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HYPOTHESES ON LUMINOUS ETHER AND ON AN EXPERIMENT THAT APPEARS TO DEMONSTRATE THAT THE MOTION OF BODIES CHANGES THE VELOCITY WITH WHICH LIGHT PROPAGATES IN THEIR INTERIOR

H. Fizeau

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HYPOTHESES ON LUMINOUS ETHER AND ON AN EXPERIMENT THAT APPEARS TO DEMONSTRATE THAT THE MOTION OF BODIES CHANGES THE VELOCITY WITH WHICH LIGHT PROPAGATES IN THEIR INTERIOR

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ABSTRACT. The author discusses Fresnel's hypothesis to explain light abberation and light waves. An experiment to determine the possible changes in the speed of light traveling through transparent bodies is discussed, as well as the apparatus used for such experiments. The author presents calculations and discusses results and possible sources of error.

Several theories on wave systems have been proposed to attempt to explain the abberation of light. First, Fresnel and, more recently, Doppler, Stokes, Challis and several others have published papers on this subject, but it does not seem that any of the theories so far proposed have been able to completely satisfy the physicists. Because of a lack of definite knowledge about the properties of the luminous ether and its relationship to ponderable matter, it has been necessary to introduce hypotheses, among which are those which are more or less probable, but none that can be considered as proven. /385*

These can be reduced to three main hypotheses, all of which refer to the state in which the ether inside a transparent body should be considered:

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*Numbers in the margin indicate the pagination in the original foreign text.

The ether adheres, or is fixed, to the molecules of the body, and, consequently, shares in the motion that may be imposed on the body;

Or, the ether is free and independent, and is not carried along by the body in its motion;

Or, finally, a third hypothesis which borrows from each of the two above, in which only a portion of the ether would be free, while the other portion /386 would be fixed to the molecules of the body and would solely share in its motion.

This last hypothesis, postulated by Fresnel, was conceived in order to satisfy at the same time the phenomenon of abberation, and a famous experiment by Arago, in which he had shown that the motion of the Earth did not have any effect upon the refraction value of starlight in a prism. These two phenomena could be explained through Fresnel's hypothesis with admirable precision. However, Fresnel's hypothesis is not regarded today as absolute truth, and the relationships between ether and ponderable matter are still generally considered as uncertain and hard to understand. This is because Fresnel's mechanical conception seems too unusual to be accepted without direct proof, or perhaps because it seemed equally possible to satisfy the observed phenomena with either of the two other hypotheses. Perhaps, finally, as other physicists have thought, certain results from this theory seemed contrary to experience.

The following considerations have led me to try an experiment, the results of which, I believe, should clarify this matter.

It is possible in the three hypotheses enumerated above that, if the body is in motion, the velocity at which light will go through it will be different from that observed if the body were at rest. For each of these hypotheses, the motion of the body would have a different effect upon the light velocity.

Thus, if ether is supposed be fixed to the body during the latter's motion, the velocity of light will be augmented by that of the body, if the direction of the light ray and of the motion are the same.

If the ether is supposed to be free, the velocity of light will not change.

Finally, if only part of the ether is attached to the body, the velocity of light will be augmented only by a fraction of the velocity of the body, /387 and not by the total amount as in the first hypothesis. This result is not as evident as in the first two hypotheses, but Fresnel has made it clear that it may be upheld by very credible mechanical considerations.

It is supposed that the speed of light in a body at rest or in motion may be determined exactly. If the body is in motion, and if the speed of light corresponding to the state of rest increases by the total speed of motion of the body, this will conform with the first hypothesis.

If the speed of light is the same in both cases (body at rest or in motion), the second hypothesis will be satisfied.

If, on the other hand, the speed of light corresponding to the state of rest is augmented by a fraction of the speed of the body, the result will be in agreement with the third hypothesis.

It is true that light travels at such a great speed — when compared to the speeds that we may impart to the bodies — that the change in the speed of light is too small to be observable. Nonetheless, by choosing the most favorable circumstances, it has seemed to me possible to submit two media, air and and water, to a decisive test. These two media, because of the mobility of their components or molecules, can be accelerated to great speeds.

We owe to Arago a method of observation, based on interference, which reveals the smallest variations in the refractive indices of bodies. Arago and Fresnel have demonstrated the extraordinary sensitivity of this procedure through several delicate observations, such as the difference in refraction between dry and humid air.

It has seemed to me that a mode of observation based on this principle is the only one that reveals the changes in speed due to motion. It consists in /388 producing interference fringes with two light rays, after they have passed through two parallel tubes in which air and water may float at great speeds and in opposite directions. The special goal that I have tried to attain has needed several innovations, which I will indicate.

Great difficulties were encountered relative to the light intensity. The tubes, with an interior diameter of 5.3 mm, had to be traversed by the light near their center and not near their sides. Thus, the two slits had to be more elongated than usual, and, consequently, the light intensity at the point of origin of the fringes was very low.

This inconvenience was overcome by placing a convergent lens behind the slits. Then the fringes were observed at the point of the beam junction where the light intensity is fairly great.

Since the length of the tubes was fairly large, 1.487 m, it was feared that any difference in temperature or pressure between the two tubes would initiate a considerable displacement of the fringes, which in turn could completely mask the displacement due to motion.

This difficulty has been obviated by means of a telescope having a mirror at its focal point. This way each beam is forced to traverse the two tubes successively, so that both beams covered exactly the same distance, but in opposite direction. The effects produced by pressure or temperature are thus compensated. I have satisfied myself, through several experiments, that the compensation is complete, and regardless of any changes in density or temperature introduced upon the medium in one of the tubes, the fringes keep their same exact position. In this type of arrangement, the fringes should be /389 observed at the same point of departure of the beams; sunlight is admitted laterally, and directed toward the tubes by its reflection on a mirror. The beams, after this double passage through the tubes, return to set up their interference pattern a short distance beyond the mirror traversed by them originally. It is here that the fringes are observed with the aid of an ocular having a divided scale.

Another advantage of the double trajectory by the beam is that of increasing the probable effect of motion; it is just as if the tubes were twice as long.

This arrangement also permits the use of a very simple means to make the fringes larger than they should be at the distance separating the two slits (this distance was 9 millimeters). This is done by placing a very thick glass in front of one of the slits inclined in such a way that, because of refraction effects, the two slits would appear very close to each other. The fringes are then as large as they would be if the slits were really a lot closer. Also, there is no appreciable loss in intensity, and, on the contrary, the intensity can be greatly increased by increasing the light source. The size of the fringes can be varied at will by changing the inclination of the glass, and so it is possible to obtain the fringe size most convenient for observing the displacement with precision.

I want to describe now the arrangement of the tubes and apparatus to set the water in motion.

The two tubes, placed side by side, were closed at either end with a single piece of glass glued into place with gum lac, in a position perpendicular to the common direction. Near each end a branch, shaped as a rounded elbow, establishes communication with a larger tube that goes to the bottom of a flask. Consequently, there were four flasks connected to the ends of /390
the two tubes.

One of the two flasks connected to a tube is full of water; a piece of tubing allows the introduction of compressed air coming from a reservoir connected to an air pump. The pressure forces the water to rise into the tube, traverse it completely, and go into the flask at the opposite end. This latter flask may, in turn, be pressurized with compressed air, and the water will return to the first flask, traversing the tube in the opposite direction. Water speeds over seven meters per second may be obtained. The same flow took place simultaneously in the two tubes, although in opposite direction to one another.

The observer has two handy stopcocks connected to the air reservoir; if either one is open, water flow is established at once in both tubes. The direction of flow is reversed with the other stopcock.

The air reservoir, where the air is usually at two atmospheres of pressure, has a 15 liter capacity. The capacity of the flasks is about two liters. They are calibrated in equal volumes, and the duration for the flow of 0.5 liters plus the water in the section of the tubes are subtracted from the speed of the water.

The apparatus arrangement, which I have just tried to describe, has only been used for experimentation with water in motion. It is also convenient for air, provided some modifications are made. The experiment with air in motion was made previously with a somewhat different apparatus, which will be dealt with later, and with which conclusive results were obtained.

I have determined that air motion does not produce a perceptible displacement of the fringes. Later I shall go over these results in greater detail.

In the case of water, there is an evident displacement.

When the water flows away from the observer in the tube on his right, and toward the observer in the tube on his left, the fringes are displaced toward the right. /391

When the water flow takes place in a direction opposite to the one described above, the fringes are displaced to the left.

The fringes remain very clear while the water is in motion. They move parallel to themselves, without disturbances, in amounts perceptibly proportional to the speed of the water. At a speed of two meters per second, the displacement is already fairly noticeable, and is perfectly measurable at water speeds between 4 and 7 meters per second.

It has been found experimentally that the displacement of a fringe occupying five micrometer divisions is 1.2 divisions to the right or 1.2 divisions to the left, at a water velocity of 7.059 meters per second.

The sum of both displacements is 2.4 divisions, which means a sensitivity of 1/2 fringe.

In order to avoid certain objections, I should say that the system of tubes and flasks in which the motion of the water took place was completely isolated from the other portion of the apparatus. This precaution was taken in order to prevent the pressure or the shock of the water from producing accidental flexural changes in certain portions of the apparatus whose movements could have influenced the position of the fringes. On the other hand, I have assured myself that motion imposed by the design upon the two-tube system had no influence upon the position of the fringes.

After having verified the existence of the phenomenon, I tried to determine the value with the greatest possible accuracy.

In order to avoid a cause for error which, I thought, would exert an influence on the results, I have changed the width of the fringes, the speed /392 of the water, and even the nature of the micrometer divisions, so as to observe the different displacements without being able to presuppose the value. In fact, the greatest influence to be feared was that of preoccupation while measuring small quantities which involved a great deal of estimation. I believe that the results I have obtained have been free of this cause of error.

The greater portion of the observations were made at a speed of 7.059 meters per second. A certain number of them were made at a speed of 5.515 meters per second, and some were made at 3.7 meters per second. The observed values were reduced to the maximum speed of 7.059 meters per second, and related to the length of a fringe taken as unity.

	Fringe displacement values for an average water speed of 7.059 m per second.	Differences between the observed values and the average.
	0,200	— 0,030
	0,220	— 0,010
	0,240	+ 0,010
	0,167	— 0,063
	0,171	— 0,059
	0,225	— 0,005
	0,247	+ 0,017
	0,225	— 0,005
	0,214	— 0,016
	0,230	0,000
	0,224	— 0,006
	0,247	+ 0,017
	0,224	— 0,006
	0,307	+ 0,077
	0,307	+ 0,077
	0,256	+ 0,026
	0,240	+ 0,010
	0,240	+ 0,010
	0,189	— 0,041
Total	4,373	
Average	0,23016	

By doubling the average value,0.46 is obtained, which is very close to half a fringe, and which represents the displacement value produced when the flow in the tubes is reversed. /393

The difference between the observed and the average values was added to the observed values in order to determine the deviation at either side of the average. It was observed that they generally represent a very minute fraction of the width of the fringe; the greatest deviation did not exceed 1/13 of a fringe.

A difficulty, impossible to avoid, furnished the explanation for these differences. The maximum displacement takes place during a very short time, and, consequently, the observation must be done rapidly. If it were possible to maintain a constant flow speed of the water for a longer time, the measurements would be more precise. But this has not been possible without introducing considerable changes in the apparatus. Such changes would have retarded this experiment to a time of the year when experiments requiring the use of sunlight become almost impossible to perform.

I want now to compare the value found for the displacement of the fringes to that which would be the result of each of the hypotheses in question.

To start with, it suffices that the motion of the water displaces the fringes in any amount to exclude the supposition that the ether is completely free and independent of the motion of the body.

It is also necessary to calculate what the displacement of the fringes would be assuming that the ether is attached to the molecules of the body so that they would share in each other's motion.

Let v = speed of light in vacuum,
v' = speed of light in still water, and /394
u = speed of water parallel to the direction of the light rays.

The speed of light in water, when this liquid is in motion, will be for both rays,

$$v' + u \text{ and } v' - u,$$

The motion takes place in a relative direction which is opposed to each of the rays.

If we call Δ the difference in speeds being sought, E the length of the column of water traversed by the rays, by applying the principles of the theory of interferences, we find that

$$\Delta = E\left(\frac{v}{v'-u} - \frac{v}{v'+u}\right),$$

or also,

$$\Delta = 2E\frac{u}{v}\left(\frac{v^2}{v'^2-u^2}\right).$$

Since u is so small in relation to v, $\left(\frac{u}{v'} = \frac{1}{33\,000\,000}\right)$, this expression may be reduced, without appreciable error, to

$$2E\frac{u}{v}\,\frac{v^2}{v'^2}.$$

Replacing the expression $\frac{v}{v'}$, by m, the refractive index of water, in the above formula we have

$$\Delta = 2E\frac{u}{v}m^2.$$

Each ray traverses the tubes twice, and so the length E is twice the actual length of the tubes. By calling L the actual length of each tube (1.4875 meters), the previous expression becomes

$$\Delta = 4L\frac{u}{v}m^2.$$

Numerical calculation yields: /395

$$\Delta = 0.0002418 \text{ millimeters}$$

This is the difference in distance that should exist between the two rays if the first hypothesis were true.

This number is actually in relation to velocity in a vacuum. In order to relate it to air, it should be divided by the refraction index of this medium. But, this index is so close to unity that, for the sake of simplification, it is possible to ignore the transformation while introducing an error no greater than unity in the last figure.

The value for the fringe displacement, as a function of the width of a fringe, is obtained by dividing the above quantity by the value of a wavelength. As a matter of fact, for a difference in speed of 1, 2, 3, m wavelengths, the fringe system is displaced by 1, 2, 3, m fringes.

The wavelength for ray E is $\lambda = 0.000526$. These are the rays that seem to maintain the greatest intensity, since the light must travel through a rather considerable thickness of water.

Finally the fringe displacement is found,

$$\frac{\Delta}{\lambda} = 0{,}4597.$$

If there were agreement with the hypothesis in question, the ether would be placed in motion at a speed equal to that of the water, which, in the preceding experiment would have caused a displacement of 0.46 fringes.

But, the average of the observations has been only 0.23, and observation of the individual values higher than the average shows that none of them approaches the number 0.46. I should also add that this number should be still greater because of a small error in the evaluation of the speed of water. The source of this error is known, as will be seen later, but it has not been possible to correct the error exactly.

It is evident that this hypothesis is not in agreement with the experiment./396

On the other hand, we shall see that the third hypothesis p[illegible] Fresnel, leads to a displacement value very close to the obser[illegible]

It is known that the ordinary phenomenon of refraction is due to the fact that the speed of propagation of light in the interior of bodies is less than in a vacuum. Fresnel admits that this change in speed takes place because the ether possesses a greater density in the interior of bodies than in vacuum. In the case of two media with the same elasticity but different densities, the squared powers of the speeds of propagation are in inverse proportion to the densities. Thus we have

$$\frac{D'}{D}=\frac{v^2}{v'^2},$$

in which D and D' are the densities of the ether in vacuum and in the body, and v and v' are the corresponding propagation speeds, respectively. Consequently,

$$D'=D\frac{v^2}{v'^2} \qquad \text{and} \qquad D'-D=D\frac{v^2-v'^2}{v'^2}.$$

This last expression gives the excess density of the interior ether.

If the body is set in motion, only a part of the interior ether is set in motion with the body; this is the portion that has a greater density than that of the surrounding ether. The density of this mobile portion is expressed by D' - D. The other portion of the ether, which remains immobile while the motion takes place, has a density D.

What is the speed of propagation of the waves in this type of medium — a portion in motion and a portion motionless — supposing, for simplicity's sake, that the body moves in the direction of propagation of the waves?

Fresnel considers that the speed assumed by the center of gravity of the system is added to the speed of propagation of the waves. /397

If u is the speed of the body, $u\left(\frac{D'-D}{D'}\right)$ will be the speed of the center of gravity of the system, and from preceding considerations, this expression is equal to

$$u\left(\frac{v^2-v'^2}{v^2}\right).$$

which is the amount by which the speed of propagation of the waves should be increased.

Also, if the speed of propagation in the state of rest is v', in the state of motion it will be

$$v'\pm u\left(\frac{v^2-v'^2}{v^2}\right).$$

Now, with the help of this expression, I am going to calculate the fringe displacement that should be observed in the experiment in question.

The speed of propagation of light in moving water, for each of the two rays that have to interfere, is one of the values expressed by the preceding formula. Using the same notation as in the previous example, the difference in velocities will be

$$\Delta = E\left[\frac{v}{v'-u\left(\frac{v^2-v'^2}{v^2}\right)}-\frac{v}{v'+u\left(\frac{v^2-v'^2}{v^2}\right)}\right];$$

By doing the calculations and some transformations, it is found

$$\Delta = 2E\frac{u}{v}\left[\frac{v^2-v'^2}{v'^2-u^2\left(\frac{v^2-v'^2}{v^2}\right)^2}\right].$$

This expression may be simplified by taking into consideration that u is very small in relation to v, $\left(\frac{u}{v'}=\frac{1}{33000000}\right)$, and that the coefficient of u^2 is /398 always smaller than unity, which permits the cancelation of the term in u^2 without appreciable error; m is the index of refraction, E is twice the length L of the tubes, and the final formula is

$$\Delta = 4L\frac{u}{v}(m^2-1),$$

By making the numerical cancelation, it is found:

$$\Delta = 0.00010634 \text{ millimeters}$$

This is the difference in speeds between the two rays that interfere, established by the motion of the water. Dividing this result by the length of a wave, λ, the fringe displacement is obtained

$$\frac{\Delta}{\lambda} = 0{,}2022\,;$$

The experimental result was 0.23.

These two values are almost identical. I also want to demonstrate that the difference between the observed and the calculated values can very likely be described by an error in the evaluation of the water speed, with a source easy to assign, and whose value can be assumed by analogy to be very small.

The speed of water in each tube has been calculated by dividing the volume of water flowing in one second by the tube section. In this way, the median speed of the water has been obtained, which would be the actual one if the motion of the liquid threads were the same through the cross section of the tube, along the center as well as along the walls. But, reasoning shows that this is not the case, and that the resistance experienced by the liquid along the walls has an immediate effect upon the neighboring layers closer to the center. This means that the speed is different for liquid threads flowing at different distances from the wall. The speed value obtained by calculation is intermediate to these different speeds. The speed near the center is much /399 greater than the median speed, which in turn is greater than the speed near the walls.

Also, the slits, placed in front of each tube to admit the light rays that will eventually cause the interference, are located in the middle of the circular end of the tubes, so that the rays traverse the central zones where the speed of the water should be greater than the median speed. (Each slit has the shape of a rectangle, 3 mm by 1.5 mm, and its surface is 1/5 of the cross section of the tube.)

Laws governing the flow of water in tubes, that would follow these speed variations, have yet to be determined, and thus it is not possible to introduce the necessary corrections. At the same time, analysis indicates that the possible error cannot be too great. As a matter of fact, a law governing the water flow in open canals has been determined, and in this case the same cause produces a similar effect. It is seen that in the middle of the canal, near the surface, the water has a greater speed than the median. It has been found that, when the median speed varies between 1 and 5 meters per second, the maximum speed is obtained by multiplying the median speed by a factor varying from 1.23 to 1.11. By analogy, it is possible to assume that the correction to use would be on the order of this magnitude.

If u is multiplied by 1.1, 1.15, or 1.2, and the corresponding fringe displacement is calculated, values of 0.22, 0.23 and 0.24 are found in place of 0.20. It is seen that the correction tends to become closer to the calculated rather than the observed result. Thus, it is possible to assume that the small difference between these two values is due to a small error in the actual water velocity: an error that cannot be corrected in a satisfactory /400 manner because of a lack of sufficiently precise data.

Thus, the fringe displacement by the movement of the water, and the amount of displacement, are satisfactorily explained by the theory proposed by Fresnel.

I said before that, where the rays travel through air instead of water, no fringe displacement is observed when the air is in motion. This fact has been proven by means of the apparatus which I will briefly describe.

A bellows, counterpoised with weights and moved by a lever, forces the air through two copper tubes closed with glass at their ends; the air moves in opposite directions in each tube. These tubes had an effective length of

1.495 meters and a diameter of 1 cm. The pressure necessary to produce the air flow was measured with a manometer connected at the entrance to the tubes; at times it would go as high as 3 cm of mercury.

The air speed was calculated from the pressure and the dimensions of the tubes, according to the known laws pertaining to gas flow. The found value was controlled by the known capacity of the bellows,and the speed at which it had to be actuated in order to produce a fairly constant pressure at the entrance to the tubes. It was relatively easy to obtain air speeds of up to 25 meters per second and, on rare occasions, much greater speeds of uncertain value.

No appreciable displacement of the fringes was detected in any of the experiments. They always occupied the same position whether the air was still, or moving at speeds of 25 meters per second or better.

When this experiment was being conducted, I had not yet thought of the possibility of using a reflecting telescope, which makes it possible to double /401 the value of the displacements by fully compensating for the effects due to accidental differences in temperature or pressure in the two tubes. I used a sure way to distinguish between the effects due to motion and the other accidental effects that could occur.

This consists of making two successive observations by passing through the apparatus beams going in opposite directions. This was done by placing the light source at the point where the central fringe had formed in the preceding experiment, and the new fringes would form at the exact point where the source had been before.

With the direction of air flow constant in both cases, it is easy to see that accidental effects should have produced displacement at the side of the same tube during both observations, while the displacement due to air motion should have taken place first to the side of one tube, and then to the side of the opposite one. In this way, a displacement due to motion would have been recognized, even if it had been accompanied by an accidental displacement due mainly to some defect of symmetry in the diameters or in the orifice of the tubes. This would have resulted in unequal resistance to the passage of the gas,and, consequently, in a difference in density.

But it has been possible to give the apparatus such a high degree of symmetry that there were no apparent density differences in the two tubes during the flow of air. Thus, the double observation would not have been necessary. Nonetheless, this second observation has been done for added assurance, and to allay the fear that the displacement being looked for could have been accidentally compensated by a small difference in density, which would have masked it completely.

In spite of these precautions, no fringe displacement by air motion could be found.

I estimate that a displacement as small as 1/14 of a fringe, produced by the motion of the air, would have been noticed. /402

Here are the calculations related to this experiment.

Considering the hypothesis where the ether is completely affixed to the air in motion,

$$\Delta = 2L\frac{u}{v}m^2 = 0^{\text{mm}},0002413,$$

where m^2 is 1.000567 at a temperature of 10°C.

Since the experiment was conducted on air, the maximum lighting is obtained from yellow light rays, and this maximum is the one that determines the width of the fringes. Thus, it is convenient to use for λ, the value corresponding to ray D. Thus, we have

$$\frac{\Delta}{\lambda} = 0,4103.$$

or some other similar displacement which could be doubled by reversing the direction of the flow. This displacement certainly could not have escaped observation.

Following are the results of the calculation according to Fresnel's hypothesis:

$$\Delta = 2L\frac{u}{v}(m^2 - 1) = 0{,}0000001367,$$
$$\frac{\Delta}{\lambda} = 0{,}0002325.$$

This is a displacement of 2/10,000 of the width of a fringe which is unobservable, even if it were 100 times greater. Thus, Fresnel's theory explains the apparent immodbility of the fringes in the experiment made with air in motion. The displacement of the fringes is not really zero, but it is so weak that it cannot be noticed.

After obtaining this negative fact, I still continued to search for an explanation for the hypotheses relative to ether that would, at the same time, /403
explain the phenomenon of abberation and Arago's experiment. It seemed to me that it was necessary to admit with Fresnel that the motion of bodies produces a change in the speed of light, and that the magnitude of this change of speed depends upon the energy with which the different media refract light. It is fairly large for highly refractive bodies, and very small for those that refract very little, such as air.

This resulted in the fringes not being displaced when light traveled through the air in motion. An appreciable displacement should have been obtained if the experiment were performed in water, whose refractive index is much greater than that of air.

One experiment performed by Babinet and mentioned in Volume 9 of the Academy's Comptes Rendus, seemed to contradict the hypothesis of the speed change in conformance with Fresnel's law. But upon considering the circumstances of the experiment, I have noticed the existence of a compensating cause that disguises the effect of motion. This cause is the reflection suffered by the light in this experiment. In fact, is is possible to show that when there is a difference in the velocity of two rays, this difference is changed when the rays are reflected by a mirror in motion. A separate calculation of the effects in Babinet's experiment shows that they have fairly equal values, but with opposite signs.

This explanation renders even more probable the hypothesis of the change of speed, and it has seemed to me that an experiment made in moving water should help to decide the question with certainty.

I believe that the success of this experiment should bring about the adoption of Fresnel's hypothesis, or at least of the law he discovered that /404 explains the change in the speed of light because of motion of bodies. Since this law is true, it constitutes a very strong proof in favor of the hypothesis, of which this law is only a consequence. It might be that Fresnel's conception will seem so extraordinary, and so hard to admit in certain respects, that additional proofs might still be required. A thorough examination by the goemetricians is required, before this can be considered to be valid.

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