REGARDING THEORETICAL WORK BY ERNEST STERNGLASS: An Alternative to Quark Theory

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SUMMARY {i.e., "ABSTRACT"}

Many years ago, before most of us were born, Dr. Ernest Sternglass (1923 --- 2015, Cornell University, B.S. 1944, M.S. 1951, Ph.D. 1953), demonstrated the possibility that the humble pi-meson might be composed of nothing but an electron-positron pair [ep-pair], in which the two little rascals (electron & positron) rotate [i.e., orbit] around each other in a very tight orbit [radius approximately 0.7 x 10^(-13) cm, (i.e., 0.7E-13 cm)], and each moves at almost the speed of light. Note that he came up with the basic idea expressed in Ref.#1 in the Caltech office of Richard Feynman, with Feynman's encouragement, and that Feynman had been one of his professors at Cornell.

At that time (1961) quark theory had not yet been proposed, which of course provides the currently accepted explanation for the structure of the pi-meson, according to the standard model of particle physics. Note that the **relativistic** electron-positron pairs in Sternglass's model are quite different from positronium, given that the electron & positron in positronium move at < 1/100 the speed of light.

Later during the 1960s Sternglass wrote papers which offered explanations for the structures of most of the then-known "particles" ----- although the word "particles" is misleading, given that most of these tiny objects live for only a tiny fraction of a second. In this essay we examine two of these papers, both from 1965.

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1. THEORETICAL CALCULATION OF ENERGY CONTENT OF TINY OBJECTS

According to Sternglass's model, all of the known tiny objects, such as K-mesons, eta-mesons, rho-mesons, omega-mesons, protons, neutrons, phi-mesons, lambda-baryons, etc. **[Refs.#2, #3]**, as well as various "excited hyperons" **[Table IV, Ref.#2]**, are composed of various molecule-like combinations of electron-positron pairs, along with unpaired electrons and/or positrons in some cases.

The proton, for example, is composed of four [4] electron-positron pairs and an unpaired positron at the center, while the neutron contains an additional electron **[Ref.#4].** All the electrons and positrons move at almost the speed of light; i.e., they are **relativistic** electrons & positrons, so they are quite unlike the electrons & positrons in positronium. In fact, Sternglass refers to the electrons in positronium, as well as the electrons in chemistry books, as "slow electrons" ----- to distinguish them from the speedy (relativistic) electrons & positrons in his model **[Ref.#4]**.

Note that Sternglass refers to the ep-pairs in his model as "pi-mesons" --- using the terms "ep-pair" and "pi-meson" interchangeably;
i.e., each ep-pair is a pi-meson, so a pair of pi-mesons is two ep-pairs. Note also that I will try to send out copies of Refs. #2 & #3 whenever I send out this essay, for the ease & convenience of readers.

In this essay we examine the "equation of state" given by Sternglass in two papers from 1965 **[Refs.#2 & #3]** to calculate numeric values for the theoretical mass/energy contents of various tiny objects, on the assumption that these objects are in fact composed of relativistic electrons & positrons, as Sternglass says.

In Refs. #2 & #3 Sternglass gives the equation of state as:

E(total) = (n + 2).(mass/energy of pi-meson) - sum of binding-energies of all pi-meson pairs + additional rotational-energy of excited state (Eqn. 1),

where "n" is the number of pi-mesons (i.e., ep-pairs) in an object. Note that the "ground state" of an object occurs when it doesn't rotate. When an object rotates, it has a greater mass/energy content, and is known as a "rotational excited state" of the object. In Eqn. 1, the sum of the first two terms gives the energy content of the ground state of an object; adding the (non-zero) third term gives the energy content of excited states.

Sternglass details structures which involve 2, 3, 4, and 5 ep-pairs, but (to keep it simple) in this essay we describe mainly structures composed of 2 and 4 pairs. Ironically, because the second term in the equation of state [Eqn. 1] carries a minus-sign, as it represents binding-energy, it's possible for an object composed of four ep-pairs to have a smaller mass/energy content than one composed of only two ep-pairs. Because an object composed of only two ep-pairs (i.e., only two pi-mesons) contains only one pair of pi-mesons, its equation of state is simpler:

E(total) = (n + 2).(mass/energy of ep-pair) - binding-energy of one pi-meson pair + additional rotational-energy of excited state (Eqn.1a).

In two papers from 1965 **[Refs.#2 & #3],** Sternglass used 140 MeV as the mass/energy content of each ep-pair, but in his 1997-book **[Ref.#4]** he states that the mass/energy content of these ep-pairs would be theoretically closer to that of 276.072 ordinary electrons, equivalent to approx. 141.07 MeV, so we use this numeric value in the following analysis.

2. BINDING-ENERGY CALCULATIONS

The second term of Eqn. 1 (and also of Eqn. 1a) refers to the total binding energy associated with all the pi-mesons in the object. Sternglass gives the binding energy associated with a single pair of pi-mesons as:

E(bind, single pair) = 2.274.K.Q.Q / (r).(e^(r/0.705E-13 cm)) [see his equation (1), Ref.#2], where "r" is the separation-distance between the two pi-mesons, "K" is Coulomb's electrostatic constant, "Q" is the electric-charge of an electron or positron, and "e" is the base of the natural logarithms, equal to approximately 2.718. Note that Sternglass expresses "K.Q.Q" in the "old-fashioned" way, as "e^2" ---(where the "e" has nothing to do with natural logarithms)--- and that in his equation (1), in Ref.#2, it's difficult to see that this "e" has an exponent of "2" attached to it.

Note also that "2.274" is equivalent to "4 / (fine-structure constant)" --- which is how Sternglass expresses it in his equation (1) in Ref.#2.

The second term of the equation of state is the sum of all the binding-energies associated with each pair of pi-mesons:

E(bind, total) = sum of { 2.274.K.Q.Q / (r).(e^(r/0.705E-13 cm)) } (Eqn. 2), where the symbols are defined as above.

One can visualize the meaning of the factor **e^(r/0.705E-13 cm)** above as follows: each ep-pair (i.e., each pi-meson) in an object is electrically attracted to every other ep-pair in the object, which means that there is a binding-energy associated with each pair of ep-pairs in the object. To calculate this binding-energy, one imagines pushing the ep-pairs apart until they are infinitely far apart. To do this, one uses the expression for the attractive electric-force between two pi-mesons (i.e., between two ep-pairs) and integrates it with respect to their separation-distance as this distance increases from its initial value "**r**" ----- to infinity. It's evident that, as the two pi-mesons move apart, the attractive force decreases, for two reasons:

(1) because their separation-distance increases, and,
(2) because the electrons and positrons in the two pi-mesons no longer rotate in synch with each other as they move farther apart, as Sternglass details on page 248 of Ref.#3. One might want to take some time to study Figure 4, on the same page, to better understand Sternglass's explanation for this.

3. ROTATIONAL-ENERGY CALCULATIONS

The rotational-energy of an excited state of an object is due to the fact that the entire object rotates around one or possibly two axes, designated as the a-axis and the b-axis. Refer to Figure 1, below, for details. Note that an object composed of only two ep-pairs has only one rotational-axis, the b-axis.

The third term of Eqn. 1 (and also of Eqn. 1a) refers to the rotational-energy associated with excited states of an object, where **J > zero.** Sternglass gives this as:
E(rotational) = [(h-bar)^2 / 2.(Mb)].[J.(J+1) + (Mb/Ma - 1).Jo^2] (Eqn. 3), where "h-bar" is Planck's constant divided by 2.pi, "Ma" & "Mb" are moments of inertia associated with an object as it rotates around its a-axis and/or its b-axis, and "J" and "Jo" quantify the magnitudes of the rotational energies associated with these rotations. See Sternglass's equation (2), and his explanation of it, on page 34 of Ref.#2, for more details.

One can combine Eqns. 1, 2, and 3:
E(total) = (n + 2).(mass/energy of ep-pair) - sum of { [2.274.K.Q.Q] / [(r).(e^(r/0.705E-13 cm))] } + [(h-bar)^2 / 2.(Mb)].[J.(J+1) + (Mb/Ma - 1).Jo^2].

On page 34 of Ref.#2 Sternglass gives the separation-distance between two ep-pairs (i.e., between two pi-mesons) as **r = h-bar / (mass of pi-meson).(c),** (where "**c**" is the speed of light), which is equivalent to 1.41E-13 cm, (1.41 femtometers), where he characterizes the separation distance as "d" rather than "r". Plus, as already mentioned, we use (276.072).(rest mass of electron) as the mass/energy content of the ep-pair, equivalent to 141.07 MeV. Inserting these numeric values into the equation above, one obtains:

E(total) = (n + 2).(141.07 MeV) - sum of { [2.274.K.Q.Q] / [(1.41E-13 cm).(e^2)]} + [(h-bar)^2 / 2.(Mb)].[J.(J+1) + (Mb/Ma - 1).Jo^2] (Eqn. 4).

Note that **e^2 = approx. 7.39.**

4. THE TWO-PI-MESON OBJECT

As already mentioned, for an object composed of only two pi-mesons the equation of state is simpler:
E(total) = (n + 2).(141.07 MeV) - 2.274.K.Q.Q / (1.41E-13 cm).(e^2) + [(h-bar)^2 / 2.(Mb)].[J.(J+1)] (Eqn. 4a),
where "Mb" (moment of inertia around b-axis) is defined as **Mb = [mass of object].[(r/2)]^2.** In this analysis, we use
(mass of pi-meson) = (276.072).(rest-mass of electron) = approx. 2.515E-25 gram.
Because the object consists of two pi-mesons, its mass is (2).(2.515E-25 gram) = 5.030E-25 gram, so its moment of inertia is given by: **Mb = (5.030E-25 gram).[(1.41E-13 cm)/2]^2 = 2.50E-51 gram.cm.cm.**

One can now use Eqn. 4a to calculate a theoretical numeric value for the mass/energy content of an object which is composed of only two ep-pairs, i.e., of only two pi-mesons. Because there are only two ep-pairs, **n = 2.** Using numeric values mass/energy of ep-pair = 141.07 MeV =

2.26E-4 erg, K.Q.Q = 2.307E-19 gram.cm.cm.cm/sec.sec, **r** = 1.41E-13 cm, h-bar = 1.0546E-27 gram.cm.cm/sec, and Mb = 2.50E-51 gram.cm.cm, one obtains:

E(total, 2-pi-meson object) = 488.6 MeV + (138.9 MeV).[J.(J + 1)]   (Eqn. 5).

As Sternglass explains on pages 34 & 35 of Ref.#2, **J** can have integer-values 0, 1, 2, ... ; **J = zero** describes the ground state of the object, i.e., its lowest energy level, while larger values of **J** describe "rotational excited states" of the same object. So, when **J = zero,** the theoretical mass/energy content of the 2-pi-meson object is approx. 488.6 MeV, which is very close to that of the K-meson. When **J = 1,** the mass/energy content of the object is approx. 488.6 MeV + (138.9 MeV).(2) = 766.5 MeV, which is very close to that of the rho-meson. Thus, according to this model, **the rho-meson is just simply the first excited state of the K-meson,** while the K-meson is just simply two pi-mesons in a stable configuration with a separation-distance of approx. 1.41E-13 cm = 1.41 x 10^(-13) cm = 1.41 femtometers, as illustrated in Figure 4 on page 248 of Ref.#3.

In other words, in the first excited state of the K-meson, the two pi-mesons (i.e., the two ep-pairs) which compose it rotate around each other, end-over-end, at almost the speed of light, so the object has a greater energy-content, so physicists perceive it as a rho-meson rather than as a K-meson.

In the next higher excited state, where **J = 2,** one calculates a mass/energy content of approx. 1322 MeV. Note that this is close to the known mass/energy content of the mysterious and short-lived object known as the f0(1370), **[see, for example, Ref.#5],** which evidently had already been observed by 1963, as Sternglass says [pages 253 & 256, Ref.#3]:   the calculated 1322 MeV **"may be compared with the f0 resonance discussed by Veillet and co-workers [Ref.#6]."**

Note that Sternglass's numeric values for the energy contents of 2-pi-meson objects {see the first three lines of Table I, page 255, Ref.#3} are very close to those above, the differences being due to our choice of 141.07 MeV rather than 140 MeV as the energy content of each of the pi-mesons which compose the object. Note also that, as Sternglass details in Refs. #3, and #4, this variety of the neutral pi-meson is slightly heavier than the "spin-zero" variety of the neutral pi-meson, because its total angular momentum is one, not zero.

5. THE FOUR-PI-MESON OBJECT

Sternglass says that there are two possible structures for the pi-mesons which compose a 4-pi-meson object, namely, **"planar**" or "close-packed, and **"tetrahedral"**.
See Table I, Ref.#3 for details. For simplicity, we examine only the 4(pi) planar structure here.

Sternglass's formula for the energy content of the "planar" type of 4-pi-meson object is:

E(total) = (3.50).(mass of pi-meson).(c^2) + (1/2).(mass of pi-meson).(c^2).[J.(J + 1) - (1/2).(Jo^2)].

Converting (mass of pi-meson).(c^2) to say 140 MeV gives:

E(total, 4-pi-meson planar) = 490 MeV + (70 MeV).[J.(J + 1) - (1/2).(Jo^2)] (Eqn. 6).

Thus, in the lowest energy state, where **J = zero** and **Jo = zero**, the 4-pi-meson planar object has a theoretical energy content of approx. 490 MeV, which is very close to that of the K-meson. As with the 2-pi-meson object discussed above, the ground state of this 4-pi-meson object seems to be a K-meson. As Sternglass notes:

"Inspection of Table I [Ref.#3] shows that the ground states (J = 0) of the 2-pi, 3-pi close-packed, and 4-pi planar structures all give mass values very close to the K-meson mass. This largely accidental mass-degeneracy could therefore account for the fact that there are three different major decay modes of the K-meson ... Thus, it appears that there may be three different particles, all of which have a mass close to the K mass, which could account for the difficulties in understanding the K-meson decay modes" [p.256, Ref.#3].

This writer remembers reading a book in which one of the chapters was titled "The Crazy Kaons"; perhaps this explanation from Sternglass helps explain why the little rascals seem so "crazy" ??

For the next higher energy state of the 4-pi-meson planar object **(J = 1, Jo = 0)** Sternglass's theoretical mass/energy content is given by:

E(total, 4-pi planar, J = 1, Jo = 0) = 490 MeV + (70 MeV).(2) = approx. 630 MeV.

This reduces to approx. **595 MeV when Jo = 1.**

When **J = 2** and **Jo = 0,** the calculated theoretical energy content is approx. **917 MeV**, which reduces to approx. **882 MeV when Jo = 1;** both of these are close to the known energy content of the K-meson resonance known as the K* vector-meson, given as 891.66 MeV for the charged variety and 896.00 MeV for the neutral variety. See Sternglass's Table I, page 255, Ref.#3: these two little rascals appear on lines 13 & 14.

When **Jo = 2,** the calculated theoretical energy content is approx. 777 MeV, close to that of the rho-meson. We see here a glimpse of the possibility that there might be a second variety of rho-meson composed of four pi-mesons, in addition to a variety composed of two pi-mesons, as already discussed.

At an even higher energy level, **J = 3** and **Jo = 0,** we have another glimpse at the mysterious and short-lived object known as the f0(1370) [see **Ref.#5**], with a calculated weight of 490 MeV + (70 MeV).(12) = approx. 1330 MeV.

Summarized below are Sternglass's results for the energy contents of the various 4-(pi)-planar systems, as they appear in the Tables 1 of both Refs. #2 & #3, along with the slightly different numbers which the present writer calculated, based on using a slightly different numeric value for the mass and energy content of the pi-meson, as explained above. As one can see, there is good agreement between the numbers. Plus, one can say that the present writer's numbers are slightly more accurate due to his choice of 276.072 times the rest-mass of an electron as the pi-meson mass, which Sternglass stipulates in his book [Ref.#4], saying that it's based on quantum theory.

TABLE 1: THEORETICAL MASS/ENERGY CONTENTS OF VARIOUS PLANAR FOUR-PI-MESON OBJECTS

J	Jo	Sternglass's results	Present writer's results	Comments
0	0	490 MeV	496 MeV	K-meson, given as 493.7 (charged) and 497.6 (neutral);
1	0	630 "	635 "	
1	1	595 "	600 "	
2	0	910 MeV	913 MeV	
2	1	875 "	878 "	
2	2	777 "	774 "	rho-meson, given as 775.5 MeV;
3	0	1330 MeV	1330 MeV	close to mass of f0(1370) [Ref.#5];
3	1	1295 "	1295 "	
3	2	1190 "	1191 "	
3	3	1015 "	1017 "	phi-meson, given as 1019.5 MeV;
4	0	1890 MeV	1885 MeV	
4	1	1855 "	1850 "	
4	2	1750 "	1746 "	
4	3	1575 "	1572 "	
4	4	1330 "	1329 "	close to mass of f0(1370) [Ref.#5];

CONCLUSION

Obviously Sternglass was onto something significant during the time from 1961, when he published his "main paper" {as he described it to me} in one of the most respected physics journals, **The Physical Review Journal** [Ref.#1]; until 2001, when he published the second edition of his book, **Before the Big Bang** [Ref.#4]. Hopefully this essay will inspire others to want to learn more about his work. The present writer could never in a million years have figured any of this out. The model described in this essay is in fact an alternative to the "quark" model, and gives accurate theoretical values for not only the energy content of many mesons, baryons, and hyperon resonances, but also predicts their lifetimes, spins, and decay modes with uncanny accuracy. See Refs.#2 & #3 for details.

REFERENCES

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(5) CERN internet-site: **https://geant4-userdoc.web.cern.ch/geant4-userdoc/UserGuides/ForApplicationDeveloper/html/AllResources/TrackingAndPhysics/particleList.src/mesons/index.html** { a list of tiny objects which you never heard of }.
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