

# Non-Thermal SNR Working Group

L.Natalucci, "Cross-calibration Matrix using Crab"

K.Madsen, "Update on Crab cross-calibration"

C.Markwardt, "Swift BAT Gain Calibration"

Presentation from M.Tsujimoto (Crab & G21.5)

WG discussion

**Attendees:** G.Randall, Xufang Li, Xiaobo Li, D.Bhattacharya, B.Wu, Y.Tan, T.Sun, L.Song, F.Pajot, N.Durham, I.Valtchanov, J.Rodi, L.Kuiper, J.Drake, Y.Terada, J.Kennea, V.Burwitz, P.Kretschmar, Craig M., J. Nevalainen, B.Grefenstette, K. Forster, K.Madsen **and others**

# Crab “multi-year” data analysis project

- Results exclusively based on the analysis of nearly simultaneous periods
- Emphasis on the hard band ( $>10$  keV)
- Instruments on board: XIS, PIN, GSO, PCA, IBIS/ISGRI, SPI, NuSTAR, (EPIC-pn), GBM, BAT
- Total of 14 nearly simultaneous epochs (2005-2016).
- Broken power law model, with  $E_{br} \sim 100$  keV
- Broad bands spectral fitting

# Energy bands

Instr.	Energy Bands (keV)
XIS	3-10
PIN	10-25, 25-80
GS0	25-80 <sup>^</sup> 100-300
PCA	3-10, 10-25, 25-80
IBIS	25-80, 100-300
SPI	25-80, 100-300
NuSTAR	3-10, 10-25, 25-80
EPIC	3-10
GBM	(25-80), 100-300
BAT	25-80

<sup>^</sup>for GS0, E >40 keV

# Epochs

Epochs	Instruments	Period	<1 week
A	PCA, PIN, GSO, IBIS, SPI	2005-09-15 to 2005-10-11	
B	PCA, PIN, GSO, IBIS, SPI	2006-09-05 to 2006-09-29	
C	XIS, PCA, PIN, GSO, , SPI, BAT	2007-03-11 to 2007-03-22	~
D	PCA, IBIS, SPI	2007-09-22 to 2007-09-27	Y
E	PCA, PIN, GSO, IBIS, SPI, GBM	2008-08-27 to 2008-09-26	
F	PCA, IBIS, SPI, GBM	2009-08-14 to 2009-08-26	
G	PCA, IBIS, SPI	2010-02-23 to 2010-03-04	
H	PCA, PIN, GSO, IBIS, GBM	2010-04-03 to 2010-04-09	Y
I	PCA, IBIS, SPI, GBM, BAT	2010-09-22 to 2010-09-25	Y
J	PCA, IBIS, SPI, GBM	2011-02-12 to 2011-02-19	Y
K	PCA, PIN, GSO, GBM	2011-03-17 to 2011-03-27	~
L	NUSTAR, (PIN, GSO), IBIS, SPI, GBM	2012-09-21 to 2012-09-26	Y
M	EPIC, NUSTAR, IBIS, (SPI), GBM	2014-10-01 to 2014-10-02	Y
N	IBIS, NuSTAR, Hitomi, ASTROSAT/CZTI	2016-03-25 to 2016-04-01	Y

(\*) except for GBM (obs. elapsed time ~40days)

**Using epochs with duration < 1 to 2 weeks**

**FLUX 10-25 keV**Fluxes in  $10^{-12}$  erg  $\text{cm}^{-2}$   $\text{s}^{-1}$ 

Ep.	XIS1	PCA	PIN	GSO	IBIS	SPI	BAT	FPMA	FPMB
C		11871.0	12024.0						
D		12081.0							
H		11133.0	12284.0						
I		11627.0							
J		11495.0							
K		11544.0	12291.0						
L								9772.00	9831.00
M								9772.00	10005.0
N								9627.00	9721.00

**FLUX 25-80 keV**

Ep.	XIS1	PCA	PIN	GSO	IBIS	SPI	BAT	FPMA	FPMB
C		13570.0	13609.0			12622.0	10550.0		
D		14649.0				12866.0			
H		12530.0	13618.0		12042.0				
I		13186.0			12629.0	12296.0	10281.3		
J		12978.0			11786.0	11480.0			
K		13078.0	13822.0						
L					12563.0	12454.0		10951.0	11112.0
M					12282.0			11618.0	11454.0
N					12206.0			10908.0	11118.0

**FLUX 100-300 keV**

Ep.	XIS1	PCA	PIN	GSO	IBIS	SPI	BAT	FPMA	FPMB
C				10872.0		10009.0			
D						10218.0			
H					9303.00				
I				10614.0	9240.00	9625.00			
J					9165.00	9776.00			
K				10613.0					
L					9380.00	9864.00			
M					9834.00				
N					9051.00				

## Power law slopes

### GAMMA\_1

Ep.	XIS1	PCA	PIN	GSO	IBIS	SPI	BAT	FPMA	FPMB
C	2.05600	2.10200	2.11100			2.07700	2.11250		
D		2.04500				2.06400			
H		2.11700	2.13100		2.06400				
I		2.11000			2.04700	2.08600	2.15300		
J		2.11400			2.06300	2.00400			
K		2.11000	2.11700						
L					2.09100	2.07500		2.12200	2.11500
M					2.07500			2.10000	2.10200
N					2.00600			2.11200	2.10300

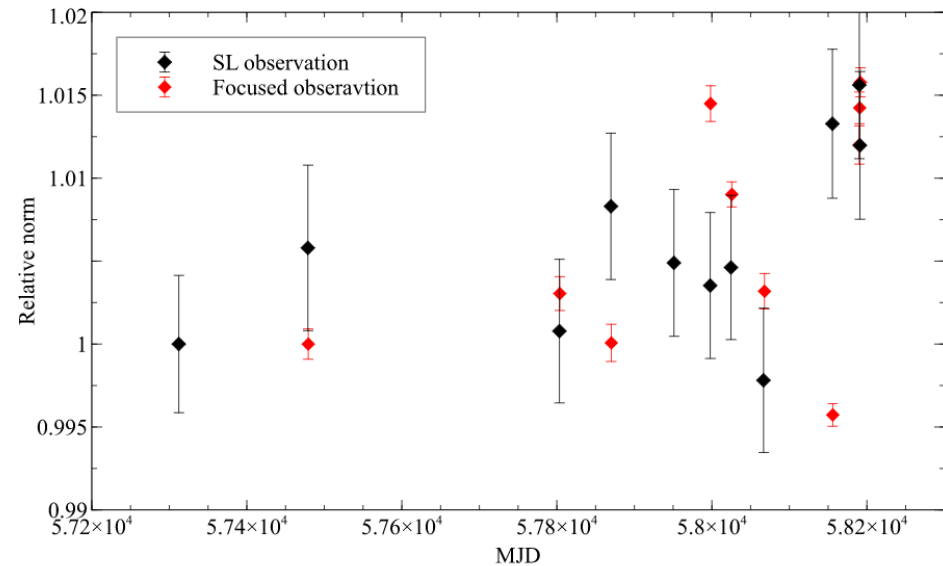
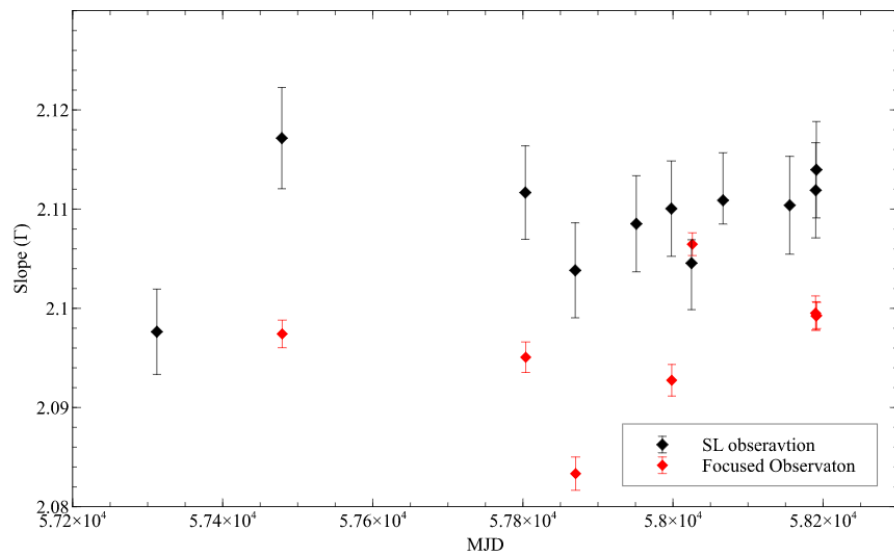
### GAMMA\_2

Ep.	XIS1	PCA	PIN	GSO	IBIS	SPI	BAT	FPMA	FPMB
C				2.16000		2.16700			
D						2.17600			
H					2.26000				
I				2.15000	2.38000	2.16900			
J					2.20000	2.13100			
K				2.12000					
L					2.38000	2.17000			
M					2.17000				
N					2.35000				

# NuSTAR Calibration Report (K. Madsen)

- Crab campaign: using straylight vs focused observations; comparison with Swift/BAT & GBM
- Acquired dataset of 24 observations
- Recalibration of NuSTAR vignetting functions and detector absorption parameters
- Assuming Crab constant flux & slope throughout the epochs
- New CALDB possibly expected ~end 2018
- See Kristin's slides

# SL v. Focused



Important: Differences are expected, primarily we calibrated the ARF against a Crab  $\Gamma=2.1$ , and this is why we are redoing the focused calibration.

Presented by K. Madsen





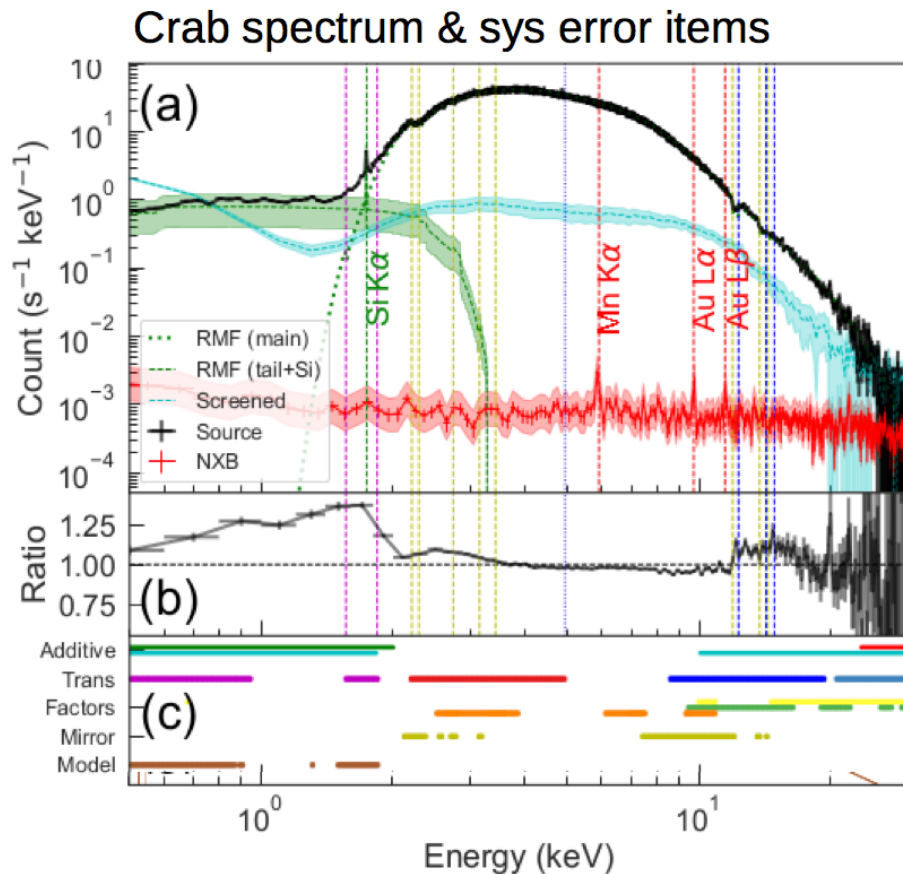
# Summary

- My apologies for not being able to attend; we have many reviews for the recovery mission this month.
- Last year, we had a great progress in Hitomi in-flight calibration using the two non-thermal SNRs.
  - (1) Crab (Tsujiimoto+18, PASJ) ... SXS calibration finished. Consistency with IACHEC verified.
  - (2) G21.5 (Uchida+18, PASJ) ... Wide-band spectral modeling finished and applied to the Hitomi data. Comparison with IACHEC not done yet.
- Next year, we want to focus on G21.5 comparison between Hitomi and others (NuSTAR, etc) in the hard band (~5-50 keV).

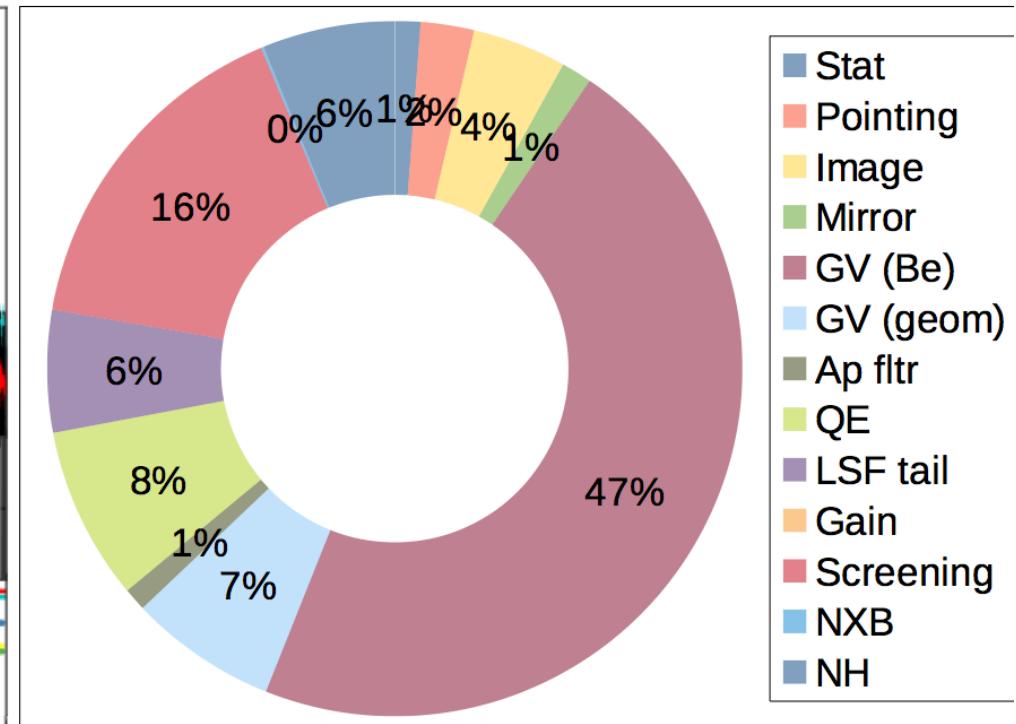
Presentation by M.Tsujiimoto



# (1) Crab: A<sub>eff</sub> calibration



Error "expenses" in 2-12 keV flux

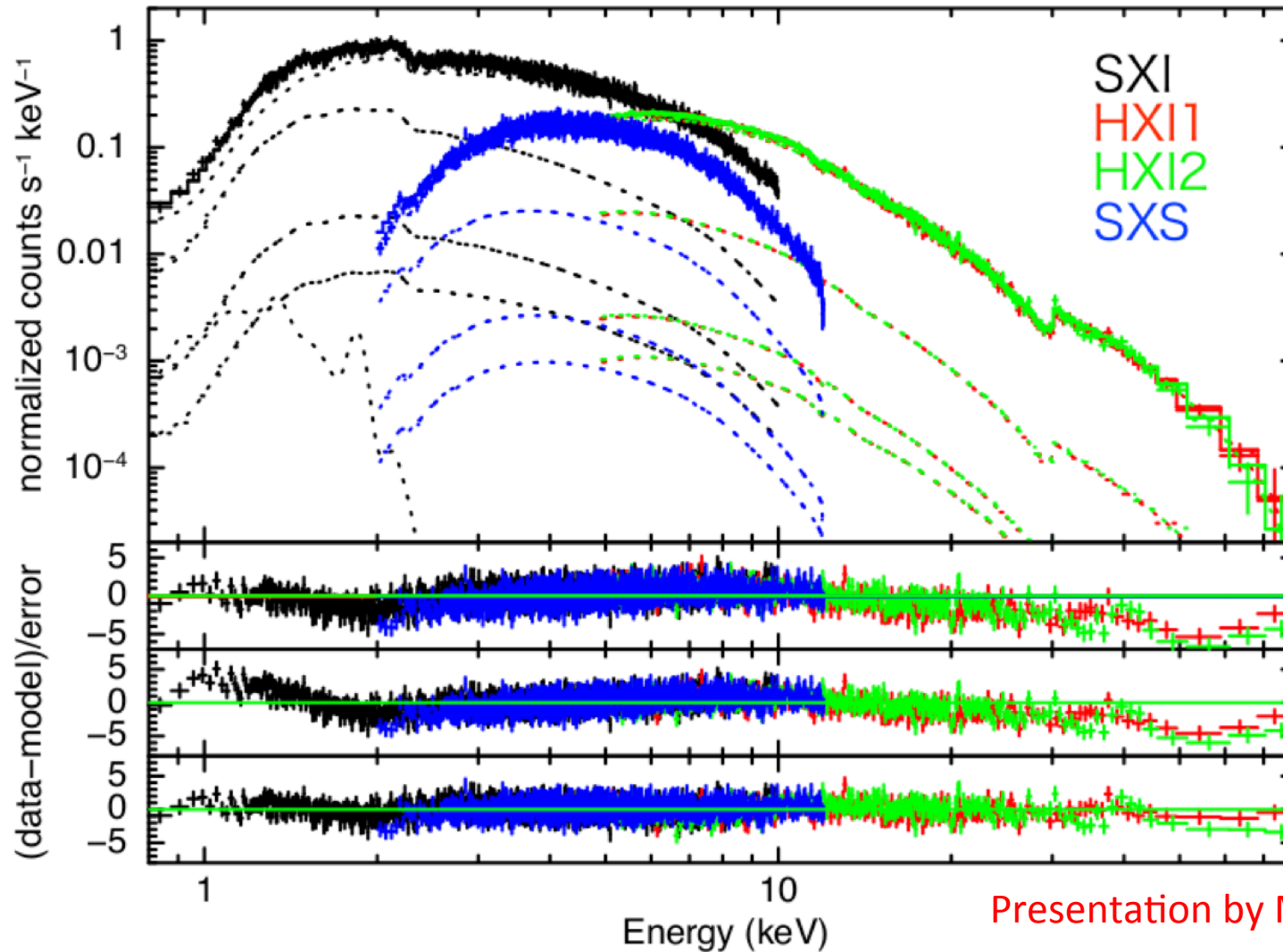


- All conceivable factors evaluated. 2-20 keV  $\Delta E \sim 5$  eV,  $\Delta t \sim 10$   $\mu$ s
- Gate valve gives the largest uncertainty.

Presentation by M. Tsujimoto



## (2) G21.5 : Hitomi data

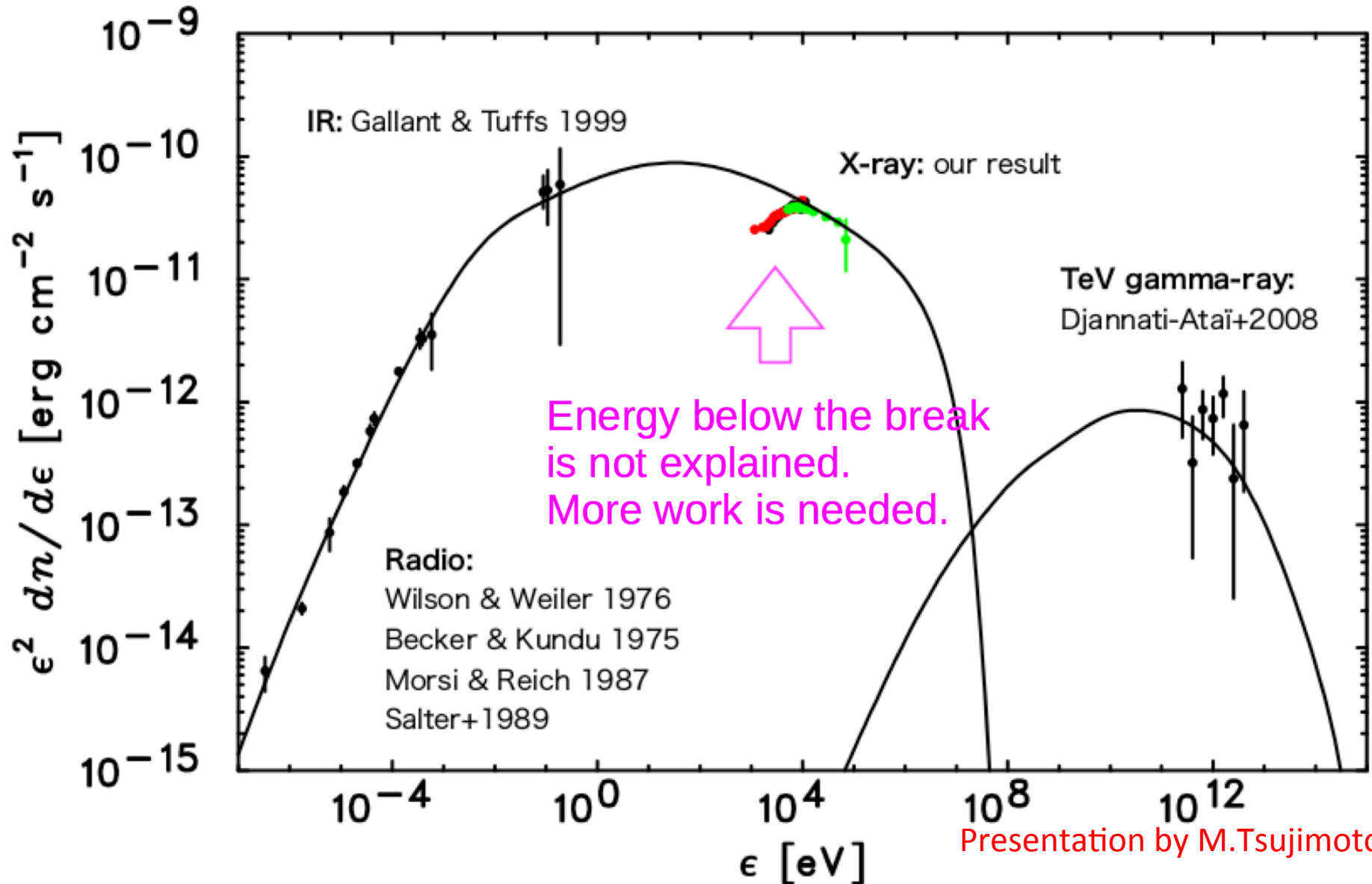


Presentation by M.Tsujimoto

2017/C  $E_{\text{break}} = 7.1 \pm 0.3 \text{ keV}$ ,  $\Gamma_{\text{soft}} = 1.74 \pm 0.02$ ,  $\Gamma_{\text{hard}} = 2.14 \pm 0.01$



## (2) G21.5 : Application to Hitomi



# Summary

- Activity of WG continues to be focused on Crab and G21.5
- Good primary standards also for new missions
- Crab matrix basically available to concordance project
- Recalibration of NuSTAR effective area expected within next IACHEC meeting
- New studies of G21.5 model and comparison with NuSTAR and Chandra

To follow (actions):

- include Hitomi & ASTROSAT Crab spectra for 2016 epoch
- Publication of Crab multi-year dataset
- Teams to assess feasibility of using Crab phase folded data to be for new cross-cal project