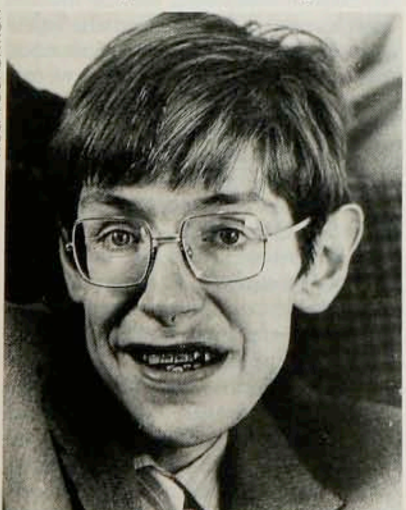
WOLF FOUNDATION HONORS HAWKING AND PENROSE FOR WORK ON RELATIVITY

In May, President Chaim Herzog of Israel presented the 1988 Wolf Prize in Physics to Stephen W. Hawking of the University of Cambridge and Roger Penrose of the University of Oxford. The prize committee cited the winners for their "brilliant development of the theory of general relativity, in which they have shown the necessity for cosmological singularities and have elucidated the physics of black holes." The two shared the \$100 000 prize money. The Wolf Foundation, established in 1976, presents six international awards each year for outstanding achievements in each of six disciplines: physics, chemistry, medicine, mathematics, agriculture and the arts.

The main contribution to general relativity for which Hawking and Penrose were honored is a cluster of theoretical results called "singularity theorems"—theorems that demonstrate the existence of a singularity in space–time based on certain initial assumptions. A singularity is, roughly, a point in space–time where the gravitational field becomes infinite or other pathological behavior occurs.

In 1965 Penrose published his first singularity theorem, which treated the specific problem of singularities in black holes. The theorem demonstrated that, given certain initial conditions on a collapsing star, a singularity would inevitably occur. Such singularities had been known previously only in certain specialized models (for example, models of stellar collapse that assumed perfect spherical symmetry). Penrose's theorem established that singularities are in fact a general feature of collapse.

Stephen W. Hawking



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The following year, Hawking announced his own singularity theorem. Applying Penrose's theorem to cosmology, Hawking proved the existence of a singularity not in a collapsing star, but at the beginning of the universe. Hawking's theorem advanced cosmology in much the same way Penrose's theorem had advanced black-hole physics. That is, it showed that singularities follow from rather general assumptions, whereas previously they had been known only for certain specific cosmological models—primarily those with perfect homogeneity.

During the next few years, Hawking worked to improve the primordial-singularity theorem. He proved several stronger theorems on his own and developed considerably the mathematical techniques he and Penrose had used. Eventually Penrose resumed his work on the problem, and the two began to collaborate toward a stronger theorem. Their definitive success came in 1970, when they jointly proved a singularity theorem much more powerful than any of the theorems they had created individually.

The theorem was a watershed in cosmology, because it asserted that a Big Bang singularity must occur in any universe with certain very fundamental properties, such as positivity of the energy density of matter. Earlier work by Evgenii M. Lifshitz and I. M. Khalatnikov had indicated that the singularities in some models—the Friedmann models, for example—were caused by the assumption of symmetry that was made in order to solve the problems. (This is analogous to the way a "singularity" arises in Newtonian mechanics when two point particles of equal energy collide head on.) Based on this work, there was reason to believe that our universe did not originate with a proper singularity. But the theorem of Hawking and Penrose showed that this belief was almost certainly erroneous.

In proving their theorem, Hawking and Penrose employed mathematical techniques that had been developed in the theory of differential topology but had never been successfully applied to Einstein's equations. While previous work had focused on rigorous solutions of Einstein's equations for each particular model, a method that necessitated making significant simplifying assumptions about the universe, Hawking and Penrose investigated the possible solutions to Einstein's equations assuming certain inequalities. Working with inequalities enabled Hawking and Penrose to sidestep many complexities and still come up with a significant result. The same mathematical techniques later enabled Hawking to prove the well-known area theorem for black holes. This theorem, to which Penrose also contributed, states that the surface area of a black hole must increase as mass is added.

The singularity theorem suggested that there was a time when cosmic distance scales were on the order of

Roger Penrose

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the Planck length ($\simeq 10^{-33}$ cm). Because the effects of quantum gravity are expected to become dominant at these scales, the theorem indicated that a theory of quantum gravity would be essential to understanding the universe. Formulating such a theory is still an open problem, but Hawking took some of the first steps toward solving it in the years after he and Penrose proved their singularity theorem. In 1974, using many simplifying assumptions to skirt some of the difficulties that still plague quantum gravity, Hawking subjected the region surrounding a black hole to a quantum mechanical treatment and produced several astonishing results. Most notably, he showed that a black hole radiates as a blackbody with a temperature inversely proportional to its mass.

Hawking was educated at University College, Oxford. He was a staff member of the Institute of Theoretical Astronomy at the University of Cambridge from 1968 to 1972, and a Fellow for Distinction in Science at Gonville and Caius College, Cambridge, from 1969 to 1977. Since 1977 he has been a professor of gravitational physics at Cambridge and a professorial fellow at Gonville and Caius. He was named Lucasian Professor of Mathematics at Cambridge in 1979.

Penrose received his BSc at University College, London, in 1952 and his PhD from the University of Cambridge in 1957. He was a research fellow at St. John's College, Cambridge, from 1957 to 1960. From 1959 to 1961 he was a NATO research fellow at Princeton, Syracuse and Cornell universities. He worked as a research associate at King's College, London, and as a visiting associate professor at the University of Texas, Austin, and then had visiting appointments at Princeton, the University of Chicago, Yeshiva University and Cornell. In 1967 Penrose became a mathematics professor at Birbeck College, London, and since 1973 he has been the Rouse Ball Professor of the Mathematical Institute at the University of Oxford.

—Matthew Siegel

OBITUARIES

Richard Christian

Richard S. Christian, an associate professor of physics at Purdue University, died suddenly and unexpectedly of a stroke on 1 March 1988 in Pennsylvania. He was 65 years old. Although his health had been fragile in the past few years, he nevertheless pursued a vigorous career as a teacher and theoretician in plasma physics and accelerator design at Purdue and Los Alamos.

Christian was born in Chicago and studied chemical engineering and physics at the Illinois Institute of Technology, where he received his BS in 1947. He earned his PhD in physics from the University of California, Berkeley, in 1951 under the direction of Robert Serber. Christian's professional career began early in World War II, when he was assigned to Los Alamos as an Army private after some training in chemical engineering. He was put to work helping Charlotte Serber in the library, which she managed. She soon pointed out to Donald Kerst and Seth Neddermeyer that Christian's scientific knowledge could be better used in the laboratory. As a result, he joined a group using the 22-MeV betatron and a cloud chamber to examine uranium motion in implosions. He worked with this group on experiments and analysis throughout the war.

After the war he went to Berkeley for his doctoral work. In his thesis he made a theoretical study of tensor forces in the deuteron, which inspired further work on nucleon–nucleon interactions at Berkeley and, later, at Los Alamos, to which he returned in 1951. Several important publications emerged from this period, some by Christian alone, and some written in collaboration with E. W. Hart, H. P. Noyes, J. L. Gammel, T. D. Lee and others.

In 1955 Christian made a major change in his scientific career. He became associated with the Midwestern Universities Research Association in Madison, Wisconsin. At about this time he became aware of the digital computer, and he learned how to exploit it for scientific calculations in a way that few of us could match. The years at MURA were a time of enormous accomplishment for him. While still at Los Alamos, he had begun to explore relaxation methods for calculating fields. At MURA, where interest in complicated magnetic fields was naturally very high because of the lab's work on fixed-frequency alternating-gradient accelerators, he pioneered these relaxation methods and demonstrated their applicability to many geometries. With help from Jackson Laslett, he demonstrated how to calculate fields in the presence of currents. FFAG fields were highly nonlinear, and Christian played a leading role in demonstrating to the