42. COMMISSION DES ETOILES DOUBLES PHOTOMETRIQUES

Report of Meetings

Business sessions: 16 and 23 August 1961.
Scientific sessions: 18 and 22 August 1961.

PRESIDENT: D. J. K. O'Connell.
SECRETARY: J. E. Merrill.

One two-hour and two three-hour sessions were held during the Congress, and a two-hour joint scientific session with Commission 27. By agreement between Dr O'Connell and Dr Oosterhoff, Presidents of the Commissions concerned, the report on the joint session is incorporated herein.

Business and Administrative Sessions

On motion of Dr Wood and by unanimous vote, the *Draft Report* was approved for publication, with thanks to the President for the work of preparation. The form and extent of future *Draft Reports* were discussed. It was agreed that the form of the present report was highly satisfactory. It was left to the discretion of future Presidents to modify or extend the Report as seems required.

A committee consisting of Drs Huffer (chairman), Schneller and Piotrowski, was appointed to receive and report on any additional items suggested for the agenda. In fact, only one such item arose; it was placed on the agenda for the second session.

Co-ordinated Programmes

Results of the Co-ordinated Programmes on β Lyrae and VW Cephei are given in the Commission Report in Volume A. To expedite the selection of stars for future co-operative effort, the following committee was appointed: Drs F. B. Wood (chairman), Kron, Kwee, Larsson-Leander and Sahade. Stars proposed were: QS Aql, ζ Aur, BM Cas, Y Cyg, V380 Cyg, 31 Cyg, Z Her, β Lyr, η Ori, AW Peg, β Per, SZ Psc, W Ser, AL Vel. On the basis of the committee's report, the following systems were adopted for co-operative photometric and spectroscopic study during the next triennium:

System	Co-ordinator
ζ Aur	Gyldenkerne
31 Cyg	K. O. Wright
AW Peg	Tsesevich
W Ser	Sahade

Several speakers emphasized the difficulties resulting from the longitude gaps (especially in the southern hemisphere) now existing. The Co-ordinated Programmes Committee was requested to consider ways of improving the situation.

Times of Minima

On motion by Dr Batten, a committee consisting of Drs Kopal (chairman), Plavec, Szafraniec and Whitney, was appointed to prepare a list of eclipsing binaries for which regular observation of times of minima on a continuing basis are particularly needed. This list will be drawn up and distributed in the near future. It was suggested that the committee contact such groups of amateur observers as might contribute effectively to these programmes.

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Orbiting Astronomical Observatory

Discussion of the desirability of observations from an Orbiting Astronomical Observatory, led to the appointment of the following committee to consider the problem: Drs Kopal (chairman), Huffer, Kron, Martynov and Merrill.

Bibliography

In accordance with the resolution adopted at the Moscow meeting, a running bibliography of eclipsing binaries has been initiated and three issues have been distributed up to date. The Commission unanimously decided that the Bibliography was of great value and should be continued. After considerable discussion as to the frequency of issue and the most suitable form, the following committee was set up to receive and consider suggestions. Drs Ovenden (chairman), Plaut and Sahade. After the report by this committee and further discussion, the Commission decided to recommend that:

1. entries in the Bibliography be classified under star names whenever possible;

2. multiple references to individual papers be abbreviated by the use of reference numbers;

3. entries include a brief statement of the essential nature of the new material in the listed paper wherever the title of the paper does not make such details explicit;

4. the editors of the principal journals be requested to send a list of papers on eclipsing binaries to a designated bibliography compiler in advance of publication;

5. an attempt be made to issue the bibliography semi-annually.

The following persons have agreed to assist in compiling the bibliography:

Mrs Kron and Dr Sahade	The Americas
Dr Cester and Dr Fresa	Italy
Dr Schneller	Germany
Dr Plavec	Czechoslavakia and Poland
Dr Shulberg	U.S.S.R.
Dr Plaut	other countries

Drs Batten and Popper are willing to assist as needed.

The Commission re-affirmed the resolution passed at the Moscow meeting, requesting authors of articles on eclipsing binaries to inform the President of Commission 42 of the fact and, if feasible, to transmit to him a copy of the manuscript.

Dr Sahade suggested that it would be very helpful if workers in the field could be kept informed of researches in progress or in prospect. It was agreed that the Commission should request that such information should be sent to the bibliographer concerned for inclusion in the bibliography.

Russell Memorial Volume

It was proposed by Dr Sahade that the Commission consider the publication of a volume in memory of Henry Norris Russell. A committee composed of Dr Sahade (chairman), Dr Merrill and Mrs Shapley was appointed to consider the proposal. After consideration of the committee's report, it was agreed that the matter was not within the exclusive competence of this Commission and the committee was requested to discuss it with other interested persons and organizations.

Proposal for a Single Commission for Binary Stars

Dr Plaut proposed the creation of a single commission for visual, spectroscopic, and photometric binaries. Since this is a matter that obviously cannot be decided by Commission 42 alone, it was recommended that the Organizing Committee refer it to the appropriate Com-

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missions. The proposal emphasized, in the opinion of those present, the importance of closer co-operation between workers in these related fields, although the majority felt that a single commission would prove too unwieldy in dealing with the diverse problems and techniques involved.

Interim Organization

It was decided that the Organizing Committee should study the future organization of the Commission, including possible by-laws. It was agreed that the following should be regarded, for the time being, as standing committees of the Commission, with the membership as listed above:

1. Co-ordinated Programmes
2. Times of Minima
3. Orbiting Astronomical Observatory
4. Russell Memorial Volume.

Resolutions

The Commission formally expressed its thanks for important services rendered:

(*a*) To the Co-ordinators of Programmes: Dr Huffer, Dr Kwee and Dr Larsson-Leander.

(*b*) To those who prepared the Running Bibliography: Dr Fresa, Mrs Kron, Dr Merrill, Dr O'Connell, Dr Sahade, Dr Schneller and Dr Shulberg.

(*c*) To Dr Batten for his lists of eclipsing binaries in need of spectroscopic observations and to Dr McLaughlin for his lists of spectroscopic binaries under observation.

(*d*) To the Cracow Observatory for the publication of the ephemerides of eclipsing binaries.

(*e*) To Dr Kordylewski for the Eclipsing Variable Circulars which he is editing at Cracow.

(*f*) To Dr Korytnikov, Dr Lavrov and Dr Martynov for the first volume of their Bibliography of Spectroscopic Binaries.

(*g*) To Dr O'Connell and Dr Merrill for their unremitting work during the past six years as President and Secretary of Commission 42.

Scientific Sessions

The contributions in the scientific session of Commission 42 and the joint session of Commissions 27 and 42 can be grouped under three general headings.

INVESTIGATIONS ON SPECIFIC STARS

M. F. Walker, "DQ Herculis"

The photo-electric observations of this system show that reliable orbital elements probably cannot be obtained. There is fairly convincing evidence that the orbital period of the system is increasing. The one-minute (more exactly 71-second) variations have been found to be strictly periodic and the period of this phenomenon shows no change; the variations disappear for about 20 minutes during primary eclipse. The spectrographic observations by Kraft and Greenstein have revealed a velocity variation for the He II and higher Balmer emission lines, and a Rossiter effect before and after eclipse.

On the basis of all the existing observations, our present picture of the system is the following. The ex-nova is extremely small and dense and the one-minute variations represent its fundamental period of pulsation. Being very small, it is totally eclipsed by the companion star during the 20 minutes when the one-minute variations are absent. The ex-nova is surrounded by a rotating disk of material ejected by the companion, which fills the inner Lagrangian surface of the system; it is the eclipse of this disk which produces the observed primary

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minimum. The variable opacity of this material in different directions around the ex-nova causes the amplitude of the one-minute variations to fluctuate in phase with the orbital period. The mass lost during the nova outburst is estimated by Ahnert from the change in orbital period before and after the explosion to be 0·43%.

M. F. Walker, "AE Aquarii"

Simultaneous photo-electric and spectroscopic observations have been obtained in order to investigate the spectroscopic changes occurring during the "explosions" characteristic of this short-period binary system. The photo-electric observations were obtained with the Crossley reflector, while the spectroscopic observations were obtained using the Lallemand Electronic Camera at the focus of the 20-inch camera of the Coudé spectrograph of the 120-inch reflector. With this equipment and a photo-cathode of only mediocre sensitivity, exposures at a dispersion of 48 Å/mm (on the cathode) could be obtained in about 20-30 minutes at minimum ($m_{uv} \approx 12^{m}\cdot5$) and 12-15 minutes at maximum ($m_{uv} \approx 11^{m}\cdot0$).

The behaviour of the system is complex; in general, a new "event" begins before the preceding one ends and it is difficult to isolate the changes occurring between undisturbed minimum and a single uncomplicated maximum. Preliminary analysis of these observations reveals that during an "explosion".

1. The emission lines of H and Ca II become stronger and broader.

2. The emission lines may broaden either symmetrically or asymmetrically to the red or to the violet, indicating that the "explosion" occurs in a restricted area in the system on or near the surface of one of the stars.

3. A hot continuum appears which fills in the late-type absorption spectrum of the companion.

It is noted that high time-resolution spectroscopy of this type could not be obtained in any other way than through the use of an image tube.

R. P. Kraft, "U Geminorum Stars as Binaries"

Several U Geminorum variables were tested spectroscopically for binary motion. Five stars are shown to be binaries with periods less than 9 hours (SS Cyg, U Gem, RX And, RU Peg, SS Aur), one spectrum is composite (EY Cyg), and one other (Z Cam) shows evidence of binary motion with an, as yet, undetermined period. There is no evidence contradicting the hypothesis that all members of this group are spectroscopic binaries of short period.

The peculiar radial velocities are small and the corresponding statistical parallax leads to $\langle M_v \rangle = +9^{m}\cdot5 \pm 1^{m}$; the blue stars in these systems are probably white dwarfs. The masses of the red components and their spectra (when photographed) seem consistent with those of a star of mass $\sim$ 1 solar mass. Thus the red components of U Gem variables are seriously underluminous for their masses. Evidence is presented which indicates that the red stars overflow their lobes of the inner Lagrangian surfaces; the ejected material forms, in part, a ring, or disk, surrounding the blue star. Several lines of argument suggest that the U Gem variables are descendants of the W UMa stars.

AUTOMATIC REDUCTION OF PHOTO-ELECTRIC OBSERVATIONS

H. Arp

The purpose of photometric reduction is to go from observed deflections at the telescope, to magnitudes and colours outside the atmosphere on some standard system. For example, if we have u, b, y raw deflections we will want to derive U, B, V magnitudes.

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The standard reduction formulae are:

$$2{\cdot}5 \log d = \text{Gain}_y - 2{\cdot}5 \log y - k_{34} \sec z \quad (1)$$

$$C_y = \text{Gain}_b - \text{Gain}_y + 2{\cdot}5 \log y/b - k_{12} \sec z \quad (2)$$

$$C_u = \text{Gain}_u - \text{Gain}_b + 2{\cdot}5 \log b/u - k_{56} \sec z \quad (3)$$

$$k_{34} = k_3 + k_4 C_y \quad (4)$$

$$k_{12} = k_1 + k_2 C_y \quad (5)$$

$$k_{56} = k_5 + k_6 C_u \quad (6)$$

$$V = 2{\cdot}5 \log d + a C_y + b \quad (7)$$

$$B - V = c C_y + d \quad (8)$$

$$U - B = e C_u + f \quad (9)$$

By using equations (4), (5), (6) we neglect second-order terms in extinction but the error introduced is very small and it is standard procedure to make this approximation. If the telescope-photometer system is very close to the U, B, V system then the linear transformation (7), (8), (9) may be used. If the natural system of the telescope-photometer is not similar to the U, B, V response then extensive empirical calibrations are required.

Advantages of Computer Reduction are:

1. The entire computation process will take about 5 minutes on a moderate-sized computer; a run of photo-electric data which would ordinarily have taken two working weeks to reduce can be finished by computer techniques in a day.

2. It can be assumed that the results are free of computational errors; any errors present in the result will reflect errors in the input data. An important practical feature of a program is the ability to locate input errors and to re-run computation immediately.

3. Most machines give permanent, condensed final results which may be annotated and filed conveniently.

There are two main desiderata in photometry: (*a*) maximum systematic identity with U, B, V system; (*b*) maximum accuracy of individual measures. In order to attain these goals I reduce from 1 to 7 nights simultaneously as one night. This is possible because the telescope-photometer system changes only slowly, and experience shows that all good nights are about the same, so the nightly differences can better be handled after this first reduction by means of small corrections. One can inspect or analyze the results for deviation of individual nights in extinction. Experience has shown that if any night is good enough to yield (after considerable special measurement) a value of the extinction coefficient, then this extinction coefficient is very close to the mean extinction coefficient. The mean extinction coefficient in turn is very close (except for a grey term) to the extinction computed from Rayleigh scattering at the altitude of the observatory. Therefore it seems reasonable to use the mean extinction coefficient.

G. O. Abell

It is assumed that many standard stars are observed during the run, and that large ranges of secant z and colour are represented among them. Then object stars, scattered widely over the sky, can be reduced by comparison to the standards. This method is not especially well suited for continuous measures of one object (say an eclipsing star) for which only differential extinction between that star and a nearby standard is applied. Even for the latter type of photometry, however, the present program provides information that makes the remaining reduction trivial.

There are two parts of the program, which operate in succession.

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1. *Extinction determined from data.* Assumes following transformation equations to go from instrumental magnitude, V_z, and colours C_{yz}, C_{uz}, as measured *inside* the atmosphere, to standard values of V, $B - V$, $U - B$, on, say, the Johnson system:

$$V = V_z + A + B \sec z + C\,C_y \qquad (1)$$

$$B - V = D + (E\,C_{yz} - F \sec z)\,(1 - 0{\cdot}03 \sec z)^{-1} \qquad (2)$$

$$U - B = G + H\,C_{uz} - I \sec z \qquad (3)$$

B, F and I are extinction constants, assumed constant (or at least that mean values are sufficient) over the period of observations included in the program.

A, C, D, E, G and H are constants in the colour equations. All nine constants are found by least squares by fitting observed standards to the Johnson system.

2. *Use of given extinction constants.* It may be that extinction is not well determined from the data, in which case it is of interest to reduce the observations with standard extinction constants, and compare the reduced values of V, $B - V$ and $U - B$.

In part 2, 8 sets of extinction data are read in:

A_1, A_2,................A_8; $K1_1$, $K1_2$,................$K1_8$; $K2_1$, $K2_2$,................$K2_8$

For each set, instrumental colours and magnitudes are computed:

$$V_o = V_z - A \sec z$$

$$C_y = (C_{yz} - K1 \sec z)\,/\,(1 - 0{\cdot}03 \sec z)$$

$$C_u = C_{uz} - K2 \sec z$$

Then, for each set, the constants in the colour equations are computed:

$$V = V_o + B + C\,C_y$$

where

$$C'_y = (C_{yz} - 0{\cdot}12 \sec z)\,/\,(1 - 0{\cdot}03 \sec z)$$

$$B - V = D + E\,C_y$$

$$U - B = G + H\,C_u$$

Finally, V, $B - V$, and $U - B$ are found for each object.

In each least-squares solution for constants, the values of V, $B - V$, $U - B$, computed from the derived constants, for each standard, are compared with the standard values. If V differs by as much as $0^m{\cdot}2$ or if the colours differ by as much as $0^m{\cdot}15$, that standard is set aside and a new solution is made. The process is repeated until the same standards are rejected twice in succession. In this way, the bad standards are eliminated from the solution. The program is written in FORTRAN, and copies can be provided on request by G. O. Abell.

R. H. Hardie

The Dyer Observatory is currently modifying the photo-electric photometer to permit measuring three colours simultaneously and recording all data automatically.

Dichroic filters are being tested for efficient separation of the desired bands; conventional filters will be used in each beam as necessary to match the bands to the U, B, V system of Morgan and Johnson. Three photo-multipliers, suitably cooled, will receive the beams, and the measured current and gain settings of the three compact amplifier units will be automatically recorded by an IBM card-punch unit. It is anticipated that the increased efficiency of this type of photometer over a conventional single-channel unit will result in obtaining up to 100 measures per hour in each of 3 colours.

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D. L. Crawford

Dr Crawford described the program for reduction of photometric measures, in use by staff astronomers and visitors at Kitt Peak National Observatory. Details are available from the Observatory and are published in *Contributions from Kitt Peak Nat. Obs.* No. 10.

H. L. Johnson

A new nine-colour photometer has been developed at the University of Texas and the McDonald Observatory. The nine wave-length bands are as follows:

Band	Wave-length, microns	Band	Wave-length, microns
U	0·35	*J*	1·3
B	0·45	*K*	2·2
V	0·55	*L*	3·6
R	0·62	*M*	5·0
I	0·85		

The *U*, *B* and *V* bands are measured by a 1P21; the *R* and *I*, by a Farnsworth FW-118; *J* and *K* by a PbS cell and *J*, *K*, *L* and *M* by an InSb cell.

The photometer is completely digitized. The three different amplifiers needed for the above cells can be fed into an integrator and digital voltmeter, and then to a tape-punch for recording on paper tape. In addition to the measured photometric deflections, all other data that are needed for the reduction of the observations are also automatically punched on the tape; this includes the date and time from a digital calendar and clock, the amplifier gain settings, the filter being used, etc. The name of the object and its right ascension and declination are read from a punched observing card which is inserted into a card-reader after the object is found.

All of these data are punched in the proper form so that the resulting tape can be fed directly into the CDC 1604 of the University of Texas. The reduction program computes extinction coefficients by one of several methods, whichever is most efficient for the data obtained on a particular night, reduces the observations, collects the several observations on an individual object, and, finally, prints a table suitable for publication. Intermediate stages in this computation use punched cards and sorting operations, as well as the computer. The program also makes an analysis of the observational precision.

This photometer is now in operation at the McDonald Observatory; the digitized portions were first used on 2 August, 1961.

W. Blitzstein

The nature of the methods used is largely dictated by the dual, pulse-counting operation of the Pierce Photometer, by the availablility of a UNIVAC I computer and by the use of a card-to-magnetic tape converter. For our purposes, then, it is planned to punch IBM cards at or near the Pierce Phötometer using an IBM 024 or 206 programmed card punch. However, the output of the storage counters is parallel in nature and the card-punch must be operated serially, so suitable converters utilizing rotary stepping switches or cross-bar switches have been designed.

It is desirable to punch more data than can be fitted on one IBM card and some of the data will be the same for all observations of a given set of measurements. Therefore data which do not change during a run will be punched manually on a master card, while data which change from measure to measure will be punched automatically.

The program for the UNIVAC will contain all the usual features for reducing the original measurements to magnitude-differences and light-ratios, making light-time corrections, cor-

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recting for differential extinction, etc. Two sub-routines peculiar to the Pierce Photometer will be included: (1) Coincidence corrections must be applied to the indicated counts since the system has a finite resolving time. This time has been measured experimentally by the two-source method which is commonly used in nuclear physics. (2) Since the operation is dual the ratio of the sensitivities of the two channels must be measured and computed for the spectral bands used. The observing sequence will provide the proper measurements for this purpose.

The card punching and the programming will be made sufficiently flexible so that data from photometers using chart recorders can be processed. Also special sub-routines will be provided for data from the lead-sulphide infra-red photometer.

F. C. Bertiau

The program developed for the reduction of photo-electric measures at the Vatican Observatory, is essentially the same as the FORTRAN program at Mount Wilson. Three interesting points should however be mentioned. (1) No constants in the reduction are assumed to be zero. (2) The observations are weighted automatically according to zenith distance, length of deflection, and quality of night. Observations at large zenith distances should have lower weight. (3) The four constants necessary to correct the yellow magnitude for extinction and reduce it to the U, B, V system should be computed simultaneously and not in two steps. This procedure makes it possible to compute the mean errors of the four constants easily and gives the best fit. The same remark applies to the colours $B - V$ and $U - B$.

MACHINE COMPUTATION OF LIGHT AND ORBITAL ELEMENTS OF ECLIPSING BINARIES

I. Jurkevich, Application of High-Speed Data-Processing Techniques to 1959 VW Cephei Observations.

The 1959 co-ordinated VW Cephei program resulted in approximately 8 000 observations, and another 5 000 data points had been obtained by Kwee prior to the campaign. The variability of the light-curve demands that each cycle be treated separately whenever observations are sufficiently accurate and numerous. Under these conditions treatment of the data by conventional means is deemed impracticable. Since much of the preparatory work, such as plotting of light-curves, conversion of magnitude differences to intensity ratios, determination of the times of minima, etc., is routine, it is felt that conventional techniques are not only wasteful of time, but unjustified in view of other methods available. It is these types of problems to which modern high-speed digital and analog machines are so admirably suited. It was decided to program for the IBM 7090, not only all preliminary steps but also the computation of elements and a perturbation analysis.

So far the entire set of observations has been punched on cards and transcribed to magnetic tape. This tape, with suitable instructions for supplying scale factors along both axes, was used to activate the digital-to-analog converters of automatic Moseley plotters. Following this an extremely simple program was employed to convert magnitudes to intensities. The operating times were as follows:

(*a*) Keypunching,	17 hours.
(*b*) Verification,	17 hours.
(*c*) Plotting,	50 pts/minute; total $\simeq$ 5·5 hours.
(*d*) Δm to intensity,	3 minutes.

A program has been written for the determination of the times of minima, based on a method which requires no assumption concerning symmetry of minima or equality of spacing between

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data points. Dispensing with these assumptions leads, however, to considerably greater complexity in the computations. The machine program in question is currently being tested; first indications are that, for a set of observations consisting of 200 points, simultaneous solution for both the period and the time of minimum requires somewhat less than 0·1 second of machine time. Plans for further work include the preparation of programs for computation of orbital elements and for perturbation analysis as developed by Kopal.

C. M. Huffer, Automatic Computation of Elements of S Cancri and AR Cassiopeiae

Light-curves of S Cnc and AR Cas on the *U*, *B*, *V*, system, were shown. The observations were made at Madison, Flagstaff, and Kitt Peak.

The rectified and reflected magnitudes, arranged in order of phase, were fed into a CDC 1604 computer. Values of *k*, the ratio of the radii, and of the darkening coefficient, u' or u'', were pre-selected. The machine solved Kopal's equation in six unknowns by the method of least squares, using individual observations. The resulting value of *k* was tested and, if Δk was less than one-half the probable error, the solution terminated; otherwise the process continued for up to 20 iterations.

After *k* was accepted, the machine computed the light-curve with residuals in both light and magnitudes. The process of solving between 250 and 600 equations for 6 unknowns took less than two minutes.

The results were as follows:

S Cancri

	U	*B*	*V*
	$u' = 0·4$	$u' = 0·4$	$u' = 0·4$
k	0·3827 ±·0245	0·4344 ±·0106	0·3979 ±·0295
i	83°·39 ±0°·23	84°·37 ±0°·11	83°·91 ±0°·30
number of observations	328	477	566

AR Cassiopeiae

	U		*B*	*V*
	$u'' = 0·4$	$u'' = 0·6$	$u'' = 0·4$	$u'' = 0·4$
k	0·5147 ±·0540	0·4742 ±·0514	0·3483 ±·0469	0·4067 ±·0875
i	90°·00 ±0°·11	90°·00 ±0°·37	88°·41 ±1°·27	90°·00 ±1°·13
number of observations	298		302	258

The large probable errors are due to the shallow eclipses, which are about $0^{m}.12$ in depth.

It is planned to publish a paper, including tables of observations, in the *Supplement* of the *Astrophysical Journal.*

A flow diagram of the process of computation was shown. The programming was by Mr George W. Collins, II, a graduate student at the University of Wisconsin Department of Astronomy.

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D. B. Wood, Machine Method for Calculation of Orbital Parameters

Traditional approach to the solution of eclipsing binary light-curves involves the mathematical and computational simplicity of rectification and tabulated values for the "spherical" model. Since high-speed digital computers are not worried about simplicity of calculation a whole new approach to the problem is possible, that is, the direct solution of all orbital parameters simultaneously by means of a least-squares iterative procedure. A program has been coded for the IBM 704 which will predict a light-curve for 11 assumed parameters. Thus by means of a first approximation at the solution, the light intensity can be predicted at each observed time and the difference in observed and computed intensities used to calculate differential corrections to the orbital elements by least squares. The problem is simplified by the following 5 assumptions: (1) the figures of the stars are similar tri-axial ellipsoids; (2) the major axes point toward each other; (3) the minor axes are perpendicular to the orbital plane; (4) limb darkening follows the usual one-parameter law; (5) brightness is independent of latitude or longitude on the star's surface. These assumptions serve a twofold purpose: (*a*) they restrict the parameters of the system, and (*b*) they simplify the geometry of the figures projected on the plane of the sky. The reflection effect is currently being investigated separately and its inclusion is being planned.

The actual calculation of observed light is done by numerical (Gauss 4- or 10-point) integration over the eclipsed area. The geometry is simplified by the use of a transformation to the eccentric projection.

Two slides were shown, one on the nature of isophotes on an ellipsoidal star, and one a parameter study showing the effect of changing the line of apsides. Many such parameter studies could be undertaken.

When solution of an actual light-curve is attempted, it is found that limb darkening gives rise to convergence problems, so that it may be possible to obtain solutions only as a function of given limb darkening. The best solution could then be found by looking for the minimum R.M.S. error of this family of solutions. Much work still remains to be done in the investigation of convergence problems and their circumvention.

P. Wellmann, Programming for the IBM 650

At Hamburg, a set of programs for the computation of orbital elements of eclipsing binaries with an IBM 650 electronic data processing machine has been in use since 1958.

The computation is done in three steps:

(*a*) harmonic analysis of the light curve outside of eclipse;

(*b*) rectification;

(*c*) computation of the elements α_0, k, $\sigma = \sin^2\theta_{n=1/2}$ for any one of the cases occultation, transit, total or annular eclipse.

The coefficients of the sine and cosine terms, determined for arguments up to 3θ if desirable, are used to obtain the constants for the rectification.

The rectified eclipse observations are used in program (*c*). The basic process in this program is: assuming α_0, compute k from the depth equation, then solve $\sin^2\theta\ (n) = \sigma \,.\, \chi(n, \alpha_0, k)$ for σ by a least-square method, compute a theoretical light curve and $S = \Sigma(l_o - l_c)^2$. The cycle is repeated with a new assumption for α_0, with the aim to minimize S. A part of the program predicts the most probable value of α_0 by comparing the values of S in the three preceding hypotheses. The iteration is stopped when the accuracy of α_0 matches a pre-set value. One cycle is accomplished in about 8 sec. Finally the mean errors of the elements are computed. The contribution of the uncertainty of the depths of minima is included.

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The time necessary in a typical case is: 1 hour for punching and checking of IBM data cards; 3 minutes for computation with program (*a*); 10 minutes for preparing the input card with constants for the rectification; 3 minutes for computing with programme (*b*); about 1 hour for derivation of weights and depths of minima, and punching of four data cards; 5 - 8 minutes for computation of final elements and their mean errors.

A wrong assumption as to the type of eclipse is recognized from the results $S(\alpha_0)$. In the course of the computation the limb darkening coefficients u_p and u_s are supposed to be known; if necessary, the program is started again with altered values.

Z. Kopal, Interpretation of Light-Curves of Eclipsing Variables in the Frequency-Domain.

Transient phenomena like stellar eclipses should properly be analyzed not in the time-domain, but in the frequency-domain, that is, it is not the light-curve which should be subject to analysis, but rather its Fourier transform.

In the time-domain the light changes of a close eclipsing binary system consist of a superposition of the photometric proximity effects, which are continuous in time, upon discontinuous effects of the eclipses. Moreover, the mutual distortion of figure of both components gives rise to photometric effects which are multiplicative (*i.e.*, are multiplied by the fractional luminosity of the respective component), those of the reflection are additive to the total light of the system. In the frequency-domain these distinctions largely disappear, for the Fourier transform of a discontinuous time-function (such as the light-changes due to eclipse) becomes continuous in the frequency parameter, and, more important still, the frequency spectrum of all proximity effects becomes discrete and its distribution known in advance. Thus a separation of the proximity effects and the eclipse effects becomes automatic in the frequency-domain, and no rectification is necessary.

The students of eclipsing variables have much to learn from the existing theory and practice of information and communication engineering. Many similar operations in the field of communication engineering have been successfully automatized, and it is perhaps not too much to expect that the same will eventually prove to be true in the analysis of the light-curves of eclipsing variables.

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