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The molecular picture for the heavy quark mesons Yan-Rui Liu[1]

[1]Institute of High Energy Physics, P.O. Box 918-4, Beijing 100049, China

The quark model proved successful in classifying hadronic states. However, the search for states deviating from this model has not been stopped. Such states include multiquarks, hybrids and glueballs which are allowed in QCD. Recently, the observation of new heavy quark mesons with strange properties provides us new chances to look for exotic hadrons. Most of the observed hadrons are near-threshold states.

In interpreting the properties, there are various proposals such as molecular states or multiquarks, hybrids, threshold effects, cusps, dynamically generated resonances, and a mixing of $q\bar{q}$ with other components. For near-threshold mesons, the molecular picture caused great interests.

The most intriguing state $X(3872)$ is close to the thresholds of $D^0\bar{D}^{*0}$, $D^+D^{*-}$, $\rho J/\psi$ and $\omega J/\psi$. Some properties may be understood with the widely used molecule assumption. But the ratios for the branching fractions indicate a purely molecular picture is problematic. We preliminarily studied the bound state problem of $D^0\bar{D}^{*0}$ with two different meson-exchange models and calculated the binding energy. We found the naive S-wave $D^0\bar{D}^{*0}$ molecule bound by one-pion-exchange interaction is disfavored. On the other hand, its bottom analogy ($c \to b$) is possible. The two approaches give consistent conclusions.

The first charged charmonium-like state $Z^+(4430)$ observed by Belle collaboration triggered heated discussions on its nature. It has at least four quarks and this state is obviously exotic. $Z^+(4430)$ is close to the threshold of $D^*D_1$ and $D^*D_1'$ and a natural proposal is a $D^*\bar{D}_1$ or $D^*\bar{D}_1'$ molecule. Many calculations indicate the molecular assumption is acceptable. However, the BaBar data do not provide significant evidence for the existence of $Z^+(4430)$. We performed studies whether a bound state exists in $D^*\bar{D}_1$ or $D^*\bar{D}_1'$ system with our models. We find the molecule assumption is acceptable in the model at hadron level and the system is unbound in the chiral quark model.

In order to give a feeling about the heavy quark molecule picture, we performed an extensive investigation for the bound state problem of S-wave heavy quark meson-antimeson systems. The binding energies were calculated. Our results disfavor the isospin-half molecules, disfavor the isovector $(c\bar{q}) - (\bar{c}q)$ and $(b\bar{q}) - (\bar{c}q)$ molecules but favor isoscalar $(b\bar{q}) - (\bar{b}q)$ molecules. In addition to the resonance X(3872) around $D\bar{D}^*$, probably there are other isoscalar resonances around the thresholds of $D^*\bar{D}^*$ and $D\bar{D}$ with positive parities $PC = ++$.

For the molecular problem, the effects due to tensor force, coupled channels and annihilation may be important and further study is essential.

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