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4. White Dwarf Atmospheres (Rainer Wehrse)

Introductory Remarks. The main characteristic of white dwarf atmospheres is a pressure that is at least two orders of magnitude higher than in main sequence star atmospheres of the same effective temperature. This is due to the high gravity (log $g \simeq 8$), extreme metal under-abundances ($\Delta \log \varepsilon_M \gtrsim 2.5$), and (in many cases) the replacement of hydrogen by helium as the main constituent. As consequences the atmospheres are very thin ($\Delta R \lesssim$ a few km) and the level populations of all species are given by the Boltzmann distribution (perhaps with the exception of the extreme outer layers, Greenstein 1973, Pilachowski 1984). Thus, models can be calculated under the assumption of plane parallel radiative transfer and local thermodynamic equilibrium , which facilitates the numerics very much; but special care has to be taken of pressure effects (e.g., broadening of spectral lines, quenching of levels, changes in the dissociation-ionization equilibria). In addition, the proper consideration of convection, which is very effective and may reach into the optically thin layers, makes the construction of model atmospheres for white dwarfs rather tedious and costly.

Mainly due to the work of Greenstein (see e.g. his paper on spectrophotometry, Greenstein 1984) and R. Green (see Green, Schmidt and Liebert 1984) the empirical basis for studying white dwarf atmospheres has recently widened very much. The new edition of the McCook-Sion catalogue (1984) contains about 1500 white dwarfs for which photometric, spectroscopic and/or astrometric data are available. Most of them are classified in the new system of Sion et al. (1983).

In the following, I want to review some selected aspects of the progress in the understanding of white dwarf atmospheres following the last extensive review (Liebert 1980). However, due to the lack of space, I will not cover the interesting effects of magnetic fields (for a review see Borra, Landstreet and Mestel 1982) and variability (see Winget and Fontaine 1982), nor discuss white dwarfs in close binary systems (see proceedings of IAU Colloquium no. 72).

Spectroscopy in the Ultraviolet. The use of the IUE satellite has revealed the existence of several interesting and unexpected features in the UV spectra of white dwarfs. The most important seem to be:

(i) Several strong CI lines (Vauclair, Weidemann, Koester 1981, Wegner 1981) in the spectral of DC and DQ stars. The resulting abundances span the wide range from C:He = 10^{-2} to 10^{-7}.
(ii) Weak metal lines (Si II - Si IV, C IV, N V) in the high dispersion spectra of some hot white dwarfs of type DA and DO (Bruhweiler and Kondo 1983, Dupree and Raymond 1982). Since they are well separated from the corresponding interstellar lines, they seem to be formed in or at least very near the photosphere. The most likely explanation for their appearance is that the ions are levitated by the strong radiation field.
(iii) Broad depressions in DA stars around 1400 and 1600 Å (Greenstein 1980, Wegner 1982, Sion, Wesemael and Guinan 1984). It seems that they are formed by satellite lines of Lyα and are caused by the interaction of the radiating atom with protons and other hydrogen atoms (Koester et al. 1984).

High Signal-to-Noise Optical Spectroscopy. The application of high efficiency linear detector systems at several observatories made possible the detection of very weak features and/or the study of small, but for the analysis significant differences from star to star.

As a result, for the first time a cooling sequence for DB stars could be constructed (Oke, Weidemann and Koester 1984). The data showed that the mass distributions of DA and DB stars are very similar so that both types seem to have the same progenitor stars.

By use of the Kitt Peak IIDS Reticon Wegner and Yackowitch (1982, 1984) were able to demonstrate that many DC objects had to be reclassified since they show weak lines of C_2, H or He in their spectra. The authors suspect that after further reduction of the noise in the spectra of all DC stars features would be visible. Of particular interest is the possibility to detect high members of the Balmer series (Liebert and Wehrse 1983) since it enables the simultaneous estimation of the gravity and the helium content, even if no He lines are seen. This method therefore completes the infra-red observations of induced H_2 opacity (Wickramasinghe, Allen and Bessel 1982) to higher temperatures.

The consequences of the recent discovery of Balmer lines in very cool white dwarfs (Greenstein 1984) are still unclear, since these lines are not predicted by existing models.

Theoretical Developments. In addition to the model atmospheres constructed to interpret the observations mentioned above, Wesemael (1982, see also Wesemael et al. 1980, Sion, Guinan and Wesemael 1982) has calculated extensive grids for hot white dwarfs composed of H and/or He that had long been missing. They have successfully been used not only in the analysis of white dwarfs (Wesemael, Green and Liebert 1983), but also for hot subdwarfs (Wesemael et al. 1982).

The atmospheric structure of very cool pure He white dwarfs has been studied by Kapranides (1983, see also Kapranides and Böhm 1982). He shows that the pressure may get so high that at an optical depth $\tau=1$ the matter is already degenerate and conduction transports a large fraction of the energy. However, a corresponding star has not yet been identified. If some metals are present the situation is much less extreme, but the additional difficulty arises that several compositions give the same synthetic spectrum to a very high accuracy, since there are no elements with lines from two ionization stages and several potential electron donors do not show up directly (Liebert, Wehrse and Green 1984).

Several papers have been devoted to the origin of the extreme abundance distributions. Although it has been clear for some time that the metal abundances must be the result of an interplay between gravitational settling and accretion (see, e.g., Vauclair and Vauclair 1982) , it was not understood how the He-rich stars could manage to accrete heavy metals, but essentially no hydrogen. Wesemael and Truran (1982) now suggest that a slowly rotating, weakly magnetized white dwarf may be screened from accreting interstellar H by the propeller mechanism of Illarionov and Sunyaev (1975), whereas metals in grains due to their different charge to mass ratio can penetrate to the stellar surface. Another long-standing question has been whether or not DA stars convert into helium rich objects. A promising clue for a solution seems to be the finding of Michaud and Fontaine (1984) that at least under favourable conditions diffusion may transport hydrogen to so deep layers that it can burn into helium.

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5. Atmospheres of accretion discs (James E. Pringle)

Accretion discs are a popular ingredient among theorists for modelling a number of high energy astronomical objects like quasars, active galactic nuclei (Rees 1984) and galactic X-ray sources (Levin and van der Heuvel 1983). However, the observational evidence (as opposed to the strong theoretical presumption) that accretion discs exist in these objects is weak, and in only one case has some attempt been made to argue the case for a disc on the basis of its spectral properties (Malkan 1983). Indeed the structure of accretion discs is sufficiently ill-understood that any progress in this area must rest on a strong interaction between theoretical modelling and the actual observation of accretion discs in action. The only