Discovery of Non-radial pulsations in PQ Andromedae

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**ABSTRACT**

We have detected pulsations in time-series photometry of the WZ Sge dwarf nova PQ And. The strongest peak in the power spectrum occurs at a period of 10.5 minutes. Similar periods have been observed in other WZ Sge systems and are attributed to ZZ Ceti type non-radial pulsations. There is no indication in the photometry of an approximately 1.7 hour orbital period as reported in previous spectroscopic observations.

*Subject headings:* binaries: close — stars: dwarf novae — stars:individual(PQ And)

1. **Introduction**

PQ And is a dwarf nova with three known outbursts in the last ~ 70 years (Richter 1990). The last outburst on 21 March, 1988 reached a visual magnitude of 10 (Hurst 1988). It had many of the characteristics of the WZ Sge class of dwarf novae including a large outburst amplitude and strong Balmer emission superimposed over broad absorption at quiescence (Howell et al. 1995). However, to be in the WZ Sge class, PQ And must have an orbital period below the period gap. Time series optical spectra of PQ And were obtained
by Schwarz et al. (2004) to determine the orbital period of the system. They found a period of 1.7 hours from the fit to the radial velocity curve as determined from the convolution of double Gaussians to the line profiles (Schafter 1985). Unfortunately the derived period was similar in length to the total observing time and couldn’t be classified as a definite period due to under-sampling. Nevertheless the Hα emission showed a clear periodic change in its blue and red components during the observing run which supported a short orbital period typical of WZ Sge systems. An optically thin disk, showing the WD absorption, is indicative of a short period, low-ṁ system (i.e. below the period gap). Likewise, the lack of an accretion disk in the optical spectrum placed a firm upper limit of 3 hours on the orbital period of PQ And.

Schwarz et al. also determined the effective temperature and surface gravity of the white dwarf (WD) using synthetic spectra from model atmospheres. The best fits gave $T_{eff} = 12,000 \pm 1,000$ K and log($g$) = $7.7 \pm 0.3$ (cgs units) which placed PQ And in the region of the ZZ Ceti instability strip (Bergeron et al. 1995; 2004). They noted that with its low accretion rate, PQ And was an excellent candidate to search for non-radial oscillations which have recently been observed in other WZ Sge novae.

In this paper we present the results of a photometric campaign to search for non-radial pulsations in PQ And. Section 2 provides details of the observations. The analysis of the data are given in Section 3 and our conclusions follow in Section 4.

2. Observations

Our photometric observations were carried out using the Orthogonal Parallel Transfer Imaging Camera (OPTIC, see Howell et al, 2003) at the WIYN observatory 3.5-m telescope located on Kitt Peak. OPTIC is the only prototype orthogonal transfer CCD imager operating (see Tonry et al., 2002) and consists of two 2K by 4K CCID-28 OTCCDs in a single dewar mounted adjacent to each other with a small gap in between the chips. OPTIC is controlled by standard SDSU-2 electronics running custom microcode and reads out the two OTCCDs via 4 video channels, one located in each corner of the device. OPTIC has a read noise of <4 electrons when read at a normal rate of 160 kpix/sec and a gain of 1.45 e/ADU.

We used OPTIC in conventional mode placing the target star and all comparison stars of interest in one of the CCDs. Two time series data sets were obtained, the first was on the night of 14 September 2004 UT and the second on 13 October 2004 UT. The September observations consisted of $\sim$125, 45 second observations using a Johnson V filter. The CCD was binned 2 X 2 (the seeing on this night was 1.6") and the readout time was 8 seconds. The October observations consisted of $\sim$100 60 second V-band integrations using 1 X 1 binning (readout time was 24 seconds) and the seeing was 0.5".

The data were reduced using the standard IRAF packages. Relative photometry was performed using four different background stars as references. Figure 1 shows a plot of the magnitude difference as a function of time for both nights. The
squares represent the difference between two of the reference stars while the triangles represent the difference between PQ And and one of the reference stars. The horizontal axis is the time since the start of observations for each night. The light curves of both nights clearly show fluctuations of up to $\sim 0.1$ magnitudes. All reference stars and PQ And were of similar magnitude therefore the scatter in the reference star data gives an estimate of the errors in the magnitude change for PQ And. From Figure 1 we see that the magnitude errors are on order of 0.015.

3. Analysis

To search for any periodicities in the light curves the data were put through a Fourier transform routine. The resulting power spectra for each date are shown in Figure 2. Based on the length of time PQ And was observed and the sampling rate of each night, we searched the frequency space from 0.5 to 30 hr$^{-1}$. To determine the level of significance for peaks in the power spectrum we added a tracer signal to our data and ran it through the Fourier routine until we were unable to detect it. From this we found that peaks with a power less than $\sim 10^{-5}$ were not significant. Three strong peaks appear in the power spectra of both nights. The strongest peak is found at a frequency of 5.6 hr$^{-1}$, a period of 10.5 minutes, in both spectra. We also see what appear to be harmonics of this peak at frequencies of $\sim 2.8$ hr$^{-1}$ and $\sim 1.4$ hr$^{-1}$. At higher frequencies the two power spectra differ slightly. In the September data we see no significant peaks beyond the three already mentioned while the October power spec-

Fig. 1.— The magnitude difference between two reference stars (squares) and PQ And and one of the reference stars (triangles) for each night. $t_0$ is taken as the time of the first observation of each night.
trum shows a few small peaks at higher frequencies. These peaks are found at 7.8, 8.4, 9.2, 22.5, and 29 hr$^{-1}$ (periods in the range of 2-8 minutes). The difference between the two nights could be due to many things including sampling rates, seeing effects, and variability in the WD itself.

Figure 3 shows the data phased to a period of 10.5 minutes and put in phase bins. The error bars have been determined from the scatter in the light curve of the reference stars. The data show an overall change in magnitude of about 0.1.

4. Discussion

The most significant period we find, 10.5 minutes, is much shorter than any expected orbital period for a CV. Several WZ Sge systems have recently been found with similar short period, low amplitude oscillations (Araujo-Betancor et al 2005; Townsley, Arras & Bildsten 2004; Woudt & Warner 2004; van Zyl et al 2004). These periodic fluctuations have been attributed to ZZ Ceti like non-radial pulsations of the WD primary. In the five systems reported to date, there appears to be a pattern in the periods found. All of the stars show periods around 10 minutes and then several other periods on shorter time scales (3-6 minutes). Long term monitoring shows that these periods are variable between subsequent observations. Our findings for PQ And match this general pattern. Some of the other ZZ Ceti systems in the literature have more complicated power spectra, showing peaks at longer frequencies that are multiples or combinations of the shorter frequency peaks. We don’t see these patterns in our data for PQ And however it could be that we have insufficient

Fig. 2.— The individual power spectra of the two dates. Both dates show peaks near frequencies of 5.6, 2.8 and 1.5 hr$^{-1}$. The observations from October show a few additional minor peaks at longer frequencies.
The available evidence points to PQ And containing a ZZ Ceti white dwarf. The primary pulsation period we find is 10.5 minutes which is similar to those found in other WZ Sge type systems with ZZ Ceti like white dwarf parameters and pulsations. More extensive observations may reveal alternate pulsation modes as has been found in other ZZ Ceti systems. We find no evidence for the 1.7 hour orbital period reported by Schwarz et al. (2004) in
Fig. 4.— The power spectrum of the combined data from 0.5 to 2 hr$^{-1}$. There is no orbital period peak at 0.59 hr$^{-1}$ as suggested by the radial velocity analysis of Schwarz et al. (2004).

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