

THE BEHAVIOUR OF LIGHT FROM EXTRATERRESTRIAL LIGHT SOURCES

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Introduction

The problem addressed by the present work refers to a sequence of ideas, which have been worked out recently by Lenard ¹), namely, whether it might be possible to demonstrate an absolute reference system, the primordial ether, using Michelson's interference experiment (M.I.). The negative outcome of Michelson's experiment in the usual setting, namely, with terrestrial light, has shown, according to Lenard's interpretation, that the ether carrying terrestrial light waves should be considered as taking part in the movement of the earth. This, however, needs not be the case with extraterrestrial light as Lenard ²) has shown. It could be that light quanta from extraterrestrial sources running with the primordial ether were still linked on the earth to the primordial ether, which should lead to an at least partially positive outcome of the M.I. with extraterrestrial light. A negative outcome should permit elucidating the behaviour of light quanta entering the ether of different property. In the following I will report on experiments conducted with extraterrestrial light.

¹) Astron.Nachr. No. 5107; "On ether and primordial ether" ("Über Äther und Uräther"). Jahrb. Radioakt. 1920; also Hirzel, Leipzig. Cited as "Ä. & U.". Page numbers cited following the 2nd ed. (1922).

²) Ä. & U., p. 31

1. Preliminary experiments

At first it was tried to find the best arrangement, starting from Morley-Miller's original disposition. The light way measured 12 m being reflected by each of eight mirrors. It turned out, however, with such an arrangement, that apart from several other difficulties, the intensity of the available star light is insufficient. Therefore, another more simple arrangement has been chosen which was based on the measurement of the difference with respect to terrestrial light. The negative outcome of M.I. was, thus, presupposed so that the experiment would show up only the differential behaviour of terrestrial and extraterrestrial light. Taking into account newer experiments which seem to indicate some positive effect ¹), any negative outcome of our experiment would have to be interpreted in the way, that light quanta from extraterrestrial sources too would take part in the relative motion with respect to the earth of the earthly ether changing over to the primordial ether, as suggested by the mentioned experiments. The arrangement consists of three pillars, the intermediate pillar carrying the semi-reflective glass plates and two pillars to the side carrying the mirrors. The two arms are directed exactly east-west and south-north respectively. The rotation of the device is then substituted by the rotation of the earth, given observations are made at different day times.

Experiments with artificial stars having a brightness in the range of Sirius or Wega, and with Sirius itself, have shown, using arm lengths as short as 50 cms, that it should be possible, under favourable conditions, to get clearly visible interference stripes even at greater distances. Therefore, trials were done with larger arm lengths, which at first, however, caused great difficulties. Experiments undertaken either within the building or with smaller pillars outside, did not show up interference stripes at a distance of the mirrors of 15 m even if monochromatic light was used. At best a barely detectable flickering of the field of view, originating from the quickly quivering stripes, could be seen. It became clear that it would be necessary to mount the device on massive rock-anchored pillars, far away from every inhabited building. Thanks to the kind cooperation of Mr. G.-R.M.Wolf, it was possible to realize the desired conditions at the Königstuhl observatory situated lonely on the summit of this mountain.

2. Outset of the experiment

A. The interferometer

The three pillars, P1 P2 P3, two of them made from sandstone, one from hard clinker stone, are founded on rock in the cellar of the eastern building of the observatory whose stony walls measure 1 m in diameter and whose bottom lies 1.5 m below the exterior soil level. They have a distance from each other of 8.6 m (according to local circumstances), their height over the bottom measured 80 cm, their squared area measured 60 cm, their orientation was adjusted exactly into the east-west and south-north direction respectively. The mirrors with a diameter of 45 mm, made from silvered glass, are mounted onto the pillars P1 and P2 being fixed to a messing plate, which could be locked to an iron plate serving as a support by means of each of three micrometer screws equipped with a spline. The inclination of the mirrors could be regulated sufficiently by means of these screws. The supporting iron plates are mounted on heavy slays, S1 and S2, each 40 cm long. Slay S1 was equipped with a micrometer screw, allowing moving the slay parallel to the east-west direction. Although 1 revolution of the screw corresponded to 1 mm, we managed to regulate the distance of the mirror satisfactorily up to an accuracy of a few wave-lengths of light. Slay S2 was equipped with a device, consisting of two electromagnets, one of them located before, the other behind of the iron support, enabling the deformation of the iron support to a tiny small degree into the north or south direction. Thus, it was possible to regulate the distance of the mirrors from the observer position by means of an electric resistor avoiding any vibrations or motions of the air by mechanical movements.

Pillar P3, mounted on tablets, kept the two glass plates, the separating plate and the compensating plate. One of the tablets could be made rotate by a micrometer screw. The glass plates measured 10 x 5 x 1.5 cm. None of them was silvered. Interference stripes which appeared on the surface of the mirrors were observed by means of a telescope, whose objective measured 6 cm in diameter allowing a magnification of 40 times. The ocular was fit with a reticule, consisting of two parallel threads, which could be shifted at the same time by means of screws on a graduated barrel. During observation, the distance between the threads equaled a little less than half the width of the stripes, thus allowing to put in position and to fix the dark stripes between both threads of the reticule. The barrel of the micrometer was graduated in 60 parts. One revolution of the barrel corresponded to a shift of the reticule by the width of one stripe. The telescope was

further equipped with an illuminating device as described by Abbé. This helped finding the reticule, if interferences from weakly shining stars were investigated. Star light entered the observing room through the window F, which was equipped with an absolutely plane glass plate and which could be closed by manipulating a damper from the standing of the observer. Between the window and the pillar a reference light source is installed. It consists of a transparent glass plate, inclined at 45° to the vertical axis, which could be passed readily by experimental light from outside, while reference light emitted from a small lamp at its front and made parallel by a diaphragm and a lens, could be reflected into the apparatus. This allowed alternating the observations with experimental and reference light. The reference light was in every case adapted to the color and brightness of the experimental light by use of a filter and by switching on a resistor.

Having roughly adapted the trajectory of both rays to each other, the optical device was adjusted, first by use of reflected light from a brightly shining lamp, then by use of a reticule installed into the ray of the reference light. Interference stripes were searched for by help of a fluorescent neon lamp, whereas the colored central stripes were detected by means of the slightly brilliant flame of a petrol lamp containing admixed sodium.

Having equalized both rays in that way, stripes were put in vertical position and their width adjusted by manipulating the micrometer screws. The width of the stripes was limited by the quality of the mirrors and glass plates causing broader stripes to exhibit some deformation of their rectilinear shape. It turned out best to adjust for a width of 4 mm (as measured on the mirror), such that on each side of the central stripe 4-5 further stripes could be recognized. In the first attempt stripes appeared all too restless because of flows of the air. Having tightened carefully every window, door and electrical tube, these disturbances were still there, although to a much lesser degree. Therefore, the total trajectory of the rays was enclosed in suitable iron stove-pipes. Although the pipes had open ends, their shielding effect was sufficient to reduce the fluctuation of the stripes so that the measurements were not markedly influenced any more as shown by the confidence limits in the results below. It was necessary, in addition, having entered the room, to wait some 10-15 minutes in a quiet position at the observer place, hidden behind a curtain, until the air flows associated with the human body became damped.

Apart from these fluctuations caused by airflows, a constant moving of the stripes could be observed probably caused by some movement of the soil, which may have been due either to temperature gradients in the soil or to some tensions in the underground caused by the weight of the observer. May be both influences were at work, because sometimes before midday, when the sun was warming, the stripes started to shift in the opposite direction as usual. The shift was of the size of $1/20$ of the width of the stripes per minute. It is shown in Fig. 2, where the abscissa gives the time and the ordinate depicts the shifting of the center of the system in units of the width of the stripes.

The optical device was very sensitive for vibrations. Although pillars were anchored in rock to a depth of about $2\frac{1}{2}$ m, paces from persons could be noticed up to a distance of 50m by the quivering of the interference stripes. Therefore, experiments had to be performed under conditions where the environment was absolutely quiet. Nevertheless, sunshine and wind were noticed by a higher restlessness of the stripes. While the weather was stable the adjustment of the stripes could be kept constant. A new adjustment with use of sodium light was necessary once, when experiments had to be stopped because of the weather.

B. Devices for the reception of experimental light

Having conducted preliminary experiments it became evident that it was necessary to use heliostats for the reception of the sun- and starlight.

(a) To receive light from the sun or the moon, a small clock governed *Silbermann* heliostat was used, which allowed projecting sunlight by but one single reflection at the variable mirror from every angle into the observation room. For the reflection of sunlight an exactly plane glass plate served as a mirror, being blackened at its back side and fixed to the heliostat. In order to receive moon light, the same heliostat was used, but provided with a silvered mirror. This device was not suited to investigate light from fixed stars, because he could not be regulated with sufficient accuracy to perform those difficult adjustments. He was, however, suited to observe light from the Sirius, which was of interest, because this device was easier to manage and allowed a simpler interpretation of the results as compared to the second device described below (page 116).

(b) To observe light from fixed stars a more sophisticated arrangement had to be installed. This has been rendered possible by the kind help of the firm C.P.Goerz which provided us with a larger heliostat, equipped with a complementary mirror and with a telescope of larger size. Having tried different arrangements on the roof of the building, it turned out necessary to install these devices immediately before the observation room in the cellar. For this end a groove measuring 6 x 2 m had to be excavated whose bottom came to be at approximately the same level as the bottom of the cellar. The arrangement was installed there.

The heliostat was kept in motion by a clock work equipped with weights, mounted on a big plate from stone and adjusted by the help of different stars.¹⁾ The heliostat was able to revolve about one axis only, parallel to the axis of the earth. Therefore, in order to project light from different stars into the direction of the observation, it was necessary to employ a second mirror. This one could be revolved exactly around a vertical axis and could be shifted on rails in exactly north - south direction in prolongation of the north-south arm of the interferometer. The rails could be fixed in horizontal position by means of adjustment screws. In addition, the second mirror could be finely tuned on the vertical axis by means of micrometer screws. Both mirrors measured 35 cm in diameter. The length of the rails measured 2 m. In this way, the heliostat, placed 60 cm away, was able to project light from all stars between Sirius and Wega horizontally into the observation room.

The light rays impinged upon the heliostat, from there onto the second mirror and from there they entered in northern direction a light intensifying telescope which was equipped with an objective of 17 cm in diameter and with an ocular of 3.5 cm in diameter. Light entered the telescope parallel and leaved it parallel again. The light gain by the telescope was somewhat damped by absorptions and reflections within the device but was nevertheless important. All parts of the light way were adjusted by means of reticules such that the middle of the mirrors and the optical axis of the telescope were all disposed in line with the optical axis of the north - south arm of the interferometer. The light way between the heliostat and the observational telescope measured about 25 m. Another small mirror, measuring 2 x 2 cm, was placed before the objective of the light intensifying telescope and tuned, so that it was able to reflect the star light into a second observational telescope installed beside the heliostat. This allowed an assistant observer to tune the heliostat, such that the starlight was held in the optical axis of the device

during observation. A telephone connected the observer standing in the cellar with the assistant observer at the side of the heliostat, such that small occasional shifts could be corrected.

¹⁾ This heliostat of Firma Goerz is the same as the one which was used by the German expedition to the solar eclipse 1914 in Norway. Ref. "Die totale Sonnenfinsternis vom 21. August 1914" by A. Miethe, Vieweg 1916.

3. Sequence of observations and types of measurement

Having adjusted the central interference stripe of the reference light to the middle of the optical field by shifting the variable interference mirror and having adjusted the position and width of the stripes, observational light is projected by means of the heliostat into the observation room and the light ray light is tuned by manipulating the heliostat and the second mirror until the light is centralized. Having accomplished that and having adapted the brightness of the reference light to that of the experimental light, measurements could be started. Meanwhile, the movement of the air caused by the stepping in of the investigators had also come to rest.

First, with the exterior light closed away, the position of the first central dark interference stripe to the left generated by the reference light was measured by reading the value on the barrel after its adjustment with the micrometer screw, then the position of the first central dark interference stripe to the right was read. Next the exterior light was allowed to enter and the reference light was switched off. Again the position of the first central interference stripe to the left and then the first one to the right were read while the optical field was illuminated by the experimental light. Next the experimental light was closed away again and the reference light was switched on and again the first left and the first right interference stripe were measured.

Using this kind of alternating measurements, it was possible to minimize the influence of the constant shifting of the stripes, such that a systematic error which would have shown up with this apparent shifting was avoided, provided, firstly, a linear interpolation was justified which was the case as demonstrated by Fig. 2 (p. 110), and secondly, both time periods with either the experimental or the reference light switched on were equal. This second condition was also fulfilled in sufficient degree.

Any error of this type could have had the following size: It takes at most one minute to perform one sequence of measurements. One single measurement takes approximately 8 seconds. Given a mean shifting per minute of 0.05 parts of the width of a stripe (see p. 110), the shifting during one single measurement could not exceed 0.006 parts of the width of a stripe. Assuming a systematic error due to an unraveled difference of 4 seconds between both time intervals - which is unlikely already - then an apparent shifting of the stripe by 0.008 parts of the width of the stripe would result. This value lies fully within the limits implied by other disturbances.

Air flows could not have provoked any systematic error, because they are completely irregular. Another systematic error, however, could have occurred, when the reference and the experimental light was exchanged, if both were not completely identical in color and brightness. In fact, it was observed, that the stripes to the left and to the right of the

middle had not exactly the same aspect. In order to investigate this influence, the same measurements were performed apart from the main ones using differently filtered and dampened light from an extra lamp. As could be expected, the influence was zero, because, in any case, only both central dark interference stripes were read, whose value was almost independent from the color of the stripe. As an example, two sequences of measurements with very reddish experimental and very greenish reference light exhibit the shifts

$$V = - 0.009 \pm 0.019 \text{ stripe widths}$$

$$V = - 0.000 \pm 0.010 \text{ stripe widths}$$

It appeared unfeasible to establish an unequivocal measure of the disturbances within one sequence of measurements. Therefore, in evaluating the readings the same weight was applied to everyone.

Tab. 1 shows an example of a sequence of measurements which have been performed in this way. A shift which would have been caused by a prolongation of the light way in the east - west arm was taken as positive. The accuracy of the adjustment by the micrometer screw of the reticule to the stripes reached $\frac{1}{2} - 1$ scale steps = 0.02 parts of the stripe width. A shift of double size was immediately recognized. This approach has been used in particular in the observations of star light: The interference stripes from star light were fixed by the reticule and then, rapidly, reference light was switched on and the star light cut off. This method was of advantage for the observation of an immediate effect, because the comparison took but 1-2 seconds which guaranteed almost full independence from air flows etc., and because the adjustments could be made with high accuracy avoiding particularly the dazzling associated necessarily with each reading from the barrel. A shift by 0.04 parts of the width of stripes would for sure have been detected in this way.

Tabelle 1.

Alles in Skalenteilen. Streifenbreite = 40,2 Skalenteile.

Zeit	Nr.	L_1	R_1	L_V	R_V	L_2	R_2	M_1	M_2	M_{12}	M_V	+ -	
8 ^h 40	428	1	41	1	43	3	44	21,0	23,5	22,2	22,0	0,2	—
	429	21	61	17	59	20	62	41,0	41,0	41,0	38,0	3,0	—
	430	34	75	35	74	32	73	54,5	52,5	53,5	54,5	—	1,0
9 ^h 45	431	37	78	36	81	40	81	57,5	60,5	59,0	58,5	0,5	—
	432	42	85	45	86	46	88	63,5	67,0	65,2	65,5	—	0,3
	433	-4	38	-2	41	+2	42	17,0	22,0	19,5	19,5	0,0	—
	434	-2	40	0	41	+2	41	19,0	21,5	20,2	20,5	—	0,3
	435	4	43	2	41	-2	40	23,5	19,0	22,2	21,5	—	0,3
	436	5	45	7	47	6	46	25,0	26,0	25,5	27,0	—	1,5
	437	7	50	10	51	10	48	28,5	29,0	28,7	30,5	—	1,8
8 ^h 53	438	10	52	13	51	13	51	31,0	32,0	31,5	32,0	—	0,5
	439	14	53	14	54	13	53	33,5	33,0	33,2	34,0	—	0,8
	440	15	53	16	53	18	59	34,0	36,5	35,2	34,5	0,7	—
	441	19	62	21	63	24	67	40,5	45,5	42,5	42,0	0,5	—
	442	32	78	35	71	31	69	55,0	50,0	52,5	53,0	—	0,5
9 ^h 05	443	0	38	1	40	5	43	19,0	24,0	21,5	20,5	1,0	—
	444	6	44	4	46	8	50	25,0	29,0	27,0	25,0	2,0	—
	445	12	60	20	63	25	63	39,5	44,0	41,5	41,5	0,0	—
	446	25	63	25	65	25	64	44,0	44,5	44,2	45,0	—	0,8
	447	32	72	30	70	29	69	52,0	49,0	50,5	50,0	0,5	—
	448	33	74	33	71	33	73	53,5	53,0	53,2	52,0	1,2	—
	449	41	81	41	81	41	82	61,0	61,5	61,3	61,0	0,3	—
9 ^h 20	450	46	84	46	83	48	89	65,0	68,5	66,7	64,5	2,2	—
	451	41	79	42	83	47	87	60,0	67,0	63,5	62,5	1,0	—
	452	52	90	51	90	52	91	71,0	71,5	71,2	70,5	0,7	—

4. Results

The extraterrestrial light sources were: first sun light resp. moon light, further light from planets, particularly Jupiter which was in an appropriate position at the time of the experiment, finally light from fixed stars, among them especially Sirius. However, due to the very unfavorable weather, measurements had to be postponed, such that only few immediate comparisons with Sirius light were feasible. Therefore, the crucial measurements involved mainly Arktur and Wega whose brightness appeared to be sufficient for the measurement of interference stripes.

(a) Sun and moon light

The sun. - In order to have most synoptical conditions, sunlight was projected by but one reflection into the observation room, using the small heliostat described on p. 111. Light is reflected from the front side of the glass plate being blackened at its back and enters the observation room through the 5 mm thick glass of the window. Behind the window a filter was installed to damp the sun light. This filter consisted of a 2 mm thick glass plate containing a dispersed dried suspension of soot particles, leaving in between them small spaces, such that the filter could act like a veil. The arrangement of the optical device assured a meridian pathway of the light ray as proposed by Vogtherr ¹⁾.

¹⁾ A.N. 5203

The following measurements are presented as means from 20 series consisting of 6 readings each. The clock time of the middle set was taken as the clock time for the whole series. One series of observations lasted 35 - 45 minutes. The following results were received: was

Day	Time	Shift (parts of the width of the stripes)
1923 April 25	9h25 am	- 0.000 ± 0.007
24	10h35 am	+ 0.023 ± 0.006
24	11h15 am	- 0.010 ± 0.007
Mai 5	11h35 am	- 0.009 ± 0.010
April 24	noon	- 0.007 ± 0.007
4	12h10 pm	+ 0.012 ± 0.006
July 4	1h05 pm	+ 0.006 ± 0.009
4	2h05 pm	+ 0.006 ± 0.006
April 4	3h05 pm	+ 0.014 ± 0.010
April 4	4h00 pm	- 0.000 ± 0.010
April 12	4h10 pm	- 0.000 ± 0.013
April 3	4h35 pm	- 0.003 ± 0.010

Moon. - The same small heliostat was used, with silvered mirror.

1923	March 26	8h00 pm	+ 0.001 ± 0.019*
	April 26	8h35 pm	+ 0.007 ± 0.006
	March 26	9h00 pm	+ 0.054 ± 0.014*
	April 26	9h40 pm	+ 0.018 ± 0.011
	April 24	10h05 pm	+ 0.011 ± 0.011
	March 26	11h00 pm	+ 0.021 ± 0.013*
	April 24	11h40 pm	- 0.007 ± 0.013
	March 26	midnight	- 0.002 ± 0.014*
	April 4	3h00 am	+ 0.006 ± 0.009
	April 4	3h45 am	- 0.002 ± 0.009
	April 4	5h00 am	+ 0.015 ± 0.008

Values indicated with an asterix have to mean that the airflows hadn't come fully to rest yet.

Jupiter. - The large heliostatus equipped with the adjuvant mirror and the light intensifying telescope, as described on p. 112, was used. Numerous immediate comparisons in several nights of april, at different night times, yielded always a negative result. In addition, extensive measurements have been done.

1923	July 6	9h25 pm	+ 0.008 ± 0.009
	July 6	9h50 pm	- 0.011 ± 0.011
	July 6	10h25 pm	- 0.005 ± 0.009
	Mai 2	0h25 am	+ 0.012 ± 0.015

(b) Light from fixed stars

Sirius. - Sirius did not comply with the weather. Once the weather complied he stood outside the optical field of the large heliostat. Therefore, experiments were conducted with the small heliostat only, employing one single reflection. Observations on march 21 at 9h30 showed no measurable shifting, as well as 50 comparative observations on april 4 from 8h30 until 9h00. There was no shifting exceeding the limit of 0.04 parts of the width of the stripes.

Arktur. - The large heliostat equipped with the adjuvant mirror and the light intensifying telescope was used. In april and mai immediate comparisons have been done during different times in the night. No detectable shifting could be found at any time. The results of detailed measurements were as follows:

1923	July 5	0h15 am	+ 0.004 ± 0.005
	Mai 15	0h25 am	- 0.025 ± 0.012
	Mai 15	2h20 am	- 0.007 ± 0.009

Wega. - The results of the measurements were as follows:

1923	July 5	1h30 am	+ 0.001 ± 0.005
	July 5	1h55 am	- 0.003 ± 0.005
	July 5	2h30 am	- 0.004 ± 0.005

5. Interpretation of the results

If the extraterrestrial light comes from the primordial ether and if it conserves its velocity relative to it, then the size of the expected effect will be given, in our view, by the velocity of the optical device relative to the primordial ether, such that Michelson's original conclusions may be applied. If the direction of the relative velocity is in line with the direction of one of both arms, then the expected shift in relation to terrestrial light will be $N = L/\lambda \cdot (v^2/c^2)$; L being the length of the arm, λ the mean wave length, v the velocity relative to the primordial ether and c the velocity of light. Because of the revolution of the earth, the value of N will change correspondingly (see below).

Four different movements are known, which could give rise to the effect. (1) First, the revolution of the earth about its axis. This effect should lead to a steady and constant positive shift relative to the terrestrial light, which, however, is much too small to be detectable with our arrangement. (2) A major effect should be caused by the revolution of the earth around the sun. The maximal effect, occurring at noon and midnight respectively, should amount to + 0.15 parts of the width of the stripes. The changes according to the day time may be calculated as:

$$N_1 = L/\lambda \cdot (v^2/c^2) \cdot [1 - \sin^2 t (1 + \sin^2 \varphi)],$$

with t as the angle of the hour (for 12h00 = 0) and φ as the geographical latitude (= 49° 24'). The effect should, therefore, be zero for our arrangement at 3h40 o'clock pm and at 8h20 o'clock am, respectively. The maximal negative shift at 6h00 o'clock in the evening and morning amounts to but 0.58 of the positive shift at noon and midnight. (3) The third movement concerns the solar system as a whole relative to the system of the surrounding fixed stars. Putting $RA = 270^\circ$, $D = + 30^\circ$ for the apex of the solar movement and setting $v_0 = 20$ km/sec, it would follow from this movement taken alone, each 5 and 19 hours after the culmination of the apex, a maximal positive shift by + 0.044 widths of stripes, and a maximal negative shift each 12 hours after the culmination by - 0.062 widths of stripes, respectively. At the time of the culmination a shift by but 0.007 widths of

stripes would be expected. The expected changes in the shift during a full astral day are to be calculated as follows:

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

with δ signifying the declination and putting t' for the culmination of the apex = $\pi/2$.

Putting together both influences, i.e the revolution of the earth around the sun and the movement relative to the system of fixed stars, both expressions for the resulting shift have to be superposed, taking into account, in addition, that in the formula for N_2 t' must be substituted by $t + \lambda$, where λ is the angle of the annual movement of the earth (= 0 on march 21). The resulting curve shows that the deviations at noon and midnight will vary, according to our arrangement, by + 0.19 and 0.08 parts of the width of the stripes, respectively, and that the best observation time is march. (4) The fourth type of movement would be given by the movement of our galaxy with respect to other such systems. Thereabout, however, nothing sure is known. Based on hitherto given estimates ¹⁾ shifts of the stripes in the range of even 10 widths of the stripes were to be expected

In summary, excluding the last mentioned movement which is uncertain but which otherwise would strengthen our conclusions, a shift by 0.1 - 0.2 parts of the width of the stripes would be expected. The experiments show that a shift of this size has not occurred. The deviations observed amounted to 1/8 of the expected size at most, this value ranging already within the limits of the instrumental error. If the aforementioned large velocities of the galactic system, which have been estimated by Sirs Courvoisier, are taken into account, then the observed shifts amount to but 1/1000 of the calculated value.

Based on our original viewpoint and given our arrangement, the experiments support the conclusion that light quantas from extraterrestrial sources are no longer in connection with the primordial ether of the universe ²⁾ but, instead, that their speed equals the speed of light in relation to the ether of the earth, which we have assumed at rest with respect to the surface of the earth. Thus, we have to recognize that the properties of the light quantas are consistent with the assumption that their velocity component in the direction of propagation is subject to a change, such that, in entering the ether of another condition of movement, the quantas will adopt the speed of light relative to this type - while the phenomenon of aberration demonstrates that the perpendicular velocity component remains unchanged under the same conditions.

1) L. Courvoisier, elsewhere

2) About this assumption see P.Lenard, Über Äther und Uräther, 2nd ed., pp. 23ff. If the Lorentz contraction is rejected as not satisfying, then the present experiments clearly show that the ether associated with the light of fixed stars exhibits, on the earth, no relative motion to the earth.

6. The reflection of aberrational light

Although we have to accept, according to the presented facts, that light from fixed stars behaves within the ether of the earth identically as terrestrial light, it is worthwhile to note that experiments with extraterrestrial light do not, at least in certain circumstances,

conform completely to the experiments carried out with terrestrial light. We consider light from terrestrial sources as being associated to the terrestrial ether, which is in full agreement with all hitherto performed experiments. The negative outcome of Michelson's experiment appears obvious hence. It is, however, very remarkable, as recently repeated experiments with terrestrial light have shown ¹⁾, that on high mountains a transition to primordial ether appears noticeably taking place. Yet, this does not affect indeed our conclusion, that light from fixed stars adopts in any case the speed of light relative to the type of ether in which it moves ²⁾. The difference between light from fixed stars as compared to terrestrial light resides, consequently, in the phenomenon of aberration. This phenomenon involves a lateral component of movement of light quantas provoked by the movement of the earth on its course ³⁾, although, as has been shown, their quantity of speed in traversing the earth bound ether is not measurably diminished. The aberration implies that the direction of the light ray (i.e. the direction of the progressing energy) does no longer conform to the direction of propagation of the light quantas. This difference gave rise, according to the traditional view implying an absolutely resting ether, to discriminate between relative and absolute ray. It is, however, to be noted that in constructing our "relative" ray, i.e. the direction of propagation of energy, although its direction will comply - except for quantities of second order - with the usually performed construction, its quantity of speed in direction of the relative ray does not. Taking, according to Fig.3a (p.124), *AB* as the direction and quantity of speed in the absolute ray (corresponding, in our view, to the longitudinal direction of light quantas), and *CB* as the direction and quantity of speed of the earth, then, according to usual constructions, *AC* will yield the direction and quantity of speed in the relative ray. This is so, because the ether is taken as being moved in the opposite direction, i.e. *BC*, with respect to the apparatus, yielding directly this construction. Our assumption is, however, that the ether is at rest with respect to the apparatus and that the light quantas exhibit the velocity of light with respect to the ether in any case in their longitudinal direction ⁴⁾. Therefore, we have to assume that only the component which is perpendicular to the direction of propagation may be superposed, such that - except for quantities of second order - the direction of aberration will conform to the construction above, the speed, however, will be of size *AC''* only. This is seen immediately, considering the special case when the movement of the earth was in the direction *BA*. Then, the relative ray (i.e. relative with respect to the apparatus) will exhibit, according to the usual construction, the velocity $c + v$ (because of the "ether wind"), whereas according to our view, since there is no lateral component of movement, it will have the simple speed c within the ether considered at rest with respect to the apparatus.⁵⁾ Thus, the usual constructions concerning the reflection of aberrational light are useless ⁶⁾, because these would require a positive outcome, i.e. a shift of the stripes. This is at variance with our data.

The most prominent influence of the aberration should have shown up in experiments with stars at noon or midnight in meridian position, when the whole path of one of the rays was in line with the meridian and, in addition, if the light was reflected only once, making the interpretation simple. Such experiments with sunlight have yielded, as p. 116 shows, a negative result.⁷⁾

The identical position of the interference stripes with use of terrestrial and extraterrestrial light means, in physical terms, that the light ways of terrestrial and extraterrestrial light are both traversed within the same time. How can this be, given the fact of aberration? This is to be discussed now.

The assumption which is first at hand states that light from fixed stars behaved in completely the same way as terrestrial light. In this case it must have lost its aberrational component before the separation at the central glass plate. This could well have occurred during the reflection at the mirror of the heliostat⁸), where the incoming light interacted for the first time intimately with the material atoms. This could have caused the loss of the lateral component, which we don't consider as a merely geometrical phenomenon of the given movements but rather as a peculiarity of the light quantas involved. The reflected ray, devoid of its lateral component, would, thus, behave identically to terrestrial light. The negative outcome of the experiment can easily be understood in this way. We have now to investigate if the presupposed loss of the lateral component during the interaction with material atoms were in agreement with established experiences concerning the reflection. If we construct an arbitrary case (Fig. 3b⁹) depicts the case of a light ray reflected by the glass plate at noon or midnight) it can be seen that an extraterrestrial ray entering in the same apparent direction as a terrestrial ray will, after being reflected, diverge from the last - neglecting quantities of second order - by the size of the respective angle of aberration. This contradicts the usually made assumption, namely, that "relative" rays (but not "absolute" rays) of the aberrational light are subject to the usual reflection laws. An unequivocal test for this behavior does, however, apparently not exist¹⁰). Therefore, the possibility of such a reflection law and, thus, of such an explanation cannot easily be refuted before appropriate experiments are carried out¹¹).

The second assumption which one can make implies no difference in the direction of the reflection between terrestrial and extraterrestrial rays and is, thus, in agreement with traditional concepts. It states that *lateral components of the light quantas accord their direction to the reflection law*. The construction of this case is depicted in Fig. 4. *AP* is the direction of the incoming light quantas, *PC* is their lateral component of movement per time unit, the "relative" ray is, therefore depicted by *AC* whereas the wave front of the incoming light quantas corresponds to *AB*. *B* is the center of a new wave, whose radius in the time unit is $BD = AP$, *CD* is its tangent line and, at the same time, also the wave front of the reflected light quantas; *BD* is the direction of propagation, to which perpendicularly the lateral component of movement has to be added, such that *DH* becomes *PC*. *BH* is the direction of energy of the reflected ray, i.e. the "relative" ray. The triangles make clear that the angle φ equals the angle Ψ , except for quantities of second order in α , and that $i = i'$, showing that the reflection law is valid for lateral components as well.¹²) The direction of the reflected starlight ray falls, therefore, in line with the direction of the terrestrial light ray, the velocity in the direction of the relative ray is, however, not the same as in terrestrial light, because of the presence of the lateral component of movement.¹³)

In applying these relationships to the circumstances of our experiment, the following picture emerges: Both parts of the ray, the one running to the north as well as the one running to the west, perform the same path as the terrestrial light. Since in both parts of the ray each component of the movement exhibits the same quantity and direction relative to the light quantum¹⁴), they take the same time to be traversed. Light paths which are of the same duration for terrestrial light are the same also for light from fixed stars, irrespective of their direction relative to the movement of the earth. In this way, the negative outcome of the comparison with terrestrial light is explained. It must be noted, however, that the time spent for traversing these ways will, for the general case, differ

from the time spent by the terrestrial light.¹⁵⁾ This assumption of a change in direction of the lateral component of movement of the light quantas according to the reflection law is in agreement, both, to the condition of the directional identity of terrestrial and aberrational light in case of refraction or reflection as well as to the result of the afore described experiment concerning the velocity of movement in different directions implied by the aberration.

Let me be allowed to express my deepest gratitude to everybody, who has lent me support in accomplishing these experiments, especially to Sir G.-R.P.Lenard for his continuous interest, to Sir G.-R. M. Wolf for multiple support at the observatory, further to Sir R. Stadler for his tireless assistance, to the *Notgemeinschaft* for German Science for financial support and, last but not least, to the firm C.P. Goerz for leaving me their precious instruments.

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- (1) Phys.Rev. 19. p. 407. 1922. A shift of the stripes in the range of about 1/10 of the effect, which would have been expected from the movement of the earth around the sun., has been found.
- (2) It has to be noted that we assume, based on the mechanism of the light quantum (see, e.g., *Ä.u.U.* p. 26), the velocity of light in the direction of propagation of the light quantas, but not in the direction of propagation of the energy (i.e. the "relative" ray). Both directions need not coincide in every case.
- (3) See "*Ä.u.U.*" p. 27, note 2.
- (4) This is evident already from the mechanism of the light quantum (*Ä.u.U.* p. 26). We have to imagine that the transition of the "absolute" velocity of light into the speed of light relative to the apparatus, or else to the earth, occurs already, as experiments have shown, far away from the earth almost.
- (5) The experiment of Majorana (*Phil.Mag.* 35. p. 163. 1918 and 37. p. 145. 1919) whose results agree with the considerations above, may be interpreted in a similar way.
- (6) E. Ketteler, *Pogg. Ann.* 144. p. 364. 1872; W. Veltmann, *Pogg. Ann.* 150. p. 511. 1873; M. Mascart, *Ann. École norm. II. Ser.* 1. p. 173. 1872. It has to be noted, however, that these constructions are valid for a mirror which is moving relatively to the earth. The experiment of Michelson, if conducted in a system which is moving relatively to the earth, should yield accordingly a positive result as Sir Lenard has already shown (*Ä.u.U.* p. 40).
- (7) The influence of the aberration in Michelson's experiment with light from fixed stars has previously been treated by Sir K. Vogtherr. *Astron.Nachr.* 5203 (vol. 217).
- (8) The possibility that this might happen already at the border between primordial ether and ether is indicated by Sir Lenard in his simultaneous treatise, see this volume of the annals.
- (9) AP is in this figure the direction and velocity of the light quantas; PS is the lateral component of movement acting from P in direction to C; AC is the direction of propagation of the energy, AB the wave front of the incoming light quantas. BD = AP (= AC neglecting quantities of third order) is the radius of the elementary wave. CR ⊥ BD is the direction of the reflected ray with DC as its wave front. CB and AC would be in this special case the wave fronts of a corresponding terrestrial ray.

- (10) The experimental verification of this question is in preparation. The angle α in Fig. 3b is not the usual aberrational angle representing a difference only, but, instead, describes the total aberrational angle comprising the combined relationship of speeds of the earthly and the primordial ether, so that determining the absolute motion (with respect to the primordial ether) would be possible.
- (11) In this case it would be possible to test by the present experiment, done *without* previous reflection at the heliostatus, if the assumption of an only *vertical* superposition of the lateral component of movement were justified.
- (12) The following relationships hold: $BC : AC = \sin(90 - \alpha) : \sin(\alpha + \varphi)$
 $BC : BH = \sin(90 - \rho) : \sin(\rho + \psi)$

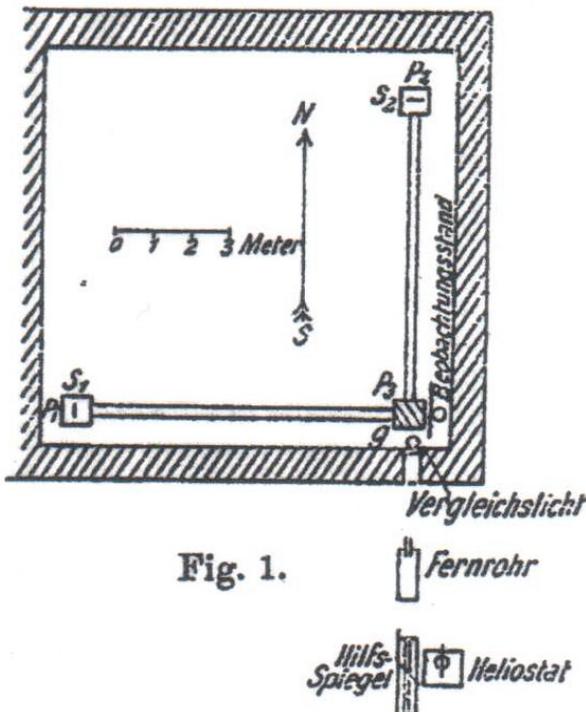
Since, neglecting quantities of third order, $AC = BH$, and since ρ and α are very small, it follows that $\alpha + \varphi = \rho + \psi$. Since $\alpha = \rho$, if $HD = PC$, it follows that $\varphi = \psi$, implying $i = i'$.

- (13) As follows from our construction, the time spent by the star light to traverse one of the arms forth and back equals

$$2l/c(1 - v^2/c^2 \sin^2\theta)$$

in the best case, where θ indicates the angle between the incoming direction of the ray and the direction of movement of the earth.

- (14) Given the fact of convection, the presence of the glass plates will not change the conditions, as the well known experiments involving telescopes filled with water have shown.
- (15) This holds, as can be seen, for the ray running to the north even before its reflection at the northern mirror.



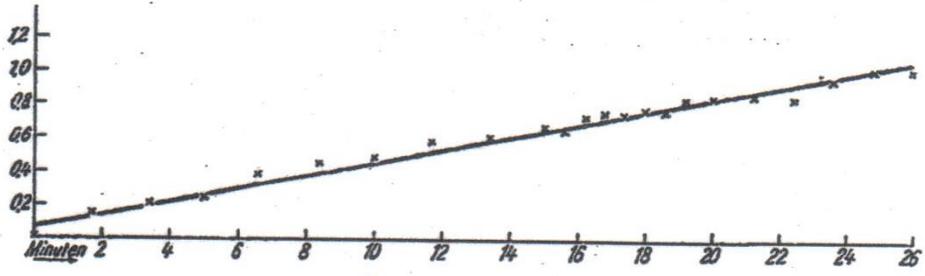


Fig. 2.

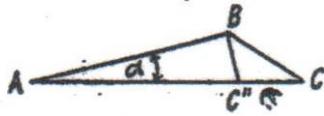


Fig. 3a.

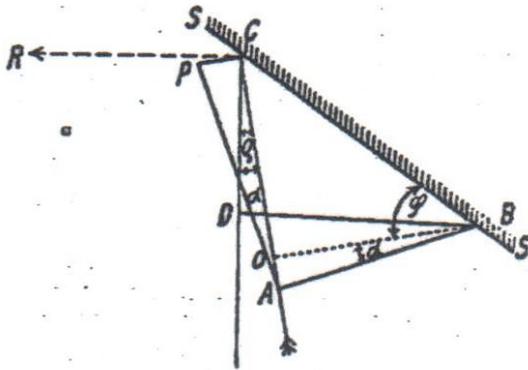


Fig. 3b.

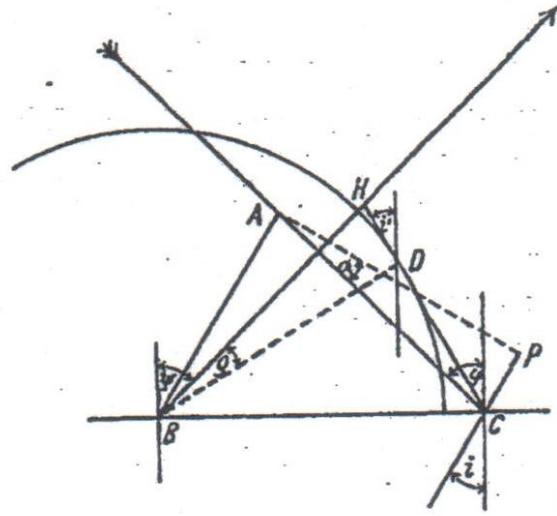


Fig. 4.