On the paper **“GLUON CONDENSATE AND LEPTON DECAYS OF VECTOR MESONS”** by A.I. Vainshtein, V.I. Zakharov and M.A. Shifman (1978)

M.A. Shifman
School of Physics and Astronomy, University of Minnesota, Minneapolis, MN 55455, USA
William I. Fine Theoretical Physics Institute, University of Minnesota, Minneapolis, MN 55455, USA

The paper [1] laid the foundation for the so-called SVZ sum ruled method (sometimes also referred to as QCD sum rules) allowing one to calculate properties of a huge variety of low-lying hadronic states basing on average characteristics of the QCD vacuum, such as quark and gluon condensates (the latter was first introduced in [1]). The main conceptual component of the method is the Wilson operator product expansion (OPE). The focus of Wilsons original work was on statistical physics, where the program is also known as the block-spin approach. Surprisingly, in high-energy physics of the early-to-mid 1970s the framework of OPE was narrowed down to perturbation theory. The authors of [1] and the subsequent publications [2] were the first to adapt the general Wilsonian construction to QCD. Their goal was to systematically include power-suppressed eﬀ ects (condensate corrections), thus bridging the gap between short and large distance dynamics.

This “bridging” did not lose its significance till this day. This route – matching between the short distance expansion and long distance (hadronic) representation – led to remarkable successes. The SVZ method was tested, and proved to be fruitful in analyzing practically every static property of all established low-lying hadronic states, both mesons and baryons. (For a review see [3].) Later, the very same OPE and the same ideas that were developed in [1, 2], was applied with triumph in heavy quark expansions blossomed in the 1990s in the framework of the heavy quark theory (reviewed in [4]).

The question we asked ourselves in 1977, which eventually led to the idea of deriving properties of matter from the vacuum condensates, was as follows (see also [5]).

What if we start from short distances, where the quark-gluon dynamics was under theoretical control, and extrapolate to larger distances using general features of QCD? What maximal information on hadronic properties could we obtain?

Surprisingly, we started getting interesting results for charmonium almost immediately. A certain success came, however, after V. Novikov, L. Okun, and M. Voloshin joined us. It turned out that a whole variety of the charmonium parameters could be (and were) predicted. A curious episode is worth mentioning. At this time, according to experiment, the only candidate for the psuedoscalar charmonim was the so-called X(2.83). Its mass seemed to be too low for this interpretation; still, with some tension it could fit potential model predictions which were widespread at that time. In [6] it was unambiguously shown from the analysis of the QCD sum rules X(2.83) could not be the psuedoscalar charmonim. The mass of the latter should have lied at 3.01±0.01 GeV. Later the experimental data regarding X(2.83) were indeed retracted. The current data give 2.983±0.0007 GeV.

For about a year, we played the game of getting cc coupling constants and masses from simple numbers. In 1977, we submitted a review report [7]. At about that time, it became clear that our success was limited; and could not be generalized to the most common light-quark mesons and baryons without new ideas. It was a hot summer, just before vacation. Our big collaboration ceased to exist. We were leisurely discussing something when the first hints appeared. The conjecture was that the vacuum is actually something like a gluon medium, and all particle properties are due to the quark interaction with this medium which can be conveniently parametrized by certain quark and gluon condensates. We worked out the first implications of the gluon condensate in fall 1977. At first, we were discouraged by a wrong sign for one of the most important particles (ρ meson). Then we suddenly understood that this sign could be compensated by the four-quark condensate – a real breakthrough. The accuracy of our predictions turned out to be much higher than anyone could expect a priori. Inspired, we worked at a feverish pace for the whole academic year. When the final paper was ready (a short one had been sent to JETP Letters in the beginning [1]), it contained more than 300 typewritten pages. We could not make a preprint out of it because, according to Soviet bureaucratic rules, preprints could have no more than 40 pages or so. So, we divided it artificially into seven or eight parts, trying to do it in such a way that it would not be immediately obvious to the censor. It appeared as three papers occupying the whole issue of Nuclear Physics B.

References

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