

UNDER THE SPELL OF LANDAU

M. SHIFMAN



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WHEN THEORETICAL PHYSICS WAS SHAPING DESTINIES

Layout



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EDITOR

M. SHIFMAN



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**UNDER THE SPELL OF LANDAU: When Theoretical
Physics Was Shaping Destinies**

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FROM THE EDITOR*

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The year 2008 marked the centenary of Landau's birth. Lev Landau created the Soviet school of theoretical physics, renowned for its seminal achievements. His life and work are legend. Although I never saw Landau with my own eyes, his students and followers taught me. His course in theoretical physics guided my path in physics. For generations of young theoreticians, his texts were a primary source of knowledge, and even today, a half century after Landau's course appeared in print, for many topics it remains definitive.^a

Landau could be thought fortunate to have lived and worked shortly after the dawn of quantum physics. He became a trailblazer in the quantum world. Among the most influential physicists of the twentieth century, Lev Davidovich Landau was a great universalist who made fundamental contributions in many different fields: quantum mechanics, the theory of magnetism, the theory of phase transitions, nuclear physics and the physics of elementary particles, quantum electrodynamics, the physics of low temperatures, hydrodynamics, the theory of atomic collisions, the theory of chemical reactions... and much more. From my vantage point as a contem-

*Parts of this article were translated from Russian by Forrest Rhoads, Milla Grin, and James Manteith.

^aFor a detailed discussion and historical perspective see Karl Hall, "Think less about foundations: A Short Course on the Course of Theoretical Physics of Landau and Lifshitz", in *Pedagogy and the Practice of Science: Historical and Contemporary Perspectives*, Ed. David Kaiser, (MIT Press, 2005), page 253.

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porary physicist, I would venture to call Landau theoretical physics' *last* great universalist.

The breadth of Landau's scientific interests was astonishing, as was the depth of his insights in various physics disciplines. An incomplete list of his eponymous achievements might include: Landau diamagnetism, Landau levels in magnetic fields, the ferromagnetic domain structure, the Ginsburg-Landau theory of superconductivity, superfluid helium, the theory of the Fermi liquid, Landau damping, the Landau zero charge in quantum electrodynamics, the two-component neutrino theory, Landau's equations for S matrix singularities... Soon after the tragic automobile accident which cut short his scientific life, he was awarded the Nobel Prize "for his pioneering theories of condensed matter, especially liquid helium" (1962).

Much has been written about Landau; his life and achievements have been examined from all sides. My idea was to compile a collection of essays and memoirs not just about Landau, but rather about the Landau School. At first I wanted to entitle this collection "The Last Wave" and even began a bit of a collaboration with Gennady Gorelik, the well-known historian of science and Landau specialist. But for several reasons this project didn't work. I returned to it in a somewhat different form after four years or so.

Why "The Last Wave"?

Landau's school was a unique, endemic event in the recent history of physics, never to be repeated. The School was born and developed in very particular conditions: a revolutionary breakthrough in physics, dramatic social changes in Russia and the accompanying great expectations, a large group of young science enthusiasts gathering in Moscow, a strong leader with unquestionable authority and readiness to assume the mission of a founding father, complete isolation from the rest of the world starting in the mid-1930s, the high prestige of physics associated with the atomic project – it's hardly conceivable that such factors will combine again in the future.

Landau was always surrounded by students. He himself hardly ever read the scientific literature. His students read and told him about it. As a rule Landau was only interested in a work's concept and in its result, which he would later reproduce himself. Shared

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day-to-day activities bonded together a group of like-minded people around Landau – people who considered physics more important than anything else and generously gave it all their heart and talent.

Landau was unquestionably *the* leader, and his school, a world-class school, was one of the very few *real* achievements of the Soviet Union. Thanks to his supreme authority among his colleagues and students, for many years he shaped his school's growth and determined the main paths for theoretical research.

It takes more than being a great physicist to establish a school. For example, Schwinger, they say, was uniquely talented but a lone wolf who disliked teaching students... In addition to demanding great scientific talent, creating a school implies willingness to surround oneself with young people, inspire them, and constantly and constructively interact with them. Then they will enthusiastically follow. This is a special skill which Landau enjoyed.

The School didn't die with Landau's automobile accident in 1962, despite the death of its founder's scientific activity. The School stayed alive in Landau's students. When I came to ITEP^b in 1969 or '70 and decided to become a theoretical physicist, I had to pass a number of examinations, the famous Landau *theoretical minimum*. My examiners were V.B. Berestetsky and K.A. Ter-Martirosyan. This was as important as keeping alive Landau's attitude to physics, his insightful informal approach to physical problems, which he so cherished. Theoretical physics, like the Olympic torch, passes from hand to hand. The understanding that theoretical physics is about developing a deep intuition in the phenomenon that you study, day after day, to the extent that you see it in dreams at night, and then, all of a sudden, the answer you look for miraculously surfaces in your mind, in the beginning quite vaguely, in an approximate form, before the actual calculation is done – this understanding is passed from hand to hand. Landau ignited the Olympic flame, and his pupils carried it on.

The situation in theoretical physics changed after the collapse of the Soviet Union. The Landau School is gradually fading. Some

^bThe Institute of Theoretical and Experimental Physics, in Moscow.

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physicists left for the West, and some have passed away. Physics doesn't hold the same attraction for the new generations coming to replace the old. To some degree this is connected with the fact that in the past physics offered an escape from the insane, inside-out world of Soviet life. Bright young people flocked to physics, as to music, wanting to have nothing at all to do with ugly official ideology or anything associated with it. This motivation fell away. "The time is out of joint,"^c and who can pass the torch from hand to hand now? To whom? Will the spirit of Landau continue to drive theoretical physics in the future?

My initial goal, as I saw it before I started, was to acquaint the reader with Landau's best students, the ones who had Landau as their thesis adviser and who later carried on his glorious legacy. Shortly after I began work on this collection, it became apparent that the Landau School is an enormous topic, a prodigious undertaking beyond my grasp for many reasons. First, some of his students, fortunately, are still with us, and in this case it makes sense for them to write their autobiographies. A couple of memoir books of this type have been published and are rather well-known. Probably the best example is the excellent book by I.M. Khalatnikov.^d My interference in these cases would be totally inappropriate.

Second, I can't write about people I didn't know personally. For a comprehensive book about Landau's disciples, a professional historian of science would be needed. (If any are listening, I offer them this topic as a generous gift.)

Accordingly, I decided to narrow my task in some ways and expand it in others. This book will focus on just a few people from Landau's "cohort" whom I knew personally and who – alas – departed this world in the years after the demise of the Soviet Union... I've put cohort in quotes because I use this term in a broad sense. This collection is not only about those who actually passed the theoretical minimum and whom Landau officially agreed to take on as his students.^e To my mind, the meaning of the Landau School is

^cWilliam Shakespeare, *Hamlet*.

^dI.M. Khalatnikov, *Dau, Kentavr I Drugie (Top Nonsecret)*, (Fizmatlit, Moscow, 2007).

^eThose who didn't pass Landau's theoretical minimum exam formally were not consid-

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broad. It includes people from Landau's circle, participants in his seminar, students of his students, and so forth – all those whose scientific vision was shaped by Landau's ideas and attitude about physics. It simplifies my task immensely that the narrative below concerns people whom I knew personally. Eight chapters, eight human beings and outstanding theoretical physicists... Migdal, Zeldovich, Smorodinsky, Ter-Martirosyan, Kirzhnits, Gribov, Larkin, Anselm. Their lives intertwined in a remarkable way. For example, Ter-Martirosyan taught Anselm. Larkin was a student of Migdal, who in turn played a very special role in Landau's circle. Larkin's excellent essay on Migdal is included here. They were all inhabitants of the small, magical world reflected in this book's pages, and they all knew each other. Their names can be found here in various combinations and episodes, scientific and non-scientific.

Besides the presence of the physicists named above, an immaterial substance permeates each of this book's chapters: the atmosphere of the age these people lived in. I wanted to convey a sense of everyday

ered by Landau to be "his" theorists. Here's how David Kirzhnits described his situation at a seminar in honor of Landau at the Institute of Theoretical and Experimental Physics in 1988: "... I want to tell the story about how I didn't become Landau's student. It was around 1948. I was working on my undergraduate thesis in quantum electrodynamics. This was a hot topic then, with Lamb shift experiments recently finished. The first publications by Weisskopf and French, by Hans Bethe, were appearing in journals, and I was right in the middle of this uproar. I had only passed half of Landau's theoretical minimum exam. To put it succinctly, I had fallen behind in my studies, because I couldn't tear myself away from my current work... The moment came when I needed serious advice. I consulted a few times with Galanin, Berestetsky and Pomeranchuk, but still this wasn't enough, and after having consulted with Kompaneyets, I decided to go to Landau, although I understood that I was in a hopeless situation, since I hadn't been preparing for his exam for a year or more. I must say that this encounter didn't end well, although it left the impression of the utmost fairness. I told Landau about the results of my work and he gave me a scolding, criticizing some parts while praising some other parts, and the parts that he praised are still viable today, and even applicable, albeit in other areas. At the end Landau said, 'I have an unbreakable rule. A person who doesn't complete my theoretical minimum exams and starts independent research is a person I want nothing to do with.' ... Of course later, when I returned from industry to the academic world, I had other meetings with Landau, but they didn't always leave a taste of perfect fairness, as in this earlier encounter, which stood as a high point in my memory." See D. Kirzhnits, "Memories of L.D. Landau," in *D.A. Kirzhnits, Trudy po Teoreticheskoy Fizike i Vospominaniya*, (Fizmatlit, Moscow, 2001), Vol. 1, p. 347.

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life in Soviet society and to provide a snapshot of the conditions which Landau and his students worked under, because without such an understanding the reader cannot fully comprehend the memories each contributor shares. A special chapter of the book entitled “Time and Destinies” will hopefully prove valuable for this purpose. In my opinion, the physicists’ memoirs in this chapter vividly depict the complexities of their time – an era gone forever. These pages could be seen as a kind of impressionistic portrait of Atlantis...

This collection bears little resemblance to a glossy magazine with fairy tales of celebrities. Stalin’s system, under which Landau lived, was built on absolute authority and the strictest hierarchy, with signals flowing only in one direction, from the top of the pyramid downward. This pyramid structure partly penetrated the Landau School as well. The School functioned to a significant degree like a medieval guild with Grand Masters and knights, with Landau the grandest of all. But instead of the brute force that reined among Stalin’s satraps, it was Landau’s scientific prowess that gave him superior authority. He had the power to “execute and pardon.” If he thought one of his pupils had erred either in physics or in life, he could “excommunicate” the offender from his seminar forever or for a season. Landau once excommunicated Pomeranchuk from the seminar over Pomeranchuk publishing a paper with Ivanenko, whom Landau considered a bad person (probably with good reason). Ioffe’s Landau memoir^f recounts an episode involving Landau’s discovery of combined parity conservation. The young theorists Ioffe, Rudik and Okun, at their own peril, had begun to research the very hot topic of parity non-conservation in field theory. Ioffe and Rudik discovered that if P is broken, so is C , and vice versa. Landau frowned on this. He didn’t believe P could be broken in any way. Pomeranchuk convinced him, with difficulty, to listen to the young people. Landau listened. Landau’s manuscript on CP conservation appeared the next morning. At first Ioffe and Rudik were not even mentioned in this article, but communal pressure forced Landau to mention them in acknowledgments, albeit not in alphabetical order.

^fSee this collection, p. 5.

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As Ioffe maintains, “If Landau thought he understood a subject more deeply than others, even if they initiated the study of this very subject, he considered himself the true originator of the discovery.”^g

A similar situation transpired between Landau and A.B. Migdal. As I.I. Goldman recounts,^h “I remember the Sunday of February 11, 1990, in Washington ... Migdal started talking about Landau. It seemed to me that his attitude toward Dau had changed, and Migdal confirmed the change. Migdal recalled the years when he was working on his doctorate, and showed his calculations on liquid helium to Landau (Landau’s work on superfluids contained a footnote acknowledging Migdal’s calculations). Migdal said bitterly that he had told Landau more than just these calculations. To my question about why he didn’t publish his research himself, Migdal responded that Landau had let him know that this was unacceptable, and that the work was Landau’s.”

That this was no careless, offhand remark is confirmed by Miron Amusia’s recollection:ⁱ

“At the Gatchina school around 1981, I heard AB’s talk in which Landau was criticized, seemingly for the first time ever. AB spoke of Landau’s categorical judgments and a sort of ‘personality cult’ around him which, being based on Landau’s enormous contributions in physics, on the one hand propelled Soviet physics to outstanding heights, but on the other hand was not always harmless. It is in this context that I first heard AB speaking publicly about the benefits of freedom in science. He remarked that one could publish not only papers in which one was certain that everything from A to Z was correct. That there should be a place for conjectures. AB said that Puritanism and extreme demands of a complete theoretical rigor to some extent hindered rather than helped the development of physics as a unified science. At that time I considered AB’s re-

^gIn this connection, an episode with A. Dykhne described by V. Pokrovsky in his article in the chapter “Some Details for Experts” adds an extra touch to the overall picture, see footnote in Pokrovsky’s article, p. 480 of this collection.

^hI.I. Goldman, “Arkady Benediktovich, Nastavnik, Drug,” in *Vospominaniya ob Akademike Migdale*, (Moscow, Fizmatlit, 2003), p. 163.

ⁱUFN Tribune, March 2011, and private communications.

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versal as something reflecting the ‘corrupting’ influence of the West, communications with which, including science, were becoming more intense.”

When the zero charge was discovered, Landau pronounced field theory dead. After this, no one doing research in field theory could remain in Landau’s circle. The Landau School’s negative attitude toward field theory continued for a long time, even after Landau’s death, until nearly 1972. The Yang-Mills theory by which our world functions was not considered a subject for serious research. I clearly remember the negative attitude toward field theory at ITEP at that time.

One additional topic I would like to touch upon in passing in my introductory note concerns Landau and women. When I was a student at MIPT^j in the late 1960s, many legends on this subject circulated among the students. All this was still very fresh in people’s “operational” memories. In his circle, Landau never tried to hide that he appreciated only one attribute in women: their sexual attractiveness.

This detail suddenly acquired a scandalous connotation in 1999 when a memoir by Landau’s wife, Kora Drobantseva-Landau, was published.^k Her memoir painted a rather unpleasant picture. In 2008, a notorious Russian TV series based on this book appeared, which – I hasten to add – was heavily criticized by some of Landau’s students.

Who knows the extent of the truth of this book and movie? I don’t think we’ll ever find the answer to this question. Landau had a multifaceted and sometimes contradictory personality. The aspects which his students saw had no meaning for his wife, and vice versa. Is this important? Not for a legend.

Landau lived in a cruel and tragic time. He was a product of the environment that created him, and if he’d acted differently, who knows if there would have been a Landau School? We value him for what he did for physics. One cannot (and should not) project

^jMoscow Institute for Physics and Technology in Dolgoprudny, 12 miles north of Moscow.

^kKora Drobantseva-Landau, *Akademik Landau. Kak My Zhili*, (Zakharov Publishers, Moscow, 1999).

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today's moral standards on an earlier time. To do so is categorically incorrect.

As time goes by, living witnesses pass away, memories fade, and the realities of the world surrounding us change. The changes are so drastic that when I tell various stories about Landau and his disciples and colleagues to my graduate students (including Russian graduate students), they don't believe me. They think these are all my fantasies. Sometimes I don't even believe myself, and find myself asking, "Could *that* really have happened?" Preserving the precious memories of this glorious and unique page of theoretical physics in the 20th century and making them available to Western readers seems to be more than timely.

All the articles in this volume were written relatively recently and are virtually unknown in the West. Don't ask why I chose these particular articles and not others. I picked the ones I liked, which held interest for me and which, in my judgment, Western readers would find instructive. There was no rigorous and scientific selection system. This volume is intended for a broad audience. At least the first (and largest) part requires minimal knowledge of physics, if at all. More technical reviews of scientific issues are collected in the final chapter, "Some Details for Experts."

The first chapter, devoted to Landau himself, plays a special role. The memoir literature on Landau is enormous. Here I could mention two books: *Academician Landau* by A.A. Abrikosov and *Memories of L.D. Landau*, edited by I.M. Khalatnikov. I made no attempt at a representative selection. Instead, to set the stage necessary for understanding the subsequent articles, I present in this chapter two recent essays, by B.L. Ioffe and S.S. Gershtein, respectively, which have never been previously translated into English.

If not stated to the contrary, the footnotes in this book belong to me.

Acknowledgments

First and foremost, I want to say *thank you* to all of this book's contributors, especially to those who wrote articles expressly for this collection: L. Anselm, Alexander Larkin, Roman Nevzorov, Yu. N.

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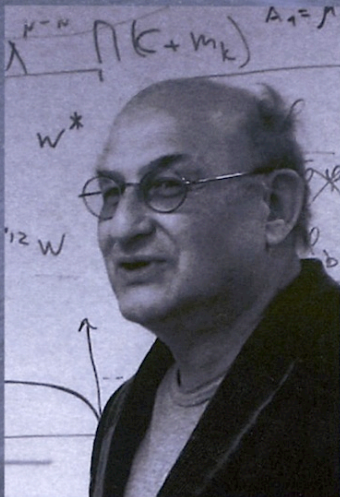
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ABOUT THE EDITOR

M. Shifman is the Ida Cohen Fine Professor of Physics at the University of Minnesota. One of the world's leading experts on quantum chromodynamics and supersymmetric Yang-Mills theories, he received his PhD (1976) from the Institute of Theoretical and Experimental Physics in Moscow. In 1990 he moved to the United States to assume his present position as a member of the William I. Fine Theoretical Physics Institute at the University of Minnesota. He has had the honor of receiving the Alexander von Humboldt Award, the 1999 Sakurai Prize for Theoretical Particle Physics, and the 2006 Julius Edgar Lilienfeld Prize for outstanding contributions to physics. He was elected as the 2007 Lauréat des Chaires Internationales de Recherche Blaise Pascal in France. He has authored several books, over 300 scientific publications, and a number of popular articles and articles on the history of high-energy physics.

ABOUT THE BOOK

This book is devoted to the outstanding Soviet theoretical physicists of Landau's School, scientists who proved instrumental in breakthrough discoveries in 20th century physics. In focus are members of Landau's circle — students of Landau, participants in his seminars, students of his students, etc. — whom the Editor knew personally and who passed away after the demise of the Soviet Union in 1991: Arkady Migdal, Yakov Zeldovich, Yakov Smorodinsky, Karen Ter-Martirosyan, David Kirzhnits, Vladimir Gribov, Anatoly Larkin, and Alexei Anselm. The atmosphere of their time permeates each of this book's chapters, conveying the flavor of everyday life in Soviet society and providing a snapshot of the conditions under which Landau and his students worked. A special chapter, "Time and Destinies," offers further striking perspectives for this purpose. More technical reviews of scientific issues are collected in the final chapter, "Some Details for Experts."

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