1 - 11 Hadronic Molecular States from K$\bar{\mathrm{K}}^*$ Interaction*

He Jun

After the observation of the exotic resonance structure X(3872) near the D$\bar{\mathrm{D}}^*$ threshold, more and more XYZ particles, which cannot be interpreted in the traditional quark model, are observed near the thresholds of two heavy mesons. This suggests that there maybe exist a close relation between the XYZ particles and the charmed (bottomed) meson and anticharmed (antibottomed) meson interactions. It is interesting to see whether it can be extended to the strange sector, *i e.*, whether there exist the strange partners of the XYZ particles from the K$\bar{\mathrm{K}}^*$ interaction. There already exist some proposals of the molecular state in the strange sector. Some observed mesons, such as the $\mathrm{f}_1(1285)$, were suggested to be from the K$\bar{\mathrm{K}}^*$ interaction. The $\mathrm{f}_1(1285)$ is an axial-vector state with quantum numbers of $I^G(J^{PC})=0^+(1^{++})$, a mass of $m=(1\ 281.9\pm0.5$ MeV, and a width of $\Gamma=24.2\pm1.1$ MeV [1]. In recent years, it has been suggested to be a dynamically generated state produced from the K$\bar{\mathrm{K}}^*$ interaction[2]. To study the nature of the $\mathrm{f}_1(1280)$ and other states near the K$\bar{\mathrm{K}}^*$ threshold, we should construct the K$\bar{\mathrm{K}}^*$ interaction and search the molecular state from such interaction. In the chiral unitary approach a chiral invariant hidden-gauge Lagrangian is often adopted and a Weinberg-Tomozawa (WT) term is derived to describe the interaction[2–4], which is identical to vector-meson exchange with some approximations[5]. However, in the study of the XYZ particles the original one-boson exchange (OBE) model is widely adopted to study the molecular state[6]. In the OBE model, the pion exchange is often more important than the vector-meson exchange due to small mass of pion meson. Hence, it is interesting to study the K$\bar{\mathrm{K}}^*$ interaction in the OBE model and compare it with the results obtained only with the WT term.

In Ref. [7], the molecular state from the D$\bar{\mathrm{D}}^*$ interaction, which is related to the $\mathrm{Z_c}(3900)$ observed at BESIII, was studied in the OBE model and relevant invariant mass spectrum from BESIII was also well reproduced. Both light-meson exchanges and J/ψ exchange were included in Ref. [7]. The larger mass of the J/ψ meson ensures that the J/ψ exchange potential can be reduced to a contact term by dropping out the exchange-momentum term q^2 in the dominator of the propagator[7]. It was found that though the J/ψ meson exchange is more important as suggested in the chiral unitary approach, the light-meson exchanges also provide considerable contribution. In the strange sector, the WT term is often regarded to be deduced from the vector-meson exchange[5]. However, the mass of exchanged vector mesons in the strange sector, *i.e.* ρ, ω or ϕ meson, is much lighter than the J/ψ meson, and even comparable to the mass of the pseudoscalar η meson. One may wonder whether the contribution from vector-meson exchange in the strange sector is numerically close to the contribution from the WT term as in the charmed sector. On the other hand, it is interesting to study the role of the pseudoscalar-meson exchange in the K$\bar{\mathrm{K}}^*$ interaction. In this work, we will make an explicit study of the K$\bar{\mathrm{K}}^*$ interaction in the OBE model including the pseudoscalar-meson exchange and the vector-meson exchange, and compare the results with those obtained from the WT term. It will be performed in a quasipotential Bethe-Salpeter equation approach, which is covariant and unitary.

In Table 1, we list our results for all quantum numbers with $J=0$ and 1. The results for the pseudoscalar-meson exchanges and direct vector-meson exchanges are also presented in the same table to show their importance in the K$\bar{\mathrm{K}}^*$ interaction. The results with the WT term are listed in the last two columns of Table 1. Because we do not consider other channels, the bound state with different G parities are degenerated. Generally speaking, this results consistent with those obtained in the chiral unitary approach with four poles produced from the K$\bar{\mathrm{K}}^*$ interaction[2]. However, in the isovector section, the direct vector-meson exchange is obviously smaller than the WT term. The WT term is analytically identical to the direct t-channel vector-meson exchange by dropping the q^2 and within an approximation of neglecting the three-momenta of external vectors. To find out the origin of this difference, we give the results by dropping the q^2 in the propagator of the exchanged vector meson in the eighth and ninth columns of Table 1. In the isoscalar sector, the bound state appears at a cutoff $\Lambda\sim0.8$ GeV, which is close to the result with the WT term. In the isovector sector, the cutoff is needed to produce a bound state decreased obviously to about 2.5 GeV. Hence, though the WT term are consistent with the direct vector-meson exchange qualitatively, dropping out the q^2 will exhibit its effect in some cases especially when the interaction is weak. Besides the state related to the $\mathrm{f}_1(1285)$, another molecular state can be produced with $0^-(1^{+-})$, which can be related to the $\mathrm{h}_1(1380)$. Those two states were also produced in the coupled-channel calculation in chiral unitary approach with the WT terms[2]. In the isovector sector, a bound state with $1^-(1^+)$, which can be assigned as the $\mathrm{b}_1(1235)$ as Ref.[2], can be produced

∗ Foundation item: National Basic Research Program of China (973 Program) (2014CB845405), National Natural Science Foundation of China (11275235, 11035006)

from the $K\bar{K}^*$ interaction but a lager cutoff is needed because the flavor factors for the isovector sector are much smaller than those for the isoscalar sector.

Table 1 The pole position of the $K\bar{K}^*$ interaction. The cutoff Λ and energy W are in units of GeV.

$I^G(J^{PC})$	Full		V_P^c		V^d		$V^d\|_{q^2\to 0}$		V^{WT}	
	Λ	W	Λ	W	Λ	W	Λ	W	Λ	W
$0^+(1^{++})$	0.6	1.389	1.0	1.387	1.0	1.383	0.8	1.380	0.7	1.381
	0.8	1.369	1.1	1.377	1.1	1.376	0.9	1.366	0.8	1.365
	1.0	1.326	1.2	1.359	1.2	1.368	1.0	1.343	0.9	1.336
	1.2	1.247	1.4	1.293	1.4	1.343	1.1	1.311	1.0	1.301
$0^-(1^{+-})$	0.8	1.385	1.2	1.386	1.0	1.383	0.8	1.380	0.7	1.381
	1.0	1.354	1.3	1.375	1.1	1.376	0.9	1.366	0.8	1.365
	1.1	1.318	1.4	1.337	1.2	1.368	1.0	1.343	0.9	1.336
	1.2	1.258	1.5	1.207	1.4	1.343	1.1	1.311	1.0	1.301
$1^-(1^+)$	–	–	–	–	4.6	1.388	2.5	1.379	1.4	1.381
	–	–	–	–	4.7	1.383	2.6	1.359	1.5	1.358
	–	–	–	–	4.8	1.376	2.7	1.332	1.6	1.336
	–	–	–	–	4.9	1.366	2.8	1.302	1.7	1.310
$1^+(1^+)$	1.8	1.389	2.7	1.389	4.6	1.388	2.5	1.379	1.4	1.381
	1.9	1.384	2.8	1.380	4.7	1.383	2.6	1.359	1.5	1.358
	2.0	1.372	2.9	1.343	4.8	1.376	2.7	1.332	1.6	1.336
	2.1	1.334	3.0	1.254	4.9	1.366	2.8	1.302	1.7	1.310

In this work, the $K\bar{K}^*$ interaction is studied in a quasipotential Bethe-Salpeter equation approach combined with the OBE model. With a model without a form factor for the exchange meson, a bound state is found with a reasonable cutoff with quantum number $I^G(J^{PC})=0^+(1^{++})$, which can be related to the f(1285). Another molecular bound state with $0^-(1^{+-})$ are also produced from the $K\bar{K}^*$ interaction, which can be related to the $h_1(1380)$. In the isovector sector, the interaction is much weaker and a bound state with $1^+(1^+)$ relavant to the $b_1(1235)$ is produced but at a larger cutoff. The three bound states produced from the $K\bar{K}^*$ interaction in the current work can be well related to the three bound states from the $D\bar{D}^*$ interaction in Ref. [7], which suggests that the $f_1(1285)$ and $b_1(1235)$ are the strange partners of the X(3872) and $Z_c(3900)$, respectively. The partner of the $h_1(1380)$ was also predicted in Ref. [7], but still not found in experiment.

References

[1] K. A. Olive, [Particle Data Group Collaboration], Chin. Phys. C, 38(2014)090001.

[2] L. Roca, E. Oset, J. Singh, Phys. Rev. D, 72(2005)014002.

[3] L. S. Geng, X. L. Ren, Y. Zhou, et al., Phys. Rev. D, 92(2015)014029.

[4] Y. Zhou, X. L. Ren, H. X. Chen, et al., Phys. Rev. D, 90(2014)014020.

[5] M. C. Birse, Z. Phys. A, 355(1996)231.

[6] H. X. Chen, W. Chen, X. Liu, et al., Phys. Rept., 639(2016)1.

[7] J. He, Phys. Rev. D, 92(2015)034004.