the general science journal

What did the 1851 "Fizeau Experiment" prove? What did it disprove?

Chunsheng Li*

(Dated: December 26, 2024)

This paper provides an alternative perspective on the 1851 flowing water dragging experiment (Fizeau Experiment) conducted by the French physicist Armand Hippolyte Louis Fizeau, uncovering experimental details that have not received sufficient attention previously. The Fizeau Experiment demonstrated that the speed of light is influenced by the motion of the medium, either adding to or subtracting from it—showing that the speed of light is variable. It confirmed the classical physics principle of velocity addition while disproving the hypothesis of the invariance of the speed of light. Science relies on experimental evidence, yet the same experiment can lead to completely opposite conclusions and give rise to different theoretical frameworks. On what basis do we determine which interpretation (or theory) is correct? It is hoped that these questions will prompt some reflection.

References: Excerpted from H. Fizeau's paper, "On the Hypotheses Relating to the Luminous Ether and an Experiment That Seems to Show That the Motion of Bodies Changes the Speed with Which Light Propagates Within Them", *Comptes Rendus de l'Académie des Sciences*, Vol. 33, 1851, pp. 349–355.

Original source link: https://www.academie-sciences.fr
(Refer to Appendix B for the English translation.)

I. THREE ETHER HYPOTHESES

What is space? What is it made of? What is light? How does it propagate? What is matter composed of? Where does mass come from? Why does matter possess inherent gravity? How is gravity transmitted? Through what medium are the fundamental forces of the universe conveyed?

The nature of space not only determines the properties of matter but also governs the operational principles of the universe. From Aristotle, Descartes, and Huygens to Maxwell, it was hypothesized that ether filled space and that light was a transverse vibration of the ether. But what is ether? What properties does it possess? Different conjectures were proposed. By the 19th century, three distinct ether hypotheses had emerged:

(1) *The Ether Drift Hypothesis.* In 1804, British physicist Thomas Young adapted Bradley's particle theory of light into an explanation where wave-like light propagates through a medium known as the luminous ether. His reasoning was similar to Bradley's but required this medium to remain stationary in the solar reference frame and pass through the Earth unaffected. Otherwise, the medium (and light) would move with the Earth, and no aberration would be observed. [1]

He believed: By studying the phenomenon of stellar aberration, I am inclined to believe that the luminous ether can pervade all material entities without resistance, or with almost no resistance, as freely as the wind passes through a forest.[2]

According to the *Ether Drift Hypothesis*, because the Earth rotates and revolves, it undergoes absolute motion relative to the stationary ether space. Consequently, an "ether wind" is expected to occur on the Earth's surface. The 1887 Michelson-Morley experiment was designed to test the *Ether Drift Hypothesis* and to explain the phenomenon of stellar aberration (analyzed in detail in another paper).

(2) *The Drag Hypothesis of the Aether.* In 1818, French physicist Augustin Fresnel hypothesized that the "luminous ether" within matter consists of two components: one part is free ether, which exists in the voids (e.g., between subatomic particles) and has lower density; the other part is ether bound to subatomic particles (including the particles themselves) and has higher density.

The free ether is unaffected by the motion of atoms (electron shells), while only the electron shells (bound ether) move within the free ether. In other words, part of the luminous ether is free, while another part is attached to the molecules of objects. Only the portion of the ether bound to the molecules is dragged along as the object moves. [3]

Experimental Validation: The dragging of light refers to the change in the path of light as it enters a moving medium. In 1886, Michelson wrote in "Influence of Motion of the Medium on the Velocity of Light":

> "The only meaningful work on the effect of a medium's motion on the velocity of light is Fizeau's experiment. He reported a remarkable result: the velocity increment experienced by light is not equal to the velocity of the medium but rather a fraction x, which depends on the refractive index of the medium. Fresnel had previously derived this result theoretically, but the most satisfactory confirmation was provided by Eisenlohr." [4]

* Contact author: elephantintheroom202ls@gmail.com

According to Fresnel's wave theory, first, the ether should remain stationary except within a transparent medium. Second, it should move at a velocity smaller than that of the medium, with the ratio given by:

$$\frac{n^2-1}{n^2} \tag{1}$$

Where n represents the refractive index. These two assumptions provided a complete and satisfactory explanation for aberration. The second assumption, although seemingly improbable, must be regarded as sufficiently proven. First, this was demonstrated by the renowned *Fizeau Experiment*, and second, it was thoroughly confirmed by our own work. [5] At that time, it was widely believed that Fizeau's 1851 experiment validated Fresnel's *Partial Ether Drag Hypothesis.*

(3) The *Complete Drag Hypothesis of the Aether.* In 1845, British physicist George Stokes argued that dividing the ether into stationary (*Ether Drift Hypothesis*) and movable (*Partial Ether Drag Hypothesis*) parts was less reasonable than assuming that objects could fully drag a portion of the ether. He proposed that there is a region near the surface of an object where the ether's velocity gradually decreases. The object (or celestial body) drags this portion of the ether along with it, while the ether in space farther from the object (or celestial body) remains completely stationary.

According to this hypothesis, at the Earth's surface, the ether moves at the same velocity as the Earth, meaning that the Earth fully drags this portion of the ether. Only at a certain height above the Earth's surface can the ether be considered stationary. [6]*pp. 17*

In this model, the ether near the surface of an object behaves similarly to the Earth's atmosphere; the portion of the ether close to the object (or celestial body) moves with the object without any relative motion between them.

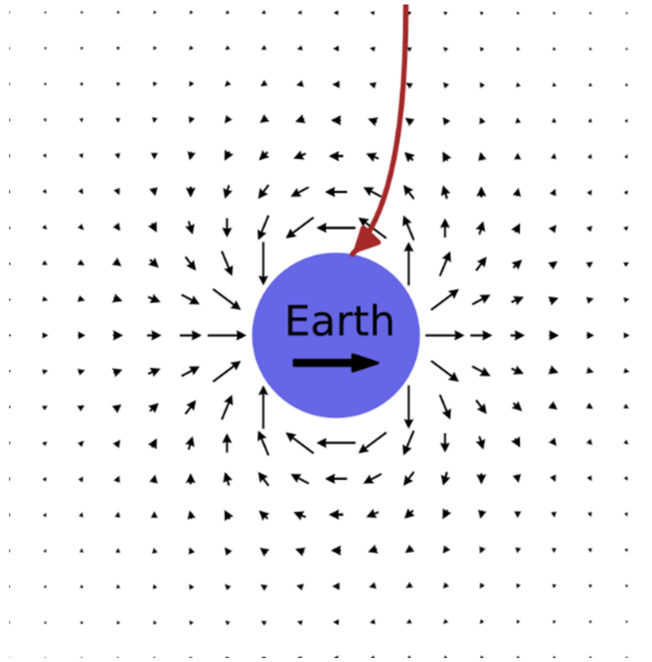

FIG. 1. Conceptual illustration of Stokes' aether drag theory. In the rest frame of the Sun the Earth moves to the right through the aether, in which it induces a local current. A ray of light (in red) coming from the vertical becomes dragged and tilted due to the flow of aether. *Source: Wikipedia*

Experimental Validation: In 1897, Michelson conducted an experiment to test the *Complete Drag Hypothesis of the Aether.* The findings were published in the paper "The Relative Motion of the Earth and the Ether" in *The American Journal of Science*, Series 4, Vol. 3, Issue 18, 1897. The author was Albert A. Michelson. [7] Michelson wrote:

> "To explain the phenomenon of stellar aberration, Fresnel hypothesized that the luminous ether is stationary and that the Earth moves through this medium, without any part of the motion being perceptible. According to this theory, it has been demonstrated that it should be possible to detect a difference in the speed of light in two perpendicular directions. Since no such difference has been observed, it seems reasonable to conclude that Fresnel's hypothesis is incorrect.
>
> Another theory is Stokes's theory, in which stellar aberration can be explained if the relative velocity between the Earth and the ether is potential. However, this requirement is inconsistent with the experimental results just cited, which indicate zero relative motion at the Earth's surface.
>
> To detect relative motion corresponding to horizontal differences, we conducted the following experiment" *(pp. 475–478).*

The conclusion of the experiment was: In any case, we are compelled to draw the extraordinary conclusion that the choice lies among these three possibilities: —the Earth moves through the ether (or more precisely, allows the ether to pass through its entire mass) without any noticeable effect.

All objects experience a change in length due to their motion through the ether (uniformly?).

The Earth drags the ether as it moves, even at distances of several thousand kilometers from its surface.

Michelson did not provide a definitive conclusion, leading to different interpretations among individuals. For unknown reasons, this experiment and the associated paper remain relatively obscure.

It should be noted that the three ether hypotheses represent different interpretations and conjectures about the nature of the ether. In essence, all theories are distinct explanations and descriptions of the same objective reality. The current issues at hand are: Has the ether been proven? Has the ether been disproven? What did the *Fizeau Experiment* prove? What did it disprove? By revisiting the *Fizeau Experiment* conducted 170 years ago, it is hoped that new clues to the truth can be uncovered from the details of this experiment.

II. FIZEAU EXPERIMENT

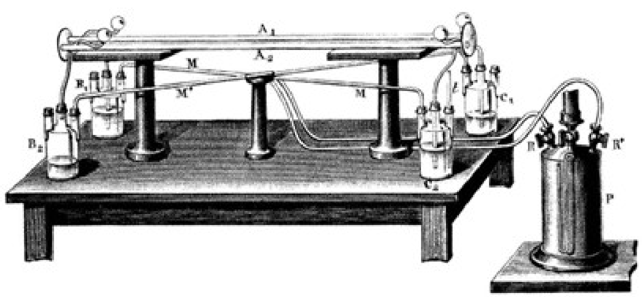

FIG. 2. Instruments used in Fizeau's experiment. *Source: Wikipedia*

In 1851, Fizeau designed a flowing water experiment (see Fig. 2) to test Fresnel's *Partial Ether Drag Hypothesis*, measuring the relative speed of light in flowing water. [3] He found that the experimental results were consistent with Fresnel's predictions. [8] Subsequent experiments confirmed Fizeau's measurements. [4]

The *Fizeau Experiment* is a variation of Thomas Young's *double-slit interference experiment*, with the addition of a set of water pipes behind the two slits. The water flows in opposite directions in the pipes to test whether the velocity of the moving water causes a shift in the interference fringes of the two light beams, thereby examining whether the ether in the water is partially dragged.

FIG. 3. The schematic diagram of Fizeau's experiment: light emitted from the source S' is reflected by the beam splitter G and then collimated into two parallel beams by the lens L. These two beams pass through slits O_1 and O_2 before entering the tubes A_1 and A_2. Water flows through the tubes in the directions indicated by the arrows. A plane mirror m, placed at the focal point of the lens L', ensures that one of the beams always travels with the water flow, while the other travels against it. After passing through the tubes, the two beams converge at S, forming interference fringes. These interference fringes can be used to analyze the speed of light in the water.[3, 9]

In his Report to the *French Academy of Sciences(Académie des sciences)*, Fizeau wrote:

> "To explain the phenomenon of stellar aberration within the framework of the wave theory, many theories have been proposed. From Fresnel's original hypothesis to the contributions of Doppler, Stokes, Challis, and other researchers, these theories have undergone significant expansion. Among these hypotheses, some are more plausible, but none have been fully confirmed. In fact, in the absence of certain concepts regarding the nature of the luminous ether and its relationship with massive matter, it is necessary to make assumptions. Among the proposed hypotheses, there is a varying degree of plausibility, but none can be definitively proven.
>
> These hypotheses can be classified into three categories concerning how the luminous ether within transparent objects is understood:
>
> 1. The luminous ether is attached to and fixed on the molecules of the object, thus moving entirely with the motion of the object.
> 2. The luminous ether is free, independent of the motion of the object, and unaffected by it. The third hypothesis combines the first two: part of the luminous ether is free, while another part is attached to the molecules of the object, and only the attached portion participates in the motion of the object.
> 3. The third hypothesis was proposed by Fresnel to simultaneously explain the phenomenon of stellar aberration and the results of Arago's famous experiment. Arago demonstrated through experiments that the motion of the Earth has a negligible effect on the refraction of starlight through a prism.
>
> We can discuss the possible effects of an object's motion on the speed of light for each hypothesis:

- If the luminous ether completely moves with the object: The speed of light would increase by an amount equal to the velocity of the object in the direction of its motion.
- If the luminous ether is completely free: The speed of light would not be affected by the motion of the object.
- If only part of the luminous ether moves with the object: The speed of light would increase, but only by a fraction of the object's velocity, rather than the full amount." [3]

The dragging (or entrainment) of light refers to the change in the path of light as it enters a moving medium. According to Fresnel's *Partial Ether Drag Hypothesis,* when the direction of water flow aligns with the direction of light propagation, the speed of light increases as the ether is "dragged" by the water, while it decreases when the ether " overcomes" the water's resistance. The total speed of light is the sum of the relative speed of light in the water and the speed of the water itself, meaning the speed of light and the velocity of the moving water are additive—resulting in an increase in the speed of light.

When the direction of water flow opposes the direction of light propagation, the light propagating against the flow moves slower than the light traveling with the flow—resulting in a decrease in the speed of light. The interference fringes observed as the two beams of light reconverge depend on the optical path difference between the two beams. This phenomenon can be used to determine the functional relationship between the speed of light and the speed of water. [10]

According to Thomas Young's *double-slit interference experiment*, interference fringes are produced only when the wavelength, frequency, and phase of the two light beams are completely identical (note: phase refers to a specific point between the crest and trough of a wave; complete overlap of crests and troughs indicates the same phase). If the two light beams have the same wavelength and frequency but different phases, no interference fringes will appear.

In the *Fizeau Experiment*, Fizeau first generated interference fringes with the two beams of light when the water flow was stationary. He then observed whether the interference fringes changed when the water flowed in opposite directions, aiming to determine whether the phase of the two light beams was altered by the velocity of the water flow. If the interference fringes changed, it would indicate that the velocity of the moving water altered the speed of light, thereby changing the optical path difference between the two beams and causing their phases to differ, resulting in a change in the interference fringes.

If the speed of light adds to or subtracts from the velocity of the moving water, it would prove that the ether in the water is being dragged. Conversely, if the moving water does not change the interference fringes or if no changes in the fringes are observed, it would indicate that the speed of light does not add to or subtract from the velocity of the moving water, thereby proving that the ether in the water is not being dragged.

Experimental Observations:

> "The observations are as follows: when the water begins to move, the fringes shift, and depending on whether the water moves in one direction or the other, the fringes shift to the right or to the left. When the water is pushed forward in the tube on the right side of the observer and flows toward the observer in the tube on the left side, the fringes move to the right. When the water flows in the opposite direction in each tube, as defined earlier, the fringes move to the left.
>
> When the water velocity is 2 meters per second, the shift is already very noticeable; as the velocity increases to 4 to 7 meters per second, the shift becomes clearly measurable. . . .
>
> If the ether is completely free and independent of the motion of objects, the displacement should be 0. Under the assumption that the ether is fully bound to the molecules of the object and shares their motion, calculations give a double displacement value of 0.92. However, the observed value is only half as large, at 0.46.
>
> According to Fresnel's *Partial Ether Drag Hypothesis*, theoretical calculations yield a displacement value of 0.40, which is very close to the experimental observation. If a correction factor—omitted due to insufficiently precise data—could be introduced into the water velocity calculation, the discrepancy between the two values might become even smaller." [3]

The results of the *Fizeau Experiment* showed that the two beams of light moving in opposite directions through the flowing water indeed caused a shift in the interference fringes, demonstrating that the path of light changes when it enters a moving medium, resulting in a dragging effect. The alteration of the light's path indicates that the speed of light is either added to or subtracted from the velocity of the moving medium. At the time, it was widely believed that the *Fizeau Experiment* validated Fresnel's *Partial Ether Drag Hypothesis.*

Due to the limitations of experimental technology at the time, the *Fizeau Experiment* was not perfect. American experimental physicists Albert Michelson and Edward Morley identified the following issues with Fizeau's original experiment:

1. Deformation of the apparatus could cause distortion of the interference fringes.
2. The observation time was very limited due to the short duration of the pressurized water flow.

3. The laminar flow effect meant that only the velocity at the very center of the water flow met the required conditions, leading to blurred fringes.

4. There was also uncertainty in Fizeau's measurement of the water velocity. [4]

The original *Fizeau Experiment* did indeed have these issues; however, it successfully detected the dragging effect, albeit much weaker than expected. As a result, efforts were made to continuously improve the experiment in hopes of obtaining more precise results and eliminating controversy surrounding the experimental conclusions.

III. REPEATED EXPERIMENTS

In 1868, Martin Hoek conducted a similar experiment, indirectly verifying the Fresnel coefficient. [11]

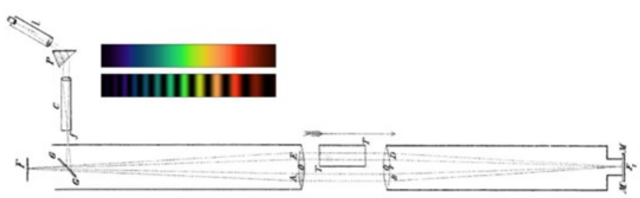

FIG. 4. Schematic diagram of the instruments used in Hoek's experiment. *Source: Wikipedia*

Hoek's experimental setup was similar to that of Fizeau's experiment, with one interference arm filled with stationary water and the other with air. From the perspective of an observer in the stationary ether, the Earth is in motion, which implies that the water in the setup is also in motion. However, since the water in Hoek's experiment was not flowing, it did not meet the conditions required to test Fresnel's *Partial Ether Drag Hypothesis* and thus could not verify the Fresnel coefficient. Nevertheless, this experiment was more suited to testing the *Ether Drift Hypothesis.*

In 1886, Michelson and Morley repeated Fizeau's experiment and published their findings in the *American Journal of Science* under the title "Influence of Motion of the Medium on the Velocity of Light." [4]

They redesigned the experimental apparatus, increasing the diameter of the tubes and using a large water reservoir capable of providing a stable water flow for three minutes. The Common Path Interferometer they designed could automatically compensate for the optical path length. Structurally, the light path was the same as that in the Sagnac Interferometer, with each light path undergoing an even number of reflections. [12]

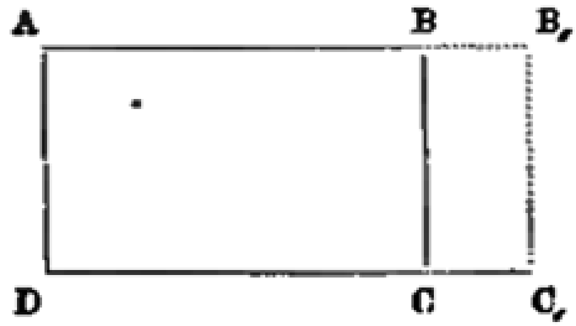

FIG. 5. Diagram of the superposition of the speed of light and the flow velocity of water.

Michelson wrote:

> "Let the prism move with a velocity θ relative to the ether in the direction AB. Assume the density of the external ether is 1, while the density of the ether inside the prism is $1+\Delta$. During the time interval dt, the prism will advance a distance $\theta dt = BB'$. At the beginning of this time interval, the amount of ether within the volume BC (assuming the base area of the prism is S) is: $S\theta dt$. At the end of this time interval, the amount of ether within the volume BC will be: $S\theta dt(1+\Delta)$. Thus, during this time, the amount of ether entering this volume is equal to: $S\theta dt\Delta$."

This apparatus demonstrated very high stability for first-order effects and was insensitive to the displacement of any of its components. Even placing a glass plate at position h or introducing a lit match into the light path did not cause the fringe center to shift. Using this apparatus, Michelson and Morley confirmed Fizeau's results. [4]

In 1886, Michelson and Morley repeated Fizeau's experiment.

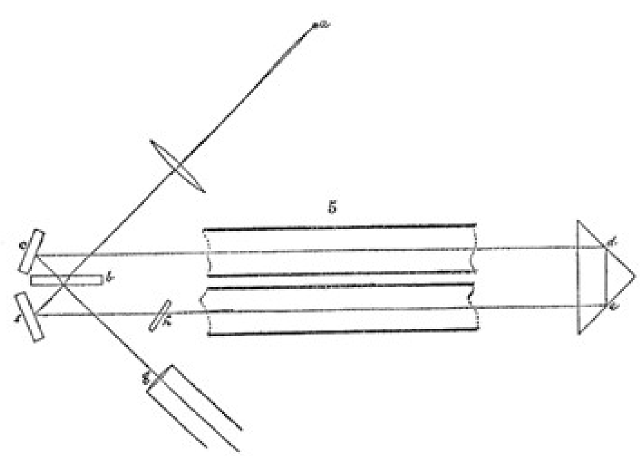

FIG. 6. A plan view of the refractometer used in Michelson and Morley's improved *Fizeau Experiment* in 1886. *Source: Wikipedia*

Michelson's conclusion was:

> "The result of this work is that Fizeau's announced result is essentially correct; and the luminous ether is entirely unaffected by the motion of the matter through which it permeates." [3]

The *Fizeau Experiment* repeated by Michelson and Morley demonstrated that the moving medium (water) indeed alters the speed of light—proving that the speed of light adds to or subtracts from the velocity of the water.

In 1910, Franz Harress repeated the *Fizeau Experiment*. Harress used a rotatable apparatus to verify the Fresnel drag coefficient. However, he discovered a "systematic deviation" in the data. He later identified this deviation as being caused by the Sagnac Effect. [13]

In 1915, Dutch physicist Pieter Zeeman also repeated the *Fizeau Experiment*. He further scaled up Michelson's apparatus and connected it directly to Amsterdam's main water supply pipeline. Zeeman also conducted measurements using monochromatic light with wavelengths ranging from 4358 Å (violet) to 6870 Å (red) to verify the modified coefficient proposed by Lorentz. [14, 15]

Although these related experiments all validated Fresnel's *Partial Ether Drag Hypothesis*—showing that moving water does indeed alter the interference fringes—doubts about the hypothesis still persisted. In Fizeau's experimental report, he wrote:

> "This explanation makes the hypothesis of velocity changes more plausible, and the experiment conducted in flowing water seems to me perfectly suited to definitively resolve this issue. In my view, the success of this experiment led to the adoption of Fresnel's hypothesis, or at least to the adoption of the law he discovered for expressing the variation of the speed of light due to the motion of objects.
>
> For although this law has been found to be correct, it serves as very strong evidence supporting this hypothesis, even though the hypothesis itself is merely one of its results. Perhaps Fresnel's concept appears so extraordinary, and in certain respects so difficult to accept, that we would require further proof and thorough examination by geometers before adopting it as an expression of the reality of things."

It is worth noting that although Fizeau had to admit that his experiment supported Fresnel's *Partial Ether Drag Hypothesis,* he also acknowledged that "this law is merely one of its results," recognizing that contemporary alternatives, such as the *Ether Drift Hypothesis* and the *Complete Ether Drag Hypothesis,* also existed. Fizeau further acknowledged the influence of the velocity of the "moving body"—the moving medium—on the speed of light. However, whether this influence occurred because the medium dragged the ether along with it or because the ether itself was an integral part of the medium, Fizeau did not find an answer to this question.

Similarly, when repeating Fizeau's experiment, researchers found that the experimental results varied with different light sources. In 1870, Fizeau proposed that the drag coefficient differs for different wavelengths of light because the refractive indices of different colors of light are not the same. In 1872, Mascart obtained similar results when measuring the behavior of polarized light in birefringent media. In other words, the ether would need to possess two different drag coefficients simultaneously. [16]

Although researchers found that repeating Fizeau's experiment with different light sources yielded varying results (e.g., different wavelengths and frequencies of light correspond to different drag coefficients), the crucial finding remains that Fizeau's experiment demonstrated that moving water can indeed alter the interference fringes. This indicates that the path of light undergoes a dragging effect when it enters a moving medium. The alteration of the light's path means that the speed of light is either added to or subtracted from the velocity of the moving medium.

IV. DOES THE PRINCIPLE OF VELOCITY ADDITION IN CLASSICAL PHYSICS HOLD TRUE?

At the time, Fizeau's experiment was conducted to test Fresnel's *Partial Ether Drag Hypothesis.* However, people did not realize that the dragging effect observed in the path of light entering a moving medium—where the speed of light adds to or subtracts from the velocity of the medium—indicated that the speed of light is variable.

When Einstein proposed the theory of special relativity based on the postulate of the invariance of the speed of light, it became evident that the assumption of a constant speed of light was inconsistent with the variable speed of light revealed by Fizeau's experiment. In response to the challenges posed by Fizeau's findings, Einstein defended his theory in *Relativity: The Special and the General Theory.*

In *Relativity: The Special and the General Theory*, Section 6, "The Addition of Velocities as Required by Classical Mechanics," Einstein wrote:

Let us suppose that our old friend, the railway carriage, is traveling along the rails with a constant velocity ν, and that a man is walking inside the carriage in the direction of travel with a velocity ω relative to the carriage. How quickly is this man moving forward as observed from the embankment? In other words, what is the velocity W of the man relative to the embankment?

The only possible explanation seems to follow from the following reasoning: if the man stands still for one second, during this second he moves forward relative to the embankment by a distance ν, numerically equal to the velocity of the carriage. However, since he is walking forward within the carriage, during this same second he covers an additional distance ω relative to the carriage, which corresponds to an additional distance ω relative to the embankment, numerically equal to his walking speed inside the carriage.

Thus, in the second under consideration, he covers a total distance relative to the embankment of $W = \nu + \omega$. As we shall see later, this result, which expresses the classical law of the addition of velocities, cannot be upheld; in other words, the law we have just written down is actually not valid. For now, however, we shall assume this law to be correct. [6]*pp. 15*

If the train's speed is 100 km/h and the person's speed, measured relative to the train carriage, is 5 km/h, according to the classical law of velocity addition—Galilean transformation, $W = \nu + \omega$. In this case, with the embankment as the reference frame, an observer on the embankment would measure the person's speed (when moving in the same direction as the train) as $100 + 5 = 105$ km/h.

If the person's speed does not add to (in the same direction) or subtract from (in the opposite direction) the train's speed, then, with the embankment as the reference frame, an observer on the embankment would measure the speed of the person walking inside the carriage in either direction as the same 5 km/h, as measured relative to the train carriage. Whether the person walks in the same direction as the train or in the opposite direction, their speed remains 5 km/h. In this case, the train's speed does not alter the person's walking speed. This conclusion could also be referred to as "invariance of walking speed."

We need to answer one question: What is common sense?

In Section 13, "The Addition of Velocities—The Fizeau Experiment," Einstein wrote:

"In Section 6 ("The Addition of Velocities as Required by Classical Mechanics"), we derived the law of the addition of velocities, which can also be deduced from the assumptions of classical mechanics. This law can be easily derived from the Galilean transformation (Section 11). We replace the man walking inside the carriage with a material point moving relative to the coordinate system k' according to the following equations."

$$x' = wt' \tag{2}$$

By using the first and fourth equations of the Galilean transformation, we can express x' and t' in terms of x and t. We obtain the following relationship:

$$x = (v + w)t \tag{3}$$

This equation represents the law of motion of the point relative to the coordinate system K (the law of motion of the person relative to the embankment). Using the symbol W to denote this velocity, as in Section 6, we obtain:

$$W = v + w \tag{4}$$

However, we can also approach this from the perspective of relativity. In Equation (2), we must use the first and fourth equations of the Lorentz transformation to express x' and t' in terms of x and t. In doing so, the resulting equation is no longer Equation (4), but instead:

$$W = \frac{v + w}{1 + \dfrac{v + w}{c^2}} \tag{5}$$

This equation corresponds to another law of velocity addition based on the theory of relativity. [6]*pp. 30*

It is important to note that the invariance of the speed of light implies that the speed of light remains constant in any medium, regardless of the medium's velocity. This means that the speed of light measured in any reference frame is always exactly the same.

If the speed of light does not add to or subtract from the velocity of the moving medium, it confirms the invariance of the speed of light and disproves the principle of velocity addition. Conversely, if the speed of light adds to or subtracts from the velocity of the moving medium, it demonstrates that the speed of light is variable, thereby confirming the principle of velocity addition.

Both the relativistic velocity addition law and the classical velocity addition law are forms of the principle of velocity addition! Both imply that the speed of light would add to or subtract from the velocity of the moving medium. The crux of the debate is not about verifying which version of the velocity addition principle is more precise—it is about whether the speed of light is invariant or variable.

Einstein continued:

> "The question now arises: which of these two laws agrees better with experience? Regarding this question, we can gain insight from an extremely important experiment conducted more than half a century ago by the distinguished physicist Fizeau. This experiment was later repeated by some of the most eminent experimental physicists, making its results beyond doubt.
>
> The experiment concerns the following question: light propagates at a certain velocity ω in a stationary liquid. If the liquid now flows through a tube T at a velocity ν, how fast does the light propagate in the direction indicated by the arrow (Fig. 4) within the tube?"

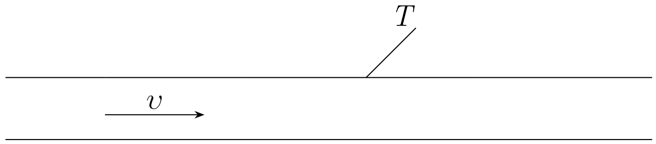

FIG. 7. Einstein's illustration of the speed of light in a moving liquid: T represents the water pipe, and ν represents the water flow. The experiment measures whether the speed of light is the same when referenced to the water or to the wall of the pipe. *Source: Relativity: The Special and the General Theory, p. 31.*

According to the principle of relativity, we must, of course, assume that light always propagates at the same velocity ω relative to the liquid, regardless of whether the liquid is in motion relative to other objects or not (note Einstein's conclusion! — Author's note). Therefore, the velocity of light relative to the liquid and the velocity of the liquid relative to the tube are both known. What we need to determine is the velocity of light relative to the tube.

Clearly, we are once again confronted with the problem discussed in Section 6, "The Addition of Velocities as Required by Classical Mechanics." The tube corresponds to the railway embankment or coordinate system K, the liquid corresponds to the carriage or coordinate system K', and the light corresponds to the man walking inside the carriage or the moving material point introduced in this section.

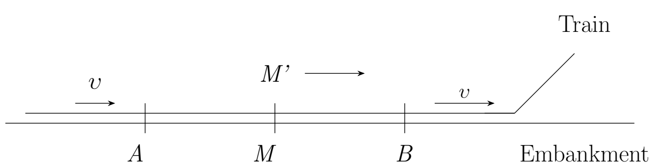

FIG. 8. Illustration of Einstein's famous thought experiment involving the train and the embankment, from *Relativity: The Special and the General Theory*, p. 21.

If we denote the velocity of light relative to the tube as W, then W should be determined according to Equation (3) or Equation (5).

> "The calculation depends on whether the Galilean transformation or the Lorentz transformation aligns with reality. The experimental determination supports the equation (5) derived from the theory of relativity, and the agreement is indeed very precise." [6]*pp. 31*

If the speed of light within the tube, measured relative to the walls of the tube, remains $W = \nu$ or $W = \frac{c}{n}$ (the speed of light in still water), regardless of the water flow and in the direction indicated by the arrow (Fig. 4)—that is, if the speed of light remains constant—this would validate the Lorentz transformation of relativity.

However, if the measured speed of light relative to the walls of the tube is the sum of or a reduction by the velocity of the water flow, this would indicate that the speed of light is variable and would validate the Galilean transformation of classical physics.

The editor of *Relativity: The Special and the General Theory* provided the following annotation regarding Equation (5):

Fizeau discovered that $W = \omega + v\left(1 - \frac{1}{n^2}\right)$, where $n = \frac{c}{\omega}$ is the refractive index of the liquid. On the other hand, since $\frac{v\omega}{c^2}$ is relatively small compared to 1, we can initially replace Equation (5) with $W = (\omega + v)\left(1 - \frac{v\omega}{c^2}\right)$. Subsequently, to the same order of approximation, we can further replace it with $W = \omega + v\left(1 - \frac{1}{n^2}\right)$, which aligns with the results of Fizeau's experiment. [6]*pp. 31*

It is important to note that Fizeau's experiment concluded that the moving medium altered the speed of light—the speed of light is added to or subtracted by the velocity of the water flow, thereby confirming Fresnel's *Partial Ether Drag Hypothesis.* Einstein explained:

> "This Equation (5) corresponds to another law of velocity addition based on the theory of relativity." [6]*pp. 30*

With the walls of the tube as the reference frame, is the speed of light in moving water greater than or equal to the speed of light in still water? Einstein's conclusion was:

> "According to the principle of relativity, we must, of course, assume that light always propagates at the same velocity ω relative to the liquid, regardless of whether the liquid is in motion relative to other objects or not." [6]*pp. 31*

Relativity is founded on the invariance of the speed of light. If the speed of light remains constant under all circumstances, the equation can only be $W = \nu$ or $W = \frac{c}{n}$. Regardless of how the equation is reformulated, any result differing from $W = \nu$ or $W = \frac{c}{n}$ would demonstrate that the speed of light adds to or subtracts from the velocity of the moving medium, thereby proving that the speed of light is variable.

Fizeau's experiment demonstrated that when measuring the speed of light in water using the walls of the tube as the reference frame, the result is not the speed of light in still water ($W = \frac{c}{n}$). Instead, it is the combination of the speed of light and the velocity of the water flow—showing that the speed of light adds to or subtracts from the velocity of the moving medium, thus proving that the speed of light is variable.

It should be noted that the results of Equations (3) and Equations (5) are both greater than the speed of light in still water (note: the speed of light varies in different media). This means that both options provided by Einstein demonstrate that the speed of light adds to or subtracts from the velocity of the moving medium. (Why didn't Einstein's equations take the form $W = \nu$ or $W = \frac{c}{n}$?)

Thus, the relativistic velocity addition law actually proves that the speed of light is variable, not invariant. Replacing the Galilean transformation's velocity addition law with the relativistic velocity addition law is akin to using a white swan to prove that swans are black—it is a form of conceptual substitution, a reversal of facts.

Due to the limitations of the era, Fizeau's experiment concluded that a moving medium alters the speed of light, thereby confirming Fresnel's *Partial Ether Drag Hypothesis.* However, when Einstein proposed the principle of the invariance of the speed of light—that light's speed is constant relative to any reference frame under all circumstances—the focus of the debate shifted to whether the speed of light measured in different reference frames remains constant.

The *Fizeau Experiment* demonstrated that, using the walls of the tube as the reference frame, the speed of light in water is not the same as the speed of light in still water ($W = \frac{c}{n}$). Instead, it is the combination of the speed of light and the velocity of the water flow, meaning the speed of light adds to or subtracts from the velocity of the moving medium—showing that the speed of light is variable. This is expressed by the equation $W = \nu + \omega$.

Importantly, the *Fizeau Experiment* demonstrated that the speed of light measured relative to the water differs from that measured relative to the walls of the tube—showing that the speed of light varies between different reference frames. This result directly contradicts Einstein's hypothesis of the invariance of the speed of light and confirms the classical physics principle of velocity addition.

The classical physics principle of velocity addition is the foundation of the Galilean transformation. The conclusions of the *Fizeau Experiment* determine whether the Galilean transformation or the Lorentz transformation is correct.

It is evident that mathematics alone cannot independently decide which interpretation is correct; it requires logic to reach a conclusion. Mathematics is merely a tool of science—a servant, not its master. Mathematics cannot represent science in its entirety.

V. GALILEO'S THOUGHT EXPERIMENT

What principle is the Galilean transformation based on? To answer this, we need to understand the logical foundation upon which Galileo constructed the Galilean transformation.

To refute the Aristotelian-Ptolemaic view of space and time, Galileo expressed his ideas through the character Salviati in his 1632 book *Dialogue Concerning the Two Chief World Systems*:

> "Shut yourself with some friends in the main cabin below decks on a large ship, and bring along some flies, butterflies, and other small flying creatures. Also, hang a large water bottle so that it drips water, drop by drop, into a wide-mouthed jar below.
>
> When the ship is stationary, observe carefully: the small creatures will fly at equal speeds to all parts of the cabin, the fish will swim freely in all directions, and the water drops will fall into the jar below. When you throw something to your friends, provided the distances are equal, you will not need to exert more force in one direction than in another. When you jump with both feet, you will leap the same distance whether in one direction or the other.
>
> Now, if the ship begins to move at any speed, provided the motion is uniform and does not sway from side to side, you will find that all the previously described phenomena remain unchanged. You will not be able to determine, from any of these observations, whether the ship is moving or stationary. Even if the ship is moving very fast, you will jump the same distance on the deck as before. When jumping toward the stern, you will not leap farther than when jumping toward the bow, even though the deck beneath you is moving in the opposite direction to your jump. Similarly, when throwing something to a companion, whether they are at the bow or stern, you will not need to use more force as long as you stand opposite them.
>
> The drops of water will fall into the jar below just as they did before; not a single drop will fall toward the stern, even though the ship will have traveled a great distance during the drop. If incense is burned, the smoke will rise in a column as if in a stationary cabin, without drifting to any side.
>
> All these phenomena occur uniformly because the motion of the ship is shared by everything within it, including the air. This is why I insist that you conduct this experiment below deck. If the experiment were performed in the open air (on the ship's deck), the results would differ significantly, as the objects would not share the motion of the ship. For example, the smoke would trail far behind due to the resistance of the external air, and the flies or butterflies, having moved a certain distance away from the ship's motion, would fail to keep up due to air resistance." [17]*pp. 130-131*

In Galileo's thought experiment, within the uniformly moving cabin of a ship, flies, butterflies, and other small insects (hereafter referred to as butterflies and insects) can fly freely, and water droplets fall vertically. Similarly, in a uniformly moving train carriage or airplane cabin, butterflies and insects can also fly freely, and water droplets fall vertically. We can even play ping-pong as we would on the ground, without needing to consider whether the train or airplane is moving at high speed.

Galileo's conclusion is that without a reference frame for comparison, we cannot perceive whether we are in a state of uniform linear motion.

If we remove the deck of the ship's cabin in Galileo's thought experiment, we will find that the butterflies and insects will be blown away by the wind at a speed equal to that of the ship. The reason is simple: the air inside the enclosed cabin is isolated from the air outside the cabin. The air within the cabin moves relative to the air outside, and it is stationary relative to the cabin itself. This synchronization between the air and the cabin creates an internal space that moves with the ship. In other words, the ship drags the internal air along with it.

The fact that butterflies and insects can fly freely within the enclosed space of the cabin demonstrates that the internal space of the cabin and the external space outside the cabin are two independent spaces, functioning as two distinct reference frames. The butterflies and insects move relative to the stationary air inside the cabin, taking it as an absolute reference frame for their motion, rather than using the external space outside the ship as their reference frame.

However, if the deck is removed, the internal space of the cabin merges with the external space outside. The cabin and the external space are no longer two independent reference frames but combine into a single reference frame. In this case, the ship loses its independent, synchronized internal space and effectively becomes a single point-like object. As a result, the butterflies and insects can only use the external space as an absolute reference frame, leading to relative motion with the ship. In other words, they will be blown away by the wind at the same speed as the ship's motion.

If the deck of the cabin is restored, the internal space of the cabin once again becomes an independent, stationary absolute space, synchronized with the ship's motion. The butterflies and insects will once again take this internal absolute space as their reference frame for absolute motion.

Whether butterflies and insects can fly freely within the cabin depends on whether the internal space of the cabin is isolated from the external space. It depends on whether the cabin constitutes a relatively stationary absolute space.

VI. CAN EXPERIMENTS VERIFY THE EXISTENCE OF ABSOLUTE SPACE?

Science requires experimental evidence, and Galileo's thought experiment is not a real experiment; it cannot serve as proof for the existence of absolute space. Are there any actual experiments that can verify whether absolute space exists? Can it be proven that the Earth's surface also constitutes an absolute space?

A. How Can Experiments Be Used to Verify the Existence of Absolute Space?

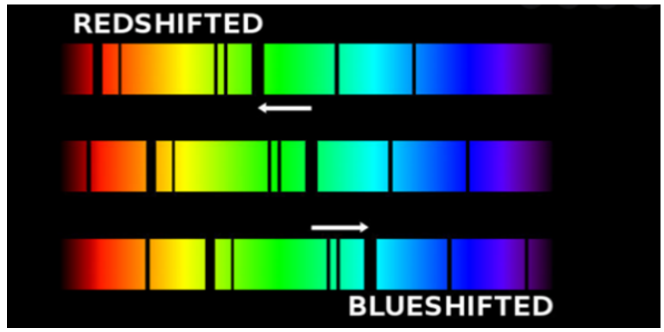

FIG. 9. The Doppler Effect of Light. Excerpted from *Phoenix News*

According to the Doppler effect, a moving light source will cause a shift in the observed frequency or wavelength of light. However, does every moving light source produce a Doppler effect?

Experiment:
Place one light source inside and another outside a closed train carriage. Both light sources emit light waves in the direction of the train's motion and the opposite direction. When the train is in high-speed motion:

1. External Light Source: The light source outside the train will exhibit the Doppler effect. Light waves emitted in the direction of the train's motion will show a "blue shift," while those emitted in the opposite direction will show a "red shift."

2. Internal Light Source: The light source inside the carriage will show no Doppler effect.

Principle:
The internal space of the carriage moves in sync with the carriage itself, with no relative motion between the light source and the internal space. As a result, no Doppler effect occurs for the light emitted by the internal source. Conversely, the external light source behaves as a single point object with respect to the external space, experiencing absolute motion relative to the external medium, thus generating the Doppler effect.

The same principle can be applied in the interiors of high-speed airplanes or spacecraft. In these cases, the internal space is fully enclosed and moves synchronously with the craft, forming a relatively stationary absolute space. Since the light source has no absolute motion relative to the internal space, no Doppler effect will be observed for light emitted inside. This conclusion is based on common sense, often overlooked.

Conclusion:
Strictly speaking, this is not an experiment but a matter

of common sense. Not all moving light sources produce a Doppler effect. The Doppler effect occurs only when the light source has absolute motion relative to the spatial medium.

The absence of the Doppler effect in experiments conducted in closed spaces (e.g., within trains, airplanes, or spacecraft) demonstrates that these internal spaces are absolute spaces. It also confirms that all enclosed spaces, regardless of their state of motion, are absolute spaces.

B. How Can Experiments Prove That the Earth's Surface Is an Absolute Space?

Due to its rotation and revolution, the Earth is in a state of motion. However, since the space on the Earth's surface is not enclosed by a physical container, is the space on the Earth's surface also a kind of closed absolute space?

Experiment:
Set up a light source on the ground near the Earth's equator and conduct an optical Doppler experiment. Emit light waves toward the east and west directions, respectively. If a Doppler effect occurs (e.g., "blue shift" for eastward light waves and "red shift" for westward light waves), it would indicate that the Earth is in absolute motion relative to a space medium (commonly referred to as "ether wind" or "dark matter wind," though the name is irrelevant).

However, if the light waves emitted to the east show no blue shift and those emitted to the west show no red shift—i.e., no Doppler effect occurs—it means that the light source is not in absolute motion relative to the space medium. The question then arises: since the space on Earth's surface lacks a surrounding material container, why doesn't the space on the Earth's surface exhibit absolute motion relative to the Earth? This, too, is a matter of common sense, often overlooked.

It is well-known that the atmosphere consists of air molecules, which are matter. As matter, they inherently possess gravitational attraction, both attracting other matter and being attracted by the Earth's gravity. According to Newton's law of gravitation, air molecules are drawn by the Earth's gravity to form an atmosphere surrounding the Earth, with greater air density closer to the surface. The part of the atmosphere near the Earth's surface is completely dragged along by the Earth and moves synchronously with it. This completely dragged portion of the atmosphere is stationary relative to the Earth's surface and constitutes an absolute space.

Although the Earth rotates and revolves, birds, butterflies, insects, and airplanes can fly freely within this portion of the atmosphere without the risk of being flung off into space. Similarly, in this absolute space, light sources do not exhibit absolute motion relative to the medium of space, and therefore no Doppler effect is observed.

The Doppler effect observed in earlier experiments on the Earth's surface occurred because the light source was artificially accelerated, creating absolute motion between the light source and the space medium, thus naturally generating the Doppler effect.

Conclusion:
Even without considering Stokes's *Complete Ether Drag Hypothesis* or the role of the ether, Doppler experiments conducted on the Earth's surface can demonstrate that the atmosphere near the Earth's surface constitutes a relatively stationary absolute space.

Additionally, according to Newton's law of gravitation, air molecules are drawn by the Earth's gravity to form an atmosphere governed by gravitational laws, with air density increasing closer to the surface. As light passes through layers of air with varying densities, it refracts, creating a lensing effect. This "atmospheric lensing effect" is caused by gravity—gravity attracts matter, and differences in the density of matter result in refraction, forming the lensing phenomenon. In other words, gravity produces a lensing effect.

C. How Can Experiments Prove That Water Is Also an Absolute Space?

In Galileo's thought experiment, the ship's cabin contains a fish tank filled with water, where small fish swim freely. Regardless of whether the deck is open or closed, the fish in the tank can swim freely. The question arises: why can the fish in the tank move freely without being affected by the ship's motion, even though the tank lacks a lid? Is the water in the tank an independent reference frame? How can we verify whether the water in the tank serves as an absolute reference frame?

The *Fizeau Experiment* demonstrated that the speed of light measured relative to the walls of a water-filled tube differs from the speed of light measured relative to the water itself. When measured with the walls of the tube as the reference frame, the speed of light in moving water is the sum of the speed of light and the velocity of the water. In the moving medium, light maintains its speed relative to the medium (accelerated medium), without exceeding the maximum speed allowed by the medium. However, when measured in another reference frame, the speed of light adds to or subtracts from the velocity of the moving medium—indicating that the speed of light is variable.

This experimental result proves that the water inside the tube acts as an independent reference frame and constitutes an absolute space.

If there is moving water outside the tube (e.g., river or seawater), the water inside the tube and the water outside are distinct, independent reference frames—different absolute spaces. In the case of a fish tank within the ship's cabin, the water in the tank is isolated from the water outside the cabin. The water in the tank moves in sync with the tank itself, unaffected by the external water flow, and there is absolute motion between the water in the tank and the water outside the cabin.

The key point is that the fish in the tank calculate their velocity relative to the water inside the tank, not relative to the water outside the cabin. Similarly, the water in the tank is also isolated from the cabin's internal space. Therefore, the water in the tank, the cabin's internal space, and the external water are three independent absolute spaces and reference frames, with absolute motion existing between them.

Experimental evidence proves that the portion of the atmosphere fully dragged by Earth's gravity, like the internal spaces of ships, airplanes, and spacecraft, constitutes absolute spaces and absolute reference frames. This demonstrates that any space isolated from other spaces is an absolute space and an independent absolute reference frame.

Materials like water, glass, ice, and crystal are examples of enclosed spaces, and even a vacuum can be considered an absolute space and one of the absolute reference frames.

VII. FACTS

The purpose of constructing physical theories is to coherently explain objective phenomena and consistently describe the principles governing the operation of the objective world. Is the goal to develop a self-consistent explanation of nature or to construct an unquestionable "correct" theory? Between Galileo's relativity and Einstein's special and general relativity, which theory more coherently explains phenomena and consistently describes the workings of the physical world? In practical scenarios, which theory is applied to explain and describe motion on Earth?

For instance:

1. If a train is moving at 100 km/h and a person walks at 5 km/h inside the train, what is the speed of the person relative to an observer on the ground? Is it 100+5=105 km/h, or is it simply 5 km/h?

2. If a boat is traveling at 30 km/h downstream in a river with a flow rate of 4 km/h, and a person walks at 5 km/h on the deck in the opposite direction of the boat's motion, what is the speed of the person relative to an observer on the riverbank? Is it 30+4-5=29 km/h, or is it just 5 km/h?

3. If an airplane is flying at 900 km/h and a butterfly inside the cabin flies at 5 km/h in the direction of the airplane's motion, what is the speed of the butterfly relative to an observer on the ground? Is it 900+5=905 km/h, or is it simply 5 km/h?

4. A bird is flying northward at 20 km/h in a westward wind blowing at 10 km/h, and a fish is swimming southward at 7 km/h in a river flowing westward at 5 km/h. What is the relative speed between the bird and the fish?

These scenarios raise fundamental questions about how motion is explained and described in different theoretical frameworks. The answers depend on whether the classical Galilean transformation or Einstein's relativistic transformations are used. Furthermore, they reveal the practical implications of choosing one theory over the other for describing everyday phenomena.

The speeds of the train, person, boat, airplane, butterfly, river, and wind, as calculated using Galilean transformations, all rely on an absolute reference frame. Listing the results of these calculations using Galilean transformations helps to illustrate differences in velocity. However, if one assumes the Lorentz transformation to be correct and insists on using it to calculate motion, the original questions should be reframed as follows:

1. What are the speeds of the moving train and the person walking on the train relative to an observer on the ground?

2. What are the speeds of the sailing boat and the person walking on the boat relative to an observer on the riverbank?

3. What are the speeds of the flying airplane and the butterfly inside the airplane cabin relative to an observer on the ground?

4. What is the relative speed between a bird flying northward in a westward wind and a fish swimming southward in a westward-flowing river?

The above examples involve simple motion phenomena, but the motion phenomena in the real world are far more complex. Trains, people, boats, airplanes, butterflies, rivers, and winds all exhibit relative motion. For instance, if one measures the speed of butterflies and insects relative to the water, air, or shore outside a boat, the motion of the boat itself must be factored into the calculation. If the boat is moving in a flowing river, the river's current must also be included, meaning that the butterflies' and insects' speeds must be added to or subtracted from the river's flow velocity.

If another moving boat contains a closed cabin with butterflies and insects flying inside, the relative motion between the butterflies and insects in the two boats requires accounting for the velocities of both boats and the river's flow velocity (neglecting for now the complexities of motion direction).

On Earth, countless objects with enclosed spaces, such as ships, cars, trains, and airplanes, move in different directions and at different speeds. Inside their enclosed spaces, countless butterflies and insects move at various speeds. Calculating the velocities of these butterflies and insects still requires taking their respective absolute spaces as reference frames, and the velocities of these absolute spaces must be included in the calculation.

If one denies the existence of absolute space or absolute motion, it becomes impossible to calculate the velocity of any moving object. Therefore, calculating the velocity of objects in motion requires accounting for the motion of their absolute reference frames as well as the relative motion between different absolute spaces.

The principle of velocity addition relative to absolute space forms the theoretical basis of the Galilean transformation, which is a cornerstone of classical mechanics. This highlights the characteristics of Galilean relativity and the Galilean transformation. (For brevity, the distinctions between Galilean relativity and special/general relativity, as well as the differences between the Galilean and Lorentz transformations, are not discussed here.)

Facts are the best evidence. In reality, do people use the Galilean transformation of classical mechanics or Einstein's Lorentz transformation for calculations?

The answer is that, to date, all motion phenomena on Earth and in the universe are described using the Galilean transformation of classical mechanics, which is based on Galilean relativity—without exception. Facts speak for themselves.

(Discussions on related issues represent the current mainstream perspective.)

Suggested Readings (related discussions): (a), (b), (c)

VIII. CAN CLASSICAL PHYSICS ONLY DESCRIBE LOW-SPEED MOTION?

Currently, a common viewpoint holds that special/general relativity describes high-speed motion phenomena, while classical physics is used to describe low-speed motion. However, this perspective has several issues:

1. The Difference Between Galilean and Lorentz Transformations Is Not About Speed:
    - The Galilean transformation is based on an absolute space as an absolute reference frame, whereas the Lorentz transformation rejects the concept of absolute space and absolute reference frames. The Lorentz transformation does not account for the velocity of the moving medium or reference frame.
    - Using classical physics to describe motion means applying the Galilean transformation and its velocity addition principle, which considers the velocity of the absolute reference frame. On the other hand, using relativity implies the invariance of the speed of light—meaning light does not add to or subtract from the velocity of the moving medium—and relies on the Lorentz transformation, which excludes the velocity of the medium or absolute reference frame from calculations.
    - For example, relativity can only calculate the relative motion of two ships in a river, but it cannot determine the speed of the river itself, nor the relative speed of butterflies and insects inside the cabins of the two ships.
2. Ambiguity in the Definition of "High Speed":
    - If "high speed" refers to the speed of light, this contradicts Einstein's conclusion, which states that accelerating any massive object to the speed of light would require infinite energy, and a massive object moving at the speed of light would have infinite mass.
    - If "high speed" refers to 90% of the speed of light, then transitioning to 91% during acceleration would create inconsistencies. Below 90%, one would use the Galilean transformation and classical physics' velocity addition principle, which considers the velocity of the absolute reference frame. Upon reaching 90%, one would switch to the Lorentz transformation, ignoring the velocities of all moving media, such as air, water, cars, trains, and airplanes. This would discard the concepts of absolute space and absolute reference frames.
    - Describing the motion of the same object using two entirely contradictory principles clearly violates the principle of logical consistency.
3. The Galilean Transformation Has No Speed Limit:
    - The Galilean transformation allows for phenomena beyond the speed of light and has no inherent speed restrictions. Thus, there is no issue of the Galilean transformation being unable to describe high-speed motion phenomena.
4. The Fizeau Experiment Describes High-Speed Motion Phenomena:
    - The *Fizeau Experiment*, which investigates the behavior of light, directly involves light—a high-speed phenomenon. The experiment demonstrated that the speed of light adds to or subtracts from the velocity of the moving medium, thereby validating the classical physics principle of velocity addition.

These points suggest that classical physics, particularly the Galilean transformation, is not limited to low-speed motion and remains applicable to describing high-speed phenomena.

The fact is that, to date, whether for low-speed or high-speed motion, humans have used the Galilean transformation of classical mechanics to describe all motion phenomena on Earth—without exception. No one has been able to use the Lorentz transformation of relativity to describe any motion phenomenon on Earth. This is a fact, and facts are the best evidence and proof.

Suggested Readings (related discussions): (d), (e)

IX. REFLECTION

Modern science requires experimental evidence. However, when the same experiment yields completely opposite conclusions, and these different interpretations evolve into distinct theoretical frameworks, the correct interpretation of an experimental result becomes critical in determining the direction of physics.

What did the *Fizeau Experiment* prove? What did it disprove? These questions will determine the nature of space, the essence of light, the way motion is described, the understanding of matter, and the interpretation of fundamental forces. The *Fizeau Experiment* stands as a pivotal test in addressing these fundamental questions.

A. Can the Fizeau Experiment Prove the "Partial Ether Drag Hypothesis"?

Although the *Fizeau Experiment* demonstrated that the speed of light adds to and subtracts from the velocity of the moving medium—a result favorable to Fresnel's *Partial Ether Drag Hypothesis*—this hypothesis itself has unresolved issues. Specifically:

- What mechanism causes matter to drag the surrounding ether along with it?
  - Is it universal gravitation?
  - Does the ether possess mass?
  - Does the ether move with matter because it is part of the structure of matter itself?

If the ether constitutes part of matter itself, then the *Partial Ether Drag Hypothesis* is an incorrect assumption. Proving a hypothesis that is itself questionable makes the proof equally doubtful.

Since the assumption underlying the *Partial Ether Drag Hypothesis* is vague and represents only one of the three ether hypotheses, we cannot conclude that the *Fizeau Experiment* proves the existence of ether.

Similarly, the Michelson-Morley experiment only disproved one of the three ether hypotheses—the *Ether Drift Hypothesis*—but it could not disprove Fresnel's *Partial Ether Drag Hypothesis* or Stokes's *Complete Ether Drag Hypothesis*. Therefore, it cannot be concluded that the Michelson-Morley experiment disproved the existence of ether.

In fact, as long as one ether hypothesis remains unrefuted, it cannot be definitively concluded that the concept of ether is invalid.

B. Did the Fizeau Experiment Prove or Disprove the Invariance of the Speed of Light?

The *Fizeau Experiment* inferred, from the observed shift in interference fringes, that the motion of the medium alters the speed and direction of light propagation, causing changes in the phase of light waves and leading to shifts in the interference pattern. This demonstrated that the speed of light is added to or subtracted by the velocity of the moving medium, proving that the speed of light can be altered—that is, light speed is variable.

Some may counter this by arguing that the Principle of the Constancy of the Speed of Light states that, regardless of the inertial reference frame, the speed of light in a vacuum remains constant relative to the observer and does not change due to the relative motion of the source or the observer's reference frame. This principle is based on the assumption of a vacuum and refers specifically to the invariance of light speed in a vacuum. Since the *Fizeau Experiment* was conducted in a non-vacuum environment (in water), it cannot refute the principle of the constancy of light speed in a vacuum.

This rebuttal contains severe logical inconsistencies, and addressing these issues does not require mathematical proof but can be resolved through logical reasoning:

1. While it is true that the *Fizeau Experiment* was conducted in a non-vacuum environment and thus cannot refute "the constancy of the speed of light in a vacuum," why is this non-vacuum experiment considered as evidence supporting the constancy of light speed in special relativity? Similarly, the Michelson-Morley experiment, often cited as evidence for the constancy of light speed, was also conducted in a non-vacuum environment. Therefore, the Michelson-Morley experiment cannot serve as proof of the constancy of light speed in a vacuum either.

2. The principle of the constancy of the speed of light in a vacuum asserts not only that light speed remains constant in any reference frame, but also that it is unaffected by the relative motion of the light source or observer's reference frame. If light speed is truly invariant in all moving reference frames, the measured variation in light speed across reference frames must be zero. However, the *Fizeau Experiment* and subsequent related experiments consistently yielded results that were not zero. As long as the measured result is not zero, it implies that the speed of light is added to or subtracted by the velocity of the medium, meaning light speed can indeed be altered—proving that light speed is variable.

3. What experiments can prove "the constancy of the speed of light in a vacuum"? To date, no one has conducted an experiment in a vacuum specifically designed to test whether the speed of light is the same in reference frames with different velocities. The principle of the constancy of light speed has neither been proven nor refuted.

Does it meet Popper's criterion of "falsifiability"? Suggested Readings (related discussions): (f), (g)

4. The principle of the constancy of the speed of light in a vacuum relies on the assumption of a vacuum, and special relativity is based on this principle. The question then arises: is special relativity, which is founded on the assumption of a vacuum, applicable to non-vacuum environments like Earth? If the universe is filled with "dark matter," is there any environment where special relativity would apply?

The results of the *Fizeau Experiment* are unequivocal: a non-zero measurement indicates that light speed is variable. Why do people ignore the fact that the *Fizeau Experiment* yielded a non-zero result? How can an experiment that refutes the constancy of light speed be considered evidence for it? Can one use a white swan as proof that all swans are black?

C. Is the Principle of the Constancy of the Speed of Light an Objective Phenomenon?

The principle of the constancy of the speed of light cannot coherently explain any objective phenomena on Earth, nor is there any objective phenomenon that supports the invariance of light speed. On the contrary, it is a fundamental scientific fact that the speed of light varies in different media. There is no evidence to suggest that the so-called principle of the constancy of the speed of light is an objective phenomenon.

Newton stated: "Whatever is not deduced from phenomena must be called a hypothesis; whether it is metaphysical or physical, whether it is about occult qualities or mechanical ones…" [18]*pp. 349*. Science must be based on facts; its starting and ending points must be rooted in evidence. Scientific conclusions require proof, and all evidence and conclusions must withstand scrutiny. Any theory or hypothesis that cannot withstand questioning and testing is, at its core, merely a hypothesis.

If the principle of the constancy of the speed of light is not an objective phenomenon and has not been experimentally verified, should it be considered a scientific law?

Science is not about seeking infallible truths but about using scientific methods to continually uncover and validate the principles governing the objective world, grounded in facts. The crucial aspect of science is its commitment to truth and its unwillingness to avoid inconvenient facts.

The essence of scientific spirit lies in rationality, skepticism, criticism, and experimental validation. Questioning exposes both truths and errors. Before praising a theory for its elegance, one should first evaluate whether its logical foundation can withstand scrutiny and whether there is experimental evidence to support it. If questioning is treated as heretical, then there is neither rationality nor science.

If a hypothesis or theory becomes immune to questioning, science loses its mechanism for self-correction, and its trajectory deviates from the truth. Only by adhering to the scientific spirit can we avoid the trap of "confirmation bias" (the tendency to search for, interpret, and remember information that confirms one's preconceptions, while ignoring or distorting contradictory evidence). While the scientific spirit cannot guarantee that we will find all the truths, it ensures that our exploration does not stray off course.

Philosophy progresses through self-criticism and self-negation, and the entire history of philosophy is marked by philosophers criticizing, overturning, and replacing each other's ideas. Similarly, the history of science reflects humanity's evolving understanding of nature. From the ancient Greek philosophers to Copernicus, Galileo, Descartes, Newton, Hooke, Huygens, Maxwell, Planck, Einstein, Bohr, and Feynman, each thinker contributed perspectives that were inherited, developed, criticized, and even refuted.

Science, too, advances through self-criticism and self-negation. The intellectual legacy accumulated over thousands of years continues to enrich our understanding. These pioneers lit one beacon after another, guiding humanity's development. No one's ideas are entirely correct, nor are they entirely wrong. Even ideas later proven erroneous served as milestones, marking the way to truth and providing invaluable guidance.

> "It is better to debate a question without settling it than to settle a question without debating it."
>
> — Joseph Joubert (1754–1824)

Appendix A: Suggested Readings (related discussions)

a. *Can General Relativity Be Used to Calculate the Relative Speeds Between a Fish in a River, a Running Horse on Land, and a Bird in the Wind?* Quora, 2019. Available at: https://qr.ae/p2B705.

b. *On a straight track, two trains are moving in the same direction and at the same speed, but one train is moving in the opposite direction. Can special relativity be used to calculate the speeds and independent times of these three trains?*) Available at: https://qr.ae/pszfD3.

c. *If classical mechanics is just an approximation of special general relativity at low speeds, then to what speeds can special and general relativity be applied?*) Available at: https://qr.ae/p2aKmn

d. *Can the curvature of space-time in general relativity be used to explain natural phenomena such as mirages, rainbows, and parhelias? Why do people generally choose the classical optical explanation?*) Available at: https://qr.ae/p2H7qM

e. *Can general relativity describe an apple falling from a tree?*) Available at: https://qr.ae/p2BRhV.

f. *How is the "constancy of the speed of light in a vacuum" proven? How could the "constancy of the speed of light in a vacuum" be disproven?*) Available at: https://qr.ae/p2q4mW.

g. *Armand Fizeau's experiment in 1851 (Fizeau Experiment) disproved what misconception? What did it prove?*) Available at: https://qr.ae/p2VJHx.

Appendix B: Translation of Fizeau's Original Paper

(Note: This paper was translated by ChatGPT for reference only. Original French paper: https://www.academie-sciences.fr)

French Academy of Sciences Member: Hippolyte Fizeau

"On hypotheses relating to the luminous ether, and on an experiment which seems to demonstrate that the motion of bodies changes the speed at which light propagates within them(*Sur les hypothèses relatives à l'éther lumineux, et sur une expérience qui paraît démontrer que le mouvement des corps change la vitesse avec laquelle la lumière se propage dans leur intérieur*"

Extract from a memoir by H. Fizeau, *Comptes Rendus de l'Académie des Sciences*, Vol. 33 (1851), pp. 349-355

(349)

. . . . . .

Physics:

On hypotheses relating to the luminous ether, and on an experiment which seems to demonstrate that the motion of bodies changes the speed at which light propagates within them By M. H. FIZEAU (Excerpt by the author) (Reviewers: MM. Arago, Pouillet, Babinet)

"Several theories have been proposed to account for the phenomenon of aberration in the wave theory. Fresnel first introduced a theory, followed more recently by MM. Doppler, Stokes, Challis, and others, who have published significant works on this subject. However, it seems that none of the proposed theories has received unanimous acceptance among physicists."

"Indeed, due to the lack of precise knowledge about the properties of the luminous ether (*éther lumineux*) and its relationships with ponderable matter, it has been necessary to propose hypotheses. Among these, some are more probable than others, but none can be considered proven."

"These hypotheses can be reduced to three main ones, which concern the state of the ether within a transparent body:

The ether adheres to and is fixed to the molecules of the body, and thus shares the motions imparted to the body; The ether is free and independent and is not carried along by the body in its motion; A third hypothesis combines elements of the first two: part of the ether is free, while another part is fixed to the molecules of the body and alone shares its motion."

(350)

"The last hypothesis, proposed by Fresnel, was conceived to account simultaneously for the phenomenon of aberration and a famous experiment by M. Arago, which demonstrated that the motion of the Earth has no influence on the refraction of starlight through a prism."

"One can consider the value to be attributed to the speed of light in a moving body under each of these hypotheses. This speed may be altered by the motion of the body."

"If the ether is entirely carried along with the body, the speed of light must increase by the full speed of the body, assuming the ray travels in the direction of the motion."

"If the ether is free, the speed of light will remain unchanged."

"Finally, if only part of the ether is carried along, the speed of light will increase, but only by a fraction of the speed of the body, not by the full amount as in the first hypothesis. This conclusion is less evident than the previous ones, but Fresnel demonstrated that it can be supported by highly probable mechanical considerations."

"Although the speed of light is enormous compared to the velocities we can impart to bodies, we now have such precise observational methods that it seems possible to determine, through a direct experiment, the actual influence of the motion of bodies on the speed of light."

(351)

"M. Arago devised a method based on the phenomenon of interference, which is capable of revealing the smallest variations in the refractive indices of materials. Observations by MM. Arago and Fresnel on the difference in refraction between dry air (*air sec*) and moist air (*air humide*) demonstrated the extraordinary sensitivity of this method. Using the same principle, I combined M. Arago's double-tube apparatus with my previous setup for determining the absolute speed of light, enabling me to directly study the effects of motion in air and water on light passing through them."

"I will attempt to describe the course of light in this experiment without using a diagram."

"From the focus of a cylindrical lens (*lentille cylindrique*), solar rays entered the first telescope almost immediately through a lateral opening very close to its focus. A transparent glass plate inclined at an angle of 45 degrees to the telescope's axis reflected the rays towards the objective."

"Emerging from the objective, the rays became parallel and encountered a double slit, each slit corresponding to the entrance of one of the tubes. Thus, a very narrow beam of light penetrated each tube and traversed its entire length (1.487 meters)."

"These two parallel beams reached the objective of the second telescope, where they were refracted and converged at its focus. There, they encountered the reflecting plane of a mirror perpendicular to the telescope's axis and were reflected back towards the objective. As a result of this reflection, the paths of the rays were exchanged: the ray previously on the right now emerged on the left, and vice versa."

"After passing through the objective again and becoming parallel, the rays entered the tubes a second time. However, due to the path reversal, the ray that had passed through one tube on its outward journey now traversed the other tube on its return."

"After their second passage through the tubes, the two beams passed through the double slit again, re-entered the first telescope, and finally interfered at its focus after passing through the transparent glass. At this point, their mutual interaction produced interference fringes (*franges d'interférence*), which were observed using an eyepiece with divisions at its focus."

(352)

"In this arrangement, it is easy to see that all points along the path of one ray are equally along the path of the other ray. Thus, a change in density at any point along the path affects both rays in the same way and therefore cannot influence the position of the interference fringes."

"This compensation mechanism was confirmed experimentally by placing a thick glass plate in front of only one of the slits or by filling one tube with water while leaving the other filled with air. Neither of these tests caused any change in the position of the fringes."

"In terms of motion, however, we observe that the two rays are subjected to opposing effects."

"If, for instance, we assume that water is flowing towards the observer in the right-hand tube, the ray coming from the right will traverse the tube in the direction of the flow, while the ray coming from the left will traverse the tube in the opposite direction to the flow."

"By simultaneously moving water in opposite directions in the two tubes, we observe that the effects are additive. Once the double current is established, we can reverse the flow in both tubes, and the effect will still be doubled."

"All these water movements were produced in a very simple manner. Each tube was connected, near its ends, to two glass reservoirs through branching pipes, where air pressure was alternately applied using compressed air. Under this pressure, water flowed from one reservoir to the other, passing through the tube whose ends were sealed with glass. The internal diameter of the tubes was 0.3 centimeters, and their length was 1.487 meters. They were made of glass."

"The pressure under which the water flowed could exceed two atmospheres. The flow velocity was calculated by dividing the volume of water passing through the tube in one second by the cross-sectional area of the tube. To prevent any objections, great care was taken to avoid accidental movements caused by water pressure or impacts. Thus, the tubes and the reservoirs generating the water flow were supported by structures independent of the rest of the apparatus, particularly the telescopes. Therefore, only the tubes themselves could experience any accidental movements, but reasoning and experiments showed that such movements or flexures of the tubes had no influence on the position of the fringes."

(353)

"The observations were as follows:
When water flows, the fringes are displaced, and the direction of displacement depends on whether the water flows in one direction or the other. The fringes shift to the right when water flows towards the observer in the right-hand tube and away from the observer in the left-hand tube. Conversely, the fringes shift to the left when the flow in each tube is reversed." "With a water velocity of

2 meters per second, the displacement of the fringes was already noticeable; at velocities of 4 meters per second, it was perfectly measurable."

"After noting the existence of this phenomenon, I sought to determine its numerical value as accurately as possible. When the water was initially at rest and then set in motion, the resulting displacement was referred to as 'simple displacement.' When the motion was reversed, it resulted in a 'double displacement.' From an average of 19 consistent observations, the simple displacement was found to be 0.23, and the double displacement was 0.46, taking the width of one fringe as the unit of measurement. The velocity of the water was 7.069 meters per second."

"This result was then compared with theoretical values derived from various hypotheses concerning the ether."

"If the ether is entirely free and independent of the motion of bodies, the displacement should be zero. If the ether is entirely dragged along with the molecules of the body, sharing their motion, the calculated double displacement is 0.92, whereas the observed value is half of this, or 0.46. According to Fresnel's hypothesis, in which the ether is only partially dragged, the calculated displacement is 0.60, a value very close to the observed result. The difference between these two values would likely be even smaller if a correction could have been applied to the calculated water velocity. However, this correction was neglected due to insufficiently precise data and relates to the unequal velocities of different liquid filaments. Estimating the correction as plausibly as possible shows that it slightly increases the theoretical value, bringing it even closer to the observed result."

(354)

"A similar experiment had been previously conducted with moving air, where I observed that the motion of air produced no significant displacement of the fringes. In the conditions of that experiment, with an air velocity of 25 meters per second, the hypothesis of fully dragged ether predicted a double displacement of 0.82. Under Fresnel's hypothesis, the displacement should have been only 0.000465, an entirely imperceptible value. Thus, the apparent immobility of the fringes in the air experiment is in complete agreement with Fresnel's theory."

"Having noted this negative result and attempted to explain it within the framework of various ether hypotheses, while also satisfying the aberration phenomenon and M. Arago's experiment, I concluded that Fresnel's hypothesis must be accepted. According to this hypothesis, the motion of bodies induces a change in the speed of light. This change is more or less pronounced depending on the medium's refractive power, being significant in strongly refractive bodies and negligible in weakly refractive ones, such as air."

(355)

"It follows that while the fringes do not move when light passes through moving air, they should exhibit a perceptible displacement when the experiment is conducted with water, whose refractive index is significantly higher than that of air."

"An experiment by M. Babinet mentioned in Comptes Rendus de l'Académie des Sciences, Vol. IX, seemed to contradict the velocity change predicted by Fresnel's law. However, upon analyzing the circumstances of this experiment, I identified a compensatory factor that must have rendered the effect of motion imperceptible. This factor lies in the reflection of light in the experiment: when two rays have a certain difference in optical path, this difference is altered by reflection on a moving mirror."

"By separately calculating the two effects in M. Babinet's experiment, it was found that their magnitudes were essentially equal but opposite in sign."

"This explanation further strengthened the plausibility of the velocity change hypothesis, and an experiment conducted in moving water seemed to me particularly suitable for definitively resolving the question."

"The success of this experiment seems to necessitate the adoption of Fresnel's hypothesis, or at least the law he discovered to describe the change in the speed of light caused by the motion of bodies. Although the validity of this law strongly supports Fresnel's hypothesis, his conception may still appear so extraordinary and, in some respects, so difficult to accept, that further evidence and rigorous examination by mathematicians may still be required before fully accepting it as a representation of reality."

---

[1] E. Whittaker, *A History of the Theories of Aether and Electricity* (Longmans, Green and Co., London, 1910).

[2] K. F. Schaffner, *Nineteenth-century aether theories* (Pergamon Press, Oxford, 1972) pp. 99–117, 255–273.

[3] H. Fizeau, Sur les hypothèses relatives à l'éther lumineux, et sur une expérience qui paraît démontrer que le mouvement des corps change la vitesse avec laquelle la lumière se propage dans leur intérieur, Comptes Rendus **33**, 349 (1851).

[4] A. A. Michelson and E. W. Morley, Influence of motion of the medium on the velocity of light, American Journal of Science **31**, 377 (1886).

[5] A. A. Michelson and E. Morley, On the relative motion of the earth and the luminiferous ether, American Journal of Science **34**, 333 (1887).

[6] Einstein, *Relativity: The Special and the General Theory.* (Peking University Press., Peking, 2006).

[7] A. A. Michelson, The relative motion of the earth and the ether, American Journal of Science 4, **3**, 475 (1897).

[8] E. Falkner, Fizeau Experiment, The General Science

Journal (2018).

[9] H. Fizeau, Sur les hypothèses relatives à l'éther lumineux, Ann. Chim. Phys. **57**, 385 (1859).

[10] R. W. Wood, *Physical Optics* (The Macmillan Company, New York, 1905) p. 514.

[11] M. Hoek, Détermination de la vitesse avec laquelle est entraînée une onde lumineuse traversant un milieu en mouvement, Verslagen en Mededeelingen **2**, 189 (1868).

[12] P. Hariharan, *Basics of Interferometry*, 2nd ed. (Elsevier, 2007) p. 19.

[13] R. Anderson, H. R. Bilger, and G. E. Stedman, Sagnac effect: A century of earth-rotated interferometers, American Journal of Physics **62**, 975 (1994).

[14] P. Zeeman, Fresnel's coefficient for light of different colours. (first part), Proc. Kon. Acad. Van Weten. **17**, 445 (1914).

[15] P. Zeeman, Fresnel's coefficient for light of different colours. (second part), Proc. Kon. Acad. Van Weten. **18**, 398 (1915).

[16] J. Stachel, Fresnel's (dragging) coefficient as a challenge to 19th century optics of moving bodies, in *The Universe of General Relativity*, edited by A. J. Kox and J. Eisenstaedt (Birkhäuser, Boston, 2005) pp. 1–13.

[17] Galileo, *Dialogue Concerning the Two Chief World Systems* (Peking University Press, 2006) pp. 130–131.

[18] Newton, *Mathematical Principles of Natural Philosophy* (Peking University Press, Peking, 2006).