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On Academician E K Zavoisky's centenary

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Zavoisky V K ***Minuvshee*** (The Past) (Kazan': Tatpoligraf, 1996) 226 pp.
Charodei Eksperimenta (Magician Experimentalist) Sbornik Vospominanii ob Akademike Zavoiskom (Collected Reminiscences about Academician Zavoisky) (Exec. Ed. S T Belyaev; composed by Eds V D Novikov, N E Zavoiskaya) 2nd ed. (Moscow: Nauka, 1994) 256 pp.
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28 September 2007 is the 100th anniversary of the birth of the brilliant Russian physicist Academician Evgenii Konstantinovich Zavoisky (1907 – 1976). A considerable number of publications have been devoted to the memory of Evgenii Konstantinovich in recent years; their contents are briefly outlined in this note.

Evgenii Konstantinovich, the discoverer of electron paramagnetic resonance, active team member of the Soviet Atomic Project, outstanding experimentalist in studying rapid phenomena and high-temperature plasma, designer of devices and instruments for physics experiments in various fields of science, lives on in our memory as a role model for scientific and civic bravery. Certain features of his personal and scientific biography made him a cult figure for the physics community and especially for physicists in Kazan' and for specialists in magnetic resonance.

His main achievement was the discovery of electron paramagnetic resonance (EPR) — something Zavoisky accomplished during WWII, "in the days of severest ordeals and abominable living conditions." Later on, he had to banish, for many years, even the mere thought of communication with scientists abroad as a precondition for working on the Soviet Atomic Project; this in fact meant renouncing all hope for international recognition of his discovery. Such was the fate of the founder of the Kazan' scientific school of physicists engaged in studying paramagnetic resonance. To recapitulate other dramatic events of his difficult life, he resigned on his own initiative from the Institute of Atomic Energy to protest the ban on international visits to the West, and there was also a brief but brilliant stint as Editor-in-Chief of *Physics – Uspekhi*.

The discovery of EPR was the only major achievement of Soviet physics in the 1930s – 1940s not in the research centers of Moscow, Leningrad, or Khar'kov — but in the 'provinces', in Kazan'. A number of publications outline this discovery and its place in the history of physics. In 1896, P Zeeman discovered the magnetic-field-induced splitting of lines of optical spectra. In 1922, O Stern and W Gerlach discovered the spatial quantization of the atomic magnetic moment (and later on, of the magnetic moment of the atomic nucleus). In the same year, Albert Einstein and Paul Ehrenfest predicted the possibility of spontaneous and stimulated emission and absorption of electromagnetic energy in transitions between states with different orientation of the atomic magnetic moment. In 1938 – 1939, I Rabi, P Kusch, and others discovered such transitions first between the states of nuclear magnetic moments in molecular beams and then between states of the electron spin in atomic beams in vacuum. The question still remained unanswered about the possibility of observing magnetic resonance — already discovered for isolated particles — in condensed media. Despite considerable achievements by many physicists — theorists (J H Van Vleck, USA; I Waller, Sweden; H Bethe, Germany, and some others) and a group of experimenters led by C J Gorter (the Netherlands) — it was still unclear in the 1930s whether it was realistic to hope to observe magnetic resonance phenomena in condensed media. It was not difficult to meet the resonance condition $\omega = \gamma H$ for a particle with an arbitrary value of the gyromagnetic ratio γ but the width of the spectral contour of the anticipated resonance line and the relaxation rate of thermal-equilibrium population of energy levels were still a matter of hypothesis. It was E K Zavoisky who was the first to demonstrate on 21 January 1944 the possibility of observing EPR in paramagnetic salts of transition group elements. Despite his very limited technical experimental resources, his breakthrough discovery left his colleagues (C Gorter and coworkers) behind because he chose not to limit himself to

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searching for conditions for magnetic resonance in matter, widened the frequency range of his search, and studied all paramagnets he could lay his hands on. It appears that in 1941 Zavoisky was able to sporadically observe even nuclear (proton) magnetic resonance. By 1948, Evgenii Konstantinovich authored 18 publications on the subject of paramagnetic resonance and paramagnetic relaxation. In the meantime, the groups of E M Purcell and F Bloch in the USA observed nuclear magnetic resonance (NMR) at some point at the turn of 1945 – 1946, and the groups of D Kammerow (USA) and B Bleaney (Great Britain) started in 1947 a program of EPR research on transition metal compounds (their first publications cited E K Zavoisky's priority).

Note that it was the efforts of E K Zavoisky and his younger colleague and successor, theoretical physicist S A Al'tshuler, that overcame the severest crisis in teaching physics at Kazan' State University (KGU), which was in full swing at the turn of 1920s – 1930s. No wonder Kazan' physicists cherish the memory of Zavoisky with special warmth. In 1957, Zavoisky's discovery of electron paramagnetic resonance (EPR) was awarded the Lenin prize. In 1977, already after Evgenii Konstantinovich's untimely death, he received (posthumously) the Medal of the International Society of Magnetic Resonance (ISMAR). In 1991, a prestigious E K Zavoisky International Medal for Outstanding Achievement in EPR Research was founded on the initiative of the Director of the E K Zavoisky Kazan' Physical-Technical Institute, K M Salikhov (presently Corresponding Member of RAS). People working on magnetic resonance will not forget the wonderful jubilee conferences of the European Society of Magnetic Resonance Researchers AMPERE in Kazan' for the 25th (1969) and 50th (1994) anniversaries of the discovery of EPR. E K Zavoisky's brother Vyacheslav Konstantinovich[1] and daughter Natal'ya Evgen'evna[2] collected reminiscences written by colleagues and relatives (and by E K Zavoisky himself) on the life and work of this scientist; the book ran though several reprints. B I Kochelaev and Yu V Yablokov, well-known representatives of the Kazan' school of magnetic resonance research, published a book in English on Zavoisky's creative life and on his discovery of paramagnetic resonance,[3] and Yu V Yablokov and S D Fanchenko published a biobibliographic work of reference with a complete list of Zavoisky's published and unpublished papers.[4]

In the 1970s, RAS Corresponding Member S A Al'tshuler, having become a leader of the Kazan' school of EPR research, suggested to then student at KGU I I Silkin creating a Museum-Laboratory of E K Zavoisky at the KGU Physics Department. The enthusiastic work of Igor Ivanovich Silkin, master of laboratory experiment, experienced radio enthusiast and photographer, and indefatigable collector of books, documents, and technical rarities, overcame many a hurdle and presented to the citizens of Kazan' and to numerous participants in international gatherings of scientists regularly convened in Kazan' the joy of sharing in the implementations of the ideas and achievements of the outstanding physicist.

It is no secret that Zavoisky's discovery appeared so unexpected to many experts — not so much in essence but largely due to spurious circumstances (such as a seemingly simplistic experimental method, or that the author did not belong to any respected science school) — that the response was partly skeptical. The group who decisively supported Zavoisky's EPR work were the physicists of the Institute for Physical Problems (IFP) led by P L Kapitza and A I Shal'nikov, who made it possible for Zavoisky to repeat and improve his experiments in laboratories of the Academy of Sciences of the USSR. In his wonderful book, I I Silkin[5] quotes, among other things, Zavoisky's report on his work at the IFP between 2 and 28 January 1945. It would be quite fitting in connection with the 100th anniversary of the birth of discoverer of EPR to initiate the preparation of a similar documentary chronicle of E K Zavoisky's work on the Soviet Atomic Project at the Institute of Atomic Energy (1947 – 1972). One wishes to believe that the example of the highest professionalism and selfless service to science and motherland shown by Academician Zavoisky will encourage us again and again to think about the fate of science in Russia, about ways for its rebirth and progress. Note that his daughter has now prepared for publication the history of the discovery of EPR which analyzes, among other aspects, the causes of the insufficient international recognition of the discovery (this 'Nobel level' event never received what it deserved). Clearly, these were mostly political factors stemming from the isolation from the international scientific community imposed on Soviet scientists.[6]

The magnetic resonance study of matter spurred on by Zavoisky's work spawned a variety of very efficient methods for monitoring and controlling the composition of materials and for studying the molecular dynamics and structure of molecules; these methods permeated solid-state physics, chemistry, life sciences, and geology, and became largely indispensable. Rapid progress in theoretical concepts and in experimental methods of magnetic resonance continues. Evidence of this can be found, in particular, in the *Program of the Jubilee-Year International Scientific Conference 'Modern Development of Magnetic Resonance'*[7] that was scheduled for the end of September 2007 at the Kazan' Physical-Technical Institute of the Russian Academy of Sciences. The program of the conference includes the following main topics: theory of magnetic resonance of low-dimensional and nanosystems, molecular magnets and liquid crystals, strongly correlated electron systems, chemical and biological systems, medical physics, other applications of magnetic resonance, and novel experimental methods based on magnetic resonance phenomenon.

[1] See Zavoisky V K *Minuvshee* (The Past) (Kazan': Tatpoligraf, 1996) 226 pp.

[2] See *Charodei Eksperimenta* (Magician Experimentalist) Sbornik Vospominanii ob Akademike Zavoiskom (Collected Reminiscences about Academician Zavoisky) (Exec. Ed. S T Belyaev; composed by Eds V D Novikov, N E Zavoiskaya) 2nd ed. (Moscow: Nauka, 1994) 256 pp.

[3] See Kochelaev B I, Yablokov Yu V *The Beginning of Paramagnetic Resonance* (Singapore: World Scientific, 1995) 176 pp.

[4] See *Evgenii Konstantinovich Zavoisky* Materialy k Biografii (More on Zavoisky's Biography) (Kazan': Unipress, 1998) 96 pp.

[5] See Silkin I I *Evgenii Konstantinovich Zavoisky* Documented Chronology of Research and Teaching Career at Kazan' State University (Kazan': KGU, 2005) 240 pp.

[6] Evaluation of the role played by Zavoisky in the history of physics and of the events related to how the international scientific community regarded his contribution can be found in the collection *Charodei Eksperimenta* (Magician Experimenter), in I I Silkin's book and in A V Kessenih's "K istoriografii i bibliografii magnitnogo rezonansa" ("To a historiography and bibliography of magnetic resonance"), in *Issledovaniya po Istorii Fiziki i Mekhaniki 2005* (Research on the History of Physics and Mechanics 2005) (Exec. Ed. G M Idlis) (Moscow: Nauka, 2006) p. 219.

[7] See *Program of Jubilee-Year International Scientific Conference 'Modern Development of Magnetic Resonance', Kazan', 24.09.2007 – 29.09.2007*; http://www.kfti.knc.ru/zavoisky100/.