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

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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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  - TeV (MAGIC) & GeV (AGILE)
- $P_{\text{orb}} = 3.4$ years
- $R_{\text{orb}} > 0.7$ 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

Detection up to 60 keV
Spectral break
\( \varepsilon_{\text{br}} = 4.5 \text{ keV} \)
\( \Gamma_1 = 1.25 \)
\( \Gamma_2 = 1.76 \)

Spectral break
\( \leftrightarrow \) Low-energy cutoff of electron spectrum corresponding to \( \gamma_1 \) 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

Fermi LAT light curve

photon index

Abdo+ 2011
Suzaku Observation during Flare

Pre-Flare

\[
N_H = (0.573-0.575) \times 10^{22} \text{ cm}^{-2} \\
\Gamma = 1.76-1.78
\]

During Flare

\[
N_H = (0.491-0.499) \times 10^{22} \text{ cm}^{-2} \\
\Gamma = 1.42-1.50
\]

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 $t_{\text{acc, min}} = \frac{r_g}{c}$

$t_{\text{syn}} = t_{\text{acc, min}} \rightarrow$ synchrotron cutoff energy $\varepsilon_c = 160$ MeV
- $P_{\text{orb}} = 3.9$ days
- $R_{\text{orb}} \sim 0.1$ AU
- O6.5V
- NS or BH (unknown)
- Non-thermal X-rays
- GeV/TeV detection
LS 5039 with Suzaku

Covered continuously more than orbital period

Folded Lightcurves

Detection up to $\sim 70$ keV
Power law with $\Gamma \approx 1.5$
No emission lines
Modest Luminosity $L \sim 10^{33}$ erg/s
Synchrotron origin

Takahashi+ (2009)
Efficient Acceleration

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

Adiabatic Cooling?

Then, $t_{ad} \sim 1 \text{ s} > t_{acc}$

The acceleration timescale must be almost at limit

$$t_{acc, min} = \frac{r_g}{c} = 1 \left(\frac{E_e}{10 \text{ TeV}}\right)\frac{1}{(B/G)} \text{ s}$$

Extreme electron acceleration

Takahashi+ (2009)
LS 5039: Long-Term Stability

Stable over a Decade


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

Swift XRT (2011)

Suzaku XIS (2012)

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

Suzaku (6m, 1.7t)
ASTRO-H Instruments

**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)

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

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

**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

Wide-band Spectroscopy with SXS

40 ks observation of LS I +61°303

Simulation by M. Chernyakova
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