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PHOTOSPHERIC AND CHROMOSPHERIC ACTIVITY OF THE BRIGHT AND SINGLE G5 DWARF HR 4864 = HD 111395

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Stars similar to our Sun are an important test field for the deeper understanding of solar physics. So it is no surprise that much effort has been put into the study of magnetic activity of these stars culminating in the still ongoing, long-term Mt. Wilson H&K project initiated by the late Olin C. Wilson in the sixties. However, there is a real problem finding solar twins, i.e. stars that exactly match the Sun's astrophysical parameters (see, e.g., the annual Lowell workshops) and even if stars are found with only approximate solar parameters they are usually faint and not easily accessible for high-resolution spectroscopy. In this paper we draw attention to a single and bright G5 dwarf that deserves further high-resolution monitoring.

Table 1. NSO and KPNO radial velocities (for HJD 2,450,000+, in km s^{-1})

HJD	v_r	σ	Obs.	HJD	v_r	σ	Obs.	HJD	v_r	σ	Obs.
432.037	–8.6	1.3	NSO	439.022	–6.4	1.3	NSO	541.815	–10.8	0.75	KP
433.022	–9.6	1.2	NSO	441.032	–8.7	1.2	NSO	548.729	–9.2	0.37	KP
434.028	–8.4	1.2	NSO	442.036	–5.7	1.7	NSO	549.881	–8.9	0.39	KP
435.040	–8.5	1.2	NSO	447.016	–7.2	1.3	NSO	550.903	–9.3	0.39	KP
436.057	–10.2	1.5	NSO	448.024	–9.1	1.4	NSO	553.824	–9.0	0.48	KP
437.062	–10.0	1.5	NSO	451.027	–8.4	1.5	NSO	554.831	–9.1	0.49	KP
438.023	–9.5	1.6	NSO	458.018	–7.0	1.3	NSO				

Spectroscopic data were obtained in April 1997 at KPNO using the coudé feed telescope with camera 5, grating A, the long collimator and the 3k×1k F3KB CCD. This set up allows a resolution of $R = 35,000$ in the red wavelength regions and $R = 30,000$ in the blue. The summation of several short exposures enables a S/N ratio of close to 800:1 for the red spectra and approximately 300 for the Ca II H&K spectra centered at 3950 Å. Earlier 6420-Å spectra were obtained in December 1996 with the NSO McMath telescope and the stellar spectrograph at a resolution of 40,000 and varying S/N of 150–200:1. Table 1 presents 20 new radial velocities for HR 4864 that were obtained from cross correlations of the entire HR 4864 spectra with spectra of the IAU radial velocity standards β Gem, 16 Vir, and α Ari. These data indicate a constant velocity of –8.7±1.3 km s^{-1} in good agreement with earlier data by Beavers & Eitter (1986) and Duquennoy et al.

(1991) who found average velocities of −8.6 and −9.1 km s^{-1}, respectively. It seems now safe to say that we can exclude any binarity for HR 4864.

Figure 1 shows three interesting spectral regions of HR 4864; the 6420-Å region with several unblended photospheric absorption lines (a region that is frequently used for Doppler imaging), a spectrum of Hα, and a spectrum including the two Ca II resonance lines at around 3950 Å. Cross correlations of the many weak and moderately-strong photospheric lines (residual intensity above 0.6) showed an average FWHM of 0.123±0.002 Å, and with the calibration of Fekel (1997) this value relates to a projected rotational velocity $v \sin i$ of 2.9±0.4 km s^{-1} (adopting a radial tangential macroturbulence velocity of 3 km s^{-1}). A comparison of the overall spectral appearance of HR 4864 in the 6340–6600 Å wavelength region is in very good agreement with its G5V classification from prism spectra at 75 Å/mm by Harlan & Taylor (1970). The only significant disagreement is the Fe I 6430/Fe II 6432 line ratio (Figure 1, upper panel) that indicates a more solar-like temperature (G1 to G2) rather than G5. However, the singly-ionized line may overlap with an (unresolved) water vapor line at exactly the same wavelength. Also, Eggen (1978) mentioned a slight overabundance of iron relative to the Sun, [Fe/H]=+0.2, which could affect the observed B−V color and thus the line ratio versus $T_{\rm eff}$ calibration.

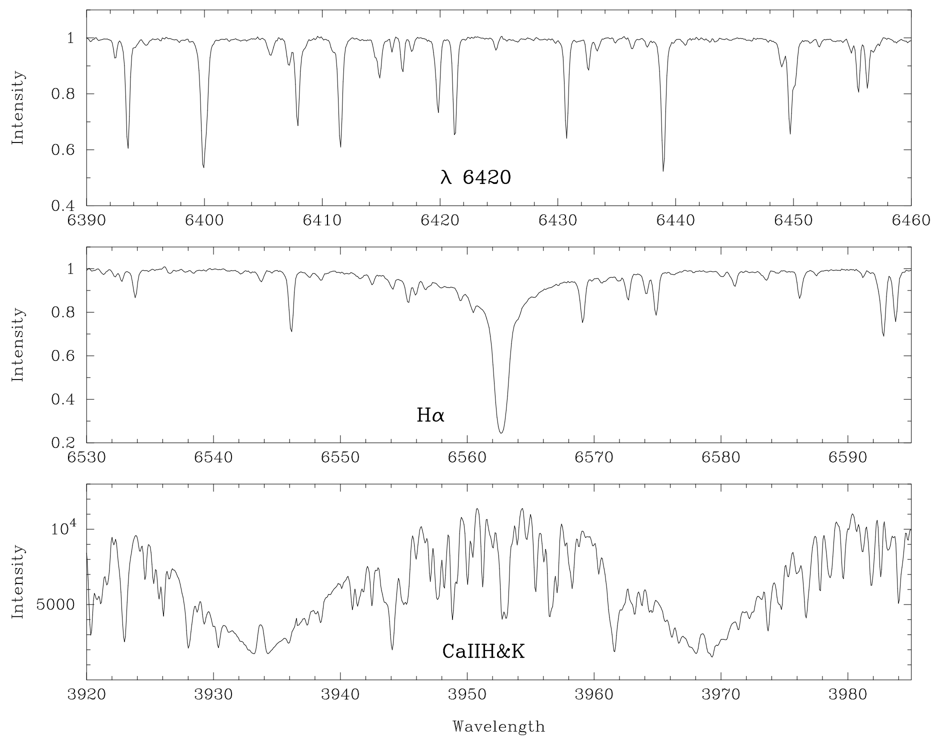

Figure 1. KPNO spectra of HR 4864 for three spectral regions of interest. From top to bottom: photospheric lines near 6420 Å, Hα, and Ca II H&K. Note the core emission at the bottom of the Ca resonance lines typical for chromospherically active stars

The Hα line appears like a normal absorption feature with line wings typical for a G-dwarf slightly cooler than the Sun. A comparison with spectra of other G dwarfs (not obtained with the same equipment though) indicates very small filling in of the line core, but this needs to be confirmed with higher resolution data.

Our single Ca II spectrum in Fig. 1 clearly shows emission in the cores of the H and K lines. In a G5V star we interpret these due to an active chromosphere. Their emission strengths significantly exceed the line strength seen in solar plage regions of the active Sun. Using the calibration of Linsky et al. (1979) and V−R=0.54 we measure an absolute emission surface flux in the H and K lines of 2.1×10^6 and 2.2×10^6 erg cm^{-2}s^{-1}, respectively.

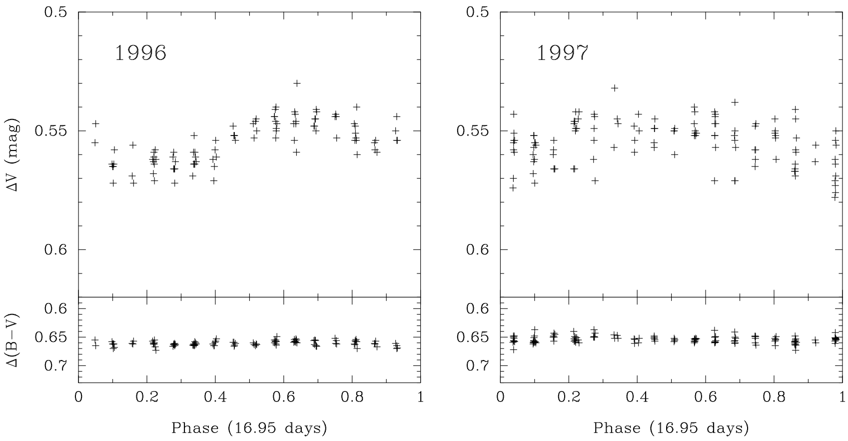

Figure 2. Seasonal V and B−V light and color curves of HR 4864. The 1996 light curve combines 53 consecutive nights starting at JD 2,450,212 while the 1997 data cover 92 consecutive nights beginning at JD 2,450,429

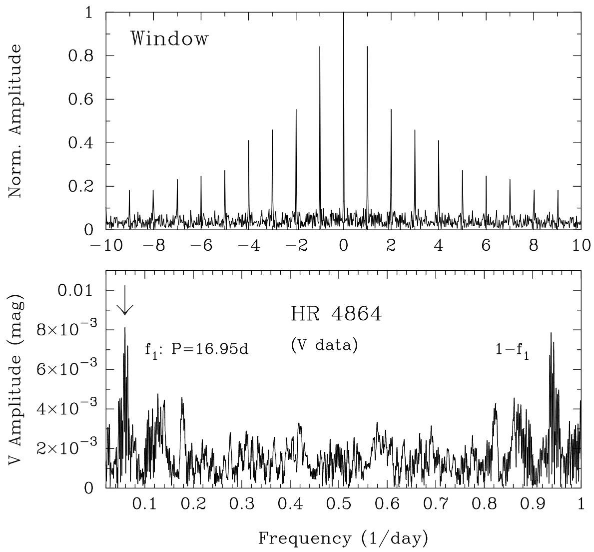

Figure 3. Periodogram from the combined 1996 and 1997 V-band photometry. The data indicate a best-fit frequency at $f_1 = 0.059$ cycles/day corresponding to a period of 16.95±0.50 days.

Continuous photometry of HR 4864 has been carried out with one of the University of Vienna twin APTs at Washington Camp in southern Arizona (Strassmeier et al. 1997) since early 1996 and a first light curve was presented in that paper. Here we analyse this data and present additional BV-photometry from 1997 (Figure 2). The comparison and check stars were HD 111469 (V=5.78, B−V=0.03 mag) and HD 111812 (V=4.94, B−V=0.67 mag), respectively. All readings incorporated a 2.5-mag neutral-density filter.

Figure 3 shows the periodogram and the window function for all available V data of HR 4864. A single period of 16.95±0.50 days gives the largest reduction of the squared residuals and we interpret this period as the rotation period of the star. In 1996 the light curve was nearly sinusoidal with a full peak to peak V amplitude of just 0.019±0.003 mag, while in 1997 the light curve appeared to have significantly changed in amplitude at around JD 2,450,500 from 0.025 mag before to 0.015 mag thereafter.

The Hipparcos catalog (ESA 1997) lists HR 4864 with a V magnitude of 6.29, and B−V=0.703 mag and a parallax which implies a distance of 17.2 pc. The absolute visual brightness is thus +5.1 mag in perfect agreement with the tabulated brightness of a G5V star according to Gray (1992). The expected B−V color, on the other hand, is 0.672 mag and our measured B−V was 0.690±0.003 (std) mag in 1996 and 0.680±0.003 (std) mag in 1997. The decrease of 0.01 mag is barely significant but still noticeable in Figure 2 and could be attributed to overall changes of the starspot activity.

Our new measure of $v \sin i = 2.9 \pm 0.4$ km s^{-1} and $P_{\rm rot} = 16.95 \pm 0.50$ days determines the minimum stellar radius to $R \sin i = 0.97$ $R_\odot$. The nominal radius of a G5V star is tabulated as 0.96 $R_\odot$ (e.g. Gray 1992). HR 4864 is thus seen almost equator-on, i.e. $\sin i \approx 0.988$ or $i \approx 81°$.

With all these parameters known, HR 4864 might also be a good candidate to search for further extra-solar planets by means of high-precision radial velocities or eclipse techniques and could eventually help to resolve the 51 Peg debate.

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