This will contain the two unknown quantities, $x=\rho\cos\xi$, and $y=\rho\sin\xi$. The solution will give us $\rho\cos\xi=\pm m$, $\rho\sin\xi=\pm n$, and from the nature of the case ρ will always be a real, positive qauntity. The small values of ρ show that the variations of latitude are also small, and it is from the values of ξ that we must judge whether the results are harmonious and really probable. Reducing the values of ξ to a common epoch, the agreement is not good. We infer, therefore, that these investigations do not indicate with any certainty a variation of latitude having the period of 305 days.

From what precedes it appears that observations do not prove that latitudes are variable, and the evidence points rather to other sources of small changes that may depend on the seasons. Perhaps some of these may arise from the tables of refraction which are in common use, and which are assumed to fit the whole Earth. It is possible that for the best absolute determinations of zenith distances, the question of refraction will need to be investigated for each observatory *. The method of observation proposed by Mr. Fergola seems to have a great advantage over those that have been followed heretofore from the fact that it is differential. But it is evident that even in this method the observations must be made with the utmost care, and with due consideration of all the surroundings, in order to detect the variations of latitude, which we know must be very small. ASAPH HALL.

Naval Observatory, January 21, 1885.

The Motions of Stars in the Line of Sight.

If the definition attributed to Bessel be a correct one, that "astronomy is the study of the movements of the heavenly bodies," spectroscopy had no claim to be regarded as a branch of astronomy until Dr. Huggins obtained his first measure of the displacement of the F line in the spectrum of Sirius, and thus proved that it was possible to ascertain the speed with which a star was moving in the direction of the visual ray—an observation which deserves to rank in importance with the first detection of the proper motions of stars, or the first determination of their annual parallax, or even somewhat higher, as being more entirely a novel enterprise. The theory of the displacement of the lines in the spectrum of a rapidly moving body has never met with any serious opposition, and it has now been carried from the region of theory into that of observed phenomenon. Since the Sun rotates on its axis, the east limb is always approaching us, whilst the west limb is always receding. If, then, the theory be correct, a line in the spectrum of

* It is not uncommon to exaggerate the accuracy with which latitudes are known. We have only to refer to our ephemerides to find much larger differences than the probable errors will warrant. Thus the latitudes of Greenwich given in the 'Berliner Jahrbuch' and the 'American Ephemeris' differ by 0″·3.

the one limb ought to be slightly displaced relatively to the same line in the spectrum of the other. This has been observed to be the case, and the period of rotation of the Sun as deduced by the present Astronomer Royal, by Prof. Young, and other observers, from measures of the amount of this displacement, agrees very fairly well with that derived from observations of Sun-spots.

But this displacement has been exhibited in a much more striking manner. Many of the lines in the solar spectrum are due to the action of our own atmosphere, and as this of course does not partake in the solar rotation these lines do not suffer displacement at the limbs. Prof. Hastings, and following him M. Thollon, brings the images of the east and west limbs into juxtaposition on the slit, and is able at once to discriminate between the lines of solar and those of telluric origin; the former not corresponding in the two spectra, the latter coinciding throughout. M. Cornu has developed the same idea in a very pretty and ingenious manner, and by making the image of the Sun oscillate across the slit, he makes the solar lines seem to oscillate also, whilst the telluric lines remain unmoved.

The planet Jupiter, from the wonderful velocity with which it rotates, affords another means of demonstrating this displacement to the eye. The difference of motion of the two limbs is more than 15 miles per second, and the effect of this difference is doubled by the fact that Jupiter shines by reflected, not inherent light. The relative displacement therefore is equivalent to that produced by a motion of 30 miles per second, a very appreciable amount. If the image of the planet be made to move rapidly to and fro across the slit, the slit being placed parallel to the axis of the planet, the lines of the spectrum will show an obvious oscillation backwards and forwards to correspond; and that this is no fictitious effect can be ascertained by turning the spectroscope until the slit is parallel to the equator, when no such effect can be produced. With the slit on the equator of the planet the lines of the spectrum are inclined, and their extremities bend different ways; with the slit at right angles to the equator and on the central meridian, the lines are upright and straight.

There is therefore no doubt as to the truth of the theory. If a heavenly body is approaching us at a sufficiently high speed, the lines of its spectrum will suffer an observable displacement towards the violet; if it be receding from us, the displacement will be towards the red. But the actual measurement of the amount of this displacement is, in the case of a star, not altogether an easy matter. There is, first, the smallness of the amount to be measured. A spectroscope which will not clearly separate between the two lines of the close pair at λ 4890 will certainly be inefficient for this purpose. Angström gives these lines as being 0·79 tenth-metres apart, which would correspond to a motion of 32 miles per second. Before, therefore, we can express the motion of a star in miles per second, and attribute any real meaning to the figure in the unit's place, we must be able to measure accurately the $\frac{1}{30}$th part of this minute distance. This implies a great dispersion—what for a star must be regarded as an enormous one; and by a necessary consequence the spectrum can only be but faint.

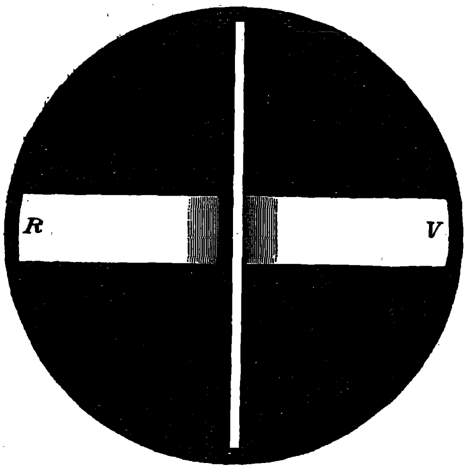
Three other considerations render it necessary to still further enfeeble this already faint spectrum. First, the spectrum of a star is only a line, and needs to be broadened out to a very considerable extent by the use of a cylindrical lens before the dark absorption lines can be seen to advantage. Next, the pointer or threads used for measurement must be rendered visible in some way or other. Thirdly, the entire light of the star cannot be utilized, as the slit *must* be so narrow, that some of it at least is cut off.

But when this difficulty is successfully overcome, and the eye, grown accustomed to a feeble light, can detect the lines in the spectrum of the star, there are difficulties of another kind to be overcome. It is exceedingly easy to produce a fictitious displacement, and the spectroscope must therefore be so adjusted that this is impossible. In measuring the displacements of lines from the limbs either of Jupiter or of the Sun, we have the lines from the centre of the disk to serve as fiducial points from whence to measure the deviation; but for stars we must have recourse to comparison with some artificially produced spectrum. We therefore compare the absorption lines due to hydrogen with the bright lines in the spectrum obtained from an hydrogen vacuum-tube; the lines due to magnesium with the spectrum of an electric spark taken between magnesium electrodes, and so on. But it is manifestly possible that our comparison spectrum may be badly adjusted and that our resulting displacement may be the index, not of the speed with which the star under observation is travelling, but of the error of adjustment of the comparison spectrum.

The first point to insist upon is that the object-glass of the collimator must be filled with light. This can be readily tested, in instruments in which this object-glass is accessible, by slipping a piece of white paper immediately behind it; if the circle of light be complete the adjustment is correct. This must be tested both for the star and for the comparison light.

The instrument must of course be in perfect focus, both because the lines of the spectrum will not otherwise be well defined enough for measurement, and because there will be danger of parallax affecting the measures. Five different focussing adjustments have to be made—1st, the eyepiece must be focussed on the threads of the micrometer; 2nd, the true lines of the spectrum, and, 3rd, the lines running the length of the spectrum, caused by dust on the slit or defects of its edges, must be brought into the sharpest possible definition. If these three adjustments have been properly effected all danger of error from parallax will have been removed. 4th, the slit must be in the primary focus of the great telescope; not necessarily in the visual focus, but in the focus for the particular ray to be examined. In the present research the F or *b* lines are nearly always employed, and the object-glass being corrected so as to bring together these rays and the yet more brilliant part of the spectrum towards the yellow, the visual focus is practically correct; but if a line in the violet were used, the difference between the two foci would be too great to be neglected. Lastly, an image of the vacuum-tube or spark is formed by a small condensing-lens and brought to focus on the slit. In the Greenwich spectroscope the vacuum-tube is to the left of the slit, and nearly in the same plane as the face of the slit plate, the rays being reflected into the spectroscope by means of a small piece of unsilvered plate glass, placed before the slit and making an angle of 45° with the slit plate. A better arrangement, in some respects, would be to fix the spark-holder either above or below the slit, and the reflector with its edge perpendicular to the slit instead of parallel to it. The light from the star passes through the plane glass reflector and the two spectra are therefore superposed, as seen in fig. 1, which

Fig. 1.



F line in the Spectrum of Sirius as compared with Hβ line of Hydrogen, 1875 December.

represents the relative positions and appearances of the F line in Sirius, and the hydrogen line Hβ given by a vacuum-tube as observed in December 1875. This arrangement is found to answer better than the employment of total reflection prisms, since with these the two spectra can only be seen side by side, and fresh possibilities of error in measurement are introduced. The loss of light from the vacuum-tube or spark by the reflection from the unsilvered glass is a positive advantage, as otherwise the comparison spectrum is so brilliant as to "kill" the spectrum of the star.

These points having been duly attended to, the telescope may be turned to some bright star. A cylindrical lens is then placed in front of the slit and at such a distance from it as to give a convenient breadth to the spectrum. The cylindrical lens is placed before the slit, rather than in the viewing telescope, on account of the facility for making the next adjustment: viz. turning the lens until the line of light, which the image of the star forms after passing through the lens, is *exactly* parallel to the jaws of the slit. The last point to be attended to is the width of the slit. It must be so narrow that part of the star's light is cut off by it, otherwise it would be possible for the image of the star to move about on it, and the lines of its spectrum would move accordingly, and a fictitious displacement would be caused. Besides, the narrower the slit, the sharper the lines of the spectrum. These last adjustments are easily effected by the help of a reflecting prism and lens which can be slipped down behind the slit, and which enable the observer to look out *through* it.

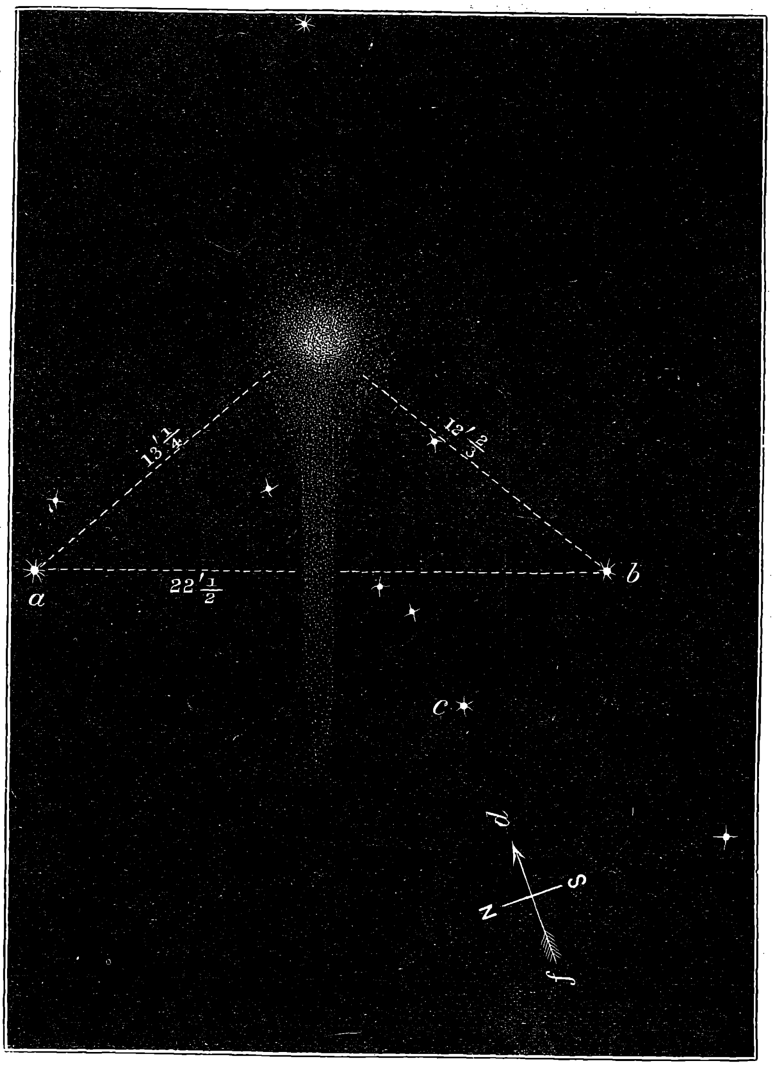
It is the practice in the observations made at Greenwich, the spectroscope having been carefully adjusted as described above, to bring the pointer of the micrometer carefully and slowly up to the line in the star spectrum; and when a satisfactory bisection has been made, instantly, and without the eye being moved in the slightest degree, a button is pressed rendering complete the connection between the battery and induction-coil, and the comparison spectrum flashes in. The distance by which the pointer is removed from the centre of the comparison line is then estimated in terms of the breadth of that line. Thus if it were exactly on the edge of the line the displacement would be estimated as one-half. The reading of the micrometer-head is then taken, the comparison line is bisected, and the micrometer-head read again. Usually two such observations are made for each star, the micrometer-screw being turned through three or four revolutions in the interval, so that the two observations are perfectly independent. The pointer also, as a general rule, is brought up to the star-line from the one side in the first observation, and from the other in the second, it having been found that there is a tendency to stop a little short of the centre of the line in the case of very faint spectra. Finally, a set of measures of the breadth of the comparison line are made for the reduction of the estimations. It is particularly important that the estimation be made instantly after bisecting the star-line, and before the eye has been moved, since errors which might arise from parallax, from "loss of time" in the micrometer-screw, or from want of firmness in the mounting either of the prisms or viewing telescope are thereby detected at once, by the discordance between the displacement as estimated and as measured. The estimation, therefore, affords a most valuable check upon the measure; it is nominally rougher, but practically as accurate, and in deducing the motion of the star it is considered as of equal weight.

Various devices have been tried at Greenwich Observatory for illuminating the wires or pointer used in measuring, but none have been *wholly* satisfactory. Most generally therefore these are discarded, and the tip of the pointer is rendered visible by allowing it to project some little way on the spectrum of the star. This practically lessens the breadth of the spectrum available for observation, but the drawback is a smaller one than those accompanying most of the methods of illumination. E. W. MAUNDER.

[To be continued.]

Astronomical Notes.

ENCKE'S COMET.—This comet has been observed here frequently since January 2, mostly with the 5-inch telescope, while comet-seeking.



On the night of February 11 a faint tail was noticed at about 7 P.M.; this extended some 10′ in a direction slightly *n.f.* The