Using very-faint LMXBs to probe ultra-dense matter

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Physics of Neutron Stars
St. Petersburg, Russia
### Galactic LMXBs

<table>
<thead>
<tr>
<th>Class</th>
<th>$L_x$ (2-10 keV)</th>
<th>Persistent</th>
<th>Transient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bright to very bright</td>
<td>$10^{37-39}$ erg s$^{-1}$ $\geq 10% L_{Edd}$</td>
<td>• Mostly NS systems</td>
<td>• Mostly BH</td>
</tr>
<tr>
<td>Faint</td>
<td>$10^{36-37}$ erg s$^{-1}$ $\sim 1-10% L_{Edd}$</td>
<td>• Mostly NS systems</td>
<td>• Mostly NS</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• At least some ultra-compact</td>
</tr>
<tr>
<td>Very faint</td>
<td>$10^{34-36}$ erg s$^{-1}$ $\sim 0.01-1% L_{Edd}$</td>
<td>• Only confirmed NSs</td>
<td>• Mostly NS systems?</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Ultra compact?</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• BD/planet companion?</td>
</tr>
</tbody>
</table>

*Note the energy range used*

Arbitrary, inspired by observations!
Very-faint persistent NS systems

- 1RXS J171824.2-402934 and 1RXS J173523.7-354013
  - In ‘t Zand et al. 2005
    • $\sim 10^{34}$ and $\sim 10^{35}$ erg s$^{-1}$
- AX J1754.2-2754
  - Sakano et al. 2002
  - Chelovekov et al. 2007
  - Del Santo et al. 2007
    • $\sim 3 \times 10^{34}$ erg s$^{-1}$ (2-10 keV)
Very-faint quasi-persistent NS sources

- XMMU J174716.1-281048
  - Sidoli & Mereghetti 2003
  - Del Santo et al. 2007, 2009-11
  - Degenaar et al. 2011
  - $5 \times 10^{34}$ erg s$^{-1}$
• AX J1745.6-2901
  - Maeda et al. 1996
    • 8 hr eclipsing system
  - Swift J174535.5-290135.6
    • Kennea et al. 2006
    • $< 5 \times 10^{35-36} \text{ erg s}^{-1}$

2006-2010 light curve
Degenaar & Wijnands 2010
Very-faint transient X-ray binaries

- Sub-luminous outbursts: $10^{34-36}$ erg s$^{-1}$
- About half are neutron stars
- Type-I X-ray bursts observed

Muno et al. 2005

GRS 1741.9-2853

XMM J174457-2850.3

Degenaar & Wijnands 2010

Wijnands et al. 2006
Binary evolution and population synthesis

• What kind of binary and how are they formed?
  – Orbital period, companion star
  – Why are they so faint?

• How many in our Galaxy and where located?
  – Are we ignoring a large population or not?
  – A few arcminutes to >100 degrees from Sgr A*
    • Averaged distance from Sgr A* ~ 17 degrees

• Where are the black hole systems?

• What can we learn about NSs?
What can we learn about NSs?

• Accreting millisecond X-ray pulsars

See talk by Alessandro Patruno
3 persistent
1 transient
No pulsations seen with XMM

NGC 6440 X-2
• Thermonuclear flashes
  – New accretion rate regime
  – Peng et al. 2007
  – Cooper & Narayan 2007

In ‘t Zand et al. 2007

Cornelisse et al. 2003
Intermediate long bursts

SLX 1737-282: Falanga et al. 2008

See talks of Jérôme Chenevez and Ed Brown
• Cooling of accretion heated neutron stars

Heinke et al. 2010

GC?

47 Tuc Grindlay et al. 2002
Conclusion

• A variety of sub-luminous accreting NS LMXBs
  – Difficult to find and get high quality data
    • But making progress!
    • Finding more sources: eRosita/NuSTAR
    • LOFT to study rapid variability
    • Sensitive all-sky monitors

• New insights into fundamental (astro-)physics
  – NS properties
  – Accretion and binary evolution
  – Comparison with bright transients at very low Mdot
Comparison with bright transients

SAX J1808.-3658: In ‘t Zand et al. 2001