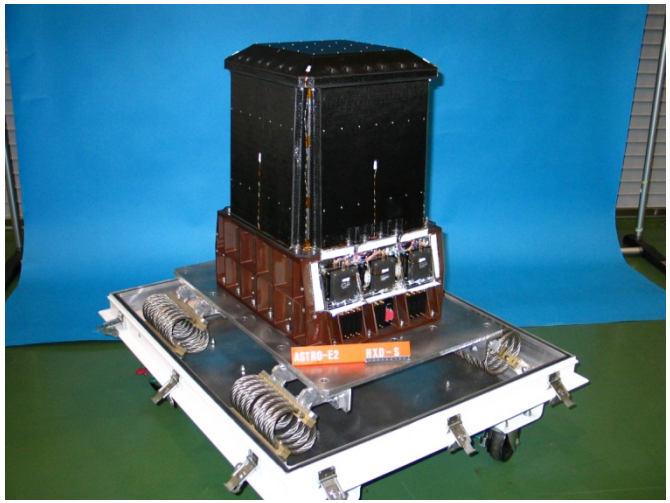


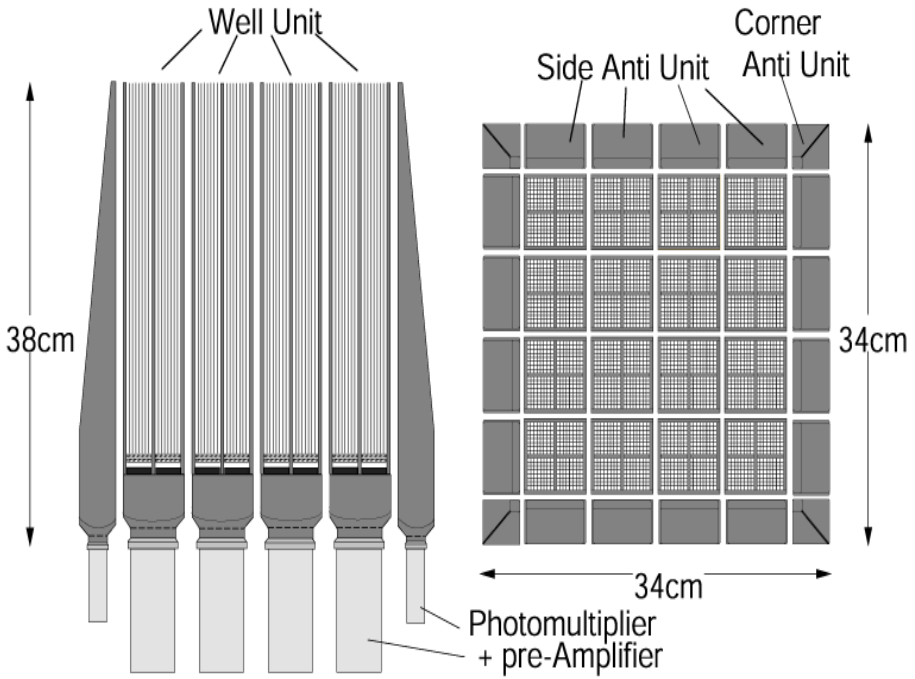
Calibration Status of the *Suzaku* HXD (major updates since the previous meeting)

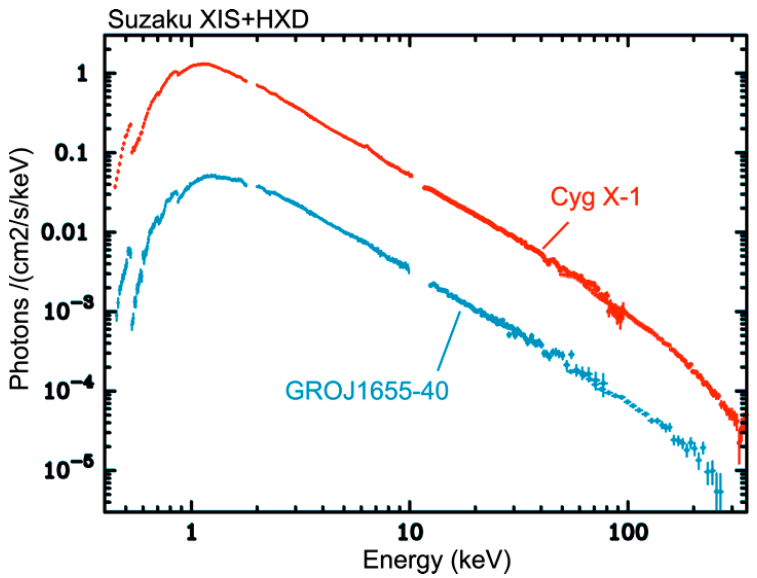
M. Kawaharada (RIKEN)

on behalf of the HXD team

2008/05/19 3rd IACHEC meeting @Schloss Ringberg, Germany

Hard X-ray Detector





64 PIN-Si diodes : 10-70 keV, dE~4keV(FWHM)

16 well-type phoswich (GSO) : 40-600 keV

Wide-band All-sky Monitor (WAM) as a GRB detector

Changes from the ver1 to ver2

4 epochs defined by PIN bias voltages and lower energy threshold.

Epoch1 2005/8/17 – 2006/5/25 ; All 500V, ae_hxd_pinthr_20060727.fits

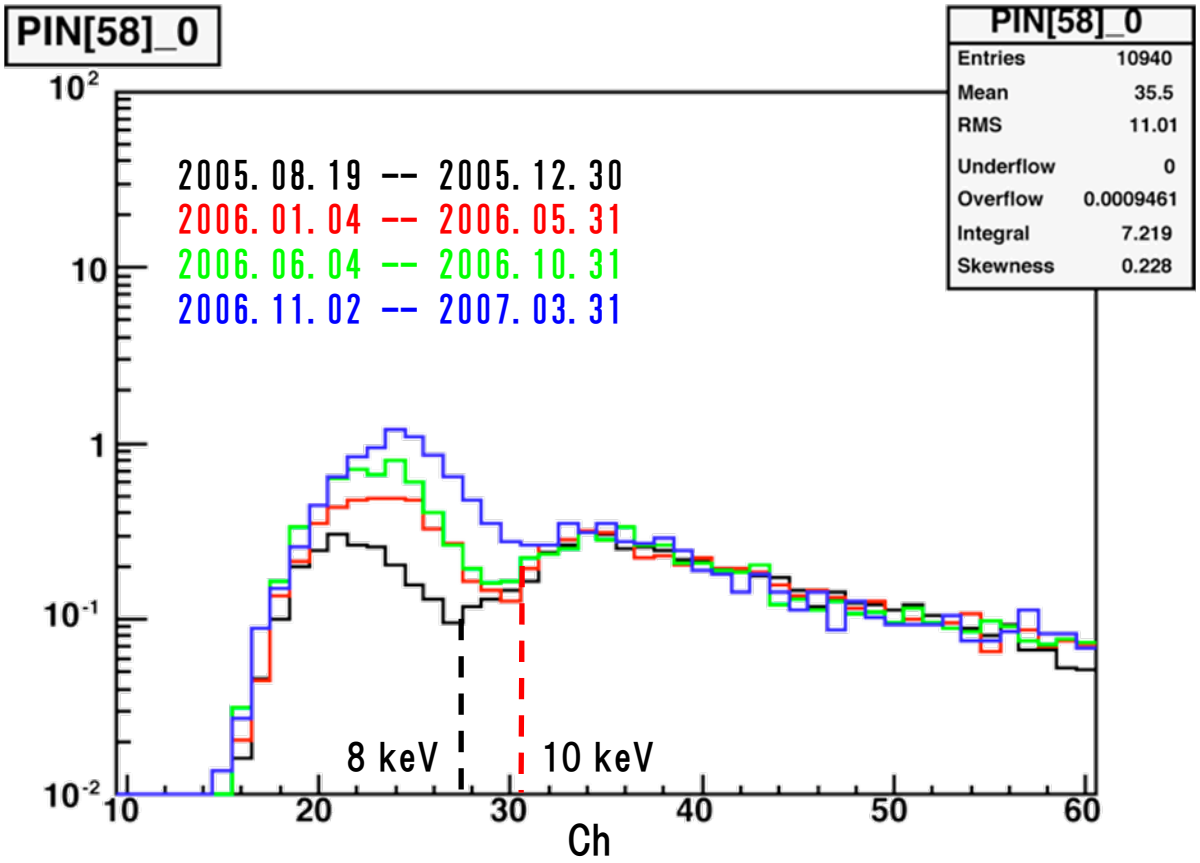
Epoch2 2006/5/25 – 2006/10/3; W0 400V , ae_hxd_pinthr_20060727.fits

Epoch3 2006/10/3 – 2007/7/28; W0 & W1 400V, ae_hxd_pinthr_20070522.fits

Epoch4 2007/7/28 - ; PIN lower threshold changed. ae_hxd_pinthr_20070822.fits

- **Responses and NXBs are available for all the 64 PINs, regardless of the bias voltage.**
- **PIN lower energy cutoffs are optimized for each epoch.**
- **GSO NXBs are available for all the GO data.**

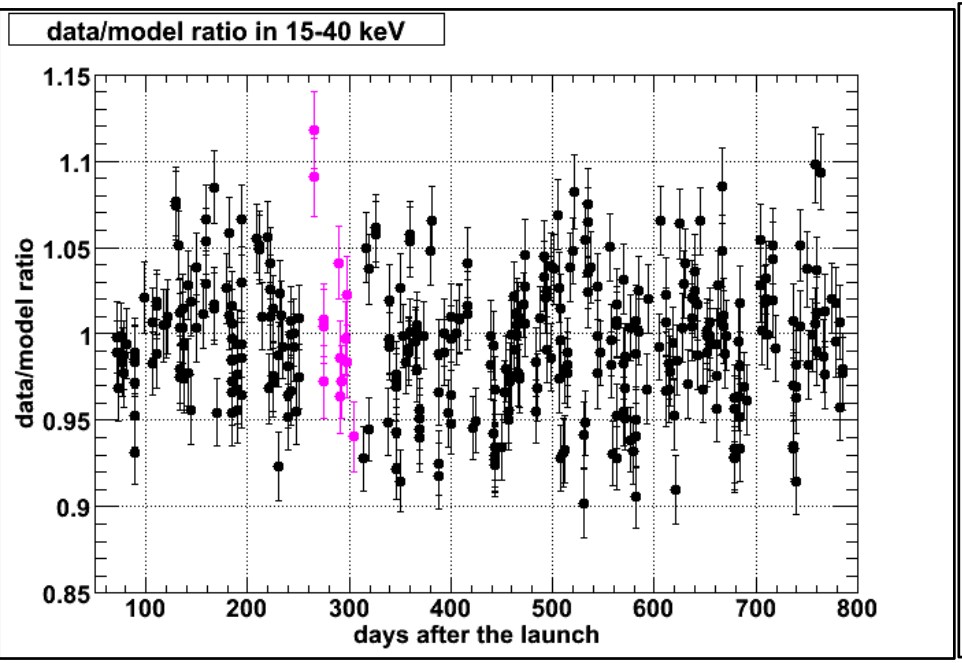
PIN LD optimization

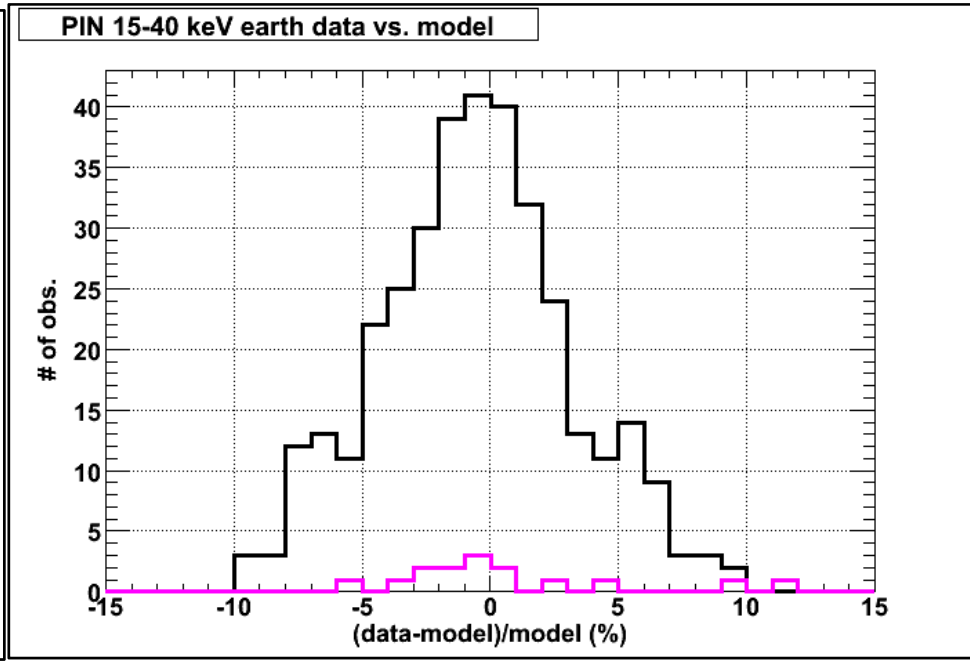


- In <10 keV, noise is gradually increasing probably due to the lattice defect in PIN diodes made by cosmic ray particles.
- The noise is cut by “hxdgrade” on the ground.
- Responses and NXBs are made to match this cut.
- Change of PIN LD (making another epoch) is discussed for recent obs.

Ver2 PIN NXB reproducibility

Suzakumemo-2007-09

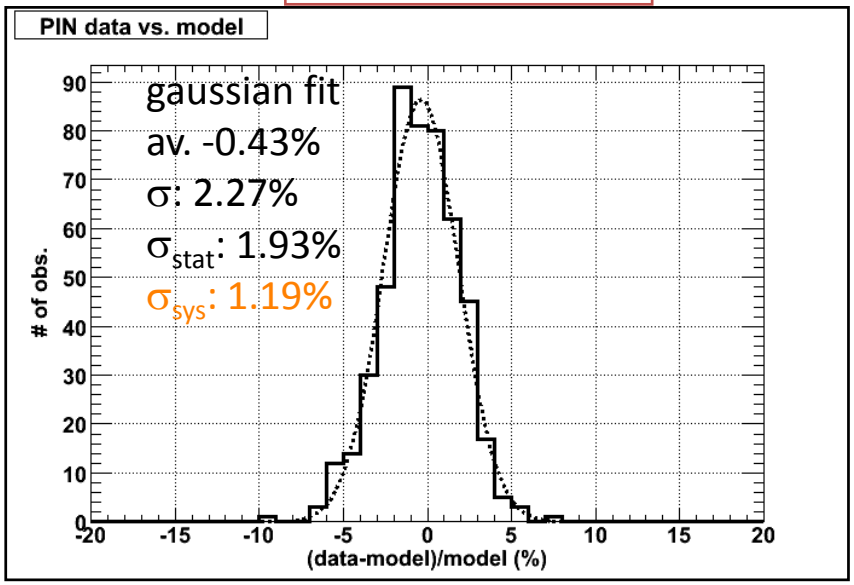




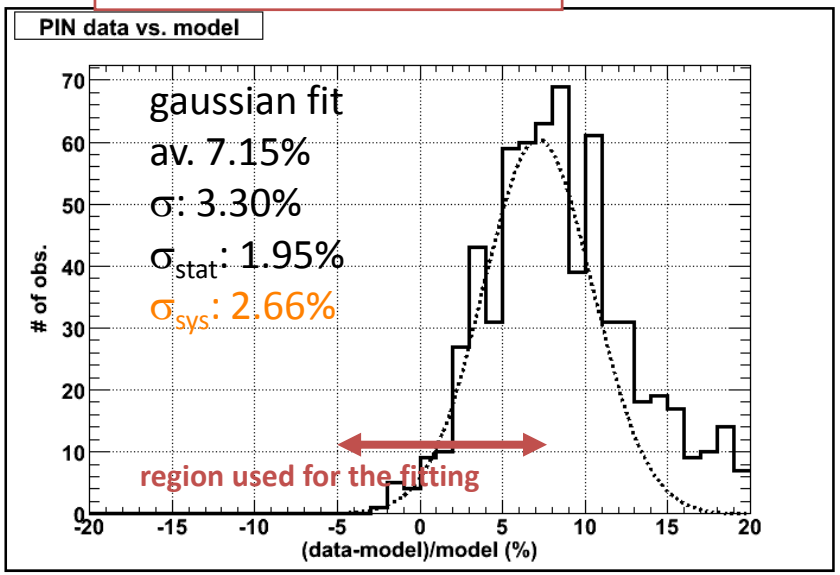
- Each point is 10 ks in 15-40 keV.
- purple: data in period when bgd_d is recommended (2006-03-23 - 2006-05-13)
- average = -0.49%, σ=3.8% (σ_{stat}=2.0%)
- σ_{sys} = 3.2%

Upcoming New PIN NXB (bgd_d)

Earth 15-40 keV, 10ks



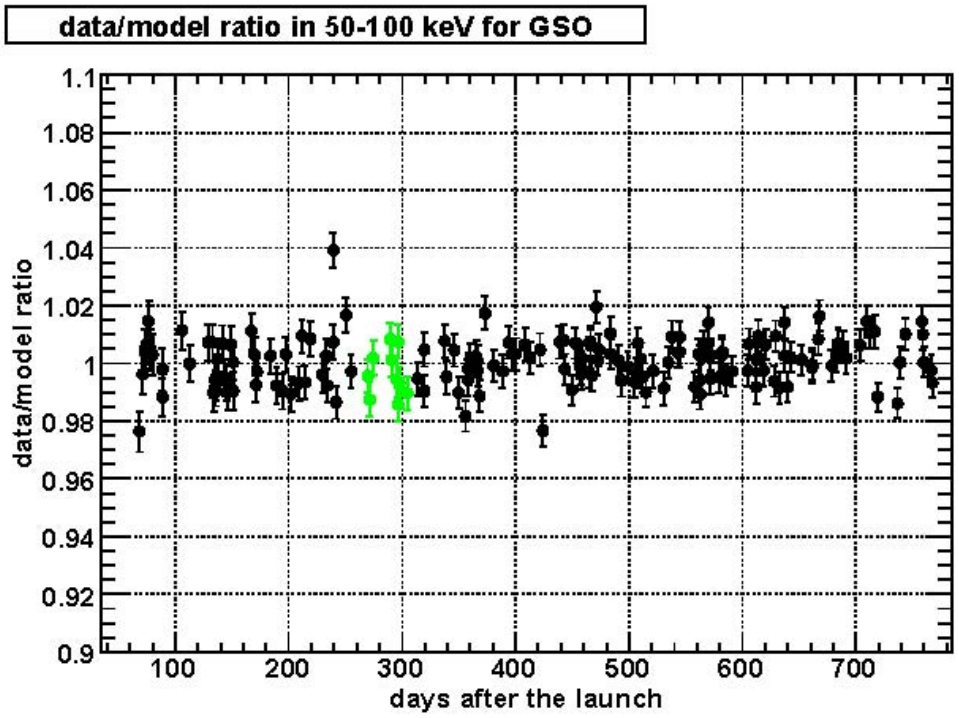
Sky Obs. 15-40 keV, 10ks

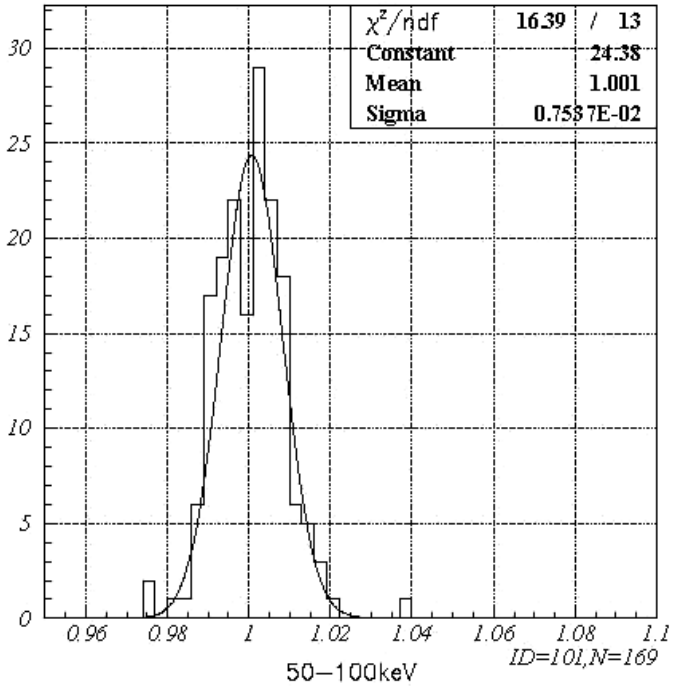


- New PIN NXB (bgd_d) will be delivered soon (maybe in this month), along with suzakumemo.
- Reproducibility is drastically improved. σ_{sys} = 1.2% for earth data.
- However, reproducibility for dark sky data (no strong emission in XIS) is worse.
- Contamination of hard point sources in PIN FOV is suspected.
- PIN bgd_d will be delivered 1.5 month after the observation like GSO NXBs.
- Current version (bgd_a) will be also provided for quick analysis.

GSO NXB reproducibility

Suzakumemo-2008-01



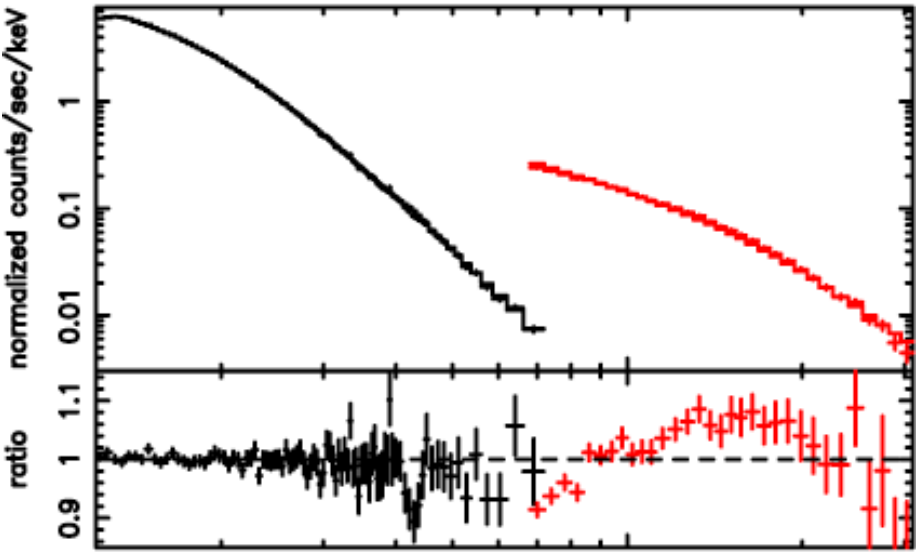


- each point is 10 ks earth data in 50-100 keV and 100-200 keV.
- average = 0.1 and 0.1%,
- σ=0.75 and 0.69% (σ_{stat}=0.40 and 0.36%)
- σ_{sys} = 0.64 and 0.59%

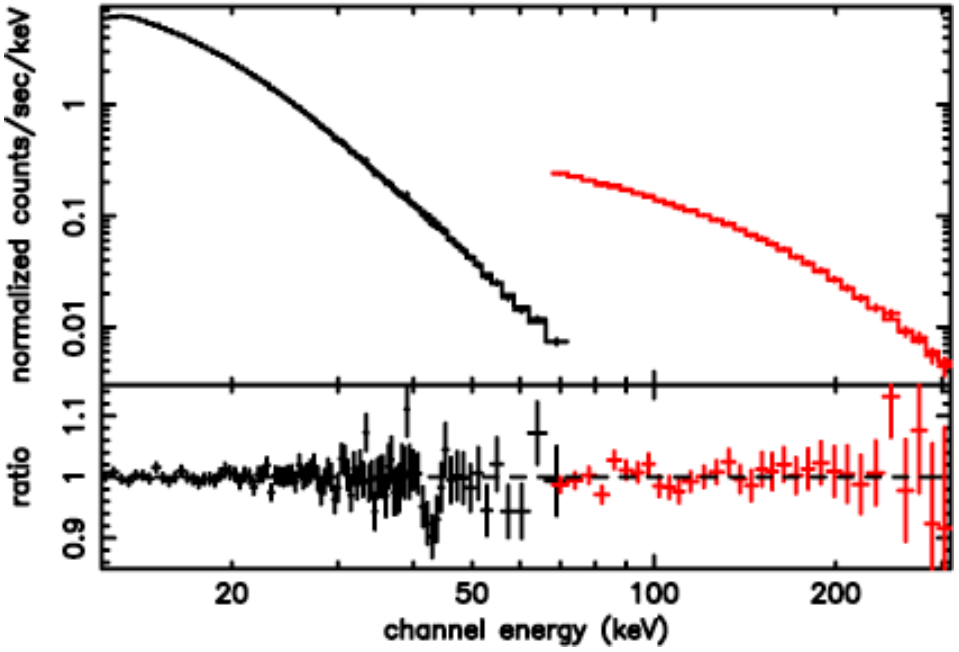
GSO response and GSO arf

Crab (2007/03/20 HXD nominal) spectrum

Without GSO arf



with GSO arf

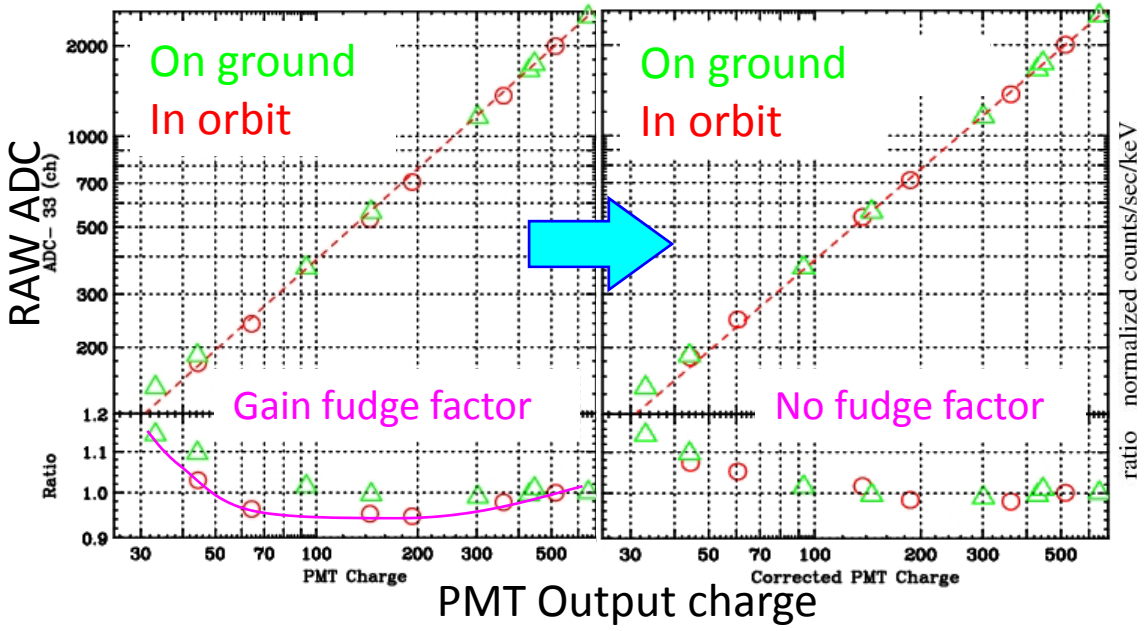


- Cross normalization PIN : GSO = 1: 0.80, and residual ±10% .
- We prepared fudge GSO arf file as,

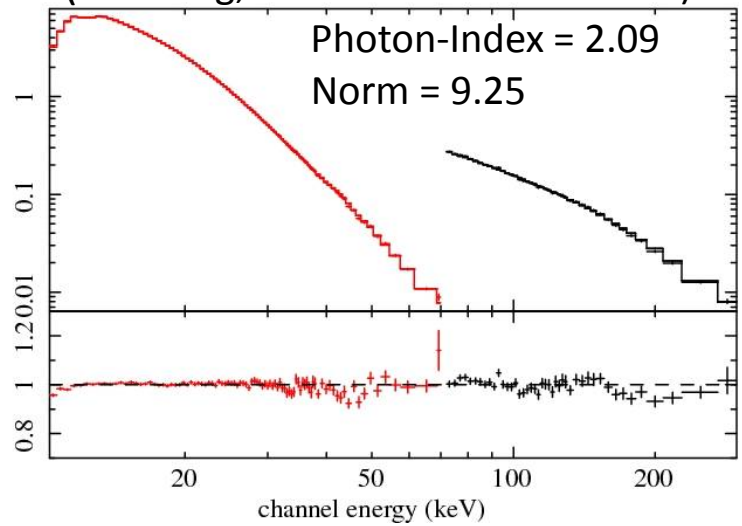
  C(E) = 1.36 * (E/100)^0.65 * exp(-E/230) @ XIS nominal

  1.18 * (E/100)^0.55 * exp(-E/320) @ HXD nominal
- GSO arf just adjusts the GSO spectrum to fit the Crab with a single PL.

Future improvement of GSO response

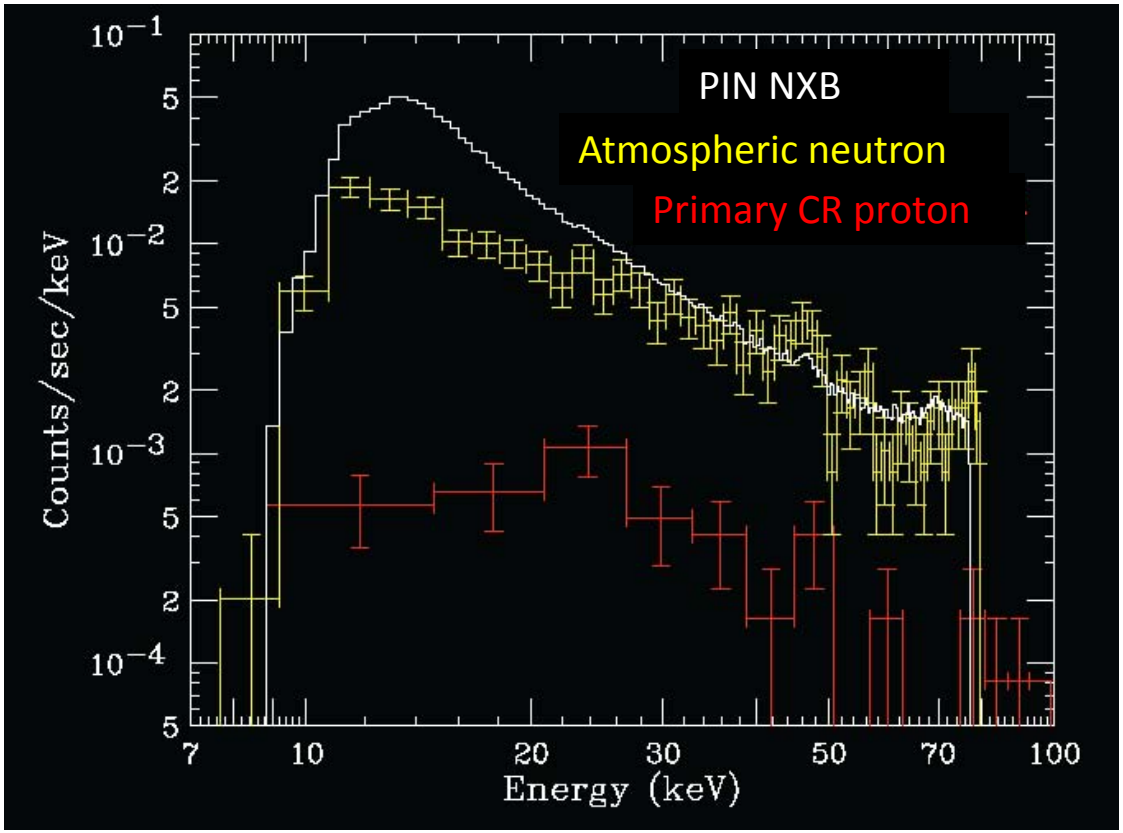


Crab with a GSO rsp tested
(no fitting, PIN norm corrected 15%)

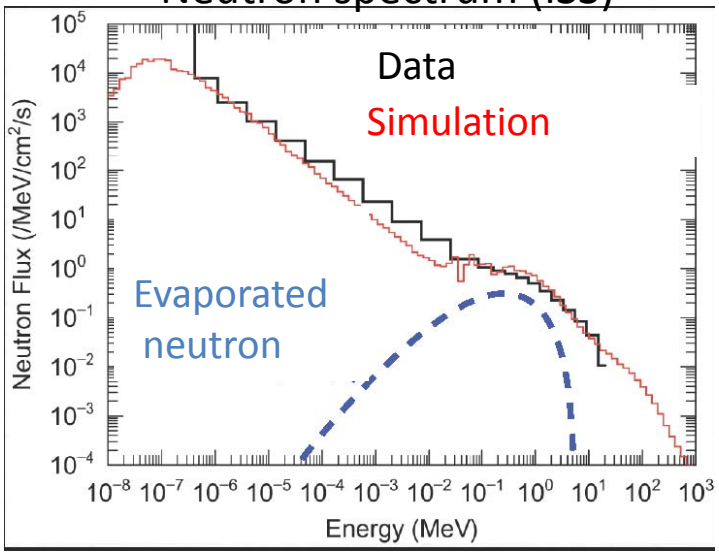


- **Energy (PMT charge) of activation lines are re-calculated. The corrected curve becomes consistent with the ground calibration.**
- **Improvement of GSO response is now going on.**
- **The new GSO response, together with new CALDB files and new GSO NXBs, will be delivered this summer (after 2008 July).**
- **The empirical correction will not be needed, or at least become smaller.**

Origin of PIN NXB



Neutron spectrum (ISS)

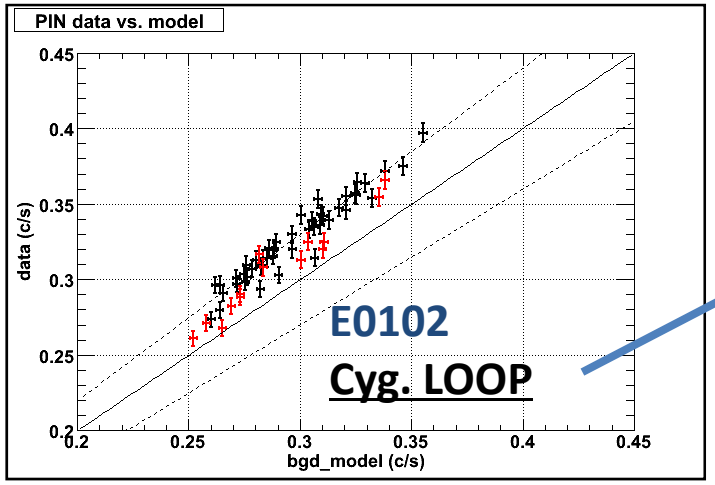


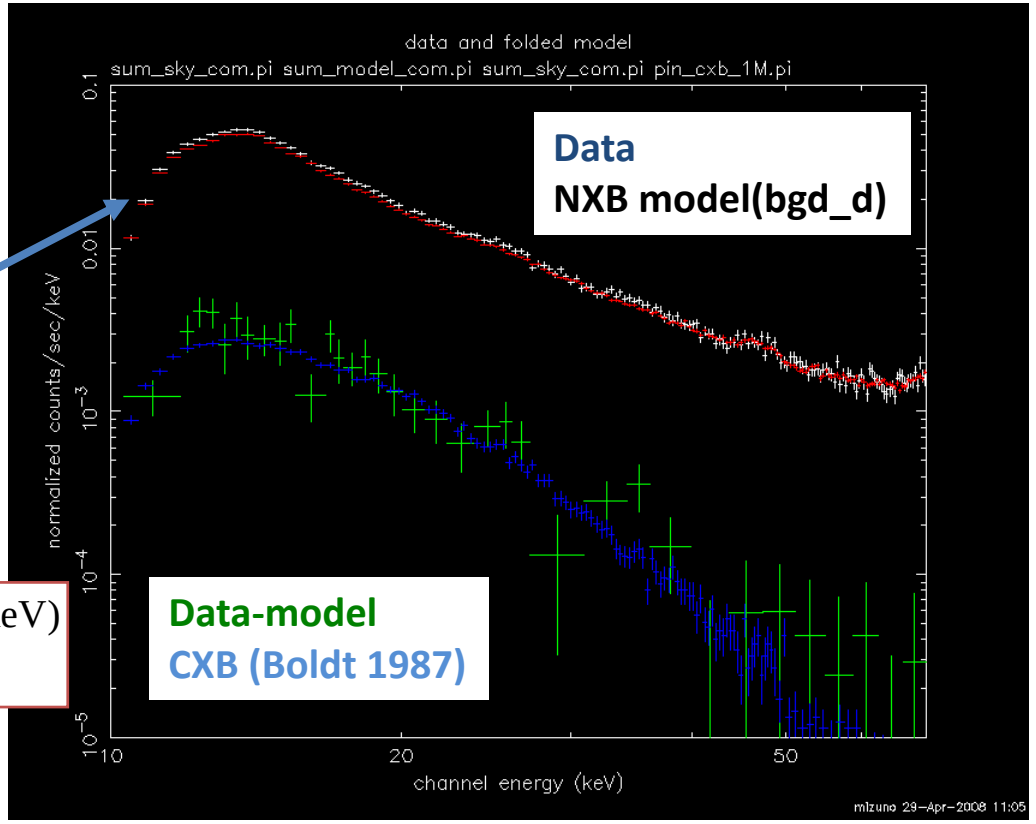
- PIN NXB is dominated by a component which varies with COR.
- PIN NXB cannot be fully explained by primary cosmic rays.
- Neutrons from the earth atmosphere is suspected to be the primal contributor.
- PIN NXB may be further improved by monitoring the neutron flux.

Thank you

(photo; 2004/04/30 HXD completed)

Absolute CXB Level

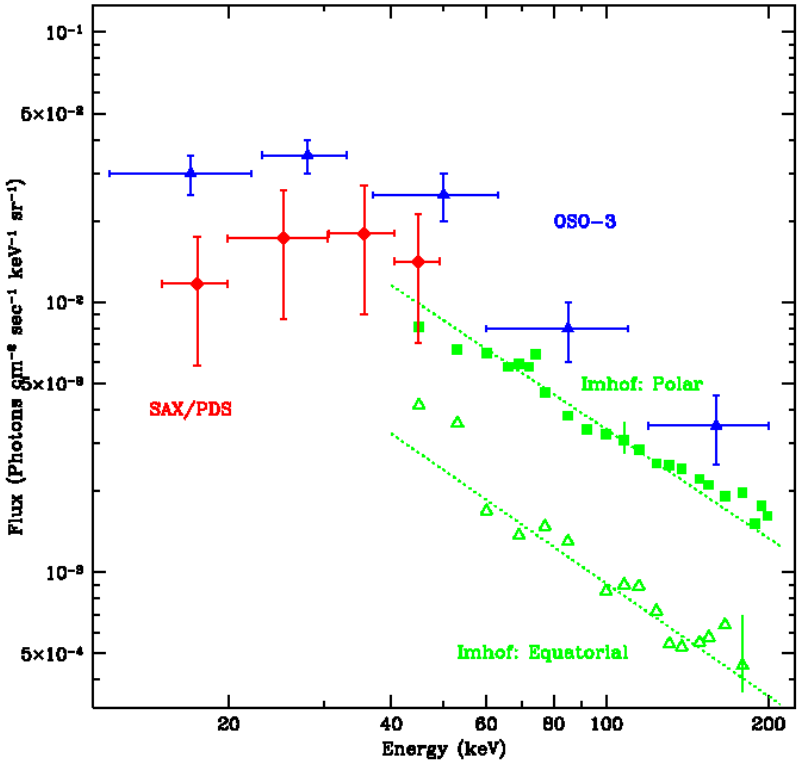


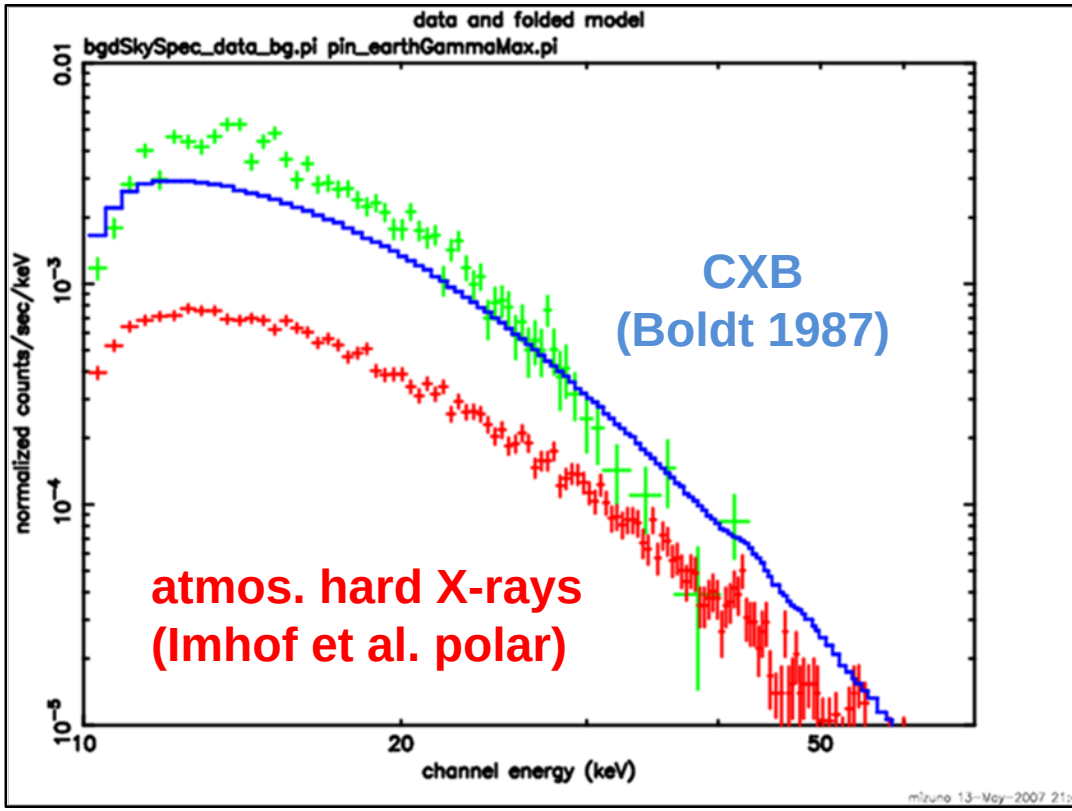


$$\mathrm{CXB}(E) = 9.412\times10^{-3}\times\left(E/\mathrm{keV}\right)^{-1.29}\times\exp(-E/40\mathrm{keV})$$
$$[\mathrm{p/s/cm^2/keV/FOV}]$$

- Summed spectrum of Cyg. LOOP multi-pointing data (240ks) vs. NXB model.
- If Cyg. LOOP obs. is free from hard X-ray sources, this can be regarded as an absolute CXB level.
- The residual agrees with CXB spectrum by Boldt (1987).

Effect of atmospheric hard X-rays

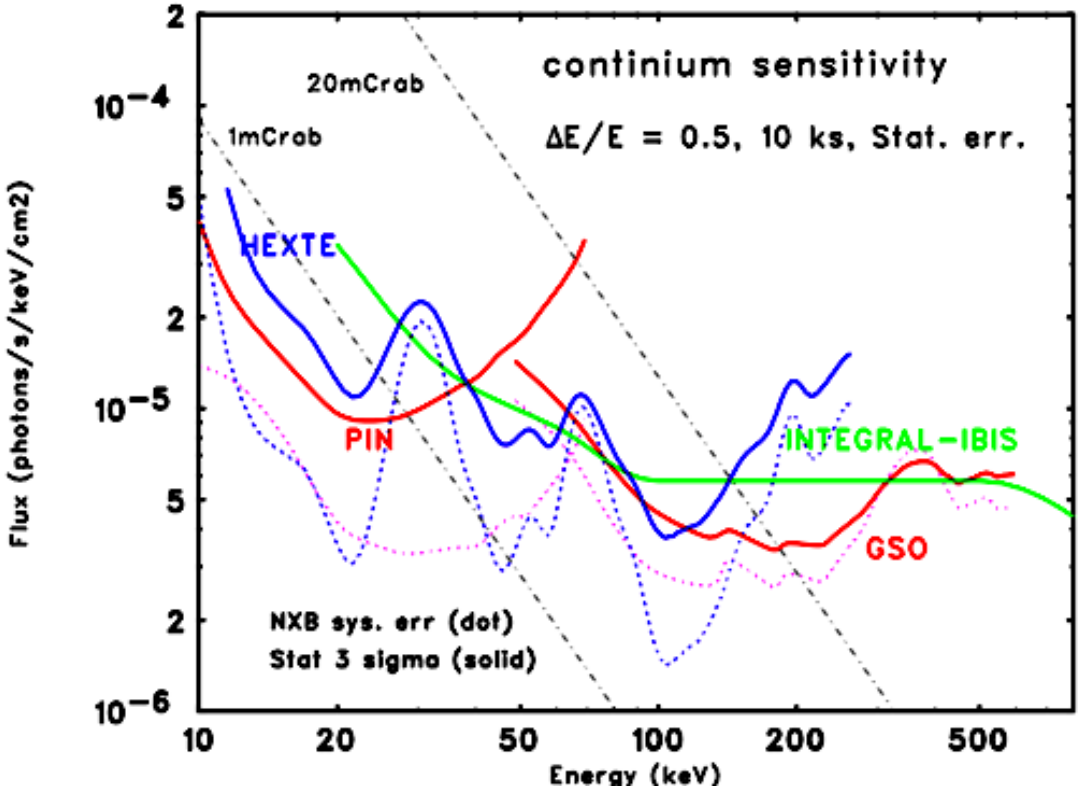




- If the result of imhof et al. is adopted, hard X-rays from atmosphere is ～1/3 of CXB, ～3% of NXB model.
- Current NXB may be ～3% overestimated by this atmospheric emission.

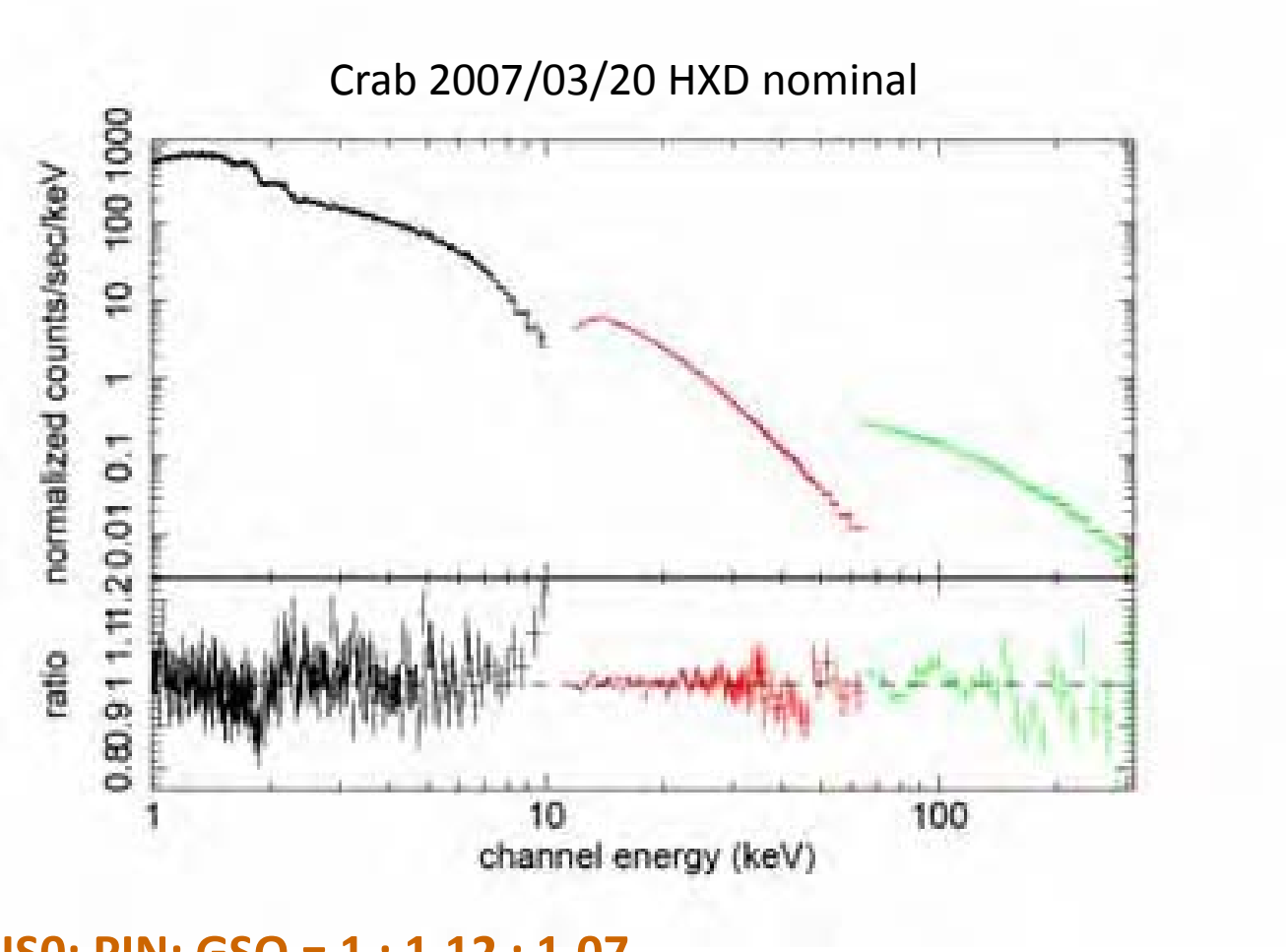
Current Sensitivity

Calculated Sensitivity for point source (10 ks exp.)



➢ **With relatively short (~10 ks) exposure, the HXD provides high sensitivity.**

Crab ; XIS and PIN and GSO



- **XIS0: PIN: GSO = 1 : 1.12 : 1.07**
- **NH = 0.33×10^{22}, Γ = 2.10, Norm = 9.54, χ^2/dof = 1.2**
- **2-10 keV 2.12E-8 erg/s/cm2, 20-50 keV 9.92E-9 erg/s/cm2**

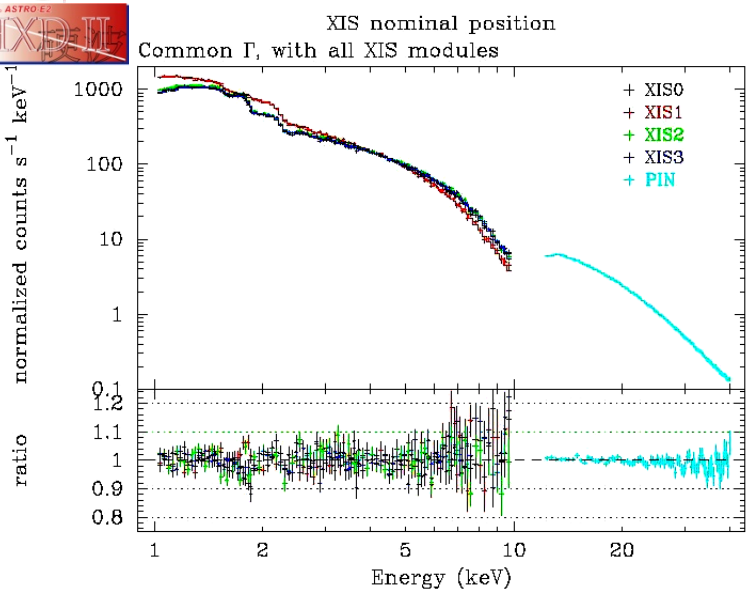
Crab cross cal. (IACHEC 2007)

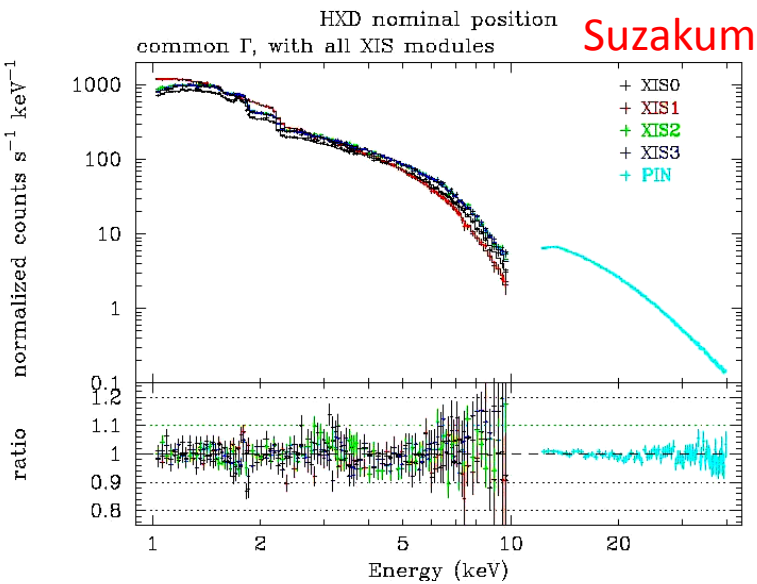
Satellite	Det	xsect	Abun	E-band for fit	N_H 10^{21}cm^2	ph. Index	Norm (2-10) 10^{-8}erg/cm^2/s	$\chi^2\nu$	Observed Flux (10^{-8}erg/cm^2/s) 0.5–2	2–10	20–50	50–100
Suzaku	XIS	bcmc	wilm	1.0-10.0	4.61±0.10	2.070±0.008	2.239±0.012	1.19	–	2.170	–	–
			angr	1.0-10.0	3.19±0.07	2.077±0.008	2.244±0.012	1.19	–	2.169	–	–
	PIN		angr	12.0-70.0	3.19 (fixed)	2.110±0.007	2.267±0.023	1.03	–	–	1.039	–
RXTE	HEXTE	bcmc	angr	20-240	3.19 (fixed)	2.087±0.008	1.929±0.027	0.99	–	–	0.928	0.657
XMM	pn	bcmc	angr	1.0-10.0	$2.41^{+0.03}_{-0.07}$	$2.107^{+0.004}_{-0.009}$	$1.876^{+0.003}_{-0.006}$	1.31	–	1.827	–	–
INTEGRA	SPI	bcmc	angr	22-100	3.19 (fixed)	2.123±0.014	±	0.7	–	–	1.04	0.73
RXTE	PCA			3-50	3.19 (fixed)	2.114	2.4018	2.63	–	2.320	1.09	–
Swift	BAT	bcmc	angr	30-100	3.19 (fixed)	2.10±0.06	1.74±0.25	0.82	–	–	0.82	0.57

ASCA 2.16E-8 erg/s/cm2 2-10 keV Kushino et al.
BeppoSAX 9.22E-9 erg/s/cm2 20-50 keV Frontera et al.

Cross normlization; XIS and PIN

Suzakumemo-2007-10





XISnominal

Detector hline	N_H [10^{22}cm^{-2}]	Γ	const	Norm[a]	Flux [b]	χ^2_ν (dof)
XIS0	0.311±0.008	2.080±0.006	1.000 (fix)	9.89±0.10	2.190	1.56 (476)
XIS1	0.290±0.007		1.026±0.009			
XIS2	0.288±0.008		0.999±0.009			
XIS3	0.321±0.008		0.984±0.009			
PIN	0.3 (fix)		1.086±0.012			

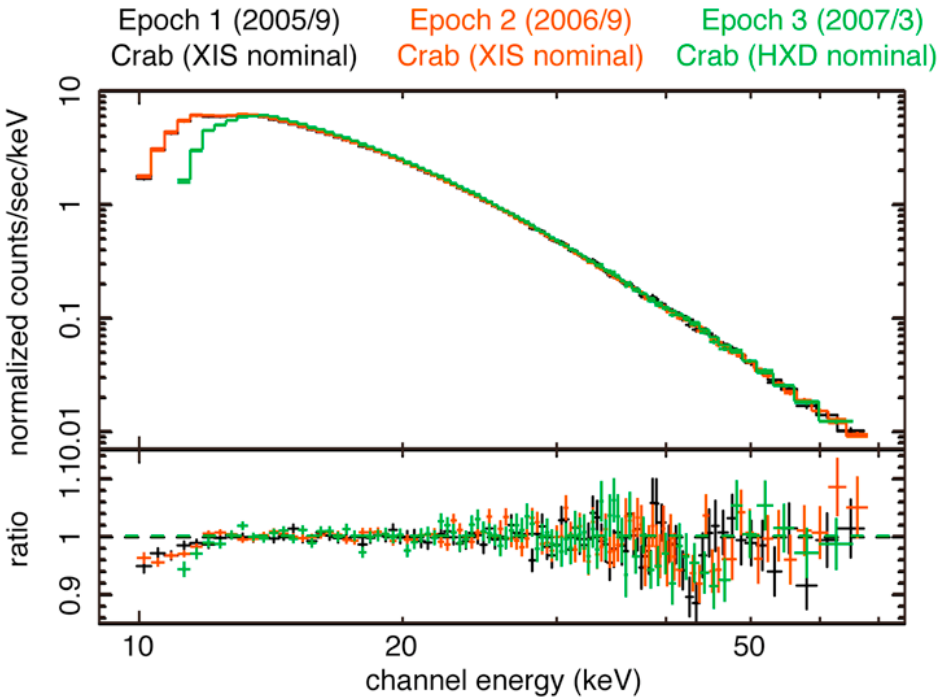
HXDnominal

Detector hline	N_H [10^{22}cm^{-2}]	Γ	const	Norm[a]	Flux [b]	χ^2_ν (dof)
XIS0	0.300±0.010	2.073±0.006	1.000 (fix)	9.21±0.10	2.063	1.43 (476)
XIS1	0.282±0.008		1.065±0.011			
XIS2	0.278±0.009		1.035±0.011			
XIS3	0.297±0.009		1.067±0.011			
PIN	0.3 (fix)		1.132±0.014			

a: photons cm^{-2}s^{-1}keV^{-1} at 1 keV.
b: 10^{-8}erg cm^{-2}s^{-1} in 2-10 keV.

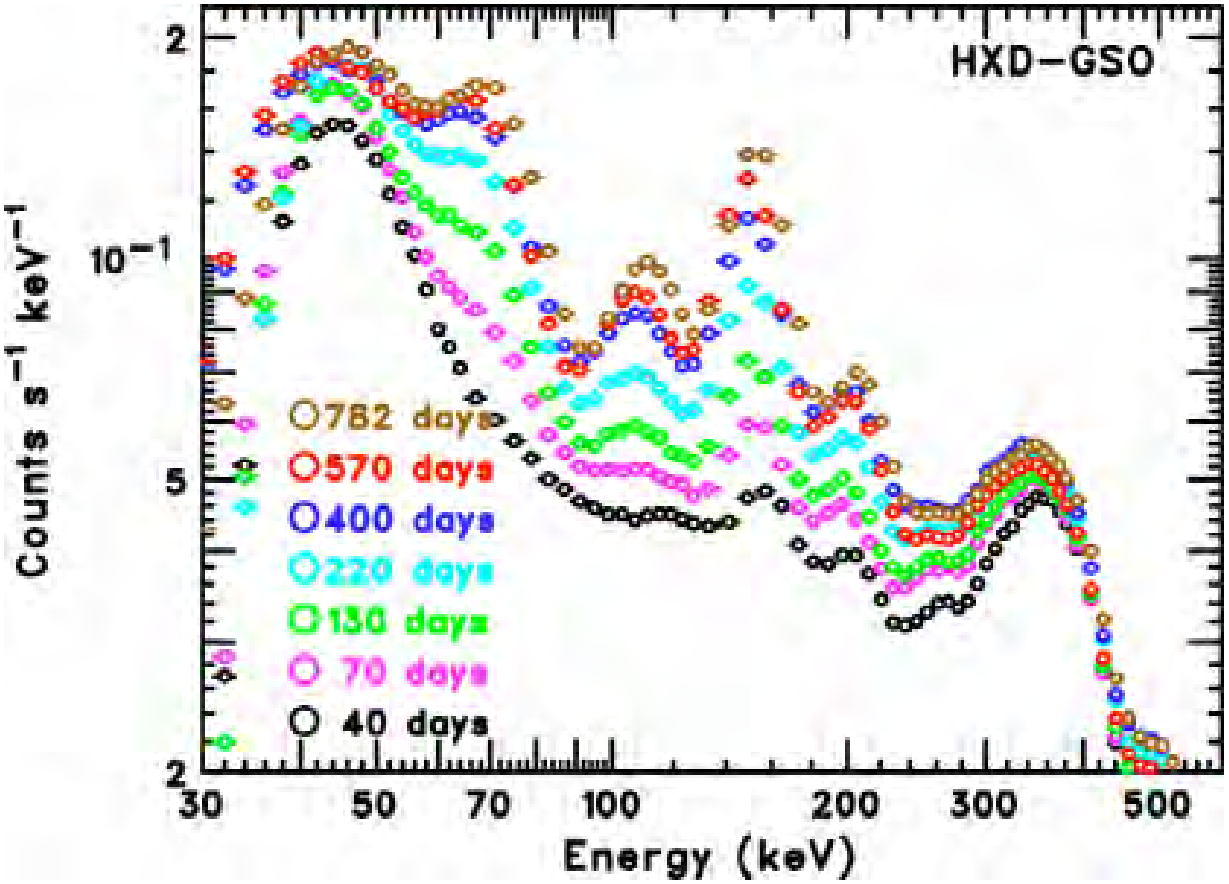
- Cross normalization is the same level as ver1.
- NGC2110 (XIS nominal), XIS:PIN=1:1.13

PIN Crab fit



Epoch	Nominal	gamma	norm (@ 1 keV)	chi2/dof	constantfactor
1	XIS	2.11 (±0.01)	11.6 (+0.2,-0.3)	79.6/89	1.16 (±0.01)
1	HXD	2.09 (±0.01)	10.9 (+0.3,-0.2)	63.6/83	1.15 (±0.01)
2	XIS	2.11 (±0.01)	11.4 (±0.2)	99.3/94	1.15 (±0.01)
3	HXD	2.11 (±0.01)	11.0 (+0.2,-0.3)	95.1/81	1.11 (±0.01)

GSO NXB

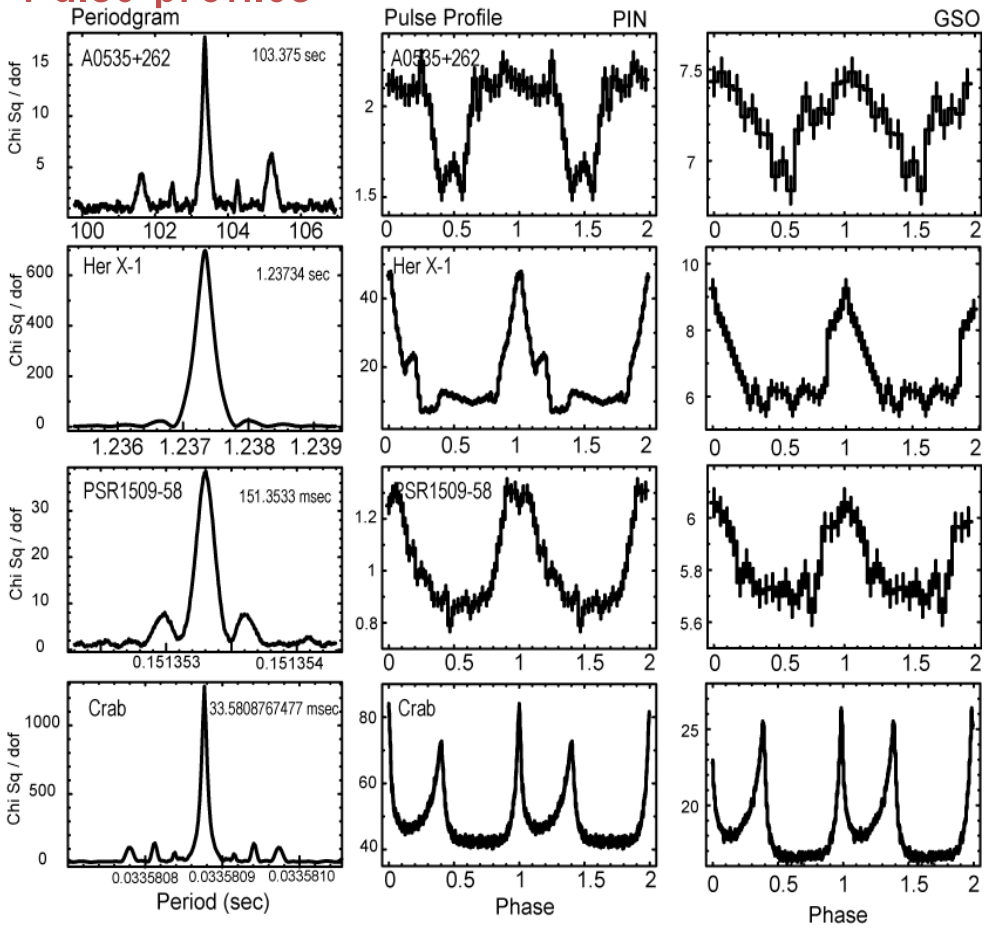


- GSO NXB is almost saturated to the expected level.
- Activation lines appears as expected, and are used for the energy calibraion.
- GSO NXB is provided 1.5 month after the observation.

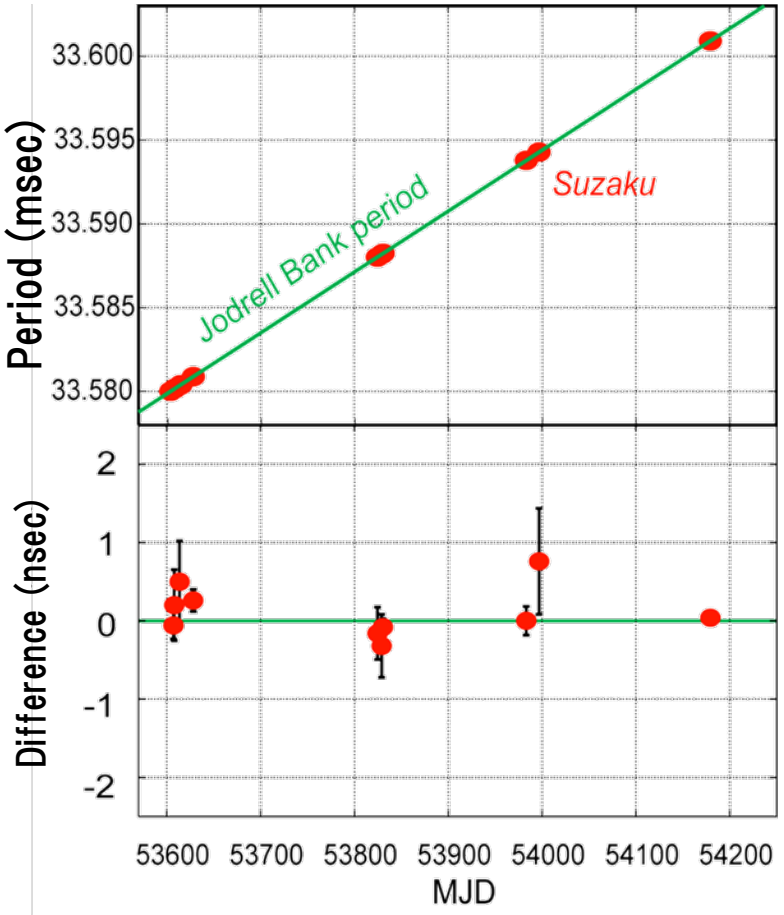
Timing Calibration

Y.Terada etal 2008 PASJ

Pulse profiles



History of Period of Crab pulsar

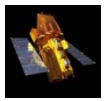


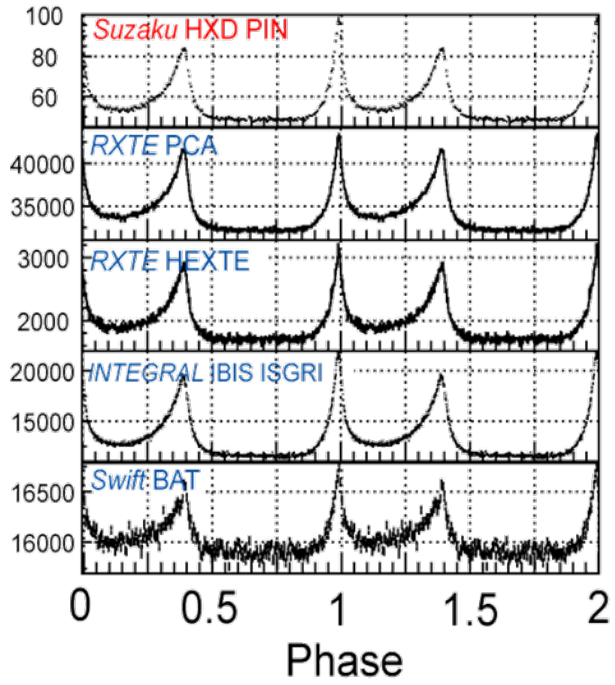
→ No problem at 33msec – 103 sec

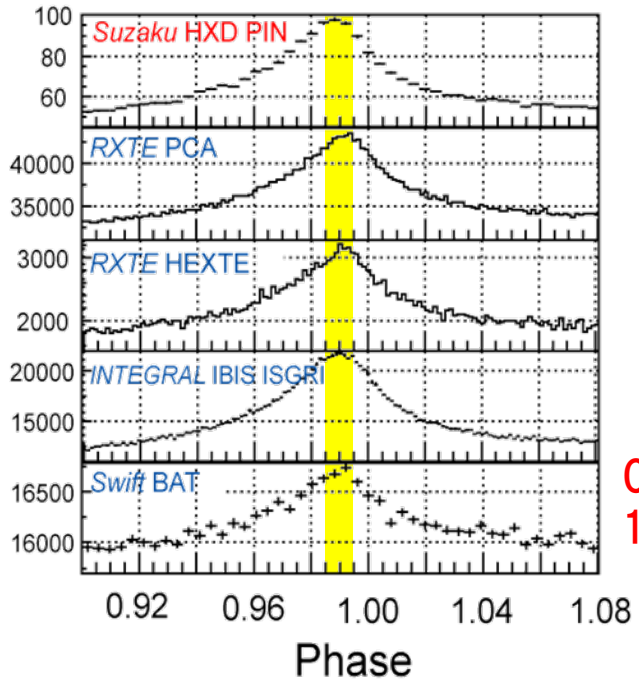
P and P_dot (~4.12×10^{13} s s^{-1})
consistent with Radio results

Simultaneous observation of Crab pulsar (20 March 2007)



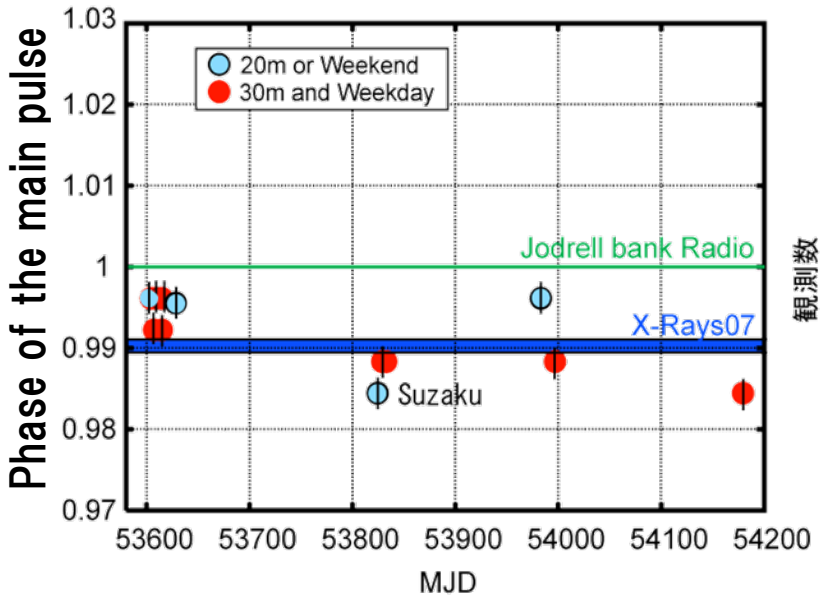



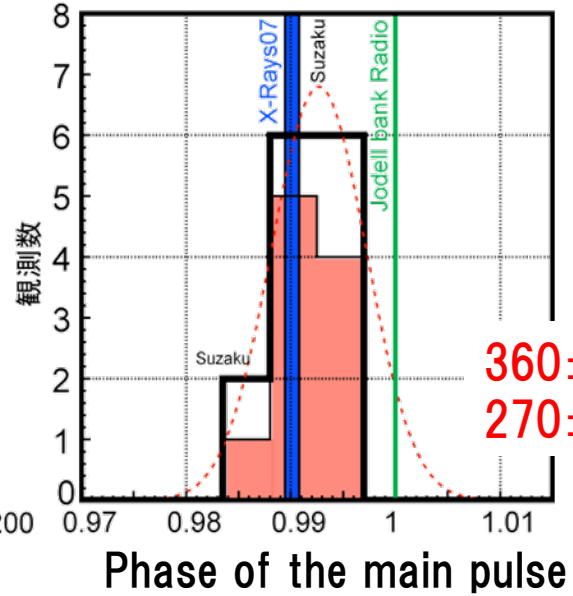




Y.Terada+ 2008
PASJ

Consistent within
100 μ sec



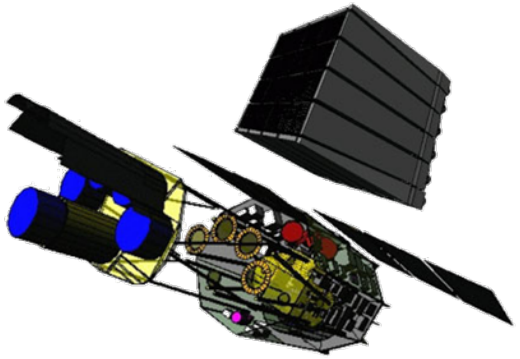


360$\pm$150 μ sec or
270$\pm$130 μ sec (in condition)

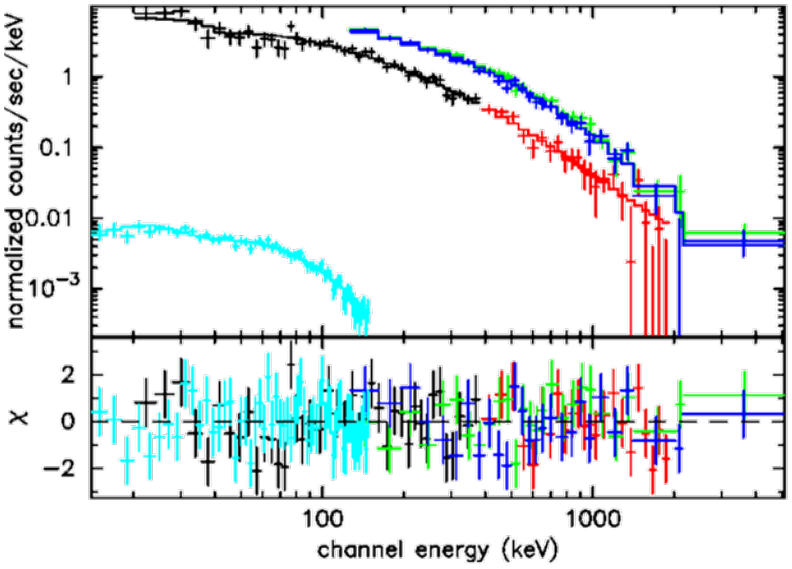
WAM status

*** Summary (2005 Ag. -- 2007 Oct.) ***

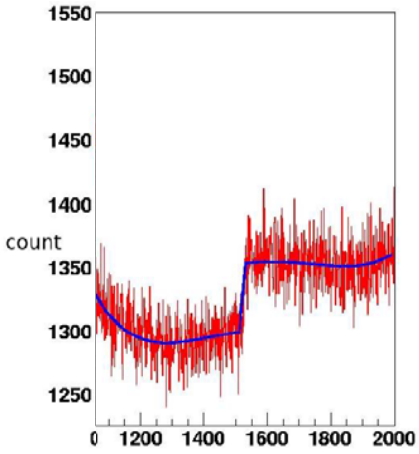
confirmed GRB	317 (194)
possible GRB	223 (97)
SGR	68 (6)
Solar flare	166 (28)

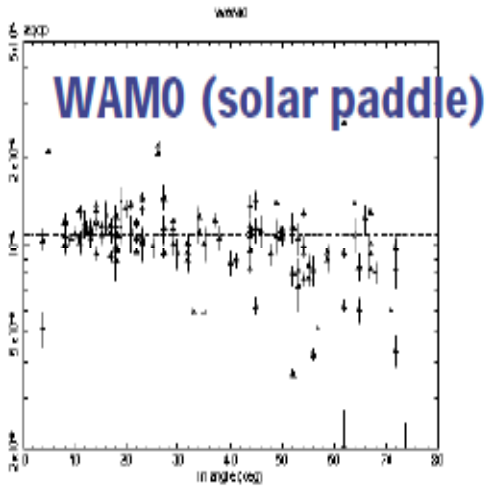


Cross calibration with Konus/Wind, RHESSI, Swift BAT
using GRB events and Solar flares



Calibration with Crab spectra by the Earth
Occultation technique





Please visit the WAM WWW page (http://www.astro.isas.ac.jp/suzaku/research/HXD-WAM/WAM-GRB/)

Calibration items

Table: Error Budgets of Scientific Instrument Calibrations

Instrument	Calibration Item	Present Uncertainties (July 2007)	Requirement	Goal
HXD	Absolute effective area	20%	20%	5%
	Relative effective area	15%	10%	5%
	Angular response	5%	10%	5% ✓
	Background modeling (PIN)	5~10%	10%	5% ✓
	Background modeling (GSO)	3%	10%	3% ✓
	Energy scale	1% (PIN)	**%	**%
	Absolute timing	360 mu s	300 mu s	100 mu s
	Relative timing	1.9×10^{-9}	10^{-8}	10^{-10}
HXD-WAM	GRB absolute timing	2 ms	1 ms	1 ms
	Absolute effective area	10~40%, depending on the incident angle	20%	20% ✓

Warnings of HXD analysis

- PIN bgd_d of ver1.* can be used for 2006/03/** -- 2006/05/** data. This ver1.* PIN bgd_d has to be corrected for dead time by GOs.
- MJDREF keyword of PIN and GSO data was wrong. Exposures of data can be several 10 sec different from NXBs. This issue will be announced soon.
- An option of hxdgrade in 7 steps was wrong. hxd_** = 2.0 should be 2.1. The wrong psdcut reduces GSO flux by 2%. NXBs has been made by the correct option. This issue will be announced soon.
- GSO and PIN data of ver2.0 after 2007/7/28 have to be reprocessed by GOs.