THE 1981 OUTBURST OF THE OLD NOVA GK PERSEI

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ABSTRACT

GK Per was observed in 1981 with the IUE, during its rise, maximum, and subsequent return to minimum. In outburst, GK Per is luminous but much redder than dwarf novae or standard model accretion disks. The observed spectrum can be explained qualitatively with the Ghosh and Lamb model for the interaction of an accretion disk with the magnetic field of the accreting white dwarf. N V and He II are enhanced relative to other emission lines during outburst. This can be understood with photoionization by very soft X-rays having a luminosity comparable to that of the hard X-rays.

Keywords: Cataclysmic Variables, Old Nova, Dwarf Nova, Intermediate Polar, Ultraviolet

1. INTRODUCTION

GK Per is an old nova which continues to have dwarf nova-like outbursts of 2.5-3.0 magnitudes since reaching minimum after the 1901 nova event. These outbursts occur irregularly every few years and each last a few months. In early 1981 it underwent such an outburst. The distance to GK Per is well established at 470 pc (Ref. 6) from the observed expansion of the nova shell. It is a double-lined spectroscopic binary (Ref. 7 and references therein) with a period of 1.996803 days, a mass ratio of 3.6±0.5, inclination of $\lesssim$ 73 degrees. The white dwarf primary has a mass of 0.9±0.2 M⊙ with a rotation period of 351.34s as measured by EXOSAT. The secondary is a KO IV star of 0.2 M⊙. GK Per has been suggested as an intermediate polar.

Here we report the IUE observations of the outburst which occured in early 1981, and optical and infrared photometry before and after the outburst. Photographic spectra of this same outburst has been described in Ref. 1. More detailed discussion on the data, results and interpretations is given in Ref. 12.

2. RESULTS

Figure 1 shows the observed IUE spectra of GK Per. The continuum is dominated by the strong 2200 A interstellar absorption feature. Dereddening procedure using the extinction curve of Savage and Mathis (Ref. 8) yields an E(B-V)=0.3 which is three times higher than that deduced by McLaughlin (Ref. 6). After correcting for the reddening and assuming the secondary star contributes about 1/3 of the blue light, we estimate that the outbursting component brightened by a factor of 60 in the UV and a factor of 20 at V. With the known distance, we further estimate that the system has L = 20 L⊙ at maximum (adopting a bolometric correction of a B8 star) and L = 2.3 L⊙ at minimum (combined UV optical and IR data) with a third of the luminosity at minimum coming from the secondary star. The dereddened flux distribution at different outburst stages is shown in Figure 2. In the 1200-3300 A region, GK Per is much redder than dwarf novae and novalike variables (e.g. Refs. 11, 9) during outburst. It is also impossible to fit GK Per with the standard, optically thick accretion disk models (e.g. Ref. 4).

The following emission lines are definitely present in GK Per: N V λ1240, Si IV λ1400, C IV λ1550, He II λ1640, and Mg II λ2800. N IV] λ1486 is probably present in some spectra and the strong feature at 3133 A which is present only in the spectrum when GK Per was at maximum is tentatively identified as originated from O III. During outburst N V and He II lines are enhanced relative to C IV, and Mg II seems to have decreased relative strength.

3. DISCUSSION

GK Per is relatively luminous both at minimum and maximum states, yet its intrinsic flux distribution is much redder than any of the dwarf novae. The observed 351-second X-ray pulsations (Ref. 10) and the related optical modulation (Ref. 5) suggest that GK Per is an intermediate polar, a system whose white dwarf has a strong enough magnetic field to disrupt the inner accretion disk, but not the outer disk. Ghosh and Lamb (Ref. 3) predicts that the disruption of the accretion disk by the interaction with the stellar magnetic field leads to the modification of disk temperature distribution. The calculations of Ghosh and Lamb estimate the degree of penetration of the stellar magnetic field in the accretion disk outside the very narrow boundary layer in which the disk is disrupted, and they find that the field dominates the transport of angular momentum in a very large transition zone. The field modifies the temperature distribution in this zone such that the temperature is lower inside the corotation radius than predicted by a standard accretion disk model, and higher outside. The cooler temperatures at small radii prevent the disk from being too blue, and the hotter outer regions provide the necessary luminosity with a smaller accretion rate. The model based on the Ghosh and Lamb predictions fit the spectrum and luminosity of GK Per with an inner radius and accretion rate about 20 times smaller than the model based on a standard disk with its center removed.

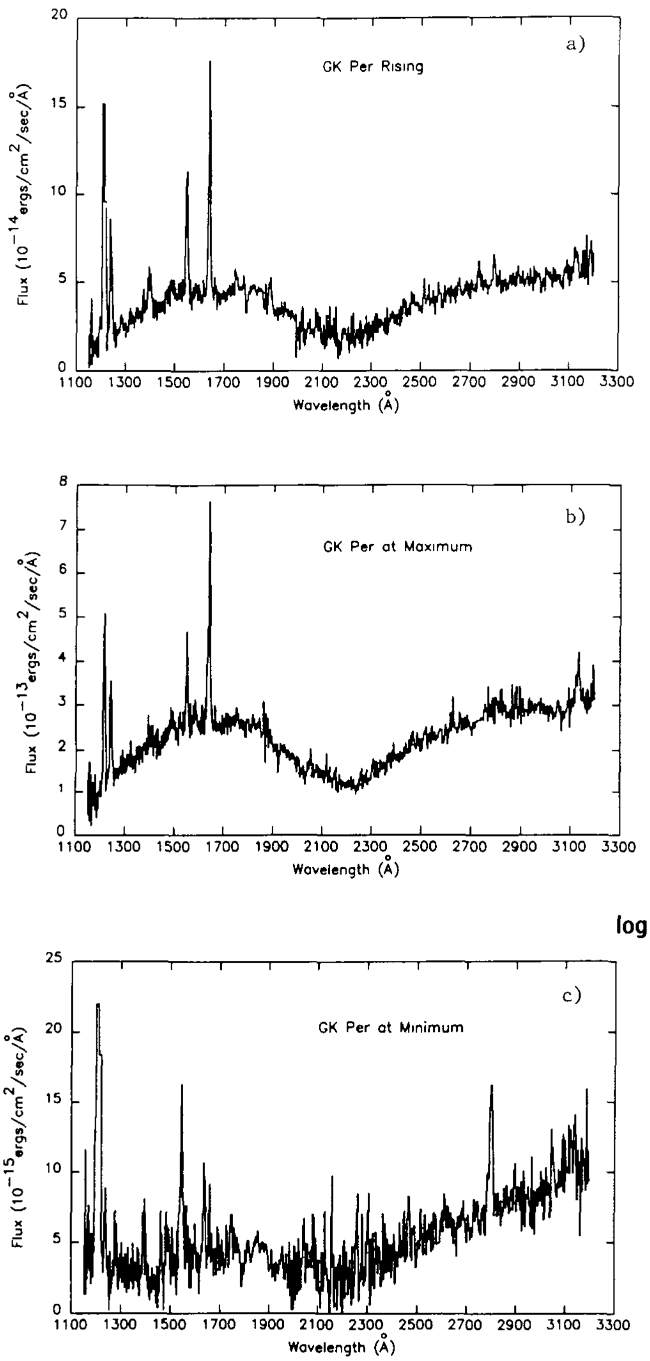

Figure 1. Observed IUE spectra of GK Per: a) during rise to maximum, b) at maximum, c) after return to minimum

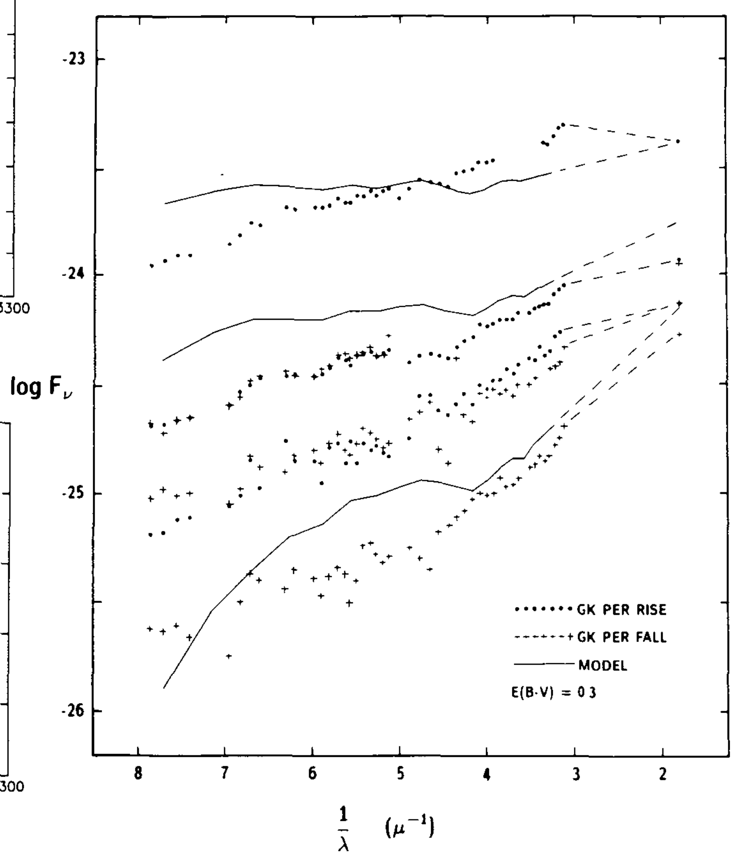

Figure 2. The dereddened continuum flux distribution of GK Per during the outburst of early 1981. The filled circles show the flux disbtribution during the rising and maximum states, the plus symbols show the flux distribution during the decline from maximum. The solid lines show the flux distributions of the three models discussed in Wu et al. 1988. The dashed lines are not estimates of flux but serve only to connect the flux at V to that at the long wavelength end of LWR.

X-ray emission in the 0.2-4 keV range was observed from GK Per at minimum (Ref. 2) and that in the 2-20 keV range was observed during maximum (Ref. 10). The observed luminosities can be reconciled within factors of two of those expected from the accretion rates derived from the UV and optical emission in an intermediate polar model. The He II intensities and enhancement during outburst are compatible with a soft X-ray luminosity equal to the observed hard X-ray luminosity. Furthermore, it is plausible that the increase in soft X-ray luminosity during outburst is accomplished by increasing the temperature of the heated portion of the white dwarf surface. Consequently carbon is mostly ionized to C V leading to the increased N V / C IV ratio observed during outburst.

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