MAXI Calibration Status

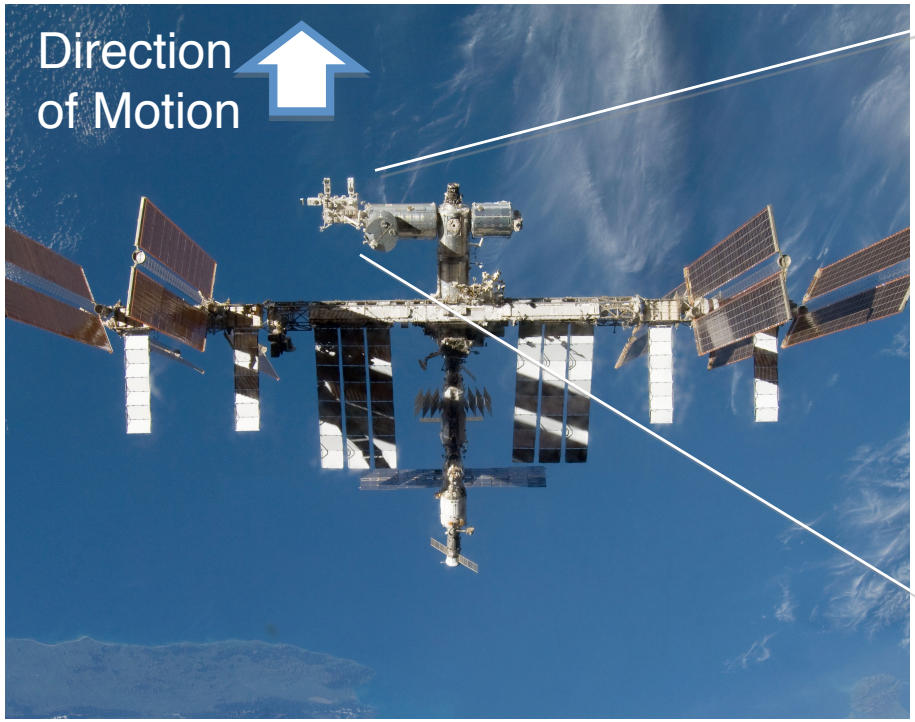
(Update from IACHEC 2010)

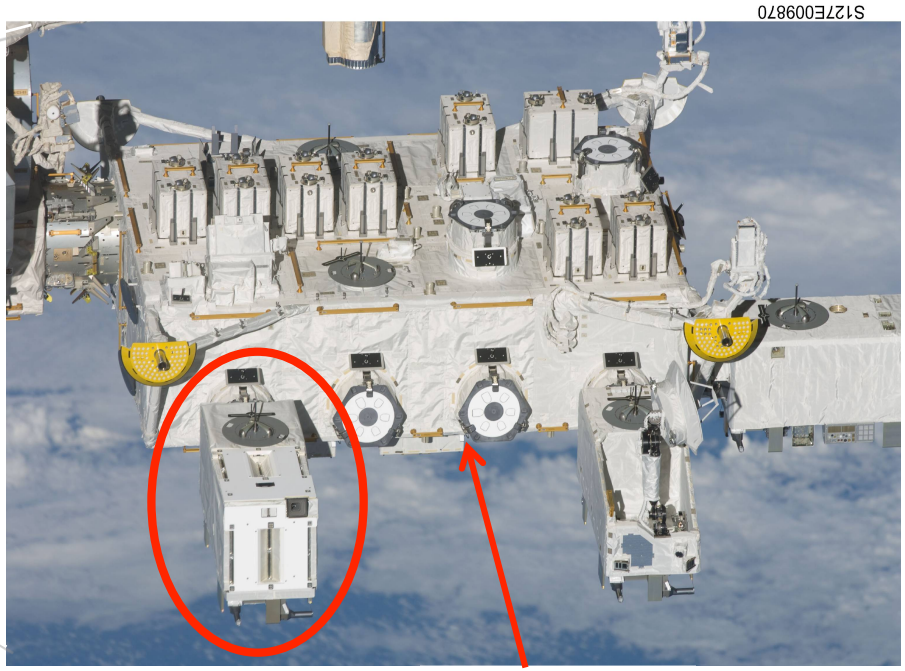
- Overview of MAXI mission on ISS
- GSC (Gas Slit Camera) issues
- SSC (Solid-state Slit Camera) issues
- Summary

Mutsumi Sugizaki (RIKEN)

on behalf of MAXI Team

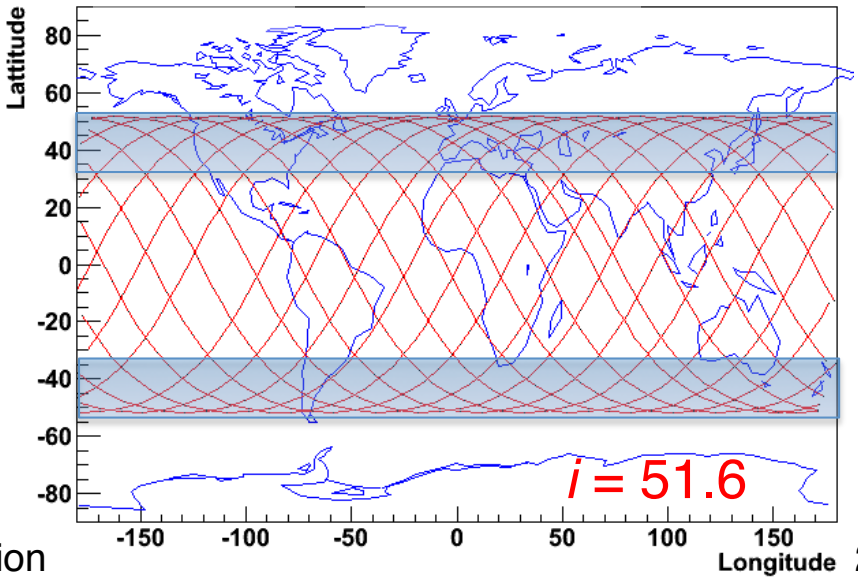
MAXI (Monitor of All-sky X-ray Image) on ISS



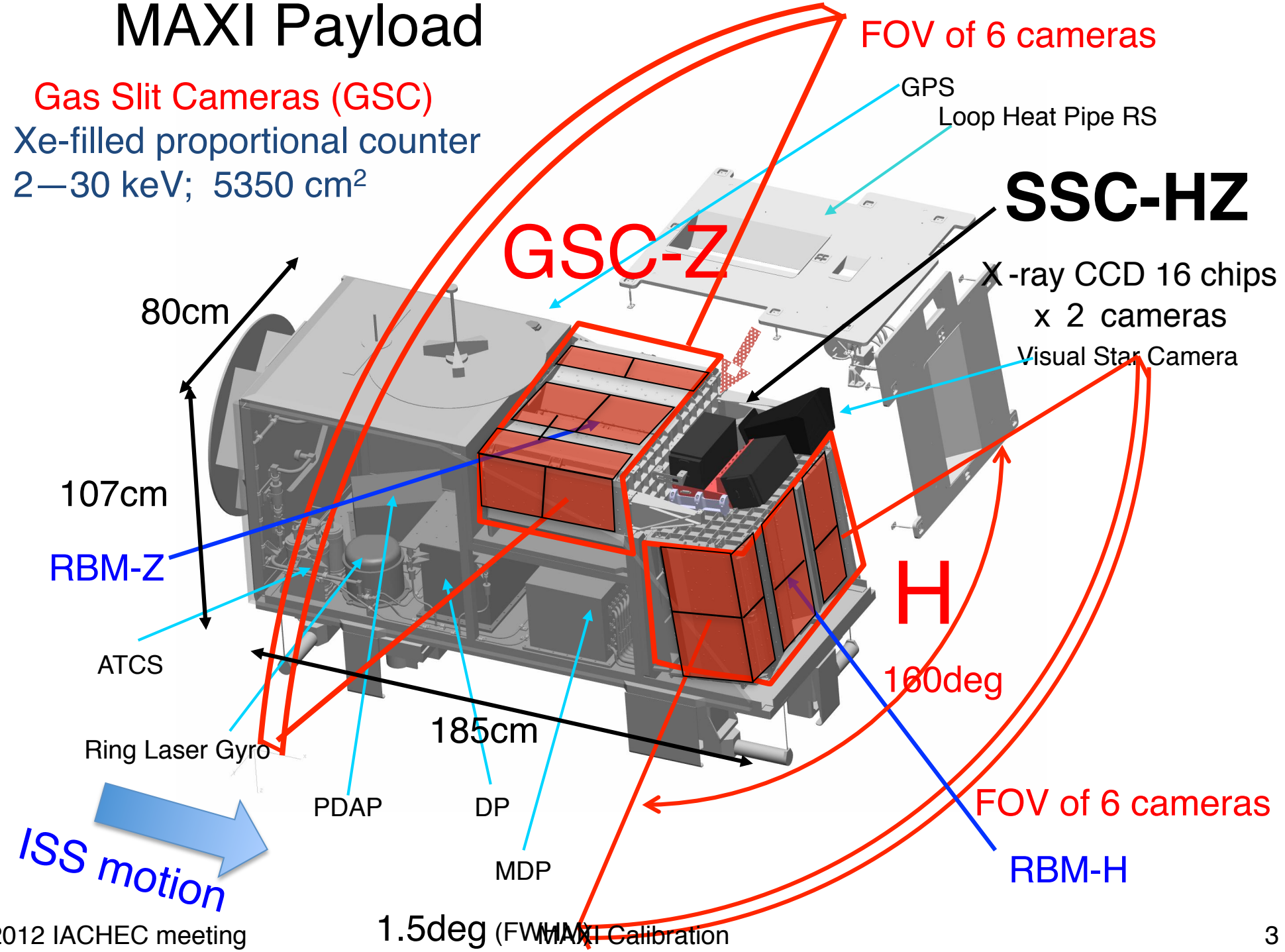


- The first astronomical mission on ISS
- Attached on ISS experimental module on July 23 2009.
- First Light on August 15 2009.

- Large inclination angle (51.6 deg)
- Heavy ISS structures

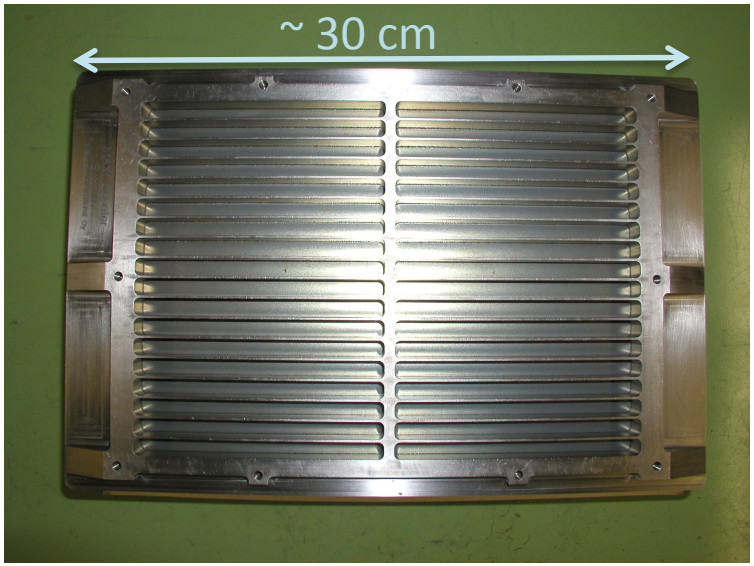


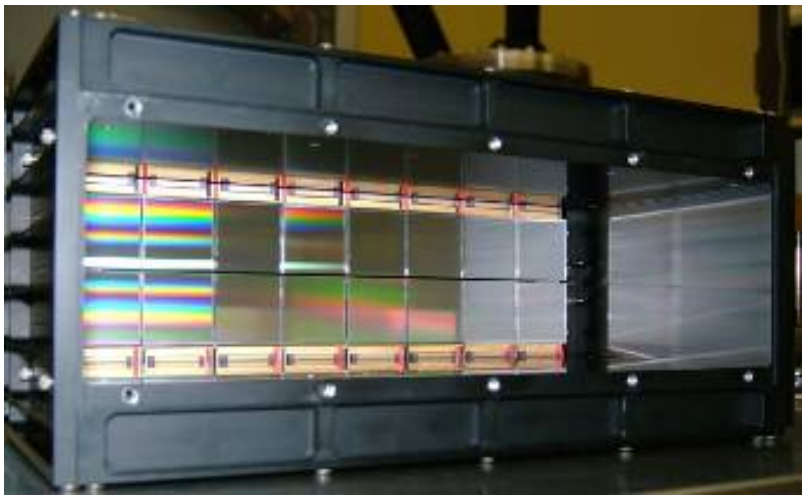
MAXI Payload



GSC & SSC

	GSC	SSC
Detector	Xe-gas counter x12	16 CCD chips x 2
Energy band	2−30 keV	0.5−12 keV
Detector Area	5350 cm^2	200 cm^2
Δ Energy (FWHM)	15.7% at 8.0keV	2.5%(150eV) at 5.9keV
Δ Time & accuracy	＜200 μs	～6 s
Instantaneous FOV	160 deg x 3 deg x 2	90 deg x 3 deg x 2
PSF (FWHM)	1.5 degree	1.5 degree



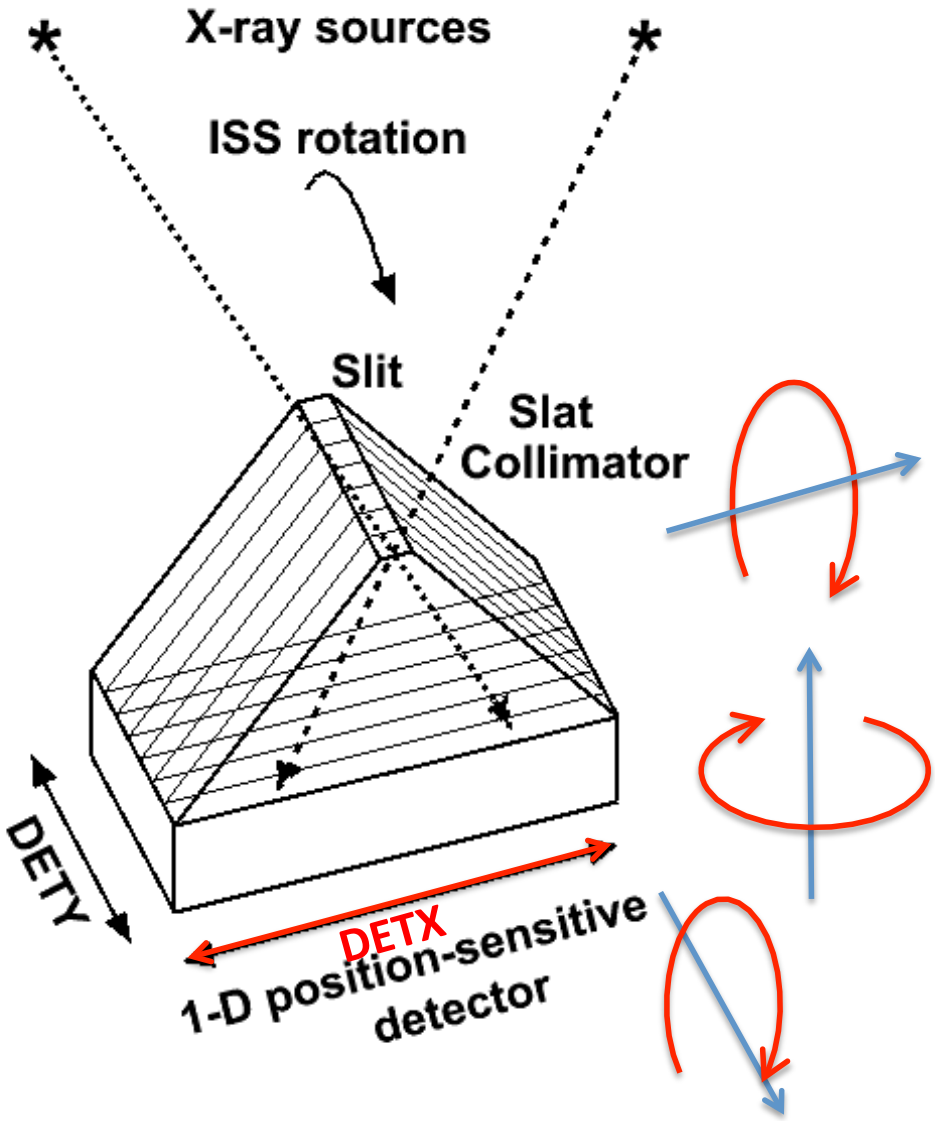


GSC Status and Issues

- HV Operation
  - 4 out of 12 gas counters were stopped after the initial test operation of one month. Fractures of carbon anode wires are suspected.
  - Operation HV was reduced from the nominal 1650 V to 1550 V to mitigate the operation damage.
  - Operation in the high earth-latitude is also stopped.
  - 3 counters operated in 1650 V, 4+0.5 counters in 1550 V.
  - Short term source sensitivity is reduced.
  - 1-day sky coverage, long-term sensitivity are almost kept.
  - Operation is getting stable after 1.5 year.

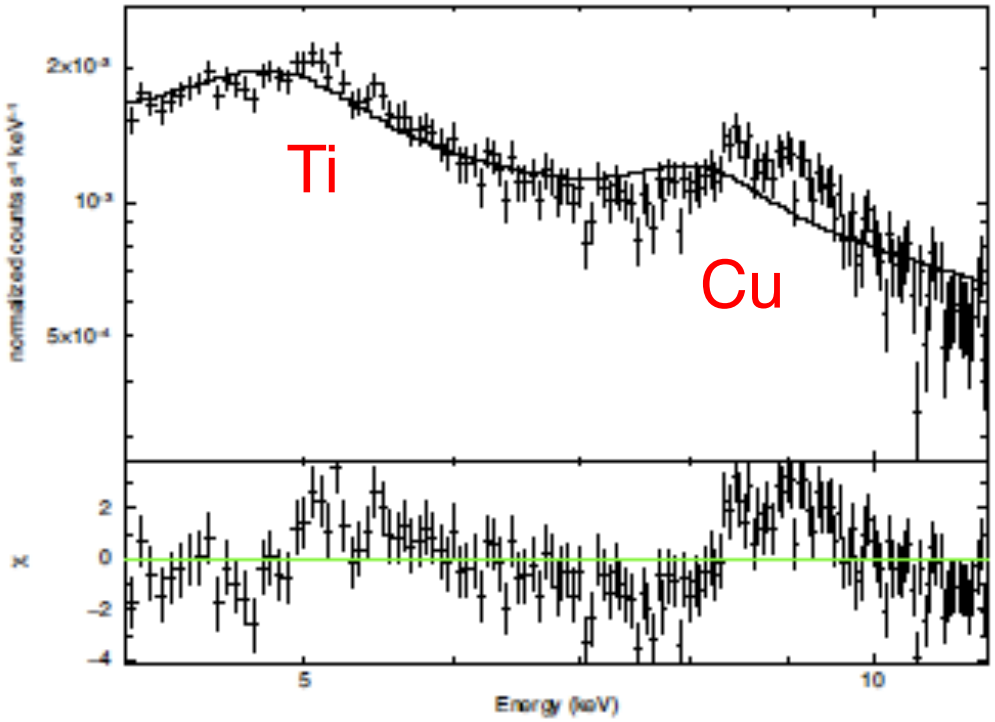
- Calibration
  - Alignment and position accuracy (1650V+1550V ready)
  - Energy-PHA(PI) relation (1650V only)
  - Effective area and RMF (1650V only)
  - Timing
  - Background Problem

Attitude and Alignment Calibration



- Attitude of MAXI payload module is always monitored by ADS (Attitude Determination System). Its accuracy is << 0.1 deg
- Direction of incident X-ray is determined from the attitude and alignments of collimator and detector.
- The alignments were calibrated using standard X-ray sources whose positions and intensities are well-known.
- GSC detector position (DETX) response depends on HV
- In-orbit cal. for 1550-V data has been done.
- Data reprocess is now going.

Gain, Offset In-orbit calibration



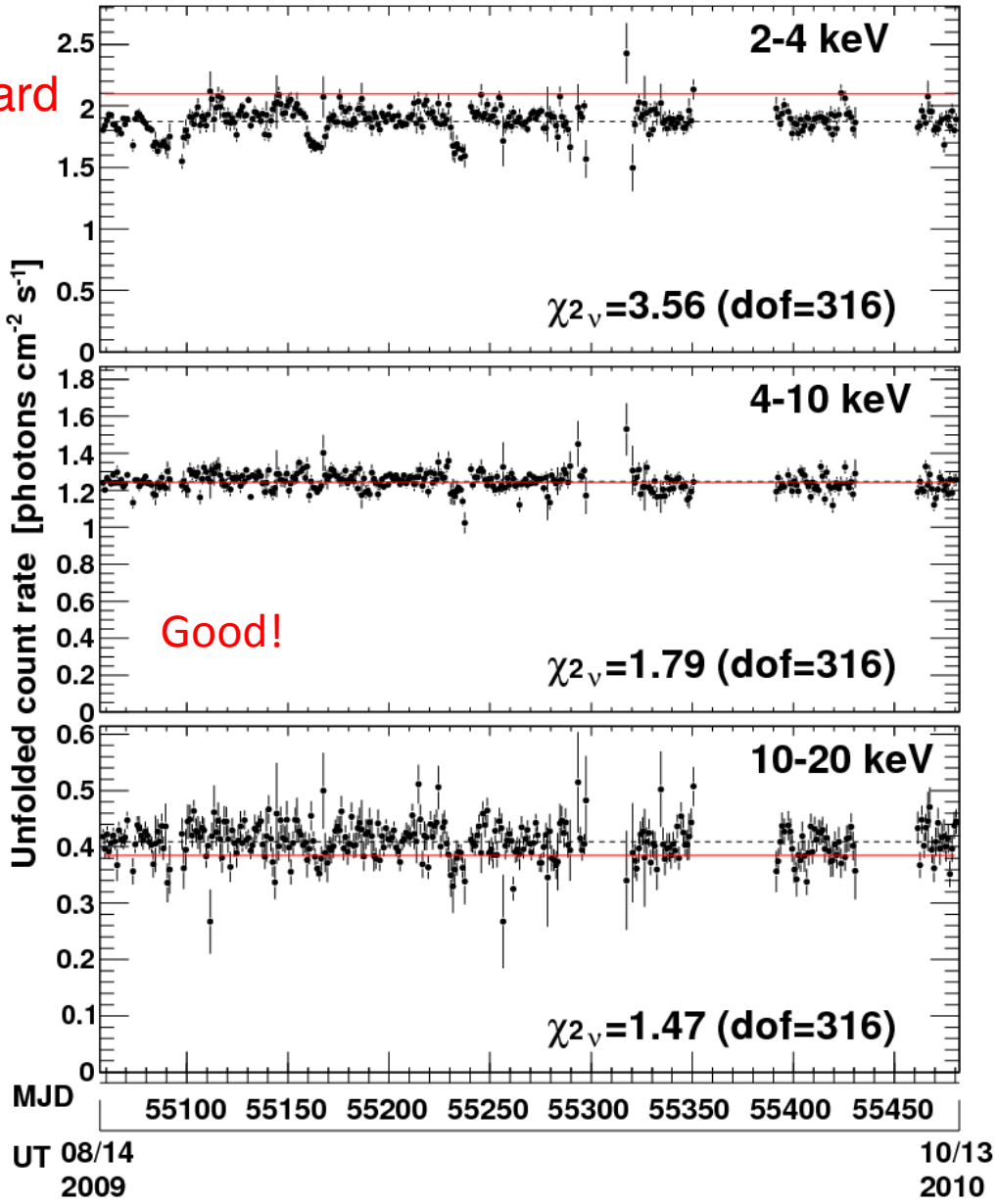
Data: BGD spectrum including Ti, Cu lines

Model: folded with a response built from ground CALDB

- Gas gains should increase from the ground test by ~ 2-10% for the detector expanded in the vacuum. (done)
- Shifts of PHA-zero offsets are suggested from the change of energy-PHA relation at the low PHA . The PSF is also improved.
- Need update all CALDB information for 1550V data. (not yet)

Effective area cal. with Crab light curve

Standard Crab model

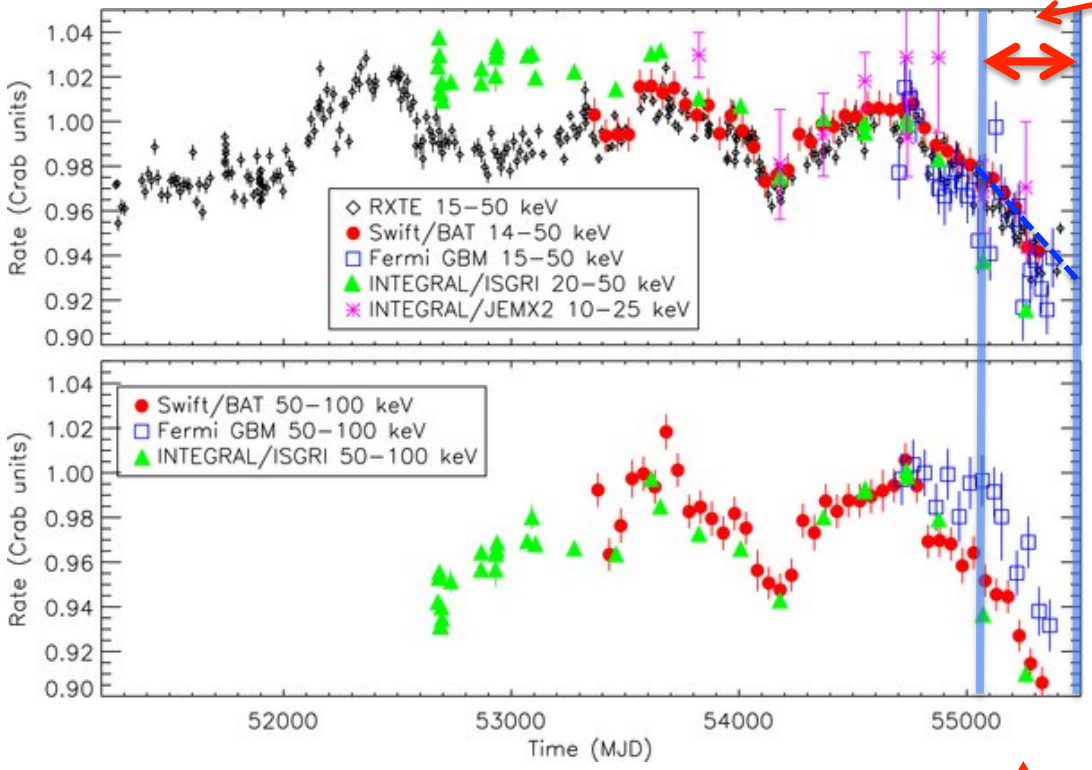


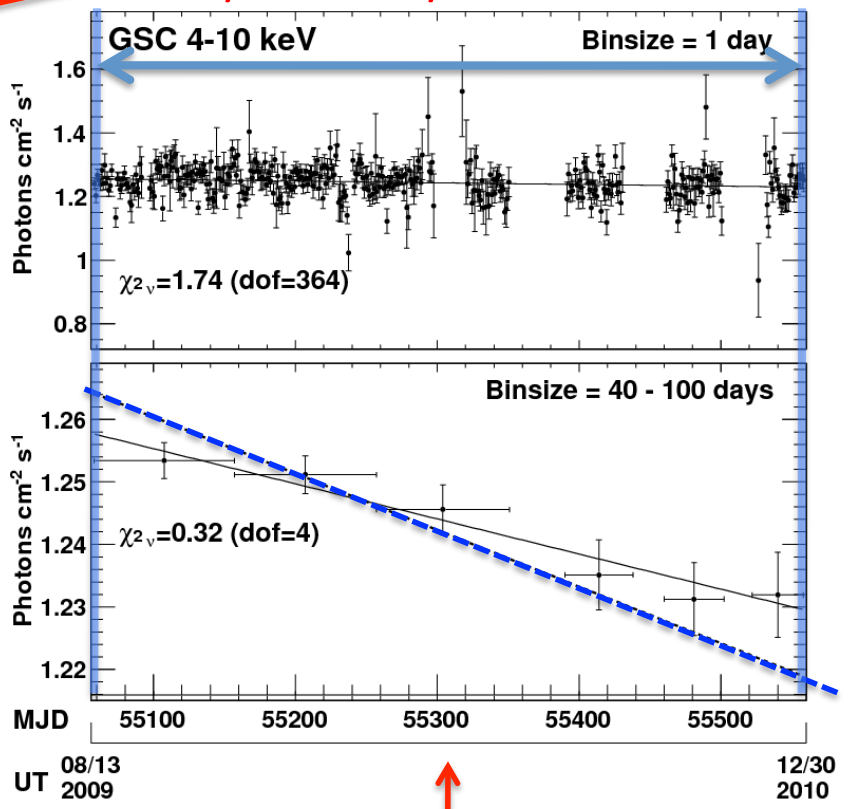
- Info of in-orbit energy-response is implemented.
  - gain variation
  - LD change
- 1650 V data only
- Data of a few anodes (2 out of 6 wires) with extraordinary responses are ignored.
- Event screening need to be improved to eliminate bad data.
- Need more extensive response calibration to use
  - all anodes
  - 1550V data
  - with better accuracy

Comparison of Crab flux change

Wilson-Hodge et al. 2011
1998/5 - 2010/8

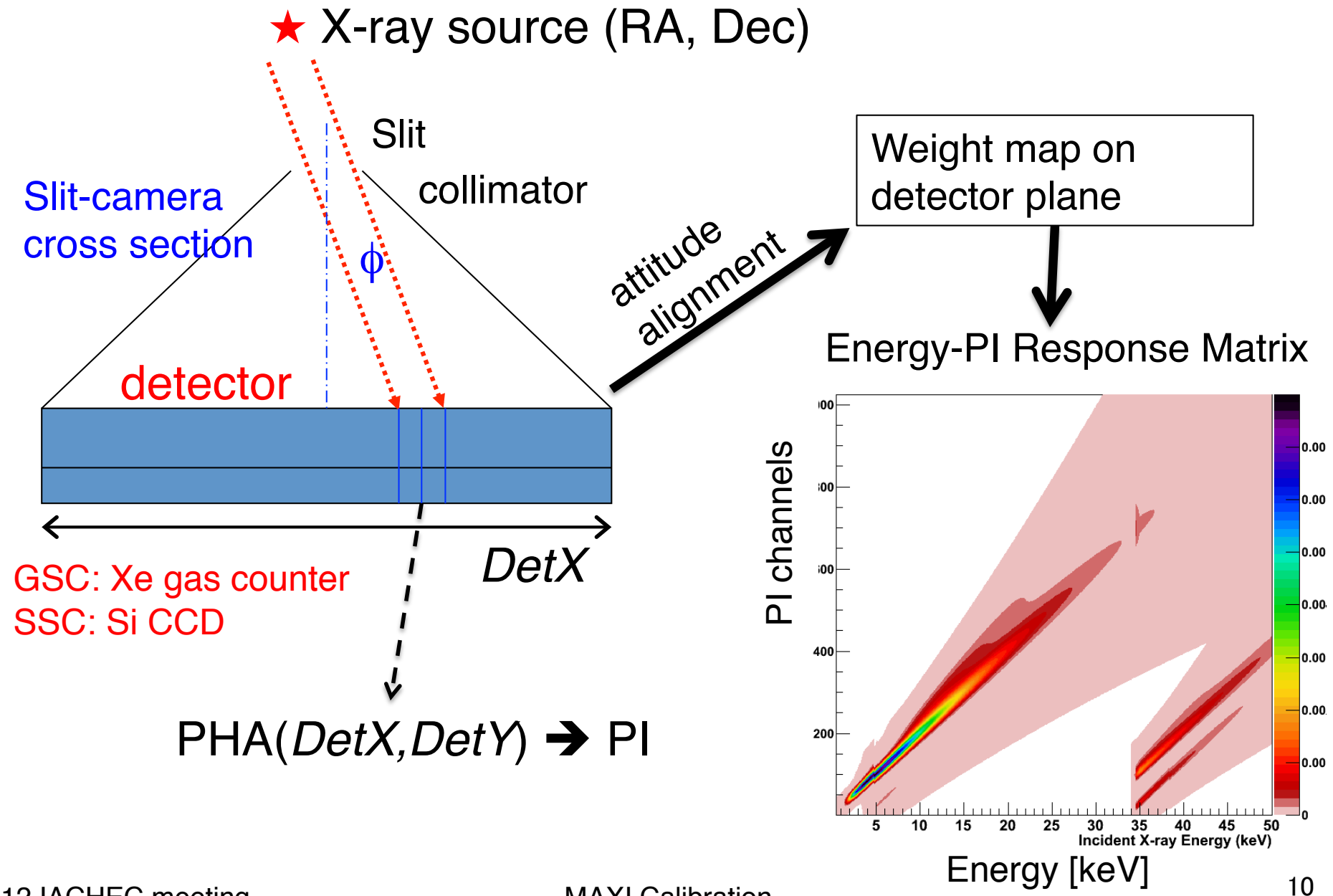
GSC 4-10 keV (MS et al. 2011)
2009/8 - 2010/12





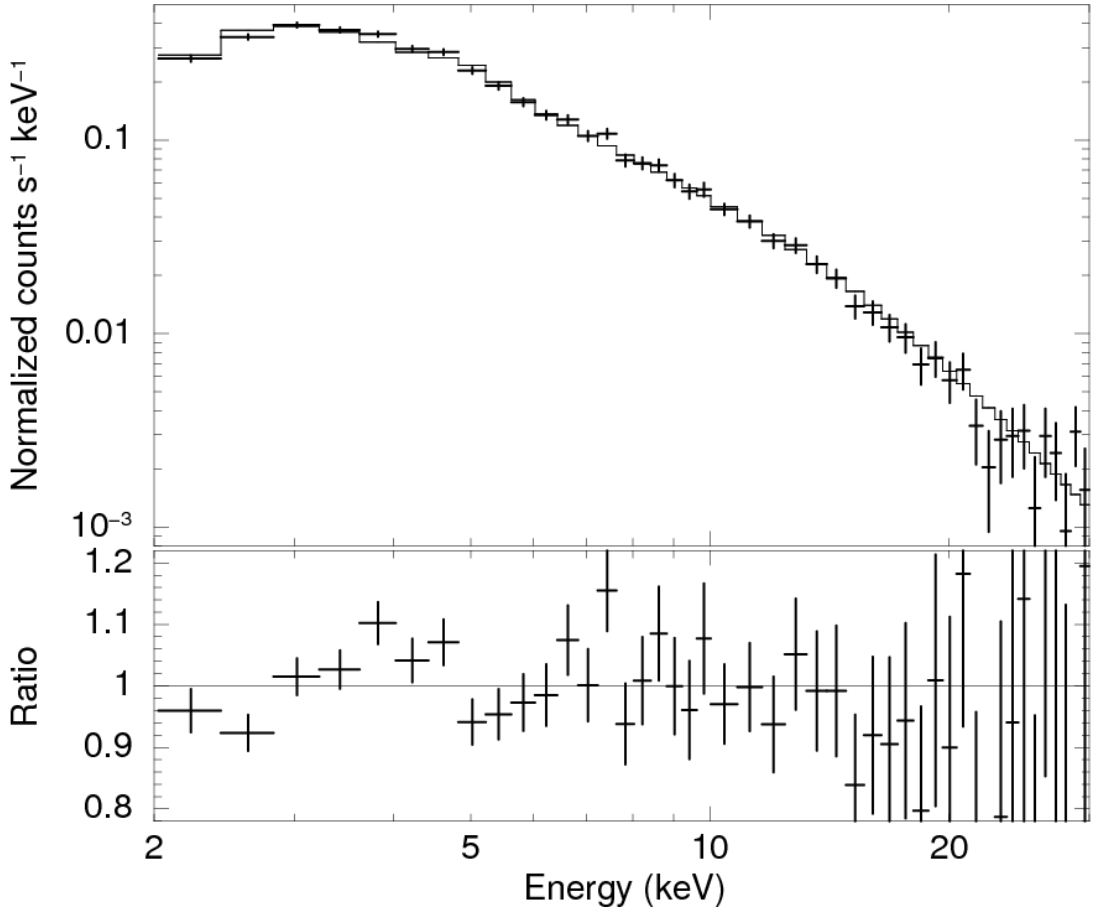
Both decline slopes are confirmed to be consistent.

Data process and RMF builder (GSC and SSC)



GSC RMF

- Daily Spectrum and RMF archive started on 2010/10 for selected bright X-ray sources.
- Data of anode #1,#2 are currently not used for their insufficient calibration. (They have an extraordinary response.)
- Applicable to 1650V data only



Crab 1-day specrum
Wabs*Powerlaw
Model parameters:

N_H = 0.72 +/- 0.22
Γ = 2.15 +/- 0.05
Norm. = 11.4 +/- 1.0
c^2_n = 1.08

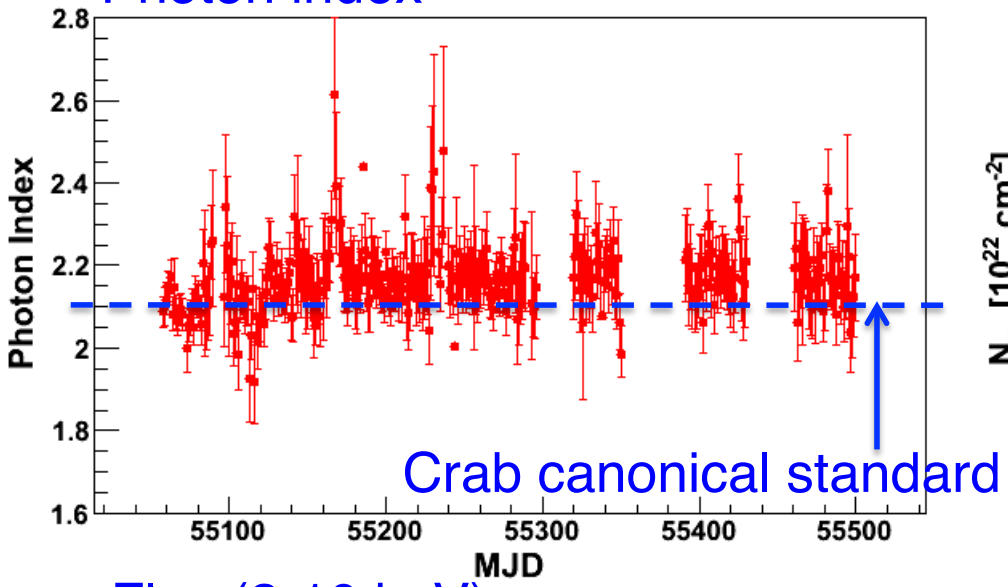
Reasonably agree with standard Crab model

(MS et al. 2011)

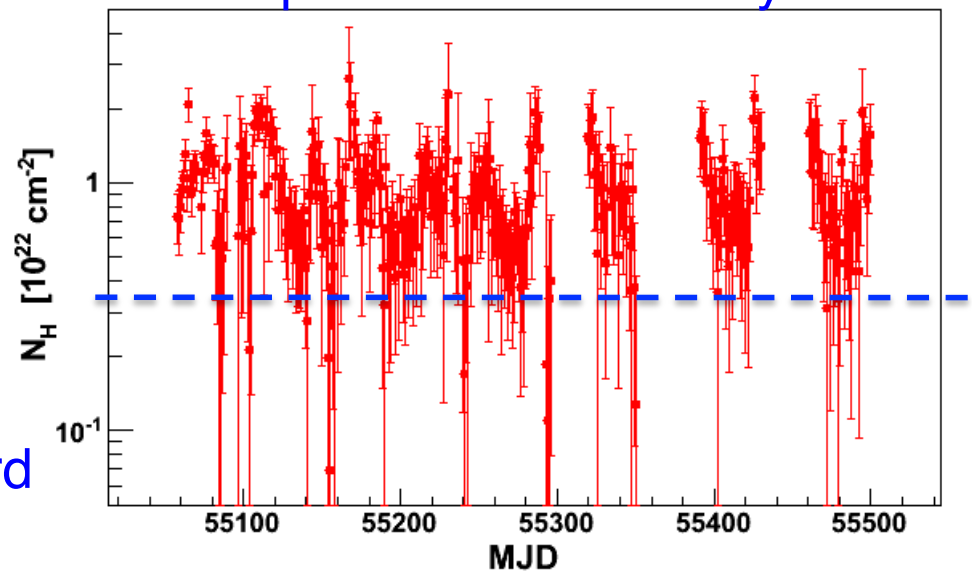
Variation of daily Crab spectral parameters

(2009/08/15 - 2010/10/31)

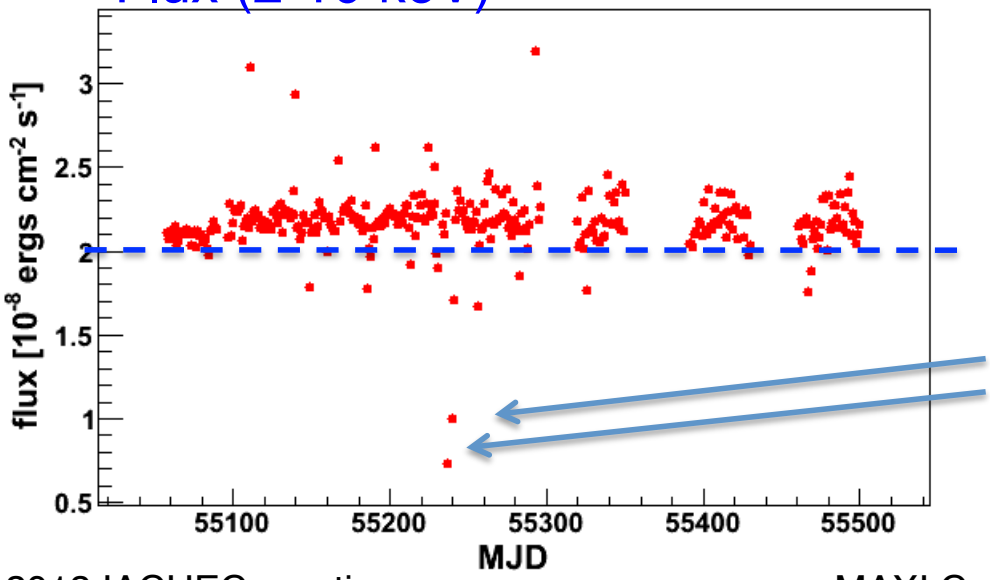
Photon index



Absorption column density



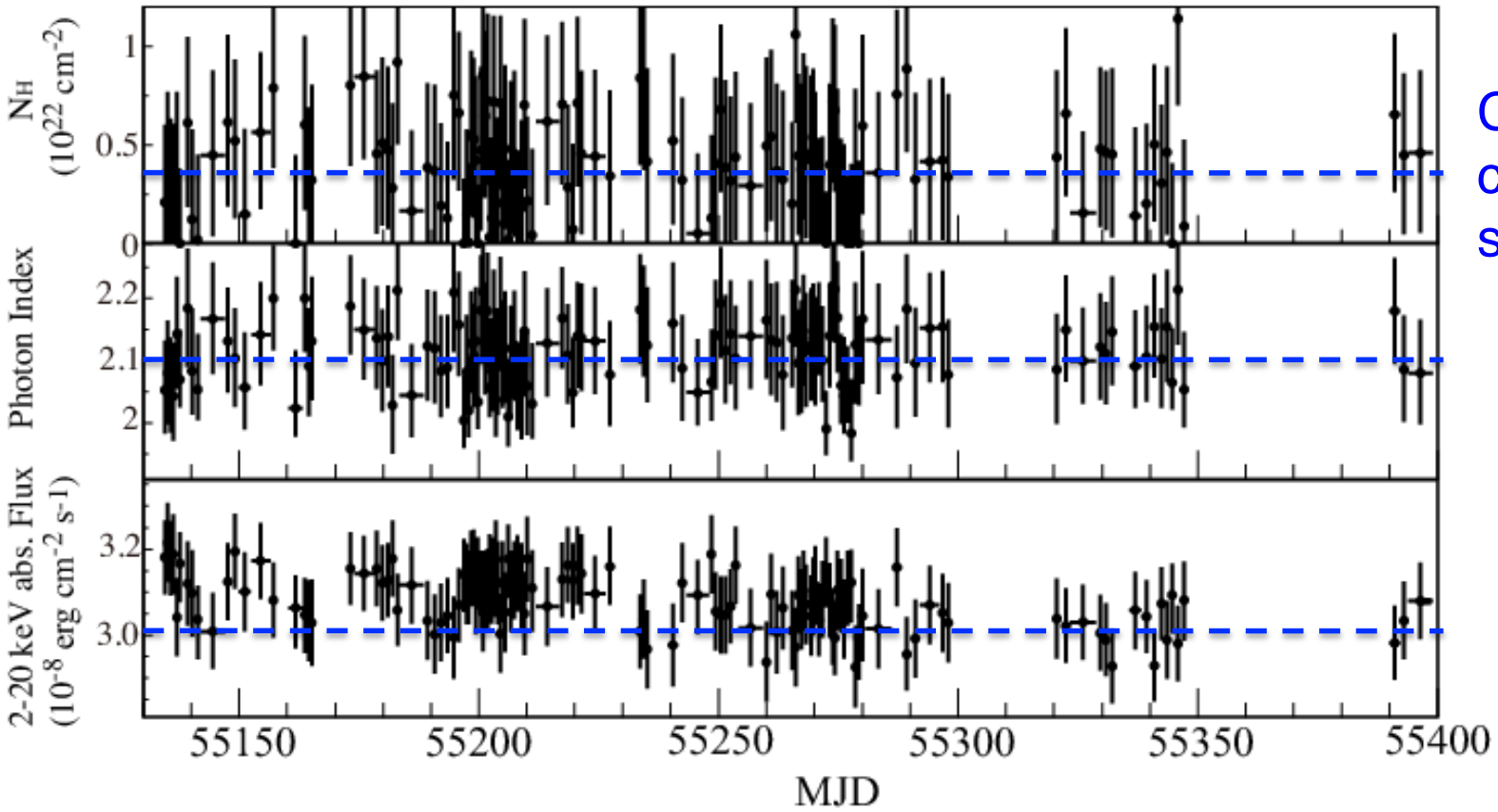
Flux (2-10 keV)



- Error bar: 90% conf. limit
- $N_{H:}$ slightly higher than the standard value
- Automatic analysis process is not always perfect.

Improvement by tuning event-cut condition

- Data are corrected from the good anodes (C0,2,3,5) of detector operated at 1650 V.
- Good time intervals are selected taking care of the good BGD coverage as well as the source coverage.



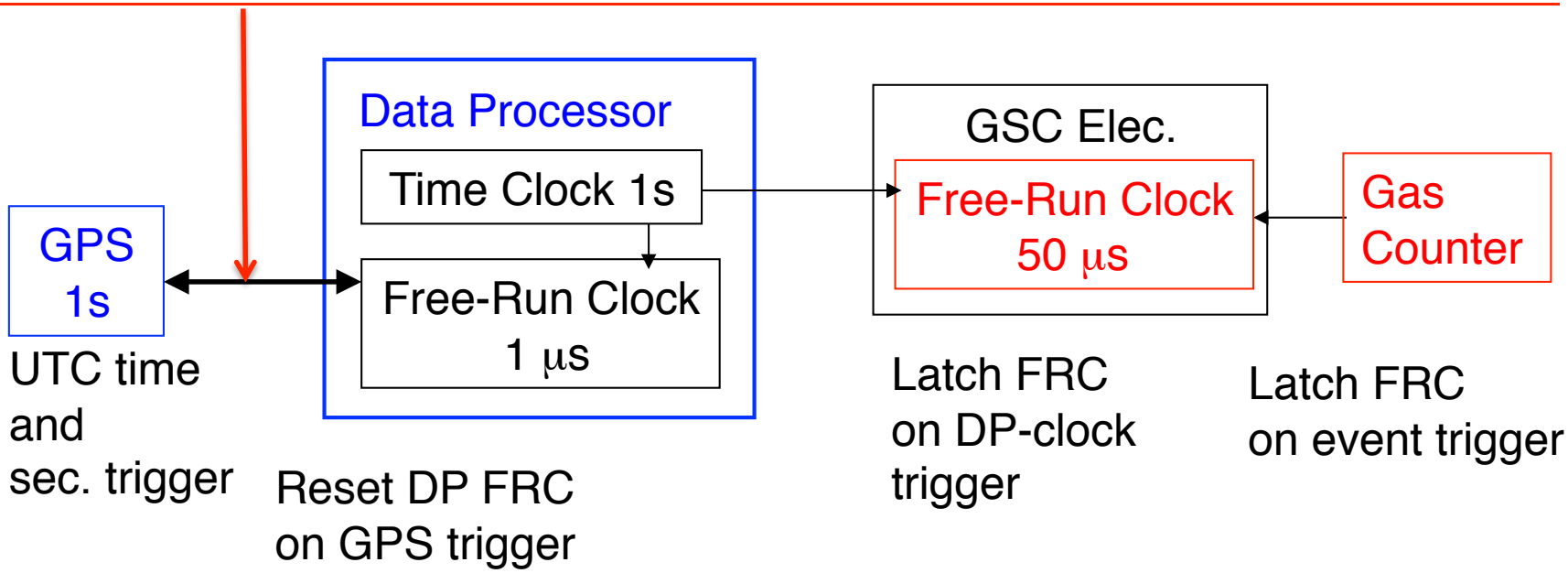
(Nakahira et al. 2012)

GSC Event Timing

- GSC event data has a 50-μs time resolution
- MAXI DP time clock can always be calibrated using on-board GPS.
- Timing precision was calibrated using Crab pulsar and Cen X-3 binary X-ray pulsars.

Event timing scheme

Relation between GPS and DP clock has to be established once in orbit

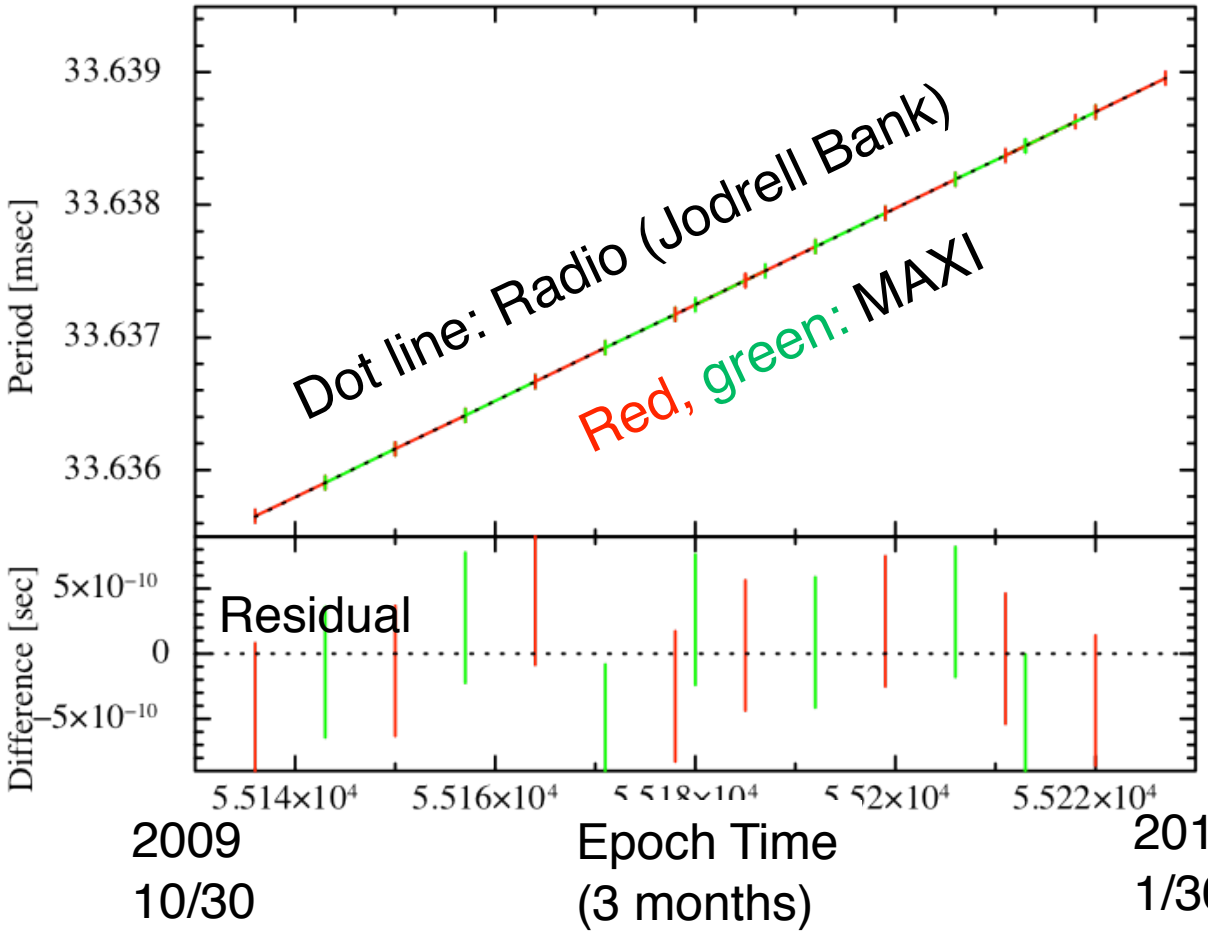


Timing Cal. with Crab Pulsar

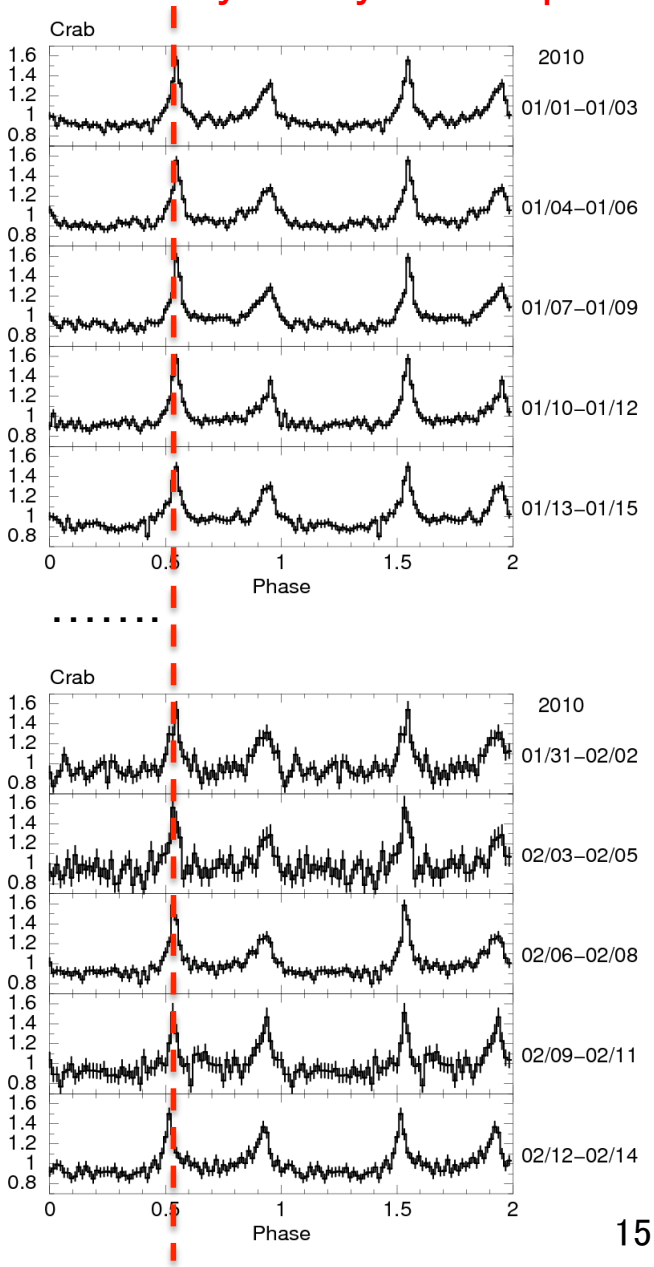
(Morii + 2011, MS+2011)

- Relative stability is verified (10^{-9})
- Need calibration of absolute timing

Comparison of pulse period with radio-pulse period

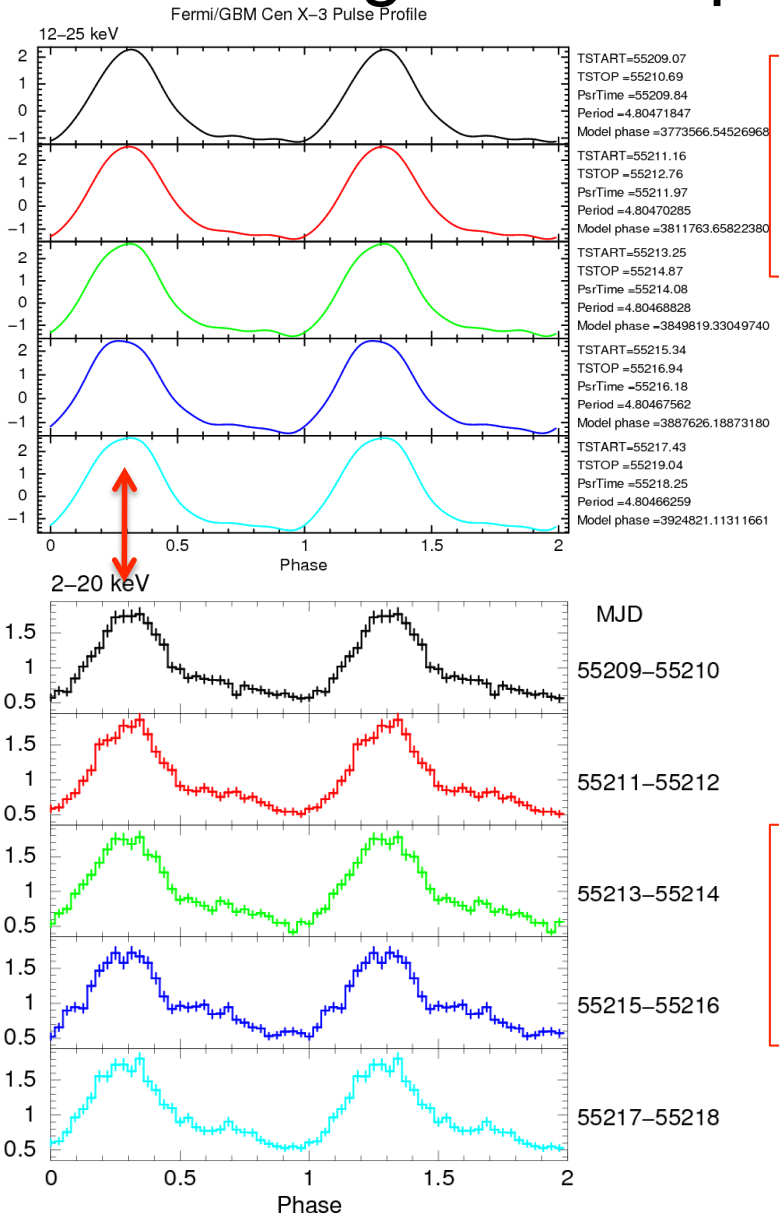


GSC every 3-day folded pulse



Cross timing calibration with Fermi/GBM using another pulsar, Cen X-3

Every
2 days



Fermi/GBM pulse profile (12-25 keV)

- Sparse GSC data is hard to determine any transient event with the better accuracy than ~ 1 s.
- Use folded pulse profile
- Cen X-3: P=4s < a scan transit (~40s)

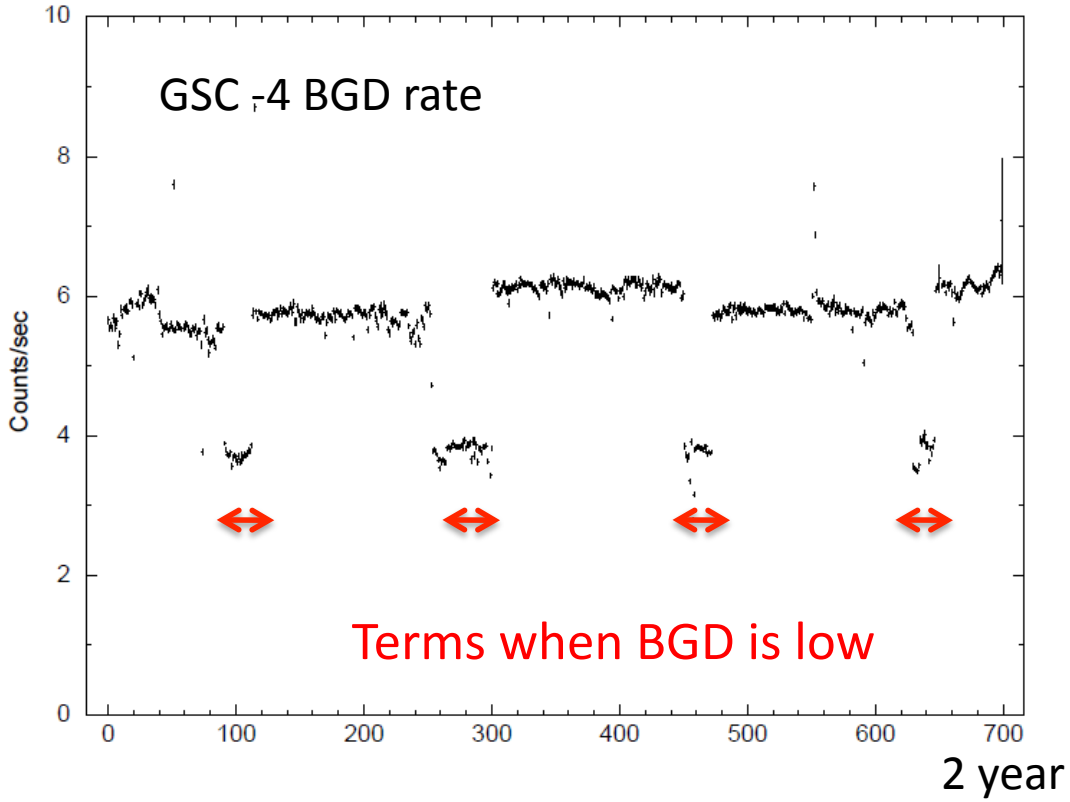
MAXI/GSC pulse profile (2-20 keV)

Absolute time is established !

using the pulsar ephemeris determined by Fermi/GBM

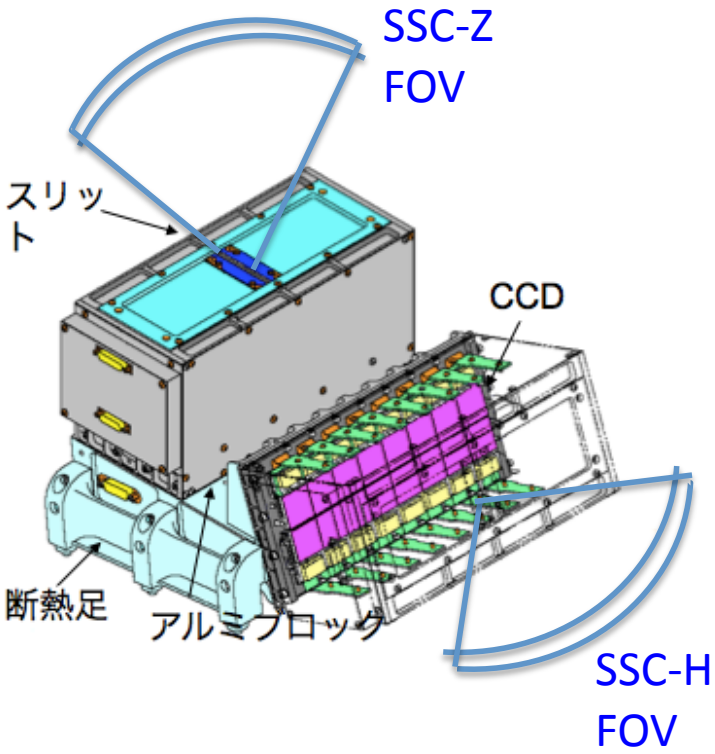
GSC background issues

- BGD rates sometimes dropped almost to the half for a few weeks.
- The events correlated with absence of Soyuz, Russian Spacecraft.
- Gamma-ray source (137Cs and 60Co) equipped on Soyuz is found to be the origin.
- (ISS environment is hard to be understood throughout)



SSC (Solid-state Slit Camera) instrument

Schematic view



- Energy range: 0.5-12keV
- 16 CCDs per camera x 2 (H, Z view) achieve 200 cm^2
- 24x24μm x1024x1024 pixels
- Front Illuminated (FI) chip
- One readout per camera (16 CCDs)
- Readout speed: 8μs/pixel
- Parallel-sum mode (for 1-D sensitivity and fast readout of large CCD).
- Charge-Injection functionality for radiation tolerance.
- Cooled by Peitier device

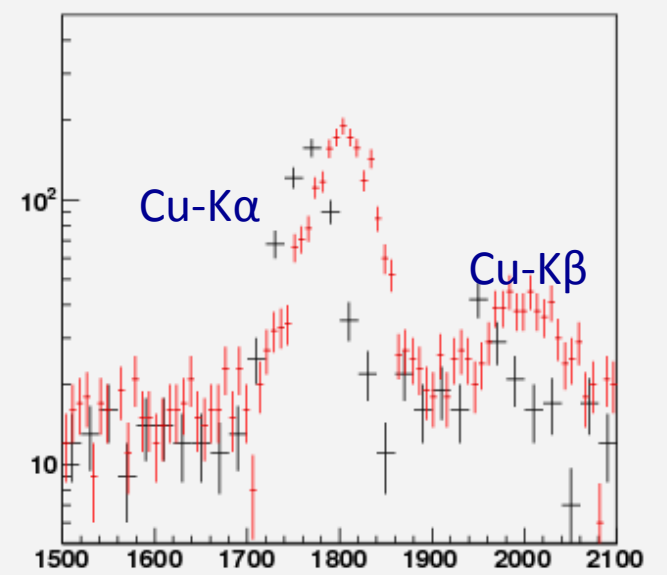
SSC Team: H.Tomida (JAXA) H.Tsunemi, M.Kimura, H.Kitayama (Osaka Univ.), T.Hanayama, K.Yoshidome (Miyazaki U.)

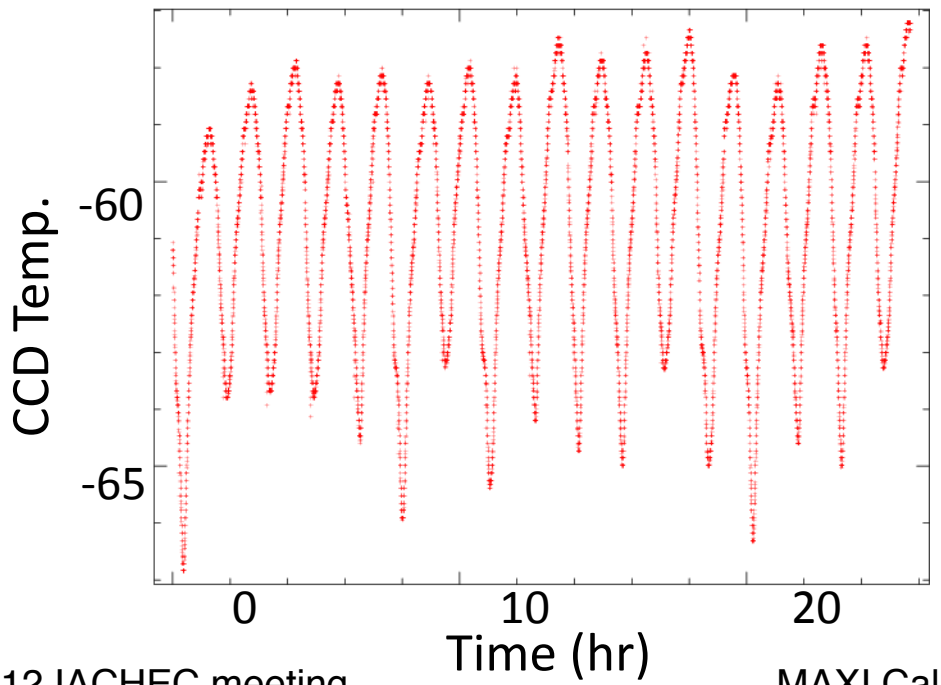
SSC status and issues

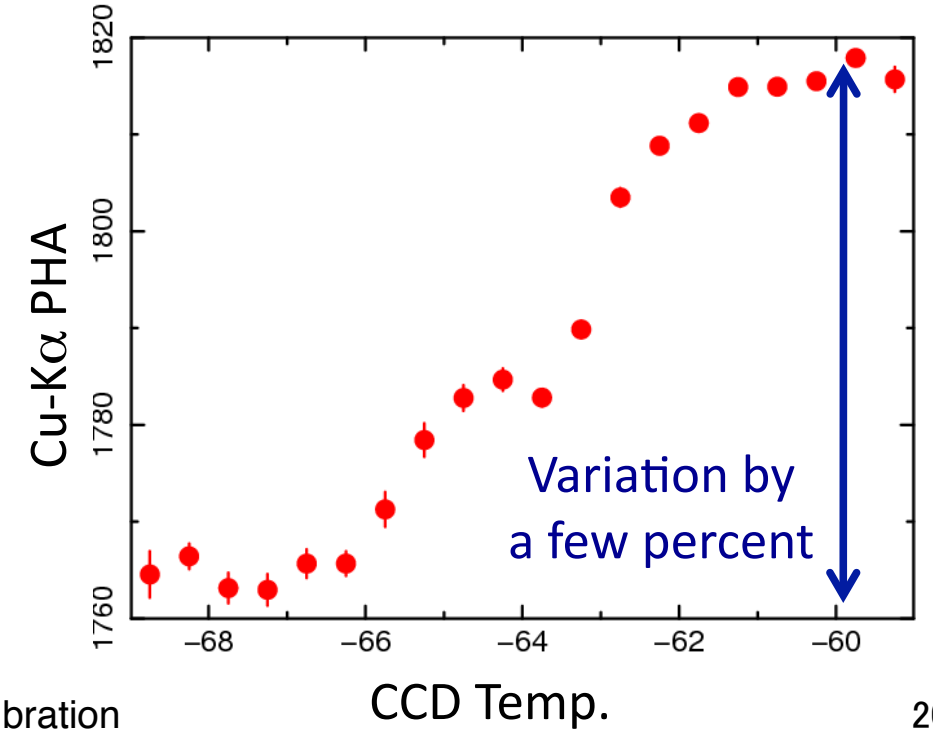
- Operation
  - All 32 CCDs are operational.
  - Performance is almost as expected.
    - Energy resolution is about 150eV@5.9keV (FWHM)
  - Light leak from the side of CCD
    - Observation time is limited to the time when the ISS is in the night.
  - Data-transfer problem on ISS
    - Data confliction in the ISS intranet.
    - An astronaut solved the problem by installing a new computer on the down-link path.
- Calibration
  - Energy – PHA gain correction
    - Temperature variation
    - CTE degradation by radiation damage
  - Effective area, RMF

Gain correction for temperature variation

- Temperatures of CCDs and amplifiers vary by ~10 deg every orbital cycle according to the ISS attitude and the Sun angle.
- Calibration is being carried using the background Cu-Kα line. (Kitayama 2012)
- Typical results of one CCD (out of 32)

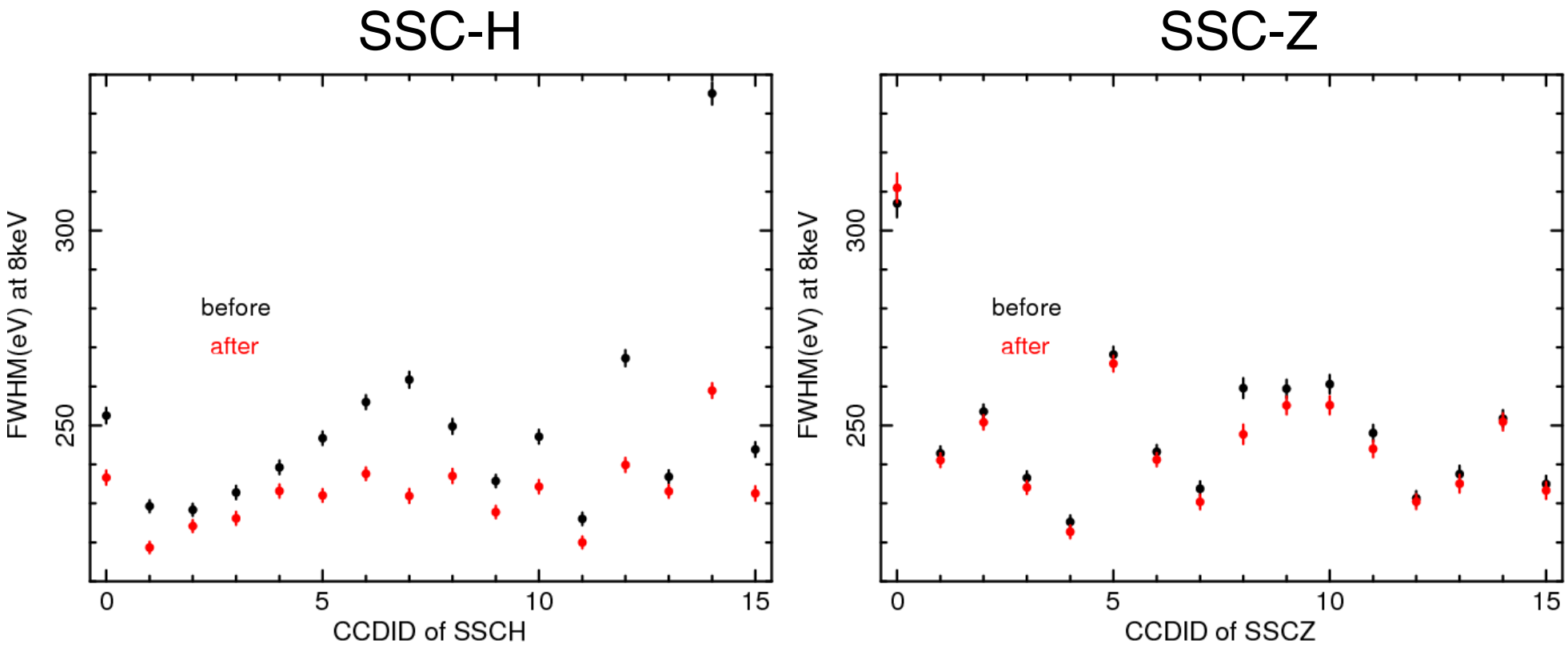






Gain correction for temperature variation

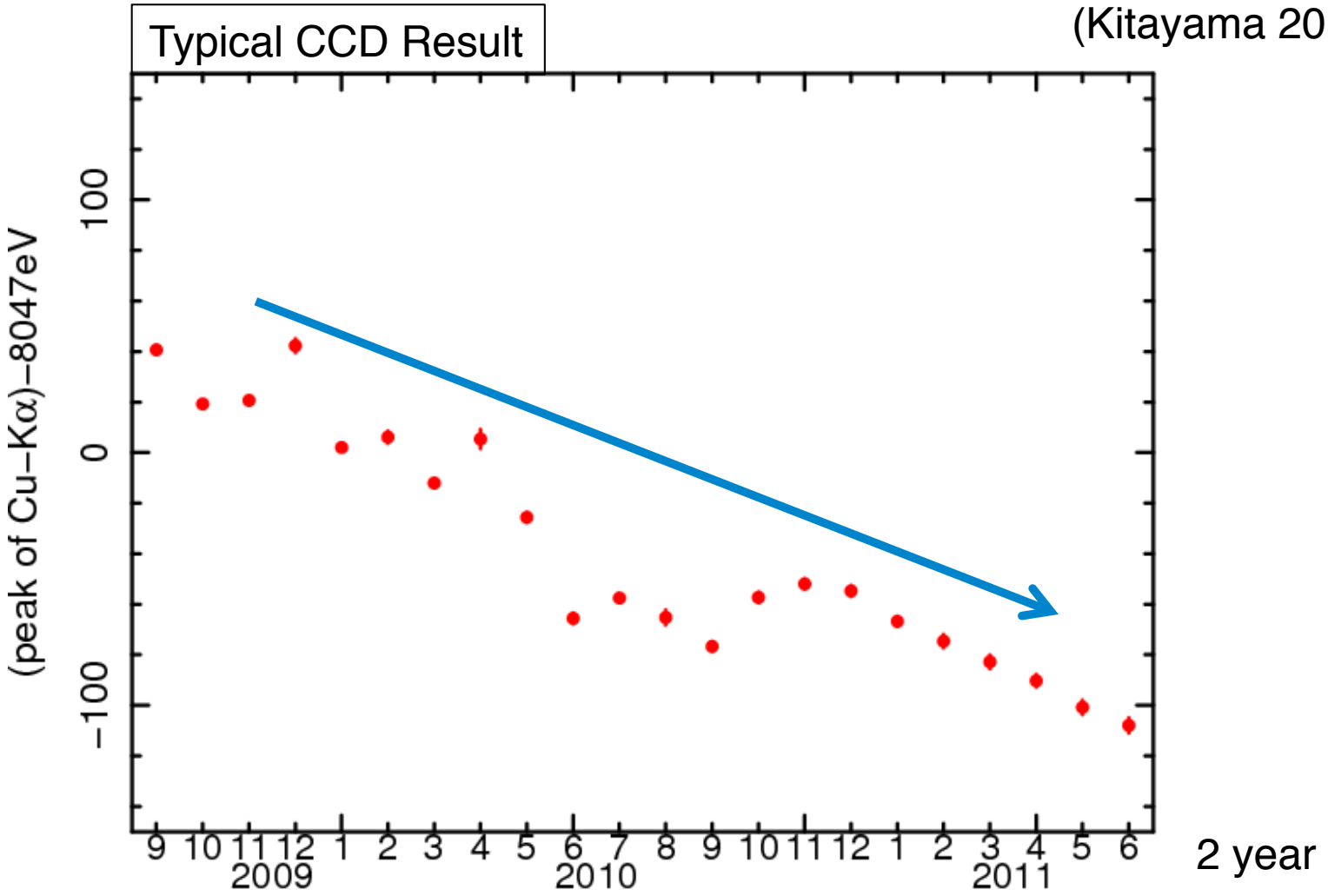
- Energy resolution improved by ~10% after the correction for the gain-temperature dependence.
- The degree of improvement depends on the CCD.



(Kitayama 2012)

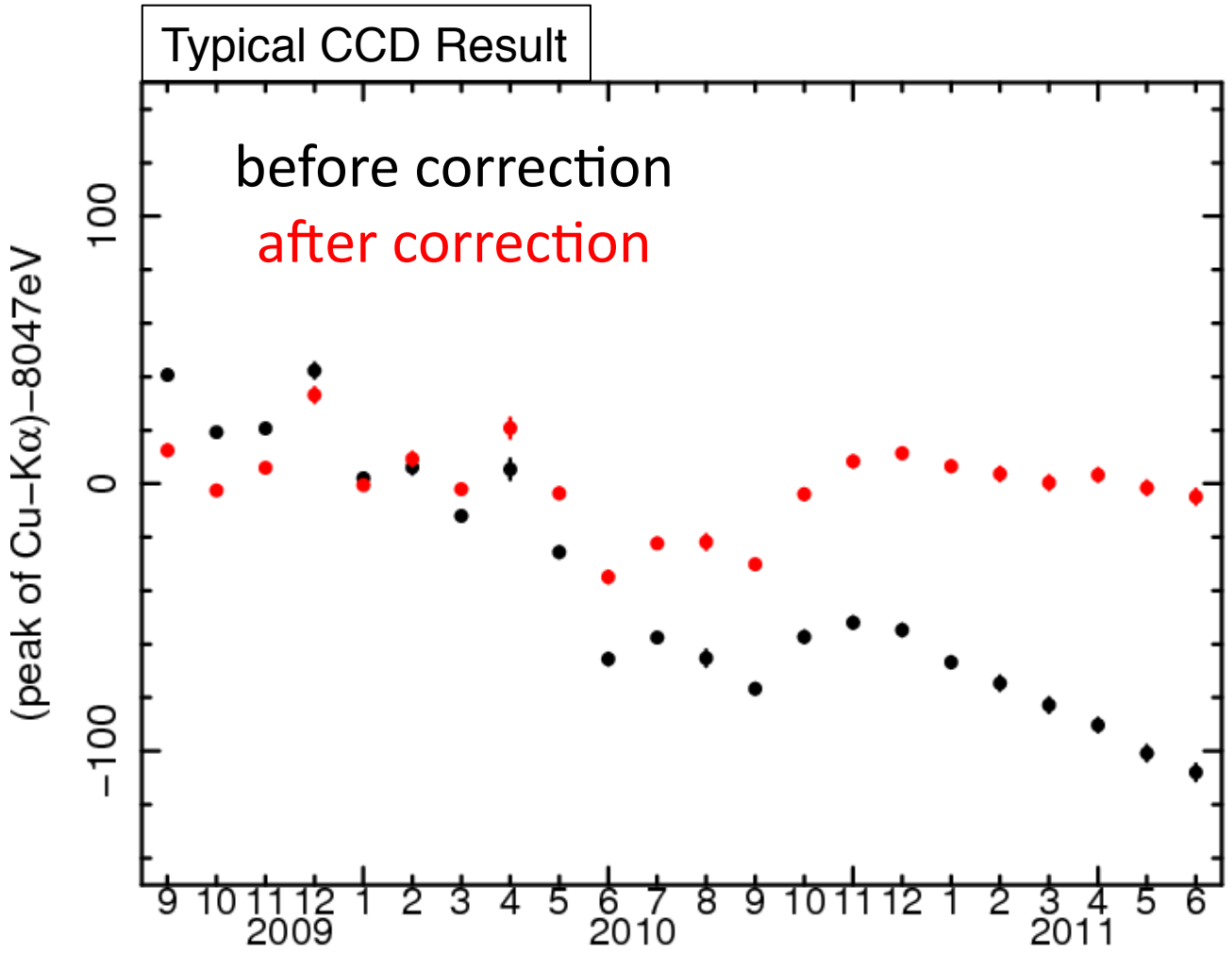
CTE degradation

- PHA for Cu-Kα line decreases due to CTE degradation caused by radiation damage



Correction of CTE degradation

- Energy shift of Cu-Kα line before/after CTI correction
- (The degradation is approximated by a linear function.)



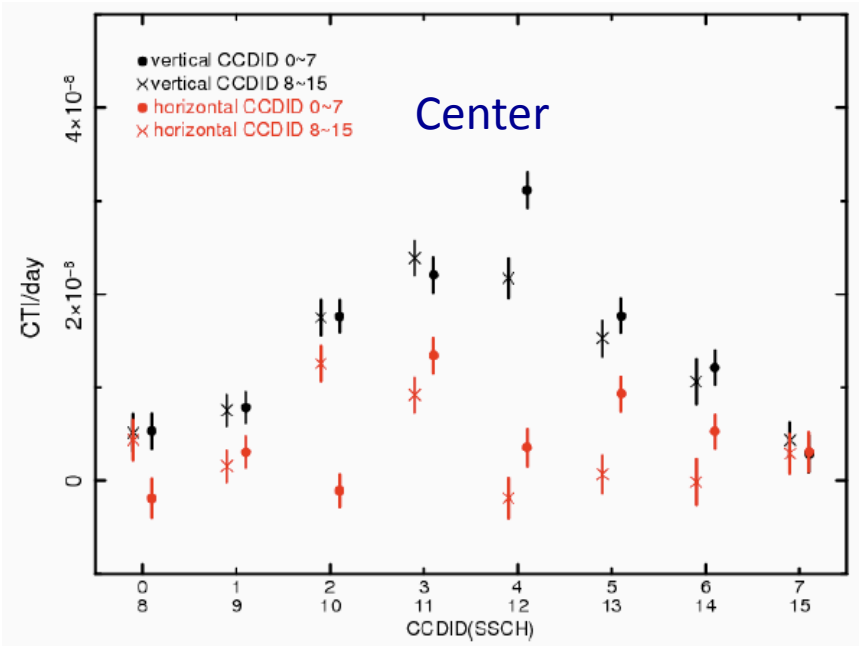
(Kitayama 2012)

2 year

CTI position dependence

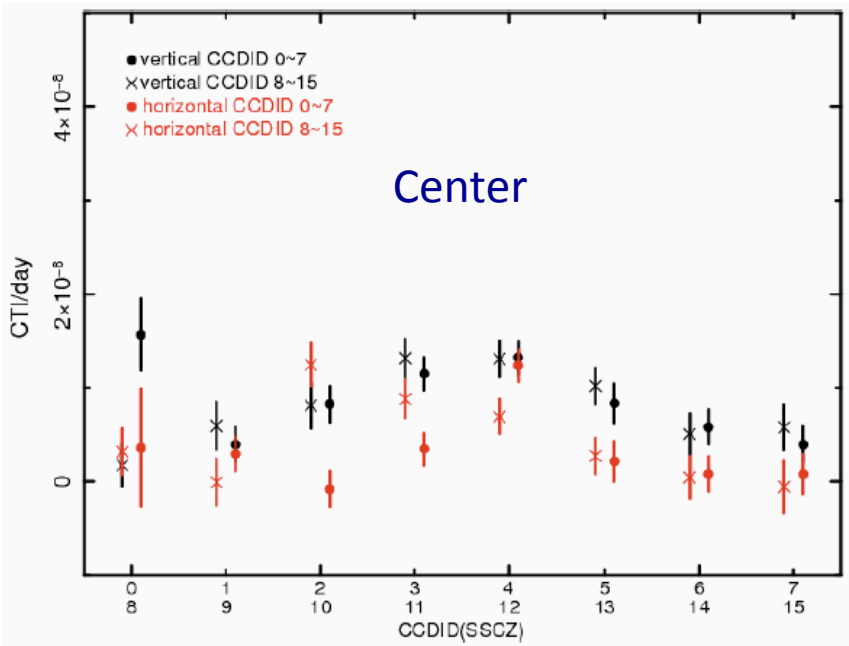
- CTE degradation appears to be larger at the SSC-H central area.
- Does charged particle pass through the slit?
  - Large number of trapped particles by geomagnetic field circulate on the horizontal plane.

SSC-H



Edge Edge

SSC-Z

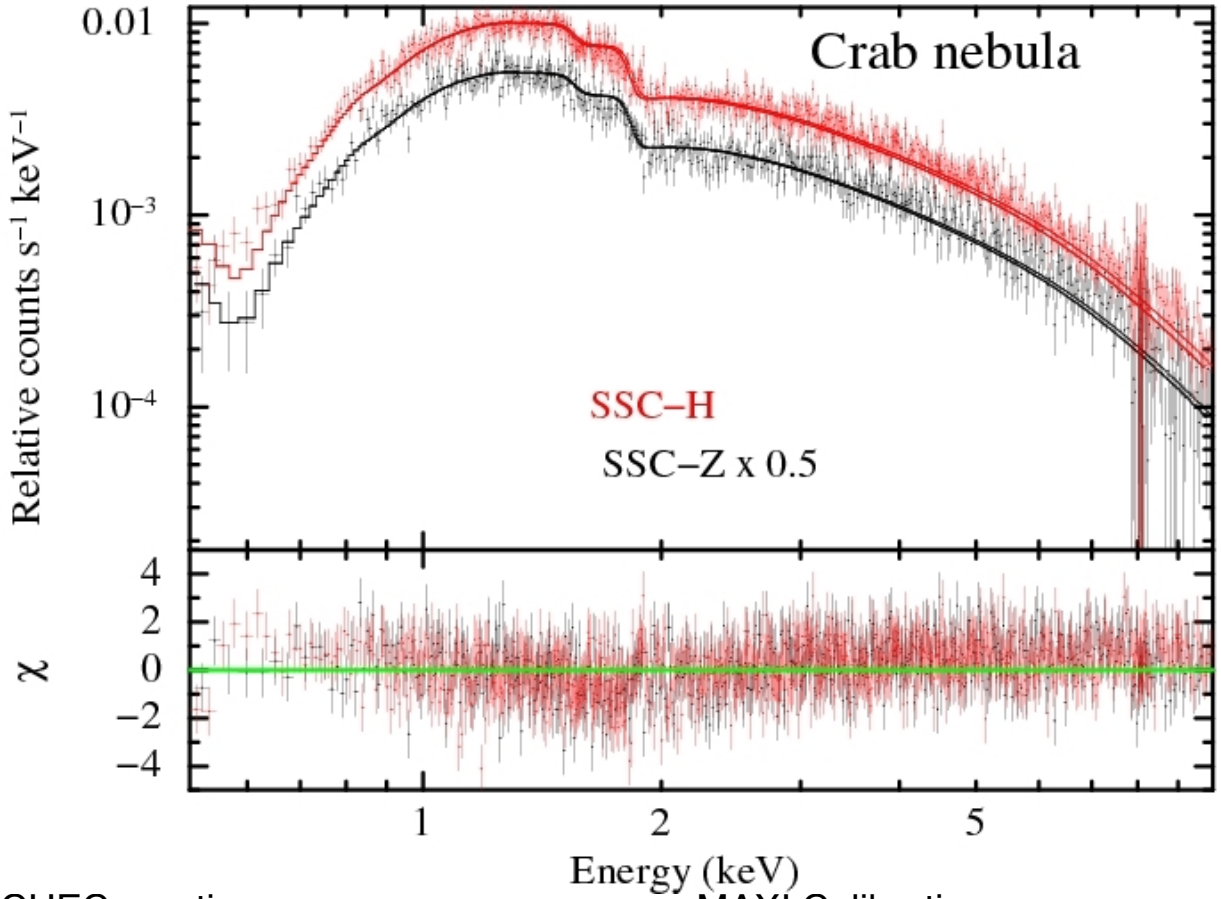


Edge Edge

(Kitayama 2012)

SSC RMF

- We started the early SSC RMF builder from that for the Suzaku XIS.
- Method of exposure weighting on 32 CCD chips are same as the GSC.
- The current is fairly good for large integrated (averaged) data.
- Very huge calibration and verification of 32 CCD data are necessary to support any observation data (still under development)



Initial performance test result

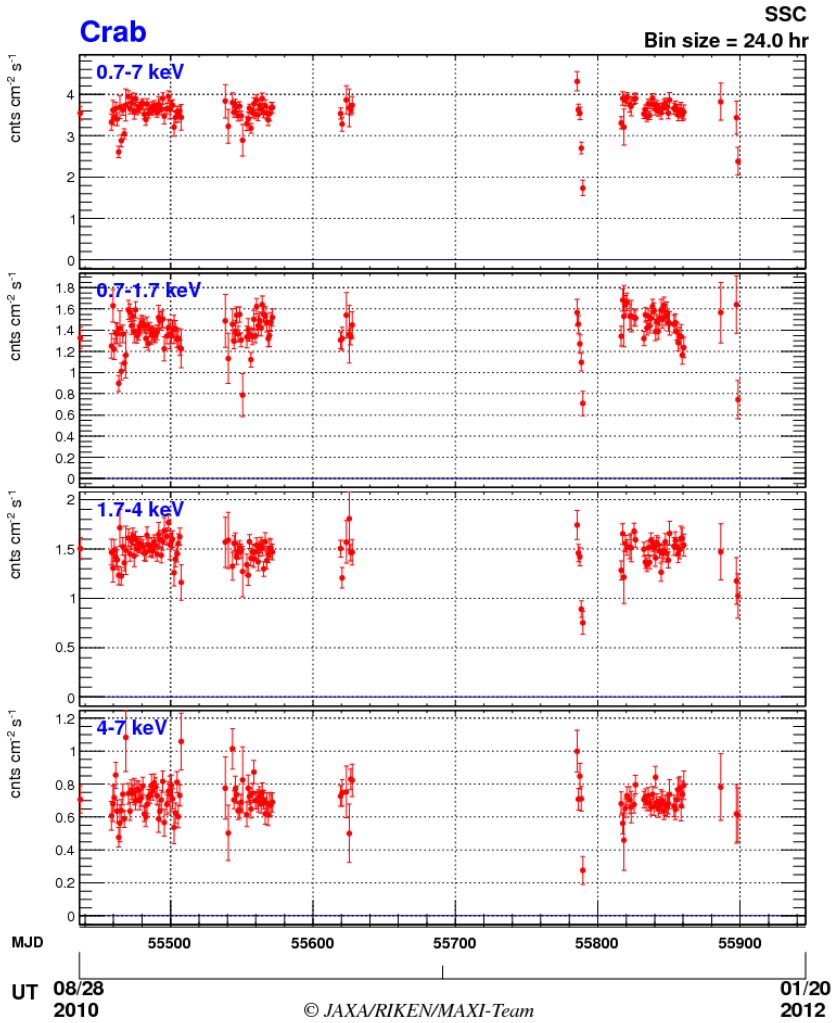
$\Gamma = 2.1$

$N_H = 3.8 \times 10^{21}$ cm^{-2}

(Tsunemi+ 2010)

Effective area

- The calibration and analysis software are getting close to ready.
- Improvement of data screening for visible-light contamination, saturation events and telemetry are still required.



Crab light curve (SSC-H only) (Tomida)

Summary

- MAXI instrument (GSC and SSC) calibration and data reduction required for optimal science results are still going.
- Standard data products of image, light curve of pre-listed sources start to open to public from the MAXI home page.
- Web page for on-demand data products is released. (http://maxi.riken.jp/mxondem)

- Please check the latest info on MAXI home page (http://maxi.riken.jp) or contact us.

On-demand Data Archive

- Daily standard products for pre-registered sources
  - Light curve, Image, Spectrum (http://maxi.riken.jp/top)
- On-demand archive (http://maxi.riken.jp/mxondem)
  - standard products for any user-specified source