A solution to the transition phase in classical novae

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Abstract. One century after the discovery of quasi-periodic oscillations in the optical light curve of Nova GK Per 1901 the cause of the transition phase in a certain part of the nova population is still unknown. Three years ago we suggested a solution for this problem and proposed a possible connection between the transition phase and intermediate polars (IPs). About 10% of the cataclysmic variable population are classified as IPs, which is consistent with the rarity (~15%) of the transition phase in novae. Recent observations of three novae seem to support our prediction. The connection is explained as follows: The nova outburst disrupts the accretion disc only in IPs. The recovery of the disc, a few weeks-months after the eruption, causes strong winds that block the radiation from the white dwarf, thus dust is not destroyed. If the winds are very strong as is probably the case in DQ Her (perhaps since its spin period is very short) this leads to a dust minimum.

1. Introduction

The optical light curve of a classical nova is typically characterized by a smooth decline. Certain novae show, however, a DQ Her-like deep minimum in the light curve while others have slow oscillations, during the so called ‘transition phase’ (Fig. 1). The minimum is understood by the formation of a dust envelope around the binary system. It is still not known, however, what causes the oscillations during the transition phase (Warner 1995) and why only a small fraction (about 15%) of the nova population has the transition phase.

The models offered so far to the oscillations during the transition phase (Bode & Evans 1989; Leibowitz 1993; Warner 1995) are:

- Oscillations of the common envelope that surrounds the binary system after the nova outburst.
- Dwarf-nova outbursts.
- Formation of dust blobs that move in and out of line of sight to the nova.
- Oscillations in the wind (see also Shaviv, these proceedings).
- Stellar oscillations of the hot white dwarf.
The first model can be rejected very easily as the common envelope phase ('fireball') lasts less than 1-2 days (Hauschildt, personal communication), so it is much shorter than the typical time scale of the transition phase. The second idea is almost certainly wrong as the accretion discs in post-novae are thermally stable (e.g. Retter & Naylor 2000), so they cannot have dwarf-nova outbursts for at least many decades following the nova eruption.

Retter, Liller, & Gerradd (2000a) suggested another solution for this problem and we show here that it can be combined with two of the models listed above. The observations of Nova LZ Mus 1998, which had oscillations during the transition phase revealed a few periodicities in its optical light curve. Retter et al. thus classified LZ Mus as an IP candidate. IPs are cataclysmic variables in which the primary white dwarf has a moderate magnetic field and thus spins around its axis with a period shorter than the orbital period. Hernandez & Sala (this volume) detected X-ray emission from LZ Mus three years after its outburst despite its extremely large distance. This fact is consistent with the IP classification.

Retter et al. further proposed a possible connection between the transition phase and IPs and predicted that novae that have a transition phase should be IPs. About 10% of the cataclysmic variable population are IPs, which is consistent with the rarity (∼15%) of the transition phase in novae. We note that these numbers represent lower limits as not all systems have been well studied. The correct ratios may be as high as ∼30%. Recent observations of three young novae seem to support our idea.
2. The early presence of the disc in young novae

It was believed that the accretion disc is destroyed by the nova event and that it takes only a few decades for the disc to re-establish. In my Ph.D. thesis I studied this claim. Contrary to the common belief we found very strong evidence in at least two cases for the presence of the accretion disc only a few months after the nova outburst (Retter, Leibowitz, & Ofek 1997; Retter, Leibowitz, & Kovokariti 1998). We note that the time-scales of the transition phase are similar to the time-scales of the appearance of the accretion disc in post-novae. It is still unknown whether the disc can survive the nova explosion. The various bright sources, which contribute to the optical light curve of post-novae, may, however, overcast the light from the disc and complicate the observations. We may have found now the solution to this question. This work suggests that the accretion disc is destroyed by the nova outburst only in IPs and that discs in other subclasses of CVs survive the nova event.

3. Observations and Analysis

Recent observations of three young novae seem to support the suggested connection between the transition phase and IPs. The optical light curve of Nova V1494 Aql 1999#2 showed transition phase oscillations with a quasi-period of \( \sim 7 \) days (Kiss & Thomson 2000). A period of 3.2 h (presumably the orbital period) was discovered in its optical light curve (Retter et al. 2000b). Krautter et al. (2001) and Drake et al. (2002, in preparations) detected a 2523-s periodicity in two X-ray runs using Chandra. The short period can be interpreted as the spin period of the binary system and the nova can thus be classified as an IP. We note, however, the suggestion of an alternative model to the variation – stellar oscillations of the white dwarf (Krautter et al., these proceedings).

On the other hand, Nova V382 Vel 1999 had a smooth decline in the optical (Liller & Jones 2000) and X-ray observations did not reveal any short-term periodicity (Orio et al. 2001). So, it is unlikely that it is an IP.

In addition, Nova V1039 Cen 2001 had oscillations during the transition phase as well ([http://vsnet.kusastro.kyoto-u.ac.jp/vsnet/etc/drawobs.cgi?text=CEUnova2001](http://vsnet.kusastro.kyoto-u.ac.jp/vsnet/etc/drawobs.cgi?text=CEUnova2001)). Preliminary analysis of 6 nights of optical photometry using small telescopes + CCDs shows several peaks in its power spectrum (Fig. 2). They can be explained within the IP model, so this nova could also be an IP, consistent with our prediction.

Additional possible support for our idea might come from the detection of oscillations in an X-ray source, which is located near the nucleus of M31. Osborne et al. (2001) proposed that the \( \sim 865\)-sec periodicity represent the spin period of a magnetic white dwarf. The high X-ray luminosity and the transient nature of the object led them to propose that this is a recent novae. King, Osborne, & Schenker (2002), however, argued against this suggestion.

4. Discussion

There seems to be a strong connection between the transition phase in classical novae and IPs. Two famous cases are Nova GK Per 1901 (oscillations) and Nova
Figure 2. Power spectra of six nights of photometry of Nova V1039 Cen 2001 obtained in 2002. The lower two panels show two different sets and the top panel displays the combined data. The several groups of peaks may correspond to the orbital period, the spin period and some combinations of the two. V1039 Cen may thus be grouped with IPs.)
DQ Her 1934 (minimum), which are well-known IPs. Another possible example is Nova V603 Aql 1918 (oscillations), which was suggested several times as an IP candidate (e.g. Schwarzenberg-Czerny, Udalski & Monier 1992) and whose X-ray light curve show strong variations (Mukai et al., this volume). We note, however, that there has been a long argument whether this nova is indeed an IP (e.g. Mukai et al., these proceedings).

We suggest that this link is connected with the presence of the accretion disc in post-novae. In IPs, the magnetic field truncates the inner part of the disc, making it less massive than in non-magnetic systems (this is, by the way, the reason why IPs do not have dwarf-nova outbursts or only have short and weak outbursts). The nova outburst can, therefore, disrupt the disc in IPs. Its re-establishment and the subsequent interaction with the magnetosphere of the primary white dwarf is a violent process that forms strong winds at the inner part of the disc. The winds block the radiation from the hot white dwarf and the dust is not destroyed. The accretion disc oscillates until finally reaching stability at the end of the transition phase. In non-magnetic systems the disc is barely disturbed and becomes stable much faster and in polars (AM Her systems) there is no accretion disc at all. In both groups there is no transition phase since dust cannot be formed.

The long-term oscillations during the transition phase could be explained if the inner accretion disc lies very close to the co-rotation radius, so the disc and the magnetic field would rotate (almost) together at that point. The relative rotational timescale (the beat period) could be very long – of the order weeks, as observed in the transition phase.

If the winds are very strong, as might be the case in DQ Her (perhaps since its spin period is very short) this leads to the formation of more dust and to a minimum in the light curve. IPs with longer spin periods should show oscillations. Naturally, our model has a strong dependence on the inclination angle.

Further X-ray and optical observations of novae that have a transition phase should confirm or refute our suggestion.

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