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THE 2003 EXTENDED LOW STATE OF LQ Peg

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Cataclysmic Variables (CVs) are semi-detached binary systems, consisting of a white dwarf primary star accreting from its lower main sequence, Roche-lobe filling companion. The gravitational potential energy of the accreted material is converted into radiation, much of which is emitted in the optical. Most of the long-time-scale variability is thought to be due to changes in the mass accretion rate ($\dot{M}$). LQ Peg (also known as PG2133+115 or Peg 6) is a poorly-studied CV, with a suggested orbital period of $2^{h}.9$ (Ringwald 1993; however see Misselt & Shafter 1995). It is classified as a thick-disk, UX UMa system (Ferguson, Green & Liebert 1984) and has been reported to have occasional low-amplitude (∼0.25 mag) outbursts and dips (Honeycutt & Kafka 2004; hereafter HK04). It is a member of the VY Scl subclass of CVs, containing systems with large (up to 5 mag) drops in their optical light curves, presumably due to disruptions of the mass transfer.

A low state of LQ Peg was first recorded photographically in 1969 (Sokolov et al. 1996) and the second one was noted in 1999 (Kato & Uemura 1999). Schmidtke et al. (2002) reported that considerable flickering was present during recovery from the 1999 fading, but no coherent orbital modulation was found. The rise from the 1999 low-state was also recorded by RoboScope, a 16-inch automatic telescope located in central Indiana (Honeycutt & Turner 1992). HK04 included the 1999 low state in a study of the transitions of 8 disk VY Scl systems, in which the shapes of the transitions to and from the low state were argued to be consistent with being due to disruption of $\dot{M}$ as the umbra and penumbra portions of starspots on the secondary star migrate underneath the L1 point (Livio & Pringle 1994). The last datum of the RoboScope light curve presented in that study was taken in 2003 July, where the system appeared to have faded towards a new low state. We present here the new (2003) low state of LQ Peg, in which the system seems to have dropped to its faintest observed brightness. This current study complements the HK04 paper, which will help understand the long-term behavior of the system and perhaps put constraints on the cause of the low states.

About 11 years of RoboScope photometry of LQ Peg have accumulated since 1993-July; a description of the data acquisition/reduction of the RoboScope photometry can be found in HK04. The 1993-July to 2004-June light curve is shown in Fig. 1, where we have numbered the 1999 and 2003 low states as 2 and 3 respectively (the Sokolov et al. low state of 1969 (not shown) being number 1). Unfortunately, only the recover from the low-state was observed for each of these three events, due to yearly gaps in the coverage.

Fig. 2 shows the two RoboScope low states. A 1-magnitude displacement on the vertical axis facilitates the distinction between low state 2 and 3 which are drawn with

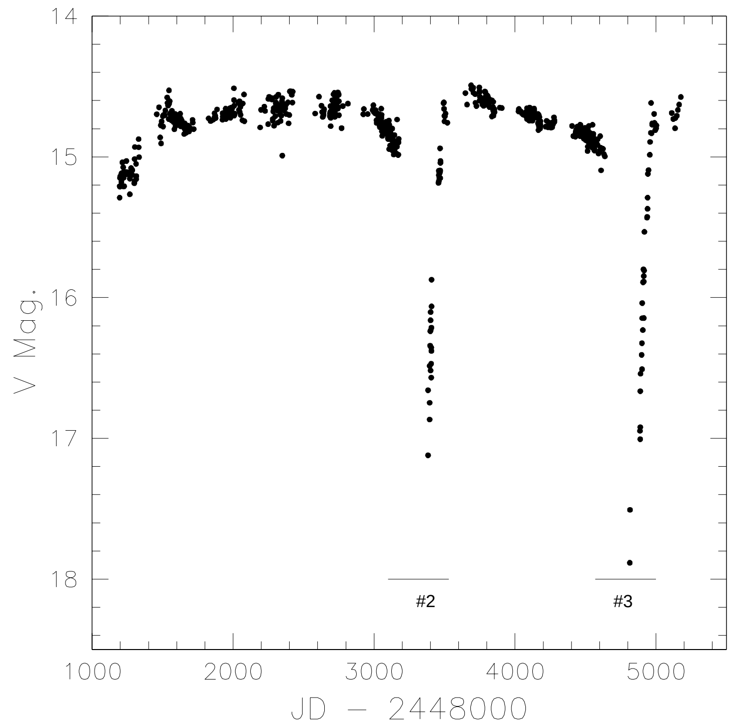

Figure 1. 1993-2004 V-band light curve of LQ Peg

Table 1: LQ Peg low states

Low State	Duration(d)	Amplitude(mag)	τ_{fall}(d)	τ_{rise}(d)
1	<1500:	3.2:	-	50:
2	<250:	<2.6	<100	52
3	<250:	3.3:	< 65	52

triangles and crosses respectively. Table 1 displays the low state characteristics as recorded by RoboScope. For completeness, we also include the low state of 1969, as presented in Sokolov et al. (1996). We would like to caution the reader about the entries for the 1969 low state, since they are estimates from the B light curve of Fig. 1 in Sokolov et al. (1996). Since neither of the declines to the low states was recorded we take the last high-state data point for the beginning, to determine the upper limit of the duration of the low state. The speed of each rise is characterized by the e-folding time (τ), defined as:

$$\tau = \frac{(log_{(10)}e/0.4)}{(\Delta m/\Delta t)} = \frac{1.086}{(\Delta m/\Delta t)} \quad (1)$$

Because of the data gaps many of the parameters are only limits. Nevertheless, there are remarkable similarities, including a very slow ~0.3 mag decline in the year preceding the low state, and a recovery to a level ~0.4 mag brighter than before the low state. The shapes of the recoveries for low states 2 and 3 are similar, being steeper when fainter (see HK04), and the overall speeds of the rises are the same within the errors, at τ~50 days.

VY Scl low states are often described to be random. There is undeniably a significant stochastic component to the spacings and depths of VY Scl low states, as well as a

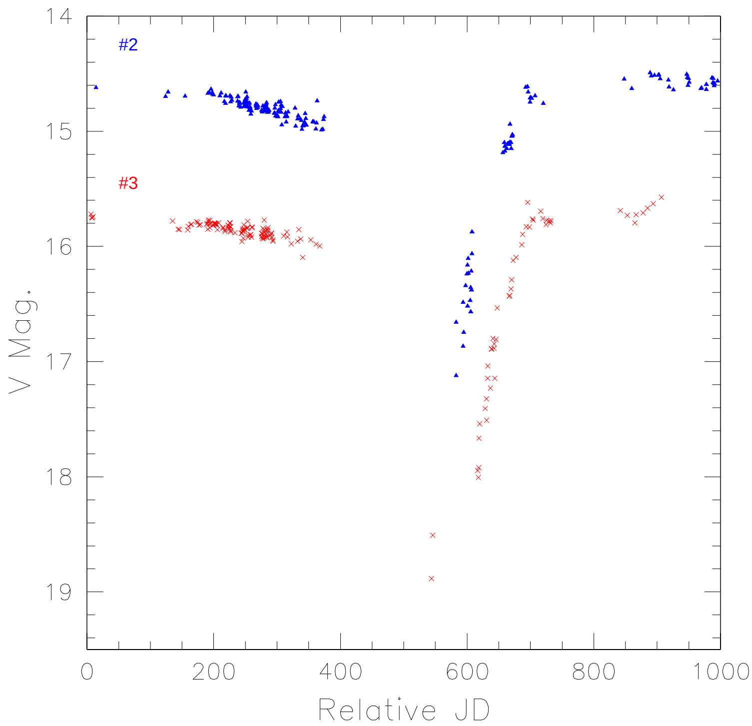

Figure 2. Low states 2 and 3, aligned on the JD axis to show the similarities. The light curve for low state 3 has been offset 1 mag for clarity

distribution to the shapes and speeds of the transitions, which nevertheless seems to peak around 20-30 days. On the other hand, individual systems often show a clear preference for certain transition speeds and for pairs (or series) of low states with nearly identical parameters. V794 Aql is one of the best examples of such behavior (Honeycutt & Robertson 1998; HK04), and it appears that LQ Peg is another. In HK04, the transitions to and from the low states in VY Scl systems were interpreted as being due to the umbra/penumbra portion of starspots on the secondary star drifting underneath the L1 point, consistent with the Livio & Pringle (1994) scenario. Outside the low states, the characteristic light curve modulation of ∼0.5 mag in amplitude can be interpreted as being due to starspot cycles on the secondary star (as described in Warner 1988 among others) which modulate mass transfer.

The time between successive low states in LQ Peg does not appear to be constant. Although there are only three recorded low states, from the RoboScope long term light curve we can infer that the time interval between low states 1 and 2 is greater than 6 years whereas between low states 2 and 3, only 3 years lapsed. It will be interesting to see if there is a consistent, cyclic-like behavior of the occurrence of low states in such systems, but another decade of continuous monitoring is essential for this. On the other hand, the ∼0.4 mag drop of the systems's brightness preceding low states 2 and 3 may be a characteristic of all the low states of the system and may help predict the occurrence of future low states.

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