WANTED
THE TRUE
BOUNCE-BACK SYSTEMS

Sergey Zharikov & Gagik Tovmassian
After reach the period minimum the CVs should be evolving back toward longer periods and form so-called bounce-back systems.

Paczynski, 1981, AcA, 31, 1
<table>
<thead>
<tr>
<th>Star</th>
<th>$P_{e, o}$ (d)</th>
<th>$d$ (pc)</th>
<th>$q^1$</th>
<th>$(M_\ast)^2$</th>
<th>$(M_\ast)^3$</th>
<th>$&lt;M_\ast&gt;$</th>
<th>$T_{\ast}^3 \times 1000$ K$^6$</th>
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<tr>
<td>GD 552</td>
<td>0.0713</td>
<td>74</td>
<td>$&lt;0.052\nu$</td>
<td>13.2</td>
<td>$&gt;11.7$</td>
<td>10.5 gsd</td>
<td>Unda-Sanzana et al. 2008, Patterson et al. 2009</td>
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<tr>
<td>RE 1255+266</td>
<td>0.0830</td>
<td>180</td>
<td>$&lt;0.052\nu$</td>
<td>13.6</td>
<td>$&gt;11.6$</td>
<td>$&lt;12 g$</td>
<td>PTK</td>
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<tr>
<td>EG Cnc</td>
<td>0.0600</td>
<td>330</td>
<td>0.035 s</td>
<td>12.3</td>
<td>11.2</td>
<td>12 gsd</td>
<td>Patterson et al. 1998, Szkody et al. 2002</td>
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<td>SDSS 1035+05</td>
<td>0.0570</td>
<td>170</td>
<td>0.055 e</td>
<td>14.0</td>
<td>$&gt;10.4$</td>
<td>10.7 sa</td>
<td>Littlefair et al. 2006</td>
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<td>RX 1050–14</td>
<td>0.0815</td>
<td>80</td>
<td>$&lt;0.056\nu$</td>
<td>14.0</td>
<td>$&gt;10.9$</td>
<td>$&lt;12 g$</td>
<td>Monnickent et al. 2001, PTK</td>
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<td>WZ Sge</td>
<td>0.0567</td>
<td>43</td>
<td>0.045 s</td>
<td>12.8</td>
<td>12.8</td>
<td>11.6</td>
<td>13.5 s</td>
<td>Patterson et al. 2002, P98, Thorstensen 2003, Godon et al. 2006</td>
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<td>V455 And</td>
<td>0.0563</td>
<td>90</td>
<td>0.06 s</td>
<td>12.2</td>
<td>$&gt;10.8$</td>
<td>$&gt;10.0$</td>
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<td>Betancor et al. 2005, Patterson et al. 2009 in prep</td>
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<td>SDSS 1216+05</td>
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<td>$&lt;0.06\nu$</td>
<td></td>
<td>$&gt;9.9$</td>
<td>$&lt;12 g$</td>
<td>Southworth et al. 2008</td>
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<td>140</td>
<td>0.065 s</td>
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<td>$&gt;11.4$</td>
<td>PTK, Patterson et al. 2009 in prep</td>
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<td>PG And</td>
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<td>160</td>
<td>$&lt;0.07\nu$</td>
<td>13.8</td>
<td>$&gt;10.8$</td>
<td>$&gt;10.8$</td>
<td>$&lt;11$</td>
<td>Patterson et al. 2005b</td>
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<td>0.06 s</td>
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<td>11.1</td>
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<td>Patterson et al. 1996, this paper</td>
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<td>0.069 e</td>
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<td>13.5 gsd</td>
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<td>Zhanikov et al. 2006</td>
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<td>0.047</td>
<td>11.8</td>
<td>$&gt;10.2$</td>
<td>$&lt;11 g$</td>
<td>Zhanikov et al. 2008, Pavlenko et al. 2008</td>
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<td>BW Scl</td>
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<td>110</td>
<td>12.3</td>
<td>$&gt;11.5$</td>
<td>14.6 s</td>
<td></td>
<td>Patterson et al. 2009</td>
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<td>IX Dra</td>
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<td>Olech et al. 2004</td>
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<td>SDSS 1501</td>
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<td>0.067</td>
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<td></td>
<td>Littlefair et al., 2008</td>
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</tr>
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</table>

1. $q = \frac{R_{\ast}}{a}$, where $R_{\ast}$ is the radius of the primary and $a$ is the semimajor axis of the orbit.

2. $(M_\ast)^2 = M_\ast^2 / (1 - e^2)$, where $M_\ast$ is the mass of the primary and $e$ is the eccentricity of the orbit.

3. $(M_\ast)^3 = M_\ast^3 / (1 - e^2)^{3/2}$

4. $<M_\ast> = \frac{1}{2} (M_\ast + M_\ast')$, where $M_\ast'$ is the mass of the secondary.

5. $T_{\ast} = \frac{T_{\ast,0}}{1 - e^2}$, where $T_{\ast,0}$ is the period of the primary.

6. $T_{\ast,0} = 2\pi \sqrt{a^3 / G (M_\ast + M_\ast')}$, where $G$ is the gravitational constant.
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Mass ratio $q$ versus $P_{\text{orb}}$. Circles are positive measurements from eclipses and super-humps; triangles are upper limits on $q$ from radial-velocity studies. The curve is the predicted trend if CV evolution is driven by angular-momentum loss at the gravitational-radiation (GR) rate.

Patterson, J. astro-ph: 0903.1006

SDSS1035 is the first solid example bounce-back system.
Littlefair et al. 2006
SDSS1035 is the first solid example bounce-back system. Littlefair et al. 2006, Southworth et al 2006

\[
\begin{array}{c|c|c|c}
\hline
q & 0.055 \\
M1 & 0.94 \\
M2 & 0.052 \\
Porb & 0.0570 \\
\hline
\end{array}
\]
WANTED THE TRUE BOUNCE-BACK SYSTEMS

Mass ratio $q$ versus $P_{\text{orb}}$. Circles are positive measurements from eclipses and super-humps; triangles are upper limits on $q$ from radial-velocity studies. The curve is the predicted trend if CV evolution is driven by angular-momentum loss at the gravitational-radiation (GR) rate.

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SDSS 1035

SDSS 1238

SDSS 0804
WANTED THE TRUE BOUNCE-BACK SYSTEMS

SDSS 1238 was identified by Szkody et al. (2003) as a weak cataclysmic variable star (\( r = 17.82 \) mag), whose spectrum is characterized by a blue continuum with double emission Balmer lines, originated in a high inclination accretion disk, surrounded by absorption lines formed in the photosphere of the white dwarf. By the way, Zharikov et al. (2006) establish its orbital period, been 80.5 min, using spectroscopic data, they also computed a surface temperature for the white dwarf of 15 600 +/- 1000 K, which is in the temperature range observed in short period systems below the period gap, this calculation was made using stellar atmosphere models. A particular feature of SDSS1238 was observed in its light curve in a way of a variability with 40.25 minutes period and 0.15 mag of amplitude. The presence of double-humped light curve has been proposed as an additional criterion for a WZ-Sge classification in short period CV. The most intriguing feature of this object is an abrupt increase in brightness of 0.45 mag in a time scale near half orbital period, after which the system go back to its quiescence state in a scale of 3 – 4 hours, such brightening occurred cyclically about every ~9 hours.

A similar behavior was found late in the light curve of another short period cataclysmic variable, SDSS J080434.20+510349.2 (Szkody et al 2006) which was observed in super outburst in 2006 (Pavlenko et al. 2006) and exhibits all the necessary attributes to be classified as a WZ Sge type system. Since both objects show similar spectral features in their quiescence level; we carried out multi longitude photometric observations of SDSS 1238 to establish the origin of the brightening and its relation with the amplitude on the light curve of the double hump.

SDSS 1238

Szkody et al., 2003, Zharikov et al., 2006

SDSS 0804

Szkody et al., 2006, Pavlenko et al., 2006, Zharikov et al., 2008
HJD 53384.8
~1 year before the outburst

(SDSS 1238 with shifted mag. scale)
SDSS 0804

Szkody et al., 2006, Pavlenko et al., 2006, Zharikov et al., 2008, in preparation

Porb = 85 ± 3 min
q ~ 0.05
WANTED THE TRUE BOUNCE-BACK SYSTEMS

Mass ratio q versus P_{orb}. Circles are positive measurements from eclipses and super-humps; triangles are upper limits on q from radial-velocity studies. The curve is the predicted trend if CV evolution is driven by angular-momentum loss at the gravitational-radiation (GR) rate.

Patterson, J.  
http://xxx.lanl.gov/abs/0903.1006

SDSS1035 is the first solid example bounce-back system.  
Littlefair et al. 2006
There are six WZ Sge-type systems that have shown double-peaked humps in outbursts: AL Com (Kato et al. 1996; Patterson et al. 1996), EG Cnc (Patterson et al. 1998), RZ Leo (Ishioka et al. 2001), HV Vir (Ishioka et al. 2003), Var Her 04 (Price et al. 2004), and WZ Sge itself (Kato et al. 2004).

SDSS 1238 and SDSS0804 have shown permanent double-peaked humps in quiescence together with the cyclic brightenings. SDSS0804 shows such brightening before the outburst 2006, SDSS 1238 have shown the cyclic brightening until now. The double-peaked light curve in SDSS 0804 observed after super-outburst too.
WANTED THE TRUE BOUNCE -BACK SYSTEMS

Mass ratio $q$ versus $P_{\text{orb}}$. Circles are positive measurements from eclipses and super-humps; triangles are upper limits on $q$ from radial-velocity studies. The curve is the predicted trend if CV evolution is driven by angular-momentum loss at the gravitational-radiation (GR) rate.

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In order to avoid an earlier occurrence of normal outburst in WZ Sge-type systems, we must choose an extremely low viscosity parameter $\alpha \sim 0.001$ (Smak (1993), Osaki (1994, 1995,1996), Howell (1995)).
The WZ Sge stars are thought to be of the lowest end of cataclysmic variable’s evolution in that they pass the period minimum of the cataclysmic variables, having a degenerate secondary star. The extremely large and rare outbursts of WZ Sge are understood in term of extremely low viscosity in quiescence (Osaki, 2005).

Lower mass transfer -> lower viscosity -> larger accretion disk size.

**Figure 1.** Mass transfer rate versus orbital period for sequences of Set A (white dwarf mass 0.6 $M_\odot$). Labels indicate the initial donor mass (in units of $M_\odot$). Kolb & Barafe, 1999
Figure 1. SPH simulation of the disk of WZ Sge during the early superhump phase. Left: Snapshot of the disk, the two-armed spiral is clearly visible. Right: Phase-resolved pseudo-lightcurve.

We propose that the double-humped light curve in quiescence in short-period WZ Sge type CVs could be indirect evidence to classify such system as a bounce-back object.