The white dwarf in V842 Cen (Nova Cen 1986)

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Abstract. High speed photometric measurements made in February and March 2008 of the remnant of Nova Cen 1986 show that in the interval since 2000 a strong 56.83 s signal has appeared. We interpret this as the rotation period of the white dwarf (the third shortest known), now visible since the mass transfer rate has dropped, allowing the primary’s magnetosphere to expand and produce an intermediate polar structure. Optical sidebands to the 56.83 s signal support the model and enable us to measure an orbital period of 3.94 h; there is also a strong negative superhump in the light curve, with a period of 3.78 h. An additional signal at 2.886 h is of unknown origin, but is probably an example of the mysterious GW Lib phenomenon.

1. Introduction
V842 Cen is the remnant of Nova Centauri 1986, a moderately fast nova with a pre-eruption magnitude \( \sim 18.5 \) (McNaught 1986). Our current measurements give \( V \sim 16.3 \), so 22 years after maximum it is still \( \sim 2 \) magnitudes above its expected quiescent brightness. Schmidobreick et al. (2005) report a spectrum obtained in 2003 which shows a strong blue continuum with weak high ionization lines (e.g. C IV), probably arising in the nova ejecta, but accompanied by strong Balmer emission lines running to high series members and by He I emission, yet with only moderate He II and 4650 Å Bowen fluorescence lines, which they describe as more characteristic of dwarf novae in quiescence than of a nova.

Our previous high speed photometry of V842 Cen, runs S6096 and S6097 obtained in 2000 (Woudt & Warner 2003: hereafter WW03), showed rapid activity with flares up to 0.25 mag on time scales \( \sim 5 \) mins, but no coherent short period brightness modulations (though quasi-periodic oscillations in the range 750 – 1300 s were observed).

To check on the current status of the nova remnant we re-observed it in February and March 2008 – and found that it had developed a number of optical modulations since we last observed it, some of which are of relevance to the state of the cooling white dwarf.

2. Observations and Analysis
Our observations were made on the 74-in Radcliffe telescope at the Sutherland site of the South African Astronomical Observatory, using the University of Cape Town’s frame transfer CCD photometer with no optical filter. Integration times were 6 s. This ‘white light’ photometry was placed on an approximate magnitude scale using a white dwarf standard star. A list of our observations is given in Table 1.
Table 1. Observing log of photometric observations

| Run No. | Date of obs. (start of night) | HJD of first obs. (+2450000.0) | Length (h) | V (mag) |
|---------|--------------------------------|-------------------------------|------------|---------|
| S7791   | 2008 Feb 17                    | 4514.54882                    | 2.14       | 16.2    |
| S7795   | 2008 Feb 18                    | 4515.45960                    | 3.18       | 16.3    |
| S7798   | 2008 Feb 19                    | 4516.45845                    | 4.34       | 16.3    |
| S7803   | 2008 Mar 13                    | 4539.41017                    | 5.83       | 16.3    |
| S7806   | 2008 Mar 14                    | 4540.39963                    | 3.67       | 16.3    |
| S7809   | 2008 Mar 16                    | 4542.39838                    | 6.25       | 16.3    |
| S7811   | 2008 Mar 17                    | 4543.43785                    | 3.05       | 16.3    |
| S7813   | 2008 Mar 18                    | 4544.40490                    | 6.12       | 16.2    |

Figure 1. The 2008 March light curves phase folded on the 3.780 h superhump period. The light curves are labelled with the run numbers (see Table 1) and offset vertically for display purposes.

A selection of the light curves is shown in Figure 1, where we have phased them on a period of 3.780 h, which illustrates the periodically recurring narrow peak that we attribute to a superhump, arising from a precessing disc, which is not of direct relevance here. These light curves show also the presence of rapid low amplitude variations which we find have periodic and quasi-periodic components, but mostly they are flickering caused by the mass transfer process.
In Figure 2 we compare the Fourier transform (FT) of our two nights of observation made in 2000 (WW03) with that of our observations in 2008. The most immediately obvious difference is the appearance of a strong coherent periodicity at \( \sim 57 \) s in the latter data set. We begin our analysis by looking at this more closely.

The left panels in Figure 3 show the FT of our March 2008 observations (omitting run S7813, where the spiky superhumps cause some problems) in the vicinity of the 57 s modulation. The dominant signal is an FT window pattern centred on \( 56.825 \pm 0.001 \) s, with amplitude 4.2 mmag. Prewhitening at that period leaves a signal (visible as a sideband 70.5 \( \pm 0.6 \) \( \mu \)Hz away on the low frequency side in Fig. 3) at \( 57.054 \pm 0.002 \) s and amplitude 1.6 mmag. Prewhitening the light curve with these signals leaves no significant signals in their vicinity in the FT (bottom left panel of Fig. 3), which shows that both are stable over the five day baseline.

The February FT is shown in Figure 3 (right panels), and shows both the principal signal and the longer period sideband, but in addition a short period sideband is present. The mean period of the principal signal, over the three day baseline, is \( 56.828 \pm 0.002 \) s with amplitude 3.9 mmag, which further establishes its stability. By simultaneously fitting three sinusoids to the light curves, by least squares, the two side bands are found to be at 57.054 \( \pm 0.002 \) s and amplitude 1.6 mmag. After prewhitening with these three periodicities there is no significant remaining signal (bottom section of the right panel of Fig. 3). The frequency difference between the additional and the principal signals is 71.6 \( \pm 2.3 \mu \)Hz, which is equal within errors to the splitting on the low frequency side of the principal. Thus in February 2008 we have equally split sidebands but in March 2008 only the lower
Figure 3. Fourier transforms in the vicinity of the 57 s signals.

There is no sign in the FTs of a harmonic to the 56.83 s modulation.

Seeking the 70.5 µHz frequency at the low frequency end of the FT reveals an interesting set of long period modulations – full details will be given elsewhere, but, in summary, the largest signal is at 2.886 h (96.26 µHz) and the next largest is at the 3.780 h (73.5 µHz) period mentioned above. This latter modulation had strong higher harmonics, as is evident from the profiles seen in Fig. 1; this is characteristic of a superhump, not an orbital modulation. If the 70.5 µHz sideband separation of components in the 57 s modulation is an orbital sideband it implies an orbital period of 3.94 h, which is not itself directly seen in the FT.

If \( P_{\text{orb}} \) is indeed the value we have deduced, then the superhump period is shorter than the orbital period, implying that V842 Cen possesses a negative superhump, which is not unusual for high \( M \) systems. In particular, TT Ari, which we previously pointed out (WW03) has a very active light curve similar to V842 Cen, usually has a negative superhump which is 3.4% shorter than its \( P_{\text{orb}} \) of 3.30 h (Skillman et al. 1998); in V842 Cen we find the difference is 4.1%.

In the FTs there are also quasi-periodic oscillations with time scales \( \sim 2000 \) s. These are related to conditions in the disc and are not directly relevant to the white dwarf, but we note that TT Ari, as well as having a negative superhump, has QPOs on time scales ranging over 900 to 1500 s (Kim et al. 2008).

3. Discussion

The derivation of \( P_{\text{orb}} \) that we have given above implies that the 57.04 s sideband is caused by reprocessing of the 56.825 s signal off a surface sharing in the orbital motion; this is the classic situation for an intermediate polar where gas accretes onto a rotating white dwarf primary and radiation from the accretion zones is reprocessed from the bright spot region of the accretion
disc or from the secondary star (e.g. Warner 1995). The 56.60 s sideband adds weight to this interpretation – denoting the orbital frequency by $\Omega$ and the white dwarf rotational frequency by $\omega$, we have detected three signals at $\omega$, $\omega - \Omega$ and $\omega + \Omega$, which are characteristic of an intermediate polar (IP) - see Warner (1986).

Thus V482 Cen joins the group IPs that are known novae (four definite, 13 possible – Mukai 2008), but has the shortest rotation period of them all, the previously known shortest being V533 Her (Nova Her 1963) with $P_{rot} = 63.33$ s (Patterson 1979), and as such may be classified as a member of the DQ Her subclass of IPs (Chapter 8 of Warner 1995), and is the first in the southern sky.

Recognising that the long-known 71 s signal in DQ Her (Nova Her 1934) is now sometimes attributed to two-pole accretion onto a 142 s rotating white dwarf (Zhang et al. 1995), we looked for a 113.6 s signal in our FTs, but without success. The next shortest solid body rotations known for white dwarfs in cataclysmic variables are 33.06 s in the nova-like AE Aqr and 27.87 s in the dwarf nova WZ Sge (Warner & Pretorius 2008), so V842 Cen contains the third fastest known rotating white dwarf.

An obvious question is why the rotation modulation has appeared between our observation in 2000 and those in 2008. It is probable that in the earlier observations, made 14 years after the nova eruption, the irradiation enhanced $\dot{M}$ from the secondary was high enough to compress the primary’s magnetosphere down to its surface, whereas eight years later the white dwarf had cooled and $\dot{M}$ had fallen sufficiently to allow the magnetospheric radius to exceed the primary’s radius, establishing an IP structure. The lowered $\dot{M}$ suspected from recent spectra (Schmidtobreick et al. 2005) is compatible with this model. There is, however, some conflict in interpretation of the observations – the existence of superhumps normally implies a high $\dot{M}$ disc, especially for a relatively large value of $P_{orb}$.

Finally, the mysterious 2.886 h modulation is probably an example of the ‘GW Lib’ phenomenon, seen in some cataclysmic variables (see Table 2 of Woudt, Warner & Pretorius 2004).

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