The connection between AMXPs & tMSPs

Alessandro Patruno
Transitional MSPs

Four systems known:
- 3 never went into full outbursts
- 3 show radio/X-ray pulsations
- orbital periods 5–11 hours

Archibald+ 2009
Papitto+ 2013
Bassa+ 2014, Roy+ 2014
Bogdanov & Halpern 2015
Redbacks

Black widows:  
(semi)-degenerate companion

Redbacks:  
non-degenerate companion

All 4 tMSPs belong to the Redback class

See e.g., M. Roberts 2012
Unexplained Flickering

- Patruno+ 2014
- Kong+ 2014
- Tendulkar+ 2014
- Bogdanov+ 2015

X-Ray Flickering:
- 10-1000 s
- Luminosity:
  - 1e32 – 1e34 erg/s

Swift/XRT 0.3-10 keV

- Patruno+ 2014
- Kong 2014
- Takata+ 2014
Unexplained Flickering

X-Ray Flickering: 10-1000 s
Luminosity: 1e32 – 1e34 erg/s

qLMXB?
Unexplained Flickering

X-Ray Flickering: 10-1000 s

Luminosity: 1e32 – 1e34 erg/s

qLMXB?
Unexplained Flickering

X-Ray Flickering: 10-1000 s

Luminosity: $10^{32} - 10^{34}$ erg/s

Low Mode $10^{32}$ erg/s

Bogdanov+ 2015

qLMXB?
Unexplained Flickering

X-Ray Flickering: 10-1000 s

Luminosity: $10^{32} - 10^{34}$ erg/s

Low Mode $10^{32}$ erg/s

High Mode $10^{33}$ erg/s

Bogdanov+ 2015

qLMXB?
Unexplained Flickering

X-Ray Flickering: 10-1000 s

Luminosity: $10^{32} - 10^{34}$ erg/s

Flaring Mode

High Mode: $10^{33}$ erg/s

Low Mode: $10^{32}$ erg/s

Bogdanov+ 2015
Unexplained Flickering

X-Ray Flickering:
10-1000 s

Luminosity:
$10^{32} - 10^{34}$ erg/s

$q$LMXB?
The first accretion powered quiescent LMXB

Archibald+ '14

(See talk of A. Papitto for XSS J12270)
PSR J1023+0038 Energy and Power Spectra

- Identical power spectra
- Very similar energy spectra

Tendulkar+ 2014
Bogdanov+ 2015
M28I: The First AMXP/Radio Pulsar

Completely different luminosity scale!
AMXP Family (tMSP excluded!)

- Redback-like
  - XTE J1814-338
  - AQL X-1
  - SAX J1748.9-2021
  - IGR J17511-3057
  - Swift J1749.4-2807
  - IGR J17498-2921

- Black-Widow like
  - SAX J1808.4-368
  - HETE J1900.1-2455
  - IGR J00291+5934

- MS/SubG
  - $P_{\text{orb}} > 3.5 \text{ hr}$

- BD
  - $1 \text{ hr} < P_{\text{orb}} < 3.5 \text{ hr}$

- WD
  - $P_{\text{orb}} < 1 \text{ hr}$

(Patruno & Watts 2012 for a review)
### Similarities/Differences

<table>
<thead>
<tr>
<th></th>
<th>tMSPs</th>
<th>Redback like AMXPs</th>
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<tbody>
<tr>
<td><strong>MS companion star</strong></td>
<td>Pb ~ 5-10 hours</td>
<td>Pb ~ 4-20 hours</td>
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<tr>
<td><strong>B ~ 10^8-10^9 G</strong></td>
<td>Flickering in outburst</td>
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<td>Flickering in quiescence</td>
<td>No Flickering (Obs. Bias?)</td>
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<td><strong>Radio Pulsations</strong></td>
<td>No Radio PSR (yet?)</td>
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Radio pulsar search in AMXPs

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<tr>
<th>Source Name</th>
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<th>Dist. (kpc)</th>
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<td>SAX J1808.4–3658</td>
<td>2.0</td>
<td>≈ 3</td>
<td>BW</td>
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<td>2.5</td>
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<td>≈ 7</td>
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By far the deepest radio pulsar search so far (1.6-2.4 GHz) (Jaodand, Patruno, Hessels in prep.)

(See other searches by Iacolina+ 2010 at 4.8-8.4 GHz)
Radio pulsar search in AMXPs

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Preliminary results → no radio pulsations (Jaodand, Patruno, Hessels in prep.)
What about BW-like AMXPs?

SAX J1808.4-3658 behaves exactly as a BW:

1. shows anomalies in the orbital evolution

2. shows spin down compatible with magnetic dipole radiation in quiescence

3. indirect evidence for a radio pulsar (in quiescence)

Still no radio pulsar (and no BWs ever turned into LMXBs!)

Homer+ (2001); Burderi+ (2003); Campana+ (2004); Deloye+ (2008); Wang+ (2009)
Conclusions

Transitional Pulsars have opened a window on unexplored accretion regimes at low luminosities.

1. Pulsations detected at the lowest luminosities (qLMXB)
2. Unexplored accretion regime with fast flickering
3. Connection between radio pulsar “redbacks” and LMXBs: are they the same?
4. Will some AMXPs turn into tMSPs?