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Sergeĭ Ivanovich Vavilov — the man and the scientist: a view from the threshold of the 21st century

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Abstract. The scientific and social activities of S I Vavilov are discussed based on documents that have become available in the last decade.

There are many published accounts that, apparently, describe in detail the life and work of Sergeĭ Ivanovich Vavilov (1891 – 1951), an outstanding Russian physicist and President of the USSR Academy of Sciences (1945 – 1951) who conducted classic research in physical optics and luminescence (a collection of stories about him was published in three editions [1], L V Levshin published two books about him entitled *Sergeĭ Ivanovich Vavilov* [2] and *Light is My Calling* [3], and numerous articles appeared in various magazines). But the published sources either fail to reveal some aspects of Vavilov's life or do not display them in full thus making it impossible to obtain a reasonably comprehensive understanding of his personality for those who have not known him in person.

The third expanded edition of the book *Sergeĭ Ivanovich Vavilov. Stories and Memories* was published on the hundredth anniversary of Vavilov's birth. This edition, as were the previous two, was compiled and edited by Nobel Prize winner I M Frank who was Vavilov's disciple. His long well-written paper on Vavilov's life and work ([1], p. 9) opens the book. It was the first time that Frank could give a detailed account of the tragic aspects of Vavilov's life under Stalin's dictatorship. The torment inflicted upon Vavilov's soul in these years was undoubtedly the cause of his untimely death.

The third edition of *Stories and Memories* came out in 1991. New documents that have become available since then significantly expand our knowledge of Vavilov's life. The present paper makes use of these documents (or at least some of them). Apart from the availability of new information on Vavilov, there are quite a few other significant reasons why the publication of the present paper is pertinent and imperative. The following reasons may be cited. Many physicists from the countries of the former Soviet Union (especially, the younger generation for whom the best traditions of Russian science should be preserved) are unaware of the contributions Vavilov made to science, in particular, his role in the discovery of Vavilov – Cherenkov radiation; Vavilov is little known in foreign countries; and some writers [4, 5] have made unjustified charges against him amounting almost to accusations of servility to Stalin's regime.

The violent reforms occurring in the USSR and Russia in the years after Frank completed his paper (in 1990) provided another reason for writing the present paper. The reforms have made the Russian society more open and substantially weakened or even eliminated the censorship that had largely impeded freedom of information. On the other hand, the ongoing economic crisis resulted in a rapid deterioration of the position of Russian physics and now threatens the very existence of the science that had until recently been among the best of the world. Some authors now tend to underestimate the achievements of Soviet science and to put forward biased and unfair assessments of some scientists including Vavilov. One must bear in mind that during those years the progress in physics in the USSR was largely due to the research work conducted by Vavilov himself and to his activities as a mentor of young scientists, as well as to his administrative effort as the founder of the Physics Institute of the USSR Academy of Sciences (FIAN), manager of the State Optics Institute and later as President of the USSR Academy of Sciences.

We hope that the present paper will also be of interest for foreign readers who have scarce, and sometimes distorted, information about the history of science in Russia. The Western science community know little of and often fail to appreciate the many scientific results of Soviet scientists including some world-class discoveries. The same may be said about some Soviet scientists who made great contributions to world science. Relevant examples are L I Mandel'shtam and G S Landsberg who discovered the effect known as Raman scattering in the West and E K Zavoĭskiĭ who discovered electron paramagnetic resonance.

In our earlier papers on Vavilov [6, 7] we noted that the Western science community is practically unaware of a scientist who contributed to the discovery of a phenomenon named after him (the Vavilov – Cherenkov effect) for which the Nobel Prize was awarded after his death (in 1958). Our arguments had some effect. The British scientists E Pike and R Brown [8] agreed with our opinion on Vavilov's research work; they referred to him as an outstanding personality in 20th century physics and suggested that the term 'Vavilov – Cherenkov radiation' should be more widely used in the West†. They noted also that Vavilov was, apparently, the first scientist (together with V L Levshin) to observe a nonlinear optical effect [9], namely, a decrease in the absorption by uranium glass with increasing of intensity of

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† In this connection it is noteworthy that the editors of our recent paper published in Physics Today gave it the title *Sergeĭ Vavilov Honored in Russia is Little Known in the West* [7].

the light source, back in 1926, many years before the first lasers. It was the first experiment demonstrating that a light wave of a sufficiently high intensity changes the optical properties of an absorbing medium while passing through it. The concept of nonlinear optics was introduced by Vavilov in his book *The Microstructure of Light* [10] which will be discussed in more detail below. In summary of his results reported in [9] he wrote, ''An absorbing medium must exhibit a 'nonlinearity' not only with respect to absorption. The latter is related to dispersion, and therefore the velocity of light propagation in a medium must generally depend on the light power, too. For the same reason other optical properties of a medium — birefringence, dichroism, rotation capacity, and so on — must generally exhibit a dependence on the light power, that is, a violation of the superposition principle.'' (The principle of superposition essentially states that the net effect produced by several independent forces is the sum of the effects produced by each of the forces by itself.) Concluding the chapter entitled ''Limits of Validity of the Optical Superposition Principle'' Vavilov writes, ''...Severe violations of the superposition principle can occur when light travels through a medium owing to the quantum properties of light and matter.'' It should be noted that research in nonlinear optics, that was greatly intensified by the emergence of the laser in the early sixties, is still a highly interesting field and it is not only optical physicists proper but a wider range of scientists who study and make use of nonlinear optical effects.

In order to be able to understand better Vavilov's thinking in his mature years let us look back at his first steps as a scientist. He entered Moscow University in 1909 and graduated in 1914. Vavilov wrote in his autobiography [11], ''I was significantly affected by the events of 1910 – 1911 when most liberal professors resigned from the university under the effects of the policies of Kasso, the education minister. I transferred my research activities to the private laboratory of Professor P N Lebedev which after his death was taken over by Professor P P Lazarev. My first published papers were completed in this laboratory (1913 and 1914). To register my protest I refused to take a tenure position at the University department and under the then current legislation I was obliged to enter the military service. Soon the war began, I was sent to the front line and from late July of 1914 to February 1918 served in various technical regiments (the sappers, the road construction company, and radio engineering detachments). In February 1918 I was taken prisoner by the Germans in the town of Dvinsk but managed to escape in two days. While at the front line I completed an experimental and theoretical study concerning the frequency of oscillations of a loaded antenna''. As a young man Vavilov exhibited varied talents and interests. In 1914 and 1916 he published two fascinating essays on Italian cities in the Transactions of the Society of Graphic Art Teachers presenting his impressions from his Italian trips made as a student.

Vavilov spent his entire working life in Russia (with the exception of a six-month stay in Germany in 1926 where he worked at the laboratory of P Pringsheim). The thirties when he was yet not overburdened with administrative duties were the years of his most active experimental work when he conducted fundamental research in the fields of physical optics and luminescence. His most celebrated results in physical optics include the discovery of the first nonlinear optical effect, namely a deviation from the Bouguer law for high-intensity light in uranium glass, the studies of the quantum fluctuations of light carried out at the State Optics Institute starting from 1932, and, ultimately, the famous Vavilov – Cherenkov effect discovered in 1933 together with P A Cherenkov. Vavilov's research in luminescence is now regarded as classic, and we shall not discuss it in detail here. We shall only note that it was his profound understanding of this field that enabled Vavilov and Cherenkov to discover the effect later named after them. In 1958 the Nobel Prize in physics was awarded to P A Cherenkov, I M Frank and I E Tamm for the discovery and interpretation of this effect. Unfortunately, S I Vavilov had died by this time (the Nobel Prize cannot be awarded posthumously).

S I Vavilov during the First World War (1914 or 1915).

Below we shall discuss the discovery of the Vavilov-Cherenkov effect which Western scientists refer to as the Cherenkov effect, thus ignoring Vavilov's contribution to its discovery though practically the entire Russian science community agree that it is wrong. Here we shall just quote from L I Mandel'shtam, a highly esteemed contemporary authority in the field. S M Raiskiĭ writes in his reminiscences [12], ''One of the examiners of the famous dissertation by P A Cherenkov was L I Mandel'shtam. I was sitting in Mandelshatam's living room when Mandel'shtam emerged from his den having finished writing his review. He gave it to me to read. After reading the review I asked why S I Vavilov featured so prominently in a review of a dissertation by P A Cherenkov. Mandel'shtam answered, ''Vavilov made such a contribution to the discovery of the effect that it should be emphasized each time this discovery is discussed''''. To be fair not everybody was appreciative of the significance of the

discovery. V L Ginzburg [13] remembers that when L D Landau signed a collective letter to the Nobel Committee nominating Tamm, Frank and Cherenkov for the Nobel prize (the original 'official' nomination was for Cherenkov alone and the letter was written to endorse all three nominees) he said that he did not really think much of the Vavilov–Cherenkov effect. So he stipulated as the condition of his signing that instead of "must be awarded" the letter should say "if awarded" it should be to three of them (Tamm, Frank and Cherenkov)". When this amendment was made in the letter, Landau signed it, and Ginzburg believes that Landau's conduct in this affair was irreproachable. It should be added here that some prominent physicists (in particular, F Joliot–Curie, P L Kapitza and some others) voiced scepticism about the FIAN results in the first years after the discovery.

We should note specifically Vavilov's skills as an experimenter, especially as this aspect of his research work is rarely mentioned. The experimental techniques he designed and the results he obtained with them are admirable. Vavilov and his assistant E M Brumberg developed a photometric quenching technique using the human eye as an instrument for measuring exceedingly low light intensities. The technique makes it possible to determine not only the brightness but also the spectral composition of weak-intensity radiation at the vision threshold. The latter aspect is especially surprising because the human eye does not distinguish colors in weak-intensity light ("all cats are black in the dark"). The technique employs the human eye adapted to darkness as a light receiver. Vavilov made use of the fact that when the eye has adapted to darkness its sensitivity is greatly enhanced. His experiments with various observers demonstrated, in particular, that the vision threshold in the green spectral range was equivalent on average to 20 light quanta. The technique was employed in studies of quantum fluctuations of low-intensity radiation. Cherenkov used the technique for his studies of the newly discovered radiation. No other technique was available for this purpose at the time.

Vavilov's progress deserves especial praise as experimental research in Russia had considerably poorer support than in Europe. Vavilov spent the first half of 1926 in Berlin working at the laboratory of P Pringsheim known for his work on luminescence. The research Vavilov conducted in Berlin was to a large extent a continuation (sometimes a repetition) of the studies he had initiated in Moscow, though using better, more accurate optical instruments (unavailable in Russia at the time) and chemically purer dyes. When Vavilov was in Berlin he wrote a letter back to Moscow addressed to his closest collaborator V L Levshin. Some of these letters were cited in the book *Sergeĭ Ivanovich Vavilov* by V L Levshin's son, L V Levshin [2]. In a letter of March 1926 Vavilov writes, "Visited Zeiss with Pringsheim one day and again kept licking my chops. Goodness gracious, how well stocked they are. On each desk they have all those arcs, polarization installations, and interferometers..." [2]. As was often the case in Russia, though, the constraints on available material resources promoted inventiveness. The following passage from another letter illustrates Vavilov's attitude to experimental research [2]: "...I work every day but my efficiency is rather low since any small item has to be given away to the technician to complete and it is a day wasted on average."

During this stay in Germany, Vavilov met many outstanding physicists including A Einstein, M Born, M Laue, J Franck, O Hahn, and L Meitner. Being modest and fairly young Vavilov felt too shy to present a report at a conference in the presence of "the entire Olympus: A Einstein, W Nernst, M Planck, M Laue, W Bothe and others", as he wrote to V L Levshin (a letter of May 13, 1926 [2]). Instead, Vavilov asked Pringsheim to make a report on his Moscow research. In particular, the report presented the results on light absorption in uranium glass acclaimed in our days as classic (Pike and Brown, mentioned above, noted these results not only in their paper [8] but also in their review of 20th century optics [15]). Vavilov wrote to Levshin that their results had been approved by "Einstein himself".

Vavilov's stay in Germany happened during the "golden age" of 20th century physics — the time when the theories of relativity and quantum mechanics were born and accepted. Vavilov had the good luck to attend lectures on relativity theory and quantum mechanics delivered by such authorities as Planck, Heisenberg and Born in Berlin and Göttingen. His German was good enough to enable him to grasp the basics of the 'new physics' as told directly by some of its creators.

As was and is typical for experimental physicists, Vavilov proposed to analyze the behavior of materials under extreme conditions and designed special instruments and research techniques for this purpose. These days the extreme experimental parameters achieved by Vavilov would seem unimpressive. Physicists who nowadays employ the state-of-the-art laser systems would regard as primitive the condensed arc used by Vavilov and Levshin as a light source when they observed the first nonlinear optical effect. With highly sensitive photoelectric multipliers being available nobody in his right mind would suggest now that human eye should be used for recording single photons. But no multipliers were available for counting photons in the thirties, and it was only the emergence of lasers in the early sixties that initiated rapid progress in nonlinear optics. We can thus state that Vavilov's results in the fields of physical optics and luminescence were outstanding achievements made possible at that time only by his proficiency as an experimenter.

Vavilov's fundamental research in physical optics and luminescence is highly regarded in Russia. This is why the famous physicist R V Khokhlov (1926–1977) who made outstanding contributions to nonlinear optics initiated a regular Vavilov Conference on Nonlinear Optics, traditionally held in Novosibirsk. We shall not discuss here Vavilov's research in luminescence which is known very well. We shall note only that he founded the Russian school of luminescence research and the scientists taught by Vavilov's disciples are active now not only in the laboratories of Moscow and Saint Petersburg but in other cities and towns of Russia and countries of the former Soviet Union.

The monograph *The Microstructure of Light* [10] summarizes the results of thirty years of research in physical optics and luminescence by Vavilov and his co-workers. He completed it in August 1950, and it was published just before his death. The monograph comprises the following sections: (1) experimental studies of quantum light fluctuations using the visual technique; (2) fundamentals and some results of the elementary theory of light interference; (3) the properties of light emitted by an absorbing medium. Vavilov and his co-workers employed the available experimental techniques to discover the first nonlinear optical effect and to verify the validity of the principle of superposition in experiments. Obviously, Vavilov had been conceptually prepared for the discoveries that were made possible only by the emergence of lasers in the mid-sixties, that involved studies of nonlinear optical effects, the coherence of light, compressed light,

cooperative optical effects and so on. It was Vavilov's direct guidance that fostered the finest culture of optics research at the physics institute FIAN contributing to the flourishing of research in quantum electronics at the institute for which N G Basov and A M Prokhorov were awarded the Nobel Prize for physics in 1964.

Vavilov was not only a distinguished researcher. From 1932 until the end of his life he had to spend a part and later most of his time performing administrative functions in science and supervising young scientists. Soon after he had been elected to full membership of the USSR Academy of Sciences in 1932 he was appointed Head of Research at the State Optics Institute (GOI) and Head of the physics department of the Institute of Physics and Mathematics of the USSR Academy of Sciences in Leningrad. When the USSR Academy of Sciences was moved to Moscow the physics department was transformed into the Physics Institute of the USSR Academy of Sciences (FIAN). Vavilov was appointed its director and suggested that the institute be named after P N Lebedev. Vavilov made a colossal contribution to the progress of research and growth of GOI and FIAN [1, 6, 16, 17]. Note that the GOI was instrumental in the emergence of an advanced optics industry in Russia where no optics engineering had ever existed before. The physics department of the Institute of Physics and Mathematics that had not more than two dozen staff researchers and graduate students in Leningrad in 1932 grew into the famous FIAN, an institution unparalleled anywhere at home or abroad for its scope of physics research. When FIAN moved to its present specially constructed main building on Leninskiĭ prospekt in Moscow in 1951 (the year Vavilov died) its laboratory space and number of employees had grown immensely compared to 1932. The research conducted in the institute covered most of the primary fields of physics. The concept of a multidisciplinary institution that was put at the foundation of the institute naturally resulted in the emergence of new research fields and provided most suitable conditions for conducting complementary experimental and theoretical research. Several new institutes grew out of FIAN's laboratories because more comprehensive studies in new directions were needed. Vavilov, as the director, made a great contribution to initiating research in new physics fields and to the overall concept of administering FIAN as a multidisciplinary institution. At first many of his collaborators were surprised that Vavilov was supporting research not only in the fields that he was personally involved in, such as optics and luminescence, but promoted work in other fields, too, in particular, nuclear physics and cosmic rays†, solid state physics, radiophysics and theoretical physics. FIAN was designed as an institution conducting fundamental research in many fields. But each time the national interest called for applied science inputs into vital defense projects, FIAN took part and in many instances made highly successful contributions (including the thermonuclear weapons projects).

† One example of how broad Vavilov's thinking was and how concerned he was with the development of new fields in physics in our country is that he was instrumental in setting up the chair of nuclear physics and radioactivity at the physics department of Moscow State University in 1940. The chair was headed by D V Skobeltsyn, later elected to the USSR Academy of Sciences, and it was also Vavilov who invited him to work at FIAN. In 1946 the chair was expanded into the Institute of Nuclear Physics of the Moscow Sate University and a sector of nuclear physics at the department of physics.

Vavilov had reason to be proud of his creation. Even in Vavilov's lifetime FIAN became one of the international leaders in many fields of physics. Since Vavilov's death five FIAN researchers have been awarded Nobel Prizes in physics. I E Tamm, I M Frank and P A Cherenkov received this most distinguished international award for the discovery and interpretation of the Vavilov – Cherenkov effect (and if Vavilov were alive he would have shared the distinction with them). Later N G Basov and A M Prokhorov were awarded the Nobel Prize for their fundamental research in quantum electronics and the associated development of lasers and masers. Other discoveries made by FIAN scientists are comparable in significance with these. One of them is the principle of phase stability put forward by V I Veksler. The concepts of controlled nuclear fusion developed by I E Tamm and A D Sakharov are in the same class. Incidentally, A D Sakharov was the sixth FIAN researcher to receive a Nobel Prize, though in his case it was the Peace Prize. There are not many institutes in the world which have simultaneously employed six Nobel Prize winners.

Though the thirties were a very difficult time of political hysteria in Russia, FIAN surprisingly managed to continue working productively while preserving a positive internal ambience. That was largely due to the efforts of Vavilov. It is well illustrated by G E Gorelik in his essay *Moscow, Physics, 1937* [18] where he cites the transcript of a conference of the top FIAN researchers held soon after the Plenary session of the Central Committee of the Communist Party in February and March of 1937 which had purged the former top Communist leaders Bukharin and Rykov who had then been arrested by secret police as Japanese and German spies. At this conference Vavilov's behavior was both bold and decent as he fielded political accusations. He spoke of B M Gessen, who had been jailed as 'an enemy of the people' in August 1936, as of a normal human being and admitted responsibility for inviting him to FIAN to the position of deputy director. He shielded Landsberg and Tamm from attacks by Communist zealots (the latter's brother, the chief engineer of the Berezniki Chemical Factory, had been

S I Vavilov in FIAN 1937.

arrested for political reasons) and thus prevented a hate campaign that raged in the country from taking over the institute. Vavilov, of course, had to make ceremonial statements during this conference as on many other occasions as the director of the institute and later as the President of the Academy of Sciences (for instance, he started his address to the conference with quotes from Stalin's speech) but such were the rules of the game and as an administrator holding high rank he was helpless in this respect. Still the tranquil atmosphere (so unusual for that time and even for our time) at FIAN was in startling contrast to what happened, for instance, in Moscow State University (see, for example, [19]). It is not surprising, therefore, that Vavilov managed to attract to FIAN such outstanding physicists as L I Mandel'shtam, N D Papaleksi, G S Landsberg, I E Tamm, V A Fok, N N Andreev, and M A Leontovich and to maintain an atmosphere at FIAN that differed strikingly from the political frenzy ruling over the nation at the time.

In his reminiscences of the time I M Frank wrote, "...In my youth I was lucky in that even as a student I was accepted into the circle where genuine and varied science interests were the dominant factor. I am speaking about the school of L I Mandel'shtam which included my direct mentors and the prominent physicists S I Vavilov, G S Landsberg, and I E Tamm whose individualities were sharply different. They had, though, one trait in common for the entire school — the unceasing scientific communication going on between them. They kept on discussing theoretical issues and experimental results and nobody regarded these frequent and long discussions (in and out of academic conferences) as wasted time. At first I was astonished that these outstanding individuals spent hours of their valuable time, which could have been devoted to doing something remarkable, for just talking, often about things that went wrong or proved to be simply irrelevant. At that time I failed to realize that these conversations had often introduced new concepts long before they were published and, of course, nobody was scared of somebody else publishing them first. Moreover, nobody spared any effort to contribute to shaping up a new concept or cared about a share in the proceeds. It was quite natural in the moral atmosphere that permeated the school of L I Mandel'shtam.

Until the end of his life Vavilov preserved the custom of continuously discussing new results and the associated concepts with his co-workers and disciples. Naturally, I knew about all the details of Cherenkov's research project from its very beginning. Soon Vavilov introduced me to Cherenkov and we started to communicate closely after I took a position at FIAN. After the USSR Academy of Sciences had been moved to Moscow in 1934 Vavilov repeatedly discussed this research project with Tamm, and I was in constant communication with him, too. The results I am writing about in this paper would not have been obtained without these numerous joint discussions. Frank goes on to say, "Vavilov enthralled me by his fascination with Cherenkov's research..."

The above quotes are from Frank's paper entitled *On the Coherent Radiation of a Fast Electron in a Medium* published in *Memories of I E Tamm* [20]. Frank preserved his respect and affection for his beloved teacher Vavilov till the end of his days. We noted above that Frank compiled and edited a collection of reminiscences about Vavilov that was published in three editions. Each edition was revised and enlarged. One of the best contributions to the third edition was written by the editor himself. Frank was very ill when he completed revising the third edition. He was afraid he would die without finishing the job. When he completed the manuscript he emerged from his study at home and joyfully informed the family that the book had been finished adding, "Now at last I can die". He died in a few days.

G Bernal, known for his X-ray diffraction studies of crystal structure and his public activities, met with Vavilov several times. He wrote in Nature of October 20, 1952 about Vavilov's gift as a research administrator, "He never imposed his opinions on other people. His authority was based on rational thinking and integrity."

We have mentioned already that Mandel'shtam, Papaleksi, Landsberg, Tamm, Fok, Leontovich and other prominent physicists were employed by FIAN in 1935. Vavilov was entirely successful in his effort to draft a strong research team. A N Krylov, a famous Russian mathematician and ship architect who was a member of the Academy, commented on Vavilov's attitude to hiring researchers, "Indeed, Vavilov is a remarkable person. He founded an institute and was not scared to invite people who were better physicists than himself" [21].

In 1936 Vavilov invited the young physicist V I Veksler to FIAN who later became an authority in high-energy physics and developed the famous principle of phase stability used in all modern particle accelerators. Veksler gave the following account of the role Vavilov's FIAN played in his life when speaking at the presentation of the Atom for Peace award he received together with the American physicist E McMillan [22], "I was lucky in that as a young scientist I was invited to join the staff of the Lebedev Physics Institute which included such exceptional Soviet scientists as Vavilov, Mandel'shtam, Tamm and many others and, finally, the person whom I regard as my teacher and to whom I am greatly indebted — D Skobel'tsyn.

An exciting atmosphere of complete commitment to science prevailed in the institute. I had opportunities for regular live contacts with these outstanding scientists, and with my contemporaries in the laboratory, Frank and Cherenkov, who later received the Nobel Prize, with Professors S Vernov and N Dobrotin, with attentively supportive theoreticians, primarily, E Feinberg and M Markov, and with a large group of gifted younger physicists — this is a far from complete list of people with whom I worked closely for decades and who definitely have reasons for treating our success as a joint achievement..."

Veksler wrote in his paper entitled *S I Vavilov in FIAN* [1], "My first strongest impression of him was that Vavilov's attitude was extremely affable and straightforward." (Veksler speaks about his first meeting with Vavilov in which they discussed hiring him to a position in FIAN.)

"...The impression of Vavilov's remarkably unassuming behavior remained with me throughout my life. Later I was repeatedly impressed with the most attractive traits of Vavilov's personality: his unassuming attitude to everybody irrespective of position, rank, and age and his unvarying affability..."

Cherenkov noted in his reminiscences, "Vavilov's research results made up the foundation of the modern understanding of luminescence. This foundation made possible one of the most significant discoveries of contemporary physics — the radiation by charged particles moving at a velocity higher than the velocity of light.

Without going into details of this discovery I shall note that it could be achieved only in such a school as Vavilov's

school which had studied and defined the basic properties of luminescence and determined strict criteria for distinguishing between luminescence and other types of radiation. It was not an accident thus that even such a large physics school as the Paris school failed to recognize this phenomenon taking it for conventional luminescence.''

In 1945 A D Sakharov, then an engineer at Ulyanovsk munitions plant, was admitted to FIAN as a post-graduate student. His supervisor was I E Tamm. Later Sakharov became an outstanding scientist and a celebrated public figure. Sakharov's book of reminiscences includes a passage about his years as a post-graduate student at FIAN where he mentions his meetings with Vavilov. To understand the following quote from Sakharov's book [23] one should bear in mind that when Sakharov came to Moscow with his wife and little daughter he had no permanent place to live, had to pay exorbitant rents to various landlords from his meager earnings and his family never could get enough food under the food rationing system that was in effect at the time.

Sakharov writes, ''In January 1947 FIAN booked a room for us at the hotel of the Academy of Sciences (known as 'Lodgings for Visiting Scientists' though most of the lodgers were in a predicament similar to mine and were even not associated with the Academy at all). FIAN paid the rent partially or in full — I do not remember exactly. To discuss this arrangement I had an appointment with the FIAN director, a prominent optical physicist, academician Sergeĭ Ivanovich Vavilov, who was a brother of another, even better known academician, Nikolaĭ Ivanovich Vavilov, a biologist who had been arrested and died in prison a few years before. It was one of the most terrible pages in the tragic history of Soviet biology. Vavilov was soon appointed (or had already been appointed) President of the USSR Academy of Sciences. In this capacity he had to meet regularly — at least once a week — T D Lysenko, an Academy Presidium member who had been a principal persecutor of his brother, responsible for his death. I just cannot imagine how he took these meetings...

...Vavilov was a nice person to meet — good-hearted and gentle. As a deputy of the Supreme Soviet, he received numerous complaints and pleas presented by visitors from his constituency. I know how hard it is from my personal experience with the Human Rights Committee in the seventies. He had placed a number of envelopes with cash in a drawer of his desk (his personal money) and he pressed on the destitute visitors these envelopes as in most cases he was unable to give them the support they really needed. The authorities learned of this and attempted to prohibit it. Vavilov was a director of another institute in addition to FIAN and he carried out his duties without sparing himself (in this respect I can compare him to only one other person — Yuliĭ Borisovich Khariton, the Head of Research at the institution I was later employed at for many years, though he was quite different from Vavilov in some other respects). Vavilov always took good care of the personal circumstances of his employees, he deeply and sincerely loved science and was an excellent specialist in optics and a good popularizer of science. As Academy President he often had to deliver official addresses. In one such speech he referred to Stalin as the 'Coryphaeus of Science' and this expression later became almost a part of Stalin's official title (apparently he liked it).

The fates of two brothers — one dying of starvation while cleaning latrines in a Saratov prison while the other was a President enjoying all official honors — was a rare paradox even for that time though it was highly typical in some ways, too.

Vavilov, who had been highly attentive to my needs even before, remembered well that I had nowhere to live. Tamm later told me that this factor had influenced my fate to some extent.''

Sakharov makes an error in saying that it was Vavilov who invented the appellation the 'Coryphaeus of Science' for Stalin. Vavilov's official position made it imperative to glorify Stalin in public speeches and in written contributions. Vavilov could not avoid it. He published articles entitled *Stalin's Scientific Genius, Science of Stalin's Era* and so on. As for the title the 'Coryphaeus of Science', the historian Esakov [24] writes that, ''...this appellation came forth long before Vavilov was elected Academy President — in the year Stalin's 60th birthday was celebrated. The then First Secretary of the Moscow Communist Party Committee Shcherbakov was one of the first — if not the first — to call Stalin the Coryphaeus of Science. In December of 1939 he published an article entitled *The Communist Party is an Impregnable Fortress* in which he wrote that Stalin, ''made a creative contribution to the revolutionary theory and gave an impetus to the theory of Marxism – Leninism as a true coryphaeus of science''. Many of the people singing praise to the dictator, including academics, grasped at the fancy term. On Stalin's 60-year jubilee the general conference of the USSR Academy of Sciences sent to him a congratulatory message calling him ''the greatest thinker of our time and the coryphaeus of progressive science''. Vavilov thus employed an approved cliche — a trick he made use of each time he had to do his 'duty' in his official capacity.''

Many authors pay especial attention to the fact that Vavilov was appointed President of the USSR Academy of Sciences. For instance, Solzhenitsyn censures him for that saying [4], ''...Academician Vavilov agreed to become a servile President of USSR Academy of Sciences after his celebrated brother had been brutally purged''. But Solzhenitsyn does not bring up any arguments to support his bitter accusation. Let us look into the matter more carefully.

Vavilov became President of the USSR Academy of Sciences in July 1945. People often ask why Vavilov agreed to take the position (after Stalin had given his approval, election to the office was just a formality) One should also ask why Vavilov was chosen for the position. It is impossible to give a definite answer to this question. In our opinion one of the main reasons was that after the Second World War, out of which the USSR emerged victorious by exerting all available resources at the cost of immense human and material losses, it became abundantly clear that the country could hardly retain its place as a leading world power unless it possessed a well-developed science (including the fundamental science that provides a basis for developing most applications in military technologies and engineering). Of course, in order to take a firmer hold over the Academy of Sciences, Stalin could have had appointed one of his trusted henchmen as the President (for instance, A Vyshinskiĭ or T Lysenko; some physicists who knew Vavilov personally suggest that one of the reasons why Vavilov agreed to take the position was that if he had refused it would have been given to one of those people). Under the circumstances, the person to occupy the position had to be a reputable scholar, preferably a scientist, possessing effective administrative skills, rather than just a tough executive (the main objectives of the Academy were in

Vavilov addressing the Presidium of the USSR Academy of Sciences after his election as President, July 17, 1945.

sciences and nuclear weapons development was becoming an immediate concern). Similar appointments were made soon after the war started and the nation was at the brink of catastrophe — the government had to release the surviving army officers and executives of the defense industries earlier imprisoned as enemies of the people and to reappoint them to top positions. Vavilov had all the qualities needed for supervising science development under the new conditions. This can be seen from the short assessments of the academicians considered for appointment as the Academy President cited by Volkogonov [25]. Stalin instructed the secret police chief Beria to prepare these assessments. The fact that Vavilov's brother had been purged was not regarded as an impediment to his appointment. Vavilov's assessment says, "Brother N I Vavilov, geneticist arrested in 1940 for sabotage in agriculture, sentenced to a 15-year term of imprisonment, died in Saratov prison..." [25]. It should be noted that Stalin 'approved' of the arrangement under which close relatives of top government and public figures were purged (this was true for Kalinin, Molotov and other officials).

Still one may ask why Vavilov agreed to take the post of Academy President while his brother had been murdered by Stalin's regime. The answer is that Vavilov served science and the nation, not Stalin. He had no doubts that his brother was innocent. We believe that the following unpublished information is important for understanding Vavilov's feelings. In 1955 V F Sennikov examined the documents stored in the archives of the Ministry of State Security with the purpose of rehabilitating the innocent victims of Stalin's purges. Sennikov recalls [26] that among other documents he was particularly impressed with Vavilov's letter of 1949 addressed personally to Stalin in which he appealed for the exoneration of his brother. The letter included a detailed account of the life and work of N Vavilov, described his openness and honest and straightforward manner of speaking. Vavilov firmly rejected all subversive actions attributed to his brother claiming that the accusations against him were slanderous. Vavilov ended the letter saying, "if my brother N Vavilov is not exonerated I cannot remain President of the USSR Academy of Sciences". The letter bears an inscription signed by Beria "Not authorized". There are no marks suggesting that the letter was shown to Stalin.

To conclude the discussion of this issue let us quote Frank [1] who believed that Vavilov's appointment as Academy President was unavoidable under the circumstances of 1945. "Many are now asking how Vavilov could agree to become President even though his beloved brother had perished in prison. A pertinent question to those asking is what would have happened if he had refused? I am not sure that he would have been allowed to stay alive as had happened with Kapitza who had shown obstinacy.

...Even if Stalin had not destroyed him he would definitely have been stripped of his rank and removed from all his positions, in particular, from running his favorite creation — the Institute of Physics of the USSR Academy of Sciences. I am absolutely convinced that the least of Vavilov's concerns was his own destiny. He felt deeply his personal responsibility for the destiny of science and culture. I am sure that if Vavilov had been purged the Institute of Physics would have been branded an asylum for enemies of the people. It was a well-known fact that we, his absolutely loyal disciples in science and life, were greatly indebted to him. He would not have been able to protect us from inevitable persecution.

...The entire system of overall control in the country was such that the slightest motion of Stalin's hand, anything he uttered, was supreme law. I know not a single instance when somebody refused to follow Stalin's instruction."

While Vavilov was President of the USSR Academy of Sciences (1945 – 1951) he accomplished much to foster science in Russia — the laboratories were better supplied with instruments, the salaries of the researchers were increased, and publishing activities were expanded — a matter of especial concern for Vavilov. It is instructive to compare what was done by Vavilov in science administration to what the present authorities are doing for Russian science and culture – the time of Vavilov's administration just after the war in the late forties and early fifties was hardly more favorable than our time. (As noted above, in those days the government made extremely generous allocations for science development or, more exactly, the development of those sciences that were instrumental in enhancing the military might of the Soviet Union. At the same time the government intensified the ideological control over science, purging a number of disciplines, and even physics was threatened with a political purge.) An apt illustration is given by the following words of Vavilov which he addressed one day in 1948 to his assistant Antonov – Romanovskii who was asking about some minor managerial issue, not recognizing Vavilov's obvious preoccupation with something else. Vavilov said sadly, "Alas, my concern now is how to save Soviet physics!" [1]. It would be surprising to hear such words from a high official these days — the more the pity! Now it is once again time 'to save the Russian physics', though the reasons are different from those of 1948. Most probably, Vavilov was concerned about the Communist ideological pressure that threatened to crush the best in science at the time. It was at that time that the Communist officials started attacking M A Markov who had published a paper entitled *On the Origin of Physical Knowledge* in the journal *Problems of Philosophy* in which he had put forward a profound philosophical analysis of quantum mechanics as a new field of physics [27]. Vavilov wrote the foreword to the paper. He emphasized that the problems treated in Markov's paper were essential for understanding new physics, that different

opinions on them could be put forward, and that Markov's exposition of his views could start a debate. It was exactly what Vavilov called for — a serious debate without "merely throwing political accusations at each other". Markov's paper is still relevant nowadays for understanding the fundamentals of quantum physics but, unfortunately, at the time at became a target for a blatant critical campaign waged by cynical and highly arrogant Communist theoreticians employing detestable and incongruous arguments [28]. This 'debate' that essentially amounted to a vilification of Professor Markov was a precursor of the conference on the philosophical aspects of physics that was planned for 1949 and that could have had disastrous consequences for Soviet physicists (as the purge of Soviet biologists that was conducted after a similar academic conference on biology held in 1948). Luckily, the planned conference was not convened and we shall discuss the events leading to it in more detail below.

As Academy President, Vavilov had an ambiguous standing with respect to the vilification campaign. On December 3, 1948, Kaftanov, the Minister for Higher Education, and Vavilov authored a letter to the Secretary of the Communist Party Central Committee, Malenkov, asking for permission to convene a national conference for the heads of the university departments of physics [29]. The top Communist Party and government officials had suggested conducting such a conference. This can be seen from the resolution of the Central Committee Secretariat [30] issued on December 4, 1948, the day after Vavilov signed the above letter, apparently, under coercion. The resolution charged Minister Kaftanov and the head of the propaganda and agitation department of the Central Committee, Shepilov, to draft the text of the forthcoming decree on this subject. A joint resolution by the Ministry for Higher Education and the USSR Academy of Sciences of December 17, 1948, selected an Organizing Committee for the conference with Topchiev, the Deputy Minister for Higher Education, appointed as the committee head [31]. The archive documents quoted in [24] indicate that Vavilov spared no effort in trying firstly to postpone the conference to a later date and then to cancel it altogether. At Vavilov's suggestion on January 31, 1949 the Central Committee postponed the conference to March 21 – 27. Meanwhile the Organizing Committee was eagerly conducting preparatory work for the conference. Vavilov failed to attend any of the committee sessions. Topchiev and Vul visited him to present the suggestions of the committee members and to discuss the draft of his planned address to the conference. Vavilov's report was entitled *Philosophical Problems of Modern Physics and the Objectives of Soviet Physicists*. Its first draft was intensely debated when it was presented to the committee at the sessions held on February 16 and 18, 1949, and the committee members voiced significant criticism of it. Vavilov then submitted a second draft of his report in which he agreed to change the title to *Ideological problems of...* but actually made only minor alterations in the text itself. At the same time, management changes were made in the Presidium, the ruling body of the USSR Academy of Sciences [24]. In January 1949, at the time originally planned for the physics conference, Vavilov petitioned the Central Committee for permission to set up a special secretariat office at the Presidium. Stalin approved the concept and on February 26, 1949, the Central Committee passed a resolution to establish the Academic Secretariat at the Presidium of the USSR Academy of Sciences. Its

Vavilov in the Presidium of the USSR Academy of Sciences; L A Orbeli, Zelinskiĭ, and D N Pryanishnikov to the right. Probably July 17, 1945.

responsibilities were specified as supervising the schedules of the research activities of the Academy's institutions, managing operations specially ordered by the government, and conducting human resources policies. A V Topchiev was appointed Chief Academic Secretary and Yu A Zhdanov, head of the science division of the Central Committee, was made one of the academic secretaries. It has been suggested [24] that under the rigid totalitarian rule, the only way to operate that remained for Vavilov was to engage in an ingenious bureaucratic intrigue. Thus, setting up the Academic Secretariat made it possible to cancel the planned conference of physicists as "it was no longer essential since the 'ideology-pushers' were granted a role in running science" [24]. Esakov [24] reviews two possible reasons for the cancellation of the planned purge of physics — Vavilov's efforts noted above and the energetic opposition by I V Kurchatov and other prominent physicists involved in the nuclear weapons projects — and suggests that the former was the decisive factor. He believes that it was Kurchatov who protected Soviet physicists and mathematicians from purges at the time of relentless strife against idealism in 1951 – 1952 but in 1949 the nuclear weapons projects fully absorbed their participants' attention and nobody would have allowed them to waste time on minor matters. Sonin [19] puts forward a different opinion. He suggests that the conference was canceled to prevent the damage to Soviet physics and to the nuclear weapons research that could have been caused by the ensuing purge. Only Stalin had the decision-making power on that matter. We believe that this suggestion is entirely valid. Actually, Kurchatov and other prominent nuclear researchers did not have to spend too much time on any efforts aimed at canceling the conference; it would have been enough to let Beria know what they thought about the possible harm the conference could produce and Stalin would have immediately been informed about their views. The nuclear weapons projects were known to be in full swing at the time, most of the fundamental problems had been resolved, and it was only the completion date that was still unclear despite a variety of serious difficulties that had yet to be overcome. Both Beria and Stalin must have been aware of this. The bureaucratic infighting by Vavilov could have made a contribution to the cancellation of the conference. At any rate it was with great relief that he received the news of the cancellation.

These days the circumstances of the Russian science differ significantly from those prevailing in Vavilov's time. There is not even a hint of the brutal ideological repression exerted by Stalin's regime on scientists. But a different kind of devastation is looming over Russian science now — governmental funding has been curtailed to such an extent that not only further progress but the very existence of science in Russia is now being threatened.

Not much is known, unfortunately, about the assistance Vavilov managed to render to individual scientists in the difficult years before and after the Second World War and the little information available is largely disregarded. A A Kapitza, the widow of P L Kapitza, gives the following account of the period when Kapitza was expelled from the faculty of Moscow State University (in punishment for his refusal to take part in the celebratory conferences in 1949 – 1950 commemorating Stalin's 70th birthday and for his rejection of the invitation to contribute to the nuclear weapons projects). "Vavilov rendered him great assistance. He always helped Kapitza in any way he could but he never made his assistance known. I believe that Kapitza was not even aware of the many things Vavilov had done for us in those years and this has come to light only now" [33]. In June 1950 Shubnikov, Director of the Crystallography Institute of the USSR Academy of Sciences, gave Kapitza a position at his institute as a 'senior research officer in a consulting capacity'. Shubnikov [1] recalls, "when the Academy Presidium was ordered to remove one of the most prominent Academy members from the directorship of the institute he himself had established, Vavilov asked me to help the academician by taking him on the payroll of the institute of which I was the head, without informing the Presidium. Of course, I could not fail to carry out Vavilov's request." Kapitza was stripped of his position as director of the Institute for Physical Problems in August 1946 by a decree of the USSR Council of Ministers signed by Stalin [33]. A lesser-known episode is the assistance rendered by Vavilov (and by Kapitza) to I V Obreimov, a physicist arrested in 1938 and accused of anti-Soviet propaganda. In April 1940 Obreimov sent a letter from prison to Vavilov asking him to 'take care of his research records' [11]. In May 1941 Obreimov was released from prison and in 1942 Vavilov endorsed Obreimov as a candidate for full membership of the USSR Academy of Sciences as recommended by the Bureau of the Division of Physics and Mathematics of the Academy [11] (though Obreimov became a full member of the Academy only as late as 1958). Very few people know about the support Vavilov gave to S M Rytov (who was made a corresponding member of the USSR Academy of Sciences in 1968) who had been sentenced to two years in prison on a trumped-up charge of illegal arms possession in 1937. Rytov recalls the support given to him by Leontovich and the active involvement of Vavilov (the latter appealed directly to the USSR Chief Public Prosecutor Vyshinskiĭ, [34], p. 46). The sentence was suspended on appeal and in 1939 the Supreme Court revoked it altogether.

The fifth volume of the Collected Works of L I Mandel'shtam published in 1949 gave rise to an officially inspired savage campaign of accusations of idealism (though the real reason was the anti-semitism prevailing in the country). Vavilov's conduct in the affair is revealing. The government censors ordered the entire print run of the fifth volume to be destroyed. Rytov was the editor of this volume. He recalls, "We had to save the book as it included valuable lecture notes and Vavilov managed to obtain an official sanction for a compromise solution and a new, 'revised' version of the volume was published the next year. I inserted the 'revisions' and comments myself so I am in a position to identify them accurately" [34] (all the revisions amounted to a page and a half, the name of Rytov as the editor was replaced with that of Leontovich, and Ginzburg, Khaikin and Rytov were removed from the commission which oversaw the publication and thus the book was in essence preserved intact!).

The above stories illustrate the extent of the efforts made by Vavilov, while occupying the high positions of FIAN director and GOI Head of Research (from the early thirties) and later Academy President, in his attempts to promote the progress of science in the country and to support individual scientists while preserving his own dignity and integrity. He had, of course, to strike compromises in the process, to deliver distasteful addresses, and in certain circumstances, when nothing more could be done, he had to sign notorious documents (in his capacity as Academy President, Vavilov signed the Resolution of the Presidium of the USSR Academy of Sciences of September 20, 1946 endorsing the governmental decision to remove Kapitza from the post of the director of the Institute for Physical Problems which will be considered in more detail below).

While for many years Vavilov was running the two largest physics institutions in the country, he was also concerned with the general issues of national science administration, the development of higher education and training of scientists and technologists, practical applications of the results of research, and the broad cultural progress of the nation. His activities were so extensive that he had practically no time left to pursue his personal research interests. This can be inferred from the memorandum he submitted to the Academy Presidium in 1936 arguing that he was unable to perform his multiple duties satisfactorily at the Academy [11]. Vavilov did not limit his arguments to his own personal affairs writing, "We should be wary of distorting the basic concept that Academy members, that is, highly competent scientists, must comprise the mainstay of the Academy. The academicians must have sufficient time to conduct research work in person and be able to devote enough time to reading if they are to have the right to continue holding their positions. It is abundantly clear to me that academicians must do much for administration, for training and for actual management operations, but they can do that successfully only if they are engaged in personal research activities and are sufficiently concerned with expanding their personal scientific experience." Vavilov illustrates his reasoning with his own schedule in which he allocates approximately 50 hours a month to conduct his own research projects and not a single moment for any experimental work that could be done with his own hands rather than by post-graduate students and assistants. In conclusion of his memorandum Vavilov requested a reduction of the scope of his responsibilities at the Academy. On the contrary, the burden of his Academy duties kept on growing and reached a peak in 1945 when he was appointed President. Unfortunately the weighty administrative responsibilities encumbering Vavilov from the early thirties till the end of his life did not leave him enough time to pursue his own research objectives and thus fully realize his scientific potential. In addition, the continual overloads adversely affected his health. Vavilov could not behave otherwise, though: he was a man of integrity and his personal advantages were never his primary concern.

Vavilov's activities as a teacher are not known so well. It is not surprising because starting from the mid-thirties he was too busy with his administrative duties and regular travel from Moscow (FIAN) to Leningrad (GOI) and back to conduct any teaching. At different periods he taught at the Moscow Higher Zootechnical Institute, the Moscow Higher Technical School and at Moscow State University where he remained on the faculty continually from 1919 to 1932. Vavilov supervised the laboratory training of the undergraduates and delivered several courses of lectures. When he was appointed to the chair of general physics in 1928, he delivered a lecture course of general physics and an extensive course of physical optics. As the professor, Vavilov completely rearranged the presentation of the general physics course which had been hopelessly neglected before his appointment (apparently, since the death of A G Stoletov). The content of the lecture course and the style of its presentation were radically upgraded and brought up to reflect the fundamental progress made in physics in the 20th century. Importantly, Vavilov coordinated his reformist activities concerning the university curriculum with those of the school headed by Prof. Mandel'shtam which had been active in the university since 1925. I A Yakovlev, a veteran professor at the physics department of Moscow University, noted that "a comparatively brief term of Vavilov's work as head of the chair of general physics (1929 – 1932) had yielded results that served as the foundation for undergraduate training in physics that remained in place until the early seventies" [35]. Everybody who had a chance to listen to Vavilov's lectures noted his remarkable gift as a speaker. At the same time he insisted that students had to study independently, too, reading classic works and current academic journals. Yakovlev recalls how Vavilov told undergraduates in his very first lecture that his lectures were not enough and that they had to read science publications by themselves. He recommended the classic physics texts by Michelson, Einstein, Lorentz and Drude and such physical journals as *Uspekhi Fizicheskikh Nauk* and some German journals.

Undergraduates in Vavilov's classes had to write short essays on such basic subjects of optics as "The phase and group velocity of wave propagation", "Michelson's experiment and Lorentz transformations", "The velocity of light in a moving medium — the Foucault and Fizeau experiments", and so on. He read all the essays (!) and had a discussion with each (!) of the undergraduates.

In his course Vavilov presented general physics in more detail but made the presentation more analytic and included the derivation of many equations important in physics. In particular, the presentation of kinetic theory was much more detailed and sophisticated and included the derivation of the Maxwell velocity distribution for molecules.

S E Khaikin, P N Belikov, S G Kalashnikov, and V I Iveronova who successively took the chair of general physics after Vavilov were successful in maintaining the teaching quality at the high level set by Vavilov till 1972.

Numerous publications describe Vavilov's teaching at Moscow University (see for instance, the contributions by Frank and Fabrikant in [1]). I L Fabelinskii recalls [36], "To initiate the students into the range of problems they were to study, Vavilov delivered a brilliant introductory lecture on the nature of forces. Students were very greatly impressed and captivated by the lecturer, wishing that he would not stop his presentation." Unfortunately, Vavilov's lecture notes have not been published. It is noteworthy that Vavilov played a role in the preparation of one of the best collections of problems in general physics written for undergraduates Russia [37]. The preface to the fourth edition of this collection emphasizes that it was Vavilov who initiated the compilation of this collection by the physics faculty of Moscow University. In addition, Vavilov was involved in the establishment of the Moscow Institute of Physics and Technology. He chaired the session of the Board of the USSR Higher Physical and Engineering School on April 10, 1946 (see the minutes in [38]). The session was attended by academicians A I Alikhanov, S I Vavilov, I V Vinogradov, P L Kapitza, I V Kurchatov, N N Semonov, and S A Khristianovich, and by S V Kaftanov and D Yu Panov. The session elected the heads of departments (Nuclear Physics — Kurchatov, Low-Temperature Physics — Kapitza, Optics — Vavilov, Physics of Combustion and Explosion — Semenov, Radiophysics — Papaleksi, Aerodynamics — Khristianovich), approved the list of chairs, elected the chair heads, and set the overall curriculum structure. Vavilov's contribution, apparently, was to put his influence behind the concept of a new type of educational institution. He could hardly devote any time to the actual teaching (remember that at that time he was not only the head of two institutes but also the Academy President).

Vavilov made considerable contributions to the general cultural development in the country. In particular, he initiated the publication of an extensive classical literature series known as the *Literary Masterpieces*. The famous historian of literature D S Likhachev [1] emphasizes that Vavilov was always deeply concerned with all aspects of cultural life writing, "He was interested in all cultural initiatives in the country and in many instances he was the driving force behind them." He continued, "The concept of the literature series bears an imprint of Vavilov's remarkable personality. If there were a tradition to name a book series after an outstanding figure of culture, I would give the name of Vavilov to our series *Literary Masterpieces*. More than three hundred books were published in this series and each one of them reminds us of Vavilov." It should be stressed that Likhachev speaks not about the physicist Vavilov, the Academy President, but about Vavilov, an outstanding cultural figure.

As we started discussing Vavilov's publishing activities we should note that from his youth he was always involved in publishing — first as a reviewer, translator, editor and referee, and later, in the post-war period, as an administrator. From 1918 he published several dozen review papers in *Uspekhi Fizicheskikh Nauk* as well as commentaries including reviews of the works by Einstein, Bohr, Planck and Heisenberg as he was regularly following the latest developments in science. Readers always found Vavilov's reviews highly useful (Vavilov also published several original papers in *Uspekhi*).

The expansion of the publishing industry in the country was a major specific result of Vavilov's effort as President of the USSR Academy of Sciences. In addition to the *Literary Masterpieces* series he started some publishing initiatives even outside the Academy's domain. For instance, the State Publishing House for Foreign Literature was founded in 1946 according to his suggestion [34]. It was Vavilov who recommended candidates for appointment as academic supervisors of various departments of the new publishing house. For instance, Leontovich and Kolmogorov were appointed the supervisors of the departments of physics and mathematics, respectively, on his advice. The literature issued

by the new publishing house included books of general cultural interest and fiction by foreign authors in addition to academic books. Other publishing activities of Vavilov included holding the positions as Chief Editor of *Journal of Experimental and Theoretical Physics* (from 1939 to 1951), Chief Editor of the journal *Doklady Akademii Nauk* (1945–1951), and Chief Editor of the *Great Soviet Encyclopaedia* (1945–1951) for which he wrote a large number of contributions.

The *Literary Masterpieces* series and other book series established by Vavilov (*Science Heritage* and *Science Classics*) were allocated large budgets to cover fees for outside consultants and experts [39]. They provided a means of livelihood for scientists recently released after serving prison sentences for political crimes who were not allowed to hold permanent jobs (M E Ramenskaya [39] mentions in this connection the names of the literary critic M K Azadovskii, the historian A I Dovatur, and the linguist S P Markish). The All-Union Institute of Scientific and Technical Information and the All-Union Research Institute of Patent Information also were established in accordance with Vavilov's instructions (though they started operating after his death). Many scientists received a significant additional income from preparing reviews and working on consulting contracts for these institutes. Probably, Vavilov remembered his experience as a young scientist writing reviews for *Uspekhi* and other journals when he initiated the establishment of these institutes.

Vavilov was greatly interested in the history and popularization of science. He wrote popular articles about Grimaldi, Huygens, Faraday, Michelson, Newton, Euler, Lomonosov, Lebedev, Lazarev and other scientists. In the apocalyptic days of the Second World War when the decisive battle of Stalingrad was in progress he was writing a biography of Newton [40]. This highly acclaimed book presenting an excellent description of the life and work of the great English physicist and mathematician was published in early 1943 to commemorate the 300th anniversary of Newton's birth. For many years before that Vavilov had collected material for the biography. In particular, he published Russian translations of two of Newton's books *Optics* (translated from the third English edition, Moscow 1927) and *Lectures on Optics* (included in the commemorative volume *In Memory of Isaac Newton, 1643–1943* published by the USSR Academy of Sciences). Newton's biography by Vavilov was published in four editions, the last edition coming out in 1989. V L Ginzburg wrote in an addendum to the fourth edition that almost 50 years had passed since the book was written, "on the whole it is not dated and remains the best of the brief and popular biographies of Newton". The third volume of Vavilov's *Collected Works* includes many of his papers on the history of natural sciences.

The numerous documents that have come to light over the last ten years allow us to understand better Vavilov's attitudes and behavior as a public figure. When we analyze his actions in relation to the governmental authorities (whom he referred to as the 'overlords') as the head of FIAN and GOI and Academy President we realize that they were dictated not by an anxiety for his personal safety but by his concern for the research teams he headed and the actual people whose fates depended on his own destiny. An apt illustration of that is given by Vavilov's role as Academy President in Kapitsa's dismissal from the position of director of the Institute for Physical Problems in 1946. We have mentioned already that the relevant resolution of the Academy Presidium was, indeed, signed by Academy President Vavilov on September 20, 1946 (see [33], p. 476). In fact, the decision had been made before that and the resolution of the USSR Council of Ministers was signed by Stalin back on August 17, 1946 (see [33], pp. 473–475). Vavilov's signature merely signified that the decision made by the Council of Ministers had been made known to the Academy. What else could Vavilov do? The alternative was to resign as President. His resignation would have hardly helped Kapitza, indeed, it would have caused him even more harm. No other Academy head would subsequently have dared to render any genuine backing to the ruined Kapitza. V Vs Ivanov writes in his reminiscences of Kapitza [41], "When I met him in the early fifties he was out of Stalin's favor and the only place where he could conduct research was his country house outside Moscow where he had equipped a fairly sophisticated laboratory (paying for it with money from his personal fund controlled only by him, and by the then Academy President Vavilov, brother of the great biologist destroyed by Stalin)."

Vavilov made appeals to defend purged scientists but such facts of his life are not so well known as, for instance, similar attempts by Kapitza. In recent years new information has appeared on Vavilov's efforts to help scientists subjected to political persecution. We have mentioned above how Vavilov defended Tamm and Landsberg, attacked at a FIAN conference held at the peak of the 1937 purges, and how he pleaded for Rytov and Obreimov. We should also cite here the letter Vavilov wrote to Ogol'tsov, USSR Deputy Minister for State Security, asking for the removal of restrictions of the civil rights imposed on the geographer P N Kapterev because he had served a prison sentence [42], and a letter to the USSR Chief Prosecutor Vyshinskiĭ, written by Vavilov in 1938 together with the prominent astronomer academician G A Shain, in which they pleaded for reappraisal of the prosecution case against the arrested researchers from the Pulkov observatory [43].

This letter was not the only one Vavilov wrote together with other members of the Academy requesting protection for persecuted scientists. In 1939 Vavilov and the academicians Ioffe, Krylov, Muskhelishvili and Fok sent a letter to Beria, the People's Commissar of Internal Affairs, requesting a re-examination of the cases of the prominent physicists V K Freedericks, Yu A Krutkov, and P I Lukirskiĭ, all charged with treason [11]. It was this letter that saved Krutkov and Lukirskii from death. Vavilov was known to support scientists purged by Lysenko, and his clique, and to get them new jobs [39].

In 1947 Vavilov spoke against the suggestion of bringing the geneticist N P Dubinin, a corresponding member of the Academy, to the so-called 'court of honor' for his contribution to a foreign journal in which he presented a critique of the absurd theories put forward by Lysenko [44]. At the time such a critique was regarded as treason or at least as an anti-patriotic deed.

We can confidently state that as new documents about Vavilov's life emerge we shall find more evidence of his actions in a similar vein.

Acting as Academy President under the conditions of a brutal dictatorial regime generated appalling stress. Vavilov's health was broken and he died two months before his sixtieth birthday.

One of the writers of the present paper (Yu V) recalls the following words of Vavilov spoken in the summer of 1950,

Vavilov with a group of scientists. Front row, from left to right: S I Vavilov, A N Krylov, V I Smirnov, N I Idel'son. Standing: Radovskiĭ on the left, T P Kravets on the right (1945).

"The job of Academy President is not fit for a dog — I would gladly swap it for a plumber's job" (see [1], p. 158). In this connection Frank recalls Vavilov's words, "When he was already the Academy President he said to me, "Each time I go for an appointment at the Kremlin I am not sure whether I shall return home or they will take me to Lubyanka (the headquarters of the secret police)". Later Khrushchev said the same thing in public and it became general knowledge" [1].

The reminiscences by the prominent optical physicist S E Frish [45] and the paper [5] by science historian A Kojevnikov include some biting remarks about Vavilov. Frish remembers Vavilov as a career-minded scheming individual who did not care for anybody. But Frish actually had a very limited knowledge of Vavilov as a person and drew his conclusions from some indirect evidence. In those days it was sometimes fatally dangerous to talk openly to somebody you did not know as a trustworthy person. Apparently, Frish based his assessment of Vavilov on the concept put forward by the French thinker Michel Montaigne. In his essays Montaigne wrote that even if he liked a person and knew him well he tended to re-examine his attitude to him if he rose too fast to glory and eminence. This manner of thinking is quite understandable; it should be noted, though, that it is one thing to re-examine a point of view, while changing it for a worse one is an entirely different matter. Vavilov never gave cause for the unfriendly feeling expressed by Frish in his memoires. One of the writers of the present paper (B B) highly praised the reminiscences by Frish but at the same time deplored Frish's attitude to Vavilov (see his afterword to Frish's paper originally published in *Priroda* journal [46]). Frish also believed that Vavilov's contribution to the discovery and interpretation of the Cherenkov effect was highly overestimated. This view is wrong and contradicts the opinions of the people directly involved in the work that led to the discovery and of their contemporaries who were witnesses to it. The same can also be said about the critical remarks [5], that are groundless. We shall discuss this issue in more detail below.

We must note here that Kapitza, a man of exceptional integrity, who never concealed his opinions, was initially hostile to Vavilov, too. But when Kapitza came to know Vavilov better, his attitude was radically reversed. When he learned of Vavilov's sudden death Kapitza wrote, "It may be truly said that Vavilov has contributed all his energy to the nation and science" ([33], p. 440). But it took Kapitza quite a while to change his attitude to Vavilov. In a letter to Rutherford, written in March of 1936, Kapitza speaks sharply of Vavilov as a poor scientist and a detestable individual ([14], pp. 64 – 65).

P E Rubinin, editor of the collection of Kapitsa's letters [14] and who was his assistant for many years, provides the following comment to this letter, "It should be noted that Vavilov's research, for which Kapitza spares no irony in the letter, later led to the discovery of the so-called Vavilov – Cherenkov effect".

In the course of his long life Kapitza had many occasions to realize how unjustified his initial dislike of Vavilov was. We have already mentioned the support Vavilov, as Academy President, rendered to Kapitza when he fell under official persecution. It was Zakharchenya who told Ginzburg a revealing story from the days when Kapitza was dismissed from his director's position at the Institute for Physical Problems. While meeting a group of his disciples Vavilov mentioned his visit to Kapitsa's country house outside Moscow where he had gone to enquire what support Kapitza

needed. One of those present inquired in surprise, "You know what Kapitza thinks of you, and still you go and visit him, you give him a hand? Why do you do that?" Vavilov retorted, "You may call what I am doing a sophisticated revenge".

* * *

Practically everybody would agree that the major developments in the 20th century physics have been relativity theory and quantum mechanics (perhaps a more exact term would be quantum physics). Certainly, quite a lot of new developments and discoveries have been made in other fields of physics, too, but the emergence of relativity theory and quantum physics signified the attainment of a qualitatively new level of understanding that made possible not just the explanation of previously inexplicable data but also resulted in a reform of physical thinking itself, a profound revision of the basic concepts of physics. Indeed, the revision was so radical that many physicists, including some outstanding scientists, refused to accept the new message. Incidentally, Planck, one the men who created quantum physics, remarked, "A great concept in science is rarely introduced by a gradual process of persuading its opponents and converting them; immediate Saul-to-Paul-type conversions are a rarity. In practice, the opponents gradually die out while those belonging to the emerging generation get used to the new concept from the very beginning".

Lively discussion of the vital issues of the theories of relativity and quantum mechanics frequently arose among physicists. It was a quite natural phenomenon and it was even essential for the proper development of physical science. But the Communist ideology reigning in the Soviet Union frequently and fatally intruded into discussions of purely scientific issues. The history of science knows of other periods in human history when similar intrusions occurred, it was not something that was unique to Soviet life in that period. In his *Philosophy of Physics* F Frank remarks that each time new knowledge contradicts philosophic dogmas the adherents of the dogmas invariably tend to reject and prohibit the new knowledge rather than to renounce their dogmatic concepts. A classic example is Galilei's persecution by the Catholic inquisition. Galilei's view on the arrangement of the solar system was declared to contradict the Christian faith and thus to be false. The religious ban on Galilei's views remained in place for centuries even after they became generally accepted. It was officially repealed only fairly recently. The contemporary Russian poet L Martynov wrote a perceptive poem about 'Galilei's case', "Scholastic savants, you were celebrating Ptolemy's jubilee and it took you a hundred years or so to learn of the news that Galilei was right. You just shrugged saying "Galilei has recanted!" and kept on celebrating Ptolemy's jubilee."

Marxist dialectic materialism was adopted as the official philosophy science in the USSR. It was claimed to be the only correct progressive philosophy and anybody suspected of deviating from its dogmas was to be harshly disciplined. When a physical theory was discussed it was enough to allege that it was contrary to dialectic materialism and the theory would be questioned and banned and its adherents would be penalized. The evaluation of whether a theory agreed with dialectic materialism or contradicted it was made by humdrum Communist functionaries ignorant of any physics, dialectic materialism or philosophy but officially recognized as outstanding experts on philosophy and natural sciences. These experts were allowed to pronounce any rubbish and the government officials took it as gospel truth. It can even be said that these experts expressed the regime's mind. Looking back at what they said one wonders what the most impressive component in their speeches was — ignorance or demagoguery. Here is an appropriate illustration. One such leading 'philosophy expert', academician M B Mitin, made a contribution to the notorious discussion of the current status of biological sciences held in 1948. He referred to classical genetics as a Bukharinite deviation in biology. Bukharin had been one of the top Communist government figures until the early thirties when Stalin ordered him purged and he was sentenced to death as an enemy of the people and executed. Stalin regarded Bukharin as his personal enemy and Bukharin had nothing to do with genetics or biology in general. But Mitin shrewdly calculated the accusations he used in the discussion. It was irrelevant whether Bukharin had any relation to biology. What was relevant was that Stalin followed the progress of the discussion. Mitin knew that Stalin had spoken in favor of Lysenko, an opponent of classical genetics, who in fact had been the driving force behind the discussion as he hoped to discredit genetics politically and thus put an official ban on it. Mitin knew that the outcome of the discussion was predetermined and exhibited his clumsy eagerness to join the winning side by linking genetics to the name of Bukharin that was so hateful to Stalin.

In addition to Mitin attacking classical genetics, most of the participants in the discussion were Lysenko's accomplices and the future of genetics in the Soviet Union was unfortunate. Formal genetics was entirely banned for fifteen years and those who worked on it were purged and persecuted in various ways. The 'materialistic' biology preached by Lysenko triumphed over the 'idealistic' genetics.

A reasonable question to ask at this point is whether a theory of natural sciences can be either materialistic or idealistic? One would suggest that the only relevant question in natural sciences is whether a theory is true or false. Take any physical law, for instance, the Boyle and Mariotte law — a physicist is able to verify whether it is true or false using physical instruments. But a physicist is unable to determine whether the Boyle and Mariotte law is materialistic or idealistic. There are no physical instruments that can resolve this issue and thus it is meaningless in the context of physics. The same is true for chemistry, biology, and generally any natural sciences.

Both relativity theory and quantum mechanics were repeatedly and brutally criticized in the Soviet Union, accused of being physical idealism. Those who attacked them included physicists who failed to understand the new physics and philosophers who did not know physics but knew by heart the dialectic materialism which they had learned from the Communist party primer rumored to be written by Stalin (or Stalin's ghost writer) and intended for indoctrination of the rank-and-file party members. This indoctrination was assumed to be quite sufficient for resolving any problems encountered in natural sciences. Their ignorant but vociferous attacks were frequently upheld by government leaders and that meant that major scientific fields could be banned altogether and the scientists who worked in them could lose their jobs and sometimes their freedom.

A well-known Russian expression is 'knowledge is power' which certainly seems to be true. The stories above suggest that under certain circumstances it is ignorance that is power and often it proves to be a greater power than knowledge.

The Communist regime developed an ideological framework for resolving problems of science using not scientific but administrative arguments. According to Marxist theory, the primary force driving social development was the struggle between different social classes. The foreign and domestic policies of the Soviet government were guided by the concept of conflict between classes. The concept of a class struggle was applied to any sphere of life, even where it was entirely irrelevant, such as research in natural sciences. The official view was that the class struggle was raging in the sphere of natural sciences and those who questioned the premise were in trouble. Some sciences, for instance, cybernetics, were rejected because of their 'bourgeois character' (The official Soviet Encyclopaedia described cybernetics as a bourgeois pseudo-science). As mentioned above, the philosopher Mitin referred to genetics as a 'Bukharinite deviation in biology'. Academician Lysenko invented the terms 'kulaks in biology'†. He used the term in his address to the National Congress of Collective Farmers in the presence of Stalin who sat at the presidium of the congress. When Lysenko was claiming that kulaks were undermining not only Soviet agriculture but also biology Stalin interrupted his speech exclaiming "Bravo, Comrade Lysenko!". In Lysenko's terms the kulaks in biology were the geneticists including the great biologist and geneticist Nikolai Vavilov. Nikolai Vavilov was probably the primary target of Lysenko's vilification; he was the phantasmagoric 'kulak in biology'.

While Stalin was loudly proclaiming his approval of Lysenko's words, he quite probably had in mind Nikolai Vavilov, whom he disliked.

The philosophical accusations against biologists were similar to those put forward against physicists in that despite the philosophical phraseology they were essentially political in their implications. In the mid-thirties the outstanding physicist Tamm (Sakharov's future mentor and Nobel Prize winner) published a paper entitled *The Objectives of Marxist Philosophers in the Field of Physics*. In the paper he deplored the fact that many philosophers, specifically those who did research in the philosophy of natural sciences, were entirely ignorant of physics. Relativity theory and quantum mechanics were fields of physics where their knowledge was especially poor. The paper quoted some singularly ignorant statements (the names were given, of course) and called on philosophers to study the new physics. In response one of the quoted philosophers published a long article provocatively entitled *How Tamm Attacks Marxists*. The article made a weird accusation against Tamm referring to him as a 'Menshevik idealist'. The implied charge was that this kind of idealism was doubly sinister as it was politically tainted by a Menshevik deviation. (The Mensheviks were a social-democratic party crushed by Stalin's communists.) One might ask what the relation is between physics and Mensheviks, but the accuser knew what he was doing. Mensheviks as a party had been destroyed but there still remained at least one Menshevik surviving in physics. That was an oversight by the authorities.

When Lysenko introduced the concept of 'kulaks in science' and accused his opponents as such he implied that he belonged to the opposing class who were known as 'the toiling peasants' in Communist terminology. To say 'toiling peasants in science' would have looked so incongruous that the term was not employed. However, the designation 'kulak in biological science' grew to become a common and ruinous accusation. If one was denounced as a 'kulak in science' it was time to get ready for a visit from the secret police. People in science who attacked their opponents in academic discussions with such political accusations, in lieu of any of reasonable scientific arguments, often attracted the benign attention and support of the almighty regime. The regime could promote one's career, though could not guarantee the quality of one's research. What kind of research can be conducted by a person who introduces the concept of 'kulak in biological science' and employs it as an academic argument?

Academician D N Pryanishnikov refused to recognize Lysenko as a scientist and continued to refute him even when others were too terrified. At one of his lectures he received a note from the audience saying "Lysenko's students do not agree with your views". Pryanishnikov read aloud the note and said, "Something is wrong here. Lysenko cannot have any students. What can he teach them? He can have only supporters". Pryanishnikov was fearless. He was not afraid to nominate Nikolai Vavilov for the Stalin Prize (the highest academic award in that period in the USSR) even after Vavilov had been arrested and put into prison. Pryanishnikov was never openly persecuted for his upright position because he was too famous. He was an exception, of course. Hundreds of researchers were dismissed from their jobs after the nation-wide purge of classical genetics conducted in August 1948 at a session of the All-Union Academy of Agricultural Sciences (VASKHNIL). Genetics was removed from the curricula of all secondary and higher educational institutions. As a result the development of the Soviet biology suffered a tremendous setback. Meanwhile, Communist and government leaders hailed the purge as a major breakthrough in biology.

What could have been expected from a similar discussion devoted to the new physics if it had been held? A purge in physics comparable to that of biology, especially as it had been planned as a nation-wide event.

There was another reason for the persecution of academics by the Communist regime. The supreme Soviet leaders Lenin and Stalin and their henchmen despised and did not trust the intelligentsia, that is, intellectuals distinguished by integrity. They classified people as 'friend' or 'foe' and intellectuals were immediately identified as 'foe'. This was not surprising because the members of the intelligentsia are typically independent in their thinking and, moreover, Lenin believed that they were incapable of decisive action. The Communist regime persecuted intellectuals, or members of the intelligentsia, in various ways, by imprisoning them, exiling them from Russia, or stripping them of all civil rights to the extent that their children were not admitted to universities. The very word 'intellectual' was used as a derogatory term, often with the addition of the adjective 'rotten'. One of the writers of the present paper (B B) remembers hearing one Communist functionary speaking of another, "It was my mistake to nominate him as Party

† Kulaks were the comparatively prosperous and thus more independent-minded peasants who resisted the collectivization of agriculture conducted by the Soviet government in the early thirties. Many of them were executed or imprisoned and entire families — from 10 to 15 million people altogether — were stripped of all property and exiled to Siberia or the Far North where many perished from starvation and unendurable living conditions. In this respect, the fate of a scientist accused of being a 'kulak in science' was quite similar to that of a real kulak from the countryside. That was the tragic destiny of Nikolai Vavilov and his closest collaborators (as well as of many other researchers in other sciences).

secretary. He has only been at the post for four months and already there is a rumor that he is an intellectual''.

The novelist V Kochetov, who was a member of the Central Committee of the Communist Party, tended to portray intellectuals in his books as depraved people, disgusting in all ways. An eminent literary critic Z Papernyi imitated Kochetov's style in a parody of one of his novels in which a character — a typical intellectual — was immediately recognizable by the stench of rot emanating from him. That was Kochetov's attitude to intellectuals in a nutshell. Despite the fact that Papernyi was a prominent figure in the literary world and a respected war veteran, he received a severe official punishment for his burlesque of a work by a member of the Communist Party Central Committee and for his attempt to uphold the honor of the intelligentsia.

Old hands at FIAN remember Dr G M Kovalenko who was on the staff of the laboratory of semiconductor research. During the Second World War he was the secretary of the Communist Party cell at FIAN and later he was appointed head of the department of post-graduate studies. He had been a post-graduate student at FIAN at the same time as Cherenkov, though Cherenkov's supervisor was Vavilov and Kovalenko's was G A Gamov. Kovalenko told a writer of this paper (B B) how he and a few other prospective post-graduate students had been invited for indoctrination to the district Party committee before they were admitted to the course. The Party secretary told them, ''The ambience in science is currently foul. We must open the window to bring in fresh air''. These words should be understood in the context of our discussion, meaning that intellectuals were highly suspect, and they should be carefully watched.

This discussion may seem unrelated to the life and work of Vavilov. In our opinion, it is highly relevant because it may help us to understand the true significance of many events in Vavilov's life. He lived through that period, he experienced those anxieties as a scientist and as an intellectual but in addition he was responsible not just for his personal affairs but for the future of large teams of researchers and later for the entire USSR Academy of Sciences. It was a troublesome and often perilous responsibility. The Communist diehards regarded him as an unreliable individual — his father was a rich merchant (not from the favored classes of manual workers or peasants) who escaped abroad after the Communist takeover, his brother was an 'enemy of the people', a 'kulak in science' who had died in Saratov prison in 1943. Vavilov never denounced his father nor brother and after the latter's arrest supported his two children. Nikolai Vavilov's widow wrote from Saratov to Vavilov in 1943, ''We would not have survived without your help'' ([1], p. 156). Despite these worries, Vavilov managed to conduct fruitful and extensive research; in particular, he developed the basic principles of luminescence, performed the first experiments in nonlinear optics with Levshin, and made the discovery with Cherenkov, Tamm, and Frank that later rated a Nobel Prize. He kept on promoting new concepts of physics, relativity theory in particular, and contributed to a deeper understanding of the physical meaning of quantum mechanics even though these sciences were repeatedly accused of being idealistic.

In 1928 Vavilov published a book entitled *Experimental Substantiation of Relativity Theory*. The first page of the book carries Michelson's portrait. Being a researcher in optics Vavilov had reason for an especial appreciation of the elegance and precision of Michelson's interference experiment to which he refers in his book as ''laying the foundation for the principal postulates of the special theory of relativity''. Vavilov wrote in the preface, ''The main purpose of the book is to verify the soundness of the experimental basis of the theory and hence the soundness of the theory itself. There are no reasons to question the mathematical framework of the theory as it is continually being analyzed and developed. The philosophical debates about relativity, space and time are irrelevant to the accuracy of the theory''. In conclusion Vavilov thanks Tamm for useful discussions of the subject of the book.

Each chapter of the book starts with a highly apt quotation from Newton's Philosophiae Naturalis Principia Mathematica very carefully selected by Vavilov. In the preface he mentions the reasons behind this selection saying, ''The quotations from Newton remind us that many postulates and results of the theory of relativity were not unexpected nor unacceptable even to the creator of classical physics''. The selected quotations from Newton are highly impressive and sound as prophesies. For instance, the quotation put as an epigraph to the section entitled ''First-Order Relativity'' says, ''The identification of true motions of individual bodies and the exact differentiation of them from apparent motions is very difficult because our senses do not perceive the regions of stationary space in which true motions occur''. The following quotation was used as the epigraph before the section entitled ''The Michelson Experiment, Its Duplication and Analogues''. ''It may be that in reality there is no stationary body with respect to which the positions and motions of other bodies can be referred.'' Another epigraph says, ''May it be that bodies act upon light at a distance and bend its rays by their effect; the other conditions being equal, may it be that this action is the strongest at the smallest distance?''.

It was one of the first Russian books on relativity theory. Though it was comparatively short (165 pages) it was a skilful presentation of all the available information from the history of science and the latest advances in physics.

Vavilov did not consider himself to be as knowledgeable in quantum mechanics as he was in optics. This is why he would never have dared to write on the basic physical concepts of quantum mechanics. But he was profoundly interested in the field and willingly took part in discussions with experts on the fundamental problems of quantum physics. His background in optics helped him to grasp easily the wave aspects of the theory, such as the penetration of particles through a potential barrier, the indeterminacy principle and so on. He wished to see a sufficiently advanced presentation of these concepts that would be easy enough to understand. This is why he asked Markov to write the paper we mentioned earlier. Markov, who had been a post-graduate student under Vavilov wrote in his reminiscences of him ([1], p. 261; see also [28]), ''Some time in late 1946 Vavilov asked me to write a paper on what he called ''your views on the philosophical problems of quantum mechanics''. He added, ''It is not just my personal desire''. I kept on refusing but Vavilov kept on asking... and I realized that I could not go on resisting and started working on the paper.''

The clearly written and highly informative paper by Markov was published in *Problems of Philosophy* [27]. Now, many years later, it is abundantly clear how right Vavilov was in commissioning the paper. Vavilov wrote a preface to the paper indicating his sense of responsibility for it. The preface emphasized the significance of the paper's subject, praised the author's competence in the field, and expressed a hope that the paper would initiate a discussion of the fundamental

issues raised in it that would be conducted on a properly qualified level and would not just consist in issuing accusations. The hope proved to be futile...

Markov told one of the writers of the present paper (B B) that before submitting his contribution to the *Problems of Philosophy* he had given it to A A Maksimov for an informal review who was regarded as the leading Communist expert on the philosophy of natural sciences.

Maksimov could not comprehend the new physics (though neither could he the ''old'' classical physics) and he tried to disguise his ignorance with Communist jargon. Like Vavilov, Markov was wary of being the subject of political accusations — Maksimov was a past master of that — and he hoped to forestall such a development.

Maksimov said he liked the paper, in fact he absolutely approved it and endorsed it for publication. Markov remarked tentatively, ''They will attack it.'' Maksimov retorted, ''Let them, we have fangs of our own!''.

It was, indeed, Maksimov who was the first to bare his fangs with a mighty roar after the paper had been published. He sank his fangs into Markov's back by publishing an article filled with outrageous charges. It started a veritable hurricane of frenzied ignorant allegations. The editor-in-chief of *Problems of Philosophy* was dismissed and its editorial board was dissolved. Markov was accused of idealism in physics and his future seemed frightening. Apparently, Vavilov had to apply considerable pressure to secure official permission to retain Markov on the staff of FIAN.

Now, fifty years later, Markov's paper entitled *On the Nature of Physical Knowledge* is still relevant and fascinating to read indicating how deeply perceptive Vavilov was when he insisted that Markov should write it.

Veksler [1] describes the circumstances that arose after the publication of Markov's paper, ''Vavilov deeply appreciated Markov's original and profound mind and kept on insisting on the paper's publication. The publication gave rise to furious attacks. Things were so bad that the Government Certification Board refused to issue a certificate confirming Markov's rank as a full professor though he was a prominent researcher. Vavilov was very distressed by the affair and apprehensive for Markov's future as he realized his unintentional responsibility. The attacks on Markov were ultimately stopped only through highly determined actions taken by Vavilov''.

Frank, who edited the book *Sergeĭ Ivanovich Vavilov* [1] added the following personal remark, ''Markov's apprehension that his paper would become a target of disgraceful attacks by the reactionary philosophers was fully justified. Veksler dictated his reminiscences to his wife in 1966 in the short period when he felt better after his heart attack. Here I would like to add remarks that neither Veksler in 1966 nor I in 1981 could make (the previous edition of the book [1] was published in 1981 — authors' note). At approximately the same time when the sordid affair of Markov's paper was progressing, some other events were taking place that could end in tragedy for the science of physics. A group of physicists and philosophers were preparing a conference along the lines of the infamous VASKHNIL conference when genetics was destroyed. The target of the conference was to ostracize all physicists who recognized quantum mechanics and relativity theory as being idealists and cosmopolitans. They obviously were supported by somebody holding a high governmental position... I believe that Vavilov was very apprehensive and feared that the events could spring out of his control and do immeasurable harm to science and researchers. But they were, apparently, successful in convincing the authorities that nuclear weapons could not be developed without recognizing relativity theory and quantum mechanics. Stalin ordered the preparations for the conference to be discontinued and a tragedy was avoided. Now it can be said openly.'' Academician Kurchatov was probably the person who informed the authorities that a 'discussion' of the new physics was extremely inappropriate. Meanwhile, Vavilov was doing everything in his power to protract the preparations for the conference, to avoid it altogether if possible, and if not, then to conduct it in such a way that it would produce the least harm to physics.

Vavilov in the Polytechnic Museum. (1947 or 1948).

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The contribution made by Vavilov to the discovery and interpretation of the Vavilov – Cherenkov effect is a fact that has been generally recognized in Russia. It was Vavilov who designed the research project on the luminescence of the uranyl salt solutions under the effect of hard gamma radiation and suggested it to Cherenkov as a subject for a PhD dissertation. In his studies Cherenkov discovered that not only solutions but also pure solvents emitted radiation under the effect of gamma rays. This phenomenon proved to be a great nuisance to Cherenkov because the radiation emitted by the dissolved material was difficult to observe against the background of the radiation emitted by the solvent. Initially Cherenkov thought that his assignment was impossible to complete [47, 48]. Then Vavilov suggested to Cherenkov that a more detailed study of the luminescence of the pure solvents had to be made. Cherenkov conducted the standard measurement procedures developed in Vavilov's laboratory for determining the luminescence parameters. Vavilov evaluated the measurement results, arrived at the conclusion that the effect observed by Cherenkov was not luminescence, and suggested the first explanation for it — that the radiation was produced by the electrons displaced from the atoms of the liquid by the gamma rays. Vavilov suggested that the detached electrons were slowed down by the liquid and the resulting radiation known as bremsstrahlung was the effect observed by Cherenkov. Later analysis demonstrated that the observed radiation could not be attributed to the bremsstrahlung phenomenon and Vavilov had been mistaken in this respect. But his initial assumption that it was the electrons detached from atoms by the gamma

rays was correct and determined the further course of research. Vavilov closely followed the progress of the research, he often participated in taking the measurements in person and invited Tamm and Frank, who later brought forward a full theoretical interpretation for the effect, to take part in the analysis of the experimental results.

At first sight the interpretation suggested by Frank and Tamm contradicted both classical electrodynamics and relativity theory. It amounted to a statement that the radiation was emitted by electrons uniformly traveling in a refracting medium with a velocity exceeding the velocity of light in that medium. It had always been a generally recognized fact that a uniformly traveling charge did not emit radiation. It was also commonly accepted that the theory of relativity did not allow for material bodies traveling at a velocity exceeding the velocity of light. The interpretation put forward by Frank and Tamm seemed to contradict both statements. After some time it became generally understood that there was no contradiction either to electrodynamics or to relativity theory. The discovery was generally recognized as such, though initially many physicists, including such outstanding ones as Joliot–Curie and Kapitza, voiced doubts about Cherenkov's experimental results (they proved to be faultless though they were conducted under extremely difficult conditions at the vision threshold), scepticism about Vavilov's claim that it was a highly significant discovery, and reservations about the interpretation given by Frank and Tamm.

Incidentally, Vavilov was one of the first to recognize and approve the theory by Frank and Tamm. Almost immediately he suggested a highly visual way to demonstrate the Vavilov-Cherenkov effect by means of a hydrodynamic model. He filled a flat glass container with water and put an electric lamp underneath it so that the image of the water-filled container was projected on the ceiling. Then he took a sharp pencil and drew its tip rapidly along the water surface. The image projected on the ceiling clearly displayed two waves traveling at an acute angle from the 'path' of the pencil tip.

Nowadays the Vavilov–Cherenkov effect is extensively employed in high-energy physics. Any laboratory conducting research in nuclear physics, high-energy physics or the physics of cosmic rays is equipped with Cherenkov counters intended for detecting fast particles. The discovery of the Vavilov–Cherenkov effect gave rise to a new approach in modern physics which went far outside the scope of this effect in that it involves the common properties of phenomena occurring in conditions of synchronicity between a wave and its generating source (or a wave and a system whose motion is synchronous with the wave and which can interact with it). It can definitely be stated that this discovery would have been impossible without Vavilov just as without Cherenkov, Frank, or Tamm.

Still, though Vavilov's contribution to the discovery of the effect was evident to everybody who had any knowledge of it, the effect was named the Cherenkov effect and it was, apparently Vavilov himself who was the first to use this term. It was only thirty years after the discovery and six years after Vavilov's death that Vavilov's disciples and co-workers in the Soviet Union decided to revive Vavilov's priority and to replace the internationally accepted term 'the Cherenkov effect' with the more fair term 'the Vavilov–Cherenkov effect'. Unfortunately, the new term was used only in the Soviet scientific literature, and not always even there, while the researchers in the West continued calling the phenomenon 'the Cherenkov effect'.

One of the writers of the present paper (B B) heard from M N Alentsev, a close collaborator of Vavilov, that those who knew how the discovery had been made had repeatedly suggested different names more suitable, but each time Vavilov had resolutely rejected the use of his name in association with the effect. Why did he do that? Could it be that he did not believe that the effect had any significance? No theoretical interpretation had yet been put forward for the effect. Many prominent scientists questioned the very existence of the effect as they did not trust the experimental results obtained by Vavilov and Cherenkov. The PhD dissertation by Cherenkov included only the results on the luminescence of the uranyl salts under the effect of hard gamma rays. Vavilov, as the supervisor of Cherenkov's post-graduate project, wrote in his official supervisor's report that Cherenkov had successfully completed his PhD assignment on the luminescence of uranyl salts and at the same time had discovered a new effect whose nature was still unclear but would, undoubtedly, make a significant contribution to nuclear physics. This phrase clearly demonstrates that Vavilov was fully aware of the significance of the discovery. Why then did he reject the suggestions that his name should be assigned to the effect? Apparently, he did not thing that his contribution to the research project was significant enough. Such self-underestimation, so to say, was largely caused by his singular modesty.

A Russian proverb says that a man's modesty is his decoration. This saying may be rephrased depending on the specific circumstances of one case. We may state that under certain conditions one man's modesty is another man's decoration.

Another reason for Vavilov's underestimation of his contribution lies in the extremely wide scope of his knowledge — not only in optics and physics in general but also in the history of science and philosophy. His own achievements seemed to him to be minor in significance in comparison with what he knew about the overall human effort in natural sciences. On the other hand, he was very attentive to the research results presented by other scientists. He was very sensitive to the issues of priority in science and he was very careful about referring to the results of other researchers in his publications. As the Russian saying goes, he loved not himself in science but science in himself.

In connection with the issue of priority in science we shall cite here a relevant quotation from a letter Vavilov wrote to V L Levshin approximately two weeks before his departure from Berlin ([2], p. 376) showing his attitude to the subject. Vavilov was writing about a talk he had had with Pringsheim, "I had a funny conversation with him yesterday. He came with an embarrassed look saying that he would like to have a business talk. What he was saying amounted to the following — "You have done something without me but let us publish the results together". Of course, I readily agreed, firstly, because it is really a petty affair, not worth discussing much, and, secondly, because the diplomatic considerations of such a joint publication could be only useful for us. This project is closely related to our previous one using phosphors and our technique (spectrophotometer). It's amusing, though, that it was he who made the suggestion..."

It would be unthinkable for Vavilov to make a similar suggestion to any of the co-workers in his laboratory.

Vavilov's name was as well-known internationally as Pringsheim's and it would, perhaps, be more understandable if Vavilov had refused to include Pringsheim's name as one of

the authors of the paper presenting the results obtained by Vavilov and Levshin. But what Vavilov cared about was, above all, his research results while the priority issues were not essential for him. Thus, Pringsheim's suggestion meant to him primarily that it was an opening for fruitful cooperation in research with an eminent expert in optics.

We do not know how the Vavilov–Cherenkov effect will be named in future. Possibly, it will still be referred to as the Cherenkov effect in the West. It is ultimately not the term that is really important. One should just remember that Vavilov made a decisive contribution to the discovery of this effect. In our opinion the appellation 'the Vavilov–Cherenkov effect' in no way diminishes Cherenkov's role but is more fair in reflecting Vavilov's contribution to the discovery, analysis and interpretation of the effect.

* * *

Contemporary physics is a far-reaching and very extensive science. It is not easy for researchers working in a certain field of physics to assess the research conducted in another field. A researcher always feels a special affinity to 'his own' field (as a Russian proverb says "one's own shirt is the closest to one's body") and this is why he may fail to appreciate or unjustly ignore results obtained in an 'alien' field. The same is true about appreciating the human qualities of a person — those who do (or did) not know him closely may easily be mistaken if they have only meager and fortuitous information.

The present paper puts forth some facts that were not previously known or known to only a few and that could not be reviewed in public because of the censorship restrictions. We hope that the documents cited here and the discussion of them will help readers understand why Vavilov's disciples and collaborators (in fact, everybody who met him) treated him with love, respect and gratitude as a wise teacher, provident administrator, prudent mentor and a man of irreproachable integrity. The writers are grateful to V L Ginzburg and E L Feinberg who read the manuscript of the paper and made useful suggestions.

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References

1. *Sergeĭ Ivanovich Vavilov. Ocherki i Vospominaniya* (Essays and Reminiscences), 3rd ed. (Moscow: Nauka, 1991)
2. Levshin L V *Seregeĭ Ivanovich Vavilov* (Moscow: Nauka, 1977)
3. Levshin L V *Svet Moe Prizvanie* (My Lifelong Road to Light) (Moscow: Moskovskiĭ Rabochiĭ, 1987) [Translated into English (Moscow: Mir, 1989)]
4. Solzhenitsyn A *Arkhipelag GULAG* Vol. 2 (The Gulag Archipelago, 1918–1956) (Moscow: Tsentr Novyĭ Mir, 1990) p. 426 [Translated into English (New York: Westview Press, 1991–1992)]
5. Kojevnikov A *Isis* **87** 8 (1996)
6. Bolotovsky B M, Vavilov Yu N, Kirkin A N *Kratk. Soobshch. Fiz.* (3–4) 85 (1995) [*Bull. Lebedev Phys. Inst.* (3–4) 32 (1995)]
7. Bolotovsky B M, Vavilov Yu N *Physics Today* **48** (12) 11, 13 (1995)
8. Pike R, Brown R G W *Physics Today* **49** (9) 120, 122 (1996)
9. Wawilow S J, Lewschin W L *Z. Phys.* **35** 920–936 (1926)
10. Vavilov S I *Mikrostruktura Sveta* (Light Microstructure) (Moscow: Izd. AN SSSR, 1950) [Translated into German: *Die Mikrostruktur des Lichtes* (Berlin: Akademie, 1954)]
11. *Fiziki o Sebe* (Physicists about Themselves) (Leningrad: Nauka, 1990)
12. *Akademik L I Mandel'shtam. K Stoletiyu so Dnya Rozhdeniya* (Commemorating 100-Year Jubilee of Academician L I Mandelshtam) (Moscow: Nauka, 1979) p. 219
13. *Vospominaniya o L D Landau* (Remembering Landau) (Moscow: Nauka, 1991) p. 84
14. Kapitsa P L *Pis'ma o Nauke* (Letters about Science) (Moscow: Moskovskiĭ Rabochiĭ, 1989)
15. Brown R G W, Pike E "A History of Optical and Optoelectronic Physics in the Twentieth Century", in *Twentieth Century Physics* (Eds L M Brown, A Pais, S B Pippard) (Philadelphia: IOP Publishing, 1995) p. 1403
16. Gekker I R, Starodub S A, Fridman S A, Preprint No. 224 (Moscow: FIAN, 1985); Preprint No. 78 (Moscow: FIAN, 1989)
17. *50 Let Gosudarstvennogo Opticheskogo Instituta im. S I Vavilova* (50-Year Anniversary of the Vavilov State Optical Institute) (Leningrad: Mashinostroenie, 1968)
18. Gorelik G E 'Moscow, Physics, 1937', in *Tragicheskie Sud'by* (Tragic Destinies) (Moscow: Nauka, 1995) pp. 54–75
19. Sonin A S *Fizicheskiĭ Idealizm* (Physical Idealism) (Moscow: Fiz. mat. lit., 1994)
20. *Vospominaniya o I E Tamme* 3rd ed. (Reminiscences of I E Tamm) (Moscow: Izd AT, 1995) p. 347
21. Feinberg E L *Nauka i Zhizn'* (8) 34–40 (1990)
22. *Vospominaniya o V I Vekslere* (Reminiscences of V I Veksler) (Moscow: Nauka, 1987) p. 281
23. Sakharov A D *Vospominaniya* Vol. 1 (Memoirs) (Moscow: Prava Cheloveka, 1996) p. 115
24. Esakov V *Nauka i Zhizn'* (11) 110–118 (1991)
25. Volkogonov D A *Triumf i Tragediya. I V Stalin. Politicheskiĭ Portret* (Stalin: Triumph and Tragedy) (Moscow: Izd. APN, 1989) [Translated into English (New York: Grove Weidenfeld, 1991)]
26. Sennikov V F RAN Archive, fond 596, opis' 2, delo 133B, list 1
27. Markov M A *Voprosy Filosofii* (2) (1947)
28. Markov M A *Razmyshlyaya o Fizikah... o Fizike... o Mire* (Thinking of Physicists... Physics... the World) (Moscow: Nauka, 1993)
29. MGU Archive, fond 596, opis' 2, ed. khran. 173, list 7–9
30. RTsKhIDNI Archive, fond 4, opis' 4, ed. khran. 775, list 146
31. GARF Archive, fond 9396, opis' 1, ed. khran. 229, list 67–68
32. *Sozdanie Pervoĭ Sovetskoĭ Atomnoĭ Bomby* (Development of the First Soviet Atom Bomb) (Eds V N Mikhaĭlov et al.) (Moscow: Energoatomizdat, 1995) p. 52
33. *Petr Leonidovich Kapitsa. Vospominaniya. Pis'ma. Dokumenty* (Petr Leonidovich Kapitsa. Reminiscences. Letters. Documents) (Moscow: Nauka, 1994) p. 88
34. *Vospominaniya ob Akademike M A Leontoviche* (Reminiscences of Academician M A Leontovich) (Moscow: Nauka, 1996)
35. Yakovlev I A *Vest. Akad. Nauk USSR* (3) 132 (1991)
36. *Grigoriĭ Samuilovich Landsberg: Ocherki i Vospominaniya* (Essays and Reminiscences) (Moscow: Nauka, 1993) p. 136
37. Strelkov S P et al. *Sbornik Zadach po Obshchemu Kursu Fiziki. Mekhanika* 4th ed. (Moscow: Nauka, 1977) [Translated into English: Strelkov S P, Yakovlev I A *Problems in Undergraduate Physics*. Vol. 1. *Mechanics* (Oxford, New York: Pergamon Press, 1965)]
38. Shchuka A A *Fiztekh i Fiztekhi* (Fiziko-Technical Institute and Its People) (Dolgoprudnyĭ: Vestnik VVTs, 1996) p. 317
39. *Brat'ya Nikolaĭ i Sergeĭ Vavilovy* 2nd ed. (Brothers Nikolaĭ and Sergeĭ Vavilov) (Moscow: FIAN, 1994) p. 39, 40
40. Vavilov S I *Isaac N'yuton* (Isaac Newton) (Moscow, Leningrad: AN SSSR, 1943) [Translated into English (Berlin: Akademie-Verlag, 1951)]
41. Ivanov V Vs *Nashe Nasledie* (1) 3–7 (1989)
42. Goncharov V *Istochnik* (1) 88–89 (1996)
43. AAN SSSR Archive, fond 596, opis' 3, delo 17, list 2–3
44. RTsKhIDNI Archive, fond 17, opis' 125, delo 547, list 151–152
45. Frish S E *Priroda* (12) 88 (1990)
46. Bolotovsky B M *Priroda* (12) 97 (1990); (3) 117 (1991)
47. Gorbunov N, Tamm E I Introduction to *Pavel Alekseevich Cherenkov. Bibliograficheskiĭ Sbornik* (P A Cherenkov. Bibliography) (Moscow: Nauka, 1997)
48. Dobrotin N A, Feinberg E L, Fok M V *Priroda* (11) 58 (1991)