Photometric long-term variations and superhump occurrence in the Classical Nova RR Pictoris

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ABSTRACT
We present an analysis of all available time-resolved photometry from the literature and new light curves obtained in 2013–2014 for the old nova RR Pictoris. The well-known hump light curve phased with the orbital period reveals significant variations over the last 42 years in shape, amplitude and other details which apparently are caused by long-term variations in the disc structure. In addition we found evidence for the presence of superhumps in 2007, with the same period (∼9% longer than the orbital period), as reported earlier by other authors from observations in 2005. Possibly, superhumps arise quickly in RR Pic, but are sporadic events, because in all the other observing runs analysed no significant superhump signal was detected. We also determined an actual version of the Stolz–Schoembs relation between superhump period and orbital period, analysing separately dwarf novae, classical novae and nova-like stars, and conclude that this relation is of general validity for all superhumpers among the cataclysmic variables (CVs), in spite of small but significant differences among the sub-types mentioned above. We emphasize the importance of such a study in context with the still open question of the interrelation between the different sub-classes of CVs, crucial for our understanding of the long-term CV evolution.

Key words: accretion, accretion discs – stars: individual RR Pic – novae, cataclysmic variables.

1 INTRODUCTION
Cataclysmic variables (CVs) are close interacting binary systems where a late-type dwarf star fills its Roche lobe and transfers mass towards the white dwarf (WD) primary component. In case of a weak or absent magnetic field of the WD, the transferred material from the secondary star is accumulated forming an accretion disc around the WD. Once the accumulated mass on the primary reaches a critical value, the surface temperature of the WD increases and triggers nuclear fusion reactions producing a thermonuclear runaway, which is known as a nova eruption. CVs that underwent a nova eruption are called classical novae (for details see Warner 1995). RR Pictoris is one of the brightest and nearest novae known (distance $d = 388 \pm 88$ pc; Ramsay et al. 2017). Its nova eruption was discovered by Jones (1928) at its maximum brightness $V = 1.2$ mag in 1925. Currently the stellar remnant appears to be in a state of quiescence, with $V \sim 12.7$ mag. The photometric light curves of RR Pic show as a permanent feature a periodic hump of $P_{\text{orb}} = 3.48$ h, which has been identified as the orbital one (Vogt 1975). Additionally, they have undergone several changes and transient features over the decades since its eruption, showing eclipse-like characteristics (Warner 1986), 15 min periodicities (Kubiak 1984), QPOs and positive superhumps (Schmidtbreick et al. 2008). Time-series spectroscopy and Doppler mapping found evidence for two emission sources, the hotspot and a source opposite. (Haefner & Metz 1982; Schmidtbreick et al. 2003; Ribeiro & Diaz 2006). In a recent work Vogt et al. (2017) derived a more precise orbital ephemeris from all available photometric humps observed in the past five decades. They furthermore found variations in the O–C diagram that could imply the presence of a third body.

The motivation for the present investigation was the discovery already mentioned of an additional period that is 8.6 percent longer than the orbital one, which was interpreted as a superhump period ($P_{\text{sh}}$) by Schmidtbreick et al. (2008). Superhumps are photometric modulations in the light curve with periods slightly different from the orbital period, which are present in SU-UMa type dwarf novae during superoutburst (Vogt 1974) and also as ‘permanent superhumps’ in some nova-like CVs (Patterson 1999).
If $P_{\text{orb}}$ is a few percent longer than the orbital period we call this a "positive superhump", while the case $P_{\text{orb}} < P_{\text{sh}}$ refers to "negative superhumps". Vogt (1982b) was the first who proposed superhumps are associated to an eccentric accretion disc during superoutburst, based on spectroscopic observations of Z Cha. Later studies have established that the disc becomes eccentric when it reaches the 3:1 resonance, due to the interaction with the secondary, causing the elongated section of the disc moves to different time-scale respect to the orbital period (Whitehurst 1988; Osaki 1989; Patterson et al. 2005 and references therein). Thus, the presence of superhump in classical novae can be used as a tool to understand the state of the system in general, and of the disc properties decades after the nova eruption.

In this paper, we present a re-analysis of all available photometric data of RR Pic, between 47 and 89 years after its classical nova explosion observations. We also add new data taken during 2013–2014 and study the orbital hump light curves during the past decades in a systematic way. Furthermore we perform a methodical search for superhumps in RR Pic and compare our results with those known for other classical novae, nova-like stars and dwarf novae.

## 2 OBSERVATIONS

### 2.1 Compilation of historical light curves and new observations

The light curves of RR Pic analysed here consist of published observations made by different authors, complemented by new data obtained in 2013 and 2014. The different campaigns are summarised in Table 1, which contains: the Heliocentric Julian date (HJD) at start and at the end of each campaign (HJD$_{\text{start}}$ and HJD$_{\text{end}}$), the total number of light curves (N), the total time covered by observations ($\Delta t$), the identification of the observer and the campaign name (see Fig. 2). An observing log for hitherto unpublished data is given as on-line supplementary data. In particular, we can distinguish the following campaigns:

1. **UBV** photometry observed by Vogt (1975) during four nights in December 1972 and three nights of white light data in January 1974; from the $UBV$ data we analysed only the $V$ band light curves, given that the color index $B-V$ is close to 0 (see fig. 5 in Vogt 1975). All these observations have covered more than one orbital cycle.

2. High-speed photometry in white light of Warner (1986) from 1972 to 1984 over 23 nights. In eight of them at least one orbital period was covered. Only raw instrumental values (count rates per second) are available, without observations of comparison stars nor any other calibration. Details on how this data were analysed are described in section 2.2.

3. Light curves in five nights observed in January 1980 by Haefner & Metz (1982) in the $V$ band. In all of them at least one complete orbital cycle was observed.

4. Kubiak (1984) obtained $UBV$ photoelectric photometry in five nights in October 1982. We analysed the published $B$ differential band light curves. Only in one night an entire orbital period was covered.

5. The Center Backyard Astrophysics (CBA)$^1$ kindly provided us with additional unpublished differential photometry in white light of RR Pic, obtained in a total of 50 nights between 1999 and 2007 by different amateur astronomers.

6. Differential photometric data obtained by Schmidtobreick et al. (2008) during the first semester of 2005, covering 18 complete orbital cycles.

7. ROAD

In addition one of us (FJH) has obtained new $V$ band photometry in 81 nights between 21 November 2013 and 16 March 2014, using the robotic 40 cm telescope at the Remote Observatory Atacama Desert (ROAD), situated in San Pedro de Atacama, Chile (Hambsch 2012). This telescope is equipped with a CCD camera that contains a Kodak 16803 chip of 4k $\times$ 4k pixels of 9–$\mu$m size. The integration time was 30 seconds with a cadence of 2–3 minutes. Normally, one entire orbital period per night was covered. However, due to the coordinates of RR Pic, only a partial coverage of the orbital period was possible at the end of this run (February to March 2014).

We had access to the original data of Vogt (1975), Warner (1986), Schmidtobreick et al. (2008) and those of the Center Backyard Astrophysics, all in digital form. The light curves of Haefner & Metz (1982) and Kubiak (1984) were only available as figures. Therefore, we digitised them from the respective publications, using the DEXTER$^2$ service from the website of the German Astrophysical Virtual Observatory (GAVO).

In Fig. 1 we present examples of the light curves corresponding to hitherto unpublished campaigns: 2005 and 2007 from CBA and 2013 from ROAD. In all light curves we also show the mean sine fit curve of the orbital hump with an adopted amplitude $A = 0.14 \pm 0.01$ mag and the global orbital period according to ephemeris (1).

### 2.2 Homogenization of the data

All historical data were converted to a standard format: HJD and differential magnitude with respect to the comparison star used by Vogt (1975). Additionally the data were normalised by subtracting the mean magnitude of each data set. Warner’s uncalibrated data files were treated in a special way, transforming his counts per second into magnitudes and adjusting their zero points to fit Vogt’s

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1. http://cbastro.org/
2. http://dc.zah.uni-heidelberg.de/dexter/
phased light curves. This was possible because both data sets cover partly the same epoch. For the same reason, we combined Vogt’s and Warner’s data in two campaigns, 1972–1973 and 1973–1974. The 1972–1973 campaign contains all B band light curves obtained during 1972 by both authors, and observations from 1973 January 11 and 13 from Warner. The 1973–1974 campaign was composed of white light data from seven nights between 1973 December 7 and 1974 January 17 from both authors. Haefner & Metz’s light curves (campaign 1980–1) were combined with two light curves of Warner (campaign 1980–2), which were observed in high resolution compared with Haefner & Metz. To obtain the same time resolution as in the 1980–1 campaign, we re-binned the data set of Warner (1986).

3 RESULTS

3.1 Variations of orbital light curve

We used the period04 software (Lenz & Breger 2005) to search for periodicities in the light curve via Discrete Fourier Transform (DFT). All campaigns are sampled until the Nyquist frequency. However, since we are searching for frequencies close to the orbital one, the examined frequency range was from 0 to 30 c/d. For all campaigns the respective periodogram shows the known orbital frequency as the dominant peak close to $f_0 = 6.895$ c/d, corresponding to $P_{\text{orb}} = 3.48$ h. The orbital phase of each sample was calculated using the new long-term ephemeris of the orbital hump maximum:

$$HJD(\text{max}) = 2438815.3664(15) + 0^d.145025959(15)E$$

(1) determined by Vogt et al. (2017). The mean phased-folded light curves were computed by averaging the data points into 0.02 phase bins. The results are shown in Fig. 2.

The orbital light curve has notably changed its shape over the course of the last 42 years (Fig. 2). During the data from 1972 to 1974 the light curves predominantly showed humps of amplitude $\sim 0.2^m$ and smooth minima at phase 0.55, being about 0.05$^m$ deeper in 1973–1974 than one year before. In addition, there was a step-like feature at phase 0.65–0.70. From 1980 to 1982, the light curve underwent dramatic changes: in January 1980, the orbital hump was still present, although with a smaller amplitude, and there was a deep minimum at phase 0.7 (1980–1). However, in two observing runs obtained only one month apart (1980–2), the orbital hump practically disappeared, showing a predominantly flat light curve, interrupted only by the minimum at phase 0.7. Then in 1981, there was a very shallow maximum at phase $\sim 0.9$, immediately after the minimum around phase 0.7 which now seems to be broader than before. A similar light curve was observed in 1982 with a larger scatter, possibly due to enhanced flickering. The earlier step-like feature already present in the 1970s at phase $\sim 0.7$ has transformed into a relatively sharp eclipse-like feature in 1980–1982, seen at the same phase which represents, at this epoch, the total minimum of the light curve. Almost twenty years later, in 2000–2001 the orbital hump had recovered with total amplitude of $\sim 0.15^m$ followed by a flat minimum at phases 0.40–0.65. In 2005 the hump amplitude had increased considerably to about 0.28$^m$, showing now a pronounced minimum at phase 0.45 and a small secondary minimum at phase 0.7. In 2007 the hump amplitude had diminished to 0.20$^m$, and the step-like feature at phase 0.7 was recovered, similar to the situation in the 1972 to 1974. More recently, in 2013–2014 we observe still slightly reduced hump amplitudes (0.18$^m$) with a pronounced main minimum at phase 0.5 and a shallow secondary one at phase 0.7.

We can summarise the orbital light curve properties of RR Pic during the past 42 years in the following way: the dominant orbital hump was always present, but with variable amplitude between $0.28^m$ in 2005 and $\sim 0.05^m$ in the early 1980s. As a second permanent light curve property we found a secondary minimum or step-like feature at phases 0.65–0.7 which seems to be always present, but more pronounced as an ‘eclipse’ corresponding to the total minimum in the whole orbital light curve, whenever the hump amplitude is low, or less pronounced (‘step-like feature’) when the orbital hump had a large amplitude ($> 0.2^m$).
3.2 Search for superhumps: a new detection in 2007

In RR Pic, the superhump phenomenon is an additional periodic modulation in the light curve with smaller amplitude than that of the orbital hump. Therefore, a search for superhumps is only possible in the residual data after subtraction of the dominant frequency. Any additional frequency found close to the orbital one could be potentially associated with a $P_{\text{sh}}$. For sufficiently long data sets, the presence of the beat period of about 1.8 days provides an additional confirmation.

To ensure that the residual light curves of all campaigns were not contaminated by the presence of harmonics and aliases of the orbital period, we extracted up to the sixth orbital harmonics from the data. In order to check that the orbital features have been completely removed we have folded these residuals to the phase of $P_{\text{orb}}$. These folded light curves were completely flat. In this manner, we analyse all campaigns. In Fig. 3 we show the Fourier spectra of the residuals light curves for selected campaigns which covered at least two orbital cycles. To check the possible presence of any periodic signal associated directly to the sampling, we created an artificial sample containing the same time values of each set data versus a constant magnitude value. Periodograms of those artificial data represent the individual spectral windows, which are shown as inserts in Fig. 3, centred on the orbital frequency and scaled to the residual amplitudes for each campaign. The noise spectrum was calculated as the average of the remainder amplitudes in certain frequency steps of a size defined by the box size parameter (see Lenz & Breger 2005 for details) in the range from 0 to 30 c/d. A signal near the orbital period that exceeds the 3σ noise level, which corresponds to 80% confidence limit for non-normal distributions (Kuschnig et al. 1997, dashed line in Fig. 3), is considered for further superhump analysis. Only in the 2005 data (Schmidtobreick et al. 2008, hereafter campaign 2005–2) and the 2007 CBA campaign we found signals according to these criteria, which are highlighted with an arrow in Fig. 3.

Although the 2005 CBA observations (campaign 2005–1) were performed only about one month before the 2005–2 campaign (see Table 1), we did not find any significant signal close to the 2005–2 signal ($f_{\text{sh}} = 6.33 \pm 0.02$ c/d; $P_{\text{sh}} = 3.79 \pm 0.01$ h, where we have used the actual frequency resolution of this campaign as error in frequency, i.e., $1/\Delta t$). In order to check whether this null detection can be attributed to the time resolution and the coverage of the data instead of the real absence of the superhump, we folded those with ephemeris corresponding to the first minimum observed in 2005–2.

$$\text{HJD(min)} = 2453409.54719 + 0^d.1577(4)$$

Comparing both averaged phased light curves, the superhump found in 2005–2 (February–April; Fig. 4 b) is clearly absent in the 2005–1 data (January; Fig. 4 a). Instead, we do find a clear detection of the superhump in the 2007 data. This campaign was composed of six light curves observed between January 13 and February 7 in 2007. The residual spectrum showed several peaks close to the orbital signal. The highest peak found at $f_{\text{sh}} = 6.37 \pm 0.04$ c/d is equivalent to $P_{\text{sh}} = 3.77 \pm 0.02$ h. The other neighbouring peaks refer to one-cycle per day aliases, as is evident from the spectral window (Fig. 3). Choosing the minimum as zero point for the superhump phase yields the ephemeris

$$\text{HJD(min)} = 2454114.07167 + 0^d.1569(6)$$

The corresponding phase-folded light curve is shown in Fig. 4 (c). Within the errors, this new superhump period is identical to that.
found by Schmidtobreick et al. (2008) in 2005, with a period excess $\epsilon \approx 8.6$ per cent longer than the orbital period ($\epsilon = (P_{\text{sh}} - P_{\text{orb}})/P_{\text{orb}}$, Patterson 1998). The amplitudes of the superhump were $\approx 0.07^n$ and $\approx 0.09^n$ in 2005–2 and 2007, respectively, corresponding to 25 and 45 per cent of the orbital hump amplitude. The superhump light curves shapes in both sets are similar, being slightly asymmetric with maxima around superhump phases 0.6–0.7 (Fig. 4 b and c).

4 DISCUSSION

4.1 Is RR Pic a permanent or a sporadic superhumerper?

The extra periodicity $P_{\text{sh}} = 3.77 \pm 0.02$ h found in 2007 data, which is comparable to the detection found in 2005 ($P_{\text{sh}} = 3.79 \pm 0.01$ h), certainly supports the idea that RR Pic is an old nova with a reformed disc sufficiently hot and stable to present positive superhumps.

However, only in two out of eleven comparatively short-spanned data sets taken in the last 42 years, superhumps could be detected. RR Pic is not a permanent superhumerper. Especially striking is the emergence of superhumps within the 10 days that mark the time between the 2005–1 and the 2005–2 data set. They are also present in the next available data set, 2007. However, we have no information on the behaviour during the 643 days in-between. Were the superhumps present all through that time? Our newest data set, 2013–2014, has been obtained more than 6 years later and cover several months, but no extra frequency up to 3$\text{n}$ level close to the orbital frequency was found. The superhumps of 2005 and 2007 had disappeared.

Our current understanding of the superhump phenomenon is that it is correlated to the relative dimension of the accretion disc (Whitehurst 1988; Patterson et al. 2005). Assuming that a larger disc is also more luminous, the superhump in RR Pic should be accompanied by a corresponding change in the brightness of the system. Nevertheless, observations recorded in the American Association of Variable Star Observers (AAVSO) do not show a significant variation in the brightness during these epochs (see Fig. 5). Instead, the light curve presents a comparatively smooth decrease with a slope of $+7.8 \pm 0.2$ mmag/yr during the last five decades, which indicates that RR Pic has not yet reached a stable state. Furthermore, the orbital phased light curves in epochs with superhumps (see in Fig. 2 campaigns 2005–1, 2005–2 and 2007) did not exhibit any eclipse feature although the disc is expected to be larger than normally.

RR Pic is catalogued as a SW Sex star (Schmidtobreick et al. 2003). This subtype is characterised by high mass transfer rates, which could result in a disc sufficiently hot and stable to reach the 3:1 resonance, where the tidal forces cause it to become elliptical. Since the superhump seems to be a sporadic event, the border of the disc of RR Pic is probably located near the 3:1 resonance level, implying that small variations in mass transfer rate and/or disc size trigger occasionally the appearance of superhumps, without being accompanied by significant variations in the overall disc brightness.

4.2 RR Pic in context with other superhumpers

Among all CVs which are neither dwarf novae nor AM CVn stars, positive superhumps (with $\epsilon > 0$) have been reported for seven classical post-novae and 17 nova-like variables (Table 2). RR Pic is the sole Nb type nova, while all the remaining six cases belong to the Na class with a more rapid decline rate. This relation is similar to the general ratio between Na and Nb novae, 83% and 17% respectively, according to The International Variable Star index (VSX, Watson 2006).

Dothea et al. (2008) collected a sample of those post-novae for which the mass ratio $q = M_2/M_1$ could be derived, in order to correlate $q$ with the superhump occurrence, which is expected theoretically for cases with $q < 0.35$. In their sample (see their table 2) a total of 21 post-novae have mass ratio below or near to the critical value $q \leq 0.35$, but actually only seven of those, i.e. a third, have been reported to show superhumps. On the other hand, only in two of eleven data sets of RR Pic superhumps were present (18%). Therefore, it is possible that all post-novae with $q < 0.35$ occasionally develop superhumps, but that these events escape detection because of incomplete monitoring.

For RR Pic, Haefner & Metz (1982) had presented a model with a ratio $q = 0.42$, larger than the critical value expected to present superhumps. While their adopted WD mass of 0.95 $M_\odot$ is in good agreement with a recent model by Sion et al. (2017) based on far UV spectroscopy (~ 1 $M_\odot$) the mass of the secondary seems to be smaller, according to a systematic investigation the properties of the secondary stars in CVs by Smith & Dhillon (1998). When applying the empirical orbital period-mass relation given by these authors we get $q = 0.33 \pm 0.08$ for RR Pic (according to their equation (9)), well in agreement with Schmidtobreick et al. (2008), who determined $q = 0.31$ from the period excess relation $\epsilon = 0.0860$, and the mass ratio relation formulated by Patterson et al. (2005) valid for high $q$ ($\epsilon = 0.18q + 0.29q^2$).

We also investigated the role of RR Pic in context of the well-known close relation between $P_{\text{orb}}$ and $P_{\text{sh}}$ found first by Stolz & Schoembs (1984), Gänsicke et al. (2009) gave a new version of this relation, in the form

$$P_{\text{sh}} = a + b \cdot P_{\text{orb}}$$

for the period range $P_{\text{sh}} < 120$ minutes, i.e. below the period gap between 2 and 3 hours. Most SU UMa stars are located below this gap, and the Stolz–Schoembs relation is now a popular tool for period determination because it is normally much easier to observe superhumps than any orbital variation, at least for non-eclipsing cases. Gänsicke et al. (2009) derived a standard deviation of only 0.53 minutes for this method to get $P_{\text{sh}}$ from equation (4). We have repeated the calculation of these authors including new data, and extended it for cases with $P_{\text{sh}} > 2$ h. The results are listed in Table 3. For the dwarf novae below the period gap, slope $a$ and standard deviation ($\sigma = 0.89$ minutes) are larger in the actually available sample of 182 cases, compared to Gänsicke et al. (2009). If we consider all dwarf novae, we even get $\sigma = 1.32$ minutes. Nova-like stars seem to have smaller slopes than the remaining groups while the post-novae behave similar to the dwarf novae, however suffering from the small number of only seven post-novae. All groups display larger standard deviations above the period gap, compared to those of $P_{\text{sh}} < 2$ h. Generally, the differences between the groups considered here are marginal, confirming that the Stolz–Schoembs relation seems to be valid for most superhumpers of any sub-type of CVs, as shown in Fig. 6, where all novae and nova-like stars are individualised, as well as the SU UMa type dwarf novae above the period gap ($P_{\text{sh}} > 3$ h).

Of special interest is the case of V4633 Sgr, because Lipkin & Leibowitz (2008) have suggested that the second peri-
Table 2. Properties of post-novae and nova-like stars with confirmed positive superhumps.

| Name       | Type  | $P_{\text{orb}}$ (d) | $P_{\text{sh}}$ (d) | Ref. | Remarks |
|------------|-------|----------------------|---------------------|------|---------|
| Classical  |       |                      |                     |      |         |
| CP Pup (1942) | Na    | 0.06126              | 0.0625              | (1), (2) |         |
| V1974 Cyg | Na    | 0.08126              | 0.08522             | (3), (4) | (a)     |
| V630 Sgr  | Na    | 0.11793              | 0.1242              | (5), (6) |         |
| V4633 Sgr | Na    | 0.12557              | 0.1277              | (6), (7) | (b)     |
| V603 Aql (1918) | Na  | 0.13820              | 0.14646             | (8), (9) | (a)     |
| RR Cha    | Na    | 0.14010              | 0.1444              | (10) |         |
| RR Pic (1925) | Nb   | 0.14502              | 0.1577              | (11), (12) |         |
| Nova-like stars |       |                      |                     |      |         |
| BK Lyn    |       | 0.07498              | 0.0786              | (13), (14) | (a), (c) |
| V348 Pup  |       | 0.10184              | 0.10857             | (15), (16) |         |
| V795 Her  |       | 0.11438              | 0.12245             | (17), (18) |         |
| J1924+4459 |       | 0.11506              | 0.12228             | (19), (20) |         |
| LQ Peg    |       | 0.12475              | 0.143               | (21) | (a)     |
| AH Men    |       | 0.12721              | 0.1385              | (22) |         |
| MV Lyr    |       | 0.13233              | 0.1377              | (23) |         |
| DW UMa    |       | 0.13661              | 0.146               | (24) | (a)     |
| TT Ari    |       | 0.13755              | 0.14881             | (25) | (a)     |
| PX And    |       | 0.14635              | 0.1592              | (26) |         |
| AO Psc    |       | 0.14963              | 0.1658              | (27) |         |
| BB Dor    |       | 0.15353              | 0.15634             | (28) |         |
| BH Lyn    |       | 0.15587              | 0.1666              | (29) | (a)     |
| UU Aqr    |       | 0.16381              | 0.1751              | (30) | (a)     |
| TV Col    |       | 0.22860              | 0.264               | (31) | (a)     |

Remarks:
(a) shows also negative superhumps
(b) possibly asynchronous rotation of the white dwarf (see more detail in the text)
(c) possibly the remnant of a classical nova, observed on 101 December 30 (Patterson et al. 2013)

5 CONCLUSIONS

We present the first systematic analysis of collected optical light curves of the classical nova RR Pic spanning 42 years, from 1972 to 2014, including new observations 2013–2014 obtained by one of us (FJH) with a robotic telescope in San Pedro de Atacama. We found that the light curve shape of the orbital hump and its amplitude varies significantly over the different observing epochs, suggesting that the accretion disc is undergoing long-term changes. Furthermore, we corroborate the superhump detection made by Schmidtobreick et al. (2008) and additionally we find evidence for the presence of most likely the same positive superhump in 2007 CBA data, a period ~9% longer than the orbital period. Equally important was the fact that CBA data have been obtained in 2005 only one month before those by Schmidtobreick et al. (2008), but did not reveal any evidence for superhumps, implying the superhump is a repetitive, but sporadic event, arising quickly.

We give a list of seven post-novae and 17 nova-like stars with

odicity could correspond to the spin of the magnetic white dwarf of this system that rotates nearly synchronously with the orbital revolution. However, it would be a very strange coincidence that the white dwarf rotation fits quite well the Stolz–Schoembs relation; we therefore believe that we could have a superhump also in this case. Finally, for 29% of the classical novae and 41% of the nova-likes stars also negative superhumps ($P_{\text{sh}} < P_{\text{orb}}$) have been detected, as marked in Table 2. The simultaneous presence of superhumps above and below the orbital period strongly suggests that independent physical mechanisms are responsible for this behaviour. The longer period ("positive superhump") could arise from the prograde motion of the line of apsides of an eccentric disc (Vogt 1982b) while the shorter period ("negative superhump") could be due to the retrograde motion of the line of nodes of a tilted disc (Skillman et al. 1998).
positive superhumpers recorded, and conclude that in order to determine whether the superhump phenomenon is an unusual event or common in classical novae, it is imperative to monitor post-novae systematically for long time intervals. In addition, we also determine a revised version of the Stolz–Schoembs relation between $P_{sh}$ and $P_{orb}$ for dwarf novae, classical novae and nova-like stars, and conclude that this relation is of general validity for all superhumpers among CVs.

This apparently also includes post-novae, with RR Pic being just one more case in a still small sub-sample. This should not come as a surprise, since it has long been suspected that the nova eruption represents a recurrent event in a CV long-term cycle (Vogt 1982a; Shara et al. 1986), with more recent observational evidence corroborating this hypothesis (e.g. Patterson et al. 2013; Mróz et al. 2016; Shara et al. 2017). The fact that post-novae present the same phenomenon as other CVs, further strengthens our understanding of the long-term evolution of CVs.

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Figure 3. Periodograms for the residual data after subtracting the orbital frequency and its harmonics for selected campaigns (see text). The dashed line corresponds to the noise level of 3σ, the arrows point to suspected superhump frequencies and the inset plot shows the spectral window centred at the dominant orbital frequency.
Superhump occurrence in the Nova RR Pic

**Figure 4.** Superhump phase averaged into 0.02 phase bins for normalised differential magnitude light curves after subtracting the orbital frequency. (a) residuals of the 2005–1 data folded with superhump ephemeris (2) (b) the same but for the 2005–2 data (c) 2007 data folded with superhump ephemeris (3).

**Figure 5.** AAVSO light curve of RR Pic from 1965 until May 2017. A slight decline in brightness is observed during the last five decades. Epochs where superhumps were detected are marked with arrows in the plot.

**Figure 6.** The Stolz–Schoembs relation ($P_{sh} - P_{orb}$) for all sub-types of CVs in the entire range of $P_{sh}$. Dwarf novae with $P_{sh} > 120$ min are represented as crosses, all nova-like stars as filled squares, all classical novae as empty squares and the classical nova RR Pic as an inverted empty triangle. The grey line corresponds to the linear fit found by Gänsicke et al. (2009) for SU UMa type dwarf novae with $P_{sh} < 120$ min.