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CHROMOSPHERICALLY ACTIVE STARS. XXVI. THE DOUBLE-LINED LATE-TYPE BINARY HD 19485 = WZ ARIETIS[1]

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ABSTRACT

We have used spectroscopic observations to determine the orbital elements and some basic properties of the double-lined spectroscopic binary HD 19485 = WZ Ari. The orbital period is 6.247854 days, and the orbit is circular. The G5 V primary and K0 V secondary are chromospherically active. One star or possibly both are synchronously rotating. Based on the *Hipparcos* parallax and the magnitude differences derived in this work, we find that both components are approximately 1 mag above the zero-age main sequence, a result that is inconsistent with the assumption that the components are coeval. We discuss some possible solutions to this anomaly, but none of them satisfactorily resolve the problem.

Key words: binaries: spectroscopic — stars: late-type

1. INTRODUCTION

HD 19485 (WZ Ari, HIP 14610; $\alpha = 03^h08^m40.7^s$, $\delta = 25°35'30.6''$ [J2000.0]; $V = 8.2$ mag) was observed at the David Dunlap Observatory (DDO) as part of a radial velocity survey of over 1000 late-type stars (Heard 1956). When the extensive results were published, Heard (1956) reported HD 19485 to be a double-lined spectroscopic binary with a composite spectral type of G5 V. Strassmeier et al. (1990) presented a spectrum of HD 19485 that showed the modest Ca II H and K emission of both components. Hooten & Hall (1990) analyzed three photometric data sets and found periods ranging from 5.79 to 6.45 days and a maximum *V*-magnitude amplitude of 0.03. The *Hipparcos* team (Perryman et al. 1997) determined a similar photometric period of 6.59 days from satellite observations. Kazarovets et al. (1993) gave HD 19485 the variable star name WZ Ari and assigned it to the RS CVn variability class. The system is listed among the more than 200 binaries collected for the second edition catalog of chromospherically active binaries (Strassmeier et al. 1993).

2. SPECTROSCOPIC OBSERVATIONS AND REDUCTIONS

From 1991 December through 2006 September we obtained 29 red wavelength spectrograms of HD 19485, 28 of which show double lines. The observations were acquired with the Kitt Peak National Observatory (KPNO) coudé feed telescope, coudé spectrograph, and a TI CCD detector. All the spectrograms are centered at 6430 Å, cover a wavelength range of 84 Å, and have a resolution of 0.21 Å. Typical signal-to-noise ratios are 150–200. A single blue wavelength observation was obtained on 2006 September 27. This spectrogram is centered at 4500 Å, covers a wavelength range of 87 Å, and has a resolution of 0.22 Å.

Heard (1956) reported that 17 moderate-dispersion blue wavelength spectrograms, some of them showing two sets of lines, were acquired at the DDO. Although Heard (1956) stated that an orbit would be computed from the radial velocity measurements, neither the velocities nor an orbit were ever published. The 17 DDO observations were acquired from 1947 through 1950. A final spectrogram was taken in 1958 November, after the velocity survey of Heard (1956) was published. The first two DDO spectrograms have dispersions of 33 Å mm^{-1} at Hγ, while the remainder have a dispersion of 66 Å mm^{-1} at Hγ. The radial velocities measured from those 18 photographic spectra are listed in Table 1.

Radial velocities from the KPNO spectrograms were determined with the IRAF cross-correlation program `fxcor` (Fitzpatrick 1993). The primary cross-correlation reference star was the IAU velocity standard 10 Tau, for which a velocity of 29.7 km s^{-1} (Scarfe et al. 1990) was adopted. Those radial velocities are also given in Table 1.

In 2006 December, seven echelle spectrograms were obtained with the Tennessee State University 2 m automatic spectroscopic telescope (AST) at Fairborn Observatory, situated near Washington Camp, Arizona. The spectra were not measured to determine radial velocities but were examined for the presence of the lithium line at 6708 Å. Because of their relatively low signal-to-noise ratios, the spectra first were shifted in wavelength and then added together to enhance visibility of the lines of the primary. The shift-and-add procedure was performed a second time on the original spectra to improve detection of the secondary spectrum.

3. ORBIT

An initial spectroscopic period of 6.248 days was determined by fitting a sine curve to the 30 KPNO velocities of the primary (Table 1) for trial periods between 1.0 and 20 days with a step size of 0.001 days. For each period the sum of the squared residuals was computed, and the period with the smallest value of that sum was identified as the preliminary value of the orbital period. Initial orbital elements for the primary then were computed with BISP (Wolfe et al. 1967), a computer program that

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TABLE 1
Radial Velocities of HD 19485

Hel. Julian Date (HJD − 2,400,000)	Phase	V_A (km s^{-1})	$(O-C)_A$ (km s^{-1})	V_B (km s^{-1})	$(O-C)_B$ (km s^{-1})	Source[a]
32,503.725[b]	0.033	69.2	0.9	. . .	. . .	DDO
32,846.786[b]	0.941	61.5	−4.0	−56.3	1.3	DDO
33,168.897	0.497	−48.6	4.0	. . .	. . .	DDO
33,173.898	0.297	−6.5	2.9	. . .	. . .	DDO
33,190.842	0.009	67.3	−2.2	−59.7	2.5	DDO
33,203.857	0.092	57.3	−2.3	. . .	. . .	DDO
33,205.829	0.408	−42.5	0.2	81.2	13.4	DDO
33,209.843	0.050	64.8	−1.8	−62.9	−4.1	DDO
33,217.822	0.328	−15.8	4.3	. . .	. . .	DDO
33,218.800	0.484	−53.3	−1.0	78.0	−0.9	DDO
33,222.679	0.105	59.0	2.2	−55.4	−7.9	DDO
33,253.667	0.065	63.7	−0.9	. . .	. . .	DDO
33,253.713	0.072	68.4	5.0	−60.8	−5.6	DDO
33,265.740	0.997	70.0	0.4	−59.2	3.1	DDO
33,280.652	0.384	−38.2	−1.2	. . .	. . .	DDO
33,281.657	0.545	−49.6	0.6	74.8	−1.7	DDO
33,293.628	0.461	−49.2	1.5	81.9	4.8	DDO
36,508.856	0.074	60.8	−2.3	−55.2	−0.4	DDO
48,605.820[c]	0.253	8.3	1.0	. . .	. . .	KPNO
48,913.892	0.561	−48.4	−0.3	74.9	0.8	KPNO
49,245.930	0.706	−7.6	0.7	26.4	−1.5	KPNO
49,248.861	0.175	36.6	0.3	−24.6	−0.9	KPNO
49,250.933	0.507	−52.0	0.6	78.5	−0.7	KPNO
49,302.904	0.825	37.2	1.0	−22.7	0.9	KPNO
49,622.988	0.056	65.9	0.0	−58.6	−0.6	KPNO
49,968.982	0.434	−47.6	−0.2	73.6	0.3	KPNO
50,362.856	0.475	−51.3	0.6	78.5	0.0	KPNO
50,363.878	0.639	−30.6	0.2	54.3	0.3	KPNO
50,365.905	0.963	67.3	−0.7	−60.3	0.1	KPNO
50,399.882	0.402	−41.4	−0.1	66.2	0.0	KPNO
50,719.959	0.631	−32.8	0.1	56.2	−0.3	KPNO
50,753.858	0.057	65.7	0.0	−57.8	0.0	KPNO
50,755.874	0.380	−36.3	−0.3	59.7	−0.4	KPNO
51,089.961	0.852	44.9	−0.2	−33.7	0.2	KPNO
51,091.868	0.157	42.2	0.1	−29.8	0.6	KPNO
51,093.879	0.479	−52.2	−0.1	78.8	0.1	KPNO
51,094.950	0.651	−27.8	−0.6	49.7	−0.2	KPNO
51,471.940	0.990	69.7	0.2	−61.7	0.5	KPNO
51,474.928	0.468	−51.2	0.2	77.8	−0.1	KPNO
51,802.916	0.964	67.9	−0.2	−60.2	0.3	KPNO
52,540.997	0.098	58.4	−0.1	−50.2	−0.8	KPNO
52,902.932	0.027	68.8	0.1	−60.5	0.8	KPNO
53,276.969	0.894	56.4	0.0	−47.5	−0.4	KPNO
53,277.957	0.052	66.4	0.0	−58.6	0.0	KPNO
53,639.922	0.986	69.0	−0.4	−61.9	0.1	KPNO
54,002.907	0.084	61.6	0.2	−53.5	−0.7	KPNO
54,004.964	0.413	−43.8	−0.1	69.3	0.4	KPNO
54,005.835[d]	0.552	−49.9	−0.6	75.7	0.2	KPNO

[a] DDO = David Dunlap Observatory, KPNO = Kitt Peak National Observatory.
[b] Dispersion = 33 Å mm^{-1} at Hγ. All other DDO spectrograms have dispersions of 66 Å mm^{-1} at Hγ.
[c] Spectrum is single-lined, given zero weight in the orbital solution.
[d] Central wavelength 4500 Å.

implements a slightly modified version of the Wilsing-Russell method. The orbit was then refined with SB1 (Barker et al. 1967), a program that uses differential corrections. An orbit for the KPNO velocities of the secondary was also computed. The variances of the solutions for the primary and secondary resulted in weights of 0.5 for the secondary velocities relative to those of the primary. Then the primary and secondary velocities were solved simultaneously with SB2, a modified version of SB1. Because the eccentricity of this solution is extremely small, 0.0023 ± 0.0015, a circular orbit solution was computed with SB2C (D. Barlow 1998, private communication), which also uses differential corrections to determine the elements. The tests of Lucy & Sweeney (1971) indicate that the circular orbit solution is to be preferred.

One of us (C. T. B.) examined the original DDO measuring sheets to extract the observation times and radial velocities of the DDO spectra. The composite spectrum of this late-type, double-lined spectroscopic binary has an extremely high line density in the blue region. Even with a modest magnitude difference between the

TABLE 2
ORBITAL ELEMENTS AND RELATED PARAMETERS OF HD 19485

Parameter	Value
P (days)	6.2478536 ± 0.0000054
T_0 (HJD)	2,451,472.0040 ± 0.0017
γ (km s^{-1})	8.497 ± 0.060
K_A (km s^{-1})	61.100 ± 0.088
K_B (km s^{-1})	70.81 ± 0.12
e	0.0 (adopted)
$M_A \sin^3 i$ ($M_\odot$)	0.7993 ± 0.0031
$M_B \sin^3 i$ ($M_\odot$)	0.6898 ± 0.0023
$a_A \sin i$ (10^6 km)	5.2493 ± 0.0075
$a_B \sin i$ (10^6 km)	6.0832 ± 0.0107
Standard error of an observation of unit weight (km s^{-1})	0.4

components, the lines of the secondary are difficult to identify and measure. Thus, we used only the primary star velocities to obtain orbital elements from the DDO spectrograms. With all elements varied, we obtained a circular orbit solution with a period of 6.24763 ± 0.00017 days and a center-of-mass velocity of 10.8 ± 0.8 km s^{-1}, compared with a period of 6.247865 ± 0.000007 days and a systemic velocity of 8.50 ± 0.06 km s^{-1} for the KPNO circular orbit solution noted above.

Before the velocities of the two observatories were combined to determine an orbital solution, the zero points of the velocity systems were examined to assess possible differences. In the case of HD 7308 Griffin (1980) added −5 km s^{-1} to the DDO velocities to offset the systematic velocity difference between the DDO velocities and those obtained with the photoelectric spectrometer at Cambridge, England. Combining DDO velocities from the Heard (1956) survey with those from KPNO for HD 136901, Fekel et al. (1989) added −3 km s^{-1} to the nine DDO velocities. In the present instance, the center-of-mass velocity difference of the DDO and KPNO solutions for HD 19485 is 2.3 km s^{-1}, which, given the uncertainty of the DDO systemic velocity, is almost a 3 σ result. These three comparisons indicate that the DDO velocities should be decreased, and so, like Fekel et al. (1989), we have added −3 km s^{-1} to the DDO observations. This correction is in the same sense as, but slightly larger than, the corrections derived for DDO radial velocities by Wilson (1953). We then combined the revised DDO velocities for the primary, adopting weights of 0.02 for each velocity, with our KPNO velocities of both components and computed a new circular orbit solution. This resulted in a period of 6.247854 ± 0.000005. While the uncertainty of the orbital period was reduced, the errors of the other elements remained the same or increased slightly. Thus, we adopted this improved orbital period and obtained a final circular orbit solution using only the KPNO velocities (Table 2).

For a circular orbit the element T, a time of periastron passage, is undefined. So, as recommended by Batten et al. (1989), T_0, a time of maximum velocity for the primary, is given instead. The phases of the observations and the residuals to the final computed curves are listed in Table 1 for all of the DDO and KPNO velocities. Given the complexity of the composite spectrum in the blue region and the relatively low resolution and signal-to-noise ratio of the DDO spectrograms, we are impressed with the quality of the measures done by the numerous astronomers, students, and technicians that were involved in this work. Nonetheless, the residuals are so much larger than those from the KPNO velocities that in Figure 1 only the latter are compared with the computed velocity curves. Zero phase is a time of maximum velocity.

4. SPECTRAL TYPES, MAGNITUDE DIFFERENCE, AND $v \sin i$

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. Thus, a red wavelength spectrum of HD 19485 (Fig. 2) was compared with those of G and early-K dwarfs and subgiants from the lists of Keenan & McNeil (1989), Fekel (1997), and Gray et al. (2003). The reference spectra were obtained at KPNO with the same telescope, spectrograph, and detector as our spectra of HD 19485. Comparison spectra were created with a computer program developed

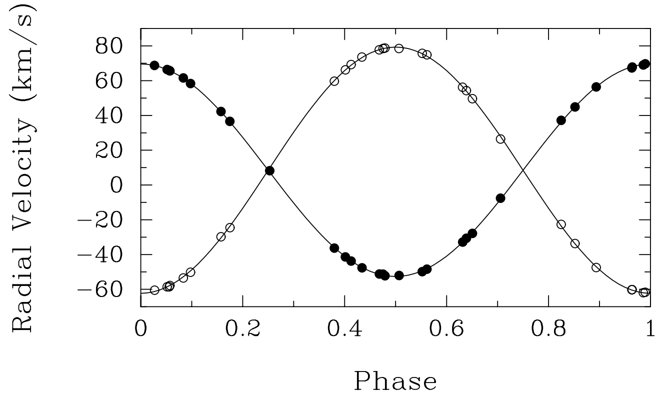

FIG. 1.—KPNO velocities (component A, *filled circles*; component B, *open circles*) compared with the computed radial velocity curves of HD 19485. Zero phase is a time of maximum velocity of the primary, component A.

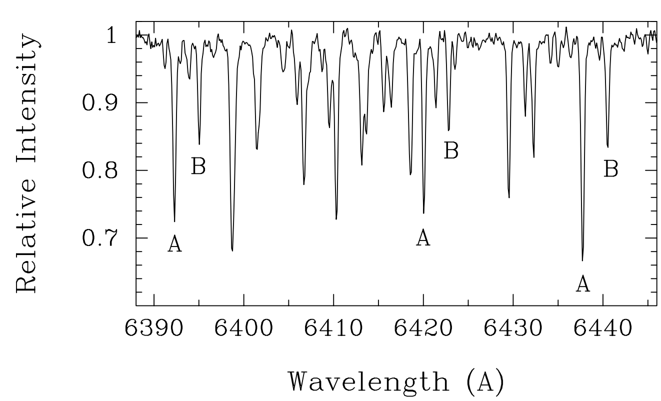

FIG. 2.—Spectrum of HD 19485 in the 6430 Å region. Several line pairs of components A and B are identified.

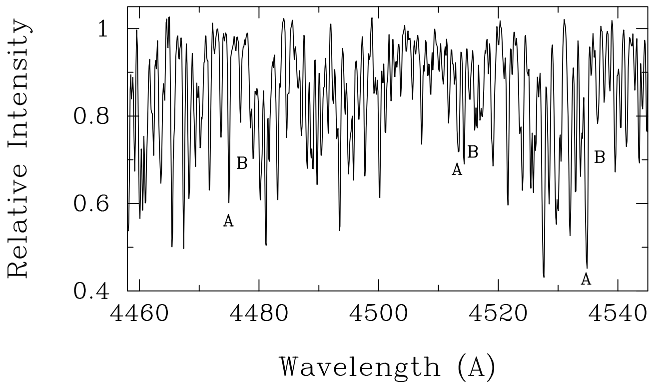

FIG. 3.—Spectrum of HD 19485 in the 4500 Å region. It is difficult to find relatively unblended lines of component B, but several line pairs of components A and B are identified.

by Huenemoerder & Barden (1984) and Barden (1985). Various combinations of reference-star spectra were rotationally broadened, shifted in radial velocity, appropriately weighted, and added together in an attempt to best reproduce the spectrum of HD 19485 in the 6430 Å region. A good fit to the whole spectrum was found with a combination of κ Cet (G5 V [Keenan & McNeil 1989] and mean [Fe/H] = 0.08 [Taylor 2003]) plus HD 221354 (K0 V and [Fe/H] = 0.0; Gray et al. 2003). At 6430 Å the continuum intensity ratio $I_B/I_A = 0.429$, resulting in a magnitude difference of 0.92. Because the secondary is the cooler star, its line strength is greater than that of the primary, and so the computed magnitude difference is a minimum value. Comparing the line strengths of our two reference stars in the 6430 Å region, we determine that the average of the Fe I line strengths in κ Cet relative to those in HD 221354 results in a line-strength ratio B/A = 1.25. This produces a luminosity ratio of 0.343, corresponding to a magnitude difference of 1.16 mag, in the 6430 Å region. However, such a revision appears to overcorrect the magnitude difference. The number of moderate and strong lines at red wavelengths is not as great as in the blue, and so there are wavelength regions in the red where a pseudocontinuum of very weak lines appears. Correcting the continuum luminosity ratio by a factor similar to that found for the blue observations, discussed below, produces a magnitude difference of 1.0 and brings the red magnitude differences into accord with that predicted from the 4500 Å region.

We also obtained and analyzed a spectrum of HD 19485 in the 4500 Å region (Fig. 3). Fewer reference stars were available for this wavelength region, but we found a reasonable fit to the spectrum of HD 19485 with a combination of κ Cet (G5 V) and HR 511 (K0 V). At 4500 Å the resulting continuum intensity ratio $I_B/I_A = 0.350$. A comparison of the line strengths of our two reference stars indicates that the continuum intensity ratio should be multiplied by 0.94, resulting in a luminosity ratio of 0.329. This produces a magnitude difference of 1.2 for which we estimate an uncertainty of 0.1 mag. Adopting the mean colors of G5 V and K0 V stars (Johnson 1966), we obtain $\Delta V = 1.05$ mag for HD 19845 and estimate an uncertainty of 0.1 mag. Because the 6430 Å region is about 0.6 of the way between the effective wavelengths of the Johnson V and R passbands, we compute a magnitude difference of 1.0 mag, which is between the minimum and maximum values obtained from our red spectra.

Our comparisons indicate that the components of HD 19485 are fitted well by reference stars with near-solar metal abundances. Thus, we conclude that the metal abundances of the two components of HD 19485 are also close to solar.

TABLE 3
FUNDAMENTAL PROPERTIES OF HD 19485

Parameter	Value	Reference
V (mag)	8.21	1
$B - V$ (mag)	0.70	1
π (arcsec)	0.01290 ± 0.00119	1
Spectral type of A	G5 V	2
Spectral type of B	K0 V	2
$v_A \sin i$ (km s^{-1})	10.9 ± 1.0	3
$v_B \sin i$ (km s^{-1})	9.4 ± 1.0	3
M_V (A) (mag)	4.11 ± 0.21	2
M_V (B) (mag)	5.16 ± 0.22	2
L_A ($L_\odot$)	2.0 ± 0.4	2
L_B ($L_\odot$)	0.8 ± 0.2	2
R_A ($R_\odot$)	1.5 ± 0.1	2
R_B ($R_\odot$)	1.1 ± 0.1	2

REFERENCES.—(1) Perryman et al. 1997; (2) this paper; (3) Fekel 1997.

From four of our spectra Fekel (1997) determined $v \sin i$ values of 10.9 and 9.4 km s^{-1} for components A and B, respectively. Measurement of a number of additional spectra produces essentially the same results, and so we adopt the values of Fekel (1997), which have estimated uncertainties of 1 km s^{-1}.

5. BASIC PROPERTIES

We adopt a V magnitude of 8.21 and $B - V$ of 0.70 for HD 19485 (Perryman et al. 1997). Based on our estimate of $\Delta V = 1.05$ mag, the individual V magnitudes for components A and B are 8.56 and 9.61. The *Hipparcos* parallax of $0.01290'' \pm 0.00119''$ (Perryman et al. 1997) corresponds to a distance of 77.5 ± 7.2 pc from the Sun, so we assume no interstellar reddening. This yields absolute magnitudes of $M_V = 4.11 \pm 0.21$ and 5.16 ± 0.22 mag for components A and B, respectively. We adopted $B - V$ colors of 0.66 and 0.82 from Johnson (1966) for the G5 V and K0 V components, respectively. Those colors and our derived V-magnitude difference reproduce the combined $B - V$ color of HD 19485. We then used our adopted colors to obtain bolometric corrections and effective temperatures for components A and B from Table 3 of Flower (1996), which yielded luminosities of $L_A = 2.0 \pm 0.4$ and $L_B = 0.8 \pm 0.2$ $L_\odot$ and radii of $R_A = 1.5 \pm 0.1$ and $R_B = 1.1 \pm 0.1$ $R_\odot$. The uncertainties in the computed quantities are dominated by the parallax and magnitude difference uncertainties. The effective temperature uncertainty, which we estimate to be ±100 K, makes a smaller contribution to the error in the luminosities and radii. Most chromospherically active dwarfs have modest amounts of light variability with amplitudes typically less than 0.1 mag and are not believed to be heavily spotted (e.g., Henry et al. 1995). However, if the true unspotted V magnitude were 0.1 mag brighter than our adopted value, the luminosity would be increased by 10% and the radius by 5%. The basic properties of components A and B that we have derived are summarized in Table 3.

6. DISCUSSION

While Kazarovets et al. (1993) assigned WZ Ari to the RS CVn variability class, it would be just as appropriate to call it a BY Dra variable. Fekel et al. (1986) argued that the original definition of BY Dra stars, single or binary stars with K or M dwarf spectral types that have strong Ca II H and K emission and periodic light variation (Bopp & Fekel 1977), should be expanded to include main-sequence F and G dwarf stars with similar characteristics, since they are in the same evolutionary state. Such an expanded definition overlaps the domain encompassed by the RS CVn binaries (Hall 1976; Strassmeier et al. 1988). Because of the overlap of their properties, today both types of variables are generally referred to as chromospherically active stars.

The two main theories of orbital circularization and rotational synchronization (e.g., Zahn 1977; Tassoul & Tassoul 1992) disagree significantly on absolute timescales but do agree that synchronization should occur first. Light variability in chromospherically active stars results from a nonuniform distribution of cool star spots rotating in and out of view. The photometric periods found for HD 19485 range from 5.79 to 6.59 days (Hooten & Hall 1990; Perryman et al. 1997) and bracket the orbital period value of 6.25 days, indicating synchronous rotation. However, because both components are chromospherically active, it is not clear whether the light variability period belongs to just the primary, which we have found to be about 1 mag brighter than the secondary, or is the rotational period of both components. If we adopt the value of the orbital period as the rotational period and combine it with the $v \sin i$ values of 11 and 9 km s^{-1} (Fekel 1997) for components A and B, respectively, we obtain minimum radii of 1.36 and 1.11 $R_{\odot}$ for the corresponding components. Compared with the canonical radii for G5 V and K0 V stars (Gray 1992), 0.96 and 0.81 $R_{\odot}$, respectively, the computed minimum radii are nearly 50% larger than expected. To produce the canonical radii values, rotational velocities of 7.8 and 6.6 km s^{-1} would be required for components A and B, respectively. However, Fekel et al. (1999) found that the minimum radii, computed from $v \sin i$ values, for some chromospherically active stars were larger than those computed with the Stefan-Boltzmann law, so the results for HD 19485 are not without precedent.

The values for the radii and absolute magnitudes of G5 V and K0 V stars that Gray (1992) listed are also significantly different from our computed values (Table 3) of those basic parameters. Indeed, our radii from the Stefan-Boltzmann law are similar to the minimum radii computed above rather than those of Gray (1992). In this case the larger radii result because both binary components are about 1 mag brighter than expected. This latter result can be seen in a comparison with evolutionary tracks such as those of Girardi et al. (2000) or Charbonnel et al. (1999). In Figure 4 we compare the positions of HD 19485 A and B with the solar abundance evolutionary tracks of Girardi et al. (2000). An additional comparison is provided by plotting the results for HD 144110 (Fekel et al. 2005), which also has components with G5 V and K0 V spectral types. The basic parameters for the components of HD 144110 were computed in the same manner as those for HD 19485. The positions of HD 144110 A and B are reasonably close to the zero-age main sequence, while those of HD 19485 are clearly significantly evolved although not yet in the subgiant region. If the components are coeval, as is almost universally assumed for binary stars, the G5 V and K0 V stars cannot be at similar evolved positions above the zero-age main sequence, since this indicates very different ages for the two stars. Thus, our result is both contrary to expectations and hard to explain.

While the luminosities and radii we derived for the components of HD 19485 appear to be discrepant, our mass ratio of 0.86 and the magnitude differences are in excellent agreement with values listed by Gray (1992) for G5 V and K0 V stars. From the canonical masses for such stars, 0.96 and 0.81 $M_{\odot}$, respectively, we estimate an orbital inclination of 70°.

In an attempt to produce a more consistent picture of HD 19485, we examine various possible scenarios. Low-mass pre-main-sequence tracks pass through the area of the H-R diagram above the zero-age main sequence region (e.g., Charbonnel et al. 1999). So we first investigate whether the components of HD 19485 might be pre-main-sequence stars.

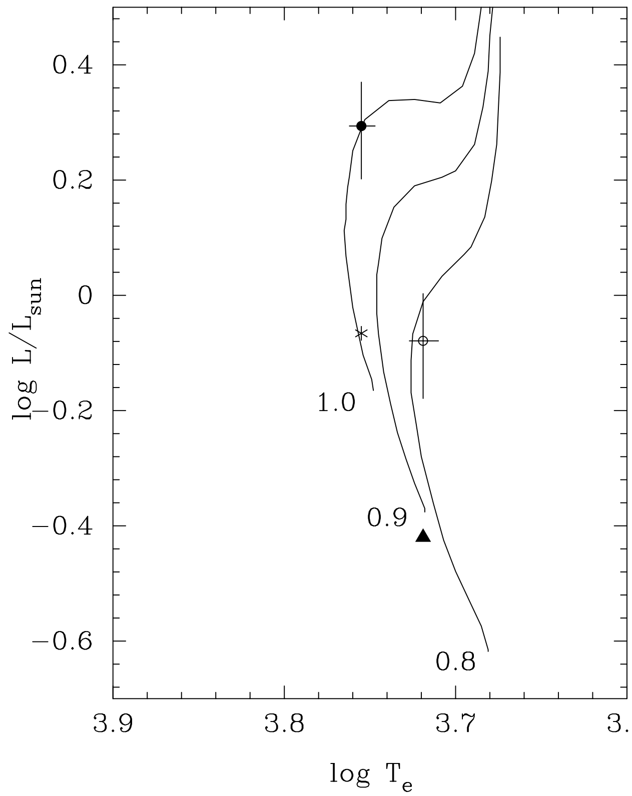

Fig. 4.—Theoretical H-R diagram, showing the positions of HD 19485 A and B (*filled and open circle, respectively*) and their uncertainties compared with the 0.8, 0.9, and 1.0 $M_{\odot}$ solar abundance evolutionary tracks of Girardi et al. (2000). Also shown for comparison are the G5 V and K0 V components of HD 144110 (*asterisk and triangle, respectively*).

The abundance of lithium is one possible way to determine the youth of HD 19485. In late-type stars, which have convective atmospheres, the abundance of lithium decreases with age (e.g., Michaud & Charbonneau 1991). Thus, pre-main-sequence stars, like extremely young main-sequence stars, have a very strong lithium line at 6708 Å. For example, in the Pleiades, Soderblom et al. (1993) found that the equivalent width of the 6708 Å line, for stars with $B - V$ colors similar to the components of HD 19485, ranges from about 130 to 200 mÅ.

To determine whether the components of HD 19485 are extremely young and perhaps even pre-main-sequence stars, we compare them with the G6 V star HD 166181. According to Fekel et al. (1986), the 6708 Å lithium line of HD 166181 is greater in strength than the nearby relatively strong calcium line at 6717 Å. From its lithium equivalent width Wichmann et al. (2003) concluded that HD 166181 has an age similar to that of the Pleiades, about 100 million years (Meynet et al. 1993). An examination of the co-added Fairborn Observatory echelle spectra of HD 19485 shows that although the calcium line at 6717 Å is clearly visible in both components, there is no evidence of a significant 6708 Å lithium feature for either component. Thus, we conclude that the components of HD 19485 are not pre-main-sequence stars or extremely young main-sequence objects.

If the components are not pre-main-sequence stars but are coeval, then one or both stars must be shifted to lower luminosities in the H-R diagram to produce a consistent picture of the evolutionary state of the system. We previously mentioned that both components are chromospherically active. Because cool starspots in active stars cause the brightness to decrease (e.g., Henry et al. 1995; O'Neal et al. 1996), correcting for this effect, as noted in § 5, increases the luminosity, the opposite of what is needed. Likewise, postulating some interstellar extinction also results in the components being intrinsically brighter, not fainter.

Another possibility to consider is that the parallax of the system is too small. The presence of a third component with an orbital period of several years could bias the *Hipparcos* parallax determination. Fekel et al. (2005) found this to be the case for the triple system HD 166181, which had previously been flagged in the *Hipparcos* catalog (Perryman et al. 1997) as a problem system. However, that catalog indicates no difficulties with the parallax solution for HD 19485. In addition, our center-of-mass velocity has such a small uncertainty that it provides no hint of a possible third component. To place the components of HD 19485 close to the positions of the HD 144110 components in Figure 4 requires increasing the parallax from 0.0129″ to 0.02″, which is a very substantial 6 σ increase. There is no reason to expect the *Hipparcos* parallax to be so discrepant.

A new analysis of the *Hipparcos* parallaxes has recently been completed by van Leeuwen (2007). He reported that for two types of stars the new reduction provides more than average improvement. The first group of objects consists of the secondary stars of double-star systems, where separate measurements are available for two close components. The second group consists of stars with extremely red color. HD 19485 is not a member of either class of objects.

It might be possible to obtain an orbital parallax, determined from the linear and angular semimajor axes of the system, to confirm the *Hipparcos* parallax. From the adopted inclination, our value of $a \sin i$, and the *Hipparcos* parallax we estimate an angular semimajor axis of 0.001″, so the stars can be resolved with the various 300 m baselines of, for example, the CHARA interferometric array (H. McAlister 2007, private communication). However, according to the 2MASS catalog (Skrutskie et al. 2006), the K magnitude of the system is 6.75, which places it at the current limit of observation for the CHARA array.

As pointed out earlier, the mass and luminosity ratios determined for the components of HD 19485 are in excellent accord with those expected for the adopted spectral types. However, increasing the magnitude difference between the components from $\sim$1 to $\sim$2 mag would solve the apparent age problem by placing the secondary close to the beginning of the main-sequence evolutionary track, where a K0 V star would be expected to reside for billions of years (Girardi et al. 2000). This might seem to be an attractive possibility. Thus, we discuss one particular spectral-type combination to highlight the problems encountered if the spectral types and magnitude differences are significantly revised.

A major increase in the magnitude difference requires a greater difference in the spectral types of the two components. However, the K0 V spectral type of the secondary is constrained in the 6430 Å region because, for spectral types later than K0 V, the wings of the strong lines are significantly too strong. Thus, we adopt a model with spectral types G1 V and K0 V for the components and examine the consequences. From Gray (1992) such stars have a V magnitude difference of 1.5, which is a 50% increase, only half of the estimated shift that is needed. Component A becomes about 200 K hotter and 0.1 mag brighter, while its radius decreases slightly. Thus, there is only a modest change in the position of component A in the H-R diagram. Component B becomes 0.4 mag fainter, roughly half the distance from its current position to the base of the 0.9 $M_{\odot}$ main-sequence track in Figure 4. Thus, its position with respect to the evolutionary tracks is certainly improved. However, this model of the components produces a $B - V$ color of 0.66 mag for the composite system versus the observed value of 0.70. In addition, from Gray (1992) the mass ratio of the components is 0.75 compared with an observed value of 0.86. A red wavelength spectrum addition fit with G1 V plus K0 V stars that have solar abundances shows that the lines of the reference stars are much too weak. Thus, to reproduce the spectrum of HD 19485 would require extremely metal-rich stars. These difficulties, with a solution that only goes, at best, halfway in repositioning component B in the H-R diagram, highlight the fact that there is no simple solution to the apparently conflicting evolutionary states of the two components and the different ages that are implied.

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