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LOOKING BACK BEYOND A HALF CENTURY

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Fifty years are about to pass since the appearance of the first issue of the journal, *Eesti Teaduste Akadeemia Toimetised* (*Proceedings of the Estonian Academy of Scienc*es). Its imprint reads: Submitted for type-setting 14th November 1951, Submitted for printing 22nd April 1952. Slightly over a month later, on 31 May 1952, occurred the death of Jüri Nuut, full member of the ESSR Academy of Sciences, the man who had written the only article on physics in this opening issue and in the whole of the first volume. His paper bore the title, "On hyperbolic mechanics and problems of cosmogony", written in Russian [1]. As the month of July 2002 will see the passing of 110 years from his birth, we have now three good reasons to recall the above paper and its author, Academician Jüri Nuut [2,3].

Jüri Nuut was born on 10 July 1892, in St. Petersburg, where his parents had emigrated from the county of Pärnumaa. In autumn 1909 he commenced studies in the department of mathematics, faculty of physics and mathematics, of the University of St. Petersburg. In spring 1914 he passed the state examinations and, after submitting his diploma work, was awarded a First-Class Diploma at the end of the year. In September 1915 he was conscripted into the army, completed a crash course at the Mikhailovskoye Artillery School and was sent to the Rumanian front. In accordance with the Peace Treaty of Brest, in March 1918, he was demobilized, being then a Junior Lieutenant in rank, but in summer of the same year he joined an engineering unit of the Red Army. He fought in battles at Nizhniy Novgorod, Tsaritsyn, and Voronezh. In December 1920 he was released from the Red Army in connection with being recognized as an Estonian citizen, and he repatriated to Estonia with his family in July of the following year.

During the years 1921–28 Nuut worked as a high-school mathematics teacher in Narva and Tartu and became intensely active in the field of teaching methods in mathematics. As a natural part of this interest, he authored a series of mathematics textbooks for high schools during 1932–35. In parallel with school teaching he began to fulfil pedagogical responsibilities at the university, commencing in the 1926 spring semester. In autumn 1926 he presented to the University of Tartu his doctoral thesis, “Der lineare Raum als topologische Grundlage des Zahlbegriffs” (Linear space as topological foundation of the number concept), after the successful defence of which on 27 November 1926 he was awarded the degree of *dr. phil. nat.* Having completed a research project on the four-colour problem a year later, he presented his habilitation lecture before the faculty in March 1928 on that subject, was granted the status of Privatdozent and was then elected to the post of Docent of Mathematics of the University of Tartu on 9 May 1928.

Here Nuut lectured on the fundamentals of higher mathematics, on higher algebra, non-Euclidean geometry (in the spring semester 1930), mathematical methods etc., and eagerly participated in efforts towards reformation of school mathematics and the working out of new curricula. At the same time he developed a serious interest in the theory of relativity. In 1930 he published the first popular book in the Estonian language on this subject, *Millest kõneleb Einsteini relatiivsuse teooria* (What does Einstein’s theory of relativity speak about). In the 1932/33 academic year he taught the first full course of relativity theory at the University of Tartu, “The mathematical foundations of the theory of relativity”.

In July 1936 Nuut became Professor of Mathematics and Mechanics at the newly founded Tallinn Technical University and established there a pertinent laboratory in which the later well-known mathematicians Albert Borkvell and Gunnar Kangro also worked. During two spring semesters he continued to lecture in theoretical physics at the University of Tartu, teaching the optional courses “The Lorentz transformation” (1937) and “Mathematical foundations of atomic physics” (1938). In October 1939 Nuut was named Rector of Tallinn Technical University. At the beginning of July 1941 he evacuated to the rear of the Soviet Union, where he found employment as Mathematics Professor and Department Head in institutes of mechanization of agriculture, first in Chelyabinsk and later in Moscow.

Having returned to Estonia, Nuut worked in 1944–46 as People’s Commissar of Education and in 1946–50 as Academician-Secretary of the newly founded Academy of Sciences of the Estonian SSR. In the course of a Soviet ideological purge he was dismissed from the latter post, being accused of “bourgeois nationalism”. He spent the last two years of his life as Senior Scientific Officer in the Institute of Physics and Astronomy of the Academy of Sciences.

His interest in relativity theory led him to begin developing a new model of the expanding universe based on non-Euclidean geometry. His first papers [4,5] appeared as early as 1935 in publications of the University of Tartu and its Observatory. In *Tallinna Tehnikaülikooli Toimetised* (*Proceedings of the Tallinn Technical University*) Nuut published an extensive two-part article in 1939, "Expansionistische Dynamik" (Expansionist dynamics) [6,7], whose first part dealt with particle mechanics and the second part with foundations of wave mechanics.

During the postwar years, as Academician, Nuut published two papers [8,9] in the Records of scientific sessions of the Academy, a publication which could be viewed as the forerunner of the *Proceedings* launched in 1952. In addition to the article [1], there appeared two further papers of his during the same 1952 in publications of Tartu Observatory [10,11]. They contain material from the type-written manuscript of his capacious two-part Russian-language monograph, *Lobachevskian Geometry and Its Significance to Some Problems of Physics*. The two parts have been signed by the author on 25/3/1951 and 28/10/1951 and are preserved in the library of Tartu Observatory at Tõravere (Reg. No. 1440, 51/xx7). The contents and fate of this manuscript have been the subject of another article [12].

Based on this manuscript, the publishing department of the USSR Academy of Sciences in Moscow issued in 1961 a Russian-language monograph, *Lobachevskian Geometry in Analytic Representation* [13]. Here an *n*-dimensional geometry of Lobachevskian space was developed by analytical methods in accordance with the Cayley–Klein interpretation. The text was polished and prepared for print editorially by Professors H. Keres (Tartu) and B. A. Rosenfeld (Moscow). Nuut's remarks were supplemented by those of Rosenfeld. It was indicated in the foreword that the book was a mathematical introduction into a new theory of space and time based on the application of Lobachevskian geometry and that the creation of this theory had been the principal aim of the author for a number of years. Notwithstanding, the book devotes to this theory a brief final section only, "Lobachevskian geometry and contemporary physics".

The second part of the manuscript, "Redshift theory of the spectra of extragalactic nebulae", has not been published to this day. It amounts to 298 pages of typewritten text divided into 25 sections. Here are some section headings [12]. Sect. 12: Foundations of hyperbolic wave mechanics. Sect. 18: On the hyperbolic modification of Newton's law for the Sun-Planet system. Sect. 19: Cosmogonic considerations. Sect. 22: Quantum particle in a gravitational field.

The reason why the second part of the monograph was never put to print can only be guessed. It seems that Nuut's treatment of the universe, in which the three-space expansion was prepostulated, was essentially phenomenological and not as convincing as the cosmological models founded on general relativity. Also the relationship of the observable effects of the gravitational redshift, bending of light rays, and advancement of planetary perihelia between Nuut's theory and general relativity remained obscure.

As it appears from the article [1] which occasioned this review, Nuut took the customary kinematical Dopplerian interpretation of the spectral redshift of outer galaxies and the 1929 Hubble's law of proportionality of the redshift to the distance as the basis for his universe model. E. P. Hubble's discovery had led at once to a boom of cosmological theories of the expanding universe. The possibility of such models as solutions of Einstein's equations of general relativity had already been proved in 1922 by the St. Petersburg theoretician A. A. Friedmann, the pioneering importance of whose work, however, was not generally recognized until more than a quarter century later. In a remark contained in the monograph [[13]] Nuut referred to W. de Sitter, G. Lemaitre, A. S. Eddington and others as the creators of the expanding universe theory, but unlike the work of these predecessors, his own treatment was not founded on general relativity. His was the "principle of equivalence of all epochs", which he held to be of such importance that in its light he criticized a number of positions of the then existing theories of the expanding universe [[12]].

It is worthwhile to quote a couple of paragraphs from the article [[3]] to explain the mathematical concept of Nuut's theory. Its authors write (translation by L. Kaagjärv): 'In his final years of his working period at the University of Tartu J. Nuut arrived at an interpretation of space-time, that is, the world of events, as a four-dimensional Lobachevskian space, which made it possible to explain the phenomenon of expansion of the cosmic space. As is generally known, there are three-dimensional so-called boundary spheres within a four-dimensional Lobachevskian space which are the orthogonal surfaces to bundles of straight lines parallel in the sense of Lobachevski. The lines of the bundles are called the axes of the boundary spheres. All the spheres are congruent to one another in the sense of motions of the Lobachevskian space, and Euclidean geometry holds on each of them.

'According to the idea of J. Nuut our three-dimensional Euclidean "present" is a boundary sphere which is sinking uniformly into the "temporal abyss", that is, it changes uniformly in such a way that all its points move equal distances in equal time intervals along the axes of the boundary spheres in a direction opposite to that of the parallelism of the axes. The time between two events is then measured by a parameter which depends linearly on the distance on the axes between the boundary spheres passing through the points representing these events. Seeing that the axes of the boundary spheres, being Lobachevskian parallels, recede exponentially in the direction opposite to that of the parallelism, the incident boundary sphere expands. J. Nuut faces a big task of working out in detail the physical world picture on this expanding boundary sphere.' (A footnote in [[3]] says that use has been made here of Prof. H. Keres' notes.)

To give an idea of Nuut's physical pursuits, we recall briefly the main tenets of his article [[1]].

Events are described in three-dimensional Euclidean space in which there is a fixed rectangular Cartesian coordinate system whose origin O is permanently attached to a particle and wherein is defined a physical time scale t. The time t may be viewed as a parameter which labels the instantaneous Euclidean three-spaces. The position of an arbitrary particle P at time t is defined by coordinates x_α $(\alpha = 1, 2, 3)$. Using a dot to denote differentiation with respect to time, the proper velocity of the particle is defined by

$$v_\alpha = \dot{x}_\alpha - \sigma x_\alpha, \tag{1}$$

where σ is the Hubble constant. Thus the basis of the treatment is the moving (expanding) boundary sphere of Euclidean three-space within Lobachevskian four-space. The value of σ was taken as $1.5 \times 10^{-17}\ \mathrm{s}^{-1}$ (= 480 km/s · Mpc); according to modern data the value is $(1.7–3.3) \times 10^{-18}\ \mathrm{s}^{-1}$. It is assumed, furthermore, that the maximum value of a proper velocity is the speed of light, $c = 3 \times 10^{10}$ cm/s.

An inertial system O is taken to be the set of all the particles whose proper velocity is zero. In consequence of the expression (1) an inertial system is in a state of expansion according to the exponential law

$$x_\alpha = x_\alpha^{(0)} \mathrm{e}^{\sigma t}, \tag{2}$$

and the time t is measured everywhere in this inertial system in the same way (by a clock at the point O). Such a definition of an inertial system is justified by the consideration that the proper velocity of an arbitrary particle should not depend on the choice of origin within the inertial system. It is not clarified, however, whether the use of a common time scale within the inertial system is merely postulated or whether the clocks are actually synchronizable by some particular method.

The basis of hyperbolic mechanics is the following principle: the momentum and energy of a particle depend only on the proper velocity of the particle; they do not depend explicitly on the so-called inertial velocity σx_α. Thus the momentum is

$$p_\alpha = M v_\alpha. \tag{3}$$

There are two possible alternatives in this mechanics: (1) Newtonian version (N), in which mass does not depend on proper velocity or time, i.e. $M = m = \mathrm{const}$, and (2) Einsteinian version (E), in which

$$M = \frac{m}{\sqrt{1 - v^2/c^2}} \quad (m = \mathrm{const}, v^2 = v_\alpha v_\alpha). \tag{4}$$

For the energy of the particle the usual expressions hold: $E = \frac{1}{2} m v^2$ in version (N) and $E = Mc^2$ in version (E). In both cases

$$\dot{E} = \dot{p}_\alpha v_\alpha. \tag{5}$$

Next, so-called conservative potentials Π are defined for which, in both versions, the total energy $W = E + \Pi$ is conserved. Such, for example, is the potential which depends only on the reduced coordinates $q_\alpha = x_\alpha \mathrm{e}^{-\sigma t}$, and also the expression $\Pi = (E/c^2)\,\Phi(q_1, q_2, q_3)$ suitable for representing the gravitational potential. Proceeding from the modified law of inertia (3), it is possible to construct a theory of mechanical motion in Euclidean three-space.

In a centrally symmetric force field the law of conservation of angular momentum takes a modified form: by virtue of the inertial velocity (expansion of three-space) the moment of inertia with respect to the centre grows according to the already familiar exponential law (see (2)). It transpires in the final part of the article that this result is significant for cosmogony because, according to Nuut's mechanics, the total angular momentum of the planets should have increased by a factor of about 25 during the time of their independent existence. This circumstance, in his opinion, considerably weakens one of the major objections against the cosmogonic hypothesis of Kant–Laplace, which does not clarify why the planets of the Solar System have seized about 98% of the total angular momentum of the system, although they carry only about $\frac{1}{800}$ of its total mass.

In this mechanics the total momentum of an isolated system of particles is also conserved. In version (N), in which the centre of mass of the system is definable, this centre travels with constant proper velocity. Somewhat unexpectedly its trajectory is a ray which starts at $t = -\infty$ from the point $-a_\alpha/\sigma$. As a special case, however, the centre of mass can remain at rest.

As an application of his mechanics, Nuut considers the motion of planets in the gravitational field of a central stationary body, restricting himself to version (N). The conservation of total energy is here assured by exponential increase, in time, of the gravitational constant $G = G_0\,\mathrm{e}^{\sigma t}$. The planet's trajectory

$$\rho = \frac{P\,\mathrm{e}^{\sigma t}}{1 + \varepsilon \cos\varphi} \tag{6}$$

may be interpreted as an ellipse expanding in time while the length of the planetary year is also increasing. The value of the Hubble constant used in the paper would lead to a lengthening of the Earth's year by 1.6×10^{-2} s, Mercury's year by 9.4×10^{-4} s, and Pluto's year by 990 s. In the course of the remaining (infinitely long) future Mercury would make 8.1×10^9 revolutions, the Earth 2.0×10^9, and Pluto 7.9×10^6 revolutions. The present value of the constant would give figures up to an order of magnitude smaller for the lengthening of the year and about an order of magnitude larger for the remaining number of revolutions.

Estimates of planetary ages derived from Nuut's model lead to cosmogony. He reasons in the following way. The matter constituting a planet detached itself from the surface layer of radius r of the primordial Sun in a state of rotation with angular velocity ω at the instant $t\,(<0)$ when the equality between the centrifugal and gravitational forces was violated:

$$\omega^2 r = \mu G \mathrm{e}^{\sigma t} r, \qquad (7)$$

where μ is the mass of the Sun. Henceforth the distance r undergoes slow exponential growth to the present value of the perigee. The angular velocity ω probably begins to increase due to the decreasing size of the Sun. On the assumption that this occurs in accordance with the same exponential law (2) it is possible to estimate the ages of planets and arrive at a scheme of the genesis of the Solar System. First, about 7.7×10^9 years ago, Pluto and Neptune separated, thereafter Uranus (7.0×10^9), Saturn (5.9×10^9), Jupiter (5.0×10^9), the minor planets (4.0×10^9), Mars (3.1×10^9), Earth (2.6×10^9), Venus (2.2×10^9), and Mercury (0.89×10^9). Calculations were also made of the values of the distance r and angular velocity ω, and the stability of the Sun was estimated. It would be hard to elucidate how and to what extent these results might be altered by use of the present value of the Hubble constant and by a possible refinement of the initial hypotheses. This jubilee article is certainly not the most appropriate place in which to seek the answers.

The article by Nuut here reviewed is a child of its time. Its basic conception was formulated 60–70 years ago when the relativity boom of the 1920s had subsided and a search set in for alternatives to the general theory of relativity that could be simpler to deal with and perhaps easier to comprehend. Nuut can be rightly considered the first Estonian theoretical physicist. His theory is a typical one-man's creation which sank into oblivion when its author died. But then, half a century ago, younger Estonian theoretical physicists were finding their own research topics of more contemporary significance. Already by the end of the 1930s astrophysicist Aksel Kipper, stimulated by Ernst Öpik, delved into the problems of quantum mechanics and quantum electrodynamics. On his recommendation and that of Professor D. D. Ivanenko of Moscow, postgraduate students here began to investigate various generalizations of relativistic quantum mechanics in the hope of overcoming difficulties in the theory. First to be completed was a Candidate's thesis of Paul Kard, "Vesinikusarnane aatom kvanditud ruumis" (Hydrogen-like atom in quantized space). In 1950 Ilse Kuusik and Harry Õiglane commenced postgraduate studies in this field. Also in 1950 Kipper studied two-photon transitions in hydrogen atoms to explain the formation mechanism of continuous spectra of nebulae. In 1947 Harald Keres defended his Doctor's thesis, "Ruumi ja aja relativistlik teooria" (Relativistic theory of space and time) at the University of Tartu for the second time, after some revision, because the All-Union High Attestation Commission did not recognize the defence which had taken place there in 1942. His first postgraduate students Ruth Lias and Ivar Piir were directed to the area of quantum theory of gravitation, which was then regarded as quite topical. However, a more detailed treatment of these matters is a topic of its own.

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