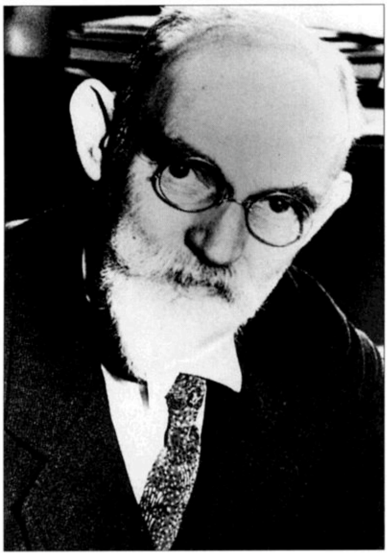

Willem de Sitter

The Twenty-Sixth Bruce Medalist

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Willem de Sitter born May 6, 1872, died Nov. 19, 1934. De Sitter received the ASP's Bruce Medal in 1931 for his research achievements. Photo courtesy of Yerkes Observatory.

Often in the history of astronomy, chance meetings have changed lives. Readers of this series may recall the fruitful collaboration between Jacobus C. Kapteyn, "the astronomer without a telescope" at the University of Groningen, and David Gill, Her Majesty's Astronomer at the Cape of Good Hope (September/October 1991, p. 145; May/June 1990, p. 84). Gill photographed the southern sky from Cape Town, Kapteyn did the measurement and analysis in Holland.

On a visit to Groningen in 1896, Gill met a mathematics student in Kapteyn's lab. The following morning he sent for the young man and, with Kapteyn's wife acting as interpreter, offered him a job in Cape Town. Thus began Willem de Sitter's astronomy career.

"I had never made a specialty of astronomy and intended to become a mathematician," de Sitter recalled later. He accepted Gill's offer, but delayed his departure a year to complete his doctoral qualifying exams. In South Africa, de Sitter learned to use the difficult heliometer to make high-precision visual measurements of stellar parallaxes and, hence, distances. He checked the colors of stars, both visually and photographically, to investigate whether stars near the plane of the Milky Way are systematically bluer than those away from the plane. (This turned out to be the case. Blue stars have short lives, so they cannot move far from the plane of the galaxy, where they form.)

De Sitter's most important work in Cape Town involved a problem that would occupy much of his career: the motions of the Galilean satellites of Jupiter. In those days, Io, Europa, Ganymede, and Callisto appeared simply as points of light, rather than the richly textured worlds that *Pioneer* and *Voyager* spacecraft revealed in the 1970s. Still, measuring their positions and timing their eclipses made it possible for a skilled mathematician to estimate their masses, as well as the mass of Jupiter. De Sitter's work on the Jovian system earned him a Ph.D. and a job with Kapteyn when he returned to Holland two years later.

Over the next three decades, de Sitter encouraged observers in Cape Town, Greenwich, Leiden, and Pulkovo to photograph the Galilean satellites. For years his mass and orbit calculations were considered definitive. In 1908, de Sitter went to Leiden University as professor; in 1918, he became director of the Leiden Observatory. With Kapteyn's advice, he modernized the venerable institution, adding astrophysical and theoretical departments and hiring scientists such as Ejnar Hertzsprung, who would become his successor. He recognized the potential in Jan Oort, Kapteyn's last student, and arranged for Oort to spend two years at Yale learning positional astronomy from Frank Schlesinger (May/June, p. 26). One of de Sitter's own students, Dirk Brouwer, went to Yale and became a leading celestial mechanician.

De Sitter also thoroughly re-analyzed fundamental astronomical constants, including the distance to the sun, the constants of aberration and nutation, and the rotation of the earth. He sent observers to Kenya and South Africa to gather data and bring it back to the (cloudy) Netherlands. These painstaking efforts detected minuscule effects due to varying tidal friction and changes in the mass distribution over the Earth.

These achievements alone would justify his medals from the ASP and the Royal Astronomical Society of London, but it is for relativistic cosmology that de Sitter's name is most remembered today.

De Sitter started to work on Einstein's theories in 1911, when he applied the 1905 special theory of relativity to planetary motion. Special relativity, he discovered, predicted small precessions of the perihelia of the inner planets (only one-sixth of what general relativity would later predict).

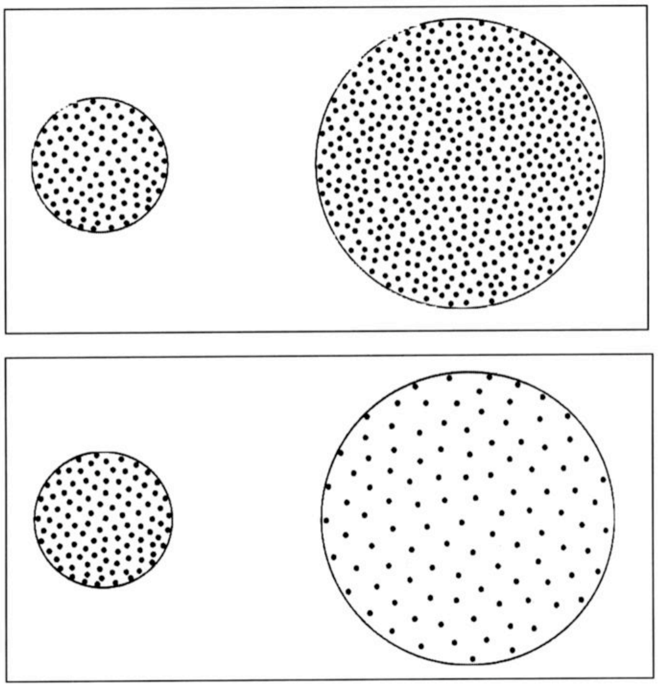
Meanwhile, the political situation in Europe forced de Sitter to become the liaison between relativists in Germany and in England. Holland remained neutral during the First World War, and Einstein, then director of the Kaiser Wilhelm Institute of Physics in Berlin, visited Leiden often. A widely reproduced photo, taken after the war, shows Einstein and Cambridge astronomer

Arthur S. Eddington visiting de Sitter and Leiden physics professors Hendrik A. Lorentz and Paul Ehrenfest (July/August 1993, p. 120). As Europe disintegrated in war, these scientists were themselves tearing up the old paradigms of physics and building up a new physics based on Einstein's general theory of relativity. As he could not communicate directly with Allied countries, Einstein sent his papers to de Sitter, who forwarded them to Eddington, the secretary of the Royal Astronomical Society. Eddington, in turn, invited de Sitter to write about the radical new theory.

De Sitter published three lengthy papers in the *Monthly Notices of the Royal Astronomical Society* in 1916 and 1917. The first two revealed to the English-speaking world the content of Einstein's new theory, while the third added de Sitter's own contribution. British cosmologist William H. McCrea later remarked that Einstein, a physicist with little knowledge of astronomy, thought of astronomy as a means to test the theory, while de Sitter thought of the theory as a means to understand astronomy.

By making certain assumptions about what the universe contains, a mathematician can apply Einstein's equations to determine the shape of the universe. This is what de Sitter did in his third paper. He revealed a second possible shape of the universe. Einstein had found the first: a closed, spherical universe forced to stand still by the "cosmological constant," a repulsive force that acts over immense distances to counterbalance gravity.

De Sitter's universe was stranger still. It was empty. If Einstein's model had matter without motion, de Sitter's model had motion without matter. This is not as strange as it might seem, since cosmic densities are low. In de Sitter's model, space expands forever at a steady rate. Objects would appear to move apart from one another, because of gravitational redshift. The more familiar Doppler redshift causes light from receding objects to redden. Einstein's theory allows for a second type of redshift due to gravity. As de Sitter put it: "The frequency of light-vibrations diminishes with increasing distance from the origin of coordinates. The lines in the spectra of very distant stars or nebulae must therefore be systematically displaced towards the red, giving rise to a spurious positive radial velocity." Except for being empty, de Sitter's universe is equivalent to the steady-state models developed by Hermann Bondi, Thomas Gold, and Fred Hoyle three decades later (see diagram).



By applying Einstein's general theory of relativity, de Sitter predicted that the universe expands. He was the first to make this prediction. His model also predicted that the overall nature of the universe would not change with time, an idea known as the "perfect cosmological principle." But astronomers discarded this principle as they found that the universe does change over time. The top drawing illustrates a version of the perfect cosmological principle. The universe (circle) expands, but the distribution of galaxies (dots) remains the same. The bottom drawing illustrates an expanding and evolving universe.

De Sitter concluded his paper by comparing his and Einstein's models with observations. "Spiral nebulae most probably are amongst the most distant objects we know," he wrote. "Recently a number of radial velocities of these nebulae have been determined." He went on to list the three spiral nebulae whose radial velocities had been reported by more than one observer. Of these, the great nebula in Andromeda (M31) had a large blueshift, the other two large redshifts. De Sitter's comparisons were the first attempt to relate the geometry of the universe to observational evidence.

De Sitter did not know it, but Vesto M. Slipher of the Lowell Observatory had already measured radial velocities of more than fifteen spiral nebulae; by 1922, he had forty, with 36 redshifts to 4 blueshifts (see "Echoes of the Past," p. 6). By 1929, Carl Wirtz and Edwin Hubble had established it beyond doubt: The universe was indeed expanding.

Although de Sitter's model was progress, he recognized its contradictions: The universe apparently contained enough matter to make it an Einstein world, and enough motion to make it a de Sitter world. Both models were wrong: They failed to predict that the universe changes with time. Georges Lemaître in Belgium and Alexander Friedmann in Russia published dynamic models, and cosmologists have used evolving universe models ever since.

Never robust, de Sitter died of pneumonia at 62. Forty years later, McCrea remembered: "As to the man himself, he possessed all the qualities in keeping with the part he played.... He bore himself with quiet gentle dignity and it was difficulty to realize how hard he must have worked throughout his life. It was good simply to be in his presence; he was so completely un-self-conscious himself that he seemed naturally to banish self-consciousness in those around him."

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