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**PERSONALIA**

# Vadim Nikolaevich Tsytovich

(on his 80th birthday)

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On March 17, 2009, the well-known physicist-theorist, the author of more than ten reviews in journal UFN, the Doctor of Physical and Mathematical Sciences, Professor Vadim Nikolaevich Tsytovich will have his 80th birthday.

Vadim Nikolaevich Tsytovich (VN) was born in St. Petersburg (then Leningrad) on March 17, 1929. His family was evacuated from Leningrad in the summer of 1941 when the German army had already approached to a city. VN's father was a civil engineer, who had built defensive constructions, and was in a city until the siege ended in 1943. During their evacuation (first in Perm', then in Yaroslavl'), it was a hard time for the family: they starved sometimes, the school was far away, and the children were ill during winter frosts, VN often missed school, and the school even planned him to repeat a year. He nevertheless was allowed to sit the examinations in the 7th year classes without attending school, and he was successful. Then he successfully passed the examinations for the 8th-year classes in the same summer without attending lectures. Thus, having returned to Leningrad in 1944, VN finished the last two classes of his high school course a year early. At age 17 he entered the Leningrad State University (LSU), in the faculty of physics. The experience of sitting exams without attending lectures was useful: VN successfully entered another faculty of LSU — the mathematical-mechanical faculty — and passed all its examinations for three years with the 'five' grade. After the family moved to Moscow, VN transferred to Moscow State University, where he finished the last two years of his studies. In all his records the only marks were 'five = excellent'. (Even in chemistry, which VN did not like, there was a 'five' mark!) The family had moved to Moscow in 1949 because his father, N.A. Tsytovich, became the Director of the Institute of Soil Permafrost Research. (At that time his father also became a corresponding member of the USSR Academy of Sciences and the winner of the Stalin Prize).

VN completed postgraduate study at the Moscow State University in 1954. After his PhD thesis defense he remained at the Moscow State University for scientific and teaching work in theoretical physics within the physical faculty. Three years later in the same place he has met the future wife, a physics student in her fifth year, Emma Andryuhina.

VN's creativity and his interest in the theoretical physics were clearly expressed already in his first research works. The degree work done in 1949 and published in 1951 (years later this work was translated into English by D. Melrose) was the first scientific work of VN. In essence of this work connects two effects: super-light radiation (I.E. Tamm and I.M. Frank received the Nobel Prize for the theory of this effect) and synchrotron radiation. Today this effect is widely used for interpretation of radio emission in space plasmas and is called the Tsytovich – Razin effect. For his candidate thesis VN worked on another theme: the structure of positronium (i.e. an atom consisting of an electron and a positron), taking into account the effects of then newly developed theory of quantum electrodynamics. Knowledge of quantum physics and relativistic quantum electrodynamics considerably helped him subsequently.

Vadim Nikolaevich Tsytovich

In 1957 he started research on the collective acceleration of relativistic particles. This was under the initiative of academician V.I. Veksler who initiated this new research direction in the USSR. VN worked with V.I. Veksler on these subjects for about two years (1957 – 1959) and Veksler (at that time the director of Department of Accelerators at the P.N. Lebedev Physics Institute) insisted on his transfer to this Institute. Thus VN applied for and successfully got the position of the Senior Scientist at the Lebedev Physics Institute. Later Veksler became the director of a new department at the Joint Institute of Nuclear Research (Dubna, the Moscow region) and constructed there a new accelerator. VN for some years worked part-time at JINR, after the change in research direction of the Department of Accelerators at the Lebedev Institute to thermonuclear fusion (this laboratory began to be called the Laboratory of Plasma Physics).

Having begun work in the Lebedev Physics Institute in 1959, VN was engaged also in the general properties of

relativistic plasma, using in his work the methods of quantum electrodynamics and quantum statistics. Here, there were many interesting problems which led to years of work. The first publication on collective acceleration appeared as a result of a joint report with V.I. Veksler at the Geneva conference in 1959. During this time, VN also actively worked in the field of relativistic quantum plasma, radiation of pairs by plasma fluctuations, coherent transition radiation, induced radiation of plasma waves, nonlinear relativistic wake waves for collective accelerators and stochastic acceleration of particles by plasma waves. One of the interesting results found by VN, — radiation of electron-positron pairs by plasma fluctuations — was picked up by the Americans and expanded into neutrino physics; on this topic, a number of reviews and chapters in monographs on neutrinos have been written by American physicists. In those years VN often reported at V.L. Ginzburg's seminars. On the basis of these works, in 1962 VN defended in Dubna his thesis for the Doctor of Science's degree (one of the official referees was V.L. Ginzburg). Direct continuations of this research on nonlinear effects and acceleration of particles in a plasma has since occupied scientific interests of VN for many years.

In 1960 – 1970, VN actively participated in research on new plasma effects. When studying induced and spontaneous scattering of plasma waves, a new mechanism of scattering by polarising clouds of ions and electrons (1964) was discovered. In the beginning this mechanism was called nonlinear scattering, due to it arising from nonlinear responses to the scattered wave and polarising fields around particles. After its generalisation to other environments in the work together with V.L. Ginzburg in 1976, this mechanism began to be called transition scattering.

Taking into account nonlinear (transition) scattering, VN demonstrated that all nonlinear interactions of stochastic waves in nonequilibrium plasma are reduced to processes of the induced scattering and induced decay, and derived a criterion for stochastic waves, confirmed subsequently within the limits of the theory of dynamic chaos. In 1967, VN's first monograph *Nonlinear effects in plasma* was published.

VN's big monograph *Plasma turbulence* had been written earlier, but the manuscript was delayed in the review by one and a half years. Without waiting for the response of reviewers, VN for some months has re-stated the basic results and new approaches in a simplified way in the monograph *Nonlinear effects in plasma*. Soon, following an initiative by academician E.K. Zavoisky and with his preface, the (first written) book under the name the *Theory of the turbulent plasma* was published in 1971. It thus became his second published monograph. Then both monographs appeared in the English editions (the first in 1970, and the second in 1977, with the second revised by adding new material so that it became approximately 120 pages longer).

After publication of the English edition of the book *Nonlinear effects in plasma* for which the scientific editor was S. Hamberger from Oxford University (he later moved to Australia), VN was invited to read a course of lectures (basically to scientific researchers and post-graduate students) at Oxford University (in the spring semester of 1970) as a Visiting Professor. VN based this course of lectures on his old books, and included new results. Basis of these lectures he wrote a book in English *An introduction to the theory of plasma turbulence* (1973). This book was published under the editor D. ter Haar, who read almost all courses of theoretical physics at Oxford University, knew more than a dozen foreign languages (including Russian), and translated set of the Russian physical literature (in particular, the books of Landau and Lifshits). Later, he also translated another VN's book, *Plasma astrophysics*, and edited VN's *Lectures on nonlinear plasma kinetics*. VN and D. ter Haar with his post-graduate students wrote about 10 scientific works.

Since 1960 – 1964, VN developed scientific cooperation with the Kharkov Physicotechnical institute. At this time, he produced a number of works on the nonlinear theory of particle beam instability, and its nonlinear stabilisation, that was used in the first work on interpretation of type III radio bursts on the Sun and fast particle beams passing through the solar chromosphere. This type of research was actively developed further in Colorado (USA) in connection with measurements of spike turbulence observed on NASA satellites, reaching distances of 0.3 distances from the Earth to the Sun and the particle beams passing through areas causing type III bursts on the Sun. These works led to VN being actively engaged in astrophysical applications of plasma physics.

In 1970 VN became interested in astrophysics. The subject of plasma effects in astrophysics was absolutely new (modern plasma physics had basically been formulated in 1960 – 1970). Results of the research of VN and his colleagues on plasma astrophysics was presented in monographs *Plasma astrophysics* (1972) and *Physics of plasma of solar atmosphere* (1978). These books were co-authored with well-known astrophysicists S.A. Kaplan and S.B. Pikelner with whom VN shared interests in plasma effects in astrophysics. VN could calculate quickly the theories needed , and these collaborators provided the astrophysical motivations and detailed knowledge of the observational data. The objective was the interpretation of satellite data (equipment for measurement of plasma parameters had then only just been launched spacecraft). At the same time, there was already many data on solar radio emission, on the physics of processes in interplanetary and interstellar plasma, on radiation of quasars and pulsars (the last beginning in 1969). In 1970, a year after the discovery of pulsars was announced, VN was invited to Rome to an international conference about mechanisms of pulsar emission. The basic results received then by VN and published, in particular, in *Nature* (1973) contained two features which then became well-accepted: that plasma of pulsars is relativistic, and a theoretical estimation of effective temperature of their radio emission.

Later there were interesting data from satellites about non-stationary space phenomena, and the need for new books on plasma astrophysics became obvious. In particular, the book on plasma astrophysics was written by the Australian scientist D. Melrose who had become interested in the works by VN, in particular translated into English a number of VN's works published originally in Russian only. D. Melrose began to propagandise actively this area, and in 1990 he established the Research Centre for Theoretical (mostly plasma) Astrophysics at the University of Sydney in Australia. When VN worked during two semesters in UK in the Rutherford-Appleton laboratory in 1996, there was an idea to write a book based on the results of the latest astrophysical observations, but his co-author did not provide his contribution, and the project did not get completed: those chapters written by VN remained in a desk.

In 1970 – 1980 VN worked intensively with present Nobel Prize winner V.L. Ginzburg, co-authoring about 10 scientific works with him. In particular, a not trivial result they proved is that the Thomson spontaneous scattering on fluctuations in the plasma, used in all modern experiments, reduces to the sum of spontaneous scattering on separate 'dressed' electrons and 'dressed'ions, the scattering amplitudes including interference between the usual scattering and nonlinear (transition) scattering. These results were the subject of a joint report with V.L.Ginzburg at the international conference in Yerevan in 1987. The basic theme of collaboration with Ginzburg these years was the theory of transition radiation and transition

scattering. In particular, the work of VN of 1961 on the change of mass of particles on transition from one medium in another gave a new interpretation to transition radiation, discovered earlier by V.L. Ginzburg and I.M. Frank. Cooperation on these subjects with V.L. Ginzburg continued and included studies of transition scattering, radiation of particles because of vacuum nonlinearities, radiation of toroidal moments, transition radiation in environments with sharp jumps of dielectric permeability in time. In 1984 there was a big monograph *Transition radiation and transition scattering*, written under the suggestion and together with V.L. Ginzburg. In the book essentially new mechanisms of radiation and scattering of electromagnetic waves by heavy particles, including mechanisms of transition braking radiation (bremsstrahlung) were stated. In 1990 an English edition of this book was published, including revised and added material. Further development these ideas resulted in a monograph *Polarization bremsstrahlunbg of particles and atoms*, edited by VN and published in 1987 (English edition of 1992).

The subjects of nonlinear processes and turbulence of plasma during this period were a subject of a large number of studies in an already established group of colleagues, doctorants, post-graduate students and students of VN. In 1995, in the co-authorship with the former post-graduate students S.V. Vladimirov and S.I. Popel and doctorant F.H. Khakimov he publishes (only in English) the monograph on *Modulational interactions in plasmas*. This book contains in details developed general kinetic consideration of modulational interactions and their consequences, including those for laser and beam interactions with plasma.

VN established and successfully developed cooperation with various foreign research centres (United Kingdom, Italy, Norway, Sweden, France, etc.). Through the results of joint studies (1972-1982) with the Swedish scientists H. Wilhelmsson and L. Stenflo of Goeteborg and Umeo on nonlinear interaction of intensive laser beams with plasmas, a new nonlinear mechanisms of amplification of plasma waves were identified. In 1982 VN was awarded Doctor Honoris Causa by the Chalmers University (Goeteborg, Sweden). In 1984, for his research of nonlinear effects in plasmas, VN won the M.V. Lomonosov Prize by the USSR Academy of Sciences.

The 1990s were also fruitful for VN. In 1995, there was an edition (only in English) of VN's lectures at the Chair of Problems of Physics and Astrophysics of the Moscow Institute of Physics and Technology (MIPT): *Lectures on Nonlinear Plasma Kinetics*. In Russian it was at that time impossible to publish, and the text required editing into good English, which again an old friend of VN, and Professor of the Oxford University, D. ter Haar undertook.

Astrophysical problems also attracted considerable interest from VN these years. In 1989 – 1992, a series of works was completed on the interpretation of results of measurements from the European space program AMPTE, with participation of UK colleagues and scientists from the Institute of Space Research (ISR, Moscow). In the earlier monograph Plasma astrophysics, VN suggested a model of the plasma 'turbulent reactor' which predicts cosmic rays with a universal spectrum close to that observed. This model has been developed in a series of works in cooperation with one of the founder of modern plasma physics D. Pines (USA). In another series of works, VN investigated a new mechanism for acceleration of cosmic rays up to the highest energies observed — the radiation-resonant acceleration, appearing due to virtual pairs and radiation corrections to resonant stochastic acceleration. Results are summarised in a major review published in *Physics Reports* in 1989. In a further article published in 1998, VN demonstrated the close analogy between radiation-resonant acceleration and Hawking radiation, with the birth of pairs attributed to acceleration rather than a gravitational field. The works done in collaboration with scientists at the Rutherford – Appleton Laboratory in the mid-1990s, allowed calculation of plasma corrections to the known factors of opacity used for radiation transfer problems. These effects can elucidate models of radiation transfer in the Sun's centre, lowering by a few percent the temperature at the Sun's centre, and changing conclusions about radiation of the most energetic neutrinos from the Sun. This served as one more step in the solution of the problem of the deficiency of observable solar neutrino. Together with scientists from the Pavia University (Italy), VN investigated the influence of a dense plasma on the speeds of thermonuclear reactions in Sun. The essential step made by VN in subsequent publications where the inaccuracy of estimation of the influence of plasma widely used in astrophysics for the speed of thermonuclear reactions had been shown to lead to an incorrect limit of strong shielding. VN demonstrated the validity of only weak shielding due to ignored earlier effects of correlations of plasma number densities in thermonuclear reactions. This result is important because (in the absence of a theory of strong correlations) many existing models of stellar evolution should be reconsidered.

Over these same years, VN vigorously developed (being one of the founders) a new direction in the physics of plasmas — the physics of dusty (complex) plasmas. The first works of VN on this subject involved the mechanism of transition scattering on dust particles for the interpretation of observable backscattering of radar radiation by noctilucent clouds in the ionosphere (1988 – 1990). These works were done together with an international group of scientists at different centres. Furthermore, there was a long-term cooperation with different centres on research on dusty plasmas (Russia, Ukraine, Germany, Australia, USA, Norway, Italy, UK). In dusty plasmas, essentially new phenomena appear for interactions between heavy charged dust particles, there are self-organised plasma-dust structures and crystals, there is a possibility of modelling of biological systems (in particular, VN proposed an hypothesis on the possibility of an inorganic origin of living systems). It has been proven that dusty plasma is a new state of matter in which there are new mechanisms of interaction peculiar to this state. Mechanisms of interaction and agglomeration of dust particles were proposed and investigated by VN, including theory of formation of plasma-dust crystals discovered experimentally in 1994. Understanding these mechanisms is important for many problems: phase transitions in dusty plasmas, production of computer microchips, influence of dust on the operation of thermonuclear devices. After the international agreement between Russia and Germany, research on dusty plasma was carried out through numerous experiments on the International Space Station (ISS). The related interpretation demanded profound physical, theoretical and numerical studies, done by VN together with his colleagues. A theory was constructed for the coherent dust structures observed experimentally onboard the ISS, a mechanism was proposed, based on fundamental physical principles, for the various conditions and parameters for the formation of dust crystals, and the kinetic theory of dusty plasma was developed. These results are important for research involving new space telescopes to study dust components in the rings of planets and formation of dust clouds in the vicinity of stars. Results of numerous studies of VN in this area were summarized, in particular, in the book Elementary physics of complex plasmas published in 2007 (only in English). This book was co-authored with G. Morfill and H. Thomas from the Max Planck Institute for Extraterrestrial Physics in Garching (where VN worked for a number of years within the limits

of the Russian–German collaboration program and also as the winner of the Humboldt Award), and also with S.V. Vladimirov from the University of Sydney (which VN visited a few times). In this book results of theoretical and experimental studies in this absolutely new area of physics are expounded.

Besides monographs (the number of the published books is 14 taking into account extended English editions, but without pure translations) VN has published in the journal *Uspekhi Fizicheskikh Nauk* [*Physics-Uspekhi*] 12 major reviews: one of them "Collective plasma processes in the solar interior and the problem of the solar neutrinos deficit" co-authored with R. Bingham, U. de Angelis, and A. Forlani, has attracted significant interest of readers: this review was downloaded from only the UFN web-site www.ufn.ru more than seven thousand times!

Also VN has published 9 reviews in English in the journal *Physics Reports*, and about 10 reviews in other editions such as *Proceedings of the Lebedev Physics Institute* and the *Plasma Physics Reports* (Russia). The total number of his scientific publications exceeds 500. The citation index (number of citations per year) became very high (over 200 references in a year) already in 1970s, and remains high today: according to the site www.scientific.ru by the end of 2007 year there were 5494 references to VN's articles, published in scientific periodics. Most highly cited are VN's books *Nonlinear effects in plasma* (over 800 references in Russian and English editions) and *Theory of turbulent plasma* (over 500 references to Russian and English editions). These seemingly boring statistical data clearly emphasize VN's outstanding achievements in physics.

In addition VN was 'lucky' with co-authors: at first his co-author was V.I. Veksler, well-known for his discovery of principles of particle acceleration, then well-known astrophysicists S.A. Kaplan and S.B. Pikelner, then our Nobel Prize winners I.M. Frank and V.L. Ginzburg, and well-known foreign scientists D ter Haar (UK), D. Pines (USA, one of founders of the concept of plasmon) J. Wharton (USA, experimental research on nonlinear processes in plasma), G. Morfill (Germany, the well-known space physicist and astrophysicist, and Director of the Max Planck Institute in Garching), and many other very good physicists.

Besides successful and productive scientific work, Vadim Nikolaevich conducted and continues to conduct an extensive teaching: in the beginning (1954–1959), he taught students of the physics faculty of the Moscow State University, and then (since 1977 and to this day) he is Professor of the Chair of the Problems of Physics and Astrophysics (MIPT), headed by V.L. Ginzburg. He supervised 21 post-graduate PhD students, and 6 of them have received Doctor of Science degrees, and in Doctor of Science studies, 3 more doctorants from Dushanbe, Dubna, General Physics Institute (Moscow) have obtained Doctor of Science degrees. Some of his former post-graduate students are already professors (including at foreign universities), and supervise large scientific groups.

V.N. Tsytovich conducted also the big organizational work, being a member of the international committees of many international conferences; for 17 years, he headed the Soviet committee of the International Conference on Phenomena in Ionised Gases, he also headed the section of the Council of the USSR Academy of Sciences on the physics of low-temperature plasmas, organised many international meetings and workshops, including those in Sochi and Capri.

Physics is not the only talent of VN. He plays the piano and during the evacuation he finished musical school, where the piano was an obligatory subject, and where he concentrated on the oboe. After the family returned from evacuation to Leningrad (at the end of 1944), VN concentrated on the piano more seriously performing in a city amateur's competition at which he played Rachmaninov and Sibelius preludes. After moving to Moscow in 1949, VN almost stopped music, but during study at the Moscow State University he sometimes played Chopin, Rachmaninov, Schubert, Tchaikovsky, Sibelius at amateur performance concerts.

Tennis was one of VN's first sports hobbies. The peak of his form was in 1970 when he played in a team of the Oxford University. VN always liked to travel; in his student's years with a backpack he went with friends to the Caucasus mountains, where there were many adventures. Later, with his family and friends, VN has travelled by car all the Caucasus and across the Baltics, complementing car travel by kayaking. Up to present day, VN has a passion for mountain skiing. For many years, VN with family and friends went to Cheget in the Caucasus where once, while in a hotel, they were caught by an avalanche. The desire to go to Caucasus was gone after that. But the desire for a mountain skiing remains. When extensive international collaboration began, VN often intentionally chose to travel in winter. Skiing is a part of life in winter, and there is less variety in the summer. And there is also his hobby of wind-surfing. VN began to participate in all-Union competitions on wind-surfing, and in 1987 (when he was 58!) he bypassed two candidates for the master of sports although he was the 'eternal' second-degree rank.

It is not excluded, that these 'outside' (to science) hobbies, as well as the remarkable climate in the family that VN and his beautiful wife, Emma, created, were a basis for his surprising creative activity and productivity in theoretical physics. Colleagues, students, co-authors and friends wish Vadim Nikolaevich further "So to hold!", and to have fine health, exclusive luck and inexhaustible energy and optimism for many fruitful and happy years!

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