NATIONAL ACADEMY OF SCIENCES

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1920–2004

A Biographical Memoir by

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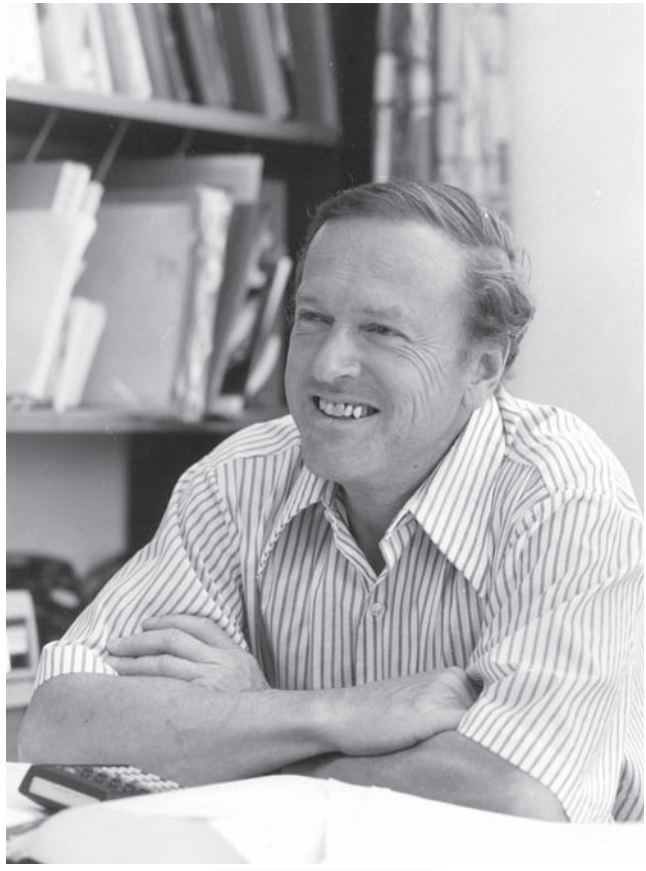
Biographical Memoirs, VOLUME 88

PUBLISHED 2006
NATIONAL ACADEMY OF SCIENCES
WASHINGTON, D.C.



THOMAS GOLD

May 22, 1920–June 22, 2004

BY GEOFFREY BURBIDGE AND MARGARET BURBIDGE

THOMAS GOLD WAS BORN in Vienna, Austria, on May 22, 1920, and he died in Ithaca, New York, on June 22, 2004. His father was a director of a large mining and metal fabrication company in Austria, and his mother had a theatrical background and had been a child actress.

In 1930 they moved to Berlin, where his father became director of another large company. By 1933 when Hitler came to power, it was clear that since his father was Jewish, they would have to leave, though they were not immediately persuaded since they were Austrians. But Tommy was sent to a boarding school in Zuoz in the Engadine in Switzerland, and by the late 1930s his parents had moved to England. At his school in Zuoz he soon found that he was high up in every class, and was very clever. He was also good at sports, and he became an excellent skier. In sports he was always aggressive. He had to win—he had to be the best. If he was not, for example at chess, he refused to play at all.

Tommy left Zuoz in 1937. In 1938, at the *Anschluss*, Germany invaded Austria and occupied it, and Gold and his family went to England with stateless papers. Gold entered Cambridge University and began to study in mechani-

cal sciences. In September 1939 war was declared, and the following May the British government rounded up and interned many men who were technically enemy aliens. Gold was picked up in Cambridge and a few weeks later he was shipped with some 800 others to Canada. Within a year, however, he was shipped back to England and released. It was during this internment that he met his close friend Hermann Bondi.

Gold went back to Cambridge University in 1942, having lost about a year, and began to realize that he much preferred physics to mechanical sciences. Bondi had already graduated from Cambridge, taking part III in mathematics in April 1942, joined the naval research establishment, and gone over to the radar establishment at the Admiralty, where he worked in the theory group headed by Fred Hoyle. Gold graduated with a pass degree in June 1942. Because Gold had not done very well at Cambridge it took several months before Hoyle, assisted by Bondi, could arrange for Gold to join them. In that period Gold worked as an agricultural laborer in the north of England, cutting pit props for the mines. This was work he enjoyed; he became a lumberjack and was proud that he could cut down more trees with an axe that anyone else in the camp.

By the end of 1942 he had joined Bondi and Hoyle in the radar research group and in a few months was put in charge of new radar devices, designing and building new kinds of radar systems. It was in this period that the three of them began to talk about and work on problems in astronomy. Soon after the end of the war in 1945, Hoyle and Bondi returned to Cambridge, but Gold was not able to get back to Cambridge until 1947, when he started first to work on magnetron design.

He ultimately got involved with R. J. Pumphrey, a zoologist in the Zoology Department, whom he had originally

met when Pumphrey was deputy head of the radar establishment. Thus he began to work in the zoology laboratory on the problem of hearing. This led to his first really original discovery. His studies of the cochlea showed that a passive cochlea where elements are brought into mechanical oscillation solely by the incident sound would not work. The degree of resonance of the elements of the cochlea can be measured, and the results are not compatible with the very heavy damping that must arise from the viscosity of the liquid. He proposed a regeneration hypothesis in which electromechanical action takes place whereby a supply of electrical energy is employed to counteract the damping. This feedback mechanism by the microphotonic potential forms an important link in the chemical events. This revolutionary idea was published by Gold (1948) and Pumphrey and Gold (1948), and Gold was awarded a prize fellowship at Trinity College Cambridge for his thesis on this topic. Unfortunately, the hearing specialists of that period with no physicists involved could not believe that the cochlea must incorporate such a mechanical feedback system. It took more that 40 years for this proposal to be understood and accepted. Gold's discouragement at this response led him to move into other fields, in particular, into astrophysics. On the basis of his radar work and a Trinity fellowship, Gold finally obtained a junior lectureship (a demonstratorship) in the Cavendish Laboratory.

STEADY STATE COSMOLOGY

Gold often discussed a wide range of problems in astrophysics with Hermann Bondi and Fred Hoyle. A major puzzle was Hubble's discovery of the redshift, the apparent magnitude relation that is interpreted as a clear indication that the universe is expanding. Gold pointed out in his

1978 interview with Spencer Weart[1] that Hoyle was talking endlessly about Hubble's result. As Gold put it,

> Everyone [else] had supposed that matter was created at one moment in the past because it was the obvious thing to say. There had been the Gamow discussion, but frankly it wasn't an awfully tight discussion. One didn't take it very seriously. But it was the obvious thing to say that if you see things flying apart you can work out when it [they] were together. People say it was all done at once. I don't see why you shouldn't think that it's done all the time and then none of the problems about fleeting moments arise. It can be just in a steady state with the expansion taking things apart as fast as new matter comes into being and condenses into new galaxies.

This was the basis of the idea that led Bondi and Gold to publish their paper on the steady state cosmology derived from what they called the "perfect cosmological principle," and Hoyle to publish separately on the steady state, basing his analysis on a field theoretical approach. Both papers appeared in 1948 and generated tremendous interest and a good deal of controversy.

For the next 10 to 15 years there was much debate about the steady state universe model. Most astronomers were opposed to it, some because of what they thought was good observational evidence against it, but nearly all of which turned out to be flawed. Others objected to it on religious grounds, though this was never admitted openly. It was Fred Hoyle and his student, and later collaborator, Jayant Narlikar, who devoted much of their energy making the case for the steady state model. They were strongly opposed by the Cavendish Laboratory's Martin Ryle and his radio astronomy group, who claimed that the distribution of distant radio sources that had been found showed that the universe is evolving and that the steady state theory could not be correct. Ryle began this crusade in 1955, and Hoyle and Narlikar tried not too successfully to deal with Ryle's observations; in the end it turned out that indeed

Ryle's initial data were flawed. From the beginning, the establishment and its followers believed Ryle. Ironically Ryle's whole argument was based on the belief that the radio sources were extragalactic, and at great distances—something that had only been established in 1952 but which Gold had suggested at a meeting in 1951. The circumstances were as follows.

For the first few years after the discovery of the radio sources, Ryle passionately believed that they were flare stars in our own Galaxy. At a meeting in London in 1951 it was Gold who first proposed that the sources might be very distant, and not very close by. When he said this (one of us, G.B., was present), he was harshly attacked by Ryle and several mathematical cosmologists who told him he didn't know what he was talking about. But by 1952 the first distant source had been identified, and at an International Astronomical Union meeting in Rome, Gold was able to get up and show that he was right, and that Ryle had been wrong.

By the early 1960s the apparent discovery[2] of the microwave background radiation, the black body radiation, led nearly everyone to believe that there must have been a beginning—a big bang. We suspect that Gold never believed this. Certainly Hoyle never did.

In 1952 Gold left Cambridge and became chief assistant to Astronomer Royal Sir Harold Spencer-Jones. He spent three productive years at the Royal Observatory. After Spencer-Jones retired and was replaced by Sir Richard Woolley, Gold resigned and left England in 1956. For the period 1957-1959 he was a professor of astronomy at Harvard University. In1959 he moved to Cornell University as chairman of the Department of Astronomy. He remained there as a professor and successively director of the Center for Radio Physics and Space Research (responsible for the Arecibo

Observatory in Puerto Rico) and assistant vice-president for research. He stayed at Cornell for the rest of his life.

In the period 1953-2004 he worked in many fields and demonstrated his amazing versatility in understanding and solving many geophysical and astrophysical problems. Some of his most notable achievements apart from those already mentioned are as follows.

While at the Royal Observatory, Gold became interested in the instability of the earth's axis of rotation (the wandering pole). He also wrote many papers on plasmas and magnetic fields in the solar system and the general problem of charged particles in the sun and the solar system. He invented the term "the earth's magnetosphere." With Fred Hoyle he developed a theory of solar flares.

In the 1950s and the 1960s he became active in many areas of space research and served on numerous U.S. national committees and as a consultant to the National Aeronautics and Space Administration. In the run-up to the manned space program and the lunar landing, there was much debate and confusion about the nature of the surface of the moon. Was it hard rock or was there a layer of fine dust? If the latter were true, the designers of the moon lander and the astronauts needed to know. By making use of the evidence from micro-impacts, craters, electrostatic fields, and other arguments, Gold predicted that the astronauts' boots would not sink in to more than about 3 centimeters. Within the range of possibilities this turned out to be close to the truth. But his popular approach to this problem had infuriated other experts; for example, he talked of "moon dust" instead of the "lunar regolite." Thus, he was unfairly attacked for being a centimeter or two wrong in his estimate.

Later on, Gold's relationship with NASA became very bad. This in large part was because Gold was outspokenly

critical of NASA's programs. In the 1970s he was highly critical of the space shuttle program, arguing correctly that it would never achieve low-cost or 50 flights a year. He testified to congressional committees along these lines, although he was warned by NASA officials that if he did this, his own research proposals, which were well supported by NASA at the time, would be in peril. There is clear documentary evidence that the threat was carried out. In 1973 the deputy administrator for NASA wrote to James Fletcher, then the administrator, that he had explained to Gold that adverse comments about the space program had negated the possibility of Gold being funded for his current proposal or any other. He wrote, "Gold should realize that being funded by the Government and NASA is a privilege, and that it would make little sense for us to fund him as long as his views are what they are now." After this (in 1973), Gold received almost nothing from NASA, and had to give up research in planetary sciences.

PULSARS

In 1968 a number of pulsed radio sources with periods of 0.25 to 1.33 seconds were discovered by a graduate student in radio astronomy at Cambridge, Jocelyn Bell, and her supervisor, Anthony Hewish. The very short and precise periods meant that the sources must be very small and either pulsating or rotating. Gold immediately deduced that the only viable model was one in which the period is associated with the rate of rotation of a neutron star. This was a major conclusion reached by Gold, and it is now considered to be the correct explanation. Because of the strong magnetic field and the high rotation speed, relativistic velocities will be set up in any plasma in the surrounding magnetosphere, leading to radiation in the pattern of a rotating beacon. Gold's analysis was immediately accepted,

and it has opened up many areas of research, such as those involving supernova studies, solid state physics (the composition of neutron stars), and galactic structure (using pulsars as probes of the galaxy).

GEOPHYSICS

In his last 20 years Gold returned to studies of the earth. He pointed out that some old deep gas bore holes, which theoretically should be exhausted, were still producing methane at a low but constant level. Isotope dating suggested that this was very old. He suggested that we might be seeing primeval methane trapped during the formation of the earth and continuously rising from the deep interior. If this were the case the amounts might be prodigious and of extreme importance. This gas might be trapped in fault structures and could both trigger and possibly enable us to predict the onset of earthquakes. Of course, such an hypothesis infuriated many petroleum geologists and others who believed in the conventional theory that the gas and oil have a very different origin. Small deep boreholes put down in the 1980s by the Swedish government to test Gold's hypothesis yielded only a small flow of methane, but it seemed to be ancient and to continue to flow.

Gold modified his original hypothesis to propose a "deep hot biosphere" of methane-producing organisms. The essential idea that he left with us is that hydrocarbons are not a by-product of prehistoric plant life but were present when the earth was created some 4.6×10^9 years ago. Geological pressure forced the hydrocarbons, accompanied by helium, up toward the surface from several hundred kilometers deep in the mantle. The hydrocarbons then formed the deposits of gas, oil, and coal. Micro-organisms that feed on hydrocarbons grew up in these deposits, and it is these that have

given rise to life on Earth. Such processes could also have taken place on other planets.

PERSONAL

Gold was married twice. In 1947 he married Merle Tuberg, an American theoretical astrophysicist who had worked with S. Chandrasekhar in Chicago. They had three daughters, Linda, Lucy, and Tanya. Later, in 1972, he married Carvel Beyer, whom he had met at Cornell. They had one daughter, Lauren. He is survived by six grandchildren.

He received many honors, including the Gold Medal of the Royal Astronomical Society. He was elected to the Royal Society in 1964, the National Academy of Sciences in 1968, and the American Philosophical Society in 1972.

He was one of the outstanding physicists of his time. His versatility was unmatched. As Freeman Dyson has said, "His theories were always original, always important, usually controversial—and usually right."

NOTES

1. Interview. Thomas Gold by Spencer Weart, recorded April 1, 1978. American Institute of Physics Oral History Archives.

2. It is often claimed that the Penzias and Wilson discovery is proof of the big bang hypothesis. This is not correct. In fact, the radiation had been indirectly discovered by McKellar in Canada long before (in 1941) the development of the big bang theory by Gamow and others in the 1950s. The cosmologists were completely unaware of this.

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