PHOTOMETRIC VARIABILITY IN CHROMOSPHERICALLY ACTIVE STARS. I.
THE CONSTANT STARS

KLAUS G. STRASSMEIER and DOUGLAS S. HALL
Dyer Observatory, Vanderbilt University
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ABSTRACT

Over 3800 differential UBV observations for 15 known or suspected chromospherically active stars are presented. All stars turned out to exhibit no light variations over the period of observation from 1983 through 1987. Three additional nonactive stars already known to be constant have been used to determine the external and internal precision of our data. All observations were made with the prototype automatic photoelectric telescope.

Subject headings: photometry — stars: chromospheres — stars: variables

I. INTRODUCTION

This is the first in a series of papers dealing with photometric variability in chromospherically active (CA) stars. We now report differential UBV photometry for 18 stars, made between 1983 and 1987, which turned out to be constant in light. Three of them are known to be constant nonactive stars; two are listed in the Catalog of Chromospherically Active Binary Stars (CABS catalog; Strassmeier et al. 1988) with unknown photometric behavior; four stars are rapidly rotating single giants; and the rest are binaries with suspected light variability due to spot activity and/or chromospheric activity. One of our goals in this survey is to answer the question whether all CA stars show spots or, conversely, if all spotted stars are CA stars. Of the 168 CA binaries in the CABS catalog, 80% have an entry in the "spot-wave amplitude" column. A recent discussion of the variability in CA stars at all time scales has been given by Hall (1988).

The second paper in this series will present photoelectric UBV measures for a group of spotted rapidly rotating single CA stars. The third paper will concentrate on the binary CA stars. A fourth paper will present all individual nightly means (approximately 25,000) for the stars discussed in the first three papers. A later paper will deal with a statistical interpretation of all available photometry of chromospherically active stars.

II. OBSERVATIONS AND PRECISION OF THE PHOTOMETRY

The telescope used was the 10 inch (25 cm) f/6 Newtonian which performs differential photoelectric photometry completely automatically under microcomputer control, as described by Boyd, Genet, and Hall (1984). In the summer of 1986 it was moved from its original Phoenix, Arizona, site to its new site at the Whipple Observatory atop Mount Hopkins south of Tucson, Arizona (Baliunas et al. 1985). The photometer utilizes an unrefrigerated 1P21 photomultiplier and filters selected to match the UBV standard photometric system.

The first observation included in our analysis was on the night of JD 2,445,620.5 and the last was on the night of JD 2,446,976.5, a total time span of 3.7 years. The capacity of the observing program stored in memory is approximately 80 variable-comparison-check groups, the number which should not be exceeded by much if one wants the telescope to obtain one observation per night of every star which enters the observing cone sometime during the night. All together, during the 3.7 years, observations were recorded for more than 80 variables, namely, 114, because several program stars were replaced by others during that time. All of the photometry for the 114 stars will be published in tabular form in a separate paper by Boyd et al. (1988). Not analyzed in our paper and not included in the Boyd et al. paper are data obtained at the request of, and sent directly to, other astronomers, as part of the “Second Service” provided by the Automatic Photoelectric Telescope Service (Boyd, Genet, and Hall 1985).

Each “nightly mean” referred to in our paper results from the sequence of 33 10 s integrations given in Table 1 of Boyd, Genet, and Hall (1984). It is a mean of three integrations on the variable star, each bracketed between four integrations on the comparison star, with integrations on the check star and the sky background as well. Such a “nightly mean” is accomplished in approximately 7 minutes.

Actually there was sometimes more than one “nightly mean” of the same star on some nights, as explained by Boyd, Genet, and Hall (1984). A statistical consistency check applied to the integrations in real time sometimes (if the check failed) caused the 33 integration sequence to be repeated immediately. Whenever there are so few stars in the observing cone that every star was observed once, the telescope observed accessible stars until a new one entered the cone from the western perimeter. On one night, all stars were temporarily removed from the observing program except the newly discovered eclipsing binary HR 6469, so that a primary minimum could be observed from first to fourth contact in detail. See Boyd et al. (1985).

Each integration was corrected for dead time, each of the individual differential magnitudes (three for the variables and two for the check stars) was corrected for differential atmo-
spherically extinction and transformed differentially to the $UBV$ system with known coefficients, and the heliocentric correction was applied to each Julian date.

The internal uncertainty of a nightly mean is estimated from the standard deviation of the three individual differential magnitudes. Thus we have

$$\sigma_{\text{int}} = \left[ \frac{\sum (\Delta m - \langle \Delta m \rangle)^2}{n(n-1)} \right]^{1/2},$$  \hspace{1cm} (1)

where $n = 3$ and $\langle \Delta m \rangle$ is the mean of the three in a given bandpass. This quantity is used to remove photometrically inferior data resulting almost always from the presence of thin clouds. An observation for which $\sigma_{\text{int}}$ exceeded 0.02 mag was simply not reported to the user. The choice of this 0.02 mag value as the cutoff was discussed in greater detail by Hall, Kirkpatrick, and Seufert (1986).

To look for photometric variability or (in the case of nonvariable stars) to obtain another measure of photometric precision, we examined the quantity

$$\sigma_{\text{ext}} = \left[ \frac{\sum (\langle \Delta m \rangle) - [\Delta m]_k^2}{k} \right]^{1/2}, \hspace{1cm} (2)$$

where $k$ is the total number of nightly means and $[\Delta m]$ is the overall 3.7 year mean in a given bandpass.

Before computing $\sigma_{\text{ext}}$, however, we dealt with the five problems summarized in Table 1. The first four, A–D, are discussed in more detail by Hall, Kirkpatrick, and Seufert (1986); the last (E) occurred most recently. Data affected by problems A, B, and E were simply not included in our analysis. Fortunately, the first two involved only a few stars on one or two nights. The power supply malfunction was corrected in 1986 March, and quality-control procedures were initiated to prevent the reoccurrence of that and similar problems which might affect the photometry (Genet et al. 1987). The number of nightly means excluded is given in Table 2. Data affected by problems C and D were corrected by determining an additive correction in each bandpass. In the case of the 18 stars in this paper, which we conclude are not variable, this was quite easy to do. We computed mean brightness levels separately for the affected and unaffected portions of the data and considered the difference between the two levels as the additive correction needed. The shifts are given in the last two columns of Table 2.

In addition to remove the few observations affected by gross errors of generally undetermined origin, we used a statistical procedure similar to what is generally called the "3σ test." This same approach was used by Hall, Kirkpatrick, and Seufert (1986) and explained in more detail. The number of nightly means excluded by this test are given in Table 2.

Three of the star pairs included in Table 2, placed on the observing program to assess photometric quality, are not known to be chromospherically active, nor are they suspected of variability. The values of $\sigma_{\text{int}}$ and $\sigma_{\text{ext}}$ for these three pairs should be useful in judging the photometric precision of the differential photometry obtained by the 25 cm telescope. The $\sigma_{\text{int}}$ values can be regarded as lower limits to the precision on short time scales. For 27 and 28 LMi, the pair with the most data, the mean values are

$$\sigma_{\text{int}}(V) = \pm 0.005 \text{ mag},$$

$$\sigma_{\text{int}}(B) = \pm 0.005 \text{ mag},$$

$$\sigma_{\text{int}}(U) = \pm 0.009 \text{ mag}.$$  

The $\sigma_{\text{ext}}$ values can be regarded as upper limits to the precision on longer time scales. The mean values (in mag) for

<table>
<thead>
<tr>
<th>Duration</th>
<th>Problem Description</th>
<th>Influence on Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>6031.5–6032.5</td>
<td>Interaction with peripheral electronics</td>
</tr>
<tr>
<td>B</td>
<td>6069.94–6070.3</td>
<td>Filter slide stuck in the $V$ position</td>
</tr>
<tr>
<td>C</td>
<td>5620.5–6102.5</td>
<td>Pulse coincidence problem</td>
</tr>
<tr>
<td>D</td>
<td>6218.5–6245.5</td>
<td>$V$ filter fell out of the filter slide</td>
</tr>
<tr>
<td>E</td>
<td>~ 6400–6550.0</td>
<td>Power supply malfunction</td>
</tr>
</tbody>
</table>

TABLE 1

PROBLEMS ENCOUNTERED WITH APT

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### TABLE 2

**Number of Observations and Corrections Applied to Original Data Set**

<table>
<thead>
<tr>
<th>Star Name</th>
<th>(Comparison Star)</th>
<th>Total of Observed Nightly Means $(V/B/U)$</th>
<th>Total of Nightly Means Used for Analysis $(V/B/U)$</th>
<th>Points Excluded Because of Problems A, B, and E $(V/B/U)$</th>
<th>Points Excluded Because of $3\sigma$ Test $(V/B/U)$</th>
<th>Shifts $(\delta V/\delta B/\delta U)$ Due to Problem</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(C)</td>
<td>(C)</td>
<td>(C)</td>
<td>(C)</td>
<td>(C)</td>
</tr>
<tr>
<td><strong>Pairs of Known Constant Stars without Chromospheric Activity</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>27 LMi</td>
<td>(28 LMi)</td>
<td>645/654/629</td>
<td>539/550/532</td>
<td>94/94/94</td>
<td>12/1/3</td>
<td>$-18/19/30$</td>
</tr>
<tr>
<td>51 Aur</td>
<td>(52 Aur)</td>
<td>230/230/230</td>
<td>228/226/229</td>
<td>0/0/0</td>
<td>2/4/1</td>
<td>$0/0/0$</td>
</tr>
<tr>
<td>HD 210434</td>
<td>(HD 210419)</td>
<td>47/47/47</td>
<td>46/47/47</td>
<td>0/0/0</td>
<td>1/0/0</td>
<td>$0/0/0$</td>
</tr>
<tr>
<td><strong>Constant Stars (singles + binaries with CA and CA candidates)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13 Cet</td>
<td>(HD 3807)</td>
<td>183/183/183</td>
<td>154/153/154</td>
<td>27/27/27</td>
<td>2/3/2</td>
<td>$-7/-17/-11$</td>
</tr>
<tr>
<td>81 $\psi$ Psc</td>
<td>(HD 6695)</td>
<td>185/185/185</td>
<td>153/151/152</td>
<td>32/32/32</td>
<td>0/2/1</td>
<td>$-4/20/24$</td>
</tr>
<tr>
<td>HR 503</td>
<td>(HD 11007)</td>
<td>241/241/241</td>
<td>203/205/205</td>
<td>35/35/35</td>
<td>3/1/1</td>
<td>$12/19/15$</td>
</tr>
<tr>
<td>HR 1023</td>
<td>(HD 20791)</td>
<td>194/194/194</td>
<td>173/172/168</td>
<td>21/21/21</td>
<td>0/1/2</td>
<td>$5/13/1$</td>
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<tr>
<td>HD 27691</td>
<td>(HD 27561)</td>
<td>150/150/150</td>
<td>107/107/107</td>
<td>42/42/42</td>
<td>1/1/1</td>
<td>$12/12/9$</td>
</tr>
<tr>
<td>3 Cam</td>
<td>(HD 29316)</td>
<td>297/297/297</td>
<td>227/230/231</td>
<td>65/65/65</td>
<td>5/2/1</td>
<td>$-9/16/27$</td>
</tr>
<tr>
<td>1 Gem</td>
<td>(HD 41543)</td>
<td>242/242/242</td>
<td>198/200/200</td>
<td>41/41/41</td>
<td>3/1/1</td>
<td>$-58/-88/-53$</td>
</tr>
<tr>
<td>11 $\epsilon$ Hya</td>
<td>(HD 76294)</td>
<td>200/200/200</td>
<td>195/198/198</td>
<td>0/0/0</td>
<td>5/2/2</td>
<td>$-1/-2/-31$</td>
</tr>
<tr>
<td>(HD 75137)</td>
<td></td>
<td>161/161/161</td>
<td>104/104/104</td>
<td>56/56/56</td>
<td>1/1/1</td>
<td>$-24/15/52$</td>
</tr>
<tr>
<td>HD 108078</td>
<td>(HD 108693)</td>
<td>184/184/184</td>
<td>156/157/157</td>
<td>26/26/26</td>
<td>2/1/1</td>
<td>$-13/21/82$</td>
</tr>
<tr>
<td>31 Com</td>
<td>(HD 111469)</td>
<td>363/363/363</td>
<td>313/320/320</td>
<td>42/42/42</td>
<td>8/1/1</td>
<td>$-26/-5/3$</td>
</tr>
<tr>
<td>37 Com</td>
<td>(HD 111469)</td>
<td>317/317/317</td>
<td>255/267/267</td>
<td>56/49/49</td>
<td>6/1/1</td>
<td>$-29/3/3$</td>
</tr>
<tr>
<td>HR 6950</td>
<td>(HD 169414)</td>
<td>202/202/202</td>
<td>199/202/200</td>
<td>0/0/0</td>
<td>1/0/2</td>
<td>$75/69/18$</td>
</tr>
<tr>
<td>HR 7260</td>
<td>(HD 178619)</td>
<td>234/234/234</td>
<td>202/204/203</td>
<td>29/29/29</td>
<td>3/1/2</td>
<td>$-7/-8/-2$</td>
</tr>
<tr>
<td>HD 217183</td>
<td>(HD 216998)</td>
<td>117/117/117</td>
<td>116/114/117</td>
<td>0/0/0</td>
<td>1/3/0</td>
<td>$-13/-9/13$</td>
</tr>
</tbody>
</table>

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III. RESULTS

Figures 1–20 show the differential $V$-light curves plotted against Julian date. Notice that all light curves are upside down. Two of the stars, 11 e Hya and HR 6950, had two different comparison stars and therefore appear twice. Table 2 contains the comparison stars used and summarizes the number of observations and shifts applied to the data. Table 3 presents the mean differential $UBV$ magnitudes and their external uncertainties calculated with equation (2). Individual stars are discussed below.

a) 27 and 28 LMi

This is one of the three pairs of known nonactive stars put on our observing list in order to check the long-term constancy and accuracy of the automatic photoelectric telescope (APT). A total of 645 nightly means in $UBV$ from 1983 through 1987 makes 27 and 28 LMi our most observed object (Fig. 1). Nicolet (1978) assigned her listed $UBV$ magnitudes a quality of 3 on a scale of 1–4 (i.e., probable error between 0.01 and 0.02 mag) for 28 LMi = HD 90040 ($V$ = 5.50 mag, $B-V = +0.98$ mag, $U-B = +0.83$ mag) and for HD 210419 ($V$ = 6.27 mag, $B-V = -0.01$ mag, $U-B = -0.07$ mag); thus, the differential magnitudes $\Delta V$, $\Delta B$, and $\Delta U$ in the sense HD 210434 minus HD 210419 should be $-0.26$, +0.73, and +1.63 mag, respectively. Comparison with our mean values listed in Table 3 shows that our means are systematically smaller than Nicolet’s values by 0.041, 0.041, and 0.167 mag in $\Delta V$, $\Delta B$, and $\Delta U$. This discrepancy can perhaps be attributed to our “pulse coincidence” problem (code C in Table 1). This is discussed in more detail in § II.

d) 13 Cet = HR 142 = HD 3196

The active star in this (F7 V +?) + G4 V triple system belongs to the A component of the visual binary ADS 490AB. The third component (G4 V) is seen at red wavelengths. Although the unseen Ab component may contribute to the $H$ and $K$ emission, the observed weak emission feature comes mostly from the rapidly rotating F7 star ($v$ sin $i$ = 24 km s$^{-1}$; Fekel 1988). The star 13 Cet is listed as NSV 212 in the New Catalog of Suspected Variable Stars (Kholopov et al. 1982). Earlier, Slavenas (1928) reported a photographic variability of nearly 0.2 mag with a period of 0.4692 days, both derived from about 40 plates. The Yale Bright Star Catalogue (Hoffleit and Jaschek 1982) mentions “8 Set ?” type variability, but that was merely a guess and is unconfirmed. The present data set (Fig. 4) does not show any variability. Periodograms around the orbital period of 2.08200 days (Mayor and Mazeh 1987) as well as around Slavenas’s photometric period did not reveal any periodicities. With our external uncertainty for 13 Cet, ±0.010 mag in $V$ (Table 3), we conclude that 13 Cet is actually constant in light.

e) 81 Psc = $\psi^3$ Psc = HD 6903

This star, a rapidly rotating single G0 giant ($v$ sin $i$ = 95 km s$^{-1}$; Alschuler 1975) was put on our observing list because of its interesting position in the Hertzsprung gap and its similarity to HR 9024, the earliest giant for which photometric variability has been confirmed (Hopkins et al. 1985). Baliunas et al. (1983) measured a 6.2 day rotation period from variations in the $H$ and $K$ emission-line fluxes, which implies an equatorial velocity which is too low for the measured $v$ sin $i$. As the authors explain, either the radius has been underestimated or their 6.2 day period is an alias of an expected shorter period. Stickland and Williams (1983) discuss the rotation-activity connection and report strong UV emission lines in $\psi^3$ Psc, typical for CA stars. Our photometric observations covered nearly three observing seasons from 1983 through 1986, but no variability could be detected. With the external uncertainty of a nightly mean from these 3 years of data, ±0.0086 mag in $V$, $\psi^3$ Psc was thus remarkably constant (Table 3). A plot of the differential $V$ magnitudes against Julian date is given in Figure 5. Note that the fourth edition of the Bright Star Catalogue (Hoffleit and Jaschek 1982) inadvertently has $\psi^3$ Psc listed as $\phi^3$ Psc.

f) HD 9312

This star, the brighter companion of the visual binary system ADS 1202, is a single-lined spectroscopic binary with an orbital period of 36.588 days (Heard 1940). Because of its late spectral type, G5, the star was a candidate for light variability due to starspots. The present data set, however,
Fig. 1.—27 LMi minus 28 LMi vs. Julian date

Fig. 2.—51 Aur minus 52 Aur vs. Julian date

Fig. 3.—HD 210434 minus HD 210419 vs. Julian date

Fig. 4.—13 Cet minus HD 3807 vs. Julian date

Fig. 5.—81 ψ1 Psc minus HD 6695 vs. Julian date
Fig. 6.—HD 9312 minus HD 10164 vs. Julian date

Fig. 7.—HR 503 minus HD 11007 vs. Julian date

Fig. 8.—HR 1023 minus HD 20791 vs. Julian date

Fig. 9.—HD 27691 minus HD 27561 vs. Julian date

Fig. 10.—3 Cam minus HD 29316 vs. Julian date
Fig. 11.—1 Gem minus HD 41543 vs. Julian date

Fig. 12.—11 e Hya minus HD 76294 vs. Julian date

Fig. 13.—11 e Hya minus HD 75137 vs. Julian date

Fig. 14.—HD 108078 minus HD 108693 vs. Julian date

Fig. 15.—31 Com minus HD 111469 vs. Julian date
Fig. 16.—37 Com minus HD 111469 vs. Julian date

Fig. 17.—HR 6950 minus HD 169414 vs. Julian date

Fig. 18.—HR 6950 minus HD 170897 vs. Julian date

Fig. 19.—HR 7260 minus HD 178619 vs. Julian date

Fig. 20.—HD 217183 minus HD 216998 vs. Julian date

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uncertainties of our data for HR 1023 are ± 0.0087 mag and metric variability. Our UBV photometry from 1983 through 287 days and measured a $v \sin i$ of 23 km s$^{-1}$ for this G5 giant. Fekel, Moffett, and Henry (1986) found Hα to be a strong absorption feature and suggested a search for photospheric activity. IUE satellite observations by Parthasarathy, Sneden, and Böhm-Vitense (1984) revealed possible that this star might be a low-amplitude variable with a total range of variability less than 0.01 mag in $F$. A period analysis (Fig. 21) revealed two uncertain periods of 3.557 and 4.905 days. Unfortunately, it is not possible to say anything more specific from the present observations, so we hold with the preliminary conclusion that HD 27691 is constant in light.

Further photometry of this interesting star might eventually establish microvariability.

i) HD 27691

This star is the A component of the visual system Ωξ 82, and is itself a spectroscopic binary. The B component is a ninth magnitude star only 0.7 away and therefore included in our photometric observations. The orbit of the single-lined spectroscopic binary with a 4 day period is from Sanford (1920). This star is listed in the $\text{CA}$ $\text{S}$ $\text{A}$ $\text{B}$ $\text{S}$ catalog as a candidate for chromospheric activity. Our photometry covered two observing seasons from 1984 through 1986 (Fig. 9). The mean standard deviation of the nightly means from the overall 2 year mean is less than ± 0.009 mag in $V$ and $B$ (Table 3). The differential $V$ magnitudes for HD 503 are plotted against Julian date in Figure 7.

h) HR 1023 = HD 21018

This star is listed in the $\text{C}$ $\text{A}$ $\text{S}$ $\text{B}$ $\text{S}$ catalog as a candidate for chromospheric activity. IUE satellite observations by Parthasarathy, Sneden, and Böhm-Vitense (1984) revealed only two lines in emission, the N v and the O m line at 1663 A. Lucke and Mayor (1982) determined the orbital period of 287 days and measured a $v \sin i$ of 23 km s$^{-1}$ for this G5 giant. Fekel, Moffett, and Henry (1986) found Hα to be a strong absorption feature and suggested a search for photospheric variability. Our $UBV$ photometry from 1983 through 1987 shows the star to be essentially constant. The external uncertainties of our data for HR 1023 are ± 0.0087 mag and ± 0.010 mag in $V$ and $B$, respectively (Table 3). All 4 years of $V$ observations are plotted against Julian date in Figure 8.

j) 3 Cam = HR 1467 = HD 29317

The $New$ $Catalog$ of $Suspected$ $Variable$ $Stars$ (Kholopov $et$ $al$. 1982) lists this star as a suspected "Cepheid" variable (NSV 1681). The active star in this 121 day spectroscopic binary (Cannon 1918) is a K0 giant with weak H and K emission (Wilson 1976). The star is also listed in the $\text{C}$ $\text{A}$ $\text{S}$ $\text{B}$ $\text{S}$ catalog. Baliunas $et$ $al$. (1983) found the star to have variable H and K emission-line flux with a period consistent with the orbital period of 121 days. They also detected shorter term
fluctuations. Our differential $UBV$ photometry shows no clear indication of variability. A plot of $\Delta V$ versus Julian date is given in Figure 10. A periodogram analysis over a wide range of periods around the orbital period shows a very small dip at about 112±3 days. If real, the total range of variability must be smaller than 0.01 mag in $V$. For a long-period star like 3 Cam this is about the detection limit for the 25 cm APT.

$k) 1$ Gem (B) = HB 2134 = HD 41116

The visually fainter star, which is also the bluer, is the short-period spectroscopic binary 1 Gem B; component A (K0 III) dominates in the red wavelength region. Our photometry with a 60" diaphragm includes components A and B. Fekel (1988) estimates the spectral type for the visible (spectroscopic) component of B to be F6-7 from IUE observations instead of the widely referenced G8 IV-III classification of Abt and Kallarakal (1963), which makes it unlikely to find photometric variability due to spot activity. A period search over a wide range of periods around the orbital period of 9.5966 days (Griffin and Radford 1976) showed no hints of any periodic light variations in the $K$ and $B$ bandpasses, as is apparent from Figure 11. We note, however, that our external uncertainties for 1 Gem (Table 3) are somewhat higher than normal, perhaps indicating a low-amplitude variability.

$l) 11$ Hya = $\epsilon$ Hya = HD 74874

The star 11 $\epsilon$ Hya (K III; Cowley 1976) is the brighter component of the visual multiple system ADS 6993. Weak chromospheric activity of this rapidly rotating ($v \sin i = 19$ km s$^{-1}$; Uesugi and Fukuda 1982) K giant has been reported by Stickland and Williams (1983). Ishida (1985) reviewed the orbital elements of the AB pair, $P_{\text{orb}} = 15.05$ yr and a semi-major axis of 0″226. The C component ($V \sim 7.5$ mag, F5, about 3′′ from AB) is itself a spectroscopic binary with an orbital period of 9.9047 days and $e = 0.62$ (Sanford 1926). Thus, several components are within our 60″ diaphragm. For a more detailed discussion and further references see Batten, Fletcher, and Mann (1978). The star $\epsilon$ Hya has been on our observing program with two different comparison stars (Figs. 12 and 13 and Table 2). Neither of the two data sets exhibits variability. A periodogram analysis for each individual season also failed to detect any periodicities in the present data.

$m) HD 108078

This star is a K1 giant (Upgren 1962) in a single-lined spectroscopic binary system with an orbital period of 61.411 days and an eccentric orbit with $e = 0.398 \pm 0.009$ (Griffin 1980). Griffin also noted that the separation of the components can be no more than a few times the radius of the K giant. Thus, the star is likely to be a candidate for light variations due to the ellipticity effect as well as spot activity. Visual inspection of our $V$ photometry (Fig. 14) shows no evidence for variability. A periodogram analysis allowing for a wide range of periods around and less than the orbital period also failed to detect any periodicities. A fit at exactly half the orbital period showed that the Fourier coefficient of the ellipticity effect must be less than $A_2 = 0.00083$. The somewhat high external uncertainties listed in Table 3 arise partially from the displacement of several nightly means because of problem D (see Table 1).

$n) 31$ Com = HR 4883 = HD 111812

This star is another example of a rapidly rotating single giant ($v \sin i = 80$ km s$^{-1}$; Uesugi and Fukuda 1982) in the Hertzsprung gap. Our photometric observations covered three seasons from 1983 through 1986. No definite variability can be seen in the data plotted in Figure 15, although we note that the scatter in $V$ was about twice as high during the 1983–1984 season as in the middle of the following 1984–1985 season. Nevertheless, the overall external uncertainties are fairly small, ±0.009 mag in $V$ and ±0.011 mag in $B$, and the periodogram covering a wide range of periods showed nothing, so we conclude that 31 Com does not vary in light.
Fig. 22.—Periodograms for HR 6950. The two upper panels are from the data portion with HD 169414 as a comparison star (upper panel: 1983–1984; middle panel: 1985). The lower panel is from the data portion with HD 170897 as a comparison star (1985). A dip at about 10 days shows up in both data sets, as can be seen in the middle and in the lower panel, but none in the upper panel. This might be a hint that HR 6950 is a possible microvariable. The two arrows indicate the orbital and one-half of the orbital period. Note that the two 1985 periodograms are derived from the first half of the observing season (middle panel) and from the second half (lower panel), respectively, and do not overlap.
The star 37 Com is a very interesting single G9 giant (MK type III–II) having lines rotationally broadened by $v \sin i = 10.4 \pm 0.3$ km s$^{-1}$ (Smith and Dominy 1979). Tomkin, Luck, and Lambert (1976) have found indications that 37 Com is a fairly evolved and well-mixed star, contrary to what could be expected from its high rotational velocity. Thus, 37 Com seemed to be a good candidate for spot activity. Our differential UBV photometry covered nearly three observing seasons from 1983–1984 through 1985–1986. Visual inspection of the light curve in Figure 16 might reveal that our data mimic an approximately 60 day period low-amplitude variability. A periodogram over a wide range of periods shows several shallow dips around a period of $\sim 25$ days and one at $\sim 67$ days. The significance of these periods, however, is so small that we are not convinced they are real. Therefore, we conclude that 37 Com is constant within our external uncertainty of $\pm 0.01$ mag in $V$.

HR 6950 has been on our observing program with two different comparison stars (Table 2). Differential $V$ magnitudes in the sense HR 6950 minus HD 169414 are plotted in Figure 17, and in the sense HR 6950 minus HD 170897 in Figure 18. Since JD 2,446,284 the APT used HD 170897 as the comparison star. Hall et al. (1986) reported HR 6950 to be a new variable star. Their judgment was based on an approximate 0.02 mag dimming of the mean $V$ light level between 1983–1984 and 1984–1985 (i.e., the first two data blocks in Fig. 17). Visual examination of the check minus comparison magnitudes (i.e., HD 168720 minus HD 169414) did not show a similar dimming. On the other hand, because HD 169414 ($\sim$109 Her) is listed as NSV 10742 in the New Catalog of Suspected Variable Stars with a 0.04 mag variability, a new comparison star was used after mid-1985. This rendered the discovery of the variability of HR 6950 meaningless. But, to make the confusion perfect, as is apparent from a
comparison of Figures 17 and 18, we were again unlucky and chose another suspected variable as our comparison star, this time HD 170897 = NSV 10958. The entry of this star into the NSV catalog is based on an old note by Zacharov (1924), who used it as a comparison star for his visual eye estimates of AC Her.

Our $UBV$ photometry of HR 6950 minus HD 170897 (Fig. 18) shows more than twice the scatter of the earlier photometry versus HD 169414 (Fig. 17), namely, $\pm 0.026$ mag in $V$ and nearly $0.1$ in $U$ as compared with $\pm 0.012$ and $\pm 0.015$ in $V$ and $U$ for the first comparison star. A plot for the magnitude differences between the check star (106 Her) and the comparison star HD 170897 shows the same scatter, indicating that the comparison star is the likely variable. Thus, we arrive at following conclusion: (1) HR 6950 is constant in light, (2) the suspected variable NSV 10742 = HD 169414 is also a constant star, and (3) the suspected variable NSV 10958 = HD 170897 is a low-amplitude variable star having a peak-to-peak variation of $\sim 0.07$ mag in $V$ and $\sim 0.1$ in $U$ but no periodicity greater than 0.5 days appeared in our periodograms. Figure 22 shows our unsuccessful search for a period in our $V$ photometry of HR 6950. The two upper periodograms are from the HR 6950 minus HD 169414 data set, and the lower periodogram is from our HD 170897 data set. Note that a dip occurs near 10 days in the lower two panels, namely, at 9.3 $\pm$ 0.3 and 9.6 $\pm$ 0.3 days, but not in the upper panel. That might indicate some low-amplitude variability of HR 6950.

This star was put on our observing list because of the 21.998 day orbital period (Albitzky 1933) and its late spectral type of G5 V. Thus, spot activity similar to the RS CVn stars might be expected. Our differential $UBV$ photometry (Fig. 19) from 1984 through 1987, however, does not show any variability in excess of our external uncertainty of $\pm 0.008$ in $V$ and $B$, and $\pm 0.010$ in $U$ (Table 3).

Very little is known for this 7.0 mag K5 star; the $Sky$ $Catalogue$ $2000.0$ (Hirshfeld and Sinnott 1982) lists it with a "giant" luminosity classification. Visual inspection of our $V$ photometry (Fig. 20) shows no variability over the period of observation. The external uncertainty of a nightly mean is $\pm 0.012$ in $V$ (Table 3). Several periodograms over a wide range of periods failed to detect a short-term variability. A representative periodogram for the 1984–1985 season is given in Figure 23.

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Douglas S. Hall and Klaus G. Strassmeier: Dyer Observatory, Department of Physics and Astronomy, Vanderbilt University, Nashville, TN 37235

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