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AN OVERVIEW ON EFFECTIVE LAGRANGIANS AND SKYRME SOLITONS

by
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Abstract

Effective Lagrangeans containing mesonic degrees of freedom only are discussed.

QCD is believed to be the underlying theory of strong interactions. However, for processes of interest in nuclear physics or in low energy hadron physics in general, it is very difficult to deal directly with QCD since non perturbative methods are indispensable. One is then led to modelling non-perturbative QCD. For example, in bag models, non perturbative effects are simulated by the pressure on the bag, in string models they are described by the tension, etc... All these models make explicit use of the quark degrees of freedom.

Since the fundamental constituents in QCD, quarks and gluons, are confined it might be more convenient to eliminate their degrees of freedom not directly observable and incorporate their effects into an effective theory framed in terms of observable hadronic degrees of freedom but including as many relevant properties of QCD as possible.

This alternative is given support by the important result of Witten[1)] that, in the large N_c limit, N_c being the number of colors, QCD is equivalent to a theory of weakly coupled MESONS (and glueballs). BARYONS emerge in the theory as SOLITONS. The Skyrme model[2)] proposed twenty years earlier, falls precisely in this class of effective theories.

The Skyrme model has been extensively studied in many low energy hadron processes such as the baryon static properties[3], the pion-nucleon scattering[4], the baryon-baryon interaction[5]. The results obtained are in good qualitative agreement with experiment. There are, however, a few noticeable exceptions like the smallness of the axial coupling constant g_A or the lack of medium-range attraction in the nucleon-nucleon potential, this attraction which is responsible for binding nucleons in nuclei.

The afore mentioned studies can be regarded as part of a more general program attempting to deduce baryon physics from meson physics via solitons[6]. In this context the Skyrme model, taken as an effective Lagrangian is probably too crude for a simultaneous good fit to the meson physics and the baryon physics. It contains only the pion field.

The next improvement consists of implementing the known phenomenological features of meson physics at energies below about 1 GeV. In particular, one must incorporate the observed low mass mesons which, on the other hand, are known to couple into baryons. Following this viewpoint, Lacombe et al.[7] have constructed an effective Lagrangian from the non linear σ model along with the low lying mesons, namely, isovector vector mesons (the ρ and its chiral partner A_1), a chiral singlet vector meson (the ω), and a chiral singlet scalar meson (the ϵ which is responsible for the enhancement at around 1 GeV of the $\pi\pi$ S wave). The Wess-Zumino anomalies are fully taken into account.

In the meson sector, this Lagrangian describes the low energy dynamics of pions and the other mesons. When the U field acquires the soliton configuration, and is identified as a baryon, it also accounts for the coupling of these mesons with baryons.

The parameters of the model are determined by theoretical constraints as well as experimental observables in the meson sector. Other observables in the meson sector are then predicted in agreement with experiment. The soliton solutions of this Lagrangian are found. These are used to predict static properties of baryons. The results obtained compare well with experimental data except for the soliton mass which comes out too high. In any case, the improvement over the original Skyrme model is quite significant.

It must be stressed that the good description of baryons provided by the above Lagrangian has been obtained with very little freedom in its form and in the choice of the parameter values and the results give strong support to the idea that one can predict the low energy physics of baryons to a good approximation from an effective Lagrangian constructed with meson fields alone. The better is the description of the meson sector the better are the predictions in the baryon sector.

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References

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