29. STELLAR SPECTRA (SPECTRES STELLAIRES)

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In the triennium under review, from the late second half of 1987 to the early second half of 1990, Commission 29 has sponsored or cosponsored the following IAU Conferences: Coll. No. 106, "Evolution of Peculiar Red Giant Stars," Bloomington, Indiana, July 1988; Coll. No. 114, "White Dwarfs," Hanover, New Hamsphire, August 1988; Coll. No. 113, "Physics of Luminous Blue Variables," Val Morin, Quebec, August 1988; Coll. No. 122, "Physics of Classical Novae," Madrid, Spain, June 1989; Symp. No. 143, "Wolf-Rayet Stars and Interrelations with Other Massive Stars in Galaxies," Denpasar, Indonesia, June 1990; Symp. No 148, "The Magellanic Clouds and their Dynamical Interaction with the Milky Way," Sydney, Australia, July 1990; Symp. No. 145, "Evolution of Stars: the Photospheric Abundance Connection," Druzba, Bulgaria. August 1990.

This report, concerning several aspects of stellar spectroscopy, has been prepared with the assistance of various pundits. Short reports on the activities of four working groups (WG) sponsored by Commission 29 prepared by their Chairmen are also included.

Working group on PRG Stars (by H.R. Johnson)

Keeping up with the research in this active field has kept the Working Group (WG) on Peculiar Red Giant Stars busy. At the 1988 General Assembly of the IAU the current officers were elected: H. R. Johnson, Chairman, with R. de la Reza, R. Foy, R.F. Garrison, A. Renzini, V.Straizys, T. Tsuji, and R.F. Wing as members of the Organizing Committee. Under the editorship of S.J. Yorka, we have continued the twice-yearly PRG Newsletter, adding a general overview of some aspect of the field to each issue. For our most recent issue (No. 8, June 1990), we sent the Newsletter by email to as many scientists as possible.

The WG has promoted the two activities voted most valuable by the membership in 1988: a meeting on red-giant binaries and a meeting on chromospheres and CSE of red-giant stars. The WG joined efforts to organize an IAU Symposium on the first topic. As a result, the president of the WG is serving on the SOC of IAU Symposium 151: Evolutionary Processes in Interacting Binary Stars, to be held 5-8 August 1991 in Cordoba, Argentina, at which red-giant binaries will be represented. Efforts on the second project will likely result in a day-long Joint Commission Meeting on Chromospheres and CSE of Red Giant Stars as part of the IAU General Assembly in July 1991. The SOC for this meeting consists of R. de la Reza, A.G. Hearn, H.R. Johnson (Chair), C. Jordan, M. Jura, and F. Querci, and speakers will address all aspects of the subject.

Working Group on Standard Stars (by. A. H. Batten)

Activities of this Working Group have continued through the last triennium, but at a somewhat reduced level. The Standard Star Newsletter has continued to appear, at six-monthly intervals, under the editorship of Laura Pasinetti, to whom the Group expresses its gratitude. The numbers of this Newsletter that have appeared since the Baltimore General Assembly contain a record of the activity stars of members of the Group on different kinds of standard stars.

It appears likely that the I.A.U. will be considering the status of a number of working groups, including this one, and it may be considered desirable to merge our Group into a larger unit.

D. McNally (ed.), Reports on Astronomy, Vol. XXIA, 309–326.

Working Group Be Stars (by D. Baade). The Working Group had a two-session meeting during the XXth IAU General Assembly in Baltimore. In the business part, a new Organizing Committee consisting of D. Baade (chair), L. Balona, J. Dachs, V. Doazan, J.M. Marlborough, J. Percy, and G.J. Peters was elected for the period 1988-91. During the scientific part, several papers dealing with correlations between various observational quantities were presented (summaries appeared in *Be Star Newsletter* No. 19). This rather condensed overview demonstrated that not only is there a dearth of observations but this material also shows much significant structure. Therefore, in principle, it should give a handle on many unsolved problems in Be stars although much hard work and some novel ideas will be needed to bundle the numerous loose ends. The big challenge but also great potential of Be stars is that the combination of variability, rapid rotation, and large radial extent demands/permits a time-dependent, three-dimensional model of a stellar atmosphere.

The main carriers of the observational and subsequent interpretational progress have in the last decade been IUE, IRAS, and modern detectors and instruments used with ground-based telescopes. The results coming in from these sources have now reached sort of a steady state. In the Working Group, plans are therefore taking on shape to organize, after 1975 and 1980, a new IAU-level meeting to round off this past phase and to prepare for the new results that can be expected in the next one, e.g., probably from ROSAT and certainly from ISO. The Working Group will also meet during IAU GA XXI in Buenos Aires.

During the report period, research on Be stars was again one of the largest, if not the largest, contributors to the total amount of literature on OB stars. The summary given in the section on B and Be stars in the Commission's triennial report reflects only a fraction of the spectroscopic work done. A much more complete overview can be obtained from the compilation of new publications which was provided every six months in the *Be Star Newsletter* by A.M. Hubert, J. Jugaku, P. Koubský, G.J. Peters, M. Ruusalepp, and A. Slettebak. Special thanks of the Working Group are due to these colleagues and especially to Gerrie Peters who edited another six issues of the *Newsletter* which continues to be an efficient forum for fast communications about recent results, the coordination of observing campaigns, announcements of meetings, etc. With financial support by the European Southern Observatory, the *Newsletter* is being distributed to over 210 libraries and individuals in 32 countries.

Working Group on Ap Stars (by K. Sadakane)

IAU Symposium 145 (*Evolution of Stars: the Photospheric Abundance Connection*) was held in Bulgaria, August 27 - 31, 1990. Ten invited papers related to Ap stars were presented at the Symposium. These speakers were B. Baschek, P. Demarque, R. Robolo, R. Cayrel, M. Takada-Hidai, G. Michaud, L. Lyubimkov, T. Ryabchikova, J. Landstreet and C. Cowley.

The working group is planning a next meeting on Ap stars in Summer of 1992. The meeting will be held in Trieste, Italy and the chairperson of the SOC is M. Hack. It will be titled as *"Peculiar versus Normal Phenomena in A-Type and Related Stars"* and will include fields of research not covered by IAU Symposium 145. The first announcement of the meeting will appear on the *Peculiar Newsletter* in the second half of 1991.

Symbiotic stars (by Angelo Cassatella)

Considerable progress has been made in the last few years in the understanding of the complex phenomena taking place in symbiotic stars, as documented in the proceedings of IAU Coll. No. 103 ("The Symbiotic Phenomenon", Eds. Mikolajewska et al. 1988, Kluwer) and by many other recent investigations. Ultraviolet to near-IR simultaneous observations of the prototype of the class, Z And, during quiescence were modelled by Fernandez-Castro et al. (1988: ApJ 324, 1016) in terms of three components: a hot compact source with $T > 100000$ K; an asymmetric nebula giving rise to the recombination continuum and the emission lines; and a M3.5 non variable giant. An asymmetric nebula is produced by photoionization of the red giant's wind by the hot compact companion. A similar model was proposed by Fernandez-Castro et al. (1990, A&A 227, 422) and by Mikolajewska et al.(1989, AJ 98, 1427) for another typical symbiotic star, BF Cyg.

Detailed photoionization equilibrium calculations applied to Z And by Nussbaumer and Vogel (1989: A&A 213, 137) indicate that the coexistence of two stellar winds, from both the hot and the cool components, can substantially modify the ionization structure of the nebula. The asymmetry of the nebulae in symbiotic stars naturally accounts for the phase dependent variability seen in the emission lines and in the UV continuum of objects like Z And, BF Cyg, and the six symbiotics studied in the UV by Munari (1989, A&A 208, 63). It has been realized that Rayleigh scattering by atomic hydrogen in the red giant's extended atmosphere causes the hot components in high inclination systems to suffer from a strong and periodic wavelength dependent obscuration in the range 1200-1600 A when the objects are observed near phase zero, as found for BF Cyg (cf. Isliker et al. 1989: A&A 219, 271; Fernandez-Castro et al. 1990: A&A 227, 422; Mikolajewska et al. 1989: AJ 98, 1427).

The physical mechanisms causing the active phases of symbiotic stars are still poorly known. Observations of symbiotic systems in activity, particularily important in this respect, have been carried out by Munari and Whitelock (1989: MNRAS 239, 273), and Munari et al. (1989: A&A 214, L5) for the symbiotic nova AS 296. Observations of V1329 Cyg (=HBV475) have been interpreted by Munari et al. (1988: A&A 202, 83) in terms of a probable nondegenerate Hburning flash on the white dwarf companion. Further observations of this object were presented by Arkhipova and Ikonnikova (1989: Sov. Astron. Lett. Vol. 15, p.60) and Wallerstein et al. (1989: PASP 101, 189). An interesting approach aiming to explain the complex phenomenology seen in RX Pup within a new self-consistent model was given by Allen and Wright (1988: MNRAS 232, 683) who propose that the hot companion in a phase of shell flash.

Modelling of symbiotic stars in terms of triple systems composed of a cool giant, a white dwarf with an accretion disk and by an early type main sequence star has been proposed by Gurzadyan (1989: Astrophys. Space Sci. 158, 123) to explain objects like SY Mus and BX Mon. Schild (1989: MNRAS 240, 63) studied a sample of symbiotic systems containing a Mira variable and found that they cluster in a transition zone in the massloss vs. period diagram which is intermediate between single Miras and OH/IR stars. In this zone the mass loss increase is at its steepest suggesting that these symbiotic stars are in an evolutionary phase near the onset of a superwind which ultimately leads to the formation of a planetary nebula.

Chemical abundances in symbiotic stars were determined in HM Sge by de Freitas Pacheco et al. (1989: ApJ 337, 520) who find helium and nitrogen to be overabundant compared to solar values. A general survey of C/N and O/N abundance ratios in symbiotic stars by Nussbaumer et al. (1988: A&A 198, 179) reveals that symbiotic systems best fit the CNO abundance ratios of normal red giants. Orbital periods have been determined for V1016 Cyg (Nussbaumer and Schmid 1988: A&A 192, L10; and Munari (1988: A&A 200, L13) and for TX CVn (Kenyon and Garcia 1989: AJ 97, 194).

Two new symbiotic stars have been discovered in the LMC: S147 (Morgan and Allen 1988: MNRAS 234, 1005) and a carbonsymbiotic (Cowley and Hartwick 1989: PASP 101, 917). These discoveries are important to assess the energetics of symbiotic systems. Another (galactic) carbon star, HD59643 has been reported by Johnson et al. (1988: A&A 204, 409) to contain a hot (likely white dwarf) companion.

Luud and Tuvikene (Astrofisika 1987, 27, 457) found that nearly 40% symbiotic stars in the Allen's catalogue show an infrared excess in the IRAS range indicating that dust emission is a more spread phenomenon in these stars than was believed before. IRAS survey data reported by Kenyon et al. (1988, AJ 95, 1817) show a much larger 25 micron excess for the cool components of S-type symbiotic stars than for single red giants suggesting a larger mass loss rate for the former, while the near-IR extinctions of the D-types indicate that their Mira components are enshrouded in optically thick dust shells. Further studies in the IR have been carried out by Kenyon (1988 AJ 96, 337) who studied the CO absorption-band strength as a classification criterion for the cool components of symbiotic stars. New infrared photometry was presented for the symbiotic nova HM Sge by Munari and Whitelock (1989: MNRAS 237, 45p). Infrared photometry and optical spectroscopy of BI Cru by Rossi et al. (1988: A&A 206, 279) are interpreted in terms of a Mira-type spectrum and thermal emission from a dust envelope.

High resolution infrared spectroscopy (1-2.5 micron) has been reported by Bensammar (1989, 22nd ESLAB Symp. p. 339) for T CrB, RW Hya, CI Cyg and PU Vul and by Hinkle et al. (1989: AJ 98,

1820) for R Aqr. Radio observations of five symbiotic stars at 6 cm by Torbett and Campbell (1989: ApJ 340, L73) indicate a large variability for CI Cyg.

Identification of the emission bands at 6830 and 7088 A has been proposed by Schmid (1989: A&A 211, L31) as due to Raman scattering of the OVI doublet 1032-1038A by neutral hydrogen. Spectrophotometry of ten emission line objects by Acker et al. (1988: A&AS 73, 325) shows that seven of them, previously classified as planetary nebulae, are symbiotic stars. Optical spectroscopy was carried out by Wallerstein (1988: A&A 197, 161) for V1016 Cyg during 1983-1985 and by Tamura (1989: PASP 101, 250) for HBV 475.

AG Peg has been studied in H-alpha through image sharpening techniques by Fuensalida et al. (1988: A&A 191, L13) who find evidence for two lobes resolved at 5 and 4 arcsec and another unresolved emission at less than 1.7 arcsec. Hollis et al. (1988: ApJ 337, 795) studied the spatially resolved structure of the nebula around R Aqr in H-alpha, H-beta and in the 6 cm radio continuum and concluded that the observations are accounted for by bremsstrahlung from hot optically thin gas. In the absence of a photoionizing source, it is suggested that shockwave heating is responsible for the emission. Further results on the R Aqr are given by Michalitsianos et al.(1988: AJ 95, 1478) and Hinkle et al. (1989: AJ 98, 1820). Another outstanding, although not well understood representative of the class, CH Cyg, has been the subject of several investigations (e.g. Taranova and Yudin 1988: Astr. Space Sci. 146, 33). A detailed discussion of the IUE observations of CH Cyg during 1979-1986 was given by Mikolajewska et al. (1988: A&A 198, 150) while the results of optical spectroscopy were presented by Hack et al. (1988, A&AS 72, 391).

The Spectra of White Dwarfs (by D. Koester)

During the period covered by this report two major conferences were to a large part or entirely devoted to white dwarfs: "The Second Conference on Faint Blue Stars" (IAU Coll. 95, eds. A.G.D.Davis Philip, D.S.Hayes, and J.Liebert), and "White Dwarfs" (IAU Coll. 114, ed. G.Wegner). Both proceedings contain numerous review papers on topics such as metals in white dwarfs, traces of H in DB, the relation between and evolution of different spectral types. Due to severe space limitations only a very brief (and probably biased) account of the most important developments can be given below; the reader is referred to these two publications for more details.

The second edition of the Catalog of Spectroscopically Identified White Dwarfs (McCook and Sion, Ap.J.Suppl.65, 603,1987) contains entries for 1279 white dwarfs, as compared with less than 500 in the first edition 10 years earlier. Most of this increase was a result of the extremely successful Palomar-Green survey of faint blue objects. This success has motivated a number of similar surveys, which are currently in progress or in the stage of follow- up spectroscopy and photometry, and which have added large numbers of white dwarfs as well as individually interesting objects. Among these surveys are the Kiso survey (see Wegner et al., IAU95, 501), the Case low-dispersion northern sky survey (Pesch and Sanduleak, IAU95, 505), the Montreal-Cambridge survey of southern subluminous blue stars (Demers et al., IAU95, 497), the Edinburgh-Cape blue object survey (Stobie et al., IAU95, 493), and the Hamburg Quasar survey. It is highly likely that the number of objects in the next edition of the McCook-Sion Catalog will pass the 2000 mark. More detailed spectral information can be found in the "Atlas of Optical Spectra of DZ White Dwarfs and Related Objects" (Sion et al., Ap.J.Suppl. 72, 707), and in the spectrophotometric atlas of 775 low resolution IUE spectra of white dwarfs, currently being prepared by Swanson and Wegner (IAU114, 149).

Far UV and EUV observations. The report period was marked by an enormous increase of white dwarf observations at wavelengths below the IUE range. A few observations were obtained with VOYAGER, leading e.g. to improved temperature estimates for DO stars (Poulin et al., IAU114, 144). By far the largest impact came, however, from observations with EXOSAT. Among the few objects, for which spectra could be obtained, were 3 white dwarfs (HZ43, Sirius B, Feige 24). From the non-visibility of the HeII absorption edge at 228 Å Paerels and Heise (IAU114, 198) derive an upper limit on the He/H number ratio of 10^{-5}. The spectrum of Feige 24 seems to defy any explanation in terms of homogeneous hydrogen/ helium mixtures, but might be explained with the presence of small traces of a number of heavy elements (Vennes et al., Ap.J. 336, L25).

Far more objects have been observed with the broad band filters of EXOSAT (34 white dwarfs, 21 DA). The analysis of the DA observations confirmed and extended to a larger sample the previous result from EINSTEIN observations (Petre et al., Ap.J. 304, 356) that many of these objects must have absorbing elements other than hydrogen in their photospheres (Jordan et al., Astr.Ap. 185, 253; Paerels and Heise, Ap.J. 339, 1000). The most natural assumption for this absorber is helium, although contributions from heavier elements cannot be ruled out at present.

These observations are very puzzling, because selective radiative forces on helium fail by at least two orders of magnitude to support helium against gravitational separation (Vennes et al., Ap.J. 331, 876) and convection zones that could lead to mixing are not expected at these high temperatures. These theoretical problems provoked the search for an alternative explanation, assuming that gravitational settling has indeed led to an equilibrium distribution with a smooth transition from pure hydrogen on top to helium in deeper layers. In order to "see" the effects of helium (at least in the EUV, where the hydrogen opacity is very low) one has to demand extremely thin hydrogen layers and a total hydrogen mass of the order 10^{-15} $M_{\odot}$, much smaller than predicted by standard stellar evolution theory (10^{-4}). Stellar atmosphere and synthetic spectra calculations, using the abundance profile as obtained from the equilibrium solution of the diffusion equations, can indeed explain the EXOSAT photometric observations (Koester, Ap.J. 342, 999; Vennes et al., IAU114, 368).

Optical spectroscopy. The new generation of detectors, with the possibility to obtain high resolution, high signal to noise spectra of faint objects continued to have strong impact on white dwarf studies. Shipman et al. (Ap.J. 315, 235) found several more DB with traces of hydrogen (DBA), and estimated that this class might contain 20% of the helium rich objects. Sion et al. (Ap.J. 330, L55) found Ca in 2 DBA and 2 DB. The resolved core of H alpha was used to determine very accurate gravitational redshifts for DA in wide binaries or common proper motion pairs (Wegner, IAU114, 401). Even the apparently simple DA white dwarfs can bring surprises: from a large sample of high S/N spectra in conjunction with new model atmospheres using the Hummer-Mihalas occupation probability formalism Bergeron et al. (Ap.J. 351,L21) found an apparent jump to higher than average surface gravity below the lower limit of the ZZ Ceti instability strip (11500 K). Assuming that the masses are the same as for the hotter DA they interpret this result as a contamination by helium (up to a ratio He/H = 20), which cannot be seen directly in the spectra.

The puzzle of L870-2, long known for a discrepant surface gravity, was finally solved with the discovery that is actually a binary of two close but detached DA (Saffer et al., Ap.J. 334, 947). New detections were made in all classes of variable white dwarfs ZZ Ceti, DBV, PG1159), as well of new magnetic white dwarfs, but the limited space does not allow a more detailed discussion.

B and Be Stars (by D. Baade)
Observers often seem to have a preference for objects which in one way or the other appear unusual. However, certainly for the B-type stars, the routine usage of modern observing techniques more and more necessitates a revision of the concept of 'normal' stars. – For a more complete overview of current research in B-type stars, this summary should be read in conjunction with other Commissions' reports on stellar variability, close binaries, and stellar atmospheres. There are also a fair number of various reviews. However, in favour of original results, they are here assigned rather little weight. References to conference proceedings, etc. are by *Astronomy and Astrophysics Abstracts* numbers, where available. Papers which mention other recent work by their author(s) on closely related subjects are marked "_+".

High-luminosity stars. From low-resolution IUE spectra of OB supergiants in the SMC, Prinja (*MNRAS* **228**, 173) confirms that terminal velocities are up to 50% lower than in the Galaxy as predicted by stellar wind theory; however, there is no significant difference in mass loss rates. From the analysis of two B supergiants in the LMC, Kudritzki et al. (45.114.011) conclude that strong mass loss leads to CN-burned material appearing at the stellar surface.

Because of their migratory behaviour, luminous blue variables (LBV's) often appear only temporarily among the B-type stars. But they permit concepts which were developed for more normal stars to be tested under extreme conditions. E.g., Leitherer et al. (*ApJ* **346**, 919) find that after a strong decrease in stellar effective temperature, the wind adjusts to this in that the ionization of iron group elements drops from the second to the first stage so that the effective line absorption increases and with it the mass loss rate. The detection even of CO emission by McGregor, Hyland & Hillier (*ApJ* **324**, 1071; see also McGregor, Hyland & McGinn *AA* **223**, 237) underlines the large diversity of physical conditions in the extended atmospheres and circumstellar environments. An intriguing direct observation of the latter is the coronographic discovery by Nota & Paresce (*ApJ (Letters)* **341**, L83) of an apparent double-helix winding out of AG Car. Complex structures around SN1987A (Wampler et al., *ApJ (Letters)*, 1990 Oct. 10) seem to trace the mass loss of the precursor during its blue and red supergiant periods and are not unlike some planetary nebulae which, too, have a two-stage mass loss history. A first IAU Coll. (No. 113) was devoted to LBV's; the proceedings (eds. Davidson, Moffat & Lamers) also cover the less elusive B[e] stars, i.e. supergiants that share many of the properties of LBV's during qiescence but are much less variable. Work by Winkler & Wolf (*AA* **219**, 151) supports an earlier suggestion by Zickgraf et al. of a two-component structure of B[e] star winds with a dense, slowly expanding equatorial disk and a more normal OB-star wind at higher latitudes.

Envelopes of Be stars. A polar-equatorial dichotomy is widely accepted for the mass loss of non-supergiant emission-line B stars. The statistical evidence from the available UV observations now also includes the cooler half of the B sequence (Grady et al. *ApJ* **339**, 403). Theoretical predictions of reduced terminal wind velocities in very rapid rotators could observationally only marginally be confirmed by Friend (*AJ* **353**, 617). The recognition of two-component Hα profiles by Hanuschik, Kozok, & Kaiser (*AA* **189**, 147_+) may be related to the results of Taylor et al. (*AA* **231**, 453_+) who succeeded in detecting radio emission from 6 Be stars. A steepening of the excess flux between far-IR and radio wavelengths suggests a structural change of the disk, albeit with considerable individual variations, which implies radial outflow also in the disk. That some radial support of at least the optical line emitting regions is provided also by fast rotation was again concluded from the correlation between stellar $v \sin i$ and the width of emission lines (Hanuschik, Astrophys. Space Sci. **161**, 61_+). The rotation of the disk of γ Cas was spectro-interferometrically visualized by Mourad et al. (*Nature* **342**, 520). Using another novel technique, lunar occultation spectroscopy, Gies et al. (preprint, *AJ*) find the light center of the Hα line emitting region to be displaced from the position of the central star. The inferred non-axisymmetric morphology is perhaps due to a companion which might furthermore tidally trigger the recurrent shell episodes. Such long-term variations over a decade or more were studied in a number of other stars (e.g., Koubský et al. *BAI Czech.* **40**, 31; Doazan et al. *AA* **210**, 249_+; Hubert et al. *AA Suppl.* **70**, 443). Reports about concommittant variations in the photospheric UV flux distribution met some skepticism (Zorec, Höflich & Divan *AA* **210**, 279). Kogure (*Astrophys. Space Sci.* **163**, 7) has developed a geometrical model of disk height variations for the transitions between Be and shell phases. Evidence of increased electron scattering during high-brightness phases led Dachs and Rohe (*AA* **230**, 380) to propose a similar model. Several papers (e.g., Waters et al. *AA* **198**, 200; Waters et al. *AA* **220**, L1; Mi & Shen *Chin. AA* **13**, 300) discuss the diagnostics of the variable X-ray flux from Be stars with a compact companion which accretes mass at varying rates as it moves through the extended atmosphere of the Be star.

Rapid variability. The occurrence of mass loss outbursts in Be stars is now well documented (e.g., Baade et al. *AA* **198**, 211). But it is still unknown whether large outbursts merely are a combination of many minor ones. During small events, the Hα emission strength increases within 2 days or less;

the subsequent decay lasts several times as long. In Hα as well as UV resonance lines (Grady et al. *ApJ Suppl.* **65**, 673; Sonneborn et al. *ApJ* **325**, 784), phases of enhanced mass loss were observed to repeat at intervals of weeks to months. The detection of outbursts partly refuelled speculations about a connection between mass loss and photospheric short-term variability. In contrast, in λ Eri the evidence upon which the first suggestion of such a correlation had been based was found not to be sustained by observations extending over a longer time (Bolton & Štefl, preprint, *ESA SP-310*). Detailed monitoring showed this star's short-term behaviour to be an erratic superposition of similar sequences of events which were proposed to be connected to plasma parcels riding on transient magnetic surface structures (M.A. Smith *ApJ Suppl.* **71**, 357). A rather unique case is at present HD 58978 (a binary?) which displayed indications of recurrent shell infall events (Grady et al. 46.112.189; Peters *ApJ (Letters)* **331**, L33).

Photospheric variability is very widespread among B-type stars; only a spectroscopic survey of late-B, non-supergiant stars furnished no positive detection (Baade *AA* **222**, 204_+). No general consensus has been reached for the explanation of the variability. Spectroscopists tend to prefer nonradial pulsation (e.g., Yang, Ninkov & Walker *PASP* **100**, 233; Baade *Inf. Bull. Var. Stars* No. 3124; Kambe, Ando & Hirata, preprint, *PAS Japan*; see also Hill et al. *PASP* **101** 258) although interpretations in terms of co-rotating surface features have been put forward (Harmanec *BAI Czech.* **40**, 201). In photometry, where periods are the dominating observational result, their broad overlap with and even proportionality to (Balona *MNRAS* **245**, 92) estimated rotation periods has been a much stronger driver for adopting the starspot hypothesis. The basis for this interpretation was widened by the detection of short-periodic double-wave variability also in the broad-band polarization of several Be stars; an oblique magnetic rotator model similar to helium-strong stars has been proposed (Clarke *AA* **232**, 411_+; Minikulov & Tarasov *Bull. Crimean Astrophys. Obs.* **79**, 88). Because of the severe bias of the discussion towards Be stars, a stronger synopsis of the photospheric variability over the whole OB stars domain is desirable.

Furenlid et al. (*ApJ* **319**, 264) presented very detailed simultaneous optical spectroscopy and photometry of the extreme β Cephei star BW Vul. They caution that any signature of properties of the stellar core will be strongly masked by radiation transfer effects. A phase-dependent atmosphere analysis of another β Cephei star, σ Sco, by vander Linden & Butler (*AA* **189**, 137) yielded amplitudes of effective temperature and gravity which agree well with radial pulsation. Crowe & Gillet (*AA* **211**, 365) conclude from their high-quality spectra that such high-amplitude pulsators can be understood in terms of a double compression (shock) wave whereas low-amplitude stars display only one shock per pulsation cycle.

Magnetic fields and abundances. Wollaert, Lamers & de Jager (*AA* **194**, 197) proposed that, in the absence of peculiar initial abundances, OBN stars may owe their pecularities to evolution whereas the OBC stars could rather have discrepant atmospheric structures. From NLTE fits of OBN- and normal B-star line profiles, Schönberner et al. (*AA* **197**, 209) diagnosed not only the usual CNO abundance pattern but also a significant helium overabundance in the OBN sample. One possible explanation is that during early evolutionary stages rapid rotation strongly enhanced internal mixing. A new search for a Galactic abundance gradient from the analysis (Fitzsimmons et al. *AA* **232**, 437) of 20 B-type stars in 4 open clusters was completed; the result was again negative. In two non-supergiant B-type members of Magellanic Cloud globular clusters, Reitermann et al. (*AA* **234**, 109) observed apart from traces of CNO burning other metall abundances which lie roughly a factor of 3 below those of field stars in the Clouds.

Among the helium-weak stars, Shore, Brown & Sonneborn (*AJ* **94**, 737) discovered three sn stars to have magnetically controlled mass outflows which in two stars take on the form of jets above the magnetic poles whereas two others have a corotating magnetosphere (Shore et al. *ApJ* **348**, 242) which normally is typical of helium-strong stars.

Miscellaneous. Becker & Butler presented grids of non-LTE equivalent widths of CII, NII, OII, and SiII, III and IV (*AA.* **235**, *326*_+) lines in B stars. A new absolute luminosity calibration of Hγ equivalent widths was given by Klochkova & Panchuk (*Pisma Astron. Zh.* **16**, 435).

The discussion about the existence and origin of faint Pop. I early-type stars at high Galactic latitude continues. Waelkens et al. (*AA* **181**, L5_+) suggest to delete two of the candidate stars from the list because they are post-AGB stars whereas Conlon et al. (*AA* **224**, 65; see also Conlon et al. *AA* **236**, 357) add a new one. Waelkens & Rufener (*AA* **201**, L5; see also Kilkenny & van Wyk *MNRAS* **244**, 727) introduced a new line of reasoning with their discovery in another such object, PHL 346, of light variations which are indistinguishable from the ones of β Cephei stars. A β Cephei star of normal age and at this location could not have formed in the Galactic plane.

As yet unexplained quasi-emission features have been detected (Porri & Stalio *AA Suppl.* **75**, 371; Baade *AA* **222**, 204_+) near the center of rotationally broadened absorption lines of several B and Be stars. 'Simple' explanations such as line emission, binarity, etc. seem excluded. Rotationally induced equator-to-pole variations of atmospheric parameters would have to be rather large.

Spectroscopy of Horizontal Branch Stars (by B. Carney)

a) Definitions

Horizontal branch stars are core-helium burning stars, with the dispersion across the "horizontal" branch in a cluster's color-magnitude diagram caused by differences in the mass of the hydrogen envelope. In old solar metallicity clusters, the envelope is usually large and the stars are confined to a "clump" near the middle of the red giant branch. In more metal-poor globular clusters, the envelope masses may cover a large range, and the horizontal branch stars temperatures/colors range from red (RHB) to stars within the instability strip (RR Lyraes) to blue (BHB). Field counterparts to all these cluster HB stars are known. In some cases, the envelopes are nearly absent and the stellar temperatures are so hot that in optical color-magnitude diagrams, the "horizontal" branch plummets to faint magnitudes at nearly fixed color indices. These are the "extended horizontal branch" stars (EHB). Apparently, their field counterparts are classified as sdB or sdOB (but not sdO) stars (Heber, A&A, 155, 33, 1986).

b) Radial Velocities

i) Galactic Structure

Because HB stars are giants, they may be recognized to quite large distances, and because most of them (excluding the EHB stars) share a common luminosity, their distances may be determined to good precision. They are thus excellent probes of Galactic structure. At large Galactocentric distances, they may be used as test particles to probe the Galaxy's mass distribution, but of course they must first be discovered in large numbers at faint magnitudes. Beers, Preston, and Shectman (ApJ Suppl, 67, 461, 1988) have provided such a list, containing 4408 candidate BHB stars, based on objective prism techniques. One fascinating early result is the discovery of apparent clustering within this sample (Doinidis & Beers, ApJ, 340, L57, 1989), suggesting the existence of loose groups of stars in the Galactic halo. This supports the previous claim of Sommer-Larsen and Christensen (MNRAS, 225, 499, 1987), who found an apparent group of five BHB stars, based on common distances and velocities. Sommer-Larsen and Christensen (MNRAS, 239, 441, 1989) have conducted a larger radial velocity study of BHB field stars selected from the Gilmore and Reid Schmidt-based photometric survey. The 185 such stars studied to date show little net rotation as a system, typical of the halo. The data were also used to further test dynamical models of the halo.

Probing toward the central regions of the Galaxy is also possible, of course, although RR Lyraes are more commonly used. Gratton (MNRAS, 224, 175, 1987) obtained radial velocities for 17 such stars in Baade's Window, finding a line of sight dispersion of 133 ± 25 km/sec. Several groups are continuing this work, including the stars in the Plaut fields.

ii) Baade-Wesselink Analyses

In the last few years, major efforts by at least five groups have been made to apply the Baade-Wesselink method to RR Lyraes, with apparently good success. A critical component in such work is high-precision radial velocities. Cacciari and her colleagues (A&A, 209, 141 and 154, 1989) have used the CORAVEL "speedometer" to obtain such data for six field variables. Cohen & Gordon (ApJ, 318, 215, 1987) obtained coude spectra for 4 variables in the globular cluster M5 to obtain velocity curves, and are continuing their work in M92. Carney and his collaborators (ApJ, 278, 241, 1984; ApJ, 312, 254, 1987; ApJ, 314, 604, 1987; ApJ, 326, 312, 1988; ApJ, 332, 206, 1988) have obtained complete velocity curves for 7 field variables (with one more yet unpublished), and have continued work on two variables in M5, two in M92, and the one RR Lyrae in 47 Tuc. Liu & Janes have obtained similar data for 13 field stars (ApJ Suppl, 69, 593, 1989) and four variables in M4 (ApJ, in press). They are continuing their work on variables in M15. A somewhat lower precision but nonetheless valuable set of radial velocity data for field RR Lyraes has also been obtained at McDonald Observatory (Barnes et al., ApJ Suppl, 67, 403, 1988; Wilson et al., ApJ Suppl, 69, 951, 1989).

c) Chemistry

Chemical abundances of HB stars bear on a wide variety of astrophysical problems, from Galactic structure to Galactic chemical evolution to stellar evolution. The temperature scale is always important for such work, and we note the recent comparison of spectrophotometric scans with model atmospheres by Hayes & Philip (Publ. ASP, 100, 801, 1988) to establish such a scale.

i) Galactic Structure

The metallicity gradient of the halo population continues to receive much attention, and the ΔS and related Ca II K line metallicity indicators have been used to estimate globular cluster metallicities by Rodgers & Harding [Publ. ASP, 99, 961, 1987 (NGC 1851); Publ. ASP, 101, 40, 1989 (NGC 3201)], and by Costar and Smith (AJ, 96, 1925, 1988), who reported results for 7 clusters and summarize all the available cluster results. An improved phase correction for ΔS measures was published by Smith (Publ. ASP, 98, 1317, 1987). Zajkova and Romanov (Per. Zv., 22, 905, 1988) have recommended a change in the relation between ΔS and [Fe/H]. No sign of a halo metallicity gradient is discernible in the cluster data. New results for 28 field stars have been published by Smith (Publ. ASP, 102, 124, 1990) and Mendes de Oliviera and Smith (Publ. ASP, 102, 652, 1990). Meanwhile, the Lick survey of RR Lyraes has continued, with a detailed analysis (Suntzeff, Kraft, and Kinman) submitted for publication. No metallicity gradient in the halo is seen beyond the solar circle, but one is present within the inner halo.

ii) Mixing

Extensive spectroscopic studies of red giants in the field and within clusters has revealed abundance peculiarities expected for mixing of CN-cycling processed material to the stellar surfaces. Some clusters' asymptotic giant branch stars (which are post-HB) show other unusual spectra, suggesting the HB itself may be a site of some mixing processes. Recent work now suggests this is not the case. Smith & Penny (AJ, 97, 1397, 1989) obtained spectra for RHB stars in M71, finding the same percentage of CN-strong stars as had been found on the red giant branch. Briley et al. (ApJ, 359, 307, 1990), observing AGB rather than HB stars in NGC 6397, have shown that the AGB stars are similar to the red giants in the cluster, showing there is no need to invoke mixing during the HB stage.

iii) Diffusion

One of our great frustrations has been the inability to determine primordial helium abundances in the metal-poor EHB and BHB stars. The diffusion processes that have distorted the atmospheric compositions of such stars are, nonetheless, of interest in their own right. Crocker and Rood (IAU Sym. No. 126, p. 509, 1988) reported strong helium lines in low-resolution spectra of two stars in NGC 6752 and three stars in M92. Working at higher resolutions, however, Heber et al. (A&A, 162, 171, 1986) and Glaspey et al. (ApJ, 339, 926, 1989) found large helium deficiencies in the spectra of the NGC 6752 BHB stars they studied. The latter group utilized especially high resolution and found overabundances of a factor of 50 in iron in the hotter (T = 16,000 K) star. Lamontagne et al. have used the IUE satellite to obtain high dispersion ultraviolet spectra of two field relatively cool sdB stars, finding the carbon deficiency, normal nitrogen abundances, and silicon deficiencies seen in hotter stars. They also review the state of chemical abundances in such stars.

d) Stellar Evolution

Model stellar evolution calculations of the zero-age HB (ZAHB) and HB evolution require comparisons with observations. Problems certainly still exist, especially in the identification of the physical parameters responsible for the dispersion in envelope masses inferred for many globular clusters and the "second parameter problem" (an unexpected distribution of HB stars toward the cooler or hotter domains for a cluster's mean iron-peak metallicity). A similar problem is the "Sandage period shift" (see Sandage, ApJ, 350, 631, 1990). Spectroscopy is the ideal tool to test the obvious parameters (rotation, CNO abundances, helium abundances, magnetic fields). Few new results are available, although Khochkova & Panchuk (Astr. Zh., Tom 64, 74, 1987—see also Soviet Astr, 31, No. 1, 37, 1987) reported rotational velocities for several field BHB stars consistent in the mean with the field star results of Peterson et al. (ApJ, 265, 972, 1983) and her cluster results (see ApJ, 294, L35, 1985 and references therein). Khochkova and Panchuk also determined mean iron-peak chemical abundances for 7 field BHB stars, while Adelman and Hill (MNRAS, 226, 581, 1987) did so for 3 field BHB stars. Cluster work is needed, however, and Crocker et al. (ApJ, 332, 236, 1988) have determined log T and log g from spectra for BHB stars in M3, M5, M15, M92, and NGC 288. Detailed comparisons with ZAHB and HB theory show good agreement for M5, but not for the blue extensions in M3 and NGC 288. Rotation or helium enhancements may have to be invoked. A happy consequence of their work is the new ability to derive precise reddenings for globular clusters, as was done by Crocker (AJ, 96, 1649, 1988) for M22.

e) Pulsation Theory

Aside from the "Sandage period shift", which is being tested via Baade-Wesselink studies, a number of interesting other problems remain in pulsation theory as applied to RR Lyrae variables. Why does the Blazhko effect (a long-period modulation of the fundamental mode period and amplitude) exist? Romanov et al. (Pis. Astr. Zh., Tom 17, 69, 1987– see also Soviet Astr. Lett., 13, 1987) have made observations of the magnetic field of RR Lyrae (which shows the effect) and have suggested the field may play a major role. With the many high-precision radial velocity curves available for field RR Lyraes, one sees the same structures as in the light curves, especially the "bumps" (just before minimum radius). These "bumps" have been thought to be caused by either an "echo" from the previous cycle's compression wave being reflected back to the surface from the stellar core or from a collision of free-falling higher atmospheric layers onto the more slowly falling lower layers. Recent spectroscopic work on H_α line profiles by Gillet and Crowe (A&A, 199, 242, 1988) suggest the latter explanation is correct.

f) Assessment

Excellent progress has been made from the spectroscopic studies of HB stars in the field and in clusters, especially in tests of diffusion theory, of chemical abundances and radial velocities of such objects throughout the Galaxy, and in the Baade-Wesselink analyses. however. We need, however, more work on rotational velocities of cluster HB stars along the length of the HB to understand why stars are so dispersed. The CNO abundances still require attention, especially resolving the unusual [O/Fe] trend found by Laird et al. (AJ, 91, 570, 1986) for field RR Lyraes that is opposite in sign to that found for field halo dwarfs and giants. Finally, while extensive work has been done on binary companions to field dwarfs and field and cluster red giants, little attention has been paid to companions of HB stars. Radial velocity monitoring of such stars is recommended.

F, G, and K stars (by M.Spite)

Such stars form an extremely diverse class of objects. Many of them have chromospheres, coronae, and are loosing mass. Some are very young but some of them are as old as the Galaxy, and as a consequence this type of star is commonly used to study the chemical evolution of our Galaxy.

Several reviews of stellar abundance trends have appeared during the report period: one by Gustafsson (1987, in "Stellar evolution and dynamics of the outer Halo" ESO workshop proc.), another by Lambert(1989, in "Cosmic Abundances of Dark Matter" AIP Conf. proc. 183), and most recently a very complete review of the abundance ratios as a function of metallicity has been made by Wheeler, Sneden and Truran in Annu. Rev. of A&A 27 (1989).

A monograph "F G K stars and T Tau stars" has been completed by Cram and Kuhi (Monograph series on non thermal phenomena in stellar atmospheres NASA-SP CNRS,1989): D. Gray reviews the non thermal broadening of spectral lines due to hydrodynamic and magnetic phenomena in the photospheres. Reimers describes the outer atmospheric layers of the stars. Cram provides a summary of the theory of the structure of stellar atmospheres and of the phenomena which occur inside the star and control the dynamical behaviour of the atmosphere (rotation, pulsation...) and Zwan and Cram review current ideas regarding the role played by magnetic fields in cool stars.

Let us note also the review-paper of Gilmore, Wyse and Kuijken (1989 Annu. Rev. of A&A 27) who try to deduce physics involved in galaxy formation from observations of old stars.

Chromospheres, coronae and winds: Katsova *et al.* (Astron. Zh 64, 1243) from the X ray emission of 45 G-M stars have shown that the density in stellar coronae increases from G to M. The kinematics of hot regions around cool stars could be studied in a few bright stars from line profiles (mainly CaII H line or CaII infra red triplet) or displacements of ultraviolet lines of highly ionized atoms. Pasquini *et al.* (A&A 191, 253 and A&A 213, 261) found high chromospheric activity for several F G giants but a lack of activity in most late type giants. Strassmeier *et al.* (ApJS 72, 191) have correlated the chromospheric activity in single and binary stars with effective surface temperature and rotation. Let us note also the atlas of high resolution CaII profiles from Rebolo *et al.* (A&AS 80, 135). On the other hand, occurrence of gas dynamic flows in F G stars has been clearly found by Ayres *et al.* (ApJS 66, 51).

Stellar granulation: The effect of the fine structure of a stellar atmosphere on spectral line profiles is presented by Dravins (A&A 228, 218) in different F G K stars using a four component model to reproduce the asymmetries of the lines.

Interiors of late-type stars: Several attempts have been made to confirm the detection of solar-like oscillations in stars: search for Doppler shift variations and search for variations in the ratio of the core to the continuum. Both α Cen and β Hyi have been surveyed and no convincing evidence for oscillations has been found (Frandsen, A&A 181, 289 and Brown and Gilliland ApJ 350, 839).

Gilroy (ApJ 347, 835) in open cluster stars, and Smith and Suntzeff (AJ 97, 1699) and Brown and Wallerstein (AJ 98, 1643), in globular cluster stars, showed that the ratio $^{12}C/^{13}C$ is lower than that predicted by the standard evolutionary models. Comparing the oxygen isotopic ratios in K giants and in stars of more advanced evolutionary phase Harris *et al.* (ApJ 325, 768) confirm that extra-mixing of CNO cycled material into the stars' envelopes occurs as a result of the helium core flash.

The abundance of Lithium in our Galaxy: Lithium is one of the few elements synthesized during the Big-Bang. It is destroyed at high temperature in the deep layers of the stars and it is diluted in the atmosphere of the giant stars. Therefore the abundance of lithium is used to check first the models of stellar interiors and second the models of primordial nucleosynthesis. Numerous papers concerning these problems have appeared recently. What follows is only a personal selection of the many results. Pavlenko (Kinematics Phys. Celest. Bodies 5, 55) has shown that, in the computation of lithium abundance, even in giant stars, the NLTE effect is negligible when the lithium line is saturated.

Many studies have been directed at determining the character and intensity of the "lithium gap" as a function of cluster age. The abundance of lithium has been measured in several open clusters by Boesgaard and collaborators (*e.g.* ApJ 332, 410) and Pilachowski *et al.* (*e.g.* PASP 99, 1288 or ApJ 334, 734 see also Twarog, AJ 97, 759) to determine the intensity of the "lithium gap" (Boesgaard and Tripicco, ApJ 302, L49) as a function of the age of the cluster. Soderblom *et al.* (AJ 99, 595) have discussed the decline of lithium in clusters and find that lithium depletion for solar type stars starts on the ZAMS and not before. Their data also indicate that the correlation between Li depletion and rotation, if it exists, is weak. Moreover Balachandran (ApJ 354, 310) in 200 main sequence stars finds that there is no correlation between lithium abundance and the present projected rotational velocity, ruling out meridional circulation as the cause of Li depletion. On the other hand Gilroy (ApJ 347, 835) and Brown *et al.* (ApJS 71, 293) have shown that there is less lithium in the giant stars than is predicted by the dilution theory. A lithium abundance $\log N_{Li} = 2.07$ has been measured by Hobbs and Pilachowski in one more extreme halo star (BD $+ 3°740$) in agreement with previous results.

Cayrel and Cayrel de Strobel (Lect. Notes in Phys. 366) have attempted to measure the $^{6}Li/^{7}Li$ ratio in 14 field dwarfs. No ^{6}Li has been found in any of them. Neither ^{6}Li nor ^{9}Be nor Boron could be detected in the galactic halo stars (Pilachowski *et al.* ApJ 345, L39, Rebolo *et al.* A&A 193, 193, Ryan *et al.* ApJ 348, L57, Molaro A&A 183, 241). A large Li content has been found in a young K dwarf by Cayrel de Strobel and Cayrel (A&A 218, L9) and in a K giant by Gratton and D'Antona (A&A 215, 66).

Chemical evolution of our Galaxy: Luck and Bond (ApJS, 71, 559) have measured have measured the chemical composition of a large sample of distant F G supergiants which should provide the basis for a determination of the abundance gradient in the galactic disk. Rich (AJ 95, 828) has determined metallicities for late type giants in Baade's window, near the Galactic center, discovering some very strong lined stars and Taylor and Johnson (ApJ 322, 930) further demonstrate that the "very strong lined" G and K stars (generally called SMR) exist really and that no satisfactory explanation other than supermetallicity is known at the moment.

Boyarchuk *et al.* (Astrofizika 28, 335 and 342) and Korortin and Komarov (Astron. Zh. 66, 866) have shown that the influence of the non-LTE effect is not sufficient to explain the sodium abundance anomalies in giant and supergiant stars.

The chemical composition of several disk stars has been measured *e.g.* : Perrin *et al.* (A&A 191, 121), Abbia *et al.* (A&A 206, 100), Cayrel de Strobel and Bentolila (A&A 211,324), Klochkova and Panchuk (Astrofiz. Issled. Izv. Spets. Obs. 26, 14). The chemical composition of more halo stars has been analyzed by Hartman and Gehren (A&A 199, 269), Gratton and Sneden (A&A 204, 193), Magain (A&A 208, 171), Molaro and Castelli (A&A 228, 426).

An important feature for the models of the chemical evolution of our Galaxy is the overabundance of oxygen found in the oldest stars. This overabundance (relative to iron) is found to be about +0.5 dex by Barbuy *et al.* (A&A 191, 121 et A&A 214, 239) or Peterson *et al.* (ApJ 350, 173) who used the forbidden oxygen lines but as high as +1.2dex by Abia and Rebolo (ApJ 347, 186) who used the permitted lines; non-LTE effects could perhaps explain this difference.

The origin of the neutron capture elements in PopII stars has been carefully studied by Gilroy *et al.* (ApJ 327, 298) who show that the *r* process is dominant at the early stage of the Galaxy. The variation of the abundance of thorium (a radioactive element) as a function of age has been measured by Butcher (Nature 328, 127) in an attempt to measure the age of the Galaxy. This is also discussed in detail by Malaney and Fowler (MNRAS 237, 67).

Iron and carbon abundance of bright open clusters have been determined by Boesgaard and Friel (ApJ 336, 798, ApJ 351, 467 and 480). Abundance of stars in globular clusters has been discussed by several authors: *e.g.* Campbell and Smith (ApJ 323, L69), Suntzeff *et al.* (AJ 95, 91), Francois *et al.* (A&A 191, 267), Pilachowski (ApJ 326, L57), Caldwell and Dickens (MNRAS 233, 367 and 234, 87), Paltoglou and Norris (ApJ 336, 185) and Smith *et al.* (ApJ 341, 190) in order to understand the abundance anomalies.

Abundance of stars in the nearby galaxies: The abundance of the elements in the field stars is about −0.6 dex in the SMC and −0.3 dex in the LMC (Russell and Bessell ApJS 70, 865, and Spite *et al.* A&A 210, 25 and 222, 35). In particular the ratio C/Fe is the same in the Magellanic Clouds and in the Galaxy, whereas in the HII regions the carbon abundance seems to be low by about 0.6 dex. From Richtler *et al.* (A&A 225, 351) the abundances in NGC1818, a young globular cluster of the LMC, would be significantly lower than in the LMC field stars.

Late-Type Stars by H.R. Johnson

This is a sketch, with a few representative references, of some of the main trends in research during the past three years. Perhaps the best way for members to keep track of current progress is to read the proceedings of the several meetings sponsored or cosponsored by IAU Commission 29, as listed at the beginning.

Properties of Stars. Progress continues in deducing the properties of late-type stars of all spectral types (Keenan and McNeil, ApJ Supp 71, 245). Angular diameters have been measured for a large number of objects by lunar occultation (White and Feierman AJ 94, 751) and interferometry (Di Benedetto and Rabbia AA 188, 114; Hutter et al. ApJ 340, 1103). Values of effective temperatures obtained by several methods have accuraces close to 1% (Bell and Gustafsson MNRAS 236, 653; Blackwell et al. AA 232, 396).

Line Identification and Chemical Composition. A useful catalogue of spectral lines in the visible (580-680 nm) for several SC stars has been completed (Wallerstein ApJ Supp 71, 341). Reliable abundances are becoming available for an increasing number of late-type stars, especially giants, where the chemical composition provides significant information on evolution. A study of CNO abundances in M, MS, and S giants shows that, like G and K giants, these stars have experienced the first dredge up. The MS and S stars evidence further an enrichment of s-process elements and nitrogen as expected from the third dredge up in thermally pulsing AGB stars (Smith and Lambert ApJ Supp 72). Carbon and oxygen isotopic ratios in 7 AGB (MS,S, and SC) stars show a spread which suggests a range in evolutionary histories (Dominy & Wallerstein ApJ 318, 810). Oxygen isotopic abundances were obtained for many carbon stars (Harris et al. ApJ 316, 297).

The ratio of C/N in M67 at almost exactly the point (but not the amount) predicted for the first dredge up (Brown ApJ 317, 701.) Tc and Nb abundances were studied in 4 MS and S stars (Wallerstein and Dominy ApJ 330, 937). No evidence of ^{14}C was found in atmospheres of evolved stars (Harris and Lambert ApJ 318, 568). Abundances of s-process elements in S stars with and without Tc have been analyzed (Smith and Lambert ApJ 333, 219) to investigate both AGB evolution and the supposed binarity of Tc-deficient stars.

A comprehensive survey of Li extends to M giants (Brown et al. ApJ Supp 71, 293). The discovery of a high Li content in some of the brightest AGB stars in the SMC, which are metal-poor but s-process enriched -- but not in less luminous stars -- hints strongly that these are former carbon star reconverted to M stars by hot-bottom carbon burning (Smith and Lambert ApJ 345, L75; ApJ 361, L69).

Atmospheric structure. Improved model photospheres form the basis for interpreting spectra. An opacity-sampled treatment of H2O (Alexander et al. ApJ 345, 1014) was employed to compute a new grid of models for K and M giants (Brown et al. ApJ Supp 71, 623). For a static model of a mira variable star, synthetic colors show reasonable agreement with both photometric (Bessell et al. AA Supp 77, 1) and spectroscopic (Brett AA 231, 440) observations. A shock traveled through the photosphere to simulate variation with phase (Bessell et al. AA 213, 109). Model atmospheres for carbon stars incorporating polyatomic molecular opacities either as ODF or OS are available; synthetic spectra from carbon-star models have been shown to match violet and ultraviolet spectra (Johnson et al. ApJ 332, 421) and infrared spectra (Jorgensen ApJ 344, 90) of TX Psc. A useful critique is that by Tsuji (Evolution of Peculiar Red Giant Stars, p. 87).

Realistic modeling of convection represents a significant breakthrough (Nordlund and Dravins AA **228**, 155). Calculations with simplified four-component models have been extended to giants as late as Arcturus (Dravins AA **228**, 218), and we eagerly await their extension to M, S, and C stars.

Hydrodynamics of the outer stellar atmosphere/CSE. Acoustic waves generated stocastically by turbulence from the stellar convection zone produce a flux of short-period (SP) acoustic energy which may heat the chromosphere (Ulmschneider AA **222**, 171; Schmitz AA **229**, 177; Gail et al. AA **234**, 359). Because of their heating effect, these SP waves puff up or extend the chromosphere by small factors (1.1-1.3) (Cuntz ApJ **349**, 141). Acoustic waves may drive mass loss (Pijpers and Hearn AA **209**, 198; Pijpers and Habing AA 215, 334). Pulsation-driven periodic shocks greatly extend the atmosphere of mira variable stars and lift the gases to the point where grains may form and contribute to the mass flow (Bowen ApJ **329**, 299).

Chromospheres. Ultraviolet spectra of all types of late red giants are now available (Judge, Evolution of Peculiar Red Giant Stars, p. 303; Johnson and Luttermoser ApJ **314**, 329; Oznovitch and Gibson ApJ **319**, 383; Eaton and Johnson ApJ **325**, 355; Carpenter et al. ApJ Supp **68**, 345). No chromospheric models are yet available for M giants, but a semi-empirical model for the cool carbon star TX Psc has been obtained by fitting the Mg II h line (Luttermoser et al. ApJ **345**, 543). A chromospheric model for Betelgeuse has also been reported (Dupree et al. preprint). Studies of chromospheric evolution are underway (Simon and Drake ApJ **356**, 303; Rutten and Pylyser AA **191**, 227; Pasquini et al. AA **234**, 277). Mechanisms for chromospheric heating are under intense investigation (cf. Narain and Ulmschneider, Space Sci. Rev in press). A "molecular formation layer" of CO may exist outside the chromosphere (Tsuji AA **197**, 185).

Circumstellar matter and winds. A few years ago, the first radio observations of CO, H_2O, SiO, and OH lines produced a forward leap in the study of CS gas and mass loss (cf. Olofsson, Evolution of Peculiar Red Giant Stars, p. 321; Claussen et al. ApJ Supp **65**, 385; Knapp et al. ApJ **336**, 822) by providing evidence of a low-velocity wind and high mass-loss rates, the values and causes of which are subjects of current study (Holzer in Circumstellar Matter; van Veen and Rugers AA **226**, 183). Infrared observations of stars with IRAS have again opened a new spectral region, a region especially important to cool stars. This has led to a spate of papers aiming at a determination of the composition of and the physical conditions in the dust (Van der Veen and Habing AA **194**, 195; Bedign AA **186**, 136; Olofsson, Space Sci. Rev. **47**, 145; Schutte and Tielens ApJ **343**, 369) and dust formation (Hashimoto et al. AA 227, 465; Gail et al. AA in press; Sedlmayr, Stellar Atmospheres: Beyond Classical Models). Considerable attention has been given to carbon stars with silicate shells (cf. Willems and de Jong AA 196, 173; Lloyd Evans (preprint)).

M dwarf stars. Besides their intrinsic interest (Caillault and Patterson AJ **100**, 825), one of the salient features of M dwarf stars is their vigorous chromospheric and coronal activity, and both observational and theoretical research continues. This includes observations of Balmer alpha and x-rays (Doyle AA **218**, 145; Ambruster et al. ApJ Supp **65**, 273); observations of Ly alpha and Mg II (Doyle et al. AA **228**, 443); chromospheric lines (Pettersen AA **209**, 279); microflaring (Andrews AA **220**, 504); high resolution spectra of many dKe and dMe stars (Pettersen and Hawley AA **217**, 181), the connection between coronal activity and rotation (Byrne and McKay **237**, 480), and theories of formation of chromospheric lines (Cram and Giampapa ApJ **323**, 316).

A, Ap, Am and CP Stars (by. K. Sadakane)

Spectroscopic studies of *Chemically Peculiar* stars have shown steady progresses in recent years. Three main fields of research are 1) abundance analyses in visual, near-IR, and UV regions, 2) measurements of magnetic fields and surface mapping, and 3) efforts to detect rapid oscillations by spectroscopic observations. Progresses in these fields depend largely on the high sensitivity of modern detecting devices. Main achievments in these field are summarized in the following.

Two meetings were held during the review period. A meeting devoted to *elemental abundance analyses* was held in Lausanne, Switzerland in September, 1987 (Proceedings, 1988, ed. Adelman and Lanz, University of Lausanne), and the other one devoted to Ap stars was held in Nizny Arkhyz, USSR in October, 1987 (Proceedings, ed. Glagolevsky and Kopylov, 1988, Nauka).

1. Abundances: Abundance analyses in the optical region have shown a significant progress in quality in recent years. Adelman carried out extensive analyses of Hg-Mn and related stars based on high resolution and high *S/N* ratio spectrograms (*MN* **230**, 671, **235**, 749, **235**, 763, **239**, 487). Dobrichev et al. (*Astrophys* **30**, 53) and Ryabchikova and Smirnov (*Astron Tsirk* **1534**, 21) analyzed abundances of He and Xe, respectively, in the Hg-Mn star κ Cnc. Adelman and Gulliver (*ApJ* **348**, 712) obtained abundances in the superficially normal star Vega based on high S/N ratio data and confirmed the star to be a metal deficient star with a mean under-abundances of 0.60 dex. This work shows a new standard in quality in stellar abundance determinations. Lemke (*AA* **225**, 125) analyzed Ti and Fe lines in 17 stars near spectral type A0 and found a correlation between Ti and Fe abundances. Gigas (*AA* **192**, 264) performed *non-LTE* analyses of Mg and Ba lines in Vega. The hot Am star Sirius was analyzed by Savanov (*Bull Crimean Ap Obs* **76**, 38) and by Sadakane and Ueta (*PASJ* **41**, 279). Abundances of Li in Hyades Am stars are analyzed by Burkhart and Coupry (*AA* **220**, 197).

In the near *IR* region, high quality spectroscopic work is now possible thanks to the introduction of solid state detectors such as CCDs. Faraggiana and her group carried out systematic surveys of the O I triplet lines for normal, Ap, and Am stars (*AA* **201**, 259, *AA Suppl* **81**, 127, *AA* **224**, 171). Roby and Lambert (*ApJ Suppl* **73**, 67) analyzed C I, N I, O I lines and Sadakane and Okyudo (*PASJ* **41** 1055) analyzed N I and S I lines in the near IR region for a number of stars and found significant anomalies of these elements in CP stars.

In the *UV* region, Rogerson (*ApJ Suppl* **71**, 369) published a spectroscopic ATLAS of Vega. Artru et al. (*AA Suppl* **80**, 17) prepared ATLASES for the two B-type stars ν Cap (B9) and π Cet (B7). These ATLASES are quite useful because they can be used as guides in studying UV spectra of peculiar stars which show more complicated spectra. Sadakane et al. (*ApJ* **325**, 776) determined abundances of Zn in Hg-Mn stars. Baschek and Slettebak (*AA* **207**, 112) analyzed abundances in λ Boo stars. Identifications of heavy elements in the UV region are discussed by Fuhrmann (*AA Suppl* **77**, 345, and **80**, 399), Cowley and Greenberg (*MN* **232**, 763), and by Faraggiana (*AA* **224**, 162). As discussed in these papers, a plenty of information on abundances of elements not accesible from ground based observations are expected in the UV region not only for peculiar stars but for normal stars. It will be important to search for heavy elements in this region. However, high resolution data obtained with the IUE satellite are insufficient in both resolution and S/N to carry out quantitative analyses.

One of the obstacles in abundance studies in CP stars is the difficulty in determining stellar parameters (*Teff* and log *g*). Calibrations of these quantities are discussed by Meggessier (*AA Suppl* **72**, 551), Stepien and Dominiczak (*AA* **219**, 197), North and Kroll (*AA Suppl* **78**, 325), and by North and Nicholet (*AA* **228**, 78). Another difficulty lies in the accuracy of available atomic data such as log *gf* values. R. Kurucz of SAO carried out extensive semiempirical calculations of atomic data for iron group elements. Critically evaluated log *gf* values for Ti through Ni have been published by Martin et al. and by Fuhr et al. (*J Phys Chem Ref Data* **17**, Suppl., 3 and 4). A meeting entitled *Atomic Spectra and Oscillator Strengths for Astrophysics and Fusion* was held in August, 1989, in Amsterdam. In view of the coming availability of high resolution UV spectroscopic data obtained with the HST, the need of reliable atomic data in that region can not be overemphasized.

2. Magnetic Field and Surface Mapping: Observations and modeling of magnetic fields in CP stars play a key role in understanding the origin of these objects. Landstreet (*ApJ* **326**, 967) and Landstreet et al.

(*ApJ* **344**, 876) constructed detailed models of magnetic fields and distributions of elements over the surfaces of magnetic stars 53 Cam and HD 215441, respectively. They showed magnetic fields of these stars can be modeled as superpositions of dipole, quadrapole, and octpole components. Hatzes et al. (*ApJ* **341**, 456) and Hatzes (*MN* **245**, 56) obtained distributions of Si over the surfaces of γ^2 Ari and BP Boo, respectively, by the Doppler imaging technique. Rice et al. (*AA* **208**, 179) discussed the capabilities and limitations of solution of the inverse problem in deriving maps of stellar surfaces from observed line profiles using the Doppler imaging technique. Piskunov and Wehlau (*AA* **233**, 497) discussed mapping of stellar surfaces from medium resolution spectra and Rice and Wehlau (*AA* **233**, 503) recalculated distribution of elements on the surfaces of ϵ UMa and θ Aur. Semel (*AA* **225**, 456) proposed a method to disclose magnetic field distribution over rapidly rotating stars. Donati et al. (*AA* **225**, 467) applied this technique to the magnetic Ap star α^2 CVn.

Mathys (*AA* **232**, 151) reported observations of profiles of the two Fe II lines near 6150 Å in magnetic stars which exhibit Zeeman split lines. He found asymmetries in these lines and suggested these may be due to partial Pashen-Back effect. He also discovered three stars which exhibit Zeeman split lines. Mathys and Lanz (*AA* **230**, L21) reported a detection of a magnetic field of the order of 2 kG in the hot Am star o Pegasi. This finding is based on an analysis of lines widths and an anomaly in the line intensity ratio which is found in magnetic stars. They suggested that the magnetic field of o Peg may have a complex structure which can not be modeled as a simple dipole. This is a striking finding because Am stars have long been believed to be non-magnetic. Further observations of other Am stars and also of other types of *non-magnetic* CP stars are highly desirable.

3. Rapid Oscillation: A group of CP stars which shows photometric rapid oscillations have attracted attentions since these stars are expected to provide a seismological diagnostic tool in investigating stellar interiors. They are cool magnetic stars which show strong lines of Sr, Cr and rare earth elements. Presently at least a dozen of such stars are known. A review paper has been written by Kurtz (*Ann Rev Astr Ap* **28**). Several groups tried spectroscopic observations of these stars in an attempt to detect rapid oscillations in radial velocities. These groups include Ando et al. (*PASJ* **40**, 249), Libbrecht (*ApJ* **330**, L51), Matthews et al. (*ApJ* **324**, 1099), Belmonte et al. (*AA* **221**, 41), and Schneider and Weiss (*AA* **210**, 147). Data obtained by different groups for a star often show discrepant results. It shows the difficulty in detecting a very small amplitude variation in radial velocity. An extreme stability of the spectrogragh and also the detector system is needed in such an observation. Weiss and Schneider (*AA* **224**, 101) critically reviewd previous observations and emphasized the importance of *simultaneous* spectroscopic and photometric observations and making observations in various wavelength regions using multiple spectral lines.

O-type and Wolf-Rayet stars — K.A. van der Hucht

During the past triennium several symposia, colloquia and workshops have been concerned with O-type and WR stars, the proceedings of which contain many comprehensive review papers. Among these are: the El'va (USSR) Conference 'Wolf-Rayet Stars and Related Objects' (Nugis & Pustyl'nik, eds., 1988, *Tartu Astrofüüs. Obs. Teated* No. 89); IAU Coll. No. 113 'Physics of Luminous Blue Variables' (Davidson *et al.*, eds., 1989, Dordrecht:Kluwer); the First Boulder-Munich Workshop 'Intrinsic Properties of Hot Luminous Stars' (Garmany, ed., 1990, *ASP Conf. Series* Vol. 7); the Ames Workshop 'Angular Momentum and Mass Loss for Hot Stars' (Willson & Stalio, eds., 1990, *NATO ASI Series* Vol. C316, Dordrecht:Kluwer); and IAU Symp. No. 143 'Wolf-Rayet Stars and Interrelations with Other Massive Stars in Galaxies' (van der Hucht & Hidayat, eds., 1991, Dordrecht:Kluwer, in press). In addition, review papers on hot luminous stars have been given by Abbott & Conti (1987 *Ann. Rev. A&A* **25**, 113), Humphreys (1987 *PASP* **99**, 5), Willis & Garmany (1987, in: Y. Kondo, ed., Exploring the Universe with the *IUE* satellite, Dordrecht:Reidel, p. 157), Conti (1988, in: V.M. Blanco & M.M. Phillips, eds., *ASP Conf. Series* Vol. 1, p. 100), and Kudritzki & Hummer (1990, *Ann. Rev. A&A* **28**, 303). The long awaited monograph 'O Stars and Wolf-Rayet Stars' by Conti & Underhill (eds., 1988 *NASA SP-497*) deserves a special mention. The authors present conflicting views about the origin and evolutionary status of the WR phenomenon. One of the final confrontations of those views was presented at the Ames Workshop, where the notion that WR stars are the evolved descendants of massive O-type stars won on points (Lamers *et al.* 1990, Ames Workshop p. 349, *vs.* Underhill 1990, *ibid.* p. 353).

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Slit spectral classification of O-type stars has been continued by Garmany *et al.* (1987 *AJ* **93**, 1070) and Massey *et al.* (1989 *AJ* **98**, 1305) for the SMC, following similar work in the LMC (Conti *et al.* 1986 *AJ* **92**, 48).

There are now 172 WR stars known in the Galaxy, 115 in the LMC, still 8 in the SMC, and many becoming familiar in other Local Group galaxies and beyond (*e.g.*, Lequeux *et al.* 1987 *A&A Suppl.* **67**, 169; Massey *et al.* 1987 *AJ* **94**, 1538; Massey *et al.* 1987 *PASP* **99**, 816; Moffat & Shara 1987 *ApJ* **320**, 266; Azzopardi *et al.* 1988 *A&A* **189**, 34; Rosa & Richter 1988 *A&A* **192**, 57; Smith 1988 *ApJ* **327**, 128). Very large numbers of WR stars are thought to be responsible for the dominating WR features found in some dwarf irregular galaxies and blue compact galaxies (*e.g.*, Armus *et al.* 1988 *ApJ* **326**, L45; Keel 1987 *A&A* **172**, 43). In the latter galaxies indications have been found of bursts of massive star formation.

Many important spectral atlases and studies from the ultraviolet to the infrared have appeared, as tools for probing the ionization conditions in WR winds. A major quantitative *IUE* (no single observatory has ever had such a profound effect on the research into hot luminous stars) survey of the stellar winds of 203 galactic O-type stars has been performed by Howarth & Prinja (1989 *ApJ Suppl.* **69**, 527). Prinja *et al.* (1990 *ApJ* **361**, 607) argue that the terminal velocity v_∞ of WR winds is related to the violet limit of the zero residual intensity in saturated UV P-Cygni profiles, rather than to their extreme violet edges. They use these estimators and high resolution *IUE* spectra to conclude that for OB stars v_∞ = 0.80-0.85 v_{edge} and for WR stars $v_\infty = 0.76\ v_{edge}$. This means that previously derived mass loss rates using UV P-Cygni profiles have to be proportionally reduced. Earlier, Williams and Eenens (1989 *MNRAS* **240**, 445) reached for WR stars a similar conclusion from the observed displacement of *HeI* 2.058μ absorption lines. Low resolution *IUE* spectra of galactic and LMC WR stars have been used to determine the strength of the interstellar 2200Å absorption feature per star, related to its color excess (*e.g.*, Vacca & Torres-Dodgen 1990 *ApJ Suppl.*, in press).

Optical spectral atlases of WR stars have been presented by Torres & Massey (1987 *ApJ* **65**, 459) for WC stars and by Lundström & Stenholm (1989 *A&A* **218**, 199). Near-infrared spectral atlases have been published by Vreux *et al.* (1989 *A&A Suppl.* **81**, 353), Conti *et al.* (1990 *ApJ* **354**, 359), and Vreux *et al.* (1990 *A&A*, in press). Conti & Massey (1989 *ApJ* **337**, 251) presented optical spectrophotometry of leading emission line features for nearly all galactic and LMC WR stars, and performed a quantitative WR subclass classification. They noted among the WN stars eight objects (presumably single WR stars) with inordinately strong *CIV*. Those stars are labelled WN/WC and may have a chemical composition between that of the WN and WC subclasses. Their fraction of about 3% is in good agreement with evolutionary studies of Langer (1990, in: Garmany, ed., *ASP Conf. Series* Vol. 7, p. 328) and Maeder (1990 *A&A*, in press), who identify WR stars as evolved massive stars. A similar study for the eight SMC WR stars has been presented by Conti *et al.* (1989 *ApJ* **341**, 113), who found generally weaker helium and nitrogen line strengths and weaker stellar winds than in galactic and LMC WR stars, but similar *N/He* line ratios. New spectrophotometric methods based on emission line strengths and ratios, to determine absolute visual magnitudes of WN stars, interstellar reddening of WN stars and distances of WC stars, have been developed by Conti & Massey (1989 *ApJ* **337**, 251), Conti & Morris (1990 *AJ* **99**, 898) and Smith *et al.* (1990 *ApJ* **358**, 229), respectively.

Quantitative spectroscopy of O-type and WR stars has been reviewed by Kudritzki & Hummer (1990 *Ann. Rev. A&A* **28**, 303). The techniques discussed combine hydrostatic NLTE model photospheres for the absorption lines formed in the subsonic layers with a radiation driven wind theory for modeling the emission and P-Cygni type lines formed in the surrounding stellar winds, and have been compared with observations. In this way precise information is obtained not only on the effective temperatures, gravities and abundances, but also on stellar masses and luminosities, independent of the distances. NLTE stratified expanding model atmospheres for pure helium WR stars have been reviewed by Hamann *et al.* (1990, in: Garmany, ed., *ASP Conf. Series* Vol. 7, p. 259), Hillier (1990 *ibid.* p. 340), and Schmutz (1990 *ibid.* p. 117). The more recent models also include nitrogen and carbon. They calculate continuum energy distributions, line strengths and line profiles for WN and WC stars, which match the observations to a satisfactory accuracy. They show that the WN and WC sequences arise from different surface abundances of *He* and *CNO*. Typical number abundance ratios derived from those detailed model atmospheres in comparison with observations are $N/He \approx 4 \times 10^{-3}$ and $C/N \approx 0.07$ for the WN5 star HD 50896 (Hillier 1988 *ApJ* **327**, 822), and $C/He >$ 0.1 for the WC5 star HD 165763 (Hillier 1989 *ApJ* **347**, 392). Smith & Hummer (1988 *MNRAS* **230**, 511) and Smith & Maeder (1990 *A&A*, in press) find a continuous increase in the *(C+O)/He* number ratio for the sequence WCL → WCE → WO, ranging from 0.03 to > 1.

Studies of intrinsic spectral variability of O-type stars in the *IUE* UV have been reviewed by Henrichs (1988, in: Conti & Underhill, eds., *NASA SP-497*, p. 199) and Kaper *et al.* (1990, in: Willson & Stalio, eds., *NATO ASI Series* Vol. C316, p. 213). They emphasize the rapid variability of discrete absorption components in UV P-Cygni profiles. The behaviour is different from star to star and rather constant over years of observations for a given star. The physical mechanism may be described qualitatively by time-dependent models of radiatively driven stellar winds (Owocki *et al.* 1988 *ApJ* **335**, 914). Intrinsic spectral variability in the WN6 + compact companion candidate HD 192163 has been reported in the *IUE* UV by St.-Louis *et al.* (1989 *A&A* **226**, 249). They find a rise and decay timescale for *NIV* and *CIV* lines of ~ 1 *d*, whereas its optical radial velocity period is P = 4.55 *d*. A comparable UV spectral study has been carried out by Willis *et al.* (1989 *A&A Suppl.* **77**, 269) for the WN5 + compact companion candidate HD 50896. They also find line variability with P ≈ 1 *d*, whereas its optical radial velocity period is P = 3.76 *d*. Optical spectral variability is reported by, *e.g.*, Moffat *et al.* (1988 *ApJ* **334**, 1038), Shylaja (1990 *ApSS* **164**, 63) and Robert & Moffat (1990, in: Garmany, ed., *ASP Conf. Series* Vol. 7, p. 271). The first and the last find evidence for rapid blob ejection from blue- and red-ward moving narrow components.

We refer here only to a few striking results of the numerous studies of individual O-type and WR binaries. Stickland and co-workers have demonstrated over the years the usefulness of *IUE* for radial velocity studies, *e.g.*, in the cases of Plaskett's (O8e) star (1987 *Observatory* **107**, 68), the O9.5I binary δ Ori (1987 *Observatory* **107**, 205), the O8.5n binary AO Cas (1988 *Observatory* **108**, 174), the O8.5If binary 29 CMa (1989 *Observatory* **109**, 74), and theWC8+O9I binary γ^2 Vel (1990 *Observatory* **110**, 1), yielding in many cases better results than previous optical studies. WR binary studies for the LMC and the SMC have been performed by Moffat *et al.* (1990 *ApJ* **348**, 232). After many years of struggling by various investigators, Williams *et al.* (1987, in: Lamers & de Loore, eds., Instabilities in Luminous Early Type Stars, Dordrecht:Reidel, p. 221; 1990 *MNRAS* **243**, 662) have finally succeeded in finding a radial velocity solution for HD 193793, making it the WR binary with the longest known period: P = 7.94 *d*, and the prototype of a new class of long period eccentric binaries (Williams *et al.* 1990 *MNRAS* **247**, 18P). The colliding winds in WR+O binaries can give rise to variability of the UV P-Cygni profiles, as observed, *e.g.*, in V444 Cyg by Shore & Brown (1988 *ApJ* **334**, 1021), who explain the variations in terms of shock-dominated wind-wind interactions.

The past triennium has shown many promising results and has paved the way to much needed future research of those arresting physics laboratories called WR and O-type stars.