High-speed photometry of the recurrent nova IM Normae

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ABSTRACT

The recurrent nova IM Nor is found to have an orbital period of 2.462 h, shown by periodic dips in brightness. This is only the second recurrent nova known to have such a short period. We interpret the light curve as largely produced by a reflection effect from the heated face of the secondary star, probably with the addition of a partial eclipse of the accretion disc.

Key words: techniques: photometric – binaries: close – binaries: eclipsing – stars: individual: IM Nor – novae, cataclysmic variables.

1 INTRODUCTION

The light curve of Nova Normae 1920 was constructed from archived plates by Elliot & Liller (1972), who noted that it could be grouped with slow novae such as DQ Her and T Pyx. A poorly determined original position resulted in no certain identification of the remnant (Duerbeck 1987), which was designated IM Nor. A second eruption in 2002 January (Liller 2002) showed that IM Nor is in fact a recurrent nova, and the improved accuracy of position enabled the pre-nova to be identified as a star with variations in brightness around $V \sim 18$ (Kato et al. 2002). The eruption light curve derived by Kato et al. led them to conclude that, although it is indeed like T Pyx, a better comparison may be made with CI Aql, which is another recurrent nova. The spectra obtained during outburst show that all of these stars resemble each other in having strong Fe II emission lines, and late appearance of forbidden lines (Kato et al. 2002; Duerbeck et al. 2003). Kato et al. proposed that CI Aql and IM Nor form a distinct subclass with massive ejecta and long recurrence intervals.

At maximum light, IM Nor reached $V \sim 7.8$ and decayed as a fast nova with $t_2 \sim 20$ d. The eruption amplitude of $\sim 10$ mag agrees with that expected for a fast nova of low orbital inclination (see fig. 5.4 of Warner 1995). However, CI Aql also showed such an initial steep fall, but this was succeeded by a long-lived phase of slow decline (Matsumoto et al. 2001), uncharacteristic of a fast nova. IM Nor is behaving similarly, so in neither case can the usual amplitude/rate of decline/inclination relationship be trusted. CI Aql is an eclipsing system with a period of 14.8 h (Mennickent & Honeycutt 1995).

IM Nor is currently at $V \sim 16.5$ and is thus still far from its quiescent magnitude. We have observed it photometrically with good time resolution in order to look for any orbital modulation.

2 PHOTOMETRIC OBSERVATIONS

Our observations were made in white light using the University of Cape Town (UCT) CCD Photometer (O’Donoghue 1995) attached to the 40-inch reflector at the Sutherland site of the South African Astronomical Observatory. The observing log is given in Table 1 and the reduced light curves are shown in Fig. 1. The average light curve is shown in Fig. 2.

IM Nor has a clear periodic brightness modulation with a range of $\sim 0.3$. The mean brightness of the system varies by at least 0.1 mag from night to night, and can vary by that amount over a few hours. The dominant feature is an eclipse-like recurrent dip, with a depth of 0.2 mag, from which a period of 2.462 h is derived. The ephemeris for this dip is

$$HJD_{\text{min}} = 2452696.526 + 0.1026(\pm 0.1) \times E$$

Interpreted as an orbital period, the modulation at 2.462 h places IM Nor towards the low end of the range of orbital periods for novae and squarely in the centre of the ‘period gap’ that exists for dwarf novae (but probably not for novae: Warner 2002). Of the nine known recurrent novae, only T Pyx ($P_{\text{orb}} = 1.83$ h) and IM Nor have orbital periods at the lower end.

In the Fourier transforms of individual nights, and the whole data set, no periods other than the 2.462-h modulation and its harmonics were found.

3 DISCUSSION

The width of the main brightness dip is too large for it to be the eclipse of an accretion disc (or of the primary, even though it is possibly bloated by the effects of the recent eruption). To assist in interpretation, we examine the light curve of CI Aql during its decline from eruption. Fig. 4 of Matsumoto et al. (2001) shows the folded light curve during the decline. This light curve is described in that paper as a ‘primary eclipse with very broad wing extending to $\sim 0.7$ orbital phase duration’. Of course, the whole of this feature cannot be an eclipse – it is impossibly wide. We suggest that the light curve is that resulting from a moderate reflection effect from the secondary, irradiated by the very hot primary left after eruption. This produces a single hump per orbital period, and the minimum of the reflection effect may be pulled even lower by partial eclipse of the accretion disc by the secondary at that phase.

During quiescence, in the absence of the reflection effect, CI Aql has a primary eclipse of normal width that is in phase.
Table 1. Observing log.

| Object | Type | Run no. | Date of obs. | HJD of first obs. (+2452000.0) | Length \(t_{in}\) (h) | Tel. | \(V_{(start of night)}\) (mag) |
|--------|------|---------|--------------|-------------------------------|------------------------|------|---------------------|
| IM Nor | RN   | S6807   | 2003 Feb 25  | 696.46942                    | 2.93                   | 40-inch | 16.5               |
|        |      | S6811   | 2003 Feb 26  | 697.42046                    | 1.56                   | 40-inch | 16.6               |
|        |      | S6813   | 2003 Feb 26  | 697.54623                    | 2.35                   | 40-inch | 16.5               |
|        |      | S6816   | 2003 Feb 27  | 698.41376                    | 5.14                   | 40-inch | 16.5               |
|        |      | S6824   | 2003 Mar 02  | 701.55380                    | 2.25                   | 40-inch | 16.6               |

Notes: RN = Recurrent Nova; \(t_{in}\) is the integration time.

The short orbital period for IM Nor requires another model to be explored. At this period – and with the high rate of mass transfer expected for a recent nova, which is irradiating its secondary – the accretion disc may be excited into an elliptical shape, and the observed recurrent humps could be due to superhumps (Warner 1995). The observed amplitude of 0.3 mag is compatible with a superhump but, at that amplitude, superhumps seen in dwarf nova outbursts are usually triangular in profile. The superhumps seen in other recent novae of short period, namely V1794 Cyg (Retter, Leibowitz & Ofek 1997), DD Cir (Woudt & Warner 2003), V4633 Sgr (Lipkin et al. 2001), have much lower amplitudes (∼0.05 mag). IM Nor has at least 1.5 mag of decaying nova luminosity added to its quiescent brightness, which should result in dilution of any superhump modulation. We note that the basic profile of the modulation remains roughly symmetrical about minimum light, i.e. there is no sign of a superhump drifting relative to an orbital eclipse as seen in some nova remnants (e.g. RR Cha: Woudt & Warner 2002). We conclude that the modulation seen in IM Nor is unlikely to be due to superhumps.

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