29. STELLAR SPECTRA (SPECTRES STELLAIRES)

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During the interval covered by this report, Commission 29 has sponsored or cosponsored the following IAU meetings: Symposium 98 on "Be Stars," Munich, FRG, April 1981; Colloquium 59, "Effects of Mass-Loss on Stellar Evolution," Trieste, Italy, September 1980; and Colloquim 70, "The Nature of Symbiotic Stars," Haute-Provence, France, August 1981. In addition, Commission 29, through its Working Group on Ap Stars, collaborated in the organization of the 23rd Liege International Astrophysical Symposium on Upper Main-Sequence Chemically Peculiar Stars. Several IAU symposia and colloquia proposed for 1982 and 1983 are also cosponsored by Commission 29.

This report is condensed from reports on highlights of progress in subfields of the subject of stellar spectra, which were prepared by members of the Organizing Committee and collaborators, whose names appear in the headings of sections below. Reports on progress in the areas of Be stars and Ap stars have been prepared by the chairman of the Working Groups on these subjects (which are cosponsored by Comm. 45), and these are given without condensation at the end of this report.

1. WR Stars -- Y. Andrillat

The current state of knowledge concerned Wolf-Rayet stars has been reviewed at IAU Symposium 99, held in 1981 September. An important recent publication is van der Hucht et al. (1981, Space Sci Rev 8, 227), which provides a catalogue of the 159 known galactic WR stars, their classifications, finding charts, discussions, and bibliographies for each object.

The evolutionary scheme proposed by Conti (O-Of-transition WN-classical WN-WC) requires a link between late Of stars with elevated mass loss rates and the transition WR stars of types WN7-WN8. Several such stars have been found, including HR 15570 (Willis and Stickland 1980, MNRAS 190, 27p), type 04f; and Sk 65-22 (Nandy et al. 1980, MNRAS 193, 43p), type 06Iaf+. The latter is particularly important, since it is within the LMC and an absolute magnitude Mv=-7.0 can be determined. If Sk 65-22 is a binary, the value of Mv is still compatible with that of a WN7 star.

Several studies of the transition WR stars have reached the following conclusions (Moffat and Seggewiss 1979, in *Mass Loss and Evolution of O-Type Stars*, IAU Symp 83, 447): (a) the stars are, in the mean, 2 mag more luminous than other WR stars, which is confirmed by UV observations (van der Hucht et al. 1980, PASP 92, 837); (b) the spectra contain very sharp lines; (c) the stars are very young; (d) the structure of ionization and excitation in the envelopes is different; and (e) hydrogen is present (H/He $\simeq$ 10), while it is absent or weakly present in other WN stars (H/He $\simeq$ 0.4). The WN7-8 stars have clearly been formed from massive Of stars ($M > 35\ M_\odot$), binaries or not, which have lost mass. They can be "runaway stars" in the second WR phase.

Several interesting stars have been discussed by Moffat and Seggewiss (1978, AA 70, 69; 1979, AA 77, 128; 1980, AA 86, 87), and Seggewiss and Moffat (1979,

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AA 72, 332). HD 197406 (WN7) is a single-line binary with a small mass function and a location 1000 pc from the galactic plane. The companion (≈ 4 $M_\odot$) is probably the compact remnant of a supernova explosion which accelerated the system to its present location--a clear example of a runaway star. HD 197406 is apparently in the last phase of the evolutionary scheme for extreme Of binaries proposed by van den Neuvel: OB(1)+OB(2) - WR(1)+OB(2) - supernova - compact star +OB(2) - compact star +WR(2). Two stars previously considered to be binaries have been found to be single stars: HD 151932, a member of Sco OB1 with Mv=-6.5; and HR 93131. HD 92740 is a single-line binary which may be as massive as its companion, in contrast to several other WR+OR systems with mass ratios WR/OB in the range 0.2 to 0.4.

Massey and Conti (1980, Ap J 242, 638) have found that HD 177230, considered a standard WN8 star, has a spectrum not resembling WN8, including the presence of hydrogen in the envelope. Further, it is apparently not a binary star.

Among the early WN stars, HD 50896(WN5) and HD 192163(W6) are of interest in that they are surrounded by ring nebulae (S 308 and NGC 6888 resp.). Van den Heuvel considers these stars to be in the second WR phase, which requires that they have compact companions. No evidence for binarity has yet been presented. Photometric, spectroscopic, and polarimetric variations of HD 50896 been discussed by various authors (Ebbets 1979, PASP 91, 804; Moffat and Seggewiss 1979, AA 77, 128; Firmani et al. 1980, IAU Symp 83, 421; McLean 1980, Ap J 236, L149; Cherepashchuk 1981, MNRAS 194, 755). A period of 3.763 d implies a close binary system with a companion of small mass (1.2 $M_\odot$), which is probably a neutron star accreting material from the wind of the WN5 star. The radial velocity of HD 192163 is in accord with that expected for a runaway O star, and the variations of its line profiles and wavelengths suggest that the star is binary (Koenigsberger et al. 1980, Rev Mexicana Astron Astrof 5, 45).

Several investigations have dealt with the properties of WC stars. HD 152270 (WC6-7+05), a member of the cluster NGC 6231, undergoes peculiar variations in the profile of the C III line, which Neutsch et al. (1979, Veroff Astron Inst Bonn, No. 92) have explained in terms of pertubations of the C III envelope by the hot star. The double-lined system HD 97152 (WC7+OB) has been discussed by Davis et al. (1981, Ap J 244, 528), who find the companion to have type 07V and obtain a mass ratio WC7/07 = 0.59 $\pm$ 0.02; in good accord with similar systems in the galaxy. Sahade and van der Hucht (1980, Ap Space Sci 69, 369) have found flux variations in the region 2770-2870 A in γ^2 Vel (WC8+09I).

Moffat and Seggewiss (1980, IAU Symp 88, 181) have given a list of WR binaries with established orbits, consisting of 12 double-line systems and 9 single-line systems. Apparently a maximum of 25% are WR+0 binaries. Among the double-line system, the mass ratio is sensibly constant for WN and WC stars of different subclasses. This result imposes constraints on the hypothesis of the evolution of WN to WC stars with additional mass loss. The mass ratio is also independent of the orbital period. Among the single-line systems, primarily of class WN7, the mass ratio M(WR)/M(2) is larger than in the double-line systems.

Williams et al. (1980, MNRAS 192, 25) find that the infrared (H-K) color indices of WR stars are strongly perturbed by emission lines, such that the observed differences between WC and WN stars in this index are due entirely to that effect. IR photometry demonstrates the presence of dust envelopes for late WC stars, but Williams and Allen (1980, Observatory 100, 220) find no evidence for dust around HR 115473 (WC5). However, an excess in H-K was observed by Allen and Puster in 1972, and a UV deficiency was noted by van der Hucht et al. (1979, AA Suppl 38, 279). Williams and Allen suggest that the star may have lost a thin dust envelope, as did HD 193793 (WC7).

HD 50896 (WN5) and HD 191765 (WN6) have UV deficiencies and IR excesses beyond the predictions of the empirical model adopted for these stars. Van der Hucht et al. (1979, AA Suppl 38, 279) suggest that these stars have very extended envelopes and/or that they are enveloped in dust. The latter hypothesis is quite plausible, since these stars are in the centers of ring nebulae.

The infrared spectra (8-13 μm) of late WR stars have been studied by Aitken et al. (1980, MNRAS 192, 679), who found peculiarities in the spectra of WC10 stars. Two unidentified lines, not present in WC8-9, appeared, and, in general, the spectra resembled that of a planetary nebula. For WC8-9, the spectra could be interpreted as that of a blackbody at 900 K with absorption at 10 μm due to grains of SiC. Such a temperature is too low for the WC10 stars.

Underhill (1979), Ap J 234, 137; 1980, Ap J 239, 220; 1981, Ap J 244, 963) has discussed the relationship between O and WR stars. WN7-8 stars are situated on the HR diagram near the B0Ia stars, but beyond B0.5III. The temperatures of these stars are near 26000 K, in good accord with ε Ori, B0Ia. She suggests that the WR state is a short phase in the evolution of a massive star.

Many WR stars have been found in the Magellanic Clouds, and recently Conti and Massey (1981, Ap J, in press) have found 14 WR stars in M33, among which 6, enclosed in small H II regions, resemble galactic WR stars. The remaining, located in giant H II regions, resemble the superluminous WR stars found in 30 Dor, the LMC, and NGC 3063. Kunth and Sargent (1981, AA 101, L5) have found strong and broad emission lines in the spectrum of the dwarf galaxy Tololo 3, which they attribute to WR stars.

2. Normal Stars of Types B-F -- J. Jugaku

2.1 B-type stars. Ultraviolet observations of early-type stars have yielded information on mass loss and on the adequacy of model atmospheres. Spectral atlases in the UV have been published by Meade and Code (Ap J Suppl 42, 283) for 132 stars, and for ι Her (B3V) by Upson and Rogerson (Ap J Suppl 42, 175). Ultraviolet spectra have been compared satisfactorily with theoretical models except for early main-sequence stars and supergiants by Llorente de Andrés et al (AA 100, 138). Dufton and McKeith (AA 81, 8) have observed He I lines for 29 stars O8-B7 and have compared with LTE and NLTE calculations. Mass loss characteristics displayed in UV spectra are discussed by Gathier et al. (Ap J 247, 173), Hutchings and von Rudloff (Ap J 238, 909), and Underhill (Ap J 235, L149).

Studies of equivalent widths and line profiles in ground-based data have yielded information on abundances and non-LTE effects in B-star atmospheres. Heasley and Wolff (Ap J 245, 977) have studied the 4922 A line of He I and found that the core and red wing agree with model predictions, but that the forbidden component in the blue wing is deeper and broader than predicted. Leparskas and Marlborough (PASP 91, 101) have studied He II λ4686 and C II λ5696. Ebbets and Wolff (Ap J 243, 204) have found the behavior of C III λλ9701-9718 inconsistent with model calculations in 28 O and B stars; the multiplet is in emission in stars earlier than O8. Dufton et al. (MNRAS 194, 85) observed N II lines in 29 B stars, and, using NLTE calculations of line strengths, derived a N/H ratio agreement with the solar value. Thomas et al. (MNRAS 188, 19) have verified that the strength of the O I λ7773 triplet may be used as a luminosity indicator in stars later than B1. Evidence of autoionization and dielectric recombination in Si II in B stars has been presented by Underhill (AA 97, L9).

Rotational effects in ultraviolet spectra have been discussed by Llorente de Andrés and Durán (AA 72, 318), Hutchings et al. (PASP 91, 313), and by Kodaira and Hoekstra (AA 78, 292). It appears to be possible to recognize rapidly rotating pole-on B stars; ξ Cas and ι Her may be examples.

Bates et al. (MNRAS 190, 611; 195, 9p) have studied the supergiant β Ori (B8Ia) using IUE and balloon-borne observations. They have found evidence for an expanding shell photoionized by stellar radiation. The B1 supergiant ξ^1 Sco has a UV spectrum dominated by blue-shifted resonance absorptions; there is weak evidence for a wind velocity up to 400 km/s (Appenzeller and Wolf AA Suppl 38, 51; AA 78, 15; and Hutchings Ap J 233, 913). Underhill (Ap J 239, 414) has determined effective temperatures, radii, and luminosities for several B supergiants, and has found that the rate of mass loss is not solely a function of luminosity. Dufton (AA 73, 203) has made an abundance analysis of the supergiants HD 96159 and HD 96261 and found a normal composition except for an 0.8-dex deficiency of nitrogen. Kane et al. (MNRAS 194, 537), on the other hand, found the BN0.5Ia star HD 163181 to have a nitrogen excess by a factor 2 to 4, and to be underabundant in C and O by a factor of 5. They have interpreted the result as compatible with a star stripped to its convective core.

Ambartsumian et al. (Ap J 227, 519) have observed P Cygni with a Copernicus satellite and found evidence for a wind with low terminal velocity and low ionization, unlike other B supergiants. The line profiles have been analyzed by Nugis et al. (IAU Symp 83, 39), who have concluded that deceleration of the envelope may be present. Wolf et al. (AA 99, 351) have suggested that R81 (HDE 269128) in the LMC may be a close counterpart of P Cygni.

Smith and Karp (Ap J 230, 156) have analyzed weak ultraviolet lines in τ Sco and found a flow of material present in the deep photosphere, which may heat the chromosphere and corona. A study of UV resonance lines in τ Sco by Hamann (AA 100, 169) has confirmed an outward decrease of ionization and yielded a mass loss rate of $10^{-8.9}$ $M_\odot$/yr. Fraquelli (PASP 91, 501) has found rapid velocity and Hβ V/R variations in HR 9070, and Wolstencroft et al. (MNRAS 195, 39p) have found evidence for a magnetic field in α Leo (B7V) from circular polarization measurements across the Hβ profile.

Observations of B stars associated with X-ray sources include HDE 226868, which is suggested by several models to have a luminous companion. Shafter et al. (Ap J 240, 612) were unable to find evidence for such a companion. HD 102567 (BIV), proposed counterpart of 4U 1145-61, has been observed with the IUE by Bianchi and Bernacca (AA 89, 214), who find evidence for an expanding envelope with a terminal velocity of 1800 km/s.

2.2 A-type stars. Line-profile changes in the spectrum of the supergiant α Cyg (A2Ia) have been studied by Inoue (PAS Japan 31, 11) and interpreted as due to temporary ejection of matter. A magnetic field has been detected in ν Cep (A2Ia) by Scholz and Gerth (MNRAS 195, 853; Astr Nach 301, 211). Praderie et al (AA 86, 271) have derived mass loss rates from UV resonance lines in five supergiants and obtained rates less than that of α Cyg.

The standard A0V star α Lyr continues to be the subject of investigations. Applications of new model atmospheres to UV and visible data have been carried out by Praderie et al. (AA 98,92); Hubený (AA 98, 96); Castelli and Faraggiana (AA 79, 174); Sadakane and Nishimura (PAS Japan 31, 481; 33, 189); and Dreiling and Bell (Ap J 241, 736). Gray (PASP 92, 154) has analyzed the profile of five lines to obtain a projected rotation velocity of 23.4 km/s. The near-infrared absolute energy distribution has been obtained by Arkharov et al. (Astr Tsirk, No. 1046), and the visible energy distribution has been discussed by Kharitonov et al. (Astr Zh 57, 287).

Abundances of B and Be in γ Gem (A0V) were investigated by Boesgaard and Praderie (Ap J 245, 219), who found both elements substantially depleted (factor 4-10) relative to α Lyr. Dravins (AA 96, 64) found no evidence for chromospheric emission in the Ca II H and K lines in 8 AV stars in the young cluster C0838-528

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and in the Hyades. Böhm-Vitense (Ap J 244, 938) found no differences in the energy distributions in the UV of slowly-rotating normal A stars and Am stars.

2.3 F-type stars. Boyarchuk et al. (22nd Liege Symp, p. 361) have determined abundances in three F-type supergiants and found them solar except for Na. Luck (Ap J 232, 797) determined abundances in nine supergiants of types F-K. Atmospheric effects, including non-LTE and mass loss effects, in F supergiants have been studied by Sonnenborn et al. (Ap J 232, 807), and by Hopkinson and Humrich (MNRAS 195, 661). Gehren (AA 75, 73) has obtained [M/H] = -.51 to +.14 in seven near main-sequence field stars of types F6-G0.

Böhm-Vitense and Dettmann (Ap J 236, 550) have used UV spectra of A-, F-, and G-type stars to discuss the boundary line in the HR diagram for stellar chromospheres. Other studies of chromospheric models and relevant data for F stars include those of Brown and Jordan (MNRAS 196, 757), and García-Alegre et al. (AA 96, 197). The latter paper demonstrates a Wilson-Bappu-type relationship for the Mg II emission line widths.

3. Non-Variable Stars of Types M, C, S -- R. Viotti and M. F. McCarthy

The importance of UV observations in providing diagnostics of the outer atmospheres of cool stars has been demonstrated by several papers. Surveys of Mg II emission were published by Weiler and Oegerle (1979), Ap J Suppl 39, 537) and Basri and Linsky (1979, Ap J 234, 1023) who found that the ratio of Mg II surface emission to total flux is independent of luminosity. The UV spectra indicate the presence of a solar-type transition region in cool giants and supergiants earlier than type K1, and of chromospheres only in cool stars (Linsky and Haisch 1979, Ap J 229, L27). Reimers (1980, ESA SP-157, 33rd) and van der Hucht et al. (1980, AA 82, 14) showed that absolute mass loss rates may be established from UV observations of cool giants with hot companions. A useful collection of papers may be found in the transactions of the conference, "The Universe at Ultraviolet Wavelengths" (1980, NASA: Greenbelt).

The HEAO-2 survey of X-ray emission (Vianna et al. 1981, Ap J 245, 163) indicates that all dM stars show X-ray emission between 10^{26} and 10^{29} erg/s, which is probably correlated with multiplicity and emission-line behavior. Only upper limits are given for M giants and supergiants, confirming a decrease of the incidence of hot coronae in luminous stars of late type. Pallavinci et al (1981, Ap J 248, 279) show that the X-ray luminosity of G to M stars depends strongly on rotation rate, but not upon the bolometric luminosity.

The circumstellar envelopes of M giants were studied by Boesgaard and Hagen (1979, Ap J 231, 128), who found mass loss rates of 10^{-9} to 10^{-8} $M_\odot$/yr. Fe II shell emission in α Ori was studied by Boesgaard (1979, Ap J 232, 485), and Linsky et al. (1979, Ap J Suppl 41, 47) reported a survey of Ca II chromospheric profiles. Giampapa et al. (1981, Ap J 246, 502) derived chromospheric radiation loss rates from Hα and Na line profiles in M dwarfs; these imply a high degree of nonradiative heating of the upper atmospheres.

Studies of line identifications and abundances in cool stars include a high resolution study of the violet spectrum of the cool carbon star 19 Psc by Peery (1979, PAS Japan 31, 461), and a study of the H_2 bands in UU Aur and S Cep by Goorvitch et al. (1980, Ap J 240, 588). Titanium isotopic abundance ratios for cool stars are reported by Clegg et al. (1979, Ap J 235, 188); Dickens et al. (1979, Ap J 232, 428) determined C and N abundances in red giants in 47 Tuc; and the TiO strength in metal-rich globular clusters are studied by Mould et al. (1979, Ap J 228, 423). Molecular band identifications in S stars were carried out by Murty (1980, Ap J 240, 363 and 585), and by Lindgren and Olofsson (1980, AA 84, 300). TiH was identified in M stars by Yerle (1979, AA 73, 346). New molecular

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bands in S stars were also identified by Lambert and Clegg (1980, MNRAS 191, 367). Gahm et al. (1981, AA 98, 341) found low lithium abundances in ten luminous cool stars in reflection nebulae and young star clusters.

Ake and Greenstein (1980, Ap J 240, 859) studied four low-metal abundance sdM stars with weak molecular bands and strong Ca I 4227 A and found that they are subluminous for their colors.

Humphreys (1978, Ap J Suppl 38, 309; 1979, 39, 389; 1979, Ap J 231, 384) studied the spectra of the brightest M supergiants in the Milky Way and in the Magellanic Clouds. The maximum visual luminosity is near Mv=-8 in the LMC and the Galaxy, but no stars later than M1I were found in the SMC. The lower metallicity of the SMC may produce a shift to earlier spectral types through lower atmospheric opacity. Richer (1981, Ap J 243, 744) studied spectroscopically and photometrically a complete sample of 71 carbon stars in the LMC and derived a surface density 10 to 50 times higher than in our Galaxy. SMC carbon stars may be a few tenths of a magnitude brighter than those in the LMC. An SC star was identified in the LMC by Richer and Frogel (1980 Ap J 242, L9).

Mould and Aaronson (1980, Ap J 240, 464) found carbon stars and M giants with luminosities appropriate to the upper asymptotic giant branch in red globular clusters in the LMC and SMC. A similar result was derived by Frogel et al. (1980, Ap J 239, 495). These results, which are contrary to theoretical expectations, have been discussed by Iben (1981, Ap J 246, 278).

After the pioneering work of Demers and Kunkel (1979, PASP 91, 761), carbon stars and late giants have been detected in the Fornax, Sculptor, Draco, and Carina dwarf galaxies; many of these stars have bluer colors, as do those in the SMC, compared to galactic stars (Aaronson and Mould 1980, Ap J 240, 804; Westerlund 1979, ESO Messenger 19, 7; Frogel et al. 1981, Ap J, in press; Aaronson 1981, BAAS 13, 506; Cannon et al. 1980, MNRAS 196, 1p).

A catalog of S and SC stars on the revised MK system was prepared by Keenan and Boeshaar (1980, Ap J Suppl 43, 374) giving estimates of ZrO, TiO, and YO band strengths, and Na and Li lines.

4. Interacting Binary Systems -- K. O. Wright

4.1 The ζ Aurigae stars. The VV Cephei eclipse of 1976-1978 has been analyzed by Mollenhoff and Schaifers (1980, AA 94, 333), Kawabata et al. (1981, PAS Japan 33, 177), Saito et al. (1980 PAS Japan 32, 163), and Saijo (1981, PAS Japan 33, in press). They find that the emission lines at Hα and Hβ can best be explained by a flattened rotating envelope (300-400 R_o) surrounding the early-type secondary star; the radius of the M-type primary star is 1700-1900 R_o. Mid-eclipse occurred at JD 2 443 360 confirming the 7430-day period. IUE spectra of VV Cep have been obtained by Faraggiana (1980, IAU Symp 88, 549) and Hagen et al. (1980, Ap J 238, 203); the Mg II lines have different shapes but show chromospheric emission and indicate an expanding atmosphere for the M-type star.

Stencel et al. (1979, Ap J 233, 621 analyzed IUE spectra of 32 Cygni. All UV resonance and strong lines show P Cygni profiles and multiple absorptions with velocities up to 400 km/s, twice as large as observed for the K line. The B6 star probably lies within the atmosphere of the K5 supergiant and, as a result, moving shocks may be set up in the atmosphere. The mass loss rate is 4 x 10^{-7} $M_\odot$/yr. 32 Cyg was studied extensively at the 1981 eclipse by Stencel et al. (private communication) with the IUE, and preliminary analysis shows that the temperature increase with height in the upper chromosphere, observed at optical wavelengths, continues in the ultraviolet.

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4.2 Interacting binaries: Algols and longer periods. IAU Symposium 88 provides an excellent survey of close binary research in 1979. Algol has been studied by Soderhjelm (1980, AA 89, 100), who concluded that the secondary component fills its Roche lobe, that period changes show that mass and angular momentum are lost, and that the 32-yr period may be a magnetic cycle. Rucinski (1979, Act Astr 29, 339) studied the rotation of the primary star using the N II 1075.5 A line and concluded that rotation and orbital motions are synchronous. White et al. (1980, Ap J 239, L69) observed Algol with Einstein; there was no X-ray eclipse, indicating that emission probably comes from an active corona surrounding the K star.

β Lyrae continues to be studied extensively. Sahade (1980, Sp Sci Rev 26, 349) provided a general review of the system; it is rapidly evolving and the B8 star now fills its Roche lobe. Plavec (1980, IAU Symp 88, 251) contends that the W ser stars RX Cas, SX Cas, V367 Cyg, W Cru, β Lyr, and W Ser are related, as shown by IUE observations, with mass transfer from 10^{-6} to 10^{-4} $M_\odot$/yr; color temperatures in the UV are higher than in the optical region, and strong emission of N V, C IV, Si IV, Fe III, Al III are present; these phenomena are the result of accretion onto nondegenerate stars. Kondo et al. (1979, Ap J 233, 906, 1980, IAU Symp 88, 237) found that IUE spectra of U Cep showed broad lines of Si II-IV, Al II-III, etc., associated with the B star, which, from their variable absorptions, suggest hot spots and gas streaming. The secondary spectrum of U Cep was studied by Parthasarathy et al. (1979, MNRAS 186, 391), who found that the s-process elements had normal abundances, and that the data indicate an active chromosphere as a result of tidal effects.

4.3 Contact binaries: W UMa Stars. Carroll et al. (1980, Ap J 235, L77) identified VW Cep with a faint X-ray source that shows some variation of flux with phase. Dupree (1981, Cent Ap Prepr 1433) discusses chromospheres and coronas in 44 Boo, VW Cep, and ε CrA; UV spectra show lines of C II, Si IV, C IV, and N V. In the X-ray region there is a relation between luminosity and period, but the X-rays are not always in phase with the optical variation. Mochnacki (1981, Ap J 245, 650) studied 37 W UMa systems, and concluded that the A-type stars are more evolved with lower angular momentum and density than W UMa, possibly as the result of stellar winds and magnetic braking.

4.4 RS CVn stars. The unresolved problems of these systems, which show surface activity and photometric pecularities, were discussed by Hall at the 1979 General Assembly (1980, Highlights Astr 5, 841), including the relative importance of rotation and duplicity, and the significance of spots in producing the photometric moving wave. Walter et al. (1980, Smithsonian Spec Rep 389, 35) discussed HEAO-1 X-ray observations and concluded that there are two types of coronae in these systems; the most extreme activity found in short-period systems may be the result of rapid rotation and magnetic flux in the convective zone.

The discovery of radio flares in HR 1099 resulted in an international campaign of UV, optical, and radio observations for HR 1099 and UX Ari (Weiler et al. 1978, Ap J 225, 919); variable Hα emission was observed by Bopp (1979, IBVS 1669) and by Nations and Ramsey (1980, A J 85, 1086); Ca II H and K and hydrogen line variations were studied by Oswalt (1979, PASP 91, 222). Simon and Linsky (1979, Ap J 24, 759) analyzed emission line profiles in HR 1099 and UX Ari and found that the fluxes could be reproduced with a chromosphere of low surface pressure. Swank and White (1980, Smithsonian Spec Rep 389, 47) found that X-ray observations could be fit with a two-component model: a high temperature, large-volume component which is not eclipsed, and a lower-temperature component that might be associated with a star spot.

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4.5 X-Ray binaries. Crampton (1980, IAU Symp 88, 313) has summarized the data on these systems, especially from the optical viewpoint. Cyg X-1, Cir X-1, and GX 339-4 are the most probable candidates for black holes. HZ Her = Her X-1 has been studied in the UV by Kippenhahn et al. (1980, IAU Symp 88, 349), by Joss et al. (1980, Ap J 235, 592), and by Gursky et al. (1980, Ap J 237, 163). Strong emission lines of N V and C IV vary with phase, the ratio N V/C IV being 2 at phase 0.5 and 1 near eclipse; they probably arise from both the heated photosphere and the accretion disk.

De Loore et al. (1979, AA 78, 287) organized a coordinated X-ray and ground-based campaign for X Per in 1977; there was a less marked Balmer excess than in 1971-1972, weaker emission than in 1970, and a double-peaked Hα emission; Mufson et al. (1980, BAAS 12, 500) found a rapid variation in Hα. Bernacca and Bianchi (1981, AA 94, 345) found a good fit for the 1000-1900 A continuum for Te = 30000K; Si IV and C IV resonance lines indicate the presence of a variable envelope.

4.6 AM Her stars. AM Her systems are close binary stars with a mass-losing nondegenerate star and a magnetized accreting degenerate dwarf. The AM Her system has been reviewed by Chiapetti et al. (1980, Sp Sci Rev 27, 3) with its 3.1-h period observed from X-ray to infrared frequencies and in linear and circular polarization; the results of such simultaneous observations were given by Szkody et al. (1980, Ap J 241, 1070). IUE observations by Raymond et al. (1979, Ap J 230, L95) showed strong emissions from O I to N V; similar data were presented by Tanzi et al. (1980, AA 83, 270). A thorough study of AM Her was made by Crosa et al. (1981, Ap J 247, 984), who derived a model involving accretion on both magnetic poles of the white dwarf: the X-ray and optical radiation come from different poles which are of different strengths.

4.7 SS 433. Crampton et al. (1980, Ap J 235, L131) observed a 13-d binary period and deduced masses <2 M_o; the 164-day period is now considered to be the result of precession of the accretion disk which produces most of the observed spectrum, with the 5000 km/s jets (Crampton and Hutchings 1981, Ap J, in press). Models for the system have been proposed by Martin and Rees (1979, MNRAS 189, 19p), van den Heuvel et al. (1980, AA 81, L7), Whitemore and Matese (1980, MNRAS 193, 707), Begelman et al. (1980, Ap J 238, 722), Margon et al. (1981, Ap J 241, 306), and Collins et al. (1981, Astr Sp Sci 76, 417).

5. Pre-Main-Sequence Stars -- C. Jaschek

In this section, references are given, when possible, in the form of abstract numbers from *Astronomy and Astrophysics Abstracts*.

Two meetings have been held during the period covered by this report on the subject of pre-main-sequence stars: "Protostars and Planets" (25.003.008), held at Tucson; and "Flare Stars, Fuors (FU Ori stars), and Herbig-Haro Objects" held at Byurakan (27.012.053). In both meetings, a number of excellent reviews were given. In addition, more than 100 research papers have been published in this area.

It should be kept in mind that not all authors agree on the subdivisions of T Tau, YY Ori, FU Ori, and Herbig Ae/Be stars, so that the reader may not find a particular star in the expected subsection of this report. Often the designation "T Tau" is used in the sense that it includes the other groups.

5.1 Discovery and general description. The most important work is that of Cohen and Kuhi (27.114.029), who obtained optical scanner data from 4270 to 6710 A of some 500 Hα emission-line stars, including those in the Herbig-Rao list. Among the many interesting results, a good correlation is obtained between the strengths of the emission features Hα, Fe II, and [O II], and that of He I,

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suggesting a common, perhaps chromospheric, origin.

Searches for new members of the group in associations and/or clusters were performed, among others, by Rydgren (27.152.004; 27.131.111), Gahm and Malmort (27.114.043), and Gahm et al. (1981, AA 98,341).

5.2 T Tauri stars. Observations are now available for the whole range of wavelengths, from X-rays (Gahm, 28.121.018), satellite ultraviolet (Gurzedyan, 25.121.030), visible (Kuhi, 25.121.015), and infrared Rydgren, 25.121.013; Herbig and Soderblom, 28.121.012). Line profiles were secured for the Balmer lines and the Na D lines (Ulrich and Knapp, 25.121.018; Schneeberger et al. 26.121.016), and for the infrared Ca II triplet (Shanin 27.121.028). All authors confirm the rapid variability and the complicated line profiles which sometimes appear.

Detailed studies were made of a number of objects. BM And (Walter, 27. 121.019), RW Aur (Shanin, 25.121.002; Cram et al. 27.121.030; Petrov, 27.121.033), DI Cep (Bastian and Mundt, 26.121.003), V 1331 Cyg (Chavarria et al. 25.121.017; Chavarria, 27.121.023), RU Lup (Cram et al. 27.121.030) T Tau (Zajtseva, 25.121. 020), DR Tau (Appenzeller et al. 27.121.021; Krautter and Bastian, 28.121.002), V 380 Tau (Shannin and Shevchenko, 25.121.021). RW Aur (Imhoff and Giampapa, 28.121.006) and RU Lup (Gahm et al. 25.121.004; Gahm et al. 28.121.005; Gahm et al. 1981, MNRAS 195, 59p) were studied in the ultraviolet. Ulrich and Wood (1981, Ap J 244, 147) observed two helium recombination lines to see if it possible to decide between different proposed models; apparently no single model can satisfy all observations. Campli (1981, Ap J 244, 124) showed that no satisfactory explanation exists for maintaining in the "average" T Tau star a mass loss of a few 10^{-8} $M_{\odot}$ year; but the true mass loss rate may be smaller.

Although outside spectroscopy, attention should be called to the paper by Worden et al. (1981, Ap J 244, 520) on the photometry of T Tau stars. They found indications of an intense flare activity on time scales comparable to the sun (10^{2}-10^{4}s), but much more energetic.

5.3 YY Ori stars. General papers on these stars are those of Mundt (26.121. 003) and Appenzeller (25.121.001). Two objects were analyzed in detail S CrA by Mundt (25.121.005), Appenzeller and Wolf (25.121.019), Edwards 26.121.001), and Stahl and Wolf (28.121.008); and YY Ori by Walker and Burstein (28.121.014).

5.4 FU Ori stars (fuors). General papers on these objects were written by Welin (25.121.011), Larson (27.121.004), Gyul'budagyan (27.121.039), and Gershberg (27.121.043). Other properties are discussed by Rustamov (27.121.041), Shanin (27.121.042), Pogodin (27.121.044), and Chochol and Tremko (27.121.045).

5.5 Herbig Ae/Be stars. A list of possible members of this group was provided by Finkenzeller (IAU Symp 98, in press). A study of the energy distribution from the ultraviolet to the infrared was carried out by Sitko (1981, Ap J 247, 1024). HD 200775 was analyzed in detail by Altamore et al. (28.114.082), Finkenzeller (IAU Symp 98, in press, and Baschek et al. (IAU Symp 98, in press).

5.6 Herbig-Haro objects. Seaches for new objects were made by Adams et al. (25.121.023), Canto et al. (27.121.017), Cohen (27.131.028), and Reipurth (1981, AA Suppl 44, 379). General papers on these objects are by Böhm (25.121.006), Boehm (25.121.012), Imhoff (25.121.014), and Gyul'budagyan (27.121.046). Observations of the HH objects are reported by Schwartz and Dopita (27.121.002), and, of the blue continua, by Brugel et al. (1981, Ap J 243, 874).

Individual objects were studied in detail in a number of papers. HH1 was studied by Boehm and Brugel (25.121.010), Cohen and Schwartz (26.121.004), and Ortolain and d'Odorico (27.121.006); HH7 and 11 were studied by Boehm et al.

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(27.121.001), and HH24 by Schmidt and Miller (26.121.013).

6. Highly-Evolved Stars -- J. P. Swings

The most noticeable characteristic of the literature during 1979-1981 is the large number of publications based on data obtained from space, particularly with the Einstein and IUE satellites (e.g., see Proc. 2nd IUE Conf, Tubingen, 1980, ESA-SP-157). The present survey of results on the spectra of symbiotic stars, subdwarfs, white dwarfs, novae, and nuclei of planetary nebulae leads to the recommendation that simultaneous observations in the various spectral regions, from X-rays to radio, which have been performed in a few cases, be extended to more targets in order to provide better understanding of these exciting and exotic objects.

6.1 Symbiotic stars. Observations of symbiotic stars in the X-ray, UV, and IR regions are described at length and are confronted with theory (single star and/or double star models) in the proceedings of two meetings held in 1981: a workshop in Boulder (Allen 1981, Nature 293, 99), and IAU Colloquium No. 70 at the Observatoire de Haute Provence (the concluding remarks are available from J. P. Swings).

Additional recent results on these objects include the fact that [Fe V, VI] and [Ni V, VI] were discovered in the spectrum of RR Tel (Raasen and Hansen 1981, Ap J 243, 217); that the compilation of Carlson and Henize (1979, Vistas Astr 23, 213) contains several symbiotics, to which should be added BI Cru (Henize and Carlson 1980, PASP 92, 479), that there seems to be a class of "yellow" symbiotics, including M1-2 (see sec. 6.2), HD 330036 (Allen 1981, IAU Colloq 70, in press), and He 2-467 (Kaler and Lutz 1980, PASP 92, 81); and that a prototype of related objects, VV Cep, was also studied on the basis of IUE data (e.g., Faraggiana and Selvelli 1979, AA 76, L18; Hagen et al. 1980, Ap J 238, 203--see also Sec. 4.1).

As a transition to other types of objects, Allen (1980, MNRAS 192, 521) argues, "that the various types of symbiotic stars and the slow novae are the same phenomena exhibiting a range of associated time scales, the slow novae being of intermediate speed."

6.2 Central stars of planetary nebulae. Ultraviolet observations from the TD1 and IUE satellites, in addition to those from the ground, have been reported of, among others, NGC 246, He 2-131, and He 2-138 (Mendez and Niemela 1979, Ap J 232, 496); M1-2 (sec 6.1), a possible eclipsing binary central star (Drummond 1980, AA 88, L11); the nucleus of NGC 7009, where N V and O V, but not C IV, have P Cygni profiles (Perinotto and Benvenuti 1981, AA 101, 88); and the central star of NGC 6543, where C IV, N IV, O IV, and Si IV show P Cygni profiles, indicating $V_\infty \approx 2000$ km/s, and $\dot{M} \approx 10^{-7}\ M_\odot$/yr (Castor et al. 1981, MNRAS 194, 547).

Seaton (1980, Highlights Astr 5, 247) has reviewed the UV spectra of planetary nebulae and their central stars, Pottasch (1981, AA 94, L13) has reanalyzed available observations to show that "a substantial fraction of the central stars are hot objects" (1-6 x 10^5 K).

6.3 Novae. Among interesting recent observations are the CO emission (1.6-2.2 μm, 4.8 μm) in Nova Vul (NQ) (Ferland et al. 1979, Ap J 227, 489); the use of He line intensities to derive abundances in CP Lac and V446 Her (Ferland 1979, Ap J 231, 781); the large expansion velocities (300 km/s) in Nova Cyg 1978 (Cassatella et al. 1979, AA 74, L18); the UV spectra of two old novae, HR Del and V603 Aql (Dultzin-Hacyan et al. 1980, 2nd IUE Conf); and the "X-ray nova", Cen X-4

(Matsuoka et al. 1980, Ap J 240, L137). In addition, Clayton (1981, Ap J 244, L97) has predicted γ-ray fluxes in novae explosions on the basis of nucleosynthesis of Li^7.

Two objects, DQ Her and WZ Sge, have been particularly well studied. Papers regarding DQ Her include a study of line profiles and velocities (Hutchings et al. 1979, Ap J 232, 500); high time resolution observations between 3200 and 11000 A (Schneider and Greenstein 1979, Ap J 233, 935); the eclipse of emission lines (Young and Schneider 1980, Ap J 238, 955); a CCD search, 7000-9000 A, for a red companion (Young and Schneider 1981, Ap J 247, 960); and an X-ray model by Ferland and Truran (1981, Ap J 244, 1022). WZ Sge had an outburst during 1978; visible-light spectra showed an enlarged disk plus contribution from a stream or hot spot (Crampton et al. 1979, Ap J 234, 182; Brosch et al. 1980, Ap J 236, L29; Walker and Bell 1980, Ap J 237, 89). In addition, rapid oscillations were studied by Patterson (1980, Ap J 241, 235), UV spectra by Friedjung (1981, AA 99, 226); and a distance estimate was made by Fabian et al. (1980, MNRAS 191, 457).

6.4 White dwarf and subdwarfs. Three important review papers appeared during the report interval: White dwarf stars (Liebert 1980, Ann Rev Astr Ap 18, 383); hot subluminous stars (Greenstein 1980, Highlights Astr 5, 255); and pulsations of ZZ Ceti stars (DA dwarfs) (McGraw 1980, Sp Sci Rev 27, 601). In addition, there have been a number of surveys; multichannel spectra of 78 faint stars, including 51 new degenerates (Greenstein 1979, Ap J 227, 244); 49 faint blue stars near the galactic anticenter (Chromey 1979, Astron J 84, 534); H-line strengths in 19 DAs (Greenstein and Vauclair 1979, Ap J 231, 491); searches for hot subluminous stars (Berger and Fringant 1980, AA Suppl 39, 39; AA 85, 367); 150 DA stars (Greenstein 1979, Ap J 233, 239); model atmosphere analysis of 21 DAs (Schulz and Wegner 1981, AA 94, 272); a quantitative study of IDS spectra of 11 subluminous O stars (Teff = 35 to 50000 K, log g = 4 to 6.5) (Hunger et al. 1981 AA 95, 244); and a comparison of OB stars within 0.5 kpc of the galactic plane with those more than 1.5 kpc distant, finding no differences (Tobin and Kilkenny 1981, MNRAS 194, 937).

AM Her stars, magnetic white dwarfs with nondegenerate companions were discussed in sec. 4.6; several additional papers may be mentioned here. Zeeman-shifted multiplets of Balmer lines from the accreting polar cap were found in AM Her by Young et al. (1981, Ap J 245, 1043), who derived a magnetic field of 1.3×10^7 gauss; a similar result was obtained from the circular polarization (Schmidt et al. 1981, Ap J 243, L157; Young and Schneider 1980, Ap J 238, 955). Szkody (1981, Ap J 247, 577) has examined continua from the UV to 3 μm in AM Her and 7 similar systems and finds slopes from λ^{-1} to λ^{-4}.

Recent results from space observations include abundance anomalies and a "corona" in the hot halo star Feige 86 (Hack 1979, AA 74, L4; 1980, 81, L1); a corona around 40 Eri was found by Cash et al. (1981, Ap J 239, L23). Böhm-Vitense (1980, Ap J 239, L79) has found a white dwarf companion to the Ba II star ζ Cap. Wray et al. (1979, Ap J 234, L187) find from IUE spectra that HD 149499B has Teff = 85000 K; making this the hottest known white dwarf. Strong absorptions have been found at 1900 A in the C_2 white dwarf LP 145-141 by Weidemann et al. (1980, AA 83, L13); at 1391 A in 40 Eri by Greenstein (1980, Ap J 241, L89); and due to C I (first detection in stellar spectra) in the C_2 dwarf L97-2, yielding He/C $\simeq 10^7$, by Weidemann et al. (1981, AA 95, L9) and in LDS 678B (DC) by Wegner (1981, Ap J 245, L27). HZ 43 was observed from Voyager 2 in the 500-900 A and 900-1200 A regions, and by IUE, leading by Teff $\simeq$ 55000 K and log g $\approx$ 8 (Holberg et al. 1981, Ap J 242, L119).

Subluminous stars found in clusters include an O subdwarf in the globular cluster NGC 6712 by Remillard et al. (1980, Ap J 240, 109); and four faint blue objects (m $\simeq$ 20) in the galactic clusters M41 and NGC 2422 (Romanishin and Angel

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1980, Ap J 235, 922), which were confirmed to be white dwarfs by Koester and Reimers (1981, AA 99, L8). The remnant star of SN 1006 has been shown to be a blue subdwarf by Simon (1981, AA 98, 211) on the basis of the Balmer line profiles. Two cases of degenerates in binaries have been reported; HZ9 in the Hyades is a spectroscopic binary, according to Lanning and Pesch (1981, Ap J 244, 280), and G61-29 is described by Nather et al. (1981, Ap J 244, 269) as consisting of two white dwarfs with an accretion disk, giving rise to broad emissions of He I and He II.

Finally, some miscellaneous interesting results may be mentioned. Koester et al. (1979, AA 71, 163) have fit hot subdwarf model atmospheres to spectrophotometric data; a similar comparison for a DA star is made by Wickramasinghe and Bessel (1979, MNRAS 186, 399). Spectroscopic data show that the primary eclipse of the O-subdwarf binary system HDE 269696 is a transit, not an occultation--a case of common envelope evolution (Conti et al. 1981, MNRAS 195, 165). The spectrum of CPD -46° 3093, for which IUE data shows no mass loss, is fit with a synthetic spectrum of 800 lines by Heber and Hunger (1981, AA 101, 269), and the gravitational redshift in o^2 Eri B appears to be in agreement with expectations from general relativity, according to Wegner (1979, A J 84, 650).

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

Studies of G- and K-type stars have increased dramatically in recent years, as these stars are used as probes of abundances in the solar neighborhood, of abundance gradients across the galactic disk, and of compositions of open and globular clusters and nearby galaxies. Extremely metal-poor stars provide important constraints on theories of nucleosynthesis. Approximately 150 papers were reviewed in compiling this summary; space limitations allow only a minority to be mentioned. References are given as abstract numbers in *Astronomy and Astrophysics Abstracts*, where possible.

7.1 G and K field stars. Iron abundances in giants have been derived from high-resolution near-infrared spectra by Branch and Bonnell (22.114.540), and discussed with regard to the existence of super-metal-rich stars (25.114.026); general agreement with photometric abundances was obtained. Analysis of the spectra of supergiant stars has been carried out by Luck (26.114.015) and by Luck and Bond (28.114.083) in order to use these stars as indicators of radial abundance gradients in the galaxy. They have obtained $d[Fe/H]/dr = -0.24 \pm 0.04\ \mathrm{kpc}^{-}$ for the galactic disk between 7.7 and 10.2 kpc from the center. In addition, Komarov and Shcherbak (28.114.080) have studied 21 giant stars and found the iron abundance to decrease by 0.8 dex in the solar neighborhood toward the anticenter.

Tomkin and Lambert (27.114.015) have used low-noise Reticon spectra to study the MgH bands in several dwarfs, and also in the barium star HR 774 (25.114.002). The magnetism isotope ratios were found to be solar, and the expected s-process element overabundances were found in HR 774.

Hardorp (28.114.088) studied the energy distributions of G dwarfs and identified two solar spectrum analogs. He found the reliability of the stellar flux calibrations to be superior to the solar calibration. Cayrel de Strobel et al. (1981, AA 94, 1) found that none of four stars proposed as solar twins were identical to the sun in all atmospheric parameters within observational accuracy, while Perrin and Spite (1981, AA 94, 207) studied 16 Cyg A and B and found that the parameters of the latter were identical to those of the sun.

Evidence for solar-type activity cycles has been sought by several investigators. Vaughan and Preston (28.114.107) have given a preliminary report on a program to monitor fluxes in the central 1 A of the Ca II H and K lines in main-

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sequence stars of classes F-M. Activity appears to decline with age among these stars. Vaughan (28.114.108) finds evidence of cyclic variation of the activity only in old stars. Middelkoop et al. (1981, AA 96, 401) find that rotation periods may be inferred from the variation in H and K emission fluxes for only a minority of 14 main-sequence stars studied, and Vaughan, Preston et al (1981, Ap J, in press) give evidence that solar-type activity cycles are found only in stars with rotation periods in excess of 20 days, and that the activity periods are otherwise uncorrelated with the rotation. Short-time-scale variability in chromospheric emission has been studied by Baliunas et al. (1981), Ap J 246, 473) in α Tau K5 III), λ And G8 III-IV), and ε Eri (K2 V), and time scale from minutes to hours detected. Gray (28.114.042) has obtained high-resolution line profiles of the K line in Arcturus and found that the K2V emission peak variation is anti-correlated with the K2R peak. Barry et al (1981, Ap J 247, 210) have found that chromospheric activity declines with age for solar-type stars in clusters between 10^7 and 5×10^9 years old.

Other physical properties of the stellar atmospheres have also been studied. Gray and Martin (25.114.43) studied line profiles in five normal and three SMR stars and found no systematic difference in microturbulence, macroturbulence, or rotation between the groups. Gehren (1981, AA 100, 97) has investigated the effective temperature scale for solar-type stars by comparing hydrogen line profiles observed for 20 main-sequence stars with scaled solar model atmospheres. He obtains temperatures for G-type stars which are 200-300 K higher than those obtained from synthesis of color indices with model atmospheres with statistical line distribution functions.

7.2 Population II and metal-poor field stars. Previous analyses of subdwarfs were criticized by Desikachary (27.126.007), who found no evidence for the low masses derived by Hearnshaw, nor for the low odd-Z and r-process element abundances found by Peterson. Foy and Proust (27.126.087) similarly do not confirm the correlation between metal deficiency and gravity proposed by Hearnshaw; nor do they find evidence for inadequacies in the model atmospheres. Carney (26.126.021) used temperatures, bolometric correlations, metallicities, and parallaxes for subdwarfs and Hyades dwarfs to show that the subdwarfs lie well below the Hyades main sequence.

Peterson and Sneden (22.114.041) have studied the ratio C/Fe in field dwarfs and subgiants by spectral synthesis of the CH features. The stars, which have metallicities from 1/5 to 1/100 solar, were all found to have essentially solar C/Fe ratios. A similar result was obtained by Barbuy (1981, AA 101, 365) in the case of unevolved extreme Pop. II stars, but carbon depletions appear for evolved stars, indicating mixing. Peterson (1981, Ap J 244, 989) has determined relative abundances of elements from sodium through the iron peak in 30 metal-poor dwarfs and giants and finds that the ratios Na/Fe and Al/Fe decline with metallicity. These results support explosive nucleosynthesis as the source of the heavy elements in these stars. Luck and Bond (1981, Ap J 244, 919) determined abundances in 21 giants in the halo and found that Ba/Fe is deficient by 1.6 dex in the most metal-poor stars and rises to solar values by [Fe/H] = -2.0 to -1.5. A similar effect occurs in Y and Zr, suggesting that the synthesis of s-process elements was most efficient early in the formation of the halo. Leep and Wallerstein (1981, MNRAS 196, 543) determined abundances of elements from oxygen to barium in 11 field stars with Fe/H between 1/10 and 1/200 solar. They confirmed an odd-even effect, with Ca and Ti deficient with respect to Si and Sc. Field stars with [Fe/H] < -1.5 show significant barium deficiencies, but stars in the globular clusters M15 and M92, which have similar Fe/H, do not, suggesting that the field stars may be older than the clusters. Four high-velocity stars and one Pop. I giant were analyzed by Foy (27.114.142), who found the high-velocity stars to be only moderately metal deficient and found a sodium excess in the giant. Bessell and Norris (1981, IAU Colloq 68) found [Fe/H] = -4.6 in CD -38° 245, which may be the prototype of Pop. III. Abundance deficiencies with respect to Fe are found in Sr, Ba, and possibly Na; ratios in excess of solar are found for Mg, Ca, Ti, and, significantly, CN.

7.3 Open cluster stars. Branch et al (28.153.017) have used low-noise Reticon spectra of the moon and two Hyades dwarfs to derive the metallicity of that cluster, obtaining [Fe/H] = 0.20 ± 0.10, in good agreement with photometric determinations. Griffin (25.114.037) has analyzed a second giant in M67, confirming that the cluster giants are not "super-metal-rich." Foy and Proust (1981, AA 99, 221) have repeated Griffin's analysis using high-dispersion electronographic data and model atmospheres and obtained [Fe/H] = -0.1 ± .1 for M67. Barry et al. (26.153.011) have carried out a quantitative spectral analysis of pre-main-sequence stars in NGC 2264 and found that [Fe/H] is quite homogeneous and equal to that of the Coma cluster of stars.

Hardorp (28.080.006) has used stellar interior and atmosphere models together with new scanner observations of nine Hyades dwarfs to argue that the solar color index, the Hyades distance, and its metal content are not independent of each other. Christian (1981, Ap J 246, 827) has used IIDS spectrophotometry of two F-G stars in King 8 to show that [Fe/H] $<$ -0.5 in this disk cluster.

7.4 Globular cluster stars. Detailed chemical compositions of evolved G and K stars in globular clusters have been derived through the application of sophisticated spectroscopic observations and analyses; the results have far-reaching consequences with regard to questions of nucleosynthesis, stellar evolution, and the chemical history of the galaxy.

High-dispersion studies of cluster giants have been carried out by several investigators. Cohen (26.114.007) studied four stars in M92, obtaining [Fe/H] = -2.34, and two stars in M15, which yielded [Fe/H] = -2.20. Wallerstein et al. (27.154.058) studied two stars each in M5 and M13, finding [Fe/H] = -1.4 for both clusters, and a strong excess of oxygen in one star in M5. Further results on M5 and M13, plus M3, are given by Pilachowski et al. (27.154.006), who find [Fe/H] equal to -1.55 for M3, -1.33 for M5, and -1.42 for M15; an oxygen excess relative to iron is found in M3 and M5 but not M15. Peterson (27.154.066) has found an order-of-magnitude variation in the sodium abundance among the red giants in M13. Cohen (28.154.025) has compared the metal-rich globular cluster M71 with the old open clusters M67 and NGC 2420 and obtained [Fe/H] = -1.27, -0.39, and -0.61 for M71, M67, and NGC 2420, respectively. NGC 2420 was compared with the globular cluster 47 Tuc by Pilachowski et al. (27.154.001), who find [Fe/H] = -1.2 for 47 Tuc and -0.7 for NGC 2420; oxygen is enriched relative to iron in 47 Tuc but not in NGC 2420. Photometric data suggest that CN or CH is also enhanced in 47 Tuc.

Carbon and nitrogen abundances have been the subjects of several studies. Hesser (22.114.004) has obtained low-resolution spectra of more than 80 stars in 47 Tuc, and found that CN strength variations persist down to subgiants with M_V = 3.5, and that weak spectral differences may be present among main-sequence stars with M_V = 4. Additional observations of this type, and interpretation by means of spectral synthesis, were carried out by Hesser and Bell (26.114.201), who concluded that star-to-star N abundances differ by factors of 5 in 47 Tuc. Norris and Freeman (25.154.021) discussed CN measurements in 142 giant stars in 47 Tuc and concluded that the CN distribution is bimodal, with CN-rich stars preferentially near the cluster center. A bimodal distribution of CN has also been found in M4 by Norris (1981, Ap J 248, 177); there appears to be an anticorrelation between CN and CH. Studies of low-dispersion spectra in M71 and M10 by Gratton (28.154.017), using a rough analysis technique, yielded suggestions of a relative Na deficiency in M71.

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The peculiar cluster ω Cen continues to be the subject of research. Mallia and Pagel (1981, MNRAS 194, 421) studied the spectra of eight stars in the blue or red flank of the giant branch and found a metal abundance range $1.2 \leqslant [H/Fe] \leqslant 2.0$, in fair agreement with previous studies. Oxygen and carbon are somewhat enhanced with respect to Fe. Cohen (1981, Ap J 247, 869) studied five giants in ω Cen and three in M22. The latter three stars are chemically identical with $[Fe/H] = -1.78$, except for a possible range in Na and Ba. The ω Cen giants show a range of abundances in all elements, with the light elements, Ba, and the rare earths more enhanced than the Fe peak in the more metal-rich stars.

Finally, Peterson (1981, Ap J 248, L31) has obtained high-resolution spectra of luminous giants in several clusters and finds blue shifted cores in the Na D lines and Hα, which are characteristic of stellar winds.

7.5 CNO and Li in field stars. These elements are indicators of nucleosynthesis and mixing processes in the stars.

Lambert and Ries (1981, Ap J 248, 228) have determined C, N, and O abundances for 32 giants and subgiants and find evidence that CN-processed material has been dredged to the surface: C is depleted, N is increased, O is constant. Isotope ratios in the Hyades giants (clump giants) are in accord with this interpretation. Lower-mass giants are ^{13}C-rich, suggesting a larger mass of less-processed material mixed to the surface than in the more massive stars. Branch (25.114.038) has found $^{12}C/^{13}C$ and Fe/H to be correlated in the atmospheres of K giants; stars which have low isotope ratios are either metal- deficient or are high-luminosity stars. Sneden et al. (26.114.095) have derived oxygen abundances in unevolved stars using the triplet at 7700 A. They find that metal-deficient stars show substantial excesses of oxygen. Pilachowski (25.114.019) used a photometric CO index to show that CO decreases with metallicity in giants with $[Fe/H] > -1.5$ and is weak or undetectable in stars of lower metallicity, but shows a scatter greater than the observational errors in the intermediate cases. Sneden et al. (1981, Ap J 247, 1052) studied C, N, and O abundances in seven mild barium stars and two classical Ba stars. The former show CNO abundances equal to normal stars, while the latter show the well-known C enhancement.

Lambert et al. (27.114.006) have determined Li abundances for 50 G and K giants from high-resolution, low-noise spectra and find that the Li abundance and the $^{12}C/^{13}C$ ratio are correlated. They conclude that Li must be produced in the weak G-band stars, and that stars of high ^{13}C are giants with $M \leqslant 1.3\ M_\odot$. Spite and Spite (1981, IAU Coll 68) have obtained Li observations with a Reticon detector for several bright Pop II dwarfs and found strong Li in all but the coolest of these. The wavelength appears to be that of ^7Li. These results may provide information on the primordial Li abundance in the galaxy. Duncan (1981, Ap J 248, 651) has compared Li abundances with chromospheric fluxes in the cores of the Ca II K line in over 100 F-G field dwarfs. Both quantities decrease statistically to older stars, but they are not well correlated. A sudden decrease of chromospheric emission at an age of 1 to 2×10^9 years is a possible explanation. Parthasarathy and Kameswara Rao (28.114.106) found that the lithium abundance in weak-G-band stars is linearly correlated with CH deficiency.

7.6 Ultraviolet observations. Stencel and van der Hucht (22.114.548) have given identifications of 383 absorption and 6 emission lines in the spectrum of Arcturus (K2 IIIp) between 2736 and 3303 A, based on 0.1-A resolution spectra obtained with the JSC/SRL BUSS experiment. Eight possible continuum windows are also noted.

Basri and Linsky (27.114.096) have obtained IUE high-resolution spectra of the Mg II resonance lines at 2796 and 2803 A in 15 stars of types G2-M2 of a wide range of luminosities. The spectra were calibrated in absolute flux units, and chromospheric radiative loss rates are compared with the Ca II lines. The authors find that the ratio of Mg II surface flux to total flux is independent of luminosity, but may decrease slowly with effective temperature. Among the RS CVn binaries, the Mg II flux increases with decreasing period.

Gustafsson et al. (28.114.067) have investigated the ultraviolet flux of the metal-deficient giant HD 122563 in connection with previous suggestions that metal-deficient stars are brighter in the UV than the corresponding model atmospheres. The IUE observations suggest that this effect may not exist at wavelengths less than 2700 A.

7.7 Atlases and catalogs.

Griffin and Griffin (26.002.028): *A Photometric Atlas of the Spectrum of Procyon, $\lambda\lambda$3140-7470 A.* Based upon photographic spectrograms.

Barkevicius (27.002.40): *The Catalog of Metal-Deficient F-M Stars. Part I. The Stars Classified Spectroscopically.*

Ardeberg and Virdefors (27.114.127): *A Catalogue of Stellar Spectrophotometric Data.* A list of energy distributions for 356 stars.

Cayrel de Strobel et al.(28.114.010): *A Catalog of [Fe/H] Determinations.* A compilation of results for 628 stars.

8. Report of the Working Group on Ap Stars -- C. R. Cowley

This review covers the period 1 January 1979 through ca. 1 October 1981; it is necesarily incomplete. Magnetic as well as photometric and taxinomic aspects of CP stars are included in this report of the joint Working Group.

In January 1979, Weiss and Kreidl published the results of a workshop on "Ap Stars in the Infrared." An outgrowth of that workshop was the circular *A Peculiar Newsletter* (PN), edited by Henseberge, Deridder, and van Rensbergen, to be published every four months. A primary purpose is to encourage collaboration through the exchange of information and observational materials. PN also serves as an official voice of the IAU Working Group on Ap Stars; it is currently distributed to members. A European Working Group has been established, with plans to meet every six months, primarily for the purpose of coordinating research programs, especially those involving E.S.O.

Review papers from the 1979 IAU session on diffusion in stellar atmospheres and envelopes have been published (Michaud AJ, 85, 589; Bonsack and Wolff AJ, 85, 599; Landstreet AJ 85, 611; Vauclair AJ 86, 513). An informal meeting on Ap stars was held at the Warner and Swasey Observatory (USA) on 10 October 1980; a résumé will appear in PN. A series of papers on Ap stars (Russian texts with English abstracts) appears in *Nauchnye Informatsii*, Vol. 43. We note two recent translation series by Allerton Press, which contain frequent papers on Ap stars: *Bull Crimean Ap Obs* and *Bull Spec Ap Obs N Caucasus*.

The entire 1981 Liége Symposium was devoted to chemically peculiar (CP) and related stars. Publication is anticipated near the end of the year. This volume will not be covered in detail in this report, although a few references indicated by (LS) will be given.

Recent work on abundances, photometric variability, and X-ray fluxes have undermined the concept of the "normal A stars with a quiescent atmosphere and solar abundances." In Vega itself, subsolar abundances have been found by Dreiling and Bell (Ap J 241, 736), Sadakane and Nishimura (PASJ 33, 189), and others. Fernie (PASP 93, 333) confirmed earlier reports of light variations. Subnormal abundances in A stars (cf Sadakane PASJ, in press, also older work on Lambda Bootis stars) appear to be well established, they may not be rare.

Investigations of Ap stars in open clusters have been undertaken by Abt (Ap J 230, 485). Wolff (Ap J 244, 221), van Rensbergen et al. (AA 64, 131), Maitzen and Hensberge (AA 96, 151), and others. This work provides evidence for enrichment and braking (cf Fleck Ap J 240, 218) during the main- and pre-main-sequence phases.

Polosukhina (PN 6, 8) has proposed intensive collaboration to study rapid light and spectral variations in Ap stars. The reality of at least some reports has received support by the beautiful photometry of Kurtz (LS, see also Weiss et al. AA 90, 18), which clearly establishes rapid light variability among magnetic stars. Long-term variability, which was reported by Böhm-Vitense and Johnson (Ap J 225, 514) for Am stars was supported by Lane and Lester (Ap J 238, 210).

UV spectroscopy has been most active. Papers range from detailed study of single stars, e.g., Hack's work on Fiege 86 (AA 81, L1), to Leckrone's discussion of boron (Ap J, Nov 81, see also Borsenberger et al. AA 76, 287), and Megessier et al (Ap J 239, 237) on mercury. Considerable effort has been devoted to UV continuous energy distributions (cf Böhm-Vitense Ap J 244, 938), which can now be compared with detailed theoretical calculations (e.g. Muthsam and Stepien AA 86, 240). Artru et al. (AA 89, 380) studied the stellar and atomic spectra of Si II as a means of interpreting the absorption at 1400A. Their results were incorporated into the theoretical calculations of Alecian and Vauclair (AA 101, 16). Spectral classification based on UV data has been discussed in a series of papers (see Jaschek et al. AA 89, 380). Adelman and his coworkers (cf Ap J Suppl 42, 289) have made extensive photoelectric scanner measurements. Most of the bright CP as well as normal A stars can now be found in the new catalogue of Geneva photometry by Rufener. Hauch (IAU Colloq 47, 161) discusses the interrelationship of spectroscopic and a number of photometric classification systems. The infrared excess (Groot and Kaufmann AA 94, L23) discussed by Havnes (LS) provides still another dimension to the CP phenomena.

Borra and Landstreet (Ap J Suppl 42, 421) reviewed the observational problems of magnetic fields in Ap stars. Recent observational work has concentrated on the hotter helium anomalous stars (see review by Jaschek, LS) and on efforts to reduce the upper limits in Am and manganese stars. Hartoog and A. Cowley (Ap J 228, 229) studied the He-3 phenomenon. Khokhlova et al. (LS) gave a new discussion of the problem of mapping surface geometry from time-dependent observations. Hensberge et al. (AA 75, 83) have found, contrary to earlier results, no evidence against random orientation of rotational and magnetic axes. Theoretical aspects of stellar magnetism were discussed by Moss (LS), Krause (*Planetary and Stellar Magnetism)*, and Schussler (*Nukleonika* 1425).

Abundance studies using both conventional and UV spectroscopy have shown an increased diversity of the CP phenomena (see Hack's review, LS). Dworetsky and Stickland's (AA 85, 138) work calls attention to the extreme variations of cobalt. Heacox's (Ap J Suppl 41, 675) extensive survey of manganese stars included the region of the Be II doublet near 3130A. In some manganese stars the lines are very strong--in others they cannot be found. IUE studies (Jacobs and Sworetsky LS; Guthrie and Stickland *The First Year of IUE)* have qualitatively confirmed the mercury and gallium anomalies.

Published abundances cannot be accepted uncritically. Cowley and Aikman (Ap J 242, 684) conclude that abundances estimated from wavelength coincidence statistics are in numerous cases of comparable accuracy to those using much more sophisticated methods. At Liége, the WG on Ap stars agreed that it would be useful to publish some general guidelines for abundance workers. This task is currently under advisement.

Theoretical efforts to explain the CP stars have primarily invoked the diffusion hypothesis. Many references are cited in the reviews listed above as well as by Michaud (LS). A recent paper by Alecian and Michaud (Ap J 244, 226) treats the temperature-abundance relation in the manganese stars.

Alternate ideas have been discussed, e.g.. by Ohnishi (Nature 277, 545) or Rajamohan and Pati (JAA 1,155). Accretion is also discussed (cf Joncas and Borra AA 94, 134) but recent theoretical developments in this field have primarily been concerned with white dwarfs (see Alcock and Illarionov Ap J 235, 541).

9. Report of the Working Group on Be Stars -- M. Jaschek

This report is written six months after the IAU Symp. No. 98 "Be Stars," held in at Munich on April 1981. By the time this report is distributed, the Symposium will have appeared in print. The eight review papers given at the Symposium provide a detailed overview of the subject, and for this reason it seems somewhat pointless to furnish another summary. Besides the complete bibliography listed in the symposium volume, interested colleagues may also consult the "Be Newsletter" published twice a year, and edited by me at the Strasbourg Observatory. The "Newsletter" regularly includes the most recent bibliography. Since the Montreal General Assembly more than 250 papers concerning Be stars have been listed.

I shall comment now very briefly upon general topics. A number of surveys for H-alpha emissions were made, resulting in the discovery of a large number of new objects. We mention Irvine and Irvine (1979, PASP 91, 195), Kucewicz (1980, Bull Arg Astr Soc 18, 10), McConnell (AA Supl, in press), Sanduleak and Bidelman (1980, PASP 92, 72), and Cardon (IAU Symp 98).

An Atlas illustrating the evolution of the spectra of 35 Be stars over 20 years in the photographic region was published by Hubert-Delplace and Hubert (1979, Paris). A catalog of 1100 Be stars of luminosity classes III to V has been published by Egret and M. Jaschek and in microfiche at Strasbourg (1981).

Several observing campaigns have been launched on a few selected stars. Detailed references can be found in "Be Newsletter" nos. 2 and 4; see also the Symposium volume.

An excellent review paper on Be stars was published by Slettebak in Space Sci Rev 23, 54 (1979).

I thank all those colleagues who have sent me reports on their work. In order not to re-quote papers already published and listed in the Newsletters, I shall quote very briefly only papers in press. Sletteback (Ap J) studied a large sample of bright Be stars; Plavec et al. report in that using the Einstein satellite they discovered that CX Dra (HD 174237) is an X-ray source; Andrillat, Ringuelet, and Sahade (PASP) study V 923 Aql; Ringuelet et al. (Rev Mexicana AA) study the ultraviolet continuum of several Be stars; Mermilliod (AA) studies the evolution of Be stars in open clusters.

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In the space available, it has been possible to present only a very condensed summary of the research activity in the field of stellar spectra in the last three years; many important and interesting results have been omitted. In addition, two entire topics -- O- and Of-type stars, and variable stars of types M, C, and S -- were omitted because the original reports were received too late to include in this condensation.

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