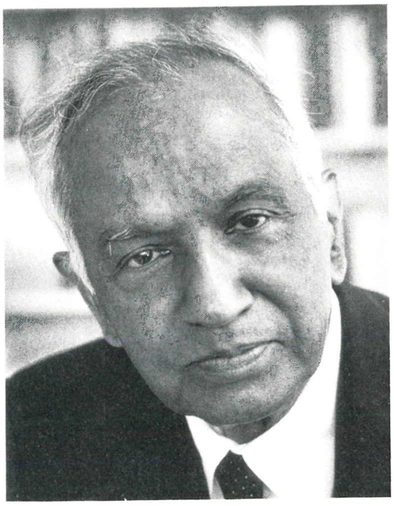
man Beller Medal from OSA. In the words of the award citation, "Goodman and his approximately 50 doctoral students have made major contributions in numerous areas of optical information processing, including synthetic aperture optics, volume holography, optical matrix processors, space-variant optical systems, speckle theory, optical interconnects and switching, integrated optics, digital optical computing and digital image processing."

There are six recipients of Engineering Excellence Awards from OSA: **Francisco J. Duarte, John D. Gonglewski, Gary Guenther, Melvyn H. Kreitzer, Frank Luecke** and **David G. Voelz.** Duarte, a business leader at Eastman Kodak in Rochester, New York, is recognized for "the invention of an electro-optic coherent interferometer for direct applications to imaging diagnostics of transparent surfaces, such as photographic film and film substrates." Gonglewski, a research optical physicist at the US Air Force Phillips Laboratory in New Mexico, is cited for "exceptionally creative optical engineering that produced the first high-resolution images of satellites passing over optical space surveillance sites during the daytime." Guenther is a general physical scientist at the National Oceanic and Atmospheric Administration; OSA recognizes him for "significant contributions to airborne lidar bathymetry and in particular development of the depth extraction algorithm." Kreitzer, an optical designer for Opcon Associates in Cincinnati, Ohio, is recognized for "contributions to the design of numerous photographic lenses and projection displays and for advancing the state of the art in these fields." Luecke, a vice president and founder of New Focus of Santa Clara, California, is cited for "achieving elegance in products that exemplify sound integration of mechanical, optical and electronic elements." Voelz, the active imaging program manager at the US Air Force Phillips Laboratory, is credited with "the development of the first optical synthetic aperture space object imaging system."

OBITUARIES

Subrahmanyan Chandrasekhar



SUBRAHMANYAN CHANDRASEKHAR

Subrahmanyan Chandrasekhar, who died on 21 August, appeared on the physics scene in 1929 with two papers written while an 18-year-old student at Presidency College, Madras, India. Chandrasekhar (Chandra to everyone) sent the first paper, "The Compton Scattering and the New Statistics," to Ralph H. Fowler of Cambridge University's Trinity College. Fowler was so pleased with it that he offered to communicate it to the Royal Society for publication in its *Proceedings*; the second paper appeared in *Philosophical Magazine*.

Chandra was born on 19 October 1910. He graduated from Presidency College with a bachelor's degree in theoretical physics. While there he won an Indian government scholarship to Trinity College. He left India by ship on 31 July 1930.

As is well known, on his two-and-a-half week journey to England Chandra occupied himself by reformulating the statistical mechanics of the degenerate electron gas, recognizing that the higher quantum states are relativistic under the conditions in white dwarf stars. Contrary to his expectations he found that the electron pressure is limited to something of the order of $\hbar c N^{4/3}$, where N is the number density. The equivalent temperature is $kT \sim \hbar c N^{1/3}$. On the other hand, supporting a self-grativating sphere of mass m against contraction requires a mean equivalent temperature of the order GmM/R, where M is the ionic mass associated with each electron. Because $N \sim m/MR^3$ it follows that m must not exceed the order of $(\hbar c/G)^{3/2}/M^2$, which turns out to be about 1.4 solar masses, now known as the "Chandrasekhar mass limit."

Later in the 1930s he made another important discovery at Cambridge: Fowler, Edward A. Milne and others were not able to grasp the reality and implication of this fundamental result. One of these others, Arthur Eddington, made no comment in private but publicly denounced Chandra's result, declaring, "I think there should be a law of nature to prevent a star from behaving in this absurd way." Later, Eddington argued that the Pauli exclusion principle could not be applied to relativistic systems. Léon Rosenfeld, Niels Bohr, Wolfgang Pauli and Paul A. M. Dirac upheld Chandra's result in private, but Eddington's cocksure faith in his own whims was unshaken, and the astronomical community largely accepted his authority. Thus arose the 50-year delay in Chandra's receiving the Nobel Prize in Physics in 1983.

Chandra received his PhD in December 1933, writing his thesis on rotating self-gravitating polytropes. But Eddington's authoritative wishful thinking on the mass limit of the white dwarf prevented Chandra from obtaining a proper position in England, while political bickering and favoritism blocked his chances in India. This situation led to his accepting an invitation from Otto Struve to join the faculty at the Yerkes Observatory of the University of Chicago.

In 1936 Chandra returned briefly to India to marry Lalitha Doraiswamy, with whom he had attended physics classes at Presidency College in Madras, and who was then working in the Bangalore laboratory of Chandra's uncle, Nobel laureate Chandrasekhara Venkata Raman.

Chandra and Lalitha arrived in Chicago at the end of 1936, and Chandra began his 58-year career at the University of Chicago, becoming Morton D. Hall Distinguished Service Professor in Astronomy and Astrophysics in 1952. They spent the first 27 years at the Yerkes Observatory and the last 31 years at the Chicago campus. Lalitha's broad interests and good judgment complemented Chandra's more severe outlook, and they got on well in the Chicago academic community.

Chandra developed his theoretical work on stellar interiors, including degenerate matter, into a treatise, *An Introduction to the Study of Stellar Structure* (University of Chicago Press, 1939), which still makes an excellent textbook on the basic properties of a star.

Chandra had also become interested in the gravitational frictional drag on a star passing through a tenuous cloud of stars as a key to understanding the ages of the globular clusters. He summarized this work in his 1943 book *Principles of Stellar Dynamics* (University of Chicago Press) and in his penetrating article on "Stochastic Problems in Physics and Astronomy," published in *Reviews of Modern Physics* in the same year. It is interesting to think of this work as the forerunner of plasma physics without the convenience of the Debye radius and without the inconvenience of a large-scale magnetic field.

Chandra continued his work on stellar interiors, with calculations on opacities and the basic theory of radiative transfer, doing fundamental work on the negative hydrogen ion as the principal cause of the opacity of hydrogen at stellar surface temperatures. His systematic formulation of the subject appeared in 1950 in his monumental *Radiative Transfer* (Oxford University Press). In the 1950s he investigated plasma physics and hydrodynamics and concentrated on the stability of a variety of magnetic fluid configurations. Much of his work in this area is to be found in *Hydrodynamic and Hydromagnetic Stability* (Clarendon Press, 1961), which has been a benchmark since its first appearance.

Chandra next directed his attention to the classical problem of the stability of rotating ellipsoidal figures. The results in the framework of Newtonian mechanics and gravitation were organized in the monograph *Ellipsoidal Figures of Equilibrium* (Yale University Press, 1968). This line of thought brought him to the gravitational theory of general relativity, with which he treated stellar pulsations, discovering the relativistic instability of radial oscillations of white dwarf stars, and the Chandrasekhar–Friedman–Schutz instability, which has ultimately developed into a mechanism for the gravitational wave emission of black holes. The dynamical properties of the rotating black hole were expounded by Chandra in *The Mathematical Theory of Black Holes* (Oxford University Press, 1983). His discoveries did not stop there. In his subsequent work with Valeria Ferrari on exact solutions of the equations of general relativity, the singularities that arise in interacting gravitational waves came to light. Chandra also developed the post-Newtonian approximation that has become the standard formal approach to calculating the gravitational waves from dynamical systems of massive particles and has served as the basis for the post-post-Newtonian formalism.

Chandra accomplished the difficult task of a formal general-relativistic treatment of the instability of radial stellar pulsations in recent work with Ferrari, and the final paper was essentially finished at the time of his death. The problem is of particular interest because without the emission of gravitational waves (that is, in Newtonian gravitation) the system is stable unless some other form of dissipation is introduced. In his last years Chandra became increasingly interested in Newton's *Principia*. He published his review of Newton's work in a monograph, *Newton's Principia for the Common Reader* (Oxford University Press), which appeared just two months before his death.

Chandra's book *Truth and Beauty* (University of Chicago Press), published in 1987, contains a number of essays, including his well-known Ryerson Lecture, "Shakespeare, Newton and Beethoven," which is only one of his explorations of the motivations, ambitions and aesthetic rewards of the artist and the scientist.

Chandra served as editor of the *Astrophysical Journal* from 1952 to 1971, transforming it from a more or less private journal of the University of Chicago into the national journal of the American Astronomical Society, still published by the University of Chicago Press.

Chandra maintained uncompromising standards of integrity and excellence for his own research, for his editing and for his students, associates and acquaintances. It did not always foster the smoothest personal relations, because there were occasional misunderstandings on both sides. But it was an integral part of Chandra's scientific prowess, and his friends and acquaintances respected him for it.

In spite of the difficulties that Eddington's mulish attacks had created for him, Chandra ranked Eddington next to Karl Schwarzschild as the greatest astronomer of his time when he presented an obituary address for Eddington in 1944.

Now Chandra's own death at the age of almost 85 marks the passing of an era in which physicists first reached inward to understand the atom and the fundamental particles and outward to embrace the stars. Chandra never wavered in his pursuit of the physics of the stellar object in its diverse forms.

Eugene N. Parker
University of Chicago
Chicago, Illinois

T. Keith Glennan

Thomas Keith Glennan, the first administrator of the National Aeronautics and Space Administration, passed away on 11 April, in Mitchellville, Maryland, after a stroke. During a career that spanned more than half a century, he achieved success as a leader of institutions in both the public and private sectors.

Glennan had been president of the