

COMMISSIONS 27 AND 42 OF THE IAU
INFORMATION BULLETIN ON VARIABLE STARS

Number 5581

Konkoly Observatory
Budapest
9 December 2004

HU ISSN 0374 – 0676

**SPECTROSCOPIC CONFIRMATION OF THREE SUSPECTED BY Dra
VARIABLES**

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The BY Dra variables are late-type (G – M) over-active stars, showing photometric variability on time scales on the order of a few days. The variations are caused by stellar activity and surface nonuniformities probably in the form of large spots being rotated across the stellar disk. In the 77th namelist of variable stars (Kazarovets et al. 2003) there are three stars suspected of BY Dra type variability:

V573 Pup (SAO 154153, M0, $V=8^m98$) was discovered to be variable by Lebzelter & Posch (2001) with a period around 25 d. The authors were reluctant to classify it as a BY Dra type because of its unusually high $V - I$ amplitude compared to V amplitude.

HL Cnc (HD 77191, G0, $V = 8^m86$) was presented as a solar twin by Lebzelter (2000), except for the photometric variation with a 10 d period, which were proposed to be due to stellar surface spots.

GQ Leo (GSC 00870-00798, K4, $V = 10^m7$) is a known as an X-ray and EUV source (e.g. Mason et al. 1995), and was found by Robb et al. (2001) to show photometric variability with a period of 4.45 d. From the known X-ray and UV flux and the period, they argue that the star could be a BY Dra type variable.

We have obtained high-resolution ($R \sim 48\,000$) spectra of the three stars using FEROS at the ESO/MPI-2.20m telescope at La Silla Observatory, Chile. Standard data reduction was performed with MIDAS including bias and flatfield correction, order extraction and wavelength calibration. Flux calibration was performed using only one standard star observation. The spectra have a FWHM resolution of 0.15\AA and cover the range 3800–9000 \AA .

In Figs. 1 and 2 we show the spectra of V573 Pup and HL Cnc around the Ca II H+K lines. The spectrum of GQ Leo shows very strong emission in H+K and $H\alpha$ as shown in Fig. 3. As we show in Fig. 4, also the rest of the Balmer lines are in emission, and the Ca II triplet at $\lambda\lambda 8498, 8542, 8662$ have strong emission cores, revealing an extremely active system, usually indicative of youth (e.g. Montes et al. 2001).

Over-active stars are often young and rapidly rotating. A commonly used indicator of youth is the lithium doublet at 6707.8\AA , which, as shown in Fig. 5, we find to be clearly present in GQ Leo and HL Cnc, while the red spectrum of V573 Pup is dominated by strong molecular absorption, typical for M-dwarfs.

At this resolution the Li lines are blended with a Fe I line at 6707.41\AA , and we measure the combined width to 95 m\AA for GQ Leo and 83 m\AA for HL Cnc using the *splot* tool of IRAF.

For HL Cnc we could measure nine of the line ratios established by Kovtyukh et al. (2003) to determine the effective temperature, and we find $T_{\text{eff}} = 5765\text{ K} \pm 92\text{ K}$.

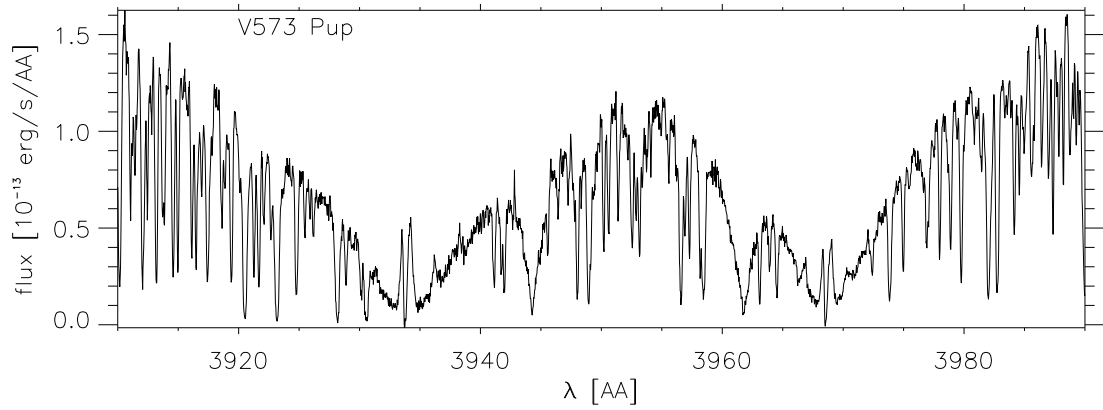


Figure 1. The Ca II H+K lines of V573 Pup. Note the very strong self-absorption.

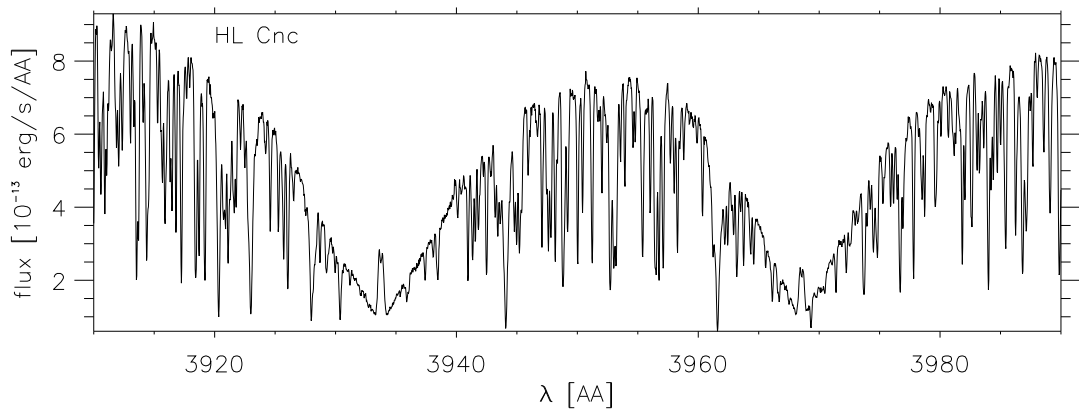


Figure 2. The Ca II H+K lines of HL Cnc. This is clearly an overactive star.

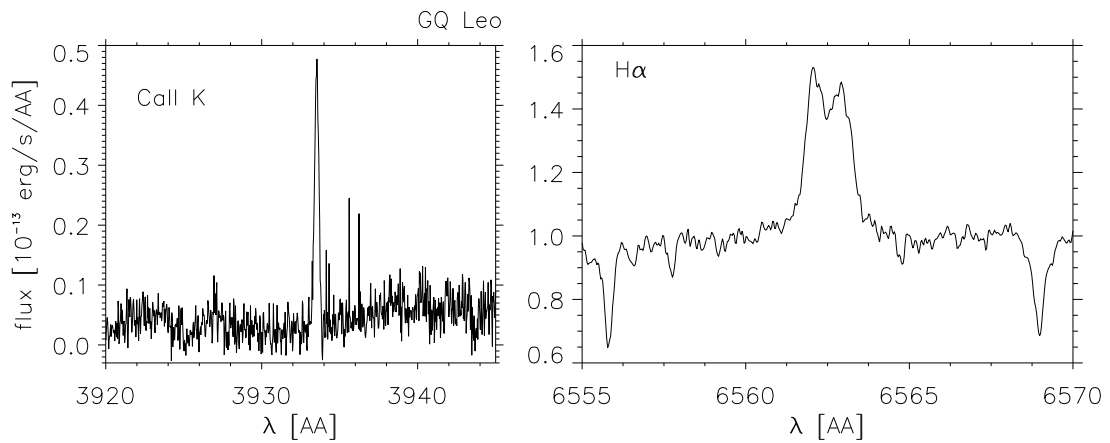


Figure 3. Ca II and H α K of GQ Leo. This is obviously an extremely active object.

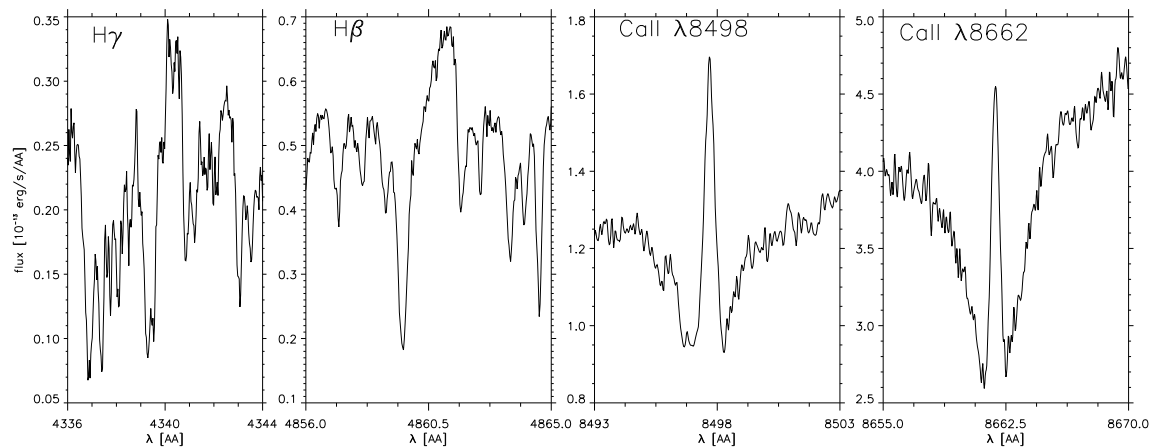


Figure 4. The Balmer lines of GQ Leo have clear emission or emission fill-in, while the Ca II infrared triplet have strong emission cores ($\lambda 8542$ falls partly in an inter-order gap and is not shown).

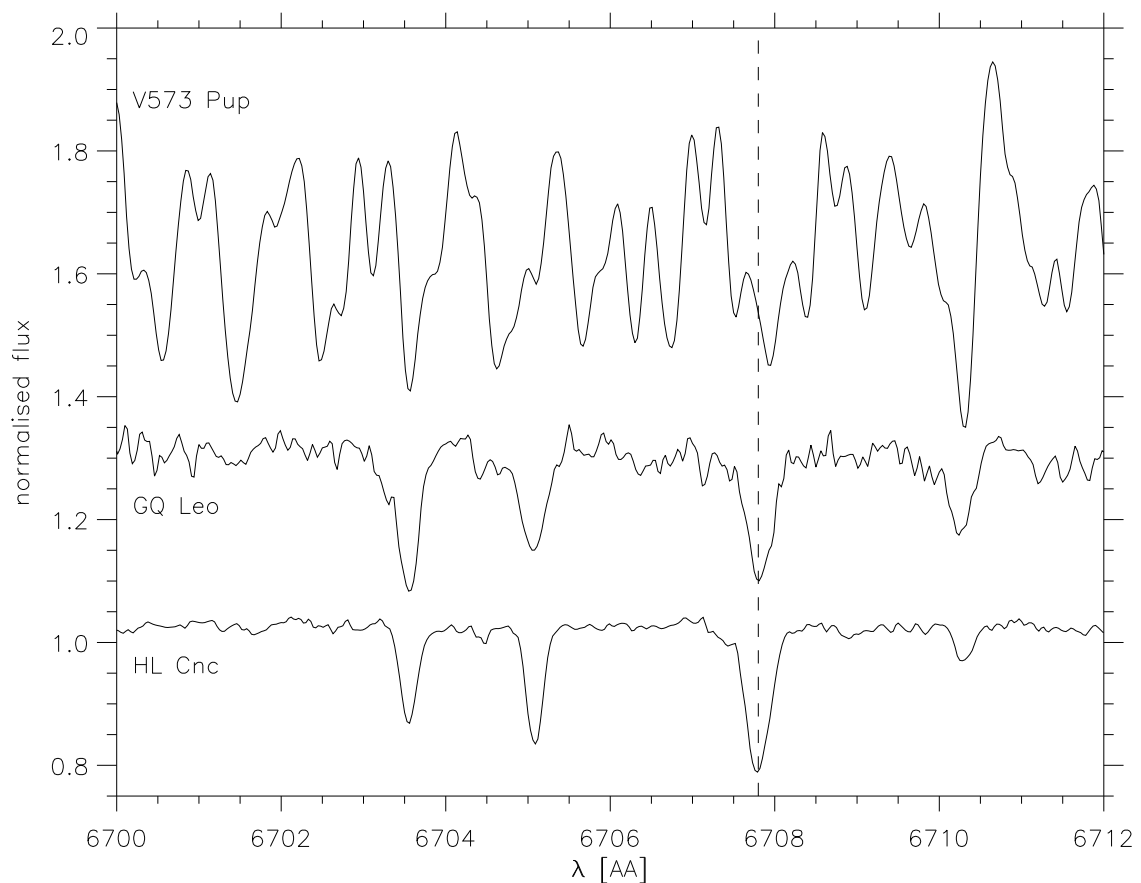


Figure 5. The region around the Li I line at 6707 Å (position marked by the dashed line). The line is present in HL Cnc and GQ Leo, while in V573 Pup the spectral region is dominated by molecular bands making interpretation difficult.

Hence the assessment of Lebzelter of HL Cnc as a solar twin was indeed quite accurate. For GQ Leo the scatter is much larger due to the low S/N spectrum, and we find $T_{\text{eff}} = 4370 \text{ K} \pm 300 \text{ K}$, which is consistent with classifying the star as a K4 dwarf, although the temperature together with the youth indicates a somewhat later spectral type. Since V573 Pup is outside the valid range of the calibrations of Kovtyukh et al. we do not attempt to refine the classification. It is clearly a M-star with strong molecular absorption bands.

In conclusion, we have shown that all three objects are active late-type stars and we have refined the classifications for HL Cnc and GQ Leo. Based on the emission properties, the youth and the spectral types we conclude that the three stars examined here can consistently be classified as BY Dra variables.

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