Papers by A.S. Borovik-Romanov, M.P. Orlova, and I.E. Dzialoshinskii on weak ferromagnetism and piezomagnetism

In 1916 a weak spontaneous magnetization (a few orders of magnitude less than that of ferromagnetic iron) was discovered in a natural hematite α-Fe_2O^3 [1]. It was not until forty years later that this effect has been experimentally proven to be a thermodynamic property of the system rather than originating from impurities or other inhomogeneities of the magnetic structure [2]. The most convincing arguments have been put forward by A.S. Borovik-Romanov and M.P. Orlova (*Magnetic properties of cobalt and manganese carbonates,* Sov. Phys. JETP **4** (4), 531 (1957)), who carried out magnetization measurements in high quality polycrystals of $MnCO_3$ and $CoCO_3$, in which the value of the spontaneous moment turned out to be 1-2 orders of magnitude larger than in other systems. They suggested the weak ferromagnetic moment to result from a small canting of antiferromagnetic sublattices. This effect was explained by I.E. Dzialoshinskii, who showed that the antiferromagnetic structure formed in these crystals in the exchange approximation can be distorted due to a weak relativistic interaction, which gives rise to ferromagnetic moment. Calculations in the framework of the Landau theory have shown that the resulting moment must be much smaller than the magnetization of a typical ferromagnet (*Thermodynamics theory of weak ferromagnetism in antiferromagnetic substances,* Sov. Phys. JETP **5** (6), 1259 (1957)). Since then, the Dzyaloshinsky--Moria interaction (also named after the Japanese physicist T. Moria, who pointed out its microscopic origin [3]) plays a key role in the physics of multiferroics, spintronics, and other modern trends in magnetism.

The same theoretical approach enabled I.E. Dzialoshinskii to predict a new phenomenon, piezomagnetism. He considered symmetry conditions in an ordered magnet allowing invariants that are linear in the magnetic field and in the stress tensor components (*The problem of piezomagnetism,* Sov. Phys. JETP **6** (3), 621 (1958)). Piezomagnetism was experimentally discovered in antiferromagnets MnF_2 and CoF_2 by A.S. Borovik-Romanov. Using a special home-made torsion balance with a press, he managed to observe spontaneous magnetization of the sample under stress in theoretically predicted directions (*Piezomagnetism in the antiferromagnetic fluorides of cobalt and manganese,* Sov. Phys. JETP **11**(4), 786 (1960)). Take together, these works can be considered a remarkable example of fruitful collaboration between experimental and theoretical physicists.

[1] T.T. Smith, Phys. Rev. **8**, 721 (1916).
[2] L.M. Mataresse, J.W. Stout, Phys. Rev. **94**, 1792 (1954).
[3] T. Moriya, Phys. Rev. **120**, 91 (1960).

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