examined when still at a considerable distance east of the meridian, and an unsuccessful search was made for the companion. The absence of ghosts and the small amount of diffuse light when this brilliant star was in the field were particularly noted. The color correction of the forty-inch objective is, according to my best recollection, almost precisely the same as that of the Lick objective.

From these tests it appears that the character of the image varies with the position of the lenses relatively to each other, and, to a less extent, with the position of the objective as a whole relatively to its cell. It is probable that flexure of the lenses is the principal cause of the observed changes, and it is interesting to note that there is here evidence, for the first time, that we are approaching the limit of size in the construction of great objectives. A more complete investigation of the subject can be made only after the objective is permanently mounted, so that stars can be observed at widely different hour angles. The flexure seems to be of the kind frequently noted in the construction of large mirrors, which are found to give the best definition when a certain diameter is placed vertical. It is not likely that the effects of flexure will be appreciable in the case of the forty-inch objective when the lenses are properly adjusted; for larger objectives, it is possible that the limit above referred to may be extended by providing their cells with a position circle, so that they can be rotated about the axis of the telescope tube.

All the tests described above were made jointly by Professor Hale and myself, and the conclusions at which we arrived are substantially the same.

James E. Keeler.

NOTE ON THE APPLICATION OF MESSRS. JEWELL, HUMPHREYS AND MOHLER'S RESULTS TO CERTAIN PROBLEMS OF ASTROPHYSICS.

The fact that the wave-length of a spectral line is a function of the pressure of the gas or vapor producing it, is obviously of prime importance in astrophysics. In spite of certain well-established phenomena, such as the unsymmetrical reversal of metallic lines in the arc and the interesting observations by Ebert of a change in the position of a line when the amount of material in a flame is varied, the Fraunhofer lines have been regarded as fixed marks of reference, subject to no possible
change in position. Moreover, but little evidence has been advanced to show that any of the Fraunhofer lines vary in intensity, though that a secular change is going on is indicated by the variety in type of stellar spectra. Some remarkably fine photographs of the B group in the solar spectrum, made by the Rev. Walter Sidgreaves in 1891 with a Rowland plane grating of 14,438 lines to the inch, seemed to show that the line No. 17 of Professor Winlock’s maps in the Proceedings of the American Academy had decreased in intensity.¹ Professor Hastings’ observations in 1873 of the different intensities of certain lines at the center of the solar disk and near the limb may also be mentioned in this connection.² Ångström had previously pointed out some apparent variations of a more general character.³ It seems, however, to have remained for Mr. Jewell to establish with certainty a variation in the intensity of an absorption line in the general spectrum of the Sun. Every photograph of the solar spectrum taken with high dispersion must now be regarded as a document of great value, which may ultimately reveal irregular or periodic changes in the condition of the gases and vapors of the solar atmosphere.

The double reversal of the H and K lines was discovered almost simultaneously by M. Deslandres and myself in 1891. In the following year I pointed out the lack of symmetry in the reversals,⁴ without offering an explanation of this peculiarity. In the same year M. Deslandres⁵ and the Rev. Sidgreaves found the double reversals in the spectrum of general sunlight, and showed that the Sun might therefore be classed as a bright line star. M. Deslandres has recently investigated the displacement of the central absorption line of the double reversal, and ascribes it to motion of the absorbing gas.⁶

It now appears that all of these observations were anticipated by Mr. Jewell, who discovered the double reversals in the general spectrum and in various parts of the solar disk in 1889. He detected the displacement of the central line, and somewhat later attributed it to motion in the line of sight.

In connection with Mr. Jewell’s paper it will be of interest to consider some of the results arrived at by M. Deslandres in the article already referred to. After remarking that the dark absorption line is usually central over faculae, M. Deslandres adds: “En dehor des facu-

¹ A. and A. 11, 79, 1892.
² Nat. 8, 77, 1873.
³ C. R. 69, 648, 1866.
⁴ A. and A. 11, 813, 1892.
⁵ C. R. 1892.
⁶ C. R. 119, 457.
les, par contre, la dissymétrie des composantes brillantes, qui, d'ail-
leurs, sont faibles, est le cas le plus fréquent; elle est nette, en général,
au moins sur les trois quarts de la surface, dans le sens de la lumière
générale, et est plus ou moins accentuée, étant quelquefois telle que la
composante rouge est invisible. Elle se présente aussi bien près de
l'équateur que près des pôles, mais très rarement à une faible distance
du bord.”

My own photographs seem to show that the disappearance of the
red component of the emission line is not always due to the displace-
ment of the central absorption line, but usually simply results from
the fact that this component is less brilliant than the more refrangible
one. Mr. Jewell's curve (Fig. 7, p. 100) closely represents the distribu-
tion of light in the doubly-reversed line.

Mr. Jewell and M. Deslandres consider that the displacement of the
central line is due to motion of the absorbing gas. In M. Deslandres'
words, "L'ensemble des faits précédents peut s'expliquer par un
mouvement général de circulation verticale et horizontale des couches
hautes et basses de la chromosphère, analogue à celui que pré-
senté notre atmosphère. Les couches basses s'élèveraient et seraient
attirées vers l'équateur, comme les vents alizés, d'où un rapproche-
ment vers la Terre; les couches élevées auraient un mouvement
inverse." M. Deslandres endeavored to determine the absolute dis-
placement of the central dark absorption line at the center of the disk
and the corresponding emission line in the chromosphere at the limb
by comparing them with lines in the spark spectrum of iron. He found
an apparent slight shift of certain parts of the absorption line toward
the red, with respect to the iron lines, while the emission line of the
chromosphere “présentait un déplacement moindre ou inverse.” M.
Deslandres concludes that the dispersion employed (4th order of a
Rowland grating, with observing telescope of 1".30 focus) was insuffi-
cient for the purpose. It was noticed, however, that “les composantes
brillantes de la raie du calcium dans l'étincelle présentent aussi une
légère dissymétrie dans le même sens que la raie solaire,” and it is sug-
gested that these similar displacements may be due to similar causes.¹

We now know that the reversed line in the spark spectrum should be
unsymmetrical, if the pressure conditions in the arc and spark are
similar. The emission line, produced by the radiation of the vapors
in the central part of the spark, should be displaced—not, as M. Des-

¹C. R. 119, 459, 1894.
landres' words would seem to indicate, toward the violet, but toward the red. The central line of absorption would thus appear to be displaced toward the violet with respect to the emission line, an appearance exactly the reverse of that existing in the spectrum of the solar surface. It therefore seems to be impossible to account for the lack of symmetry of the H and K reversals in the Sun by ascribing it to the different pressures of the upper and lower strata of the chromosphere. That such a difference exists is indicated by the broadening of the lines at the lower level. There is therefore in all probability a displacement of the emission lines toward the red, due to this cause, but it is partly or wholly overcome by a displacement in the opposite direction, due apparently to motion in the line of sight.

But even this latter explanation is not free from difficulties. M. Deslandres' suggestion that the vapors in the lower stratum of the chromosphere have an ascending motion, and are drawn toward the equator, while the vapors of the upper stratum move inversely, would seem to apply perfectly, were it not for the fact that the displacement of the central absorption line, according to his observations, is well defined over at least three-quarters of the surface, and is as commonly present near the equator as near the poles, though rarely at a slight distance from the limb. In other words, the vapor which produces the central absorption line, on whatever part of the surface it may be found (except near the limb) is moving away from the observer. In the absence of further information, there would seem to be as much evidence of descending vapor flowing east and west from the central meridian (which is manifestly out of the question), as there is of descending vapor flowing north and south from the equator. Many solar theories have postulated such a current, but hitherto its existence has not been certainly established. It will be a matter of extreme interest to investigate this question further. I very much regret that the numerous photographs of the H and K reversals on the Sun's surface made at the Kenwood Observatory during the last five years have been taken with a dispersion insufficient to permit of their use in a case of this kind. The solar spectroscope now in process of construction for the forty-inch Yerkes telescope will, it is hoped, be sufficiently powerful for the purpose.

The difference in behavior of H and K and the blue line of calcium discovered by Messrs. Jewell, Humphreys and Mohler seems to support Lockyer's views as to the dissociation of calcium in the arc
and Sun. The remarkable variations of the calcium spectrum with temperature have long been known, principally through the investigations of Lockyer. The writer has shown that the H and K lines are produced at the temperature of burning magnesium and in the oxy-coal-gas flame. They could not be photographed in the spectrum of the Bunsen burner, though an exposure of sixty-four hours was given. Since these experiments were made I have been informed by Professor Eder that his own efforts to photograph the lines in the Bunsen burner were no more successful, though an optical train of quartz and fluor spar was employed. It would thus appear that the temperature of dissociation of calcium is between that of the Bunsen burner and that of the oxy-coal-gas flame. The high molecular weight of calcium has hitherto conflicted with our belief in the presence of this metal in prominences. If, however, it be granted that dissociation can be brought about by temperatures even lower than that of the arco, the difficulty is very greatly lessened.

Although it has been shown that the range of pressure in the reversing layer is considerable, it would probably be premature to argue that its depth must therefore be comparable with that of the corona. There seems as yet to be no certain evidence that any absorption line in the solar spectrum has its origin above the upper limits of the chromosphere. Mr. Jewell suggests that the central dark line of the H and K reversals is produced by the corona. In this case it should show a very decided relative shift toward the violet, due to the different pressures of the chromosphere and corona, and be subject to relative displacements near the east and west limbs of the Sun toward the violet and red respectively, due to the difference between the components in the line of sight of the velocities of rotation of the chromosphere and corona. These displacements would be complicated with those resulting from internal motions of the coronal vapors, but a careful study of the H and K reversals in various parts of the solar surface, made with very high dispersion, would probably decide the question. However, the close similarity of the central absorption line on the disk and the emission line in the upper part of the chromosphere at the limb, seems to make unnecessary the assumption that the corona plays any part in the absorption. In this connection it would be interesting to determine whether the distance between the components of the 1474 line is constant over the entire surface of the Sun.

The problem of the solar rotation, so admirably investigated by
Crew and Dunér, gains new interest in the light of present knowledge. It is now possible to determine whether the lines employed in these two researches originate in different parts of the reversing layer, in which case it might become possible to harmonize the results. It can hardly be said that the ideas of Brester on this point are sufficiently plausible to gain general acceptance.

It is impossible in a limited space to even touch upon the numerous applications of the new results to astrophysical problems. That the effect of pressure must receive attention in future investigations of the motions of stars and nebulae in the line of sight cannot be doubted. The fact that narrow spectral lines are not always inconsistent with high pressures is of great importance in this connection. The close similarity of stellar spectra of Class IIα with the solar spectrum indicates that the conditions of temperature and pressure in the atmospheres of these stars cannot differ widely from those existing in the Sun. The displacements due to pressure must therefore in such cases be in general too small to be detected with an ordinary spectrograph, and the measures of motion in the line of sight may be relied upon. In stars whose reversing layers are subject to higher pressures the displacements due to this cause may become appreciable. Fortunately, however, it has been shown that the wave-lengths of certain lines in the spectrum are apparently unaffected by pressure. These lines, if they can be found in the stars under investigation, may serve for the determination of motion in the line of sight. The pressures in the reversing layer might also be measured with other lines. It is evident, as Mr. Jewell has pointed out, that the vacuum tube should replace the spark or arc for this work. The form used by Professor Michelson, and described in a recent number of this journal, is probably the best for the purpose.

George E. Hale.

ON THE SPECTRUM OF CLÈVEITE GAS.

Through a mistake in the types, it was made to appear that Professors Runge and Paschen's article in the last number of this journal had been published elsewhere. This, however, was not the case. The footnote on page 4 was intended to refer to previous papers by the same authors.

1 Théorie du Soleil.