Solar Metallicity Problem from TGD Perspective

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Abstract

For ten years ago it was thought that Sun is a well-understood system but more precise computations demonstrated a problem. The metallicities deduced from the spectroscopic data deviate strongly from those deduced from helio-seismology and solar neutrino data.

The abundances used are determined from meteorites and these estimates are more accurate and consistent with the values determined by Asplund et al using 3-D modelling of solar surface used also to extrapolate the metallicities in core.

1. The metallicity of Sun deduced from spectroscopy by Asplund et al would be 1.3 per cent whereas the older model and also helio-seismology give 1.8 per cent metallicity. Is the metallicity indeed 1.3 per cent using standard model to extrapolate the spectroscopic data at surface? Or is it 1.8 per cent deeper in the interior in which case the extrapolation used to deduce metallicity in the interior would not be realistic.
2. There are also other discrepancies. The height of convective zone at which radiative energy transfer is replaced with convection is given by $R_{CZ} = .724R$. The predicted He abundance at surface is $Y_{surf} = .231$. These values are in conflict with $R_{CZ} = .713R$ and $Y_{surf} = .248$ deduced from helio-seismological data. Also density and sound velocity profiles deviate from those deduced from the helio-seismology. Ironically, the earlier model approximating solar surface as 2-D structure is in excellent accordance with the helio-seismological data.

When one has a paradox one must challenge the basic assumptions. Do the metallicities outside Sun and inside solar core really mean same thing? Dark matter identified as $h_{eff} = nh_0$ phases has become key player in TGD inspired new physics being now a crucial element of TGD based view about living matter. Dark nuclear fusion is proposed to provide the new physics allowing to understand "cold fusion". In the following it will be found that dark matter in TGD associated with solar core could provide an elegant solution also to the solar metallicity problem.

In TGD classical physics is an exact part of quantum physics. The tunnelling phenomenon essential for nuclear physics based model of solar nuclear fusion would correspond in TGD to a state function reduction creating a phase consisting of dark nuclei which can fuse without tunnelling due to the reduction of the binding energy scale. State function reduction to ordinary phase leads to the final state of the reaction. In ZEO "big" (ordinary) state function reduction (BFSR) would reverse the arrow of time so that if tunnelling phenomenon is assignable to BFSR rather than "small" state function reduction (SFSR) as TGD counterpart of "weak" measurement, ZEO would make possible nuclear fusion.

The missing nuclear matter inside core would be dark variants of nuclei associated with dark flux tubes. This would explain the conflict between the metallicities deduced from spectroscopic and meteoritic data on one hand and those derived from helio-seismic data. The reason is that sound waves and photons in the core couple to both ordinary and dark matter so that helio-seismology gives metallicities as sums of ordinary and dark metallicities. Using the estimate for the thickness of the dark flux tube coming from the TGD based model of "cold fusion", one can estimate the length of dark flux tube inside solar core and it turns out to fill about 30 per cent of its volume.

One can relate the model also to the model for the formation of galaxies, stars, and planets as tangles assignable to cosmic strings thickened to flux tubes implying the decay of their Kähler magnetic energy to ordinary matter in analogy with the decay of inflaton field and nice quantitative estimates follow. Also a connection with twistor lift of TGD predicting hierarchy of cosmological constants emerges and the radius of solar core turns out to corresponds to the value of cosmological constant implied by the amount of missing matter identified as dark matter at flux tubes.

Contents

1 Introduction

For ten years ago it was though that Sun isa well-understood system but more precise computations demonstrated a problem. The metallicities deduced from spectroscopic data deviate strongly from those deduced from helio-seismology and solar neutrino data as described in the Annual Review of Astronomy and Astrophysics by Martin Asplund et al [E1] (see `http://tinyurl.com/y4bmbjzg`), who were pioneers modelling solar surface as 3-D structure rather than idealizing it with 2-D structure.

Calculations of metallicities and their comparison with the helio-seismological results are discussed in [E3] (`http://tinyurl.com/yyxw9bpn`). The abundances used are determined from meteorites and these estimates are more accurate and are consistent with the values determined by Asplund et al and used also to extrapolate the metallicities in core.

1. The metallicity of Sun deduced from spectroscopy by Asplund et al would be 1.3 per cent whereas the older model and also helio-seismology give 1.8 per cent metallicity. Is the metallicity indeed 1.3 per cent using standard model to extrapolate the spectroscopic data at surface? Or is it 1.8 per cent deeper in the interior in which case the extrapolation used to deduce metallicity in the interior would not be realistic?

2. There are also other discrepancies. The height of convective zone at which radiative energy transfer is replaced with convection is given by $R_{CZ} = .724R$. The predicted He abundance at surface is $Y_{surf} = .231$. These values are in conflict with $R_{CZ} = .713R$ and $Y_{surf} = .248$ deduced from helio-seismological data. Also density and sound velocity profiles deviate from those deduced from the helio-seismological data. The earlier model approximating solar surface as 2-D structure is in excellent accordance with the helio-seismological data.

1.1 Is there something wrong with the standard solar model?

I received interesting links to a couple of popular articles (see `http://tinyurl.com/y4zxmdqz` and `http://tinyurl.com/y52clelq`) suggesting that the physics of solar core, where nuclear fusion is assumed to take place, might not be quite what it is believed to be. Here is the abstract of the first popular article:

Analysis of sound and light transmission from solar surface using a new 3-D model instead of the standard 2-D standard model suggests that the chemical composition of the Sun is far different from what has been assumed. There appears to be significantly less elements heavier than hydrogen than had been estimated using obsolete models that use calculations assuming completely flat surface for the Sun. Sun's missing metals means that there is a large mass, several billion megatons, of material that is unaccounted for. One possibility that has been suggested is that the Sun's core may be comprised dark matter - a source of mass that exerts gravitational force and does not interact in the same way that ordinary matter does.

The popular article talks about 1500 Earth masses of missing matter particles heavier than hydrogen and helium so that the amount of missing mass would be about $M_D \sim 8 \times times 10^{27}$ kg, perhaps dark matter. Solar mass is about $M(Sun) = 2 \times 10^{30}$ kg. The fraction M_D/M would be $M_D/M \sim 4 \times 10^{-3}$. This missing mass is obtained if the metallicities deduced from the spectroscopy are indeed correct.

Just to check that there are no mis-understandings, one can estimate the missing mass in core by using the fact that in the core (see http://tinyurl.com/nrcojr2) has about 34 per cent of solar mass and the reduction of metallicity 1.3 per cent deduced from the earlier value 1.8 per cent is .5 per cent. This gives the estimate $M_D/M \simeq 1.7 \times 10^{-3}$, which is roughly 1/2 of the estimate.

The metallicity deduced from spectroscopy is 1.3 per cent, and helio-seismology gives metallicity of 1.8 per cent. Who is right: spectroscopists or helio-seismologists? Or could both be right: could the very notion of metallicity used by them be actually different?

1. The first option is that spectroscopists are right and that there is some form of matter in the core not behaving like ordinary matter and has different opacity and acoustic resonances. The higher the metallicity, the higher the opacity since metals absorb light. The exotic state of of matter should have higher opacity and absorb light more effectively so that it would give too high metallicity in standard model for the core.

   If so, the amount of elements heavier than Helium could be what 3-D spectroscopy predicts. There is some empirical support for this expectation from the opacity measurements for Fe at temperatures and pressures expected to prevail in solar core by Jim Bailey working at Sandia National Laboratories in New Mexico (see http://tinyurl.com/y5fp4fhk and http://tinyurl.com/yxqtpe34).

   The model introduced by Vincent et al [E4] discussed in popular article (see http://tinyurl.com/y68p4lqb) assumes the missing matter to be dark matter with rather exotic and implausible-to-me properties. If I have understood correctly, the model of Vincent et al claims that if the abundances in the interior are indeed lower if there is a dark mass about $M_D \sim 10^{27}$ kg in the core of the Sun giving $M_D/M \sim 2^{-11}$.

2. Second option would be that helio-seismology gives a correct estimate for the metallicity and that that the extrapolation of the spectroscopic data obtained from the surface layer of Sun to interior is somehow wrong. Also this brings also in mind some new physics: what comes in mind in TGD framework is many-sheeted space-time and magnetic flux tube structures with non-standard value of effective Planck constant $h_{eff} = nh_0$.

3. The third option is that both spectroscopists and helio-seismologists are right and that metallicity means different thing for them. TGD based model for cold fusion on the vision about dark matter as hierarchy of $h_{eff} = nh_0$ phases predicts the possibility of dark nuclei. Spectroscopists measure only the abundance of ordinary dark matter but helio-seismologists measure also the contribution of dark nuclei present in core and perhaps also in convective zone to metallicity.

1.2 More precise statement of the problem

Consider now a more precise statement of the metallicity/abundance problem. This problem can be seen a problem of the entire astrophysics since the model of Sun is extrapolated to deduce the structure other stars from the spectroscopic data. Estimates for the metallicity and abundances of elements heavier than He in Sun can can be deduced in several manners.

1. One can deduce metallicity by spectroscopy based on emission and absorption lines at solar surface and here the work of Martin Asplund and his group developing 3-D models for the atmosphere of Sun (photosphere,chromosphere, and solar corona) has been of utmost importance and deduce that the metallicity should be 1.3 per cent. This model also gives for the thickness of the convection zone a value smaller than older approach approximating the surface with 2-D structure.

2. Metallicity can be deduced also from helio-seismology by studying the oscillations of Sun allowing to deduce information about the inner structure of Sun. This gives metallicity of about 1.8 per cent consistent with the earlier 2-D model. For instance, it was found that the light from the Sun suggests that it had about 20 to 25 per cent less C, N, and O than thought previously. These findings contradict the data from helio-seismology which can deduce precise information about the abundances of elements heavier than helium since they affect the sound wave propagation within the star.

   Earlier 2-D model however agrees with helio-seismological data. Ironically, a more precise model for the solar atmosphere leads to a conflict with other data. Could the approximation of solar surface as 2-D structure be better than 3-D description for some reason: in TGD framework one can ask whether the notion of many-sheeted space-time - in particular p-adic length scale hypothesis) suggesting layered structure - could somehow relate to this. This does not look plausible.

3. Metallicities can be also deduced very accurately from meteorites and these abundances are in good accordance with the the 3-D model and are used in the comparison. This gives support for the model of Asplund but means that meteoritic abundances would be lower than those expected in the solar interior on basis of standard solar model.

4. A further approach is based on solar neutrinos (see `http://tinyurl.com/yy5ewynp`). This approach gives a result consistent with 1.8 per cent. The model of solar neutrinos is very sensitive to metallicity.

It seems that without new physics one has a paradox.

1.3 Possible approaches to the problem

One should explain the conflict between the two determinations of metallicities. The first option would be that the spectroscopic determinations give correct result. The optical and acoustic properties of the matter in the core could however differ from those assumed in standard model. Due to unexpectedly high opacity of the core the metallicity determined from standard helio-seismology would be too high. Also acoustic characteristic should be different. The many-sheeted space-time of TGD and the notion of magnetic body could provide concrete ideas in this respect.

Second possibility is that there is a new physics mechanism increasing the rate of production of nuclei as one goes deeper. Even more, the produced nuclei could exist in some exotic states not possible outside solar interior. If a production mechanism involving some new physics exists, one can wonder whether it could allow to understand the nuclear abundances outside stars in the framework of standard model.

1. Standard model has already a problem with elements heavier than Fe. The generation of elements heavier than Fe in stellar interiors is not possible, and one proposal has been that they are generated in supernovas but this model has not received empirical support (see `http://tinyurl.com/y74rh5rw`).

2. If the abundances of elements heavier than He are small in solar core, then also the elements lighter than Fe could pose a problem. Super-nova explosions should scatter elements lighter than Fe to interstellar space and their amount in interstellar space could be smaller than predicted by the standard model. Could the fusion of these elements take place also outside core or even in interstellar space?

TGD based model of “cold fusion” relies on the notion of dark nucleus [L4]. Could also dark nuclei be possible inside Sun and contribute also to metallicity? The paradox would dis-solve due to the different notion of metallicity used outside Sun and in the interior of Sun. TGD based view about quantum tunnelling essential for the modelling of solar fusion indeed predicts that both ordinary and dark nuclei are in kinetic equilibrium inside solar core at least.

1.3.1 The model proposed by Aaron Vincent

Could the dark matter model proposed by Aaron Vincent et al [E4] (see `http://tinyurl.com/y68p4lqb` and `http://tinyurl.com/yy5ewynp` relate to ZEO based model? The weird looking assumption of the model is that the dark particles in question would have higher probability of having collisions with larger energy and momentum transfer than those with small energy transfer. In the hot solar core these dark particles would get heated and then propagate to cooler parts of Sun and in interactions with would provide very effectively their energy to ordinary.

I must admit that I do not really understand the argument leading to the increase of the metallicity as one goes deeper into the sun. One might however think that this energy feed raises the temperature faster towards core than standard model predicts so that also the metallicities should increase faster.

1.3.2 How TGD could cure the problem?

TGD based new nuclear physics suggests both spectroscopists and helio-seismologists are right.

1. Solar core and also convective zone could contain dark nuclear matter explaining the missing mass. The amount of dark nuclei would be fraction of order 4×10^{-2} of the ordinary matter. TGD based model for the formation of galaxies, stars and planets involves magnetic flux tubes carrying dark energy and possibly also dark matter as key elements, and the dark matter might be assigned to a dark nuclear flux tubes going through the solar core.

   The dark nuclei at the magnetic body would affect the model for the propagation of light and sound in the solar core and also outside it. For instance, photons could be transformed to dark photons at flux tubes an this would increase opacity. Also sound waves would interact with dark nuclei since the acoustic oscillations could be transformed to oscillations of magnetic fields tubes (dark Alfwen waves) and oscillations of dark nuclei.

2. TGD based models of "cold fusion" [L4] and of Pollack effect [L1] [L1] led to a proposal of what I call dark nuclear physics. Dark nuclear physics explaining "cold fusion" in TGD framework could play a central role even in the pre-stellar evolution and in nuclear fusion in stars. As will be found, this suggests a new manner to see tunnelling crucial for nuclear fusion inside stars and even in laboratory.

   Tunnelling is not allowed in TGD since classical physics is exact part of quantum TGD, and would be replaced by a generation of dark nuclei with $h_{eff} = nh_0$ by state function reduction and having lower nuclear binding energy scale making possible to overcome Coulomb wall so that nuclear fusion would be possible without tunnelling.

   The most conservative expectation is that this model for tunnelling reproduces the nuclear physics of ordinary nuclear matter in good approximation. What is however new is that the dark nuclei are present as new exotic states of nuclei, and must be taken in the modelling of sound waves and photons. Therefore helio-seismology and solar neutrinos would allow to deduce the total metallicity as sum over ordinary and dark metallicity whereas spectroscopy and meteorite determinations would provide only the ordinary metallicity since the attention is paid only to ordinary nuclei as outcomes of reactions.

2 Could solar metallicity problem reflect the presence of dark matter in solar core?

Dark matter identified as $h_{eff} = nh_0$ phases has become key player in TGD inspired new physics being now a crucial element of TGD based view about living matter. Dark nuclear fusion is proposed to provide the new physics allowing to understand "cold fusion" [L4]. In the following it will be found that dark matter in TGD associated with solar core could provide an elegant solution also to the solar metallicity problem.

In TGD classical physics is an exact part of quantum physics. The tunnelling phenomenon essential for nuclear physics based model of solar nuclear fusion would correspond in TGD to a state function reduction creating a phase consisting of dark nuclei which can fuse without tunnelling due to the reduction of the binding energy scale. State function reduction to ordinary phase would lead to the final state of the reaction. In ZEO "big" (ordinary) state function reduction (BSFR) would reverse the arrow of time so that if tunnelling phenomenon is assignable to BFSR rather than "small" state function reductions (SFSRs) as TGD counterparts of "weak" measurements, ZEO would make possible nuclear fusion. The recent findings of Minev et al [L16] provide support for ZEO [L16].

The missing nuclear matter inside the core would be dark variants of nuclei associated with dark flux tubes. This would explain the conflict between the metallicities deduced from spectroscopic and meteoritic data on one hand and those deduced from helio-seismic data on the other hand. The reason would be that sound waves and photons in the core would couple to both ordinary and dark matter so that helio-seismology would give metallicities as sums of ordinary and dark metallicities. Using the estimate for the thickness of the dark flux tube coming from the TGD based model of "cold fusion", one can estimate the length of dark flux tube inside solar core and it turns out to fill about 30 per cent of its volume, which is rather near to the maximal allow value and implies that dark nuclear strings must be taken into account.

One can relate the model also to the model for the formation of galaxies, stars, and planets [L8, L10, L3, L14] as tangles assignable to cosmic strings thickened to flux tubes implying the decay of their Kähler magnetic energy to ordinary matter in analogy with the decay of inflaton field and nice quantitative estimates follow. Also a connection with twistor lift of TGD predicting hierarchy of cosmological constants emerges and the radius of solar core turns out to corresponds to the value of cosmological constant implied by the amount of missing matter identified as dark matter at flux tubes.

2.1 Could "cold fusion" come in rescue?

TGD based on the model of "cold fusion" [L4] predicting that all elements can be produced by what I call dark fusion outside stellar cores could come in rescue.

1. Standard model has what I tend to see as a potential problem related to the temperature in the solar core. Naively the nuclear fusion in stellar temperatures around 1.5×10^3 eV is not possible since nuclear binding energy scale is above MeV. Quantum tunneling is however believed to make it possible to overcome the Coulomb wall. The main argument against "cold fusion" is that the colliding nuclei cannot overcome the Coulomb wall at room temperatures. TGD provides a mechanism allowing to overcome the problem [L4]. Could this mechanism be at work also in ordinary nuclear fusion in stars and make it possible outside stellar core?

2. The model relies on the notion of dark nuclei as dark nuclear strings [K3], flux tubes containing sequences of dark protons and neutrons and having non-standard value of effective Planck constant $h_{eff} = nh_0$. Also ordinary nuclei would be nuclear strings but for their dark variants the binding energies would scale like inverse of size scale and thus like $1/h_{eff}$. The binding energy scale would therefore be lower for dark nuclei and they could be formed at lower temperatures.

3. This suggests a model for pre-stellar evolution in which dark nuclei would be formed first. Their transformation to dark nuclei with smaller h_{eff}, even ordinary nuclei with $h_{eff} = h$, would liberate energy and cause heating making possible the fusion of dark nuclei with various values of h_{eff}. Eventually the temperature would reach the value making formation of ordinary nuclei possible. Heavier elements could be generated also outside stellar cores. Also now the mechanism would be formation of dark nuclei, possibly fusing to form heavier nuclei, and decaying to ordinary nuclei.

4. Dark nuclear physics would be present also at low temperatures. For instance, in Pollack effect [L1] [L1] dark nuclei could be formed at room temperature by irradiation of water

in presence of gel. The transformation of dark nuclei to ordinary nuclei could explains the reported bio-fusion [C1, C2]. The dark nuclei would give rise to a realization of genetic codons in terms of linear dark proton triplets [L2]. Chemical codons would be kind of secondary representation.

In "cold fusion" [L4] dark nuclei would be formed in the similar manner and they could transform to ordinary nuclei liberating essentially entire nuclear binding energy. Could the ridiculed "cold fusion" provide a possible mechanism generating not only only the elements heavier Fe but all elements heavier than He outside stellar cores in the case that core consists of dark matter - and perhaps also in interstellar space? One can however counter argue.

1. Ordinary nuclear physics provides a well-tested description of fusion reactions in laboratory and the model based on "cold fusion" in TGD sense should be consistent with the standard model for cold fusion. In stellar core the temperature is however not much higher than $T \sim 1.5 \times 10^3$ eV. Tunnelling effect should be involved in an essential manner. These models are phenomenological potential models. What the TGD description of tunnelling could be?

   In TGD framework all quantum processes should have exact classical space-time correlates as space-time surfaces analogous to Bohr orbits, preferred extremals. Quantum state would be superposition of these. The first new elements would be the description of nuclear dynamics in terms of space-time surfaces obeying classical dynamics.

   By definition, tunnelling represents a process impossible classically. Could the TG counterpart of tunnelling involve a state function reduction creating a superposition of space-time surfaces for which tunnelling is replaced by a process possible classically? Could the tunnelling involve the formation of dark intermediate state with much smaller nuclear binding energy scale and its decay to the final state containing the fused nuclei?

2. What could the creation and decay of this dark intermediate state mean? If it corresponds to ordinary state function reduction, it means in zero energy ontology (ZEO) reverse the arrow of time. The recent strange findings of Minev et al [L16] about state function reduction in atomic systems provide rather strong support for ZEO based quantum measurement theory [L16], whose main justification is that it solves the basic paradox of quantum measurement theory.

   The time reversed zero energy state would be a superposition of preferred extremals starting from final dark nucleon state and going to geometric past and decay to state consisting of ordinary nucleons in accordance with the generalized second law.

   During subsequent time evolution by SSFRs as analogs of "weak" measurements nuclear fusion would occur easily due to the small binding energy.

   After that second BSFR replacing the arrow of time with original one would occur and induce the decay of dark nuclei to ordinary nuclei including the fusion products. This process could take place also in "cold fusion". This description might make sense since also ordinary nuclei are in TGD framework string like entities [K3].

3. One must be however cautious here. One cannot exclude the possibility that also SSFRs increasing the value of h_{eff} could give rise to tunnelling but to me the proposed model looks more attractive.

   (a) ZEO based quantum measurement theory [L9] combined with $M^8 - H$ duality ($H = M^4 \times CP_2$) [L5] and number theoretic vision [L18, L17] leads to the view that preferred extremals in M^8 consists of a sequence of 4-D pieces glued together at preferred values of M^4 time $t = r_n$, which correspond to the roots of a polynomial with rational coefficients determining the extension of rationals characterizing the adele in adelic physics which can be seen as a fusion of real physics of sensory experience and various p-adic physics of cognition [L6, L7].

   This polynomial would determine octonionic polynomial as its analytic continuation in turn defining 4-D space-time surface in M^8 as an algebraic surface identified as a root of its "real" or "imaginary" part in quaternionic sense. The roots $t = r_n$ would correspond to special 6-D brane like solutions of the polynomial having topology and metric of 6-sphere S^6 and intersecting M^4 along the 3-ball $t = r_n, r < r_n$ defining a "special moment in the life of self" in TGD inspired theory of consciousness [L17].

This surface would be mapped by $M^8 - H$ duality to a preferred extremal in H, which is minimal surface having string world sheets and partonic 2-surfaces as singularities. At the 2-D singularities 4-D quaternionic tangent or normal space in M^8 would degenerate to 2-D space.

(b) One can say that incoming and outgoing space-time surfaces representing particles are glued together along their ends at these hyperplanes of M^4. These time values would naturally correspond to the time values at which SFRSs take place. SSFRs correspond to quantum measurements that commute with the observables, whose eigenstates the states the passive boundary of CD are. Time would be one of the observables measured in SSFR and involve temporal localization for the position of the active boundary of CD determining the size of CD.

4. The most conservative picture is that the existing nuclear physics deduced from laboratory experiments provides a faithful phenomenological description of nuclear physics of ordinary nculei. However, if this picture is correct, nuclear fusion might occur also in the convective zone with dark fusion as intermediate step. One expects that the rate is very sensitive to the temperature and becomes very small near the surface of Sun. Dark fusion could increase the temperature and this could reduce the thickness of the convective zone deduced from the model of Asplund et al [E1, E3].

Could this model solve the metallicity problem?

1. In spectroscopic determinations only ordinary matter becomes visible. Also spectroscopic determinations detect only the ordinary matter. On the other hand, the intermediate states with non-standard value of Planck constant would be however real rather than virtual states. Therefore dark nuclear matter should be taken into account in the models the propagation of sound waves and photons in solar interior.

2. For sound wave propagation the time scale of propagation is much longer than the time scale assignable to the dark nuclei. This is the case also for photons with energies below the scale of dark nuclear energies if they have same value of h_{eff} and are thus dark. This would suggest that the density of dark nuclei contributes to the total density of nuclei deducible from the opacity, sound velocity, and density as parameters. The solar abundance problem would be thus provide direct evidence for dark matter in TGD sense.

3. Dark nuclei would correspond to magnetic flux tubes carrying dark nucleon sequences and the mass fraction of dark nuclei would correspond to the fraction of missing matter estimated to be 1500 Earth masses giving $M_D/M/ \sim 4 \times 10^{-3}$. The ratio of the dark metallicity to ordinary metallicity would be about 5/13 from the metallicities 1.3 per cent *resp.* 1.8 per cent deduced from spectroscopy *resp.* helio-seismology.

2.2 Could Sun contain dark magnetic flux tubes carrying dark matter?

The proposal of metallicity problem proposed above relies on dark matter in TGD sense - that is as $h_{eff} = nh_0$ phases. TGD predicts however also galactic dark matter assignable to long cosmic strings which thicken to magnetic flux tubes during cosmic evolution. These objects carry dark energy as magnetic and volume energy and it might be that one should dark about galactic dark energy. They can carry also dark matter in TGD sense. In any case, they would produce ordinary matter and its dark variants as $h_{eff} = n \times h_0$ phases in the thickening process reducing string tension somewhat like the decay of inflaton field produces ordinary matter.

2.2.1 Galactic dark matter in TGD

Consider first the model for galactic dark matter in TGD

1. TGD explains galactic dark matter as being associated with long cosmic strings, which form tangles at which the cosmic string thickens to flux tube and part of its Kähler magnetic energy transforms to ordinary particles and creates the ordinary matter associated with galaxy (this might included also $h_{eff} = nh_0$ phases which also behave like dark matter whereas galactic dark matter could correspond to dark energy alone). The thickening however generates volume energy and the process must stop.

   A phase transition reducing the value of thel ength scale dependent cosmological constant proportional to the inverse square of p-adic length scale $L_p \propto \sqrt{p}$, $p \simeq 2^k$ [K6], and thus reducing the contribution of volume energy however initiates the expansion again. Accelerating cosmological expansion and inflationary cosmology would represent examples of these accelerating periods. This gives a sequence of expansion period first accelerating and then decelerating. The values of cosmological constant and string tension come in some powers of 2. $T_{tube} = 2^{-k}T_{max}$, $k > 0$ some integer. In this picture cosmological expansion would mean generation of space-time sheets with larger size scales and smaller cosmological constant but also the space-time sheets with smaller cosmological constant would be present unlike in standard cosmology.

2. This model assigns galactic dark matter with long cosmic strings and automatically predicts flat velocity spectrum with velocity proportional to $\sqrt{T_{tube}G}$, T_{tube} string tension. It also explains the old observation that galaxies form long linear structures.

   Here one must stop and ask what string tension does mean. T_{tube} has been taken to mean classical string tension determined by the Kähler magnetic energy and volume energy. What about the contribution of dark matter inside flux tube and consisting at fundamental level of quarks? Should one count it separately? Or does quantum classical correspondence (QCC) imply that the classical contribution is equal to the quantum contribution? QCC as basic principle of TGD indeed suggests that the latter option is correct. But does this mean that dark matter and dark energy in TGD sense should be regarded as equivalent?

3. The fractality of TGD Universe suggests that stars and even planets are sub-tangles of the tangles associated with galaxies. Even the TGD counterparts of galactic magnetic fields as flux tube structures could be understood as tangles resembling field line structures of dipole magnetic field. This could apply to stars and even planets. Stars and planets emerge at later stages of cosmic evolution so that one would have $T_{tube} << T_{max}$. One would have fractal structure: tangles along tangles along ...

2.2.2 Could solar core contain dark matter as dark nuclear strings at magnetic flux tubes?

The proposed explanation assumes that dark nuclear strings assignable to magnetic flux tubes define the intermediate states providing the TGD counterpart of quantum tunnelling impossible in TGD The flux tubes would be generated by the thickening of cosmic strings during cosmic evolution and it is interesting to look whether this picture conforms with this model.

1. The expression for string tension T_{max} for cosmic string as an object of form $X^4 = X^2 \times S^2 \subset M^4 \times CP_2$, where X^2 is minimal surface and S^2 is homologically non-trivial geodesic sphere, is deduced in [K5] and is given by

   $$T_{max} = \frac{1}{8\alpha_K R^2_{CP_2}} \ .$$

   Here one assumes that only Kähler action contributes. The volume contribution is expected to be of same order of magnitude and of the same sign since in twistor lift volume contribution is also essentially magnetic energy. For $\alpha_K = 1/137$ and $R^2_{CP_2} \sim 10^7 G$ one would obtain $T_{max} \sim 10^{-6}/G$.

   p-Adic length scale hypothesis suggests that the thickening reduces T_{tube} by powers of 2 in equilibria in which magnetic energy does not transform to particles anymore. Note that the decay of magnetic energy to particles is analog for the decay of inflaton field in inflationary cosmology.

2. To get an idea about the value of reduced string tension T_{tube}, one can estimate the mass of a straight string portion with length of solar diameter $D(Sun) = 2R(Sun) = 1.4 \times 10^6$ km going through the Sun and having string tension $T_{tube} = T_{max}$. Solar mass $M(Sun)$ corresponds to a blackhole with Schwartschild radius $R_S \sim 3$ km. Solar diameter corresponds $D(Sun) = 2R(Sun) \sim .46 \times 10^6 \times R_S$.

   For $T_{max} \sim 10^{-6}/G$ and for $D(Sun) = 2R(Sun)$ the mass of straight string portion the mass would be about $2.3M(Sun)$. This option would suggest that a portion of long string with length of solar diameter of Sun and having solar mass has thickened to a flux tube forming a tangle filling the entire Sun and perhaps also the Kähler magnetic flux tubes assignable to the solar magnetic field.

3. If only the solar mass has been produced by the transformation of the dark energy of cosmic string to particles and dark flux tubes, the string tension should be corrected to $T_{max}/2.3$ to give just the solar mass. The mass for the portion contained in the core would be $M(Core) \sim 8 \times 10^{-3} M(Sun)$, which is roughly twice the estimated missing mass if it is 1500 Earth's masses mentioned in the popular article would correspond to a fraction of 4.5×10^{-3} of solar mass. My own estimate gave roughly twice this value, which happens to co-incide with the above value. Is this a mere co-incidence?

4. The discrepancy could be resolved by assuming that the flux tube has formed a tangle extending outside Sun. Roughly half of the flux tube mass should go to the tangle outside Sun. The general proposal indeed is that the tangle represents also the Kähler magnetic field of Sun. It could even give rise to the planetary tangles.

One can imagine two extreme options.

1. The thickness of the flux tube would be very small in the core for $T_{tube} = T_{max}/4$. For T_{tube} not much smaller than $T_{max}/4$ it would take negligibly small volume and could not have strong effects on opacity, acoustic properties, and nuclear fusion by the proposed counterpart of tunnelling. This option seems to be excluded.

2. If the flux tube is strongly thickened and has thus small T_{tube} it must be much be considerably longer than core diameter and thus form a spaghetti like structure filling a considerable portion of the volume of core. Filling fraction must be however smaller than 1. This could increase opacity and modify acoustic properties, and most importantly make possible nuclear fusion. The thickened flux tube would serve as seat of dark nuclei and give rise to dark nuclear strings. This option is favored by the proposed solution of the abundance problem.

Consider now a more detailed estimate.

1. The model for "cold fusion" [L4] suggests that at least in this case the flux tube thickness corresponds to electronic Compton to which one can assign Mersenne prime $M_{127} = 2^{127} - 1$. A good guess is that this is the case also in nuclear core.

   One would have $L_e \simeq \sqrt{5}L(127) = 2.4 \times 10^{-12}$ meters assignable to electrons essentially equal to the electron Compton length about 10^{-12} meters. The p-adic length scale assignable to proton and neutron corresponds to $L(107)$ and if this scale characterizes also the nuclear strings, the scaling of the nuclear flux tube thickness would be roughly by a factor $\sqrt{5} \times 2^k$, $k = (127 - 107)/2 = 2^{10}$, giving roughly the scaling factor 2^{11}.

   The ratio of the flux tube thickness to the thickness of cosmic string given by $R_(CP_2) \simeq 10^{3.5} L_{Pl}$, where L_{Pl} is Planck length, would be roughly the ratio $L_e/R_{CP_2} \sim 4.7 \times 10^{19}$. The string tension of cosmic strings would be reduced by a factor of order $L_e^2/R_{CP_2}^2 \sim .45 \times 10^{-39}$. The reduction of string tension from the estimate for T_{max} to L_e^2 would give 10 times larger estimate $L_e^2 T_{max} \sim 4.5 \times 10^{-39}$.

2. If nuclear binding energy scales like inverse of p-adic length scale $L(k)$, the nuclear binding energy scale would be reduced roughly by the ratio L_p/L_e of Compton length scales of proton and electron scaling roughly by a factor $m_e/m_p \sim 2^{-11}$ from the maximal value about 7 MeV to 3.5 keV. The temperature of the solar core corresponds to thermal energy larger than 1.5 keV. Thus the "cold fusion" inspired estimate for the flux tube thickness seems to make sense.

3. The condition that string tension is $T_{tube} \sim 1/L_e^2$ and the dark mass is about $M_D \sim 4 \times 10^{-3} M(Sun)$ gives and estimate for the length L_{tube} of the flux tube inside solar core from the equation

$$T_{tube}L_{tube} \sim \frac{L_{tube}}{L_e^2} \sim M_D \sim 4 \times 10^{-3} M(Sun) \sim T_{max}R(core) \ . \quad (2.1)$$

This gives for L_{tube} the estimate

$$L_{tube} = L_e^2 T_{max} R(core) \quad (2.2)$$

giving

$$\frac{L_{tube}}{R(core)} = L_e^2 T_{max} \sim 2.2 \times 10^{39} \quad (2.3)$$

using the earlier estimate.

4. Does this make sense? In other words, is the volume fraction filled by the flux tube smaller than one? The fractional volume taken by the flux tube of transversal area $S \sim \pi L_e^2$ would be

$$\frac{V_{tube}}{V_{core}} \sim \frac{3}{4} \frac{L_{tube} L_e^2}{R(core)^3} = \frac{3}{4} L_e^2 T_{max} \frac{L_e^2}{R(core)^2} \sim .3 \quad (2.4)$$

for $R(core) = 1.4 \times 10^5$ km. 30 per cent of volume would be filled by flux tube so that dark nuclear physics would be important and could explain the missing mass. This estimate is rough but suggests that the model might work.

One can look the situation from the viewpoint of twistor lift predicting a hierarchy of cosmological constants depending on the p-adic length scale [L8, L15, L13, L19, L20].

1. The value of the cosmological constant in cosmic scales would correspond to an effective volume energy density proportional to $1/GL_{p_H}^2$ with $L_{p_H} \sim 10^9$ ly H refers to "horizon". The effective volume energy density could be expressed at GRT limit as proportional to $1/L_{p(small)}^4$. One has $L_{p(small)} \sim L_{neuron} \sim 10^{-4}$ m, the size scale of large neuron, which suggests a connection between cosmology and quantum biology. $1/L_{neuron}^2$ defines order of magnitude for string tension of the flux tubes involved and having thickness of order $1/L_{neuron}^2$.

2. In the case of nuclear flux tubes in solar core the dark energy density in scale of large neuron would be larger by fact L_{neuron}^4/L_e^4 by a factor of order 10^{-32}. The scale L_{p_H} defining scale of horizon would be reduced by factor of order 10^{-16} from its cosmological value $L_{p_H} \sim 10^9$ ly to $L_{p_H} \sim 2.5 \times 10^8$ m to be compared with the radius $R(core) \sim 1.4 \times 10^8$ meters of the solar core. In many-sheeted cosmology nuclear core could be seen as scaled down cosmology.

To sum up, these estimates are rough and involve numerical factors but it seems to me that the model survives the simplest quantitative tests.

2.2.3 Is there a relation to the model of solar dark matter inspired by Nottale's proposal?

One can look the situation also in the TGD based model of solar dark matter [K5, K7] [L12, L11] inspired Nottale's proposal [E2] that planetary orbits could be interpreted as Bohr orbits. In TGD framework the Bohr orbits could be assigned with dark matter accompanying ordinary planetary matter perhaps assignable as distributions with the flux tubes along orbits.

First a couple of general comments about the TGD variant of the generalization of the model of Nottale to TGD framework.

1. What is new that the perturbative expansion for scattering amplitudes would be in powers of the gravitational analog of fine structure constant equal to $GMm/\hbar_{gr}(M,m) = v_0/c < 1$ and is expected to converge. This would make possible quantal perturbation theory for $GMm >> 1$.

2. Since the orbital radii do not depend at all on M (by Equivalence Principle dictating the form of h_{gr}) one can imagine decomposing m as $m = \sum m_i$. One indeed expects that gravitational flux tubes with a spectrum of $h_{eff} = h_{gr}$ is involved.

3. Can one assume that flux tube connects masses M and m forming its ends or does m correspond to space-time sheet having wormhole contacts with the gravitational flux tubes rather than serving as the end of flux tube? For the first option one would have decomposition to $M = \sum M_i$ to dark parts M_i and $m = \sum m_i$ with $\hbar_{gr} = GM_im/v_0(M_i, m_i)$ at corresponding flux tubes connecting them to masses m at orbit with given radius. One would have partitioning of M and m to interacting pairs. There would be no gravitational interaction between M_i and m_j for $i \neq j$, and this does not conform with the universality of gravitational interaction.

   Note that would differentiate between gauge interactions and gravitational interactions. For the gauge of gauge interactions one could say that the flux tube as wormhole throats as its ends and there would be screening. Note however that flux tubes carrying monopole must be closed, and could be 2-sheeted with return flux going to a parallel sheet through wormhole contact and returning along it.

Consider now the possible relationship with the proposal that solar core carries dark matter.

1. $v_0 = 2^{-11}c$ appears as a velocity type parameter in the Bohr orbit model for planetary system proposed first by Nottale and later developed in TGD further [K5, K4, K7] [L12, L11]. The value of the gravitational Planck constant $h_{eff} = nh_0$ for the dark flux tubes mediating gravitational interaction between large mass M and small mass m would be $\hbar_{eff} = \hbar_{gr} = GMm/v_0$. M would be solar mass. By Equivalence Principle m can the mass of the planet or of any particle composing it. $v_0/c \simeq 2^{-11}$ is the value required for the inner planets.

2. The article mentions also the value of $M_D/M \sim 2^{-11}$ for the fraction of dark matter in the solar core. One would have $M_D/M = v_0/c$: is this mere accident? Notice however the value $M_D/M \sim 4\times2^{-11}$ is from $M_D = 1500$ Earth masses and my own estimate $M_D/M \sim 2\times2^{-11}$. I

   If one takes these estimates seriously, it would seem that the value of v_0/c in the core is larger than outside Sun. In this case flux tubes are longer and since flux tube length as quantal length is expected to increase with h_{gr}, one expects that h_{gr} is larger. Indeed, for the outer planets the Nottale model requires $v_0 \rightarrow v_0/5$.

2.2.4 What about galaxies?

I have proposed that this general vision applies also to the formation of spiral galaxies. This can be tested in the case of Milky Way at order of magnitude level.

1. The mass $M(gal)$ of the Milky way is estimated to be in the range $[.8, 4.5] \times 10^{12} M(Sun)$. For a string with maximal string tension this would correspond to a direct string portion with length $L(gal) = M(gal)/R(Sun) = M(gal)/M(Sun)$. In fact, this stringy mass formula

is known to hold for quite a many astrophysical objects as I learned decades ago in a particle physics conference - in good old times times particle physics conferences allowed non-main-stream talks during the last conference day. This gives the estimate $L(gal) \in [.6, 3.3] \times 10^5$ ly. The radius R_{gal} of galaxy is estimated to be in the range $[.75, 1.0] \times 10^5$ ly. The length of string within galactic radius would satisfy $L_{gal} = [.8, 3.3]R_{gal}$. The estimate excludes the lower bound. For the upper bound the one has $L_{gal} \sim 3.3 \times R_{gal}$.

The thickness of the Milky Way is about 2×10^3 ly which suggests that the portion of long string making galaxy is soaked up to the galactic plane [L14].

The supermassive blackhole in the galactic center is estimated to have mass $M(BH) = 4 \times 10^6 \times M(Sun)$. By scaling this would correspond to a straight cosmic string portion with length $L_{BH} \sim .1$ ly. The size of the galactic blackhole (see `http://tinyurl.com/od3spdu`) is $R_{S,BH} \sim 4.4 \times 10^{-5}$ ly giving $R_{S,BH}/L_{gal} \sim 4.4 \times 10^{-4}$. One has $T_{max} \sim 10^{-6}/G$ and blackhole corresponds effectively to a string with tension $T_G \sim 1/2G$ and length $R_{S,BH}$ so that the ratio would be $R_{S,BH}/L_{gal} \sim 2G/T_{max} \sim 2 \times 10^{-6}$. The straight string with length L_{BH} would have been compressed to a volume of Schwartchild radius $R_{B,S} \sim 2^{-11}L_{BH}$.

2. Could the spiral structure of spiral galaxies involving several spiral correspond to a rotating cosmic string thickened to a flux tube? The original model for the spiral structure as a cosmic string at rest in in Robertson-Walker coordinates and seemingly rotating in linear Minkowski coordinates failed [K1] since it predicted too weak spiralling. The observed spiral structure could however corresponds to a thickened dark flux tube with lower string tension and longer length.

   If so the length of the original spiral should be about $L_{gal} = 3.3 \times R_{gal}$. Perhaps the primordial configuration of the dark flux tube could be modelled as a cosmic string solution at rest in Robertson-Walker coordinates, which then thickened and gained length becoming more spiral.

3. For elliptic galaxies (see `http://tinyurl.com/ayyvg9n`) the sizes vary in the range $3 \times 10^3 - 7 \times 10^5$ ly (roughly 2 orders of magnitude) and masses in the range $[10^5, 10^{13}]$ ly (8 orders of magnitude!) so that linear relationship between size and mass is excluded. The length $L(gal)$ of the original straight string would be in the range $[10^{-8}, 7.4 \times 10^5]$ ly giving $L_{gal} \in [.3 \times 10^{-6}, 1.0] \times R_{gal}$. Thus elliptical cannot correspond to cosmic strings. At the upper limit elliptic galaxy could correspond to straight cosmic string and the visible matter would not come from the decay of the cosmic string. This estimate conforms with the earlier proposal that only spiral galaxies correspond to cosmic strings.

2.3 Conclusions

First a general comment about nuclear physics, which applies with appropriate modifications also to the evolution of theoretical particle physics (or lack of it) after the emergence of standard model followed by GUTS and superstring models.

1. One can see the standard nuclear physics as a tragic Odysseia due to the stubborn sticking to the naive length scale reductionism. All began with the modelling of nucleons as point like particles inspired by the successes of atomic physics. It turned out that the model for nucleons as point like particles failed and we still do not understand low energy nuclear physics. The wave-mechanical potential models and QFT models assuming the notion of point-like nucleon led to an inflation of nuclear models each of them explaining some aspects of nuclei but a real theory is still missing.

2. Dark nuclear physics was originally suggested in TGD framework to explain "cold fusion" and later conjectured to allow the understanding of pre-stellar evolution as a step-wise process leading to the gradual heating of matter leading to nuclear fusion. The model relies on nuclear strings and their dark variants as dark nuclear matter. In this article it is argued that this picture leads to a realistic model of nuclear fusion and of stellar core and perhaps entire stellar interior as a dark spaghetti like structure. Ironically, "cold fusion" researchers regarded for decades as the pariahs of physics community, would show the path to follow.

The proposed model involves several new deep ideas inspired by the fusion of general TGD based visions about nuclear physics on one hand and about the formation of galaxies, stars, and planets on the other hand. Behind both visions is the notion about fractal hierarchy of flux tubes formed from cosmic strings by gradual thickening during the cosmic evolution. A further important piece is ZEO based view about quantum state and quantum measurement forcing to modify ordinary quantum mechanical description.

1. The idea is that Sun and its Kähler magnetic field form a sub-tangle of the galactic tangle associated with a long cosmic string and extending outside Sun, and perhaps including also planets as sub-tangles. This can be made more precise by assuming that total mass of the straight cosmic string portion involved equals to the total mass of the system considered. The estimate from the diameter of Sun suggests that the total mass is few times the solar mass. This model connects closely with the problem of cosmological constant solved by the twistor lift of TGD and solar physics can be associated with one particular value of length scale dependent cosmological constant: also this idea forced by TGD is revolutionary.

2. Quantum classical correspondence stating that quantum states are superpositions of Bohr orbit like preferred extremals challenges the idea about tunnelling as an essential element of nuclear physics. The first option is that BSFR - identified as ordinary $\rightarrow$ dark phase transition increasing the value of h_{eff} and involving time reversal followed by its reversal - allows wave-mechanical tunnelling as an approximate description. An alternative realization encouraged by M^8-H duality would be as SSFR involving no time reversal but discontinuity at the level of space-time development involving TGD counterparts of branes. This option resonates with the idea about sequence of SRFFs as TGD counterpart of a unitary time evolution suggested by the wave mechanical model. In any case, both TGD view about dark matter and ZEO would become part of nuclear physics, and mean giving up standard ontology and standard wave mechanics as a description of nuclei.

   It would not be surprising if similar view about tunnelling could apply also to particle reactions and I have proposed that dark variants of nuclei of M_{89} hadron physics as scaled variant of ordinary M_{107} hadron physics have made themselves visible via the observed (but neglected) bumps with masses obtained by scaling up the masses of ordinary mesons by factor 512 [K2]. Tunnelling would be now from ordinary hadron physics to dark M_{89} hadron physics.

3. When one has paradox, one knows that something is wrong with the basic conceptualization. The presence of dark variants of nuclei makes itself directly visible via the conflict between metallicities deduced from spectroscopy and meteorite abundances and those derived from helio-seismology and solar neutrino physics. Besides ordinary nuclei also their dark variants would present and contribute to metallicity in the solar interior.

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