1 - 8 DD* and BB* Interactions in the Bethe-salpter Equation Approach*

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The deuteron is a loosely bound state of two nucleons. It is natural to expect other bound states composed of two hadrons, that is, hadronic molecular states[1]. After the observation by the Belle Collaboration, the X(3872) was related to a loosely bound state of $D\bar{D}^*$ immediately due to the fact that its mass is near the $D\bar{D}^*$ threshold. Recently, the Belle Collaboration announced two charged bottomonium-like structures $Z_b(10610)$ and $Z_b(10650)$ near the $B\bar{B}^*$ and $B^*\bar{B}^*$ thresholds[2]. The analysis of the angular distribution indicated both $Z_b(10610)$ and $Z_b(10650)$ favor $I^G(J^P) = 1^+(1^+)$. A structure $Z_c(3900)$ close to the $D\bar{D}^*$ threshold was also observed by the BESIII collaboration in the decay of Y(4260), $Y(4260) \rightarrow \pi^+\pi^- J/\psi$[3].

In this work, the $B\bar{B}^*$ and $D\bar{D}^*$ systems are studied in a Bethe-Salpter equation approach with quasipotential potential approximation by adopting the covariant spectator theory which is suitable to study a system with different constituents as shown in Fig. 1. In our calculation, both the direct and cross diagrams are considered in the one-boson-exchange potential so that the π exchange which was found more important in the $B\bar{B}^*$ and $D\bar{D}^*$ interactions[4] is included. Partial wave expansion is used to reduce the Bethe-Salpter equation to a one-dimension equation, which is solved by a recursion method. The numerical results indicate the existence of a isoscalar bound state $D\bar{D}^*$ with $J^{PC} = 1^{++}$, which may be related to the X(3872). In the isovector sector, no bound state is produced from both the $D\bar{D}^*$ and $B\bar{B}^*$ interactions, which disfavors the molecular state explanations for $Z_b(10610)$ and $Z_c(3900)$.

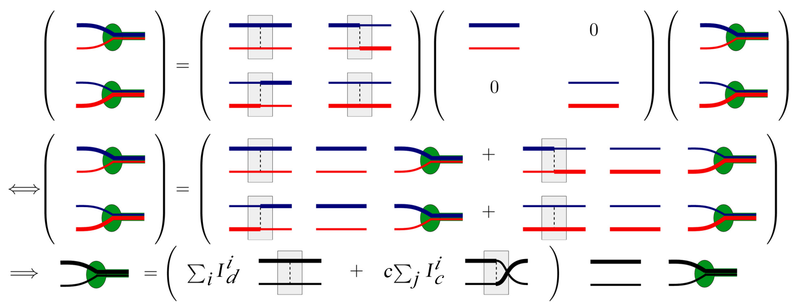

Fig. 1 (color online) The BS equation for $|Z^{(T)\,+}_{P\bar{P}^*}\rangle$. The thick and shin lines are for pseudoscalar and vector mesons, respectively. The red and blue lines are for charged and neutral mesons, respectively. The black lines are for the diagram after isolating the flavor factors to I^i. In the last line the $SU(2)$ symmetry is applied.

It is found in our calculation that for the cross diagram, the Bethe-Salpter equation can not be transformed to the Schrödinger equation with potential in coordinate space $V(\boldsymbol{r})$. This problem appears in all the systems composed of two constituents with different masses and /or spins which can convert to each other, such as the K exchange potential between s quark and u/d quark in the constituent quark model and NN^* interaction where a potential in coordinate space is used. The results obtained in this work show there does not exist isovector $B\bar{B}^*/D\bar{D}^*$ bound state, which is more consistent with the experiment and the lattice QCD[5]. Hence, one should be cautious in the direct application of potential in coordinate space obtained by a simple Fourier transformation, which has been widely used in the studies of the hadron spectrum, hadronic molecular states and other fields[1, 4].

References

[1] N. A. Tornqvist, Phys. Rev. Lett. 67(1991)556.

[2] A. Bondar et al. , Phys. Rev. Lett. 108(2012)122001. [arXiv:1110.2251 [hep-ex]].

[3] M. Ablikim et al., Phys. Rev. Lett. 110(2013)252001. [arXiv:1303.5949 [hep-ex]].

[4] Z. F. Sun, J. He, X. Liu, Z. G. Luo, S. L. Zhu, Phys. Rev. D, 84,(2011)054002. [arXiv:1106.2968 [hep-ph]].

[5] Y. Chen, M. Gong, Y. H. Lei, et al., Phys. Rev. D, 89(2014)094506. [arXiv:1403.1318 [hep-lat]].

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