Identification of seven persistent low-luminosity pulsators

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Physics of neutron stars -2011

St Petersburg, Russia
Low-luminosity pulsators

- Slowly pulsating ($Ps > 150s$)
- Luminosity - $10^{34} - 10^{36}$ ergs$^{-1}$
- Persistent
- Initial studies expects them to be Be/X-ray binaries or Intermediate Polars (IPs).
- Present in the Galactic plane.
- However their nature is not yet known.
Different pulsators

Be Star

Neutron Star

$r_x \approx 15-50 \, R_*$

$r_p \approx 7-20 \, R_*$

$r_d \approx 6-20 \, R_*$

Be/X-ray Binary System (not to scale)

HMXB

neutron star

supergiant
Different pulsators

Be Star

$r_p \approx 15-50 \, R_*$

Be/X-ray Binary System (not to scale)

Neutron Star

$r_p \approx 7-20 \, R_*$

$r_d \approx 6-20 \, R_*$

HMXB

LMXB

supergiant

neutron star

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Different pulsators

Neutron Star

Be Star

$R_d \approx 6-20 \, R_*$

$r_p \approx 7 - 20 \, R_*$

Be/X-ray Binary System (not to scale)

HMXB

LMXB

neutron star

IP
What makes these sources special?
What makes these sources special?
What makes our sources special?
What makes our sources special?

- Classical Be/X-ray binaries have moderately eccentric orbits \((e > 0.3)\).

- Pfahl et al. (2002) proposed a class of Be/X-ray binaries which has low eccentricities \((e < 0.2)\) and long orbital periods \((> 30 \text{ d})\).

- It is possible only if these eccentricities are primordial.

- Which means that these sources would have formed in a different type of supernova explosion without or with a small kick to the neutron star.

- e.g. X-Per/4U0352+309 (837s).

- Proposed sources - RXJ0146.9+6121 (Haberl et al. 1998a, 1998b), RX J1037.5-5647, RX J0440.9+4431 (Reig et al. 1999).

<table>
<thead>
<tr>
<th>Source name</th>
<th>Pulse period</th>
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<tbody>
<tr>
<td>SAX J1324.4-6200</td>
<td>171s</td>
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<tr>
<td>SAX J1420.8-5949</td>
<td>437s</td>
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<tr>
<td>AX J1700.1-4157</td>
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<td>AX J1820.5-1434</td>
<td>152s</td>
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<tr>
<td>AX J1832.3-0840</td>
<td>1549s</td>
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Selection criterion

- ASCA and BeppoSAX Galactic plane surveys
- Pulse periods > 150s
- Hard X-ray spectrum ($\Gamma \sim 1.0$)
- $X$-ray luminosity = $10^{34}$ - $10^{36}$ ergs$^{-1}$
- These selections helped us to exclude anomalous X-ray pulsars, LMXB pulsars and to some extend IPs also.
Observations

- **Chandra** - to identify X-ray counterparts
- **XMM-Newton** - spectral and timing analysis
- **ESO-NTT imaging** - to identify near-infrared counterparts
- **ESO-VLT nir spectroscopy** - to study the near-infrared counterparts.
Chandra

SAX J1324.4-6200

*BeppoSAX error circle*
Chandra

SAX J1324.4-6200

BeppoSAX error circle
ESO-NTT (NIR)

SAX J1324.4-6200

Chandra error circle
SAX J1324.4-6200

XMM-Newton
**SAX J1324.4-6200**

**AX J1832.3-0840**

**XMM-Newton**

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Spin period derivative = $6.34 \times 10^{-9}$ s/s

Ps $\sim$ 170s
X-ray timing

\textbf{SAX J1324.4-6200} \quad Ps \sim 170s

\textbf{Spin period derivative} = 6.34 \times 10^{-9} \text{ s/s}
SAX J1324.4-6200 - NIR imaging

- Supergiant or a O-type star -> outside the Galaxy
- Late-type ms star < 1.3 kpc.
- Ms B-type star -> 4 - 9 kpc.
- Late-type giant -> 2 - 11 kpc.
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**SAX J1324.4-6200**

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**AX J1832.3-0840**

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SAX J1324.4-6200

Hip065565 (G2V)

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SAX J1324.4-6200

**B-Gamma**  
SAX J1324.4–6200

**Hip065565 (G2V)**

**normalized counts**

**wavelength (microns)**
Figure 2.7 The Main Sequence in the H-band infrared. The spectra in this figure are from Meyer et al. (1998) and have been rectified. They have been given half-integer vertical offsets.
Stellar spectral classification
- Richard O. Gray and Christopher J. Corbally

Figure 2.7 The Main Sequence in the H-band infrared. The spectra in this figure are from Meyer et al. (1998) and have been rectified. They have been given half-integer vertical offsets.
Be/X-ray binary
Be/X-ray binary

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Conclusions.

- Sources (SAX J1324.4-6200, AX J1820.5-1434) which showed H absorption lines are either HMXBs or IMXBs.
- AX J1749.2-2725 is likely HMXBP.
- Three of our sources (AX J1700.1-4157, AX J1740.1-2847, AX J1832.3-0840) are likely IPs.
- SAX J1452.8-5949 - likely IP or LMXB.
- It is possible that the three HMXBs belong to the persistent Be/X-ray binaries class. However they could also well be members of some other unexplored class of sources at low-luminosities.