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A FALSE PLANET AROUND HD 192263

Gregory W. Henry[1]
Center of Excellence in Information Systems, Tennessee State University, 330 10th Avenue North, Nashville, TN 37203; henry@schwab.tsuniv.edu
and
Robert A. Donahue and Sallie L. Baliunas[2]
Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138; baliunas@cfa.harvard.edu, donahue@cfa.harvard.edu
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ABSTRACT

We present new high-precision Strömgren photometry and Ca II H and K spectrophotometry of HD 192263. Based on radial velocity variations detected previously by two groups, this K2 V star was thought to host a 0.75 $M_{\rm Jup}$ (minimum mass) planetary companion in a 24 day orbit. Our photometric observations reveal periodic variations that match the purported planetary orbital period, while the Ca II H and K emission fluxes are modulated on half the planetary period. This suggests that rotational modulation of the visibility of stellar surface activity is the source of the observed radial velocity variations. Therefore, HD 192263 should be removed from lists of stars with well-established planetary companions unless further observations and analysis can support the existence of the planet in spite of the star's intrinsic variations.

Subject headings: planetary systems — stars: individual (HD 192263) — stars: late-type — stars: rotation — stars: spots — stars: variables: other

On-line material: machine-readable tables

1. INTRODUCTION

A planet with a minimum mass of 0.75 $M_{\rm Jup}$ in a 24 day orbit around the K2 V star HD 192263 was announced independently by Santos et al. (2000) and Vogt et al. (2000). Table 1 gives the orbital parameters derived by the two groups. Vogt et al. (2000) found a somewhat larger eccentricity than Santos et al. (2000), but their periods, velocity semiamplitudes, and minimum masses are all quite similar.

The stellar properties of HD 192263 are discussed in Santos et al. (2000) and Vogt et al. (2000). The *Hipparcos* mean V magnitude of 7.79, the $B-V$ color index of 0.938, and the parallax of 50.27 mas (ESA 1997) imply the star is an early K dwarf. Strömgren *ubvy* photometry (Olsen 1984) reveals the star is slightly metal-poor compared to the Sun. Of particular interest is the star's relatively high level of chromospheric activity; Santos et al. (2000) give $\log R'_{\rm HK} = -4.37$, compared to the Sun's mean $\log R'_{\rm HK} = -4.89$ (Baliunas et al. 1995; Henry et al. 1996).

Both Santos et al. (2000) and Vogt et al. (2000) noted that surface magnetic activity in young stars can lead to observed radial velocity variations. For example, Queloz et al. (2001) found radial velocity variations with an amplitude $K = 83$ m s^{-1} in the young G0 dwarf HD 166435 that were, at first, interpreted as the signature of a 0.6 $M_{\rm Jup}$ planet in a 3.8 day orbit around the star. Later photometric and Ca II H and K spectrophotometric observations showed clearly that starspots producing a photometric amplitude of 0.05 mag were the cause of the observed radial velocity variations. Both Santos et al. (2000) and Vogt et al. (2000) concluded that starspots were *not* the likely primary cause of the velocity variations in HD 192263 because the estimated stellar rotation period predicted from its mean activity level was much shorter than their radial velocity period and because the *Hipparcos* photometry (ESA 1997) did not reveal any light variations. Santos et al. (2000) checked further for line-bisector variations correlated with their radial velocities but did not find anything significant (their Fig. 3). However, Vogt et al. (2000) remained somewhat cautious, saying "we are not yet completely convinced of a planet-companion interpretation for the velocity variations."

Both planet search groups contacted us to inquire about possible photometric variations in HD 192263 before announcing the planetary companion, but the star was not yet on our observing program. In this Letter, we report the results of our subsequent high-precision Strömgren photometry and Ca II H and K spectrophotometry. These observations strongly suggest that the 24 day radial velocity variations are due to rotational modulation in the visibility of stellar surface activity rather than reflex motion induced by a planetary companion.

2. OBSERVATIONS AND ANALYSIS

2.1. *Photometry*

The photometric observations were acquired between 2001 April and 2002 July with the T11 0.8 m automatic photoelectric telescope (APT) at Fairborn Observatory.[3] The T11 APT measures the difference in brightness between a program star (P) and nearby comparison stars ($C1$ and $C2$) in the Strömgren b and y passbands. The observing procedures and data reduction techniques employed with this APT are identical to those for our T8 0.8 m APT described in Henry (1999). Comparison star 1 ($C1$) is HD 193328 ($V = 7.48$, $B-V = 0.12$, A2), while comparison star 2 ($C2$) is HD 193225 ($V = 7.35$, $B-V = 0.29$, F0). The external precision of our differential magnitudes, defined as the standard deviation of a single differential magnitude from the seasonal mean of the differential magnitudes, is typically around 0.0012 mag for this telescope, as determined from observations of pairs of constant stars. The standard deviation of the ($C2 - C1$) differential magnitudes are somewhat larger than this (~0.0024 mag) because HD 192263 lies near the ce-

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[1] Also Senior Research Associate, Department of Physics and Astronomy, Vanderbilt University, Nashville, TN 37235.

[2] Also at Mount Wilson Observatory, 740 Holladay Road, Pasadena, CA 91106.

[3] Further information about Fairborn Observatory can be found at http://www.fairobs.org.

TABLE 1

Published Orbital Parameters for HD 192263b

Period (days)	K (m s^{-1})	e	$M \sin i$ ($M_{\rm Jup}$)	a (AU)	rms (m s^{-1})	Source
24.13 ± 0.09	62 ± 2	0.05 ± 0.04	0.73	0.15	13	Santos et al. 2000
24.36 ± 0.07	68 ± 11	0.22 ± 0.14	0.78	0.15	4.5	Vogt et al. 2000

lestial equator and thus is observed through somewhat larger air mass than usual. Our 244 individual photometric observations are given in Table 2 and are also available on the Tennessee State University Automated Astronomy Group Web site.[4]

The photometric observations in the combined Strömgren $(b+y)/2$ bandpass are plotted in the three panels of Figure 1. The low photometric amplitude makes it advantageous to average the b and y differential magnitudes to reduce the scatter in the light curves. We used the method of Vaniĉek (1971), based on least-squares fitting of sinusoids, to search for periodicities in these three light curves. The resulting power spectra are shown in Figure 2, where we plot the fractional reduction of the variance (reduction factor) versus trial frequency. Further details on the application of this method can be found in Henry et al. (2001 and references therein). The resulting periods are 26.3 ± 0.8, 23.7 ± 0.5, and 24.5 ± 0.5 days. These periods closely match the radial velocity periods of 24.13 ± 0.09 and 24.36 ± 0.07 days reported by Santos et al. (2000) and Vogt et al. (2000), respectively. Our photometric periods have somewhat larger uncertainties than the radial velocity periods in part because we have fewer cycles included in our analyses. The peak-to-peak photometric amplitudes range from about 0.01 mag or a little less in the first two light curves to about 0.04 mag or a little more in the third. Because of the higher photometric amplitude and greater coherence of this third data set, we take its resulting 24.5 day period as our best measurement of the photometric period in HD 192263. The light curves look very similar to those of other active stars (e.g., Henry, Fekel, & Hall 1995b), and we interpret the 24.5 day light variation as the rotation period of the star, made apparent by rotational modulation of the visibility of a nonuniform distribution of photospheric starspots.

Strassmeier et al. (2000) also placed HD 192263 on their photometric and spectroscopic survey of activity in 1058 late-type stars. Based on 24 photometric measurements, they found light variations with an amplitude of 0.03 mag and a period of 23.98 days, in agreement with our photometric results.

2.2. Ca II H *and* K *Spectrophotometry*

From 1999 October to 2001 September, 113 Ca II H and K measurements were made on 37 nights with the 100 inch telescope at Mount Wilson Observatory as part of the HK Project (Baliunas et al. 1998). In that program, measurements of the Ca II H and K lines of several thousand stars are made as a proxy for surface magnetism.

The observed quantity, S, is the flux measured in two 0.1 nm passbands centered on the H and K lines normalized by two 2.0 nm wide sections of photospheric flux centered at 390.1 and 400.1 nm. A nightly calibration factor is determined from measurements of a standard lamp and standard stars (Baliunas et al. 1995). The night-to-night rms precision of the lamp is on the order of 0.5%, while the standard stars have an average standard deviation of ~1.5%, which limits the lowest amplitude of variability that can be detected to approximately 1%.

The Ca II H and K observations of HD 192263, acquired at three different epochs, are listed in Table 3 and plotted in the top panel of Figure 3. Our power spectrum of the third cluster of observations, which has the largest number of measurements, is shown in the second panel of Figure 3, where we find a period of 12.2 ± 0.1 days. If active regions on the surface of a star become fairly uniformly distributed in stellar longitude, then the amplitude of rotational modulation becomes quite low and the dominant period often shifts to half the rotation period (Henry et al. 1995a). Because the bright plage areas observed in H and K emission cover a larger area than the dark starspots

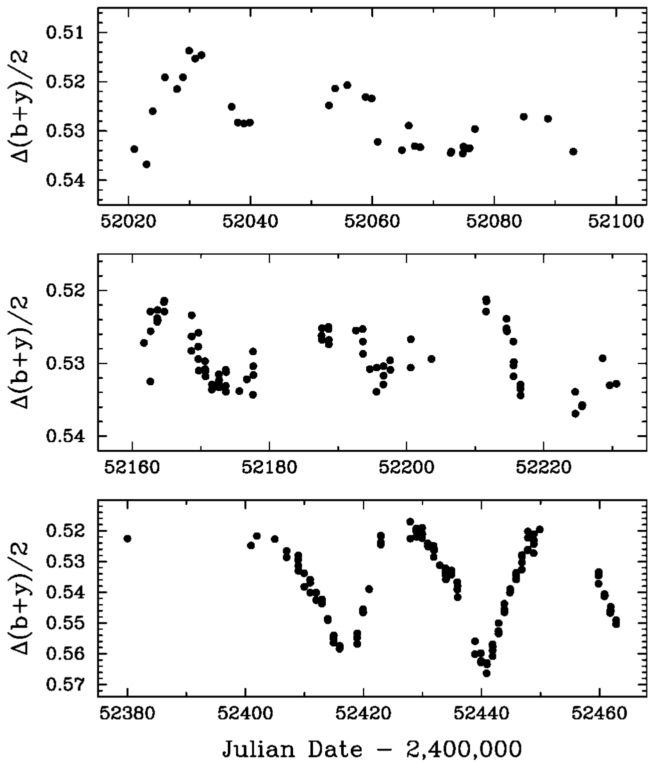

Fig. 1.—Strömgren photometry of HD 192263 with the T11 0.8 m APT at three epochs over the past 2 yr. Light variations due to rotational modulation of the visibility of photospheric starspots is seen in all three light curves, with amplitudes from roughly 0.01 mag (*top two panels*) to about 0.04 mag (*bottom panel*).

TABLE 2

Photometric Observations of HD 192263

Heliocentric Julian Date (HJD − 2,400,000)	$(P-C1)_b$ (mag)	$(P-C1)_y$ (mag)	$(C1-C2)_b$ (mag)	$(C1-C2)_y$ (mag)
52,020.9783	0.7788	0.2885	0.0117	0.1413
52,022.9700	0.7793	0.2944	0.0071	0.1349
52,023.9680	0.7699	0.2820	0.0101	0.1369
52,025.9669	0.7621	0.2761	0.0121	0.1379
52,027.9535	0.7645	0.2785	0.0089	0.1357

Note.—Table 2 is published in its entirety in the electronic edition of the *Astrophysical Journal Letters*. A portion is shown here for guidance regarding its form and content.

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[4] See http://schwab.tsuniv.edu/papers/apj/hd192263/hd192263.html.

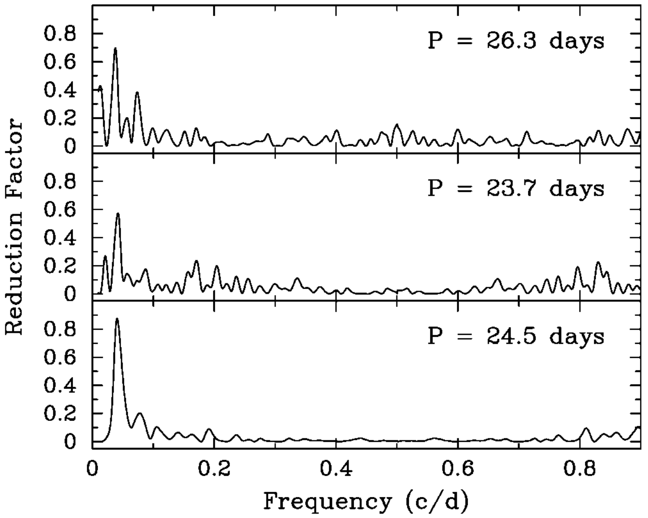

FIG. 2.—Period analyses of the photometric data in the three panels of Fig. 1. Uncertainties in the periods are approximately half a day. Therefore, the stellar rotation period is equal to the radial velocity period within their respective uncertainties.

(by analogy with the Sun) and are seen with greater contrast than spots in broadband photometry, the H and K observations can detect active regions that are invisible in the photometry. During epochs of low photometric variability when active regions might be more uniformly distributed in longitude, it is not surprising that the photometry would detect only the largest spot concentration and therefore vary on the 24 day rotation period while the H and K observations might detect active regions on opposite hemispheres of the star and thus vary on a 12 day cycle. Therefore, the true rotation period of the star from the H and K observations is 24.4 ± 0.2 days, in close agreement with our photometric rotation period. The third group of Ca II H and K observations, phased with this stellar rotation period, is replotted in the bottom panel of Figure 3; two minima and two maxima can be seen per rotation cycle.

Vogt et al. (2000) performed a period analysis of their *S* measurements derived from their spectra and found a weak indication of a 26.7 day period, which they noted was “uncomfortably close to the observed Doppler velocity period of 24 days.”

3. DISCUSSION

The rotation period of HD 192263 determined explicitly from our photometric and Ca II H and K observations closely matches the radial velocity period of Santos et al. (2000) and Vogt et al. (2000). This rotation period is much longer than expected by Santos et al. (2000), who estimated a rotation period of 9.5 days from their log $R'_{\rm HK}$ value of −4.37 and the rotation-activity calibration of Noyes et al. (1984). However, our 113 Ca II H and K observations result in a mean log $R'_{\rm HK}$ of −4.558 on the Mount Wilson system, which predicts a rotation period of 21.3 days from the Noyes et al. (1984) calibration. This is much closer to the observed 24 day rotation period. Without explicit comparison to the data of Santos et al. (2000), it is difficult to judge the origin of the disagreement between their value of log $R'_{\rm HK}$ and ours. The Mount Wilson value rests on measurements taken with the instrument defining the $R'_{\rm HK}$ scale and averaged over 2 years' data. Figure 3 displays a substantial variance owing to activity in the star's Ca II H and K flux. One possible explanation for the difference between our average log $R'_{\rm HK}$ and that of Santos et al. (2000) is sampling bias; the Santos et al. measurements may have occurred at times of relatively high activity. We note that our log $R'_{\rm HK}$ value and the age-activity calibration of Donahue (1993) result in an estimated age of 1.1 Gyr for HD 192263. Thus, HD 192263 turns out to be older, more slowly rotating, and less active than estimated by Santos et al. (2000). Our measured rotation period is consistent with its activity level and matches the radial velocity period within the uncertainties. This places the existence of the 24 day planet in doubt.

TABLE 3

Ca II H AND K OBSERVATIONS OF HD 192263

Heliocentric Julian Date (HJD − 2,400,000)	*S*
51,464.6396	0.5219
51,464.6411	0.5213
51,464.6431	0.5013
51,471.6094	0.5698
51,471.6118	0.5074

NOTE.—Table 3 is published in its entirety in the electronic edition of the *Astrophysical Journal Letters*. A portion is shown here for guidance regarding its form and content.

The 24 day rotation period, along with a stellar radius of 0.77 $R_\odot$ computed from the *Hipparcos V* magnitude, $B-V$ color index, and parallax (ESA 1997), gives an equatorial rotation velocity of 1.6 km s^{-1}, compared to the measured projected rotation velocity, $v \sin i = 1.8 \pm 1.2$ km s^{-1}, of Santos

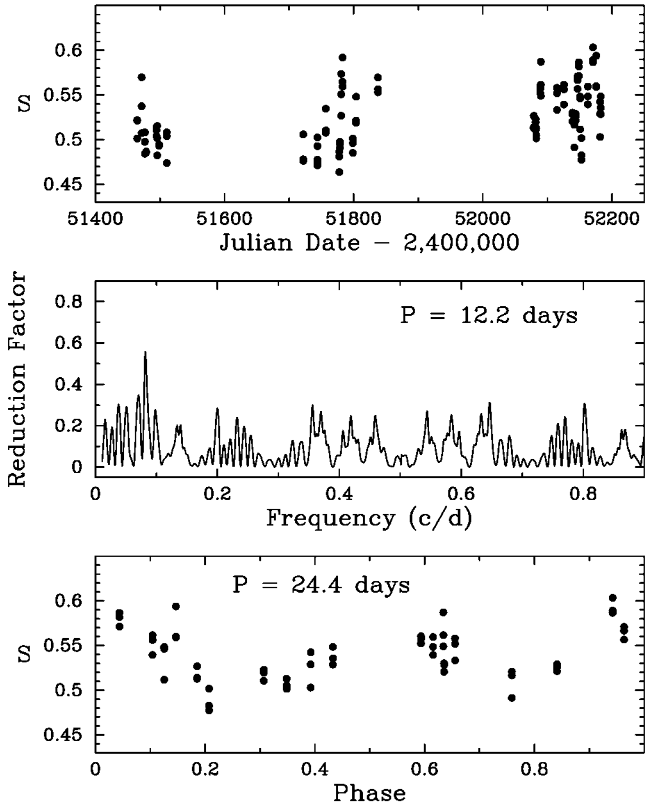

FIG. 3.—*Top*: Ca II H and K spectrophotometric observations from Mount Wilson Observatory. *Middle*: Power spectrum of the third group of *S* measurements, which gives a period of 12.2 ± 0.1 days, representing half the stellar rotation period. *Bottom*: Third group of *S* measurements replotted and phased with the resulting 24.4 day rotation period of the star. Two maxima and minima can be seen per rotation cycle.

et al. (2000). Since HD 192263 is rotating more slowly than previously expected, the improbably low inclination of 30° suggested by Vogt et al. (2000) is no longer needed to explain its low $v \sin i$ value. The low equatorial rotation velocity and consequent low $v \sin i$ may explain why Santos et al. (2000) failed to resolve bisector variations in their observations. With few resolution elements across a line profile, the determination of line-bisector variations is subject to additional uncertainty (but see the further discussion of stellar activity and radial velocity dispersion below).

Santos et al. (2000) and Vogt et al. (2000) both cited the lack of photometric variability in the *Hipparcos* photometry as supporting evidence for a planet around HD 192263. However, Henry et al. (2000) point out that the vast majority of low-amplitude variables found with the APTs have no indication of variability in the *Hipparcos* Catalogue. Their survey of 187 G and K giants demonstrated that a star is very unlikely to be listed as a variable in the *Hipparcos* Catalogue unless its photometric amplitude is 3% or greater. Our photometric observations of HD 192263 show that it often has an amplitude of only 1%–2%, so it is not surprising that its variability was not detected by *Hipparcos*. Knowing the true rotation period of HD 192263, we searched the *Hipparcos* photometry for periods in the range 1–100 days and found the strongest periodicity at 12.9 days with a peak-to-peak amplitude of 0.02 mag. This is close to half the rotation period of HD 192263, as detected in our Ca II H and K observations, and so may represent a true detection of variability, but such a claim could not have been made with any confidence from the *Hipparcos* photometry alone.

The only radial velocity measurements of HD 192263 explicitly tabulated in the literature are those of Vogt et al. (2000), acquired with the Keck I telescope and HIRES spectrograph. The rms dispersion of those velocities is 34 m s^{-1} before removal of any periodic signal, compared to the typical precision of 3 m s^{-1} with that instrument. The empirical models of Saar & Donahue (1997) and Saar, Butler, & Marcy (1998) predict a radial velocity dispersion due to dark photospheric spots of only ~10–12 m s^{-1} for HD 192263, given its low $v \sin i$ of 1.8 km s^{-1} and modest photometric amplitude of 0.04 mag. However, D. Paulson et al. (2002, in preparation) show a relationship between radial velocity dispersion and photometric variability for six single, solar-type (early G to early K) dwarfs with spot-induced, radial velocity variations. A linear fit to these six stars gives a slope of 3.3 m s^{-1} mmag^{-1} with an rms of only 4.8 m s^{-1}. HD 192263 falls on this best-fit line with virtually zero residual. Although $v \sin i$ is not included explicitly in this relationship, it *is* included implicitly through the relationship between activity and rotation (Noyes et al. 1984). Thus, the empirical models of Saar & Donahue (1997) and Saar et al. (1998), based on spot filling factors and projected rotational velocities, predict somewhat lower radial velocity dispersion than the relationship of D. Paulson et al., based on photometric dispersion alone. It is clear that more detailed investigation of the relationship between radial velocity dispersion and stellar activity is needed. In particular, high-quality radial velocity and photometric data sets are required, along with detailed modeling, to understand the sensitivity of radial velocity dispersion to photospheric spots in stars with low $v \sin i$.

Finally, we note that Vogt et al. (2000) were puzzled by the fact that the rms of their velocity residuals to their Keplerian fit for HD 192263 was only 4.5 m s^{-1}, much lower than the expected radial velocity jitter from the models of Saar & Donahue (1997) and Saar et al. (1998). If the radial velocity variations were due primarily to a planetary companion, the orbital fit to the radial velocity data should have exhibited an rms of 10–12 m s^{-1} or more. Therefore, we can say that at least part of the observed radial velocity variability in HD 192263 must be due to surface activity on the star while the contribution from a possible planet has been overestimated. Furthermore, since the stellar rotation period and the radial velocity period agree within their uncertainties and the dispersion of our photometric observations successfully predicts the velocity dispersion based on the D. Paulson et al. (2002, in preparation) calibration, we suggest that most, if not all, of the radial velocity variability is due to stellar activity. Additional evidence for intrinsic variability comes from a careful examination of Figure 1 of Santos et al. (2000), where small systematic differences in the maxima and minima of the radial velocity variations can be seen from cycle to cycle. Clearly, HD 192263 should be removed from lists of stars with well-established planetary companions unless further observations and analysis can firmly establish a planetary-reflex contribution to the radial velocity variability.

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