Ultra-Compact Binaries: LISA Verification Sources

Mukremin Kilic (U. Oklahoma)
1 - AM CVn Systems
(5-65 min)

P = 17 min

d = 606 pc

0.13 + 0.71 Msun

(Roelofs et al. 2007)
RX J0806.3+1527 (HM Cnc)

Chandra ACIS-S

$P = 321 \text{ s}$

$P_{\text{dot}} = 3.75 \times 10^{-11} \text{ s/s}$

(Strohmayer 2005)
RX J0806.3+1527 (HM Cnc)

<table>
<thead>
<tr>
<th>Wavelength (Å)</th>
<th>Normalized flux</th>
</tr>
</thead>
<tbody>
<tr>
<td>3820</td>
<td>1.2</td>
</tr>
<tr>
<td>3888</td>
<td>1.15</td>
</tr>
<tr>
<td>3968</td>
<td>1.1</td>
</tr>
<tr>
<td>4026</td>
<td>1.05</td>
</tr>
<tr>
<td>4100</td>
<td>1.0</td>
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<tr>
<td>4178</td>
<td>1.1</td>
</tr>
<tr>
<td>4240</td>
<td>1.15</td>
</tr>
<tr>
<td>4302</td>
<td>1.2</td>
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<tr>
<td>4379</td>
<td>1.15</td>
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<td>4447</td>
<td>1.1</td>
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<td>4586</td>
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<td>4652</td>
<td>1.1</td>
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<tr>
<td>4718</td>
<td>1.15</td>
</tr>
<tr>
<td>4794</td>
<td>1.2</td>
</tr>
</tbody>
</table>

0.27 + 0.55 Msun system at i=38 deg, d ~ 5kpc
Pdot = 3.75 e-11 s/s (Strohmayer 2005)

Roelofs et al. (2010)
2 - Ultra-Compact X-ray Binaries

4U 1820-30
(in NGC 6624, d=7.6 kpc)

P = 685 s
Pdot = 7.53 e-13 s/s
0.06 Msun WD + 1.4 Msun (NS)

Lower secondary mass means lower chirp mass and GW strain
Hulse Taylor pulsar

Hulse-Taylor
P = 7.8 hr
Pdot = 2.42e-12

PSR B1534+12
P = 10 hr
Pdot = 1.4e-13 (Stairs +02)

PSR J0737-3039
P = 2.4 hr
Pdot = 1.25 e-12 s/s
d = 1.15 kpc
1.25 + 1.34 Msun 2.7 s and 22 ms pulsars.
4 - Double WDs

WD 1101+364 (Marsh et al. 1995)
P = 3.5 h, d = 135 pc, 0.31 + 0.36 Msun WDs
Merger time 2.5 Gyr
Double WDs

WD 0957-666 (Moran et al. 1997)
P = 1.46 h, d = 135 pc, 0.32 + 0.37 Msun WDs
Merger time 200 Myr.
Is the period shrinking?
Figure showing a graph with data points labeled as follows:
- AM CVn systems
- Ultra-compact X-ray binaries
- Double WD/sdb+WD
- Galactic foreground

The graph plots strain $h$ against logarithm of frequency $f$ in Hz.

Nelemans (2005)
SPY survey

HE 1414-0848

0.71 + 0.52 M\(\odot\) WDs

at 0.6 day period

(Napiwotzki et al. 2002)
SPY survey

S. Geier, priv. comm.
The ELM Survey

ELM WDs in the SDSS

ELM WDs in the Hyper-velocity Star Survey
ELM WDs in the SDSS

**Teff, log g, and Mass**
5.9 hr period binary
1.9 hr period binary
1.0 hr binary
# 6 ELM WD systems (Kilic et al. 2009, 2010)

<table>
<thead>
<tr>
<th>Object</th>
<th>Companion Mass</th>
<th>Neutron Star</th>
<th>X-ray</th>
<th>Radio</th>
<th>Merger Time (Gyr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>J0822</td>
<td>&gt;0.76</td>
<td>18%</td>
<td>CXO</td>
<td>GBT</td>
<td>&lt;8.4</td>
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<td>J0849</td>
<td>&gt;0.64</td>
<td>15%</td>
<td>CXO</td>
<td>GBT</td>
<td>&lt;0.47</td>
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<tr>
<td>J1053</td>
<td>&gt;0.26</td>
<td>4%</td>
<td>CXO</td>
<td>GBT</td>
<td>&lt;0.16</td>
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<td>J1436</td>
<td>&gt;0.46</td>
<td>9%</td>
<td></td>
<td>GBT</td>
<td>&lt;0.10</td>
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<td>LP400-22</td>
<td>&gt;0.37</td>
<td>7%</td>
<td>CXO</td>
<td>GBT</td>
<td>&lt;230</td>
</tr>
<tr>
<td>J0917</td>
<td>&gt;0.28</td>
<td>5%</td>
<td>XMM</td>
<td>GBT</td>
<td>&lt;36</td>
</tr>
</tbody>
</table>
The Shortest Period Detached Binary WD
The Shortest Period Detached Binary WD

P = 39.1 min (Kilic +11)

First detection of ellipsoidal variations in a WD.
i = 67 deg, 0.17 + 0.43 Msol WD.
Merger time = 37 Myr
Is the period shrinking?
J0651+2844: $\text{Teff} = 16,400 \text{ K}, \text{ M} = 0.25 \text{ M}_{\odot}, \text{ d} = 1 \text{ kpc}$

Discovered in March 2011

Brown et al. (2011)
J0651

P = 765 s
J0651

\[ i = 86.9 \text{ deg} \]
\[ 0.25 + 0.55 \text{ Msol WDs at 0.17 Rsol separation.} \]
\[ R_1 = 0.035 \text{ Rsol} \]
\[ R_2 = 0.013 \text{ Rsol} \]
Mass transfer in 0.9 Myr.
Is the period shrinking?
The ELM Survey: 24 new systems

*24 new systems that will merge within a Hubble time

* Radio/X-ray (for 5) observations rule out NS companions

* This has been the most successful search for WD merger systems.

Kilic+12
Gravitational Wave Detection

\[ \log h \ vs \ \log \nu (\text{Hz}) \]

Kilic+12
Gravitational Wave Detection

![Graph showing log h vs log (Hz) with labeled points J0923, J1630, J1436, J1056, J0651, and J0106.](image)
Gravitational Wave Detection
Summary

- There are a dozen known LISA verification sources.
- The sample will increase in this decade (surveys by Nelemans & Co and by our group, and PTF + Panstarrs, LSST).