ΛN-ΣN and ΛΛ-ΞN Coupling Effects in Light Hypernuclei

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We have solved the overbinding problem in ${}^{5}_{\Lambda}$He and fitting Λ separation energies of all the s-shell Λ hypernuclei consistently by introducing coherent Λ-Σ coupling effect [1]. In the process of coherent Λ-Σ coupling, a nucleon remains in its ground state after converting Λ to Σ, giving all the other nucleons an equal chance to interact with the Σ. This coherent Λ-Σ coupling effect can be equivalently represented by three-body ΛNN force of the following form;

$$U_{\Lambda NN} = \sum_{\alpha} W_3^{\alpha}(r_{1\Lambda}, r_{\Lambda 2})[a_\alpha + b_\alpha(\vec{\sigma}_1\vec{\sigma}_2) + c_\alpha \frac{1}{2}\vec{\sigma}_\Lambda(\vec{\sigma}_1 + \vec{\sigma}_2)], \tag{1}$$

$$W_3^{ts} \equiv V^t_{\Lambda N,\Sigma N}(r_{1\Lambda})\frac{1}{\Delta M}V^s_{\Sigma N,\Lambda N}(r_{\Lambda 2}) + V^s_{\Lambda N,\Sigma N}(r_{1\Lambda})\frac{1}{\Delta M}V^t_{\Sigma N,\Lambda N}(r_{\Lambda 2}), \tag{2}$$

where $\alpha = tt, ts, ss$ with t and s stand for triplet and singlet, respectively.
We have found that in the case of single-channel YN description, the three-body ΛNN force is repulsive in isospin saturated hypernuclei and either attractive or repulsive in other hypernuclei. The effect is found to become strongly attractive in the ground states of ${}^{4}_{\Lambda}$He and ${}^{4}_{\Lambda}$H and neutron-rich Λ hypernuclei [2].
In the strangeness -2 sector, we also found a significant role of ΛΛ-ΞN coupling effects on double-Λ hypernuclei. This coupling gives about 0.5 MeV Pauli suppression in ${}^{6}_{\Lambda\Lambda}$He if we use Nijmegen soft-core 97e [3] for coupling potential. For single channel ΛΛ interaction we modified NSC97e to fit the recent experimental data on ${}^{6}_{\Lambda\Lambda}$He of the "Nagara" event [4]. The most exciting finding of our calculations is the ΛΛ-ΞN coupling effect gives extra attraction of about 1 MeV in ${}^{5}_{\Lambda\Lambda}$He and very weak suppression in ${}^{5}_{\Lambda\Lambda}$H comparing to the six-body system, due to the formation of an α particle in the intermediate Ξ hypernuclear states [5]. The ΛΛ-ΞN coupling gives ∼0.5 MeV repulsion for ${}^{6}_{\Lambda\Lambda}$He, ∼0.1 MeV repulsion for ${}^{5}_{\Lambda\Lambda}$H and ∼1.0 MeV attraction for ${}^{5}_{\Lambda\Lambda}$He. This theoretical finding will be justified when the five-body double Λ-hypernuclei are experimentally observed.

References

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