RIAP BULLETIN

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RIAP: SOME BASIC DATA

Research Institute on Anomalous Phenomena (RIAP) has been established in 1992 by the VERTICAL Aerospace Company. It is an independent research body, aimed at scientific studies in the fields of the UFO problem and non-classical SETI (Search for Extraterrestrial Intelligence). The Institute makes its investigations in strict conformity to requirements of the scientific method and in close collaboration with the CIS Academy of Cosmonautics and the Russian and Ukrainian Academies of Sciences.

Specific features of the UFO problem are well-known. UFO sightings are unpredictable and therefore difficult to be investigated with "normal" scientific methods and equipment. Although an evident progress has been made in the last few decades in collecting and analyzing raw data on UFO observations, the nature of "genuine UFOs" (GUFOs) still remains an open question. The ufological community has in its disposition a huge amount of UFO reports (mostly of low quality), together with undeveloped methods of data treatment and hypotheses testing. As a result, the "big science" tries to keep aloof from this field of research.

To open the way to the solution of the UFO problem, it should be posed as a normal scientific problem, in complete conformity to the cognitive standards of science. Being multidisciplinary, it is to be divided into narrow mono-disciplinary sub-problems which could be developed methodologically rigorously with providing efficient interdisciplinary coordination. It is most essential to organize systematic gathering and processing of instrumental information on UFO sightings, to obtain really "hard" data on the phenomenon. This information will give basis for its complete picture and well-founded theoretical models.

The principal trends of researches of the Institute in the UFO field are as follows: development of methods and strategies of active monitoring of UFOs by means of radar, optical, infra-red and other detection systems; instrumental studies of supposed landing sites, impacts on biological systems and UFO samples; creation of an efficient system of reconstruction of an anomalous event on the basis of witnesses' testimonies; creation of a unified UFO data base and a computer expert system to identify GUFOs; development of physical models of GUFOs; psychophysiological investigations of contactees and abductees; studies in the history of the Soviet ufology.

In the SETI field, we are realizing the program "Search for Alien Artifacts on the Moon" (SAAM). This program includes: search for sunlight reflections from flat (mirror-like) surfaces of hypothetical ET objects (say, reconnaissance devices monitoring the Earth); search for other probable artificial ET phenomena on the Lunar surface; examination of the possibility of interaction between the terrestrial and extraterrestrial civilizations on the Moon; simulation of probable ET strategies for the Moon.

These investigations employ photographs of various regions of the Lunar surface taken from "Apollo", "Lunar Orbiter", "Luna" and "Zond" spacecraft, as well as the existing catalogues of Lunar Transient Phenomena (LTP) and the data obtained by the network of LTP observers that has been recently set up by the Institute specially for this purpose. The network involves at present a group of competent observers in Ukraine, Russia and Byelaruss.

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Another important line of inquiry in non-classical SETI is paleovisitology — that is, exploration of the possibility of past extraterrestrial visits to the Earth. The major research program of the Institute in this field is the program "Direct Traces". It is a common opinion that searches for ETAs — ancient extraterrestrial artifacts should be the main task of paleovisitology. Yet there is in fact no real search; there have been only a few attempts to apply rather vague ideas of extraterrestrial artifacts to certain enigmatic finds. A real ETA may be accidentally discovered any moment. One can even suppose that such a discovery has been made more than once. But to understand it, we have to set up an efficient system for gathering and evaluating reliable information. This system would enable us to accumulate a data bankand to develop well-founded theoretical models and systematic experimental procedures in this field.

RIAP has at its disposal the so-called "Kassimov ball" — a small (diameter some 4.5 cm) black ball of unknown origin, found in 1983 on the depth 7 meters, in a layer of pure red clay, in Central Russia. Judging from tentative conclusions of several geologists and paleontologists, this ball is very unusual and worthy of deep investigation.

The Institute staff consists of RIAP Fellows — the scientists and scholars, permanently employed by the Institute, and RIAP Contributing Fellows, who are temporarily engaged under contracts. They are distinguished specialists in physics, astronomy, history, psychology, and other disciplines.

Formally RIAP is divided into four Departments: 1) Ufological Department; 2) Astronomical Department; 3) Paleovisitological Department; 4) Information Department. But the main *research* unit is a problem-oriented team which is specially created to work on a mono- or multidisciplinary problem. Such a team is headed by a chief researcher, who is wholly responsible for quality of its work to the Scientific Council and Director of the Institute.

There participate in the work of the Scientific Council and Advisory Board of the Institute such Russian and Ukrainian specialists in the UFO problem and SETI field as A.V.Arkhipov (radio astronomer who has discovered supposed ETI radio sources near some distant stars), A.V.Beletsky (historian studying pre-1917 UFO waves in Russia), Dr. E.A.Ermilov (specialist in radio detection of aerial anomalous phenomena), Dr. V.N.Fomenko (investigator of the famous Vashka find, as well as other supposed ET artifacts), Yu.A.Fomin (doyen of UFO studies in Russia), Dr. L.M.Gindilis (astronomer and SETI expert), Dr. Yu.V.Platov (Vice-Chairman of the Academic UFO Study Group), Dr. A.V.Zolotov (investigator of the Tunguska explosion), and others. The Advisory Board includes also a group of well-known Western scientists, scholars and engineers — V.-J.Ballester Olmos (Spain), Dr. T.E.Bullard (USA), Dr. R.F.Haines (USA), Dr. A.Meessen (Belgium), et al. Dr. V.V.Rubtsov has been appointed the Director of the Institute.

The Scientific Council is very much interested in establishing contacts and collaboration between RIAP and serious anomalistic bodies, journals, researchers from other parts of the world. For further details please write to: RIAP, P.O.Box 4684, 310022 Kharkov-22, UKRAINE.

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UFOs AS OBJECTS OF STUDY BY TERRESTRIAL PHYSICS

Valeriy A. Buerakov

1. There is no escape from the conclusion that some UFOs may prove to be interstellar probes of Extraterrestrial Civilizations (ETCs) [1; 2]. We will not discuss the possibility of existence of civilizations capable of such a step. We just postulate this issue regarding it as a working hypothesis. Then a certain part of collected observational data, however scanty it may be, can be expected to contain information on extraterrestrial objects. If unreliable, less informative and "not too strange" observations are set aside, then the remainder of the data form a certain "queer" image of an object having the properties which do not fit into the conventional laws of terrestrial physics. Attempts to prove or disprove the existence of such an object have inspired no confidence, and not without reason. Indeed, if it is not a phantom but reality, then understanding it needs, at least, knowledge of the physical laws which provide its existence. But the language of the laws governing UFOs and similar objects does not seem, as yet, to have become a "mother tongue" of terrestrial science, and what is actually suggested by observations of UFOs cannot be fully understood. And taking into account the paradoxical silence of ETCs within the framework of the SETI programme, the conclusion suggests itself that we, terrestrials, and highly developed cosmic civilizations speak different information languages, i.e. we are in different information "niches".

What does it imply? Cosmic civilizations, active as they may be even within the Galaxy, cannot use electromagnetic waves as the information carrier in their space activities. Even for the Galaxy spatial scales ($\sim 10^5$ light years), the velocity of light (3×10^8 m/s) is much too small and the use of electromagnetic waves leads to an information deadlock (the value of information reaching the addressee in 10^5 years after its sending is practically zero). Therefore, the activity of cosmic civilizations on the Galaxy scale will be senseless, unless a physical mechanism exists, which provides sending of messages with velocities considerably exceeding that of light (but finite). Knowledge of this mechanism specifies the minimum of the civilization level of development which is to be attained by the terrestrials if they are to enter the information niche of highly advanced civilizations. The terrestrial (precosmic) civilization knows and can use in its space activities only the electromagnetic information carrier and, therefore, it is blocked by dead silence of incomprehension, although it possibly is indeed in the sphere of intensive activities of the space community.

2. If that vague image of the UFO as a space probe, which has been formed by the most reliable, strange and informative part of the observational data acquired is not a phantom, then it may be expected to provide a certain (possibly distorted) idea of the minimum level of scientific and technological development of cosmic civilizations. The circumstances under which UFOs appear, their mode of movement, their glow in the atmosphere, their effects on material objects and observers suggest that UFOs use certain processes which in modern physics and quasi-physics terminology are referred to as teleportation, antigravitation, super-high electromagnetic fields. The first (quasi-scientific) term 'teleportation' will be taken to mean the transport of material objects outside the space-time we are accustomed to. Terrestrial physics totally ignores even the problem as such. The other two concepts are really scientific, but there is no solution whatever to the problems associated. Both antigravitation and super-high electromagnetic field (of the order of the intra-atomic field or higher) are currently "blank spaces" of physics. The solution of these problems can hardly be expected to be found in terms of long-standing physical traditions. There is an urgent need for fresh ideas and concepts, a non-orthodox physics.

In its centuries-long evolution the terrestrial science has often reached points where the acquired experimental and observational data were inconsistent with the existing concepts of physics. This conflict is more probable in those areas of physics which are its "blank spaces". Now a question arises if the terrestrial science reached such a point by the end of our millennium. If so, the next step may bring us into the information niche of the cosmic community. Since the problems to be faced will be really intricate, one would hardly expect this way to be smooth. Yet each good idea, each successful experiment, an appropriate solution of a specific problem will bring us closer to the encounter with ETCs.

Let us think what can be actually done now to tackle the problems associated with UFOs in the context of up-to-date physical concepts. Let us consider, in particular, the problem arising in connection with super-high electromagnetic fields.

The case in point are electromagnetic fields of intensities of the order of intra-atomic ones and up. At the micro-level (atoms, nuclei) the corresponding interactions of charged particles are described by the laws of quantum electrodynamics which, as is known, differs essentially from the classical Maxwell-Lorentz theory.

Our concern is the possibility of existence of charged *macro*-objects capable of generating electromagnetic fields (electrostatic fields) of intensities of the order of or even higher than intra-atomic field.

3. An electric charge of about 5 C distributed in volume with a diameter of some 30 cm represents a system of charged particles of a high density ($\sim 10^{21}$ particles/m^3). In this case the external electrostatic field of this system should be very high, of the order of the intra-atomic field ($10^9 - 10^{10}$ V/cm). However, according to the laws of classical physics (Coulomb law) such a system of like charges cannot be stable and, consequently, there cannot be a stable macro-object. Is it really the case? Strictly speaking, such a conclusion is scientifically incorrect, because neither such densities of charged particles having one sign nor so high macro-fields have so far been experimentally investigated. At best their theoretical analysis is made using the Maxwell equations that were derived one hundred years ago and have remained totally unchanged till now. Their validity is indeed corroborated by experiments, but in these experiments the electric charge density and the charge-generated field are several orders of magnitude smaller than the above values. However in the cases where they are comparable, for instance, in atoms, the Maxwell equations are not valid, giving way to quantum electrodynamics. Hence, the natural question arises: may the laws of the traditional electrodynamics be legitimately applied to charged macro-systems whose electric characteristics are comparable to intra-atomic? At this point there is no question of these systems having quantum properties. Everything appears simpler: the Maxwell-Lorentz equations derived in the weak field approximation and corroborated by experiments are only assumed to be invalid, without corrections, for strong fields and highly concentrated charges. These corrections should tend to zero for ordinary fields and charge densities.

What else is to be taken account of? Our belief is that there exist at least two characteristics of the electromagnetic interaction in vacuum, which are neglected by the Maxwell theory and are important for the case of strong fields. These are polarization of physical vacuum and 'self-action' of strong electromagnetic field.

4. When the Maxwell theory was taking shape, vacuum was thought to be just empty space. This concept was incorporated in the theory that was being constructed, in particular in the Maxwell-Lorentz equations describing the electromagnetic interaction of a charged particle system in vacuum. However, further evolution of the quantum theory and the experiment led to the suggestion that physical vacuum is not an inert (absolute) void, but an electrodynamically (and not only so) active medium. It reacts to the presence of a charge and its magnitude and changes the electromagnetic field. And while in the quantum theory attempts to take account of this fact resulted in quantum electrodynamics, the classical (deterministic) Maxwell-Lorentz theory remained unchanged. Because of the linearity of its field equations, this theory also neglects the possibility of 'self-action' of a strong electromagnetic field.

The author has made an attempt to describe the interaction of an electric charge with physical vacuum (its polarization) and the 'self-action' of the electric field. Without going into details, we shall only dwell on the results which are useful for the solution of the UFO problem.

The theory is based on the postulates of modern relativistic physics of the material continuum. We shall attempt to include (if possible) the polarization of the vacuum and the possible 'self-action' of the field in the derivation of the Maxwell-Lorentz equations. The derivation is based on the integral equations of charged matter balance. No specific assumptions going beyond the scope of modern physics are made. As a result of relatively simple mathematical manipulations a system of differential (quasi-Maxwell) equations is obtained, which differs from the Maxwell-Lorentz system in non-linear additions tending to zero for weak fields and low charge densities.

Consider the particular case of a new set of equations describing the interaction of steady-state currents with an electrodynamically active medium (vacuum):

$$\begin{aligned} &div\,\vec{D} = \omega - \psi\,(V_\sigma\,\tau^{\sigma 0}),\\ &div\,\vec{B} = 0,\\ &rot\,\vec{E} = 0,\\ &rot\,\vec{H} = \omega\,\vec{V} - \psi\,\vec{\tau}c, \end{aligned} \tag{1}$$

where $\vec{E}$, $\vec{D}$, $\vec{B}$, $\vec{H}$ are the traditional vectors of the electromagnetic field; $\tau^{\sigma 0}$ and $\vec{\tau}$ are the components of the tensor of the density of the energy-momentum of the field ($\sigma = \overline{0,3}$) ; V_σ are the components of the 4-velocity; ω is the charge density; φ a certain function.

The quantities $\tau^{\sigma 0}$ and $\vec{\tau}$ are expressed in terms of the field vector components in a non-linear fashion, which renders the system quasi-linear.

For further consideration, the set of equations (1) is too general. It is sufficient to confine ourselves to its particular case:

$$\begin{aligned} &div\,\vec{D} = \omega - \psi\,(\vec{E}\cdot\vec{D})/2\\ &rot\,\vec{E} = 0 \end{aligned} \tag{2}$$

Equations (2) were intended to define the electrostatic field of a set of like charges located in a spherical volume of the radius R_s. We were to find the external field of this set for the case of spherically symmetrical distribution of charges. In this case the structure of distribution of the charges within the sphere is of no importance; therefore, the version of the charge distribution over the spherical surface (conducting shell) of the radius R_s was chosen. In this case the system of equations (2) reduces to one non-linear ordinary differential equation:

$$\frac{1}{r^2}\cdot\frac{d(r^2 E_r)}{dr} + \frac{Q_s}{2 m_s c^2}(E_r)^2 - \frac{Q_s\,\delta(r - R_s)}{4\pi\beta r^2} = 0 \tag{3}$$

for the radial component $E_r(r)$ of the electrostatic field. The new quantities entering into (3) are the charge Q_s and the mass m_s of the system of the electric charges, the dielectric constant of vacuum β and the delta function $\delta\,(n - R_s)$.

The solution of equation (3) is:

$$E_r(r) = \frac{Q_s}{(4\pi\bar{\varepsilon}_0)\,r^2}\times \frac{1}{\varepsilon\,[1 - \frac{Q_s^2}{8\pi\beta m_s c^2}(\frac{1}{r} - \frac{1}{R_s})]} \tag{4}$$

where $\beta = \bar{\varepsilon}_0\cdot\varepsilon$; $\bar{\varepsilon}_0$ and ε are the absolute and relative dielectric constants of vacuum (in the SI).

The first factor in expression (4) represents the traditional Coulomb interaction. When $Q_s/m_s \to 0$, the additional term in (4) also $\to 0$ and therefore may be neglected, and the solution only describes the Coulomb interaction.

5. Solution (4) of the differential equation (3) determines the local properties of the present physical system. However, the charge-field system is inherently global, since the electric field should occupy the entire space outside the sphere of the radius R_s. For this reason and with consideration for the present-day concepts of vacuum and the structure of the Universe [4], it becomes possible to obtain the phenomenological relations specifying the charge-field system as a whole.

Let us write out one of these phenomenological relations defining the critical charge Q_0.

$$Q_0^2 = 8\pi\bar{\varepsilon}_0(D-1)c^2(R_s\,m_s)/\varepsilon D \tag{5}$$

If $Q_s < Q_0$, the behavior of the charge system under investigation does not differ from the classical. In this case the electric field (as is customary) occupies the whole volume of the Universe, whereas the charges themselves tend to scatter from the conducting shell due to the explosive autoelectronic emission. As the charge reaches the values $Q_s \geq Q_0$ (with the same R_s and m_s), the classical behavior of the system is disrupted. For $Q_s = Q_0$ the system (charged matter plus field) changes as it were to a new state, and with $Q_s > Q_0$ the electric field generated starts to "convolve" into a region of a radius R, where

$$R = \frac{X R_s (D-1)}{(D-1)X - 1}$$

$$X = \frac{\varepsilon^2 D^2}{8\pi\beta (D-1)^2} \cdot \frac{Q_0^2}{R_s m_s c^2} \qquad (6)$$

Here $D = Const$ is determined by the global structure of the Universe, topology and configuration of the convolved field (RP^3 and elliptical, respectively), with R varying within $R_s < R < R_B$, R_B being the radius of the Universe.

As $Q_s > Q_0$ and increases, then $R \to R_s$, and the electric field outside the sphere of the radius R approaches an infinitely small value, whereas its concentration inside it grows. While the charges tend to scatter away when $Q_s < Q_0$, in the case of $Q_s > Q_0$ there appear collective attraction forces between like charges, these forces having the corresponding binding energy which increases as $R \to R_s$. Thus, there is ample evidence of a new phase state.

If the initial charges are on a rigid conducting (e.g., metallic) shell, the present object is stable. Provided that a sufficient quantity of charge (Q_s) has, in some way, accumulated within a region of the radius R_s filled with an aerosol having a total mass m_s, then the object is also formed; its stability is, however, disturbed by charge motion. It will become quasi-stable, its lifetime specified by the integrated balance of forces.

6. An object we shall call an EC (electromagnetic "cocoon") is quite similar to ball lightning, in the case of an aerosol core. Indeed, the concentration of the electrostatic field in the field layer of the EC is very high (~10^9 V/cm or more). This causes air molecules in it to glow through ionization processes. One can easily see that the quantitative characteristics calculated by the formulae obtained are in good agreement with the most trustworthy observations of ball lightning. Consider, for instance, the case [5] which appears inexplicable in the context of the existing theory, but which is most trustworthy: a 1.5 m ball lightning that was observed by many witnesses had left a material trace, viz. a patch of fused soil 1.5 m across and 20 to 25 cm deep. Experimental investigations of these remnants made it possible to estimate the amount of released energy (~10^{10} J) and identify the probable mechanism of soil fusion. The amount of the released energy was enormous, 10^4—10^5 times as great as the quantity admitted by the present-day ball lightning models [6; 7]. If the fireball is thought to consist of an aerosol core some 20 cm in diameter and a (glowing) field shell about 1.5 m across, then in our model the parameters $m_s \approx 5$ g, $Q_0 \approx 3.3$ C, $Q_s > Q_0$ are obtained, and the amount of energy contained in the field shell is ca. 10^{12} J. The latter, with consideration for the possible efficiency (some 1 %) of the field-to-field thermal energy conversion, yields the value around 10^{10} J. It should be added that according to the results of studies made by the Hungarian researcher G.Egely (as described in [7]) severe destructions caused by the ball lightning are due to release of ~ 1 — 5 C electric charge (in the case [5] there was a break-down of the electric wiring at a distance of some 100 m away from the area). The explanation of this fact given in [6; 7] cannot be considered to be correct, because it is virtually based on the

assumption that the Coulomb law holds true invariably even for super-high fields, on the order of intra-atomic fields (though, as is known, it is at the atomic scale that this law becomes invalid).

Note that in terms of the EC model with an aerosol core, all the particulars of behavior can be explained quantitatively and qualitatively of both the observation of the ball lightning mentioned and all the most reliable and informative observations of the body of data acquired.

7. The model of the EC having a rigid core (metallic shell) is stable. Given the characteristics of the shell $R_s \approx 1$ m, $m_s \approx 30$ kg, the critical charge is up to $Q_0 \approx 900$ C, whereas for $Q_s \geq Q_0$, in the field layer adjacent to the shell, an electrostatic field with the energy some 10^{16} J is concentrated. The field is nonexistent both within the metallic shell and outside of the field layer. Therefore, measuring instruments, facilities, equipment, etc. can be placed in the core. Besides, using the non-linear equivalent of the Einstein equation the EC gravitational field was calculated. It was shown that a super-high electric field which affects the topology and geometry of space results in "convolution" of gravitational field of the EC. This means that outside a sphere with the radius R the field is zero and there is no gravitational interaction of the EC with bodies located beyond the radius R. In this case, movement of such a body across the gravitational field of the Earth would possess many (now almost inexplicable) features of UFO movement.

Thus, UFOs (as space probes) may be expected to use physical mechanisms governing the interaction of super-high electromagnetic field with the Universe vacuum and making it possible to influence the topology and geometry of space. In our immediate terrestrial environment, the natural object in which these mechanisms are realized is ball lightning which still remains a "blank space" in physics, despite 150 years of fairly intensive studies. In this connection, we are to do justice to the intuition of J.McCampbell, an American engineer who put forward a hypothesis on similarity of the mechanisms of glow of some UFOs and ball lightning [8].

8. Now let us consider to what extent convincing the proof of the existence of such an object as an EC can be. There are two possible avenues of approach. The first approach is to single out in the EC mathematical model those key elements which are responsible for its formation and test them on experimentally verified problems. The second approach is in direct laboratory confirmation.

The main physico-mathematical element responsible for formation of the EC was found to be the non-linear addition in the quasi-Maxwell equations (2). In order to check it, two more complicated problems were set, their particular case being the problem of the EC. These were the models of the spherical condenser and the hydrogen atom which had been well studied in physics both theoretically and experimentally.

Without going into particulars, it should be noted that the results obtained from the solution totally coincide (to an adequate level of approximation) with those well-known and thoroughly checked by experiment. Specifically, for the hydrogen atom, all the formulae known from quantum mechanics (for energy levels, orbit radii, etc.) have been obtained. Therefore, the quantum mechanics experiments corroborating the hydrogen atom model indirectly support the EC model.

At present, experimental verification is also quite feasible. Two points are important here. The first consists in verifying the EC model using an aerosol core as the ball lightning model. All reliable data, including the experiments made by American scientists Corums (according to [7]), lend further support to the validity of this model. The second is the checking of the EC model having a rigid core (metallic shell). The technical difficulties that arise in this case are more complicated, but they may well be overcome by the potentialities of the modern physical experiment.

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ASTRODYNAMICAL ASPECT OF PALEOVISITOLOGY

Alexey V. Arkhipov

Scientific search for traces of paleovisits ([7], [15]) could be more efficient if the most probable epoch of interstellar travels from a nearest star to the Sun were known. Obviously, the interstellar flight is a very difficult task [6]. Still, the technical obstacles are easier to overcome in the case of short-range flights [19]. That is why the probability of a paleovisit is higher when a star, favorable for intelligent life, closely approaches the Sun.

Some years ago, Cesarone and Sergeyevsky [3] published a table of the past stellar flybys at less than 5 l.y. to the Solar System. Unfortunately, they only referred to the Gliese Catalogue [9]. Besides, the minimum distance uncertainties were identified with the major semi-axis of the positional dispersion ellipsoid (σ_{SMAA}) in the flyby epoch. However, these are quite different parameters. Indeed, the shortest distance is determined by the direction of the stellar velocity, whereas σ_{SMAA} depends rather on the uncertainty of the stellar velocity modulus than on its direction errors. Therefore, the estimates of the shortest distances should be revised. Moreover, the errors of the flyby epoches have not been estimated. That is why we felt it suitable to carry out the whole study anew.

The author has been searching for close stellar passages near the Sun in the Quaternary period (up to 1.5 pc, what is a realistic limit in view of the Daedalus Project [19] of a probe flight to the Barnard's star located at 1.8 pc from the Sun.) For this purpose the Gliese [9] and Wooley et al. [18] catalogues of nearby stars were used. These catalogues contain the proper motion and parallaxes of stars located at distances of ≤ 25 pc from the Sun. The search results are shown in Table 1. The Gliese 231.2 star was omitted because of its uncertain radial velocity. Nevertheless, this star closely approached the Sun in the Quaternary period, but its epoch of minimum distance was roughly between 0.7×10^6 and 3×10^6 years ago ($\pm\,\sigma$ limits). The Gliese 66 star is absent in the list of Cesarone and Sergeyevsky. In addition, the revised standard errors of the minimum distances are, as determined in this study, substantially lower than the estimates of ref. [3].

Here it is assumed that trajectories of stars are straight lines, since the considered time intervals are small fractions of the periods of the stellar orbital motion around the Galaxy center. However, the closest encounters with other stars could perturb the stellar trajectories. But the probability of such events is negligible.

Indeed, the widest possible angle of deviation (β) from the initial direction of the motion of a star is (according to [13]):

$$\beta = \pi - 2\arccos\left[\left(1 + \frac{p^2\omega^4}{G^2(m+m_*)^2}\right)^{-0.5}\right] \quad (1).$$

where p is the minimum distance of the Sun-approaching star (SAS) to the continued initial trajectory of the perturbing star; ω is the velocity of the perturbing star relative to the SAS; G is the gravitational constant; m and m_* are the masses of the SAS and the perturbing star, respectively. The encounter is closest if $\beta L \geq 1$ pc, where L is the star distance (in parsecs) from the Sun. Hence, p could not be larger than

$$p_{\max} \approx \frac{G(m+m_*)}{\omega^2}\left[\cos^{-2}\left(\frac{\pi L - d}{2L}\right) - 1\right]^{0.5} \text{pc} \quad (2),$$

where $d = 1$ pc.

In practice, it is necessary to calculate $p_{max,\,i}$ for the i-th narrow interval of stellar masses. In such an interval, $m_{*,\,i}$ and the root-mean square of stellar velocity (σ_i) are assumed to be constant. Estimates of $m_{*,\,i}$ and σ_i are given by Heisler, Tremaine and Alcock [11] for the stars of each of the twenty stellar classes. According to ref. [14], ω_i may be estimated by the equation:

$$\omega_i^2 = V^2 + \sigma_i^2 + \frac{1}{3} \times 17^2\,(\text{km/s})^2 \quad (3)$$

where V is the velocity of a star from Table 1, relative to the Sun.

The upper limit of the space volume of the closest encounters (VCE) of the SAS with the stars from the i-th interval is $\frac{4}{3}\pi(p_{max,\,i})^3$. But the vacant space volume around two interacting stars is about $2/n_i$. Hence, the probability (η_i) that a star comes into the VCE is:

$$\eta_i \leq \frac{2}{3}\pi n_i\, p^3_{max,\,i} \quad (4)$$

The upper limit of the space volume of closest encounters along the trajectory of the SAS from the Sun vicinity to the present star position is about $\pi L p^2_{max,\,i}$, larger than the VCE by a factor of $k_i = (3/4) \times L/p_{max,i}$. Therefore, the probability (W) of a closest encounter can be estimated as:

$$W \leq \sum_{i=1}^{20} \left[1 - (1-\eta_i)^{k_i}\right] \approx \approx \frac{\pi L}{2}\sum_{i=1}^{20} n_i\, p^2_{max,\,i} \quad (5)$$

Table 1

Star	Coordinates		Spectral class	Magnitude	Epoch of minimum distance	Minimum distance	Modern distance	Reference
	α_{1950}	δ_{1950}		V	1000 y	pc	pc	
Gliese 66	$01^h37^m54^s$	-56°26',9	K2V K0V+K0V	5.75 5.07+5.09	−289±2 −289±2	1.5±0.2* 1.5	6.5 6.5	[9] [18]
Gliese 208	$05^h33^m44^s$	+11°17',9	M0 dM0	8.82 8.82	−483±6 −503±9	1.2±0.3* 1.4	11.5 12.2	[9] [18]
Gliese 279	$07^h31^m55^s$	-22°11',2	F5V F7IV	4.45 4.45	−270±3 −296±6	1.3±0.1** 1.1	16.9 18.9	[9] [18]
Gliese 773.5	$19^h58^m26^s$	-22°52',6	G7V:***	5.96	-1400±500	1.4±0.6*	11.8	[9]

* The errors of the stellar proper motion are taken from: Star Catalog. Positions and proper motion of 258,997 stars from the epoch and equinex of 1950,0. Smithsonian Institution, Washington, D.C., 1966.

** The stellar proper motion and its errors are taken from: Flicke, W. et al. Fifth Fundamental Catalogue (FK5). Part I. The Basic Fundamental Stars. Veroeffentlichungen, Astronomisches Rechen-Institut Heidelberg, Nr. 32, Verlag G. Braun, Karlsruhe, 1988.

*** The spectral class is taken from: Komarov, N.S. et al. Photometric and Spectral Catalogue of Bright Stars, Naukova Dumka, Kiev, 1979 (in Russian).

The results of the calculation are shown in Table 2. Obviously, the probabilities of closest encounters of these stars with other ones (apart from the Sun) are negligible.

Are the stars in Table 1 favorable for intelligent life? According to the conservative estimate by Hart [10], planets of stars having the spectra from F7V to K0V could be inhabited. On the other hand, there are more optimistic opinions: the spectra F2V—K1V [4] and even to K5V [12] may be favorable for life. The habitability of a planet of an M-dwarf is not improbable if the planet has a massive nearby satellite [4]. Hence, the spectra of the stars of Table 1 do not contradict the idea of existence of intelligent life there. Gliese 66 has a physical satellite at the distance of about 51 a.u. (its orbital period P = 483.66 y) [9]. It is known that inhabited planets can exist in such a wide binary system ([4], [16]).

Apparently, paleovisits were somewhat more probable some 280,000 years ago, because the stars Gliese 66 and Gliese 279 were at the minimum distances from the Sun. Another possible epoch of paleovisits is about 1,400,000 years ago, when Gliese 773.5 approached our planetary system. Therefore, the corresponding geological strata are promising as regards search for alien artifacts. It seems that the well determined case of Gliese 208 is the least interesting for paleovisitological investigations because of the star's spectral class.

Unfortunately, search for nearby stars in earlier epoches is very difficult. This problem could not be solved for $t \geq 10^7$ years ago. Nevertheless, it is useful to estimate the total number (N) of stars having likely habitable planets that had approached the Sun to within $r = 1.5$ pc during the history of the Earth. According to [11], the number N of the stars having masses (0.70 — 1.33) M_{sun} and therefore favorable for life [4] may be estimated as:

$$N \approx (8\pi)^{0.5}(1-c)r^2 T \sum_{i=4}^{6} \sigma_i n_i \approx$$
$$\approx (6.0\text{—}10.8) \times 10^3 \qquad (6),$$

where $T = 4.55 \times 10^9$ y is the age of the Earth [1], c=0.1—0.5 is the frequency of close binaries among

Table 2

Star	Probabilities of closest encounters with other stars, apart from the Sun (W)
Gliese 66	$< 9.7 \times 10^{-9}$
Gliese 208	$< 1.1 \times 10^{-8}$
Gliese 279	$< 1.5 \times 10^{-8}$
Gliese 773.5	$< 8.0 \times 10^{-9}$

the main sequence stars [8]. We can see that only a small fraction (about 6×10^{-4}) of close passages of stars with inhabitable planets falls within the Quaternary period. Hence, the older epoches may be even more promising for the search of paleovisit traces, than the period of the human history.

If $r = 10^4$ a.u. (4.85×10^{-2} pc), then $N = 6$—11. During such closest passages even spontaneous short-range panspermia was possible [17]. A probe flight for such a distance is quite practicable even today (the Pioneer and Voyager missions, for example).

It is most probable that epoches of closest stellar passages could be found by their indirect effects. For example, a stellar passage across the Oort cloud of comets (its radius is about 10^4 a.u. [5]) increases the influx of comets and asteroids to the inner regions of the Solar System [11]. A consequence of a stellar perturbation would be a higher frequency of impact crater formation on the lunar surface.

According to Baldwin [2], the formation rate of lunar craters was not constant during the last 3.95×10^9 years. Apart from a slow variability, there are some short time intervals when the craters were formed more often. The typical duration of such an event is $\leq 10^8$ y. The real duration may well be much shorter, because the errors of crater age estimation are about 10^8 y. The epoches of the most frequent infalls (when the number of impacts for a 10^8 y interval was larger than the average value for a 10^9 y interval by more than 1.5 standard deviation) are: -1.5×10^8 y, -1.95×10^9 y and -3.83×10^9 y. These events could be indicators of closest stellar passages. Of course, it is only a suggestion. Nevertheless, such an approach at least gives us some promising epoches.

Therefore, visits of extraterrestrial beings to the Earth were somewhat more probable in the following epoches: 2.8×10^5, 4.9×10^5, 1.4×10^6, 1.5×10^8, 1.95×10^9 and 3.83×10^9 years ago. This list is not exhaustive, of course. However, it would be especially reasonable to search for extraterrestrial artifacts in the geological layers corresponding to the above-mentioned dates. In addition, the paleovisit search on the Moon and other space bodies can be more successful than on the Earth because of the weaker erosion there.

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