Semen A. Altshuler: scientist, mentor, teacher

Boris I. Kochelaev
Kazan Federal University, Kremlevskaya, 18, Kazan 420008, Russian Federation
E-mail: bkochelaev@gmail.com

Abstract. International Conference “Resonances in Condensed Matter” is devoted to 100 years of the birthday of the Corresponding member of Academy of Sciences of the USSR, Professor of the Kazan University Semen Alexandrovich Altshuler (1911-1983). He is well known by pioneer works on EPR, the prediction and grounds for an existence of the neutron magnetic moment, the prediction and the theory of the acoustic paramagnetic resonance, and as a founder of the Kazan scientific school “Magnetic radiospectroscopy of condensed matter” (with E.K. Zavoiskii and B.M. Kozyrev)

1. Childhood, youth, education
Semen Altshuler was born 24 September in Vitebsk (Belorussia). It is remarkable that it was a native town for many outstanding persons: Field-Marshall Alexander Menshikov (the closest retainer to the Emperor Peter I), a painter Marc Shagal, academicians Zhores Alferov, Vitalii Goldanskii, Boris Zaharchenya. Later the Altshuler’s family moved to Nizhnii Novgorod, where Semen Altshuler graduated the school (1927) being 15 years old.

In his school testimonial was written: “… showed abilities for critical thinking and a strongly pronounced attraction to studies mathematical subjects in abstract aspects.” Semen Altshuler decided to become a physicist, however he was too young to enter the university. One year Altshuler studied in the Industrial school.

In summer of 1928 Altshuler came to Kazan to join the university. He was lucky since at that time the regular session of the USSR-Association of physicists took place at the Kazan University. Many famous physicists were present: P. Dirac, M. Born, P. Debye, L. Brillouin, A. Ioffe, L. Mandelstam, Ya. Frenkel… Altshuler was impressed by the greetings of guests given by prof. Ulyanin in German, English and French.

Altshuler studied with enthusiasm. Kazan University had a brilliant mathematical school which was founded by the great mathematician N.I. Lobachevsky, the originator of a non-Euclidean geometry. So, Altshuler got here a good mathematical education. He took an active part in a work of the scientific student’s society and became its chairman. He graduated the university in 1932 and became a post-graduate student.

2. The first steps in science and teaching
Semen Altshuler dreamed of theoretical physics. However, the only theorist at the university professor A.D. Goldhammer left at that time Kazan for Leningrad. Altshuler decided to find Igor Tamm in Moscow, whom he knew only due to his excellent text-book on the theory of electricity. As a matter of fact Tamm was an outstanding theorist; he became later a Nobel Prize winner. After some short tests Tamm suggested possible topics for research: one in physics of metals, another in quantum chemistry and the third in physics of atomic nucleus.
It was a romantic time in physics: only few years left after creation of quantum mechanics, neutron and positron have been just discovered (1932); nuclear physics started to develop. Altshuler had chosen the third problem from suggested. Tamm proposed a problem to analyze optical spectra of atoms with nucleus having odd number of neutrons on the basis of an idea that the neutrons have magnetic moment. Altshuler started with enthusiasm the development of a quantum theory of magnetic properties of elementary particles and atomic nuclei. As a result the magnetic moment of the neutron was predicted and its value was correctly estimated [1]. The proposal of magnetic moment for an electrically neutral particle was so unusual that even Niels Bohr, who visited Moscow in 1934, could not accept this idea. Nevertheless, the magnetic moment of the neutrons was discovered later and magnetically polarized beams of neutrons are used now as a powerful method to study the condensed matter.

Contacts with Tamm were important for Altshuler not only in the field of science. He was a teacher for him in the full sense of this word. Tamm's rich individuality, his enthusiasm for science, his views of principle, and his tact in relation with people had a profound influence on Altshuler. Their meetings, correspondence continued till the Tamm’s decease.

In 1934 Altshuler was recalled back to Kazan University for lecturing on theoretical physics. He had ten lectures a week; nevertheless, he finished his thesis in 1936. Shortly after that the collaboration with E.K.Zavoiskii and B.M.Kozyrev was established, which developed soon into the tight friendship. Zavoiskii was investigating at that time the energy absorption of radiowaves in liquids and solids by his very sensitive electronic method.

In 1939 S.A.Altshuler reported at the seminar about experiments of Rabi on measuring of nuclear magnetic moments of atomic beams using the resonant method. Zavoiskii became very interested and the team decided to look for nuclear magnetic resonance in condensed matter using protons of water. At the beginning 1941 the first NMR signal were obtained; however, they were not stable… The team needed several months more, but the war started…

3. The Second World War stops the scientific work

Soon after the beginning of the war most of the institutions of the Academy of Sciences had to move from Moscow and Leningrad to Kazan University. The Zavoiskii’s laboratory was closed down. S.A. Altshuler as a volunteer joined the army.

Zavoiskii was able to resume his research work only in 1943. However, he did not continue the search for NMR, but began studies of the electron paramagnetic relaxation in orthogonal magnetic fields. These measurements led him to the discovery of the electron paramagnetic resonance (EPR) in 1944. The EPR rather soon became a powerful method to study the condensed matter on a microscopic level in physics, chemistry, geology, biology, medicine. The EPR discovery was one of the most important achievements in physics of the 20th century. At least five the following discoveries related to magnetic resonance in condensed matter were crowned by the Nobel Prizes. In particular, the first one among them was NMR, discovered by E.M.Purcell. H.C.Torrey and R.V.Pound in 1946 using the installations similar to that of Zavoiskii.

Let us return to our story about S.A. Altshuler. In July 1941 the Hitler’s troops took his native town Vitebsk, at the beginning of October they were approaching Moscow. Altshuler deemed it is his duty to defend own country, though he had an official release from army as a university teacher, the family (the wife Eugeniya and the daughter Tanya who was only nine months old), an interesting work and scientific community. After some training S.A. Altshuler got an appointment to the First Separate Fighter Antitank Artillery Brigade of the Reserve of General Head-quarters. This unit was used to close breaches of our defense or for a break-through of the enemy front. One of officers of a similar unit recollected P.M. Borodin (later a professor of physics): “Our autos with guns were moving to meet an advanced enemy. Often they had to enter into a battle immediately without any preparation. However it was not usual battle with an artillery cannonade and crackling of machine-guns. The defenseless anti-tank gun is waiting in silence allowing the armored tank to come closer. When the
duel between the gun and tank started, the gun is able to fire only 2-3 shots. If they are beside the tank, then the gun and the crew will be annihilated.”

Since December 1942 till the end of the war S.A. Altshuler participated in heavy battles from Kursk till Eastern Prussia. Some fragments from Altshuler’s letters to his wife Eugeniya give some impression of these events.

April 1943. “...It seems to happen that I will participate in decisive battles, which shall lead Hitler’s villains to the catastrophe...”

From the decree concerning the first Altshuler’s order (Red Star): “… Near village Samodurovka the antitank regiment on 11-12 July (1943) had a severe battle with new German tanks T-6. Comrade Altshuler showed fearlessness by personal example. The regiment destroyed 10 enemy’s tanks…”

During the month (24.06.44-24.07.44) Altshuler participated in the raid about 900 km till Brest mostly in the rear of enemy. Before it he wrote:

24.06.44. “What is going on around! ...I could write a lot, but it is not allowed and I have no time. The only what I want to tell to you. In the next several weeks don’t wait letters from me... All my thoughts about you and Tanyusha! So long! Be happy!

S.A. Altshuler finished the war as a Major and was awarded by three Orders of the Patriotic War, one Order of the Red Star and many medals.

4. Back to the university, new fields of research and teaching

S.A. Altshuler left the army only in 1946 according to the Moscow Physics Institute inquires. However, he decided to return to Kazan University. Altshuler joined to Zavoiskii and Kozyrev in their work on EPR. This common work lasted not very long, since Zavoiskii left Kazan in 1947 to participate in the atomic project.

Altshuler started to develop a theory of the spin-lattice interaction and relaxation in paramagnetic crystals. In 1952 the studies of spin-lattice relaxation led Altshuler to the prediction of a new physical phenomenon, namely, the acoustic paramagnetic resonance (APR) [2]. The main idea of the APR concerned the selective absorption of the energy of the acoustical wave in paramagnet which occurs under the coincidence of the sound frequency with the interval between the quantum energy levels of the paramagnetic ion or the nucleus with nonzero spin.

The nuclear acoustic resonance was observed in 1955 by Proctor and Tantilla. The electron acoustic resonance was detected in 1959 in the USA by Jackobson, Shiren and Tucker. The APR discovery was the beginning of a new field in physics: quantum acoustics. The Altshuler's Doctorate was submitted for approval in 1955 at Physical Institute of Academy of Sciences in Moscow. In 1956 he became a professor.

Experimental studies in the field of the EPR were resumed at the Kazan University due to Altshuler's efforts. He involved to this research work several gifted postgraduate students from other fields. Some of them participated in the interpretation of experimental results.

An important step was made in 1956 when M.M. Zaripov and Yu.Ya. Shamonin detected and interpreted the EPR spectrum of trivalent chromium in a ruby. The analogous research was performed independently by A.M. Prokhorov and A.A. Manenkov in Moscow. Later the ruby became "the touchstone" of quantum electronics. A.M. Prokhorov and N.G. Basov together with C. Towns got the Nobel Prize in this field.

In 1954-1961 S.A. Altshuler headed the chair of the experimental and theoretical physics. He started to deliver a new course of lectures “Quantum theory of paramagnetism”. In 1956 was created a group of students in theoretical physics, to which I joined too. To improve their mathematical education Altshuler invited the well known algebraist professor V.V. Morozov to deliver lectures on the group theory. The first graduation of the theorists was in 1957.

5. A new turn: the head of experimental laboratories

In 1950s important engineering applications of crystals with paramagnetic impurities, as the working substance of quantum amplifiers of microwaves (maser), were advanced. Masers produced a
revolution in cosmic communications and radio-astronomy due to the extremely low level of background noises.

The Magnetic Radio-Spectroscopy (MRS) laboratory (1957) and the chair of magnetic radio-spectroscopy and quantum electronics (1961) were established at Kazan University for the research and for the training of highly qualified specialists in this field (the head of the chair– M.M.Zaripov). All these institutions (involving the chair of Theoretical Physics) formed at that time a joint collective body under the leadership of S.A. Altshuler.

At first, before the laboratory succeeded in growing the synthetic crystals, minerals from the geological museum were investigated with help of professor V.M. Vinokurov, a specialist on mineralogy. On occasions the magnificent jewels from women's decorations belonging to relatives and friends got into the cavities of spectrometers. A number of crystals were recommended and applied later as working substances in quantum paramagnetic amplifiers.

However, the most important results of these investigations consisted in forming a large team of highly qualified specialists in the scope of magnetic radio-spectroscopy and optics of solids. This group included M.M. Zaripov, L.Ya. Shekun, Yu.Ye. Polsky, A.L. Stolov, V.G. Stepanov, I.N. Kurkin A.A. Antipin, R.M. Valishev, A.Kh. Khasanov, M.A. Teplotov, L.D. Livanova and many others.

In 1973 the head of the MRS chair M.M. Zaripov was appointed as a director of the Kazan Physico-Technical Institute. S.A. Altshuler decided to take care of the MRS chair; to be the head of the theoretical physics chair he suggested to me.

6. Development of the scientific school at the Kazan University

It is evident that the Kazan School of Magnetic Radiospectroscopy started by the EPR discovery of E.K. Zavoiskii. Its following development was going under the leadership of S.A. Altshuler at the Kazan University and B.M. Kozyrev at the Kazan Physical-Technical Institute.

After discovery of the APR the most impressive results of S.A. Altshuler were related to so-called Van Vleck’s paramagnets (in collaboration with M. Zaripov, M. Teplotov, L. Aminov, B. Malkin, Yastrebov and others) and non-linear spin-phonon phenomena (with R. Valishev, A. Khasanov, B. Kochelaev). His idea to use the Van Vleck's paramagnets to achieve super low temperatures [3] was very successive (up to tenths of a millidegree K). Altshuler’s idea to use the Mandelshtam-Brillouin scattering of the laser light to observe the resonant phonons in solids resulted in the discovery of an avalanche of phonons radiated by the saturation of the wing of the EPR line by powerful microwave impulses. The effective temperature of these phonons raised to several million degrees, whereas the temperature of the sample was retained at a level of 2 K [4].

Altshuler initiated and supported all trends in magnetic spectroscopy: NMR, EPR, optical and gamma resonance spectroscopy. “Magnetic Seminar”, headed by Altshuler, was playing an important role in developing of his school.

The books of Altshuler and Kozyrev related to the electron paramagnetic resonance [5] helped to spread the resonant methods in our and other countries. It was translated into German, English and Polish.

Altshuler had a rare intuition in physics. He did not believe that fundamental results in physics could be obtained only by mathematical calculations without understanding of phenomena in a simple way. An important feature of his school is a tight collaboration experimentalists and theorists.

Altshuler took care of his post-graduates without patronizing them, trying to explain to them the nature of physical phenomena rather than training them in calculation techniques. He did it so tactfully that a student began to think that he came to the solution of a problem himself. Altshuler always related to his colleagues and students with kind attention which favored the conversation. He was using only polite form in conversation (in German “Sie”); Russian equivalent to “Du” was used with close friends only.

Altshuler never hurried and was never late, whether it was an official session or a meeting with a post-graduate, or a friendly visit. He usually was among the first guests, and he never changed his habits.
Now the scientific school “The Resonance Spectroscopy of Condensed Matter” is recognized as one of the leading school of Russia. It includes researchers of the five chairs: Theoretical physics, Magnetic radio-spectroscopy and quantum electronics, General physics, Physics of molecular systems, Solid state physics.

7. National and international contacts

Altshuler was well known among the national and international magnetic resonance and other scientific communities. However the international contacts had difficulties during the Soviet time. For example, in 1965 N. Bloembergen being in Moscow by the invitation of the rector of the Moscow University R.V. Khokhlov could not come to Kazan to meet Altshuler and myself (I was Bloembergen’s postdoc at Harvard university during 1963-64 academic year), since Kazan was a closed city at that time. Altshuler and I had to go to Moscow for this meeting.

For the first time Altshuler participated in the international conference in 1966 (the Congress AMPERE in Ljubljana) with a plenary lecture. He met there many well known researcher in the field of magnetic resonance: Anatole Abragam, Alfred Kastler, Alex Müller, Dan Bolef and others.

In 1968 the Congress AMPERE was organized in Grenoble. The Ministry of education of the Soviet Union included to the soviet delegation Altshuler, Zaripov and me from the Kazan University. Nevertheless Altshuler could not go because the Communist Party committee of the Tatar Republic did not give permission. When we met Anatole Abragam, he related this incident to the anti-Semitic campaign at that time.

In 1969 Altshuler managed to organize in Kazan a conference dedicated to 25 years of the EPR discovery. For the first time (after 1928) to Kazan came well known scientists from other countries: K. Gorter, C. Jeffries, M. Strandberg, B. Judd, A. Abragam, A. Kastler, K.A. Müller, D. Bolef, and many others. Later Altshuler participated also at the Congresses AMPERE in Bucharest, Turku, Heidelberg, and Tallinn.

S.A. Altshuler was a chairman of the Council “Radiospectroscopy of condensed matter” and a member of the Council “Physics of low temperatures” (Academy of Sciences of the USSR); a member of the editorial board of “Journal of Experimental and Theoretical Physics”; a chairman and member of different Councils at the Kazan University.

8. Not only the science...

Altshuler started a tradition to organize seminars somewhere outside the city (say, on Volga river). After the report the participants took part in inconceivable play with a ball, the play being something between football and basketball. Altshuler often happened to be the goalkeeper. He seemed to enjoy himself in the young company. He joked, told stories, and sang old student songs (having a strong baritone) which he knew a lot.

It was known, also, that if a musical event took place in Kazan, one would certainly meet him there together with his friend a mathematician B.L. Laptev. His favorite hobby was also reading novels, especially dedicated to historical and biblical events.

Altshuler’s jubilees were celebrated cheerfully, with enthusiasm: a lot of songs, humor, cartoons… According to this tradition we celebrated his 100th birthday. Besides the International Conference “Resonances in the condensed matter” the premiere of a humorous opera “Eugeny Zavoisky or the Epochs Paradoxical Resonance (EPR-2)” took place at the Cultural Center of the Kazan University. This opera was created by professor of the magnetic radio-spectroscopy chair N.I. Silkin. It is based on the student’s songs of the Kazan, Moscow and Petersburg universities and contains a lot of humor and irony. A performance of the opera was realized by the producer of the Kazan Academic Theater of opera and ballet E. Treskin, who graduated the Physics Department of the Kazan University in 1969 and later became a professional opera-soloist. The premiere had a great success.

Many years are over since that time when Semen Alexandrovich Altshuler left us, but many meetings with him, conversations, and events recall to me so clear like they took place yesterday. I will be always grateful that fate brought us together with my Teacher.
9. Instead of Conclusion

Here I site some quotations from letters of well known persons addressed to S.A. Altshuler on different occasions.

“…We have always found your work a source of great stimulation. There can be no doubt that you have not only done the first work in the field of acoustic paramagnetic resonance, but your work is of the most basic type…”

Prof. M.W.P. Strandberg
MIT, Boston, USA, 1961

“Our personal contacts with you always give rise to sensation of a resonant sympathy and delicacy; it is symbolic that you discovered an acoustical paramagnetic resonance, every conversation with you retains a sharp resonant trace.”

A.S. Borovik-Romanov, I.M. Lifshits, A.F. Andreev, et al.
Institute of Physical Problems, Moscow, 1971

“I want cordially congratulate you with your election as a Corresponding member of the Academy. It makes me glad for many reasons besides, of course, recognition of your scientific deserts. It is not the last of them that our Section enriched itself by the person of really high moral properties, in which it so needs.”

E.M. Lifshits
Institute of Physical Problems, Moscow, 1976

“You are highly intellectual and harmonic person… It is very pleasant and joyful for us to note that you among your wide interests always gave a place for music, an intercourse with it became for you a vital requirement…”

Professor N.G. Zhiganov,
Rector of Conservatory, Kazan, 1981

“...I remember S.A. Altshuler very well... I have the greatest regard for him as an outstanding physicist, a pioneer in the field of ESR, and as a man highly respected by all those who had the privilege of interacting with him, which includes myself.”

Anatole Abragam
France, 2001

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Semen A. Altshuler (1979)

The dissertation is finished (1936)
Major S.A. Altshuler (1945)

With N. Bloembergen and B. Kochelaev at the Moscow University (1965)
With C.J. Gorter and C.D. Jeffries at the Conference in Kazan (1969)

With A. Kastler on Volga-river during the Conference in Kazan (1969)