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The Astronomical Journal, 122:991–996, 2001 August

CHROMOSPHERICALLY ACTIVE STARS. XIX. A REEXAMINATION OF THE VARIABILITY OF HD 10909 = UV FORNACIS

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Received 2001 April 3; accepted 2001 April 25

ABSTRACT

We have obtained new spectroscopy and photometry of the K0 IV, chromospherically active, single-lined spectroscopic binary HD 10909. Those observations show that the previously reported orbital and light variability periods are incorrect. HD 10909 has an orbital period of 30.1067 days and an eccentricity of 0.499. Its rotation period of 64.1 days is more than twice as long as its orbital period. The primary is situated near the base of the first-ascent red giant branch. Thus, its asynchronous rotation is likely the result of its recent evolution through the Hertzsprung gap, combined with its relatively long orbital period and high eccentricity.

Key words: binaries: spectroscopic — stars: late-type — stars: rotation — stars: spots — stars: variables: other

On-line material: machine-readable table

1. INTRODUCTION

HD 10909 = UV Fornacis [$\alpha = 01^{\rm h}46^{\rm m}41\overset{\rm s}{.}6$, $\delta = -24°00'50''$ (J2000.0), $V = 7.9$ mag] was a star of little interest until Bidelman & MacConnell (1973) examined its spectrum on an objective-prism plate and classified it as a K0 IV star with Ca II H and K emission. As a result, it was included in several surveys of chromospherically active stars. Fekel, Moffett, & Henry (1986) obtained spectroscopic observations at several different wavelengths. They found that HD 10909 has moderate Ca II H and K emission, but its Hα line is a rather strong absorption feature. The lone component visible in their red wavelength spectra had a variable velocity, and they estimated a very modest projected rotational velocity of 6 km s^{-1}. The $v \sin i$ values determined more recently by Fekel (1997) and de Medeiros & Mayor (1999) are even smaller, about 3 km s^{-1}. Balona (1987) obtained numerous radial velocities from which he computed an orbit with a period of 15.05 days and an eccentricity of 0.39. Lloyd Evans & Koen (1987) obtained complementary photometric observations that showed the star to have light variations with a period of 32.54 days. Hooten & Hall (1990) analyzed additional seasons of photometry from which they found a best period of 31.54 ± 0.02 days.

HD 10909 was also included in surveys made at radio and X-ray wavelengths. Slee et al. (1987) used the Parkes 64 m telescope to observe over 50 chromospherically active binaries at 5 and 8.4 GHz but did not detect emission from HD 10909. Morris & Mutel (1988) included HD 10909 in a VLA survey of late-type binaries at a frequency of 4.9 GHz. Although they detected emission from over half of the stars in their sample, only a radio flux density upper limit was found for HD 10909. At X-ray wavelengths, HD 10909 was successfully detected, but the estimated X-ray luminosity was relatively low when compared with many other chromospherically active stars (Dempsey et al. 1997).

Finally, HD 10909 was included in a lithium abundance survey of chromospherically active stars. Randich, Gratton, & Pallavicini (1993) found that HD 10909, unlike a number of those stars, does not have a large lithium abundance.

Over the past decade we have obtained additional red wavelength spectra and photometric observations of HD 10909. Our analyses of these new observations show that both the orbital and rotation periods are quite different from the previously determined values. With this new information we have reexamined the properties of HD 10909.

2. SPECTROSCOPIC OBSERVATIONS AND REDUCTIONS

From 1980 August to 2000 September we made 24 high-resolution spectroscopic observations of HD 10909. The first two spectrograms were obtained in 1980 and 1981 with the 2.7 m McDonald Observatory telescope, coudé spectrograph, and a Reticon detector. Those two observations were centered at 6430 Å, had a wavelength range of 110 Å and a resolution of 0.36 Å. After a hiatus of a dozen years we began to observe the star more intensively, collecting 22 additional spectrograms over the course of the next seven years. These latter observations were made with the Kitt Peak National Observatory (KPNO) coudé feed telescope, coudé spectrograph, and a TI CCD detector. All of the KPNO observations are centered in the red at 6430 Å, cover a wavelength range of about 80 Å, and have a resolution of 0.21 Å.

Velocities for the two McDonald Observatory observations were previously given by Fekel et al. (1986). We determined the radial velocities of the KPNO observations with the IRAF cross-correlation program FXCOR (Fitzpatrick 1993) and used HR 8551 as the primary cross-correlation reference star. The velocity of this IAU radial velocity standard (Pearce 1957), adopted from the work of

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TABLE 1

RADIAL VELOCITIES OF HD 10909

HJD − 2,400,000	Phase	Velocity (km s^{-1})	$O - C$ (km s^{-1})	Weight	Reference[a]
44,178.471	0.127	−2.5	1.1	0.0	B87
44,179.403	0.158	−5.8	−4.0	0.0	B87
44,180.370	0.190	−0.1	−0.1	0.0	B87
44,181.376	0.223	1.8	0.1	0.0	B87
44,183.462	0.293	5.7	1.0	0.0	B87
44,236.333	0.049	−4.4	1.8	0.0	B87
44,237.301	0.081	−6.3	−0.3	0.0	B87
44,238.348	0.116	−3.3	1.0	0.0	B87
44,239.307	0.148	−3.1	−0.7	0.0	B87
44,240.302	0.181	1.7	2.2	0.0	B87
44,241.315	0.214	−0.1	−1.3	0.0	B87
44,242.301	0.247	5.2	2.4	0.0	B87
44,415.614	0.004	1.8	1.9	0.0	B87
44,416.668	0.039	−3.8	1.9	0.0	B87
44,421.654	0.204	−3.4	−4.1	0.0	B87
44,422.650	0.237	4.9	2.6	0.0	B87
44,423.645	0.270	2.8	−1.0	0.0	B87
44,424.679	0.305	6.8	1.6	0.0	B87
44,425.625	0.336	9.1	2.7	0.0	B87
44,426.639	0.370	5.2	−2.3	0.0	B87
44,427.621	0.402	8.8	0.2	0.0	B87
44,428.646	0.436	10.8	1.2	0.0	B87
44,443.693	0.936	17.3	2.8	0.0	B87
44,444.706	0.970	11.0	2.6	0.0	B87
44,475.998	0.009	−1.4	0.0	1.0	FMH86
44,506.499	0.022	−1.9	1.9	0.0	B87
44,509.610	0.126	−2.0	1.7	0.0	B87
44,511.510	0.189	3.2	3.3	0.0	B87
44,512.513	0.222	0.0	−1.6	0.0	B87
44,535.402	0.982	6.7	1.4	0.0	B87
44,536.432	0.017	−5.7	−2.8	0.0	B87
44,537.432	0.050	−7.6	−1.3	0.0	B87
44,538.427	0.083	−5.3	0.6	0.0	B87
44,539.432	0.116	−9.3	−5.1	0.0	B87
44,540.475	0.151	−2.7	−0.5	0.0	B87
44,592.391	0.875	18.1	−0.2	0.0	B87
44,593.373	0.908	16.8	−0.3	0.0	B87
44,627.586	0.044	−6.0	0.0	1.0	FMH86
49,248.883	0.541	12.8	0.3	1.0	KPNO
49,968.968	0.459	10.3	0.0	1.0	KPNO
50,361.884	0.510	11.6	−0.1	1.0	KPNO
50,363.842	0.575	13.2	−0.2	1.0	KPNO
50,364.842	0.608	13.8	−0.4	1.0	KPNO
50,365.886	0.643	15.0	−0.1	1.0	KPNO
50,720.905	0.435	9.6	0.0	1.0	KPNO
50,753.800	0.527	12.5	0.3	1.0	KPNO
50,757.751	0.659	15.4	−0.1	1.0	KPNO
51,089.852	0.689	16.2	0.0	1.0	KPNO
51,091.814	0.755	17.8	0.2	1.0	KPNO
51,092.847	0.789	18.3	0.2	1.0	KPNO
51,093.835	0.822	18.5	0.0	1.0	KPNO
51,094.802	0.854	18.5	−0.1	1.0	KPNO
51,471.810	0.376	7.9	0.2	1.0	KPNO
51,472.775	0.408	8.8	0.0	1.0	KPNO
51,731.984	0.018	−3.1	0.0	1.0	KPNO
51,734.987	0.118	−4.3	−0.2	1.0	KPNO
51,735.984	0.151	−2.1	0.1	1.0	KPNO
51,737.981	0.217	1.5	0.1	1.0	KPNO
51,740.980	0.317	5.5	−0.1	1.0	KPNO
51,802.893	0.373	7.5	−0.1	1.0	KPNO

[a] B87: Balona 1987, FMH86: Fekel et al. 1986, KPNO: this paper.

Scarfe, Batten, & Fletcher (1990), is 54.3 km s^{-1}. For a few velocity measurements, β Aql was used as the reference standard. A velocity of −40.2 km s^{-1} was adopted from our unpublished results. All our radial velocities are given in Table 1.

3. PHOTOMETRIC OBSERVATIONS AND REDUCTIONS

We obtained our photometry of HD 10909 with the T3 0.4 m automatic photoelectric telescope (APT) at Fairborn Observatory in the Patagonia Mountains of southern Arizona. This APT uses a temperature-stabilized EMI 9924B bi-alkali photomultiplier tube to acquire data through Johnson B and V filters. The APT is programmed to measure stars in the following sequence, termed a group observation: K, sky, C, V, C, V, C, V, C, sky, K, where K is a check star, C is the comparison star, and V is the program star. A total of 712 group observations of HD 10909 were obtained with the APT during 12 observing seasons from 1988 to 2001, with HD 10701 ($V = 9.37$, $B-V = 1.02$, G8 III) as the comparison star and HD 10830 ($V = 5.29$, $B-V = 0.39$, F2 IV) as the check star.

For each group observation, three $V-C$ and two $K-C$ differential magnitudes in each photometric band were computed and averaged together to create group means. The group means were then corrected for differential extinction with nightly extinction coefficients, transformed to the Johnson system with yearly mean transformation coefficients, and treated as single observations thereafter. The external precision of the group means, based on standard deviations for pairs of constant stars, is typically ~0.004 mag on good nights with this telescope. Group mean differential magnitudes with internal standard deviations greater than 0.01 mag were discarded. The individual differential magnitudes are given in Table 2.[2] Further details of telescope operations and data reduction procedures can be found in Henry (1995a) and Henry (1995b).

4. SPECTROSCOPIC ORBIT

When we resumed observing HD 10909 in the 1990s, we

[2] The photometric observations are also available on the Tennessee State University Automated Astronomy Group Web site, at http://schwab.tsuniv.edu/t3/hd10909/hd10909.html.

TABLE 2

PHOTOMETRIC OBSERVATIONS OF HD 10909

HJD − 2,400,000 (1)	Var B (mag) (2)	Var V (mag) (3)	Chk B (mag) (4)	Chk V (mag) (5)
47415.8503	−1.495	−1.380	−4.731	−4.081
47417.8349	−1.481	−1.381	−4.743	−4.091
47417.9664	−1.477	−1.399	−4.735	−4.115
47418.8399	−1.485	−1.379	−4.740	−4.081
47421.8225	−1.447	−1.357	−4.747	−4.092
47421.9788	−1.460	−1.343	−4.752	−4.089
47422.9441	−1.437	−1.345	−4.737	−4.100
47423.8188	−1.428	−1.319	−4.741	−4.084
47423.9536	−1.426	−1.323	−4.737	−4.079
47424.8197	−1.420	−1.329	−4.746	99.999
47427.8088	−1.374	−1.281	99.999	−4.094
47427.9432	−1.376	−1.298	99.999	99.999

NOTE.—Table 2 is presented in its entirety in the electronic edition of the Astronomical Journal. A portion is shown here for guidance regarding its form and content.

TABLE 3

ORBITAL ELEMENTS OF HD 10909

Parameter	Value
P (days)	30.10674 ± 0.00018
T (HJD)	2,451,099.201 ± 0.052
γ (km s^{-1})	8.761 ± 0.061
K (km s^{-1})	12.53 ± 0.11
e	0.4992 ± 0.0081
ω (deg)	115.20 ± 0.72
$a \sin i$ (km)	4.495 ± 0.045 × 10^6
$f(m)$ ($M_\odot$)	0.00400 ± 0.00012
Standard error for an observation of unit weight......	0.2 km s^{-1}

found that our velocities did not agree with the ephemeris from the orbit of Balona (1987). Thus, we have reexamined the available velocities to determine the correct orbital period. We applied two different period search techniques to the velocities of Balona (1987), which were obtained at the South African Astronomical Observatory (SAAO). In all the following analyses, however, we have excluded the SAAO velocity of HJD 2,444,244.299, which may be a misprint or perhaps belongs to a different star. First, a sine curve was fitted to the remaining 36 SAAO velocities and the sum of the residuals squared was computed for various trial periods between 1.0 and 100 days. The minimum of the summed squared residuals was at 15.06 days, in agreement with the period found by Balona (1987), with a second but less deep minimum at about twice that value. A similar analysis of the SAAO velocities with the least-string method implemented by Deeming (Bopp et al. 1970) resulted in a best period of 30.125 days. Application of both period search techniques to the complete set of velocities, SAAO and McDonald/KPNO, confirmed the 30 day period. The combination of a high eccentricity and a lack of SAAO velocities over nearly half of the orbit contributed to the misidentification of the period.

We analyzed our 24 velocities alone (Table 1) with the period-finding program of Deeming (Bopp et al. 1970) and found a best period of 30.105 days. Adopting this period, we computed preliminary orbital elements with BISP, a computer program that uses a slightly modified version of the Wilsing-Russell method (Wolfe, Horak, & Storer 1967). We refined those elements with a differential corrections program, called SB1, of Barker, Evans, & Laing (1967). With the period fixed at the value determined from that solution, we used SB1 to obtain orbital elements from the 36 SAAO velocities. A comparison of the variances of the two SB1 orbital solutions indicated that the SAAO velocities should be given weights of 0.01 relative to ours. The two center-of-mass velocities were not significantly different, and so our velocities and those obtained at the SAAO were combined in an all-data solution. The orbital elements of that solution were nearly identical to those computed from our velocities alone, and the inclusion of the SAAO velocities did not significantly improve the uncertainties of the elements. Thus, Table 3 lists the orbital elements from the solution of the McDonald and KPNO velocities only. We have, however, included in Table 1 the 36 SAAO velocities along with our 24 velocities. Figure 1 compares both our velocities and those from the SAAO with the computed velocity curve. Zero phase is a time of periastron passage.

5. PHOTOMETRIC VARIABILITY

The 656 good $V-C$ differential magnitudes in the Johnson V photometric band are plotted in Figure 2. Our $K-C$ differential magnitudes are constant from night to night to about 0.008 mag, a scatter somewhat larger than the typical 0.004 mag precision for this telescope. This is due to the star's declination of $-24°$ and the resulting higher than average air mass of our observations. The yearly mean $K-C$ differential magnitudes are constant to better than 0.002 mag. Therefore, the photometric variability in Figure 2 can be completely attributed to HD 10909 with no significant contributions from the comparison star. The photometric amplitude of HD 10909 is observed to vary from a

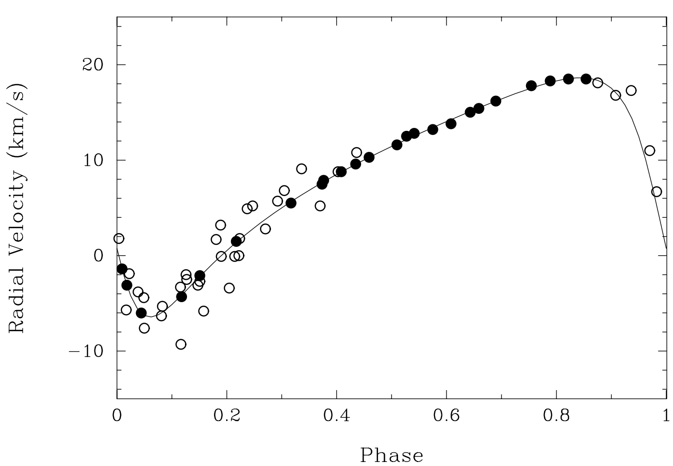

FIG. 1.—Plot of the computed radial-velocity curve of HD 10909 compared with the observations. Filled circles refer to this paper, open circles to Balona (1987). Zero phase is a time of periastron.

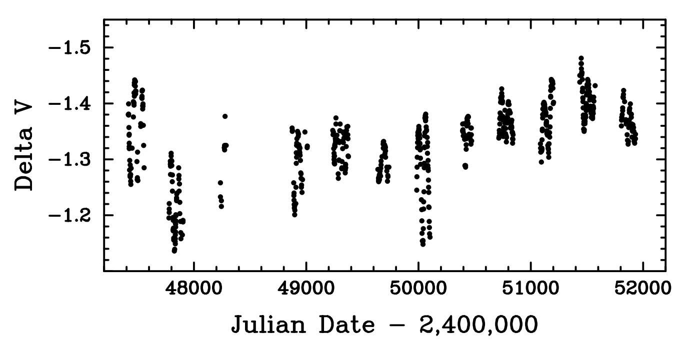

FIG. 2.—Johnson V photometric observations of HD 10909 over 12 observing seasons. Large changes in amplitude and mean magnitude are seen from season to season.

TABLE 4

RESULTS FROM PHOTOMETRIC ANALYSIS

Season (1)	Photometric Band (2)	Date Range (HJD − 2,400,000) (3)	N_{obs} (4)	Mean Brightness (mag) (5)	Period (days) (6)	Full Amplitude (mag) (7)
1	*V*	47,415–47,556	62	−1.3581	65.2 ± 0.6	0.17
1	*B*	47,415–47,556	63	−1.4516	64.4 ± 0.6	0.21
2	*V*	47,777–47,903	57	−1.2182	62.7 ± 0.5	0.16
2	*B*	47,777–47,903	59	−1.2967	62.5 ± 0.6	0.19
3	*V*	48,235–48,288	9	−1.2887	67.3 ± 7.7	0.16
3	*B*	48,235–48,288	8	−1.3630	62.3 ± 2.1	0.15
4	*V*	48,874–49,009	44	−1.2910	65.1 ± 1.3	0.14
4	*B*	48,872–49,009	48	−1.3818	64.9 ± 1.2	0.19
5	*V*	49,236–49,374	56	−1.3215	32.4 ± 0.3	0.10
5	*B*	49,236–49,374	54	−1.4250	32.8 ± 0.3	0.14
6	*V*	49,638–49,736	38	−1.2922	82.0 ± 3.0	0.07
6	*B*	49,638–49,736	39	−1.3907	79.7 ± 3.2	0.09
7	*V*	49,983–50,101	77	−1.2948	65.6 ± 0.7	0.22
7	*B*	49,983–50,101	80	−1.3948	65.4 ± 0.8	0.29
8	*V*	50,391–50,473	36	−1.3471	39.6 ± 1.9	0.09
8	*B*	50,391–50,470	32	−1.4550	38.4 ± 1.0	0.11
9	*V*	50,713–50,841	70	−1.3713	66.2 ± 2.0 28.9 ± 0.8	0.08
9	*B*	50,718–50,841	68	−1.4765	65.6 ± 2.7 28.7 ± 0.8	0.11
10......	*V*	51,085–51,201	70	−1.3742	65.8 ± 1.2	0.14
10......	*B*	51,085–51,201	67	−1.4850	65.6 ± 1.2	0.15
11......	*V*	51,434–51,571	87	−1.4061	64.1 ± 1.0	0.12
11......	*B*	51,429–51,569	86	−1.5139	63.3 ± 1.0	0.12
12......	*V*	51,805–51,932	50	−1.3679	62.8 ± 1.4 30.6 ± 0.9	0.09
12......	*B*	51,805–51,932	50	−1.4736	62.9 ± 1.8 30.7 ± 0.9	0.12

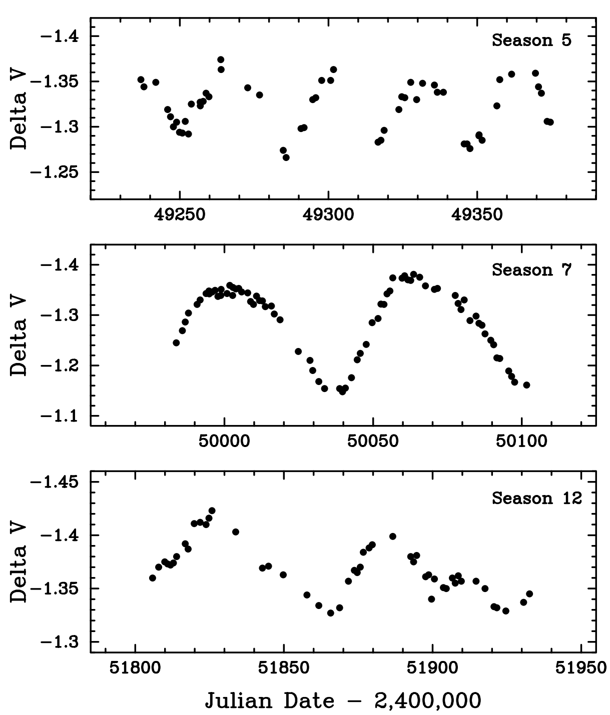

FIG. 3.—Three selected seasons of the Johnson *V* photometry from Fig. 2, replotted with identical expanded scales on the abscissa. Season 5 (*top*) exhibits a photometric period of 32 days. Season 7 (*middle*) has a photometric period close to 64 days. Season 12 (*bottom*) shows the star in transition from the long to the short period.

bit less than 0.1 mag to over 0.2 mag in *V*. The seasonal mean magnitudes are also observed to vary by nearly 0.2 mag in *V*.

We performed separate periodogram analyses on the *V* and *B* observations within each observing season. For each season we also computed the mean magnitude in *V* and *B* and estimated the total light-curve amplitudes. The results are given in Table 4. In the majority of cases, we found photometric periods clustering around 64 days, very close to twice the periods reported earlier by Lloyd Evans & Koen (1987) and Hooten & Hall (1990). However, in seasons 5 and 8, we found the photometric periods to be in essential agreement with the earlier published values. Furthermore, in seasons 9 and 12, we found that both the longer and shorter periods were present simultaneously.

In a chromospherically active star, the day-to-day photometric variations are due primarily to the star's rotation, which modulates the visibility of an asymmetrical distribution of dark starspots, while the longer year-to-year variations are caused by slower variations in the total filling factor of spots (e.g., Eaton, Henry, & Fekel, 1996). At times, many chromospherically active stars display two separate concentrations of spots on nearly opposite hemispheres, causing two photometric maxima and minima per stellar rotation. Thus, the longer period derived from our photometric observations corresponds to the true stellar rotation period, while our shorter period and the periods reported previously in the literature correspond to half the stellar rotation. The weighted mean of our longer periods from

Table 4, excluding the longest periods from season 6 (which, given the small amplitude, we surmise are probably affected by relatively rapid changes in the spot distribution), is 64.1 ± 0.2 days. The weighted mean of our short periods is 32.0 ± 0.2 days, which within the errors is exactly one-half of the longer period value. Thus, we adopt 64.1 ± 0.2 days as our best determination of the true rotation period of HD 10909.

Three selected seasons of the V photometry from Figure 2 are replotted with identical expanded scales on the abscissa in Figure 3. The top panel illustrates an epoch when the 32 day period is dominant, indicating separate concentrations of spots on opposite hemispheres. The middle panel reveals the true stellar rotation period of 64 days, when only one concentration of spots dominates. The bottom panel shows the star in transition between these two spot configurations. We note that the amplitude of the light curve is always relatively small whenever the star has well-separated spot concentrations on opposite hemispheres.

6. SPECTRAL TYPE

The spectral type of HD 10909 was determined by visual comparison with the spectra of late-G and early-K dwarf, subgiant, and giant stars from the lists of Keenan & McNeil (1989) and Fekel (1997). The spectra of those reference stars were obtained at KPNO with the same telescope, spectrograph and detector as our spectra of HD 10909. Strassmeier & Fekel (1990) identified several luminosity-sensitive and temperature-sensitive line ratios in the 6430–6465 Å region. Those critical line ratios and the general appearance of the spectrum were employed as spectral-type criteria. Our red wavelength spectra of HD 10909 appear nearly identical to the spectrum of δ Eri, which has a spectral type of K0 IV (Keenan & McNeil 1989) and [Fe/H] $= -0.07$ (Hearnshaw 1976). Thus, we concur with Bidelman & MacConnell (1973) and Houk & Smith-Moore (1988) that HD 10909 has a K0 IV spectral type. Its iron abundance may be slightly less than that of the Sun.

6.1. *Discussion*

The behaviour of HD 10909's light curve, as exhibited in Figures 2 and 3, can be understood, at least qualitatively, in terms of the random-spot model (RSM) of Eaton et al. (1996). The RSM departs from previous geometric (e.g., Henry et al., 1995) or physical (e.g., Oláh et al., 1997) two-spot models and, instead, uses large numbers (10–40) of moderately sized dark spots placed randomly on a differentially rotating star to reproduce the light curves of chromospherically active stars. The continual redistribution of spots due to stellar differential rotation accounts for much of the changing shape of the light curves. If the spots are also allowed to decay and reappear at random on the star, with typical lifetimes on the order of one year, then, in addition to further changes in the shape of the light curve, the RSM also predicts the kind of long-term light variations observed in most chromospherically active stars, *without* the necessity of invoking magnetic cycles to drive these variations. Eaton et al. (1996) display several light curves computed with the RSM that show uncanny resemblance to the light curves of individual stars, including HD 10909. Hence, this model effectively accounts for the shape and mean light level changes that we observe in the light curve of HD 10909. Because of the RSM's somewhat surprising prediction of slow, long-term variations in mean brightness, we do *not* attribute the long-term variations in HD 10909 seen in Figure 2 to a magnetic cycle operating in the star.

We searched the literature and examined our own data for the brightest known visual magnitude and corresponding $B-V$ of HD 10909. From the APT data in Figure 2, HD 10909 is brightest at the beginning of season 11, where its differential V magnitude is -1.48. To convert this to an apparent V magnitude, we adopted $V = 9.38$ (ESA 1997) for our comparison star, HD 10701. This resulted in a maximum APT magnitude of $V = 7.90$ for HD 10909, which is brighter than any other value found in the literature. O'Neal, Saar, & Neff (1996) showed that on some heavily spotted stars the observed maximum V magnitude underestimates the brightness of the unspotted star by 0.3–0.4 mag. Nevertheless, we have adopted the APT maximum value as the unspotted V magnitude of the primary since for HD 10909 we are unable to determine a specific correction. This magnitude, combined with the *Hipparcos* parallax (ESA 1997), which corresponds to a distance of 130 ± 19 pc, and the assumption of no interstellar reddening, resulted in $M_v = 2.3 \pm 0.3$ mag. A $B-V$ of 0.90 mag from our data was used in conjunction with Table 3 of Flower (1996) to obtain a bolometric correction and effective temperature. These values were used to compute a luminosity $L = 12.1 \pm 0.1$ $L_\odot$ and a radius $R = 4.6 \pm 0.2$ $R_\odot$. The errors in the computed quantities are dominated by the error in the parallax and to a lesser extent by the effective temperature, with the latter error estimated to be ± 100 K. If the unspotted V magnitude were 0.2 mag brighter than our adopted value, the luminosity would be increased by 20% and the radius by 10%. The various quantities are summarized in Table 5. Comparison of our results with the solar abundance evolutionary tracks of Schaller et al. (1992) indicates that the K0 IV primary has a mass of 1.5 ± 0.3 $M_\odot$, a typical value for evolved chromospherically active stars (Popper 1980).

Glebocki & Stawikowski (1997) compared the orbital and rotational inclinations for each of 41 chromospherically active binaries that have asynchronous rotation. For this group of systems they found that the rotational axes are randomly inclined to the orbital planes. Included in their sample was HD 10909, for which they computed an orbital inclination of 22° and a rotational inclination of 43°. They estimated uncertainties of less than 16° for each inclination. The two inclination values resulted in an inclination difference, Δi, of 21°.

Using our newly determined orbital and photometric results, we have redetermined the two inclinations. Fekel (1997) found $v \sin i = 3.0 \pm 1$ km s^{-1}, which was confirmed

TABLE 5

FUNDAMENTAL PROPERTIES OF HD 10909

Parameter	Value	Reference
V (mag)	7.90	This paper
$B-V$ (mag)	0.90	This paper
π (arcsec)	0.00767 ± 0.00110	ESA 1997
Spectral type	K0 IV	This paper
$v \sin i$ (km s^{-1})	3.0 ± 1.0	Fekel 1997
M_V (mag)	2.32 ± 0.31	This paper
L ($L_\odot$)	12.1 ± 0.05	This paper
R ($R_\odot$)	4.6 ± 0.2	This paper
M_A ($M_\odot$)	1.5 ± 0.3	This paper
$M_B(i = 50°)$ ($M_\odot$)......	0.3	This paper

by de Medeiros & Mayor (1999), who determined a value of 2.7 km s^{-1}. From our new rotation period and a mean projected rotational velocity of 2.8 km s^{-1}, we computed $R \sin i = 3.5 \pm 0.9\ R_{\odot}$. With the radius determined above from the *Hipparcos* parallax, this leads to a rotational inclination of 50°.

Stawikowski & Glebocki (1994) noted that for single-lined spectroscopic binaries, an accurate determination of the orbital inclination is not usually possible. They concluded, however, that if the mass function value is less than 0.005 $M_{\odot}$, the mass function is not very sensitive to the adopted primary mass and mass ratio. For such cases they stated that the orbital inclination is relatively well determined with an uncertainty of about 10°.

With our mass function of 0.004 $M_{\odot}$ and an assumed primary mass of 1.5 $M_{\odot}$, we computed the range in orbital inclination for a variety of secondary masses. The secondary is presumably a white dwarf or late-type main-sequence star. However, if the secondary is a white dwarf, we would expect the orbit to be nearly circular like those of most barium stars (Boffin, Cerf, & Paulus 1993). Assuming the secondary is a main-sequence star, its absorption lines should have been detected in our red wavelength spectra if its mass is greater than about 1.1 $M_{\odot}$. Secondary masses of 0.23 and 1.1 $M_{\odot}$ resulted in orbital inclinations of 84° and 16°, respectively. Thus, despite the very small mass function, the orbital inclination of HD 10909 is very poorly constrained at $50° \pm 34°$, and we cannot determine with any accuracy whether the values of the rotational and orbital inclinations are the same. We note that for an orbital inclination of 50°, the value of our mass function, combined with the adopted primary mass, results in a secondary mass of 0.3 $M_{\odot}$.

The two main theories of orbital circularization and rotational synchronization (e.g., Zahn, 1977; Tassoul & Tassoul, 1992) disagree significantly on absolute timescales, but they do agree that synchronization should occur first. Fekel & Eitter (1989) used the data from the first edition of A Catalog of Chromospherically Active Binary Stars (Strassmeier et al. 1988) to determine that only about 10% of the systems with periods less than or equal to 30 days are asynchronously rotating. HD 10909 was identified as one of the systems for which the rotation period of the primary is not approximately equal to the orbital period. Our new analysis indicates that both periods are a factor of 2 larger than previously determined, although for different reasons. Thus, HD 10909 remains an asynchronously rotating system similar to some other chromospherically active binaries such as λ And (e.g., Strassmeier et al., 1993).

Hut (1981) has shown that in an eccentric orbit a star's rotational angular velocity will tend to synchronize with that of the orbital motion at periastron, a condition called pseudosynchronous rotation. With equation (42) of Hut (1981) we calculated a predicted pseudosynchronous period of 10.7 days, a factor of 6 less than the actual rotation period. Its effective temperature and luminosity place HD 10909 near the base of the first-ascent red giant branch. Thus, it appears that its rapidly expanding radius, resulting from its recent evolution through the Hertzsprung gap and current red giant ascent, combined with its relatively long 1 month period and high eccentricity, has produced the current asynchronous rotation situation.

Lou Boyd's dedicated efforts at Fairborn Observatory have been invaluable. The automated astronomy program at Tennessee State University (TSU) is supported in part by NASA grant NCC5-511, which funds TSU's Center for Automated Space Science, NASA grant NCC5-96, and NSF grant HRD-9706268, which funds TSU's Center for Systems Science Research.

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