Exotic dibaryons with an anti-heavy quark

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Investigation of exotic hadrons with heavy quarks (especially charm and bottom quarks) has attracted our interest. Recently, there have been many analyses for exotic heavy quarkoniums such as $X$, $Y$, and $Z$ series which are expected to have multi-quark or hadronic molecular structures. In particular, twin resonances $Z_b(10610)$ and $Z_b(10650)$ which are bottomonium states with isospin $I = 1$ are suggested as mostly of $B\bar{B}^*$ and $B^*\bar{B}^*$ molecular states. Study of exotic hadrons with heavy flavor which shows us rich structures is an interesting subject in hadron and nuclear physics. It is expected that a system with heavy quarks can obtain a strong attraction because of (i) a suppression of a kinetic term due to heavy quark mass, and (ii) existence of one pion exchange potential due to Heavy quark spin symmetry.

The Heavy quark spin symmetry manifests mass degeneracy of heavy pseudoscalar meson ($P = D$ and $B$ mesons) and heavy vector meson ($P^* = D^*$ and $B^*$). Thanks to this degeneracy, for example in a heavy meson-nucleon system, the mixing of $PN$ and $P^*N$ channels is induced, where $N$ is a nucleon. Hence, one pion exchange potential emerges between $P$ and $N$ through $PP^*\pi$ vertex.

It is known that $\pi$ exchange potential plays an important role to bind atomic nuclei. A tensor force of $\pi$ exchange potential which mixes channels with different angular momenta, i.e. $L$ and $L \pm 2$, yields a strong attraction. In a similar way, the tensor force is expected to generate a rich structure of bound as well as resonant states in not only heavy mesons systems, but also heavy meson-nucleon systems.

We investigate exotic dibaryons as $DNN$ and $BNN$ for three-body systems. Since $D$ and $B$ mesons are composed of an anti-heavy quark ($\bar{c}$ and $\bar{b}$ respectively) and a light quark ($q$), there are no $q\bar{q}$ annihilation and absorption processes. Such a mesonic nuclei system is absent in light quark sector because $KN$ interaction is not attractive, while $\bar{K}N$ one is strong attraction.

By performing variational calculation and complex scaling method, we study bound and resonant states with $J^P = 0^-$ and $1^-$, and $I = 1/2$. We employ $\pi$ exchange potential for $P^{(*)}N$, which is given by the heavy quark effective theory and the Bonn model. For $NN$ interaction, we apply the Argonne $v'_8$ potential.

As a result, we find bound states with $J^P = 0^-$ and resonances with $J^P = 1^-$. The tensor force from $PN - P^*N$ mixing plays a crucial role to yield these states.

The existence of $DNN$ and $BNN$ bound states opens new challenging fields for exotic nuclei systems with single anti-heavy quark.