ri classification (8) based on the quark model did not lead to any good results. Moreover, we learned from the U(3)⊗U(3) analysis of the mesons that the simple quark model does not fit into this picture. It is obvious that a mixture of representations must take place also in the mesonic case. Several of the SU(3) results as well as U(3)⊗U(3) selection rules for the mesons turned out to be in perfect agreement with experiment. We found a specific scheme to accommodate the $J_z = 0$ known mesonic states. In order to include possible higher states, one should enlarge the reducible representation. We saw that such an enlargement is essentially necessary in the case of the baryon resonances, and this fact makes the utility of the theory questionable.

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$_{\Lambda\Lambda}He^6$ DOUBLE HYPERFRAGMENT*

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An event has been found in an emulsion stack exposed to about 10^6 K^- mesons at 4 to 5 BeV which appears to be consistent with the production and decay of a $_{\Lambda\Lambda}He^6$ double hyperfragment. It confirms that double hyperfragments exist and confirms the value of the low-energy Λ-Λ interaction, first measured by Danysz et al.,[1] at some 4.6 ± 0.5 MeV.

Description of the event.—(1) Production: The event shown in Fig. 1 is initiated by a Ξ^- hyperon which is apparently captured at rest by a light emulsion nucleus producing only two products, which are collinear. Their ranges are 13.4 and 30.0 μ; the shorter track appears by inspection to be caused by a fragment of a higher charge than the other track. Assuming that the fragment initiating the two-star chain is a double hyperfragment, there are three interpretations involving double hyperfragments and a relatively stable recoil fragment which balance momentum, and which are consistent with the capture of a Ξ^- hyperon by a light emulsion nucleus.

These interpretations, shown in Table I, are $_{\Lambda\Lambda}He^6$ together with Li^7, $_{\Lambda\Lambda}He^8$ with Be^7, or $_{\Lambda\Lambda}Li^7$ with Be^{10}. The visible energies for each of these possibilities are 14.5, 18.3, and 23.9 MeV, respectively. The Q values for the nuclear capture of a Ξ^- hyperon giving two free Λ hyperons are negative except for the $_{\Lambda\Lambda}He^6$ possibility. The total binding energies of the Λ hyperons necessary to explain the measured visible energies are 10.9, 27.8, and 32.0 MeV, respectively.

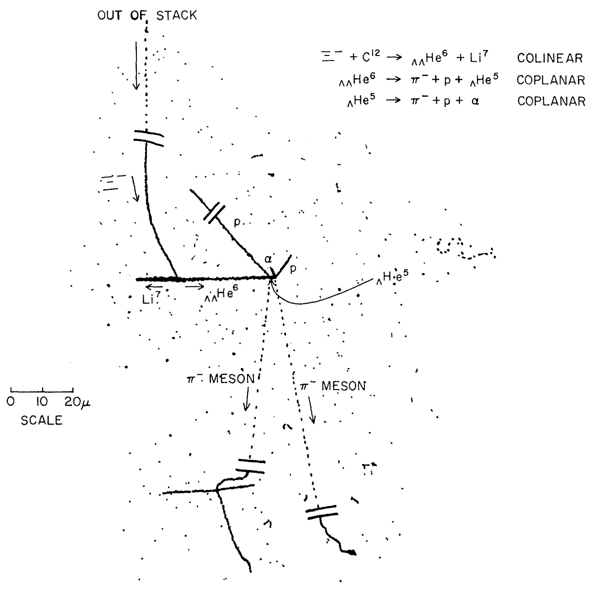

FIG. 1. Drawing of the event.

To evaluate the Λ-Λ interactions, the total Λ binding energy must be reduced by twice the Λ binding to the core, which is the Λ binding in ${}_{\Lambda}He^5$, ${}_{\Lambda}He^7$, and ${}_{\Lambda}Li^6$, respectively. The Λ binding is well known[2] for ${}_{\Lambda}He^5$ to be 3.1 ± 0.1 MeV; ${}_{\Lambda}He^7$ is known to exist in an isomeric state,[3] for which the binding energy can be 3.3 or 5.0 MeV; ${}_{\Lambda}Li^6$ has not been unambiguously observed. The European collaboration[2] has given one possible event with a binding of 4.5 ±0.6 MeV. Taking these values, we get Λ-Λ interaction energies of $(10.9-2\times3.1)=4.7$ MeV for ${}_{\Lambda\Lambda}He^6$, 21.2 and 17.8 MeV for the ${}_{\Lambda\Lambda}He^8$ hypothesis, and 23.0 MeV for ${}_{\Lambda\Lambda}Li^7$. Λ-Λ interaction energies as high as 17 MeV are not expected, and this would tend to support the ${}_{\Lambda\Lambda}He^6$ interpretation. Confirmation of this is obtained by consideration of the decay chain.

(2) The decay: The details of the double-hyperfragment decay are given in Table II. Again momentum appears to be conserved with the visible particles assuming ${}_{\Lambda}He^5$, a π^- meson (identified as such by the observation of a capture star at its stopping point) and a proton. With these three particles there is a total visible energy of 30.0 MeV, leaving 7.6 MeV for the ${}_{\Lambda}He^5$ Λ binding plus the Λ-Λ interaction. Thus, a value of 4.5 MeV is obtained for the Λ-Λ interaction—in excellent agreement with that obtained from the analysis of the production event, i.e., the decay is consistent with the production.

In the decay, the track of the ${}_{\Lambda}He^5$ cannot, of course, be identified as such because of its short range and, in fact, a different assumption (such as ${}_{\Lambda}He^6$ or ${}_{\Lambda}He^4$) does not seriously change the visible energy or the momentum balance. Looking now at the next step in the decay chain—the details of which are shown in Table III—we find that the three decay products are coplanar, and momentum appears to be balanced by the visible particles alone. The decay appears to be somewhat typical of ${}_{\Lambda}He^5$. However, the topology is bad since the α particle is too short for positive identification and could well be He^3; momentum would still balance and the binding energy of the Λ hyperon is not materially affected by the assumption—at 2.7 ± 0.6 MeV it is consistent with both ${}_{\Lambda}He^5$ and ${}_{\Lambda}He^4$, 0.4 MeV away from the best value for the former and 0.6 MeV too high for the latter for which the best value is 2.1 ±0.1 MeV.[2]

Discussion.—The single-hyperfragment decay is well identified as ${}_{\Lambda}He^5$ or ${}_{\Lambda}He^4$, although ${}_{\Lambda}He^6$ is not completely ruled out. Projecting

Table I. Possible interpretations for the production star which conserve momentum and are consistent with Ξ^--hyperon capture by a light emulsion nucleus.

Possible interpretations	Momenta (MeV/c)	Q Value to two free Λ hyperons (MeV)	Visible energy (MeV)	Total Λ binding (MeV)	$B_{\Lambda\Lambda}$ or Λ-Λ interaction (MeV)
$\Xi^- + C^{12} \rightarrow {}_{\Lambda\Lambda}He^6 + Li^7$	298 and 300	3.6 ± 0.4	14.5 ± 0.4	10.9 ± 0.8	4.7 ± 1.0
$\Xi^- + N^{14} \rightarrow {}_{\Lambda\Lambda}He^8 + Be^7$	356 and 358	-9.5 ± 0.4	18.3 ± 0.5	27.8 ± 0.9	21.2 ± 1.5 or 17.8 ± 1.5[a]
$\Xi^- + O^{16} \rightarrow {}_{\Lambda\Lambda}Li^7 + Be^{10}$	422 and 432	-8.1 ± 0.4	23.9 ± 0.6	32.0 ± 1.0	23.0 ± 2.2

[a]Isomeric state of ${}_{\Lambda}He^7$ exists.

Table II. Details of the first decay star. The hyperfragment is assumed to be ${}_{\Lambda}He^5$. A contrary assumption would not seriously change the momentum balance or visible energy.

Particle	Space angle with respect to the pion	Range	Momenta (MeV/c)	Energy (MeV)
${}_{\Lambda}He^5$	113°	2.1 μ	70	0.5 ±0.05
Pion	···	1.15 cm	88	25.4 ±0.4
Proton	133°	125 μ	88	4.1 ±0.05
				30.0 ±0.5

Table III. Details of the second decay star. The second track is assumed to be an alpha particle. It could well be He^3—this would not seriously change the momemtum balance or visible energy. If the proton were a deuteron, momentum balance would be disturbed, but it cannot be ruled out. ${}_{\Lambda}He^4$, ${}_{\Lambda}He^5$, and ${}_{\Lambda}He^6$ are all possible interpretations, although ${}_{\Lambda}He^5$ is the most likely.

Particle	Space angle with respect to the α particle	Range	Momenta (MeV/c)	Energy (MeV)
Pion	161°	18.2 mm	102	33.3 ±0.5
α particle (or He^3)	···	3.4 μ	80	0.9 ±0.05
Proton	67°	8.0 μ	36	0.7 ± 0.05

these uncertainties back into the decay of the double hyperfragment, we would have to have ${}_{\Lambda\Lambda}He^6$, ${}_{\Lambda\Lambda}He^5$, or ${}_{\Lambda\Lambda}He^7$ for the interpretation. The total Λ binding would not be materially affected if it were ${}_{\Lambda\Lambda}He^5$ or ${}_{\Lambda\Lambda}He^7$, as the track of the single hyperfragment is so short, and the momentum balance would also not be seriously affected. At production, however, we would have to have (a) ${}_{\Lambda\Lambda}He^7+Li^6$ or (b) ${}_{\Lambda\Lambda}He^5+Li^8$. While neither balances momentum (they are four standard deviations away), we can now also demand consistency between production and decay to eliminate ${}_{\Lambda\Lambda}He^5$ and ${}_{\Lambda\Lambda}He^7$. In case (a), from the decay, the Λ-Λ interaction is about 3.6 MeV (assuming that the Λ binding energy B_Λ in ${}_{\Lambda}He^6$ is 4.0 MeV); at production, at least 14.4 MeV would be visible. The Q value to two free Λ hyperons is −4.6 MeV. Assuming that B_Λ in ${}_{\Lambda}He^6$ is 4.0 MeV, $B_{\Lambda\Lambda}$ is at least 10.9 MeV, i.e., not consistent with the decay. In case (b), from the decay, the Λ-Λ interaction is about 5.5 MeV (assuming that B_Λ in ${}_{\Lambda}He^4$ is 2.1 MeV); at production, 15.1 MeV would be visible. The Q value to two free Λ hyperons is −14.9 MeV. Assuming that B_Λ in ${}_{\Lambda}He^4$ is 2.1 MeV, $B_{\Lambda\Lambda}$ is 25.8 MeV, i.e., not consistent with the decay. Neither alternative gives a consistent answer, so we may conclude that the event is uniquely described as the production and decay of ${}_{\Lambda\Lambda}He^6$.

The accuracy with which the production event gives the Λ-Λ interaction energy is basically limited by the errors in the Ξ^-- and Λ-hyperon masses. Values of 1320.8 ± 0.2 and 1115.4 ± 0.1 MeV have been used as given in the most recent compilation.[4] The nuclear masses were taken from the tables provided by König et al.[5] These hyperon mass errors lead to an irreducible error of 0.4 MeV. The error on the Λ binding in ${}_{\Lambda}He^5$ contributes another 0.2 MeV and the range straggling in emulsion contributes another 0.4 MeV, making a total of 1.0 MeV.

The plates involved have been calibrated, and the range-energy relationship used for the various heavy ions was generated by computer from the empirical form of the curve recently determined by Lou et al.[6] The curve does not differ seriously from that obtained by other workers in the field.[7-9] The range straggling adopted for the various tracks is that given by Barkas.[10] Measurement errors on the long tracks are negligible compared with the straggling error. However, for the heavy ions this is not so, and measurement errors of ±1 μ have been used for the Li^7 track (13.4 μ long), and for the $_{\Lambda\Lambda}He^6$ track, which is 30.0 μ long.

The decay event gives somewhat better accuracy for the interaction energy as there are fewer mass errors contributing. The visible energy in the decay is 30.0 ± 0.5 MeV. Most of this error is due to the pion range straggling. The Λ-hyperon Q value adds an error of 0.1 MeV. The total error on the value of 4.5 is thus 0.6 MeV. Combining the two independent determinations, 4.7 ± 1.0 MeV from production and 4.5 ± 0.6 MeV, we get a final result of 4.6 ± 0.5 MeV. As the $_{\Lambda\Lambda}He^6$ core has no spin, the question of the hyperon-core spin interaction does not arise. This value then is the true binding between the two Λ hyperons in $_{\Lambda\Lambda}He^6$.

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SEARCH FOR QUARKS IN THE FAR ULTRAVIOLET SOLAR SPECTRUM*

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The sharp emission lines in the range 200 to 1700 Å originate from regions of the sun where quarks may be found mainly as bound to the nuclei of carbon, nitrogen, and oxygen. Electronic transitions of such species are predicted and a search is carried out in the far uv solar spectrum.

As a possible explanation of the approximate SU(3) symmetry and the meson and baryon multiplets, Gell-Mann[1] and Zweig[2] have proposed a fundamental triplet of constituents, the fractionally charged "quarks" ($Q_{p'} = +\frac{2}{3}e$; $Q_{n'} = Q_{\Lambda'} = -\frac{1}{3}e$). The SU(6) classification[3] acquires a particularly simple interpretation in terms of the generalized Pauli principle in this model, although its predictions may be obtained with or without models. The higher meson and baryon resonances so far seem to fit quite well into the quark model with the introduction of orbital angular momentum,[4] $\vec{L}$, though here again many of the predictions seem to follow quite equally either from abstract group-theoretic[5] or Lie-algebraic methods or from specific dynamical models.[6,7] The question of whether such triplets do actually exist and are not just mathematical artifacts seems to acquire further significance as the dimension of the unitary irreducible representations of the groups grow, whereas models though crude retain a certain amount of specific calculational features.

A number of other integrally charged triplets have also been proposed[8,9] to get around the antisymmetric spatial wave-function difficulty of the ground-state baryon quark model. This involves a large number of constituent