OPTICAL AND X-RAY OUTBURSTS IN THE INTERMEDIATE POLAR GK PER

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ABSTRACT

We present the properties of the complicated long-term evolution of the dwarf nova-like outbursts of the intermediate polar GK Per. We show how the maximum brightness of the outbursts has stabilized during the interval following the abrupt increase of the recurrence time in the early 1970's. We show and discuss the complicated relation between the profiles of the light curves of outbursts, observed in X-ray ($ASM/RXTE$ data; 1.5–12 keV) and optical regions – the largest discrepancies between the light curve in these regions occur near the maximum of the optical light. $ASM/RXTE$ observations show the onset and end of the recent outbursts to be simultaneous with those of the optical event (when covered by the observations) – the large delay of the optical outburst seen in 1978 (King et al., 1979) does not repeat at present. We discuss the implications of our observations on the physical processes in the system.

Key words: Stars: white dwarfs; accretion, accretion discs; binaries: close; circumstellar matter; X-rays: binaries; Stars: individual: GK Per.

1. INTRODUCTION

GK Per (Nova Per 1901), an optical counterpart of A 0327+43, is an intermediate polar with $P_{\rm orb} = 1.99$ days (Crampton et al., 1986) and $P_{\rm spin} = 351$ sec (Watson et al., 1985). The optical outbursts of GK Per are accompanied by brightenings in X-rays (e.g. King et al. (1979); Šimon (2002)). The basic features of three similar outbursts were modeled by Kim et al. (1992) in the framework of the thermal instability disk model.

2. DATA SOURCE AND ANALYSIS

The optical data come from the AFOEV database (CDS, Strasbourg, France). The individual observations were grouped into the night bins. The X-ray data are the daily means of the $ASM/RXTE$ sum band 1.5–12 keV observations (Levine et al., 1996) (`http://xte.mit.edu`), shifted to achieve the zero intensity in quiescence.

3. RESULTS

We show that the variations of the outburst recurrence time $T_{\rm C}$ in GK Per are large but generally not chaotic (Fig. 1a). A long-term trend of an increase of $T_{\rm C}$ can be resolved in the $O-C$ curve beyond any doubt and is accompanied by a brightening of the peak magnitude and increase of the relative energy RE of outburst (Fig. 1bc). RE is obtained by the transformation of the light curve from magnitudes into intensities and its integration over the outburst. It appears that both the peak magnitude and RE stabilized within a few epochs (Fig. 1abc) and remained at the values significantly different from those before the jump of $T_{\rm C}$ (see Šimon (2002)). A possible solution of the recent behaviour is as follows. $T_{\rm C}$ in quiescent dwarf novae is inversely proportional to the quiescent viscosity parameter $\alpha_{\rm cool}$ (e.g. Warner (1995)). If $\alpha_{\rm cool}$ is allowed to have a lower value after the jump of $T_{\rm C}$ than before it then a larger amount of matter can accumulate in the disk during a longer quiescent interval. This can then power a brighter outburst.

We find that each of the four optical outbursts which occurred during the operation of $ASM/RXTE$ is accompanied by an X-ray brightening in the 1.5–12 keV passband. The onsets of outburst and the initial rises of the flux in the optical and X-ray passband can be regarded as simultaneous, taking the rounding of the profile of the X-ray light curve by the moving averages into account. However, the profiles of the light curve in the optical and X-ray regions are largely discordant. While the optical light curves display a sharp top, the X-ray curves possess clearly flat-topped maxima, even with a depression coincident with the moment of the optical maximum in outburst at the epoch $E = 6$ (Fig. 1g, see also Šimon (2002)). The X-ray flux largely rises only during the rapid initial rise of the optical outburst in the events at $E = 5$, 6, 7, and remains roughly constant or even decreases even when the optical flux continues to rise (Fig. 1fgh). The duration of the X-ray outburst is about as long as that of the optical event when a good coverage is available (e.g. Fig. 1de).

The previous X-ray observations of GK Per were interpreted in terms of a lower absorption in quiescence than in outburst (Norton et al., 1988). We thus offer the following interpretation of the relation of the X-ray and optical behaviour. During phase 1, the heating front propagates both outside-in and inside-out. This is the phase of the steep rise of the flux in both the X-ray and optical passband. The accretion curtain is not fully formed yet and the X-ray flux can therefore rise because of a low absorption. During the subsequent phase 2, the heating front propagates only inside-out – this is the phase of a slow rise of the optical brightness to the optical maximum. The accretion curtain is already developed and the X-ray flux remains roughly constant or even decreases because of a large absorption. The models by Kim et al. (1992) predict that a brightening in the X ray and UV passbands can precede the optical outbursts in GK Per by 80–120 days. Such a precursor is absent at least from the outbursts at $E = 5$, 6, 7. The case of the outburst at $E = 8$ is uncertain but due to the noise the onset of the X-ray outburst can be consistent with the optical one. Nevertheless, the long precursor did occur in the much fainter and shorter 1978 outburst (King et al., 1979).

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REFERENCES

Crampton D., et al. 1986, ApJ, 300, 788

Kim S.-W., et al. 1992, ApJ, 384, 269

King A.R., et al. 1979, MNRAS, 187, 77

Levine A.M., et al. 1996, ApJ, 469, L33

Norton A.J., et al. 1988, MNRAS, 231, 783

Šimon V. 2002, A&A, 382, 910

Vondrák J. 1969, BAIC, 20, 349

Vondrák J. 1977, BAIC, 28, 84

Warner B. 1995, Cataclys. Var. Stars, Cambridge Univ. Press

Watson M.G., et al. 1985, MNRAS, 212, 917

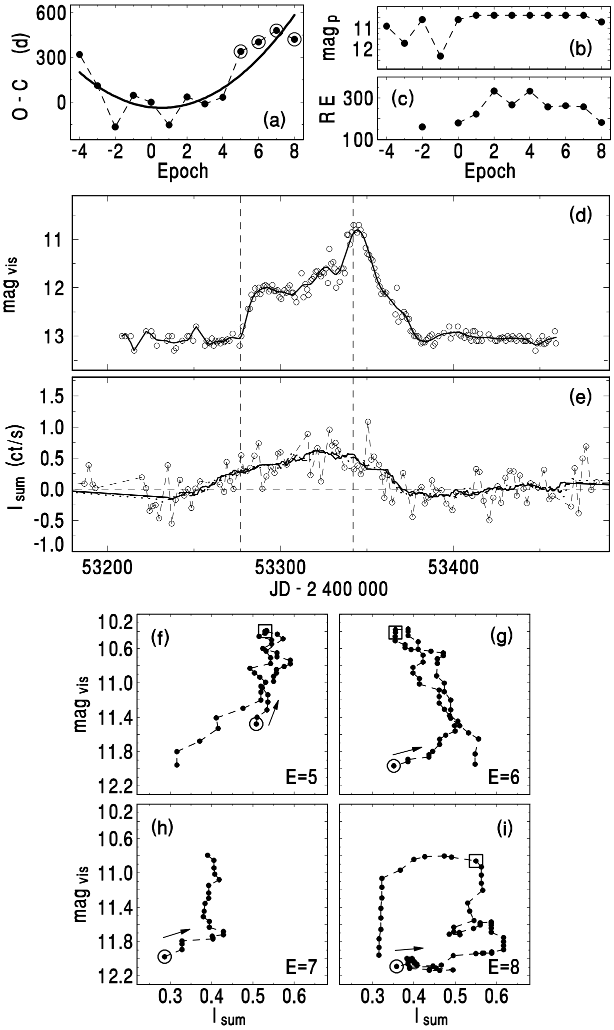

Figure 1. (a) O–C diagram for the moments of the outburst maxima in the years 1970–2005. The ephemeris $T_{\max} = 2\,444\,681 + 1030\,E$ was used. Four outbursts for which $ASM/RXTE$ data exist are marked by the open circles. Variations of the peak magnitude (b) and the relative energy RE (c). An example of the relation between the outburst light curves in the optical (d) and X-ray (e) passbands. The optical data are fitted by the code HEC13 (author: Dr. P. Harmanec, method: Vondrák (1969, 1977)). The X-ray data are two-day means, formed from the daily means that had the quoted uncertainty $\sigma_{\rm q} < 0.4$ ct/s, and are fitted by the moving averages for various filter half-widths ($Q = 10 - 15$ days). The moments of the onset and the maximum light of the optical outbursts are marked by the vertical dashed lines. (fghi) The relation between the optical magnitude and X-ray intensity during outburst. The individual outbursts are abbreviated by their epochs. Only the parts of the optical light curve brighter than 12 mag$_{\rm vis}$ are used to avoid artifacts caused by the moving averages of the steep initial rise in X-rays. The initial point (open circle) and the moment of the maximum of the optical light of the outburst (open box) are marked if covered by observations.