Physics – Uspekhi **41** (1) 103 – 104 (1998)

PERSONALIA

PACS number: **01.60.+q**

In memory of Boris Arkad'evich Tverskoĭ

National and world science has suffered a heavy loss. On August 6, 1997, Professor of Moscow State University Boris Arkad'evich Tverskoĭ, an outstanding Russian physicist and one of the world's leading cosmophysicists, left us after a long and debilitating disease. It was in his time and with his active participation that the science of cosmophysics began and evolved into a large and distinct branch of physics, many fundamental results of which are credited to Boris Arkad'evich.

Tverskoĭ was born on February 5, 1936, in Novosibirsk. Even as a schoolboy he became interested in space, enthralled with the mysteries of cosmic phenomena. In 1950 Boris Tverskoĭ, then in his seventh year at school, made two presentations at a scientific conference of the "Siberia" Geographical Society entitled "What is new in the cosmogony of the Solar system", and "Geological phenomena in the light of the theory of O Yu Schmidt". The correspondence between the 14-year-old schoolboy and Academician O Yu Schmidt has survived. The famous polar explorer gave much attention to the young natural philosopher, and sent him reprints of his papers. In his school years Tverskoĭ also met the renowned theoretical physicist Yu B Rumer who was living in Novosibirsk in exile. This acquaintance predetermined his future career. In 1952 Tverskoĭ was admitted to the Department of Physics of Moscow State University. His research work started in his undergraduate years at the Kurchatov Institute for Atomic Energy in the group headed by M A Leontovich.

Tverskoĭ's early studies were concerned with the search for cosmophysically realistic flows that could generate magnetic fields. Even his first results received universal acclaim. As a postgraduate, Tverskoĭ prepared a thesis on free thermal convection in a rotating gravitating sphere, in which he obtained the complete spectrum of proper oscillations of an incompressible fluid in a rotating sphere. This direction was developed in a cycle of his further works, which led to the conclusion that the basic structural element of thermal convection — the convection cell — may produce magnetic field. He succeeded in demonstrating that a characteristic feature of the amplification of the magnetic field in Benard cells is the establishment of a bipolar magnetic field distribution similar to the pattern observed in a sunspot. On the basis of these studies he proposed and substantiated a hypothesis which linked the 22-year solar cycle with his mechanism of the development of sunspots and the nonuniform rotation of the Sun. Today his classical results on toroidal vortices are incorporated in the theory of solar dynamo.

Uspekhi Fizicheskikh Nauk **168** (1) 111 – 112 (1998)
Translated by A S Dobroslavskiĭ

Boris Arkad'evich Tverskoĭ

From 1961 Tverskoĭ's life and academic activity were inseparably linked with the Skobel'tsyn Institute of Nuclear Physics of Moscow State University, where he defended his candidate's thesis in 1962, and his doctorate in 1966. Having become a doctor of physics and mathematics at the age of 30, he began several new directions of research which continue to be actively pursued today.

From 1961 – 65 Tverskoĭ developed the theory of the Earth's radiation belts which won recognition worldwide. The terrestrial radiation belts are formed by the radial diffusion of particles into the region of strong magnetic field from the periphery of the geomagnetic trap. The conservation of adiabatic invariants results in the acceleration of particles. The large-scale induction electric fields, or sudden impulses, that arise as the geomagnetic trap contracts are the main factor of transport. Tverskoĭ was able to calculate the transport coefficients for near-equatorial particles in excellent agreement with experiment and to develop a theory of steady and unsteady processes of the interaction of radial diffusion with various phenomena resulting in particle losses. He

theoretically determined the limit of stability of the radiation belts with respect to the excitation of oscillations of the magnetospheric plasma. Observations made from the "Electron" satellite and from a number of US satellites fully confirmed his theoretical conclusions. They discovered the belt of alpha-particles predicted by Tverskoĭ, as well as nonstationary diffusion waves of relativistic electrons. The theory of the radiation belts was systematized in his monograph entitled *The Dynamics of the Radiation Belts of the Earth* (1964), which has become a classic reference in all centers concerned with these problems. The theory has not become obsolete over the years. It was used, for example, for quantifying the process of the fast injection of high-energy particles into the inner belt in the course of a powerful short sudden impulse registered in 1991 by the US CRRES orbiter.

An extremely important contribution to space physics is associated with Tverskoĭ's studies of magnetospheric storms and substorms and the aurora. Using the solution of the self-consistent problem of magnetospheric – ionospheric interactions (1969), he was able to predict the pattern of field-aligned currents that link the hot magnetospheric plasma with the cold ionospheric plasma. These currents were so large in magnitude that Tverskoĭ had to assume a considerable nonequipotentiality of the magnetic field lines. The predicted longitudinal electric fields were later measured experimentally. Magnetospheric – ionospheric interactions result in the expulsion of low-frequency electric fields from the low-latitude regions of the magnetosphere to be concentrated in the auroral region. The band of the field-aligned current coming out of the ionosphere was found to be unstable with respect to splitting into narrower bands. Tverskoĭ's theory made it possible to predict the number of structures resulting from the splitting of the outgoing field-aligned current. The theoretical predictions were confirmed by measurements made by the "Intercosmos – Bulgaria – 1300" satellite. In 1989, the phenomenon of magnetospheric–ionospheric interactions which Tverskoĭ found was registered as a scientific discovery.

A large cycle of Tverskoĭ's works was devoted to the theory of statistical particle acceleration. He was able to give a quantitative description of diffusion in momentum space for the cases of Fermi acceleration and statistical acceleration by hydromagnetic turbulence. If the spectrum of turbulence is broad, and the energy of pulsations is maximum at wavelengths much greater than the Larmor radius of thermal particles, then the decay of turbulence will not result in the heating of the bulk of these particles, but rather in the acceleration of a small group of particles to high energies (the principle of turbulent acceleration). This theory supports the hypothesis of the acceleration of protons to energies of the order of 1 MeV in interplanetary space.

In 1971, Tverskoĭ founded the Department for Theoretical and Applied Space Physics at the Institute of Nuclear Physics of Moscow State University to develop fundamental theories and to investigate processes in the Earth's magnetosphere and interplanetary space, the processes of practical importance for space exploration. He supervised the design and construction of instruments for the study of plasma and hard corpuscular radiation in the energy range from a few electron-volts to tens of MeV, which operated on many space probes. The results of these experiments were used to increase the reliability and service life of communication and navigation satellites, as well as to improve the radiation safety of manned flights.

Tverskoĭ was much involved in the training of young research workers. He taught a course "Introduction to cosmophysics" at the Department of Physics of Moscow State University; fifteen of his disciples became candidates of science, and four received their doctorates. Tverskoĭ created a school of science concerned with studying the linkage between the plasma processes in the Sun, in interplanetary space, and in the magnetosphere and ionosphere of the Earth. He was one of the editors of the *Geomagnetism and Aeronomy* magazine, and member of a number of scientific councils.

The outstanding achievements of Boris Arkad'evich Tverskoĭ were rewarded with the Lomonosov Prize of Moscow State University in 1971, and the State Prize in 1978. He was honored with the Order of Merit, the Gold Medal of the Exhibition of Economic Achievements of the USSR, and the Academician Korolev Medal of the Federation of Cosmonautics of the USSR. In 1994 he was elected a full member of the International Academy of Astronautics. In 1996 he was granted the title of Merited Scientist of the Russian Federation.

Everyone who knew Boris Arkad'evich was impressed by his encyclopedic knowledge of history, art and literature, and by the latitude of his interests. He knew and loved music and poetry. We will always remember the great scientist, one of the best among the Russian intellectuals, whose whole life was devoted to the advancement of science.

A A Galeev, G T Zatsepin, M I Panasyuk,
R Z Sagdeev, V A Sadovnichiĭ, E N Sosnovets