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REVIEW

The Discovery of Magnetic Resonance in the Context of 20th Century Science: Biographies and Bibliography. II: Magnetic Resonance Discovery in the Mirror of the Nobel Prize Award

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Abstract—In this chapter, Zavoisky' history of Nobel Prize nominations is discussed. Once his name became publicly known after a decade of obscurity due to his involvement in the Soviet nuclear program, Zavoisky began to be proposed for the Prize by his international peers. C. J. Gorter, Zavoisky's competition in his search for EPR, was the first to nominate him, in 1958. On the Soviet side, the first nomination came from the physicist I. M. Frank, in 1959. In the next decade, Zavoisky's most persistent nominee was Croatian-Swiss chemist L. Ružička. The period covered herein ends in 1966, as information for later years was not yet disclosed by the Nobel Organization at the time of writing the original publication.

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INTRODUCTION

The annual Nobel Prize award ceremony is by no means a pinnacle of scientific success or importance; for over 120 years, only briefly interrupted (mainly by the World Wars), it has undoubtedly been the most prestigious event in the world of natural science. A nomination for the Nobel Prize is definitely a strong argument in favor of significance of a scientific discovery, even if it only reflects judgement of scientific community, rather than its objective scientific value.

It is common knowledge that E. K. Zavoisky's discovery of electron paramagnetic resonance was never recognized by the Nobel Prize. Unfairness of this circumstance was as obvious to the world scientific community, as it was to their Soviet colleagues. To this, for example, speaks the ISMAR Prize conferred to Zavoisky in 1977, posthumously. A. Abragam, at one of the international fora, "toasted two "fussy ladies", the Swedish Academy and the Soviet Academy of Sciences, urging both to right the historical wrong by giving the Nobel Prize to E. K. Zavoisky for his discovery of paramagnetic resonance, and by electing S. A. Altshuler to the Academy of Sciences" [1].

There have been numerous discussions as to why the history was unfair to Zavoisky and his work, an assortment of hypotheses suggested, including those of political and ethical nature. N. E. Zavoiskaya offered her prospective on the matter in her fundamental monograph [2]. In this book, she has gathered

Deceased.

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an unparalleled collection of materials on the discovery, its history, its path to recognition by the scientific community in the USSR and in the world, and its track record in terms of the Nobel Prize nominations. In her research, Zavoiskaya was guided, among other things, by the archival documents found by A. M. Bloch [3], an outstanding Russian historian specializing in the history of Science, specifically history of the Nobel Prize awards. In particular, Zavoiskaya wrote in her book that, according to the Soviet archives, his colleagues in the USSR nominated Zavoisky for the world's most prestigious scientific award several times. By the time the book came out (2007), however, it had not yet been 50 years since the country and the world came to recognize the outstanding scientist and his work. In other words, the 50-years restriction period for the Nobel Prize nominee names disclosure was not over yet, and, therefore, it was impossible to know whether Zavoisky was proposed for the Prize on other occasions or not. One decade passed since 2007, and new documents came to light [4]. Below is an overview of the archival materials made available by the Nobel organization as of 2018, in the context of the discovery of EPR.

IN THE MIRROR OF THE NOBEL PRIZE AWARD

Let us begin with a quick account of "The Nobel Relay" starring F. Bloch and E. M. Purcell. Both were first nominated almost immediately after each published his pioneering research, F. Bloch – in 1948, and E. M. Purcell – in 1949. Given that the papers came out in January, 1946, and candidates for the Nobel Prize 1948 were due to be submitted to the Nobel Committees no later than in January, 1948, the world scientific community had less than 2 years to recognize the importance of both their works. Interestingly, it all started with C. Gorter and G. Wentzel, who submitted F. Bloch as a candidate for the Nobel Prize in 1948. In 1949, van Vleck nominated both F. Bloch and E. Purcell. In 1950, A. Kastler and S. Quimby followed suite. In addition, W. Lamb, in the same year, proposed F. Bloch alone for the Prize. In 1951, two nominators submitted the names of the two of them, and two – that of F. Bloch unaccompanied. In 1952, the year Bloch and Purcell shared the Prize, there were three persons who nominated Bloch and Purcell, and four more who chose F. Bloch on his own. Among the nominators were I. Rabi, who had discovered molecular beam resonance method just before the World War II, E. Fermi, K. Siegbahn, M. von Laue, and others. During the five years (for E. M. Purcell – four years) before Purcell and Bloch were given the Nobel Prize, F. Bloch was a nominee 18 times, and E. M. Purcell – 10 times. It is noteworthy that no other scientist engaged in the magnetic resonance related research was nominated for the Prize in those years. C. Gorter and A. Kastler were first nominated in 1956, B. Bleaney – in 1957, while A. Abragam and N. Bloembergen – in 1960. There was only one exception – J. van Vleck who was first proposed for the Nobel Prize in 1951, his next nomination to happen ten years later, in 1961.

Therefore, it took a surprisingly short and easy effort, by Nobel standards, for Purcell and Bloch to "take the gold". This effort, however, was made by the most renowned scientists of the time.

E. K. Zavoisky, according to the documents made available by the Nobel organization as of 2018, has "the Nobel history" no less interesting or rich. The Nomination Archive documents reveal that his name was proposed for the Prize every single year in the period of 1958 through 1966; a summary of Zavoisky's nominations is given in Table 1 (data for later years had not yet been disclosed as of 2018[1]). In total, in those years, he was nominated on 17 (!) occasions by different nominators. Twice he was chosen for the Chemistry Prize (the other 15 nominations were all for the Physics Prize). Furthermore, only five of the nominations came from the Soviet Union, the other twelve coming from other countries. Among his international nominators were: Cornelius Gorter (the Netherlands), he proposed Zavoisky's name four times in different years; Leopold Ružička (Switzerland) – Zavoisky was his nominee five times; Erik Rudberg (Sweden), Joseph Weiss (United Kingdom) and Arne Ölander (Sweden). In the political language of that time, none of the international nominators belonged to the Soviet bloc, that is E. K. Zavoisky was obviously held in high regard by the scientific world and their choice was not politically motivated.

On the Soviet side, as of 1966, E. K. Zavoisky was nominated for the Nobel Prize on three occasions: in 1959 (by I. M. Frank), in 1964 (by A. P. Alexandrov, L. A. Artsimovich, N. N. Semenov, and I. E. Tamm), and in 1966 (by A. M. Prokhorov and B. P. Konstantinov).

C. J. Gorter, who first nominated Zavoisky for the Nobel Prize in Physics in 1958, was the early bird. In the same year, J. Weiss proposed Zavoisky for the Chemistry Prize. Why was it that E. K. Zavoisky and his work started to draw attention beginning with the year 1958? Although it is only a hypothesis, it looks like the impetus came from the Lenin Prize awarded to E. K. Zavoisky a year before. The Prize, in terms

[1] As of 2023, when this monograph was translated into English, data for the years up to 1970 was disclosed. Table thus includes data for the period of 1958-1970, although herein the period of 1967-1970 is scarcely discussed.

Table 1. Zavoisky's Nominations for the Nobel Prize in Physics and in Chemistry for the period of 1958-1970

Year	Nomination	Nominator	The prize to be shared with	Laureates	(Number of nominations) Zavoisky's Co-Nominees
1958	physics	C. J. Gorter	–	P. A. Cherenkov, I. M. Frank, I. Y. Tamm	**(50)** H. A. Bethe (1967), D. J. Bohm, O. Chamberlain (1959), S. A. Goudsmit, M. Goeppert Mayer (1963), A. Kastler (1966), P. Kapitsa (1978), L. D. Landau (1962), A. Landé, L. Néel (1970), L. Onsager (1968), J. H Oort, I. Prigogine (1977), E. Segrè (1959), C. H. Townes (1964), G. E. Uhlenbeck, E. P. Wigner (1963)
1958	chemistry	J. J. Weiss	–	F. Sanger	**(85)** M. Calvin (1961), M. Goeppert Mayer, J. Heyrovský (1959), C. K. Ingold, S. Ochoa (1959), L. Onsager, V. Prelog (1975), E. Segrè, R. B. Woodward (1965)
1959	physics	I. M. Frank, L. Ružička	–	E. Segrè, O. Chamberlain	**(62)** H. A. Bethe, B. Bleaney, N. N. Bogoljubov, S. N. Bose, O. R. Frisch, M. Goeppert Mayer, C. J. Gorter, A. Ioffe, A. Kastler, P. Kapitsa, L. D. Landau, L. Meitner, L. Néel, J. H Oort. C. H. Townes, V. I. Veksler
1960	physics	C. J. Gorter	–	D. A. Glaser	**(80)** A. Abragam, N. G. Basov (1964), H. A. Bethe, N. N. Bogoljubov, L. Brillouin, R. P. Feynman (1965), M. Goeppert Mayer, D. C. Hodgkin (1964), A. Kastler, P. Kapitsa, J. C. Kendrew (1962), L. D. Landau, L. Néel, J. H. Oort, A. W. Overhauser, M. F. Perutz (1962), A. M. Prokhorov (1964), J. Schwinger (1965), C. H. Townes, E. P. Wigner
1960	chemistry	A. Ölander	–	W. F. Libby	**(82)** M. Calvin, D. C. Hodgkin, C. K. Ingold, L. Onsager, M. F. Perutz, M. Polanyi, I. Prigogine, M. Volmer, R. B. Woodward
1961	physics	C. J. Gorter	–	R. Hofstadter, R. L. Mössbauer	**(54)** J. Bardeen (1956, 1972), L. N. Cooper (1972), O. R. Frisch, M. Gell-Mann (1969), W. H. Heitler, D. C. Hodgkin, A. Kastler, J. C. Kendrew, L. Meitner, L. Néel, L. Onsager, J. H. Oort, M. F. Perutz, M. Polanyi, J. R. Schrieffer (1972), C. H. Townes, J. H. van Vleck (1977), E. P. Wigner

Table 1 (*cont.*)

Year	Nomination	Nominator	The prize to be shared with	Laureates	(Number of nominations) Zavoisky's Co-Nominees
1962	physics	C. J. Gorter, L. Ružička	–	L. D. Landau	**(79)** N. G. Basov, N. V. Belov, H. A. Bethe, N. Bloembergen (1981), S. N. Bose, S. Chandrasekhar (1983), R. P. Feynman, M. Goeppert Mayer, W. H. Heitler, A. Kastler, L. Néel, A. M. Prokhorov, J. Schwinger, C. H. Townes, E. P. Wigner
1963	physics	L. Ružička	–	E. P. Wigner, M. Goeppert Mayer, J. H. D. Jensen	**(79)** A. Abragam, N. G. Basov, N. Bloembergen, M. Delbrück (1969), R. P. Feynman, O. R. Frisch, W. H. Heitler, A. Kastler, L. Néel, L. Onsager, A. W. Overhauser, A. M. Prokhorov, J. Schwinger, C. H. Townes
1964	physics	L. A. Artsimovic, L. Ružička	–	C. H. Townes, N. G. Basov, A. M. Prokhorov	**(89)** H. A. Bethe, R. P. Feynman, S. A. Goudsmit, M. Gell-Mann, A. Kastler, L. Meitner, L. Néel, L. Onsager, I. Prigogine, J. Schwinger, R. J. Van de Graaff, G. E. Uhlenbeck, V. I. Veksler
		I. E. Tamm, A. P. Alexandrov, N. N. Semenov	C. J. Gorter		
1965	physics	L. Ružička	–	S.-I. Tomonaga, J. Schwinger, R. P. Feynman	**(111)** J. Bardeen, H. A. Bethe, L. Brillouin, L. N. Cooper, S. A. Goudsmit, M. Gell-Mann, W. H. Heitler, E. Hückel, P. Kapitsa, A. Kastler, L. Meitner, L. Néel, L. Onsager, J. R. Schrieffer, G. E. Uhlenbeck, V. I. Veksler
1966	physics	R Ritschl, C. J. Gorter, L. Ružička	–	A. Kastler	**(118)** J. Bardeen, H. A. Bethe, N. N. Bogoljubov, L. N. Cooper, V. A. Fok, S. A. Goudsmit, M. Gell-Mann, W. H. Heitler, E. Hückel, P. Kapitsa, L. Néel, L. Onsager, A. Salam (1979), J. R. Schrieffer, G. E. Uhlenbeck, R. J. Van de Graaff, J. H. van Vleck
		B. P. Konstantinov, A. M. Prokhorov	B. Bleaney		
		E. Rudberg	C. J. Gorter		
1967	physics	–	–	H. A. Bethe	**(120)**
1968	physics	A. M. Prokhorov	C. J. Gorter, I. Waller	L. Alvarez	**(133)** A. Abragam, H. Alfvén (1970), J. Bardeen, N. N. Bogoljubov, S.N. Bose, S. Chandrasekhar, L. N. Cooper, M. Gell-Mann, B. D. Josephson (1973), L. Néel, L. Onsager, A. W. Overhauser, M. Polanyi, A. Salam, J. R. Schrieffer, S. Vernov
		A. Kastler	C. J. Gorter, J. H. Van Vleck		

Table 1 (*cont.*)

Year	Nomination	Nominator	The prize to be shared with	Laureates	(Number of nominations) Zavoisky's Co-Nominees
1969	physics	C. J. Gorter, S. V Vonsovskij	–	M. Gell-Mann	**(140)** H. Alfvén, J. Bardeen, N. Bloembergen, N. N. Bogoljubov, S. N. Bose, L. Brillouin, CERN, S. Chandrasekhar, L. N. Cooper, G. N. Flerov, S. A. Goudsmit, W. Heisenberg, W. H. Heitler, A. Landé, A. Salam, J. R. Schrieffer, G. E. Uhlenbeck
		J. Chariton	J. G Dorfman		
		A. B. Migdal	M. Gell-Mann, P. L. Kapitsa		
		A. P. Alexandrov, S. V. Vonsovskij	C. J. Gorter, I. Waller		
1970	physics	C. J. Gorter	–	H. Alfvén, L. Néel	**(130)** A. Abragam, A. A. Abrikosov (2003), J. Bardeen, N. N. Bogoljubov, S. N. Bose, S. Chandrasekhar, L. N. Cooper, G. N. Flerov, S. A. Goudsmit, W.H. Heitler, B. D. Josephson, M. Polanyi, I. Prigogine, A. Salam, J. R. Schrieffer, E. Teller, G. E. Uhlenbeck, V. F. Weisskopf
		A. B. Migdal	P. L. Kapitsa		
		G. Feher	J. H. Van Vleck		
		A. M. Prokhorov, S. V. Vonsovskij	C. J. Gorter, I. Waller		

Note. The table includes a list of Zavoisky's nominators and co-nominees. For each year, a list of the winners and a total number of nominations (in brackets) are given, along with a list of selected nominees. At the first reference, the nominee is underlined and the year of the award (if awarded) is indicated in brackets. Surnames are spelled as per the Nobel Nomination Archive. The table is based on the data from the Nomination Archive [4].

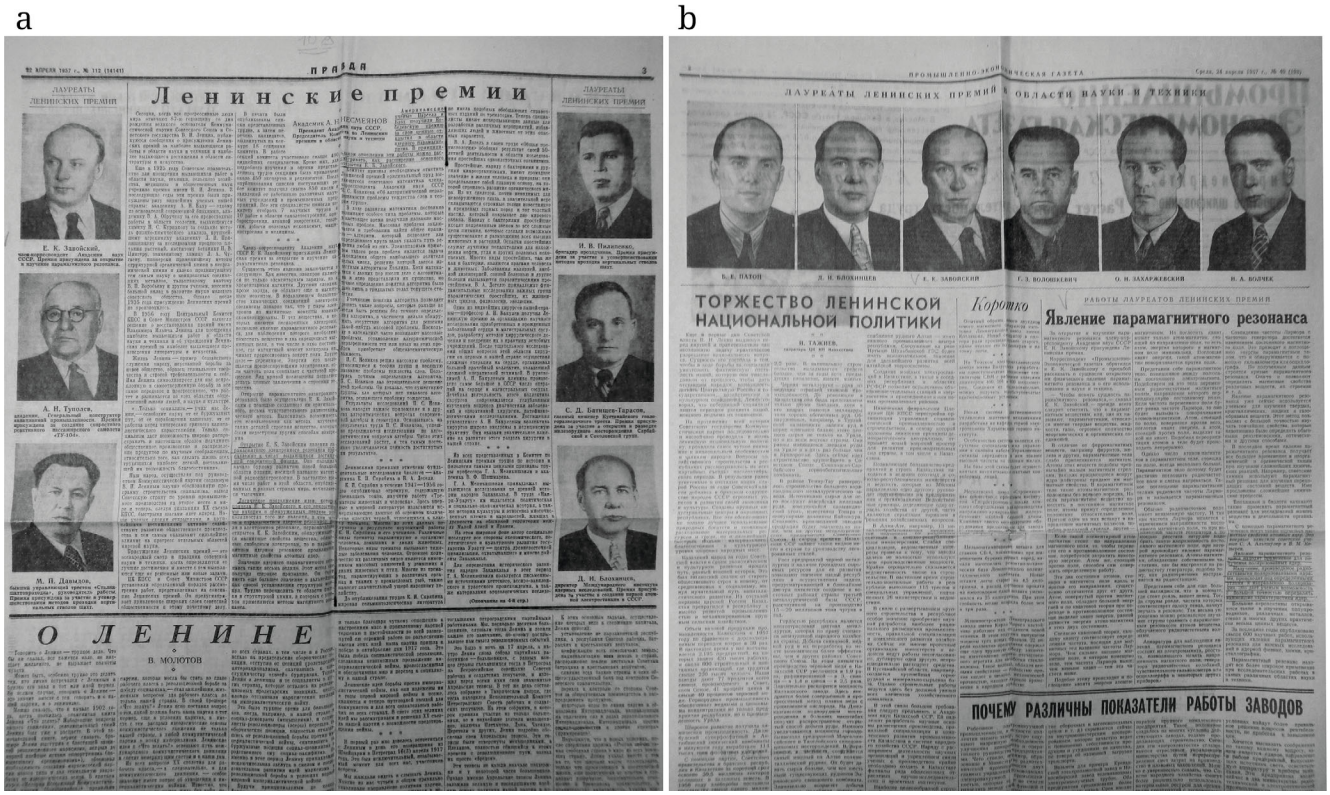

Fig. 1. Pages from the newspapers *Pravda* (a) and *Industry and Trade Newspaper* (b) [in Russian] featuring Lenin Prize 1957 laureates, E. K. Zavoisky included [top left in (a) and third left in (b)]. The latter (b) as well features his paper "The phenomenon of paramagnetic resonance" ("Явление парамагнитного резонанса" [in Russian]). Source: N. E. Zavoiskaya's personal archive.

Fig. 2. Cornelis Jacobus Gorter (right) with Nicolaas Bloembergen (left) outdoors at Lake Chuzenji, Nikko, Japan, circa 1953. Source: Bloembergen and Gorter. Niels Bohr Library & Archives, American Institute of Physics. One Physics Ellipse, College Park, MD 20740.

of its prestige in the USSR somewhat similar to the Nobel Prize, seems to have made the name of Evgeny Zavoisky publicly known, for the first time since he had made his groundbreaking EPR discoveries ten years before. In the Soviet newspapers, including Pravda ("the Truth"), an official newspaper of the Communist Party and one of the most influential media outlet in the USSR, a feature on Lenin Prize laureates was published, an article by Zavoisky and his portrait included. In a way, this feature must have been a proof for the Western world that Evgeny Zavoisky was a "real person" (Fig. 1). As is known, C. J. Gorter, when in the USSR attending the Third All-Union Conference on the Physics of Magnetic Phenomena (1956), wanted to talk to Zavoisky in person, but this was not allowed due to Zavoisky's previous involvement in the Soviet nuclear program [2]. Recognition of a scientist in his homeland is most certainly an important part of international acknowledgment, of which Zavoisky is a vivid example. This circumstance makes it all the more important for the nation to honor its scientific developments and the scientists behind them in the first place.

Below is a detailed account of who nominated Zavoisky for the Nobel Prize and who was his major competition for the world's most important scientific award year by year, beginning with 1958 through 1966.

In 1958, as was said earlier, two nominators proposed E. K. Zavoisky for the Nobel Prize: J. Weiss recommended him for the Chemistry Prize, and C. Gorter – for the Prize in Physics.

Joseph Joshua Weiss (1905-1972), Professor at the Newcastle University, was a pioneer and an authority in the field of radiation chemistry. Among the other things, he studied interaction between free radicals and biologically important molecules [5, 6]. In 1972, upon his death, the Association for Radiation Research established the Weiss Medal [6] to honor his contribution to science.

Cornelius Jacobus Gorter (1907-1980), a Dutch physicist, was a pioneer of magnetic resonance experimentation and, in a way, Zavoisky's competitor (Fig. 2). He himself, however, held E. K. Zavoisky in very high esteem. Once he came to know of Zavoisky's works on magnetic resonance, he added a reference to them to the final proof of his book [7] before it was published in 1947.

In the later years, as was already mentioned, C. J. Gorter nominated Zavoisky for the Nobel Prize multiple times. In 1958, apart from Evgeny Konstantinovich, he proposed the candidature of Lois Néel (1904-2000), a French physicist who eventually won the Prize but a decade later – in 1970 he shared the Prize with Hannes Alfvén "for fundamental work and discoveries concerning antiferromagnetism and ferrimagnetism, which have led to important applications in solid state physics".

In 1958, the Nobel Prize in Physics was awarded to a group of Soviet scientists – P. A. Cherenkov., I. M. Frank, and I. E. Tamm – "for the discovery and the interpretation of the Cherenkov effect". All three of them were nominated for the Prize in the previous year, 1957. P. A. Cherenkov was first proposed

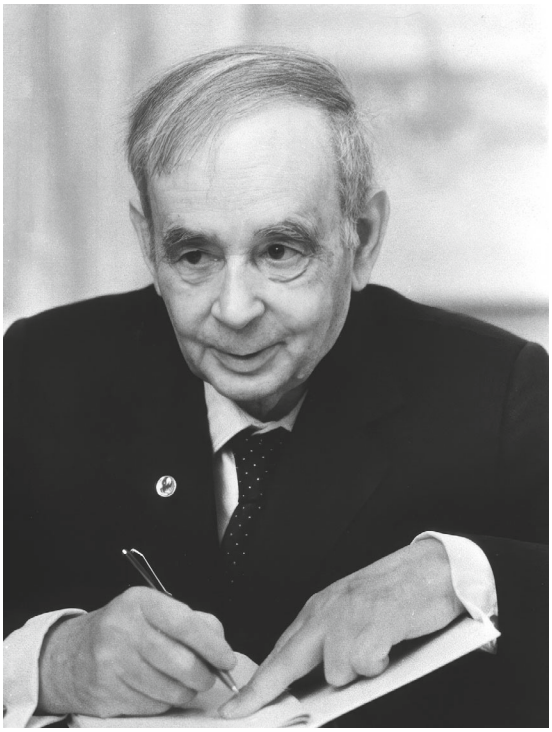

Fig. 3. Ilya M. Frank. Source: A. I. Frank's personal archive. Photo by Yu. Tumanov.

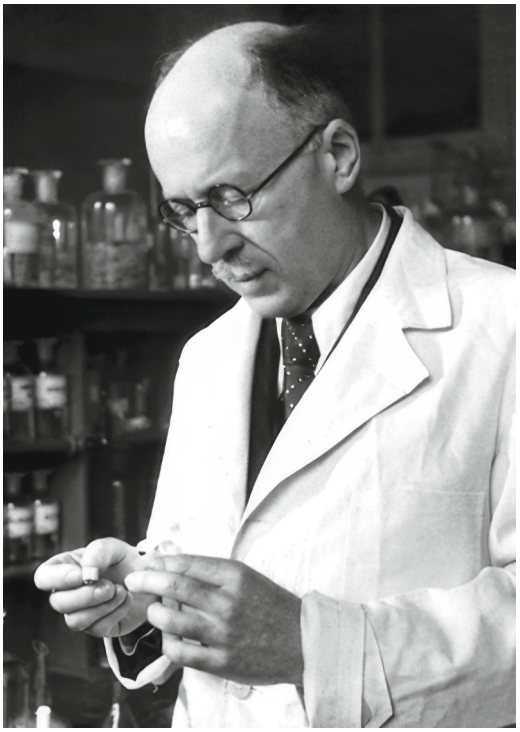

Fig. 4. Leopold Ružička. Source: The Nobel Foundation – http://nobelprize.org/, Public Domain, URL: https://commons.wikimedia.org/w/index.php?curid=9713540.

as a candidate back in 1952 and had been among the nominees every year starting with 1955. The Chemistry Prize for that year went to F. Sanger, who won the Nobel Prize twice – in 1958 and in 1980. That year, 1958, the following candidates for the Chemistry and Physics Prizes were also submitted: P. L. Kapitsa, L. D. Landau, I. Prigogine, E. Wigner, H. Bethe, J. Oort, D. Bohm, L. Onsager, M. Goeppert Mayer, M. Calvin, C. Ingold, R. Woodward, V. Prelog, and many others (in total, several dozen candidates in every category, many of whom were eventually awarded the Prize in the decades to come).

In 1959, Zavoisky was proposed by two nominators: Il'ja (Ilya) Mikhailovich Frank (1908-1990), a Soviet physicist and the 1958 Nobel Prize laureate (Fig. 3), and Leopold Ružička (1887-1976), a Croatian-Swiss organic chemist and the 1939 Nobel Prize in Chemistry laureate (Fig. 4). Ružička was quite a diligent nominator – over the period ending in 1966 he made at least 42 nominations for the Prizes in Chemistry and in Physics. Starting with 1959, he persistently proposed Zavoisky for the Physics Prize with two exceptions only – in 1960 he did not submit any candidates at all, and in 1961 his choice was R. Mössbauer who won the Prize that same year. For I. Frank, Zavoisky was his second choice that year with V. I. Veksler, another Soviet experimental physicist, proposed as his first choice. In 1959, the Nobel Prize in Physics was awarded to O. Chamberlain and E. Segrè "for their discovery of the antiproton". Among the nominees who did not win the Prize that year were: N. Wiener, C. Townes, L. Meitner, C. Kittel, A. Kastler, A. Ioffe, N. N. Bogolyubov, and many of those who had been nominated a year before (L. Landau, E. Wigner, L. Néel, and others).

In 1960, C. Gorter nominated Zavoisky again, this time as his only choice. In the same year, Zavoisky was nominated for the Chemistry Prize by Arne Ölander (1902-1984), a Swedish chemist and member of the Nobel Committee for Chemistry. This was Zavoisky's last nomination for the Prize in Chemistry, until 1966 at least. In 1960, the Chemistry Prize went to W. F. Libby "for his method to use carbon-14 for age determination in archeology, geology, geophysics, and other branches of science". The Physics Prize was awarded to D. Glaser "for the invention of the bubble chamber". Names of the majority of the candidates for the years 1958-1959 listed above (P. L. Kapitsa, L. Landau, E. Wigner, H. Bethe, J. Oort, L. Onsager, M. Goeppert Mayer, M. Calvin, C. Ingold, R. Woodward, C. Townes, A. Kastler, N. N. Bogolyubov, L. Néel, I. Prigogine) were among the nominees for this year as well and would be, repeatedly, throughout the years to come, often submitted for different Prizes or, at times, for several Prizes simultaneously. (In 1960, only V. Prelog and L. Meitner out of the previous two-year period nominees were absent from the list of candidates to be nominated again

in the later years. For C. Kittel, 1959 was the last year when he was nominated for the Nobel Prize, at least in the period the documents are disclosed for. N. Wiener and A. Ioffe both were nominated only once, in 1959.) On these grounds, their names will be skipped further on. In 1960, the 1958-1959 candidates were joined by N. G. Basov and A. M. Prokhorov, A. Abragam, M. Gell-Mann, R. Feynman, D. Hodgkin, J. Kendrew, and M. Perutz nominated for the Prize in Physics, and by M. Volmer, M. Polanyi, F. Crick, and J. Watson proposed for the Prize in Chemistry. Please note, this list of names is far from being complete and features only a small part of all the Nobel Prize candidates for the period discussed.

In 1961, E. K. Zavoisky once again was the C. J. Gorter's choice for the Prize. In that year, as was said earlier, the Nobel Prize was awarded to R. Mössbauer, nominated by L. Ružička, "for his researches concerning the resonance absorption of gamma radiation and his discovery in this connection of the effect which bears his name" and to Robert Hofstadter "for his pioneering studies of electron scattering in atomic nuclei and for his thereby achieved discoveries concerning the structure of the nucleons". Among the nominees, apart from those mentioned earlier, there were W. Heitler, O. Frisch, and J. van Vleck.

In 1962, once again, E. K. Zavoisky was nominated for the Prize by C. Gorter and L. Ružička. That year, Lev Landau, another Soviet physicist, was awarded the Nobel Prize "for his pioneering theories for condensed matter, especially liquid helium" (earlier the same year he had barely survived a car accident, a circumstance that probably prompted the Royal Academy to put him on the fast track for the Nobel Prize). In addition to the previously listed scientists, in 1962, among the candidates were S. Bose, N. Bloembergen, S. Chandrasekhar, J. Schwinger, and N. V. Belov.

In 1963, Zavoisky was nominated by L. Ružička once more. The Nobel Prize for that year was divided between E. Wigner "for his contributions to the theory of the atomic nucleus and the elementary particles…", and M. Goeppert Mayer and J. Hans D. Jensen "for their discoveries concerning nuclear shell structure". J. Bardeen, L. Cooper, and A. Overhauser, all of them having been nominees before but not yet mentioned here, were proposed this year as well, along with the group of scientists previously discussed. M. Delbrück, first appeared as a candidate for the Nobel Prize also in 1963.

1964 was the year when Soviet scientific society displayed a new wave of interest in seeking international recognition for E. K. Zavoisky. That year, apart from L. Ružička, his devoted nominator, the name of Zavoisky was submitted by four Soviet academicians: L. A. Artsimovich, A. P. Alexandrov, N. N. Semenov, and I. E. Tamm, the latter two the Nobel Prize laureates. For Ružička and Artsimovich, E. K. Zavoisky was their only choice, while the three other physicists suggested "the prize to be shared between E. K. Zavojskii[2] and C. J. Gorter".

In the very same year though, D. V. Skobeltsyn, director of the Physical Institute of the Academy of Sciences, proposed N. G. Basov, A. M. Prokhorov, and C. Townes for the Prize, and, in the end, they were the winners of the Nobel Prize for that year. Two different nominations from the Soviet Union obviously competed against each other. This incident is a persuasive example of the hypocrisy thriving in the Soviet scientific community that seldom lived up to its declared principles of integrity, solidarity, concerted efforts, and united front on the international arena. It was well known in the local scientific community, D. V. Skobeltsyn included, that the four academicians were nominating Zavoisky for the Nobel Prize that year. Yet, he chose to make a decision that, to a certain extent, devalued their effort, instead of supporting it. His candidates won the Nobel competition for that year and, thus, in terms of the USSR "team score", his decision was not unjustified.

In 1965, L. Ružička was the only one who nominated Zavoisky for the Nobel Prize, which was awarded that year to S.-I. Tomonaga, J. Schwinger, and R. Feynman "for their fundamental work in quantum electrodynamics…".

In 1966, L. Ružička was no longer alone in proposing E. K. Zavoisky for the Prize. He was joined by C. J. Gorter (who had previously been nominating L. Néel for two years in a row) and E. Rudberg. The latter, apart from Zavoisky, made two more nominations: one proposing to divide the Prize between A. Kastler and J. Brossel, and the other one suggesting the Prize to be shared by L. Néel and J. van Vleck. A. Kastler was the one who was awarded the Nobel Prize in 1966, others (but J. Brossel) to follow suite in later years. Ružička, Gorter, and Rudberg were not the only ones for whom E. K. Zavoisky was their choice for that year. A. M. Prokhorov and B. P. Konstantinov nominated him in the company of B. Bleaney, while R. Ritschl proposed Zavoisky as a solo candidate. Like in the previous years, the list of candidates for the Prize included H. Bethe, P. L. Kapitsa, M. Gell-Mann, L. Néel, L. Onsager, N. N. Bogolyubov, W. Heitler, G. Uhlenbeck and S. Goudsmit, and E. Hückel. This is the last year for which the archival documents of the Nobel organization were available as of 2018, the year the original monograph was finished in.

By the time the English translation was prepared (2023), more data was made available (up to 1970)

[2] Another way to spell Cyrillic "Завойский" in English.

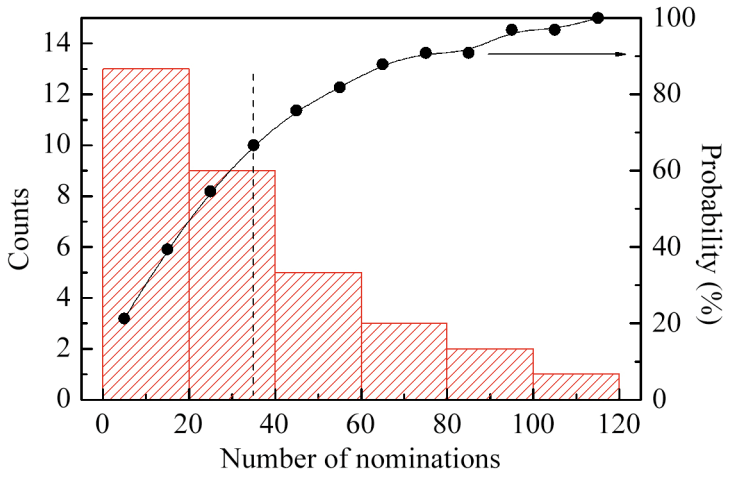

Fig. 5. Histogram and cumulative distribution function of nominations among the eventual Nobel Prize winners-Zavoisky's co-nominees in 1958 (for the period of 1958-1970). The dashed vertical line marks the "position" of Zavoisky against his competitors. Source of the data: the Nomination Archive [4].

providing for a total of 13-years of Zavoisky's nominations history. Cumulative distribution analysis of the total number of nominations received by Zavoisky and by the eventual Nobel Prize winners who entered (or continued) the "Nobel Prize Relay" in the same year (1958) puts him in the upper tercile (Fig. 5). Nominated on 35 occasions known of as of 2023, E. K. Zavoisky, in other words, was among the strongest candidates for the Nobel Prize.

From the data already disclosed, it is clear that Zavoisky, firstly, had always been held in high esteem by the world scientific community – year by year he was a nominee for the Nobel Prize in Physics or for the Prizes in Physics and Chemistry at the same time. And secondly, he was never awarded the Nobel Prize in the times when competition was particularly intense between the discoveries as well as between the scientists. While the unfairness of him never winning the Nobel Prize is painfully obvious, it is hard to pinpoint the exact moment when it took place or, strictly speaking, who exactly and when precisely unfairly took Zavoisky's place among the Nobel Prize laureates. When you look at the names listed above, an incomplete (!) list of them, it is hard to decide on the answer. Apparently, the only chance for Zavoisky to squeeze into that never-stopping overcrowded train of Nobel Prize-worth scientific advances was in 1952, sharing the Prize with F. Bloch and E. M. Purcell. Unfortunately, it was the period when the Soviet government (meaning the entire Soviet science as well) chose to completely isolate itself from the rest of the world, international versions of the Soviet peer-reviewed journals were discontinued and scientific ties with the world were cut off. N. E. Zavoiskaya located the archival documents cancelling the trip of the Soviet delegation to Amsterdam to take part in the International Conference on Spectroscopy at Radiofrequencies (18-23 September 1950) – M. A. Suslov, Secretary of the Communist Party of the Soviet Union and its chief ideologue, deemed it "inexpedient" [2]. One can only guess how many of such "inexpedient" rulings remain buried in the archives. The officially sanctioned policy of delaying paper publications did not help either. Of this, the example of S. A. Altshuler and B. M. Kozyrev, Zavoisky's closest collaborators, is very illustrative – they made a discovery of the hyperfine structure in the paramagnetic resonance spectrum [8] in 1948, that is one year before R. Penrose [9], but their paper had been "sitting on the shelves" in *Doklady of the USSR Academy of Sciences* for two long years to result in the findings of the Soviet physicists to lose their scientific priority [1]. Finally, in 1952, the Nobel Prize award may have cost a Soviet scientist his career at the least, if not his life or freedom. In 1947, for example, international recognition of their achievements took N. G. Klueva and G. I. Roskin to the "court of honor" (for the review of their book see the *British Medical Bulletin* [10]); V. V. Parin[3], who made their findings known abroad while on an official visit to the US,

[3] In 1947, V. V. Parin, a Soviet physiologist and Secretary of the Soviet Academy of Medical Sciences, was accused of spying for the United States of America following his sharing a manuscript on the Soviet anti-cancer treatment ("crucine") research with his American colleagues. In the wake of Parin's arrest following the manuscript incident, its authors, Soviet scientists N. G. Klueva and G. I. Roskin, were publicly reprimanded in the "court of honor", established by the Ministry of Health. This incident had far-reaching consequences for the Soviet science, in particular with regard to sharing its achievements with the international community – an extraordinarily restrictive procedure for any scientific research to come out in print was established.

was arrested in the same year. In a much less "carnivore" 1958, a campaign of abuse was waged against B. L. Pasternak[4], a Soviet poet awarded the Nobel Prize in Literature for that year. All these exemplify the possible fate of a Nobel Prize laureate in the USSR in 1952.

It looks like Zavoisky still had a chance to win the Nobel Prize in later years. The long repeating list of candidates, only briefly referred to above, demonstrates what a lengthy way (for decades!) of year-after-year nominations it took for the outstanding scientists to be justly awarded the Nobel Prize. H. Bethe, for example, had been a nominee for 24 (!) years, his candidature proposed on 48 occasions, before he was awarded the Nobel Prize. L. Onsager had been nominated at least 47 times during 16 years. L. Néel became a Nobel Prize laureate after 18 years and 77 nominations. Respect of the world's leading scientists willing (and asked) to make a nomination and a nominee's long life both seem to be of help in winning the Prize. It is obvious from the known 17 nominations that Zavoisky had enough of the first, but unfortunately was not meant to have the latter. It is noteworthy, that magnetic resonance methods won their next Nobel Prizes again nearly half a century later (for example, R. Ernst, 1991, and K. Wüthrich, 2002, more on this later).

Lack of enthusiasm on the part of Soviet nominators, meanwhile, stands out. Zavoisky was nominated for the Nobel Prize by his Soviet colleagues only three times in the 9 years reviewed: in 1959, in 1964, and in 1966. Such feeble enthusiasm was characteristic of their involvement in the nominating process in general, irrespective of Zavoisky. Unfortunately, it is impossible to know who were the Soviet scientists asked each year to submit their candidates for the Nobel Prize. What is known for a fact is that Nobel Prize winners are welcome to submit their choices every year. Strange as it might seem, Nobel Prize laureates in the USSR took little advantage of their status to nominate candidates, fellow Soviet scientists or not. As of the year 1966, Soviet Nobel Prize laureates were at liberty to make a total of 42 nominations (all candidates proposed by one person for a year counted as one nomination; since one person is allowed to nominate several scientists for a given year, that number increases exponentially). In the meantime, according to the data disclosed by the Nobel organization as of 2018, only 8 nominations came from the USSR Nobel Prize winners, that is ⅕ of the minimum possible count! Unlike their Soviet colleagues, Nobel Prize laureates from other countries took their privilege more seriously. Above mentioned E. Segrè, W. F. Libby, and R. Mössbauer, for example, exercised their right every year. Renowned Nobel Prize laureates of the previous years paid attention to the findings worth of the Nobel Prize too. N. Bohr (Nobel Prize 1922), except for the war time, skipped 12 years only in the 40-year period since the year he was awarded the Nobel Prize till the end of his life (that is the period he had the right to submit his choices for the Prize). L. de Broglie (Nobel Prize 1929) "missed" two years only, W. Heisenberg (Nobel Prize 1932) – eight years, apart from the war period, E. Fermi (Nobel Prize 1938) never missed a year, except for the World War II, M. Born (Nobel Prize 1954) took a pause only three times. One could only assume that Soviet scientists might have not perceived the Nobel Prize as prestigious an honor as their Western colleagues have, or they might have judged the discoveries worth of the Prize by a higher standard.

Let us see who else, other than E. K. Zavoisky, his nominators proposed for the Nobel Prize over the period under discussion. For E. Rudberg, 1966 was the first year in his nominating history. J. Weiss took part in the nominating process only once – in 1958. Arne Ölander, after 1960, submitted his choice twice more – in one instance he proposed the name of N. V. Belov, a Soviet crystallographer and geochemist, in the other instance he suggested the prize to be shared between R. Norrish and G. Porter. C. J. Gorter, starting with 1948, made 11 nominations, his choices being L. Néel, F. Bloch, and B. Matthias, among others. L. Ružička made 42 nominations (since 1934, for the Chemistry Prize, and, since 1951, for the Prize in Physics as well). He was very persistent in supporting his choices – most of them he nominated repeatedly, many of them – until they finally became Nobel Prize laureates (such was the case with him nominating R. Woodward, T. Reichstein, J. Heyrovsky, R. Robinson, W. Stanley, and others).

As for his fellow countrymen, neither A. P. Alexandrov nor I. E. Tamm made any other nomination in the period ending with 1966. L. A. Artsimovich, prior to nominating Zavoisky, proposed L. D. Landau and P. L. Kapitsa for the Nobel Prize, twice. I. M. Frank, in 1966, nominated P. L. Kapitsa. N. N. Semenov made the most considerable effort, having submitted P. L. Kapitsa as his choice for the Nobel Prize in Physics to be followed by two nominations for the Nobel Prize in Chemistry he made twice for each group of scientists: A. N. Frumkin and M. Volmer, and A. P. Vinogradov and A. Holmes.

[4] Boris Pasternak, a Russian poet and a Nobel Prize laureate. In 1958, he was awarded the Nobel Prize in Literature for his novel "Doctor Zhivago". Having first accepted the honor, he later declined it, amid a campaign of abuse it brought to him in the Soviet Union.

In conclusion, it needs to be said that this overview covers the period that was probably not the most intriguing in the Nobel Prize nomination history of the EPR discovery. Late 1940s-early 1950s was the time when the Soviet science was heavily veiled from the world, while late 1950s and the first half of the 1960s was the period of the Thaw[5] in the USSR with the ties between the Soviet and the world science at their strongest. In this later part of the period reviewed, Soviet scientists were awarded the Nobel Prize nearly every other year (1956, 1958, 1962, 1964). This "flow" of Nobel Prizes going to the Soviet Union might have been perceived by the international scientific community as a sufficiently high recognition, enough for the Soviet science. In that period the candidature of E. K. Zavoisky was often in competition with his fellow Soviet scientists. It would be interesting to know what was the situation in the late 1960s and in the years that followed: whether Zavoisky was ever nominated for the Nobel Prize again and, if he was, whether the pool of his nominators got larger or smaller, and who was his competition. The answer is in the archival documents that are yet to be disclosed during the current decade[6].

CONCLUSION

The Nobel Prize history of magnetic resonance related phenomena shows that electron paramagnetic resonance had little luck in terms of its recognition – the discovery of EPR brought the Nobel Prize to no scientist. Isidor Rabi who was the first to observe EPR but in an atomic beam (E. K. Zavoisky referred to Rabi's experiment in his doctoral dissertation) won the Nobel Prize "for his resonance method for recording the magnetic properties of atomic nuclei". Pierre Curie was awarded the Nobel Prize "in recognition of the... joint researches on the radiation phenomena discovered by Professor Henri Becquerel", but not for Curie's law. Neither G. Uhlenbeck nor S. Goudsmit was awarded the Prize for the discovery of electron spin. J. van Vleck was the only one whose EPR-related work was recognized by the Nobel Prize which he shared, in the twilight of his life, with P. Anderson and N. Mott for "fundamental theoretical investigations of the electronic structure of magnetic and disordered systems". Verdicts given by the Nobel Committee for Physics reflected general consensus (that we share) that magnetic resonance was not the phenomenon to be discovered through a one-and-done process, although for a specific media it could be. According to our estimation, roughly 60% of all the Nobel Prizes in Physics ever given had a motivation containing the words "discovery", "discoveries" or "discovering". Meanwhile, I. Rabi was awarded the Prize "for his resonance method", Bloch and Purcell shared the Prize "for their development of new methods for nuclear magnetic precision measurements and discoveries in connection therewith". That is, in the view of the Nobel Committee, they, for the most part, developed (different) methods, which helped them discover something. The Prize motivation does not state directly that magnetic resonance in a substance was discovered, let alone magnetic resonance in general as a phenomenon. In other words, scientific priority of E. K. Zavoisky's discovery was in no way undermined. To add to the picture, in 1966, A. Kastler was awarded the Nobel Prize for his discovery of magneto-optical resonance, yet the Nobel Committee's motivation wording was "for the discovery and development of optical methods for studying Hertzian resonances in atoms".

Eventually, some works related, directly or indirectly, to magnetic resonance phenomena and their applications were recognized by "long-overdue" Nobel Prizes. These were the Nobel Prizes awarded to J. van Vleck in 1977, to N. Ramsey in 1989 ("for the invention of the separated oscillatory fields method..."), and to A. Leggett in 2003 ("for pioneering contributions to the theory of superconductors and superfluids"). After that, magnetic resonance related breakthroughs were awarded the Nobel Prize in Chemistry (R. Ernst, 1991; Kurt Wüthrich, 2002) and in Physiology or Medicine (P. Lauterbur and P. Mansfield, 2003). More on this in [11]. A. Leggett was given the Prize for his theoretical work on superfluid ^{3}He (this Prize was erroneously omitted in [11]), for which NMR methods were apparently instrumental (for references see the book by A. Abragam and M. Goldman [12], for example [13]).

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[5] The Khrushchev's Thaw, a period of general liberalization of life in the post-Stalin Soviet Union.

[6] The data for the years 1967-1970 presented in table shows that 1967 was the only year when Zavoysky was not among the nominees for the Nobel Prize. In 1968-1970, several nominators proposed his candidature every year. C. J. Gorter remained his staunch nominator. Fellow Soviet scientists grew to become more involved than in previous years, which does them credit. On the Soviet side, stand out two nominations made by S. V. Vonsovsky in the same 1969. Vonsovsky must have submitted the first of the two in 1968 but too late to meet the Nobel Committee's deadline for that year. This could have accounted for his 1968 nomination to be registered for the next year's award instead, that is for 1969.

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Conflict of interest
The authors of this work declare that they have no conflicts of interest.

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