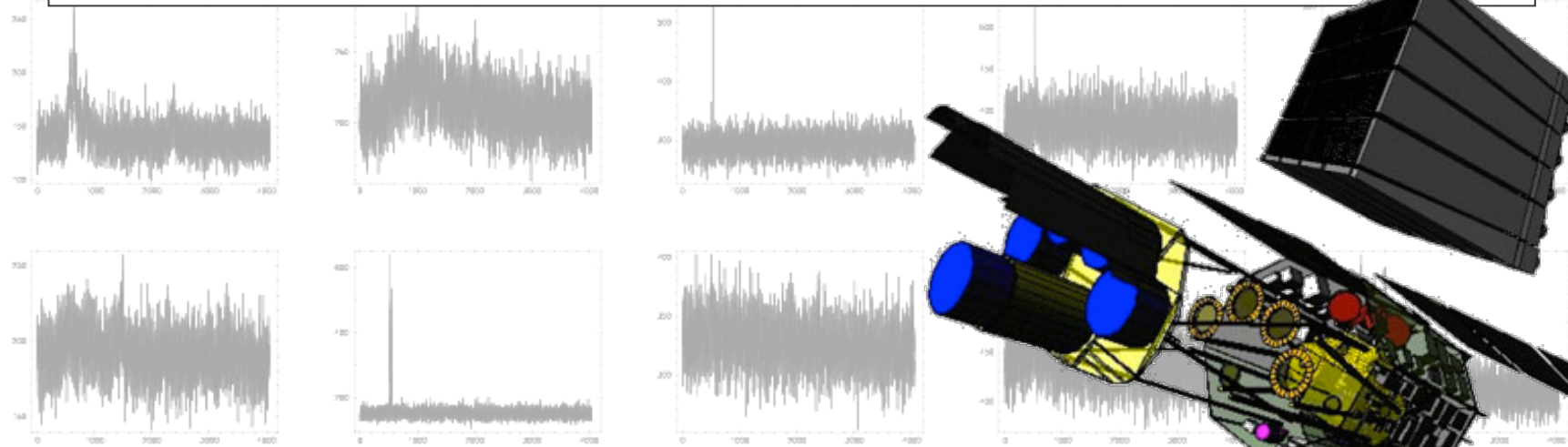


# The Six Year Results of Suzaku Wide-band All-sky Monitor

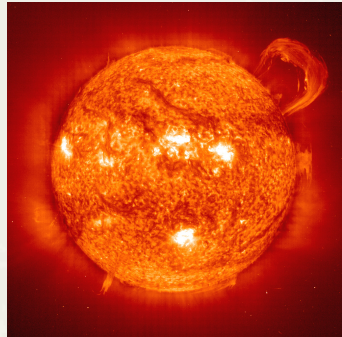


Masanori Ohno(Hiroshima U.)

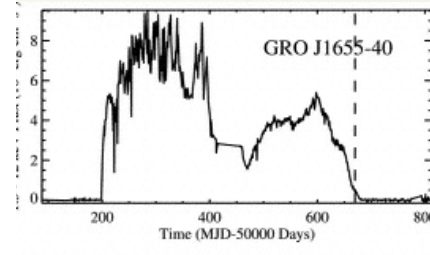
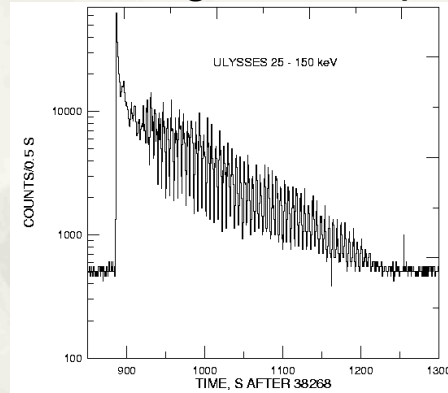
Y. Hanabata, T. Uehara, T. Takahashi, M. Mizuno, Y. Fukazawa (Hiroshima U.),  
K. Yamaoka (Aoyama Gakuin U.), S. Sugita (Nagoya U.),  
N. Ohmori, M. Akiyama, M. Yamauchi (Univ. of Miyazaki),  
T. Yasuda, Y. Terada, W. Iwakiri, K. Takahara, M. Asahina, S. Kobayashi,  
M. Tashiro (Saitama U.), M. Kokubun, T. Takahashi (ISAS/JAXA),  
Y. E. Nakagawa (Waseda U.), Y. Urata, P. Tsai, C-J. Chuang (NCU),  
K. Nakazawa, K. Makishima (Univ. of Tokyo), T. Murakami (Kanazawa U.),  
H. Tajima (Nagoya U. STE)

# Hard X-ray sky is very active !

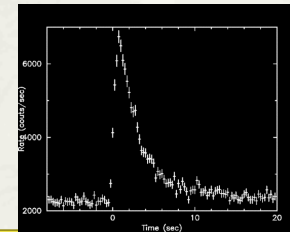
Solar flares



Outburst from black hole binaries, soft gamma repeaters..



Gamma-ray Bursts (GRBs)



Solar system

Cosmological distance

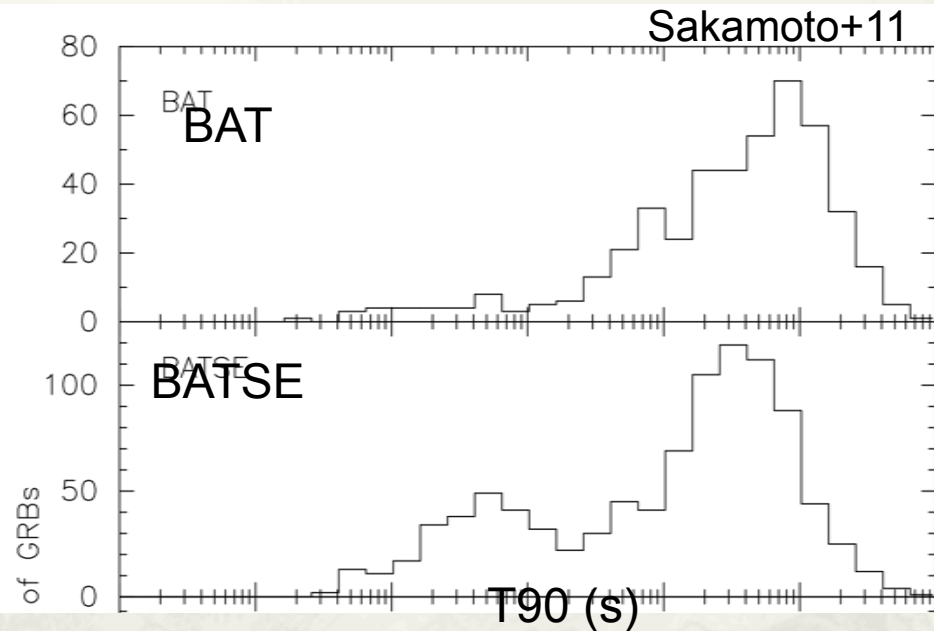
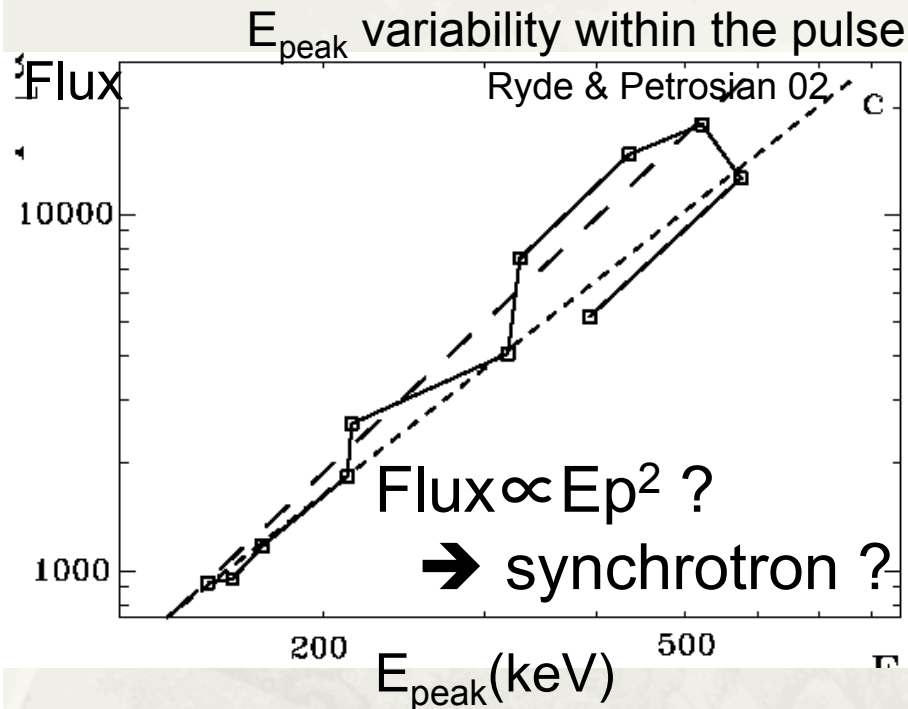
**Monitoring all-sky in hard X-ray is very important**

- non-thermal phenomena becomes to be dominant for emission process.
- there are many bright transient sources in hard X-ray ranging very wide distance scale (solar system to cosmological)

# GRB is still unknown..

Emission mechanism ?

Different class ?

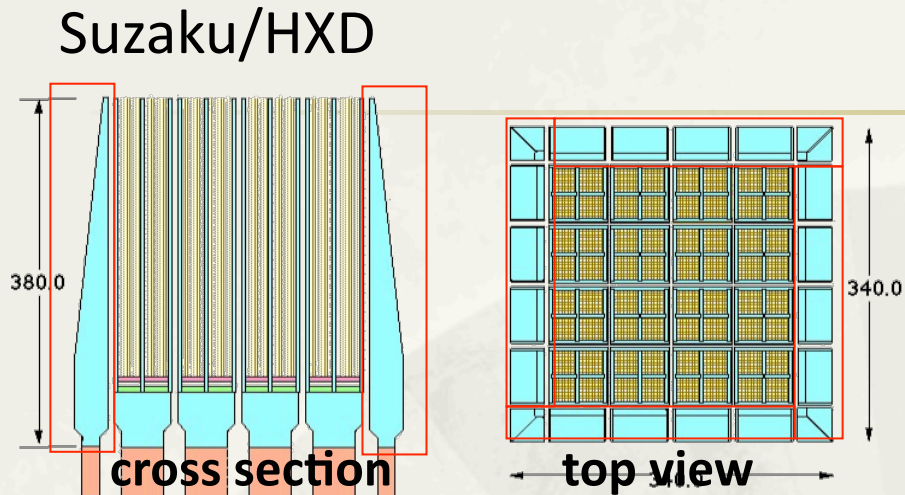


Variability of the  $E_{\text{peak}}$  is useful to constrain the emission model.

Short / Long classification depends on sensitivity of the instruments  
Is their origin different ?

**Larger effective area and wide energy coverage are essential for investigating these problems**

# Suzaku Wide-band All-sky Monitor



Suzaku/HXD is surrounded by thick (4cm), large (40cm) 20 high-Z BGO crystals for active shielding.

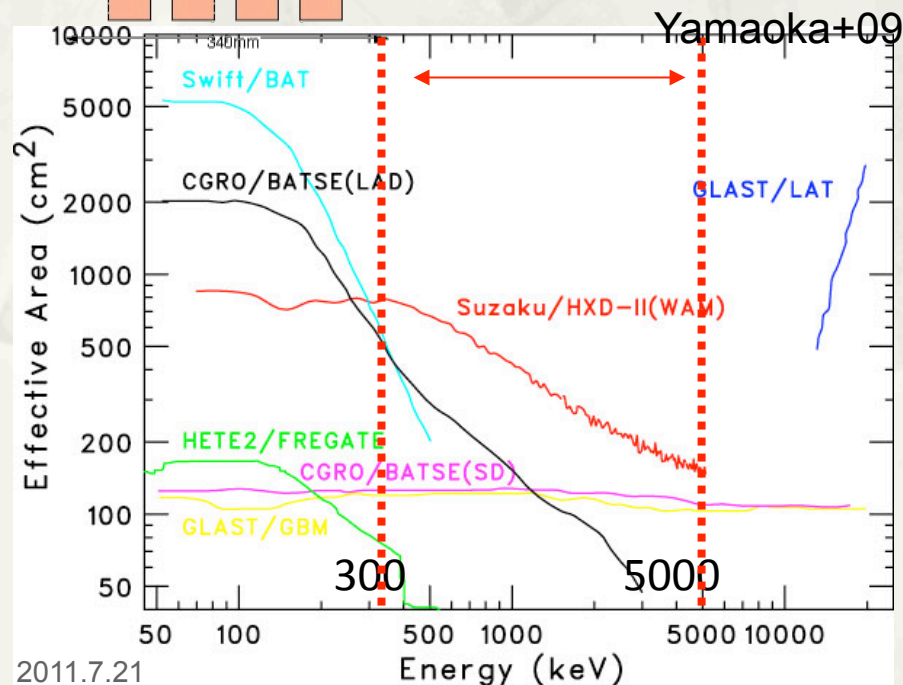


Wide-band All-sky Monitor  
(Suzaku/WAM)

Energy band: 50—5000 keV

Effective area: 400cm<sup>2</sup>@1MeV

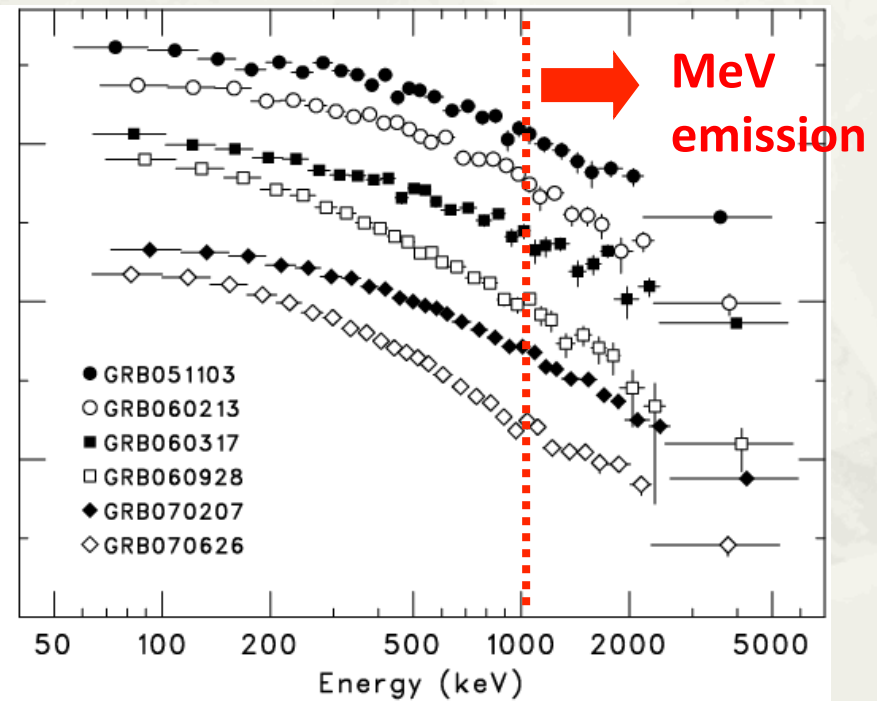
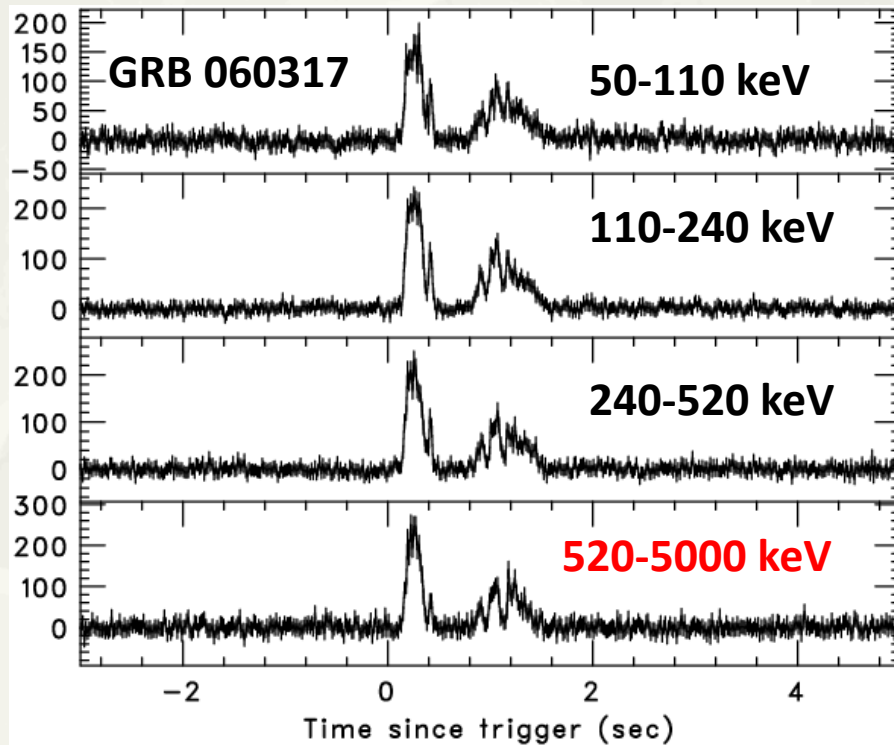
Largest effective area  
above 300 keV than any  
other all-sky monitors.



# GRB light curves and energy spectra

- \* Thanks to the WAM large effective area, high quality light curves and spectra can be obtained.

1/64 sec, 4 energy bands (BST data)



# Today's topic

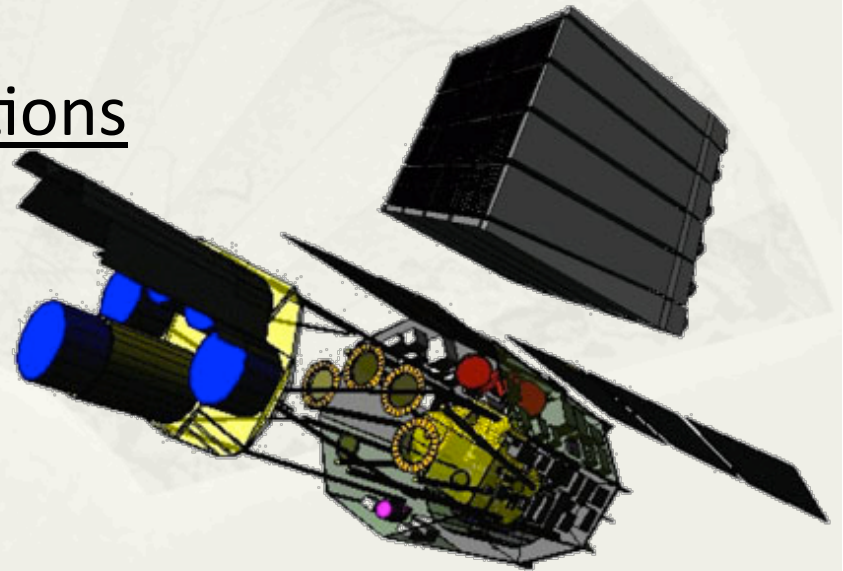
Suzaku Wide-band All-sky Monitor is a very powerful all-sky monitor in hard X-ray/soft gamma-ray band.

## I. WAM operation status

- WAM operation
- Trigger status
- Energy and flux calibration

## II. Highlights of 6 years observations

- GRB spectral/timing analysis
- Solar flare results
- MeV emission from SGR
- Monitoring hard X-ray sources

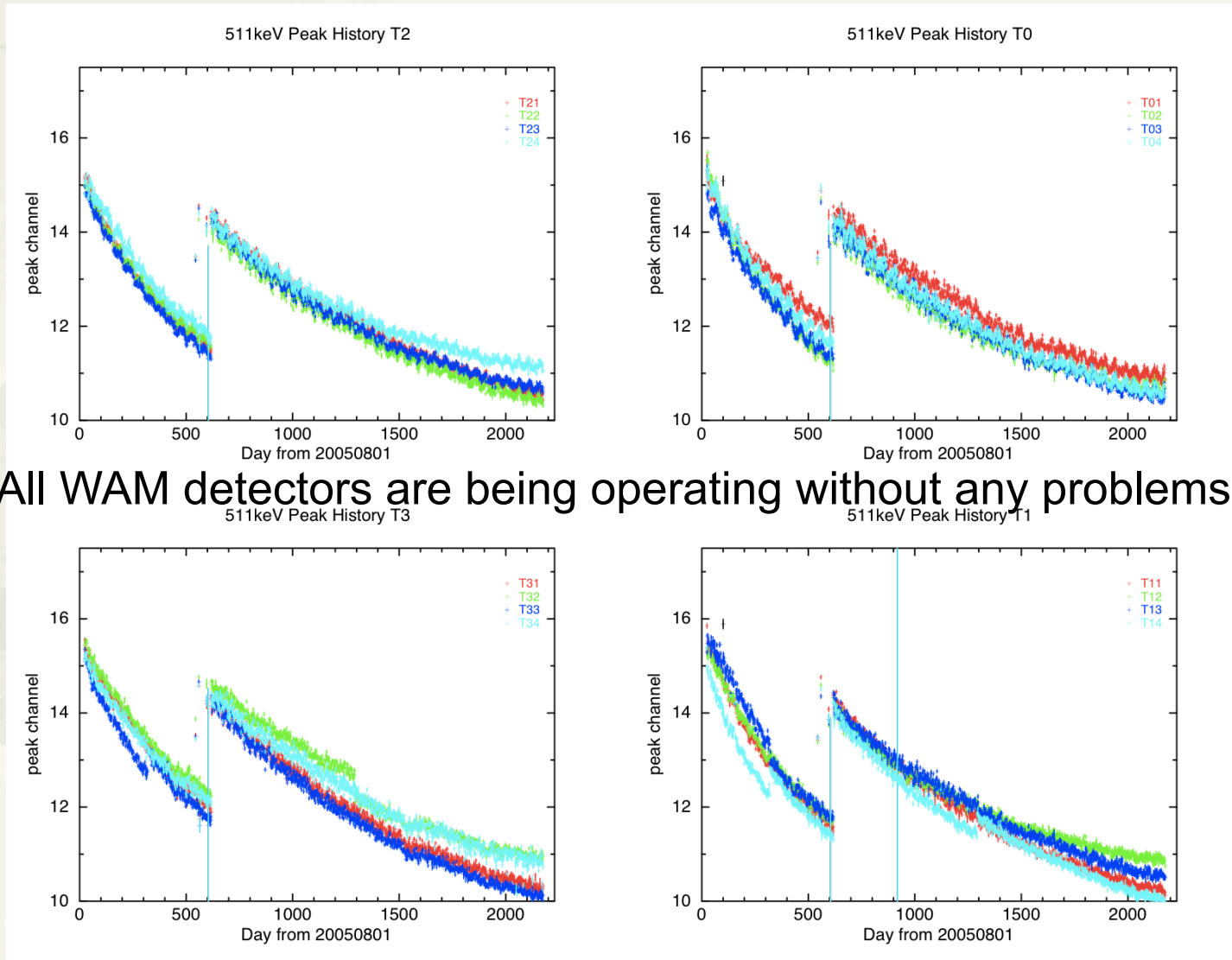


The background of the slide is a large, semi-circular mosaic of X-ray detector images. The mosaic is composed of many small, rectangular segments, each showing a different view of the universe in the X-ray spectrum. The overall appearance is a complex, multi-colored pattern of light and dark regions, representing the data collected by the Suzaku satellite. The mosaic is centered on the slide and occupies most of the visual space.

# I. Operation status

# WAM operation status

Gain check of all 20 detector by daily 511keV line



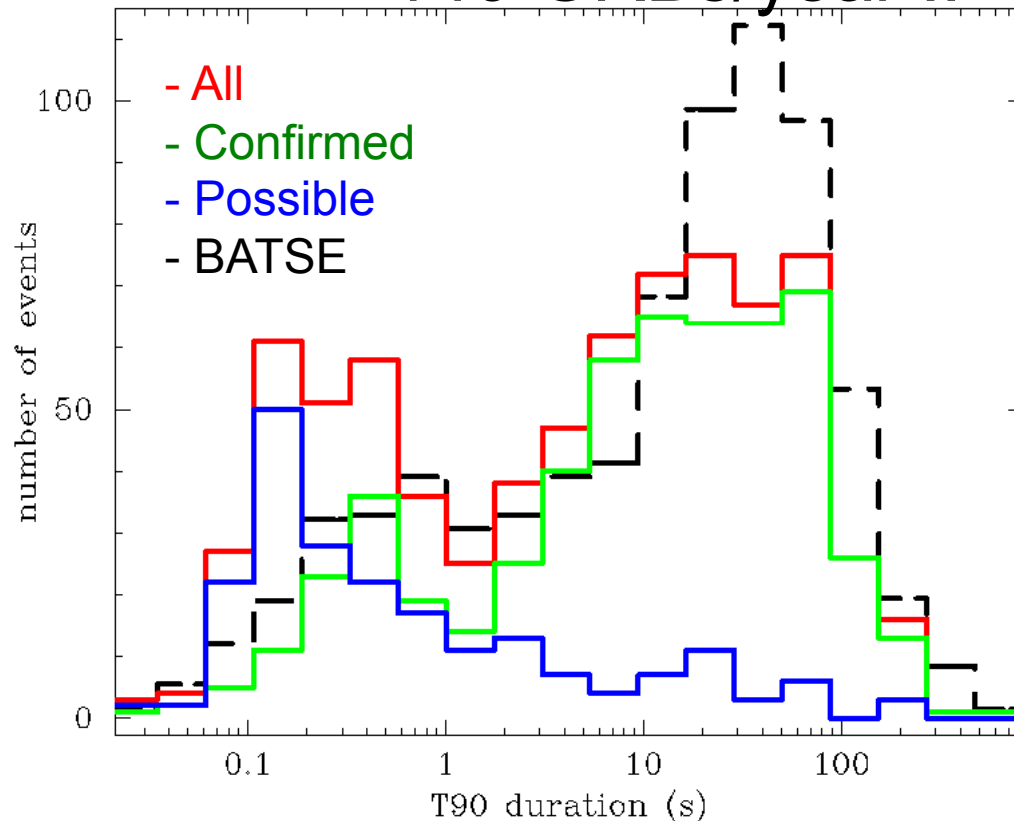
All WAM detectors are being operating without any problems !



# Trigger status

WAM event list from Aug. 2005 to June 2011 (~5.9 yrs)

140 GRBs/year !!



- Confirmed GRB 866 (532)
- Possible GRB 485 (209)
- SGR 378 (15)
- Solar flare 269 (35)  
(triggered)

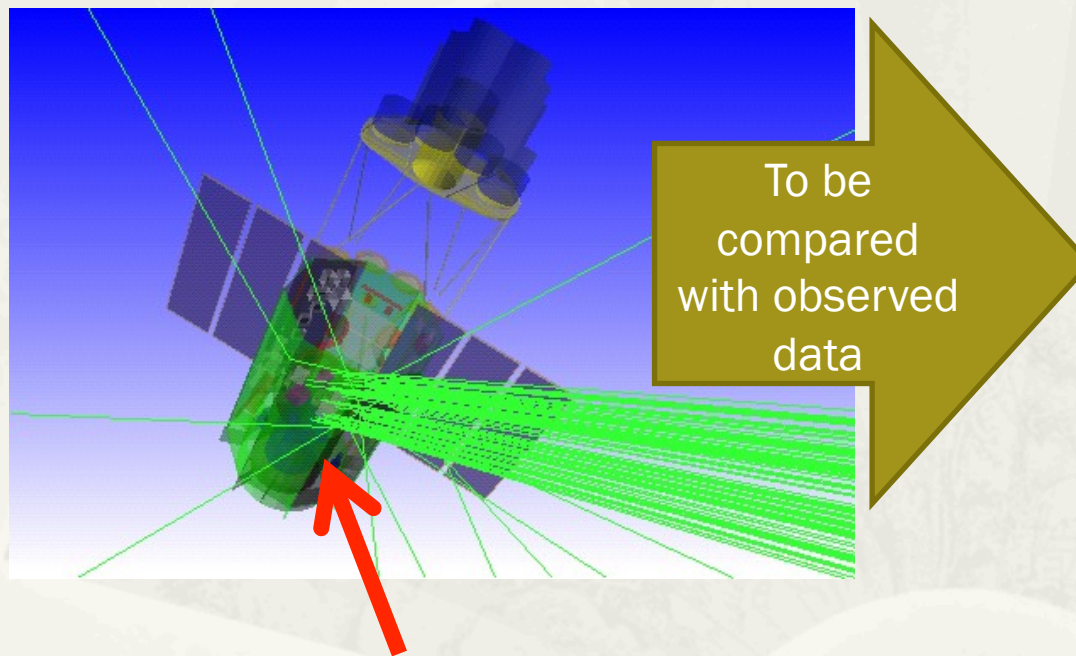
## GCN circulars

GRB: 156 (as IPN=39,  
See Kevin Hurley's poster (#89)  
WAM spectrum=137)  
SGR: 4, CygX-1: 1

Bimodal duration distribution → consistent with BATSE

# WAM Calibration Strategy

Energy response is generated by Geant4-based simulation with satellite mass model (Ohno+04)



To be compared with observed data

## A. Cross-calibration

Joint spectral analysis using simultaneously detected GRB or solar flare data with Swift/BAT, Konus-Wind, and RHESSI

## B. Crab calibration

Compare with Crab spectrum obtained by the earth occultation technique

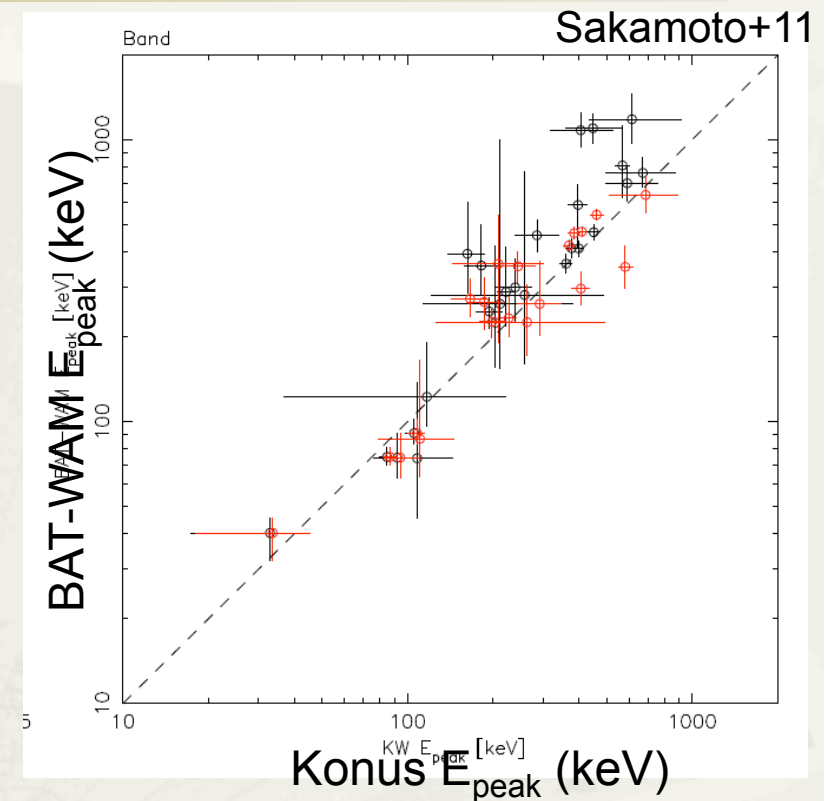
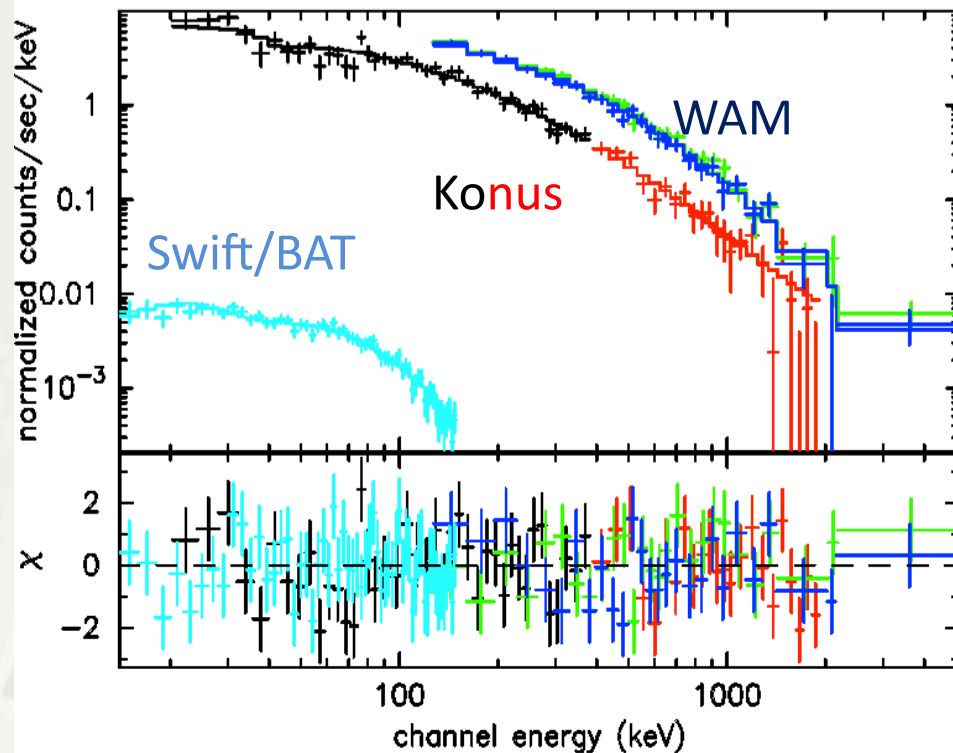
WAM locates inside the satellite body!

Response changes with direction of the gamma-ray source

# Calibration status

## A. Cross calibration with GRBs

Example of the cross-calibration analysis



Uncertainty of the flux and spectral parameters are within 20-30 % compared with other detector for almost case.

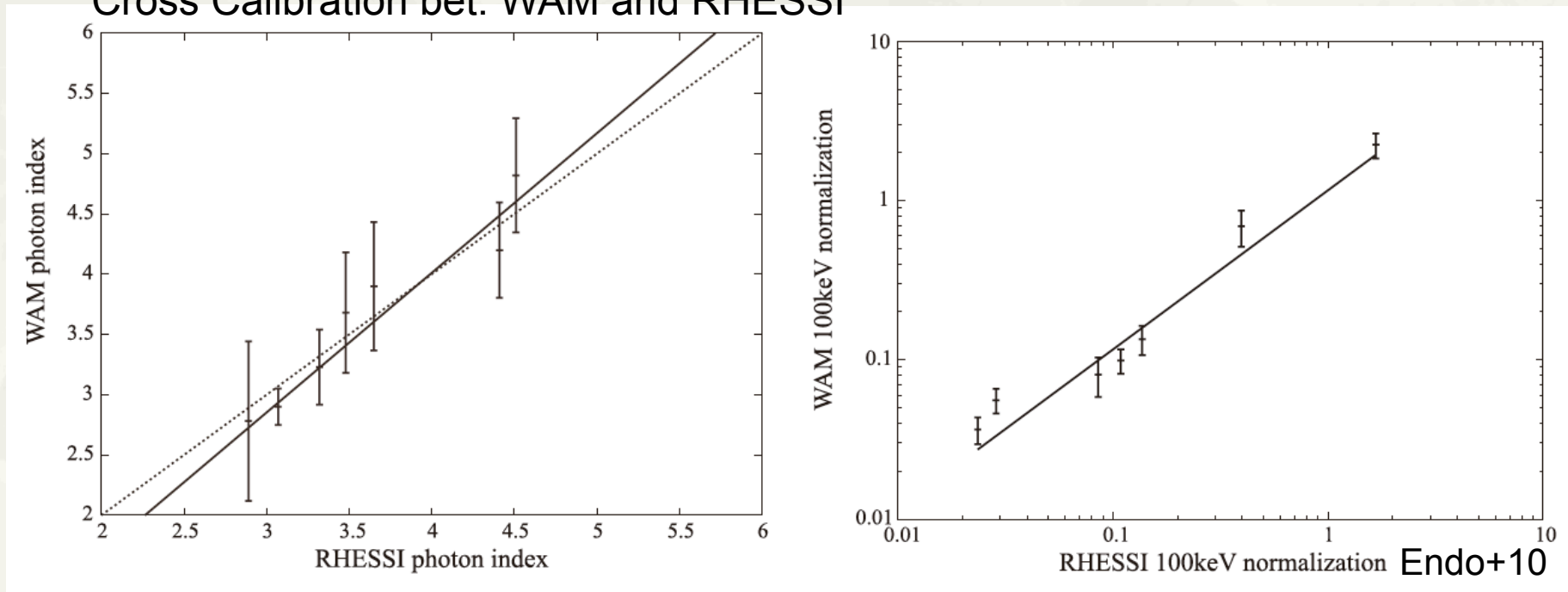
# Calibration status

## A. Cross calibration with solar flares

Solar flares come from solar paddle direction (=WAM0)

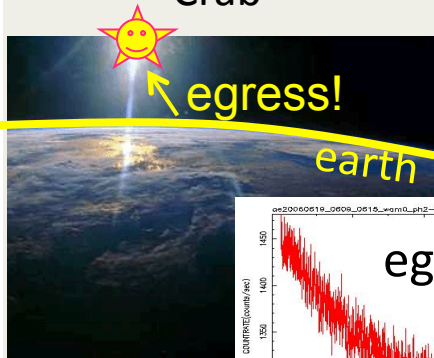
Cross calibration using solar flare is mainly used for WAM0 calibration

Cross Calibration bet. WAM and RHESSI



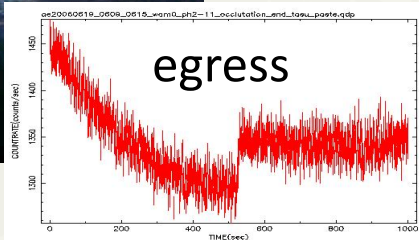
WAM0 shows less than 10% uncertainty of its spectrum and flux

Crab

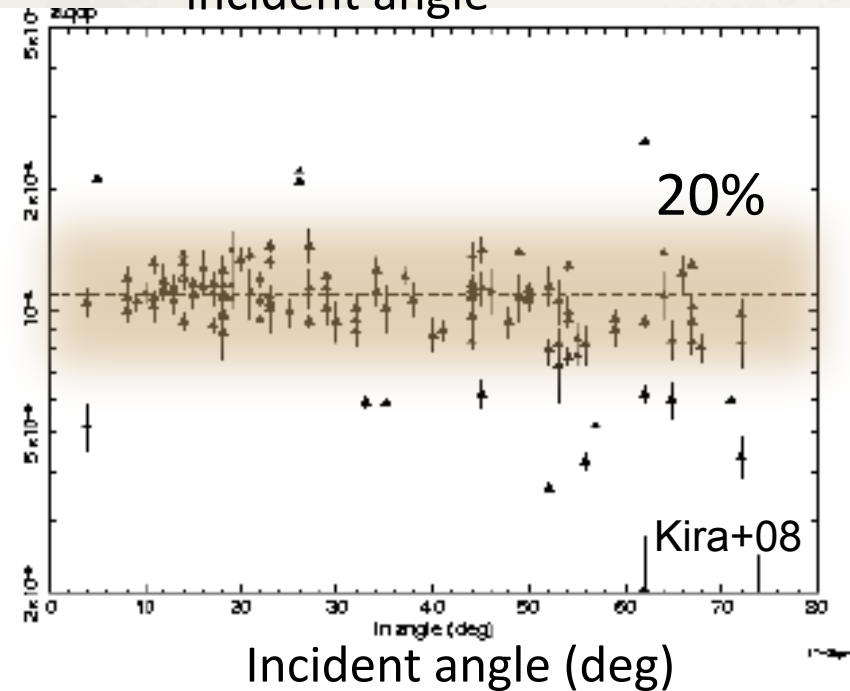
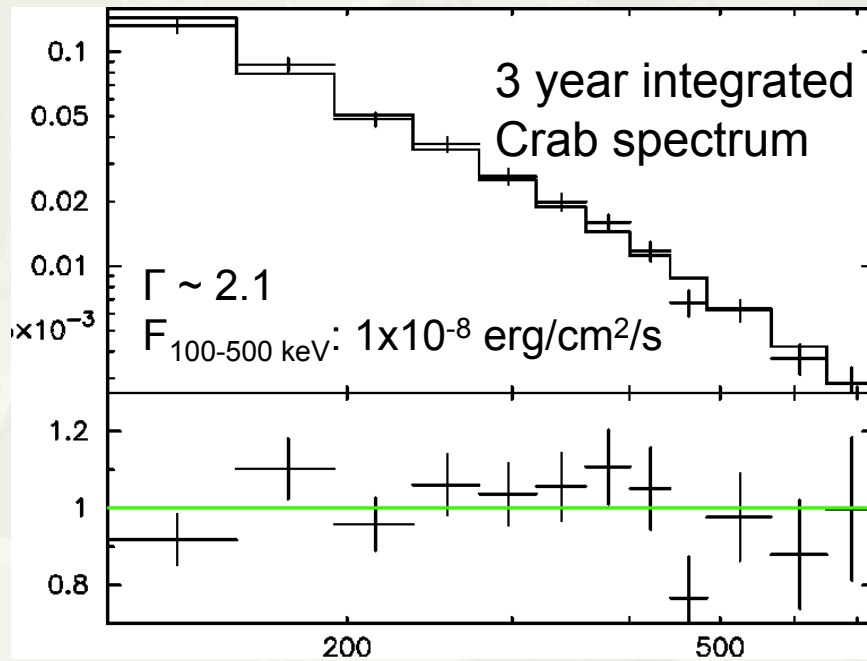


# Calibration status

## B. Crab Calibration



Fitted Crab flux for various incident angle



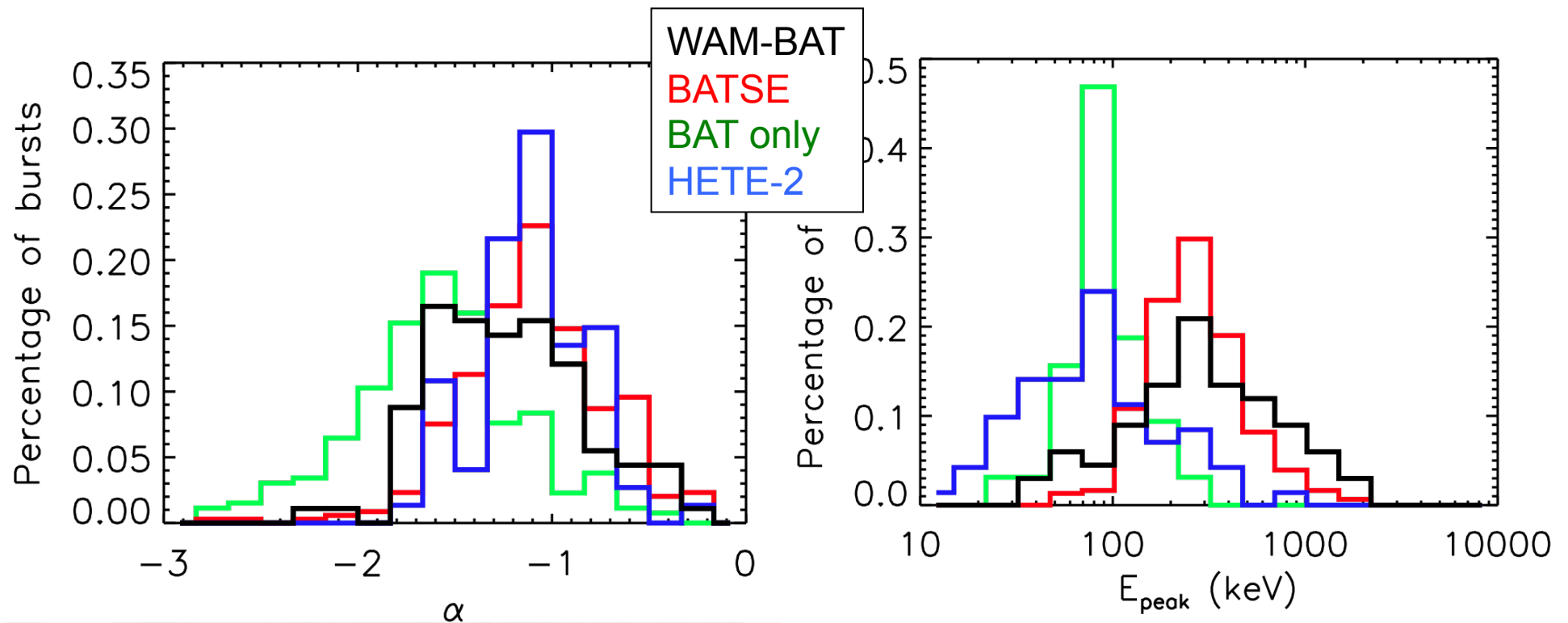
Uncertainty of the WAM energy response is 10-30 % for almost case



## II. Highlights of WAM result

# GRB Spectral parameter distribution

Joint WAM-BAT spectral analysis for 91 GRBs (Krimm+09)



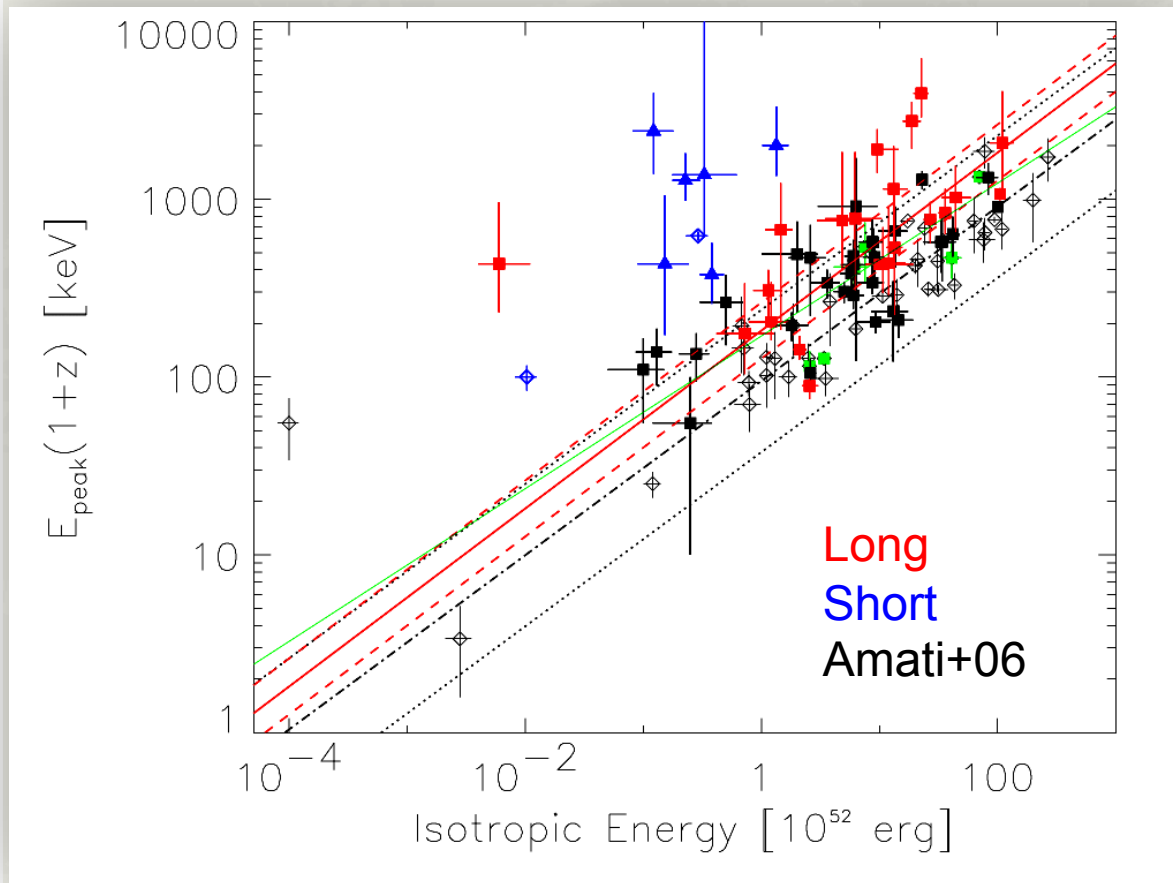
Distribution of Low-energy index  $\alpha$  is quite consistent with BATSE

$E_{\text{peak}}$  distribution is also consistent. Larger winds at high/low energy are due to larger effective area

# GRB parameter correlations

Correlation between  $E_{\text{peak}}$  and  $E_{\text{iso}}$  ( $L_{\text{iso}}$ ) is reported (Amati+02, Yonetoku+04.)  
Important to investigate emission mechanism of GRBs

$E_{\text{peak}}-E_{\text{iso}}$  for individual GRBs (Krimm+09)



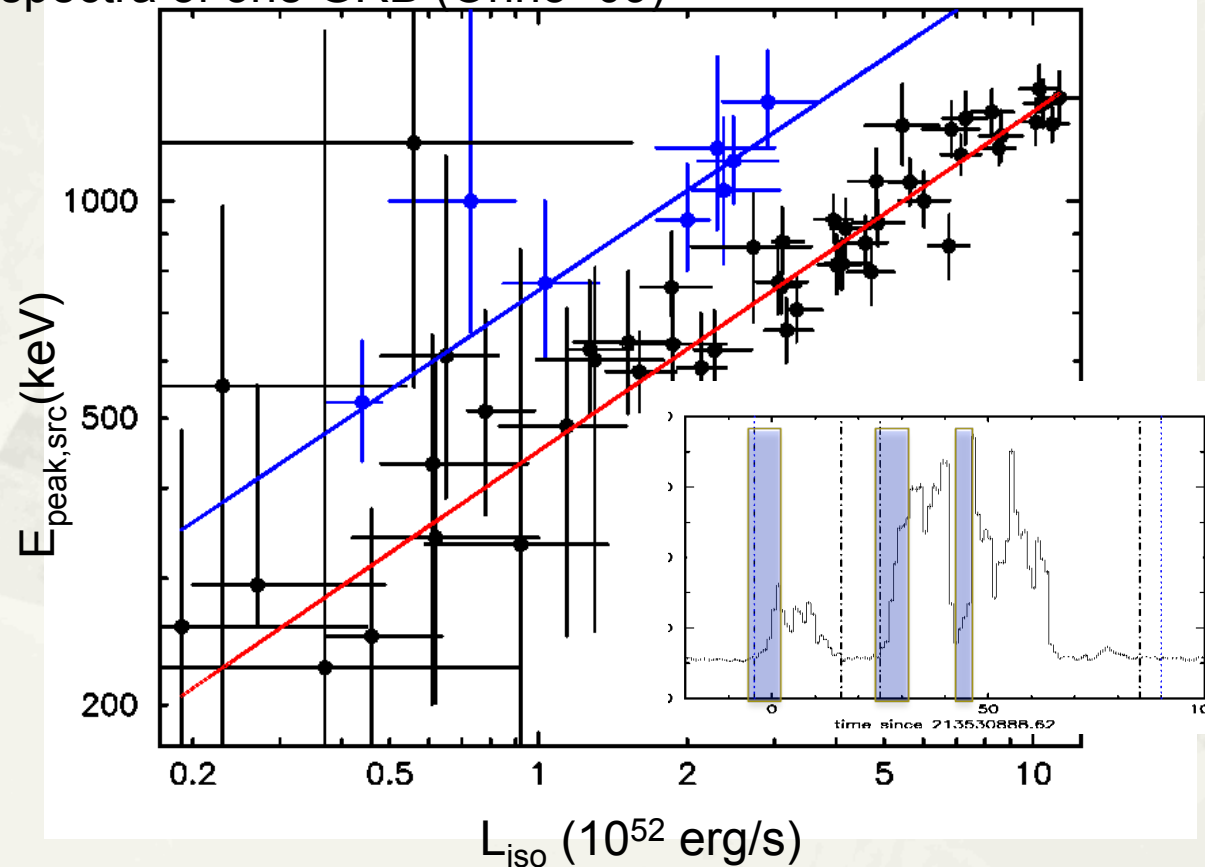
Short GRBs do not satisfy  
the same correlation as  
long GRBs  
→ imply different origin



# GRB parameter correlations

Large effective area of the WAM allow us to investigate the correlation not only time-integrated spectrum but also time-resolved spectra

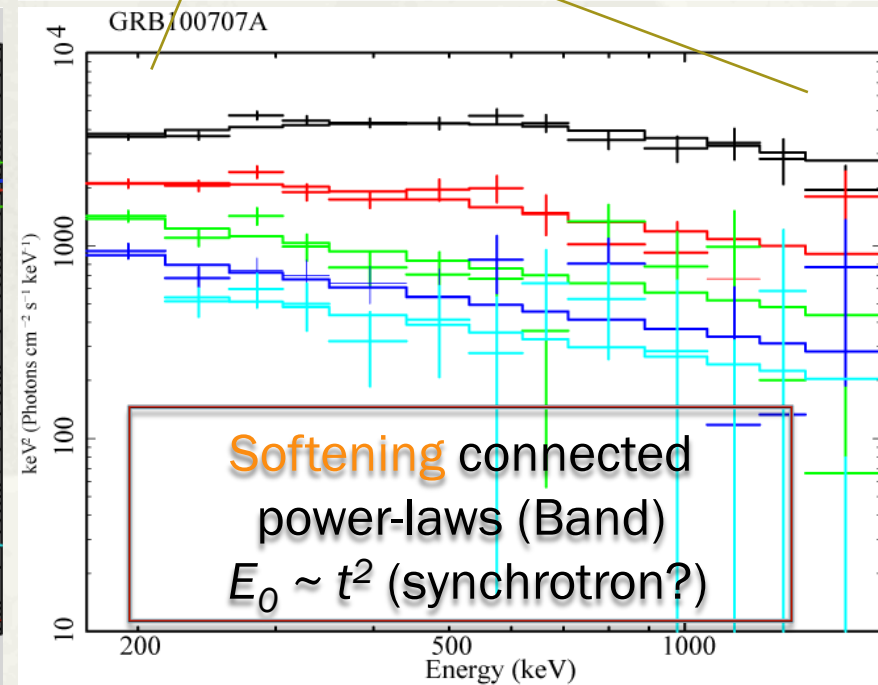
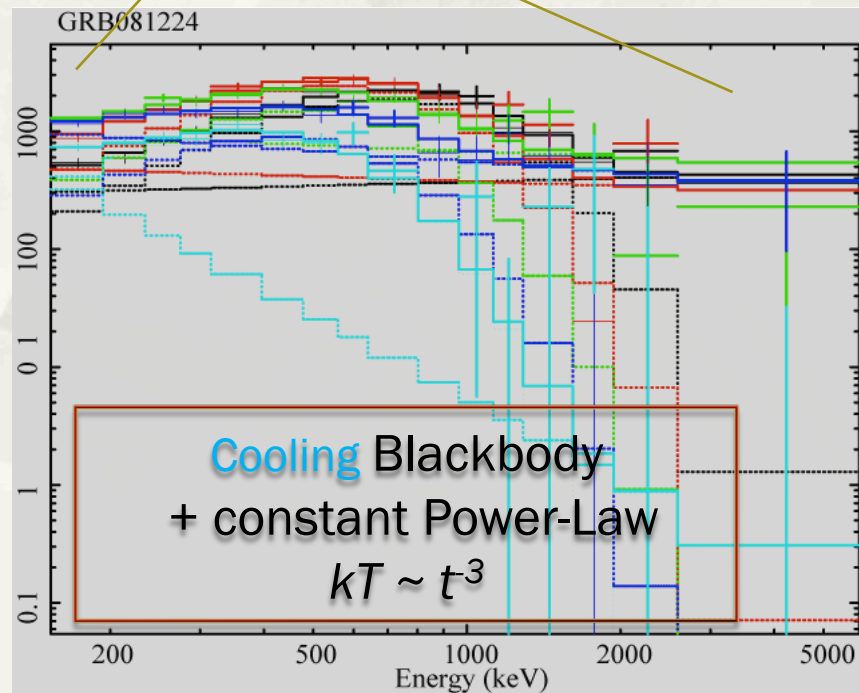
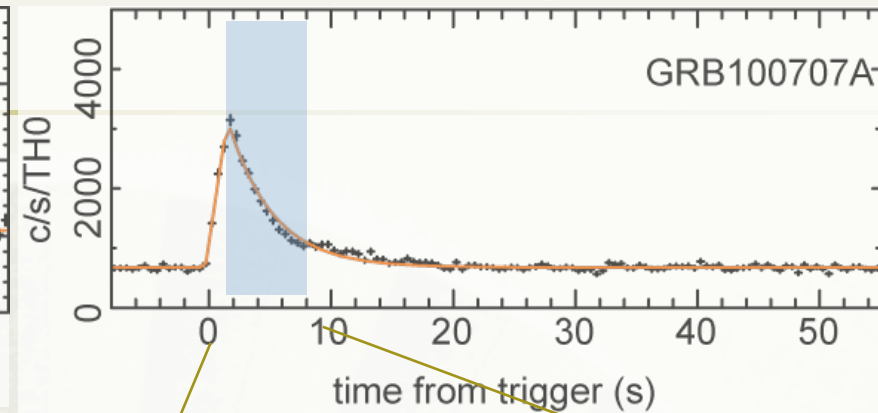
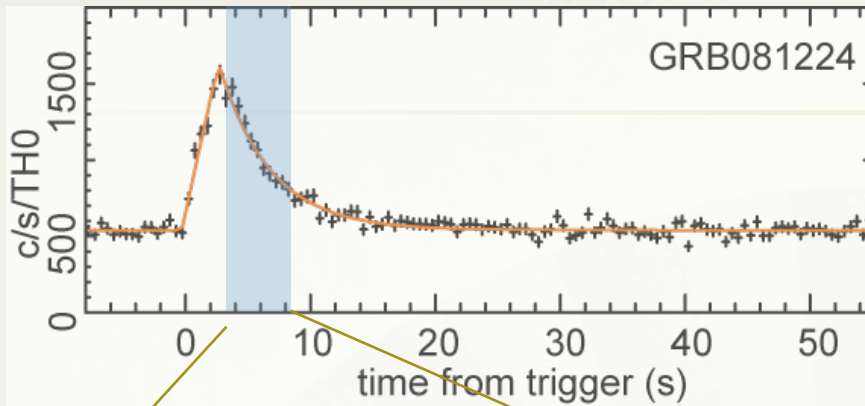
$E_{\text{peak}}-L_{\text{iso}}$  for time-resolved spectra of one GRB (Ohno+09)



Pulse rising phase shows different correlation from decay phase  
→ different Lorentz factor or emission region

# FREDS of thermal & non-thermal origins

Tashiro+ PASJ submitted

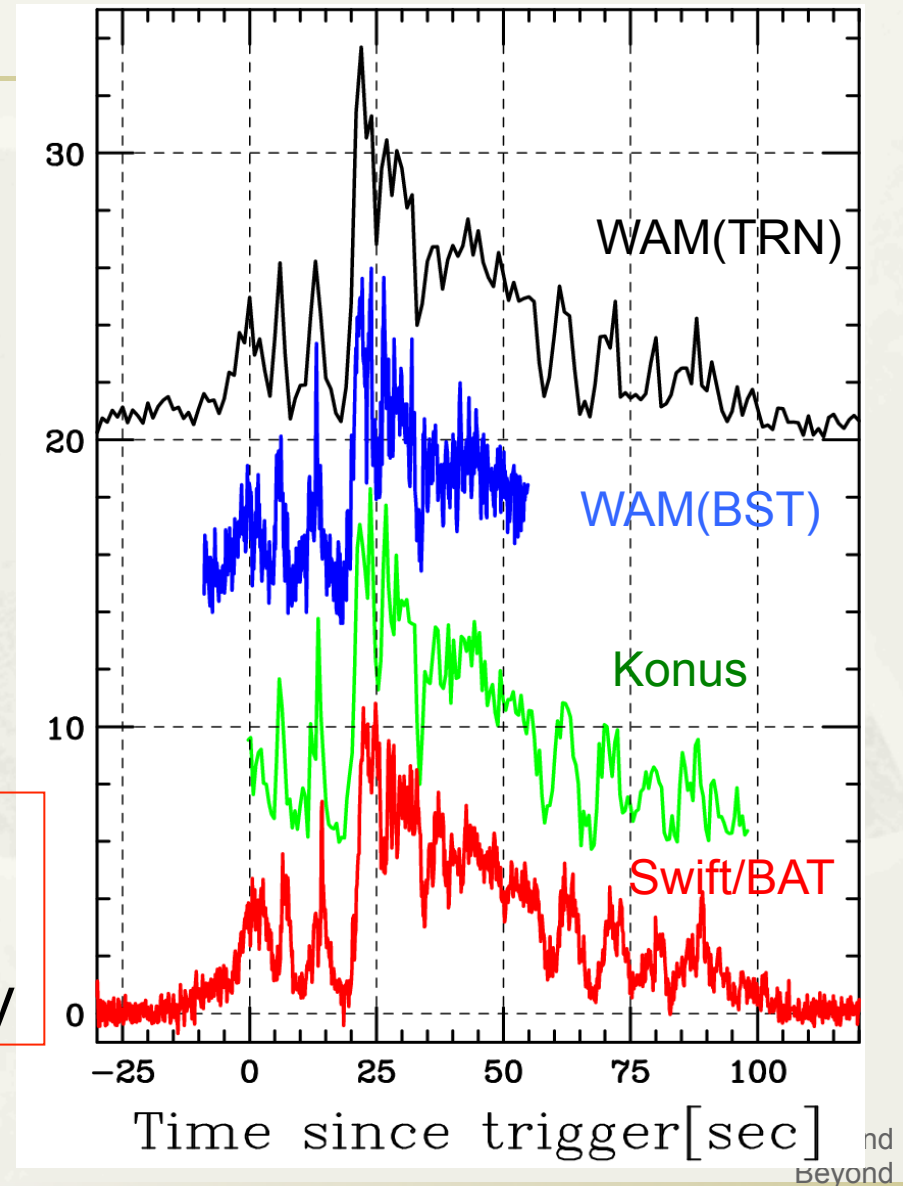


# Unusual GRB 090709A

- \* T0=07:38:34 (UT)
- \* T90 = 89 sec
- \* Fluence=  $2.57(\pm 0.03) \times 10^{-5}$  erg/cm<sup>2</sup>
- \* **8 s periodicity !?**

Following papers reported less than 3 sigma significance of periodicity **using only BAT data** (Cenko+10, De Luca+10)

Sum up 3 detector light curves  
→ improve signal to noise ratio  
expect to enhance the periodicity

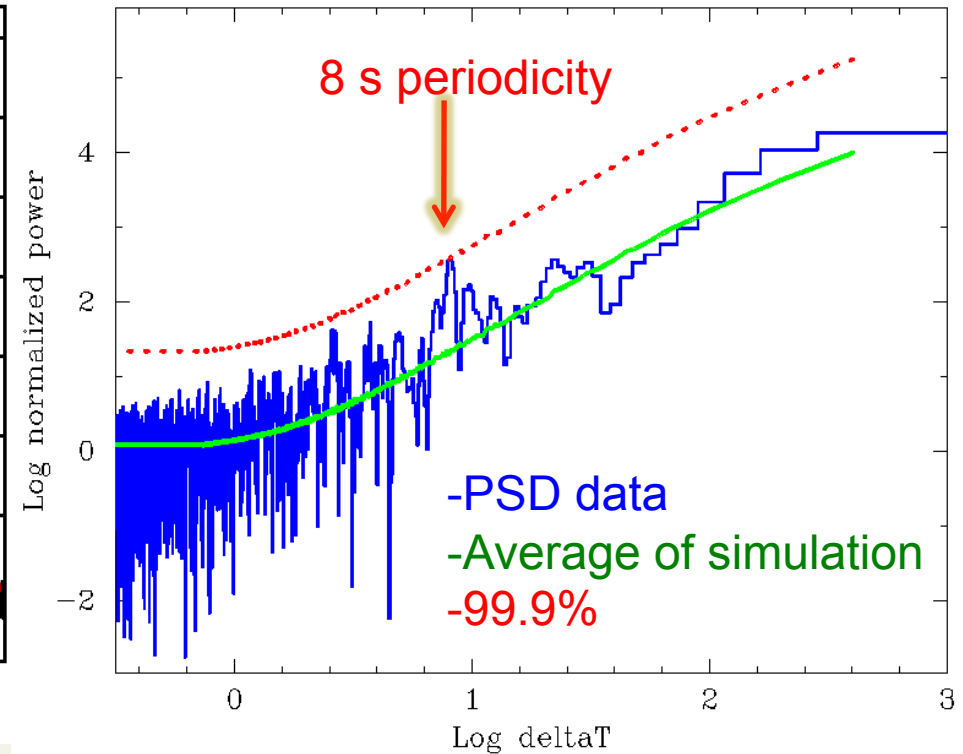
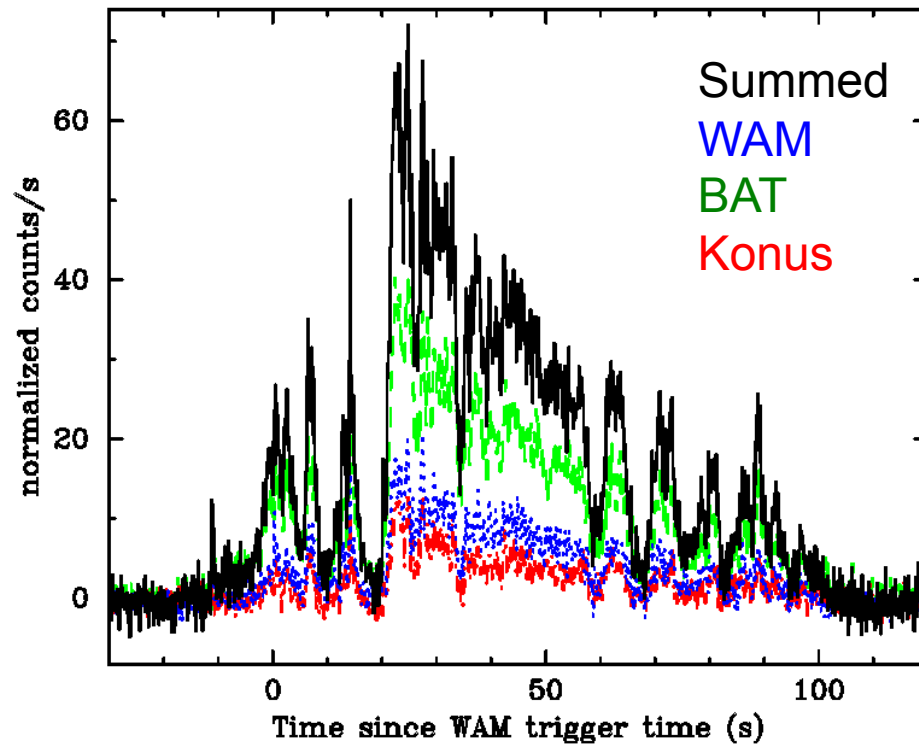


# Unusual GRB 090709A

Iwakiri+ in prep

3 detector summed light curve

PSD and simulated color noise



Comparison the 1000 times color noise simulation and observed power spectrum density, we detected the 8 sec periodic signal with the significance level of about 99.9%.

# WAM 1<sup>st</sup> GRB catalog

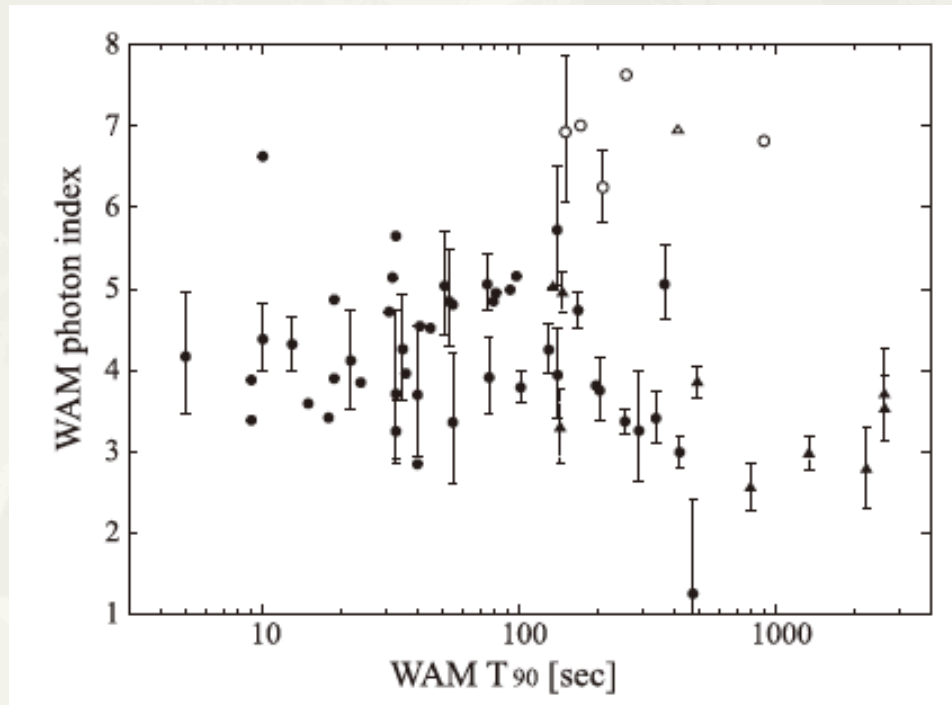
We are now compiling the 1<sup>st</sup> WAM GRB catalog. In this catalog, following items will be included. (Ohmori+ in prep)

- Event name
- Trigger number
- Trigger time or detection time
- Triggered or not triggered
- Detected WAM unit
- GRB position
- Other satellite detection
- Redshift
- T90 and T50 distribution for each energy band
- 1s peak flux (50-300keV, 100-1000 keV)
- Fluence (50-300 keV, 100-1000 keV)
- Photon index and hardness ratio

# Solar flares

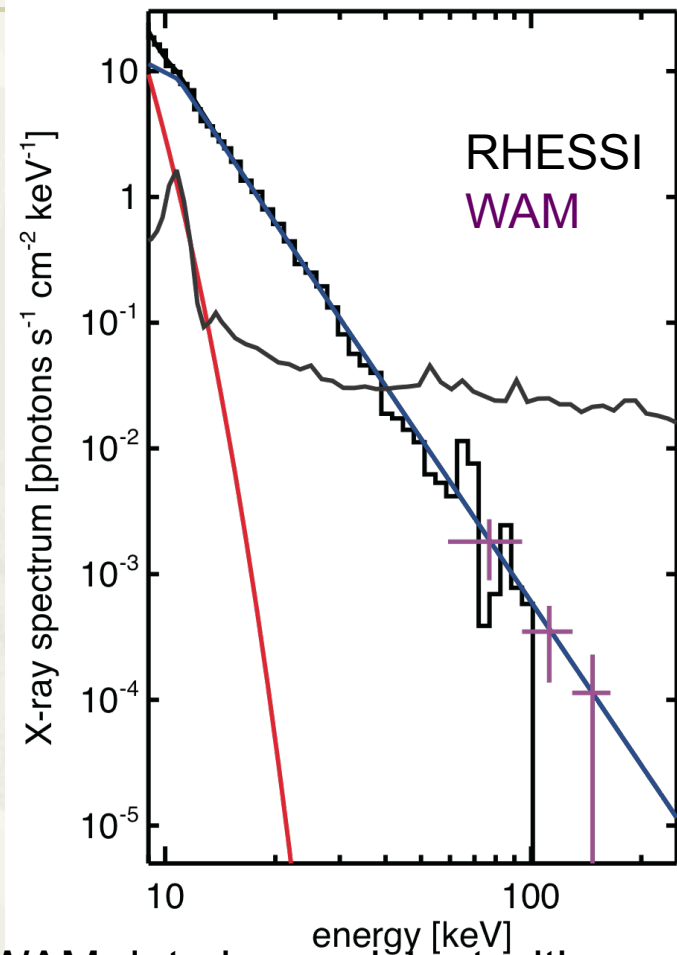
Solar flare catalog (Endo+10)

Analysis results of 105 solar flares are summarized



Particle acceleration and heating processes in the Sun are discussed

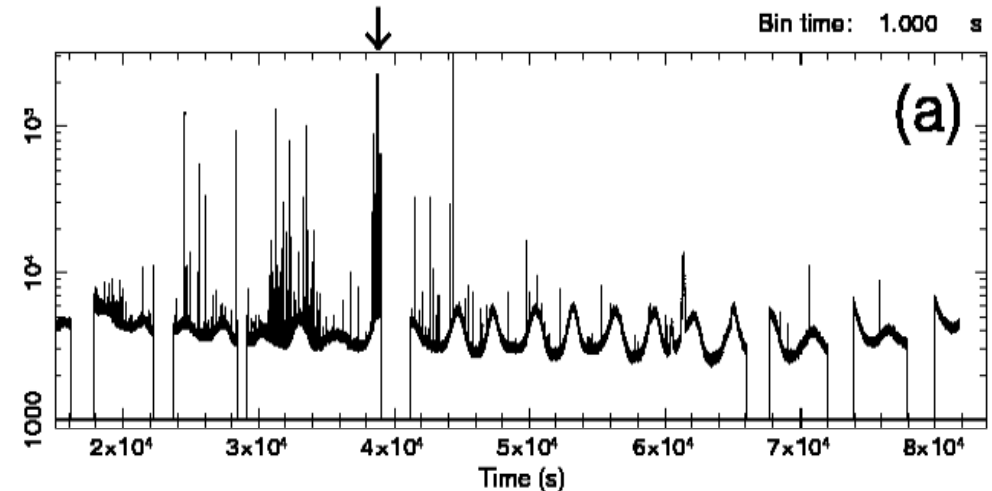
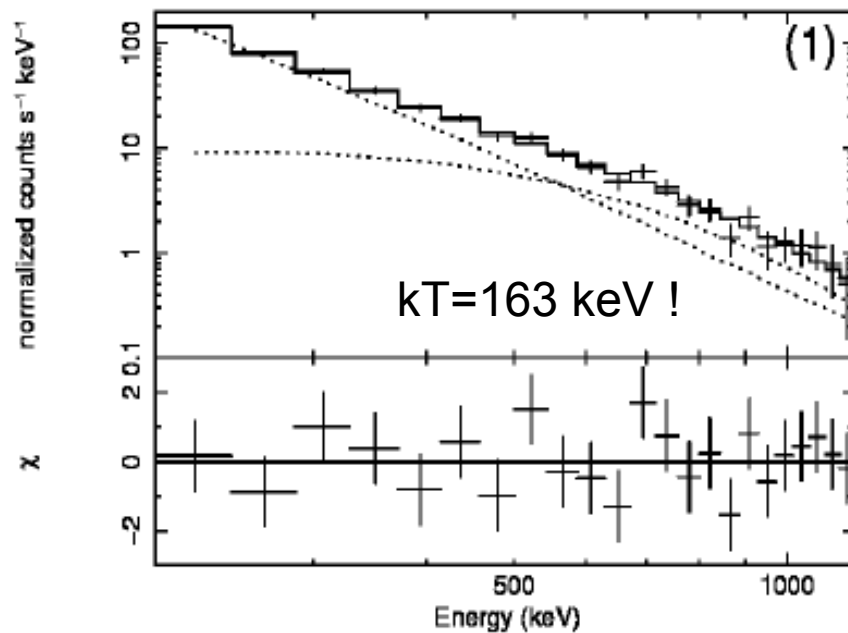
WAM/RHESSI joint analysis (Ishikawa+ in prep poster #91)



WAM data is consistent with extent of RHESSI power law spectrum

# SGR

WAM detected more than 250 bursts from AXP1E1547.0-5408 in 2009 Jan. 22. (Yasuda+11)



High energy photons  $> 1MeV$  are detected with  $\sim 3.2\sigma$  confidence from one very hard burst  
Any cut-off can not be found

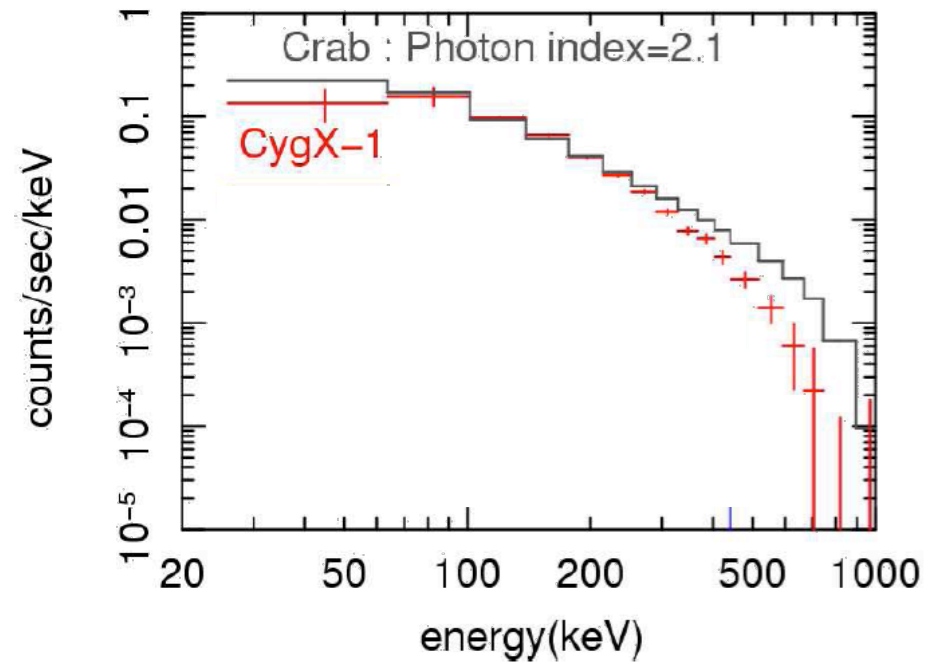
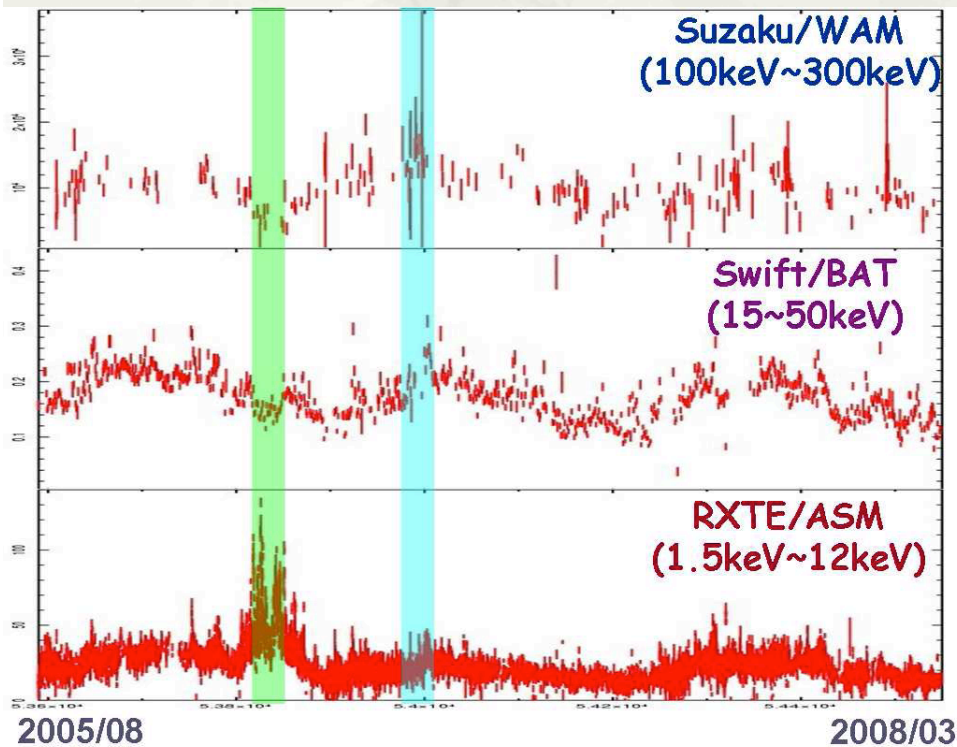
Constrain region for black body radiation of neutron star.

# Monitoring soft gamma-ray sky with earth occultation technique

The WAM can monitor bright hard-X-ray/gamma-ray sources utilizing Earth occultation technique. Sensitivity for such all-sky monitor is estimated to be 30 mCrab for 3-year integration.  
(Kira+09)

Example of long term light curve of Cyg X-1

Three year integrated CygX-1 spectrum





# Summary

The Suzaku Wide-band All-sky Monitor is very powerful all-sky monitor in hard X-ray/soft gamma-ray band

- All 20 detectors are operated without problems in 6 years
- Strong GRB detection rate of 140 GRBs per year.
- Current uncertainties of the energy response : 10-30 %.
- GRBs: spectral parameters and their correlations  
emission mechanism and origin are discussed  
1<sup>st</sup> WAM GRB catalog is now under development
- Solar flare: WAM hard X-ray data provides info. of particle acceleration
- SGR: detection of MeV photons could constrain the emission region  
of neutron star
- Monitoring Hard X-ray sources by earth occultation  
ABC guide is now available  
<http://www.astro.isas.jaxa.jp/suzaku/HXD-WAM/WAM-GRB/analysis/abcguide/index.html>