A Fresh Science-History Journal: Cost-Free to Major Libraries

DIO

Tel 410-889-1414 **dioi@mail.com**

***DIO* — *The International Journal of Scientific History*.**
Deeply funded. Mail costs fully covered. No page charges. Offprints free.

- Since 1991 inception, has gone without fee to leading scholars & libraries.
- Contributors include world authorities in their respective fields, experts at, e.g., Johns Hopkins University, Cal Tech, Cambridge University, University of London.
- Publisher & journal cited (1996 May 9) in *New York Times* p.1 analysis of his discovery of data exploding Richard Byrd's 1926 North Pole fraud. [*DIO* vol.4.] Full report co-published by University of Cambridge (2000) and *DIO* [vol.10], triggering *History Channel* 2000&2001 recognition of Amundsen's double pole-priority. New photographic proof ending Mt.McKinley fake [*DIO* vol.7]: cited basis of 1998/11/26 *New York Times* p.1 announcement. *Nature* 2000/11/16 cover article pyramid-orientation theory: *DIO*-corrected-recomputed, *Nature* 2001/8/16. Vindicating DR longtime Neptune-affair charges of planet-theft and file-theft: *Scientific American* 2004 December credits *DIO* [vols.2-9]. *DIO*-opposites mentality explored: *NYTimes* Science 2009/9/8 [nytimes.com/tierneylab].
- Journal is published primarily for universities' and scientific institutions' collections; among subscribers by request are libraries at: US Naval Observatory, Cal Tech, Cornell, Johns Hopkins, Oxford & Cambridge, Royal Astronomical Society, British Museum, Royal Observatory (Scotland), the Russian State Library, the International Centre for Theoretical Physics (Trieste), and the universities of Chicago, Toronto, London, Munich, Göttingen, Copenhagen, Stockholm, Tartu, Amsterdam, Liège, Ljubljana, Bologna, Canterbury (NZ).
- New findings on ancient heliocentrists, pre-Hipparchos precession, Mayan eclipse math, Columbus' landfall, Comet Halley apparitions, Peary's fictional Crocker Land.
- Entire *DIO* vol.3 devoted to 1st critical edition of Tycho's legendary 1004-star catalog.
- Investigations of science hoaxes of the -1^{st}, $+2^{\text{nd}}$, 16^{th}, 19^{th}, and 20^{th} centuries.

Paul Forman (History of Physics, Smithsonian Institution): "*DIO* is delightful!"

E. Myles Standish (prime creator of the solar, lunar, & planetary ephemerides for the pre-eminent annual *Astronomical Almanac* of the US Naval Observatory & Royal Greenwich Observatory; recent Chair of American Astronomical Society's Division on Dynamical Astronomy): "a truly intriguing forum, dealing with a variety of subjects, presented often with [its] unique brand of humor, but always with strict adherence to a rigid code of scientific ethics. . . . [and] without pre-conceived biases . . . . [an] ambitious and valuable journal."

B. L. van der Waerden (world-renowned University of Zürich mathematician), on *DIO*'s demonstration that Babylonian tablet BM 55555 (100 BC) used Greek data: "*marvellous*." (Explicitly due to this theory, BM 55555 has gone on permanent British Museum display.)

Rob't Headland (Scott Polar Research Institute, Cambridge University): Byrd's 1926 latitude-exaggeration has long been suspected, but *DIO*'s 1996 find "has clinched it."

Hugh Thurston (MA, PhD mathematics, Cambridge University; author of highly acclaimed *Early Astronomy*, Springer-Verlag 1994): "*DIO* is fascinating. With . . . mathematical competence, . . . judicious historical perspective, [&] inductive ingenuity, . . . [*DIO*] has solved . . . problems in early astronomy that have resisted attack for centuries . . . ."

Annals of Science (1996 July), reviewing *DIO* vol.3 (Tycho star catalog): "a thorough work . . . . extensive [least-squares] error analysis . . . demonstrates [Tycho star-position] accuracy . . . much better than is generally assumed . . . . excellent investigation".

British Society for the History of Mathematics (*Newsletter* 1993 Spring): "fearless . . . . [on] the operation of structures of [academic] power & influence . . . much recommended to [readers] bored with . . . the more prominent public journals, or open to the possibility of scholars being motivated by other considerations than the pursuit of objective truth."

Vol. 17 **2011 December** ISSN 1041-5440

DIO

The International Journal of Scientific History

Searching for the Ether

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

NOTICE:

Libraries will always receive the printed version of DIO in order to assure archiving.

But the principal delivery method of DIO and all back issues for individual subscribers is henceforth through the free-access DIO website at www.dioi.org. Web-compatible DIO issues are found at the subdirectory www.dioi.org/vols.

Printed copies of DIO issues for individuals will, however, be mailed upon request. (Just send a note or phone or email the publisher.) However, notice that, from the subdirectory www.dioi.org/bk, anyone may download booklet-compatible PDFs of DIO issues, and have them printed and stapled for trivial cost at a photocopy shop.

Both web and booklet versions are conveniently accessible via the indices at www.dioi.org homepage.

DIO

DIO: The International Journal of Scientific History [www.dioi.org] is published by *DIO*, Box 19935, Baltimore, MD 21211-0935, USA.
Telephone (answering machine always on): 410-889-1414.
[Email: dioi@mail.com]

Research & university libraries may request permanent free subscription to *DIO*.
Each issue of *DIO* will be printed on paper which is certified acid-free. The ink isn't.

Editor[2006-2012]: Dennis Duke, FSU. Publisher: Dennis Rawlins (DR), address above.

DIO is primarily a journal of scientific history & principle. However, high scholarship and-or original analytical writing (not necessarily scientific or historical), from any quarter or faction, will be gladly received and considered for publication. Each author has final editorial say over his own article. If refereeing occurs, the usual handsome-journal anonymity will not, unless in reverse. No page charges.

The circumstance that most *DIO* articles are written by scholars of international repute need not discourage other potential authors, since one of *DIO*'s purposes is the discovery & launching of fresh scholarly talent. Except for equity&charity reply-space material, submissions will be evaluated without regard to the writer's status or identity. We welcome papers too original, intelligent, and-or blunt for certain handsome journals. (Dissent & controversy are *per se* obviously no bar to consideration for *DIO* publication; but, please: spare us the creationist-level junk. I.e., non-establishment cranks need not apply.)

Other journals may reprint excerpts (edited or no) from any issue of *DIO* to date, whether for enlightenment or criticism or both. Indeed, excepting *DIO* vols.3&5, other journals may entirely republish *DIO* articles (preferably after open, nonanonymous refereeing), so long as *DIO*'s name, address, & phone # are printed adjacent to the published material — and to all comments thereon (then *or later*), noting that said commentary may well be first replied to (if reply occurs at all) in *DIO*'s pages, not the quoting journal's.

DIO invites communication of readers' comments, analyses, attacks, and-or advice.

Written contributions are especially encouraged for the columns: Unpublished Letters, Referees Refereed, and regular Correspondence (incl. free errtime for opponents). Contributor-anonymity granted on request. (Though, most unattributed text is DR's.) Deftly or daftly crafted reports, on apt candidates for recognition in our occasional satirical *J. for Hysterical Astronomy* will of course also be considered for publication.

Free spirits will presumably be pleased (and certain archons will not be surprised) to learn that: at *DIO*, there is not the slightest fixed standard for writing style.

Contributors should send (expendable photocopies of) papers to one of the following *DIO* referees — and then inquire of him by phone in 40 days:

 ISSN 1041-5440. This printing: 2015\4\20.
Pages 2-38 first linked 2009/11/30; pp.39-46, 12/18.

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.

Searching for the Ether

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

by ROBERTO DE ANDRADE MARTINS
Physics Department, State University of Paraiba (UEPB), Brazil
roberto.andrade.martins@gmail.com

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).[1] 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 Valentiner. In 1900 he obtained his Doctorate degree in Straßburg. 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.

astronomical observer, under the direction of Karl Hermann Struve. In 1913 the Berlin observatory moved to its new site, in Babelsberg,[2] and one year later Courvoisier became its chief observer and professor. He worked at Babelsberg up to his retirement in 1938, when he was 65 years old. In 1943 he moved to his birthplace, where he kept making observations and publishing papers up to his death. Back in Switzerland, he was the editor of several of Leonhard Euler's astronomical works.

B3 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.[3] 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.

B4 Coursoisier 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.

B5 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.

B6 Historians of science have also neglected those researches,[4] 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

C1 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,

[2] The history of the Berlin/Babelsberg observatory is described in Julius Dick, "The 250th anniversary of the Berlin observatory", Popular astronomy, lix (1951), 524-35.

[3] Paul Weinmeister (ed.). J. C. Poggendorff's biographisch-literarisches Handwörterbuch für Mathematik, Astronomie, Physik, Chemie und verwandte Wissenschaftgebiete (1904 bis 1922), vol. 5 (Leipzig, 1926); Hans Stobbe (ed.), J. C. Poggendorff's biographisch-literarisches Handwörterbuch für Mathematik, Astronomie, Physik mit Geophysik, Chemie, Kristallographie und verwandte Wissenschaftgebiete (1923 bis 1931), vol. 6 (Leipzig, 1936-1938); Rudolph Zaunick and Hans Salié (eds.), J. C. Poggendorff biographisch-literarisches Handwörterbuch der exakten Wissenschaften (1932 bis 1953), vol. 7 (Berlin, 1956-1962).

[4] Klaus Hentschel studied some of Courvoisier's works but he did not analyse the researches described in this paper. See Klaus Hentschel, "Freundlich, Erwin, Finlay and testing Einstein's theory of relativity", Archive for history of exact sciences, xlvii (1994), 143-201; Klaus Hentschel, The Einstein tower. An intertexture of dynamic construction, relativity theory, and astronomy (Stanford, 1997).

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.

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

[46] Courvoisier met Einstein in January 1924 and corresponded with him until October 1928, with no agreement being reached. Cf. Klaus Hentschel, "Einstein's attitude towards experiments", Studies in history and philosophy of science, xxiii (1992) 593-624, p. 613.

[47] Some 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.

[48] Rosemarie Ritschl (fn 47).

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-relativist 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

[40] This was also the main reason why Quirino Majorana's measurements of the absorption of gravitation and Kurt Bottlinger's explanation of the anomalies of the motion of the moon using the same assumption 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.

[41] The 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.

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

[43] Nowadays, 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.

[44] David E. Rowe, "Einstein's allies and enemies: debating relativity in Germany, 1916-1920", in Vincent F. Hendricks, et. al. (eds.), Interactions: mathematics, physics and philosophy, 1860-1930 (Dordrecht, 2006), 231-280; Hubert Goenner, "The reaction to relativity theory I: the anti-Einstein campaign in Germany in 1920", Science in context, vi (1993), 107-33; idem, "The reaction to relativity theory in Germany III. Hundred authors against Einstein", Einstein studies, v (1993), 248-73.

Figure 1: Leopold Courvoisier (about 30 years old). Portrait painted by Alexander Perandin Moreira, from a photo published in Carl V. Charlier and Folke Engström (eds.), Porträtgallerie der astronomischen Gesellschaft (Stockholm, 1904), 17.

he called it "annual refraction". His first work on the subject was published in 1905,[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.[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".[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.[8] According to Courvoisier's own declaration, his early calculations concerning the motion of the Earth were an outcome of routine work.[9] 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 $10^{-4}\ c$ (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

[5] Leopold Courvoisier, "Kinemara's Phänomen und die 'jährliche Refraktion' der Fixsterne", Astronomische Nachrichten, clxvii (1905), 81-106.

[6] Hentschel, The Einstein tower (fn 4), 10-11.

[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.

[8] Leopold Courvoisier, "Zur Frage der Mitführung des Lichtäthers durch die Erde", Astronomische Nachrichten, ccxiii (1921), 281-8; idem, "Über astronomische Methoden zur Prüfung der Lichtätherhypothese", Astronomische Nachrichten, ccxiv (1921), 33-36.

[9] Leopold Courvoisier, "Ergebnisse von Beobachtungen und Versuchen zur Bestimmung der 'absoluten' Erdbewegung", Scientia, xlvii (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.

L Final comments

L1 Courvoisier's measurements of the absolute velocity of the Earth belong to the same group of Dayton Miller's and Ernest Esclangon's works.[34] 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,[35] 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.[36] In a second paper, von Gleich presented several independent confirmations of Courvoisier's measurements of the motion of the solar system.[37] He reported that Carl Wilhelm Wirtz and Gustaf Strömberg had evaluated this motion analyzing the velocities of spiral nebulae, obtaining speeds compatible with Couvoisier's results (from 630 to 820 km/s) and directions roughly compatible with his.[38] 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.[39]

[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).

[35] 36 Joseph Wodetsky, "Gerold von Gleich", Astronomische Nachrichten, cclxvi (1938), 63-4.

[36] Gerold von Gleich, "Translation des Fixsternsystems und Aberrationskonstante", Astronomische Nachrichten, ccxli (1931), 201-02.

[37] Gerold von Gleich, "Bemerkung zur absoluten Translation unseres lokalen Fixsternsystems", Astronomische Nachrichten, ccxlii (1931), 273-8.

[38] Carl Wilhelm Wirtz, "Einiges zur Statistik der Radialbewegungen von Spiralnebeln und Kugelsternhaufen", Astronomische Nachrichten, ccxv (1922), 349-54; idem, "Die Trift der Nebelflecke", Astronomische Nachrichten, cciii (1916), 197-220; idem, "Über die Eigenbewegungen der Nebelflecke", Astronomische Nachrichten, cciv (1917), 23-30; Gustaf Strömberg, "Analysis of radial velocities of globular clusters and non-galactic nebulae", Astrophysical journal, lx (1925), 353-62.

[39] Von Gleich, "Translation des Fixsternsystems und Aberrationskonstante" (fn 37) 278.

K10 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.[32] 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:

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

K11 Secular aberration of light. According to the theory of ether accepted by Courvoisier, the speed of light is constant relative to the ether, but could not be constant relative to the Earth: there should be an observable anisotropy of the speed of light due to the absolute motion of the Earth. He assumed that this would produce an observable difference in measurements of stellar aberration observed in different directions.[33] Using the available data, Courvoisier obtained the following results:

$$A = 112^\circ \pm 20^\circ; D = +47^\circ \pm 20^\circ; v = 600 \pm 305 \text{ km/s}$$

[32]Leopold Courvoisier, "Ableitung der 'absoluten' Erdbewegung aus beobachteten Längen der Jupiter-Satelliten", Astronomische Nachrichten, ccxxxix (1930), 33-38.

[33]Leopold Courvoisier, "Bestimmung der absoluten Translation der Erde aus der säkularen Aberration", Astronomische Nachrichten, ccxli (1932), 201-12.

effect. For the stars listed in the Leyden catalogue, he computed the difference $z - z'$ between the direct zenith distance z and the reflected zenith distance z', attempting to find a systematic effect that varied in a periodic way with the sidereal time of observations. Using a graphical method, he did find such an effect, and then he submitted the data to quantitative analysis. He derived an equation to describe the reflection of light in a moving mirror and determined the relevant parameters from an analysis of the Leyden data, using the method of least squares. He obtained an effect corresponding to a speed of about 800 km/s in the direction of the Auriga constellation. This speed is, of course, much larger than the orbital speed of the Earth. Courvoisier interpreted it as due to the motion of the whole solar system through the ether. A few years later, Courvoisier obtained new data, using the same method (direct versus reflected direction). Using the vertical circle of the Babelsberg observatory, he made a long series of observations (1921-1922) that led to results similar to those that had been obtained from the Leyden observations.

C4 After obtaining his first positive result, Courvoisier attempted to find other independent methods of measuring the speed of the Earth (or the solar system) relative to the ether. He conjectured that the Lorentz contraction of the Earth and of optical instruments could have some small observable influence on astronomical observations. According to Courvoisier, the motion of the Earth relative to the ether produces a contraction that transforms its spherical shape into an ellipsoid with the smaller axis in the direction of its motion (Fig.9). The surface of the ellipsoid, at each point, was supposed to be perpendicular to the local gravitational field. As the Earth rotates, each place on the surface of the Earth passes through different points of the mean ellipsoid, and the angle between the axis of the Earth and the local vertical direction should undergo a periodic change. Of course, it is impossible directly to measure the angle between the local vertical and the axis of rotation of the Earth. However, since the direction of this axis is fairly constant relative to the fixed stars (for short time periods), it is possible to choose a star very close to the North celestial pole and to measure its zenith distance. This angle, according to Courvoisier's theory, should undergo a periodic change, as a function of the sidereal time.

C5 As a matter of fact, Courvoisier had already measured the position of a star very close to the North pole, in a long series of observations from 1914 to 1917, using the Babelsberg observatory vertical circle.[10] Those measurements were very accurate and were evenly distributed as regards the sidereal time of the observations. They were therefore suitable for looking for the influence of the Lorentz contraction on astronomical measurements.

C6 As in the former case, Courvoisier first plotted the zenith distances of the star against sidereal time, and found a regular fluctuation of the angle. He then developed an equation to account for the effect, analyzed the data using the least squares method, and obtained his second measurement of the velocity of the Earth relative to the ether. The speed obtained in this case was about 700 km/s, in the direction of the constellation of Perseus (not very far from Auriga). Courvoisier regarded the agreement of those two earliest results as satisfactory, and this led him to further researches. There was a delay of 5 years between Courvoisier's first positive results and his next publication on the subject.[11] In this period he accumulated a series of positive results by different methods, obtained the equations required for the analysis of his data, and devised new methods for measuring the absolute speed of the Earth. The delay shows he was careful enough to resist publishing preliminary results before he was able to amass a large amount of evidence for his claim.

[10]Leopold Courvoisier, "Zenitdistanzbeobachtungen der Polarissima am Vertikalkreise der Sternwarte Berlin-Babelsberg", Astronomische Nachrichten, ccviii (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: Ramachrisna Teixeira and Paulo Benevides Soares, "Absolute azimuth determination", Astronomy and astrophysics, clxv (1986), 251-3.

[11] Leopold Courvoisier, "Bestimmungsversuche der Erdbewegung relativ zum Lichtäther", Astronomische Nachrichten, ccxxvi (1925), 241-64.

D The method of the moving mirror

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

$c =$ the speed of light relative to the ether = 300,000 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:

$$\alpha = (v/c)[\cos\phi \sin D - \sin\phi \cos D \cos(\theta - A)] \tag{1}$$

$$\beta = (v/c)[\sin\phi \sin D + \cos\phi \cos D \cos(\theta - A)] \tag{2}$$

$$\gamma = -(v/c) \cos D \sin(\theta - A) \tag{3}$$

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,[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).

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 θ be the angle of incidence and θ' the angle of reflection of a light ray in a moving mirror, measured relative to the ether (Fig.5).[15] According to Harnack's analysis, instead of $\theta = \theta'$ the following equations would hold:

$$\sin\theta' = (1 - \beta^2)\sin\theta/(1 + 2\beta\cos\theta + \beta^2) \tag{4}$$

$$\cos\theta' = [(1 + \beta^2)\cos\theta + 2\beta]/(1 + 2\beta\cos\theta + \beta^2) \tag{5}$$

[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.

[13] Courvoisier, "Bestimmungsversuche der Erdbewegung relativ zum Lichtäther" (fn 11).

[14] Adolf von Harnack, "Zur Theorie des bewegten Spiegels", Annalen der Physik, series 4, xxxix (1912), 1053-8.

[15] In his equations Courvoisier used θ 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.

K7 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° and obtained $A = 104° \pm 9°$ and $v = 750$ km/s.

K8 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

$$48\text{mm} \cos(\theta - 146.1°) + 25\text{mm} \cos(\theta - 244.6°) \tag{17}$$

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 3x106, 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:

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

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

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

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]

K9 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.

[28] Ernest Esclangon, "La dissymétrie de l'espace sidéral et le phénomène des marées", Comptes rendus de l'académie des sciences de Paris, clxxxiii (1926), 116-18.

[29] Leopold Courvoisier, "Über die Translationsbewegung der Erde im Lichtäther", Physikalische Zeitschrift, xxviii (1927), 674-80.

[30] Rudolf Tomaschek and Walter Schaffernicht, "Zu den gravimetrischen Bestimmungsversuchen der absoluten Erdbewegung", Astronomische Nachrichten, ccxliv (1932), 257-66.

[31] James Clerk Maxwell, "On a possible mode of detecting a motion of the solar system through the luminiferous ether", Proceedings of the royal society of London, xxx (1879-1880), 108-10.

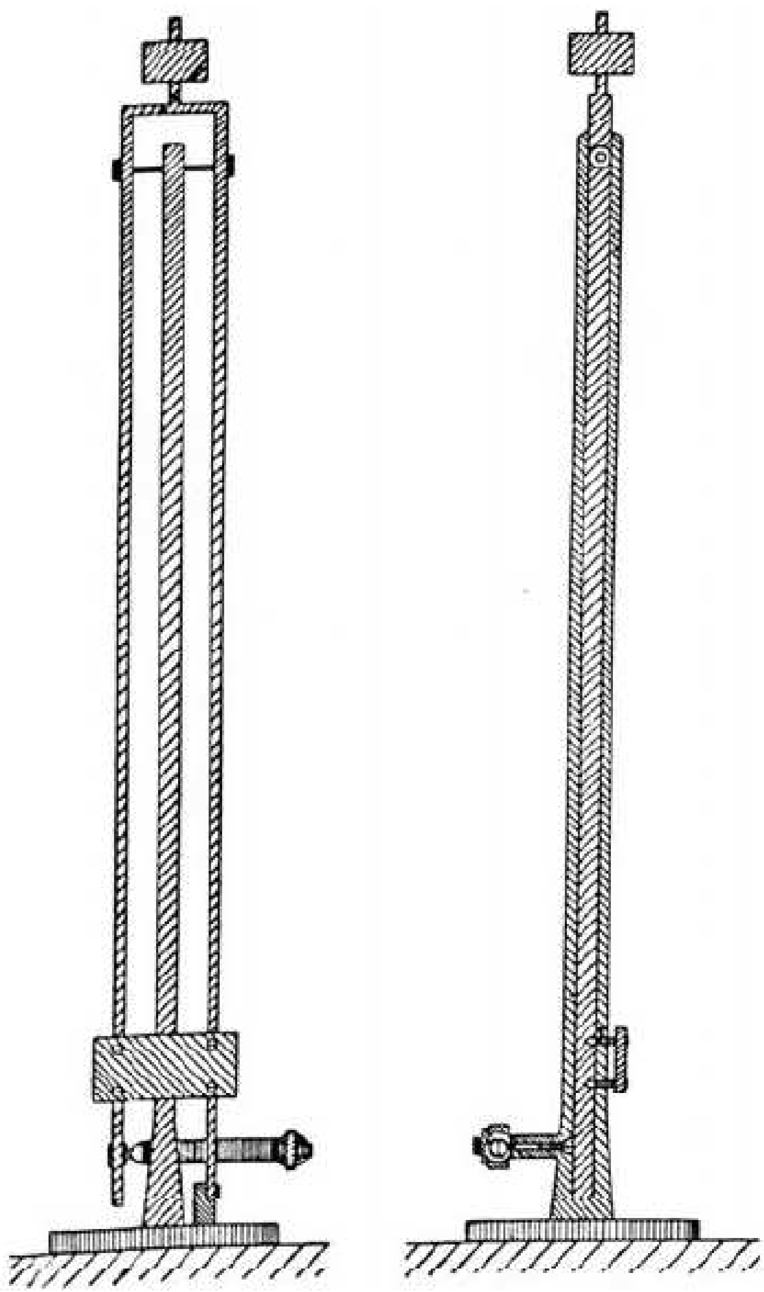

Figure 10: Courvoisier's plumb line apparatus for measuring oscillations of the local gravitational vertical due to Lorentz contraction.

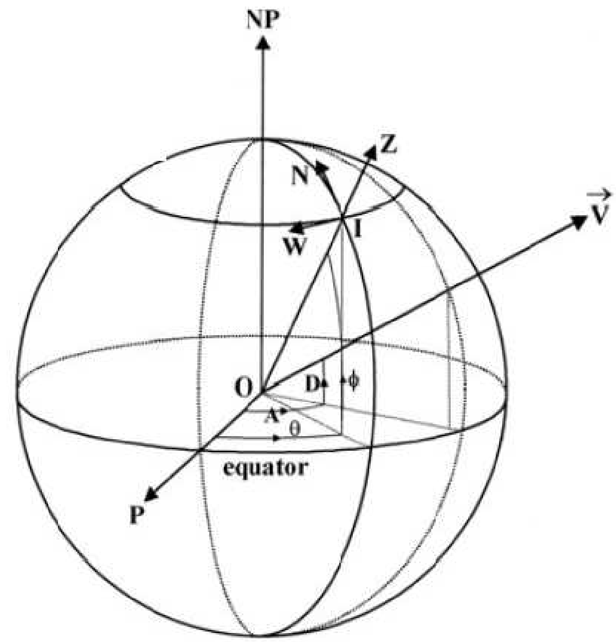

Figure 2: This diagram shows the main geometrical parameters used in Courvoisier's theoretical analysis of ether effects. The spherical surface represents the Earth, and the observer is at point I, and the local directions Z, N, W correspond to Zenith, geographical North and West. The North Pole is in the direction NP. The Earth's speed v is the magnitude of the boldface arrowed vector **V**.

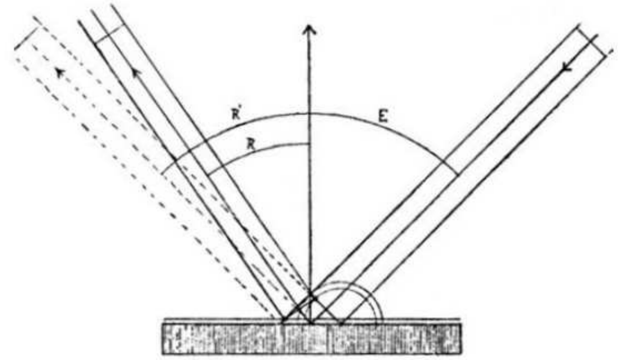

Figure 3: Following a theoretical analysis by Adolf von Harnack, Courvoisier accepted that the angle of reflection of light in a moving mirror is influenced by its motion through the ether, and that there is a second-order effect that can be measured in the reference frame of the mirror.

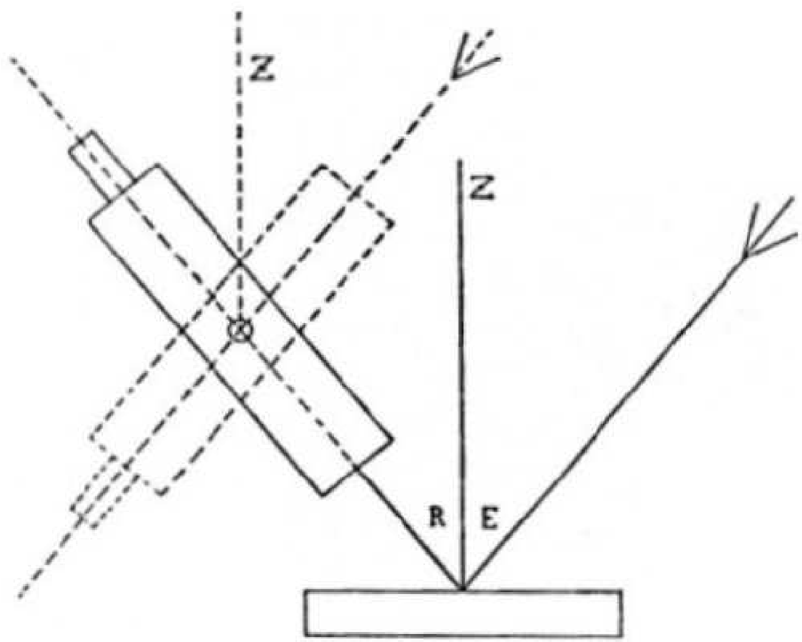

Figure 4: Courvoisier compared the direct measurement of the direction of a star with its direction observed by reflection on a mercury mirror.

this instrument led to a speed of the Earth of about 400 km/s, assuming $A = 75°$ and $D = +40°$. 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:

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

K3 Similar observations were made by Esclangon, with the help of André-Louis Danjon, using two horizontal pendulums with perpendicular motions.[24] One of the pendulums led to $A = 69°$; for the second pendulum, $A = 52°$. Esclangon did not provide other information and did not attempt to compute the speed of the Earth.

K4 Bubble. 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:

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

K5 Comparison between pendulum clocks at different places. According to Courvoisier's hypothesis, the Earth undergoes a real contraction in the direction of its motion through the ether, and this contraction would produce observable periodic changes 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.

K6 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:

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

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

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

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.

---

[24] Ernest Esclangon, Sur la dyssimétrie mécanique et optique de l'espace en rapport avec le mouvement absolu de la Terre, Comptes rendus de l'académie des sciences de Paris, clxxxii (1926), 921-3.

[25] Leopold Courvoisier, Bestimmungsversuche der Erdbewegung relativ zum Lichtäther IV, Astronomische Nachrichten, ccxxxvii (1930), 337-52; idem, "Ist die Lorentz-Kontraktion von Brehungsindex abhängig?", Zeitschrift für Physik, xc (1934), 48-62.

[26] Leopold Courvoisier, "Bestimmungsversuche der Erdbewegung relativ zum Lichtäther II", Astronomische Nachrichten, ccxxx (1927), 425-32.

[27] Leopold Courvoisier, "Der Einfluss der 'Lorentz-Kontraktion' der Erde auf den Gang der Quarzuhren", Experientia, ix (1953), 286-7; xiii (1957), 234-5.

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

J1 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 was led to think that the effect could also be detected in an experiment using a terrestrial light source.
J2 He placed a mercury mirror directly below the observatory 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:

$$\Delta z = -(v/c)^2[\sin\phi \sin 2D \sin(\theta - A) + \cos\phi \cos^2 D \sin 2(\theta - A)]/4 \qquad (16)$$

J3 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:

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

Applying a temperature correction, he obtained the following results:

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

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° and D = +40°. After applying temperature corrections, he obtained a speed of 753 ± 57 km/s.

K Other methods

K1 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.
K2 Plumb line motion. 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.[23] Measurements made in 1925 with

[23] Leopold Courvoisier, "Ableitung der Bahngeschwindigkeit der Erde aus der auf Grund der Lorentz-Kontraktion (Zeigerstabversuch) betimmten Absolutbewegung",Astronomische Nachrichten, ccxlvii (1932), 105-18.

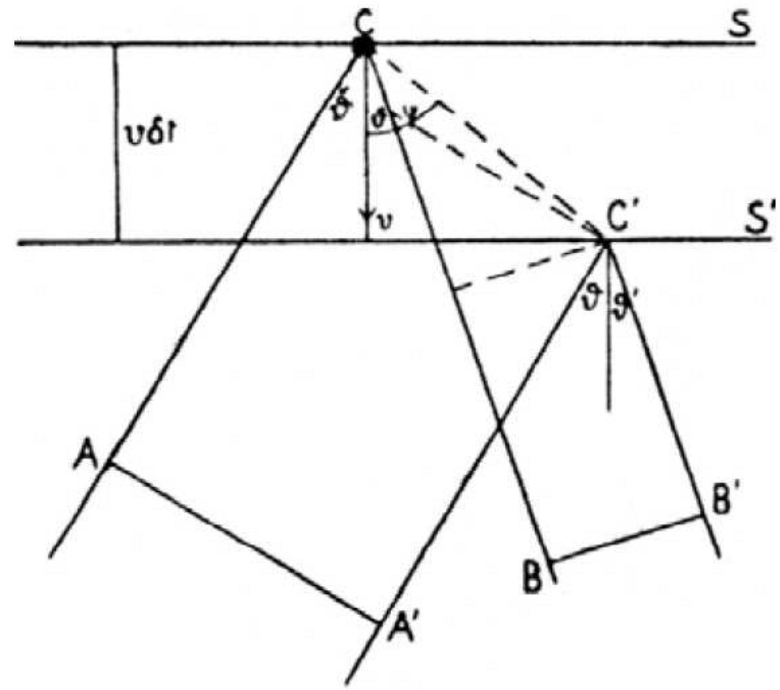

Figure 5: Harnack's diagram for analyzing the reflection of light in a moving mirror. The initial position of the mirror is S, and after a time dt its position is S'. AA' is a wave front of the incident light beam, and BB' is a wave front of the reflected beam.

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 β (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 β, 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:

$$z = \theta + \alpha \cos\theta + \beta \sin\theta. \tag{6}$$

$$z' = \theta' + \alpha \cos\theta' + \beta \sin\theta' \tag{7}$$

where α 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:

$$z' - z = (\theta' - \theta) + \alpha(\cos\theta' - \cos\theta) + \beta(\sin\theta' - \sin\theta) \tag{8}$$

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

$$z' - z = 2\alpha\beta \sin^2 z \tag{9}$$

Replacing α and β by their values in eqs.1&2,[16] one obtains:

$$\begin{aligned} z' - z = {} & [(v/c)^2 \sin^2 z] \\ & \cdot[\sin 2\phi \sin^2 D + \cos 2\phi \sin 2D \cos(\theta - A) - \sin 2\phi \cos^2 D \cos^2(\theta - A)] \end{aligned} \tag{10}$$

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:

$$A = 104° \pm 21°; D = +39° \pm 27°; v = 810 \pm 215 \text{ km/s}$$

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, θ is used again to represent sidereal time.

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

θ	$D_1 - D_2$ observed	$D_1 - D_2$ observed (corrected)	$D_1 - D_2$ prediction
0 h	$+0.35''$	$+0.35''$	$+0.26''$
1 h	$+0.21''$	$+0.21''$	$+0.16''$
2 h	$+0.01''$	$+0.01''$	$+0.04''$
3 h	$-0.07''$	$-0.07''$	$-0.07''$
4 h	$-0.17''$	$-0.17''$	$-0.16''$
5 h	$+0.03''$	$+0.03''$	$-0.17''$
6 h	$+0.17''$	$+0.17''$	$-0.14''$
7 h	$-0.03''$	$-0.03''$	$-0.06''$
8 h	$+0.07''$	$+0.07''$	$+0.04''$
9 h	$+0.10''$	$+0.10''$	$+0.14''$
10 h	$+0.08''$	$+0.08''$	$+0.25''$
11 h	$+0.09''$	$+0.09''$	$+0.32''$
12 h	$+0.29''$	$+0.29''$	$+0.34''$
13 h	$+0.32''$	$+0.35''$	$+0.32''$
14 h	$+0.29''$	$+0.39''$	$+0.29''$
15 h	$-0.04''$	$+0.22''$	$+0.25''$
16 h	$-0.21''$	$+0.13''$	$+0.20''$
17 h	$-0.23''$	$+0.18''$	$+0.19''$
18 h	$-0.29''$	$+0.12''$	$+0.20''$
19 h	$-0.31''$	$+0.10''$	$+0.23''$
20 h	$-0.17''$	$+0.17''$	$+0.29''$
21 h	$+0.04''$	$+0.30''$	$+0.33''$
22 h	$+0.26''$	$+0.36''$	$+0.34''$
23 h	$+0.38''$	$+0.41''$	$+0.32''$

function of sidereal time. To test the existence of this effect, Courvoisier analyzed the catalogues containing measurements made at Heidelberg ($\phi_1 = +49.24°$) and at Cape Town, South Africa ($\phi_2 = -33.48°$). 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:

$$\Delta z_1 = \alpha_1\beta_1/2 \qquad \Delta z_2 = \alpha_2\beta_2/2 \tag{13}$$

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

$$D_1 - D_2 = (\alpha_1\beta_1 - \alpha_2\beta_2)/2 \tag{14}$$

I2 Using the typical values $A = 75°$ and $D = 40°$ 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:

$$D1 - D2 = +0.16'' - 0.18'' \cos(A - 5^{\text{h}}) - 0.16'' \cos 2(A - 5^{\text{h}}) \tag{15}$$

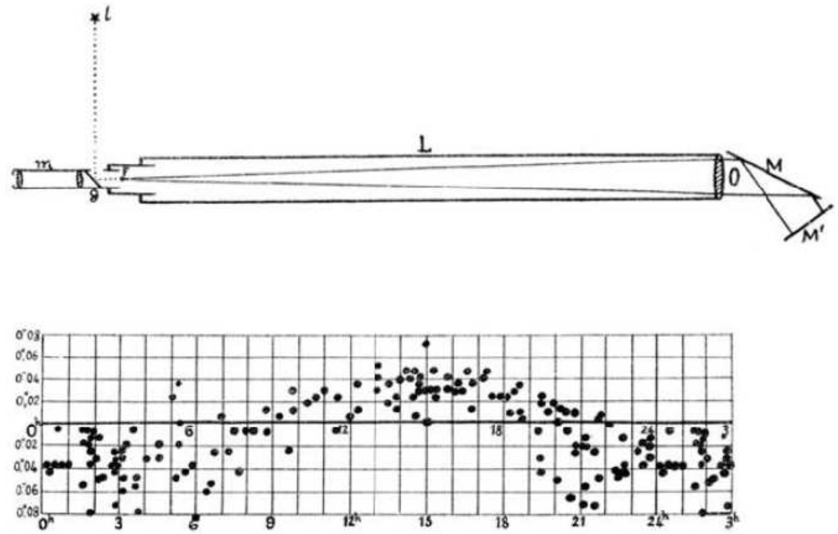

Figure 8: Esclangon's coupled mirror device for measuring the motion of the Earth through the ether (upper diagram, above), and a graphical representation of his results (lower diagram, above), showing the observed angular fluctuations as a function of sidereal time.

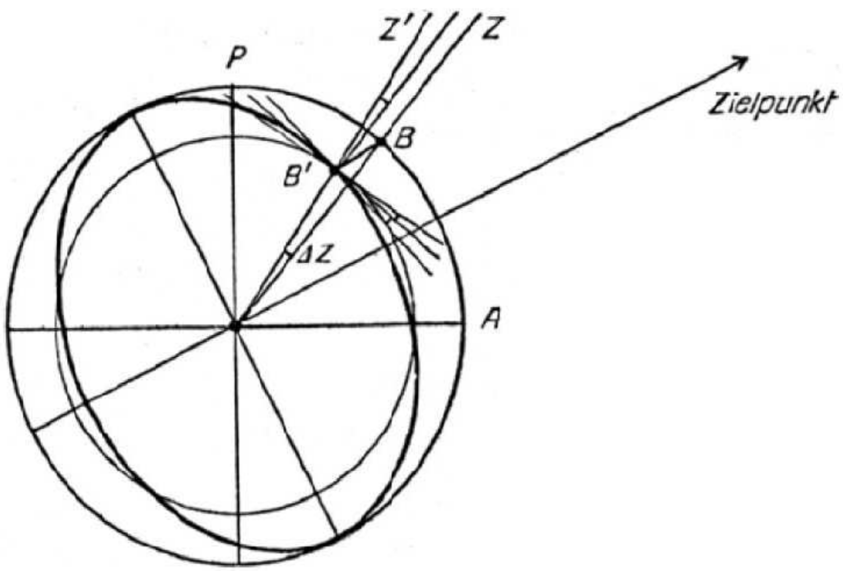

Figure 9: According to Courvoisier, the Lorentz contraction of the Earth and of optical instruments could have a small observable influence on astronomical observations and terrestrial experiments.

$$A = 93° \pm 7°; D = +27° \pm 12°; v = 652 \pm 71 \text{ km/s}$$

The estimated relative error of the speed was reduced to about 10% and the errors of the right ascension and declination amounted to less than 1/30 of the full circle. Courvoisier's work called the attention of a French astronomer, the director of the Strasbourg observatory, Ernest Esclangon, who repeated those measurements.[17] He confirmed the existence of a systematic effect of the same order of magnitude, and computed the values of $A = 69°$ and $D = 44°$. Esclangon did not publish the estimated errors of his evaluation, nor the estimated speed of the Earth.

E2 Other evaluations were later obtained by Courvoisier using measurements made at München (1930-1931) and Breslau (1933-1935), with the following results:[18]

München	Breslau (1)	Breslau (2)
$A = 73° \pm 6°$	$A = 92° \pm 12°$	$A = 80° \pm 4°$
$D = +40°$ (estimated)	$D = +44° \pm 25°$	$D = +30° \pm 10°$
$v = 889 \pm 93$ km/s	$v = 927 \pm 200$ km/s	$v = 700 \pm 60$ km/s

The results obtained in the second Breslau series presented the smallest errors. In 1945, after his retirement, Courvoisier made a final series of observations from Basel. He obtained the following results:

$$A = 60° \pm 14°; D = +40° \text{ (estimated)}; v = 656 \pm 157 \text{ km/s}$$

E3 If we compare all the series of measurements, we notice that the right ascension varied between 60° and 104° (more than the estimated errors); the declination varied between 39° and 44° (within the estimated errors);[19] and the speed varied between 652 and 927 km/s (within estimated errors). Notice that it is very hard to explain away Courvoisier's results as due to instrument errors, because the observed effect varied with periods of one sidereal day and half a sidereal day. All common causes of error (gravity changes, temperature changes, etc.) would vary with periods of one (or half) solar day. Tidal influences due to the Moon would have periods that could also be easily distinguished from the effects predicted by Courvoisier. Besides that, the data used by Courvoisier was obtained with different instruments at different places, and covered a time span of 80 years. The results presented by Courvoisier are therefore highly impressive and cannot be dismissed lightly.

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

[17] Ernest Esclangon, "Sur la dyssimétrie mécanique et optique de l'espace en rapport avec le mouvement absolu de la Terre", Comptes rendus de l'academie des sciences de Paris, clxxxii (1926), 921-3.

[18] In some of his analysis, Courvoisier found that the effect with one sidereal day period was not clearly noticeable. In those cases, he assumed an estimated value of 40° for the declination, and computed the right ascension and speed of the Earth.

[19] The slight variations of the values found for the declination led Courvoisier to assume this value as known, as remarked above (fn 18), in all cases when it was impossible to compute A, D and v/c.

[20] Leopold Courvoisier, "Bestimmungsversuche der Erdbewegung relativ zum Lichtäther II", Astronomische Nachrichten, ccxxx (1927), 425-32; idem, "Über die Translationsbewegung der Erde im Lichtäther", Physikalische Zeitschrift, xxviii (1927), 674-80.

temperature was fairly constant. Both telescopes pointed obliquely (zenith distance $= 60°$) 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.

H The second method: Lorentz contraction

H1 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.

H2 Courvoisier's theoretical analysis led him to predict that the variation Δz of the zenith distance of a star close to the North Pole would obey the approximate relation:

$$\Delta z = \alpha\beta/2 \tag{11}$$

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:

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

H3 Using the data he had already obtained from 1914 to 1917, and combining those results with other measurements he made in 1921-1922 and 1925-1926, with the same instrument, Courvoisier obtained the following result:

$$A = 74° \pm 3°; [D = +40°]; v = 587 \pm 48 \text{ km/s}$$

He also analyzed measurements that had been obtained in routine observations at the Paris observatory, in the period 1899-1901. All those series of observations exhibited similar variations with a period of 12 sidereal hours. Assuming a value of 40° for the declination, he obtained the following results:

$$A = 70° \pm 11°; [D = +40°]; v = 810 \pm 166 \text{ km/s}$$

Afterwards Courvoisier also computed the motion of the Earth using measurements from Breslau (1923-1925 and 1933-1935) and from München (1927-1931). Taking into account all the observations, he obtained the following final result:

$$A = 65° \pm 10°; [D = +40°]; v = 574 \pm 97 \text{ km/s}$$

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

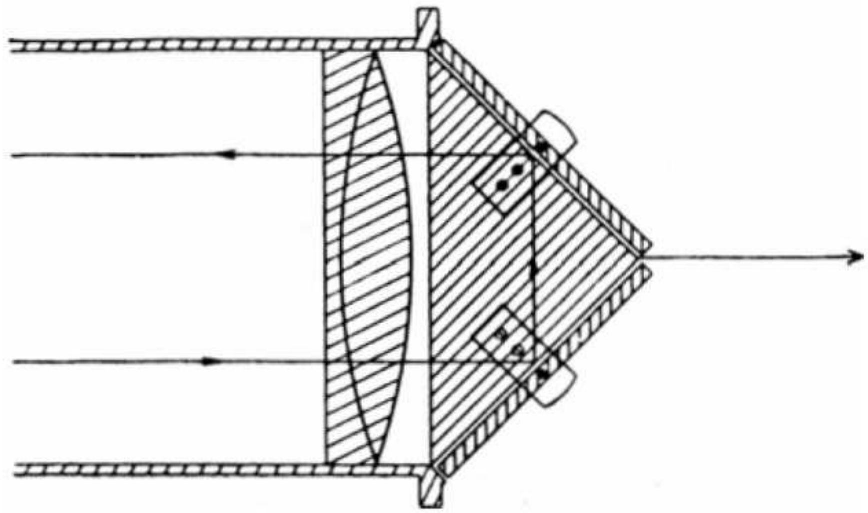

Figure 7: Courvoisier's coupled mirror device for measuring the motion of the Earth through the ether.

G The double mirror experiments

G1 In 1928 Courvoisier built another device to measure the speed of the Earth using the principle of the moving mirror. Instead of using two telescopes, he used a single telescope, with two perpendicular mirrors in front of its objective (Fig.7).[21] The body of the telescope was placed in a horizontal position. The mirrors were adjusted so that it was possible to observe the reflected image of the thread micrometer of the telescope in close coincidence with the real micrometer thread. He predicted that the relative position of the image and the thread should undergo periodic fluctuations, and computed the predicted effect.
G2 From April to June 1928 Courvoisier obtained a series of 53 measurements, both in the North-South and in the East-West directions, and he computed the following values:

$$A = 74^\circ \pm 1^\circ; D = +36^\circ \pm 1^\circ; v = 496 \pm 10 \text{ km/s}$$

G3 Courvoisier's new experiment was probably suggested by a similar arrangement that had been used by Esclangon in 1927.[22] The French astronomer used two mirrors, but light underwent three reflections (Fig.8). The maximum effect occurred at 3^h or 15^h sidereal time, corresponding to A = 45° or 225°. Esclangon did not compute the speed of the Earth through the ether — indeed, he did not even provide a definite interpretation of the phenomenon.

[21] Leopold Courvoisier, "Bestimmungsversuche der Erdbewegung relativ zum Lichtäther III", Astronomische Nachrichten, ccxxxiv (1928), 137-44.
[22] Ernest Esclangon, "Sur la dissymétrie optique de l'espace et les lois de la réflexion", Comptes rendus de l'académie des sciences de Paris, clxxxv (1927), 1593-5 ; idem, "Sur l'existence d'une dissymétrie optique de l'espace", Journal des observateurs, xi (1928), 49-63.

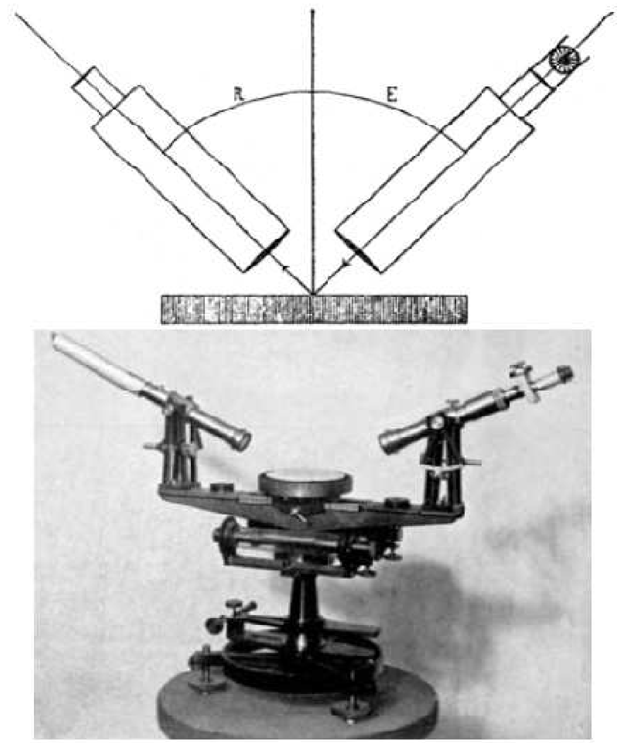

Figure 6: Courvoisier's double telescope apparatus for measuring the motion of the Earth through the ether.

Table 1: Measurements made by Courvoisier in 1926 with the double telescope instrument.

Sidereal time θ	$(z - z') +$ constant	# of measurements
2.9 h	$+ 1.54''$	4
7.3 h	$+ 0.28''$	6
8.2 h	$+ 0.28''$	7
9.1 h	$- 0.01''$	7
10.1 h	$+ 0.23''$	6
11.4 h	$+ 0.56''$	5
12.3 h	$+ 0.60''$	5
13.7 h	$+ 0.52''$	7
15.5 h	$+ 0.84''$	6
17.9 h	$+ 0.88''$	7
19.9 h	$+ 0.80''$	7

Table 2: Measurements made by Courvoisier in 1927 with the double telescope instrument.

Sidereal time θ	$(z - z') +$ constant	# of measurements
0.32 h	$- 0.08''$	21
1.23 h	$+ 0.04''$	64
2.45 h	$+ 0.07''$	14
3.31 h	$- 0.38''$	56
4.28 h	$- 0.38''$	14
5.28 h	$- 0.57''$	68
7.37 h	$- 0.58''$	55
9.29 h	$- 0.57''$	64
11.24 h	$- 0.24''$	30
12.73 h	$- 0.04''$	20
21.91 h	$+ 0.21''$	38
23.32 h	$+ 0.08''$	45

F2 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:

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

From the second series, he obtained the results:

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

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.