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(*b*. Biebrich, Germany, 29 May 1885; *d*. Wiesbaden, Germany, 24 July 1964)

astronomy.

Freundlich was the son of a German businessman, E. Philip Freundlich, and his British wife, Ellen Elisabeth Finlayson. He had four brothers and two sisters. Like his brothers he received his primary schooling in Biebrich and completed a classical education at the Dilthey School in the neighboring and larger town of Wiesbaden. After leaving this school in 1903, Freundlich worked at the dockyard in Stettin before beginning a course in naval architecture at the Technical University of Charlottenburg. After a heart condition forced him to discontinue this course for about a year, he decided to begin anew and went to Göttingen to study mathematics, physics, and astronomy. With the exception of the winter semester 1905–1906, which he spent as a student in Leipzig, the rest of his higher education was confined to Göttingen University, from which he obtained his Ph.D. in 1910 with a thesis entitled "Analytische Funktionen mit beliebig vorgeschriebenem unendlich viel blättrigem Existenzbereiche."

At the suggestion of his tutor, Felix Klein, Freundlich applied for the post of assistant at the Royal Observatory in Berlin and was appointed on 1 July 1910. In the following year Albert Einstein, having heard that Freundlich was investigating the possibility of gravitational absorption, requested Freundlich's cooperation in observing the motion of the planet Mercury. Einstein himself had his own reasons for doubting that its position would coincide with that predicted on the basis of Newtonian mechanics. Freundlich's observations fully confirmed earlier evidence for such a discrepancy, and he insisted on publishing that discovery in 1913, against the wishes of the director of the Berlin observatory. That same year he married Kate Hirschberg in a civil ceremony in the Herder House in Weimar, and a small house was built for the couple at the Berlin observatory's new site in Neubabelsberg (Berlin). The German chemist Emil Fischer, impressed by Freundlich's insistence on the validity of his revolutionary conclusion, introduced him to his wealthy friend Gustav Krupp von Bohlen und Halbach, who financed Freundlich's first solar eclipse expedition to Feodosiya in the Crimea in 1914, which unfortunately had to be abandoned owing to the outbreak of World War I. Freundlich was interned for a short time before being allowed to return to Berlin.

The object of the expedition was to test the validity of a prediction of Einstein's still incomplete theory of general relativity relating to the deflection of a ray of light from a star by the sun's gravitational field, to which Freundlich drew attention in an article published in 1914. A further prediction, also mentioned in that article, which followed from the application of Einstein's principle of equivalence to light rays, was that the wavelength of light should be increased in the presence of a strong gravitational field such as the sun's; but Freundlich was obliged to conclude that the well-known phenomenon of the solar red shift could not be regarded as constituting a decisive verification of the theory.

Not having the necessary facilities at his disposal for making new reliable observations of the solar red shift, Freundlich turned his attention to the measurement of wavelength shifts in the spectra of stars in various star systems but obtained inconclusive results because so little was known about stellar masses. He later tried to reduce this deficiency by researches on the distribution of stars in globular star clusters. An increasing amount of attention was focused on Freundlich's work after Einstein's publication of 1916 had revealed the immense significance of his theory of general relativity for the future development of physics, and after Freundlich had discussed the means of testing it in his first book, *Die Grundlagen der Einsteinschen Gravitationstheorie* (Berlin, 1916). An article by him on this subject appeared in *Naturwissenschaften* (1917), and a second edition of his book was published at Leipzig in 1920. Freundlich resigned his post in 1918 to work full-time with Einstein, financed by the Kaiser Wilhelm Gesellschaft. He always modestly regarded himself as less of a collaborator with Einstein than as a butt for the latter's highly original ideas. His occasional inability to comprehend these ideas had the salutary effect of making Einstein seek to simplify their mathematical formulation, for if one of Felix Klein's pupils could not make sense of his equations who could? Through his intimate contact with Einstein, Freundlich was the first to become thoroughly acquainted with the fundamental principles of the new gravitational theory and, as Einstein himself remarks in the foreword of Freundlich's book, he was particularly well qualified as its exponent because he had been the first to attempt to put it to the test.

After Arthur Eddington confirmed that Einstein's theory accounted quantitatively for the discrepancy in the position of the planet Mercury, on whose reality Freundlich had boldly insisted in 1913, the validity of the principle of relativity itself could no longer be doubted and Freundlich's scientific reputation was fully vindicated. Thus, in 1920, the Prussian Ministry of Culture decided to support the creation of the Einstein Institute at the Astrophysical Observatory, Potsdam; Freundlich was appointed observer in 1921 and later chief observer and professor of astrophysics. This institute was designed specifically to strengthen the empirical foundations of Einstein's gravitational theory and was equipped with an astrophysical laboratory and a powerful tower telescope for solar work, the *Einsteinturm*. Here, from 1921 to 1933, Freundlich encouraged his co-workers to tackle problems that appeared at the time to be of particular significance in the solution of the solar red-shift problem, such as the origin of the ultraviolet cyanogen bands (1924) and the measurement of the center-to-limb variation in wavelength along different radii on the solar disk (1930). Simultaneously he was supervising the construction of specially designed equipment for observing light deflection; and he planned three further eclipse expeditions, two of which (in 1922 and 1926) were unsuccessful because of bad weather conditions. The third (to Sumatra in 1929) was a complete success—even though the final result proved to be significantly in excess of what Einstein's theory had predicted.

It was typical of Freundlich that he was less concerned about the negative role of this discrepancy in casting doubt upon Einstein's assumption that the laws of motion for matter are also valid for the energy contained in a light ray than about the positive and exciting possibility that its very existence might hold the key to the still unexplained rift between relativity theory and quantum mechanics, and thereby assist the unification of the macroscopic and microscopic patterns of nature. To say that Freundlich wished to disprove Einstein is to mistake entirely the motivation which caused him in later years continually to stress the excess of his observed value for the lightdeflection over that predicted by general relativity theory—a fact, incidentally, which subsequent independent eclipse experiments have served only to confirm, and for which no satisfactory interpretation has as yet been forthcoming.

When Hitler came to power in 1933, Freundlich reluctantly resigned his post in Potsdam and emigrated to Turkey, a decision partially determined by the fact that his wife's sister had died earlier that year and he had assumed the guardianship of her two young children, whose lives he considered—with some justification—to be in danger.

From 1933 to 1937 Freundlich helped to reorganize the University of Istanbul and to create a modern observatory. He also wrote, for translation into Turkish, the first astronomical textbook published in that language (1937). He left Turkey for an appointment as professor of astronomy at Charles University in Prague, but Hitler's policy toward Czechoslovakia forced him to leave this post in January 1939. One month later, in Holland, he received an offer from Sir James Irvine, principal of St. Andrews University, of a lectureship there, on the understanding that he would be encouraged to build an observatory and create a new department of astronomy. The St. Andrews University Observatory was completed in 1940. In the following year Freundlich—or Finlay-Freundlich, as he preferred to call himself since he was now resident in Scotland—was elected a fellow of the Royal Society of Edinburgh. During the rest of World War II he lectured on astronomy to undergraduate students and taught celestial navigation to Air Ministry cadets who were taking special short courses at St. Andrews as part of their basic training.

Although useful for demonstration purposes, the instruments at Freundlich's observatory scarcely constituted the basis for observational research in a rapidly expanding and increasingly competitive field, so he had the inspiration to construct the first Schmidt-Cassegrain telescope, which reduces the spherical aberration and length of tube from those of the conventional Cassegrain type and gives a plane image conveniently located just outside the back of the main mirror. It is undoubtedly more than a mere coincidence that about this time Freundlich was occupied with further studies on the structure of globular star clusters, since the Schmidt-Cassegrain arrangement is eminently suited for astrographic work. An eighteen-inch-aperture pilot model was constructed under Freundlich's supervision in the workshops of the St. Andrews University Observatory and was mounted at the Mills Observatory, Dundee, in 1949. Theoretical calculations on the design of this new telescope were carried out by E. H. Linfoot of Cambridge University. The results of tests made with this pilot model in February 1950 proved to be so encouraging that work was begun on a larger-scale telescope thirty-seven inches in diameter. Experimental researches on the preparation of multilayer coatings for interferometer plates were simultaneously being carried out at the observatory by Alan Jarrett; these led to a long and fruitful program of research on the aurora borealis, resulting in the observation of certain emission lines of the solar corona with the aid of a Fabry-Pérot interferometer by Jarrett and H. von Klüber during the total solar eclipses of 1954, 1955, and 1958. Bad weather conditions during the eclipses in 1954 and 1955 foiled Freundlich's own attempts to repeat his light-deflection experiment with the instruments he had used in 1929.

On 1 January 1951, Freundlich became the first Napier professor of astronomy at St. Andrews University. In his inaugural lecture, delivered just over a year later, he characteristically stressed the broad cultural value of the study of astronomy as well as the more specialized aims of that science and again made reference to the importance of the lightdeflection experiment as a means of verifying the fundamental principles of Einstein's theory. The related problem of interpreting the nonkinematic red shifts observed in solar, stellar, and galactic spectra was one that he began to reconsider seriously during his recovery from a heart attack in 1953; and his researches led him to jeopardize his scientific reputation once again by proposing the revolutionary hypothesis that the entire range of unexplained astrophysical data could be comprehended by an empirical formula relating the red shifts to the temperature of the radiation field and the distance through it which a ray of light would have to traverse before reaching a terrestrial observer.

Apart from the objection that this interpretation denied the existence of the gravitational red shift predicted from the general relativity theory, the majority of the criticisms which were immediately raised against Freundlich's red-shift formula centered on the unreliability of the observational data that he had cited in support of it. This led him to concentrate his attention on the particular problem of the solar red shift, for which reliable measurements could be made (at any rate, in principle); and he engaged a research assistant to examine whether or not the gravitational red shift was implicit in observations of this phenomenon. The initial aim of this research was inverted by the results of independent experiments in nuclear physics using gamma rays and the earth's gravitational field instead of light rays and the sun's gravitational field, which seemed to confirm the quantitative value of Einstein's prediction. Nevertheless it served to show that Freundlich's formula is merely an alternative empirical expression of the so-called relativity-radial current interpretation of the solar red shifts; moreover, it is one that is restricted to Fraunhofer lines of moderate intensity, for which the Doppler effects associated with the solar granulation are determinative in producing the observed shifts. This conclusion, derived from an analysis only of solar observations, would appear to imply that Freundlich's hypothesis is invalid as the basis of a general interpretation of the still unexplained red shifts of stars and galaxies; but this is an inference that Freundlich himself was not prepared to draw, as is evident from his last paper on the subject (1963).

Freundlich continued to act as director of the St. Andrews observatory until he resigned his chair in 1959. In the latter half of the 1950's he composed his book *Celestial Mechanics* (1958) and made plans for his retirement to Wiesbaden.

The closing years of Freundlich's life were marred by incidents arising out of the reluctance of his successor, D. W. N. Stibbs, to grant him open access to the St. Andrews observatory in order to witness the final stages of the work on the thirty-seven-inch Schmidt-Cassegrain telescope. The tensions that thus arose occasioned, *inter alia*, the resignation of his highly skilled technician, Robert L. Waland, before the optical components were satisfactorily completed and adjusted, and partly explain why that instrument has never yielded the results of which it might otherwise have been capable. At the time of his death Freundlich was an honorary professor at the University of Mainz.

BIBLIOGRAPHY

A complete list of Freundlich's publications, collated by Tadeusz B. Slebarski, is in an obituary notice by H. von Klüber in *Astronomische Nachrichten*, **288** (May 1964–December 1965), 281–286. A less detailed obituary by the same author is in *Quarterly Journal of the Royal Astronomical Society*. **6** (Mar. 1965), 82–84. *The Alumnus Chronicle* (University of St. Andrews), no. 36 (June 1951), 23–28, contains Freundlich's article "The Schmidt-Cassegrain Telescope"; and no. 40 (June 1953), 2–14, his inaugural address, "The Educational Value of the Study of Astronomy." A detailed account of researches on the solar red-shift problem, which gives due weight to Freundlich's contributions, is Eric G. Forbes, "A History of the Solar Red Shift Problem," in *Annals of Science*, **17** (1961), 129–164.

Eric G. Forbes