IX. The Density of the White Dwarf A. C. + 70° 8247.

By E. Öpik.

For this star Kuiper finds a density of the order of $> 10^7$ gr/cm^3 (Publ. Astr. Soc. Pacific **47**, 307, 1935); a revision of his data indicates that his estimate cannot be accepted, and that the star must have a density of $\sim 10^5$ gr/cm^3, thus nothing exceptional as compared with the two well determined cases (Sirius B, 3.10^4 gr/cm^3; o^2 Eridani B, 5.10^4 gr/cm^3; cf. Gabovitš and Öpik, T. P. $\mathbf{28}_3$, 1935). The absence of the hydrogen Balmer lines in the spectrum of this star is explained as the result of the exhaustion of hydrogen, the main source of subatomic energy.

Kuiper's estimate is based on a comparison of the colour of A. C. + 70° 8247 with 10 Lacertae (H. R. 8622, mag. 4,91; H. D. 214680, sp. Oe 5); he finds the colours of the two stars essentially equal, and concludes that the effective temperature of the white dwarf is equal to 28000°, the "true" effective temperature of the O star; he thinks that space reddening does not affect the colour of the comparison star, 10 Lacertae. The latter assumption is quite arbitrary. The distance of 10 Lacertae (absol. mag. ~ -5 to -6) exceeds 1000 parsecs and space reddening at such a distance cannot be entirely absent. For the white dwarf, at ~ 15 parsecs distance, the space reddening is negligible. Thus the colour of the white dwarf must be redder than the "true" colour of 10 Lacertae by the whole amount of space reddening over 1000 — 1600 parsecs.

In the general catalogue of stellar colours by the writer (T. P. $\mathbf{27}_1$, 1929), the colour of 10 Lacertae is $C = -0.41 \pm 0.03$; the system of these colours is connected with the effective temperature by the relation

$$\frac{C_2}{T} = 1.47\, C + 1.82 \text{ (cf. Öpik, Ap. J. } \mathbf{81}, 177, 1935),$$

which gives $T = 11700^0 \pm 300^0$. If the temperature is too low for the O star on account of space reddening, it must be accurate for A. C. + 70⁰ 8247 if the colours are equal. Our empirical formula for the colour temperature cannot be much in error for such a low temperature as $12\,000^0$; Wien's formula which underlies theoretically (not empirically) the linear relation leads to an error in the colour temperature of only -100^0, as compared with Planck's law, and the actual error must be smaller on account of the empirical derivation of the relation. As no spectral lines appear in A. C. $+70^0$ 8247, there can be no question of the spectral energy distribution to be distorted by absorption lines.

On the other hand, there is a direct indication of a not inconsiderable space reddening of 10 Lacertae. In the above mentioned catalogue of stellar colours we find fifteen northern stars which are at least as blue, or bluer than 10 Lacertae:

Harvard Revised Photometry Numbers

Star No.	153	6787	7298	7426	7739	7131	8603
m	3.7	4.3	4.5	4.8	4.8	5.5	5.1
H. D. Sp.	B3	B3	B3	B3	B3	B3	B3 + B5
C	− 0.43	− 0.42	− 0.62	− 0.48	− 0.45	− 0.45	− 0.45
p. e.	± 0.03	± 0.04	± 0.04	± 0.04	± 0.03	± 0.04	± 0.04

Göttingen Aktinometrie Numbers

Star No.	584	720	791	1016	1068	2766	2772	2950
m	7.3	6.4	7.2	7.1	6.8	6.7	7.2	8.0
H. D. Sp.	B3	B3	B8	B2	B5	AO	B3	B5
C	− 0.53	− 0.41	− 0.46	− 0.44	− 0.41	− 0.45	− 0.49	− 0.42
p. e.	± 0.04	± 0.04	± 0.04	± 0.04	± 0.04	± 0.04	± 0.04	± 0.04

The prevalence of spectrum B3 in this list is remarkable. Thus, a number of stars of spectra later than 10 Lacertae show the same colour (and colour temperature) in spite of the well known effect of the wings of hydrogen Balmer lines which tend to make the B and A spectra redder[1]; the ionization temperatures of these stars are about $15\,000^0$; a comparison of the colour of A. C. $+70^0$ 8247 with one of these B3 stars would have led, according to Kuiper's way of reasoning, to a tempe-

[1] Violet — blue colour indices of AO stars are almost equal to those of KO stars, on account of Balmer absorption, cf. T. P. **26**$_3$, 1925.

rature of 15 000^0 for the white dwarf; but even this must be considered as too high because some space reddening is doubtlessly present already in the B3 stars.

There is no reason to assume that the colour temperature of 11700^0 for A. C. + 70^0 8247 is systematically in error, as it is from space reddening for the distant B and O stars, and for the B and A stars on account of Balmer absorption. As the estimated density varies with the sixth power of the effective temperature, Kuiper's density must be decreased 190 times; his estimate of mass as a function of radius (Chandrasekhar's relation) must also require a reduction factor of ~ 2.5, and the corrected density of A. C. + 70^0 8247 becomes

$$\frac{3,6.10^8}{190.2,5} = 70\,000 \text{ gr/cm}^3,$$

or by only 40 per cent greater than for o^2 Eridani B.

The absence of lines (cf. Kuiper, loc. cit.), chiefly of the Balmer lines of hydrogen in the spectrum of A. C. + 70^0 8247 (which should be the most prominent lines at 11 700^0, corresponding to a normal B9 — A0 star) may be considered as a proof of Atkinson's theory of atomic synthesis; a star cannot become a white dwarf before all its internal store of hydrogen is exhausted. For Sirius B and o^2 Eridani B the mixing is apparently incomplete, so that some hydrogen is preserved at the surface; in A. C. + 70^0 8247 the mixing is probably complete, and hydrogen absent from the atmosphere, as it must be absent from its interior.

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