STRANGE DIBARYONS IN THE SKYRME MODEL

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The phenomenological consequences of the existence of different local minima in the SU(3) configuration space of B=2 skyrmions are discussed.

1. Since the prediction of the existence of $H$-dibaryon in the framework of MIT quark-bag model and confirmation of this prediction also in the framework of Skyrme model many efforts have been done to study theoretical predictions for the spectrum of baryonic systems within different approaches. The chiral soliton approach is of special interest because it provides unconventional point of view at the baryonic systems and/or nuclear fragments. Bound states of chiral solitons or skyrmions appear as objects where the baryons individuality is lost and can be reconstructed when quantum effects are taken into account.

Till now three different types of dibaryons have been established within the chiral soliton approach. Historically the first one was obtained as $SO(3)$ soliton. The state with the lowest possible winding number is $B = 2$ hedgehog being interpreted as $H$-dibaryon, the state with the azimuthal winding $n = 2$ has $B = 4$ and the torus-like form of mass and $B$-number distributions. It is bound relative to the decay into two $B = 2$ hedgehogs. Recently the bound state of two $H$-dibaryons was obtained also within the framework of quark-cluster model (T.Sakai, the talk at this Workshop). As it was shown in the $H$-particle can be unbound when Casimir energies (CE) of solitons are taken into account.

It should be noted that within the framework of the chiral soliton models the $H$-particle is a rather small object, $\sqrt{R_H^2} \sim 0.5 - 0.6 Fm$, see also. So, it can be considerably smaller than the deuteron, and this may be the reason why the $H$-particle was not observed experimentally up till now: in theoretical estimates of the cross sections it was assumed often that the

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$H$-particle is an extended object, similar to the deuteron.

2. The second type of dibaryons is obtained by means of quantization of bound $SU(2)$-solitons in $SU(3)$ collective coordinates space $^{3-5,8}$. The bound state of skyrmions with $B=2$ possesses generalized axial symmetry and torus-like distributions of the mass and $B$-number densities. Now it is checked in several variants of chiral soliton models and also in the chiral quark-meson model. Therefore, the existence of $B=2$ torus-like bound skyrmion seems to be firmly established.

After the zero-modes quantization procedure the $SU(3)$ multiplets of dibaryons appear with the ratio of strangeness to baryon number $S/B$ down to $-3$. The possible $SU(3)$ multiplets which could consist of minimal number of valence quarks are antidecuplet, $27-$, $35-$ and $28-$plets. The contribution to the energy from rotations into "strange" direction is the same for all minimal irreps satisfying the relation $\frac{p+2q}{3} = B$, due to cancellation of second order Casimir operators of $SU(3)$ and $SU(2)$ groups $^8$. All these states are bound when contributions linear in $N_c$, the classical mass, and of the order $N_c^{-1}$, the zero-modes quantum corrections, are taken into account. However, after renormalization of masses which is necessary to take into account also the $CE$ of the torus (of the order $N^0_c$) and to produce the nucleon-nucleon $^1S_0$-scattering state on the right place all states with strangeness different from zero are above thresholds for the strong decays $^8$. Therefore, it will be very difficult, if possible, to observe such states experimentally. Another, quite realistic, possibility is that these states represent virtual bound states in $\Lambda N$, $\Lambda \Sigma$, etc. systems, similar to the $^1S_0$ $NN$ -scattering state. In $\Lambda N$ system the virtual state has been seen many years ago in reactions $pp \to \Lambda pK^+$, $^9$, see also the talk by Y.Fujiwara at the present Workshop.

3. The third type of states is obtained by means of quantization of strange skyrmion molecules found recently $^{10}$. To obtain the strange skyrmion molecule we used the ansatz of the type

$$U = U(u, s)U(u, d)U(d, s)$$

where $U(u, s)$ and $U(d, s)$ describe solitons located in $(u, s)$ and $(d, s)$ $SU(2)$
subgroups of $SU(3)$, one of $SU(2)$-matrices, e.g. $U(u, d)$ depends on two parameters:

$$U(u, d) = \exp(ia\lambda_2) \exp(ib\lambda_3)$$

and thus describes the relative local orientation of these solitons in usual isospace. The configuration considered depends totally on 8 independent functions of 3 variables.

To get the $B = 2$ molecule we started from two $B = 1$ skyrmions in the optimal attractive orientation at relative distance between topological centers close to the optimal one, a bit smaller. Special algorithm for minimization of the energy functionals depending on 8 functions was developed and used. After minimization we obtained the configuration of molecular type with the binding energy about half of that of the torus, i.e. about $\sim 70\ Mev$ for parameters of the model $F_\pi = 186\ Mev$ and $e = 4.12$. The attraction between unit skyrmions which led to the formation of torus-like configuration when they were located in the same $SU(2)$ subgroup of $SU(3)$ is not sufficient for this when solitons are located in different subgroups of $SU(3)$. It is connected with the fact that solitons located in different $SU(2)$ subgroups interact through only one common degree of freedom, instead of 3 degrees, as in the first case.

4. The quantization of zero modes of strange skyrmion molecules cannot be done using the standard procedure, its substantial modification is necessary. As a result, the quantization condition established first in is changed, and for strange skyrmion molecule we obtained

$$Y_{R \min} = -1$$

instead of $Y_R = B$, (we put here the number of colors of underlying QCD $N_c = 3$).

The lowest multiplets obtained by means of quantization of strange skyrmion molecule are octet, decuplet and antidecuplet. Within the octet the states with strangeness $S = -1, -2$ and $-3$ are predicted. They are coupled correspondingly to $\Lambda N$, $\Sigma N$, $\Lambda\Lambda - \Xi N$ or $\Lambda\Sigma$ and $\Lambda \Xi - \Sigma \Xi$ channels.

The mass splittings within multiplets considered are defined, as usually, by chiral and flavor symmetry breaking mass terms in the effective la-
Their contribution to the masses of the states in the case of strange skyrmion molecules equals to

\[ \delta M = -\frac{1}{4}(F_K^2 m_K^2 - F_\pi^2 m_\pi^2)(v_1 + v_2 - 2v_3) < \frac{1}{2} \sin^2 \nu > \quad (4) \]

\( v_1, v_2 \) and \( v_3 \) are real parts of diagonal matrix elements of unitary matrix \( U \), the function \( \nu \) parametrizes as usually the \( \lambda_4 \) rotation in the collective coordinates quantization procedure and the average over the wave function of the state should be taken for \( \sin^2 \nu \). For two interacting undeformed hedgehogs at large relative distances \( v_1 + v_2 - 2v_3 \to 2(1 - \cos F) \) where \( F \) is the profile function of the hedgehog. Note, that the sign in (4) is opposite to the sign of analogous term when \( (u, d) \) \( SU(2) \) soliton is quantized with \( SU(3) \) collective coordinates.

The result of calculation depends to some degree on the way of calculation. We can start with the soliton calculated for all meson masses equal to the pion mass (flavor symmetric, \( FS \)-case), and in this case the central values of masses are \( \sim 4.3, 4.6 \) and \( 4.8 \) Gev for the octet, decuplet and antidecuplet, the mass splittings are within \( 130 - 170 \) Mev. This should be compared with the central values of masses of the octet and decuplet of baryons within the same approach, \( 2.64 \) and \( 3.05 \) Gev. Another possibility is to start with the soliton with the kaon mass being included into lagrangian (flavor symmetry broken, \( FSB \)-case). The static energy of solitons are greater in the \( FSB \) case, the moments of inertia are smaller, and the mass splittings within the \( SU(3) \) multiplets are squeezed by a factor about \( \sim 2.7 \) in comparison with the \( FS \)-case. The central values of masses in \( FSB \) case are about \( 4.33, 4.9 \) and \( 5.4 \) Gev. The results of both ways of calculation are close to each other for the octet of dibaryons, the difference increases for decuplet and is large for antidecuplet. By this reason the method of calculation should be found where results do not depend on the starting configuration. It can be, probably, some kind of "slow rotator" approximation used previously in \( 13, 86 \).

The inclusion of the configuration mixing into consideration \( 14 \) usually increases the mass splittings within multiplets, although it does not change the results crucially.
5. The main uncertainty in the masses of all predicted states comes from the poor known Casimir energies (CE) of states - the loop corrections of the order of $N_c^0$ to the classical masses of solitons. The CE was estimated for the $B = 1$ hedgehog $^{15}$ and also for $B = 2$ $SO(3)$ hedgehog $^7$. For $B = 1$ case it has right sign and order of magnitude, about $(-1 - 1.5)$ Gev. For the torus-like states $^3$ the CE was not estimated yet.

The skyrmion molecules found in $^{10}$ should have the lowest uncertainty in Casimir energies relative to the $B = 1$ states since in the molecule unit skyrmions are only slightly deformed in comparison with starting unperturbed configurations. Therefore, one can hope that the property of binding of dibaryons belonging to the lowest multiplets, octet and decuplet, will not disappear after inclusion of Casimir energy.

The prediction of the existence of multiplets of strange dibaryons (also tribaryons, etc.), some of them being bound relative to strong interaction, remains a challenging property of the chiral soliton approach. This prediction is on the same level as the existence of strange hyperons in the $B = 1$ sector of the model because, within the chiral soliton approach, skyrmions with different values of $B$ are considered on equal footing. However, further theoretical studies and comparison with predictions of other models (see, e.g. $^{16}$) is of interest.

Probably, we are standing now before the gate into "strange" world, the world of strange nuclear fragments, strangelets, etc. But this gate can be much more narrow than it was believed up till now. The realization of the Japan Hadron Project could help much to find and to open this gate.

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