Quark-Pauli effect in the three baryon-octet systems

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The Pauli principle among the quark-constituents of baryons often brings important repulsive effects in the two-baryon system. For example, the repulsive Σ single-particle potential in nuclei [1] is considered to originate from the strong Pauli repulsion in the $\Sigma N(I = \frac{3}{2})\,{}^3S_1$ state. [2] It is interesting to study the quark Pauli effect in the three-baryon system because it is relevant to the neutron-star structure as well as the hypernuclear structure. [3]

The nine-quark three-cluster wave function for the $B_1B_2B_3$ system may be expressed as

$$\Psi_{SS_z\,II_z} = \mathcal{A}\Phi_{SS_z\,II_z} = \mathcal{A} \sum_{S'\,I'(\lambda'\mu')(\lambda\mu)} C_{S'I'(\lambda'\mu')(\lambda\mu)} \left[[\phi_1\phi_2]_{S'\,I'(\lambda'\mu')}\,\phi_3\right]_{SS_z\,II_z(\lambda\mu)} \chi(\vec{R}_{12}\,,\vec{R}_{12-3})$$

Here ϕ_i is the three-quark octet-baryon wave function, $\mathcal{A}$ the antisymmetrizer, and $C_{S'I'(\lambda'\mu')(\lambda\mu)}$ is the unitary transformation matrix from the SU(3) basis to the particle basis. The quark Pauli effect becomes strongest when the nine quarks all occupy the 0s orbit. This corresponds to choosing the 0s oscillator functions for the relative motion function $\chi(\vec{R}_{12}\,,\vec{R}_{12-3})$. The effect of the Pauli repulsion is estimated by calculating the norm

$$\mu_{SI} \;=\; \langle \Psi_{SS_z\,II_z} | \Psi_{SS_z\,II_z} \rangle,$$

which is not always unity even though $\Phi_{SS_z\,II_z}$ is normalized because of the effect of the antisymmetrization among the three baryons. $\mu = 0$ means the complete Pauli-forbidden state. The Pauli repulsion is stronger as μ gets closer to zero.

We show in Table some interesting cases with $S = \frac{1}{2}$. It turns out that the strong Pauli repulsion exists in the $NN\Sigma(I = 2)$ and $\Xi\Xi\Xi(I = \frac{1}{2})$ systems, but no strong Pauli repulsion appears in the $NN\Lambda$ systems. The Pauli repulsion is not the origin of the universal repulsion that is proposed to resolve the too soft equation of state of hyperonic neutron-star. [4]

$B_1B_2B_3$ (isospin)	NNN $\left(I = \frac{1}{2}\right)$	$NN\Lambda$ $(I = 0)$	$NN\Lambda$ $(I = 1)$	$NN\Sigma$ $(I = 2)$	$NN\Xi$ $\left(I = \frac{3}{2}\right)$	$\Xi\Xi\Xi$ $\left(I = \frac{1}{2}\right)$
$\mu_{S=\frac{1}{2}I}$	$\frac{100}{81}$	$\frac{25}{27}$	$\frac{25}{27}$	$\frac{4}{81}$	$\frac{10}{27}$	$\frac{4}{81}$

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