29. STELLAR SPECTRA (SPECTRES STELLAIRES)

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During the triennium under review, Commission 29 has sponsored or cosponsored the following IAU meetings: Symposium 102, "Solar and Stellar Magnetic Fields," Zurich, Switzerland, August 1982; Symposium 108, "Structure and Evolution of the Magellanic Clouds," Tübingen, FRG, September 1983; Symposium 111, "Calibration of Fundamental Stellar Quantities," Como, Italy, May 1984; and Colloquium 82, "Cepheids: Observation and Theory," Toronto, Canada, May-June 1984. Commission 29 has also supported or sponsored several IAU meetings proposed for 1985 and 1986. They include "Luminous Stars and Associations in Galaxies," Porto Heli, Greece, May 1985; "Upper Main Sequence Stars with Anomalous Abundances," Crimea, USSR, May 1985; "Astro-chemistry," Goa, India, December 1985; "Hydrogen Deficient Stars and Related Objects," Bangalore, India, December 1985; "Circumstellar Matter," Heidelberg, FRG, June 1986; and "Be Stars," Boulder, USA, August 1986.

This report has been prepared by members of the Organizing Committee and several other members of the Commission and collaborators. Reports on Be stars and CP stars have been written in close contact with the Working Groups (cosponsored by Commission 45) on these subjects. Similarly a short report on the Working Group (cosponsored by Commissions 30 and 45) on standard stars has been prepared.

1. O, Of and Wolf-Rayet Stars -- P. S. Conti

Dr. Underhill and I are completing a monograph volume on O and W-R stars for the NASA series of special publications on stars. Since the review there is much more complete than I can discuss here, I will only consider the highlights of work in this field in the last few years. This short review should be considered a highly personalized account of recent efforts. Interested readers should also see Dr. Abbott's discourse of problems of W-R star's atmospheres which is carried in the reports of Commission 35.

Several recent IAU Colloquia and Symposia have been concerned with O and W-R type stars. Among these are Symposia No. 99 on Wolf-Rayet Stars, edited by de Loore and Willis (1982, Reidel); No. 105 on Observational Tests of Stellar Evolution Theory, edited by Maeder and Renzini (1984, Reidel); Colloquium No. 59 on The Effects of Mass Loss on Stellar Evolution, edited by Chiosi and Stalio (1981, Reidel). Kitchin (1982, Adam Hilger) has published a monograph on Early Emission Line Stars.

A review of the properties of the most luminous stars, in our galaxy and elsewhere in the Local Group, and beyond, has been provided by Humphreys and Davidson (1984, Science 223, 243). Extensive spectrophotometry of faint W-R stars in our galaxy has been provided by Lundstrom and Stenholm (1984, AA Suppl 56, 43). These data supplement the W-R catalogue of van der Hucht et al. (1981, Space Sci Rev 28, 227).

There has been considerable recent activity in discovery of W-R stars in other galaxies. Massey (1985, PASP in press) has written a very nice review paper concerning this topic. There are some 100 W-R stars now known in M33 (Massey and Conti 1983, ApJ 273, 576), some 17 in M31 (Moffat and Shara 1983, ApJ 273, 544), although Massey and Conti have readily discovered another dozen or so, and a half dozen or so each in NGC 6822 and IC1613 (Armandroff and Massey 1985, preprint). The exciting objects of giant H II regions sometimes are found to be W-R like in their spectra. Conti and Massey (1981, ApJ 249, 471) and D'Odorico and Rosa (1981, ApJ 248, 1015)

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found this to be the case for several objects in M33; similar results were found for a few H II regions in M101 and other galaxies (see D'Odorico et al. 1983, AA Suppl 53, 97). The centers of some distant galaxies also appear to contain W-R like objects, often hundreds or thousands in number (e.g. Tololo 3: Kunth and Sargent 1981, AA 101, L5; NGC 6764 and Mkn 309: Osterbrock and Cohen 1982, ApJ 261, 64; NGC 5430: Keel 1982, PASP 94, 765). Apparently, star formation in some galaxies may have proceeded in bursts, in which many massive stars were born in a short time scale; the presence of short-lived W-R stars illustrates this concept.

Bertelli and Chiosi (1982, IAU Symp No. 99, 359), Garmany et al. (1982, ApJ 262, 777), and Conti et al. (1983, ApJ 274, 302) have discussed the distribution of O and W-R stars near the sun. These authors have pointed out the galactic distribution of O stars has a gradient in that fewer are seen towards the anti-center direction compared to the galactic center. Such a gradient is presumed to be similar to the overall stellar mass distribution: however, they find that the brightest O stars, those with masses greater than some 35-40 solar masses have an even steeper gradient. This observational anomaly is shared by the W-R star distribution: none are observed in the anti-center region indicating a steep gradient in the numbers. The similar galactic distributions of massive O stars and W-R stars suggest they are a related population. No other spectral type of star shows the steep gradient in numbers that is indicated by these massive stars. Since the W-R stars have masses, on the average, appreciably smaller than 40 solar masses (Massey 1981, ApJ 246, 153), it is clear from these arguments that they are decendant from the massive O star population. Such a result was also being found from evolutionary models of massive stars with mass loss and mixing processes at work (e.g. Maeder 1984, IAU Symp No. 105, in press; Doom et al. 1984, AA in press; Conti 1983, IAU Symp No. 99, p. 3), and W-R composition arguments (e.g. Smith and Willis 1982, MNRAS 201, 451). The overall evolutionary picture that emerges for O and W-R stars is that the massive O stars are the progenitors for the highly evolved decendants, the helium burning W-R objects. The WN subtypes are seen as showing CNO equilibrium products (enhanced helium and nitrogen) on their surfaces due to mass loss and mixing; the WC stars, generally more highly evolved, have the products of helium burning (enhanced helium, carbon and oxygen) visible. Thus the W-R stage is a natural occurrence in the evolution of massive stars. These stars can then be used as probes of the massive star population in other galaxies (Massey 1985, PASP in press).

Considerable notoriety has been associated with the central exciting object of the 30 Doradus complex in the LMC: R 136a. Its spectrum appears to be a mix of O and WN type (Vreux et al. 1982, AA 113, L10; Ebbets and Conti 1982, ApJ 263, 108) and has been claimed to be a single supermassive star (Cassinelli et al. 1981, Science 212, 1497). During IAU Symposium No. 108 on the Magellanic Clouds (proceedings edited by van den Berg and de Boer, 1984) a panel discussion was held on the nature of R 136a, and a review prepared by Walborn on the stellar content of the surrounding star field. The consensus that seems to be emerging is that the central object is made up of several very luminous components with individual masses greater than some hundred solar masses (Chu 1984, preprint). There is also a surrounding star cloud which contains a number of very luminous stars, some of O3 spectral type. These very bright stars provide the excitation for the 30 Dor complex, a "hypergiant" H II region.

Important spectroscopic work on W-R eclipsing binaries, particularly V444 Cyg has been carried out by Cherepashchuk and collaborators (e.g. Cherepashchuk et al. 1984, ApJ 281, 774; Eaton et al. 1984, ApJ in press). They have combined optical and IUE data to arrive at a reasonably consistent picture of the eclipse phenomena, both in the continuum and in several of the emission lines. An important finding is that the radius of this well known WN5 star is dependent upon the continuum wavelength under consideration and is small, thus leading to a relatively high "effective" temperature near 10^5 K. Strong phase dependent behavior is found for various emission lines, both in the optical and in the UV.

Interesting spectroscopic work has been reported for a few of the very luminous, often variable, blue supergiants readily visible in our galaxy and others. The results of a mini-workshop on P Cygni was published by de Groot and Lamers (1983,

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Irish Astr J 16, 162). High dispersion studies of P Cyg (Lamers et al. 1983, AA 128, 289), and the LMC stars R66 (Stahl et al. 1983, AA 120, 287), and R127 (Stahl et al. 1983, AA 127, 49) are noteworthy. P Cygni stars may be intermediate in evolution between red supergiants and W-R stars (Lamers et al. 1983, AA 123, L8) as well as the S Doradus stars (Stahl et al. 1983, AA 127, 49) or they may represent a stage which never becomes a red supergiant but turns directly into a W-R object. Walborn (1982, ApJ 256, 452) has noted the similarity of some very luminous Of stars to some WN9 subtypes in their spectroscopic properties.

I would be amiss were I not to mention the "alternative" models for O and W-R stars, particularly, suggested by Underhill (1983, ApJ 265, 933). In this type of model, magnetic fields, analogous to what is seen on the sun, play a major role in the heating and support of the stellar winds. Their resultant interaction with the low density plasma also alters atmospheric properties of the stars themselves, along with the deduced effective temperatures and compositions. More detailed summaries of these suggestions are completely discussed in the forthcoming NASA monograph. My personal feeling is that magnetic fields may play some role, but not to the extent claimed by Underhill.

Ending on a very speculative note, Vreux et al. (1985, AA in press) have found a short period, 0.4 day, in the line profile variation of the WN6 star HD 192163. Vreux (1985, PASP in press) has reexamined the periods of several previously identified W-R plus compact systems found by Moffat and associates and concludes very short periods might also be present in them. He suggests these periods, if confirmed by further work, might be evidence of non-radial pulsations. Such pulsations appear to be present in the well known O-type star, ζ Oph according to Vogt and Penrod (1983, ApJ 275, 661). Perhaps these non-radial pulsations are a key feature of the dynamics of stellar winds in luminous early type stars. Certainly more observations will be necessary on this fascinating new topic.

2. Stars of Types O-F -- H. Levato

2.1 O-type stars. The satellite UV data was the base of several studies as has happened in previous periods. Carrasco et al. (1981, AA 100, 183) reported changes in the resonance line profiles in the far-UV spectra of HD 175754. They interpreted these changes as variations in the dynamics and density-ionization structure of the star's wind. Gathier et al. (1981, ApJ 247, 173) determined empirical mass-loss rates for 25 O and B stars (range O4-B1) using ultraviolet line profiles of O IV, N V, P V, Si IV, Si III and C III lines observed with Copernicus. Garmany et al. (1981, ApJ 250, 660) derived mass-loss rates for 31 O-type stars in clusters and associations with IUE observations. Lamers et al. (1982, ApJ 258, 186) found narrow shifted absorption features superposed on the wide P Cygni profiles of the UV resonance lines, in 17 out of 26 OB stars. They considered several explanations, among them, one in which the wind consists of a two-component gas. Franco et al. (1983, AA 122, 9) monitored with IUE in the far UV five O-type stars to study resonance line profile variability. Walborn and Panek (1984, ApJ 280, L27) performed an extensive survey of ultraviolet O-type spectra using high resolution data from IUE. They found a strong correlation between the photospheric and stellar wind features and the optical spectral types. They described the behaviour of the Si IV resonance doublet and reported a new emission feature at 1574 Å. Olson and Ebbets (1981, ApJ 248, 1021) matched the observed Hα profiles of 10 stars ranging from O4f to B3 Ia against computed profiles to derived mass-loss rates.

Fundamental parameters of the stars were the subjects of some important papers. Massa and Conti (1981, ApJ 248, 201) found that the ultraviolet energy distributions of O-type stars in the open cluster NGC 2264 have cooler ultraviolet color temperatures than the cluster early B-type stars. They considered the possible origins of this effect. Underhill (1982, ApJ 263, 741) determined temperatures, radii and luminosities of 24 O3, O4 and O5 stars. She used ultraviolet and visible photometry. The effective temperatures range from 24,800 K to 63,000 K and a typical radius for an O star of the main sequence is 13.4 solar radii. The errors of the determination are discussed.

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Underhill (1984, ApJ 285, 668) published information about the irregular, small amplitude ultraviolet light changes of four O and B supergiants. One possible interpretation is in terms of a rotating spotted disk. Underhill (1985, ApJ in press) studied line strengths and profiles in 10 Lac, S Mon, HD 46223 and ζ Pup demonstrating that although these 4 stars have about the same effective temperature and similar photospheres, their mantles differ widely. This observation raises the problem of how stars can have similar photospheres but different mantles.

Kudritzki et al. (1983, AA 118, 245) performed a non-LTE analysis of the O4f ζ Pup. They derived effective temperature, gravity and helium abundance. Simon et al. (1983, AA 125, 34) analyzed three O3 stars (HD 93128, HD 93129A and HDE 303308) using non-LTE models. They derived effective temperatures and surface gravities, masses and radii. Sakhibullin and Solovéva (1983, Tr Kazan Gorod Astr Obs Vyp 48, 27) performed a detailed non-LTE analysis of the intensities of the triplet lines of twice ionized carbon in the spectra of O stars.

2.2 B-type stars. Underhill (1981, AA 97, L9) demonstrated observationally that the $3s3p3d^{2}F^{\circ}$ levels of Si II autoionize in the atmospheres of B-type stars.

UV observations were used by several investigations on B stars. Hamann (1981, AA 100, 169) fitted the UV resonance lines of τ Sco using an empirical wind model and derived a mass loss rate log $(\dot{M}/M_{\odot}/yr) = -8.9 \pm 0.5$. Burki (1982, AA 107, 205) using IUE observations studied the variation of the shapes of the UV lines of the spectrum of ξ^1 Sco and the UV flux variability.

Rogerson and Upson (1982, ApJ Suppl 49, 353) presented an ultraviolet spectral atlas of β Ori (B8 Ia) between 999 and 1561 Å. Holberg et al. (1982, ApJ 257, 656) provided observations of some B-type stars in the spectral region between 912 Å and 1200 Å obtained with Voyager 1 and 2.

Malagnini et al. (1983, AA 128, 375) compared the UV and visual spectral distributions of a group of B5-A0 stars with Kurucz's models. They used an automatic procedure first applied to A and F stars. They derived T_e values which are in good agreement with other determinations.

Underhill and Fahey (1984, ApJ 280, 712) reviewed the observations of narrow absorption components of the UV resonance lines in the spectra of O and B stars. They presented new observations for ρ Leo (B1 Ib) and outlined a theory to account for the observations. They also made some suggestions on how to make progress with understanding the spectra of early type stars, which concern basically with modelling the mantle in terms of closed and "open" magnetic loops. Underhill (1983, ApJ 268, L127) showed that supergiants with similar T_{eff} can have winds widely differing terminal velocities. This observation suggests that more than one accelerating force acts on the wind.

Adelman and Pyper (1983, ApJ 266, 732) presented the energy distribution in the optical region for 13 normal stars B, A and F. They derived effective temperatures. Adelman (1984, AA Suppl 55, 479) in an attempt to derive more useful indices to describe the peculiarities of the energy distributions of CP stars in the optical region, used the energy distributions of normal main sequence stars (B and A types) to derive the behaviour of the indices as a function of photometric colour indices.

Didelon (1982, AA Suppl 50, 199) collected information on the equivalent widths of spectral lines of B-type stars published in the literature.

M. Smith and Ebbets (1981, ApJ 247, 158) studied Reticon spectra of ρ Leo (B1 Iab) and found variations of a few percent in the absorption lines of Si III λλ4552-74. The time scale is three hours or less. There is also present a variable Hα incipient emission. They suggested an intimate link between subphotospheric processes and the outer atmosphere in this supergiant. Walker et al. (1982, PASP 94, 143) studied line profile variations in the double line spectroscopic binary Spica (B1.5 IV, V). They used high signal-to-noise Reticon spectra covering from Hα to He I λ6678. They found features which move linearly through He I and O II λ6721 lines of the primary. They found also the width of the primary lines variable. Meisel et al. (1982, ApJ 263, 759) provided profiles of He I λ10830 lines for 65 early type stars (O6 to A1). They compared the results with model calculations.

Dufton et al. (1981, AA 97, 10) have shown that the method of determining microturbulent velocities in B-type stars from the requirement that abundances derived from individual lines show no systematic effect with line strength provides results that overestimate the microturbulent velocity. Sadakane (1981, PASP 93, 587) derived abundances in 21 Peg (B9.5 V). Adelman (1984, MNRAS 206, 637) made an abundance analyses of six B-type stars with moderately sharp lines (π Cet, 134 Tau, HR 2154, HR 5780, 21 Aql and ν Cap). All of them present abundance values similar to those of the Sun.

Casinelly and Swank (1983, ApJ 271, 681) presented X-ray observations of the three stars in the Orion's Belt. The observations are tested against different models.

Several papers were published concerning with the rotation of B-type stars. The distribution of rotational velocities of late B-type stars in galactic clusters was analyzed by Guthrie (1982, MNRAS 198, 795) and found it clearly bimodal. Levato and Morrell (1983, Astrophys Lett 23, 183) determined rotational velocities of OB stars members of the open cluster NGC 6231. García and Levato (1984, Rev Mex Astr Astrofis 9, 9) determined V sin i values for 207 stars of types B, A and F. Guthrie (1984, MNRAS 210, 159) compared the distribution of rotational velocities of B0-B5 stars for young and older subgroups of OB associations and the field. He discussed the excess of slow rotators in the older distribution in connexion with the problem of star formation.

Barsukova et al. (1984, Bull Spec Astrophys Obs North Caucasus 16, 30) published an Atlas of the Spectra of eight supergiants of spectral types in the range O9.5-A2.5 and in the wavelength region 3819-4927 Å.

2.3 A-type stars. Among the investigations on individual stars we noted that using the UV region Saha and Oke (1982, PASP 94, 802) combined IUE and optical data of the supergiant BD 39°4926 and they compared it with model atmospheres. They obtained temperatures and gravity. Kunasz et al. (1983, ApJ 266, 739) analyzed the Mg II line 2802 and the profile of H in the supergiant HR 1040 (A0 Ia). They derived the mass loss rate.

Vega and Sirius were the subject of some papers. Michelson (1981, MNRAS 197, 57) compared high resolution near-ultraviolet observations of α Lyr and β Ori with synthetic spectra. Model atmospheres in LTE were used. The basic parameters of the stars' atmospheres are derived. The velocity fields in the atmosphere of β Ori are discussed. Bell and Drilling (1982, PASP 94, 50) compared theoretical spectra with observations of Sirius and Vega and Lambert et al. (1982, ApJ 254, 663) derived the abundances of C, N and O in the atmospheres of Vega and Sirius. Vega has normal abundances, while Sirius is C and O defficient with respect to Vega. Dragomiretskij et al. (1983, Probl Kosm Fiz Vyp 18, 101) made an absolute calibrations of the energy distribution of Vega in the region 0.8-2.3 μm.

Among the general investigations on A-type stars based on UV data, we mention the paper by Crivellari and Praderie (1982, AA 107, 75) who obtained observations of the region 1400-1800 Å in late A-type stars with IUE. After looking for emission lines formed in the transition region they proposed a schematic model for the outer layers in A-type stars.

Glushneva (1984, Sov Astr 28, 193) determined effective temperatures, radii and bolometric corrections and surface gravities for a sample of stars in the range A-G. Glushneva (1984, Sov Astr 28, 305) determined electron temperatures of the mantles of the A2 supergiants α Cyg and ν Cep, on the basis of an analysis of the enery distributions.

Among the optical studies C. Cowley et al. (1982, ApJ 254, 191) examined high dispersion spectra of a sample of superficially normal late B and early A-type stars with low V sin i values by the methods of wavelength coincidence statistics. They used around 70 strong and weak Fe I lines. They suggest that several stars in the sample may be deficient in iron and they mentioned some possibilities that may be responsible for the peculiar chemistry of these stars. Sadakane (1981, PASP 93, 587) derived abundances in HR 7338, an A0 III star.

C. Cowley and Adelman (1983, QJRAS 24, 393) discussed a variety of new techniques to determine more accurate abundances for stars near spectral type A. They

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gave some suggestions for avoiding the most common sources of error in abundance work.

2.4 F-type stars. During this period the work of Gray applying Fourier analysis of spectral lines has continued. He performed (1981, ApJ 251, 152) a Fourier analysis of 34 individual lines in the spectrum of Procyon. He found a projected rotation rate of 2.8±0.3 km/s. Gray (1981, ApJ 251, 583) measured asymmetries in the lines of the spectrum of Procyon. He found a blueshifted core in all of the lines. Finally, Gray (1982, Ap J 258, 201) looking the Fourier transforms of the line profiles of seven F-type stars found evidence of rigid rotation.

Among the abundance studies Clegg et al. (1981, ApJ 250, 262) determined CNO abundances in a sample of 20 F and G stars. They used Reticon spectra and they also obtained Fe and S abundances.

Brown and Jordan (1981, MNRAS 196, 757) obtained IUE observations of Procyon. They discussed the range of electron pressure and calculated several models. The maximum temperature for a model with uniform emission is deduced to be 3×10^5 K, which is lower than that in the solar corona.

Desikachary and Hearnshaw (1982, MNRAS 201, 707) obtained the atmospheric parameters of the F-type supergiant Canopus using spectrophotometry and Balmer line profiles. They derived abundances for 33 elements and found tentative evidence that nitrogen in Canopus may be five times more abundant than in the sun. Boyarchuk and Lyubimkov (1984, Bull Crimean Astrophys Obs 64, 1) performed a detailed analysis of the F supergiants γ Cyg and α UMi.

3. G- and K-type Stars -- G. Cayrel de Strobel

G- and K-type stars are important not only because our Sun is among them, but because they are indicators of galactic and extragalactic evolution and are used to study implications on nucleosynthesis imposed by their chemical composition. The spectroscopic analysis of these stars not only gives information on effective temperatures, spectroscopic gravities, chemical abundances but also on velocity fields, rotations, magnetic fields, chromospheric activities, mass loss etc. in stars. More than 190 papers were analyzed for this report. In the past three years the spectroscopic researches on G and K stars rely more and more on high resolution, high S/N spectra taken with solid state detectors. The increase in accuracy in spectroscopic measurements has sometimes been by a full order of magnitude. References are given as abstract numbers in Astronomy and Astrophysics Abstracts.

3.1 G and K field stars. The researches of Gray in the field of turbulence and rotation of G and K stars have been remarkable during these three years. Gray (30.116.041) has studied rotation and turbulence in G giant stars and made an essential discovery in finding along the giant sequence a rotational discontinuity at G5. He proposed a dynamo generated magnetic brake as the cause (32.116.015). Gray (32. 116.006) extended somewhat his discovery to main-sequence stars. He (31.114.304) discovered and measured stellar granulation in 27 F, G and K stars of luminosity classes III, IV and V. Another essential result of Gray (37.116.045) is that he is now able to discriminate between lower and higher rotational velocity scales for G and K dwarfs. Gray (37.116.009) has measured Zeeman broadening in G and K dwarfs. Vaughan et al. (30.116.029) have measured stellar rotation in lower main sequence stars from time variations in H and K emission line fluxes. Durney et al. (30.116. 035) have interpreted in terms of dynamo concepts stellar rotation measurements combined with Wilson's stellar cycle observations. Middelkoop and Zwaan (30.116.003) and Middelkoop (31.116.013) have studied the relation between rotation and Ca II H and K emission in main sequence stars. A possible detection of oscillations or running waves in Aldebaran and Arcturus has been made by M. A. Smith (33.114.008). Very interesting results are those of M. A. Smith (33.116.017) who gives the values of rotational velocities for a sample of F and K dwarfs with X-ray emissions. Rengarajan (38.114.-) has studied the relationship: age-rotation in late type main-sequence stars. Marcy (34.116.004) presented the results of measurements of magnetic

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fields in a sample of 29 G and K main-sequence stars, and found 19 detections of magnetic field. Booth and Blackwell (34.114.012) discuss the effect of hyperfine structure on abundance analyses.

The Fe-content of G and K Ib supergiants has been found by Luck (26.114.015) enhanced by a factor of 2 in respect to the Sun. Luck (31.114.043) reanalyzed a sample of 19 of these supergiants and found that their Fe-abundance decreased from +0.3 to about +0.1 dex of the solar value. Hardorp et al. (31.114.047) and Hardorp and Tomkin (34.114.042) proposed HD 44594 and 16 Cyg B as solar analogs. A sample of solar type stars of known age is presented by Duncan (37.113.039). Tomkin et al. (39.114.-) have determined the abundances of Na, Mg, Al, Si, Ca, and Sc in 20 F, G and K disk stars and discussed them in terms of even-Z and odd-Z nucleosynthesis. Cayrel de Strobel et al.(39.114)have produced a renewed version of their [Fe/H] catalogue, which contains 1035 field and cluster stars analyzed in detail on high resolution material.

3.2 Population II field stars. Bessel and Norris (31.114.092) have discovered the most metal deficient star known up to now: CD -38°245, with [Fe/H] = -4.60. Griffin and Griffin have discovered also one of the most metal poor stars: HD 115444 with [Fe/H] = -2.95. R. Gratton (34.114.005) has studied the abundance in 11 metal poor inner-halo stars. The range of Fe-abundances of these stars goes from -0.4 to -2.5 dex. In a new detailed analysis of the halo dwarfs HD 19445 and HD 140283 Magain (37.114.029) finds them much more metal poor than previously thought. Arpigny and Magain (34.114.041) have determined the Al/Mg abundance ratio in the halo dwarfs HD 19445 and HD 140283. M. Spite et al. (34.114.055) have given an upper limit to the deuterium abundance in a few halo dwarfs.

3.3 G and K stars in open clusters. Two K giants in the old open cluster MEL 66 and NGC 2243 have been analyzed by R. Gratton (31.153.035). The four stars have been found quite metal poor by ~ -1.01. Duncan and Jones (34.153.015) combined new Reticon spectrographic observations with spectrometer and image tube spectrogram measurements, in order to obtain independent information on the age of the Pleiades G and early K stars by determining their Li-abundances and comparing it with the Hyades stars.

Brown and Twarog (33.153.027) have investigated on Reticon spectra the photometric CN anomaly of the Hyades, indicating possible CN variation among main-sequence stars. No anomaly in the Hyades in respect to normal stars of similar temperature was found.

3.4 G and K stars in globular clusters and galaxies. A rather large range in chemical composition has been found by Bell et al. (30.114.105) in analyzing a sample of subgiants belonging to ω Cen. The inhomogeneities in the chemical composition of this cluster have been confirmed by R. Gratton (32.114.145). Pilachowski et al. (34.154.005) have analyzed in detail stars in seven globular clusters bringing to 23 the number of globular clusters having their chemical composition determined by means of detailed analyses.

Bessell (34.154.017) has determined the Fe abundance relative to H and those of Ti, V, and Zr relative to Fe on IPCS spectra of a giant in 47 Tuc and 2 giants in M 71. The abundances found for these stars are in very good agreement with the photometric ones and are definitively smaller than some recent echelle derived abundance analyses. Metal abundances of some giants in four distant globular clusters were determined by Pilachowski et al. (34.154.050). Pilachowski et al. (34.154.083) found for the Fe-abundances in M71 a value of -1.0 dex. R. Gratton et al. (37.114.028) have also presented new data on Hα emission in 24 globular cluster giants. Suntzeff (30.154.037) has analyzed low resolution spectrophotometric scans of 29 giants in M3 and 35 giants in M13 in order to determine their C and N abundances. A G-type supergiant, AZ 369 analyzed by Foy (30.114.136) in the Small Magellanic Cloud on high dispersion echelle electronographic spectra, exhibits a metal deficiency of -0.4 ± 0.3 dex. Withford and Rich (34.114.102) have determined the metal content of K-giants in the nuclear bulge of the Galaxy, and found a very important

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result, namely that the majority of the stars are metal rich with a mean of [Fe/H] ~ +0.35. Available data on the metal abundances of globular clusters are combined by Pilachowski (37.154.086) to examine the question of the existence of metallicity gradient in the halo of the Milky Way. Although the gradient is weak, its existence implies that the clusters did participate in a general, homologous collapse of the Milky Way and did not form separately.

3.5 Ba stars. The discovery by McClure et al. (27.117.045) and by McClure (33.120.019) that Ba stars appear to be members of binary systems where the companions might be white dwarfs has in these three years reanimated the interest in Ba stars. McClure (37.114.069) dedicated to the Ba stars a review paper in which he emphasizes the impact of these stars on nucleosynthesis and on advanced stellar evolution researches.

3.6 Li in field stars. In 1981, F. and M. Spite (30.114.104, 31.114.090, 31. 162.122, 32.114.146, 34.114.020, 34.114.070, 38.114.--) have discovered the Li-resonance line at 6708 Å in extreme Pop II turn-off dwarfs. This discovery is of paramount importance because it provides information about the primordial Li-abundance in the Galaxy. The preservation of Li in Pop II turn-off dwarfs is due to the shallowness of their convection zone, and to the smaller temperature at its bottom than for normal metal-abundance dwarfs of the same effective temperature. Duncan (30.114.022) has studied in over 100 field dwarfs and subgiants their Li-abundances. Duncan has discussed different mechanisms which may explain Li-depletion in the Sun and in solar type stars.

The relatively low luminosity giant HD 112127 exhibits an extremely strong Li resonance line in its spectrum; Wallerstein and Sneden (31.114.035) have carried out a detailed analysis of this star. Luck (32.114.208) has discovered strong Li-lines in two early G-type supergiants.

Steenbock and Holweger (37.114.004) have searched for non-LTE effects in the Li resonance lines of the Sun, a K3 Ib supergiant, halo dwarfs and halo giants. R. Cayrel et al. (37.114.145, 38.114.-) have put into shape an observational test on stellar interior mixing in studying the Li-depletion in twelve Hyades solar type dwarfs and later. The authors have found in analyzing high quality Reticon CFHT spectra of Hyades G and K dwarfs that their Li-abundances decline more rapidly with decreasing temperature than heretofore realized.

3.7 C, N, O, in field stars. The synthetic spectrum technique was employed by Barbuy (30.114.094) to obtain C abundances in some very old extremely metal deficient Pop II stars. For unevolved stars she found [C/M] = 0, whereas for the evolved ones C-depletion appears as a signature of mixing effects. Red and near-infrared high resolution Reticon spectra have been analyzed by Clegg et al. (30.114. 128) in order to determine C, N, O and S abundances in a sample of 20 F and G stars. Barbuy (33.114.096) has derived N abundances for 8 Pop II stars and O abundances for two of them. Sneden (34.114.117) has analyzed in detail several CH stars and Lambert (37.114.078) has determined N abundances in disk and halo dwarfs covering a metal deficient range $-2.3 \leqslant$ [Fe/H] $\leqslant -0.3$. Langer and Kraft (37.114.141) reviewed C and N abundances of nearly 300 old, very metal poor stars [Fe/H] $\lesssim -1.3$.

3.8 Chromospheric activity: Optical and IUE observations of field and cluster stars. Fernandez-Figueroa et al. (32.114.096, 32.114.219, 33.112.013) and Rego et al. (33.114.022) have studied and interpreted UV and far-UV emission in solar type stars observed with IUE. M. Spite (30.114.137) interpreted in terms of mass loss far-UV emission in two Pop II stars. Boesgaard and Simon (32.114.215) have analyzed and interpreted IUE spectra of several young solar type stars and have compared with T Tauri stars. Ayres et al. (32.114.205) compared IUE spectra of α Cen A and Arcturus. Signatures of chromospheric activity in cool stars are discussed by Dupree (32.114.211). Evidence of high chromospheric activity in the Hyades has been found by R. Cayrel et al. (33.114.097). Cram (37.114.031) has outlined contemporary ideas regarding the physical phenomena responsible for stellar chromospheric structure.

Campbell (38.114.-) correlates color anomalies in Hyades solar type dwarfs with star spots. Herbig (39.114.-) has compared Hα emission in G-type dwarfs with Hα emission in T Tau stars. Rose (38.114.-) has studied spectral line anomalies in the Hyades, Pleiades and field stars.

4. M, S, C Stars -- P. C. Keenan

The spectra of many of the groups of cooler stars are discussed and interpreted in two books:

1. V. Straižys, Zvezdy s defitsitom metallov (Metal-deficient stars), 1982; Institut Fiziki AN Litovskoj SSR. Molkslas, Vil'nyus.

2. C. and M. Jaschek, Stellar taxonomy, in press; Cambridge Univ. Press.

A general review of infrared spectroscopy of late-type stars was given by Ridgway (in Galactic and extragalactic infrared spectroscopy, ed. M. F. Kessler and J. P. Phillips, p. 309, 1984; Reidel) and an atlas of the 2400-2778 cm^{-1} region in K, M, C and S stars was prepared by Ridgway et al. (1984, ApJ Suppl 54, 177).

Bessell (1982, Proc Astr Soc Australia 4, 417) obtained spectra of faint high-velocity M dwarfs, and found that they divided into two groups: 1. Similar to ordinary old-disk dwarfs, but about 1 mag fainter, and 2. Having weak TiO but very strong CH, MgH, CaH bands. These lie 2-4 mag below the old-disk dwarfs. Computations show that the spectra can be explained by the very low content of metals.

Liebert et al. (1983, IAU Colloquium 76, Van Vleck Obs Contr No. 1, 361), from CCD spectrograms of the extremely red proper-motion star, LHS 2924, concluded that it is the coolest M-dwarf known.

Linsky et al. (1982, ApJ 260, 670) used IUE spectra of 10 dM stars to study their chromospheric emission lines. At higher resolution Ayres et al. (1983, ApJ Lett 270, L17) examined the UV spectrum of the dM1.6e star AU Mic, and Worden et al. (1981, ApJ Suppl 46, 159) obtained echelle spectrograms of 17 M dwarfs, studying emission in the cores of Na D and the Balmer lines.

For the stars of higher luminosity two atlases based on IUE ultraviolet spectra have been published:

1. C. C. Wu et al., The IUE ultravioelt spectral atlas, 1983; NASA Newsletter No. 22. λλ2400-3400 Å and resolution 7 Å.

2. R. F. Wing et al., Atlas of high-resolution spectra of late-type stars, 1983; Perkins Obs Sp Pub, No. 1. λλ2500-3230 Å and resolution 0.3 Å.

Also in the ultraviolet, Stickland and Sanner (1981, MNRAS 197, 792) identified lines between λλ1296 Å and 1915 Å in M giants. Other studies of the UV spectra include that of Johansson and Jordon (1984, MNRAS 210, 239), who used new laboratory spectrograms to identify lines previously observed in β Gru (M3 II), including the strong emission feature at 1870 Å, as due to Fe II levels excited by Lyα pumping. Earlier work on Fe II fluorescence was reported by Engvold (1983, Inst Theor Astrophys Blindern-Oslo, Rep No. 59, 65).

Changes in the line spectrum of the peculiar M-type variable, CH Cyg, have been followed at 30 Å/mm between 3600 Å and 6950 Å by Galkina (1983, Izv Crimean Obs 67, 33) and at higher resolution by Yoo (1984, Ann Tokyo Astr Obs 20, No. 2). Tomov (1984, IBVS No. 2610) concluded that the active phase beginning in 1977 had ended by 1984.

Another star with variable emission, 24 Ser (HD 139216, M5: II-III) was monitored spectroscopically by Yamashita et al. (1982, Ann Tokyo Astr Obs 19, No. 1).

Among Mira variables, R Cyg (Type S) experienced its faintest recorded maximum (9.9 mag) in 1983, and Wallerstein et al. (Univ. of Washington preprint) found that the velocity of the emission lines correlated with the magnitude at maximum, their negative displacement being less at faint maxima. In another Mira variable (R Aqr, M7e at max) H. M. Johnson (1982, ApJ 253, 224) studied the UV spectrum between 1300 and 3100 Å obtained by the IUE satellite. In Mira itself, line-weakening in the period 1965-1980 was reviewed by Yamashita et al. (1981, Ann Tokyo Astr Obs 18, No. 3).

In M giants the λ6707 Li doublet has been measured by Luck and Lambert (1982, ApJ 256, 189), Hänni (1983, Tartu Obs Publ No. 49, 62), and Boyarchuk et al. (1983,

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Astrofiz 19, 265). A large project to measure Li, as well as Na and TiO bands, is under way at the South African Observatory by Evans and collaborators. Also, a correlation between lithium excess and UV excess was found by Melik-Alaverdyan (1981, Astrofiz 17, 225).

Among individual M-giants β Peg (M2+ II-III) has been studied most extensively. Orlov et al. (1983, Astrometr Astrofiz 50, 3) found sodium to have nearly solar abundance, while the heavy elements Mo and Ru were underabundant by a factor of 20 (1984, Pisma Astr Zh 10, 135 and Sov Astr Lett 10, 53).

Much work has been done on their molecular spectra, particularly in the infrared. Hänni (1981, Tartu Obs Publ 48, 138) measured the relative abundance of ^{46}TiO and ^{47}TiO in 15 stars, mostly M giants. First overtone SiO bands, in the 4μ region were found by Rinsland and Wing (1982, ApJ 262, 201) to strengthen with advancing type in M stars. The weak but important H_2 quadrupole line, observed by Hinkle, Ridgway and others, were compared with synthetic spectra by Tsuji (1983, AA 122, 314).

The ratio of $^{16}O/^{18}O$ was found by Harris and Lambert (1984, ApJ 285, 674) to be essentially solar in 7 stars, including β And (M0+ IIIa), β Peg (M2+ II-III), μ Gem (M3 III) and α Her (M5 Ib-II). The $^{16}O/^{17}O$ ratios, however, ranged from ~1000 for β Peg to 160 for β And. The IR observations of α Her by Connes have been analyzed by Tsuji (1984, Colloquium on Cool Stars with Excesses of Heavy Elements, Strasbourg, in press).

An extensive analysis of M and MS giants is under way by V. Smith and Lambert (Texas).

Turning to the cool supergiants, we find measurements of mass loss in α Sco by Bernat (1982, ApJ 252, 644) and in α Ori by Stencel et al. (1982, in Advances in UV Astronomy, NASA CP-2238, p. 259). In these two stars Harris and Lambert (1984, ApJ 281, 739) measured the abundances of the oxygen isotopes. Lambert et al. (1984, ApJ 284, 223) also determined the abundances of C, N and O in α Ori. For this same supergiant Carpenter (1984, ApJ 285, 181) studied the velocity field through the chromosphere by means of Fe II lines observed by the IUE. Mass loss from the supergiant binary system TV Gem was estimated at from 10^{-3} to 10^{-5} $M_\odot$/yr by Michalitstanos and Kafatos (1982, in Advances in UV Astronomy, NASA CP-2238, p. 213) by means of IUE spectra. Details of the blended spectra of the B3.5 and M1 components were studied by Underhill (1984, PASP 96, 305).

High-resolution spectrograms of six objects near the galactic center were used by Lebofsky et al. (1982, ApJ 263, 736) to show that they are all supergiants. On the other hand, Luck (1982, ApJ 263, 215) analyzed echelle data of 27 stars of types F to M within 1 kpc of the sun.

Among stars in the sequence M, MS, S, SC and C, Murty (1982, Astrophys Space Sci 88, 189; 1982, Astrophys Lett 23, 7; 1983, Astrophys Space Sci 94, 295) identified new bands of YO and CeO in R Cyg (Se) and π^1 Gru (S5). The presence of Nb in the atmospheres of S stars was discussed by Locanthi (1984, Colloquium on Cool Stars with Excesses of Heavy Elements, Strasbourg, in press), while abundances of Nb and Te were measured in R CMi (SCe) and CY Cyg (SC2/7.5) by Smith and Wallerstein (1983, ApJ 273, 742).

Technetium lines in these stars continue to receive much attention. A systemmatic search for them is being carried out by Little-Marenin. The abundance of Tc has been measured by Orlov and Shavrina (1983, Astr Tsirk No. 1271, 7) in MS and C stars, and a program to study the lines in Mira and χ Cyg has been started by Dominy and Wallerstein.

Dominy and Wallerstein analyzed 4 SC stars in the 2μ region (in press), finding low nitrogen abundances. In the same spectral region Catchpole and Whitelock (in press) found that the 3.1μ absorption feature is a sensitive indicator of the C/O ratio when it is near 1.0. They observed also the 2.3μCO band, finding a correlation with the lithium 6707 Å lines.

A spectacular change in the spectrum of the SC Mira variable BH Cru was observed by Evans (1984, Colloquium on Cool Stars with Excesses of Heavy Elements, Strasbourg, in press). In the early 1970's the spectrum showed little evidence of either ZrO or C_2 at any phase, but the recent spectra are dominated by strong C_2 bands.

https://doi.org/10.1017/S0251107X00006416 Published online by Cambridge University Press

A review of the spectra of carbon stars forms chapter 1 in the book "Carbon stars," by Z. K. Alksne and Y. Y. Ikaunieks (1981, translated and edited by J. H. Baumert, Pachart Publ. House). Alksnic (1983, Izv Acad NAUK Latvia SSR No. 4, 93 and 98) has continued the Latvian work.

Carbon stars have received particular attention in Japan. Fujita (1983, Proc Japan Acad 59B, 145) identified bands of HCN in HD 182040 (C2,2 Hd) and W Ori (C5,4) and studied also H_2O lines in the near IR (1984, Proc Japan Acad 60B, 217) and criteria for the ratio $^{12}C/^{13}C$ (1981, Proc Japan Acad 57B, 169). Hirai used high-dispersion spectra from Palomar to resolve the double lines in the spectrum of U Cyg near maximum light (1982, Bull Fukuoka Univ 31, 81; 1984, ibid in press). Tsuji (1981, AA 99, 48) has applied new models to predict the infrared flux and determine the effective temperatures of carbon stars.

Extensive spectrographic investigations of carbon stars are under way at the University of Washington, where Dominy has obtained about 50 image-tube spectra of cool carbon stars, and at the South African Observatory, where Catchpole is working on the southern R stars. At Indiana University the UV spectra of R stars are being studied by Eaton et al., while abundances in 11 R stars were estimated by Dominy (1984, ApJ Suppl 55, 27).

Among individual carbon stars, the obscured object IRC +10216 was searched unsuccessfully in the 3μ region by Clegg et al. (1982, MNRAS 201, 95) for evidence of interstellar HCl. In HD 218875 (C1,3:) Oganesyan (1982, Astrofiz 18, 460) observed the variations of the absorption bands. Goebel et al. (1983, ApJ 270, 190) measured C_2H bands at 2.9 and 3.6μ in HD 19557 (C4,5 J), but did not detect any SiC emission. Evidence that hydrogen may be deficient in late carbon stars was found by H. R. Johnson et al. (1983, ApJ Lett 270, L63) by measuring the quadupole 1-0S(1) line at 4712.9 cm^{-1}, and by Goebel and H. P. Johnson from airborne spectrophotometry of the 1.6μ flux peak due to H^-.

Variations of C_2, CN and rare-earth ions were followed in X Cnc (C5,9) and UU Aur (C6,4) by Eglitis (1983, Nauchnya Inform No. 57, 142), who noted that the lines of neutral metals did not change with phase. In the ultraviolet, both rapid and slow changes in the emission lines in the spectrum of TW Hor (C7,2) have been observed by M. and F. Querci (1985, AA in press), and similar work on 19 TX Psc (C7,2) by H. R. Johnson et al. is under way.

5. Stars in the Late Stage of Evolution -- R. Viotti

This review covers the spectroscopic observations of highly evolved stars. The systematic study, especially in the ultraviolet with the IUE satellite during the last three years has provided a large amount of new results, which have been discussed during the ESA and NASA IUE Conferences held in 1981, 1982 and 1984. The spectra of highly evolved stars are also discussed in the Proceedings of the IAU Symposia 103 (33.012.005) and 105 (37.012. 078), and of the IAU Colloquia 59 (30. 012.015), 70 (32.012.045), 72 (33.012.019), and 80 (37.012.031).

5.1 Hot subluminous stars. Hot subdwarf stars are normally faint in the visual, but because of their high effective temperature and low interstellar extinction, they can be easily observed at high resolution in the IUE ultraviolet. For this reason they are also good spectrophotometric standards for the UV as, for example, discussed by Code in the IAU Symposium 111. Several investigations have been devoted to these stars. The evolutionary scenario was discussed among others by Wasemael et al. (31.126.010) and Bergeron et al. (37.113.037). The high resolution UV spectrum of sdO contains a large number of lines, mostly of metals in different ionization stages, whose identification is still a problem. Extensive line identifications were made of sdO by Bruhweiler et al. (30.126.021) and Rossi et al. (37.126.014), and of the sdOB star HD 149382 and Feige 66 by Baschek et al. (31.126.022; 32.126.008). In sdO Fe V is by far the ion with the largest number of lines. Narrow absorption lines of Fe IV and Fe V were also found in the UV spectrum of WR stars by Fitzpatrik (32.114. 106) and Wills and Stickland (33.117.050), and of the central star of the planetary nebula IC 3568 by Harrington and Feibelman (33.134.007). Heber et al. (37.114.002)

https://doi.org/10.1017/S0251107X00006416 Published online by Cambridge University Press

derived T_e, gravity and helium content from the study of the optical and UV spectra of eight sdB stars, and concluded that they are He-main-sequence stars with a mass of about 0.5 $M_\odot$. The UV flux distribution of 13 extreme helium stars was investigated by Drilling et al. (37.114.067) who found T = 8500 to 32000 K. The IUE low resolution spectra of eight very hot sdO were used by Schönberner and Drilling (37.114.091) to derive their temperatures much higher than 60000 K. Three turned out to be central stars of planetary nebulae and four near the WD stage. Detailed studies of stellar winds from sdOs, extreme He stars and central stars of planetary nebulae by Hamman (37.112.106) revealed that these stars fit well into the general picture of stellar winds from early type stars. An upper limit to the X-ray flux from the mass-losing sdO BD -3°2179 was derived by D'Antona et al. (33.126.029) from HEAO-2 observations.

Two workshops were held in Paris (1981) and Kiel (1984) entirely devoted to the white dwarfs (no published proceedings). The main result is the discovery of the carbon absorption features in the ultraviolet spectrum of the DC white dwarfs G33-49 by Vaclair et al. (30.126.002) and G218-8 by Wegner (30.126.007). These features were later identified in a number of white dwarfs by Vauclair et al. (31.16.029) and Wegner (33.126. 021). A high resolution study of the UV spectrum of eight white dwarfs with IUE was undertaken by Bruhweiler and Kondo (33.126.033) who found lines of ionized heavy elements in three DA and indication of mass loss in two of them. Greenstein et al. (34.126.010) analyzed the optical spectrum of the new WD binary Sanduleak-Pesch, and found that they are young Pop I stars with masses of 0.80 and 0.43 $M_\odot$. Extensive multicolour spectrophotometry of white dwarfs was performed by Greenstein (37.126.027) and Oke et al. (37.126.085).

Photospheric X-ray emission has been detected by Kahn et al. (37.126.049) in four DA white dwarfs.

A number of studies were devoted to the determination of the physical parameters of the central stars of planetary nebulae (CPN) mainly based on IUE observations. The main result is the discovery of stellar winds with velocities from 1000 to 3000 km/s and mass loss rates of 10^{-10} to $10^{-8} M_\odot$/yr (33.134.043; ESA SP-218, p. 333)

Non-LTE model atmospheres were used to determine T_e, log g and helium abundance in many CPN by Mendez et al. (1981, AA 101, 323; IAU Symp 103; and AA in press), and by Kudritzki et al. (1981, AA 94, L15).

5.2 Symbiotic stars and related objects. A great progress in the knowledge of the nature of symbiotic stars was made in recent years especially from observations outside the visual region and with satellites.

Two meetings held in 1981 on this subject (Boulder Workshop and IAU Colloquium 70) have given fresh ideas for new investigations both observationally and theoretically, and several research papers were published in the following years. Excellent reviews on the previous works on the subject can be found in the Proceedings of the IAU Colloquium 70 (32.012.045), in the Ph. D. dissertation of Kenyon (1983, Univ Illinois), and in a review by Allen (37.117.131). Blair et al. (34.117.142) and Kenyon and Webbink (37.117.176) presented a broad spectroscopic survey of symbiotic and related objects. An extensive catalogue of the optical spectra of symbiotic stars was made by Allen (1984, Proc Astr Soc Australia 5, 369).

Special efforts were devoted to the detailed study of several individual objects, mostly based on IUE observations, such as: Z And (29.122.058), CH Cyg (32.122.021, 040; 37.117.046), CI Cyg (31.117.017; 1984, AA 140, 91), V 1016 Cyg (30.114. 006; 32.114.172), V 1329 Cyg-HBV 475 (34.117.034), AG Dra (33.117.042), YY Her (37.117.220), SY Mus (37.117.081), RX Pup (31.117.060), HM Sge (Mueller and Nussbaumer 1984, AA in press), RR Tel (33.117.024). Additional IUE observations of symbiotic stars are discussed by Michalitsianos et al. (32.117.015), and Sahade et al. (37.117.084). Observation of these objects in other galaxies may provide a new understanding of their nature. Three symbiotics were discovered in the SMC (33.117.028). The IUE and optical spectrum of the LMC object S63 is described by Kafatos et al. (34.114.137). Lutz found that HDE 330036 is a dense planetary nebula with a central binary system (37.134.046). Allen (34.117.017) established the presence of a variable M giant in the high excitation symbiotic H1-36. From the detailed analysis of the optical spectrum of the Kuwano object (PU Vul) a binary model was suggested consisting of an M giant and of a variable low luminosity star. Additional results include the study of the symbiotic stars CI Cyg and AR Pav during eclipse (31.117.017; 34.117.233) and the spectral variations of CH Cyg (31.117.032).

It is noticeable to recall that two objects, AG Dra and Z And, underwent an outburst which was followed with IUE (Viotti et al. 1984, ApJ 283, 226; EAS SP-218, p. 403). In general these works give support to a binary model where the mass exchange is supported by the stellar wind from the cool component or in a few cases by Roche lobe outflow [as suggested by Iijima for CI Cyg (32.117.199)]. Various binary models are discussed by Kenyon and Webbink (37.117.176). A colliding winds model is developed by Wallerstein et al. (37.117.093) to explain the emission line spectrum of V1016 Cyg and HM Sge. Friedjung et al. (34.117.053) give evidence for the presence of a warm wind from the red component of symbiotic systems. Johansson (34.117.130) proposed a fluorescence mechanism for the Fe II emission lines in RR Tel and V1016 Cyg.

Kenyon and Truran (34.124.007) proposed a model of thermonuclear burning episodes onto accreting white dwarfs to explain the nova-like outbursts. A bipolar mass outflow was found by Solf (33.112.011; 1984, AA 139, 296) in V1016 Cyg and HM Sge from very high spatial and spectral resolution observations. Actually, VLA radio maps of many symbiotics revealed the presence of compact asymmetric nebulae (29.116.034; 32.116.017; 1984, ApJ 284, 202). Fundamental information on the nature of the cool component of the symbiotic systems was derived from observations in the infrared. Systematic monitoring of northern objects was carried out by Taranova and Yudin (30.113.061; 30.117.065; 31.113.003,007,024; 32.122.168; 33.117.004), who found large optical and infrared variability in several symbiotics. Large amplitude Mira-type oscillations were found in many southern D-type symbiotics by the South Africa Astronomical Observatory group (33.117.024, 030, 031, 032). Roche et al. (34.117.033) discussed the IR photometry of 20 objects, mostly dust-rich. Kenyon and Gallagher (33.117.119) and Allen et al. (31.112.059) studied the spectroscopic features in the infrared.

6. Pre-main-sequence Stars -- I. Appenzeller and B. Wolf

The period covered by this report (1982-1984) was characterized by a significant improvement of the spectral resolution and signal-to-noise ratio which could be achieved in the spectroscopy of faint stellar objects. This progress resulted from the introduction of new efficient spectrographs and new linear detectors (notably CCDs) at all major observatories. Due to these technical advances much new information and important new insights into the physics of PMS stars and their circumstellar envelopes and gas flows could be derived.

Comprehensive reviews and many original papers on the spectra of PMS stars can be found in the proceedings of the following recent meetings: IAU Colloquium No. 71 (Activity in red dwarf stars) held 1982 in Catania, Italy; "Symposium on Herbig-Haro Objects, T Tauri Stars, and Related Phenomena" held 1983 at Mexico City and published in Rev Mex Astr Astrofis Vol. 7, 1983; "Third Cambridge Workshop on Cool Stars" held 1983 in Cambridge, Massachusetts and published as Springer Lecture Notes in Physics Vol. 193; "Second Meeting on Protostars and Planets" held 1984 in Tucson, Arizona (Proceedings in preparation). General reviews on PMS objects have been presented by Appenzeller (1982, Fund Cosmic Phys 7, 313) and Mirzoyan (1982, Astrofiz 18, 463).

Progress on the various classes of PMS objects can be summarized as follows:

6.1 T Tauri stars. An excellent overview of our present knowledge on the T Tauri stars has been published by Bertout (1984, Rep Prog Phys 47, 111). Recent developments in the T Tauri star research were also reviewed by Appenzeller, Calvet, Kuhi, and by S. E. Strom in the proceedings of the 1983 Mexico City Symposium.

Spectroscopic searches for new T Tauri stars were carried out successfully by Ogura and Hasegawa (1983, PAS Japan 35, 299) and by Duerr et al. (1982, ApJ 261, 135). The three puzzling and disputed emission line objects TW Hya, BM Cha, and LkHα 324 were confirmed to be T Tauri stars (cf. Rucinski and Krautter 1983, AA 121, 217; Krautter and Mouchet 1983, AA 125, 378; Chavarria et al. 1983, AA 118, 189). Appenzeller et al. (1983, AA Suppl 53, 291) published a catalog and spectral atlas of the T Tauri stars south of $\delta = -35°$, which were not included in the Cohen-Kuhi catalog.

With the IUE satellite additional UV spectrograms of T Tauri stars were obtained. The corresponding results were reported and discussed by Penston and Lago (1983, MNRAS 202, 77), Giampapa (1984, Proc Third Cambridge Workshop on Cool Stars, p. 14), Imhoff and Giampapa 1982, Smithsonian Astrophys Obs Spec Rep 392, 175), and by Brown et al. (1984, MNRAS 207, 831; 1983, Proc IAU Coll No. 71, p. 509).

Gahm and Krautter (1982, AA 106, 25) determined upper limits for the coronal line emission of T Tauri stars. They could prove that, compared to normal late type stars, in T Tauri stars the coronal emission (if present at all) is much less enhanced than the chromospheric emission.

Detailed spectroscopic investigations of individual T Tauri stars were carried out for RU Lup by Lago and Penston (1982, MNRAS 198, 429 and 495; 1984 MNRAS 210, 323) and by Boesgaard (1984, AJ 89, 1635), for S CrA and GQ Lup by Bertout et al. (1982, AA Suppl 47, 419) for AS 353, DI Cep, and RY Tau by Krasnobabtsev (1982, Bull Crimean Astrophys Obs 65, 100), for RW Aur by Appenzeller and Wolf (1982, AA 105, 313) and by Aiad et al. (1983, PASP 95, 656) and for DR Tau by Ulrich et al. (1983, ApJ 267, 199).

Papers concerning the theoretical interpretation of the T Tauri spectra and the problem of line formation in T Tauri atmospheres and circumstellar envelopes were presented by Bastian (1982, AA 109, 245), Bertout (1982, Third European IUE Conference, p. 89), Chevalier 1983 (ApJ 268, 753), Edwards and Strom (1984, Proc Third Cambridge Workshop on Cool Stars, p. 1), by Hartmann (1984, Proc Third Cambridge Workshop on Cool Stars, p. 60), Jordan (1983, Obs 103, 129), Katyesheva (1981, Astrofiz 17, 301), and Wagenblast et al. (1983, AA 120, 6).

Several extended observing programs were devoted to studies of the spectral variability of T Tauri stars on time scales between minutes and years. Aiad et al. (1984, AA 130, 67) organized an international observing campaign to monitor the spectral variations of several YY Ori stars continuously over a four day time interval. Making use of the long winter nights north of the arctic circle Appenzeller et al. (1983, AA 118, 75) used the Skiboth Observatory of the University of Tromsö in North Norway to obtain an almost continuous record of the spectral variations of RW Aur during a 12 day period. Mundt and Giampapa (1982, ApJ 256, 156) observed line profile variations of RW Aur on time scales as short as 10 minutes. The spectral variability of this star on longer time scales (days to months) was studied extensively by Bukach et al. (1982, Sov Astr Lett 8, 172) and Grinin et al. (1983, IAU Coll No. 71, 513). Efimov et al. (1980, Perem Zvesdy 21, 247) studied the spectral variability of DI Cep. Very interesting information on the variability of the emission line spectrum of T Tauri stars (variations of the Hα line emission) resulted from the photometric monitoring program of Herbst et al. (1982, AJ 87, 1710) which included Hα intensity measurements.

Hartmann (1982, ApJ Suppl 48, 109) and Mundt (1984, ApJ 280, 749) used high resolution absorption line profiles to derive fundamental physical properties of the T Tauri stellar winds. Jankovics et al. (1983, PASP 95, 883) and Appenzeller et al. (1984, AA 141, 108) found the forbidden lines in the spectra of the T Tauri stars to be systematically blueshifted, with line profiles indicating highly anisotropic mass flows already in the nonresolved close circumstellar envelopes of these stars.

Meyer and Ulrich (1984, ApJ 283, 98) used the diffuse interstellar bands in the spectra of T Tauri stars to study the properties of their circumstellar dust.

6.2 Post-T Tauri stars (PTT). The evaluation of Einstein X-ray observations of star forming regions led to the discovery of PTTs which seem to be PMS stars in an evolutionary stage between the T Tauri phase and the ZAMS (cf. Mundt et al. 1983, ApJ 269, 229; Walter 1984, Third Cambridge Workshop on Cool Stars, p. 75). Additional PTTs were observed spectroscopically by Feigelson and Kriss (1983, AJ 88, 431) and by Smith et al. (1983, ApJ 271, 237).

6.3 Herbig Ae/Be stars (HBeS). Finkenzeller and Mundt (1984, AA Suppl 55, 109) and Finkenzeller and Jankovics (1984, AA Suppl 57, 285) obtained high quality

https://doi.org/10.1017/S0251107X00006416 Published online by Cambridge University Press

spectrograms and collected fundamental data on all known HBeS. Their data support the PMS nature of these stars. Talavera et al. (1982, Third European IUE Conference, p. 99) and Tjin et al. (1984, AA 134, 273) investigated the UV spectra of HBeSs. Harvey (1984, PASP 96, 297) obtained IR spectrograms of nine HBeSs. Detailed spectroscopic studies were carried out for HD 200775 by Baschek et al. (1982, AA 105, 300) and for AB Aur by Praderie et al. (1982, ApJ 254, 658), Felenbok et al. (1983, Rev Mex Astr Astrofis 7, 239), Finkenzeller (1983, AA 124, 157), and Catala et al. (1984, AA 134, 402).

6.4 FU Ori objects. New spectroscopic observations of V 1057 Cyg were obtained by Kolotilov (1983, Sov Astr Lett 9, 622) and by Chalonge et al. (1982, Astrofiz 18, 263). Kolotilov and Petrov (1983, Sov Astr Lett 9, 171) also observed V 1515 Cyg. Levreault (1983, ApJ 265, 855) used molecular line spectroscopy to study the wind from the FU Ori object Elias 1-12. Graham and Frogel (1985, ApJ in press) discovered and investigated a new FU Ori star. Interestingly this fifth known FU Ori object appeared on the edge of a known HH object (No. 57).

6.5 Herbig-Haro objects (HH); jets. The last three years brought decisive progress in the understanding of the HH objects. It now seems to be generally accepted that these line emitting gaseous nebulae are caused by collimated mass ejection from very young low mass stars or protostars. Recent general reviews of the HH objects have been given by Schwartz (1983, Ann Rev Astr Astrophys 21, 209; 1983, Rev Mex Astr Astrofis 7, 27). The stars exciting the HH objects were studied by M. Cohen and Cohen et al. (1982, PASP 94, 266; 1983, ApJ 265, 877; Rev Mex Astr Astrofis 7, 241; 1984, ApJ 278, 671) and by Mundt and Hartmann (1983, ApJ 268, 766).

New spectroscopic data on individual HH objects were collected by Dopita et al. (1982, ApJ 263, L73), Meaburn and White (1982, MNRAS 199, 121), Böhm et al. (1983, AA 125, 23), Graham and Elias (1983, ApJ 272, 615), Axon and Taylor (1984, MNRAS 207, 241), and by Krautter et al. (1984, AA 133, 169). IUE-UV spectrograms were obtained by Böhm et al. (1982, ApJ 262, 224; 1982, ApJ 263, L35; 1984, ApJ 277, 216), Brugel et al. (1982, ApJ 262, L35), and by Meaburn (1982, AA 114, 367). Brown et al. (1983, ApJ 203, 785) and Schwartz (1983, ApJ 268, L37) observed molecular hydrogen in the spectra of HH objects. A highly interesting new phenomenon discovered during the period covered by this report is strongly collimated HH-like gas flows (or "jets") close to young stars (cf. Mundt et al. 1983, ApJ 265, L71; 1983, ApJ 274, L83; 1984, AA 140, 17; Strom et al. 1983, ApJ 271, L23). An excellent review of this exciting new topic has been prepared by Mundt (1984) and will be published in the proceedings of the Second Meeting on Protostars and Planets.

7. Be Stars -- A. Slettebak

The field of Be-star research has been very active since the last Commission 29 report. Earlier research was summarized in the proceedings of IAU Symposia No. 70 (1976, "Be and Shell Stars," ed. A. Slettebak) and No. 98 (1982, "Be Stars," ed. M. Jaschek and H.-G. Groth). More recent general reviews include those by Doazan (1982, in "B Stars With and Without Emission Lines," ed. A. Underhill and V. Doazan, NASA-CNRS, NASA SP-456), Harmanec (1983, in Proc Workshop on Rapid Variability of Early-Type Stars, Hvar Obs Bull 7, No. 1), Kogure and Hirata (1982, Bull Astr Soc India 10, 281), Hirata and Kogure (1984, Bull Astr Soc India 12, 109), and Thomas (1983, in "Stellar Atmospheric Structural Patterns," NASA-CNRS, NASA SP-471).

Several catalogues of Be-star data, very useful for researchers in this field, appeared during this report period. The Catalogue of Stellar Groups by M. Jaschek and D. Egret (1982, Publ Spec CDS No. 4) lists some 1000 Be stars. Photometric data for these objects have been collected by B. Hauck and M. Mermilliod (1984, Bull Inf CDS No. 26). Both catalogues are available through the Centre de Données Stellaires (CDS) of the Strasbourg Observatory. Also, Page of the Mount Tamborine Observatory (Australia), has made his Be Spectrum and Magnitude Databank (1981, Be Star Newsl No. 4, 2) available in several forms through both the CDS and ADS (NASA), and completed a revision in 1984.

Of special importance is the Be-Star Newsletter, edited by M. Jaschek and distributed twice annually by the Strasbourg Observatory. This very valuable publication makes reports such as this one somewhat superfluous. Thus, during the three-year period covered by this report, the Newsletter included 44 research contributions and 382 references to Be-star research, plus regular reports on international observing campaigns, announcements of meetings, etc. Since it is neither possible nor very meaningful to attempt to summarize this vast amount of work into a short report, only some highlights will be discussed in what follows.

It should be stated at the outset that we still do not understand why or how Be stars throw off shells, nor is their evolutionary status clear. This seemingless slow progress is due in part to the nature of Be-star observations in earlier years: sporadic "looks" at individual stars, usually in visual or blue light only. The past several years have seen a dramatic change in this respect, however: increasingly, long series of observations of a given star are being made, often simultaneously in different wavelength regions. Such observations should be very fruitful toward understanding Be stars which are, after all, (on various time scales) variable stars.

Mention should be made, especially, of two international observing campaigns started several years ago. One, a spectroscopic campaign, was initiated by Barker and concentrates on Hα observations of Be stars (cf. Baker 1983, PASP 95, 966). Other large programs of Hα observations include those of Andrillat and Fehrenbach (1982, AA Suppl 48, 93), Andrillat (1983, AA Suppl 53, 319), Dachs et al. (1981, AA Suppl 43, 427), and Fontaine et al. (1982, ApJ Suppl 49, 259; 1983, AJ 88, 527).

The other international observing campaign is a photometric one and was initiated by Harmanec, Horn, and Koubsky, with many participating observers. A successful mini-campaign on five rapid Be variables was organized by Percy and Stagg in 1983. Among the many papers on Be star photometry and variability written during this report period are those by Alvarez and Schuster (1982, Rev Mex Astr Astrofis 5, 173), Ashok et al. (1984, MNRAS 211, 471), Bhatt et al. (1984, AA Suppl, in press), Dachs and Wamsteker (1982, AA 107, 240), Goraya (1984, AA 138, 19), Huang (1984, Publ Beijing Obs, in press), Kogure (1984, Publ Beijing Obs, in press), Mazeh and Brosch (1981, AA 95, 3), Mendoza et al. (1983, PASP 95, 48), Mermilliod (1982, AA 109, 48), Neto and Pacheco (1982, MNRAS 198, 659), Schuster and Alvarez (1983, PASP 95, 35), Sharov and Lyuty (1984, Astr Tsirk No. 1333, 1), and Zorec et al. (1983, AA 126, 192). An excellent review of Be star variability was presented by Harmanec at the Hvar Workshop on Rapid Variability of Early-Type Stars (1983, Hvar Obs Bull 7, No. 1).

Long series of observations of a number of bright Be stars now exist, as well as simultaneous observations in different wavelength regions, which permit modelling of these objects in a number of cases. Recent papers include studies of o And (Pastori et al. 1982, Astrophys Space Sci 86, 179; Poeckert et al. 1982, PASP 94, 87; Harmanec 1984, IBVS No. 2506), V 923 Aql (Ringuelet et al. 1984, AA 131, 9), 28 CMa (Baade 1982, AA 105, 65; 1982, AA 110, L15), γ Cas (Doazan et al. 1983, AA 128, 171; Galkina 1981, Bull Crimean Astrophys Obs 64, 72; Henrichs et al. 1983, ApJ 268, 807; Lowe et al. 1985, ApJ, in press), μ Cen (Baade 1984, AA 135, 101; Peters 1984, PASP, in press), θ CrB (Doazan et al. 1984, AA 131, 210; Harmanec 1984, Bull Astr Inst Czech 34, 324; Underhill 1984, AA, in press), 59 Cyg (Barker 1982, ApJ Suppl 49, 89; 1983, ApJ 88, 72; Hubert-Delplace and Hubert 1981, AA Suppl 44, 109; Tarasov and Shcherbakov 1983, Sov Astr Lett 9, 350), 88 Her (Doazan et al. 1982, AA 115, 138; Barylak and Doazan 1984, Fourth European IUE Conference; Barylak et al. 1985, AA in press), EW Lac (Kogure and Suzuki 1984, Publ Astr Soc Japan 36, 191), ω Ori (Hayes and Guinan 1984, ApJ 279, 721), ϕ Per (Poeckert 1981, PASP 93, 297), ζ Tau (Dawanas and Hirata 1984, Astrophys Space Sci 99, 139; Harmanec 1984, Bull Astr Inst Czech 35, 164), HR 2142 (Peters 1983, PASP 95, 311), and HR 5223 (Dachs and Hanuschik 1984, AA 138, 140).

The above papers generally support the picture, which was already developing at IAU Symposium No. 98, of the Be envelope consisting of a cool, low-velocity, flattened Balmer-emitting region plus a hot, high-velocity, spherically-symmetrical stellar-wind region. See also the papers by Marlborough and Zamir (1984, ApJ 276, 706) and Oegerle and Polidan (1984, ApJ 285, 648). Not all researchers accept this picture, however (cf. Doazan and Thomas 1982, "The B Stars With and Without Emission

Lines," ed. Underhill and Doazan, NASA SP-456), and the relationship between the cool and hot regions is not yet clear. Various possible scenarios were discussed by Poeckert (1982, IAU Symp No. 98, p. 480).

An exciting development, already suggested in papers by Baade and by Bolton at IAU Symp No. 98, is the presence of nonradial pulsations in Be stars. Recent work includes papers by Baade (for example, 1984, AA 135, 101), Percy (1983, AJ 88, 427) and Vogt and Penrod (1983, ApJ 275, 661). The latter suggest that sporadic release of pulsation energy during mode switching provides a plausible explanation for Be-type outbursts in ζ Oph, and for the occurrence of the Be phenomenon in general.

An especially interesting aspect of ultraviolet observations of Be stars is the discovery of narrow, high-velocity absorption components in the spectra of γ Cas (Hammerschlag-Hensberge 1979, IAU Circular No. 3391), 59 Cyg (Doazan et al. 1980, ApJ 235, L17), and ω Ori and 66 Oph (Peters 1982, ApJ 253, L33). The observations and possible models were reviewed by Henrichs (1984, Fourth European IUE Conference), who points out that while 50 percent of luminous stars show narrow absorptions, their occurrence in less luminous stars is strongly connected with the Be phenomenon.

Another interesting ultraviolet result, in this case from Voyager in the far-UV (910-1700 Å), comes from Polidan et al. (1985, in preparation), who find that the energy distributions of Be stars in the ultraviolet are identical to those of non-Be stars of similar ground-based spectral type. This result (no gravity darkening) implies that Be stars do not rotate at the critical velocity.

In addition to the above and to the ultraviolet studies of selected bright Be stars already referenced, the following investigators were among those who wrote papers based on IUE and Copernicus observations of Be stars: Barker et al. (1984, NASA Goddard Conference, "Six Years of IUE Research"), Bernacca et al. (1983, AA 122, 17), Codina et al. (1984, AA Suppl 57, 239), Hubert-Delplace et al. (1983, AA 121, 174), Kitchin (1982, MNRAS 198, 457), Molaro et al. (1983, AA 119, 150), Oegerle et al. (1983, PASP 95, 147), Selvelli (1984, Fourth European IUE Conference), Slettebak and Carpenter (1983, ApJ Suppl 53, 869), and Tarafdar (1983, MNRAS 204, 1081).

The association of low-luminosity X-ray sources with Be stars was established with the detection of X-ray emission from X Per and γ Cas. Among papers written during this report period on these and other X-ray sources are those by Charles et al. (1983, MNRAS 202, 657), Corbet and Mason (1984, AA 131, 385), Grindlay et al. (1984, ApJ 276, 621), Kelley et al. (1983, ApJ 274, 765), Koenigsberger et al. (1983, ApJ 268, 782), Kriss et al. (1983, ApJ 266, 806), Mazeh et al. (1982, ApJ 256, L13), Peters (1982, PASP 94, 157), Sanwal et al. (1984, Astrophys Space Sci, submitted), Steiner et al. (1984, ApJ 280, 688), van der Klis et al. (1983, MNRAS 203, 279), Weisskopf et al. (1984, ApJ 278, 711), and White et al. (1982, ApJ 263, 277). Mention should also be made of the Bologna-Frascati Be-star working group (Giovannelli, Bartolini, Bianco, Guarnieri, Piccioni, Giangrande, Ferrari-Toniolo, Persi and others), who published a number of papers on Be X-ray sources during the report period.

Several investigators have attempted to measure shell sizes for Be stars. Thus, Schmidtke and Africano (1984, AJ 89, 663) observed a lunar occultaion of the B1 IV shell star, ζ Tau, in Hα light to determine an upper limit to the shell size of about four stellar radii. Granes, Vakili, and collaborators have undertaken an interferometric program to determine sizes of Be stars. They obtain an upper limit to the diameter of γ Cas of about 46 solar radii (Vakili et al. 1984, Publ Astr Soc Japan 36, 231).

Magnetic fields have been suggested as playing a role in Be star models. A recent search for magnetic fields in Be stars by Barker et al. (1984, ApJ in press) finds these objects to be magnetically indistinguishable from normal upper main-sequence stars. The authors point out, however, that large surface fields could escape detection, depending upon field geometry and orientation, and that circumstantial evidence suggests that many Be stars may indeed be magnetic.

Rotation in Be stars has been studied by several investigators during the report period. Thus, Ruusalepp and Sapar (1983, Publ Tartu Obs vol 50; 1984, Publ Tartu Obs vol 51) have attempted to separate V from sin i for rotating stars, while Slettebak (1982, ApJ Suppl 50, 55) and Gao (1984, Publ Beijing Obs, in press) estimated V sin i for a number of bright Be stars.

Abt and Cardona (1984, ApJ 285, 190) investigated Be stars in binaries, confirming the known near-absence of Be binaries with periods less than 0.1 year, but finding no difference in binary frequencies of Be and B stars for longer periods, up to the 10^4 AU limit of their survey.

A principal activity of the Working Group on Be Stars (IAU Commissions 29 and 45) was the planning of a conference on the Physics of Be Stars. This has been designated as IAU Colloquium No. 92 and will be held in Boulder, Colorado, U.S.A. during the period August 18-22, 1986. The undersigned is Chairman of the Scientific Organizing Committee and T. P. Snow, Jr. is Chairman of the Local Organizing Committee for this colloquium.

Finally, I would like to thank my many colleagues who sent reprints, preprints, and reports of their work -- I regret that there is not more space available to include all of the research done during this report period. In particular, since this section has been restricted to work done on "classical" Be stars, research dealing with Herbig Ae/Be (pre-main-sequence) stars, emission-line supergiant stars, and interacting binary systems will be found in other sections of this Commission 29 report.

8. CP Stars of the Upper Main Sequence -- D. S. Leckrone and S. J. Adelman

A new monograph by S. C. Wolff, "The A-Type Stars: Problems and Perspectives," (1983, NASA SP-465) provides a comprehensive review of research on the various subclasses of CP stars. A major review (in Russian) of magnetic stars is given by Khokhlova (1983, in Astrophysics and Space Physics, ed R. A. Syunyaev, p. 233).

Radiatively driven diffusion remains the dominant model for the production of anomalous elemental abundances in CP star photospheres. Alecian and Vauclair (1983, Fundam Cosmic Phys 8, 369) and Vauclair (1983, in Astrophysical Processes in Upper Main Sequence Stars, ed B. Hauck, A. Maeder, Geneva Obs p.167) presented reviews of the theory. Diffusion computations for specific ions suggest important observational tests of the theory. Megessier (1984, AA 138, 267) computed the time variations of the silicon abundance and distribution over the surface of magnetic CP stars with effective temperatures of 12000 K and 14000 K. Silicon overabundances occur over the entire surface of a young magnetic star; in middle age the equatorial regions become Si-free; and Si will be concentrated at the poles of the oldest magnetic stars. Alecian and Grappin (1984, AA 140, 159) studied the temporal building of density inhomogeneities due to the diffusion of a single ion in CP stars. A transient phase occurs prior to the final equilibrium state during which time significant temporal and spatial fluctuations occur. Borsenberger et al. (1984, AA 139, 147) investigated the radiative acceleration of Be, Mg, and Ba in HgMn stars. They predicted overabundances of Be and Ba and underabundances of Mg. A possible merger of the diffusion and magnetic accretion theories was proposed by Havnes and Goertz (1984, AA 138, 421). Neutral diffusion may lead to elemental segregation and overabundances of several heavy elements in some parts of the stellar magnetosphere, with sporadic violent distortions and re-combination of magnetic field lines accelerating particles to the stellar surface.

Moss (1984, MNRAS 209, 607) developed time-dependent models for the structure of rotating magnetic stars, based on a two-dimensional time-dependent solution of the MHD equation. Many of the restrictions previously found for static models disappear. Carpenter (1984, ApJ in press), continuing work begun by Stepien and Muthsam, explored the influence of magnetic field lines on the structure and predicted spectra of model atmospheres with normal composition. Some effects attributed to overabundances may be partly due to Zeeman broadening of the individual lines analyzed, Zeeman broadening of UV lines contributing to line blanketing, and contributions of magnetic pressure to the hydrostatic equilibrium of the atmosphere.

A substantial body of data now support the existence of a new type of variability among the CP stars - rapid oscillations of the surface layers. Kurtz (1984, MNRAS 209, 841 and references therein) has found nine cool, magnetic CP stars which vary photometrically with periods of 6-14 minutes and with amplitudes in the B-band of 0.002-0.016 mag. These stars appear to pulsate in non-radial modes of very high overtone, with the pulsation and magnetic axes co-aligned. Kurtz suggests an "oblique pulsator" model from which he derives angles of inclination of the magnetic and rotational axes and rotational periods independent of the spectroscopic and magnetic oblique rotator models. Shibahashi (1983, ApJ Lett 275, L5) and Cox (1984, ApJ 280, 220) propose an explanation of the rapid oscillations in terms of magnetic over-stability in a superadiabatic shell in the magnetic polar regions of the star. Weiss (1983, AA 128, 152) discusses the existence of a second group of rapidly varying magnetic CP stars with about five members - low overtone pulsators of the δ Scuti type with periods of 1-2 hours.

Adelman and Pyper continued their extensive scanner measurements of CP stars (cf. 1983, AA 118, 313)and attempted to relate them to Stromgren and other photometric systems (cf. 1984, AA Suppl 55, 479). Hauck and North (1982, AA 114, 23) investigated the photometric properties of CP stars in the Geneva system. The peculiarity parameter Δ(V1-G), the rotational velocity, and the effective magnetic field strength are found to correlate with one another. Maitzen (1984, AA 138, 493) discovered that the magnetic field strength and the λ5200 feature appear to be correlated in He-weak stars. Efforts continue to reduce and improve photometric periods of CP stars (e.g. Manfroid and Renson 1983, AA Suppl 51, 267).

Lane and Lester (1984, ApJ 281, 723) derived effective temperatures for several classical Am stars using Kurucz line-blanketed model atmospheres and ultraviolet energy distributions. Their results are systematically cooler than previous determinations. They also noted that blanketed models with solar composition are uniquely able to match simultaneously the observed optical and UV flux distributions of numerous Am stars, suggesting that these stars may be Ca-deficient rather than metal-rich. Nicolet (1983, AA Suppl 51, 245) used the Geneva photometric parameter m to select Am star candidates. Wiertz and van Genderen (1983, AA 121, 35) discussed the properties of Am stars in the Walraven photometric system.

Infrared measurements of magnetic CP stars were made by Groote and Kaufmann (1983, AA Suppl 53, 91; 1984, AA 130, 184). But neither Bonsack and Dyck (1983, AA 125, 29) nor Odell and Lebofsky (1984, AA 140, 468) support their finding of infrared excesses at 5μm in these stars.

With the extended life of the IUE satellite, ultraviolet spectroscopy of CP stars moved rapidly from qualitative surveys to detailed quantitative analyses - a trend that will surely continue with the expected launch in 1986 of the Hubble Space Telescope and its High Resolution Spectrograph. Jacobs and Dworetsky (1982, Nature 299, 535) identified in the extreme HgMn star HR 7775 numerous lines of Bi, whose only stable isotope is the heaviest in the period table and measured its abundance to be $\simeq 10^6$ x solar. Bi was not found in the 12 other HgMn stars they examined. Ultraviolet lines of Pt II in IUE spectra of HgMn stars were analyzed by Dworetsky et al. (1984, Phys Scr T8), who found a Pt abundance log A $\geqslant$ 6. Leckrone (1984, ApJ 286, 725) studied the ultraviolet resonance lines of Hg II in IUE spectra of CP stars and found abundances for five HgMn stars in the range log A = 6.0-6.4, consistent with values obtained from Hg I λ4358. The Hg II λ3984 line was found to be poorly suited to abundance studies. Ultraviolet resonance lines of Al II and Al III in 35 CP and 7 normal stars were observed by Sadakane et al. (1983, ApJ 274, 261). Aluminum is, in general, underabundant in CP stars, in apparent disagreement with predictions of diffusion theory. Sadakane (1984, PASP 96, 259) reported anomalously strong C IV and Si IV resonance lines, and an anomalous ratio of C IV to Si IV line strengths, in the IUE spectra of the Bp star, 36 Lyn. IUE data for the remarkable CP star HD 101065, Przybylski's star (Wegner et al. 1983, ApJ 272, 646), demonstrate the clear presence of singly-ionized iron-peak elements. This observation, combined with the ultraviolet flux distribution, implies that HD 101065 has an effective temperature between 7500 and 8000 K, which is hotter than found in some previous studies. Application of the technique of wavelength coincidence statistics by Bord and Davidson (1982, ApJ 258, 674; 1982, AA 111, 362) and Chojnacki et al. (1984, ApJ 286, 736) to IUE spectra showed promise of revealing the presence of interesting species and establishing statistical abundances. Lanz (1984, AA 139, 161) used IUE low dispersion spectra to derive semi-empirical bolometric corrections for CP stars whose flux distributions are distorted by enhanced UV blanketing and backwarming effects.

Interest continues in the remarkable long period variable HR 465, which according to Cowley and Rice (1981, Nature 294, 636), was returning to rare earth maximum when observed in late 1981. Guthrie (1982, Astrophys Space Sci 85, 315) found Cr to vary out of phase with the rare earths and also with respect to Sc, Ti, V, and Ni. The Cr/Fe ratio is abnormally large at rare earth minimum and abnormally small at rare earth maximum. Scholz (1983, Astrophys Space Sci 94, 157) established HR 465's magnetic period as 23.3 years and found that the extrema in the absorption line strengths occur at magnetic cross-over.

The current University of Michigan program to reclassify all the HD and numerous fainter stars on the MK system, using an objective prism all-sky survey, is yielding an abundance of new candidate CP stars as well as other interesting objects (Bidelman 1983, AJ 88, 1182).

Didelon's (1983, AA Suppl 53, 119) new catalogue of published magnetic field measurements covering the years 1958-1981 will be valuable to workers desiring data on specific stars or interested in the statistics of magnetic fields. Borra and Landstreet (1983, ApJ Suppl 53, 151) detected fields in 12 He-weak CP stars which appear to be hot extensions of the magnetic Ap stars. But they were unable to detect fields at the 100-400 gauss level in any of the P- and Ga-rich B stars such as 3 Cen A. These latter stars may be hot extensions of the HgMn group.

Walborn (1983, ApJ 268, 195) presented a homogeneous list of He-rich stars, to visual magnitude 10-11. The frequency of slowly rotating He-rich stars is similar to that of normal early B stars, so that slow rotation does not appear to be a fundamental parameter of the He-rich phenomenon.

Cowley and Adelman (1983, QJRAS 24, 393) discussed the status of abundance analyses of CP stars as well as the prospects for substantial improvements. Fine analyses of specific CP stars which attempt to implement some of their suggestions include those by Adelman et al. (1984, MNRAS 206, 640), Adelman (1985, AA and AA Suppl, in press), and Cowley and Muthsam (1984, AA 130, 348). Boesgaard et al. (1982, ApJ 259, 723) determined beryllium abundances from observations of the Be II resonance doublet near λ3130 in normal and HgMn stars. 75% of the HgMn stars, particularly the hotter ones, showed values at least 20 times solar. Guthrie (1984, MNRAS 206, 85) surveyed the abundances of 14 elements in the photospheres of 20 sharp-lined HgMn stars. By using mainly weak lines, he hoped to better define the abundance anomalies of this class. Johansson and Cowley (1984, AA 139, 243) identified numerous Fe II with lower excitation potentials of at least 10 eV in several CP stars. Many other high level transitions are probably present in their spectra. Cowley (1984, Phys Scr T8, 28) reviewed the rare earth abundance determinations of CP stars and evaluated the status of rare earth partition functions.

Goncharskij et al. (1982, Astr Zh 59, 1146; 1983, Astr Zh 60, 83) and van Rensbergen et al. (1984, AA 136, 31) have attempted to map the surface distributions of elements from time dependent observations. Higher signal-to-noise observations with good phase coverage are needed to resolve ambiguities in the results.

Maitzen and his colleagues (cf. 1984, AA 138, 189) as well as Borra et al. (1982, AA 111, 117) continued the search for CP stars in clusters and in the field by obtaining of the measured Δa index. North (1984, AA Suppl 55, 259) has determined periods for 25 CP stars in clusters or associations from Geneva photometry. One of these stars, Cox 38, in NGC 2516 is an eclipsing binary. Studies of CP stars in binary systems included orbital determinations by Dworetsky (1982, Observatory 102, 138) and Stickland et al. (1984, Observatory 104, 74). Abt and Cardona (1984, ApJ 276, 266) classified stars with Ap or Am primaries and found an apparent excess of Am secondaries. According to Lamb et al. (1983, ApJ Lett 274, L71) the magnetohydrodynamic torque due to electric currents produced by the asynchronous rotation of magnetic stars in close binary systems can lead to rotational synchronization in binaries with a magnetic CP star component.

Cowley et al. (1982, ApJ 254, 191) suggested that weak-lined stars including λ Boo stars may represent a sizable fraction of the late B and early A stars. Hauck and Slettebak (1983, AA 127, 231) proposed a new spectroscopic definition of the λ Boo class and showed how their intermediate band colors could be used to distinguish them from other types of stars with similar temperatures. Baschek et al.

(1984, AA 131, 378) observed several classical and suspected λ Boo stars with IUE and found inconsistencies between ultraviolet and optical classification criteria.

9. Working Group on Standard Stars -- L. E. Pasinetti

This report covers the period 1 January 1982 - 1 October 1984.

The Working Group deals with the problem of identifying "normal" standard stars and providing standard reference data for various problems in stellar astronomy. A Standard Star Newsletter (SSN) edited by Pasinetti at the Department of Physics of the Milan University, is published twice a year since November 1982. SSN also serves as an official voice of the IAU Working Group on Standard Stars; it is currently distributed to members and, on request, to interested colleagues and institutes.

The Working Group participated in organizing the IAU Symposium No. 111 "Calibration of Fundamental Stellar Quantities." By the time this report is distributed, the Proceedings of the Symposium will be published, edited by Hayes, Pasinetti and Philip. The colleagues can find in the 20 review papers reported in them, recent data and exhaustive discussions on the topics. Other problems are also reported in the 65 contributed papers. As the Symposium No. 111 has provided a detailed overview of the subject, I will not report all the results appeared in the last three years, but I will give some additional information.

Calibrational lists are published in The Astronomical Almanac. Preliminary lists of standard stars were published in Bull Inf CDS (Strasbourg) by Breger and Hsu (1982, No. 23, 51) Batten, Glushneva, Keenan, Fracassini et al. (1983, No. 24, 3, 7, 19, 31, respectively). A microfiche concerning standard stars in various systems, to be included with the Proceedings of the Symposium No. 111, has been prepared by Philip and Egret.

Comparison stars which turn out to be variable are regularly reported in the SSN. The listed references are also sent to IBVS.

SSN is covering regularly the literature of all the countries since October 1984. Besides the papers already quoted in the past Newsletters, the following ones are relevant for our Working Group:

9.1 Standard stars and standardizations. Lists of standard stars (also for use on large telescopes) for JHKL, H_2O and CO photometry are given by Elias et al. (1982, AJ 87, 1029, 1983). Taylor (1982, ApJ Suppl 50, 391) has presented new spectrophotometric data in the range λλ4040-6180 for the standards of the Spinrad-Taylor scanner photometric system and has made a calibration to absolute units. Koornneef (1983, AA Suppl 51, 489) has made a homogenization of near-infrared data from southern bright stars and gives a list of 290 stars and data suitable for standardization purposes. Landolt (1983, AJ 88, 439) has provided new UBVRI standard stars, available to telescopes of a variety of sizes in both hemispheres. Batten et al. (1983, Publ Dominion Astrophys Obs 16, 143) observed most of the 60 stars selected as velocity standards in 1955 by the IAU. A list of stars which are not suitable as standards is given. McAlister and Hartkopf (1983, PASP 95, 775) have proposed a list of 26 binary-star systems as standards for interferometric observations of binary stars. Relationships between the Johnson and Kron-Cousins VRI photometric systems have been investigated by Fernie (1983, PASP 95, 782) using the new Johnson UBVRI standards appeared in The Astronomical Almanac. Trefzger et al. (1983, AA 117, 347) report on an empirical calibration of the RGU system and give colors of a first set of standard stars.

9.2 Energy distributions. New absolute energy distributions for seven standard stars in the region λλ3200-7600 Å are derived by Glushneva and Ovchinnikov (1982, Sov Astr 26, 548) from spectrophotometric comparison with α Lyr. Moreover, for the same stars and α Lyr, Glushneva (1983, Sov Astr 27, 326) gives effective temperatures, bolometric corrections, radii and surface gravities. The following papers are devoted to studies of bright and faint (6-8 mag) standard stars: Ipatov 1982, Astr Zh 59, 607; Ipatov 1981, Astr Zh 58, 569; Depenchuk and Komarov 1982, Astrometr Astrofiz No. 46, p. 15. A determination of the absolute monochromatic flux from Vega at λ2.20

https://doi.org/10.1017/S0251107X00006416 Published online by Cambridge University Press

and 3.80 μm has been made by Selby et al. (1983, MNRAS 203, 795) by comparison with a furnace. Oke and Gunn (1983, ApJ 266, 713) give absolute fluxes of four F type subdwarfs, intended as secondary standards for absolute spectrophotometry. Energy distributions for 18 stars intended as flux standards for large southern hemisphere telescopes are given by Stone and Baldwin (1983, MNRAS 204, 347).

9.3 Polarization. Bailey and Hough (1982, PASP 94, 618) present UBVRIJHK polarization measurements of standard stars with large interstellar polarizations and give normalized interstellar polarization curves. Hsu and Breger (1982, ApJ 262, 682) made linear polarimetric measurements to improve the system of standard polarized stars. Polarimetric variability was found in three stars.

9.4 Variability in "standards." Some evidence for variation of the spectrophotometric standard 109 Vir is reported by Taylor (1982, PASP 94, 663). Philip and Hayes, on the contrary, have not found evidence for any variations over the period 1969-1980. McClure (1983, PASP 95, 201) gives results on HD 184467, a double-line spectroscopic binary, which was an IAU velocity standard.

Abbreviations

AA	Astronomy and Astrophysics
AA Suppl	Astronomy and Astrophysics Supplement Series
AJ	Astronomical Journal
ApJ	Astrophysical Journal
ApJ Suppl	Astrophysical Journal Supplement Series
Astr Tsirk	Astronomicheskij Tsirkulyar
Astr Zh	Astronomicheskij Zhurnal
Astrofiz	Astrofizika
Astrometr Astrofiz	Astrometriya i Astrofizika
Astrophys Space Sci	Astrophysics and Space Science
Bull Inf CDS	Bulletin d'Information du Centre de Données Stellaires
Fund Cosmic Phys	Fundamentals of Cosmic Physics
IBVS	Information Bulletin on Variable Stars
Izv Crim	Izvestiya Ordena Trudovogo Krasnogo Znameni Krymskoj Astrofizicheskoj Observatorii
MNRAS	Monthly Notices of the Royal Astronomical Society
PAS Japan	Publications of the Astronomical Society of Japan
PASP	Publications of the Astronomical Society of the Pacific
Perem Zvesdy	Peremennye Zvezdy
Phys Scr	Physica Scripta
Pisma Astr Zh	Pis'ma v Astronomicheskij Zhurnal
QJRAS	Quarterly Journal of the Royal Astronomical Society
Rev Mex Astr Astrofis ...	Revista Mexicana de Astronomia y Astrofisica
Sov Astr	Soviet Astronomy

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https://doi.org/10.1017/S0251107X00006416 Published online by Cambridge University Press