PHOTOMETRY OF γ EQUULEI AND HD 140728

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The peculiar A stars γ Equulei[1] and HD 140728[2] have been observed photoelectrically for light variability. Gamma Equulei showed none while HD 140728 was found to vary with a period of 1.30508 days and an amplitude of 0^m01 in the blue.

The 1958 and 1959 observations were made with a 10-inch refractor; the 1960 observations were made with a 12-inch reflector. All observations were transferred to the *B, V* system of Johnson and Morgan by transformations previously given.[3,4] The same observing procedure was used for both stars; two comparison stars were used and were observed alternately. Since none of the comparison stars showed any significant variability, the magnitudes for one comparison star were reduced to the equivalent values for the other by adding the mean difference in magnitude. During 1958 the average number of observations per night was three for each comparison star and five for the star under investigation. During 1960 the numbers were five and nine, respectively. During 1959 about 15 observations per night were made in a search for short-period variations.

Gamma Equulei, of spectral type F0p(A7p), shows a magnetic field that is of constant polarity and irregular amplitude;[5] it is the prototype of the gamma magnetic variables. According to the *Catalog of Magnetic Stars*[5] the magnetic field varies between +185 and +880 gauss, and the radial velocity varies from −14.3 to −18.2 km/sec. The spectral lines are sharp, implying either that the star is seen nearly pole-on or that it rotates very slowly. With the generally similar, peculiar A star β Coronae Borealis, it lies about one magnitude above the main sequence.

The comparison stars were δ Equulei (F8 V) and 6 Equulei (A2). The magnitude differences between γ Equulei and the comparison stars, and between the two comparison stars are shown in Figure 1. With the possible exception of the difference between the comparison stars for JD 2437146.7 there appears to be no deviation from the mean that cannot be attributed to ob-

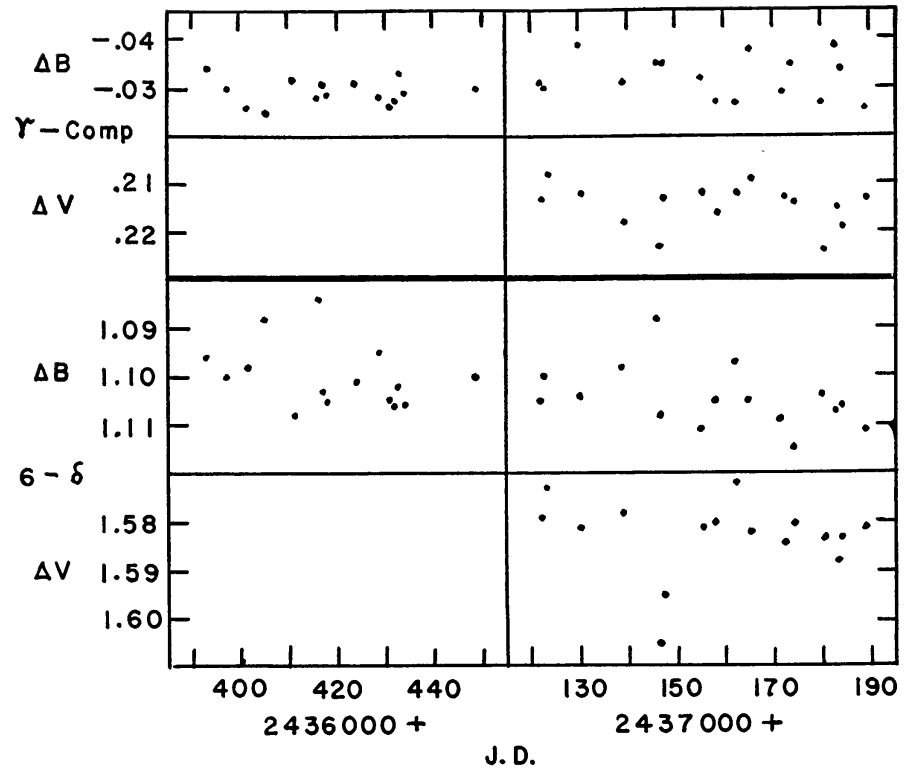

FIG. 1.—*Above:* magnitude differences γ Equulei minus δ Equulei and 6 Equulei (equivalent values). *Below:* magnitude differences 6 Equulei minus δ Equulei.

servational error. The smaller range for γ Equulei is to be expected because of the larger number of deflections per night and the alternation of the measurements on the comparison stars. The difference of the mean values for the differences in the two years in the blue is 0^m003 for γ Equulei, and 0^m005 for the comparison stars, which may be attributed primarily to errors in correcting the magnitudes to the same system. The observations in 1960 covered an interval of about two hours each night. No short-period variations were found that could not be attributed to observational error.

This conclusion may be placed on a quantitative basis by applying the χ^2 test as discussed by E. L. Scott.[6] The test consists of saying that the star is variable if

$$\frac{1}{\sigma^2}\Sigma(\Delta m - \overline{\Delta m})^2 \geqq \chi^2_{a,n-1} \ ;$$

the tabulated value of χ^2 may be found on p. 626 of reference 6, and n is the number of nights. We take $\alpha = 0.1$, which means that there is one chance in ten of saying that the star is variable when it is really constant. The value of the dispersion, σ, for one night may be estimated from the differences between pairs of comparison stars, both those discussed here and similar observations. Values of these quantities are listed in Table I, showing that the test indicates no variability. The values of $1/\sigma^2$ $[\Sigma(\Delta m - \overline{\Delta m})^2]$ may be somewhat low, since no allowance was made for the fact that the interval of time between deflections on comparison stars was longer than the interval between γ Equulei and its comparison stars. From the above-mentioned discussion by Scott, it can be seen that for a sinusoidal variation, an amplitude of $0^m.008$ in the blue or $0^m.012$ in the yellow would have a probability of detection of 0.97 by this test.

TABLE I

TEST FOR VARIABILITY OF γ EQUULEI

Wavelength region	B	V
σ	0.004	0.006
$1/\sigma^2[\Sigma(\Delta m - \overline{\Delta m})^2]$	17.0	8.3
χ^2	22.31	22.31

HD 140728, A0p, was selected from a list of peculiar A stars showing strong lines of Si II, supplied by A. J. Deutsch. The comparison stars were HD 139493 (A0) and HD 141675 (A2). Observations in the blue on 22 nights in 1958 indicated a dispersion in the magnitude difference between HD 140728 and its comparison stars twice as great as that between the two comparison stars. (The number and order of the observations of the stars on each night should have resulted in an effect in the opposite sense if the three stars were constant.) Since this established HD 140728 as a variable, it was observed in two colors in 1959 and 1960.

Initially a period of 4.2283 days was found, but this appears to be the beat period owing to spacing of the observations at an interval of approximately one sidereal day. The best representation seems to be given by a period of 1.30508 days, although the

associated period, 0.80695 day, also gives a satisfactory representation of the 1958 observations.

The elements adopted are

$$\text{Maximum light} = \text{JD } 2436400.95 + 1.30508 \cdot \text{E}\,.$$

The light curve is shown in Figure 2, where the magnitude differences refer to HD 139493. The amplitude in the blue is $0^m.014$. The dashed curve was drawn freehand and is intended only to indicate the general trend of the light variation. In the yellow, a light curve is not clearly defined, but the amplitude is certainly smaller than in the blue—perhaps $0^m.004$. A plot of the color variation, $\Delta(B - V)$, shows a shape similar to the blue curve but with an amplitude of about $0^m.010$. The yellow variation is in phase with the blue, and the star is bluer at maximum.

Babcock[7] lists the line width as approximately 2Å—too broad for measurements of the Zeeman effect. If the line width and the

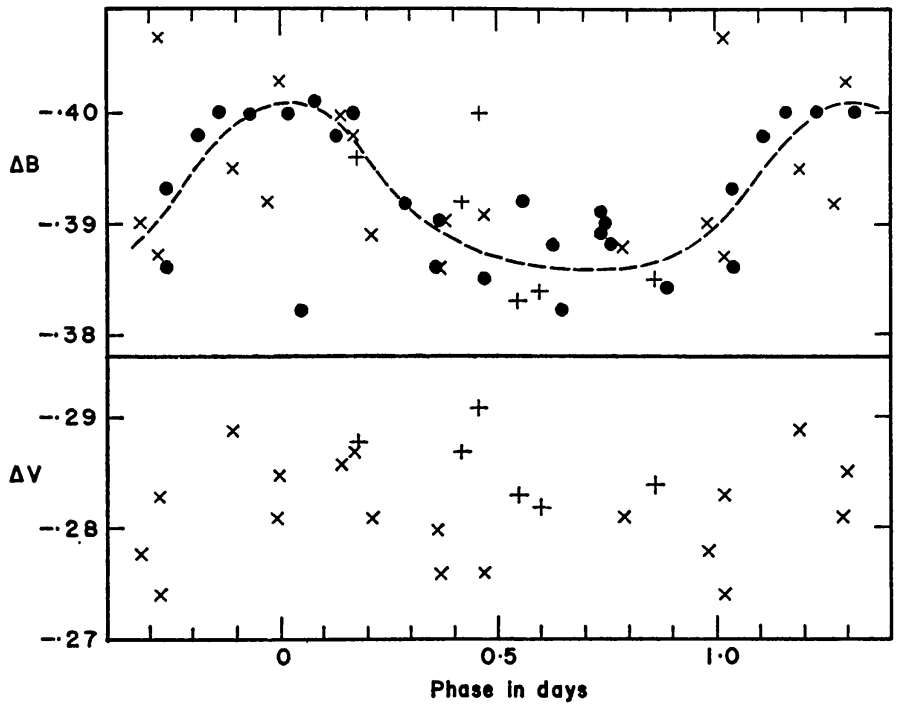

FIG. 2.—*Above,* light curve (freehand) in the blue, and *below,* magnitude differences in the yellow for HD 140728 with a period of 1.3051 days. The comparison star values are for HD 139493 and HD 141675 corrected to the equivalent values for HD 139493. The dots are for 1958, the plus signs for 1959, and the crosses for 1960.

light variability are attributed to rotation, the angle of inclination of the axis of rotation, i, may be derived. From the broadening of the spectral lines, the period of rotation is $1.8 \sin i$ days. With the observed period of light variability this gives an inclination of the axis of rotation of approximately 45°; however, a more precise value of the line width would be required to make this determination reliable.

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[1] HD 201601 = HR 8097 = ADS 14702: $\alpha = 21^h\ 5^m5$, $\delta = +9°\ 44'$ (1900), $m_{pg} = 5.04$, F0p(A7p).

[2] HR 5857: $\alpha = 15^h\ 40^m2$, $\delta = +52°\ 40'$ (1900), $m_{pg} = 5.48$, A0p.

[3] A. Wehlau and W. Wehlau, *A.J.*, **64**, 465, 1959.

[4] W. Wehlau, *Pub. A.S.P.*, **74**, 137, 1962.

[5] H. W. Babcock, *Ap. J. Supplements*, **3**, 198, 1958 (No. 30).

[6] In *Statistical Astronomy*, by R. J. Trumpler and H. F. Weaver (Berkeley: University of California Press, 1953), pp. 203–11.

[7] H. W. Babcock, in *Stellar Atmospheres*, J. L. Greenstein, ed. (Chicago: University of Chicago Press, 1960), p. 307.