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About the *Michelson* experiment with fixed star light. By *R. Tomaschek*.

Mr. Lenard made the proposal in No. 5107 of this magazine and later in a paper "About Ether and Uräther†" [1]) about implementing the *Michelson* interference experiment with fixed star light. In the following, [2]) the experimental execution and the results of these attempts will be reported.

Since preliminary tests had shown that a swiveling arrangement of the entire equipment, according to the kind original to *Michelson,* was for these purposes, mainly from lack of light, not favorable therefore a simpler arrangement was selected, which is only based on difference measurements in relation to terrestrial light. The negative result of the attempt with terrestrial light is thus presupposed [3]), and this attempt indicates only the difference in the behavior of the terrestrial and extraterrestrial light. The arrangement consists of three steady pillars, the central pillar which carries the dividing glass plates, and two mirror pillars. The two arms lie exactly east-west, and/or south-north. The turn of the apparatus is then replaced by the rotation of the earth, as the observations are to be employed at different times of day. The arm lengths amounted to 8.6 m. The whole arrangement was built up in the cellar of the East Institute of the Königstuhl Observatory, whose walls are formed at 1 m thick from sandstone and whose floor is about 1.5 m under the outside ground. The round silvered glass mirrors had a diameter of 45 mm; the division and compensation plates had a size of 10 x 5 x 1.5 cm and one was un-silvered for the attempts. The observations of the interference fringes took place by means of a telescope with thread micrometer, whereby a whole drum revolution corresponded approximately to a fringe width. The starlight could enter by a small window into the observation area. A small glow lamp served as comparison light, whose rays were thrown by a glass plate arrangement into the path of rays of the starlight. The light of the comparison small lamp was always equalized by filters and switching on in opposition in color and strength to the light being examined. The interference fringes were from top to bottom continuously adjusted so that on both sides of the central fringe about 4-5 fringes could be seen. The initially very disturbing air currents could be decreased to a large extent by cladding of the optical path into long iron pipes. Besides the irregular variations as a result of the air currents the interference fringes still showed a steady walking of about 1/20 of a fringe width per minute which was caused by internal movements of the ground. [4])

For catching light for the trial, heliostats were used. A small Silbermann heliostat [5]) was used to study the sun and moon, but for fixed stars, in general, it was too faint. One was able to put up a useful arrangement by the obligingness of the company C. P. Goerz which made available a big heliostat, a big auxiliary mirror and an observation telescope for the investigation of fixed star light. The catching arrangement was set up directly in a pit outside of the building before the observation cellar. Because this heliostat is swiveling only around an axis which is parallel to the axis of the earth [6]), a second mirror had to be used to help throw the light of different stars in the steady direction for observation. This is swiveling and on rails which lie exactly in the extension of the north south arm of the interferometer, adjustable around an exactly vertical axis. The two mirrors have a diameter of 35 cm each. At first on the heliostat and from there falling onto the auxiliary mirror, the north running light continues through a telescope of 17 cm objective diameter and 3.5 cm ocular diameter. The parallel entering light leaves the telescope again parallel and enters then by a small cellar window to the observation mirror and interferometer. The optical path between heliostat and observation telescope was about 25 m.

For the first making of the measurements, the external light was closed off by a slide-gate and the position of first left dark central interference fringe was measured by adjusting the micrometer screw and reading based on the drum, then the situation was repeated for the first right central dark interference fringe. The slide-gate valve was opened and the comparison light was switched off, and now again the situation of measuring the first left and then the first right dark central interference fringe. Then the attempt light was blocked off again by the slide-gate, the comparative light was switched on, and again the first left and first right interference fringe was measured. By this kind of the reading, the elimination of the influence of constant walking of the fringes took place. About 20 such observations were always combined to an observation row and the average value was taken. A deviation due to extension of the optical path in the direction of the east west arm is always counted as positive in the following.

[1]) *Yearbook of Radioactivity and Electronics*, 1920; also separately with Hirzel, Leipzig, 2nd edition 1922.

[2]) The attempts were implemented during the years 1922 and 23 in the Radiological Institute of the University of Heidelberg and later, thanks to the kind accommodation of Mr. Professor *M. Wolf*, situated more favorably at the Königstuhl Observatory.

[3]) However in addition, e.g., see. *Physical Rev*., **19** p. 407, 1922, over perhaps partial positive loss of the attempt with terrestrial light on high mountains.

[4]) A detailed description of the test appears in the *Annalen der Physik*.

[5]) Siehe z. B. *Ambronn*, Handbuch der Astronom. Instrumentenkunde II, 648.

[6]) It is the same heliostat of the company Goerz which was used with the German solar eclipse expedition in Norway 1914, see *A. Miethe*, “The Dead Acres Solar Eclipse of 21 August 1914”, Vieweg, Braunschweig, 1916.

That color and luminous intensity of the comparison light also deviating, which were made as alike as possible by the way always for the attempt light do not pretend shift, showed own control attempts. The accuracy of the settings of the threads of the micrometer on the fringes amounted to about 1/2 to 1 of drum scale parts = about 0.02 fringe widths. A shift of approximately double that size was immediately recognizable; this was often used in particular with fixed-star observations, as the interference fringes of the fixed-star light by the threads was fixed and then rapidly the comparison light switched on and the fixed star light cut off. This method was for the direct observation of an effect very favorably, since the comparison needed only about 1-2 sec., one thus was very independent to a large extent of air flows, etc. A movement of about 0.04 fringe-widths would be to be discovered in this manner with certainty.

The results are the following:

Sunlight. For the observation the small heliostat, which needs only one reflection, was used. As for the mirror, a back blackened glass plate was used. Behind the window of the observation area, a filter was attached, consisting of a glass plate for weakening, on which was a dried coating of small soot particles.

1923	Zeit	Verschiebung Streifenbreiten
April 25	$9^h 25^m$ a	−0.000 ±0.007
24	10 35 a	+0.023 ±0.006
24	11 15 a	−0.010 ±0.007
5	11 35 a	−0.009 ±0.010
24	12 0	−0.007 ±0.007
4	12 10 p	+0.012 ±0.006
3	3 5 p	+0.014 ±0.010
3	4 0 p	−0.000 ±0.010
12	4 10 p	−0.000 ±0.003
3	4 35 p	−0.003 ±0.010

Moonlight. The arrangement was the same like with sunlight, but with a silver mirror in the heliostat and without a filter.

1923	Zeit	Verschiebung Streifenbreiten
März 26	$8^h 0^m$ p	+0.001 ±0.019*
April 26	8 35 p	+0.007 ±0.006
März 26	9 0 p	+0.054 ±0.014*
April 26	9 40 p	+0.018 ±0.011
24	10 5 p	+0.011 ±0.011
März 26	11 0 p	+0.021 ±0.013*
April 24	11 40 p	−0.007 ±0.013
März 26	12 0	−0.002 ±0.014*
April 4	3 0 a	+0.006 ±0.009
4	3 45 a	−0.002 ±0.009
4	5 0 a	+0.015 ±0.008

In the experiments with *, the air turbulence was not yet entirely satisfactorily off.

Jupiter. The big heliostat was used in the arrangement described above with auxiliary mirror and telescope. Numerous immediate comparisons at several nights of April at different nighttimes proved all a negative result. In addition, according to the other method was measured:

1923	Zeit	Verschiebung Streifenbreiten
Mai 2	$12^h 25^m$ a	+0.012 ±0.015

Sirius. With Sirius, since it was not appropriate at present the favorable weather for it was no more in the visual field of the large heliostat, only correspondence attempts were made, with unique reflection at the mirror of the small heliostat. Observations on the 21st of March around 9^h 30^m showed no discernible movement, just as little with about 50 comparative observations on the 4th of April from about 8^h 30^m to 9^h. There was no movement available which would have been greater than 0.04 of a fringe-width.

Arcturus. The large heliostat with auxiliary mirror and telescope was used. In the months April and May direct comparisons were made at different night hours, without a noticeable shift could ever be recognized. The detailed measurements showed:

1923	Zeit	Verschiebung Streifenbreiten
Mai 15	$12^h 25^m$ a	−0.025 ±0.012
15	2 20 a	−0.007 ±0.009

We want to compute the size of the effect which can be expected due to those concepts which led to the execution of this attempt. Afterwards, if necessary, the possibility exists that the light quanta of the extraterrestrial sources of light possess relative to the Uräther speed of light and in this run. The apparatus however possesses a relative velocity due to the earth movement to the Uräther, so that then an effect, completely the original *Michelson* consideration accordingly, would be to be expected. If an arm lies exactly in the direction of the movement, the other arm perpendicularly to it, then the effect is largest and the shift given by $N = l/\lambda \cdot v^2/c^2$, whereby l means the arm length, λ the average wavelength, v the relative velocity to the Uräther and c the speed of light.

The shift due to the turn of the earth around its axis, which would have to be continuously constant in the positive direction, is too small, in order to be able to be examined with our arrangement.

Probably this is however with the shift the case, which would have to enter due to the movement of the earth around the sun. The maximum shift would have to enter around noon or midnight and amount to about + 0.15 fringe widths. The change of this deviation with the time of day is given by the expression

$$N_1 = l/\lambda \cdot v^2/c^2 \cdot \left[1 - \sin^2 t\left(s + \sin^2 \varphi\right)\right]$$

where t is the hour angle (for $12^h = 0$) and φ the mean geographical latitude. The effect would therefore be for our arrangement = 0 around 3^h 40^m and 8^h 20^m after noon and/or after midnight. The maximum of the negative deviation around 6^h in the evening and/or only 0.58 + of the shift amounts to early around 12^h.

Also the movement of the whole solar system is to be taken into account. If we take as an apex of the movement R.A. = 270°, Dekl. = +30° and the speed = 20 kms / sec, so the maximum movement is in the +direction is about 5 and/or 19 hours after culmination of the apex in the amount of +0.045 fringe-widths, the maximum negative shift around 12 hours after culmination of the apex with -0.062 fringe widths. At present the culmination of the apex the shift amounts to only – 0.007 fringe widths. The change of the shift within one star day is given through

$$N_2 = l/\lambda \cdot v^2/c^2 \cdot \left[1 - \sin^2 t'\left(1+\sin^2\varphi\right)\cos^2\delta + \sin t' \cdot 1/2 \sin 2\varphi \cdot \sin 2\delta - \left(\cos^2\varphi + 1\right)\sin^2\delta\right]$$

where δ is the declination of the apex is designated and t' for the culmination of the apex = $1/2\pi$ is to be set.

If one connects the influence of the movement of the earth around the sun and their movement in the fixed star system, then the resulting fringe shift arises as a result of superposition of the two expressions whereby to be noted is that in N_2 for t' the value is to be used $t+\lambda$ where λ indicates the angle of the yearly movement of the earth (= 0 for 21st of March). The resultant curve shows that the divergences sway around 12^h between +0.19 and +0.08 fringe-widths and the most favorable observation time is possibly March.

About the movement of the Milky Way system compared with other such systems nothing is known for certain. If one takes some of the information of *Wirts* [1]), the fringe shifts would be in the magnitude of about 10 fringes-wide.

Therefore, if we refrain from the latter movement whose size is too uncertain, we are to expect movements from 0.1 to 0.2 fringe-widths for at convenient times of day according to the above. The attempts show that a shift in the order of magnitude which can be expected did not arise, but that the deviations amounted to at best about 1/8th of those which can be expected, which deviation is to be probably already assumed as within the margins of error of the observations.

The non-appearance of the effect leads thus in pursuit of the opinions of Mr. Lenard [2]) to the realization of the remarkable characteristic of the light quanta to lose a speed component lain in the direction of progressing with the entering Aether of other movement condition and to accept speed of light relative to this, shows during the aberration that the lateral component is preserved under the same circumstances.

In A.N. 5203, Mr. *Vogtherr* discussed different possibilities of this attempt. His assumption b (p. 392), transverse and longitudinal mass of the light quanta, coincides with the above computations at the based views of Mr. *Lenard*. For Mr. *Vogtherr's* assumption a (only transversal mass) mainly only the attempts come into question, which are implemented with only once reflected light, thus in the presence the observations with sunlight and moonlight and of these above all those, which around noon and/or around midnight with full moon are implemented. The attempts with Sirius which are likewise explained with an easy reflection probably give no other explanation, because Sirius stood at the moment of the observations already very much deeply in the horizon. The remaining fixed star attempts are done with double reflection (heliostat and auxiliary mirror) and offer for this view, hence, no easy relations. Nevertheless, it is unlikely that fixed star light would show another effect than sunlight with an easy reflection. After the latter acceptance of only transverse mass, after Mr. *Vogtherr's* expression, is to be expected around 12^h a shift, how she corresponds to the shift N_1 of our computation, however with the opposite sign, since the light would need the larger time in the north-south arm. The attempts show that also the movements appearing after this acceptance from possibly -0.15 fringe-widths have not appeared in bigger amount than about 1/10th. This loss of the attempt is however, like a closer view [3]) shows, in informal way derivable from the opinions of Mr. *Lenard*.

It would be here permitted for me to express most cordial thanks to all those who supported me with these attempts, and in particular my heartiest thanks to Mr. Geh.-Rat. *P. Lenard* for his constant interest, Mr. Geh.-Rat. *M. Wolf* for the multiple support of the observatory, furthermore Mr. *R. Stadler* for his untiring assistance, the Emergency Community of German Science for the grant of the funds, and the company *C.P. Goerz* for providing their valuable instruments.

Radiological Institute of Heidelberg. 1923 June 6. *R. Tomaschek.*

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[1]) *AN* **203** p.197. See also *L. Courvoisier, AN* **213** p. 281, **214** p. 33.

[2]) *Über Äther und Uräther*. 2nd Edition, p. 27 and 31.

[3]) Further concerning this, see in the detailed publication in the *Ann. d. Phys.*, by myself where still further observation results are to be communicated.

† "Lenard distinguishes two different types of aether, using the terms *"Äther"* and *"Uräther"* — but then leaving no separate term to cover both cases. In an attempt to rectify this mildly confusing point, it seems helpful to translate these terms as *"Local-aether"* and *"Cosmic-aether"* respectively — thus leaving the unqualified single word "aether" available to apply generally to either-or-both. (The German prefix *"Ur-"* usually implies something particularly ancient or fundamental or basic, and that fits in with Lenard's usage implying the situation throughout the most of space — here translated as *"cosmic"*)." R. R. Traill: http://www.wbabin.net/physics/traill.htm