# TGD and Astrophysics

M. Pitkänen[1], May 28, 2007

[1] Department of Physical Sciences, High Energy Physics Division,
PL 64, FIN-00014, University of Helsinki, Finland.
matpitka@rock.helsinki.fi, http://www.physics.helsinki.fi/∼matpitka/.
Recent address: Puutarhurinkatu 10,10960, Hanko, Finland.

## Contents

**Abstract**

In this chapter some applications of TGD based view about cosmology and astrophysics are discussed.

p-Adic length scale hypothesis can be applied in astrophysical length scales, too and some examples of possible applications are discussed. One of the most interesting implications of p-adicity is the possibility of series of phase transitions changing the value of cosmological constant behaving as $\Lambda \propto 1/L^2(k)$ as a function of p-adic length scale characterizing the size of the space-time sheet.

A model for the solar magnetic field as a bundle of topological magnetic flux tubes is constructed and a model of Sunspot cycle is proposed. This model is also shown to explain the mysteriously high temperature of solar corona and also some other mysterious phenomena related to the solar atmosphere. A direct connection with the TGD based explanation of the dark energy as magnetic and $Z^0$ magnetic energy of the magnetic flux tubes containing dark matter as ordinary matter, emerges. The matter in the solar corona is simply dark matter leaked from the highly curved portions of the magnetic flux tubes to the space-time sheets where it becomes visible. The generation of anomalous $Z^0$ charge caused by the runoff of dark neutrinos in Super Nova could provide a first principle explanation for the avoidance of collapse to black-hole in Super Nova explosion.

D. Da Rocha and Laurent Nottale have proposed that Schrödinger equation with Planck constant $\hbar$ replaced with what might be called gravitational Planck constant $\hbar_{gr} = \frac{GmM}{v_0}$ ($\hbar = c = 1$). $v_0$ is a velocity parameter having the value $v_0 = 144.7 \pm .7$ km/s giving $v_0/c = 4.6 \times 10^{-4}$. This is rather near to the peak orbital velocity of stars in galactic halos. Also subharmonics and harmonics of $v_0$ seem to appear. The support for the hypothesis coming from empirical data is impressive.

Nottale and Da Rocha believe that their Schrödinger equation results from a fractal hydrodynamics. Many-sheeted space-time however suggests astrophysical systems are not only quantum systems at larger space-time sheets but correspond to a gigantic value of gravitational Planck constant. The gravitational (ordinary) Schrödinger equation would provide a solution of the black hole collapse (IR catastrophe) problem encountered at the classical level. The resolution of the problem inspired by TGD inspired theory of living matter is that it is the dark matter at larger space-time sheets which is quantum coherent in the required time scale.

I have proposed already earlier the possibility that Planck constant is quantized. The spectrum is given in terms of integers $n$ characterizing the quantum phases $q = exp(i\pi/n)$. The Planck constants associated with $M^4$ and $CP_2$ degrees of freedom are predicted to be different in general and arbitrarily large values of Planck constants are possible so that $\hbar_{gr} = GMm/v_0$ can be understood in this framework. The general philosophy would be that when the quantum system would become non-perturbative, a phase transition increasing the value of $\hbar$ occurs to preserve the perturbative character. This would apply to QCD and to atoms with $Z > 137$ as well.

The integers $n$ which correspond to polygons constructible using ruler and compass are number theoretically preferred. This gives very strong constraints on planetary masses, their general mass scale, and also on the value of $v_0$. The constraints are satisfied with accuracy better than 10 per cent.

TGD predicts correctly the value of the parameter $v_0$ assuming that cosmic strings and their decay remnants are responsible for the dark matter. The harmonics of $v_0$ can be understood as corresponding to perturbations replacing cosmic strings with their n-branched coverings so that tension becomes $n^2$-fold: much like the replacement of a closed orbit with an orbit closing only after $n$ turns. $1/n$-sub-harmonic would result when a magnetic flux tube split into n disjoint magnetic flux tubes.

Long ranged classical electro-weak and color gauge fields are unavoidable in TGD framework. The smallness of the parity breaking effects in hadronic, nuclear, and atomic length scales does not however seem to allow long ranged electro-weak gauge fields. The problem disappears if long range classical electro-weak gauge fields are identified as space-time correlates for massless gauge fields created by dark matter. The identification explains chiral selection

in living matter and unbroken $U(2)_{ew}$ invariance and free color in bio length scales become characteristics of living matter and of bio-chemistry and bio-nuclear physics. An attractive solution of the matter antimatter asymmetry is based on the identification of also antimatter as dark matter.

The last section of the chapter is devoted to some astrophysical and cosmological anomalies such as the apparent shrinking of solar system observed by Masreliez, Pioneer anomaly, Flyby anomaly and new anomalies in cosmic microwave background.

# 1 Introduction

The concept of 3-space in TGD is considerably more general than in the conventional theories. 3-space is not any more connected but can have arbitrary many disjoint components. Even macroscopic boundaries are allowed: macroscopic bodies are interpreted as 3-surfaces having outer boundary. There are strong indications that 3-space has a hierarchical fractal structure: 3-surfaces topologically condensed on 3-surfaces condensed on..., where topological condensation means that 'small' 3-surface is 'glued' to a larger 3-surface by connected sum operation.

The fundamental feature of the topological condensation is the generation of Kähler electric fields implied by the minimization of Kähler action: gravitational gauge fields are always accompanied by long range electro-weak gauge fields with Kähler charge, which in the astrophysical scales is apart from a small but non-vanishing numerical factor equal the mass of particle using Planck mass as unit. In shorter length scales the Kähler charge can be larger and reflects the development of long range $Z^0$ fields. Topological field quantization is a central concept: the presence of Kähler charge implies that 3-surface has outer boundary: the larger the charge the smaller the size of the 3-surface. This makes it possible to relate the size of the 3-surface (topological field quantum) to the Kähler charge of a typical particle in the condensate. The formation of macroscopic quantum systems, such as super conductors, corresponds to the formation of bonds between the boundaries of the neighboring topological field quanta. A possible astrophysical example is neutron star: join along boundaries bonds are formed between neutrons so that single giant nucleus results.

## 1.1 p-Adic length scale hypothesis and astrophysics

Various levels of the topological condensate obey effective p-adic topology and form p-adic hierarchy ($p_1 < p_2$ can condense on $p_2$ ). Physically interesting length scales should come as square roots of powers of 2: $L(k) \simeq 2^{\frac{k}{2}} l$, $l = 1.288 \cdot 10^4 \sqrt{G}$ and various considerations suggest that prime powers are especially interesting values of $k$. For astrophysical applications interesting prime values of $n$ are: $n = 229, 233, 239, 241, 251, 257, 263...$ and it is of considerable interest to find whether these length scales correspond to astro-physically interesting length scales.

The combination of p-adic length scale hierarchy idea with the concepts of topological evaporation and condensation, join along boundaries bond and long ranged weak and color forces, is an exciting challenge. In this chapter these concepts are applied in astrophysical length scales. The identification of the prime power length scales as fundamental astrophysical length scales is proposed and the identification of the fundamental cosmological length scale identified by Einasto *et al* [16] as a p-adic length scale is proposed. One of the most interesting implications of p-adicity is the possibility of series of phase transitions changing the value of cosmological constant behaving as $\Lambda \propto 1/L^2(k)$ as a function of p-adic length scale characterizing the size of the space-time sheet.

## 1.2 The high temperature of the solar corona and dark matter

The high temperature of the solar corona: about $10^6$ K is mystery and a model of magnetic field consisting of microscopic flux tubes regarded as space-time sheets explains this phenomenon and

several other mysterious looking phenomena related to the solar atmosphere in elegant manner. A direct connection with the TGD based explanation of the dark energy as magnetic and $Z^0$ magnetic energy of the magnetic flux tubes containing dark matter as ordinary matter, emerges. The matter in the solar corona is simply dark matter leaked from the highly curved portions of the magnetic flux tubes to the space-time sheets where it becomes visible.

## 1.3 Quantum criticality, hierarchy of dark matters, and dynamical $\hbar$

Quantum criticality is the basic characteristic of TGD Universe and quantum critical superconductors provide an excellent test bed to develop the ideas related to quantum criticality into a more concrete form.

### 1.3.1 Quantization of Planck constants and the generalization of the notion of imbedding space

The recent geometric interpretation for the quantization of Planck constants is based on Jones inclusions of hyper-finite factors of type $II_1$ [A9].

1. One can argue that different values of Planck constant correspond to imbedding space metrics involving scalings of $M^4$ *resp.* $CP_2$ parts of the metric deduced from the requirement that distances scale as $\hbar(CP_2)$ *resp.* $\hbar(M^4)$. Denoting the Planck constants by $\hbar(M^4) = n_a\hbar_0$ and $\hbar(CP_2) = n_b\hbar_0$, one has that covariant metric of $M^4$ is proportional to $n_b^2$ and covariant metric of $CP_2$ to $n_a^2$.

   This however leads to difficulties with the isometric gluing of $CP_2$ factors of different copies of $H$ together. Kähler action is however invariant under over-all scaling of $H$ metric so that one can scale it down by $1/n_a^2$ meaning that $M^4$ covariant metric is scaled by $(n_b/n_a)^2$ and $CP_2$ metric remains invariant and the difficulties in isometric gluing are avoided. This means that if one regards Planck constant as a mere conversion factor, the effective Planck constant scales as $n_a/n_b$.

   In Kähler action only the effective Planck constant $\hbar_{eff}/\hbar_0 = \hbar(M^4)/\hbar(CP_2)$ appears and by quantum classical correspondence same is true for Schödinger equation. Elementary particle mass spectrum is also invariant. Same applies to gravitational constant. The alternative assumption that $M^4$ Planck constant is proportional to $n_b$ would imply invariance of Schrödinger equation but would not allow to explain Bohr quantization of planetary orbits and would to certain degree trivialize the theory.

2. $M^4$ and $CP_2$ Planck constants do not fully characterize a given sector $M^4_\pm \times CP_2$. Rather, the scaling factors of Planck constant given by the integer $n$ characterizing the quantum phase $q = exp(i\pi/n)$ corresponds to the order of the maximal cyclic subgroup for the group $G \subset SU(2)$ characterizing the Jones inclusion $\mathcal{N} \subset \mathcal{M}$ of hyper-finite factors realized as subalgebras of the Clifford algebra of the "world of the classical worlds". This means that subfactor $\mathcal{N}$ gives rise to $G$-invariant configuration space spinors having interpretation as $G$-invariant fermionic states.

3. $G_b \subset SU(2) \subset SU(3)$ defines a covering of $M^4_+$ by $CP_2$ points and $G_a \subset SU(2) \subset SL(2,C)$ covering of $CP_2$ by $M^4_+$ points with fixed points defining orbifold singularities. Different sectors are glued together along $CP_2$ if $G_b$ is same for them and along $M^4_+$ if $G_a$ is same for them. The degrees of freedom lost by $G$-invariance in fermionic degrees of freedom are gained back since the discrete degrees of freedom provided by covering allow many-particle states formed from single particle states realized in $G$ group algebra. Among other things these many-particle states make possible the notion of N-atom.

4. Phases with different values of scalings of $M^4$ and $CP_2$ Planck constants behave like dark matter with respect to each other in the sense that they do not have direct interactions except at criticality corresponding to a leakage between different sectors of imbedding space glued together along $M^4$ or $CP_2$ factors. In large $\hbar(M^4)$ phases various quantum time and length scales are scaled up which means macroscopic and macro-temporal quantum coherence. In particular, quantum energies associated with classical frequencies are scaled up by a factor $n_a/n_b$ which is of special relevance for cyclotron energies and phonon energies (superconductivity). For large $\hbar(CP_2)$ the value of $\hbar_{eff}$ is small: this leads to interesting physics: in particular the binding energy scale of hydrogen atom increases by the factor $(n_b/n_a)^2$.

### 1.3.2 Preferred values of Planck constants

Number theoretic considerations favor the hypothesis that the integers corresponding to Fermat polygons constructible using only ruler and compass and given as products $n_F = 2^k \prod_s F_s$, where $F_s = 2^{2^s} + 1$ are distinct Fermat primes, are favored. The reason would be that quantum phase $q = exp(i\pi/n)$ is in this case expressible using only iterated square root operation by starting from rationals. The known Fermat primes correspond to $s = 0, 1, 2, 3, 4$ so that the hypothesis is very strong and predicts that p-adic length scales have satellite length scales given as multiples of $n_F$ of fundamental p-adic length scale. $n_F = 2^{11}$ corresponds in TGD framework to a fundamental constant expressible as a combination of Kähler coupling strength, $CP_2$ radius and Planck length appearing in the expression for the tension of cosmic strings, and the powers of $2^{11}$ seem to be especially favored as values of $n_a$ in living matter [M3].

### 1.3.3 How Planck constants are visible in Kähler action?

$\hbar(M^4)$ and $\hbar(CP_2)$ appear in the commutation and anticommutation relations of various superconformal algebras. Only the ratio of scalings of $M^4$ and $CP_2$ metrics appears in Kähler action. The most natural assumption at the level of hyper-octonion space $HO = M^8$ is that $M^4$ metric is proportional to $n_b^2$ and $E^4$ metric to $n_a^2$. For $H = M^4 \times CP_2$ the assumption that $CP_2$ metric is proportional to $n_a^2$ however leads to mathematical difficulties and to a rather weird looking prediction that $CP_2$ can have arbitrarily large size. Hence the most natural conclusion is that the scaling of $CP_2$ metric is universal [A9]. This is achieved elegantly by performing over-all scaling of scaled up $H$ metric allowed by the invariance of Kähler action in this scaling so that a scaling of $M^4$ covraint metric by $(n_b/n_a)^2$ results and effective Planck constant as a mere conversion factor is scaled by $n_a/n_b$.

This implies that Kähler function through its dependence on $n_a/n_b$ codes for radiative corrections to the classical action, which makes possible to consider the possibility that higher order radiative corrections to functional integral vanish as one might expect at quantum criticality. For a given p-adic length scale space-time sheets with all allowed values of Planck constants are possible. Hence the spectrum of quantum critical fluctuations could in the ideal case correspond to the spectrum of $\hbar$ coding for the scaled up values of Compton lengths and other quantal lengths and times. If so, large $\hbar$ phases could be crucial for understanding of quantum critical superconductors, in particular high $T_c$ superconductors.

### 1.3.4 Phase transitions changing the level in dark matter hierarchy

The identification of the precise criterion characterizing dark matter phase is far from obvious. TGD actually suggests an infinite number of phases which are dark relative to each other in some sense and can transform to each other only via a phase transition which might be called de-coherence or its reversal and which should be also characterized precisely.

A possible solution of the problem comes from the general construction recipe for S-matrix. Fundamental vertices correspond to partonic 2-surfaces representing intersections of incoming and outgoing light-like partonic 3-surfaces.

1. If the characterization of the interaction vertices involves all points of partonic 2-surfaces, they must correspond to definite value of Planck constant and more precisely, definite groups $G_a$ and $G_b$ characterizing dark matter hierarchy. Particles of different phases could not appear in the same vertex and a phase transition changing the particles to each other analogous to a de-coherence would be necessary.

2. If transition amplitudes involve only a discrete set of common orbifold points of 2-surface belonging to different sectors then the phase transition between relatively dark matters can be described in terms of S-matrix. It seems that this option is the correct one. In fact, also propagators are essential for the interactions of visible and dark matter and since virtual elementary particles correspond at space-time level $CP_2$ type extremals with 4-dimensional $CP_2$ projection, they cannot leak between different sectors of imbedding space and therefore cannot mediate interactions between different levels of the dark matter hierarchy. This would suggest that the direct interactions between dark and ordinary matter are very weak.

   If the matrix elements for real-real partonic transitions involve all or at least a circle of the partonic 2-surface as stringy considerations suggest [C2], then one would have clear distinction between quantum phase transitions and ordinary quantum transitions. Of course, the fact that the points which correspond to zero of Riemann Zeta form only a small subset of points common to real partonic 2-surface and corresponding p-adic 2-surface, implies that the rate for phase transition is in general small. On the other hand, for the non-diagonal S-matrix elements for ordinary transitions would become very small by almost randomness caused by strong fluctuations and the rate for phase transition could begin to dominate.

### 1.3.5 Transition to large $\hbar$ phase and failure of perturbation theory

A further idea is that the transition to large $\hbar$ phase occurs when perturbation theory based on the expansion in terms of gauge coupling constant ceases to converge: Mother Nature would take care of the problems of theoretician. The transition to large $\hbar$ phase obviously reduces gauge coupling strength $\alpha$ so that higher orders in perturbation theory are reduced whereas the lowest order "classical" predictions remain unchanged. A possible quantitative formulation of the criterion is that maximal 2-particle gauge interaction strength parameterized as $Q_1Q_2\alpha$ satisfies the condition $Q_1Q_2\alpha \simeq 1$.

A justification for this picture would be that in non-perturbative phase large quantum fluctuations are present (as functional integral formalism suggests). At space-time level this would mean that space-time sheet is near to a non-deterministic vacuum extremal. At parton level this would mean that partonic surface contains large number of $CP_2$ orbifold points so that S-matrix elements for the phase transition becomes large. At certain critical value of coupling constant strength one expects that the transition amplitude for phase transition becomes very large.

### 1.3.6 Dark matter as large $\hbar$ phase

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Nottale and Da Rocha believe that their Schrödinger equation results from a fractal hydrodynamics. Many-sheeted space-time however suggests astrophysical systems are not only quantum systems at larger space-time sheets but correspond to a gigantic value of gravitational Planck constant. The gravitational (ordinary) Schrödinger equation would provide a solution of the black hole collapse (IR catastrophe) problem encountered at the classical level. The resolution of the problem inspired by TGD inspired theory of living matter is that it is the dark matter at larger space-time sheets which is quantum coherent in the required time scale.

### 1.3.7 Prediction for the parameter $v_0$

TGD predicts correctly the value of the parameter $v_0$ assuming that cosmic strings and their decay remnants are responsible for the dark matter. The harmonics of $v_0$ can be understood as corresponding to perturbations replacing cosmic strings with their n-branched coverings so that tension becomes $n^2$-fold: much like the replacement of a closed orbit with an orbit closing only after $n$ turns. $1/n$-sub-harmonic would result when a magnetic flux tube split into n disjoint magnetic flux tubes.

Also a heuristic formula for the dependence of $v_0$ on p-adic length scale can be deduced and predicts a logarithmic dependence on the p-adic length scale. This gives some flexibility so that the prediction of mass ratios following from ruler and compass quantum phases is not so deadly strong anymore. The planetary mass ratios can be produced with an accuracy better than 10 per cent assuming ruler and compass phases, and the dependence of $v_0$ on p-adic length scale characterizing the space-time sheets carrying the planet-Sun gravitational force might relate to the discrepancies.

### 1.3.8 Further predictions

The study of inclinations (tilt angles with respect to the Earth's orbital plane) leads to a concrete model for the quantum evolution of the planetary system. Only a stepwise breaking of the rotational symmetry and angular momentum Bohr rules plus Newton's equation (or geodesic equation) are needed, and gravitational Shrödinger equation holds true only inside flux quanta for the dark matter.

1. During pre-planetary period dark matter formed a quantum coherent state on the $(Z^0)$ magnetic flux quanta (spherical cells or flux tubes). This made the flux quantum effectively a single rigid body with rotational degrees of freedom corresponding to a sphere or circle (full SO(3) or SO(2) symmetry).

2. In the case of spherical shells associated with inner planets the $SO(3) \to SO(2)$ symmetry breaking led to the generation of a flux tube with the inclination determined by m and j and a further symmetry breaking, kind of an astral traffic jam inside the flux tube, generated a planet moving inside flux tube. The semiclassical interpretation of the angular momentum algebra predicts the inclinations of the inner planets. The predicted (real) inclinations are 6 (7) resp. 2.6 (3.4) degrees for Mercury resp. Venus). The predicted (real) inclination of the Earth's spin axis is 24 (23.5) degrees.

3. The $v_0 \to v_0/5$ transition allowing to understand the radii of the outer planets in the model of Da Rocha and Nottale can be understood as resulting from the splitting of $(Z^0)$ magnetic flux tube to five flux tubes representing Earth and outer planets except Pluto, whose orbital parameters indeed differ dramatically from those of other planets. The flux tube has a shape of a disk with a hole glued to the Earth's spherical flux shell.

   It is important to notice that effectively a multiplication $n \to 5n$ of the principal quantum number is in question. This allows to consider also alternative explanations. Perhaps external gravitational perturbations have kicked dark matter from the orbit or Earth to $n = 5k$,

$k = 2, 3, ..., 7$ orbits: the fact that the tilt angles for Earth and all outer planets except Pluto are nearly the same, supports this explanation. Or perhaps there exist at least small amounts of dark matter at all orbits but visible matter is concentrated only around orbits containing some critical amount of dark matter and these orbits satisfy $n \; mod \; 5 = 0$ for some reason.

4. A remnant of the dark matter is still in a macroscopic quantum state at the flux quanta. It couples to photons as a quantum coherent state but the coupling is extremely small due to the gigantic value of $\hbar_{gr}$ scaling alpha by $\hbar/\hbar_{gr}$: hence the darkness.

   The rather amazing coincidences between basic bio-rhythms and the periods associated with the states of orbits in solar system suggest that the frequencies defined by the energy levels of the gravitational Schrödinger equation might entrain with various biological frequencies such as the cyclotron frequencies associated with the magnetic flux tubes. For instance, the period associated with $n = 1$ orbit in the case of Sun is 24 hours within experimental accuracy for $v_0$.

### 1.4 Dark matter as a source of long ranged weak and color fields

Long ranged classical electro-weak and color gauge fields are unavoidable in TGD framework. The smallness of the parity breaking effects in hadronic, nuclear, and atomic length scales does not however seem to allow long ranged electro-weak gauge fields. The problem disappears if long range classical electro-weak gauge fields are identified as space-time correlates for massless gauge fields created by dark matter. The identification explains chiral selection in living matter and unbroken $U(2)_{ew}$ invariance and free color in bio length scales become characteristics of living matter and of bio-chemistry and bio-nuclear physics. An attractive solution of the matter antimatter asymmetry is based on the identification of also antimatter as dark matter.

## 2 p-Adic length scale hypothesis at astrophysical and cosmological length scales

p-Adic length scale hierarchy gives quantitative contents for the idea about fractal many-sheeted cosmology and therefore deserves a brief discussion.

### 2.1 List of long p-adic length scales

There are not very many p-adic lengths scales $L(k)$ ($p \simeq 2^k$, $k$ power of prime ) between 1 meter and $10^{11}$ light years as the approximate density $\Psi(n) \simeq \frac{1}{ln(n)}$ of prime numbers as function of $n$ shows. Therefore the length scale hypothesis is nontrivial and the attempt to identify physically the length scales is perhaps worth of the trouble although detailed identifications are not attempted in the following. If physics is indeed p-adic below length scale $L_p$ at level $p$, one expects p-adic fractality, when length scale resolution is smaller than $L_p$. Length scales $L(k)$ coming as twin pairs corresponding to primes $k$ and $k+2$ seem to define particularly interesting biological length scales. Therefore it is of interest look whether something similar might happen in astrophysical context. $L_p$ is the infrared cutoff scale for p-adic field theory limit of TGD but the idea that quantum effects might be important in astrophysical length scales looks admittedly rather wild.

| k | 227 | 229 | 233 | 239 | 241 |
|---|---|---|---|---|---|
| $L_p/m$ | $2.3E+3$ | $4.6E+3$ | $1.9E+4$ | $1.5E+5$ | $3.0E+5$ |
| k | 251 | 257 | 263 | 269 | 271 |
| $L_p/m$ | $.96E+7$ | $7.7E+7$ | $6.0E+8$ | $4.8E+9$ | $.9E+10$ |
| k | 277 | 289 | 293 | 307 | 311 |
| $L_p/m$ | $7.7E+10$ | $5.0E+12$ | $2.0E+13$ | $2.5E+15$ | $1.0E+16$ |
| k | 313 | 317 | 329 | 331 | 337 |
| $L_p/ly$ | 2.2 | $5.4E+2$ | $1.0E+3$ | 2.2E+3 | $8.4E+3$ |
| k | 347 | 349 | 353 | 359 | 367 |
| $L_p/ly$ | $2.8E+5$ | $5.6E+5$ | $2.2E+6$ | $1.8E+7$ | $2.9E+8$ |
| k | 373 | 379 | | | |
| $L_p/ly$ | $2.2E+9$ | $1.9E+10$ | | | |

Table 1. p-Adic length scales $L_p = 2^{(k-127)/2}L_{127}$, $p \simeq 2^k$, $k$ prime, $L_{127} \equiv \sqrt{5+Y}\pi/m_e$, $Y \simeq .0317$ possibly relevant to astrophysics. The definition of the length scale involves an unknown factor $r$ of order one and the requirement $L(151) \simeq 10^{-8}$ meters, the thickness of the cell membrane, implies that this factor is $r \simeq 1.1$.

The length scales can contain some overall factor $r$ of order order one. If this factor is chosen so that the length scale $L(151)$ is the thickness of the cell membrane, one must multiply p-adic length scales of the table by a factor $r \simeq 1.1$ to obtain $\hat{L}(k) = r * L(k)$.

1. $L(227) \sim 2.3$ kilometers, $L(229) \sim 4.6$ kilometers (twin pair) and $L(233) = 19.0$ kilometers. It would be interesting to find whether these length scales could be identified as geo-physically important length scales or/and length scales relevant to the internal structure of stars or planets. $L(233)$ is the order of magnitude for the size of neutron star.

2. $L(239) \simeq 1.5E+5$ $m$ and $L(241) \simeq 3.0E+5$ $m$ form a twin pair and could represent geophysically/astrophysically interesting length scales.

3. $L(251) = .96E+7$ $m$ and $L(257) = 7.7E+7$ $m$. The radii of the planets are of this order of magnitude.

4. $L(263) = 6.0E+8$ $m$ is of same order of magnitude as solar radius ($\sim 6.96E+8$ $m$). Note that $\hat{L}(263) \simeq 6.6E+8$ m is considerably nearer to the solar radius. $L(269) \simeq 4.8E+9$ meters and $L(271) \simeq .9E+10$ meters form a twin pair. Titius-Bode law for planetary distances reads as $r = r_0 + r_1 2^n$ $AU$, $r_0 = .4$ and $r_1 = .3$. A(stronomical) U(nit) corresponds to distance between Earth and Sun: $r_1 \simeq .3AU \simeq 4.5E+10m \sim 2^2 L(271)$ holds in a reasonable approximation. $2^2\hat{L}(271) \simeq 4.4E+10$ m is quite near to $r_1$! $L(271)$ is a member of twin pair and it might be that length scales corresponding to twin primes lead to approximate 2-adicity of the mass distribution. If primordial mass distribution is 2-adic and of form $((r-r_0)/r_1)^n$ it has peaks at $r - r_0 = r_1 2^k$ and Titius-Bode law is natural consequence. If this is the case then the planetary distance ratios might be universal!

5. For $k = 277, 289 = 17^2, 293, 307$, $L(k)$ varies between $7.7E+10$ $m$ and about $2.5E+15$ $m$. $L(277)$ is of same order as the distance from Earth to Sun. The size of the solar system is about $L(289)$. $L(311) \simeq 1.0$ $ly$ and $L(313) \simeq 2.0$ $ly$ form a twin pair. Could these distances have a tendency to appear as distances between binaries? Or could the distances have a tendency to come as powers $2^n L(313)$?

6. $L(329) \simeq 1.0E+3$ and $L(331) \simeq 2.0E+3$ light years form a twin pair. Sizes for the galactic nuclei are of this order of magnitude. The very powerful energy sources in the nuclei of the

galaxies are associated with regions of this distance. A suggested explanation is black hole in the region between the object and also TGD allows galactic black holes. $L(337) \simeq 8.4 \cdot 10^3$ light years corresponds to the size of the central region of the galaxy. $L(353) \simeq 2.2 \cdot 10^6$ light years corresponds to a typical size scale of the galaxy [18].

7. $L(367) \simeq 2.2 \cdot 10^8$ light years is same order of magnitude as the size of the large voids and perhaps corresponds to the length scale identified by Einasto.

## 2.2 p-Adic evolution of cosmological constant

One of the most fascinating outcomes of the new view about gravitational energy is the resolution of the most gigantic failure in the art of order magnitude estimates. The naive estimate for the cosmological constant predicted also by TGD is by a factor $10^{120}$ larger than its value deduced from the accelerated expansion of the Universe. The resolution comes naturally from the p-adic fractality predicting that cosmological constant is reduced by a factor of 2 in a step wise manner in phase transitions occurring at times $T(k) \propto 2^{k/2}$, which correspond to p-adic time scales. On the average $\Lambda(k)$ behaves as $1/a^2$, where $a$ is the light-cone proper time. This predicts correctly the observed value of $\Lambda$.

p-Adic length scale hypothesis plus the detailed study of membrane like vacuum extremals lead to the hypothesis that cosmological constant depends on p-adic length scale $\Lambda/R^2 \propto 1/R^2L^2(k) \propto 2^{-k}$. Amazingly, the recent value of the cosmological constant suggested by the accelerated expansion of the Universe comes out as a correct prediction!

Cosmological expansion at a particular space-time sheet becomes a TGD counterpart for a sequence of periods of increasingly slow inflation which a reduction of $\Lambda$ by a factor of 2 at each time when the size of space-time sheet exceeds a p-adic length scale. It must be however emphasized that Kähler action determines the classical dynamics and it is by no means clear that exponential expansion is involved. What certainly occurs is liberation of gravitational energy, which means that the difference of inertial energy densities for matter and antimatter is reduced in a phase transition like manner. Maybe the interpretation in terms of annihilation of matter and antimatter is appropriate. Perhaps particles with masses of order p-adic length scale become non-relativistic and annihilate to lighter particles, most naturally those corresponding to the next p-adic length scale.

## 2.3 Evidence for a new length scale in cosmology

There is evidence [16] for a cubic lattice structure in the length scale of the large cosmic voids containing matter near their boundaries. Single void having galaxies on its boundaries would be the basic unit of this structure. This means a characteristic length scale of order 1.2 Megaparsecs, which in light years makes $7.8E+8$ light years. As noticed in the paper, these observations do not fit with the prediction of the cold dark matter scenarios predicting random distribution of galaxies and galaxy clusters at long length scales.

The first task is to find whether one could understand the length scale of order 1.2 Megaparsecs p-adically. In TGD, the cosmological evolution means the gradual emergence of longer and longer p-adic length scales, that is space-time sheets with size of order not too many p-adic length scales $L(p)$, where $p$ is assumed to be near prime power of two by experience with the p-adic mass calculations: $p \simeq 2^k$, $k$ power of prime. These regions (3-surfaces with outer boundaries!) do not expand any more but move like comoving particles in the expanding background (surface of larger p-adic prime).

There are not too many physically interesting p-adic primes near prime powers of two and the p-adic length scale associated with the prime $p \simeq 2^k$, $k = 367$ is $\hat{L}(367) \simeq 3.2E+8$ light years, whereas the length scale $L(Einasto) = 7.8E+8$ light years, deduced by Einasto *et al* is roughly *two*

*times* this length scale. The two nearest length scales correspond to $p \simeq 2^k$, $k = 359$ with 16 times smaller length scale and $k = 373$ with 8 times larger length scale so that identification is unique. Therefore, it seems that p-adic length scale hypothesis might work even in the cosmological length scales.

The problem is to understand the origin of the lattice like structure. The least radical suggestion mentioned in [16] is that some kind of acoustic waves during the early cosmology have left their trace in the background and caused the periodicity. Also a new physics in the inflation period has been speculated.

A priori, one can consider in TGD framework two alternative scenarios for the origin of the lattice structure. Either the structure is created during the very early cosmology and during cosmic expansion its size has gradually increased to its recently measured value. Or the structure is created later. TGD inspired cosmology is based on the hypothesis that new p-adic length scales emerge in the topological condensate during the cosmic evolution. Therefore one can consider the possibility that the large voids are structures, which have appeared later rather than having been present all the time. Of course, nothing excludes the possibility that the voids have expanded until they have reached the critical p-adic size for which the expansion has ceased.

The mechanism creating lattice structure could be based on so called p-adic fractals and be a consequence of the effective p-adic topology rather than result from some delicate dynamical mechanism. Already the existence of the p-adic length scales implies one kind of fractality. There is however also a second kind of fractality associated with a given value of the p-adic prime $p$. This latter kind of fractality, p-adic fractality for short, might provide an explanation for the lattice like structures as the following argument suggests.

p-Adic fractality for the real mass density $\rho_R$ means that the density can be regarded as a map

$$\rho_R = I^{-1} \circ \rho \circ I \ ,$$

where $\rho$ is the p-adic valued mass density in p-adic space-time and $I$ denotes the so called *canonical identification* ,

$$I : \sum_n x_n p^n \rightarrow \sum_n x_n p^{-n} \ ,$$

mapping p-adics to reals and inducing a map from real space-time region to p-adic space-time region. Thus, given a p-adically analytic mass density function $\rho$, the map $\rho_R = I \circ \rho \circ I^{-1}$ induces real density function $\rho_R$, which turns out to be a fractal as the numerical study of simple examples for small values of $p$ shows.

This lattice structure of the p-adic fractals follows directly from the basic properties of the canonical identification mapping p-adics to reals. The point is that canonical identification in range $[0, p)$ for the real numbers induces discontinuities of the real density $\rho_R = I \circ \rho \circ I^{-1}$ at the points $x = k = 0, 1, ...p-1$. Same occurs in each interval $[n, n+1)$ at $x = n + kp$, $k$ integer, which are mapped to the reals in the interval $[n, n+1)$ and so on ad infinitum. Therefore the powers $p^{k/2}$ of the basic length scale are preferred scales for this structure. In higher-dimensional case one clearly obtains lattice like structure for the discontinuities. The lattice structure is not quite obvious in the illustrations of the 2-dimensional p-adic fractals represented in the first part of the book. If one plots p-adic fractal of the planar coordinates using different colors for different value ranges of the function, the cubic structure becomes manifest and one obtains extremely beautiful pictures.

# 3 Solar magnetic fields and Sunspot cycle

The behavior of the solar magnetic fields is difficult to understand using Maxwellian electrodynamics. The time scale involved with the change of the polarity of the magnetic field (11 years) is by a

factor of $10^9$ shorter than the time scale predicted by the naive magnetohydrodynamics considerations! The second puzzling feature is the rich spatial structure associated with the solar magnetic field: observations indicate that the field decomposes into discrete flux tube like structures and a lower bound for the sizes of these structures is set only by the observational limitations. Sunspots correspond to the largest structures of this kind and their dynamics possesses several mysterious looking regularities.

In the following a model explaining the peculiar features of the solar magnetic field in terms of the topological field quantization is proposed. The appearance of the strong long range $Z^0$ fields inside the magnetic flux tubes plays key role in the proposed possible solution of the solar neutrino puzzle discussed in this chapter.

Since solar magnetic field indeed consists of discrete elements the idea, which comes almost irresistibly into mind is that these elements, in particular solar spots, correspond to the topological field quanta of the induced gauge fields and are therefore direct manifestations of the $CP_2$ geometry. In the sequel the general features of the solar magnetic fields and Sunspot cycle will be discussed. A TGD inspired simple model of the Sunspot as a helical vortex is constructed and using this model, a model for the Sunspot cycle explaining the basic topological features of the Sunspot cycle and predicting a correct order of magnitude for the period of the cycle, will be developed.

## 3.1 Sunspot cycle

To begin with, consider the general properties of the solar magnetic fields and Sunspots [19].

1. The average magnetic field of the Sun is dipole field and reverses its polarity with a period of eleven years. The actual solar magnetic field consists of the discrete elements (flux tubes) and all element sizes and magnetic field strengths seem to be possible. The appearance of the discrete structures is not in accordance with the naive magnetohydrodynamics expectations [19]: the stability argument (magnetic pressure plus the plasma pressure inside the flux tube equals to the plasma pressure outside the flux tube) gives a lower bound of about $0.1\ T$ for the magnetic field of a stable flux tube and smaller field strengths have been observed.

2. The short time scales associated with the dynamics of the magnetic structures are not in accordance with the magnetohydrodynamics expectations [19]: in magnetohydrodynamics diffusion determines the time scale for the change of the magnetic fields and the time scale for changes in length scale $L$ is of the order of $T \simeq L^2/\sigma$, where $\sigma$ is the conductivity of the plasma. For the changes taking place in the length scale of Sun the time is of the order of $T \simeq 10^{10}$ years: dipole field changes its direction during a year! For Sunspots having typically the size of the order of $L \simeq 10^7\ m$, the corresponding time is of the order of $T \simeq 10^6$ years.

3. The appearance of the Sunspots is related to the change of the polarity of the Solar magnetic field. Sunspots appear first at latitudes $\pm 40$ *degrees* and gradually the region, where new Sunspots appear, drifts to the direction of the equator. Sunspot magnetic field is bipolar and the field strength is typically about $0.1\ T$. The magnetic pole is referred to as $p$ or $f$ pole depending on whether the pole in question precedes or follows in the solar rotation (the western pole is by definition the leading pole). The polarity of the leading spots is same (Hale-Nicholson law) for all Sunspots in a given hemisphere and for a given solar cycle. The polarity of the $p$ spot is opposite for the two hemispheres and for two successive cycles. The opposite polarity of the southern and northern $p$ spots guarantees the dipole field nature of the average magnetic field. The change of the polarity in the beginning of the solar cycle (implying the change of the polarity of the dipole field) is however not well understood in the present models.

4. Sunspots seem to be related to the convective motion of the matter. There is a net outward and inward flow of the matter with a velocity of order $\beta \simeq 10^{-5}$ at $p$ and $f$ poles of the Sunspot respectively so that Sunspots take part in the convection. There are also indications that the fibril like structures on the penumbra of $p$ pole are convective rolls [19]. These features suggest that Sunspots are magnetized helical vortices.

5. The appearance of the Sunspots is accompanied by a reduction of the solar constant: a possible explanation is that part of the solar energy is stored as a kinetic energy of the fluid motion associated with the Sunspots and as a magnetic field energy [19].

### 3.2 Sunspots as helical vortices

TGD suggests an explanation of the discrete magnetic structures as a direct manifestation of the $CP_2$ geometry. The TGD inspired model for the Sunspot is motivated by the general ideas described earlier and by the basic features of Sunspots. For the reader's convenience only the general ideas are described and calculational details are left later.

1. In accordance with the ideas about the generation of hydrodynamical turbulence as spontaneous $Z^0$ magnetization, it is assumed that the structures of the solar magnetic field correspond to $Z^0$ magnetized domains, i.e. vortices of some kind.

2. The TGD based concept of the 3-space suggests strongly that vortices correspond to topological field quanta, that is 3-surfaces of a finite size and with outer boundary, glued to a background 3-space. The outer boundary corresponds to the critical radius for the imbedding of the $Z^0$ magnetic field created by the moving matter. The requirement that the critical radius of the magnetic flux tube is of the order of Sunspot size or smaller, implies that the values of the vacuum quantum numbers associated with the Sunspots must be considerably smaller than those associated with the background 3-space.

3. Also the background space is a carrier of a $Z^0$ magnetic field (which can be weak) and helical vortex interacts with this field by $Z^0$ magnetic dipole interaction, which explains the motion of the ends of the helical vortex in the Sunspot cycle.

4. The simplest ($Z^0$) magnetized domains are vortex like structures and Sunspots are identified as helical vortices, one of whose functions, besides maximizing Kähler function, is the convective transport of heat. This function explains why the ends of the Sunspot are at the surface of the Sun and why the main part of the structure is beneath the surface of the Sun, possibly at the bottom of the convective zone. It should be emphasized that Sunspots are not the only structures of this type: also smaller structures are possible and the radius of the vortex is determined by the value of the fractal quantum number $m$ and magnetic quantum numbers. The small size of these structures however makes them invisible.

5. The velocity field of the vortex serves as a source of $Z^0$ magnetic field:

$$\nabla \times \bar{B}_Z \;=\; N K_Z \bar{v} \;, \tag{1}$$

where $N \equiv \rho_m/m_p$ denotes nucleon density and $K_Z = \epsilon_1 10^{-19} = g_Z/\sqrt{\epsilon_Z}$ describes the strength of the $Z^0$ force. By neutrino screening, the average $Z^0$ charge density is expected to be much smaller than the density of the nuclei. It has been assumed that neutrinos do not participate in the rotational motion so that nucleons serve effectively as the source of the $Z^0$ magnetic field. This means that $\epsilon_Z$ appearing in the formula refers to the $Z^0$ gauge

flux coming from the 'previous' condensate level. For the condensate level at which the elementary particles feed their $Z^0$ charges, one has therefore $\epsilon_Z = 1$. At the astrophysical scales $\epsilon_1$ is smaller than one.

6. The magnetic field of the Sunspot is generated, when the integers $n_i$ change so that their ratio differs from the value $n_1/n_2 = \omega_1/\omega_2$ guaranteing the vanishing of the electromagnetic fields. This process implies that $Z^0$ magnetic line dipole becomes also an ordinary magnetic line dipole and therefore visible, when the ends of the vortex are at the surface of the Sun. This mechanism implies also that magnetic and $Z^0$ magnetic fields are parallel to each other.

7. Magnetohydrodynamic stability conditions are satisfied if the magnetic field of the Sunspot is parallel with the electric current so that the Lorentz force vanishes: $\nabla \times \bar{B} = \bar{v} \propto \bar{B}_{em}$ [19]. This condition holds true also for the $Z^0$ magnetic field. If the magnetic field is generated by changing the values of the magnetic quantum numbers $n_1$ and $n_2$, then $Z^0$ magnetic and magnetic fields are parallel so that also $Z^0$ magnetic and velocity fields are parallel:

$$\bar{B}^Z \propto \bar{v} \quad . \tag{2}$$

Helical vortices are the simplest objects allowing this kind of structure. A more detailed model for the helical vortices is postponed to the last subsection.

### 3.3 A model for the Sunspot cycle

Consider now a simplified model of the Sunspot cycle in terms of the helical vortices.

1. Sunspots correspond to helical vortices, whose main part is parallel to the surface of the Sun and whose ends are vertical vortices. In accordance with the idea that 3-space is a hierarchical condensate of 3-surfaces of various sizes, it is assumed that helical vortices correspond to topological field quanta condensed to the background 3-space. Also the background 3-space is a carrier of $Z^0$ magnetic field $B_Z$, which might be identified as the "average" or "self consistent" magnetic field created by the other topological field quanta.

   Helical vortices possess a definite $Z^0$ magnetic moment $d\bar{\mu}_Z/dl$ per unit length in the direction of the vortex: magnetic moment is due to the rotational motion of the matter inside the helical vortices. Therefore the vortices interact with the average $Z^0$ magnetic field of the Sun by the usual dipole interaction. Observations suggests that the poles of the Sunspot behave like independent dynamical objects so that in the first approximation the constraint forces can be neglected the ends of the vortex and vortices suffer a force per unit length given as the gradient of the dipole interaction energy per unit length

$$\frac{d\bar{F}}{dl} \quad = \quad \nabla(\frac{d\bar{\mu}_Z}{dl} \cdot \bar{B_Z}) \quad . \tag{3}$$

   At the beginning of the Sun spot cycle only the radial component of the magnetic field contributes to the force since $p$ and $f$ poles of the Sunspot are to a good approximation at the same latitude. The force is in the direction of the meridian. Since the sign of $d\bar{\mu}/dl$ is opposite for $p$ and $f$ poles they begin to move in opposite directions. The contribution of $B_r$ to the force changes its sign at equator and this motivates the assumption that the $p$ end of the Sunspots oscillates between the latitudes $+40$ and $-40$ degrees.

The nice feature of the proposal is that the force is indeed in the right direction at the beginning of the solar cycle and the forces on $p$ and $f$ have opposite directions. The details of the force are not important for the estimate of the duration of solar cycle. It is the latitude at which the Sunspot formation begins, which depends on the detailed properties of the force.

2. The motion of poles and in particular, differential rotation of the Sun implies the stretching of the vortex. If the flow is incompressible the volume of the vortex remains constant ($V_0$) so that the area ($S$) of the vortex decreases as $1/L$ as function of the vortex length $L$:

$$L = L_0 \frac{S_0}{S} \ . \tag{4}$$

Typical initial values of $S$ and $L$ are $S_0 \simeq \pi \cdot 10^{12}\ m^2$ and $L_0 \simeq 10^7\ m$. The decrease of the cross sectional area implies that the Sunspot becomes invisible after having reached some critical radius.

3. After having reached a certain critical radius of the order of the radiation length $L_{rad} \simeq 3 \cdot 10^4\ m$, vortex becomes unstable against pinch and splits to two pieces. The reason is that vortex must be cooler than its surroundings by the magnetic equilibrium conditions ($B^2/2 + nkT_{in} = nT_{out}$) and this is not possible if the radius of the vortex is too small since the radiation flux of the Sun destroys all temperature gradients in the length scales smaller than $L_{rad} \simeq 3 \cdot 10^4\ m$. The critical length of the vortex is therefore given by $L_f \sim L_0 S_0/S_f \simeq 4 \cdot 10^{11}\ m$.

4. Since the stretching of the vortex results mainly from the differential rotation of the Sun (rotation period is $T_{rot} = 25\ d(ays)$ and $T_{rot} = 30\ d$ on poles and equator respectively). This means that the upper bound for the time required to achieve instability is of the order of $T_{cycle} \leq (L_f/R_{Sun})T_{rot} \simeq 4 \cdot 11$ years ($R_{Sun} \simeq 8 \cdot 10^8\ m$) and of the same order of magnitude as the period of the Sunspot cycle (recall that the naive magnetohydrodynamic estimate is about $10^{10}$ years!). The actual value is smaller since in the beginning of the cycle the effect of the differential rotation is considerably smaller than at the end of the cycle.

5. The stretched magnetized vortices give the dominant contribution to the average dipole field of the Sun and the entanglement of the dipole field lines resulting from the freezing of the magnetic field lines to differentially rotating matter corresponds to the stretching of the co-rotating vortices. The dipole nature of the average solar magnetic field requires that $p$ type poles must have same polarity on the given hemisphere and that the polarities of $p$ type poles are opposite for Southern and Northern hemispheres.

6. The vortices started from the latitude of 40 ($-40$) degrees achieve critical length at the latitude $-40$ (40 ) degrees begin to split to pieces. The resulting pieces achieve their equilibrium volume $V_0$ by increasing their transverse size from the critical size $S_f$ to $S_0$ implying the increase of the radius by a factor of order $10^{3/2}$. The pieces are observed as new Sunspots and the gradual splitting starting from the end explains why the Sunspot active region proceeds gradually to the direction of equator. The mysterious reversal of $p$ type polarity results from the opposite polarities of $p$ poles at Northern and Southern hemispheres. This in turn implies the change of polarity of the solar magnetic field at each Sunspot cycle.

7. The energy needed to generate the magnetic field of the thickened vortex and the kinetic energy of the vortex motion is provided by the energy production in the interior of the Sun and the process explains the decrease of the Solar constant.

### 3.4 Helical vortex as a model for a magnetic flux tube

The detailed model of the magnetic flux tube as a helical vortex is based on the following physical picture.

1. The velocity field of the vortex serves as source of $Z^0$ magnetic field

$$\begin{aligned} \nabla \times \bar{B}^Z &= K_Z N \bar{v} \ , \\ K_Z &= -\frac{g_Z^2}{4\sqrt{\epsilon_Z}} \frac{A-Z}{A} \ . \end{aligned} \tag{5}$$

   where $N \equiv \rho_m/m_p$ denotes nucleon density and $K_Z$ describes the strength of $Z^0$ force. $\epsilon_1 \leq 1$ measures the relative strength of $Z^0$ and gravitational forces. For the gravitational interaction to dominate over $Z^0$ force the condition $\epsilon_Z > 10^{36}$ must hold true.

2. The magnetic field is generated, when the integers $n_i$ change so that their ratio differs from the value $n_1/n_2 = \omega_1/\omega_2$ guaranteing electrovac property. This mechanism implies that magnetic and $Z^0$ magnetic fields are parallel to each other.

3. Magnetohydrodynamic stability conditions are satisfied if the magnetic field of the Sunspot is parallel with the electric current so that the Lorentz force vanishes: $\nabla \times \bar{B} = \bar{v} \propto \bar{B}_{em}$ [19]. If the magnetic field is generated by changing the values of the magnetic quantum numbers $n_1$ and $n_2$ then $Z^0$ magnetic and magnetic fields are parallel so that also $Z^0$ magnetic and velocity fields are parallel:

$$\bar{B}^Z \propto \bar{v} \ . \tag{6}$$

   Helical vortices are the simplest objects allowing this kind of structure and cylindrical symmetry fixes the structure of the helical vortex almost completely.

The helical vortex possesses cylindrical symmetry in the sense that $Z^0$ magnetic field and velocity field have only $z$ and $\phi$ components, which depend on the cylindrical coordinate $\rho$ only, so that one has

$$\begin{aligned} \Phi &= \omega_1 t + k_1 z + n_1 \phi \ , \\ \Psi &= k\Phi = \omega_2 t + k_2 z + n_2 \phi \ , \\ r &= tan(X(u)) \ , \\ X(u) &= ln((k+u)/C)\epsilon/2 \qquad u = u(\rho) \ , \\ \frac{\omega_2}{\omega_1} &= \frac{k_2}{k_1} = \frac{n_2}{n_1} \ . \end{aligned} \tag{7}$$

The relationship between the velocity field and $Z^0$ magnetic field is dictated by the condition that matter flow serves as source of the $Z^0$ magnetic field.

The expressions for the non-vanishing components of the induced $Z^0$ magnetic field are given by

$$
\begin{aligned}
B_z^Z &= -\frac{3}{(3+p)} n_1 sin^2 X \frac{\partial_\rho u}{\rho} \ , \\
B_\phi^Z &= -\frac{3}{(3+p)} k_z sin^2 X \frac{\partial_\rho u}{\rho} \ . \qquad (8)
\end{aligned}
$$

The requirement $\nabla \times \bar{B^Z} \propto \bar{B^Z}$ implies the condition

$$
\frac{\partial_\rho B_z^Z}{\partial_\rho B_\phi^Z} = -\frac{B_\phi^Z}{\rho^2 B_z^Z} \ . \qquad (9)
$$

Using the explicit representation as an induced gauge field one obtains the differential equation

$$
\begin{aligned}
\partial_\rho Y &= \frac{(1-(\rho/\rho_1)^2)}{(1+(\rho/\rho_1)^2)\rho} Y \\
Y &= sin^2 X \partial_\rho u \ , \\
\rho_1 &= \frac{n_1}{k_z^1} \ , \qquad (10)
\end{aligned}
$$

which gives

$$
\begin{aligned}
\partial_\rho Y &= \frac{(1-(\rho/\rho_1)^2)}{\rho(1+(\rho/\rho_1)^2)} Y \ , \\
Y &= sin^2 X \partial_\rho u \ . \qquad (11)
\end{aligned}
$$

By integrating this equation, one obtains

$$
\begin{aligned}
B_z^Z &= -\frac{3}{(3+p)} \frac{n_1}{[(1+(\rho/\rho_1)^2)\rho_0^2]} \ , \\
B_\phi^Z &= \frac{k_z^1}{n_1} \rho^2 B_z^Z \ , \qquad (12)
\end{aligned}
$$

where $\rho_0$ is an integration constant possessing the dimension of length.

The magnitudes of the velocity components $\beta_z$ and $\beta_\phi$ are

$$
\begin{aligned}
\beta_z &= \frac{2k_z^1}{NK_Z\rho_0^2} \frac{p}{2(3+p)} \frac{1}{(1+(\frac{\rho}{\rho_1})^2)} \ , \\
\beta_\phi &= \frac{\rho}{\rho_1} \beta_z \ . \qquad (13)
\end{aligned}
$$

Stability requirements for helical vortices [20] suggest that the value of $n_1/k_z^1$ is of the same order as critical radius. Notice that the vortex rotates like a rigid body near the z-axis and that the longitudinal velocity is also approximately constant near the z-axis.

The above described imbedding of the helical $Z^0$ magnetic field fails at the critical radius $\rho = \rho_{cr}$, which corresponds to the value of $r = \infty$. The expression for the critical radius in present case is obtained from the condition $r = \infty$ and reads as

$$
\begin{aligned}
\rho_{cr} &= \rho_1\{exp[4(\frac{\rho_0}{\rho_1})^2(u_0+k)exp(-\frac{2\pi m}{\epsilon})X_0]-1\}^{1/2} \ , \\
&\simeq 2\rho_0 exp(-\frac{m\pi}{\epsilon})[(u_0+k)X_0]^{1/2} \ , \\
X_0 &= \frac{(2+\epsilon^2)exp(\frac{\pi}{\epsilon})+\epsilon^2}{1+\epsilon^2} \ ,
\end{aligned}
\tag{14}
$$

where it has been assumed that the value of the exponent is small. It will shortly found that the assumption is physically well founded. Notice that the critical radius depends extremely sensitively on the value of the "fractal" quantum number $m$ and that the critical radii are related by a power of a discrete scaling transformation in the approximation used.

If one requires that $Z^0$ magnetic flux is quantized with $n_1$ multiple of some integer $n$, one has simpler condition

$$
\begin{aligned}
\frac{3}{3+p}2(u_0+k)exp(-2\pi m/\epsilon)X_0 &= \frac{1}{n} \ , \\
\rho_{cr} &= \rho_1\{exp[2\frac{\rho_0^2}{n\rho_1^2}]-1\}^{1/2} \ .
\end{aligned}
\tag{15}
$$

If one requires flux quantization without any conditions on $n_1$, one must assume $n=1$.

Vortex carries also radial $Z^0$ electric field: the magnitude of this field is given by

$$
|E^Z| = |B^Z_\phi|(\omega_1\rho/n_1) \ . \tag{16}
$$

The parametrization $\omega_1 = \sqrt{\epsilon_Z}x$, $x \sim 1$ is expected to hold true for $\omega_1$.

## 3.5 Estimates for the vacuum parameters of magnetic flux tube

Consider next the values of the various vacuum parameters appearing in the embedding of the helical vortex.

### 3.5.1 An estimate for the quantum number $\omega_1$

From the requirement that gravitational interaction is stronger than $Z^0$ force in long length scales one obtains $\omega_1 \leq 1/R \sim 10^{-4}m_{Planck}$ and $\epsilon_Z > 10^{38}$. The other extreme correspond to the condensate level $n = n_Z$ with $\epsilon_Z(n_Z) \sim 10^{20}$. One must however remember that neutrinos are not expected to serve as the source of $Z^0$ magnetic field and therefore $\epsilon_Z(n-1)$ appears in the expression of the magnetic field at level $n$ and at level $n_Z$ the total unscreened nuclear charge serves therefore as the source of $B_Z$. Lorentz invariance implies that the value of $k_z^1$ is given by

$$
k_z^1 \simeq \omega_1\beta_z \ . \tag{17}
$$

### 3.5.2 An estimate for the quantum number $n_1$

The requirement that angular momentum density is of correct order of magnitude gives an estimate for the value of the parameter $n_1$. The expression of the conserved angular momentum current in the z-direction is given by

$$J^\alpha = T^{\alpha\beta}\partial_\beta m^k m_{kl} j^l \ , \tag{18}$$

where $j^k$ denotes the vector field associated with an infinitesimal rotation and $T^{\alpha\beta}$ denotes energy momentum tensor. For the angular momentum density one obtains in the cylindrical $M^4$ coordinates for $X^4$ the expression

$$\begin{aligned} J^t &= T^{t\phi}\rho^2 \ , \\ T^{\alpha\beta} &= \frac{1}{16\pi G} G^{\alpha\beta} \ , \end{aligned} \tag{19}$$

where the second equation is Einstein's equation.

*Case a:*

If the contribution of $CP_2$ curvature to the curvature tensor is not dominating the leading order contribution to $G^{t\phi} = R^{t\phi} - g^{t\phi}R/2$ comes from the non-vanishing of the metric component $g_{t\phi}$:

$$g_{t\phi} = s^{eff}_{\Phi\Phi}\omega_1 n_1 = -\frac{R^2}{4}(cos^2(X)(k+u)^2 + 1 - u^2)sin^2(X)\omega_1 n_1 \ , \tag{20}$$

and one obtains the order of magnitude estimate

$$J^t \simeq -T^{tt} g_{t\phi} \simeq \rho_m \frac{R^2}{4}\omega_1 n_1 \ . \tag{21}$$

In order to obtain a correct order of magnitude for the angular momentum density associated with rotational flow one must have

$$\frac{R^2}{4}\omega_1 n_1 \sim \rho\beta(\rho) \ , \tag{22}$$

which implies

$$\begin{aligned} n_1 &\simeq \frac{L}{R^2\omega_1}\beta \sim \frac{10^{19}}{\sqrt{\epsilon_Z}x}\frac{L}{R}\beta \ , \\ \omega_1 &\equiv x\sqrt{\epsilon_Z} m(proton) \ , \end{aligned} \tag{23}$$

where $L$ and $\beta$ are typical scale and velocity associated with the flow and $x \sim 1$ is expected to hold true. If $L$ is taken to be the radius of the vortex ($L \sim 10^7$ $m$ ) and $\beta_\phi \sim 10^{-5}$ the rotation velocity of the vortex, one obtains: $n_1 \sim \frac{10^{55}}{x\sqrt{\epsilon_Z}}$. If $L$ is taken to be the radius of the Sun and $\beta$, the rotation velocity of the Sun the value of $n_1$ is about hundred times larger. The order of magnitude for $E^Z$ is

$$E^Z \sim a\frac{B^Z}{\beta_{rot}} \ ,$$

with

$$a = x\sqrt{\epsilon_Z}Gm_p\omega_1 << 1 \ ,$$

and is consistent with the assumption that the density of $Z^0$ charge is much smaller than the density of the nucleons.

*Case b:*

If $Z^0$ field is strong as compared to the gravitational field, the dominating contribution to $G^{t\phi}$ comes from the contribution of the $CP_2$ curvature to $R^{t\phi}$ and is proportional to the quantity $J^t{}_\rho J^{\rho\phi}$: in this case the previous estimate doesn't hold anymore and one obtains the estimate

$$\frac{n_1}{\omega_1} \simeq \beta L \ . \tag{24}$$

Since $Z^0$ field is strong inside the Sunspots one must use this estimate for $n_1/\omega_1$ and one obtains the estimate

$$E^Z \sim \frac{B^Z}{\beta_{rot}} \ .$$

The result would mean that the density of $Z^0$ charge is of same order of magnitude as the density of the nucleons and by the presence neutrino screening this is not possible. Therefore case 1) is closer to the actual physical situation.

### 3.5.3 An estimate for the radius $\rho_0$

An estimate for the radius $\rho_0$ is obtained by substituting the estimate of $k_z$ to the general expression of $\beta_z$ at z-axis and one obtains the condition

$$\begin{aligned} \rho_0 &\sim [10^{19}\frac{p}{(3+p)}\frac{1}{\sqrt{G}N\epsilon_1}]^{1/2} \\ &\sim (\frac{1}{\epsilon_1})^{1/2}10^{11} \ m \ , \\ \epsilon_1 &\equiv K_Z 10^{19} \ , \end{aligned} \tag{25}$$

where the estimate $N \sim 10^{30}/m^3$ for the nucleon density has been used.

### 3.5.4 An estimate for the fractal quantum number $m$

En estimate for the value of the fractal quantum number $m$ is obtained from the condition that the exponent appearing in the expression of the critical radius is small:

$$4(\frac{\rho_0}{\rho_1})^2 exp(-2m\pi\epsilon)[(u_0+k)X_0] \ll 1 \ . \tag{26}$$

Since one has $\rho_0 \simeq \sqrt{1/\epsilon_1}10^{11} \ m$ and $\rho_1 \sim \rho_{cr} \sim 10^6 \ m$, one obtains an order of magnitude estimate $exp(-2m\pi/\epsilon) \ll 10^{-10}\epsilon_1/(u_0+k)$ so that the value of $m$ must be rather large unless the value of the parameter $u_0 + k = u_0 + n_2/n_1$ is very small or the value of $\epsilon_1$ is sufficiently large: the value $\epsilon_1 \geq 10^5$ implies that $m$ is of order 2: a rather natural looking value unlike the large values implied by $\epsilon - 1 \sim 1$.

### 3.5.5 Estimate for the magnetic field

If the magnetic field is generated by the change of $n_1$ so that the condition $\omega_1/\omega_2 = n_1/n_2$ ceases to hold true one obtains the following approximate expression for the magnetic field at the z-axis

$$B_z^{em} \simeq \frac{\Delta n_1(3+p)}{\rho_0^2} \quad . \tag{27}$$

The requirement that the magnetic field is of the order of $B_{em} = 10^3\ Gauss$ gives the estimate $\delta n_1 \simeq 10^{36}/\epsilon_1$ so that the relative change of $n_1$ is given by $\Delta n_1/n_1 = 10^{-19} x\sqrt{\epsilon_Z}/\epsilon_1 << 1$ for alternative 1) in which $n_1$ is very large. The argument related to the destruction of the super fluidity by the generation of $Z^0$ magnetic fields suggests the range $\epsilon_Z \in (10^{20} - 10^{22})$ at the condensation level level $n_Z$, at which elementary particles feed their $Z^0$ gauge fluxes for $\epsilon_Z$ (recall that $1/\sqrt{\epsilon_Z(n)}$ tells which fraction of total nuclear $Z^0$ charge the unscreened $Z^0$ charge is at the condensate level $n$ and therefore flows to level $n+1$ via the # throats located near the boundaries of level $n$ surface). This number corresponds to $\epsilon_1(n_Z) = 10^{19} g_Z/\sqrt{\epsilon_Z} \in (10^8 - 10^9)$. Quite strong $Z^0$ magnetic fields are possible: the strength of the $Z^0$ magnetic field at the level $n = n_Z + 1$ is below $10^4\ Tesla$ for $\epsilon_Z(n_Z) = 10^{22}$ and $\rho_{cr} \sim 10^6\ m$!

# 4 Explanation for the high temperature of solar corona

The mysterious feature of the solar corona is its high temperature $T \sim 10^6\ K$, as compared with the temperature of the chromosphere of order $10^4\ K$ [19] (the book of Zirin provides excellent introduction to the physics of Sun). The temperature rises very rapidly to $10^6\ K$ at height $h \sim 2 \cdot 10^6\ m$ from the surface of Sun. The problem is to identify the mechanism leading to the heating of the particles of the solar wind after leaving solar surface: no convincing mechanism has been identified and this suggests that many-sheeted space-time concept might be involved in an essential manner. Indeed, the high temperature matter in the solar corona can be interpreted as a dark matter leaked from the highly curved portions of magnetic flux tubes to the space-time sheets where it becomes visible.

## 4.1 Topological model for the magnetic field of Sun

The basic observation is that solar corona cannot behave like single homogenous object possessing high temperature $T \sim 10^6$ K: the effective black body temperature deduced from the net radiation flux is not larger than 7000 K [19] corresponding energy density is more than $10^{-9}$ times smaller than the energy density associated with $T$. This suggests the existence of local high temperature regions giving rise to characteristic spectral lines in X ray region serving as a signature of the high temperature.

It is also known that the dynamics of the solar atmosphere and convective zone is very strongly correlated with magnetic fields, which from Zeeman splitting are known to have typical magnitudes of order .3 Tesla [19]. Furthermore, only those stars which have convective zone, possess corona and the size and shape of corona varies during the sunspot cycle.

Also solar constant is found to vary during sunspot cycle, which is difficult to understand in the standard picture about solar energy transfer. Solar wind is known to be associated with the non-closed magnetic fields lines and with the coronal holes in which temperature is lower than in the surroundings. High temperature regions in corona in turn correspond to regions at which field lines tend to be tangential to the surface and temperature. This suggests that magnetic fields provide the basic mechanism of convective energy transfer and that magnetic fields somehow make it possible to heat the solar corona locally.

These considerations suggests that magnetic flux tubes realized as tube like space-time sheets having radius $\rho \geq \rho_0 = \sqrt{1/eB}$ provide a TGD based topological realization for the convective energy transfer. This hypothesis reduces the problem to microscopic level and rather precise quantitative predictions should become possible. Protons and electrons can topologically condense at the magnetic flux tubes and move along them. It is assumed that in good approximation all protons, electrons and also heavier elements are condensed at the magnetic flux tubes.

The magnetic field of the flux tube confines charged particles and in transversal degrees of freedom they behave quantum mechanically like 2-dimensional harmonic oscillators with wave functions localized around Landau orbits with radius of order $\sqrt{n}\rho_0$, $n = 0, 1, 2..$ whereas in longitudinal degrees of freedom they behave like free particles locally. If $n$ is sufficiently large, classical description as continuous matter should become possible. In the classical description charged particles are confined around magnetic lines of force and rotate with frequency $\omega = eB/E$, where $E$ is total relativistic energy. The radius of the orbit is $\rho = \beta/\omega$, where $\beta$ is rotational velocity. For sufficiently small values of $\beta$ the radius of orbit is so small that particle is confined inside the flux tube. The dominant component of velocity is along the direction of flux tube.

In magneto-hydrodynamical description the basic equations state the conservation of magnetic flux, of various particle numbers (electron and proton numbers for magnetic flux tubes and neutron and neutrino numbers for $Z^0$ magnetic flux tubes) and conservation of momentum and energy along the flow lines. Energy density contains the energy density $\sigma T^4$ of from black body radiation, kinetic energy density $\rho v^2/2$ of the macroscopic motion, pressure contribution $p$ and the density $B^2/2$ of the magnetic energy. Gravitation is assumed to couple to the size and shape of the flux tube rather than to individual particles inside the flux tube so that gravitational energy density does not contribute to energy conservation conditions. If the particles slow down somewhat as they approach to the highly curved portions of the flux tubes, the increase of the temperature along the flux tube is implied by the conservation of energy $\sigma T^4 + \rho v^2/2 \simeq constant$. This explains why the local temperature of the corona is higher than the temperature at the surface of Sun and why the temperature is lowest and streaming velocity highest at the coronal holes with non-closed magnetic field lines extending to interplanetary space. The leakage of the particles to other space-time sheets at the highly curved portions of the flux tubes could in turn cause local heating of the matter.

Since the particles entering the closed flux tubes have some kinetic energy and since most of them return to the convective zone, there must be a momentum transfer from particles to the flux tube and flux tube must receive momentum. In equilibrium this force and gravitational force affecting the shape and size of the entire flux tube cancel each other. This is nothing but a topological representation for the freezing of magnetic field lines to moving matter. In this picture it is possible to understand the mysterious looking ability of the solar prominences to defy the force of gravity. Solar wind corresponds to particles glued to open flux tubes or closed flux tubes formed via the recombination of flux lines in solar atmosphere and having velocity larger than the escape velocity.

The model predicts correctly the basic qualitative properties of the solar wind [19].

1. The highest velocity streams come from the coolest part of corona, coronal holes: these regions correspond to open magnetic field lines extending into interplanetary space. This follows from the energy conservation and from the fact that temperature is lower for coronal holes so that kinetic energy must be larger.

2. The velocity of the solar wind protons is found to decrease with the increasing density of electrons at the base of Corona [19]. By charge neutrality inside flux tubes also proton density is reduced and conservation law for energy requires the increase of the velocity of protons. Streaming velocity is also found to increase with the electron temperature at the base of the corona [19]. Assuming thermal equilibrium this means that the radiative contribution to energy is reduced so that kinetic energy density must increase.

If flux tube is closed, particles return to the convective zone and one can indeed speak about convective motion also in solar atmosphere. The confinement of radiative energy to the closed magnetic flux tubes (space-time sheets actually!) might explain why solar constant depends on the phase of the sunspot cycle being smallest at sunspot maximum when the number of closed field lines is maximum. Neutrinos and neutrons are expected to suffer topological condensation on $Z^0$ magnetic flux tubes and the obvious explanation for the solar neutrino deficit is that some fraction of neutrinos is confined to these tubes returns back to Sun. The reduction of the neutrino flux is possible even without absolute confinement inside flux tubes: already the dispersion of the neutrino flux caused by the change in the direction of motion during the travel inside the flux tube reduces neutrino flux from the solar core.

## 4.2 Quantitative formulation

Magnetic flux tubes are assumed to have fractal 'flux tubes inside flux tubes' structure and decompose ultimately into microscopically thin flux tubes. Furthermore that protons and electrons are assumed to suffer magnetic confinement inside these flux tubes. Classical rotational motion around field lines occurs with frequency $\omega = eB/m$ and the rotational velocity satisfies $\beta = \omega\rho$. For small values of rotational velocity the particle remains confined inside the flux tube. The observed Zeeman splitting suggests that $B$ is of order .1 Tesla. Quantum mechanically the confined particle is essentially equivalent with a harmonic oscillator with frequency $\omega$ in transversal degrees of freedom and behaves like free particle in longitudinal degrees of freedom. $B \simeq .3$ Tesla gives in case of proton the estimate $\omega \sim 10^{-7}$ eV for the frequency $\omega$ serving as the energy unit of the harmonic oscillator in question. Clearly, quasi-continuous spectrum is in question. The width of the ground state Gaussian wave function is $\rho_0 = \sqrt{\frac{1}{eB}}$ giving $\rho_0 \sim 10^{-8}$ meters for $B \sim .3$ Tesla. This gives the constraint $\rho > \rho_0$ to the thickness of the flux tube.

Higher Landau levels correspond to the radii $\rho_n = \sqrt{n}\rho_0$, $n = 1, 2, ...$ with energy spectrum given by $E_{n,m} = (n + m/2)\omega$, with angular momentum quantum number $m$ varying in the range $-2n \leq m \leq 2n$. Transversal excitations with energies up to thermal energy must be allowed and this allows excitations up to $n = 10^7$ and thermal stability against the transfer of proton to larger space-time sheets requires $\rho > 10^{-5}$ meters. Since rather large values of $n$ are excited thermally, it is possible to treat the matter inside flux tubes as continuous matter obeying hydrodynamic equations and ordinary Boltzmann statistics (rather than behaving as degenerate Fermi gas). The dominant component of the velocity is along the flux tube. The requirement that the Compton wavelength of the thermal photon is smaller than $\rho$ gives $\rho > 10^{-8}$ meters for $T \sim 10^2\ eV$.

The effective black body temperature for the radiation from corona determined from the entire energy flux is not larger than 7000 K and corresponding energy density is roughly a fraction $10^{-9}$ of black body radiation temperature associated with the real temperature of order $T \sim 10^6$ K. Near the solar surface the density of matter is roughly $10^9$ times that in corona [19]. In the approximation that the matter density inside flux tubes is same in the corona and at the solar surface these observations suggest that the matter inside the magnetic flux tubes behaves as a dark matter and that the matter visible in the corona corresponds to a fraction $10^{-9}$ of dark matter leaked out from the magnetic flux tubes to space-time sheets where it becomes visible. This interpretation is consistent with the TGD based explanation of dark energy and dark matter in terms of magnetic energy of magnetic and $Z^0$ magnetic flux tubes and particles residing inside them (see the chapter "Cosmic Strings").

The particle density in the corona is of order $10^{14}/m^3$ particles [19]. This implies a density of order $10^{23}/m^3$ particles (protons dominate in the mass density) inside flux tubes in corona. The density of solar wind particles is roughly $10^6/m^3$ at the solar surface [19] and forms a fraction of order $10^{-17}$ of the density of matter at solar surface. If all solar wind particles are condensed at magnetic flux tubes, this means that only a fraction $10^{-17}$ of all magnetic flux tubes runs out of

Sun! If flux tube structure is described as ordinary classical magnetic field one would say that most of magnetic energy resides in turbulent magnetic fields.

The basic equations of the model state the conservation of magnetic flux, particle number, energy and momentum. The requirement that the magnetic flux is conserved implies that the magnitude of $BS$, where $S$ is the transverse area of the flux tube, is constant along the flux tube. Together with the conservation of particle number this gives the conditions

$$\begin{aligned} BS &= B_0 S_0 \ , \\ n_p v S &= n_p^0 v_0 S_0 \ . \end{aligned} \tag{28}$$

Since the flux tubes turns back to the solar surface in corona, the vertical component of $v$ is reduced at the corona whereas the tangential component increases by energy conservation. If the particle density inside the flux tubes were much smaller at the solar surface than in corona, the fraction of volume occupied by the magnetic flux tubes at solar surface would be larger than one so that the changes of $\rho$ and $v$ must be rather small.

The conservation of energy, assuming that gravitational force couples to the flux tube geometry rather than the matter inside flux tube, gives

$$\sigma T^4 + \frac{1}{2}\rho v^2 + \frac{1}{2}B^2 + p = constant \ . \tag{29}$$

Here one has $\sigma \simeq 51.95/2\pi^2 \sim 3$. The pressure term associated with matter is in a good approximation negligible as compared to the energy density of the kinetic energy since the thermal velocity of proton at corona is about $10^{-3-1/2}$. The dominating part in the energy density at solar surface corresponds to the density of kinetic energy which is roughly $10^2$ times larger than the thermal energy density of photons at corona and $10^4$ times larger than the density of the magnetic energy. If one assumes that the thickness of the flux tubes does not change, magnetic energy remains constant and one has $\rho v = \rho_0 v_0$, and energy conservation gives

$$\sigma \Delta(T^4) = -\frac{1}{2}\rho_0 v_0 \Delta v \ ,$$

which gives

$$\frac{\Delta v}{v_0} = -\frac{2\sigma\Delta(T^4)}{\rho_0 v_0^2} \ . \tag{30}$$

For $T = 10^2$ eV and $v_0 = 10^{-2}$ [19] and $\rho_0 = 10^{23} m_p/m^3$ this gives $|\Delta\rho/\rho| = |\Delta v/v_0| = 6\cdot 10^{-2} \ll 1$ so that the scenario is internally consistent. The slowing down of the particles as they approach the highly curved portion of the flux tube inside corona is natural.

As such the matter inside flux tubes is invisible and the high temperature matter in the corona results from a partial leakage of the particles from the magnetic flux tubes to other space-time sheets. The leakage of a fraction $10^{-9}$ would be caused by the large centrifugal acceleration at the highly curved portion of the flux tube. This would also explain why coronal holes are cooler than other regions of the corona.

The conservation of momentum together with the assumption that (most) matter flowing around flux tube returns back to the Sun implies that the matter topologically condensed at the flux tube feeds momentum in the degrees of freedom characterizing the size and shape of the flux tube and this must give rise to over all cm motion of the flux tube. The net force acting on the flux tube is obtained by integrating the divergence of the energy momentum tensor over the entire

flux tube. Assuming that the velocity of matter at the return end is not considerably reduced, the contributions from the two ends are roughly identical and the expression for the resulting force acting on the cm of the flux tube reads as

$$F \simeq 2\rho_0 v_0^2 A \ , \tag{31}$$

where $A$ is the transverse area of the flux tube. Also gravitational force acts on the cm motion of the flux tube and in equilibrium the two forces must cancel each other.

$$GM(Sun)L\langle \frac{\rho}{(R(Sun)+h)^2} \rangle = \rho_0 v_0^2 \ , \tag{32}$$

where $h$ is the height from the surface of Sun and brackets denote averaging along the length of the flux tube of length $L$.

It can quite well happen that the momentum feed is so large that equilibrium is not possible and flux tube rises gradually and, if recombination of the flux tube ends giving rise to a closed flux tube occurs, runs away. This effect is enhanced by the fact that at large values of distance from Sun, where gravitational force is weakest, the mass density of the flux tube is largest. From the dependence of the gravitational force on height $h$ it is clear that the eruption should occur when the height of prominence is same order of magnitude as solar radius: solar prominences have indeed the mysterious looking property of being unstable against upwards rather than downwards perturbations.

# 5 General ideas about dark matter and condensed matter

In the sequel general ideas about the role of dark matter in condensed matter physics are described.

## 5.1 General view about dark matter hierarchy and interactions between relatively dark matters

The identification of the precise criterion characterizing dark matter phase is far from obvious. TGD actually suggests an infinite number of phases which are dark relative to each other in some sense and can transform to each other only via a phase transition which might be called de-coherence or its reversal and which should be also characterized precisely.

A possible solution of the problem comes from the general construction recipe for S-matrix. Fundamental vertices correspond to partonic 2-surfaces representing intersections of incoming and outgoing light-like partonic 3-surfaces.

1. If the characterization of the interaction vertices involves all points of partonic 2-surfaces, they must correspond to definite value of Planck constants and more precisely, definite groups $G_a$ and $G_b$ characterizing dark matter hierarchy. Particles of different $G_b$ phases could not appear in the same vertex since the partons in question would correspond to vacuum extremals. Hence the phase transition changing the particles to each other analogous could not be described by a vertex and would be analogous to a de-coherence.

   The phase transition could occur at the incoming or outgoing particle lines. At space-time level the phase transition would mean essentially a leakage between different sectors of imbedding space and means that partonic 2-surface at leakage point has $CP_2$ projection reducing to the orbifold point invariant under G or alternatively, its $M^4_\pm$ projection corresponds to the tip of $M^4_\pm$. Relative darkness would certainly mean different groups $G_a$ and $G_b$. Note that $\hbar(M^4)$ *resp.* $\hbar(CP_2)$ can be same for different groups $G_a$ *resp.* $G_b$ and that only the ratio of $\hbar(M^4)/\hbar(M^4)$ appears in the Kähler action.

2. One can represent a criticism against the idea that relatively dark matters cannot appear at the same interaction vertex. The point is that the construction of S-matrix for transitions transforming partonic 2-surfaces in different number fields involves only the rational (algebraic) points in the intersection of the 2-surfaces in question. This idea applies also to the case in which particles correspond to different values of Planck constant. What is only needed that all the common points correspond to the orbifold point in $M^4$ or $CP_2$ degrees of freedom and are thus intermediate between two sectors of imbedding space. In this picture phase transitions would occur through vertices and S-matrix would characterize their probabilities. It seems that this option is the correct one.

If the matrix elements for real-real transitions involve all or at least a circle of the partonic 2-surface as stringy considerations suggest [C2], then one would have clear distinction between quantum phase transitions and ordinary quantum transitions. Note however that one could understand the weakness of the quantal interactions between relatively dark matters solely from the fact that the $CP_2$ type extremals providing space-time correlates for particle propagators must in this case go through an intermediate state with at most point-like $CP_2$ projection.

At quantum level the phase transition is possible only at quantum criticality and number theoretic considerations lead to the hypothesis that super-canonical conformal weights for partons reduce to zeros of Riemann Zeta in this situation. In the general case the imaginary parts of conformal weights would be linear combinations $y = \sum_k n_k y_k$ of imaginary parts of zeros $1/2 + iy_k$ of $\zeta$ with integer coefficients.

### 5.1.1 Are particles characterized by different p-adic primes relatively dark?

Each particle is characterized by a collection of p-adic primes corresponding to the partonic 2-surfaces associate with the particle like 3-surface. Number theoretical vision supports the notion of multi-p p-adicity and the idea that elementary particles correspond to infinite primes, integers, or perhaps even rationals [E3, F6]. To infinite primes, integers, and rationals it is possible to associate a finite rational $q = m/n$ by a homomorphism. This would suggest generalization of p-adicity with q-adicity (q-adic topology does not correspond to number field) but this does not seem to be a promising idea.

The crucial observation is that one can decompose the infinite prime, call it $P$, to finite and infinite parts and distinguish between bosonic and fermionic finite primes of which infinite prime can be said to consist of [C6, E3, H8]. The interpretation is that bosonic and fermionic finite primes in the *infinite* part of $P$ code for p-adic topologies of light-like partonic 3-surfaces associated with a given *real* space-time sheet whereas the primes in the *finite* part of $P$ code for p-adic lightlike partonic 3-surfaces.

This raises two options.

1. Two space-time sheets characterized by rationals having common prime factors can be connected by a $\#_B$ contact and can interact by the exchange of particles characterized by divisors of $m$ or $n$ since in this case partonic 2-surface with same p-adic or effective p-adic topology can be found. This is the only possible interaction between them.

2. The number theoretic vision about the construction of S-matrix however allows to construct S-matrix also in the case that partons belong to different number fields and one ends up with a very elegant description involving only finite number of points of partonic 2-surfaces belonging to their intersection consisting of rational (algebraic points of imbedding space), which by algebraic universality could apply also to diagonal transitions. Also now the interactions mediated between propagators connecting partons with different effective p-adic topologies might be very slow so that this would give rise to relative darkness.

### 5.1.2 Interpretation of super-canonical conformal weights

Super-canonical conformal weights [B3, C1] are in general complex and define a new kind, presumably conserved, quantum number which could be called scaling momentum. There are strong number theoretic reasons to believe that the conformal weights are expressible in terms of zeros of Riemann Zeta.

*1. Generalization of the notion of super-canonical conformal weight, p-adicization, and number theoretical universality of Riemann Zeta*

It has clear that super-canonical conformal weights could actually depend on the $CP_2$ of the partonic 2-surface via the formula $\Delta = \zeta^{-1}(z)$, where $z$ is the complex coordinate of the projection of the point of partonic to the geodesic sphere of $CP_2$ transforming linearly under $U(2) \subset SU(3)$. Note that $\Delta$ has infinite number of branches corresponding to the zeros of $\zeta$, and the region of partonic 2-surface given branch generalizes the notion of constant conformal weight. Several branches can be associated with a given partonic 2-surface.

In the most general case $\Delta$ could be sum of $\delta M^4_{\pm}$ and $CP_2$ parts where $M^4_+$ part is of same form but now argument corresponds to the standard projective complex coordinate of $S^2$. Also now orbifold points would be introduced and the interpretation would be in terms of a selection of the quantization direction of angular momentum occurring already at the level of configuration space of 3-surfaces.

Suppose that one accepts the hypothesis of the number theoretical universality of $\zeta$ stating that the zeros $s_k = 1/2 + iy_k$ of $\zeta$ have the property that the factors $1/(1 + p^{s_k}$ are algebraic numbers for all zeros of zeta [C1, E8]. This is guaranteed if $p^{iy_k}$ is algebraic number for any value of $p$ and $y_k$. Under this assumption, p-adicization requires that the intersections of partonic 2-surfaces belonging to different number fields must correspond to points which are linear combinations of zeros of $\zeta$ with integer coefficients. Zeros of Riemann Zeta in turn correspond to orbifold points which are common to the sectors of the imbedding space characterized by different groups $G_b$ and thus possessing different values of $\hbar(M^4)$ in general.

This means that a collection of super-canonical conformal weights can be associated with the intersection points of real parton surface with a given effective p-adic topology and that each value of conformal weight defines a number theoretic braid. Same applies to the intersections of partonic space-time sheets with different p-adic topologies. The sum of these conformal weights associated with the interaction points can be said to define the net super-canonical conformal weight of the particle. Obviously super-canonical conformal weights do not define quantum number in the standard sense of the word. In particular, the new effective quantum number does not allow an effective violation of Fermi statistics.

What is important that conformal weights associated with the quantum critical partonic 2-surface must correspond to zeros or infinite values of Riemann Zeta for quantum critical points since these points correspond to north and south poles of $\zeta$ remaining invariant under $G_b$.

*2. Is conformal confinement needed?*

The first guess was that the net value of super-canonical conformal weight is real for physical states. This would give rise to the notion of conformal confinement. It was thought that a particular kind of dark matter would correspond to a conformally confined matter with particles having complex conformal weights such that the net conformal weight is real. The proposed identification of the net super-canonical conformal weight does not support this identification.

It has also become clear that there is no strong physical reason to require the reality of conformal weights at single particle level [C1]: in zero energy ontology the reality of the net conformal weight for zero energy states is predicted in any case since all conserved quantum numbers vanish for them. Furthermore, the conjugation of the conformal weight has interpretation as generalization of phase conjugation of photons in laser physics. This means that time orientation becomes an

inherent characteristic of a particle so that positive energy particles propagating in the direction of the geometric future can be distinguished from negative energy particles propagating to the direction of the geometric past.

*3. Bound states and zeros of polyzetas*

Also bound many-particle states must be considered. In [A7] I introduced the notion of bound state conformal weight generalizing the notion of binding energy. The zeros of polyzetas generalizing Riemann Zeta to functions of $N$ complex arguments define a candidate for the building blocks of complex conformal weights of $N$-particle bound states at the first level of the hierarchy and perhaps also at higher levels of hierarchy. It turns out that number theoretical constraints imply that total bound state conformal weights are of precisely same form as single particle conformal weights and that only 2- and 3-particle bounds states are non-trivial suggesting very strongly an interpretation in terms of mesons and baryons [C1].

### 5.1.3 Hierarchy of infinite primes and dark matter hierarchy

In previous consideration only the simplest infinite primes at the lowest level of hierarchy were considered. Simple infinite primes allow a symmetry changing the sign of the finite part of infinite prime. A possible interpretation in terms of phase conjugation. One can consider also more complex infinite primes at this level and a possible interpretation in terms of bound states of several particles. One can also consider infinite integers and rationals: the interpretation would be as many particle states. Rationals might correspond to states containing particles and antiparticles. At the higher levels of the hierarchy infinite primes of previous take the role of finite primes at the previous level and physically these states correspond to higher level bound states of the particles of the previous level.

Thus TGD predicts an entire hierarchy of dark matters such that the many particle states at previous level become particles at the next level. This hierarchy would provide a concrete physical identification for the hierarchy of infinite primes identifiable in terms of a repeated second quantization of an arithmetic super-symmetric QFT [E3] including both free many-particle states and their bound states. The finite primes about which infinite prime is in a well defined sense a composite of would correspond to the particles in the state forming a unit of dark matter. Particles belonging to different levels of this hierarchy would obviously correspond to different levels of dark matter hierarchy but their interactions must reduce to the fundamental partonic vertices.

## 5.2 Dark atoms and dark cyclotron states

The first naive guess was that dark atom would be obtained by simply replacing Planck constant with its scaled counterpart in the basic formulas and interpreting the results geometrically. The work with attempts to understand dark matter hierarchy however led to an alternative model of dark atoms in which the energy spectra of dark atoms and molecules are nearly the same as their ordinary counterparts due to the assumption implying that Schrödinger equation remains invariant in the scalings of Planck constants.

Eventually it became clear that original model is probably correct and is definitely the only option consistent with the quantization of planetary orbital radii and follows naturally from the picture based on Jones inclusions. The quantized values of effective Planck constant appearing in Schrödinger equation are given as ratios $\hbar_{eff}/\hbar_0 = n_a/n_b$ and in principle the binding energy scale of any atomic system can change in this kind of transition.

### 5.2.1 A model for dark N-atom

For the sector of imbedding space corresponding to Jones inclusion defined by $G_a \times G_b$ $\hbar_{eff}/\hbar_0 = n_a/n_b$ results and hydrogen energy spectrum is scaled by the factor $(n_b/n_a)^2$ and the sizes of states are scaled up by a factor $(n_a/n_b)^2$. For $n_a/n_b < 1$ the binding energies are scaled up so that a phase transition this kind of phase would liberate usable energy.

The topological condensation of electrons, ordinary atoms, and molecules at $N(G_b)$-sheeted (now in the sense of "Riemann surfaces" over $M^4$) dark magnetic flux quanta is however possible, $G_b$-covering of $M^4_\pm$ means that each particle has $N(G_b)$ identical geometric copies where $N(G_b)$ is the order of $G$. These copies can however carry different fermionic quantum numbers and statistics allows these quantum numbers to be identical. The possibility means scaling up of energies by a factor $n \leq N(G_b)$ giving the number of non-vacuum partons with identical quantum numbers making possible cyclotron Bose-Einstein condensates at high temperatures identifiable as dark quantum plasmas. The same scaling by $n$ occurs to the energy of dark plasma oscillations so that their energies can be above thermal threshold. Dark plasmoids and plasma oscillations are indeed fundamental in the TGD based model of quantum control in living matter.

### 5.2.2 Could the nucleus of N-atom be ordinary nucleus?

The first possibility is that there is a single atomic nucleus only and that it resides at ordinary space-time sheet and there are up to $N(G_b)$ identical electrons at the covering of $M^4_\pm$ so that the total binding energies of N-atom can become $N(G_b)$-fold. It is not difficult to develop critical arguments against N-atom concept in this form but it also seems possible to circumvent them.

1. The description of the Coulomb interaction between nucleus and electrons is conceptually fuzzy. By the previous argument the exchange of virtual bosons identified as $CP_2$ type extremals cannot mediate this interaction.

   Bound states are however in question and it might be possible to find space-time correlate for the bound state formation allowing to circumvent the difficulty. What is clear that the space-time region between ordinary nucleus and dark electrons must contain a 3-D surface for which $CP_2$ projection is orbifold point. The hasty conclusion would be that electric flux at this surface must vanish and thus cannot be mediated. This conclusion is however premature.

   In standard coordinates for the geodesic sphere of $CP_2$ the orbifold point corresponds to $\Theta = 0$. For instance, $\Phi = \omega t$ at this surface is possible and corresponds to the same point. The radial component of the induced Kähler electric field would be proportional to $sin(\Theta)\partial_r\Theta\omega$. The electric flux would be proportional to $J_{tr}/\sqrt{g_{tt}g_{rr} - g_{tr}^2}$ and since $\sqrt{g_4}$ vanishes at the causal determinant, both numerator and denominator would be vanishing. Therefore there could be a net electric gauge flux through orbifold surface.

2. Also the following observation would seem to challenge the interpretation of the interaction potential in terms of a classical electric field at the sheets of an $N(G_b)$-fold covering of $M^4_\pm$ (the nature of this covering is discussed in [A9]). If the classical electric flux of nucleus divides to $N(G_b)$ identical fractions and flows along the N space-time sheets, the charge experienced by a given electron is $1/N(G_b)$-fold and energy level would be scaled down by $1/N(G_b)^2$. Hence single particle energies would be scaled down by the factor $(n_b/N(G_b))^2 \leq 1$ which has the value 1 *resp.* 1/4 for $A_n$ *resp.* $D_{2n}$.

3. One can also consider the fractionization $n \to n/n_b$ of the principal quantum number analogous to that occurring for angular momentum. Since s-wave states correspond to orbits which represent radial motion between two extremes, one could consider the possibility of periodic radial orbits which run to maximal orbifold radius, back to the maximum orbifold

radius at the opposite side and close after $N_b$ loops of this kind, where $N_b$ is the order of maximal cyclic subgroup of $G_b$. This would be direct a counterpart for a rotational orbit which closes only after $N_b$ full $2\pi$ rotations. The interpretation in terms of a transition to chaos might be appropriate by period $N_b$-folding and suggest fractionization of the radial quantum number to $n/N_b$. Similar fractionization could makes sense for all orbits which are not precisely circular. This fractionization would increase the energy scale by a factor $n_b^2$. The simplest explanation is that the fractionization is equivalent to the modification of $\hbar_{eff}$.

In empty space fractional diagonal quantum number would mean that ordinary hydrogen atom wave functions diverge at spatial infinity. This kind of scaling is consistent with finiteness inside dark sector if the copies of sheet fuse together at at 3-surface having orbifold point as $CP_2$ projection to a flux flowing to a real space-time sheet so that the wave functions would remain finite everywhere and the vanishing of the determinant of the induced metric would cause the vanishing of the wave function at this surface. This point could correspond to South Pole of $S^2$ if the flux arrives from ordinary space-time sheet at North pole. It is also possible that dark protons neutralize the electronic charges at various space-time sheets: note however that they cannot neutralize the fractionized electric flux of proton at each sheet separately. One could say that electrons become radial anyons.

4. Since there would be no interaction between electrons at different copies of the space-time sheet, the states could have high electronic charges without a loss of stability. Distant enough dark protons neutralize the high negative charge of N-atom. This interpretation is also consistent with total em neutrality of a system consisting of N-atoms.

5. An interesting possibility is the formation of stable hydrogen bonds as a fusion of N-hydrogen atoms with $N-k$ and $k$ electrons to give rise to a full shell of electrons possessing an exceptional stability. $G_b$-invariance in purely fermionic degrees of freedom probably poses also some conditions on the electronic configuration. The degeneracy of states is $N(G_b)^2$ fold corresponding to the group algebra of $G_b$. This would mean that the full shell for states with given energy $E_n$ would have total energy $N_b^2 E_n$.

### 5.2.3 Dark $N$-atoms for which also nuclei are dark

Also $N$-atoms for which *dark* rather than ordinary space-time sheet contains identical nuclei are predicted. The energy scale would be scaled up by a factor $(n_b/n_a)^2$. Note that it is possible to have a situation in which only a *single branch* of the multiple covering contains nucleus (as a fermionic state, geometric copy is there unavoidably!) although other branches of the covering are geometrically identical. This can be also achieved if nucleus is delocalized with respect to branch. This is essential for the notion of N-hydrogen atom and N-hydrogen bond.

The total energy of the ordinary photon resulting in decoherence would be scaled up by this factor. The claims of Mills [54] about the scaling up of the binding energy of the hydrogen ground state by a square $k^2$ ($k = 2, 3, 4, 5, 6, 7, 10$) of an integer in plasma state are a challenge for the theory. The simplest explanation is that single electron energies with the values $k = n_b/n_a$ are in question. $n_i > 2$ for Jones inclusions is not a problem since one can have $n_b = kn_a$ without difficulty.

Before I had realized that $\hbar_{eff}$ satisfies the formula $\hbar_{eff}/\hbar_0 = n_a/n_b$ rather than $\hbar_{eff} = \hbar_0$, the presence of $k = 2$ state in spectrum was a difficult problem and I ended up with the idea that the quantum variant of Laguerre polynomials associated with quantized radial motion could explain $n = 1/2$ and also other fractional states. Later it will be found that this approach indeed predicts these quantum numbers approximately! This raises the question whether these states might appear as metastable intermediate states for hydrogen atom in the phase having $\hbar_{eff}/\hbar_0 = 1$

and $n_a = n_b > 1$. These states would be unstable against the phase transition leading to $n_b > kn_a$, $k = 2, 3, .....$

### 5.2.4 Possible experimental implications

Consider next the possible experimental implications of N-atom concept.

1. The chemistry of bio-molecules identified as $N$-molecules would definitely differ from the ordinary chemistry. Fermionic $N_e = N(G_b)$-states are expected to have a special role since these configurations are analogous noble gas atoms with full shells of electrons and to magic nuclei with full cells of nucleons. Most biologically important ions are fermions and $N = N(G_b)$ states would give rise to what might be regarded as fermionic analogs of Bose-Einstein condensates. For bosonic ions there is no restriction to the occupation numbers of single particle states involved.

2. Quite generally, the presence of spectral lines of transitions of atoms or molecules which are not stable at the temperature of environment, would serve as a signature for the presence of $N$-particles. Interestingly, spectral analysis demonstrates the presence water inside sunspots [55], where the temperature varies in the range 3000-4500 K. The de-coherence of $N$-photons emitted by thermally stable $N$-water molecules with $N > 10$ would explain the finding.

3. Also the quite recently discovered evidence [56] that Sun has a solid surface consisting mostly of calcium-ferrite is inconsistent with the fact that photosphere has temperature 5800 K. The explanation of the puzzle would be in terms of dark $N$-iron and other $N$-elements.

4. Living matter could perhaps be understood in terms of quantum deformations of the ordinary matter, which would be characterized by the quantum phases $q = exp(i2\pi/N)$. Hence quantum groups, which have for long time suspected to have significance in elementary particle physics, might explain the mystery of living matter and predict an entire hierarchy of new forms of matter.

For $N = N(G)$ molecules which dark photons emitted in the rotational and conformational transitions would be above thermal threshold. The fact that also fermionic ions (such as $Na^+$, $K^+$, $Cl^-$) are important for living system suggests that corresponding N-atoms are realized. This would also provide a justification for the hypothesis that microtubular conformations represent bits and allow conformational dynamics to serve as metabolic controller by providing microwave dark photons with energies above thermal threshold.

As demonstrated in [L2], the notion of $N$-atom leads to an elegant model for the lock and key mechanism of bio-catalysis as well as the understanding of the DNA replication based on the spontaneous decay and completion of fermionic $N < N(G)$-particles to $N = N(G)$-particles. Optimal candidates for the $N$-particles are $N$-hydrogen atoms associated with bio-molecules appearing as letters in the "pieces of text" labelling the molecules. Lock and key would correspond to conjugate names in the sense that $N_1$ and $N_2$ for the letters in the name and its conjugate satisfy $N_1 + N_2 = N = N(G)$: as the molecules combine, a full fermion shell represented by $\lambda^k$- fermion is formed.

### 5.2.5 What about cyclotron states?

Dark cyclotron states have been scaled spectrum $E_n = (n_a/n_b)E_n$ and for large values of $n_a$ one can have energies above thermal threshold. The crucial observation is that the flux of ordinary magnetic field cannot divide into $N(G)$ dark fluxes since magnetic fluxes necessarily vanish at orbifold surfaces. Hence dark magnetic field would carry total flux which is $N(G)$ times higher than the flux of ordinary magnetic field of same intensity. Fermionic analogs of Bose-Einstein

condensates are possible so that each cyclotron energy $E_n = n\hbar_0\omega$ would be replaced with spectrum extending from $(n_a/n_b)E_n$ to $(n_a/n_b)N(G_b)E_n$ in case of fractionization.

# 6 Gravitational Schrödinger equation as a quantum model for the formation of astrophysical structures and dark matter?

D. Da Rocha and Laurent Nottale, the developer of Scale Relativity, have ended up with an highly interesting quantum theory like model for the evolution of astrophysical systems [36] (I am grateful for Victor Christianito for informing me about the article). In particular, this model applies to planetary orbits. I learned later that also A. Rubric and J. Rubric have proposed a Bohr model for planetary orbits [37] already 1998.

The model is simply Schrödinger equation with Planck constant $\hbar$ replaced with what might be called gravitational Planck constant

$$\hbar \quad \rightarrow \quad \hbar_{gr} = \frac{GmM}{v_0} \quad . \tag{33}$$

Here I have used units $\hbar = c = 1$. $v_0$ is a velocity parameter having the value $v_0 = 144.7 \pm .7$ km/s giving $v_0/c = 4.6 \times 10^{-4}$. The peak orbital velocity of stars in galactic halos is $142 \pm 2$ km/s whereas the average velocity is $156 \pm 2$ km/s. Also sub-harmonics and harmonics of $v_0$ seem to appear.

The model makes fascinating predictions which hold true. For instance, the radii of planetary orbits fit nicely with the prediction of the hydrogen atom like model. The inner solar system (planets up to Mars) corresponds to $v_0$ and outer solar system to $v_0/5$.

The predictions for the distribution of major axis and eccentrities have been tested successfully also for exoplanets. Also the periods of 3 planets around pulsar PSR B1257+12 fit with the predictions with a relative accuracy of few hours/per several months. Also predictions for the distribution of stars in the regions where morphogenesis occurs follow from the gravitational Schödinger equation.

What is important is that there are no free parameters besides $v_0$. In [36] a wide variety of astrophysical data is discussed and it seem that the model works and has already now made predictions which have been later verified. In the following I shall discuss Nottale's model from the point of view of TGD.

## 6.1 TGD prediction for the parameter $v_0$

One of the basic questions is the origin of the parameter $v_0$, which according to a rich amount of experimental data discussed in [36] seems to play a role of a constant of Nature. One of the first applications of cosmic strings in TGD sense was an explanation of the velocity spectrum of stars in the galactic halo in terms of dark matter which could consists of cosmic strings. Cosmic strings could be orthogonal to the galactic plane going through the nucleus (jets) or they could be in galactic plane in which case the strings and their decay products would explain dark matter assuming that the length of cosmic string inside a sphere of radius $R$ is or has been roughly $R$ [D4]. The predicted value of the string tension is determined by the $CP_2$ radius whose ratio to Planck length is fixed by electron mass via p-adic mass calculations. The resulting prediction for the $v_0$ is correct and provides a working model for the constant orbital velocity of stars in the galactic halo.

The parameter $v_0 \simeq 2^{-11}$, which has actually the dimension of velocity unless on puts $c = 1$, and also its harmonics and sub-harmonics appear in the scaling of $\hbar$. $v_0$ corresponds to the velocity

of distant stars in the model of galactic dark matter. TGD allows to identify this parameter as the parameter

$$\begin{aligned} v_0 &= 2\sqrt{TG} = \sqrt{\frac{1}{2\alpha_K}}\sqrt{\frac{G}{R^2}} \ , \\ T &= \frac{1}{8\alpha_K}\frac{\hbar_0}{R^2} \ . \end{aligned} \tag{34}$$

Here $T$ is the string tension of cosmic strings, $R$ denotes the "radius" of $CP_2$ ($2R$ is the radius of geodesic sphere of $CP_2$). $\alpha_K$ is Kähler coupling strength, the basic coupling constant strength of TGD, whose evolution as a function of p-adic length scale is fixed by quantum criticality. The condition that $G$ is invariant in the p-adic coupling constant evolution and number theoretical arguments predict

$$\begin{aligned} \alpha_K(p) &= k\frac{1}{log(p)+log(K)} \ , \\ K &= \frac{R^2}{\hbar_0 G} = 2\times 3\times 5\times 7\times 11\times 13\times 17\times 19\times 23 \ , \ k \simeq \pi/4 \ . \end{aligned} \tag{35}$$

The predicted value of $v_0$ depends logarithmically on the p-adic length scale and for $p \simeq 2^{127}-1$ (electron's p-adic length scale) one has $v_0 \simeq 2^{-11}$.

## 6.2 Model for planetary orbits without $v_0 \to v_0/5$ scaling

Also harmonics and sub-harmonics of $v_0$ appear in the model of Nottale and Da Rocha. For instance, the outer planets (Jupiter, Saturn,...) correspond to $v_0/5$ whereas inner planets correspond to $v_0$. Quite generally, it is found that the values seem to come as harmonics and sub-harmonics of $v_0$: $v_n = nv_0$ and $v_0/n$, and the argument [36] is that the different values of $n$ relate to fractality. This scaling is not necessary for the planetary orbits in TGD based model.

Effectively a multiplication $n \to 5n$ of the principal quantum number is in question in the case of outer planets. If one accepts the interpretation that visible matter has concentrated around dark matter, which is in macroscopic quantum phase around Bohr orbits, this allows to consider also the possibility that $\hbar_{gr}$ has the same value for all planets.

1. Some gravitational perturbation has kicked dark matter from the region of the asteroid belt to $n \simeq 5k$, $k = 2,..,6$, orbits. The best fit is obtained by using values of $n$ deviating somewhat from multiples of 5 which suggests that the scaling of $v_0$ is not needed. Gravitational perturbations might have caused the same for the visible matter. The fact that the tilt angles of Earth and outer planets other than Pluto are nearly the same suggests that the orbits of these planets might be an outcome of some violent quantum process for dark matter preserving the orbital plane in a good approximation. Pluto might in turn have experienced some violent collision changing its orbital plane.

2. There could exist at least small amounts of dark matter at all orbits but visible matter is concentrated only around orbits containing some critical amount of dark matter.

| | Exp. | T-B | $\text{Bohr}_1$ | $\text{Bohr}_2$ |
|---|---|---|---|---|
| Planet | $R/R_M$ | $R/R_M$ | $[n, R/R_M]$ | $[n, R/R_M]$ |
| Mercury | 1 | 1 | [3, 1] | |
| Venus | 1.89 | 1.75 | [4, 1.8] | |
| Earth | 2.6 | 2.5 | [5, 2.8] | |
| Mars | 3.9 | 4 | [6, 4] | |
| Asteroids | 6.1-8.7 | 7 | [(7, 8, 9), (5.4, 7.1, 9)] | |
| Jupiter | 13.7 | 13 | [11, 13.4] | [2 × 5,11.1] |
| Saturn | 25.0 | 25 | [3 × 5, 25] | [3 × 5, 25] |
| Uranus | 51.5 | 49 | [22, 53.8] | [4 × 5,44.4] |
| Neptune | 78.9 | 97 | [27 , 81] | [5 × 5, 69.4] |
| Pluto | 105.2 | 97 | [31, 106.7] | [6 × 5,100] |

Table 1. The table represents the experimental average orbital radii of planets, the predictions of Titius-Bode law (note the failure for Neptune), and the predictions of Bohr orbit model assuming a) that the principal quantum number $n$ corresponds to best possible fit, b) the scaling $v_0 \to v_0/5$ for outer planets. Option a) gives the best fit with errors being considerably smaller than the maximal error $|\Delta R|/R \simeq 1/n$ except for Uranus. $R_M$ denotes the orbital radius of Mercury. T-B refers to Titius-Bode law.

#### 6.2.1 How to understand the harmonics and sub-harmonics of $v_0$ in TGD framework?

Also harmonics and sub-harmonics of $v_0$ appear in the model of Nottale and Da Rocha. In particular, the outer planets (Jupiter, Saturn,...) correspond to $v_0/5$ whereas inner planets correspond to $v_0$ in this model. As already found, TGD allows also an alternative explanation.

Quite generally, it is found that the values seem to come as harmonics and sub-harmonics of $v_0$: $v_n = nv_0$ and $v_0/n$, and the argument [36] is that the different values of $n$ relate to fractality. This quantization is a challenge for TGD since $v_0$ certainly defines a fundamental constant in TGD Universe.

1. Consider first the harmonics of $v_0$. Besides cosmic strings of type $X^2 \times S^2 \subset M^4 \times CP_2$ one can consider also deformations of these strings defining their multiple coverings so that the deformation is $n$-valued as a function of $S^2$-coordinates $(\Theta, \Phi)$ and the projection to $S^2$ is thus an $n \to 1$ map. The solutions are higher dimensional analogs of originally closed orbits which after perturbation close only after $n$ turns. This kind of surfaces emerge in the TGD inspired model of quantum Hall effect naturally [E9] and $n \to \infty$ limit has an interpretation as an approach to chaos [G2].

   Using the coordinates $(x, y, \theta, \phi)$ of $X^2 \times S^2$ and coordinates $m^k$ for $M^4$ of the unperturbed solution the space-time surface the deformation can be expressed as

$$\begin{aligned} m^k &= m^k(x, y, \theta, \phi) \ , \\ (\Theta, \Phi) &= (\theta, n\phi) \ . \end{aligned} \tag{36}$$

   The value of the string tension would be indeed $n^2$-fold in the first approximation since the induced Kähler form defining the Kähler magnetic field would be $J_{\theta\phi} = nsin(\Theta)$ and one would have $v_n = nv_0$. At the limit $m^k = m^k(x, y)$ different branches for these solutions collapse together.

2. Consider next how sub-harmonics appear in TGD framework. Cosmic strings are predicted to decay to magnetic flux tube structures by absolute minimization of Kähler action. The Kähler magnetic flux $\Phi = BS$ is conserved in the process but the thickness of the $M^4$ projection of the cosmic string increases field strength is reduced. This means that string tension, which is proportional to $B^2S$, is reduced (so that also Kähler action is reduced). The fact that space-time surface is Bohr orbit in generalized sense means that the reduced string tension (magnetic energy per unit length) is quantized.

The task is to guess how the quantization occurs. There are two options.

1. The simplest explanation for the reduction of $v_0$ is based on the decay of a flux tube resembling a disk with a hole to $n$ identical flux tubes so that $v_0 \to v_0/n$ results for the resulting flux tubes. It turns out that this mechanism is favored and explains elegantly the value of $\hbar_{gr}$ for outer planetary system. One can also consider small-p p-adicity so that $n$ would be prime.

2. Second explanation is more intricate. Consider a magnetic flux tube. Since magnetic flux is quantized, the magnetic field strengths are quantized in integer multiples of basic strength: $B = nB_0$ and would rather naturally correspond to the multiple coverings of the original magnetic flux tube with magnetic energy quantized in multiples of $n^2$. The idea is to require internal consistency in the sense that the allowed reduced field strengths are such that the spectrum associated with $B_0$ is contained to the spectrum associated with the quantized field strengths $B_1 > B_0$. This would allow only field strengths $B = B_S/n^2$, where $B_S$ denotes the field strength of the fundamental cosmic string and one would have $v_n = v_0/n$. Flux conservation requires that the area of the flux tube scales as $n^2$.

Sub-harmonics might appear in the outer planetary system and there are indications for the higher harmonics below the inner planetary system [36]: for instance, solar radius corresponds to $n = 1$ orbital for $v_3 = 3v_0$. This would suggest that Sun and also planets have an onion like structure with highest harmonics of $v_0$ and strongest string tensions appearing in the solar core and highest sub-harmonics appearing in the outer regions. If the matter results as decay remnants of cosmic strings this means that the mass density inside Sun should correlate strongly with the local value of $n$ characterizing the multiple covering of cosmic strings.

One can ask whether the very process of the formation of the structures could have excited the higher values of $n$ just like closed orbits in a perturbed system become closed only after $n$ turns. The energy density of the cosmic string is about one Planck mass per $\sim 10^7$ Planck lengths so that $n > 1$ excitation increasing this density by a factor of $n^2$ is obviously impossible except under the primordial cosmic string dominated period of cosmology during which the net inertial energy density must have vanished. The structure of the future solar system would have been dictated already during the primordial phase of cosmology when negative energy cosmic string suffered a time reflection to positive energy cosmic strings.

### 6.2.2 Nottale equation is consistent with the TGD based model for dark matter

TGD allows two models of dark matter. The first one is spherically symmetric and the second one cylindrically symmetric. The first thing to do is to check whether these models are consistent with the gravitational Schödinger equation/Bohr quantization.

*1. Spherically symmetric model for the dark matter*

The following argument based on Bohr orbit quantization demonstrates that this is indeed the case for the spherically symmetric model for dark matter. The argument generalizes in a trivial manner to the cylindrically symmetric case.

1. The gravitational potential energy $V(r)$ for a mass distribution $M(r) = xTr$ ($T$ denotes string tension) is given by

$$V(r) = Gm\int_r^{R_0} \frac{M(r)}{r^2}dr = GmxTlog(\frac{r}{R_0}) \ . \tag{37}$$

   Here $R_0$ corresponds to a large radius so that the potential is negative as it should in the region where binding energy is negative.

2. The Newton equation $\frac{mv^2}{r} = \frac{GmxT}{r}$ for circular orbits gives

$$v = xGT \ . \tag{38}$$

3. Bohr quantization condition for angular momentum by replacing $\hbar$ with $\hbar_{gr}$ reads as $mvr = n\hbar_{gr}$ and gives

$$\begin{aligned} r_n &= \frac{n\hbar_{gr}}{mv} = nr_1 \ , \\ r_1 &= \frac{GM}{vv_0} \ . \end{aligned} \tag{39}$$

   Here $v$ is rather near to $v_0$.

4. Bound state energies are given by

$$E_n = \frac{mv^2}{2} - xTlog(\frac{r_1}{R_0}) + xTlog(n) \ . \tag{40}$$

   The energies depend only weakly on the radius of the orbit.

5. The centrifugal potential $l(l+1)/r^2$ in the Schrödinger equation is negligible as compared to the potential term at large distances so that one expects that degeneracies of orbits with small values of $l$ do not depend on the radius. This would mean that each orbit is occupied with same probability irrespective of value of its radius. If the mass distribution for the starts does not depend on $r$, the number of stars rotating around galactic nucleus is simply the number of orbits inside sphere of radius $R$ and thus given by $N(R) \propto R/r_0$ so that one has $M(R) \propto R$. Hence the model is self consistent in the sense that one can regard the orbiting stars as remnants of cosmic strings and thus obeying same mass distribution.

*2. Cylindrically symmetric model for the galactic dark matter*

TGD allows also a model of the dark matter based on cylindrical symmetry. In this case the dark matter would correspond to the mass of a cosmic string orthogonal to the galactic plane and traversing through the galactic nucleus. The string tension would the one predicted by TGD. In the directions orthogonal to the plane of galaxy the motion would be free motion so that the orbits would be helical, and this should make it possible to test the model. The quantization of radii of the orbits would be exactly the same as in the spherically symmetric model. Also the quantization of inclinations predicted by the spherically symmetric model could serve as a sensitive test. In this

kind of situation general theory of relativity would predict only an angle deficit giving rise to a lens effect. TGD predicts a Newtonian $1/\rho$ potential in a good approximation.

Spiral galaxies are accompanied by jets orthogonal to the galactic plane and a good guess is that they are associated with the cosmic strings. The two models need not exclude each other. The vision about astrophysical structures as pearls of a fractal necklace would suggest that the visible matter has resulted in the decay of cosmic strings originally linked around the cosmic string going through the galactic plane and creating $M(R) \propto R$ for the density of the visible matter in the galactic bulge. The finding that galaxies are organized along linear structures [22] fits nicely with this picture.

*3. MOND and TGD*

TGD based model explains also the MOND (Modified Newton Dynamics) model of Milgrom [38] for the dark matter. Instead of dark matter the model assumes a modification of Newton's laws. The model is based on the observation that the transition to a constant velocity spectrum seems in the galactic halos seems to occur at a constant value of the stellar acceleration equal to $a_0 \simeq 10^{-11}g$, where $g$ is the gravitational acceleration at the Earth. MOND theory assumes that Newtonian laws are modified below $a_0$.

The explanation relies on Bohr quantization. Since the stellar radii in the halo are quantized in integer multiples of a basic radius and since also rotation velocity $v_0$ is constant, the values of the acceleration are quantized as $a(n) = v_0^2/r(n)$ and $a_0$ correspond to the radius $r(n)$ of the smallest Bohr orbit for which the velocity is still constant. For larger orbital radii the acceleration would indeed be below $a_0$. $a_0$ would correspond to the distance above which the density of the visible matter does not appreciably perturb the gravitational potential of the straight string. This of course requires that gravitational potential is that given by Newton's theory and is indeed allowed by TGD.

## 6.3 The interpretation of $\hbar_{gr}$ and pre-planetary period

$\hbar_{gr}$ could corresponds to a unit of angular momentum for quantum coherent states at magnetic flux tubes or walls containing macroscopic quantum states. Quantitative estimate demonstrates that $\hbar_{gr}$ for astrophysical objects cannot correspond to spin angular momentum. For Sun-Earth system one would have $\hbar_{gr} \simeq 10^{77}\hbar$. This amount of angular momentum realized as a mere spin would require $10^{77}$ particles! Hence the only possible interpretation is as a unit of orbital angular momentum. The linear dependence of $\hbar_{gr}$ on $m$ is consistent with the additivity of angular momenta in the fusion of magnetic flux tubes to larger units if the angular momentum associated with the tubes is proportional to both $m$ and $M$.

Just as the gravitational acceleration is a more natural concept than gravitational force, also $\hbar_{gr}/m = GM/v_0$ could be more natural unit than $\hbar_{gr}$. It would define a universal unit for the circulation $\oint v \cdot dl$, which is apart from $1/m$-factor equal to the phase integral $\oint p_\phi d\phi$ appearing in Bohr rules for angular momentum. The circulation could be associated with the flow associated with outer boundaries of magnetic flux tubes surrounding the orbit of mass $m$ around the central mass $M \gg m$ and defining light like 3-D CDs analogous to black hole horizons.

The expression of $\hbar_{gr}$ depends on masses $M$ and $m$ and can apply only in space-time regions carrying information about the space-time sheets of $M$ and and the orbit of $m$. Quantum gravitational holography suggests that the formula applies at 3-D light like causal determinant (CD) $X_l^3$ defined by the wormhole contacts gluing the space-time sheet $X_l^3$ of the planet to that of Sun. More generally, $X_l^3$ could be the space-time sheet containing the planet, most naturally the magnetic flux tube surrounding the orbit of the planet and possibly containing dark matter in super-conducting state. This would give a precise meaning for $\hbar_{gr}$ and explain why $\hbar_{gr}$ does not depend on the masses of other planets.

The simplest option consistent with the quantization rules and with the explanatory role of magnetic flux structures is perhaps the following one.

1. $X_l^3$ is a torus like surface around the orbit of the planet containing delocalized dark matter. The key role of magnetic flux quantization in understanding the values of $v_0$ suggests the interpretation of the torus as a magnetic or $Z^0$ magnetic flux tube. At pre-planetary period the dark matter formed a torus like quantum object. The conditions defining the radii of Bohr orbits follow from the requirement that the torus-like object is in an eigen state of angular momentum in the center of mass rotational degrees of freedom. The requirement that rotations do not leave the torus-like object invariant is obviously satisfied. Newton's law required by the quantum-classical correspondence stating that the orbit corresponds to a geodesic line in general relativistic framework gives the additional condition implying Bohr quantization.

2. A simple mechanism leading to the localization of the matter would have been the pinching of the torus causing kind of a traffic jam leading to the formation of the planet. This process could quite well have involved a flow of matter to a smaller planet space-time sheet $Y_l^3$ topologically condensed at $X_l^3$. Most of the angular momentum associated with torus like object would have transformed to that of planet and situation would have become effectively classical.

3. The conservation of magnetic flux means that the splitting of the orbital torus would generate a pair of Kähler magnetic charges. It is not clear whether this is possible dynamically and hence the torus could still be there. In fact, TGD explanation for the tritium beta decay anomaly citeTroitsk,Mainz in terms of classical $Z^0$ force [F8] requires the existence of this kind of torus containing neutrino cloud whose density varies along the torus. This picture suggests that the lacking $n = 1$ and $n = 2$ orbits in the region between Sun and Mercury are still in magnetic flux tube state containing mostly dark matter.

4. The fact that $\hbar_{gr}$ is proportional to $m$ means that it could have varied continuously during the accumulation of the planetary mass without any effect in the planetary motion: this is of course nothing but a manifestation of Equivalence Principle.

5. It is interesting to look for the scaled up versions of Planck mass $m_{Pl} = \sqrt{\hbar_{gr}/\hbar} \times \sqrt{\hbar/G} = \sqrt{M_1 M_2/v_0}$ and Planck length $L_{Pl} = \sqrt{\hbar_{gr}/\hbar} \times \sqrt{\hbar/G} = G\sqrt{M_1 M_2/v_0}$. For $M_1 = M_2 = M$ this gives $m_{Pl} = M/\sqrt{v_0} \simeq 45.6 \times M$ and $L_{Pl} = r_S/2\sqrt{v_0} \simeq 22.8 \times r_S$, where $r_S$ is Schwartshild radius. For Sun $r_S$ is about 2.9 km so that one has $L_{Pl} \simeq 66$ km. For a few years ago it was found that Sun contains "inner-inner" core of radius about $R = 300$ km [21] which is about $4.5 \times L_{Pl}$.

## 6.4 Inclinations for the planetary orbits and the quantum evolution of the planetary system

The inclinations of planetary orbits provide a test bed for the theory. The semiclassical quantization of angular momentum gives the directions of angular momentum from the formula

$$cos(\theta) = \frac{m}{\sqrt{j(j+1)}} \quad , \quad |m| \leq j \quad . \tag{41}$$

where $\theta$ is the angle between angular momentum and quantization axis and thus also that between orbital plane and (x,y)-plane. This angle defines the angle of tilt between the orbital plane and (x,y)-plane.

$m = j = n$ gives minimal value of angle of tilt for a given value of $n$ of the principal quantum number as

$$cos(\theta) = \frac{n}{\sqrt{n(n+1)}} \ . \tag{42}$$

For $n = 3, 4, 5$ (Mercury, Venus, Earth) this gives $\theta = 30.0$, 26.6, and 24.0 degrees respectively.

Only the relative tilt angles can be compared with the experimental data. Taking as usual the Earth's orbital plane as the reference the relative tilt angles give what are known as inclinations. The predicted inclinations are 6 degrees for Mercury and 2.6 degrees for Venus. The observed values [39] are 7.0 and 3.4 degrees so that the agreement is satisfactory. If one allows half-odd integer spin the fit is improved. For $j = m = n - 1/2$ the predictions are 7.1 and 2.9 degrees for Mercury and Venus respectively. For Mars, Jupiter, Saturn, Uranus, Neptune, and Pluto the inclinations are 1.9, 1.3, 2.5, 0.8, 1.8, 17.1 degrees. For Mars and outer planets the tilt angles are predicted to have wrong sign for $m = j$. In a good approximation the inclinations vanish for outer planets except Pluto and this would allow to determine $m$ as $m \simeq \sqrt{5n(n+1)/6}$: the fit is not good.

The assumption that matter has condensed from a matter rotating in (x,y)-plane orthogonal to the quantization axis suggests that the directions of the planetary rotation axes are more or less the same and by angular momentum conservation have not changed appreciably. The prediction for the tilt of the rotation axis of the Earth is 24 degrees of freedom in the limit that the Earth's spin can be treated completely classically, that is for $m = j >> 1$ in the units used for the quantization of the Earth's angular momentum. What is the value of $\hbar_{gr}$ for Earth is not obvious (using the unit $\hbar_{gr} = GM^2/v_0$ the Earth's angular momentum would be much smaller than one). The tilt of the rotation axis of Earth with respect to the orbit plane is 23.5 degrees so that the agreement is again satisfactory. This prediction is essentially quantal: in purely classical theory the most natural guess for the tilt angle for planetary spins is 0 degrees.

The observation that the inner planets Mercury, Venus, and Earth have in a reasonable approximation the predicted inclinations suggest that they originate from a primordial period during which they formed spherical cells of dark matter and had thus full rotational degrees of freedom and were in eigen states of angular momentum corresponding to a full rotational symmetry. The subsequent $SO(3) \to SO(2)$ symmetry breaking leading to the formation of torus like configurations did not destroy the information about this period since the information about the value of $j$ and $m$ was coded by the inclination of the planetary orbit.

In contrast to this, the dark matter associated with Earth and outer planets up to Neptune formed a flattened magnetic or $Z^0$ magnetic flux tube resembling a disk with a hole and the subsequent symmetry breaking broke it to separate flux tubes. Earth's spherical disk was joined to the disk formed by the outer planets. The spherical disk could be still present and contain super-conducting dark matter. The presence of this "heavenly sphere" might closely relate to the fact that Earth is a living planet. The time scale $T = 2\pi R/c$ is very nearly equal to 5 minutes and defines a candidate for a bio-rhythm.

If this flux tube carried the same magnetic flux as the flux tubes associated with the inner planets, the decomposition of the disk with a hole to 5 flux tubes corresponding to Earth and to the outer planets Mars, Jupiter, Saturn and Neptune, would explain the value of $v_0$ correctly and also the small inclinations of outer planets. That Pluto would not originate from this structure, is consistent with its anomalously large values of inclination $i = 17.1$ degrees, small value of eccentricity $e = .248$, and anomalously large value of inclination of equator to orbit about 122 degrees as compared to 23.5 degrees in the case of Earth [39].

## 6.5 Eccentricities and comets

Bohr-Sommerfeld quantization allows also to deduce the eccentricities of the planetary and comet orbits. One can write the quantization of energy as

$$\begin{aligned} \frac{p_r^2}{2m_1} + \frac{p_\theta^2}{2m_1 r^2} + \frac{p_\phi^2}{2m_1 r^2 sin^2(\theta)} - \frac{k}{r} &= -\frac{E_1}{n^2} \ , \\ E_1 = \frac{k^2}{2\hbar_{gr}^2} \times m_1 &= \frac{v_0^2}{2} \times m_1 \ . \end{aligned} \tag{43}$$

Here one has $k = GMm_1$. $E_1$ is the binding energy of $n = 1$ state. In the orbital plane ($\theta = \pi/2, p_\theta = 0$) the conditions are simplified. Bohr quantization gives $p_\phi = m\hbar_{gr}$ implying

$$\frac{p_r^2}{2m_1} + \frac{k^2\hbar_{gr}^2}{2m_1 r^2} - \frac{k}{r} = -\frac{E_1}{n^2} \ . \tag{44}$$

For $p_r = 0$ the formula gives maximum and minimum radii $r_\pm$ and eccentricity is given by

$$e^2 = \frac{r_+ - r_-}{r_+} = \frac{2\sqrt{1 - \frac{m^2}{n^2}}}{1 + \sqrt{1 - \frac{m^2}{n^2}}} \ . \tag{45}$$

For small values of $n$ the eccentricities are very large except for $m = n$. For instance, for ($m = n-1, n$) for $n = 3, 4, 5$ gives $e = (.93, .89, .86)$ to be compared with the experimental values (.206, .007, .0167). Thus the planetary eccentricities with Pluto included ($e = .248$) must vanish in the lowest order approximation and must result as a perturbation of the magnetic flux tube.

The large eccentricities of comet orbits might however have an interpretation in terms of $m < n$ states. The prediction is that comets with small eccentricities have very large orbital radius. Oort's cloud is a system weakly bound to a solar system extending up to 3 light years. This gives the upper bound $n \leq 700$ if the comets of the cloud belong to the same family as Mercury, otherwise the bound is smaller. This gives a lower bound to the eccentricity of not nearly circular orbits in the Oort cloud as $e > .32$.

## 6.6 Why the quantum coherent dark matter is not visible?

The obvious objection against quantal astrophysics is that astrophysical systems look extremely classical. Quantal dark matter in many-sheeted space-time resolves this counter argument. As already explained, the sequence of symmetry breakings of the rotational symmetry would explain nicely why astral Bohr rules work. The prediction is however that delocalized quantal dark matter is probably still present at (the boundaries of) magnetic flux tubes and spherical shells. It is however the entire structure defined by the orbit which behaves like a single extended particle so that the localization in quantum measurement does not mean a localization to a point of the orbit. Planet itself corresponds to a smaller localized space-time sheet condensed at the flux tube.

One should however understand why this dark matter with a gigantic Planck constant is not visible. The simplest explanation is that there cannot be any direct quantum interactions between ordinary and dark matter in the sense that particles with different values of Planck constant could appear in the same particle vertex. This would allow also a fractal hierarchy copies of standard model physics to exist with different p-adic mass scales.

There is also second argument. The inability to observe dark matter could mean inability to perform state function reduction localizing the dark matter. The probability for this should be proportional to the strength of the measurement interaction. For photons the strength of the interaction is characterized by the fine structure constant. In the case of dark matter the fine structure constant is replaced with

$$\alpha_{em,gr} \;=\; \alpha_{em} \times \frac{\hbar}{\hbar_{gr}} = \alpha_{em} \times \frac{v_0}{GMm} \quad . \tag{46}$$

For $M = m = m_{Pl} \simeq 10^{-8}$ kg the value of the fine structure constant is smaller than $\alpha_{em} v_0$ and completely negligible for astrophysical masses. However, for processes for which the lowest order classical rates are non-vanishing, rates are not affected in the lowest order since the increase of the Compton length compensates the reduction of $\alpha$. Higher order corrections become however small. What makes dark matter invisible is not the smallness of $\alpha_{em}$ but the fact that the binding energies of say hydrogen atom proportional to $\alpha^2 m_e$ are scaled as $1/\hbar^2$ so that the spectrum is scaled down.

## 6.7 Quantum interpretation of gravitational Schrödinger equation

Schrödinger equation in astrophysical length scales with a gigantic value of Planck constant looks sheer madness idea from the standard physics point of view. In TGD Universe situation might be different.

1. In TGD inertial four-momentum (or conserved four-momentum) is not positive definite and the net four-momentum of the Universe vanishes. Already in cosmological length scales the density of inertial mass vanishes. Gravitational masses and inertial masses can be identified only at the limit when one can neglect the interaction between positive and negative energy matter. The masses appearing in the gravitational Schrödinger equation are gravitational masses and one can ask whether inertial and gravitational Planck constants are different.

2. The fractality of the many-sheeted space-time predicts that quantum effects appear in all length and time scales. In particular, dark matter is at larger space-time sheets and hence almost invisible.

3. An even more weirder looks the idea that Planck constant could have a gigantic value in astrophysical length scales being of order of magnitude of product of masses using Planck mass as a unit for $\hbar = c = 1$. This would mean that gravitation at space-time sheets of astrophysical size would have super quantal character! But even the gigantic value of Planck constant might be understood in TGD framework.

### 6.7.1 Beraha numbers and spectrum of Planck constant

The infinite-dimensional Clifford algebra of the configuration space ("the world of classical worlds") gamma matrices defines so called von Neumann algebra with a hierarchy of type $II_1$ sub-factors. So called Beraha numbers

$$B_n \;=\; 4cos^2(\frac{\pi}{n}), \;\; n \geq 3 \tag{47}$$

relate very closely to these factors as also to braid groups and quantum groups. Roughly, $B_n$ corresponds to the quantum dimension $d$ of Clifford algebra of 2-component spinors. There is also a continuum of dimensions $D \geq 4$ for the dimensions of sub-factors of type $II_1$. Obviously, the

dimensions behave like energy spectrum of a quantum mechanical systems. That $D = 4$ is the limiting value of bound state dimensions suggests strongly a connection with the fact that the infinities of quantum field theory appear for $D \geq 4$.

The first attempts to understand large values of Planck constant led to a formula for the dependence of Planck constant on $B_n$, which turned out to be badly wrong. The improved understanding of Jones inclusions and their role in TGD however led eventually to an extremely simple formula for the Planck constant, as a matter for separate Planck constants associated with $M^4$ *resp.* $CP_2$ degrees of freedom appearing as scaling factors of $CP_2$ *resp.* $M^4$ metric. This theory is summarized in [C6] and in the introduction and will be briefly summarized below.

### 6.7.2 Jones inclusions and quantization of Planck constants

Quantum TGD emerges from infinite-dimensional Clifford algebra defined as infinite power of 8-dimensional Clifford algebra $C(8)$ generalized to a local algebra by constructing power series of quantum octonionic variable having the elements of this Clifford algebra as coefficients. The eigenstates for the commuting hermitian coordinates assignable to this octonionic variable have $M^8$ as spectrum and extremely general arguments imply both classical and quantum TGD. The construction works only for $D = 8$ (by non-associativity of the octonionic units) since for other dimensions the local field defined by algebra could not be distinguished from algebra itself.

Perhaps the most important outcome is a general master formula for S-matrix with interactions described as a deformation of ordinary tensor product to Connes tensor products and new view theory of quantum measurement. Further outcomes are prediction the spectra of the quantized values of $M^4$ and $CP_2$ Planck constants as characterizers of Jones inclusions associated with quantum phases $q = exp(i\pi/n)$.

*1. Some background*

It has been for few years clear that TGD could emerge from the mere infinite-dimensionality of the Clifford algebra of infinite-dimensional "world of classical worlds" and from number theoretical vision in which classical number fields play a key role and determine imbedding space and space-time dimensions. This would fix completely the "world of classical worlds".

Infinite-dimensional Clifford algebra is a standard representation for von Neumann algebra known as a hyper-finite factor of type $II_1$. In TGD framework the infinite tensor power of C(8), Clifford algebra of 8-D space would be the natural representation of this algebra.

*2. How to localize infinite-dimensional Clifford algebra?*

The basic new idea is to make this algebra *local*: local Clifford algebra as a generalization of gamma field of string models.

1. Represent Minkowski coordinate of $M^d$ as linear combination of gamma matrices of D-dimensional space. This is the first guess. One fascinating finding is that this notion can be quantized and classical $M^d$ is genuine quantum $M^d$ with coordinate values eigenvalues of quantal commuting Hermitian operators built from matrix elements. Euclidian space is not obtained in this manner. Minkowski signature is something quantal and the standard quantum group $Gl_(2,q)(C)$ with (non-Hermitian matrix elements) gives $M^4$.

2. Form power series of the $M^d$ coordinate represented as linear combination of gamma matrices with coefficients in corresponding infinite-D Clifford algebra. You would get tensor product of two algebra.

3. There is however a problem: one cannot distinguish the tensor product from the original infinite-D Clifford algebra. $D = 8$ is however an exception! You can replace gammas in the expansion of $M^8$ coordinate by hyper-octonionic units which are non-associative (or

octonionic units in quantum complexified-octonionic case). Now you cannot anymore absorb the tensor factor to the Clifford algebra and you get genuine $M^8$-localized factor of type $II_1$. Everything is determined by infinite-dimensional gamma matrix fields analogous to conformal super fields with z replaced by hyperoctonion.

4. Octonionic non-associativity actually reproduces whole classical and quantum TGD: space-time surface must be associative sub-manifolds hence hyper-quaternionic surfaces of $M^8$. Representability as surfaces in $M^4 \times CP_2$ follows naturally, the notion of configuration space of 3-surfaces, etc....

*3. Connes tensor product for free fields as a universal definition of interaction quantum field theory*

This picture has profound implications. Consider first the construction of S-matrix.

1. A non-perturbative construction of S-matrix emerges. The deep principle is simple. The canonical outer automorphism for von Neumann algebras defines a natural candidate unitary transformation giving rise to propagator. This outer automorphism is trivial for $II_1$ factors meaning that all lines appearing in Feynman diagrams must be on mass shell states satisfying Super Virasoro conditions. You can allow all possible diagrams: all on mass shell loop corrections vanish by unitarity and what remains are diagrams with single N-vertex.

2. At 2-surface representing N-vertex space-time sheets representing generalized Bohr orbits of incoming and outgoing particles meet. This vertex involves von Neumann trace (finite!) of localized gamma matrices expressible in terms of fermionic oscillator operators and defining free fields satisfying Super Virasoro conditions.

3. For free fields ordinary tensor product would not give interacting theory. What makes S-matrix non-trivial is that *Connes tensor product* is used instead of the ordinary one. This tensor product is a universal description for interactions and we can forget perturbation theory! Interactions result as a deformation of tensor product. Unitarity of resulting S-matrix is unproven but I dare believe that it holds true.

4. The subfactor $\mathcal{N}$ defining the Connes tensor product has interpretation in terms of the interaction between experimenter and measured system and each interaction type defines its own Connes tensor product. Basically $\mathcal{N}$ represents the limitations of the experimenter. For instance, IR and UV cutoffs could be seen as primitive manners to describe what $\mathcal{N}$ describes much more elegantly. At the limit when $\mathcal{N}$ contains only single element, theory would become free field theory but this is ideal situation never achievable.

*4. The quantization of Planck constant and ADE hierarchies*

The quantization of Planck constant has been the basic them of TGD for more than one and half years and leads also the understanding of ADE correspondences (index $\beta \leq 4$ and $\beta = 4$) from the point of view of Jones inclusions.

1. The new view allows to understand how and why Planck constant is quantized and gives an amazingly simple formula for the separate Planck constants assignable to $M^4$ and $CP_2$ and appearing as scaling constants of their metrics. This in terms of a mild generalizations of standard Jones inclusions. The emergence of imbedding space means only that the scaling of these metrics have spectrum: no landscape.

2. In ordinary phase Planck constants $\hbar(M^4)$ and $\hbar(CP_2)$ are same and have their standard values. Large Planck constant phases correspond to situations in which a transition to a phase in which quantum groups occurs. These situations correspond to standard Jones inclusions in which Clifford algebra is replaced with a sub-algebra of its G-invariant elements. G is product $G_a \times G_b$ of subgroups of $SL(2,C)$ and $SU(2)_L \times \times U(1)$ which also acts as a subgroup of SU(3). Space-time sheets are $n(G_b)$-fold coverings of $M^4$ and $n(G_a)$-fold coverings of $CP_2$ generalizing the picture which has emerged already. An elementary study of these coverings fixes the values of scaling factors of $M^4$ and $CP_2$ Planck constants to orders of the maximal cyclic sub-groups. Mass spectrum is invariant under these scalings. The values of Planck constants are $\hbar(M^4) = n_a\hbar_0$ and $\hbar(CP_2) = n_b\hbar_0$ and scaling factor of $M^4$ covariant metric is $n_b$ and that of $CP_2$ metric $n_a$. In Kähler action only the ratio $n_a/n_b$ occurs and the Planck constant $\hbar_{eff}$ occurring in Schrödinger equation is by quantum classical correspondence $\hbar_{eff}/\hbar_0 = n_a/n_b$.

3. This predicts automatically arbitrarily large and also small values of Planck constant depending in the value of the ratio $n_a/n_b$ and assigns the preferred values of Planck constant to quantum phases $q = exp(i\pi/n_i)$, $i = a, b$ expressible in terms of iterated square roots of rationals: these correspond to polygons obtainable by compass and ruler construction. In particular, experimentally favored values of $\hbar$ in living matter correspond to these special values of Planck constant. This model reproduces also the other aspects of the general vision. The subgroups of $SL(2,C)$ in turn can give rise to re-scaling of $SU(3)$ Planck constant. The most general situation can be described in terms of Jones inclusions for fixed point subalgebras of number theoretic Clifford algebras defined by $G_a \times G_b \subset SL(2,C) \times SU(2)$.

4. These inclusions (apart from those for which $G_a$ contains infinite number of elements) are represented by ADE or extended ADE diagrams depending on the value of index. The group algebras of these groups give rise to additional degrees of freedom which make possible to construct the multiplets of the corresponding gauge groups. For $\beta \leq 4$ the gauge groups $A_n$, $D_2n$, $E_6$, $E_8$ are possible so that TGD seems to be able to mimick these gauge theories. For $\beta = 4$ all ADE Kac Moody groups are possible and again mimicry becomes possible: TGD would be kind of universal physics emulator but it would be anyonic dark matter which would perform this emulation.

### 6.7.3 Bohr quantization of planetary orbits and prediction for Planck constant

The predictions of the generalization of the p-adic length scale hypothesis are consistent with the TGD based model for the Bohr quantization of planetary orbits and some new non-trivial predictions follow.

*1. Generalization of the p-adic length scale hypothesis*

The evolution in phase resolution in p-adic degrees of freedom corresponds to emergence of algebraic extensions allowing increasing variety of phases $exp(i\pi/n)$ expressible p-adically. This evolution can be assigned to the emergence of increasingly complex quantum phases and the increase of Planck constant.

One expects that quantum phases $q = exp(i\pi/n)$ which are expressible using only square roots of rationals are number theoretically very special since they correspond to algebraic extensions of p-adic numbers involving only square roots which should emerge first and therefore systems involving these values of $q$ should be especially abundant in Nature.

These polygons are obtained by ruler and compass construction and Gauss showed that these polygons, which could be called Fermat polygons, have $n_F = 2^k \prod_s F_{n_s}$ sides/vertices: all Fermat primes $F_{n_s}$ in this expression must be different. The analog of the p-adic length scale hypothesis emerges since larger Fermat primes are near a power of 2. The known Fermat primes $F_n = 2^{2^n} + 1$

correspond to $n = 0, 1, 2, 3, 4$ with $F_0 = 3$, $F_1 = 5$, $F_2 = 17$, $F_3 = 257$, $F_4 = 65537$. It is not known whether there are higher Fermat primes. $n = 3, 5, 15$-multiples of p-adic length scales clearly distinguishable from them are also predicted and this prediction is testable in living matter. I have already earlier considered the possibility that Fermat polygons could be of special importance for cognition and for biological information processing [H8].

This condition could be interpreted as a kind of resonance condition guaranteing that scaled up sizes for space-time sheets have sizes given by p-adic length scales. The numbers $n_F$ could take the same role in the evolution of Planck constants assignable with the phase resolution as Mersenne primes have in the evolution assignable to the p-adic length scale resolution.

*2. Do the values of gravitational Planck constant correspond to polygons obtained by ruler and compass construction?*

Since the macroscopic quantum phases with minimum dimension of algebraic extension should be especially abundant in the universe, the natural guess is that the values of the gravitational Planck constant correspond to $n_F$-multiples of ordinary Planck constant.

1. The model can explain the enormous values of gravitational Planck constant $\hbar_{gr}/\hbar_0 = \simeq GMm/v_0) = n_a/n_b$. The favored values of this parameter should correspond to $n_{F_a}/n_{F_b}$ so that the mass ratios $m_1/m_2 = n_{F_{a,1}} n_{F_{b,2}}/n_{F_{b,1}} n_{F_{a,2}}$ for planetary masses should be preferred. The general prediction $GMm/v_0 = n_a/n_b$ is of course not testable.

2. Nottale [36] has suggested that also the harmonics and subharmonics of $\lambda$ are possible and in fact required by the model for planetary Bohr orbits (in TGD framework this is not absolutely necessary). The prediction is that favored values of $n$ should be of form $n_F = 2^k \prod F_i$ such that $F_i$ appears at most once. In Nottale's model for planetary orbits as Bohr orbits in solar system $n = 5$ harmonics appear and are consistent with either $n_{F,a} \to F_1 n_{F_a}$ or with $n_{F,b} \to n_{F_b}/F_1$ if possible.

The prediction for the ratios of planetary masses can be tested. In the table below are the experimental mass ratios $r_{exp} = m(pl)/m(E)$, the best choice of $r_R = [n_{F,a}/n_{F,b}] * X$, $X$ common factor for all planets, and the ratios $r_{pred}/r_{exp} = n_{F,a}(planet) n_{F,b}(Earth)/n_{F,a}(Earth) n_{F,b}(planet)$. The deviations are at most 2 per cent.

| *planet* | $Me$ | $V$ | $E$ | $M$ | $J$ |
|---|---|---|---|---|---|
| $y$ | $\frac{2^{13}\times 5}{17}$ | $2^{11} \times 17$ | $2^9 \times 5 \times 17$ | $2^8 \times 17$ | $\frac{2^{23}\times 5}{7}$ |
| $y/x$ | 1.01 | .98 | 1.00 | .98 | 1.01 |
| *planet* | $S$ | $U$ | $N$ | $P$ | |
| $y$ | $2^{14} \times 3 \times 5 \times 17$ | $\frac{2^{21}\times 5}{17}$ | $\frac{2^{17}\times 17}{3}$ | $\frac{2^4\times 17}{3}$ | |
| $y/x$ | 1.01 | .98 | .99 | .99 | |

Table 1. The table compares the ratios $x = m(pl)/(m(E)$ of planetary mass to the mass of Earth to prediction for these ratios in terms of integers $n_F$ associated with Fermat polygons. $y$ gives the best fit for the allowed factors of the known part $y$ of the rational $n_{F,a}/n_{F,b} = yX$ characterizing planet, and the ratios $y/x$. Errors are at most 2 per cent.

A stronger prediction comes from the requirement that $GMm/v_0$ equals to $n = n_{F_a}/n_{F,b}$ $n_F = 2^k \prod_k F_{n_k}$, where $F_i = 2^{2^i} + 1$, $i = 0, 1, 2, 3, 4$ is Fibonacci prime. The fit using solar mass and Earth mass gives $n_F = 2^{254} \times 5 \times 17$ for $1/v_0 = 2044$, which within the experimental accuracy equals to the value $2^{11} = 2048$ whose powers appear as scaling factors of Planck constant in the

model for living matter [M3]. For $v_0 = 4.6 \times 10^{-4}$ reported by Nottale the prediction is by a factor 16/17.01 too small (6 per cent discrepancy).

A possible solution of the discrepancy is that the empirical estimate for the factor $GMm/v_0$ is too large since $m$ contains also the the visible mass not actually contributing to the gravitational force between dark matter objects whereas $M$ is known correctly. The assumption that the dark mass is a fraction $1/(1+\epsilon)$ of the total mass for Earth gives

$$1 + \epsilon = \frac{17}{16} \tag{48}$$

in an excellent approximation. This gives for the fraction of the visible matter the estimate $\epsilon = 1/16 \simeq 6$ per cent. The estimate for the fraction of visible matter in cosmos is about 4 per cent so that estimate is reasonable and would mean that most of planetary and solar mass would be also dark (as a matter dark energy would be in question).

That $v_0(eff) = v_0/(1-\epsilon) \simeq 4.6 \times 10^{-4}$ equals with $v_0(eff) = 1/(2^7 \times F_2) = 4.5956 \times 10^{-4}$ within the experimental accuracy suggests a number theoretical explanation for the visible-to-dark fraction.

*3. Can one really identify gravitational and inertial Planck constants?*

The original unconsciously performed identification of the gravitational and inertial Planck constants leads to some confusing conclusions but it seems that the new view about the quantization of Planck constants resolves these problems and allows to see $\hbar_{gr}$ as a special case of $\hbar_I$.

1. $\hbar_{gr}$ is proportional to the product of masses of interacting systems and not a universal constant like $\hbar$. One can however express the gravitational Bohr conditions as a quantization of circulation $\oint v \cdot dl = n(GM/v_0)\hbar_0$ so that the dependence on the planet mass disappears as required by Equivalence Principle. This suggests that gravitational Bohr rules relate to velocity rather than inertial momentum as is indeed natural. The quantization of circulation is consistent with the basic prediction that space-time surfaces are analogous to Bohr orbits.

2. $\hbar_{gr}$ seems to characterize a relationship between planet and central mass and quite generally between two systems with the property that smaller system is topologically condensed at the space-time sheet of the larger system. Thus it would seem that $\hbar_{gr}$ is not a universal constant and cannot correspond to a special value of ordinary Planck constant. Certainly this would be the case if $\hbar_I$ is quantized as $\lambda^k$-multiplet of ordinary Planck constant with $\lambda \simeq 2^{11}$.

The recent view about the quantization of Planck constant in terms of coverings of $M^4$ seems to resolve these problems.

1. The integer quantization of Planck constants is consistent with the huge values of gravitational Planck constant within experimental resolution and the killer test for $\hbar = \hbar_{gr}$ emerges if one takes seriously the stronger prediction $\hbar_{gr} = n_{F,a}/n_{F,b}$.

2. One can also regard $\hbar_{gr}$ as ordinary Planck constant $\hbar_{eff}$ associated with the space-time sheet along which the masses interact provided each pair $(M, m_i)$ of masses is characterized by its own sheets. These sheets could correspond to flux tube like structures carrying the gravitational flux of dark matter. If these sheets corresponds to $n_{F_a}$-fold covering of $M^4$, one can understand $\hbar_{gr}$ as a particular instance of the $\hbar_{eff}$.

### 6.7.4 Gravitational Schrödinger equation as a means of avoiding gravitational collapse

Schrödinger equation provided a solution to the infrared catastrophe of the classical model of atom: the classical prediction was that electron would radiate its energy as brehmstrahlung and would be captured by the nucleus. The gravitational variant of this process would be the capture of the planet by a black hole, and more generally, a collapse of the star to a black hole. Gravitational Schrödinger equation could obviously prevent the catastrophe.

For $1/r$ gravitation potential the Bohr radius is given by $a_{gr} = GM/v_0^2 = r_S/2v_0^2$, where $r_S = 2GM$ is the Schwartchild radius of the mass creating the gravitational potential: obviously Bohr radius is much larger than the Schwartschild radius. That the gravitational Bohr radius does not depend on $m$ conforms with Equivalence Principle, and the proportionality $\hbar_{gr} \propto Mm$ can be deduced from it. Gravitational Bohr radius is by a factor $1/2v_0^2$ larger than black hole radius so that black hole can swallow the piece of matter with a considerable rate only if it is in the ground state and also in this state the rate is proportional to the black hole volume to the volume defined by the black hole radius given by $2^3 v_0^6 \sim 10^{-20}$.

The $\hbar_{gr} \to \infty$ limit for $1/r$ gravitational potential means that the exponential factor $exp(-r/a_0)$ of the wave function becomes constant: on the other hand, also Schwartshild and Bohr radii become infinite at this limit. The gravitational Compton length associated with mass $m$ does not depend on $m$ and is given by $GM/v_0$ and the time $T = E_{gr}/\hbar_{gr}$ defined by the gravitational binding energy is twice the time taken to travel a distance defined by the radius of the orbit with velocity $v_0$ which suggests that signals travelling with a maximal velocity $v_0$ are involved with the quantum dynamics.

In the case of planetary system the proportionality $\hbar_{gr} \propto mM$ creates problems of principle since the influence of the other planets is not taken account. One might argue that the generalization of the formula should be such that $M$ is determined by the gravitational field experienced by mass $m$ and thus contains also the effect of other planets. The problem is that this field depends on the position of $m$ which would mean that $\hbar_{gr}$ itself would become kind of field quantity.

### 6.7.5 Does the transition to non-perturbative phase correspond to a change in the value of $\hbar$?

Nature is populated by systems for which perturbative quantum theory does not work. Examples are atoms with $Z_1 Z_2 e^2/4\pi\hbar > 1$ for which the binding energy becomes larger than rest mass, non-perturbative QCD resulting for $Q_{s,1}Q_{s,2}g_s^2/4\pi\hbar > 1$, and gravitational systems satisfying $GM_1M_2/4\pi\hbar > 1$. Quite generally, the condition guaranteing troubles is of the form $Q_1Q_2g^2/4\pi\hbar > 1$. There is no general mathematical approach for solving the quantum physics of these systems but it is believed that a phase transition to a new phase of some kind occurs.

The gravitational Schrödinger equation forces to ask whether Nature herself takes care of the problem so that this phase transition would involve a change of the value of the Planck constant to guarantee that the perturbative approach works. The values of $\hbar$ would vary in a stepwise manner from $\hbar(\infty)$ to $\hbar(3) = \hbar(\infty)/4$. The non-perturbative phase transition would correspond to transition to the value of

$$\frac{\hbar}{\hbar_0} \quad \to \quad \left[\frac{Q_1Q_2g^2}{v}\right] \tag{49}$$

where $[x]$ is the integer nearest to $x$, inducing

$$\frac{Q_1Q_2g^2}{4\pi\hbar} \to \frac{v}{4\pi} \quad . \tag{50}$$

The simplest (and of course ad hoc) assumption making sense in TGD Universe is that $v$ is a harmonic or subharmonic of $v_0$ appearing in the gravitational Schrödinger equation. For instance, for the Kepler problem the spectrum of binding energies would be universal (independent of the values of charges) and given by $E_n = v^2 m/2n^2$ with $v$ playing the role of small coupling. Bohr radius would be $g^2 Q_2/v^2$ for $Q_2 \gg Q_1$.

This provides a new insight to the problems encountered in quantizing gravity. QED started from the model of atom solving the infrared catastrophe. In quantum gravity theories one has started directly from the quantum field theory level and the recent decline of the M-theory shows that we are still practically where we started. If the gravitational Schrödinger equation indeed allows quantum interpretation, one could be more modest and start from the solution of the gravitational IR catastrophe by assuming a dynamical spectrum of $\hbar$ determined by Beraha numbers. The implications would be profound: the whole program of quantum gravity would have been misled as far as the quantization of systems with $GM_1M_2/\hbar > 1$ is considered. In practice, these systems are the most interesting ones and the prejudice that their quantization is a mere academic exercise would have been completely wrong.

An alternative formulation for the occurrence of a transition increasing the value of $\hbar$ could rely on the requirement that classical bound states have reasonable quantum counterparts. In the gravitational case one would have $r_n = n^2\hbar_{gr}^2/GM_1^2M$, for $M_1 \ll M$, which is extremely small distance for $\hbar_{gr} = \hbar$ and reasonable values of $n$. Hence, either $n$ is so large that the system is classical or $\hbar_{gr}/\hbar$ is very large. Equivalence Principle requires the independence of $r_n$ on $M_1$, which gives $\hbar = kGM_1M_2$ giving $r_n = n^2 kGM$. The requirement that the radius is above Schwartshild radius gives $k \geq 2$. In the case of Dirac equation the solutions cease to exist for $Z \geq 137$ and which suggests that $\hbar$ is large for hypothetical atoms having $Z \geq 137$.

## 6.8 How do the magnetic flux tube structures and quantum gravitational bound states relate?

In the case of stars in galactic halo the appearance of the parameter $v_0$ characterizing cosmic strings as orbital rotation velocity can be understood classically. That $v_0$ appears also in the gravitational dynamics of planetary orbits could relate to the dark matter at magnetic flux tubes. The argument explaining the harmonics and sub-harmonics of $v_0$ in terms of properties of cosmic strings and magnetic flux tubes identifiable as their descendants strengthens this expectation.

### 6.8.1 The notion of magnetic body

In TGD inspired theory of consciousness the notion of magnetic body plays a key role: magnetic body is the ultimate intentional agent, experiencer, and performer of bio-control and can have astrophysical size: this does not sound so counter-intuitive if one takes seriously the idea that cognition has p-adic space-time sheets as space-time correlates and that rational points are common to real and p-adic number fields. The point is that infinitesimal in p-adic topology corresponds to infinite in real sense so that cognitive and intentional structures would have literally infinite size.

The magnetic flux tubes carrying various supra phases can be interpreted as special instance of dark energy and dark matter. This suggests a correlation between gravitational self-organization and quantum phases at the magnetic flux tubes and that the gravitational Schrödinger equation somehow relates to the ordinary Schrödinger equation satisfied by the macroscopic quantum phases at magnetic flux tubes. Interestingly, the transition to large Planck constant phase should occur when the masses of interacting is above Planck mass since gravitational self-interaction energy is $V \sim GM^2/R$. For the density of water about $10^3$ kg/m$^3$ the volume carrying a Planck mass correspond to a cube with side $2.8 \times 10^{-4}$ meters. This corresponds to a volume of a large neuron, which suggests that this phase transition might play an important role in neuronal dynamics.

### 6.8.2 Could gravitational Schrödinger equation relate to a quantum control at magnetic flux tubes?

An infinite self hierarchy is the basic prediction of TGD inspired theory of consciousness ("everything is conscious and consciousness can be only lost"). Topological quantization allows to assign to any material system a field body as the topologically quantized field pattern created by the system [L4, K1]. This field body can have an astrophysical size and would utilize the material body as a sensory receptor and motor instrument.

Magnetic flux tube and flux wall structures are natural candidates for the field bodies. Various empirical inputs have led to the hypothesis that the magnetic flux tube structures define a hierarchy of magnetic bodies, and that even Earth and larger astrophysical systems possess magnetic body which makes them conscious self-organizing living systems. In particular, life at Earth would have developed first as a self-organization of the super-conducting dark matter at magnetic flux tubes [L4].

For instance, EEG frequencies corresponds to wavelengths of order Earth size scale and the strange findings of Libet about time delays of conscious experience [68, 69] find an elegant explanation in terms of time taken for signals propagate from brain to the magnetic body [K1]. Cyclotron frequencies, various cavity frequencies, and the frequencies associated with various p-adic frequency scales are in a key role in the model of bio-control performed by the magnetic body. The cyclotron frequency scale is given by $f = eB/m$ and rather low as are also cavity frequencies such as Schumann frequencies: the lowest Schumann frequency is in a good approximation given by $f = 1/2\pi R$ for Earth and equals to 7.8 Hz.

*1. Quantum time scales as "bio-rhythms" in solar system?*

To get some idea about the possible connection of the quantum control possibly performed by the dark matter with gravitational Schrödinger equation, it is useful to look for the values of the periods defined by the gravitational binding energies of test particles in the fields of Sun and Earth and look whether they correspond to some natural time scales. For instance, the period $T = 2GM_S n^2/v_0^3$ defined by the energy of $n^{th}$ planetary orbit depends only on the mass of Sun and defines thus an ideal candidate for a universal "bio-rhytm".

For Sun black hole radius is about 2.9 km. The period defined by the binding energy of lowest state in the gravitational field of Sun is given $T_S = 2GM_S/v_0^3$ and equals to 23.979 hours for $v_0/c = 4.8233 \times 10^{-4}$. Within experimental limits for $v_0/c$ the prediction is consistent with 24 hours! The value of $v_0$ corresponding to exactly 24 hours would be $v_0 = 144.6578$ km/s (as a matter fact, the rotational period of Earth is 23.9345 hours). As if as the frequency defined by the lowest energy state would define a "biological" clock at Earth! Mars is now a strong candidate for a seat of life and the day in Mars lasts 24hr 37m 23s! $n = 1$ and $n = 2$ are orbitals are not realized in solar system as planets but there is evidence for the $n = 1$ orbital as being realized as a peak in the density of IR-dust [36]. One can of course consider the possibility that these levels are populated by small dark matter planets with matter at larger space-time sheets. Bet as it may, the result supports the notion of quantum gravitational entrainment in the solar system.

The slower rhythms would become as $n^2$ sub-harmonics of this time scale. Earth itself corresponds to $n = 5$ state and to a rhythm of .96 hours: perhaps the choice of 1 hour to serve as a fundamental time unit is not merely accidental. The magnetic field with a typical ionic cyclotron frequency around 24 hours would be very weak: for 10 Hz cyclotron frequency in Earth's magnetic field the field strength would about $10^{-11}$ T. However, $T = 24$ hours corresponds with 6 per cent accuracy to the p-adic time scale $T(k = 280) = 2^{13}T(2, 127)$, where $T(2, 127)$ corresponds to the secondary p-adic time scale of .1 s associated with the Mersenne prime $M_{127} = 2^{127} - 1$ characterizing electron and defining a fundamental bio-rhytm and the duration of memetic codon [11].

Comorosan effect [66, 67, J5] demonstrates rather peculiar looking facts about the interaction

of organic molecules with visible laser light at wavelength $\lambda = 546\ nm$. As a result of irradiation molecules seem to undergo a transition $S \to S^*$. $S^*$ state has anomalously long lifetime and stability in solution. $S \to S^*$ transition has been detected through the interaction of $S^*$ molecules with different biological macromolecules, like enzymes and cellular receptors. Later Comorosan found that the effect occurs also in non-living matter. The basic time scale is $\tau = 5$ seconds. p-Adic length scale hypothesis does not explain $\tau$, and it does not correspond to any obvious astrophysical time scale and has remained a mystery.

The idea about astro-quantal dark matter as a fundamental bio-controller inspires the guess that $\tau$ could correspond to some Bohr radius $R$ for a solar system via the correspondence $\tau = R/c$. As observed by Nottale, $n = 1$ orbit for $v_0 \to 3v_0$ corresponds in a good approximation to the solar radius and to $\tau = 2.18$ seconds. For $v_0 \to 2v_0$ $n = 1$ orbit corresponds to $\tau = AU/(4 \times 25) = 4.992$ seconds: here $R = AU$ is the astronomical unit equal to the average distance of Earth from Sun. The deviation from $\tau_C$ is only one per cent and of the same order of magnitude as the variation of the radius for the orbit due to orbital eccentricity $(a - b)/a = .0167$ [39].

*2. Earth-Moon system*

For Earth serving as the central mass the Bohr radius is about 18.7 km, much smaller than Earth radius so that Moon would correspond to $n = 147.47$ for $v_0$ and $n = 1.02$ for the sub-harmonic $v_0/12$ of $v_0$. For an afficionado of cosmic jokes or a numerologist the presence of the number of months in this formula might be of some interest. Those knowing that the Mayan calendar had 11 months and that Moon is receding from Earth might rush to check whether a transition from $v/11$ to $v/12$ state has occurred after the Mayan culture ceased to exist: the increase of the orbital radius by about 3 per cent would be required! Returning to a more serious mode, an interesting question is whether light satellites of Earth consisting of dark matter at larger space-time sheets could be present. For instance, in [L4] I have discussed the possibility that the larger space-time sheets of Earth could carry some kind of intelligent life crucial for the bio-control in the Earth's length scale.

The period corresponding to the lowest energy state is from the ratio of the masses of Earth and Sun given by $M_E/M_S = (5.974/1.989) \times 10^{-6}$ given by $T_E = (M_E/M_S) \times T_S = .2595$ s. The corresponding frequency $f_E = 3.8535$ Hz frequency is at the lower end of the theta band in EEG and is by 10 per cent higher than the p-adic frequency $f(251) = 3.5355$ Hz associated with the p-adic prime $p \simeq 2^k$, $k = 251$. The corresponding wavelength is 2.02 times Earth's circumference. Note that the cyclotron frequencies of Nn, Fe, Co, Ni, and Cu are $5.5, 5.0, 5.2, 4.8$ Hz in the magnetic field of $.5 \times 10^{-4}$ Tesla, which is the nominal value of the Earth's magnetic field. In [M4] I have proposed that the cyclotron frequencies of Fe and Co could define biological rhythms important for brain functioning. For $v_0/12$ associated with Moon orbit the period would be 7.47 s: I do not know whether this corresponds to some bio-rhytm.

It is better to leave for the reader to decide whether these findings support the idea that the super conducting cold dark matter at the magnetic flux tubes could perform bio-control and whether the gravitational quantum states and ordinary quantum states associated with the magnetic flux tubes couple to each other and are synchronized.

## 6.9 p-Adic length scale hypothesis and $v_0 \to v_0/5$ transition at inner-outer border for planetary system

$v_0 \to v_0/5$ transition would allow to interpret the orbits of outer planets as $n \geq 1$ orbits. The obvious question is whether inner to outer zone as $v_0 \to v_0/5$ transition could be interpreted in terms of the p-adic length scale hierarchy.

1. The most important p-adic length scale are given by primary p-adic length scales $L(k) = 2^{(k-151)/2} \times 10$ nm and secondary p-adic length scales $L(2, k) = 2^{k-151} \times 10$ nm, $k$ prime.

2. The p-adic scale $L(2,139) = 114$ Mkm is slightly above the orbital radius 109.4 Mkm of Venus. The p-adic length scale $L(2,137) \simeq 28.5$ Mkm is roughly one half of Mercury's orbital radius 57.9 Mkm. Thus strong form of p-adic length scale hypothesis could explain why the transition $v_0 \to v_0/5$ occurs in the region between Venus and Earth ($n = 5$ orbit for $v_0$ layer and $n = 1$ orbit for $v_0/5$ layer).

3. Interestingly, the *primary* p-adic length scales $L(137)$ and $L(139)$ correspond to fundamental atomic length scales which suggests that solar system be seen as a fractally scaled up "secondary" version of atomic system.

4. Planetary radii have been fitted also using Titius-Bode law predicting $r(n) = r_0 + r_1 \times 2^n$. Hence on can ask whether planets are in one-one correspondence with primary and secondary p-adic length scales $L(k)$. For the orbital radii $58, 110, 150, 228$ Mkm of Mercury, Venus, Earth, and Mars indeed correspond approximately to k= $276, 278, 279, 281$: note the special position of Earth with respect to its predecessor. For Jupiter, Saturn, Uranus, Neptune, and Pluto the radii are 52,95,191,301,395 Mkm and would correspond to p-adic length scales $L(280 + 2n))$, $n = 0, ..., 3$. Obviously the transition $v_0 \to v_0/5$ could occur in order to make the planet–p-adic length scale one-one correspondence possible.

5. It is interesting to look whether the p-adic length scale hierarchy applies also to the solar structure. In a good approximation solar radius .696 Mkm corresponds to $L(270)$, the lower radius .496 Mkm of the convective zone corresponds to $L(269)$, and the lower radius .174 Mkm of the radiative zone (radius of the solar core) corresponds to $L(266)$. This encourages the hypothesis that solar core has an onion like sub-structure corresponding to various p-adic length scales. In particular, $L(2,127)$ ($L(127)$ corresponds to electron) would correspond to 28 Mm. The core is believed to contain a structure with radius of about 10 km: this would correspond to $L(231)$. This picture would suggest universality of star structure in the sense that stars would differ basically by the number of the onion like shells having standard sizes.

Quite generally, in TGD Universe the formation of join along boundaries bonds is the space-time correlate for the formation of bound states. This encourages to think that ($Z^0$) magnetic flux tubes are involved with the formation of gravitational bound states and that for $v_0 \to v_0/k$ corresponds either to a splitting of a flux tube resembling a disk with a whole to $k$ pieces, or to the scaling down $B \to B/k^2$ so that the magnetic energy for the flux tube thickened and stretched by the same factor $k^2$ would not change.

## 6.10 About the interpretation of the parameter $v_0$

The formula for the gravitational Planck constant contains the parameter $v_0/c = 2^{-11}$. This velocity defines the rotation velocities of distant stars around galaxies. The presence of a parameter with dimensions of velocity should carry some important information about the geometry of dark matter space-time sheets.

Velocity like parameters appear also in other contexts. There is evidence for the Tifft's quantization of cosmic redshifts in multiples of $v_0/c = 2.68 \times 10^{-5}/3$: also other units of quantization have been proposed but they are multiples of $v_0$ [64].

The strange behavior of graphene includes high conductivity with conduction electrons behaving like massless particles with light velocity replaced with $v_0/c = 1/300$. The TGD inspired model [J1] explains the high conductivity as being due to the Planck constant $\hbar(M^4) = 6\hbar_0$ increasing the delocalization length scale of electron pairs associated with hexagonal rings of mono-atomic graphene layer by a factor 6 and thus making possible overlap of electron orbitals. This explains also the anomalous conductivity of DNA containing 5- and 6-cycles [J1].

### 6.10.1 Is dark matter warped?

The reduced light velocity could be due to the warping of the space-time sheet associated with dark electrons. TGD predicts besides gravitational red-shift a non-gravitational red-shift due to the warping of space-time sheets possible because space-time is 4-surface rather than abstract 4-manifold. A simple example of everyday life is the warping of a paper sheet: it bends but is not stretched, which means that the induced metric remains flat although one of its component scales (distance becomes longer along direction of bending). For instance, empty Minkowski space represented canonically as a surface of $M^4 \times CP_2$ with constant $CP_2$ coordinates can become periodically warped in time direction because of the bending in $CP_2$ direction. As a consequence, the distance in time direction shortens and effective light-velocity decreases when determined from the comparison of the time taken for signal to propagate from A to B along warped space-time sheet with propagation time along a non-warped space-time sheet.

The simplest warped imbedding defined by the map $M^4 \to S^1$, $S^1$ a geodesic circle of $CP_2$. Let the angle coordinate of $S^1$ depend linearly on time: $\Phi = \omega t$. $g_{tt}$ component of metric becomes $1 - R^2\omega^2$ so that the light velocity is reduced to $v_0/c = \sqrt{1 - R^2\omega^2}$. No gravitational field is present.

The fact that $M^4$ Planck constant $n_a\hbar_0$ defines the scaling factor $n_a^2$ of $CP_2$ metric could explain why dark matter resides around strongly warped imbeddings of $M^4$. The quantization of the scaling factor of $CP_2$ by $R^2 \to n_a^2 R^2$ implies that the initial small warping in the time direction given by $g_{tt} = 1-\epsilon$, $\epsilon = R^2\omega^2$, will be amplified to $g_{tt} = 1-n_a^2\epsilon$ if $\omega$ is not affected in the transition to dark matter phase. $n_a = 6$ in the case of graphene would give $1 - x \simeq 1 - 1/36$ so that only a one per cent reduction of light velocity is enough to explain the strong reduction of light velocity for dark matter.

### 6.10.2 Is $c/v_0$ quantized in terms of ruler and compass rationals?

The known cases suggests that $c/v_0$ is always a rational number expressible as a ratio of integers associated with n-polygons constructible using only ruler and compass.

1. $c/v_0 = 300$ would explain graphene. The nearest rational satisfying the ruler and compass constraint would be $q = 5 \times 2^{10}/17 \simeq 301.18$.

2. If dark matter space-time sheets are warped with $c_0/v = 2^{11}$ one can understand Nottale's quantization for the radii of the inner planets. For dark matter space-time sheets associated with outer planets one would have $c/v_0 = 5 \times 2^{11}$.

3. If Tifft's red-shifts relate to the warping of dark matter space-time sheets, warping would correspond to $v_0/c = 2.68 \times 10^{-5}/3$. $c/v_0 = 2^5 \times 17 \times 257/5$ holds true with an error smaller than .1 per cent.

### 6.10.3 Tifft's quantization and cosmic quantum coherence

An explanation for Tifft's quantization in terms of Jones inclusions could be that the subgroup $G$ of Lorentz group defining the inclusion consists of boosts defined by multiples $\eta = n\eta_0$ of the hyperbolic angle $\eta_0 \simeq v_0/c$. This would give $v/c = sinh(n\eta_0) \simeq nv_0/c$. Thus the dark matter systems around which visible matter is condensed would be exact copies of each other in cosmic length scales since $G$ would be an exact symmetry. The property of being an exact copy applies of course only in single level in the dark matter hierarchy. This would mean a delocalization of elementary particles in cosmological length scales made possible by the huge values of Planck constant. A precise cosmic analog for the delocalization of electron pairs in benzene ring would be in question.

Why then $\eta_0$ should be quantized as ruler and compass rationals? In the case of Planck constants the quantum phases $q = exp(im\pi/n_F)$ are number theoretically simple for $n_F$ a ruler and compass integer. If the boost $exp(\eta)$ is represented as a unitary phase $exp(im\eta)$ at the level of discretely delocalized dark matter wave functions, the quantization $\eta_0 = n/n_F$ would give rise to number theoretically simple phases. Note that this quantization is more general than $\eta_0 = n_{F,1}/n_{F,2}$.

## 6.11 Further evidence for dark matter

The notion of many-sheeted space-time has been continually receiving qualitative support from various anomalies. In the following two latest anomalies are summarized briefly.

### 6.11.1 First dark matter galaxy found

The propose model for dark matter suggests an existence of dark matter planets and even dark matter galaxies. Therefore the news about finding of the first dark galaxy in New Scientist [47] came as a pleasant surprise. The galaxy is located at a distance of $10^7$ light years. It contains 1 per cent hydrogen gas and and 99 per cent dark matter and is identified by 21 cm hydrogen line: hence the name VIRGOH21. The amount of dark matter counts as $10^8$ average stars.

### 6.11.2 Anomalous chemical compositions at the surface of Sun as evidence for dark matter

Physics in Action, February 2005 contained the popular article "Chemical Controversy at the Solar Surface" by J. Bahcall in Physics in Action [48]. The article describes the problems created by results reported in the article "The Solar Chemical Decomposition" by M. Asplund, N. Grevesse, J. Sauval [49]. The abundances of C, N, O, Ne, Ar at the solar surface are about 30-40 per cent less than predicted by the standard solar model. If these abundances are feeded into the standard solar model as input the predictions change in the range $.45R - .73R$ of distances from solar interior ($R$ is solar radius). In particular, sound velocity is predicted incorrectly. Interestingly, these abundances are consistent with the abundances in the gaseous medium in the neighborhood of our galaxy.

In TGD framework a possible solution of paradox comes from already old model of solar corona and solar magnetic field. Part of matter resides as dark matter at magnetic and $Z^0$ magnetic flux tubes of Sun (dark energy) and enters to the solar corona along these. That also gaseous medium in the neighborhood of our galaxy contains same abundances suggests that the formation of Sun has proceeded by a transformation of part of dark matter to a visible matter by leakage to space-time sheets visible to us. This is indeed what TGD inspired model for the formation of solar system based on quantal dark matter suggests.

### 6.11.3 Does Sun have a solid surface?

$n = 1$ Bohr orbit corresponds in a reasonable approximation to $L(276)/9 \simeq L(270)$ and thus to solar radius. This raises the question whether solar surface could contain spherical shell representing a topological condensate of dense matter around dark matter, kind of spherical preform of planet below the photosphere.

Recently new satellites have begun to provide information about what lurks beneath the photosphere. The pictures produced by Lockheed Martin's Trace Satellite and YOHKOH, TRACE and SOHO satellite programs are publicly available in the web. SERTS program for the spectral analysis suggest a new picture challenging the simple gas sphere picture [56]. The visual inspection of the pictures combined with spectral analysis has led Michael Moshina to suggests that Sun has a solid, conductive spherical surface layer consisting of calcium ferrite. The article of Moshina [56]

provides impressive pictures, which in my humble non-specialist opinion support this view. Of course, I have not worked personally with the analysis of these pictures so that I do not have the competence to decide how compelling the conclusions of Moshina are. In any case, I think that his web article [56] deserves a summary.

Before SERTS people were familiar with hydrogen, helium, and calcium emissions from Sun. The careful analysis of SERTS spectrum however suggest the presence of a layer or layers containing ferrite and other heavy metals. Besides ferrite SERTS found silicon, magnesium, manganese, chromium, aluminum, and neon in solar emissions. Also elevated levels of sulphur and nickel were observed during more active cycles of Sun. In the gas sphere model these elements are expected to be present only in minor amounts. As many as 57 different types of emissions from 10 different kinds of elements had to be considered to construct a picture about the surface of the Sun.

Moshina has visually analyzed the pictures constructed from the surface of Sun using light at wave lengths corresponding to three lines of ferrite ions (171, 195, 284 Angstroms). On basis of his analysis he concludes that the spectrum originates from rigid and fixed surface structures, which can survive for days. A further analysis shows that these rigid structures rotate uniformly.

The existence of a rigid structure idealizable as spherical shell in the first approximation could by previous observation be interpreted as a spherical shell corresponding to $n = 1$ Bohr orbit of a planet not yet formed. This structure would already contain the germs of iron core and of crust containing Silicon, Ca and and other elements.

There is also another similar piece of evidence [58]. A new planet has been discovered orbiting around a star in a triple-star system in the constellation Cygnus. The planet is a so-called hot Jupiter but it orbits the parent star at distance of .05 AU, which much less that than allowed by current theories of planetary formation. Indeed, the so called migration theory predicts that the gravitational pull of the two stars should have stripped away the proto-planetary disk from the parent star. If an underlying dark matter structure serves as a condensation template for the visible matter, the planetary orbit is stabilized by Bohr quantization.

There is however a problem: ordinary iron and also ordinary iron topologically condensed at dark space-time sheets, becomes liquid at temperature 1811 K at atmospheric pressure. Using for the photospheric pressure $p_{ph}$, the ideal gas approximation $p_{ph} = n_{ph}T_{ph}$, the values of photospheric temperature $T_{ph} \sim 5800$ K and density $\rho_{ph} \sim 10^{-2}\rho_{atm}$, and idealizing photosphere as a plasma of hydrogen ions and atmosphere as a gas of $O_2$ molecules, one obtains $n_{ph} \sim .32n_{atm}$ giving $p_{ph} \sim 6.4p_{atm}$. This suggests that calcium ferrite cannot be solid at temperatures of order 5800 K prevailing in the photosphere (the material with highest known melting temperature is graphite with melting temperature of 3984 K at atmospheric pressure). Thus it would seem that dark calcium ferrite at the surface of the Sun cannot be just ordinary calcium ferrite at dark space-time sheets.

The following explanation for the solid surface is perhaps the simplest one found hitherto. Since the atomic energy spectrum is unaffected it seems that $n_a = n_b = 1$ holds true and the radii of Bohr orbitals are scaled up by the factor $n_a^2/n_b = n_a$. If the density of dark matter is roughly the same as that of ordinary matter, the larger size of atoms suggests that melting temperature must be higher than for ordinary matter. Ordinary photons would result via dark-visible phase transition from dark photons emitted by these atoms. Quite generally, spectral lines of molecules in environments in which they should not be thermally stable, would serve as a signature of dark matter with $n_a/n_b = 1$.

### 6.11.4 How to create dark matter in laboratory...

The creation of dark matter at laboratory is of course the crucial test. The hints for what to do come already from the findings of Tesla, which did not fit completely with Maxwell's electrodynamics (, which, using M-theory inspired jargon, had become "the only known classical theory of electromagnetism",) and were thus forgotten.

To transform visible matter to dark matter in laboratory one might try to generate conditions in which visible matter leaks to larger space-time sheets. What one could try is to generate pulsed current of electrons. For instance, current could flow to a circuit component acting as a charge reservoir. When the circuit is opened, and current cannot leave the charge reservoir, a situation analogous to a traffic jam occurs and some electrons might leak to larger space-time sheets via join along boundaries bonds generated in the process. Di-electric breakdown along larger space-time sheet would be in question. Recoil effects and zero point kinetic energy liberated as ionizing radiation would serve as a signature of the process. The production of dark matter might occur also in the usual di-electric breakdown and lead to the appearance of electrons in much larger volume after it partially re-enters original space-time sheets. The change of zero point kinetic energy would be liberated as radiation and would cause formation of plasma. Tesla detected dramatic effects of this kind in experiments utilizing sharp pulses.

### 6.11.5 ..or has it already been done?

In their article "Investigation of high voltage discharges in low pressure gases through large ceramic super-conducting electrodes", Modanese and Podkletnov [50] report a fascinating discovery suggesting that some new form of radiation is generated in the di-electric breakdown of a capacitor at low temperature and having super-conductor as a second electrode. This radiation induces oscillatory motion of test penduli but, and this is very strange, its intensity is not reduced with distance.

The TGD based explanation [G3] would be in terms of either "topological light rays" or what I call in honor of Tesla "scalar wave pulses" (much like a capacitor moving with velocity of light predicted by TGD but not allowed by Maxwell's ED). This radiation would induce the formation of join along boundaries bonds between atomic and larger space-time sheets and part of electrons from penduli would leak to larger space-time sheets and their motion would result as a recoil effect. The radiation would have only the role of control signal and this would explain why its intensity is not weakened.

From the point of view of single sheeted space-time an over-unity device would be in question since the zero point kinetic energy would be transformed to kinetic energy. The transformation of visible matter to dark matter is in TGD Universe the basic mechanism of metabolism predicting universality of metabolic energy currencies and living matter in TGD Universe has developed a refined machinery to recycle the dropped charges back to the atomic space-time sheets to be used again. Combined with time mirror mechanism this makes, not a perpetuum mobile, but an extremely flexible mechanism of metabolism.

## 6.12 Anti-matter and dark matter

The usual view about matter anti-matter asymmetry is that during early cosmology matter-antimatter asymmetry characterized by the relative density difference of order $r = 10^{-9}$ was somehow generated and that the observed matter corresponds to what remained in the annihilation of quarks and leptons to bosons. A possible mechanism inducing the CP asymmetry is based on the CP breaking phase of CKM matrix.

The TGD based view about energy [D3, D5] forces the conclusion that all conserved quantum numbers including the conserved inertial energy have vanishing densities in cosmological length scales. Therefore fermion numbers associated with matter and antimatter must compensate each other. Therefore the standard option as such is definitely excluded in TGD framework although CKM matrix might well relate to the generation of matter antimatter asymmetry as discussed in [F6].

An early TGD based scenario explains matter antimatter asymmetry by assuming that antimatter is in topological vapor phase. This requires that matter and antimatter have slightly

different topological evaporation rates with the relative difference of rates characterized by the parameter $r$. A more general scenario assumes that matter and antimatter reside at different space-time sheets.

The reader can easily guess the next step. The strict non-observability of antimatter finds an elegant explanation if matter and anti-matter are dark relative to each other. For instance, the masses of particles of antimatter could be scaled down so that antimatter could be practically everywhere without appreciably affecting the density of gravitational mass.

The matter antimatter asymmetry should be generated during cosmic evolution already before the formation of nucleons during the primordial synthesis of matter and antimatter. The number theoretical model for topological condensation based on formation of # contacts between space-time sheets of opposite time orientations (and thus opposite signs for energies) leads to a more detailed view about what might happen.

# contacts can be modelled as $CP_2$ type extremals which simultaneously topologically condense to the two space-time sheets with Minkowskian signature of induced metric. The resulting two causal horizons are carriers of elementary particle quantum numbers and are identifiable as partons. The # contacts with vanishing net quantum numbers could be generated spontaneously and the splitting of # contact would create positive particle and negative energy particle at the two space-time sheets involved. The requirement that the net quantum numbers of Universe vanish is consistent with this kind of pairing of positive and negative energy space-time sheets.

Number theoretical vision [E3, F6] leads to a vision in which elementary particles correspond to infinite primes, perhaps also integers, or even rationals which in turn can be mapped to finite rationals. To infinite primes, integers, and rationals is is possible to associate a finite rational $q = m/n$ by a homomorphism. $q$ defines an effective q-adic topology of space-time sheet consistent with p-adic topologies defined by the primes dividing $m$ and $n$ ($1/p$-adic topology is homeomorphic to p-adic topology).$m$ and $n$ are exchanged by super-symmetry and the primes dividing $m$ ($n$) correspond to space-time sheets with positive (negative) time orientation. The largest prime dividing $m$ ($n$) determines the mass scale of the space-time sheet in p-adic thermodynamics. Two space-time sheets characterized by rationals having common prime factors can be connected by a $\#_B$ contact and can interact by exchange of particles characterized by divisors of $m$ or $n$. Thus fundamental topological selection rules would be coded by the hierarchy of infinite primes.

A possible interpretation is that particle (in extremely general sense that even entire universe can be regarded as a particle) corresponds to a pair of positive and negative energy space-time sheets labelled by $m$ and $n$ characterizing the p-adic topologies consistent with $m-$ and $n$-adicities. This looks natural since Universe has necessary vanishing net quantum numbers. Unless one allows the non-uniqueness due to $m/n = mr/nr$, positive and negative energy space-time sheets can be connected only by # contacts so that positive and negative energy space-time sheets cannot interact via the formation of $\#_B$ contacts and would be therefore dark relative to each other. Negative energy antiparticles would also have different p-adic mass scales. If the rate for the creation of # contacts and their CP conjugates are slightly different, say due to the presence of electric components of gauge fields, matter antimatter asymmetry could be generated primordially.

# 7 Explanations of some astrophysical and cosmological anomalies

In the sequel some astrophysical and cosmological anomalies such as the apparent shrinking of solar system observed by Masreliez, Pioneer anomaly, Flyby anomaly and new anomalies in cosmic microwave background.

## 7.1 Apparent shrinking of solar system

### 7.1.1 The findings of Masreliez

There are two means of determining the positions of planets in the solar system [40, 41, 42, 44]. The first method is based on optical measurements and determines the position of planets with respect to the distant stars. Already thirty years ago [44] came the first indications that the planetary positions determined in this manner drift from their predicted values as if planets were in accelerated motion. The second method determines the relative positions of planets using radar ranging: this method does not reveal any such acceleration.

C. J. Masreliez [41] has proposed that this acceleration could be due to a gradual scaling of the planetary system so that the sizes $L$ of the planetary orbits are reduced by an over-all scale factor $L \to L/\lambda$, which implies the acceleration $\omega \to \lambda^{3/2}\omega$ in accordance with the Kepler's law $\omega \propto 1/L^{3/2}$. This scaling would exactly compensate the cosmological scaling $L \to (R(t)/R_0) \times L$ of the solar system size $L$, where $R(t)$ the curvature parameter of Robertson-Walker cosmology having the line element

$$ds^2 = dt^2 - R^2(t)\left(\frac{dr^2}{1+r^2} + r^2 d\Omega^2\right) \quad . \tag{51}$$

According to Masreliez, the model explains also some other anomalies in the solar system, such as angular momentum discrepancy between the lunar motion and the spin-down of the Earth [41]. The model also changes the rate for the estimated drift of the Moon away from the Earth so that the Moon could have very well formed together with Earth some five billion years ago.

Bohr quantization of planetary orbits predicts that orbital radii are constant in Minkowski coordinates. Hence solar system would not participate cosmic expansion and the radii of planets shrink in Robertson-Walker coordinates. This model is definitely the simplest one.

### 7.1.2 The basic coordinate systems

Consider now the previous argument in more detail. The first task is to identify the coordinates appearing in the equations of motion of the planetary system. Denote the standard spherical Minkowski coordinates by $(m^0, r_M, \theta, \phi)$. The line element reads as

$$ds^2 = d(m^0)^2 - dr_M^2 - r_M^2 d\Omega^2 \quad . \tag{52}$$

Light cone coordinates are related to these coordinates by the relationship

$$a = \sqrt{m_0^2 - r_M^2} \quad , \quad r = r_M/a \quad . \tag{53}$$

Here $a$ is the light cone proper time along radii from the tip of the light cone $a = constant$ surfaces are hyperboloids. The line element is given

$$ds^2 = da^2 - a^2\left(\frac{dr^2}{1+r^2} + r^2 d\Omega^2\right) \tag{54}$$

and is nothing but the empty space Minkowski metric.

The Robertson-Walker metric for the space-time sheet reads as

$$ds^2 = g_{aa}da^2 - a^2\left(\frac{dr^2}{1+r^2} + r^2 d\Omega^2\right) \quad . \tag{55}$$

The space-time sheet possessing this metric as induced metric is obtained as a map $M^4_+ \to CP_2$ having the form $s^k = s^k(a)$, where $s^k$ denote $CP_2$ coordinates satisfying the constraint

$$g_{aa} = 1 - s_{kl}\partial_a s^k \partial_a s^l \quad , \tag{56}$$

where $s_{kl}$ denotes the metric tensor of $CP_2$.

One can introduce cosmic time as proper time coordinate $t$, or Hubble time as it is called, by the equation

$$\frac{dt}{da} = \sqrt{g_{aa}} \quad . \tag{57}$$

For the matter-dominated cosmology one as

$$\frac{t}{t_0} = (\frac{a}{a_0})^{3/2} \quad . \tag{58}$$

$t \simeq 1.5 \times 10^{10}$ ly is the value which explains the planetary acceleration in the model of Masreliez.

The basic question concerns the connection between cosmic coordinates and the radial and time coordinates $(r_{PN}, t_{PN})$ used in Post-Newtonian approximation. The correspondence $(t = t_{PN}, r = r_{PN})$ is the natural first approximation.

The cosmic time dilation would slow down the time scale of the planetary dynamics and cosmic expansion would lead to adiabatic expansion of the size of the solar system. This would predict the scaling $L(a)/L(a_0) = a/a_0$ for the sizes of the planetary orbits as measured using the $r_M$ coordinate of $M^4_+$ metric whereas angular velocities of planets would remain constant $\omega(a)/\omega(a_0) = constant$. The solar system would gradually decay.

### 7.1.3 The condition that solar system does not participate cosmic expansion

If the solar system does not participate in cosmic expansion, one has $L(a)/L(a_0) = constant$ and the scalings

$$\frac{\omega(a)}{\omega(a_0)} = (\frac{a}{a_0})^{3/2} = \frac{t}{t_0} \quad , \quad \frac{v(a)}{v(a_0)} = (\frac{a}{a_0})^{1/2} = (\frac{t}{t_0})^{1/2} \tag{59}$$

for the angular velocity $\omega$ and and tangential velocity $v$ along the orbit. The equation for the angular acceleration is $d\omega/dt = \omega/t$. This result differs by a factor of 3 from the equation $d\omega/dt = 3\omega/t$ of Masreliez [41]. On basis of work of Masreliez one can conclude this kind of scaling indeed explains the observed drift quite satisfactorily for $t \simeq 5$ billion years (instead of $t = 15$ billion years of [41]). Thus the effect would allow to see the effects of the cosmic expansion in human time scale and would make possible to determine the value of cosmic time $t$ from the planetary dynamics.

### 7.1.4 Compensation of cosmic expansion from Bohr quantization of planetary orbits?

The Bohr quantization for planetary orbits predicts that the orbital radii measured in terms of $M^4$ radial coordinate $r_M$ are constant. This means that planetary system does not participate cosmic expansion so that the orbital radii expressed in terms of the coordinate $r = r_M/a$ shrinking. Therefore the stars accelerate with respect to the Robertson-Walker coordinates $(t, r, \Omega))$ defined by the distant stars since in this case the radii correspond naturally to the coordinate $r = r_M/a$ and time variable corresponds to the $dt/da = \sqrt{g_{aa}}$ giving $dr/dt = -Hr_M$ so that cosmic expansion

is exactly compensated. This model for the anomaly brings in no additional assumptions besides Bohr quantization and is favored by Occam's razor.

There is an objection against the model based on the effective shift of the space-time sheet of solar system towards geometric future in each quantum jump so that cosmic expansion is compensated and time effectively ceases to flow. The simplest model for the arrow of psychological time found hitherto [E10] assumes however that this kind of effective shifting indeed occurs but in the reverse direction so that the radii would seem to increase rather than decrease. If the $M^4$ size remains constant, apparent reduction of radii is predicted.

Quite recently (August 2008) there appeared a new experimental claim related to the problem discussed. There is evidence that the value of astronomical unit AU (distance between Sun and Earth) is increasing with a rate about $dAU/dt = 7$ cm/year [43]. Expressed in terms of the Minkowski proper time $a = R(t)$ the rate is about

$$\frac{dlog(AU)}{da} \simeq 4.6 \times 10^{-13} \quad .$$

If the solar system indeed participates cosmic expansion, one has $\frac{dlog(AU)}{da} = 1/a$ and the prediction for the recent Minkowski age of the Universe is $a_{now} = 2.2 \times 10^{12}$ years. If one assumes $a_R \simeq 3.3 \times 10^7$ y for the time when matter began to dominate, one obtains

$$t - t_R = \int_{a_R}^{a} \sqrt{g_{aa}} da \quad , \quad g_{aa} = (\frac{a}{a_R})^{1/2} \quad .$$

This would give $t_{now} \simeq 4 \times 10^{10}$ years which is about 8 times longer than the age $t_{now} = 0.5 \times 10^{10}$ ly explaining the claims of Mazreliez. The latter would give $a_{now} \simeq 4 \times 10^{11}$ y, which is ten times shorter than the value required by the interpretation of the increase of AU as being due to the cosmic expansion.

In any case, if the increase of AU is real, it challenges the hypothesis that the quantum size of the solar system remains exactly constant and increases only in the phase transitions increasing the value of the gravitational Planck constant. One could consider the possibility that some new effect which is by a factor 1/10 smaller than that caused by the cosmic expansion is present. A possible explanation consistent with the constant $M^4$ size of the solar system is based on the idea that the space-time sheet along which the radar radiation propagates, develops gradually riples. Also the emergence of new space-time sheets condensed to the space-time sheet along which rader photons propagate could be involved. This increasing metric noise would mean that the distance traveled by the radar photons along the space-time sheet in question gradually increases so that the time taken by the radar signal to travel from Earth to Sun and back increases.

## 7.2 Pioneer anomaly

The data gathered during one quarter of century ([29, 28]) seem to suggest that spacecrafts do not obey the laws of Newtonian gravitation. What has been observed is anomalous constant acceleration of order $(8 \pm 3) \times 10^{-11} g$ ($g = 9.81\ m/s^2$ is gravitational acceleration at the surface of Earth) for the Pioneer/10/11, Galileo and Ulysses [28]. The acceleration is directed towards Sun and could have an explanation in terms of $1/r^2$ long range force if the density of charge carriers of the force has $1/r$ dependence on distance from the Sun. From the data in [29, 28], the anomalous acceleration of the spacecraft is of order

$$\delta a \sim .8 \times 10^{-10} g \quad ,$$

where $g \simeq 9.81\ m/s^2$ is gravitational acceleration at the surface of Earth. Using the values of Jupiter distance $R_J \simeq .8 \times 10^{12}$ meters, radius of Earth $R_E \simeq 6 \times 10^6$ meters and the value Sun to Earth mass ratio $M_S/M_E \simeq .3 * 10^6$, one can relate the gravitational acceleration

$$a(R) = \frac{GM_S}{R^2} = \frac{M_S}{M_E}\frac{R_E^2}{R^2}$$

of the spacecraft at distance $R = R_J$ from the Sun to $g$, getting roughly $a \simeq 1.6 \times 10^{-5} g$. One has also

$$\frac{\delta a}{a} \simeq 1.3 \times 10^{-4} \quad .$$

The value of the anomalous acceleration has been found to be $a_F = (8.744 \pm 1.33) \times 10^{-8}$ cm/s$^2$ and given by Hubble constant: $a_F = cH$. $H = 82$ km/s/Mpc gives $a_F = 8 \times 10^{-8}$ cm/s$^2$. It is very difficult to believe that this could be an accident. There are also diurnal and annual variations in the acceleration anomaly [59]. These variations should be due to the physics of Earth-Sun system. I do not know whether they can be understood in terms of a temporal variation of the Doppler shift due to the spinning and orbital motion of Earth with respect to Sun.

The most plausible model for the acceleration anomaly relies on the presence of dark matter increasing the effective solar mass. Since acceleration anomaly is constant, a dark matter density behaving like $\rho_d = (3/4\pi)(H/Gr)$, where $H$ is Hubble constant giving $M(r) \propto r^2$, is required. For instance, at the radius $R_J$ of Jupiter the dark mass would be about $(\delta a/a)M(Sun) \simeq 1.3 \times 10^{-4} M(Sun)$ and would become comparable to $M_{Sun}$ at about $100R_J = 520$ AU. Note that the standard theory for the formation of planetary system assumes a solar nebula of radius of order 100AU having 2-3 solar masses. For Pluto at distance of 38 AU the dark mass would be about one per cent of solar mass. This model would suggest that planetary systems are formed around dark matter system with a universal mass density. For this option dark matter could perhaps be seen as taking care of the contraction compensating for the cosmic expansion by using a suitable dark matter distribution.

In [59] the possibility that the acceleration anomaly for Pioneer 10 (11) emerged only after the encounter with Jupiter (Saturn) is raised. The model explaining Hubble constant as being due to a radial contraction compensating cosmic expansion would predict that the anomalous acceleration should be observed everywhere, not only outside Saturn. The model in which universal dark matter density produces the same effect would allow the required dark matter density $\rho_d = (3/4\pi)(H/Gr)$ be present only as a primordial density able to compensate the cosmic expansion. The formation of dark matter structures could have modified this primordial density and visible matter would have condensed around these structures so that only the region outside Jupiter would contain this density.

## 7.3 Fly-by anomaly

The so called flyby anomaly [59] might relate to the Pioneer anomaly. Fly-by mechanism used to accelerate space-crafts is a genuine three body effect involving Sun, planet, and the space-craft. Planets are rotating around sun in an anticlockwise manner and when the space-craft arrives from the right hand side, it is attracted by a planet and is deflected in an anticlockwise manner and planet gains energy as measured with respect to solar center of mass system. The energy originates from the rotational motion of the planet. If the space-craft arrives from the left, it loses energy. What happens is analyzed in [59] using an approximately conserved quantity known as Jacobi's integral $J = \mathcal{E} - \omega \overline{e}_z \cdot \overline{r} \times \overline{v}$. Here $\mathcal{E}$ is total energy per mass for the space-craft, $\omega$ is the angular velocity of the planet, $\overline{e}_z$ is a unit vector normal to the planet's rotational plane, and various quantities are with respect to solar cm system.

This as such is not anomalous and flyby effect is used to accelerate space-crafts. For instance, Pioneer 11 was accelerated in the gravitational field of Jupiter to a more energetic elliptic orbit

directed to Saturn ad the encounter with Saturn led to a hyperbolic orbit leading out from solar system.

Consider now the anomaly. The energy of the space-craft in planet-space-craft cm system is predicted to be conserved in the encounter. Intuitively this seems obvious since the time and length scales of the collision are so short as compared to those associated with the interaction with Sun that the gravitational field of Sun does not vary appreciably in the collision region. Surprisingly, it turned out that this conservation law does not hold true in Earth flybys. Furthermore, irrespective of whether the total energy with respect to solar cm system increases or decreases, the energy in planet-spacecraft cm system increases during flyby in the cases considered.

Five Earth flybys have been studied: Galileo-I, NEAR, Rosetta, Cassina, and Messenger and the article of Anderson and collaborators [59] gives a nice quantitative summary of the findings and of the basic theoretical notions. Among other things the tables of the article give the deviation $\delta\mathcal{E}_{g,S}$ of the energy gain per mass in the solar cm system from the predicted gain. The anomalous energy gain in rest Earth cm system is $\Delta\mathcal{E}_E \simeq \overline{v}\cdot\Delta\overline{v}$ and allows to deduce the change in velocity. The general order of magnitude is $\Delta v/v \simeq 10^{-6}$ for Galileo-I, NEAR and Rosetta but consistent with zero for Cassini and Messenger. For instance, for Galileo I one has $v_{\infty,S} = 8.949$ km/s and $\Delta v_{\infty,S} = 3.92 \pm .08$ mm/s in solar cm system.

Many explanations for the effect can be imagined but dark matter is the most obvious candidate in TGD framework. The model for the Bohr quantization of planetary orbits assumes that planets are concentrations of the visible matter around dark matter structures. These structures could be tubular structures around the orbit or a nearly spherical shell containing the orbit. The contribution of the dark matter to the gravitational potential increases the effective solar mass $M_{eff,S}$. This of course cannot explain the acceleration anomaly which has constant value. One can also consider dark matter rings associated with planets and perhaps even Moon's orbit is an obvious candidate now. It turns out that the tube associated with Earth's orbit and deformed by Earth's presence to equatorial plane of Earth explains qualitatively the known facts.

Roughly half year after writing this, a rather convincing and very simple model explaining the effect as a relativistic transverse Doppler effect appeared [61] (see the comment at the end of this section). Therefore the dark matter ring - if present - can give only an additional contribution to the transverse Doppler effect.

### 7.3.1 Dark matter at a spherical cell containing Earth's orbit?

For instance, if the space-craft traverses shell structure, its kinetic energy per mass in Earth cm system changes by a constant amount not depending on the mass of the space-craft:

$$\frac{\Delta E}{m} \simeq v_{\infty,E}\Delta v \quad = \quad \Delta V_{gr} = \frac{G\Delta M_{eff,S}}{R} \quad . \tag{60}$$

Here $R$ is the outer radius of the shell and $v_{\infty,E}$ is the magnitude of asymptotic velocity in Earth cm system. This very simple prediction should be testable. If the space-craft arrives from the direction of Sun the energy increases. If the space-craft returns back to the sunny side, the net anomalous energy gain vanishes. This has been observed in the case of Pioneer 11 encounter with Jupiter [59].

The mechanism would make it possible to deduce the total dark mass of, say, spherical shell of dark matter. One has

$$\begin{aligned} \frac{\Delta M}{M_S} &\simeq \frac{\Delta v}{v_{\infty,E}}\frac{2K}{V} \quad , \\ K &= \frac{v_{\infty,E}^2}{2} \quad , \quad V = \frac{GM_S}{R} \quad . \end{aligned} \tag{61}$$

For the case considered $\Delta M/M_S \geq 2\times 10^{-6}$ is obtained. Note that the amount of dark mass within sphere of 1 AU implied by the explanation of Pioneer anomaly would be about $6.2\times 10^{-6}M_S$ from Pioneer anomaly whereas the mass of Earth is $M_E \simeq 5\times 10^{-6}M_S$. Since the orders of magnitude are same one might consider the possibility that the primordial dark matter has concentrated in spherical shells in the case of inner planets as indeed suggested by the model for quantization of radii of planetary orbits. Of course, the total mass associated with $1/r$ density quite too small to explain entire mass of the solar system.

In the solar cm system the energy gain is not constant. Denote by $\overline{v}_{i,E}$ and $\overline{v}_{f,E}$ the initial and final velocities of the space-craft in Earth cm. Let $\Delta\overline{v}$ be the anomalous change of velocity in the encounter and denote by $\theta$ the angle between the asymptotic final velocity $\overline{v}_{f,S}$ of planet in solar cm. One obtains for the corrected $\mathcal{E}_{g,S}$ the expression

$$\mathcal{E}_{g,S} = \frac{1}{2}\left[(\overline{v}_{f,E}+\overline{v}_P+\Delta\overline{v})^2-(\overline{v}_{i,E}+\overline{v}_P)^2\right] \ . \tag{62}$$

This gives for the change $\delta\mathcal{E}_{g,S}$

$$\begin{aligned}\delta\mathcal{E}_{g,S} &\simeq (\overline{v}_{f,E}+\overline{v}_P)\cdot\Delta\overline{v}\simeq v_{f,S}\Delta v\times cos(\theta_S)\\ &= v_{\infty,S}\Delta v\times cos(\theta_S) \ .\end{aligned} \tag{63}$$

Here $v_{\infty,S}$ is the asymptotic velocity in solar cm system and in excellent approximation predicted by the theory.

Using spherical shell as a model for dark matter one can write this as

$$\delta\mathcal{E}_{g,S} = \frac{v_{\infty,S}}{v_{\infty,E}}\frac{G\Delta M}{R}cos(\theta_S) \ . \tag{64}$$

The proportionality of $\delta\mathcal{E}_{g,S}$ to $cos(\theta_S)$ should explain the variation of the anomalous energy gain.

For a spherical shell $\Delta\overline{v}$ is in the first approximation orthogonal to $v_P$ since it is produced by a radial acceleration so that one has in good approximation

$$\begin{aligned}\delta\mathcal{E}_{g,S} &\simeq \overline{v}_{f,S}\cdot\Delta\overline{v}\simeq\overline{v}_{f,E}\cdot\Delta\overline{v}\simeq v_{f,S}\Delta v\times cos(\theta_S)\\ &= v_{\infty,E}\Delta v\times cos(\theta_E) \ .\end{aligned} \tag{65}$$

For Cassini and Messenger $cos(\theta_S)$ should be rather near to zero so that $v_{\infty,E}$ and $v_{\infty,S}$ should be nearly orthogonal to the radial vector from Sun in these cases. This provides a clear cut qualitative test for the spherical shell model.

### 7.3.2 Dark matter at the orbit of Earth?

An alternative model is based on dark matter on the orbit of Earth. One can estimate the change of the kinetic energy in the following manner.

1. Assume that the the orbit is not modified at all in the lowest order approximation and estimate the kinetic energy gained as the work done by the force caused by the dark matter on the space-craft.

$$\begin{aligned}\frac{\Delta E}{m} &= -G\frac{d\rho_{dark}}{dl}\int_{\gamma_E}dl_E\int_{\gamma_S}d\overline{r_S}\cdot\frac{\overline{r}_{SE}}{r_{SE}^3}) \ ,\\ \overline{r}_{SE} &\equiv \overline{r}_S-\overline{r}_E \ .\end{aligned} \tag{66}$$

Here $\gamma_S$ denotes the portion of the orbit of space-craft during which the effect is noticeable and $\gamma_E$ denotes the orbit of Earth.

This expression can be simplified by performing the integration with respect to $r_S$ so that one obtains the difference of gravitational potential created by the dark matter tube at the initial and final points of the portion of $\gamma_S$:

$$\begin{aligned} \frac{\Delta E}{m} &= V(\overline{r}_{S,f}) - V(\overline{r}_{S,i}) \ , \\ V(\overline{r}_S) &= -G\frac{d\rho_{dark}}{dl} \times \int_{\gamma_E} dl_E \frac{1}{r_{SE}} \ . \end{aligned} \tag{67}$$

2. Use the standard approximation (briefly described in [59]) in which the orbit of the spacecraft consists of three parts joined continuously together: the initial Kepler orbit around Sun, the piece of orbit which can be approximate with a hyperbolic orbit around Earth, and the final Kepler orbit around Sun. The piece of the hyperbolic orbit can be chosen to belong inside the so called sphere of influence, whose radius $r$ is given in terms of the distance $R$ of planet from Sun by the Roche limit $r/R = (3m/M_{Sun})^{2/5}$. $\gamma_S$ could be in the first approximation taken to correspond to this portion of the orbit of spacecraft.

3. The explicit expression for the hyperbolic orbit can be obtained by using the conservation of energy and angular momentum and reads as

$$\begin{aligned} u = \frac{r_s}{r} = \frac{2GM}{r} &= \frac{u_0^2}{2v_0^2}[1 + \sqrt{1 + 4u_0^2 \frac{v_\infty^2 v_0^2}{sin^2(\phi)}}] \ , \\ u_0 &\equiv \frac{r_s}{a} \ , \ |v \times r| \equiv vr \times sin(\phi) \ . \end{aligned} \tag{68}$$

The unit $c = 1$ is used to simplify the formulas. $r_s$ denotes Schwartschild radius and $v_\infty$ the asymptotic velocity. $v_0$ and $a$ are the velocity and distance at closest approach and the conserved angular momentum is given by $L/m = v_0 a$. In the situation considered value of $r_S$ is around 1 cm, the value of $a$ around $10^7$ m and the value of $v_\infty$ of order 10 km/s so that the approximation

$$u \simeq u_0 \frac{v_\infty}{v_0} sin(\phi) \tag{69}$$

is good even at the distance of closest approach. Recall that the parameters characterizing the orbit are the distance $a$ of the closest approach, impact parameter $b$, and the angle $2\theta$ characterizing the angle between the two straight lines forming the asymptotes of the hyperbolic orbit in the orbital plane $P_E$.

Consider first some conclusions that one can make from this model.

1. Simple geometric considerations demonstrate that the acceleration in the region between Earth's orbit and the part of orbit of spacecraft for which the distance from Sun is larger than that of Earth is towards Sun. Hence the distance of the spacecraft from Earth tends to decrease and the kinetic energy increases. In fact, one could also choose the portion of $\gamma_S$ to be this portion of the spacecraft's orbit.

2. $\Delta E$ depends on the relative orientation of the normal $n_S$ of the the orbital plane $P_E$ of spacecraft with respect to normal $n_O$ the orbital plane $P_O$ of Earth. The orientation can be characterized by two angles. The first angle could be the direction angle $\Theta$ of the position vector of the nearest point of spacecraft's orbit with respect to cm system. Second angle, call it $\Phi$, could characterize the rotation of the orbital plane of space-craft from the standard orientation in which orbital plane and space-craft's plane are orthogonal. Besides this $\Delta E$ depends on the dynamical parameters of the hyperbolic orbit of space-craft given by the conserved energy $E_{tot} = E_\infty$ and angular momentum or equivalently by the asymptotic velocity $v_\infty$ and impact parameter $b$.

3. Since the potential associated with the closed loop defined by Earth's orbit is expected to resemble locally that of straight string one expects that the potential varies slowly as a function of $\overline{r}_S$ and that $\Delta E$ depends weakly on the parameters of the orbit.

The most recent report [60] provides additional information about the situation.

1. $\Delta E$ is reported to be proportional to the total orbital energy $E_\infty/m$ of the space-craft. Naively one would expect $\sqrt{E_\infty/m}$ behavior coming from the proportionality $\Delta E$ to $1/r$. Actually a slower logarithmic behavior is expected since a potential of a linear structure is in question.

2. $\Delta E$ depends on the initial and final angles $\theta_i$ and $\theta_f$ between the velocity $\overline{v}$ of the space-craft with respect to the normal $\overline{n}_E$ of the equatorial plane $P_E$ or Earth and the authors are able to give an empirical formula for the energy increment. The angle between $P_E$ and $P_O$ is 23.4 degrees. One might hope that the formula could be written also in terms of the angle between $v$ and the normal $n_O$ of the orbital plane. For $\theta_i \simeq \theta_f$ the effect is known to be very small. A particular example corresponds to a situation in which one has $\theta_i = 32$ degrees and $\theta_f = 31$ degrees. Obviously the $P_O \simeq P_E$ approximation cannot hold true. Needless to say, also the model based on spherical shell of dark matter fails.

### 7.3.3 Is the tube containing the dark matter deformed locally into the equatorial plane?

The previous model works qualitatively if the interaction of Earth and flux tube around Earth's orbit containing the dark matter modifies the shape of the tube locally so that the portion of the tube contributing to the anomaly lies in a good approximation in $P_E$ rather than $P_O$. In this case the minimum value of the distance $r_{ES}$ between $\gamma_E$ and $\gamma_S$ is maximal for the symmetric situation with $\theta_i = \theta_f$ and the effect is minimal. In an asymmetric situation the minimum value of $r_{ES}$ decreases and the size of the effect increases. Hence the model works at least qualitatively of the motion of Earth induces a moving deformation of the dark matter tube to $P_E$. One can actually write $\Delta E$ in a physically rather transparent form showing that it is consistent with the basic empirical findings.

1. By using linear superposition one can write the potential as sum of a potential associated with a tube associated with Earths orbit plus the potential associated with the deformed part minus the potential associated with corresponding non-deformed portion of Earth's orbit:

$$\begin{aligned} \frac{\Delta E}{m} &= V(\overline{r}_{S,f}) - V(\overline{r}_{S,i}) \ , \\ V(\overline{r}_S) &= -G\frac{d\rho_{dark}}{dl} Z(\overline{r}_S) \ , \end{aligned}$$

$$
\begin{aligned}
Z(\overline{r}_S) &= X(\gamma_{orb};\overline{r}_S) + X(\gamma_d;\overline{r}_S) - X(\gamma_{nd};\overline{r}_S) \ , \\
X(\gamma_i;\overline{r}_S) &= \int_{\gamma_i} dl \frac{1}{r_{Si}} \ . \qquad (70)
\end{aligned}
$$

Here the subscripts "orb", "d" and "nd" refer to the entire orbit of Earth, to its deformed part, and corresponding non-deformed part. The entire orbit is analogous to a potential of straight string and is expected to give a slowly varying term which is however non-vanishing in the asymmetric situation. The difference of deformed and non-deformed parts gives at large distances dipole type potential behaving like $1/r^2$ and thus being proportional to $v_\infty^2$ by the above expression for the $u = r_s/r$. The fact that $\Delta E$ is proportional to $v_\infty^2$ suggests that dipole approximation is good.

2. One can therefore parameterize $\Delta E$ as

$$
\begin{aligned}
\frac{\Delta E}{m} &= V(\overline{r}_{S,f}) - V(\overline{r}_{S,i}) \ , \\
V(\overline{r}_S) &= -G\frac{d\rho_{dark}}{dl} Z \ , \\
Z(\overline{r}_S) &= X(\gamma_{orb};\overline{r}_S) + \frac{dcos(\Theta)}{r_S^2} \ . \qquad (71)
\end{aligned}
$$

where $\Theta$ is the angle between $\overline{r}$ and the dipole $\overline{d}$, which now has dimension of length. The direction of the dipole is in the first approximation in the equatorial plane and and directed orthogonal to the Earth's orbit.

Consider now the properties of $\Delta E$.

1. In a situation symmetric with respect to the equator $E_d$ vanishes but $E_{nd}$ is non-vanishing which gives as a result potential difference associated with entire Earth's orbit minus the part of orbit contributing to the effect so that the result is by the definition of the approximation very small.

2. As already noticed, dipole field like behavior that the large contribution to the potential is proportional to the conserved total energy $v_\infty^2/2$ at the limit of large kinetic energy.

3. From the fact that potential difference is in question it follows that the expression for the energy gain is the difference of parameters characterizing the initial and final situations. This conforms qualitatively with the observation that this kind of difference indeed appears in the empirical fit. $1/r^2$-factor is also proportional to $sin^2(\phi)$ which by the symmetry of the situation is expected to be same for initial and final situation. Furthermore, $\Delta E$ is proportional to the difference of the parameter $cos(\Theta_f) - cos(\Theta_i)$ and this should correspond to the reported behavior: it indeed does as I learned after having received the article in email (the prices of PRL on line articles are too dirty for me!). Note that the result vanishes for the symmetric situation in accordance with the empirical findings.

To sum up, it seems that the qualitative properties of $\Delta E$ are indeed consistent with the empirical findings. The detailed fit of the formula of [60] should allow to fix the shape of the deformed part of the orbit.

### 7.3.4 What induces the deformation?

Authors suggest that the Earth's rotation is somehow involved with the effect. The first thing to notice is that the gravimagnetic field of Earth, call it $B_E$, predicted by General Relativity is quite too weak to explain the effect as a gravimagnetic force on spacecraft and fails also to explain the fact that energy increases always. Gravito-Lorentz force does not do any work so that the total energy is conserved and $\Delta E = -\Delta V = -\nabla V \cdot \Delta \overline{r}$ holds true, where $\Delta \overline{r}$ is the deflection caused by the gravimagnetic field on the orbit during flyby. Since $\Delta \overline{r}$ is linear in $v$, $\Delta E$ changes sign as the velocity of space-craft changes sign so that this option fails in several manners.

Gravimagnetic force of Earth could be however involved but in a different manner. The gravimagnetic force between Earth and flux tube containing the dark matter could explain this deformation as a kind of frame drag effect: dark matter would tend to follow the spinning of Earth.

1. If the dark matter inside the tube is at rest in the rest frame of Sun (this is not a necessary assumption), it moves with respect to Earth with a velocity $v = -v_E$, where $v_E$ is the orbital velocity of Earth. If the tube is thin, the gravito-Lorentz force experienced by dark matter equals in the first approximation to $F = -v_E \times B_E$ with $B_E$ evaluated at the axis of the tube. TGD based model for $B_E$ [D3] does not allow $B_E$ to be a dipole field. $B_E$ has only the component $B^\theta$ and the magnitude of this component relates by a factor $1/sin(\theta)$ to the corresponding component of the dipole field and becomes therefore very strong as one approaches poles. The consistency with the existing experimental data requires that $B_E$ at equator is very nearly equal to the strength of the dipole field. The magnitude of $B_E$ and thus of $F$ is minimal when the deformation of the tube is in $P_E$, and the deformation occurs very naturally into $P_E$ since the non-gravitational forces associated with the dark matter tube must compensate a minimal gravitational force in dynamical equilibrium.

2. $B_E^\theta$ at equator is in the direction of the spin velocity $\omega$ of the Earth. The direction of $v_E$ varies. It is convenient to consider the situation in the rest system of Sun using Cartesian coordinates for which the orbital plane of Earth corresponds to (x,y) plane with x- and y-axis in the direction of semi-minor and semi-major axes of the Earth's orbit. The corresponding spherical coordinates are defined in an obvious manner. $v_E$ is parallel to the tangent vector $e_\phi(t) = -sin(\Omega t)e_x + cos(\Omega t)e_y$ of the Earth's orbit. The direction of $B_E$ at equator is parallel to $\omega$ and can be parameterized as $e_\omega = cos(\theta)e^z + sin(\theta)(cos(\alpha)e_x + sin(\alpha)e_y)$. $F$ is parallel to the vector $-cos(\theta)e_\rho(t) + sin(\theta)cos(\Omega t - \alpha)e_z$, where $e_\rho(t)$ is the unit vector directed from Sun to Earth. The dominant component is directed to Sun.

### 7.3.5 Fly-by anomaly as transverse relativistic Doppler effect?

A new twist in the story of fly-by anomaly emerged at September twelfth 2007. The proposal of Jean-Paul Mbelek [61] explains fly-by effect as a relativistic transverse Doppler effect and thus purely kinematic effect. Also the functional dependence of the parameter $K$ characterizing the size of the effect on the kinematic parameters is predicted and the prediction is consistent with the empirical findings in the example considered. Therefore the story of fly-by anomaly might be finished and dark matter at the orbit of Earth could bring in only an additional effect. It is probably too much to hope for this kind of effect to be large enough if present.

## 7.4 New anomaly in Cosmic Microwave Background

A new anomaly in CMB has been found. The article by L. Rudnick, S. Brown, L. R. Williams is *Extragalactic Radio Sources and the WMAP Cold Spot* tells that a cold spot in the microwave background has been discovered. The amplitude of the temperature variation is -73 $\mu$K at maximum. The authors argue that the variation can be understood if there is a void at redshift $z \leq 1$,

which corresponds to $d \leq 1.4 \times 10^{10}$ ly. The void would have radius of 140 Mpc making $5.2 \times 10^8$ ly.

In New Scientist [63] there is a story titled about Neil Turoks recent talk at PASCOS entitled Is the Cold Spot in the CMB a Texture?. Turok has proposed that the cold spot results from a topological defect associated with a cosmic string of GUT type theories.

### 7.4.1 Comparison with sizes and distances of large voids

It is interesting to compare the size and distance of the argued CMB void to those for large voids [34].

The largest known void has size of 163 Mpc making $5.3 \times 10^8$ ly which does not differ significantly from the size $8 \times 6.5 \times 10^8$ ly of CMB void. The distance is 201 Mpc making about $6.5 \times 10^8$ ly and roughly by a factor 1/22 smaller than CMB void.

Is it only an accident that the size of CMB void is same as that for largest large void? If large voids follow the cosmic expansion in a continuous manner, the size of the CMB void should be roughly 1/22 time smaller. Could it be that large voids might follow cosmic expansion by rather seldomly occurring discrete jumps? TGD inspired quantum astrophysics indeed predicts that expansion occurs in discrete jumps [D8].

### 7.4.2 TGD based quantum model for astrophysical systems

A brief summary of TGD based quantum model of astrophysical systems is in order.

1. TGD based quantum model for astrophysical systems relies on the evidence that planetary orbits (also those of known exoplanets) correspond to Bohr orbits with a gigantic value of gravitational Planck constant $h_{gr} = GMm/v_0$ characterizing the gravitational interaction between masses $M$ and $m$. Nottale introduced originally this quantization rule and assigned it to hydrodynamics.

2. TGD inspired hypothesis is that quantization represents genuine quantum physics and is due to the fact that dark matter matter corresponds to a hierarchy whose levels are labelled by the values of Planck constant. Visible matter bound to dark matter would make this quantization visible. Putting it more precisely, the each or the space-time sheets mediating interactions (electro-weak, color, gravitational) between the two physical systems is characterized by its own Planck constant which can have arbitrarily large values. For gravitational interactions the value of this Planck constant is gigantic.

3. The implication is that astrophysical systems are analogous to atoms and molecules and thus correspond to quantum mechanical stationary states have constant size in the local $M^4$ coordinates $(t, r_M, \Omega)$ related to Robertson Walker coordinates via the formulas $(a, r, \Omega)$ by $(a^2 = t^2 - r_M^2, r = r_M/a)$. This means that their $M^4$ radius $R_M$ remains constant whereas the coordinate radius $R$ decreases as $1/a$ rather than being constant as for co-moving matter.

4. Astrophysical quantum systems can however participate in the cosmic expansion by discrete quantum jumps in which Planck constant increases. This means that the parameter $v_0$ appearing in the gravitational Planck constant $\hbar = GMm/v_0$ is reduced in a discrete manner so that the quantum scale of the system increases.

5. This applies also to gravitational self interactions for which one has $\hbar = GM^2/v_0$. During the final states of star the phase transitions reduce the value of Planck constant and the prediction is that collapse to neutron or super-nova should occur via phase transitions increasing $v_0$. For black-hole state the value of $v_0$ is maximal and equals to 1/2.

6. Planetary Bohr orbit model explains the finding by Masreliez that planetary radii seem to decrease when express in terms of the cosmic radial coordinate $r = r_M/a$ [D8]. The prediction is that planetary systems should experience now and then a phase transition in which the size of the system increases by an integer n. The favored values are ruler-and-compass integers expressible as products of distinct Fermat primes (four of them are known) and power of 2. The most favored changes of $v_0$ are as powers of 2. This would explain why inner and outer planets correspond to the values of $v_0$ differing by a factor of 1/5.

### 7.4.3 The explanation of CMB void

Concerning the explanation of CMB void one can consider two options.

1. If the large CMB void is similar to the standard large voids it should have emerged much earlier than these or the durations of constant value of $v_0$ could be rather long so that also the nearby large voids should have existed for a very long time with same size.

2. One can also consider the possibility that CMB void is a fractally scaled up variant of large void. The p-adic length scale of the CMB void would be $L_p \equiv L(k)$, $p \simeq 2^k$, $k = 263$ (prime). If it has participated cosmic expansion in the average sense its recent p-adic size scale would be about $16 < 22$ times larger and p-adic scale would be $L(k)$, $k = 271$ (prime).

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