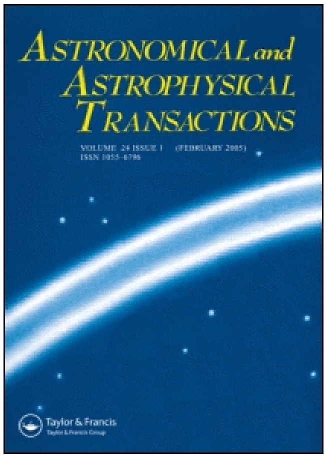

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TWO YEARS OF DETECTING DARK MATTER OBJECTS: THE SOLAR SYSTEM MEMBERS

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With a probability greater than 99% there are grounds to believe that our works on the detection of dark electric matter objects (daemons), which were launched in 1996, are crowned with success. The daemons are the relic elementary Planckian black holes ($m \approx 30\,\mu g$) carrying a stable electric charge $Z = 10e$. During the last 2 years, a detector made of two horizontal ZnS(Ag) screens of $1\,m^2$ area has been recording the correlated time-shifted scintillations corresponding to flux $f_{\oplus} \approx 10^{-5}\,m^{-2}\,s^{-1}$ of extraordinary penetrating nuclear-active particles which moved both downwards and upwards with a velocity of only about 5–$30\,km\,s^{-1}$. The flux experiences seasonal variations with maxima supposedly corresponding to the Earth transition through the shadow and antishadow created by the Sun in its motion relative to the Galaxy disc daemon population. An accumulation of negative daemons, which stimulate the proton decay in about $1\,\mu s$ inside the Earth and the Sun is capable of explaining a many facts that have previously not been understood.

Keywords: Dark matter; Dark matter in the Solar System; Elementary black holes; Planckian scale; Proton decay

1 INTRODUCTION: GENERAL IDEOLOGY AND HISTORY OF OUR SEARCH

We started from a working hypothesis that the dark matter (DM) of the Galactic disc consists of electrically charged Planckian elementary black holes ($m = 3 \times 10^{-5}$ g; $r_g = 2 \times 10^{-33}$ cm). The charge of these dark electric matter objects (daemons) may be $Z = 10e$ (Markov, 1965).

As they have a large charge, they are slowed down fairly efficiently in their passage through the Sun and become captured in strongly elongated orbits with perihelia inside it. Because of the resistance offered by the solar matter, these orbits contract and move into the Sun, with daemons building up in the latter. In 4.5 Gyears, their number could reach approximately 2.4×10^{30} (Drobyshevski, 1996). If a daemon captured in such a heliocentric orbit passes through the Earth's sphere of influence, it will be deflected, and its perihelion will move out of the Sun, to produce a fairly stable population in strongly elongated Earth-crossing heliocentric orbits (SEECHOs). Optimistic estimates yield for its concentration a value about 10^3–10^5 larger than that of daemons in the Galactic disc (Drobyshevski, 1997). Perturbations by the Earth transfer some of the daemons from here to near-Earth almost-circular heliocentric

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orbits (NEACHOs), whence they can fall on the Earth with a velocity of about 11–15 $\mathrm{km\,s^{-1}}$. At a velocity close to 11.2 $\mathrm{km\,s^{-1}}$, the slowing down rendered by the Earth's material may turn out to be sufficient to transfer a daemon from a NEACHO to a geocentric Earth-surface-crossing orbit (GESCO). GESCOs contract, and daemons go into the Earth. Thus, we see that the Solar System should harbour more than one population of daemons moving with velocities $V < 50\,\mathrm{km\,s^{-1}}$ relative to the Earth. Therefore, in contrast with all other scientific teams that made a search for objects of the Galactic halo DM with $V \approx 200$–$300\,\mathrm{km\,s^{-1}}$ their goal, we decided to look for objects (more specifically, daemons) with $V < 50\,\mathrm{km\,s^{-1}}$.

The large charge and the large mass make daemons nuclear-active particles. The possibility of using negative daemons for catalysis of light nuclei (up to O and F) fusion appears obvious (Drobyshevski, 1997). This is why we made an attempt to use this property for their detection. One might expect that, when a daemon passed through Li or Be with $V \approx 50\,\mathrm{km\,s^{-1}}$, up to 10^2–$10^3\,\mathrm{erg\,cm^{-1}}$ would be released along its trajectory. Expansion of heated material would generate a sound wave, whose detection should permit one to determine the daemon velocity and trajectory. However, experiments undertaken with Li (from the end of 1996 to the beginning of 1998) revealed a strong damping of ultrasound of 20–30 MHz frequency along a path of only about 1 cm. An analysis of the possibility of using Be showed the corresponding frequency to be 500–600 MHz. Its detection would require employing a fairly sophisticated technique. Therefore, in March 1998, we terminated the experiments on acoustic detection of daemons.

As a daemon enters or exits Be, some of the ^{18}O nuclei forming in the catalytic fusion of ^{9}Be nuclei should escape outwards. If the surfaces of Be plates are coated with a scintillator, for example ZnS(Ag), the shift in the signals initiated in them would indicate the passage of a daemon. However, an exposure of Be plates 0.12 $\mathrm{m^2}$ in area carried out in June 1999 for 300 h did not yield any sensible result; hence we concluded that the flux $f_\oplus$ of the SEECHO daemons was less than $3 \times 10^{-4}\,\mathrm{m^{-2}\,s^{-1}}$ (Drobyshevski, 2000b). Extending the exposure to 500 h did not change anything.

The experiments with Be, which in our case contained up to 0.1 at. % impurities with $Z_n > 10$, suggested a possible role of 'poisoning' of the catalyst as a result of the fact that the daemon captured heavy nuclei. As follows from an analysis of solar energetics (which was not quite correct, as we understand it now), a daemon should free itself of a heavy nucleus in a time $\tau_{ex} \approx 10^{-7}$–$10^{-6}$ s because of the disintegration of the daemon-containing protons (Drobyshevski, 2000a,b).

This led us to a radically new ideology of their detection, which is based on the assumed fast daemon-stimulated proton decay.

The system constructed in October–November 1999 consisted of four moduli. Each module had two parallel transparent polystyrene screens 4 mm thick coated on the underside with ZnS(Ag) and arranged at the centre of a cubic tinned-sheet case with a side of 51 cm. The case was covered on the front with black paper (for more details, see Drobyshevski (2002b)). The screens were mutually light isolated and situated at a distance of 7 cm from one another. Each screen was viewed by a separate photomultiplier (PM) tube, whose output signals were fed to a double-trace oscilloscope. It was assumed that, on passing through the first screen and on capturing a Zn or S nucleus in the scintillator on the way, the daemon, in crossing the gap of 7 cm, while releasing the nucleus because of the proton decay, would excite a scintillation, which would trigger the oscilloscope. On entering the second ZnS(Ag) layer, it would capture another nucleus and, on initiating its disintegration, would excite a scintillation to be detected by the second PM tube connected to the second trace of the oscilloscope. The magnitude of the signal shift Δt would then provide a judgement of the daemon velocity V.

Initially, we attempted to detect the SEECHO population, for which purpose the system was continuously oriented at the desired point on the celestial sphere (its coordinates for different dates were kindly calculated by Yu. D. Medvedev). A round-the-clock exposure run during December 1999–January 2000 did not, however, produce any definite result.

In February 2000, the system was oriented horizontally and was switched on only in the day time. An analysis of the distribution $N(\Delta t)$ of the upper and lower PM tube signals in the relative time shift Δt exhibited a certain indication of statistically significant deviations from the constant background originating from natural radioactivity and intrinsic PM noise. After this, the system in its horizontal arrangement was switched on February 24, 2000, the round-the-clock operation. By now, this operation has yielded the discovery of negative daemons and of their slow populations in the Solar System and revealed the main modes of daemon interaction with matter.

2 KEY STAGES IN THE EXPERIMENT

2.1 The First Statistically Significant Results

The March 2000 experiment revealed within the interval $-100\,\mu s < \Delta t < +100\,\mu s$ an $N(\Delta t)$ distribution which deviated from $N =$ constant by the χ^2 criterion, with a probability of 99%. This distribution, for a total number of 417 events, exhibited a sufficiently distinct maximum in the interval $+20\,\mu s < \Delta t < 40\,\mu s$. It exceeded the average level of 41.7 events per bin by 2.7σ (where $\sigma = (41.7)^{1/2}$). Its presence aroused some optimism, albeit not without a trace of perplexity, because the velocity derived from the base length of 7 cm constituted only 3–4 km s^{-1}.

Because of the extreme potential significance of this result, we carried out a large number of check experiments to reveal possible artefacts or faults in the operation of our simple equipment. None was revealed. Simultaneously the detector itself was modified. For instance, experiments with tinned iron sheets placed between the scintillators were performed (Drobyshevski, 2000c). Although this arrangement produced some effect, we did not succeed in drawing any definite conclusions therefrom. It should be emphasized that we have not succeeded in finding any relation between the events responsible for the maximum in the interval $20\,\mu s < \Delta t < 40\,\mu s$ and cosmic rays. To enhance the detector sensitivity, the thickness of the ZnS(Ag) layer was increased from $\eta \approx 3.5\,\mathrm{mg\,cm^{-2}}$ to 5–6 mg cm^{-2} (which, as we understand it now, should not be done; see below). The PM tube output circuit was simplified by replacing the inductance in the anode load with a resistance of 30 kΩ. The software intended for triggering the oscilloscopes after each event and for signal processing was improved. The irreproducibility of some experiments, which were carried out one after another in seemingly the same conditions (although slight changes were continuously introduced), was deeply annoying.

2.2 Revealing the Important Role of Heavy-particle Scintillations

The experiments revealed scintillations of two types. Belonging to the first of these are long events, with a smooth maximum, 2–2.5 μs after the beginning. This shape is characteristic of the scintillations produced by α particles (heavy-particle scintillations (HPSs)). The short scintillations have a maximum forming immediately after the trigger (less than 0.5 μs). Their decay is determined only by the parameters of the PM tube–oscilloscope circuit. This shape is typically observed in scintillations excited by electrons, as well as in those occurring without any time shift ($\Delta t = 0$) on both traces, and sometimes in several modules simultaneously. The zero-shift signals are caused by muons and electron avalanches of cosmic rays, whose primary particles, judging from the frequency of their occurrence, have an energy of 10^{11}–10^{13} eV. These events were used by us to determine the relative sensitivity of the channels but were disregarded in drawing $N(\Delta t)$ histograms. The pure PM noise signals have the same shape. Therefore we call them noise-like scintillations (NLSs).

An important observation was made in October 2000. If one takes into account only the HPS events from the top PM tube, the significance of the deviation in $N(\Delta t)$ from a constant background increased, despite the general decrease in the number of points in the March experiment to 231, to $1 - \alpha = 99.7\%$ and the maximum at $20\,\mu s < \Delta t < 40\,\mu s$ was found to exceed the average level of 23.1 even per bin by 3.7σ (where $\sigma = (23.1)^{1/2}$). Therefore we included in our analysis subsequently only the events triggered by a HPS in the upper scintillator.

2.3 Using the Heavy-particle Scintillation Shape for Detection of the Near-Earth Almost-circular Heliocentric Orbit, Geocentric Earth-surface-crossing Orbit and, Possibly, Strongly Elongated Earth-crossing Heliocentric Orbit Populations

In November, 2001, we became confident that the system operated without malfunctions, and that the irreproducibility of the monthly averages was caused apparently mainly by the seasonal variations in the daemon flux. It was decided to conduct the experiment on a round-the-clock basis, without changing the system parameters. These observations (April–June 2001) did indeed reveal a strong variability in $N(\Delta t)$ from one month to another.

By this time, we not only understood the reason for the significance of the HPSs in the top scintillator but also realized the possibility of using the specific features in the HPS shape, which depend on the actual direction of daemon propagation, for diagnostics. The point is that the daemon binding energy to a nucleus, $W = 1.8ZZ_nA_n^{-1/3}$ MeV, is 130 MeV for Zn. Therefore, the first to be emitted in the capture of a nucleus by the daemon are the atomic Auger electrons with an energy of up to about 1 MeV. They excite NLSs. On the latter, however, are immediately superimposed the HPSs, which are created by the nucleons and their clusters ejected by the excited nucleus. As a result, the oscilloscopic traces of scintillations produced by sufficiently fast daemons propagating downwards (first through the polystyrene and, after that, through the ZnS(Ag) layer) should have a large area S (normalized to the amplitude); that is, they should be wider than those generated by the upward-flying daemons, where some of the nucleons are ejected already in polystyrene and, hence, do not reach the ZnS(Ag) layer. This effect is indeed observed, if one separates the 'wide' from 'narrow' scintillations and constructs for them separate distributions: $N_w(\Delta t)$ and $N_n(\Delta t)$. The number of events per $0\,\mu s < \Delta t < 20\,\mu s$ bin for $N_w(\Delta t)$ invariably exceeds that for $-20\,\mu s < \Delta t < 0\,\mu s$, and vice versa.

While the situation becomes more complicated for lower velocities and larger ZnS(Ag) thicknesses η, nevertheless, it allows interpretation along the same lines (Fig. 1). We note also that, because our ZnS(Ag) powder consists of light-scattering grains differing in size (with an average size of about 12 μm), the light transmission is not related to η through a simple exponential (see also Birks (1964)). From our calibration, it can be accepted as a rough estimate that, for $\eta = 2.5\,\mathrm{mg\,cm^{-2}}$, the layer transmits 30% of the incident light and, for $5\,\mathrm{mg\,cm^{-2}}$, 20%. One should bear in mind that, for $\eta < 2\,\mathrm{mg\,cm^{-2}}$, ZnS(Ag) grains do not cover completely the screen surface, whereas a substantial increase in η increases the number of background HPSs owing to the impurities present in ZnS(Ag).

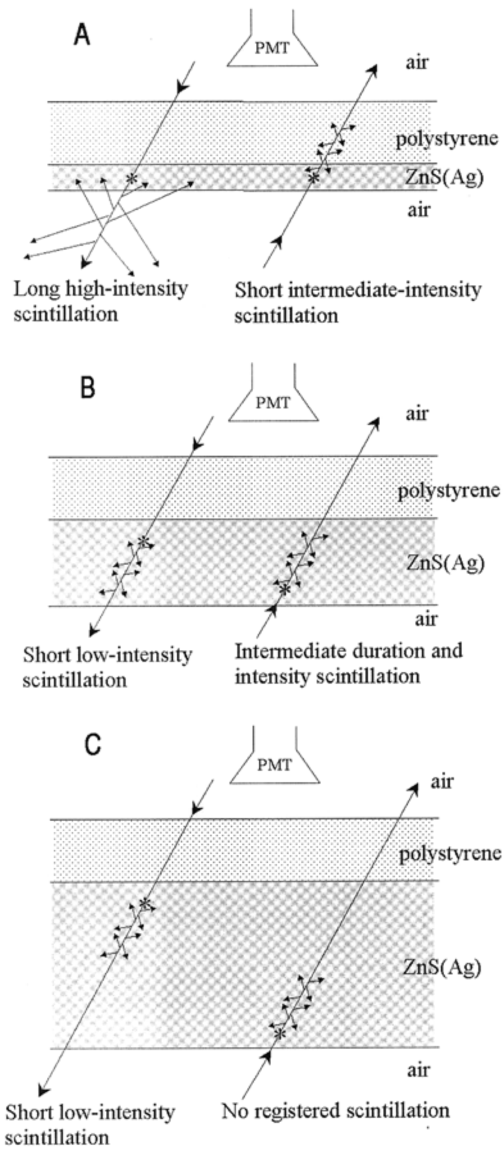

FIGURE 1 Parameters of the scintillations produced by slow ($V \approx 10\,\mathrm{km\,s^{-1}}$) daemons in ZnS(Ag), an intermediate-atomic-weight low-transparency scintillator for (a) a thin-layer scintillator ($\eta \le 3.5\,\mathrm{mg\,cm^{-2}}$), (b) a thick-layer scintillator ($\eta \approx 6$–$8\,\mathrm{mg\,cm^{-2}}$) and (c) a very-thick-layer scintillator ($\eta \ge 10\,\mathrm{mg\,cm^{-2}}$): $*$, point of a nucleus capture and emission of Auger electrons; after this point, the excited captured nucleus emits about ten nucleons.

Realization of the role of the HPSs and of the dependence of their shape on the magnitude and direction of velocity and on the ZnS(Ag) thickness permitted us to construct a non-contradictory scenario of the sequence of the events involved.

On entering the detector on its way down, the daemon captures a Zn (or S) nucleus with emission of Auger electrons and nucleons (and of their clusters) from the excited nucleus. A ‘wide’ HPS is produced. After this, a successive decay of daemon-containing protons starts in the remainder of the nucleus. As long as the daemon–remainder complex is positively charged, (re)capture of another nucleus is not likely. Therefore, the daemon crosses the bottom ZnS(Ag) layer without exciting a scintillation. However, when approaching the bottom lid of the case with the velocity $V \approx 10\,\mathrm{km\,s^{-1}}$, the daemon is already capable of capturing here a Sn (or Fe) nucleus with the emission of electrons at first via the Auger process and then by means of internal conversion of the excited nucleus energy to the refilling (*i.e.* captured anew by the nucleus from the ambient metal) electrons. Some of them, on traversing the distance of about 22 cm to the bottom scintillator, excite in it a NLS shifted by Δt (22 cm of air are impenetrable for the nucleons evaporating from the nucleus), and this event is detected.

When moving upwards with a velocity $V \approx 10\,\mathrm{km\,s^{-1}}$, the daemon is poisoned by a Sn nucleus and does not have sufficient time to 'digest' it before entering the top ZnS(Ag) layer. This accounts for the absence of a maximum in the interval $-40\,\mu\mathrm{s} < \Delta t < -20\,\mu\mathrm{s}$ in the March 2000 distribution $N(\Delta t)$. For $V > 10\,\mathrm{km\,s^{-1}}$, it crosses the thin (2 μm) Sn layer without capturing Sn but captures Fe. For $10\,\mathrm{km\,s^{-1}} < V < 15\text{–}20\,\mathrm{km\,s^{-1}}$, the Fe nucleus can be digested by the daemon before it strikes the top ZnS(Ag) layer, and then the upward crossing of the detector by the daemon will be registered.

Thus, the distance of 29 cm between the top ZnS(Ag) layer and the bottom lid of the case is the base length in our experiment. For $V > 40\,\mathrm{km\,s^{-1}}$, a detector of our dimensions becomes 'transparent' to daemons. For $V < 3\text{–}5\,\mathrm{km\,s^{-1}}$, the base length would be the separation between the top and bottom scintillators (as was supposed initially).

By comparing the parameters of our system with the data obtained, we found (Drobyshevski *et al.*, 2001) that the ejection time of Auger electrons in ZnS(Ag) is $\tau_{\mathrm{Aug}} \approx 0.1$ ns, the ejection time of nucleons from a nucleus is $\tau_{\mathrm{ev}} \leq 1$ ns and the decay time of a daemon-containing proton is $\Delta\tau_{\mathrm{ex}} \approx 1\,\mu\mathrm{s}$. The fact that A_{n} of the nuclei of our scintillator turned out to be optimum for our search played here a significant role. The antisymmetric pattern of the $N_{\mathrm{w}}(\Delta t)$ and $N_{\mathrm{n}}(\Delta t)$ distributions for $|\Delta t| < 20\,\mu\mathrm{s}$ suggests the existence of a SEECHO population with $20\,\mathrm{km\,s^{-1}} < V < 35\text{–}40\,\mathrm{km\,s^{-1}}$ (and/or of the Galactic disc population). The maximum at $20\,\mu\mathrm{s} < \Delta t < 40\,\mu\mathrm{s}$ can be assigned to the fact that NEACHO daemons strike the Earth. A comparison of the April with May–June 2001 $N(\Delta t)$ distributions reveals maxima for $|\Delta t| > 50\,\mu\mathrm{s}$ moving away from one another, which may originate from the GESCO population's sinking under the Earth's surface in a time of 1–2 months (Drobyshevski *et al.*, 2001). The total daemon flux on the Earth is $f_{\oplus} \approx 10^{-5}\,\mathrm{m^{-2}\,s^{-1}}$, a factor of about 300 less than our original (Drobyshevski, 1997) optimistic estimates.

3 SEMIANNUAL DAEMON-FLUX CYCLE AND ITS ORIGIN

Further exposure of the detector (to April 2002) completed the year cycle and favoured our expectations that the Sun moves with respect to the daemon component of the Galactic disc and creates in the process a shadow and an antishadow of the SEECHO objects.

It should be recalled that we still do not discriminate between the scintillations excited by a daemon crossing the detector from most of the other background scintillations. The only thing that we do know is that the daemon must produce a HPS-type scintillation in the top scintillator. Our judgement of the daemon flux and of its characteristics draws on statistics only. If there were no nuclear-active, strongly penetrating low-velocity objects, the $N(\Delta t)$ distribution for $|\Delta t| > 1\,\mu\mathrm{s}$ would be close to a constant level, because it would be produced by non-correlated background events such as the natural radiation, which is excited by cosmic rays as well. In particular, as pointed out in Section 2.2, the March

2000 distribution $N(\Delta t)$ is, by the χ^2 criterion, different from $N =$ constant at a confidence level $1 - \alpha = 99.7\%$.

These data were processed practically manually. At present, the processing is computerized. Firstly, the monthly cosmic-ray signal statistics is used to determine the relative sensitivity of the scintillator–PM tube–amplifier systems for the upper and lower channels of each module. After this, the computer calculates a table whose cells correspond to a predetermined equal number N_{mod} of events to occur in each module during a given time interval (month). The events chosen are such that their oscilloscopic trace amplitudes exceed their minimum values in the upper ($U_{1\mathrm{min}}$) and lower ($U_{2\mathrm{min}}$) channels, with an additional condition imposed that a fixed ratio $\omega = U_{1\mathrm{min}}/U_{2\mathrm{min}}$ is the second parameter determining the table cell. Experience showed the meaningful ranges for our detector arrangements to be $50 \leq N_{\mathrm{mod}} \leq 120$ and $1 \leq \omega \leq 7$. Each cell of the table contains the values of $1 - \alpha$ which are actually centre-line deviations of the $N(\Delta t)$, $N_{\mathrm{w}}(\Delta t)$, $N_{\mathrm{n}}(\Delta t)$, and $N_{\mathrm{w}}(\Delta t)+N_{\mathrm{n}}(-\Delta t)$ from a constant level. Already a cursory glance at the table reveals cells with maximum values of $1 - \alpha$. For $N(\Delta t)$, they usually lie in the ranges $N_{\mathrm{mod}} = 80$–90 and $\omega = 4$–5.

Figure 2 presents a plot of $1 - \alpha$ for the detector with $\eta \approx 5\,\mathrm{mg\,cm^{-2}}$ at the upper polystyrene screen 1 mm thick (with a $\eta \approx 3.5\,\mathrm{mm\,cm^{-2}}$ lower screen 4 mm thick) obtained for the period from April 2001 to April 2002, which actually characterizes $N(\Delta t)$ (for $N_{\mathrm{mod}} = 90$ and $\omega = 4$). It can be fitted by a sine function (with a correlation coefficient of 0.9, whose confidence level is 0.999) with a period of half a year and minima in the first decades of May and November (while the March 2000 data correlate quite well with this relation, a certain misfit present emphasizes once more the importance of maintaining the scintillator density η at an optimum level). In our opinion, the results presented here are fairly unambiguous and would hardly allow any other interpretation except that the Earth crosses the solar shadow and antishadow in the SEECHO daemon flux, where parts of the NEACHOs crossing

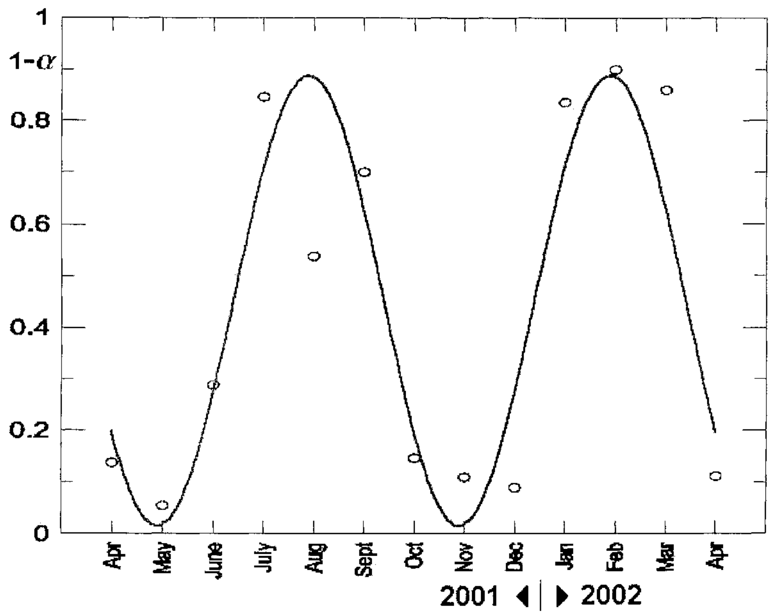

FIGURE 2 Monthly plot of $1 - \alpha$, the extent to which the $N(\Delta t)$ distribution deviates from the constant level produced by background events (see text for details).

the Earth's orbit also become concentrated. This scenario does not contradict the opinion (see for example Freese *et al.* (1988)) that at the beginning of June the orbital velocity of the Earth adds to the Sun's velocity relative to the DM of the Galactic halo and, at the beginning of December, is subtracted from it. This means that the Earth must cross the solar shadow in the DM population some time in February–March.

4 CONCLUSION

Our original plans were aimed at the detection of slow DM objects, which represent a population of the Solar System captured from the Galactic disc. Assuming them to be multiply negatively charged Planckian objects, namely daemons, we looked for a manifestation of strong nuclear effects and, more specifically, simultaneous ejection of many scores of particles, internal conversion and/or Auger electrons and nucleons, in each interaction event. The crucial point in our ideology was the use of a supposedly fairly fast decay of the daemon-containing proton. Judging from the totality of the data obtained in our straightforward experiment, where it is simply unclear where an error could come from, we have succeeded in revealing the existence of the particles that we have been looking for; these might perhaps be called superslow cosmic rays penetrating through the Sun and the Earth. It would appear close to inconceivable to assign these results to the action of the conventional cosmic rays. An analysis of the scintillation shape permitted us to understand a number of fine details in the daemon interaction with matter, that is with the main components of our detector. We have estimated the time of Auger electron emission in the daemon capture of a nucleus (about 0.1 ns), the time of evaporative de-excitation of the nucleus and of the time taken by the daemon to reach the ground state in its remainder (about 1 ns), and the time of the daemon-stimulated proton decay (about 1 μs). We revealed generically coupled daemon populations in various heliocentric orbits, as well as in geocentric orbits with perigees inside the Earth. The observed seasonal variations of the daemon flux correlate at a high confidence level (99%) with the semiannual cycle. They are due to the Earth's motion around the Sun, and of the Sun, relative to the DM of the Galactic disc; they can be accounted for in a non-contradictory way by the existence of daemon populations of several types.

Finally, the build-up of negative daemons in the Earth in an amount, as follows from our measurements, of about 10^{23} creates in it a kernel not more than a few centimetres in size (Drobyshevski, 2002a). Disintegration by the kernel daemons of Fe nuclei and of their protons is fully capable of explaining, besides many other phenomena that have been remaining unclear heretofore, the excess heat flux of about 20 TW and the ^{3}He flux emanating from the Earth's interior. Obviously, the daemons accumulated in the Sun (about 2×10^{30}) are capable of accounting for, through proton disintegration, a noticeable part of its luminosity and the emission of the recently discovered neutrinos of non-electron flavour. Note that an analysis of the processes occurring in the Sun's daemon kernel (with a radius of about 10 cm) suggests the existence of negative daemons only (Drobyshevski, 2002c).

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