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Ludwik Silberstein and General Relativity

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We present the life and work of the Polish–American mathematical physicist Ludwik Silberstein (1872–1948), who was known for his numerous publications and books on general relativity and cosmology. His scepticism of some aspects of General Relativity led, several times, to reactions around the world, and often did not enhance his popularity among his colleagues.

His cosmological studies were connected mainly with the attempt to establish a velocity–distance relation and to determine the curvature of the Universe. Several times his attacks against established opinions were incorrect, but forced his opponents to express their views more precisely, and sometimes showed an astonishing far-sightedness. His activity during scientific meetings and his correspondence with many famous physicists also strongly influenced the development of our knowledge of the Universe.

Keywords: Silberstein, General Relativity

1 Introduction

Ludwik Silberstein is usually regarded as a Polish mathematical physicist. He was born at a time when Poland was divided into three parts, and, as someone born in Warsaw, he was formally a Russian subject. Later, he became a British citizen, probably in connection with his work for the British War Office during the First World War, and finally, in 1935, he became a naturalized US-American. There is no evidence that he visited Poland when it reappeared on the map after World War I; apparently at the time Silberstein lived, worked and lectured solely in the United States and Canada. He was a colorful person, active in many fields of pure and applied physics.

No one deserves to be called 'Einstein's antagonist' more than Ludwik Silberstein, having influenced the development of relativity theory through numerous articles and two textbooks. As much as he was an adherent of the theory, all his life he maintained

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a sceptical distance to it, and asked critical questions at times when others propagated Einstein's theses uncritically or damned them without good reason. Part of this reserve is possibly due to the fact that Silberstein could not properly be Einstein's 'disciple', since he was seven years older than Einstein, and another part can probably be found in his character. Silberstein was very critical about many points in numerous fields, not only connected with general relativity. His very polemic tone of writing was certainly not very pleasant to his opponents, and certainly he was not very much liked. His style was very specific, as can be seen in the title of his paper *On the Expanding-Universe Doctrine* or that of the book *Causality; A Law of Nature or a Maxim of the Naturalist?*. In this book, when discussing the problem of the First Cause in a footnote (page 50), he wrote: "Curiously enough, Sir J. H. Jeans, who is otherwise so soberly critical, jumps in this situation to a wholly unjustified conclusion. . . ."

When we overview Silberstein's life in the following sections, we note that he often made serious scientific blunders (as, indeed, did Einstein, whose "greatest blunder", the cosmological constant, has resurfaced triumphantly in more recent times). Nevertheless, even Silberstein's blunders sometimes show notable talent.

2 Silberstein's life up to the publication of the *Theory of Relativity* (1914)

Ludwik Silberstein was born on May 15, 1872 in Warsaw, to Samuel Silberstein and Emilie, née Steinkalk. We know something of two other offspring: his brother Henryk (1858–1890) obtained a doctorate in chemistry under Lothar Meyer in Tübingen, while his sister Adela (1877–?) obtained a doctorate in philosophy in Zürich.

Ludwik went to high school in Warsaw, and later in Cracow. Until 1890 he studied at Cracow's Jagiellonian University, followed by a semester in Heidelberg, after which he moved to Berlin in 1891, where he completed his Ph.D. in physics. In his curriculum vitae, he counts among his most important teachers Witkowski, Koenigsberger, Planck and von Helmholtz. Von Helmholtz wrote the advisory report of Silberstein's thesis, *Ueber die mechanische Auffassung elektromagnetischer Erscheinungen in Isolatoren und Halbleitern* (Silberstein, 1894), which circulated in the faculty from December 18, 1893. On July 5, 1894, the doctoral examination took place; his examiner in physics was Max Planck. Interestingly, Silberstein's 'performance' in mathematics was not good. On November 22, 1894, he was awarded his doctorate at the faculty of philosophy at Berlin's Friedrich-Wilhelms-University. After completing his doctoral studies, he was an assistant of Prof. Olearski at Lviv Polytechnic from 1895–97. Silberstein felt that his Jewish background hampered his academic promotion; the official reason for the refusal to extend his stay in Lviv was his lack of Austro-Hungarian citizenship, similarly to other scientists who had been born in Russia. He turned to Italy and became a lecturer in mathematical physics at the universities of Bologna (1899–1904) and Rome (1904–1920). He married Rose Eisenman on 29 June, 1905. Since "he had a very beautiful wife and finding (as he thought) that his academic friends were paying her more attention that he felt desirable" – as related by a colleague – he moved to England in 1912, where he obtained a lectureship at University College London. Since the students made fun of him because of his accent, the director of the physics department arranged a job for him with the Adam Hilger company,

where he worked as a scientific advisor between 1913 and 1920. During this time he continued to visit Rome as a lecturer.

In 1920, he left London to accept the post of a mathematical physicist with the Eastman Kodak Company in Rochester, New York. He established contact with the group of physicists in Chicago (including Millikan and Michelson), became a member of the American Astronomical Society and of the Optical Society of America, and over the following years he participated in some of their meetings. He was also a guest at an 'Astronomical Lunch' of the British Association in the meeting of August 13, 1924 in Toronto, together with Eddington, Lemaître, Russell, A.V. Douglas and others. He also lectured in the theory of relativity at Cornell and the Universities of Chicago and Toronto.

3 Silberstein's studies in relativity and cosmology before the 2nd edition of the *Theory of Relativity* (1924)

Silberstein is best known today because of his long interest in the theory of relativity, and he was one of its popularizers. However, he soon understood that the theory of ether is not needed in the theory of relativity. In 1908 he wrote: "ether is superfluous fiction... the empty space is electromagnetically homogeneous and isotropic and electromagnetic displacement in it is propagated with finite speed." His first investigations into the theory of relativity started in 1911, when he published a formulation of special relativity in quaternion form (in Polish and German), which was also published in English in subsequent years and was included in his book *Theory of Relativity* (Silberstein, 1914), which was (probably) the first textbook on this theory in the world. (Quaternions are an extension of complex numbers, consisting of four numbers: one real component and three which are analogs of the complex ones. They are useful in the theory of relativity, where we have the time component and three spatial components.)

Silberstein increasingly concentrated on study of the theory of relativity, which led him to the position of one of its most intelligent critics. His critical interest in General Relativity started in 1917, when he published a paper in which he discussed the problem of the motion of the perihelion of Mercury. Using the assumptions of the Special Theory of Relativity, he derived the motion of the perihelion of Mercury and introduced a factor γ^n, with $\gamma = \sqrt{1 - v^2/c^2}$. γ was derived empirically from observations and was used to calculate the perihelion shift. He assumed that this shift is caused by the Sun. This problem led him to a discussion with Einstein, which contributed to improving the original version of General Relativity. In 1918, he proposed a "General relativity without the equivalence hypothesis" (Silberstein, 1918a). Here, Silberstein held "the principle of equivalence [as] vulnerable, because of its very special nature and the great number of assumptions which it tacitly implies." Silberstein's alternative theory was based on the postulate that spacetime has a fixed constant curvature, regardless of the nature and distribution of gravitational sources. As support for his own theory, he pointed to the apparently "bizarre conclusions" of General Relativity, contemplating empty and filled space (Silberstein, 1918b).

4 Observations of solar eclipses in 1919 in Sobral and on the Island of Príncipe

When the results of the British solar eclipse expeditions to Sobral and Príncipe were discussed in November/December 1919, he remained extremely critical. He took some of the non-radial displacements of stars more seriously than those who expressed a "confirmation" of Einstein's General Relativity. Silberstein pointed out that the observed displacements of the positions of the stars were not just radial, as would be expected from General Relativity, and were considerable (in one case by as much as 35°), and that – until they were understood – an open mind should be kept as to the interpretation of these displacements, which might need to be accounted for "in some other, non-Einsteinian way".

He also paid attention to the potential impact of photographic emulsion grain (Silberstein was an expert in the field of optics and photography) and refraction (the problem concerned refraction both in the atmosphere of the Sun and the Earth). Moreover, he pointed out that the gravitational redshift – still unconfirmed at the time – was the essential proof of the validity of General Relativity, and a failure of its existence would leave the eclipse results worthless.

Details of his ideas are expressed in a letter of November 27, 1919, addressed to Arnold Sommerfeld (and published by Duerbeck and Flin, 2005), and his contribution to the discussion of the eclipse results was published in the *Monthly Notices* in 1919 (Jeffreys, 1919). Silberstein's main objections are presented in two articles published in *The Observatory* in 1919 and 1920.

When Silberstein finished his lectures on relativity theory at the University of Chicago, Millikan and Gale attempted to hire Einstein as a full physics professor, and to have Silberstein as his assistant. However, Einstein declined the offer, and Silberstein did not return to academia. On April 15, 1923, Silberstein communicated to Einstein the results of the Lick Observatory eclipse expedition, and even Silberstein seems to have accepted the validity of General Relativity. He asked Einstein about a preprint of a forthcoming academic publication, to be used in the second edition of his book on relativity theory (Silberstein, 1924). In this book, Silberstein seems to have made his (preliminary) peace with relativity theory. However, it demonstrates a trait which he had also expressed in the preface of his small book *The Theory of General Relativity and Gravitation* (Silberstein, 1922): "Some of my readers will miss, perhaps, in this volume the enthusiastic tone which usually permeates the books and pamphlets that have been written on the subject (with a notable exception of Einstein's own writings). Yet the author is the last man to be blind to the admirable boldness and the severe architectonic beauty of Einstein's theory."

Long-term research on the problem of movement of two bodies led to fierce discussions with Einstein in the 1930s (exactly described by Havas, 1993). The equations of motion in the General Theory of Relativity are associated with the distribution of "gravitational charges" (i.e., masses), and one cannot independently set the gravitational field and the distribution of the "charges". But initially in General Relativity there was this assumption, which led to incorrect results on the problem of two bodies, in particular the movement of Mercury in the gravitational field of the Sun.

In 1921, Silberstein pointed out that the dragging of ether (in the entrained ether theory) causes an effect analogous to a change in the gravitational mass of Mercury.

Thus we have the motion of a particle with variable mass, which could explain the observed change of perihelion (Silberstein, 1922a). This problem is also associated with the Miller experiment. This particular experiment, performed at Mount Wilson (Michelson, 1928), appeared to show a constant motion of the solar system toward the constellation of Draco and a $10\,\mathrm{km\,s^{-1}}$ motion of Earth relative to the ether, which, if proved true, would be to deny the theory of relativity. These results instantly generated a lot of controversy. For example, Eddington argued that, in order to be in tune with the (known) effects of aberration, the ether should not rotate, while in the experiment the speed increases with height. Today it is believed that the observed effect was due to the faulty processing of the data by Miller.

Silberstein found a solution of Einstein's equations in which the force disappeared on the axis connecting the two bodies. In his opinion this fact refuted the theory of relativity. Einstein (Einstein and Rosen, 1936) found that such a solution is characterized by a discontinuity of the first derivatives. We now know that all Weyl solutions (of which Silberstein's solution is an example) include peculiarities. However, the original solution of Einstein, as mentioned above, was wrong and only under the influence of discussions with Silberstein did Einstein find the proper solution to the problem of motion of two bodies on the basis of General Relativity. This finally convinced the scientific community about the validity of the theory.

5 Silberstein's later years

After his retirement in 1929, he remained a scientific advisor for Eastman Kodak, and also collaborated with the Cinema Laboratories Corp., Brooklyn, N.Y., on television techniques, 3-D cinematography and color motion pictures. He also remained active in cosmology and general relativity. In the early 1930s, Hubble had published several papers on the redshift-distance relation, Eddington had taken notice of Lemaître's 1927 paper on the expanding universe, de Sitter had put to rest 'his' de Sitter universe, and had proposed jointly with Einstein the expanding Einstein–de Sitter universe without a cosmological constant. The only person who apparently eschewed the flood of new findings was Silberstein, not, however, by propagating his own interpretation of the stationary de Sitter-universe, but by attacking the "expanding universe-doctrine".

This turn of events apparently did not please Silberstein, since he did not elaborate further on this problem in his correspondence with Einstein. However, when he planned to write a (possibly unpublished) review of Eddington's book *The Expanding Universe* (1933), this served him as a good starting point to show the absurdity of "the expanding-Universe doctrine" propagated by Eddington, Einstein, de Sitter and all others: the "linearity" of the empirical correlation, first shown by Hubble in 1929, is questioned and it is shown that the matter density and the cosmological constant will cause effects that show up as higher order terms, like the "deceleration term" (differently defined in later papers), and he finished with the statement "The observational material so assiduously gathered... is comparatively very scanty and much too coarse to be considered even as a qualitative support of the expansionist doctrine; still less to say whether the next generation of astronomers will support or reject it." (Silberstein, 1935). Of course we know that not even one, but at least two generations of astronomers were eager to find deviations from linearity, deviations

that not only indicated a small matter density, but also a dominant presence of 'dark energy'. But it should be noted for the record that Silberstein was the first to indicate that the non-linearity of the redshift–distance relation would tell us something about the cosmological parameters, although he made the statement contemptuously.

Furthermore, Silberstein started a discussion with Einstein concerning the two-centers solution of the gravitational field equations, which started with an exchange of letters in late 1933, and ended with papers by Silberstein (1936) and Einstein and Rosen (1936) in the *Physical Review*, as well as with a newspaper article in the *The Evening Telegram* newspaper of Toronto with the heading "Fatal Blow to Relativity Issued Here". After a last exchange of letters concerning this topic, the Einstein–Silberstein correspondence ceased for five years. The controversy itself was actually pointless since the same problems had already been investigated by Curzon (1924a,b) more than a decade before, but neither Einstein nor Silberstein realized this. The Silberstein–Einstein debate of 1933–1936 is discussed in detail in a paper by Havas (1993); modern solutions of the problem are listed in Earman (1995).



Figure 1 Ludwik Silberstein (copyright: Courtesy of George Eastman House, International Museum of Photography and Film, Rochester, USA).

Silberstein died from a heart attack on January 17, 1948; his wife survived him by ten years. He left a son George, who worked as an engineer with Eastman Kodak, and a daughter Hannah, who was a biochemist at a hospital in Rochester, at Emory University in Atlanta, and later at a hospital in Baltimore. Her name is encountered in some reports on plutonium intake by human organisms. Another daughter, Hedwiga, had already died in 1946.

In one of the few obituaries, the one in the *Zeitschrift für wissenschaftliche Photographie, Photophysik und Photochemie* (1950), we read the peculiar sentence "His main field of research was Einstein's theory of relativity, and its proof." At that time, the theoretical physicists and astronomers had already forgotten him, or they remembered him as a know-it-all who always backed the wrong horse. Nevertheless,

the 100th anniversary of Einstein's General Relativity is a good occasion to recall this now almost forgotten scientist, whose scepticism and inquisitiveness influenced our knowledge.

This paper is a modified version of the paper by Flin & Duerbeck (2006). With great sorrow we remember our late friend, Prof. Hilmar W. Duerbeck.

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