J. Andersen (ed.), Reports on Astronomy, Vol. XXIVA, 219-230.

COMMISSION 36: THEORY OF STELLAR ATMOSPHERES

(THEORIE DES ATMOSPHERES STELLAIRES)

PRESIDENT: R. Pallavicini
VICE-PRESIDENT: D. Dravins
ORGANIZING COMMITTEE: B. Barbuy, L. Cram, I. Hubeny, S. Owocki, H. Saio, D. Sasselov, M. Spite, K. Stepien & R. Wehrse

1. INTRODUCTION

Consistently with a trend observed in recent past triennial reports, progress in the theory of stellar atmospheres continues to be made in two different directions: 1) the traditional areas of continuum and line radiation transfer, line blanketing, atomic physics and atmospheric structures controlled by the joint conditions of radiative and hydrostatic equilibrium, and 2) in areas of emerging interest such as oscillations, velocity fields, winds and mass loss, chromospheres, coronae and magnetic phenomena. Particular attention is devoted also to the accurate determination of stellar elemental abundances and their implications for stellar interior structure and evolution as well as for the chemical enrichment of the Galaxy.

The interplay between phenomena that take place in the atmosphere per se and the phenomena that often lie beneath the stellar surface, implies that the work of the Commission often extends into areas of interest of other IAU Commissions whose work is related to stars. This extension is also apparent in connections to the solar Commissions, for it is increasingly the case that large areas of interest in solar physics converge with corresponding areas of interest in stellar astrophysics. Other areas in which there is a clear overlap with the activities of other Commissions include stellar spectra, star clusters and associations, and variable stars. Interestingly, there is a growing awareness of the contribution that work in the areas covered by the Commission will contribute to progress in extragalactic investigations.

The amount of work that might be reviewed in this contribution is very large. A search of the ADS database with obvious keywords covering the work of the Commission resulted in several thousand abstracts of papers published over the past 3 years. A deeper investigation of a large subsample of these revealed that most were indeed related to the work of the Commission. For this reason, it is no longer feasible to attempt to provide in the report a comprehensive survey. Indeed, the growth of the WWW and effective search engines implies that the effort of doing this might not be repaid by the use of the report as a tool for astronomical research. It is expected anyway that the report will be of greater value to astronomers working outside the area covered by the Commission. The approach that was adopted in preparing this report was to provide the highlights of progress made in various areas related to the theory of stellar atmospheres with no attempt to completeness.

In addition to the research papers mentioned in the sections below, the following partial list of recently published monographs and proceedings in areas of interest to Commission 36 may prove to be a useful entry into the field.

References

Adelman, S. J., Kupka, F., Weiss, W. W. (eds.) *M.A.S.S. Model Atmospheres and Stellar Spectra*, San Francisco: Astronomical Society of the Pacific, ASP Conference Series 108 (1996)

Barbuy, B., Maciel, W.J., Gregorio-Hetem, J.C. (eds.) *Stellar Abundances*, Proceedings of a Workshop held at the Instituto Astronomico e Geofisico da Universidade de Sao Paulo, Sao Paulo: USP (1996)

Bedding, T.R., Booth, A.J., Davis, J. (eds.) *Fundamental Stellar Properties: the Interaction between Observation and Theory*, IAU Symp. 189, Dordrecht: Kluwer (1997)

Butler, C.J., Doyle, J.G. (eds.) *Solar and Stellar Activity: Similarities and Differences*, San Francisco: Astronomical Society of the Pacific, ASP Conference Series 158 (1999)

De Greve, J.P., Blomme, R., Hensberge, H. (eds.) *Stellar Atmospheres: Theory and Observations*, Astrophysics School IX (EADN), Berlin: Springer, Lecture Notes in Physics 497 (1997)

Donahue, R., Bookbinder, J. (eds.) *10th Cambridge Workshop on Cool Stars, Stellar Systems, and the Sun*, San Francisco: Astronomical Society of the Pacific, ASP Conference Series 154 (1998)

Holt, S. S., Sonneborn, G. (eds.) *Cosmic Abundances*, San Francisco: Astronomical Society of the Pacific, ASP Conference Series 99 (1996)

Kaper, L., Fullerton, A. W. (eds.) *Cyclical Variability in Stellar Winds*, ESO Astrophysics Symposia, Berlin: Springer (1998)

Lèbre, A., Le Bertre, T., Waelkens, C. (eds.), *Asymptotic Giant Branch Stars*, IAU Symp. 191, San Francisco: Astronomical Society of the Pacific

Micela, G., Pallavicini, R., Sciortino, S. (eds.) *Cool Stars in Clusters and Associations: Magnetic Activity and Age Indicators*, Proceedings of a Workshop held at Osservatorio Astronomico di Palermo, Società Astronomica Italiana, Memorie SAIt 68, No.4 (1997)

Pallavicini, R., Dupree, A.K. (eds.) *9th Cambridge Workshop in Cool Stars, Stellar Systems, and the Sun*, San Francisco: Astronomical Society of the Pacific, ASP Conference Series 109 (1996)

Rebolo, R., Martín, E. L., Zapatero Osorio, M. R. (eds.) *Brown Dwarfs and Extrasolar Planets*, San Francisco: Astronomical Society of the Pacific, ASP Conference Series 134 (1998)

Strassmeier, K.G., Linsky, J.L. (eds.) *Stellar Surface Structure*, IAU Symp. 176, Dordrecht: Kluwer (1996)

Uchida, Y., Kosugi, T., Hudson, H.S. (eds.) *Magnetodynamic Phenomena in the Solar Atmosphere: Prototypes of Stellar Magnetic Activity*, IAU Colloquium 153, Dordrecht: Kluwer (1996)

Wolf, B., Stahl, O., Fullerton, A.W. (eds.) *Variable and Non-spherical Stellar Winds in Luminous Hot Stars*, IAU Colloquium 169, Berlin: Springer, Lecture Notes in Physics 523 (1999)

2. PROGRESS IN STELLAR ATMOSPHERE MODELS (F.Castelli)

Over the past three years work has been done in order to:
a) improve the classical LTE models
b) compute stellar 2D and 3D hydrodynamical models
c) advance in the computation of the next generation models: spherically symmetric, line-blanketed, NLTE model atmospheres

2.1. The classical LTE models

The Kurucz models. Different grids of ATLAS9 models (opacity distribution function models), computed with different options for convection, for several metallicities and several

https://doi.org/10.1017/S0251107X00002935 Published online by Cambridge University Press

microturbulent velocities, are available at the Kurucz WWW and FTP site: kurucz.harvard.edu. Here, improved versions (with respect to those in Kurucz CD-ROMs 13 and 18) of all the codes for computing models of stellar atmospheres and spectral synthesis are also available. In addition to the ATLAS9 grids, models for arbitrary abundances and based on the opacity sampling method can be computed by any user of the ATLAS12 code (Kurucz, 1997), which is available at Kurucz's website as well. Opacities have been added for TiO (Schwenke, 1998) on CD-ROM 24 and for H_2O (Partridge & Schwenke, 1997) on CD-ROMs 25 and 26; opacities for collision induced absorption by H_2-H_2 and H_2-He from Borysow et al. (1997) and for quasi-molecular Lyman-α satellites from Allard et al. (1998) have been added in all codes.

The Gustafsson models. New results related to the latest developements of the MARCS programs can be found in several papers. The optimization of the opacity sampling method, in terms of the number of frequency points needed to treat the radiation field in hydrodynamic and dust calculations, is presented by Helling & Jørgensen (1998). The opacity was improved by Borysow et al. (1997) who computed a grid of MARCS cool, low-metallicity stellar atmospheres, which include in the opacity the contribution of the collisional induced absorption (CIA) due to H_2-H_2 and H_2-He pairs. A grid of MARCS models for R Coronae Borealis stars and hydrogen-deficient carbon stars was computed by Asplund et al. (1997) for T_{eff} from 5000 to 9500 K, log g from 0.5 to 1.0, and several different C/He ratios. Alvarez & Plez (1998) made use of spherically symmetric, hydrostatic, flux constant models in LTE computed with the SOSMARCS code to study M giants and Mira stars.

2.2. Convection in model atmospheres

Several discussions related with the influence of 1-D, 2-D, and 3-D convection on energy distributions, colors, Balmer profiles, and abundances of late A, F, G, and K stars have been published. Local 1-dimensional (1D) convection in classical LTE models was discussed by Kurucz (1997), Castelli et al. (1997), Smalley & Kupka (1997), Van't Veer et al. (1998), Gardiner et al. (1999). 2-dimensional (2D) radiation hydrodynamics (RHD) calculations were performed by Ludwig, Freytag & Steffen (1999) for solar metallicity stars in order to calibrate the parameter α=l/H_p for both standard mixing-length and for Canuto & Mazzitelli (CM) convection theories. For both convections, the α dependence on T_{eff} and log g is investigated. 3-dimensional (3D) LTE hydrodynamical model atmospheres for the metal poor stars HD 140283 and HD 84937 were computed by Asplund et al. (1999). Results from 1-D and 3-D models were compared; in particular, the 0.2-0.35 dex lower Li abundance predicted by the 3D-models as compared with that from the 1D-models is discussed.

A specific workshop devoted to the "Convection treatment in stellar atmospheres" was held at the Paris-Meudon Observatory on 31 May-2 June 1999, promoted by C. Van't Veer, R. Cayrel, J.P Zahn.

2.3. The "next-generation" PHOENIX models

Grids of "next-generation" models (spherically symmetric, line-blanketed NLTE model atmospheres) have been computed by means of the PHOENIX code (Allard & Hauschildt, 1995). A large number of models for several different objects have been produced. The last ones are: for Novae (Schwarz et al., 1997); for bright giants (Aufdenberg et al., 1998; Aufdenberg at al., 1999); for OB low metallicity stars (Pistinner et al., 1999). Furthermore, Hauschildt, Allard & Baron (1999) computed plane-parallel, NLTE, line-blanketed model atmospheres for Vega and the Sun. Results from LTE and NLTE models are compared. This work is part of a paper in which a grid of LTE models, computed with the PHOENIX code, is discussed. Models and fluxes are available, for T_{eff} from 3000 to 10000 K (in steps of 200 K), $3.5 \leq \log g \leq 5.5$ (in steps of 0.5) and metallicities $-4.0 \leq [M/H] \leq 0.0$, via anonymous FTP at calvin.physast.uga.edu/pub/NextGen. The grid is presented as the first step toward a large grid of NLTE line-blanketed models for main sequence and giant stars.

References

Allard F., Hauschildt P.H., 1995, ApJ 445, 433
Allard F., Hauschildt P.H., Alexander D.R., Starrfield S., 1997, ARA&A 35, 137
Allard N.F., Drira I., Gerbaldi M., Kielkopf J., Spielfield A., 1998, A&A 335, 1124
Alvarez R., Plez B., 1998, A&A 330, 1109
Asplund M., Gustafsson B., Kiselman D., Eriksson K., 1997, A&A 318, 521
Asplund M., Nordlund A., Trampedach R., Stein R.F., 1999, A&A 346, L17
Aufdenberg J.P., Hauschildt P.H., Baron, E., 1999, MNRAS 302, 599
Aufdenberg J.P., Hauschildt P.H., Shore S.N., Baron, E., 1998, ApJ. 498, 837
Borysow A., Jørgensen U.G., Zheng C., 1997, A&A 324, 185
Castelli F., Gratton R., Kurucz L.R., 1997, A&A 318, 841
Gardiner R.B., Kupka F., Smalley B., 1999, A&A 347, 890
Hauschildt P.H., Allard F., Baron E., 1999, ApJ 512, 377
Helling C., Jørgensen U.G., 1998, A&A 337, 477
Kurucz R.L., 1997, in Fundamental Stellar Properties: the Interaction between Observation and Theory, IAU Symp. 189, eds. Bedding T.R., Booth A.J., Davis,J, p. 217.
Ludwig H.G., Freytag B., Steffen M., 1999, A&A 346, 111
Partridge H., Schwenke D.W., 1997, J. Chem. Phys. 106, 4618
Pistinner S.L., Hauschild P.H., Eichler D., Baron E.A., 1999, MNRAS 302, 684
Schwarz G.J., Hauschild P.H., Starrfield S., Baron E., Allard F., Shore S.N., Sonneborn G., 1997, MNRAS 284, 669
Schwenke D.W.,1998, Faraday Discuss 109, 321
Smalley B., Kupka F., 1997, A&A 328, 349
van't Veer-Menneret C., Bentolila C., Katz D., 1998, Contrib. Astron. Obs. Skalnaté Pleso 27, 223, eds. North P., Schnell A., Žižňovský J.

3. VELOCITY FIELDS IN STELLAR ATMOSPHERES (D. Dravins)

3.1. The structure of stellar surfaces

Exactly how does radiation detach from the matter at stellar surfaces, and how do the fine structures in velocity, temperature and pressure look like? Building upon the solar experience, observable effects of stellar surface structure (e.g., granulation) have been identified in stellar spectra, and inhomogeneous, three-dimensional and time-dependent stellar models developed. This generation of models is free from the classical parameters of "mixing-length", "micro-" or "macro-turbulence", which during past decades dominated the description of stellar atmospheres.

3.2. 3-Dimensional vs. 2-D and 1-D models

Hydrodynamic simulations of solar and stellar surface convection have reached a high level of maturity and have passed a number of stringent observational tests (Stein & Nordlund 1998). Such models use 3-dimensional and time-dependent numerical simulations, including a detailed description of radiative-transfer and ionization effects in a compressible, stratified, and turbulent medium.

For most stars, surface fluctuations of large amplitude are predicted, affecting both spectral lines and continuum colors. Compared to equivalent 1-D models, stellar photospheres generally are "elevated" due to additional support by the turbulent pressure, and the higher average temperature, hidden from view by the temperature-sensitive opacity.

The photospheric temperature is determined by a competition between cooling by adiabatic expansion of the overshooting and rising gas, and its radiative heating from below. In metal-poor stars, the weak spectral lines contribute only little such heating, making their surfaces rather cool.

For the verification (or falsification) of such models, spectral-line asymmetries (bisectors) and absolute wavelength shifts are used as a diagnostic of velocity fields, and their correlation with e.g. temperature. Although also other effects might cause line asymmetries, the influence of pressure shifts is small in ordinary stars (Allende Prieto et al. 1997).

To avoid the extensive computations implied by a full modeling, it is desirable to understand in which cases simplified 2-D or 1-D models may give adequate approximations. Systematic differences between 3-D and 2-D models exist in the vertical velocities in the surface overturning layers: the gases turn over in one dimension in 2-D; in two dimensions in 3-D models, requiring different gradients near the surface.

3.3. Magnetic structures, and searches for exoplanets

Exoplanets are found by monitoring wavelength displacements in stellar spectra, interpreting these as velocity shifts induced by the unseen planet(s). However, at these accuracy levels, the wavelength positions need not correspond to the velocity of the stellar center-of-mass, and these may also vary in time. Near magnetic fields, solar granulation is observed to be more fragmented, exhibiting smaller line asymmetries and shifts. Modeling with magnetic fields present, indeed shows how these inhibit the development of equally dynamic motions as elsewhere (Bercik et al. 1998).

The varying area coverage of magnetic regions leads to observed changes (by ≈ 20 m/s) in spectral line wavelengths during the solar 11-year cycle (Livingston et al. 1999). This has implications in searches for exoplanets with comparable periods: e.g., Jupiter modulates the solar velocity by 13 m/s, over 12 years. Apparent radial velocities are generally observed to be more variable in magnetically more active stars (Gray et al. 1996; Saar et al. 1998).

3.4. Fluctuations in integrated starlight

Averaging over only the finite number of temporally evolving elements across a stellar surface, causes small fluctuations of irradiance or apparent velocity in integrated starlight. Required accuracies have been reached for solar observations, and are within sight also for ordinary stars (e.g., space-based stellar photometry with micromagnitude precision); corresponding hydrodynamic stellar models are now being developed (Trampedach et al. 1998).

3.5. Absolute lineshifts as a new diagnostic tool

Lines formed in convective layers normally experience shifts in wavelength. In the past, such absolute shifts (i.e. the difference to laboratory wavelengths, after correcting for the Doppler shift due to stellar motion) were measurable only for the Sun. The accuracies realized by the Hipparcos satellite now have made possible also purely astrometric determinations of radial velocities (Dravins et al. 1999). Comparisons with apparent spectroscopic velocities then reveal differences due to convective blueshifts and gravitational redshifts. Thus, absolute lineshifts may become a new diagnostic tool for analyzing stellar atmospheres (Hearnshaw & Scarfe 1999).

3.6. Accurate chemical abundances

Already small changes of the (inhomogeneous) temperature structure in stellar atmospheres may affect line intensities, causing uncertainties in abundance determinations. The determination of primordial abundances of, e.g., lithium in very old metal-poor halo stars requires care since, although such stars may be similar to, e.g., the Sun in their interior, large differences in atmospheric structure may exist. Accurate determinations require hydrodynamic modeling of spectral line synthesis (Asplund et al. 1999; Gadun & Ploner 1999; Kiselman 1998).

3.7. Giant and supergiant stars

The low surface gravities of giant and supergiant stars permit violent (even supersonic) convection, transiting into mass loss and stellar winds. The relevant scales may be comparable with stellar dimensions, requiring modeling of the entire star, rather than just a surface sample. Various velocity signatures have been observed (e.g. Hatzes & Cochran 1998), although the lack of global models precludes secure identification of convective, pulsational, or other modes.

3.8. Early-type stars

Although the often broad-lined spectra from early-type stars make direct studies of their velocity fields more difficult, efforts have been made to identify atmospheric velocity fields in A-type stars from both theory (Freytag et al. 1996) and observations (Landstreet 1998).

3.9. White dwarfs and neutron stars

Hydrodynamic 2-D convection models have been applied also to DA white dwarfs, where gas velocities reach 10 km/s over scales of only a fraction of one km (Freytag et al. 1996). Similar velocities may be reached also in the surface layers of weakly magnetized neutron stars (Miralles et al. 1997).

References

Allende Prieto, C., García López, R.J., & Trujillo Bueno, J. 1997, ApJ, 483, 941

Asplund, M., Nordlund, Å., & Trampedach, R. 1999, A&A, 346, L17

Bercik, D.J., Basu, S., Georgobiani, D., Nordlund, Å, & Stein, R.F., 1998, in The Tenth Cambridge Workshop on Cool Stars, Stellar Systems and the Sun, ed. R. A. Donahue & J. A. Bookbinder, ASPC 154, 568

Dravins, D., Lindegren, L., & Madsen, S. 1999, A&A, 348, 1040

Freytag, B., Ludwig, H.-G., & Steffen, M. 1996, A&A, 313, 497

Gadun, A.S. & Ploner, S.R.O. 1999, Kin. Fiz. Neb. Tel 15, no. 1, 17

Gray, D.F., Baliunas, S.L., Lockwood, G.W., & Skiff, B.A. 1996, ApJ465, 945

Hatzes, A.P. & Cochran, W.D., 1998, MNRAS, 293, 469

J.B.Hearnshaw & C.D.Scarfe (eds.) 1999, IAU Coll. 170, Precise Stellar Radial Velocities, ASPC 185

Landstreet, J.D., 1998, A&A, 338, 1041

Livingston, W., Wallace, L., Huang, Y., & Moise, E. 1999, in High Resolution Solar Physics: Theory, Observations, and Techniques, ed. R. Rimmele, K. S. Balasubramaniam, & R. R. Radick, ASPC 183, in press

Miralles, J.A., Urpin, V., & van Riper, K. 1997, ApJ480, 358

Saar, S. H., Butler, R. P., & Marcy, G. W. 1998, ApJ498, L153

Stein, R.F. & Nordlund, Å. 1998, ApJ499, 914

Trampedach, R., Christensen-Dalsgaard, J., Nordlund, Å., & Stein, R. F. 1998, in The First MONS Workshop: Science with a Small Space Telescope, ed. H. Kjeldsen & T.R. Bedding (Aarhus), 59

4. STELLAR MASS LOSSES (S. Owocki)

Recent studies of stellar wind mass loss have included important conceptual advances in the nature of radiative driving, as well as application to a broader range of physical domains, including rotating stars, and flows from disks in accretion systems.

A useful conceptual advance regards K. Gayley's recasting of the standard CAK line driving parameters in terms of a characteristic line-resonance quality factor, $\bar{Q} \approx 2 \times 10^3$, whose magnitude is expected to be roughly constant over a wide range of conditions. In addition to removing certain disadvantages of previous scalings (e.g. artificial dependence on a fiducial ion thermal speed), this provides a convenient means for estimating several key aspects of line driving, e.g. potential for instabilities, and a minimum Eddington parameter $\Gamma > 1/\bar{Q}$ for effective mass-loss. Further detailed NLTE analyses of line-statistics by J. Puls and colleagues in Munich generally confirm the $\bar{Q}$ picture for hot, O-type stars, but suggest key revisions are needed for the cooler B-type stars to account for a general mismatch between the spectral distributions of stellar flux and line-opacity.

R. Kudritzki and colleagues have shown that observationally inferred mass loss rates and terminal speeds of galactic O supergiants follow closely a wind-momentum-luminosity (WML) relation that is predicted from CAK line-driving theory, with a nearly constant, unique overall line normalization (corresponding to $\bar{Q} \sim 10^3$) and slope parameter ($\alpha' \sim 0.57$). Current observational programs for extragalactic stars are focussed on calibrating the metalicity dependence of this WML relation, with ultimate aim of applying it as an alternative standard candle for extragalactic distance determinations.

Observational analyses by H. Lamers and colleagues in Utrecht have revealed an abrupt decrease in the ratio of wind terminal speed to stellar escape speed for supergiants cooler than B2. Theoretical calculations by both the Utrecht and Münich groups are examining how such velocity changes may be related to the expected "bistability" shift in the line-driving distribution, particularly the slope parameter α. Independent NLTE models by both groups are also focussing on quantifying earlier suggestions that such bistability shifts in the equatorial winds of rapidly rotating B-supergiants could provide a model for the B[e] stars.

For nonsupergiant B-stars, there has recently arisen a notion of failed winds. C. Howk and colleagues have proposed that reaccretion of wind blobs in τ Sco can explain the red-shifted absorption seen in OVI lines, with reaccretion shocks also providing a means to produce the anamolous hard X-ray spectrum. Independent analyses by J. Porter suggest that such reaccretion might be a natural result of wind stalling due to runaway decoupling of the line-driven minor ions from the bulk proton-helium plasma.

J. Puls and S. Owocki have developed new escape integral methods for computing the line-driving force within numerical simulations of the strong line-driven instability of hot-star winds. An unexpected outcome has been to illuminate more clearly the limitations of the standard, Sobolev approach that forms the basis of the usual CAK theory. In particular, asymmetries in the escape probability in the trans sonic region of the flow lead to a breakdown in the usual local CAK/Sobolev approach. The effect is estimated to be most severe for lower density winds from B-stars. For O-type supergiants, coupling between line and continuum transfer in the transonic region tends to mitigate the breakdown, in accord with earlier comoving transfer calculations that had validated the CAK/Sobolev approach.

For Wolf-Rayet winds independent analyses by J. Hillier, T. Nugis, A. Cherepashchuk and colleagues indicate that extensive wind clumping may be causing a factor ~ 3 overestimate in mass loss rates inferred from standard line emission measures. The implied lower mass loss rates have important implications for both WR star evolution, and for understanding the wind dynamics. Recent dynamical models by W. Schmutz and others focus on the role of "photon loss" in He II Ly-alpha in inducing a Helium-lead wind recombination, and on the general role of ionization stratification in filling gaps in line spectral distributions. Extensive wavelet analyses by S. Lepine of emission line bumps associated with wind clumps indicate that the WR wind acceleration must extend over a scale 10-50 times the estimates WR core radius. Reproducing this extended acceleration and the large WR mass loss remain substantial challenges for dynamical models.

Seveal recent efforts have centered on extending the CAK line-driving formalism to luminous accretion disk winds, with potential application to cataclysmic variables (CV) and the broad-line flows inferred from QSO/AGNs. Numerical simulations by D. Proga and colleagues indicate that disk winds can have an intrinsic variability associated with the lack of a unique, steady outflow solution. Analytic analyses by A. Feldmeier and I. Shlosman emphasize key differences in the wind solution topology arising from non-monotonic variation of the effective gravity of disk winds. Despite these differences, the overall scalings of mass loss and flow speed are found to follow laws analogous to the CAK results for stars. For CVs, a key problem is that the disk Eddington parameters Γ are generally below the minum value $1/\bar{Q} \sim 10^{-3}$ needed for optically thick line-driving. For QSOs, a key problem is the shielding of the line-driven gas from the ionizing X-ray radiation of the central engine. Analyses by N. Murray and J. Chiang suggest that shielding of the outer disk wind might be provided by ionization of the failed wind from the inner disk.

For disks of classical Be stars, recent observational analyses by P. Hanushik and colleagues of disk emission lines indicate that Be disks must be in nearly static, Keplerian orbit, in strong contrast to predictions of the Wind Compressed Disk model proposed earlier by J. Bjorkman and J. Cassinelli. Smoothed particle hydrodynamical simulations by P. Kroll suggest an alternative picture in which material ejected isotropically from a localized surface region could feed a circumstellar disk. Observations by T. Rivinius and colleagues indicate a close connection between disk-feeding outbursts and resonances in the multiple modes of non-radial pulsation on the Be star μ Cen. A key question regards how pulsations with a sound-speed velocity amplitude of order a few times 10 km/s can induce mass ejections with a speed of some $\sim$ 200 km/s needed to reach near-star orbit.

5. PROGRESS IN THE DETERMINATION OF STELLAR CHEMICAL ABUNDANCES (M. Spite & B. Barbuy)

The chemical composition of stellar atmospheres are used to study the progressive chemical enrichment of the Galaxy as the result of cumulative stellar nucleosynthesis. The relative abundances of the elements are also used to study the mixing between the atmosphere and the deep layers where nuclear reactions take place (for example in the AGB stars). Moreover, in peculiar stars (like Ap stars) the stellar abundances are the signature of a stratification of the different elements inside the atmosphere. But in this short review the emphasis will be only on recent advances on the two first topics.

Forty years after the publication of the well known paper of Burbidge, Burbridge, Fowler and Hoyle (B2FH) which founded the theory of the stellar nucleosynthesis of the chemical elements, Wallerstein and collaborators (1997) have reviewed all the mechanisms which form the elements inside the stars.

Worth noticing is also the new version of the [Fe/H] catalogue of Cayrel et al. (1997) which contains now the metallicity and atmospheric parameters (T_{eff}, log g) of 3247 stars.

The most recent advances in the understanding of the chemical compositions of stars in the galactic field and in clusters are briefly reviewed in this report. The elements are ranked as usual according to their mass.

5.1. Li, Be, B

A very large number of papers appeared about the abundances of these light elements and their evolution. In particular several papers discuss the spread of the lithium abundance in the very metal-poor stars and their destruction in the stellar atmospheres. An excellent collection of papers can be found in the ISSI workshop (1998, Prantzos et al. eds.).

5.2. C, N, O

In young populations, Cunha et al. (1998) presented oxygen abundances in F, G stars of the Orion association, and Takeda et al. (1998) obtained oxygen and nitrogen abundances in Hyades F type dwarfs. CNO abundances were also derived for stars in the Hertzsprung gap phase by Vanture & Wallerstein (1999). CN, NH bands were used to derive C and N abundances in disk K - M giants by Aoki & Tsuji (1997), and IR spectra of C stars observed with ISO were used to derive C/O and $^{12}C/^{13}C$ ratios in N-type and SC-type giants by Aoki et al. (1998). Models developed by the Uppsala group were used to derive $^{12}C/^{13}C$ ratios in cool carbon stars by de Laverny & Gustafsson (1998a, b).

Regarding low mass old stars, an extensive spectroscopic program involving more than 100 stars in 47 Tucanae, from the red giant branch down to one magnitude below the turn-off was carried out by Cannon et al. (1998).

The oxygen abundances in the metal-poor stars controversy has been revived by the results on UV OH lines by Boesgaard et al. (1999) and Israelian et al. (1998) who find [O/Fe] $\approx +1.0$ for the most metal-poor stars, whereas Fulbright & Kraft (1999) find [O/Fe] $\approx +0.5$ for two of the same stars studied in the Boesgaard et al. and Israelian et al. papers, by employing the [OI]630 nm line.

The puzzling very metal-poor stars strongly enhanced in carbon and nitrogen were the focus of attention of several authors, among which are Norris et al. (1997a, b), Zacs et al. (1998) and Bonifacio et al. (1998).

Finally, our knowledge of CNO abundances in the Magellanic Clouds has improved with the high resolution spectroscopy of individual stars by Hill et al. (1997) and Venn (1999).

5.3. The α elements and the odd elements Na, Al

In the field metal rich stars the trend of [Mg/Fe] versus metallicity has been discussed by different teams (Castro et al. 1997, Feltzing et al. 1998).

To be noted is also the discovery of a halo star ([Fe/H]$=-1.9$) with a very low abundance of α elements (Carney et al. 1997) which reveals a peculiar chemical enrichment history.

Several important papers have been published about the abundance anomalies of sodium and aluminum in the metal-poor globular cluster stars. It has been shown that oxygen and sodium (and generally magnesium and aluminum) are anticorrelated, and that sodium and aluminum are correlated. These anomalies are explained by deep mixing and proton capture nucleosynthesis taking place inside the observed star.

5.4. Iron peak elements

The trend of the iron peak elements with [Fe/H] has been studied in the very metal poor field stars. The abundances of Cr Mn and Co deviate from a plateau below [Fe/H]$=-2.4$. Several papers about the chemical composition of the old objects can be found in particular in the ASP Conf. Ser. 92 (Morrison & Sarajedini eds., 1996).

5.5. The heavy elements

In the field metal poor stars, the Ba/Eu ratio would be consistent with a formation by a pure r-process, but the spread observed in the [Sr/Ba] ratios suggests that there is a second source of Sr from an, as yet unidentified, nucleosynthesis site (McWilliam 1998).

It should be noted that silver has been detected for the first time in metal poor stars. Using the HST, osmium, platinum, lead and also zirconium and germanium features could be detected (Sneden et al. 1998) in three halo stars. These new results support the operation of the r-process early in the history of the Galaxy.

The abundance of the heavy elements in several carbon-rich metal-poor stars has been studied. These stars are often enriched in "s" elements suggesting an intrinsic post-AGB enrichment, but the pattern of the heavy elements is not uniform: CS 22892-052 is a unique case of a pure "r" process enhanced object, and in CS 22957-027 the heavy elements are underabundant relative to iron (a classical halo pattern).

References

Aoki, W., Tsuji, T., 1997, A&A 328, 175

Aoki, W., Tsuji, T., Ohnaka, K. 1998, A&A 340, 222

Boesgaard, A.H., King, J.R., Deliyannis, C.P., Vogt, S. 1999, AJ 117, 492

Bonifacio, P., Molaro, P., Beers, T.C., Vladilo, G. 1998, A&A 332, 672

Cannon, R.D., Croke, B.F.W., Bell, R.A., Hesser, J.E., Stathakis, R.A. 1998, MNRAS 298, 601

Cayrel de Strobel G., Soubiran C., Friel E.D., Ralite N., François P., 1997, A&AS, 124 299

Cunha, K., Smith, V.V., Lambert, D.L. 1998, ApJ 493, 195

de Laverny, P., Gustafsson, B. 1998a, A&A 332, 661

de Laverny, P., Gustafsson, B. 1998b, A&A 346, 520

Fulbright, J.P., Kraft, R.P. 1999, AJ 118, 527

Israelian, G., García Lopez, R.J., Rebolo, R. 1998, ApJ 507, 805

Hill, V., Barbuy, B., Spite, M. 1997, A&A 323, 461

Morrison H. & Sarajedini A. eds., 1996, ASP Conf. Ser. 92 "Formation of the Galactic Halo: Inside and Out"

Norris, J.E., Ryan, S.G., Beers, T.C. 1997, ApJ 488, 350

Norris, J.E., Ryan, S.G., Beers, T.C. 1997, ApJ 489, L169

Prantzos N., Tosi M. and von Steiger R. eds., 1998, Space Science Series of ISSI, "Primordial Nuclei and their Galactic Evolution", Kluwer

Takeda, Y., Kawanomoto, S., Takada-Hidai, M., Sadakane, K. 1998, PASJ 50, 509

Vanture, A.D., Wallerstein, G. 1999, PASP 111, 84

Venn, K. 1999, ApJ 518, 405

Wallerstein G., Iben I., Parker P., Boesgaard A.M., Hale G.M., Champagne A.E., Barnes C.A., Käppeler F., Smith V.V., Hoffman R.D., Timmes F.X., Sneden C., Boyd R.N., Meyer B.S., Lambert D.L., 1997, Reviews of Modern Physics 69, 995

Zacs, L., Nissen, P.E., Schuster, W.J. 1998, A&A 337, 216

6. MAGNETIC FIELDS AND CHROMOSPHERIC CORONAL ACTIVITY (K. Stepien)

Conferences directly related to the chromospheric and coronal activity have been mentioned in section 1. Their proceedings contain the most comprehensive and up to date information about the progress in the covered field during the past 3 years. Readers interested in more details about the results reported below, should search the proceedings or the most recent astronomical journals for names given here in parentheses. These are the names of the author or co-author (not necessarily the first one, if a whole group is involved and/or more than one paper on a given subject has been published).

A new method of measuring surface magnetic fields of cool stars has been developed (Rüedi), which takes into account several spectral lines simultaneously. The results show that the old measurements have often led to an overestimate by a factor of 2 or more. Magnetic field intensities and filling factors were determined for a few moderately active stars. (Donati) presented new results of a magnetic field mapping technique which uses simultaneously intensities and polarization measurements across many spectral lines to localise magnetic regions on the stellar surface. This method also permits the determination of the field intensity and geometry. A strong toroidal component was detected in a few rapidly rotating stars, like HR 1099 and LQ Hya.

(Hatzes) and (Strassmeier) obtained photometric surface maps of several new stars. They observe consistently the polar spots (sometimes huge) on rapidly rotating, active stars. The radiation transfer calculations show that the existence of these spots cannot be explained by a chromospheric filling-up of the line profiles as suggested by Byrne a few years ago. All rapid rotators show much less surface differential rotation than the Sun (by an order of magnitude).

Cool prominences held by the magnetic field lines high above the photosphere have been observed in a few rapidly rotating young stars (Eibe). In no case, however, prominences extend beyond the corotation radius as observed in AB Dor (Collier-Cameron).

The theorists work hard to obtain improved models of the field generation and activity cycles by an $\alpha\Omega$ dynamo including the saturation effect (Brandenburg) and the differential rotation distribution (Rüdiger). There is an increasing number of observations suggesting the possibility of distributed dynamo operating in the whole convective zone (Saar), (Donati), and the existence of strong, large scale, poleward circulations at the base of this zone in the most active stars (Strassmeier).

While the significance of acoustic waves for chromospheric heating has been challenged (Judge) in favor of nanoflares as a more viable heating mechanism, (Cuntz) and (Ulmschneider) constructed a self consistent model of the chromosphere of a K2 V star with a magnetic field filling factor adopted from observations of stars possessing different rotation rates. The chromospheres are heated by the acoustic wave flux which is constant for all the considered stars, and by the logitudinal Magneto Hydro-Dynamic (MHD) wave flux, transmitted in the magnetic tubes and depending on rotation via the filling factor. Emission in cores of Ca II lines was computed with the non-LTE radiation transfer code. The authors were able to reproduce quantitatively both the weakest observed emission flux and the observed relation between calcium emission flux and the rotation rate of K stars. The calculations of the acoustic heating of chromospheres of stars with different temperatures (Buchholz) agree well with observations of calcium emission in giants from M67 (Dupree).

The Goddard High Resolution Spectrograph (GHRS) on the Hubble Space Telescope was used to get high quality profiles of coronal and transition region lines for a number of stars with different degrees of activity (Linsky). The lines of high activity stars show the earlier reported two-component structure with a broad component, interpreted as arising from microflaring, and a narrow one (but still broadened more than expected from thermal motions) attributed to mhd wave heating. The lines are redshifted with the redshift increasing with the temperature of formation between about 3×10^4 and 10^5 K. Lines formed at significantly higher temperatures look stationary. Giants show a larger redshift (about 10-15 km/s) than dwarfs (a few km/s) but they all suggest the existence of downflows of matter in the transition region and the upper chromosphere. The nature of the downflows is unknown. (Montes) reports the discovery of a similar two component structure of H_α and Ca II IR lines in the very active binary star EZ Peg. The GHRS has been recently replaced with a new, improved spectrograph, the Space Telescope Imaging Spectrograph.

The X-ray and EUV observations of stellar coronae confirm earlier reports about chemical anomalies present in the coronae. The most distinct anomalies are the apparent underabundances of elements having low ($\leq$ 10 eV) first ionisation potential (Jordan), (Drake). The mechanism of forming these anomalies is under debate.

The accumulated observational evidence from stellar coronae (and even more from the solar corona) points toward a high flaring rate on different scales as an important, if not dominant, at least the in case of very active stars, mechanism of coronal heating. Apart from the broad components mentioned above, another argument comes from observations of (Güdel) who showed that the high temperature coronal activity decreases considerably with age of single solar type stars, whereas the low temperature component varies much less.

They interpret this as resulting from a decrease of microflaring activity with an increase of the rotational period. Some flares are impressively hot: temperatures of the order of 100 MK have been observed during flares on very active stars (Güdel), (Pallavicini) and (Tsubai).

A large volume of stellar X-ray data, collected with the ROSAT all sky survey has been published in a series of papers (Schmitt). The data indicate, among others, that practically all cool main sequence stars emit X-rays with a minimum surface flux of about 10^4 erg s^{-1} cm^{-2} - close to the flux from a solar coronal hole. Giants lying to the left of the coronal dividing line have a minimum flux of about 10^2 erg s^{-1} cm^{-2} whereas some stars lying to the right of the dividing line have definitely much weaker fluxes. Nevertheless, several very cool giants have been detected in X-rays.

As the X-ray data on stars of different rotation rate and age become richer, the simplified picture of coronal activity being a tight and monotonic function of the rotation rate (or of the Rossby number in case of main sequence stars), seems to fade away. Profound differences in the X-ray emission of the Hyades and Praesepe stars (Randich) find no explanation when one compares all the known properties of both clusters (Barrado y Navascues). Overactivity of components of SB in Hyades was noted earlier (Stern) and is still not explained. Extremely rapidly rotating young main sequence stars, with rotation periods less than about 0.4 day, show an unexpected and unexplained decrease of activity with increasing rotation rate (Randich). (Wichman) recently confirmed the existence of this "supersaturation" effect among post-T Tauri stars. The more accurate, recent observations of the cool single giant HR 1362 showed that the star rotates very slowly, with a rotation period of about 1 year and yet it is extremely active and covered with large dark spots just like RS CVn type stars (Strassmeier). It is suggested that the giant may be a former Ap star with a strong, kilogauss field.

In July 1999 the successful launch of the Chandra Observatory (formely AXAF) has marked the beginning of a new era in X-ray research. XMM and ASTRO-E should soon join it. All three instruments will be serving the astronomical community as extremely powerful tools for investigating stellar coronae.

R. Pallavicini
President of the Commission