PERSONALIA

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Vladimir Vasil'evich Zheleznyakov (on his 80th birthday)

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Vladimir Vasil'evich Zheleznyakov, Full Member of the Russian Academy of Sciences (RAS), outstanding physicist and astrophysicist, Professor at the Higher School of General and Applied Physics of Nizhny Novgorod State University, Head of the Department of Astrophysics and Space Plasma Physics of the RAS Institute of Applied Physics, had his 80th birthday on 28 January 2011.

V V Zheleznyakov was born in the town of Gorky. In 1949–1954, he was a student at the Radiophysics Department of Gorky State University, then graduated from postgraduate courses under the guidance of the future RAS Academician and Nobel Prize winner V L Ginzburg.

Specialists in astrophysics, radio astronomy, and space plasma physics in Russia and abroad are well familiar with V V Zheleznyakov's work. Many areas of research proposed in his publications continue to be important for solving contemporary problems of the generation and propagation of electromagnetic waves in plasmas of various astrophysical objects, primarily in the magnetospheres of the Sun, magnetic white dwarfs, and neutron stars. Zheleznyakov's contribution to other areas of physics, including high-power electronics, the theory of quantum and classical superradiance, the optics of liquid crystals, and the physics of nonlinear phenomena in magnetized vacuum, is also very considerable.

V V Zheleznyakov demonstrated that the cyclotron radiation mechanism plays a decisive role in forming the frequency characteristics of the spectra of the observed radio emission from the Sun and magnetic Ap stars, of the optical radiation of magnetic white dwarfs, and of the radiation from X-ray pulsars. He also drew attention to the existence of the depression in electron cyclotron radiation at the gyrofrequency in dense plasma, the instability of nonequilibrium plasma under the conditions of the anomalous Doppler effect and synchrotron instability, and the significant influence of relativistic velocity-dependence of the electron mass exerted on the growth rate of cyclotron instability in weakly relativistic plasma. This last phenomenon proved crucial, in particular, in electronics problems and found applications in the development of cyclotron resonance masers at the Scientific Research Institute of Radiophysics and the Institute of Applied Physics of the USSR Academy of Sciences. In 1984, a series of V V Zheleznyakov's publications on cyclotron radiation in astrophysics was awarded by the A A Belopolskii Prize of the USSR Academy of Sciences.

The thermal cyclotron radiation mechanism put forward by V V Zheleznyakov is the key element of the theory of the slowly varying component of solar microwave radiation. It was found that the fundamental phenomenon in the inhomogeneous magnetic fields of the solar active regions is the combined effect of the thermal bremsstrahlung and the cyclotron mechanisms, which provides the unified interpretation of the observed characteristics of radio emission: frequency spectrum, polarization, and brightness distribution over the source. Modern methods of processing the data of radio observation of the Sun are based on the results of this theory and provide information on the distribution of temperature and magnetic fields in the active regions of the solar corona and upper chromosphere.

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V V Zheleznyakov also pioneered work on the plasma mechanism of the radiation emission, which he carried out when studying Raman scattering (merging) of plasma waves in the solar corona, accompanied by the transition to electromagnetic radiation at twice the plasma frequency. He was the first to prove the high efficiency of mechanisms of this sort in processes of the conversion of plasma waves to electromagnetic waves in outer space. This result formed the foundation of the theory of radio emission from subluminal electron fluxes in the solar corona (solar radio flares of types III and V) and predetermined all subsequent studies of this phenomenon in solar radio astronomy. It should be emphasized that this astrophysical work on the Raman scattering of plasma waves was one of the first in a series of general studies of nonlinear decay interactions, which later spread widely in plasma physics.

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V V Zheleznyakov repeatedly turned to the problems of propagation of electromagnetic waves in space. Thus, he developed the theory of linear interaction (transformation) of waves in smoothly inhomogeneous, weakly anisotropic media, including magnetoactive cosmic plasmas and plasmas in a magnetized vacuum in the neighborhood of neutron stars. The most important result was the quantitative description, thoroughly verified in observations of solar microwave radiation, of the effects of linear transformation of the modes of magnetized plasma propagating through regions of a transverse magnetic field. The theory formulated for this case led to a successful solution of the limiting polarization problem, when radiation emerges from magnetized plasma, and made it possible to identify new types of linear interactions of waves (e.g., in an inhomogeneous plasma of planetary magnetospheres and in neutral current sheets of the solar corona). In particular, Zheleznyakov's analysis of the observed polarization features of noise storms led to the conclusion that current sheets exist in active regions of the corona.

Recent observations and the ongoing development of models of the solar radio emission both in Russia and abroad are based to a large extent on the work of V V Zheleznyakov and his colleagues. It would be difficult to overestimate the importance of his theoretical papers for solar radio astronomy. Suffice it to point, for instance, to the discovery of cyclotron lines in the spectrum of solar radio emission: the above-mentioned papers indicated earlier that these lines can be detected. Another important result in this area of research was an analysis of the effectiveness of cyclotron radiation mechanism in coronas of magnetic Ap stars. He was able to show that microwave radiation from nearby stars of this class can be detected with modern radio astronomical facilities, even in rarefied coronal plasmas whose X-ray emission is too weak to be observed.

A series of Zheleznyakov's papers on the theory of radio pulsars, where he analyzed the physical conditions and processes proceeding in the magnetospheres of neutron stars, proved to appear at the right moment. Among other things, he developed in detail the synchrotron mechanism of optical and X-ray emission from the pulsar in the Crab Nebula, and showed that the radiation source should be located in the vicinity of the light cylinder. This fact is of paramount importance for the development of models of short-period pulsars.

In the last 30 years, V V Zheleznyakov has concentrated his efforts largely on the study of white dwarfs and neutron stars with superstrong magnetic fields. In the first half of the 1990s, using results of calculations of the light pressure exerted by cyclotron radiation in the plasma on degenerate stars, V V Zheleznyakov put forward and substantiated the hypothesis of the existence of a new type of astrophysical objects, now known as radiation diskons. These predicted objects are hot magnetic degenerate stars surrounded by plasma disks and envelopes. The latters are formed by way of plasma flow from the surface of the star as a result of very high light pressure of thermal radiation at cyclotron frequencies, and require no accretion of the medium from the environment. The first candidates for this class of objects are isolated magnetic white dwarfs which demonstrate a deep depression in their ultraviolet spectra. Recently, V V Zheleznyakov and his team proposed and verified an efficient method of detection and determination of the parameters of hot plasma envelopes (coronas) in single white dwarfs possessing magnetic fields on the order of 10 megagauss.

In another series of publications, V V Zheleznyakov proposed, and gave a theoretical foundation to, the model of an X-ray source on a neutron star (X-ray pulsar), which explained the formation of the continuum and cyclotron emission lines in the dense isothermal plasma of the atmosphere of a polar spot on the surface of a star; it proved useful for the interpretation of satellite observations of recent years. It was shown that the observed absorption lines are caused by the effective cyclotron scattering; they emerge against the background of the continuum weakened owing to the Thomson scattering of radiation by free electrons. Even before the development of this model of the X-ray pulsar, V V Zheleznyakov conducted studies of the conditions of propagation of X-ray radiation and of the effectiveness of its cyclotron absorption in strong magnetic fields, when the polarization of normal waves is determined by the magnetized vacuum. Later on, V V Zheleznyakov and his collaborators developed the theory of radiation transfer via cyclotron harmonics in the plasma of neutron stars and white dwarfs possessing a strong magnetic field.

Among the recent publications of V V Zheleznyakov and his team, a detailed analysis should be highlighted of the possibility of detecting cosmic synchrotron masers that he predicted; their strongest radio emission is expected at low frequencies, which implies that, to search for this signal, measuring equipment must be placed above the Earth's ionosphere. In these papers, the quasilinear theory allowed the researchers to find the frequency spectrum and intensity of the emission from the extended synchrotron maser in outer space. Another promising result of the research is the clarification of the interrelationship between the corpuscular composition of relativistic astrophysical jets and the form of frequency spectra of polarization of synchrotron radiation from these objects. The presence of this connection opens a way to solving the problems of the composition of plasma in jets by analyzing the polarization spectra of their radio emission.

The main body of V V Zheleznyakov's work on the physics of space plasma and astrophysics was presented in his monographs *Radio Emission of the Sun and Planets* (Nauka, 1964; Pergamon Press, 1970), *Electromagnetic Waves in Space Plasmas* (Nauka, 1977), and *Radiation in Astrophysical Plasmas* (Kluwer, 1996; Yanus-K, 1997), which cover a rather broad range of physical processes associated with cosmic radiation. V V Zheleznyakov wrote these books, plus a number of review articles, with all his pedagogical brilliance, care and attention to readers' needs, so these volumes became a favored tool of several generations of grateful researchers working on the problems of the generation, transport, and dynamics of radiation in magnetoactive plasmas.

V V Zheleznyakov and his coworkers also completed a number of theoretical studies on nonlinear electrodynamics of magnetized vacuum and inverted two-level systems. Thus, he pointed out that solitons and shockwaves may exist in the magnetized vacuum surrounding neutron stars. A series of papers on superradiance (collective spontaneous emission of radiation) from an ensemble of oscillators attracted researchers' attention to the possibility of developing dissipative instability of polariton modes in inverted media, established a close link between the instability of this type and the Dicke superradiance effect, and suggested a new interpretation of this effect. This research led to the disclosure and analysis of a classical analogy of this phenomenon — cyclotron superradiance. This work has stimulated the study of superradiant modes in electronics and semiconductor physics, so that in the end the effect has indeed been experimentally demonstrated. Some of the above papers were included in the volume of V V Zheleznyakov's selected works recently published by the RAS Institute of Applied Physics.

The team of researchers at the RAS IAP Department of Astrophysics and Space Plasma Physics (created by V V Zheleznyakov) continued and expanded many of his seminal works. This group of the highest-level scientists merges three generations of V V Zheleznyakov's students into a team which constitutes the core of his scientific school, 'The interaction between electromagnetic radiation and astrophysical and geophysical plasmas', which enjoys a well-deserved world-class repute. About 20 researchers in this school earned DSc degrees in physics and mathematics, and four of them were elected to the Russian Academy of Sciences. The school continues to take in young graduates of Nizhny Novgorod State University, where V V Zheleznyakov gave lectures on radio astronomy and astrophysics for more than 50 years. He is a member of the editorial board of the journal *Izvestiya Vuzov. Radiofizika* for almost half a century, and in 1998 he became its Editor-in-Chief, upholding the tradition of high quality of published papers and ensuring a distinguished place for the journal among the nation's scientific periodicals.

V V Zheleznyakov devotes a significant part of his energies to other fields of science management. He was a member of the Council of the Russian Foundation for Basic Research when it was taking its first steps from 1992–1999 and took part in the work of the RF Presidential Commission on State Prizes from 1992–2004. For many years he sat as member of the Astronomical Council and the RAS 'Sun–Earth' Council, and since 1990 has regularly been elected to the Bureau of the RAS Physical Sciences Division; his memberships in the International Astronomical Union and in its Committee on Radio Astronomy date back nearly 50 years. He was a charter member of the European Astronomical Union and of a number of other international organizations.

Vladimir Vasil'evich Zheleznyakov's colleagues, friends and disciples extend their best wishes on this occasion and their hope that he will enjoy a happy frame of mind, good health, continued creativity, and happiness for many years.

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