SEMEN ÉMMANUILOVICH KHAĬKIN (1901–1968)

V. I. IVERONOVA, N. L. KAĬDANOVSKIĬ, M. A. LEONTOVICH, Yu. N. PARIĬSKIĬ, A. E. SALOMONOVICH, S. P. STRELKOV, I. A. YAKOVLEV

Usp. Fiz. Nauk 97, 367–370 (February, 1969)

ON July 30, 1968, after a long period of sickness, professor and doctor of physics and mathematics Semen Émmanuilovich Khaĭkin, a prominent physicist, a leading specialist in the fields of radiophysics and radioastronomy, died in Leningrad.

S. É. Khaĭkin was born on August 8, 1901 in Minsk in the family of pedagogues. His father, an agriculturist by profession, was the founder and director of the Minsk private technical secondary school, which was evacuated at the time of the first world war to Penza. Semen Émmanuilovich completed this school in 1918. In the same year, he entered the Moscow Higher Technical School (MVTU) and at the same time enrolled in advanced electro-technical courses. In 1919, upon completing these courses, he volunteered into the Red Army and was in military service until 1924 in various posts and communications institutions of the Red Army. In 1920, he took part in battles on the Western front as chief of a field radio station. After the demobilization, Khaĭkin worked as a radio technician and laboratory assistant while continuing his studies, and in 1928 he finished Moscow University. After a short time working as engineer at the Leningrad Physico-technical laboratory and at the All-union Electrotechnical Institute (1928–1930), he joined in 1930 the physics faculty at Moscow University, where he worked as an assistant, assistant professor and subsequently headed the chairs of Oscillations (1935–1938) and General Physics (1938–1946). In 1930–1931 he was scientific secretary, in 1931–1933 deputy director of the Physics Institute at Moscow State University, and in 1934–1937 dean of the physics faculty. In February 1935, he received the degree of Doctor of Physical and Mathematical Sciences, and the title of professor.

During the World War, while continuing to head the chair of the physics department at the Physics Institute, Khaĭkin headed the laboratory where work was carried out on the phase radar and radio-navigation systems proposed by him. In December 1943, he joined the Communist Party. After the war, he transferred his basic work to the Lebedev Physics Institute of the USSR Academy of Sciences, where he headed the Radioastronomy Oscillations Laboratory.

Khaĭkin's scientific work is distinguished by a wide range of interests and a great degree of purposefulness. He began his scientific activities at Moscow University in 1928 in a group of young "oscillation" physicists, who were working at the department of theoretical physics headed by Academician L. I. Mandel'shtam. His first two published papers are devoted to measurements of the damping decrement of oscillations in a piezoquartz plate. In this work it is already easy to see his characteristic methods and thoroughness in carrying out painstaking high-frequency physical measurements (procedures which were rather complicated at that time), and the precision and clarity of the formulations and estimates of the obtained results, results which contained important information for practical radio technology.

The main scientific problem which stood at the center of attention of the L. I. Mandel'shtam school of oscillation physics in the first half of the 30's was the creation of methods of theoretical investigations of self-oscillations. Hence, all work carried out by Khaĭkin at that time was devoted to self-oscillations.

The first group of Khaĭkin's investigations of that time deal with the "locking" phenomenon at small values of the external signals, and the second group, with theoretical and experimental investigations of relaxation self-oscillations and related problems.

Khaĭkin solved experimentally the fundamental question of non-linear theory of self-oscillations, that of "locking" in a generator under low external harmonic signals; he has shown that the locking effect does take place in fact, and that the quantitative relation between the relative frequency locking band and the relative am-

plitude of the signal coincides with predictions of nonlinear theory. As a result of these investigations, a practical method was worked out for measuring the field intensity of radio stations, based on the use of the discovered effect.

In the second group of studies, one must mention first Khaĭkin's studies of mechanical relaxation self-oscillations in systems with dry friction. These investigations were important not only as a clear and graphic example of self-oscillation processes of this type, but also as a physical method of analyzing the characteristics of friction between surfaces of solids. Other studies of this cycle included the phenomenon of intermittent oscillations in electrical circuits with vacuum tubes. This work strongly evidences the scientific style which is seen in all of Khaĭkin's work. He shows clearly that the task of investigator consists not only in the experimental verification of a preliminary theoretical computation of the process under study, but also mainly in the analysis of the feasibility and expediency of using a simplified scheme of the phenomenon, which is necessary for the mathematical formulation of the problem. In connection with problems in relaxation oscillations, he studied first of all systems in which transitions from almost harmonic conditions of generation to intermittent oscillations are possible following smooth variation of parameters.

A significant part of Khaĭkin's results in the field of self-oscillations was later included in the basic book "Theory of Oscillations" (Teoriya kolebanii) (1937), written by him together with A. A. Andronov and A. A. Vitt, which served as the theoretical basis for the science of self-oscillations. This work, re-edited in 1959 and published more than once abroad, has served for already thirty years as the basic text for all investigators working in oscillation theory. Authoritative scientists acknowledge the Soviet priority in the field of self-oscillations, usually basing themselves in the first place on this book.

An important influence on the development of Soviet radio technology was also played by the lectures in the theory of oscillations and theoretical radio technology which Khaĭkin delivered for many years at the Moscow Institute of Communication Engineers.

At the end of the 30's, Khaĭkin's scientific interests shifted to the field of applications of radiophysics methods in the investigation of various problems in molecular physics.

The use of the resonance properties of an extremely high-Q oscillation system, such as a piezo-quartz, made it possible for Khaĭkin and his co-workers to perform a series of studies of the interaction of rubbing solids in the range of preliminary displacements. By investigating the peculiarities of the resonance curves of piezo-quartz resonators in contact with solid plates, it was possible to demonstrate the conservative and non-linear character of the interaction forces under small relative displacements (10^{-8}—10^{-6} cm). Later, electrical contacts were studied in the range of small displacements by an analogous method.

In 1939, Khaĭkin discovered the effect of superheating of a solid body: a tin monocrystal melted from the surface inward, whereas according to the conditions of the experiment the temperature at the interior was higher than the melting point. He also proposed a radiophysics method of studying the influence of rapid changes in temperature and pressure on the resistance of electrolytes, and determined the temperature and piezoelectric coefficients of resistance of a solution of silver nitrate.

The last twenty years of Khaĭkin's scientific work were totally devoted to the new scientific field of radioastronomy. Already during the war years, Academicians L. I. Mandel'shtam and N. D. Papaleksi showed the possibility of radar sounding of the moon. After the conclusion of the war, N. D. Papaleksi began preparations to study radiowave radiation from the sun. The solar eclipse in May 1947 was an excellent opportunity to perform the first observations of the radio eclipse. After Papaleksi's death, Khaĭkin headed preparations and an actual expedition to Brazil, where for the first time observations of radio eclipse of the sun were performed. They demonstrated that radio waves in the meter wave band are emitted from the solar corona.

Khaĭkin came back from the Brazil expedition filled with extensive plans for the development of Soviet observational radioastronomy, in which field he is rightly considered a pioneer. He correctly and opportunely estimated the important practical value of radioastronomy of natural radio-emission sources whose positions in the sky are accurately known. With the aid of these sources, it turned out possible to investigate the conditions of propagation of radio waves through the entire thickness of the earth's atmosphere.

Thanks to his initiative and organizational talent, his deep scientific intuition, and experience, a group of radio astronomers was trained during the short time of his leadership in the P. N. Lebedev Physics Institute. In 1948—1949, Khaĭkin headed the construction of the first Soviet radioastronomy station of the Physics Institute of the Academy of Sciences in Crimea, equipped with radio telescopes which were large for that time.

Along with investigations of an applied nature, the group headed by Khaĭkin was ever continuously more drawn into astrophysical investigations. New important data on the radio emission of the sun, moon, the interplanetary plasma and the ionosphere were obtained.

Khaĭkin devoted a great deal of attention to creating radioastronomical apparatus and devising observational methods. He was first to propose methods of diagram modulation, precise methods of absolute calibration of received radiation, and quasi-optical methods of analysis of polarized radiation. He initiated work which led to the formation of reflecting radio telescopes of RT-22 type, which are useful in investigations in the millimeter band.

In 1953, Khaĭkin founded the radioastronomy department of the Main Astronomic Observatory in Pulkovo, which he headed until his death.

Recognizing the exceptional possibilities of radioastronomy in the short-wave band of the "radio window" of transparency of the earth's atmosphere, S. É. Khaĭkin directed the efforts of the Pulkovo group of radioastronomers along the new path of mastering the centimeter band. The difficulty in constructing a very large and precise antenna required for this band should have been overcome, according to S. É. Khaĭkin's concept, by a decisive turning away from traditional construction of

radio telescopes with continuous parabolic reflectors. The reflecting surface of the new radio telescope was subdivided into a number of small and very precisely made flat elements which were positioned with the aid of mechanisms and measuring devices in such a way as to form a surface that focused the radiation coming from the source. To perform observations in various directions, the profile of the reflecting surface was to be varied, hence the new radio telescope was called the "Varying Profile Antenna" (VPA). Such a radio telescope was constructed under his leadership at Pulkovo in 1956. This telescope still has the best resolution (in one direction) of all radio telescopes in the centimeter band, namely 15 angular seconds at a wavelength of 1 cm.

First class observations were performed with this radio telescope: the strong circular polarization in the emission from the active regions of the sun was observed and studied; "radio spots" were studied in detail; the linear polarization of the thermal radiation from the moon was discovered and studied in the centimeter band, and its "roughness" was estimated; for the first time, investigations were made of the distribution of radio signal strength along the disc of Venus, and the structure of powerful radiation bands around Jupiter was studied. Observations with the Pulkovo radio telescope, made by Khaĭkin and his co-workers, made it possible to estimate the intensity of scattering of radio waves in the centimeter band by the ecliptic gas, and to estimate (by means of the Faraday effect) the magnetic field strength in interplanetary space; the first detailed morphological catalog of galactic radio-wave sources was made, and isophots were made of the centimeter band radiation of the Milky Way. Precision measurements of the coordinates of extragalactic radio sources were obtained, and it was determined that more than 40% of the bright sources in the centimeter band are of a quasi-stellar nature. The structure and polarization of complicated extra-galactic sources were studied in detail.

At the present time, a very large radio telescope, RATAN-600 of the VPA type, is under construction in the USSR. Khaĭkin headed until his death the work on the design of this gigantic apparatus, measuring 600 m in diameter.

Khaĭkin's activities in the field of radio astronomy give many examples of his unusual versatility, energy and intuition. He very successfully solved the most diverse problems, from practical problems of measurement techniques to the analysis of subtle questions of theory, and always discovered original solutions.

Khaĭkin was not only a foremost scientist, but also a talented teacher who taught an entire generation of Soviet physicists and engineers. From 1934 to 1947 he taught a general course in physics at the physics faculty of Moscow State University. From his very first lectures he became a most popular lecturer with the students, stimulating deep interest of his listeners in all scientific questions touched upon in the course. The success of his lectures was measured, of course, not only by his great talent as lecturer, but first of all by the depth and freshness of approach to all fundamentally important problems in physics.

Of special significance in physics was Khaĭkin's course in the physical foundations of mechanics. This course raised significantly the teaching level of mechanics and raised it to that height at which it is now taught at many universities. It is difficult to list all the chapters in mechanics whose physics content was enlivened by S. É. Khaĭkin's lectures. This is true in the first place of the ennunciation of the foundations of dynamics, the problem of inertial forces, laws of friction, fundamentals of hydrodynamics, elementary gyroscope theory, and of the physical meaning of so-called constraints that determine the trajectory of motion of non-free bodies. The formerly dry transfer of all these problem from textbooks in theoretical mechanics to the course of general physics was replaced with a lively exposition of essentials, almost without the use of mathematics.

The graphic and physically deep exposition of the most diverse material in Khaĭkin's lectures was strengthened through new demonstrations established by him, in which such heretofore "forbidden" phenomena as, for example, tidal waves and the action of Coriolis forces on a flowing liquid were boldly and simply shown for the first time. Thanks to Khaĭkin's suggestions, several dozens of well utilized lecture demonstrations were created at the Moscow State University.

Under his leadership the level of seminars in general physics was also greatly raised. The traditional set of problems of the 20's and early 30's was changed into new collections of problems in general physics which were edited by him. These collections were printed in several editions and translated into many foreign languages.

The end result of the repeated reading of his lectures was his textbook on mechanics, which received three editions. He continued working on this book for more than thirty years. The last edition of the significantly expanded course, named "Physical Foundations of Mechanics," was published in 1963. In this book, S. É. Khaĭkin presented for the first time in the framework of a textbook in general physics a deep physical exposition of the mechanical foundations of the special theory of relativity. A significant achievement of this book is also that he boldly and successfully expanded the number of traditional forces (gravitational, elastic, and frictional) used in "orthodox" textbooks in mechanics, by examining the basic situation of motion under the action of electrodynamic forces. This addition undoubtedly enriched the content of the new textbook in mechanics.

Of no less significance in raising the level of teaching physics was his presentation of lectures in a course on electricity and magnetism.

In his pedagogical work in the physics faculty at the Moscow State University, and later in the Moscow Engineering Physics Institute, Khaĭkin never limited himself to lectures and to heading seminars. He very successfully taught in science student clubs. He established a strong base for relations between the physics faculty and the teaching of physics in schools by organizing the first contests, and by proposing many instructive and clever problems for them. Today, physics contests have become the traditional form of work with the students at the University. In recent years, school contests in various subjects have appeared in almost all depart-

ments at the Moscow State University and at many other universities.

In his concern to raise the teaching level of physics in high schools, Khaĭkin wrote a section "Mechanics" in the well-known "Elementary Physics Textbook" edited by academician G. S. Landsberg. He is also well known as the author of many popular books in radio physics and mechanics.

Khaĭkin took an active part in the organization of Soviet science. He was chairman of the Commission on Radioastronomy of the USSR Academy of Sciences, and later a member of the Council Bureau on Comprehensive Problems of Radioastronomy of the Academy of Sciences, and a member of the staff of the journals Radiotekhnika, Astronomicheskiĭ zhurnal, and others.

The scientific and pedagogical activities of Khaĭkin are highly esteemed in our country. The USSR Supreme Soviet awarded him in 1953 with the order of Labor Red Banner. In 1965, the presidium of the Academy of Sciences of USSR awarded him for his leading work in the fields of radiophysics and radio astronomy the A. S. Popov Gold Medal.

Semen Émmanuilovich Khaĭkin, a brilliant and talented scientist, excellent teacher, a sensitive and thoughtful educator of youth, will be remembered by all who knew and loved him.

Translated by L. Garder