ULTRACAM lightcurves of the dwarf nova IP Peg: remarkable variability of its white dwarf

C.M. Copperwheat[(1)], T.R. Marsh[(1)], V.S. Dhillon[(2)], S.P. Littlefair[(2)], R. Hickman[(1)]

1 = University of Warwick
2 = University of Sheffield

ABSTRACT: Light curves of the dwarf nova IP Peg taken with ULTRACAM on the 4.2m WHT are presented which show the white dwarf with unusual clarity, including the first clear detection of its ingress which is seen just before the ingress of the bright-spot. The phase width of the white dwarf eclipse, at 0.0938 of the orbit, is significantly higher than the standard value of 0.0863 which dates back to the 1980s, meaning either a higher orbital inclination or a higher mass ratio or some combination of the two. We show that model fits strongly favour a high mass-ratio solution, leading to q ~ 0.47 and a donor mass of around 0.51 solar masses. Remarkably, the white dwarf is seen to vary significantly in flux, even between consecutive eclipses. This is seen particularly in *u-g* which varies by over a magnitude, and is not the result of flickering. We discuss possible reasons for this and the likely temperature of the WD as a rare long period constraint upon compressional heating of accreting white dwarfs in cataclysmic variable stars.

INTRODUCTION: The temperature of accreting white dwarfs is a good tracer of the long-term accretion rate (Townsley & Bildsten, 2003). IP Peg is a long period eclipsing dwarf nova, implying a high mean accretion rate and a correspondingly high white dwarf temperature. In 2004 and 2005 we observed eighteen eclipses with the high speed camera ULTRACAM mounted on the William Herschel Telescope (WHT), with the aim of determining the white dwarf temperature from its egress feature. These observations were simultaneous in the Sloan *u*, *g* and *r* bands.

q = 0.47 ± 0.02	i = 84.1° ± 0.4
R_1/a = 0.0048 ± 0.0006	K_2 = 323.2 km/s ± 3.5
M_1 = 1.09 $M_\odot$ ± 0.07 M_2 = 0.51 $M_\odot$ ± 0.05 R_2 = 0.45 $R_\odot$ ± 0.02	M_1 = 1.22 $M_\odot$ ± 0.04 M_2 = 0.57 $M_\odot$ ± 0.02 R_2 = 0.47 $R_\odot$ ± 0.02

Table 1. Parameters are listed for the scaled white dwarf radius from our model in the left panel, and the best estimate of K_2 from spectroscopy (Watson et al. 2003) in the right panel.

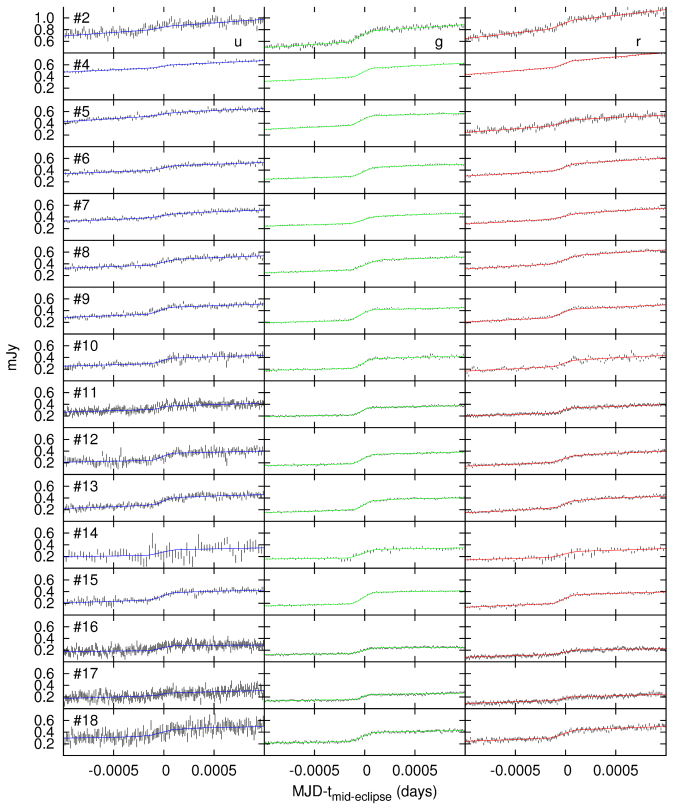


Fig 2. The figure shows the white dwarf egress feature for sixteen eclipses in *u*, *g* and *r*. The egress duration is constant but its height varies dramatically, particularly in *u* (e.g. compare eclipses #7 and #15). This is true even for consecutive eclipses, such as #6 and #7, or #12 and #13.

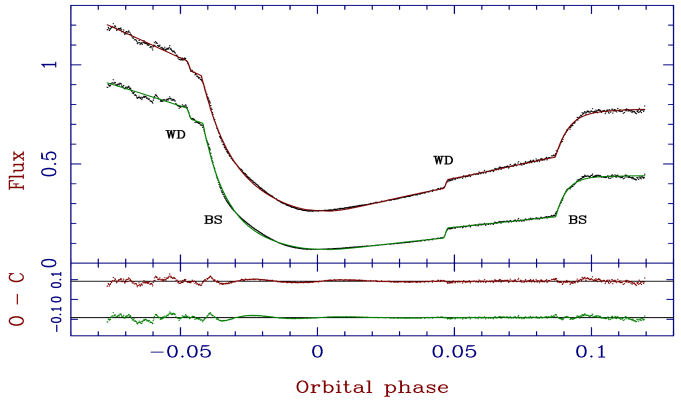
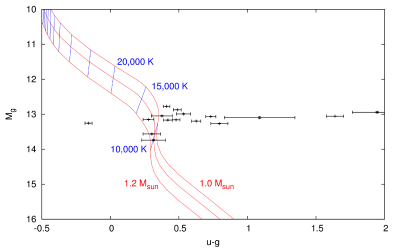


Fig 1. The phase-folded and binned light curve in *g* (green) and *r* (red). The white dwarf ingress is clearly detected for the first time. The phase width of the white dwarf eclipse is 0.0938, which is significantly higher than the value of 0.0863 suggested by Wood & Crawford (1986).

Fig 3. Absolute *g*-band magnitudes (for d=121pc, Froning et al. 1999) versus the *u-g* colour for each of our white dwarf egresses. Red lines show white dwarf models for 1.0, 1.1 and 1.2$M_\odot$ (Holberg & Bergeron, 2006). Isotherms are plotted every 5,000K (blue).



DISCUSSION: There is considerable variation in the colours, particularly in the *u* band. We propose this is due to photoelectric absorption as a result of obscuration of the white dwarf by material from the accretion disc. This is a likely cause of past reports of very extended egresses, which we suggest were simply failures to detect the variable egress at all.

Given the white dwarf mass range from our model fits, the intersection of our datapoints with the synthetic tracks suggests a white dwarf temperature of 10,000 - 15,000 K. This is low for a dwarf nova above the period gap and, following Townsley & Bildsten (2003), implies a long-term accretion rate of less than 5×10^{-11} $M_\odot$/yr. This compares with the expected rate of around 2×10^{-9} $M_\odot$/yr. This suggests that CVs can sustain accretion rates well below expected rates for more than 1000 years.

CONCLUSIONS: We have detected the ingress of the white dwarf in IP Peg for the first time. The phase width we find, 0.0938, forces a higher inclination for IP Peg of i ~ 84°. The white dwarf egress feature varies significantly in size between eclipses, particularly in the *u* band. We ascribe this variation to obscuration of the white dwarf by disc material. We find the white dwarf flux at egress to be extremely variable which we ascribe to photoelectric absorption. We measure a temperature for the white dwarf of 10,000 - 15,000 K, implying a mean accretion rate over the past 1000 years that is roughly 40x lower than expected.