

RECOLLECTIONS OF LEV DAVIDOVICH LANDAU

Landau's students and collaborators adored the great theorist. But his irreverence and nasty temper made enough powerful enemies to land him in the Gulag for a year.

Alexander I. Akhiezer

The older I get, the more I am afflicted by fits of nostalgia. Even when they recall the best days of my youth, they nonetheless weigh heavy, because it's impossible to go back. I think the best way to deal with these memories is to convey them to paper. So I'd like to share some of my recollections of a great man, my unforgettable teacher Lev Davidovich Landau, to whom I was close for several decades until his tragic death in 1968. (See also the articles by I. M. Khalatnikov and Vitaly Ginzburg in *PHYSICS TODAY*, May 1989.)

'Beware, he bites!'

In 1934, after finishing my studies at the Kiev Polytechnical Institute, I arrived in Kharkov with a "free" diploma, which allowed me to apply for a position as a doctoral candidate at the Ukrainian Institute of Physics and Technology. (It is now called the Kharkov Institute of Science and Technology.) Anton Walter, the scientific secretary of UIPT, took me to Landau for an interview. Landau's office was on the third floor, down the hall from the library. That stretch of corridor was signposted *Rue de Dau*. "Dau," I soon learned, was an affectionate truncation of his name. But another notice, hanging on the great man's door, warned: "Landau! Beware, he bites."

We knocked, and Landau himself opened the door. He was a very tall, somewhat round-shouldered young man in a light brown suit, snow-white shirt and red tie. A huge rubber crocodile hung from the ceiling, oscillating

Alexander Akhiezer is a professor of physics at the Kharkov Institute of Physics and Technology, in Kharkov, Ukraine.



Landau in 1958.

cent suit. But I managed to come up with an answer: "I am dressed like Comrade Stalin." To that he replied, "And I am dressed like Comrade Lenin." I understood that I hadn't made a bad impression on Landau.

I was appointed as a junior staff member of the institute's theory division, of which Landau was the head. He told me that in view of my illiteracy in theoretical physics, I should prepare to take the so-called

gently at the slightest air current. As I stood by his blackboard, Landau seated himself on a couch, put his feet up on the desk and started my interrogation: "Write down Maxwell's equations in four-dimensional form."

I knew the Maxwell equations very well, but not in four dimensions. I did not yet understand the great value of that covariant formulation. Then Landau asked me to write the Gibbs distribution in a general form. I couldn't do that either, though I was quite familiar with the Maxwell-Boltzmann distribution.

Landau wasn't taken aback by my inability to answer his questions. "Well," he said, "it's not surprising at all. Evidently you were taught by —. But he's not a theorist; he's a dentist. Let me check your math." He asked me to do a few integrals. Fortunately I calculated them by special tricks rather than by the common method of Euler substitution. I say "fortunately" because, to some extent, that determined my fate. Landau hated Euler substitutions.

I felt a little more at ease. But then came the next question: "By the way, how are you dressed?" I was wearing a black jacket and boots. In those days I, like many other students, didn't have a de-

AIP EMILIO SEGRE VISUAL ARCHIVES



Yakov Frenkel's seminar at the Leningrad Polytechnic Institute in 1929 included (left to right) Lev Gurevich, Landau, Lev Porenkevitch, Agnes Arsenieva, Frenkel, George Gamow, Maniusnii (first name not known), Dmitry Ivanenko and Grygory Mandel. (For more on Frenkel, see the article by Rudolf Peierls on page 44.) (Photo from AIP Emilio Segrè Visual Archives, courtesy of Victor Frenkel.)

theorminimum examination, which would include mechanics, field theory and electrodynamics, continuous media, statistical mechanics, nonrelativistic and relativistic quantum mechanics and gravitation theory. I had, in effect, to pass seven exams.

An episode from that time sticks in my memory. It was a winter night in 1934. I was sitting in the library reading a book on general relativity by Hermann Weyl. Landau, wearing a warm fur coat, came in and gestured that I should follow him. We went to his office and he asked me what I was reading. I told him, and added that I was delighted and surprised at the idea that the geometry of space is determined by its matter content; I couldn't have imagined anything like that.

Evidently Landau liked what I said. We started talking and he said: "Mathematics is too broad. It's impossible to master all of it. But one *can* master all of theoretical physics." Apparently he had done so. But of course that was the theoretical physics of the 1930s.

After I passed the *theorminimum*, Landau told me that I could now use the singular (familiar) form of the second-person pronoun with him. It was like a medieval ritual: When the apprentice passes some threshold, the master craftsman permits the familiar mode of discourse.

A world-class institution

In May 1934 an international conference on theoretical physics was held in Kharkov. The venue was chosen because that's where Landau was. He was only 26 years old at the time. I distinctly recall Landau and Niels Bohr walking around the UIPT yard in enthusiastic conversation. I also recall Bohr giving a lecture on the nucleus to a huge audience at the Röntgen Institute in Kharkov. Laszlo Tisza, a young Hungarian physicist, attended the conference and was so impressed by Landau that he wanted to return to Kharkov to work under him. Soon after Tisza's return to Kharkov in January 1935, Isaak Pomeranchuk arrived from Leningrad to do his doctorate with Landau. He and Tisza started getting ready for the

theorminimum, just as I had done.

In 1935 a session of the USSR Academy of Sciences was held at our institute. In his speech at that meeting, Academician Sergei Vavilov asserted that more than a quarter of all Soviet physics was being done at the Ukrainian Institute of Physics and Technology. It was, he said, a world-class institution, with an excellent building, a wonderful library and remarkable scholars. In addition to Landau and Walter we had Alexander Leypunsky, Ivan Obreimov, Lev Rosenkevitch, Kirill Sinel'nikov, Lev Shubnikov, Abram Slutskin and Vadim Gorsky.

The scientific staff met once a week. "Council" meetings, at which staff members reported their new results, alternated with "abstract" meetings, at which people reported on papers that had recently appeared. Landau was brilliant at both. His talks and remarks were always critical; they always addressed the very essence of the subject. It was amazing how perfectly he understood everything, all the more so because he read almost nothing himself. He just went to the library every morning with a large notebook and wrote down the titles of the papers he wanted junior collaborators and visiting theorists to read through and report on at the seminars.

Landau understood everything at once. He also discriminated between correct and what he called "pathological" work. The seminars helped him find many subjects for independent study in various specialties. I've had the good fortune to meet many fine theorists in my life, but I've never met his equal in universality, intellectual power and criticism.

Landau had excellent command of German, English and French. He loved history and the arts, and knew them well—all except music, which he neither understood nor liked.

Photon-photon scattering

After I passed the *theorminimum* Landau gave me a research subject. I was to study the scattering of light by light. Landau had earlier given this subject to

Rosenkevitch, who was another of his students. He and Landau were going to investigate the scattering of light by light in the low-frequency domain, where the photon energy is much less than the mass of the electron. (Electron-positron pair production makes the electron mass an important parameter here.) But Rosenkevitch failed to solve this problem, and besides, there soon appeared a remarkable paper by Werner Heisenberg and his student Hans Euler that gave a complete solution. Landau was upset that the problem "got away" from him.

That happened just when I was passing the *theorem*. So Landau decided to test my abilities with this difficult problem of photon-photon scattering, but this time in the high-frequency domain where the photon energy exceeds the electron mass. The phenomenon in question was a fourth-order effect in perturbation theory. To calculate the scattering probability in that approximation, one should really use Dirac's relativistic theory of the electron. But at that time, perturbation theory had been worked out only in nonrelativistic quantum mechanics. It was a hard task to calculate the scattering amplitude, because one had to take into account numerous intermediate states without overlooking any.

Eventually I had the amplitude written down and showed it to Landau. And that's when the first, and last, blowup in my relations with Landau erupted. He didn't like the nonrelativistic form of the probability amplitude. Besides, it was written in terms of photon vector potentials rather than the electromagnetic fields themselves. Therefore the expression was not gauge invariant. So Landau started getting angry, but he couldn't make my expression relativistically and gauge invariant either. Nonetheless I strongly objected to his assertion that it couldn't be done within the existing perturbation theory.

This conversation had become rather unpleasant by the time Rosenkevitch came in. Sizing up the situation, Rosenkevitch took two candlesticks standing on the desk, gave one to me and the other to Landau, and said, "Now fight it out." Landau burst out laughing and said: "The hell with you. Do the calculations the way you want." I understood that he couldn't deny my general formula. So I decided that since the formula was correct, it should lead eventually to a properly invariant expression.

'The best gammists'

It was then that Pomeranchuk began to work with me. The calculations were horrifying exercises in the manipulation of gamma matrices. Evgenii Lifshitz, coauthor of the famous Landau textbooks, joked that Pomeranchuk and I were "the best gammists in the Soviet Union." (The joke, which loses something in translation, depends on the similarity of "gamma" to an indecorous Russian word for excrement.)

Landau was insistent that we check the gauge invariance of our result. To that end we replaced the vector potential with the field itself. We got 144 terms, which had to sum to zero. Chuk (that's what we used to call Pomeranchuk) and I held our breaths as we did the sum. I can't remember any other moment when I've been as

happy as I was when I finally saw that the sum did indeed vanish. We immediately ran to Landau. He was happy too. Soon we had completed the calculation, getting a relativistically invariant expression for the scattering cross section in the high-frequency domain. We also succeeded in removing possible divergences simply by exploiting the gauge invariance of the amplitude.

We described our work to Victor Weisskopf, who had recently arrived in Kharkov. He was very pleased with it. At Landau's seminar Weisskopf reported on his own work on the nonlinear electrodynamics of the vacuum, and he gave me the galley proofs of his paper. Though he obtained the same result Heisenberg and Euler had gotten earlier, Weisskopf's method was beautiful. Landau was full of praise.

Landau suggested that we publish our results in the British journal *Nature*. Pomeranchuk and I wrote a brief paper, and Fritz Houtermans, a German émigré at our institute, promptly translated it into English. (For more on the peripatetic Houtermans see the letter by Victor Frenkel on page 104 and the article by Iosif Khriplovich in *PHYSICS TODAY*, July 1992, page 29.) Without bothering to get official permission, we took the article to the post office, and soon it was published under our three names.

Then Pomeranchuk and I concerned ourselves with the problem of the coherent scattering of gamma rays in the Coulomb field of the nucleus. This was another problem to be solved in the framework of Dirac theory. In 1937 there was a nuclear physics conference in Moscow. Pauli came, and Landau introduced Pomeranchuk and me to him. We familiarized Pauli with our work on light-light scattering and gamma scattering off nuclei. He approved.



Akhiezer and Laszlo Tisza at the Ukrainian Institute of Physics and Technology in 1936, the year they both completed their dissertations under Landau. (Courtesy of Tisza.)

It was all a brilliant success for Landau's "school," because it indicated that we were dealing with the most important theoretical problems of the day.

Shortly before this, the government had decided to reinstate the awarding of scientific degrees and ranks, which had been stopped after the revolution. At our institute Landau, Obreimov, Leypunsky and Sinel'nikov were awarded the degree of doctor of sciences without having to defend dissertations. Soon thereafter Lifshitz defended his dissertation, and then, in 1936, Tisza and I defended ours. These were the first three dissertations to come out of Landau's school.

At Tisza's and my defense, the appointed reviewers were Igor Tamm from Moscow and George Placzek, another German émigré then visiting at our institute. After the defense, there was a wonderful dinner at Landau's apartment. It seemed to us a serene time, even though it was already two years after the vicious murder of Sergei Kirov, secretary of the Leningrad Regional Party Committee. But none of us at the time understood the meaning of that murder. (It eventually became clear that Kirov was an early victim of Stalin's terror.)

Later in 1936, Landau, Pomeranchuk and I were listening to Stalin on the radio, announcing his new constitution. After that historic speech, Landau commented that this marked the beginning of "a new, good era." At that time Landau was "red," and he didn't tolerate the expression of any anti-Soviet opinion.

Friends and enemies

We adored Landau; we tried not to miss a word of his. We attended his lectures on general physics with great admiration. One of his courses was theoretical physics for experimentalists. Our attitude toward him was very vividly defined by Pomeranchuk: When Landau was later picked to pieces at a meeting of Komsomol, the official Communist youth organization, Pomeranchuk exclaimed, "I would willingly follow Landau into a labor camp!"

But what kind of a person was he really? What was his temperament? Landau was in fact very benevolent. Anyone willing to do theoretical physics could come to him. But he was a man of principle who would not compromise on issues of science or relations between people. He was absolutely intolerant of falsehood, pseudoscience and its representatives, and he did not hesitate to express his opinion about their "work." Nor did he hesitate to express his attitude toward erroneous results by well-known legitimate scientists. There was, for instance, a widely touted paper by Academician Abram Ioffe on thin-layer insulation. Landau tried to convince Ioffe that the idea of thin-layer insulation was erroneous, but Ioffe would not accept criticism. In fact he took offense. I believe that this altercation between Ioffe and Landau, who was supported by Obreimov and Shubnikov, was the reason for Landau's move from Leningrad to Kharkov. I believe Peter Kapitsa had the Ioffe incident in mind when he referred to Landau's disrespectful teasing of aging academicians in his letter to Stalin on Landau's behalf after his arrest in 1938. (We'll come to that.)

There's no need to conceal Landau's sins. He was often harsh but on the whole fair. Many people found him offensive. That gave rise, I would say, to an accumulating storage of offensive energy: At first only the offended stored it. But later, when informers flourished,

this stored energy was released, to frightening effect on Landau's life.

But let us stay for the moment with those merry days of cheerful and witty Dau. He had a passion for classifying everything. First of all, he divided theoretical physicists into six decades on a logarithmic scale. I became aware of this classification when I first crossed the threshold of his office. There were quite a few portraits on the walls. Landau explained to me that the first two portraits, of Newton and Einstein, filled the zeroth class. Then there were portraits of Maxwell, Boltzmann, Gibbs, Planck, Fresnel, Bohr, Schrödinger, Heisenberg and Dirac. These Landau assigned to the first class. At that time he put Fermi and Pauli in the second class, to which he later added himself. His fifth class included the "pathologists," whose work had no physical meaning.

Landau also classified women by their beauty. "I am," he said, "a beautist, not a soulist."

One April Fools' Day, an official notice appeared on the institute's bulletin board, classifying the entire scientific staff by ability and revising salaries accordingly. There was of course much ado, and those who felt themselves wronged ran to the director to complain. But he professed complete ignorance of this new order, even though it displayed his signature. It soon became clear that the notice was a fake thought up by Landau. The typists in the Secretariat liked Landau. So they had helped him create the document. I cannot say that this incident endeared him to the institute's big shots.

In addition to his position at the institute, Landau was a professor at Kharkov University. The faculty "buffaloes," as Landau called them, also took offense when he didn't hesitate to reveal in public their megalomania and attachment to false science.

Landau was always willing to give advice to an experimentalist. He was very close to Shubnikov. He supported Shubnikov's remarkable experiments on superconductivity and ferromagnetism. Landau and Shubnikov often worked late into the night, and Shubnikov's wife brought them dinner at the institute. Landau was also very interested in Gorsky's experiments on x-ray scattering.

Mathematical ingenuity

In 1935 Landau visited Bohr in Copenhagen for the last time. Pomeranchuk and I met him at the railway station when he came back. In the car on the way home Landau spoke nonstop about the theoretical physics he had learned on the trip. He was particularly interested in the explanation of cascades in cosmic-ray showers recently given by Robert Oppenheimer and John Carlson, and by Homi Bhabha and Walter Heitler. These investigations had explained only the essence of the phenomenon; but they didn't formulate a detailed theory of the showers. Landau himself soon constructed the detailed theory, in collaboration with Yuri Rumer.

Let me dwell a bit on this work as an illustration of Landau's mathematical talent. Being a great connoisseur of statistical physics, Landau started by formulating kinetic equations, like Boltzmann's kinetic equations, for electrons and photons generating a shower. To solve them, he essentially reinvented the Mellin transformation. I find it curious that he didn't know about this well-established mathematical technique, and impressive that



Abram Ioffe (1880–1960) was one of the pillars of the Soviet theoretical physics establishment who took offense at Landau's irreverent manner.



Evgenii Lifshitz (1915–85) was coauthor of the celebrated series of Landau–Lifshitz textbooks in theoretical physics.

he was able to invent it when the need arose.

Years later, in Moscow, I had another occasion to be amazed by Landau's mathematical inventiveness. He was dealing with the de Haas–Van Alphen effect. To describe these oscillations of diamagnetic susceptibility with increasing magnetic field, Landau devised a mathematical method we couldn't understand at first. I showed it to my mathematician brother, who explained to me that Landau had reinvented the Poisson summation formula. Landau had never heard of it.

In those days Landau had a negative attitude toward probability theory. "I'm not aware that such a science exists," he would say. "But if you give me a complicated probability problem, I'll try to solve it myself." So one morning in Moscow, Ilya Lifshitz (Evgenii's brother) gave him a hard problem. It was Andrei Kolmogorov's problem on the distribution of particles that results from grinding. That very night Landau phoned Ilya at his hotel with the solution. It was, of course, right.

Landau also didn't know much group theory. But he quickly picked up its essential wisdom one day while playing tennis with the well-known algebraist Nikolai Chebotarev. Landau soon made good use of what he learned that day on the tennis court in constructing his famous theory of phase transitions.

The range of theoretical problems on which Landau worked productively was enormous. He worked on the foundations of quantum mechanics, magnetism, quantum electrodynamics, superconductivity, quantum fluids, elementary particles, stellar energy production (he predicted the existence of neutron stars), the second law of thermodynamics, plasma physics and many other problems. And he always obtained wonderful results. Now, leafing through a collection of Landau's papers so many years after his death, you can't fail to realize how great he was. The names alone—Landau energy levels, Landau diamagnetism, Landau decay and Landau theory of second-order phase transitions—will remain as long as people study physics.

The teacher

Landau's creativity was not confined to his research. An important part of his creative activity was writing textbooks, reviews and popular books about physics. Unfortunately he never did manage to complete the most valuable work of his life: his multivolume theoretical physics course. There already existed many excellent textbooks on different fields of theoretical physics. But Landau proceeded from the viewpoint that all these areas of theory constitute a single science, whose exposition should be as unified and simple as possible. He couldn't stand excessive complexity. He strove, as he said, "to make everything trivial."

Thus he began to create the unified course that ultimately gave us his multivolume treatise, rightly characterized as the encyclopedia of 20th-century theoretical physics. It is a monument to Landau, and to Evgenii Lifshitz, his closest disciple and coauthor.

In Kharkov, Landau also began work on a general physics course. His intention was that the course should contain only fundamental ideas, with minimal mathematical apparatus and no exposition of experimental details. I became involved in that effort. Unfortunately, only the first volume of the course, devoted to mechanics and molecular physics, was ever published.

Working on this book with him enriched us. Once again we were amazed by Landau's talent, not only in pure science but also in teaching. Landau's pedagogic ideas were uncommonly deep and lucid. That was particularly true of his presentation of Newton's laws and thermodynamic concepts such as temperature and entropy.

Landau was a born teacher. I remember the brilliant lectures on general physics he gave to the first-year physics students at the university. The utmost clarity and rigor, but nothing superfluous. Landau thought it essential that we, his younger colleagues, also take part in teaching.

At one of his first lectures at the university, Landau distributed a questionnaire to his students. It contained questions like: How do fish breathe underwater? Is the Earth closer to the Sun in summer or in winter?.

Landau's teaching style at Kharkov University was annoying to some of the faculty buffaloes. He was turning everything upside down, changing the courses in both general and theoretical physics. Landau had become head of the physics faculty, replacing Andrei Zhelikhovsky. The changes in all the subjects were going to be revolutionary: The teaching of mechanics to physics students was taken away from the mechanics faculty and based on the least-action principle; the conservation laws were to be derived from the space-time symmetries. Electrodynamics was to be taught *after* special relativity, which would now be introduced early in the students' second year, rather than as an afterthought in the fifth year. Even Newton's laws in the general physics course were to be taught in a novel way. All this was contributing to the accumulation of offended feelings and thwarted ambitions. That stored animosity was soon to erupt.

As 1936 drew to a close, the situation at UIPT was getting worse and the clouds were gathering over our heads. New, unknown people were being hired. Landau, sensing the growing intrigue, started thinking about leaving Kharkov. Kapitsa had just organized a new physics institute in Moscow. Landau had known Kapitsa for a long time, and Kapitsa respected him highly.

Eruption

In December Landau was dismissed from the university. No reason was given. In March 1937 he took up a position at Kapitsa's new Institute for Physical Problems in Moscow. Eventually it became known that he had been fired from Kharkov University for spreading the heresy of "idealism."

We, Landau's colleagues and friends, thought his firing an inexcusable outrage. All of us who held part-time university appointments—Shubnikov, Gorsky, Lifshitz, Pomeranchuk, Abram Kikoin, Nikolai Brilliantov and I—submitted letters of resignation to the university administration in protest. As a result, we too were fired. Our action was regarded as a strike (something strictly forbidden in "The Workers' Paradise"), and we were strongly criticized at the labor union meetings. Before long we were summoned to appear before the People's Commissar of Education in Kiev. "What the hell is going on in your Kharkov?" he asked us. "Landau is preaching for idealism

and against dialectical materialism, even against the theorem of energy conservation, and you organized an anti-Soviet strike!"

We understood at once that somebody from the university had denounced Landau. We were quick to deny these accusations. "Just yesterday," said I, "Landau berated me and Pomeranchuk because one of our equations violated energy conservation." The commissar, who had a degree in chemistry, laughed and told us how much we were needed at the university. "Don't worry," he concluded. "Go home and get back to work." Encouraged, we went back to Kharkov in good spirits. But Landau never got his university post back.

How did Landau come to be accused of "idealist deviationism"? The answer, I think, goes back to a time before Landau came to Kharkov. In those days Landau was one of the most brilliant exponents of Bohr's scientific philosophy. The official Soviet philosophers and some physicists who sided with them rejected the philosophy of Bohr's Copenhagen school as a form of idealism incompatible with Marxist dialectical materialism.

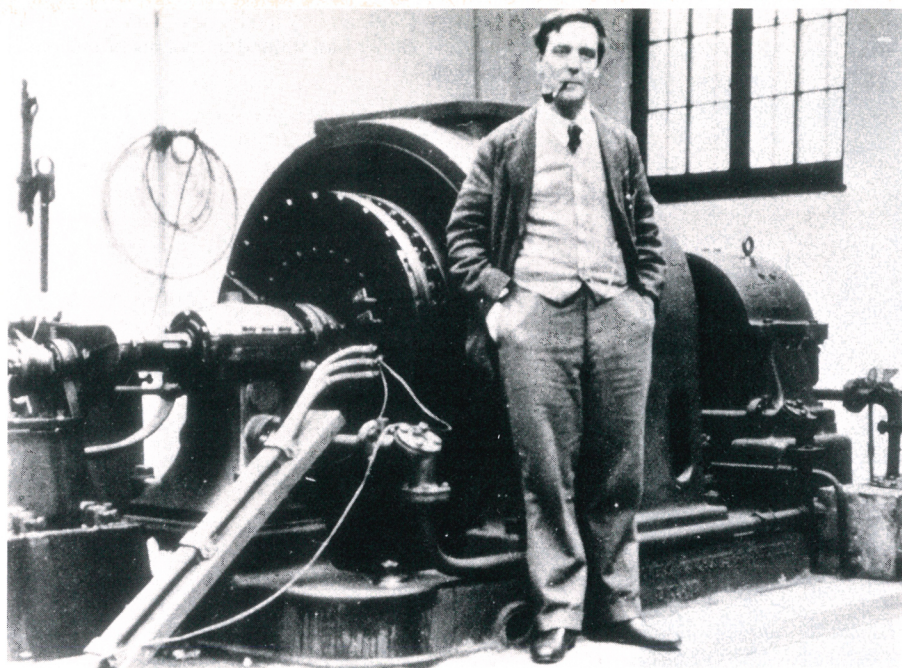
Stalin's terror was now in full bloom. All over the country the demons were raging in their bloody orgies, savoring the denunciation, degradation, torture and murder of the innocent. At night people would wait helplessly for the dreaded arrival of the NKVD (that's what the KGB was called in those days) vehicles everyone called "the black ravens." Finally the ravens showed up in our UIPT courtyard and claimed their first victims: Shubnikov, Gorsky and Rosenkevitch, wonderful men and first-rate scientists. The next day their families were thrown out into the street.

Soon we were all summoned to a staff meeting devoted to problems of "watchfulness in connection with unmasking enemies of the people at the institute." At this meeting I was asked what Landau had said about Comrade Stalin. I answered that he didn't talk about Stalin. "Then what has Landau said about Lenin and Marx?" I answered that Landau regarded Marx as a prominent scholar and that he had expressed deep respect for Lenin. Then I was asked what Landau said about the local party leaders. I replied that he had indeed said something about our former party secretary, Comrade M. "So, what did he say?" Thus prompted, I replied that "Landau said that women must find Comrade M.'s face disgusting." Amid general laughter the chairman warned me sternly not to make a mockery of this important political campaign.

After that exchange a commander of the security guard stood up and said in Ukrainian (a language rarely heard at this Ukrainian institute), that all this was a disgrace. "We just have to compile a list of bootlicking class enemies," he said. Then he started naming names, but he was cut short by the institute's new party secretary, who said that all this was good for nothing but the humor magazine *Krokodil*.

Landau arrested

Luckily Landau was already in Moscow when the others were arrested at UIPT. But the wave of terror reached him soon enough. Landau was arrested on 27 April 1938. The very next day Kapitsa wrote to Stalin, urging him "to issue instructions that the case be treated with great care,



Peter Kapitsa (1894–1984) at Cambridge University in the early 1930s, standing in front of an alternator he developed for high-field electromagnets. When Landau was arrested in 1938, Kapitsa promptly appealed to Stalin on his behalf. (Photo from AIP Emilio Segrè Visual Archives, gift of Ernest Walton.)

in view of Landau's exceptional talent. . . . It also seems to me that we must take into account Landau's temper, which is, simply put, nasty. He's a squabbler and a teaser. He looks for others' mistakes, and when he finds them, especially when they're made by pompous old academicians, he teases disrespectfully. That's why he appears to have many enemies. . . . But for all his bad temper, I can hardly believe Landau capable of anything dishonest."

While Landau was under arrest in 1938, we received the proofs of the textbook *Mechanics and Molecular Physics*, developed for the general-physics course. It was printed in Moscow by the State Technical Publishing House. On the title page, Landau's name was blotted out, because he was now "an enemy of the people." Only two names remained: Lifshitz's and mine. Correcting the proofs, we wrote in Landau's name.

But it wouldn't be that easy. Lifshitz and I were summoned to the press offices of the Central Committee of the All-Union Communist Party in Moscow. There we were received by a very cultured-looking man. "You've written a very good book," he began, "and we want to publish it. But the name of Landau cannot be among the authors. We need to get your consent to remove his name." That was impossible, we replied, because the whole book was based on Landau's ideas. And furthermore, we argued, when he's released we would appear before him as betrayers and scoundrels. "I understand," said our interlocutor. "If he's released, we will help you to put out a second printing." But this cultured gentleman wasn't very insistent. "Let it be as you like," he said. He signed our passes and we said good-bye. Soon thereafter we learned that he too was arrested. By the time our book came out, Landau had already been released and the title page had all three names.

In March 1991 the monthly newsmagazine of the Central Committee of the Communist Party of the Soviet Union published the details of Landau's case. Thus we now know that he was accused of anti-Soviet activities and participation in the creation of a counterrevolutionary leaflet. At first Landau denied all the accusations. But

later, probably under coercion, he said, "I see that it is senseless to deny any longer my involvement in drawing up the counterrevolutionary document."

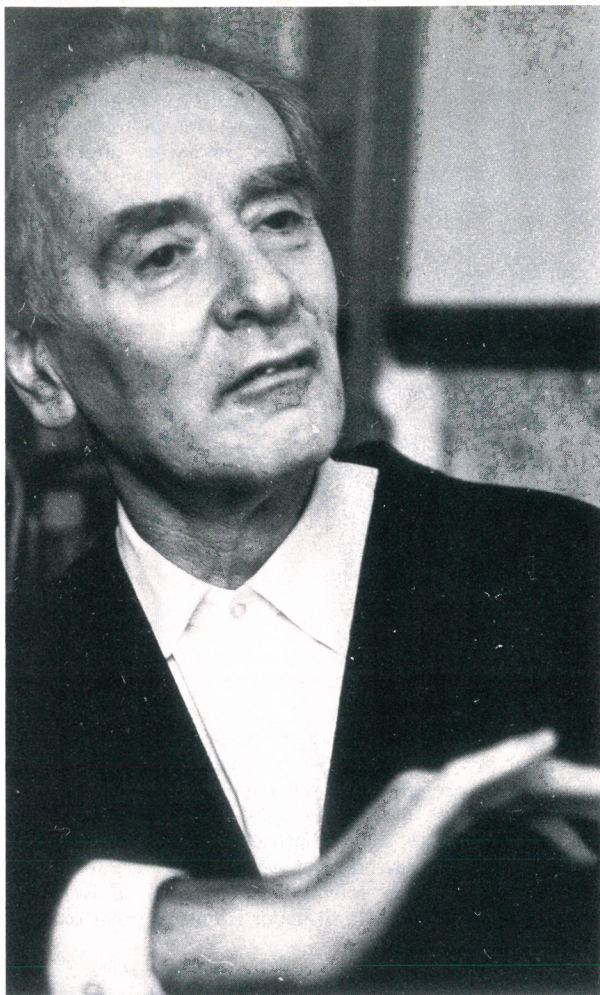
Landau was spared the worst. Thanks to Kapitsa's tremendous efforts, the authorities had to release Landau after a year in prison. But they never withdrew the charges; they simply released him on bail on Kapitsa's responsibility. We must all honor Kapitsa's great courage and fortitude.

Landau was posthumously rehabilitated only in 1990. So from 28 April 1939, the date of his release, to 1 April 1968, the day he died, Landau was officially considered guilty of "participation in anti-Soviet group activities."

I visited Landau in Moscow a few days after his release. He looked like a skeleton; I didn't see how he could have survived. Landau never talked much about that year in prison, but he gave me to understand that he had been tortured by means of lights. He also said that he hadn't been able to do any physics, but he had thought a lot about economic theory. Economics, he now believed, was a broad and interesting science.

With his health somewhat restored a few months after his release, Landau embarked upon the most creative period of his life. His fame and his legend spread. A regular theoretical seminar was organized at the Institute for Physical Problems, to which theorists came from all over the country. The seminar was remarkable. It was a daunting experience to give a talk there, because Landau understood everything and he was still quite intolerant of wrong or pathological statements. On the other hand, if he approved of your talk, you were in seventh heaven.

Landau mastered the new quantum electrodynamics of that period very quickly, and he was soon making his own excellent contributions. In 1955 he and Pomeranchuk published their paradoxical conclusion that consistent application of the pure quantum electrodynamics formalism leads to a vanishing of the physical charge of the electron. (The paradox was resolved only with the eventual introduction of the non-Abelian gauge field theories of the modern standard model of the elementary particles.)



Landau in January 1968, a few months before his death. A car crash six years earlier had robbed him of his prodigious scientific faculties.

A tragic accident

In 1958 Landau's 50th birthday was celebrated with great pomp and mirth. Admiring colleagues and former students gathered from all over the country. For the next four years Landau worked very productively, doing theory, writing books and teaching. Then on 7 January 1962 a terrible tragedy happened: A car taking Landau to Dubna collided with an oncoming truck, and Landau was very badly injured. Then began a struggle to save Landau's life. Soviet and foreign physicians, nurses and even physicians joined the struggle. They managed to save his life, but not his unique intellect. It was painful to see, but happily, Landau himself could not perceive it.

I was allowed to visit Landau when he was transferred to the Burdenko Neurosurgery Hospital in Moscow. I couldn't help crying when I saw Dau, prostrate on his bed. But he recognized me and said, "Oh Shurochka, you little bootlicker! How are Sonia and Naum?" I was stunned to hear him say "bootlicker" in Ukrainian (*pidlabuznik*). The last time I'd heard that particular Ukrainian word was 25 years earlier at the vigilance meeting in the UIPT auditorium, from the guards' captain who wanted to make short work of all class enemies. Dau's memory of the distant past, it seemed, was still fairly good. But how, I wondered, could Landau know about that "bootlickers" tirade? He had left for Moscow before the arrests and the subsequent vigilance meeting. Suddenly it occurred to me that the investigator in charge of

Landau's case knew the protocol of that famous meeting. He must have described it to Landau in some detail.

On 1 April 1968 my collaborator Vladimir Berestetsky and I were at a meeting organized by Nikolai Bogolyubov in Kiev when it was announced that Landau had died. At first we thought it was just another of Dau's April Fool jokes. But it was true. Berestetsky and I flew immediately to Moscow.

Landau's coffin lay in the conference hall of the Academy of Sciences. We still couldn't quite grasp it. Standing nearby was the driver who was giving Landau a ride on the fateful day. It was painful to look at him. There were many speeches, and then Landau was buried at Novodevichye Cemetery in Moscow.

When I visited Landau's grave a few years later, the monument created by the well-known sculptor Ernst Neizvestny was already in place. It didn't seem to me very expressive, looking rather like a bird perched on a pole. It occurred to me how right the Old Testament sages had been to forbid graven images of the ineffable. Landau's discoveries and his books, from which future generations will still learn, are a better memorial.

* * *

The editors gratefully acknowledge the generous assistance of Andrei Afanasev (Kharkov Institute of Physics and Technology and CEBAF, Newport News, Virginia), whose abridged translation of the author's longer essay in Russian was of great help in preparing this version. They also thank Laszlo Tisza (MIT, emeritus) for sharing his recollections and photographs. ■