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The forefather (about Leonid Isaakovich Mandelstam)

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Abstract. **An essay and some private reminiscences on the life, work, public activities, and the personality of the prominent scientist who established the Moscow school of theoretical physics in the second quarter of the 20th century.**

A door opened under the dust-coated bust of Newton in the vast wall of the Great Physics Hall in the old building of Moscow State University opposite the Kremlin. A group of men merged, centered on a fairly tall, slightly stooped, black-haired man in a black business suit who seemed to be getting on in age. The drooping folds of the unbuttoned jacket revealed a waistcoat underneath it. In the course of the lecture he will regularly consult a watch, taking it out of the waistcoat pocket. The pince-nez eyeglasses tightly gripped the bridge of his nose. His cheeks and jowls seemed soft, the cheeks being lined with deep wrinkles or, rather, furrows. He carried a small flat portfolio. He seemed to make hasty progress then stopped suddenly behind the nearest edge of the extensive ten-meter-long desk separating the speaker from the public. Two large blackboards on the wall behind him were draped with black cotton fabric (which could be rolled away by stooping down to turn the bright metal wheel just under the desk, though it is typically stuck) with a huge, white, collapsable screen between them. The men who had come in with him hurried to take their seats reserved for them in the front row (the group included, among others, Igor' Tamm, Grigoriĭ Landsberg, Mikhail Leontovich, the philosopher and science historian Boris Gessen who was the dean of the Physics faculty of the Moscow University in the early thirties and perished in the political purges of the late thirties as many others did). The front row consisted of chairs specially placed in front of the steeply ascending benches of the amphitheater, which was packed to its full capacity of four to five hundred people. As always happens with esteemed speakers, the initial noisy clamor in the audience rapidly gave way to a lull. Mandelstam started his lecture immediately.

He starts speaking quite confidently but somewhat stiffly. His tone and his very posture will occasionally exhibit slight overtones of shyness, even later during the lecture. However, as he goes on he gradually grows more intense, finally coming to the state when what he is thinking, saying, and trying to convey is his sole concern in the whole world. His slightly nasal voice is rather low but what he says is heard distinctly by the audience, even in the back rows, as his phrases are precisely structured and eminently logical, especially since the auditorium has the best acoustical parameters (alas, it has been rebuilt since then and does not exist anymore). Mandelstam never falters in his speech, he never corrects himself, he is saying only what he has carefully thought over and is entirely confident about. Still he will never leave the sanctuary between the edge of the desk and the blackboard until the end of the lecture. He put some notes for the lecture on the desk and sometimes he languidly leans to consult them or picks them up and brings them closer to his short-sighted eyes, having previously taken off the pince-nez, which he holds in his half-raised hand. We shall recognize the combinational of precision and firmness on the essential issues together with the suppleness of his general manner and behavior as a quality especially typical of Mandelstam. His appearance as a whole follows one of the patterns typical of both Russian and European intellectuals of the early 20th century period. His demeanor as a whole follows one of the patterns typical of these intellectuals, which is inflexibly rigid on significant issues and reasonably tolerant on nonessential ones. His outstanding intellectual insight and exceptional moral integrity make it much easier for him than for other people to identify precisely what is of genuine significance for him and what is not. Niels Bohr made a very similar impression when he made an appearance in the same auditorium in the same period. Even though Bohr, with his bushy eyebrows and large head, looked somewhat clumsy and quite different from Mandelstam, they were obviously two of a kind.

Mandelstam was delivering a lecture in one of the famous elective courses he gave in the thirties. He devoted many years to his courses on the theory of relativity, physical optics, theories of oscillations, and quantum mechanics. The appellation 'elective' might suggest that the subject is not really essential or even superfluous. When one listened carefully to what Mandelstam was saying, however, it became immediately clear that the lectures were, indeed, essential for a physicist interested in the 'nature of things'.

Mandelstam used a low-key manner of presentation in his lectures. He was brought up in the era when very few people were concerned with science in general and physics in particular. It was a fairly novel experience for him to present fine logical and historical arguments substantiating the theory of relativity or quantum mechanics to an audience of half a thousand people who strove to follow his train of thought. Moreover, the subjects of his lectures touched on issues that gave rise to noisy controversies among Russian scientists in that period. The antiquated concepts weighed heavily on the science community, even though a new generation of younger scientists was as little concerned with the 'paradoxes' of the new sciences as scientists after Copernicus had been with the concepts of a spherical Earth

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or the heliocentric arrangement of the world. The debates on academic subjects raging in Russia in that period were made much more bitter by the fact that the few physicists who were opponents of the theory of relativity and quantum mechanics were extremely outspoken and received strong support from the Marxist philosophers who held high official positions (and rigidly followed the Communist party line). Mandelstam never entered into debates, he simply explained quietly the concepts he was presenting. He was never afraid of raising a doubt, but then he enjoyed dispelling it with exact and sound argumentation. His soft voice, gentle smile, and unostentatious manner of presentation could never lessen the impression made on the audience by the extensive scope and strictest logic of his thinking.

His words flowed smoothly, delivered in a seemingly mild voice but they never seemed monotonous in tone. He made long pauses. He emphasized some words with his intonation. After putting forward an argument against the theory he was presenting, he typically announced almost triumphantly, "But this is *not* so!". Though quietly spoken, this 'not' softly jumped out as if on the end of a spring.

Mandelstam had his favorite catch phrases, mostly retained from his years of study and work in Strasbourg. When he started explaining an important and subtle concept giving a clue to resolving a major paradox, he usually proclaimed in German, "Hier springt der Frosch ins Wasser" [now the frog leaps into water]. He liked to say 'put a finger on something.' Apparently, the saying stemmed from the biblical story of the Apostle (Doubting) Thomas but Mandelstam rephrased it to make it sound more colloquial. Still, his manner of speaking sounded somewhat old-fashioned to the young generation of the thirties but it was so natural for him that it never appeared strange. As he was a witness to and participant in the development of the greatest breakthroughs in science, he often failed to appreciate which aspects already seemed ordinary and did not require special explanations for the young scientists and which were indeed still difficult to understand. For instance, he explained in detail the concept of group velocity of a wave packet using the following complicated metaphor as an illustration: a ship is moving in the water while 'boys and girls' spring out from the water, land on the stern, run along the ship, and jump back into water from the bow. One must take pity on the unfortunate listener who had relaxed while listening to the simplified metaphor and missed the point of the subsequent subtle analysis of 'Fleming's error' (identified by Mandelstam himself at an early period in his career) or failed to appreciate the discussion of the limitations imposed by the causality requirements on the definition of simultaneity in the theory of relativity. Such a listener would have missed some essential points of the lecture. The university professors occupying seats in the front row, A A Andronov, S E Khaĭkin, S M Rytov, G S Gorelik, and others, are fully aware of such a danger, which is why they are diligently taking notes on the lecture and their records will prove to be of great use later.

Other rows in the auditorium are packed not only with undergraduates and graduate students of Moscow State University but also with students, researchers, and teachers from other institutions of higher education. They comprise a select community of thinkers, people who are passionately seeking knowledge, whose only satisfaction can be found in this search, who are united by it and by the enjoyment of the spiritual fellowship of scholars. The world outside the walls of the auditorium lives in the dreadful era of Communist oppression: it is a world of lies, hypocrisy, inhumanity and terrible suffering caused by Stalin's purges. The world inside the auditorium is the clean honest world of pure thought and good will. It is a sanctuary for human spirit. A temple.

* * *

It was only ten years later that I learned how Mandelstam had prepared these lectures. When a five-volume collection of his writings was prepared for publication, I was honored by being appointed editor of the text of the lectures on the theory of measurements in quantum mechanics. Mandelstam delivered five lectures on the subject in 1939 and we used the notes from all the lectures taken by various people, in particular, the very detailed records of S M Rytov (after the book had been published I discovered my own notes on these lectures). We also used a stenographic transcript of the fourth lecture. Mandelstam had never seen or checked these notes or the transcript. However, I was given his working notebooks dating back to 1938 – 1939. These were common, thick, collegiate notebooks in which he rather haphazardly made notes on many subjects he was working on in that period. The entries included strings of equations without any explanations, some formulas with brief and unclear comments, and, most importantly for my job, random passages from the first three lectures I was working on. Each phrase was fully completed as if they were prepared for submission for publication. Each passage was repeated in several revisions, which did not differ much from each other. Obviously, Mandelstam was writing with ease in completed smoothly flowing phrases. He made only a few deletions and there were very few words added between the lines. But the very fact that whole fragments were repeated several times, amended, and sometimes shifted around, showed that the author was not entirely confident in his writing, was always unsure about the state of readiness of the text, and was continually concerned with improving it. As these text fragments were fairly close to the lecture notes taken by audience members, we could safely assume that the notes on other lectures, for which Mandelstam's notebooks contained no records, were sufficiently faithful.

Writers and thinkers can be classified into two categories. Some people formulate and modify their thoughts and compile their written record in the process of writing, talking, or arguing. Other people formulate their ideas well beforehand and express them in speech or on paper later in a fairly completed form. Mandelstam apparently was closer to the second category.

The notebooks shed light on another aspect of Mandelstam's personality. Each full member of the Russian Academy of Sciences had to submit annually a report on their activities throughout the year (the tradition dates back to the foundation of the Academy in the 18th century). Most Academy members tended not to be very serious about writing the reports and generally regarded them as a waste of time. However, Mandelstam could not be casual even about such a minor matter. I have seen several revisions of the same annual report in his notebooks. My impression was that he regarded such a trivial task as a major challenge and aimed at making a perfect piece of work out of an inconsequential one-page report.

* * *

Let us look further than my immediate impression of Mandelstam. What was he doing in science, why was he immensely respected and almost worshipped by his disciples and many colleagues, why did they admire him and often exhibit a sentiment towards him which could not be described as anything but love?

Mandelstam was not merely a scientist. He was a thinker for whom physics was an instrument for understanding the 'nature of things' (in the sense introduced by Titus Lucretius Carus in his poem 'De rerum naturae'). It was also a vast field strewn with various problems arising in the study of specific physical processes, as well as the profound mysteries of nature, and he was absolutely overwhelmed with the desire to find their solutions and to understand their hidden meaning. He was searching for answers far and wide — in optics and electrodynamics, radiophysics, quantum mechanics, the theory of relativity, and molecular physics, looking ultimately for the general principles of knowledge.

Moreover, Mandelstam was that rare type of physicist who was simultaneously experimenter, theorist, innovative technologist, teacher, and philosopher. He was also a connoisseur of the arts. He knew the poetry of Pushkin almost as well as any literature expert (the well-known Pushkin scholar A B Derman was his close friend). Here are a few illustrations of Mandelstam's creativity.

As a theorist, Mandelstam employed the results from his studies in radiophysics and optics to develop an extensive general theory of linear and nonlinear oscillations that proved to be useful for innumerable applications in many areas of physics. Mandelstam suggested the concept of a comprehensive 'oscillatory mentality'. He created a general theory of optical image formation. When he analyzed the Schrödinger equation, the principal equation of the new science of quantum mechanics, Mandelstam, together with his disciple M A Leontovich, predicted an astounding phenomenon that was unthinkable and unimaginable in terms of classical mechanics. This was the tunneling effect (the term appeared only later), which proved to be of utmost significance in theory (in physics, chemistry, and biology) and in practice.

As an experimenter, Mandelstam, in collaboration with G S Landsberg, his younger colleague and also his disciple to a certain extent, discovered the significant effect of combinational scattering of light, which is now known as Raman scattering (after Raman, who discovered it independently and received the Nobel Prize for it, but failed to understand its physical mechanism). Mandelstam discovered a number of other optical effects, too.

As an innovating engineer, he received almost 60 patents, mostly in radiotechnology (half of them were developed in collaboration with N D Papaleksi, the friend of his youth who worked almost exclusively in radioengineering).

As a teacher, Mandelstam was not merely a brilliant lecturer; his disciples comprised an influential school of high-class physicists, primarily theorists (and that was, perhaps, his greatest contribution to the development of science in Russia). Let us look at subsequent generations in his school. If we classify his immediate disciples and younger coworkers as the first generation, it includes the outstanding physicists A A Andronov, I E Tamm, G S Landsberg, M A Leontovich, N D Papaleksi, S M Rytov, the brilliant scientist S E Khaĭkin, who put forward an essentially new radiotelescope design (the first telescope using his design was completed only after his death), V A Fabrikant, an expert in optics, and others. Two promising young members of the first generation, A A Vitt and S A Shubin (who was first Mandelstam's and later Tamm's disciple), had produced promising research results in their youth but perished in Stalin's purges of the late thirties.

The next generation, the 'disciples of Mandelstam's disciples', grew numerically in geometric progression. Prominent theorists S A Al'tshuller, V L Ginzburg, L V Keldysh, D A Kirzhnits, V I Ritus, A D Sakharov, E S Fradkin, S P Shubin, and others had developed their research potential under the guidance of I Tamm, who was my teacher, too.

A Andronov, a founder of the automatic control theory, not only established a large school that included his closest disciples and coworkers M A Aĭzerman, N N Bautin, A G Meyer and others, but together with M T Grekhova, he also founded an institute in the city of Gorky (now known under its original name Nizhny Novgorod) which later gave rise to a number of research institutions that are famous throughout the world. A V Gaponov-Grekhov, V S Troitskiĭ, and many other well-known physicists benefited from his lectures when they were undergraduates there.

The disciples of M A Leontovich include E P Velikhov, B B Kadomtsev, M L Levin, R Z Sagdeev, V D Shafranov and many other scientists who are not so famous but have produced highly significant research results.

The school of optical spectroscopy, established by G S Landsberg, includes S L Mandelstam, I L Fabelinskiĭ, I I Sobelman, M M Sushchinskiĭ, V I Malyshev, and many others engaged in pure research and an extremely wide range of very significant technological applications.

All these (and other schools) exhibited to a varying degree the indelible stamp of Mandelstam's influence, both in the research style and in the prevalent moral standards. What was especially attractive about him as a person was the combinational of his firm integrity and extreme gentleness, sensitivity, and responsiveness. These qualities were especially pronounced in his relationships with younger coworkers or disciples. Often when they approached him with an incomplete or even erroneous research result, Mandelstam would suggest modifications and improvements but in such a way that they were entirely convinced that the improvements were made by themselves.

In fact, the entire science of theoretical physics in Russia in the mid-20th century was created by two outstanding schools — those of L D Landau and Mandelstam and those of the brilliant world-class theorist V A Fok (I do not include here the younger influential school headed by N N Bogolyubov who had started his career in science as a mathematician and developed a school of physics after World War II in the second half of the century).

As a philosopher, Mandelstam not only was convinced that a contemporary physicist should necessarily be concerned with philosophical aspects of physical problems (as he wrote in an unpublished manuscript which we shall discuss later) but also formulated his ideas in the theory of cognition and philosophy in general (in the same manuscript).

* * *

Before continuing our treatment of Mandelstam's research work, we should discuss the actual events in his life. We can see how sharply his life was altered in the years of dizzying changes in Russia and how his personality changed as he passed through several fairly distinct periods before, in the last decade of his life, he became the individual shown at the beginning of this essay, the person remembered by the few still-living persons who had known him.

Leonid Mandelstam was born in 1879, that is, in the same year as Albert Einstein. It was also the year Joseph Stalin (and Lev Trotskiĭ) was born. More than twenty years later, Mandelstam was exhilaratingly inspired by the ideas generated by the greatest genius of science and, more than forty years later, all of Russia and he himself fell under the vicious sway of the bloody dictatorship established by his other contemporary.

Mandelstam grew up in Odessa on the Black Sea coast. It was one of the few Russian cities resembling a European city. The port city grew rich on exports of Ukrainian wheat, it was a city of affluent grain merchants, fishermen and dock workers, and it had an extensive underworld and flourishing cultural life. The best European singers performed at the superb opera house in Odessa and many musicians trained in the city later became famous throughout the world. Many authors born in Odessa feature prominently in the history of Russian literature, in particular, in the twenties and thirties of the 20th century, and numerous scientists were brought up there.

Mandelstam's father was a highly successful gynecologist and obstetrician. Pregnant women from all over Ukraine came to Odessa to be attended by him and visitors were known to ask street car conductors for a ticket to 'Dr Mandelstam'. The childhood and youth years of Mandelstam were serene and comfortable.

After graduating from secondary school, Mandelstam entered Novorossiisky University at Odessa. Soon he was expelled from the university for taking part in the students' anti-government political actions. [1] He went abroad to complete his education as did many young Russians seriously interested in science. Like many other Russian students, he went to Germany, the world center for science at the time. Mandelstam was already determined to work in physics and he selected a fine German university in Strasbourg where the physics professor was Karl Braun, who had been one of the founders of radio engineering and had received the Nobel Prize together with Marconi in 1909. (Later modifications of the 'Braun's tube' became major components of modern oscilloscopes, television sets, and computer monitors.) Many Russian physicists, including P N Lebedev, B B Golitsyn, A A Eichenwald, and others, had studied or worked under Braun. Many prominent mathematicians were on the faculty of the university. Mandelstam established very close relations with one of them, Richard Mises, in particular, because they had agreed on their understanding of the fundamentals of statistical physics and philosophy. Strasbourg attracted Mandelstam also because his uncle A G Gurvich, who later became a prominent biologist, was working there (especially as he was only five years older than his nephew). They established a close life-long friendship. N D Papaleksi, who came independently to study at Strasbourg three years later than Mandelstam, also became his life-long close friend.

Mandelstam spent fourteen years in Strasbourg where he climbed to the very top of the academic hierarchy. He returned to Russia as a full professor on the day World War I started.

The first research projects were carried out by Mandelstam in Braun's field, that is, radiophysics (which was inseparable from radio engineering in that time). First of all, his graduate research project yielded an unexpected result that immediately attracted the attention of experts in the field. After a short time Mandelstam became the 'first assistant' to Braun. In this position he was responsible for giving out research assignments and thus supervising the activities of the young scientists who came from all over Europe to work under Braun. Papaleksi [2, p. 21] recalled the names of 12 scientists supervised by Mandelstam.

Mandelstam's reputation as a scientist was steadily growing. He was appointed to the position of associate professor (Dozent), with the right to deliver lecture courses, and Professor Braun himself often came to his lectures and took notes on them. He was collaborating with Braun in verification testing of the radiotelegraph system that they developed together (in association with the Siemens and Halske company). He made the acquaintance of the Russian radio inventor A S Popov and other Russian pioneers of radio engineering.

We see that in his young years, which are the most productive in the development of a scientist, especially a theorist, Mandelstam studied and worked at one of the best universities in peaceful and flourishing Europe and left it just when the disastrous storms of war started raging over it. He had traveled widely, met many physicists, and had grown as a mature European scientist well-known in the science community. Good evidence of that is the post card he received in July 1913 from Albert Einstein, who wrote, "Dear Dr Mandelstam, I have just presented to a colloquium your elegant paper on surface fluctuations about which Ehrenfest had told me earlier. [2] It is a pity you were not present here. Best regards, A Einstein." The post card bears the signatures of the sixteen participants (see the illustration in Ref. [2, p. 59]).

* * *

We see that by 1913, when he turned 35, Mandelstam had already moved far beyond the field of radiophysics and radio engineering which had been the objects of 'his first love'. His interest in the general theory of oscillations originated there and the results he derived in the field prompted him to extend his attention to other types of oscillations, primarily optical oscillations. In that period the most fundamental issues of physics were resolved within the framework of optics. Optics as a science was instrumental in the development of quantum physics. It was in optics that, in 1900, Planck introduced the concept of quanta emission, that is, emission of discrete portions of light, and in 1905 Einstein defined the concept of light quanta. During that period, Mandelstam was not interested in the quantum problems in optics, he was working on the issues of classical optics, in particular, light scattering in a uniform medium, for instance, in the atmosphere.

[1] Interestingly, Mandelstam wrote in his autobiography in late 1917 [1, p. 68] simply that: "In 1900 I left the university in the fourth semester and went to Strasbourg". Leaving aside the confusion in dates (N Papaleksi [2] wrote that it happened in 1899), one should note that Mandelstam failed to cite the political reason for his dismissal. Why did he not mention it? Perhaps he did not want to seem to be trying to 'ingratiate' himself with the Communist regime established in Russia at the time or perhaps he was determined to demonstrate his lack of acceptance of the regime (see below).

[2] A prominent physicist, Paul Ehrenfest, was Einstein's friend. After graduating from Vienna University, he could not find an academic position in Austria and went to work in St.-Petersburg, where he established lasting friendships with many Russian physicists and contributed significant to the development of physics in Russia in the first decades of the 20th century. Ehrenfest was seriously concerned with the discussion between M Planck and Mandelstam (see below); he repeatedly expressed a wish to come to Strasbourg to work with Mandelstam and once did so.

At that time, various aspects of the problem were largely unclear and knowledge in the field was rather confused. Readers who are familiar with physics can appreciate the degree of confusion from the fact that Mandelstam repeated the mistake of future Nobel Prize winner Stark and believed that only electrically charged molecules could scatter light [3, p. 121]. Mandelstam profoundly respected the famous British physicist Rayleigh, who assumed that the atmosphere was quite uniform when he analyzed light scattering in it. In 1902 Planck published a paper on the same subject. In contrast, Mandelstam argued in 1907 – 1908 that a dense medium could scatter light only if its density was distributed nonuniformly. It was a profoundly correct concept but it was ultimately shown to be true only much later by Einstein and Smoluchowski. It is clear now that Mandelstam's paper had an error in it. [3] I hope readers will forgive me for going into such minute detail but it will soon be clear that it is necessary for understanding Mandelstam's personal traits that he exhibited in that period. It will be surprising to those who knew him only as a much more mature scientist in Moscow after 1925.

Indeed, the young scientist Mandelstam, who had rapidly earned a respectable reputation with his research publications, refuted the arguments of the senior scientists Planck and Rayleigh in four papers in which he employed a manner of writing that would have been unthinkable for him later. At the onset of the controversy, Mandelstam was still fairly reserved in his arguments, saying, "Therefore, I believe that it is a fallacy to treat light absorption in optically uniform bodies only in terms of scattering by particles, as was done by Planck" [3, p. 118]. In the same paper, he also rejected Rayleigh's arguments [2, p. 116].

Two and a half months later, he sent another communication to press which was entirely dedicated to criticizing Rayleigh and asserted, "...it is inadmissible to explain the blue color of the sky by the scattering of sunlight by [individual] molecules" [3, p. 190] as was done by Rayleigh.

Planck soon refuted Mandelstam's arguments in a new paper published in 1908. In response, Mandelstam no longer limited himself to a single critical phrase but attacked Planck's position with a stream of fault-finding statements. He wrote [3, p. 162], "In his theory of dispersion, Mr. Planck gave a positive answer to this question. In contrast, I have employed two different approaches to derive the result that such scattering does not occur in an optically uniform medium. In other words, I came to the conclusion that Planck's model could not yield any understanding of the attenuation of the transmitted wave.

"In particular, in my second paper I demonstrated my assumption that the opposite result derived by Mr. Planck had to be attributed to a less-than-perfect calculation.

"Mr. Planck suggests that my calculation was erroneous. From his explanation I can conclude that I was misunderstood by him."

He continued [3, p. 163], "As demonstrated in the beginning, the fundamental question of absorption must be resolved in a manner opposite to that employed by Mr. Planck."

What is important here is that the great Planck objected to Mandelstam on an issue which seemed to have been ultimately resolved after the publication of Planck's paper. Several months later, Mandelstam published the fourth paper, full of more sharp criticism (expressed in formally polite language, though). He wrote, for example [3, p. 172], "The issue could have been significantly clarified if Mr. Planck had tried to demonstrate an error in my calculations as I did for his calculations."

Young Mandelstam was definitely in fine fighting spirit! I made a special point of elaborating on this episode. All of us who knew Mandelstam in the thirties could hardly believe that he had been capable of such arrogant and aggressive behavior. His disciples and coworkers invariably recall his mildness, tractability, gentle charming smile, and modesty. All such recollections are literal truth. An apt illustration is given by the story told by I E Tamm to V Ya Frenkel [4, p. 366] about an episode during the 4th congress of Russian physicists held in Leningrad in 1924. Tamm and Mandelstam occupied adjacent seats in one of the top rows of the amphitheater. Under discussion was a complicated optical issue from a report made by Ehrenfest. At some point Ehrenfest declared, "Let us now hear what the most eminent expert on optics, Prof. Mandelstam, has to say on this issue." He started looking for Mandelstam in the audience. Mandelstam was visibly alarmed and, to Tamm's surprise, slipped down in his seat so that Ehrenfest could not see him from his place in a lower row.

The above example of aggressive arrogance exhibited by Mandelstam in his youth was by no means a solitary exception. In the same period the British radio engineer Fleming published two papers on a subject on which Mandelstam had conducted research. He immediately attacked Fleming's work, found errors in it, and concluded, "even though Fleming treats the same case in both his papers he derives in them entirely different results (both of which are erroneous)." "Fleming makes use of equation (3) while retaining small terms of the second order, which is obviously inadmissible, and makes the above-mentioned mistake in the sign" [3, p. 141]. "To summarize the above discussion, Fleming's calculations are wrong" [3, p. 149].

We see that Mandelstam did not mince words in his criticism, did not soften his harsh language, and kept on repeating his charges when speaking about mistakes allegedly made by others. It is so unlike the behavior of the Mandelstam we knew in Moscow!

While his criticism of Fleming was essentially correct, his attacks on Rayleigh and Planck were far from justified.

I dare to make a suggestion (which perhaps is too bold) that *Mandelstam deeply regretted his arrogant behavior in youth and the feeling of atonement largely shaped both his professional and daily life habits*.

He was well-known to be relentless in demanding extreme clarity in understanding from himself, his coworkers, and disciples, necessitating repetition and modification of experiments and calculations. On occasion he had to pay dearly for his craving for freedom from errors. For instance, he and Landsberg failed to achieve international recognition for their discovery of combinational (Raman) scattering for which Raman received a Nobel Prize, largely because they followed their usual careful procedure after obtaining a novel result, which delayed their publishing it.

I L Fabelinskiĭ, who was Landsberg's student and collaborator for many years, described the procedure as follows. "Mandelstam and Landsberg were always particularly careful in preparing and conducting their research work, profoundly analyzed their subject matter and took their time in publishing the research results. Even when the results of a

[3] I am grateful to I I Sobel'man for a discussion that helped me to clarify the issue.

completed research project had been prepared for publication, the finished paper was not sent directly to an academic journal but stored for a while in a desk drawer. They thought an interval was required in case they had new ideas or wanted to revise something in the paper or to modify some of the statements in it. The general feeling was that a paper could be sent to press only after a suitable waiting period to make sure that everything in it had had time to settle down. ...I worked with Landsberg for twenty years and in the many research discussions we had he never voiced any dissatisfaction with their work style'' [7, p. 6].

It was their style of research that was instrumental in preventing them from receiving a Nobel Prize for discovering combinational (Raman) scattering. They had obtained reliable observation results as early as February 23 – 24 but they sent a report for publication as late as May 6. By that time they had carefully analyzed the effect, thoroughly explained it, developed its theory, and verified the experimental results against the theory. Raman published his results earlier than they did because he sent his paper for publication immediately after the first observation of the effect, even though he erroneously treated the physical nature of the effect at this stage and even in his two subsequent papers.

In fact, Mandelstam and Landsberg had observed the effect in their experiments even *before* Raman did.

It can be seen from a letter Mandelstam wrote to O D Khvolson. In response to a direct question, he wrote, ''We noticed the appearance of new lines for the first time on February 21, 1928. In the negatives made on February 23 – 24 (exposure time of 15 hours) the new lines were clearly seen'' (see below). Raman wrote in his paper in the *Indian Journal of Physics* (vol. 2, p. 287, 1928), ''We noticed the appearance of new lines for the first time on February 28, 1928. We reported our observations.''

That means that Mandelstam and Landsberg were the first to observe the new effect but not the first to publish their results or to submit their paper for publication, while Raman did so only a week later (I am grateful to I L Fabelinskiĭ for clarification of this and some other issues).

I have noted above that when Mandelstam was preparing to deliver a lecture, he tended to rewrite certain fragments of it in his notebook without making any substantial revisions of them. It was, apparently, his method of satisfying himself that he was doing his best. He was striving for perfection, trying to overcome his indecisiveness, and ensuring that he would ultimately be satisfied with the result. In his mature years he was known as an established authority, making resolute and firm pronouncements. It was only his family members (who told me about that) who knew how hard he had to work on suppressing his own irresolution and anxiety. He tended to be in a pitiful state on the day a lecture was scheduled but nobody noticed that during the lecture itself. When he had to take the train to go to Leningrad in the evening, family members knew that the clock should be moved an hour ahead to make sure that he would not be late for the train's departure.

I was told about only one case when he lost his temper. He was talking in his study with his favorite young disciple A A Andronov. The people in the adjoining room were shocked when the study door burst open, and red-faced Andronov popped out and rushed away. Mandelstam stopped speaking to Andronov for a few months but later the relationship was restored: they were too fond of one another and needed each other. The reason for Mandelstam's outburst of fury was assumed to be an attempt of Andronov to woo him over to the Communist side as he was a Communist activist at the time.

Can it be claimed that Mandelstam never committed errors in research? Unfortunately, he is often represented as an exceptionally gifted physicist who did first-class research, established a unique school in science, and was a charming person, so that an image is created of an omniscient being who simply could not make a mistake. We have discussed above his mistaken position in the case of light scattering. His mistake was rooted in the fact that, before Smoluchowski, physicists did not know about the occurrence of fluctuations (of density and other parameters) in a continuous medium (Rayleigh derived the correct formula largely by accident). Unfortunately, the compilers of the collected works of Mandelstam failed in five volumes to comment on the erroneous aspects of his position in his debates with Rayleigh and Planck (even though Mandelstam himself was well aware of the fact and inserted a passage on the correctness of Rayleigh's result into a later paper [3, p. 246]).

Another of Mandelstam's errors was related to the results on scattering of X-rays in crystals obtained by young disciples of Max Laue in 1913 (who was awarded the Nobel Prize for his part in the discovery). As was especially clearly demonstrated by L and H Bragg (who received the Nobel Prize for it in 1915), X-rays could be regarded as waves or oscillations, rather than fluxes of particles. [4]

But, however, Mandelstam did not wait for the Braggs' results and put forward a suggestion that the observed scattering of X-rays was caused by microscopic cracks on the crystal surface. He even attempted to confirm his suggestion with experimental data *while noting in the same paper that the experiment he was describing had not yet been completed!* Nobody who knew Mandelstam in his 'mature' years in Moscow could imagine him writing a paper referring to his unfinished experiment [3, p. 242].

Can we and should we criticize Mandelstam for such mistakes? This question is of fundamental significance for a scientist and an answer can be given by the shrewd words of V I Vernadskiĭ (taken from an entry in his diary made just before World War II), ''Freedom in creativity means possessing the right to make mistakes.'' There are numerous confirmations of this maxim. The great Newton mistakenly regarded light as a flow of classical particles. The great Maxwell mistakenly believed in the existence of an all-permeating mechanical ether. He had made a brilliant guess about the 'displacement current' that he introduced into the electromagnetic theory but he was mistaken in thinking that it was related to the actual displacement of the ether particles, and the belief was not merely a mistake but revealed backwardness in his thinking. It would be absurd to reproach Mandelstam for the mistakes he made in his youth.

[4] Yu B Rumer told me an interesting story (unrelated to Mandelstam). Back in 1913 quantum mechanics had not yet been developed and physicists did not know that a particle flux also possessed wave properties. A participant at a congress of German physicists at the time suggested to Laue that in order to establish completely the wave nature of the X-rays, it would be useful to run similar experiments with fluxes of electrons. It was implied that the scattering of electrons would not have produced a Bragg pattern but both physicists agreed that such experiments would, of course, have been 'superfluous'. Meanwhile, for electrons of a suitable energy, their scattering pattern would have been similar to the scattering pattern of X-rays. Perhaps in this way the quantum and wave properties of electrons could have been discovered ten or eleven years earlier than they actually were.

A A Andronov, in his concise and definitive account of Mandelstam's life and work [2, p. 190], noted, in particular, that Mandelstam "... hated making mistakes and almost never made them. In those extremely rare cases when he made a mistake [in a conversation with you], immediately after he had realized it he grew very concerned and started searching for you on the phone or sent messages inviting you to visit him to correct the small inaccuracy." Andronov first met Mandelstam as late as 1925, of course.

In his poem 'Humankind' Makhtumkuli, the great Turkmen poet of the 18th century, describes each successive decade in a human life. Here is an excerpt from it [5]:

Life changes at twenty:
Flame of youth burns plenty,
Each day is a stormy dream,
Time rushes in a wild stream.
At thirty life is full of chances,
Too many of enticing glances,
But he has mastered his thought,
He knows himself and his lot.

(At the time of his criticism of Planck and Fleming Mandelstam was 25 – 30 years old.)

Youth is but a poor teacher,
Mind is vague until you reach
Forty, when it grows ripe,
Through the lessons learned in life.

Mandelstam was 35 in 1914. He was reaching what the ancient Greeks referred to as the acme, the pinnacle of life, before which he had learned many lessons in life.

Unfortunately, this period inflicted a severe blow to his ripe mind. In the next eleven years he had too few opportunities to engage in productive research work for which he was eminently ready.

* * * *

After 14 (or 15, see the discussion above) years of absence, a young but mature and gifted scientist returned to his home city of Odessa. He had had the best European education and research experience and he had been recognized by the academic community, namely by such authorities in science as Einstein, Ehrenfest, Sommerfeld, Braun, and Mises.

First and foremost, his further academic career was blocked by the peculiar regulations imposed on academic institutions in the Russian Empire. Only those who had been awarded a Russian academic degree were admitted to teaching positions in Russian universities. To be awarded a master's degree, Mandelstam had first to receive a Russian university diploma (which he did not have), then to write a dissertation, and then to defend it. Mandelstam was thus formally not qualified for a university job. However, university regulations still allowed for some loopholes and Novorossiĭskiĭ University in Odessa elected him to the position of supernumerary instructor of physics (known as Privat Dozent). It was the position of a university teacher who was not a full-fledged member of the university teaching staff but was permitted to conduct some classes and even deliver lectures, albeit typically in elective subjects not included in the formal university curriculum. Appointments to such positions needed approval from the Minister of Education of Russia.

Obviously, this position did not allow Mandelstam to conduct significant research activities. Therefore, at the end of the year he took the radical step of accepting an offer from the Siemens and Halske company to take a consulting position at their radiotelegraph factory in St.-Petersburg (as described above he had already worked for the company together with Professor Braun)[5].

For two years Mandelstam worked in St.-Petersburg on research and development engineering projects, even such minor ones as developing a chemical process for wire oxidation or designing a rheostat, and managing the manufacture of rheostats. E Ya Shchegolev, who worked with Mandelstam and Papaleksi at the factory and later collaborated with them on research projects, recalled [2] that the factory engineers greatly admired Mandelstam's ingenuity in technical design issues. He not only received a number of patents for his inventions but also earned the admiration of his radioengineer colleagues with his clever new approaches and by generously giving them many fruitful ideas. That was when his above-mentioned 'third' talent — that of an innovator — was brilliantly manifesting itself. But that was not the kind of research he was striving for.

Soon Mandelstam realized that he would not have opportunities for research work in Russia unless he received a Russian academic degree. In late 1916 he sent a letter to his good friend T P Kravets asking for assistance in obtaining a Russian degree without having to pass an examination and write a dissertation. In exceptional cases universities had the right to award degrees to accomplished scientists who had submitted published research papers. The university academic board had to receive special permission from the Ministry of Education for issuing a degree under such circumstances. (It is unclear why Mandelstam had not tried that approach earlier. Perhaps he was apprehensive about starting any new official procedures as it would have been too harsh a test for his delicate nerves.) The ever-helpful Kravets answered warmly [2, p. 6] that he had already discussed this question with a radiophysicist, D A Rozhanskiĭ, a professor at Kharkov University. [6]

Kravets noted in his letter, "For some reason it was mostly physicists who had employed that approach for receiving an academic degree and P N Lebedev, N P Kasterin, A G Kolli, and A A Eichenwald (who also had studied abroad) had been awarded their degrees through this procedure."

I am telling this story in such detail in order to highlight the solidarity that existed among Russian intellectuals, in particular, physicists, before the Communist takeover. This can be contrasted with relations as they often existed under the totalitarian dictatorship.

* * *

After the overthrow of the monarchy in Russia in February 1917, the economic and political situation in the country rapidly deteriorated. Food supplies were rapidly running out in St.-Petersburg and as the cold winter

[5] It is noteworthy that it was a German company while Russia was at war with Germany. Perhaps the company was requisitioned or taken over by the Russian government. Thirty years later, after Mandelstam's death, this episode from his life gave rise to allegations of espionage for Germany, put forward by a corrupt physicist in the period when the Communist regime unleashed an anti-Semitic and anti-Western propaganda campaign according to Stalin's orders.

[6] The story of the man is also noteworthy. He later worked under A F Ioffe in Leningrad. In 1931 he refused to support an appeal to the Communist government demanding the death penalty for political prisoners, which all the staff of the Ioffe institute was supposed to vote for at a general meeting. Rozhansky was arrested for that and it was only Ioffe's influence with the government that saved him from death in the labor camps.

approached those who could afford it, including academics, were trying to leave the capital for the warmer southern regions of Russia where there was less political turmoil and food supplies seemed to be abundant. Mandelstam received an invitation to take a position as a full professor of physics at the state-run Tbilisi University in Transcaucasia. Simultaneously, he was invited to teach at the private Polytechnical Institute in the city of Ekaterinoslav in Ukraine. Mandelstam decided to take the professorship in Tbilisi and his appointment was confirmed by the Minister of Education. In the autumn of 1917 Mandelstam moved with his family to Tbilisi, which became the capital of the newly-established independent democratic republic of Georgia whose government was dominated by social-democrats.

Mandelstam failed to find refuge from political turmoil, however. In the first half of 1918, Communists staged armed uprisings near Tbilisi and the social-democratic government invited German troops into the country in June 1918 in the hope of stabilizing the situation. But World War I ended in November 1918 with Germany's defeat, the German troops were withdrawn, and, in December, a British expeditionary force arrived in Transcaucasia.

It is not surprising, therefore, that in the autumn of 1918 Mandelstam decided to move to his native city of Odessa even though Georgia would remain independent for another year before being overrun by the Red Army, which then violently imposed a Communist regime there. Life in Odessa proved to be much harder, as the city was taken over for rather short intervals by one regime after another. First Odessa was governed by local counsils (soviets), which gave way to the German occupation army and the troops of the Ukrainian nationalist government sponsored by Germany, who were replaced by Communist troops, and then by Deninkin's army of monarchists. The last was supported by the Allies; a French expeditionary force was sent to Odessa and remained there until just before the final victory of the Communist regime. As all these regimes were quite wobbly and unable to control the region entirely, the countryside was overrun by a multitude of larger and smaller armed bands of various political persuasions, often simple criminals.

Finally the civil war in the South of Russia ended with the victory of the Red Army and the Soviet regime was established in Odessa in late 1920.

No productive research work was possible under such unstable conditions. However, despite the horrors of the civil war, the influx of university teachers and students seeking refuge in Odessa made it possible to establish a new Polytechnical Institute there. Mandelstam and some of his close collaborators took an active part in that project. N D Papaleksi chaired the department of physics at the Institute. It seemed almost a miracle but the Institute had fairly well-equipped laboratories and the professors were actually delivering lectures even though there was no heating in the auditoriums. Mandelstam delivered brilliant lectures (it was his 'fourth talent'). It can be graphically illustrated by the preserved text of his introductory lecture, which he entitled "Why an Engineer Needs Physics." [2] A G Gurvich introduced to Mandelstam Igor Tamm, a young (16 years younger than him) man who was to become his disciple, closest friend, and associate. He came to Odessa soon after the final establishment of the Communist regime and was invited to live with Mandelstam's family in the room that had been formerly occupied by A S Isakovich, Mandelstam's brother-in-law. The room was vacant for a reason typical for that time — its former occupant had been arrested by the secret police. He was a fairly affluent lawyer and that was reason enough to be arrested by the Communist police. He was released from prison within a year, though. In those ruinous times everybody was desperate to find an additional income just to survive. Mandelstam and N D Papaleksi set up a 'vacuum cooperative' in the local radiotelegraph factory for manufacturing vacuum tubes. I E Tamm and several radio engineers were invited to work at the cooperative.

It is not surprising that Mandelstam was significantly distressed by the lack of opportunities for sustained research work. Of course, his intellect kept on functioning despite all the obstacles. We have mentioned that in his Strasbourg years he significantly extended the range of his research interests to cover the fundamental problems of optics (for instance, he developed an ingenious mathematical theory of the optical image at that time). It was in those years of privations (according to N D Papaleksi [2], it was in 1918) that Mandelstam realized that light could be scattered in a medium by elastic waves which produced the relevant nonhomogeneities. Such light scattering had to be accompanied by a slight change in the frequency of the scattered light. That meant that the spectrum of the scattered light contained not one but two lines. Mandelstam published this result only in 1926. It was not only the hardships of the civil war that explained such a significant delay in publishing: it was, probably the mature Mandelstam's typical reluctance to make his ideas known before being completely confident of them. He could be confident about his calculations being correct but he could entertain doubts about publishing a paper predicting an extremely weak effect (the frequency variation was expected to amount to 0.003%) before it could be experimentally measured. Such measurements became feasible only much later when Mandelstam entered an entirely different phase of his career, which we shall discuss later. Here we shall only note that the French physicist L Brillouin independently predicted this effect in 1922. The effect is known in Russia as the Mandelstam – Brillouin effect. New laser technologies made it possible to study the effect further and to use it in a wide variety of applications.

The above theoretical work of 1918 was the only research project in physics Mandelstam completed in his first eight years after returning to Russia. Throughout that period he was generally isolated from the academic community and had practically no opportunity to pursue his research interests. In 1922 the Communist government introduced a more liberal new economic policy which resulted in a revival of economic life in Russia. One of the manifestations of the revival was that Mandelstam and N D Papaleksi were invited to Moscow in the summer of 1922 to supervise research and development activities (as research consultants) at the radio laboratory of the State Electrotechnical Trust. Mandelstam and his family moved to Moscow in October of 1922.

Soon after that, in March 1923, Mandelstam was sent on a research trip to Germany. He met there with Einstein and other members of the research community and learned of the major developments in science that had occurred during the nine years of his absence from the European academic scene. He returned to Moscow with the latest academic publications that had not been available in Russia.

Next year the radio laboratory was moved from Moscow to Leningrad. The living and working conditions there were much better but Mandelstam was not entirely happy with working only on the radio engineering projects. Of course, his work was quite important and successful. Together with N D Papaleksi, he achieved much in the field (they developed new techniques for radiotelegraph and radiotelephone communications, frequency stabilization, high-selectivity reception, and so on). It seems astonishing now that the universities had not grabbed the obvious opportunity to hire Mandelstam as a teacher. Strangely enough, Moscow State University failed to invite Mandelstam to its faculty while he lived in Moscow in 1922–1924.

* * *

The Physics faculty of Moscow State University was in a state of utter depression in that period. The level of teaching and research work plummeted when the outstanding physicist P N Lebedev (and the best professors from other university departments) resigned in 1911 to register his protest against the government's violation of university freedoms. Many rooms in the specially commissioned building of the Physics faculty, which was completed before the war, were left empty (they remained unoccupied through the twenties). There were some competent physicists still left on the faculty in the early twenties (for instance, V K Arkadiev, Lebedev's disciple and a Corresponding Member of the Russian Academy of Science, and his wife A A Glagoleva-Arkad'eva, the young N N Andreev who had recently graduated from the University of Basel, and G S Landsberg, S I Vavilov, and S T Konobeevskiĭ who were also quite young). But it was not these faculty members but the majority who determined the general status of the faculty's teaching capability which, as evidenced by the curriculum, significantly lagged behind the latest advances in physics. For instance, the special theory of relativity had been developed in 1905 but the first (and only!) course presenting it in Russia was delivered only once, by N N Andreev in 1918. Even though some physicists on the university faculty were fairly competent, most of them refused to recognize the novel theories of relativity and later quantum mechanics, which had already been widely accepted by the world scientific community. They did all they could to prevent the propagation of this new knowledge and to 'simplify' the new theories, presenting them in the spirit of classical physics. The most hostile opponents cunningly appealed to the Communist authorities, asking them to suppress the new physical theories as the products of decadent bourgeoisie.

Meanwhile, it was not only the most cultivated young professors (N N Andreev, G S Landsberg, S I Vavilov, and others) who were deeply unsatisfied with the state of affairs at the University. The undergraduate and graduate students increasingly expressed their unhappiness with the poor quality of teaching and strongly supported demands for inviting Mandelstam to a senior faculty position. There was fierce opposition to such plans. Even though anti-Semitism was not typical for Russia at the time, some of the arguments against giving Mandelstam a university position were distinctly anti-Jewish in character. Once S I Vavilov visited his friend G S Landsberg, who lived in an apartment in the university compound, and told him, "Professor N just put forward an argument to me that if Mandelstam gets a university position he will start bringing in other Jews. I just fail to understand such people."

In that period university regulations gave younger teachers and the student community significant leverage over the decision-making process at state universities. The undergraduate and graduate students (A A Andronov, M A Leontovich, and others) were instrumental in ultimately resolving the issue. In 1925 Mandelstam was appointed to a full-professorship position as the head of the Department of Theoretical Physics of the Physics faculty. He was also given a senior position in the Research Institute of Physics attached to the University. Soon he resigned from the Department, in favor of I E Tamm who was then appointed as the head. A radically different period began in his life.

* * *

Mandelstam's family, consisting of his wife Lydia and his son Sergey (who later became a physicist, too), were given an apartment of three large rooms in the building of the Physics faculty. One peculiarity of the apartment was that it had two entrances. One led from the front residential staircase along which the doors to all professor's apartments were located. The other led to the corridor of the first floor of the business section of the building. The doors from the corridor led to the laboratories where G S Landsberg and other researchers worked. The door to the X-ray laboratory of S T Konobeevskiĭ was directly opposite Mandelstam's door. Thus, research workers had easy access to Mandelstam and he could quickly get to any laboratory he wanted. Typically, Mandelstam worked in his apartment and when he had to conduct an experiment, deliver a lecture, or run a seminar he could go to the relevant laboratory or auditorium without leaving the building. His coworkers could easily reach him when they needed him.

A daily routine was gradually established. At about 5 p.m. at the end of the work day, his closest friends came to Mandelstam's apartment for a tea party. The conversations at the tea table touched on research issues, current politics, and mundane matters of daily life. People at the table could speak absolutely frankly, as they trusted each other.

This new period in Mandelstam's life gave him ample opportunity for exceptionally fruitful research work. One could even say that his life was almost happy during that time but for the poor state of the laboratory facilities [7] and the depressing moral atmosphere in Russia under the Communist dictatorship (which was relatively mild in the twenties in comparison with the vicious oppression in subsequent years). Mandelstam was conducting successful research in an expanding range of subjects and he acquired more and more gifted disciples and young coworkers, who greatly respected and sincerely admired him.

In 1925 Mandelstam turned 46. Eleven years of his life were practically wasted because of wars and revolutions. These were precious years for an outstanding scientist in the prime of his life and most Moscow students and young researchers were barred from access to contemporary science in those years. It is not surprising that they were so strongly attracted to the school of Mandelstam and his followers: they understood that the physicist who had achieved so much in fourteen years in Strasbourg could have done much more in the subsequent years than acquiring almost sixty radio engineering patents and predicting the Mandelstam–Brillouin effect and giving a theoretical explanation for it.

[7] Even as late as 1930, when I entered Moscow State University, I saw that many rooms were empty, as were the shelves in the laboratories. But over the course of several subsequent years, the laboratories were filled with science instruments and materials manufactured in Russia.

Mandelstam's position improved even further when B M Gessen was made the dean of the Physics faculty and the director of the Research Institute of Physics. Gessen was a close friend of Tamm's from his school days. He was a refined intellectual but an ardent Communist. He served in the Red Army during the civil war and later studied at the Institute of Red Professors, specially established by the Communist government to train the intellectual elite for the regime. Later he was appointed Director of the Institute. He differed significantly from other Communist officials by his high level of education. His research interests concerned the philosophical aspects of the natural sciences and his report presenting a Marxist concept of the subject at the 2nd International Congress on the History of Science held in London in 1931 attracted significant attention in the West and was frequently referred to in academic publications (see details on Gessen's career in [6]).

Gessen profoundly respected and admired Mandelstam. I remember watching him helping Mandelstam with extreme care and gentleness to put on his overcoat in the university cloakroom. Of course, when the Institute was headed by Gessen, he ensured the most favorable conditions for Mandelstam's work. But that was the time when the Communist regime was starting its political purges, the scale of which was expanding greatly. In 1936 Gessen fell victim to a purge, was arrested, and shot (for unspecified political crimes). Everybody who knew him and worked with him was threatened with reprisals, too. But that happened much later than the period of Mandelstam's research we are discussing now.

Now that he had a choice of coworkers in the university, Mandelstam initiated research projects in various fields simultaneously. He was delivering a course on the theory of electromagnetism, which he presented in a style that was quite novel for the University. In addition to that and other teaching responsibilities, Mandelstam engaged a number of coworkers in a variety of theoretical and experimental studies. Andronov, Papaleksi, Vitt, Khaĭkin, Gorelik, Leontovich, and Rytov were working with him on the general theory of oscillations, particularly nonlinear oscillations. Together with Landsberg, he conducted experiments primarily in optics with the purpose of detecting the Mandelstam – Brillouin effect. In collaboration with Tamm, he completed a paper on the theory of relativity for an anisotropic medium.

As we mentioned above, in his Strasbourg period Mandelstam started with research in radiophysics and radioengineering and rapidly expanded his range of research activities to include the major areas of optics. Now he had moved even further.

A recent development had shaken the very foundations of physics: the emergence of quantum mechanics in pioneering studies by Heisenberg and Schrödinger in 1925 – 1926 (in two superficially different but equivalent formats). It was as soon as 1927 that Mandelstam and M A Leontovich, a recent graduate student, published an important paper in which they analyzed in detail some striking features of the Schrödinger equation, the fundamental equation of quantum mechanics [1]. They had demonstrated a paradoxical feature indicating that a quantum particle could penetrate a 'potential barrier', that is, pass through a region in which the potential energy was greater than the total energy of the particle. In terms of classical physics, it is an impossible event since it implies nonconservation of energy. It is feasible in quantum mechanics because a particle has wave properties. This effect, known as tunneling (though the authors did not use this term) is of great significance for science and technology. [8]

G A Gamow (who lived in Russia at the time but later emigrated to the USA) was the first to pay attention to the result published by Leontovich and Mandelstam; he very elegantly used it for explaining the radioactive decay of atomic nuclei. This effect was discovered near the end of the 19th century but remained absolutely inexplicable within the framework of classical physics. It was a well-known fact in the physics community that Gamow had had preliminary knowledge of Leontovich's and Mandelstam results on the tunneling effect but he failed to refer to them. [9] This fact gave grounds to the still-widespread belief that Gamow had discovered tunneling. Mandelstam never entered into disputes concerning who was first with a discovery. Some people believe that he lacked ambition, which is a necessary trait for a researcher. In my opinion, however, he just regarded such disputes as too demeaning for him. He, as many other people of the same stature as he, believed that if you were a really competent researcher, nobody could steal all your discoveries from you and it was a more effective policy not to waste time on disputes but to produce another good result.

Unfortunately, that instance was by no means an exception. Another similar incident happened when Mandelstam and Landsberg managed to prepare the extremely complicated experiment aimed at verifying the Mandelstam – Brillouin effect. They were not satisfied with the initial results they had obtained. The spectrometer they used did not have sufficient resolution for the experiments and, though it demonstrated broadening of the spectral lines indicating the effect they were looking for, they hoped to obtain more specific experimental evidence. There was a better spectrometer in the State Optical Institute in Leningrad. Mandelstam knew well and deeply respected the outstanding scientist D S Rozhdestvenskiĭ, the Director of the Institute, and asked him to instruct one of the young researchers in his Institute to repeat the measurements using their superior equipment. E F Gross was charged with the task and conducted detailed studies of the effect in 1930 – 1932. While the research project was proceeding, the research groups in Moscow and Leningrad kept in close touch by corresponding and Mandelstam visited Leningrad. The study was regarded as a joint project and it was assumed that at its completion two papers would be published, one written by Mandelstam and Landsberg and the other by Gross. When Mandelstam and Landsberg had completed the manuscript of their paper and sent its copy to Gross, he very much surprised them by writing that he had already submitted his paper, in which he included all the joint project results for publication, and it was already in press. That meant that there was no need to publish the paper written by the Moscow group.

[8] It was by no means an accidental discovery for Mandelstam. Analyzing his old experimental results in optics obtained in Strasbourg, he demonstrated and verified theoretically that the optical waves which had to undergo the so-called total internal reflection from the interface between a solid, for instance, glass, in which they were propagating, and the air actually partially passed through the air gap, where they were not allowed to propagate, when another glass was positioned near the interface. Such a holistic understanding of classical and quantum physics was typical for Mandelstam.

[9] Tamm reported that Gamow himself had admitted to him the fact that he had used this result (see [4], p. 134).

It was either at that time or under similar circumstances that Mandelstam decided to lodge a firm protest against similar misconduct with the following phrase, as reported by S M Raĭskiĭ in his reminiscences [2, p. 216]: "A grown-up person cannot be corrected. One can either cooperate with him or not. One should not deal with Mr. N."

In fact, Mandelstam was hardly devoid of 'healthy' ambition. But it was self-respect that was of paramount importance to him and it kept him from 'fighting for his discovery rights' when it concerned an issue of science. He just could not compromise the pure atmosphere of the search for knowledge even if he was unhappy with the unfairness and injustice towards him. I E Tamm was guided by precisely the same principles, as were almost all physicists of the school of Mandelstam (including members of its younger generations, though, unfortunately, to a much lesser extent).

There seemed to be too many instances in which Mandelstam's contributions to science were insufficiently acknowledged. One such case, briefly mentioned above, was a matter on a much greater scale. It was Mandelstam and Landsberg who were really the first to discover the combinational (Raman) effect but it was the Indian physicist Raman who received the Nobel Prize for it. Though he failed to give it a correct explanation, he made haste in publishing his observation results while the Russian physicists were perfecting their interpretation of the effect.

Mandelstam and Landsberg were carrying out a long series of experiments in their study of light scattering and the Mandelstam – Brillouin effect. In addition to the effect caused by the scattering of light by elastic acoustic waves in a crystal as a whole, various experimental configurations exhibited scattering of higher-frequency light waves determined by the structure of individual molecules in the crystal. This scattering gave rise to new spectral lines whose frequency depended not only on the scattered light frequency but also on the intramolecular oscillations. This is why Mandelstam and Landsberg referred to this effect as combinational scattering. They were well aware of the significance of their discovery and they immediately understood that the analysis of the scattering lines could yield significant data on the nature and structure of the scattering molecules.

But the intensity of the new scattering lines was very low and it was very difficult to record them with the experimental apparatus available at the time. An exposure time of dozens of hours was often required for photographing a spectrum. Modern photoelectric recording devices and laser technologies make such studies incomparably easier these days.

It was only in early 1928 that Mandelstam and Landsberg recorded spectra with a satisfactory photographic quality. [10] The experiments were conducted under very difficult conditions and the researchers often could not procure even the most basic materials and instruments. For instance, they could obtain quartz tubes and some other materials only when Landsberg went on a business trip abroad, saved some money from his subsistence pay, and then bought them. The only way they could obtain high-quality quartz crystals for the study of light scattering was to buy privately quartz stamps used in the 19th century for sealing parcels with wax and sold in antique shops in the 20th century.

However, though Mandelstam and Landsberg were quite confident in February that they had discovered a new effect, they followed their typical routine in unhurriedly preparing a publication, as described above. They made their first public report on the discovery at Landsberg's presentation to the Institute of Physics of the Health Ministry (which had a large department of optics) on April 27. They submitted their paper for publication on May 6 after they had developed a theoretical interpretation of the effect and verified that their experimental data agreed with the theoretical predictions. By the time their paper was published on July 9, Raman's report had already been read by many physicists, who recognized the discovery. By that time, 16 papers had been published by different researchers, who referred to the effect as the Raman effect. In their very first paper on the subject, Mandelstam and Landsberg properly noted that Raman (and his disciple Krishnan) had published a paper in *Nature* "describing observations of the same effect." In their second paper, they referred to "the paper by Raman and Krishnan which had been known to the authors before they submitted their report for publication" [8]. That was how public opinion had formed regarding the Indian physicist making the discovery first. Nobody took the trouble of investigating the true sequence of events; a special effort would have been required and it was too late for doing so.

In fact, there was another, very special reason for Mandelstam being too late in communicating the news of his discovery.

The larger, very closely-knit Mandelstam clan included, in addition to his wife and son, his sister, nephew (M A Isakovich, a physicist), two nieces, the husband of one of the nieces, S M Raĭskiĭ (who was Landsberg's disciple and coworker), and the Gurvich family. Though I did not know Mandelstam very well, I became friendly with the members of the clan after his death. I do not remember exactly who told me about a significant family scene that had taken place at the time when the research project on light scattering had just been completed (I rather think it was S M Raĭskiĭ who shared the family story with me).

One day Mandelstam came home straight from a visit to Landsberg's laboratory. Holding a still-wet photographic plate in his hand, he said somewhat shyly to his wife, "Just imagine, darling, they are awarding Nobel Prizes for things like this." His wife cut him short, "How can you even mention something so irrelevant while Uncle Lev is in prison and they do not allow us to send him food and clothes!"

Mandelstam dropped the subject shamefacedly and they began discussing what else they could do for 'Uncle Lev', L I Gurevich, a close relative of A G Gurvich, who had been jailed and sentenced to death for alleged anti-Communist activities. The Communist regime in 1928 was not yet entirely unreasonable and it was still possible to plead for unjustly sentenced prisoners. In a few years any pleas on behalf of political prisoners became too dangerous. As they were university professors, Mandelstam and A G Gurvich ventured to obtain support for their pleas for mercy for their imprisoned relative from the then rector of Moscow State University, A Ya Vyshinskiĭ. He became world-famous later in the thirties as the prosecutor at the notorious Moscow

[10] I L Fabelinskiĭ carefully studied the history of the experiments and the resulting discovery and presented them in remarkable detail in his papers [7]. One illustration shows a photographic plate with a spectrum distinctly exhibiting lines of the combinational (Raman) scattering and the date of February 23 – 24, 1928, in Landsberg's handwriting. Raman made his first observation of the effect (and immediately presented it to the Indian Physical Society) a week later than the Moscow physicists (his paper was published much later, of course). Raman submitted his paper for publication on March 8, 1928, much earlier than the Russian physicists, who did so only on May 6, 1928.

political trials of top government figures (it was rumored that he was a secret police agent throughout his entire career). Strange as it seems, now that we know what kind of a person Vyshinskiĭ was, he indeed used his influence with the authorities in response to Mandelstam's appeal for help. 'Uncle Lev' was not executed but merely sent into internal exile to Vyatka, a small town in Northern Russia. [11] This incident provides a very apt illustration of the superficially legalistic procedures employed by the 'law-and-order' agencies of the Communist regime even at the early stage of a relatively mild dictatorship. Under this arbitrary justice system, a person accused of a political crime as an 'enemy of the people' could be sentenced to death but later the sentence for the same crime could be reduced to a comparatively easy punishment of internal exile.

Let us return to the story of the Nobel Prize. Mandelstam and Landsberg never bragged about their discovery but of course did not hide it. The Sixth Congress of Soviet Physicists held in 1928 was attended by many foreign scientists, and some very prominent people were there (including Dirac, Darwin, Born, Pauli, Debye, and Peierls). Sessions of the Congress were held initially in Moscow and then onboard a river boat travelling down the Volga River and in some of the cities where the boat made stopovers. The talk given by Landsberg at the Congress produced a significant impression on the audience. Darwin (writing about the Congress for *Nature*) and Born (writing in the German academic journal *Naturwissenschaften*) lavished special praise on this brilliant talk [7].

We see that the world academic community learned fairly early about the discovery by the Russian physicists (though later than Raman had published his paper).

In 1930 Raman was awarded the Nobel Prize. Why was he alone given the prize? The Russian academic community was very unhappy about what they believed was an unfair decision. Different interpretations were attempted to account for it, such as the anti-Soviet sentiments of the Nobel Committee and so on. The issue was clarified only fifty years later when the archive documents on this award were made available to the public because the statute of the Nobel Prize stipulates that the information on awards is kept confidential for that period. [12]

According to the Nobel archives, nobody nominated Mandelstam and Landsberg for the prize in 1928 while Niels Bohr and another physicist nominated Raman. The Nobel Prize for physics was awarded in 1929 (absolutely fairly) to Louis de Broglie, who had put forward the concept of the wave properties of electrons, on which the quantum mechanics of Schrödinger was based. In 1929 Raman was nominated not only by Bohr but also by ten other prominent physicists including Rutherford. The only scientist who nominated Mandelstam and Landsberg was O D Khvolson (who nominated Raman, too!), a senior Russian physicist who had written a five-volume textbook of physics translated into several languages. At the venerable age of 76, he had mastered the new physics (and wrote an excellent book on it for the laity) and had highly valued the contribution of the Moscow physicists. And N D Papaleksi nominated only Mandelstam (and ignored Landsberg for some inconceivable reason). Several prominent Russian physicists whom the Nobel Committee asked for nominations failed to nominate Mandelstam and Landsberg but submitted names of other candidates [7]. In making the award decision, the Nobel Committee was apparently guided by the simple fact that Raman had sent his paper for publication earlier (March 8) than Mandelstam and Landsberg (May 6). The decision was certainly influenced by the fact that Raman was nominated by several internationally prominent physicists.

Why did Raman receive many more nominations than his Moscow competitors? The prominent physicists who nominated only Raman had already known about the 'brilliant' research result of Mandelstam and Landsberg, for instance, from the talk the latter gave during the 1928 Congress. Why did Russian physicists polled by the Nobel Committee fail to nominate their fellow countrymen (each of them had the right to make several nominations)?

The question is easy to answer — the nominations must be 'politically managed'. It is a well-known fact that even these days some candidates make sustained efforts in 'procuring' nominations for themselves. My Western academic friends told me a number of such stories. The late Italian physicist G P Occhialini failed to receive a share in two Nobel prizes awarded for the studies in which he had been a coauthor. Another unlucky contributor sharply reproached him for his 'passivity'. Occhialini, an intellectual of absolute integrity and unimpeachable honesty, was by no means saddened by the fact that he was incapable of 'fighting' for the Nobel prize, in contrast to some other more successful candidates. It is not surprising that Mandelstam and Landsberg, intensely proud and honorable individuals, did not even think about any action of that kind (of course, I do not mean that all Nobel prize-winners get their prizes in a similar way but the difference between the numbers of nominations for Raman and the Moscow physicists is too large to be explainable in any other way).

The primary factor was that Raman did not procrastinate in publishing his results, although in the first three papers he was entirely mistaken about the physical nature of the effect he had observed, as he believed it to be an analogue of the Compton effect. He did not even wait for the papers to appear as publications. When he had presented his report on the effect at a session of the Indian Physical Society on March 16, he printed a thousand copies of the report and the next day mailed them out all over the world. When the Indian journal with his first paper was published, he ordered 2 000 printed copies of the paper and mailed them out to all more-or-less prominent physicists in many countries [8]. He had corresponded with Bohr, Rutherford, and other influential academics even before these events. On December 6, 1929 we wrote to Bohr and directly asked for a Nobel nomination [8]. He communicated with Siegbahn, a member of the Nobel Committee, and other people who could have influenced the award decision [8].

Fabelinskiĭ [7] discussed the events he had witnessed himself while Singh and Riess [8] analyzed the information available in Western publications and from the crucial archive documents declassified after 50 – 70 years. The conclusion clearly is that the Nobel award procedure was biased to favor Raman alone who 'knew how to fight for priority' [8].

[11] I am very grateful to the daughter of A G Gurvich, N A Belousova – Gurvich, for this information.

[12] Nobel Prizes are awarded via the following procedure: a year before an award is to be given, the Nobel Committee sends out invitations to prominent academics (chosen by the Committee) to nominate candidates for the prize and the final decision is made public at the end of the following year (in the case under study the nearest possible award date was the end of 1929, so nominations had to be made in 1928).

There is no simple and straightforward explanation for the lack of nominations for Mandelstam and Landsberg from many Russian physicists. A probable explanation is that physical science in Russia had not yet been solidly established even though it had made some significant achievements. Russian academics were still experiencing an inferiority complex which prevented them from recognizing the full importance of the discovery by their fellow countrymen.

In addition to the above reasons, the decisive factor was the delay in publishing the results. As we mentioned earlier in this paper, in his mature years Mandelstam not only strove ultimately to penetrate into 'the nature of things' but also to attain absolute confidence in his reasoning. That is why he tended to delay submitting his papers for publication until the moment when he felt that he had attained a faultless clarity of presentation. The same reasons explained his habit to rewrite certain fragments of a planned lecture many times, as I described at the beginning of the present paper. As I noted, I believe that Mandelstam developed this approach as a result of making errors of judgement in his youth and using inappropriately discourteous language in his criticism of the papers and statements made by Rayleigh, Planck, and the Braggs. A frank recognition of one's preposterous errors made in youth could produce a dramatic effect on a highly sensitive and excitable person (only the closest friends and relatives of Mandelstam knew the vast extent of the anxieties to which he was subject even though he unfailingly made an impression on outsiders of a completely self-assured and resolute person in his Moscow years).

The serious internal personal problems were exacerbated by the external burdens and hardships typical for the time, which ranged from the lack of materials for experimental research to anxiety about 'Uncle Lev' and similar worries. Raman was free of such hardships and burdens that could slow down his ceaseless pursuit of a Nobel Prize. His was an entirely different mentality; he was not the idealistic Russian intellectual that Mandelstam was.

* * *

The period after the discovery of combinational (Raman) scattering was a time of what seemed to be the happy flourishing of Mandelstam's school, which continued attracting gifted young scientists. Research work was successfully going on in all fields of physics in which Mandelstam was interested and he could put his most brilliant disciples in charge of the work in relevant fields. As noted above, B M Gessen, the new director of the Institute of Physics and the Dean of the Physics faculty, appointed in 1930, was Mandelstam's staunch supporter and a competent academic himself. As a Moscow University undergraduate in the early thirties, I attended the lectures on the philosophy of the natural sciences delivered by Gessen. They were extremely erudite and lucid, differing strikingly from those of typical Communist dialectic materialism lecturers who were especially scared of deviating from the Party line.

In the same period, Stalin significantly consolidated his dictatorship, tightened the rigid ideological controls, and steadily intensified the repressive policies. Starting from 1930, the Communist-controlled press invariably referred to Stalin as the great and wise leader of the toiling masses, the greatest genius of all time, and so on. The assassination of Stalin's main rival, S M Kirov, engineered, as many people believed, by Stalin, gave the signal for massive purges greatly exceeding in scale the terrible earlier atrocities of the Communist regime. Anybody suspected of anti-Communist sentiments could be brought to summary trial under the newly adopted anti-terrorist instructions providing for swift trials in the absence of the accused and immediate execution of the condemned. No appeals or pleas for clemency were allowed. Many hundreds and thousands of innocent people were secretly executed and often no notification was issued to their families.

In 1936 Gessen was accused of political crimes and arrested. According to the general rule observed in such cases, staff meetings were conducted at the university at which participants, especially personal friends of the accused, were obliged to take part in a ritual of admitting their criminal negligence (as they failed to uncover an enemy of the people!) and to make up ridiculous 'facts' about the enemy's activities. It was only a very rare individual who managed to succeed in protecting his dignity in the atmosphere of the all-permeating horror prevalent at such meetings (Landsberg was such a rare exception). Mandelstam was, perhaps, the only physics professor who was tacitly excused from attending such meetings (at least I do not remember him attending any of them; he generally did not like official meetings and conferences). Apparently the Communist authorities preferred not to trouble excessively the respected scientist who had been instrumental in reviving the formerly dormant research work in the Physics faculty.

Many scientists perished in the subsequent period of the Great Terror. Two young gifted disciples of Mandelstam were arrested. One of them was S P Shubin, who was also Tamm's student. The other was A A Vitt, who had just completed together with A A Andronov and S E Khaĭkin a fundamental monograph summarizing their research results in the theory of oscillations, in particular, nonlinear oscillations. The authors had collaborated with Mandelstam in developing new methods for treating an extremely wide variety of problems of great technological significance. For instance, Andronov had introduced the concept of 'auto-oscillations' into the oscillation theory. It was a major breakthrough in a significant field of physics. It was also the starting point for the growth of the school of Andronov which flourished in Moscow and Gorky for many years. Censorship did not permit the publication of a book carrying the name of the 'enemy of the people' Vitt on its title page. Yet it would have been a crime against science if the authors had failed to publish it. They had to make a hard moral compromise and delete Vitt's name from the book. The fact that such profoundly honest scientists as Mandelstam, Khaĭkin, and Andronov had agreed to such a bitter sacrifice indicates how urgently the book was needed by the science community. The English translation of the book was published in the USA in the late forties (without permission of the authors, I believe). After Stalin's death a second edition of the book was published, now also bearing Vitt's name (Andronov had died by then). The fact that a science monograph was published for a second time more than twenty years after it had been written demonstrates that it is a classical work of science. The story is an apt illustration of the history of Russia and the work conditions at Mandelstam's school.

Nevertheless, the school survived, grew, and produced results even as 'the noose was tightening'.

* * *

An unexpected significant development ocurring in academic life in Moscow proved to be a life-saver for

Mandelstam's school. It was a new physics research institute established in Moscow that provided a safe haven for the best Moscow physicists.

The Russian Academy of Sciences, established by Peter the Great, and many of its research institutions were traditionally located in Saint-Petersburg (Leningrad), the capital of the Russian Empire. In 1934 the Soviet government decreed a transfer of the Academy to Moscow, the capital city of Soviet Russia. The Institute of Physics and Mathematics of the Academy was split into two institutes at that time. The newborn small Institute of Physics of the Academy (widely known as FIAN) was transferred to Moscow. It had about twenty researchers and graduate students on its staff and a dynamic young director, S I Vavilov. The most promising physicists in Moscow, including Mandelstam and his most prominent coworkers, were invited to join the staff of the Institute. Members of Mandelstam's school kept their teaching jobs at Moscow State University but also occupied positions as division heads and research associates of the new Academy Institute. The research staff of the Institute was enlarged by a factor of ten and a prevailing moral atmosphere of intellectual honesty, goodwill, and cooperation was soon established there.

The adjective 'prevailing' for the moral atmosphere was chosen carefully. In that time in Russia one could hardly find refuge anywhere from the evil powers unleashed by the totalitarian Communist regime. As a highly skilled administrator, S I Vavilov invented crafty devices for softening the outside political pressure on the researchers. As in any state-funded institution, the ultimate decision-making power in the Institute was vested in the Communist party cell. Vavilov ensured that major cell leaders were competent physicists, though zealous Communists. As scientists, they could not help respecting Mandelstam, Landsberg, Tamm, and other physicists from Mandelstam's school for their research achievements. The Communist leaders could not help toning down their ferocious attacks on the ideological errors allegedly made by the respected senior scientists, though they were especially obliged to launch regular attacks in the period of the "Great Terror" (launching political accusations was a periodic ritual in academic institutions all over the country). But Vavilov managed to mitigate the seriousness of such accusations and his institute was free of the atmosphere of mistrust and hate created for senior physicists at Moscow State University where the Physics faculty had been taken over by the group of older academics and their followers, who had been so fiercely fighting against Mandelstam's appointment as a professor in the early twenties.

The Mandelstam school rapidly relocated its primary research base to FIAN. For instance, Tamm now convened his popular weekly seminars at FIAN. It was at FIAN that Mandelstam and Papaleksi started wide-ranging studies in a field which was new for them, concerning propagation of radio waves above various types of terrain, new radiolocation techniques, and other related issues. Their only remaining link with Moscow State University was their continuing teaching activities there.

It would be worthwhile to discuss Mandelstam's lecturing manner at this point.

* * *

Perhaps it was only the lectures on field theory that Mandelstam delivered at the start of his university career (in the academic year of 1926 – 1927) that could be classified largely as a typical university course (still it carried the indelible stamp of his peculiar teaching style). His various teaching activities in the twenty years between 1925 and 1944 (the lectures he delivered and the seminars he conducted) could not be described as typical teaching in any respect. They were not regular classes, no examinations or tests had to be taken by the students, and the subjects did not follow the standard university curricula. Mandelstam selected the issues or fields of physics that he believed were not clear enough or were not adequately treated in literature, or the knowledge of which was essential for a better understanding of a wide range of other fields of physics as a whole. His courses were often arranged 'horizontally'. For instance, his longest lecture course entitled "Lectures on Oscillations", (1930 – 1932) presented a theoretical treatment of the general and special properties of oscillations in such diverse fields of physics as fluid dynamics, electrodynamics, mechanics, optics, and even quantum mechanics. These lectures comprise vol. 4, which is the largest volume of the "Collected Works" of Mandelstam. The most essential feature of the lectures, which often incorporated presentation of Mandelstam's research results (though no direct references were given), was that the teaching aspects were very closely linked with the research process. The style of lecture was exhaustively described in the preface to the reminiscences about Mandelstam [2]. Here is an excerpt from it.

"Mandelstam's lectures graphically and brilliantly illustrated the very process of scientific thinking in physics. They demonstrated how a physicist stumbles against obstacles, paradoxes, and discrepancies as he pushes forward along the road of knowledge, how he succeeds, sometimes through heroic intellectual effort needed for rejecting the stereotypes of the human thinking process, to reach a hitherto unattainable pinnacle from which new horizons open up for him. His lectures never contained a single dull or indifferent detail or feature; in discussing any problem, Mandelstam always found a special ingenious way of presenting it and making it abundantly clear to his listeners. It was not only that his incontestable logic made his audience agree with his statements; he attempted, quite successfully, to find a common language with his listeners as he was convincing them to adapt to his reasoning, thus removing the psychological block that often hinders understanding in physics. All these factors acting together gave rise to a special emotionally-charged ambience to the lectures, which stimulated the awareness of the listeners and contributed to extremely profound assimilation of the knowledge they had received from Mandelstam."

As noted above, Mandelstam's lectures (and the seminars he conducted and for which he invariably delivered an introductory lecture) attracted a wide range of listeners, from university undergraduates to distinguished university professors. Some of them came from other cities. Many of those attending the lectures were taking extensive notes, trying to record in careful detail Mandelstam's reasoning. However, no notes have been preserved from some seminars.

Mandelstam occasionally delivered lectures and reports of a different type. For instance, on April 28, 1938 he presented a report to a general session of the Russian Academy of Sciences on what seemed a very special topic, namely, radio interferometry, that is, using radio waves for measuring terrestrial distances (incidentally, Landau had been arrested on a political charge the night before). The subject of the report was of significant practical importance and Mandelstam was an expert on it as he and Papaleksi headed a division at FIAN which conducted extensive studies in the field. But how to make such a presentation so that it would be interesting to this gathering of academics, which included humanities specialists, chemists, and biologists? [13] However, A E Fersman, the mineralogist member of the Academy, expressed his appreciation for the report with a brief comment, 'Pure poetry!' (later he sent Mandelstam a brief letter full of admiration [2]).

On September 26, 1943 he presented a report to a general session of the Academy held in honor of Academy member A N Krylov who had turned 80 and who was a versatile genius — a mathematician, engineer, and naval architect. He had translated Newton from Latin into Russian, and was a wonderful person with whom Mandelstam became especially friendly as they were in the same group of senior academics that was evacuated at the beginning of the World War II for two years to a resort town in Kazakhstan. Mandelstam gave a successful lecture entitled "Krylov's Research Work", a subject far removed from the area of his professional interests. Indeed, "for Mandelstam there were no locked chambers in the magnificent edifice of physical science," as A A Andronov once remarked [2].

It is not surprising, thus, to read the following lines in a letter sent in 1944 to Mandelstam by V M Alekseev, an Academy member who was a specialist in Chinese studies: "I have repeatedly communicated to you my limited observations on my unlimited appreciation of everything that I could grasp from your talks and speeches. Apparently, you are one of those rarest academics who professes science as clear unencumbered thinking and regards any complexities as relevant factors, rather than the actual content of science" [2]. Alekseev had good reason to make such comments, inasmuch as he recently attended sessions at which Mandelstam gave a talk on Krylov's research and another one, entitled "Newton's Optical Research."

Rytov [2] writes that when the famous physicist P L Kapitza was asked to give brief descriptions of several scientists, in his comment on Mandelstam he declared "He is an aesthete!"

Andronov, Rytov, and other physicists who attended Mandelstam's lectures emphasized that he paid particular attention to the logical structure of any theory he presented. Andronov emphasized that Mandelstam was "consistently expressing an intense interest in various aspects of the theory of cognition in science." It was an interest in "emergence, development and transformation of the physical concept and their relationship to reality. His lectures and other statements demonstrate that he performed a profound analysis of the logical structure of physical theories" [2]. This is why his lectures, even on specific and narrow physical subjects, carried some philosophical overtones.

* * *

In that period, physicists were not yet fully aware of the fundamental importance of the inevitable limitations of experimental studies. The conclusions drawn from experimental results cannot therefore be regarded as being absolutely valid. Indeed, a researcher might repeat many modifications of an experiment, yielding results that invariably support his conclusions but at some point he must stop and declare, "I am done with the experiments, now I believe that my results represent the true properties of nature." To make the statement 'I believe' is an extra-logical step and it cannot be guaranteed that it is absolutely valid without limitations. The same criterion is applicable to the conclusions made by the 'collective researcher', that is, the laws of nature, mathematical axioms, etc. recognized by the science community as being valid on the strength of experimental evidence. Each natural science with mathematical foundations develops as a consistent logical process employing the *extra-logical intuitive judgment* made in the above way. The judgment is synthetic in its nature, as it is made on the basis of various types of knowledge, imperfect understanding, estimates, guesses, etc.

Physicists either failed to understand or understood only partially that scientific knowledge inevitably developed as a combinational of logical and extra-logical components (such is the reason for the philosopher's statement that the criterion of practice is always limited, that is, not absolute). The scientific principles (axioms, laws of nature) are determined in an extra-logical manner, they are not absolutely correct at all times, and might be modified as new facts are established. It is only because of that that science is capable of developing. The development of science implies using new experimental data for formulating more general laws and concepts and proving that previously acquired knowledge is relevant to special cases and is valid only under special conditions. It took science the entire 20th century to develop this broader understanding of its development process, though it is still far from been generally accepted (see, for instance, [9]).

Early in the 20th century, most physicists and mathematicians believed that the occurrence of extra-logical components in their sciences was a harmful and irrelevant factor that had to be eliminated. In particular, the great mathematician David Hilbert and the philosopher and mathematician Bertand Russel upheld this concept for mathematics. It was Mach whose writings were instrumental in making this approach prevalent in physics. The approach was supported by the rapid development of mathematical logic and produced a significant benefit for science in that it prompted scientists to analyze carefully the very origins of the concepts and definitions used in physics. That was one of the reasons why Mandelstam paid such scrupulous attention to defining concepts and determining the restrictions applied to them (in particular, in his lectures on the theory of relativity and quantum mechanics).

On the other hand, the predominance of this approach in physics resulted in the preponderance of positivist theories of all types. Einstein had initially been under the significant influence of Mach's concepts but later was abruptly dissatisfied with them. This change can be readily seen from his dialogue with Rabindranath Tagore [10] that took place in 1931. From the text of the conversation, one can see that Einstein was ultimately exasperated with Tagore's insistence on discussing certain matters. Einstein did not allow himself to be drawn into arguing about some subtle points and just kept on repeating arguments like "...this table remains in its position even if there is nobody in the house" [10]. This assertion is a good example of an *extra-logical intuitive statement*. It cannot be logically proven or disclaimed. Einstein merely accepts it as a sensible conclusion drawn

[13] I E Tamm told me once how he delivered a report to a general session of the Academy after which a member of the liberal-arts division of the Academy asked him, "As you have repeatedly mentioned certain beta-rays in your report, was I right in having assumed that there exist also certain alpha-rays and, perhaps, even gamma-rays?"

from experimental evidence, thus admitting that the knowledge necessarily includes *extra-logical intuitive statements*. What did Mandelstam think about that point? Nothing concerning that matter can be found in his published works. However, it was about twenty years ago that Mandelstam's son Sergeĭ gave me three thin school exercise books crudely stitched together with white thread and filled with notes written in longhand. I knew the handwriting very well. It was a straightforward exposition of Mandelstam's views on the above issues. It was written in the last period of his life when he was taken away to Kazakhstan during the war. In a sense it was a summary of his philosophy. We made several type-written copies of the text and kept them secretly in a safe place while waiting for a change in the political regime that would make it possible to publish them.

In his manuscript, Mandelstam insists that a physicist should not attempt to escape analyzing philosophical issues. He goes on, stating that the understanding of objective reality must be built from components that must be incontestable facts. Human feelings and senses produce precisely such facts (Mandelstam uses the word 'feelings' most often). Meanwhile, one cannot ask for a definition of the concept. It is a primary element that should be self-evident to any reasonable person. We do not have any reason to treat the 'entities external to us' as real material entities, we have only the evidence of our feelings or senses about them. *It is only the totality of the evidence of our feelings or senses that can be regarded as objective reality*. What we refer to as the laws of nature are determined by analyzing the correlation of these feeling and senses.

In his conversation with Tagore, Einstein made another assertion. "Even in our daily life we *have* to assign to the objects we use the property of being real independently of us. We do that in order to *establish a reasonable relationship among the manifold of our sense data*" [I have added the italics to the quotation]. This is, obviously, an intuitive statement, too. The difference from the approach put forward by Mandelstam seems to be that the latter does not believe that we 'have' to do that and does not want to do that. This is why Einstein is a materialist thinker. (On the other hand, Einstein stated in the same conversation, "I cannot prove that my concept is right but this is my religion." Of course, Einstein used the word 'religion' here in a purely metaphorical sense; the essential difference between religious faith and a belief in an intuitive judgement in science has been discussed in [9, Chap. 6].) Apparently, we cannot make the same statement about Mandelstam. In his words, when we say 'tree' it has meaning *only* as a brief 'shorthand' notation for the *complex of relevant feelings*.

Even though Mandelstam strove to eliminate any extra-logical statements, he failed to achieve this entirely. For instance, he declares that the complexes of feelings experienced by different people coincide. This conclusion can be drawn from the observation that the external manifestations of these feelings coincide. But the number of external manifestations under study is always limited and we still have to pass an intuitive judgment that the set of responses under study is sufficient, adding an extra-logical step to the cognitive process.

This paper is hardly a suitable vehicle for analyzing the manuscript, which includes many subtle, instructive, and fascinating statements. An appropriate example is the phrase, "I not only do not deny the existence of the external world and its reality but I also furnish the above *definition* for it" (in terms of the complex of feelings). It should be added, though, that one is left with a feeling of dissatisfaction with such an approach.

Einstein put forward the case of a table which remains in the room even when he leaves the room. In a similar way, Mandelstam cites the following. It has been argued that when a 'tree' is defined as a complex of feelings the conclusion that follows is that "the objects of the external world cease to exist immediately after we have turned away from them." This is a 'misunderstanding'. "The complex of feelings which I refer to as a tree includes a feeling of confidence that, if I turn away and do not hear, for instance, the sound of the tree falling, etc. [later Mandelstam adds "feelings produced by the communications from other people" indicating that the tree has not disappeared, etc.], when I turn my head back I shall see the tree again. *This* feeling is an *important* component of the concept of the real tree." The approach seems to be sufficiently consistent. There is still reason for confusion. A feeling of confidence has an origin which differs essentially from that of the feeling produced by sensual perception. A feeling of confidence is a product of the cognitive process in which a limited amount of indirect evidence is being gathered indicating that the tree has not disappeared while each separate component of evidence is not absolute proof by itself. The feeling of confidence emerges as an extra-logical *synthetic intuitive judgment*. It proves to be impossible to escape making an extra-logical *judgment*. Would it not be simpler to make use of it from the very beginning as Einstein did without introducing the concept of the complex of feelings? Physicists and mathematicians had not yet fully understood that by the early 20th century. Rapid progress in mathematical logic produced a major breakthrough in the early thirties when Gödel proved his theorem implying that extra-logical elements could not be totally eliminated from mathematics. As mathematics develops, the need will necessarily arise at some point to select a possible direction for its future development in an extra-logical manner. It has been *proven* that such a situation will arise an infinite number of times. By the end of 20th century, the ongoing analysis of the foundations of mathematics demonstrated that mathematics is full of arbitrary ('intuitive') definitions of concepts that cannot be logically verified. Some scientists have regarded this conclusion as a catastrophe [11] while others have worked out a new understanding of mathematics as one of the sciences, just like physics [11], or even as a part of theoretical physics [12].

Mandelstam's style of thinking was shaped in the period when the above reasoning was largely alien to the prevailing disposition in science, when the conflicting approaches in the theory of cognition clashed in a confusing atmosphere of irreconcilable differences. It is not surprising that this spiritual atmosphere affected him but he generally tended to accept one of several versions of positivism. Of course, he never exhibited a positivist trend in his lectures; that would have been a suicidal act under the Communist regime. The official Communist philosophers were closely watching scientists and fiercely attacked any alleged *deviation* from the official materialistic ideology. The fierceness of their attacks can be described by the catch phrase favored by guards in the labor camps admonishing prisoners, "A step out of line will be regarded as an escape attempt, I will shoot without giving warning!" One official philosopher felt free after Stalin's death to explain to me their train of thought in such cases: "It was in fact a cause-and-effect sequence of mounting charges: idealistic deviation equals religious leanings, equals enemy of the people, leads to arrest, leads to labor camp, and that is the end.'' The Communist philosophers had, indeed, a highly developed sense of political impropriety, like trained bloodhounds. They kept on sniffing out ideologically suspicious passages in the excellent lectures of Mandelstam and when they found something they attacked it with ferocious zeal. Several research staff meetings were convened at FIAN in the period of 1950–1953, specially dedicated to unraveling the ``ideological errors of Mandelstam and his disciples.'' Mandelstam had been dead already, his disciples valiantly and often boldly defended his 'ideologically suspicious' scientific views but the participants at the meeting inevitable voted overwhelmingly for crushing denunciations of them that could pose a mortal danger to those accused under the totalitarian regime. Many science fields — genetics, cybernetics, physiology — were purged of the best and most original researchers in that period in Russia (scientists of Jewish descent were especially vulnerable as the vicious anti-Semitic campaign unleashed by the Communist regime had reached its peak at that time).

Fortunately, the Communist bloodhounds had only a well-developed sense of scent but a poor education and little understanding of philosophy and science; the really well-educated and competent Marxist philosophers had all perished in the earlier purges. It was easier to rebuff the incompetent accusations.

The publication of the five volumes of the collected works of Mandelstam was initiated in the mid-forties. The editor-in-chief of the publication, S M Rytov, had an exceedingly hard job to perform. The principal difficulty was the preparation of the lecture texts for publication. Some lecture transcripts had been prepared but Mandelstam never had a chance to check or edit them. The principal sources were the very careful and detailed notes made by Rytov, Andronov, and many other physicists at the time the lectures were delivered. The notes had to be compared and a final text had to be compiled for each lecture. It was planned to publish lecture and seminar notes in the last two volumes of the Collected Works. Unfortunately, the political censorship authorities ordered a discontinuation of the publishing project after the first three volumes had been printed. Luckily, S I Vavilov, who always had been Mandelstam's admirer, was the President of the Academy of Sciences at the time and could use his influence to obtain permission to go ahead with the publication. The influence was sustained by several tricks invented by the publishers. First of all, Rytov made some changes in the text passages that had been attacked especially viciously by the ideological censors (that was possible to do because no original text of the lectures existed and Mandelstam's disciples, who knew well his teacher's way of thinking, could modify the texts so that the original concepts remained intact while satisfying the censors. The second trick was to dismiss Rytov as the editor-in-chief and to appoint M A Leontovich to the position (who held a more senior post at the Academy and was not a Jew, which was an advantage from the viewpoint of the Communist regime).

So, we find a very depressing situation: an outstanding scientist, who had made significant research contributions, created an influential school in science, and developed his own philosophical approach in the field, was mortally afraid even to hint about its existence, and had to keep his notes on the subject secret. And all this pertained not to a terrorist conspiracy but to mere scientific problems. Even if the scientist managed to survive, living with 'the noose tightened around his neck' took its terrible toll.

* * *

One may wonder what Mandelstam's attitude was to the totalitarian regime that had shackled the nation, what his political views were. How did he cope with the torment and agony of daily life in that terrible epoch?

We have seen that Mandelstam's life had several distinctly different periods. It started with comfortable and happy years in Odessa, which ended with his expulsion from the university for involvement as a university undergraduate in political disturbances. However, everybody who knew Mandelstam in his mature years in Moscow could see that he was always abstaining from any involvement in public or social activities and concentrating solely on science. Practically all academics in those years were obliged to take part in some sort of public activities controlled by the Communist authorities. Not all academics were driven into such activities by fear of persecution, in particular at the early stage of Communist rule in the 1920s. At that time, academics could be at best 'fellow-travelers' of the Communists, or even their supporters, if they valued the positive developments initiated by the Communist government in Russia (free comprehensive education, revival of the economy which had been practically destroyed in the civil war, rapid progress in science, and so on). In the era of the Great Terror of the thirties, Russian academics grew increasingly hostile to the Communist regime, though they were too terrified to voice any opposition. There was also a certain constant proportion of academics who always did all they could to bring themselves into the good graces of the Communist authorities in order to promote their careers.

With the exception of very close friends and relatives, Mandelstam never opened up to anyone on the subject of his political beliefs.

Of course, he started his career as a researcher when working for 14 years at a German university, where it was an established tradition for academics to abstain from any involvement in political activities or even from expressing any interest in political issues. The tradition was disrupted under the Nazi regime. German academics were simply entirely unconcerned about political life (if anti-Semitism is not regarded as a political issue, though Einstein was very worried about it as such). It would have been unthinkable for the German academics to act as the Moscow academics did in 1911 when about 150 prominent liberal academics resigned from Moscow University in protest against the repressive actions of Kasso, the Imperial Minister of Education. There were, apparently, other reasons for Mandelstam's reticence on the subject of politics.

As a matter of fact, Mandelstam had very firm and definite political views and beliefs, as in his heart he was a dedicated opponent of the Communist regime and its rigid control over both ideological and practical aspects of public life.

Many Russian intellectuals, academics in particular, had been 'infected' with republican and even Socialist ideas during the Tsarist epoch and thus tended to appreciate some of the positive features of the Communist system while deploring its most terrible aspects. Some of them, for instance, I E Tamm, had been involved in revolutionary activities aimed at overthrowing the Tsarist regime in Russia. Even after they had lost their links to the revolutionary political movements they still continued cherishing some of the Socialist ideals of their youth. Other academics, for example, S I Vavilov, had been initially enthralled with the positive aspects of the Communist regime but later changed their attitudes. There were academics like L D Landau who had been so fascinated with the splendid Communist-professed ideals in their youth that they remained ardent supporters of the Communist regime for almost twenty years. The period of the Great Terror in the thirties typically put a cruel end to such illusions (often at great personal suffering) as they discovered the true nature of the regime and became 'inner emigres'.

In contrast, Mandelstam had understood everything about the regime from the very beginning. Even though he had been involved in the left-wing political student's movement in his youth, he then lived for a long period in comfortable Europe and, on returning to Russia, he had lived through the appalling shocks and trials of the Communist revolution and the horrible years of the destructive civil war. Thus, he immediately had recognized that the Communist regime was entirely alien to him. He had deeply hidden his disgust with Communism and never admitted it in his lifetime. Now that Communism has crashed, we can examine the remaining evidence of his hate for it. For instance, as early as December 1922, Tamm wrote in his letter from Moscow to his wife about Mandelstam (at that time he had a consulting job with the Electrotechnical Trust in Moscow). "[Mandelstam's wife] says that he is extremely high-strung and she is very worried about him... Incidentally, he is so disgusted with everything done by Communists even though he is doing very well [apparently, the inference is that Mandelstam had fairly comfortable living conditions for the first time after the years of starvation in Odessa] that the disgust manifests itself in an extravagant fashion; for instance, when he had to eat supper at the same table at which a Communist sat (even on the opposite side where there was no need to talk to him) he suffered a nauseating headache all the following night even though he said the Communist had been decently behaved!" [13]

Of course, Mandelstam did not exhibit such a painful reaction to Communists and such an extreme disgust with them throughout the years he lived in Moscow. In the period Tamm's letter refers to, Mandelstam was exhausted with earlier hardships and his responses were somewhat obsessive. One of his closest disciples and a good personal friend was S E Khaĭkin, who was an ardent Communist who had fought in the Red Army during the civil war (he was to be bitterly persecuted in one of the political purges in subsequent years). Mandelstam had a very warm relationship with the prominent Communist Gessen. A zealous Communist M A Divilkovskiĭ was one of the last graduate students supervised by Mandelstam. I think, though, that Mandelstam could never forgive him for his savage attacks on the scientists whom he accused of being close to the 'enemy of the people' Gessen during the purges of 1936 – 1938. Perhaps Mandelstam could hardly endure his company but for his high professional competence and dedication to research work.

In his daily life Mandelstam inevitably tended to ignore completely any issues that could have political implications. He might say about himself what some Germans kept on repeating in Hitler's Germany: 'Ohne uns!' (that is, without us!).

The absolutely definite political beliefs and unshakeable moral integrity typical of a Russian intelligentsia, reinforced by his European academic experience, empowered Mandelstam to establish a psychological stability that helped him to overcome the tensions caused by his extreme sensitivity and private inhibitions (it was probably only the people closest to him who were aware of them) as well as by the hardships and dangers prevalent in the outside world.

He had what could be called an 'almost happy' life in the last twenty years of his life, after he had settled in Moscow. He dwelled in an 'ivory tower' protected by his great fame as an extraordinarily active and productive researcher and a fantastically successful teacher whose students rapidly developed and soon emerged as outstanding scientists (his brilliant lectures could be called a celebration of his research and teaching genius) and shielded him with their love and respect from the unspeakable terrors of the outside world. His mind had not lost any of its sharpness with the years.

An apt illustration is given by a story told by I E Tamm [2, p. 134]. It is well-known that Einstein believed that the quantum mechanics created in 1924 – 1926 (and still being developed and widely used in our day) had been started on rather imperfect foundations, even though it was he who had introduced the concept of the light quantum in 1905 and thus can be regarded as one of the creators of its primary foundations. In order to prove this deficiency, he kept designing various experimental schemes in which, he believed, a quantum-mechanical interpretation would have given an incongruous result, hence giving rise to a paradox. He continued conducting this debate for years in the press and in person, mostly with Bohr as his opponent. Bohr carried out an in-depth analysis of Einstein's paradoxes, the last two of which were particularly complex, and wrote separate papers for each paradox with a satisfactory explanation. Tamm writes, "Mandelstam never published any responses to Einstein's paradoxes because it would have been inconsistent with his research style but he used to present to his disciples a comprehensive interpretation of a current paradox a day or two after receiving a copy of a journal with the relevant paper by Einstein." Tamm told his friends privately that when he and others had tried to convince Mandelstam to publish his interpretations, Mandelstam just smiled and said that Einstein and Planck were intelligent people and, probably, knew it all by themselves (An interesting contrast to Mandelstam's behavior in his early debate with Planck, mentioned above).

Those years were almost happy, indeed, if one ignores such 'minor' circumstances as the peak of the totalitarian terror, the emergence of the Nazi regime, and the terrible years of war in which many millions of Russian lives were lost, maybe only marginally more than in the years of Communist repression.

The Moscow Zoo has a terrarium where one can see snakes quietly lying in their niches in the wall behind the thick glass. A huge well-fed python sleeps peacefully under a low-hanging electric light bulb. Small mice, the python's next meal, huddle under the bulb, enjoying the warmth. The mice are indeed happy as they are not aware of their future. People in Russia under the totalitarian Communist regime of the twenties, thirties, and later years were less fortunate.

* * *

What impressions did one gather while observing Mandelstam in his everyday life in those 'almost happy' years?

In August of 1938 my wife and I rented a private room to spend our vacation period at the resort town of Teberda in the hills of the Northern Caucasus where a very good government-owned sanatorium for academics was located. Mandelstam, Papaleksi, and Tamm were taking their vacations at that sanatorium at that time. One day my wife and I were obliged to follow the approved holiday routine and start on a mountain hike to see some boring mineral water springs. The hike proved to be exceedingly tiring. I was already quite exhausted when an unusual procession appeared before our eyes. It was Mandelstam and Papaleksi on horseback returning from the springs. They were both about sixty but they looked quite gallant in the saddle. We had been acquainted slightly with them, so we stopped and they smiled somewhat shyly. Perhaps my memory of that meeting is rather hazy after so many years, however, my recollection is that Mandelstam was wearing a characteristic outfit of a gentleman on horseback from an early-20th-century magazine photograph, complete with a riding crop. We immediately asked Mandelstam how far we still had to go to our destination and he answered soothingly that there was only a little distance left. When we parted we momentarily felt more vigorous but gradually the vigor grew depleted as there seemed to be no end of the road in sight and the weather was unbearably hot. It took us at least an hour and a half to reach the springs.

The next day I visited Tamm at the sanatorium where I bumped into Mandelstam and could not help asking him why he had lied to us the day before about the distance we still had to cover to complete our hike. The answer was a disarmingly gentle smile and an explanation, "When one sees that a person is so exhausted, how can one tell him that there is still a long way to go?" There might be a special perspective in this explanation: he apparently just could not imagine that a person could be capable of changing his target and refrain from an attempt of reaching a goal. We were perfectly capable of turning back at that point of our hike, however.

A little more than five years had passed since that meeting, but those were war years. Mandelstam was in poor health, he could not go outside the house. He was very depressed, his days were numbered (he died on November 27, 1944). Once I was talking to his son who said that his father loved listening to classical music, for instance, Beethoven's quartets, and he missed it. An opportunity to listen to music could have cheered him up but good gramophone records were scarce and tape recorders did not exist at the time, of course. My wife and I were very pleased to know that we had an opportunity to assist Mandelstam. My wife was a teacher at the Moscow Conservatoire at the time, and she often borrowed records from the rich record library there for her classes and was confident that the library administrator would allow her to take out any records for a short time. The distance from the Conservatoire to Mandelstam's apartment house was less than 500 m; we just had to find out what records Mandelstam would like to listen to and we could bring them to his home on short notice. We received an entirely unexpected answer from Mandelstam's son that borrowing records for personal use from the Conservatoire library was unthinkable for Mandelstam. He said, "It is inadmissible to use state-owned assets for private needs. Only those persons for whose use such assets are officially intended may use them." We were told it was his firm principle that he had never violated.

I mentioned that Mandelstam's apartment was in the university building and a door led from it into a corridor of the Institute of Physics. Many times a day Mandelstam, his family members, his friends, disciples, and coworkers passed through that door in both directions. Mandelstam's apartment was in a sense regarded as an integral part of the Institute. In fact, when passing through the door one crossed an invisible boundary. Mandelstam's son explained to me, "Do you think if our radio was malfunctioning and I needed an instrument to check the voltage I could borrow one from a laboratory down the corridor just for a moment? My father would be furious. His fundamental principle was that any state property was out of bounds for private use."

I O Vilner, a close friend of the Mandelstam family, tells a similar story [2, p. 207]: "Once I dropped in to see the Mandelstams and he said he would like to go to observe a tennis game but he was not feeling well. He was too ill to use public transport and I went out in search of a taxicab. [Taxicabs were a rare luxury at the time.] I failed to find one so I suggested phoning the garage of the Academy of Sciences and booking a limousine [as a full member of the Academy Mandelstam had that privilege]. Mandelstam responding to my suggestion with a scorching look that made me meek with embarrassment, "What kind of nonsense you are suggesting! To go out to watch a tennis game in an Academy limousine, indeed! How could you even think of it?"

That was many decades ago and much has changed in the world. It proved to be quite easy to replace the old-fashioned mechanical watches with state-of-the-art electronic digital watches. The 'old-fashioned' moral principles and ethical integrity exemplified by Mandelstam remain unchangeable, though it has proved to be hard to preserve them untarnished.

I was always impressed with the contrast between the mildness of his manner and the inflexibility and absolute definiteness of his statements and actions, a contrast that was noticeable under all circumstances — in everyday life, in situations involving general ethical conflicts, and in research work.

Mandelstam's inflexible moral standards were the proven standards of the Russian intelligentsia of the 19th century, as depicted in the writings of Chekhov. These standards had been distorted under the Communist regime and even betrayed by some of the intellectuals terrified by totalitarian persecution or searching for privileges. There were other, less perfect than Mandelstam, guardians of the noble moral standards who had largely preserved them and the entire great national culture. What will happen to these standards in the new age in new Russia?

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