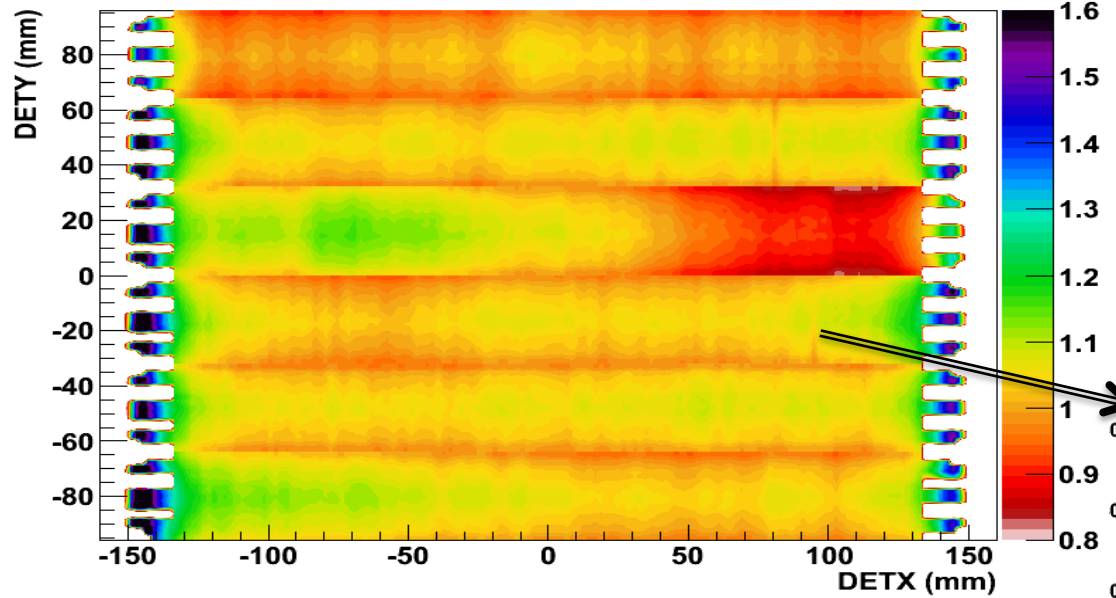
- Soft X-ray band has a large systematic errors for insufficient calibration (non-linear response at the lower energy band, absorption at the beryllium window, hardware/software LD variation)

- Down time for occultation by solar-battery paddle are implemented. However, the precision is not good enough.

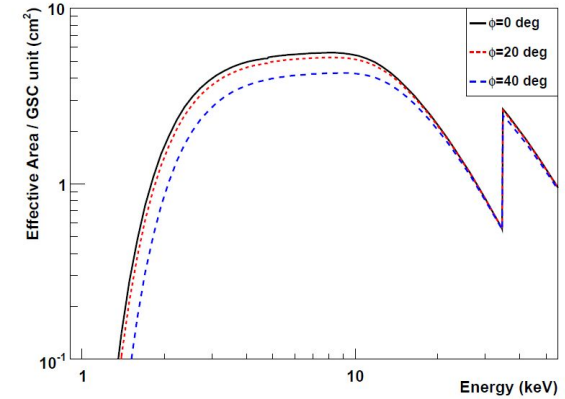
- Occultation by space-shuttle vehicle has not been accounted.

Energy response: ground cal.

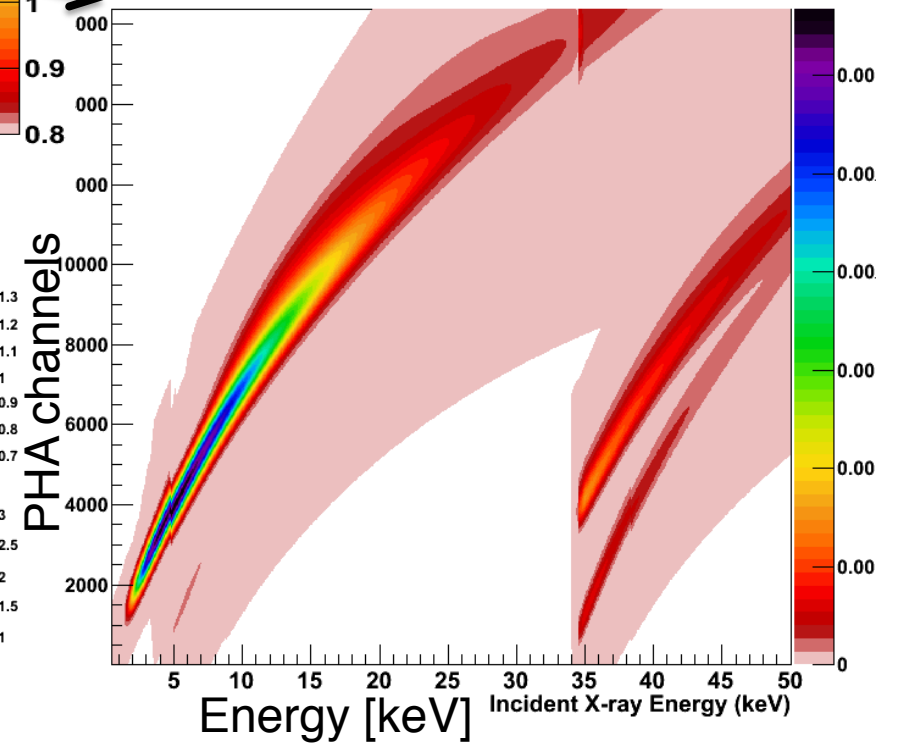
Gain: XY map per gas counter



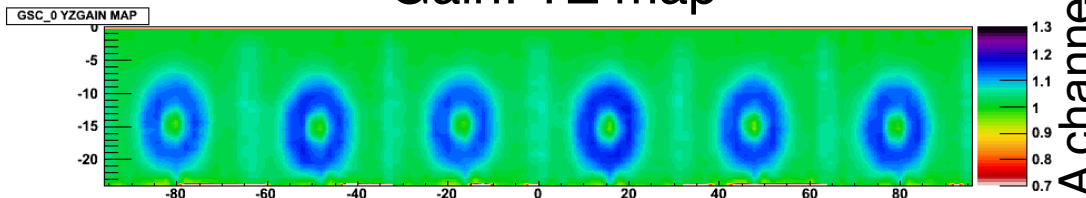
Effective area



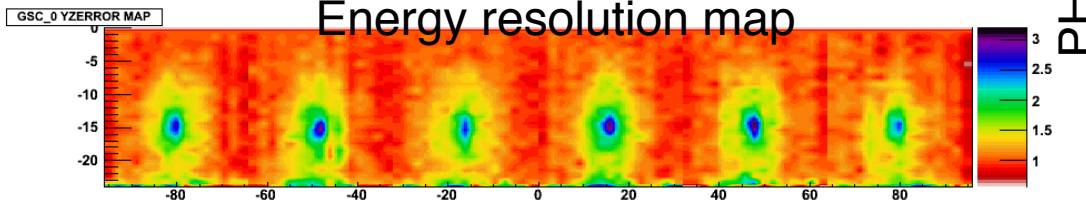
Local Energy-PHA response



Gain: YZ map

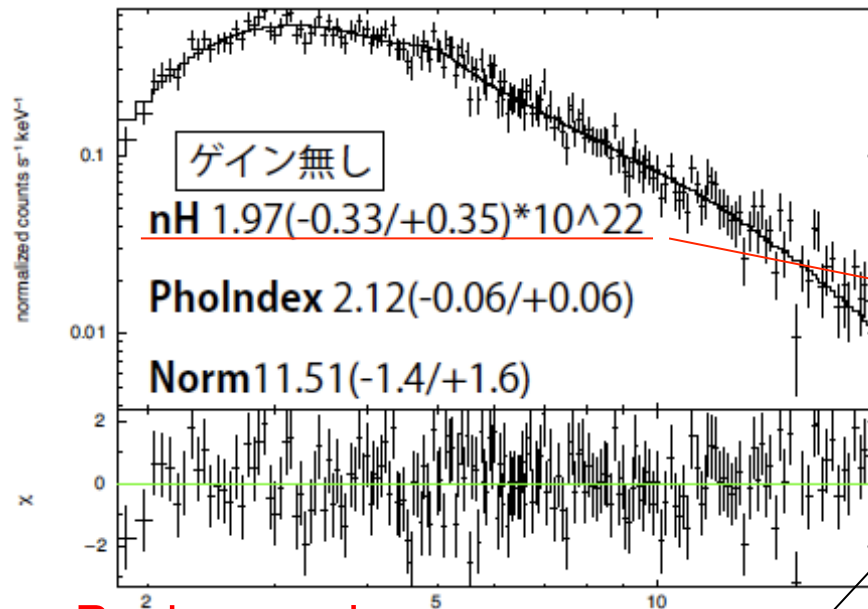


Energy resolution map

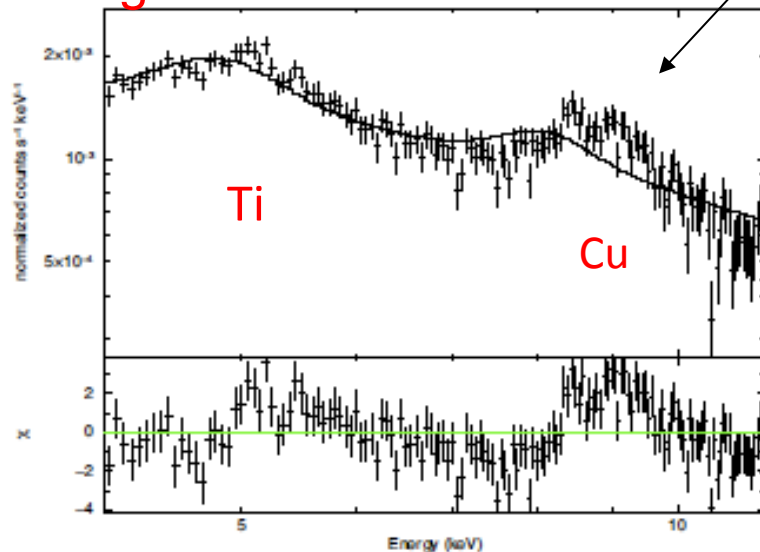


In-orbit calibration (*In progress*)

Crab



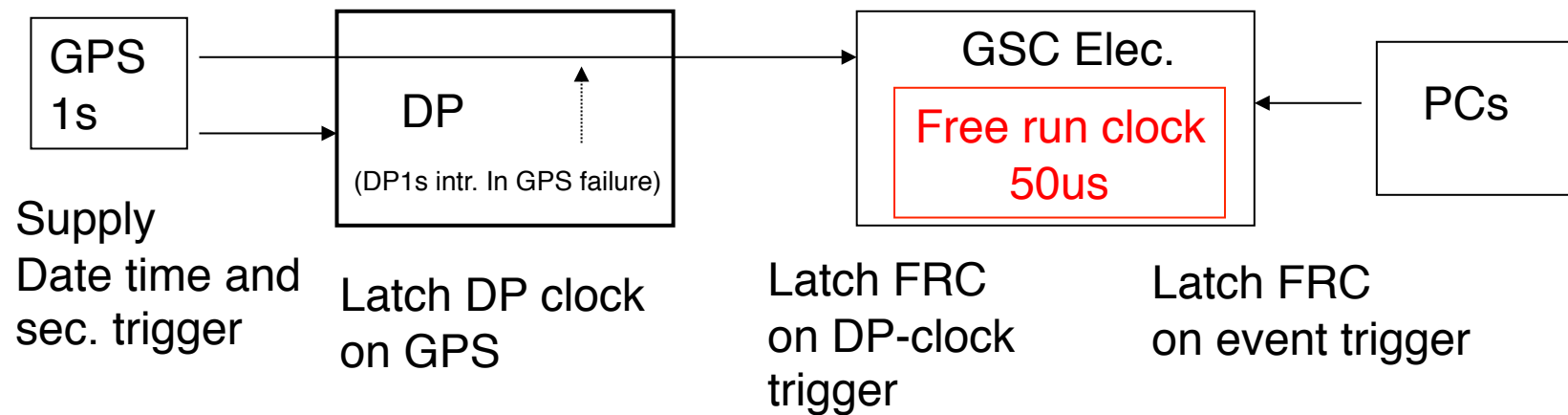
Background



- Energy response function (ver.0) built from the ground calibration-test data exhibits large nH for the Crab spectrum. ($2.0 \times 10^{22} \text{ cm}^{-2}$)
- This should be $0.3 \times 10^{22} \text{ cm}^{-2}$
- Ti, Cu lines in the background shows higher PHAs than those expected from the response function.
- The gas gains should increase from the ground test. $\sim 2-10\%$
- Expected reason:
 - The detector gas cells might slightly expand in the vacuum
 - The ground calibration test would suffer from the space charge effects. The test was done with high-rate pencil X-ray beam.

Timing of GSC

- Timing method



- Timing will be calibrated by Crab pulsar, ms pulsar, binary X-ray pulsars.

Time Cal. *(In progress)*

(Yamamoto et al.)

Calibration with Crab pulsar

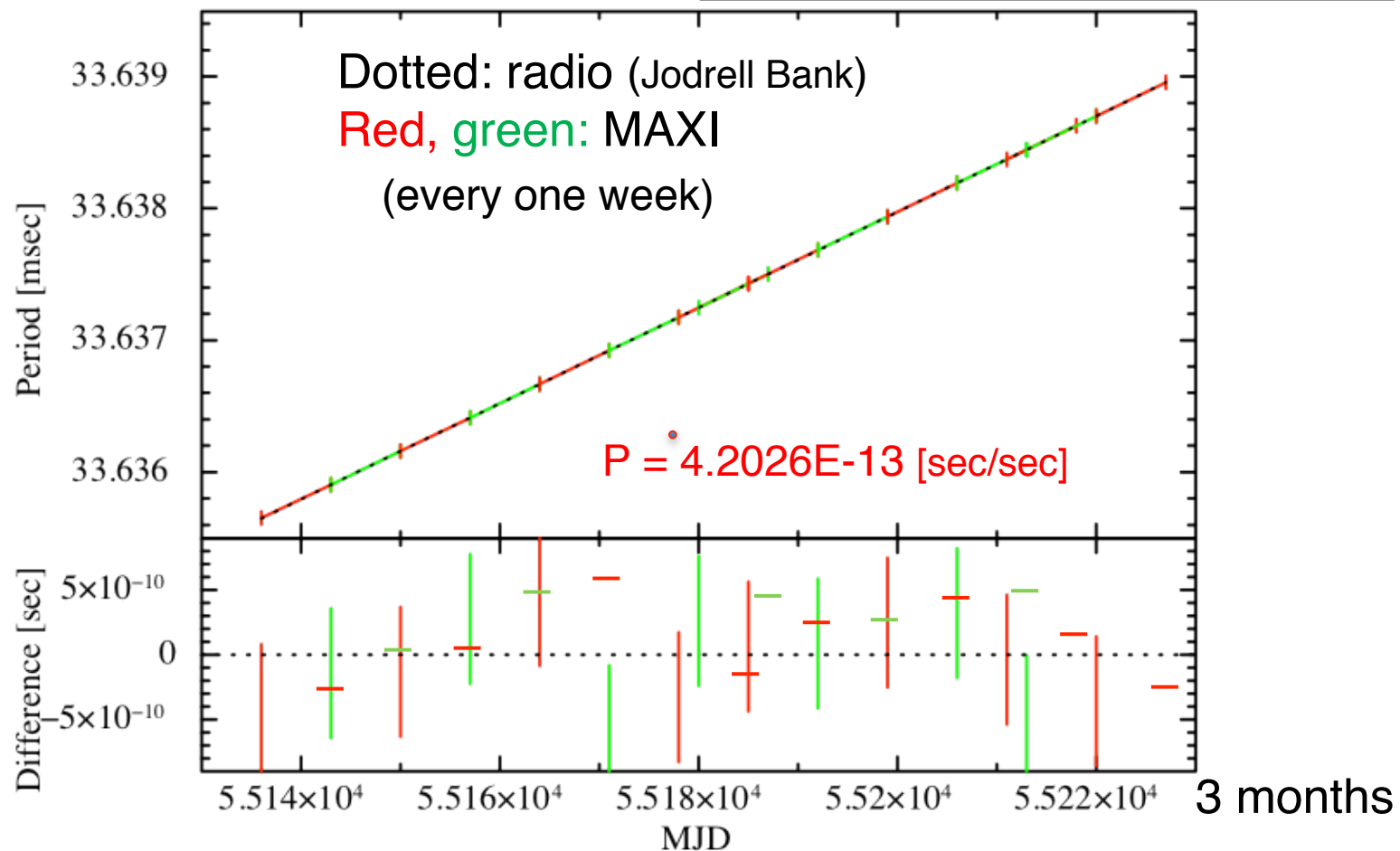
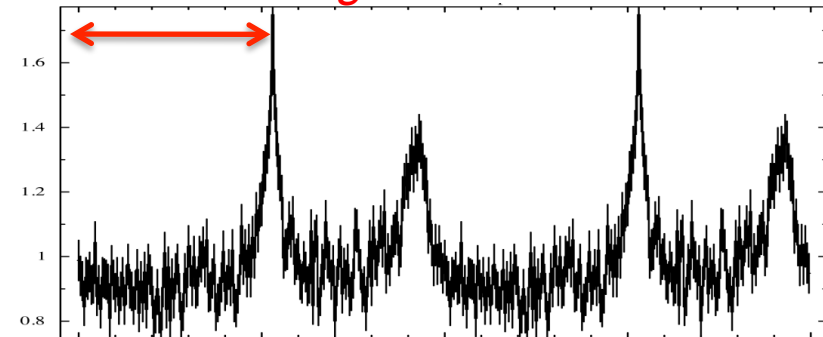
$P=33.6378715\text{ms}$

X-ray and radio period agree.

MAXI monitors continuously.

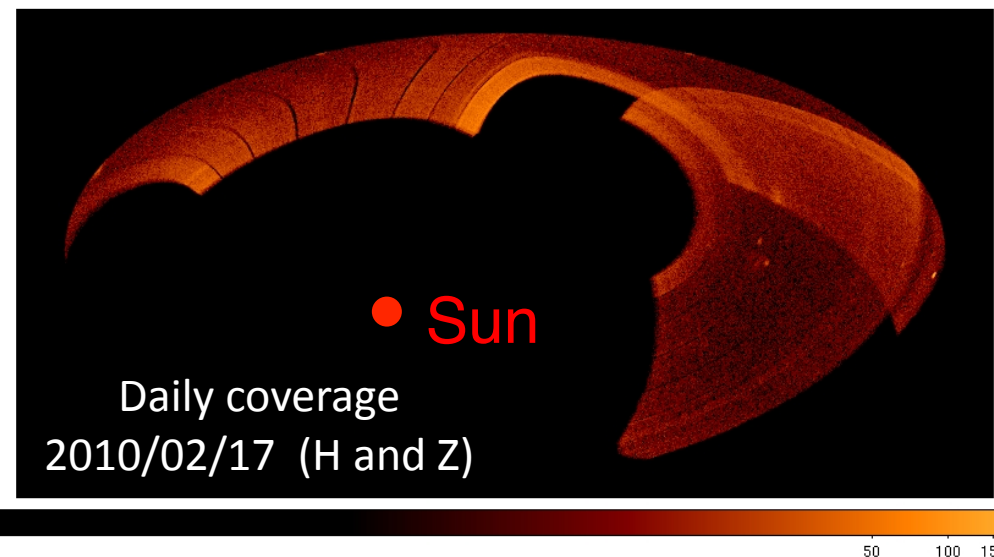
Folded light curve

Absolute timing has not been calibrated



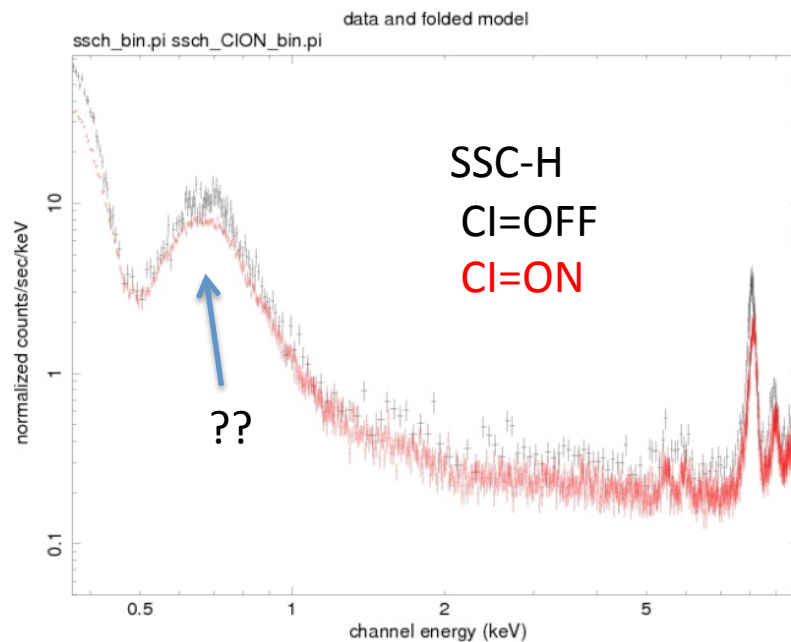
SSC Operation status

- 32 CCDs are operational.
 - Performance is as expected.
 - Energy resolution is about 150eV@5.9keV (FWHM)
- Data down-link problem in ISS
 - Med-speed (Ethernet:200-600 kbps) data had been lost by 50%. High throughput data is essential in the SSC spectrum analysis.
 - Astronaut (Mr. Noguchi) installed a new computer on the down-link path. The problem was now resolved.
- Light leak from the side of CCD
 - Observation time is limited to the time when the ISS is in the night.

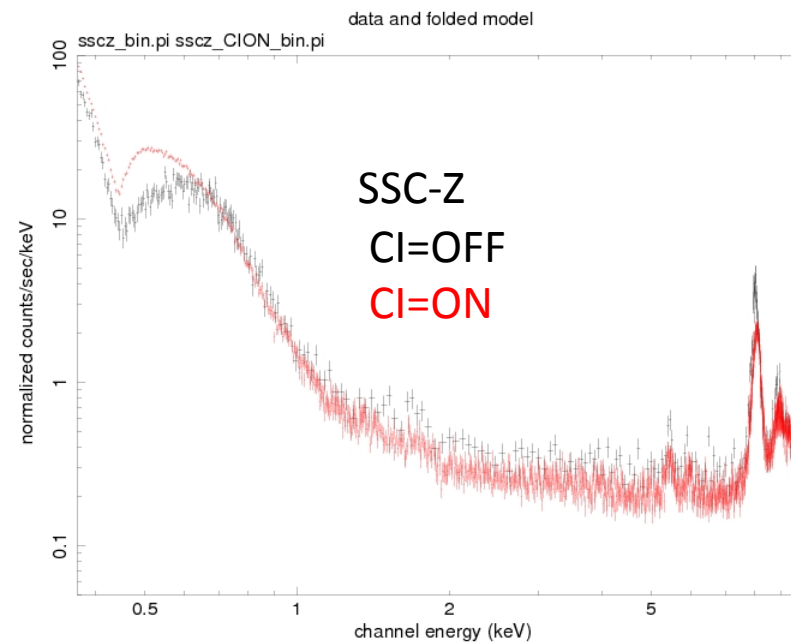


Spectrum

- Gain
 - Cu line is used for Calibration
 - Calibration source (Fe55) is onboard, but not used
- Charge Injection : Turned on since the launch
 - CI off data is taken for comparison
 - No Significant degradation so far (*Preliminary*)

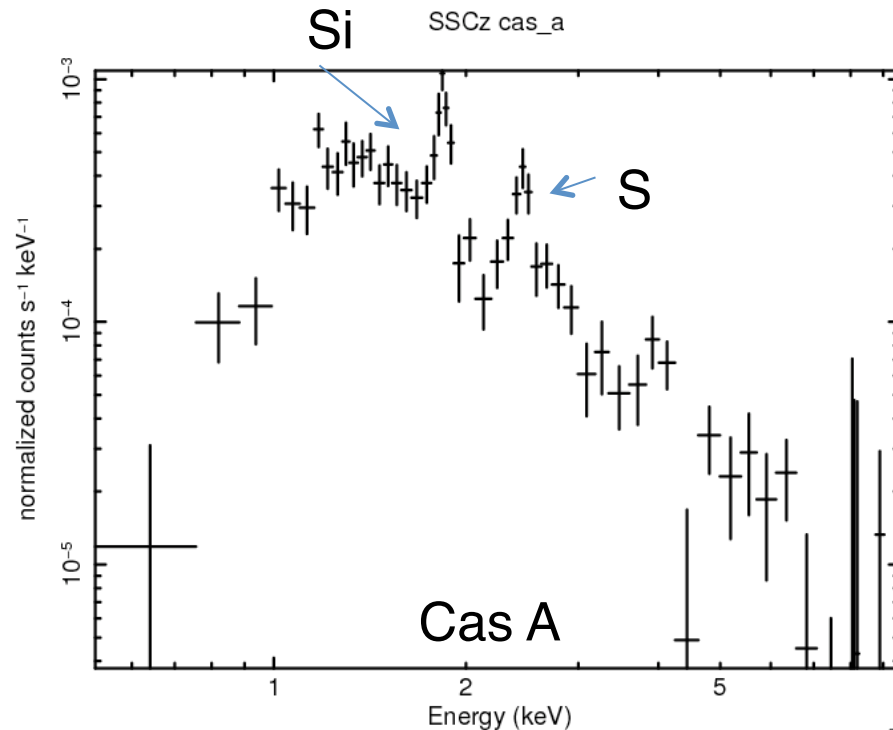
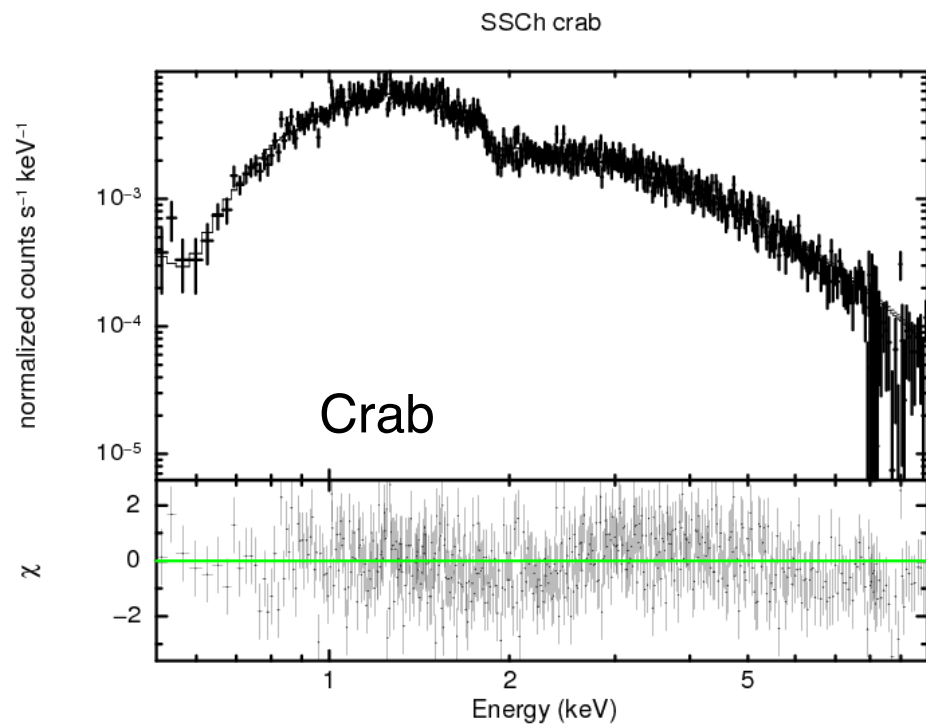


19-Feb-2010 21:41



19-Feb-2010 21:41

Spectrum response



25-Feb-2010 22:08

25-Feb-2010 14:16

wabs (nH) 10^{22} 0.458616 +/- 0.0185742
 PhoIndex 2.21846 +/- 0.0218625

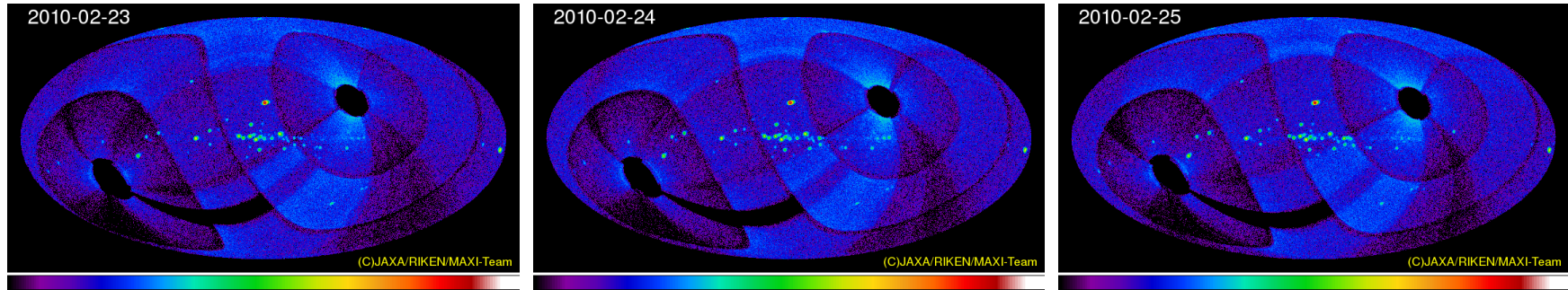
Further Calibration is Required!!

Data archive (*Plan*)

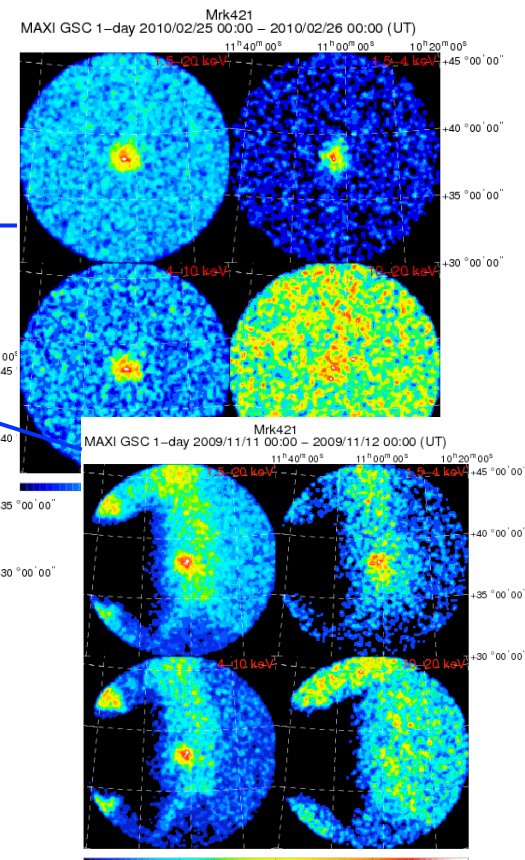
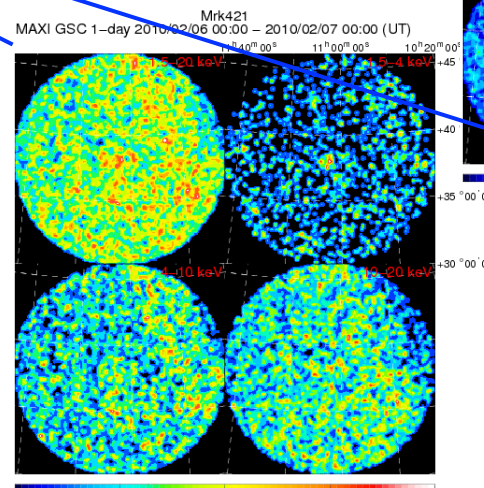
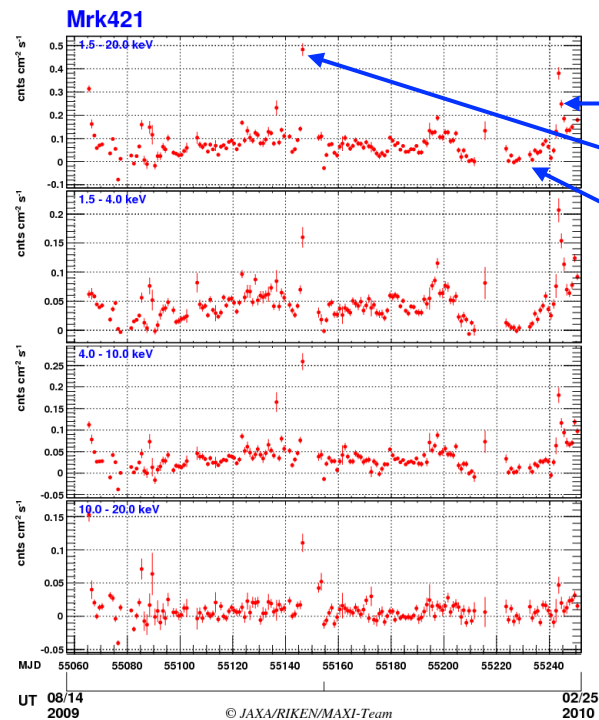
- Current early archive (from <http://maxi.riken.jp>)
 - Standard daily data products of pre-listed sources
 - Light curve
 - Image
 - Energy spectrum
 - (Spectrum is not ready at the moment. It will be released with the response file if the energy calibration reaches the acceptable level.)
 - Quick nova-alert message (will start soon)
- Future plan
 - On-demand (user-selected area, time) data
 - We are planning the release of on-demand data around the 2010 end.
 - Release formats of data, response file, software are now under discussion.

Samples of early archive products

- Daily all-sky map



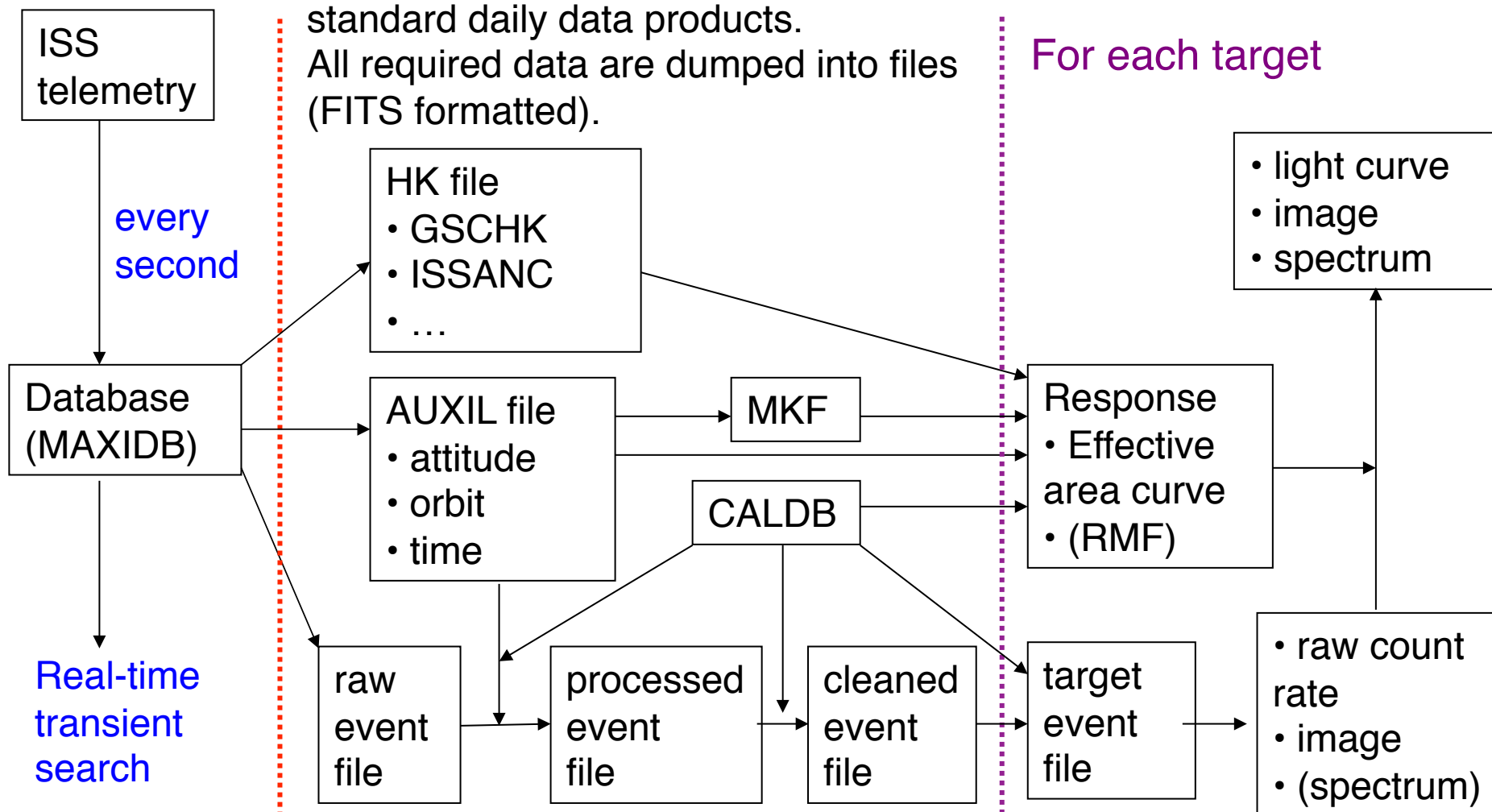
- Light curve, image, (spectrum) of pre-listed sources (130 sources on 4/10/2010)



Data Reduction and Analysis flow

These processes run once per day for standard daily data products. All required data are dumped into files (FITS formatted).

For each target



Time
Coordinate
PI (energy)

Standard HEADAS-format programs are used.

Summary

- MAXI operation on ISS started in August, 2009.
 - The observation efficiency is somehow worse than that expected before the launch for the reasons:
 - GSC: heavy background at the high geomagnetic latitude
 - SSC: light leak
- **A lot of efforts of instrument calibration required for science results are now going.**
- Standard data products of (*preliminary*) image, light curve of pre-listed sources started to open to public from the MAXI home page (<http://maxi.riken.jp>)
- On-demand data release will start around the 2010 end. Formats of data, response file, software are now under discussion.
- **Please check the MAXI latest info. on the web page.**