ON SKYRMION DESCRIPTIONS OF MULTINUCLEON SYSTEMS

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It is shown that descriptions of a system of $B > 1$ nucleons as a single skyrmion are unsatisfactory.

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It is now well known that non-linear σ models can be used to describe not only pions, but also systems with non-zero baryon number [1]. In particular, nucleons can be described as solitons of such models [1, 2]. When describing objects with baryon number $B > 1$ (nuclei or neutron stars) using solitons (skyrmions), one could either use one skyrmion with baryon number B, or more skyrmions with smaller baryon numbers, e.g. one for each nucleon. The first possibility was considered in Ref. [3], the second e.g. in Ref. [4].

In this note we consider the first possibility and conclude that it is untenable. We have solved numerically the equations for function $F_B(r)$ characterizing the skyrmion [5] for baryon numbers $B = 1, 2, \ldots, 10$. Each function F_B decreases monotonically from $F_B(0) = B\pi$ to zero for $r \to \infty$. It is related to the density of baryon charge by the formula [5]

$$\varrho_B(r) = -\frac{1}{2\pi^2}\frac{\sin^2 F}{r^2} B \frac{dF}{dr}. \tag{1}$$

Our first observation is that $\varrho_B(r)$ oscillates with increasing r in contrast to the well-known monotonic decrease of the baryonic charge density in nuclei. We conclude, in agreement with e.g. Ref. [6] that the soliton should have a quark-bag core. A lower bound for the radius R of this core may be obtained by assuming that for $r > R$ function $\varrho_B(r)$ decreases monotonically with increasing r. This lower bound is compared with a typical parametrization of experimentally measured nuclear radii ($r_B = 1.12\,B^{1/3}$) in Fig. 1. It is seen that the size of the core grows too fast and finally the core becomes bigger than the nucleus, which does not make sense. Our values of R are collected in Table I.

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TABLE I

Lower bounds for radii of quark-bag cores and constants C for skyrmions with baryon number B

B	1	2	3	4	5	6	7	8	9	10
R [fm]	0	0.5	0.8	1.1	1.4	1.6	1.9	2.1	2.3	2.6
C	8.64	25.84	51.7	86.9	130.6	183.6	245	316	395	484

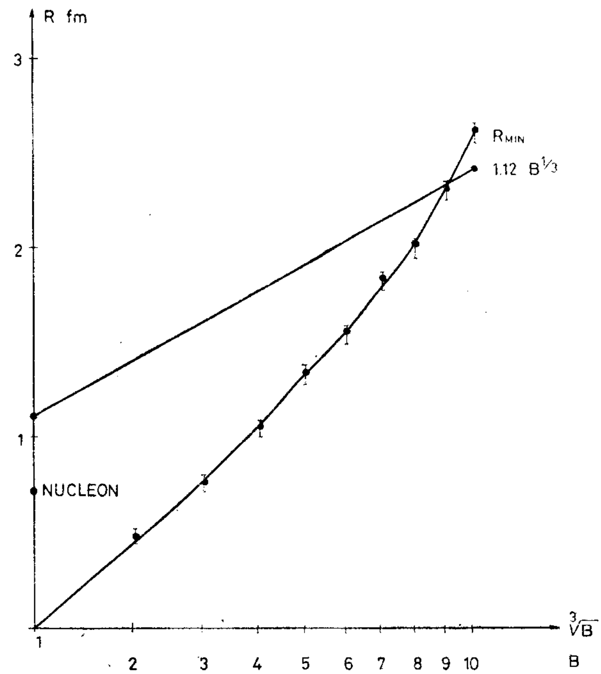

Fig. 1. Comparison of bag radii with nuclear radii

Asymptotically for large r, solutions have the form C_B/r^2 [5]. The constant C_B is proportional to both the axial vector coupling constant g_A and to the strong π-nucleus coupling constant $g_{\pi BB}$ [5]:

$$g_A = \frac{f_\pi}{2m_N} g_{\pi BB} = \frac{2\pi}{3} f_\pi^2 C_B. \tag{2}$$

Here f_π is the pion decay constant (experimentally $f_\pi = 186$ MeV) and m_N is the nucleon mass. Our values of C are collected in Table I. It is seen that they increase with B very rapidly — almost like B^2. This is another unrealistic feature of the model.

We conclude that the variant of the Skyrme-Witten model, where multinucleon systems are described as single skyrmions, is unacceptable.

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