Biographical Encyclopedia of Astronomers

Schwarzschild, Karl

Born Frankfurt am Main, Germany, 9 October 1873

Died Potsdam, Germany, 11 May 1916

German theoretical astrophysicist Karl Schwarzschild is eponymous in the Schwarzschild solution to the equations of general relativity, the Schwarzschild horizon around black holes implied by that solution, and a number of other concepts in astrophysics. He was the eldest of seven children of Moses Martin Schwarzschild, a successful member of the Frankfurt business community, whose ancestors can be traced back in the city to the 16th century, and Henrietta Sabel. One of his sisters married Robert Emden. Karl Schwarzschild married Else Rosenbach in 1909. They had three children: Agatha (later Thornton, a classicist whose later career was spent in New Zealand), Martin Schwarzschild, and Alfred (who remained in Germany into World War II).

Schwarzschild first attended the Jewish community school and completed his secondary education in 1891 at the municipal gymnasium in Frankfurt. He began studying astronomy at the Kaiser Wilhelm University in Strasbourg and, after a year of military service (1893/1894) in Munich, completed his Ph.D. in 1896 with Hugo von Seeliger at the Ludwig Maximilian University. Schwarzschild's first job was as an assistant to Leo de Ball at the Kuffner Observatory in Vienna (1896–1899), and his second at Munich as a university lecturer

In 1901, Wilhelm Schur, the director of the Göttingen Observatory, died. After Seeliger and Maximilian Wolf, Karl Schwarzschild was third on the recommendation list. Neither Seeliger nor Wolf wanted to go to Göttingen. Schwarzschild was next, but initially the ministry in Berlin did not want him as director and full professor. Two more candidates were asked, who also declined. On 10 October 1901, Schwarzschild sent his parents a telegram which read, "Extraordinarius and Director. Arrive Monday - Karl." By 24 May 1902, he was appointed to a full professorship.

Much of Schwarzschild's work of lasting importance to astrophysics dates from the Göttingen period. Papers published in 1906 established how stars could exist stably with energy carried entirely by radiation (as first suggested by Ralph Sampson in 1894), established the concept of local thermodynamic equilibrium (meaning that the same temperature described the gas and the radiation in a given volume, but that radiation could flow systematically in one direction), and developed the Schwarzschild criterion for deciding when radiation could no longer carry all the energy so that convection would set in, giving rise, for instance, to the observed granulation of the solar surface. He also analyzed the aberrations in various kinds of telescopes

Schwarzschild also considered the question of how to determine the distances of stars too far away to have measurable parallaxes, arriving at theoretical justification for a method that used only apparent brightnesses and motion across the plane of the sky. He then asked how one might best describe the motions of large numbers of stars through space, arriving (1907/1908)

at an alternative to the star streams of Jacobus Kapteyn. Schwarzschild's velocity ellipsoid recorded the fact that the dispersion of velocities seemed to be largest in two opposite directions in the sky, next largest in a direction perpendicular to that, and smallest in the third perpendicular direction. These directions are now understood as projections of the rotation of the Milky Way Galaxy and the motions of the stars perpendicular to the galactic plane. Of his students at Göttingen,

The one whose work connects most directly with modern astronomy was Hans Rosenberg, who, on Schwarzschild's advice, plotted the luminosity of members of the Hyades as a function of their spectral type, thereby publishing in 1910 what later became known as the Hertzsprung-Russell diagram

In 1909, Schwarzschild was appointed successor to Hermann Vogel at the Astrophysical Observatory at Potsdam. Although this was the most prominent position an astronomer could hope to hold in Germany at that time, Schwarzschild was not at all enthusiastic. His wife's family lived in Göttingen, he had a wide circle of friends, and, above all, Göttingen was a mathematical stronghold. Nevertheless, he finally agreed, on the condition that his assistant, Ejnar Hertzsprung, should move to Potsdam with him. Schwarzschild quickly familiarized himself with the various fields of work being carried out at Potsdam. In 1910, he traveled to the United States to attend a meeting of the American Astronomical Society and used the opportunity to visit many of the large American observatories. He returned convinced that Germany definitely needed an observatory in the Southern Hemisphere. Schwarzschild proposed Windhoek, in German Southwest Africa

Schwarzschild's research at Potsdam included additional calculations of stellar atmospheres, including the reversing-layer (or Schuster-Schwarzschild) approximation for how absorption lines are produced in stellar atmospheres, permitting calculation of how much of each element must be present. Other papers reported a study of how dark absorption lines and continuous radiation should appear as a function of position on the solar disk and the fraction of energy carried by convection. He also analyzed observations of the tails of the two great comets of 1910 (C/1910 A1 and 1P/Halley), showing that the tails contain extraordinarily tenuous material even compared to thin air. And Schwarzschild began applying Niels Bohr's atomic model to the analysis of spectra of atoms and simple molecules

In 1914, World War I broke out and increasingly affected the work of the institute. Schwarzschild immediately volunteered for service in the army. In September 1914, he was sent, as acting officer, to Namur in Belgium as head of a field weather station. He spent all of 1915 in the field, first in Belgium, later as a member of the artillery staff, partly in France and Russia. During the Russian campaign, Schwarzschild already showed symptoms of pemphigus, a painful and then incurable skin disease (now recognized as having an autoimmune component). He was disabled at home, hospitalized, and died soon after

The year of Schwarzschild's death saw the publication of three significant papers: one on ballistics (part of his war work), one explaining the broadening of atomic lines in the presence of an external electric field (the Stark effect, discovered in 1913), and the classic description of the structure of spacetime outside a spherically symmetric distribution of mass (or point

mass) within the framework of the general theory of relativity, which introduced the concepts of the Schwarzschild radius and Schwarzschild horizon.

Schwarzschild received many outstanding honors and awards. Some of the most important are ordinary member of the Göttingen Academy of Sciences and Humanities (1905), associate of the Royal Astronomical Society, London (1909), member of the German Academy of Sciences Leopoldina (1910), and member of the Prussian Academy of Sciences in Berlin (1912).

Peter Habison

Selected References

Dieke, Sally H. (1975). "Schwarzschild, Karl." *In Dictionary of Scientific Biography*, edited by Charles Coulston Gillispie, Vol. 12, pp. 247-253. New York: Charles Scribner's Sons.

Eddington, A. S. (1917). "Karl Schwarzschild." *Monthly Notices of the Royal Astronomical Society* 77: 314-319.

Einstein, A. (1916). "Memorial Lecture on Karl Schwarzschild." *Sitzungsberichte der*

Königlich Preussischen Akademie der Wissenschaften zu Berlin 1: 768-770.

Hertzsprung, Ejnar (1917). "Karl Schwarzschild." *Astrophysical Journal* 45: 285-292

Kritzinger, H. H. (1916). "Karl Schwarzschild." *Sirius* 49: 129-130.

Oppenheim, S. (1923). "Karl Schwarzschild. On the 50th anniversary of his birth date." *Vierteljahresschrift der Astronomischen Gesellschaft* 58: 191-209.

Parkhust, J. A. (1916). "Karl Schwarzschild." *Science*, n.s., 44: 232-234.

Runge, C. (1916). "Karl Schwarzschild." *Physikalische Zeitschrift* 17: 545-547.

Schwarzschild, Karl (1992). *Collected Works*, edited by H. H. Voigt. 3 Vols. Berlin: Springer-Verlag. (For his publications and for additional biographical references.)

Sommerfeld, A. (1916). "Karl Schwarzschild." *Die Naturwissenschaft* 4: 453-457.

Voigt, H. H. (1989). "From Karl Schwarzschild to Hans Kienle - The path from classical astronomy to astrophysics in Göttingen." *Sterne und Weltraum* 28: 12-17