not improbable that these linear brightenings in the broad dark lines indicate eruptions of gases from the interior of the body possessing the continuous spectrum with the dark absorption lines. Such brightenings are occasionally seen in the spectra of sun-spots. On this supposition, the fine bright lines would indicate very nearly the middle of the dark lines.

"The appearance of two maxima of intensity in the broad bright lines admits of the conclusion that two bodies with different motions possess spectra with bright lines, and that therefore the spectrum of the Nova consists of at least three spectra superposed, from the measurement of which, in connection with the comparison spectra of β Aurigæ or β Tauri on the same plate, the relative motions of the three supposed bodies, as well as their motions with respect to the earth, can be determined. Denoting the body with the dark-line spectrum by a, the two others with bright-line spectra by b and c, measurements by myself and Dr. Scheiner have given the following results:

$$a - \tfrac{1}{2}(b + c) = 120 \text{ miles},^1$$
$$b - c = 70 \text{ miles}.$$

and further with respect to the earth—

$$a = -90 \text{ miles}, \; b = -5, \; c = +65 \text{ miles}.$$

"This result is still very uncertain, and must be regarded as quite preliminary, for it is evident that with the small size of the spectra the accuracy cannot be pushed very far—a displacement of ·01 mm. corresponds, for instance, to a motion of 8 to 12 miles, according to the situation of the line in the spectrum—and that the size of the silver grain in the photographs can exert a very marked influence on the measurements.

"In the photographic spectrum of the Nova, besides the broad lines mentioned, several more bright and mostly very broad lines can be seen, whose wave-lengths I intend to communicate later on."

Prof. Pickering communicates some valuable information to the same number of the *Astronomische Nachrichten* with reference to the visibility of the Nova before its discovery by Dr. Anderson. In eighteen photographs of this region, which were taken by the 8-inch photographic telescopes between the dates November 3, 1885, and November 2, 1891, no star in the Nova's place was visible, but in those taken from December 16, 1891, to January 31, 1891, there was a star of the fifth magnitude recorded. In another series of plates taken with the transit photometer, no record of the new star up to December 1, 1891, was obtained, although χ Aurigæ (mag. 5·0 m.) was always visible, but the plates taken on the nights of December 10, 1891, and ending January 20, 1892, indicated clearly the position of the new star.

Careful examination has been made on all the above-mentioned plates, and the following extract shows the series of magnitudes which have been deduced from the measurements:—

"It appears that the star was fainter than the eleventh magnitude on November 2, 1891, than the sixth magnitude on December 1, and that it was increasing rapidly on December 10. A graphical construction indicates that it had probably attained the seventh magnitude within a day or two of December 2, and the sixth magnitude December 7. The brightness increased rapidly until December 18, attaining its maximum about December 20, when its magnitude was 4·4m. It then began to decrease slowly, with slight fluctuations, until January 20, when it was slightly below the fifth magnitude."

From this it will be seen that two months' observations have been lost, owing to its late discovery.

ABERRATION.[2]

UNDER this head may conveniently be considered not only the apparent displacement of the stars discovered by Bradley, but other kindred phenomena dependent upon the velocity of light bearing but a finite ratio to that of the earth in its orbit round the sun, and to other astronomical velocities.

The explanation of stellar aberration, as usually given, proceeds rather upon the basis of the corpuscular than of the wave theory. In order to adapt it to the principles of the latter theory, Fresnel found it necessary to follow Young in assuming that the æther in any vacuous space connected with the earth (and therefore practically in the atmosphere) is undisturbed by the earth's motion of 19 miles per second. Consider for simplicity the case in which the direction of the star is at right angles to that of the earth's motion, and replace the telescope, which would be used in practice, by a pair of perforated screens, on which the light falls perpendicularly. We may further imagine the luminous disturbance to consist of a single plane pulse. When this reaches the anterior screen, so much of it as coincides with the momentary position of the aperture is transmitted, and the remainder is stopped. The part transmitted proceeds upon its course through the æther independently of the motion of the screens. In order, therefore, that the pulse may be transmitted by the aperture in the posterior screen, it is evident that the line joining the centres of the apertures must not be perpendicular to the screens and to the wave front, as would have been necessary in the case of rest. For in consequence of the motion of the posterior screen in its own plane the aperture will be carried forward during the time of passage of the light. By the amount of this motion the second aperture must be drawn backwards, in order that it may be in the place required when the light reaches it. If the velocity of light be V, and that of the earth be v, the line of apertures, giving the apparent direction of the star, must be directed forwards through an angle equal to v/V. More generally, if the angle between the star and the point of the heavens towards which the earth is moving be α, there will be an apparent displacement towards the latter point, expressed by $\sin \alpha \,.\, v/V$, and independent of the position upon the earth's surface where the observation is made. The ratio v/V is about $\frac{1}{10000}$.

The aperture in the anterior screen corresponds to the object-glass of the telescope with which the observation would actually be made, and which is necessary in order to produce agreement of phase of the various elementary waves at a moderately distant focal point. The introduction of a refracting medium would complicate the problem, and is not really necessary for our present purpose. As has been shown (*Philosophical Magazine*, March 1881, "On Images formed without Reflection or Refraction"), the only use of an object-glass is to shorten the focal length. Our imaginary screens may be as far apart as we please, and if the distance is sufficient, the definition, and consequently the accuracy of alignment, is as great as could be attained with the most perfect telescope whose aperture is equal to that in the anterior screen.

It appears, then, that stellar aberration in itself need present no particular difficulty on the wave theory, unless the hypothesis of a quiescent æther at the earth's surface be regarded as such. But there are a variety of allied phenomena, mostly of a negative kind, which require consideration before any judgment can be formed as to the degree of success with which the wave theory meets the demands made upon it. In the first place, the question arises whether terrestrial optical phenomena could remain unaffected by the supposed immense relative motion of our instruments and of the æther; whether reflection, diffraction, and refraction, as ordinarily observed by us, could be independent of the direction of the rays relatively to the earth's motion. It may be stated at once that no such influence has been detected, even in experiments carefully designed with this object in view.

Another class of experiments, with the results of which theory must be harmonized, are those of Fizeau and Michelson upon the velocity of light in ponderable refracting media which have a rapid motion (relatively to the instruments and other surrounding bodies) in the direction of propagation, or in the opposite direction. These very important researches have proved that in the case of water the velocity of the ponderable medium is not without effect; but that the increment or decrement of the velocity of propagation is very decidedly less than the velocity of the water. On the other hand, the motion of air, even at high velocities, has no perceptible influence upon the propagation of light through it.

Again, it has been found by Airy,[1] as the result of an experiment originally suggested by Boscovitch, that the constant of stellar aberration is the same, whether determined by means of a telescope of the ordinary kind, or by one of which the tube is filled with water. It is clear that, according to Fresnel's views

[1] = about 540 English miles.—*Tr.*

[2] This paper was written in 1887, when I was occupied with my article upon "Wave Theory" for the "Encyclopædia Britannica," and at a time when a more extensive treatment was contemplated than was afterwards found practicable. Friends on whom I can rely are of opinion that its publication may be useful; and, as I am not able to give it a complete revision, I prefer to let it stand under its original date, merely warning the reader that very important work has since been published by Michelson.—*January* 1892.

[1] Proc. Roy. Soc., xx., 1872, p. 35; xxi., 1873, p. 121.

of the condition of the æther at the earth's surface, this agreement must involve some particular supposition as to the propagation of light in moving refracting media.

The theory of these phenomena must evidently turn upon the question whether the æther at the earth's surface is at rest, absolutely, or relatively to the earth;[1] and this fundamental question has not yet received a certain answer. The independence of terrestrial optical phenomena of the earth's motion in its orbit is, of course, more easily explained upon the latter alternative; or rather no explanation is required. But in that case the difficulty is thrown upon stellar aberration, which follows a more simple law than we should expect to apply in the case of an æther disturbed by the passage of a body in its neighbourhood. Prof. Stokes has, indeed, attempted a theory on these lines,[2] by supposing the ætherial motion to be what is called in hydrodynamics irrotational. In strictness there is, however, no such motion possible, subject to the condition of vanishing absolutely at a great distance, and relatively at the earth's surface; and it does not appear that the objection thus arising can be satisfactorily met.

If we start from the experimental facts which have the most direct bearing upon the question under discussion, we are led to regard Fresnel's views (doubtless in some generalized form) as the more plausible. From the results of Fizeau and Michelson relative to air, we may conclude with tolerable confidence that a small mass of ponderable matter, of very low refracting power, moving in space, would not appreciably carry the æther with it. The extension of the argument to a body as large as the earth is not unnatural, though it involves certainly an element of hypothesis. In like manner, if the globe were of water, we should expect the æther to be carried forward, but not to the full amount. The simplest supposition open to us is that, in any kind of ponderable matter, forming part of a complex mass, the æther is carried forward with a velocity dependent upon the local refracting power, but independent of the refracting power and velocity of other parts of the mass. In the earth's atmosphere, where the refracting power is negligible, the æther would be sensibly undisturbed.

If we agree to adopt this point of view provisionally, we have next to consider the relation between the velocity of luminous propagation in moving ponderable matter and the refractive index. The character of this relation was discovered by Fresnel, whose argument may be thrown into the following form.

Consider the behaviour of the æther when a plate of ponderable matter (index = μ) is carried forward through vacuum with velocity v in a direction perpendicular to its plane. If D be the density of the æther in vacuum, and D_1 the density in the refracting medium, then, according to Fresnel's views as to the cause of refraction, $D_1 = \mu^2 D$. The æther is thus condensed as the plate reaches it; and if we assume that the whole quantity of æther is invariable, this consideration leads to the law giving the velocity (xv) with which the denser æther within the plate must be supposed to be carried forward. For conceive two ideal planes, one in the plate and one in the anterior vacuous region, to move forward with velocity v. The whole amount of æther between the planes must remain unchanged. Now, the quantity entering (per unit area and time) is Dv, and the quantity leaving is $D_1(v - xv)$. Hence,

$$x = 1 - \mu^{-2},$$

so that the velocity with which the æther in the plate is carried forward is $v(1 - \mu^{-2})$, tending to vanish as μ approaches unity. If V be the velocity of light in vacuum, and V/μ the velocity in the medium at rest, then the absolute velocity of light in the moving medium is

$$V/\mu \pm v(1 - \mu^{-2}). \quad \ldots \ldots \ldots (1)$$

Whatever may be thought of the means by which it is obtained, it is not a little remarkable that this formula, and no other, is consistent with the facts of terrestrial refraction, if we once admit that the æther in the atmosphere is at absolute rest. It is not probable that the æther, in moving refracting bodies, can properly be regarded as itself in motion; but if we knew more about the matter we might come to see that the objection is verbal rather than real. Perhaps the following illustration may assist the imagination. Compare the æther in vacuum to a stretched string, the transverse vibrations of which represent light. If the string is loaded, the velocity of propagation of waves is diminished. This represents the passage of light through stationary refracting matter. If now the loads be imagined to run along the string with a velocity not insensible in comparison with that of waves, the velocity of the latter is modified. The substitution of a membrane for a string will allow of a still closer parallel. It appears that the suggested model would lead to a somewhat different law of velocity from that of Fresnel; but in bringing it forward the object is merely to show that we need not interpret Fresnel's language too literally.

We will now consider a few examples of the application of the law of velocity in a moving medium; and first to the experiment of Boscovitch, in which stellar aberration is observed with a telescope filled with water. We have only to suppose the space between the two screens of our former explanation to be occupied by water, which is at rest relatively to the screens. In consequence of the movement of the water, the wave, after traversing the first aperture, is carried laterally with the velocity $v(1 - \mu^{-2})$, and this is to be subtracted from the actual velocity v of the aperture in the posterior screen. The difference is $\mu^{-2}v$. The ratio of this to the velocity of light in water (V/μ) gives the angular displacement of the second aperture necessary to compensate for the motion. We thus obtain $\mu^{-1}v/V$. This angle, being measured in water, corresponds to v/V in air; so that the result of the motion is to make the star appear as if it were in advance of its real place by the angle v/V, precisely as would have happened had the telescope contained air or vacuum instead of water.

We will now calculate the effect of the motion of a plate perpendicular to its own plane upon the retardation of luminous waves moving in the same (or in the opposite) direction. The velocity of the plate is v, its index is μ, and its thickness is d. Denoting, as before, the velocity of the æther within the plate by xv, and supposing, in the first place, that the signs of v and V are the same, we have, for the absolute velocity of the wave in the plate,

$$V/\mu + xv.$$

We have now to express the time (t) occupied by the wave in traversing the plate. This is not to be found by simply dividing d by the above written velocity; for during the time t the anterior face of the plate (which the wave reaches last) is carried forward through the distance vt. Thus, to determine t we have

$$(V/\mu + xv)t = d + vt,$$

whence

$$\frac{Vt}{d} = \frac{\mu}{1 + (x - 1)\mu v/V}. \quad \ldots \ldots (2)$$

The time, t_0, which would have been occupied in traversing the same distance ($d + vt$), had the plate been away, is given by

$$Vt_0 = d + vt;$$

so that

$$\frac{Vt_0}{d} = 1 + \frac{\mu v/V}{1 + (x - 1)\mu v/V}. \quad \ldots \ldots (3)$$

Thus

$$\frac{V(t - t_0)}{d} = \frac{\mu(1 - v/V)}{1 + (x - 1)\mu v/V} - 1. \quad \ldots \ldots (4)$$

Substituting in this Fresnel's value of x, viz. $(1 - \mu^{-2})$, and neglecting as insensible the square of v/V, we find

$$V(t - t_0) = (\mu - 1)d(1 - v/V). \quad \ldots \ldots (5)$$

If we suppose that part of the original wave traverses the plate, and that part passes alongside, (5) gives the relative retardation—that is, the distance between the wave fronts which were originally in one plane. It would appear at first sight that this result would give us the means of rendering v evident. For the retardation, depending upon the sign of v/V, will be altered when the direction of the light is reversed, and this we have it in our power to bring about by simply turning our apparatus through 180°. A more careful examination will, however, lead us to a different conclusion.

The most obvious way of examining the retardation would be to use homogeneous light, and, by producing regular interference of the two portions, to observe the position of the fringes, and any displacement that might result from a shift of the apparatus relatively to the direction of the earth's motion. But if we employ for this purpose a terrestrial flame, *e.g.* that of a Bunsen's burner containing sodium, we have to take into

[1] An accusation of crudeness might fairly be brought against this phraseology; but an attempt to express the argument in more general language would probably fail, and would in any case be tedious.

[2] *Phil. Mag.*, xxviii., 1846, p. 76; xxix., 1846, p. 6.

account the fact that the source is itself in motion. For it is evident that the waves which pass in a given time through any point towards which the source is moving are more numerous than had the source been at rest, and that the wave-lengths are correspondingly shortened. If v be the velocity of the source, the wave-length is changed from λ to $\lambda(1 - v/V)$. At a point behind, from which the source is retreating, the wave-length is $\lambda(1 + v/V)$. We shall have occasion to refer again to this principle, named after Döppler, as applied by Huggins and others to the investigation of the motion of the heavenly bodies in the line of sight.

Referring now to (5), we see that, although the *absolute* retardation is affected by v, yet that the retardation *as measured in wave-lengths* remains unaffected. If, then, there be, in the absence of v, an agreement of phase between the two interfering beams, the introduction of v will cause no disturbance. Consequently no shifting of the interference bands is to be expected when the apparatus is turned so that the direction of propagation makes in succession all possible angles with that of the earth's motion.

The experiment has been modified by Hoek,[1] who so arranged matters as to eliminate the part of the retardation independent of v. As before, of two parallel beams A and B, one, A, passes through a plate of refracting medium; the other, B, through air. The beams are then collected by a lens, at the principal focus of which is placed a mirror. After reflection by this mirror, the beams exchange paths, B returning through the plate, and A through air. Apart, therefore, from a possible effect of the motion, there would be complete compensation and no final difference of path. As to the effect of the motion, it would appear at first sight that it ought to be sensible. During the first passage, A is (on account of v) accelerated; on the return, B is retarded; and thus we might expect, upon the whole, a relative acceleration of A equal to $(\mu - 1)d \cdot 2v/V$. But here, again, we have to consider the fact that another part of the apparatus, viz. the mirror, partakes in the motion. In the act of reflection the original retardation of A is increased by twice the distance through which the mirror retreats in the interval between the arrival of the two waves. This distance is (with sufficient approximation) $(\mu - 1)d \cdot v/V$; so that the influence of the movement of the mirror just compensates the acceleration of A which would have resulted in the case of a fixed mirror On the whole, then, and so long as the square of v/V may be neglected, no displacement of fringes is to be expected when the apparatus is turned. The fact that no displacement was observed by Hoek, nor in an analogous experiment by Mascart,[2] proves that if the stationary condition of the æther in terrestrial vacuous spaces be admitted, we are driven to accept Fresnel's law of the rate of propagation in moving refracting media.

What is virtually another form of the same experiment was tried by Maxwell,[3] with like negative results. In this case, prisms were used instead of plates; and the effect if existent, would have shown itself by a displacement of the image of a a spider-line when the instrument was turned into various azimuths.

On the basis of Fresnel's views it may, in fact, be proved generally that, so far as the first power of v/V is concerned, the earth's motion would not reveal itself in any phenomenon of terrestrial refraction, diffraction, or ordinary refraction. The more important special cases were examined by Fresnel himself, and the demonstration has been completed by Stokes.[4] Space will not allow of the reproduction of these investigations here, and this is the less necessary, as the experiment of Hoek, already examined, seems to raise the principal question at issue in the most direct manner.

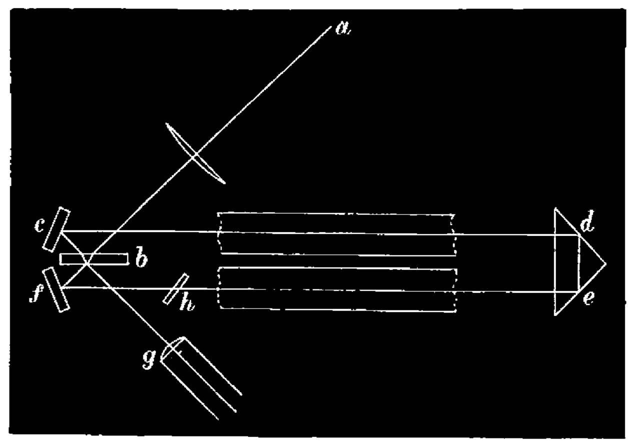
Another point remains to be touched upon. We have hitherto neglected *dispersion*, treating μ as constant. In stationary dispersing media, μ may be regarded indifferently as a function of the wave-length or of the periodic time. When, however, the medium is in motion, the distinction acquires significance; and the question arises, What value of μ are we to understand in the principal term V/μ of (1)? Mascart points out that the entirely negative results of such experiments as those above described indicates that, in spite of the difference of wave-length due to the motion, we must take the same value of μ as if the medium and the source had been at rest, or that μ is to be regarded as a function of the *period*.

Mascart has experimented also upon the influence of the earth's motion upon double refraction, with results which are entirely negative. The theoretical interpretation must remain somewhat ambiguous, so long as we remain in ignorance of the mechanical cause of double refraction.

Reference has already been made to the important experiments by Fizeau and by Michelson upon the velocity of light in moving media. The method, in its main features, is due to the former,[1] and is very ingeniously contrived for its purpose. Light issuing from a slit is rendered parallel by a collimating lens, and is then divided into two portions, which traverse tubes containing running water. After passing the tubes, the light falls upon a focussing lens and mirror (as in Hoek's experiment), the effect of which is to interchange the paths. Both rays traverse both tubes; and, consequently, when ultimately brought together, they are in a condition to produce interference bands. If now the water is allowed to flow through the tubes in opposite directions, one ray propagates itself throughout *with* the motion of the water, and the other *against* the motion of the water; and thus, if the motion has any effect upon the velocity of light, a shift of the bands is to be expected. This shift may be doubled by reversing the flow of water in the tubes.

Fizeau's investigation has recently been repeated in an improved form by Michelson.[2]

"Light from a source at a falls on a half-silvered surface, b, where it divides; one part following the path $b\,c\,d\,e\,f\,b\,g$, and the other the path $b\,f\,e\,d\,c\,b\,g$. This arrangement has



the following advantages: (1) it permits the use of an extended source of light, as a gas flame; (2) it allows any distance between the tubes which may be desired; (3) it was tried by a preliminary experiment, by placing an inclined plate of glass at h. The only effect was either to alter the width of the fringes, or to alter their inclination; *but in no case was the centre of the central white fringe affected*. Even holding a lighted match in the path had no effect on this point.

"The tubes containing the fluid were of brass, 28 mm. internal diameter; and in the first series of experiments, a little over 3 metres in length, and in the second series a little more than 6 metres."

Even with the longer tubes and the full velocity (about 8 metres per second) the displacement on reversal amounted to less than the width of a fringe. Nevertheless, fairly concordant results were arrived at; and they showed that the fraction (x) of the velocity of the water (v) by which the velocity of light is altered is ·434, with a possible error of ± ·02. The numerical value of the theoretical expression is

$$x = 1 - \mu^{-2} = \cdot 437,$$

in very close accordance.

"The experiment was also tried with air moving with a velocity of 25 metres per second. The displacement was about ·01 of a fringe; a quantity smaller than the probable error of

[1] *Archives Néerlandaises*, t. iii. p. 180 (1868); t. iv. p. 443 (1869).
[2] *Ann. de l'Ecole Normale*, t. iii. (1874).
[3] Phil. Trans., 1868, p. 532.
[4] *Phil. Mag.*, xxviii. p. 76 (1846). See also Mascart, *Ann. de l'École Norm.*, t. i. (1872), t. iii. (1874); and Verdet, "Œuvres," t. iv., deuxième partie.

[1] *Ann. de Chimie*, III. lvii. (1859).
[2] *American Journal*, vol. xxxi. p. 377 (1886).

observation. The value calculated from $(1 - \mu^{-2})$ would be ·0036."

We have seen that, so far as the first power of v/V is concerned, Fresnel's theory agrees with all the facts of the case. The question whether it is possible to contrive an experiment in which v^2/V^2 shall be sensible, has been considered by Michelson,[1] who, having arrived at an affirmative conclusion, proceeded to attack this very difficult experimental problem. In Michelson's apparatus interference is brought about between two rays, coming of course originally from the same source, one of which has traversed to and fro a distance, D, parallel to the earth's motion, and the other a like distance in the perpendicular direction. The phase of the latter ray is considered by Michelson to be unaffected by the earth's motion. As to the former, it is retarded by the amount

$$\frac{D}{V - v} + \frac{D}{V + v} - \frac{2D}{V} = \frac{2D}{V} \cdot \frac{v^2}{V^2},$$

or, reckoned in distance at velocity V,

$$2Dv^2/V^2. \quad \dots\dots\dots \quad (6)$$

"Considering only the velocity of the earth in its orbit, the ratio $v/V = 10^{-4}$ approximately, and $v^2/V^2 = 10^{-8}$. If $D = 1200$ mm., or, in wave-lengths of yellow light, 2,000,000, then in terms of the same unit, $2D\, v^2/V^2 =$ ·04.

"If, therefore, an apparatus is so constructed as to permit two pencils of light, which have travelled over paths at right angles to each other to interfere, the pencil which has travelled in the direction of the earth's motion, will in reality travel ·04 of a wave-length further than it would have done were the earth at rest. The other pencil, being at right angles to the motion, would not be affected.

"If now the apparatus be revolved through 90°, so that the second pencil is brought into the direction of the earth's motion, its path will be lengthened ·04 wave-length. The total change in the position of the interference bands would be ·08 of the distance between the bands, a quantity easily measurable."

In the actual experiment, the earth's velocity was not available to the full extent, and the displacement to be expected on this account was reduced to ·048; but Michelson considers that some addition to it should be made on account of the motion of the solar system as a whole. The displacement actually found was ·022; and when the apparatus was employed in such azimuths that the rotation should have had no effect in any case, ·034. These results are very small, and Michelson gives reasons for regarding them as partially systematic errors of experiment. He concludes that there is no real displacement of the bands, and that the hypothesis of a stationary æther is thus shown to be inconsistent with fact.

It has, however, been recently pointed out by Lorentz[2] that Michelson has over-estimated the effect to be expected according to Fresnel's views. The ray which travels perpendicularly to the earth's motion is not unaffected thereby, but is retarded to the amount represented by $D\,v^2/V^2$. The outstanding relative retardation is thus only $D\,v^2/V^2$, instead of the double of that quantity. Accepting this correction, we have to expect, according to Fresnel's views, a shift of only ·024 of a band in Michelson's experiment.

Under these circumstances Michelson's results can hardly be regarded as weighing heavily in the scale. It is much to be wished that the experiment should be repeated with such improvements as experience suggests. In observations spread over a year, the effects, if any, due to the earth's motion in its orbit, and to that of the solar system through space, would be separated.

On the whole, Fresnel's hypothesis of a stationary æther appears to be at the present time the more probable; but the question must be considered to be an open one. Further evidence would be most important; but it is difficult to see from what quarter anything essentially new can be expected. It might be worth while for astronomers to inquire whether it is really true, as is generally assumed, that stellar aberration is independent of the position upon the earth's surface from which the observation is made. Another question that might, perhaps, be submitted with advantage to an experimental examination is whether the propagation of light in air is affected by the rapid motion of heavy masses parallel to, and in the immediate neighbourhood of, the ray.

If we once admit the principle that, whatever the explanation may be, no ordinary[1] terrestrial observation is affected by the earth's motion, it is easy to give an account of what must happen when the light comes from an external source which may have a motion in the line of sight. Imagine, for example, a spectroscopic examination of a soda flame situated on a star and vibrating in identical periods with those of terrestrial soda flames. In accordance with Döppler's principle, the wave-lengths are altered by a relative motion in the line of sight, and the fact may be rendered evident by a comparison between the spectra of the star and of the terrestrial flame, held so as to be seen in the same direction. The simplest case is when the flame is entirely external to the apparatus, so that both lights are treated in precisely the same way. It is evident that, under these circumstances, the difference between the two cannot fail to become apparent; and this way of regarding the matter shows also that the apparent displacement of the bright lines in the stellar spectrum is dependent upon the relative, and not further upon the absolute, motions of the star and of the earth. The mean of observations, equally distributed over the year, would thus give data for determining the relative motion in the line of sight of the star and of the solar system.

If the external source be the sun itself, it might be thought that the spectra must agree almost perfectly, the eccentricity of the earth's orbit being so very small. But the sun is a revolving body, and consequently a distinction must be made according to the part of the sun from which the light proceeds. It is found, in fact, that a very sensible shift takes place in the position of the dark lines according as the light under observation comes from the advancing or from the retreating limb. This circumstance has been successfully employed by Thollon and Cornu to distinguish between lines having a solar and a terrestrial origin. In the latter case it is a matter of indifference from which part of the sun the light proceeds.

In general optical theory the finiteness of the velocity of light is usually disregarded. Velocities at least ten times greater than that of the earth in its orbit are, however, known to astronomers; and such must begin to exercise a sensible influence upon radiation. Moreover, in so wide a generalization as the theory of exchanges, the neglect of even a small quantity is unsatisfactory. Prof. Balfour Stewart has discussed the influence of the motion of a plate exercising selective absorption upon the equilibrium of radiation within an inclosure. He argues that a disturbance will ensue, involving a violation of the second law of thermodynamics, unless compensated by some other effect not hitherto recognized. It appears, however, more probable that the whole radiation coming *from* and *through* a plate would not be altered by its motion. Whatever effect (in accordance with Döppler's law) the motion has upon the radiation from the plate, a similar effect would probably be produced upon the absorbing power. On this view the only result of the motion would be to change the wave-length of the rays most powerfully emitted and absorbed, but without disturbing the balance required by the theory of exchanges. The moving plate would in fact be equivalent to a stationary one of slightly different quality.

RAYLEIGH.

1887.

[1] *American Journal*, xxii. p. 120 (1881).

[2] "Over den invloed dien de beweging der aarde of de licht verschijnselen uitoefent." (Amsterdam, 1886.)

[1] This qualification is inserted in order to exclude such an experiment as that of Michelson, just described, in which an attempt is made to render sensible an effect depending on v^2/V^2.

[2] B.A. Report, 1871.

SOCIETIES AND ACADEMIES.

LONDON.

Mathematical Society, March 10.—Prof. Greenhill, F.R.S., President, in the chair.—The President and Mr. S. Roberts, F.R.S., spoke upon the loss the Society had sustained by the recent decease of Dr. Hirst, F.R.S., touching more especially upon the great services he had rendered to it in the early days of its existence.—The following paper was read:—The simplest equivalent of a given optical path, and the observations required to determine it, by Dr. J. Larmor. To specify an optical path through a heterogeneous medium like the atmosphere, or through an arrangement of refracting substances like an optical instrument, we require the geometrical curve followed by the filament of light, and also the character of the modification produced on a filament following this path across the medium.