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PERSONALIA

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Semen Solomonovich Gershtein (on his 80th birthday)

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Academician Semen Solomonovich Gershtein, the outstanding physicist theoretician whose work made a fundamental contribution to atomic physics, particle physics, and astrophysics, celebrated his 80th birthday on 13 July 2009.

Semen Solomonovich* was born in Harbin (Manchuria) into a family of Soviet citizens. In 1936, the family moved to the USSR. In 1937–1938, his parents were subjected to repressions but were completely rehabilitated in 1955–1956. From the age of eight, S.S. was raised by his grandmother A I Mendelevich, who worked as a medical assistant at a first-aid post of an industrial plant.

In 1946, S.S. finished secondary school with Gold Medal and enrolled in the Physics Department of Moscow State University. In 1951, he graduated from there and was sent to teach physics at a school in the village of Belousovo in Kaluga region, even though Professor A A Vlasov, who had supervised his graduation project, did everything humanly possible to have S.S. assigned to postgraduate courses or at least to some research establishment. In Belousovo he worked for three years. Despite his two-shift labor with the 40-hours-a-week load at school, S.S. managed to successfully pass all exams of the L D Landau theoretical minimum for one year add. He was the last person whom L D Landau examined personally at each exam.

With the theoretical minimum exams out of the way, L D Landau recommended S.S. to Ya B Zel'dovich, who at that time, simultaneously with his work on 'special topics at the secret workplace', was starting to think about the theory of beta-decay. Together with Ya B Zel'dovich, S.S. studied what changes in the constants of β-decay occur because the 'bare' nucleon is surrounded by a pion 'coat'. The authors did not limit their analysis only to the scalar (S) and the tensor (T) versions of β-decay, which at that moment were considered experimentally established; they also discussed the vector (V) and the axial-vector (A) versions. Using the results of Ya B Zel'dovich's earlier paper on the β-decay of the pion, which is possible only for the vector version, the authors concluded that the constant of the vector version of β-decay is not affected by the strong interaction between nucleons and pions. They were so impressed with the emerging analogy between the weak and the electromagnetic interactions that they dared to publish this result in a letter to *Zh. Eksp. Teor. Fiz.*, where they wrote: "Being of no practical significance, it is nevertheless of interest methodologically that the identity $g_{F(V)} \equiv g'_{F(V)}$ would hold in the vector (V) version of the interaction" — that is, the value of the vector constant for the Fermi interaction be equal to its value for the 'bare' nucleon."

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And further on: "...this result can be foreseen by analogy to the Ward theorem in relation to the interaction of charged particles with the electromagnetic field: in this case the virtual processes involving the particles ... do not result in renormalizing the electric charge of the particle" (*Zh. Eksp. Teor. Fiz.* **29** 698–699 (1955)). This was S.S.'s first published paper.

Three years later, after R Feynman–M Gell-Mann and R Marshak–E Sudarshan created the $(V-A)$ theory of the universal weak interaction, this conclusion gained fundamental importance. In the process, R Feynman and M Gell-Mann rediscovered the results obtained by S.S. and Ya B Zel'dovich. They started with the observation that the lifetime of the muon calculated using the constant of the vector interaction of a neutron's β-decay coincides within 2% with the experimentally established value. They called the independence of the vector constant of the weak interaction from the strong interaction between nucleons the 'hypothesis of conservation of vector current' (CVC). For this hypothesis to be true, they had to assume that there exists the process of β-decay of the pion that Ya B Zel'dovich discussed earlier on the basis of the universality of the weak interaction and the composite structure of the isotopic triplet of pions. R Feyn-

* Below S.S. is used as an abbreviated form introduced by the authors of the *Personalia*.

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man said that he and M Gell-Mann were not aware of the work by S.S. and Ya B Zel'dovich, and consequently M Gell-Mann invariably referred to it as the priority publication. The fundamental law of Nature — the Conservation of Vector Current — and the analogy between the weak and the electromagnetic interactions played an exceptionally important role in the creation of the modern picture of the microscopic world. In fact, it was the CVC that made physicists focus on the theory of Yang–Mills, who had suggested describing interactions in terms of gauge fields whose sources are the charges being conserved. This idea provided the basis not only for creating a unified theory of electroweak interactions (the CVC being one of the fundamental statements of it) but also quantum chromodynamics. The CVC law was also starting point of such a fruitful branch of the theory, just like Current Algebra.

Another widely known result obtained jointly by S.S. and Ya B Zel'dovich was the upper limit on the total mass of all stable neutrinos, which they derived from cosmological data in 1966. This upper limit tightened by several orders of magnitude the constraint on the masses of the muon-neutrino and the later-discovered tau-neutrino, which were detected in laboratory experiments, and the very possibility of such estimates stimulated the merger of cosmology and elementary particle physics that we are witnessing today.

In the spring of 1955 when P L Kapitza returned to the post of Director of the Institute for Physical Problems, L D Landau was able to enroll S.S. as his postgraduate student. Having submitted and defended his CandSc thesis in 1958, S.S. worked for two years at the Leningrad Physico-Technical Institute, where he became a close friend of V N Gribov, Yu V Petrov, and others. At the beginning of 1960 he transferred to Dubna, responding to the invitation from A A Logunov and N N Bogoliubov, and worked at the JINR Laboratory of Theoretical Physics. This transfer was to a large degree related to the Laboratory for Nuclear Problems preparing several experiments directly stemming from his research projects. S.S. continued the line of work started by Andrey D Sakharov and Ya B Zel'dovich and developed a theory of mesomolecular processes and nuclear fusion reactions of hydrogen isotopes, caused by muons. He calculated the energy levels of mesomolecules and processes of isotopic exchange, taking into account corrections to the adiabatic approximation (in first order relative to the ratio of the masses of the muon and the nuclei); he also found the principal mechanism of formation of the mesomolecules with identical nuclei. In addition, he pointed out that the deuterium mesomolecule (ddμ) has a rotational–vibrational level with low binding energy (below 7 eV) and made a proposal that the resonance formation of mesomolecules in this state could explain the considerable increase in the rate of μ-catalysis in gaseous deuterium, which was discovered in the experiments of V P Dzhelepov's group at the JINR Laboratory of Nuclear Problems (LNP). The specific mechanism of resonance formation of ddμ mesomolecules was discovered by a postgraduate student of S.S. from Estonia, E Vesman, after S.S. made him aware of the fact that the binding energy released in the formation of a $(\mathrm{dd}\mu)^+$ mesomolecule may be transferred to the excitation of vibrations in an ordinary molecule, with a mesomolecular ion $(\mathrm{dd}\mu)^+$ becoming one of its nuclei. This result initiated a search for an analogous weakly bound level in the (dtμ) mesomolecule consisting of the deuterium and tritium nuclei. This level was indeed found by a group of physicists and mathematicians led by S.S.'s student, now RAS Corresponding Member, L I Ponomarev. Using this result, S.S. and L I Ponomarev made a prediction that one muon may catalyze more than a hundred reactions of nuclear fusion in a mixture of deuterium and tritium. This stimulated much interest in μ-catalysis all over the world. Experimental studies at Dubna, at the Petersburg Institute of Nuclear Physics, and at many meson factories abroad, confirmed the predictions made. Several international conferences on μ-catalysis were organized and even a dedicated journal, *Muon Catalyzed Fusion*, was published for some time.

One of the most interesting mesoatomic processes considered by S.S. was the fast transition between energy levels of hyperfine structure of mesoatoms occurring due to muon exchange in the collision of a mesoatom with the nucleus of the same hydrogen isotope. S.S. and Ya B Zel'dovich noticed that this transition in hydrogen mesoatoms (pμ) increased by a factor of four the probability of muon capture by a proton; this appeared to be very important for experimentally testing the $(V-A)$ version of the weak interaction for muons. According to S.S.'s calculations, the rate of transition of a pμ atom to the ground state was found to be so high that the experiment could be run in a gas, eliminating the formation of (ppμ) mesomolecules, which complicates the interpretation. An experiment along these lines was carried out in 2008, 50 years after it was suggested. It was also discovered that transitions of mesoatoms to the ground state of the hyperfine structure strongly affect the probability of μ-catalysis (the Wolfenstein–Gershtein effect). The predicted effect was observed in numerous experiments and with various mixtures of isotopes. S.S. pointed out that the large cross section of the transition of a muon from hydrogen isotopes to the nuclei of other elements with charge $Z \geqslant 3$ stems from the crossing of molecular electronic terms. The same mechanism was shown to hold in atomic physics and to be significant under the plasma conditions of controlled thermonuclear fusion (CTF).

Mesomolecular processes and μ capture were the subject of S.S.'s Doctor of Science thesis; his official reviewers at the viva voce were Academicians Andrey D Sakharov and B M Pontecorvo, and A M Baldin.

In 1962, yet before neutral currents were discovered and neutrino experiments were conducted, S.S. showed in collaboration with R A Eramzhan and Nguyen Van Hieu that in the search for neutral currents in the medium range of energies it is possible to use the process of nucleus excitation in neutrino scattering events. The authors chose the interaction which for the allowed spin-changing nuclear transitions totally coincided with the result that came later with the creation of the electroweak theory. This result stimulated the work of Yu V Gaponov and I V Tyutin on calculating the cross section of the neutrino-induced disintegration of the deuteron. This process later provided the most conclusive proof of oscillations of solar neutrinos and of the validity of the Standard Model of the Sun.

In 1964, S.S. transferred to the Institute for High Energy Physics (IHEP) and took an active role in setting up the research program for the accelerator then under construction. Together with a group of experimenters, he participated in preparing a program of neutrino experiments, including experiments with photoemulsions for searching for short-lived particles. On his initiative and following his calculations, a high-intensity 46-GeV electron beam was created for the

first time ever in a proton accelerator; this energy was unreachable for electron accelerators of the time. S.S. also took part in photoscattering experiments conducted by a joint team comprising also FIAN and the Yerevan Physics Institute.

Jointly with S P Alliluev and A A Logunov, S.S. found the explanation for the mechanism of large-angle scattering of high-energy hadrons and a quark–parton interpretation of the 'Serpukhov effect' — the increase in the total cross section of hadron interactions at higher energies.

In 1968, S.S. and his disciple V N Folomeshkin considered the possibility of the existence of, and ways of searching for the third ('heavy') lepton, its lifetime, and the most probable decay channels. At the beginning of the 1980s he suggested, in collaboration with Yu D Prokoshkin and A K Likhoded, using the mechanism of gluon discoloration to explain the typical decays of glueballs and hybrids. Later on, S.S. and his students wrote a series of papers on the creation of charmed quarks in neutrino and photon beams and also predicted both the magnitude of the scattering cross section of heavy quarks by nucleons and their penetrating power. They gave one of the first explanations of the results of experiments on production of epsilon particles and pointed to a relatively high lifetime (later experimentally confirmed) of b-quarks, and predicted the mass and energy levels of the B_c-meson consisting of heavy b- and c-quarks, as well as its lifetime, characteristic decays, and creation probabilities in various processes. They also indicated the properties of baryons incorporating two heavy quarks.

Together with V S Imshennik and others, S.S. studied the role of neutrino radiation in the thermonuclear explosions of the SN1A type supernovas. He suggested an original mechanism of collective acceleration of solar cosmic rays and advanced an idea that gamma bursts are produced in specific flares of massive stars.

In recent years, S.S. has examined certain implications of the field theory of gravitation developed by A A Logunov. Particularly, in a joint paper with A A Logunov and M A Mestvirishvili, he obtained a constraint on the possible mass of the graviton from available data on the anisotropy of the microwave background, which tightened the previous upper bound by more than three orders of magnitude.

S.S. taught physics for many years: at the Leningrad Polytechnical Institute in 1958–1959 and at the Affiliate MGU Physics Department at JINR in 1961–1962, and has given general courses of lectures on theoretical physics at MFTI since 1963. Among his former students, he counts well-known scientists who remember him with gratitude. S.S. is legitimately proud of the fact that among his pupils at the village school in Belousovo four became Doctors of Sciences, and more than ten graduated from the MIFI affiliate and worked at the Institute for Physics and Power Engineering in Obninsk. S.S. is invariably and actively supportive of young capable scientists and talented people in general. He acted as initiator and of participant in a large number of new areas of research, not only in theoretical physics but also in experimental physics.

S.S. devotes much energy to popularizing science. As a member of the Editorial Board of the *Physics of the Microscopic World Encyclopedia* and consultant-editor of the *Great Soviet Encyclopedia*, he wrote about a dozen articles for these publications. At the present moment S.S. is a member of editorial boards of the journals *Priroda* (Nature), *Yadernaya Fizika* (Nuclear Physics) and *TMF*. He is also a member of the Bureau of the Physical Sciences Division of the Russian Academy of Sciences.

S.S. is a benevolent person who at the same time refuses to tolerate any tendencies toward unscrupulous or immoral behavior in science or human relations. He has never been tainted by the clannish approach to resolving controversial issues; he never tires of repeating that "a position of principle is the most correct position."

Semen Solomonovich's colleagues, disciples, and friends warmly extend their best and wish him much health and new creative achievements.

S P Alliluev, A F Andreev, S T Belyaev,
S P Denisov, V G Kadyshevsky, A K Likhoded,
A A Logunov, V A Matveev, L B Okun,
L I Ponomarev, A N Skrinsky, N E Tyurin