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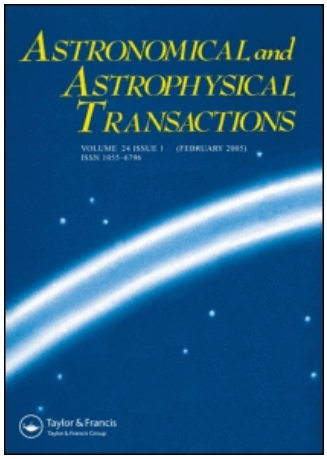

Astronomical & Astrophysical Transactions
The Journal of the Eurasian Astronomical Society
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713453505

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Online Publication Date: 01 April 2004
To cite this Article: Drobyshevski, E. M. (2004) 'The daemon kernel of the sun', Astronomical & Astrophysical Transactions, 23:2, 173 - 183
To link to this article: DOI: 10.1080/10556790310001612535
URL: http://dx.doi.org/10.1080/10556790310001612535

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Astronomical and Astrophysical Transactions
Vol. 23, No. 2, April 2004, pp. 173–183

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THE DAEMON KERNEL OF THE SUN

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(Received 30 June 2003)

Daemon-stimulated proton decay is capable of providing an appreciable part of the Sun luminosity $L_\odot$ as well as non-electron flavour component in the solar neutrino flux. This follows, firstly, from our experiments on detection of negative daemons in Earth-crossing orbits, which give $\Delta\tau_{ex} \approx 1\,\mu s$ for the decay time of a daemon-containing proton, and, secondly, from an estimate of the total number of daemons which could be captured by the Sun from the Galactic disc (up to about 2.4×10^{30}). Because of their huge mass (about 3×10^{-5} g), the captured daemons settle down to the Sun's centre to form there a kernel a few centimetres in size. The outside protons diffuse gradually into the kernel to decay there with a release of energy. If this process generates a noticeable part of $L_\odot$, physically sound estimates of the parameters of an isothermal kernel can be obtained under the assumption that it consists mainly of negative daemons. Proton decay maintains a high temperature of the daemon gas (up to about 10^{11}–10^{12} K), which makes it physically collisionless and prevents kernel collapse into a black hole.

Keywords: Dark matter; Proton decay; Solar energetics; Solar neutrinos

1 INTRODUCTION

We start with presenting a remarkable coincidence. Assuming that the dark matter (DM) of the Galactic disc to contain daemons (dark electric matter objects), that is electrically charged Planckian elementary black holes (for $Ze = -10\,e$, $m = 3.07 \times 10^{-5}$ g and $r_g = 1.8 \times 10^{-33}$ cm (Drobyshevski, 1998)), the Sun could have captured and accumulated in 4.5 Gyears up to $N \approx 2.4 \times 10^{30}$ such particles (Drobyshevski, 1996). Further, as follows from our experiments on the detection of negative daemons (Drobyshevski *et al*., 2003a), the decay time of a daemon-containing proton is estimated to be $\Delta\tau_{ex} \approx 10^{-6}$ s. If the time needed for a daemon to capture a proton is much less than $\Delta\tau_{ex}$, and the proton decay liberates $m_p c^2 = 938\,\text{MeV} = 1.5 \times 10^{-3}$ erg, the total energy release will be $L_d = (2.4 \times 10^{30}) \times (1.5 \times 10^{-3})/10^{-6} = 3.6 \times 10^{33}\,\text{erg s}^{-1}$, which is almost equal to $L_\odot = 3.86 \times 10^{33}\,\text{erg s}^{-1}$. If proton decays provide about one third of $L_\odot$, this would solve the problem of both the deficiency of solar electron neutrinos and the presence of other flavour neutrinos, even without invoking their oscillations. Therefore, we accept for further estimates $N_- \approx 10^{30}$. This value correlates with the lower bound on the amount of DM in the Galactic disc suggested by Bahcall *et al*. (1992), as well as with the present-day general trend to reduce somewhat the amount of DM in the disc (see for example Kuijken (1999)).

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ISSN 1055-6796 print; ISSN 1476-3540 online © 2004 Taylor & Francis Ltd
DOI: 10.1080/10556790310001612535

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We showed earlier that the daemon-assisted catalysis of proton fusion by the β-decay-controlled reaction $10\mathrm{p} \rightarrow 2\alpha + 4\mathrm{e}^{+} + 4\nu_{\mathrm{e}} + 2\mathrm{p}$ (+53.5 MeV), with reactions occurring in bursts at intervals of about 0.3×10^{-8} s, exceeds by a factor of about 5 the $L_{\odot}$ level (Drobyshevski, 1996). Hence it followed that about four fifths of the daemons would be poisoned by capture of heavy nuclei and, thus, would not take part in the catalysis. This led to the conclusion that the daemon recovers its catalytic properties in $\tau_{\mathrm{ex}} \approx 10^{-7}$–$10^{-6}$ s as a result of the decay of daemon-containing protons in the captured heavy nucleus (neon, iron, etc.) (Drobyshevski, 2000a,b).

For $Z = 10$, the ground state of the daemon is located inside the captured nucleus, and for $Z_{\mathrm{n}} \geq 24/Z$, even inside one of the protons of the nucleus. The daemon binding energy in a nucleus is, in these conditions, $W \approx 1.8 Z Z_{\mathrm{n}} A^{-1/3}$ MeV (Cahn and Glashow, 1981). For instance, for an iron nucleus, $W \approx 120$ MeV, which, in the case of its capture, would result in a rapid evaporation of about 15 of its nucleons, including their clusters (α particles, etc.), followed by the decay of daemon-containing protons, one after another, in the remnant of the nucleus.

Based on the expected emission of nucleons (and of electrons from the atomic shells), as well as on the fast decay of daemon-containing nucleons, a process that reduces gradually the Z_{n} of the nuclear remnant to $Z_{\mathrm{n}} < Z$ and makes possible the capture of a new nucleus with $Z_{\mathrm{n}} > Z$, we constructed a simple ZnS(Ag) scintillation detector of low-velocity daemons ($V \leq 30$–$50\,\mathrm{km\,s^{-1}}$) which are members of the Solar System. The instrument detected a flux of highly penetrating particles with the expected properties (Drobyshevski, 2000c, 2002b). The flux suffers strong seasonal variations with a half-year period (Drobyshevski *et al.*, 2003b). We detected also objects populating contracting geocentric orbits with perigees inside the Earth (Drobyshevski *et al.*, 2003a).

An analysis of experimental data permitted us to estimate also the time of consecutive decay of each daemon-containing proton in the nuclear remnant as $\Delta\tau_{\mathrm{ex}} \approx 10^{-6}$ s, which exceeds noticeably the value cited before, $\tau_{\mathrm{ex}} \approx 10^{-7}$–$10^{-6}$ s, which is the time until the daemon frees itself completely of a nucleus of neon, iron, etc., captured by it.

This contradiction increases the real value of τ_{ex} to about 10^{-5} s and more, thus casting doubt on the scenario based on the daemon-assisted catalysis of proton fusion in the Sun. This scenario contained, besides the possible catalyst poisoning by heavy nuclei, a few more weak points in the reasoning (Drobyshevski, 1996), which could hopefully be removed in the future by a more careful analysis. They are as follows.

(i) A burst of fusion reactions in the shell surrounding the daemon, whose protons are all in stable levels, releases an energy of about 53.5 MeV (see above). As follows from the momentum conservation law, most of the energy should be carried away, as a rule, by the lightest of the reaction products, that is ν_{e}, e^{+} and p. Therefore, it is hard to expect that both α particles formed in the process could easily leave the daemon surroundings. A daemon residing inside the α particle in the ground state has a binding energy $W \approx 22$ MeV and, therefore, one α particle could be expected to remain bound to the daemon. The rapid capture (much less than 1 μs) by this system of new protons will initiate formation of new unstable compound nuclei of ^{5}Li, ^{6}B, etc., with an energy release hardly high enough to remove the daemon's poisoning by ejecting a nuclear cluster of the type of an α particle or a heavier nucleus from the vicinity of the daemon. This leads us to an apparently inevitable conclusion that a major part of the energy produced by daemons in the Sun is liberated not through proton fusion catalysis but rather through proton decay in the compound nucleus with $Z_{\mathrm{n}} \leq 10$, which forms or resides in a more or less stable state in the vicinity of the daemon. Note that the mesons, which are apparently emitted in proton decay, interact with the nucleons of this nucleus so weakly that, instead of giving rise to its disintegration

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(Ashery *et al*., 1981), as a rule carry away their energy and decay in the surrounding medium with the production of neutrinos of different flavours.

(ii) Another problem is the settling down of daemons to the Sun's centre. This settling down was traditionally assumed to create three difficulties.
   (a) The fusion of daemons transforms them to conventional matter (Markov, 1966), the process releasing negligible heat in the case of the Sun (about $10^{-5} L_{\odot}$).
   (b) The daemons merge to form one black hole (about 3×10^{25} g); the black-hole scenario was analyzed more than once (Hawking, 1971; Clayton *et al*., 1975; Markovič, 1995) and, thus far, has not got observational support, because it does not solve any problem.
   (c) While solar energetics are supported to some extent by daemon-assisted catalysis of proton fusion, hydrogen (and other light elements) present in a small volume near the centre would transform very soon to nuclei with $Z_{\mathrm{n}} > Z$, and the catalytic reactions of fusion would stop.

In an attempt to avoid the settling down of daemons to the Sun's centre, a process that appeared unfavourable, we pointed out the possibility of speeding on fast daemons ($V \approx 1000\,\mathrm{km\,s^{-1}}$) in bursts of fusion reactions, which would occur primarily on their trailing side if the captured proton shell was somehow deformed or oriented by the resistance of the surrounding matter (Drobyshevski, 1996). Straightforward estimates of this possibility, however, show it to be not efficient enough in the solar conditions.

We are going to study below the consequences of the daemons' settling to the Sun's centre and see that this process is by far not so unfavourable as would seem at first glance. The daemon kernel thus formed is capable of providing a noticeable part of the Sun's luminosity not by catalysing the fusion reactions but rather through daemon-stimulated proton decay (one can see here an analogy with possible consequences of a monopole catalysis of a proton decay (Rubakov, 1981; see also Klapdor-Kleingrothaus and Zuber (1997) and references therein)). This process, as well as the recently discovered oscillations of atmospheric (Kajita and Totsuka, 2001), solar (Ahmad *et al*., 2002), and reactor (Eguchi *et al*., 2003) neutrinos, reduces considerably the acuteness of the solar neutrino deficiency problem, because now there is about one neutrino per approximately 1 GeV of released energy, rather than approximately 10 MeV, as was the case with hydrogen fusion.

By way of introduction to the problem, we are going to remind the reader in Section 2 of our earlier conclusions (Drobyshevski, 2002a; 2003) concerning the properties of the Earth's daemon kernel, which provides the lacking approximately 10–20 TW of heat, as well as the flow of ^{3}He and other light gases emanating from the interior of our planet.

Next (Sec. 3) we shall turn to the Sun. The interaction of the solar kernel with surrounding matter, primarily the hydrogen plasma, and not iron, as is the case with the Earth, has specific features. Energy liberation in the kernel extends not through a thin surface layer but over a substantial part of its volume. However, an attempt at understanding the processes occurring in the kernel made up of equal numbers of negative and positive daemons (Sec. 4) yields at a noticeable energy release (some per cent of $L_{\odot}$) an unphysical result for the daemon temperature, namely about 10^{14} K! To be able to construct physically non-contradictory models, one will have to admit a nearly complete absence of positive daemons (Secs. 5 and 6).

In the final section, Section 7, we note that an analysis of the possible consequences of a daemon kernel formation in the Sun and of the daemon-stimulated proton decays in it leads one to a conclusion that these reactions could possibly play an important part in the total energy balance of the Sun and emission of different flavour neutrinos, as well as the fact that the kernel contains apparently only negative daemons then. The desirability of an integrated study of daemon kernels in a large variety of celestial objects, starting with the Earth and ending with the pulsars and galaxies, is pointed out.

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2 THE DAEMON KERNEL OF THE EARTH

A situation similar in many respects to the Solar case is realized inside the Earth and other planets. As follows from measurements of the daemon flux through our detector and of the rate of their slowing down in crossing the Earth, the latter accumulated $N_- \approx 10^{23}$ negative daemons in 4.5 Gyears of its existence (Drobyshevski, 2000c; 2002a; 2003).

If we refuse to be frightened by the above difficulties and follow a straightforward logic, we may admit the existence inside the Earth of a kernel of daemons which interact with iron nuclei to liberate a certain energy and to produce isotopes of light gases such as ^{2}H, ^{3}H, ^{3}He and ^{4}He. Indeed, judging from many available studies, about 20 TW of energy (from the total flux of about 40 TW) emanate from the Earth's core. The origin of this energy excess, besides the flux of light rare gases, remains unclear to date (Calderwood, 2001). Intense efforts undertaken in the recent decades to unravel its nature still have not met with success (if we disregard notoriously *ad hoc* hypotheses) (Calderwood, 2001; Helfrich and Wood, 2001; Porcelly and Halliday, 2001). In accordance with our measurements, we assumed this source (its intensity was accepted for the purpose of estimation as $Q = 10\,\mathrm{TW} = 10^{20}\,\mathrm{erg\,s^{-1}}$) to be consecutive disintegration of the protons in iron nuclei captured by the kernel daemons from the surrounding material of the Earth's inner iron core. The decay time of a daemon-containing proton involving liberation of energy $m_p c^2 = 938\,\mathrm{MeV}$ is, as already mentioned, $\Delta\tau_{\mathrm{ex}} \approx 1\,\mu\mathrm{s}$ (Drobyshevski *et al.*, 2003a). The daemon is capable of capturing another iron nucleus after the charge of the previous nuclear remnant has dropped as the result of proton disintegration to $Z_{\mathrm{n}} = Z - 1 = 9$ (*i.e.* the remnant corresponds to the fluorine nucleus with an excess of neutrons, so that in a few seconds it will transform to the neon nucleus). This recapture is accompanied by an energy release $\Delta W \approx 18 \times (26 \times 56^{-1/3} - 9 \times 20^{-1/3}) = 63\,\mathrm{MeV}$, enough to evaporate nine to ten nucleons (and their clusters of the type ^{2}H, ^{3}H, ^{3}He, ^{4}He, etc.) from the newly captured nucleus in about 10^{-8} s. After disintegration of about ten to eleven protons in this nuclear remnant in $\tau_{\mathrm{ex}} \approx 10 - 11\,\mu\mathrm{s}$, recapture may again occur. If recapture of nuclei by a daemon and disintegration of their protons take place continuously, such a daemon generates an energy $q \approx 1.5 \times 10^3\,\mathrm{erg\,s^{-1}}$.

To gain an idea of the possible parameters of the kernel and of the daemon plasma in it, we accepted the following (Drobyshevski, 2002a; 2004).

(i) The kernel contains also an equal number of positive daemons ($N_+ = N_- \approx 3 \times 10^{23}$), which gives $M_{\mathrm{k}} = 1.8 \times 10^{19}$ g for its total mass.

(ii) The gas kinetic pressure $p_{\mathrm{s}} = n_{\mathrm{s}} k T_{\mathrm{k}}$ of the daemon plasma at the kernel surface of radius R_{k} is equal to the pressure at the Earths centre, $p_{\mathrm{c}} = 3.7 \times 10^{12}\,\mathrm{dyn\,cm^{-2}}$ (*i.e.* we neglect the pressure of the other plasma components, such as the pions, positrons and electromagnetic radiation).

(iii) The density of the surrounding material, that is iron, is $\rho_{\mathrm{c}} = 13\,\mathrm{g\,cm^3}$, and its temperature $T_{\mathrm{c}} = 10^4$ K (in present-day models of the Earth, the central temperature $T_{\mathrm{c}} = (5.5 - 6.5) \times 10^3$ K); thus, in this stage we almost neglect the action of the kernel on the structure of the adjoining central zone of the Earth's inner core.

(iv) Iron nuclei ($Z_{\mathrm{n}} = Z_{\mathrm{Fe}} = 26$) diffuse from outside into the kernel with a diffusion coefficient $D = \lambda_{\mathrm{Fe}} V_{\mathrm{Fe}}/3$. Here $V_{\mathrm{Fe}} = (3kT_{\mathrm{c}}/m_{\mathrm{Fe}})^{1/2}$, and the mean free path λ_{Fe} is determined by the Coulomb interaction with near-surface daemons (with due account of the nuclear remnants captured by them $Z_{\mathrm{eff}} \approx 5$) (see for example Alfvén and Fälthammar (1967));

$$\lambda_{\mathrm{Fe}} = \frac{(3kT_{\mathrm{c}})^2}{8\pi \ln\Lambda\, e^4 Z_{\mathrm{Fe}}^2 Z_{\mathrm{eff}}^2 n_{\mathrm{s}}}, \tag{1}$$

where $\ln\Lambda \approx 10$ is the Coulomb logarithm.

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(v) The kernel is approximated by a self-gravitating isothermal gas sphere, the material of which is strongly concentrated towards the centre. Within most of its volume, $\rho \approx \rho_s R_k^2/R^2$, hence $M(R) \approx M_k R/R_k$ and $\rho_m = 3M_k/4\pi R_k^3 \approx 3\rho_s$ (Chandrasekhar, 1939). The concentration of material towards the centre is characterized by the ratio of the pressure at the centre, which can be only higher than $p_0 = 3GM^2/8\pi R_k^4$ at the centre of a uniform sphere (Eddington, 1926), to the pressure ρ_s at the outer boundary (we shall see that $p_0 \gg p_s$). The isothermality is accounted for both by the major energy release occurring near the kernel surface and by the mean free path of a daemon being, as a rule, comparable with R_k.

(vi) The characteristic time scale governing the diffusion of iron nuclei into the kernel is the time $\tau_{ex} = 10 - 11\,\mu s$ between consecutive iron capture events. For $n_{Fe} \gg n_s$, an iron nucleus diffusing into the kernel penetrates to the depth where it is certain to meet a free *negative* daemon, in a time $\tau \approx 2\tau_{ex} n_{Fe}/n_s$. In this case, the depth of diffusion (and of energy release) will be $l = (D\tau)^{1/2} \ll R_k$, and for the liberated energy we can write

$$Q = 4\pi R_k^2 l q \frac{n_s}{2}. \tag{2}$$

Taking $n_s \approx n_m/3 = (N_- + N_+)/4\pi R_k^3$, $p_s = p_c$, and substituting the above relations for l, D and λ_{Fe}, we obtain the following dependence of R_k on Q and other parameters:

$$R_k = (3 \ln \Lambda\, e^4 Z_{Fe}^2 Z_{eff}^2 m_{Fe}^{1/2})^{1/4} [\pi n_{Fe} \tau_{ex} (3kT_c)^{5/2}]^{-1/4} \left(\frac{Q}{q}\right)^{1/2}. \tag{3}$$

Substituting now $T_c = 10^4$ K, $n_{Fe} = \rho_c/m_{Fe} = 1.4 \times 10^{23}\,cm^{-3}$, $Z_{Fe} = 26$, $Z_{eff} = 5$ and $q = 1.5 \times 10^3\,erg\,s^{-1}$, we obtain $R_k = 1.6 \times 10^{-10} Q^{1/2}$ cm (it does not depend on M_k) and, accordingly, for $Q = 10^{20}\,erg\,s^{-1}$, $R_k = 1.6$ cm, $\rho_s = 0.35 \times 10^{18}\,g\,cm^{-3}$, $l = 2 \times 10^{-7}$ cm and $T_k = 2.4 \times 10^6$ K, which yields for the daemon thermal velocity $V_d \approx 60\,\mu m\,s^{-1}$.

For the kernel parameters obtained, the daemon mean free path for Coulomb collisions is about 10^{-5} cm, but the time in which one daemon encounters another in at least one physical collision for the cross-section πr_g^2 is in excess of the age of the Universe. In this sense, the daemon plasma of the kernel is collisionless.

3 THE DAEMON KERNEL OF THE SUN: MAIN CHARACTERISTICS AND ASSUMPTIONS

The structure of the kernel of the Sun and the main processes occurring in it should differ from those of the Earth for at least three reasons.

(i) The total number of daemons, both negative and, presumably, positive (for $N_- = N_+$) may be as high as $N = N_- + N_+ \approx 2.4 \times 10^{30}$ (Drobyshevski, 1996), a value substantially larger than that derived from our experiments for the Earth ($N_- \approx 3 \times 10^{23}$). In view of the current trend towards decreasing the amount of DM in the Galactic disc (Kuijken, 1999), this value should possibly be reduced, say, to $N_- \approx 10^{30}$. Hence it follows that the daemon-assisted fraction of the total Sun luminosity can be only $L_d = N_- q = 1.5 \times 10^{33}\,erg\,s^{-1}$.

(ii) In contrast with the Earth, where the kernel lies inside the iron core, the material at the centre of the Sun resides in the state of ideal gas.

(iii) Because the particles diffusing into the solar kernel from the outside are primarily protons, $Z_n = Z_p = 1$ and $\tau_{ex} = \Delta\tau_{ex} \approx 10^{-6}$ s. Therefore, as soon as one of the ten protons

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captured by a daemon has been digested, a new proton can be captured. Thus, the effective charge Z_{eff} of a negative daemon in the outer active zone of the kernel has, as a rule, two values, 0 or 1.

In view of the above, we shall use a simplified model of the Sun in order to make the calculations less complicated and to gain at least a very general idea of the characteristics of the solar kernel. We shall assume the Sun to consist of hydrogen with the parameters at the centre close to those accepted in zero-age Sun models (see for example Turck-Chiéze *et al.* (1988)), namely $\rho_{\text{co}} = 90\,\text{g cm}^{-3}$, $T_{\text{co}} = 1.5 \times 10^7\,\text{K}$ and $p_{\text{co}} = 2.23 \times 10^{17}\,\text{dyn cm}^{-2}$. Within $R \approx 0.001 R_\odot$ from the centre, the Sun's density is almost constant. A comparison of the gravitation in a standard Sun with that developed by the kernel shows them to become comparable at a distance $R_{\text{x}} \approx (3M_{\text{k}}/4\pi\rho_{\text{co}})^{1/3} = 0.6 \times 10^{-3} R_\odot$. If about one fifth to one third of all the energy is liberated at the Sun's centre, the whole near-centre zone will be in a state of convection, that is have a quasi-adiabatic structure described by the equation of state $p = \kappa\rho^\gamma$. For $p = p_{\text{co}}$, $\rho = \rho_{\text{co}}$ and $\gamma = 5/3$, we have $\kappa = 1.23 \times 10^{14}\,\text{cm}^4\,\text{g}^{-2/3}\,\text{s}^{-2}$.

Integration of the equation of hydrostatic equilibrium which takes into account only the kernel gravitation yields for the hydrogen density at the kernel surface, $R = R_{\text{k}} \ll R_{\text{x}}$,

$$\rho_{\text{ps}}^{\gamma-1} = \rho_{\text{co}}^{\gamma-1} + \frac{GM_{\text{k}}}{\kappa}\frac{\gamma-1}{\gamma R_{\text{k}}} \tag{4}$$

or

$$\rho_{\text{ps}}^{2/3} = \rho_{\text{co}}^{2/3} + \frac{2GM_{\text{k}}}{5\kappa R_{\text{k}}} = a + bR_{\text{k}}^{-1} = \Theta, \tag{5}$$

where $a = 20.1\,\text{g}^{2/3}\,\text{cm}^{-2}$ and $b = 1.33 \times 10^4\,\text{g}^{2/3}\,\text{cm}^{-1}$ for $M_{\text{k}} = 6.14 \times 10^{25}\,\text{g}$ (or $b = 0.8 \times 10^4\,\text{g}^{2/3}\,\text{cm}^{-1}$ for $M_{\text{k}} = 3.7 \times 10^{25}\,\text{g}$; see below in Sec. 5).

The solar plasma temperature at the kernel's surface

$$kT_{\text{ps}} = \frac{m_{\text{p}}\kappa(a + bR_{\text{k}}^{-1})}{2} = \frac{m_{\text{p}}\kappa\Theta}{2}, \tag{6}$$

Consider now two variants of the Sun kernel model similar to the way used with the kernel of the Earth.

4 KERNEL OF NEGATIVE AND POSITIVE DAEMONS

We shall start, as before, with the energy balance, and assume for definiteness that $Q = L_{\text{d}} \approx 10^{33}\,\text{erg s}^{-1}$ and $N = N_+ + N_- = 2 \times 10^{30}$. Thus, we assume that, in contrast with the Earth, roughly about one half of all negative daemons are involved in energy liberation and, therefore, the layer thickness l to which protons have to diffuse into the isothermal kernel should make up a sizeable fraction of its radius. For $l \approx R_{\text{k}}/2$, half of the kernel mass is involved; at this depth the concentration $n_{\text{d}} \approx 4n_{\text{s}}$. Therefore, we shall consider the parameters of energy release for an average depth of about $l/2 \approx R_{\text{k}}/4 - R_{\text{k}}/3$, where the negative daemon concentration $n_-(= n_+) = n_{\text{d}}/2 \approx n_{\text{s}}$. Thus, although now we are using the approximation of a thick energy-releasing spherical layer, we retain the quasiplanar approach.

In these conditions, the energy balance can be written

$$Q = 4\pi R_{\text{k}}^2 lqn_{\text{s}}, \tag{7}$$

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where $n_s = N/4\pi R_k^3$, and $l = (V_{ns}\lambda_p\tau/3)^{1/2}$ with

$$\lambda_p = \frac{(3kT_{ps})^2}{8\pi \ln\Lambda\, e^4 Z_p^2 Z_{eff}^2 n_s} \tag{8}$$

and $\tau = \tau_{ex} n_{ps}/n_s$. Here $Z_p = 1$ and $Z_{eff} = 10$ because of the presence of positive daemons with a concentration $n_+ \approx n_s$, whose charge is not compensated by electrons because of ionization at a high T_{ps}.

Using the above adiabatic Eqs. (4)–(6) connecting ρ_{ps}, T_{ps}, and p_{ps} in the kernel gravitation field as functions of R_k, we find from Eqs. (7) and (8) that

$$R_k = \left\{ \left[\left(\frac{2}{3}\right)^{3/2} \frac{\ln\Lambda\, e^4 Z_p^2 Z_{eff}^2}{\pi m_p \tau_{ex} \kappa^{5/2}} \right]^{1/4} \left(\frac{Q}{q}\right)^{1/2} - \frac{2GM_k}{5\kappa} \right\} \rho_{co}^{-2/3}; \tag{9}$$

hence $R_k = 2.5 \times 10^3$ cm. The pressure p_{ps} of the solar material at this radius equals 4×10^{17} dyn cm^{-2} for $\rho_{ps} = 128$ g cm^{-3} and $T_{ps} = 1.9 \times 10^7$ K. To balance p_{ps}, the kernel daemons must have the temperature $T_k \approx 3 \times 10^{14}$ K, which is substantially higher than the proton rest mass ($2m_p c^2/3k \approx 7.2 \times 10^{12}$ K). This situation has apparently no physical sense. It results actually from our requirement that the proton decay initiated by negative daemons provide a sizeable fraction of $L_\odot$. In order for the protons to penetrate into the kernel to a depth large enough to be acted upon by an appreciable part of daemons, the volume concentration of the daemons must be fairly low; that is, the kernel must be loose and have a large radius. It is this that requires the uureasonably high daemon temperature.

5 KERNEL OF NEGATIVE DAEMONS: INCLUSION OF THEIR THERMAL IONIZATION

The situation changes radically if the daemons in the Sun are only (or predominantly) of the negative species. There is nothing particular in this assumption, especially if we recall that there are almost no antiparticles in our Universe. The flying apart of the kernel components due to strong electric field is precluded by their gravity which, by definition, for daemons is stronger than the electric field. The excess electrical charge of daemons in the kernel can also be compensated by both protons and positrons, which are produced in the decay of the latter.

We take again $Q = 10^{33}$ erg s^{-1}, but now $N \equiv N_- = 1.2 \times 10^{30}$ and $M_k = 3.7 \times 10^{25}$ g. The parameters of the solar material near the kernel vary adiabatically in accordance with Eqs. (4)–(6), but with $b = 0.8 \times 10^4$ g$^{2/3}$ cm^{-1}. We retain the thick diffusion layer approximation, in which the protons have to diffuse fairly deep into the kernel, where $n_d \approx 2n_s$ (*i.e.* $l \approx R_k/2$). We adopt that during the time interval $\tau \approx \Delta\tau_{ex}\, n_p/2n_s$ protons ($Z_p = 1$) diffuse through a mixture of daemons whose charge is fully compensated by ten captured protons ($Z_{eff} = 0$; it is an analogue of the antineon atom with the first ionization potential $\chi = 21.56 \times 1837$ eV $= 39.6$ keV) and thermally single-ionized antineon atoms ($Z_{eff} = Z_\alpha = 1$) (positive daemons, if present, are fully ionized, so that consideration in their presence of thermal ionization of negative daemons, which we are going to do below, would hardly affect λ_p in the estimates we made in the preceding Sec. 4).

Then the proton mean free path in a daemon plasma will be

$$\lambda_p = \frac{(3kT_{ps})^2}{8\pi \ln\Lambda\, e^4 Z_p^2 Z_\alpha^2 2n_s \alpha}, \tag{10}$$

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where the degree α of ionization is determined from the Saha equation (see for example Allen (1973)) for $T = T_{ps}$, with due inclusion of the fact that the pressure of the proton component is $p_{ps}/2$:

$$\alpha = 2p_{ps}^{-1}\left[\left(\frac{U_1}{U_0}\right)^2 2(2\pi m_p)^{3/2}(kT_{ps})^{5/2}h^{-3}\exp\left(\frac{-\chi}{kT_{ps}}\right)\right] \tag{11}$$

or, because $T_{ps} = (\kappa m_p/2k)\Theta$ and $p_{ps} = \kappa\Theta^{5/2}$,

$$\alpha = 2\pi^{3/2}\frac{U_1}{U_0}m_p^4h^{-3}\kappa^{3/2}\exp\left(\frac{-2\chi}{\kappa m_p\Theta}\right). \tag{12}$$

For neon, the distribution functions ratio $U_1/U_0 = 5.5$ (Allen, 1973); here h is the Planck constant.

Now we can write the energy balance

$$Q = 4\pi R_k^2 q l 2n_s \tag{13}$$

in the form

$$Q = \left[\frac{3}{4}\left(\frac{3}{2\pi}\right)^{1/2}\left(\frac{h}{m_p}\right)^3\frac{U_0}{U_1}\left(\frac{\tau_{ex}\kappa}{\ln\Lambda}\right)\right]^{1/2}\frac{qR_k^2\Theta^2}{e^2Z_pZ_\alpha}\exp\left(\frac{\chi}{m_p\kappa\Theta}\right). \tag{14}$$

Its solution yields $R_k = 400\,\text{cm}$; hence $n_s = 1.5\times10^{21}\,\text{cm}^{-3}$, $T_{ps} = 3\times10^7\,\text{K}$, $p_{ps} = 1.25\times10^{18}\,\text{dyn cm}^{-2}$, $\alpha = 0.015$ and $T_k = 6.1\times10^{12}\,\text{K}$.

Now the daemon temperature in the kernel appears more reasonable (in any case, $kT_k < 2m_pc^2/3$; we may recall that the difference between T_k and T_{ps} seems only natural because of the huge difference between m and m_p, with the energy being released predominantly in one of the plasma components – a phenomenon well known, for example, from the glow gas discharge). At this T_k, daemons move with a velocity of only $V_d = 9\,\text{cm s}^{-1}$. The value of T_k can be reduced by a few times (possibly, by an order of magnitude; see also the next Sec. 6) if we take into account that the pressure of the solar matter is compensated not in a thin surface layer of the kernel but rather by a pressure gradient across a thick layer $l \approx R_k$, and that electrons of the outer plasma cross possibly nearly all the kernel. We have also disregarded the heating of the proton component inside the kernel, a factor that increases its diffusibility and, hence, reduces R_k and T_k. At the same time, however, the presence of helium and heavier nuclei in the solar material may act in the opposite sense.

6 KERNEL OF NEGATIVE DAEMONS: THE CASE OF THEIR IONIZATION DUE TO PROTON DECAY

In the preceding Section 5 we have considered thermal ionization of antineon atoms, that is formations in which a negative daemon ($Z = 10$) is surrounded by ten non-fused protons moving around it. The lifetime of this system until proton fusion reactions flare up in it $\tau_{pp} \approx 3\times10^{-8}\,\text{s}$ (Drobyshevski, 1996). We have, however, pointed out in the introduction that the situation in which the daemon is embedded in a compound nucleus representing a product of numerous previous proton fusion events in its vicinity is a more probable case. We accept $Z_n = Z$ for the nuclear charge. Obviously enough, for a binding energy $W \approx 68\,\text{MeV}$, thermal

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ionization, that is detachment, of this nucleus from the daemon at T_{ps} is impossible. Ionization occurs once in $\Delta\tau_{ex} \approx 10^{-6}$ s only owing to daemon-stimulated proton decay in the nucleus itself. The lifetime τ_{cap} of the system in the ionized state ($Z_{eff} = 1$) is determined by the capture of a new proton from the surrounding matter. The capture may occur when two protons collide within a sphere of radius r_{cap} near the Z_{eff} daemon. The radius r_{cap} is determined by the condition

$$\frac{Z_p Z_{eff} e^2}{r_{cap}} \approx \frac{3kT_{ps}}{2}, \text{ that is } r_{cap} = \frac{2Z_p Z_{eff} e^2}{3kT_{ps}}. \tag{15}$$

The proton Coulomb collision frequency per unit volume for $Z_{eff} = Z_p = 1$ can be written as (Alfvén and Fälthammar, 1967)

$$\nu_{pp} = \frac{0.714 \times 8\pi \ln\Lambda\, e^4 n_{ps}^2}{m_p^{1/2}(3kT_{ps})^{3/2}}. \tag{16}$$

Hence for the time between collisions of two protons in a sphere of radius r_{cap}, that is the capture time, we obtain

$$\tau_{cap} = \xi \frac{3m_p^{1/2}(3kT_{ps})^{9/2}}{0.714 \times 256\pi^2 \ln\Lambda\, e^{10} n_{ps}^2}. \tag{17}$$

Here the factor ξ accounts for the fact that not each proton collision by far in a sphere with $r = r_{cap}$ will result in a proton capture by a daemon with $Z_{eff} = 1$. Assuming now that $Z_\alpha = 1$ and $\alpha = \tau_{cap}/\Delta\tau_{ex}$ in Eq. (10), Eq. (13) for the energy balance reduces to

$$Q = \frac{32\pi}{9}\left(\frac{2 \times 0.714\pi}{\xi}\right)^{1/2}\left(\frac{e}{m_p}\right)^3 \frac{\tau_{ex}}{\kappa} q\Theta^{5/4} R_k^2. \tag{18}$$

Hence for $\xi = 10$ we obtain only $R_k = 11$ cm. The reason for such a small value of R_k is the negligibly small effective cross-section of interaction of protons diffusing into the kernel with daemons, with the charge of most of them being compensated by the charge of the compound nucleus in which it resides. For $R_k = 11$ cm, $\Theta = 740\,\mathrm{g}^{2/3}\,\mathrm{cm}^{-2}$; hence $\rho_{ps} = 2 \times 10^4\,\mathrm{g\,cm}^{-3}$, $n_{ps} = 1.2 \times 10^{28}\,\mathrm{cm}^{-3}$, $\rho_{ps} = 1.83 \times 10^{21}\,\mathrm{dyn\,cm}^{-2}$, $T_{ps} = 0.55 \times 10^9$ K, $n_s = 0.7 \times 10^{26}\,\mathrm{cm}^{-3}$, $T_k = 1.9 \times 10^{11}$ K and $V_d \approx 1.6\,\mathrm{cm\,s}^{-1}$.

Hopefully, a careful inclusion of the energy exchange between the daemon component and solar plasma will show, firstly, that the kernel is fairly transparent for the diffusion of radiation and protons into it (so that the daemon gas will not be required to compensate all of the external pressure), secondly, that the energy released in the kernel $L_d \approx Nq$ and thirdly, that its radius R_k will somewhat exceed the value found here.

7 CONCLUSION

The above reasoning suggests the following two important conclusions.

(1) The existence of daemons and their accumulation at the Sun's centre is capable of accounting for a sizeable fraction of solar luminosity through daemon-stimulated proton decay, with the corresponding decrease in the electron neutrino yield. Now the exact contribution of the daemon luminosity remains unclear, if for no other reason than the inevitably rough estimate of the low-velocity daemons captured by the Sun. Their spatial

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concentration in the Galactic disc and, hence, the flux on to the Sun, may undergo noticeable fluctuations, say, as a result of modulation by the spiral density waves. It is hoped that a definite opinion concerning the number of daemons in the Sun, their contribution to $L_\odot$ and possible modes of the daemon-containing proton decay will emerge on the basis of results of experiments detecting fluxes of solar neutrinos of different flavours (see for example Ahmad *et al*. (2001)). The kernel existence, to say the least, does not contradict the different helioseismological data which confirm the standard solar model (SSM) and provide fairly self-consistent results down to a depth $R \approx (0.1\text{–}0.15)R_\odot$ (Bahcall *et al*., 1998), that is down to the region inside which about $2/3L_\odot$ is liberated. Moreover, some helioseismological data reveal an increase in the sound speed (and/or smaller density if compared with the SSM) in the Solar core at $R < (0.1\text{–}0.15)R_\odot$ (see for example Gough *et al*. (1996)) that can be interpreted as favouring the ideas developed.

(2) It possibly appears that only negative daemons exist in our Universe. If one takes into account their negligibly low number when compared with protons, this does not contradict known facts. Moreover, an excess of negative electric charge could account for a part of the cosmological constant (in this connection, one can recall a paper by Lyttleton and Bondi (1959) on a general excess of charge as a cause of the Universe expansion). Additional light may be shed on this problem by comprehensive calculations of evolutionary models of the Sun, stars, planet, and other bodies, made with due account of the gradual growth of the kernel with time and in comparison with further neutrino and more advanced daemon experiments. Development of such models requires taking into account radically new processes at diverse physical levels and is, therefore, a much more complex problem than, say, calculations of stellar models with inclusion of only thermonuclear processes in quasi-equilibrium thermodynamic conditions (we may recall here the large difference between T_k and T_p).

The absence of positive daemons should not affect as critically the parameters of the Earth's kernel found earlier, because here Z_eff remains large ($Z_\mathrm{eff} \approx 5$) as a result of the negative daemons capturing multiply charged iron nuclei. Clearly, studying the kernels of the Earth, planets, pulsars, etc., should be pursued in close correlation with the investigation of the kernels in the Sun and the stars.

It might seem at first glance that the daemon kernel is almost an analogue of the black hole. This is not so, however, because while transforming the surrounding matter to energy it does not increase in mass. Therefore, the process does not progress, and there are no grounds to fear that, say, the Sun could disappear under some conditions to become a black hole.

Despite the huge density of matter in the kernel (about $10^{20}\,\mathrm{g\,cm^{-3}}$), the daemons in it constitute actually a collisionless plasma, where the time of at least one encounter of two daemons to a distance of about $3r_\mathrm{g}$ in the whole kernel may be measured in months and years. Therefore, in the conditions favourable for energy release in proton disintegration occurring in stars and planets, daemon fusion and kernel transformation into a black hole are hardly conceivable. However, in the case of originally much more massive condensations of daemons their relativistic collapse at a certain evolutionary stage (and with due regard for an excessive electric charge) should not possibly be excluded (quasars, active galactic nuclei, etc.?).

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