Speculation on a new physics

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I suggest in this short article that a new theory beyond the standard model is necessary for the multiquark system.

Twenty-one years ago, collaborating with Arita and Mori, I put forward a new theory in which two conjectures for the multiquark system were presented.[1] The first is the jj-coupling scheme. That is, the structures of multiquark systems are well described by the jj-coupling scheme. The second is the polarization of quanta. This means that any plus and minus quanta in a multiquark system gather to the plus and minus poles, respectively, and finally the system splits into two hadrons with high quantum number.

It is very interesting that the implications of these two conjectures, especially of the latter, seem inconsistent with the standard model. Therefore, if they are right, a new physics is required for the multiquark systems. Let us begin with the first conjecture. Konno and I developed this conjecture and presented a model, the diquark cluster model (DCM), in 1982.[2] In this model, a very simple mass formula is derived from the jj-coupling scheme as in the nuclear shell model. Until now, many experimental data which seem to support DCM mass formula have been reported not only for dibaryon (six quark system) but also for exotic meson (four quark system). Here I summarize them.

Both of the broad dibaryons [3] and narrow ones [4] were analyzed using the formulas of mass and width based upon DCM. The excellent agreement between the calculated results and data [5,6] was obtained for both of them. I emphasize that the DCM mass formula predicts a very narrow state $I(J^P) = 0(0^-)$ with mass 2070 MeV, which can be naturally assigned to the narrow dibaryon resonance of the same quantum numbers with mass 2060 MeV recently found by Bilger et al.[7].

In DCM, the exotic mesons with mass 1300-2100 MeV can be the candidate of four quark state. In ref.[8], our group calculated the mass spectrum and the widths of the four quark states which consist of u and d quarks and compared them with the experimental data of $f_0, f_2, \eta, \rho, \omega$ and $\hat{\rho}$-families. In any case, the DCM prediction for mass spectrum was quite consistent with data. Especially, inf_2, η and $\hat{\rho}$-families, the agreement was excellent. In this conference, one (H.Noya) of our group reported the comparison between the data of h_1, f_1 and a_1-families and the DCM predictions. Again, the agreement was excellent, though more precise data may be necessary to confirm the validity of the model. He also showed that the puzzle with respect to the anomalous mass spectrum of narrow $\pi - \pi$ resonance at around 2050 MeV [9] is solved very naturally by the use of DCM. I emphasize that DCM predicts the existence of many narrow four quark states [8] and

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their mass spectrum is quite consistent with the data by Chiba et al.[10] obtained by antiproton annihilation experiments at KEK. Besides their data, the former data for the mass spectra of baryonium and high energy narrow exotic meson ($>$ 2000MeV) agree quite well with the predictions of DCM mass formula for the $q^k\bar{q}^k$ systems ($k \geq 3$).[11]

Now, I discuss the problem of the jj-coupling scheme in multiquark system. In the jj-coupling scheme, it is assumed that each constituent particle moves around a fixed center independently. Consequently, the center of mass of the system moves around the center, too. This is, of course, an unreal picture. However, as well-known in the nuclear shell model, the structure of system is well described by this picture, when the number of the constituent particles is sufficiently large. In other words, the jj-coupling scheme can be a good approximation, provided that the system is heavy enough as compared with the mass of single constituent particle. Evidently, this necessary condition is not satisfied in the extremely small systems such as four and six quark systems. Nevertheless, why do the predictions by DCM mass formula, which is based on the jj-coupling scheme, agree with the experiments excellently in four and six quark systems? It seems very difficult to solve this hard puzzle within the framework of the standard model. Then, I think that a new theory beyond the standard model is necessary.

The unbelievably good agreement between the predictions of DCM mass formula and various experiments indicates strongly that the fixed center should exist really in some sense. The main purpose of the new theory must be to unmask this magical fixed center. Another problem in DCM is that both of the two quark state (meson) and three quark state (baryon) seem to be out of the applicable region of DCM. It is known that the structures of these states are well described by the standard model, in which of course no fixed center is assumed. This fact suggests strongly the existence of two kinds of hadrons. I think that meson $q\bar{q}$, baryon qqq, glue-ball gg and hybrid $q\bar{q}g$ belong to one kind (first kind) and the multiquark states with $n_T \geq 4$ belong to another kind (second kind), where n_T(total quark number) is the sum of the numbers of quarks and antiquarks in the system. Why do two kinds of hadrons exist? The new theory must be able to answer this question.

The point of the second conjecture, the polarization of quanta, is that the production of a large hadron with high quantum number is possible, if this mechanism exists. Originally, this mechanism was introduced to solve the problem of *Centauro* which had been found in cosmic-ray events. [12] I considered Centauro to stand for the production and decay of the above-mentioned large hadron with high baryon number and/or high strangeness. Unfortunately, there is no evidence for this conjecture by accelerator yet. Then, the test of this mechanism is a problem in future. However, it may be very interesting to note that this mechanism is closely related with a problem of universe, the formation of matter in the beginning of universe. Usual answer for this problem is based on the grand unified theory. In the beginning of universe, quarks were produced a little more than antiquarks and finally quarks remained, forming world of matter. In this scenario, the world of antimatter does not exist. But, if in the beginning of universe the polarization of baryon number occurred as our conjecture implies, an alternative answer is possible. That is, the separation of the world of matter and the world of antimatter may occur. In this alternative scenario, the world of antimatter exists at present somewhere in the universe, and then one can expect that the anticarbon, which comes from the world of antimatter, will be found in cosmic ray.

In conclusion, I think a new physics is necessary for multiquark system. This new physics must satisfy the following two conditions.

1) The cause of the incomprehensible fixed center should be found.

2) The mechanism of the polarization must be clarified, if anticarbon is found in cosmic ray.

Finally, I enumerate the future experiments and the machines, to which the new physics will be relevant, with brief comments.

The first is Japan Hadron Facility (JHF), which involves 50 GeV proton synchrotron. I emphasize that this machine can be used for the further test of DCM. [13] The second is Alpha Magnetic Spectrometer (AMS). The search for the anticarbon in cosmic ray is possible by this setup. And the third is a large electron-positron linear collider in TeV region. With this machine, the observation of various polarization phenomena is possible.

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