Over Be-sterren en de bouw en samenstelling van Wolf-Rayet-sterren

Weenen, J.

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On Be stars and the structure and composition of Wolf-Rayet stars.

SUMMARY.

In order to explain the large colour indices for Be stars and an anomaly in the temperature determination from HeII and HeI lines of Wolf-Rayet stars by Zanstra's method, Kosirev assumed a model of an extended photosphere which appeared to produce an ultraviolet excess, thus eliminating the difficulty. In the first part of the dissertation, §1-§12, Kosirev's treatment is improved upon by assuming, instead of an absorption coefficient independent of wavelength, the absorption coefficient of hydrogen with its dependence on \( \lambda \). The numerical quantities were chosen with a view of representing a Be star, of which 48 Librae is a typical example.

The star is represented by a black body of a temperature of 25000° at the boundary between star and envelope. In choosing the density, care was taken to have a certain amount of absorption of the star light by the envelope in the observable region, mainly due to the Balmer- and Paschen continua. The optical depth in the Lyman continuum then became very large.

The equation of radiative transfer for curved layers was used. For that part of the envelope having temperatures of 15000° and higher, it turned out that scattering by free electrons became of much greater importance than the Rosseland mean of the hydrogen absorption. Assuming local thermodynamic equilibrium, the temperature could be determined as a function of the radius (§4) choosing the thickness of the shell equal to the radius of the star (§1).

The intensity distribution in the spectrum was then derived. For the Lyman continuum the star plus surrounding shell then behaved as a black body of a temperature equal to the outside boundary temperature (§7). Other wave-lengths gave rise in some cases to predominant absorption (\( \lambda \) 3000, \( \lambda \) 6000, \( \lambda \) 8000, §9), in other cases to predominant scattering by electrons (\( \lambda \) 1000, \( \lambda \) 12000, \( \lambda \) 14000, §8). As compared with a black body of the same total radiation, the spectrum turns out to be strongly distorted: the Lyman continuum is extremely weak, likewise the region near the Balmer limit, while in the visual region this loss is compensated and the radiation is much stronger (§10, Fig. 2 and §11). Indeed this gives rise to a large colour index in the visual region, but not to Kosirev's excess of radiation in the ultraviolet, which, to the contrary, becomes very weak (§11).

A comparison of our theoretical results with the observation of a typical Be star like 48 Librae, showed that the observed electron concentration according to Struve is much smaller than used in our model, and therefore insufficient to produce a notable absorption of the underlying star light by the envelope (§12). The possibility naturally remains that, among the many known Be stars one might find a group satisfying the theoretical model used, but certainly this is not so for the large majority of cases.
Now turning to the Wolf-Rayet stars, Kosirev's idea of an extended photosphere encounters even greater difficulties. If those show also a large optical depth in the Lyman continuum, as in fact Kosirev assumes, a proper treatment with the absorption coefficient dependent on \( \lambda \) gives rise to a lack of radiation for wavelengths shorter than \( \lambda_{H_{\alpha}} \). This however is in contradiction with the observations of Wolf-Rayet stars which are surrounded by a planetary nebula (\$12) where always hydrogen emission is observed in the nebula. Thus one is forced to conclude that the optical depth of Lyman continuum is small in the Wolf-Rayet envelope, and Kosirev's treatment can no longer be upheld. So we return to Beals' original model of a Wolf-Rayet star, viz, a hot star eventually with an ultraviolet excess in itself, surrounded by an envelope in which the mechanism of nebular luminosity is applicable. Such a treatment of Wolf-Rayet stars is now presented in the following sections of the dissertation, after the introductory \$13.

A discussion of spectra of planetary nebulae which surround Wolf-Rayet stars shows that a concentration of radiation in emission lines of high ions which subsequently escapes the Wolf-Rayet envelope is unlikely (\$14). The same material provides an argument in favour of Beals' hypothesis for the Wolf-Rayet envelope: ionisation from the ground state by stellar radiation followed by recombination (mechanism of nebular luminosity). With this mechanism the transition of the inner HeII shell to the outer HeI shell in the Wolf-Rayet envelope is then investigated, and it proves to be very abrupt, so that practically never the spectra HeII and HeI are emitted together (\$18). The Wolf-Rayet envelope can therefore be divided into successive shells of predominantly HeII+ and HeI+ ions, eventually followed by a shell of neutral helium.

This sharpness of the ionisation limit and consequent division of the atmosphere in subsequent layers is then used for determining the abundance of carbon with respect to helium, using Beals' observed band intensities. This is likewise based on the assumption of the mechanism of nebular luminosity applied to the Wolf-Rayet envelope, as in the above, but now the assumptions are more general, since it is no longer assumed that the star behaves like a black body, except in the visual region (\$19). To this end two models have been postulated. In model I the CIII and HeII shells terminate together and adjoin there the combined CII and He I shell. By this method, which is entirely based on numbers of recombinations, the electron concentration drops in the abundance formulae. For ions not of the hydrogen type the numbers of recombinations are also determined by means of the collision factors, which approximation has some justification for higher levels. The computations for this Model I (Fig5) are contained in \$20-\$28.

In Model II (\$30 and Fig.7) it was assumed that the first transition layer separates the CIV from the CIII region, while farther outward the HeII is separated from the HeI region, but that then the CIII region extend to infinity.

In addition to this, the ratios of the radii of the shells were determined. The results for both models are summarised in \$31, tables 17 and 18.
The abundance ratios of carbon with respect to helium determined in this way are very high. Aller, who assumes thermal equilibrium for various excitation temperatures derived from his observations, finds 10 to 20 times lower abundances for the same stars.

Finally the ratio of hydrogen to helium is determined in a corresponding manner for one star for which Beals disentangled the blends of hydrogen and helium lines, one finds abundance ratio of the order 1 (§32). Neubauer and Aller, assuming thermal equilibrium, obtained similar results for a different Wolf-Rayet star.

The conclusion based on the foregoing is that one should seriously face the possibility that the Wolf-Rayet envelopes the abundance ratios are quite different from those in other stars and that the abundance of carbon may even be of the same order as that of helium and hydrogen.