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Hidden baryons: The physics of Compton composites

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Abstract – A large fraction of the mass-energy of the Universe appears to be composed of Compton composites. How is it then that these composites are not frequently observed in experiments? This paper addresses this question, and others, by reviewing recent publications that: 1) introduced Compton composites, 2) showed how and where they are formed and 3) explained how they interact with other systems. Though ubiquitous in many physical situations, Compton composites are almost completely *hidden* in experiments due to their unique interaction characteristics. Still, their presence has been indirectly observed, though not interpreted as such until recently. Looking to the future, direct-detection experiments are proposed that could verify the composites' components.

It is with deep sadness that I dedicate this paper to my mentor, collaborator, and friend, Dr. John R. Reitz, who passed away within days of the publication of our paper "Compton Composites Late in the Early Universe".

Introduction. – Over the past several decades, there have been a number of experimental observations that appear to be difficult to interpret within our present understanding of atomic, nuclear, and cosmological physics. Many of the observations have been viewed as paradoxical, controversial, or even fabricated. Heat producing electrochemical experiments, later called (incorrectly) "cold fusion", is one such example. These experiments in the late 1980's were a starting point for thinking about composite particles, primarily hydrogen nuclei and electrons. Could some composite systems have been overlooked in the early days of developments in atomic and nuclear physics? In attempting to answer this question my late colleague, John Reitz, and I uncovered some early publications of Barut [1,2]. Barut thought that it was somewhat strange that most of our well-studied physical composites, *e.g.*, atoms, resulted from electrostatic interactions at large distances while neglecting magnetic interactions at short distances. When considered at all, magnetic interactions were treated as perturbations to electrostatic interactions. We wondered if perhaps there might be resolution of some of the above-mentioned paradoxes if magnetic and electric forces were considered on an equal footing.

Because many readers will not be aware of Compton composites, this review begins with a brief "classical" picture of one important composite and its configuration. John and I had examined a number of different ideas but discarded them because they conflicted with otherwise well-known physics. But, after recalling Barut's point of view, we started to examine composite models consisting of a nucleon and two electrons that might form bound states different from, but in some ways similar to, atoms. After a few false starts, this point of view eventually led us to examine a class of bound-state systems that we called Compton composites; we first described these in [3]. In that paper, we introduced the most important composite, the *tresino*, as it is composed of *three* common particles. This review shows how the *tresino* composite, and a few others, resolves a number of decades-old paradoxes and sets the stage for research in other areas of physics.

Figure 1 is a classical illustration of the tresino Compton composite. Needless to say, the quantum mechanics of a system of these three particles is a very difficult problem (a quantum mechanical model solution was presented in [3]). However, the basic physics formulation of this system is instructive and easily understood by considering the centrifugal force balance of one electron experiencing both electrostatic interaction with a nucleon (charge Z) and a second electron as well as the dipole-dipole interactions between the electrons. It is an example of a system

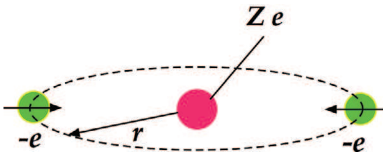

Fig. 1: (Color online) The classical tresino configuration with a nucleus of charge Z (in red) and two opposing dipole electrons (in green).

that treats both the electrostatic and magnetic fields on an equal footing with the two electrons considered to be strongly correlated. The classical centrifugal force on RHS electron is simply written as

$$F_e = \frac{Ze^2}{r^2} - \frac{e^2}{4\,r^2} - \frac{3\,e^2\,{\lambda_c}^2}{32\,r^4}, \tag{1}$$

where the first-term on the RHS is the electrostatic (attractive) force of the nucleon of charge Z, the second-term on the RHS, is the electrostatic (repulsive) force of the LHS electron, and the third-term on the RHS is the magnetic dipole-dipole (repulsive) force between the two electrons in terms of the electron Compton wavelength, $\lambda_c \approx 3.8 \times 10^{-11}$ cm. Setting the centrifugal force to zero, *i.e.*, no rotation, one calculates the bound-state radius and the binding energy to be given by

$$r_{bs} = \sqrt{\frac{3}{32\,(Z-1/4)}}\,\lambda_c; \quad E_{bs} = \sqrt{\frac{32\,(Z-1/4)}{3}}\,\frac{e^2}{\lambda_c} \tag{2}$$

with the tresino energy scale being set by $E_c = e^2/\lambda_c \approx 3.7\,\mathrm{keV}$. So, the result is a deep-well of about 11 keV for $Z=1$ and about 16 keV for $Z=2$; these are clearly deep bound-states when compared to hydrogen bound states. Our quantum mechanical model, presented in [3], results in a binding energy of $E_{bs} \approx 3.7\,\mathrm{keV}$ for $Z=1$ and $E_{bs} \approx 14\,\mathrm{keV}$ for $Z=2$. The proton, deuteron, and triton tresinos ($Z=1$) are discussed most often in this review. Importantly, note that the dimensions are at the electron Compton wavelength-scale; *i.e.*, quite small compared to, for example, the Bohr radius; this is a key point in why tresinos appear to be *hidden*, an aspect further discussed below.

Note that a proton (deuteron or triton) tresino ($Z=1$) has a net negative charge, whereas the helium tresino ($Z=2$) is charge-neutral. Furthermore, it should be obvious that, in a collision, a deuteron-tresino d^* is attracted to an ordinary deuteron electrostatically rather than being repelled by it, as in the usual *d-d* nuclear collision (from hereon asterisks* denote tresinos). Interestingly, the depth of tresino bound-states places them energetically intermediate between atomic binding energies (eV) and nuclear binding energies (MeV).

Recall that in the hydrogen atom an electron is trapped in its bound-state at 13.6 eV. To ionize the hydrogen atom, its binding energy must be supplied. In a similar fashion, the tresino can be ionized but to do so requires a much larger amount of energy to be supplied – its binding energy ≈ 3.7 keV. Hence, in low-energy interactions, tresinos remain unaffected by collisions with atomic and molecular systems, *i.e.*, it is quite robust with respect to collisions under normal conditions; this characteristic clearly plays a role in why Compton composites are generally *hidden*.

Formation energy and recoil. – Recall that hydrogen atom recombination proceeds when a free electron falls into the electrostatic potential of a proton, *i.e.*, into a hydrogen atom bound-state; the recombination process releases a photon to conserve energy and momentum. Given a high-density of free electrons (*e.g.*, in a metal) two electrons can simultaneously fall into the proton's electrostatic potential forming a tresino and thereby releasing its binding energy. Although possible, this formation process is very infrequent because: 1) tresinos do not have excited states and 2) possible electron spin-misalignment. On the other hand, tresino formation on a proton that is in close proximity to another atom/ion will be more frequent, as we first discussed in [4]. An atom/ion close to a proton may "donate" two electrons to the proton in a single formation event. In this case, the binding energy thereby released ≈ 3.7 keV is distributed to the newly formed tresino and the donor atom/ion —see fig. 2(a). Thus, there are now two recoiling particles with keV kinetic energies that may then collide with other atoms or ions and the newly acquired kinetic energy may be spread around among other particles. In the formation of a proton or deuteron tresino in the Earth, it appears that the most probable electron donors are O^{2-} ions. These ions are ubiquitous in common clay materials (*e.g.*, zeolites) in the Earth and the protons from acidic water. So the result of a single tresino formation event is that two ions or atoms are given a substantial energy "kick", *i.e.*, recoil kinetic energy.

Another tresino formation collision was described in [5]; this collision process is illustrated in fig. 2(b). Here, a three-body scattering resonance (we called a *ptre*, short for proton-tresino, composed of two protons and an electron), is impacted by a second electron releasing the binding energy as recoil kinetic energy to the tresino and the second near-by proton. The result, in this case, is that both the newly-formed tresino and proton each recoil with roughly half of the tresinos binding energy. Both of the formation collisions are conceptually simple but are extremely difficult many-body quantum mechanical problems.

In both formation processes, the interaction deposits the binding energy not via photon emission, but by the release of recoil kinetic energy to two-charged particles, one of which is the tresino, as illustrated in fig. 2(a). This situation starts a process by which many such formations, both on protons and deuterons in sea water, generates large amounts of thermal energy release in the Earth both directly in the formation process itself and later indirectly

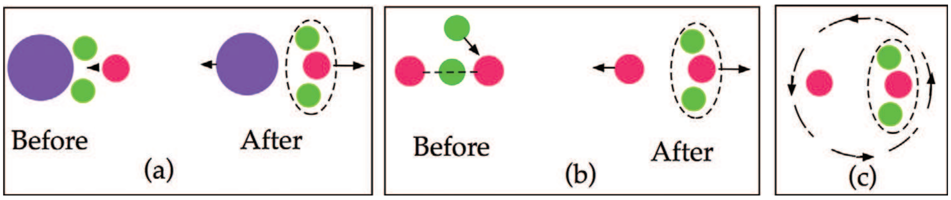

Fig. 2: (Color online) (a) The proton-tresino formation on an O^{2-} ion (purple) protons (red) and electrons (green). (b) Proton-tresino formation in an electron collision with a *ptre* with the same color coding (see text for explanation). (c) A proton-tresino molecule (PTM) or rotor with the same color coding.

through a d^* tresino-driven nuclear reaction chain initiated by the formation of the deuteron-tresinos. In [4], we showed that the largest portion of the heat generated in the Earth comes from the formation of proton tresinos not from Uranium and Thorium alpha-particle decays because there are so many more protons than deuterons in sea water (by about 6600). However, even though small, this number of deuterons initiate a deuteron-tresino reaction chain that generates both ^{3}He and ^{4}He. In this picture of energy generation in the Earth, there are no *sequestered* sources of either helium nuclides required, a common geophysical explanation for the observed helium isotopes released from the Earth. Thus, the small amount of deuterium in sea water resolves the otherwise paradoxical geophysical observations of the heat and helium isotopic generation paradoxes.

Tresino energy release in the Earth allows for steady low-level energy release but also for very large explosive releases (*i.e.*, volcanoes) when large numbers of tresinos are formed at roughly the same time. Volcanoes release not only the energy driving the explosion but also the tresinos that produced it. But then what has happened to the tresinos that have been released? The answer is that they are neutralized by pairing-up with available protons to form charge-neutral *rotors* as illustrated in fig. 2(c). Note that the rotors have the same mass as hydrogen molecules and therefore they are not retained in the atmosphere by gravity, *i.e.*, the rotors disappear from the Earth into space just like hydrogen molecules do.

Tresino phase transition cosmology. – In our early work on Compton composites, we recognized an important characteristic of tresinos: they had no excited states. So tresinos would not support radiative interactions either in emission or absorption. The lack of excited states further suggested a possible connection to the mysterious *dark matter* in cosmology. But to understand such a connection, we had to develop a cosmological model in which the tresino phase transition could be examined quantitatively. Proceeding on this path eventually led us to a modification of the big-bang theory of the Universe —see [5]. The modification included the tresino phase transition that, in turn, gave rise to new interpretations of both *dark matter* and *dark energy*.

Our tresino phase transition cosmology indicated how, at about three hundred years after the big-bang, an equilibrium early Universe plasma transformed most of the protons and ^{4}He nuclei into their respective tresinos and a small amount of ordinary matter plasma as well as generating a few other low-Z nuclides, all occurring via collisions during the tresino phase transition era. In addition, we showed that many of the protons and proton-tresinos created during the transition later came together in a different configuration also through collisions. Many of the protons and proton-tresinos, attracted to each other, ultimately paired-up by rotating around each other and radiatively spun-down to a minimum size becoming *dark rotors* —see fig. 2(c). After examining the interactions, or rather lack thereof, it was clear that the rotors could be the unseen so-called, dark matter as indicated in astrophysical observations. Yet, the dark rotors are not completely unobservable as discussed in the "Direct-detection experiments" section.

In my recent paper [6], I showed that about 25% of the protons and proton-tresinos created during the phase transition can be understood as a result of collision dynamics in a central-force problem (familiar in celestial mechanics) in the p-p^* collisions. Those collisions that result in circular or elliptical orbits will eventually spin-down to form dark rotors. Some of the remainder may still be spinning-down after the tresino-transition era. Those protons and tresinos that have not collided may be dispersed into cosmic structures acting as gravitational centers that may later form into galaxies of normal matter stars —see [6]. The just-mentioned components (incompletely spun-down rotors, free protons, and free proton-tresinos) appear to be present and probably account for the missing mass-energy fraction that represents *dark energy* in our critically-dense cosmology. The large number of dark rotors created at the tresino-transition have essentially *hidden* a large fraction of the matter in our present Universe. Each dark rotor, fig. 2(c), has two protons and is mostly unseen in astrophysics except for their gravitational effects. Even so, indications of the rotors presence was noted in their rotational radiation after having been "spun-up" by near-by energetic astrophysical sources and re-radiating this energy as we discussed in appendix D of [5]. Some other direct astrophysical observations of the dark rotors have been discussed in my recent paper [6]. Specifically, weak rotational absorption effects of the rotors in the late Universe including the attenuation of optical signals from distant supernovae.

So, our tresino phase transition cosmology has identified all of the matter and energy from the early Universe to the present and is in agreement with most astrophysical observations.

The solar corona. – A totally unexpected result was uncovered after deriving the equilibrium plasma conditions at the tresino phase-transition late in the early Universe. We found that roughly the same plasma density and temperature conditions obtained at the base of the solar corona. Interestingly, this solar region had already been designated as the solar corona *transition region* due to the obvious change of plasma conditions in this region. Remarkably, the tresino transition provides the required extra energy input to heat the corona. The energy source of the heating of the solar corona has been a decades-old paradox. As noted in [6], the escape kinetic energy of a proton (or tresino) from the solar surface, is about 2 keV. So, the escape kinetic energy is quite close to that delivered to both particles during tresino formation. Thus the energy input at the base of the corona not only delivers the required energy but also releases the charged-particle streams, of protons and proton tresinos, at close to their escape velocities, carrying along the attendant currents and magnetic fields.

Given the solar corona observations, the turbulent magnetic fields and currents, what might these same dynamics have to say about the tresino phase transition late in the early Universe? This question was examined in my recent paper [6]. The tresino phase transition at the base of the corona generates very large fluxes of both protons and proton-tresinos whose magnetic fields interact with each other and with the solar dipole magnetic field. The interaction gives rise to magneto-hydrodynamic turbulence, enormous eruptions, and the solar wind, all having been observed, but not well-understood for decades.

So, it appears that the tresino phase transition, at the surfaces of certain stars, is now converting the $\approx 5\%$ of ordinary matter in stars that had initially not been converted to dark matter in the early Universe, is now doing so at this much later time. Therefore, the remaining normal hydrogen in today's stars may ultimately become either dark rotors or free-streams of protons and proton-tresinos similar to that in the solar corona.

Dark rotors. – In most formation situations, tresinos eventually collide and pair-up with a proton. The p-p^* pair, held together by a balance of electrostatic and centrifugal forces, eventually spins-down to the ground state becoming a dark rotor —fig. 2(c). The rotors are charge-neutral and very small ($\approx 14\,\lambda_c$). At this size (about a tenth of the Bohr radius) they easily escape atomic-scale materials or plasmas in which they are formed. Furthermore, having no charge, they do not interact with close-by atoms, ions, or molecules. These characteristics naturally bring to mind the most famous "*ino*", the neutrino, that also reacts very weakly with usual nuclear systems, but for a different reason. Namely, the neutrinos have very small interaction cross-sections with nuclei. On the other hand, for rotors the interactions are also quite weak but the rotors escape not because of a small interaction cross-section, but rather by essentially passing through atomic systems, at most exchanging a small amount of momentum but otherwise moving freely. Note that the rotors are quite stable requiring a few hundred eV to break them into their composite parts, a proton and a proton-tresino. To break the tresino itself apart, its binding energy ≈ 3.7 keV would have to be delivered to it. So the rotors are clearly quite robust in most collisions with other atoms, ions, or molecules, certainly under usual laboratory situations. Also, because the rotors are so light, they quickly equilibrate to the temperature of their surroundings as they continue to stream through them.

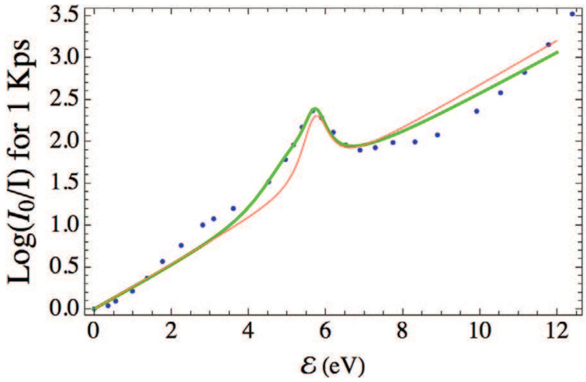

Fig. 3: (Color online) The least-squares data fits: the red curve is the one-level fit, the green curve is the two-level fit.

As previously noted, the tresino phase-transition and some secondary nuclear reactions are the energy source driving volcanic eruptions. Here again, most tresinos and protons pair-up as p-p^* and spin-down to form rotors. What happens to these rotors was also answered above; they escape the Earth's atmosphere as do hydrogen molecules. With the same mass as H_2 they are too light to be retained by Earth's gravity and so they escape into space.

It is clear that the rotors are able to absorb and re-radiate rotational energy just as molecular rotors do except at their own characteristic rotational frequencies. These are rotations of the entire rotor not the internal quantum rotation levels of the p-p^* pair. The latter levels have been considered in my recent paper [6] and are mentioned briefly again here. The extinction model represents the quantum rotational level jumps of the rotor's internal constituents (p and p^*). In addition, there are extinction peaks due to the rotations of the rotor itself in the infrared region of the spectrum. The IR extinction peaks represent the compliment of the radiative emission peaks, the so-called "unidentified infrared bands", as we described in appendix D of [5].

Figure 3, taken from my recent paper [6], shows the absorption of light from distant stars as a function of photon energy. In particular it shows a well-measured "extinction bump" with a peak at 5.72 eV. This absorption peak is coincident with the dark rotor transition from its ground state to the first rotational excited state. The data points were taken from a classic paper on this 2175 Å extinction line. In the figure, the red curve is a least-squares fit to the data with only one excited level and the green curve is a least-squares fit assuming two adjacent levels. It is clear that the rotor extinction model is a reasonably good fit. From the data fitting of the resonances it was possible to extract the average rotor density over a kilo-parsec distance; the density obtained was between five and ten rotors per cm^3. It is interesting to note that at this density, if all of the rotor mass along the entire one kilo-parsec path was compressed to solid-density it would amount to a layer of only about 1000 Å thick.

Finally, in my recent paper [6], I showed that extinction from distant supernovae provides an alternative explanation to so-called *dark energy* that would have implied an accelerating Universe. Rotor extinction of supernovae light as a function its distance z in the late Universe was shown to match the observed data as closely as the so-called dark energy picture. It remains to be seen whether rotor extinction or the accelerating Universe is the correct interpretation of the reduction in the expected supernovae signal levels.

Direct-detection experiments. – It should be clear from the discussion above that there are two rather different situations in which tresinos, and therefore rotors, may be formed: 1) at very low densities, as in the solar corona ($\approx 10^9\,\mathrm{cm}^{-3}$) and 2) at very high densities, as in the Earth ($\approx 10^{23}\,\mathrm{cm}^{-3}$). Laboratory experiments at the very low densities appear to be nearly impossible because the densities required are below those achieved in the best vacuum systems. However, experiments in space may be accessible but, of course, still very difficult. On the other hand, experiments at high-densities appear to have already been done but not interpreted as such; specifically, in the (so-called) light-water "cold fusion" electrolytic cells. In these experiments, the p-p^* rotors that are formed are readily lost from the experimental chamber after depositing some kinetic energy precisely because they have essentially no other interactions with atomic systems. But, in the (so-called) heavy-water "cold fusion" electrolytic cells deuteron-tresinos d^* may undergo nuclear reactions as discussed in Section III thereby enhancing the energy release substantially. The results of these two types of experiments were consistent with their respective p^* and d^* tresino origins —see [3].

Given the characteristics of rotors, it is perhaps obvious that direct-detection experiments will be difficult; finding a controllable source of rotors is the first big challenge. A rotor has a geometrical cross-section of only about $10^{-18}\,\mathrm{cm}^2$, a few orders of magnitude smaller than typical atomic cross-sections. Crossed-beam experiments could initiate collisions between rotors and a beam of energetic particles having kinetic energy greater than the rotor's binding energy (a few hundred eV) but less than the tresinos binding energy ≈ 3.7 keV. Some collisions could disassemble a rotor into its constituent protons and proton-tresinos. If the experiment was initiated in a magnetic spectrometer, this would allow separating and detecting both components individually, hence a direct-detection.

Rotor Sources I: In a laboratory setting, electrochemical cell sources appear to be a possible choice for forming a flux of rotors. Prior to entering the spectrometer, a magnetic field might be required to sweep-out other charged-particles from the cell-source leaving the charge-neutral rotors unaffected. This rotor source is likely to be difficult to control and obtain high rotor densities but appears to be accessible as a laboratory-scale source.

Rotor Sources II: Volcanoes on Earth produce and release a very large numbers of rotors during an eruption (see [4]). Of course, getting some detecting equipment into this stream of rotors will be a difficult task. One advantage, in this case, is that the source intensity should make some aspects of such an experiment, helpful. Here again, a crossed-beam type of experiment could disassemble and identify the rotor's constituent protons and proton-tresinos.

Rotor Sources III: Larger numbers of rotors are released in the corona of the Sun. Experimental observations in this environment, however, is also clearly a formidable challenge. Still, near-Earth detection might be feasible in an orbiting spacecraft equipped with the crossed-beam experiments as just described. Finally, in the far reaches of the solar corona, it may be possible to directly detect proton-tresinos separating them from the protons of the solar wind in a magnetic spectrometer.

Final remarks. – The tresino phase transition provides a straightforward resolution of a number of paradoxes that have been baffling for several decades. This paper has presented a summary of how the physics of the phase transition resolves a number of specific paradoxes. Still, many physicists have and will object because tresinos and rotors have not yet been directly detected. It remains to be seen if some of the experiments described in the preceding section (or others) can definitively, and directly detect tresinos or by disassembling rotors. There may be observations in other research arenas which might, in a similar way, be connected to the tresino phase transition. For example planetary volcanoes such as those on Io [7] and Enceladus [8]. However, for now this remains a speculation.

Another example of the possible role of the tresino phase transition is the recent observation that the d/h ratio from the comet 67P/Chuyumov-Gerasimenko by the Rosetta spacecraft [9] was shown to be considerably higher than the ratio found here on Earth. This possibility was anticipated in [4] because roughly one quarter of the energy released in heating the Earth originated from the deuteron-tresino chain reaction that consumes three deuterons in the process. The heating and reduction of the amount of deuterium in the early-Earth is described in my recent paper [10].

Finally, recall that many decades ago, understanding the physics of how the Sun generated its energy led to a number of important concepts to harness fusion reactions for power production. Likewise, reactor concepts using the energy production processes of the Earth should be considered after a detailed understanding of the various aspects of the tresino phase transition have been completed. These concepts could eventually allow building of power reactors that may be easier to design and construct than are present-day fusion reactors.

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