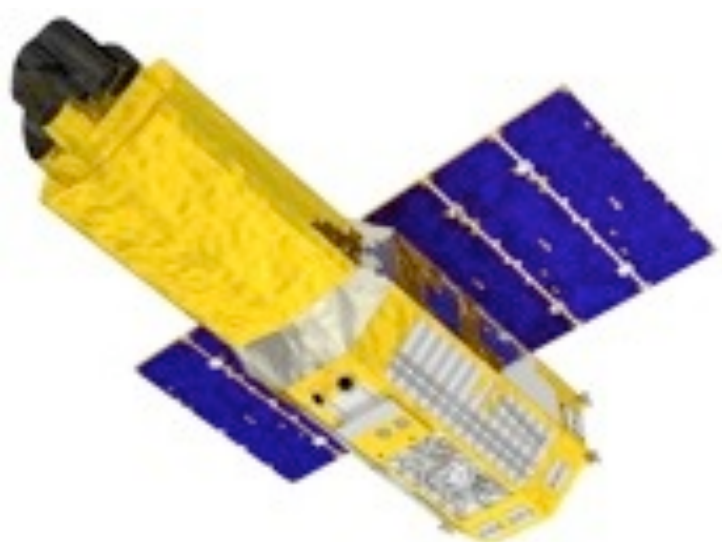
Suzaku Observations of Gamma-Ray Binaries and Prospects for ASTRO-H



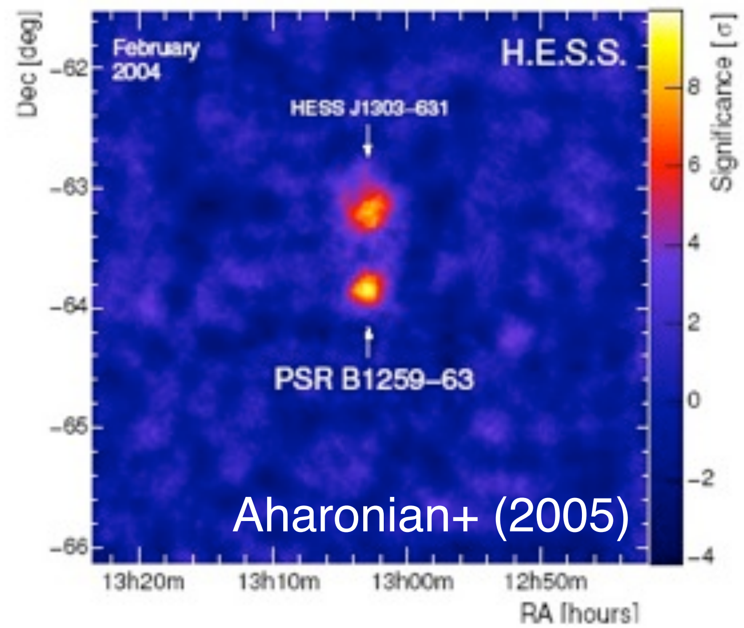
Takaaki Tanaka

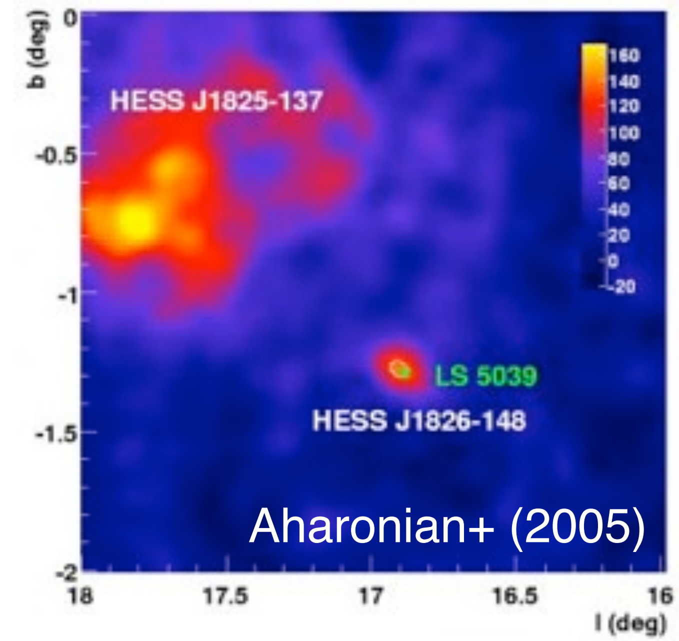
Kyoto University

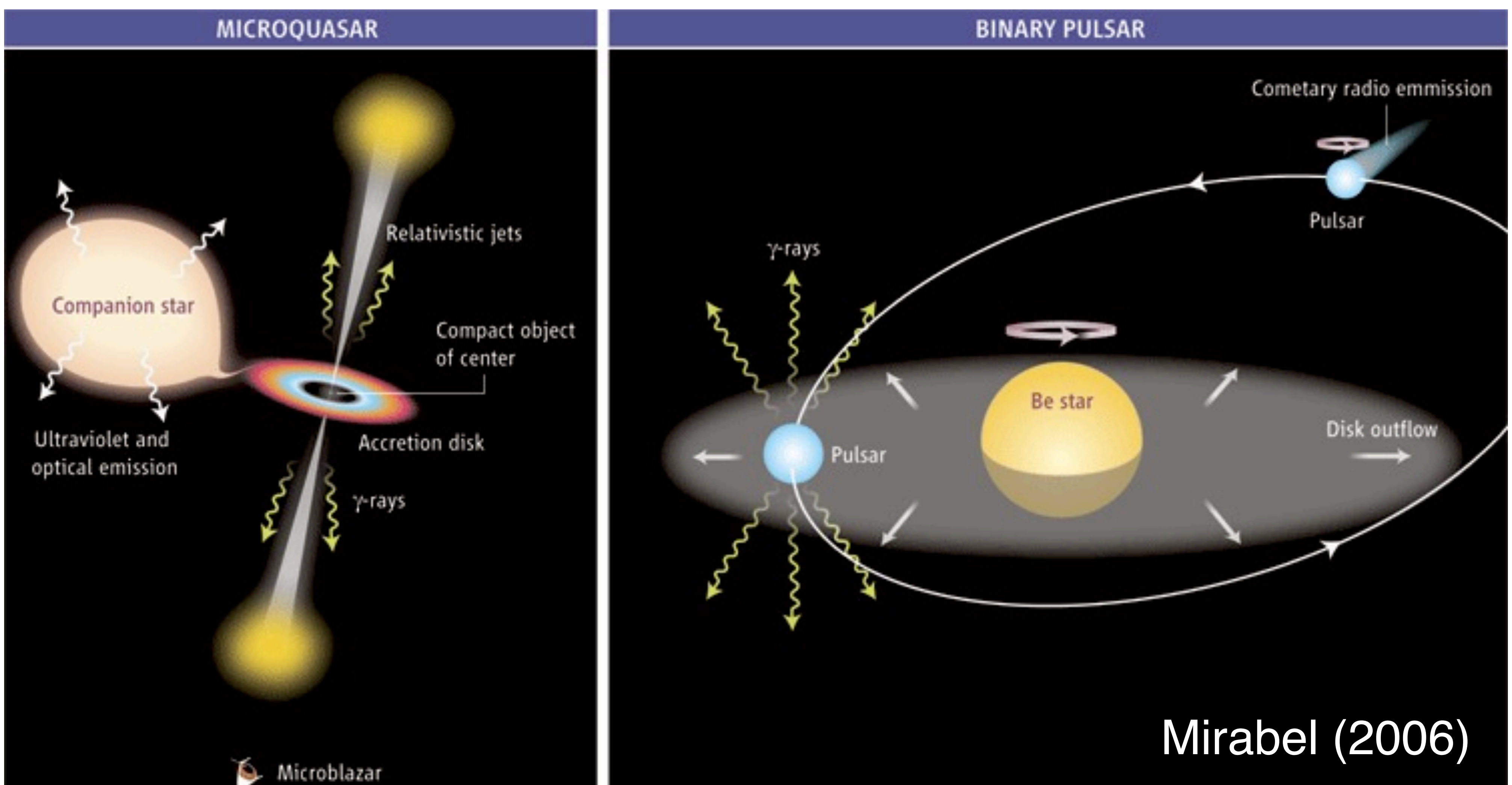
XMM-Newton 2013 Science Workshop
22nd–24th May 2013 @ Madrid, Spain

Gamma-Ray Binaries

Recent GeV/TeV detections
from X-ray binaries
↓
Gamma-Ray Binaries







Gamma-Ray Binaries

- PSR B1259–63 (pulsar)
  - TeV (H.E.S.S.) & GeV (Fermi LAT)
- LS 5039 (unknown)
  - TeV (H.E.S.S.) & GeV (Fermi LAT)
- LS I +61°303 (unknown)
  - TeV (MAGIC/VERITAS) & GeV (Fermi LAT)
- HESS J0632+057 (unknown)
  - TeV (H.E.S.S./MAGIC/VERITAS) & GeV (Fermi LAT)
- 1FGL J1018.6–5856 (unknown)
  - GeV (Fermi LAT)
- Cyg X-3 (unknown)
  - GeV (Fermi LAT/AGILE)
- Cyg X-1 (blackhole)
  - TeV (MAGIC) & GeV (AGILE)

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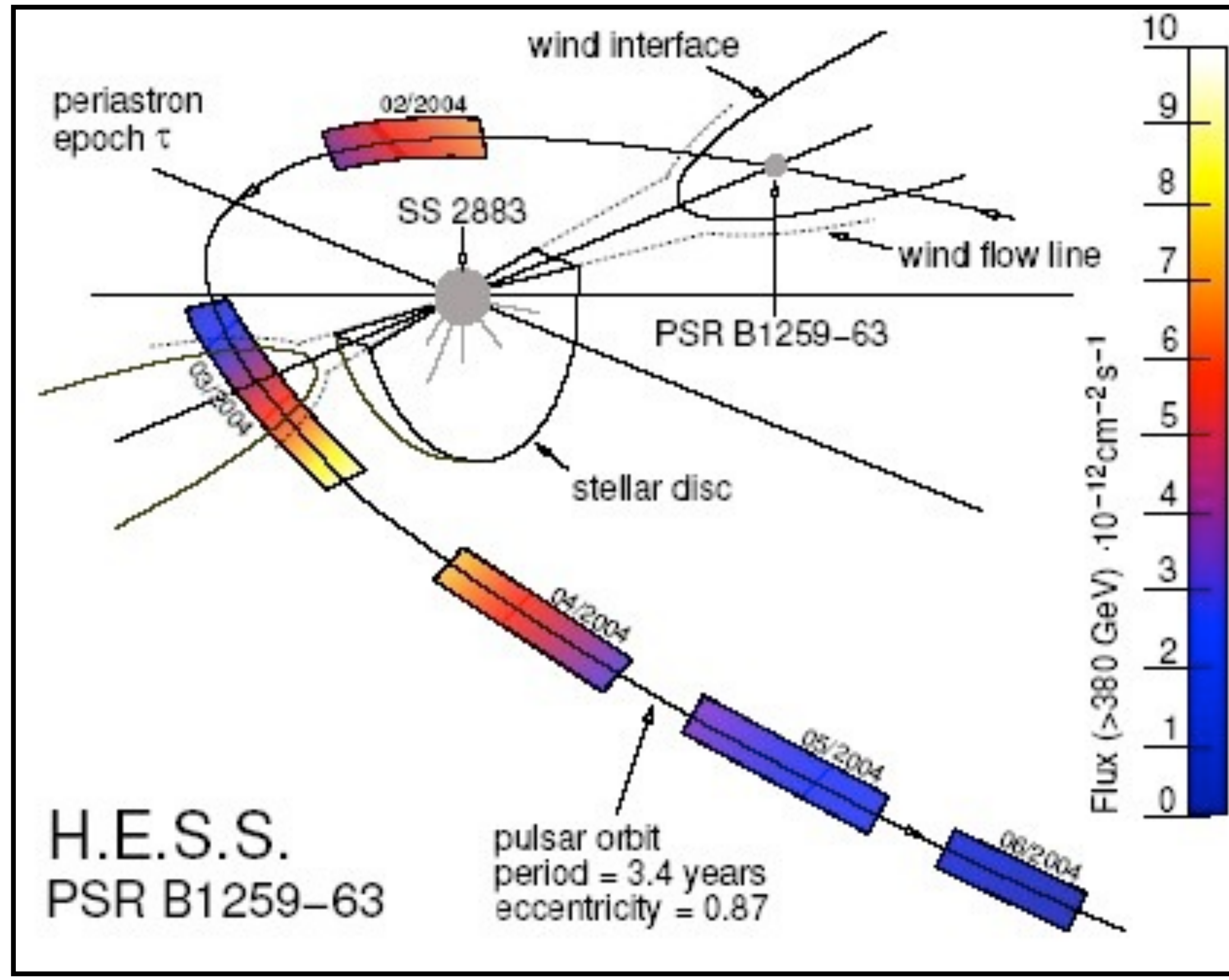
PSR B1259–63

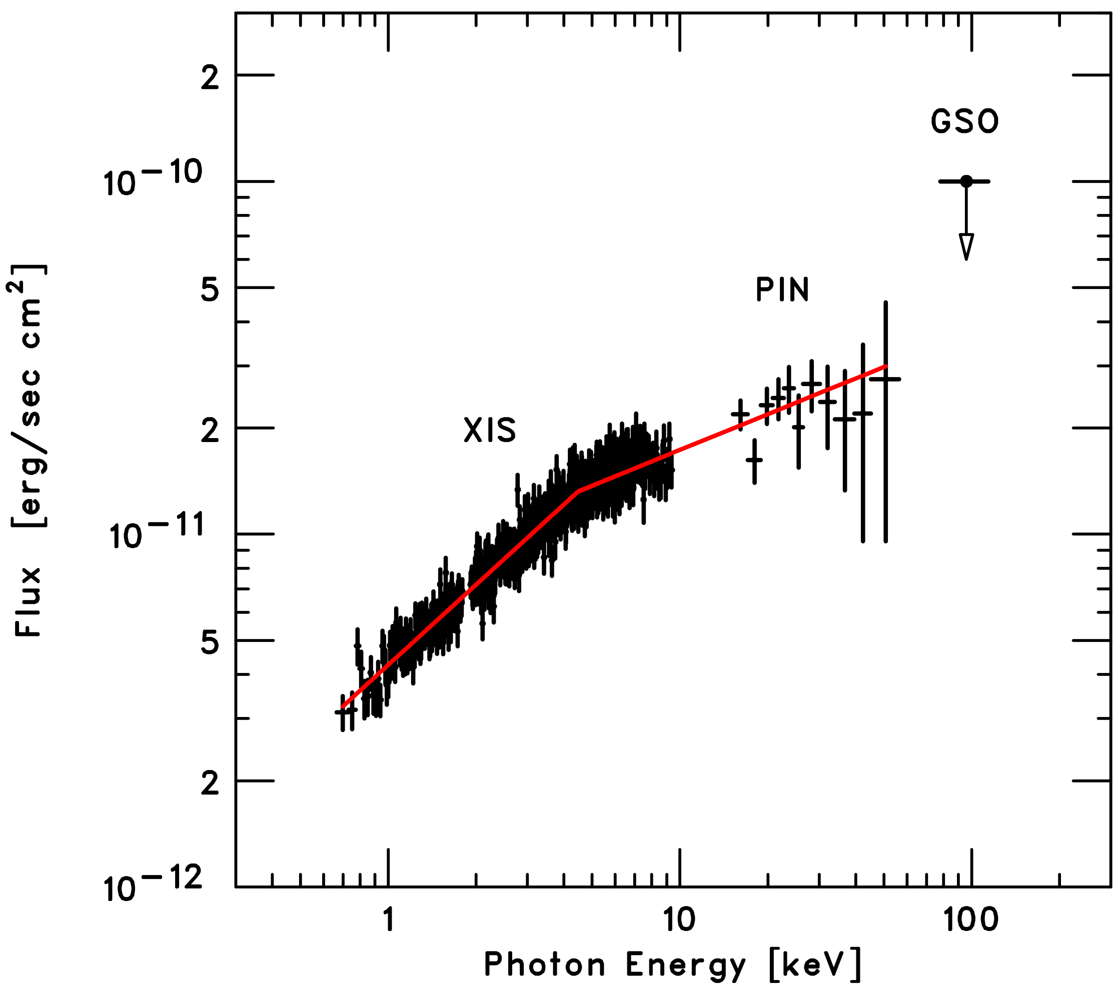
- P_{orb} = 3.4 years
- R_{orb} > 0.7 AU
- LS 2883: Be Star
- Pulsar (P = 48 ms)
- Non-thermal X-rays
- TeV Detection

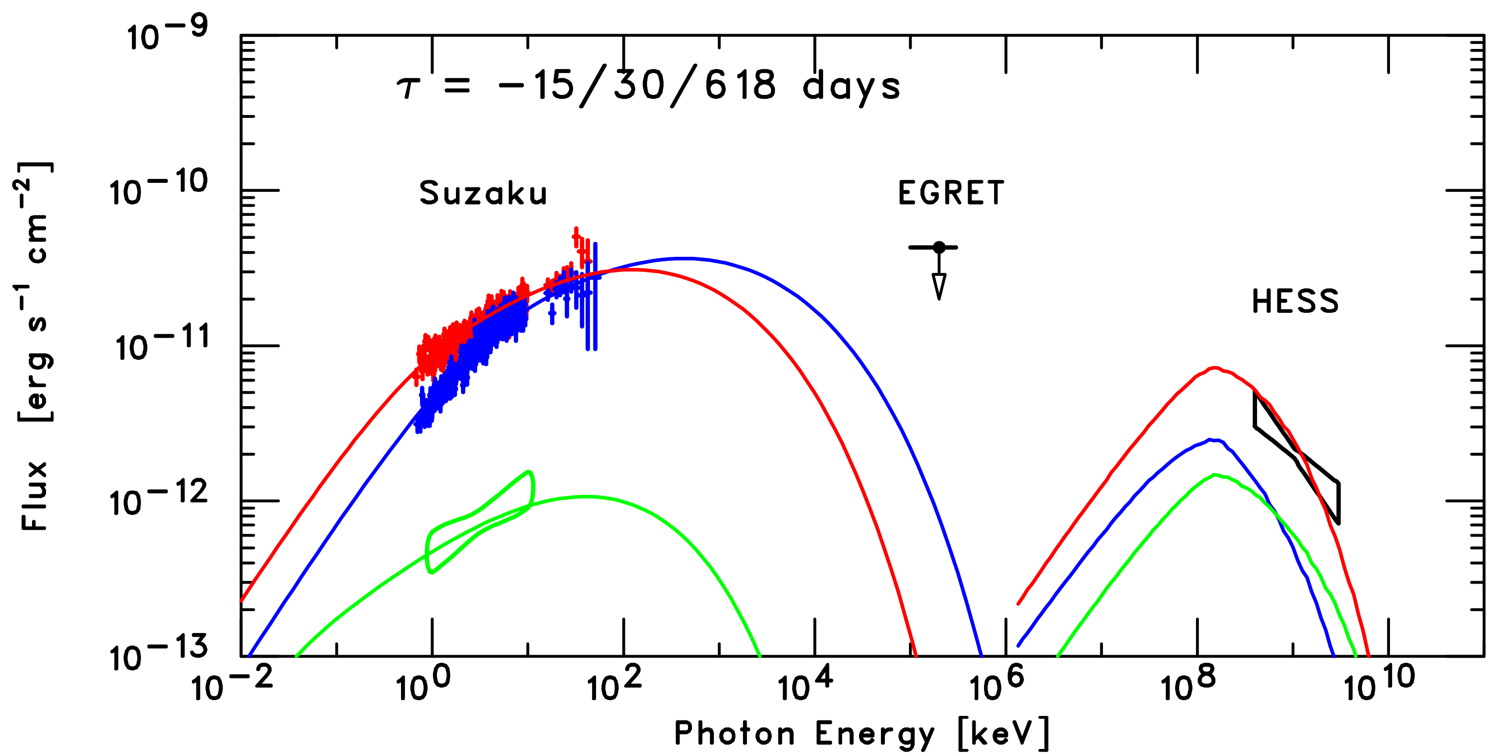


PSR B1259–63 with Suzaku

Suzaku observation of 2007 periastron passage

Uchiyama, TT+ 2009





Detection up to 60 keV
Spectral break
ε_{br} = 4.5 keV
$\Gamma_1 = 1.25$
$\Gamma_2 = 1.76$

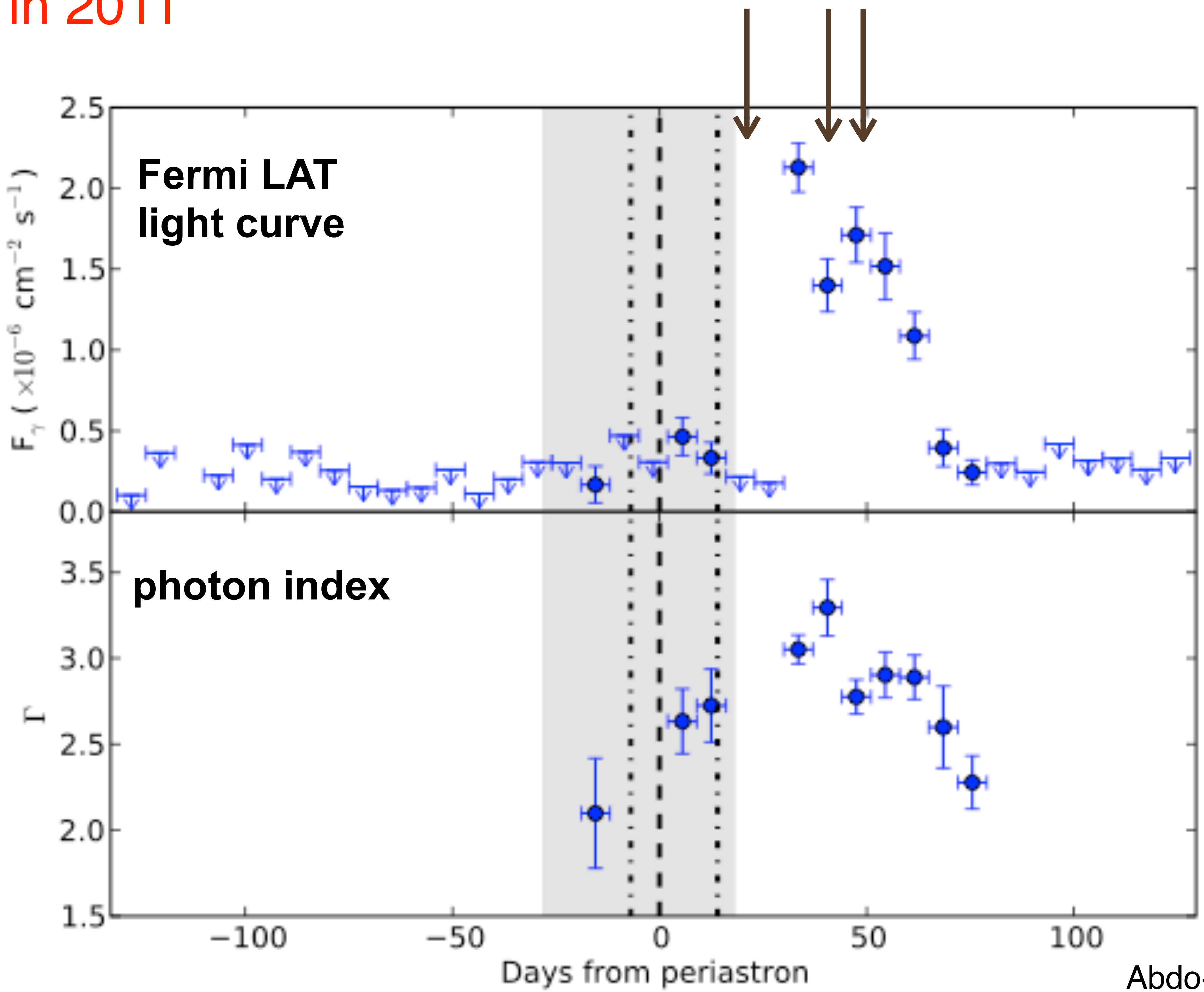
Spectral break
↔ Low-energy cutoff of electron spectrum corresponding to γ_1 of pulsar wind

$\gamma_1 = 4 \times 10^5$

PSR B1259–63 Gamma-Ray Flare

Fermi-LAT detected
GeV flare after periastron
in 2011

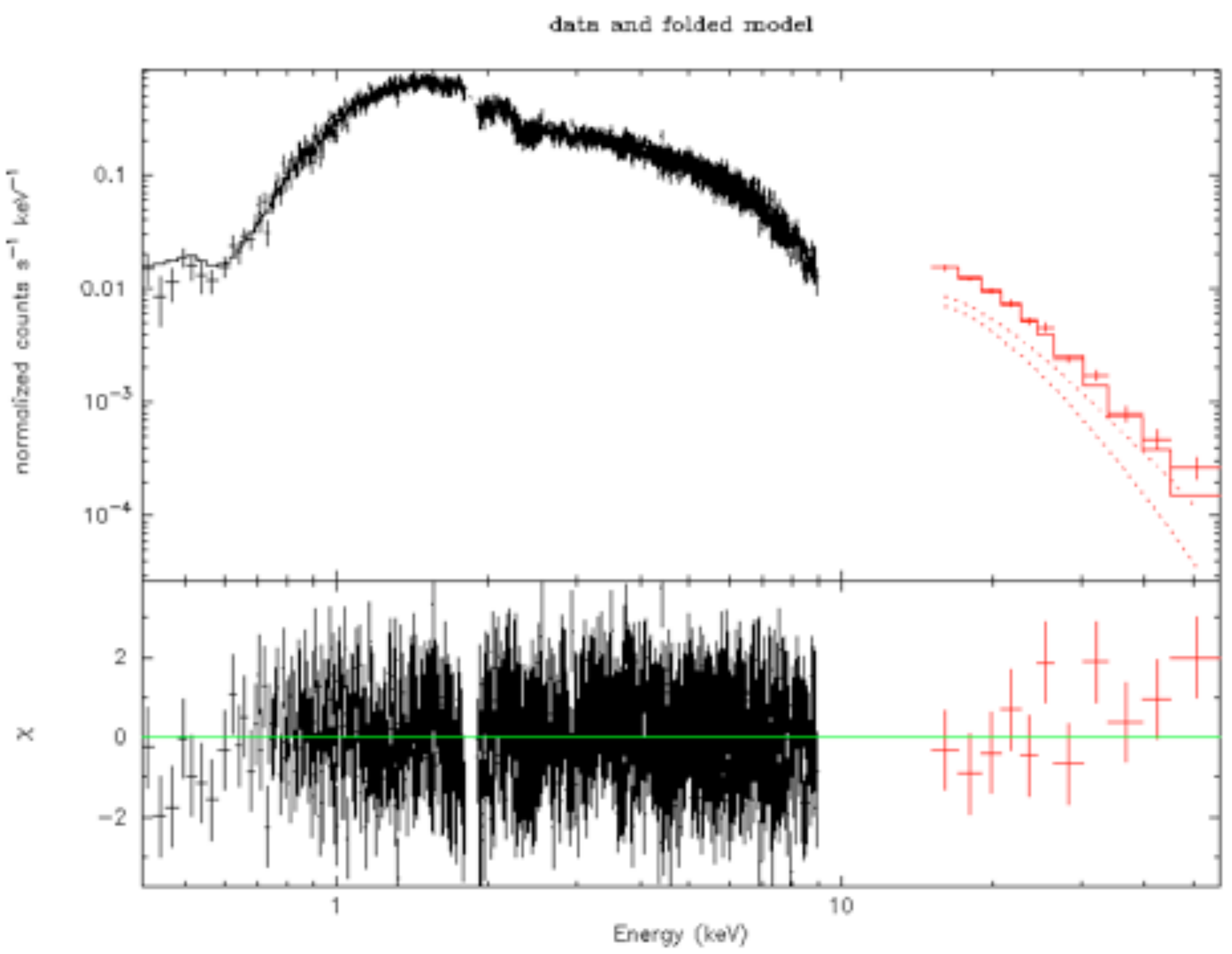
Suzaku Observations
80 ks, 40 ks (ToO), 20 ks



Abdo+ 2011

Suzaku Observation during Flare

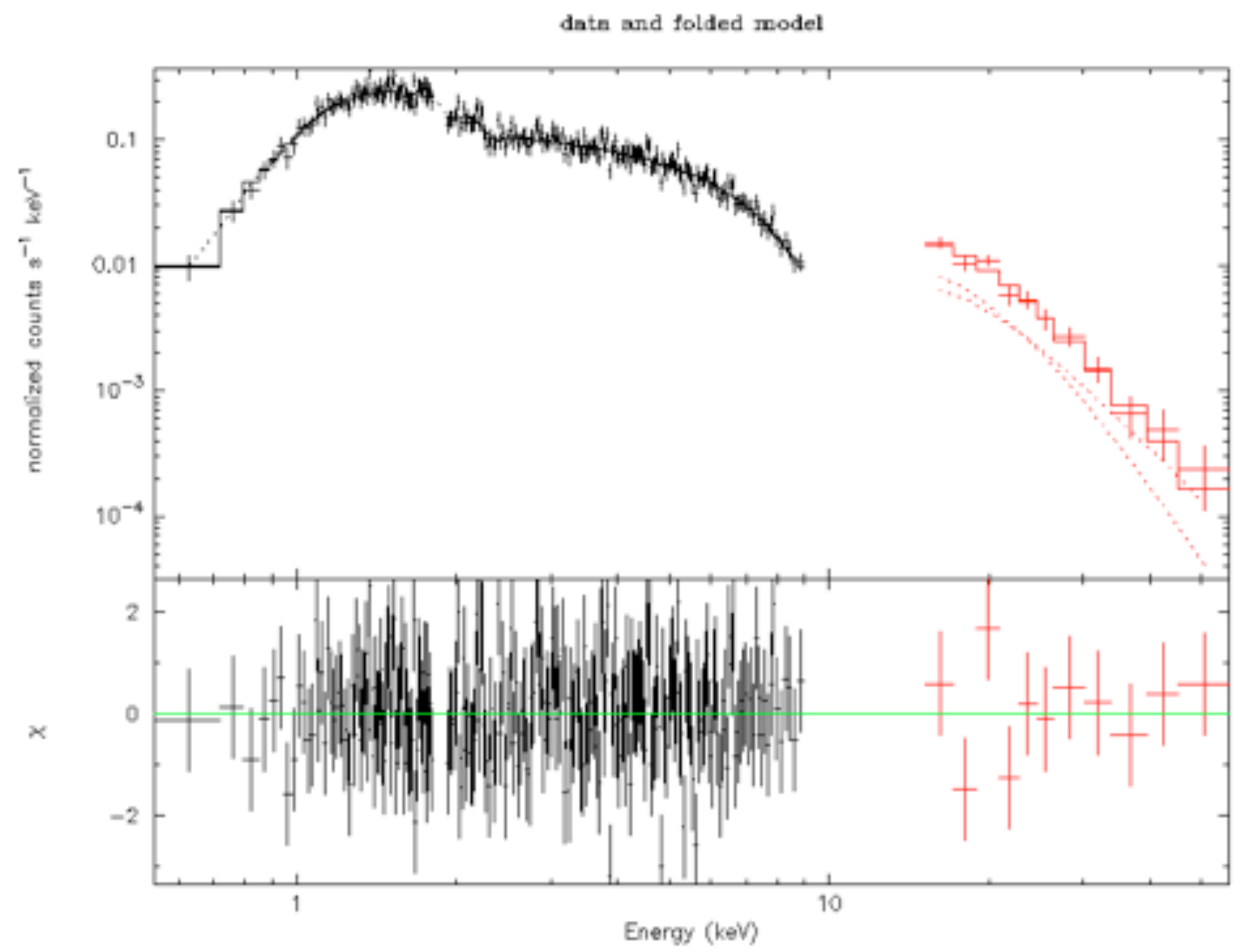
Pre-Flare



$N_H = (0.573\text{-}0.575) \times 10^{22}\ cm^{-2}$

$\Gamma\ = 1.76\text{-}1.78$

During Flare

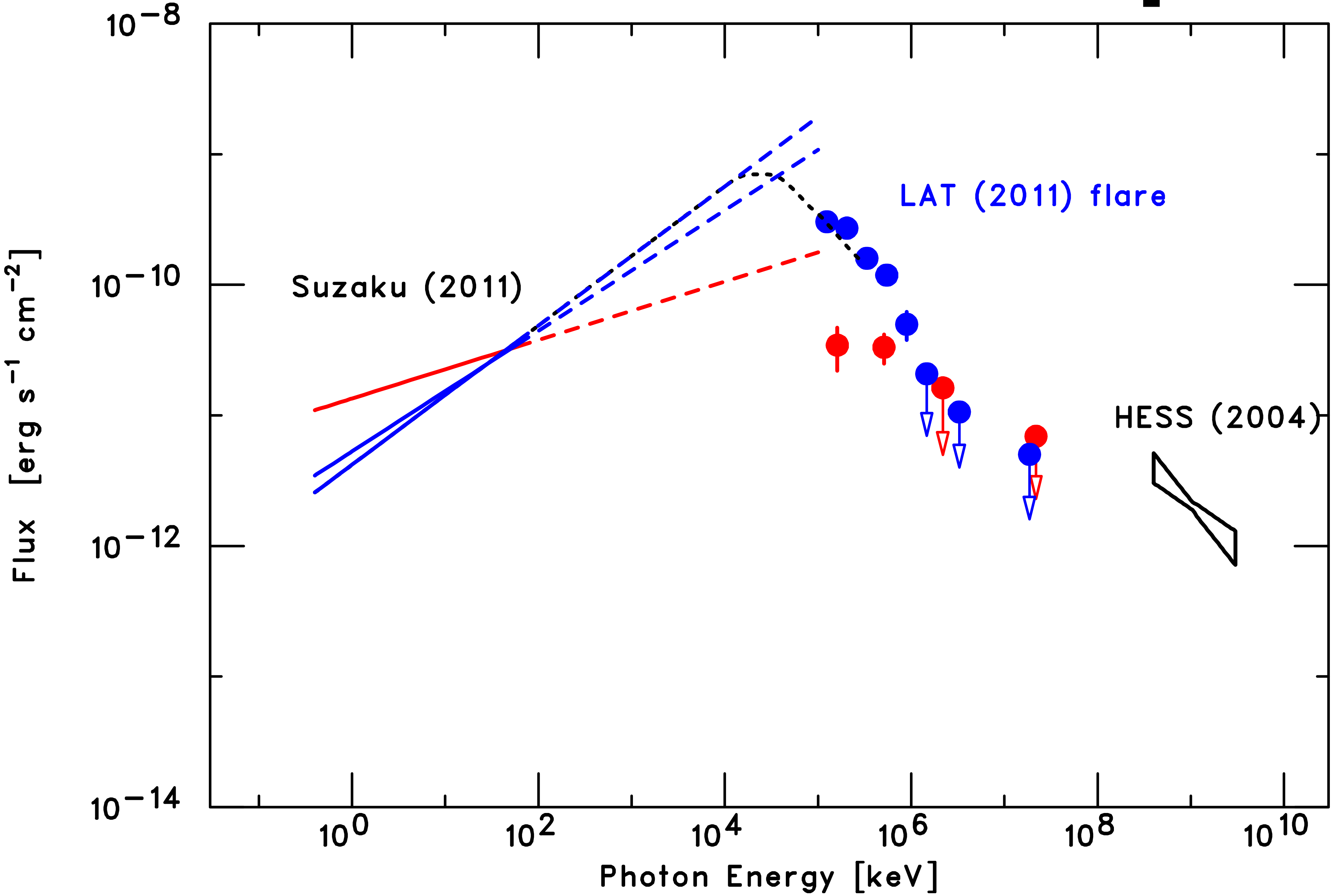


$N_H = (0.491\text{-}0.499) \times 10^{22}\ cm^{-2}$

$\Gamma\ = 1.42\text{-}1.50$

Detection of power-law spectra up to 60 keV

Suzaku & Fermi-LAT Spectra



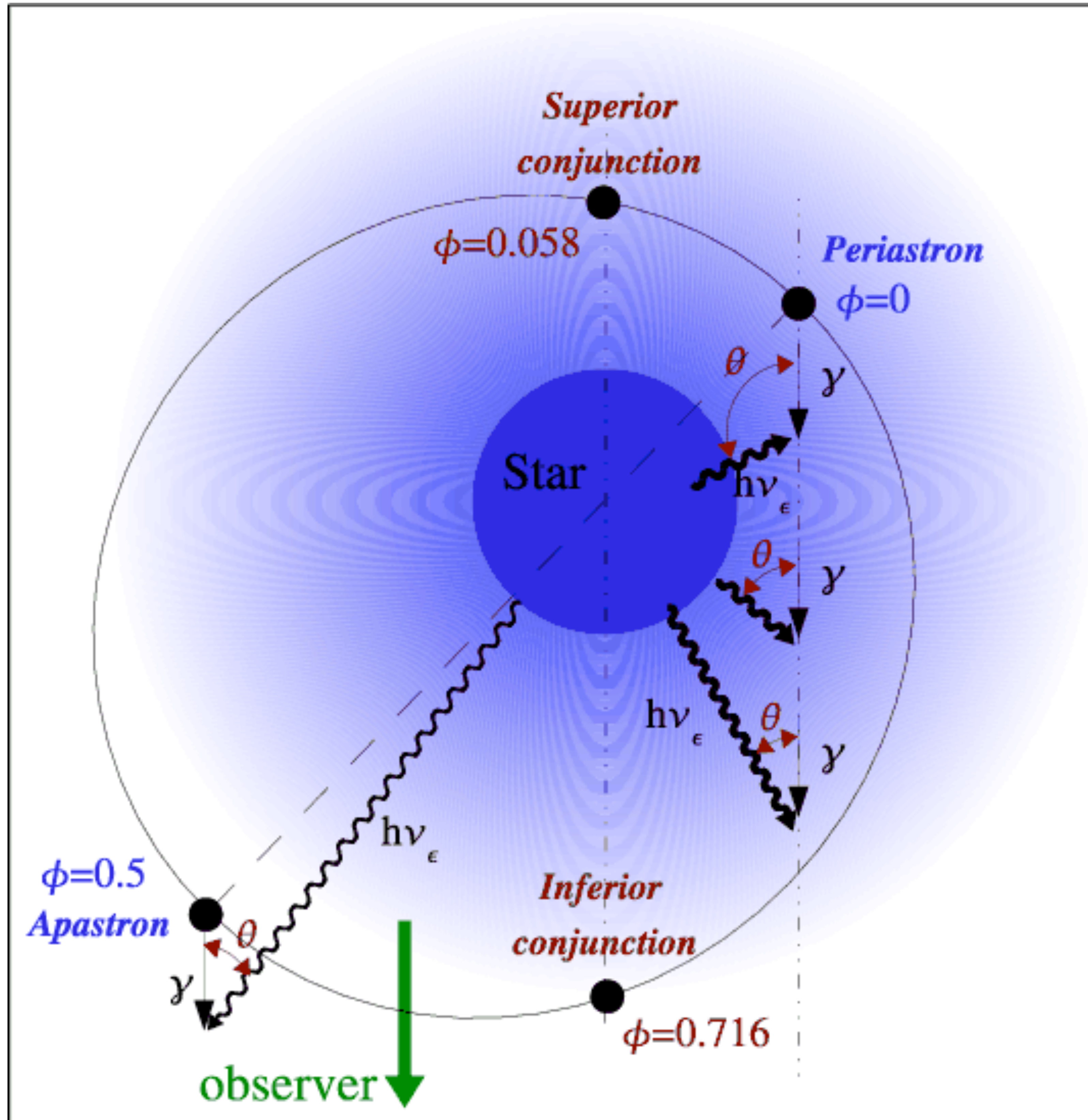
Synchrotron up to GeV like Crab Nebula?

The acceleration timescale must be almost at limit $t_{acc,min} = r_g/c$

$t_{syn} = t_{acc,min}$ → synchrotron cutoff energy ε_c = 160 MeV

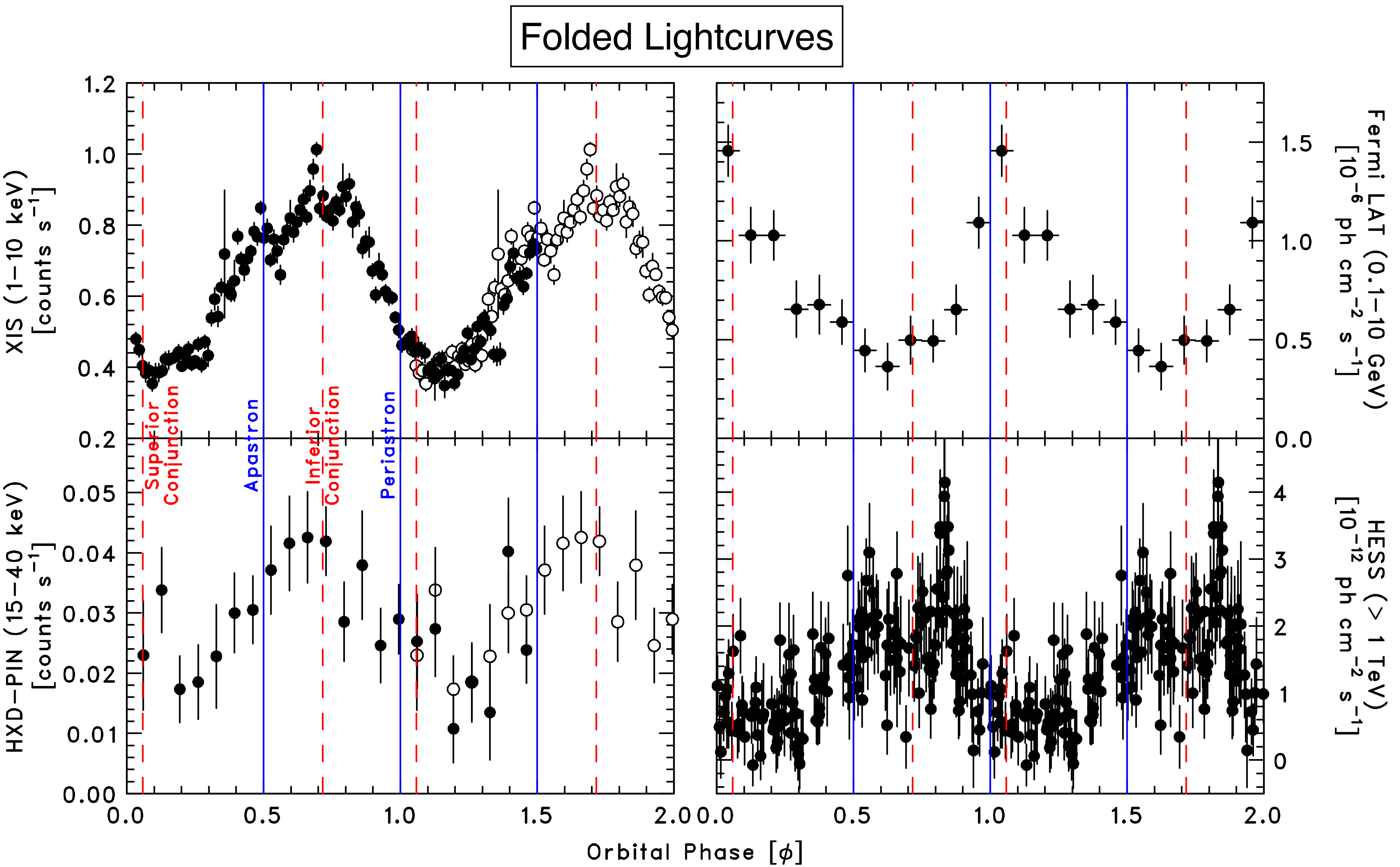
LS 5039

- P_{orb} = 3.9 days
- R_{orb} ~ 0.1 AU
- O6.5V
- NS or BH (unknown)
- Non-thermal X-rays
- GeV/TeV detection



LS 5039 with Suzaku

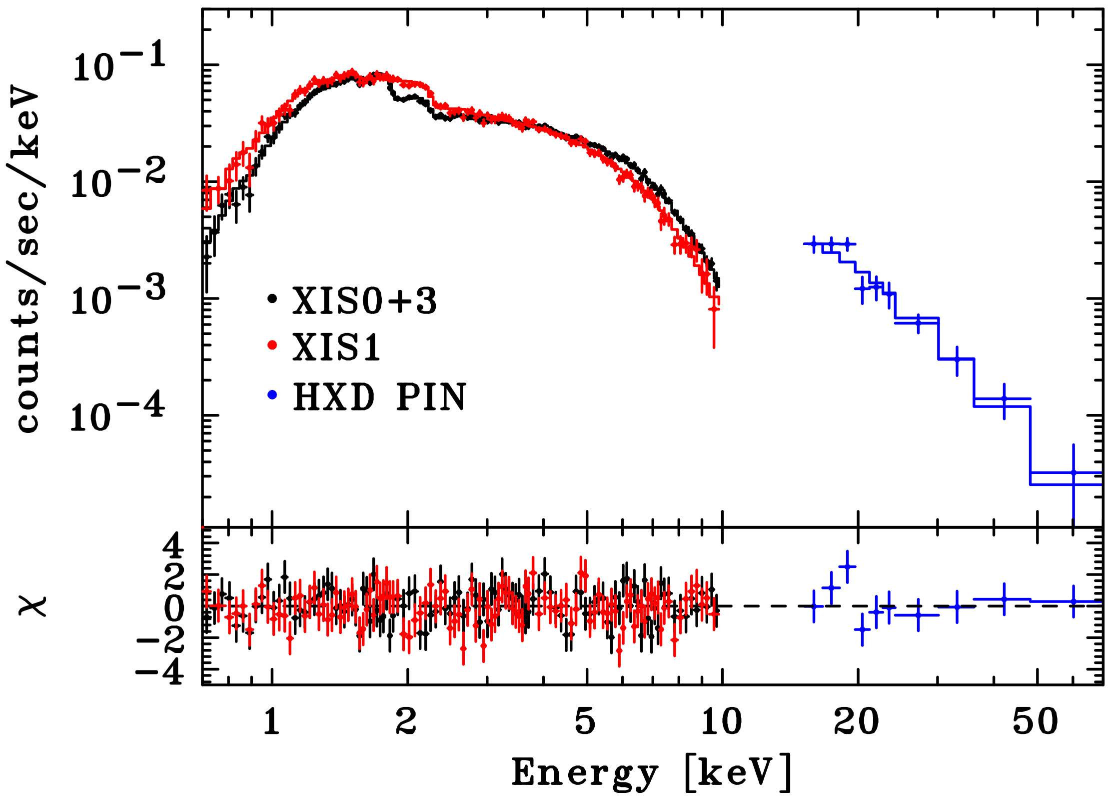
Covered continuously more than orbital period



Takahashi+ (2009), Aharonian+ (2006), Abdo+ (TT as a corresponding author) (2009)

LS 5039 with Suzaku

Phase-averaged Spectrum



Detection up to ~ 70 keV

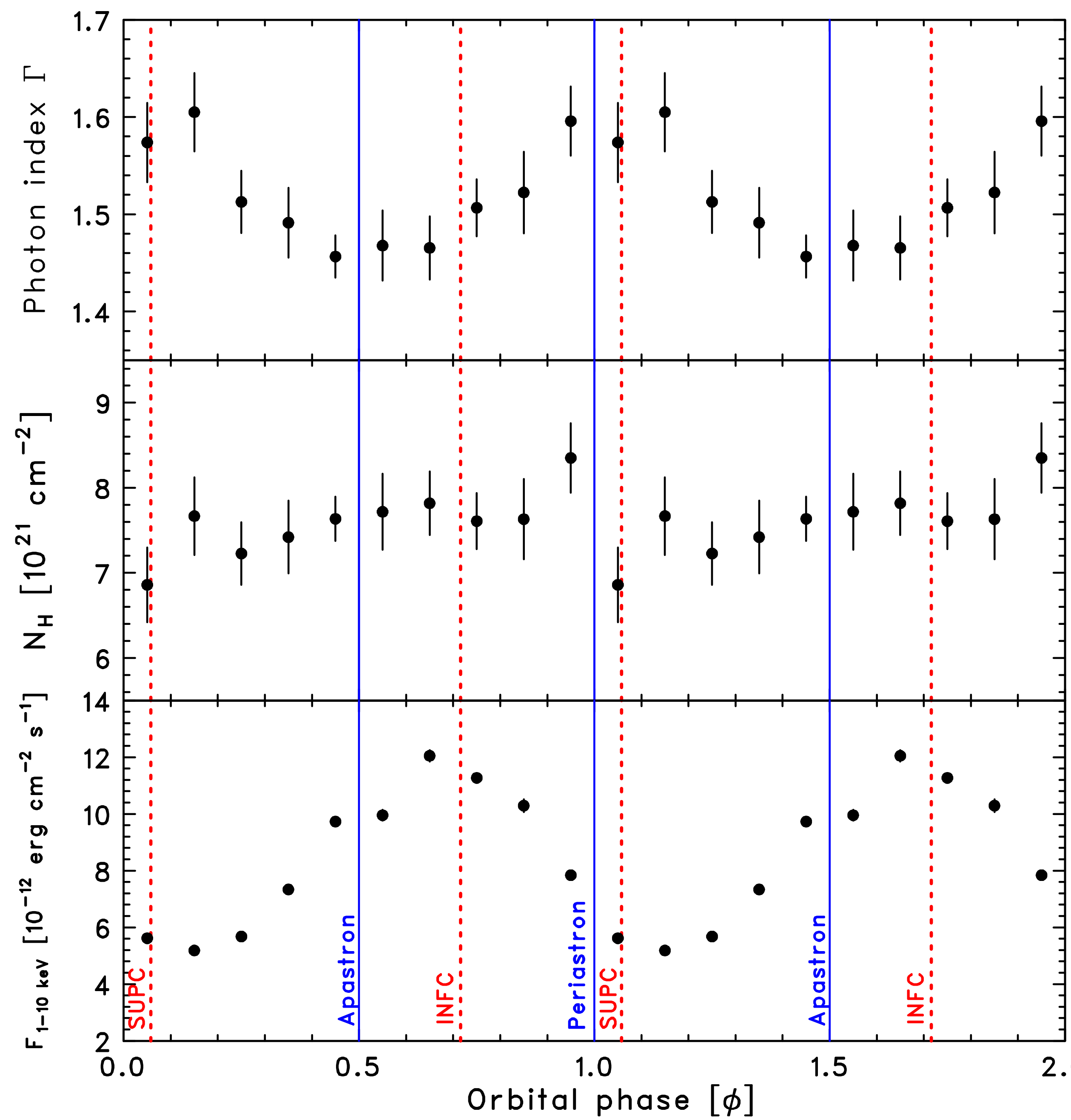
Power law with Γ ≃ 1.5

No emission lines

Modest Luminosity $L \sim 10^{33}$ erg/s

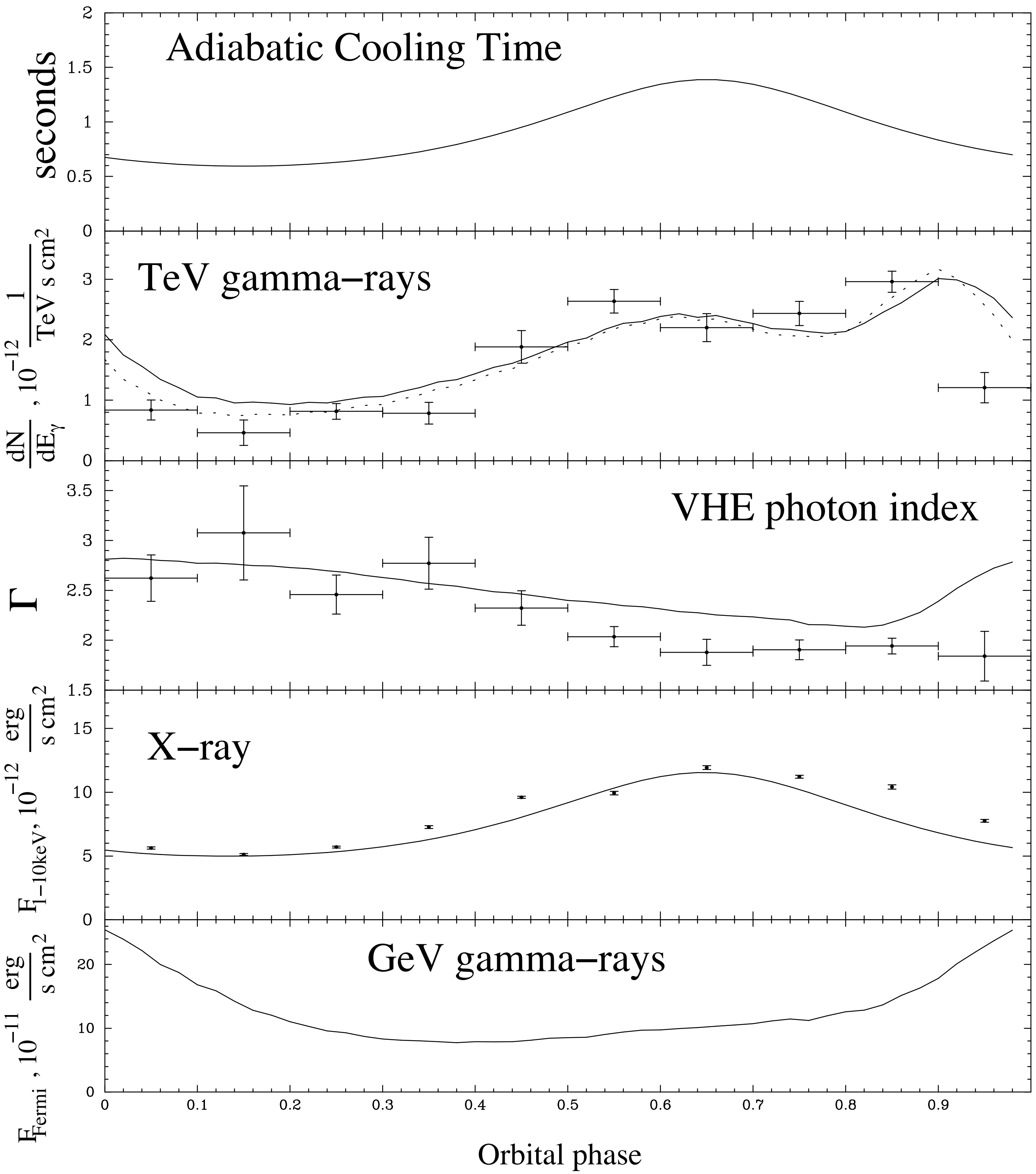
Synchrotron origin

Spectral Parameters (XIS)
vs
Orbital Phase



Takahashi+ (2009)

Efficient Acceleration



Takahashi+ (2009)

Difficult to explain the X-ray variability with e.g. *B* changes

Adiabatic Cooling?
Then, $t_{ad} \sim 1$ s $> t_{acc}$

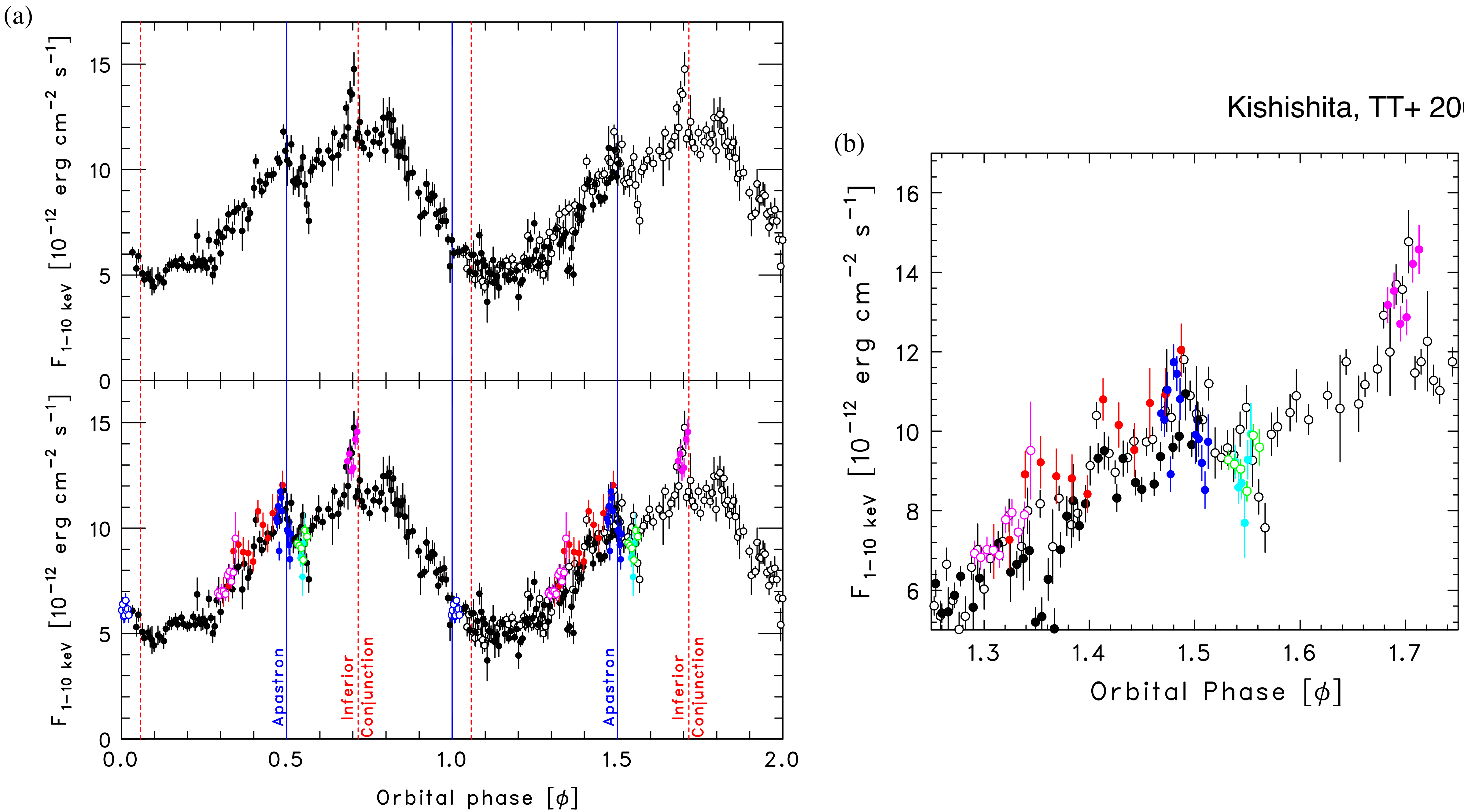
The acceleration timescale must be almost at limit
$t_{acc,min} = r_g/c$
$= 1\ (E_e/10\ \mathrm{TeV})(B/\mathrm{G})^{-1}$ s

Extreme electron acceleration

LS 5039: Long-Term Stability

Stable over a Decade

Suzaku data (2007; black) compared with
ASCA (1999), Chandra (2004), and XMM-Newton (2003 & 2005)

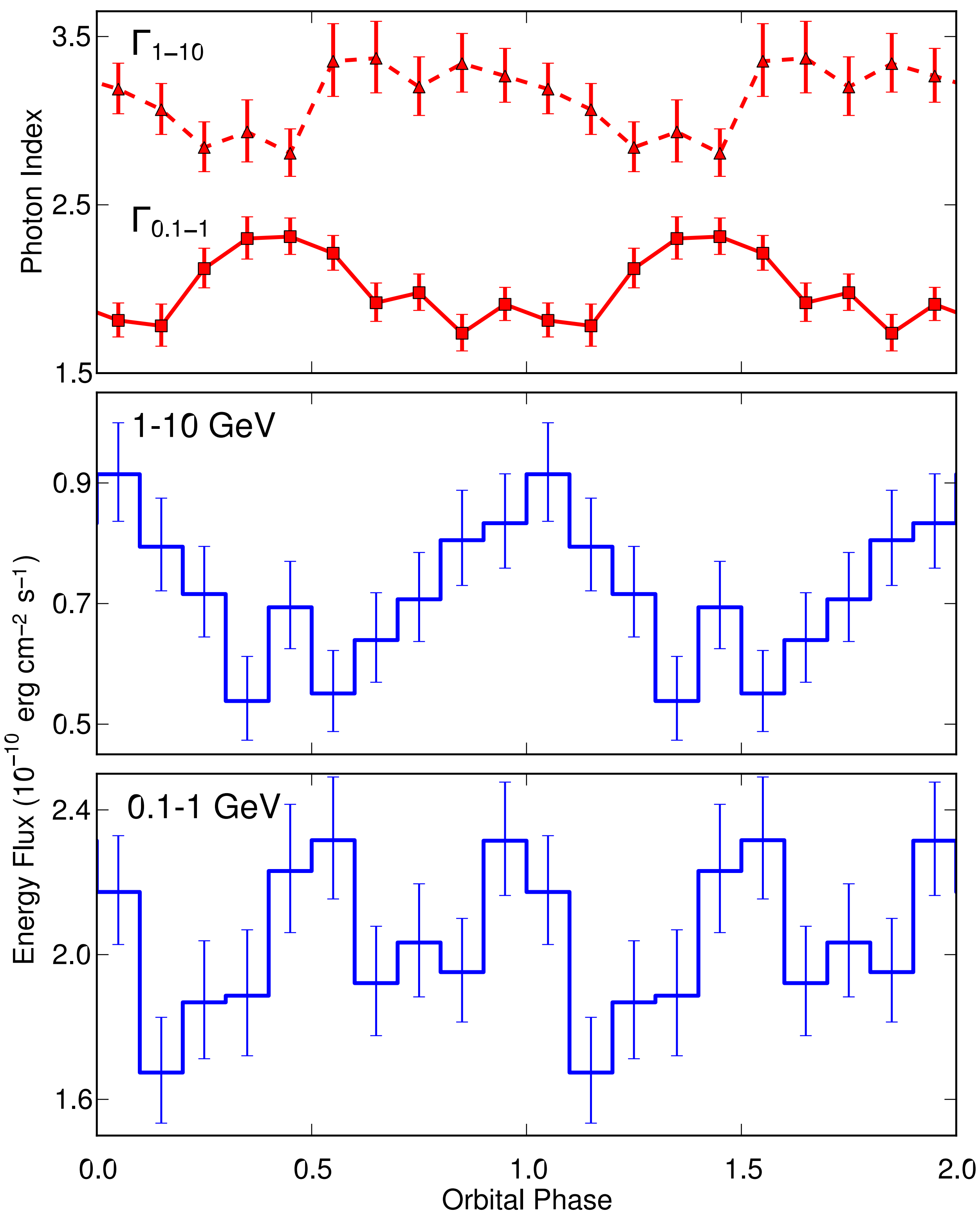


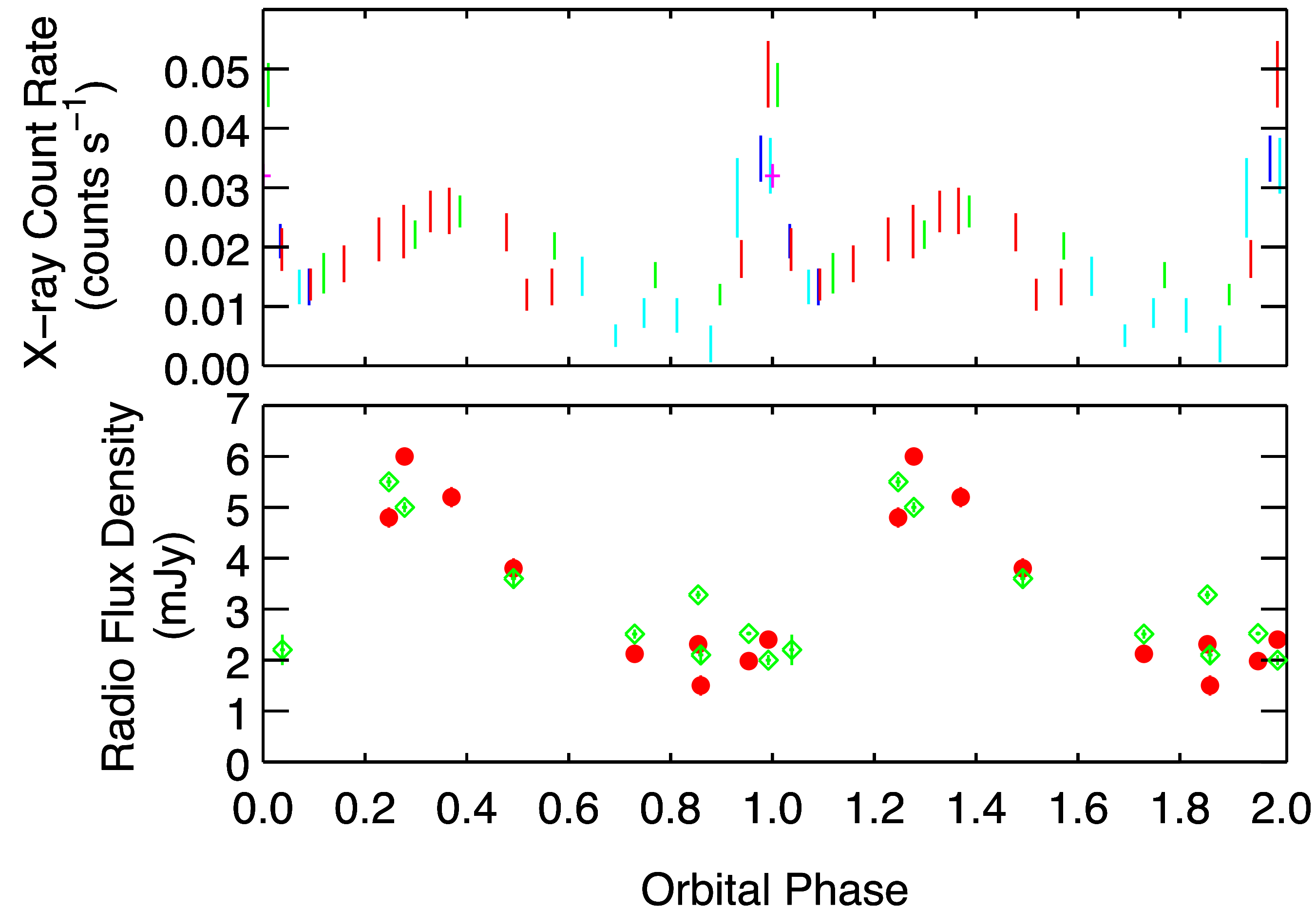
Kishishita, TT+ 2009

The Pulsar scenario would better explain the stability
O-star (c.f. Be star) binaries more stable?

1FGL 1018.6–5856

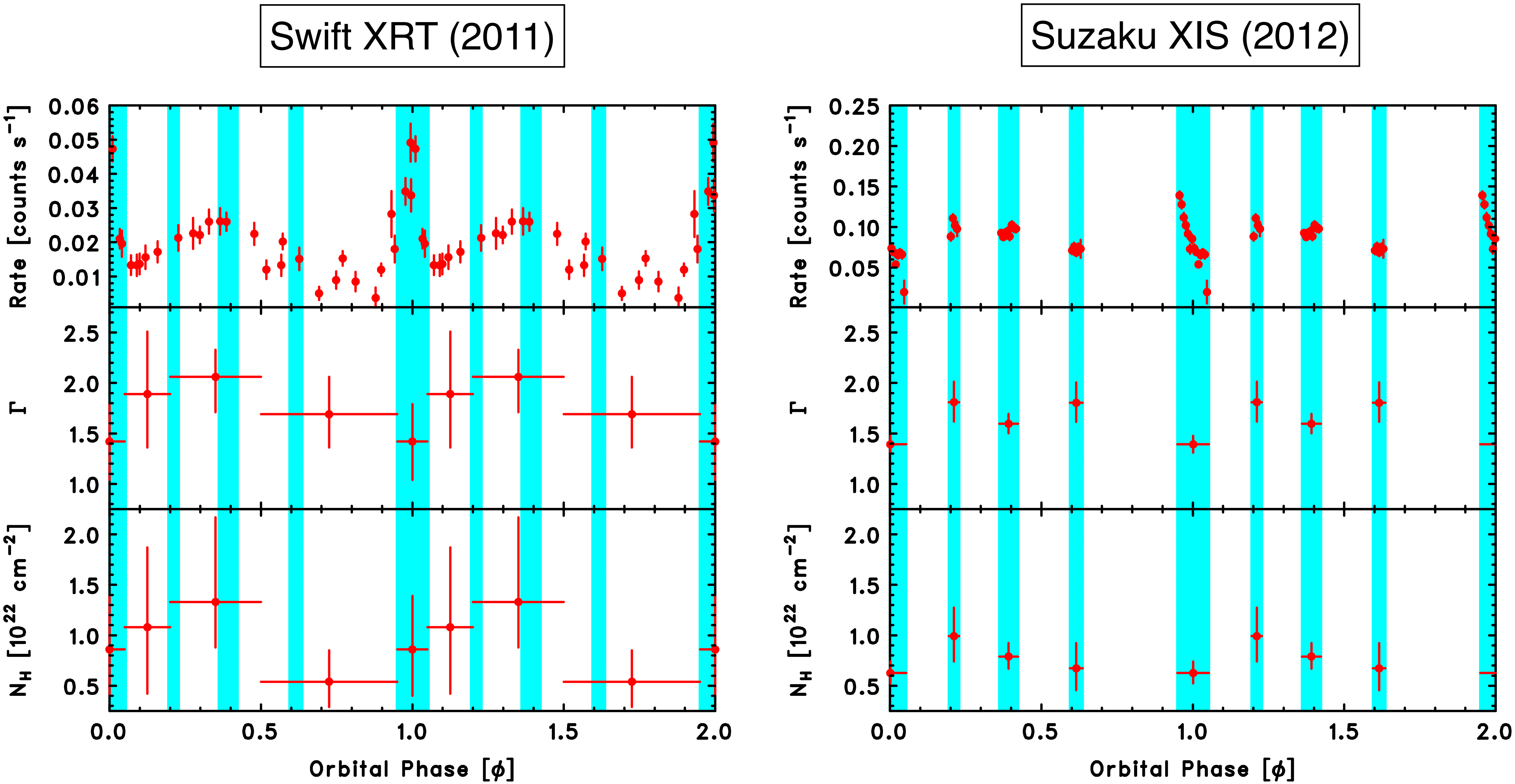
Ackermann+ 2012





- Gamma-ray properties and host star type (O6V) similar to LS 5039
- Characteristic X-ray peak detected by Swift XRT

1FGL 1018.6–5856 with Suzaku



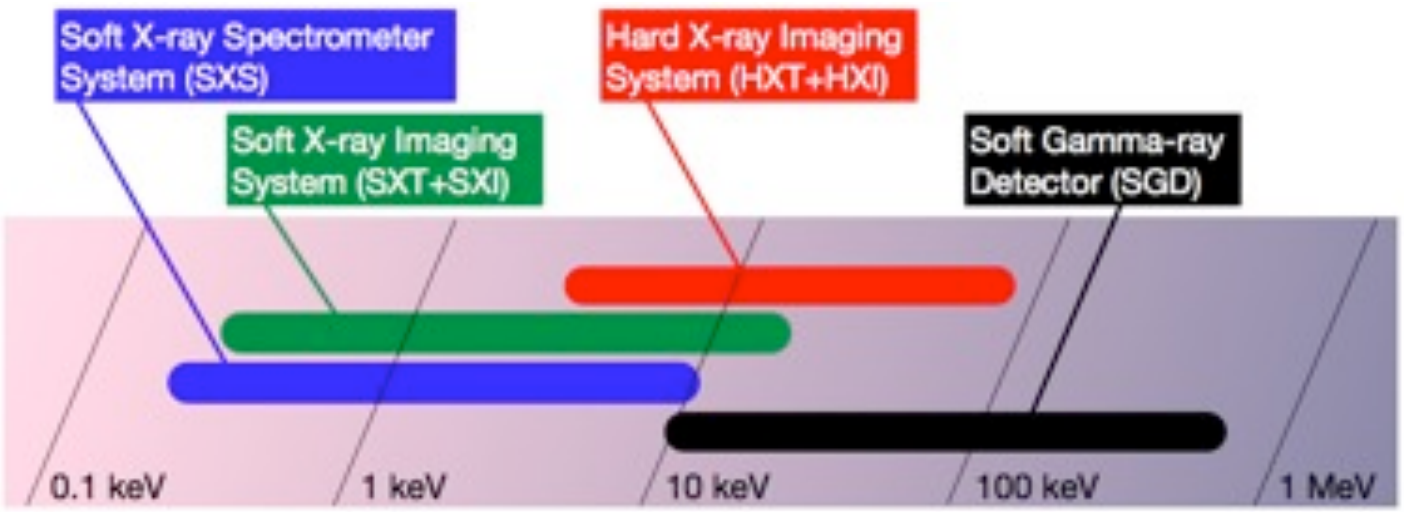
The X-ray peak shifted toward earlier orbital phase
Harder spectrum during the peak
Detailed analysis underway (TT+ in prep)

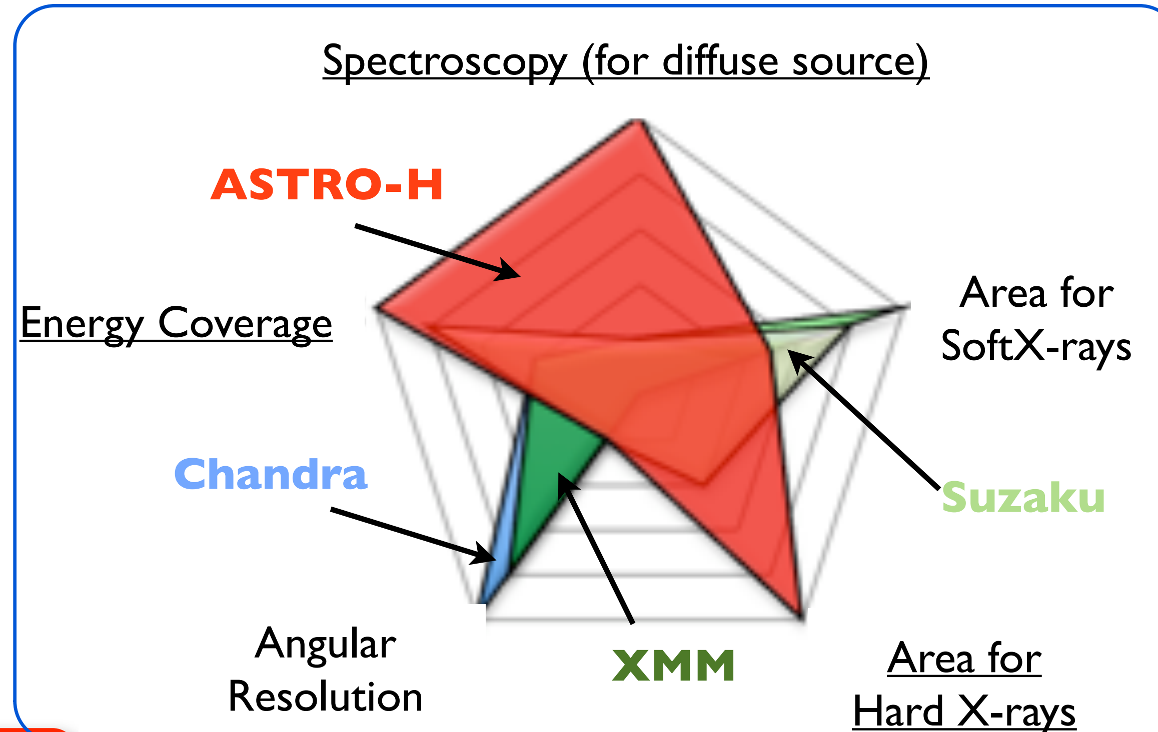
ASTRO-H

- **Launch in 2015**
- **Launch site:**
  Tanegashima Space Center, Japan
- **Launch vehicle: JAXA H-IIA rocket**
- **Orbit Altitude: 550 km**
- **Orbit Type: Approximate circular orbit**
- **Orbit Inclination: ~ 31 degrees**
- **Orbit Period: 96 minutes**

- **Total Length: 14 m**
- **Mass: < 2.6 metric ton**
- **Power: < 3500 W**
- **Telemetry Rate: > 8 Mbps (X-band)**
- **Recording Capacity: > 12 Gbits**
- **Mission life : > 3 years**

ASTRO-H Instruments





SXT-S (telescope) | SXS

Soft X-ray Spectrometer System

- 0.3-12 keV
- Large Area Soft X-ray Telescope
- X-ray micro calorimeter
- super resolution (<7eV at 6 keV)

SXT-I (telescope) | SXI

Soft X-ray Imaging System

- 0.4-12 keV
- Large Area Soft X-ray Telescope
- Large FOV 38x38 arcmin^2
- CCD spectroscopy

HXT (telescope) | HXI

Hard X-ray Imaging System

- Hard X-ray Telescope (5-80 keV)
- Focal Length 12 m
- New CdTe Imager (Fine Pitch Strip)

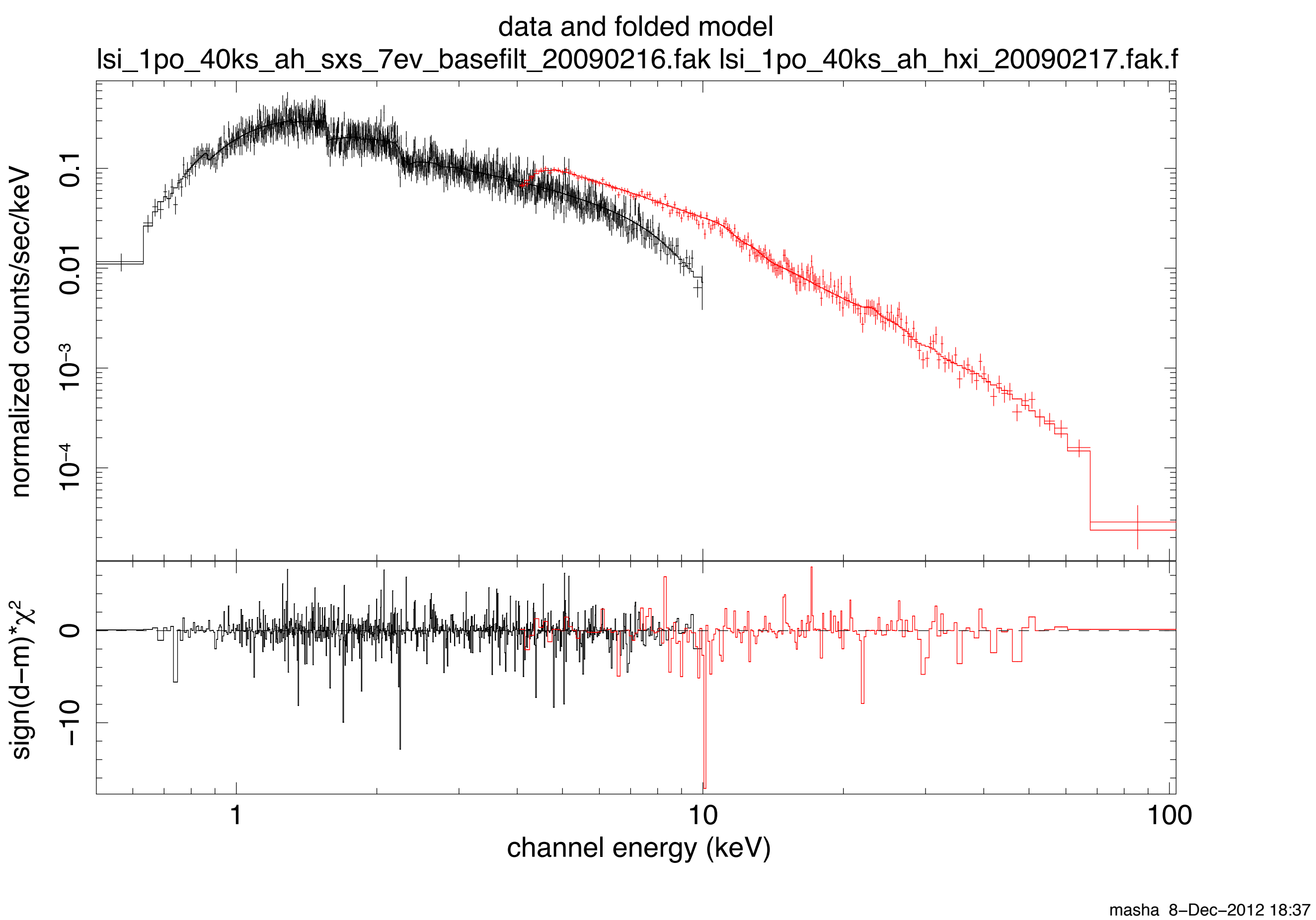
SGD

Soft Gamma-ray Detector

- 10-600 keV non-imaging
- Si/CdTe Compton Camera with Narrow FOV Active Shield
- most sensitive gamma-ray detector ever

Gamma-Ray Binaries with AH

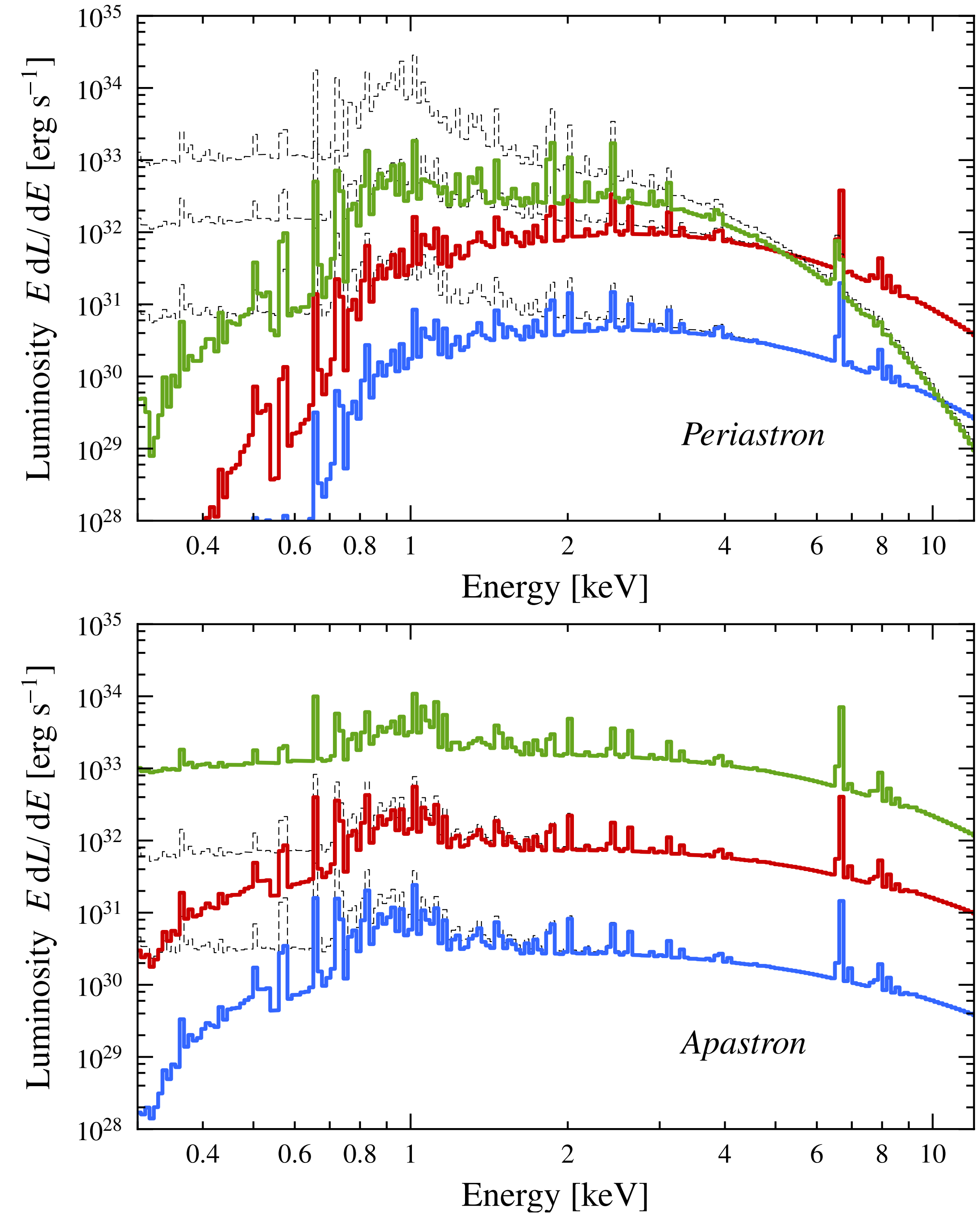
Wide-band Spectroscopy with SXS + HXI + SGD



40 ks observation of LS I +61°303

Simulation by M. Chernyakova

Wide-band Spectroscopy with SXS



Model by Zabalza+ (2012)

Summary

- Suzaku observed gamma-ray binaries such as PSR B1259–63, LS 5039, and 1FGL 1018.6–5856
- Wide-band coverage of Suzaku is a powerful tool to study non-thermal emission from gamma-ray binaries
- Suzaku results suggest extreme electron acceleration in PSR B1259–63 and LS 5039
- Suzaku observations of 1FGL J1018.6–5856 revealed a shift of a lightcurve structure, which was not observed in a similar system, LS 5039
- ASTRO-H will probe gamma-ray binaries with its excellent energy resolution and wide-band coverage