

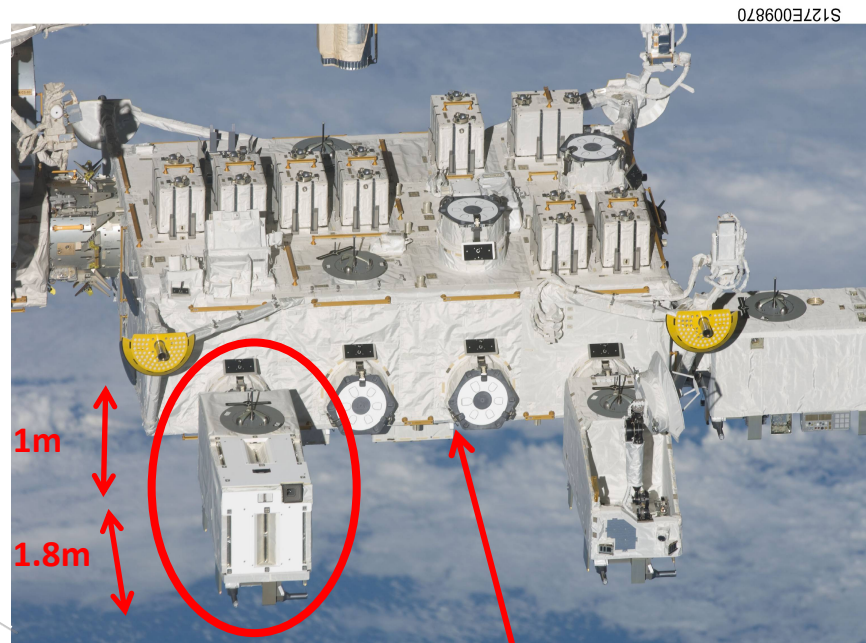
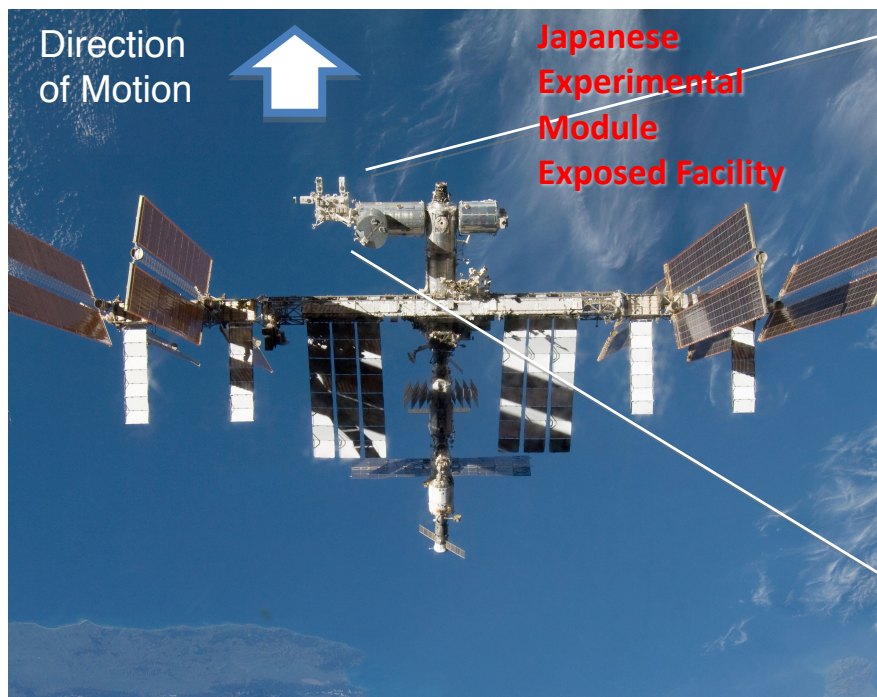
MAXI GSC calibration for 10 years data



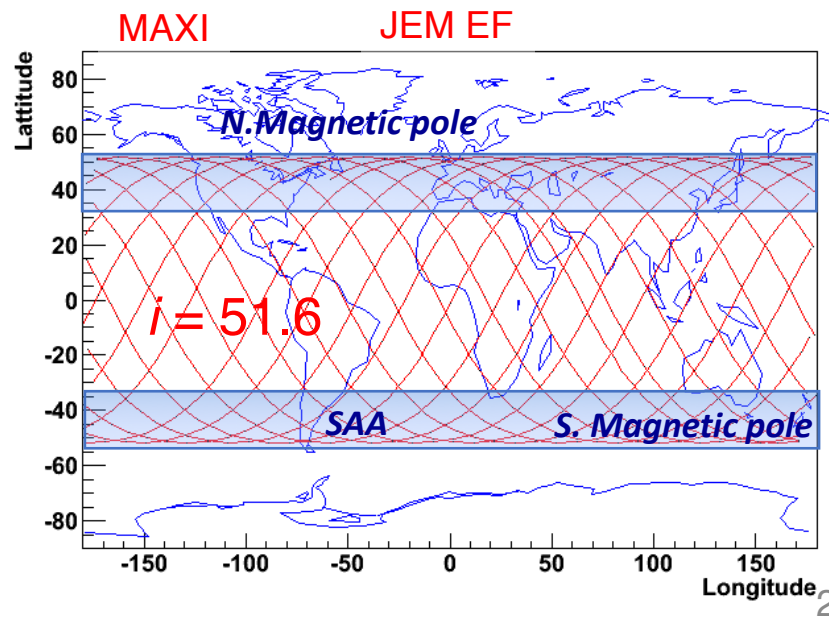
- Overview of MAXI GSC 10 years
- In-orbit response calibration
 - Detector position response / PSF
 - Energy-PHA matrix / effective area
 - (Attitude / Alignment)
 - (Timing)
- Summary, A/I

Mutsumi Sugizaki (Tokyo Institute of Technology)
on behalf of MAXI Team

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

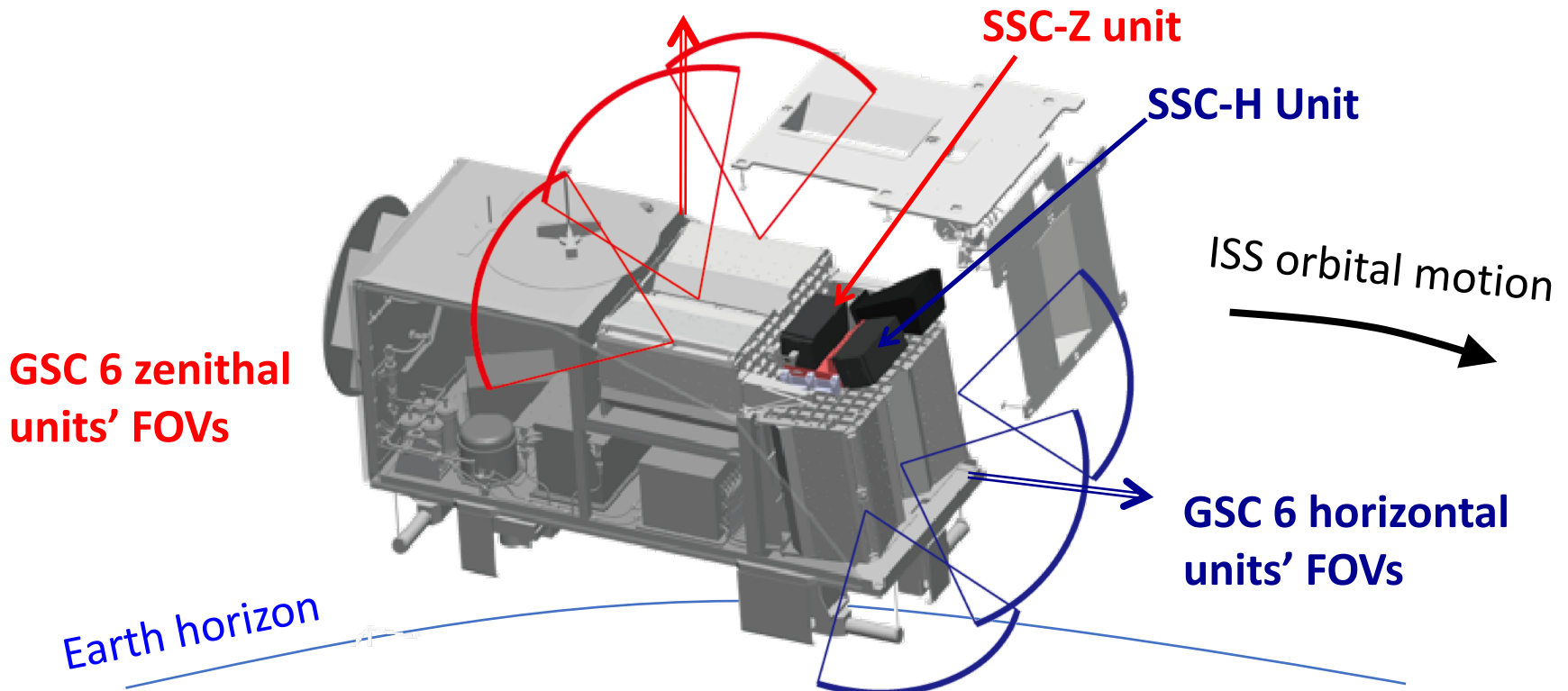


- MAXI 1-D slit camera scans the whole sky according to the ISS rotation coupled with the orbital motion
- Large inclination angle (51.6 deg)
- Various ISS structures sometimes interfere the MAXI FOV.



MAXI Mission Instruments

- **GSC (Gas Slit Camera)** 2-30 keV band **Large area**
 - 1-D position-sensitive Xe-gas counters and slit collimators with slit
 - Anti-coincidence BGD rejection (e.g. Ginga/LAC, RXTE/PCA, ASM)
 - 12 identical units to cover 1-D horizontal and zenithal FOVs.
- **SSC (Solid-State Slit Camera)** 0.5-12 keV band **Good energy resolution**
X-ray CCDs + Slat Collimator and Slit

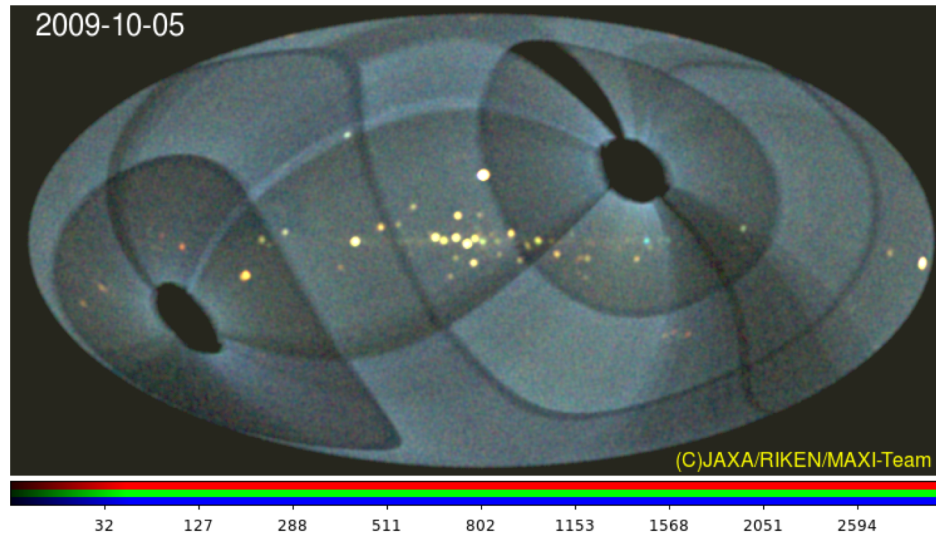


GSC scan image

2011-11-11 00:00-00:05

(C)JAXA/RIKEN/MAXI-Team

Daily all-sky coverage



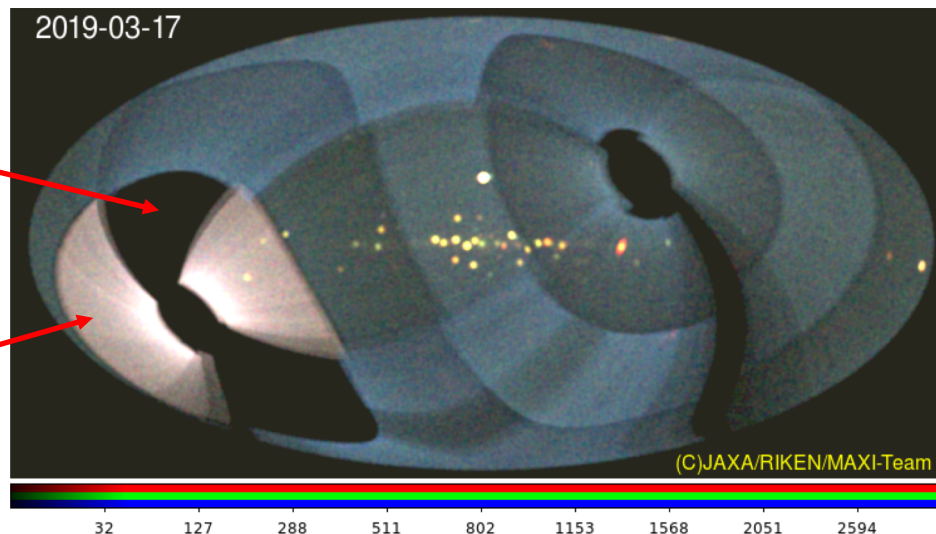
2009-10-05

10 years

2019-03-17

Gas leak

The charged-particle veto is not working. The BGD level is higher by a factor of ~ 10 .



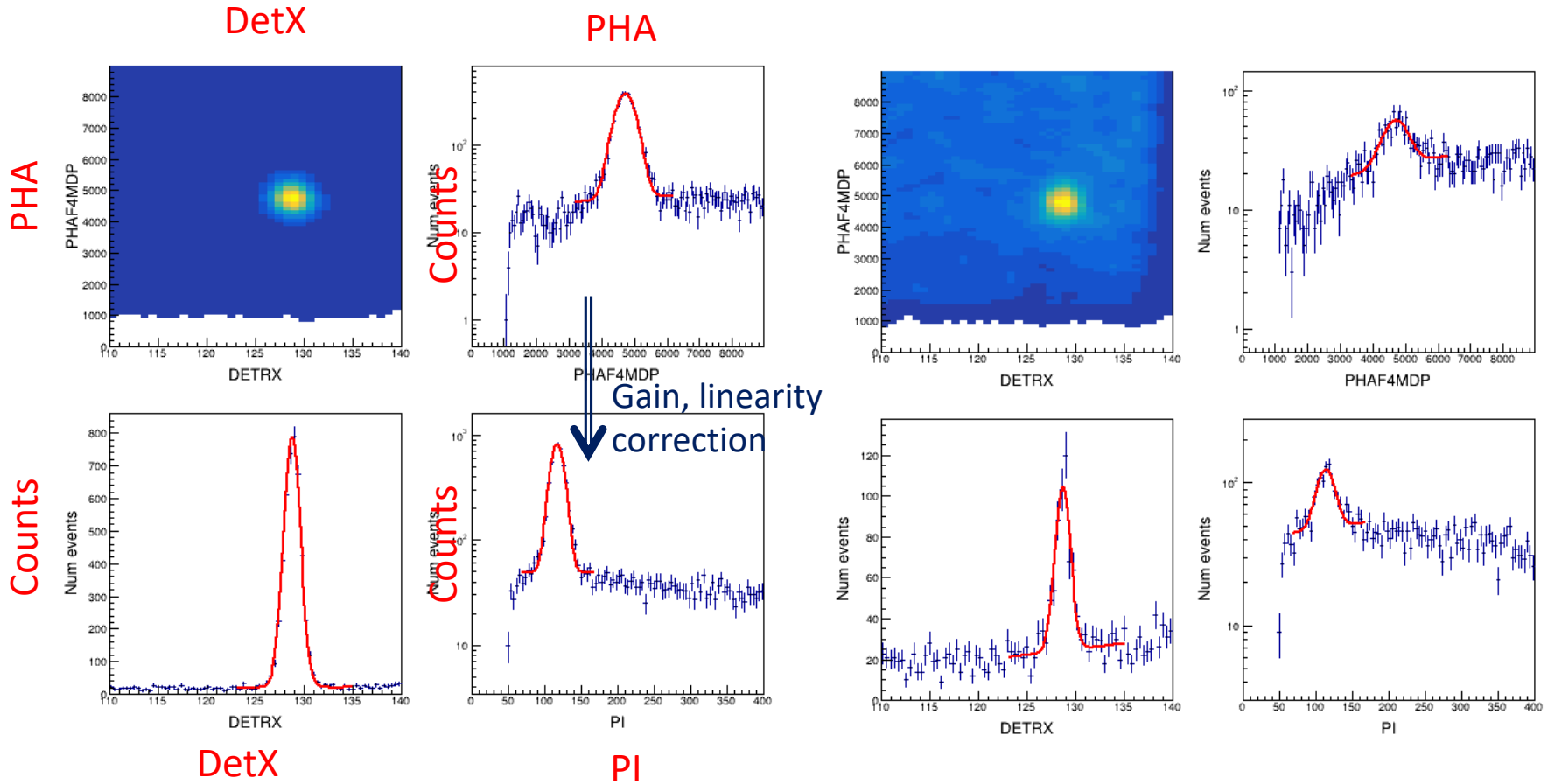
$\sim 80\%$ of the sky are covered.

Calibration

Gain & efficiency monitor with ^{55}Fe 5.9 keV cal. source

2009-08-14 $\xrightarrow{9 \text{ years}}$ 2018-11-15

$$0.5^{\left(\frac{9.25 \text{ yr}}{2.73 \text{ yr}}\right)} = 0.09$$



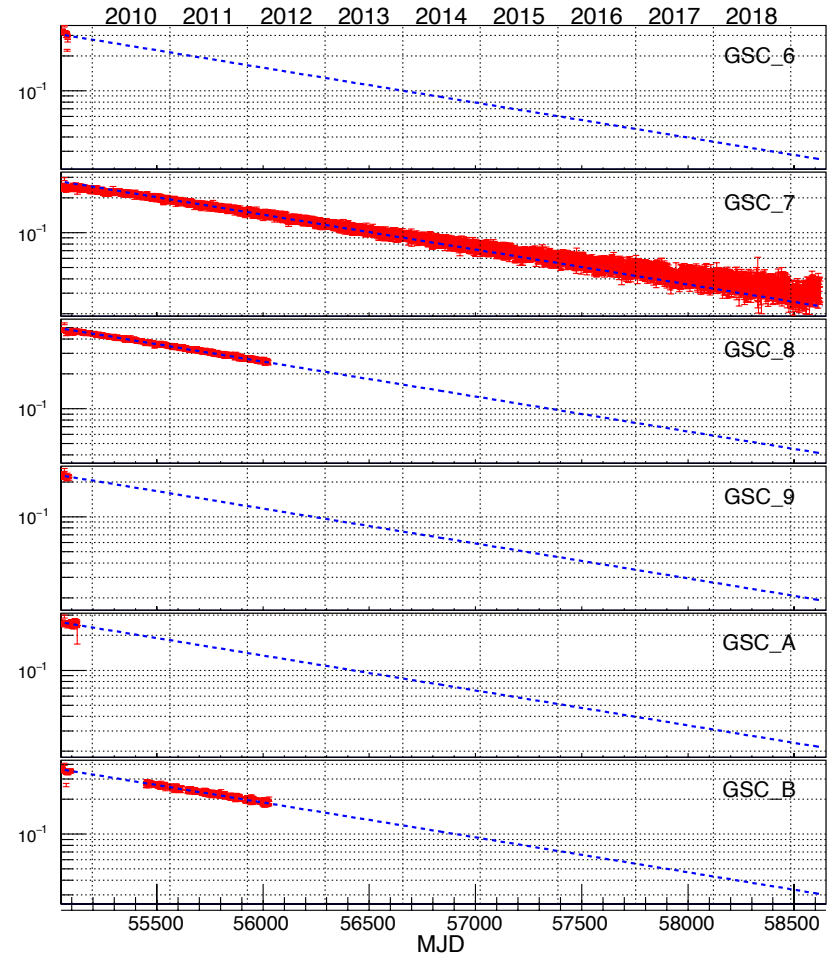
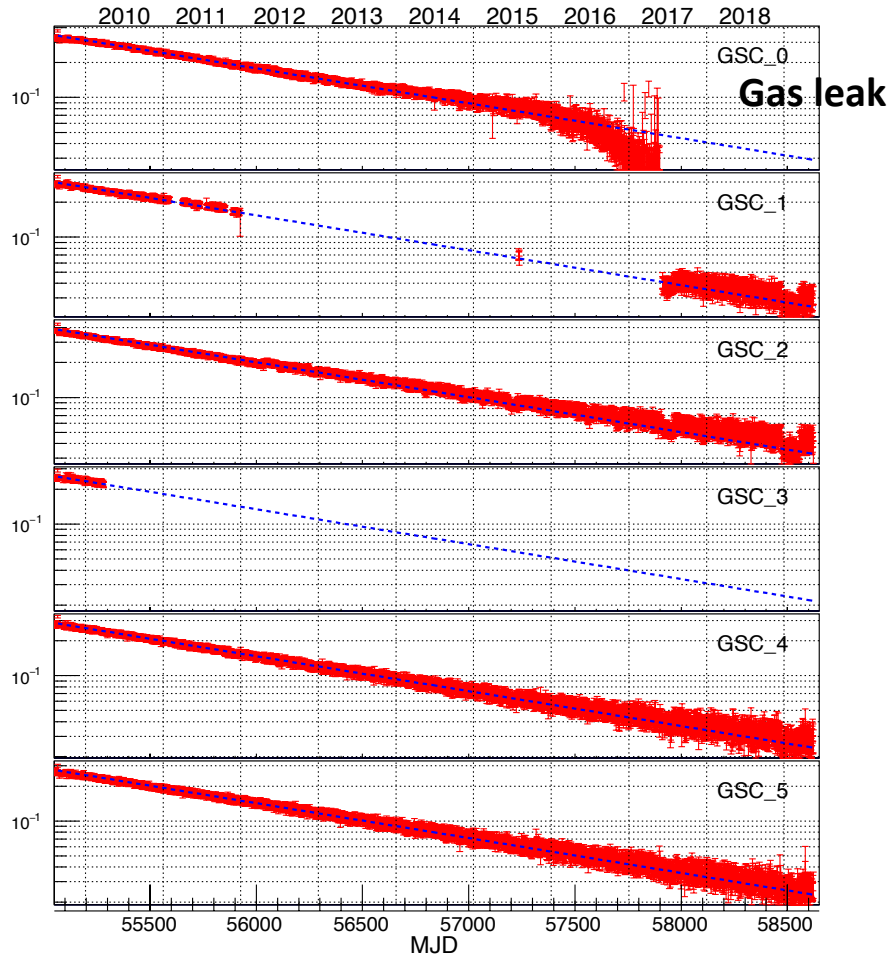
Position resolution

Energy resolution

^{55}Fe 5.9 keV cal. source rate (efficiency)

2009 $\xrightarrow{10\text{ years}}$ 2019

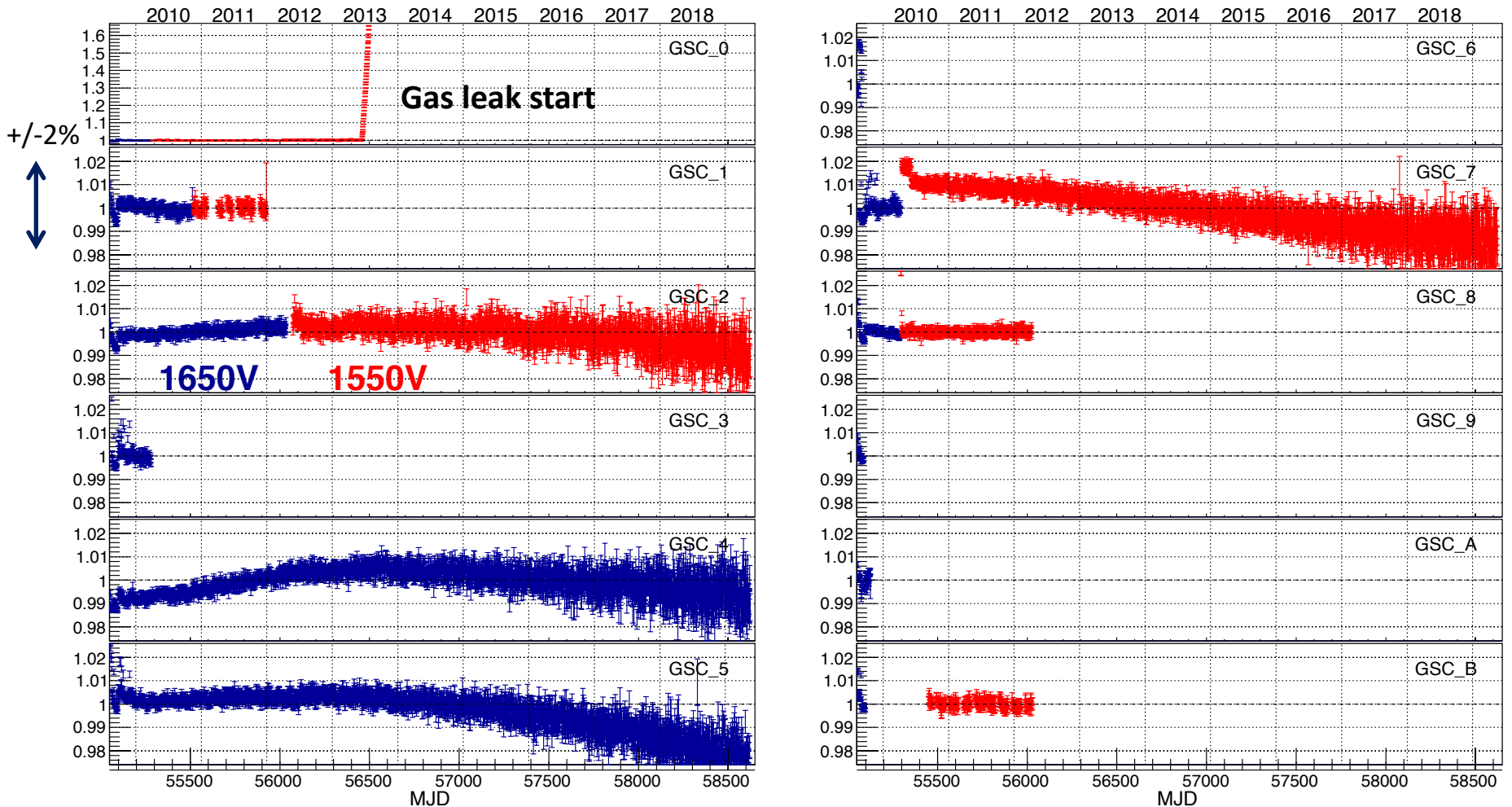
$T_{1/2} = 2.73\text{ year}$



Except for GSC_0, the Iron-55 rate agree with that expected from $T_{1/2} = 2.73\text{ yr}$.

Gain stability (PHA for 5.9 keV X-ray)

2009 $\xrightarrow{10 \text{ years}}$ 2019



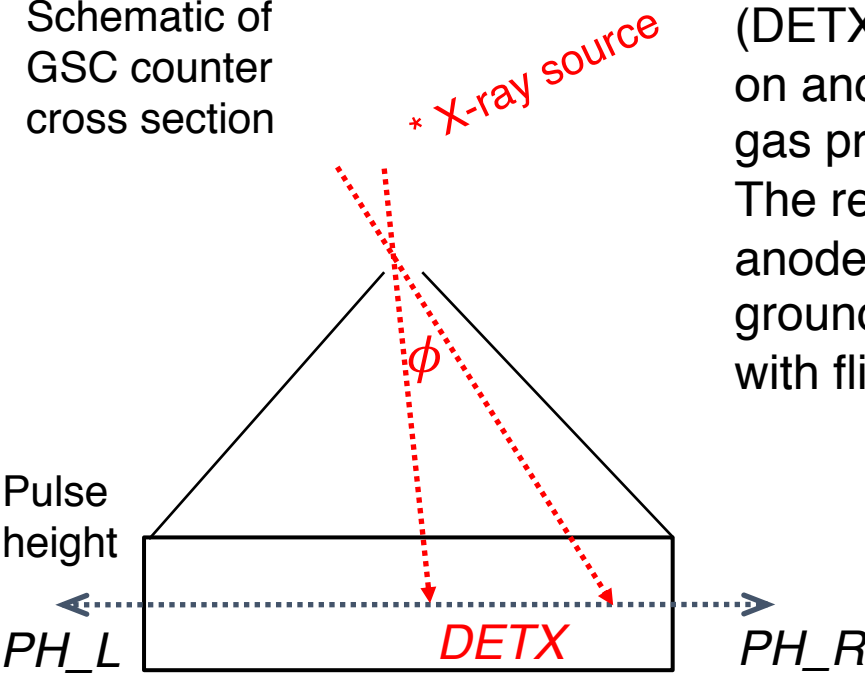
Except for GSC_0, the gas-amplifier gain is stable within 2 %.

Difficulties in GSC calibration

- Wide-field, sparse coverage
 - 12 independent detector units, each has 6 anodes read out into the both (left and right) ends. $12 \times 6 = 96$ channels.
 - Need to accumulate long-term data
 - Data accumulation require precise relative calibration
- GSC specific issues
 - In position-sensitive proportional counters, position and PHA responses are coupled
 - HV changes according to the in-orbit degradation
 - Fracture of carbon anode wire / gas leak
- Target of calibration precision
 - Position determination accuracy ~ 0.1 degree
Requirement for multi-wavelength observational studies.

Detector position response

Schematic of GSC counter cross section



Resistive anode length = l

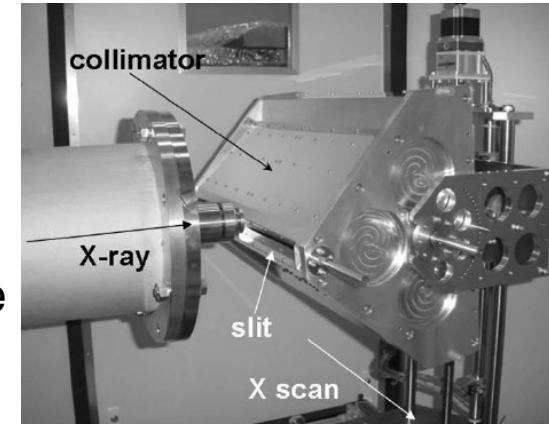
$PH_L =$ Pulse height L $\propto l / (l - DETX)$

$PH_R =$ Pulse height R $\propto l / DETX$

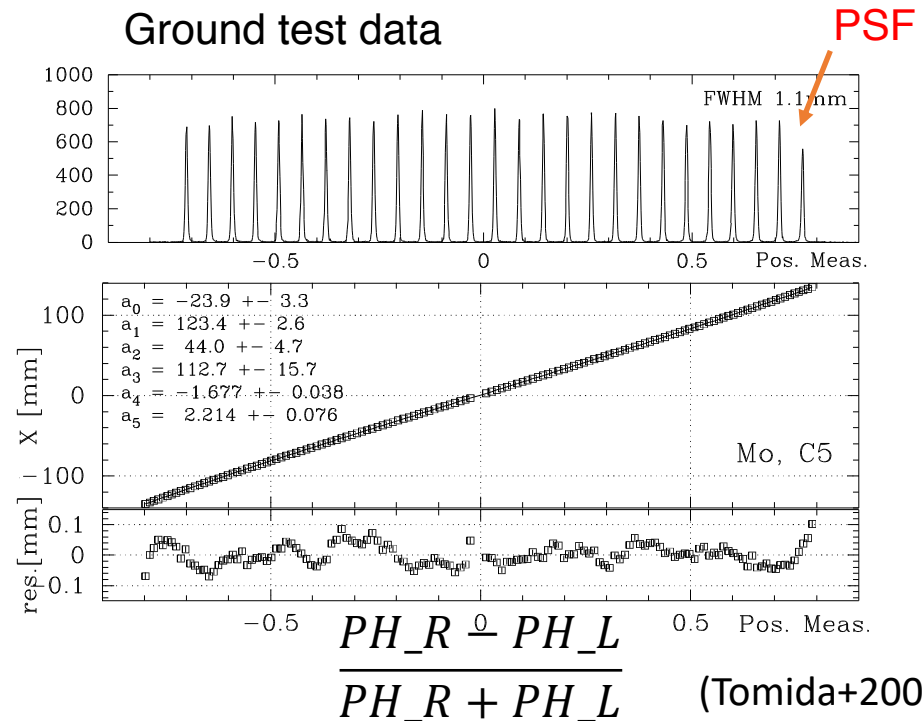
$$DETX = f \left(\frac{PH_R - PH_L}{PH_R + PH_L} \right)$$

GSC detector position (DETX) response depends on anode resistance, HV, gas pressure.

The response of $12 \times 6 = 96$ anodes are measured in the ground test, and calibrated with flight data.



Ground test data



(Tomida+2000)

In-orbit position-response calibration

Ground calibration (CALDB)

Data for Sco X-1

80 deg.

3 deg.

Anode #0

Ψ

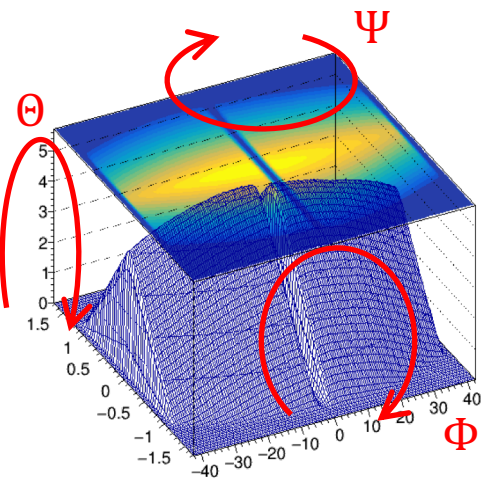
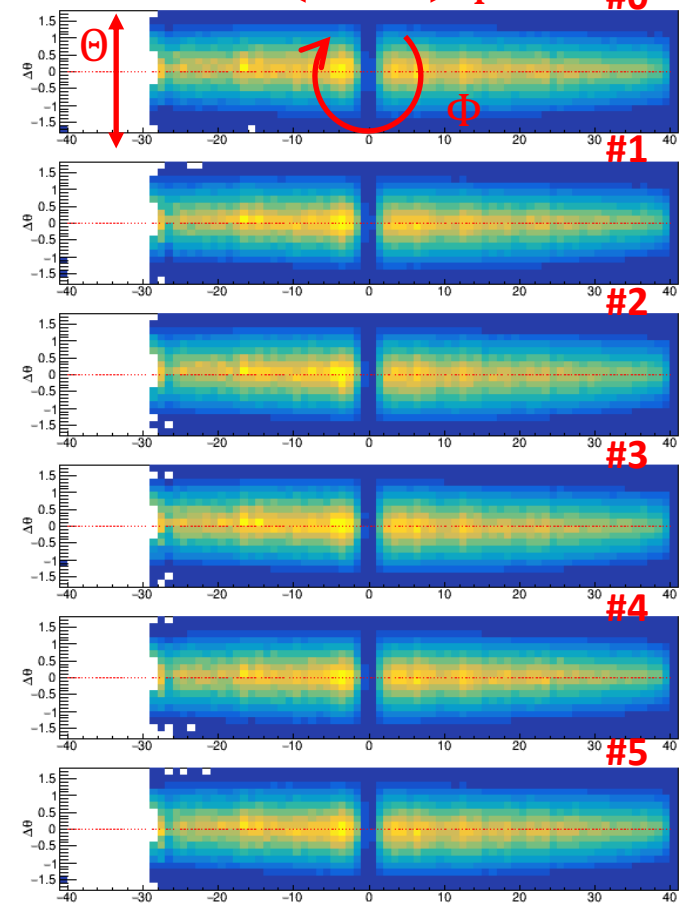
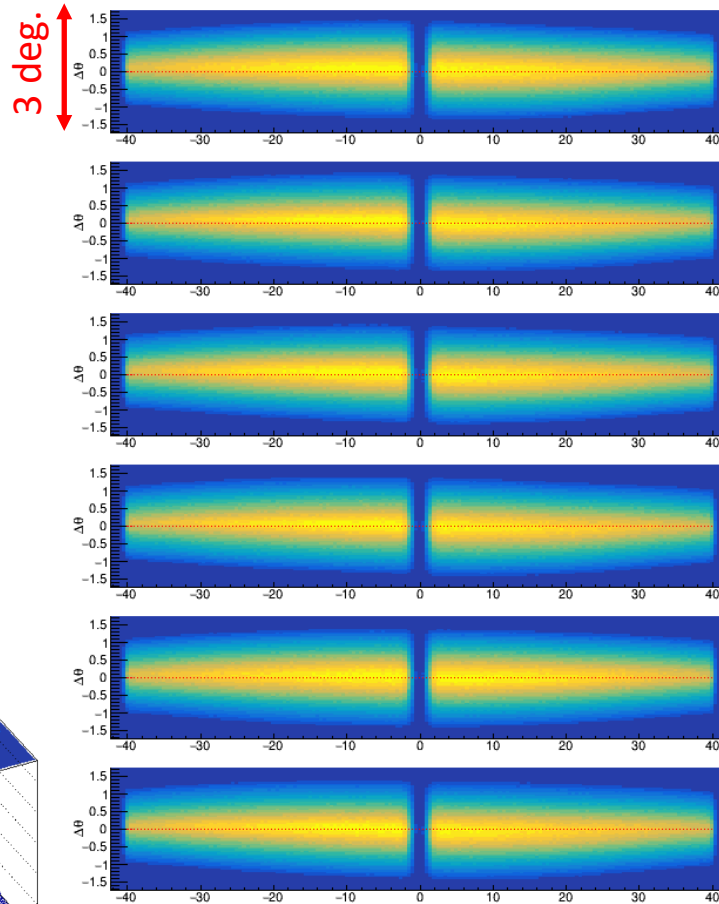
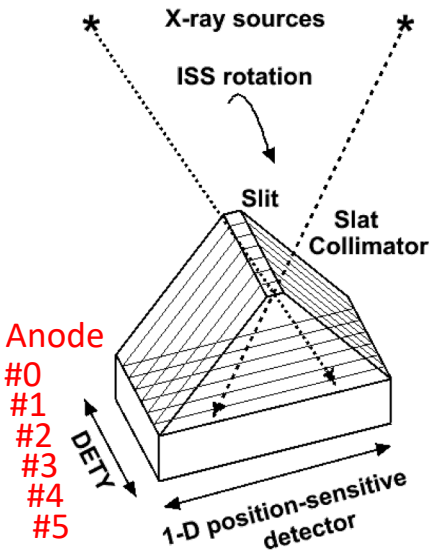
#1

#2

#3

#4

#5

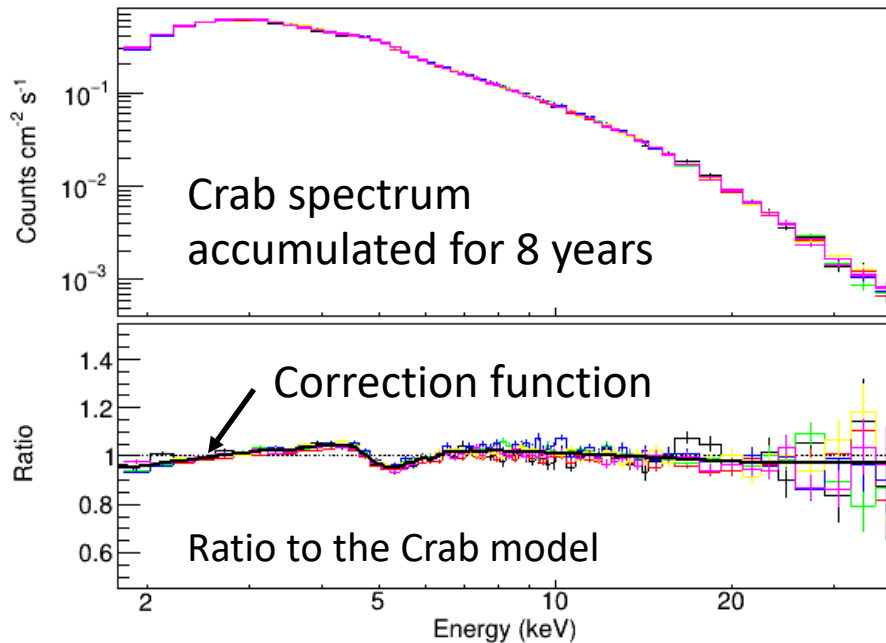


- Fit to refine alignment parameters Θ , Φ , Ψ , and PHA ratio-DETX relation
- Source localization accuracy became ~ 0.1 deg.

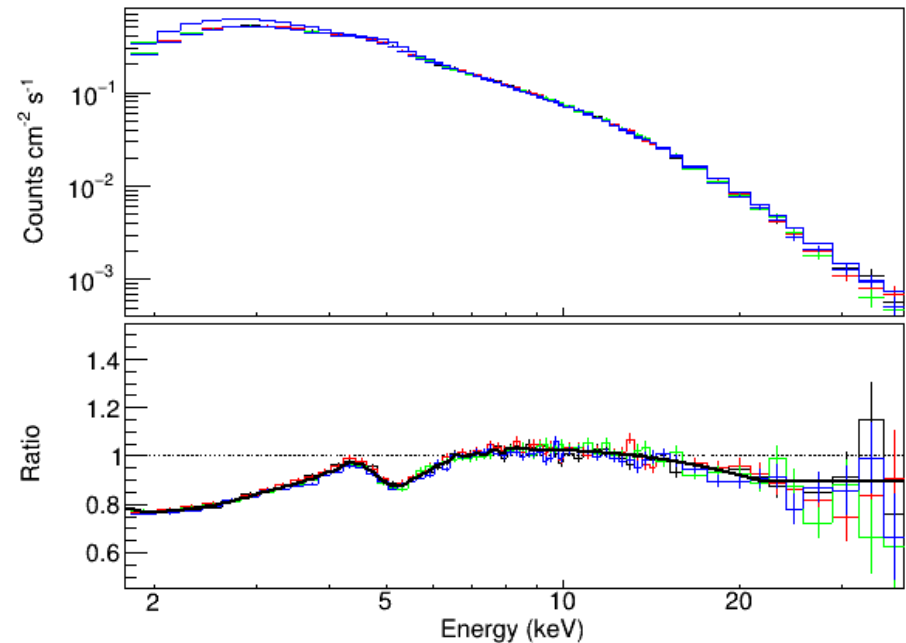
Effective area and Energy-PHA response

- Correction from the ground RMF measured at HV=1650V

GSC_4: HV=1650V

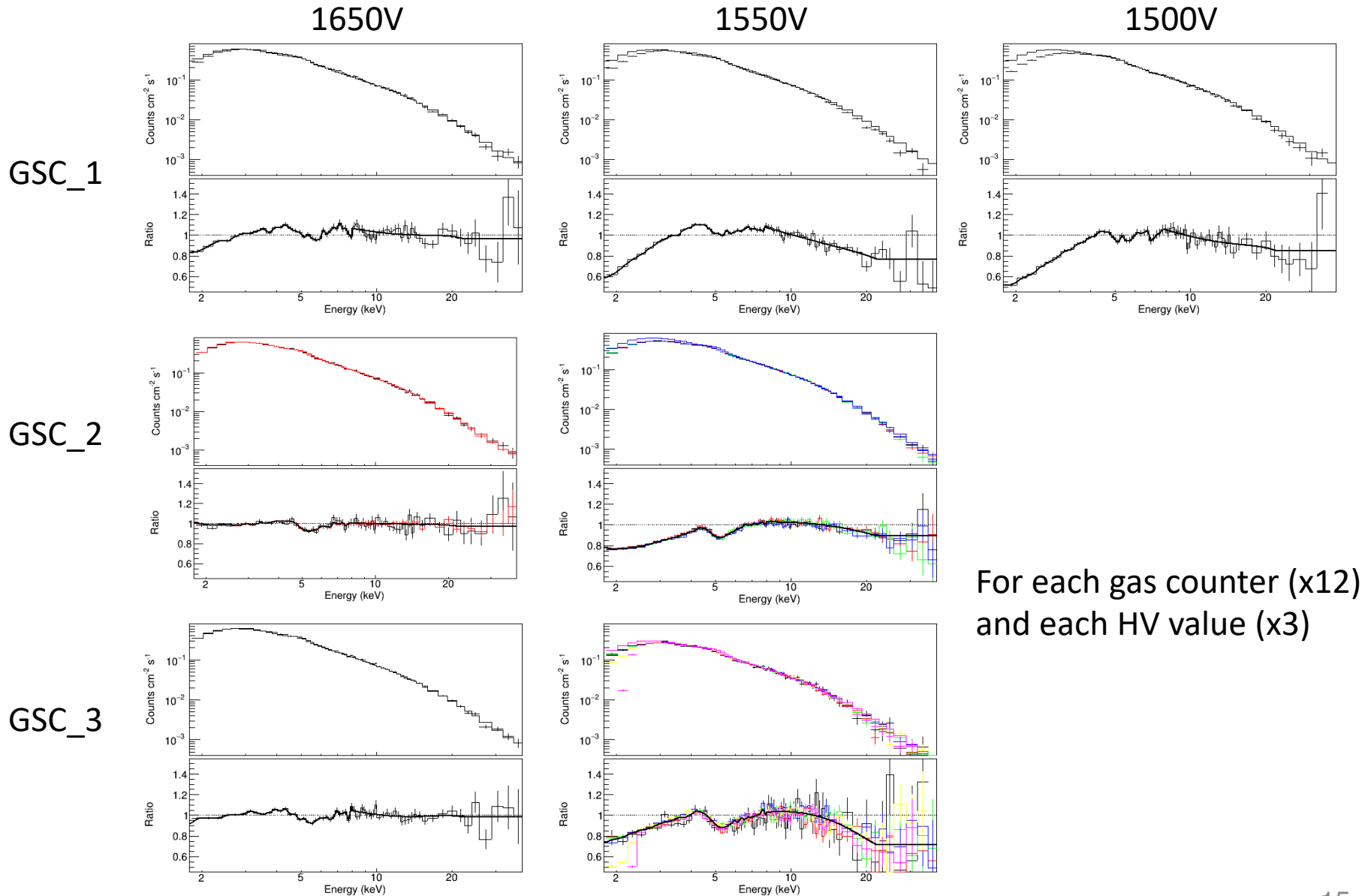


GSC_2: HV=1550V

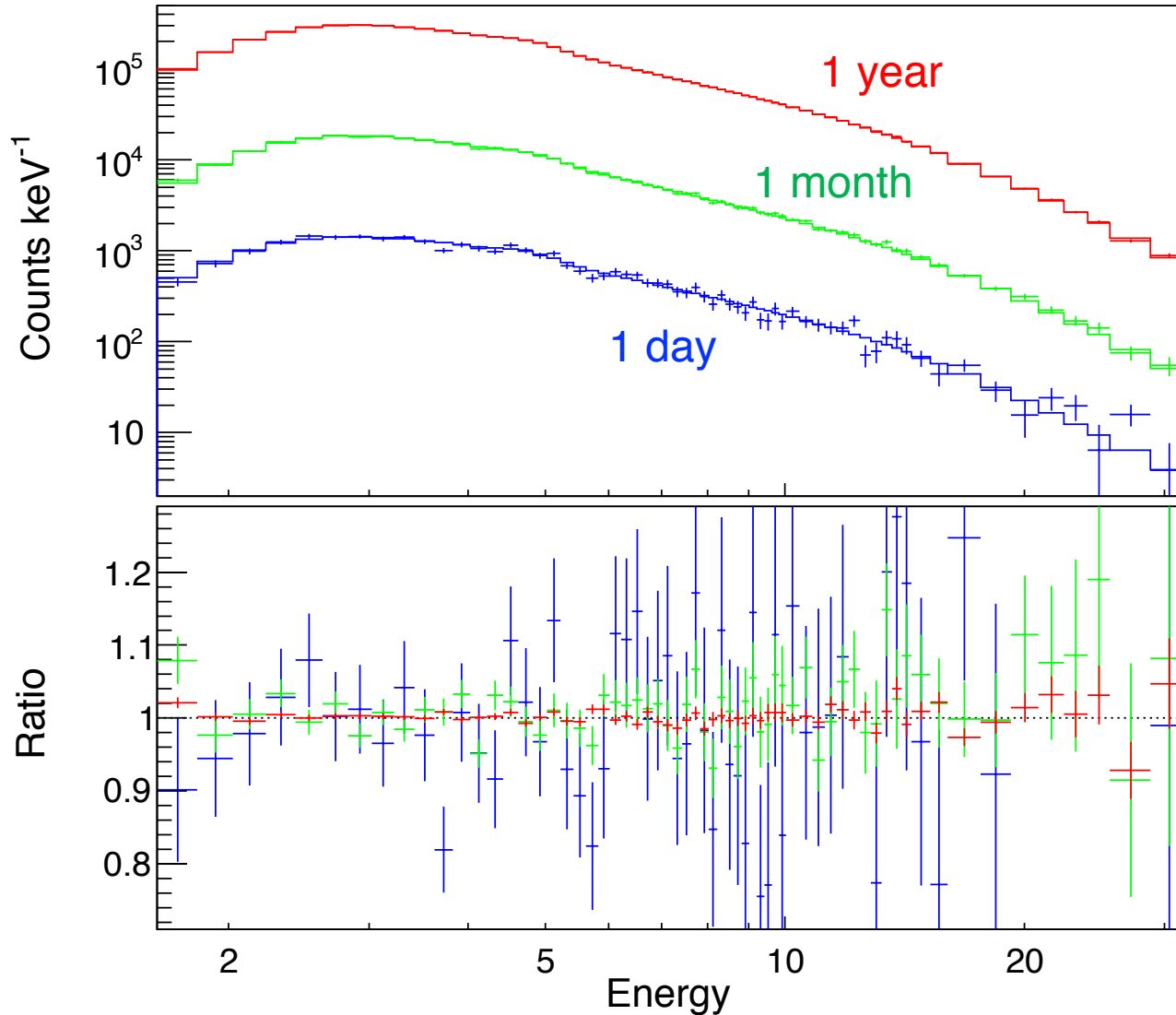


As for good GSC units, the average RMF is calibrated in a precision of 1-2 %.

Response correction function



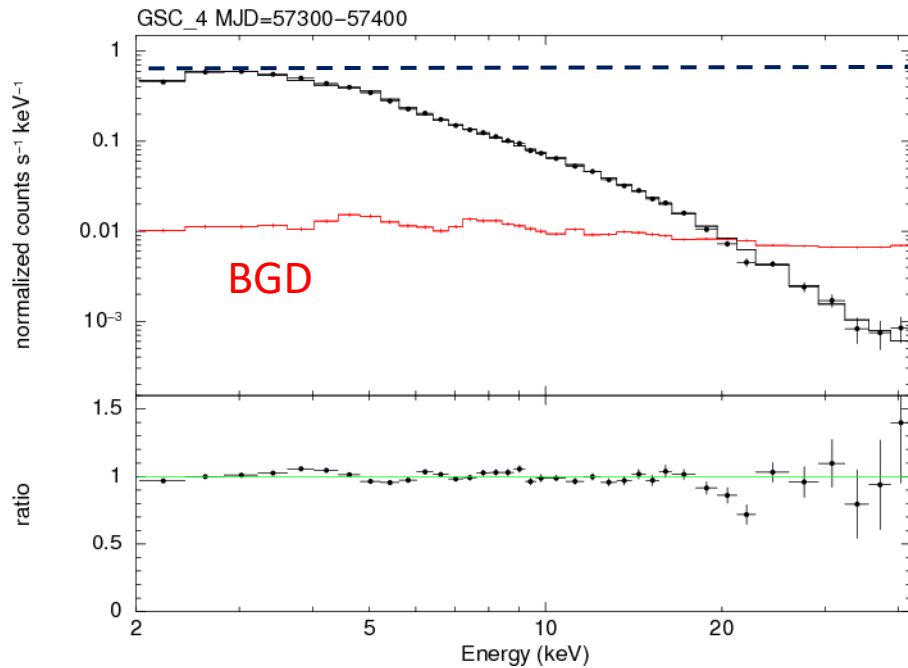
1-day 1-month 1year Crab spectrum



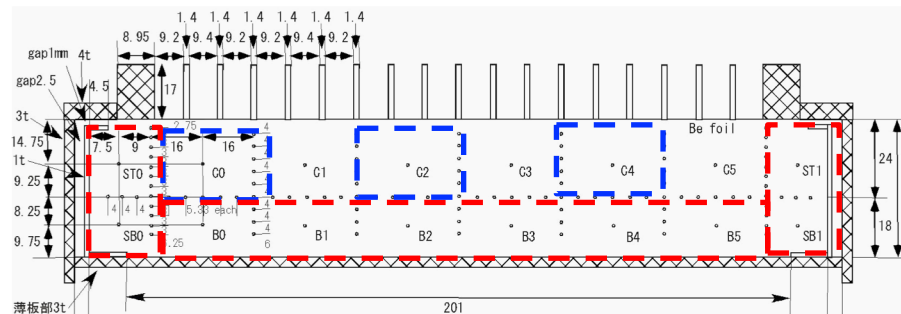
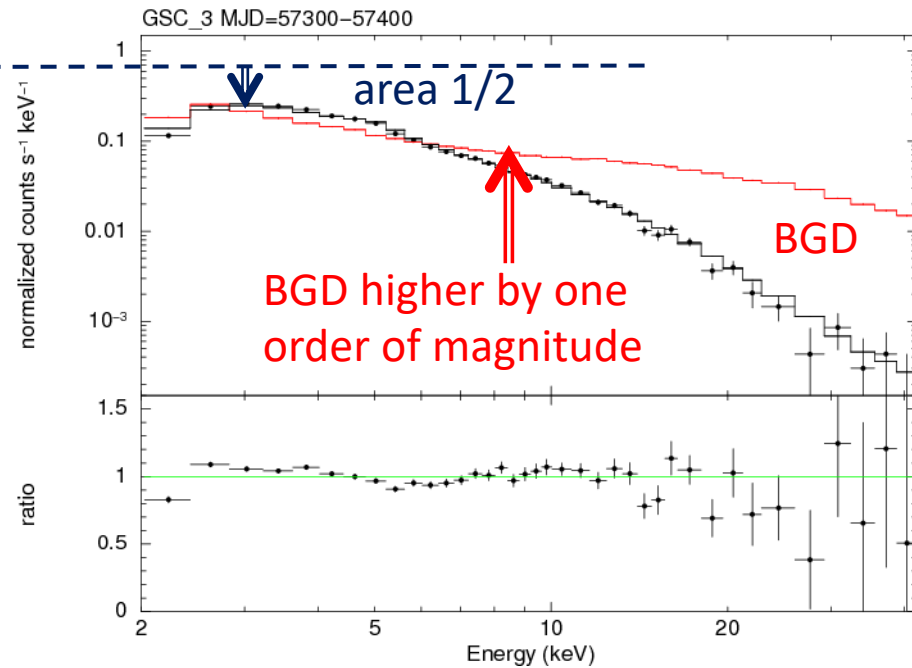
1-year Crab data reaches ~1% statistical precision.

Response of GSCs with a fractured anode (GSC_3, 6)

GSC 4: normal detector



GSC 3: half area, no veto



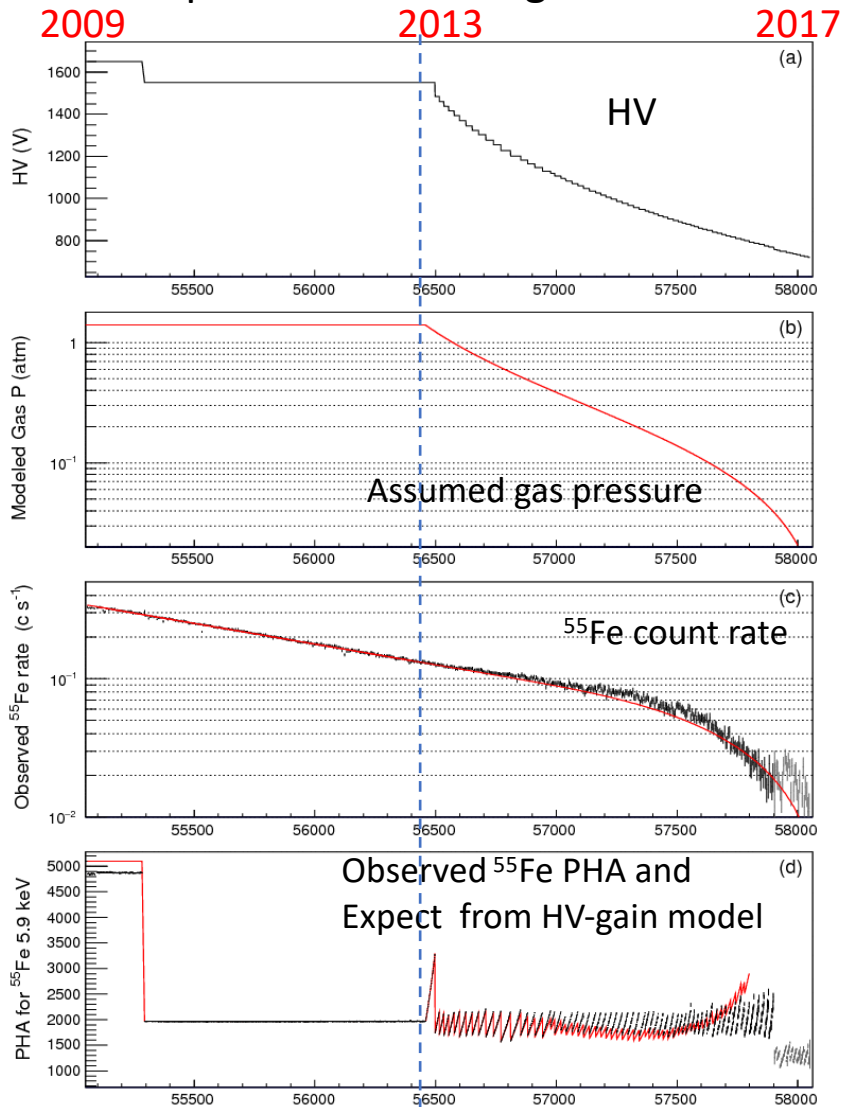
Alive anode cells

Malfunctional cells

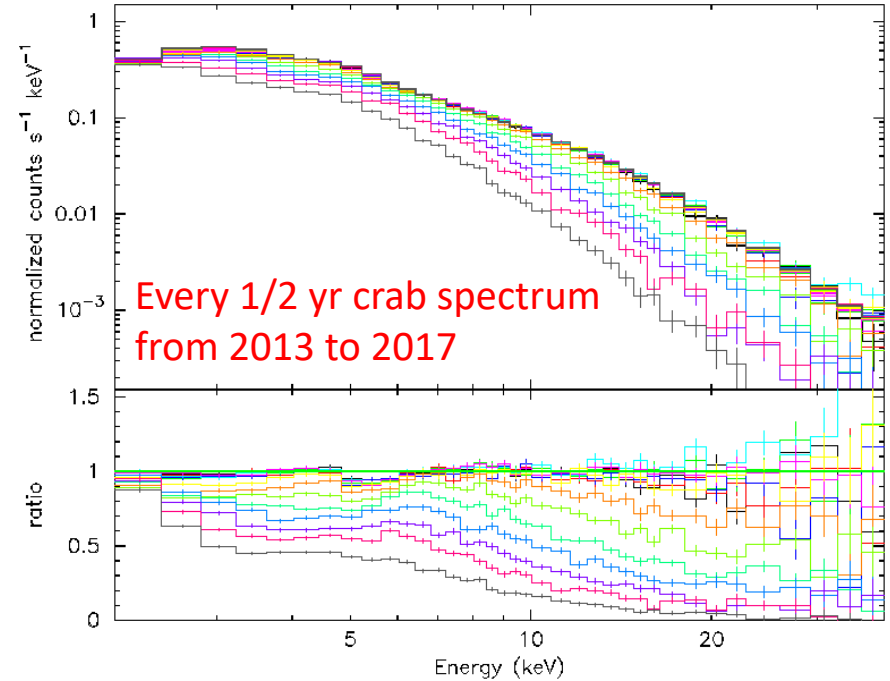
Gas counter cross section

Response of GSC_0 after gas leak

Gas pressure modeling

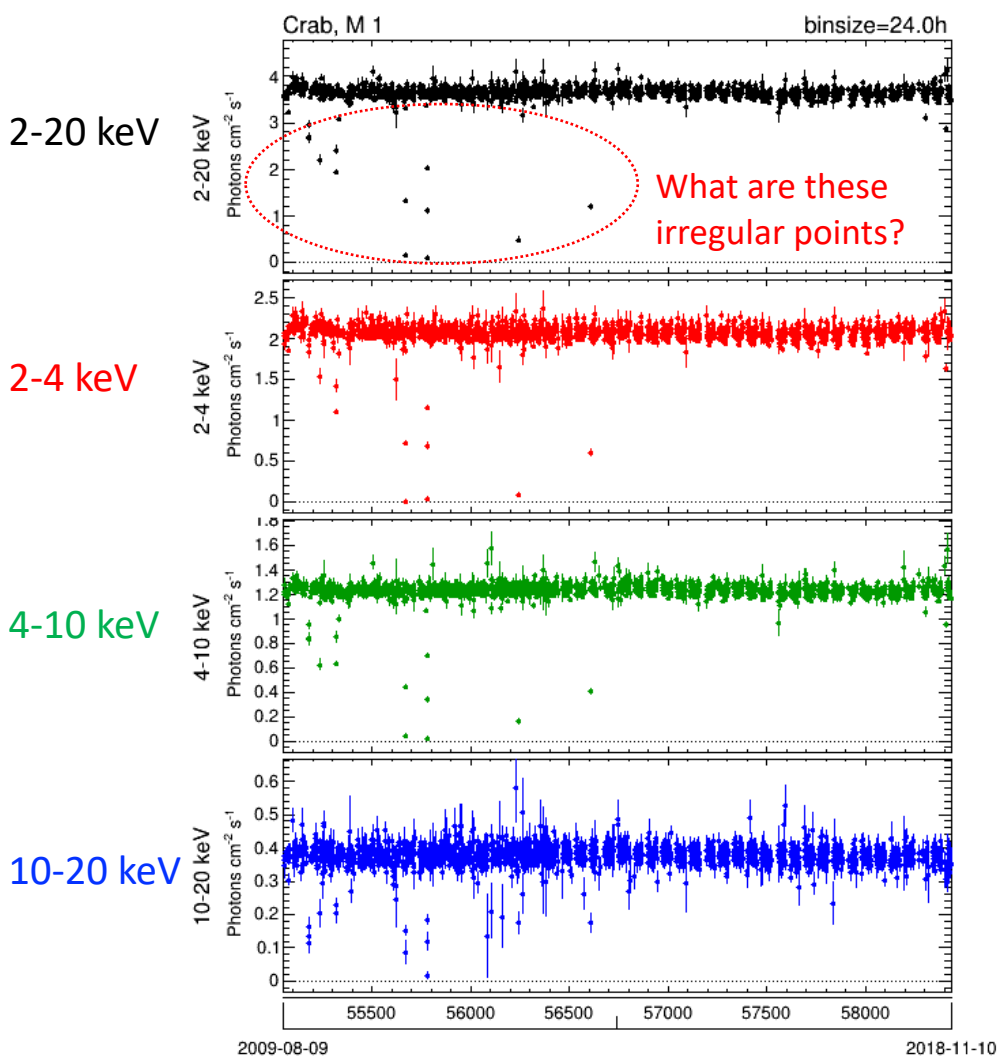


Degradation of observed Crab spectrum

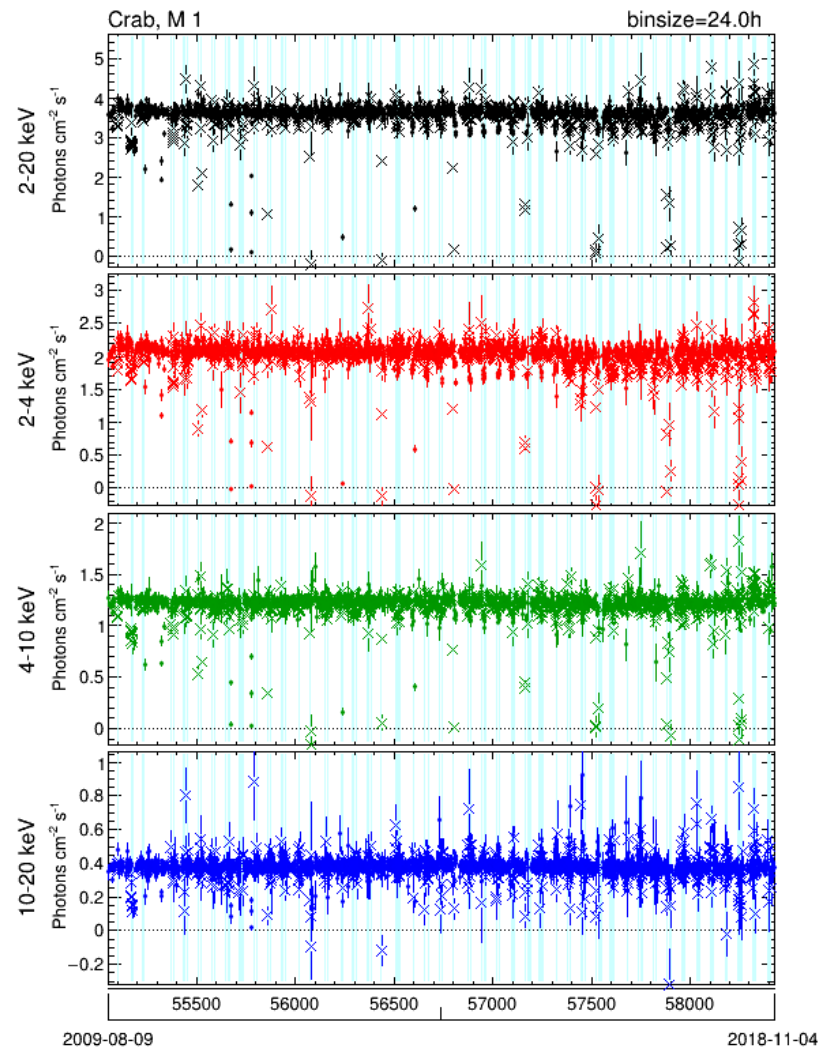


Crab light curve for 9.5 years (~3500 d)

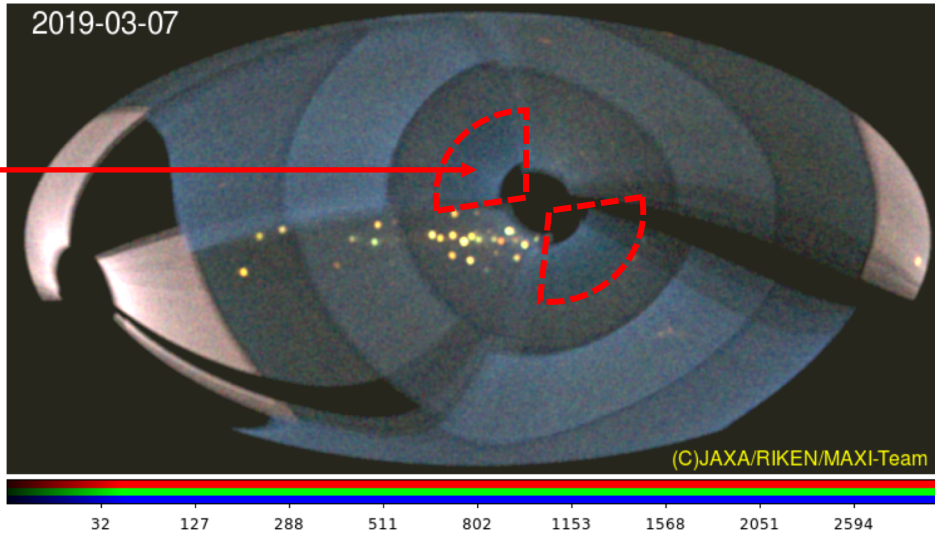
With good GSC units



With degraded GSC units



What caused the eclipse-like feature ?

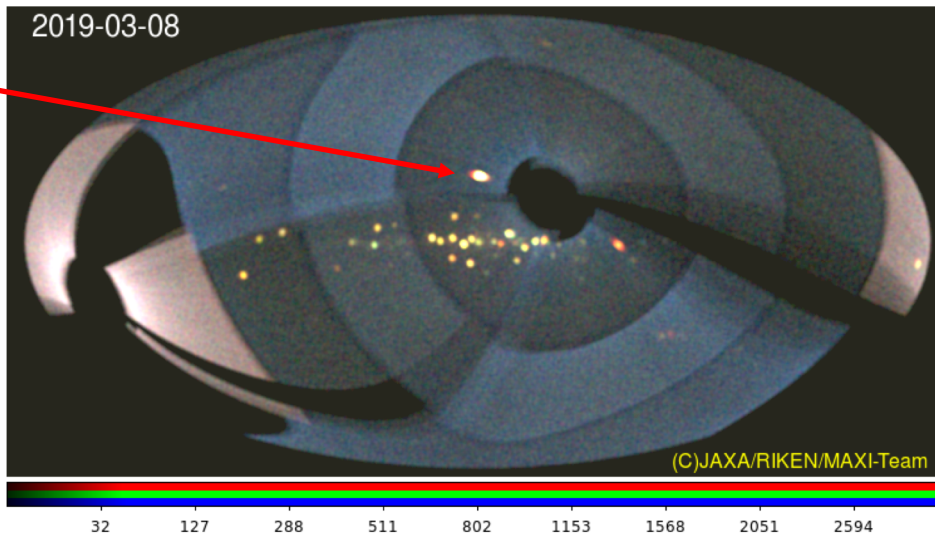


2009-03-07



2019-03-08

Undocked



One example.
Careful inspections
are still required.

Summary

- GSC calibration
 - Thanks to the ~10-years data
 - Position response accuracy reach ~0.1 deg
 - Effective area calibration of good GSC units reached ~2% precision
 - Remaining issues
 - Response of limited-function detectors including
 - Gas leak
 - Malfunctional anode
 - FOV Interference by solar-battery paddles, ...