How relativity starts with a simple umbrella

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In the basement of the eastern dome of the former Astrophysical Observatory on the *Telegrafenberg* in Potsdam, Michelson intended to measure the ether wind in 1881. In this short and snappy form it may be read anywhere. But why an ether wind, and **why on earth should it be found in a basement?**

The story of the Michelson experiment commences with an observation which we all make, but never mind. Who stands in the rain keeps the umbrella upright not to get wet. He starts to go by foot when the bus is late. In this case he has to incline the umbrella forward. The direction from which the rain hits us is inclined into the direction of motion. — This effect is known for the light of starts, too: When the earth moves on its orbit towards the constellation of Aquarius (beginning June), the stars seem to shift there (only a tiny amount, one in ten thousands of the arc of the circle). When it moves towards the constellation Leo (beginning December), the stars seem to shift there. This effect is called **aberration of starlight**. It was found by J.Bradley in 1725. It demonstrated the motion of the earth with the period of a year.

However, the light is not an emanation of particles, as Newton assumed, but a wave (metaphorically ”ether wave”), as it is required to explain the phenomena of interference. But waves do not show any effect of aberration, and cannot explain this observation.

> *Observing incoming waves on the shore, one sees that the angle of wave fronts with the shore does not depend on our moving or resting on the shore.*

The question arises, how the observed aberration is generated. The pretext, which is found in many books more or less explicitly and which goes back to Th.Young and A.Fresnel, refers to the action of a telescope: The aperture cuts from the wave a short piece like a crest which moves through the tube like a drop of rain, and the aberration is obtained. This can happen only if the propagation of the waves is not hampered by the structure of the telescope, in particular the material of the tube itself.

> *Remind again the shore. We may catch a crest which rides a wave through a fyke. The direction of the motion of the crest is observed to be orthogonal to the wave fronts. When we run along the shore, we have to lead the fyke forward in order that the crest may pass it undisturbed. Thus, the direction of the motion of the crest shows the aberration, but is no more perpendicular to the wave front. In order that the creast is unhampered, the fyke should not stir the water: it must be ideally subtle.*

Walls ought not hamper or stop the ether of the ether waves. Fresnel's contemporaries accepted this supposition only with reluctance, but the observed aberration and the many demonstrations of calculated interference patterns left no other choice at this time.

When the light propagates in the ether with a certain speed, and when the detector moves with respect tothe ether, its velocity should be added to the speed of light. The light from the direction into which the earth moves should be faster by the velocity of the earth, the light from the opposite correspondingly slower. And all this without any respect for the walls around the detector.

> *At least the police patrol on the highway calculates this way when it measures oncoming or overtaking cars.*

In 1881, Michelson could start to test this composition of the speed of light with the velocity of the earth. He used his invention of the interferometer. As can be seen here, the interferometer consists of a arrangement of mirrors which admits to observe two images of the same source of light through the ocular simultaneously, more precisely, the interference pattern that is produced by any tiny distance between these images. The observation of these pattern admits to measure changes of distance in the nanometer region. This technology won the Nobel price in 1907. It is still one of the most precise measurement technologies in physics. Inter alia, interferometer with arm lengths of nearly a million kilometers are designed to find gravitational waves.

The compositon of the propagation speed **in** the ether with the motion of the earth **through** the ether should produce a correction of the distance of the two images of the source. This correction on its own could not be distinguished from other errors, but it depends on the orientation of the interferometer. When the latter is turned, the correction changes because one arm of the interferometer points along the direction of motion first, and after a quarter turn the other one. The distance of the mirror images must change. This change is only a part of the wavelength of the light, but Michelson could it observe when the scheme worked. To his disappointment, Michelson found no effect of the expected magnitude. He had to conclude that the ether is enclosed in the basement like the air (as everybody had expected before Fresnel demonstrated that his conjecture is necessary). That is, Fresnel's conjecture collapses, it cannot be true. **Exactly this** is proven by the result of the experiment. One often reads, Michelson had proven the universal constancy of the speed of light, but this is nonsense, of course.

The aberration of starlight is tiny and technologically insignificant, but herewith it becomes the stumbling block of just that celestial mechanics which was backed so much in the time of its discovery. Hendrik A. Lorentz (its name was given later to the transformation formulae between observers in relative motion) put the question of what it would mean when the wave fronts themselves would show aberration. He found that in the end this leads to a curious consequence: The question whether two distant events are simultaneous must be assessed **differently** by obervers in relative motion.

> *When one stands still on the shore and seees the waves rolling on perpendicular to the shore, an observer moving along the shore sees aberrated waves as inclined to the shore. The first one observes that the wave fronts reach the shore simultaneously on the right as on the left. The moving one sees them reaching the shore in front earlier than behind.*

This is the **relativity of simultaneity**. It is the crucial notion to understand all the curious consequences in the geometry of space and time, which we call time dilation, length contraction, twin paradox, and so on. In everyday life, we have never a problem with simultaneity. Therefore, Lorentz distrusted the concept. On the contrary, one was ready to abandon the ether and **together with it** Galileo's principle of relativity. This principle supposed that velocities can be observed **exclusively** in relation to other material objects (for light with respect to some ether). Because of the many problems in the mechanically understood electrodynamics, one expected Galileo's principle to hold only in mechanics, and not in combination with electromagnetic phenomena.

It was Einstein's flash of genius which disentangled and solved all these problems. In his first article about the problem he subrogated Galileo's principle and changed only the rule of the composition of velocities. The new rule — assumed as axiom — requires that the speed of light is composed with other velocities in such a way that its norm (modulus) remains unchanged. (This is called the constancy of the speed of light, although it has **nothing** to do with any constancy in space and time.) Einstein's axiom was not so much the indirect result of the Michelson experiment, but the more the result of the concept of Gauss to define electromagnetic units by mechanical means.

> *This concept inspired R.Kohlrausch and W.Weber (1856) to an experiment, in which the speed of light was found as a quantity **without** direction, i.e. which by no means could be composed with directed velocities. The **norm** of the velocity of light is a constant in the conversion of electric and magnetic units.*

Independent of whether Einstein knew about the Michelson experiment in 1905 or not, the theory of relativity cannot be derived directly from the experiment. Only **after** the construction of the theory of relativity, the experiment could be seen as backing of the new rule of composition of velocities and as fundament of the theory. The experiment became important in 1907 when Michelson had won the Nobel price for the interferometer technology. Because the outlay of the experiment was so clear and simple, and because the explanation of its outcome by Einstein's axiom was so short, it paved the way for the theory to its general acceptance. Michelson himself was always reluctant to accept this rôle. He saw in his result only the rebuttal of Fresnel's conjecture of an ether which can freely pass through matter. For many years, he tried to find an ether wind atleast in free air, always in vain.

Today, the theory of relativity is backed far better than by the Michelson experiment, which observes only a small effect. It is backed in particular by the prediction of the existence of anti-particles and by the explanation of the electron spin. Both facts are independent of any comparison between detectors in relative motion.

June 1, 2012