27. VARIABLE STARS (ÉTOILES VARIABLES)

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1. INTRODUCTION

This Report in arrangement of the material follows closely that written by Dr. Herbig for the last IAU General Assembly. It consists of four parts, each written by a different author. The first deals with variable stars in general, and was prepared by the President of Commission 27, with the exception of a section on the Theory of Variable Stars, very kindly written at his request by Prof. Kippenhahn. Appendix I on the Spectra of Variable Stars was prepared by Dr M. W. Feast, Chairman of that Committee of Commission 27. Appendix II covers the Variable Stars in Clusters, written by Dr Helen Sawyer-Hogg, Chairman of that Committee. Appendix III is a Report of the Working Group on Flare Stars, prepared by Drs Andrews, Chugainov, Gershberg and Oskanjan. No report has been received from the Working Group for Nomenclature for Magellanic Cloud Variables. About supernovae see the report of the Committee of Commission 28 for Research on Supernovae. On pulsars see the Reports of Commissions 25 and 40. Our thanks are due to all members of the Commission and to other astronomers occupied in variable star research, who have assisted in collecting the material for this report. Great help was a general report on flare stars by the competent Working Group.

The drastic reduction of this report, in accordance with a decision of the Executive Committee, to half its extent in the *IAU Transactions* XIIIA, made some changes necessary. We tried to make up for lost extent using references condensed in the text in the most abbreviated form. In addition to the usual brief abbreviations the following have been used: *AA* = *Astronomy and Astrophysics*; *AcA* = *Acta Astronomica*; *AZ* = *Astr. J. U.S.S.R.*; *IB* = *Var. Star. Inf. Bull. Budapest*; *MAI* = *Mem. Soc. astr. it.*; *MVS* = *Mitteilungen über Veränderlichen Sterne*, *Sonneberg*; *ROB* = *Royal Observatory Bulletins*; *PZ* = *Peremennje Zvjozdy*. About references to Proceedings of Symposia or Colloquia see Sections 2 and 3. References without volume or page numbers are in press.

2. MEETINGS AND SYMPOSIA

An IAU Colloquium on Non-Periodic Phenomena in Variable Stars was held in Budapest in September 1968, the fourth in the triennial series of meetings on variable star topics. A Colloquium on Mass Loss from Stars was organized at Trieste in September 1968 by Mrs Hack. Many papers on variable stars were presented at the IAU Symposium no. 36 on Ultraviolet Stellar Spectra and Related Ground-Based Observations held in Lunteren, Netherlands, from 24 through 27 June 1969 (referred in the following as *Lunteren*). Some material on our topic was presented on the Liège Colloquia on Forbidden Transitions in Stellar Spectra in 1968 (ref. *Liège*, 1968), and on Pre-Main Sequence Evolution in 1969 (*Liège*, 1969), both organized by the Institut d'Astrophysique, Cointe Sclessin, further at the ESO Symposium held at ESO headquarters in Santiago, organized by Blaauw, the scientific director of ESO, following the ESO's dedication ceremonies 1969 March (ref. *ESO*). In May 1969 X-ray stars were discussed in Rome at the IAU Symposium no. 37 organized by Gratton and the Dudley Observatory (ref. *Rome*). A Conference on pulsars was held in New York City on May 20–21, 1968 (*Sky Telesc.*, **36**, 4). A three-day international symposium on low-luminosity stars was held in March at the University of Virginia, Charlottesville, where very young stars and flare stars were the subject of several papers. Several papers on supernovae, pulsars and

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X-ray objects were read at the Eleventh International Conference on Cosmic Rays in Budapest, August 1969.

3. CATALOGUES, CHARTS, BOOKS AND INFORMATION BULLETIN

The Moscow team headed by B. V. Kukarkin and P. N. Holopov prepared for publication the third Edition of the *General Catalogue of Variable Stars* containing information on 20437 variables discovered and designated up to 1968. The increased number of data necessitated to publish the Catalogue in two volumes. The first volume containing the list of references for the whole catalogue and the variables in the constellations Andromeda to Grus was distributed in December, 1969.

An Identification List of 1648 new variables nominated in 1968 has been published by the Commission for Variable Stars of the Astronomical Council of the Academy of Sciences in the U.S.S.R. in *IB*, 311.

Nikolov constructed a *Catalogue of the Light and Colour Curves of Cepheids in the U, B, V system* containing about 300 stars. The catalogue was published by the Bulgarian Academy of Sciences in 1968. The possibilities for editing a similar catalogue of RR Lyr stars are under consideration between the Sternberg Institute at Moscow University, the Department of Astronomy at Sofia University and Odessa Observatory. Fernie and Hube published a Catalogue of Fundamental Data for 362 Classical Cepheids in the Galaxy (*AJ*, **73**, 492, 1968). Maffei intends in collaboration with Blaghikh to compile a catalogue of irregular variables. A catalogue of suspected symbiotic objects (mainly southern) is being prepared by Miss Nordström (Stockholm).

H. Huth has so far prepared about 10% of the material for the new edition of the *Geschichte und Literatur des Lichtwechsels* (*GuL*), begun by the late Dr Schneller. Printing will be started as soon as the discussions on the intended international co-operation and the kind of the publication (whether volumes, booklets or cards) have been closed.

Bateson, A. F. Jones and Stranson of the VS Section, RAS of New Zealand are editing charts for southern variables. Ultimately, the complete series, totalling ten, will cover all variables other than those of short period classes south of declination S. 30° and brighter than visual magnitude 13 at maximum. They hope to complete the work before the XIVth General Assembly. Cesevič together with his collaborators prepares the *Atlas of Finding-Charts for Variable Stars*. Four volumes containing charts for 5000 stars have been completed.

The proceedings of the Budapest Colloquium were printed at Academic Press Budapest (ref. *Budapest*), edited by Detre and sold by Reidel Publishing Company as co-publisher. The proceedings of the two Trieste Colloquia were edited by Mrs Hack (ref. *Trieste*, 1966 and *Trieste*, 1968, the latter is Vol. 13 of Astrophysics and Space Science Library). The Symposium volume of IAU Symposium no. 30 on *Radial Velocities*, held in Toronto in June, has also been published containing one section on radial velocities of variable stars (ref. *Toronto*). The symposium volume *Low Luminosity Stars* was edited by Kumar (Gordon and Breach, London, 1969).

A series of monographs dedicated to variable stars will soon be published in the U.S.S.R. The first volume of *Pulsating Stars* (Ed. B. V. Kukarkin) and the second volume of *Eruptive Stars* (Ed. A. A. Bojarčuk, R. E. Gershberg, Crimea) will appear in 1970. V. B. Nikonov's *Methods for the Study of Variables and Non-Stationary Objects and Stellar Evolution* are under preparation.

51 articles on pulsars, which appeared in *Nature* till about September 1968 were collected in a volume entitled *Pulsating Stars* and edited by Macmillan with introductions by Professor F. G. Smith and Dr A. Hewish. A very useful popular book on variable stars was written by Glasby. As more than a quarter of all the studies in the field of astronomy is directly or indirectly connected with the problem of stellar variability, many other books contain topics relevant to our field.

The issue of special magazines (cf. *Peremennje Zvjozdy*) and circulars in the domain of variable star investigations was continued. At the end of 1969 the fourth volume of the *Information Bulletin on Variable Stars* of Commission 27 was completed, each volume containing 100 numbers, edited by Detre and Szeidl at the Konkoly Observatory, Budapest. The support of the *Bulletins* has been guaranteed by the Hungarian Academy of Sciences for a further 3-yr period. In order to avoid unnecessary duplication of work, the *Bulletins* should more often bring information on variables which are being observed or which have been put on an observing program, creating in this way a real communication centre. The Sonneberg Observatory provides further for the edition of the *Mitteilungen über Veränderliche Sterne* (*MVS*).

4. GENERAL PROBLEMS, DEVELOPMENTS AND TRENDS IN VARIABLE STAR RESEARCH

The most significant new development in the field of variable stars was the discovery of pulsars early in 1968 by Miss Bell and Dr Hewish, and especially the optical observation of NP0532, the pulsar in the Crab Nebula by Cocke, Disney and Taylor at Steward Observatory on January 16, 1969, and the identification a few days later by Lynds, Maran and Trumbo at Kitt Peak NO as the south preceding star of the pair near the centre of the nebula. There is agreement that pulsars are neutron stars, and in this way Zwicky's 1933 hypothesis of some supernovae being caused through the collapse into neutron stars seems to have found its confirmation. Yet, there is some controversy about whether the observed periods are rotation periods of magnetic neutron stars (Gold's hypothesis), or pulsation periods of neutron stars with small mass ($\sim 0{\cdot}1 \odot$, Saakian, Vartanian, *Astrofizika*).

The optical identification of the Crab Pulsar was made possible by the use of the new techniques of synchronous signal averaging first developed by Clark (W. A. *MIT Res. Lab. El. Qu. Progr. Rep.* 114, 1968) in order to reduce the effects of the sporadic variations in light common to old novae and similar variables. Using these techniques, the search for optical objects associated with other pulsating radio sources has been continued by Kristian at Mt. Wilson to look for pulsations at the known radio frequencies. No pulsing optical objects have been found in the fields of 11 pulsars, with limits ranging from 20th to almost 25th magnitude. The Crab Pulsar seems to be of exceptionally high absolute luminosity compared with other known pulsars.

In the discovery and observation of pulsars high time resolution techniques are of paramount importance. Application of these techniques to other types of variables, to old novae, X-ray stars, symbiotic variables, also led to interesting results. In addition, high time resolution observation may reveal short time variation in properties of stars previously thought to be stable. In April 1967, Westphal and Sandage began an experimental monitoring of the optical flux of Sco X-1 with time resolutions as small as 2 s. At the Kenneth Mees Observatory, Savedoff, in collaboration with Dutton, Sturch, Rosenberg and Hamann, has assembled equipment which permits the rapid digital recording of photoelectric signals. At Victoria, Hutchings has obtained photoelectric observations of line profiles in B and Be Stars with high time resolution (*Budapest*, p. 191).

A program is being carried out by Hesser, Lawrence and Ostriker (*ApJ*, **148**, L161, 1967; **153**, L151, 1968; **155**, 919, 1969) for acquiring long ($\sim$ 7200 s) continuous, digitized records of the apparent luminosity of various stars in the lower lefthand portion of the HRD. These records are then searched for low-amplitude, periodic variability using modern autocorrelation and power-spectrum techniques. Various noise statistics are also developed which help to distinguish objects possessing intrinsic but non-coherent variability from either quiet objects or objects exhibiting periodic behaviour superimposed upon an otherwise quiescent radiation field. About application of power-spectrum techniques to irregular variables see Plageman, *Budapest*, p. 21.

Sometimes the components of close visual binaries are variable stars. Till now, it was impossible to get accurate photoelectric magnitude differences and colours for the components of very close double stars. A new instrument for variable star work is the photometer developed by Rakos and called *Area scanner* (*Appl. Opt.* **4,** no. 11, *Acta phys. Austria*, XXV, no. 4, 1967; Franz, *Lowell Bull.* 134; J. S. Hall, *ibid.*, 143; A. Elvius, *ibid.*, 142; Boyce, *AJ*, **71**, 847). It enables accurate photoelectric photometry of close binaries with a separation as small as one second of arc. The apparatus is very suitable also for polarimetric work. Complete equipments can be ordered at the Austrian company A. Pear KG., Graz.

Bakos, at the University of Wisconsin, is examining the properties of image orthycons and their use in variable star work. He is now processing the photographic material obtained by him by means of an image orthycon system at Dearborn Observatory (see Appendix **II**, 2b). The television equipment employed at the Crimean Astrophysical Observatory was described by Abramenko and Prokofjeva (*Budapest*, p. 57).

Mt. Cuba Observatory recently initiated a program of photoelectric photometry including differential photometry of variable stars and monitoring of flare-stars using a 70 Å-wide filter centred on the Ca II K line. This is very effective in reducing the sky background more than the signal from flare stars which are characteristically emission-line objects. Ultraviolet monitoring can then be carried further into bright moon periods (R. D. Herr).

A photometer for simultaneous stellar photometry in three colours has been constructed in the laboratories of the Catania Observatory (*Budapest*, p. 51), where four instruments are available for variable star work. An apparatus for the automatic converting of analogic data, given by the photometer, into digital data on punched cards is under construction. Similar equipments are already in use or in construction at several observatories.

An increasing convergence is apparent between the fields of stellar physics and solar physics stellar analogues of solar phenomena are becoming the subjects of specific researches (*Budapest*, pp. 10–12). The example of flare stars is well known. The spectral study of chromospheres of dwarf M and K stars has been fruitful, and efforts are under way to detect the stellar analogues of the solar magnetic cycle. It would be extremely valuable if sunlike activity were discovered in other stars, not only because it might explain the variability of the Sun but also because it should help to answer basic questions about the physics of a hot magnetic plasma. Since 1967 a wide program on stellar activity of solar type was undertaken at Catania (see Godoli *Atti dell'XI. Convegno, Padova*, p. 224, 1967; *Catania Pubbl.* 118, *Nobel Symposium* no. 9, 221, 1968), observing photoelectrically α Boo, α Tau, HD 119850, that show variable H_2 and K_2 emission components. Also the magnetic stars 21 Com and 20 χ Ser, and probably the flare star BD $+51°$ 2402 belong to this class. Photoelectric flux measurements at the center of stellar H and K lines with the coudé scanner of the 100-inch telescope at Mt. Wilson and its associated pulse-counting equipment started in 1967 in a search for stellar analogues of the solar cycle (O. C. Wilson). A number of main-sequence stars are being followed, covering the spectral-type range F 5 to M 2. The fluxes at the center of the H and K lines of Ca II are measured as frequently as possible in order to detect changes in the chromospheric components of the radiation. A preliminary analysis of the observations shows that nearly all stars whose spectra reveal H and K reversals on 10 Å/mm spectrograms have undergone some changes in chromospheric emission. Liller (*ApJ*, **151**, 589, 1968) has found short term K 2 intensity changes of about 20% in α Tau. No periods can be determined yet. In 61 Cyg A *and* B the chromospheric fluxes are varying in a roughly cyclical manner, but these cycles may be the rotation periods of the stars. It is hoped to extend this investigation soon to giants and supergiants. At Washburn Observatory Ch. Anderson expects to utilize the échelle spectrometer to monitor the Ca II K emission in several late-type stars in an attempt to detect solar-cycle-like variations either through changes in the integrated emission flux or through variations in the frequency of K-line flare activity. Boesgaard (*PASP*, **81**, 283, 1969) called attention to the presence of fairly strong Ca II emissions at H and K in the spectrum of the M3S star 4 Ori = HD 30959 which were absent some time ago (Warner, *MN*, **129**, 263, 1965). This evolved star thus shows a substantial variation in the intensity of Ca-emission presumably due to chromospheric changes.

A similarity to the 5-min oscillation of the Sun has been noted by H. John Wood (*ApJ*, **152**, 117, 1968). He developed the use of photoelectric narrow-band photometers for measurements of Balmer-line variations (line-curves, *Leander McC Publ.* **15**, Part II, 1965). Photoelectric line curve observations of HR 9080 show time variations of about 10% in the effective equivalent width of Hβ, Hγ, and Hδ. Quasiperiods of about 35 min are found. The oscillations become unrecognizable after several cycles.

Although the K-lines are the principal features in late-type spectra that have been related to stellar chromospheres, the Mg II lines at 2974 Å and the hydrogen $L\alpha$- and $L\beta$-lines have been found to show similar structure. Zirin has observed the He I line at 10830 Å with an infrared image con-

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verter at the 200″ coudé spectrograph and found emission in β Dra and in ε Gem; in the latter star emission was not present a few years ago.

Another possibility to discover sunlike activity in stars may be the observation of emission lines of highly ionized atoms in their spectra, that might reveal the existence of stellar coronas. On the average the intensity of these emissions lines should go up and down in unison with the star-spot cycle in a period not unlike that of the solar cycle although the length of the period might be quite different. Longterm variations in the statistical parameters of irregular variables showing flare activity (T Tau stars, flare stars, X-ray stars, old novae), as found for RW Aur stars by Cesevič and Dragomineskaja (*Sky Tel.*, **34**, 366, 1967), might be the manifestations of activity cycles.

The length of the period of some magnetic variable stars seems to change periodically. Assuming that the stellar surface has some kind of bright or dark magnetic spots and the magnetic and light variations are apparently induced by stellar rotation (oblique rotator hypothesis), the change of period can be explained by spots moving from high latitudes towards the equator or from the equator toward high latitudes. A similar effect is caused by the sunspots during the 11 year solar cycle (Rakos, *PASP*, **80**, 563, 1968). To find the first measurable connection between stellar and solar magnetic fields, Albrecht, Maitzer and Rakos (*AA*, **3**, 236, 1969) succeeded to prove that the sun varies its brightness synchronously with its rotation. The question was investigated using the most extended photometric observations of very high precision carried out at Lowell Observatory during the period 1950–1966 (see e.g. *Lowell Bull.*, 137). They also proved the dependence of the period of the light variation upon the solar cycle. As the amplitude of the variations is very small ($<0{\cdot}01$ magnitude), a continuation of the observations is highly desirable.

Be stars and shell stars exhibit cycle of activity, that may be of magnetic origin. Crampin and Hoyle's (*MN*, **120**, 33, 1960) idea, that a weak initial magnetic field should be amplified by the differential rotation to a maximum value, until an explosive dissipation of the material in the extended atmosphere occurs, was recently discussed and compared with observations by Henriksen (*AA*, **1**, 457, 1969).

Of considerable importance is Eggen's effort to construct a classification system for intrinsic variables based on our present knowledge of the evolutionary and dynamical history of galactic stars. He has given an excellent review of the problem (*Sigma Reviews prepr.*). He makes a basic subdivision on the basis of the region occupied by the variables in the luminosity-temperature plane; a second parameter in his system of classification is the star's age. He uses for the recognition of disk populations data on space motion, ultraviolet and infrared radiations, TiO absorption measured by the colour (**65, 62**) i.e. the magnitude difference between the bandpasses of narrow band filter at 6250 Å and 6500 Å.

F. W. Wright and P. W. Hodge (*PASP*, **81**, 238, 1969) called attention to HV 13055 in the LMC which has a very unusual light curve. We do not know of any other variable star with properties like those of HV 13055 and do not know to what class of variables it belongs.

In a manuscript by G. A. Richter (*AN*) problems with regard to the determination of the probability of discovery are discussed. Another publication concerns a general error analysis of the method used to estimate the number of variable stars (together with L. Winkler, of Pennsylvania State University, *MVS*, **4**, 143, 1968).

5. THEORY OF VARIABLE STARS

(by R. Kippenhahn)

After Christy's pioneering work on the theory of *non-linear radial pulsation* one is puzzled with the discrepancy between the masses of cepheids derived from normal stellar evolution theory and the masses determined from the "second bumps" in the light curves derived from the nonlinear pulsation theory (Christy, *ESO*). The recent work by Stobie (*MN*, **144**, 485, 511, 1969) using a similar code confirmed Christy's results, suggesting that stars have undergone a considerable mass loss before they became cepheids. Baker and von Sengbusch (*AG. Mitt.*, **27**, 1969) now are investigating nonlinear radial pulsations with a new numerical method.

The cepheids are still the only pulsating variables where a combined approach of stellar evolution theory and pulsation theory has been carried out. The RR Lyrae variables probably would give good tests for the different ideas of the horizontal branch stars. δ Scuti stars and dwarf cepheids probably offer similar opportunities to get information by comparing light curves with nonlinear pulsation theory.

Work is going on at different places on the theory of Mira type variables, but the work suffers from the insufficient knowledge about the interaction between pulsation and convection.

The question whether the vibrational instability of main sequence stars above 60–90 solar masses can cause the *P Cyg phenomenon* has recently been discussed by Appenzeller (*AG Mitt.*, **27**, 1969) by the nonlinear pulsation theory for a star of 130 solar masses driven by the fluctuating nuclear energy output.

The cause of the β CMa pulsation still seems to be unknown. Two possible mechanisms have been discussed recently:

(a) Stothers and Simon (*ApJ*, **157**, 673, 1969) suggest that a helium enriched layer in the outer part of an otherwise normal (hydrogen rich) envelope changes the pulsational properties of the stars in such a way that the nuclear energy generation produces a vibrational instability. In order to obtain stars of this type they have to assume that all β CMa stars are members of close binary systems and that during the mass exchange a considerable amount of helium enriched material is transferred to the companion. Then for the helium enriched companion the mass critical for vibrational instability (caused by fluctuation of the nuclear sources) is reduced from the well-known 60 solar masses for a normal population I mixture down to the mass range of β CMa stars. In contradiction to the last assumption, in all cases of mass exchange in close binary systems computed up to now never a considerable amount of the helium enriched material is transferred, but mass exchange stops as soon as the top of the helium enriched core approaches the surface of the star which looses mass.

(b) Stars above 10 solar masses form a semi-convective region during the exhaustion of their central hydrogen. At the transition zone a region can be formed which is dynamically stable (i.e. the Ledoux criterion is fulfilled) but vibrationally unstable against nonspherical oscillations (i.e. the classical Schwarzschild criterion is violated) (see Gabriel, *AA*, **1**, 321, 1969). In these layers oscillations could occur and – since the mass range and the evolutionary state fit well to the β CMa stars – the phenomenon could be connected with these variables. Unfortunately, it seems that the region which is able to drive the nonspherical pulsation contains only little mass and probably will not be able to overcome the damping in the rest of the star.

For *late type stars* an appreciable part of the star's mass is in the state of transient ionization reducing the $\gamma = C_p/C_v$ below $\frac{4}{3}$ in a large part of the star and making the star eventually dynamically unstable. This mechanism was used independently by Lucy and Paczynski to explain the formation of planetary nebulae. Up to now all efforts to follow up the evolution of stars into this instability failed and it might be that during their red giant and supergiant phases stars in the HRD never penetrate into the region of instability caused by ionization. But in the case of mass exchange in close binary systems the ionization effect becomes important. If a red giant star fills its critical volume and mass exchange sets in, the outburst becomes rather violent. This mechanism recently was used as an explanation of *novae and U Gem variables* by Bath (1969, reprint).

The Loreta-hypothesis that the light variation of *R CrB* stars is due to obscuration by a soot cloud is worth being discussed again since the amount of radiation missing in the optical range if the star is not of normal brightness has been discovered as black body radiation of about 1000° in the infrared by Stein, Gaustadt, Gillett and Kancke (*ApJ*, **155**, L3, 1969). A similar effect has been found for RY Sgr by Lee and Feast (*ApJ*, **157**, L173, 1969).

6. PHOTOGRAPHIC SURVEYS, SPECIAL FIELDS

The systematic photographic search for new variables inaugurated in 1959 by Strohmeier at Remeis Observatory in Bamberg, and extended to the southern heavens in 1964, is continuing

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highly successfully, recently in cooperation with Professor F. B. Wood. In addition to the set of cameras working at the Boyden Observatory there is now another in New Zealand, at Mount John University Observatory, Lake Tekapo. A new, six-camera unit will soon be operated at La Plata, Argentina. All the cameras are fitted with inexpensive $f/6$ Tessar lenses of 4″ aperture, and cover a 13-by-13 degree field. The number of new Bamberg variable stars (*BV*) now exceeds 1200. For many of *BV* additional observations back to about the year 1900 have been made using the plate collections at Harvard Observatory and at Sonneberg, GDR. The results are announced from time to time in the *IB*. From December, 1969, U.S. participants from the University of Florida, Gatesburg will supervise the program at the New Zealand station and probably help at Bamberg in plate measurements.

Hundreds of plates have been taken in fields in the southern sky with the Metcalf 10″ telescope at Boyden Station by van Hoof. Tens of new variables have already been discovered.

The search in selected fields for variable stars, begun by C. Hoffmeister, is continued by G. A. Richter at Sonneberg, in order to obtain further material for such statistical investigations as derived from previous material and published in *Ver. Sternw. Sonneberg* **7**, no. 3, 1968. Lists of recently discovered variables and also their newly derived elements are published continuously in the *MVS*. Hoffmeister published 223 new variables in 19 fields (*AN*, **290**, 277, 1968). The elements of light variations of variables near the galactic pole have been published by L. Meinunger and Wenzel in *Ver. Sternw. Sonneberg*, **7**, no. 4, 196, those in areas around ν Gem, δ Aql, ϱ Cyg and ε Pav by Gessner (*ibid.* **7**, no. 5, 1970; *MVS*, **5**, 96, 1969), and those around α Pav by I. Meinunger (*MVS*, **5**, 1969). Ahnert using the 20/30/30-cm Schmidt-cameras derives normal maxima for Cepheids in Cas.

The processing and publishing of faint variable stars in the Cygnus Cloud and adjoining areas in Lyr and Vul have been steadily continued at the Fordham University Astronomical Laboratory. Since the 1967 Draft Report ten more brochures have appeared on 88 Cyg Cloud Variables and 12 variables in Lyr and Cyg (VV 151–250, *Ric. astr.*, **7**, 197, 217, 241, 261, 315, 411, 435, 459, 499). At least 150 additional Cyg Cloud variable stars remain to be studied at the FUA Laboratory, and they will be published in future issues of *Ric. astr*. Accurate positions and comparison star sequences have already been measured for virtually all of these variables by Father Miller.

At his request, in July 1969 Father O'Connell, Director of the Vatican Observatory, loaned 438 plates centered on BD $+53°3167$ to Dr Wachmann of Hamburg Observatory.

Dr Wachmann will process for future publication about 150 variable stars discovered in this part of the Cep-Lac-Cyg star clouds, taken most of these by Miller on the Zeiss 16″ quadruplet astrograph at Castel Gandolfo. The variables will be published under joint authorship in *Ric. astr.*

Romano at Treviso has continued the photographic survey of variable stars using Asiago Schmidt plates. In particular, he has examined the fields of ϱ Cyg (*MAI*, **38**, 138, 1967), γ Cyg and δ Com (*ibid.*, **39**, 236, 1968 = *Pubbl. Padova*, no. 149), γ UMa, 89 Psc and γ Com (*ibid.*, **38**, 621, 1967), finding new variable stars and giving improved elements and magnitudes for those already known. Results of the photographic observations of 27 variable stars in two fields around o Per and k And are reported in *MAI*, **40**, 261, 1969. Researches on the following fields: η Cyg, γ Lyr, $19^h04^m +43°$, are in progress.

Maffei at Frascati started a search for infrared variable stars in 6 fields, using the Asiago Schmidt telescopes. Preliminary work shows these variables have in general long periods. The collection of plates will be continued another year at least.

The Palomar-Groningen search for faint variable stars in four selected regions (see *Trans. IAU*, **XIIA**, p. 361) is now approaching its conclusion. Results on Fields 1 and 2 are published in the *BAN Suppl.* **1**, 105, 1966; **2**, 293; **3**, 1, 1968. The data for Field 3 are now ready for discussion and will be published in 1970. Field 4 is in the hands of de Kort at Nijmegen. The study of magnitude and spectral variability of giant M stars in Field 2 and in VSF 193 Sgr by Miss Houk (*Trans. IAU*, **XIIIA**, p. 544) was published as a thesis (1967).

Kooreman discussed 80 variable stars in the region of CPD-31°5547 (*BAN Suppl.*, **3**, 41, 1968). Oosterhoff and Ponsen published an investigation of 96 variables in the galactic window 17^h53^m, $-29°02'$, 1900 in Sgr (*ibid.*, **3**, 79, 1968).

Landolt is studying two regions of the dark nebulosities in Tau (4^h05^m, $+25\overset{\circ}{.}4$; 4^h30^m, $+24\overset{\circ}{.}8$) using photographic plates extending over a 7-yr interval and obtained at Dyer Observatory's 24″ reflector-corrector camera. *UBV* photoelectric sequences reaching to $V = 16{\cdot}8$ were published in *AJ*, **72**, 1012, 1967.

Geyer started a study of variables at $l^{II} = 180°$, $b^{II} = \pm 60°, \pm 30°, \pm 10°$ with the Bruce 40-cm astrograph at Heidelberg. Gieseking at Observatorium Hoher List uses a 30 cm *f*/5 Sonnefeld-Vierlinser for searching variables in $6° \times 6°$ fields around the associations Cep OB2, Cyg OB9, Lac OB1, Per OB2.

At the Harvard Observatory Miss Harwood and her assistant, Mrs Swam, continue to investigate the variable stars in the Scutum Cloud, using plates made with the Bruce 24″ refractor. Estimates of magnitudes have been made of 316 stars. This number includes the remainder of the new variables discovered at the Maria Mitchell Observatory by Heath. The stars having variations of long period are being edited and prepared for publication. 174 stars, which have short period variations, are being measured also on a series of 50 plates made with the 48″ Palomar-Schmidt telescope by Sandage and loaned recently to Harvard. These plates, of 10^m exposures, were taken throughout each of the five nights of June 20–24, 1955. From these results they hope to derive periods of many RR Lyr stars. Their future program will continue the variables in the Scutum Cloud until all variables old and new, for which type and period are not known, have been investigated.

At the Maria Mitchell Observatory Miss Hoffleit and her associates published several notes on new variables in Sgr (*AJ*, **72**, 711, 1967; **74**, 718, 1969; *Irish AJ*, **8**, 149, 1968, *IB*, 254, 277, 312). Identification charts have been prepared for the majority of recently published and unpublished variables in VSF 193. It is expected that they will publish them in 1970. After the preliminary results have been obtained for all of the new variables, they plan to bring the observations of selected interesting variable stars in this field up to date, and eventually do the same kind of work in Cyg and Com.

L. Evans has begun at Pretoria a new photographic search for red variables in three fields near the galactic centre. At the Konkoly Observatory Jankovics has started a search for faint variables in a region of Cep (22^h6^m, $+52\overset{\circ}{.}2$, 1950) using plates obtained at the 60/90/180 cm Schmidt-camera. The magnitude limit is about 19. The Auckland members of the Var. Star Section, RAS of New Zealand, are photographing with a 20″ reflector variable star fields, especially for recurrent novae.

The photographic program of Weber at Mainterne was continued until his death on 27 July 1969. His last list of new variable stars appeared in *IB*, 321, bringing up the total number of Wr variables to 188. He was one of the most successful private astronomers in our field. Beside his discoveries, he has published many interesting notes on variables of special interest.

A recent search for bright variable stars in M 31 has been made by Moffat on 52″ Tautenburgh Schmidt plates obtained by van den Bergh (*AJ*, **72**, 1356, 1967). Five new variables have been found in M 31 and two in the Galaxy in the direction of M 31. Van Agt discovered 92 variables in the UMa dwarf galaxy on plates obtained by Baade 1953–58 (*BAN*, **19**, 275, 1967).

Since 1895 till 1950 the Harvard College Observatory searched variable stars in the Magellanic Clouds, finding more than 3000 variables to which 150 were added during the investigation from 1962 performed by the Gaposhkins. They thoroughly sieved all announced variables by making more than two million photographic and more than 10000 photovisual observations on some 2000 plates. The final results on the distribution of eleven classes of variability in the two nearest galaxies are given in *IB*, 420.

7. VISUAL OBSERVATIONS

The Variable Star Section, RAS of New Zealand, directed by Bateson, has remained very active and continues to observe southern variables, especially of U Gem, T Tau, recurrent novae, R CrB, UV Cet types as well as the Mira and semiregular variables. Several groups within the Section are conducting researches into specialized fields. A list of variables under observation was published in *IB*, 236. Members of the Section now operate several photoelectric photometers thus determining accurate sequence magnitudes for comparison stars for southern variables. A report has appeared in *Southern Sky*, **23**, 47, 1969.

Acting on suggestion made by our Commission at the last IAU General Assembly, Glasby, Director of the Variable Star Section of the British Astronomical Association extended his program to include more U Gem, flare stars and T Tau variables. Mrs Mayall, Director of the American Association of Variable Star Observers, continues her monthly articles in *J. R. astr. Soc. Canada*. Members of the Variable Star Section of the Swedish Astronomical Society have made visual observations of novae, U Gem stars and long period variables. A local amateur group in Malmö, South Sweden, is also active in this field. The reports of the Variable Star Section of the Danish Astronomical Society appear in *Nord. Astr. Tidsskr.*

The late A. W. Roberts made during two decades with the year 1900 as a "mean epoch" about 75000 observations of southern variables. The observations of six stars (R Ara, U, X and 1 Car, S Mus and RS Pup) were placed at Nielsen's disposal by the Council of the Boyden Observatory where the observations are now kept. The final discussion of about 5000 observations is proceeding.

Beyer in Hamburg continues observing 16 interesting objects at 26 cm refractor. He publishes his work from time to time in *AN*. Peltier at Delphos, Ohio, with his assistant Mrs Hurless concentrated their efforts on faint variables of irregular types and on M-type stars in their faint stages, thus about 80 per cent of their total estimates range from 14th to 16th magnitudes.

At the statutory meeting of the new International Union of Amateur Astronomers (IUAA) at Bologna in Italy April 19–21, 1969, it was decided that the IUAA will mainly be concerned with variable stars.

8. RR LYRAE VARIABLES

Considerable work is directed toward the determination of the absolute magnitudes of the RR Lyr variables. It is clear that only a large-scale concerted effort on proper motions, radial velocities and accurate photometry will yield the desired increase in precision.

Clube, Jones and Evans (*Mem. RAS*, **72**, 101, 1969) presented photometric and spectroscopic data for 62 southern RR Lyr variables brighter than $B = 14$ at minimum, observed at the Cape and Radcliffe observatories. The work may be regarded as an extension to Kinman's paper (*ROB*, **37**, 1961). The immediate aims of the investigation have however been to provide sufficient data for each star to assist in population classification and to determine the statistical parallaxes for pulsating stars with periods less than one day broken down by population groups. The absolute proper motions of most of these stars have also been determined and are being published in *ROB* (Clube I *ROB*, **136**; II in press). The photometry was secured at the Cape with the 24-inch Victoria refractor at first, and then from mid 1966, with the 40-inch reflector. The spectra were obtained at the 74-inch Radcliffe reflector. For the most part they have succeeded in deriving period, brightness in three colours, mean radial velocity, spectral type from Ca II and hydrogen lines, producing an estimate of the Preston-index ΔS.

Members of the Greenwich Observatory have obtained radial velocities for a number of RR Lyr stars at Kottamia. Proper motions for over 80 southern RR Lyraes have been determined.

The Leiden Observatory is engaged in determining or improving upon proper motions of RR Lyr variables. Van Herk is entangled in an investigation of 18 RR Lyr variables based on five-colour photoelectric photometry made by van Genderen, Pel, Velthuyse and Wamsteker in 1966–68 at the Leiden Southern Station in S.A. The investigation is aimed to find a correlation between ΔS and the colours of the variables. This work is still in progress.

By summer 1970 Fitch and his collaborators should have finished the observational phase of the *UBV* photometry program on about 170 RR Lyrae field stars. Fitch hopes that new, accurate photometry combined with improved proper motion data could yield a significant improvement in the absolute magnitude calibration.

At Torun, Burnicki (*AcA*, **17**, no. 2, 1967) made a discussion of colour indices of RR Lyr stars with respect to the population type, using photographic observations made at Torun and photoelectric observations of 74 variables compiled from published data. After correcting for interstellar reddening, he found in the colour-period diagram a shift to the red by $0^m_.11$ of variables assigned to pop I, what can be accounted for by differential line-absorption. The same stars are shifted in the light amplitude-period diagram towards lower amplitude values.

At the Uttar Pradesh Observatory *UBV* observations on AC And, RZ Cep, SV Eri, SS Leo, V 986 Oph, KN Per, RU Psc have been completed by Joshi and Mahra. Observations on AE Boo are in progress. At the Skalnate Pleso Observatory, Tremko is observing W CVn, DM Cyg, TT Lyn and VY Ser. Photoelectric observations of RR Lyr variables with the 16-inch telescope of Edinburgh Observatory have been continued by M. J. Smyth and Sherwood, and some results are being made ready for publication. Stepien is going to reduce and interpret the *UBV* observations of about 30 RR Lyr stars. At the Mees Observatory, photometry of bright RR Lyr stars on the Strömgen *u*, *v*, *b*, *y* system is being pursued by Sturch to try to distinguish surface gravity and metal abundance differences. A program of 4-colour narrow-band photometry is in progress at Pretoria. Identifications and spectral types of stars used as comparison for field RR Lyr stars were published by Kim and Sturch (*PASP*, **79**, 72, 1967). Onderlička and Vetesnik of the Astronomical Institute Brno published (*Mem. Czech. AS*, **13**, 1968) 4106 observations on RR Lyr obtained 1961 Aug.–1963 July with a 24-inch telescope at $\lambda_{\text{eff}} = 4420$ Å. Epstein, Columbia University New York, obtained 4-colour (*u*, *v*, *b*, *y*) photometry at the McDonald, Kitt Peak, and Cerro Tololo Observatories, 1966–68, on 35 RR Lyrae stars (*AJ*, **74**, 1131, 1969). Hill (*PASP*, **80**, **309**, 1968) published *UBV* observations for ST CVn and VV Vir. At the Observatory Cluj (Roumania) neglected, mostly faint RR Lyr variables are being observed photographically. Todoran published his observations of SX Cnc, TX Com, and XY Eri in *Stud. Astr. Bucuresti* and is continuing the observations of the following RR Lyraes: RU, XX, WW, SV, WZ, Boo, UX, UU Cet, RT Com, AC, BE, BG, BK, UZ Eri, SW Psc.

RR Lyr stars are intensively observed at Odessa and Rostov, mostly visually. Elements of variability are regularly revised at Odessa. On the basis of these data new ephemerides are calculated and edited at Cracow (*Roczn. astr.*).

In the investigations mentioned, detailed consideration of secondary periods and period changes was mostly avoided, and have been published, what are effectively time averages for each cycle over several years. At the Konkoly Observatory, the processing of about 100000 photographic and 120000 photoelectric observations obtained since 1934 for the study of the Blashko-effect and construction of O-C diagrams should be completed in 1970 for 39 RR Lyrae stars. Szeidl has found the secondary period of 89^d for TT Cnc, and 105^d for AR Ser. He studied the variations in the Blashko-effect of RR Lyr (*Budapest*, p. 17). Kanyó has finished a photometric study of RV UMa (*Bp. Mitt.*, 63) complementing Preston and Spinrad's (*ApJ*, **147**, 1025, 1967) study of the same star. RW Dra shows 9–10 year cycles in the variation of the amplitude and period of the Blashko effect (Detre, *Wien*, *Ann.*), which are correlated with changes of the fundamental period. Similar cycles are apparent in RR Lyr and XZ Dra. Also the magnetic behaviour of RR Lyr is subjected to considerable changes, as Preston has not found a measurable magnetic field in 1963 and 1964 (*The Magnetic and Related Stars*, p. 3), whilst Babcock had observed a strong and variable magnetic field about ten years earlier. At the Observatory Cluj, the Blashko-effect in DP Aqr and WY Dra is being studied. Cesevič supposed that the effect appears due to superposition of two independent radial oscillations of the outer zones of the stars (*IB*).

The number of RR Lyr stars with known secondary period is still very small (see Table I prepared by Szeidl). A rapid increase of our knowledge of the Blashko-effect could only be achieved through a concentrated observational effort to determine secondary periods for RR Lyr stars in a few selected globular clusters containing many variables, particularly in ω Cen, M 3, M 5 and M 15. For the exact determination of O-C diagrams the availability of old plate material, especially that in the files of the Harvard and Mt. Wilson Observatories, would be very important. Robinson is now using the Harvard material for the determination of O-C diagrams of field RR Lyr stars.

479 faint RR Lyr variables were found and discussed by Plaut (*BAN Sup.*, **2**, 293, 1968) in Field 2 of the Palomar-Groningen survey at $l^{II} = 4°$, $b^{II} = +12°$ with regions of very heavy interstellar absorption. He attempted to use the material for a first determination of the space density

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Table 1. RRab-Stars with Secondary Periods

Star	P	P'	ΔS	References
RS Boo	$0^{d}377$	537^{d}	2	Oosterhoff, *BAN*, **10**, 101.
RR Gem	0·397	40:	3	Budapest, unpublished.
SW And	0·442	36·8	0	Balázs, Detre, *Bp. Mitt.*, **36.**
RW Dra	0·443	41·7	3	Balázs, Detre, *Bp. Mitt.*, **27.**
RV Cap	0·448	221·9:	6	Cesevič, *Sternberg Tr.*, **23.**
XZ Cyg	0·466	57	6	Muller, *BAN*, **12**, 11.
RV UMa	0·468	90·1	8	Preston, Spinrad, *ApJ*, **147**, 1025; Kanyó, *Bp. Mitt.*, **63.**
AR Her	0·470	31·6	6	Almár, *Bp. Mitt.* **51.**
XZ Dra	0·476	77	3	Balázs, Detre, *AN*, **271**, 231.
X Ret	0·492	45:	–	Hoffmeister, *Ver. Sonn.*, **5**, 3, 1.
V 674 Cen	0·494	29·5	–	Hoffmeister, *Ver. Sonn.*, **5**, 3, 1.
RZ Lyr	0·511	116·7	9	Romanov, *IB*, 205.
V 434 Her	0·514	26·1	–	Rozovsky, *PZ*, **15**, 211.
Y LMi	0·524	33·4	–	Martynov, *Eng. B.*, **18.**
V 30 in M 53	0·535	37·0	–	Wachmann, *Hamburg Abh.*, **8**, 114.
UV Oct	0·543	80:	–	Hoffmeister, *Ver. Sonn.*, **5**, 3, 1.
RW Cnc	0·547	29·9	–	Balázs, Detre, *Bp. Mitt.*, **23.**
TT Cnc	0·563	89	7	Szeidl, *IB*, 278.
RR Lyr	0·567	40·8	6	Preston, Smak, Paczynski, *ApJ Sup.*, **12**, 99.
AR Ser	0·575	105	8	Szeidl, *IB*, 220.
DL Her	0·592	33·6	–	Szeidl, *IB*, 36.
V 365 Her	0·613	40·6	–	Cesevič, *AZ*, **38**, 293.
AT And	0·617	82·7	3	Tchumak, *PZ*, **15**, 569.
Z CVn	0·654	22·7	8	Kanyó, *IB*, 146.

The stars are arranged according to the length of the fundamental period. In RR Gem the Blashko-effect ceased to exist since about 1940, and the same happened in SW And around 1956. Probably all RRc stars have, at least temporarily, secondary periods, but their length has so far been determined only for three: TV Boo, $P = 0^{d}313$, $P' = 31^{d}2$ (Detre, *Festschrift f. C. Hoffmeister*), RU Psc, $P = 0^{d}390$, $P' = 28^{d}8$ (Tremko, *Bp. Mitt.*, **55**), and V 68 in M 3, $P = 0^{d}356$, $P' = 10^{d}9$: (Szeidl, *Bp. Mitt.*, **58**, p. 74). The secondary periods are still unknown for DP Aqr, WY Dra, SZ Hyd, CZ Lac, BB Pup, V 703 Sco, AT Ser, all showing strong light curve variations.

of these stars adopting a mean absolute photographic magnitude $\langle M_{pg} \rangle = +1{\cdot}0$ and making use of Hidajat's extensive discussion (Cleveland thesis, 1965) of the interstellar absorption in this region.

An RR Lyr variable projected on the Andromeda Nebula was found by Moffat and van den Berg (*Zf. Ap.* **67**, 246, 1967) on plates obtained with the Tautenburg Schmidt telescope. Its distance is ~ 19 kpc. HD 176387 was shown by Przybylsky (*MN*, **136**, 185, 1967) to be a metal poor RRc star with retrograde orbit.

Rosino and Capelli (*Padova Publ.*, no. 144, 1968) have investigated the statistical properties of galactic RR Lyr stars from the point of view of the frequency distribution of periods and amplitudes, comparing them with the RR Lyraes of globular clusters. It has been confirmed that an important group of RR Lyraes of low galactic latitude have periods distributed around $0^{d}45$. No counterpart of this group exists in the globular clusters of the Milky Way.

9. POPULATION I CEPHEIDS

The theoretical prediction of the cepheid instability strip near its low temperature boundary is complicated by the onset of convection, which dominates the heat transport in the surface layers that are responsible for the instability. Sandage and Tammann (*ApJ*, **155**, 531, 1969) approached the problem in an empirical manner. Using the observational data for the cepheids in galactic clusters, in the LMC and SMC, and in M 31 and NGC 6822, they constructed the ridgeline *P-L* relation (see Appendix II). The dispersion of the individual stars about this line is enclosed by parallel envelopes displaced by $\pm 0{\cdot}6$ magnitude. It seems certain that the known cepheids of pop I all lie in the instability strip (see Eggen's discussion in *Intrinsic Variable Stars, Sigma Reviews*), however, the question is outstanding, whether or not all stars in the instability strip are variable. Fernie has completed a program looking for low-amplitude pulsation in stars which have spectral types like those of cepheids. 49 supergiant having MK classification between F5Ib and G5Ib and not previously known to be variable have been monitored photoelectrically. Preliminary indications are that no more than two or three of these are variable by more than about 0·02 magnitude.

It is of considerable interest from the standpoint of the *P-L* relation to find classical cepheids of particularly short or long period which might have main-sequence companion associated with them, because there exist almost no direct sources of information on the luminosities of cepheids with periods less than 3^d or longer than 15^d. The distance of SU Cas ($P = 1\overset{d}{.}9$) has now been determined by Racine at Mt. Wilson using nearby field stars that, like the variable, are seen to illuminate reflection nebulae, and are presumably connected with the same dust cloud. Its absolute magnitude was found to be $\langle M_V \rangle - 2{\cdot}45 \pm 0{\cdot}2$ mag, in good agreement with predictions based on modern calibration of the *P-L* relation. Fernie has determined the absolute magnitude of l Car (*AJ*, **72**, 1327, 1967; $P = 35\overset{d}{.}6$), and Sandage and Tammann obtained separate light curves in two colours for the companions of CE Cas. 13 cepheids in the period-interval $1\overset{d}{.}95 - 41^d$ are now available, and they have rediscussed the *P-L-C* relation using the new data (see Appendix II).

Several authors have anew derived the *P-L* relation for cepheids in the Magellanic Clouds. In spite of the efforts of the past decade there is still no general agreement on some of the fundamental questions including the form of the *P-L* and *P*-colour relations in the two Clouds, and whether these relations differ from Cloud to Cloud or between the Clouds and the Galaxy. It is clear they cannot be answered without more accurate data for the shorter-period cepheids. To obtain such data, Gascoigne observed at Mt. Stromlo *B*, *V* light curves for 13 SMC and 7 LMC cepheids with periods in the range 1·24 to 6·69 d. (*MN*, **146**, 1, 1969). The following *P-L* and *P-C* relations were found

LMC $\langle V \rangle = 17{\cdot}58 - 3{\cdot}072 \log P$, $\langle B \rangle - \langle V \rangle = 0{\cdot}49 + 0{\cdot}191 \log P$
SMC $\langle V \rangle = 17{\cdot}73 - 2{\cdot}879 \log P$, $\langle B \rangle - \langle V \rangle = 0{\cdot}26 + 0{\cdot}306 \log P$

Wright and Hodge (*ApJ Sup.*, **17**, 467, 1968) used ADH Schmidt and Harvard Bruce plates for a section of the LMC. Work is nearing completion for a similar study, in the same region of 21 more variables, ten of which were recently discovered. Van Genderen (*BAN Sup.*, **3**, 221, 1969) finished his major work on two-colour photographic photometry of 105 cepheids near the centre of the SMC, based on plates taken by Arp. The variables appeared to fit well into the instability-gaps of the young SMC clusters NGC330 and NGC458. In a further comparative study between the Pop I cepheids of both the Magellanic Clouds, the Galaxy and the Andromeda Nebula, van Genderen (*BAN Sup.*, **3**, 299, 1969) found indications that the cepheids of the two Magellanic Clouds are more luminous than the galactic ones and those of M31. In another investigation based on five-colour photoelectric observations of 12 SMC cepheids he (*BAN*, **20**, 317, 1969) found that the intrinsic colours of these cepheids were bluer than those of the Galactic cepheids. He suggested that metal deficiency might be the cause (see also Christy, *ESO*).

Feinstein and Murzio (*AA*, **3**, 388, 1969) discussed the light curve of the brightest cepheid, l Car, from 178 photoelectric observations distributed over a 17 year interval. Beside the main period of $35\overset{d}{.}5330$ periodicities of $190\overset{d}{.}1$ and $29\overset{d}{.}92$ were found, both with an amplitude of $\sim 0\overset{m}{.}02$ in *V*. The main period shows no evolutionary change. Light curves in blue have been obtained at Kottamia (*ROB*, 15).

Eggen (*ApJ*, **156**, 617, 1969) obtained *UBV* photoelectric photometry of 18 cepheids in Cyg and 10 in Mon with the 200″, 100″ and 60″ Palomar-Mt. Wilson and 40″ Siding Spring telescopes. Takasa carried out *UBV* photoelectric photometry for 29 cepheids during 1965–68 with the Okayama Observatory's 91-cm reflector (*Tokyo Bull. II. ser.*, 191, 1969). Mavridis and Tsiomis started a new series of photoelectric three-colour observations of the 18 cepheids observed in 1955–58 at Heidelberg by Bahner and Mavridis. The aim of these observations, carried out with the 38-cm reflector of Stefanion Astronomical Station in Greece, is to get complete and accurate new light and colour curves for these stars. Abaffy at Konkoly Observatory observed in 1967 about 40 cepheids in *UBV*. Detre (*Wien Ann.*) used these observations together with those obtained by him in 1953–54 for a study of period changes. No evolutionary changes were found. Butenko investigated period variations of about 100 cepheids. Makarenko studied cepheids with small amplitude, and determined colour excess for 204 cepheids from *UBV* data. Nielsen at Aarhus is processing with the photoelectric *BV* observations of about ten mostly bright cepheids.

On the basis of his catalogue of light and colour curves, Nikolov derived the principal photometric characteristics of the light curves and colours of about 300 cepheids (*PZ*, **16**, 312, 1968). During 1969 the Department of Astronomy at the University of Sofia came to an agreement for cooperation with the Sternberg Institute for investigation of the morphological, spatial and evolutionary characteristics of cepheids. Nikolov and Kunchev discussed the *U-B* versus *B-V* diagrams (*Aph. Sp. Sc.*, **46**, 3; *Budapest*, p. 481, 1969). They attempted to obtain more precisely the reddening lines of cepheids using values of *U-B* and *B-V* for cepheids at maximum (*ApL*, **1**, 151, 1968).

Pel, Velthuyse and Wamsteker made five-colour photoelectric observations of BK Cen and QT CrA during their stay at the Leiden Southern Station in S.A. The reductions are still in progress.

For the determination of the absolute magnitude of Polaris new *B*, *V*, *B-Y*, *C*, *m* and Hβ photometry of αUMiB have been obtained by McNamara (*AJ*, **73**, S 106, 1968), carefully excluding the light of Polaris (αUMiA) in the measurements. If *A* and *B* form a physical system, the absolute magnitude of Polaris is $M_v = -3{\cdot}7$, a value somewhat brighter than predicted by the *P-L* relation. At Georgetown College Observatory, Kessler is starting observations on several cepheids in *B*, *V*, Hα and Hβ with a new photometer.

Wisniewski and Johnson (*Comm. Lunar Planet. Lab.*, **112**, 1968) have made multicolour photoelectric observations on the *UBVRIJKL* system for 20 cepheids. The data are sufficient to define light curves. These exhibit the well-known shift of phase with wavelength. The combination of the data with the known radial velocity curves makes possible the computation of the absolute magnitude for each of these cepheids entirely empirically which does not depend upon stellar model computations. Eggen is making *UBVRI* photometry of cepheids at Mt. Stromlo in both the disk and halo population.

A critical study on Wesselink's method for determining radii of pulsating stars was published by Fernie and Hube (*PASP*, **79**, 95, 1967). On the basis of a *P-R* relation obtained from radii determined for 15 cepheids by this method, it is suggested by Fernie (*ApJ*, **151**, 197, 1968) that η Aql, W Sgr, β Dor and X Cyg are pulsating in the first overtone, and that U Car may be pulsating in the third overtone (*ApJ*, **151**, 197, 1968). Opolski points out that new observations of radial velocities combined with simultaneous *UBV* photometric data would be very valuable. This problem needs international cooperation.

Fitch extended Schwarzschild's standard model computations to the first six radial pulsation modes of a set of polytropes. Comparison of these theoretical calculations with published results on the cepheids showing two excited radial pulsation modes has led to the result that all are pulsating simultaneously in both fundamental and first overtone mode.

Christy has completed a study of pulsation in cepheid type models. The most useful general results of his study are as follows:

(a) The general cepheid type instability strip can be most simply outlined in a log Period log T_e diagram independent of the Mass-Luminosity Relation. The blue boundary, including dependence on the mass fraction of Helium, *Y*, is approximately given by $\log T_e\,(\text{blue}) = 3{\cdot}797 + 0{\cdot}1\,Y - 0{\cdot}057 \log P_{\text{Fund}}$ and an estimate of the red boundary is $\log T_e(\text{red}) = \log T_e(\text{blue}) - 0{\cdot}06$.

(b) The pulsation calculations show that the light curve structure associated with the Hertzsprung progression is caused by a compression wave originating near the surface at the time of minimum radius and travelling to the center of *the star and out again*, arriving again at the surface some $1{\cdot}1 - 1{\cdot}5$ periods later. The travel time of this wave is proportional to the stellar radius and

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the appearance of the reflected wave can be used to determine the (mean) radius of certain variable stars where it is found (*Qu. J. RAS*, **9**, 13, 1968).

(c) For such stars (of period near 10 days) the radius, so determined, leads also to a mass determination, and, if the mean T_e is available, also to a mean luminosity determination and to a distance determination. This procedure should be quite useful when it has been appropriately calibrated.

Millis (*Lowell Bull.*, **148**, 1969) called attention to a cepheid with a period of 3·335 d and $A_v = 0{\cdot}16$. The abnormal small amplitude is explained by the fact that it has a close companion of similar brightness. Since the first micrometer measurement in 1886, the separation of the two components has diminished from 0″.3 to 0″.1. This system may offer the opportunity for the direct determination of the mass of a supergiant.

Radial velocities of cepheids have been obtained at Kottamia (*ROB*, 114). Feast determined velocity curves for some distant cepheids near $l^{II} = 290°$ (*MN*, **136**, 141, 1967, *Radcliffe Com.*, 94). Crampton of Victoria has discussed with Fernie a new determination of Oort's constant *A* from cepheids.

At Harvard Observatory, the Gaposhkins have catalogued 1155 cepheids in the SMC and 1111 in the LMC. They have also determined light curves for many of these stars. The number of known cepheids per square kiloparsec is about four times greater in the SMC than in the Large. With this increased material, previously suspected differences between the cepheids in the two Clouds have been confirmed. For instance the SMC contains an unusually high percentage of short-period cepheids. In the *P-A* relation, SMC cepheids with $P < 10^d$ have the largest amplitudes, while those in the LMC have the smallest. At the longest periods, however, cepheids in our own galaxy have the largest amplitudes, those in the SMC the smallest.

10. POPULATION II CEPHEIDS AND RV TAURI VARIABLES

The photometric study of RU Cam by Szeidl during 1967–69 on over 600 nights shows that the same star can in rapid succession change the character of its light variation from W Vir to RV Tau type, even becoming sometimes semiregular or completely irregular. Eggen also points out that the distinction between the long-period cepheids of the halo and old disk population and the RV Tau stars is obscure (*Sigma Reviews*).

Similar to RU Cam is V 725 Sgr. The peculiar behaviour of this object was first announced in 1936 by Swope. From 1889 to 1926 the star showed only slight, very gradual change around magnitude 13 on Harvard plates. But then the star began varying like a cepheid, with a period that lengthened steadily from 14 days in 1928 to 21 days in 1935. Meanwhile, the amplitude of the variable was diminishing while the average magnitude stayed near 13·2. No observations of the star have been published since 1935. Unpublished data indicated little or no periodic variations in 1959 (Plaut) and in 1960 (A. T. Young). In 1968 Demers began photoelectric measurements of the object on Cerro Tololo. The star was variable with a period of $15^d.5$ and an amplitude of only about $0^m.2$. The light curve changes from cycle to cycle. The average *V* magnitude is 12·55 and the average *B-V* colour index 1·35. An image-tube spectrum at the dispersion 100 Å/mm revealed a G 5 spectrum with giant or supergiant characteristics (*BAAS*, **1**, 185, 1969).

Kwee's work on galactic population II cepheids, based on *UBV* observations made at the McDonald Observatory in 1963, have been finished and published in a series of four papers (*BAN Sup.*, **2**, 77 and 97, 1967; *BAN*, **19**, 260, 1967; 374, 1968). It was shown that pop II cepheids can have changes in the period amounting to the order of 0·4% of the period. The stars with periods between 13 and 20 days can be divided into two groups with different shape of the light curve, and when data on cepheids found in globular clusters are considered, both groups have different ages and metal contents. In order to extend this investigation to more pop II cepheids, during the years 1967 and 1968, Pel, Velthuyse and Wamsteker have made five-colour photoelectric observations of 27 more variables at the Leiden Southern Station. The reduction of these new data is still in progress.

Woolley pointed out that W Vir stars have not got high velocities relative to the sun characteristic

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of halo objects. But the fact that some variables with periods > 1ᵈ.0 occur in globular clusters suggests that there ought to be some stars with periods > 1ᵈ.0 occurring free in the galactic system, and having the kinematic properties of the RR Lyr stars. Attention has been given at Greenwich Observatory to searching for such stars by collecting radial velocities of suitable candidates. At Mt. Wilson and Kottamia, Woolley and Palmer obtained velocities for seven W Vir stars. Three stars, FM Del, UY Eri and V 716 Oph are really fast moving objects and in this way kinematically halo objects. All three have periods less than 2ᵈ.5 and seem to be an extension of the RR Lyr stars beyond the conventional limit of a period of 1ᵈ.0. There are now 13 variables known to have periods around 1 or 2 days in 5 dwarf galaxies (Swope, *AJ*, **73**, S205, 1968). They are however from 0·4 to 0·8 mag brighter than the usual member variables of the RR Lyr type variables found in Leo II and in van Agt's UMi system. In addition to the meridian observations at Cape and Greenwich Observatories astrometric proper motion for 167 semiregular and RV Tau variables are being determined from plates taken with the astrographic telescope. Only stars which are brighter than $m_{pg} = 11$ at maximum are being measured. First epoch plates for 18 stars in the Vatican zone have been lent by O'Connell. Blackwell and Lowne (*ROB*, 142) published the proper motion of 182 semiregular and RV Tau variables on the system of the FK4. At the Leiden Observatory van Herk is engaged in determining or improving upon proper motions of RV Tauri variables.

Serkowski is continuing his polarimetric observations of RV Tau stars. The position angle of the intrinsic polarization for the RV Tau star U Mon remains close to 0° around and before the deep light minima and close to 105° around and before the shallow light minima occurring half-way between the deep minima. This suggests the non-spherical oscillations of the star. The position angle changes abruptly at the time when the doubling of the spectral lines is observed about 14 days after each light minimum. The changes in polarization of another RV Tau star R Sct are less regular than those for U Mon. For both stars the amount of intrinsic polarization is reaching the largest values in the ultraviolet spectral region during the light minima (*ApJ*).

At Sonneberg, Huth (*MVS*, **4**, no. 7, 1968) studied the period changes of the pop II cepheid CC Lyr. In Hodge and Wright's work (*ApJ Sup.*, 153) on LMC variables two W Vir variables are included, each with changing period and each subluminous for its period in comparison with the classical cepheids. At Dushanbe, Erleksova found that the character of period variations of RV Tau stars is similar to that of W Vir stars.

11. LONGPERIOD AND SEMIREGULAR VARIABLES OF BOTH POPULATIONS

About Eggen's efforts for obtaining population discriminants see Section 4. About spectroscopic observations see Appendix I.

At the Warner and Swasey Observatory, a detailed paper on spectral variations of 121 faint long-period variables is in preparation (*AJ*, **73**, 518, 1968). Houk plans to extend her studies on magnitude variability of giant M stars (*AJ*, **73**, S99, 1968) above 3 additional Palomar-Groningen Fields. This will be carried out at the Kapteyn Laboratory, Groningen, between February and September 1970, in collaboration with Plaut. The research on spectral changes in 51 variable stars and correlations with corresponding light changes was reported by Terrill (*AJ*, **74**, 413, 1969). These stars are of Mira type, semiregular and irregular variables. 19 are S stars, 31 are M stars, and R CMi is a weak carbon star.

Nancy Evans (Thesis) observed 48 Mira stars in *UBV* at maximum light at the David Dunlap Observatory. She found both $(B\text{-}V)_0$ and $(U\text{-}B)_0$ bluer at maximum than would be expected for stars of spectral type M. Students working under van den Bergh's direction are continuing *UBV* photometry of Mira stars near maximum light. Barnes is carrying out an extensive program of near infrared (*V*, *R*, *I*) photometry of Mira stars. Electrophotometry of red variables in the region 3800–11 000 Å is carried out at Odessa. The program of *UBV* measurements of various long-period variables has been continued by Landolt at Kitt Peak and Cerro Tololo (*PASP*, **78**, 531, 1966; **79**, 336, 1967; **80**, 228, 450 and 680, 1968; **81**, 134, 1969). Smak observed 11 S-type and 11 C-type stars in *UBV* (*AcA*, **18**, 317, 1968). Szeidl observes UZ Aur and VZ Cam in UBV. At Riga, Alksnis and Alksna observe *UBVR* magnitudes of carbon stars, Kiselev and Kiseleva record fast brightness variations in long-period variables at Dushanbe (*AC*, **436**, 1967). Mendoza presented multicolour data in *U, B, V, R, H, I, J, K* for a number of long-period variables (*Tonantz. Bol.*, **28**, 1967). These data can be used to separate carbon stars and M and S unreddened stars. At Cape, photographic curves in B are being obtained for W Cam, U CVn, ME Cep, UZ Gem, WX Her, and VX UMa, all having unknown minima. The regular visual observations of long-period and irregular variables has been continued.

Eggen is making *UBV* and narrow band (**102**, **65**, **62**) photometry of red variables in both the disk and halo populations. Approximately 50% of the HD stars of type M are variable. Most of these stars are old disk objects. Light variations with amplitude greater than $0\overset{m}{.}05$ have been found in 78 bright, M-type stars. The boundary of the red instability region in the (M_B, T_e) plane is near the temperature represented by (**102**, **65**) $= -0\overset{m}{.}6$ for disk population stars (*IB*, 355).

Price (*AJ*, **73**, S32, 1968) reported on a survey of the southern sky in the $2{\cdot}2\mu$ region. Approximately 50% of the area between $-30°$ and $-52°$ has been covered to a sensitivity of about $1{\cdot}5 \times 10^{-15}$ W cm^{-2} μ^{-1}. 57 late-type variable stars were detected or suspected. There seems to be a trend that for Miras and semiregular variables the longer the period, the greater the $m_v - m_{2.2\mu}$ index for a given spectral type. BM Sco is anomalous, the infrared irradiance from it is too large by a factor of 10 for its listed spectral type.

Light variations in the Taurus infrared object were found by Cannon (*Obs.*, **86**, 150, 1966; **87**, 231, 1967) and Wing, Spinrad and Kuhi (*ApJ*, **147**, 117, 1967). Assuming that the Taurus object is also a Mira variable, continued observations at the Greenwich Observatory show that the only regular period which could fit their observations in the *V* region is $390^d \pm 5^d$.

A large number of Mira and semiregular variables have been found to exhibit time dependent polarization discovered by Serkowski (Shakhovskoy at Crimea, *Krym. Izv.*, **39**, 11, 1968: Vardanian at Byurakan, *Budapest*, p. 33; Zappala, *ApJ*, **148**, L81, *AJ*, **72**, 838, 1967; Kruszewski *et al.*, *AJ*, **73**, 677; Dyck, *AJ*, **73**, 688, 1968). The polarization rises steeply into the ultraviolet, attaining in some cases 8% or more. Both the degree of polarization and the position angle usually show large variations with time, together with the wavelength dependence of the polarization. The absorption by graphite platelets can work in carbon stars but it cannot explain the generally large polarization in M-type stars. Some authors considered silicate grains which have a higher emissivity than graphite in the far infrared (Gilman, *ApJ*, **155**, L185; Knacke, Gaustad, Gillett and Stein, *ibid.*, L189, 1969).

A rediscussion of the absolute magnitudes of Mira variables derived from statistical parallaxes has been completed by Clayton and Feast. The results agree satisfactorily with absolute magnitudes derived from membership of Miras in clusters and double stars. Feast has concluded that the distance of far-off Miras have been underestimated, and that some of those he observed towards the galactic centre actually lie near the galactic nucleus. Further work is planned on stars in this region.

The lack of population discriminants complicates the interpretation of the observed motions, particularly the shapes of velocity ellipsoids and the dependence of the solar velocity on *z* for the Miras. At present, the only parameter that can be used to subdivide the Miras is the period of light variation. Clearly, there can be no definitive discussion of the kinematical properties of the Miras until some reliable photometric or spectroscopic population discriminant is found. Radial velocities of semiregular variables have been obtained at Kottamia (*ROB*, 114). At the Leiden Observatory van Herk is engaged in determining proper motions of long-period variables.

Ahnert discussed the correlations between the irregularities of the period and radial velocity, length of period, amplitude and spectrum of Mira variables (*Budapest*, p. 325), Fischer (*ibid.*, 331, *Wien Ann.*) has collected and studied the whole material on the light-changes of Mira Ceti. Feuchter (*AJ*, **72**, 702, 1967) supplemented Harrington's (*AJ*, **70**, 569, 1965) statistical studies.

12. BETA CANIS MAJORIS STARS AND OTHER EARLY-TYPE VARIABLES

Percy has given (*Can. JRAS*, **61**, 117, 1967) a review of the observational problems of the βCMa stars. A great advance in this area was Hill's extensive photoelectric search for βCMa stars among a sample of 153 early B stars in the nearest associations and galactic clusters which yielded 24 new βCMa stars. These new observations have extended considerably the limits of spectral type, luminosity class, absolute magnitude, period, and rotational velocity for these variables. The limits now become O9·5 – B3 (sp. type), V-I (luminosity class), $3^h - 10^h$ (period) V, 0–300 km(s /rotational velocity) (*ApJ Sup.*, **14**, 263, 1967).

At Steward Observatory, Fitch is beginning feasibility tests for observations of accurate line profiles and velocities of selected βCMa stars, using the new coudé spectrograph and image tube camera on the 36-inch telescope. He hopes to obtain a fairly complete record of variations in profiles and velocities during individual pulsation cycles and through the course of the long period variation, for one or two bright βCMa stars which display pronounced double periodicities. He intends to make simultaneous photometric measures using the 21-inch telescope.

At Uttar Pradesh Observatory, Bondal made (*Obs.*, **87**, 220, 1967) a photoelectric study of 53 Ari. Shapes of the maxima and minima on different nights vary appreciably. Joshi has found a beat period of 17ᵈ1 for KP Per. Observations on 25 Sex, 16 Lac and BW Vul are being analyzed by Mahra and Joshi. *UBV* photometry of γ Peg was obtained by Jerzykiewicz at the Lowell Observatory (*IB*, 382). At Radcliffe Observatory Breger has re-observed τ Lup and has found evidence that β Cen may belong to the β CMa stars (*MN*, **136**, 51, 1967). Shobbrock and Robertson obtained from radial velocity measures a period of 0ᵈ1348 (*Proc. AS Austr.*, **1**, 82, 1968).

Leung (*ApJ*, **150**, 223, 1967) using visual absolute magnitudes from spectroscopic H γ equivalent widths of 17 β CMa stars derived a period-luminosity and a period-colour-luminosity relation. The latter leads to the existence of a set of linear equal period-contours across the instability strip in the HRD. The same problem was treated by McNamara and Matthews (*Mod. Astrophys.*, **127**, 1967) based on measurements of the β index and equivalent widths of the Hγ and Hδ lines.

Van Hoof has given a review (*ZfAp*, **68**, 156, 1968) of all the radial velocity and photometric observations of δ Cet since the beginning of the century, and made new photoelectric observations at Boyden. The period 0ᵈ1611366 remained constant over the whole time interval considered. Briers finds for the beat period in θ Oph 3ᵈ9 instead of that found by van Hoof (6ᵈ). At the University of Western Ontario, Gray is observing β Cep. Additional light curves have been obtained to study the period. The intensive photoelectric observations of a few southern β CMa stars (σ Sco, θ Oph, α Lup, HD53435 and HD53974) has been continued both at the Boyden and ESO observatories. The periods proposed for the latter two by Hill have been found to be erroneous (van Hoof). An extensive search for new β CMa stars among fainter early B-type stars is planned. Shobbrook *et al.* at the Siding Spring Observatory have shown that the primary of the binary system α Vir is a β CMa variable. The light shows a 4ᵈ17036 period of amplitude 1·6%, in addition, there is a 3% variation over the 4ᵈ014 orbital period, which can be accounted for by aspect changes of the tidally distorted primary (*MN*, **145**, 131, 1969).

Fitch, extending his study of σ Sco (*ApJ*, **148**, 481, 1967) reported (*Budapest*, p. 287) 16 Lac to have three excited pulsation modes, the third being excited by the primary mode through a tidal resonance at ¼ the orbital period. Fitch believes that the primary mode is the nearly radial fundamental pulsation mode and the secondary mode is the nearly axisymmetric S-mode discussed by Chandrasekhar and Lebovitz. All three modes have velocity-to-light amplitude ratios which differ significantly from each other. Fitch also has performed an analysis of the velocity measures on β Cep, and found the star is apparently a single-line spectroscopic binary with an orbital period near 10ᵈ9 and orbital eccentricity of about 0·5. The adopted elements show that the primary pulsation (P = 0ᵈ19049) undergoes a strong, non-resonant amplitude modulation around the time of periastron passage, with maximum amplitude probably occurring at maximum apparent tidal compression and minimum amplitude at maximum apparent tidal expansion (*ApJ*, **158**, 269, 1969). Theoretical work on non-radial oscillations is being carried out by Smeyers at Leuven.

Slettebak has given a thorough review of the problems of Of and Be stars (*Budapest*, p. 179). Mass loss from stars in general was reviewed by Deutsch (*Trieste*, 1969, p. 1) and for WR stars by Underhill (*ibid*, p. 17). Rocket observations of mass loss from hot stars was discussed by Morton (*ibid*, p. 36).

A study of the shell star 48 Lib in the period 1950–62 was published by Faraggiana (*AA*, **2**, 162, 1969). The observed radial velocity curves suggest that an eruption took place in the star and material from the shell is now moving outwards. The radial velocity fluctuations are probably the result of an eruptive force and the deceleration due to gravity. Radial velocities of o And were studied by Galeotti and Pasinetti (*Contr. Milano-Merate*, 300, 1968) and Pasinetti (*ibid.*, 276), those of ζ Tau by Hack and Steiner (*MAI*, **40**, 87, 1969).

Mayall has published a light-curve for AG Cas, 1940–69, a star with a spectrum similar to P Cyg (*Can JRAS*, **63**, 221, 1964). Brodokoja carried out three colour observations for EW Lac (*PZ*, **16**, 423, 1968), AB Aur, XX Oph, X Per and MWC 374 (*ibid.*, 435). *UBV* observations of P Cyg by Fernie (*PASP*, **81**, 168, 1968) revealed no short-period variability. Feinstein at La Plata obtained from 1967 to 1969 new observations in *UBVRI* of all Be stars published in *ZfA*, **68**, 29, 1968. Wallerstein made a search for rapid light variations in WR stars (*PASP*, **80**, 483, 1968), as these have been suggested as possible X-ray sources (Bless *et al.*, *ApJ*, **151**, 2117; Wallerstein, *ibid.*, 1421, 1968). For no star were any variations noted that were greater than the limit set by the noise. But there is irregular variability in these stars in their emission-line intensities (Kuhi, *PASP*, **79**, 57, 1966). Mendoza confirmed that Of and Be stars exhibit infrared excesses (*Cerro Galan Publ.*, 7, 106, 1969). The main cause of these excesses could be the presence of stellar shells.

Polarimetric observations were made for 40 Be and shell stars by Serkowski (*ApJ*). About half of these stars show evidence of intrinsic polarization, in most cases changing with time. Kruszewski *et al.* explained the observed wavelength-dependence of the polarization by scattering from electrons in an asymmetrical envelope together with self-absorption in a hydrogen plasma.

13. MAGNETIC VARIABLES

A great activity was displayed in spectral (see Report of Commission 29) and photometric observations and theoretical studies of magnetic variables, but little is being done in measurements of stellar magnetic fields. This important subject was widely reviewed and found ample attention in the books *The Magnetic and Related Stars* (Ed. R. C. Cameron, Mono Book Corp.) and *Magnetism and the Cosmos* (Ed. Hindmarsh *et al.*, Oliver and Boyd, Section II).

On the theoretical side, the oblique rotator hypothesis seems to come to the front with the model developed by Böhm-Vitense (*Mod. Astrophys.*, 97). She found great inclinations between the magnetic and rotation axes. Preston has demonstrated in a statistical study (*ApJ*, **150**, 547, 1967) that approximate orthogonality of the rotation axis and the hypothetical magnetic axis is a general characteristic of the periodic magnetic stars, if they are treated as oblique rotators. It may be necessary to modify the interpretation if the stellar magnetic fields are not dipolar. Anharmonic variation in HD 125 248 is according to Preston due to the location of two regions of opposite polarity, both near the rotational equator, but separated by considerably less than 180° of longitude. Neither is the magnetic field of HD215 441 dipolar (Preston, *ApJ*, **156**, 967, 1969). Mester (*Magnetic and Related Stars* p. 101) pointed out that a spheroidal star with axis of symmetry inclined to the axis of rotation might result from an internal poloidal magnetic field, that can exhibit a light variation due to the variation of the area of the disk projected on the line of sight. In a discussion of the variability of HD 19 216 (*ApJ*, **156**, 1175, 1969) Preston suggests that this may be the origin of at least a component of the light variation. Kodaira (*Tokyo Ann. II, ser. X*, no. 4, 1967) finds in a spectroscopic study of HD 221 568 inconsistency with the oblique rotator hypothesis.

S. C. Wolff measured magnetic field variations in HR 7575 at Lick Observatory. She found that the amplitude of the magnetic variations derived from measurements of lines of Mn, Gd and Ca were decidedly smaller than the magnetic amplitudes derived from lines of Cr, Eu, Ti and Ce. These groups of elements must, therefore, exist in different location on the stellar surface having different magnetic field intensities (*ApJ*, **158**, 1969).

Preston's Zeeman spectrograms of HD215441 give evidence for a periodic variability of its large magnetic field in concordance with the $9^{d}.5$ photometric period (*ApJ*, **156**, 967, 1969). He is using Zeeman doublets to study the large (~ 15 kpc) magnetic field of HD126515. Both the mean surface field and the effective field of this star appear to vary smoothly in a period of 130^d.

At Oxford, Hockey finished off his work on HD125148 (*MN*, **142**, 453). The measurements and reductions of the Lick spectra of HD153882 are now completed, and are being used to test magnetic rotator models. Pyper has made study of the spectrum, radial velocity, magnetic and *UBV* variations of α^2 CVn at Lick, and found that the magnetic configuration is represented by a combination of dipole and quadrupole fields. Preston and Stepien discussed the light, magnetic, and radial velocity variations of HD10783 (*ApJ*, **154**, 971, 1968). Preston at Mt. Wilson is obtaining rotational velocities from coudé spectrograms of all known Ap stars brighter than the 9th magnitude and north of $\delta = -40°$.

In virtually every case if enough data are obtained, it is possible to find periods. A period of $3^d.7220$ has been established for 78 Vir by Preston (*Astrophys. J.* **158**, 243, 1969). He, Stepien and Wolff have derived $P = 5^d.08$ for 17 Com A. A provisional $P = 5^d.00$ was obtained for κ Cnc (*ApJ.* **156**, 652, 1969). Preston has found that the radial velocities and line intensities in the spectrum of 21 Per vary periodically in the $2^d.88$ photometric period derived by Stepien (*Astrophys. J.* **158**, 251, 1969). Steinitz and Pyper obtained for 3 Hya $P = 4^d.606$ (*IB*, 413) from Babcock's measurements. Stepien obtained for HD 19216 $P = 7^d.7$, Wolff (*ApJ*, **158**, 1969) for HR 7575 $P = 224^d.5$, showing that the phenomena of magnetic variability is not confined to periods of the order of a few days. Berg improved the period of 73 Dra to $20^d.2755$ (*Leander McC Publ.*, **15**, Part IV, 1967). Gökkaya found $P = 6^d.143$ for HD 151199 (*Astrophys. Space Sci.* **6**, 141, 1969).

Random fluctuations seem to be superimposed on periodic variations that will have to be explained by some irregular distortions of the lines of force possible due to some activity (see Bonsack, *AJ*, **72**, 876). This theme was reviewed by Jarzebowski (*Budapest*, p. 227).

Finzi and Wolf suggested a model (*ApJ*, **153**, 865, 1968) that may help to explain the random fluctuations as well as peculiar chemical composition and slow rotation velocities. According to them the fields are produced in the convective cores of these stars and they suggest a mechanism by which magnetic energy could be carried from the core to the surface.

Abt called attention (*PASP*, **80**, 637, 1968) to the fact that periods are more easily obtained from spectral variations, even with moderate dispersion, than from the small light variations or by the difficult field measurements. In this way, Guderley succeeded in deriving a period of $2^d.156$ for the magnetic variable HR234 (*PASP*, **79**, 588, 1967).

Rakos has obtained extensive series of photoelectric observations of four magnetic variables, HD25823, 32633, 71866 and 65339 at Lowell Observatory during 1968. The length of the period of HD65339 seems to change periodically within a time interval of $1^y.8$. Similar change in the period ($2^y.7$) is indicated for HD215441. Three other stars, HD32633, 224801 and 71866 also show definite changes in the period (*AJ*, **73**, 114, 1968). Cester at the Trieste Observatory initiated a long range program on Ap and Am stars in *UBV*. Catania Observatory is continuing *UBV* observations of magnetic variables (*Budapest*, p. 243, *MAI*, **39**, 579, 1968). A photometric study of magnetic stars has been carried out at Lick Observatory (Stepien) concurrently with spectroscopic observations (Preston). The obtained *V* curves are in phase as well as in antiphase with the magnetic curve. The $B-V$ and $U-B$ curves present a variety of phase dependence relative to *V*-curves (*AJ*, **73**, S36; *ApJ*, **151**, 577, 583, 1968; **153**, 165; **154**, 945 and 971, 1968; **156**, 653; *Budapest*, p. 239). The photometry of several Ap stars is being continued at the University of Western Ontario and at the University of Hawaii. Schöneich, Zehwanova, Hildebrandt and Folge (Potsdam) obtained *UBV* magnitudes of magnetic stars and of Ap stars in clusters. At Leiden, van Genderen has made five-colour observations of 16 magnetic variables. The work is still in progress.

Polosukhina (*Krym Izv.*, **39**, 34, 1969) found irregular changes in the polarization of HD215441 between 0·5–1·7%. The dependence of the polarization on wavelength is changing too. Serkowski and Chojnacki observed (*AA*, **1**, 442, 1969) for polarization some magnetic stars with negative results.

14. DELTA SCUTI VARIABLES AND DWARF CEPHEIDS

Both types of variables have ultrashort-periods, the dwarf cepheids representing the old disk

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population, the δ Scuti stars the young disk population among these objects (see Eggen, *Sigma Reviews*, in press). The dwarf cepheids have larger amplitude variations and are slightly hotter than the δ Scuti stars, and in most cases the kinematical separation of the two groups is clear. Yet, the two dwarf cepheids with known trigonometric parallaxes differ considerably in space motion and metal abundances (see Bessell, *ApJ Sup.*, **18**, 167, 1969 and Appendix I) AD CMi and VZ Cnc also have space motions characteristic of the young disk. The solar motion relative to δ Sct stars was determined by Millis (*AJ*, **73**, S26, 1968) with $v_0 = 21$ km/s, $l^{II} = 32°$, $b^{II} = +25$. Therefore, it can be concluded that these stars are older pop I objects. A δ Sct type variable was found in the Coma cluster (see Appendix II).

Breger (*ApJ Sup.*, **19**, 79, 1969) has completed an important survey of 213 bright field stars which were tested photoelectrically for short-period variability with special attention being given to the constancy of the non-variables. 17 new δ Sct variables were found. He has listed 39 such stars known at present. The amplitude and incidence of variability depends critically on the colour. The large proportion of variables with small amplitudes close to the observational limit of detection indicates that most stars inside the instability strip probably pulsate. The variables and non-variables in the instability strip show similar galactic U, V, W velocities. Narrow-band photometric and spectroscopic data have been collected for most of the 39 δ Scuti variables published so far.

Breger (*ApJ Sup.*, **19**, 99, 1969) has also studied the lower instability strip which extends from the main sequence upward to the RR Lyrae region. Hot and cool borders were established which intersect the main sequence at A 4 and F 2. In the instability strip more than 20% of the stars show regular variability larger than 0·010 magnitude. These variables have normal masses and show a wide range in metal abundances and rotational velocities. Metal abundance and binary characteristics appear to have no influence on the incidence of variability. Pulsation is found to be strongly related to rotational velocity, $v \sin i$. The variables of small amplitudes share the high rotational velocity of the non-variables, while the incidence of larger amplitudes depends critically on low rotational velocity. The mean rotational velocity of the variables two magnitudes above the main sequence is less than 0·3 that of similar non-variables. This effect decreases as the main sequence is approached.

A period-luminosity-colour relation is established with an average deviation of less than 0·3 magnitude in M_v. The pulsation constant Q is found to vary slightly along the instability strip and a preliminary value of $Q = 0{\cdot}029 \pm 0{\cdot}007$ is derived indicating that the variables pulsate in the fundamental and/or first overtone. It is proposed that the period differences between classical cepheids, δ Scuti stars, RR Lyrae stars and dwarf cepheids are caused not only by luminosity differences, but also by large mass differences.

A search for short-period variability among the brighter giants and subgiants between spectral types A 7 and F 5 has also been made by Millis with the 21-inch reflector at Lowell Observatory. Of the 59 field stars observed, at least 10 are variable. The newly discovered variables cover a considerably larger range in spectral type, colour, period, and rotational velocity than did the original δ Sct group members. In the colour-magnitude diagram the variables which he observed, lie immediately above the main sequence between $B-V = +0{\cdot}20$ and $+0{\cdot}35$. Their periods range from $0^d\!.037$ to $0^d\!.194$ with amplitudes in V between 0·015 and 0·3 magnitude. A few non-variable stars were found which definitely fall among the variables in the colour magnitude diagram. Strong evidence of low-amplitude variation has been found in two Hyades stars.

The bright star HR 2707 has been found to be a δ Sct variable by Eggen (*IB*, 250).

Fitch has given a summary of presently available information relating to tidal modulations of δ Sct stars CC And, 14 Aur, and δ Del (*ApJ*, **158**, 279, 1969).

Fullerton (*AJ*, **72**, 797, 1967) has analysed the light curves of all the well observed δ Sct stars for multiple periodicities. The secondary frequencies close to the primary might be due to differing polar and equatorial radii just as may be the case for β CMa stars. The close frequency pairs may be due to tidal effect from binary companion.

Johnston and Chambliss obtained observations in U, B, V and Hβ on several dwarf cepheids and δ Scuti stars on Cerro Tololo. At Leiden Station XS Phe was observed by Wamsteker photoelectrically in five colours during 10 cycles in 1968. Reductions are still in progress. SZ Lyn has been

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observed by van Genderen (*BAN*, **19**, 74, 1967), Joshi and Srivastava (*ZfAp*, **67**, 456, 1967), Binendijk (*AJ*, **73**, 29) and the Wisses (*BAN*, **20**, 333, 1969). Szeidl observes the same star together with several dwarf cepheids in *UBV*. Mahra and Sanyal observed VZ Cnc (*Obs.*, **88**, 59, 1968). The Joshis and Gurthu have found (*Obs.*, **89**, 112, 1969) that γ UMi is a dwarf cepheid.

Hayes and Heiser published photoelectric observations of 4CVn finding $P = 0^d.170934$ with a possible beat period of $0^d.855$ (*PASP*, **80**, 57, 1968). Five-colour observations have been made of δ Del by van Genderen and Wamsteker in 1966 and 1968. The reduction of these observations are still in progress. Wehlau at the University of Western Ontario is continuing the study of δ Sct stars. Light curves of δ Sct have been combined with those of Fath for a reinvestigation of the light variability. Other δ Sct stars are being studied to compare the light and radial velocity variations together with Leung (*ApJ*, **149**, 39, 1967). Crampton at Victoria has begun observations of the velocity variations of the three δ Sct stars 4CVn, 20CVn, and κ Boo.

Fitch was led by his theoretical results to the conclusion, that the AI Vel stars SX Phe, RV Ari, AI Vel, V 703 Sco, VX Hya, and the δ Sct star 4CVn are all pulsating simultaneously in both fundamental and first overtone mode, while the AI Vel star VZ Cnc is pulsating in the first and second overtone modes with its fundamental mode unexcited.

15. HERBIG-HARO OBJECTS AND T TAURI STARS

Wenzel has given a review of contracting, extremely young variables at the Budapest Colloquium (p. 61) and Kuhi in *Interstellar Ionized Hydrogen* (Ed. Terzian, p. 13, 1968).

Herbig (*Budapest*, p. 75) has made a very important study of the light variations in Herbig-Haro object No. 2, which consists of a number of bright nuclei together with considerable fainter structure enclosed in an elliptical area about $25'' \times 40''$. Three nuclei show strong variability. On the basis of this investigation it can be ascertained that the spectacular brightening of two nuclei in the early 1950's (*Non-Stable Stars*, *IAU Symposium* no. 3, p. 8, 1957) must not be associated with the birth of two new stars. There is still no completely straightforward interpretation of these light variations in H-H objects.

At Sonneberg, the program of photoelectric measurements in three colours on extremely young variables is continued. The discussion of the large material for RW Aur (*MVS*, **4**, 71) gave hints to a very complex behaviour. The investigation of SU Aur (*MVS*, **5**, 53) showed that the appearance of minima in brightness is apparently not correlated with changes of spectral type. These results and especially those on SV Cep (*MVS*, **5**, part 5) suggest that variable circumstellar extinction might be efficient. The measurements of RY and T Tau are finished, those of BH and BO Cep are well advanced (Wenzel, Götz).

At the Boyden Observatory, a program for investigating the photometric behaviour of RW Aur variables has been started in 1962 by Geyer. He and Seggewiss reported on UBV observations of DI, ES Car, SY, SZ, TT Phe, and BS Vel (*Budapest*, p. 85). Seggewiss obtained at the ESO in Chile *UBV* magnitudes for the RW Aur stars S6326 Cha and S6343 Cha. Vardanian (*Byurakan Soob.*, **39**, 1969) published a series of three colour photoelectric observations of RW Aur variables.

Landolt published photoelectric *UBV* sequences in Taurus to be used in multicolour studies of the irregular variable stars in the Taurus-Auriga dark cloud (*AJ*, **72**, 1012, 1967).

Gratton, Maffei and Martino presented an interpretation of the light curves of RW Aur stars as the result from a large number of correlated flares (the occurrence of a flare might enhance or decrease the probability of another flare occurring soon after the first) at the 9th *Nobel Symposium* (p. 231, 1968). A general catalogue of all known variables of the T Tau-type is being prepared at the Astrophysical Laboratory at Frascati.

Mendoza continued the infrared photometry of T Tau stars and related objects (*AJ*, **72**, 816, 1967; *ApJ*, **151**, 977, 1968). The new *UBVRIJHKLM* observations of 33 stars confirm the previous result that T Tau stars have large infrared excess. According to Poveda (*AJ*, **72**, 824, 1967), very young stars may be accompanied by a thick circumstellar cloud which absorbs most of the visual radiation of the star and reradiates it in the infrared. He interprets FU Ori's hundredfold increase in luminosity during 1936 as a consequence of the coalescence of the particles into large planetesimals, or because they were blown away by the stellar wind.

A search for radio emission from infrared and T Tau stars with the Arecibo 1000-ft telescope ended with a negative result (Cornella, *ApJ*, **149**, L91, 1967).

The intrinsic polarization of T Tau stars confirms the rule (Serkowski, *ApJ*, **154**, 125, 1968), that it is always associated, both in the early-type stars as in the late-type stars, with the emission lines in the spectrum. This may be a clue for finding the explanation for this intrinsic polarization. Serkowski found changes in the polarization of the T Tau star AK Sco from 0·3 to 0·8% (*ApJ*, **156**, L55, 1969). Polarization in the blue spectral region in R CrA increased during 3 weeks from 9 to 18% (*ApJ. L.*, 1969). Efimov found a correlation between polarization and $B-V$ variations in RW Aur, where the polarization changed between 0·5 to 1%.

One Orion-type variable, NU Ori, was observed by the Celescope and found fainter in the ultraviolet than expected by factors of 10 at 2700Å, 5 at 2320Å, and 40 at 1500Å (*Sky Tel.*, **37**, 281).

16. FLARE STARS

The general subject of flare stars has been reviewed by Haro (*Stars and Stellar Systems*, vol. VII, p. 141, 1968). Geršberg has given an introductory report of observational and theoretical results bearing on the classical flare stars of UV Cet type (*Budapest*, p. 111). Light variability of dMe and dM stars was discussed by Krzeminski (*Low Luminosity Stars* p. 57). About cooperative programs see Appendix III.

Geršberg and Čugainov considered about a hundred photoelectric light curves of flares and found the following characteristics:

(a) the total energy of a flare in the blue region is $\sim 3 \times 10^{31}$ ergs;

(b) characteristic rates of the increase of flare energy output is $10^{27}-10^{28}$ erg/s;

(c) time of light growth 10–30 s for half of the flares, 3–100 s for 90% of them. They discussed various criteria of flare activity and found that the recorded flares released $0{\cdot}1-1$% of the energy radiated by the quiet star.

Oskanian (*Budapest*, p. 131) proposed a classification of flare light-curves based on two parameters of the light-curve: (a) the rate of brightness increase; (b) the character of the decreasing branch of the light-curve. He distinguished four types of light-curves. Individual flares of a given star may have entirely different characteristics.

Kunkel (*IB*, 294) has detected ultraviolet flares in two stars listed in the *Lowell Proper Motion Catalogue*. Photoelectric patrolling of a number of dM and dMe stars is being carried out by Shakhovskaya at the Crimean Astrophysical Observatory. Two bright dMe stars, BD + 13°2618 and 20 C 1250 are found to flare (*IB*, 361). Flare activity of seven dMe stars within ten parsecs of the Sun has been determined by Kunkel (*AJ*, 1969). He has found CoD-32°16135AB to be the most active flare star, and Wolf 359 the least active. Faint flare stars were discovered by Hoffmeister (*IB*, 203 and 251) and Sanduleak (in the Coal Sack, *IB*, 275). At Catania, the flare stars BD + 51°2402 and PZ Mon of spectral types K6Ve and K2e, respectively, are under observation (*Catania Pubbl.*, 114 and 124; *IB*, 252; *Budapest* p. 149).

The variety of spectral types displaying flares continues to be remarkable. The star SS 199 II (Slettebak-Stock II faint-star list of stars near the NGP, *Hamb. Abh.*, **5**, No. 5), a halo Pop II A0 type star, was found to flare by Philip (*PASP*, **80**, 171, 1968). This star has now been placed on the patrol program of the Tonantzintla Observatory, and Philip also plans to monitor it further. A finding chart is given in *ApJ*, **148**, L143. Butler's flare star, HD6090, has been classified by Thackeray as dKO (*PASP*, **79**, 368, 1967), and certainly deserves further attention by southern observers. A long monitoring run of 114 h on V 1216 Sgr is reported by Andrews (*PASP*, **78**, 542, 1966). MacConnell has discussed several flares observed by him in BD – 8°4352 AB and AD Leo in the ultraviolet (*ApJ*, **153**, 313, 1968). The much neglected flare star discovered 45 yr ago by Hertzsprung, DH Car, has been observed to flare by Tapia (*IB*, 286). Proxima Centauri has been patrolled by Bateson and members of the New Zealand team (*IB*, 353).

A further attempt has been made to detect optical polarization associated with flares for EQ Peg and AD Leo by Cubičela and Arsenjevič. Efimov has investigated theoretically the accuracy of such investigations (*Budapest*, p. 169). He measured the polarization of AD Leo (*Krym. Izv.*, **39**, 42, 1969). Vardanian made polarimetric observations during the light decrease of YZ CMi and UV Cet. No polarization greater than 0·8% was found (*AC*, 508, 1969).

Colour changes during flares were investigated by Andrews (*IB*, 265). A statistically important project has been undertaken by Kunkel at the McDonald Observatory using sequentially-sampled *UBV* measures of flares in several stars (*Diss. Austin*, 1967; *ApJ*, 1969). At Crimea, a number of flares of EV Lac have been observed by Čugainov (*Krym. Izv.*, 1969) with a photoelectric spectro-colorimeter, that gives the possibility to record simultaneously the radiation in three spectral intervals, 3350–3650, 4155–4280 and 5120–5320 Å. Kunkel (*loc. cit.*) obtained time-resolved spectra of flares in EV Lac, AD Leo and YZ CMi, together with $(U-B)$ and $(B-V)$ colours, the Balmer jump, the slope of continuum emission redward to the Balmer jump, and the Balmer decrement. These data enabled him to construct a two-component spectroscopic model of flare in which the dominant emission process is hydrogen recombination with descriptive parameters similar to those of solar flares. The second component consists of impulsive heating of the photosphere beneath the flare. He also obtained evidence that the surface extent of the flares covers only a few percents of the apparent stellar disk. The ratio of radio to optical energy of the flares was found by him to be the same for dMe stars, as for the Sun. Lovell's earlier result (*Obs.*, **84**, 191, 1964) is found to be in error because bolometric corrections were not applied by him. The values of the Balmer jump obtained by Čugainov for flares on EV Lac are smaller than those given by Kunkel, especially near the flare maximum. Čugainov has also observed that the intensity of the Hβ emission line relative to the neighbouring continuum emission decreases near the flare maximum (*Krym. Izv.*, **38**, 200, 1967; 1969 in press). Taking into account both these facts, Čugainov concluded that the hydrogen recombination makes only a small contribution to the total radiation near the maximum of a flare.

Arakelian investigated the luminosity function of normal and flare red stars in the vicinity of the sun (*Budapest*, p. 161). He was able to conclude that the space density of flare stars in the solar neighbourhood is higher than in the general galactic field.

The most distant red dwarf star, the non-thermal radio emission of which has been detected so far, is the flare star V371 Ori at a distance of ~ 15 pc. Slee, Higgins, Roslund and Lyngå recently reported the probable detection of radio emission from a number of flare stars near the Orion Nebula at a distance of ~ 400 pc (*Nature*, **224**, 1087, 1969). Compared with the flare stars in the solar neighbourhood, there is a dilution factor of ~ 10^3 in intensity on account of the greater distances, but this must be largely compensated for by the much greater amounts of energy released during flares on these stars.

Since flare activity seems to be a common property of all low-mass red stars, the existence of normally invisible examples of such objects of very low luminosity may be established by observing them during flares. Van de Kamp reported on the flare-up of a previously unseen companion of the proper motion star Groombridge 1830 (*Low Luminosity Stars*, Ed. Kumar, p. 199).

17. R CORONAE BOREALIS VARIABLES

Stein *et al.* (*ApJ*, **155**, L3, 1969) have reported a large infrared excess for RCrB. They suggest that this excess is due to blackbody radiation from a cloud of particles at a temperature of 940 K. If their model is correct, a cloud with an angular radius of 0″07 would be required, and the authors propose that such a cloud could have formed by the ejection of particles during the past deep minimum, about 7 years ago. These ideas are consistent with the Loreta-O'Keefe hypothesis of carbon particle formation to explain the deep minima of RCrB stars. RY Sgr also exhibits a large excess of radiation at long wavelengths. (Lee and Feast, *ApJ*, **157**, L173, 1969). The K-M index is larger for this star than that found for most infrared stars, including NML Cyg. During a recent 8-month interval the visual brightness increased, while the radiation in the 2–3·4 μ region decreased.

Serkowski and Kruszewski found changes in polarization of RY Sgr (*ApJ*, **155**, L15, 1969).

During the minimum the percentage polarization increased from 0·5 to at least 1·3%, and the position angle changed from about 10° to 150°.

Extensive three colour photometry and spectroscopy of RY Sgr has been carried out at Pretoria and the Cape since the beginning of the deep minimum of 1967 (see Appendix I). At Ottawa a photometry of RCrB itself will continue for another season, the principal aim being to investigate the stability of the star at maximum light. According to Meinunger (*MVS*, **4**, 8, 1968) the light of BH Lac, classified as an RCrB variable in the GCVS, is constant. Herbig has already shown (*ApJ*, **13**, 632) that the spectrum is not that of an RCrB star.

Hill (P. W.) of University Observatory St. Andrews pointed out the similarity in composition between the hot helium stars and the RCrB variables. Yet, he found no large brightness variations in the He stars (*IB*, 357). Landolt also observed some helium stars with the same negative result (*PASP*, **80**, 318, 1968).

An RCrB star with a single observed minimum of 2300 days was detected in the LMC by Hodge and Wright (*ApJ Sup.*, 153, 1969).

18. SYMBIOTIC VARIABLES

The spectral observations of the symbiotic stars are considered in Appendix I. Photoelectric observations are carried out at a number of observatories. Tempesti observes since November 1968 EG And every clear night in *V* and *B* light, in a combined program with spectrographic observations at the Asiago Observatory. Beliakina (Crimea) showed that brightness and colour changes of Z And, AG Per and AG Dra confirm the hypothesis on the duplicity of these stars. The light variations in the blue and yellow regions are caused by the effect of heating of the cool component by the hot component radiation. The ultraviolet variation results from the ionization of the outer atmosphere of the cool star by $L\alpha$-radiation of the hot component. Luud (Tartu) carried out photoelectric and spectral studies of CH Cyg. The peculiarities are probably caused by the excitation of the outer atmosphere of the gM 6 star by the variable radiation of the hot component of low luminosity. The gM 6 star is also variable. Extensive photoelectric three-colour and objective-prism observations on CQ Tau by Götz and Wenzel show a lot of remarkable effects, partly not yet observed at any other star. Martel and Févre observed photoelectrically CH Cyg in *UBV* at Haute Provence (*IAU Cir.*, 2027, 1967). The same star is observed by Cester (*Trieste Publ.*, 368). A long term program of *UBV* photometry of symbiotic stars has been initiated for about two years at Ottawa. The variability of AG Peg in its spectroscopic period has been confirmed. Philip presented *UBV* and four-colour photometry for MHα 328–116 (*ApJ*, **151**, L69, 1968; *PASP*, **81**, 248, 1969). Johnson and Golson (*ApJ*, **155**, L91, 1969) observed HD4174, AG Dra, AG Peg, MHα 328–116 and CH Cyg with narrow band filters. Robinson published the photometric history of AG Dra from 1890 to 1966 (*PZ*, **16**, 507, 1969). Hoffleit discovered a new variable with symbiotic spectrum, MHα 208–51 (*IB*, 254).

19. NOVAE DURING OUTBURSTS

Nova (T) Pyx 1890, 1902, 1920, 1944, 1966 was observed by Landolt photoelectrically.

Nova (GK) Per 1901 exhibited a recent outburst in September 1967 (IAU Circ., 2037).

Nova CrA 1967 was discovered in 1969 by Sanduleak on objective prism plates taken on Cerro Tololo. The nova must have been in maximum light about the 8th magnitude at the beginning of 1967 (*IB*, 368).

Nova (HR) Del 1967 was discovered by Alcock on July 8 at ~5th magnitude. It attained its peak brightness of 3·5 magnitude in December. Tempesti observes the star continuously since August 1967. Photoelectric observations were published by Stokes (*IB*, 224), Il-Slong Nha (*IB*, 238) Mollerus (*AA*, **3**, 376, 1969). Narrow band photoelectric observations were carried out at Catania (*Atti XII. Conv. SAI l'Aquila*, 1968).

Nova Her 1968 = *S 10376*, a very fast nova was discovered by Richter (*IB*, 293). The object must be in the intergalactic space with $z = 42$ kpc.

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Nova (RS) Oph, 1898, 1933, 1958 recurred again in October 1967; the flare up was detected first by Beyer.

Nova Oph 1967 was detected by Stephenson on objective prism plates taken by Sanduleak on Cerro Tololo. The maximum must have been near $V = 9{\cdot}5$, presumably during the first half of 1967(*IB*, 323).

Nova Sgr 1969 was found by Bateson on Galactic Centre Patrol Plates in June. The maximum brightness was reached on 11th July with 6·5 magnitude.

Nova Vul 1968 (no. 1) was discovered by Alcock on April 15. Photoelectric observations have been obtained by Quast (*IB*, 306), Fernie and Tempesti.

Nova Vul 1968 (no. 2) was discovered by Kohoutek (*IAU Cir.* 2106). The maximum ($B = 9{\cdot}25$) was reached on July 19. From the light curve the nova can be classified as a normal fast nova (Rosino *et al.*, *Astr. Space Sci.*, **4**, 392, 1969).

Nova Ser 1970 was discovered by Honda on February 13 (*IAU Cir.* 2212 and 2214).

Rosino has continued the systematic search of novae in M 31 and M 33. Many novae have been found during the last years.

Gyldenkerne, Mejdahl and West published photoelectric observations of Nova Her 1960 (*Køb. Publ.*, 201) obtained at Brorfelde by means of standard *B* and *V* filters and 6 narrow interference filters.

Intrinsic polarization in the light of an active nova was first reported by Eggen, Mathewson and Serkowski (*Nature*, **213**, 1261, 1967), who found the recurrent nova T Pyx to be variable in the degree, position angle, and wavelength-dependence of polarization. Zellner observed Nova Del 1967, and found variations of polarization, with both a small-amplitude fluctuation with a time scale of days and a secular variation with a time scale of months. A few observations of Nova Vul 1968 (no. 1) suggest that it also has variable polarization (*Trieste*, 1968, p. 300).

Rose discussed a model for the nova outburst (*ApJ*, **152**, 245, 1968). Sobolev published a theoretical study of galactic novae in *Vistas in Astronomy*, **11**. The dynamics of a nova outburst were studied by Sparkes (*ApJ*, **156**, 569, 1969). A computer program has been prepared by Casinelli and Wegner to trace the physical conditions behind the shock wave during an outburst of RS Oph. The calculations predict detectable X-ray emission for about a month after light maximum. According to Kraft's assumption, explosive novalike phenomena occur in binary systems, when a white dwarf-like object accretes mass from an expanded companion. Secco has calculated (*Att. Cong. SAI, Padova*, 292, 1967) first approximation models of the degenerate star for different values of the mass, and the explosion periods have been evaluated for different mass increase rates. Friedjung summarized reasons (*Trieste*, 1968, p. 303) for believing that ejection of matter by novae continues long after maximum light.

20. OLD NOVAE AND HOT SUBLUMINOUS VARIABLES

An excellent review on the general subject of novae and novalike variables has been published by Mumford (*PASP*, **79**, 283, 1967).

A. *Novae near minimum light*

Mustel and Boyarčuk studied photographs of T Aur, GK Per, V 603 Aql and DQ Her, and found that the envelope of novae consists of an equatorial belt and two polar caps. In 1968 the envelope of DQ Her had the electron density of $2 \times 10^3/\text{cm}^3$ and the mass $\sim 10^{29}$ g. With the purpose of studying the interaction of matter ejected in nova explosions with surrounding interstellar material, a number of old novae are being photographed anew with the 200″ by Münch and compared with earlier images obtained by Baade and others. The envelopes of N Her 1934 and N Per 1901 show indications of deceleration but a few of the filaments in the complex envelope appear to be accelerating.

Nova (HR) Del 1967 may have been variable in brightness before outburst according to Van den Bergh and Racine (*IB*, 212). A pre-outburst spectrum was found on a plate exposed July 16, 1960 at 580 Å/mm (*PASP*, **79**, 584, 1967). The prenova was a very blue star of magnitude $12 < V < 13$.

Nova (DQ) Her 1934 was studied by Nather and Warner at McDonald Observatory (*MN*, **143**, 145, 1969) using synchronous signal averaging in order to obtain the properties of the 71ˢ7 pulsations discovered by Walker in 1956 (*ApJ*, **123**, 68). They obtained a light curve which is a pure sinusoid

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within the accuracy of measurement. The pulsation amplitude is ⩾ 1 magnitude, it varies by at least a factor of 5. The binary period is increasing probably as a result of mass loss from the system at a rate $2{\cdot}03 \times 10^{-8}$ $M_{\odot}$/yr. Variations in light intensity from DQ Her seem to be a superposition of several components. Beside the regular pulsation of the 71ˢ7 period and the eclipse phenomenon there are very short sporadic variations (flickering) and longer-term changes in light level which cause the shape of the eclipse curve to vary from cycle to cycle, as well as affecting the light level outside of eclipse. The flickering appears undiminished even at central eclipse and probably arises throughout the nebula.

Nova V603 Aql 1918 undergoes small light fluctuations, and present data by Landolt (*PASP*, **80**, 481, 1968) indicate the object to be fainter than has been reported in the past.

Nova Vul No. 1. 1968 has been studied by L. Meinunger on old plates. He could not find any obvious variability before the outburst (*IB*, 272, 1968).

Nova (WZ) Sge 1913, 1946 has been observed photoelectrically in July 1969 by Krzeminski and Bretz at Haute Provence Observatory. Krzeminski and Smak proposed a new model of the binary system (*Budapest*, p. 371).

B. *Hot variables, and short-period eclipsing systems with additional activity, X-ray variables*

At the Kenneth Mees Observatory, Savedoff *et al.* has assembled equipment which permits the rapid digital recording of photoelectric signals. Preliminary observations made at the rate of 10 per second of *40 Eri B* indicate that the star has no variation greater than 0·01 magnitude in the period range between 1 and 10 s. *HZ 29*, a peculiar, hydrogen deficient white dwarf with broad, apparently double absorption lines of He I, was shown by Smak to be a variable star with a period of about 18 min (*IB*, 182, *AcA*, **17**, 255, 1967). The available photometric and spectroscopic data support the hypothesis that HZ 29 might be a close binary system. Stothers suggests (*ApJ*, **154**, L91, 1968) that HZ 29 is a luminous star of high mass and heavy composition and that its variability is due to radial pulsation. According to Bomy and Ledoux (*Ad'Ap*, **28**, 358), stars composed essentially of pure He become unstable against nuclear-energized pulsations above 7–8 $M_{\odot}$. Ostriker and Hesser got for the period from new photometric data and autocorrelation analysis technique the improved value of 17ᵐ52. In addition null results have been established for a group of white dwarfs for which, in some cases, a limit of $A \leqslant 0{\cdot}003$ magnitude can be set for the maximum Fourier amplitude between 300ˢ and 2 . Analysis of extensive observations of novae and nova-like objects is in progress. Smak presented a new interpretation of *HZ 22*, which was considered till now a normal B-type binary with $P = 3^d\!.58$ (*AcA*, **19**, 165, 1969). According to Smak the star is a peculiar hot subdwarf binary with period shorter than one day ($P = 0^d43234$). Landolt derived from *UBV* photoelectric data a $P = 12^m\!.5$ variation in the brightness of a white dwarf-like blue star (*ApJ*, **153**, 151, 1968). The variable may be an eclipsing system since the radial velocity varies with an amplitude ~ 500 km/s. He also observed in *UBV* the nova-like variables AG and HR Car. Hesser *et al.* discovered a new, blue, short-period ($P \sim 10^m$) variable star, G-44-32, which is catalogued by Eggen and Greenstein as a white dwarf. They found the central stars of planetary nebulae extremely quiet with regards to both intrinsic flickering and coherent, low amplitude variability.

EM Cyg was observed by Mumford and Krzeminski (*PASP*, **79**, 283, 1967; *ApJ Sup.*, **18**, 429, 1969). The observations suggest that the star is an eclipsing system in which the greatest diminution of light at primary minimum may be attributed to an eclipse of a gaseous disk or shell. The light curves exhibit quite complex behaviour. Many features in the light curves are reminiscent of those found for old novae and novalike variables.

TT Ari was observed by Smak and Stepien at Lick and Haute Provence. Over 3000 measurements were made mostly in the ultraviolet. The light variation can be resolved into three activities. It is suggested that the star is a hot, subluminous close binary system with $P = 0^d\!.2658$ (*Budapest*, p. 355).

UX UMa was observed by M. F. Walker photoelectrically in 1967 and 1968 at Lick. The period, which apparently increased from 1937 to 1953 and then decreased from 1953 to 1962, has continued to decrease since 1962, but at a slower rate. Bretz also observed the star in February and March 1967.

Sco X-1 holds a position in the front of interest since its optical identification in June 1966 Rapid variations in the optical radiation has been reported by many observers (cf. Hiltner and Mook, *ApJ*, **150**, 851, 1967; Osawa and Ichimura, *Tokyo Bul.*, 185). Hiltner organized a world-wide monitoring program of this object for 1970. Its X-flux decreased exponentially over the period 1965–68 with a time constant of about 4ʸ1 (Roco *et al.*, *ApJ*, **157**, L133, 1969). Van Genderen published (*AA*, **2**, 6, 1969) an investigation of the object based on photoelectric five-colour observations made at the Leiden SS in 1966–68. He found a semi-periodic light variation with $P = 0^d5276$. Apart from some irregularities, the light curve and the colours are characteristic for a pulsating star. The object is bluer when brighter (Stepien *ApJ*, **151**, L15, 1968). Narrow-band and *UBV* photometry was carried out by Johnson (H. M.) and Golson (*ApJ*, **153**, 1968). Radio emission of the object was detected by Andrew and Preston (*Nature*, **218**, 855, 1968) with the 46-m radio telescope of the Algonquin Radio Observatory. Ables has shown that the radio emission of Sco X-1 is also variable (*Publ. AS Austr.*, **1**, 237, 1969).

Cen X-2 is a highly variable X-ray star, very much like a nova emitting in the visible spectral range (Roco *et al.*, *ApJ*, **157**, L127, 1969). Its optical identification with WX Cen is yet not certain.

Cyg X-2 may be considered fairly well identified with a bluish optical object. Kristian, Sandage and Westphal's photoelectric measures show in the star variations similar to Sco X-1. The star seems to be a spectroscopic binary.

C. *U Gem and Z Cam stars*

Smak discussed in his introductory report at the Budapest Colloquium some problems connected with the interpretation of U Gem type stars (p. 345).

Z Cam is found to be a double-line spectroscopic binary with an orbital period of $0^d.289834$ and mass ratio near unity (Kraft, Krzeminski and Mumford, *Ap. J.* **158**, 589, 1969). Though eclipses have not been detected, the light curves show a number of features which recur with the same period as the spectroscopic orbit. The light curves reveal major eruptions and rapid, irregular fluctuations.

Z Cha was shown by Mumford to be an eclipsing binary with period of $0^d.0745$ (*IB*, 337). The entire eclipse lasts some 7^m, with minimum being $2^m.5$ to 3^m long.

SS Cyg has according to Walker (*ApJ*, **154**, 157, 1968) an increasing period giving a computed minimum mass loss of $\simeq 1{\cdot}8 \times 10^{-7}\ M_\odot$/yr. The periods, masses, and separation of the components are very similar to those of DQ Her. The greater rate of mass loss in the case of SS Cyg may have some direct influence on the nature and frequency of the nova outburst. Walker and Chincarini observed rapid flares having their maximum amplitude in the far ultraviolet, and decreasing rapidly in intensity with increasing wavelength, becoming invisible around 4100 Å (*ApJ*, **154**, 157, 1969, see Appendix I). Reduction of the observations obtained in September 1966 by Bretz and Mirzoyan at the Haute Provence Observatory are well advanced. The star has again been observed in *UBV* July 1969.

U Gem was discussed by Mayall (*Budapest*, p. 377) using 97 eruptions.

EX Hya, an eclipsing variable with two eclipses and $P = 0^d.068$, was treated by Mumford (*ApJ Sup.*, **15**, 1, 1967).

Mumford obtained fairly extensive data for BV Cen, μ Cen, BP CrA, VW Hyi, HP Nor, HH Tel. There are only in the light curves of BV Cen and VW Hyi phenomena that recall such known eclipsing variables as EM Cyg.

Romano has continued the observations of some U Gem stars. Four new variables of this type have been discovered during his survey = GR 135, 141, 166, 177.

Gorbatzkij and his students considered the influence of gas streams in binaries on the brightness and colour of U Gem type stars. It was found that inhomogeneities in a stream can produce rapid brightness fluctuations. Koroviakovsky studied the exchange of matter in U Gem stars (*Budapest*, p. 391). Osaki proposed a mechanism for the outbursts (*BAAS* **1**, 357, 1969).

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