Two Means by which Magnetized Cosmic Bodies can Seed the Universe with Life

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Abstract:

There is currently much interest in the source of life on Earth and whether other objects in the Solar System or other planetary systems contain life. In my view, there are two dominant themes. First and maybe the oldest is that life developed in the seas of the Earth itself and developed out of a random conglomeration of chemicals, conditions and events. The second view is that life developed somewhere in the universe and somehow migrated to the Earth. Indeed, a good deal of effort goes into looking for "Earth" like (habitable) planets around other stars. One prevalent idea is that in environments that are similar to what we have on the Earth, life could develop spontaneously anywhere in the universe – maybe even life that is similar to that on Earth. In this paper, I suggest that magnetized cosmic bodies can seed the universe with life, in the form of spores or viruses (and likely other microorganisms). Firstly, life can be transported from any life bearing planet to other cosmic bodies by the actions of what are called magnetic substorms. Secondly, I suggest that life can 'leak' from near Earth, or other magnetized cosmic bodies, environments onto the Interplanetary Magnetic Field to be swept away by that field.

Key words: Spontaneous generation of life, geomagnetic substorms, transfer of life, microorganisms, panspermia, geomagnetic tail, Interplanetary Magnetic Field

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1. Introduction – Other Ideas Regarding Life on Earth and How It Came To Be Here

There are differing ideas on how life came to exist on Earth. Possibly the earliest came from the teachings of the Greek philosopher Anaxagoras, circa 499 – 428 BC [1]. He advanced the idea that everything (including living objects) has always existed, everywhere, and "The seeds of life which continued floating in the air were carried down with the rains and produced vegetation". More than twenty four hundred years later, Arrhenius (1908) [2], without stating where or how it began, proposed that spores journey through space propelled by light. These ideas have been extensively developed in a modern astrophysical context by Hoyle and Wickramasinghe (1986,

1991) [12, 13]. They have argued over many years that a large fraction of interstellar dust and interstellar organics are identifiable with bacteria and their degradation products.

Another idea, advanced by Francis Crick is that life, once created somewhere in the universe, can be distributed by a process he called *Panspermia* (1981) [7]. Crick proposed that life, trapped in debris ejected from collisions between a life-bearing planet and smaller bodies can travel in a dormant state for long periods of time until encountering another planet with suitable conditions where it becomes active once again. Balkwill, et al. (1988) [3], have given estimates of Bacteria and Archaea in the size range from 0.3 – 2 μm of population density of 10^1 - > 10^8/g of material in both surface and subsurface environments on Earth. If only a small percentage of the organisms survive the ejection there still can exist in space very large numbers of them just after an event causing ejecta from a planet with a healthy biosphere. Certainly some of these will be individual cells free of any other material from the ejection, Napier (2004) [18]; Wallis and Wickramasinghe, (2004) [22]; Wickramasinghe, et al. (2010) [23].

Beyond Francis Crick's ejecta hypothesis, there are other ways to transport living cells into space in the immediate vicinity of the Earth. In a NASA press release, Savage and Steigerwald, (1998) [20], using ion instrumentation on the TIDE satellite, measured a significant increase in oxygen and hydrogen ions out-flowing from the Earth's atmosphere following the impact of a large Coronal Mass Ejection (CME) on the Earth's magnetosphere. CMEs are large ejections of hot material from the sun which, with proper Earth-Sun alignment, can impact the Earth's magnetosphere causing large, temporary variations in the Earth's field. It is not a very great leap of logic to conclude that if living cells are present in the upper mesosphere, some of them may be driven into space along with the oxygen and hydrogen by the action of large CMEs. In support of this, Imshenetsky, et al. (1978) [14] have detected microorganisms in the mesosphere at an altitude of 48 to 77 km. The microorganisms are microscopic fungi having black conidia or spores (Circinella muscae, Aspergillus niger, Papulaspora anomala) and one species forming green conidia (Penicillium notatum). More recently, Harris et al. (2002) [11] and Wainwright et al. (2003) [21] have detected bacteria in samples collected from heights of 41km.

For informative reviews on life outside the Earth's biosphere I suggest the book by Hoyle and Wickramasinghe (1991) [13] and the article by Joseph, R. (2009) [16].

Dehel (2006) [8], in a talk given at the 36th COSPAR Assembly in Beijing, China suggested that bacterial spores can by transported by means of plasmoids into outer space and "spread bacterial life throughout the galaxy". The plasmoid is one of a number of consequences of magnetic reconnection in the Earth's field and likely other magnetized cosmic bodies. In Dehel's proposal, living cells are trapped in magnetic bottles that form in the reconnection process and are ejected towards the tail with the bottle. Dehel advanced this idea as a possible means of transferring life back and forth between the Earth and Mars. The theory goes that during the substorm process, a plasmoid is formed which is ejected from the Earth. Such plasmoids have been measured with velocities of 200 – 700 km/second, more than sufficient velocity to escape the Earth into interplanetary and interstellar space.

2. Populating The Universe By Means Of Magnetic Substorms

In this paper, it is suggested that there are other ways that substorms can transfer life. One idea presented here is that life can be transported from one planet to another and even from one stellar system to another by a process similar to what frequently goes on in the Earth's magnetosphere. That process is the geomagnetic substorm. In a simple view of the substorm, charged particles like electrons and ions are accelerated to high energies, sometimes from a few keV to thousands of keV, by the process of the conversion of magnetic field energy into kinetic energy of the particles. In the substorm process, some of the particles thus energized stream Earthward along magnetic field lines thus producing the aurora-borealis but others are directed outward along field lines connected directly to the interplanetary field.

Geomagnetic substorms occur when the solar magnetic field at the Earth has had a southward component for a period of time. Under these circumstances field lines emanating from the Earth's Polar Caps are forced tail ward and inward toward the neutral plane of the Earth's magnetotail. This process produces a loading of the Earth's field in a region somewhere from 13 - 20 Earth radii in the anti-solar direction pinching the lines towards the neutral plane. When the loading becomes strong enough and the distance between the north field lines and the south field lines decreases enough, the north and south field-lines connect, magnetic reconnection occurs and the energy stored in the built up magnetic field is transformed into kinetic energy of whatever charged particles are in the reconnection zone. If the reconnection zone contains life forms that are electrically charged, they will also be accelerated. As already stated, some will be accelerated back towards the Earth but others will be accelerated away from the Earth towards interplanetary and interstellar space.

One might ask; how do microscopic life forms find their way out of an object like the Earth's biosphere to the tail of the object's magnetosphere where they can be ejected into interplanetary space by the action of magnetic substorms? As mentioned above, microscopic organisms have been detected in the mesosphere at an altitude of 48 to 77 km [14]. In addition, there is a well established phenomenon called "Polar Wind" which is an upwelling of oxygen, nitrogen and other atmospheric gasses into space above the Polar Regions of the Earth. By the very nature and location of this upwelling, many of these atoms find themselves on field lines that map to the distant geomagnetic tail mentioned above, see also Section 6 below. Once ionized, the atoms are subject to exactly the forces and behavior of electrons and protons on field lines, that is, they move along and spiral around the field lines. It is not a great leap to imagine microorganism in the mesosphere, subject to charging by light from the sun, upwelling along with the atmospheric gasses into the near Earth environment and hence populating the geomagnetic tail.

Or as indicated above, possibly they are individually ejected from the planet by solid body collisions. However, these events are infrequent compared to the upwelling processes discussed above. This "squeezing out" process by the action of CMEs should result in the ejection of life forms just as they do electrons and protons.

Regardless of how living cell get to the space environment, they are subjected to solar radiations and will become charged. Some of the living cells that well-up from the Earth in the polar regions of the Earth will find themselves on field lines that map out away from the Earth and into the tail. Once charged they will act just like any other charged particle, that is, they will be captured by and drift along the field lines towards the tail and will participate, just like electrons and protons, in the substorm energization process.

In the following argument I assume a virus with a smooth spherical shape and a density about that of water. The virus is captured on outer field lines of the Earth's magnetosphere. A free, smooth surfaced, spherical object with a diameter of about 50 nanometers (viruses) will become fully charged after accumulating an excess of about 8 electrons. In a large Earth-based magnetospheric substorm, protons can achieve energies up to 4 MeV, Belian, R. D., (circa 1980) [4]. The energy that any charged object can gain as the result of a substorm is directly dependent on the net charge (q) on the cell – the virus in our calculation can retain a charge of roughly 8 electrons. In a large substorm, a virus with a charge of 8 electrons can achieve energies of 3.2×10^7 eV. A 50 nanometer diameter virus with 3.2×10^7 eV of energy will achieve a resulting speed of about 13 km / sec, definitely sufficient speed to escape to interplanetary and interstellar space. I submit that this is a mechanism for biological entities to escape the Earth into interplanetary and even interstellar space. At this speed it would take the microorganisms roughly 10^5 years to make a journey of 4.37 LY to our closest star.

There are two assumptions in the above argument that, when examined in greater detail can affect the speed microorganisms can obtain in the substorm process.

1. The argument assumes a smooth spherical body. The reality is that viruses are not smooth, they are often very rough and consequently the surface area available for charging will be greater than that of a smooth sphere so that the final charge on the virus can be greater than the 8 electrons of our example.
2. It assumes a mass due to a density equivalent to water. After a period of time in space, the spores or viruses should desiccate so that their masses can be much less than what are used in the calculations. Since the final charge will be the same, or even greater after desiccation, the energization will be at least the same as our calculation or it can be even greater depending on the amount of surface area available for charging. Then, with the lower mass the final speed will be greater than our example.

Both of the above effects result in greater energization. Thus the speed achieved by the microorganisms will be greater than the 13 km/sec noted.

Beyond the above, there are two other effect that can greatly affect the final energization of viruses or spores. First consider the strength of the magnetic field of the object energizing them. As an example, Jupiter has a magnetic field that is about 10 times stronger than the Earth's so that organisms in a Jupiter like field would achieve even higher velocities. Of course we know of no life on Jupiter but the magnetosphere of Jupiter should be able to capture organisms that have been ejected from the Earth or other cosmic bodies, further energizing and ejecting them.

Secondly, consider the effects of solar radiation pressure on the out flowing microorganisms as proposed by Arrhenius (1908) [2] and recently studied in some detail by Wickramasinghe, et al. (2010) [23]. They discuss the effects of radiation pressure on the speed of clumps of bacteria. Is it reasonable to consider the possible effects of light pressure on an individual virus? The answer is yes. Their Figure 6.3 clearly shows that the ratio of light pressure to the force of gravity increases rapidly the smaller the clump and the thinner the coating of dark material on the clump. In our case the individual virus with a radius of 0.025 µm the ratio of light pressure to the force of gravity will be greater than 4, making light pressure very effective in accelerating the virus away from the sun. Clearly, individual microorganisms energized by magnetic substorm will have their speeds enhanced by radiation pressure since the action of the substorm is in the same direction as the solar radiations themselves, therefore, continuously increasing the speed of the particles.

3. Populating The Universe By Means Of microorganism leaking out of the magnetosphere on open magnetic field lines

The second proposal presented in this article is the streaming of spores or viruses out of the Earth's (or other magnetized cosmic bodies) vicinity by means of open magnetic field lines. This may occur any time the Earth's magnetic field is directly connected to the IMF and the organisms are present in the magnetosphere above the polar area. The propagation of charged organism away from a magnetized body may not be restricted to the action of magnetic substorms alone. During times that the IMF has a southward component, the outermost field lines of the Earth's field can be connected directly to the interplanetary field on what are called 'open field lines', first proposed by Dungey J. W. (1961) [9]. Charged organisms, like charged atomic particles, trapped on these field lines can move slowly along those lines to the point where the Interplanetary Field Lines (IMF) join with the Earth's field lines, there to be caught up and swept along with the IMF. The question here is whether the Larmor Radii (or gyroradii) of the charged organisms are small enough so that they can smoothly transition from the Earth connected field line to the open IMF field line?

Considering the same virus as was used in Section 2 above, I calculate the gyroradius for a virus with a perpendicular velocity of 1 m/sec in a typical Earth's field of 0.0085 gauss at an altitude of about 3 Re (Earth radii). Perpendicular velocity refers to the component of the virus' velocity that is perpendicular to the magnetic field. This calculation yields a gyroradius of about 55 km. Now as the gyroradius scales directly with the perpendicular velocity, a virus with a perpendicular velocity of 100 m/sec will result in a gyroradius of only 5500 km, less than 1 Re.

It is not known how smoothly the Earth connected field lines transition to the open IMF field lines. However, models of the magnetosphere show transition curves with radii of curvature on order of or more than one R_e, see Russell, C. T. (2000) [19] Figure 9 for example. If we adopt the reasonable assumption that any charged particle whose gyroradius is of order or less then the radius of curvature of the field line transition zone then any viruses whose perpendicular velocity is $\leq$ 100 m/sec will have gyroradii small enough to transition smoothly from the Earth connected field line to the open IMF field line. There is also the real possibility of transitions that are nearly without kinks for field lines directly above the auroral oval. In this case microorganism with a greater range of perpendicular velocities will have free access to the IMF.

However, I submit that, for the purposes of this paper, the gyroradii of the charged organisms aren't critical. I argue that even if the gyroradius is so large that the organism experiences a sharp kink at the transition zone they will simply scatter at the kink. If that happens, some of the organism will have their perpendicular velocity vectors pointing such that they will scatter into the IMF anyway. From this argument it follows that even microorganisms much larger than viruses can themselves be scattered into the IMF.

Those organisms that transition onto the IMF will eventually reach the speed of the IMF. The IMF is carried by the solar wind where speeds greater than 400 km/sec are common and speeds near a thousand km/sec are sometimes measured. The same arguments as given at the end of 2 above obtain here so that the already freed and fast moving microorganisms will continuously accelerate due to solar radiation pressure.

4. Living organisms in space.

On first thought, it doesn't seem likely that living material could survive 10^5 years in the environment of space or even thousands of years so what we might have reaching the surrounding solar systems would be dry, formerly-live, organic material. However, this material should contain the DNA and/or RNA and all the chemical agents necessary for life. I submit that, if life can or has at anytime, anywhere in the universe, assembled itself out of a random soup of chemicals in the proper conditions on the primordial Earth or other cosmic bodies, then life can most certainly assemble itself out of the exact ingredients for life as contained in the viruses or spores once they reach the favorable conditions of another cosmic body.

On the other hand consider tardigrades. These little creatures are known to survive extremes of temperature, dehydration and high levels of ionizing radiation, May, R.M., et al. (1964) [17]. Indeed, a quantity of tardigrades were launched into low Earth orbit on September 14, 2007, subjected to the space environment for 12 days and returned to Earth. Many of the critters survived the space environment, were revived and were even able to reproduce, Jonsson, K. I., et al. (2008) [15]. I don't mean to suggest that tardigrades themselves might be transported to other cosmic bodies, they are likely much too large and heavy – I only mention them to illustrate that there are Earth-bound life forms that can survive periods in the space environment.

5. Long dormant organisms on Earth

Consider the findings of Cano, R. J. and Borucki, M. K.(1995) [6]. They claim to have been able to isolate and amplify a bacteria closely related to Bacillus sphaerium from the stomach of extinct bees preserved in Dominican amber 25 to 40 million year old. Modern day Bacillus sphaerium is commonly found in the stomachs of bees. Given the controls and cleanliness of their procedure, it seems there's a good chance that in fact the investigators did revive 25 to 40 million year old bacteria. If bacterium can be revived after being dormant for millions of years, then it is not too great a leap of logic to conclude that it may be possible that spores and/or viruses can survive in the relatively benign conditions of interplanetary and interstellar space for hundreds of thousands of years.

6. Tests of the hypotheses.

There are, of course, tests for the hypothesis that viruses or other microorganisms can leak or be ejected along the Earth magnetic field lines into interplanetary space. What is needed is a retrievable space probe, similar to the "Stardust" or "Genesis" missions but dedicated to sampling emissions from the Earth's magnetosphere. Consequently the probe would have to spend significant time in the far Earth magnetotail, close to but outside the normal range of reconnection areas. It would have to be equipped with collectors for capturing particles streaming away the Earth and with the ability to return the material to Earth for analysis. This might be similar to the Stardust space probe that was used by Elsila, J. E., et al. (2009) [10]. Elsila , analyzed data from the cometary collectors on the probe and revealed "the first detection of the cometary amino acid" , i.e., glycine.

It would also be most advantageous but not exactly necessary for the probe to be in the magnetotail during or soon after one or more large magnetospheric substorm so as to maximize the chance for capturing the cells. Therefore, the probe would have to be in place when the incidence of substorms is greatest, that is the part of the Earth's orbit where the Earth's dipole has the maximum tilt (35 degrees) relative to the normal to the ecliptic plane. This condition occurs around the time of the equinoxes and is the time of maximum substorm activity and the best chance for collecting meaningful quantities of microorganisms streaming out from the Earth.

I envision a polar-orbiting satellite with a highly elliptical orbit so that it can spend some time near the area where the Earth's magnetic field transitions into the IMF and some time above the magnetotail. The probe should have several collectors, to be opened at different places in the orbit. One or more sets to open when the spacecraft is in or near the magnetotail and exposed to the particles streaming along open Earth's field-lines. These collectors would test the hypothesis that charged microorganisms propagate into space along open field lines without regards to substorm reconnection events.

Another set of collectors would be triggered to open quickly at times of substorms. The triggering could be easily accomplished by a detector set to trigger at the onset of a spike in the flux of energetic-particles – a known product of substorms, see for instance Belian, R. D., et al. (1978) [5]. Two detectors would be required, one to trigger on energetic-particles streaming away from the Earth and the other set to trigger on energetic-particles streaming towards the Earth. A pair of simple, collimated, solid state particle detectors with a level discriminator set at about 100 keV for electrons or protons should suffice. When either energetic-particle detectors registers a rapid count increase above some level, the door to the collector would be opened for a few tens of minutes and then closed to await the next substorm.

A third set of collectors would be opened in the part of the orbit where the satellite transitions out of the magnetosphere and into the area above and/or downstream from the Earth's Auroral Oval preferably as it skims tail ward along but above the last closed field lines. These collectors would be there to test the hypotheses that virus and/or spores leak out of the Earth's magnetosphere and unto interplanetary field lines.

7. A final thought.

The arguments and calculations given above obtain for microorganisms that make their way into a magnetized cosmic body's magnetosphere – they can be energized in magnetic substorms and/or subjected to movement along field lines open to the IMF. The organisms thus escaping the Earth will aid in the production of a sort of soup of organic materials in interplanetary and interstellar space. Again, as mentioned above and as stated by the Greek philosopher Anaxagoras [1], maybe "everything (including living objects) has always existed, everywhere". To the end of this statement by Anaxagoras I would add, "once life has started anywhere on a suitably magnetized body".

Acknowledgements

The author would like to thank the following for reading and critiquing draft copies of this manuscript and for the many valuable suggestions concerning the content: Ray Engelke, Mario Perez and Tom Cayton

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