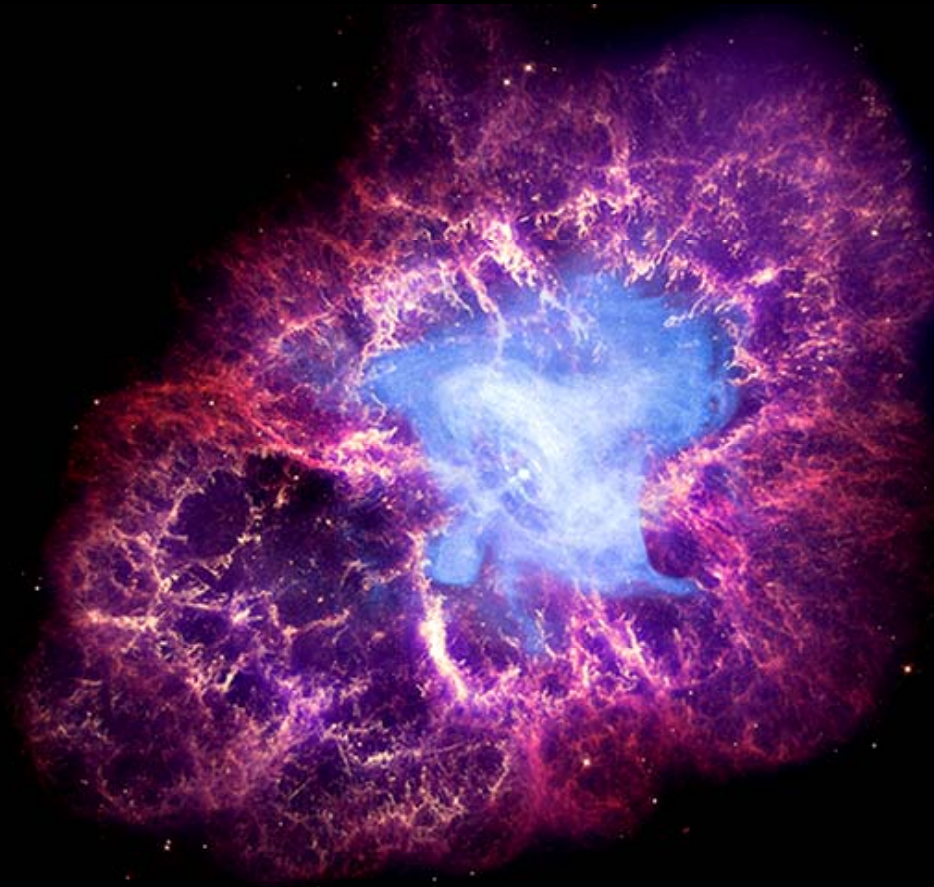


# When a Standard Candle Flickers: An Update on the Crab



**Gary Case**  
**Louisiana State University**

IACHEC, Napa, CA, 27 March 2012

# Collaborators

## GBM Occultation Team:

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MAXI data from: <http://maxi.riken.jp>

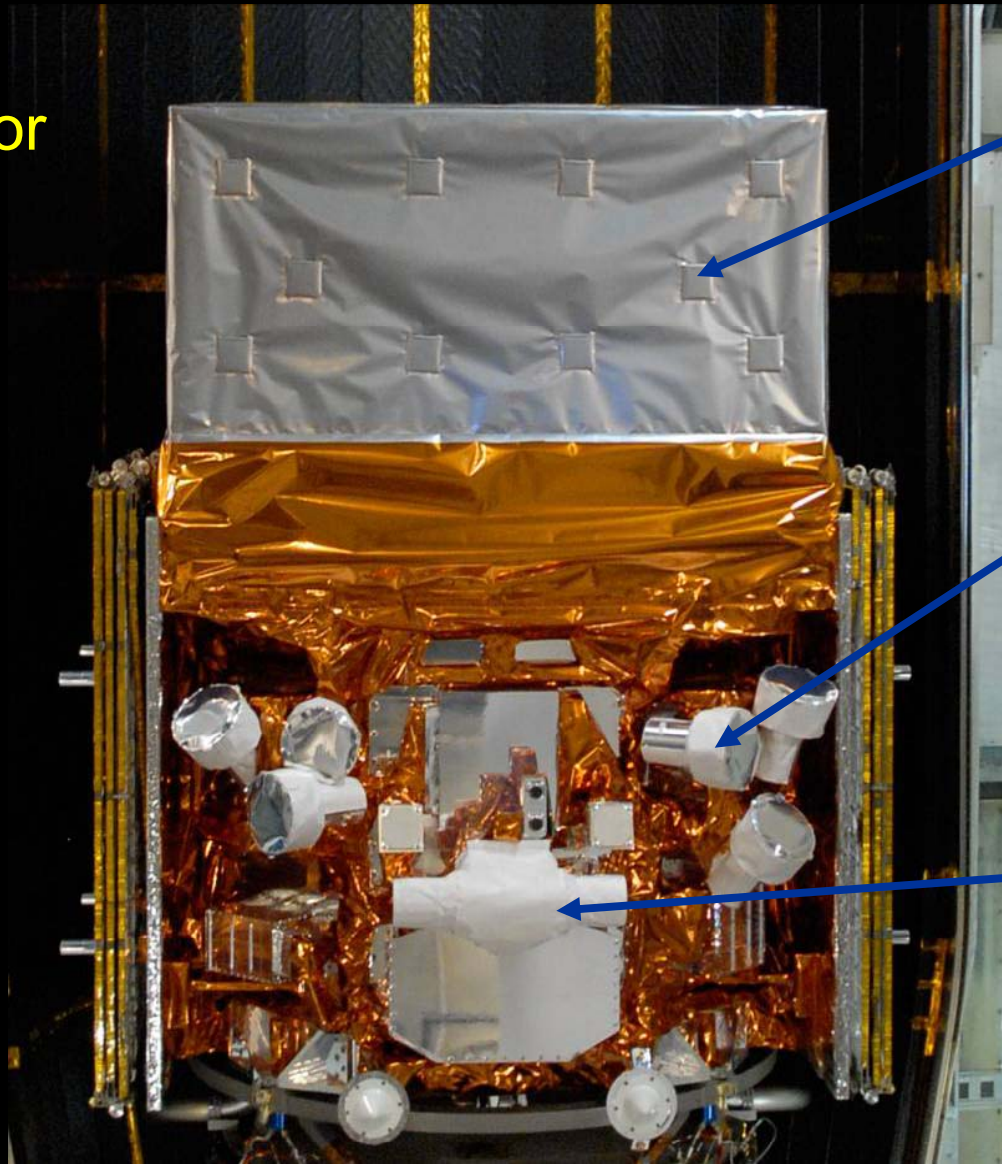
Swift/BAT Transient Monitor data from:

<http://heasarc.gsfc.nasa.gov/docs/swift/results/transients/>

# The *Fermi* Satellite

## Gamma-ray Burst Monitor (GBM)

- 12 NaI detectors
  - 12.5 cm diameter x 1.25 cm thick
  - 8 keV - 1 MeV
- 2 BGO detectors
  - 150 keV - 40 MeV
  - 12.5 cm diameter x 12.5 cm thick
- All GBM detectors are non-imaging



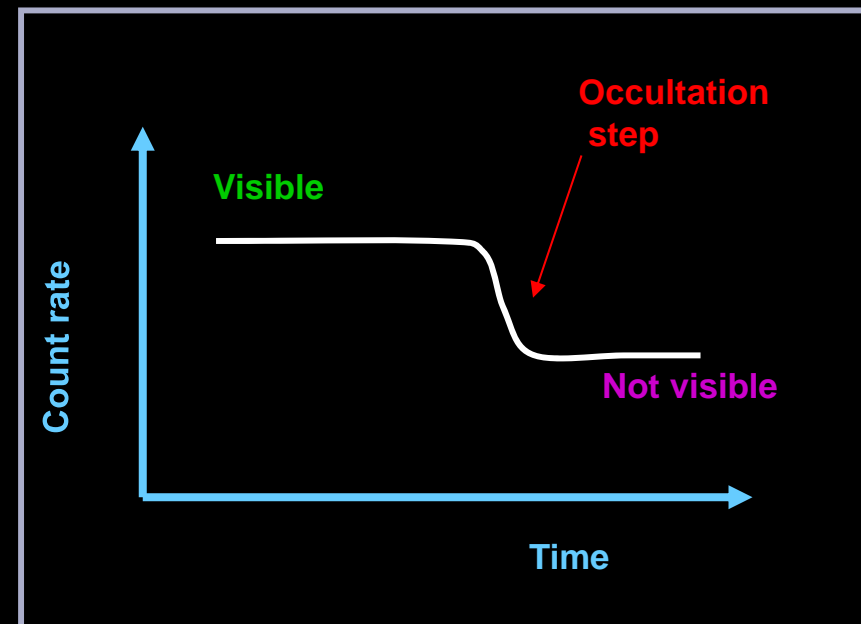
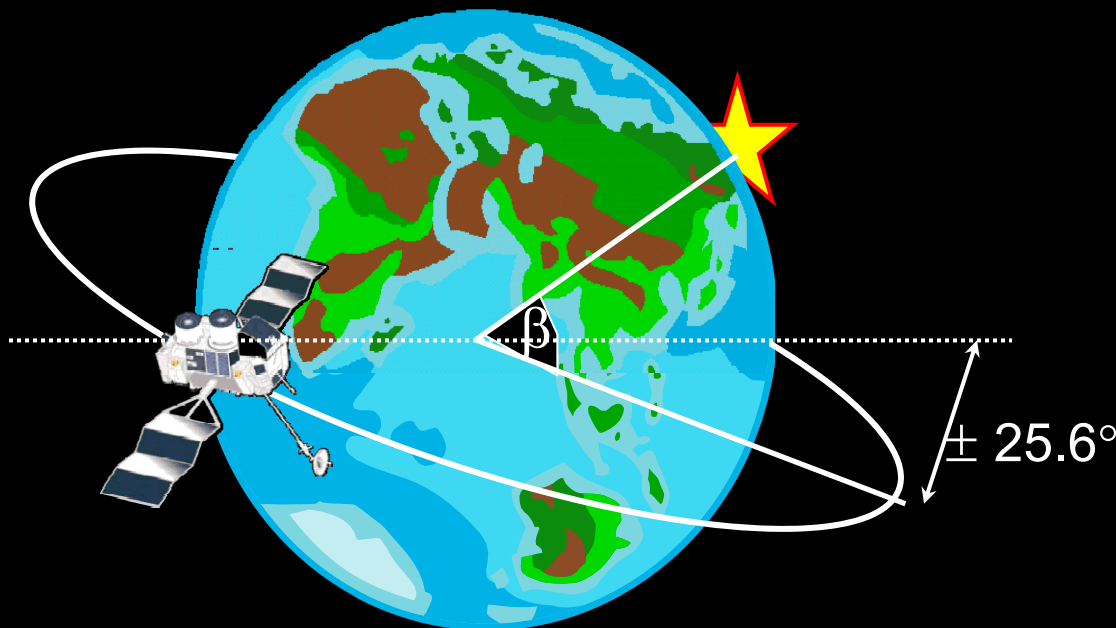
LAT

GBM  
Sodium Iodide  
(NaI)  
Detector

GBM  
Bismuth  
Germanate  
(BGO)  
Detector

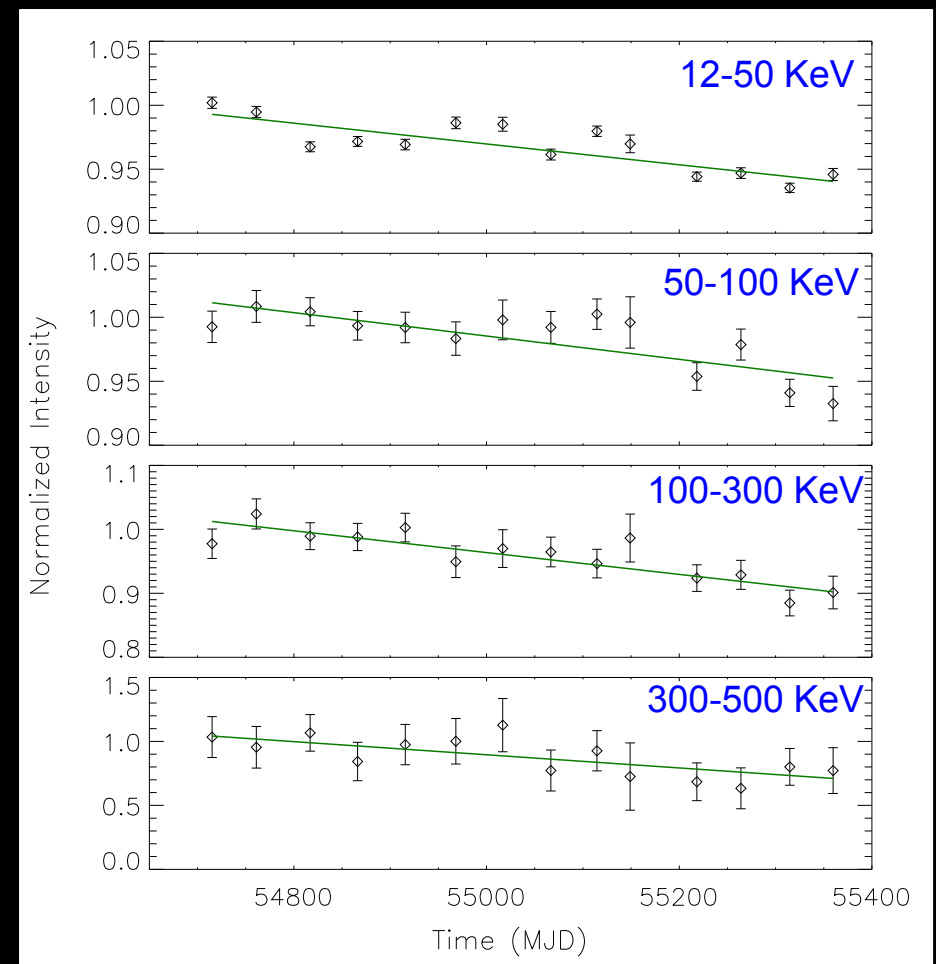
# Earth Occultation

- Non-imaging detectors can monitor the gamma-ray sky utilizing the Earth occultation technique
- 85% of the sky is occulted in one orbit. The precession of the orbit allows the entire sky to be occulted every  $\sim 26$  days.
- Requires a predetermined input source catalog (currently  $\sim 210$ )
- Daily updated light curves available at:  
<http://heastro.phys.lsu.edu/gbm>



# Fermi/GBM: Crab Light Curves

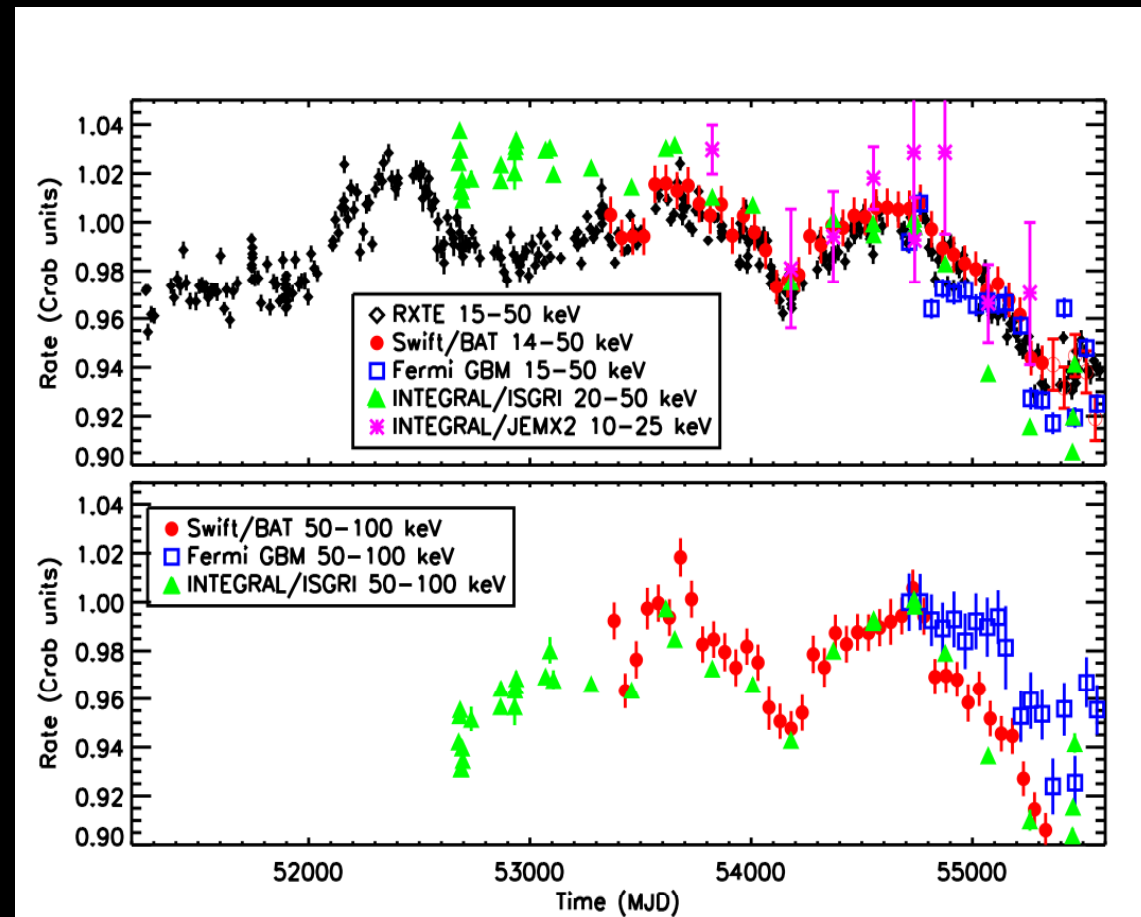
- Updated with Occfit 1.6
- 50-day averages
- Normalized to MJD 54690-54790 in each band
- Decline in Crab flux:
  - $5.4 \pm 0.3\%$  12-50 keV
  - $5.7 \pm 0.9\%$  50-100 keV
  - $11 \pm 2\%$  100-300 keV
  - $30 \pm 12\%$  300-500 keV
- No changes in GBM response or calibration
- Decline appears to become larger as energy increases – spectral softening





# Comparing Instruments

- Light curves for each instrument are normalized to its average rate from MJD 54690-54790.
- GBM – Blue squares
- RXTE/PCU2 – Black diamonds
- BAT – Red circles
- ISGRI – Green triangles
- JEM-X – Orange asterisks

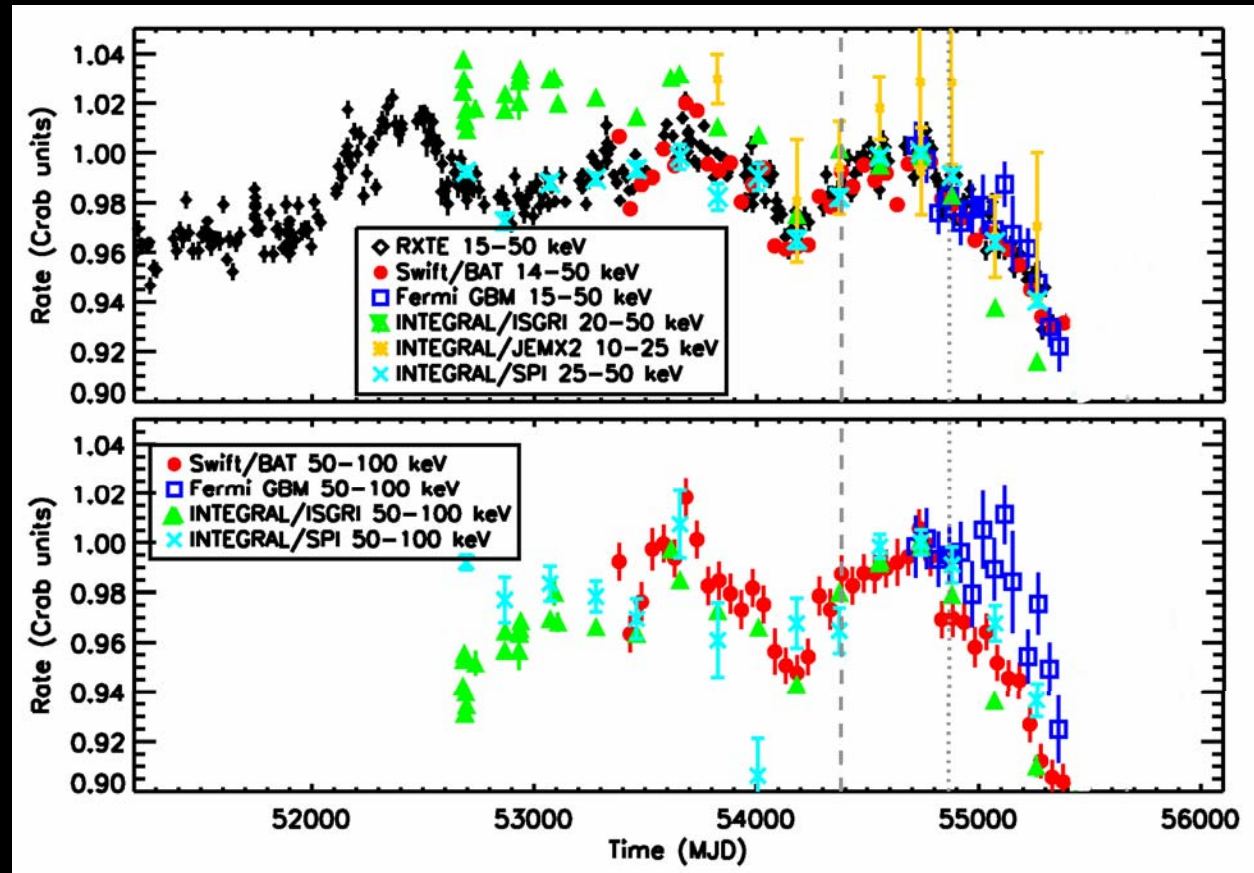


Instruments on four separate spacecraft show  $\sim 7\%$  decline in Crab flux from August 2008-May 2010!

Wilson-Hodge et al. 2011, ApJ, 727, L40

# Comparing Instruments

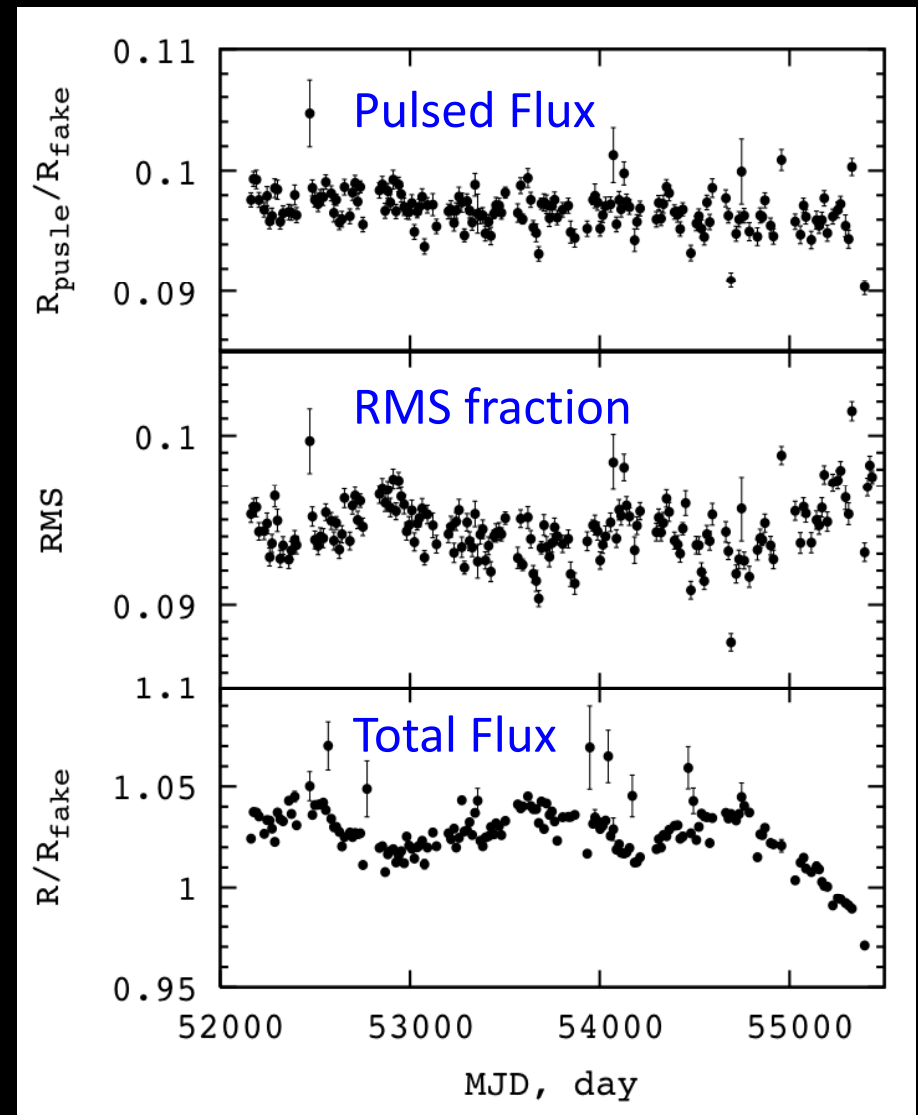
- Light curves for each instrument are normalized to its average rate from MJD 54690-54790.
- GBM – Blue squares
- RXTE/PCU2 – Black diamonds
- BAT – Red circles
- ISGRI – Green triangles
- JEM-X – Orange asterisks
- SPI – light blue x's



Instruments on four separate spacecraft still show  $\sim 7\%$  decline in Crab flux from August 2008-May 2010!

# RXTE Crab Pulsed Flux

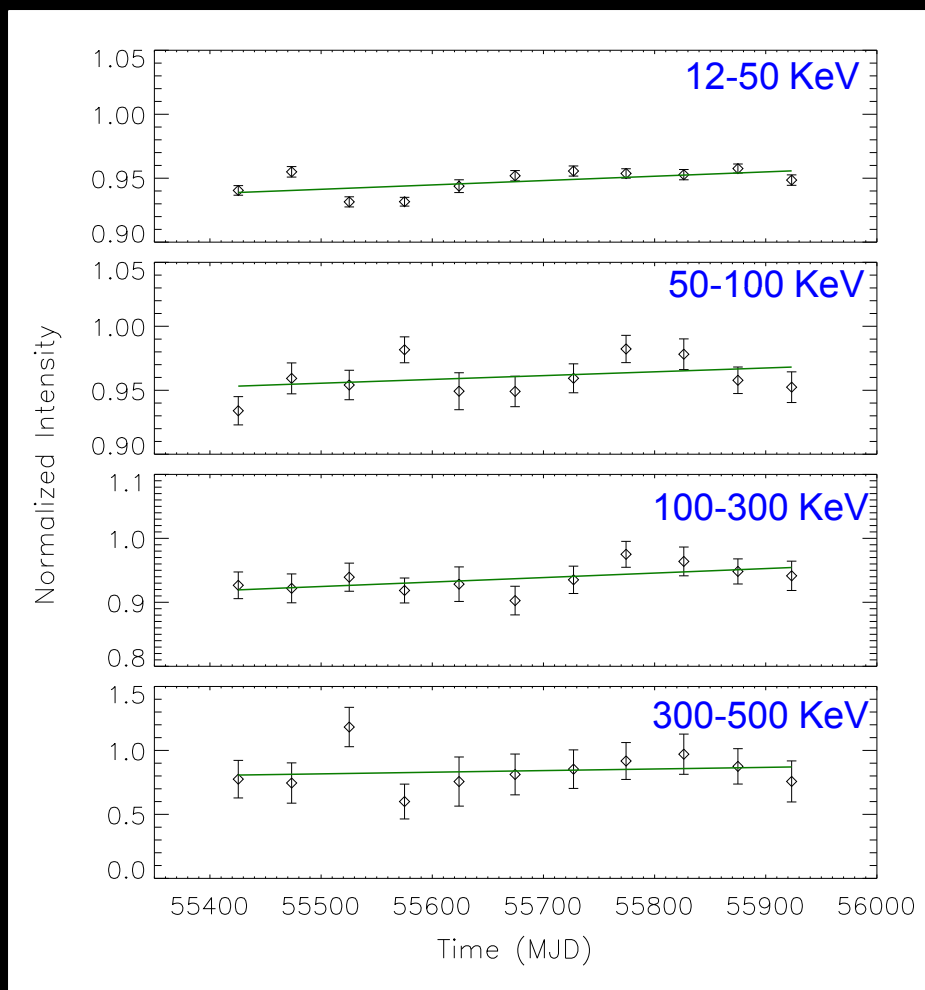
- 3.2-35 keV, all PCU2 layers
- Pulsed flux shows steady decrease at 0.2% per year – consistent with pulsar spin down.
- The larger  $\sim 5\%$  per year variation is not seen in pulsed emission
- Likely has nebular origin





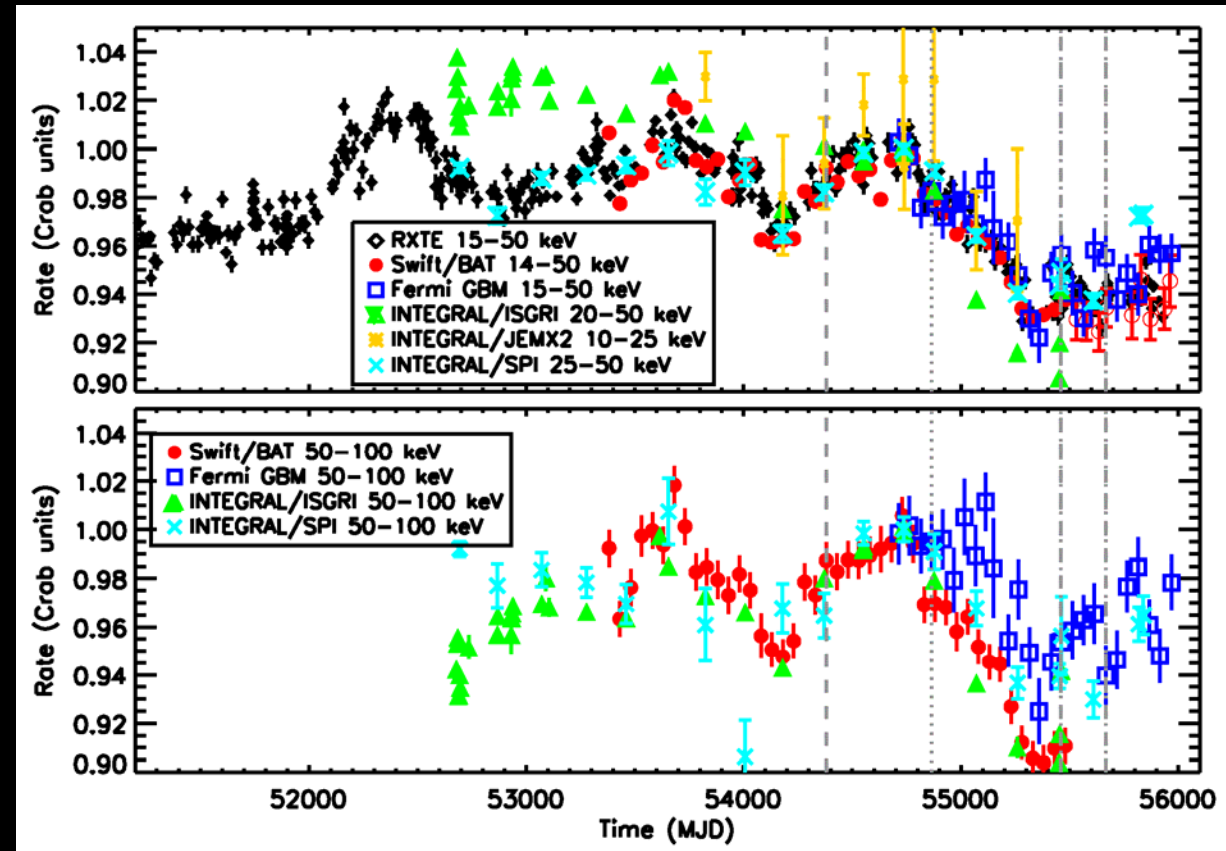
# What has the Crab been up to?

- Fermi/GBM 50-day averages
- Normalized to flux in each band from 54690-54790
- Increase in Crab flux:
  - $1.8 \pm 0.4\%$  12-50 keV
  - $1.6 \pm 1.3\%$  50-100 keV
  - $3.8 \pm 1.9\%$  100-300 keV
  - $8 \pm 12\%$  300-500 keV



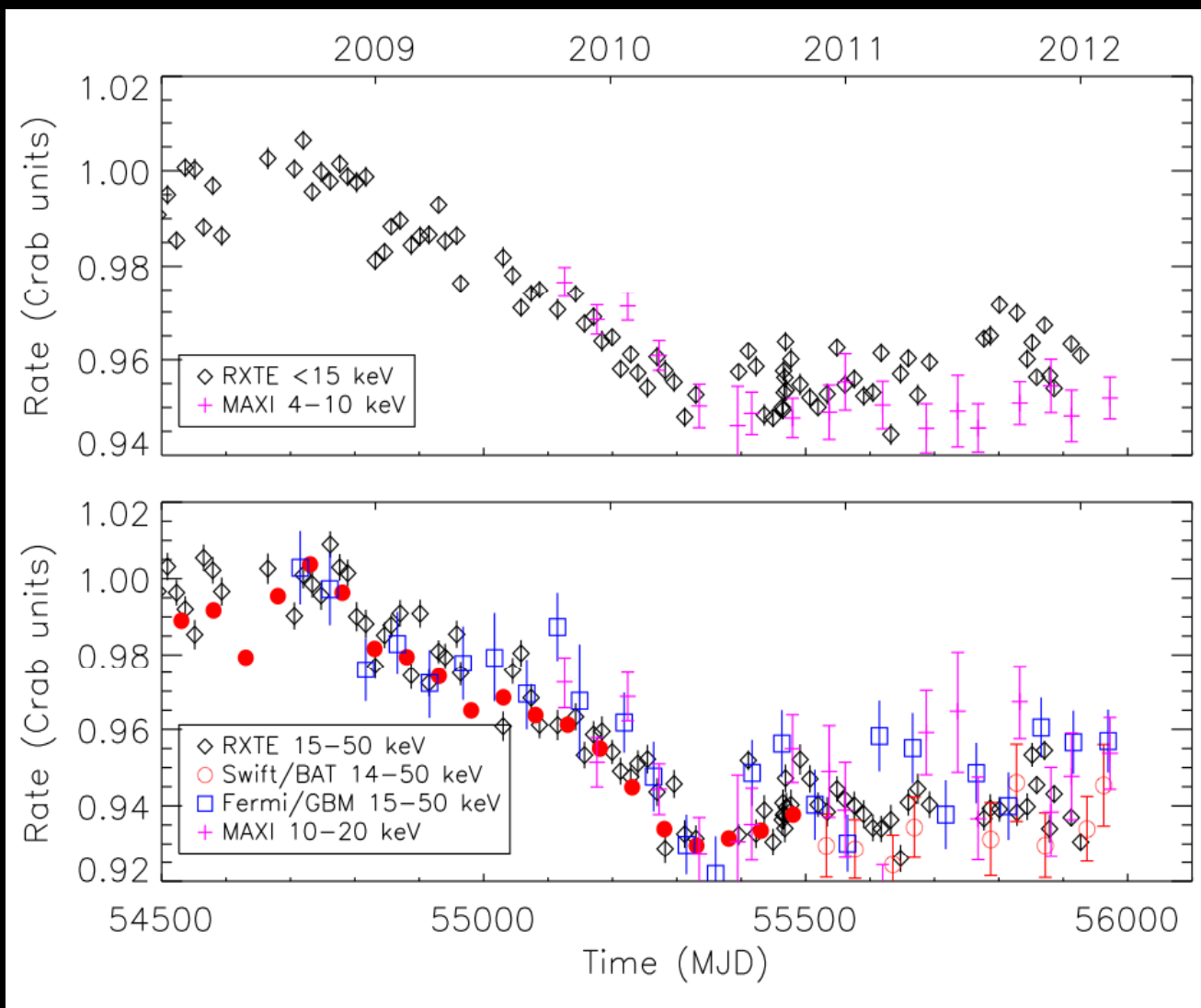
# What has the Crab been up to?

- Added INTEGRAL/SPI
- Dashed/dotted vertical lines → AGILE/Fermi flares



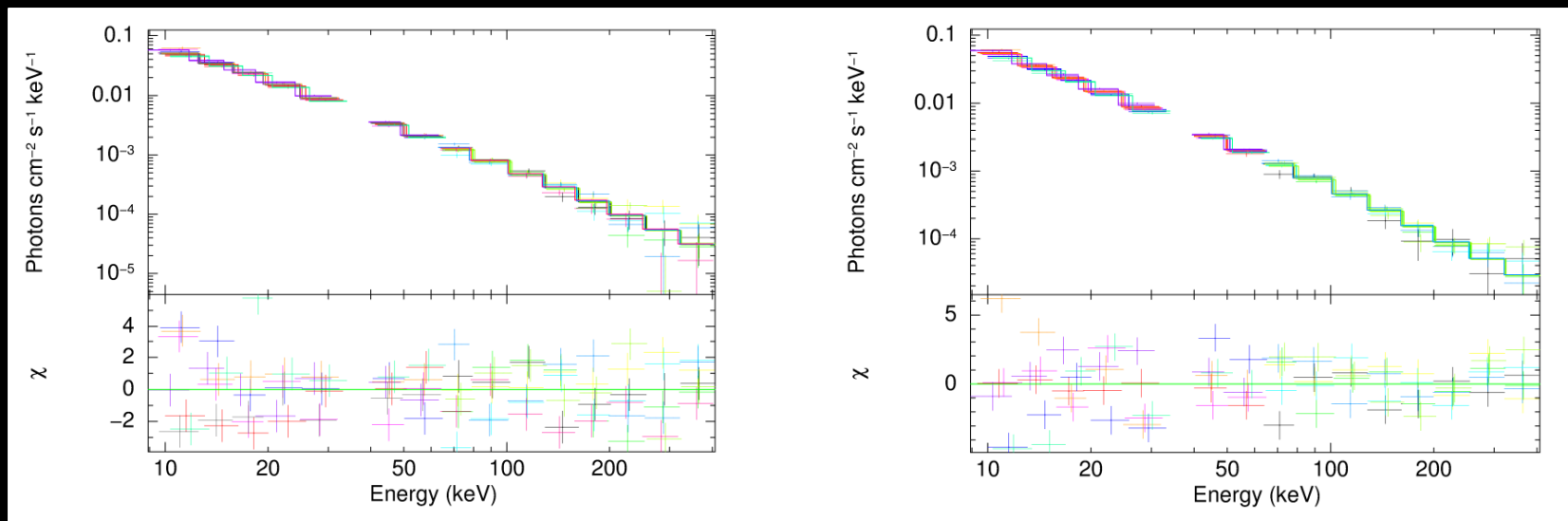
# What has the Crab been up to?

Adding publically  
available  
MAXI/GSC data



# Fermi/GBM: Spectra

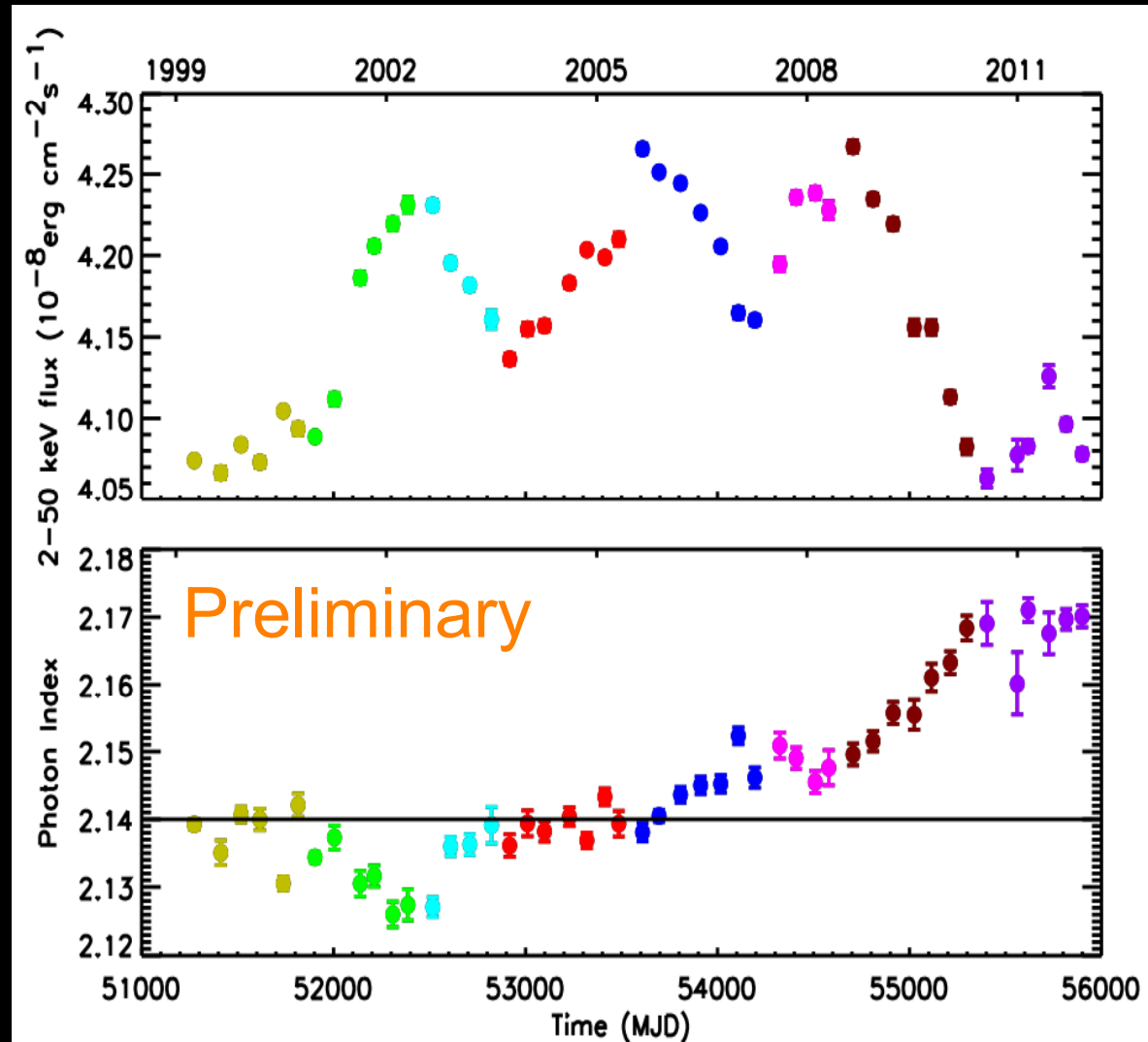
- Use CSPEC data binned into 16 channels from ~10-400 keV
- Remove bin that contains residual due to iodine fluorescence line
- Best fit model is double broken power law – break at ~100 keV (as seen by BATSE, SPI)
- No systematic errors yet



Time	$\Gamma_1$	$E_{b1}$	$\Gamma_2$	$E_{b2}$	$\Gamma_3$	$\chi^2$
54690-54790	$1.59 \pm 0.04$	$17.9 \pm 0.5$	$2.105 \pm 0.007$	$125 \pm 18$	$2.40 \pm 0.01$	2.83
55243-55343	$1.77 \pm 0.03$	$18.4 \pm 0.8$	$2.090 \pm 0.009$	$105 \pm 12$	$2.39 \pm 0.07$	2.19

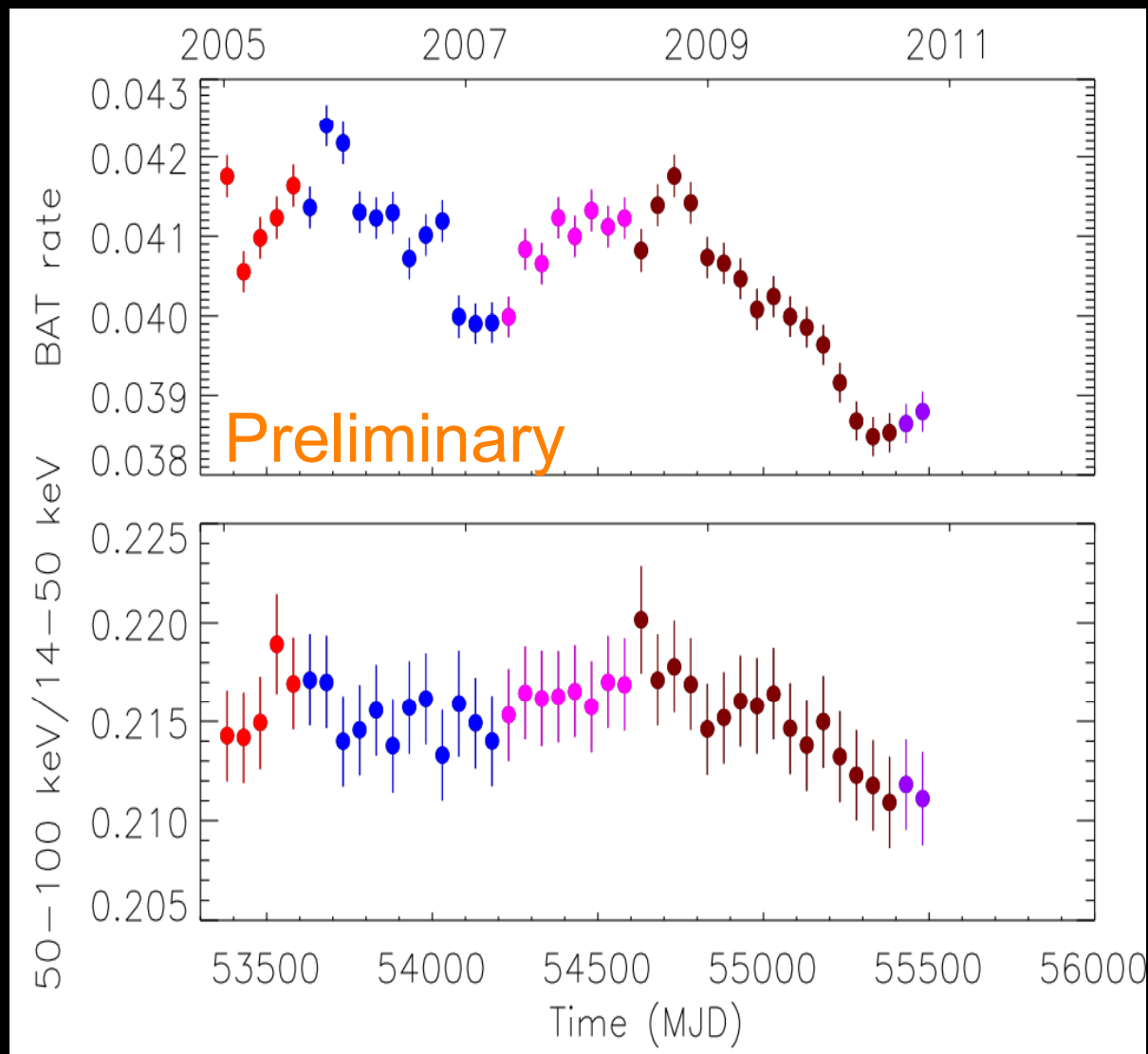
# RXTE PCA Spectra

- Colors denote “rising”, “declining” and “flat” intervals.
- Photon index softens from 2.15 to 2.17 during 2008-2010 flux decline
- Individual observations fitted, results averaged
- PCU2 layer 2&3 data
- Absorbed Power-law
- $N_{\text{H}}$  fixed  $0.97 \times 10^{22} \text{ cm}^{-2}$



# Evidence for Softening in Swift/BAT

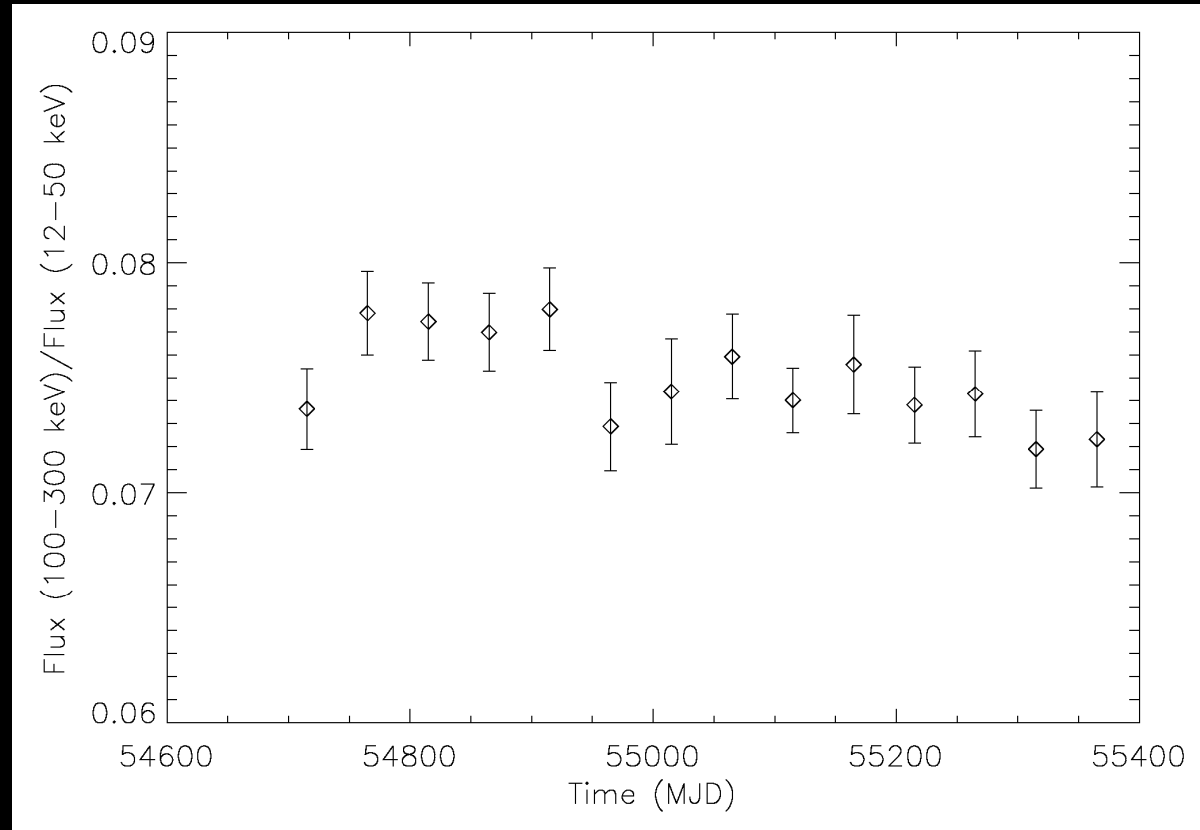
- Color scheme matches RXTE softening during 2008-2010 decline
- Earlier intervals consistent with constant hardness
- Hardness ratios 14-50 keV/50-100 keV BAT 58-month survey data
- 50-day averages





# Evidence for Softening in Fermi/GBM

- Hardness ratios for 12-50 keV/100-300 keV
- 50-day averages



# Conclusions

- Data from seven instruments (Fermi/GBM, RXTE/PCA, Swift/BAT, INTEGRAL/ISGRI, INTEGRAL/JEM-X, INTEGRAL/SPI, MAXI/GSC) are consistent with a  $\sim 7\%$  (70 mCrab) decline in the Crab from Aug 2008 – Jun 2010.

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- The Crab has been roughly constant over the past  $\sim 500$  days above 15 keV.
- The initial decline appears to be larger with increasing energy  $\rightarrow$  preliminary spectra and hardness ratios show evidence of softening.
- All-sky monitors play an important role in hard x-ray instrument calibration/cross-calibration.