Suzaku Observations of HESS sources

Hironori Matsumoto (Kyoto Univ.)

Hideki Uchiyama (Kyoto Univ.), Aya Bamba, Ryoko Nakamura, Takayasu Anada (ISAS/JAXA), and the Suzaku team
Outline

• HESS unID objects: “Dark particle accelerators”
• Suzaku Observations
  – HESSJ1614-518
  – HESSJ1616-508
  – HESSJ1713-381 (CTB37B)
  – HESSJ1804-216
  – HESSJ1825-137
  – HESSJ1837-069
• Summary
First systematic Galactic plane survey with TeV $\gamma$-ray (>200 GeV)

New TeV objects with no obvious counterpart.

Dark particle accelerators

(Aharonian et al. 2005, 2006)
HESSJ1614-518

HESS TeV γ-ray image (excess map)

Brightest among the new objects.

(l, b) = (331.52, -0.58)

XIS FOV 50ks
XIS FI (S0+S2+S3): 3-10keV band

Extended object

Obs. 50ks

Src A

Src B

Swift XRT also detected
(Landi et al. 2006)
XIS spectra

Src A spectrum

\[ \begin{align*}
    \text{NH} &= 1.2(\pm 0.5) \times 10^{22} \text{cm}^{-2} \\
    \Gamma &= 1.7(\pm 0.3) \\
    F_{(2-10\text{keV})} &= 5 \times 10^{-13} \text{erg/s/cm}^2
\end{align*} \]

Featureless, \rightarrow non-thermal

Src B spectrum

\[ \begin{align*}
    \text{NH} &= 1.2(\pm 0.1) \times 10^{22} \text{cm}^{-2} \\
    \Gamma &= 3.6(\pm 0.2) \\
    F_{(2-10\text{keV})} &= 3 \times 10^{-13} \text{erg/s/cm}^2
\end{align*} \]

Featureless, but extremely soft
Plausible X-ray counterpart: src A

• Difficult to explain both the TeV gamma-ray and X-ray from the electron origin.
• The origin of srcA is not clarified.

Matsumoto et al. 2008, PASJ, 60. S163 (Suzaku special issue No.2)
HESSJ1616-508

HESS TeV image (excess map)
Provided by S. Funk (MPI)

(l, b) = (332.391, -0.138)

XIS FOV
45ks

HESSJ1616
XIS FI (S0+S2+S3): 3–12keV

- No X-ray counterpart
- $F(2-10\text{keV}) < 3.1 \times 10^{-13} \text{erg/s/cm}^2$

$F(\text{TeV})/F(X) > 55$
If we assume electrons...

Matsumoto et al. 2007, PASJ, 59, 199 (Suzaku Special Issue No.1)
PSRJ1617-5055?

INTEGRAL 18-60keV

XMM-Newton 0.5-10keV

Why is there no trace in X-ray band?
Why is there no clear PWN in the radio (Kaspi et al. 1998) and X-ray bands?

Landi et al. 2007
HESSJ1713-381 (CTB37B)

HESSJ1713-381 coincides with the SNR CTB37B
Non-thermal hard X-ray

Suzaku 0.3-3.0keV

Suzaku 3.0-10.0keV

Reg1: coincides with the TeV peak
Reg2: offset hard emission

Green: TeV (HESS)
Blue: radio
White: X-ray (Suzaku)

Nakamura 2008 in preparation
• Thermal ($kT=0.9\text{keV}$)+PL ($\Gamma=3.0$)
• A point source discovered by Chandra (Aharonian et al. 2008) contributes much to the PL component.

Hard PL ($\Gamma=1.5$) + Leakage from reg1 due to PSF.
• Roll-off energy > 15keV
• The hard PL suggests efficient acceleration.

$F(\text{TeV})/F(\text{X}) \sim 0.2 \rightarrow B \sim 8\mu\text{G assuming IC}$.
$E_{\text{max}} > 170 \text{ TeV}$
HESSJ1804-216

HESS TeV $\gamma$-ray image (excess map)

Softer TeV spectrum among the new objects.

$(l, b) = (8.401, -0.033)$

Provided by S. Funk (MPI)
XIS image

XIS FI (S0+S2+S3): 3-10keV

src1: point-like
src2: extended or multiple

Swift XRT (Landi et al. 2006)
Chandra (Kargaltsev et al. 2007)

Chandra (Kargaltsev et al. 2007)

TeV image

src1: point-like
src2: extended or multiple
XIS spectra

src1: point-like

src2: extended

<table>
<thead>
<tr>
<th></th>
<th>src1</th>
<th>src2</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Gamma$</td>
<td>$-0.3 \pm 0.5$</td>
<td>$1.7 \pm 1.2$</td>
</tr>
<tr>
<td>NH</td>
<td>$0.2 (&lt;2.2)$</td>
<td>$11 \pm 8$</td>
</tr>
<tr>
<td>$F(2-10\text{keV})$</td>
<td>$2.5$</td>
<td>$4.3$</td>
</tr>
<tr>
<td>$F(\text{TeV})/F(X)$</td>
<td>50</td>
<td>25</td>
</tr>
</tbody>
</table>

See Bamba et al. 2007, PASJ, 59, S209 (Suzaku Special Issue No.1)
HESS J 1825-137

• Spin-down luminosity
  $\sim 2.8 \times 10^{36}$ erg s$^{-1}$
• Characteristic age
  21.4 kyr (Clifton 1992)
• D $\sim$ 4 kpc

IC by high-energy electrons from the pulsar?

- Spin-down luminosity $\sim 2.8 \times 10^{36}$ erg s$^{-1}$
- Characteristic age 21.4 kyr (Clifton 1992)
- D $\sim$ 4 kpc

Softening
Previous X-ray study (XMM-Newton)

PSR J1826-1334 (B1823-13)

Photon index $\sim 2.3$

$NH \sim 1.4 \times 10^{22}/cm^2$

$L_x \sim 3 \times 10^{33}$ erg s$^{-1}$

Why is the X-ray image much smaller?

More extended if observed with high sensitivity?

→ Suzaku observation!
Suzaku: Very extended PWN

TeV image

Source region

XIS 3F 1-9 keV

2006/9 50ksec

Suzaku can detect X-rays much more extended than the XMM results.
X-rays are extended at least up to 15 arcmin (~15 pc)
X-ray spectra

Region A
= pulsar+PWN
\[ \Gamma = 1.78 (1.68-1.88) \]

Region B
\[ \Gamma = 1.99 (1.91-2.08) \]

Region C
\[ \Gamma = 2.03 (1.95-2.14) \]

Region D
\[ \Gamma = 2.03 (1.95-2.14) \]

Reg B-D: no change in photon index. \( \rightarrow \) electrons reach to 15pc before cooled.

Synchrotron cooling time~1400yrs. \( \rightarrow \) Velectron~10000 km/s
X-rays were detected up to 300 keV by INTEGRAL
X-ray counterparts are offset from the TeV gamma-ray peak.

Pulsations of 70.5 ms were recently discovered from AXJ1838 with RXTE (Gotthelf et al. 2008).
## Summary

<table>
<thead>
<tr>
<th></th>
<th>X-ray</th>
<th>Origin</th>
</tr>
</thead>
<tbody>
<tr>
<td>HESSJ1614-518</td>
<td>O</td>
<td>?</td>
</tr>
<tr>
<td>HESSJ1616-508</td>
<td>X</td>
<td>?</td>
</tr>
<tr>
<td>HESSJ1804-216</td>
<td>2</td>
<td>?</td>
</tr>
<tr>
<td>HESSJ1825-137</td>
<td>Very extended</td>
<td>PWN</td>
</tr>
<tr>
<td>HESSJ1837-069</td>
<td>2 extended</td>
<td>Offset PWN</td>
</tr>
</tbody>
</table>

Can you construct a “Grand Unification Theory (GUT)” of the dark particle accelerators?