29. COMMISSION DES SPECTRES STELLAIRES

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La Commission a trois Sous-Commissions: 29*a*, 29*b*, 29*c*.

INTRODUCTION

An increasing level of activity characterizes the field of stellar spectroscopy as studies of stellar spectra give continuing support to other branches of astronomy. For example, two-dimensional spectral classifications are of great assistance in investigations of galactic structure, studies of variable stars and binaries are of great importance to theories of stellar evolution, as are researches related to chemical compositions and element building processes in stars.

Technological improvements are aiding the progress of stellar spectroscopy. These include instruments for objective measurements of wave-lengths in spectrograms, direct-intensity micro-photometers, and improved intensity and wave-length standards. Most important of all are the increasing efficiencies and numbers of coudé spectrographs. New high quality coudé spectrographs are currently in operation at the Haute Provence, Lick and Radcliffe Observatories and are under construction or are being tested at the Dominion Astrophysical Observatory, at the new Okayama Observatory, Japan, and at the Mount Stromlo Observatory. The absolute magnitude work of O. C. Wilson and Deutsch's study of circumstellar envelopes of stars offer beautiful examples of important contributions that can be made by coudé spectroscopy. It should be emphasized that in spite of these new coudé spectrographs, facilities for stellar spectroscopy are still inadequate; the difficulty really arises from the fact that not enough large optical telescopes have been provided in recent years to meet the increased demand in stellar astronomy. A large telescope, devoted exclusively to spectroscopic problems (as has been done at Victoria, B.C.) and preferably entirely coudé work, should be provided in the southern hemisphere.

The interpretation of stellar spectra depends increasingly on supporting laboratory data and theoretical work on optical spectra. At the low-temperature end of the scale one may mention the work of Phillips and Brewer at Berkeley on the spectra and dissociation constants of many molecules of astrophysical interest, that of the group at London, Ontario, and the contributions of the spectroscopic laboratory of the Institute of Astrophysics at Liège where B. Rosen (1959) and his associates have studied the spectra of CaO, LaO, ThO, TiO and ZrO. Studies of H_2, D_2 and HD have been carried out in the near ultra-violet (Herzberg, Monfils and Rosen, 1960).

Experimental determinations of *f*-values and damping constants are a fundamental necessity for interpretations of spectroscopic data (see reports of Commission 14). Important investigations are being carried out in the laboratory of Lochte-Holtgreven in Kiel, by R. B. King and his associates at the California Institute of Technology, by Branscomb's group at the National Bureau of Standards (U.S.A.), and at Oxford and London. The shock tube as a tool for astrophysical research is being exploited particularly by workers at the University of Michigan, by A. C. Kolb's group at the Naval Research Laboratory, Washington D.C., and by Slettebak at Ohio State University. Studies are also being carried out in the U.S.S.R., particularly at Leningrad. An extensive compilation of f-value data for solar type stars has been given by Goldberg, Müller and Aller (1960).

Theoretical f-value studies have been carried out by Layzer and associates at Harvard, by Miss Trefftz at Munich, and by Garstang at London. From a study of intensities in lines of quadruple multiplets of iron in η Carinae and XX Ophiuchi, Melnikov (1959) found that line strengths derived from these intensities are in good agreement with quantum mechanical predictions. Also from studies of multiplets in the iron arc, he finds (1958) that transitions involving high levels (6 eV excitation) are in poor LS coupling; those involving low levels (multiplets, simple and complex super-multiplets) are in good LS coupling. Gutman and Levinson (1960) studied inhomogeneous coupling in atomic spectra in configurations with strongly excited electrons.

STELLAR SPECTROPHOTOMETRY

We discuss here only spectrophotometric problems involving the continuous spectrum, or the continuous spectrum plus lines; the spectrophotometry of lines is considered by K. O. Wright (Sub-Commission 29*b*).

Absolute spectrophotometry and photometric standards

At the Happel Laboratory for Radiation Measurements, in Heidelberg, Kienle's group has considered the following standards:

(*a*) Black-body. For temperatures up to 3000 °K, a tungsten furnace has been improved to provide a small chamber whose walls have a strictly uniform temperature which can be determined by direct spectrophotometric comparison with the gold point. The constancy of the temperature is controlled by an objective photo-electric pyrometer.

(*b*) The tungsten ribbon lamp permits a standardization to about one per cent intensity ($\lambda = 5000$ Å, $T = 2500$ °K) only if the area used for measurements is localized to $\pm 0{\cdot}2$ mm on the filament. The lamp current must be exact to about 5×10^{-4} of the required value.

(*c*) Carbon arc. With fixed conditions of voltage supply, air pressure, humidity, type of electrodes, the radiative intensity of the center of a positive crater of a carbon arc is reproducible to $\pm 2\%$. They plan to calibrate a carbon arc as a standard source to 2000 °Å.

Kienle's laboratory has calibrated lamps for various scientific enterprises and fluorescent powders for Chalonge.

Sitnik (1960) has studied the general principles of getting a black-body model suitable for spectrophotometric purposes at high temperatures. Also, he has studied the general properties of a new type of ribbon-filament lamps as a radiative energy source for spectrophotometry (Sitnik, 1959).

At the Jungfraujoch, Chalonge has compared the energy curves of several stars (S Monocerotis, 10 Lacertae, ϵ Persei, etc.) with that of a well-known source: artificial, fluorescent salts, whose energy distribution had been determined by J. P. Mehltretter (1960). With low dispersion they can obtain results only for O and B stars but by using high-dispersion coudé spectra they can extend the investigations to late-type stars.

Parijsky and Gindilis (1959) studied the properties of new constant-action luminofors for spectrophotometry of faint objects.

Bahner, working at McDonald, has compared α Lyrae and α Leonis with an artificial star consisting of a small hole illuminated by a tungsten-filament lamp, at the focus of a collimating mirror.

Spectrophotometric aids for spectral classification

Among the most important applications of precise spectrophotometry has been its use in spectral and luminosity classification. We mention for example the work of the Walravens (1960) who used a photo-electric spectrum analyzer to observe more than a thousand early-type stars in five spectral regions.

Both from the point of view of stellar model-atmosphere applications and spectral and luminosity classifications one of the most interesting developments has been the Chalonge 3-parameter system.

Of the three parameters, two (D, which is a measure of the Balmer discontinuity and λ_1, its position) measure the specific property of the star and are completely independent of stellar absorption, while the third, the spectrophotometric gradient in the blue, ϕ_b, depends on it very strongly. Hence if one can utilise λ_1 and D for the classification (quantities which can always be determined) one can construct a diagram analagous to the HR or color-luminosity diagram without any correction for distance or interstellar absorption, and this diagram can be used in problems of stellar evolution. The method is particularly useful in clusters where some components are located in absorbing clouds. Also by plotting the components of multiple stars on this diagram one may use the positions of the points with respect to curves for clusters of known age to obtain the age and stage of evolution of the particular multiple stars.

Various checks may be applied to see how well the three parameters of Chalonge's three-dimensional classification characterize fundamental properties of stars, such as absolute magnitudes. J. Berger (1958) has used close binaries (where the difference in absolute magnitude between the two components is accurately known) and obtains reassuring results.

The use of these parameters in the interpretation of star clusters, associations, etc. is well illustrated by studies of NGC 2264, the association ζ Persei, the aggregate 10 Lacertae, the Pleiades, M 39, Hyades and Coma cluster (Berger *et al.* 1958).

The method proposed by Chalonge and Divan (1950) to get surface temperatures and diameters of stars was applied by G. Cayrel de Strobel (1960) to get T and g for a certain number of stars between B3 and F8.

The relation between the *UBV* and Chalonge parameters has been considered by A. M. Rozis-Saulgeot (1959, 1960) who has demonstrated the importance of the choice of appropriate filters in establishing the exact amount of reddening due to inter-stellar absorption.

Variations of the Strömgren technique (which combines features of continuous spectrum and line photometry) have been proposed by various workers. At Naini Tal, Vainu Bappu used interference filters with a half-intensity band pass of 40 angstroms centered at 4270 Å, 4340 Å and 4410 Å to get the intensity of the Hγ absorption in 300 stars in the general galactic field and in clusters and associations. He uses Hγ indices in conjunction with $(U-B)$ color indices corrected for inter-stellar reddening to get spectral classes and absolute visual magnitudes. $(U-B)$ plots for different associations and clusters show age effects. He has studied h and χ Persei, the Perseus cluster, the ζ Persei association, Pleiades, the Scorpio Centaurus cluster—Praesepe, NGC 2362, NGC 2264 and Orion.

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Relative stellar energy distributions (*Standard star programs*)

Photo-electric spectrum scanners have beeen built by a number of observers for use in determining precise energy distributions in the continuous spectra of stars. Oke has developed Cassegrain and coudé scanners for the Mount Wilson telescopes. At Kodaikanal, Bappu has constructed a photo-electric scanner and a monochromator for use on a 20-inch reflector. In the Crimea, N. A. Dimov (1960) has built a new type of integrating spectrophotometer in which the observed spectrum interval of 110 Å is scanned by an exit slot.

Code (1960) has published monochromatic magnitudes for a number of stars ranging in spectral class from O9 V to M2 I (mostly in the northern hemisphere) and covering the wavelength range from 3400 Å to 10000 Å. The fluxes are referred to the standard wave-length 5560 Å.

Oke (1960) has observed a sequence of early type standard stars around the sky and compared them with α Lyrae in the wave-length range from 3400 Å to 5900 Å. The wave-length range is to be extended to the infra-red.

At Mount Stromlo and at Mount Bingar, L. H. Aller and D. J. Faulkner have set up a number of early-type southern photometric energy distribution standards, by comparing the stars with 58 Aquilae, ξ^2 Ceti, (observed by Oke) and β and ϵ Orionis (observed by Code). These early-type southern standards (established so far) include β Centauri, α Pavonis, α Gruis, α Sculptoris, κ Eridani, 41 Eridani, α Eridani, α Carinae, and ζ Puppis. In addition a number of metallic-line and later-type stars have been observed in this program, *e.g.* α Centauri, ϵ Indi, and β Gruis. The spectral range covered is the same as that observed by Oke. Because of the low spectral purity of the scans (about 10 Å), photometrically-calibrated slit spectra are obtained with a conventional Cassegrain spectrograph to determine in the influence of lines on the spectrum. The procedure is similar to that employed by others who have used low-dispersion material (*e.g.* Chalonge, Oke, Melbourne).

Oke has obtained spectral scans for about thirty A, F and G giants and super-giants as comparisons for Cepheids and RR Lyrae stars and also a number of scans for selected stars in the Hyades to give data for standard main-sequence stars.

On the basis of newer measurements of stellar colors and spectral scans, the stellar temperature scale as given by Morgan and Keenan in Hynek's *Astrophysics* has been revised by Popper, by Oke, and by Aller.

EARLY-TYPE STARS

O-Stars. Miss Underhill has completed detailed wave-length and equivalent width studies in HD 188001 (9 Sagittae) 3100-6680 Å, O 7f. The spectrum shows a wide range of excitation from C II to O VI, the profiles of lines of low excitation are narrower than those of high excitation. Probably the sharp lines are formed in a shell. The radial velocity varies irregularly with a range of the order of 30 km/sec. Spectral details between 4585 and 4603 Å are best explained as broad shallow absorption lines of B III at 4487 and 4497 Å. She is also studying the spectrum of 10 Lacertae, making use of Palomar plates. Mount Wilson and McDonald coudé spectra of this star and λ Orionis have been studied by Aller and Jugaku who have determined line profiles and equivalent widths for all lines measurable on the plates.

B-type super-giants. Miss Underhill has measured spectrograms of χ^2 Orionis (B2 Ia), 55 Cygni (B3 Ia), and 67 Ophiuchi (B5 Ib) for radial velocity. The velocity of each star varies in an irregular manner with a range of 30 km/sec. In 67 Ophiuchi and ρ Leonis, Hα is a pure absorption line. In 55 Cygni, Hα shows sometimes a weak absorption and sometimes a weak

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emission while in χ^2 Orionis, the emission is strong. The widths of the emission lines suggests that velocities greater than 200 km/sec occur in the extended envelopes of these stars.

B-type main-sequence stars. Supplementing earlier work done on γ Pegasi, Aller and Jugaku have measured line profiles and equivalent widths on coudé spectra of ξ and 15 Canis Majoris, ϕ and 22 Orionis, HD 36959, HD 36960, 114 Tauri. The data are being analysed for abundances.

Equivalent widths for 60 lines in the spectra of twenty B 2-type stars and of 80 lines in the spectra of 25 B stars have been published by Butler and Seddon (1958). Butler and Thompson have obtained equivalent widths for 56 lines in the spectra of ten stars of MK class B 5. All of the spectra were obtained with a two-prism spectrograph attached to the 36-inch reflector at Edinburgh. With the replacement of the prism spectrograph by a grating instrument the program is being extended to measurement of line intensities in spectra of stars between spectral classes F 5 and G 5 with luminosity classes between III and V and with different space velocities.

The Jascheks are studying HD stars south of $-30°$ in the range O-B 8 and between the 5th and 7th magnitudes.

Spectrophotometry. In addition to the previously cited work of Oke, Code, and others mention may be made of the work of Bless who measured the energy distributions in stars of spectral class A associated with clusters in an effort to find evolutionary effects. He was able to demonstrate that energy distributions obtained by a photo-electric scanner were capable of detecting these effects.

Bahner of Heidelberg used a photo-electric grating monochromator to get observations with the McDonald 36-inch. He carried out a relative spectrophotometry of 25 bright stars observed at 16 wave-lengths in the range 3200 to 6400 Å with a band pass of 55 Å. The stars covered the spectral range from B 0 to F 5 with luminosity classes I, III and V.

By means of photo-electric photometry, O. A. Melnikov, L. N. Żhukova and N. F. Kuprevitch obtained the gradients of a number of A 0 stars by comparing them with a star whose continuum (as deformed by the filter) corresponds to a very high temperature. Thus they found the color temperatures of A 0 stars to be of the order of 16 000 °K.

WOLF-RAYET STARS

At the Dominion Astrophysical Observatory, Miss Underhill (1959) has made a detailed study of the spectra of HD 192 103 WC7 and HD 192 163 WN6 in the wave-length range from 3100 to 6680 Å giving intensity tracings and lists of lines and their indentifications. The principal conclusions of this study are:

(*a*) Both stars are single.

(*b*) Both stars are bright in the ultra-violet, their spectral energy distributions resembling those of O stars rather than objects with color temperatures of 12 000 °K.

(*c*) The main part of each spectrum is formed in relatively-dense layers where large chaotic motions exist, but each star is surrounded by a low-density rapidly-expanding shell of gas observed in the absorption lines of He I 3888 Å, 3965 Å, C III 4647-51 Å, N IV 3478-84 Å and (in emission) C III 5696 Å.

(*d*) Line profiles are determined by atmospheric motions; in particular the He II lines are not affected by the Stark effect.

(*e*) Since the spectrum of N III definitely occurs in the spectrum of HD 192 103 and N IV and N V may also be present, and since O III occurs in the spectrum of HD 192 163 and

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O IV, O V and O VI may be present, the gross spectral differences may be due to different excitation conditions rather than abundance differences.

The last-mentioned conclusion is also of interest in connection with a recent suggestion by Sahade (1958). From a study of masses of Wolf-Rayet and of components of binary systems, he concludes that these objects are still in the gravitational stages of their evolution. Gamow and many others have suggested that Wolf-Rayet stars are in late stages of their evolution at least as main-sequence objects.

Dolidze observed the spectra of P Cygni and three Wolf-Rayet stars and finds changes in the temperature of P Cygni sometimes accompanied by variations in intensities and positions of the spectral lines.

Wilson and Bappu have measured line intensities and identifications in BD $+30°$ 3639. Bappu has measured line intensities and profiles at 10 Å/mm in the blue and 20 Å/mm in the red for HD 192 103, HD 192 163, HD 192 641 and HD 191 765 and has obtained infra-red spectra of HD 192 103 and 192 163.

Westerlund and Rodgers (1959) have identified numerous Wolf-Rayet stars in the Large Magellanic Cloud.

The bright southern Wolf-Rayet star, γ^2 Velorum, has been studied spectroscopically by Sahade. The energy distribution in its spectrum and the intensities of the emission features have been observed by Aller and Faulkner with a spectrum scanner at Mount Bingar.

Code and his associates have observed the spectral energy distributions in northern Wolf-Rayet stars with a spectrum scanner.

ATMOSPHERES OF GIANT AND SUPER-GIANT STARS

F-type super-giants. Semi-regular variations in the velocity of the super-giant *Deneb* were noted many years ago by Paddock, and the problem has been studied more systematically in recent years by Abt (1957). At La Plata, A. Feinstein finds that the super-giant *Canopus*, (F O I b-II) presents semi-regular variations with a period between 40 and 70 minutes and an amplitude of about 4 km/sec. A longer period of about 80 days and an amplitude of 4 km/sec can also be detected. Another super-giant of the same luminosity and spectral class (absolute magnitude about $-4{\cdot}5$) did not show radial velocity variations. Both of these stars are located between the regions occupied by the β Canis Majoris stars and the Cepheids.

Studies of late-type stars. At the abnormally low maximum of the S-type long-period variable R Cygni, Deutsch and Merrill found an array of hundreds of sharp metallic emission lines, representing all the expected transitions in abundant atoms and ions except those to the ground level, which were mostly missing. At the 1958 maximum, which was brighter than average, the usual S-type absorption lines spectrum was shown. From these spectroscopic features and accompanying radial-velocity effects, Deutsch and Merrill proposed a complex, stratified model of the R Cygni atmosphere in which the temperature rises outwards from the photosphere (as in the solar chromosphere), reaches a maximum and then falls off to a low temperature. Shock waves may play a role in the heating and levitation of the atmosphere (Deutsch and H. Liepmann).

The S-type variable, π^1 Gruis, whose interesting properties were noted by Feast, has been studied with a spectrum scanner by Aller and Faulkner at Mount Stromlo.

Mira-variables of type M e are being studied by Keenan at the Perkins and Mount Wilson Observatories. Low dispersion data are used to compare the behaviour of stronger lines and bands near maximum light in a number of stars observed over as many cycles as possible; he secures data on the Balmer emission lines, the calcium 4226 Å and other absorption lines, and certain band intenity ratios, AlO/TiO and VO/TiO. Coudé dispersion is used to study the sodium D lines.

The spectral features of M, S and C stars have been studied by Fujita and his associates (1959) in the visual region. A comparison of theoretical and observed profiles of C_2 and CN bands in 8 carbon stars have been made by F. Kamijo (1959). Fujita and Yamashita have studied V Aquilae in the visual and infra-red regions on coudé plates (1960). Nishimura (1958) has carried out a spectrophotometry of W Cygni, obtaining an excitation temperature of 2800 °K from a curve of growth analysis using TiI and TiO lines.

From a study of the far ultra-violet emission lines in M giants Bidelman finds that the occurrence of permitted Fe II emissions is a 'normal' phenomenon. Several lines are weakened by overlying absorption due to the resonance sodium 3302 Å lines. Hence these emissions are of chromospheric or sub-chromospheric origin rather than of coronal origin. Presumably they are formed in the shock-wave or hot lower regions of the atmosphere.

Circumstellar envelopes. Deutsch has established that virtually all M giants and supergiants exhibit circum-stellar absorption lines at H and K. The strength of these lines correlates very well with spectral types among M giants with absolute visual magnitudes fainter than −2·5. Perhaps mass-ejection sets in abruptly at type M o among these stars and increases its rate steeply with advancing spectral type, or the rate of mass ejection is fairly constant among all late-type giants, the observed enhancement being due to a decrease of second ionization of the metals towards the lower temperatures. Deutsch concludes that it is more likely that the ejected material is mostly highly ionized, but the problem can be studied only theoretically until observations are secured in the vacuum ultra-violet. Furthermore, the ionization is probably not uniform throughout the envelope but decreases at greater distances from the star. Besides α Herculis, several other binaries showing late-type giants exhibit evidence of cool envelopes many times larger than the star. Notable examples are η Geminorum M3II, which has a G8III visual companion, and *Antares* M1Ib, which has a B4V companion that excites a nebula produced from the layers ejected from the supergiant component. The spectroscopic binary μ Ursae Majoris, M o III, likewise shows absorption components that do not exhibit the orbital Doppler shifts of other spectral lines. Circumstellar lines are found in some K-type super-giants and in some long-period variables; χ Cygni shows a doubling of all strong resonance lines in absorption. Another example is *Mira*, which has a hot, faint companion, presumably an incipient white dwarf. Deutsch suggests that the variability of this hot companion may be produced by infalling material from the late-type star.

Complex emission lines are sometimes seen with superposed absorption cores due to the circumstellar envelopes. In the spectrum of an M giant or super-giant, the circumstellar core of the K line first appears at an expansion velocity of about 20 km/sec, near the shortward edge of the chromospheric emission lines. With advancing type and increasing luminosity, it grows in strength and gives a smaller expansion velocity. Other abundant atoms and ions begin to show circumstellar cores when the core of K exceeds about 300 milli-angstroms equivalent width.

Absolute magnitude effects. In 1957 Wilson and Bappu called attention to the existence of a relation between the width of the reversed H and K lines in late-type stars and their absolute magnitude. Specifically the logarithm of the width of the H and K reversal depends linearly on the absolute magnitude. It is independent of the intensity of the reversal and of the spectral type (surface temperature) of the star. The correlation extends from stars as bright as −6 absolute magnitude to faint main sequence stars, *i.e.* over a range of 15 magnitudes. Wilson (1960) has used measurements of the widths of bright reversals in H and K in the Sun and yellow giants of the Hyades to correlate log ($\Delta\lambda$)—and M_v. For giants and super-giants the probable error of a single measurement is ±0·26 magnitudes, whereas the probable error due to intrinsic scatter is ±0·20 magnitudes. Probably the scatter is caused by stellar rotation.

Wilson will publish a complete list of results soon. The color-magnitude diagram which he finds agrees quite closely with Sandage's results on NGC 188 as far as the location of the break-off point from the main sequence and the lower boundary of the sub-giant region.

Bidelman has studied the Hα line in many high luminosity stars to see if Hα emission can be used as a luminosity indicator. There is a well-marked correlation between emission strength and luminosity although some stars (*e.g.* P Cygni) show abnormally strong emission for their luminosity. Also binaries often have abnormally strong emission.

SHELL STARS AND EMISSION LINE STARS

A number of new stars with bright Hα emission lines have been discovered in the Orion region by G. A. Manova at Abastumani (1959). These stars plus those discovered by Haro and Joy form an elongated system with one condensation in the CO Orionis region and one in the region of emission nebulae S 280 near FU Orionis. For Hα emission stars see also M. V. Dolidze (1960). Lists of many new early-type stars with emission lines have been published by M. V. Dolidze and V. V. Viazov (1959) and by Dolidze (1959).

Bright emission-line shell stars are being studied at Liège with objective prisms.

Individual Stars

Pleione. Using high dispersion spectra obtained in 1943–6 and 1951–2 Bappu has tried to work out a physical picture of the shell of *Pleione.*

Individual Stars

υ Sagittarii. Mrs Hack has studied high dispersion spectra in red and yellow to find the profile variations in Hα and the variations of absorption lines and emission component and the correlation between phase and relative strength of the so-called B and F components of the spectrum.

HD 50138. Houziaux has described the spectrum of this B e star, giving the observed wave-lengths and profiles of the Balmer lines. The rotational and turbulent velocities are 150 and 22 km/sec respectively.

48 *Librae.* Miss Underhill finds the radial velocity to vary in a more or less periodic manner with a period of about ten years. Analysis of the spectrum is complicated because the observed stellar lines are confused with those of the overlying shell.

Shell stars and P Cygni stars are also being investigated at Haute Provence by Ch. Bertaud.

γ Cassiopeia. A spectro-photometric study has been undertaken by Bojartchuk (1958).

Various shell and P Cygni stars, as well as A emission stars are being investigated by Bertaud and associates at Haute Provence.

The V/R variables, HD 20 336, β^1 Monocerotis, and π Aquarii have been discussed by McLaughlin (1958). Positive wave-length shifts of both central absorption and emission accompany the maximum values of V/R and negative shifts go with minimum V/R. He concludes that his alternately expanding-contracting model is not satisfactory and the best model is that proposed by Struve in which an elliptical ring has an advance of the line of apsides.

SUB-DWARFS

An O star discovered by Slettebak and Stock has been found to be an O-type sub-dwarf by G. Münch (Münch and Slettebak, 1959). The star may be a member of the Lacerta association and possibly represents the evolutionary product of the high-luminosity star that gives rise to the association.

In the course of a survey of southern proper-motion stars, Przybylski has found about 20 new sub-dwarfs. A few others have also been studied by Buscombe and Miss Morris. At Radcliffe T. J. Deeming has found a considerable number of southern sub-dwarfs.

Review articles have been published by Buscombe (1959) and in the report on the conference on sub-dwarfs at Pittsburgh *Astr. J.*, **65**, 391.

In sub-dwarfs, the ratio of metals to hydrogen is very much lower than in normal stars. Hence not only the line spectrum, but the continuum as well are affected by this difference in composition. Stars, which appear to be F-type or even A-type stars are found to be actually G stars on the basis of detailed examinations. Thus the Burbidges, Sandage, and Wildey (1959) showed that when appropriate corrections are made for the blanketing effect, the *UBV* colors for HD 19 445 are the same as for the Sun. Melbourne (1960) obtained spectral energy scans of HD 19 445 and HD 140 283. He then corrected the energy distributions for blanketing and compared the results with theoretical fluxes from model atmospheres to obtain the effective temperatures for these stars. He also examined the quantitative effects of line blanketing (with and without the hydrogen lines) on the *UBV* colors. When the effects of lines are removed from both main-sequence and sub-dwarf stars, it is found that both can be made to fit on the same curve relating $(U-B)$ and $(B-V)$ colors.

The composition of HD 140 283 has been studied by Baschek (1959) from Mount Wilson coudé plates. Greenstein and Aller (1960) using coudé plates secured at Mount Wilson and Palomar have examined the three G-type sub-dwarfs, HD 19 445, HD 140 283 and HD 219 617 and the A-type sub-dwarf HD 161 817. As compared with the Sun, they find that the metal/hydrogen ratio shows a deficiency of 20 for HD 219 617, 40 for HD 19 445 and 100 for HD 140 283; Baschek finds an even greater metal deficiency than this for HD 140 283. The deficiency is not the same for all elements, *e.g.* nickel seems less depleted than iron, and cannot be accounted for by diffusion effects operating in a normal atmosphere for long periods of time. Nucleo-genesis arguments have been proposed to account for these differences.

PECULIAR STARS AND MAGNETIC STARS

A number of investigators have undertaken searches for peculiar and metallic-line stars, or have made more detailed studies of individual objects with higher dispersion. Slettebak and Nassau (1959) carried out an objective-prism survey followed by slit spectrograms to identify 48 new ML stars and 15 new peculiar A stars.

M. and C. Jaschek (1959) have surveyed the peculiar stars in the Henry Draper catalogue covering the spectral ranges B 8 – F 0 and the 5th to 7th magnitude and south of $\delta = -30°$. They give detailed line identifications for certain 'peculiar', 'silicon' and 'silicon—λ4200' stars.

At the Merate Observatory, Mrs Hack is undertaking the classification of A p stars (using low dispersion material) and is doing quantitative analyses with Mount Wilson coudé material.

On the basis of analyses of several magnetic stars studied by herself and by the Burbidges, Mrs Hack concludes (1958) that the abundance excesses of the rare earths are larger for stars that show magnetic fields with an inversion of polarity than for stars which show even stronger magnetic fields, *e.g.* HD 133 029 but without an inversion of polarity.

Mrs Hack also finds that the peculiar F stars β Coronae Borealis and λ Equilei show a peculiarity common to metallic-line stars, *i.e.* the electron pressure obtained from metallic lines is about ten times lower than the electron pressure obtained from Balmer-line profiles. There also exists the possibility that different patches on the surface correspond to areas of different electron pressure and temperature.

Interest continues to be focussed on the magnetic fields associated with peculiar A stars (cf. also Com. 43 report). One problem is the use of the observed line intensities to deduce the strength of the magnetic field. The magnetic field influences the atomic absorption coefficient and has an effect on the transfer equations. The problem has been discussed by Unno, Warwick, and more recently by V. E. Stepanov (1958, 1960).

In this connection Stawikowski of Torun (1959) has attempted to check the presence of strong magnetic fields in stellar atmospheres through the effects of magnetic intensification of spectral lines. He compared the total absorptions of lines with rich and poor Zeeman patterns in the spectra of 16 RR Lyrae type variables, using Fe II and Eu II lines. He found significant intensification of lines with rich Zeeman patterns for four variables, the same which deviated towards later spectral classes from the period-spectrum relation as found previously by W. Iwanowska. Presumably strong magnetic fields are present in these stars. Short-period variables of population I seem more likely to have strong magnetic fields.

The following report on *magnetic stars* has been prepared by H. W. Babcock (apart from the last three paragraphs):

Magnetic Stars

'The A-type star HD 215 441 has been found to have a magnetic field of 34 kilogauss, the strongest known in nature. The field is sufficiently strong and uniform so that many lines show distinct resolution into the π and σ groups of components of the Zeeman patterns, with overall widths of the order of one angstrom. Other sources of line broadening are relatively insignificant. The mean field intensity obtained from nine resolved lines on four plates is $+34400 \pm 266$ gauss. Twenty plates distributed over an interval of a year all show a strong field of positive polarity, but with irregular fluctuations. These fluctuations, as well as observed variations in velocity in the range $+3$ to -9 km/sec, are attributed to intrinsic magnetic-hydrodynamic processes within the star. The sharpness of the components of the Zeeman patterns shows that the field is remarkably uniform, while the relative strength of the π and σ components permits estimation of the mean angle between the field vector and the line of sight—roughly 50°. Apparently the star's field is essentially dipolar and the axis of the dipole, as well as the axis of rotation, has at most only a moderate obliquity to the line of sight.

'The energy density, $H^2/8\pi$, of the magnetic field at the surface of HD 215 441 is $4{\cdot}6 \times 10^7$ ergs/cm^3; therefore, if the star is uniformly magnetized, the total internal magnetic energy is about 10^{41} ergs—roughly equivalent to the energy radiated by the star in five weeks. This is probably a minimal figure, for there are good arguments that the field in the deep interior is much stronger than at the surface. The influence of magnetic fields has been neglected in current theories of stellar structure, but the strength of the field of HD 215 441 suggests that this subject deserves further consideration.

'There is evidence in the sharpness of the π profiles that local turbulent velocities are insignificant at the surface of the star. This, as well as the uniformity of the field, can be attributed to the dominance of magnetic forces in the outer layers. The large-scale velocity fluctuations, of the order of $\pm$ 6 km/sec, must originate at a depth at least as great as that at which the local kinetic energy of gas motion is equal to the magnetic energy density; this is estimated to be one tenth of the stellar radius below the surface.

'The general appearance of the spectrum of HD 215 441 is not particularly unusual compared to other A o p stars, except for the line profiles and for the anomalous presence of several lines of Fe III. It may be concluded that a very strong magnetic field does not necessarily result in an extreme degree of spectral peculiarity.

'Measurement of magnetically unresolved lines in the spectrum shows that they yield an effective field intensity about one third as great as that of the true field, which is derivable with unusual precision from the resolved Zeeman patterns. This result was anticipated in 1946. Thus the effective field strengths measured for most stars can be multiplied by a factor of about 3 to yield the true field intensity.

'Prominent sharp H and K lines of Ca II are judged to arise in a circum-stellar cloud around HD 215 441. These lines show a field of +600 gauss. Because the field varies inversely as the cube of the distance from the center, it is calculated that the Ca II cloud has an effective height of 1·2 stellar radii above the surface. The Ca II lines also show a mean outward relative velocity of 5 km/sec, suggesting that mass loss, probably related to the strong field, proceeds at a significant rate.

'The southern star HD 187 474 has been found to be one of the slowest of the known magnetic variables. Observations in 1957 suggested that it might be unique in having a constant field; the value was about −1870 gauss. Gradually, however, the field weakened and reached zero in the summer of 1959. By June 1960, the polarity had reversed and the field had strengthened to about +2000 gauss. The star is also an outstanding spectrum variable, for an unusual number of lines, including many of chromium, show large intensity changes that occur very slowly. The observations to date suggest that HD 187 474 may be a regular magnetic variable with a period of perhaps six years. Its relationship to the typical α variables with periods of a few days deserves study.

'Additional observations have resulted in improved elements of variation for the outstanding magnetic variable 53 Camelopardi. The period is 8·025 days and the range of the effective field is from −5 to +3·5 kilogauss, with some irregularities in amplitude. The lines are systematically sharper early in the cycle of variation, counting from positive cross over, when the field seems intrinsically weak. Later, the lines become much wider, remaining so at negative cross over, and there are marked variations of line intensity. Ti II, for example, becomes much stronger when the field has negative polarity. Mg II is unusually weak, but shows variations, as Deutsch has noted. When the field is strong, the line profiles indicate that it is almost purely longitudinal.

'The large-amplitude magnetic variable HD 32 633 was once suspected of having a 4-day period, but additional observations now prove that the magnetic variations, though rapid, are irregular. The extreme observed range is from −5870 to +2220 gauss. Other characteristics are the occasional appearance of an extreme "cross over effect". Sometimes this occurs when the mean field is far from zero. The absence of spectral variability is attributed to uniformity of surface composition resulting from mixing by the irregular intrinsic magneto-hydrodynamic fluctuations.'

The A0*p* star HD 125 248, for which Babcock has measured a magnetic field that varies between −1900 and +2100 gauss with a period of 9·3 days also shows synchronous variations in line strength and radial velocity. Deutsch found that the lines of Eu II, Gd II and Ce II showed one characteristic variation pattern, those of Cr I and Cr II a second and different pattern, and those of Fe I, Fe II and Ti II a third pattern. He attempted to explain these changes with a rigid rotator model in which the geometric patterns of the different spectroscopic areas and the associated magnetic field, H, is obtained from observed variations of H, radial velocity and line strength. From a careful study of available coudé material, he has shown that the

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data are compatible with the model and has mapped the stellar surface and magnetic field. Deutsch and Miss Middlehurst find similar agreement with the rigid rotator model for HD 124 224 (A 0 *p*, $P = 0{\cdot}52$ days).

With the 120-inch coudé-spectrograph, Bidelman has studied the spectra of sharp-line early stars with high dispersion. Many of these stars are peculiar and much remains to be done in these predominantly magnetic stars. He has found strong lines of P II in the manganese star κ Cancri and several other objects.

G. and M. Burbidge (*Ap. J.* **127**, 557, 1958) have suggested an explanation for the anomalous strength of Cr and Mn in peculiar A magnetic stars in terms of surface nuclear reactions of the type (n, p) and $(n, 2n)$ acting in a sequence starting with the most abundant isotope normally present Fe^{56}.

METALLIC LINE STARS

A catalogue of 476 metallic-line and peculiar A stars has been prepared by Bertaud (1959) and a supplement is in press bringing the total number up to 660. He is also carrying out further observations of metallic line and peculiar A stars at Haute Provence.

The Jascheks (1959) have classified 23 ML stars (B 8 – F 0) and find that the hydrogen-line spectral classification is related to the $(B-V)$ color of these objects, permitting them to be placed in physically meaningful sub-groups. They find that the principal quantum number, n, of the last visible Balmer line is approximately constant, a result which conflicts with the super-giant-like electron pressure derived for several ML stars by the curve of growth method.

Mrs Hack (1959) and Mrs Böhm-Vitense (1960) also conclude that the temperature of a ML star is essentially the same as that of main sequence stars of the same hydrogen line intensity. The K line indicates an earlier spectral class and the metallic lines a later spectral class. There is a correlation between colors and degree of metallicism in the sense that the reddest stars have a more pronounced metallicism. The Jascheks (1960b) conclude that in a majority of ML stars, the elements behave normally except Ca, Sc, Ni, Sr and Y. All over-abundant elements fall after the iron peak while abnormally abundant elements lighter than iron are under-abundant.

Mrs Hack finds that the metallic-line stars are located on a sequence that runs parallel to the main sequence about a half magnitude above it and that the strengthening of metallic lines is due to an actual excess of metallic abundances of about a factor of 3 or 4 compared with the Sun. She also postulates an agency (similar to that proposed by Greenstein) that produces abnormal ionization. On the other hand, Mrs Böhm-Vitense concludes that all proposals brought forth so far to account for ML spectra cannot explain the observed results. She finds that in high atmospheric layers, the electron pressure is lower, whereas in deeper atmospheric layers it is about equal to the electron pressure in main-sequence stars of the same temperature. Possibly the peculiar features of the spectra can be accounted for by an atmosphere that is distended in its outer layers, possibly by magnetic fields.

From a spectrophotometric study of stars with strong metallic lines, Kuznetzova finds that that the absolute spectrophotometric gradient of ML stars in the photographic and ultra-violet spectral regions varies with time.

A study of the metallic-line star 60 Leonis by Galkin (1958) confirms earlier results by Mustel and Galkin and shows that the chemical composition of ML stars on the left end of the sequence of these stars (in the region A 4 – A 6) differs less from that of main sequence stars, than does the chemical composition of stars in the spectral region F 0 – F 6. Mustel and Galkin (1960) find that the hydrogen line profiles in silicon stars are the same as in A 0 V stars, while those in the Mg and Mn stars are narrower and flatter than in spectra of A 0 III stars.

Abt finds that all metallic line stars are spectroscopic binaries (see report for Commission 30).

Spectrophotometry of ML stars on the Chalonge system is being carried out by C. Van't Veer.

STELLAR CHEMICAL COMPOSITIONS

Since the subject of stellar chemical compositions involves applications of certain aspects of theoretical astrophysics to spectroscopic data, a critical discussion of this subject properly belongs to Commission 36. Some aspects of this problem, *i.e.* those concerned with the application of well-known techniques (such as the curve of growth) to individual stars may be summarised here.

For about 50 normal stars from O 9 to K 5 Mrs Hack (1959) has examined the dependence of electron pressure, effective gravity, excitation and ionization temperature, line depth and turbulent velocity on spectral class and chemical composition. For these stars she finds solar abundances, but for super-giants from O 9 to B 3, she suggests that helium, carbon, nitrogen and oxygen are systematically more abundant by a factor of two. These super-giants and the magnetic and metallic line stars may fall in a group 0·5 to 1·0 magnitudes above the main sequence.

The compositions of the B stars: γ Pegasi, 22 Orionis, 15 Canis Majoris, ξ^2 Canis Majoris and 114 Tauri have been examined by Aller and Jugaku (1959) and by Aller, Jugaku and Boury using the Pecker theory with appropriate model atmospheres. The abundances derived for elements common to the B stars and the Sun (as analysed by Goldberg, Müller and Aller) appear to be in good agreement. Jugaku has derived the hydrogen/helium ratio in B stars by model-atmosphere methods (1959). An accurate abundance ratio is difficult to derive because of uncertainties in the line broadening data.

In the high latitude super-giants, 89 Herculis and HD 161 796, Abt (1960) found that elements formed by the capture of slow neutrons are deficient, whereas elements formed in equilibrium mixtures seem to have normal abundances. These stars are so far above the plane that they probably did not originate there.

In about 30 G dwarfs of both high and low velocities, Helfer and Wallerstein find that the abundance of metals range from an excess of about a factor of two compared with the Sun to a deficiency of about a factor of five. They found no star for which they could be certain of an abundance of metals greater than that observed in the Hyades G-dwarfs, *i.e.* about 25% greater than in the Sun. They find that almost every metal-deficient star and some normal stars are deficient in manganese relative to iron, chromium and nickel. They find an excellent correlation between ultra-violet excess and metal deficiency, and are looking for correlations between stellar abundances and their galactic orbits. Helfer and Wallerstein are studying the K giants in the Hyades in order to use them in further abundance studies in K giants. They are making applications to some late G and early K giants that are members of visual binary systems of known orbits. The parallaxes of these stars are being determined by O. C. Wilson from his K-line method. A study of one K giant in each of the globular clusters M 13 and M 92 along with the extreme high velocity star HDE 232 078 and a star in the galactic cluster M 41 has been published (1959).

From a plot of Eggen's photo-electrically measured colors against spectral type for main-sequence stars later than A 5, Olin Wilson finds that although the scatter of points about a mean curve is small from A 5 to G 5, the scatter increases at lower temperatures. This widening of the main sequence is too great to be attributed to errors in colors or spectral classes and occurs in that region of the spectral sequence where the supply of electrons from hydrogen is diminishing to the point where the metals are coming into equilibrium with their own electrons. Wilson attributes the spread to a variation in the metal/hydrogen ratio, finding that among main sequence K stars, a total range of metal/hydrogen ratio over a factor of a hundred is needed to account for the spread. This conclusion is supported by spectroscopic observations of the H and K lines, the Balmer lines, and other spectral features.

HD 101 065, classified in the HD as a B5 star, has been observed by Przybylski as a peculiar G star with a high metal content. The abundances of calcium and iron are relatively low, whereas strontium, barium and some rare earths appear to be very over-abundant.

Hydrogen-deficient Stars

The helium rich B star, HD 96 446 (discovered by the Jaschecks (1959c)) and also the late-type hydrogen deficient star RY Sagittarii have been studied spectrophotometrically by Aller and Faulkner at Mount Bingar. Bertaud is studying the hydrogen deficient star HD 30 353.

MISCELLANEOUS STUDIES

K. O. Wright (1959a) has studied the line intensities in Arcturus. The spectrum of ρ Cassiopeiae has been investigated by G. Larsson-Leander, by Bertaud and by Deutsch. AG Pegasi has been investigated by Larsson-Leander, by Bertaud and at the University of Michigan. Sahade has undertaken studies of V346 Centauri, V453 Scorpii and W. Crucis. ζ Horologii is being investigated by Sahade and Hernandez.

Visual Binaries. Slettebak has observed the spectra of both components of 150 visual binaries. Spectral classes, luminosity classes and rotational velocities are estimated for all stars; these will be used to discuss evolutionary aspects of visual binaries and luminosity calibrations for certain peculiar stars.

Stellar rotation. The statistical relation between axial velocity of rotation and spectral class and luminosity have been studied by Kopylov and Bojartchuk (1959) from published data for 2362 stars. The results are discussed in terms of modern ideas on stellar evolution. Slettebak finds that at high galactic latitudes, the axial rotation in type I stars appears to be smaller than for similar objects near the Sun.

SPECTROSCOPIC BINARIES

(a) β Lyrae

β Lyrae continues to stimulate much interest. In 1959 an international campaign was carried out to secure systematic observations of this star.

Abt, Jeffers, Sandage and Gibson studied the visual multiple system (ADS 11745) containing β Lyrae. From spectra and astrometric measurements of the four brighter components and photo-electric photometry of all six, they conclude that the system is physical but that all except β Lyrae itself are members of the main sequence. They find an absolute visual magnitude of $-3{\cdot}9$ for β Lyrae, the secondary star being the more massive. Struve and Sahade (1958), from studies of the system in the infra-red, find no evidence of a late-type companion.

Struve is publishing soon a complete list of absorption lines belonging to the B 8 component of the system. The spectrum seems to be abnormal in that lines of He I and also of Fe I, Fe II, Fe III and Ti II are abnormally strong. Thus the spectrum reminds one of υ Sagittarii, but the anomaly in β Lyrae is less pronounced. The sodium and helium lines in the visual spectrum of β Lyrae have been studied by Houziaux (1958) who finds that one of the components of the sodium D lines comes from the shell around the system, one is of inter-stellar origin, and one varies in the same way as the B 8 primary star spectrum. He has also estimated the absolute magnitude of the system.

Using curve of growth methods, Bojartchuk (1959) studied the abundances of elements in the atmosphere of the bright component of β Lyrae and a number of standard stars. He finds that hydrogen is five times less abundant and helium is fifty times more abundant than in a normal star.

From Mount Wilson plates, Sahade (1958b) concludes that β Lyrae is a system formed by a B 8 giant primary plus a more massive under-luminous bright-line secondary that has evolved faster than its companion and is now below the main sequence in the left region of the H-R diagram. See also Sahade, Huang, Struve and Zebergs (1959).

(*b*) *Individual Stars*

Spica (α *Virginis*). Struve, Sahade, Huang and Zebergs suggest that although the spectra displayed by the components are B 2 and B 3, the secondary is actually of spectral class B 7 and its atmosphere mimics that of a B 3 because of radiation from the hotter star. The period of rotation of the apsidal line is 133 years.

The spectrum of 27 Canis Majoris in 1957–59 has been discussed by Mrs Ringuelet-Kaswalder, Sahade, and Struve (1960), and in 1960 by Sahade (1960). Mrs Ringuelet-Kaswalder has made a thorough investigation of this object by using the old Yerkes and Lick material and more recent Mount Wilson and Cordoba spectra; she finds that the underlying stellar lines vary in velocity and suggest a period of six hours.

The orbital elements of γ *Andromedae* have been given by Maestre and Wright (1960). Stanger and Hynek have discussed the composite spectra of 5 Lacertae.

SPECTROSCOPIC STUDIES OF ECLIPSING BINARIES

ϵ *Aurigae* has been studied by Struve, Larsson-Leander, Mrs Hack, Sahade and others.

Sahade concludes that the secondary component of ϵ Aurigae has a mass either larger or not very different from that of the primary component, and therefore it must be an under-luminous star which is older from the evolutionary point of view.

Mrs Hack, from a study of high-dispersion spectra, finds irregular changes in the profiles of spectral lines caused by variations of turbulence (mostly micro-turbulence).

K. O. Wright (1958) has studied the chromospheric lines.

Sahade (1960) has considered evolution in close binary systems, and concludes that W Ursae Majoris type stars are old systems that evolved from early-type systems by mass loss. The idea was suggested by the fact that W Ursae Majoris stars belonged to clusters that were a hundred million years old (Sahade and Frieboes 1960). Sahade has also proposed a model for 29 Canis Majoris and similar systems (1959*a*). See also Struve, Sahade, Zebergs and Lynds (1958).

Algol (β Persei). Studies of the infra-red spectrum by Sahade and Wallerstein (1958) showed that no late-type lines were present.

Y Cygni. Struve, Sahade and Zebergs (1959) obtained the orbital elements for this star and obtained a rate of apsidal motion in good accord with Redman's and Dugan's results.

The eclipsing binaries *DO Cassiopeiae* and *AO Cassiopeiae* have been studied by G. Mannino (1958, 1959).

Emission lines in the spectra of AR Pavonis have been studied by A. D. Thackeray (1959).

W Serpentis has been studied in great detail by Mrs Hack. The star has a shell spectrum with strong, sharp, deep lines of ionized elements, *e.g.* Fe II, Ti II, Cr II and emission lines of Si II, Mg II and [Fe II]. The underlying stellar spectrum, which she suggests is similar to that of α Persei F 5I b, displays broad rotational profiles.

The interpretation of the spectrum is complicated by the shell lines and further observations are necessary to decide whether we observe gas streaming as suggested by Sahade and Struve (1958) or a normal rotational distortion.

31 *Cygni.* Wright and Lee have discussed the atmospheric effects at the 1951 eclipse (1959) and the inner chromosphere of the K-type component (1959*b*).

ζ *Aurigae.* Wright (1960) gets a mass ratio of 1·2 from the secondary spectrum (in good agreement with Popper's result) but the geometry of the system indicates a mass ratio of 2. The secondary is B 6·5, the luminosity is $M = 1{\cdot}6$. Grant and Abt (1959) from 3-color photometry of the 1955 ingress of the system found an absolute visual magnitude of $-2{\cdot}2$ for the K 4 II primary if it is slightly evolved.

V 367 *Cygni.* A. M. Heiser finds this eclipsing system to have a rich spectrum due to gas streams. The primary (A 2 Ib) is less massive than the invisible secondary. Probably both stars fill the inner Lagrangian surfaces and are losing mass.

VV Cephei. Searches for the secondary spectrum have been made at Victoria. The egress phase has been studied by B. Peery at Michigan. It is also being studied by Bertaud.

CEPHEIDS AND PULSATING STARS

Abt (1959a) has examined Wesselink's method for getting the absolute magnitude of pulsating stars and concludes that the success or failure of the method depends on whether or not the total radial expansion is much greater than the atmospheric scale height. During the mid-rising branch of the light curve of RR Lyrae, the ultra-violet excess, the hydrogen emission lines, the double absorption lines, and the hump in the light curve are all attributed to the existence of a shock wave and the hot emitting region behind it.

Mlle A. M. Fringant has studied δ Cephei, and RR Lyrae from the point of view of the Chalonge parameters to establish basic relationships.

Oke has measured the absolute energy distributions in η Aquilae and δ Cephei using high-dispersion spectra to correct the effects of the low-wave-length resolution of the spectrum scanner and to get the absolute energy distribution in the continuum. He gets the effective temperature by comparing the measured fluxes with model-atmosphere fluxes and concludes that the effective temperature is 6140 °K for F 6·5 Ib and 5320 °K for G 2 Ib. The radius-displacement curves computed from the observed magnitudes and derived fluxes are in good agreement with those obtained from the radial-velocity curves. The derived radii and temperatures are used to compute absolute magnitudes for these Cepheids which are in good agreement with those obtained from Kraft's study of the Cepheids in galactic clusters, thus suggesting that the temperature scale used is approximately correct.

For RR Lyrae, the matching of the observed absolute energy distribution with model atmospheres give the effective temperature and surface gravity. At maximum light the effective temperature is 7200 °K and the energy distribution is similar to an F 2 II star; the temperature may depend on the 41-day cycle. The surface gravities obtained from the observed energy distributions reflect accurately the accelerations predicted by the radial-velocity curve. Observations were also obtained for T Monocerotis (27^{d} Cepheid) and SU Draconis (RR Lyrae star).

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The Jascheks (1960) find that the Ca II emission in Cepheids obeys the Wilson-Bappu relation.

Individual stars

RT Aurigae: Bappu has measured the radial velocities of Fe I and Fe II lines in this 3·7 day Cepheid and gets the curve of growth.

FF Aquilae has been found by Abt (1959*b*) to be one of four known Cepheids in spectroscopic binaries. He has also derived a new velocity curve for SU Cassiopeiae (1959*c*).

BL Herculis, which has many of the characteristics of stars of the same period in globular clusters, has been studied by Hardie and Abt (1960). Deutsch has observed RU Camelopardi, a Cepheid with carbon bands.

β Canis Majoris stars

Struve, Sahade, and Zebergs (1960) studied σ Scorpii in 1960 and found no infall of hydrogen atoms relative to ionized oxygen toward the star, contrary to the results from 1954 plates discussed by Struve, McNamara, and Zebergs. Struve finds that σ Scorpii shows a strange systematic difference in radial velocities of hydrogen and helium relative to those of ionized oxygen.

NOVAE AND NOVA-LIKE STARS; 'SYMBIOTIC' STARS

The problem of novae has been studied from the theoretical point of view by Gorbatsky (1960). He suggests that gas clouds ejected by a nova have greater velocities of motion and collide with the main envelope of the star. This process leads to the passage of kinetic energy of ejected matter into the thermal energy in the layers of the principal envelope, which is accompanied by certain spectroscopic phenomena. After the collision, the temperature of these layers may rise to values between 20 000 °K and 400 000 °K which explains the presence in nova spectra of emission lines of highly ionized elements, O III, O V, O VIIm N IIIm N IV, N V, Ne III Ne V, and at the same time the presence in the main spectrum of bright lines of neutral and once ionized atoms.

N. Herculis 1934. Using curve-of-growth methods and Shajn's spectra, Mustel and Bojartchuk (1959) have found that the abundances of metals are the same as in standard stars, whereas that of the elements O, C and N are much greater. They also studied (1958) the absorption spectra at the light maximum. Mustel and Kumaigorodskaja (1958) have studied the emission spectra of the same nova.

RS Ophiuchi 1958 has been studied by observers at the University of Michigan and at the Haute Provence Observatory by the Dufays, Bloch and Bertaud, who have secured spectra covering the region 3500-8900 Å.

Nova Herculis 1960 has been studied with objective prism techniques at Liège (where the emphasis has been on the infra-red) and at Uppsala. Slit spectrograms of medium dispersion were obtained at Stockholm by Larsson-Leander. At Haute Provence, Bloch and Dufay observed the star with high dispersion in its brighter phases, while Chalonge has observed it with the quartz spectrograph. The French observers noted the resemblance to the Wolf-Rayet stars. The star has also been observed by McLaughlin and his associates at the University of Michigan.

RR Telescopii has been observed by J. Landi Dessy and J. Sahade and by Thackeray who notes an increase towards higher excitation as the [Fe VI] and [Fe VII] lines continue to increase and the fluorescent O III lines are strong. Longward components have been discovered by Thackeray on coudé spectra.

Spectral scans have been secured at Mt. Stromlo by Aller and Faulkner.

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η *Carinae* has been studied in the infra-red by Thackeray who finds a deficiency of oxygen. At Mount Bingar Aller and Faulkner have made spectrophotometric measurements of this star with the photo-electric spectrum scanner.

The *super-nova* in NGC 4496 discovered by Humason has been observed by Bloch, Dufay and Chalonge at Haute Provence (1960) in the interval 1960 April 21 to May 23.

From a study of the super-nova that appeared in 1954 in the irregular galaxy NGC 4214, McLaughlin (1959) showed that some strong absorption-like minima might be interpreted as absorption lines of He I, and several weaker minima gave displacements that were fairly accordant (of order 5 000 km/sec) when interpreted as other lines of He I, N II, O II etc., *i.e.* this super-nova spectrum could be interpreted as a very hydrogen-poor B-type spectrum. similar interpretations were obtained for the super-novae in NGC 3992 (1956), NGC 4374 Si(1957), and NGC 5668 (1954), (McLaughlin 1960*a*).

Spectrophotometric studies of *AX Monocerotis* and *FU Orionis* have been carried out by R. A. Bartaya and E. K. Kharadze at Abastumani. FU Orionis seems to show a surplus of radiation in the ultra-violet region of the spectrum.

An outburst of *SS Cygni* has been observed in *U*, *B* and *V* colors by Grant and Abt (1959).

At Haute Provence Miss Marie Bloch has studied the following symbiotic stars: T Coronae Borealis, FR Scuti, RY Scuti, MWC 603, BF Cygni, CI Cygni, AG Pegasi, A Andromedae, AX Persei. Her observations cover the range 3700-6800 Å and each plate is carefully calibrated to give the relation between density and intensity and with the aid of a comparison star. Since August 1960 the spectral range has been extended to 3100 Å thanks to a two-prism spectrograph provided by D. Chalonge. In 1959 Z Andromedae brightened sufficiently to be observed at dispersions of the order of 10-20 Å/mm with the coudé. Emission lines of high excitation were reduced in intensity and there were prominent absorptions.

Dossin (1959) of Liège, studied BF Cygni in the red and infra-red at Haute Provence, investigating the principal emissions of helium, oxygen, sulphur, nitrogen and hydrogen and the effects of short-term variations.

The non-stable star AG Draconis has been studied spectrophotometrically by Arakelian and Ivanova, while Bartaya and Mirzojan have studied the non-thermal continuous emission in this star.

The continuum of the variable X Persei (R Coronae Borealis type) has been studied by Ivanova (1958).

A spectrophotometric study of X Ophiuchi has been carried out by Kupo.

Pottasch (1958) has investigated the chemical compositions of novae.

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