Does ionized matter exhibit a third kind of relativistic effect?

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Some Information about the Author:

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About the Discussion that Follows:

It pertains directly to the topics of *Gravity, Relativity, Dark Matter, Solar Neutrinos, Eclipsing Binary Stars.* I have divided the discussion into two parts: First, a nontechnical, plain-language summation, and second, the more formal, mathematical development itself.

Table 1 is on page 33, and there is a Final Note on page 34.

1. Plain-Language Summary

Background

The Sun is a typical star. There are about 10^{11} stars in the Milky Way, our own rather typical galaxy. One arrives at this number from the Milky Way's overall brightness, which is about 10^{11} times that of the Sun. So the mass of the Milky Way is estimated to be about 10^{11} solar masses. The Milky Way is often referred to as "the Galaxy," and a solar mass is often denoted by the symbol $m_{\odot}$. The mass of the Galaxy is thus about 10^{11} $m_{\odot}$. The stars in the Milky Way (and other typical galaxies) are spread out predominantly in a thin, circular disk. The disk, in turn, is contained in a "halo," a huge, roughly spherical volume of very thin, hot gas. There are extensive magnetic fields and cosmic rays (fast-moving nuclei and electrons) also throughout the halo.

The Problems

Dark Matter: Galaxies group into clusters. Our cluster – that is, the cluster in which the Milky Way is situated – is called the "Local Group" and has somewhat more than twenty members. They all move around one another, "orbiting," so to speak, under their mutual gravitational attraction.

By measuring the Doppler shifts of their light, one can infer the orbital speeds of the galaxies in our own Local Group and in other clusters of galaxies. From these speeds, along with distance estimates, one can from Newton's (or Kepler's) laws infer the masses of the galaxies. This process generally leads to surprising results: galactic masses are much larger than one would infer from the brightness of the galaxies. A typical galaxy like the Milky Way, in fact, appears to have about 10^{12} $m_{\odot}$ as inferred from its gravitational properties, or to be about 10 times too massive. The discrepancies are often much larger.

Hence the mysterious notion of "dark matter" has been introduced into astronomy: There must be something out there, comprising 90% or more of the mass of the universe, that so far we have been unable to see or detect other than gravitationally. The alternative solution would seem to be to modify our theories of gravity, Newton's gravitational law and general relativity. This, the question of the "dark matter," is the first problem that I take up. I don't modify these theories but rather the characteristics of the *spacetime* stage in which they are strictly correct. The need for "dark matter" is eliminated.

Solar Neutrinos: The second problem concerns the Sun. The Sun, as is commonly known, produces energy in its core by nuclear fusion. The rate of energy production can be accurately determined from measurements of sunlight at Earth. The rates of the nuclear reactions believed to be responsible for, or associated with, this energy production are then inferred. Some of these nuclear reactions emit particles called neutrinos. Since the nuclear reactions are presumably well understood, the Sun's rate of neutrino emission can be reasonably accurately predicted.

When the neutrino flux at Earth was measured some years back, however, there was a big surprise: it was only about one-third that expected. So the nearest star to us, the one we think we understand best, resists theoretical explanation. There are a number of tentative explanations extant that attempt to account for the discrepancy. They range from neutrinos that somehow "oscillate" into other kinds of neutrinos while in flight from the Sun, to a rapidly spinning mass at the Sun's center. None of them account for other phenomena. That is, they are all ad hoc –

and all have fundamental problems. My own approach accounts for the discrepancy as a gravitational effect, following from the alterations of space and time.

Eclipsing Binary Stars: The third problem treated concerns eclipsing binary stars. These are what you might expect: double stars whose orbital planes are viewed edge-on, so that the stars alternately eclipse each other as they go around. Because of the eclipsing effect, one gains otherwise unattainable information about the stars. The orbit in each case is an ellipse. Due to subtle tidal effects and, independently, due to subtle general relativistic effects, the ellipse's orientation (or the long axis of the ellipse) is expected to turn in the plane also – very slowly. The rates can be calculated, and for eclipsing binary stars, the combined rate for the two effects can be observed and compared with the summed theoretical predictions. Two binary star systems that have been extensively studied in this regard yield observational results that contradict the theories: in each case the ellipse is observed to turn much too slowly. No one doubts that this must be a gravitational effect – that is, no one who doesn't just wave it away with some set of circumstances contrived to save our present understanding of gravity. Most astronomers appear to be just ignoring the eclipsing-binary problem altogether.

This Theory

When matter is *extremely* hot, as in stars, it becomes completely ionized. That is, the electrons and nuclei separate and move independently. The theory proposes that space and time are scaled by ionized matter, and the amount of scaling, or the scaling factor, depends on the electron speeds and distances from the nuclei. This scaled space and time is then the stage for the matter's gravitational interactions. When matter is cool enough to be in the ordinary gas, liquid, or solid form, the scaling factor becomes unity, or one, and there is no effect. Otherwise, the scaling factor is either greater than or less than one, depending on the speeds and distances. The speeds and distances are here, as in other physical theories, conventionally represented by temperature and density.

It is assumed that, in the scaled gravitational spacetime, the speed of light remains unchanged. That is, it remains the familiar universal constant. This enables one to determine the *time* scaling factor to be just the reciprocal of the *spatial* scaling factor, which has earlier been obtained from the initial assumptions. This makes the theory rather a third kind of relativity because of the mathematical relationship (Lorentz transformation equations) between the two spacetimes, electromagnetic and gravitational. *The theory does not replace special or general relativity in its applications but, where called for, is used in addition to them.*

The Solutions

Dark Matter: Halo gas is mostly ionized hydrogen; it is also extremely thin and very hot. The electrons are thus comparatively far from the nuclei and moving very fast, which means that the scaling effects are substantial. Starting with reasonable estimates of the gas density, composition, and temperature, one calculates the scaling factors for the Galactic halo using the theory. Since magnetic fields and cosmic rays in the halo contribute substantially to the gas pressure (and temperature), they must be taken into consideration. It turns out that, for the Milky Way, the halo material *by itself* has a gravitational effect equivalent to that of about 10^{12} $m_{\odot}$. There is no need to postulate "dark matter."

Solar Neutrinos: The Sun, except for a thin layer at its surface, is made up of nearly completely ionized material, again, mostly hydrogen. The theory then leads to the conclusion that the gravitational pressure in the Sun's core is very slightly less than what it has been thought to be – which leads to slightly reduced temperatures and densities there. These in turn lead to rather appreciable reductions in the rates of the nuclear reactions responsible for the neutrinos that are measured finally at Earth, since the reaction rates are extremely temperature sensitive.

In solving the problem, the procedure followed is this: Scaling factors for the Sun are first calculated, and from them revised temperatures and densities for the core are obtained. From these, reduction factors for the reaction rates there are then calculated and applied to the previously published reaction rates. From the reduced rates, a revised neutrino count rate is obtained.

In light of the chain of complex computations that is required, the agreement between theory and observation that finally ensues is so good that it might be termed "stunning."

Eclipsing Binary Stars: This is largely a mathematical exercise. One first shows how the equations describing the orbital motion must be modified (scaled) when the space and time scaling are taken into consideration. The stars in question are at the "hot" end of the spectrum of stellar types, so the scaling effects are appreciable.

Using typical values for density, temperature, and composition in the interiors of these type stars, one gets the scaling factors. They are again composed mostly of hydrogen, a fact that greatly simplifies the theorizing at this early stage. The modified equations of motion then give “apsidal advance rates” (turning rate of an orbit in its plane) that agree nicely with the observations.

2. Formal Development

Does ionized matter exhibit a third kind of relativistic effect?

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Abstract: Special and general relativistic effects are manifested through direct changes in space and time measures. A number of current astrophysical problems suggest that there may be a third relativistic effect, associated with ionization. It is proposed that there are two natural measures of spacetime, gravitational and electromagnetic. For its gravitational interactions, ionized matter scales the former with respect to the latter. A quantitative model of the scaling is developed from simple basic assumptions analogous to those underlying special relativity. Introducing this scaling effect by means of suitable approximations into the theoretical treatments of the problems of “dark matter” in the Galaxy, “missing” solar neutrinos, and the eclipsing binary systems DI Herculis and AS Camelopardalis leads to agreement between theory and observation in each case, and with no additional assumptions. The theory has no adjustable parameters. A class of experiments to test directly for the effect is proposed.

1. Introduction

Years ago when I wrote the article on the concept of *force* for a popular encyclopedia, I was pleased to learn that the philosophical background was to be contributed by Max Jammer, a man whose work I greatly admired. His closing thought there has stayed with me: “Certainly [force] is not an illusion . . . . it enables us to discuss the general laws of motion irrespective of the particular physical situation with which these laws happen to be associated” [1].

Paradoxically, the underlying premise of this discussion is that the statement is false. I propose that ionized matter obeys altered laws of gravitation. The changes are introduced through a scaling of space and time at the atomic level by the ionized material. It is the failure to incorporate these differences of scale into theoretical treatments that gives rise to the well-known discrepancies between prediction and observation in the three classes of phenomena to be discussed: galactic dynamics, or the presence of what is presumed to be “dark matter”; the apparent deficit in solar neutrino production as observed at Earth; and the unexpectedly slow apsidal motion of the eclipsing binary star systems DI Herculis and AS Camelopardalis. An incorporation of the scaling effects as developed here leads to agreement between the corrected theory and observation in each case.

This is a preliminary investigation. It introduces quantitative evidence for an unanticipated electromagnetic effect. The problems selected share four simplifying characteristics: The gravitating bodies involved (1) are composed predominantly of hydrogen; (2) are nearly completely ionized throughout, to include helium and the more-abundant heavier nuclei such as oxygen; (3) may be treated as perfect gases in thermal equilibrium (composed of stripped nuclei and electrons); and (4) are very nearly spherically symmetric. The present discussion is restricted to problems displaying these characteristics. If there is in fact a connection at the quantum level between the electromagnetic force and gravitation as some have proposed (see e.g. [2, 3]), it is reasonable to expect that one might observe its effects under these conditions.

2. Development of theory

Gravitational effects originate ultimately within each atom. Our starting premise is that the electromagnetic characteristics of each atom, under conditions to be specified shortly, alter spacetime for it, but *only* with respect to the gravitational force. That is, there are two natural representations of spacetime: one electromagnetic, here to be denoted by E, and the other gravitational, to be denoted by G_*. When matter is ionized, E and G_* differ in scaling of time and distance.

Since only nondegenerate, fully ionized matter is considered, quantization of states is not a direct concern. Each atomic unit, that is, each nucleus and its neighboring electrons, scales G_* in terms of its own space and time dimensions. (Where it is helpful to make the distinction explicit, star subscripts will be used to denote variables evaluated in G_*.) For matter in bulk, the gravitational scaling factors are functions of the temperature T, the density ρ, and the elemental composition. If the temperature and density in a problem are static, the gravitational scaling factors are constant. Deductions from astronomical observations often involve employment of gravitational laws. When they do, it is implicitly assumed that E and G_* are the same. Thus astrophysical problems are a likely place for the effects to manifest and a good place to test the theory.

We begin by considering a fully ionized plasma at thermal equilibrium, consisting of hydrogen. Let *a* be a measure of the mean distance between electrons and protons, and v_e the RMS electron speed. We postulate that distances in E and G_* are scaled at the atomic level according to the relationship

$$\Delta r_* = \Delta r \gamma^{-1}. \quad (1)$$

As well as being dimensionless, γ is assumed to be a function of v_e and *a* and not singular at $v_e = 0$. We set $\gamma = \gamma(v_e, a)$, $d\gamma = (\partial\gamma/\partial v_e)dv_e + (\partial\gamma/\partial a)da$.

At fixed temperature T, $dv_e = 0$ and $d\gamma = (\partial\gamma/\partial a)da$. A simple solution meeting the above criteria is obtained by setting $(\partial\gamma/\partial a) = (v_e/c)(1/a)$, c being the speed of light. Then $(d\gamma)_T = (v_e/c)(da/a)$. Setting $\beta = v_e/c$ and integrating, $\gamma - \gamma_0 = \beta\cdot\ln(a/a_0)$. At $a = a_0$, a_0 taken to be the radius of the first Bohr orbit, we set $\gamma = \gamma_0 = 1$. Generalizing to elements of atomic number Z is accomplished by replacing a_0 with a_0/Z. The Debye-Hückel radius R_D is adopted as the measure of a. Finally, v_e is set equal to $(3kT/m_e)^{1/2}$, where k is Boltzmann's constant and m_e is the mass of the electron.

In summary, the gravitational scaling factor (GSF), $_j\gamma$, for element Z_j in a homogeneous plasma made up of elements of atomic number Z_i and atomic weight A_i, each with fractional mass abundance X_i, is

$$_j\gamma = 1 + \beta\cdot\ln(Z_jR_D/a_0), \qquad (2)$$

where $\beta = (3kT/m_ec^2)^{1/2}$, $R_D = (kTm_p/4\pi e^2\rho\zeta)^{1/2}$, $\zeta = \Sigma_i(X_i/A_i)(Z_i^2+Z_i)$, $a_0 = h^2/4\pi^2e^2m_e$, m_p is the mass of the proton, h is Planck's constant and e the charge of the electron.

It is assumed that the speed of light is the same in E and G_* and that the systems are related through a Lorentz transformation in vector form [4]. One obtains the transformation equations:

$$\mathbf{r}_* = \gamma\mathbf{r} - (\gamma^2 - 1)^{1/2}ct\hat{\mathbf{e}} \qquad ct_* = -(\gamma^2 - 1)^{1/2}\mathbf{r}\cdot\hat{\mathbf{e}} + \gamma ct \tag{3a,b}$$

$$\mathbf{r} = \gamma\mathbf{r}_* + (\gamma^2 - 1)^{1/2}ct_*\hat{\mathbf{e}}_* \qquad ct = (\gamma^2 - 1)^{1/2}\mathbf{r}_*\cdot\hat{\mathbf{e}}_* + \gamma ct_* \tag{4a,b}$$

where $\hat{\mathbf{e}} = \Delta\mathbf{r}/\Delta r = \Delta\mathbf{r}_*/\Delta r_* = \hat{\mathbf{e}}_*$.

In the E system, one considers two events that are at the origin and separated by a time interval Δt. From Eq. (3b),

$$\Delta t_* = \gamma\Delta t. \tag{5}$$

The gravitational force exerted on or by a body depends linearly on its mass. To calculate the effective GSF, γ_1, for a spherically symmetric body of mass m_1 for which ρ, T and the X_i are known everywhere, one first determines the weighted mean GSF at each value of r, using equation (2), as it is determined by the local composition. That is, one obtains $[\Sigma_i X_i(r)\cdot {}_i\gamma(r)]$. One then has

$$\gamma_1 = (1/m_1)\int_V [\Sigma_i X_i(r)\cdot {}_i\gamma(r)]\cdot dm_1. \tag{6}$$

We now consider two spherically symmetric, gravitationally interacting bodies of masses m_1 and m_2 respectively. The distance between their centers is Δr in the E system. We set

$$\Delta r_* = \Delta r\gamma_*^{-1}, \tag{7}$$

where $\gamma_* = \gamma_1\gamma_2$. The scaling effects of each body are independently imposed. As a consequence, Newton's Third Law of motion holds. As in Eq. (5) then,

$$\Delta t_{*} = \gamma_{*}\Delta t. \qquad (8)$$

3. "Dark matter"

The rotational speeds of stars about galactic centers often imply galactic masses significantly greater than the collective mass of stars, gas and dust in the galaxy. The movements of galaxies within clusters often exhibit the effect to a marked degree, typically implying galactic masses about an order of magnitude greater than that observed [5-9].

Our own galactic halo is reasonably approximated by a uniform sphere of dilute, mostly ionized gas in which cosmic rays are evenly distributed, trapped by random, weak magnetic fields [10-12]. The gravitational effect of this material is greatly enhanced by the scaling effect. The magnitude of the enhancement can be easily estimated.

To start, mean values of halo variables must be adopted. These are: radius of the halo, $R \cong .5\text{x}10^{23}$cm; composition of the gas, $X \cong .73$, $Y \cong .25$, $Z \cong .02$ (X,Y,Z the fractional mass abundances of H, He and heavier elements, respectively); mean mass density, $\rho \cong 1.67\text{x}10^{-26}$g cm^{-3}; mean magnetic field strength, $B \cong 6\text{x}10^{-6}$gauss. Hayakawa suggests $B \cong 3\text{x}10^{-6}$gauss, with an uncertainty of a factor of 2, as a reasonable estimate of the average field strength as inferred from cosmic rays [10]. Radio-luminosity data, however, suggest B $\cong$ 6x10^{-6} gauss [10,13]. The higher value has been adopted. Proceeding, we first get an estimate of the mean temperature of the gas.

From the density and composition of the gas, the mean particle density n is obtained, assuming H and He to be fully ionized and the heavier nuclei not appreciably ionized. It is, taking $^{16}_{8}O$ as representative of the heavier elements,

$n = [2X+(3/4)Y+(1/16)Z](\rho/m_H) = 1.65x10^{-2}cm^{-3}$.

Halo energy appears to be equipartitioned between gas, cosmic rays and magnetic fields [10]. The total pressure is the sum of the partial pressures of these components, $P = P_g + P_{CR} + P_B$. Let u represent the energy density contributed by each component. Then P = (2/3)u + (1/3)u + u = 2u. From the ideal gas law one has $P = 2u = 2x(B^2/8\pi) = nkT$, T = 1.26x10^6 K.

With these values, using Eq. (2) and Eq. (6) one gets $_H\gamma_1 = 1.757$, $_{He}\gamma_1 = 1.774$, $_Z\gamma_1 = 1.000$, and $\gamma_1 = .73x1.757+.25x1.774+.02x1.000 = 1.746$. For gravitational interactions of this halo material with an element of gas near the edge of the halo or with the halo of another, similar galaxy in our own Local Group, $\gamma_* = \gamma_1\gamma_2 \cong \gamma_1^2 = 3.05$.

Periods and distances used to estimate galactic masses are determined spectroscopically and photometrically. They are related, however, through the virial theorem or, alternatively for two bodies, Kepler's Third Law. Setting $t_{*} = \gamma_{*} t$ and $r_{*} = r/\gamma_{*}$, and assuming for a cluster of galaxies a uniform value of γ_{*} (that is, assuming the same value of γ_1 for each galaxy), the virial theorem becomes $\langle T \rangle = -(1/2)\, \gamma_{*}^{5} \langle U \rangle$, where T is the summed kinetic energy of the galaxies and U is their gravitational potential energy. As written in the G_{*} system for two galaxies of halo masses M_{h1} and M_{h2} respectively, with orbital motions characterized by period P_{*} and semimajor axis A_{*}, Kepler's Third Law is $P_{*}^{2} = (4\pi^2 A_{*}^{3})/G(M_{h1} + M_{h2})$. Transformed to the E system it becomes $P^2 = (4\pi^2 A^3)/\gamma_{*}^{5} G(M_{h1} + M_{h2})$.

The mass of our own galactic halo is, using the mean density ρ and radius R adopted above, $M_{h1} \cong .44\text{x}10^{10} m_{\odot}$. Taking $M_{h1} \cong M_{h2}$, one has $\gamma_{*}^{5}(M_{h1} + M_{h2}) \cong 2.3\text{x}10^{12} m_{\odot}$. The halo itself produces a gravitating effect an order of magnitude greater than that ordinarily attributed to stars, gas and dust. It thus becomes unnecessary to postulate "dark matter."

To gain a measure of how this result varies with values of halo variables chosen, it is useful to divide the values of ρ and B adopted above by 2, while keeping the composition unchanged (with the result that $T \rightarrow T/2$ also). Expanding the halo radius then by a factor of 1.97 to 10^{23} cm leaves the net result unchanged. Recent measurements of intergalactic magnetic fields in a sampling of 16 normal Abell clusters are consistent with such extended halos [14].

4. Solar Neutrino Problem

A detailed, standard model of the Sun produced some years back has led to a perplexing result. The rate of energy production in the solar interior can be directly inferred from measurement of sunlight at Earth. Associated with the energy production is a predictable rate of neutrino emission, the magnitude of the predicted rate following from the model. The predicted neutrino flux, however, is not observed. The measured flux at Earth is only about one-third that expected [15-19]. A widely held opinion is that both the model and the neutrino flux measurements are unassailable; the discrepancy is likely due to unexpected phenomena.

Models of the solar interior are based on reasonable suppositions about its structure and composition, and upon the numerical solution of five equations plus boundary conditions [5,20,21]. Gravitational effects enter through the equation of hydrostatic equilibrium, $dP/dr = -\rho GM(r)/r^2$, where M(r) is the solar mass within radius r. It is my contention that the unexpected phenomena are introduced at this point.

First, the value of the solar mass is acquired through the use of Kepler's laws and observations of the orbital motions of planetary objects. Again, relationships involving gravitational forces must first be written in G_{*} and then transformed to E. Otherwise, errors are introduced. Calculating a weighted-mean GSF for the Sun using equations (2) and (6), and introducing it into Kepler's Third Law as corrected, leads one to a value for the solar mass that is slightly lower than that presently accepted.

Secondly, inside the Sun there is a variation in the GSF with distance from the Sun's center. Since the pressure near the center is the result of the gravitational attraction of the outer material by the inner material, a further change in the central pressure is introduced.

It is in this central region that neutrino production predominantly occurs. Though the two effects are small, they compound in the Sun's core to produce sufficiently lowered temperatures and densities to account for the reduced neutrino flux observed.

To obtain a revised estimate of the expected neutrino flux, the following procedure is adopted: (a) Table VII in Ref. [17] is used as a basis. In it there are 27 entry lines, each for a radial distance $r/R_{\odot}$ from the Sun's center. Each entry line provides data to support the calculation of the ${}_{j}\gamma$ according to Eq. (2), the weighted-mean GSF at that r value, or

$[\Sigma_i X_i(r)\cdot_i\gamma(r)]$, and finally, an overall GSF for the Sun using Eq. (6).[1] (b) The GSF obtained are then used to effect consecutive homology transformations, one for each of the two physical changes described above. Homology transformations carry the ρ and T values of the model over into those that would have resulted had the GSF been introduced at the outset. In this way, reduced values for temperature and density near the Sun's center are arrived at. (c) With these revised ρ and T values, reduction factors for each of the neutrino fluxes expected from the five nuclear reactions contributing to the measured flux are calculated. From these reduction factors and the updated theoretical fluxes and capture rates tabulated in Ref. [19], a revised total neutrino capture rate is obtained.

The overall mean solar GSF obtained with these data and with the use of Eq. (2) and Eq. (6) is $\gamma_1 = 1.0035$. A complication arises in calculating it: heavier elements are not completely ionized throughout the Sun. To accommodate this fact, two calculations of γ_1 were made, the first assuming the heavier elements are completely ionized throughout, the

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[1] It can be argued that one requires $\langle\gamma^n\rangle$ and not $\langle\gamma\rangle^n$ in what follows. In any event, writing $\gamma_k = 1+\varepsilon_k$ for the m_k mass element, one has that the two are equal to first order in the ε_k.

second assuming they are not ionized at all where $T \leq 9x10^6$ K. The results are γ_1= 1.0042 and γ_1= 1.0028, respectively. The average of the two values is γ_1= 1.0035. For planetary objects in the solar system, γ_1= 1.0000.[2] Then $\gamma_* = \gamma_1\gamma_2$ = 1.0035. The solar mass is thus overestimated by a factor of γ_*^5 = 1.0176. To correct for this in the solutions of the equations plus boundary conditions that serve as foundations for models of the solar interior, a homology transformation can be used.

If $M \rightarrow \gamma_*^{-5}M$ =.9827M, then in the solutions, $\rho \rightarrow .9827\rho$ and $T \rightarrow .9827T$ everywhere [20].

The pressure near the center of the Sun is due to the gravitational attraction by the material there of material overlying it. The GSF in this particular circumstance, γ_c, is approximated by the product of the GSF value at the center of the Sun, γ_0 = .9616, and γ_1=1.0035; or γ_c =.9650.

At this point the Lane-Emden functions can be used to effect a homology transformation specific to standard models [21]. For the temperature T_c and density ρ_c at or near the Sun's center, if $r \rightarrow r = r\gamma_c^{-1}$ in

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[2] Jupiter may present an exception.

solutions, then $T_c \to \gamma_c T_c$ and $\rho_c \to \gamma_c^3 \rho_c$. Alternatively, one can argue directly that if $r \to r = r\gamma_c^{-1}$, then $\rho_c \to \gamma_c^3 \rho_c$. From $dP/dr = -\rho GM(r)/r^2$, one concludes that $P \to \gamma_c^4 P$. From the ideal gas law then, $T_c \to \gamma_c T_c$. The two effects compound giving the net result, $T_c \to \gamma_*^{-5}\gamma_c T_c = .9483 T_c$ and $\rho_c \to \gamma_*^{-5}\gamma_c^3 \rho_c = .8831\rho_c$. The fractional changes in the neutrino production rates brought about by these reductions in density and temperature can now be estimated.

The reaction rates for nonresonant nuclear reactions in the Sun's core can be approximated by the relationship [5,21]

$$r_{12} \cong C_i \rho^2 T^n \ , \qquad (9)$$

where C_i is a proportionality constant, $n = (\tau - 2)/3$, $T_6 \equiv T/10^6$ K, and $\tau = 42.46[Z_1^2 Z_2^2\{(A_1A_2)/(A_1 + A_2)\}/T_6]^{1/3}$. Each reaction is taken up separately.

Source, ^7Be: $^3He + {}^4He \to {}^7Be + \gamma$, $^7Be + e^- \to {}^7Li + \nu_e$,

$r_{12} \cong C_1 \rho^2 T^{16.64} \to (.8831)^2(.9483)^{16.64} r_{12} = .3224 r_{12} \equiv f_{Be} r_{12}$.

Source, ^8B: $^7Be + p \to {}^8B + \gamma$, $^8B \to {}^8Be + e^+ + \nu_e$,

$r_{12} \cong C_2 \rho^2 T^{13.16} \to (.8831)^2(.9483)^{13.16} r_{12} = .3878 r_{12} \equiv f_B r_{12}$.

Source, ^{13}N: $^{12}C + p \to {}^{13}N + \gamma$, $^{13}N \to {}^{13}C + e^+ + \nu_e$,

$r_{12} \cong C_3 \rho^2 T^{17.78} \to (.8831)^2(.9483)^{17.78} r_{12} = .3035 r_{12} \equiv f_N r_{12}$.

Source, ^{15}O: $^{14}N + p \rightarrow {}^{15}O + \gamma$, $^{15}O \rightarrow {}^{15}N + e^{+} + \nu_e$,

$r_{12} \cong C_4\rho^2T^{19.86} \rightarrow (.8831)^2(.9483)^{19.86}r_{12} = .2717r_{12} \equiv f_O r_{12}$.

Source, p-e-p: $p + e^{-} + p \rightarrow {}^{2}H + \nu_e$.

The p-e-p reaction can be related approximately to the p-p reaction by $r_{pep} \cong r_{pp}C_5(1+X)\rho T_6^{-1/2}(1+.02T_6)$, [17]. These reactions occur in a more extensive region of the solar interior than those considered above. For the approximation here, the above GSF are used, but at T_6= 12.41, very nearly the midpoint for the p-p reaction. The preceding relationship at that temperature becomes approximately

$r_{pep} \cong C_6(1+X)\rho T_6^{-1/2}(1+.02T_6)\rho^2T^{4.19} \rightarrow$

$1.0163(.8831)^3(.9483)^{4.19}r_{pep} = .5603r_{pep} \equiv f_{pep}r_{pep}$.

In Table 1 of Ref. [19], expected neutrino capture rates for the ^{37}Cl detector employed in the observations discussed there are listed by neutrino-source reaction. The rates are in solar neutrino units: 1 SNU = 10^{-36} captures per target atom per second. In Table 1, these values are listed and then multiplied by the respective reduction factors, f_X, arrived at above for each contributing reaction. Totals can then be compared with the observed capture rate of 2.1±0.3 SNU.

To best interpret the significance of Table 1, however, it is more meaningful to anticipate the contingency in the model of extension of the energy production region of the Sun to compensate for the lowered core densities and temperatures. Setting the p-e-p reduction factor equal to unity while keeping the other reduction factors unchanged reasonably approximates the consequence of this. The estimated resultant capture rate is then 2.3 SNU.

5. Eclipsing binary stars

The eclipsing binary star systems DI Herculis and AS Camelopardalis offer exceptional opportunities to test gravitational theories. In each of these systems, appreciable apsidal-advance rates are expected to arise from both general relativistic and classical effects, these latter a result of tidal and rotational distortions [22,23].

Sizable differences between observation and theory for the apsidal-advance rates of these two binary systems are reported in Refs. [22-25]. Maloney, Guinan and Mukherjee conclude that the differences call attention to possible problems with our understanding of classical or general relativistic gravitation as it occurs in close binary systems [25].

The theory introduced here implies discrepancies in both the classical and general relativistic contributions if calculations are done without consideration of the scale differences between the E and G_* systems. Again, periods and distances are determined from spectroscopic and photometric measurements in the E system. They are then related through gravitational laws that are correct as conventionally written only in the G_* system. Inclusion of the scale differences between systems through introduction of the GSF, however, leads to reconciliation between theory and observation for both DI Her and AS Cam.

Apsidal motion is treated in a very general way by Robertson and Noonan [4]. The procedure adopted below is patterned after theirs.

Central force equations of motion can be written

$$d^2r_*/dt_*^2 - r_*(d\theta/dt_*)^2 = -F(r_*) \equiv -F_* \qquad (10a)$$

$$(dr_*/dt_*)^2 + r_*^2(d\theta/dt_*)^2 = 2J(r_*) \equiv 2J_* \qquad (10b)$$

$$r_*^2(d\theta/dt_*) = H(r_*) \equiv H_* \qquad (10c)$$

where F, J and H are *arbitrary* differentiable functions. Equations of motion under a gravitational force as conventionally written above are correct only in the G_* system. The radius vector in the orbital plane, r_*, and t_*, the time in G_*, and F_*, J_*, and H_* are subscripted to make this explicit. The angle θ is the angle in the orbital plane as conventionally defined; it is invariant.

Setting $u_*=1/r_*$, one gets from Equations (10),

$$d^2u_*/d\theta^2 + u_* = N_*, \qquad (11)$$

where $N_* = (1/H_*^2)(dJ_*/du_*) - 2(J_*/H_*^3)(dH_*/du_*)$. One then sets $\eta_* = u_* - u_{0*}$, where $u_{0*} = N_*(u_{0*})$ is the solution to Eq. (11) when $d^2u_*/d\theta^2 = 0$. That is, $u_{0_*} = 1/ r_{0_*}$, where r_{0_*} is the radius of a circular orbit. Deviations from a circular orbit satisfy the equation

$$d^2\eta_*/d\theta^2 + [1 - (dN_*/du_*)_{uo_*}]\cdot\eta_* \cong 0. \tag{12}$$

The fraction of an orbit advanced each orbit is then

$$\sigma_* = (1/2)\cdot(dN_*/du_*)_{uo_*}, \tag{13}$$

and the rate of apsidal advance is

$$\langle d\omega/dt\rangle_* = 2\pi\sigma_*/P_*, \tag{14}$$

P_* the binary period in G_*.

One then transforms σ_* and P_* to obtain $\langle d\omega/dt\rangle$, the rate of apsidal advance in E.

It is useful at this point to quote again from Max Jammer's discussion: "Long ago, George Berkeley (*On Motion,* 1721) said that the notion of force is a fiction just like that of epicycles in astronomy. He declared that concepts such as force, attraction, and gravitation are convenient for purposes of computation but do not increase real understanding. David Hume, Pierre de Maupertuis, and the early proponents of modern positivism (Gustav Kirchoff, Heinrich Hertz, Ernst Mach) similarly contended that the concept of force is only a methodological device devoid of any real content. At best, according to Kirchoff, it is an abbreviation for the product of mass and acceleration" [1].

Setting $r_* \to r\gamma_*^{-1}, t_* \to \gamma_* t$ in Equations (10), and adopting the above viewpoint, one gets the scale changes

$$F_* = F(r_*) \to \gamma_*^{3} F(r) \tag{15a}$$

$$J_* = J(r_*) \to \gamma_*^{4} J(r) \tag{15b}$$

$$H_* = H(r_*) \to \gamma_*^{3} H(r) \tag{15c}$$

From Equations (15), $N_* \to \gamma_*^{-3} N(u)$, $dN_*/du_* \to \gamma_*^{-4} dN/du$. Since $P_* = \gamma_* P$,

$$\langle d\omega/dt \rangle = (\pi/P)\, \gamma_*^{-5} (dN/du)_{u_{0*}}. \tag{16}$$

To find the transformed value of u_{0*}, Eq. (10c) can be used to eliminate t_* in Eq. (10b) which, on setting $u_* = 1/r_*$, becomes

$$(du_*/d\theta)^2 + u_*^{2} = 2J_*/H_*^{2}. \tag{17}$$

Setting $(du_*/d\theta) = 0$ in Eq. (17) and making use of Eq. (15), one has that $u_{0*}^{2} = 2J_{0*}/H_{0*}^{2} \to \gamma_*^{-2}(2J_0/H_0^2) = \gamma_*^{-2} u_0^2$, so that $u_{0*} \to \gamma_*^{-1} u_0$, the subscript "0" denoting functions evaluated at u_{0*} and u_0 respectively, and $u_0 = 1/r_0$, where r_0 is the radius of a circular orbit in E. Then

$$\langle d\omega/dt \rangle = (\pi/P)\, \gamma_*^{-5} (dN/du)_u, \quad u = \gamma_*^{-1} u_0\,. \tag{18}$$

The general relativistic and classical treatments of apsidal motion coincide to this point but now separate. The general relativistic case is taken up first.

Levi-Civita first treated the relativistic two-body problem as a perturbation on a Newtonian representation [26]. He arrived at a potential function that leads one directly to an expression for N(u),

$$N(u) = \beta_0 + \beta_1 u + \beta_2 u^2, \qquad (19)$$

where $\beta_1 = 6[1-(1/2)(\mu^2/m_1m_2)]\cdot[G^2m_1^2m_2^2/L^2c^2]$ and

$\beta_2 = (3/2)[(\mu^2m_1m_2G^2A(1-e^2)]/L^2c^2$; m_1 and m_2 are the masses of the gravitating bodies, μ is their reduced mass, and L is the system's angular momentum. From Eq. (19) one has for σ evaluated at $u = \gamma_*^{-1}u_0$,

$$\sigma = (1/2)\cdot(dN/du)_u = \beta_1/2 + \beta_2\gamma_*^{-1}u_0. \qquad (20)$$

A simplifying approximation can be justified by setting $m_1 = m_2$ and taking $\gamma_* \sim 4/3$ in Eq. (20). One finds that ignoring γ_* in Eq. (20) introduces an error of less than 3% into the calculated apsidal advance rates. From Eq. (18) then, the corrected general relativistic rate of apsidal advance, $\langle d\omega/dt\rangle_{GR,GSF}$, is given to sufficient accuracy by

$$\langle d\omega/dt\rangle_{GR,GSF} \cong \gamma_*^{-5}\langle d\omega/dt\rangle_{GR}. \qquad (21)$$

The classical apsidal-advance rate relationship made use of in Refs. [22-25] has been derived by Cowling [27]. From Ref. [27] one obtains an expression for N(u),

$$N(u) = [G(m_1 + m_2)/h^2](1 + \delta_R u^2 + \delta_T u^5), \qquad (22)$$

where $h = r^2 d\theta/dt$; $\delta_R = (k_1R_1^5/Gm_1)(d\theta_1/dt)^2 + (k_2R_2^5/Gm_2)(d\theta_2/dt)^2$; $\delta_T = 6k_1R_1^5(m_2/m_1) + 6k_2R_2^5(m_1/m_2)$; $d\theta/dt$ is the orbital angular velocity; $d\theta_1/dt$ and $d\theta_2/dt$ are the rotational angular velocities of the stars; R_1 and R_2 are their radii; and k_1, k_2 are weakly varying functions of their masses and compositions [28].

Choosing an orbit that approaches arbitrarily close to circular, setting $(d\theta/dt)^2 = G(m_1 + m_2)u_{00}^3$ and $h = (d\theta/dt)/u_{00}^2$, one gets from Eq. (22),

$$(1/2)(dN/du)_{uo} \cong u_{00}[\delta_R u_0 + (5/2)\delta_T u_0^4]. \qquad (23)$$

The δ_R term represents apsidal motion resulting from rotational distortion, the δ_T term that from tidal distortion. To compare their typical magnitudes, we set $d\theta_1/dt = d\theta_2/dt = d\theta/dt$ and $m_1 = m_2$. One notes that $u_{00} \cong u_0$. Then

$$\delta_R u_0 = 2k_1R_1^5u_{00}^3u_0 + 2k_2R_2^5u_{00}^3u_0, \qquad (24a)$$

$$(5/2)\delta_T u_0^4 = 15k_1R_1^5u_0^4 + 15k_2R_2^5u_0^4. \qquad (24b)$$

As a simplifying approximation, the correction to the larger term, that due to tidal distortion, is taken as representative. From Eq. (18) and Eq. (23) one has then for the corrected classical rate of apsidal advance, $\langle d\omega/dt\rangle_{Cl,GSF}$,

$$\langle d\omega/dt\rangle_{Cl,GSF} \cong \gamma_*^{-9}\langle d\omega/dt\rangle_{Cl}. \qquad (25)$$

To estimate the GSF for DI Her and AS Cam, approximate values of the masses of the stars are needed so that temperatures and densities in their interiors can be estimated from an acceptable model. Since the masses may be inaccurately determined to start with, this conceivably presents a difficulty. In a comprehensive assessment of the published orbital parameters of DI Her, Popper has concluded that for DI Her these are well established and consistent with those of similar main sequence B stars [29]. Maloney *et al.* conclude that the orbital parameters of AS Cam are also self-consistent and those expected of similar main sequence B stars [25].

For our purposes, the mass values used in predicting the published apsidal advance rates are acceptable since we use them merely as an entry point into tabulated (by stellar mass) T_c and ρ_c values for model stellar interiors. As a further simplifying approximation, the stars in each binary system are taken as a pair to be alike with respect to T_c and ρ_c. To approximate a weighted mean GSF for each star, representative mean temperatures and densities are adopted. These are $T \cong T_c/2$ and $\rho \cong \rho_c/8$ (corresponding to a polytropic index of 3). These choices appear to be the most reasonable when compared to the results obtained earlier in detailed calculations for the Sun. For the composition, the values adopted for all four stars are X=.60, Y=.37, Z=.03, [21], the heavier nuclei represented by oxygen in calculating the GSF. The GSF are then calculated using these values in equation (2) and from

$\gamma_1 = \gamma_2 = [\Sigma_i X_i(r) \cdot {}_i\gamma(r)]$.

The mass values for DI Her are $m_1 = 5.15m_\odot$, $m_2 = 4.53m_\odot$ [29]. From Ref. [21], $T_c \cong 26 \times 10^6$ K and $\rho_c \cong 21$ g cm^{-3}. Then $T \cong 13 \times 10^6$ K and $\rho \cong 2.6$ g cm^{-3}. For AS Cam, the mass values are $m_1 = 3.3m_\odot$, $m_2 = 2.5m_\odot$ [23]. From Ref. [21], $T_c \cong 23 \times 10^6$ K and $\rho_c \cong 42$ g cm^{-3}. Then $T \cong 11.5 \times 10^6$ K and $\rho \cong 5.2$ g cm^{-3}.

The results are as follows: DI Her: $\gamma_* = \gamma_1\gamma_2 = 1.23$. From Ref. [22], the predicted apsidal advance rates are $\langle d\omega/dt \rangle_{GR} = 2.34\ ^o/100yr$, $\langle d\omega/dt \rangle_{Cl} = 1.93\ ^o/100yr$. From Eq. (21) and Eq. (25) one has for the corrected total apsidal advance rate $\langle d\omega/dt \rangle_{GSF}$,

$$\langle d\omega/dt \rangle_{GSF} \cong \gamma_*^{-5} \langle d\omega/dt \rangle_{GR} + \gamma_*^{-9} \langle d\omega/dt \rangle_{Cl} = 1.13\ ^o/100yr, \quad (26)$$

in agreement with the observed rate as revised in Ref. [24], $\langle d\omega/dt \rangle_{Obs} = 1.00\ ^o/100yr \pm .30\ ^o/100yr$.

AS Cam: $\gamma_* = \gamma_1\gamma_2 = 1.14$. From Ref. [23], the predicted apsidal advance rates are $\langle d\omega/dt \rangle_{GR} = 8.5\ ^o/100yr$, $\langle d\omega/dt \rangle_{Cl} = 35.8\ ^o/100yr$. From Eq. (21) and Eq. (25) one has for the corrected total apsidal advance rate $\langle d\omega/dt \rangle_{GSF}$,

$$\langle d\omega/dt\rangle_{GSF} \cong \gamma_*^{-5}\langle d\omega/dt\rangle_{GR} + \gamma_*^{-9}\langle d\omega/dt\rangle_{Cl} = 15.4\ ^o/100yr, \quad (27)$$

in agreement with the observed rate, $\langle d\omega/dt\rangle_{Obs} = 15.0\ ^o/100yr \pm 5.3\ ^o/100yr$, as reported in Ref. [23].

6. Conclusion.

Though other possible explanations for each of the three classes of anomalies considered have been proposed, each relies on adjustable parameters, compounds assumptions, and is narrowed to the single problem at hand. By contrast, the proposed theory has no adjustable parameters and solves problems of all three classes; in each case it accomplishes this with no additional assumptions. One eliminates the troublesome and embarrassing need to postulate a persistently elusive, invisible form of matter that comprises nearly all of the physical universe; and our present-day formulations of known *fundamental* physical laws are not challenged. In light of this rather striking comparative economy and the theory's simplicity, it is reasonable that it be given further attention by others, both in furthering its basic development and in applying it to similar and related problems.

In this latter regard, one notes in particular that over 1000 eclipsing binary stars are known [21]. It is clear that upper main-sequence binary stars, with their high interior temperatures and comparatively low densities, should exhibit these gravitational scaling effects to a pronounced degree, while those of the lower main sequence should be little affected.

A solar system demonstration of the effect appears to have been secured some years ago by H. Hill, who considered the Sun's oblateness and its effect on the apsidal motion of Mercury [30]. His result, a correction factor to the predicted general relativistic apsidal advance rate, is in agreement with the result that immediately follows from the discussion of apsidal motion presented here. The value for the correction factor found here, taken directly from the solar-neutrino discussion: .9827; Hill's values: $.987 \pm .006$, or $.991 \pm .006$, depending on the set of planetary radar observations chosen. Although Hill's work apparently remains controversial, its potential importance is unquestionable. As Hill points out, his approach involves redundancy – unlike the binary pulsar results for example which, though they indeed demonstrate consistency of approach, cannot be relied upon to reveal unanticipated effects.

Jupiter also may reveal the scaling effect. This follows from the expectation that there may be appreciable ionized material deep in its interior. Specifically, if Jupiter is used in ranging calibrations for deep-space probes, a small error should be introduced in that accepted (ephemeris) values of its range should, as a consequence of the ionization, be slightly in error.

Finally, and this is a cardinal point, a connection at the quantum level between the electromagnetic force and gravitation is indicated, and in a way that should suggest a number of potentially fruitful experimental procedures to examine its fundamental properties in greater detail. In particular, different materials ionized to varying degrees and subjected to either the Sun's or Earth's gravitational field should accelerate at rates different from those of non-ionized material. These rates can be correlated with the material's controlled properties.

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Table I. The reduction factors discussed in the text are listed in the third column. The last column lists the products of the capture rates from Ref. [19] and their corresponding reduction factors.

Neutrino Source	Capture Rate, Ref. [19] (SNU)	Reduction Factor, f_x	Revised Rate (SNU)
p-e-p ……..	.24	.5603	.1345
^{7}Be ………	.95	.3224	.3063
^{8}B ……….	4.3	.3878	1.6675
^{13}N ………	.08	.3035	.0243
^{15}O ………	.24	.2717	.0652
Totals …………	5.8		2.2

A Final Note:

None of the referees who reviewed the paper for journal publication could find fault with it that wasn't easily refuted. Nevertheless, no editor would accept it for publication. Anyone who wants to view these interesting exchanges is invited to write me. I will be happy to send you photocopies.

To conclude things on a happier note, I quote some beautiful lines from Robert Browning's "Abt Vogler" that succinctly describe why I chose to undertake this study, and in fact why I chose to study physics in the first place.

> But here is the finger of God, a flash of the will that can,
> Existent behind all laws, that made them and, lo, they are!
> And I know not if, save in this, such gift be allowed to man,
> That out of three sounds he frame, not a fourth sound, but a star.
> Consider it well: each tone of our scale in itself is naught;
> It is everywhere in the world – loud, soft, and all is said:
> Give it to me to use! I mix it with two in my thought:
> And, there! Ye have heard and seen: consider and bow the head!