IRNIL 7600533
WIS-76/20-Ph

WHO NEEDS HYPERON BEAMS?

H.J. LIPKIN
Department of Nuclear Physics
Weizmann Institute of Science
Rehovot, Israel

Abstract : Hyperon beams can provide new interesting information about hadron structure and their strong, electromagnetic and weak interactions. The dependence of hadron interactions on strangeness and baryon number is not understood, and data from hyperon beams can provide new clues to paradoxes which arise in the interpretation of data from conventional beams. Examples of interesting data are total and differential cross sections, magnetic moments and values of G_A/G_V for weak semileptonic decays.

1. INTRODUCTION

The first question to ask about any new topic is "who needs it?" One possible answer to "who needs hyperons" is "seen one hadron, seen them all." The devil's advocate can assert that experiments with pions, ..ons, and nucleons give sufficient information about hadron behaviour and hyperon beams will tell us nothing new.[1] The quark model, for example, gives a good description of hadron physics with pion, kaon and nucleon beams and predicts results of experiments with hyperon beams. Why bother with hyperon beam experiments just to test quark model predictions?

The one trouble with this argument is that it is wrong. Experiments on pions, kaons and nucleons don't tell us how quarks behave. There are many ambiguities, paradoxes and inconsistencies in the quark model description of hadron behavior. No model gives unambiguous predictions of results of hyperon beam experiments, and new interesting physics awaits discovery with hyperon beams.

With pions, kaons and nucleons we have studied strange and nonstrange mesons and nonstrange baryons. Hyperon beams offer the opportunity to study strange baryons. We cannot predict the behavior of hyperons from the behavior of kaons, pions and nucleons because we do not understand baryon number and strangeness. These internal quantum numbers satisfy conservation laws like electric charge but we do not understand them anywhere near as well as electric charge. For example, there is no description of the dependence of strong interaction scattering on B and S analogous to the Rutherford formula for the dependence of Coulomb scattering on electric charge. The best we have are quark-counting rules for the difference between meson and baryon scattering and SU(3) symmetry for the strangeness dependence. But these descriptions are highly inadequate and the differences between mesons and baryons and between strange and nonstrange hadrons are not really understood.

Conventional hadron beams, electron and muon beams and neutrino beams have been used primarily for the separate study of strong, weak and electromagnetic interactions. This has encouraged both theorists and experimentalists to become specialized experts in one interaction and remain unfamiliar with others. Specialized models are developed which work well in one area but are incompatible with models used in other areas. This specialization is seen in the division of this Rencontre into strong and weak sessions with very little overlap between the participants.

The two discussions of hyperon beam physics provide an interesting bridge between the strong and weak sessions. The new hyperon beams described by the experimentalists are a qualitatively new facility for investigating strong, electromagnetic and weak interactions of hyperons. In contrast to the conventional beams the hyperon beam studies all three areas. A particular experimental setup originally planned to study one type of interaction may well turn out to be most useful for another. Hyperon beam physicists should therefore have the versatility to switch from one area to another in order to fully exploit the potentialities of the facility.

The unifying element in hyperon beam experiments is the structure of the hyperon itself, which is the same whether probed by strong, electromagnetic or weak interactions. Hyperon beam experiments not only give further information on each of the three individual interactions. They also give new information about hyperon structure from all three interactions. A good model for hadron structure should give a correct unified picture of all these hyperon properties.

Hyperon beams can thus provide new insight into hadron structure and interactions by exploring those areas where our imperfect understanding has led to paradoxes, puzzles and ambiguities. In this talk we critically examine the particular problems of understanding strangeness and baryon number and obtaining a unified description of hadron structure for all three interactions. We look for difficulties which might be resolved by new information from hyperon beam experiments.

2. THE PION-KAON WAVE FUNCTION PARADOX

As one example of the paradoxes encountered in trying to understand strangeness and in separately treating strong and weak interactions, consider the description by conventional models of the difference between pion and kaon wave functions. The quark model says that both are made from a quark-antiquark pair.[2] But there is a "weak" quark model and a "strong" quark model which have different wave functions. Weak interaction quarkists explain the ratio of the $\pi \to \mu + \nu$ and $K \to \mu + \nu$ decay by requiring the wave functions at the origin to be very different as described by Weisskopf-Van-Royen[2] formula

$$\frac{|\psi_K(0)|^2}{|\psi_\pi(0)|^2} = \frac{M_K}{M_\pi} \quad . \tag{1}$$

Strong interaction quarkists say that the difference between pion and kaon wave functions is measured by the difference between their scattering cross sections on nucleons. These differ by less than 20%. Recent data at high energies show that πp and Kp differential cross sections approach equality with increasing momentum transfer. This suggests equality within 20% of the mean square radii of pion and kaon wave functions and nearly identical short distance behavior, in sharp contrast with the weak quarkist eq. (1).

How do pions and kaons know that they have to look different when they interact weakly from when they interact strongly? Hyperon beams can provide some illumination on this question by providing information from both strong, electromagnetic and weak interactions on the difference between hyperon and nucleon wave functions. Specific examples are discussed below.

3. TOTAL CROSS SECTIONS AND TROUBLES WITH THE ADDITIVE QUARK MODEL

The additive quark model[2,4] has been used very successfully to describe and predict hadron total cross sections. But a straightforward and uncritical application of this model to predict hyperon cross sections leads to absurdities. For example, the relation

$$\sigma(\Sigma^- p) = \sigma(K^- p) + 2\sigma(\pi^+ p) + 3\sigma(\pi^- p) - \sigma(pp) - 2\sigma(\bar{p}p) \qquad (2)$$

obtained[5] directly from the additive quark model predicts ridiculously low values like 2.7 mb and 12.7 mb at 6 GeV and 50 GeV respectively. This difficulty is clarified by rewriting eq. (2).

$$\sigma(\Sigma^- p) = 2\sigma(pn) - \sigma(pp) + \sigma(K^- p) - \sigma(\pi^- p) + E \qquad (3a)$$

where

$$E = 2[\sigma(\pi^+ p) + 2\sigma(\pi^- p) - \sigma(\bar{p}p) - \sigma(pn)] \qquad (3b)$$

The quantity E defined by eq. (3b) is predicted to be zero by the additive quark model but experimentally is about 20-40 mb which is very different from zero. Thus the prediction (3a) for $\sigma(\Sigma^- p)$ is ambiguous and depends upon whether one uses the experimental value of E or the theoretical value of zero.

The source of the ambiguity is the disagreement of experimental baryon-baryon cross sections by about 20% with values predicted from meson-baryon cross sections by the additive quark model.[6] The famous ratio of 3/2 between baryon-baryon and meson-baryon cross sections is too low by about 20%. Such 10 or 20% discrepancies are expected and not considered serious in such a crude model. But serious ambiguities and inconsistencies can arise from the use of differences between two large numbers predicted to cancel exactly but missing by 20% as in the quantity (3b).

In any case, the existence of 1% experimental data is a challenge to model builders to make a 1% model. Analyses of total cross section data indicate that differences like (3b) between meson-baryon and baryon-baryon cross sections seem to be related to the difference between pion and kaon cross sections i.e. the 20% discrepancies between additive quark model predictions and experiment seems to be related to 20% SU(3) symmetry breaking. The dependences of total cross sections on strangeness and baryon number seem empirically to be related. A two-component model for the pomeron[6] suggested by this empirical relation leads to predictions for hyperon-nucleon total cross sections which differ from the simple quark model predictions.

A measurement of hyperon-nucleon cross sections therefore explores the dependence of hadron cross sections on strangeness and baryon number. Results should not be expected simply to confirm or disagree with quark model predictions, since these predictions contain unresolved ambiguities. Instead they may provide new insight into the nature of the difficulties and paradoxes already found in treating pion-nucleon, kaon-nucleon and nucleon-nucleon cross sections.

4. PARADOXES WITH DUALITY AND EXOTICS

The difficulty illustrated by the equality (3b) arises from the pomeron contribution to the total cross section. Difficulties also arise in the Regge exchange components appearing in the odd signature exchange contributions. The quark model and mathematically equivalent Regge exchange formalisms with exchange degeneracy[2,7] and universality describe very well the differences between particle-particle and antiparticle-particle cross sections. Difficulties arise in the application of duality arguments to baryon-antibaryon channels with exotic quantum numbers.[8]

These difficulties have not been resolved with data from conventional beams because exotic $\bar{B}B$ channels do not exist in the nucleon-antinucleon system. Antihyperon beams are needed to obtain exotic $\bar{B}B$ channels. The difficulties are immediately seen in the simple quark model predictions for hyperon-nucleon total cross section differences

$$\sigma(\overline{\Xi^-}p) - \sigma(\Xi^-p) = \sigma(\bar{p}p) - \sigma(pp) - 2[\sigma(K^-p) - \sigma(K^+p)] \qquad (5a)$$

$$\sigma(\overline{\Xi^0}p) - \sigma(\Xi^0p) = \sigma(\bar{p}n) - \sigma(pn) - 2[\sigma(K^-n) - \sigma(K^+n)] \qquad (5b)$$

$$\sigma(\overline{\Sigma^+}n) - \sigma(\Sigma^- p) = \sigma(\bar{p}p) - \sigma(pn) - [\sigma(K^- n) - \sigma(K^+ p)] \quad (5c)$$

$$\sigma(\overline{\Sigma^+}p) - \sigma(\Sigma^- n) = \sigma(\bar{p}n) - \sigma(pp) - [\sigma(K^- p) - \sigma(K^+ n)] \quad (5d)$$

These relations contain only contributions from ρ and ω exchange in a Regge picture and also follow from assumptions of SU(3) symmetry and/or ρ and ω universality.

However, the baryon-baryon and antibaryon-baryon channels on the left hand side of the relations (5a), (5b) and (5c) have exotic quantum numbers, whereas $\overline{\Sigma^+}p$ in eq. (5d) is not exotic. According to two-component duality exotic channels have only pomeron contributions at high energy and no contributions from the leading Regge trajectories. With this picture the left-hand-sides of eq. (5a), (5b) and (5c) should be zero in disagreement with the right-hand-sides, while the argument does not hold for the nonexotic case (5d).

The essential features of the paraox can be seen by comparing the hyperon-nucleon system with the kaon-nucleon system where the duality game works. The K^+p and K^+n channels are exotic, while the K^-p and K^-n channels are not. The leading Regge contributions to these channels come from the ρ, ω, A2 and f trajectories. Duality arguments require exchange degeneracy of the ρ and A2 trajectories and couplings to the KN system which add constructively in the imaginary part of the nonexotic K^-N amplitudes and cancel exactly in the exotic K^+N amplitudes. A similar condition is required for the isoscalar ω and f trajectories. These conditions seem to be satisfied by the experimental data and are considered good experimental evidence for the duality approach.

An analogous description is impossible for the ΞN system where all four channels are exotic, Ξ^-p, Ξ^-n, $\overline{\Xi^0}p$ and $\overline{\Xi^0}n$. The imaginary parts of all four exotic amplitudes can vanish only if the contributions of all four Regge trajectories vanish. But this requires the couplings of these trajectories to violate the SU(3) and universality relations (5a) and (5b).

In the ΣN system only three channels are exotic and the duality constraints have a nontrivial solution. An exchange degeneracy cancellation analogous to that for the KN system can make the Regge contribution vanish in the exotic baryon-baryon channels. The relative strengths of the ρ and ω exchange can then be adjusted to make the sum vanish for the exotic $\overline{\Sigma^+}n$ channel but not for the nonexotic $\overline{\Sigma^+}p$ channel. However, this solution violates the relation (5c) which uses SU(3) symmetry and/or universality to determine the ρ and ω exchange contributions to ΣN scattering.

Further insigut into the difference between the exotic and nonexotic ΣN channels is found in the crossed reactions where they appear as t-channel exchanges.

$$\bar{p} + p \to \overline{\Sigma^-} + \Sigma^- \tag{6a}$$

$$\bar{p} + p \to \overline{\Sigma^+} + \Sigma^+ \tag{6b}$$

Experimental data[9] indicate a very definite difference between the exotic exchange of reaction (6a) and the nonexotic exchange of the reaction (6b). The exotic exchange seems to behave in a very similar manner to the observed exotic exchanges in kaon-nucleon reactions. This sharpens the paradox.

If experimental data disagree with the predictions (5c) and (5d), there is a definite disagreement with the quark model, SU(3) symmetry and omega universality. If the experimental data agree with the predictions, then the exotic and nonexotic reactions behave in a similar manner, in contrast to the crossed reactions (6) where they behave very differently. Finite energy sum rules[10] applied to the reactions (6) would then require similar contributions in the low energy resonance region for both exotic and non-exotic channels.

Duality diagrams[11] provide a description of exotic baryon-antibaryon scattering consistent with the symmetry and universality realtions (5). However, these diagrams all have exotic two-quark-two-antiquark states either in the s or t channel. The exact physical interpretation of these states has never been clarified, in particular whether or not they correspond to resonances. Although planar duality diagrams can describe exotic exchanges in baryon-antibaryon scattering, no such diagrams exist for meson-baryon scattering and experiments show similar exotic exchanges in both cases. Thus, no matter which theoretical approach is used, puzzles and ambiguities in baryon-antibaryon scattering remain to be clarified by hyperon beam experiments.

5. STRANGENESS AND BARYON NUMBER DEPENDENCE IN HADRON DIFFERENTIAL CROSS SECTIONS

The apparent relation observed in total cross sections between the dependence of hadron scattering on strangeness and on baryon number[6] has been investigated also for differential cross sections and has led to new surprises and paradoxes. With only differential cross section data available and no detailed amplitude analysis, it is convenient to define the quantity[6,12]

$$S(Hp) = \left[\frac{d\sigma}{dt}(\bar{H}p) + \frac{d\sigma}{dt}(Hp) \right]^{1/2} \tag{7}$$

where H is any hadron. This quantity S(Hp) is assumed to give a good approximation for the Pomeron contribution to the Hp-scattering amplitude.

The simple additive quark model predicts

$$S(\pi p) = (2/3)S(pp) \tag{8a}$$

The assumption that the Pomeron is a singlet in SU(3) predicts

$$S(\pi p) = S(Kp). \tag{8b}$$

The two relations (8a) and (8b) describe the dependence of the scattering amplitude on baryon number and strangeness respectively. The two component Pomeron model which relates the deviations from the two predictions (8a) and (8b) predicts the weaker sum rule

$$S(\pi p) = \frac{1}{2} S(Kp) + \frac{1}{3} S(pp) \tag{9}$$

The experimental data[13] show that the weaker sum rule (9) is in much better agreement with experiment than the additive quark model prediction (8a). However, the SU(3) prediction which is not very good at t=0 becomes better at larger values of t and becomes much better than the two component Pomeron prediction (9) or the additive quark model prediction (8a). Two examples of this comparison with experiment are given in Table 1. The same qualitative features are present in all the data.

Table 1

Tests of Additive Quark Model (AQM), Two-Component Pomeron (P2) and SU(3) Relations Between Differential Cross Sections.

RHS/LHS of eqs. (8a), (8b) and (9)

P = 100 GeV/c				P = 175 GeV/c			
t (GeV/c)	AQM (8a)	P2 (8b)	SU(3) (9)	t (GeV/c)	AQM (8a)	P2) (8b)	SU(3) (9)
0.0	1.2	1.0	0.84	0.0	1.1	0.97	0.84
-0.08	1.0	0.95	0.86	-0.08	0.98	0.92	0.85
-0.16	0.94	0.91	0.88	-0.16	0.89	0.88	0.86
-0.24	0.85	0.87	0.90	-0.24	0.81	0.84	0.88
-0.32	0.78	0.85	0.92	-0.32	0.74	0.81	0.89
-0.40	0.71	0.83	0.94	-0.40	0.68	0.79	0.90
-0.48	0.66	0.81	0.97	-0.48	0.63	0.77	0.92
-0.56	0.61	0.80	1.0	-0.56	0.58	0.76	0.93
-0.64	0.56	0.80	1.0	-0.64	0.54	0.74	0.95
-0.72	0.53	0.80	1.1	-0.72	0.50	0.73	0.96
-0.80	0.50	0.80	1.1	-0.80	0.47	0.72	0.98

The comparison with experiment of relations (8a) and (9) does not really add any new qualitative information. It is summed up by the observation that at the optical point the relation (8a) is not very good and the relation (9) is much better and that baryon-baryon cross sections decrease much more rapidly with t than meson-baryon cross sections. The behavior at the optical point is expected from the similar behavior of total cross sections. The high t behavior is expected since naive additive quark model predictions (8a) and (9) neglect differences between meson and baryon wave functions. These differences introduce additional form factors into the scattering amplitudes, which cause baryon amplitudes to decrease more rapidly with increasing t than meson amplitudes.

However, the improvement of the relation (8b) with increasing t comes as a complete surprise. One can ask why pion and kaons should look more alike[14] at high t than at low t. One might also ask whether the two are really approaching equality or whether there will be a cross over and that still at higher t the amplitude will differ in the opposite direction. In any case further illumination is needed and can be sought in comparing the differential cross sections of nucleon-nucleon and hyperon-nucleon scattering. The total cross section data indicate that hyperon-nucleon cross sections are smaller than nucleon-nucleon cross sections as expected from any model which predicts a somewhat smaller cross section for strange than for nonstrange particles on a nucleon target. The question then arises whether this difference also goes away at large t, like the difference between πN and KN scattering.

C. SPIN-ISOSPIN STRUCTURE OF NUCLEONS

The simple systematics describing the experimentally observed couplings of the nucleon in strong, electromagnetic and weak interactions give essential information about the structure of the nucleon. The basic qualitative features of this analysis of nucleon structure can be seen in a few basic properties of the neutron.

1. The neutron has zero electric charge, but is not completely decoupled from the electromagnetic current. Its constitutents must be charged, but the total charges of the positively and negatively charged constituents must exactly cancel.

2. The neutron spin is 1/2. If its constituents have spin, all spins cannot be coupled parallel. At least one constituent must have its spin antiparallel to the total spin of the neutron.

3. The neutron magnetic moment -1.91 nuclear magnetons, is large and negative. The large mangitude indicates that the magnetic moments of the positively and negatively charged constitutents add constructively rather than cancelling as in the case of electric charge. This occurs if the positively and negatively charged constituents have their spins antiparallel and their magnetic moments parallel. The sign of the magnetic moment indicates that the spins of negatively charged constituents are parallel to the total spin of the neutron while the spins of positive constituents are antiparallel.

These three propertios lead automatically to the conclusion that in any model like the quark model where the nucleon is made of three spin 1/2 objects, two of them must be negatively charged and one positively charged to give the negative magnetic moment. The spins of the negatively charged quarks must be parallel to the neutron spin and the spin of the positively charged quark antiparallel to give the spin of 1/2 and the large negative magnetic moment. The total charge of zero requires the charge of negative quark Q_- to be half the charge of positive quark Q_+ .

$$Q_+ = -2Q_- \tag{10a}$$

The introduction of isospin to describe the neutron and proton as made of the same isodoublet constituents then requires a difference of one unit between the charges of the two members of the same isodoublet. These conditions

$$Q_+ - Q_- = 1 \tag{10b}$$

lead to the fractional charges of the Gell-Mann Zweig quark model with the positive and negative quarks having charges $Q_+ = +2/3$ $Q_- = -1/3$ respectively. The isospin couplings in the nucleon resemble the spin couplings. With three isospins of 1/2 coupled to a total isospin of 1/2, one of the isospins must be antiparallel to the total isospin.

One outstanding quantitative success of this approach has been the successful prediction of -3/2 for the ratio of the proton and neutron magnetic moments. Such a ratio of total magnetic moments appears simply in any formulation where the magnetic moment of the hadron is obtained by adding the contributions of its constituents, but not in the simple field theoretical picture where the nucleon is considered to be a Dirac particle with an anomalous magnetic moment. The Dirac and anomalous moments have completely different origins and are not simply related. The field theoretical picture could give simple numerical relations between the anomalous but not the total moments.

Many couplings of the hadron to electromagnetic, strong and weak interactions are also obtained by summing the couplings of the individual constituents. There are two kinds of couplings: (1) constructive couplings where contributions of all constituents add to give a large value like the magnetic moment; (2) destructive couplings where the contributions of two types of quarks have opposite sign as in electric charge, spin and isospin. The couplings of the nuclei to strong, electromagnetic and weak interactions are seen to be constructive for quantities which are either scalar or vector in both spin and isospin. They are destructive for quantities which are scalar in one and vector in the other. Examples from strong interactions are the couplings of the nucleon to isoscalar and isovector Regge trajectories with spin flip or non-flip where the ω non-flip and ρ flip couplings are large and the ω flip and ρ non-flip small in agreement with experiment.

The value of G_A/G_V is the ratio of two isovector couplings, one spin-vector, the other spin scalar and is predicted to be large, namely 5/3. Experimentally it is 1.2 which is larger than unity, but significantly different from 5/3.

One puzzle of this approach has been this failure to predict G_A/G_V with the same quantitative success as the ratio of the magnetic moments, since the calculations appear to be very similar. The discrepancy has led to considerable theoretical effort to improve the quark model and obtain a better value for G_A/G_V. However, the validity of such improved models is not easily checked since additional freedom and new free parameters are necessary in order to fit this one puzzling piece of data. Additional information on G_A/G_V and the magnetic moments of hyperons would be of considerable value. Any modification of the simple SU(6) quark model created to improve the value of G_A/G_V for the nucleon generally also predicts different values for G_A/G_V and the magnetic moments of hyperons. Additional data of this type will provide more constraints to keep the theorist honest.

7. THE SPIN ISOSPIN STRUCTURE OF HYPERONS

The SU(6) quark model which has been successful in predicting the spin-isospin structure of the nucleon leads to a very rich spin-isospin structure for hyperons and many interesting predictions. The Λ and Σ hyperons are predicted to have very different structures. They both consist of two nonstrange quarks and a strange quark. But the nonstrange quarks in the Λ are coupled to isospin zero and therefore also to spin zero by the SU(6) wave function which is symmetric in spin and isospin. The Σ has its nonstrange quarks coupled the isospin one and therefore also to spin one. Thus, in the Λ the spin of thenonstrange quarks is zero and the spin of the hyperon is entirely given by the spin of the strange quark. In the Σ the nonstrange quarks are coupled to spin one and the spin of the spin of the strange quark must be antiparallel to the total spin in order to give a spin of one half. Because of the spin couplings it turns out to be much easier to change a neutron into a Λ than a Σ^o in a strangeness-changing transition described by the additive quark model where one active quark changes in strangeness and the other two quarks are spectators and their spin and isospin couplings remain unchanged. These predictions of the additive quark model for strangeness changing scattering processes are generally in strong disagreement with experiment.[1,2] The reason why the additive quark model breaks down in the strangeness changing reactions when it works so well elsewhere is not understood. Further data on hyperon transitions may provide the answer.

The magnetic moments of hyperons are determined by SU(3) from the values of the neutron and proton magnetic moments. However, there are ambiguities due to SU(3) symmetry breaking which appears in the mass differences within the baryon octet and also between the strange and nonstrange quarks. The ambiguity arises because the unit of magnetic moment, the magneton, contains a mass factor and it is not clear which mass should be used. If quark magnetons are used, is the magneton of the strange quark different from that of the nonstrange quark? Does the magneton of a nonstrange quark depend on the mass of the state in which it is bound; i.e. is it different for a nonstrange quark in a nucleon and a nonstrange quark in a hyperon? These questions can be answered by precise values of hyperon magnetic moments because the spin and isospin couplings are so different in different hyperons and provide different information. The magnetic moment of the Λ gives directly the magnetic moment of the strange quark since the nonstrange quarks are coupled to spin zero and give no contribution. The magnetic moment of the Σ^- is predicted by SU(3) to be equal to that of the Λ but in the Σ the strange quark spin is antiparallel to the total spin. Thus, if the strange quark magnetic moment is smaller than the SU(3) value because of its larger mass its effect will be in the opposite directions for the Λ and Σ magnetic moments where the strange quark contribution to the total moment is constructive and destructive respectively.

The predictions for magnetic moments of hyperons can be arranged in a hierarchy according to their sensitivity to SU(3) symmetry breaking mechanisms.[1] The simplest SU(3) and SU(6) predictions are:

$$\mu_{\Sigma^+} = \mu_p \tag{11a}$$

$$\mu_{\Sigma^-} = \mu_\Lambda = -\mu_p/3 \tag{11b}$$

These will be broken if the magnetic moment of the strange quark differs from its SU(3) value, for example because of mass differences.

The following relations hold even if the magnetic moment of the strange quark is different from its SU(3) prediction.

$$\mu_{\Sigma^+} = \frac{8}{9}\mu_p - \frac{1}{3}\mu_\Lambda = \mu_p - \frac{1}{3}(\mu_\Lambda + \mu_p/3) \tag{12a}$$

$$\mu_{\Sigma^-} = -\frac{4}{9}\mu_p - \frac{1}{3}\mu_\Lambda = -\frac{1}{3}\mu_p - \frac{1}{3}(\mu_\Lambda + \mu_p/3) \tag{12b}$$

These predictions for the Σ magnetic moments differ from the corresponding predictions (11) by a correction term which vanishes when the Λ magnetic moment is equal to its predicted value (11h). Since μ_Λ is equal to the magnetic moment of the strange quark, this additional term corrects for the SU(3) breaking in the strange quark magnetic moment.

The relations (12) assume that the nonstrange quark magnetic moment in the hyperon is the same as it is in the nucleon and is not affected by differences in mass or binding. If this assumption is not valid another relation is obtainable which is independent of this assumption about the magnetic moments of a nonstrange quark.

$$\mu_\Lambda = -2\mu_{\Sigma^-} - \mu_{\Sigma^+} \tag{13}$$

The right hand side of this sum rule is constructed to cancel the contributions from the nonstrange quarks. Thus, only the strange quark magnetic moment contributes to the sum rule which is a direct test of the spin couplings of the quarks in the Λ and Σ hyperons.

It would therefore be interesting to test these relations and see whether there is any systematic difference in the agreement with experiment of relations (11), (12) and (13).

Similar effects are predicted in the values of G_A/G_V for hyperons. At present values of G_V and G_A for hyperons are fit with theoretical predictions using the values of G_V and G_A for the nucleon as input and SU(3) symmetry,[15] with the D/F ratio as a free parameter adjusted to fit the data. When more precise values for hyperon decays become available, one can look for SU(3) breaking effects as in the magnetic moments, and also examine SU(6) quark model predictions to see if there is consistent systematics related to the failure of the SU(6) prdiction for the nucleon.

References

1. H.J. Lipkin, "Why Are Hyperons Interesting and Different from Nonstrange Baryons?", Particles and Fields 1975, Edited by H.J. Lubatti and P.M. Mockett, University of Washington (Seattle), p. 352.

2. H.J. Lipkin, Physics Reports 8C, (1973) 173.

3. R. Van Royen and V.F. Weisskopf, Nuovo Cimento 50A (1967) 617.

4. E.M. Levin and L.L. Frankfurt, L.L. Zhur, Eksperim. i. Theor. Fiz.-Pis'ma Redakt 2, (1965) 105; translation JETP Letters 2, (1965) 65; H.J. Lipkin and F. Scheck, Phys. Rev. Letters 16, (1966), 71; J.J.J. Kokkedee and L. Van Hove, Nuovo Cimento 42A, (1966) 711; See also F. Wagner, these proceedings.

5. P.B. James and J.M. Rawls, Phys. Rev. D4, (1971) 2017.

6. H.J. Lipkin, Nucl. Phys. B78, 381 (1974); Phys. Lett. 56B, (1975) 76; Phys. Rev. D11, (1975) 1827.

7. H.J. Lipkin, Z. Physik 202, (1967) 414.

8. J.L. Rosner, Phys. Rev. Letters 21, (1968) 950.

9. H.W. Atherton et al., Phys. Letters 42B, (1967) 522.

10. H.J. Lipkin, Phys. Review D7, (1973) 237 and 2262.

11. H. Harari, Phys. Rev. Letters 22, (1969) 562; J.L. Rosner, Phys. Rev. Letters 22, (1969) 689.

12. H. Harari, Ann. Phys. 63, (1971) 432; I. Ambats et al., Phys. Rev. D9, (1974) 1179; V. Barger, K. Geer and F. Halzen, Nucl. Phys. B44, (1972) 475.

13. C.W. Akerlof et al., Phys. Rev. Lett. 12, (1975) 631; Fermilab Single Arm Spectrometer Group, Phys. Rev. Lett. 35, (1975) 1195; G. Brandenburg et al., SLAC-PUB-1607, (1975). The data in Table 1 are taken from the

Fermilab Single Arm Spectrometer group, but data from all three experiments have been used to test relations (8) and (9) with similar results. The help of all three group in making data available before publication and computing preliminary tests of relations (8) and (9) is gratefully acknowledged, and in particular correspondence and discussions with D.D. Yovanovitch, R. Diebold, D. Leith and J. Mikenberg.

14. G.F. Chew and C. Rosenzweig, Nucl. Phys. B104, (1976) 290, propose a model in which SU(3) symmetry improves with increasing t.

15. J.M. Gaillard, These Proceedings.