troubled with heat. The tube was lined with black cotton velvet to destroy reflection.

"You may remember that a great deal was written about Sir Henry Bessemer's great telescope in the *Times,* and that he was going to show how big telescopes could be made by his process at a quicker and cheaper rate for the benefit of Astronomy. But, though a clever man, he had to come to the conclusion that prolonged practical experience was at his age an important consideration. It was through Dr. Common, who was so pleased with the 37-inch that I made for him, that I got the job to make the 50-inch mirror."

The success of Mr. Calver's recent creations testifies to the value of experience. It is evident that his hand has not lost its cunning since these pioneer days in reflector-making in which he took such a large part.

The limit has been set at 20 inches, but some recent refractors not in the previous list may be mentioned: a 16-inch for Carleton College, Minnesota; a 15-inch for the Dominion Observatory at Ottawa; and another of the same aperture mounted at the Philadelphia High School—the optical work in each case being by the Brashear Company, the mounting by Messrs. Warner and Swasey; and a 16-inch visual object-glass now being made for the Madrid Observatory by Sir Howard Grubb.

Mr. Brashear informs us of an interesting instrument he is now constructing for Yale University Observatory, to be devoted almost entirely to stellar parallax. Mr. Brashear writes:—"The instrument is to be a polar telescope, with a 30-inch siderostat mirror, with a 15-inch photographic objective and a 10-inch finding objective, both to be of fifty feet focal length. The work is all completed, save the 15-inch objective, the glass for which we have just received from Jena. Warner and Swasey have constructed the siderostat and the photographic instrumental equipment, which I think is one of the most beautiful and complete pieces of work I have ever seen. The entire apparatus is mounted on firm cement piers, and it is hoped that parallaxes verging on 0''·01 may be obtained."

In the same letter Mr. Brashear informs us that the 20-inch telescope to be constructed for the Chabot Observatory of Oakland, California, is to be used largely for educational purposes.

H. P. Hollis.

Note on the General Shift of the Fraunhofer Lines towards the Red, and on the Distortion of the Lines in the Spectrum of Eccentrically Located Sun-spots.

Mr. Evershed, in a remarkable discussion of results recently obtained at Kodaikanal regarding the displacements of the lines of the solar spectrum towards the red *, throws a strong light on the insuperable difficulties involved in the generally accepted interpretation of those shifts as a pressure effect. He proposes a radical change of view, and ascribes the displacements to motion in the line of sight.

This new explanation, however, also leads to very improbable conclusions. Apart from the puzzling fact that the great variability of the shifts from line to line would indicate that electrons belonging to the atoms of one and the same substance are descending in the solar atmosphere with largely different velocities, we meet with the perplexing difficulty that the increase of the displacements from the centre of the disc towards the limb would involve the assumption of a selectively acting repelling force, exerted by the *Earth* (and not sensibly by the other planets) on the various electrons of the solar gases. According to the Mount Wilson measurements, the bright lines of the spectrum of the chromosphere are displaced towards the red just as much as the corresponding Fraunhofer lines at the limb; and from the Kodaikanal observations it follows that in the spectrum of prominences there is also a surplus of line-shift towards the red. These phenomena, if ascribed to motion in the line of sight, would seem to be in harmony with the assumed specific influence of the Earth; but the whole idea is so extremely unsatisfactory, that a better point of view is badly wanted. Neither the application of the Doppler principle, nor the pressure theory, nor any combination of both opens a way out of the labyrinth of the solar line shifts.

The case is not so hopeless though, for the discrepancies disappear if we consider the effect of anomalous dispersion.

Until lately the force of the anomalous dispersion theory of solar phenomena lay chiefly in the ease with which it furnished consistent explanations, often connecting widely different domains of solar physics; but a direct *proof* of the existence and importance of anomalous dispersion in the Sun was not available. Such a proof was rightly demanded by the opponents of the theory; they certainly would also have been glad to possess a direct proof in support of the pressure theory, or the radial motion theory, or the temperature theory to which they adhere.

But how can absolute evidence be obtained? In very few cases a phenomenon happens to be discovered which permits of only *one* interpretation on the basis of present knowledge. We may mention, *e. g.*, Hale's discovery of circular polarization in the components of doublets among the lines of the sun-spot spectrum, which is considered as indicating with certainty the presence of magnetic fields in the Sun.

With regard to anomalous dispersion we probably shall soon be

* *The Observatory*, March 1914, p. 124; *Kodaik. Observatory Bulletin*, No. 36.

in possession of equally convincing evidence. Indeed, from the tables published by St. John* in his papers entitled "Radial Motion in Sun-spots," I found that a characteristic *mutual influence of Fraunhofer lines*, foreseen by the anomalous dispersion theory, really shows itself in so many cases as to exclude the idea that we are dealing with an effect of mere chance. The phenomenon appears utterly enigmatical from the point of view of any other theory. For full particulars we must refer to a paper soon to be published in the *Astrophysical Journal*; in the present short note, lacking the aid of tables and diagrams, we can only mention the following results of the ample investigation:—

1. The systematic distortion of the lines in the spectrum of eccentrically located sun-spots, discovered by Evershed, and further investigated by St. John, shows important details that make it impossible to explain the phenomenon as an effect of radial motion in the spots.

2. The hypothesis that the darkness of the Fraunhofer lines is in the main due to anomalous dispersion, leads to an explanation of the Evershed effect that is in harmony with the general laws connecting those line-shifts with the intensity of the lines and with the wave-length. It also explains why the shifts are so strongly variable from line to line within a given intensity class and spectral region.

3. Starting from this hypothesis concerning the nature of the Fraunhofer lines, we expected to find that the amount of displacement of a line A would be sensibly influenced by a neighbouring stronger line B. The influence must be such that, if B lies on the red side of A, it reduces the displacement of A as compared with the "normal" shift peculiar to the intensity class and spectral region of A; if B is situated on the violet side of A, it must have the opposite effect, but to a lesser degree. This inference is perfectly borne out by all the evidence that can be gathered from the data published by St. John. Indeed, among the 506 lines of his Table I. there are 43 lines A with stronger neighbours B on their *red* side at distances of 0·5 Å. or less; they all show *negative* residuals, with only one exception. The mean residual is −0·0052 Å. For the 39 lines A of the table that have stronger companions B on their *violet* side, the mean residual is, on the contrary, *positive* but smaller (+0·0014). It is true that in this category 12 negative residuals occur, but the theory requires that the values fluctuate along the spectrum.

A systematic observational error may be involved in the above residuals, for it is not improbable that the proximity of lines B causes the displacements of lines A to be under-estimated. This error, however, would have the same sign on either side

* *Contributions from the Mount Wilson Solar Observatory*, Nos. 69 and 74; *Astrophysical Journal*, vol. xxxvii. p. 322, and vol. xxxviii. p. 341, 1913.

of a line B. Allowing for it, we must reduce the negative and enlarge the positive mean residual by the same amount; their characteristic difference remains unaffected.

Figures and arguments are given in detail in the paper alluded to, which will appear in the *Astrophysical Journal*.

In view of these results it seems extremely probable that the Evershed effect of a line is actually influenced by adjacent lines. In so far as other theories appear unable to account for this kind of interaction of Fraunhofer lines, we may consider the phenomenon as directly showing the active part of anomalous dispersion in determining the width of the lines of the solar spectrum, and their distortion in the spectrum of eccentrically located spots.

Since the basis of the anomalous dispersion theory has thus gained strength, we may still more frankly appeal to the same principle for also explaining the general shift of the Fraunhofer lines towards the red.

The explanation has already been given in 1909 *. It rests on the hypothesis—developed in previous papers †—that the darkness and width of the Fraunhofer lines are chiefly due to the increased refracting and scattering power of the medium for waves that are very near the regions of resonance. Denoting by R-light and V-light the waves respectively on the red and on the violet side of a region of resonance (corresponding to a proper vibration), we remark that, as a rule, the average R-light suffers stronger refraction and scattering than the average V-light. This makes the lines unsymmetrical, and produces the appearance of a displacement towards the red, increasing as we approach the limb of the solar disc.

The most prominent feature of the general shift is that it varies very strongly in amount from line to line, but that, on the average, the magnitude of the displacements decidedly depends upon the intensity of the lines. From the statistical treatment of the sun-arc shifts of 136 lines, Evershed concludes that the mean shifts increase very markedly with the intensities. Classifying the 467 limb-centre shifts measured by Adams ‡ according to the intensity of the lines, and taking the mean shift for each intensity class, we obtain the following remarkable result:—

* *Proc. Roy. Acad. Amsterdam*, vol. xii. p. 266, 1909; *Physikalische Zeitschrift*, vol. xi. p. 56, 1910; *Mem. d. Soc. d. Spettr. ital.* vol. xxxviii. p. 173, 1909.

† Cf. *Astrophysical Journal*, vol. xxi. pp. 271, 278, 286 (1905), vol. xxv. p. 95 (1907), vol. xxviii. p. 360 (1908); *Proc. Roy. Acad. Amst.* vol. xii. p. 446 (1909); *Astroph. Journ.* vol. xxxi. p. 419 (1910); *Le Radium*, Oct. 1910; *Proc. Roy. Acad. Amst.* vol. xiii. pp. 881, 1088, 1263 (1911); *Handwörterbuch der Naturwissenschaften*, vol. vii. p. 824 (1912).

‡ *Astrophysical Journal*, vol. xxxi. p. 30 (1910).

Synopsis of Adams's Measurements of the Displacements of Lines at the Limb, showing the Means for each Line Intensity.

Intensity	0	1	2	3	4	5	6	7	8	9–12	15–40
Number of Lines Measured	7	51	99	106	71	40	41	14	12	11	15
Mean Displacement (unit=0·001 Å.)	3·6	5·5	6·6	6·8	7·1	8·8	8·3	8·8	7·9	5·3	3·0

It is evident from this table that the strength of the line is a material factor in determining the amount of displacement. The mean shifts first increase with line intensity, are greatest for the classes 5, 6, 7, and smaller again for the strongest lines.

This is exactly what our interpretation requires. If the displacement is merely a manifestation of asymmetry, it must always be a *fraction* of the width of the line, and therefore decrease with decreasing line intensity. The fraction, however, will in general be smaller with wide lines than with narrow lines, for the asymmetry is caused by the fact that the refractive index n contains a term n_0 which is independent of the line under consideration; and since for a very strong line the absolute values of $\pm(n-1)$ are high (and therefore comparatively little influenced by the small term n_0-1), the asymmetry becomes less conspicuous in such a case. Lines of moderate intensity should show the largest mean displacements—as they really do.

The theory accounts as follows for the fact that in each intensity class great deviations from the mean are observed.

To every line corresponds a value n_0, which the refractive index of the medium would have for that wave-length, if the line were absent. The magnitude of the displacement depends on the intensity of the line and on n_0-1. Now, n_0 necessarily fluctuates along the spectrum, as influenced by the various lines of the region considered. Lines of a given intensity may therefore show very different shifts.

Another peculiarity of the displacements is their increase with wave-length if we compare means taken for successive parts of the spectrum. This connection is also explainable from the point of view of the dispersion theory, when taking into account the variation of n_0 and the law of molecular scattering given by Rayleigh; but as this cannot be shown without exceeding the allowable length of this note, I must once more refer to the forthcoming paper in which the subject is more fully discussed *.

Utrecht, April 1914. W. H. Julius.

In a recent number of the *Physikalische Zeitschrift* (vol. xv. p. 369) Mr. Freundlich compares the shifts observed by Evershed

* Cf. also *Versl. kon. Akad. v. Wetensch. Amsterdam*, vol. xxii. p. 1243, 1914.

with those following from the gravitation theories proposed by Einstein and Nordström. Displacements due to gravitation would be proportional to the wave-length. The suggested cause, therefore, may perhaps contribute to the production of the observed shifts, but it certainly is not their main cause, since it does not account for the principal features of the phenomenon: the great variability of the shifts from line to line, and the marked relation between the mean shifts and the intensities of the lines. W. H. J.

George William Hill.

By the death of George William Hill in his seventy-seventh year, we have lost one of the very greatest of dynamical astronomers and one of the most unassuming of mankind.

The story of his life is simply told. He was born in 1838 at New York, and spent his boyhood in a country home about twenty miles from that city. At an early age he showed definite mathematical inclinations, and was sent to Rutger's College, New Brunswick. He took his degree there in 1859, and then proceeded to Cambridge, Mass., to continue his studies. Early in 1861 he was appointed an assistant in the offices of the American Ephemeris and Nautical Almanac. He remained in this office as an assistant for thirty years, and then retired from his official duties to lead a quiet life in his country home.

Hill began his original work when still at college. Runkle, the superintendent of the Nautical Almanac, had founded a scientific journal called the *Mathematical Monthly*, which offered prizes for original research. Hill was the first to win a prize, for an essay on the configuration of the Earth. In this essay we see the hand of the future master, and it is worth noting that thus early Hill had formed the habit of following up his analytical work by reducing his results to numerical form. The attention of Runkle was thus drawn to Hill, who, as has been stated, was appointed to a post in the Nautical Almanac Office.

For convenience, we may divide Hill's scientific activity into three periods. The first extended till 1877, when Newcomb became superintendent of the Nautical Almanac office; the second from 1877 till 1892, and the third after 1892. During the first period Hill did several pieces of laborious work, the chief of which concerned the orbit of Venus and the phenomena of the transit of 1874. It was towards the end of this period that Hill produced the work by which he is best known—his researches in the lunar theory. It is impossible to go into any detail in this connection: suffice it to say that Hill's work has initiated a new struggle with the difficulties associated with the Moon's motion. Newton, Clairaut, Euler, Laplace, and others, working more or less along the same general lines, had indicated the nature of the lunar