Arkadiĭ Benediktovich Migdal (Obituary)

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The Soviet and world community of physicists have suffered an irreplaceable loss. In February 1991 Academician Arkadiĭ Benediktovich (Beĭnusovich) Migdal died after a serious illness. He was an outstanding theoretical physicist, one of the founders of theoretical nuclear physics in our country, the creator of a great scientific school, and a man of many gifts and of irresistible personal charm.

A. B. Migdal was born on March 11, 1911 in the city of Lida (White Russia). In the 1920's his family moved to Leningrad. His first work in science was done when he was 17 years old as a lab worker at school. In 1929 he was admitted to the physics department at Leningrad State University, but was discharged in 1931 because of his "nonproletarian background". He was arrested in 1933 and was under investigation for over two months. From 1931 to 1936 he worked as an engineer in an electric appliance factory and carried out some scientific work while there. In 1935 he returned to night school at Leningrad State University. After finishing his university studies in 1936, he became a graduate student at the Leningrad Physicotechnical Institute. His thesis advisor was M. P. Bronshteĭn. In spite of the fact that his association with Bronshteĭn was brief (Bronshteĭn was arrested in 1937 and executed in the beginning of 1938), this brilliant man was a crucial influence on Migdal's formative years in science.

ARKADIĬ BENEDIKTOVICH MIGDAL
(1911–1991)

In one of his first mature works, Migdal studied the ionization of an atom produced when a neutron collides with its nucleus (1939). To solve this problem Migdal developed an original approach: the shake-up method. In January 1941 he defended his candidate's dissertation on the topic "Interaction of neutrons with electron shells." Later, in Moscow as a doctoral candidate under L. D. Landau of the theoretical division of the Institute of Physics Problems, Migdal successfully used this method to calculate atomic processes accompanying alpha and beta decay of the nucleus. This work is presented in detail in textbooks in quantum mechanics and the shake-up method has become firmly established in modern theoretical physics, having been extended to purely atomic processes.

Turning to the theory of photoabsorption of nuclei, Migdal predicted the existence of a giant dipole resonance associated with the oscillations of neutrons relative to protons and he calculated the position of the resonance. This work, together with his work on alpha and beta decay, formed the basis of his doctoral dissertation, which he defended in 1943. It was published in 1944 and brilliantly confirmed by experiment in 1947. Today the physics of giant resonances has evolved to become an important branch of nuclear physics.

In 1945 Migdal went to Laboratory No. 2 of the Academy of Sciences of the USSR (later called the Laboratory of Measuring Instruments, and presently the I. V. Kurchatov Institute of Atomic Energy) and worked on the atomic energy problem. He made an important contribution to the development of a realistic theory of heterogeneous reactors. Another important result obtained by Migdal at this time was an exact solution of the problem of absorption of γ-rays by a medium with multiple scattering taken into account. This work turned out to be important for biological shielding from the radiation of the reactor. But Migdal was more interested in pure physics. I. V. Kurchatov understood very well the importance of pure science and the value of the scientific atmosphere that always surrounded people like Migdal. He placed Migdal in the theoretical "Sector 10," allowing him to concentrate on fundamental problems.

Migdal's work on the theory of nuclear reactions accompanied by the formation of slow nucleons is widely known. It was reported in Landau's seminar in 1950, but because of preposterous "secrecy" it was not published until 1955. In this paper the theory of interaction in the final state (the Migdal–Watson effect) was developed. This theory is discussed in most textbooks on quantum mechanics and the theory of nuclear reactions.

In 1951–1953 "Sector 10" was involved in the study of controllable thermonuclear fusion. The paper of Migdal and V. M. Galitskiĭ on the propagation of cyclotron radiation in a magnetized thermonuclear plasma played an important role in this work, as did a paper with S. I. Braginskiĭ, in which a qualitative theory was developed for physical pro-

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cesses accompanying the inertial pinch effect.

In 1954–1955 Migdal developed a quantitative theory of bremsstrahlung and pair creation in the case when fast particles pass through an amorphous material. Although the phenomenon was understood qualitatively (M. L. Ter-Mikaélyan took into account the polarization of the medium and L. D. Landau and I. Ya. Pomeranchuk included coherent multiple scattering), it appeared to be impossible to work out a quantitative theory because of the unusual complexity of the process. Migdal made a bet that he could solve the problem and won, solving the problem with the help of a new method: the quantum kinetic equation.

Migdal was one of the architects of the modern theory of many-body systems, which is based on using the methods of quantum field theory (the method of Green's functions). His 1957 paper on the jump in the momentum distribution at zero temperature for Fermi systems with arbitrary interactions (the Migdal jump) played an important role in the understanding of the physics of Fermi systems. His 1958 paper with V. M. Galitskiĭ on the formulation of the Green's function method for Fermi systems also became a classic. The results obtained in this paper included the analytic properties of the Green's functions, the spectral decomposition and dispersion relations for the Green's functions, and an exact formula for the energy, and this is far from a complete list. These papers are reported almost verbatim in textbooks and monographs on many-body theory. His 1958 paper in which the problem of the interaction between electrons and phonons in a normal metal is solved is also widely known. It was one of the first applications of the Green's functions method to real systems and one of the first treatments of the interactions of electrons in a metal without the use of perturbation theory. The concrete results, especially those concerning the singularities the phonon spectrum caused by interactions with electrons (the Migdal–Kohn singularities) are classic results in the theory of metals. It is indicative that in J. Bardeen's Nobel lecture, this paper was mentioned eight times. Migdal's papers on solid-state theory, though small in number, played a very important role in the development of this branch of physics.

The next stage of Migdal's scientific career involved the application of the methods of quantum field theory to nuclear physics. Migdal was a true generalist, but his greatest contributions were in nuclear physics. In this short obituary we cannot even list all the important results obtained by him. Migdal's most important papers on nuclear physics up to 1981 were listed in an article devoted to his 70th birthday in Usp. Fiz. Nauk **133**, 737 (1981) [Sov. Phys. Usp. **24**, 336 (1981)]. His theory of finite Fermi systems and subsequent theory of pion degrees of freedom in nuclei were crucial steps in the development of the modern quantitative theory of nuclear phenomena. Migdal's monographs on these topics, published in Russian and English, are indispensable references for theoretical nuclear physicists. The book "Pion Degrees of Freedom in Nuclear Matter", written by Migdal and his students, has been published posthumously.

In the 1980's Migdal became fascinated by quantum chromodynamics. Here his "super problem" was the creation of a theory of confinement. Migdal began to develop a phenomenological approach to QCD and together with his students he created a model of hadrons based on QCD ideas which was an alternative to the bag model. The model explains in a natural way why the Regge trajectories for hadrons remain linear to zero angular momentum. This approach remained unfinished; Migdal worked on it up to his final days.

In his scientific work, Migdal, a physicist "by instinct," always progressed from the phenomenon to the most adequate method of studying it theoretically. Possessing the entire arsenal of weapons of theoretical physics, from transparent qualitative arguments to complicated mathematical techniques, he nearly always attained an impressive balance between the means and the end. The scientific creativity of Migdal was based on harmony. The quest for harmony resulted in such typical characteristics of Migdal's scientific style as a masterly use of phenomenological approaches, a relatively rare use of standard perturbation theory, and his creation of qualitatively new, essentially nonperturbative approaches.

Migdal the scientist was indistinguishable from Migdal the teacher. He was very artistic in his work. There were usually one or several young colleagues in the audience who followed Migdal's reasoning behind the calculations and learned to work in theoretical physics. In this way Migdal trained dozens of actively working theoretical physicists. His students included Academicians and Corresponding Members (including A. M. Budker and V. M. Galitskiĭ, now deceased) working in very different fields of modern physics such as elementary particles, nuclear physics, solid state, plasma physics, reactors, and accelerators. This is what constitutes the "Migdal school".

Migdal did his teaching work at the Moscow Engineering Physics Institute, where he worked from the day of its foundation. Two of the fruits of his teaching work were the monographs "Approximate Methods in Quantum Mechanics" (co-authored with V. P. Kraĭnov) and "Qualitative Methods in Quantum Theory". These books were translated into English and are now rare.

In the last 10–15 years of his life, Migdal became interested in the popularization of science and wrote the fascinating book "Search for Truth" and a number of other books and articles. Migdal's appearances on television in which he more than once stated his own political position, invariably attracted interest from a very wide audience.

Mention should be made of the relationship between Migdal and A. D. Sakharov. Sakharov was always a model citizen for Migdal. It was not fortuitous that Migdal was among those who helped to save Sakharov's life in 1981, in one of the most trying periods for Sakharov of his exile to Gorkiĭ. Sakharov responded to Migdal with deep respect.

Such a great creative person as Migdal was far from being only a scientist. The words of Pushkin (about Peter the great) "Academician and hero and navigator and carpenter..." are applicable to Migdal. Artists know him as a sculptor and carver in wood, jewelers know him as a jeweler and collector of stones, underwater sportsmen know him as one of the creators of the Soviet aqualung sport as well as the organizer and first director of the Federation of Underwater Sports of the USSR, and alpine skiers and climbers rightfully consider him one of their own. The meaning of life, according to A. B. Migdal, is "not to get to your destination by the shortest possible path, but to see and experience more along the way."

In his scientific and artistic creativity and in his relationships with people the quest for harmony, the quest to be at peace with himself, led Migdal to his own perception and solution of the problems of his chosen life's work and to happiness. He found out about his fatal illness after arriving in October 1990 on an assignment to Princeton University. He bore his suffering with dignity, manfully and gave several brilliant lectures, and continued his scientific work up to his last few days. Migdal died at Princeton. The urn with his ashes was buried in the Novodevich'e Cemetery in Moscow.

Throughout his life Migdal earned deep respect and sincere sympathy of many people of all ages, professions, and walks of life. Migdal's unique charm will forever be fondly remembered by his numerous students, friends, admirers—all who had the rare good fortune to associate with this Scientist, Teacher, Man.

Translated by J. D. Parsons