29. STELLAR SPECTRA (SPECTRES STELLAIRES)

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In course of preparation of this report I have asked the help of the Vice-President, of the members of the Organizing Committee, and of the Chairmen of four Working Groups. I am very grateful to all who sent me their reports for their help.

Since the last IAU meeting an enormous amount of papers on stellar spectroscopy was published. Unfortunately, the limited volume of Commission's report does not permit to note all of them. I am sorry that I have no possibility to include all the important work carried out.

Commission 29 has co-sponsored the following meetings: *IAU Symp.* **67** on *Variables in Relation to the Evolution of Stars and Stellar Systems* (Moscow, U.S.S.R., August 1974), *IAU Symp.* **72** on *Abundance Effects in Classification* (Lausanne, Switzerland, July, 1975), *IAU Symp.* **70** on *Be and Shell Stars* (Merrill – McLaughlin Memorial) (Cape Cod, U.S.A., Sept. 1975), *IAU Colloq.* **32** on the *Physics of Ap Stars* (Vienna, Austria, Sept. 1975). The thanks of the Commission are due to their representatives on the Organizing Committees of these meetings.

Commission 29 has supported the publication of *Atlas of Spectra of Types Later than G0* by Dr. P. C. Keenan as a project of the Commission.

1. OF AND WR STARS

Underhill and Snijders (*ApJ*, in press) have identified lines in the spectrum of ζ Pup in the ranges 926 Å–1430 Å and 1713 Å to 3167 Å.

Henize, Wray, Parsons, and Benedict (*ApJ* **199**, L173) have described UV spectra of WR stars in the 1300–2000 Å region. Barnes, Lambert and Potter (*ApJ* **187**, 73) have observed γ^2 Vel and ζ Pup in the region 0.9 to 1.7μ. Barnes and Hinkle have extended the spectrum of γ^2 Vel from 1.7μ to 2.5μ. Two strong emission features near 2.1μ probably attributed to C III and C IV are seen. Barnes and Bernat have extended this work to HD 50896 and HD 151932. Andrillat and Vreux (*AA* **41**, 133) report on the near infrared spectra (0.8 to 1.1μ) of several Of stars and a few WR stars. The line He I 10830 Å is in emission or has a P Cygni profile. They describe (*AA* **34**, 313) blue and red spectra of the Of stars in the vicinity of η Car. Gehrz and Hackwell (*ApJ* **194**, 619) have measures of WC9 stars in the 2.3μ to 23μ range.

There is evidence that three of the four stars examined are embedded in thick circumstellar dust shells. Hackwell, Gehrz and Smith (*ApJ* **192**, 383) find at 3.5μ all but two of nineteen stars studied, to have an infrared excess.

Walborn has found (*AJ* **78**, 1067) two groups of peculiar spectra which differ from the normal Of Spectra. Li has in progress a detailed study of the spectra of planetary nuclei of the WR type in the 3000 Å–5000 Å region. Aller has studied many of these same objects in the 5000 Å–8400 Å region with the Lick superscanner. Many of the O VI-type objects can be assigned to equivalent carbon sequence types although no classical WR star falls in this category. Leparskas is engaged in a programme of photoelectric measurement of line profiles of C III 5696 Å and He II 4686 Å in O and Of stars.

Conti and Leep (*ApJ* **193**, 113) present information on the behaviour of 4686 Å and 6563 Å in a number of Of type stars. They show that both emission lines come from extended envelopes which appear in stars brighter than $M_v = -6.0$.

Webster and Glass (*MN* **166**, 491) have studied four emission blue stars which have low

excitation surrounding nebulae, infrared radiation from dust grains and characteristic spectra with strong C II lines. They appear to form a cool extension to the carbon sequence of the Population II Wolf Rayet stars. One of these, V348 Sgr, has features in common with both R CrB stars and the planetary nebulae. Thackeray and Webster (*MN* **168**, 101) have described the spectral evolution of a hot component in the slow nova, RR Telescopii. This component has the emission line features of a WR star, but the apparent class changes from WN6 to WN3 or earlier during the ten years of observation.

Conti and Frost (*ApJ* **190**, L137) find night to night variations in the emission profiles of 4686 Å and 6563 Å similar to those found in ζ Pup by Brucato (*MN* **153**, A35). Rapid intensity variations in the emission lines of γ^2 Vel have been reported by Jeffers, Weller and Sanyal. A later photometric study (*ApJ* **187**, L31) by these authors of the He II 4686 Å line indicates a periodicity of 154 ± 35 s. These have also been confirmed by Wood, Schneider and Austin (*BAAS* **6**, 222). Cherpashchuk (*AF* **10**, 379) has photoelectrically examined both emission lines and continuum of HD 192103 and HD 191765 over an extended period of time. Schmidt (*PASP* **86**, 767) has monitored 4686 Å in HD 50896 and has noted significant changes in emission line profile. Sherwood has monitored the Of stars HR 6245, HR 6272 for rapid changes in line profiles of Hα and Hβ. Schumann with an SEC-vidicon is searching for short time variations in the emission lines of the WR stars HD 192641 and HD 193793 that show composite spectra. Irvine and Irvine (*PASP* **85**, 403) consider the 4686Å profile variations in EZ CMa to provide evidence of the binary nature. Schmidt (*PASP* **86**, 767) reports similar phenomena. Jeffers and Weller confirm variability in this star as well as in CV Ser and HD 151932 from a series of time resolved spectra of sixteen southern WR stars.

West and Setcher have spectral scans of several UV emission lines in γ^2 Vel obtained at quarter phases of the 78-day period. The emission feature displayed P Cygni profiles. Bappu and Rajamohan have measured radial velocities of C III 5696 Å in γ^2 Vel and find that the systemic velocity derived from the velocity curve of the emission line agrees with that derived from the velocity curve of the O stars. This proves the red shift found in 4686 Å measures to arise from line asymmetry that is perhaps related to line origin. Cowley and Hutchings (*AA* **36**, 305) present evidence that anomalous red-shifts of 4686 Å in WR binaries are due to systematic errors of measurement that are nearly eliminated when oscilloscope techniques of radial velocity measurement are done. Kuhi, Pecker and Vigier (*AA* **32**, 111) outline the possibility of such red-shifts to be produced by inelastic photon boson scattering.

Schild and Liller (*ApJ* **199**, 432) find no evidence of an eclipse in CV Ser from photoelectric observations made in 1973 and 1974 through a *B* filter, though night to night changes are common with occasional flaring. Iris photometer measures of this object on Harvard patrol plates covering a fifty years period provide no evidence of a deep eclipse at all. Kartasheva (*PZ* **18**, 459) has analysed the light curve of CQ Cep by dividing it into 'stellar' and 'shell' components and employing conventional techniques. Galatola (*BAAS* **6**, 468) has discussed the structure of the envelope surrounding the WR component of V444 Cygni. Moffat and Haupt (*AA* **32**, 435) have monitored seven WR stars in the continuum and in the emission lines and detect no short period variations suggestive of their being massive He or C-burning stars at the upper limit of pulsational stability. Khaliullin (*AZ* **51**, 395) has estimated intensity of mass loss of the WR component in V444 Cygni with the aid of several models of mass loss. Nugis (*TO* **40**, 355) has studied the emission spectra of several WR stars and estimated temperatures and chemical compositions for these objects. The temperatures are derived from the assumption that the radiation from the WR star is essentially that of a black body and originates from a hot core surrounded by an envelope. Narrow band photometry in an extended range of wavelengths of the continuum of V444 Cyg have been made by Cherepashchuk and Khaliullin (*PZ* **18**, 321). Walborn (*ApJ* **186**, 611) has shown the double-lined spectroscopic binary HDE 228766 to consist of a very early Of star and a rapidly rotating late O supergiant. Walborn finds in HD 152408 the violet shifted absorption component of the P Cygni profile of He I 5876 Å to be extremely broad. The similarity between the absorption components of 5876 Å in both HD 152408 and the WN7-A star HD 151932 is striking. Hutchings, Thackeray, Webster and Andrews (*MN* **163**, 13P) report measures of the He II lines 4541 Å and 4686 Å in the spectrum of the O6f component, HD 153919, of the X-ray source 2U1700–37.

Castor (*ApJ* **189**, 273) has constructed model stellar atmospheres with the object of explaining the higher temperature derived from the line spectrum than from the continuous spectrum commonly seen in WR stars. Nugis and collaborators (*TO* **44**, **53**, **19**, **83**, **145**) have examined equilibrium level populations as inferred from He I, N III, N IV, N V, C III and C IV lines in the WR stars HD 192163, HD 191765, HD 192103 and HD 192641. Malov (*Af* **10**, 575) has invoked Thomson scattering in optically thin WR atmospheres to accelerate matter and produce the observed flow velocities and mass loss rates that are deduced. Cannon (*AA* **34**, 387) has attempted to derive physical parameters of these objects by comparison of observed lines with those synthetically evaluated from a range in parameters.

Castor, Abbott and Klein (*ApJ* **195**, 157) have shown that a large number of subordinate lines of a representative ion can have effects in mass loss which far exceed those due to resonance lines.

2. O, B STARS

A. *O Stars*

Conti (*ApJ* **179**, 161; **187**, 539) has compared equivalent widths of different lines in a large sample of O stars with predictions from the non-LTE models. Lester (*ApJ* **185**, 253) has shown that the ON9V star HD 201345 has overabundances of carbon, nitrogen and oxygen and normal abundances of helium, magnesium and silicon.

Lyubimkov (*ICAO* **52**, 49) has evaluated the helium abundance in atmospheres of about 150 O and early B stars.

Conti and Leep (*ApJ* **193**, 113) have investigated the hydrogen lines and He II 4686 in spectra O-type stars.

Nitrogen III in the O stars has been analysed by Mihalas and Hummer (*ApJ* **179**, 827).

Snijders and Underhill (in press) have analyzed the He II lines in the Spectrum of ζ Pup, which was observed by *Copernicus*.

B. *B Stars*

Jaschek and Jaschek (*PASP* **85**, 127) have reported very conspicuous variations in the strength of line in the spectrum of ζ^1 Sco. Underhill (*AA* **25**, 161) has studied the spectra of ζ Dra, β Sex and α Leo in the spectral region 1100–6700 Å. Pagel (*AA* **30**, 471) reanalyzed ζ Dra data.

Ivanova (*SB* **44**, 81) has studied the spectrum of i Her.

Dworetsky (*ApJ* **184**, L75) found Helium-3 in iota Orionis B.

Osmer (*ApJ* **184**, L127) has found that two B-type supergiants in the Small Magellanic Cloud have a normal helium abundance and deficiency of N, O, Si abundances. Jaschek and Brandi (*PASP*) have found variations in the intensity of the lines belonging to light elements in the spectrum of the oxygen-rich supergiant HD 148688.

Jaschek and Jaschek (*AA* **36**, 401) have reviewed peculiar B-type stars which exhibit anomalies in the behavior of the light elements.

Auer and Mihalas have studied the neon (*ApJ* **184**, 151) and helium (*ApJ Sup* **25**, 433) abundance in B stars by using non-LTE models.

The Ca II K-line in B stars has been analyzed by Mihalas (*ApJ* **179**, 209).

Mihalas *et al.* (*ApJ* **190**, 315) have studied He I 4471 profiles in B stars.

Blanchard *et al.* (*AJ* **79**, 809) have made photoelectric measurements of Hγ line strengths in 52 early-type stars. Auer and Norris (*ApJ* **194**, 87) have determined normal helium abundance for the population II Star Barnard 29. Higginbotham, Lee (*PASP* **85**, 215) have found a helium-to-hydrogen ratio of 2.0 for HD 184927. Hunger, Kaufmann (*AA* **25**, 271) have studied the hydrogen-deficient stars HD 144941 and CPD $-$ 69°2698. The hydrogen-deficient star HD 96446 has been analyzed by Wolf (*AA* **26**, 127).

Kaufmann *et al.* (*AA* **36**, 201) have found helium-to-hydrogen ratio 0.8 for the helium star HD 168785. Metals, especially oxygen, appear to be underabundant.

Several studies have been carried out in which *Copernicus* data have been used. Descriptions of the UV Spectra of a few stars have been published by Underhill (*ApJ Sup* **27**, 359) for B5 I a star η CMa; by Stalio and Selvelli (*AA Sup* **21**, 241) for ϵ Ori (B0Ia) and k Ori (B 0.5 Ia); and by Stalio, Selvelli and Crivellari (in press) for β Ori (B8 Ia). Detailed line profile analyses of Mg II features in early-type stars have been carried out by Snijders and Lamers (*AA* **41**, 245) and by Lamers and Snijders (*AA* **41**, 259). Kondo, Modisette, and Wolf (*ApJ* **199**, 110) and Kondo *et al.* (*ApJ*, in press) have analyzed Mg II λ 2800 profiles in B-stars, finding evidence for emission in a few cases. P-Cygni line profiles indicative of high-velocity mass loss have been noted by several authors: by Morton (*ApJ* **201**, in press) for ζ Pup (04f), 29 CMa and ζ Oph (09.5V), by McCluskey, Kondo, and Morton (*ApJ* in press), by Rogerson and Lamers (*Nat* **256**, 190) for τ Sco (BOV), by Hutchings (in press) for several O-supergiants.

Equivalent width of 15 Å (at B2.5) to 65 Å (at B8) have been found for stellar Ly-α lines from data of the Wisconsin experiment aboard OAO-2 by Savage and Panek (*ApJ* **191**, 659).

C. *Be Stars*

IAU Symp. **70** on *Be and Shell Stars* was held at Cape Cod in Sept. 1975. The papers presented give a good information of present status of work on Be Stars.

Bidelman, Forbes and Weitenbeck have obtained Hα observations for all in the stars brighter than $7^{m}.5$ and north of $\delta = -30°$ contained in the three classical Merrill-Burwell Catalogues at two epochs: 1958–59 and 1970–72. The total number of objects observed was 215. Irvine (*ApJ* **196**, 773) discovered several new bright emission-line stars. Sanduleak and Stephenson have done quite a bit of work for southern-hemisphere Be stars (*PASP*, **86**, 215; *ApJ* **185**, 899; *ApJ* **191**, 685; *PASP*, **86**, 461; *PASP*, **87**, 369). Conti and Frost (*IAU Symp.* **70**) have discussed Oe stars. These stars have relatively narrow emission in the hydrogen lines and sometimes in helium lines.

Ilmas (*TO* **47**) has calculated the Balmer decrement if statistical equilibrium is maintained both by the radiative and the collisional ionization and excitation. Luud and Ilmas (*ASS*, in press) have shown that the observed relative line intensities of γ Cas are in qualitative agreement with the calculated ones. Briot (in press) has measured Paschen decrements for 12 B0e-B5e Stars. Kogure (*PASJ* **27**, 165) has studied the Balmer series of hydrogen in the spectrum of HD 217050. No appreciable Balmer progression is found. Gray and Marborough (*ApJ Sup* **27**, 121) have investigated photoelectrically profiles of Hα and Hβ in 14 Be stars.

Hayes and Illing (*AJ* **79**, 1430) have made linear polarization measurements across the Hγ line of ten stars. A significant polarization decrease has been found in γ Cas. Coyne (*MN* **169**, 7) did not find a polarization in Hα of γ Tau. Poeckert (*ApJ* **196**, 777) has shown that the emission in Hα is unpolarized in spectra of 12 Be stars.

Bahng (*IAU Symp.* **70**) has found definite variations of Hα emission strength of a few percent with time scale of 1 to 3 minutes in four Be star. Doazan (*IAU Symp.* **70**) has found similar variations in other two Be stars.

Swings (*IAU Symp.* **70**) has prepared a review of infrared observations of Be stars. Morgan, Pottar and Kondo (*ApJ* **190**, 349) have obtained spectra of β Lyr over the spectral region 1.76–0.9 μ. UV-spectrum of β Lyr has been studied extensively by Hack *et al.* (*Nat* **249**, 534), by Kondo and McCluskey (*ApJ* **188**, L63). Observations have been made by *Copernicus* at several phases.

Andrillat and Swings (*ApJ*, in press) have investigated spectra of 25 peculiar Be star in the 0.82–1.12μ region.

3. A-TYPE STARS

A. *Normal A Stars*

Kodaira (*AA* **22**, 273) has revised chemical abundances of four Population II A-type stars.

Hutchings and Laskarides (*PDAO* **14**, 107) have investigated mass motions in the atmospheres of supergiants of spectral types B9-A3.

Wolf, Campusano, and Sterken (*AA* **36**, 87) have carried out spectroscopic investigation of the extreme galactic A supergiant HD 160529.

Boesgaard *et al.* (*ApJ* **194**, L143) have used *Copernicus* data to determine the abundance of boron in Alpha Lyrae. Praderie, Simonneau, and Snow (*ASS*, in press) found that the observed wings of Ly– α in Alpha Lyrae are too strong to be accounted for by LTE model calculations.

Severny *et al.* (*ICAO* **50**, 3) have found the weak longitudinal fields not exceeding as a rule 200 g in several A-type stars.

B. *Ap Stars*

IAU Colloq. **32** on *the Physics of Ap Stars* was held at Vienna in Sept. 1975. The papers presented form a comprehensive assessment of present status of work on Ap stars. In addition we have a good review of work on Ap and Am stars by Preston (*AR* **12**, 257) and by Jaschek and Jaschek (*VA* **16**, 131).

Adelman (*ApJ* **195**, 397) has measured the continuous energy distribution of Ap stars in the range 3300–7100 Å. It was found to be generally identical with that of normal A-type stars; however broad and shallow features are present at $\lambda\sim4200$, $\lambda\sim5300$ and $\lambda\sim6300$ Å. These broad depressions were measured by Maitzen and Vogt (*IAU Coll.* **32**). Gerbaldi, Hauck, and Morguleff (*AA* **30**, 105) have studied the Balmer discontinuity of Ap stars. The hydrogen lines have been studied by Gray and Evans (*ApJ* **182**, 147), by Glagolevskij *et al.* (*AI* **5**, 52), and by Leushin (*AI* **5**, 70). Smith and Parsons (*ApJ Sup* **29**, 341) have applied Fourier analysis of line profiles to three Mn star for determining classical microturbulence.

Ryabchikova (*ICAO* **45**, 146) has studied variations of the hydrogen lines in Si-star CU Vir. Williams, Frantz, and Breger (*AA* **35**, 381) have looked for Hβ variability in Ap and Am stars. Kumaigorodskaya and Chunakova (*AI* **7**, 3) have studied the variability of Balmer spectrum of the Ap star HD 184905.

Many stars have been studied and interpreted from the point of view of the oblique rotator model: 108 Agr (Megessier, *AA* **34**, 53; **39**, 263); 56 Ari (Mihalas, *ApJ* **184**, 851); 49 Cam (Bonsack, Pilochowski, and Wolff, *ApJ* **187**, 265); 53 Cam (AX Cam) (Faraggiana, *AA* **22**, 265); A Cen (Norris and Baschek, *AA* **21**, 385; *ApJ* **193**, 133; Mihalas, *ApJ* **184**, 851; Underhill, Fahey, and Kinglesmith, *ApJ* **197**, 393; **199**, 120; Wolff and Morrison, *PASP* **86**, 935); α^2 CVn (Kumaigorodskaya and Kopilov, *AI* **4**, 50; Kumaigorodskaya *AI* **6**, 3); 73 Dra (Sadakane, *PASJ* **26**, 93; Breger, *ApJ* **192**, 71); 21 Per (Polosukhina, Glagolevsky, and Kozlova, *Af* **10**, 4); κ Psc (Galeotti and Lovera, *MSAI* **43**, 759); χ Ser (Ryabchikova, *AZ* **51**, 761; Khoklova and Ryabchikova, *ASS* **34**, 304); HD 51418 (Jones, Wolff, and Bonsack, *ApJ* **190**, 579); HD 193722 (Aslanov *et al.*, *ASS* **21**, 477); HD 203006 (Maitzen *et al. AA* **21**, 579); HD 215441 (Polosukhina and Chuvaev, *Nat* **251**, 5477).

Scholz (*AN* **296**, 31) has measured RV and magnetic field of 53 Cam and γ Equ. RV and magnetic field measurements are made by Wolff and Wolff (*ApJ*, in press) for HR 7129 and for the *holmium* HD 101065 by Wolff and Hagen (in press). Bonsack and Pilachowski (*ApJ* **190**, 327) have found a steady decrease of magnetic field in γ Equ. The magnetic field of 49 Cam is found to vary cyclically (Bonsack, Pilachowski, and Wolff, *ApJ* **187**, 265). Hensberge (*AA* **32**, 457) has studied the magnetic field in HD 98088.

Adelman (*ApJ* **183**, 95) has investigated the chemical compositions of many Ap stars. Kodaipa (*IAU Coll.* **32**) has analyzed the chemical compositions of several Mn-Hg stars. Mn stars show abundance anomalies in conflict with predictions of nuclear astrophysics. (Cowley and Äikman, *ApJ* **196**, 521). Chemical compositions of many Ap stars have been studied: 49 Ari, β CrB, 68 Tau (Kozlova, *AI* **4**, 69); 53 Aur (Zverko, *BAIC* **24**, 71); HD 101065 (Wegner and Petford, *MN* **168**, 557); HD 111133 (Engin, *AA* **32**, 93) HD 168733 (Little, *ApJ* **193**, 639), HD 224801 (Castelli *et al.*, in press). Cowley, Aikman, and Hartaog (in press) made a high dispersion survey of spectra of 51 Ap, Am and normal A stars and have failed to find convincing evidence for any transuranic actinide. Dworetsky and Vaughan (*ApJ* **181**, 811) have studied Pt II λ 4046 in mercury stars. Polosukhina and Khokhlova have found bands of CN and CH in 73 Dra (in press).

Search for heavy elements was made for many stars. Summaries of the papers published are given in *Astronomy and Astrophysics Abstracts*.

Observations of the Li I λ 67078 in several magnetic stars have been made by Polosukhina (*ICAO* 47, 118; 50 57). Boesgaard and Heacox (*ApJ* 185, L27) have determined the abundance of boron, berylium and lithium in the Ap star Kappa Caneri.

Burger, van der Hucht, and Lamers (*AA* 26, 149, 1973) have studied the Mg II lines at 2800 Å in the spectrum of α^2 CVn. Sralio (*AA* 36, 279) has investigated UV spectrum scans of α And, obtained with *Copernicus*.

The TD-1 559 spectrometer data have been used for study of UV spectra of γ Cor (Faraggiana and van der Hucht, *AA* 38, 455), of four Mn stars (Faraggiana *et al.*, ASS in press), UV spectrum of ϵ UMa have been studied by Molnar (*AJ* 80, 137) (OAO-2 data) and by (Mallama and Molnar, *BAAS*, 7, 270) (*Copernicus* data).

C. *Am Stars*

Smith (*ApJ Sup.* 25, 277, *ApJ* 189, 101) has studied metallicism in border regions of the Am domain. Burkhart and van Veer (*CR* 278, 1103) have made a detailed analysis of non-classical Am stars (e.g. relatively fast-rotating stars). Stickland (*MN* 161, 1973) has studied the abundances of seven Am SB2 systems. The abundance analyses were made for 15 UMa (Falipon, *AA* 22, 445), 15 Vul (Boyarchuk and Mamatkazina, *ICAO* 47, 125), HD 153286 (Engin, *ASS* 29, 343). Stickland and Van der Hucht (in press) have studied UV Spectrum of β Aur. Kuvshinov (*AZr* 6 82, 3) has measured the magnetic field of 15 Vul. Kuvshinov, Heildebrand, and Shoneich (*ICAO* 53, 253) have studied the magnetic field of 15 Vul and 68 Tau.

D. *F-G-K Stars*

Many papers related to these stars were presented at *IAU Colloq.* 17, 'L'Age des Etoiles' and *IAU Symp.* 72, *'Abundance Effects in Classification'*. Many stars of each type have been analyzed. Representative papers include:

I. *F-Stars*

Metal-deficient F stars have been analyzed by Cayrel *et al.* (16 Psc., *AA* 37, 179), da Silva (HD 91324, α Crv., *AA* 41 in press) and Lambert *et al.* (HD 122563, *ApJ* 188, 97); Other F-type stars that have been investigated are: Procyon (Linsky, *BAAS* 4, 334), 5 And (Falipou, *AA* 22, 445), HD 116745 in ω Cen. (Dickens and Powell, *MN* 161, 249), and Canopus, F0 Ib for departures from LTE (Johnson *et al.*, *ApJ* 187, 147), Johnson (*ApJ* 200, 395) reported the presence of rare-Earth elements in UV Spectra of γ Cyg, which were taken by *Copernicus*. The α CMi chromospheric and coronal emission has been studied by Evans, Jordan, and Wilson (*Nat* 253, 612; *MN*, in press), who used *Copernicus* to detect Ly-α, Mg II 2800, Si III 1206 and O VI 1032.

II. *G-Stars*

Among the G stars for which analyses have been made are: the halo dwarf HD 128279 (Spite and Spite, *AA* 40, 141), 82 Eri (Hearnshaw, *AA* 29, 165), α Cen (French and Powell, *ROB* 173, 63), CH giants HR 7606, 8626 (Roberts *et al.*, *PASP* 87, 385), ϵ Leo (Williams, *MN* 162, 235), the supergiant HR 5171 (Warren, *MN* 161, 427), weak-and strong-line stars (Casini and Pasinetti, *Cont. Milan 347*), the variable EZ Peg (Irvine, *PASP* 84, 671) and the metal-deficient LMC supergiant HDE 268752, with HR 8752 (Fry and Aller, *ApJ Sup* 29, 55). Hearnshaw (*AA* 38, 271) obtained C and Fe abundances for 11 southern G stars and also (*MRAS* 77, 55) derived abundances for 19 disk G stars. Hearnshaw and Schmidt (*AA* 21, 111) computed Hα profiles for G stars. Various molecules in γ Aql (C_2, CH, CO) have been studied by Joshi *et al.* (*BAIC* 23, 301; 24, 169; 24, 171; 25, 120).

III. *K-Stars*

Numerous investigations of Arcturus have been made: A model atmosphere analysis (Mäckle *et al.*, *AA* **38**, 239) based on Griffin's spectra shows the expected under-abundance of the metals, Ayres and Linsky (*BAAS* **5**, 336) give a model for the chromosphere. For the C^{12}/C^{13} ratio, Griffin (*MN* **167**, 645) found ~ 6 while Day *et al.* (*ApJ* **185**, 213) obtained 7 for Arcturus and 12 for α Ser. Other K-type stars that have been studied are: iron-rich stars HR511 and 7670 (Hearnshaw, *AA* **30**, 203), α Tauri (van Paradijs and Meurs, *AA* **35**, 225), β Gem (R. Griffin) metal rich W Dra, K_2III (Williams, *MN* **167**, 359) and HD 6497 (Cayrel and Pasinetti, *AA*, in press). ϵ Peg K_2Ib has been studied by van Paradijs and de Ruiter (*AA* **20**, 169) and by Hyland and Mould (*ApJ* **187**, 277), who also studied HR 4050. Kipper and Hänni (*41*, 143) used curve of growth techniques to study γ Sge, K_5III, 61 Cyg A, K_5V, and 61 Cyg B, K_7V. For 15 giant stars Ridgway (*ApJ* **190**, 591) studied the CO bands and found C^{12}/C^{13} ~ 10 for normal stars though for a few stars an overabundance of CO was noted. Lambert and Tomkin (*ApJ* **194**, L89) found C^{12}/C^{13} = 5.1 for ϵ Peg (K_2); for 11 G and K giants, Tomkin *et al.* (*ApJ* **199**, 436) found C^{12}/C^{13} varied from 6 to 23, for 12 K giants and subgiants Dearborn *et al.* (*ApJ* **200**) found C^{12}/C^{13} varied from 12 to >50. Discussions on the supermetal rich stars continues (Gottlieb and Bell, *AA* **19**, 434; Oinas, *ApJ Sup* **27**, 391 and 405; Blanc-Vasiaga *et al.*, *ApJ* **180**, 871; Cayrel *IAU Coll.* **17**, LVII; Peterson, *BAAS* **5**, 401; Janes, *ApJ Sup* **29**, 161).

Chromospheric emission in K-stars has been studied by Moos *et al.* (*ApJ* **188**, L93), McClintock *et al.* (*ApJ* in press) and by Linsky *et al.* (*ApJ* **188**, L93), who have used *Copernicus* data on Ly-α and Mg II 2800 emission lines to estimate temperature, density and dynamical conditions in K-star chromospheres. Gerola *et al.* (*ApJ* **193**, L107) and Linsky *et al.* (*ApJ* **188**, L93) have detected and analyzed coronal emission, notably in β Gem (KO III), in which O V λ 1218 Å emission was seen. The 1971 eclipse of 32 Cyg has been investigated by Doherty, McNall, and Holm (*ApJ* **187**, 521), who have used OAO-2 data. The K star shows a flux excess in the UV that might be due to an extended atmosphere.

IV. *General*

With modern techniques cluster stars can be studied, sometimes in some detail. Examples of recent investigations are: metallicity for stars in M 67 (Morgan and Abt, *AJ* **78**, 386; Griffin, *MN* **171**, 181); G bands in M92 (Zinn, *ApJ* **182**, 183); G bands in globular cluster stars (White, *BAAS* **5**, 401), CN bands in 47 Tuc (McClure and Osborn, *ApJ* **189**, 405), abundance differences for stars in NGC 188 (McClure, *ApJ* **194**, 355), CH stars in M 5, M 10 and M 92 (Zinn, *AA* **25**, 409), abundances in the Hyades, M 67 and NGC 188 (Foy, *IAU Symp.* **72**).

V. *Peculiar Stars*

In FG Sag (Langer *et al.*, *ApJ* **189**, 509, Kraft, *Sky Tel* **48**, 18) the central star now shows heavy elements and its spectrum is similar to α Per, F_5Ib. The spectrum of VI057 Cyg (Schwartz and Snow, *ApJ* **177**, L85) has changed from an A to a F-type giant, and it may be related to a T Tauri star. Irvine (*PASP* **87**, 87) notes that CoD −44°3318 has a Folpe spectrum also similar to a T Tauri star. Bell and Dickens (*MN* **166**, 89) have determined CNO abundances for CH stars in ω Cen. Bond (*ApJ* **194**, 195) has studied the subgiant CH stars. Ishikawa (*PASJ* **27**, 1) finds an overabundace of metals for the δ Sct variable 20 C Vn.

Infrared observations of other late-type stars have been made. Anderson (*ApJ* **190**, 385) observed Ca II λ 8498 in 28 F_8-M_2 stars; Oinas (*PASP* **86**, 321) found a continuum depression near λ 8800. Humphreys and Ney (*ApJ* **187**, L75) observed HD 101584 and concluded that this F_2 Iape star has a M-type companion; they also (*PASP* **86**, 444; *ApJ* **193**, 623) observed silicate emission in G and K supergiants. Baldwin *et al.* (*ApJ* **184**, 427) measured bands of H_2O and CO at 2.1 and 2.3 μ for F– to M-type stars.

General analyses of late-type stellar spectra have been made by van Paradijs (G and K supergiants, *AA* **23**, 369; departures from LTE, *AA* **28**, 385), Higgins (Ti and Fe, *AA* **28**, 217), Hearnshaw (CH, *AA* **28**, 279, C and Fe, *AA* **34**, 263 and **36**, 191, Fe and CH, *AA Sup* **19**, 3),

Williams *et al.* (Fe, *MN* **158**, 361; Ca, *MN* **160**, 129; Ba, *MN* **170**, 243), Harmer and Pagel (CN, *MN* **165**, 91), Reimers (Ca II and Hα, *AA* **24**, 79) and Alschuler (Li, *ApJ* **195**, 649).

4. M, S, C-TYPE STARS

A. *M Stars*

Spectral classification and determination of radial velocity of thirty M-type giant stars within 30° of the South Galactic Pole was carried out by Crampton and Evans (*MN* **163**, 11). Wing (*BAAS* **5**, 1973) found a small group of unusual M stars including VX Sgr and NML Cyg to be spectroscopically distinguishable in that prominent bands of both VO and CN appear in 1μ region. Albers (*ApJ* **189**, 463) discussed spectral classification and luminosity effects of M-type stars from infrared spectra of moderate dispersion.

Thompson and Johnson (*ApJ* **193**, 147) obtained a lower limit on C^{12}/C^{13} ratio in α Her from the second overtone CO bands at 1.6 μ. Gautier *et al.* (1975) attacked the same problem in α Ori. Lambert *et al.* (*ApJ* **193**, 621) determined C^{12}/C^{13} ratio in α Ori from the CN (2, 0) red system and the CO second overtone bands.

Baldwin *et al.* (*ApJ* **184**, 427) measured the strengths of absorption lines due to H_2O and CO at 2.1 and 2.3μ for K-M type stars. Boesgaard determined the presence and intensity of the ultraviolet emission lines of Fe II in K and M giant and supergiant stars. Johnson *et al.* (*PASP* **84**, 775; **85**, 179) tried identification of infrared spectra of α Her and χ Cyg from 4000 to 6800 cm^{-1}. Fäy (*ApJ* **188**, 553) investigated the relation between 2μ absorptions and 11μ emissions of M-type stars and found it is consistent with CO and H_2O cooling of M star boundaries. Lambert *et al.* (*ApJ* **186**, 573) identified the H_2 quadrupole rotation-vibration band in M-type giants and supergiants. Bear *et al.* (*PASP* **86**, 806) estimated the SiO abundance and silicon isotope ratio from infrared spectra of α Ori. Boesgaard and Magnan (*ApJ* **198**, 369) discussed the circumstellar shell of α Ori from the study of the Fe II emission lines. Brooks *et al.* (*PASP* **86**, 419) discussed atmospheric motions from radial velocities obtained from interferometric spectra of α Ori, α Her, and α Sco. Huggins (*AA* **31**, 103) discussed the abundance of heavy metals in M giants, on the over-abundance of which he is suspicious. Deutsch *et al.* (*PASP* **86**, 233) investigated the spectrum of CH Cyg (M type) from 1961 to 1973. Bernat and Lambert (*ApJ* in press) have used *Copernicus* observations of Mg II emission in α Ori and α Sco to determine the properties of the chromospheres and of cool shells overlying them.

B. *C-Stars*

Yamashita (*Ann TAO* **13**, 169; *PASJ* **26**, 159) obtained radial velocities of thirty-five carbon stars for which no data could be available so far. Catchpole and Feast (*MN* **164**, 11 p.) found a carbon star in NGC 2477 to be a radial velocity member.

It should be remarked that extended and detailed survey was carried out by Yamashita (*Ann TAO* **13**, 169; **15**, 47) by classifying 291 carbon stars on the C-classification system of Keenan and Morgan. Yamashita (*PASJ* **27**, 459) interprets a poor correlation of colour temperature of carbon stars deduced from infrared photometry versus the C-type to be the blocking effect due to CN absorption and by interstellar reddening. Hardorp *et al.* (*AA* **22**, 129) classified fifty-nine carbon stars in the northern Milky Way. Stephenson finished a General Catalogue of Cool Carbon Stars which is now in preparation as Publication of the Warner and Swasey Observatory. An additional list of Carbon and S stars will appear in *AJ* **78**, 687.

Identification of spectral lines in the infrared region of carbon stars. Giguere (*ApJ* **186**, 585) made a search for HCN in TX Psc and UU Aur. Hirai (*PASJ* **26**, 163) published an identification table of spectral lines in the 1μ region for U Hya and Y CVn and presented the evidence for the possibility of C_2H_2 in U Hya. Hirai (*PJA* **50**, 743) further discussed the presence of C_2H_2 in 19 Psc and Y CVn. Querci and Querci (*AA*, in press) investigated the spectra of UU Aur and Y CVn from 4000 to 9000 cm^{-1}. Thompson (*PASP* **85**, 643) studied

the spectra of Y CVn and U Hya from 4000 to 6700 cm^{-1} . Identification of novel molecules such as CuH, ZnH, GeH, and SnH in 19 Psc tried by Wojslaw and Peery (*ApJ Sup*, 1976) should be remarked. Rybski (*PASP* **85**, 653) observed CaCl in the spectra of three carbon emission-line stars.

Isotopic abundance of C^{12}/C^{13} in carbon stars is one of interesting problems. Climenhaga *et al.* (*BAAS* **117**, 433) obtained the C^{12}/c^{13} ratio for about twenty carbon stars from the intensity of CN red system. Fujita obtained image-tube spectra of some very early-type carbon stars in the photographic infrared region for determining the C^{12}/C^{13} ratio.

Fujita (*PJA* **49**, 530) measured the intensity of the forbidden [C] λ 8727 line in seventeen carbon stars. Richer (*ApJ* **197**, 611) measured Ca II H and K lines in seven hot carbon stars and derived their absolute visual magnitudes from the widths of the reversals. Greene *et al.* (*AA* **22**, 293) investigated atomic and molecular lines of HD 156074 and discussed the relative abundance of some elements. Fäy (*ApJ* **190**, 597) proposed that carbon stars have only small change in N/O ratio from the study of CO, CN, and C_2. Th presence of Tc was indicated by Cohen (*PASP* **85**, 187) in S Scl (Me) and by Hackos (*PASP* **86**, 78) in UX Dra (N).

C. *CS and CH Stars*

Zinn (*AA* **25**, 409) found some unusual red giants in globular clusters M 5, M 7, and M 92. Bell and Dickens (*MN* **166**, 89) obtain C, N, and O abundances from the Swan bands in the spectra of the ω Cen CH stars. Yamashita (*PASJ* **25**, 57) investigated spectra of GP Ori and FU Mon in the photographic infrared region and obtained their atmospheric parameters. Yamashita (*PASJ* **27**, 325) found several CH-like stars. An unidentified absorption feature indicated by Rybski (*PASP* **85**, 751) in CS stars was identified by Catchpole (*PASP* **87**, 397) and by Irvine and Bidelman (*BAAS* **6**, 365) as the A and B bands of CaH. Greene and Wing (*ApJ* **220**, 688) found VX Aql to be the coolest known SC star. Its spectrum contains strong bands of CaCl and CaH as well as CN but has no detectable absorption of C_2 or the metallic oxides.

In connection with abundance of elements in late-type stars Tsuji (*AA* **23**, 411) published his second paper after the pioneering first paper on the dissociative equilibrium of molecules. Hinkle and Lambert (*MN* **170**, 447) examined the statistical equilibrium of electronic states of diatomic molecules in stellar atmospheres. Thompson (*ApJ* **184**, 187) shows CO first overtone bands at 4360–4000 cm^{-1} for C^{12}/C^{13} ratio determination in many late-type stars due to high degree of saturation in their bands.

Model atmosphere calculation have been intensively carried out by several authors. Among them, Fäy and Johnson (*ApJ* **181**, 851) calculation for Betelgeuse, Querci *et al.* (*AA* **31**, 265) for C-type stars, Mould (*AA* **38**, 283) for early M dwarfs, Querci and Querci (*AA* **39**, 113) for cool stars, Auman and Woodrow (*ApJ* **197**, 163) for late-type giant stars etc., should be noticed. Kilston (*PASP* **87**, 189) tried model synthesis on high-dispersion yellow-red spectra of eight N-type carbon stars.

5. BINARY STARS

A general discussion of the two topics listed below is given in *IAU Symp.* **51**.

A. *VV Cep Type Objects*

Barbier (*AA Sup* **18**, 251) has analysed in detail the star BD +54°2698 which shows numerous emission lines, mostly of [Fe II] and Fe II, but also of [Fe III] and [Ni II]. Barbier (*AA Sup* **20**, **305**, 1975) has also studied BD +63°3, which shows numerous emission lines, belonging principally to [Fe II]. Woolf (*ApJ* **185**, 229) observed in W Cep optically thin free-free emission in the far ultraviolet, probably due to the presence of the hot companion, and strong silicate emission. HD 105563 was found to be a new VV Cep type object by Lynga (*AA* **24**, 303). AZ Cas was analysed by Mendez, Münch and Sahade (*PASP* **87**, 305) during the 1956-57 eclipse.

B. *Zeta Aur Type Stars*

Bisiacchi, Flora and Hack (*AA Sup* 13, 109) have presented their extensive spectroscopic material taken during the 1971 eclipse of 32 Cygni. They provide equivalent widths and contours of the K line and radial velocities of numerous lines. Kawabata and Saito (in press) will publish a discussion of the 1971–72 eclipse of ϵ Aur, providing chromospheric K-line intensities and radial velocities of the chromospheric lines.

C. *The Lithium Abundances*

Boyarchuk (*ICAO* 55, in press) has compiled data on the lithium abundances in the atmospheres of 491 stars, which were published before 1 January 1975. Grusdalen (*ApJ* 182, 781) has studied the lithium line in the spectra of young stars FU Ori and V1057 Cyg. Bopp (*PASP* 86, 281) has studied the lithium line in dM1e stars. Warren (*MN* 163, 337) has determined the litihium abundances in F-G giants. Cohen (*PASP* 86, 31) discussed the reality of the high Li abundance in carbon stars.

ABBREVIATIONS

Af =	Astrofizika
AA =	Astronomy and Astrophysics
AA Sup =	Astronomy and Astrophysics Supplement
AI =	Astrophys. Invest. of Special Astrophys. Observatory USSR
AJ =	Astronomical Journal
AN =	Astronomische Nachrichten
Ann TAO =	Annals of the Tokyo Astronomical Observatory
ApJ =	Astrophysical Journal
ApJ Sup =	Astrophysical Journal Supplement
ASS =	Astrophysics and Space Science
AR =	Annual Reviews of Astronomy and Astrophysics
AZ =	Astronomicheskij Zhurnal
AZr =	Astron. Zir.
BAAS =	Bulletin of American Astronomical Society
BAIC =	Bulletin of Astronomical Institutes, Czechoslovakia
CR =	Comptes Rendus de l'Academie des Sciences, Paris
ICAO =	Izv. Crimean Astrophysical Observatory
MN =	Monthly Notices of the Royal Astronomical Society
MRAS =	Memoirs of the Royal Astronomical Society
MSAI =	Memoirs of the Astronomical Society Italy
Nat =	Nature
PASA =	Proceedings of the Astronomical Society Australia
PASJ =	Publications of the Astronomical Society Japan
PASP =	Publications of the Astronomical Society Pacific
PDAO =	Publications of Dominion Astrophysical Observatory
PJA =	Proceedings Japan Academy
PZ =	Peremenye Zvezdy
ROB =	Royal Observatory Bulletin
SB =	Soobsh. Byurakan Observatory
TO =	Publications of the Tartu Observatory
VA =	Vistas in Astronomy

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