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TWO NEW SPOTTED VARIABLES—HD 191262 AND HD 191011

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ABSTRACT

New 1988–1990 photometry in V and B with a 16 inch automatic telescope shows that both HD 191262, a previously known chromospherically active binary, and its comparison star HD 191011 are variable, with starspots judged to be the mechanism in both. In HD 191262 and 191011, respectively, spot rotation periods of $5^d.4<P<5^d.7$ and $17^d.4<P<23^d.0$ were found and differential rotation coefficients of $k=0.054$ and 0.28 were estimated. HD 191011, shown to be a K5 giant about 475 parsecs away, had eight different spots present during the 2.5 years of observation.

1. INTRODUCTION

HD 191262 was one of 50 suspected variables studied by Hooten & Hall (1990). Available photometry from nine different telescopes during the interval 1985.46 to 1988.75 had shown a relatively large total range of brightness in V but Fourier analysis failed to show a unique periodicity in all of the data sets and no periodicity in the vicinity of the $5^d.42$ orbital period given by Strassmeier *et al.* (1990). Their verdict on the variability of HD 191262 was "maybe."

A recent spectroscopic orbit by Griffin & Fekel (1990) found a circular orbit with an improved orbital period of $5^d.434350\pm0^d.000011$. Their observed Vsini velocities were compatible with synchronous rotation of both early G type main-sequence components.

We present B and V photometry obtained with the 16 inch automatic telescope, described most recently by Henry *et al.* (1991), between 1988.39 and 1990.86. Hooten & Hall (1990) had used only the V-band photometry from this telescope, one of the nine telescopes mentioned in the first paragraph, and only the early portion between 1988.39 and 1988.75.

It will be shown that HD 191262 is variable with a small amplitude and with periods in the neighborhood of the orbital period. As a chromospherically active binary (Strassmeier *et al.* 1988; Hooten & Hall 1990), its variability had been anticipated, the most likely mechanism being dark starspots.

A surprise in this investigation was that the comparison star, HD 191011, proved to be variable as well, with a somewhat larger amplitude and a longer period, around 20 days. The *Henry Draper Catalogue* gives K5 and $m_v=8^m.09$ and frankly we know nothing more about it. It has never been included in any catalogue of suspected variables.

Throughout this paper, HD 191262 will be referred to as "the variable" and HD 191011 will be referred to as "the comparison star."

2. THE PHOTOMETRY

The photometry used in this investigation was divided into six groups, as shown in Table 1. The second column gives the number of differential magnitudes in each group, not always exactly the same in the two bandpasses. The third column gives the median epoch. The last column gives the time interval covered, in days. During the analysis of HD 191011 we found it advisable to subdivide three of the groups (2, 4, and 5), making the breaks at JD 2447453, 2447810, and 2448027.

A check star, 14 Sge=HR 7664, was used along with the variable and its comparison star, in the symmetrical sequence of integrations described by Boyd *et al.* (1984a, Table I). The resulting photometry was in the form of two differential magnitudes, in the sense variable minus comparison and in the sense check minus comparison, both at the same Julian date. We refer to these as Δ_{vc} and Δ_{kc}, respectively.

The Δ_{vc} and Δ_{kc} magnitudes were correlated in a positive sense, indicating that the comparison star (but not the check star) was variable. There was an additional component of variability in the Δ_{vc} magnitudes which was not manifest in the Δ_{kc} magnitudes, indicating that the variable star was variable after all.

3. THE VARIABILITY OF HD 191262

To investigate the variability of HD 191262 first, we effectively removed the variability of the comparison star. We did this by forming

$$\Delta'_{vc}=\Delta_{vc}-(\Delta_{kc}-K), \quad (1)$$

where $K=-2^m.268$ in V and $-3^m.987$ in B, these constants being the mean value of Δ_{kc} in each bandpass. This was easy to do because the Δ_{vc} and Δ_{kc} values corresponded to the same Julian date. The Δ'_{vc} values now give us the light curve of the variable cleared of the variability of the comparison star.

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TABLE 1. Data groups.

data group	n (V/B)	median epoch	Δt (days) (V/B)
1	54 52	1988.39 1988.39	53 53
2	64 63	1988.83 1988.81	94 85
3	85 81	1989.34 1989.36	99 93
4	56 55	1989.82 1989.81	95 90
5	47 44	1990.34 1990.35	95 91
6	22 22	1990.86 1990.86	56 56

Then we divided this clean light curve into six parts, as specified in Table 1, and fit them using the two-spot fitting technique described by Hall *et al.* (1990). All seven parameters of that technique (the two rotation periods, the two Julian dates of maximum light loss, the amount of the two light losses in magnitude units, and the differential magnitude at maximum brightness when both spots are out of view) were varied. The results are shown in Table 2 (for the V bandpass) and Table 3 (for the B bandpass). The criterion for bestness of fit in this technique is that the sum of the squares of the residuals from the computed light curve be minimized. Some of the light curves were found to show a significant secular trend, either brightening or fading. This effect was removed by allowing the calculated curve to slope up or down. The entry in the next-to-last column indicates the slope applied, in units of magnitude/day, where negative/positive means the light curve brightens/fades. The last column is the rms deviation from the calculated curve. Uncertainties for the various parameters were determined by chi-squared analysis.

TABLE 2. Parameters of HD 191262 light curve fits in V.

data group	P(rot.) (days)	JD(min.) 2440000+	ampl. (mag.)	ΔV(max.) (mag.)	slope (mag/day)	r.m.s. (mag.)
1	5.555 ±.025	7303.24 ±.09	0.017 ±.002	-0.0192 ±.0009	-0.00023	±0.0059
	5.510 ±.047	7306.80 ±.10	0.013 ±.002			
2	5.727 ±.033	7464.25 ±.18	0.014 ±.002	-0.0229 ±.0010	+0.00012	±0.0077
	5.523 ±.016	7466.56 ±.10	0.015 ±.002			
3	5.497 ±.018	7652.76 ±.09	0.018 ±.002	-0.0318 ±.0010	-0.00012	±0.0088
	5.377 ±.022	7654.52 ±.10	0.013 ±.002			
4	5.458 ±.015	7825.25 ±.12	0.020 ±.003	-0.0275 ±.0016	+0.00015	±0.0111
	5.428 ±.067	7828.29 ±.32	0.010 ±.003			
5	5.621 ±.029	8025.51 ±.12	0.015 ±.002	-0.0249 ±.0013	0.00000	±0.0086
	5.562 ±.062	8029.37 ±.19	0.010 ±.003			
6	5.689 ±.066	8202.90 ±.16	0.020 ±.003	-0.0498 ±.0019	0.00000	±0.0074
	5.471 ±.054	8206.11 ±.14	0.023 ±.004			

TABLE 3. Parameters of HD 191262 light curve fits in B.

data group	P(rot.) (days)	JD(min.) 2440000+	ampl. (mag.)	ΔV(max.) (mag.)	slope (mag/day)	r.m.s. (mag.)
1	5.440 ±.033	7303.06 ±.08	0.018 ±.002	-0.9927 ±.0012	0.00000	±0.0082
	5.481 ±.059	7306.52 ±.08	0.014 ±.003			
2	5.687 ±.021	7463.71 ±.11	0.015 ±.002	-0.9912 ±.0011	+0.00015	±0.0081
	5.539 ±.022	7466.77 ±.12	0.014 ±.002			
3	5.500 ±.022	7652.78 ±.12	0.016 ±.003	-1.0021 ±.0012	-0.00017	±0.0102
	5.357 ±.049	7654.62 ±.23	0.008 ±.002			
4	5.521 ±.039	7825.24 ±.16	0.015 ±.003	-0.9944 ±.0013	+0.00018	±0.0090
	5.408 ±.031	7828.63 ±.14	0.011 ±.002			
5	5.601 ±.046	8025.14 ±.17	0.016 ±.003	-0.9856 ±.0018	0.00000	±0.0096
	5.591 ±.242	8029.50 ±1.15	0.003 ±.008			
6	5.597 ±.058	8202.82 ±.09	0.028 ±.003	-1.0194 ±.0017	0.00000	±0.0065
	5.558 ±.093	8205.93 ±.15	0.015 ±.003			

Because the periods in Tables 2 and 3 are uncertain by about ±1% and because the data groups are separated by more than 30 rotation cycles, we judged that correct cycle count was effectively lost between the data groups. That prevented us from investigating the long-term behavior of the spots in HD 191262.

4. THE VARIABILITY OF HD 191011

In a sense we have available four almost-independent light curves of our comparison star, the new variable we had not expected to discover.

A plot of Δ_{kc} versus Julian date, with the algebraic sign of each differential magnitude reversed, should be a light curve of HD 191011. Let us say

$$\Delta_{ck} = -\Delta_{kc} \,. \tag{2}$$

If we wish this light curve of HD 191011 to have a mean level of $0^{\mathrm{m}}.0$, we can say

$$\Delta_c = \Delta_{ck} + K, \tag{3}$$

where K has been defined already. This gives us two light curves, one in V and one in B.

If we form O−C residuals in the sense observed Δ_{vc} values (not Δ'_{vc}) minus values calculated analytically with the parameters in Tables 2 and 3, the result, after a change in algebraic sign, should be another light curve of HD 191011. Such a light curve will naturally have a mean level of $0^{\mathrm{m}}.0$. This gives us two more light curves, one in V and one in B.

To investigate the nature of the variability of HD 191011, we mixed the two V light curves together and the two B light curves together and fit each one with the same two-spot technique of Hall *et al.* (1990) described above. This implies we believe starspots are causing the variability in this star as well, which we do, as will be discussed in Sec. 6 of this paper.

The fitting was very difficult, not only because of the small amplitude of the variability but also because we had no *a priori* knowledge of the rotation period of this spotted star. Although HD 191262 had a comparably small amplitude, we knew from the previously established synchronism that its spots would rotate with periods within a few percent of the $5\overset{\mathrm{d}}{.}43$ orbital period. Fitting of starspot variability is always complicated by the fact that at least two spots may be present in the light curve at any time, different spots can have different rotation periods, and any one spot will not remain in existence indefinitely. This last complication is at its worst in this case because relatively small spots, implied by the small amplitude of the variability, have shorter lifetimes (months) than do large spots (years), as shown by Hall & Busby (1990). A generous number of data points was required if there was to be hope of finding a determinate fit. On the other hand, a data group covering too wide a time span might include the death of one spot and the birth of a new one, with a different period for each and a longitude discontinuity at the interface. By trial and error we ascertained that fitting would be most successful if three of the data groups in Table 1 were subdivided, as explained in the second paragraph of Sec. 2. Parameters were determined for the resulting nine data groups, separately in V and B. It turned out that all of the seven parameters in V and B were generally equal within their respective uncertainties, even the amplitudes. Therefore, for greater statistical weight and convenience in presenting the results, we decided to mix the two V light curves and the two B light curves together and determine parameters for the resulting nine composite data groups.

Figures 1 through 6 are these composite light curves of HD 191011, with different symbols for magnitudes derived from the check star's V and B light curves (Δ_c) and for those derived from residuals from the variable star's calculated V and B light curves. Arrows indicate the breaks which subdivided data groups 2, 4, and 5.

The resulting parameters are shown in Table 4, where the column entries are equivalent to those in Tables 2 and 3. Only the first data group showed a significant secular trend, brightening at a rate of 0.00070 mag/day.

Sense is made of these results when we compute phases for the JD(min.) values using the ephemeris

$$\mathrm{JD(min)} = 2\,447\,270.0 + 20\overset{\mathrm{d}}{.}0\ E, \tag{4}$$

where the period has been chosen arbitrarily but near the rotation period average for all of the spots. Figure 7 is a so-called spot migration curve, where the abscissa is E, number of rotation cycles, and the ordinate is fractional phase as computed with Eq. (4). The ordinate is equivalent to stellar longitude, with 0.25 in fractional phase corresponding to 90° in longitude. Although each data group yielded only one value of JD(min.) for each of the two spots, its time span generally included more than one time of minimum light for each spot. For this reason we have plotted additional values of JD(min.) in Fig. 7. For example, one of the spots in data group 1 had JD(min.) $=2\,447\,306.47$ and $P(\mathrm{rot.}) = 18\overset{\mathrm{d}}{.}31$. Therefore we have computed phases for the spot oppositions $18\overset{\mathrm{d}}{.}31$ earlier and $18\overset{\mathrm{d}}{.}31$ later and plotted all three in the migration curve, at fractional phases 0.91, 0.82, and 0.74.

Applying the double criterion of continuity in phase and constancy of slope, we have used Fig. 7 to identify eight spots, designated A through H. Those same designations are given in the last column of Table 4. All but two spots were alive in more than one data group or subgroup. For them linear fits of their JD(min.) values versus E yielded

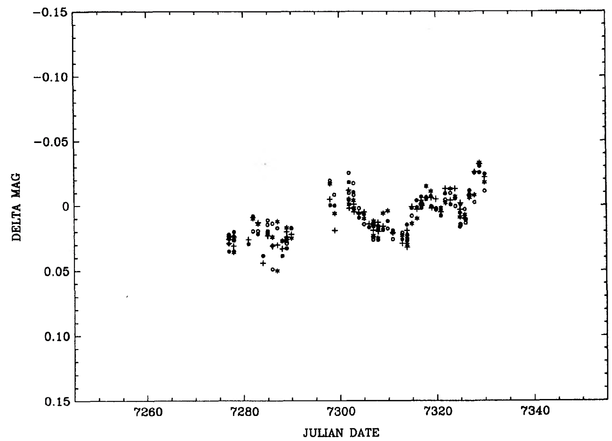

FIG. 1. Light curve of HD 191011 in early 1988, data group 1. The + and * symbols represent V and B bandpass measurements, respectively, made differentially with respect to the check star 14 Sge. The filled and open circles represent V and B bandpass measurements, respectively, made differentially with respect to HD 191262 after that star's own variability was removed with the elements in Tables 2 and 3.

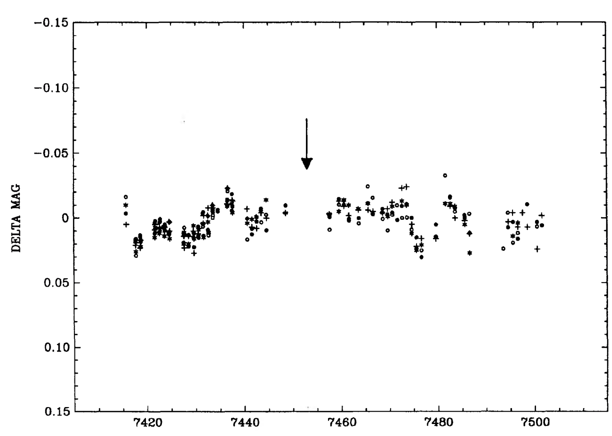

FIG. 2. The same as Fig. 1, in late 1988, data group 2. The arrow marks the break between subgroups 2a and 2b.

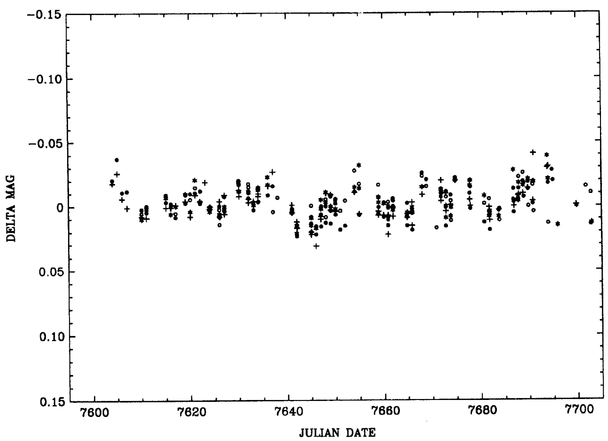

FIG. 3. The same as Fig. 1, in early 1989, data group 3.

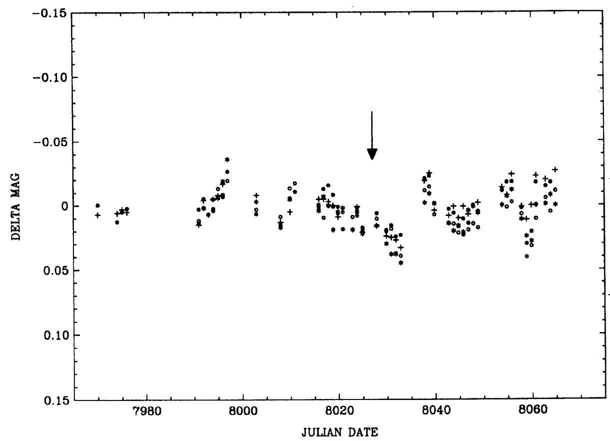

FIG. 5. The same as Fig. 1, in early 1990, data group 5. The arrow marks the break between subgroups 5a and 5b.

their rotation periods rather accurately. These periods are summarized in Table 5, along with the data groups in which they alive. For spots A and E, which were alive in only one data group, their rotation periods were taken directly from Table 4. Column 3 gives the number of values of JD(min.) included in each linear fit and column 5 is the rms deviation of those values from each fit. The last two columns list the maximum amplitude reached by each spot and the duration of its lifetime, in years. These linear fits work quite well, with the average rms deviations corresponding to only $\pm 0^{d}.6$ or ± 0.03 in phase.

5. DISCUSSION OF HD 191262

Griffin & Fekel (1990) had concluded that their observed Vsini velocities were compatible with synchronous rotation of both early G type main-sequence components, when they assumed reasonable masses to estimate the orbital inclination. On the other hand, synchronous rotation of both components is virtually assured in a binary composed of two convective stars bound in an orbit with such a short period (Hall & Henry 1990).

The rotation periods in Tables 2 and 3 show a range of $5^{d}.4 < P < 5^{d}.7$, which corresponds to $\Delta P/P = 0.054$. It is generally accepted that such a range in rotation periods reflects differential rotation as a function of latitude (Hall & Busby 1990). Traditionally one uses an expression like

$$P_\phi = P_{\rm EQ}/(1 - k \sin^2 \phi) \tag{5}$$

to describe such differential rotation, where ϕ is stellar latitude. If the spot periods in Tables 2 and 3 represent spots which occurred somewhere over most of the entire 90° range of latitude, then $k = 0.054$ for HD 191262. If their latitude range was somewhat less than the entire 90° range, then $k > 0.054$.

Hall (1991) analyzed a sample of 85 spotted stars and found a correlation between k and P(rot.), namely,

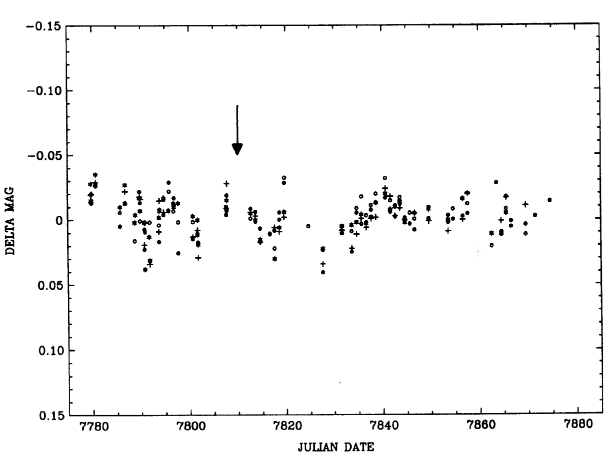

FIG. 4. The same as Fig. 1, in late 1989, data group 4. The arrow marks the break between subgroups 4a and 4b.

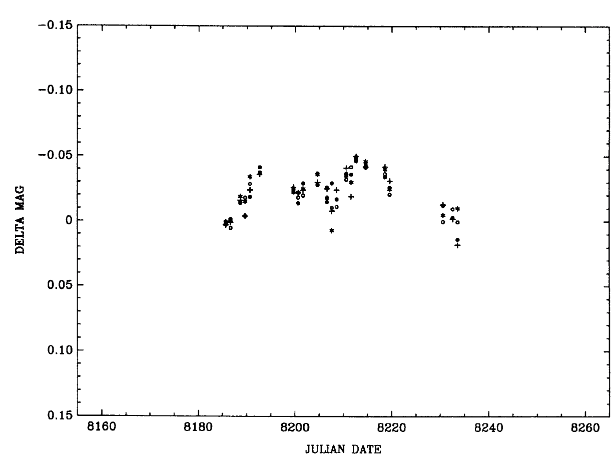

FIG. 6. The same as Fig. 1, in late 1990, data group 6. This is the only data group obtained after the new belt drive system was installed.

TABLE 4. Parameters of HD 191011 light curve fits.

data group	n	P(rot.) (days)	JD(min.) 2440000+	ampl. (mag.)	Δm(max.) (mag.)	r.m.s. (mag.)	spot name
1	208	18.31 ±.26	7306.47 ±.12	0.019 ±.001	+0.0009 ±.0007	±0.0098	A
		19.96 ±.16	7313.63 ±.17	0.025 ±.002			B
2a	146	26.11 ±.68	7428.44 ±.15	0.031 ±.001	-0.0149 ±.0006	±0.0071	B
		23.15 ±.18	7442.53 ±.16	0.026 ±.001			C
2b	104	21.45 ±.36	7476.63 ±.26	0.025 ±.002	-0.0123 ±.0009	±0.0098	D
		22.66 ±.86	7488.30 ±.51	0.013 ±.002			C
3	319	18.04 ±.23	7645.19 ±.19	0.014 ±.001	-0.0102 ±.0004	±0.0101	E
		21.38 ±.27	7662.66 ±.35	0.008 ±.001			D
4a	84	19.19 ±.48	7791.91 ±.25	0.041 ±.003	-0.0302 ±.0014	±0.0122	G
		16.50 ±.17	7799.99 ±.14	0.044 ±.003			F
4b	120	17.58 ±.08	7827.94 ±.38	0.024 ±.002	-0.0179 ±.0009	±0.0101	G
		17.90 ±.08	7834.47 ±.19	0.025 ±.002			F
5a	79	16.50 ±.37	8002.06 ±.39	0.018 ±.002	-0.0160 ±.0009	±0.0076	G
		16.30 ±.25	8007.45 ±.18	0.026 ±.002			F
5b	78	18.15 ±.17	8032.44 ±.12	0.039 ±.003	-0.0141 ±.0011	±0.0111	H
		16.08 ±.13	8043.38 ±.19	0.029 ±.002			F
6	85	20.69 ±.18	8208.78 ±.15	0.041 ±.002	-0.0560 ±.0010	±0.0088	H
		16.59 ±.16	8217.48 ±.16	0.035 ±.002			F

$$\log k = -2.02 + 0.79 \log P(\mathrm{rot.}) - 0.42\ F, \qquad (6)$$
$$\pm 0.12 \pm 0.06 \qquad\qquad \pm 0.16$$

where P(rot.) is in days and F is Roche lobe filling fraction. For HD 191262 we have P(rot.) = 5$^{\rm d}$55 and F = 1/6, so Eq. (6) indicates $k = 0.032 \pm 0.010$, which compares reasonably well with the observed $k = 0.054$. For comparison, we know $k = 0.19$ for the Sun.

The two components are virtually identical in mass and indistinguishable in spectral type and luminosity (Griffin & Fekel 1990). That means the spots we see could reasonably reside on either or both. Moreover, due to the light dilution effect, the spot amplitudes in Tables 2 and 3 which we have determined should be intrinsically greater by a factor 2, with the true maximum amplitude being 0$^{\rm m}$045 in V and 0$^{\rm m}$055 in B.

In addition to the starspot variability *per se*, the magnitude at maximum brightness varied during the 2.5 years of observation, generally brightening by 0$^{\rm m}$03 in V and 0$^{\rm m}$02 in B. Correction for light dilution, as explained in the above paragraph, would change those numbers to 0$^{\rm m}$06 in V and 0$^{\rm m}$04 in B.

We did Fourier analysis of the O−C residuals of the Δ'_{vc} values from the fits in Tables 2 and 3 to look for a measurable ellipticity effect, using the time of conjunction and orbital period of Griffin & Fekel (1990). The resulting

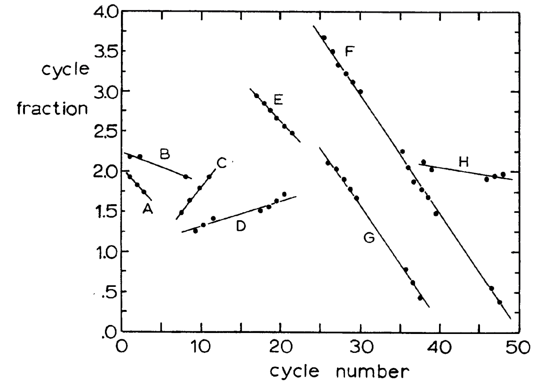

FIG. 7. The migration curve of HD 191011, where the abscissa is E, number of rotation cycles, and the ordinate is fractional phase computed with Eq. (4). The ordinate is equivalent to stellar longitude, with 0.25 in fractional phase corresponding to 90° in longitude. Eight spots, designated A through H, are identified. The points come from the values of JD(min.) in Table 4, and linear fits of JD(min.) vs E yield the rotation periods given in Table 5. From the slopes one can see that six of these spots rotated faster than 20 days, two slower. Note that spot F lived the longest, 1.24 years or more.

coefficient of the $\cos 2\theta$ term was vanishingly small to within ±0.001. A pair of equally bright early G type dwarfs in a binary with P(orb.) = 5$^{\rm d}$43435 and $i = 45°$ should (Hall 1990) produce a $\cos 2\theta$ coefficient of −0.0002, so our finding is consistent.

6. DISCUSSION OF HD 191011

Use of the two-spot fitting technique of Hall *et al.* (1990) to describe the light curves of HD 191011 implied conviction that starspots were causing the variability in this star. Frankly no other mechanism seems reasonable. The K5 spectral type rules out Cepheid, RR Lyrae, Ap, and δ Scuti variability. The time scale, around 20 days, rules out Mira or semiregular variability. The continuous nature of the variability argues against eclipses. And the lack of a single periodicity in the total data set argues against HD 191011 being an ellipsoidal variable. On the other hand, an overview of the starspot variability phenomenon (Hall 1991) indicates that any dwarf of spectral type K5 rotating faster than about 27 days *should* show

TABLE 5. Spot periods.

spot name	data groups included	number JD(min.)	P(rot.) (days)	r.m.s. (days)	max.ampl. (mag.)	lifetime (years)
A	1	3	18.31 ± 0.26	± 0.13	0.019	> 0.15
B	1,2a	3	19.23 ± 0.10	± 0.55	0.031	> 0.48
C	2a,2b	4	22.99 ± 0.05	± 0.12	0.026	0.15
D	2b,3	7	20.68 ± 0.08	± 0.94	0.025	0.68
E	3	6	18.04 ± 0.23	± 0.19	0.014	0.27
F	4a,4b,5a,5b,6	14	17.38 ± 0.03	± 0.80	0.044	> 1.24
G	4a,4b,5a	8	17.42 ± 0.05	± 0.70	0.041	0.68
H	5b,6	5	19.69 ± 0.11	± 1.05	0.042	> 0.57

measurable starspot variability, with the limits being even more generous for larger stars: 67 days for a K5 subgiant and even longer for a K5 giant.

Given that $V=5^{m}67$ and $B-V=-0^{m}10$ for the check star 14 Sge and the mean values $\Delta_{kc}V=-2^{m}268$ and $\Delta_{kc}B=-3^{m}987$, we know that $V=7^{m}94$ and $B-V=1^{m}62$ for HD 191011. A K5 star should have an intrinsic color around $(B-V)_0=1^{m}11$, $1^{m}40$, or $1^{m}71$ depending on whether it is luminosity class V, III, or I, respectively. Considering canonical values of absolute magnitude for K5 stars of various luminosity classes, the ratio between interstellar absorption and interstellar reddening ($A_V/E_{B-V}=3.0$), and a rough distance versus absorption relation ($A_V=1$ mag/kpc), one finds that HD 191011 can be understood best as a K5 giant with $M_V=-1^{m}0$, $(B-V)_0=1^{m}45$, $d=475$ parsecs, and $E_{B-V}=0^{m}2$. We have no information as to whether this is a single or a binary star or, if it is single, why it is rotating relatively rapidly compared to most other K5 giants.

The convective turnover time for a K5 giant of $(B-V)_0=1^{m}45$ should be about 400 days (Hall 1990, Fig. 3). The 20-day rotation period would make the Rossby number be 0.05, quite enough smaller than the Ro=2/3 limit required to generate strong dynamo action within the star and consequently make it chromospherically active and heavily spotted.

The range of rotation periods observed for the eight spots, $17^{d}4<P<23^{d}0$, corresponds to $\Delta P/P=0.28$. If those eight spots occurred somewhere over the entire 90° range of latitude, then $k=0.28$. If their latitude range was somewhat less than the entire 90° range, then $k>0.28$. With P(rot.)=20 days and $F=0$, Eq. (6) indicates $k=0.11\pm0.03$, which is not very far from the observed value $k=0.28$.

We can point to already known spotted variables which resemble what we see in HD 191011. One is HD 116204 =BM CVn (K1 III, $P=21^{d}7$ $\Delta V=0^{m}06$) which happens to be binary (Boyd *et al.* 1984b). Another is HD 31993 =V1192 Ori (K2 III, $P=28^{d}7$, $\Delta V=0^{m}056$) which happens to be single (Hooten & Hall 1990).

7. FINAL REMARKS

We can understand why the Fourier analysis by Hooten & Hall failed to find a periodicity in the vicinity of the orbital period for HD 191262. With two spots present in every data group and tending to be situated on opposite hemispheres, as we found to be the case, there would have been more power at P(orb.)/2 than at P(orb.). Moreover, the variability of their comparison star, with a slightly larger amplitude, which they had not suspected, further complicated the structure of the periodogram.

The rms deviations seen in the last column of Tables 2, 3, and 4 range from $\pm0^{m}006$ to $\pm0^{m}012$. As such they reflect the changes in photometric accuracy experienced by the 16 inch telescope during those years. It deteriorated progressively a little after "first light" in November 1987 up to the "summer shut down" of 1990, at which time the worn worm gear drive system was replaced with a better belt drive system (Henry *et al.* 1991). Our data group 6, the last one, was obtained after the replacement.

The full range of brightness covered during the 2.5 year time interval, including the light losses due to the two rotating spots *and* the variability in the light level at maximum from one data group to the next, was $0^{m}048$ in V and $0^{m}050$ in B for HD 191262 and $0^{m}082$ for HD 191011 in its composite V,B light curve.

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REFERENCES

Boyd, L. J., Genet, R. M., & Hall, D. S. 1984a, IAPPP Communication No. 15, 20

Boyd, L. J., Genet, R. M., & Hall, D. S. 1984b, IBVS No. 2546

Griffin, R. F., & Fekel, F. C. 1990, J. A. A. 11, 43

Hall, D. S. 1990, AJ 100, 554

Hall, D. S. 1991, in The Sun and Cool Stars: Activity, Dynamos, Magnetism, edited by I. Tuominen, D. Moss, and G. Rüdiger (Springer, Berlin), p. 353

Hall, D. S., & Busby, M. R. 1990, in Active Close Binaries, edited by C. Ibanoglu (Kluwer, Dordrecht), p. 377

Hall, D. S., & Henry, G. W. 1990, in Active Close Binaries, edited by C. Ibanoglu (Kluwer, Dordrecht), p. 287

Hall, D. S., Henry, G. W., & Sowell, J. R. 1990, AJ 99, 396

Henry, G. W., Nagarajan, R., & Busby, M. R. 1991, IAPPP Communication No. 45, 11

Hooten, J. T., & Hall, D. S. 1990, ApJS 74, 225

Strassmeier, K. G., Hall, D. S., Zeilik, M., Nelson, E., Eker, Z., & Fekel, F. C. 1988, A&AS 72, 291

Strassmeier, K. G., Fekel, F. C., Bopp, B. W., Dempsey, R. C., & Henry, G. W. 1990, ApJS 72, 191