

lels the different coal beds of northern France with those of Belgium and England.

The greater part of the volume is taken up with the insects (pp. 93-321), and the author confirms Handlirsch's conclusion that during Westphalian time hexapods were large, in fact, that as a rule they were "giants." Pruvost thinks that the Westphalian insects were not all carnivorous, but that some may have fed on the pollen, etc., of plants like the cordaites and cycadophytes; in other words, that the rise of the insect world was largely conditioned by the development of inflorescence among plants.

Insect impressions, to be preserved in the rocks, must be entombed in the very finest of sediments. The author states that they are found only in shales, in association with delicate plant remains, and with those of animals as well. The very best ones, of rare occurrence, have, however, suffered no appreciable transport or maceration, but were buried quickly along with the most fragile plants in the softest of muds; while the majority of the specimens found commonly in the "insect beds" have undergone more or less long periods of floating, and consequent maceration and dissociation. The floated specimens occur at times with stronger plant fragments and the remains of animals, all in varying degrees of decomposition.

Pruvost breaks up Handlirsch's order Protorthoptera, and puts the majority of his families in a new suborder, the Archiblattids (3 species described), which are present as early as the base of the Westphalian. These are "the simplest and oldest of Protoblattoidea" and they may have had their origin in the Paleodictyoptera, the original source-stock of all insects. Two other suborders of Protoblattids are erected, Mimoblattids (for American forms) and Archimantids (1 described). The author remarks on "the homogeneity and antiquity of the blattid phylum," describing 43 forms, and on its early separation from the rest of the orthopterids. Of Paleodictyopterids he describes but 3 forms. He believes that the greatest evolution of Paleozoic insects took place during the Westphalian, and states that at the top of the Lower Carboniferous (Dinan-

tian or Mississippian) but one order is known; early in the Westphalian three orders are "scarcely outlined"; and at the end of the Westphalian "almost all the Paleozoic phyla are fully established."

The evolution of insects was especially rapid at the base of the Westphalian (Flines member), again at the base of the upper part of the same series (Ernestine), and at the top of the Westphalian in the Edouard member. And this three-fold acceleration in insect evolution is in harmony with the floral enrichment.

We must add here that the supposed insects found in the Horton formation (early Mississippian) of New Brunswick, Canada, and mentioned in the table opposite page 293, have been shown to Professor H. F. Wickham and Dr. David White, with the result that both paleontologist and paleobotanist agree that they are not insects but the carbonized fragments of woody plants.

To the young author, a favorite student of Professor Barrois under whose direction are being carried out a series of studies designed to apply the "paleontologic method" to the problems of the coal basin of northern France, are extended our congratulations on his great achievement.

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## SPECIAL ARTICLES

### THE RELATIVITY SHIFT OF SPECTRUM LINES

THREE experimental tests of Einstein's Relativity Theory of Gravitation have been proposed. Two seem to have been verified experimentally. The third, the predicted shift of solar spectrum lines, is still very much in dispute. Evershed and Royds,<sup>1</sup> and Schwarzschild<sup>2</sup> obtained very discordant results. St. John,<sup>3</sup> with very fine apparatus, also obtained very discordant results with however a zero effect, on the average. Grebe and Bachem<sup>4</sup> at first obtained discordant results, but a more careful analysis of their

<sup>1</sup> Bulletin 39, Kodaikanal Observatory.

<sup>2</sup> *Sitzungsberichte*, Berlin Akad., p. 1201, 1914.

<sup>3</sup> *Astro. Jour.*, 46, 249, 1917.

<sup>4</sup> *Verh. d. D. Phys. Ges.*, 21, 454, 1919.

data<sup>5, 6, 7</sup> yielded more consistent results and results in agreement with theory. Using the lines near the head of the CN 3883 band, the shift of solar wave-lengths, compared to terrestrial, should be 0.0082 Å to the red, equivalent to the Doppler effect of a descending current on the sun of 0.634 km./sec.

It appears to the author that a spectral line must rigidly fulfill three conditions, in order to be suitable for use in this work. (1) It must show no pressure shift, pole-effect, or other variation of frequency with physical condition of the source (excluding gravitational effects), (2) it must be a single, sharp, symmetrical line, (3) it must, in the solar spectrum, be quite free from other "foreign" lines.

Band lines are used because they seem to fulfill condition (1). In the early work proper attention was not paid to condition (3). Grebe and Bachem,<sup>6</sup> by obtaining micro-photometric curves, have attempted to rigidly satisfy condition (3), and in doing so have had to discard all but eleven of the 36 lines formerly measured by them. But no investigators have made an attempt to rigorously satisfy condition (2). Now the author, in arriving at a new formula for band series,<sup>8</sup> obtained very fine spectrograms of the 3883 band, and made an extended investigation of its structure, supplementing the work of Uhler and Patterson.<sup>9</sup> There are a number of different series in this band (twenty in all, commonly classified as ten series of doublets), but without exception the individual members of the various twenty series are *sharp, symmetrical* lines. This is a noteworthy characteristic of most band series, differentiating them from line series, the members of which are *all* complex, according to the Bohr-Sommerfeld theory. Moreover these latter are quite susceptible to changing electrical conditions.

But the ten doublet series of the 3883 band

<sup>5</sup> *Zeit. f. Phys.*, 1, 51, 1920.

<sup>6</sup> *Zeit. f. Phys.*, 2, 415, 1920.

<sup>7</sup> *Phys. Zeit.*, 21, 662, 1920.

<sup>8</sup> *Astro. Jour.*, 46, 85, 1917; *Phys. Rev.*, 11, 136, 1918; 13, 360, 1919.

<sup>9</sup> *Astro. Jour.*, 42, 434, 1915.

have different spacing and so are continually crossing, resulting very frequently in an apparent *broad, unsymmetrical* line, even with the best resolving power at our disposal. But this *complex* is really only the superposition, or partial superposition of two or more *sharp, symmetrical* lines. It is self-evident that the *apparent* center of gravity of such a complex depends on the length of exposure, etc., while the position of the "peak" of a micro-photometric curve depends on the relative intensity and position of the component members of the complex. It is known that the relative intensity of certain series in the 3883 band changes with physical conditions, and there is evidence that their relative intensity in the sun is *different* from that in the ordinary carbon arc. Hence any apparent "line" which is really a *complex* is entirely unsuitable for the detection and measurement of so small a shift as that predicted by Einstein. This is especially true as the solar lines are in absorption, while the arc lines are in emission.

The author, in his analysis, has identified many series lines, not previously identified, and by obtaining accurate formulæ for the stronger series, has been able to compute "theoretical" positions for all lines of these series, including those entering into complexes. In all cases tested, the actual appearance of the complex was in agreement with the theoretical structure thus built up. Also, many complexes have been recognized which may not previously have been suspected as such, and the presence of several extraneous lines in the normal arc spectrum (carbon lines, but not band lines) has been detected. Thus material is at hand for a rigid investigation of the eleven lines finally used by Grebe and Bachem. The details of this work will be published elsewhere. Only the results are given here.

Of the eleven lines only *two* ( $\lambda$  3873.504 and  $\lambda$  3858.822, on the Rowland system) fully satisfy condition (2). Even this is not strictly correct, for the two lines are unresolved doublets, the 31st and 49th member, respectively, of the  $A_1$  series. But the two

components of the doublet (in the case of the hundred or so members which *can* be resolved) are of exactly equal intensity, and therefore it seems safe to assume that the unresolved doublets are at least symmetrical, and to use them. For 3873.504, Grebe and Bachem obtained a shift of 0.58 km. (average of five consistent determinations from different plates), and Schwarzschild 0.45 km. (average of four consistent plates). No other investigators have used this line. For 3858.822, Grebe and Bachem obtained 0.42 km. (average of six consistent determinations), St. John 0.40 (average of four different methods, of which only the first two are wholly independent and so entitled to the most weight, these two, *a* and *b*, yielding 0.46 km.), Schwarzschild 0.39 km. (average of four readings—three consistent).

Using the 0.46 km. value of St. John, these five determinations for the two lines average 0.46 km./sec. In all cases this is the shift between lines radiated by the center of the sun, and by the arc. But St. John (*loc. cit.*) and Adams have both obtained reliable evidence that at the center of the sun there is a rising current of about 0.12 km./sec., compared to the rim.<sup>10</sup> This tends to mask the Einstein effect. The true value of this effect, as experimentally determined, is then  $0.46 + 0.12 = 0.58$  km./sec., compared to the theoretical 0.634. While the data are far too meager to draw any final conclusions, it is worthy of notice that the results of *all* observers are truly consistent on *really* good lines. The great discrepancy between St. John's and Grebe and Bachem's general averages has been the puzzling factor, thus far. The author believes that he has a partial explanation for this, and will present it in a later paper, together with a list of lines which are suitable for use, as far as condition (2) is concerned.

It might be added that, for the nine lines quoted by Grebe and Bachem<sup>5, 6</sup> ( $\lambda$  3858.822

and  $\lambda$  3851.427 being accidentally omitted), the agreement among different observers is worse than indicated, due to Grebe and Bachem's consistent misquoting of St. John's results, as well as other errors. The correct averages are: G. and B. 0.57, Schwarzschild 0.63, St. John 0.17 (or 0.26 using methods *a* and *b* only), Evershed and Royds 0.67. General weighted average 0.50, or 0.52, using 0.26 for St. John.

If all eleven lines are used, the averages become: G. and B. 0.52 (eleven lines), Schwarzschild 0.57 (nine lines), St. John 0.22 (eight lines, or 0.30, two good methods only), Evershed and Royds 0.67 (two lines). Average (weighted according to the number of lines), 0.46, or 0.48, using 0.30 for St. John. To all these values should be added 0.12 km. to obtain the true rim—arc value.

It should also be added that, in the author's opinion, St. John's method (*c*), and Grebe and Bachem's recent calculation<sup>7</sup> of 100 CN lines add comparatively little weight to the argument, as they involve the use of Rowland's standards. Since Rowland used both terrestrial and solar wave-lengths, in obtaining his table of standard lines, the Einstein shift (if real) is hopelessly involved in the measurements and can not be definitely extricated by any such method as that recently used by Grebe and Bachem.

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#### A NEW HIGH TEMPERATURE RECORD FOR GROWTH

A RECORD of growth of young joints of a prickly pear (*Opuntia*) at 50° C. and 51.5° C., and of the active elongation of etiolated stems of the same plant growing at 49° C. was published in 1917. Previously to that time Dr. J. M. McGee had found that the mature joints of the same *Opuntia* might reach temperatures of 55° C. in the open without damage, which was a record for endurance of the higher plants in air.

In the repetition of the growth measurements at the Desert Laboratory late in March, 1921, young joints which might reach tem-

<sup>10</sup> Schwarzschild's results indicate a falling current, *not* a rising, as quoted by Grebe and Bachem, but are too discordant to have any value. St. John's are very reliable.