ΠΡΑΚΤΙΚΑ ΤΗΣ ΑΚΑΔΗΜΙΑΣ ΑΘΗΝΩΝ

ΣΥΝΕΔΡΙΑ ΤΗΣ 22ΑΣ ΦΕΒΡΟΥΑΡΙΟΥ 1979

ΠΡΟΕΔΡΙΑ ΚΑΙΣΑΡΟΣ ΑΛΕΞΟΠΟΥΛΟΥ

ΑΣΤΡΟΝΟΜΙΑ.— **Photoelectric observations of the eclipsing system AH Virginis at Kryonerion observatory,** *by P. G. Niarchos**.

Ἀνεκοινώθη ὑπὸ τοῦ Ἀκαδημαϊκοῦ κ. Ἰ. Ξανθάκη.

A B S T R A C T

During a program of photoelectric observations of eclipsing binaries, the W UMa-type system of AH Vir has been observed in two wavelengths (V and B) in the years 1977 and 1978. The light curves of the system are presented and the magnitudes and colours for both the maxima and the minima are given.

1. INTRODUCTION

Since the discovery of AH Vir by Guthnick and Prager in 1929 numerous visual, photographic and photoelectric observations of this system have been made. This variable is an eclipsing binary of W UMa-type with a period of 0.4 days. The history of AH Virginis has been summarized by Binnendijk (1960). He observed the system photoelectrically in the years 1955 and 1957. Although the 1955 and 1957 light curves belong to the same system, they are different in appearance. It has been pointed out by a number of investigators, e. g., Binnendijk (1960), Herczeg (1962), Purgathofer and Prochazka (1967) and Bakos (1971) that

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* **ΠΑΝΑΓΙΩΤΟΥ ΝΙΑΡΧΟΥ, Φωτοηλεκτρικαὶ παρατηρήσεις τοῦ Μεταβλητοῦ δι' ἐκλείψεων ἀστέρος ΑΗ τῆς Παρθένου εἰς τὸν ἀστρονομικὸν σταθμὸν Κρυονερίου.**

the light curve and the period of AH Vir are variable. More recent observations made by Bakos (1977) show a great deal of variation in both the maxima and minima of the light curves of the system. The light curve is intrinsically variable in a way which seems to affect only the photometric and not the geometric characteristics of the stars. A total eclipse occurs at primary minimum. Spectroscopic observations of the system were made by Chang (1948).

2. OBSERVATIONAL PROCEDURE

The system was observed for four consecutive nights (19 - 22) in March of 1977 and for three nights (29 - 31) in March of 1978, using the 48-inch Cassegrain reflector at the new Kryonerion Station of the National Observatory of Athens (Contopoulos and Banos, 1976). The telescope was used together with a two-beam multi-mode photometer (Goudis and Meaburn, 1973) in a program of three colour observations of eclipsing binaries.

The three intermediate pass-band filters used were selected to be in close accordance with the standard colour system U, B, V, Some details of these filters are given in Figure 1.

The two-beam photometer was attached to the 48-inch reflector in arrangement A. Only one of the photomultiplier tube was used, in front of which the three (U, B, V) filters were arranged. Each of these filters was accomodated in a four-position holder. The photometric system was highly sensitive, responding even to small flexures or movements of cables and components. To minimize these effects one should avoid contact with parts of the system as far as possible.

The observational strategy was at first to calibrate the photometric system by means of observations on a number of standard stars.

More than one hour before starting the observations, the high tension power was switched on and a suitable voltage was applied to the photomultiplier tube, in order to let the dark emission settle to a final value. The amplifier and the chart recorder could be independently controlled by separate zero sets. The procedure followed in observing a given star allowed for automatic setting of declination and right ascension from an electronic control console. Then the star image was properly focussed by the hand set unit and the final placing of the star in the centre of the diaphragm was done by means of the hand set right ascension and declination controller.

After that, the shutter, in front of the photocathode, was put at the «on» position, and then during an integration time of about thirty

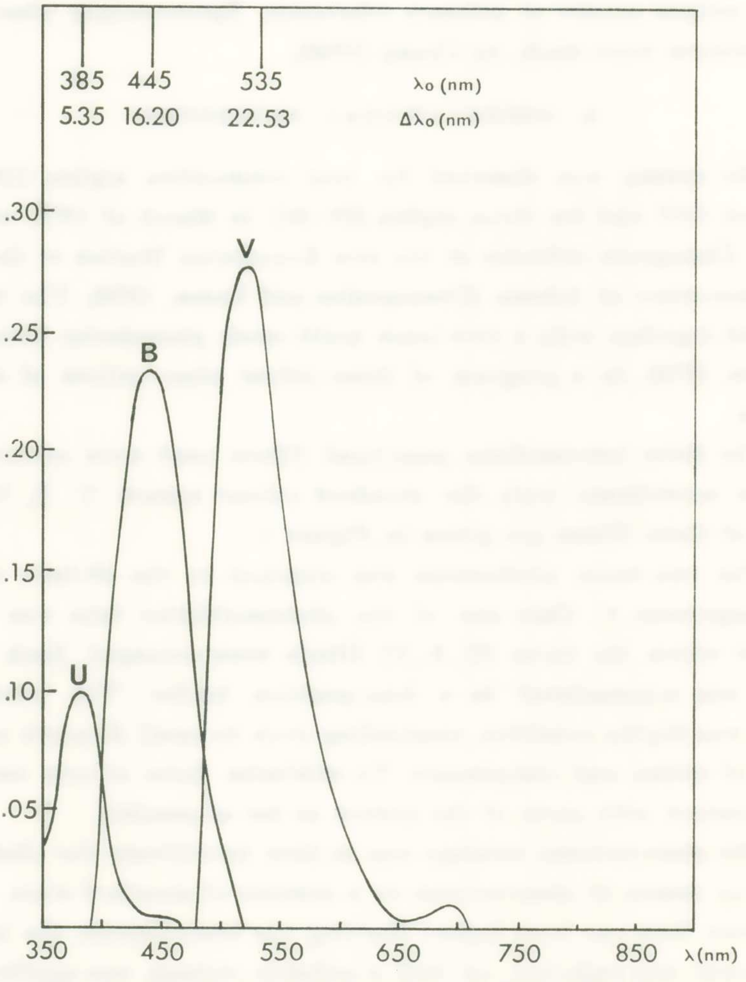

Fig. 1. Overall Spectral Response of Filter - Photomultiplier. (After Jassur, 1977).

seconds three deflections (one for each filter) were recorded on the recorder. The telescope then slightly moved away from the star, and in the vicinity of the star similar deflections due to the sky light were recorded. Then the same procedure was followed for the comparison star. The sequence for observing the variable and comparison star was as follows: Comparison - Sky - Variable - Sky - Variable - Sky - Comparison. From time to time the telescope was moved to the check star. When preparing for observing the variable or comparison star, the shutter in front of the photomultiplier window was closed. From time to time the sidereal and local time were marked on the chart.

3. REDUCTION OF OBSERVATIONS

The photoelectric reductions technique is essentially of three steps:

a) Converting the recorded deflections into observed magnitudes and colours (uncorrected for atmospheric extinction).

b) Applying the extinction corrections to bring observed values (from a) to the «natural» system of the instrument.

c) Transformation of the values in the «natural» system to the corresponding values of a «standard» system.

The method of reduction, applied to the «U, B, V system», described by Hardie (1959, 1962), was adopted in the following considerations. For the reduction of our observations the following procedure was followed.

1. For each individual observation the local Sidereal Time was calculated and the hour angle was determined.

2. The individual air masses for the variable and comparison at each observation were computed using the equations

$$M(z) = \sec z - 0.0018167 (\sec z - 1) - 0.002875 (\sec z - 1)^2 - 0.0008083 (\sec z - 1)^3 \quad (3.1)$$

and

$$\sec z = (\sin l \sin \delta + \cos l \cos \delta \cos h)^{-1} \quad (3.2)$$

where δ = declination of star,
h = hour angle, and
l = latitude of the observatory.

Then the differential magnitudes were calculated using the equation

$$\Delta m = -2.5 \log \left[\frac{V - SV}{C - SC}\right] \quad (3.3)$$

where V, SV, C and SC represent the deflections on the chart for the Variable, Sky, Comparison and Sky respectively.

3. The differential magnitudes Δm were corrected for the extinction by means of relations of the form

$$\Delta m_o = \Delta m - K_m \, \Delta M(z) \qquad (3.4)$$

where Δm = are the differential magnitudes (3. 3),
Δm_o = are the differential magnitudes outside the atmosphere,
$\Delta M(z)$ = is the difference in air-masses, calculated in step 2, between variable and comparison, and
K_m = represent the extinction coefficients.

The ephemeris used for the reduction of our observations is (Bakos, 1977)

$$\text{Min I} = \text{HJD } 2442549.6969 + 0.4075292 \, E \qquad (3.5)$$

4. MAIN RESULTS

For convenience a zero point correction was applied to the differential magnitudes for each colour in order to make the magnitude difference at maximum approximately equal to zero. The phases for each individual observation were computed using the relation

$$\text{Phase} = \frac{\text{HJD} - \text{Epoch}}{P} \qquad (4.1)$$

where Epoch = is equal to 2442549.6969,
P = is the period of the system equal to $0^d.4075292$, and
HJD = stands for the Heliocentric Julian Date for each individual observation. This can be computed by means of the formula

$$\text{HJD} = (T - 12)/24 + 2440000 + DJ + DT \qquad (4.2)$$

where T = is the Greenwich Mean Time corresponding to the individual observation quoted before,
2440000 + DJ = is the Heliocentric Julian Date at noon of the day of observation (taken from the Astronomical Ephemeris), and
DT = is a Heliocentric time-correction.

The phases and magnitude differences, so calculated, are given in Tables I and II. Figures 2 and 3 show the variation of the light curves

TABLE I

Yellow Observations of AH Vir.

Phase	Δm_v	Phase	Δm_v	Phase	Δm_v	Phase	Δm_v
.0058	.593	.1003	.214	.2258	.011	.3671	·160
.0110	.588	.1032	.227	.2312	.044	.3751	.116
.0173	.598	.1052	.267	.2351	—.001	.3781	.122
.0201	.592	.1062	.255	.2382	.021	.3782	.144
.0250	.552	.1074	.177	.2499	.035	.3884	.173
.0272	.572	.1130	.202	.2512	—.008	.3950	.198
.0301	.543	.1140	.220	.2534	—.018	.4001	.169
.0318	.552	.1151	.173	.2572	.021	.4031	.225
.0350	.534	.1160	.190	.2646	—.008	.4052	.238
.0425	.514	.1202	.148	.2671	.004	.4072	.181
.0450	.522	.1240	.192	.2705	.017	.4144	.291
.0452	.547	.1266	.150	.2753	.029	.4181	.220
.0486	.499	.1301	.163	.2783	.002	.4200	.317
.0501	.474	.1317	.127	.2846	.023	.4239	.271
.0533	.502	.1384	.112	.2931	.049	.4250	.243
.0552	.448	.1451	.128	.2941	.008	.4281	.346
.0571	.433	.1488	.115	.2966	.021	.4322	.382
.0652	.460	.1549	.077	.3001	.038	.4340	.280
.0653	.424	.1605	.107	.3121	.058	.4351	.307
.0655	.412	.1666	.091	.3175	.031	.4380	.352
.0680	.371	.1721	.105	.3205	.050	.4441	.335
.0710	.392	.1772	.051	.3212	.059	.4475	.380
.0751	.401	.1797	.070	.3238	.084	.4490	.424
.0758	.342	.1843	.059	.3332	.069	.4542	.469
.0775	.379	.1951	.040	.3391	.052	.4561	.441
.0805	.332	.1982	.021	.3420	.092	.4572	.410
.0835	.310	.2002	.057	.3456	.087	.4605	.456
.0852	.357	.2042	.005	.3500	.085	.4633	.485
.0875	.247	.2113	.038	.3520	.108	.4712	.473
.0885	.321	.2132	.037	.3580	.134	.4741	.499
.0952	.287	.2200	.033	.3618	.072	.4775	.521
.1001	.247	.2254	—.008	.3639	.097	.4861	.537

Table I (continued)

Phase	Δm_v	Phase	Δm_v	Phase	Δm_v	Phase	Δm_v
.4912	.543	.6009	.206	.7651	.013	.8974	.204
.4930	.529	.6090	.145	.7678	.029	.9002	.252
.4988	.541	.6120	.181	.7712	.005	.9023	.288
.5001	.536	.6171	.165	.7784	.032	.9073	.277
.5073	.539	.6147	.152	.7826	.030	.9092	.240
.5112	.530	.6222	.130	.7892	.019	.9111	.310
.5181	.514	.6317	.132	.7920	.049	.9134	.345
.5190	.528	.6331	.109	.7948	.062	.9172	.295
.5222	.518	.6475	.067	.7996	.023	.9205	.332
.5241	.497	.6480	.084	.8045	.065	.9230	.357
.5261	.503	.6485	.099	.8072	.043	.9250	.437
.5281	.482	.6597	.052	.8124	.052	.9271	.397
.5330	.495	.6651	.075	.8153	.061	.9298	.317
.5364	.451	.6721	.037	.8203	.077	.9345	.377
.5376	.477	.6735	.073	.8209	.055	.9350	.410
.5423	.386	.6800	.055	.8253	.069	.9361	.453
.5433	.431	.6847	.017	.8305	.105	.9402	.369
.5462	.400	.6891	.023	.8362	.092	.9415	.501
.5485	.443	.6974	.012	.8410	.069	.9451	.473
.5491	.421	.7042	.040	.8470	.080	.9487	.443
.5513	.387	.7095	.005	.8502	.109	.9515	.538
.5522	.373	.7109	.037	.8537	.095	.9552	.512
.5563	.360	.7185	.027	.8600	.176	.9598	.463
.5647	.368	.7223	.000	.8621	.115	.9606	.518
.5655	.334	.7233	—.003	.8650	.157	.9643	.547
.5691	.347	.7266	.015	.8685	.133	.9699	.582
.5696	.297	.7301	.026	.8725	.132	.9717	.546
.5732	.269	.7345	.013	.8799	.170	.9742	.561
.5762	.315	.7401	—.004	.8801	.147	.9811	.587
.5827	.283	.7445	.025	.8862	.233	.9848	.571
.5840	.216	.7472	—.001	.8875	.174	.9895	.586
.5851	.247	.7498	.010	.8892	.191	.9911	.595
.5933	.243	.7580	.001	.8900	.210	.9944	.604
.5995	.189	.7590	.024	.8948	.223	.9990	.590

TABLE II

Blue Observations of AH Vir.

Phase	Δm_b	Phase	Δm_b	Phase	Δm_b	Phase	Δm_b
.0063	.606	.0956	.280	.2270	.017	.3810	.110
.0075	.622	.1010	.206	.2300	.023	.3872	.157
.0122	.613	.1020	.237	.2318	.033	.3900	.129
.0179	.628	.1061	.212	.2387	.007	.3921	.182
.0202	.609	.1135	.196	.2451	—.007	.3950	.217
.0253	.613	.1147	.176	.2506	.025	.3962	.178
.0291	.607	.1165	.134	.2518	.019	.4001	.204
.0324	.541	.1270	.143	.2544	—.014	.4052	.139
.0381	.579	.1310	.164	.2581	.014	.4075	.210
.0411	.520	.1330	.094	.2621	.033	.4100	.247
.0452	.562	.1350	.113	.2652	.004	.4151	.199
.0493	.448	.1389	.075	.2717	.010	.4180	.218
.0498	.571	.1451	.137	.2745	.028	.4221	.266
.0502	.499	.1500	.115	.2788	—.001	.4283	.352
.0547	.363	.1521	.094	.2802	.018	.4301	.308
.0551	.419	.1555	.066	.2856	.032	.4310	.240
.0559	.534	.1602	.082	.2911	.008	.4354	.289
.0580	.474	.1654	.094	.2970	.034	.4385	.398
.0621	.503	.1671	.119	.3056	.023	.4402	.327
.0624	.449	.1711	.051	.3128	.063	.4445	.361
.0658	.322	.1737	.083	.3167	.040	.4455	.445
.0664	.376	.1751	.042	.3200	.061	.4482	.376
.0684	.397	.1804	.079	.3315	.057	.4495	.408
.0720	.430	.1832	.049	.3350	.083	.4552	.469
.0753	.359	.1915	.064	.3397	.043	.4581	.418
.0778	.334	.1940	.022	.3405	.107	.4643	.458
.0799	.232	.1988	.038	.3445	.088	.4656	.532
.0802	.316	.2054	.018	.3500	.069	.4677	.488
.0815	.380	.2118	.004	.3629	.113	.4685	.508
.0821	.259	.2140	.043	.3650	.107	.4751	.526
.0843	.290	.2201	.038	.3689	.089	.4778	.546
.0897	.335	.2259	—.007	.3751	.138	.4865	.555

Table II (continued)

Phase	Δm_b	Phase	Δm_b	Phase	Δm_b	Phase	Δm_b
.4902	.567	.5996	.194	.7585	—.007	.8969	.263
.4938	.557	.6009	.180	.7600	.020	.8981	.233
.4990	.568	.6130	.169	.7668	—.012	.9021	.226
.4995	.559	.6153	.133	.7690	.033	.9033	.279
.5031	.568	.6174	.185	.7719	.009	.9080	.255
.5081	.558	.6282	.143	.7794	.033	.9106	.338
.5150	.554	.6353	.105	.7833	.017	.9121	.268
.5195	.565	.6475	.103	.7899	.004	.9158	.328
.5230	.551	.6480	.058	.7922	.043	.9175	.299
.5241	.528	.6488	.103	.7955	.008	.9220	.378
.5270	.537	.6501	.074	.8005	.012	.9236	.303
.5335	.519	.6580	.078	.8075	.023	.9306	.356
.5350	.505	.6604	.033	.8132	.035	.9338	.374
.5368	.448	.6662	.051	.8208	.048	.9350	.418
.5378	.488	.6726	.023	.8215	.068	.9362	.477
.5425	.463	.6735	.068	.8263	.032	.9372	.459
.5436	.419	.6820	.058	.8310	.083	.9408	.342
.5445	.479	.6853	.008	.8407	.073	.9440	.528
.5469	.435	.6891	.031	.8450	.093	.9463	.472
.5488	.406	.6979	.008	.8477	.064	.9495	.443
.5499	.385	.7055	.043	.8484	.126	.9525	.579
.5513	.424	.7095	.003	.8500	.118	.9560	.514
.5552	.367	.7117	.028	.8511	.098	.9605	.498
.5568	.393	.7194	.030	.8542	.082	.9611	.541
.5647	.377	.7228	.018	.8630	.151	.9651	.553
.5652	.325	.7239	.008	.8688	.180	.9702	.569
.5658	.353	.7271	.009	.8700	.117	.9722	.590
.5673	.284	.7308	.029	.8737	.141	.9745	.592
.5701	.305	.7350	—.006	.8749	.170	.9758	.619
.5752	.269	.7411	.014	.8806	.171	.9851	.616
.5829	.243	.7448	—.011	.8851	.155	.9902	.609
.5851	.294	.7479	.004	.8867	.180	.9926	.622
.5891	.252	.7499	.000	.8897	.231	.9950	.594
.5952	.228	.7552	.008	.8901	.198	.9992	.614

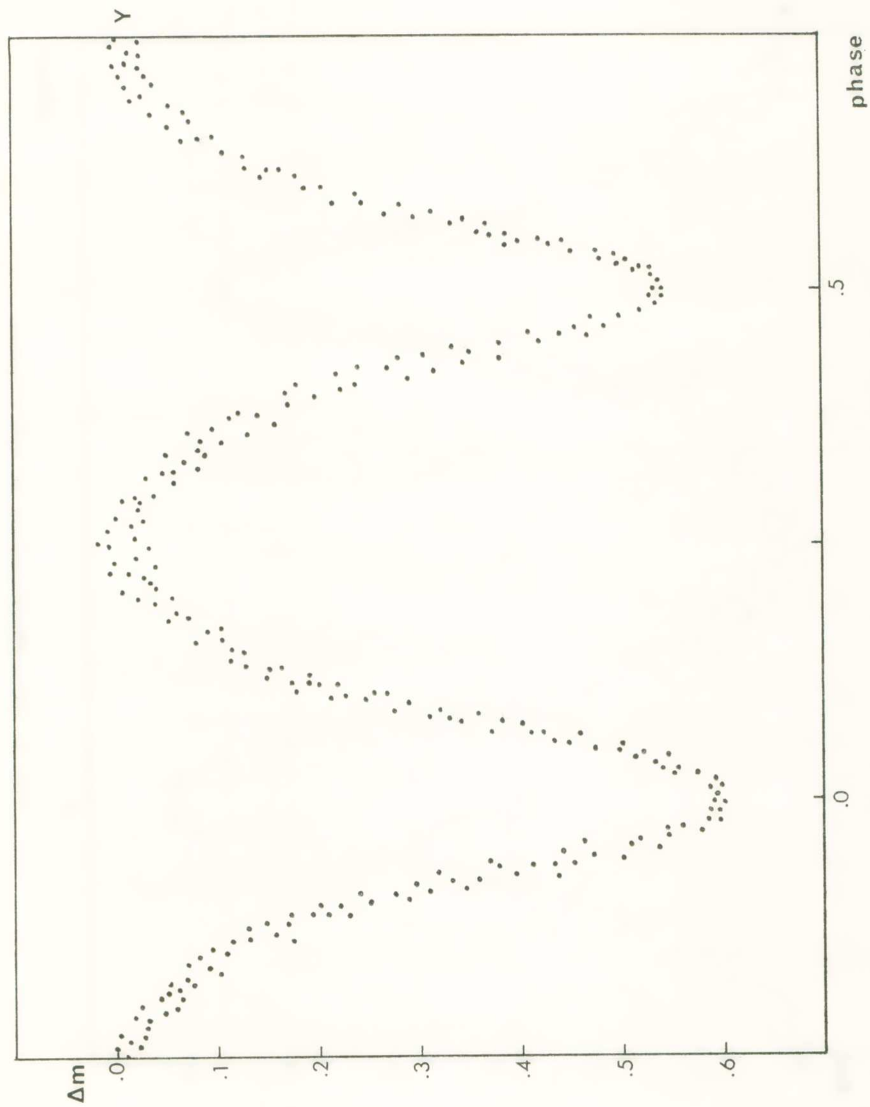

Fig. 2. Yellow Observations of AH Virginis.

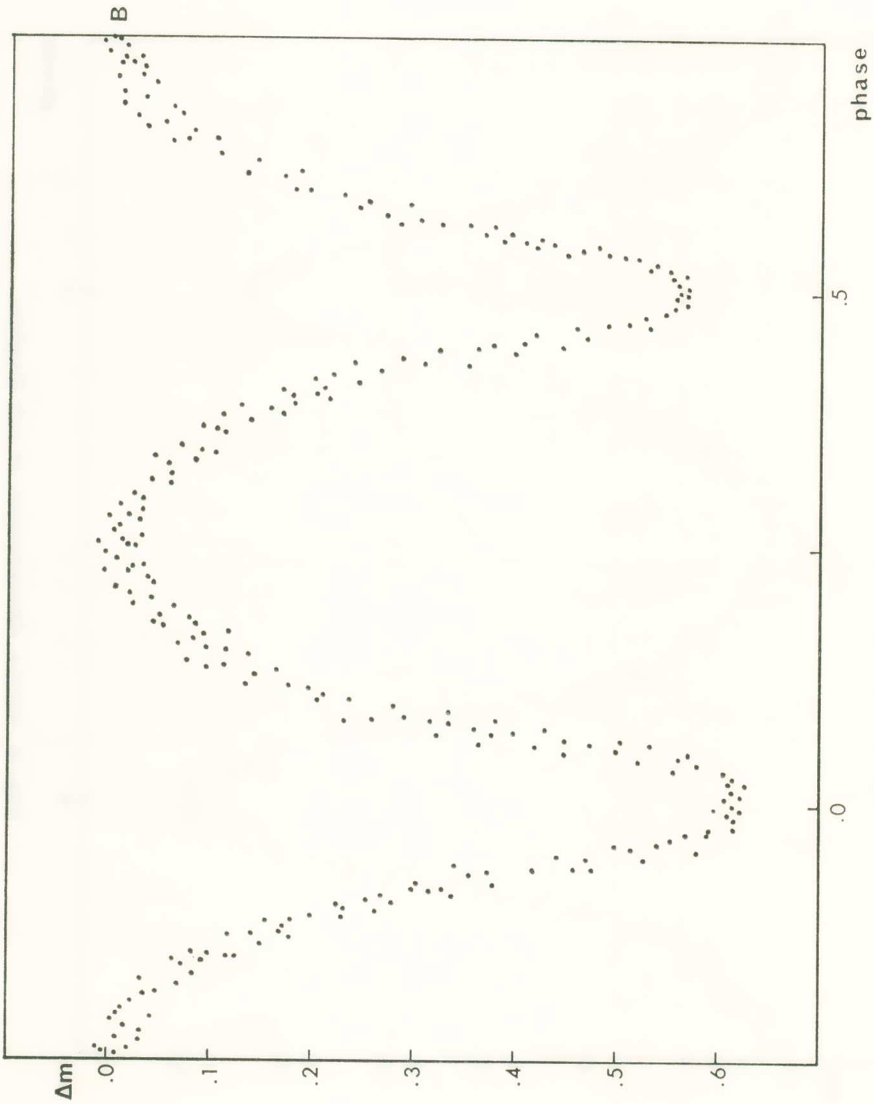

Fig. 3. Blue Observations of AH Virginis.

in two wavelengths of observation. The light curve in U is incomplete, but adequate parts of it have been observed, so that the determination of the colour U — B is possible. A time of the primary minimum has been deduced by essentially visual inspection of adequately covered regions of the light curve. We found

$$\text{Min I} = \text{HJD } 2443224.567 \qquad (4.3)$$

The next step of our analysis was the determination of the colours B — V, U — B at both the maxima and the minima and the visual magnitude V. To do so, the following Equations were used

$$(B-V)_{var} = \left(1 + K''_{bv}\, M(z)\right)(b-v)_{var}\, \mu - \mu K'_{bv}\, M(z) + \xi_{bv} \qquad (4.4)$$

$$(U-B)_{var} = \left(1 + K''_{ub} M(z)\right)(u-b)_{var}\, \psi - \psi K'_{ub}\, M(z) + \xi_{ub} \qquad (4.5)$$

$$V_{var} = v + \in (B-V)_{var} - K_v\, M(z) + \xi_v \qquad (4.6)$$

where

$$(b-v)_{var} = (\Delta m)_b - (\Delta m)_v + (b-v)_{com} \qquad (4.7)$$

$$(u-b)_{var} = (\Delta m)_u - (\Delta m)_b + (u-b)_{com} \qquad (4.8)$$

and $$(b-v)_{com} = \left\{(B-V)_{com} + K'_{bv}\, \mu\, M(z) - \xi_{bv}\right\} / \left[1 + K''_{bv}\, M(z)\right] \mu \qquad (4.9)$$

$$(u-b)_{com} = \left\{(U-B)_{com} + K'_{ub}\, \psi M(z) - \xi_{ub}\right\} / \left[1 + K''_{ub}\, M(z)\right] \psi \qquad (4.10)$$

In the last Equations (4.9) - (4.10) the following values were used (Jassur, 1977)

$$(B-V)_{com} = 0.796, \quad (U-B)_{com} = 0.601, \quad \in = -0.021, \quad \mu = 1.299$$

$$\psi = 1.123, \quad \xi_v = 19.6, \quad \xi_{bv} = -0.073, \quad \xi_{ub} = -0.521 \qquad (4.11)$$

$$K_v = 0.295, \quad K'_{bv} = 0.1, \quad K'_{ub} = 0.34, \quad K''_{bv} = -0.03, \quad K''_{ub} = -0.03$$

By insertion of the values of the coefficients from (4.11) into Equations (4.9) - (4.10) (the air-masses have been calculated in section 3 above), the differences of the left-hand sides (L. H. S.) of these Equations were evaluated. Then the differences of the L. H. S. of Equations (4.7) - (4.8) follow easily. Finally the colours $(B-V)_{var}$ and $(U-B)_{var}$ are evaluated from Equations (4.4) - (4.5).

In order to evaluate the visual magnitude V_{var} we rewrite Equation (4.6) in differential form

$$\Delta V = \Delta v + \in \Delta (B - V) \tag{4.12}$$

or

$$V_{var} - V_{com} = \Delta m_v + \in [(B - V)_{var} - (B - V)_{com}] \tag{4.13}$$

In the above Equation (4.13) V_{com} is given equal to 9.60 (Jassur, 1977), Δm_v is taken from Table I and the colours for the variable and the comparison star have been evaluated above. Therefore the magnitude V_{var} follows easily from Equation (4.13).

The average colours at both the maxima and the minima as well as the magnitude V of the variable are given in Table III.

TABLE III

Colours and Magnitude of AH Virginis.

	Minima	Maxima
B − V	0.82	0.78
U − B	0.49	0.57
V	9.50	8.89

5. DISCUSSION

The light curve of AH Vir is subject to considerable changes. Variations exist both in the heights of maxima and the depths of minima. This becomes obvious if the individual observations listed in Tables I and II are plotted instead of the normal points. The magnitude difference between the extremes of the maxima and the minima is significant especially for the maxima. This difference shows, for instance, that the outer and the inner envelope of max. I have a width of 0.045 mag. in the yellow and 0.040 in the blue.

The observations also show a very small displacement of the maximum corresponding to phase 0.75. As a rule, the variations in the blue light are greater than in the yellow light. However, the observed light curves show maxima of the same height and symmetrical minima. The analysis of the observed light curves and the derivation of the geometric and photometric elements of the system will be given elsewhere.

ΠΕΡΙΛΗΨΗ

Κατὰ τὴ διάρκεια τῶν ἐτῶν 1977 - 1978 τὸ δυαδικὸ ἐκλειπτικὸ σύστημα AH Virginis παρατηρήθηκε σὲ δύο μήκη κύματος, τὸ V (κίτρινο) καὶ B (μπλέ), στὰ πλαίσια ἑνὸς προγράμματος φωτοηλεκτρικῶν παρατηρήσεων μεταβλητῶν δι' ἐκλείψεων ἀστέρων. Γιὰ τὶς παρατηρήσεις αὐτὲς χρησιμοποιήθηκε τὸ κατοπτρικὸ τηλεσκόπιο τῶν 48 ἰντσῶν τοῦ Ἀστρονομικοῦ Σταθμοῦ Κρυονερίου Κορινθίας σὲ συνδυασμὸ μὲ φωτοηλεκτρικὸ φωτόμετρο.

Οἱ καμπύλες φωτὸς τοῦ AH Virginis παρουσιάζουν μεταβολὲς καὶ στὰ μέγιστα καὶ στὰ ἐλάχιστα. Οἱ παρατηρήσεις δείχνουν ἐπίσης μία μικρὴ μετατόπιση τοῦ μεγίστου ποὺ ἀντιστοιχεῖ στὴ φάση 0.75. Γενικὰ οἱ μεταβολὲς στὸ μπλὲ χρῶμα εἶναι μεγαλύτερες ἀπ' ὅτι στὸ κίτρινο. Τὰ δύο μέγιστα ὅμως ἔχουν τὸ ἴδιο ὕψος καὶ τὰ ἐλάχιστα εἶναι συμμετρικά. Στὴν παροῦσα μελέτη ὑπολογίστηκαν ἐπίσης οἱ δεῖκτες χρώματος B - V, U - B καὶ τὸ ὀπτικὸ μέγεθος V τοῦ συστήματος.

REFERENCES

G. A. Bakos, IAU Coll. 15, 293, 1971.

———, Bull. Astron. Inst. Czech. **28**, 157, 1977.

L. Binnendijk, Astron. J. **65**, 358, 1960.

Y. C. Chang, Astrophys. J. **107**, 96, 1948.

G. Contopoulos and C. Banos, Sky and Telescope, **51**, 154, 1976.

C. Goudis and J. Meaburn, Astrophys. Space Sci., **20**, 149, 1973.

P. Guthnick and R. Prager, Beob. Zirk. No. 13, 32, 1929.

R. H. Hardie, Astrophys. J. **130**, 663, 1959.

———, in Stars and Stellar Systems, Vol. 2, Astronomical Techniques, ed. W. A. Hiltner (Chicago: University of Chicago Press), p. 178, 1962.

T. Herczeg, Veröff. Univ. Sternw. Bonn, No. 63, 1962.

D. Jassur, M. Sc. Thesis, University of Manchester, unpublished, 1977.

A. Purgathofer and F. Prochazka, Mitteil. Univ. Sternw. Wien **13**, 151, 1967.