

Short communication

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The Phase-Transition Beneath the Solar Surface

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Abstract

This paper discusses the implications of the recently-identified composite particle (the *tresino* and its formation energy) on the unexplained heating and eruptions in the solar corona.

Keywords: Tresinos; Solar corona; Corona disturbances.

History & Background

As early as the 1990s, during discussions about energy production in the early universe, my late colleague John Reitz and I had uncovered the possibility of a new particle (i.e., a previously overlooked composite particle) in the early years of the development of atomic and nuclear physics. We felt that this oversight would have manifested itself in observations in various physical problems regarding energy generation. The formation of this composite particle, which we named the *tresino*, would result in the release of a significant amount of "binding" energy. Thereafter our research focussed on the implications of the energy released from the earth [1] and the implications relating to the energy in the Early Universe [2]. This paper examines the implications of *tresino* energy generation in the sun.

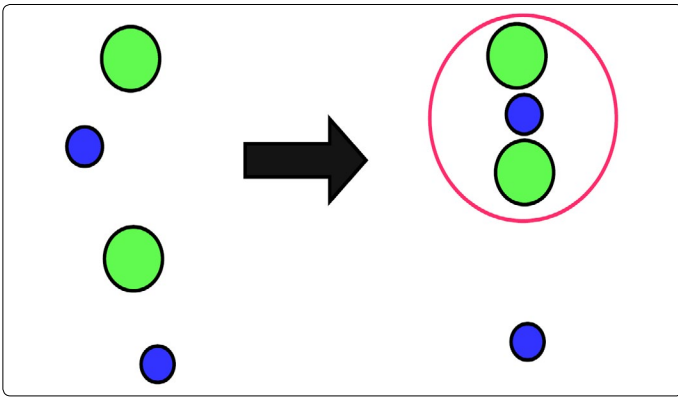
Solar Paradoxes

The most well-known solar paradox is how the corona can be so hot (≈ 100 eV) while the surface is so relatively cool (≈ 0.5 eV). Of course, there is an enormous amount of energy being produced by nuclear reactions in the solar core, but it has never been clear how these reactions could produce the high-temperatures observed in the corona. Years of magnetic field observations in the corona prompted many researchers to look to the magnetic fields as the energy source but this has generally turned out to be too difficult to understand and largely inconclusive. So, if there is some other source of energy powering the corona heating and disturbances, what might it be? This paper proposes that the phase-transition of the recently-identified composite particle (the *tresino*) may be that source.

Brief Comments about Tresinos and This Paper

As I mentioned above, my late colleague John Reitz and I began to realize many years ago that there was an overlooked set of Compton-scale composite particles, the most important of which is one that we named the *tresino*.

The illustration below shows the *tresino* transition as it forms out of the equilibrium hydrogen plasma (depicted on the left-hand side). In the illustration, protons are blue, electrons are green, and the *tresino* is shown with a red-circle around the newly-formed composite.



This picture shows the *baryon* density (here protons) changing through the transition from its plasma phase to the *new* phase where the protons and electrons change into nearly equal numbers of protons and *tresinos*. (Note: The illustration is similar in character to Figure. 4 of [3].

The reader will find several of our published papers on the *tresino* in the references, but briefly, the *tresino* is composed of two electrons bound to one proton; it was recognized as a "bound state" so, at formation, it would release its binding energy and would remain in this configuration unless or until the binding energy was in some way re-introduced. We had especially wanted to examine *tresinos* and the role they might play in the Early Universe [3]. This work later led to additional connections in other physics research arenas. In this early paper we developed a Baryon Phase Transition cosmology [6] that was so-named because of the *tresino* phase-transition. Furthermore, we needed to understand the equilibrium statistical-mechanics (Saha-Boltzmann Equilibrium Combination) for *tresino* composites [3] which, as will be seen below, is important in this paper as well. Note that the *tresinos* are composed of well-understood particles, electrons and protons, but in a new combination held together by well-understood forces that has broad implications.

Readers unfamiliar with Compton-composites or our theory of *tresinos* may find it useful to peruse my reference [5] about hidden baryons; and perhaps some of the references therein. *Tresinos* are held together in a balance between electrostatic attraction of two electrons to one proton at larger distances, and dipole-dipole magnetic repulsion, at shorter distances. Because the electrons are strongly correlated, the *tresino* composite is a resonant structure.

The origin of the present paper was initiated by a couple of questions that arose during a physics seminar soon after our first paper on the *tresino* phase-transition was published. One physicist asked "isn't this a new state of matter?" A second asked "wouldn't the sun be a good place to search for *tresinos*?" As it turned out, the answer to both of their questions is "yes". In fact, their questions inspired the present work even though I did not have the answers to their questions at the time of the seminar.

In [3] we had recognized and even mentioned that the plasma parameters at the phase-transition in the Early Universe were remarkably close to those of the solar transition-region; this closeness did suggest a possible connection between these phenomena. But examining the complexities of the solar corona didn't appear to be a fruitful direction to proceed at the time.

It's important for the reader to understand that, while the *tresino* phase-transition and the solar transition region, which have similar names and are connected, are distinct and separate. Finally, it should be emphasized that the formation of one *tresino* releases 3.7 keV of energy, a large amount on the scale of, say, hydrogen recombination. Therefore, a large number of *tresino* formations will yield large amounts of energy; this is a crucial observation of this paper.

Solar data expanded

After considerable searching, I found the excellent, highly-detailed paper by [4] that provided the data that were required to search for the *tresino* phase-transition in the sun - specifically the plasma parameters.

I thank Dr. Eugene Avrett (Harvard-Smithsonian Center for Astrophysics) and his colleague, Professor Petr Heinzel (Czech Academy of Sciences), for helping me construct a Mathematica-based computer file from the large tables of the Atmospheric Parameters for Model C7. This data file starts just above the corona through the solar transition-region to depths many kms below the surface. Figure. 1 is a plot of the data region examined in this work. Note that the index *n* refers to the row number in the C7 atmospheric data file and km is the depth beneath the solar transition zone at *n*=130, "generally considered to be the surface of the sun".

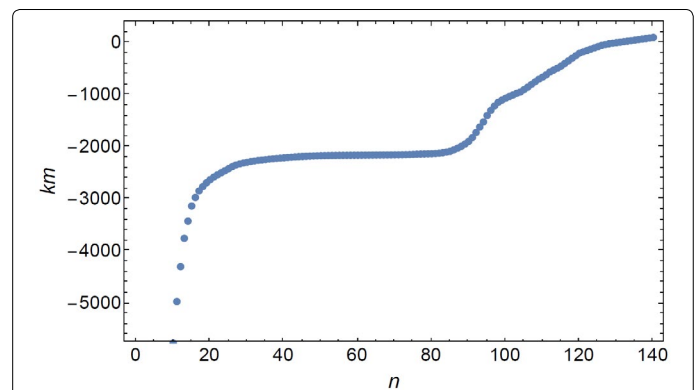


Figure. 1. Region of data showing the depth km vs. *n* of the C7 model.

Locating the Tresino Phase-Transition

The density and temperature data from the C7 model can be introduced into the Saha-Boltzmann equilibrium formula just as we did in the Early Universe calculation in [3].

$$\frac{x(2x-1)^4}{1-x} = \frac{7.4 \times 10^{99} e^{-3700/T_{ev}} T_{ev}^6}{n_o^4} \quad (1)$$

where $n_e/n_o = x$ is the ratio of electrons to hydrogen, $n_p/n_o = (2x-1)$ is the ratio of protons to hydrogen, and $n_t/n_o = (1-x)$ is the ratio of *tresinos* to hydrogen.

It is straightforward to choose values of *n* to obtain the plasma parameters for substituting in Equation (1) to see where the *tresino* phase-transition appears. The result of the search is presented in Figure. 3. Notice that the *tresino* phase-transition takes place at *n* ≈ 27. From Figure 1 or directly from the C7 data table it is found that this corresponds to a depth of about 2350 km and the plasma parameters at this location have $T_{ev} \approx 17$ and hydrogen density $n_o \approx 4700/\text{cc}$.

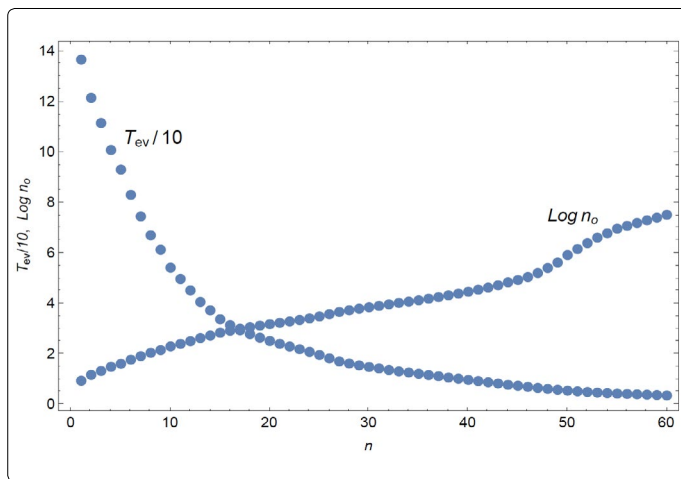


Figure 2. The combined plot of the temperature in eV and the hydrogen plasma density n_o over the region examined for locating the phase-transition.

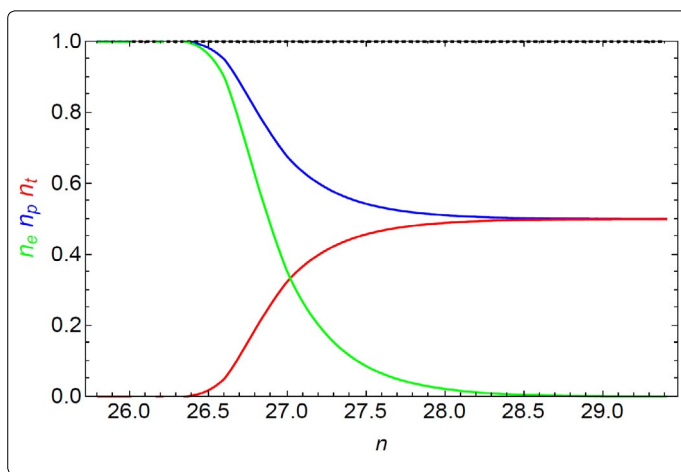


Figure 3. A plot presenting color-coded (normalized) densities of electrons, protons and *tresinos* located at the phase-transition.

Figure 3 shows that the phase-transition conserves the particle species as does the illustration presented above. This solar *tresino* phase-transition result may be readily compared to that of Figure 4 of [3]; although these two transitions are on very different time and space scales. It is quite interesting that during the *tresino* phase-transition in the Early Universe, the plasma density and temperature were indexed by z , the red-shift parameter, (essentially meaning how far away in time that it occurred). In the sun, however, it is indexed by n , the distance from the solar transition region (essentially how far away it was in space).

Tresino Phase-Transition Energies

The *tresino* phase-transition just presented was found to take place quite far under the solar surface. How this happens has to be discussed and understood. To me, the picture that seems most probable is that a large hydrogen plasma "bubble" is released from the sun's deep interior and drifts toward the surface. It finally arrives at the location of the *tresino* phase-transition and then releases the energy of the many transitions from hydrogen plasma into *tresinos*. The scale of this energy release can be enormous. The size will have to be on the order of many tens or hundreds of kms in radius. Recalling that each transition releases 3.7 keV, the

total energy release would have to be on the order of $(10^5)^3 \times 3.7 \times 10^3 \times n_t$ ev per km^3 where n_t is the number of *tresinos* generated. For the example presented in the sections above, the energy generated is somewhere between 70 to 95 kilojoules/ km^3 , assuming all of the hydrogen encountered was converted to *tresinos*. However, it seems quite likely that the hydrogen "bubble" would be many kms in transverse directions so the total energies would be many times, perhaps thousands to millions of times, larger. Recall that the energy released is found in streams of protons and *tresinos* as seen in Figure 3. The current streams will carry their associated magnetic fields as well as any entrained hydrogen plasma during its explosive expansion. In addition, the streams will be mostly unaffected by the overlying atmosphere of the sun due to its extremely low density. Hence, the streams and entrained plasma will reach into the solar corona and beyond producing solar flares and other disturbances we observe on the surface of the sun. As I had noted in [7], the kinetic energies of these charged-streams were either at or above the escape velocity of the sun. Furthermore the streams of currents would interact with each other as well as the ambient solar magnetic field as they drag some amount of background plasma along with them. Because of the large currents and magnetic energy involved, they give rise to the magnetohydrodynamic eruptions and chaos so often observed in the corona and above.

Finally, there will be a range of energies produced depending upon the sizes of the hydrogen "bubbles" in transverse directions. In the case of a smaller but continuous flow of "bubbles", a background heating of the corona would be expected; whereas, in the case of much larger "bubbles", the explosion of the outer solar material would produce the events generally referred to as coronal mass ejections.

In other words, the process of *tresino* formation and its energy generation, even though arising well below the solar surface, may explain the mysterious characteristics and behavior observed in the sun's corona and beyond.

Acknowledgments

I dedicate this paper to my mentor, collaborator, and friend Dr. John R. Reitz, without whose efforts this work would not have become possible.

Addendum: The Phase Transition at the Solar Surface

The *tresino* transition of the earlier pages was found deep under the solar surface in a region that had well resolved plasma quantities but it was not the only location wherein the transition is found. In particular, at the apply-named "solar transition region" it appears that the same phase-transition obtains there as well. But here the transition is much more abrupt (more like a "step-function") and is less resolved in the Avrett & Loeser data file. This addendum is provided in order to make clear how this occurs.

A 1. The Generalized Tresino Transition

Recall Eq.(1) that the tresino-transition takes the form:

$$\frac{x(2x-1)^4}{1-x} = \frac{7.4 \times 10^{99} e^{-3700/T_{ev}} T_{ev}^6}{n_o^4} \quad (2)$$

Let us consider the general case of Eq.(2). First, the left-hand side is required, but in order to simplify the solution, I average the LHS over the domain over which x varies, namely from 0 to 1 (actually 0 to 0.999 to avoid the singularity at $x = 1$). That average results in the LHS average value of 4.0541 for the general transition case. Then, solving Eq. (2) for n_o by taking the LHS equal to its average value results in:

$$n_o = 6.5363 \times 10^{24} \exp(-925/T_{ev}) T_{ev}^{3/2} \quad (3)$$

or in degrees Kelvin (K)

$$n_o = 5.231 \times 10^{18} \exp(-1.073 \times 10^7/K) K^{3/2} \quad (4)$$

Eq. (4) is a relationship between the hydrogen density n_o and the temperature (K) for the generalized tresino-transition that was sought.

A 2. Comparison with Model C7 Data

It is straightforward to compare the data in the Avrett & Loeser Model C7 at the solar surface (height ≈ 2100 km) as presented in their Figure 8. For heights below this point, the hydrogen density n_o is quite high and the temperature is quite low: this is not consistent with transition evaluation given by Eq.(4). But above this height, the temperature is quite high and the hydrogen density n_o is quite low. This can be noted in the plot below.

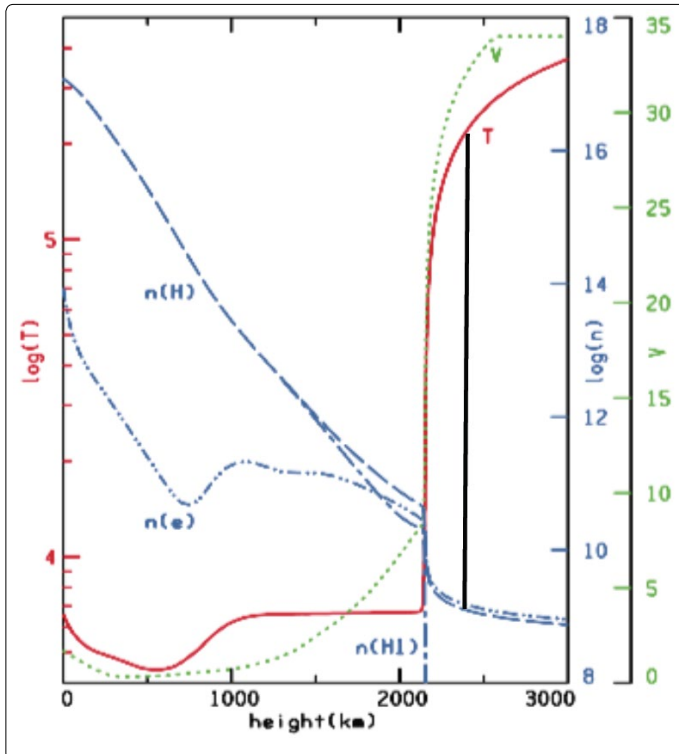


Figure 4. A reproduction of Figure 8 of Avrett & Loeser Model C7 where the (added) black-line represents a solution to the tresino-transition. Note, the transition is first completed at a point closer to the solar surface than indicated by the black-line.

The higher temperatures are a result of the transition delivering the extra energy to the outflow by converting the normal hydrogen plasma to tresino and proton streams while conserving the total numbers of electrons and protons in accord with the schematic presented at the beginning of this paper.

In summary, the tresino-phase transition has been shown to operate both deep under the solar surface as well as at the surface creating the "solar corona" producing the well-observed solar phenomena.

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