THE SOURCES OF SUPERGRAVITY

Vyacheslav A. Soroka

Institute of Theoretical Physics
National Science Center
"Kharkov Institute of Physics and Technology"
310108 Kharkov, Ukraine

Abstract
Recollections on how the basic concepts and ingredients of supergravity were formulated by Dmitrij V. Volkov and the present author in 1973-74.

When I was an undergraduate student at the Kharkov State University in 1965 my advisor Dmitrij Vasilyevich Volkov gave me a task to learn and to study the problem of quantization of the spin 3/2 field interacting with other fields. There was a problem with constructing selfconsistent theories for the interacting fields with high spins and to find the methods for quantization of such theories. In particular, Johnson and Sudarshan (1961) encountered the inconsistency under quantization of the spin 3/2 field minimally interacting with the external electromagnetic field. At that time I was a starting physicist and did not know the theories with high spins. So, I had to learn two formalisms for description of the spin 3/2 field: Bargman-Wigner and Rarita-Schwinger. By the way, from the paper of Rarita and Schwinger (1941) I learned and memorized for the future a remarkable fact that a free massless spin 3/2 field in their formalism possesses a gauge invariance with a spinor parameter. I also learned Schwinger’s quantum dynamical principle within the framework of which Johnson and Sudarshan had tried to quantize the spin 3/2 field.

At that time we had no success in quantization of the spin 3/2 fields interacting with other fields. As became clear later on, the problem in that formulation had no solutions at all. But it was elucidated only after the discovery of supergravity theory in which the problem was naturally solved. So, a solution of the problem came to a deadlock and I was forced to postpone it and switched my activity to the derivation of sum rules following from the algebra of fields which had been introduced by Kroll, Lee, Weinberg and Zumino (1967). Since the algebra of fields is based on the gauge theory, I learned the beautiful Yang-Mills theory, and the papers by Utiyama (1956) and Kibble (1961) devoted to the gauge theories with different gauge groups, including, in particular, the gauge space-time symmetries connected with gravity.

*E-mail: vsoroka@kipt.kharkov.ua
Meanwhile Volkov (1969) simultaneously with Callan, Coleman, Wess and Zumino (1969) developed a general method for constructing Lagrangians for the Goldstone particles in the case of an arbitrary spontaneously broken internal symmetry group. Later he extended this method to the case of the spontaneously broken symmetries including the Poincaré group as a subgroup (1971, 1973).

Then Gol’fand and Likhtman (1971) introduced a super-Poincaré group in connection with a parity violation problem in quantum field theory. Shortly, and independently of them, Volkov formulated the existence problem for the fermionic Goldstone particles with spin 1/2. A successful solution of this problem led Volkov together with Akulov to the discovery of the extended super-Poincaré group (1972).

After that Volkov stated the idea of gauging the super-Poincaré group, and I try to realize it. I accepted the suggestion with great enthusiasm, and we started. Then my earlier experience concerning the formalisms for high spin fields and gauge theories was very suitable and useful. We decided to consider the spontaneously broken extended super-Poincaré gauge group in order to study the Higgs effect for the Goldstone particles with spin 1/2 which had been recently introduced. Under this investigation very interesting and important features were revealed [1, 2].

- First of all, the real gauge fields with spin 3/2 were introduced as graviton superpartners. This fact was very unusual for those times, because till then the gauge fields possessed only integer spins. The graviton superpartners with spin 3/2 were later called the gravitino fields.

- Secondly, the extended super-Poincaré gauge group gives a principle possibility for the nontrivial unification of gravity with the interactions based on the internal symmetries.

- Thirdly, the Higgs effect for the Goldstone particles with spin 1/2, later called the super-Higgs effect, essentially differs from the Higgs effect for the Goldstone particles with spin 0. It results in not only the gravitinos becoming massive, but also the space-time changes its own metric and topological properties: a nonzero cosmological constant appears.

We have written down our action as a sum of five invariant terms with arbitrary constants before them. These terms contain respectively: the Einstein–Cartan action for gravity, a kinetic term for the gravitino fields, a mass term of the gravitinos, a cosmological term and a term for the Yang–Mills fields with spin 1.

Thus, we see that the main notions and ingredients of supergravity were formulated in our papers [1, 2].

Soon after and independently Wess and Zumino (1974) introduced a four-dimensional superconformal group generalizing the group of two-dimensional supersymmetric transformations found earlier in the dual models by Ramond, Neveu, Schwarz, Gervais and Sakita (1971). Then Wess and Zumino proposed a supersymmetric model (1974) which appeared to be renormalizable.
The main results of our works were used afterwards as starting points for the development of supergravity in the works by Ferrara, Freedman, van Nieuwenhuizen [3] and Deser, Zumino [1]. In particular, accepted in Ref. 4 transformation rules of the vierbein, used for the graviton description, and gravitinos coincide with ours. Explicit use of nonzero torsion, found in supersymmetric theories by us [3] and Zumino [4], also essential simplified the derivation of supergravity in Ref. 4. Moreover, as Volkov explained [7], pure N = 1 supergravity [3, 4] can be deduced from our theory [1, 2] with a special choice of the constants of our invariant terms.

The notions of superspace, introduced by Akulov and Volkov (1972), and superfields, proposed by Salam and Strathdee (1974), were used by Arnowitt, Nath and Zumino in 1975 to initiate a superfield approach to supergravity. In order to overcome the drawbacks they found at their first step in this direction, we undertook, simultaneously with Zumino [6], the development of the superspace approach to supergravity. By generalizing to superspace Cartan’s methods in differential geometry, we revealed a nonzero torsion of superspace in the supersymmetric theories and found that the true homogeneous holonomy group for the superspace in supergravity is the Lorentz group. These two points are part of the basis of any version of supergravity.

Let me also mention our construction in the superfield formulation of a version of N = 1 supergravity in the linear approximation with the so-called new minimal set of auxiliary fields [8], which we had found earlier than the old minimal set that was obtained by Ferrara, van Nieuwenhuizen, Stelle and West (1978).

So, I recalled the steps in supergravity which had been performed in our works in 1973-1977.

As the complete list of papers on the theme of my reminiscence is very huge and essentially exceeds this note, I refer only to our works and to those very closely related to them. A very extensive list of references concerning the development of supergravity can be found in Ref. 9. This list contains also our papers [1, 2, 5, 8], however, the references to the latter are omitted in the text of this review.

To finish my note, I want to cite a very surprising (for me) appraisal of supersymmetry given by Yuri Abramovich Gol’fand during the Conference ”Supersymmetry-85” at the Kharkov State University in 1985. He said that supersymmetry did not justify his hopes to find a generalization of the Poincaré group such that every its representation includes particles of different masses. So, Gol’fand and Likhtman had missed their aim, but had instead found supersymmetry, every representation of which contains fields of different spins. Maybe, somebody will succeed in their original aim too, or maybe both aims at once. Time will show.

In conclusion I would like to thank the organizers of this Symposium for the opportunity to present my recollections concerning the creation of the main ideas of supergravity at its early stages, which are usually not illuminated.

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