

Tor Hagfors

December 18, 1930 — January 17, 2007

Emeritus Professor Tor Hagfors collapsed and died of a heart attack while walking on a beach in Puerto Rico during a visit to the Cornell-run Arecibo Observatory, an observatory to which he devoted a substantial portion of his remarkable career, a career that spanned half a century, several countries, and directorships at three major observatories and a Max Planck Institute.

Born in Oslo in 1930, Tor received his education in Oslo and Trondheim, finishing with a Ph.D. degree in Physics from the University of Oslo in 1959. His first employment, from 1955-63, was with the Norwegian Defence Research Establishment, interrupted by a position as Research Associate at Stanford University in 1959-60. During this period, Tor began the research that would engage him for the remainder of his life, the study of electromagnetic scattering from planetary surfaces and the Earth's ionosphere. He made major contributions to the field of Planetary Radar Astronomy during its fledgling years in the 1960s, deriving the still widely applied Hagfors Scattering Law and co-editing the book, *Radar Astronomy*, published in 1968. Tor also formulated the theory of incoherent scatter of electromagnetic waves by the ionosphere in a paper published in 1961, one of four papers at the time that independently provided the theoretical underpinnings for this new technique to measure the properties of the ionosphere. In addition to his many scientific results in these two areas, Tor played a major role in the engineering design of two very large radar facilities, and he was a talented scientific administrator who successfully navigated the intricacies of scientific funding and politics in both the United States and Europe.

In 1963, Tor returned from Norway to the United States, this time to the MIT operated Lincoln Laboratory, where he spent 1963-67 and 1969-71, working on incoherent scattering theory (particularly the effect of collisions between charged and neutral particles) and radar scattering from plasma waves generated by ionospheric currents associated with the aurora. It was at this time that he also made his major contributions to the field of planetary radar astronomy, deriving Hagfors' law and carrying out innovative studies of the properties of the lunar surface, studies of high interest during the Apollo era.

In between his two stints at Lincoln Laboratory, Hagfors served as the Director of the Jicamarca Radio Observatory, located near Lima, Peru. Jicamarca was the first of two huge radars (the second was Arecibo) built in the early 1960s to explore the properties (e.g., densities, temperatures, ion composition, velocities) of the ionosphere, using

incoherent scatter, at altitudes ranging from below one hundred kilometers up to several thousand kilometers. While at Jicamarca, Tor made very accurate measurements of vertical plasma drift velocities (driven by natural electric fields) in the ionosphere and also continued his studies of the Moon.

After leaving Peru in 1969, and following his second stint at Lincoln Laboratory in 1971, Tor was appointed Director of Operations of the Arecibo Observatory, the enormous radar built by Cornell in Puerto Rico. This was Tor's first association with Cornell, but it would not be his last. His research highlights during this period included contributions to the theory of "heating" of the ionosphere using very powerful radio waves, the development of clever radar techniques for observing the effects of this heating and, with one of us (DC), studies of the properties of the surface of Venus.

In 1973, Tor moved yet again, returning to Norway to become Professor of Electrical Engineering at the University of Trondheim, a position he held until 1982. He taught courses there in communication and information theory, radar techniques and technology, and antenna theory. His main reason for returning to Scandinavia, however, was to explore the possibility of building a major, second generation incoherent scatter radar observatory in Europe. The contemplated size and cost of the project was such that an international collaboration was required. After much negotiation, six nations (Norway, Sweden, Finland, Germany, France, and the UK) reached agreement to build a tri-static radar observatory (named EISCAT, for European Incoherent SCATter) in northern Scandinavia, with tightly coordinated facilities in Norway, Sweden, and Finland. Hagfors was the founding director from 1976-82. Besides his role as midwife to the birth of EISCAT, Tor also contributed heavily to its unique engineering concepts. EISCAT research has greatly improved our understanding of the high latitude ionosphere, a region of fascinating "space weather," where charged particles streaming from the Sun interact with the Earth's magnetic field to produce auroral displays and many other important but less visible effects on our upper atmosphere.

Tor's wanderlust never allowed him to stay in one place too long, and so in 1982, just as EISCAT was beginning to operate smoothly, he returned to Cornell for a ten-year stay as a Professor of both Astronomy and Electrical Engineering and also as Director of the National Astronomy and Ionosphere Center (NAIC), which manages the operation of the Arecibo Observatory. Besides his administrative duties, Tor continued his work on the theory and observations of Langmuir waves driven by radio wave "heating," as well as various radar astronomy projects. Perhaps his most important contribution to the Observatory was the engineering design for an ambitious second upgrade of the antenna system, adding two additional reflectors (producing a so-called Gregorian feed) to eliminate the distortion produced by the main spherical reflector. This huge project substantially increased the sensitivity

and frequency range of the telescope. Tor oversaw the detailed design of the Gregorian system and shepherded the major proposal through the funding process. During this period, he also spent a sabbatical year (1988-89) at the Max Planck Institute for Aeronomy in Lindau, Germany—a precursor to the next step in his career.

In 1992, as the construction of the upgrade was getting underway, Tor again pulled up stakes and moved back to Europe, becoming simultaneously Professor of Astronomy at the University of Oslo (until 1998) and one of the three co-directors of the Max Planck Institute in Lindau until 1999, when he reached the mandatory retirement age of 68. During this period, he had to deal with numerous vexing political and funding issues associated with German reunification, but he managed to stay active scientifically, especially with EISCAT and various satellite projects, and he began working on a textbook on incoherent scattering with one of us (DF).

During his “retirement” from 1999 until his death, he continued his research, collaborating with colleagues at MPI, the University of Tromsø, Norway, the University of Nagoya, Japan, the University of Lancaster, UK, EISCAT (with its new radar on Svalbard), and the Mars express and CONSERT satellite missions.

Professor Hagfors was a member of a long list of professional societies, research councils and advisory committees, both in Europe and the United States, and he also received numerous honors. Among the latter are the URSI Van der Pol Gold Medal (1987), the EISCAT Sir Granville Beynon Medal (2002), memberships in the Royal Norwegian Academy of Science and Letters (1996) and the Royal Astronomical Society (UK, Associate Member, 1998), and honorary doctorates from the Universities of Oulu (2002) and Tromsø (2003). He delivered major, invited, named lectures in 1999 (Penn State University), 2002 (U. Tromsø), and 2003 (Arecibo). He published well over 150 papers (many after retiring), mostly on radio wave scattering of various kinds, but also on engineering topics such as antenna design and pulse coding. He was a versatile theorist, a creative engineer, and a scientific leader. He freely gave credit to others for joint work and was a pleasure to work with. He was also a man of grace and wry humor, which he demonstrated as an after-dinner speaker on frequent occasions!

Tor is survived by his first and second wives, Gillian Patricia Hart and Hanna Halina Zofia Repa, and his four children John, Toril, Martin, and Vivien.

We close with some remarks delivered by one of us (DC) at a memorial service for Tor at the Max Planck Institute in Lindau, Germany:

“In his slightly formal way, Tor liked to enjoy himself and was always ready for a party, and some of the parties in Arecibo were memorable. He was spontaneous, once diving into the Observatory’s pool fully clothed on a dare from our young daughter. We went sailing in the Virgin Islands on several occasions...These trips were great opportunities for relaxation, swimming, and, without fail, a few rum and cokes.

“I want to finish by saying how much Tor was admired as a scientist and teacher by the people who worked with him. He had a passion for doing science, clearly derived great enjoyment from it, and communicated this to all of us who worked with him as students and colleagues. Rather than being remembered for the many awards and medals he received, I think that Tor would want to be remembered primarily as someone who loved to do science.”

Donald T. Farley, Chair; Robert Brown, Donald B. Campbell