Suzaku Observations of Thermal and Nonthermal X-Ray Emission from the Middle-Aged SNR G156.2+5.7

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9/10 @ Johns Hopkins University

Submitted to PASJ (Suzaku 3rd Special Issue)
G156.2+5.7
- R~50’
  (=>~15 pc @1 kpc)
- Age ~15,000 yr
- X-ray bright
  (Pfeffermann+ 1991)
  Radio dim
  (Reich+ 1992)
- ASCA results
  (Yamauchi+1999)
  North: soft (ISM) and
  hard-tail emission.
  Center: soft (Si S-rich
  ejecta) and hard-tail emission.

Suzaku Observations of G156

ASCA FOV
Suzaku FOV

NW

Center

E

G156.2+5.7 (ROSAT PSPC)

Suzaku Obs.
- NW: 50.5 ks
  2/16/2007
- Center: 51.2 ks
  2/17/2007
- E: 53.3 ks
  2/19/2007
XIS Spectra in the Entire FOV

- NW
- Non X-ray BG

- East
- Non X-ray BG

- Center
- Non X-ray BG
XIS Images and Spectral Extraction Regions

XIS images (NXB-subtracted vignetting-corrected).

(b) Northwest

NW FOV

NW2

NW3

NW4

(c) Center

Center FOV

(a) East

E FOV

E1

E2

E3

E4
East Rim

Model = \text{wabs} \times (\text{vnei})
NW Rim

Model = wabs x (vnei + power-law)
Abundances in the E and NW rims

Sub solar abundances are derived => ISM origin for these plasma

- N < 0.05
- O ~ 0.4
- Ne ~ 0.6
- Mg ~ 0.5
- Si ~ 0.6
- Fe ~ 0.5

SNR outer
$N_H$, $kT_e$, $n_e$ in the E and NW rims

$N_H \sim 0.3-0.4 \times 10^{22}$ cm$^{-2}$

$=>$ consistent with ASCA results

$kT_e$ decreases toward the shock front to $\sim 0.3$ keV.

The forward shock velocity is estimated to be $\sim 500 \left(\frac{kT_e}{0.3 \text{ keV}}\right)^{0.5}$ km/sec.

NEI condition everywhere.

It decreases from the edge ($\sim 10^{11}$) toward the center ($0.3 \times 10^{11}$).
Model = wabs x (vnei(ISM) + power-law + vnei(ejecta))

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$N_H; (x10^{22})$</td>
<td>0.42 +/- 0.01</td>
</tr>
<tr>
<td>$kT_{e1}$</td>
<td>0.3 keV</td>
</tr>
<tr>
<td>log($\tau_1$)</td>
<td>10.52</td>
</tr>
<tr>
<td>$N=O$</td>
<td>2.6 +/- 0.2</td>
</tr>
<tr>
<td>Ne</td>
<td>0.9 +/- 0.1</td>
</tr>
<tr>
<td>Mg</td>
<td>1.5 +/- 0.1</td>
</tr>
<tr>
<td>Si</td>
<td>8.8 +/- 0.3</td>
</tr>
<tr>
<td>S</td>
<td>9.3 +/- 1.2</td>
</tr>
<tr>
<td>Fe</td>
<td>2.4 +/- 0.1</td>
</tr>
<tr>
<td>$\Gamma$</td>
<td>1.5 +/- 0.2</td>
</tr>
</tbody>
</table>

$kT_{e1}$: 0.3 keV
log($\tau_1$): 10.65
Ejecta Abundances: Comparison with Nucleosynthetic Models

Red: Type-Ia model (Nomoto+ 1984; Iwamoto+ 1999)
Blue: CC-SNe 11, 13, 15
Green: CC-SNe 21, 25 M$_{\text{solar}}$ (Rauscher+2002)

Black data => Ellipse
Red data => Surround

Our data prefer core-collapse origin.
Origin of the Hard-tail Emission

- Comparison with the radio morphology: The distribution of the X-ray hard-tail emission matches that of the radio emission.

- Spectral features: The SRCUT model well fits our data and the radio data.

=>Support the non-thermal origin for the hard-tail emission.

Non-thermal X-ray emission from a slow forward shock of ~500 km/sec.
We have observed the NW rim, the center, and the east rim of SNR G156.2+5.7 with Suzaku.

In the NW rim and the center, we confirm that the X-ray spectra consists of soft and hard-tail emission, while in the E rim we find no significant hard-tail emission. The soft emission in the NW and E rims is the ISM plasma. In the center, the soft emission is ISM+ejecta plasma.

The relative abundances in the ejecta component suggest that G156.2+5.7 is a remnant from a core-collapse SN explosion whose progenitor mass is less than 15 solar masses.

The origin of the hard-tail emission is highly likely non-thermal synchrotron emission from relativistic electrons accelerated by the forward shocks. The relativistic electrons seem to be accelerated by a forward shock with a slow velocity of ~500 km/sec.
HXD PIN Spectra

Consistent with the CXB.

Model=\text{CXB}
Point Source 1 (NW)

NH: $\sim0.75 \times 10^{22}$ cm$^{-2}$

$\Gamma$: $\sim2.4$

Observed Flux: $3.4 \times 10^{-13}$ erg cm$^{-2}$ sec$^{-1}$

Luminosity: $7.0 \times 10^{31}$ erg sec$^{-1}$ at a distance of 1.3 kpc

**TABLE 1.** List of the seven “confirmed” CCOs and of their basic X-ray properties. Flux is in the 0.5-8 keV energy range; the bolometric luminosity is computed for a purely thermal model (either single or double blackbody). The possible variability reported for the CCO in Cas A refers to indirect evidence for a large flare occurred around A.D. 1953. See text for details and references.

<table>
<thead>
<tr>
<th>SNR</th>
<th>Age (ky)</th>
<th>Distance (kpc)</th>
<th>Observed flux $10^{-12}$ erg cm$^{-2}$ s$^{-1}$</th>
<th>Luminosity $10^{33}$ erg s$^{-1}$</th>
<th>Variability</th>
<th>Period (ms)</th>
<th>Pulsed fraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>RCW103</td>
<td>2</td>
<td>3.3</td>
<td>0.8-60</td>
<td>1.1-80</td>
<td>factor 100</td>
<td>6.67 hour</td>
<td>12-50%</td>
</tr>
<tr>
<td>G296.5+10.0</td>
<td>7</td>
<td>2.2</td>
<td>2.</td>
<td>1.2</td>
<td>&lt; 5%</td>
<td>424 ms</td>
<td>~ 10%</td>
</tr>
<tr>
<td>Kes 79</td>
<td>7</td>
<td>7.1</td>
<td>0.2</td>
<td>3</td>
<td>&lt; 15%</td>
<td>105 ms</td>
<td>~ 80%</td>
</tr>
<tr>
<td>Cas A</td>
<td>0.3</td>
<td>3.4</td>
<td>2.</td>
<td>2</td>
<td>Flares?</td>
<td>...</td>
<td>&lt; 13%</td>
</tr>
<tr>
<td>Puppis A</td>
<td>3.7</td>
<td>2.2</td>
<td>4.8</td>
<td>5</td>
<td>&lt; 5%</td>
<td>...</td>
<td>5%? (&lt; 7%)</td>
</tr>
<tr>
<td>G347.3-0.5</td>
<td>2</td>
<td>1.3</td>
<td>3.</td>
<td>0.6</td>
<td>&lt; 5%</td>
<td>...</td>
<td>&lt; 7%</td>
</tr>
<tr>
<td>Vela Jr.</td>
<td>1</td>
<td>1</td>
<td>1.3</td>
<td>0.25</td>
<td>&lt; 5%</td>
<td>...</td>
<td>&lt; 7%</td>
</tr>
</tbody>
</table>
Point Source 2 (Center)

NH: fixed at $0.5 \times 10^{22}$ cm$^{-2}$
$\Gamma$: $\sim 2.0$
Observed Flux: $3.4 \times 10^{-13}$ erg cm$^{-2}$ sec$^{-1}$
Luminosity: $1.9 \times 10^{31}$ erg sec$^{-1}$ at a distance of 1.3 kpc

BGs are subtracted from annular region around the point source.
EM profile: Comparison with Sedov Model