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Interpretation of the "quantum-stabilized Skyrmion"

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We clarify our previous claims and results in light of recent comments.

In Ref. 1 we pointed out that the nonlinear σ model treated quantum mechanically admits stable and encouragingly reasonable solutions if a suitable "profile" function is used for the meson field. We specifically did not claim that this profile should be obtained as a classical solution of the Lagrangian. Recently, in Ref. 2 the authors have explicitly verified that there do not exist any classical solutions with the required boundary conditions. However, they appear to present this negative result as a criticism of our paper even though we are not claiming that there exist any such solutions and, in fact, agree with Ref. 2 on this point. This was instead perhaps the claim made implicitly in the approach of Ref. 3.

To avoid further confusion it may be helpful to very briefly summarize our motivation and results. First we stressed that the addition of the Skyrme term is a rather *ad hoc* device; there are many other terms which could accomplish the same purpose. Finding the correct term, or combination of such terms, from experimental data on meson interactions is a rather formidable job. Hence, we suggested that this procedure might be short circuited by simply using the collective description of the nucleon (including an additional "breathing" degree of freedom to let the soliton "choose its own radius") with a phenomenologically reasonable profile. The *ad hoc* input is then shifted to the profile choice. With the choice of a simple exponential there are no arbitrary parameters and one finds noticeably better numerical results than in the standard approach. In addition the radial nucleon and Δ recurrences are predicted in reasonable agreement with experiment.

In our approach one might, for example, determine the profile by fitting the isoscalar nucleon electric form factor to experiment. This will not be very different from the exponential form used. One might also attempt to use some theoretical ideas for this purpose. We already showed (see Sec. V of Ref. 1) that attempting to minimize the ground-state energy by adjusting the shape of the scaled profile leads to a collapse analogous to that expected from Derrick's theorem.[4] The problem was seen to be related to an undesired long-range tail. We therefore proposed that one should restrict the class of profiles under consideration to short-range ones. It seems rather intriguing that this approach suggests a feature reminiscent of the QCD ingredient of confinement. It is also conceivable that full quantum-mechanical treatment of the model *field theory* could lead to a satisfactory profile. To see this, note that the shape of the profile is of course specified by an infinite number of parameters. If one completely fixes the profile and only introduces the collective "angular" variables there is no question of collapse. However, we went a little further and allowed the entire profile to be uniformly rescaled. At the classical level this leads to the famous "collapse to the center" analogous to the s-wave hydrogen-atom state. This problem was cured by quantizing the collective variable R. Still, as we have shown, certain choices of profile can undo this stabilization. It is conceivable that the introduction of further nonscaling quantum degrees of freedom would avoid collapse in such modes as well. In any event this is rather difficult and even *a priori* debatable since the nonlinear σ model is, like general relativity, a nonrenormalizable theory.

In fact the nonrenormalizability of both theories is only one aspect of a more far-reaching similarity between them that partly motivated our treatment of the Skyrmion. In gravity also, there are topological excitations (geons[5]) which can be quantized as fermions, but which classically collapse to a singularity. That quantum effects appear to stabilize the Skyrmion suggests that they might similarly halt geon collapse, and moreover, that it would be reasonable to try to estimate the resulting ground-state energy using a "collective coordinate" or "minisuperspace" approach.

We should mention that, after Ref. 1 was published, we learned of the work of Carlson[6] who has expressed related ideas, obtaining numbers similar to ours. Furthermore, there is a recent paper[7] which confirms our numerical results by a different method. Finally, a discussion of the results obtained using a profile which fits the experimental proton electric charge density has been given.[8]

We would like to thank Herbert Weigel for helpful discussions.

[1] P. Jain, J. Schechter, and R. Sorkin, Phys. Rev. D **39**, 998 (1989). Note the following corrections: (a) In Sec. IV the predicted value of g_A should be 0.98 rather than 0.65; (b) in the last paragraph of Sec. V, $\sin^2 F$ should be replaced by $\sin^2(F/2)$; (c) the right-hand side of (7a) should be multiplied by $\frac{4}{9}$.

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[3] J. A. Mignaco and S. Wulck, Phys. Rev. Lett. **62**, 1449 (1989); Centro Brasileiro de Pesquisas Fisicas Report No. ISSN 0029-3865, 1989 (unpublished).

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[5] R. D. Sorkin, in *Geometrical and Algebraic Aspects of Nonlinear Field Theory,* proceedings of the International Meeting, Amalfi, Italy, 1988, edited by S. DeFilippo, M. Marinaro, G. Marmo, and G. Velasi (North-Holland, Amsterdam, 1989).

[6] J. W. Carlson, Nucl. Phys. **B253**, 149 (1985); **B277**, 253 (1986).

[7] R. Bhaduri, A. Suzuki, A. Abdalla, and M. Preston, Science Univeristy of Tokyo report, 1989 (unpublished).

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