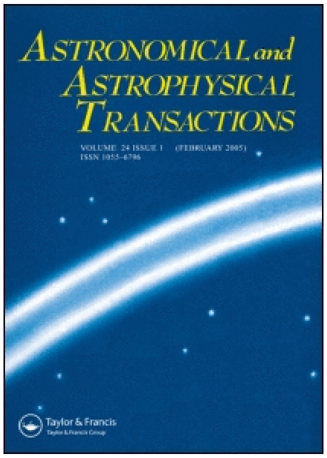

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HYPOTHESIS OF A DAEMON KERNEL OF THE EARTH

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The paper considers the fate of the electrically charged ($Ze \approx 10e$) Planckian elementary black holes, namely, daemons, making up the dark matter of the Galactic disc, which, as follows from our measurements, were trapped by the Earth during 4.5 Gyears in an amount equal to approximately 10^{24}. Owing to their huge mass (about 2×10^{-8} kg), these particles settle down to the Earth's centre to form a kernel. Assuming that the excess flux of 10–20 TW over the heat flux level produced by known sources, which is quoted by many researchers, is due to the energy liberated in the outer kernel layers in daemon-stimulated proton decay of Fe nuclei, we have come to the conclusion that the Earth's kernel is at present a fraction of a metre in size. The observed mantle flux of ^{3}He (and the limiting ^{3}He to ^{4}He ratio of about 10^{-4} itself) can be provided if at least one ^{3}He (or ^{3}T) nucleus is emitted in a daemon-stimulated decay of 10^2–10^3 Fe nuclei. This could actually remove the only objection to the hot origin of the Earth and to its original melting. The high energy liberation at the centre of the Earth drives two-phase two-dimensional convection in its inner core (IC), with rolls oriented along the rotation axis. This provides an explanation for the numerous features in the IC structure revealed in recent years (anisotropy in the seismic wave propagation, the existence of small irregularities, the strong damping of the P and S waves, ambiguities in the measurements of the IC rotation rate, etc.). The energy release in the kernel grows continuously as the number of daemons in it increases. Therefore the global tectonic activity, which had died out after the initial differentiation and cooling off of the Earth was reanimated 2 Gyears ago by the rearrangement and enhancement of convection in the mantle as a result of the increasing outward energy flow. It is pointed out that, as the kernel continues to grow, the tectonic activity will become intensified rather than die out, as was believed before.

Keywords: Dark matter; Inner core; Energy sources; Convection; ^{3}He; Ne

1 INTRODUCTION: THE PROBLEM OF THE ENERGY SOURCE IN THE EARTH AND THE DARK MATTER IN THE SOLAR SYSTEM

It appears obvious that global tectonics and generation of the Earth's magnetic field are initiated by convective motions in its mantle and the core. Recent estimates yield 44 TW for the global heat flux. Radioactive decay of the lithophilic U, Th and K, which are located primarily in the crust, produces not more than 12–20 TW (Sorokhtin and Ushakov, 1991; Calderwood, 2001; Helfrich and Wood, 2001).

The nature of the other heat generators in the mantle and the core remains unclear. The energy sources suggested besides the radioactive decay are tidal friction, the continuing gravitational separation of material, the Earth's cooling, etc. However, they all are at present believed to be insufficient. Lunar tidal friction produces now less than 1% of the heat flux. Gravitational energy of the separation could be substantial today too (Sorokhtin and Ushakov, 1991), if

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one sticks to the classical 'cold' (and slow) disc planetary cosmogonies assuming very long accretion of the Earth (0.1 Gyears and even 1 Gyears or more for the outer planets (Safronov, 1969)), when its core melted out of the cold material 2 Gyears later, primarily because of radiogenic heating of the interior. However, already the very first data on the Moon, Mercury, Venus and Mars obtained *in situ* by space missions has shown that all these planets had been igneously differentiated possibly as early as in the course of accretion, which assumes a hot protoplanetary nebula or a short scale of their formation (10^4–10^5 years). It remains unclear how a high temperature (about 1000–1500 K) in the disc, and the gaseous disc itself (inevitably turbulent), could persist for the required time of 0.1 Gyears or more. The short time scale also can hardly be accounted for by nebular cosmogonies without invoking additional hypotheses. It thus seems that a short and hot cosmogony can be provided only by the hypothesis considering the Jupiter–Sun system as the limiting case of a close binary star (Drobyshevski, 1978; 1996).

The acuteness of the problem of the inner Earth's heat is evident from the recent review by Helfrich and Wood (2001). They made in it, so to speak, the last-ditch attempt at 'squeezing' everything possible out of the radioactive sources.

In formulating the problem, Helfrich and Wood pointed out the following.

(i) The inventory of radioactive elements is capable at present of producing 20 TW (*i.e.* about 45% of the total heat flow),
(ii) The content of ^{40}Ar in the atmosphere is only one half that expected on the basis of the assumed fraction of ^{40}K in the observed heat balance,
(iii) The ^{4}He flux from the oceans is only 5% of the level expected on the basis of the oceanic heat flux.

Assuming that the outflow of heat resulting from the general cooling of the Earth can reach 5.9–20 TW, Helfrich and Wood placed radioactive energy release, firstly, in small (less than 4 km in size), seismically undetectable blobs of subducted recycled parts of the oceanic crust distributed by overall convection throughout the mantle and, secondly, a near-core laterally non-uniform D" layer (with an average thickness of about 200 km), where, in their opinion, material of the oceanic crust could also build up. These workers solved the problem of the deficiency of ^{40}Ar and ^{4}He evolving in the decay of K, U, and Th by invoking another hypothesis, namely they postulated that these gases are dissolved and accumulated in material somewhere at the mantle base and, therefore, do not reach the Earth's surface. No physicochemical arguments in favour of this assumption are offered, so that nobody will be any the wiser! At the same time, it is appropriate to note that the available isotope data argue (in accordance with the opinion of Helfrich and Wood on the whole-mantle convection) for the mantle being almost homogeneous chemically. Moreover, the ^{3}He to ^{4}He ratio turns out to be a maximum (up to about 0.5×10^{-4}) in hot mantle plumes (Hawaii, Iceland, etc.) (Mamyrin and Tolsikhin, 1984; Macpherson *et al.*, 1999), which are believed (see for example Foulger and Pearson (2001) and Trubitsyn, 2000 and references therein) to emanate exactly out of the lower mantle and maybe even from the core (Porcelly and Halliday, 2001).

Calderwood (2001) also carried out estimates of known sources of energy liberation. These are radioactive heat production in the crust (9.13 TW), in the lithosphere (0.38 TW) and in the depleted whole mantle (2.00 TW), as well as due to the secular mantle cooling (10.0 TW). He came to the conclusion that the flux leaving the core reaches as high as $Q \approx 21$ TW!

The above suggests that the missing source of energy and helium lies at a depth of 2700 km or more, that is possibly in the core, and reveals the complexity of the problem facing the researcher and the need to look for completely new approaches to its solution (Porcelly and Halliday, 2001).

It appears that the simplest and most natural mechanism of energy generation in the interior of the Earth is suggested by our experiments (Drobyshevski, 2001; 2002; Drobyshevski *et al.*, 2003a) on the search for dark electric matter objects (daemons), that is supposedly elementary Planckian black holes with $r_g = 3 \times 10^{-35}$m and $m = 2 \times 10^{-8}$ kg), which make up the dark matter (DM) of our Galaxy and of its disc. If they carry a negative electric charge $Z_e = -10e$, then their accumulation in the Sun and catalysis of proton decay there could account not only for the deficiency of the electron neutrinos but also partially for the muon neutrino's presence and the solar energetics themselves (Drobyshevski, 2004).

The daemon, in capturing a heavy nucleus and falling on the ground level located inside it, brings about its overheating and evaporation of some of the nucleons and of their clusters from the nucleus in about 10^{-9} s, as well as giving rise to subsequent decay of its protons which enter in the remnant of the nucleus (each proton decay takes about 1 μs (Drobyshevski *et al.*, 2003a) (see Section 3).

A detector built with due account of the above properties of the daemon has permitted us to record the flux of these particles, which cross the Earth's surface, downwards and upwards, with an astronomic velocity of only about 5–50 km s^{-1}, an unusually low value for cosmic rays. The flux exhibits strong seasonal variations and can be divided into several components, namely daemons moving with a velocity of about 35–50 km s^{-1} make up the population of the Galactic disc and/or of objects captured into strongly elongated heliocentric orbits, objects with $V \approx 10(11.2)$–15 km s^{-1} falling on the Earth from near-Earth, almost circular heliocentric orbits (NEACHOs), and objects of the preceding group transferred into geocentric Earth-surface-crossing orbits (GESCOs), which constitute a population with a velocity decreasing gradually from about 10 to less than 5 km s^{-1} (by about 30–40% per month) (Drobyshevski *et al.*, 2003a). Because the daemons are slowed down by the material of the Earth, these orbits contract gradually to become confined finally within the Earth. Having a huge mass compared with the nuclei of conventional elements (a difference of about 17–19 orders of magnitude), the daemons end up by reaching fairly rapidly a region near the Earth's centre.

Markov (1966), who started from the assumption that the daemons (which he called 'quantum maximons'), which build up inside the Earth and, in transforming to conventional matter in interaction with one another, release an energy of approximately mc^2, estimated their flux through the Earth's surface as $f_\oplus < 10^{-10}$ m^{-2} s^{-1}.

The purpose of this work is to consider, based on our measurements, some implications of the accumulation of daemons inside the Earth and, in particular, the possibility of their accounting for the observed heat flux from the core. This naturally suggests some conclusions concerning the properties of the Earth's inner core (IC), which are found to agree fully with (and to be explained by) the totality of the data available at present.

2 THE NUMBER OF DAEMONS INSIDE THE EARTH

By our measurements (Drobyshevski *et al.*, 2003a), the daemons fall on the Earth with a velocity of about 11.2–15 km s^{-1} apparently in the periods when it passes through the 'shadow' or 'antishadow' created by the Sun in the incoming flow of the Galactic disk daemons. This occurs only twice in a year (approximately from the end of January to the beginning of March, and from the end of July to the beginning of September) (Drobyshevski *et al.*, 2003b). This flux $f_\oplus \approx 20$ m^{-2} month^{-1} $\approx 10^{-5}$ m^{-2} s^{-1}. As already mentioned, part of this flux is captured into GESCOs, with the velocity in these orbits decaying with time as $d(\ln V)/dt = 0.3$–0.4 month^{-1}.

To estimate the slowing down of a daemon in one passage through the Earth, assume that the GESCO period $P = 6000$ s. Then in each traversal of the Earth ($2r_\oplus = 12{,}750$ km), the daemon is decelerated by $\Delta V = V_0 P\, d(\ln V)/dt = 11.2 \times 10^3 \times 6 \times 10^3 \times 0.3/2.5 \times 10^6 = 8$ m s^{-1}, which corresponds to a decelerating force $F \approx m V_0\, \Delta V / 2r_\oplus = 10^{-10}$ N.

If an object falling on the Earth with $V > V_0 = 11.2\,\mathrm{km\,s^{-1}}$ crosses it with $V \geq V_0$, it regains a NEACHO; that is, it is not captured into a GESCO. Thus, of the total number of approximately 3×10^{16} daemons that fall on the Earth's surface ($5.1 \times 10^{14}\,\mathrm{m^2}$) from NEACHOs during 1 year (more specifically, during about 2 months in a year), only $3 \times 10^{16} \times 8/(15\text{–}11.2) \times 10^3 = 0.6 \times 10^{14}$ objects will be captured by the Earth into GESCOs (if they are annihilated, the heat flux from the Earth would exceed the observed figure by three orders of magnitude). Assuming a constant flux, the Earth should have acquired during its existence 3×10^{23} negative daemons with a total mass of about $10^{16}\,\mathrm{kg} = 10$ Tt, which, generally speaking, agrees with an earlier estimate (Drobyshevski, 2001). Assuming for simplicity that positive daemons also exist in equal numbers, and neglecting the differences in the efficiency of their capture, the total mass will double to become $M_\mathrm{k} \approx 20$ Tt. Because our detector is to a certain extent transparent to the daemons crossing it, we possibly underestimate this mass slightly.

3 MAIN CONJECTURES ON THE STATE OF DAEMONS IN THE EARTH AND ON THEIR INTERACTION WITH MATTER

In passing through the Earth's material, the GESCO daemons lose their velocity rapidly, particularly if we recall that the force resisting the motion of a charged particle increases generally with decrease in its velocity (Alfvén and Fälthammar, 1967). Therefore the daemons end up near the Earths's centre in a few months. The loss in kinetic energy results in a release of energy, which is less by about six orders of magnitude than the energy Q from the core (we accept as a tentative estimate that $Q = 10$ TW (Calderwood, 2001; Helfrich and Wood, 2001)).

Our subsequent considerations will be based on the following simplifying assumptions, some of which will be validated by the results obtained on their basis.

(i) The daemons form at the Earth's centre, inside the Fe core ($\rho_0 = 1.3 \times 10^4\,\mathrm{kg\,m^{-3}}$ and $p_0 = 360$ GPa (Dziewonski and Anderson, 1981)), a kernel of an almost collisionless daemon gas.

(ii) As a consequence, the structure of the kernel can be approximated by an isothermal (T_d = constant), self-gravitating gas sphere, so that the near-surface density ρ_s of the daemon gas lies within the limits $\rho_\mathrm{m} > \rho_\mathrm{s} > \rho_\mathrm{m}/3$ (ρ_m is the mean kernel density) (Eddington, 1926; Chandrasekhar, 1939). Because of the high pressure generated by the self-gravitation of the kernel at its centre compared with p_0, one may justifiably assume that $\rho_\mathrm{s} = \rho_\mathrm{m}/3$.

(iii) The pressure of the daemon gas at the sphere's boundary is balanced by that of the Earth's material, so that $\rho_\mathrm{s} k T_\mathrm{d}/m \approx p_0 = 360$ GPa.

(iv) Most of the energy is released in the successive disintegration of daemon-containing protons ($938\,\mathrm{MeV} = 1.5 \times 10^{-10}$ J per event) in the Fe nuclei captured by the daemon. (In actual fact, this energy is liberated not in the nucleus itself but in the surrounding material, where it is transported from the nucleus by proton decay products, for instance, pions). The new nucleus is captured as soon as the charge of the remnant of the preceding nucleus decreases to $Z - 1$, making the effective daemon charge equal to $Z_{eff}\,\mathrm{e} = -1e$. In view of the fact that the binding energy of the nucleus to the daemon at the ground level, when it resides inside a nucleus, is $W \approx 1.8 Z Z_\mathrm{n} A^{-1/3}$ MeV, that is it is measured in tens and hundreds of megaelectronvolts, one readily sees that such a repeated capture brings about a release of such an energy that the remnant (say, O, F or Ne nucleus, depending on actual value of Z) is ejected, and the newly captured, strongly excited Fe nucleus, after expending the excitation energy to evaporation, during $\tau_\mathrm{ev} \approx 10^{-9}$ s, of some of the nucleons (about eight to ten in total) and/or of their clusters (^{2}D, ^{3}T, ^{3}He, ^{4}He, ^{10}Be, etc; up to five to six ^{4}He nuclei), retains $Z_\mathrm{n} \leq 14$–22 protons (Drobyshevski *et al.*, 2003a). From five to 13 of these are subsequently disintegrated by the daemon until the daemon–nuclear remnant system acquires a negative charge $Z_{\rm eff} = -1$. Therefore, on average, the charge of the daemon 'poisoned' by the Fe nucleus is $Z_{\rm m} = 5$–6. As follows from our measurements, the daemon-containing proton decays in $\Delta\tau \approx 1\,\mu$s, so that one cycle of recapture of a new iron nucleus lasts $\tau_{\rm ex} \approx 10$–$11\,\mu{\rm s} \gg \tau_{\rm ev}$ (Drobyshevski *et al.*, 2003a). Therefore, each negative daemon continuously 'poisoned' by Fe nuclei, firstly, creates, besides approximately 10^6 nucleons and their clusters, about 10^5 nuclei of O, F and Ne per second (in 4–10 s, the β-decay transforms $^{20-22}$F into Ne) and secondly, generates an energy $q \approx 1.5 \times 10^{-4}\,{\rm J\,s^{-1}}$.

4 STRUCTURE OF THE DAEMON KERNEL

One can gain a certain idea of the possible parameters of the kernel, its $\rho_{\rm m}$, $T_{\rm d}$ and radius $R_{\rm k}$, by assuming that the energy flux leaving the IC is created mainly in the disintegration of protons in the Fe nuclei captured by daemons in the kernel.

It is unclear *a priori* what part of the daemons takes part in this process. We shall assume as a first approximation that these are objects making up a surface layer of the kernel of thickness $\ell = (D\tau)^{1/2}$, into which Fe nuclei are capable of diffusing in a time $\tau (\approx \tau_{\rm ex} \approx 11\,\mu{\rm s})$. The diffusion coefficient of Fe atoms (nuclei) at the temperature $T_{\rm Fe}$ will be defined as $D = \lambda V_{\rm T}/3$, where $V_{\rm T} = (3kT_{\rm Fe}/m_{\rm Fe})^{1/2} \gg {\rm V_d}$, the daemon velocity in the kernel. The mean free path of Fe nuclei ($Z_{\rm Fe} = 26$) in the near-surface plasma of 'poisoned' daemons ($Z_{\rm m} = 5$–6) can be written as (Alfvén and Fälthammar, 1967)

$$\lambda = \frac{2\pi\varepsilon_0^2 m m_{\rm Fe}^2 V_{\rm T}^4}{e^4 Z_{\rm m}^2 Z_{\rm Fe}^2 \rho_{\rm s} \ln\Lambda}.$$

Here $\ln\Lambda \approx 10$ is the Coulomb logarithm and $\varepsilon_0 = 8.85 \times 10^{-12}\,{\rm F\,m^{-1}}$ is the electrical constant.

Taking into account that the near-surface concentration of *negative* daemons is $\rho_{\rm s}/2m$, we obtain

$$Q = \frac{4\pi R_{\rm k}^2 l q \rho_{\rm s}}{2m}.$$

This equation has to be solved for $R_{\rm k}$ and $\rho_{\rm s}$ (for $\rho_{\rm s} = \rho_{\rm m}/3$) together with $M_{\rm k} = 4\pi R_{\rm k}^3 \rho_{\rm s}$.

Hence, for $T_{\rm Fe} = 10^4$ K, $\ln\Lambda = 10$, and the other above parameters

$$R_{\rm k} = \frac{0.048 Q^2}{M_{\rm k}}\,{\rm m},$$

$$\rho_{\rm s} = \frac{700 M_{\rm k}^4}{Q^6}\,{\rm Tt\,m^{-3}},$$

where Q is in terawatts and $M_{\rm k}$ is in teratonnes. Then, at $Q = 10$ TW and $M_{\rm k} = 20$ Tt, $R_{\rm k} = 0.24$ m and $\rho_{\rm s} = 112\,{\rm Tt\,m^{-3}}$.

One readily sees that the pressure $p_{\rm c}$ at the kernel's centre generated by the self-gravitation of its material (Eddington, 1926) and given by $p_{\rm c} > 3\pi/8 \times GM_{\rm k}^2/R_{\rm k}^4$ exceeds p_0 at its boundary by more than 12 orders of magnitude, so that our approximation $\rho_{\rm s} = \rho_{\rm m}/3$ is fully justified. We may also recall that the density of atomic nuclear matter is approximately 230 ${\rm Tt\,m^{-3}}$. Equating the pressures at the kernel's boundary, $p = p_0 = 360\,{\rm GPa} = \rho_{\rm s} kT_{\rm d}/m$, yields the temperature $T_{\rm d}$ of the daemon plasma in the kernel, $T_{\rm d} = 4.6 \times 10^9$ K, so that the kernel daemons, because of their huge mass, move with a velocity of only $V_{\rm d} \approx 0.3\,{\rm cm\,s^{-1}}$. The high temperature of the kernel daemons (when $T_{\rm d} \gg T_{\rm Fe}$) is not surprising, because each proton disintegration releases 938 MeV while $m \gg m_{\rm Fe}$ so that an energy exchange between the components is strongly impeded.

One should also note the following points.

(i) The thickness of the layer in which the energy is liberated is, for our parameters, $l = 3 \times 10^{-8}$ m, which is an infinitesimal fraction of the kernel dimensions while at the same time exceeding the mean free path of the Fe nucleus, here found to be $\lambda = 1.4 \times 10^{-13}$ m. Thus, the energy release is due to the activity of an extremely small (about 2×10^{-7}) fraction of the accumulated daemons.

(ii) The mean time between the Coulomb collisions of daemons with one another for $\rho_{\rm m} = 3\rho_{\rm s}$ is estimated as (Alfvén and Fälthammar, 1967)

$$\tau_{\rm dd} = \frac{2\pi\varepsilon_0^2 m^3 V_{\rm d}^3}{0.714 \ln \Lambda 3\rho_{\rm s} e^4 Z^4} \approx 10\,{\rm s}.$$

For a velocity $V_{\rm d} \approx 0.3\,{\rm cm\,s^{-1}}$, their mean free path will be $\lambda_{\rm dd} = \tau_{\rm dd} V_{\rm d} \approx 3$ cm, which is comparable with the kernel dimensions. Therefore approximating the kernel by an isothermal gaseous sphere is in this case justified (particularly if one takes into account that the energy is liberated primarily near its surface). Hence it follows, in particular, that the cross-section of Coulomb interaction of daemons with one another is, on average, only $\sigma_{\rm dd} = (3\lambda_{\rm dd} n_{\rm s})^{-1} \approx 10^{-24}\,{\rm m}^2$.

(iii) Real physical collisions of daemons, when their centres approach a distance less than $3r_{\rm g}$, that is when one can, in principle, consider their fusion and similar processes, are extremely rare. In our conditions, $\lambda_g = (3n_{\rm s} 9\pi r_{\rm g}^2)^{-1} \approx 10^{42}$ m, so that daemons collide with one another in the above manner once approximately every 10^{45} s, that is once in approximately every 10^{21} s in the whole kernel. In this sense, the daemon plasma is collisionless with a large margin. Therefore there is hardly any sense in considering any noticeable energy release in transformation of daemons in the Earth's kernel to some particles or to conventional matter (Markov, 1966). It appears that this is valid for any conceivable conditions. The only case in which physical collisions could be realized is possibly when the daemon ensemble escapes under the gravitational radius (the case of quasars, active galaxy nuclei, etc.).

It appears more realistic to assume that the time required for daemons to diffuse into the kernel is determined by the time $\tau = 2\tau_{\rm ex} n_{\rm Fe}/n_{\rm s}$, that is the time in which each Fe nucleus of their total number $n_{\rm Fe} = \rho_0/m_{\rm Fe}$, which had diffused from the surface into the kernel, will be captured and processed by the negative daemons present in the concentration $n_{\rm s}/2$. Then $R_{\rm k} = 0.0051\,Q^{1/2}$ m, and it will be independent of $M_{\rm k}$ (so that the total energy release Q will be proportional to the kernel surface area). For $Q = 10$ TW and $M_{\rm k} = 20$ Tt, $R_{\rm k} = 1.6 \times 10^{-2}$ m, $T_{\rm d} = 1.4 \times 10^6$ K, $\rho_{\rm s} = 370 \times 10^3\,{\rm Tt\,m^{-3}}$, $V_{\rm d} = 0.54 \times 10^{-4}\,{\rm m\,s^{-1}}$ and $l \approx 2 \times 10^{-9}$ m.

Despite the considerably smaller size of the kernel obtained under these assumptions, the above arguments concerning its isothermality and the collisionless conditions for the daemon population remain valid.

Further refinement of the kernel structure should be pursued, in the first place, through a comprehensive analysis of the processes involved in the energy and mass exchange between the kernel and surrounding material of the Earth's IC.

5 SOME INFERENCES ON THE STRUCTURE OF THE EARTH'S INNER CORE

The existence of a daemon kernel at the Earth's centre and the associated strong energy generation offer the possibility of understanding a number of the following features of the Earth's IC revealed recently (Richards, 2000).

(i) It is usually believed that the IC is solid, firstly, because of a density jump at its boundary (assuming the outer liquid core to have the same composition) and, secondly, because the finite shear energy in its material permits one to reconcile the periods of normal oscillation modes of its model better with the observed periods (Dziewonski and Gilbert, 1971). However, one cannot be completely sure that the IC is fully solid (Stixrude and Brown, 1998). The calculations of Laio *et al.* (2000) show that pure Fe in the IC boundary conditions is 6% heavier than the material of the outer core, which removes the first argument. The observation of shear waves with the predicted velocity of 3.5–3.6 $\mathrm{km\,s^{-1}}$ (Okal and Cansi, 1998; Deuss *et al.*, 2000) argues for the presence of solid material in the IC. However, at frequencies $f > 0.1$ Hz, they are damped very strongly (with an amplitude proportional $10^{-13.6f}$ (Creager, 1992; Deuss *et al.*, 2000), which suggests an extremely non-uniform structure of the IC and even the presence in it of a liquid phase (Singh *et al.*, 2000; Vidale and Earle, 2000).

(ii) There is an anisotropy in the propagation velocity of longitudinal waves, with their velocity parallel to the Earth's axis of rotation being 3–4% larger than that parallel to the equator (Morelli *et al.*, 1986; Woodhouse *et al.*, 1986; Song and Helmberger, 1993). Anisotropy can be simulated within an axisymmetric approach in the form of a non-uniform IC having an inner central zone extended along the rotation axis, which has a higher P velocity (Creager, 1992; Durek and Romanowicz, 1999). The most probable cause for the anisotropy is believed to be preferential (approximately one third) orientation of the hcp crystals of the ε-Fe phase (Stixrude and Cohen, 1995) along the short basal-plane axes a and b, the direction in which the sound velocity exceeds by 12% that along the long c axis (for $T = 5700$ K, the length ratio $a : b : c = 1 : 1 : 1.7$) (see Steinle-Neumaunn *et al.* (2001) and references therein). Among causes for the orientation the magnetic field-induced Maxwell stresses (Karato, 1999; Buffett and Wenk, 2001) and structural changes in the ε-Fe crystals caused by strain (Wenk *et al.*, 1988) or their growth (recrystallization) (Jeanloz and Wenk, 1988; Buffett and Wenk, 2001) in the presence of solid-state convection can be put forward.

(iii) Seismic data reveal also a substantial azimuthal asymmetry in the IC structure. This refers both to the anisotropy, which on a large scale is asymmetric relative to the rotation axis (Stixrude and Brown, 1998) and seems to vary on a time scale of tens of years (Richards, 2000), and to the presence of small-scale (about 2 km in the outer 300 km layer) irregularities (Vidale and Earle, 2000). The latter may originate from variations in the seismic anisotropy, material composition and even melt pods in the solid matrix. The irregularities do not remain fixed with respect to observers on the Earth's surface, which produced numerous reports of observation of differential IC rotation with a rate of about 1–0.1° year^{-1}, primarily (but not always) in the easterly direction (see the references in the papers by Avsyuk *et al.* (2001) and Richards (2000)). These features in the IC structure cause strong damping (or scattering) of the longitudinal waves too.

It should be pointed out that, although heat convection in the IC is believed to be hardly likely (see for example Yukutake, 1998), nevertheless, all the above suggests that some part (if only a small part) of the material is in the molten state (Vidale and Earle, 2000) (everybody appears to believe that the temperature of the IC material is close to the melting point T_{m}).

The situation with interpretation of the above observations simplifies considerably, if the IC contains a powerful source of energy Q, which may drive a strong enough convection.

Convection sets in when the Rayleigh number (see for example Chandrasekhar, 1961)

$$Ra = \frac{\alpha g Q R_{\mathrm{ICB}}^2}{4\pi\nu\chi^2 c_{\mathrm{p}}} \geq Ra_{\mathrm{c}} \approx 3 \times 10^3.$$

In this case, if we take even the limiting values of the parameters quoted by Jeanloz and Wenk (1988) for a solid Fe core of radius $R_{\rm ICB}$ at $T = 0.85T_{\rm m}$ (thermal expansion coefficient $\alpha \approx 3 \times 10^{-6}\,{\rm K}^{-1}$; kinematic viscosity $\nu = 10^{12}\,{\rm m}^2\,{\rm s}^{-1}$ (see also Buffett, 1997); thermal diffusivity $\chi = 2.5 \times 10^{-5}\,{\rm m}^2\,{\rm s}^{-1}$ (in our opinion, $\chi \approx 10^{-6}\,{\rm m}^2\,{\rm s}^{-1}$ would be more reasonable); mass density $\rho = 13{,}000\,{\rm kg\,m}^{-3}$; specific heat $c_p = 500\,{\rm J\,kg}^{-1}\,{\rm K}^{-1}$; $g = 1\,{\rm m\,s}^{-2}$), then for $Q = 10$ TW we obtain $Ra = 0.8 \times 10^{11} \gg Ra_{\rm c}$; that is, the system is unstable to convection with a huge margin.

We readily see that in these conditions the viscosity, whose magnitude is very poorly known, exerts the largest effect on *Ra*.

For our values of Q, layers of a liquid phase are expected to form in the solid convective phase (for instance, in zones of concentrated creep, where (quasi)adiabatic shear belts are created), which, as we have seen, is in full accord with observations of irregularities in the IC. Then the effective viscosity of the system falls by many orders of magnitude. The Taylor number $Ta = (2\Omega R_{\rm ICB}^2/\nu)^2$, which characterizes the ratio of the Coriolis to viscous forces, that is, the effect of rotation on convection, may exceed its critical value $Ta_{\rm c} \approx 10$–100. Convection becomes two dimensional and takes on the form of rolls parallel to the rotation axis of the system (Chandrasekhar, 1961). In our case, this happens when $\nu \leq \nu_{\rm c} \approx 2\Omega R_{\rm ICB}^2/Ta_{\rm c}^{1/2} \approx 2.1 \times 10^7\,{\rm s}^{-1}$. This value of $\nu_{\rm c}$ exceeds by far the viscosity of molten Fe ($\nu \approx 10^{-5}\,{\rm m}^2\,{\rm s}^{-1}$) and even the lowest value $\nu \approx 10^6\,{\rm m}^2\,{\rm s}^{-1}$ quoted by Jeanloz and Wenk (1988) for solid Fe at $T \approx 0.85\,T_{\rm m}$. Therefore, there are strong grounds to believe that rotation does indeed make convection in the IC two dimensional.

Obviously enough, the existence in the IC of two-phase two-dimensional convection with rolls oriented along the axis of rotation sheds light to a certain extent on the nature of many of the above-mentioned observations. Among them are, firstly, the presence of an elongated anisotropic zone inside the IC and, secondly, the nature of the anisotropy in the velocity of longitudinal waves itself. Indeed, no assumptions on the strain or recrystallization of the ε-Fe crystals are actually needed. The fact (it can be checked by anybody in a tea cup) that elongated particles acted upon by a viscous medium in shear flow are oriented along the flux lines, which in the case of roll convection in a rotating system lie exactly in planes normal to the rotation axis, appears convincing enough.

The time-varying azimuthal irregularities (including those of a small-scale nature) should naturally appear in large-scale turbulent convection of a multiphase medium, with the solid phase prevailing. The latter makes understandable the generation and propagation in the IC of shear waves with a very strong damping, which grows rapidly with a decrease in their length. If the convection is of the roll character, probing the IC with seismic waves in different directions and at different times may produce the impression of differential core rotation, with its measured velocity being different depending on the actual conditions of observation.

6 CONCLUSIONS

The discovery of relic Planckian black holes with $m \approx 2 \times 10^{-8}$ kg, which carry several electronic charges and make up the DM of the Galactic disc, leads to a number of far-reaching implications of a fundamental nature. It appears that it offers us the long-awaited key, which will provide a solution from the same standpoint for not only new but many other, long-standing old problems, without invoking various *ad hoc* hypotheses.

Our experiments have revealed a daemon population in NEACHOs and showed that some of these objects are captured into GESCOs. As a result, because these objects are slowed down by the material of the Earth, they end up after a few months at its centre and build up there to have formed by this time a kernel about 20 Tt in mass and 1 m or less in size. (These estimates can, of course, be revised somewhat if the numbers of the positive and negative daemons in the Universe are different or they have different efficiency of capture by the Earth.)

Despite its colossal density, the daemon matter of the kernel resides in the state of a physically exotic collisionless plasma. Indeed, because of the infinitesimal cross-section (about $10^{-68}\ \mathrm{m}^2$) and a low thermal velocity ($V_\mathrm{d} \approx 0.1\ \mathrm{cm\,s}^{-1}$ at a temperature of about 10 MK!), direct collision of two daemons in the kernel occurs once in approximately 1 Tyears. In fact, inside the Earth there is a laboratory for simulation of the processes taking place in the Sun as well as, on an immeasurably larger scale, in quasars and active galactic nuclei! Nevertheless, it is clear that pairwise interaction of daemons should not produce, as a rule, a noticeable release of energy.

The existence of a daemon kernel removes a few well-known problems in the physics of the Earth and, possibly, of other planets as well (*e.g.* excess heat fluxes of the Jupiter, Saturn and Neptune, and the generation of the weak magnetic fields of Mercury and Mars).

Primarily, this is the old problem of the energy balance of the Earth, which is that known sources are capable of providing only approximately half the observed heat flux. It appears that the decay of daemon-containing Fe nuclei (more precisely, their protons) occurring in a thin outer layer of the kernel provides a solution to this problem. This also suggests reasons for convective motion in the outer core, which is believed to be necessary for generation of the geomagnetic field (the problem of the actual place of its generation now needs additional studies).

The numerous problems revealed by the recent studies of the IC are likewise solved. The presence of a powerful (about 10 TW) source of energy inevitably gives rise to convection of the mixture of solid and liquid material (Fe). An analysis based on reasonable assumptions shows that the rotation of the Earth organizes convective motions in the form of rolls parallel to the rotation axis of the Earth. Orientation of elongated ε-Fe crystals by these motions accounts fully for the anisotropy of seismic wave propagation in the IC. The existence of two-phase convection explains the nature of small-scale irregularities in the IC, and its two-dimensional character can shed light on the reasons for the ambiguities in the measurements of the differential IC rotation rate; maybe, it does not rotate differentially at all, but the existence of convective rolls is capable of simulating rotation, which is determined from the phase shift between seismic waves passing through several rolls. The existence in the Earth of a superdense kernel surrounded by a thick and hot ($T \geq 10^4$ K) plasma envelope of Fe in the supercritical state may possibly provide an explanation for the nature of some observations which remain unclear (of the kind of the quasi periodic movement of the Earth's poles, etc.), which apparently originate from the mobilities of the IC (Avsyuk *et al.*, 2001), and now of the kernel, caused by the tidal interactions in the Earth–Moon–Sun system.

The existence of a powerful unconventional nuclear source of heat under the mantle clarifies immediately the nature of the fixed hot spots and plumes on the Earth's surface and provides also an explanation for the high ^{3}He-to-^{4}He ratio found in them and the small cross-section (less than 100 km) of the conjectured ascending hot flows (Foulger and Pearson, 2001), which quite frequently escape detection by seismic methods. We may also recall the suggestion of the existence of superplumes with thermal contrasts of up to about 1000 K, which was put forward more than once but was never substantiated because of the absence of known sources of energy under the mantle. The high ^{3}He-to-^{4}He ratio itself (and even its absolute value of about 10^{-4}, but not larger) in the plumes can be understood, if one assumes that the decay of even one of approximately 10^2–10^3 Fe nuclei excited in their capture by daemons is accompanied, besides the emission of nucleons and their clusters of the type of ^{4}He and the like, by ejection of only one ^{3}He (or ^{3}T) nucleus. However, this is a rather low value, if we compare it with the reaction yield $^3He(^3T)$-to-^4He ratio of about 0.3 for the case of Fe nuclei, which become rapidly (and, possibly, even locally) overheated by high-velocity particles (cosmic rays, etc., Le Couteur, 1959). The observed ratio of $^3He(^3T)$ to ^4He of about 10^{-4} can be accounted for by the almost isothermal evaporation of nucleon clusters from the Fe nucleus heated gradually to a nearly constant boiling temperature by the daemon, which descends, step by step, down to the ground level in the nucleus owing to the stepwise energy transfer to the most stable evaporating clusters of the type of ^4He.

There is also a certain possibility that the daemon captures a ^4He nucleus, with its transformation after the proton decay to radioactive ^3T and, subsequently, to ^3He. It is conceivable that the daughter nuclei O, F and Ne likewise undergo similar transformations as well.

It appears that we have finally found the missing piece that has long been searched for by some researchers, that nuclear reaction eluding the grasp that is running (or was active in the past) in the interior of the Earth and that produces a substantial amount of the ^3He daughter isotope (Anufriev, 1985). Thus, we are witnessing the erection of a real physical foundation for fairly non-standard conclusions considering the IC as a supplier of ^3He, which were drawn recently by Porcelly and Halliday (2001) based on a comprehensive analysis of a fairly limited totality of the presently available findings and observations.

Taking into account the role of the daemon kernel provides one more argument for the fast (and hot) cosmogony of the Solar System, which considers it as the limiting case of a close binary star (Drobyshevski, 1978; 1996), because it removes the need for invoking the currently occurring (or recent) internal gravitational separation of matter as the missing additional source of heat in the Earth. Also the production of ^3He (and, possibly, ^2D, Ne, etc.) at the kernel–IC interface removes apparently the only objection to the hypothesis of the originally molten Earth, which implies that the melt should have lost the primary rare gases rapidly.

The significance of the presence of heat sources in the lower mantle and under it for global tectonics is also obvious. It is usually assumed that the Earth's heat decreases with time. While in the Protoarchaean there were many convective cells in the mantle, and the convective motions were intense, which gave rise to formation of numerous small continents, the gradual decrease in the heat flux brought about rearrangement and merging of the cells and, accordingly, formation of large continents. This activity decayed possibly to a minimum sometime about 2 Gyears ago (Khain, 1991; Dalziel, 1997) that is when the mass of the kernel in the Earth was one half its present value. One might conjecture that tectonic activity has been growing thereafter continuously (the formation and break up of the supercontinents Rodinia (about 1000–750 Myears ago), Pannotia (about 540 Myears ago) and Pangea (about 200–150 Myears ago) (Dalziel, 1997) and will increase in intensity in the future. Without questioning the valve role of individual continents in the rearrangement of convective motions in the mantle in the present epoch (Trubitsyn, 2000), one can nevertheless predict that the steady growth of energy liberation from the Earth's centre will enhance convection, which will again entail an increase in the number of cells and, as a consequence, in the number of smaller floating continents. The growth of liberated energy will be accompanied by the corresponding flux increase of the simultaneously forming light isotopes (including ^3He and Ne).

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