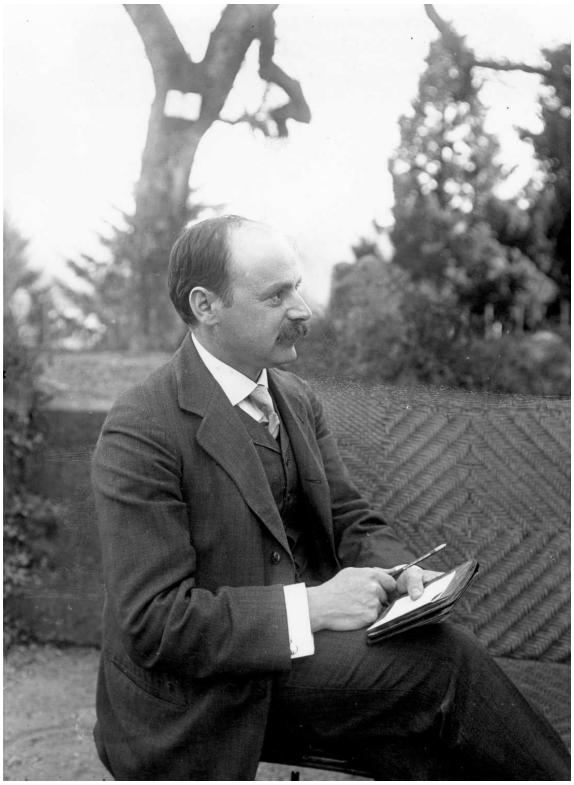
Biography of Karl Schwarzschild
(1873–1916)



Karl Schwarzschild. Courtesy AIP Emilio Segrè Visual Archives.

The celebrated German astronomer and physicist, Karl Schwarzschild, was born into a wealthy Jewish family in Frankfurt am Main, Germany, on October 9, 1873. He was the oldest of his five brothers and one sister. His mother, Henrietta Sabel, and father, Moses Martin Schwarzschild, were very nice and hearthy persons. His large, extended family was known to cultivate deep interest in art and culture. However, he became the first in the family to pursue a career in science.

Schwarzschild's prodigious talent manifested quite early on while still a student at Frankfurt Gymnasium: at the age of 16, having taught himself some advanced mathematics and studied much of contemporary astronomy, he published his first scientific paper on celestial mechanics.

Karl Schwarzschild writing in his study at Potsdam.
Courtesy AIP Emilio Segrè Visual Archives.

This was soon followed by another paper. Both papers touched upon the orbital theory of binary stars. In his Gymnasium years, he was a close friend of the famous mathematician specializing in number theory, Paul Epstein, with whom there was a sharing of real scientific interests.

He further studied astronomy at the Universities of Strasbourg and Munich, obtaining his doctorate in 1896 for a dissertation on the application of Poincaré's theory of rotating stellar bodies. His supervisor was Hugo von Seeliger whom he often mentioned with much admiration throughout his life.

From 1897 until 1899, he was employed as an assistant at the Kuffner Observatory in the suburb of Vienna called Ottakring. Here, he was engaged in the investigation and measurement of the apparent brightness of stars using photographic plates, from which he produced a formula to calculate the optical density of photographic material. This formula was especially important in dealing with photographic measurements of the intensities of distant, faint astronomical objects.

In the summer of 1899, he became a privatdozent at the University of Munich after submitting his habilitation thesis entitled *Beiträge zur photographischen Photometrie der Gestirne* which dealt with much of the astronomical work he had done at the Kuffner Observatory.

Outdoors. Sitting, second from left, with his family.
Courtesy AIP Emilio Segrè Visual Archives.

It is particularly interesting to note that already in 1900, Schwarzschild already pondered upon the possible non-Euclidean structure of space. His ideas were expounded at the meeting of the German Astronomical Society in Heidelberg that year. In the same year, he published a paper in which he gave a lower limit for the (measurable) radius of the curvature of space as 64 light years (suposing a hyperbolic space) or 1600 light years (an elliptic space). In dealing with solar radiation pressure, he assumed that the tails of comets consisted of spherical particles which acted as light reflectors. Thus he was able to calculate the size of the particles in the tails of the comets. He instinctively knew that radiation pressure had to somehow overcome gravitation, and that the particles did not scatter light. This way, he gave the exact diameters of the particles within the range of 0.07 and 1.5 microns.

From 1901 until 1909 he was an extraordinary professor at the University of Göttingen and also the director of the Observatory there. In Göttingen, he had the opportunity to work with some significant figures inhabiting the University, such as the mathematicians David Hilbert, Felix Klein, and Hermann Minkowski. He studied astrophysical phenomena associated with the energy transport mechanism in a star by means of radiation and produced an important paper on radiative equilibrium within the sun's atmosphere. Following this period, he

took up a post of the director at the Astronomical Observatory in Potsdam in 1909, a place which Eddington described for him as "... very congenial..." [1].

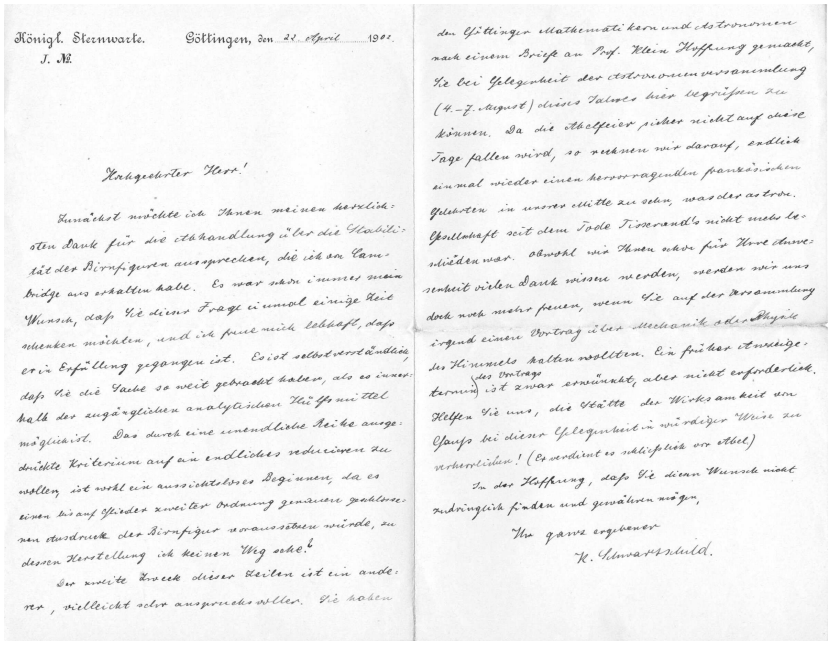
In 1913, Schwarzschild was elected a member of the Prussian Academy of Sciences in Berlin. During his election, he produced a memorable speech which outlined the essence of his attitude towards science [1]:

> "Mathematics, physics, chemistry, astronomy, march in one front. Whichever lags behind is drawn after. Whichever hastens ahead helps on the others. The closest solidarity between astronomy and the whole circle of exact science. ... from this aspect I may count it well that my interest has never been limited to the things beyond the moon, but has followed the threads which spin themselves from there to our sublunar knowledge; I have often been untrue to the heavens. That is an impulse to the universal which was strengthened unwittingly by my teacher Seeliger, and afterwards was further nourished by Felix Klein and the whole scientific circle at Göttingen. There the motto runs that mathematics, physics, and astronomy constitute one knowledge, which, like the Greek culture, is only comprehended as a perfect whole."

Soon, in 1914, Europe was plagued with the outbreak of World War I. Subsequently, he joined the German army as a volunteer despite being over 40 years old. He served on both the Eastern and Western Fronts, eventually rising to the rank of lieutenant in the artillery division. Notably, he served in Belgium where he was put in charge of a local weather station, in France where he produced calculations of missile trajectories, and then in Russia.

While in Russia, despite suffering from a rare and painful skin disease called pemphigus, he managed to write three pivotal papers: two on the exact solutions to Einstein's field equations of the General Theory of Relativity, the new theory of space-time and gravitation, and one on Planck's quantum theory. As it is well-known, his papers on the General Theory of Relativity gave the first exact solutions to Einstein's unimodular field equations of gravitation in the empty space surrounding a spherical mass, a solution which now bears his name, the Schwarzschild metric, which actually involves a slight modification of his original solution. Meanwhile, his paper on quantum theory gave a lucid explanation of the so-called Stark effect.

Upon receiving Schwarzschild's manuscripts, Einstein himself was pleasantly surprised to learn that his non-linear field equations of gravitation did admit exact solutions, despite their "prima facie" complex-



Brief letter to Henri Poincaré, April 22, 1902. Courtesy Max-Planck-Institut für Wissenschaftsgeschichte, MPIWG Library Collection.

ity, which, according to him, were elegantly shown by Schwarzschild in "...such a simple way..." [2]. Prior to this, Einstein himself was only able to produce an approximate solution, given in his famous 1915 paper on the advance of the perihelion of Mercury. In that paper, Einstein employed a rectilinear coordinate system in order to approximate the gravitational field around a spherically symmetric, static, non-rotating, non-charged mass. Schwarzschild, in contrast to Einstein's initial approach, chose a generalization of the polar coordinate system and was thus able to produce an exact solution in a more elegant manner, a manner somewhat more befitting the splendour and subtlety of the full non-Euclidean nature of Einstein's geometric theory.

In 1916, the elated Einstein famously wrote to Schwarzschild on his newly obtained result [2]:

> "I have read your paper with the utmost interest. I had not expected that one could formulate the exact solution of the problem in such a simple way. I liked very much your mathematical treatment of the subject. Next Thursday I shall present the work to the Academy with a few words of explanation."

Shortly after he sent his last two papers on the General Theory of Relativity to Einstein, Schwarzschild had to succumb to the skin disease he had contracted earlier. The disease, pemphigus, is a rare kind of autimmune blistering skin rash. It is said that for people plagued with this skin rash, the immune system mistakes the cells in the skin as foreign and attacks them, resulting in painful blisters. In Schwarzschild's time there was no known medical treatment or cure for the disease and, after being freed from his military duty to be interned at home in March 1916, he died two months later, on May 11, 1916, at the age of 42.

Schwarzschild died at the height of his scientific achievements. He certainly was a man of wide scientific interests. Apart from his earlier work on astronomy, which included celestial mechanics, observational stellar photometry, optical systems, observational and instrumental astronomy, stellar structure and statistics, comets, and spectroscopy, and his outstanding work in the area of the General Theory of Relativity, he also worked on electrodynamics and geometrical optics (while in Göttingen). He also maintained deep interest in quantum theory.

He married Else Posenbach, the daughter of a professor of surgery at the University of Göttingen, on 22 October 1909. Together, they had three children: Agathe, Martin, and Alfred. His second son, Martin Schwarzschild, followed in his father's footsteps as a professor of astrophysics at Princeton University.

Indranu Suhendro

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1. Eddington A. S. Karl Schwarzschild. *Monthly Notices of the Royal Astronomical Society*, 1917, vol. 77, 314–319.
2. Eisenstaedt J. The early interpretation of the Schwarzschild solution. In: *Einstein and the History of General Relativity: Proceedings, 1986 Osgood Hill Conference* (*Einstein Studies*, vol. 1), ed. by D. Howard and J. Stachel, Birkhauser, Boston, 1989, 213–233.

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