There are traces of other bright lines coinciding with chromospheric lines. The three-prism wavelengths are the only ones corrected for radial velocity. The lines at λ 4584 and λ 4629 apparently partake of the velocity displacement in common with the hydrogen lines.

The bright lines are not monochromatic, but broad or double. Occasionally a setting may have been made on one component only. This is perhaps the case on plate M 180 I, for λ 6493, λ 6459.8, and others. On the poorer lines the settings are not easy. λ 4584 and λ 4629 as photographed with high dispersion are very broad and hazy.

That the strong chromospheric lines should appear bright in a star is not very remarkable, since, if the solar photosphere were considerably weakened in emissive power relatively to the chromosphere, we should have the lines bright in the Sun. A possible explanation of the doubling of the lines is that of self-reversal, similar to that observed very frequently in the electric arc.⁷ As the lines are bright it is reasonable to suppose that the chromospheric layer of ϕ Persei is thicker and denser than that of the Sun, these conditions being favorable to broadening and reversal. Evidently the causes of the peculiarities of the hydrogen lines are affecting some of the metallic elements also. The separation of the double lines varies roughly as the wavelength. There is but little positive significance in this fact, but it is at least not

out of accord with the idea of reversal. The H α line offers an apparent exception. It is not resolved on my plates, and the separation is probably not so much as 7 Angströms.

The apparent absence of magnesium radiation or absorption, and the presence of the absorption of helium and sodium are striking features. D₁ and D₂ are fine sharp lines, fairly strong. D₃ is wider, but well defined. The relative intensities of the hydrogen and the other lines are of the same order as that given by Young; but the phenomena presented by helium, magnesium and sodium are anomalously at variance with the chromospheric spectrum.

A number of other Class B stars with hydrogen emission lines also show some of the chromospheric lines bright. They do not always appear double, but ϕ Persei does not offer the only instance of that phenomenon.

That the lines of the atmosphere of a solar star should be present in the spectra of Class B stars argues for the unity of the stellar system. When the luminous elements shall have become less brilliant their emission lines will disappear from the spectrum; and on losing still more ground their absorption lines⁸ will appear and the star will be well along in its life history.

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A REVIEW OF THE RADIAL VELOCITY OBSERVATIONS OF α PERSEI

A recent paper by Hnatek (*A. N.*, **192**, 18, 1912), in which he concludes that the radial velocity of α Persei varies in a period of 4.1 days, suggests the desirability of a more comprehensive treatment of the subject, based upon all available observations.

We need not consider the visual observations made at Greenwich between the years 1880 and 1890, since the radial velocity was determined from one line only and there was a range of nearly 150 km. per second. Photographic observations have shown a range about one-tenth of this amount. The first photographic determinations were made by Vogel and Scheiner (*A. N.*, **121**, 257, 1889) in December, 1888. Their results from two plates gave the velocity as -10.3 km. per second. The next observations were obtained by Campbell (*Ap. J.*, **8**, 150, 1898), who found a mean velocity of -2.4 km. per second, with a probable error of a single observation of ± 0.53 km.

⁷ In this connection cf. Kayser's *Handbuch der Spectroscopie*, Band 11, pp. 257, 350.

Newall obtained a series of observations from which he concluded (*M. N.*, **61**, 13, 1900) that the star had a variable velocity. He was unable to determine from his observations whether the orbit was circular, with a period of 4.20 days, or a very eccentric ellipse, with a period of 16.8 days. His request that other observers take advantage of the favorable position of α Persei led to the publication of a longer series by Campbell (*L. O. Bul.*, **1**, 24, 1901), with a mean velocity of -2.19 ± 0.40 km. per second, and a series by Vogel (*Ap. J.*, **13**, 322, 1901) with a mean velocity of -3.22 ± 0.69 km. per second. Newall and Goatcher published (*M. N.*, **62**, 124, 1902) another series with a mean velocity of -0.19 ± 1.32 km. per second. In this article Newall recognized that the observations at Mt. Hamilton and at Potsdam offered no support to his suggestion of a variable velocity. He further concluded that his later observations would fit neither

⁸ For some very interesting remarks on this change in the case of the hydrogen lines see papers by Campbell, *Ap. J.*, **2**, 177, 1895, and by Kayser, *Ap. J.*, **14**, 313, 1901.

of the suggested periods. He published (*M. N.*, 63, 298, 1902-03) a third series showing a mean velocity of -2.61 ± 1.07 km. per second, and later (*M. N.*, 65, 653, 1904-05) a list by Bellamy which gave a mean velocity of -4.56 ± 1.65 km. per second. In this latter paper he stated that he had not as yet any special temperature control on his spectrograph, be-

yond a thick quilted feather cover. The thermometer readings taken at the beginning and end of the Cambridge exposures show variations which are very large when compared with those of the Mills spectrograph. This probably explains a large portion of the variation in the results obtained.

The results by other observers are given below:

Observers	No. of obs.	Velocity km. per sec.	P. E. of a single obs.	References
Adams and Frost	3	-2.17	± 0.49	<i>Ap. J.</i> , 18, 255, 1903
Belopolsky	11	-2.69	± 0.79	<i>Ap. J.</i> , 19, 94, 1904; <i>Pulk. Mitt.</i> , 1, 37, 1905-6
Zurhellen	6	-2.24	± 0.55	<i>Ap. J.</i> , 27, 306, 1908
Slipher	5	-2.54	± 0.37	<i>Low. O. B.</i> , No. 23, 1905; <i>Ap. J.</i> , 22, 328, 1905
Harper and Plaskett	4	-2.10	± 0.78	<i>Rep. Ch. Ast. Can.</i> , App. 2, 1906-7-8; <i>Rep. Ch. Ast. Can.</i> , 1907, p. 93
Belopolsky	15	-1.57	± 1.43	<i>Pulk. Mitt.</i> , 3, 217, 1910
Goos	37	-1.66	± 0.61	<i>A. N.</i> , 180, 55, 1909
Hnatek	5	-3.58	± 2.67	<i>A. N.</i> , 190, 281, 1912
Hnatek	49	-3.42	± 0.87	<i>A. N.</i> , 192, 18, 1912

Figure 1

In addition to the above observations, the following unpublished results have been obtained here:

Gr. M. T.	J. D.	Velocity km. per sec.	Reduced by
1904 Oct. 18.075	2416772.075	-0.72*	R. E. Wilson
	2416772.075	+0.03	Burns
Oct. 31.929	2416785.929	-1.65	Burns
1905 Jan. 2.722	2416848.722	-2.51	Miss Hobe
Mar. 1.707	2416909.707	-3.40	Miss Hobe
	2416909.707	-3.21	Burns
1912 Oct. 11.834	2419687.834	-2.25	Miss Hobe
	2419687.834	-3.31	Pitman
Oct. 12.994	2419688.994	-2.65	Miss Hobe
	2419688.994	-2.18	Pitman
Oct. 13.833	2419689.833	-2.35	Miss Hobe
	2419689.833	-1.90	Pitman
Oct. 15.822	2419691.822	-3.06	Miss Hobe
	2419691.822	-3.28	Pitman
Oct. 16.809	2419692.809	-2.84	Miss Hobe
	2419692.809	-2.47	Pitman
Oct. 18.794	2419694.794	-1.86	Miss Hobe
	2419694.794	-1.70	Pitman

* Recent measures of this plate by Miss Hobe and Pitman give the velocity as -1.70 and -2.20 km. per second, respectively.

The six observations of October, 1912, give a mean velocity of -2.49 ± 0.42 km. per second.

Goos plotted his long series of observations on the basis of a period of 290 days, and drew a velocity curve with double amplitude 1.4 km. If we form the sum of the squares of the residuals from his curve and again from the mean of all his observations we find, in agreement with Goos's results, that the curve satisfies the observations better than a straight line does. The $[vv]$'s are 16.2 and 29.2, respectively. In order to compare Hnatek's observations with Goos's curve, we apply a systematic correction to each of Hnatek's observations (except to those which he has himself omitted) such that the mean of Hnatek's observations will equal the mean of Goos's. We then find that $[vv]$ for Hnatek's observations from Goos's curve is 22.8, whereas from a straight line it is 21.2. These results show that Goos's curve satisfies his own observations better than a straight line does, while a straight line satisfies Hnatek's observations better than Goos's curve does.

Hnatek found from his own observations that the variation had a period of 4.0938 days, and a double amplitude of 1.8 km. We note that on the first day of his cycle ten observations fall above his curve and five below it; whereas on the remaining three days nine observations are above the curve and eighteen below. These facts suggest that a curve of considerably smaller amplitude would satisfy the observations better. The $[vv]$ for Hnatek's observations with reference to his curve is 12.6, whereas with reference to a straight line it is 21.2. Hnatek's curve does not fit Goos's observations nearly so well as a straight line does, for we find that $[vv]$ with reference to the curve is 40.8, whereas it is 29.2 with reference to a straight line.

We might consider the other groups of observations separately in the same manner, or collectively. Adopting the latter plan, it is first necessary to reduce the observations to a common basis. This may be accomplished by reducing the mean of each group to the general average. For this purpose we may either use the mean of all the observations, which is -2.13 km. per second, or we may exclude those observations of Hnatek which he excludes, and five others of his (*A. N.*, 190, 281, 1912), together with those of Newall, Goatcher, and Bellamy, which were subject to large temperature variations, as the mean of the remaining observations is -2.12 km. per second. In the accompanying figures the plotted observations have been systematically corrected on the latter basis.

Figure 2

Those observations by Hnatek which have been excluded are represented by (+), and the excluded Cambridge observations by (X). The observations indicated by small circles are those which were obtained here, too late to use in this investigation.

We find that $[vv]$ from Goos's curve, for all the utilized observations, which are represented by black

dots, is 212.2 and that the $[vv]$ from a straight line is 212.0. It is interesting to note that the mean of the observations falling between 20 days and 120 days is -1.9 km., while the mean of those falling between 180 days and 280 days is -2.4 km. This range is only 0.5 km. The sums of the residuals from these two means show that if the maximum of Goos's curve were lowered and the minimum raised the curve would divide the observations more equally. If such a curve be drawn, as indicated by the discontinuous line, in Figure 1, we find that the sum of the squares of the residuals is 198.7. However, the double amplitude of this curve is only 0.8 km. per second, and there is a doubt whether the results have real significance.

If we consider Hnatek's curve with reference to the collected observations, we find that $[vv]$ is 285.9, while from a straight line it is only 212.0. We note, in Figure 2, that on the first day of his cycle about 80 per cent of the observations lie above the curve. A glance at the figure shows that his curve has no apparent relation to the observations.

Summing up, we find that Goos's curve fits his own observations better than a straight line does, but a straight line satisfies the observations better than Hnatek's curve does. Hnatek's curve fits his own observations better than a straight line does, but a straight line satisfies the observations better than Goos's curve does. A straight line satisfies the collected observations better than either of the suggested curves. While the discontinuous curve represents the

observations better than a straight line does, the improvement is slight, and the radial velocity of *a Persei* seems to be either constant, or only minutely variable in a period still undetermined.

I am indebted to Miss Hobe for the measurement of recent plates and to Director Campbell, under whose direction this work was done.

December 1, 1912.

J. H. PITMAN.