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Light Hypernuclei and the Hyperon-Nucleon Interaction

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Abstract

Light Hypernuclei are a vital testing ground for our understanding of the Hyperon-Nucleon interaction. We have performed microscopic calculations of four and five-body hypernuclei using the Nijmegen nucleon-nucleon and hyperon-nucleon interactions. Our calculations include explicit Sigma degrees of freedom. These degrees of freedom are quite important since, in contrast to the $\Delta - N$ mass difference of $\approx$ 300 MeV, the Σ resonance is only about 80 MeV above the Λ. In addition, although there is no one-pion-exchange in the ΛN diagonal channel, this longest-range term does contribute to the transition $\Lambda N - \Sigma N$ interaction.

Our variational calculations show that the A=4 spin 0 ground state binding energy is well reproduced by the Nijmegen HN interaction, a one-boson exchange model fit to the available scattering data. The spin 1 excited state and the A=5 ground state are strongly underbound, however. We demonstrate the importance of the strong tensor terms of the Nijmegen model, particularly those in the transition channel, in obtaining this result. The limited data currently available for hyperon-nucleon scattering must be greatly improved in order to place reasonable constraints on the interaction.

1. Introduction

Hypernuclei can be an important tool in furthering our understanding of QCD at low momentum scales. The strange valence quarks offer an additional probe; one that can be very important in determining whether, and at what scale, nuclei and hypernuclei can be considered systems of interacting mesons and baryons. Light Hypernuclei are particularly valuable because they offer the possibility of performing reliable calculations with 'realistic' hyperon-nucleon (HN) interactions, thus providing tests of the meson-baryon picture. Although the importance of light hypernuclei in this regard has been recognized for a long time,[1,2] progress has been severely hampered by the lack of direct experimental data on the hyperon-nucleon interaction.

Several approaches have been followed in the study of light hypernuclei. Gibson and Afnan have studied tensor and $\Lambda - \Sigma$ conversion in the hypertriton using separable potential equations.[3] Gibson and Lehman have used a similar method to study the 4-body ground and spin-flip excited states.[4] In a somewhat different vein, Usmani and Bodmer have proposed phenomenological models of the HN interaction,[5] using variational calculations to determine the properties of the HN interaction.

These models fit the scattering data below the Σ threshold, but do not include explicit Σ degrees of freedom. Therefore, in order to fit the binding energies of light hypernuclei, strong three-body Lambda-Nucleon-Nucleon (ΛNN) interactions must be included. Strong forces are expected theoretically since the Σ is only about 80 MeV above the Λ. In addition, the ΛN interaction has no one-pion-exchange term, but this long range exchange is present in the $\Lambda N - \Sigma N$ transition interaction. These strong three-body force models can provide fits to the binding energies of light hypernuclei and the 'well depth' of a Λ in nuclear matter, although they have been obtained with very simplified NN interaction models.

We have followed a somewhat different approach and include 'realistic' interactions explicit Σ degrees of freedom in our calculations. This necessarily makes the calculations somewhat more difficult, as the number of available isospin channels increases dramatically. It does have some strong conceptual advantages, however, in that results can be tied much more closely to scattering data; particularly to any data obtained near or above the ΣN threshold. Direct experimental tests of three-body interactions are very difficult to obtain, in our calculations we attempt avoid three-body forces through the introduction of Σ degrees of freedom. Of course, there are other possible contributions to a three-body HNN interaction, but these are expected to be comparatively small.

Even though the experimental data is sparse, one-boson-exchange models of the hyperon-nucleon interaction are available. Since the available data is very limited, these models makes certain rather strong assumptions, in particular the assumption of SU-3 symmetry in the meson-baryon coupling constants. In this paper, we review recent results of variational calculations with the soft-core Nijmegen hyperon-nucleon interaction,[6] and discuss the features of the interaction that are important to the structure of light hypernuclei.

2. Light Hypernuclei

Light Hypernuclei have formed the basis of many investigations into the HN interaction. In a very simple model, at least, they offer a good deal of information on the spin-dependence of the interaction. As shown in Table 1, the various nuclei contain significantly different mixtures of the spin-singlet and triplet interactions. Also given in the table are the Λ binding energies of the various states; the difference in binding between the 'core' non-strange nucleus and the hypernucleus.

Table 1. Light Hypernuclei and Λ Separation Energies

	J^π	B_Λ		S=0	S=1
$^3_\Lambda$H	1/2+	0.13	(0.05)	3/4	1/4
$^4_\Lambda$H	0+	2.04	(0.04)	1/2	1/2
$^4_\Lambda$He	0+	2.39	(0.08)	1/2	1/2
$^4_\Lambda$H	1+	1.00	(0.06)	1/6	5/6
$^4_\Lambda$He	1+	1.24	(0.06)	1/6	5/6
$^5_\Lambda$He	1/2+	3.12	(0.02)	1/4	3/4

In these calculations, we have limited ourselves to the $^4_\Lambda$H ground and excited states and the $^5_\Lambda$He ground state. As is apparent in the table, the spin-triplet part of the interaction dominates the spin 1 excitation in $^4_\Lambda$H and the $^5_\Lambda$He ground state. The triplet interaction is apparently less attractive than the spin singlet, since the spin 1 excited state is about 1 MeV higher than the spin 0 ground state of A=4. We will not address the 3-body system, as the very small binding presents some technical difficulties. We plan to address this problem in the future. Also, we will discuss charge symmetry breaking in light hypernuclei only very briefly.

Of course, in reality the picture given in the table is much too simple. In reality there are many more distinctions in the interaction than just that between spin singlet and spin triplet. For example, This simple picture completely ignores higher order tensor effects and sigma degrees of freedom (or three-body forces). Hence we consider calculations with more realistic models that include these effects.

3. Hamiltonian

For the light hypernuclei, we take a Hamiltonian of the form:

$$H = \sum_i T_i + \sum_l T_l + \sum_{i<j} V_{ij}^{NN} + \sum_{i<j<k} V_{ijk}^{NNN} + \sum_{i,l} V_{il}^{HN}, \tag{1}$$

where the sums over ij and k run over nucleons and l is the hyperon. The operator T_i is the usual non-relativistic kinetic energy for the nucleons, while T_l includes a mass-difference term in the Σ channel:

$$T_l = [\frac{-\hbar^2}{2M_\Lambda}\nabla_l^2]P^\Lambda + [M_\Sigma - M_\Lambda + \frac{-\hbar^2}{2M_\Sigma}\nabla_l^2]P^\Sigma. \tag{2}$$

We use the Nijmegen model[7] for the NN interaction; it has the general form:

$$V_{ij}^{NN} = \sum_m \frac{1}{2}\left[V^m(r_{ij})O_{ij}^m + O_{ij}^m V^m(r_{ij})\right]. \tag{3}$$

The operators O_{ij}^m may be taken as:

$$O_{ij} = \{1, \sigma_i\cdot\sigma_j, \mathrm{S}_{ij}, \mathrm{L}\cdot\mathrm{S}_{ij}, \mathrm{L}_{ij}^2, \mathrm{L}_{ij}^2\sigma_i\cdot\sigma_j, \mathrm{p}_{ij}^2, \mathrm{p}_{ij}^2\sigma_i\cdot\sigma_j\} \bigotimes \{1, \tau_i\cdot\tau_j\} \tag{4}$$

where the V^m are functions of the pair separation r_{ij} and the cross indicates any possible combination of one term in the first bracket with one in the second. In this expression S_{ij} represents the tensor operator and L_{ij} represents the relative angular momentum of the pair.

We have included the Urbana Model 7 three-nucleon interaction[8] in our calculations to provide a somewhat better fit to the ground state properties of three- and four-body nuclei. This interaction consists of a two-pion-exchange three-nucleon interaction at large distances and a short range repulsive term. While one might argue that it would be conceptually preferable to include explicit Δ degrees of freedom instead of a three-nucleon interaction, computations with such a model do not appear feasible at present due to the vast number of spin-isospin states.

The Nijmegen soft-core interaction[6] has been used for the HN interaction. This interaction may be written in the form of Eq. 3, where the operators are:

$$\begin{aligned} O_{ij} = \; & \{1, \sigma_i\cdot\sigma_j, \mathrm{S}_{ij}, \mathrm{L}\cdot\mathrm{S}_{ij}, \mathrm{L}_{ij}^2, \mathrm{L}_{ij}^2\sigma_i\cdot\sigma_j, \mathrm{p}_{ij}^2, \mathrm{p}_{ij}^2\sigma_i\cdot\sigma_j\} \bigotimes \\ & \{\Lambda N - \Lambda N, \Lambda N - \Sigma N, \Sigma N - \Sigma N(T=1/2), \Sigma N - \Sigma N(T=3/2)\} \bigotimes \{1, P^x\}, \end{aligned} \tag{5}$$

where all possibilities including one term from each bracket are allowed. Note that in addition to the spin and isospin operators, there is also a spatial permutation operator. In our current calculations we have used only the even-parity terms in the interaction. This should be a good approximation due to the dominant nature of the even-parity components in s-shell hypernuclei. We plan to investigate the importance of the odd-parity components in the future.

The central and tensor terms in the Nijmegen interaction are shown in Figure 1. Much of the attraction in the spin singlet channel comes from the central term, the (attractive) transition terms are relatively weak. In contrast, though, the central terms in the spin triplet interaction contribute almost no attraction. Whatever attraction is present arises through the couplings to the ΣN channel, in particular through the tensor couplings. Note that the diagonal tensor interaction is relatively weak in the ΛN channel, but the tensor interaction in the ΛN - ΣN transition and the ΣN diagonal channels is quite strong and includes terms with the range of one-pion-exchange.

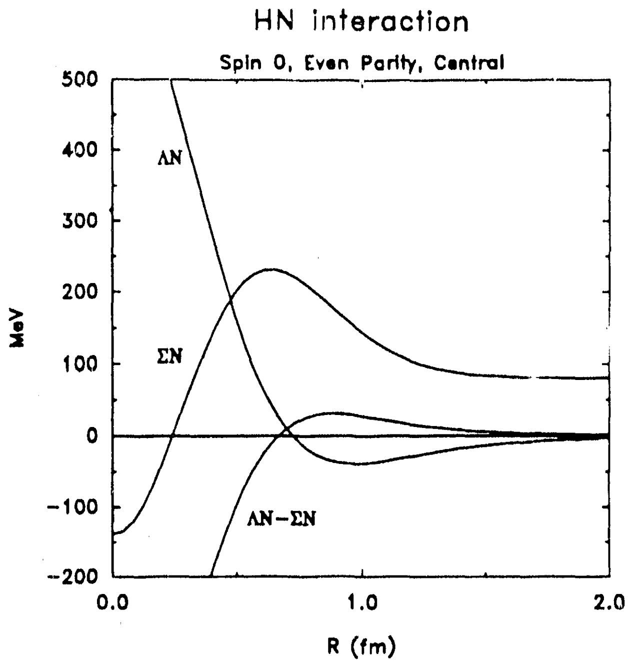

Figure 1a) Spin 0 central terms in the Nijmegen soft core interaction.

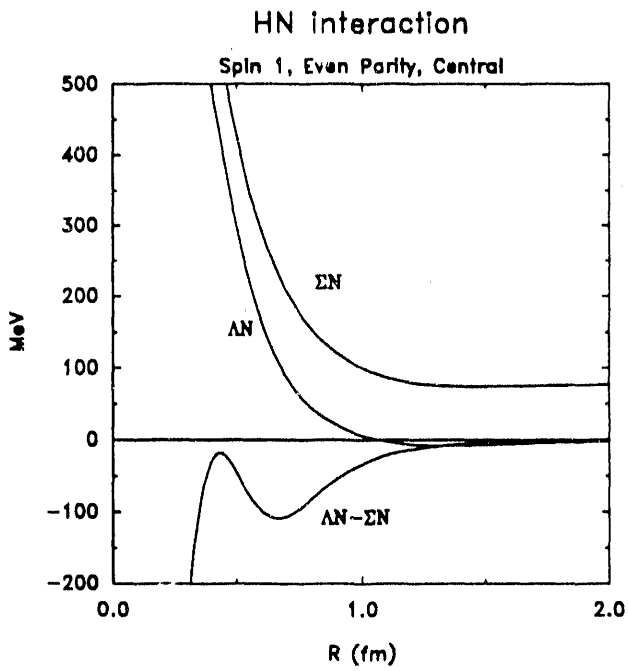

Figure 1b) Spin 1 central terms in the Nijmegen soft core interaction.

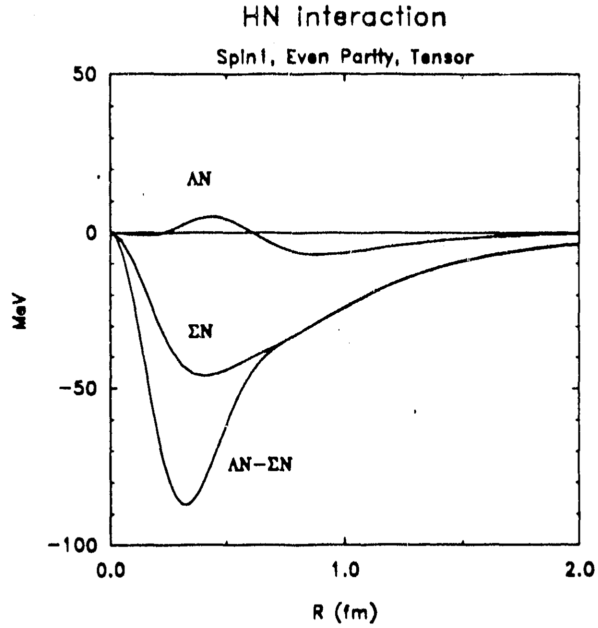

Figure 1c) Spin 1 tensor terms in the Nijmegen soft core interaction.

It should be noted that the form of the many-body Hamiltonian is not uniquely determined by the two-body results, since we are including transition operators to particles with different masses. The difficulties are associated with the fact that the Hamiltonian is not Galilean invariant. In writing down two-body equations, one usually begins with relative coordinates and reduced masses without discussing the full coordinate system. This leads to an ambiguity in few-body calculations, where other (inequivalent) choices have been made in the past, particularly in momentum-space calculations. We work in a frame such that $(\sum_i p_i)\Psi = 0$, and assume that the transition operator does not involve any spatial translation of the particles. This particular choice seems most natural, though, in that it incorporates cluster separability. It seems unlikely that these different choices significantly affect results in the low-energy regime.

4. Method

We have used the Variational Monte Carlo method to calculate the properties of the s-shell hypernuclei. As in any variational method, we assume a form of trial wave function $\Psi_T\{\alpha\}$ with a set of embedded parameters $\{\alpha\}$, and minimize the expection value of the Hamiltonian with respect to changes in the parameters $\{\alpha\}$. Monte Carlo methods are used to evaluate the necessary integrals.

Details of this method are widely described in the literature,[9,10] here we only present the form of variational wave function and describe the additions necessary to study hypernuclei. First, however, we compare Variational Monte Carlo results with 'exact' Faddeev results for the triton. For non-strange nuclei, the variational wave function is of the form:

$$\Psi_T = \mathcal{S} \prod_{i<j} F_{ij}^{NN}(r_{ij})\Phi, \tag{6}$$

where Φ is an anti-symmetrized product of one-particle states. For s-shell ground states, we can choose Φ to be independent of the spatial coordinates. For example, in the triton

$$\Phi = \mathcal{A}[(\downarrow n)_1(\uparrow n)_2(\uparrow p)_3]. \tag{7}$$

The nucleon-nucleon pair correlation operators F_{ij}^{NN} are obtained from solutions of two-body differential equations of the general form:

$$[\frac{-\hbar^2}{2\mu}\nabla^2 + v_{ij}(r) + \lambda_{ij}(r)]F_{ij}(r) = 0. \tag{8}$$

The variational parameters are embedded in the functional form of λ_{ij}. Ignoring spin dependence (which is included in the real calculation) the pair correlation operator must have the form

$$F(r) \to \exp(\sqrt{\frac{-2\mu E_{sep}}{\hbar^2}}r)/r^{1/(A-1)} \tag{9}$$

as one nucleon is separated from the remaining core. The function $\lambda(r)$ is chosen such that this asymptotic condition is satisfied, where the separation energy E_{sep} is a variational parameter which controls the long-distance properties of the wave function. There are additional parameters which govern the short-range properties of $\lambda(r)$.

An uncoupled equation is solved in the singlet channels, while coupled channel solutions are determined for the triplet states. The triplet state solutions yield both a central and a tensor correlation. The complete set of solutions in the various channels can be transformed into operator form:

$$F_{ij}^{NN} = \sum_m f^m(r_{ij})O_{ij}^m, \tag{10}$$

where the O^m include central, $\sigma_i \cdot \sigma_j$, $\sigma_i \cdot \sigma_j \tau_i \cdot \tau_j$, S_{ij}, and $S_{ij}\tau_i \cdot \tau_j$ operators. For the ground state of the triton, a variational wave function of this form gives an energy of -7.25 $\pm$ 0.03 MeV.[11] An 'exact' Faddeev calculation, in contrast, gives -7.63. The difference between variational and exact results of 0.4 MeV is fairly typical of those obtained with other realistic interaction models. Wiringa[12] has recently added three-body and $L \cdot S_{ij}$ correlations to the variational wave function and diminished the discrepancy.

When the Urbana Model 7 TNI is included, the variational ground state energy of the triton decreases to -7.86 $\pm$ 0.06 MeV. This is still somewhat above the experimental energy of -8.48, but the small difference is unlikely to affect the Λ particle separation energy significantly. Similarly, the alpha particle binding energy for the Nijmegen plus TNI model is -27.1 $\pm$ 0.2 MeV, approximately one MeV higher than the experimental -28.3 MeV. In principle we could adjust the strength of the TNI to reproduce experimental results, but this appears to be an unnecessary refinement at this stage.

The hypernuclear wave functions are obtained as straightforward generalizations of the non-strange nuclei:

$$\Psi_T = \mathcal{S}\left(\prod_{i<j} F_{ij}^{NN} \prod_{i,l} F_{il}^{HN}\right)\Phi. \tag{11}$$

The state Φ is again a Slater determinant, for example:

$$\Phi({}^5_\Lambda\mathrm{He}) = \mathcal{A}\left[(n\downarrow)_1(n\uparrow)_2(p\downarrow)_3(p\uparrow)_4\right](\Lambda\uparrow)_5, \tag{12}$$

where the anti-symmetrization $\mathcal{A}$ runs over the nucleons alone. We have also tried wave functions which in which the HN correlations act either before or after the NN interactions rather than being fully symmetrized. These forms of wave function give poorer variational bounds than the fully symmetrized product.

Of course the pair correlation operators are different in the case of a hyperon-nucleon pair. They are again obtained as solutions of two-body equations with the form of equation 8, but the operator structure is now:

$$F_{il}^{HN} = f_{il}^m O_{il}^m, \tag{13}$$

with operators

$$O_{il}^{m} = \{1, \sigma_i \cdot \sigma_l, S_{il}\} \bigotimes \{1, T_{il}\}. \tag{14}$$

The transition operator T_{il} converts a ΛN pair to an isospin 1/2 ΣN pair and vice versa. Up to the present, we do not include a distinct correlation operator for the diagonal ΣN diagonal, these higher-order effects should be small. The wave function of a 'hyper-deuteron', were one to be bound, could be expressed exactly in this form.

The asymptotic behavior of the hyperon wave function is governed by a variational parameter E^H_{sep}, just as for the nucleon above. Of course, the Σ component of the wave function must decay more rapidly due to the increased mass in the Σ channel. This difference is incorporated by taking two different asymptotic forms for the function $\lambda(r)$ in the Λ and Σ channels. Several additional variational parameters are adjusted to determine the short-range properties.

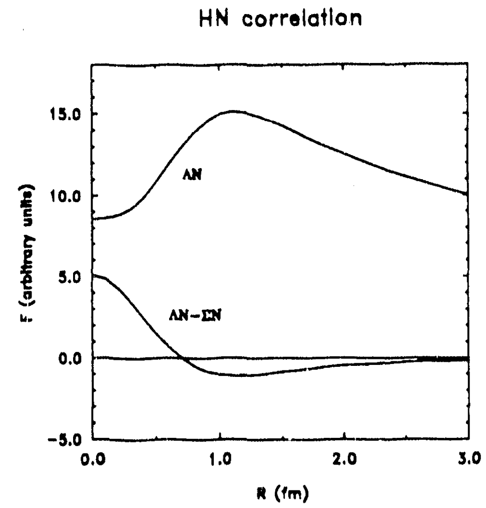

Figure 2a) Spin 0 pair correlation functions in $^5_\Lambda$He.

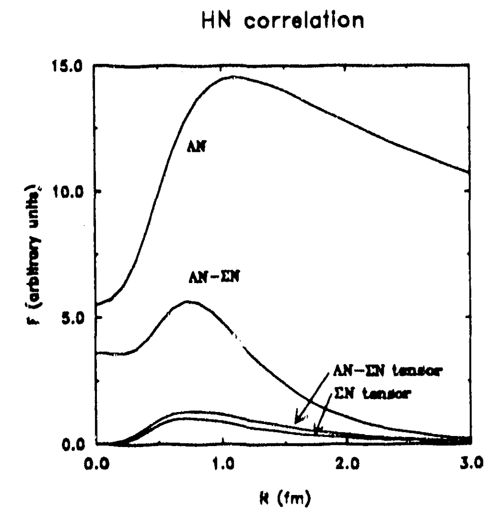

Figure 2b) Spin 1 pair correlation functions in $^5_\Lambda$He.

Examples of the HN correlation, as obtained for $^5_\Lambda$He, are given in Figure 2. The apparent small size of the tensor correlations are an artifact of the normalization chosen for the tensor operator. It differs by a factor of $\sqrt{8}$ from the coefficient usually chosen to describe the d-state component of the deuteron wave function. In fact, the tensor components of the interaction are very important, as we will show in the next section.

5. Results

We first concentrate on the ground state energy of $^{4}_{\Lambda}$He. Our calculations give a binding energy of 1.6 ± 0.1 MeV, while the experimental value is 2.0 MeV. The difference is quite small and well within the uncertainties of our variational calculations. Given the lack of experimental scattering data, obtaining agreement at this level for even the ground state is rather surprising. The agreement arises primarily because the ground state is sensitive to the singlet and triplet interactions at roughly the same level (Table 1), and hence in a simple model there are 1 1/2 singlet HN pairs and 1 1/2 triplet pairs in $^{4}_{\Lambda}$He. For this reason, second-order tensor effects should be fairly small. These effects are important when more than one HN pair are in a relative D-state at the same time.

The spin-flip excited state of $^{4}_{\Lambda}$He, however, is very strongly underbound in our calculations. Experimentally, this state should be bound by about 1 MeV, but we find it to be only very lightly bound in our calculations. In order to understand the causes of the large spin-splitting in the Nijmegen model, we have performed calculations where the variational parameter E_{sep} is fixed at the experimental separation energy of the Λ. This essentially fixes the size of the hyperon's wave function.

The $J^{\pi} = 1^{+}$ state of $^{4}_{\Lambda}$He is strongly dominated by the spin-triplet interaction. In fact, in the simple model above 2 1/2 HN pairs would be in a triplet state and only half a pair in the singlet state. Consequently, the second-order tensor effects are very important. Comparing two interactions that are 'equivalent' in terms of two-body data (the total cross-section, for example), the one with a large tensor component will provides less attraction in a few-body bound state.

These effects are very well-known in standard few-body nuclear physics, and are also very important there. Two potentials which give the same deuteron binding energy can give vastly different alpha particle binding energies if the relative strengths of the tensor interaction are very different. Fortunately, the scattering data in the NN channel is sufficient to provide reasonable constraints on the strength of the tensor interaction. The same is not true for the HN interaction, however.

Our results are summarized in Table 2, where in each case we have fixed the separation energy parameter of the variational wave function to the experimental value. As is evident from the table, the ground state of $^{5}_{\Lambda}$He is also very strongly underbound in this model. In fact, if fixing the separation energy at 3 MeV gives no Λ binding at all. Clearly we could obtain some small binding by letting the wave function extend to very large distances; in the limit that the wave function becomes very large we trivially obtain the energy of an isolated alpha + Λ.

Table 2. Calculated Λ Separation Energies

	Nijmegen		Expt	'Singlet Model'	
$^{4}_{\Lambda}$H(0^{+})	1.6	(0.1)	2.0	2.0	(0.1) [adjusted]
$^{4}_{\Lambda}$H(1^{+})	-0.2	(0.1)	1.0	2.0	(0.1)
$^{5}_{\Lambda}$He($1/2^{+}$)	-0.8	(0.4)	3.1	¿4.5	(0.7)

For comparison purposes, we also show some results labeled 'singlet model' in the Table. These results were obtained from applying a scaled version of the Nijmegen soft-core spin singlet interaction in all channels. This, of course, gives a very simple interaction with no tensor force. The importance of the Σ channel is significantly reduced in this simple model because of the lack of a one-pion tensor term. However, the cancellation between the spin singlet and triplet transition operators that occurs in the original model no longer occurs.

Of course, using the pure singlet interaction in all channels is too attractive, so we apply a common scale factor of 0.9 to all the terms to reduce the attraction and fit the ground state energy of $^{4}_{\Lambda}$He. This interaction, of course, has not been fit to the scattering data and is intended solely as a guide to understanding the few-body physics of hypernuclei. This 'singlet model' gives significantly too strong a binding energy for $^{5}_{\Lambda}$He, as indicated in the table. If we retain the earlier restriction that the variational parameter that fixes the size of the wave function be kept at the experimental separation energy (3 MeV), we find that the Λ is bound to the nucleus by 4.5 MeV. Relaxing this restriction would, of course, provide even greater binding.

These results, obtained in the absence of a tensor force, are reminiscent of the classical 'overbinding' problem in $^{5}_{\Lambda}$He. Simple two-body forces which correctly predict the 4-body binding energy tend to overbind the 5-body system. Our interaction is slightly more complicated (it includes momentum-dependent and transition terms), but still yields the same physics. The tensor interaction plays an important role in the binding energy systematics of light hypernuclei.

As a further illustration of that role, we have compiled the expectation values of various potential terms in each of the light hypernuclei. The results are given in Table 3. The total HN potential energy is given in the first row, and the contributions of selected momentum-independent interaction terms are also listed. Of particular importance is the fraction of the attraction arising through tensor terms; especially the transition tensor. The central part of the triplet interaction, in contrast, gives a slight repulsion. This is in accord with expectations based upon the interaction shown in Figure 1c.

Table 3. Potential Expectation Values of Light Hypernuclei

	$^{4}_{\Lambda}$H(0^+)		$^{4}_{\Lambda}$H(1^+)		$^{5}_{\Lambda}$He($1/2^+$)	
$\langle V_{HN}\rangle$ (MeV)	-13.1	(0.5)	-6.1	(0.4)	-12.9	(0.5)
	Spin Singlet Central					
ΛN	-2.9	(0.2)	-0.9	(0.1)	-2.8	(0.3)
$\Lambda N - \Sigma N$	-0.9	(0.1)	-0.1	(0.1)	-0.3	(0.1)
	Spin Triplet Central					
ΛN	1.8	(0.2)	0.6	(0.2)	1.8	(0.7)
$\Lambda N - \Sigma N$	-3.5	(0.2)	-1.5	(0.1)	-2.8	(0.3)
	Spin Triplet Tensor					
ΛN	-0.5	(0.1)	-0.3	(0.1)	-0.5	(0.1)
$\Lambda N - \Sigma N$	-4.5	(0.2)	-2.7	(0.1)	-5.5	(0.2)
	Transition Fraction					
$\langle V_{\Lambda N-\Sigma N}\rangle/\langle V_{HN}\rangle$	68.0	(5.0)	70.0	(5.0)	67.0	(5.0)
	Probabilities					
Λ(%)	97.8	(0.1)	99.2	(0.1)	98.5	(0.1)
Σ(%)	2.2	(0.1)	0.8	(0.1)	1.5	(0.1)

Energies are given in MeV, and parentheses indicate statistical errors.

The fraction that all momentum-independent $\Lambda N - \Sigma N$ transition terms contribute is also given in the table, it is nearly 65% for all the hypernuclei. Qualitatively, this large fraction is in agreement with the strong three-body force models of Usmani and Bodmer. It is difficult to make quantitative comparisons, however.

Also shown in the table is the probability to find a Σ hyperon in the nucleus. The fractions appear to be quite small, around 1 - 2 %. However, one must recall that the hyperons are very loosely bound, and consequently there are large portions of configuration space far from the 'core' nucleus where the presence of a Σ is energetically unfavorable. The Λ and Σ densities of ${}^{5}_{\Lambda}$He are plotted in figure 3 as a function of the distance to the center-of-mass of the core nucleus. Although this is a somewhat artificial construction of the density, it provides the best illustration of the situation.

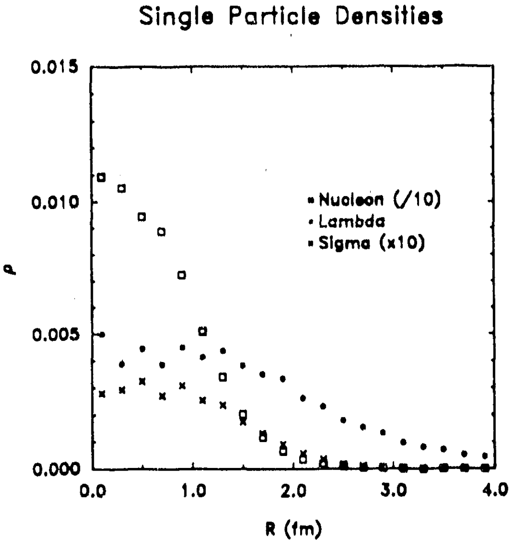

Figure 3) One body densities in ${}^{5}_{\Lambda}$He, measured from the 'core' center-of-mass.

Note that the Σ density does not fall off as fast as one might expect based upon the $\Lambda - \Sigma$ mass difference. The one-pion-exchange term in the interaction allows the Σ density to be appreciable at sizable distances from the core. Nevertheless, although the Σ density is approximately 7% of the hyperon density in the core region, it is only about 2% overall.

We have also briefly examined the charge-symmetry breaking terms in the Nijmegen interaction. The CSB is quite small in the Nijmegen soft-core interaction, and consequently it cannot explain the ${}^{4}_{\Lambda}$H $-$ ${}^{4}_{\Lambda}$He separation energy difference. Earlier Nijmegen HN interaction models included a larger CSB component.

6. Conclusions

From the results presented in the previous section, it is apparent that the current Hyperon-Nucleon interaction models provide a good fit to the ground state ^{4}He binding energy, but do not reproduce the spin-splitting in the four body hypernuclei or the ground state of ${}^{5}_{\Lambda}$He. This is perhaps not surprising, given the fact that the $J^{\pi} = 1^{+}$ ${}^{4}_{\Lambda}$H state and the 1^{+} are strongly affected by higher-order tensor effects, and that there is no scattering data which would help to pin down the spin dependence of the Hyperon-Nucleon interaction.

Clearly one could construct a phenomenological HN interaction model which fits the binding energies of 4 and 5-body hypernuclei as well as the current scattering data. We have not attempted this exercise, but possible general features of such an interaction are clear. As compared to the Nijmegen soft-core interaction, the spin-singlet interaction need not be changed a great deal. In the triplet channel, though, one could reduce the discrepancies by decreasing the tensor and tensor-transition strengths while simultaneously increasing the attraction in the central term.

The real test of any interaction model, however, will only come with a much larger array of Hyperon-Nucleon scattering data. Two elements are particularly important: (1) spin-dependence below Σ threshhold and perhaps even more importantly (2) further tests of the strength of $\Lambda\Sigma$ coupling and its spin dependence. This scattering data will put rather severe constraints upon the meson-baryon based HN interaction models, and allow us to determine if they provide a reasonable approximation to hypernuclear physics.

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