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STUDIES OF THE WHITE DWARFS. I. BROAD FEATURES IN WHITE DWARF SPECTRA

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ABSTRACT

The method for measuring broad, shallow features in white dwarf spectra is described. Unidentified bands in AC+70°8247, W 219, and L 879-14 are illustrated in Figures 1–3. Broad, very shallow lines of He I are found in HZ 29, a probable white dwarf, and illustrated in Figure 4.

TECHNIQUE

It is possible, by careful spectrophotometry, to detect the presence of lines or bands with a central absorption of only a few per cent. However, in stars in which the lines are broad, shallow, and even unidentified, the personal prejudice of the measurer may force incorrect shapes or even wave lengths on such weak features. As a result, in the spectrophotometry of the peculiar white dwarfs we have used an impartial technique similar to that of Baker (1949) and of Greenstein and Richardson (1951). Essentially, it depends on averaging several unsmoothed microphotometer tracings of several spectra of each star.

The material here discussed includes several nearly featureless spectra. These were obtained with the 200-inch Hale reflector, either at the coudé focus (Pe series, 38 A/mm) or at the prime focus (N series, 180 A/mm). Baked II*a*-O spectra, with wedge-spectrograph calibration, were analyzed either on the Babcock direct-intensity or on a normal transmission-type microphotometer. The spectra were moderately wide (0.25–0.85 mm on the plate), and a wide analyzing slit was used. A smooth background was drawn on the tracings; a sharp-lined early B star was used as a guide in the location, slope, and curvature of the background. The tracings were then analyzed, point by point, at a regular wave-length spacing, with no smoothing of the actual record. Deflections with respect to the arbitrary, smooth background continuum were measured, reduced to an intensity scale, and plotted. Data from many tracings were combined, and averages taken of the unsmoothed apparent absorptions (or emissions).

If the background has been placed too high on one tracing, for example, out of n, it will result in a spurious absorption $1/n$ times the error, appearing in the mean at all wave lengths. If the slope of the spectrum has been incorrectly estimated, apparent emission lines will dominate at one end of the spectrum, absorption lines at the other. However, only abnormally large fluctuations will persist, in the mean, and introduce spurious lines. The final means are corrected for errors of slope and level of continuum, by drawing a new continuum, and the data are presented graphically. The method is slow and laborious, but it seems to reveal most clearly features which are invisible to the eye on the original spectra or seen only as broad and featureless. It should be understood that there is no doubt of the reality of features with depth greater than 3 per cent.

AC+70° 8247

The white dwarf, AC+70°8247, has been previously observed by Minkowski (1938) and by Kuiper (1941). Preliminary results based on Pe plates were given by Greenstein (1956). In this special case the importance of these still unidentified "Minkowski bands" led to a further development of the technique. Some of the suspected bands are so broad and shallow that it was necessary to determine the location of the background accurately and over a wider range of wave lengths. For this purpose, measurements were taken along the *smoothed* continuum of a comparison early B star, and the difference between the stellar magnitude in the unsmoothed spectrum of the white dwarf and that in the B star was plotted as a function of $1/\lambda$; differences in temperature and, to a certain degree, in the extinction appear as a straight line in such a plot and were removed by a linear correction which was applied to the *unsmoothed* individual measures.

In addition to three Pe plates, two good low-dispersion N plates have now been measured. The results of the measurements are shown graphically in Figure 1, which gives A_λ (the "absorption" at any wave length) over the entire observed spectral range. Points at $\lambda > 4600$ A and at $\lambda < 3600$ A are of relatively low weight. This figure indicates that the Minkowski bands at λλ 4466, 4135, and 3650 A are undoubtedly real and that additional bands may exist at λλ 4650, 3915, and 3425. The reliability of the wave lengths can best be judged from the figure. In the process of measurement, the zero point of the wave-length scale was reliable, on any one tracing, to about 5 A; the means should be good to about ±2 A systematically. On the other hand, the width of the features makes more accurate wave lengths meaningless. Only λ 4135 can be seen clearly; the other features are barely visible on the broad, low-dispersion N plates.

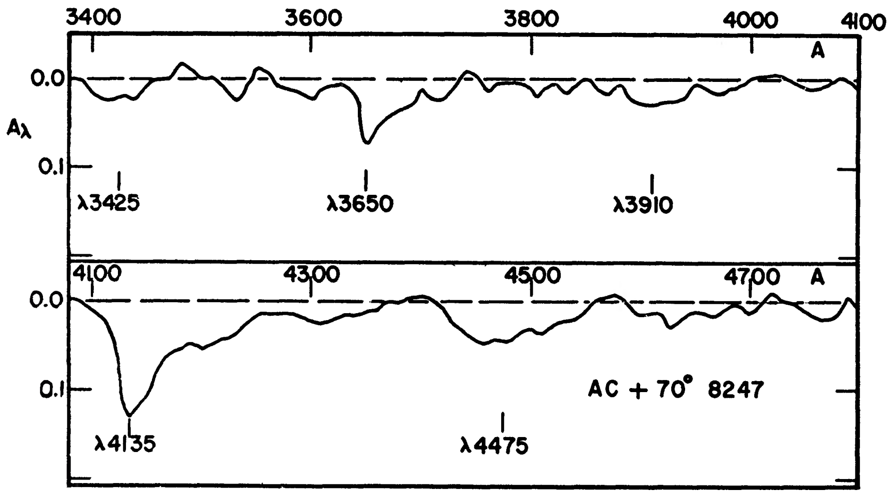

FIG. 1 —The profile of absorption bands in the white dwarf AC+70°8247, as derived from five plates. Note that the line depth, Aλ, seldom exceeds 10 per cent.

A photolectric color by Daniel L. Harris III (1956), kindly communicated in advance of publication, is $B-V = +0^m.05$, $U-B = -0^m.85$. Kuiper (1941) had originally given a rough spectrophotometric color which was very blue; this is not confirmed. G. P. Kuiper kindly informs us, in advance of publication, that he reported photoelectric colors at the December, 1949, meeting of the American Astronomical Society, which first demonstrated that the star was not very blue. The luminosity, from a trigonometric parallax of 0".066, is $M_V = +12.3$; from the calibration of the $B-V$ and $U-B$ colors of a black body by Bonsack *et al.* (1957), the temperature is near $T_e = 11500°$, and the radius, therefore, is near 0.012 $R_\odot$. The star is not exceptional in radius or temperature (and therefore probably not outstanding in density). It is, in fact, somewhat yellowish compared to many of the hydrogen-line DA stars. Its composition must therefore be very peculiar to produce a spectrum which so far defies identification. The low temperature suggests that He I, which might account for the features at λλ 4466, 4135, and 3910, cannot be involved. Mg II λ 4481 and Si II λ 4128, λ 4132 seem not to be satisfactory. No other white dwarfs, of approximately fifty which have been studied at Palomar, show these Minkowski bands.

THE λ 4670 BAND IN L 879-14 AND W 219

A new white dwarf, Luyten 879-14 (Greenstein and Luyten 1957), and a well-known object, Wolf 219, prove to have one very strong, broad feature in their spectra. This feature is at closely the same wave length in both stars. It is deeper in L 879-14, where it has an equivalent width of 18 A; in W 219 it has $W = 11$ A; the band is illustrated in Figures 2 and 3. There is a possible weak feature at λ 4355. The λ 4670 band is quite easily visible at 180 A/mm.

A photoelectric color of W 219 by Harris is $B-V = +0^{m}.30$, $U-B = -0^{m}.52$. The star is yellowish, and Luyten has also noted that L 879-14 is yellowish photographically.

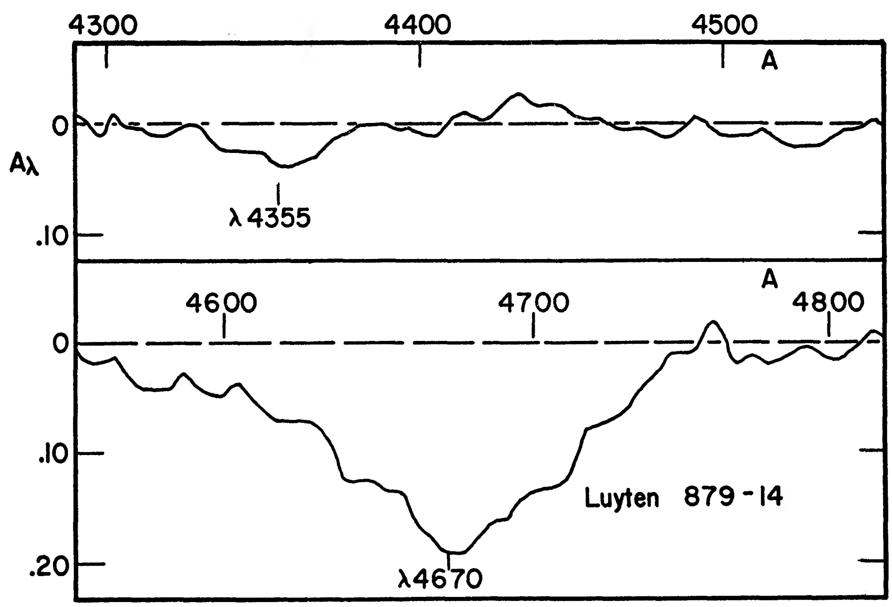

FIG. 2 —The profile of the absorption band, λ 4670, in the white dwarf, Luyten 879-14, based on two plates.

Since the spectrum is so nearly featureless, the black-body calibration of the temperature from the colors should be quite good. From the results of Bonsack *et al.* (1957) we obtain $T_e = 7500°$ for W 219. The parallax is 0".068, which gives $M_V = +14.5$ and a radius of 0.0065 $R_{\odot}$. This is, in fact, one of the smallest radii derived among the white dwarfs studied by Greenstein (1957). The width and strength of the band may be correlated with high pressure and possibly also an abundance anomaly. The temperature is too low to permit identifiction of λ 4670 with He II λ 4686 or the blend of C and N ions at λλ 4640–4650. It should be noted that the λ 4135 and λ 4670 bands appear in stars cooler than those in which the Balmer lines are strong. They replace the normal metallic spectrum (Ca II, Fe I, etc.) of the main-sequence A and F stars. One may ask whether molecular compounds may not, in fact, appear, with structure blurred, altered, and shifted by high pressure. The bands of C_2 heading normally at λ 4737 may be mentioned. Only two low-dispersion N plates each were available for these stars, and the spectral region is limited to the blue and violet. Further exploration in longer-wave-length regions is planned.

With the temperature and luminosity given, W219 has a mass of 1.2 ⊙, if $\mu_e = 2$, and the star is completely degenerate. The surface gravity is then log $g = +8.9$; this is high compared to the average white dwarf and may demand exceptional high-pressure phenomena in the spectrum.

THE PECULIAR DB STAR, HZ 29

Among the faint blue stars discovered by Humason and Zwicky (1947), HZ 29 has the most peculiar spectrum observed. Greenstein (1956) suspected weak, shallow hydrogen lines. More careful measurement of better spectra, including two Pe and three N plates, gave the extraordinary spectrum shown in Figure 4. In HZ 29 identification seems quite

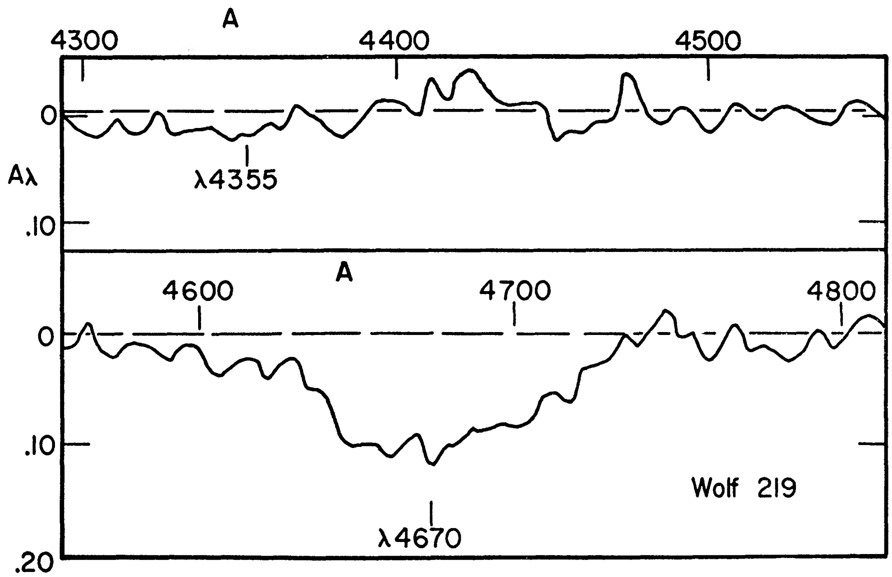

FIG. 3.—The profile of the absorption band, λ 4670, in the white dwarf, Wolf 219, based on two plates. This star has the low luminosity of $+14^{m}.5$.

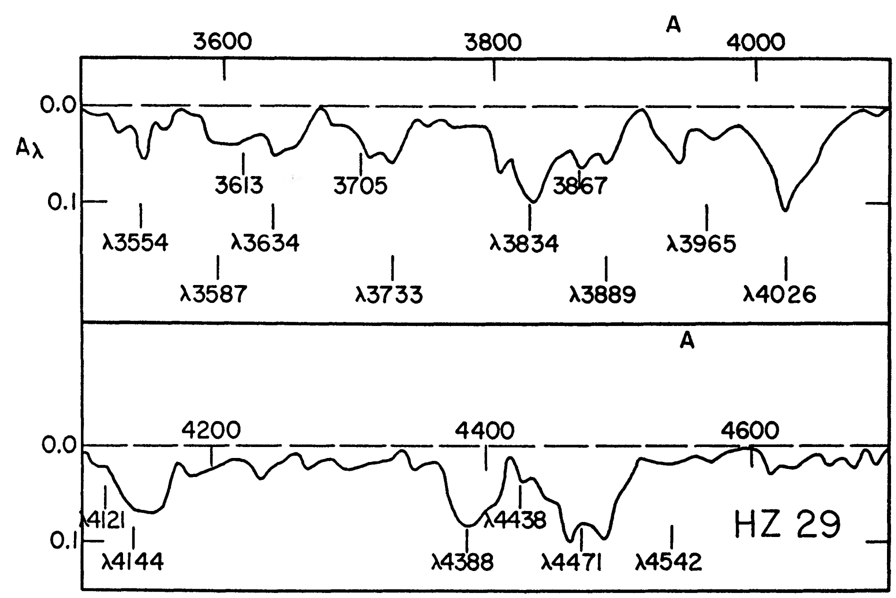

FIG. 4.—The profile of the absorption lines in HZ 29, based on five plates. This star is either a very faint hot subdwarf or a bright white dwarf. The vertical dashes and wave lengths are lines of He I, which is clearly dominant in HZ 29; no hydrogen lines seem to exist.

straightforward. The He I lines agree quite well in position and often in relative intensity with the shallow features in HZ 29. Most of the strong features in HZ 29 are thus accounted for, and there seems to be good evidence that the Balmer lines and the bands at λ 4135 and λ 4670 are absent. Thus HZ 29 resembles L 930-80 and L 1573-31 in the absence of H and the strength of He I. It differs substantially, however, from the normal helium-rich white dwarf. In the latter, the He I lines are strong, easily visible, and relatively deep. In HZ 29 they are very shallow and so diffuse as to appear almost double. In addition, such features as the sharp cores in λ 3889 and λ 3965 seen in L 1573-31 are definitely absent in HZ 29. The spectral region well covered is $3600 < \lambda < 4650$.

In color HZ 29, according to Harris, has $B-V = -0^{m}.23$, $U-B = -1^{m}.01$; it is therefore quite hot. No parallax is known, and the proper motion is small, $\mu = 0''.045$. Only a rough estimate of luminosity can be given; the star is in the north galactic polar region and is obviously of low luminosity. If we treat it as having the same space motion as a typical white dwarf, $M_V \approx +9$. It is either a faint hot subdwarf or a bright white dwarf.

The peculiar, nearly double, structure shown in the lines suggests rotation. The lines are too diffuse for velocity measurement. Plates taken at short intervals and on successive nights failed to show any large shifts such as might be expected if the star were a binary with an amplitude comparable to its possible rotation.

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