

In memory of Veniamin Sergeevich Berezinsky

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Veniamin Sergeevich Berezinsky — an outstanding representative of Soviet, Russian, and world science, who outlined and developed new fields in neutrino physics, cosmic ray physics, and some areas of theoretical astrophysics and cosmology — passed away on April 16, 2023.

Veniamin Sergeevich Berezinsky was born on April 17, 1934 in Volgograd. In 1962, he graduated from the Physical Department of M V Lomonosov Moscow State University (MSU) and, in 1965, from postgraduate studies at the P N Lebedev Physical Institute of the USSR Academy of Sciences, where, in 1967, he defended his candidate thesis, “Radiation decay of charged pion and reverse processes.” V S Berezinsky attended L D Landau’s lectures and called him one of his scientific cult figures and one of the main landmarks in theoretical physics.

The main areas of V S Berezinsky’s scientific work were largely formed under the influence of academician Georgy Timofeevich Zatsepin. In 1969, together with G T Zatsepin, he was the first to put forward the idea of the generation of high-energy cosmogenic neutrino fluxes in collisions of ultrahigh-energy protons with black-body photons of relic origin and proposed a method for calculating these fluxes. This and following studies made V S Berezinsky a universally recognized founder of the scientific area in world science, called high-energy neutrino astrophysics. A diffusion high-energy neutrino flux was further detected in experiments using the IceCube and Baikal-GVD neutrino telescopes.

Almost from the moment the Institute for Nuclear Research of RAS was founded in 1970 and till 2009, V S Berezinsky worked at the Laboratory of Neutrino Astrophysics of the Department of High-Energy Leptons and Neutrino Astrophysics at INR RAS, headed by G T Zatsepin, moving up from junior to lead researcher. In 1975, V S Berezinsky defended his doctoral thesis, “Ultrahigh-energy cosmic rays and their interaction with matter.”

In 1975, Veniamin Sergeevich, together with A Yu Smirnov, discovered the relation between diffusive high-energy neutrino fluxes and gamma-ray fluxes. This result underlies what is now called multimessenger astrophysics. Among other things, this result allowed setting a strict upper limit on the diffusive neutrino flux (cascade limit). The further development of this method in studies with O E Kalashev and other co-authors led to the strongest and most general limits on extragalactic neutrino fluxes and imposed serious restrictions on possible mechanisms of the origin of ultrahigh-energy cosmic rays.

As V S Berezinsky himself noted, a great role in his life was played by his joint work with Vitaly Lazarevich Ginzburg in the field of cosmic-ray and neutrino physics and the personal



Veniamin Sergeevich Berezinsky
(17.04.1934 – 16.04.2023)

friendship with him. V S Berezinsky appreciated V L Ginzburg’s style of work, which he called a “formulaless attack on the problem,” that is, the ability to see a new problem and quickly clarify it at a qualitative level and only after that perform complicated calculations if necessary. Together with V L Ginzburg, V S Berezinsky obtained interesting results: a model of hidden sources of neutrinos from an active galactic nucleus in a cocoon was developed and the possibility of distinguishing between galaxies and antigalaxies with the help of ultrahigh-energy neutrinos was shown. They also discussed (together with O F Prilutsky) the possibility of observing neutrinos from young remnants of supernova outbursts.

V S Berezinsky also worked extensively with theoreticians from ITEP and MEPHI, in particular, with B L Ioffe, and was a regular participant in seminars given by B L Ioffe and L B Okun.

In 1977, V S Berezinsky, along with A Z Gazizov, formulated a theory of resonant growth of the cross section of electron antineutrino scattering by electrons with the subsequent decay of the resultant W-boson in the hadronic channel, bearing in mind the Weinberg–Salam model. This process is a direct analogue of Glashow resonance, but substantially differs from it, leading to the appearance of a narrow sharp peak in the spectrum of nuclear electromagnetic cascades, which is directly related to the mass of the heavy W-boson. Among other things, decays into quark-antiquark pairs were considered with allowance for quark color. It was shown that the expected number of resonant events exceeds the number of nonresonant events in a narrow energy range. In 2016, the IceCube neutrino telescope registered for the first time a resonant interaction between an electron antineutrino and an electron by means of a W-boson, the characteristics of this event, with allowance for the currently-known W-boson mass, being fully consistent with calculations.

V S Berezinsky, together with O F Prilutsky, proposed a model for the escape of protons from a magnetized region of the source due to their transformation into neutrons in pp - and $p\gamma$ -collisions, with their subsequent decay. At the suggestion of V S Berezinsky, limits on high-energy neutrino fluxes were obtained in 1984 for the first time from the measured spectrum of horizontal showers with the Gran Sasso EAS-TOP telescopes.

In work in 1988, done together with S I Grigoryeva, and in 2006, in co-authorship with A Z Gazizov and S I Grigoryeva, he proposed and elaborated in detail the ‘dip’ model (a dip in the ultrahigh-energy cosmic ray spectrum due to the interaction of protons with photons of relic radiation with the production of electron–positron pairs), which has now been well confirmed by experimental data. The study of 2006, “On the astrophysical solution to ultrahigh-energy cosmic rays,” was one of the most well-known works in high-energy physics. V S Berezinsky and his colleagues worked out a formalism that makes it possible to describe the evolution of the spectrum of cosmic rays upon their propagation in the expanding Universe with allowance for energy loss, the fragmentation of nuclei, and diffusion in intergalactic magnetic fields.

V S Berezinsky proposed and developed (together with A Vilenkin and other colleagues) models for the generation of ultrahigh-energy neutrinos, photons, and cosmic rays by topological defects. He was the author of one of the models of mirror matter in the Universe. Considered in his studies (together with R Aloisio, M Kachelriess, and others) were the properties and possible observational manifestations of supersymmetric and supermassive dark matter particles, as well as their role in cosmic ray physics. Together with P Blasi, he investigated the possibility of cosmogenic neutrino production by the first generations of stars.

Veniamin Sergeevich began his pedagogical activity when a postgraduate student and at the same time taught students at the pedagogical institute. Later on, diplomas and dissertations were defended under V S Berezinsky’s guidance, both in our country and abroad. Several of his disciples became world-renowned specialists in their fields of research. Co-authors of V S Berezinsky’s scientific papers obtained invaluable experience of joint work with this outstanding scientist and remember profound scientific discussions with his participation at seminars, at conferences, and privately.

V S Berezinsky is a co-author of the widely known monograph, “Astrofizika kosmicheskikh luchei” (V S Bere-

zinsky, S V Bulanov, V L Ginzburg, V A Dogel, V S Ptuskin), Moscow: Nauka (1984), ed. by academician V L Ginzburg. The revised edition appeared in 1990 and was also published in the English language (North-Holland, 1990). V S Berezinsky is the author of the books, *Neutrino* (1973) and (in co-authorship with G T Zatsepin) *Neutrino astrophysics* (1975).

Veniamin Sergeevich paid close attention to work on the editorial boards at leading scientific journals. In 1983–1997, he was a member of the editorial board of the journal *Pis'ma v Astronomicheskii Zhurnal* (*Letters to the Astronomical Journal*); he was one of the organizers, as well as the coordinating and host editor of the journal *Astroparticle Physics* (1992–2007); and he was a member of the expert-editorial board of the journal *Nuclear Instruments and Methods* (1995–2007).

V S Berezinsky was a member of the scientific council Neutrino Physics and Neutrino Astrophysics of the Academy of Sciences, headed until 1993 by B M Pontecorvo, and of the scientific council of the Academy of Sciences on the complex problem Cosmology and Microphysics.

Beginning 1990, V S Berezinsky worked in Italy. In 1992, he became director of research at the Gran Sasso National Laboratory (Italy)—Laboratori Nazionali del Gran Sasso (LNGS), and from 1996 to 2014 was head of the Astroparticle group at LNGS. V S Berezinsky’s research supervision and his active work in the development of priority areas of research largely determined the course of theoretical and experimental work at LNGS. His broad scientific outlook and skills allowed V S Berezinsky to be the Italian Coordinator of the European Network for Particle Astrophysics from 1992 to 1997. From 1995 to 2002, he was a nominator on the Nobel Committee for Physics. V S Berezinsky was member of many international collaborations, including JEM-EUSO.

V S Berezinsky’s scientific research received deserved international recognition. Veniamin Sergeevich was a laureate of the international A Humboldt Prize (1990). In 2007, he was awarded the O’Ceallaigh medal of the International Union of Pure and Applied Physics for “outstanding contributions to cosmic ray physics.” In 2010, he was awarded the M A Markov Prize (INR RAS) for an outstanding contribution to cosmic ray physics and formulation of the theory of cosmogenic high-energy neutrinos. V S Berezinsky received the 2017 Enrico Fermi Prize of the Italian Physical Society “for his theoretical contribution to the cosmogenic production of ultrahigh-energy neutrinos, to high-energy neutrino astronomy, and to the solar neutrino problem.” V S Berezinsky was elected a member of the Venetian Academy of Sciences (Istituto Veneto di Scienze, Lettere ed Arti). In 2010, V S Berezinsky was included in the INR RAS Book of Honor for his longstanding fruitful activity and great personal contribution to implementation of the program of scientific work of the Institute for Nuclear Research of RAS.

V S Berezinsky was the author of a number of publications in the journal *Uspekhi Fizicheskikh Nauk* (*Physics Uspekhi*), including the 1977 paper with G T Zatsepin about the DUMAND project. In 2014, a review paper by V S Berezinsky was included on the list of the best *Physics Uspekhi* reviews of 2014. V S Berezinsky found the opportunity to arrive in Russia to present diplomas to the laureates. Colleagues remember V S Berezinsky’s talk at this ceremony.

Working in recent years mainly in Italy, V S Berezinsky continued maintaining close scientific and personal ties with the staff of INR RAS, MSU, and other Russian scientific

organizations, which had a grate positive impact both on research in Russia and on the international cooperation of Russian scientists with Gran Sasso National Laboratory and other foreign institutions. He headed the INTAS scientific grant and the federal target program Scientific and Scientific-Pedagogical Personnel of Innovative Russia for 2009–2013 on the topic High-Energy Astrophysics and Cosmology, in which researchers from several Russian scientific organizations took part.

V S Berezinsky was not only an outstanding physicist but also a deep extraordinary person with a special disposition. Those who knew Veniamin Sergeevich can note his immense interest in and love for Russian literature, especially poetry. Among his favorite poets was primarily Aleksandr Pushkin: at a banquet during a scientific conference in Norway he read from Pushkin, and foreign colleagues, fascinated by the sound of the poems, asked him respectfully about the great poet. V S Berezinsky was also very fond of Osip Mandelsham, Boris Pasternak, and Iosif Brodsky, whose poetry he appreciated highly, and he could enthusiastically read their verses from memory for hours. Veniamin Sergeevich was closely acquainted with famous actors and directors, and even while in Italy, he took cultural and other news from Russia to heart. Veniamin Sergeevich himself possessed an undoubted literary gift. He wrote a humoresque for the book “Ways to the unknown,” No. 3, 1963, later reprinted in the famous collection “Physicists continue to joke.” Veniamin Sergeevich’s improvised performances at evenings at the Central House of the Writer enjoyed great success with the audience. Along with the intellectual talents, Veniamin Sergeevich had excellent sports abilities from his youth. He played professionally on the football team of Moscow regional Spartak.

The guardian angel in the life of Veniamin Sergeevich was his wife Yulia Yakovlevna, who did her best to facilitate his scientific work.

We express our deepest condolences to all the relatives, friends, and colleagues of Veniamin Sergeevich Berezinsky. The radiant memory of him will always live in our hearts.

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