International Journal of Modern Engineering Research (IJMER)
www.ijmer.com Vol.2, Issue.3, May-June 2012 pp-722-727 ISSN: 2249-6645

Estimation of the Frequency of Artifacts Likely to Fall Down to Earth and Other Planets

A. B. BHATTACHARYA
Department of Physics, University of Kalyani, Kalyani 741235, West Bengal, India
J. PANDIT
Department of Physics, JIS School of Polytechnic, Kalyani 741235, West Bengal, India
B. RAHA
Department of Physics, University of Kalyani, Kalyani 741235, West Bengal, India
A. SARKAR
Department of Physics, University of Kalyani, Kalyani 741235, West Bengal, India

ABSTRACT
The spontaneous leakage of artifacts into the interstellar medium and the associated orbital characteristics of different planets have been considered for estimating the frequency of the artifacts likely to fall down to the Earth and the other planets. Information about the astrodynamical aspect of paleovisitology, particularly regarding the formation and extent of the artifacts in the solar planetary systems has been emphasized.

Key words **– Artifacts, Interstellar medium, Planets, Solar system, Universe.**

I. INTRODUCTION
Interest has developed among researchers, in recent years, to search traces of extraterrestrial intelligence within the solar system. It has already been reported that within the time of existence of our planet, about 10^4 stars capable of having inhabited planets approached the Sun to distances within 1.5 pc (1 pc = 3.09 x 10^{13} km) which can be covered by space probes using present day technology [1, 2]. Early works [3, 4] have attempted in a scattered way on a search for artifacts which are in orbit, on the Earth or on asteroids. It seems that this list should also include by elaborately considering orbits of different planets and their moons as well. In this paper we have considered the orbital characteristics of different planets for estimating the frequency of the artifacts likely to fall down to earth and other planets.

II. SPONTANEOUS LEAKAGE OF ARTIFACTS
Space activities largely contribute to a long duration pollution of the interstellar medium [5]. In a similar way, the interplanetary space of other inhabited planetary systems could contain artifacts. The spontaneous leakage of artifacts into the interstellar medium in absence of interstellar flights is also reasonably expected. This is mainly because of the following three reasons:

(1) A considerable portion of any large artifacts would be ejected by gravitational interaction with the planets. According to computer simulations of the asteroid and comet motion, 10-30 percent of small bodies leave the Solar system [6 - 8].

(2) Collisions between artifacts or their explosions (like spontaneous explosions of Earth satellites) in the outer parts of the planetary system could accelerate their debris up to hyperbolic velocities.

(3) Light pressure expels micron-sized debris particles (*e.g.* from rocket engines) out of the planetary system.

Hence, technical activities even within a planetary system lead to a diffusion of artifacts into the interstellar medium. If there are alien artifacts between the stars, some of them are likely to fall down to Earth at some time. So it is interesting to estimate the frequency of such events.

III. THEORETICAL CONSIDERATIONS
In this section we have considered some mathematical equations used for calculating the probability of the fall of artifacts on Earth and other planets of the solar system.

The velocity (v) of all artifacts relative to the Sun in interstellar medium is given by

$$v = [X^2 + Y^2 + Z^2 + (\sigma_1^2 + \sigma_2^2 + \sigma_3^2)/3]^{1/2} \qquad \ldots (1)$$

where, σ_1, σ_2 and σ_3 are the orthogonal dispersions in velocity of nearby stars; X, Y and Z are the components of the velocity vector of the Sun relatively to nearby stars [Allen (1973)].

Putting the widely accepted values of σ_1 = 38 km/s, σ_2 = 24 km/s, σ_3 = 18 km/s and X = 9 km/s, Y = 12 km/s, Z = 7 km/s, we get v = 32.48 km/s.

The effective radius of the Earth's orbit (A) and the effective radius of Earth (R_e) are respectively given by

$$A = a\,[1 + (V/v)^2]^{1/2} \qquad \ldots (2)$$

$$R_e \approx R\,[1 + u^2/\langle v_a^2 \rangle]^{1/2} \qquad \ldots (3)$$

where a is the radius of the Earth's orbit which is 1.5x10^8 km (on an average); V =42.1 km/ s is the escape velocity at 1.5x10^8 km distance from the Sun; R = 6371 km is the Earth's radius; u = 11.2 km/s is the geocentric escape velocity of Earth and $\langle v_a^2 \rangle$ is the average square geocentric escape velocity of artifact which is given by

$$\langle v_a^2 \rangle = v^2 + 1.5V^2 \quad \ldots (4)$$

The probability of the fall of an artifact on the Earth at the distance of $r \leq a$ from the Sun can be expressed as,

$$\omega = (R_e/a)^2 \quad \ldots (5)$$

Again, the number density (ρ) of the artifact is given by

$$\rho = \rho_o \gamma e M C / m \quad \ldots (6)$$

where, ρ_o = 4.43x10^{-42} km^{-3} is the stellar density close to the Sun [9]
γ = 0.3 is the fraction of stars with planets among the nearby stars.
M = 2.3x10^{21} kg is the mass of potential raw material for the artifact manufacturing in the planetary system *e.g.* the total mass of asteroids in the solar system [9]
C = Part of raw material transformed into the interstellar artifacts
m = The typical mass of artifact and
e = Fraction of planetary systems generating interstellar artifacts among the nearby planetary systems.

If v_h is the heliocentric velocity of nearby stars; T, the age of the planet, v^*, the artifacts injection velocity and T_{max}, the maximum duration of exposure such that T = 1.43x10^{17} sec, v^*~10 km/sec, $L = v^* \times T_{max}$ = 3x10^{13} km, then maximum number of stars which could infect the planet is

$$N \sim \pi \rho_0 \gamma v_h T L^2 \quad \ldots (7)$$

and the frequency of *Extraterrestrial Intelligence* artifact falls is,

$$f = \pi \rho r v A^2 \omega \approx 3.5 \times 10^{-11} \text{ e C/m. in s}^{-1} \quad \ldots (8)$$

Taking m = 0.1kg, the upper limit of f could be calculated. In practice, e and C should be less than 1 *i.e.* $e \leq 1$ and $C \leq 1$. Putting the maximum value of e and C i.e. 1, we can estimate the frequency of artifact; which becomes f = 3.5x10^{-11} if we put m = 1 kg. Then the average time between the falls of such ETI artifacts become $1/f \geq$ 91yrs.

Again if e =10^{-2}, C = 10^{-2} and m = 0.1 kg, then the Earth could accumulate about five thousand of 0.1kg-artifacts during 4.5x10^9 years.
The probability of survival conditions of artifact is given by

$$W = [1 - (v_h^2 + v_e^2 - 9.2/\sigma) / (2 v_h v_e)] / 2 \quad \ldots (9)$$

where v_h is the heliocentric velocity of artifact near the Earth and it is related by the equation

$$v_h = [u^2 + V^2 + v^2]^{1/2} \quad \ldots (10)$$

Using the appropriate values of u, V and v we get v_h = 54.33 km/s and v_e, the orbital speed of the Earth 29.78 km/s.

IV. ESTIMATION OF POSSIBLE ARTIFACTS

In our estimation of the possible artifacts we have considered the planets Mercury, Venus, Earth, Mars, Jupiter and Saturn. The orbital characteristics of all these planets are given in TABLE 1.

We estimate the probability of the artifacts fall on the Earth and the other five planets due to the Sun and draw the histogram shown in Fig. 1. Fig. 2 shows the % contributions of falling artifacts.

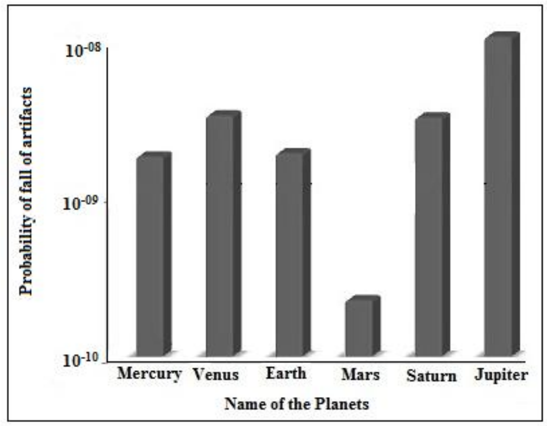


Fig.1 Probability of the fall of artifacts on Earth and other planets

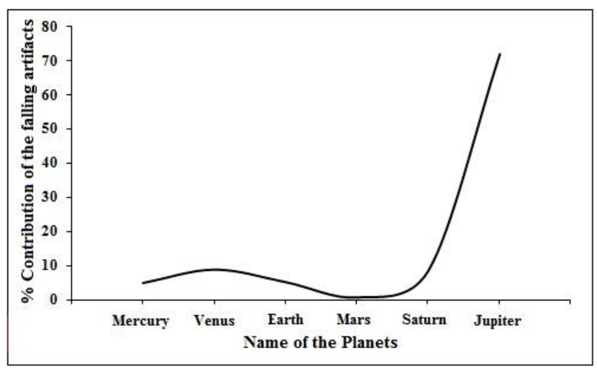


Fig.2 Percentage contribution of various Planets in the falling of artifacts

From both the figures, it is clear that contribution of artifacts to Jupiter is maximum among all the planets considered. Geocentric escape velocity (u) of the six planets of the Sun as well as, the square root of the average square geocentric velocities [$\langle v_a^2 \rangle$] have been calculated and shown in Table 2.

Table 2. The Geocentric velocity (u) and the square root of average square geocentric velocity (v_a) for various planets including Earth

Planets	u in km/s	v_a in km/s
Mercury	4.25	89.25520713
Venus	10.46	68.99337215
Earth	11.186	60.93903019
Mars	5.027	53.08133382
Jupiter	59.5	39.60909681
Saturn	35.5	36.53551423

TABLE 2 shows that the values of v_a are decreasing from the planet Mercury to the planet Saturn but it is not true for u. It is noted that the value of u is increasing from Mercury to the Earth. Then it diminishes for the planet Mars and again it increases for the other two planets considered. It appears from the table that the value of u is maximum for Jupiter and minimum for Mercury while the value of v_a is maximum for Mercury and minimum for Jupiter.

Table 1. Orbital characteristics of the different planets considered

Planet	Mercury	Venus	Earth	Mars	Jupiter	Saturn
Aphelion in km	69,816,900	108,942,109	152,098,232	249,209,300	816,520,800	1,513,325,783
Perihelion in km	46,001,200	107,476,259	147,098,290	206,669,000	740,573,600	1,353,572,956
Semi-major axis in km	57,909,100	108,208,930	149,598,261	227,939,100	778,547,200	1,433,449,370
Radius of the orbit (a) in km	5.79×10^7	1.08×10^8	1.5×10^8	2.27×10^8	7.78×10^8	1.43×10^9
Mean radius in km	2,439.7	6,051.8	6,371.0	3386.2	69,911	57,325
Mass in kg	3.3022×10^{23}	$4.868\ 5\times10^{24}$	5.9736×10^{24}	6.4185×10^{23}	1.8986×10^{27}	5.6846×10^{26}
Mean density in gm/cm^3	5.427	5.204	5.515	3.9335	1.326	0.687
Geocentric Escape Velocity (u) in km/s	4.25	10.46	11.186	5.027	59.5	35.5
Escape Velocity at orbital distance (V) in km/s	67.88	49.70	42.1	34.28	18.51	13.66
v in km/s	32.48	32.48	32.48	32.48	32.48	32.48
$A=a[1+(V/v)^2]^{1/2}$	1.34×10^8	1.97×10^8	2.45×10^8	3.30×10^8	8.95×10^8	15.5×10^8
Effective Radius of the Planet R_e in km	2442.464	6120.956	6477.444	3401.351	126160.7	79929.18
Average square of Geocentric Velocity $\langle v_a^2 \rangle$	7966.492	4760.085	3713.565	2817.628	1568.881	1334.844
$\omega = (R_e/a)^2$	1.780×10^{-9}	3.212×10^{-9}	1.865×10^{-9}	2.245×10^{-10}	2.630×10^{-8}	3.124×10^{-9}

The variations of u and v_a corresponding to all the six planets have taken into account and are shown in Fig. 3.

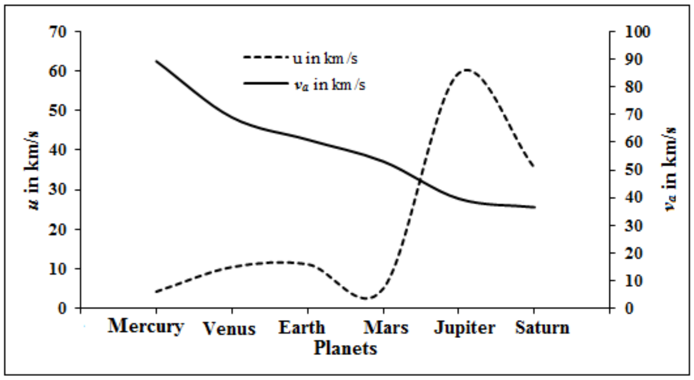


Fig.3 variations of u and v_a for various planets

A plot of u^2 in logarithmic scale *vs.* $<v_a^2>$ is made in Fig. 4 which exhibits an interesting characteristic variation. The figure clearly shows that the variation of u^2 with $<v_a^2>$ is non-liner in characteristic.

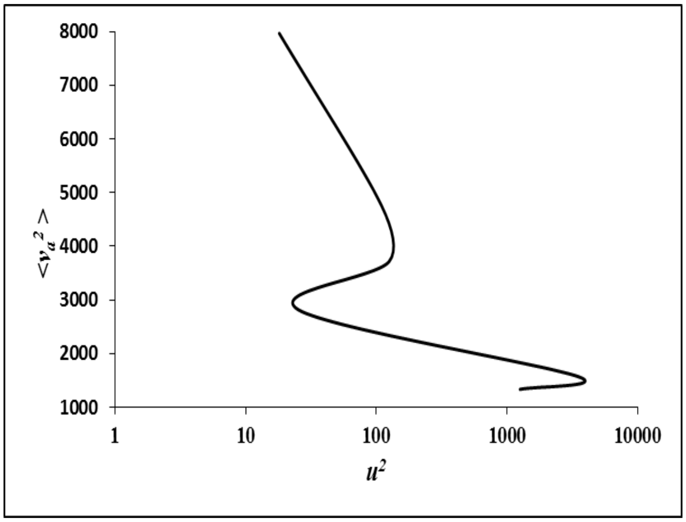


Fig.4 Plot of u^2 in log scale against $<v_a^2>$

The effective radius R_e as derived from equation (3), can also be obtained from

$$R_e \approx Rk \qquad \ldots (11)$$

where, $k = [1+ u^2 /<v_a^2>]^{1/2}$

In TABLE 3 we have shown the calculated values of k as obtained by using equation 12 and also the corresponding planet's radius R.

Table 3. Calculated values of k of the six planets and their corresponding radius in km

Planets	***K***	***R* in km**
Mercury	1.001133013	2,439.70
Mars	1.004474259	3386.2
Venus	1.011427317	6,051.80
Earth	1.016707659	6,371.00
Jupiter	1.804590059	69,911
Saturn	1.394316304	57,325

The variations of the two parameters k and R have shown in Fig. 5. It appears from the figure that when we go to the higher values of the radius (R), particularly above the value of 62 $\times 10^3$ km, the k values are no longer linear.

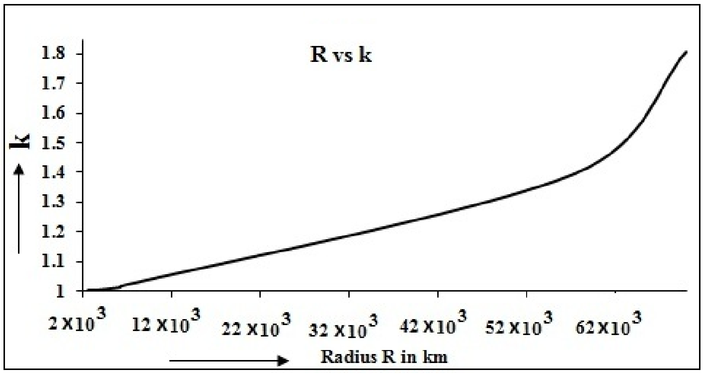
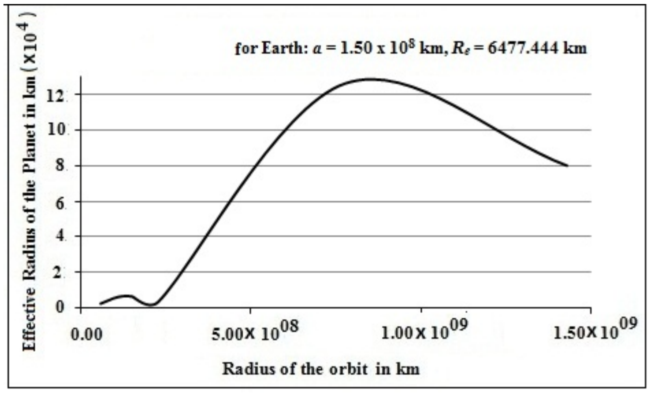
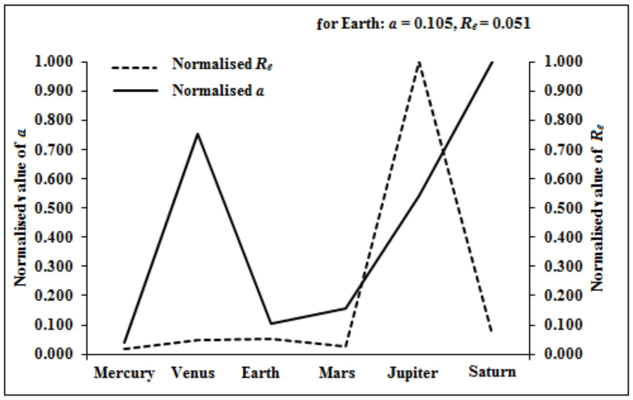


Fig.5 Plot showing the variation of R and k

This variation prompted us to re-examine the radius of the orbit (a) with the corresponding effective radius of different planets (R_e). A plot of a *vs* R_e is made in Fig. 6(i) and their normalized values in fig. 6(ii). From these figures we can compare the values of a and R_e of different planets with reference to Earth.



(i)



(ii)

Fig.6(i) Plot of radius of the orbit (a) *vs.* effective radius of the Planets (R_e),
(ii) Normalized values of a *vs* R_e

In TABLE 4 we have calculated the heliocentric velocity of nearby stars with the maximum number of stars which could infect the planets. The table shows that the order of the maximum number of stars for all the planets are same (~ 10^4) but the heliocentric velocity varies from 50 to 75 km/s. This indicates that the heliocentric velocity (v_h) has not a major role in counting the maximum number of stars that could infect the planets.

V. DISCUSSION

The probability of the fall of the artifacts and their percentage contribution to different planets is a subject to be examined in greater details with the help of additional future information. Observational data supported by the future models developed can provide light towards falling of artifacts and eventually to the existence of extraterrestrial intelligence at our planetary systems. It has been reported that Mercury and Mars is less than 1 percent while that for the Venus and Saturn is greater than 1[10]. There is a higher chance that the artifacts on the Earth may arise from Venus or Saturn than Mercury or Mars.

Table 4. Heliocentric velocity of nearby stars and the corresponding maximum number to infect the planets

Name of the planets	**Heliocentric velocity of nearby stars $v_h = [u^2 + V^2 + v^2]^{1/2}$ km/s**	**Maximum number of stars which could infect the planet ($N \sim \pi \rho_0 \gamma v_h T L^2$)**
Mercury	75.37	$4.0\text{x}10^4$
Venus	60.29	$3.2\text{ x}10^4$
Earth	54.34	$2.9\text{ x}10^4$
Mars	47.49	$2.5\text{ x}10^4$
Jupiter	70.27	$3.7\text{ x}10^4$
Saturn	50.02	$2.6\text{ x}10^4$

Some recent theories suggest that Venus and the Earth may have started out alike [11]. There might have been a lot of water on Venus and there might have been a lot of carbon dioxide on Earth. But all that was to change. On Earth, life in the oceans took in carbon dioxide and turned it into limestone. On Venus, 30% closer to the Sun, any oceans boiled away and the water vapor added to the runaway greenhouse effect. It is largely believed that microbes could survive and reproduce; floating in the thick, cloudy atmosphere and also widely protected by a sunscreen of sulfur compounds [12, 13].
"Panspermia" the theory that life on Earth came from space, comets, or other planets, has an ancient history [14-18]. There are more promising non-classical SETI possibilities than the conventional search for radio/laser signals. But these approaches conflict with the mental habits of astronomers, geologists and geochemists in studying natural formations and processes. This habit factor leads most specialists to a priori rejection of search for alien artifacts on the surfaces of the planets and their moons. Invaluable information about the astrodynamical aspect of paleovisitology, particularly regarding the formation and extent of the artifacts as well as migration of small bodies in the solar planetary systems to be considered at a greater length for evaluating ETI problems.

ACKNOWLEDGEMENTS

We are thankful to the Council of Scientific and Industrial Research for financial support in this work [Project No. 03(1153)/10/EMR-II, dated 26.04.2010]. J. Pandit expresses sincere thanks to the Director of JIS group Prof. A. Guha for constant encouragement and support. Two of us (A. Sarkar and B. Raha) are thankful to the UGC and the CSIR for awarding them Net fellowships.

REFERENCES

[1] A. B. Bhattacharya, S. Das, A. Sarkar, M. Debnath and A. Bhoumick, A new technique for investigating extrasolar planets. *International Journal of Physics, 4(1)*, 2011, 31-42.
[2] A. B. Bhattacharya , D. K. Tripathi, A. Sarkar, A. Bhoumick, Implementation of Radio Technique in Interstellar Radiation Field for Locating Distant Stars. *International. Journal of Applied Engineering Research*, Dindigul, *2(1)*, 2011, 63-69.
[3] A. V. Arkhipov, Astrodynamical aspect of paleovisitology. *RIAP Bulletin, 1(1)*, 1994, 7-10.
[4] A.R. Martin, Project Daedalus: bombardment by interstellar material and its effects on the vehicle. *Journal of the British Interplanetary Society, supplement*, 1978, S116-S121.
[5] H. Heusmann, Space Debris. *Spaceflight, 35*, 1993, 182-184.
[6] M.; Duncan, T.Quinn and S. Tremaine, The formation and extent of the solar system cloud. *Astronomical Journal*, *94*, 1987, 1330-1338.

[7] P. Farinella, Ch. Froeschlé, C.Froeschlé, R. Gonczi, G. Hahn, A.Morbidelli and G.B. Valsecchi, Asteroids failing into the Sun. *Nature*, *371*, 1994, 314-317.
[8] S. I. Ipatov, Migration of Small Bodies to the Earth. *Astron. Vestn*., *29*, 1995, 304-330.
[9] C. W. Allen, *Astrophysical Quantities* (The Athlone Press, London 1973).
[10] A. Tough, A critical examination of factors that might encourage secrecy. *Acta Astronautica*, *21 (2)*, 1990, 97-102.
[11] M. Mark, Why SETI is science and UFOlogy is not. *Skeptical Inquirer*, 2004.
[12] M. Chown, *The Alien Spotters (*New Scientist, 1997) 28. Venus clouds 'might harbour life'. BBC News (2004-05-25). Retrieved on 2007-12- 01. (file:///G:/universe203/3746583.stm.html).
[13] P. Curd, *Anaxagoras of Clazomenae: Fragments and Testimonia* (University of Toronto Press, Toronto 2007).
[14] F. Hoyle and C. Wickramasinghe, *Our place in the cosmos* (J. M. Dent, London, 1993).
[15] F. Hoyle and C. Wickramasinghe, *Astronomical origins of life, steps towards Panspermia* (Klewer Academic Publishers, 2000).
[16] S. Arrhenius, *Worlds in the Making* (Harper & Brothers, New York 1908).
[17] F. Crick, *Life Itself. Its Origin and Nature* (Simon & Schuster, New York 1981).