Accreting compact object binaries in transient surveys

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Accretion-driven transients

- Compact object (BH, NS, WD)
- Accreting from companion star
- Accretion disc
- Evolve by angular momentum loss -- same physics!
Characteristics of an AM CVn star

- Accreting white dwarfs
- Hydrogen-deficient
- Ultra-short periods: $P_{\text{orb}} = 5 - 65 \text{ min}$
AM CVn donor stars

Period-density relation for Roche lobe-filling stars:

\[ < \rho_2 > \approx 107 \, P_{\text{orb},h}^{-2} \, \text{g cm}^3 \]

⇒ Donors stars of AM CVn binaries are evolved (another WD, or a partially degenerate star)

(Gaensicke et al 2003)
Evolution driven by gravitational wave radiation (Paczynski 1967)

Strongest known low-frequency GW sources (verification sources for eLISA)

Formation channels / evolution

- Double WD binaries
  (Paczynski 1967; Nelemans et al 2001)

- WD + He-star
  (Iben & Tutukov 1991; Yungelsson 2008)

- Evolved CV
  (Sienkiewicz 1984; Podsiadlowski et al 2003)

\( \dot{m} \) stable?
(Marsh et al 2004)

AMCVn stars: Nelemans (2005)

First contact
Accretion phase
Detached double WD
Helium star
Evolved CV
Formation channels / evolution

First contact at short $P_{\text{orb}}$ -- evolve to long periods

Roche lobe + GWR + degenerate star + Kepler III

$\Rightarrow \dot{m} \propto P^{-14/3}$

(e.g. Warner 1995; Cannizzo & Nelemans 2015)

Sharp drop in $\dot{m}$ as the system evolves to longer periods
Formation channels / evolution

First contact at short $P_{\text{orb}}$
-- evolve to long periods

Roche lobe + GWR + degenerate star + Kepler III

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(e.g. Warner 1995; Cannizzo & Nelemans 2015)

Sharp drop in $\dot{m}$ as the system evolves to longer periods

(Ramsay et al 2012)
The AM CVn population in numbers

50 known systems
38 with known $P_{\text{orb}}$

g mag = 13.5 − 24

Oberved space density $5 \times 10^{-7}$ pc$^{-3}$

(Carter et al 2013)
The AM CVn population in numbers

50 known systems

38 with known $P_{\text{orb}}$
Pros:
★ Much deeper than possible with spectroscopy
★ Wide sky coverage
★ No colour pre-selection
★ High event rates, so it also finds the rare objects

Cons:
❖ Selects AM CVns from only a specific period range
❖ Statistics are harder
❖ Many too faint for spectroscopic follow-up

Recent advances as a result of follow-up of transient events
➢ Helium disc instability - link to CV DNe
➢ Long term photometric variability - low mass AM CVn
➢ First deeply eclipsing AM CVn
i) Disc phenomena

- **Superoutburst “dips”**

  (Wood et al 2011; Cannizzo et al 2012; Osaki & Kato 2013)

- **Echo outbursts**

  EG Cnc
  (Patterson et al 1998)
i) Disc phenomena

- Superhumps

Only observed during superoutburst

Efficient way of measuring the orbital period

Requires rapid follow-up → Gaia alerts!

(HS0417+7445 - J. Shears, B.T. Gänsicke et al. 2011, New Astronomy, 16, 5)
i) Disc phenomena

Recent discoveries:

- ASASSN-14mv $P_{sh} = 40.52$ min $q = 0.08$ (vsnet-alert 18230)
- ASASSN-14ei $P_{sh} = 42.89$ min 14 rebrightenings! (Prieto et al 2014 ATEL#6475)
- ASASSN-14fv $P_{sh} = ?$ (Wagner et al 2014 ATEL#6669)
- ASASSN-15kf $P_{sh} = 27.68$ min (vsnet-alert 18669)
- ASASSN-14cc $P_{sh} = 22.46$ min Very freq outbursts (Kato et al 2015)

(Carter, Breedt et al, in prep)
ii) Long term photometric behaviour

Modified DIM: unstable disc for $20 \leq P_{\text{orb}} \leq 40$ min
(Tsugawa&Osaki 1997; Kotko et al 2012)


$T_{\text{rec}} \propto m^{-1} \propto P_{\text{orb}}^{7.35}$

Cannizzo & Nelemans (2015):
- systems with higher primary masses have a steeper $m - P_{\text{orb}}$ relation
- Parameter studies are still important!
iii) Eclipsing systems

SDSSJ0926+3624
The first-ever eclipsing AM CVn

WHT+
ULTRACAM

$P_{\text{orb}} = 28.3 \text{ min}$

$q = 0.043$

$i = 82.5$

$T_{\text{WD}} = 17000 \text{ K}$

$M_1 = 0.82 \, M_{\odot}$

$M_2 = 0.035 \, M_{\odot}$
### iii) Eclipsing systems

**ASASSN-14cn / Gaia14aae**

First AM CVn in which the WD is fully eclipsed  
- ideal for parameter studies

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_{\text{orb}}$</td>
<td>49.71 min</td>
</tr>
<tr>
<td>$T_{\text{WD}}$</td>
<td>12900 K</td>
</tr>
<tr>
<td>$a$</td>
<td>0.41 $R_\odot$</td>
</tr>
<tr>
<td>$q$</td>
<td>0.019</td>
</tr>
<tr>
<td>$M_1$</td>
<td>$0.79 M_\odot$</td>
</tr>
<tr>
<td>$M_2$</td>
<td>$0.015 M_\odot$</td>
</tr>
<tr>
<td>$M_2$ (in J)</td>
<td>15.7 M$_J$</td>
</tr>
</tbody>
</table>

(Campbell et al 2015)

Longest $P_{\text{orb}}$ with outbursts

(Time [mins])

(Green et al, in prep)
Final thoughts

- **18** new AM CVns from *variability surveys*; several surveys to come: *Gaia*, PanSTARRS, LSST - but follow-up observations are essential.

- Huge interest and involvement from *citizen scientists* (aka amateur astronomers)

- *Gaia14aae*: extremely valuable discovery, both for the eclipse and for helium disc instability models. Thank you for all your observations!

- Future observations: phase resolved spectroscopy; could we detect the *donor star* directly?

- Future work with Gaia: *space density* of AM CVn stars