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Keith David Cole 1929–2010

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Keith Cole grew up in Cairns, attended the local high school, and became the first in his family to attend university. Trained in physics and mathematics, he taught in secondary schools before joining the 1956 Australian National Antarctic Research Expedition to Macquarie Island as Auroral Physicist. This was the start of his lifelong career in space physics, exploring primarily the space environment of the Earth. He had a remarkable ability to identify the important physical processes underlying many phenomena, often when only limited data or observations were available. Thus early in his career he correctly explained several puzzling phenomena, particularly in the ionosphere and thermosphere, and quickly established himself as a leader in space physics, a position he maintained throughout his career. He also made very significant contributions as an educator (he was a Foundation Professor of Physics at La Trobe University) and through leadership positions in national and international science organizations.

Keith David Cole, an eminent space physicist and Fellow of the Australian Academy of Science died on 13 December 2010 of complications related to Parkinson's disease at the age of 81. He was an outstanding scientist who made many original contributions in solar-terrestrial physics. He provided excellent leadership in his field, both nationally and internationally, and served the Australian Academy of Science as Foreign Secretary, Council Member and chair of committees, including the National Committee for Solar-Terrestrial Physics.

Cole was born on 2 March 1929 in Cairns, Queensland, and grew up there, the youngest of five children of John and Jessie Cole. They lived in Scott Street, Cairns and his father was a carpenter with the Queensland Railways. The family lived a relatively simple life in Cairns with John Cole being content to provide for his family and take them on holidays to local areas such as Green Island on the Great Barrier Reef (well before the island was commercialized). Keith Cole attended the local primary and secondary schools and graduated dux at Cairns High School. This was a remarkable achievement as it was the first year in which Cairns High had ever offered Year 12 studies and, without a science teacher, Cole had to teach not only himself, but the other students in the class. Life was not all study as he was an avid trumpet player, fished regularly in the local rivers and rode his bicycle around Cairns and the nearby Atherton Tablelands. He won a scholarship to the University of Queensland and was the first person in his family to attend university. He graduated BSc (Hons) in 1952, undertook a Diploma of Education in 1953 and then, while completing a Master's degree on relativity theory, taught in secondary schools in Queensland (including a period at Cairns High School as a teacher, not, as previously, a student teaching fellow pupils!).

In 1956 Cole was appointed Auroral Physicist on the Australian National Antarctic Research Expedition to Macquarie Island and this was the start to his life-long research into the aurora and other solar-terrestrial phenomena. Typically of the time, he had a broad, in-depth background in physics but no specific training in auroral physics or related high-latitude phenomena. At Macquarie Island the auroral observatory was located well away from the main base and he spent days waiting for the notoriously cloudy weather to clear sufficiently to permit night-time auroral observations. As well as observing and sketching the aurora, during cloudy periods he also drew cartoons depicting events on the base and these were enjoyed by his fellow expeditioners on his return to the main base.

At the end of the year-long expedition, Cole returned to Australia, married Ailsa Moore, also a Queenslander, and took up a position as a theoretical physicist with the Australian Antarctic Division, then based in Melbourne. He and Ailsa had three children (Maxine, James and David) between 1959 and 1962. Cole remained with the Australian Antarctic Division until 1962 when he was seconded to the CSIRO Upper Atmosphere Section in Camden, New South Wales, headed by D. F. Martyn, the renowned radio physicist who made many fundamental contributions to ionospheric physics and the understanding of ionospheric radio propagation.

During this early period of his career Cole published, in 1962, one of his most important contributions to solar-terrestrial physics: that Joule heating by electric currents in the ionosphere is a major source of energy input into the upper atmosphere, producing very significant effects (14). The existence of these currents was well known from the geomagnetic disturbances they produce at ground level but Cole was the first to recognize that these currents would produce considerable local heating that modifies the behaviour of the upper atmosphere. In the more than fifty years since he identified the importance of this Joule heating, our ability to model the behaviour of the upper atmosphere and predict impacts of space weather on the Earth's environment depends critically on knowing when, where and at what strength Joule heating is occurring. Consequently providing observations that adequately map Joule heating is required and it is still a major challenge to provide real-time descriptions.

Keith and his family moved to the USA in 1963 where Cole took up Research Associate positions, first at the University of Chicago and then at the University of Colorado. During this period he proposed three more very significant scientific ideas.

The first was an explanation of stable red arcs or SARARCs (31). These usually sub-visual arcs were discovered in 1956 and were particularly curious because they are purely red in the visible part of the spectrum. While understanding of the cause of auroras was still very crude at that time, it was believed (correctly as was later shown by satellite observations) that the aurora is caused primarily by energetic electrons precipitating down the Earth's magnetic field lines from altitudes of several Earth radii (that is, from the magnetosphere) and losing their energy by collisions with neutral atoms. As atmospheric density in the upper atmosphere increases exponentially with decreasing height, the result is that the energetic particles lose most of their energy at an altitude of around 100–250 km. Consequently there is a surge in the numbers of excited atoms, particularly of atomic oxygen, and it is the de-excitation of these atoms that produces green and red light seen in auroras. The excited states involved require the atoms to absorb very small amounts of energy (just a few electron volts) with the red emission requiring less. However, the electrons precipitating down the magnetic field lines are very energetic (typically tens of kilo-electron-volts), so they will always produce both the red and green light. Thus the challenge was to identify an energy source sufficient to provide just enough energy to excite the red emission but insufficient to excite the green emission. Cole proposed that this arose from heat conduction from the magnetosphere, produced at specific locations and under certain conditions by the ring current of energetic particles that flows in the magnetosphere around the equator at 3–5 Earth radii, the properties of which vary significantly during magnetic storms. The higher temperatures produced by the heat conduction mean that the ambient electrons have on average higher energies and, as the temperature increases, a point will be reached at which the red emission can be excited but not the green which would require an excessive increase in temperature. Hence heat conduction can produce a purely red emission. It is important to appreciate that Cole proposed this process at a time when very little was known about the structure, composition and processes that occur in the magnetosphere. The existence of the ring current had only been inferred from ground-based magnetic measurements—confirmation by satellite in-situ measurements came in the next decade—and as yet there were no measurements to show that the high temperatures that Cole proposed existed.

The basic idea of excitation by heat conduction as the source of SARARCs has stood the test of time but the actual details of how the energy is released from the region of the ring current is still debated. Whenever a paper proposing a ‘new’ theory of SARARCs appeared, invariably the new ideas were about how the energy was provided by the ring current and Cole would comment ‘they have just added a new front-end to my theory’.

In 1965 he explained a second phenomenon in a rather analogous way (30). A sub-visual red airglow is emitted throughout the thermosphere, primarily as a result of recombination of electrons and ions in the ionosphere. Its existence currently provides an important means of observing, from the ground, neutral winds and temperatures at ~250 km altitude. In the 1960s the cause of much of the behaviour of airglow was either unknown or uncertain. In particular, an unexpected pre-dawn enhancement of red airglow was occasionally observed, again unaccompanied by any increase in green airglow emission.

The Earth’s magnetic field is approximately that of a simple bar magnet (that is, a dipole) with axis tilted relative to the Earth’s rotation axis. Magnetic field lines provide connectivity between the ionosphere in the northern and southern hemispheres and at some locations at certain times of the year the foot of a field line in one hemisphere can become sunlit at sunrise while the foot in the other hemisphere remains in darkness for a short period before dawn. As one end becomes sunlit, photoionization occurs, increasing the electron and ion concentration of the ionosphere but also producing photoelectrons with energies of a few electron volts. Some of these photoelectrons are guided along the magnetic field lines to the other hemisphere where they have sufficient energy to excite, through collisions, the atomic oxygen red emission producing an enhancement of the red airglow just before dawn.

Keith Cole’s third insight was that charge exchange of energetic protons with ambient hydrogen atoms in the magnetosphere would produce ‘hot’ hydrogen atoms with enough energy to escape the Earth, and that this process was a significant contributor to the escape flux of hydrogen from the Earth (33). This type of charge-exchange process has proved to be a very basic and important one that occurs in other planetary atmospheres as well.

These important successes over just a few years established Cole as a leading theorist in solar-terrestrial physics or space physics, the term used to describe the field in which the world-wide scientific effort was then expanding rapidly due to the emergence of satellites that provided the means to explore the Earth’s space environment directly.

Cole was keen to return to Australia and particularly to Melbourne where he and Ailsa had retained a house and where he could readily develop further research collaboration with the Australian Antarctic Division, then still located in Melbourne. At least two institutions offered him suitable positions but he was attracted to the newly established La Trobe University where he became one of two Foundation Professors in Physics. On his appointment in 1966, Cole, at age 37, did not have a PhD, which was very unusual for a professorial appointment in physics at an Australian university. But clearly he had established himself as a world leader in his research field and in 1967 he was awarded a DSc by the University of Queensland on the strength of his outstanding research publications.

At La Trobe, Cole continued his theoretical research into a wide range of phenomena in the magnetosphere-ionosphere system as well as on other topics. He formed the Theoretical and Space Physics Group that initially included five other academic staff. The group’s main interest was in theoretical and experimental studies of the magnetosphere-ionosphere-thermosphere system but it also included staff doing research on liquids and relativity. Since La Trobe was newly established, many staff and postgraduate students were new residents in Melbourne and Keith and Ailsa were generous hosts, making people welcome in their new environment. Sadly, the marriage ended in divorce in 1981.

From the outset, the space-physics experimentalists in Cole’s research group required a field station for radio, optical and magnetic instruments. It was clear, however, that it would take some time to convince the University to establish such a facility, as some senior administrators regarded the outlay of around $15,000 to purchase suitable land as a poor investment. To get the experimental work started, instruments were initially located on a five-acre block owned by Keith and Ailsa at Yarrambat, ~15 km from the La Trobe University campus. A year or so later, the University finally agreed to establish a field station at Beveridge, ~35 km north of La Trobe, and this site was used by the group for some forty years by which time the value of the land was in excess of a million dollars.

During his time at La Trobe, Cole developed many collaborations with other scientists around the world. The most notable were with scientists at the NASA/Goddard Space Flight Center in the USA and the Institute of the Physics of the Earth (IPE) in Moscow. Nationally he revived his links with the Australian Antarctic Division and in most years he was actively involved in research carried out at one or more Australian stations in Antarctica in collaboration with either a postgraduate student or one or more young scientists who had 'gone south' as Antarctic Expeditioners.

Cole's international links also involved other members of the Theoretical and Space Physics Group, particularly with the IPE in Moscow headed by Professor Valery Troitskaya, a pioneer in experimental observations of short-term variations in the Earth's magnetic field known as geomagnetic micropulsations, many of which relate to magnetospheric and ionospheric phenomena. A significant collaboration developed involving extended exchange visits of staff and transfer of equipment between IPE and La Trobe. An important motivation was that the magnetic field line from the Beveridge field station terminates in the northern hemisphere near the Kamchatka Peninsula in eastern Siberia. Beveridge and an IPE field station in the Kamchatka Peninsula could therefore provide almost conjugate observations of hemispherical coupling of phenomena along the magnetic field lines. IPE provided La Trobe with components for magnetic instruments and La Trobe built an ionospheric radar for IPE. Unfortunately for the project, when the USSR intervened in Afghanistan, the Australian Government suspended scientific collaboration with the USSR, causing the project to be officially terminated. A magnetometer developed at La Trobe using the basic IPE detector but with improved electronics and data-logging system was nevertheless installed in Antarctica. This instrument provided new observations of micropulsation phenomena that led to the development of theoretical explanations identifying the responsible magnetospheric processes.

The Earth's magnetosphere is populated by a plasma consisting of equal numbers of positively-charged ions and negatively-charged electrons. This state of matter, which exits widely throughout the universe, is characterized by a vast range of oscillations, waves and turbulence that can be either generated within the medium or propagated through it. Many of these plasma wave phenomena occurring in the magnetosphere manifest themselves as micropulsation oscillations in the Earth's magnetic field at ground level. This is particularly so at high latitudes because the magnetic field lines at the Earth's surface at high latitudes extend out well above the Earth, crossing the equator at a distance of several Earth radii where the solar wind interacts directly with the Earth's magnetosphere. Cole and his colleagues provided some of the first digital magnetometer observations from what is known as the polar cusp region and particularly of pulsations resulting from ultra-low-frequency plasma waves. One of Cole's important contributions was the first reasonable explanation of short bursts of wave activity that are characteristic signatures of the day-side cusp (104). Cole provided many of the theoretical ideas including an explanation of the sustained intervals of pulsations with varying period that are (somewhat enigmatically) called serpentine emissions (92). He was also instrumental in explaining the source of irregular, high-frequency pulsations that occur in bursts accompanying auroral luminosity variations (84). His ideas and models continue to provide a foundation for understanding the sources of wave phenomena in the polar cap, cusp and auroral regions.

After the formal suspension of the IPE-La Trobe collaboration, Cole maintained personal links with IPE and several papers were published with Cole and Valery Troitskaya as co-authors with others. This collaboration was advanced by regular meetings between Cole and Troitskaya, both of whom were actively involved in international scientific organizations in which they held senior positions. With changes in the political landscape, Troitskaya again visited La

Trobe in 1989, officially formally to re-establish the scientific collaboration between IPE and La Trobe. However, a few weeks after the visit ended, she suddenly reappeared in the Department and she and Cole happily announced that they were now married. While it was the period of Perestroika and Glasnost in the USSR, a decision not to return to USSR as expected after an official visit could not be made lightly. The reaction in the USSR could not be predicted, and neither would it necessarily be straightforward to meet Australian visa requirements to remain in Australia. Consequently her decision to stay in Australia had required very careful planning that had to be conducted in the strictest confidence. Cole of course played a leading role in successfully negotiating expeditiously the various hurdles presented by the administrative processes so that Troitskaya could not only remain in Australia, but could immediately have valid Australian travel documents so that they could both continue their international scientific activities. Because of the need to preserve confidentiality, their colleagues at La Trobe were mostly taken by surprise to learn of their marriage but were very pleased to then express their delight and honour them with a celebratory dinner. They had many happy years together, living in both Australia and the USA, pursuing scientific research and attending many international scientific conferences together.

As a consequence of Cole's theoretical expertise and wide knowledge of solar terrestrial phenomena, he was sought out as an advisor and collaborator by many scientists internationally. Of particular note is an event that occurred In September 1979. Two 'Vela' US security satellites detected what was described as a 'spark in the dark' that was then considered characteristic of an atmospheric nuclear test detonation. However, aircraft immediately scrambled by the US did not detect any radioactive residue. Could the feature detected by the satellites have been caused by solar activity? The US National Oceanic and Atmospheric Administration (NOAA) was charged with answering this question and Cole was one of the international experts brought in to assist. NOAA's investigation was inconclusive, finding that although it was possible that a nuclear test had taken place and been detected, it was also possible that a burst of solar activity had provided the high-energy particles that caused the responses reported by the Vela satellites. Many satellites now provide extensive monitoring of solar activity and emissions so that today a definite answer to such a question would be readily forthcoming.

Cole's more conventional scientific international collaborations were many. For example, throughout his time at La Trobe he regularly spent periods at the NASA/Goddard Space Flight Centre in Maryland, USA, where he joined scientists using space probes to explore the plasma environment of other planets, extending his research interests to studies of the space environment of Venus in particular. Observations by space probes of 100 Hz signals in the ionosphere of Venus are generally interpreted as 'whistler' emissions produced by lightning, even though there are no direct observations of lightning on Venus and the extensive cloud cover is thought to make lightning unlikely. As an alternative, Cole and Hoegy proposed controversially that the 100 Hz emissions result from Joule heating by alternating-current electric fields (118). They did not dismiss the possibility that lightning does occur on Venus, rather they suggested that it cannot produce the most intense 100 Hz emissions observed. Consequently, even if lightning is a cause, they argued that another mechanism is needed to produce the most intense emissions.

Cole's early and most significant research successes were made at the beginning of the space age and showed incredible insight at a time when relatively little was known about the Earth's space environment. As the exploration of this environment expanded dramatically through satellite programmes, the complexity of the phenomena occurring in the magnetosphere-ionosphere system became more and more apparent and most new scientific developments provided steps towards a more complete understanding of the processes involved. Nevertheless, Cole continued to make very significant contributions on a broad range of topics, of which the later work on geomagnetism pulsations described above is just one example. Major themes of his papers were the consequences of Joule heating, the initial energy source of SARARCs, Mathematical Physics and Astrophysics including papers on hydromagnetic waves, pulsars and cosmic rays, sun-weather relationships, and phenomena and processes in the ionosphere of Venus. His collaboration with Russian colleagues included important papers on magnetospheric plasma-wave phenomena and on auroral kilometric radiation, as well as the work on geomagnetic micropulsations described above.

Cole supervised many postgraduate students whom he guided in the study of a wide range of topics—much broader than just the topics of special interest to him. For example, some of his students undertook experimental rather than theoretical research. These projects generally involved the study of geomagnetic micropulsations, either at Beveridge or in Antarctica. Joint publications with students included papers on supersonic winds in an atmosphere, energy dissipation of atmospheric gravity waves, numerical modelling of the ionospheric dynamo and important observations of geomagnetic pulsations at mid and high latitudes. Many of his former students have pursued very successful careers in space physics, in Australia and elsewhere, while others have pursued careers in unrelated areas of science, in government organizations and in industry.

Cole did not confine himself to the pursuit of research. He also made major contributions to the organization of science both nationally and internationally. Solar-terrestrial physics studies phenomena that occur on a global scale and its progress has depended critically on international collaborative programmes such as the International Geophysical Year and subsequent programmes involving scientists from many countries at observatories around the world. Cole was an important international leader in the strategic planning and implementation of several of these international research programmes. His involvement included terms as President of the Scientific Committee on Solar-Terrestrial Physics (SCOSTEP) and President of the International Association of Geomagnetism and Aeronomy (IAGA). One secretariat head described him as a very energetic person who undertook everything with an infectious zest. A notable recognition of his contributions was the award of Life Membership of SCOSTEP, a rare honour that had previously been bestowed on only nine other people.

One of his initiatives was in 1979, when he brought to La Trobe an important international science workshop on the first results obtained from a programme called the International Magnetosphere Survey. The meeting attracted not only the leading scientists in the field at the tme, including the Nobel Prize winner Hannes Alfvén, but also young researchers several of whom became the field's next generation of outstanding research leaders.

In planning for the meeting, Cole wanted to liven up the workshop dinner because he thought conference dinners were often rather boring, staid affairs. So he decided to have a dinner-dance. The major problem was of course that, especially then, the research field was male-dominated and the number of females attending the meeting could be counted on one hand. His idea to overcome this problem was to invite female research students at the university to attend for free. Most would not be physical-science students, but Cole felt this would broaden the topics of conversation at the tables. His idea received an unsympathetic response from some sections of the University who, in keeping with the mores of that time, wondered what type of event Cole was actually running that required female companions. He was offended by this but was able to provide appropriate assurances and the dinner-dance proceeded and was a great success. On meeting any of the now elderly attendees at international meetings today, they will invariably still talk about that event.

Nationally, Cole was a very active Fellow of the Australian Academy of Science, serving as Foreign Secretary, Council Member and chair of Academy committees including the National Committee for Solar-Terrestrial Physics, a very important committee for the relevant Australian science community because it provided the official national links to the international science programmes being conducted at the time. The position of Foreign Secretary is also an important one because much of the Academy's activities revolve around international connections. By bringing his many skills to this position and ensuring that Australian scientists had influence at the international level, Cole served the Academy very well.

In 1987 the International Geosphere-Biosphere Program, sponsored by the International Council for Science, was launched 'to coordinate international research on global-scale and regional-scale between the Earth's biological, chemical and physical processes and their interactions with human systems'. The IGBP is a major programme focused on acquiring basic scientific knowledge about the relevance of these interactive processes to global change. At the time IPBP was launched, Cole was Foreign Secretary of the Australian Academy of Science and he played a leading role in making Australian scientists aware of the importance of the programme and in setting up an Academy committee and work programme to facilitate the involvement of Australian scientists.

Scientifically, Cole was above all a person of ideas that he promoted with infectious enthusiasm. While always ready to give advice to his staff, he led primarily by example, encouraging people to take the initiative and develop their own ideas. He was sought after as a speaker at international meetings. On a few occasions he was invited to review topics (such as energy processes and solar impacts in the neutral upper atmosphere) in which he was not necessarily a leading expert, but to which he could provide a fresh view and challenge people with new ideas. In proposing new and sometimes untested ideas, Cole often created controversy. But he could hold his own in any forum and he never shirked a drawn-out battle with critics, including the occasional belligerent reviewer of one of his manuscripts.

In the last years of his life he suffered from Parkinson's disease and lived in a retirement home where he continued to write and publish scientific papers as long as he was able. In spite of the limitations imposed by the disease, a visitor would usually find him at his computer, working on a manuscript. The last paper he published (though not the last he worked on) appeared in 2003, a single-author paper published at the age of 74 (127). Fittingly, the topic was again red arcs, the puzzling phenomenon he first explained back in 1965.

Cole received many honours recognizing his contributions to science. These included the Royal Society's Appleton Prize, presented at the 1984 General Assembly of the International Union of Radio Science (URSI) held in Florence. The citation stated that the award was for 'Contributions to the understanding of the basic processes taking place in the magnetosphere and the ionosphere'. As well as Life Membership of SCOSTEP, other awards were Honorary Membership of IAGA, Fellowships of the Australian Academy of Science, the Australian Institute of Physics, the Institute of Physics (UK), the Indian Institute of Geomagnetism and the Explorers Club of New York, and Associateship of the Royal Astronomical Society, London.

Cole was a very keen advocate for the development of Australian activities in space science and technology and he worked very hard, trying to bring politicians and others to understand that involvement in new space technologies required more than just the provision of tracking stations for the USA. He was involved in many approaches to government and in 1989 chaired the committee that produced the report *Ready for Launch: Space Science in Australia* (102). Although little action resulted at the time, the report was one of the factors that led eventually to the launching of FedSat in 2002 and the later government initiative to fund an Australian Space Research Program.

Cole's important contributions to La Trobe University included terms as Chairman of the Department of Physics and Dean of the School of Physical Sciences. A very significant contribution to the Physics teaching programme was his initiative in developing a stream of courses in Physics of Music that became part of the innovative music degree set up by Professor Keith Humble. These courses introduced music students to the physical and technical background of music and addressed the increasing interest and opportunities in the reproduction of sound and music.

Cole's contributions to space physics and to science teaching and research in Australia and internationally are a remarkable legacy. He had the ability to sift through puzzling and often incomplete information to identify the essence of a phenomenon. This is especially evident in the examples from the beginning of his career where he was able to explain several phenomena that bewildered his peers. He was the one who identified the essential fundamental processes involved and confirmation of his theoretical ideas has resulted in many of them becoming part of the solar-terrestrial physics knowledge-base described in textbooks.

Cole outlived two of his children (Maxine and James) who died separately a few years before he did. His first wife Ailsa died in 1994 and Valery died twelve months before him. He is survived by his son David and six grandchildren

(Dylan, Alex, Mica, Frazer, Vivienne and Jarvis). He would be proud of his grandchildren and their achievements. Dylan is running his own restaurant business in Port Fairy, Victoria, Alex is also in the catering industry, Mica is in her final year of an Arts/Law degree at La Trobe University, Frazer is doing a double degree in Science and Commerce at Deakin University, Vivienne is completing secondary school, Jarvis is also completing secondary school and, like his grandfather, is an avid trumpet player.

Honours, Awards and Appointments

1952	Bachelor of Science with Honours (BSc (Hons)), King's College, University of Queensland
1953	Diploma in Education (DipEd), University of Queensland
1953–5	Secondary school teacher in Queensland
1954	Master of Science (MSc), University of Queensland
1956	Auroral Physicist, Australian National Antarctic Research Expedition, Macquarie Island
1957–63	Theoretical Physicist, Australian Antarctic Division
1961	Member, Institute of Physics (UK)
1962	Fellow, Australian Institute of Physics
1962	Seconded to CSIRO Upper Atmosphere Section, Camden, NSW
1963–4	Research Associate, University of Chicago
1965–6	Research Associate, University of Colorado
1966	Foundation Professor of Physics and Head of Theoretical Physics, La Trobe University, Bundoora, Victoria
1967	Doctor of Science (DSc), University of Queensland
1969–70	Senior Research Associate, US National Academy of Sciences/ US National Research Council, NASA Goddard Space Flight Center (twelve months)
1970–3	Chairman, Department of Physics, La Trobe University
1973	Fellow, Institute of Physics (UK)
1974	Senior Research Associate, NASA Goddard Space Flight Center.
1976–8	Chairman, Department of Physics, La Trobe University
c. 1976–9	Vice-President, International Association of Geomagnetism and Aeronomy (IAGA)
1977–86	President, Special Committee on Solar-Terrestrial Physics (SCOSTEP)
1979–83	Member, International Union of Geodesy and Geophysics
1980	Fellow, Indian Institute of Geomagnetism
1980–1	Dean, School of Physical Sciences, La Trobe University
1980–3	President, IAGA
1982	Associate, Royal Astronomical Society, London (ARAS)
1982	Senior Research Associate, NASA Goddard Space Flight Center
1983	Fellow, Australian Academy of Science (FAA)
1984–8	Chairman, Department of Physics, La Trobe University
1984	Appleton Prize, Royal Society of London
1985	Foreign Secretary and Member of Council, Australian Academy of Science
1989	Honorary Member, International Association of Geomagnetism and Aeronomy
1989–91	Senior Research Associate, NASA Goddard Space Flight Center for several months each year.
1992–3	Visiting Professor, Kyoto University
1995	Emeritus Professor of Physics, La Trobe University
2003	Life membership, SCOSTEP
2003	Centenary Medal, Australian Government

Acknowledgements

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