A SKY SURVEY FOR δ SCUTI STARS

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Abstract

A photoelectric survey is being conducted at the San Francisco State University Observatory for undetected δ Scuti variables, with a preliminary conclusion that these stars may be quite common among late A and early F class field stars.

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δ Scuti Stars

The δ Scuti stars are a class of pulsating variables with a characteristic period of from 1 to 3 hours, and a blue light amplitude of generally less than $0^m.1$. The spectral class ranges from about A3 to F6, with the luminosity class typically class IV (sub-giant), although occasionally class III (giant) or class V (dwarf). In addition, these stars are often observed to be spectroscopic binaries with a period of orbit of a few days. The position of this class of stars on the H-R diagram suggests a relation with the Dwarf Cepheids, which have similar spectral characteristics but a greater light amplitude, and the RR Lyrae stars, which also have a longer period.

Photoelectric photometry of the Alpha Persei cluster (Slovak 1978) and of the Pleaides (Breger 1972) revealed an incidence of 20% and 31%, respectively, of δ Scuti pulsation among cluster members. Work that has been done with other clusters revealed incidences of from 0 to 32%, with no obvious relation to cluster age or size. Many of the stars observed showed variations at the limits of instrumentation, about 0.001 magnitudes with the largest telescopes. It is unknown, however, whether these incidences are also characteristic of the field stars. Such a project is in progress at the San Francisco State University Observatory, and will be described in this paper.

Equipment

The equipment used for this survey is a 1P21 photomultiplier, with support electronics and standard UBV filters, used with either the 16-inch Cassegrain reflector or the 10-inch Celestron located at the SFSU Observatory. On nights when San Francisco is under local coastal clouds, visits are made to the Chabot Observatory, in Oakland, for use of the 20-inch refractor located there. The data are gathered by a microcomputer and stored on tape for later analysis. The amplified, analog signal generated by the photomultiplier is converted to a digital form by a digital voltmeter, which is interfaced directly to the computer. To handle the large amount of data generated and to give an accurate data reduction, all phases of data acquisition and analysis are microcomputer-controlled.

Techniques

Because of the urban sky brightness, turbulent coastal atmosphere, and modest telescope apertures used, selection of the potential variable stars to observe is limited to those listed in the Yale Bright Star Catalog (stars brighter than $6^m.5$). Candidate variables are chosen from those cataloged stars with spectral classes between A3 and F6, luminosity classes III and IV (the δ Scuti "instability zone"),

and especially those observed to have short period spectroscopic binary companions. Comparison stars are chosen to be as similar in color and brightness as possible, without actually being in the instability strip.

During an observing run, 100 samples of the star's brightness are taken during a 30-second interval by the computer. The values are averaged to form one reading, with the standard deviation providing a quantitative measure of turbulence - and hence data quality. The number of samples, and the 30-second interval, are sufficient to average out the high-speed scintillation found in any photoelectric measure of starlight. Each reading of the candidate variable is bracketed by a pair of comparison star readings, with the brightness of the comparison star taken to be a linear interpolation of the two readings, at the time of the variable star reading. In this way compensation is made for any possible systematic errors caused by changing atmospheric opacity between the readings, or changes in the sensitivity of the electronics. A similar bracketing with the sky readings is also done. The sequence of candidate variable, comparison, and sky readings is done for up to three hours for each variable.

Because of the very small amplitudes of δ Scuti variables, and because suitable comparison stars for the bright stars observed are often several degrees apart in the sky, extinction coefficients are extremely important. Differential atmospheric extinction is measured at various times of the year to reflect changing weather conditions. The values used for data reduction are 0.19 for visual light, and 0.39 for blue light, which are consistent with the values reported by other maritime observatories (Galloway 1975).

Findings

The survey data to date are summarized in Table 1. At the beginning of the program, observations of two known δ Scuti variables (14 Aurigae and 44 Tauri) were undertaken to determine the accuracy of the equipment and the adequacy of the observatory location. The observed light curves of these stars are shown in Figures 1 and 2. From these observations it was found that a measurement accuracy of about 0.005 is achievable with the best of seeing, and that an accuracy of 0.01 is possible with more typical local seeing. Measurements of these stars taken in three color UBV show that their variations are most pronounced in blue light, a finding that is consistent with other observers.

The remaining figures show the light curves obtained for the observed program stars which are apparently variable. For some of these stars, light curves were obtained on more than one night if the data on hand were ambigious and a follow-up observation was considered necessary. The stars listed in Table 1 as not variable showed no systematic variation greater than $0^{m}02$ - $0^{m}03$, which does not preclude an amplitude of less than this amount. If the data were too uncertain to make a determination that the star was not variable, the status is listed as "possible" in the table. This status is given only if a cyclical light curve through the data points is as or more plausible than a straight line fit.

Other than the two known δ Scuti variables observed at the beginning of the program, a total of 18 different stars has now been observed, of which five are variable, four are possibly variable, and nine are not. Of the five variables, four lie in the instability strip, while the fifth (HR 4594) is a magnetic A star. Of the stars found not to vary, only one (HR 6561) lies in the instability strip. Again, this does not preclude variations of less than $0^{m}02$ in this star. Of the stars observed that are in the instability strip, 40%

were found to be variable, although a larger sample size is needed to determine if this trend is valid.

The anticipated relation of spectroscopic binaries to δ Scuti pulsations has not been observed. Only one (HR 5317) of the variables is a known spectroscopic binary, while eight of the nine non-variable stars are spectroscopic binaries. It should be noted, however, that although the stars HR 3450 and HR 6561 are spectroscopic binaries and lie in the instability strip, they are not found to be variable. The other six non-varying binaries do not lie in the instability strip.

Some remarks on the individual stars observed follow:

58 Tauri — This star was observed on three occasions in an effort to obtain a period for the detected variations. On the first two attempts only partial light curves were obtained (see Fig. 3), but on the third try a complete light cycle seems to be recorded (Fig. 4). The period is 1.5 hours with an amplitude of about $0^{m}.04$.

29 Ursae Majoris — Table 1 shows this star observed once on J.D. 2444319 with the comparison star 23 UMa. Later observations, however, determined that the comparison star is possibly variable itself. Additional data needs to be taken for 29 UMa.

67 Ursae Majoris (a) — The period observed is about 1.5 hours with an amplitude of $0^{m}.025$. (Fig. 5)

23 Ursae Majoris — The period observed is about 2.0 hours with an amplitude of $0^{m}.07$. (Fig. 6)

HR 5317 — A complete light curve has not been obtained for this star, but the data (Fig. 7) show the period to be greater than 2 hours and the amplitude to be greater than $0^{m}.05$.

21 Bootis — This star may be one of the fastest known pulsating variables. The period observed in a light curve obtained on J.D. 2444415 (Fig. 8) is 40 minutes, with an amplitude of $0^{m}.025$. A follow-up observation made later in the season (Fig. 9) also shows a period of 35-40 minutes and an amplitude of $0^{m}.025$.

Although the sample size is too small for substantive interpretation, the incidence of δ Scuti pulsation in field stars in the instability strip is high. If the pattern found in this survey is an accurate representation of the stellar population, then this class of variable stars may be much more common than previously thought.

For the continuing success of this program I would like to thank Prof. Charles Hagar, Director, San Francisco State University Astronomy Program; Dr. Kingsley Wightman, Director, Chabot Observatory; and Kenneth Letsch, SFSU, for invaluable assistance.

REFERENCES

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Slovak, Mark. 1978, Astrophys. Journ., 223, 192.

TABLE 1

Observational Program

Star Observed: Designation	HR	Spec. Class	Julian Date (+2444000)	Comparison Star: Designation	HR	Observatory & Telescope	Results	Data Quality
14 Aur	1706	A9V sb	196	16 Aur	1726	SFSU 10"	Known Var.	Good
58 Tau	1356	sgA8	196	73 Tau	1396	SFSU 10"	Variable	Good
44 Tau	1287	dF3	197	41 Tau	1268	SFSU 10"	Known Var.	Good
70 Cet	691	A5 sb	203	- - -	732	SFSU 10"	Possible	
9 Tri	664	A0V	203	4 Tri	622	SFSU 10"	Not Var.	
60 Ori	2103	A1 sb	220	56 Ori	2037	Chabot 20"	Possible	Good
60 Ori	2103	A1 sb	221	56 Ori	2037	SFSU 10"	Not Var.?	Poor
58 Tau	1356	sgA8	223	73 Tau	1396	Chabot 20"	Variable	
29 UMa	3888	F2IV	319	23 UMa	3757	SFSU 16"	Possible?	Poor
8 Cnc	3163	A0IV sb	320	12 Cnc	3184	SFSU 10"	Not Var.	Good
14 Leo	3852	A2+F6II sb	320	30 Leo	3975	SFSU 10"	Not Var.	Good
45 Cnc	3450	A9s sb	321	50 Cnc	3481	SFSU 10"	Possible	Good
51 Cnc	3519	Am sb	321	- - -	3528	SFSU 10"	Not Var.?	Poor

TABLE 1 (cont.)

Star Observed: Designation	HR	Spec. Class	Julian Date (+2444000)	Comparison Star: Designation	HR	Observatory & Telescope	Results	Data Quality
14 Aur	1706	A9V sb	322	16 Aur	1726	SFSU 10"	Known Var.	Good
45 Cnc	3450	A9s sb	325	50 Cnc	3481	SFSU 10"	Not Var.	Good
26 Gem	2466	A2V sb	326	30 Gem	2478	SFSU 10"	Not Var.	Fair
- - -	3486	A2 sb	328	14 Hya	3500	SFSU 10"	Not Var.	Good
67 Cnc	3589	A5 sb	339	70 Cnc	3601	SFSU 10"	Possible	
67 UMa a	4594	Am	354	67 UMa b	4594	SFSU 16"	Variable	
23 UMa	3757	F0IV	364	54 UMa	4377	SFSU 16"	Variable	
- - -	5317	F6IV sb	404	- - -	5342	SFSU 10"	Variable	Good
21 Boo	5350	A7V	415	- - -	5360	SFSU 10"	Variable	Good
21 Boo	5350	A7V	452	- - -	5360	SFSU 10"	Variable	Good
55 Ser	6561	F0IV sb	452	56 Ser	6581	SFSU 10"	Not Var.	Fair
65 Cyg	8130	F0IV	452	64 Cyg	8115	SFSU 10"	Possible	Fair
58 Tau	1356	sgA8	452	57 Tau	1351	SFSU 10"	Variable	Good

Notes: 1. An sb after the spectral class indicates a spectroscopic binary

2. Data quality is determined by the following criteria: Good is an uncertainty in the reduced data of less than $0^m.01$; Fair is an uncertainty of $0^m.01$ to $0^m.02$; Poor is an uncertainty greater than $0^m.02$.

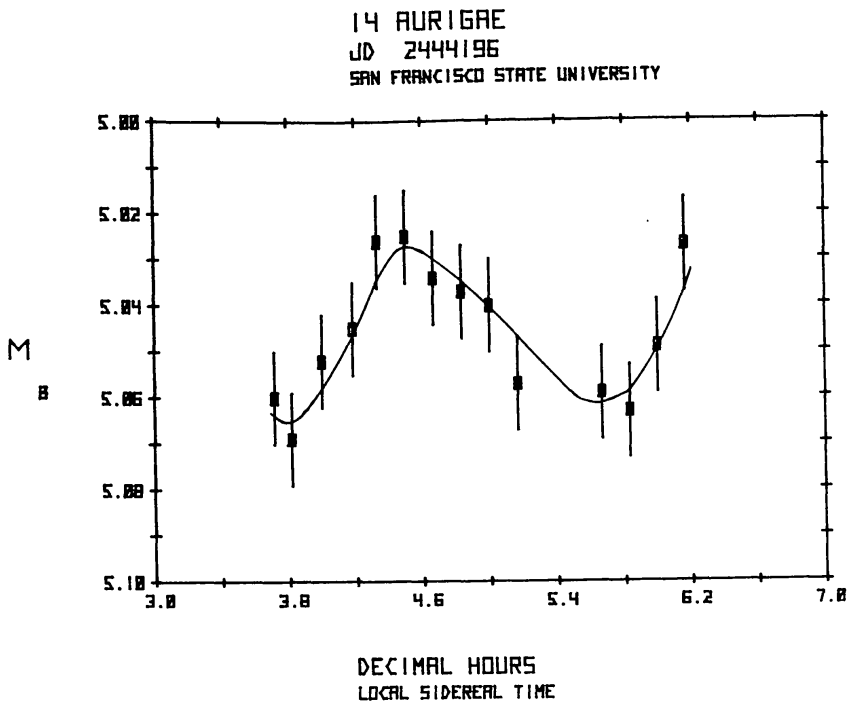

Figure 1. A test observation of 14 Aurigae, known to be variable, was made at the beginning of the program to test the equipment, the sky, and the data aquisition methods. The data points were found to lie within $0^{m}.005$ of a smooth light curve

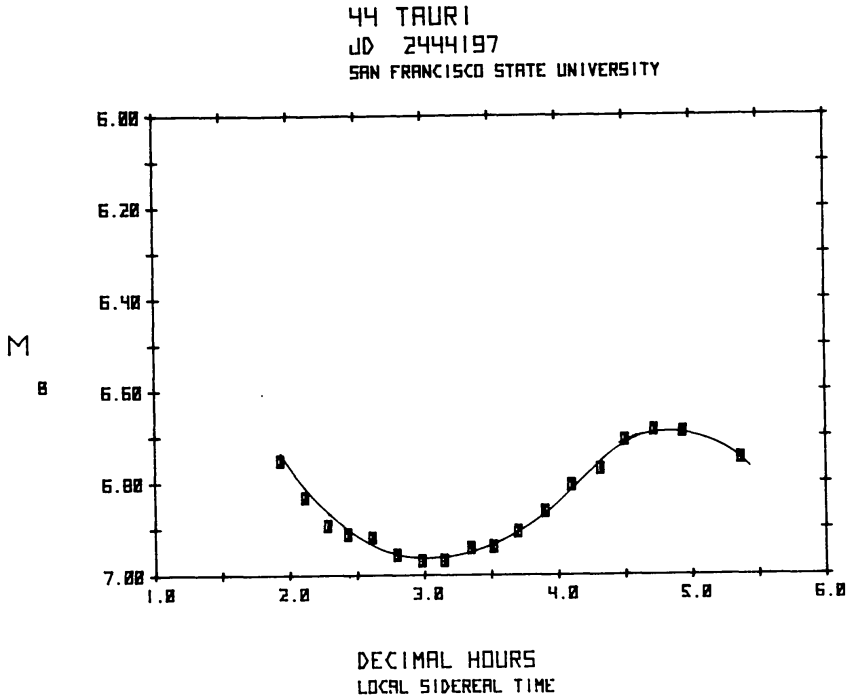

Figure 2. Similar test results to Fig. 1. were obtained with a test observation of 44 Tauri. This star is known to have one of the largest amplitudes in the Delta Scuti class.

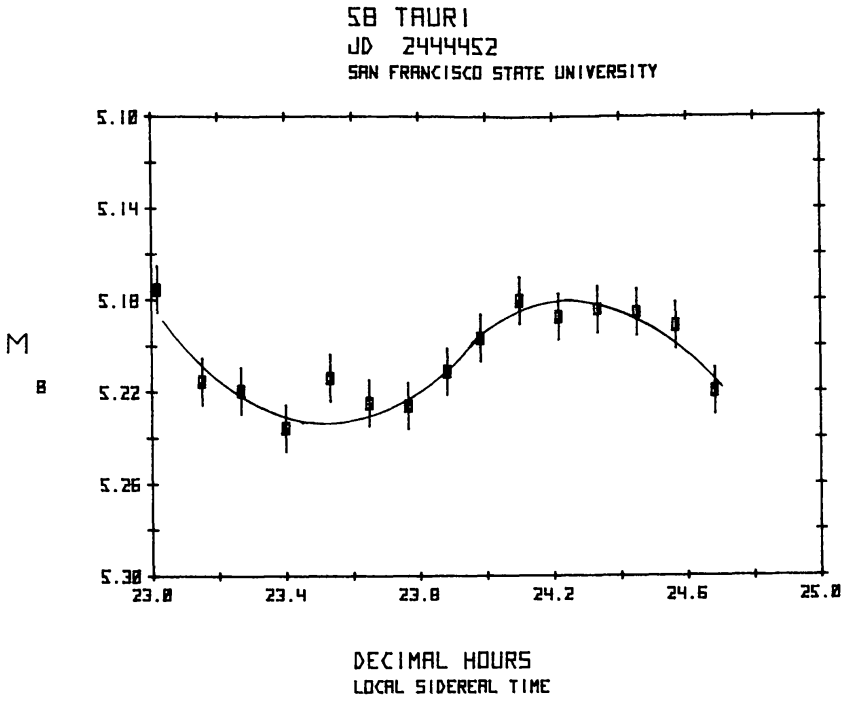

Figure 3. An incomplete light curve obtained of this star in the Hyades Cluster suggested variability.

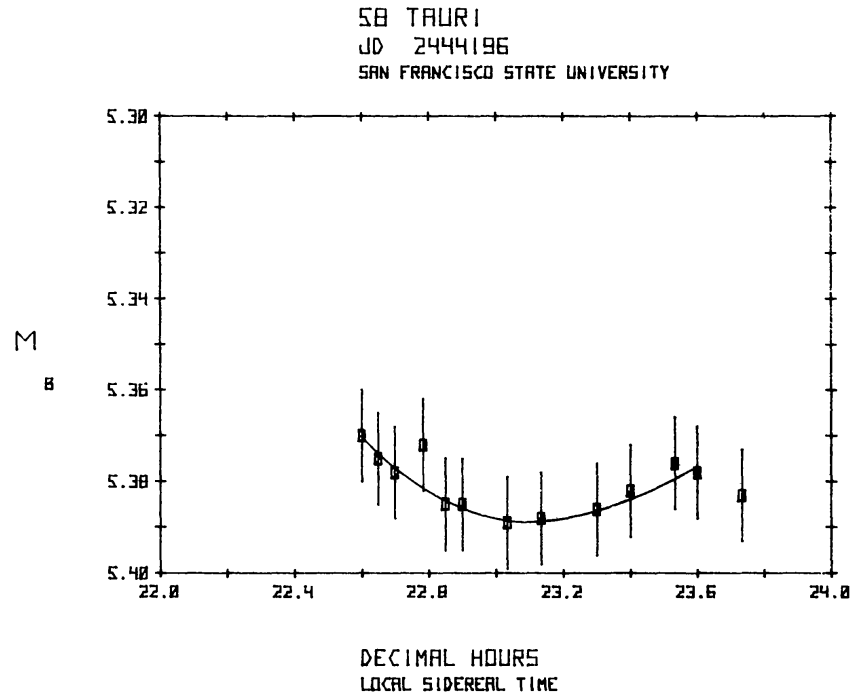

Figure 4. A follow-up observation to Fig. 3 revealed the full light curve of 58 Tauri.

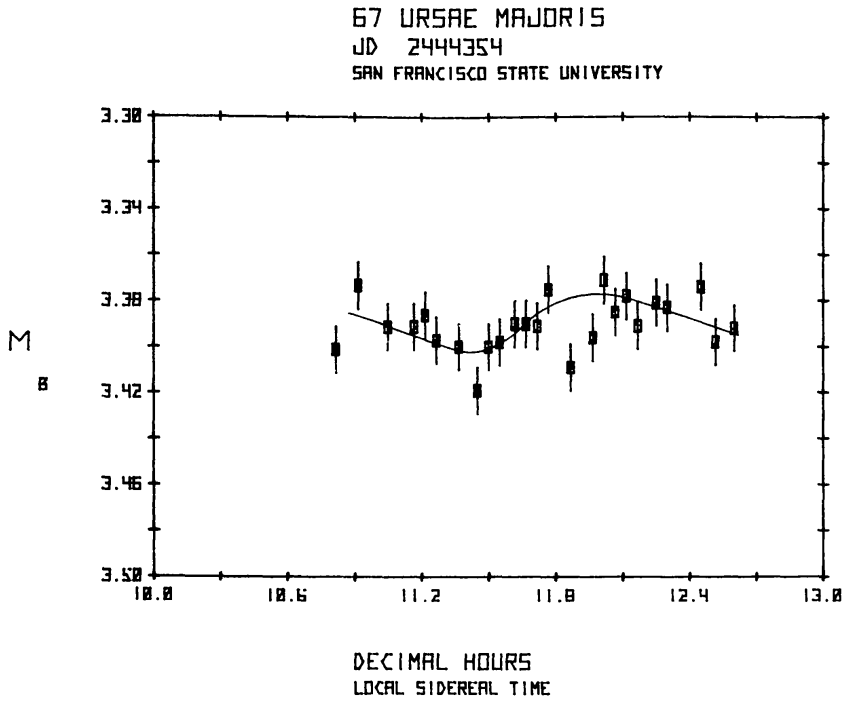

Figure 5. A light curve obtained for 67 Ursae Majoris showed a very small amplitude of $0^{m}.025$ during a 1.5 hour period.

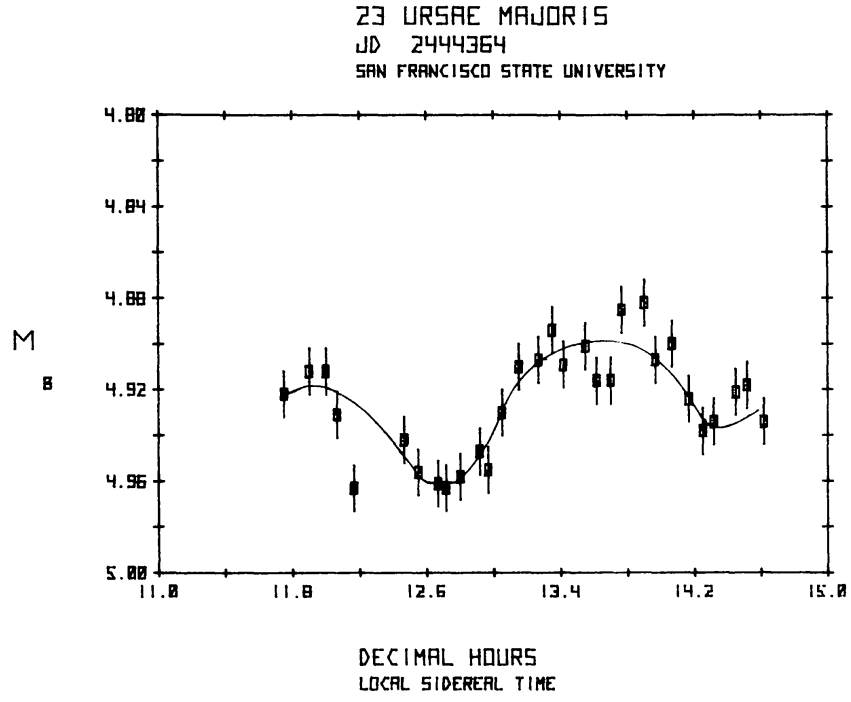

Figure 6. The light curve obtained for 23 Ursae Majoris.

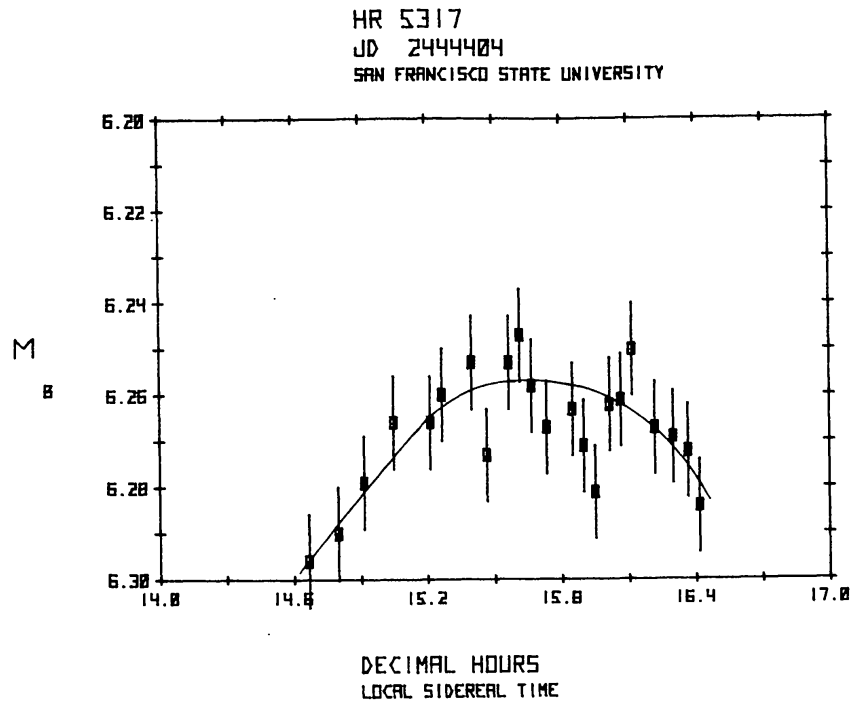

Figure 7. An incomplete light curve of HR 5317, but strongly suggestive of a cyclical variation in light.

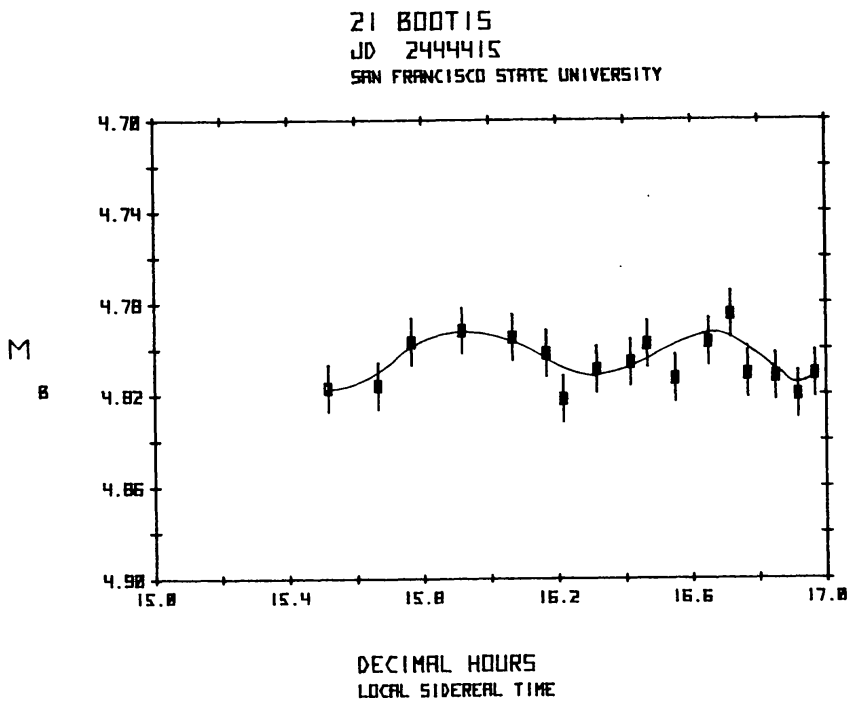

Figure 8. An observation of 21 Bootis showed this star to have one of the fastest periods of any known pulsating variable. The light curve shows a variation of $0^{m}.025$ over a 40 minute period.

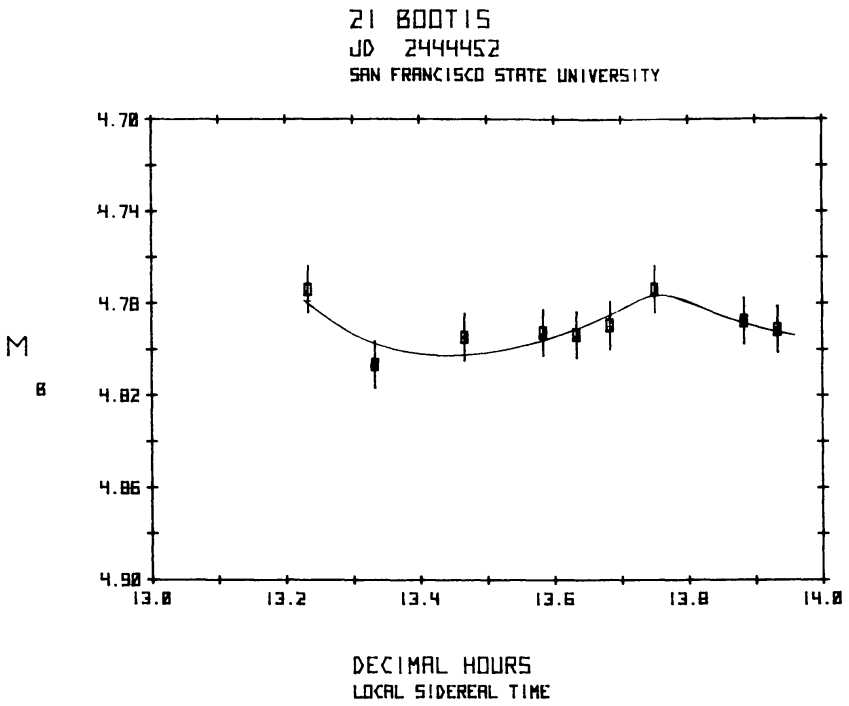

Figure 9. A follow-up observation to Fig. 8 again showed 21 Bootis to have an extremely short period of 35 - 40 minutes with an amplitude of $0^{m}.025$.