

# Biographical Encyclopedia of Astronomers

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Birkhoff, George David

Born Overisel, Michigan, USA, March 21, 1884

Died Cambridge, Massachusetts, USA, November 12, 1944

American mathematician George Birkhoff developed two theorems with astronomical applications, one (the ergodic theorem) relevant to systems where one wants to take averages over time and space, and one (Birkhoff's theorem) showing that some results of Newtonian gravitation also apply to general relativistic models of the Universe under certain circumstances. He was the son of David Birkhoff, a doctor, and Jane Gertrude Droppers. At the age of 12, Birkhoff entered the Lewis Institute, a West Side Chicago liberal arts and sciences college that merged in 1940 with the Armour Institute to become what is now the Illinois Institute of Technology. In 1901, a year before his graduation from Lewis Institute, he began a correspondence with mathematician Harry Vandiver on number theory that would lead to his first publication in 1904.

Upon graduation from Lewis Institute, Birkhoff entered the University of Chicago, spending only a year there before transferring to Harvard in 1903. He received an A.B. in 1905 and an A.M. in 1906, both in mathematics. Birkhoff returned to the University of Chicago in 1906 to study for his doctorate. His doctoral thesis, purely mathematical in nature, was submitted in 1907 under the title *Asymptotic Properties of Certain Ordinary Differential Equations with Applications to Boundary Value and Expansion Problems*. Also in 1907, Birkhoff accepted a post as a lecturer at the University of Wisconsin at Madison. It was in Madison that he married Margaret Elizabeth Grafius in 1908. The couple had three children, including their son Garrett Birkhoff, a well-known mathematician. In 1909, Birkhoff accepted the post of preceptor of mathematics at Princeton, where he became a professor in 1911. However, in 1912, Birkhoff moved again, this time back to his alma mater, Harvard, where he became a full professor in 1919 and remained for the rest of his life. Also in 1919, he served as vice president of the American Mathematical Society (AMS). In 1923, the AMS awarded Birkhoff the first Bôcher Memorial Prize, and he served as president in 1925 and 1926. In 1932, Birkhoff was given the post of Perkins Professor, and in 1936 he became the Dean of the Faculty of Arts and Sciences.

There is a crater on the Moon named after Birkhoff; his other awards and honors are too numerous to name. However, he had one serious character flaw that had a significant effect on his relations with other scientists of his day: Birkhoff was unabashedly anti-Semitic. Some of his actions included hindering the appointment of Jews to posts at Harvard and making openly anti-Semitic remarks in his correspondence. During the 1930s and 1940s, Birkhoff did help a few European refugees get jobs, though none at Harvard.

Birkhoff was primarily a mathematician, but several aspects of his work were to become useful in astrophysics. Jules Poincaré was considered Birkhoff's greatest influence, though this influence stemmed purely from Birkhoff's intensive reading of Poincaré's work. In 1913, Birkhoff proved Poincaré's last geometric theorem, which is a special case of the three-body problem. His main body of work was on dynamics and ergodic theory. In fact, he developed the ergodic theorem that transformed the Maxwell-Boltzmann kinetic theory of gases into a rigorous principle using a process known as the Lebesgue measure. Ergodic theory has been applied to numerous astrophysical processes, including orbital mechanics, stellar dynamics, gravitation, the propagation of photons in the solar corona, and relativistic cosmology.

Within astrophysics, Birkhoff was perhaps best known for what is now referred to as Birkhoff's theorem. In 1923, he proved generally that there is a unique solution to Albert Einstein's field equations

for a spherically symmetric distribution of matter. One way of writing this solution is:

$$(d^2R)/(dt^2) = -(4/3)\pi G\rho R(t),$$

where  $R(t)$  represents a dimensionless factor that describes an expansion, in this case, of the Universe. This equation describes the acceleration of a mass shell in the Universe and shows that it is dependent only on  $\rho$  and  $R$ . Birkhoff's theorem holds even when general relativity is included, making it a vital component in the study of cosmology. It was, for example, an important starting point for Georges Lemaître in the evolution of his primeval-atom hypothesis.

*Ian T. Durham*

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