Á Propos *SAGNAC*

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In 2013, we commemorate the centenary of several marked events in physics among which one is particularly dear to the NPA family: The publication of *Sagnac*'s famous rotating interferometer experiment in the scientific French journal *Comptes Rendus*. Apart from that widely known experiment conspicuously little is officially communicated about *Sagnac*'s life. Is it because he was a decided opponent (*un opposant ardent*) to special relativity? Here we have a chance and a duty to bring back the memory of *Georges Marc Marie Sagnac* (1869 - 1926) who is also credited for pioneering work with X-rays and the discovery of X-ray fluorescence. The *Sagnac Award* combines the merits of our fellow scientists with those of the still deplorably neglected namesake of the Award. Not only has *Sagnac*'s research brought forth a wealth of technical applications - important lessons due to his work await to be learned. One of them is so elementary it is easily overlooked: We have to say farewell to the dogmatism which arouse from the overestimation of the observers' role. *Uniqueness* is the solid ground on which we may cautiously proceed. The technical and theoretical background of the *Sagnac effect* have been discussed extensively in original publications and review articles. Here we focus on aspects of *Sagnac*'s work that provoke further thought, including the importance of psychology in natural sciences, physics in particular.

1. The Year That Was 1913
Some Centenaries in Physics

Centenaries are a welcome opportunity to revive the memory of some events whose fame (more or less) outlasted their age.

One of them, although it became obsolete by later research, is *Niels Bohr*'s celebrated planet model of the atom introducing early elements of quantum mechanics with its orbits and all that. Driven to solve the puzzle of the spectral lines, *Bohr* stayed still deeply rooted in classical mechanics and submitted his paper dated April 5 to Philosophical Magazine where it was published in the July issue. *Bohr*'s model has become the everyday symbol of atoms.

The 1913 Nobel Prize is awarded to the Dutch physicist *Heike Kamerlingh Onnes*, one of the pioneers of cryophysics, for his work on the properties of solids at very low temperatures. In his research, *Onnes* succeeded to liquefy Helium, the "last of the permanent gases", and he happened to discover superconductivity, a sudden vanishing of the resistivity of Hg below some critical temperature. Superconductivity has opened great technological opportunities ever since.

My choice of centenary concerns a sadly unknown paper: *Peter Debye* and *Arnold Sommerfeld* [1] publish an unusual view of the photo effect based on the quantum of action which (in my opinion) reaches beyond *Einstein*'s world famous 1905 paper. *Debye* and *Sommerfeld* make an interesting approach that considers an accumulation time. *Sommerfeld*'s contributions to 20th century physics should have earned him a Nobel Prize.

And - we have 1913 research that was reported in France by a gentleman named *Georges Sagnac*, the “French Connection” of NPA (note the French title of this essay!). He still does not enjoy the world-wide recognition of the above scientists. It is hard to find his picture. The photo below shows him at the age of 21. Recently, *Sagnac* receives more attention in the discussion of high-precision devices derived from his rotating interferometer, namely the ring laser. There's material galore on *Sagnac*'s rightfully famous because far-reaching experiment in internet which saves us a lot of repetitive work here. Up to you to hunt for it. The *Sagnac* effect has been thoroughly discussed by our NPA fellow *Evert Jan Post*, himself one of the 2010 *Sagnac Award* winners, in his 1967 review article [2].

Fig. 1: This distinguished and definitely French gentleman is monsieur Georges Marc Marie Sagnac at the age of 21
Photo taken from *M. Quintin*'s article [3].
Sagnac was born Oct. 14, 1869 in a small village named Périgueux in the SW of France (if you wish to look it up - you'll find it halfway between Bordeaux and Limoges - they don't have a Rue *Sagnac* there...). He passed away Feb. 26, 1926 in Meudon-Bellevue.

2. History

Speaking of *Sagnac* spontaneously provokes the idea of a rotating interferometer. Two kinds of rotation are at hand, natural (or terrestrial, with Earth as “turntable”) and artificial (or technical, with rotating device in laboratory).

The earliest idea of using technical rotation (his “whirling machine”) may be traced back to Sir *Oliver Joseph Lodge* (1893) [4]. The pioneer of natural rotation seems to have been *Albert Abraham Michelson* (1904) [5], the one who never believed in special relativity theory (SRT) and who yet had to see his experiment ("I created a monster") being used as propaganda for SRT against his conviction.

»Je fais *tourner* uniformément, à un ou deux tours par seconde, autour d'un axe vertical, un plateau horizontal (50 cm de diamètre) portant, solidement vissées, les diverses pièces d'un interféromètre analogue à celui que j'ai employé dans mes recherches antérieures et décrit en 1910«. This is the opening of the original publication in the *Comptes Rendus* (C.R.; *Compte rendu* is French for report; the full title of the journal is »Comptes Rendus des Séances de l'Académie des Sciences«) [6]. Self-confident words ("*I* make a horizontal plateau rotate uniformly...") of a scientist referring to his theoretical analysis preceding his experiment who knows what he is doing and who clearly expresses himself and who strongly advocates a unique reference for the velocity of light. The *Sagnac* effect and its setup are fairly well known. For us NPA members, its welcome significance is its being not exactly a support of SRT - in spite of arguments issued by relativists to propagate their interpretation. We find a reference to *Sagnac* in just a few books on relativity. One of the early authors who mention *Sagnac* is *Einstein*'s close friend, *Max von Laue* [7]. He presents *Sagnac*'s original sketch (Fig. 2). For historical reasons, we may understand why: In 1911, v*on Laue* [8] presented a relativistic theory of the experiment proposed by *Michelson* [5] (see below). This definitely contrasts Sagnac [9] who was very strict and clear about an absolute reference for the velocity of light.

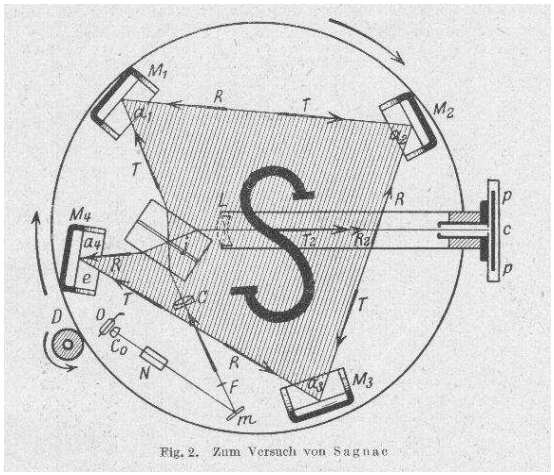

Fig. 2. Zum Versuch von Sagnac

Fig. 2 *Sagnac*'s now famous original sketch [10] of his rotating interferometer as represented in *Max von Laue*'s book [7]. The big **S** symbolizes the the shaded area enclosed by the out and back light beams. Other than in *Harreß*' experiment (see below), *Sagnac*'s light source and the detector (photographic film) co-rotate.

Sagnac was not the first to perform an experiment with a rotating interferometer, but he is reported to have been crucial in grasping its essentials and its consequences.

From *Max von Laue* [7] we learn that the German physicist *Franz Harreß* (who died young as victim of WWI) has performed an experiment with the light path totally in glass and source and detector co-rotating - three years before *Sagnac*'s experiment. *Harreß* was assistant to the astronomer *Otto Knopf* from whom [11] we learn that *Harreß*' post doc research was to explore the drag coefficient of light in a moving medium for a distinction between the models of *Fresnel* and *Lorentz*. In this experiment, rotation was just considered a means to have a simple device to make a medium (glass in that case because water did not allow the distinction) move. *Harreß* expected the fringe shift he observed to vanish when the experiment were carried out in air because he attributed it to the dragging of light by the rotating ring of glass prisms. This was definitely disproved by *Sagnac*.

The importance of *Sagnac*'s 1913 experiment has been realized quite early and it has initiated a wealth of subsequent experimental and technical activities. See *Post*'s review [2] for details.

3. Sagnac's Pioneering Works

When we speak of *Sagnac*'s pioneering works, we have to take into consideration at least one more. He is reported as one of the first scientists to work with Xrays (this was the name given to them by *Wilhelm Conrad Röntgen* in 1895) in combination with the discovery of Xray fluorescence [3].

Each of the above works, Xray fluorescence and the rotating interferometer effect named after him (*»effet tourbillonnaire optique«* in his own words, freely translated optical effects on a merry-go-round) suffices to buy him a reputation as a pioneering scientist who has greatly contributed to modern technology: Xray fluorescence analysis (a powerful tool for the identification of chemical elements) and the *laser gyroscope* (the latter serving as standard guidance system in spacecraft, planes, and satellites).
The "laser on a merry-go-round" has become a science in its own right (see below).

4. »Effet Tourbillionnaire Optique« Light Propagation on a Merry-Go-Round *Sagnac*'s Experiment in a Nutshell

The family of interferometer experiments, all dealing with light propagation, is a large one. Well-known historic members of this large family are the experiments by Michelson-Morley ([12] MM; static setup in different orientations) and Michelson-Gale ([13] MG;.using Earth as turntable – natural rotation, symbol **Ω**). More recently, Hector Múnera et al [14] reported beautiful results obtained on an interferometer fixed on the terrestrial turntable. The practically static MM and the slow dynamics of MG and Múnera must be seen in a context with *Sagnac* who, on his local turntable (technical rotation, symbol **ω**), provided the fastest dynamics in the above family.

For each sense of rotation (»rotation dextrorsum et sinistrorsum«), *Sagnac* [6, 9, 10] arrives at the dimensionless fringe shift

$$\Delta = \frac{4\mathbf{A}\boldsymbol{\omega}}{\lambda c} \qquad (1)$$

with angular frequency vector **ω**, wavelength λ, and area **A** enclosed by the light beams. **ω** and **A** are vectors because their mutual orientation influences the result. *Sagnac*'s geometry is particularly simple and $\mathbf{A}\boldsymbol{\omega} = A\omega$. *A. Michelson* [5] had the same formula in 1904 for natural rotation **Ω**. Here, the position of **A** on Earth's surface comes into play and only $\Omega\sin\Phi$ is effective with Φ the geographical latitude; the expected effect is maximum at the poles ($\Phi = 90°$) and zero at the equator ($\Phi = 0°$). (In 1904, Michelson [5] even considered applying the principle of the proposed experiment to the revolution of Earth about the Sun, but found it "less promising".) As **Ω** is much smaller than **ω**, the area must be correspondingly larger than *Sagnac*'s (0.0866 m²). In their famous 1925 experiment *A. Michelson* and *Henry Gale* [13] used $A \approx 2\cdot10^5$ m² [2010 feet by 1113 feet] and a parallel loop (small enough to ignore its area) for comparing of the influence of A.

The authors were polite (or cautious?) enough to concede that the "calculated value of the displacement on the assumption of a stationary aether as well as in accordance with relativity is"

$$\Delta = \frac{4\mathbf{A}\Omega\sin\Phi}{\lambda c} \qquad (2)$$

5. Sagnac and Relativity

Relativists claim that SRT can produce the non-zero result of *Sagnac*'s experiment like they claim to produce the zero result of MM. Of course they can because mathematics allows them to do so. Maybe this is the reason why even the great *Michelson* was polite or cautious regarding relativity? *Von Laue* arrives at the result of *Michelson*'s 1904 proposition to probe Earth's rotation by interferometry comparing different theories, among them what he calls “Absoluttheorie” à la *Lorentz* and, of course, relativity [8] *Von Laue* is not bothered applying relativity and claims that *Michelson*'s proposition does not allow a distinction between relativity and *Lorentz*' theory. Relativists should be careful. One must clearly be aware that a "correct" result is *only necessary* but by far *not sufficient* to prove a theory right. Usually, it does *not* suffice. SRT may reproduce the experimental results of both experiments, MM and MG - that is not hard to do if one leaves physics to mathematics, changing assumptions accordingly if needed. *Evert Post also* considers the treatment of the *Sagnac* effect under the viewpoint of transformations [2]. Left alone without physical analysis, math is blind in physics and forgives false assumptions all too easily.

The main problem with relativity boils down to the question of reference for the velocity of light, **c**.

Lacking precision, "relativity" gives rise to confusion. Local relativity (applicable e.g. to sound or the dynamics underlying the concept of temperature) must not be confused with global relativity. Event relativity (as e.g. effective for induction) must not be confused with observer relativity. The latter, domain of SRT, does physics no service, neither do the transformations invented for its justification. All that is (or should be) pretty trivial. "Everything is relative" (a sentence often ridiculed, even by relativists) is indeed consistent if it expresses the existence of a global unique system, the stage for all physical events. Uniqueness is the remarkable merit of *Sagnac*'s work (see below).

It should be carved in stone: *A numerically correct result does not prove a theory right*! If a theory fails just once in consistency (as SRT clearly does in more than one way) it must be discarded. The naive observer-related view of SRT doesn't work as a physical principle. It seems that the human mind likes illusions and sticks to them (one of the reasons to consider psychology, see below). There is no place for a multitude of "inertial systems" in physics. Inertia is a strict consequence of energy conservation and dynamics. As such it has nothing to do with kinematics. Kinematics and its transformations are sometimes helpful when it comes to unravel the observers' impression of the effect from the effect itself, but they become fatal when they provoke to change assumptions and mix up dynamics and kinematics. The physical effect (event) belongs to dynamics. Kinematics is no more than its shadow.

Experimental conditions may change, but our assumptions must not; we are dealing with one and the same phenomenon, the propagation of light in its very reference system. We have to stick to a *consistent* model of the propagation of light for *any* kind of motion of the source, accelerated or the (approximate) case of uniform rectilinear motion (URM). That we can't tell URM under certain (academic) conditions like a closed elevator (one of *Einstein*'s favorites) does not mean a thing. Without critical analysis, the observers' impression is meaningless.

Sagnac does not care for relativity and its fame. He is aware of the importance of his experiment also for the identification of the one consistent reference system for light.

In his review of the »effet tourbillionnaire optique« [9] *Sagnac* again refers to his 1910 analysis which preceded his experiment. He explicitly defines an absolute reference for the propagation of light at constant velocity **c** (»quand le plateau tourne, *nous supposons que les ondes lumineuses se propagent dans l'éther avec la vitesse inalterée* V_0« - his italics; his V_0 is our c).

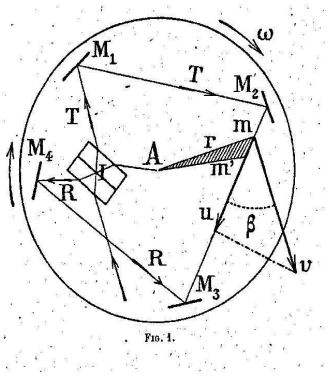

Fig. 3 *Sagnac*'s sketch to derive Eq. (1) (from his 1914 review [9] where he applies the concept of circulation to his view of the aether).

6. Uniqueness is it! The Relative and the Absolute

"Absolute" may trouble some people because they take it as the opposite of "relative" where they feel better at home. Relative has become the symbol for a democracy of references. But “relative“ is one more item out of the bag of religious and therefore easily dogmatized concepts. Nature isn't democratic. She sticks to her own iron hierarchy. Relativity fakes solid ground where there is none. The absolute (literally translated from Latin it means disseparated) may make us feel uneasy as its meaning is not as readily grasped as its alleged opposite, relative. It would be more helpful if "absolute" were replaced by (or at least understood in the sense of) "unique", a term that reminds us of the name rightfully given to the whole system: Uni-verse. Nature's one and only one true blue inertial system. With o*ne inertial system*, science faces more than enough problems . As is (or should be) clear since *Newton*, rotation is unique (that makes *Sagnac*'s such a beauty of an experiment!). Any kind of motion is unique. The global principle of energy conservation demands that any object has only *one* unique velocity $\mathbf{v}_{abs}$ (that makes MM such a beauty of an experiment). As far as we can follow up the hierarchy, the absolute velocity of a locally fixed object consists of three parts; eigen rotation of Earth ($\mathbf{v}_{rot}$), orbit of Earth around Sun ($\mathbf{v}_{orbit}$) and cosmic velocity of Solar System ($\mathbf{v}_{cosmic}$). Ironically, the usual discussion had focused on $\mathbf{v}_{orbit}$ - the part that matters least for the problem in question! In *Sagnac*'s experiment, we have the additional contribution $\mathbf{v} = [\boldsymbol{\omega}\times\mathbf{r}]$ due to technical rotation.

Interferometers on a natural or technical merry-go-round have shown non-zero fringe shifts in proportion to the rotation vectors, $\boldsymbol{\Omega}$ or $\boldsymbol{\omega}$, respectively, according to experimental conditions. The effect due to natural rotation demonstrates that the setup may rotate as well about an axis outside the area enclosed by the light path. *Sagnac*'s technical rotation has great advantages: The axis of rotation is perpendicular to the plane of the setup; two senses of rotation and a range of $\boldsymbol{\omega}$ between zero and some maximum (which was 2 turns/second = 4π/s in *Sagnac*'s experiment) can be chosen.

. *Michelson-Gale* type experiments are low-frequency versions of *Sagnac*'s with a narrow range of accessible frequencies according to and depending on the position on Earth's surface. The unanimous outcome is of no surprise: Rotation is accepted as absolute. But this is no reason to single out URM when analyzing experiments on light propagation. because all motion is individual and unique in Nature's one-and-only inertial system.

With the fatal effort to skeletonize Nature's tremendously complex scenario we fool ourselves to believe: "We can't tell which of the objects in a two-object world (!) is moving". Gedanken experiments reduce Nature to a ridiculously simplified scenario, jump at a false conjecture, and then generalize it to a natural law. The contrary is true - if we respect the scenario as what it is, we always can tell what is moving. We cannot tell why it is moving as we cannot possibly know all of the dynamic history of the event. For practical reasons, it is legitimate (and necessary, too) to single out the tiny part accessible and of interest to us on Nature's stage - keeping in mind that we did single it out, neglecting everything else. This is the justification for inventing kinematics and the relativity of velocities. However, the consistent definition of relative velocities necessitates a unique global reference: The relative velocity between any two objects is the *vector difference* between their respective absolute velocities. Note: This relative velocity does *not* have physical relevance (unless in a dynamic context, that is, some physical interaction like radiation or collision). An object may appear to have as many different velocities as there are other objects around chosen as references, but the global principle of energy conservation dictates a unique absolute velocity. This argument is independent of our knowledge of the whole hierarchy of motion. We may content ourselves with the above vector parts of $\mathbf{v}_{abs}$.

Bradley aberration, *MM*, *Michelson-Gale*, *Fizeau*, *Hoek*, *Sagnac*, and many more - experiments on the propagation of light demand the unique reference as the one consistent way to *account* for the experimental results (we refrain from "understanding" or "explaining" for good reasons). Now we are in a position to answer the question:

Where is relative motion in *Sagnac*'s experiment? All parts on the circle of rotation have the same speed and their distances remain unchanged. But their *velocity vectors* change continuously, so there *is* relative motion. (Here, we have to correct a remark in [18], p. 13). On the other hand, to a very good approximation, there is zero relative velocity between the parts of the MM setup during a (quasi-static) turn. On the other hand, a setup fixed to rotating Earth will show fringe shifts if conditions (duration of experiment, position on Earth's surface etc) allow.

It is a pity that we still have to discuss the mistakes of SRT and (worse yet) its followers. It is a calamity that math is blind to physics and leads to fatal consequences like believing in transformations and "inertial frames" (the mistake is in the plural). There are good reasons why we are always picking on poor old SRT. One of them is: Any physically relevant motion, including URM, is unique - whether we like it or not, whether it may be detectable experimentally or not.

7. S.A.G.N.A.C. - a Little Game for Exercise

There are good reasons to revive the memory of *Georges Marc Marie Sagnac* as an important scientist of the late 19th and early 20th century and his outstanding contributions to physics not only in his day. Especially since the advent of the ring laser (see below), he certainly made it into the charts with his rightfully celebrated experiment. But there is much more to be told about him, and we will not wait till October 14, 2019 - we will continue to do it now!

Here's a little playful exercise for you to bring our Award namesake to your own attention.

S.A.G.N.A.C. may serve as an acronym for notable sentences focusing on the symbolic message behind the work of *Sagnac*.

An example?

Science **A**dvances **G**iving **N**ature **A**ll **C**redit

What is the reason for this game? First, it's fun - but it's not as innocent as it may look, because, second, it sharpens our usage of language as well as our view and our fantasy to keep asking questions:

"What could be wrong with the mainstream interpretation of...?"
"How can we do better finding more consistency in our reasoning?"
There is more to science than just intellectual work. This brings us to...

8. Psychology in Science

Psychology in Science? Why - of course! This is a larger chapter than we might be willing to accept. And it's gaining importance. A good deal of science (particularly physics within the field of natural sciences) is governed by the subconscious performance of the human brain.

There's a lot of psychology in science. We can't get rid of it, but we can (and must) keep an eye on it.

We must not believe somebody just because they are considered "authorities". Science requires more than a few selected minds. There can be no "authorities" that stand all by themselves.

As the renowned philosopher-scientist *Karl Raimund Popper* put it: "Die Wissenschaft und insbesondere der wissenschaftliche Fortschritt ist nicht das Ergebnis isolierter Leistungen, sondern der *freien Konkurrenz des Denkens*." (Science and especially its advancement is not the result of isolated achievements but of the *free competition of thinking*.)

Relativists are eager to justify "their" theory whenever they believe to have a good reason. But they should feel uneasy when they see they can't get around the effect and yet try to discuss *Sagnac* in their terms. Changing scenario ("inertial" vs "non-inertial" systems) when they get into trouble does not help. URM, the proper self-chosen playground of SRT, should not be artificially be separated from the general concept of motion. In the language of potentials, motion is a matter of the local dynamic condition. The case of force-free motion occurs in a constant potential which should not be disregarded by arbitrarily setting the potential equal to zero. Nature provides all kinds of potential gradients from zero to very steep which makes the description of various forces so difficult.

8.1 The Zoo of Aether Models

Sagnac, like many of his time, was an "aether man" (spelling intentionally antiquated). He finds himself in a prominent league including *Hendrik Antoon Lorentz*, *Albert Abraham Michelson*, *Ernst Mach*, (the one with the Principle relating the subway jerking and the distant fix stars), *Oliver Lodge*,...and even *Einstein* in his post-relativity years (see his famous 1920 address at Leiden University [15]).

Aether has become the multifarious expression for something we actually don't know and yet try to explore asking the practically undying question "what fills space?". (We remember vivid arguments at former NPA conferences, don't we?)

The ongoing discussions reflect themselves in the multitude of models.

Both the aether and its strict denial have a religious touch.

It is quite frivolous to maintain the aether *is* solid, liquid, a plasma, a field, dark matter, a particle ocean à la *Dirac*, neutrinos, etc. (Particles experience a renaissance - remember the recent CERN sensation about *Higgs*' "God Particle"?) The zoo of aether models is full of strange animals. Everybody to their own pet. Pet ideas are fine. They make us happy. I know what I'm talking about - I adopted my pet from the late *Paul Wesley* who came up with the idea, but felt uncomfortable with it: The c^2 background potential due to all the masses distributed in an infinite universe [18]. That c^2 occurs in quite a few places in physics, including the absolute gamma factor $\gamma = (1 - (v/c)^2)^{-1/2}$ of neomechanics (a term coined for high-velocity dynamics and for distinction from relativistic mechanics [18]). I admit I like my pet because it de-mystifies the notorious $E = mc^2$.

I'm aware it's a pet that should not be allowed to become a pest. It would become a pest if I made propaganda telling everybody that it "explains everything" – something no model in physics ever can do. Fancy names do not bring us any closer to an "explanation". We might as well call the community of our aether pets a Latin "ubiquitum". Our ubiquitum has one important point in its favor – the uniqueness of the reference.

On the other hand, aether deniers are no better off. Totally empty space is a dogma that does not add much insight, either, and contradicts established findings like the 2.7 K background radiation from deep space and the fact that "radiation" continuously tells us about distant regions of our one-and-only Universe, but we were educated to buy emptiness for the sake of SRT in introductory lessons on physics.

8.2 Pets and Pests (aka Dogmas)

Pet ideas are quite natural and should be accepted as such. But: If a pet idea is adopted by many who never rose a pet by themselves, it easily turns into a dogma. A dogma claims to offer understanding and truth where there is none. And, worse yet, it is immune against criticism. A dogma is a huge pet (too big to fail?) that has turned into a pest. There are a lot of huge pet ideas running wild through physics.

It is dangerous to make ourselves believe that our very own pet is the one on the right track and stays there. If it runs into trouble, we should let go of it. Up to now, it seems, that pets in science prefer to run loose, although their owners try to keep a firm grip on the other end of the leash. And there are pretty large pets at large – leaders of whole communities who blindly adopted them.

Worshiped dogmas must have no place in science.

How can you tell a dogma? Easy: From the perpetuated propaganda to make it immune against objections or criticism. Popular presentations of the wonders of modern physics don't tire to praise questionable cult theories and their creators and the poor innocent public is left at the mercy of that praise.

This may sound like defeatism. But it is not intended to. In science it's always a good idea to be one's own worst enemy (remember *Planck* who was reluctant to accept the idea of quantization suggested by his radiation formula).

8.3 The Psychology of Success in Science "Correct" and (Hopefully) Correct Results

Everybody has the right to feel satisfaction when their analysis of an experiment (or pet idea for that matter) finally arrives at a result complying with the experiment. Math usually allows to do that, and may do so even for competing or contradicting models. This is one of the reasons why SRT managed to survive. For fun, let's demonstrate the benevolent assistance of math with yet another way to arrive at *Sagnac*'s result Eq. (1).

Interferometry means interference patterns. Changing interference patterns due to phase shifts may be used to tell about light propagation under respective changing conditions. Phase shifts arise from wavelength shifts. And where do we get wavelength shifts from? This brings us to the...

8.4 Doppler Effect

This is a long and strange chapter of physics – and a brilliant lesson about psychology in physics. The *Doppler* effect is gratefully welcomed wherever it can be exploited to serve a dogma in mainstream physics ("Big Bang", SRT). On the other hand, its physical meaning is often buried under false reasoning.

Textbooks start discussing the three different scenarios of the *Doppler* effect (source or observer or both moving) in terms of a change in frequency registered by an observer, thus putting the cases $\mathbf{v}_s$ nonzero and $\mathbf{v}_o$ nonzero on an equal footing. There is no symmetry in the effect, although deniers (including relativists) of an absolute reference like to sweep it under the carpet. They tend to neglect second order terms $(v/c)^2$ and tie the effect to the relative velocity between source and observer which is highly misleading. (Beware of neglects, however small, of all kinds! They are always dangerous in physics - an important lesson to be kept in mind.) The only consistent treatment of the *Doppler* effect is *uniqueness* for sound and light alike. That rules out the source à la *Ritz* and the observer à la *Einstein* as a viable reference for light. The problem with the reference for light is obvious in the aether hassle. But hold - the analogous problem exists with sound, say, in air, too. What reference is "air"? Certainly none of the atoms/molecules swirling around. Their presence is the necessary condition for "air" as reference. The basic formula for the speed of sound, $(\text{compression modulus/density})^{1/2}$, already known to *Newton*, contains two collective (or ensemble) parameters. That still does not tell us much about the nature of the reference. "Air" as a reference is due to the presence of matter but it is not matter. Reference systems need not consist of matter; just think of the center of mass of a ring-shaped object. Light propagates "everywhere" as far as our experience goes which suggests to accept this *ubiquitum* as unique reference system. There is a lot of matter present in that *ubiquitum* which contributes to its properties. We might as well stick to the time-honored distribution of gravity in space for the time being and think of absolute space as the unique stage on which we place the *Doppler* effect for light.

It is generally overlooked that "observer in motion" is the *kinematic* part of *Doppler*'s scenario whereas "source in motion" is the *dynamic* part which matters in physics. The two frequency changes are due to fundamentally different reasons. A moving observer's primary impression is an *apparent* change of **c** (sound or light alike):

$$c' = c\left(1 - \frac{\mathbf{v}_o \mathbf{c}}{c^2}\right) \qquad (3)$$

The source in absolute motion (necessary condition!) produces a *real* change of λ

$$\lambda' = \lambda\left(1 - \frac{\mathbf{v}_s \mathbf{c}}{c^2}\right) \qquad (4)$$

In forward direction, light cannot „outrun" the source at **c**, so its wavelength is squeezed in front and the backward beam experiences the contrary (here, **c** becomes **-c**). Yes, light waves *are contracted* (*and dilated*)! Why relativists prefer to sacrifice the stability of a solid(!) steel interferometer to their blind faith in an utterly rigid wave pattern of light(!) remains a mystery.

To repeat, the dynamic part of the *Doppler* effect must not be confused with the kinematic part. The co-moving observer (zero relative velocity) registers the original frequency of the source. But there is always the shift in wavelength whenever the source moves, $\mathbf{v}_s \neq 0$, Eq. (4). As the phase velocity $c = f\lambda$ remains constant in absolute space as clearly realized by *Sagnac*, a wave passing by with contracted (dilated) λ passes by with enhanced (reduced) frequency *f*. Generally, both observer and source are moving which results in a tricky mixture of dynamics and kinematics. Uniqueness helps us to tell them apart: N Observers at different velocities reporting N different frequencies means kinematics. Moving observers don't qualify as reference in physics!

Ironically, in 1887 the German physicist *Woldemar Voigt* [16] started the history of what became famous as *Lorentz* transformations with the *Doppler* effect, with a false assumption (constancy of the speed of light with respect to the observer) and with a fatally wrong treatment (transformation of "space and time" instead of wave parameters). The rest is silence (or should be).

Careful use of the *Doppler* effect, however, may lead to unexpected insight. The late *Paul Wesley* [17; 18] has analyzed the MM experiment in terms of a *Doppler* effect in absolute space and shown that the MM null result is due to isotropy. (Some people may be tempted to say "With zero relative velocity between the various parts of the setup, there is no Doppler effect". Again: The occurrence of the effect should be distinguished from its visibility under specific conditions as those of the MM experiment!) The total number of *Doppler*-shifted wavelengths out-and-back is proportional to $1 - (v_s/c)^2$ and hence the phase does not change with the orientation of the interferometer. *Wesley*'s isotropy factor $1 - (v_s/c)^2$ is constant under the conditions of the MM experiment (no fringe shift upon changing orientation). However, when the component of the absolute velocity in the plane of the experiment is allowed to change, so does the interference pattern. The latter is the case for natural (terrestrial) rotation. Changes are due to the fastest changing vector part of the absolute velocity. The lion's share of changing direction is Earth's rotation, not its orbiting around the Sun. In retrospect we may wonder why *Michelson* et al focused their interest on the orbital velocity at the time of their 1887 experiment. No wonder "partial fringe shifts" (i.e. smaller than erroneously expected for the orbital velocity of Earth) have later been observed (and puzzled the early researchers)! In retrospect, this looks encouragingly consistent.

8.5 *Sagnac*'s Result in Few Easy Steps

We are now encouraged to take the various kinds of motion aboard (rectilinear and rotating) and propose to interpret *all* experiments on light propagation in absolute space in terms of the *Doppler* effect. As mentioned above, there *is* relative motion between the parts of a rotating set-up, so we should expect to notice a fringe shift. Modeling *Sagnac*'s experiment as circular motion of a light source emitting light either way (clockwise and counterclockwise), we calculate the number of *Doppler* shifted wavelengths along one turn both ways, keeping in mind that a *shift of phase* is due to the quickly changing rotational velocity part only (we need not bother here about the remaining constant lion's share of the absolute velocity) and we symbolize it by **v**.

Technical circular rotation is particularly simple: The radius **r** and the angular frequency **ω** are constant and the velocity **v** = [**ω**×**r**] of the source is equal to the scalar v = ωr because **v, r** and **ω** are mutually perpendicular and **v** is parallel to **c** which gives **vc**/c² = v/c.

We are left with calculating the total length of the phase shifts along a closed loop of length 2πr using the *Doppler* shift from Eq. (4) and divide by λ to arrive at the dimensionless phase shift

$$\Delta = \frac{(\lambda' - \lambda)}{\lambda}\frac{2\pi r}{\lambda} = \frac{-2\omega \mathrm{A}}{\mathrm{c}\lambda} \qquad (5)$$

for the forward ("clockwise") wavelength and, changing the sign of v, we get its negative for the backward ("counterclockwise") wavelength where $A = \pi r^2$ is the area bounded by the light paths (circular geometry!). The interference pattern results from the difference between the two *Doppler* effects. In total, the interference pattern experiences the phase shift

$$\Delta = \frac{4\mathbf{A}\boldsymbol{\omega}}{\lambda c} \qquad (1)$$

Voilà the desired result! The mathematics here is even simpler than the treatment of the MM null result.

For the counter rotation (now **-ω** replaces **ω** and the *Doppler* shifts are opposite) we get another shift, same magnitude, opposite sign which doubles the effect when comparing the shifts due to each sense of rotation.

Should we be happy now? Have we understood why **ω** and **A** enter the result and why it is first order in (v/c) and independent of the shape of A and of the position of the axis of rotation? Hint: No. What do you think? Hint in addition: Don't worry about the *Doppler* shift on λ; it does occur whenever the source moves as a consequence of absolute motion. We might confidently state that all sources move in the unique reference system, Nature's one-and-only inertial system. Whether the *Doppler* shift may be noticed/recorded by observer/receiver depends on the specific conditions and is quite a different story. Our math here is backed up by something more solid than a kinematic approach with transformations and all that.

Success is a nice reward in science, but premature happiness should not take away our caution. No formula and none of its derivations can give us the security of a full understanding. At least here we found a route to *Sagnac*'s result that, agreeing with his own definition of a unique reference, clearly points away from SRT as does *Wesley*'s analysis of the MM null result

9. Sagnac's Renowned Heritage The Laser Ring

1913 marks the beginning of a new branch of applied physics that may be traced back to propositions by *Lodge* and *Michelson* and *Sagnac* is rightfully recognized for turning a page in physics. *Sagnac* proposed the first application of his effect – as detectors of curvilinear motion mounted on a ship [9].

The development of modern laser ring devices has revived *Sagnac*'s reputation and he is rightfully considered the pioneer of the merry-go-round for light. But this is only part of his significance. His equally important message is about the only consistent reference for the propagation of light. *Sagnac*'s fervent rejection of SRT is tacitly ignored by the official physicists' community. And they stick to the untenable dogma of "inertial systems". The analysis of *any* experiment on light propagation, however, must not depend on artificial separation into different classes of motion. Instead, it should be based on the same principle.

For fun, let us apply our above *Doppler* approach to the performance of a laser ring which is based on a beat frequency Δ*f* between the forward and backward partial beams.

The *Doppler* shift of wavelength (Eq. 4) due to $v_s = \Omega r$ (terrestrial rotation) results in a complementary shift of frequency ($c = f\lambda$ = constant):

$$f' = \frac{f}{(1 - \frac{\mathrm{v_s}}{c})} \qquad (6)$$

for the contracted λ ahead and with a + sign in the denominator for -c and the dilated λ behind.

The difference between both is the beat frequency observed in the laser ring:

$$\Delta f = f[\frac{1}{(1 - \frac{\mathrm{v_s}}{c})} - \frac{1}{(1 + \frac{\mathrm{v_s}}{c})}] \approx \frac{2 f \mathrm{v_s}}{c} = \frac{2 f \Omega r}{c} \qquad (7)$$

with the usual approximation $v_s/c \ll 1$ which safely applies here.

It is customary to express the beat frequency in terms of the resonator length L and the area A enclosed. Accepting that the effect is independent of the shape of A, we may pass over to circular circumference L = 2πr and area, enlarging Eq. (7) by 2πr/ 2πr. As the ring laser probes the terrestrial rotation vector **Ω** not necessarily parallel to **A**, the general equation contains the scalar product **AΩ** and we arrive at

$$\Delta f = \frac{4\, f\mathbf{A\Omega}}{cL} \qquad (8)$$

Voilà again! Eq. (8) is the ring laser (aka *Sagnac*'s) equation with Δf the *Sagnac frequency.* Our derivation is the natural consequence of what we did before using the *Doppler* effect in absolute space. And what a simple procedure!
We stayed on the boat of the *Doppler* type analysis applied to the uniform rectilinear motion of MM and did not have to change our assumptions when passing over to rotation. No separate treatment of uniform rectilinear and circular motion. No discussing "inertial" and "non-inertial" systems. No transformations.

The performance of laser rings is impressive. They provide practically continuous monitoring of earth's rotation and approach the sensitivity of Very Long Baseline Interferometry (VLBI). Fig. 4 shows the daily variation of Earth's rotation probed by a ring laser (red) as compared with the theoretical expectation (black). One horizontal scale is 5 days and the vertical scale unit is in µHz. The 14day periodic beat with amplitudes between ± 40µHz is caused by the moon.

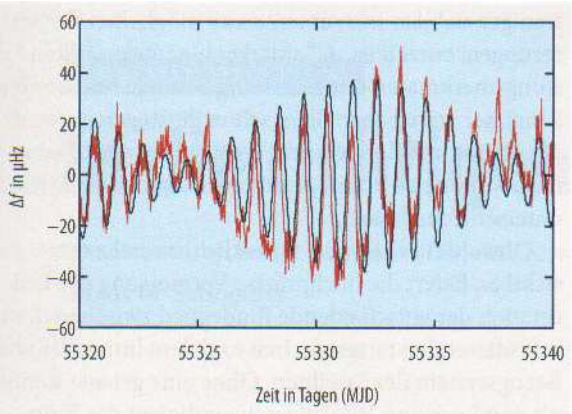

Fig. 4: One of the fruits of *Sagnac*'s contribution to the frontiers of present precision measurement (from [19])

High precision devices will develop further. Maybe someone will take up *Wesley*'s proposition of a one-way *Sagnac* interferometer [18] to make them simpler, too. Maybe the orbital frequency of Earth around Sun and its changes will some day prove more promising for experimental detection than in *Michelson*'s day. *Sagnac*'s heritage promises further rich harvest.

10. The Award - Its Design and Significance

This is *Sagnac*'s special heritage.
Three intertwining rings are to symbolize the three-ring model of the electron.
We may find yet another symbol behind the design:
Three essential ingredients that should be natural to all scientific efforts; modesty, courage, and honesty as an ever-present message from psychology.

11. It must be so because I want it to be so! Beware of the Subconscious!

The (psychologically quite understandable) anthropocentric view has given the observer too important a status and is misleading in natural science. You will recognize this mistake in the big cult theories (SRT, Big Bang, Uncertainty, Probability Waves, etc). And sometimes our expectations hold a firm grip on our thinking. The MM experiment is a brilliant example: Nature did not give the answer they *wanted* to have – yet She *did* give a very clear answer. Was it not seen as such because it was too secret in all its simplicity or because it did not meet the expectations? There are basically two kinds of errors at work in science. The *Kaplan*s [20] summarize the dangers when the unconscious is at large: "Beyond knowledge-based mistakes lies a forest of error yet more dark and formidable, because it lies closer to the unexamined mind, where desire breeds monsters out of logic: the realm of motivated reasoning."
It's advisable we focused our attention on the doings of the ever-present unconscious and include that in our criticism.

Encouragements

We should not be bothered if our criticism buys us a ticket as "cranks" (or worse). Sooner or (probably) later it will buy physics a ticket for fresh thought.
Fresh thought means:
Don't let a dogma stop you - keep on thinking!
Science, after all, is a process of continuous learning.

If you wish to venture into French: Sagnac's meticulous original description of his work is worthwhile to read, even without a deep knowledge of French.
And you may wish to look up the article [3] by *Michel Quintin* of the Université Paris 6. Here is where I finally found Sagnac's photo Fig.1

If you wish to venture into psychology, I highly recommend the brilliant book "Bozo Sapiens" by *Michael* and *Ellen Kaplan* [20], a mother and son author team, who excellently combine the pleasures of humor and intelligence, of laughing and learning.
A feast!

Congratulations to all winners of the *Sagnac Award*, past, present and future, and to its creators.

Acknowledgement

I am deeply grateful to *Dorothea Hochscheid*, librarian at the Cologne universitary physics institutes, for kindly providing me with valuable historical literature.

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The final letter "ß" in Harreß' name is the old German letter for "ss". It is still in use when it follows a long vowel. What a language!

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"Recapitulating, we may say that according to the general theory of relativity space is endowed with physical qualities; in this sense, therefore, there exists an ether."
(It's on internet)

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In his 1991 Book "Selected Topics in Advanced Fundamental Physics", § 2.7 "*Sagnac* Experiment Reveals Absolute Space" *Wesley* mentions in passing: "The same result [optical path difference] may be obtained as a superposition of two Doppler effects; one for the observer moving away from the source and the other for the observer moving toward the source". *Paul* never explored this idea further until he came back(?) to it in about 2005 and applied it to the MM experiment. Which goes to show how long a mental process may stay in the subconscious awaiting its rebirth. Here we complete the process.

Concerning the c^2 potential: I had a hard time talking *Paul* into including this as a separate chapter on c^2 in his book [18]. The late *Bob Heaston* was kind enough to share the c^2 pet with me. I gratefully remember our enjoyable collaboration which is documented in the *Proceedings of the 13th Annual Conference of the NPA* at the University of Tulsa.

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