Binaries (and pulsars) session highlights

Alessandro Papitto
(ICE CSIC-IEEC Barcelona)
Why pulsars? Why binaries?

Pulsars in binary systems are clocks that are falling in the gravitational potential of the companion star.

Their motion and the path followed by the radiation emitted provide a clean test of GR at different regimes.
Why millisecond pulsars?

(J. Hessels, J. van Leeuwen, M. Berezina talks)
Exploration in Discovery Rate

43 Fermi targeted
27 HTRU (Parkes)
17 PALFA (Arecibo)
16 Drift/CC (GBT)

Ransom

More Galactic MSPs than in GCs for the first time in a decade!
A ms pulsar in a triple system as a GR test? (Jason Hessels)

**PSR J0337+1715 Triple System**

**Outer Orbit**
- $P_{\text{orb}} = 327\text{ days}$
- $M_{\text{WD}} = 0.41M_{\text{Sun}}$

**Inner Orbit**
- $P_{\text{orb}} = 1.6\text{ days}$
- $M_{\text{PSR}} = 1.44M_{\text{Sun}}$
- $M_{\text{WD}} = 0.20M_{\text{Sun}}$

**Orbital inclinations**
- $39.2^\circ$

**Figure credit:** Jason Hessels
A ms pulsar in a triple system as a GR test? (Jason Hessels)

Strong Equivalence Principle
How exotic binaries form? (Thomas Tauris talk)

Stellar Forensics
Trace the evolution backwards

- Applying constraints from knowledge of stellar evolution and mass transfer (RLO).
- Simulations of the dynamical effects of the supernova explosion.
- At all stages ensuring that the triple remains dynamically stable on a long timescale.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Millisecond pulsar mass</td>
<td>$1.438 , M_\odot$</td>
</tr>
<tr>
<td>inner WD mass</td>
<td>$0.197 , M_\odot$</td>
</tr>
<tr>
<td>inner WD temp</td>
<td>$15,800 , K$</td>
</tr>
<tr>
<td>inner P_{orb}</td>
<td>1.63 days</td>
</tr>
<tr>
<td>inner ecc</td>
<td>0.00069</td>
</tr>
<tr>
<td>outer WD mass</td>
<td>0.410 , M_\odot</td>
</tr>
<tr>
<td>outer P_{orb}</td>
<td>327 days</td>
</tr>
<tr>
<td>outer ecc</td>
<td>0.035</td>
</tr>
<tr>
<td>angle between orb. planes</td>
<td>0.01°</td>
</tr>
</tbody>
</table>

Ransom et al. (2014)
ms radio pulsars and X-ray binaries, mates but how close? (Papitto, Ferrigno, Jaodand, Parfrey, Wadiasingh, Cruces talks)

**Radio PSR** (rotation power)  
**X-ray pulsar** (accretion power)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>IGR J18245−2452</th>
<th>PSR J1824−2452f</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right Ascension (J2000)</td>
<td>18 h 24 m 32.53(4) s</td>
<td></td>
</tr>
<tr>
<td>Declination (J2000)</td>
<td>−24° 52′ 08.6(6) s</td>
<td></td>
</tr>
<tr>
<td>Reference epoch (MJD)</td>
<td>56386.0</td>
<td></td>
</tr>
<tr>
<td>Spin period (ms)</td>
<td>3.931852641(2)</td>
<td>3.93185(1)</td>
</tr>
<tr>
<td>Spin period derivative</td>
<td>&lt; 2 × 10⁻¹⁷</td>
<td></td>
</tr>
<tr>
<td>RMS of pulse time delays (ms)</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>Orbital period (hr)</td>
<td>11.025781(2)</td>
<td>11.0258(2)</td>
</tr>
<tr>
<td>Projected semi-major axis (RMs)</td>
<td>0.76591(1)</td>
<td>0.7658(1)</td>
</tr>
<tr>
<td>Epoch of zero mean anomaly (MJD)</td>
<td>56395.216889(5)</td>
<td></td>
</tr>
</tbody>
</table>

Papitto et al. 2013,  
Nature, 501, 517
The discovery of transitional millisecond pulsars
(Papitto, Ferrigno, Jaodand, Parfrey, Wadiasingh, Cruces talks)

Low Mass in-flow rate:
Magnetic field dominates
→ rotation powered Radio PSR

High Mass in-flow rate:
Gravity dominates
→ accretion powered X-ray PSR

[Stella+ 1994; Campana+ 1998; Burderi+ 2001]

Credits: NASA's Goddard Space Flight Center
How do radio pulsars actually work? (Wim Hermsen talk)

Discovery of Synchronous X-ray and Radio Mode Switches

XMM-Newton
EPIC PN + MOS-1 & MOS-2

Detection of pulsed X-ray emission in radio Q mode

Difference between X-ray emissions in radio B and Q mode is addition of pulsed X-ray emission in Q mode!

X-ray pulse is aligned with radio main pulse with precursor
What is the nature of ultraluminous X-ray sources?
(M. Bachetti, A. Sutton talks)

ULTRALUMINOUS X-RAY SOURCES

IMBH?  > EDDINGTON?

Soft excess  Hard turnover
Low-frequency variability  “Strange” variability!
High luminosity (of course)  High luminosity (of course)

More likely above $10^{42}$ erg/s  More likely below $10^{40}$ erg/s
A 1.3 s ultraluminous X-ray pulsar in M82 (M. Bachetti talk)

Magenta:
pulse-on - pulse off

NuSTAR image
A few gravitational radii from a ms pulsar surface (T.Di Salvo talk)

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### Results of the fitting with a diskline

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>$E$ (keV)</td>
<td>$6.47 \pm 0.06$</td>
</tr>
<tr>
<td>Betor</td>
<td>$-2.2 \pm 0.3$</td>
</tr>
<tr>
<td>$R_{\text{in}}$ (Rg)</td>
<td>$&lt; 10$</td>
</tr>
<tr>
<td>$R_{\text{out}}$ (Rg)</td>
<td>$240 \div 1800$</td>
</tr>
<tr>
<td>Incl (deg)</td>
<td>$50$ (fixed)</td>
</tr>
<tr>
<td>$E_{\text{FWHM}}$ (eV)</td>
<td>$100 \pm 10$</td>
</tr>
<tr>
<td>$\chi^2$</td>
<td>$1676/1663$</td>
</tr>
</tbody>
</table>

The broad Fe line is visible in the residuals. Gaussian sigma would be $\approx 0.7$ keV

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The diagram shows the distribution of energy (keV) against frequency (Hz) with a fitted curve and residuals.
X-ray binaries at low luminosity (R. Wijnands talk)
So many kinds of binaries

High mass X-ray binaries with gamma-ray emission
Labs to study interbinary shocks 'close' to the pulsar light cylinder
(D. Torres, G. Dubus, P. Munar Adrover talks)

Transient high mass X-ray binaries (P. Romano, A. Lutovinov)

Modelling of the high energy emission in individual sources
Low Mass companions
(N. Schulz, F. Koliopanos, R. Iaria, F. Capitanio, L. Ducci, A. Fragkos, T.İÇLİ)
High Mass companions
(A. Manousakis, P. Pradhan, N. Islam, C. Maitra, I. El Mellah)

3 sessions, 34 contributions, a lot of young people
Stay tuned for more!!!