THE PHOTOMETRIC VARIABILITY OF Ap STAR 10 AQL

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RIASSUNTO. — Vengono presentate le osservazioni fotoelettriche nei colori B e V eseguite nel 1972 all'Osservatorio di Merate sulla stella Ap 10 Aql. Esse mettono in dubbio il periodo e l'ampiezza di variazione luminosa ottenute da STEPIEN (1968). Si è trovato un nuovo periodo di variazione di $6^d.05$, che però può non essere reale. Anche l'ipotesi di PRESTON (1970), relativa a variazioni di lungo periodo, pare molto discutibile.

SUMMARY. — Photoelectric observations obtained at the Merate Observatory during the year 1972 in the B and V colours are reported. The period and amplitude of the light variations given by STEPIEN (1968) are questioned, and a new period of $6^d.05$ days is proposed, which however may be unreable. Also the proposal by PRESTON (1970) of a much longer period seems very questionable.

1. - INTRODUCTION

BABCOCK (1958) classified 10 Aql as an Ap star and he measured a variable magnetic field from about 400 Gauss to about -300 Gauss during a period of years. The star belongs to the *Cr-Sr-Eu* group (AUER 1964). STEPIEN (1968), on the grounds of photoelectric observations made during seventeen nights, proposed a period of $9^d.78$ and a variation amplitude of $0^m.01$ for the V, B-V, U-B curves. However PRESTON (1970) measured a constant magnetic field of approximately 500 Gauss for ten consecutive nights: this result casts doubt on Stepien's period, since the magnetic and photometric periods seem to coincide for all the Ap stars examined up to now. Moreover the extremely low value of *vseni* (≤ 5 km/sec), if the pole-on configuration is not true, indicates a very slow rotational velocity and consequently, if we accept the oblique rotator theory, quite a long period of variation.

This dilemma, in connection with the problem relating to the long periods of Ap stars, compelled us to make further photoelectric observations of 10 Aql.

(*) Ricevuta il 13 Settembre 1973. Testo definitivo il 22 Novembre 1973.

2. - The observations and the research of the period

We observed 10 Aql in the *B* and *V* light with the 40" reflector of the Merate Observatory during twenty-seven nights distributed over the interval 2441477-621 *J. D.* The photometer was equiped with a Lallemand photomultiplier having a *S*4 surface and Schott *BG* 12 (1) + *GG* 13 (2) and *OG* 4 (1) filters.

Each night 10 Aql was compared with the star *HD* 175922, spectral type *A*3; *HD* 175579, sp. type *A*0, was the check star. Every night when we could, we carried out the determination of differential extinction coefficients K_V and K_B, making use of the method proposed by Gutierrez-Moreno et al. (1967); for the remaining nights we used mean extinction coefficients. The correction for the differential extinction due to colour was not made because the variable and comparison stars have pratically the same colour index.

The light constancy of the comparison stars is very important in these studies on small amplitudes: the Tables I and II show the ΔV and ΔB between *HD* 175922 and *HD* 175579; e.m. is the standard deviation and *n* the number of measures comprised in each normal. The mean values of the ΔV and ΔB contained in Tables I and II are presented in the following prospectus:

Observing period	$\overline{\Delta V}$	$\overline{\Delta B}$
2441502.47-621.28	$+ 0^m.172$ (.003)	$+ 0^m.402$ (.006)
	$\pm$ .001	$\pm$ .001

The standard deviation of a single normal is given in parenthesis; the standard error of the mean is given below.

Considering the observations during five consecutive hours, we also verified that the comparison star did not vary with a small period. In effect we formed the normals averaging the measures included in every hour and we obtained the respective standard error. The standard deviation of a single normal as regards the mean is $0^m.005$ for *B* and $0^m.004$ for *V* values. (The mean was calculated averaging the normals with a weight which was the reciprocal of the standard error of the normals).

The normals Δm between 10 Aql and *HD* 175922 are the average of the observations made in every night and are the result of a reduction program suitable for *CDC* 6600 and *UNIVAC* 1106 computers: they are given in Tables III and IV (*n* and *e.m.* have the same meaning as in Tables I and II). For *JD* 2441502 two separate means are given, because we performed two series of measures in *B* and *V* at a few hours one from the other; the *B-V* index appears in Table V. In some nights observations in *V* or *B* only have been carried out because of the bad weather conditions which prevent us to perform the complete cycle of measures.

As regards the research of the period, first of all we applied Stepien's period

TABLE I

N.	*J. D.* 2441000.+	ΔV	*e.m.*	*n*
1	502.49	.173	.002	17
2	506.56	.174	.004	6
3	533.55	.172	.001	34
4	536.54	.174	.001	19
5	539.52	.172	.001	28
6	581.38	.177	.004	6
7	582.36	.165	.007	6
8	588.35	.166	.007	8
9	595.37	.175	.004	8
10	596.37	.173	.003	8
11	607.33	.173	.005	8
12	608.34	.172	.005	8
13	621.31	.165	.001	6

TABLE II

N.	*J. D.* 2441000.+	ΔB	*e.m.*	*n*
1	502.47	.410	.001	13
2	506.53	.409	.005	8
3	533.52	.406	.001	30
4	536.51	.396	.002	14
5	539.48	.397	.002	24
6	581.35	.400	.004	8
7	582.33	.409	.003	8
8	588.30	.386	.007	8
9	589.32	.400	.010	4
10	595.34	.397	.003	8
11	596.35	.412	.002	8
12	607.29	.394	.002	6
13	608.30	.411	.002	8
14	614.29	.404	.004	6
15	621.28	.391	.003	6

to our data. Since the distribution of our normal points did not show any periodicity, we tried out a new period making use of the method proposed by LAFLER and KINMAN (1965), for the range between 2^d and 50^d with the step of $0^d.01$ for $2^d \leq P \leq 15^d$ and $0^d.1$ for $15^d \leq P \leq 50^d$. The light curves in agreement with the series of the above-mentioned periods indicate the probable period $P = 6^d.05$ and the following ephemeris:

$$\max V = 2441517.4 + 6^d.05\, E$$

The corresponding light curves are plotted in Fig. 1.

As regards Stepien's results, apart from the value of period, we do not confirm the antiphase relation between V and B-V curves.

TABLE III

N.	*J. D.* 2441000.+	ΔV	*e.m.*	*n*
1	477.521	− 1.281	.001	24
2	487.487	− 1.282	.002	17
3	502.457	− 1.283	.002	13
4	502.543	− 1.278	.002	17
5	506.486	− 1.285	.002	10
6	511.404	− 1.286	.001	10
7	517.389	− 1.296	.006	19
8	522.366	− 1.288	.007	8
9	523.384	− 1.273	.002	10
10	530.371	− 1.284	.002	32
11	533.388	− 1.290	.001	18
12	534.367	− 1.286	.002	24
13	536.491	− 1.278	.001	16
14	539.345	− 1.295	.001	22
15	546.380	− 1.292	.002	14
16	550.403	− 1.291	.003	6
17	554.409	− 1.287	.002	21
18	555.346	− 1.287	.002	13
19	572.348	− 1.290	.003	20
20	582.380	− 1.287	.002	17
21	588.385	− 1.285	.003	16
22	590.371	− 1.292	.002	20
23	596.360	− 1.286	.001	21
24	621.315	− 1.299	.002	20

TABLE IV

N.	*J. D.* 2441000.+	ΔB	*e.m.*	*n*
1	477.549	− 1.342	.004	7
2	487.545	− 1.345	.001	20
3	502.474	− 1.338	.002	12
4	502.567	− 1.339	.002	12
5	506.503	− 1.345	.003	13
6	511.431	− 1.367	.003	16
7	530.458	− 1.354	.002	8
8	533.427	− 1.356	.001	25
9	536.521	− 1.342	.001	23
10	539.485	− 1.359	.002	20
11	540.350	− 1.354	.001	28
12	554.459	− 1.352	.002	20
13	555.464	− 1.337	.003	7
14	582.362	− 1.362	.001	14
15	588.365	− 1.356	.005	21
16	589.339	− 1.372	.004	10
17	590.347	− 1.351	.002	21
18	595.346	− 1.359	.006	6
19	596.329	− 1.359	.002	25
20	607.304	− 1.348	.004	10
21	608.298	− 1.354	.002	22

TABLE V

N.	*J. D.* 2441000.+	Δ (*B-V*)	*e.m.*
1	477.535	− 0.061	.004
2	487.501	− .063	.002
3	502.466	− .055	.003
4	502.555	− .061	.003
5	506.495	− .060	.003
6	511.418	− .081	.003
7	530.415	− .070	.003
8	533.408	− .066	.001
9	536.506	− .064	.001
10	539.415	− .064	.002
11	554.434	− .065	.003
12	555.405	− .050	.003
13	582.371	− .075	.002
14	588.375	− .071	.006
15	590.359	− .059	.003
16	596.322	− .073	.002

3. - DISCUSSION

From the light curves we can see that: 1) the variation amplitude is very small: $0^m.015$ for V and $0^m.020$ for B; 2) the dispersion of the normals is very large. Therefore it is natural to ask if our variations are true: the $6^d.05$ period might be a chance result caused by a relatively small number of observations. Calculating the average of the normals of 10 Aql weighted inversely to related *e.m.* given in Tables III and IV, we find that the standard deviation of these normals is $0^m.006$ for V and $0^m.009$ for B colour, while the mean values of *e.m.* (Tables III and IV) are $0^m.002$ for V and $0^m.003$ for B. Nevertheless we must remark that the last errors represent only the intrinsic error of every normal and include the errors due to the instrumentation, reduction and condition of the sky, but it does not include the error due to bad evaluation of extinction coefficients. This latter is represented by $\varepsilon_K \cdot \Delta X$, where ΔX is the difference of air mass between the two stars and ε_K is the error concerning the determination of K_V and K_B (when these coefficients were measured directly) or concerning the use of a mean value $\overline{K}_V$ and $\overline{K}_B$. It is possible to estimate the error in this last case: considering the values of the air mass and the mean deviation of the $\overline{K}_V$ and $\overline{K}_B$, we obtain the following ranges respectively for V and B: $0^m.002$-$0^m.006$ and $0^m.002$-$0^m.007$. Moreover it is reasonable that the variations of K_V and K_B during the same night are comparable to the variations during the subsequent nights: indeed the standard deviation of the normals relating to the only nights in which we found the values of K_V and K_B is entirely comparable to that relating to all the normals. So the total error (i.e. intrinsic error plus that due to extinction coefficients) approximates the dispersion of the normals.

The mean deviation of Δm between the comparison stars, $0^m.006$ for *B* and $0^m.003$ for *V*, give further evidence for this supposition. The difference with the dispersion of the normals can be explained by pointing out that the air mass difference between the two comparison stars and between 10 Aql and *HD* 175922 are in the ratio 1/2: so the error due to extinction coefficients is halved.

All this support our conviction that the $6^d.05$ period is not true.

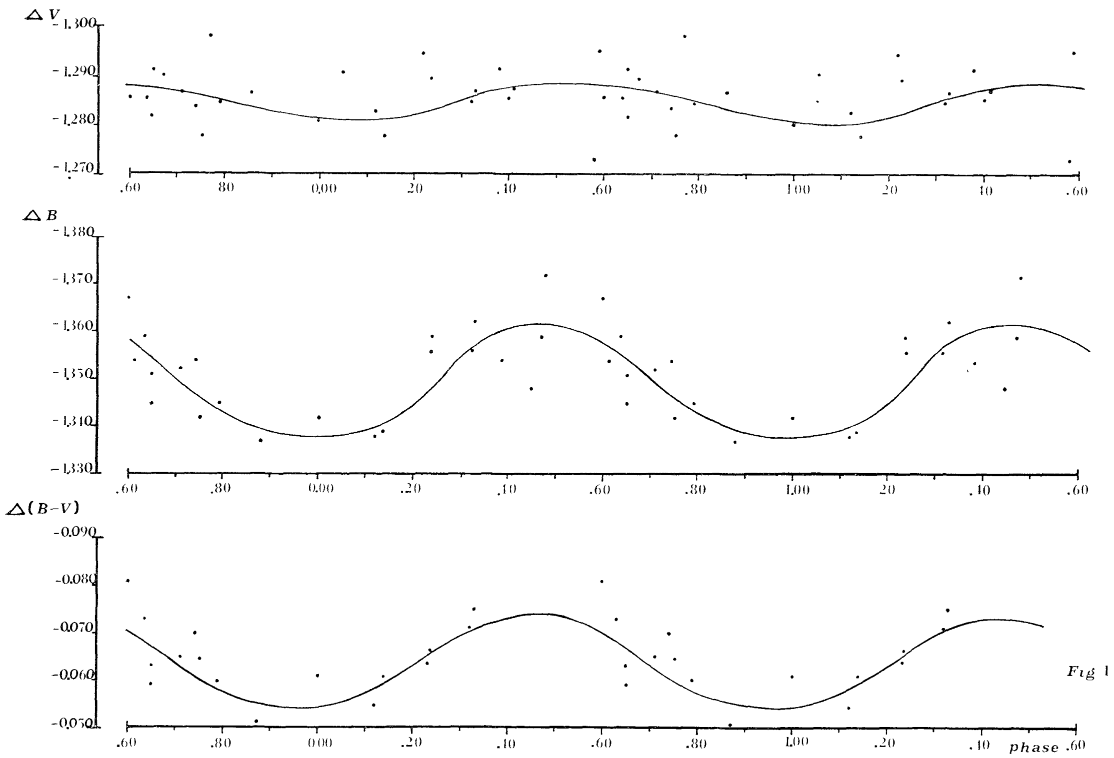

FIG. 1

Light and colour curves of 10 Aql according to the period $P = 6^d.05$ (our observations).

4. - CONCLUSIONS

The above mentioned considerations can be applied also to Stepien's results. In fact:

1) the probable error of every normal and the standard deviation of the data have the same value ($0^m.005$);

2) if we apply our period to Stepien's data, the dispersion around the mean curve is not greater that the dispersion relative to the $9^d.78$ period (see Fig. 2).

Our hypothesis on the constancy of 10 Aql is supported also by a contemporary work of Wolff and Morrison (1973). According to the photoelectric measures of these Authors, 10 Aql does not show light variations in a period of a few days.

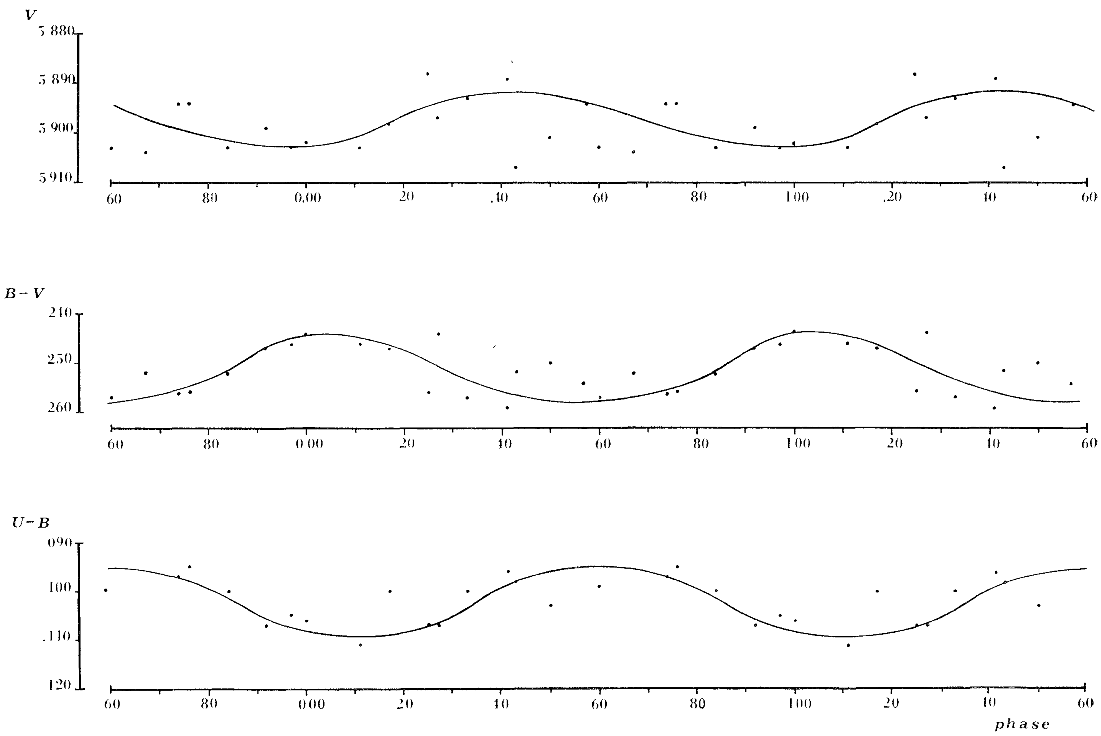

Fig. 2

Light and colour curves of 10 Aql according to the Stepien's normals phased with the period $P = 6^d.05$.

To check Preston's hypothesis on the possibility of variations of 10 Aql in a very long period, we report the mean values of the photoelectric observations of Abt and Golson (1962), Cameron (1966), Stepien (1968), Wolff and Morrison (1973) and of the present Authors for the *V* colour:

Year	*V*	Observers
1960	5.87	Abt and Golson
1963	5.93	Cameron
1967	5.90	Stepien
1970	5.90	Wolff and Morrison
1971	5.90	» » »
1972	5.92	Guerrero and Mantegazza

The *V* values are rounded to the hundreth of magnitude. The our value is determined adding the ΔV_S between 10 Aql and *HD* 175922 and between *HD* 175522 and *HD* 175579 to the magnitude of the last star, which is given by Stepien. This was possible since the our ΔV_S result practically in the standard system (by control with standard stars).

Bearing in mind that the observations have been made with different equipments and different comparison stars have been emploied, we can assume that the aforesaid annual variation may be unreliable and that 10 Aql can be considered constant in all these years.

Therefore it is necessary to continue the photoelectric observations for many years with the same photoelectric equipment, with the aim to obtain the greatest precision as possible, and consequently to give a definitive answer to the problem.

The research of a possible spectrum variability of 10 Aql is also important. It is well known that the spectrum variability of Ap stars consists in variations of intensities and radial velocities of spectral lines with the same period of magnetic and brightness variations. According to recent works it seems that this spectrum variability is due to the concentration of peculiar elements in superficial spots. For this reasons we intend to do this research in future at the Merate Observatory to see if 10 Aql is a spectrum variable and if so to have further confirmation of the period of variability of this star.

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