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Searching for the Ether

Leopold Courvoisier’s Attempts to Measure the Absolute Velocity of the Solar System

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A Introduction

Leopold Courvoisier (1873-1955) was an observer at the Berlin/Babelsberg astronomical observatory from 1905 up to his retirement in 1938. Most of his work was traditional astrometrical observation resulting in the publication of several star catalogues. A relevant part of his publications was devoted, however, to another subject: the attempt to detect the motion of the solar system through the ether. Most of Courvoisier’s search for measurable effects of the ether was based upon two “principles”. According to him, (1) the angles of incidence and reflection of light could be different, relative to the proper reference system of the mirror, if it moved through the ether; and (2) the Lorentz contraction of the Earth due to its motion through the ether produced observable effects relative to the Earth’s reference system. Both “principles”, of course, violate the principle of relativity. Courvoisier presented theoretical arguments attempting to show that there should exist second order measurable effects. He searched for those effects using both astronomical observations and laboratory experiments and claimed that he had measured a velocity of the solar system of about 600 km/s. This paper presents a description and analysis of Courvoisier’s ether researches.

B Leopold Courvoisier

B1 Leopold Courvoisier was born on 24 January 1873 in Rihen near Basel (Switzerland). His father Ludwig Georg Courvoisier was a physician and was in charge of the surgery chair of the University of Basel. Leopold (or Leo, as he was usually called) passed away in the same city where he was born, on 31 December 1955. However, most of his professional life was spent in Germany.

B2 Courvoisier exhibited an interest for astronomy since he was 15 years old. In 1891 he began his university studies, first in Basel and later in Strasbourg — at a time when this city belonged to Germany. In 1897 he completed his dissertation, on the absolute height of the pole as observed from Strasbourg (“Die absolute Polhöhe von Straßburg”). The next year he became an assistant observer at the Königstuhl astronomical observatory near Heidelberg, under Karl Wilhelm Valentin. In 1900 he obtained his Doctorate degree in Strasbourg. From 1905 onward he worked at the Berlin/Babelsberg observatory as an

\(^1\) For biographical information, see Courvoisier’s obituary: Nikolaus Benjamin Richter, “Leopold Courvoisier”, Astronomische Nachrichten, cclxxxiv (1957), 47-48.
Courvoisier's main astronomical contribution was a large series of routine astrometrical observations and the production of star catalogues. Volumes 5, 6 and 7 of Poggendorff's Biographisch-literarisches Handwörterbuch provide references of about 10 large works (astronomical catalogues) besides nearly 100 minor contributions by him. However, Courvoisier's work was not restricted to common astrometrical observations. From his tedious measurements there soon came out evidences that he regarded as disproof of the theory of relativity.

Courvoisier did not accept the theory of relativity. He believed there was an ether, and attempted to measure the absolute velocity of the solar system relative to this medium. From 1921 to his death, Courvoisier published a series of over 30 papers where he described the theoretical basis of his search and the several experimental techniques he used in attempting to detect the motion of the Earth relative to the ether. Some of his measurements used astronomical observations; other measurements depended on other physical effects (gravitational, etc.). As a result of his observations he claimed that he had measured a velocity of the solar system of about 600 km/s in a direction close to 75° right ascension and +40° declination.

The papers describing those researches were published in several scientific journals — especially Astronomische Nachrichten, Physikalische Zeitschrift and Zeitschrift für Physik. His work was largely ignored and had a small impact. A few authors (e.g. Ernest Esclangon and Dayton Miller) who also claimed they had observed effects due to the ether have cited his works.

Historians of science have also neglected those researches, although they present the largest set of empirical results that was ever published against the theory of relativity by a professional scientist. Courvoisier exhibited an outstanding theoretical and experimental skill, and his results can be regarded as one of the strangest puzzles in the history of relativity.

C Courvoisier and relativity

Courvoisier's earliest involvement with relativity was an outcome of his routine measurements of star positions. In the beginning of the twentieth century, Courvoisier had noticed that the right ascension and declination of fixed stars suffered a small influence when they are observed close to the Sun. As this influence had a period of one year,
he called it “annual refraction”. His first work on the subject was published in 1905,\textsuperscript{5} that is, much earlier than the development of the general theory of relativity. In 1911, after the publication of Einstein’s early thoughts on the gravitational deflection of light rays, Erwin Freundlich recalled that Courvoisier’s work had exhibited an effect that was qualitatively similar to the one predicted by Einstein.\textsuperscript{6} Courvoisier interpreted the effect he had measured as due to refraction of light by a denser medium around the Sun, not as a consequence of relativity. It seems that Courvoisier’s opposition to Einstein’s work grew steadily from this time onward and he became one of the most intransigent supporters of ether theory after the theory of general relativity received strong confirmation (the eclipse measurements), in 1919. Courvoisier’s main anti-relativistic work, however, is not directly linked to “annual refraction”.\textsuperscript{7} Courvoisier accepted the existence of a static ether, similar to the medium proposed in the early eighteenth century by Augustin Fresnel. That theory led to the conclusion that there could be no first-order influence of the motion through the ether upon optical experiments performed in the Earth. Besides that, the negative outcome of the Michelson-Morley experiment required an additional hypothesis, and Courvoisier accepted that motion through the ether produced a real contraction of all moving bodies, according to the early explanation proposed by Fitzgerald and Lorentz.

C2 According to Lorentz, the principle of relativity would hold exactly for any optical or electromagnetic phenomenon, but Courvoisier did not follow Lorentz’s theory in this respect. He directly denied the principle of relativity and attempted to measure the motion of the solar system through the ether using several different techniques. In 1921 Courvoisier published his first thoughts on the possibility of measuring the absolute velocity of the Earth through the ether. According to Courvoisier’s own declaration, his early calculations concerning the motion of the Earth were an outcome of routine work.\textsuperscript{8} In 1920 the Leyden observatory published the details of a large series of observations of stars close to the North Pole that had been made between 1862 and 1874. Those measurements used an old method aiming to reduce observational errors: the stars were observed both with the meridian telescope directly pointed to them, and with the telescope pointed to the images of the stars reflected by a mercury mirror. This double assessment allowed corrections for any changes of the local vertical due to geological motions. It occurred to Courvoisier that those determinations could be used to measure the speed of the Earth through the ether.

C3 Courvoisier assumed that the reflection of light by a mirror could undergo some influence of the motion of the mirror through the ether, even when the effect was observed relative to the proper reference system of the mirror. Any observable effect should be of the second order in \(v/c\). It would be impossible to detect such a small effect if the speed of the Earth relative to the ether was about \(10^{-5}\) c (that is, its orbital velocity), because for usual angle measurements (let us say, 60°) a relative difference of \(10^{-8}\) would amount to only 0.002° — an effect that could not be observed. However, Courvoisier assumed that there could exist a much larger speed of the whole solar system relative to the ether, and analyzed the data published by the Leyden observatory searching for some systematic

\textsuperscript{5}Leopold Courvoisier, “Kinemara’s Phänomen und die ‘jährliche Refraction’ der Fixsterne”, Astronomische Nachrichten, clxvii (1905), 81-106.

\textsuperscript{6}Hentschel, The Einstein tower (fn 4), 10-11.

\textsuperscript{7}Klaus Hentschel, The Einstein tower (fn 4), 11, claimed that Courvoisier derived the speed of the Earth’s motion through the ether from his data on annual refraction, but his data for the computation of the speed of the Earth was taken from completely independent sources, as will be shown in this paper.

\textsuperscript{8}Leopold Courvoisier, “Zur Frage der Mitführung des Lichtathers durch die Erde”, Astronomische Nachrichten, cxxiii (1921), 281-8; idem, “Über astronomische Methoden zur Prüfung der Lichtättherhypothese”, Astronomische Nachrichten, cxxiv (1921), 33-36.

\textsuperscript{9}Leopold Courvoisier, "Ergebnisse von Beobachtungen und Versuchen zur Bestimmung der ‘absoluten’ Erdbewegung", Scientia, xlvi (1930), 165-74; French translation: "Résultats d’observations et d’expériences faites pour la détermination du mouvement ‘absolu’ de la Terre", Scientia (supplément), xlvii (1930), 76-84.

\textsuperscript{10}Leopold Courvoisier, “Zenitdistanzbeobachtungen der Polarissima am Vertikalkreise der Sternwarte Berlin-Babelsberg”, Astronomische Nachrichten, ccxvii (1919), 349-64. He made this series of measurements as routine observations to ascertain the latitude of the Babelsberg observatory. The method used by Courvoisier is very precise, and was recently used for the determination of the azimuth of a transit instrument in Brazil: Ramachandra Teixeira and Paulo Benevides Soares, “Absolute azimuth determination”, Astronomy and astrophysics, clxv (1986), 251-3.

\textsuperscript{11}Leopold Courvoisier, “Bestimmungsversuche der Erdbewegung relativ zum Lichten”, Astronomische Nachrichten, ccxvi (1925), 241-64.
D The method of the moving mirror

D1 Courvoisier derived equations\textsuperscript{12} that related the relevant measurements to the parameters of the motion of the Earth relative to the ether.\textsuperscript{13} The main parameters that appear in his equations (Fig.2) are:

- $c =$ the speed of light relative to the ether $= 300,000 \text{ km/s}$
- $v =$ speed of the Earth (or the solar system) relative to the ether
- $A =$ right ascension of the apex of the absolute motion
- $D =$ declination of the apex of the absolute motion
- $\alpha =$ North local component of $v/c$
- $\beta =$ Zenith local component of $v/c$
- $\gamma =$ West local component of $v/c$
- $\phi =$ latitude of the terrestrial observatory
- $\theta =$ sidereal time of measurement

A straightforward geometrical analysis shows that the components of $v/c$ are:

\begin{align}
\alpha &= (v/c)[\cos \phi \sin D - \sin \phi \cos D \cos(\theta - A)] \\
\beta &= (v/c)[\sin \phi \sin D + \cos \phi \cos D \cos(\theta - A)] \\
\gamma &= -(v/c) \cos D \sin(\theta - A)
\end{align}

D2 In Courvoisier's first method, as described above, light was reflected by a mirror. To derive the theoretical effect, it was necessary to study the influence of the motion of the mirror through the ether upon the direction of the reflected ray. Courvoisier made use of the non-relativistic analysis, developed by Adolf von Harnack,\textsuperscript{14} that predicted that the angle of reflection would be different from the angle of incidence, relative to the proper reference system of the mirror (Fig.3). This was one of Courvoisier's main assumptions that was incompatible with the principle of relativity. Taking into account this “principle of the moving mirror”, Courvoisier predicted that the angle between the local vertical (zenith) and the direction of observation of a given star would be slightly different from the angle between the zenith and the direction of the star observed using a mercury mirror (Fig.4).\textsuperscript{15}

D3 In this case, the Earth's contraction could produce no effect, because both measurements were made relative to the same reference (the local vertical) and the surface of the mercury mirror is, of course, perpendicular to the local vertical, whatever the changes that the gravitational field could undergo due to Lorentz contraction. The predicted effect was a small systematic difference between the direct and the reflected angles, which should depend on the angle between the vectors $Z$ and $V$ in Fig.2.

D4 Let $\theta$ be the angle of incidence and $\theta'$ the angle of reflection of a light ray in a moving mirror, measured relative to the ether (Fig.5).\textsuperscript{16} According to Harnack's analysis, instead of $\theta = \theta'$ the following equations would hold:

\begin{align}
\sin \theta' &= (1 - \beta^2) \sin \theta / (1 + 2\beta \cos \theta + \beta^2) \\
\cos \theta' &= [(1 + \beta^2) \cos \theta + 2\beta] / (1 + 2\beta \cos \theta + \beta^2)
\end{align}

\textsuperscript{12}Courvoisier never published the details of his derivations — he only presented his main assumptions, a few steps and the final results. In all relevant cases, however, I have been able to confirm that his equations do follow from his assumptions.

\textsuperscript{13}Courvoisier, “Bestimmungsversuche der Erdbewegung relativ zum Lichtäther” (fn 11).


\textsuperscript{15}In his equations Courvoisier used $\theta$ as a symbol of sidereal time, but in this particular derivation we are following Harnack's notation in his paper “Zur Theorie des bewegten Spiegels” fn 14.
Figure 4: Courvoisier compared the direct measurement of the direction of a star with its direction observed by reflection on a mercury mirror.

Figure 5: Harnack’s diagram for analyzing the reflection of light in a moving mirror. The initial position of the mirror is $S$, and after a time $\Delta t$ its position is $S'$. $AA'$ is a wave front of the incident light beam, and $BB'$ is a wave front of the reflected beam.
In eqs. 4&5, the component of the speed of the mercury mirror in the direction perpendicular to the mirror (vector $Z$ in Fig.2), is $\beta$ (eq.2). Any motion of the mirror parallel to its surface would have no influence upon the direction of light. In the case of the mercury mirror, the relevant direction of the local vertical, and therefore $\beta$, here, has the same general meaning ascribed by Courvoisier to this symbol. Relative to the proper reference system of the mirror there is an aberration effect, and the angles of incidence ($z$) and reflection ($z'$) are:

$$z = \theta + \alpha \cos \theta + \beta \sin \theta.$$  \hfill (6)

$$z' = \theta' + \alpha \cos \theta' + \beta \sin \theta'.$$  \hfill (7)

where $\alpha$ is component of the velocity $v/c$ of the mirror parallel to its surface. Notice that this is the classical aberration effect. A relativistic analysis would lead to a different result. The measured effect is the difference between $z'$ and $z$:

$$z' - z = (\theta' - \theta) + \alpha (\cos \theta' - \cos \theta) + \beta (\sin \theta' - \sin \theta).$$  \hfill (8)

Taking into account the above equations and making suitable substitutions, one obtains the approximate result:

$$z' - z = 2 \alpha \beta \sin^2 z.$$  \hfill (9)

Replacing $\alpha$ and $\beta$ by their values in eqs.1&2, \(^{16}\) one obtains:

$$z' - z = \left[ (v/c)^2 \sin^2 z \right] \left[ \sin 2\phi \sin^2 D + \cos 2\phi \sin 2D \cos(\theta - A) - \sin 2\phi \cos^2 D \cos^2 (\theta - A) \right].$$  \hfill (10)

Notice that this equation contains a constant term and two periodic components with different periods — one sidereal day $[\cos(\theta - A)]$ and half a sidereal day $[\cos^2(\theta - A)]$. Therefore, from a suitable analysis of the data it should be possible to obtain the speed $(v/c)$, the declination $(D)$ and the right ascension $(A)$ of the motion of the Earth relative to the ether.

### E Repetition of the Leyden measurements

**E1** The Leyden measurements had used four stars close to the North Pole. The difference $z' - z$ was measured in a series of observations, at the times of upper and lower culmination of each star. The observed values of the periodic components of $z' - z$ amounted to less than 1”, varying from 0.04” for one of the stars to about 0.5” for another. The error of the measurements was estimated as 0.01”, therefore the effect was regarded as significant. From the Leyden data Courvoisier obtained the results:

$$A = 104^\circ \pm 21^\circ; D = +30^\circ \pm 27^\circ; v = 810 \pm 215 \text{ km/s}$$

The estimated error of the speed amounted to about 25%. The errors of the right ascension and declination amounted to about 1/15 of the full circle. Between 1921 and 1922 Courvoisier repeated the Leyden measurements, but with a slight change of method. Instead of a meridian circle he used a Wanschaff vertical circle that enabled him to make measurements of the stars at any time during the night. Therefore his measurements were not limited to two sidereal times for each star. From 4 June to 14 December 1921 he made a series of 142 measurements of the polar star BD +89.3°, and from 18 March to 23 May 1922 he made 64 further determinations of $z' - z$. From those measurements Courvoisier obtained:

\(^{16}\)From this point onward, $\theta$ is used again to represent sidereal time.

### F Courvoisier’s device for measuring the absolute speed of the earth

**F1** In the first method used by Courvoisier, the stars work as mere point-like light sources. There is nothing peculiarly “astronomical” in the observed effect because, according to Courvoisier’s theory, this was ascribed to the “principle of the moving mirror”. Therefore, similar effects should occur for terrestrial light sources, too. Accordingly, Courvoisier was led to build a new instrument: an optical device for measuring absolute motion (Fig.6).\(^{20}\) He used two small telescopes that were placed in an underground room where the


temperature was fairly constant. Both telescopes pointed obliquely (zenith distance \(= 60^\circ\)) to a mercury mirror that was placed between them. They were mounted in a vertical plane in the East-West direction. One of the telescopes had a small electric light close to its reticule, and this was the light source that was observed from the second telescope. Both telescopes were first adjusted so that it was possible to see the reflection of the illuminated reticule of the first telescope from the second telescope. They were then fastened in those directions. Of course, the angles of the telescopes with the local vertical were sensibly equal. The experiment did not try to measure any difference between those angles. It attempted to detect small periodic changes of the position of the image of the first telescope reticule as observed from the second one. The apparent motion of the reticule was measured with the aid of the ocular micrometer of the second telescope. Using this device, Courvoisier made two series of observations in 1926 and 1927. Afterwards, he had a special instrument built for this purpose, and made a third series of observations in 1932. In his first experiments the telescopes were placed in a vertical plane in the East-West direction. In 1926 and 1928 Courvoisier built two new instruments that could be rotated. He expected that this would improve his measurements. However, he found out that it was impossible to compare measurements when the device was rotated, due to mechanical problems, and the instruments could only be effectively used in a fixed position. The equation used to compute the effect was similar to that used in the case of the observation of stars, but instead of the North component of the speed, it was necessary to take into account the West component. As in the former case, the resulting equation has a constant term plus variable components with periods of one sidereal day and half sidereal day.

Figure 6: Courvoisier’s double telescope apparatus for measuring the motion of the Earth through the ether.
The first series of measurements (Table 1) was made from 31 July and 6 August 1926, with observations spanning between 3 and 20 o’clock sidereal time; the second one (Table 2), from 28 February to 29 May 1927, with observations covering the period from 21 to 13 o’clock sidereal time. Together, the two series comprised more than 500 measurements. Tables 1 and 2 show the mean results obtained by Courvoisier for each sidereal time.

From the first series, Courvoisier computed the following values:

\[ A = 70^\circ \pm 6^\circ; \quad D = +33^\circ \pm 11^\circ; \quad v = 493 \pm 54 \text{ km/s} \]

From the second series, he obtained the results:

\[ A = 22^\circ \pm 6^\circ; \quad D = +72^\circ \pm 11^\circ; \quad v = 606 \pm 45 \text{ km/s} \]

Of course, the results obtained from the second series of measurements seemed more reliable than those from the first series, and they exhibited a closer agreement with former measurements. Notice that, although those measurements attempted to detect the same kind of effects as the astronomical observations — that is, a difference between angle of incidence and angle of reflection in a moving mirror — the star observations used the North-South direction, and the cave experiments employed the East-West direction. The equations were different, but nevertheless Courvoisier obtained a nice agreement between the new device and the former results.
H The second method: Lorentz contraction

As described above, Courvoisier’s second attempt to measure the absolute velocity of the Earth was grounded upon his analysis of the Lorentz contraction of the Earth (Fig.9). In this case, Courvoisier supposed that the local vertical would undergo a change, due to the Lorentz contraction of the Earth, and this change would be observable as a periodic fluctuation in the angle between the North Pole and the zenith, as a function of the sidereal time.

Courvoisier’s theoretical analysis led him to predict that the variation $\Delta z$ of the zenith distance of a star close to the North Pole would obey the approximate relation:

$$\Delta z = \alpha \beta / 2$$  \hspace{1cm} (11)

There are some special observational difficulties in this second method. If it were possible to observe a star laying exactly in the direction of the celestial North Pole, the observation would be quite simple. However, if the star is not exactly in the direction of the pole, its zenith distance will depend on the sidereal time of the observation. This classical large effect would have, therefore, a period of one sidereal day and would interfere with any attempt to measure any influence due to the motion through the ether with a period of one sidereal day. Other interfering effects, such as temperature changes, vary with a period of about one solar day, and they are very large and irregular. For those reasons, Courvoisier gave up the attempt of finding the amplitude of the sidereal day effect, and only computed the half sidereal day effect. It was impossible, therefore, to find all parameters, and he assumed a value of 40° for the declination $D$, and computed the speed and right ascension $A$ of the motion of the Earth relative to the ether. Dropping out the component corresponding to the period of one sidereal day, he obtained the following equation:

$$\Delta z = -(v/c)^2 \sin 2\beta [\text{const.} - \cos^2 D \cdot \cos^2 (\theta - A)] / 4$$  \hspace{1cm} (12)

I Comparison between measurements from different places

I1 The effects predicted by Courvoisier as a consequence of the Lorentz contraction of the Earth should depend on the latitude of the observatory. For that reason, if the same set of stars was observed from two observatories at very different latitudes, there should exist a systematic difference between the measured declinations of the stars, as a
Figure 8: Esclangon’s coupled mirror device for measuring the motion of the Earth through the ether (upper diagram, above), and a graphical representation of his results (lower diagram, above), showing the observed angular fluctuations as a function of sidereal time.

Figure 9: According to Courvoisier, the Lorentz contraction of the Earth and of optical instruments could have a small observable influence on astronomical observations and terrestrial experiments.

Table 3: Difference between the declinations of a star ($D_1 - D_2$), observed from two distant observatories, as a function of sidereal time $\theta$.

<table>
<thead>
<tr>
<th>$\theta$</th>
<th>$D_1 - D_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>observed</td>
</tr>
<tr>
<td>0 h</td>
<td>+0.35“</td>
</tr>
<tr>
<td>1 h</td>
<td>+0.21“</td>
</tr>
<tr>
<td>2 h</td>
<td>+0.01“</td>
</tr>
<tr>
<td>3 h</td>
<td>−0.07“</td>
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<tr>
<td>4 h</td>
<td>−0.17“</td>
</tr>
<tr>
<td>5 h</td>
<td>+0.03“</td>
</tr>
<tr>
<td>6 h</td>
<td>+0.17“</td>
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<tr>
<td>7 h</td>
<td>−0.03“</td>
</tr>
<tr>
<td>8 h</td>
<td>+0.07“</td>
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<tr>
<td>9 h</td>
<td>+0.10”</td>
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<tr>
<td>10 h</td>
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<tr>
<td>11 h</td>
<td>+0.09”</td>
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<td>17 h</td>
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<tr>
<td>22 h</td>
<td>+0.26”</td>
</tr>
<tr>
<td>23 h</td>
<td>+0.38”</td>
</tr>
</tbody>
</table>

function of sidereal time. To test the existence of this effect, Courvoisier analyzed the catalogues containing measurements made at Heidelberg ($\phi_1 = 49.24^\circ$) and at Cape Town, South Africa ($\phi_2 = 33.48^\circ$). Let $D_1$ be the declination of some star measured from Heidelberg, and $D_2$ the declination of the same star measured from Cape of Good Hope. Each declination, according to Courvoisier’s analysis, undergoes a periodic change:

$$\Delta z_1 = \frac{\alpha_1 \beta_1}{2} \quad \Delta z_2 = \frac{\alpha_2 \beta_2}{2}$$

Those effects are not equal; therefore, the difference between the declinations measured at the two observatories should undergo a periodic change:

$$D_1 - D_2 = \frac{(\alpha_1 \beta_1 - \alpha_2 \beta_2)}{2}$$

Using the typical values $A = 75^\circ$ and $D = 40^\circ$ obtained in former measurements, and taking into account the latitudes of Heidelberg and Cape Town, Courvoisier predicted that there should exist a difference between the measured declinations of the stars that should depend on their right ascension $A$:

$$D_1 - D_2 = +0.16'' - 0.18'' \cos(A - 5^h) - 0.16'' \cos 2(A - 5^h)$$
The amplitude was obtained by comparing the astronomical data of the two observatories, and led to $v = 750$ km/s. Table 3 contains Courvoisier’s comparison between the observed and (column 3) predicted values of $D_1 - D_2$. The second column of the table presented the observed values corrected for null declination, in order to avoid classical errors due to atmospheric refraction, etc. There is a better agreement between the theoretical prediction and the corrected values than with the raw data.

J Nadir observations

In his analysis of the second method, Courvoisier assumed that the Lorentz contraction of the Earth produces a local periodic change of the direction of the gravitational field. This effect was not compensated by changes in the direction of the astronomical instruments. Therefore, he led to think that the effect could also be detected in an experiment using a terrestrial light source.

He placed a mercury mirror directly below the observational meridian circle and pointed the telescope downward. The instrument was then delicately adjusted in such a way that it was possible to observe the reflected image of the micrometer threads superimposed to the real threads. The position of the telescope was locked, and observations were made of the relative displacement of the micrometer thread and its image. He predicted the following deflection in the East-West direction:

$$\Delta z = - (v/c)^2 \left[ \sin \phi \sin 2D \sin (\theta - A) + \cos \phi \cos^2 D \sin 2(\theta - A) \right] / 4$$

Courvoisier made two series of observations: 22-24 October and 22-25 November 1922. He noticed that temperature changes affected the position of the telescope, and that this influence had to be taken into account. From the uncorrected observed measurements he computed the following values:

$$A = 74^0 \pm 10^0; \quad D = +67^0 \pm 13^0; \quad v = 920 \pm 73 \text{ km/s}$$

Applying a temperature correction, he obtained the following results:

$$A = 98^0 \pm 7^0; \quad D = +25^0 \pm 11^0; \quad v = 500 \pm 47 \text{ km/s}$$

This experiment was repeated by August Kopff, of the Heidelberg observatory, from 10 to 29 June 1923. As in the case of Courvoisier’s experiment, there was a strong effect due to temperature changes (temperature varied between +6°C and +17°C). Courvoisier analyzed Kopff’s data assuming the values $A = 75^0$ and $D = +40^0$. After applying temperature corrections, he obtained a speed of 753 ± 57 km/s.

K Other methods

Courvoisier also attempted to detect the motion of the Earth relative to the ether by other methods. He regarded the positive result of the nadir observation method as a confirmation of his hypothesis that the Lorentz contraction produced an observable periodic change of the local vertical. He soon devised other ways of observing such an effect.

One of the instruments he used was a plumb line attached to one of the columns of the Babelsberg observatory. The main body of the plumb line was a metallic rod, 95 cm long. At its lower end there was a mark that was illuminated and projected upon a wall. It was possible to observe deflections of about 0.05° of the direction of the plumb line, in the East-West direction. Measurements made in 1925 with this instrument led to a speed of the Earth of about 400 km/s, assuming $A = 75^0$ and $D = +40^0$. In 1931 Courvoisier improved this instrument observing the motion of its tip with the aid of a microscope (Fig.10). Now he was able to compute the three parameters of the Earth’s motion, obtaining:

$$A = 64^0 \pm 6^0; \quad D = +50^0 \pm 9^0; \quad v = 367 \pm 29 \text{ km/s}$$

Similar observations were made by Esclangon, with the help of André-Louis Danjon, using two horizontal pendulums with perpendicular motions.\(^{23}\) One of the pendulums led to $A = 69^0$; for the second pendulum, $A = 52^0$. Esclangon did not provide other information and did not attempt to compute the speed of the Earth.

Another way of observing the variation of the local vertical direction, according to Courvoisier, was with the aid of bubble levels.\(^{25}\) He used two very sensitive level meters. One of them was attached to the floor of the Babelsberg underground clock room, and the other one was attached in a horizontal position to one of the columns of the same room. Courvoisier measured the difference between the marks of the two level meters. The maximum predicted effect was about 0.30°, and with the delicate instruments used by Courvoisier it was possible to measure angular changes as small as 0.03°. In the first series of measurements between 15 and 26 June 1929; Courvoisier obtained the following results:

$$A = 59^0 \pm 6^0; \quad D = +51^0 \pm 9^0; \quad v = 446 \pm 34 \text{ km/s}$$

Courvoisier’s analysis of Wanach’s data led to the confirmation of his hypothesis that the Lorentz contraction produced an observable periodic change of the local value of gravity as a function of sidereal time. Pendulum clocks at different places of the Earth should show slightly different readings, and their phases should exhibit a periodic relative fluctuation. Courvoisier analyzed data on pendulum clocks of different astronomical observatories, in an attempt to detect this effect.

Using radio signals it was possible to compare the rates of clocks at very distant observatories. The Annapolis observatory emitted regular time signals from its pendulum clocks. It was possible to compare the rate of those pendulums to those at another place. Courvoisier asked the help of Bernhard Wanach, from Potsdam, who compared the rate of the pendulum clocks of that observatory to the signals received from Annapolis, from September 1921 to November 1922.\(^{26}\) Courvoisier’s analysis of Wanach’s data led to the following results:

$$A = 56^0 \pm 12^0; \quad D = +40^0 \text{ (estimated)}; \quad v = 873 \pm 228 \text{ km/s}$$

Afterwards, a comparison was made using a comparison between the clocks of Annapolis, Potsdam, Ottawa, and Bordeaux. The mean result obtained by Courvoisier was:

$$A = 81^0 \pm 5^0; \quad D = +34^0 \pm 5^0; \quad v = 650 \pm 50 \text{ km/s}$$

Much later, Courvoisier presented another confirmation of this effect. He compared the catalogues of time correction of the observatories of Greenwich, Potsdam, Buenos Aires and Mount Stromlo for the period from 1948 to 1954.\(^{27}\) There was a nice agreement between the theoretical predictions and the observed time differences, especially in the case of the years 1951-1954.

\(^{26}\) Leopold Courvoisier, ‘Der Einfluss der ‘Lorentz-Kontraktion’ der Erde auf den Gang der Quarzuhren’, Experientia, ix (1953), 286-7; xii (1957), 234-5.
Local comparison between pendulum clock and chronometer. Courvoisier supposed that the rate of pendulum clocks would vary because of the periodic gravity changes, but mechanical chronometers should not suffer similar changes. Therefore it should be possible to observe effects due to the absolute motion of the Earth comparing pendulum clocks to mechanical chronometers at a single place. Comparisons were made both at Babelsberg and at Potsdam (with the help of Wanach). In his analysis, Courvoisier assumed the value $D = +40^\circ$ and obtained $A = 104^\circ \pm 9^\circ$ and $v = 750 \text{ km/s}$.

Gravimetric observations. If the Lorentz contraction of the Earth produces gravitational effects, then it should be possible to find its influence on the tides. Esclangon analyzed a set of 166,500 tide measurements, made at Pola, on the Adriatic sea, from 1898 to 1916. He obtained a term with the period of one sidereal day, that could not be associated with the Sun or the Moon, and ascribed it to a “dissymmetry of space”. 28 This tidal effect could be described as

$$48 \text{ mm} \cos(\theta - 146.1^\circ) + 25 \text{ mm} \cos(\theta - 244.6^\circ)$$  \hspace{1cm} (17)

If the local gravity undergoes periodic changes, it should be possible to detect this effect with sensitive gravimeters. In 1927 Courvoisier (with the help of Sergei Gaposchkin) attempted for the first time to measure gravity variations using a very sensitive torsion gravimeter. 29 The instrument could detect a change $\Delta g/g$ of $3 \times 10^{-6}$, corresponding to a displacement of 0.2 mm of the gravimeter pointer. From a series of measurements undertaken from 1927 to 1928 Courvoisier computed the following values:

$$A = 62^\circ \pm 5^\circ; D = +32^\circ \pm 8^\circ; v = 543 \pm 55 \text{ km/s}$$

In 1932 Courvoisier obtained new results, taking into account in this new paper some effects due to temperature and humidity. The new results obtained by him were

$$A = 50^\circ \pm 7^\circ; D = +45^\circ \pm 18^\circ; v = 498 \pm 78 \text{ km/s}$$

For the first time, Courvoisier’s results were criticized and checked. In 1932, Rudolf Tomaschek and Walter Schaffernicht reported gravity measurements made with a new kind of gravimeter that was able to detect changes $\Delta g/g$ of $10^{-8}$. The instrument was placed inside a cave in a mountain, where the temperature was constant to 0.001°C. No effect of the order of magnitude predicted by Courvoisier was observed. 30

Eclipses of Jupiter’s satellites. It is well known that in 1879 James Clerk Maxwell wrote to David Peck Todd asking him about the possibility of computing the velocity of the solar system through the ether using available data on occultations of Jupiter’s satellites. 31 Maxwell supposed that the motion of the solar system would produce an anisotropy of the speed of light that could be detected as a fluctuation of the times of occultation of Jupiter’s satellites, observed from the Earth, with a period of about 12 years. Todd answered, however, that the measurements available at that time were not precise enough for such computations.

In 1930 Courvoisier published a paper where he presented an analysis of available observations of Jupiter’s satellites and claimed that they led to a new determination of the velocity of the solar system relative to the ether. He used data relative to the three inner Galilean satellites published by the Johannesburg observatory (1908-1926), comparing those measurements to those of the observatories of Cape Town, Greenwich and Leyden (1913-1924). He confirmed Maxwell’s anticipation of a fluctuation with a period of about 12 years and obtained the following results:

\[ A = 126^0 \pm 10^0; D = +20^0; v = 885 \pm 100 \text{ km/s} \]

Courvoisier’s measurements of the absolute velocity of the Earth belong to the same group of Dayton Miller’s and Ernest Esclangon’s works. However, Courvoisier’s work embodied a much wider and more impressive group of measurements than those of his contemporaries. Courvoisier measured the velocity of the Earth relative to the ether using several different methods. The effects he was searching for were very small (second order in \( v/c \)), but the results presented were significantly larger than the estimated experimental error. The measured values of the right ascension of the Earth’s motion apex varied from 52° to 126°, with a strong concentration of values between 60° and 90°. The measured declination varied between +27° and +55°, most values falling between +34° and +46°. The values obtained for the speed of the Earth varied between 300 km/s and 927 km/s, most results falling between 500 km/s and 810 km/s. What impact did Courvoisier’s work have? His researches were seldom cited. Miller and Esclangon did refer to some of his researches, because they were also reporting positive effects ascribed to the motion of the Earth through the ether. Besides those citations, there were just a few other references. General Gerold von Gleich, a well-known anti-relativist, did refer to Courvoisier’s results in two papers. In a short note, von Gleich mentioned fluctuations of the aberration constant that could be an indirect confirmation of Courvoisier’s results. In a second paper, von Gleich presented several independent confirmations of Courvoisier’s measurements of the motion of the solar system. He reported that Carl Wilhelm Wirtz and Gustaf Strömbarg had evaluated this motion analyzing the velocities of spiral nebulae, obtaining speeds compatible with Courvoisier’s results (from 630 to 820 km/s) and directions roughly compatible with his. He also described his own analysis of the fluctuation of the aberration constant, and the analysis of circumpolar stars, as compatible with Courvoisier’s results. His conclusion was:

Personally, I have no doubt that the works of Mr Courvoisier, especially those on the fluctuations of the constant of aberration and those on the light speed (Jupiter’s moons) prove the existence of an absolute translation of our local star system with a speed of about 600 km/s towards a point close to the ecliptic, with a longitude of about 110°... Therefore, the foundations of special relativity theory are completely shattered by astronomical means.

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34 There is a detailed historical study of Miller’s work: Lloyd S. Swenson, Jr., The ethereal aether. A history of the Michelson-Morley-Miller aether-drift experiments, 1880-1930 (Austin, 1972).
39 Von Gleich, “Translation des Fixsternsystems und Aberrationskonstante” (fn 37) 278.
L2 Few astronomers and physicists of that time agreed with this opinion, however. Courvoisier’s researches were neither accepted, nor criticized — they were just ignored by most scientists. Notice also that Courvoisier was a professional astronomer, and his routine measurements were always accepted and used without further questioning. Why did the scientific community ignore Courvoisier’s anti-relativistic results? Several factors may have contributed to that attitude:

1. In the 1920s Einstein’s theory had been successfully confirmed and most physicists and astronomers were convinced that it was the correct theory. Attempts to bring the ether again to life seemed too old-fashioned and most scientists would not be willing to hear or to read about such attempts.40

2. Many of Courvoisier’s papers were published in the Astronomische Nachrichten, a journal that was clearly opposed to Einstein’s theory. Most scientists supporting the theory of relativity would dismiss any anti-relativistic account published in that journal.41

3. Courvoisier did not build a comprehensive theory that could be regarded as an alternative to the theory of relativity. He used a strange combination of classical physics together with the hypothesis of Lorentz contraction, and never published a detailed derivation of his equations.42

4. The observed effects were very small (usually a few arc-second tenths) and there were always large relative fluctuations of the measurements. Any single measurement published by Courvoisier could be regarded as the result of random or unknown systematic errors. The agreement between different measurements could be regarded as due to chance, or to a process of “cooking” the results. Notice, however, that several of Courvoisier’s computations were grounded upon published data obtained by other observers. Whenever Courvoisier himself made the observations, he published the data used for his computations. Anyone wishing to check his calculations could have used the available data to do so. It was not too difficult to repeat some of his observations.43 It is difficult to understand why the physicists and astronomers of that time did not care to do that.

L3 Some historical circumstances may explain, in part, the neglect of Courvoisier’s researches. After the end of World War I there was a strong opposition, in Germany, to Einstein and relativity theory.44 Everything that could be used against the theory of relativity was used — from serious scientific arguments to empty rhetoric. In this historical context, one could think that Courvoisier’s work was just a biased piece of anti-Einstein propaganda, and had no scientific value. One might think that he was not an honest scientist: perhaps he falsified his data, described experiments he never made, “cooked” his results, and so on. Or maybe he was a careless scientist and just observed what he wanted to observe.

L4 It is therefore relevant to elucidate that Courvoisier did not belong to the strong anti-relativist and anti-Einstein group of the early 1920s. He was never personally associated with Philipp Lenard and Ernst Gehrcke, for instance. His name was not included in the 1931 publication Hundert Autoren gegen Einstein.45 Instead of irrationally opposing Einstein, he met him and exchanged letters with him for several years without reaching any agreement, but adopting a scientific attitude.46 Notice, also, that Courvoisier never cited the anti-Einstein scientists. Another relevant piece of information concerns Courvoisier’s political viewpoint.47 He was strongly opposed to national socialism, and spoke about Nazis in a negative tone. He always kept his Swiss citizenship, and this helped him to keep out of the political turmoil that was going on around him. In 1943, during World War II, he obtained permission to spend his summer vacations in Switzerland with his family, and never returned to Germany. When the war was over, the Babelsberg observatory and the house belonging to Courvoisier (built close to the observatory) became part of East Berlin. He preferred to remain in Switzerland, but suffered many difficulties, because his pension (he had retired in 1938) was not paid anymore. He lived for several years thanks to a Swiss social insurance, and to the payment he received for the edition of Euler’s works. About ten years after the end of the war, West Germany began to pay his pension again.

L5 According to Courvoisier’s daughter, “He was convinced that he had found something that was true. He was convinced that this truth would find its way in the long run”.48 Leopold Courvoisier produced his research, published his data and conclusions, and expected some positive response, but he never tried hard enough to publicise his results and to convince other people that he had obtained very important results. It seems that he kept a low profile, and never attempted to join other researchers who had also obtained similar results (such as Miller or Esclangon) to produce an anti-relativist front.

L6 Since this is the first study of Courvoisier’s researches on the motion of the Earth through the ether, there is much more work to be done. It is desirable to plunge deeper into the scientific and extra-scientific features of this puzzling historical episode.

40This was also the main reason why Quirino Majorana’s measurements of the absorption of gravitation in 1907-1938 were dismissed by the scientific community. See Roberto de Andrade Martins, “The search for gravitational absorption in the early 20th century”, in H. Goemmer, J. Renn, and J. Ritter (eds.) The expanding worlds of general relativity (Boston, 1999), 3-44.

41The editor of Astronomische Nachrichten from 1907 to 1938 was Hermann Kobold, who supported the publication of anti-Einstein and anti-relativistic papers, regardless of their scientific merit. This journal published, for instance, the works of Thomas Jefferson Jackson See, that were not accepted in any other journal. Cf. Thomas J. Sherrill, “A career of controversy: the anomaly of T. J. J. See”, Journal for the history of astronomy, xxx (1999), 25-50.

42Notice that Courvoisier’s work was incompatible with Lorentz’s mature ether theory, which incorporated the principle of relativity.

43Nowadays, it would be possible to check the reality of Courvoisier’s effects using more precise routine experimental data available, and using better (computer) numerical methods. Several of his experiments could also be repeated using automatic instruments with a higher precision and in improved controlled conditions.


45Cf. Goenner, “The reaction to relativity theory in Germany III. Hundred authors against Einstein” (fn 44), 273.


47Some personal information presented here concerning Leopold Courvoisier was obtained in an interview with his daughter Rosemarie and her husband Dietrich Ritschl, in Basel, on 31 August 1999.

48Rosemarie Ritschl (fn 47).
M Acknowledgements

I am grateful to the State of São Paulo Research Foundation (FAPESP) and to the Brazilian National Council for Scientific and Technological Development (CNPq) for supporting this research. I am grateful to Dr. Istvan Domsa who helped me to obtain Courvoisier’s portrait, and to Prof. Wolfgang Dick for valuable suggestions and bibliographical help concerning this work. I am also very grateful to Mrs. Rosemarie Ritschl and Prof. Dietrich Ritschl, who kindly provided valuable personal information about Leopold Courvoisier.
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