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Comment

Comment on: "From classical to modern ether-drift experiments: the narrow window for a preferred frame" [Phys. Lett. A 333 (2004) 355]

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Abstract

In a recent article [M. Consoli, E. Costanzo, Phys. Lett. A 333 (2004) 355], M. Consoli and E. Costanzo have investigated classical and modern aether drift experiments and explored the narrow window for detection of a preferred reference frame. This Letter proposes an easy to perform variant of Fizeau's experiment, which may confirm or deny Consoli–Costanzo's claims.

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1. Introduction

Although special relativity has been proved a powerful predictive tool for already one century, its interpretation has been challenged since its origin. As a matter of fact, the outstanding historical works of Lorentz and Poincaré maintained the existence of a preferred frame, which would be experimentally inaccessible. As it is well known, this view has been almost completely abandoned, with subsequent profound philosophical implications. However, in recent years a growing number of articles questioning the standard interpretation of special relativity is appearing. For instance, John Bell [1] has noted that Lorentz's view is consistent and that "the facts of physics do not oblige us to accept one philosophy rather than the other". Leubner, Aufinger and Krumm [2] have shown that Einstein's view can be adopted only "on purely practical grounds, and not on philosophical ones". And Franco Selleri [3,4] has systematically developed Bell's idea and obtained a true Lorentzian theory, fully compatible with Einstein's special relativity in what concerns the description of physical phenomena, but very different in philosophical terms. Another Lorentzian theory, very close to Selleri's formulation, was derived independently in [5].

This freedom in the interpretation of special relativity comes from a too strong formulation of its postulates, i.e., the theory involves additional assumptions than those implied by experiment. Actually, each of the postulates can be formulated in more general terms, while keeping fully compatible with the observed physical reality. However, there is an indeterminacy in the theory, since there are quantities which eventually cannot be measured, such as the one-way speed of light. As a consequence, a deadlock arises in practical terms—although not in fundamental ones—and some additional assumptions may have to be required to cut this "Gordian knot". Einstein's theory solves the problem in an extremely simple and elegant way, providing a straightforward and effective *operational procedure* to study physics. Nonetheless, other solutions are possible, fully compatible with Einstein's relativity in practice, but with very different assertions in fundamental and philosophical terms.

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If these different views are indeed truly compatible, it can be argued the discussion is merely an academic and philosophical one. In that case, although of great interest, these contrasting formulations should be seen just as different aspects of the same theory. However, the recent article by M. Consoli and E. Costanzo [6] reopens the discussion, by suggesting a possible way to distinguish between the different formulations and an unambiguous detection of a preferred frame. According to [5], the various alternative presentations of the theory would be fully compatible only in vacuum. Nonetheless, differences may appear when light propagates in transparent media. This is also the idea defended in [6–10].

In this short comment we do not intend to enter the debate around theories defending a preferred reference system. By adopting a pragmatic point of view, our aim is simply to propose a very simple variant of Fizeau's experiment, capable of confirming or denying the allegations from [6] as to the experimental detection of a preferred frame.

2. The interpretation of M. Consoli and E. Costanzo of the aether drift experiments

As carefully discussed in [6,10,11], the Michelson–Morley experiment is often said to have given a null-result, as it should be according to Einstein's relativity. However, there have always been claims this was not the case, including the famous work by Miller [12]. The experiment and some of its variations have been repeated, and it is being argued nowadays that the available data point towards a remarkable consistency of non-null results when the interferometer is operated in the "gas-mode", corresponding to light propagating through a gas (like the cases of air or helium, for instance) [6–11].

A null result is expected for *light propagating in vacuum*, which seems to be confirmed experimentally [6,13,14]. Hence, the non-null results are likely to be related to the absolute motion of a moving transparent medium in the preferred rest system. This suggestion is discussed in [5] and is based on the recent analyses of Consoli and Costanzo [6,7] and of Cahill and Kitto [8–10].

Take note that special relativity predicts a null result for the interferometer experiments in vacuum, and the same prediction results from the Lorentzian theories from [3–5]. In a recent paper [15], it was even shown that such null result is implied by the very notion of time. But the insertion of a gas in the interferometer apparently takes the experiment outside the scope of the theory [5].

The results obtained from of the original interferometer experimental data as reported by Múnera [11] are given in Table1. Very remarkably, both Lorentz and Einstein were aware of Miller's results and were truly convinced that Michelson–Morley–Miller experiments had not given a null result. Shankland made a series of visits to Einstein in the 1950s, later reported in two articles [16,17], in which he confirmed that Lorentz and Einstein felt Miller's results could not be ignored. In the last of his visits to Einstein, Shankland suggested that the positive result of the experiments could probably be explained by temperature gradients across the interferometer. The idea was published by Shankland and co-workers in 1955 [18], who nevertheless admitted they could not establish a direct and general correlation between Miller's results and the thermal conditions during the experiments. Moreover, Miller addressed the question of possible temperature effects in his 1933 article. He made temperature control experiments, and has shown "the periodic displacements could not possibly be produced by temperature effects".

Table 1
Múnera's interpretation of observable Earth velocity from the classical aether-drift experiments

Data from	Observable velocity [km/s]
Michelson–Morley [19]	
noon sessions	6.22 ± 0.93
18h00 sessions	6.80 ± 2.49
Miller [12]	8.22 ± 1.39
Illingworth [20]	3.13 ± 1.04

The basic hypothesis advanced in [6] to explain this data is that the speed of light traveling through a rarefied gas is still c/n in the preferred frame, *independently* of the state of rest or motion of the gas (being consequently non-isotropic in other inertial frames), n denoting the refractive index of the medium. In vacuum, the speed of light in the preferred frame Σ is c and there is not any drag-like effect. When a gas starts to be inserted in the cabin, the speed of light in Σ becomes c/n, with n very close to 1, and this value seems *not* to depend on the state of motion of the "few" particles of the gas. Since $n_{\mathrm{air}} = 1.00029$, Cahill [10] and Consoli and Costanzo [6] have shown that this assumption allows to infer, from the observed speed of about 7–8 km/s in the original Michelson–Morley experiment (about a factor of four lower than the expected orbital speed $\simeq 30$ km/s), an absolute speed of the Earth through space of ~ 330 km/s and ~ 205 km/s, respectively (although the main idea is the same, there are minor differences on the analysis of both authors, of about a factor of $\sqrt{3}$). They have further shown that the later results from Miller provide perfectly compatible absolute Earth speeds. Moreover, and extremely interesting, an interferometer experiment was performed in helium by Illingworth in 1927 [20]. Since the refractive index of helium is $n_{\mathrm{He}} = 1.000036$, the proposed dependence of the results on n could be tested. From the Illingworth experiment, Cahill and Consoli and Costanzo obtain, respectively, absolute velocities of 368 km/s and 213 km/s, in excellent agreement with the values deduced from Michelson–Morley–Miller experiments. And a further confirmation of the idea of the importance of the index of refraction of the medium on the results is given by the interferometer experiments performed in vacuum cited above [13,14], which *do* give a null-result (in rigor, the observed relative anisotropy of the speed of light is at most of the order of 10^{-15}).

The second crucial point is the following. As the gas becomes denser it seems some effect formally equivalent to a "Fresnel drag" exists, and if the transparent medium is already a liquid or a solid the speed of light through a moving medium is given by c/n *in the system in which the medium is at rest*, S'. If S' goes with speed v, the speed of light in Σ is given by the well-known velocity addition formula,

$$c_{n,v} = \frac{\frac{c}{n} + v}{1 + \frac{v}{nc^2}} = \frac{\frac{c}{n} + v - \frac{v}{n^2} - \frac{v^2}{nc}}{1 - \frac{v^2}{n^2c^2}} \simeq \frac{c}{n} + v\left(1 - \frac{1}{n^2}\right), \tag{1}$$

which is the Fresnel drag expression with

$$k = 1 - \frac{1}{n^2}. \tag{2}$$

Thus, *an interferometer experiment performed in a transparent solid should give a null-result*. Such experiment was performed by Shamir and Fox in 1969 [21], for a medium with $n \simeq 1.5$, and as a matter of fact gave a null-result.

In summary, the paper from M. Consoli and E. Costanzo [6] explains the available experimental results of aether-drift experiments and points towards the detection of a preferred frame, under two important assumptions (which up to date still lack a truly solid justification):

(i) light in a transparent liquid or solid of refractive index n propagates with speed c/n, isotropically, in the system in which the medium is at rest;
(ii) light in a rarefied gas of refractive index n very close to 1 propagates with speed c/n, isotropically, in the preferred frame Σ.

Condition (i) is the usual assumption made in accordance with a strict view of the principle of relativity and can easily be justified by very simplified models for the refractive index,[2] whereas condition (ii) holds exactly for vacuum ($n = 1$) and is therefore also believable. However, if both assumptions prove to be true, it has to be conceded that it is still not clear nowadays how the transition from vacuum to gas mode interferometers and then to solid mode interferometers really occurs. Notice still that the word "speed" in condition (i) refers actually to the "Einstein speed" defined in [5,22], but this detail is of no importance here.

3. The proposed Fizeau experiment

In 1851 Armand Fizeau made an interferometer experiment designed to detect the effect of the motion of water in the speed of light going through it. Water was passed at high speed along two glass tubes that formed the optical paths of the interferometer, as shown in Fig. 1. The light emitted from the source is divided in two rays in mirror M. Light going on path A crosses the tube with flowing water in the direction contrary to the water flow, whereas light on path B does so in the direction of the water flow. After successive reflections, both rays recombine at

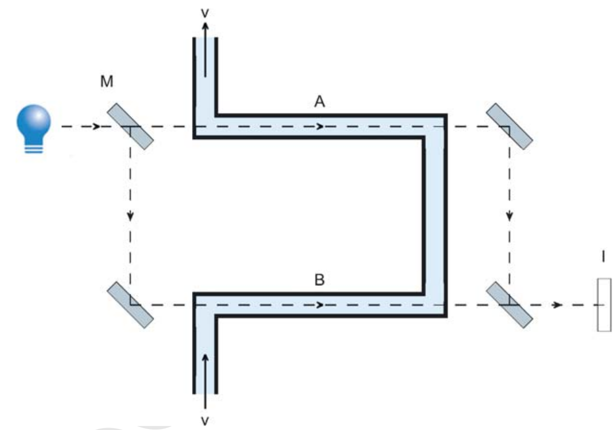

Fig. 1. The experiment of Fizeau.

I and the their interference is observed. It was found that the fringe shifts were as predicted by Fresnel's drag coefficient (2).

That being so, the result of the classic Fizeau experiment is readily explained from the velocity addition expression (1). This means that assumption (i) holds and light propagates with speed c/n in the frames in which the water is at rest, as expected from the principle of relativity. Notice that in this case, both Einstein's special relativity and the Lorentzian theories [3–5] predict the result of the Fizeau experiment from the velocity addition expression without any need for an aether nor its drag. This should not be surprising, taking into account the compatibility of the "different" theories in what concerns the description of the observable phenomena, as pointed out by Bell [1]. Such compatibility was unambiguously established for vacuum in [5]. It seems it can be extended for the case of transparent liquids and solids, under assumption (i).

Now, let us look at the same experiment, but making a rarefied gas flow in the interferometer instead of water. According to the analysis from [6], in this case we should be under assumption (ii). If this idea is correct, if for a rarefied gas the speed of light in Σ is indeed c/n independently of the state of motion of the gas, then the times light takes across paths A and B is precisely the same, and *the Fizeau experiment must give a null-result if performed with a rarefied gas* flowing in the tubes instead of water (i.e., no fringe shift should be observed). This very simple experiment provides an easy way to verify the validity of assumptions (i) and (ii). Hence, it gives a verification of how narrow the window for a preferred frame really is.

The original experiment was performed with water flowing at a speed of about $v = 5$ m/s in tubes of length $L = 1.5$ m. The observed fringe shift is proportional to $(Lvn^2/c)(1 - 1/n^2)$, where L is the length of the arms of the interferometer. Since n_{air} is about 1.00039 and $n_{\text{water}} \simeq 1.33$, for the same flow speed and interferometer lengths, the effect predicted by special relativity is about 2000 times smaller in air than in water. The resolution can be improved by increasing the flow speed and the length of the interferometer. One can easily arrive at a device that, still according to special relativity, is supposed to give an effect only about 10 times smaller than the one from the original experiment. A failure to detect such effect would provide

[2] For instance, a very simple picture of the medium can be given by a series of parallel sticks, corresponding to the one-dimensional position of the atoms or molecules in the solid structure; light then propagates with speed c in the rest system between the sticks, but has a certain delay at each stick; it is not difficult to show that in this case the results are compatible with Eq. (1), thus explaining the experiment by Fizeau, and further predicting that an interferometer experiment performed in a transparent solid should then give a null-result.

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a strong result in favor of the detection of a preferred frame as suggested in [6].

In summary, the variant of the Fizeau experiment proposed in this paper offers one additional possibility to confirm or refute the crucial assumptions of the modern interpretation of the aether drift experiments.

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