Moiseĭ Aleksandrovich Markov (on his seventieth birthday)

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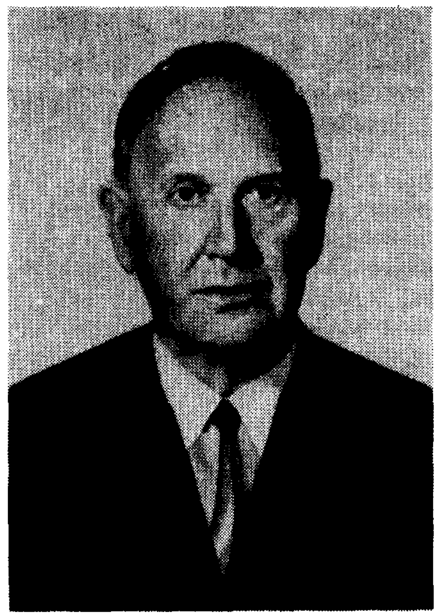
Moiseĭ Aleksandrovich Markov attained the age of 70 on 13 May 1978. Forty-five years ago in 1933 his first paper was published which became the first step along the path of his investigations of specific properties of the microworld. The subsequent forty-five years were then devoted to these investigations. In the development of his work M. A. Markov never confined himself within the framework of some one narrow direction of investigations. In different years of his scientific activity he concerned himself with problems of nonrelativistic quantum mechanics and problems of nonlocal field theory, problems of the systematics of elementary particles and with neutrino physics, classical electrodynamics and (in recent times) with gravitational theory. But with all the diversity in the subjects of investigation one aspect of the work of M. A. Markov remained unaltered: the desire to penetrate the essence of the laws governing nature and the properties of elementary particles.



MOISEĬ ALEKSANDROVICH MARKOV

The brief review of the principal papers of M. A. Markov given below has the aim to give an idea of the nature and of the results of the investigations of M. A. Markov from the very beginning of his scientific career.

The first paper of M. A. Markov[1] (1933) belongs to the then new field of quantum chemistry. It was devoted to an investigation of the quantummechanical stability of the benzene molecule.

In subsequent papers[2,3] M. A. Markov considered the generalization to the case of orbital angular momenta of the spin exchange operator $\mathscr{P}^0_{12} = (1 + \sigma_1\sigma_2)/2$ where σ_1, σ_2 are the Pauli matrices.

In the joint paper[2] with Yu. B. Rumer the form of the exchange operator for orbital angular momenta was obtained which is represented by a polynomial in terms of the scalar product of the orbital angular momenta of atoms a and b:

$$\mathscr{P}^M = \sum_n \beta_n \theta^n, \text{ where } \theta = M^a M^b.$$

Subsequently (1935) the exchange operator formalism developed in Ref. 2 was applied to the calculation of the energy levels of complex spectra.[3]

In a 1936 paper[4] M. A. Markov for the first time obtained with the aid of the well-known theorems of E. Noether all the conservation laws in Dirac's theory of the electron.

In a 1937 paper[5] M. A. Markov investigated the solutions of a second-order equation for the spinor field. He showed that the second order equation describes on an equal basis both a particle of negative charge and positive energy and a particle of positive charge and also of positive energy. Moreover, each of these particles has its antiparticle, it being noted in addition that particles of opposite charge and with positive energy cannot mutually annihilate each other.

Later (1964) M. A. Markov proposed[6] to interpret the second order equation for the lepton spinor field as an equation describing an electron and a μ meson which have the same mass prior to switching on all the interactions. Interactions can be identified which remove this degeneracy and lead to a difference in the values of the μ meson and electron masses.

The formalism being described leads to the idea of the existence of two types of "related" Dirac fields, and in particular to two types of neutrinos, etc.[7,8] In accordance with this idea either there exist no leptons other than $\mu, e; \nu_\mu, \nu_e$, or they must be subject to additional interactions (Ref. 8, p. 37). It is essential that in virtue of the doubling of the number of solutions of the second order equation compared with the usual Dirac equation any new leptons must appear in groups

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$\mu', e'; \nu'_\mu, \nu'_e$ etc., analogous to the group $\mu, e; \nu_\mu, \nu_e$.

A long series of papers of M. A. Markov beginning with a 1937 paper and right up to the most recent papers is devoted to an analysis of the well-known fundamental difficulty of field theory associated with divergences. This direction of investigations in the papers by M. A. Markov is ordinarily associated with the direction referred to in the literature by the term "theory of nonlocal fields". And yet the ideas of M. A. Markov developed by him in connection with the problem indicated above differ essentially from other ideas of this direction which, in essence, are jointly characterized by attempts to introduce into the theory objects which possess dimensions in the literal sense of this word. In contrast to this M. A. Markov from the very beginning proposes in his 1937 paper[10] to seek such a formalism which would automatically impose limitations on the very concept of the field in small regions of space and, consequently, on the possibility of measuring the field in these small regions.

This idea reached a certain stage of completion in the formalism proposed by M. A. Markov in a 1940 paper[11] (c.f., also Ref. 12).

In these papers it was proposed to impose on the field additional commutation relations of the form

$$\varphi_\mu x_\nu - x_\nu \varphi_\mu = i r_\nu \varphi_\mu, \tag{1}$$

where φ_μ is a vector field, and r_ν is a certain constant vector.

This relation leads to a limitation on the measureability of the field with the vector r_ν characterizing those distances at which the usual concepts of the measureability of fields become inapplicable.

Later the proposed formalism was developed in an original manner in the papers of Yukawa related to the theory of the so-called bilocal fields.[13,14]

In later papers both by Yukawa and by M. A. Markov variants of such theories were developed involving internal degrees of freedom of elementary particles. In particular, the description of the internal degrees of freedom was investigated in detail on the basis of the model of a four-dimensional oscillator. In this connection M. A. Markov found an additional condition which led to the removal of degeneracy of the energy levels of the four-dimensional oscillator and which, in contrast to those available in the literature, was compatible with all the basic equations of the given formalism.[15,16]

In a series of papers by M. A. Markov published in the early fifties the model of the four-dimensional oscillator was utilized in treating hyperons as excited states of nucleons.[18] Such a concept of hyperons associated with the introduction of internal degrees of freedom had its logical foundation in M. A. Markov's idea concerning a so-called "dynamically deformable formfactor" enunciated by him in those years (cf., Refs. 15–17).

The nondeformable rigid formfactors of particles usually introduced into the theory lead to a direct contradiction with the finite velocity of propagation of the signal within the region occupied by the particle. This difficulty was investigated in detail in earlier papers by M. A. Markov summarized in his doctoral dissertation[19] (1943). (cf., also Ref. 20).

But the dynamically deformable formfactors are free of the above difficulty. Basing himself on the assumption of the existence of excited states of nucleons and utilizing the ideas of Fermi and Yang on nucleon-antinucleon systems, M. A. Markov in 1955 constructed a systematics of mesons and hyperons[21] in a number of aspects anticipating the ideas of the Sakata model (1956).

In his well-known paper[22] Sakata quoting Ref. 21, wrote: "Markov proposed also a composite model which is very similar to ours".

It is of interest to note that starting with the concept of a Λ-hyperon as an excited nucleon, M. A. Markov (together with V. Stakhanov) in 1955 for the first time pointed to the possibility of β-decay of a Λ-hyperon and gave an estimate of the probability of this decay.[23]

We should also note that M. A. Markov was the first to pose the problem of the role played by the interaction between nucleons in the final state in the effect of the creation of π^0-mesons in the collision of a proton and a neutron with the formation of a deuteron (1950).[24]

In the monograph "Hyperons and K-mesons"[18] published in 1958 M. A. Markov gave a critical analysis of the data concerning elementary particles which were known in the middle fifties, and raised a number of important questions concerning their nature and properties. This monograph, the writing of which coincided with the moment of starting up of the Dubna 10 GeV synchrophasotron (1957), played an important role in developing a program of investigations using this accelerator in the preliminary work on the construction of which M. A. Markov actively participated earlier.

A significant place in the work of M. A. Markov is occupied by problems of neutrino physics. The main results of this work are summarized in his monograph[8] "The Neutrino".

In 1958 there was carried out in the Moscow State University at the suggestion and under the direction of M. A. Markov an investigation of the possibilities of an experimental study of the interaction of neutrinos with matter which found expression in two diploma theses: one by I. M. Zheleznykh "On the Interaction of High Energy Neutrinos in Cosmic Rays with Matter" (cf., Refs. 25, 26) and the other one by D. G. Fakirov "On the Possibility of Investigating the Interaction of High Energy Neutrinos with Matter using Accelerators" (cf., Refs. 18b, 25, 27).

In Ref. 26 it was concluded on the basis of estimates that had been made that an experiment on detecting cosmic neutrinos is realizable if the linear increase with energy of the cross section for the interaction of a neutrino with a nucleon would persist up to energies $E_\nu \sim 10^{11}$ eV.

At that time there existed a conviction that strong interactions (nucleon formfactors) would cut off the linear increase in the cross sections of weak interactions already at energies of the order of 1 GeV, and since the intensity of cosmic neutrinos falls off with energy, the effect would be unobservably small. Contrary to the commonly accepted opinions, M. A. Markov introduced the hypothesis[8,9] that strong interactions cut off only the elastic processes. He wrote: "It is not excluded that the large number of new channels appearing with increasing neutrino energy will introduce so significant a contribution to the total cross-section that this effect on the whole can increase linearly up to values close to critical ones" (cf., Ref. 8, p. 81; Ref. 9, p. 110).

At the CERN-JINR seminar on prospects in high energy physics (Riga, June 1967) M. A. Markov formulated an hypothesis[28] according to which the total cross sections for the interaction of leptons with hadrons as the lepton energy tends to infinity are equal to, or even exceed, the cross sections for the interaction with point hadrons. The paper recommended carrying out appropriate experiments, in particular those involving inelastic scattering of electrons by nucleons. Such experiments were carried out in 1968 at the Stanford electron linear accelerator and confirmed M. A. Markov's ideas concerning the behavior of total cross sections for the interaction between electrons and nucleons.

The set of papers by M. A. Markov indicated above initiated the carrying out of experiments on cosmic neutrinos in mineshafts in India and South Africa and served as the basis for developing the construction of a deep underground neutrino station in the Caucasus.

At the same time (1960) M. A. Markov proposed the idea of utilizing large masses of water as a large scale detector of neutrino interactions by recording the interaction event by means of the Cherenkov radiation emitted by the secondary particles.[25] Quite recently this idea was revived and became popular within the framework of the DUMAND project. But the proposals concerning the carrying out of neutrino experiments using accelerators remain little known.

In other papers of this period M. A. Markov by analyzing the different types of empirically obtained selection rules on the weak decays of elementary particles came to the conclusion that together with the neutrino ν it is necessary to introduce another neutrino $\nu' \equiv \chi$ with a different "strangeness" (cf., Ref. 18a, p. 295). In 1962 the existence of two types of neutrinos was demonstrated experimentally.

In the introduction to the monograph "The Neutrino" M. A. Markov fifteen years ago insistently emphasized the role played by neutrino processes in astrophysics: "There is reason to suppose that a number of astrophysical problems may find its solution in a further study of the laws of neutrino physics. It is not excluded that neutrino processes are of essential significance for cosmology and cosmogony. Neutrino astronomy may become a reality in not such a distant future...".

In analyzing the astrophysical manifestations of the existence of neutrinos M. A. Markov noted that if the neutrino had a proper mass different from zero, then a peculiar neutrino atmosphere should be formed surrounding massive atronomical objects.[29] At the same time formation of specific neutrino stars with masses of order of $(m_N/m_\nu)^2 M$ would be possible.[30]

Such ideas could be extended also to heavy neutrinos of new types if some of them should turn out to be stable.

Noteworthy is the set of papers by M. A. Markov which is devoted to investigating classical analogs of the formalism of quantum theory. Within the framework of Hamilton-Jacobi theory in classical electrodynamics M. A. Markov developed a perturbation theory method based on expanding the action S in powers of the electric charge[31] (1948).

The classical perturbation theory was applied to the calculation of the transverse and the longitudinal electron self-energy[31,32] in order to obtain the classical analog of the Möller formula[31] and for investigating a number of other problems.

In a 1946 paper[33] M. A. Markov analyzed the difficulties which were being discussed at that time in connection with the presence in the equation $mx - (2e^2/3c^3x = F$ of the third derivative with respect to time. In Ref. 33 it was shown that indeed the equation is derived only for positive values of the time, and in a properly carried out investigation no so-called "growing" solutions appear.

In a 1941 paper[34] M. A. Markov developed a classical analog of the well-known many-time formalism due to Dirac-Fock-Podolskiĭ. In this paper it is shown that this consistent relativistically invariant formalism for the many-body problem does not have any specifically quantummechanical aspects and can be completely carried over into classical physics.

In developing the series of his papers M. A. Markov periodically returns to the investigation of the fundamental difficulties of field theory associated with divergences. Already in his doctoral dissertation[19] M. A. Markov considered, as a possible way out of the difficulty, the idea of introducing nonlinear interactions into the theory. Specifically, he proposed to replace the interaction Lagrangian $\mathscr{L}_{\text{int}} = ie\psi\gamma_\mu\psi A$ by a Lagrangian of the form

$$\mathscr{L}_{\text{int}} = b\left[\exp\left(\frac{ie\bar{\psi}\gamma_\mu\psi A_\mu}{b}\right) - 1\right], \qquad (2)$$

where b is a certain constant.

The first term in the expansion of (2) in terms of e obviously yields the usual expression for the electrodynamic interaction Lagrangian. Nonlinear interactions subsequently became the object of investigations by many authors.

In Ref. 35 an attempt was made to alter the propagation functions in field theory by shifting their singularities from the light cone to a hyperboloid but not in the spacelike, but in a timelike direction, i.e., by replacing $x^2 - x_0^2$ by $x^2 - x_0^2 + a^2$, where a is a constant. However, such a replacement, as has been elucidated in Ref. 36 by M. A. Markov (jointly with A. A. Komar), does not prevent within the framework of the traditional scheme of field theory the appearance of signals propagated with a speed greater than the speed of light. Nevertheless propagation functions with such singularities are at present considered within the framework of quite different approaches.

It should be noted that in seeking the solution of the problem of divergences M. A. Markov already in 1947 placed great hopes in the possible role played by gravity. In Ref. 37 he wrote in 1947: "...Gravitational effects must be taken into consideration in a consistent manner and might turn out to be decisive in removing the difficulties under consideration".

A 1965 paper[38] begins a series of investigations by M. A. Markov aimed at the elucidation of the possible effect of gravitation on the properties of microscopic objects. In Ref. 38 he notes that taking gravity into account gives an upper bound to the possible masses of different elementary formations, in particular of the structural units of hadrons if the latter are considered to be very heavy. Dimensional considerations utilizing the gravitational constant $\varkappa$ led M. A. Markov to a series of limiting values of masses at a level of 10^{-5}–10^{-6} g:

$$m_e = \frac{e}{\sqrt{\varkappa}} \approx 10^{-6}\ g, \quad m_g = \frac{g}{\sqrt{\varkappa}} \approx 10^{-5}\ g, \quad m_h = \sqrt{\frac{\hbar c}{\varkappa}} \approx 10^{-5}\ g. \tag{3}$$

He gave the name "maximons" to particles of such maximally large masses[38,39,42].

Bound systems of maximons, if they could be realized, would have (in virtue of the small Bohr radius) a collossal mass defect ($\sim m_h$) and in principle could be lead to agglomerations with masses close to nucleon masses. One could for example suppose that maximums might play the role of quarks.

M. A. Markov also calls our attention[38] to the fact that if maximons are not particles of the type of quarks, i.e. if they as elementary particles exist by themselves, then even a very low density of "relict" maximons of the order of 10^{-24} particles/cm^3 could under the condition that they are stable increase the average density of our Universe up to 10^{-29}g/cm^3, i.e., in this case our Universe would be a closed Friedmann universe. In this case the interaction even of charged maximons with matter would be so weak (cf., Refs. 38, 39) that the Universe would to a significant extent consist of objects eluding observation.

In a series of papers[40,41,43] M. A. Markov analyzed the problem of the self-energy of extended sources of gravitational field considering them from the point of view of closed or semi-closed Friedmann universes. Such an investigation enables one to conclude that the total mass of an electrically neutral extended source of gravitational field vanishes as its dimensions tend toward zero (the universe becomes closed). At the same time for an electrically charged source of a gravitational field of charge q the mass is finite and is equal to $q/\varkappa^{1/2}$, its external dimensions are also finite and are equal to $q\varkappa^{1/2}/c^2$ (the universe is slightly open). Thus, taking gravitation into account the problem of the divergences of self-energy disappears in a classical investigation. To classical charged systems which as $q \to 0$ become closed Friedmann universes M. A. Markov gave the name "friedmons"[45] (1969). For an external observer friedmons appear as some elementary structures of small mass and of very small but finite dimensions (for $q = e$ the dimensions are $\sim 10^{-34}$ cm).

Moreover in the paper by M. A. Markov and V. P. Frolov[44] (1972) attention is called to the fact that in the general theory of relativity it is in principle not possible to obtain a charged point source of gravitational field, i.e., the classical (unquantized) gravitational field turns out to be nonlocal.

In another paper M. A. Markov and V. P. Frolov[43] have shown that if the friedmon charge q is considerably greater than the electron charge then the tremendous electrostatic field of the friedmons will lead to the production of electron-positron pairs the consequence of which would be the diminution of the charge and of the mass of the system.

The classical friedmon represents a classical charged black hole. Thus, in the 1970 paper[43] essentially the first indication was given of the possibility of a quantum decay of a charged black hole, i.e., of the possibility of a quantum violation of the earlier obtained Hawking theorem from which it followed that a diminution in the mass of a black hole is forbidden.

In the report given by M. A. Markov in 1973 at the Jubilee celebrations in Warsaw devoted to Copernicus[46] a graphic interpretation was given of the possibility of quantum violations of Hawking's theorem, and it was shown specifically that in such cases oppositely charged particles of the created pair appear on opposite sides of the Schwarzschild surface. Hawking's considerations concerning the quantum instability of black holes to which he came later (1974) are of a somewhat different nature and in the presence of a charge relate to holes the mass of which is $M > q/\varkappa^{1/2}$. Friedmons of mass $M = q/\varkappa^{1/2}$ diminish their mass only as a result of the process of pair creation in the Coulomb field of the charge q considered in Ref. 43.

At present M. A. Markov is continuing work on the study of the consequences for cosmology and for the theory of elementary particles arising from the quantization of the gravitational field and we wish him great successes in this activity.

We conclude the present review by some brief biographical information concerning M. A. Markov.

M. A. Markov was born in 1908 in the village of Mal'shchino in the Rasskazovskaya district of Tambov province. His father Aleksandr Rodionovich Markov was the first chairman of the village Soviet in that village. His mother's name is Mar'ya Vasil'evna Markova (Ustinova).

M. A. Markov's education began in the village church parish school and continued in 1922 in the secondary school in Moscow. After graduating from the secondary school M. A. Markov in 1926 entered the Physics Faculty of the Moscow State University. After graduating from the Moscow State University (1930) he began work at the Scientific Research Institute of Physics at the Moscow State University, while from 1934 until the present time he is a member of the P. N. Lebedev Physics Institute of the Academy of Sciences of the USSR.

In 1953 M. A. Markov was elected a corresponding member of the Academy of Sciences of the USSR, and in 1966 he was elected a Full Member of the Academy. From 1967 until now M. A. Markov has been working as an Academician-Secretary of the Nuclear Physics Division of the Academy of Sciences of the USSR.

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