L.I. Mandelstam

Chapter 1

MANDELSTAM, Leonid Isaakovich (1879–1944)

1.1 Progenitor

A right-hand door under a dust-laden bust of Newton opens in a massive wall of a big physics auditorium in an old building of the Physics Faculty of Moscow University (still standing in Mokhovaya!). A relatively tall, slightly stooping, still dark-haired but already aging man in a dark suit enters the auditorium together with a group of people. Under an unbuttoned jacket which is hanging, due to his round-shouldered figure, one sees a waistcoat. In the waistcoat pocket the man has a watch that he will later check. On the nose he has frameless pince-nez which clip on to the nose bridge. He has soft cheeks and chin with rare but massive deep folds on the cheeks. A flat bag in the hands, he hastily stops behind the end of a ten meter long desk that separates the audience from the lecturer. Behind him are two big blackboards covered by black calico, which one can move, with a slight bow, by rotating by handle a glittering wheel below to the right, and a moving giant white screen between the two blackboards. The entourage (Igor Evgen'evich Tamm, Grigori Samuilovich Landsberg, Mikhail Aleksandrovich Leontovich, Boris Mikhailovich Gessen [philosopher and historian of science, a dean of the faculty at the beginning of the thirties until his, characteristic to these times, death], some more people) rush to their places in the first row. This is a row of chairs specially placed for today in front of the steep amphitheatre which, having altogether about four of five hundred seats, is full and buzzes, but sharply fells silent — a usual accompanying sound of the beginning of a lecture of a respected lecturer. Mandelstam starts at once.

Although he speaks with quite precise phrases, but he begins somewhat awkwardly. Something apologetic in his tone and even pose will also burst open later. However, he gradually warms up and reaches the state in which the only thing that is relevant for him in the world are the words spoken, the thought expressed. His voice is slightly nasal, not loud, and only the wonderful acoustics of the auditorium (subsequently reconstructed and now, unfortunately, non-existent), a clarity of the structure and contents of every phrase make this voice understandable, even for listeners in rear rows. Mandelstam does not make slips while speaking, does not need to correct himself, he pronounces only something he is sure upon and has been thought of. But, until the end of the lecture, he does not leave the saving spot between the end of the desk and the blackboard behind him. On the desk he places his lecture notes which he sometimes bends over or which he, having taken off the pince-nez and holding them with a hand somewhat aside, brings closer to near-sighted eyes. This combination of clarity and firmness in something important and softness of behavior is, as we shall see, characteristic of him. His entire appearance is a variant of that of a Russian-European intelligent[1] of a pre-revolutionary epoch. His entire behavior is that of such an intelligent, unbending in important matters, understanding and yielding in minor. An extraordinary mind power and a high spiritual, moral culture allows him to understand, better and clearer than others, what is truly important, and what is not. Niels Bohr behaves in the same auditorium in the same way a few years later. And, although the facial features of both are very different, and although in comparison to Mandelstam, Bohr is big-headed with bushy eyebrows and looks somewhat like a clodhopper, common generic features are evident.

This was one of the famous Mandelstam 'optional courses' of the thirties. They continued for many years — on theory of relativity, physical optics, theory of oscillations, quantum mechanics. The very word 'optional' always contains a shadow of being not really obligatory, not really useful. It was however sufficient to start thinking on what Mandelstam was talking about to understand its necessity for a physicist striving to 'get to the very essence'.

Mandelstam lectured in a somewhat 'chamber' manner. His formation as a person took place during an epoch in which science in general and physics in particular was the destiny of only a few. An audience of half a thousand

[1]The word 'intelligent', widely used in this book, means belonging to intelligentsia, a social layer for which education and moral values are equally important. This term is specifically Russian and is in some way related but not equivalent to 'intellectual'.

people which, together with a lecturer, contemplated on fine details of a basis, historical and logical, of relativity theory or quantum mechanics was something new. The issues discussed were, in addition, an arena of loud fighting among ourselves. Although a whole generation of young scientists had grown up, for whom the 'paradoxes' of these disciplines were as non-existent as ones of a round form of the Earth or heliocentricity of the world for those that came after Copernicus, an influence of old concepts in scientific community was still strong. And in Russia an "authoritative" support which some (few in number, but loud-voiced) physicists, anti-relativists and anti-quantumists, got from some high-ranked (but too submissive to an official hard ideology) philosophers heated the atmosphere. Mandelstam did not argue, he quietly clarified. He was not afraid of evoking doubt and then having the pleasure of dispelling it by finding exact argumentation. The wide scale of thought, the boldness of following through an argumentation overrode the 'chamberness' and softness of speech, smile and gesture.

The words were pronounced seemingly evenly, but the voice did not sound lullingly murmuring. There were some significant pauses. Some words were stressed. Having formulated some objection to a theory he would say slightly triumphantly, 'But this is not so!', and on 'not' jump softly, apparently vigorously pressed against an invisible spring.

He had his favorite sayings mainly originating from years of studying and working in Strasbourg. "Hier springt der Frosch ins Wasser (here jumps the frog in water)," he said when coming to express an important and sophisticated idea for resolving a difficult paradox. He liked the expression "put a finger on this" that probably replaced the biblical "to put fingers into the wound" (on a doubting Thomas). All this was somewhat old-fashioned for the young people of the thirties but so organic for Mandelstam that did not seem strange. As a witness and participant of great events in science he often did not distinguish between something that was already not worth explaining to the young audience and something that was really difficult. So, giving a detailed explanation of a notion of group velocity of a wave packet he would clarify it by using a complex image: A moving steamboat with "boys and girls" jumping from the water on the stern, running along the ship, and jumping back into the water from the prow. However it was easy to feel sorry for a student who would become so relaxed in the course of this explanation that would miss the subsequent subtle analysis of the "Fleming error" (found by Mandelstam himself in his younger years) or would not be attentive to a discussion of restrictions imposed by causality requirement on a definition of simultaneity in relativity theory. Here something important

would be missed. This is understood in the first row of the auditorium: A.A. Andronov, S.E. Khaikin, S.M. Rytov, G.S. Gorelik and everybody else, all professors themselves, are diligently writing down the lecture — to a future benefit.

And the auditorium was filled by students and Ph.D. students, not only from the university, but from other places, and also lecturers and professors from many institutes. Here they all lived in a high spiritual world, here reigned a passion and a joy of scientific understanding, a unity in comprehending the truth, a delight of belonging to a scientific brotherhood. Behind the walls there laid the dreadful world of the Stalin era: a world of lies and hypocrisy, a horror of "big terror", an inhumanity. Inside there was a pure honest world of deep thinking and benevolence. A shelter for a person. A temple.

Only after about ten years since that time did I learn how these lectures had been prepared. When working on a five-volume edition of Mandelstam's scientific work I was offered a honorable task of preparing for print a text of his lectures on theory of measurement in quantum mechanics. The original material was in the form of lecture notes, taken by different listeners, of all five lectures given in 1939, in the first place the especially thorough notes by S.M. Rytov (I found my own notes long after these lectures were published). One lecture (the fourth) was taken down in shorthand. Leonid Isaakovich had never seen neither the notes, nor the shorthand and had not checked them. However his extant working notebooks of the period of 1938–1939 were given to me. These were usual thick (relatively disorderly) school notebooks containing much relating to his work in these years: fragments of calculations without comments, some notes with formulae without clarification and, amongst all this, disjoined pieces of the first three lectures that I needed. Leonid Isaakovich wrote them with full phrases, as if preparing them for print. Each such piece existed in several not too distinct variants. One saw that he was essentially writing with ease, with complete, literary perfect sentences. Very little was crossed out or written between the lines. At the same time a multiple reiteration and variation of the whole excerpts, sometimes with mutually exchanging positions in the text, reflected some sort of indecision, a constant doubt in the readiness, in the finality of the written, a constant care on its improvement. A closeness of these texts to the notes made by listeners allowed to trust the notes of other lectures, for which nothing could be found in the extant notebooks, as well.

There exist two types of thinking and writing people. Some are working out, making things more precise, formulating their very thoughts in the

process of writing or discussing or arguing. Others think everything over and make their statements, oral or written, in a quite complete fashion. Mandelstam was probably closer to being of the second type.

The character of Leonid Isaakovich also oozed in these notebooks in the following episode. Each academician had to present a yearly report on what he had been doing during the year (this was done already by Lomonosov). In their majority academicians did not consider this to be something really serious, but rather as something just stealing their time. However also here Mandelstam could not be negligent. Variant after variant of the same report can be found in these notebooks. One gets the impression that this essentially trifling task was tortious and he considered making this report, of one page long, perfect. Let us remember this persevering reiteration. It probably reflects something important in his character.

Let us however temporarily digress from these impressions. Who was Mandelstam in science, why was he infinitely respected, almost worshiped by his students and many colleagues who combined this respect with an admiration of his personality, with a feeling that in many cases could not be defined other than as love?

He was not just a scientist. He was a thinker for whom physics was a way to understand "the nature of things" (in the sense of '*De rerum naturae*' by Lucretius Carus). And, at the same time, physics was an unbounded field of various puzzles arising in the course of studying the concrete physical processes as well as the deep mysteries of nature in general, where Mandelstam was irreversibly taken over by the desire to find the answers and understand their deep meaning. In optics and electrodynamics, in radio- and molecular physics, in quantum mechanics and relativity theory, in general principles of scientific understanding of the world — everywhere.

Besides that, Mandelstam belonged to a rare type of physicist combining a theorist, an experimentalist, an engineer-inventor, a teacher and a philosopher. He was a 'lyric' as well. Mandelstam knew and understood art, adored Pushkin and knew his works at an almost professional literary studies level (a well-known Pushkinist A.B. Derman was his friend). Here are several examples.

As a theorist, based on his experience from studies in radiophysics and optics, he developed a far-reaching general theory of linear and nonlinear oscillations having innumerable concrete applications in various domains of physics and technics. He spoke of an existence of a universal "oscillation thinking". He developed a general theory of an optical image. Based on the newly born quantum mechanics he, together with his Ph.D. student

M.A. Leontovich, discovered a new paradoxical phenomenon, a tunnel effect (see below).

As an experimentalist, he discovered (together with G.S. Landsberg, his junior friend, in some way his student) an important phenomenon of combination scattering of light (the Nobel prize went to C. Raman who simultaneously discovered the effect but did not understand its meaning, see below) as well as other optical phenomena.

As an inventor he owned more than 60 patents, mainly in the field of radiotechnics (half of them together with Nikolai Dmitrievich Papaleksi, his childhood friend who specialized almost exclusively in radiotechnics). As a teaching scientist, not only was he a brilliant lecturer, but (and this could be the most important of what he has done for a development of physics in our country) he created a powerful school of physicists of the highest level, mainly theorists. For example: the, conditionally speaking, first generation (his students and younger scientists) — the outstanding physicists A.A. Andronov, I.Ye. Tamm, G.S. Landsberg, M.A. Leontovich, N.D. Papaleksi, S.M. Rytov; the brilliant S.E. Khaikin, a creator of a principally new system of radio-telescopes (a construction of the first such telescope was completed after his death); an optician V.A. Fabrikant and others. Two among them, talented professors A.A. Vitt and at first his (and then I.E. Tamm's) student S.A. Shubin, had already accomplished much in science in their young years before being killed in the epoch of Stalinist "big terror".

If one takes the next generation of "students of his students", there arises a spectacular geometric progression. In the school of my teacher I.E. Tamm there formed as scientists S.A. Altshuler, V.L. Ginsburg, L.V. Keldysh, D.A. Kirzhnitz, V.I. Ritus, A.D. Sakharov, E.S. Fradkin, S.P. Shubin and a number of other brilliant theorists.

Speaking on the school of Andronov, one of the founders of a theory of automatic regulation, one has to mention not only the names of his closest students and coworkers M.A. Aiserman, N.N. Bautin, A.G. Meyer and others, but also the fact that, together with Maria Tikhonovna Grekhova he was a "founding father" of an institute that subsequently grew into a powerful constellation of scientific institutes in Gorky (Nizhny Novgorod) having international importance. Here, as students, there listened to his lectures A.V. Gaponov-Grekhov, V.S. Troitsky and many other prominent physicists.

Near M.A. Leontovich there grew E.P. Velikhov, B.B. Kadomtsev, M.L. Levin, R.Z. Sagdeev, V.D. Shafranov and an army of not necessarily highly titled, but very significant scientists.

Near G.S. Landsberg there grew S.L. Mandelstam, I.L. Fabelinski, I.I. Sobelman, M.M. Sushinski, V.I. Malyshev and many, many others comprising his giant school of optical spectroscopy — both purely scientific and, infinite in its applications, extremely valuable applied ones.

With this (and other) schools one can recognize, with varying clarity, an easily distinguishable Mandelstam seal — his scientific style, the norms of human relations. A charm of his personality was combining firmness and clarity of principles and opinions with an unusual delicacy. Softness and tactfulness revealed itself, in particular, in *how* he worked together with a young student or colleague. Often, when somebody had brought him a raw or even wrong result, L.I. began, together with the colleague, to improve the work, but did it in such a fashion that the colleague left convinced that he had done everything himself.

As a matter of fact, our theoretical physics of the middle of the twentieth century was created by two brilliant schools, those of L.D. Landau and L.I. Mandelstam, and by an outstanding world-class theorist V.A. Fock (here I do not mention the third, younger, very strong school of N.N. Bogoliubov, at the beginning of his career more a mathematician, which, with an exception of the founder, "came into play" in physics only after the war, in the second half of the century).

Finally, as a philosopher, not only was Mandelstam convinced that a modern physicist can not escape relating his work with philosophical problems (a conviction expressed in an unpublished manuscript that we shall discuss later), but also formulated (in the same manuscript) his position on the theory of knowledge, on philosophy.

Before elaborating on what was said it is, however, necessary to talk about the real facts from L.I.'s life. From them one can see how drastic were the changes in its conditions due to the events of violent times and how he changed himself, living through several sharply distinct periods before becoming, in the last decade of his life, the person described at the beginning of this chapter still remembered by a few living people that knew him.

Leonid Isaakovich was born in 1879, in the same year as Einstein, but also as Stalin (and Trotsky!). More than two decades had passed before he enthusiastically experienced a powerful influence of the greatest scientific genius, and more than four decades had passed before a bloody hand of his contemporary fell on him and the whole country.

He grew up in Odessa, one of the few Russian towns of European type, with characteristic features of a port that had grown on exporting Ukranian bread, with merchants that had become rich on this, with the

ragged dockers and fishermen, bandits, but also with a lot of intellectuals, a magnificent opera building, in which there performed the best singers of Europe. In Odessa that would soon give to the country so many virtuoso musicians who conquered the world, and also writers, the cream of the Russian literature of the period, who are still extremely important at present, and also many scientists.

The father of L.I. was a well-known and successful gynaecologist. Women in labour from the whole Ukraine came to him and in the tram one could hear people ask a conductor for a ticket "to doctor Mandelstam". The childhood and youth of L.I. were serene.

After finishing gymnasium Leonid Isaakovich went to the University of Odessa (at that time the Novorossijskij) but soon was expelled from it because of participation in student political upheaval[2] and went to continue his studies abroad, as did almost all young Russians that took a great interest in science. As did many, he went to a main scientific country of the time, Germany. L.I. had already selected physics and chose the excellent University of Strasbourg, where physics was headed by Carl Brown, one of the founders of radio engineering. Together with Markoni, Brown received a Nobel Prize in 1909 (for "Brown tube", with corresponding improvements this led to an oscillograph, a television set and a computer monitor). Many Russian physicists — P.N. Lebedev, B.B. Golytsin, A.A. Eichenwald and others studied or worked with Brown. In this university there also worked outstanding mathematicians. L.I. became very close to one of them, Richard Mises, a like-minded person in understanding the foundations of statistical physics and philosophy. Another attraction to this university was that Aleksandr Gavrilovich Gurvich (later a well-known biologist), an uncle of L.I., although he was only five years older than his nephew, also worked in Strasbourg. He became a lifelong friend of Mandelstam. Another lifelong friend was Nicolai Dmitrievich Papaleksi, who came to Strasbourg three years later, also to continue his education.

Here L.I. spent 14 years and went orderly through all levels of the scientific hierarchy. He returned to Russia as a full professor (titular professor) at the day when the First World War was declared.

[2]It is interesting that in the autobiography written at the end of 1917 [Frenkel (1997), p. 68], he simply writes "In 1900 I left from the IV semester and went to Strasbourg". Leaving aside an uncertainty in timing (N.D. Papaleksi writes that this was in 1989 [Prokhorov (1979)]), it is worth noting that L.I. does not mention anything about the political background of his "leaving". Why? It is possible that he did not want, out of self-esteem, to create for himself a "good" political past at times of already established Soviet power or, possibly, already wanted to distance himself from it.

It is natural that his first scientific works were done on Brown's theme, radiophysics (which was at that time inseparable from radio engineering). This refers not only to the diploma work containing a result important for radio communication that at once made him known among the experts. Very soon he became "the first assistant" of Brown. This meant that he began supervising scientific work, giving the research topics to young scientists from all over Europe that were coming to Strasbourg. Papaleksi recalls 12 names [Prokhorov (1979), p. 21].

Mandelstam's scientific authority grew. When he obtained a title of a docent with an accompanying right of delivering courses of lectures, Brown himself often attended them and made notes in his notebook. Together with Brown he participated in his works (related to the firm Siemens and Galske) in practical tests of their system of radio-telegraphy. He made an acquaintance with A.S. Popov and other Russian pioneers of radio engineering.

Therefore, at the most important age for formation of a scientist, in particular a theoretical physicist, L.I. studied and worked in one of the best universities of prospering Europe which only at the end of this period began to feel the approach of stormy times. He made acquaintances with many physicists, visited many countries and became in the full sense a European and a mature scientist well known in the scientific world. An illustration is a postcard from Einstein received in July 1913 in which he writes, "Dear Mr. Mandelstam! I have just reported at colloquium your beautiful work on surface oscillations about which Ehrenfest[3] told me earlier. It is a pity that you are not here. With best regards, A. Einstein." On the postcard one sees 16 other signatures of the participants of this colloquium (see a figure in [Prokhorov (1979), p. 59]).

Already from this one sees that in 1913, at the age of 35, Mandelstam went far beyond the borders of radiophysics and radio engineering that remained his first love. On this basis there grew his interest in a theory of oscillations in general, first of all in optics. At that time optics played a fundamental role in understanding the foundations of physics. An appearance of quantum physics was tightly related to it. It was optics where M. Planck introduced in 1900 a notion of quanta, i.e. of a portion — like emission

[3]A friend of Einstein, one of the most prominent physicists of his time, Ehrenfest had not got a job in his native country after graduating from the University of Vienna and at that time worked in Petersburg where he became close to Russian physicists and did much good for developing modern physics in this city. He also kept these ties later, after the revolution. Ehrenfest was very seriously interested in a discussion between L.I. and Planck (see below) and expressed a wish of coming to Strasbourg to work with Mandelstam which at some point came true.

of light and Einstein in 1905 introduced a notion of quanta of light. But then L.I. was interested not in quantum problems, but in those in classical optics, mostly a problem of light scattering in homogeneous medium, e.g. atmosphere.

One should imagine a "childish" situation in this field at those times, when this problem was to a large extent unclear. An illustration for readers who are physicists can be that L.I., following Stark (later a Nobel Laureate) erroneously thought that molecules can scatter light only if being electrically charged [Rytov (1948), p. 121]. At the same time the scattering in atmosphere, assumed to be quite homogeneous, was studied by the Englishman Rayleigh, the physicist highly esteemed by Mandelstam. Planck himself published a paper on this topic in 1902. Mandelstam, however, argued in 1907–1908 that a dense medium can scatter light only if its density is inhomogeneous. This was a correct, deep idea, but its validity was finally proven much later by Smolukhovski and Einstein. And the work by L.I., as is now clear, contained an error[4].

I would ask a non-physicist reader to forgive me such an extensive deviation towards professional issues. It will immediately become clear, why this is essential for understanding the personality of L.I. of that period. Those knowing him only as much more mature, in Moscow after 1925, would be surprised.

The issue is that a young, having had rapidly established a name, L.I. refuted both Rayleigh and Planck by launching (in four papers) a discussion in a tone impossible in later times. At the beginning L.I. was still reserved: 'Therefore it seems to me that to reduce, as done by Planck, an absorption in an optically homogeneous body to scattering by particles constitutes a delusion' [Rytov (1948), p. 118]. In the same paper he objects to Rayleigh (p. 116).

Two and a half months later he publishes another note exclusively devoted to Rayleigh: it turns out 'inadmissible to reduce the blue color of sky to the scattering of light by air molecules themselves' (i.e. individual molecules — E.F.) [Rytov (1948), p. 190], as done by Rayleigh.

Soon (1908) Planck refutes the conclusion by L.I. in a new paper, but L.I. responds and at this time does not restrict himself to a single restrained sentence, but hurls at Planck a flood of attacking statements.

"Mr. Planck in his theory of dispersion answers this question affirmatively. On the contrary, by following two different lines of reasoning I come

[4]I am grateful to I.I. Sobelman for a clarifying discussion on this issue.

to a conclusion that in the optically homogeneous medium such scattering does not take place. In other words, I have come to a conclusion that the Planck model can not provide any understanding of the attenuation of propagating wave in general.

"In particular, in my second paper it was, in my understanding, shown that an opposite conclusion of Mr. Planck should be explained by an imperfect calculation." [Rytov (1948)]

"Mr. Planck considers my calculation to be wrong. From his motivation I conclude that is was not correctly understood" [Rytov (1948), p. 162].

"As shown at the beginning, a principal question of absorption is treated oppositely to Mr. Planck," [Rytov (1948), p. 163], etc.

We have to recognize an important fact: the great Planck objects to Mandelstam on a question that should have been settled after his work. In a few months L.I. publishes a fourth paper filled by equally harsh (but formally polite) phrases. For example, "The settlement of the issue would be much easier if Mr. Planck would want to find a mistake in my calculations as I have done with respect to his" [Rytov (1948), p. 172]. Planck did not respond to this paper.

We see that a young cockerel L.I. just flew up! I have described this episode in such detail on purpose. To all of us who knew Mandelstam in the thirties it is difficult to believe that he could be so opinionated, could behave in such an aggressive way. In all recollections of his students and colleagues, simply those having known him, the first quality mentioned is his softness, pliability, nice smile, immediately-acting charm, modesty. And all this is literally true. One knows an episode at the Fourth Congress of Russian physicists in Leningrad (1924) narrated by I.E. Tamm to V.Ya. Frenkel [Feinberg (1992), p. 366]. There was a discussion on the talk by Ehrenfest concerning one difficult question from optics. Tamm sat next to Mandelstam somewhere higher than the tenth row of the auditorium ascending as an amphitheatre. At some moment Ehrenfest said, "Let the most prominent expert on optics Professor Mandelstam express his opinion on this issue" and started to search for Leonid Isaakovich with his eyes. Mandelstam, strongly embarrassed, to Tamm's astonishment literally slipped down the bench so that he could not be seen from below where Ehrenfest was standing.

But then, in his younger years, the above-described episode of L.I.'s opinionated aggressiveness was not the only one. In the same period the English radiophysicist and radio engineer Fleming published two papers on a question that L.I. also worked upon. L.I. immediately pounced upon

Fleming, found errors and concluded, "... although Fleming considers in both papers the same case, he arrives at different (in both cases erroneous) results"; "Fleming uses the formula (3) keeping the terms of the second order which is clearly inadmissible and makes the above-mentioned error in sign" [Rytov (1948), p. 141]; "Summarizing the above discussion: the calculations by Fleming are wrong" [Rytov (1948), p. 149].

We see that he did not spare accusing phrases, did not soften them when talking again and again about the author's mistake. This is so unlike the "Moscow" Mandelstam!

Whereas the critique of Fleming was essentially grounded, in the case with Rayleigh and Planck this was not quite so.

I dare make a (perhaps too bold) suggestion that *a realization of his error and of an inadequacy of his behavior in younger years exerted a big influence on L.I.'s later life, both scientific and everyday.*

It is well known how insistently did he demand from himself, his students and coworkers to repeat and make more precise experiments, calculations, understandings. On more than one occasion this costed him dearly. In such a way, essentially because of their usual style of behavior after obtaining a new result and its publication, he and Landsberg did not get a Nobel Prize for a discovery of combinational scattering of light (Raman effect).

A student and a collaborator of G.S. Landsberg of many years, I.L. Fabelinski witnesses.

"Investigations of G.S. Landsberg and L.I. Mandelstam were always characterized by particular thoroughness, carefulness, deep understanding of a studied subject and deliberation in publishing the results obtained. Moreover, when the work was completed and even written for publication, it was put for some time into a desk drawer. For the case if a different idea would come into head or it would be necessary to make the text more precise or change nuances in argumentation. And in general, it was necessary that everything had settled, after that one could send the paper for publication".

"At the same time (continues I.L. Fabelinski. — E.F.), ... after working with G.S. Landsberg for 20 years and having discussed the questions related to the origin of the new phenomena (discussed in this chapter. — E.F.), I never heard that G.S. Landsberg regretted their line of behavior" [Fabelinsky (1978), p. 6].

Precisely this style showed itself in the story of the discovery of combinational scattering and of not getting the Nobel Prize. Having had made reliable observation already on February 23–24, they first sent a report for publication only on May 6, after having had fully understood the essence

of the phenomenon, developed its theory and been convinced that their observations agreed with theoretical predictions. Because of this Raman, who sent a report into a journal right after getting the first result, although having an incorrect understanding of the essence of the phenomenon at that time and in the two subsequent publications, was ahead of them *in publication*.

In fact they had observed the effect in the experiment even *earlier* than Raman.

This is clear from a letter by L.I. sent to O.D. Khvolson. Answering his direct question L.I. wrote: "We first noticed an appearance of new lines on February 21, 1928. On negatives dated February 23–24 the new lines were already clearly seen." (see below, Fabelinsky (1978), (1998), (2000), (1982)).

Raman, in his turn, wrote (in the *Indian J. Phys.*, p. 287, 1928): "First time we noticed an appearance of new lines on February 28, 1928. The observation was made public". Thus the first actual observation of the new effect by Landsberg and Mandelstam (*not* the date of sending a report for publication and *not* the publication date) *was ahead* of the observation by Raman at a week[5].

It was already mentioned how, in the course of preparing his lectures in the thirties, L.I. many times rewrote in his notebook almost the same fragments. In such a way he sort of sealed and established his confidence in the correctness of what was written, in the perfection of the form. He always strived for completeness, overcame his uncertainty. In his mature years everybody knew him as a quiet expert, always definite and assured in his statements, and only the members of his family (they told me about this) knew how he suppressed a neurasthenic in himself. On lecture day his condition was awful. At the lecture itself, however, no traces of this could be spotted[6]. When he had to go to Leningrad in the evening then, as known only by the people closest to him, the clocks in the house were put one hour ahead so he would not be late.

[5] I am grateful to I.L. Fabelinski for full clarification of this issue.

[6] However, it is worth paying attention to some sentences at the beginning of this essay: "He hastily stops behind the end, of a ten meter long desk" (p. 5) and "..until an end of a lecture, he does not leave the saving spot between the end of the desk and the blackboard behind him" (p. 6), and also "Something apologetic in his tone and even pose will also burst open later" (pp. 5–6). They are taken from my very brief recollections of 1979 ([Feinberg (1992)], see p. 235, line 13 from below and p. 236, lines 5–6 and 13–14 from above) and were written 20 years before I learned about his neurasthenia. It is possible that I felt its signs already then. It is like written by Fazil Iskander about a boy Chick: "He knew it, but he did not know he knew."

I was told about only one episode in which he exploded. In his office he had a discussion with his favorite young student A.A. Andronov. Suddenly Andronov, with a crimson face, rushed out of the office and through the common office, where there were other people, and ran away. The breach with L.I. lasted for several months but then, of course, everything was settled. One assumes that a young, then of pro-communistic views, Andronov tried to turn L.I. to his beliefs, provoking his fury.

But was Mandelstam always unerring in science? Alas, those writing about Mandelstam, justly enraptured with him as a physicist of an exceptionally high class, with what he accomplished and his scientific work, with creation of such an amazing phenomenon as the Mandelstam school with its successors, with his charming personality, often create an impression on some never erring deity. We have already described a story with the scattering of light in opaque media. A mistake was that at that time, before Smolukhowski, neither he, nor other physicists knew about an existence of (density) fluctuations in continuous media (Rayleigh obtained the correct formula in some sense by chance). Characteristically, in the 5-volume collection of the Mandelstam scientific works the corresponding papers are not commented upon and the partial fallacy of his position in a dispute with Rayleigh and Planck is not mentioned (although L.I. himself understood it and a later paper on other subject contained a piece on Rayleigh's rightfulness [Rytov (1948), p. 146]).

There was another case when following an idea by Max Laue (who received Nobel Prize for this) his younger students, studying in 1913 a scattering of X-rays in crystals arrived at a result which (as especially clearly shown by L. and G. Braggs who received a 1915 Nobel Prize for this) proved that rays are oscillations, waves, and not a flux of particles which could have been the case[7]. Mandelstam, not waiting for Bragg's result, put forward an assumption that the observed scattering of X-rays was caused

[7] A curious episode (completely unrelated to L.I.) was told to me by Yu.B. Rumer, a well-known physicist who lived in the twenties in Germany and thus knew much that remained unpublished. "Then, in 1913, it still remained a long time until quantum mechanics and physicists did not know that a flux of particles has wave properties as well. At the nearest meeting of German physicists one of the participants told Laue that to fully prove the wave nature of X-rays one should repeat the same experiment with a flux of electrons and convince oneself that in the latter case the scattering does not give a Bragg picture. However, as agreed by both participants of the conversation, this was surely unnecessary". In reality the wave properties of electrons could lead (at appropriate electron energies) to the same picture as with X-rays. Would not the wave properties of electrons had been discovered 10–11 years before it actually happened?

simply by microscopic cracks on the crystal surface and even tried to prove this experimentally, mentioning in the same paper that *a described experiment is still not completed*! Can one imagine that in a paper by "mature", "Moscow" Mandelstam there appeared argumentation based on an unfinished experiment [Rytov (1948), p. 242].

Could one, should one accuse Leonid Isaakovich for such mistakes? This is a principal question for a scientific researcher which is fully answered by a brilliant aphorism by V.I. Vernadski (in his diary before the Second World War): "A freedom of creative work is a right to err". And this is undoubtedly true. There erred a great Newton who considered light to be a flux of classical particles. There erred a great Maxwell who believed in the existence of an all-penetrating mechanical ether and thought that his ingeniously guessed "displacement current" introduced into his theory of electromagnetism reflects a real displacement of ether particles (that was not only wrong but reflected a retrograde understanding). It is absurd to reproach Mandelstam for the mistakes of his younger years.

A.A. Andronov in his unusually capacious and meaningful characteristics of L.I. [Frenkel (1997), p. 190], writes, in particular, that L.I. "... did not like making mistakes and almost never erred. When having made a mistake, and this happened very seldom, then, when he realized that he had made a mistake, he became very anxious about it, started calling you or asked, through other people, to visit him to improve a little mistake". Andronov, however, knew Mandelstam only after 1925. A great Turkmen poet of the eighteen century Makhtumkuli characterizes, in his verse "Humanity II", distinctive features of each decade in human life in their turn [Makhmutluli (1948)]. In particular, he writes[8]:

> At twenty life is not the same,
> Bursts away a youthful flame,
> Every day he's drunk with dream,
> Every moment captures him.
> At thirty is his life diverse,
> With temptation's idle growth,
> He is thinking clear though
> He has understood himself.

(In the period of disputes with Planck and Fleming, L.I. was 25–30 years old.)

[8]Translated into English by A. Leonidov.

Youth experience is cheap,
No medicine when eye's not sharp,
Thoughts cohere only at forty,
With life experience in veins.

In 1914 Mandelstam was 35 and by the time of his return to Russia, almost at a doorstep to an age of 40, the Greek *akme* (flowering, flowering force), an experience of life had penetrated into the veins of this remarkable man. He had already "comprehended himself".

And here the epoch delivered him a heavy blow. There came an 11-year period in which all this "flowering" could not be realized in the fruitful scientific work for which he was destined and so well prepared.

A young but already experienced, "having comprehended himself", talented scientist known and cherished by a scientific world even embodied by its highest representatives such as Einstein and Ehrenfest, Sommerfeld, Brown and Mises, a thoroughly educated European at the peak of his creative power returns to the motherland, to Odessa, after 14 (15?, see the footnote on page 18) years of absence. First of all absurd delights of tsarist Russia pounced upon him. To have the right of lecturing in a Russian university one had to have a Russian master's degree. To get this he had to defend once again a thesis, and for this to get a diploma (L.I. did not have such a one). Thus formally L.I. was a nobody. However the university charter contained certain reservations and the Novorussian university elected him as a private docent in physics. This was a non-permanent staff position of an instructor who was allowed to conduct seminars and even deliver lectures but usually on optional, facultative courses. Besides that an approval of the minister of education was required.

It is clear that in such conditions L.I. could not launch real scientific research so at the end of the year he undertook a decisive step by accepting an invitation from Siemens and Galske firm in Petrograd (with which, as already mentioned, he and Brown had already collaborated) to become a consultant on their radiotelegraph plant[9].

Two war years in Petrograd were filled with consultations on research development, sometimes down to purely engineering, to working out a

[9]Let us notice a curious detail: this was a German firm (perhaps under temporary administration by the Russian government or temporarily confiscated) and this was a time of war with Germany. After 30 years already after the death of L.I. this provided, in the disgusting after-war soviet atmosphere of the attacks on "low bowing towards abroad" and state antisemitism, a ground for some careerist physicists to accuse L.I. in spying for Germany (!).

technology of wire oxidation, construction of rheostates and launching their production. A future coworker of Mandelstam and Papaleksi, E.Ya. Shegolev, who also worked there, recalls [Prokhorov (1979)] that this work was also done by L.I. with such a brilliance that not only did he get patents for his inventions, but the sagacity of his approach evoked an admiration of radio-engineers. At the same time he generously shared fruitful ideas. Here his "third" above-described talent, that of an engineer-inventor, showed itself. This was, however, not the kind of science his soul was longing for.

At the end of 1916 L.I. approached one of his friends, T.P. Kravets, with a letter in which he recognized that without having a Russian scientific degree, scientific work would probably be impossible. He asked for help in getting the degree without passing an exam and defending a thesis, replacing it by some of his published papers (why had not he done this before? Perhaps he had considered this humiliating? Or, as it had always been in the past, new exams would have become a tortuous experience for his weak nervous system?). Kravets, a cordial person, answered with a warm brief telling [Prokhorov (1979), p. 6], that he had already discussed this issue with a radiophysicist from Kharkov, Professor Rozhansky[10], and had found out that such a possibility is granted by the University Charter: a scientific council had the right of approaching, with a corresponding application, a Ministry of Education. "For some reason the physicists used this option most often and it was in this way that P.N. Lebedev, N.P. Kasterin, A.G. Kolli and A.A. Eichenwald (who had also studied abroad) got a scientific degree", writes Kravets.

I am describing this in such detail to show a corporate solidarity of Russian intelligents-physicists, although we will soon meet with an opposite phenomenon during Stalin times.

There came, however, a year of 1917. After the February revolution the disturbances, fueled by a diarchy of an Interim Government and Soviets, grew, the food in Petrograd was becoming scarcer and scarcer and a winter of cold and starvation was looming ahead. Many who could, including scientists, tried to leave for the southern provinces, at that time still quiet, warm and having plenty of food. L.I. was simultaneously invited by the Council of Tiflis University and the council of the private Polytechnic Institute in

[10]This person is also worth mentioning. Later, in 1931, when working in a Leningrad institute of A.I. Ioffe he dared *not to vote* at a staff meeting for a demand of capital punishment for another group of "people's enemies" (from "Prompartiya"; even a tribunal did not sentence them to death by shooting). Rozhansky was sentenced but, thanks to the efforts of influential Ioffe, his imprisonment was not long and he survived.

Ekaterinoslav and was elected as an acting ordinary professor of physics. He chose Tiflis and was approved for this position by the Minister of Education in July. In the autumn of 1917, L.I. moved, together with his family, to the Menshevist Georgia which, in May 1918, declared itself an independent democratic republic. However, here there was also no peace. Already in the first half of 1918 there were Bolshevist uprisings around Tiflis and in June, due to a treaty with the Menshevist government, German troops entered Tiflis. However, in November the First World War ended and in December these were replaced by English troops.

It is easy to understand that already in the autumn of the same 1918, a year before the bolshevization of Georgia (as in many other cases it was simply a capturing of Tiflis by the Red Army waiting at the Georgian border and "coming to help" a bolshevist committee organized in the city that declared itself a government with the menshevist one still being in power) L.I. preferred to be in a native although, as it turned out, even more starving and, in addition, freezing and having been torn into parts by changing authorities. Odessa, first Soviet, it was after some time occupied by Germans and a Ukranian government of Skoropadski supported by them, then again taken by reds, then by a White army of Denikin. Then it followed a French Entente intervention. Around the city raged Makhno, "Greens" (not to be mixed with modern ones), Petluyra.

Finally, Odessa became Soviet. After the expulsion of Vrangel from the Crimea, the Civil War in the south came to an end.

In these conditions one could not even dream of a quiet atmosphere and scientific work. Still, an appearance of many professors and students from the north allowed, even in these circumstances, the organization of a new Odessa polytechnical institute. L.I., together with friends who also came there, actively participated in it. N.D. Papaleksi became head of the physics chair. Astonishingly it turned out possible to assemble relatively good laboratories and deliver lectures in the freezing auditoriums. L.I. was a brilliant lecturer ('talent number 4'). It is sufficient just to look through his introductory lecture on a topic "Why engineers need physics" [Prokhorov (1979)] to see his talent.

When the soviet power was already established there arrived a yet unacquainted, but recommended by A.G. Gurvich, young (16 years younger than L.I.) Igor Evgen'evich Tamm who became a lifelong closest student, friend, colleague. Together with his wife, Tamm settled in the house of the Mandelstam family where they occupied an empty room of A.S. Isakovich, a brother of L.I.'s wife. The room was empty due to a then usual reason.

Its inhabitant was imprisoned by Cheka, probably because of being a "burzhui". He was a lawyer, had contacts with an international "Society of Indo-European Telegraph" and was relatively wealthy. In a few months or a year he was released. At the same time, saving themselves from starvation and in order to get additional payment and food rations, Leonid Isaakovich and N.D. Papaleksi organized, at a radio-telegraph plant, a "vacuum artel" producing radio valves. Its staff included radio technicians and the new friend I.E. Tamm.

It is easy to understand that a prolonged absence of regular scientific work tormented L.I. It is however equally clear that it was impossible to fully stop his head from working. As we saw, already in Strasbourg he expanded his scientific interests in the fundamental issues of optics (a remarkable mathematical theory of optical images, etc.). It was in these starving years (N.D. Papaleksi writes, in 1918 [Prokhorov (1979)]) that he understood that light scattering in the medium can occur on elastic waves creating a necessary inhomogeneity. Then it should be accompanied by a small shift in the frequency of the scattered light. In other words, a spectrum of this light should contain two lines, not one. This work was however published only in 1926. Clearly, such pause could not be explained only by the Civil War conditions. Probably, the L.I.'s hesitation played a role here. He was sure that calculations were correct but could also doubt a necessity of publishing an article predicting a very small effect (the frequency change should have constituted 0.003 percent) before it could be verified in an experiment. This turned out possible much later, in a completely new period of L.I.'s life. We shall return to this later. Here we just note that independently this effect was predicted in 1922 in France by a French physicist L. Brillouin. Therefore in physics it is known as a Mandelstam-Brillouin effect. Its studies continue even nowadays. Using lasers it turned out possible to explore it in more detail and use it in other studies, also for applied purposes.

This theoretical work of 1918 was for L.I. the only one in the first eight years of living in Russia. This did not alter a general situation of isolation from scientific research. Therefore when, in the summer of 1922, a transition to NEP[11] had already begun making its beneficial influence on a real life of the country, L.I. accepted an offer from a board of an electrotechnic trust of weak current plants (a NEP child!) to supervize (as a scientific consultant) together with Papleksi the scientific and scientific-technical research in the

[11] New economic policy. A.L.

Moscow radio-laboratory of the trust. In October, L.I. Mandelstam and his family and N.D. Papaleksi moved to Moscow. Soon (in March 1922) L.I. made a scientific trip to Germany where he met Einstein and many other scientists and returned to Moscow with a baggage of scientific news from the nine years of his absence and the newest scientific literature.

The next year the laboratory moved to Leningrad where L.I. had much better conditions for work but ... only on radiotechnics. Certainly this was also important work for him as in this field he had made, with Papaleksi, many useful things (new ways of radio-telegraph and radio-telephone communication, frequency stabilization, etc.). However, there remained a question: Why had the best universities been silent? Is it possible that when L.I. was in Moscow (1922–1924), the Moscow University did not realize what a promising possibility was at hand?

At that time a physics faculty of MSU (just separated from that of physics and mathematics) was in a state of despondency. When in 1911 P.N. Lebedev (together with the best professors from other faculties) had resigned, the level of teaching and research work had sharply declined. Many rooms of the wonderful newly-built building of the physics faculty were simply empty (this was in the twenties). It is true that also in the NEP years there remained several true physicists (a corresponding member of the Academy, Lebedev student V.K. Arkadjev and his wife A.A. Glagoleva-Arkadjeva; a young N.N. Andreev who had just graduated from Basel University; equally young G.S. Landsberg, S.I. Vavilov, S.T. Konobeevski). However, not them, but quite different people determined a general level and, most importantly, its general inadequacy with respect to the comprehensive scientific knowledge. For example, the only course on a special theory of relativity, created in 1905, was given in 1918 by N.N. Andreev (at that time the only case in Russia!). The majority, even when including some gifted people, fought with relativity theory and later with quantum mechanics with all means, tried to "simplify" these disciplines, already reigning in the world, down to the level of notions of classical physics. Some of them declared the new physics to be a bourgeois distortion of science.

At the same time not only the best young professors (S.I. Vavilov, G.S. Landsberg, N.N. Andreev and others), but also other young people, students and Ph.D. students that were highly sensitive to new tendencies felt a clear dissatisfaction with this situation. At the faculty there began a furious struggle for making an offer to Mandelstam. Among the argument "against" were also anti-Semitic ones (these were at those times

not common at all). S.I. Vavilov, visiting his friend G.S. Landsberg whose apartment was at that time in the yard of the university building, told him, with hands perplexedly stretched out: 'P. told me, "How don't you understand, Sergei Ivanovich, that if Mandelstam comes, he will bring others like him, of his kind". I do not understand such people'.

At that time an important role in decisions on all issues was played by the young. Students, Ph.D. students (A.A. Andronov, M.A. Leontovich and others) essentially influenced the positive decision on the matter. In 1925 L.I. finally became a professor, a head of theoretical physics chair of the physics faculty and a staff member of a then existing at the faculty scientific research institute, NIIF. Soon the responsibilities of the head of the chair were transferred to I.E. Tamm. There began a totally different life.

Leonid Isaakovich, together with his wife Lidia Solomonovna and his son Sergei Leonidovich, who later also became a physicist, obtained an apartment with three large rooms in the building of the physics faculty. Its important distinctive feature was that along with a "parade" exit to the stairs common for all the professor's apartments and separate from the auditoriums and laboratories it had another exit directly to a corridor at the first floor of the "working" part of the building. Right behind this door there followed, one after another, those to the rooms of the laboratory of G.S. Landsberg and others. Straight ahead was a X-ray laboratory of S.T. Konobeevsky, etc. For sure at those times there were no guards at this door and a communication of the apartment with the rest of the building was completely free. L.I. used to work at home and when it was necessary to participate in an experimental work in the laboratory, or conduct seminars and lectures in auditoriums. He went there without leaving the building. At the same time his colleagues had direct access to him.

Gradually there formed a following habit. At the end of a working day, at 5 p.m., his closest friends gathered at his place around a tea table. Here they discussed a wide range of topics: scientific, political issues, discussion of students that were of interest to somebody, of mutual acquaintances. Here everybody trusted each other and was open-hearted. The new life was, scientifically, extraordinarily fruitful. If one ignores a lack of equipment[12] and a depressing social and political atmosphere in the country (up to an end of NEP, still not completely horrible) it could be considered as an almost happy one for L.I. At last he had lived up to the time when the scope

[12]Even in 1930 when I came to the university I saw many empty rooms and empty shelves for instruments, but very soon these started to fill with instruments made in the country.

of his scientific work was becoming broader and broader, an entourage of talented colleagues and young scientists was expanding fast and he was deeply and sincerely respected and esteemed by them.

In 1925 Leonid Isaakovich was 46. Wars and revolutions had, without sense, practically taken away eleven most precious years from the life of an outstanding scientist at the peak of his talent. These were also taken away from a large part of the young university population in Moscow who had been deprived of modern science. Now they were passionately striving after the Mandelstam school and his colleagues. In spite of sixty patents and a theoretical foresight and comprehension of the Mandelstam-Brillouin effect, these years had not been those appropriate for the physicist who had accomplished what he had done in fourteen Strasbourg years. This was evident.

Things became even better when in 1930 B.M. Gessen, a close friend of I.E. Tamm from gymnasium years but, unlike him, a convinced bolshevik and, at the same time, a highly intelligent person, became a dean of the faculty and a director of NIIF. He graduated from an institute of red professorship and for some time even was its director. In this entourage he was certainly distinguished by a general education, general culture. He studied natural philosophy. It is suffices to mention that his talk at the 2-nd International congress on the history of science in 1931 in London in which his Marxist position was presented drew serious attention and was broadly quoted afterwards in western literature (for more details on him see [Gorelik (1995)]).

Gessen deeply respected Mandelstam, admired him. I recall a scene in the cloak room when he helped Mandelstam to put on his coat, literally blowing off specks of dust from it. It was not surprising that with such a director the most favorable conditions for L.I. that were possible at that time were created. This was, however, the time of the beginning of horrible processes followed by the "big terror". In 1936 Gessen was (with no reason) arrested and executed. This brought new troubles to everybody close to him. We have, however, run far ahead. Let us return to the scientific work of L.I.

The university and the presence of many coworkers provided L.I. with the possibility of expanding it simultaneously in several directions. Besides giving a course on a theory of electromagnetism in a completely new style for the university, he began theoretical and experimental studies in various directions. With Andronov, Papaleksi, Vitt, Khaikin, Gorelik, Leontovich and Rytov, work on theory of oscillations in general, of nonlinear

ones in particular, was carried out. Together with G.S. Landsberg, L.I. began expanding experimental studies in optics with a focus on finding the Mandelstam-Brillouin effect. With Tamm he finished work on a relativity theory for anisotropic media.

During the Strasbourg period, after beginning with radiophysics and radiotechnics, L.I. had already significantly expanded an area of his research by examining, as already mentioned, the most serious problems in optics. Now he went even further.

Right before this time, in 1925–1926, a new quantum mechanics of Heisenberg-Schroedinger (in two apparently different but equivalent forms) had appeared and had shaken the foundations of physics. And, as has been already mentioned, L.I. published with M.A. Leontovich an important paper in which remarkable properties of the main equation of quantum mechanics, the Schroedinger equation, were studied in detail. Discovered, in particular, was an astonishing paradox: A quantum particle can go through a "potential barrier", through the domain, in which its kinetic energy is smaller than its potential one! This phenomenon is completely impossible in classical physics, makes no sense in it, violates the law of energy conservation. However, due to the wave properties of a particle, it takes place. Called later a "tunnel effect" (in the paper of our authors this term is still absent) it plays nowadays a great role in physics and technics[13].

G.A. Gamov (at that time a Soviet, later an American physicist) was the first who noticed the discovery of Leontovich and Mandelstam. He applied it, very elegantly, to explain a radiative decay of atoms and nuclei, the phenomenon discovered already at the end of the nineteenth century which was totally incomprehensible in classical physics. Although, as was well known in the physics community, Gamov knew about the work of Leontovich and Mandelstam before publication and relied on the properties of tunneling effect established in it but, unfortunately, did not cite it, so up to now a dominating opinion of physicists around the world is that the author of "tunneling effect" is Gamov. Mandelstam never argued about authorship. Some have an opinion that he lacked ambition that a scientist nevertheless needs. I believe, however, that he considered such disputes humiliating

[13]This discovery was for L.I. not accidental at all. In Strasbourg, when studying optics, he had already demonstrated both theoretically and experimentally that optical waves that should have experienced a so-called complete internal reflection from a border of a solid body, e.g. glass, in which they propagated, with air, did in fact partially jump through the gap with air if the same glass was placed nearby. Such integral understanding of classical and quantum physics was characteristic of Mandelstam.

(people like him think that if you are really worth something as a scientist then all of your results will not be stolen anyway so, instead of arguing, it is better to write another good paper).

This was by no means a unique episode. When an extraordinary difficult experiment on finding the Mandelstam-Brillouin effect had finally been started L.I. and Landsberg were not satisfied with how things proceeded. A spectrometer they had used was not good enough and, although an observed broadening of a spectral line constituted a clear indication of the sought phenomenon, they wanted something better. State Optical Institute in Leningrad possessed a better instrument. They turned to its director, an outstanding scientist D.S. Rozhdestvensky, with whom they had perfect relations based on mutual respect, to ask him to charge one of his young researches to repeat the measurements at this better device. This was done in 1930–1932 by E.F. Gross who studied the effect in detail. During a parallel work in Moscow and Leningrad there was an extensive exchange of letters. L.I. visited Leningrad. One thought this was considered a common work that should have resulted in two publications, one by Mandelstam and Landsberg, another by Gross. However, when Mandelstam and Landsberg sent him a manuscript of their paper, Gross surprised them by telling that his own paper, covering all relevant questions, had been already in press. Thus the publication of the Moscovites turned out to be unnecessary.

It was perhaps one of similar episodes when L.I., replying to someone convincing him to protest, told a phrase quoted in the memoirs of S.M. Raisky [Prokhorov (1979), p. 16]: "One does not educate an adult person. One either deals with him or not. One should not deal with N".

In fact L.I. could have "good" ambitions. But above them was his self-respect that did not allow him to mix a humiliating "fight for priority" with questions related to science, to comprehending the truth, even when he himself internally suffered from a complete injustice. I.E. Tamm, and almost all the physicists of Mandelstam school (including those, unfortunately much more rarely, belonging to the next generations) also behaved in the same way.

These cases of the unjust oblivion of Mandelstam's name seem to constitute some kind of a pattern. An even more important episode took place in connection with a very big discovery of Mandelstam and Landsberg, the combination light scattering that has already been mentioned. As mentioned, they did not receive a Nobel Prize for it. It went to an Indian physicist Raman who gave a wrong interpretation but was faster in publishing a

paper while our physicists were polishing their experiments and theoretical understanding to achieve a perfect sheen.

The thing is that in the process of experimental studies of light scattering and Mandelstam-Brillouin effect, over a long period of time many versions of these experiments were performed. In the course of this work it was discovered that apart from the Mandelstam-Brillouin scattering happening due to an interaction of light with elastic acoustic waves in the crystal as a whole, there existed a scattering of light with higher frequencies in which a structure of individual molecules of a body is of importance. Here there also appeared new spectral lines with a frequency depending on intramolecular vibrations and not only on that of the scattered light. Therefore it was called a combination light scattering. The authors had a clear understanding of the importance of this discovery that led to many practical applications because, by studying new lines, one could learn a lot on the nature and structure of scattering molecules.

To catch these lines at that time was, however, difficult; their intensity was too weak. With the technique available one had to photograph the spectrum with an exposition of tens of hours. Nowadays, due to photoelectric registration and lasers, this is much more easy.

Finally, at the beginning of 1928, L.I. and Landsberg obtained photos of a quality that was satisfactory to them[14]. This was achieved in difficult conditions when at times the most necessary materials were lacking. For example, a required quartz tube and many other supplementary materials were brought by Landsberg from a scientific trip abroad with his personal saved money. High quality quartz crystals in which the scattering was studied were found in second-hand shops by buying the quartz seals used before the revolution to seal letters by the sealing wax.

Having had already surely discovered the new phenomenon in February our physicists, following their usual above-described line of behavior, did not, as already written, hasten to publish. So the first public talk was made by Landsberg in the Institute of Physics of Ministry of Health (that had a big optical department) on April 27 and sent the paper, as

[14] A history of these experiments and discovery is diligently studied and explained in the papers of I.L. Fabelinsky [Fabelinsky (1978, 1998, 2000)]. In particular he reproduces a photo-plate with a spectrum in which the combination scattering lines are clearly seen. On the plate it is written, by the hand of Landsberg, the date: February 23–24, 1928. This is before an oral presentation of Raman in the Indian Physical Society (which was of course published much later) and long before publication of Raman's paper sent to the journal on March 8, 1928. Our physicists sent their first paper later, on May 6. One could think that they had other successful observations earlier than on February 23–24.

already mentioned, on May 6 after constructing a theory of the phenomenon that agreed with their experimental observations. By the time their paper came out in print (July 9) many physicists had already understood an importance of this discovery as described in Raman's talk. There appeared 16 papers by different authors, these were already calling the discovered phenomenon a 'Raman effect'. Our authors themselves, with their characteristic decency wrote in their first paper that Raman (and his student and coworker Krishnan) had published in *Nature* the work "describing an observation of the same effect" and in the second paper "the authors refer to the work by Raman and Krishnan which was known to them before sending the paper for publication" [Singi and Riess (2001)]. A public opinion on the precedence of the Indian scientist was already formed. Only special study could restore the story in its details. Who would have done this? It was too late . . . .

There was, in fact, another reason for the delay that has to be mentioned.

The Mandelstam clan included, besides a wife and a son, also L.I.'s sister, a nephew (a physicist M.A. Isakovich), two nieces, a husband of one of them (a student of G.S. Landsberg) S.M. Rajsky and a Gurvich family. Having no close relations with L.I. himself I had, after his death, friendly relations with this circle. I do not remember who it was (most probably it was S.M. Rajsky) who told me about a characteristic episode that took place at the end of the study.

Once L.I. returned home from Landsberg laboratory holding in his hands a still wet, after development, photographic plate and told his wife with a squirming smile: "Imagine, Mizya (an intrafamily name of Lidiya Solomonovna), one gets Nobel Prizes for such things". L.S. replied indignantly: "How could you think about such things when Uncle Lyova is in jail and they have already stopped taking parcels!"

L.I. squirmed even more and there began a discussion on what could be done for "Uncle Lyova"-L.I. Gurveich, a close relative of A.G. Gurvich, who was already sentenced to death. This was 1928 and at that time one could still petition for mitigating a person's fate. Very soon it became totally forbidden, but in that situation L.I. and A.G. Gurvich dared to talk with a then rector of MSU, A.Ya. Vyshinski. He was still not a prosecutor general at the bloody trials of the thirties (although probably already in contact with 'organy'[15]). Improbable as it seems, after knowing about him what we

[15]The word 'organy' is a Russian colloquial for inland security bodies that were, in particular, instrumental in Stalin's repressions.

now know, Vyshinski said he would try to help. As a result the execution was replaced for "Uncle Lyova" by exile to Vyatka (now Kirov)[16]! This gives a clear idea on how already at those still "mild" NEP times did the "organy" "administrate justice". It would seem that an inveterate outlaw and an enemy of Soviet power should have been sentenced to a capital punishment. It turned out however that without harming the state interests it could be replaced by the peaceful exile.

So, what did happen with the Nobel Prize? Having made their discovery Landsberg and Mandelstam surely did not make a secret of it. In summer of 1928 there was a sixth congress of Soviet physicists at which many scientists from abroad, including the most famous (Dirac, Darwin, Born, Pauli, Debye, Peierls and others), were invited. The sessions first took place in Moscow, then on a ship sailing down Volga and in several towns down the way. At this congress Landsberg gave a talk on this work that made a strong impression (in their correspondences Darwin [in the English journal *Nature*] and Born [in the German *Naturwissenschaften*]) put a special emphasis on this talk using for its characterization the highest epithets [Fabelinsky (1978, 1998, 2000)].

Therefore the discovery of Moscow scientists became known to the world scientific community very soon (although after the publications by Raman).

In 1930 Raman received the Nobel Prize. Why him alone? This injustice caused a painful reaction in our country. There appeared a lot of versions: an anti-Soviet sentiment of the Nobel Committee, etc. The question was clarified 50 years later when, in accordance with a Nobel Committee Charter, all documentation related to this matter that previously had been kept secret was published[17]. It turned out that in 1928, our physicists were not nominated by anybody while Raman was suggested by Bohr and by another physicist. The 1929 prize went (quite justly) to Louis de Broglie, an author of an idea of wave properties of an electron on which a Schroedinger picture of quantum mechanics is based. In 1929 Raman was nominated not only once again by Bohr but also by Rutherford and other, in total 10 (!) authoritative physicists. At the same time Landsberg and Mandelstam (Raman as well!) were nominated by O.D. Hvolson, our senior remarkable physicist, a honorary academician, an author of a five-volume course on physics issued

[16]These details were communicated to me by the daughter of A.G. Gurvich, Natalia Aleksandrovna Belousova-Gurvich. I am very grateful to her for them.

[17]We should clarify a mechanism behind a decision on Nobel Prizes. A year before the decision (in our case for the nearest possible decision in 1929 this was a year of 1928) the Committee invites a group of prominent scientists of its choice to present their candidates ("nominees") and, in the end of the next year, announces a final decision.

in several languages who, at his age of 76, could understand the new physics (later he wrote a remarkable book on it) and appreciated the new discovery under discussion, and N.D. Papaleksi who due to some reason nominated only Mandelstam. Some other of our prominent physicists did not nominate any of them but gave other names [Singi and Riess (2001)]. The Committee, apparently guided by the difference in the dates of sending the papers to the journals (March 8 for Raman and May 6 for Mandelstam and Landsberg), made a simple decision which was certainly influenced by the difference in number and international prominence of those who nominated.

What could have been expected with such a difference? But the difference itself is not easy to understand. Everybody who nominated Raman did already know about the "brilliant" work from the Landsberg talk in the summer of 1928. Why were our other physicists silent and modest in nominating the candidates (everyone had a right of nominating several works)?

The first question is easy to answer: an "organizational" work among the scientists the committee chose for nomination was required. Alas, we know that also nowadays some nominees are intensively working in this direction as well. I was told about this by my Western friends as well. An extraordinarily intelligent, late remarkable Italian physicist, Jiuseppe Occialini, "fell off" two Nobel Prizes given for works in which he co-authored. He was strongly reproached with this by another similarly unlucky participant. Occialini told me how some scientists "struggle" for the prize. He himself was completely incapable of doing this because of his character and did not worry. It would have been crazy to expect such activity from our two Moscow physicists with their decency, intelligence, feeling of self-respect (I am by no means generalizing this on all Nobel Prize winners but 10 nominations for Raman and 1–2 for Landsberg and Mandelstam is too an absurd, blatant difference).

The reason lied primarily with the fact that Raman did not hesitate to publish his papers, even the first three in which he gave a totally erroneous interpretation of the phenomenon considering it to be analogous to Compton effect. He could not wait until these papers came out in press. Having informed about his discovery at a meeting of the Indian Physical Society on March 16, on the next day he prints thousands of copies of this talk and sends them around the world. When an Indian journal containing this talk comes out he gets 2000 reprints and mails them again to all prominent physicists in different countries [Singi and Riess (2001)]. He had been in correspondence with Borh, Rutherford and other influential people before

that. On December 6, 1929 he writes a letter to Bohr in which he directly asks Bohr to nominate him for the Nobel Prize [Singi and Riess (2001)]. His contacts with a member of the Nobel Committee Siegbahn are also established [Singi and Riess (2001)].

In general, while Fabelinski relied upon what he witnessed, the authors of the important paper [Singi and Riess (2001)] made a detailed study of Western papers and materials from numerous archive funds that were opened 50–70 years later. They clearly see an injustice of giving the prize to Raman alone. "He knew how to fight for precedence", they conclude.

It is more difficult to explain the silence of our physicists many of whom could have nominated Landsberg and Mandelstam for the prize but did not do it. Perhaps in spite of existing achievements (and they did exist) in our then young physics a feeling of lagging behind, a kind of an inferiority complex led to an underestimation of an importance of this discovery.

But above all there was a mere delay in publication and this was decisive. Let us repeat what was already said. In his ripe years, L.I.'s striving not just to "get to the very essence" but to reach an unbreakable confidence in being right was particularly strong. Thus the delay of publication until full clarity was reached. Thus a multiple rewriting of fragments of the forthcoming lecture as described at the very beginning of this article. As I have already written I dare to think that this could be considered as a distant consequence of the mistakes of his younger years and a strange undue opinionated familarity in a tone of his polemics with Rayleigh, Planck and Bragg's. For a person with such a sensitive and vulnerable nervous system, which was a characteristic of L.I. (although only the most close to him new about it, for others in his Moscow years he always seemed to be calm and self-assured), an evaluation of this behavior in his young years should have meant a lot.

To all this there added external, societal conditions of existence at those times — from the lack of instruments to concerns, to worries of "Uncle Lyova". Raman did not have such problems, hence his unrestrained strive for a Nobel Prize. A completely different person. *Not* a Russian intelligent.

After a discovery of the combination scattering for Mandelstam and his school which was rapidly expanding by attracting, as it turned out, quite broad circles of talented young people, there came at first sight happy times. In all the branches of physics that interested him the work was progressing and each of them could be committed to some of his brilliant disciples. In addition, as already mentioned, in 1930 B.M. Gessen, who took care of

Leonid Isaakovich, became a director of NIIF and a dean of the physics faculty. Accepting his support was not shameful. I listened to his lectures on philosophy of natural history when studying at MSU in the beginning of the thirties. They were distinguished by their high level and a definiteness of thought. Lectures of stupid staff "diamatchiks"[18] were of no comparison to them.

This same period was characterized by a constantly growing autocracy of Stalin, intensification of terror and ideological pressure. It was from 1930 when Stalin was called nothing else but a great leader of all working people, ingenious, sage, etc. An atmosphere was building and the murder of Kirov on December 1, 1934 became a signal for a beginning of "big terror" in the face of which there faded everything, terrible enough by itself, that had happened before. Almost on the same day came changes in a criminal code and a code of practice which are impossible either to forget or to underestimate. In cases of terrorist organizations to which almost all arrests were tied to it was now prescribed: investigation should be completed in the shortest time possible, within several days; cases could be heard in the absence of the accused (this had been a case in Russia before the reforms of Alexander the Second); appeals or pardons were not allowed. Death sentences should be carriesd out immediately. The newspapers published lists of hundreds of sentenced and executed. And how many were executed without an announcement!

As was common in those times when in 1936 Gessen was arrested in the University there began meetings at which staff members, especially those close to him, had to confess a lack of watchfulness (they had failed to recognize an enemy!) and absurd "facts" of his sabotage activity. Few could keep their human dignity in this atmosphere of horror (as could, for example, G.S. Landsberg, see below p. 238). Mandelstam, who was about the only one who did not attend these meetings (at least I just can not remember him present; he did not like meetings and sessions but these were, of course, singular cases), was probably pardoned for doing so, so big was a respect for a man who breathed new life into university science which had been falling into decay for years before him.

Then came a horrible epoch. Other arrests followed. There disappeared young and very talented disciples of L.I., S.P. Shubin, (who was also a disciple of Tamm) and A.A. Vitt who, in co-authorship with A.A. Andronov and S.E. Khaikin had just finished a fundamental work summarizing the results

[18] Lecturers in dialectic materialism.

of joint research with L.I. on theory of oscillations, especially nonlinear ones, for which new methods of studying numerous problems of practical importance were developed. In particular Andronov introduced a notion of "auto-oscillations". This was a new breakthrough in one of the most important domains of physics and gave birth to a school of Andronov that formed in Moscow and Gorky. The book, however, could not be printed with the name of "the enemy of people" Vitt on the cover, but not to publish it was a crime against science. So a heavy moral sacrifice, to leave only the names of Andronov and Khaikin on the cover, was necessary. The fact that these highly moral people and L.I. decided to do so (it was without any doubt a sacrifice for them) shows how necessary this book was! After the war it was translated in the USA (it seems to me, without the author's permission) and after Stalin's death was reprinted with Vitt's name restored (more than 20 years after the first edition which shows by itself that this was a classical work that remained important for a long time). This is also a characteristic episode from the history of both our epoch and the Mandelstam school.

In spite of all, even with "a noose around a neck", the school of Mandelstam developed and worked.

Nobody could say, however, for how long they could have endured all this if an unexpected even had not taken place. In Moscow there appeared a new scientific center in physics that turned out to be an oasis, a salutary pillar for Moscow physics.

The thing is that in 1934, according to government decision, the Academy of Sciences and many of its scientific institutions that since the times of Peter the First resided in Petersburg-Petrograd-Leningrad were transferred to the capital, to Moscow. Among those was a small (about 20 researchers and Ph.D. students) Physics Institute of the Academy of Sciences, FIAN, that had separated from an Institute of Physics and Mathematics. The director of this institute was a young academician Sergei Ivanovich Vavilov. He immediately invited to the institute the best Moscow physicists, first of all Mandelstam, his main collaborators, his school (but certainly not only them). They kept their university positions and also became heads of the main laboratories of the new institute or researches in them (see an essay Section 4.3 in this book). There arose an institute (the number of staff grew about 10 times) where there dominated an atmosphere of devotion to science, decency, intelligence, good will, mutual help and cooperation.

My usage of the word "dominated" is not occasional. In the reality of our country in those days it was impossible to be completely free from the

pressure of evil characteristic for its life. But the most clever organizer Vavilov did not only take a blow by himself when it was necessary. A younger "helping" and "directing" party section that was at those times mandatory in such institutes was selected to include, in particular, several (three or four) furious supporters of the regime. A distinguishing feature of these people was however that they really loved science, were in some cases talented physicists and already because of this could not but respect Mandelstam, Landsberg, Tamm and others as scientists. Therefore their fury could not completely spoil a general style even in most difficult situations when, in the epoch of "big terror", they (as it was in the university and basically everywhere) attacked their scientific mentors with accusations that were at those times dangerous. This left Vavilov a possibility of softening all the blows and to not allow an establishment in the institute of an atmosphere of baiting which these scientists experienced in the MSU where the same people that had previously fought against inviting Mandelstam and their disciples were now in power.

Very soon all the "Mandelstamovists" transferred their main scientific activity to FIAN (for example, Tamm moved his weekly seminar there; it was FIAN where, together with N.D. Papaleksi, Mandelstam launched large-scale research on a new subject of radio-geodesy, propagation of radio waves around the Earth, new methods of radio-location, etc.). In the university they basically limited themselves to lecturing.

Here we should pause to discuss how Mandelstam was lecturing.

Perhaps only the first course on field theory given at the very beginning of his work at the university (1926–1927) could basically be described as a usual university lecture course (although these lectures bore a seal of an individuality of L.I.). The rest of his lecturing and seminar activity during 20 years (1925–1944) was completely unusual. These were not courses that ended by exam and they did not conform to a usual set of university courses. Mandelstam simply chose some problems, domains of physics, that were in his opinion relevant, contained unclear points or were not covered in the literature with a sufficient depth and were of great importance for understanding of physics in general. Often it was a "horizontal" scientific slice. For example the biggest course "Lectures on oscillations" (1930–1932) covered theoretical consideration of general and specific properties of oscillations in many different domains of physics, in hydrodynamics and electrodynamics, in mechanics and optics, even in quantum mechanics. They constitute the thickest, fourth volume of his collected works. The most important thing in the character of his lectures that often included research results of L.I.

himself (without mentioning it) was that in these lectures pedagogics was inseparably tied with scientific research in general. A wonderful characterization of these lectures is given in [Prokhorov (1979)], see the Introduction. We will just simply quote from it.

Lectures by L.I. were a bright and non-disguised demonstration of a process of physical thinking as such. There one saw how a physicist stumbles against an obstacle, how paradoxes and contradictions accumulate on the way and how he manages, sometimes through a mental feat, through pushing aside the habits most rooted in human consciousness to free oneself from contradictions and reach a new previously unreachable height from which there open new horizons. Not a single detail in the lectures of L.I. was vapid, lifeless; in each problem he was able to find and bring to the audience some special sharpness and beauty. Not only did he force by the perfect logic to agree with his statements but tried hard, with success, to find a common language with his listeners, convince them "from inside", remove those difficulties formed due to psychological protests that so often hinder understanding in physics. Taken together all this created some unusual emotional richness and ensured that everything heard from L.I. reached the deepest layers of consciousness.

When Mandelstam analyzes at a lecture a scientific question he first casts doubt on everything, shakes loose usual understanding. Nevertheless this generates firm knowledge. Here is, for example, a problem of a Heisenberg microscope used to justify an uncertainty relation (vol. V, p. 396): "I would first criticize what is usually told about the microscope and what always shocked me '... each word in this reasoning is, in my opinion, incorrect (although in essence it is the case)', writes Mandelstam and then completely destroys the usual line of reasoning. Mandelstam mentions at least three flagrant absurdities. When they are pointed at one feels awkward for not noticing them before. Having seen any of them an ignoramus not possessing an ingenious intuition of Heisenberg has a right of declaring that the uncertainty relation is not proved or, at least, can not be proved *like this*. Then, however, Mandelstam gives a correct proof for the same microscope and there opens something more essential and it becomes clear why he did confidently tell that "in essence it is the case". Mandelstam's confidence was always based on his own, well thought, judgement.

As a physicist who had been growing in parallel with relativity theory and quantum concepts he, it would seem, had more reasons to loose his head from the new miracle and could have praised the science of twentieth century as something fundamentally different from all the previous physics

than the scientists of forthcoming generations. Even now, half a century later, one often encounters an opinion that this physics is something totally special. One refers to a supposedly new rejection of a principle of intuitive obviousness, etc. How weighty there sound the sober and exact words of Mandelstam:

... *principles* of constructing quantum theory or, if one might put it so, a structure of a frame with which the quantum theory is framed by, is the same as in any other physical theory. However one can not deny that a structure of the picture itself is quite different from the classic one and a statement that here we are dealing with a new physical paradigm could hardly be considered as an overstatement (vol. V, p. 402).

This statement is then substantiated in details. Mandelstam explains what "intuitive obviousness" means and shows that its rejection and a change of paradigm took place at each turning point in physics, in particular when a Maxwell electromagnetic theory established itself.

This somewhat old-fashioned and, in the eyes of my generation, soft person spoke for many decades to come.

To these lectures and also to seminars (at which L.I. always gave an introductory lecture) there came, as was already mentioned, different listeners, from students to academicians, sometimes from other cities. They were catching every thought, many made notes. The texts of lectures at some seminars are, however, lost irretrievably.

Seldom there were also other lectures — talks. So on April 28, 1930 (let us parenthetically mention an unrelated significant fact: Landau had been arrested at previous night) L.I. gave a talk at a general assembly of the Academy of Sciences on a seemingly very special subject, a radio interferometry, i.e. on measuring distances on the Earth with the help of radiowaves (as was told above large-scale research on this and related topics was launched by L.I. together with N.D. Papaleksi and a large group of co-workers at FIAN). It is clear to everyone that this can be of practical importance, but how could this talk be of interest to the general assembly of academicians including those specializing in liberal arts, chemistry, biology[19]? Nevertheless after the talk a mineralogist academician A.E. Fersman summarized his impression in one word "Poem!" (and then sent Mandelstam a short exalted letter [Prokhorov (1979)]).

[19]I.E. Tamm told me that after one of his talks at a general assembly an academician in liberal arts told him: "From your numerous referrals to some beta-rays I conclude that there also exist alpha-rays and, possibly, gamma-rays as well."

On September 26, 1943, also at a general assembly of the Academy devoted to the eightieth anniversary of academician Aleksei Nikolaevich Krylov, a mathematician, mechanician, ship-builder, translator of Newton from Latin, engineer, an amazing person (L.I. had become very friendly with him during the wartime two-year evacuation of a large group of old and ill academicians to a resort, Borovoe, in Kasakhstan). L.I. gave a talk "On scientific works of A.N. Krylov" on a subject seemingly very distant from his domains of physics. But, as told about Mandelstam by A.A. Andronov [Prokhorov (1979)]: "For him there were no locked doors in the huge building of physics".

Is it then surprising that, when congratulating him on some occasion in 1944, a philologist-sinologist academician V.M. Alekseev adds:

On many occasions I had a pleasure of sharing with you my limited opinions on my unlimited admiration of everything in your talks and speeches that was understandable for me. You are probably belonging to the rarest kind of scientists that profess and preach science as a clear, not cumbersome, thought and treat its difficulties as circumstantial and not essential [Prokhorov (1979)].

This was told not without ground. Back in Borovoe, Alekseev had listened to the talks by L.I. "Optical works by Newton" and that on the works of academician A.N. Krylov.

Academician P.L. Kapitsa was answering questions on different scientists and when it came to L.I. he exclaimed: "Oh! This is an aesthete!" [Prokhorov (1979)].

Andronov, Rytov and others underlined that an emphasis on a logical structure of a theory was an important feature of his lectures. Andronov thinks that a "watchful and consistent attention to questions of epistemology" belongs to most characteristic features of L.I. He was interested in "how do physical notions arise, develop and transform, how are they related to objective reality ... From his lectures and statements it was clear that he studied a logical structure of physical theories in depth" [Prokhorov (1979)]. Therefore his purely physical lectures possessed a philosophical flair.

At that time physicists did not completely realize the importance of a simple fact that experience is necessarily limited. Conclusions therefore can not be considered as universally applicable. Indeed, after many repetitions and variations of an experiment producing results conforming to a conclusion there always comes a moment when a researcher should say: "Enough, now *I am convinced* that these results reflect a true property of nature". This "I am convinced" is, however, an act outside logic and therefore its

unbounded unconditional applicability is not guaranteed. Same is true for conclusions of a "collective researcher" when, based on experimental data, science recognizes a validity of a law of nature, of mathematical axioms, etc. Each natural mathematical science arises through consecutive logical construction based on a *out-of-logic intuitive statement* adopted in an above-described way. It is synthetic by its very nature because of being made based on taking into account knowledge of different sorts, half-knowledge, estimates, guesses, etc.

Physicists either did not realize or did insufficiently realize that scientific knowledge is necessarily built as a combination of logical and out-of-logics elements (this is meant when one says that a criterion of practice is always relative, does not have an absolute validity). Only due to this, only because earlier out-of-logic established principles (axioms, laws of nature) are not unconditionally valid for all times and can be changed when new facts appear, can a development of science consisting in finding out (based on new experimental knowledge) more general laws, for which previous knowledge turns out to be a particular case valid in specific circumstances, take place. This more general understanding formed (although by no means becoming universal) only in the twentieth century (see, e.g. [Feinberg (1992)]).

At the beginning of the twentieth century an overwhelming majority of physicists and mathematicians thought that a presence of out-of-logic elements in their sciences was an evil from which they ought to and could be freed. In mathematics this conviction was shared by such people as a great mathematician David Gilbert and a philosopher and mathematician Bertrand Russell. In physics this direction of thought became dominant basically after Mach. Such tendencies backed by a powerful development of mathematical logics were very useful in stimulating a detailed analysis of notions that science operates with, of definitions introduced. Therefore, in particular in the lectures by Mandelstam (especially in those on relativity theory and quantum mechanics) such great an attention is paid to a question of defining the notions and restrictions thereby imposed on them.

On the other hand this movement led to a domination of positivist views of various kinds. Einstein, who had at first also been under the influence of Mach, soon parted from him. It is most clearly seen from his discussion (in 1931) with Rabindranat Tagore [Tagore (1931)]. Tagore's perseverance finally causes an openly strong irritation of Einstein. Not going into detail, he just insistently repeats phrases like "... this table will stay on its place even when nobody is at home" [Tagore (1931), p. 132]. This thought of

his is an example of an *out-of-logics intuitive statement*. One can neither prove nor disprove it. Nevertheless Einstein just accepts it as a reasonable conclusion from experiment accepting thereby that knowledge necessarily includes out-of-logics intuitive statements. What about Mandelstam? In his published works there is nothing on this. However, about 20 years ago (I do not remember it more exactly), his son Sergei Leonidovich handed me three school copybooks clumsily sewn with white thread. In them, written by the handwriting so familiar to me, one finds a very simple exposition of the philosophical views of L.I. on the above-discussed issues. It was written in one of the last years of his life in the wartime evacuation in Borovoe. It was thus like settling the accounts. Several typewritten copies of these copybooks had been made and they had been kept in absolute secrecy up until new times came.

It is in these copybooks where L.I. says that a physicist can not avoid considering philosophical questions. He continues with saying that an understanding of objective reality should have its origin from those elements that constitute facts one can not doubt. To his opinion such facts are in our experience and our feelings (more often L.I. uses the word experience). Here one should not ask what these are. This is a basic element with the meaning clear to any normal person. We do not have a ground to speak on "taking place outside us" as of some material reality, it is not given to us, only a combination of feeling and experience is. *Only this set of feelings can be considered as objective reality.* Correlation of these feelings is being studied by us and helps to establish what we term 'laws of nature'.

After all, Einstein, in a phrase preceding the above-quoted one says: 'Even in our everyday life we "have to" ascribe to things we use the reality that does not depend on a person. We do it in order to establishe in a reasonable way an *interrelation between the data provided by our senses.* (NB. Author's italics). This is, of course, another intuitive statement. One has an impression that a difference with L.I. is in that L.I. does not think that "we have" to do it and so does not do it. Therefore Einstein is a materialist, although on the preceding page he says: "I can not prove that my concept is true but this is my religion". Here the word religion does not, of course, have anything in common with a standard notion, Einstein uses it purely metaphorically; on the principal distinction between the religious faith and the trust into an intuitive statement in science see [Feinberg (1992), Ch. 6]. One can not say the same thing about Mandelstam. In his words when we say "a tree" this makes sense *only* as a short "shorthand" notation for the complex of corresponding feelings.

Nevertheless, in spite of an aspiration of cutting away all the out-of-logic statements, L.I. could not avoid them. He says, for example, that complexes of feelings of different people coincide. This can be judged from the coincidence of external manifestations of these impressions. A number of external manifestations is however always limited and we still have to make an intuitive statement on the sufficiency of a set of reactions in question and this introduces an out-of-logic element.

This is of course not an appropriate place to consider the manuscript by L.I. containing many sophisticated, instructive and very interesting arguments in more detail. For example, the following phrase is worth quoting: "Not only do I not deny the existence of the external world and its reality but... give it the above-mentioned *definition*" (in terms of complexes of feelings). Yet one should say that a feeling of dissatisfaction does nevertheless remain.

Similar to Einstein discussing a table that remains in the room in his absence, L.I. discusses, among possible objections, the following. One says that from defining "a tree" as a complex of feelings there follows that "objects of the outside world discontinue their existence as soon as we turn away from them". This is a "misunderstanding". "The complex of feelings that I call a tree contains a feeling-confidence that if I turn away and after that do not hear, say, the sound of a falling tree, then, when I turn my head back, I will see this tree again. *This* feeling constitutes an *important* part of a notion of a real tree". Here everything seems to be consistent. Still there arises a bewilderment. The feeling-confidence is of a principally different nature than the feeling. It is a product of a functioning consciousness that joins together some limited number of indirect indications of the non-disappearance of the tree, each of them individually not constituting a proof. The confidence arises as a out-of-logic *synthetic intuitive statement*. One can not avoid an out-of-logic *statement*. Is it not simpler to use it from the very beginning, as Einstein does, without introducing a feeling complex. At the beginning of the twentieth century all this was not sufficiently clear to physicists and mathematicians. Yet a rapid development of mathematical logic led, already at the beginning of the thirties, to the most important result: A mathematician Goedel *proved*, using the apparatus of this discipline, that it is impossible to banish out-of-logic elements from mathematics. In the course of the development of mathematics there necessarily come moments when it is necessary to choose, in the out-of-logics way, one of the possible directions of its further development. It is *proved* that the development of mathematics will be characterized by an

infinite number of such moments. A further study of foundations of mathematics showed, by the end of the century, that it is rich with arbitrary ("intuitive") definitions of notions that can not be logically proved. Some authors considered this to be a catastrophe (see [Klein (1984)], others came to a different understanding of mathematics as the the same science as physics [Klein (1984)]), even as a part of theoretical physics based on an out-of-logics generalization of experimental data [Arnold (1999)].

L.I. formed as a thinker at times when all this was alien to the spirit dominating in science, in the hazy atmosphere of competing ideas. There is nothing surprising in his exposure to this atmosphere, basically inclining to one of versions of positivism. Nevertheless in his lectures he never speaks about this position. At that time it would have been a suicide. Soviet philosophers were violently chasing any "deviation", of positivist type, from the official ideology. This fury can be characterized by paraphrasing the well-known command of a guard in a Stalin camp: "Step to the right, step to the left is considered to be an idealism, shoot without warning". One philosopher dared, after Stalin's death, to tell: "There practically existed a cause-effect relation: ah, idealistic deviation, therefore "popovshina", therefore an "enemy of the people" — arrest — camp — an end". These philosophers, like hounds, had good scent. They were seeking in remarkable lectures by L.I. suspicious places and pounced on them with ferocious energy. In 1950–1953 there were several populous meetings in FIAN specially devoted to "ideological mistakes of Mandelstam and his disciples". In spite of the statements, sometimes harsh, of these disciples (L.I. himself was already dead) in defense of "suspicious points", menacing and at those times dangerous resolutions were adopted. This was the time when many branches of science — genetics, cybernetics, physiology, — were smashed (in addition in 1951–1953, anti-Semitism reached its peak).

Fortunately the "scent" alone of the persecutors was not sufficient. All more or less qualified Marxist philosophers had been killed a long time ago and the existing ones had a poor knowledge of both physics and philosophy. One could argue with them.

For example, after the war there began the preparation of the five-volume edition of works of L.I. A careful preparatory work (a titanic labor!) was carried out by the editor-in-chief S.M. Rytov. The main difficulty was in publication of lectures. Only a minuscule number of lectures were stenographed, but these were neither read nor proofread by L.I. himself. Everything was based upon the notes (very detailed) of Rytov himself and also of Andronov and many others. One had to compare different notes.

Lectures and seminars constitute the last two volumes. After publication of the first three volumes the printing was stopped by ideological bosses. Nevertheless it turned out possible to resume and complete the publication. On the one hand this was due to the fact that a deep admirer of Mandelstam, S.I. Vavilov, was a President of the Academy and used his influence. On the other hand this was due to some tricks: Firstly, Rytov slightly edited some places causing a special fury of philosophers (this was possible because, as was already mentioned, shorthand notes were effectively absent and, with a knowledge of a true opinion of L.I., it was possible to slightly change the text but preserve the meaning put in by Mandelstam). Secondly, it was written that the editor-in-chief of the last two volumes was not Rytov but M.A. Leontovich (he was more suitable, perhaps because of being an academician and not being a Jew — unlike Rytov).

So, here is a depressing fact. An outstanding scientist that made so much for science itself and for creating a huge school of leading scientists of our country, that thought so much on fundamental philosophical questions and developed certain views in this field did not even dare to openly hint at this, had to keep them in absolute secret, although this was about science, not terroristic preparations. Terrible evidence of a horrible time. A "loop on the neck" did not loosen even if a scientist managed to survive.

Now, what was the attitude of Mandelstam himself to what was going on in the country; what was his social and political position? How did he behave himself in this horrible and complicated epoch?

We saw that in the life of L.I. there were several well-separated periods. First, a safe youthhood in Odessa, ending in participation in student political disorder in the university from which, for this, he was expelled. At the same time everybody who knew him in his mature Moscow period stress that he distanced himself from any type of social activities outside science. Others, almost everybody, had to yield to the humiliating norms of social behavior. Not all of them, especially in the twenties, did this out of fear. Yet almost everyone in the best case were "fellow travellers" of Soviet power, sometimes even its supporter, appreciating the positive development (general education, intensive development of science, rapid reconstruction of the economy that had been totally destroyed during the civil war, etc.). Nevertheless, already during the next decade, in the epoch of the "big terror" of the thirties and even earlier, more and more intelligents came to a sharp denial of the Stalin regime but did not show it, the fear "holding in leash", while the number of adaptive careerists did not decline.

L.I. himself was in political questions "completely buttoned" with respect to everybody save for the people closest to him and did not reveal his position.

Of course he could not escape the influence of his 14-year stay in Germany where, up until Hitler times, the scientific world traditionally stayed away from any kind of political activity and even from being interested in political questions. Academic life did not have anything in common with them (except for the problem of anti-Semitism which bothered, for example, Einstein). In Germany a mass protest of scientists against government actions like the one that in 1911 forced 150 progressive professors, indignant at the actions of minister Kasso, to leave Moscow University was impossible. This was however not sufficient.

In fact the political position of L.I. was extremely resolute and clear: he fully and sharply denied the Soviet regime and all the ideology and practice of social life enforced by the party.

Many Russian intelligents, in particular scientists, that already in tsarist times were "infected" by liberal and even socialist ideas found in the revolution and the societal structure that followed, with all its horrible features, positive sides. Some, like I.E. Tamm, participated before the revolution in political life, in revolutionary movement and, even when this participation had been over, remained faithful to some of the socialist ideas of their youth. Others, like S.I. Vavilov, had at first deeply accepted and highly esteemed the positive features of the new life and changed their attitude later. Third, like the young L.D. Landau, were charmed by high communist ideals and in the course of almost 20 years were ardent supporters of the Soviet power. One had to experience (often at oneself) the horrors of the "big terror" of the thirties in order to understand the essence of Stalinism and go into "internal emigration".

For Mandelstam everything was clear from the very beginning. In spite of participating in student disturbances in his youth, after experiencing life in civilized Europe and living through the Bolshevist revolt and horrors of the civil war in the Ukraine, he once and for all completely rejected the Soviet system. He had kept his disgust to it inside and only after its breakdown did we learn the strength of this disgust from those close to him. It turned out, for example, that in December 1922, I.E. Tamm had written about him from Moscow (where at that time, as mentioned before, L.I. worked in the trust of weak current plants):

Lidiya Solom[onovna] tells that his nerves are in extremely bad shape and finds it very worrying... By the way the disgust to everything

bolshevistic, in spite of things going well for him, became for Leonid Isaakovich quite extreme, up to the fact that a necessity of sitting at dinner (in different corners and not talking) with a communist, with this communist behaving, in L.I.'s own words, very decently, caused a terrible migraine for the whole following night [Andreev (1998)].

Of course such an extreme attitude towards Communists, such a sharp reaction, were not characteristic of all years in Moscow. From Tamm's letter it is clear that his nervous system was at that time in particularly bad shape. Besides that, a party member and a participant of the civil war, S.E. Khaikin (later falling victim to the merciless "ideological" witch-hunting), belonged to his closest disciples and his attitude to him was very warm. He was in very good relationship with B.M. Gessen. Among his last Ph.D. students was a feverish Bolshevik Maksim Andreevich Divilkovski. (I do not think, however, that L.I. forgave his active, one can say, leadership in the attack of 1936–1938 on those close to the "enemy of the people" Gessen. Probably he, with difficulty, tolerated him because of professional capabilities and a serious attitude to work.)

In the everyday behavior of L.I. in all situations where political issues showed up, one could observe nothing but his complete absenteeism. He could say, as some Germans in Hitler times: "*Ohne uns!*" ("Without us!").

This total clarity of position, together with unshakable moral values of a Russian intelligent, in addition a European, helped L.I. to gain a psychological stability that overcame both the ever present elements of nervous sensitivity of his finely organized soul and the difficulties of existence of that time.

The last "Moscow" twenty years of his life can be considered as almost happy ones. An unusual intensity of his scientific and of the, inseparable from this, pedagogical activities (what were his above-described brilliant lectures, a scientific or pedagogical creative activity?), a fabulous growth of a number of disciples surrounding him, from Ph.D. students to academicians, their respect and love — all this protected his "temple" from the horrors of the surrounding world, softened its blows. The power of his thought did not weaken with the years.

Here is characteristic evidence by I.E. Tamm [Prokhorov (1979), p. 134]. As is well known, Einstein, who had introduced a notion of light quantum in 1905 and can thus be considered to be one of creators of the fundamental principles of quantum theory, considered the quantum mechanics worked out in 1924–1926 (still developing and fruitful up until now) to be incomplete in its foundations. To prove this he, in the course of several years,

invented various experiments in which a quantum-mechanical treatment led to senseless results. There arose a paradox (see also a chapter on Bohr, p. 293). Discussion, both oral and written, occurred mainly between him and Bohr. A deep analysis, in particular for two last very difficult paradoxes, always led to their full clarification and after a reply by Bohr appeared in the journal the question was settled. 'Because of the features of his character L.I.', says Tamm, "did not publish anything on Einstein paradoxes but to us, his disciples, he explained their complete resolution a day or two after appearance of the next paper by Einstein". One has to mention that when telling this Tamm added that he and other people urged L.I. to publish his reasoning but L.I. only smiled and said that Einstein and Bohr are very clever people and this reasoning is surely known to them. (It is interesting to compare this behavior of L.I. with his own actions of his youth in the above-described arguing with Planck. It can be that precisely this unpleasant experience of his youth explained his behavior with respect to Einstein — Bohr discussion.)

Yes, almost happy years, with a correction "only" on them being filled with Stalinism having reached its climax, Hitlerism and war that probably took away only a little fewer lives than terror.

Moscow Zoo has a terrarium. In niches in the wall, separated from visitors by thick glass, one sees snakes. Here a gigantic, coiled-up python sleeps peacefully in the light of a low electric lamp hanging from the ceiling. And under the lamp there gather, to warm themselves in its light, mice for the python's future meal. They are really happy, because they do not understand the situation. For people of the twenties, thirties and later periods this lack of understanding was not that easy.

What about L.I.'s everyday life in these "almost happy" years?

In August of 1938 my wife and I did in a "savage" fashion spend our vacation in Teberda in the Caucasus. At that time there existed a, very popular among the scientists and indeed a very good, sanatorium of CAS, Commission for Assistance for Scientists (a governmental organization helping the scientists in both everyday and professional matters). In this sanatorium there spent their vacation L.I., Papaleksi and Tamm. Once, obeying to a burdensome tourist ritual, we went on a hike to some miserable sources. This turned out to be an uneasy enterprise. I was already quite exhausted when I saw an unusual picture. In the opposite direction, returning, rode on horses Leonid Isaakovich and Nikolai Dmitrievich. At that time they were both in their sixties and rode well. We were already sort of acquainted and the riders stopped smiling — it seemed to me, somewhat awkwardly.

It can be that recalling this encounter now, after many years, I am imagining something. It can be that Leonid Isaakovich did not wear leggings, did not have a riding-crop in his hand and a flat kepi on his head but this is an image I have before my eyes even now, that of a rider from some old pre-revolutionary photograph. On a natural question on how far do we still have to walk we got a reassuring answer: no, do not worry, not so far. We parted. At first we were heartened but we walked and walked and, in the heat, finally dragged ourselves to these sources only after about an hour and a half.

The next day, when visiting Igor Evgen'evich in the sanatorium, I met Leonid Isaakovich and wondered why had he cheated us. He answered with a disarmingly kind smile and an explanation: "If somebody is so tired, how could one tell him that he still has a long way to go?" One can also see another aspect of this: he probably could not imagine that one can have his intentions and give up reaching the set goal. We could have turned back though.

There passed only a little more than five years after this encounter but these were hard, wartime years. The health of Leonid Isaakovich declined, he did not leave his home, was sad. There remained less than a year until the end (November 27, 1944). Sergei Leonidovich told me once that his father's spirit could be improved by good music, for example, Beethoven quartets that he liked. At that time there tape recorders were not available and good vinyl discs were rare. My wife and I were very lucky: At that time she worked at the Conservatory and in her classes with students made wide use of a rich collection of vinyl discs of a gramophone recordings fund. She had no doubt that a supervisor of the fund would give her, for some time, any disc. It was less than half-kilometer between the Conservatory and Mandelstam's apartment. It remained to understand more precisely what Leonid Isaakovich would like to listen to. The answer, corresponded by Sergei Leonidovich, was unexpected: bringing discs was completely out of question. "It is inadmissible to use state property for private purposes. It can be used only by those for whom it is destined". It turned out this was an "iron", unbreakable rule.

As already told the Mandelstams lived in the apartment where one exit led directly into the corridor of the University Physics Institute. This door was used, all day long, by friends, colleagues, disciples of Leonid Isaakovich, by himself and his family. The apartment was perceived as a part of the institute. In fact an invisible border existed in this case as well. "Do you really think", Sergei Leonidovich explained to me, "that if our radio set

does not function and one has to check voltage on one of the valves it is possible to bring, for a minute, a laboratory voltmeter? This would cause a real anger by the father. Principle is a principle — state property is untouchable.

A very similar case is recalled by a close acquaintance of the Mandelstams, I.O. Vilner [Prokhorov (1979), p. 2]:

Once when I visited the Mandelstams, L.I. told me that although he did not feel well he would like to go and see a tennis match. Because it was difficult for L.I. to go by public transport I tried to get a taxi but did not succeed and, after returning empty-handed, suggested to call the garage of the Academy and ask for a car. L.I. gave me such a look that I could have rid from embarrassment: "What are you talking about? To go to see a tennis match in an academic car? How could such a thing occur to you?".

Many decades passed. Much has changed around us. It turned out easy to replace an old-fashioned watch in the waistcoat watch-pocket by modern electric watch with a LCD-screen. However, the "old-fashioned" principles and high moral characteristic for L.I. remain irreplaceable and keeping them intact turns out to be an uneasy business.

The contrast, so striking for me, between the softness of his manners and the complete clarity, sureness of his statements showed up in everything — in life situations, in general moral problems, in science.

Moral norms that he undeviatingly followed were those of the Russian intelligentsia, Chekhov and zemsky doctors. They were shaken within intelligentsia in Soviet times. Even these norms were sometimes betrayed due to the dominating general fear or due to careerist intentions. Nevertheless, of course not only due to such master exponents as L.I., much was carried through to new times, including the whole great culture of the country. What will be their fate in the new century, in new Russia?