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The Discovery of Microbial Life on Mars

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Abstract

The Discovery of life on Mars, and by extension, the stars, could be proven by discovery of a single living microbe on the Red Planet. But, at the same time, a mass of independently derived data all indicating a finite probably of life, indicating Occam's Razor as a factor, can also form the basis for the following Inductive Reasoning: 1. The Conditions on Early Earth, where life appeared, and Early Mars, have now been found to be basically identical; therefore, based on the Principle of Mediocrity, the probability of life is estimated to be P_L=0.5 on Mars, an estimated 50% probability. 2. Complex organic matter has been found in recently formed aqueously altered terrains on Mars, and in both ancient and young meteorites from the Red Planet, in aqueously deposited minerals found within them, suggesting a further probability of biological origin versus abiotic of P_L=0.5. 3. Reexamination of the Viking Life Experiment results, given new knowledges of both Mars surface chemistry and biologically generated super-oxides on Earth, strongly support the conclusions of Levin that life was found in 1976, 4. The seasonal variations of two biologically produced gases, O_2 and CH4 recently discovered, are consistent with widespread microbial life on Mars, and along with the Life Experiment results, again can be estimated to indicate a P_L=0.5 for each test. In the article we will explore these four findings holistically and draw the overall Inductive Conclusion that the simplest interpretation for this body of data is that Life began and persists on Mars as surely as it does on Earth. We assume here that, using a probabilistic model, the probability of Mars being sterile is $P_S=(1-P_L)^{N+1}$ and yields an estimated probability of Life on Mars as 97%. Life on Mars is thus discovered. This conclusion, similar to a court case built on circumstantial evidence, can also be likened to a Second Copernican Revolution, wherein the Earth is now displaced from the center of the Biological Universe, just as it was formerly displaced from its geometric center.

Introduction Mars, and the Second Copernican Revolution

The Discovery of life on Mars, and by extension, the stars, could be proven by discovery of a single living microbe on the Red Planet. But, at the same time, a mass of independently derived data all indicating a finite probably of life, indicating Occam's Razor as a factor, can also form the basis for the following Inductive Reasoning: 1. The Conditions on Early Earth, where life appeared, and Early Mars, have now been found to be basically identical, with a liquid ocean and magnetic field therefore, based on the Principle of Mediocrity, Life on Mars could be an estimated to be 50% probable [1,2]. Complex organic matter has been found in recently formed aqueously altered terrains on Mars, and in both ancient and young meteorites from the Red Planet, in aqueously deposited minerals found within them, suggesting a further 50% probability of biological origin versus abiotic [3]. Reexamination of the Viking Life Experiment results, given new knowledges of both Mars surface chemistry and biologically generated superoxides on Earth, strongly support the conclusions of G. Levin that biochemistry was found in 1976, and can also be equated to a 50% probability of life being discovered [4,5]. The seasonal variations of two biologically produced gases, O_2 and CH_4 recently discovered, are strongly consistent with widespread microbial life on Mars [6,7]. Here again we will we conservatively assume a 50% probability to this atmospheric phenomena being truly biogenic. In the article we will explore these four findings holistically and draw the overall inductive conclusion that Life began and persists on Mars as surely as it does on Earth. This is done with an Inductive Proof Probabilistic Model. This conclusion, similar to a court case decided on circumstantial evidence, can also be likened to a Second Copernican Revolution, wherein the Earth is now displaced from the center of the Biological Universe, just as it was formerly displaced from its geometric center.

The criterion that a single living microbe found on Mars would prove that the Red Planet is the abode of life, is worthy of some discussion. In times past, such a finding would automatically be extrapolated as indicating life in the stars. However, now, if such a microbe is found, it would lead to a debate as to whether it was actually native to Mars, and not from Earth. This due to the fact that so many probes from Earth, unsterilized, have landed or crashed on Mars. This discussion must also acknowledge that, only the hardiest of extremophiles from Earth could survive a trip and crash landing on Mars, and thrive there, and such extremophiles are immune to standard sterilization procedures. It is also true that since antiquity Mars meteorites have landed on Earth, and , though less likely, meteorites from Earth have impacted on Mars. Mars being smaller and further from the Sun, probably accreted and cooled earlier to allow a liquid ocean before Earth did. Mars then could easily have preceded Earth as an abode of life. Mars and Earth, when the possibility of swapping meteorites and extremophiles is included, can no longer be considered as mutually isolated, biofriendly, environments. Accordingly, all life on Earth may have a Martian ancestry. Finally, since both planets Mars and Earth, are surrounded by a Cosmos much older than themselves, the existence of extremophiles capable of long term survival in space means that neither Mars or Earth can be considered biologically isolated from the rest of a possibly living Cosmos. Ultimately, these questions are questions of probabilities, the one type of mathematical analysis that is applicable in both a test tube and a Casino. Based on this reasoning, it seems highly likely that a living microbe found on Mars would be native to Mars rather than Earth given the harshness of Mars environment relative to

Earth. That is, anything that could survive and thrive on Mars is most likely not from the comparative paradise of Earth. To posit that such a microbe was originally from Earth, requires that Earth life is not originally from Mars, or did not arrive on both planets as extremophiles via Panspermia. Panspermia, it should be pointed out, does not solve the question of how life originated, it merely moves the ultimate origin of life to a "galaxy far, far away, a long time ago." Therefore, with all this considered, we will thus adopt the viewpoint, for this article, that finding microbial life on the Red Planet, would establish it as an abode of life, and that "in all probability" this result of Life on Mars can be extrapolated to Life in the Stars, that is, a living Cosmos where life is a favored outcome of Early Earth-like conditions.

Conditions on Early Earth and Mars

Evidence recently discovered in the 3.5 billion year old Australian Pilbara formation, of fossil Stromatolites strongly supports the conclusion that cyanobacteria, possessing DNA, RNA, enzyme systems, and chlorophyl had appeared shortly, in geologic time, after the formation of a liquid ocean [1,8]. The conditions of Early Earth, a liquid water environment, a magnetic field shielding the surface from radiation, and abundant organic matter, were conducive to life [2]. The details of life's appearance on Earth are unknown, however, proceeding phenomenologically, this fossil stromatolite discovery supports the concept that the appearance of life on Earth was both likely and part of a natural process.

Mars, based on careful study of Mars Meteorites, and lander analysis of surface materials, was assembled from the same body of nebular dust and rocks as Earth, with only slight differences in composition. This body of matter, likely including large amounts of CI and CM carbonaceous chondrites, would have contained abundant organic matter, as well as water [9].

Based on the most recent data, gathered by orbiters, rover-landers, and Mars Meteorites, conditions on Early Mars were basically identical to those found on Early Earth. In particular, the existence of a Paleo-Ocean on Mars, and other signs of persistent liquid water conditions made Mars environment conducive to life as we know it [1]. Mars contains large areas of fossil magnetization, showing that like Earth, it had a protective shield against radiation, making it even more conducive to the appearance of life [2].

Accordingly, the basically identical conditions on both early Mars and early Earth, argue, by Mediocrity, that life should have appeared on Mars as it did on Earth. Therefore, since Mars is neither Mercury or the Moon, but globally an Earthlike planet, we will assign an a priori probability of life as $P_L = 0.5$ for life past and present on Mars.

Figure 1: Early Mars complete with a Paleo-Ocean

Organic matter found on Mars

The identification of complex organic matter on Mars in aqueously altered terrain, and in aqueously deposited minerals in the both the young (180 Myrs) Mars Meteorite EETA79001, one of intermediate age (1.4 Byrs) Nakhla and the very ancient one, (4 Byrs) ALH84001 show the abundance and persistence of organic matter on Mars since its formation [10-13]. Organo-synthesis in this context can be either biochemical or geochemical, and since the Mars meteorites represent local samples of the Mars global surface, we will attach a probability $P_L = 0.5$ for the origin as biochemical, as we did for Early Mars global conditions.

Figure 2: Ancient Mars meteorite (4 Gyr old) ALH84001

Figure 3: Intermediate age Mars meteorite (1. 4 Gyr old) Nakhla

Figure 4: Young Mars meteorite (0.2 Gyr old) ETA79001

This is particularly so in the case of organic-rich CI carbonaceous ,such as the very ancient (~4.5 Byrs) CI materials are thought to form the late accretion veneer on both Early Mars and Earth, starting each planet with organic precursors of life [9].
CI, which, based on oxygen isotopes , and trapped Noble Gases,

can be identified as “Old Mars lake bottom”, part of the late accretion veneer on Mars, being heavily aqueously altered material, before it dried, and was then ejected into space by an asteroidal impact, to find its way to Earth [14].

The CI meteorites, like their isotopically distinct cousins the CM Carbonaceous Chondrites, illustrate the paradoxical nature of organic matter from Mars. This occurs even if microbes existed on Early Mars, since much of the organic matter in the CI and CM type meteorites is apparently prebiotic and formed in the hydrogen rich preplanetary nebula before the planets accreted. Thus, the CI may demonstrate both biosynthesis and abiotic synthesis of complex organic matter on Early Mars could have occurred simultaneously.

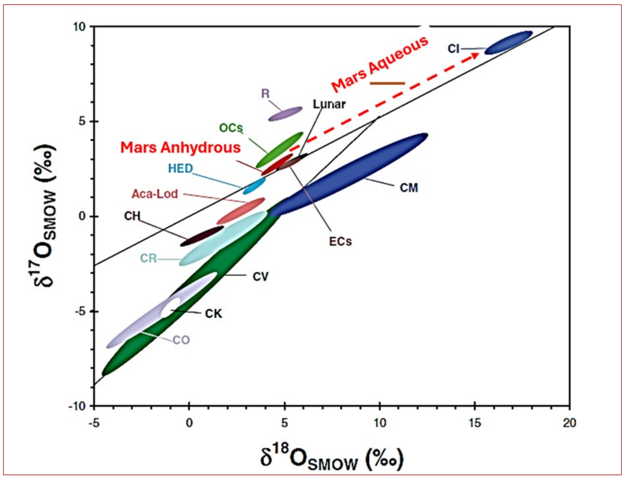

Figure 5: Oxygen Isotope graph showing various meteorite group materials, including for the heavily aqueously altered CI type materials, as well as Mars meteorite materials, both anhydrous and aqueous deposited. As can be seen the CI materials fall within the aqueous Mars material region of the graph. (adapted from graph in [15])

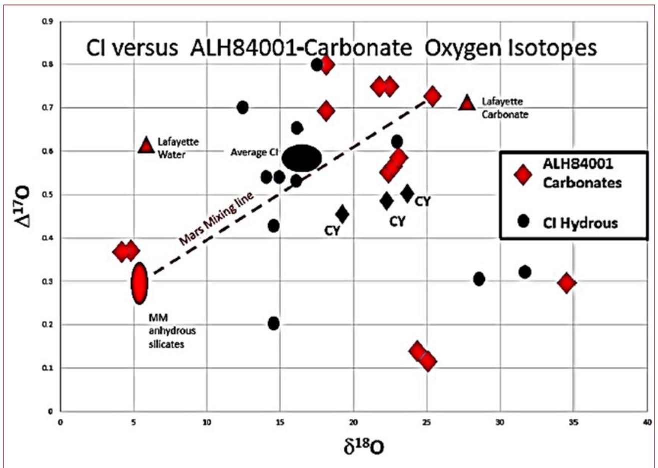

Figure 6: Oxygen Isotope graph showing various Meteorite Group materials and CI materials. Note that the dtata groups are interpenetrating. Taken from [14}

Figure 7: A fragment of the Orgueil meteorite

Orgueil, a well known CI meteorite, contains even more dramatic evidence of microbial life on early Mars is found, in the form of apparent diatoms [16].

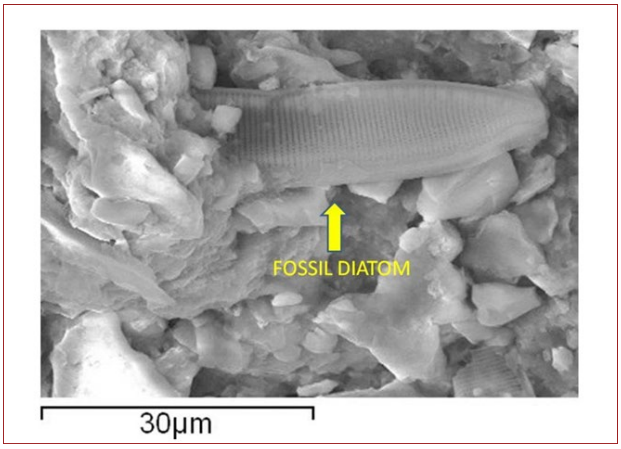

Figure 8: Apparent Diatom Microbial Fossils Found in the Orgueil Meteorite

Complex organic matter has also been found directly on Mars, by the Curiosity Rover, in an ancient lakebed on Mars [3]. Taken together, these findings suggest Mars is an engine of biosynthesis, since this data showing organics is the result of samples gathered randomly across Mars surface and at different epochs. Such a result is startling, given the barren appearance of Mars surface.

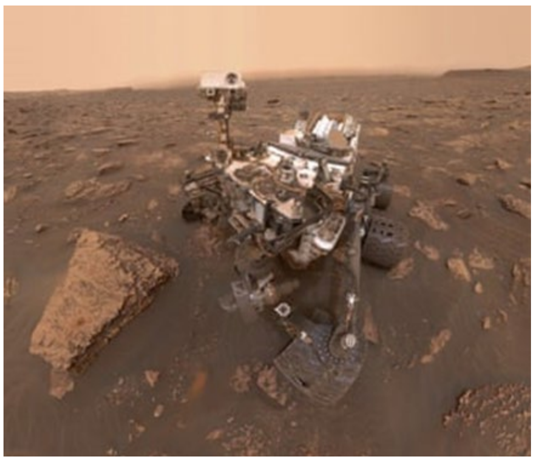

Figure 9: The Curiosity Rover on Mars.

For the purposes of this study, we will consider the multiple instances of organic matter being found in Martian materials, as effectively one event. This is done because of the aqueous nature of the host materials, since it can be argued that they are not independent events if there is a Martian global aquifer containing abundant organics from some source. Therefore, we will conservatively evaluate of the finding of organics, from all sources as indicating life with a probability of 50% , since the organics can be created abiotically, as in the Urey Experiment and Fischer Tropsch Process. However, it must be also noted that abiotic formation of organic matter requires hydrogen rich environments, conditions that would be rare and fortuitous on the highly oxidized environments found on Mars.

A Reexamination of the Viking Life Experiment Results Based on New Data

The results of the historic JPL Viking life experiments have been examined carefully in the half-century since their occurrence, and this analysis has now been vastly improved by data from Mars surface, Mars meteorites, and a better understanding of biology on Earth [17]. The three life experiments , were the GEX (Gas EXchange), PR (Pyrolytic Release) and LR (Labled Release) were all designed to detect CO_2 and hydrocarbon emissions indicative of microbial growth and metabolism. All originally designated life experiments gave results basically consistent with biology in the soil. However, the presence of an unknown oxidizing agent in the soil, which might mimic microbial metabolic activity by creating CO_2, by oxidizing the nutrients, understandably caused hesitation. To solve this confusing situation on Mars, data from the on-board GCMS (Gas Chromatograph Mass Spectrograph) was used, which heated the soil samples, and whose resulting gases, organic molecules were not detected. Despite the fact that the GCMS was never intended to be part of the life experiments, its results were used to refute all the positive original life experiment results. However, this refutation has now been rendered useless in the evaluation of the results of the life experiments by new data concerning Mars soil chemistry.

Given the unexpected results of the three life experiments, where the soil samples were measured to emit large amounts of oxygen when first moistened, the presence of unidentified superoxides were indicated [18,19]. Despite the fact that the presence of such oxidizing agents would be expected to destroy any organic matter upon heating of soil samples in the GCMS, the GCMS results were used to rule out the possibility of organics in the soil. This result was further extrapolated to use the presence of unidentified oxidizing agents to explain all the results of the life experiments, which by otherwise indicated biology. The presence of chlorinated hydrocarbons in the GCMS results was also noted, was said to be due to cleaning solvent used on the spacecraft.

This invocation of unknown oxidizing agents to rule out a biological interpretation of the life experiment results, was protested by various investigators, principally Dr. Gil Levin, the designer and chief investigator of the Labled Release experiment [5]. He was able to show that, Antarctic, “dry valley,” soil samples, containing small numbers of microbial spores, which awakened upon exposure to water, could explain the LR experiment results biologically. These same soil samples, containing such small amounts of organic matter before application of water and nutrient, gave null results in the GCMS instrument, like those seen on Mars. Thus, it was seen that the LR instrument, relying on the tendency of microbial life to “be fruitful and multiply” in a watery nutrient rich environment, was far more sensitive detector of organic matter, in this case living, than the GCMS. This refutation of the GCMS organic matter search results has been made complete by the discovery of organics and perchlorates in the Martian soil and meteorites [3,20].

In close duplication of the results of the GCMS results on mars it was discovered that heating of soils containing both organic matter and perchlorates generated gas containing chlorinated hydrocarbons [21]. Therefore, the results of GCMS experiment, with the discovery of perchlorates on Mars, confirm rather than refute the presence of organic matter in the Mars soil samples at the lander sites.

Perchlorates are stable molecules even in the presence of water and found in such differing soils as those from the high altitude, extremely dry, Atacama desert, and southern Kansas. They can be formed inorganically by the reaction of hydrogen peroxide or alkali superoxide on hypochlorite. The main feedstocks for these reaction pathways both hypochlorite and hydrogen peroxide, can be produced by microbes [22].

The production by biology of concentrated hydrogen peroxide, normally considered a disinfectant, is demonstrated most remarkably by the “Bombardier Beetle” which uses it with a hypergolic co-reactant to produce a hot irritating spray for defense.

Superoxides, such as magnesium or sodium superoxide can also be produced by microbes or desert photochemical processes and are unstable in the presence of liquid water [23,24]. The most important instance of this for this discussion is the production of superoxide by bacteria as a reaction against desiccation during dry periods. This curious chemical response to lack of water, could be understood as a way to dispose of oxygen while preserving water. For desert adapted cyanobacteria, operating at low metabolic rates, oxygen from photosynthesis is mostly a waste product, and must be excreted with minimum exposure of the cytoplasm to air. Superoxides, being solids, solve this problem. The two most likely candidates for biosynthesized superoxides on Mars are magnesium and sodium superoxides, the latter being the approximately same color as the Martian soil.

Figure 10: A fragment of Sodium Superoxide

The well known property of superoxides to decompose, releasing oxygen, in the presence of moisture, accounts for its early consideration by Viking investigators trying to explain the results of the GEX experiment. This also means that superoxides had to have a source in the soil itself, to renew them after wet spells on Mars.

Therefore, the GCMS experiments have been shown as too insensitive to the presence organic matter in the Martian soil samples to rule out microbial spores in the sample , that could produce a life signal from the LR release experiment. Additionally, the presence of perchlorate in the soil samples would have masked the direct detection of sample organics by the heating-induced oxidation of any organics present. This would involve organics similar to those already found on Mars by rovers [3]. Perhaps most importantly, the detection of chlorinated hydrocarbons from the heating of perchlorate infused soil is actually evidence of organics in the soil. Thus, the GCMS results are actually consistent with the presence of organics mixed with perchlorates in the Martian soil, and by inference , biology, rather than establishing the verdict of "no life" in the Viking experiments.

Finally, the mystery of the "unknown superoxides" in the soil samples, readily decomposed by water, as opposed to water soluble perchlorates, is solved. The release of oxygen upon wetting of the samples, which so confused in the Viking investigators at the time, and suggested inorganic oxidation of the nutrients rather than microbial metabolism as the source for CO_2 emission, could itself be due to biology seen to operate on Earth. On Mars "Bombardier Bacteria " making both hydrogen peroxide and alkali superoxides to allow excretion of oxygen waste from photosynthesis in a desert environment, must be considered as the reason for superoxides in the soil. These superoxides would be destroyed periodically by wetting events , such as frosts on Mars (see Figure 11) and so would have to be renewed. Thus, the presence of superoxide is possibly an indicator of life rather than of lifelessness.

Figure 11: Frost at the Viking 2 Lander Site on Mars

Therefore, life may have been discovered in 1976 by the Viking life experiments, but given the vast unknowns of the Mars environment at the time, and the unexpected oxidizing agent in the soil, the consensus was made to err on the side of caution, and defer to the insensitive and perfunctory results of the GCMS to yield a "safe" verdict of "no life". However, given the benefit of 50 years of hindsight and new data concerning Mars, the verdict must now be changed: their was a high probability of microbial life in the soil samples at the two Viking life experiment sites. Here, again we will assign a 50% probability to the concept that the superoxides and other chemical activity in the Mars samples was biologic.

Seasonal Variation of Atmospheric Oxygen and Methane at Mars Surface

The simplest observational test for life in an organism, is whether it is breathing. Likewise, the simplest confirmation for the inference of Earth-Mars parallel biogenesis, the meaning of Martian organics associated with aqueous deposits, or various ages, and the positive biology results, upon reexamination, of the Viking Life experiments, is provided by the observation of the seasonal "respiration' of the present Mars biosphere.

Two molecular gases O_2 and CH_4, both with limited lifetimes in the Mars atmosphere due to ultraviolet bombardment, are observed to "bloom" in concentration in the local Mars Fall and Summer, and to decline in the Winter [6,7].

Molecular oxygen, the forth most abundant molecule in the Mars atmosphere, has always suggested photosynthesis, since its production by UV photolysis of CO_2, the most obvious inorganic source, would result in CO being of higher concentration than O_2, when, in fact, the reverse is the case. On Mars the preferred color for photosynthesis would be red, not green, since green light is more intense from the Sun and its photons carry more energy. On Earth the red-dye, phycoerythrin, combined with chlorophyll system, makes the chlorophyll absorb green and blue light rather than reflecting it thus making it more efficient in low-light environments. This pigment is seen in red algae and other plants that grow under reduced light conditions on Earth. Therefore, durable plant life, in the form of lichens , could "hide in plain sight" in the red landscape of Mars.

Figure 12: The red algae Gracilaria contains phycoerythrin to use sunlight more effectively in the lower light levels at depth below the ocean surface.

The fact that the O_2 level increased in the local fall and Summer on Mars is easily explained by the increase of sunlight during those seasons and the warmer temperatures more conducive to active cell metabolism. As would be expected for photosynthesis, or photolysis, this activity peaks, along with sunlight in late summer.

Methane, on Earth is the well known result of anaerobic microbial digestion of buried organic deposits. It naturally would become higher in concentration due to warmer local ground temperatures and the resultant local melting of permafrost. Because it depends on near surface temperatures rather than sunlight, it displays a characteristic "lag" behind oxygen production, peaking in local Autum rather than Summer. Methane is quickly destroyed by UV photolysis in the Mars environment and so whatever methane is seen is recently produced, possibly by busy colonies of anaerobes. (see Figure 13)

Thus, in accordance with previous discussions, Mars may be breathing, because it is alive. Given the dramatic chemical differences between O_2 and CH_4, and the lag time between their peak concentrations, we will count these two distinct measurements as independent cases, and, because both cases can be explained without biology, the same P_L=0.5 for each.

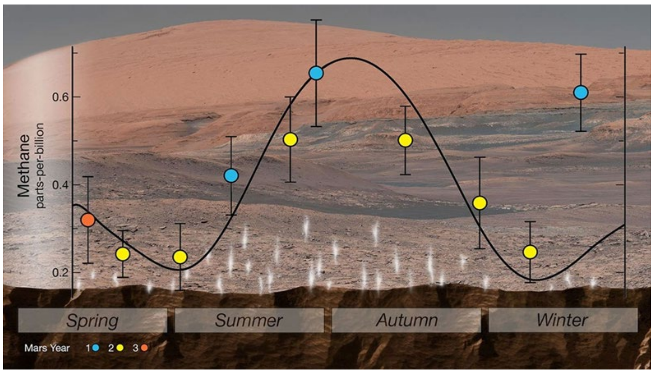

Figure 13: Seasonal variations of methane recorded on Mars surface

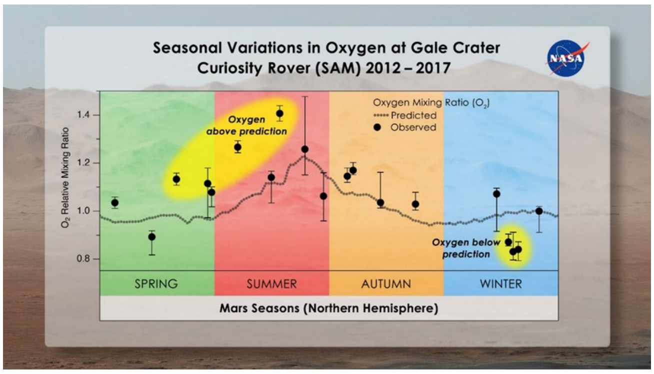

Figure 14: Seasonal variations of molecular oxygen on Mars surface

Inductive Proof of Life on Mars

Given the large amounts of data from various sources, consistent with a strong possibility of microbial life on Mars, it is possible to analyze these reports with a holistic math model and draw a conclusion on the question of microbial life on Mars. This will be done based on an inductively calculated probability of biology on the Red Planet.

Inductive proof is a powerful tool for mathematically analyzing large amounts of data, in the particular circumstance that each piece of data, in isolation, is not definitive. By analogy, it is like building a case in court based on several independent pieces of circumstantial evidence [25]. Accordingly, we can construct a mathematical model to provide an estimate of the cumulative probability of microbial life on Mars, based on many independent tests. The model chosen here draws its inspiration from the "Correlation of Forces Model" used by the Soviets during the Cold War, where even difficult to quantify factors such as morale of armed forces where assigned numerical values for the purposes of analysis. Such a model suffers from the procedural weakness of assigning numbers to that which is inherently nonnumerical, but it is none-the-less useful for estimation of probabilities and seeing trends in the data [26]. Here, we will adopt a simple math model to estimate the probability of finding microbial life on Mars, based on the that it requires probabilities will all lie between 1 and zero, that is gives a probability of zero if all data shows an absence of the possibility of microbial life on Mars and conversely if a "single living microbe" is found on Mars it gives the probability of 1, for Mars being the abode of microbial life.

In this model we define an a priori probability of life on Mars P_L =0.5 based on we of the basically identical condition on Early Earth and Early Mars. The complementary probability of Mars being sterile, thus devoid of life, we will call P_S=(1-P_L). As was discussed, one viable bacterium being found on Mars, is enough to prove life on Mars. Accordingly, as discussed previously, we will regard, P_L = 0.5 as being insensitive to any specific test for Mars life at any one spot, since microbial life could exist in localized patches anywhere from a few millimeters to several meters below the surface in certain localized "oases" on Mars. Thus, for null tests in isolation, P_S =1, but, as will be seen, this has no overall effect on the calculation.

We can define then, the cumulative probability of finding life on Mars based on a both its global past environment and a local discovery of organic matter or other possible biosignature, to which, as we discussed earlier, we assign a P_L =0.5 . We write, for N independent tests, each giving a value P_{LN} showing possible localized biosignatures, an expression for the cumulative probability of Mars being sterile,

$$P_{SC}=(1-P_{LN})^{N+1} \qquad (1)$$

The base case of N=1 test, again using global past and present Mars conditions is

$$P_{SC}=(1-P_{L1})^2 \qquad (2)$$

Which is the probability of two independent events, each of probability PL1 occurring, and we also have the inductive base case of N-1, which is the probability of Mars being sterile for the parallel global conditions of early Mars and Earth

$$P_{SC}=(1-P_{Lo}) \qquad (3)$$

Which is also the simple complementarity definition for probabilities.

This model of Eq. 1 gives P_{SC} =1 for any series of tests that all show P_{LN} = 0 test indications. However, since P_{SC} is a product of probabilities, it incorporates the "one microbe rule" for indicating life on Mars in that Eq. 1 gives P_{SC} =1 for any test of life that is unambiguous, that is, P_{LN} =1.0 . However, ambiguity in the meaning of any one test is to be expected in an alien planetary environment. Short of seeing a moving Martian Protozoa under a microscope-equipped rover camera, P_{LN} <1 can always be expected for any one test. Despite this, the effect of repeated findings of possible biosignatures , indicating 1 > P_{LN} > 0, is cumulative in this model, just as are pieces of circumstantial evidence are used to "build a case" in a courtroom. It can be said that the mathematical model of Eq. 1 incorporates Occam's Razor as a factor. Microbial life is the simplest unifying explanation for what is observed on Mars, rather than an ensemble of fortuitous instances.

Using this model, and assuming P_{LN} = 0.5 as a simple general case, it is seen by inductive proof:

$$P_{SC}\rightarrow 0 \quad \text{as } N\rightarrow\infty \qquad (4)$$

Therefore, we see the while PL is insensitive to the outcome of a number of independent tests, the "one microbe rule", requires the PSC to be a product of probabilities and requires that PSC changes with the outcome of a number of independent tests even if they present P_{LN} <1 . Thus, because of Mars past and present global conditions the probability of Mars being sterile goes down rapidly , in this model, with the discovery of each new possible microbial biosignature, until P_S =0.

In this limited set of N=4 life tests, with a conservative avoidance of possible non-independent results, notably where the O_2 and CH_4 variation, are counted as two separate tests, we obtain for the approximate Total Probability of Life on Mars as P_{TL} = (1-P_s) = 97%. This means , by this model, that the numerous pieces of data, possibly consistent with Life on Mars, taken together, yield the result that Life on Mars is effectively a certainty. If this was a wager in a Casino, one would be very unwise to bet against these odds. That is, the coexistence of numerous possible biosignatures, and the parallel conditions of Early Mars and early Earth, where life appeared, taken together, indicate an effective certainty the Life on Mars exists. To think otherwise is to imagine that Mars the planet is acting like a living organism and engaging in widespread abiotic organo-synthesis across its surface and across the eons. Microbial Life on Mars is then therefore, the simplest explanation for all the existing data. Accordingly, put in terms of this probabilistic model, the mass of data concerning Mars has yielded by Inductive Proof, that Life on Mars, both past and present, exists.

Summary and Conclusions

We now have every reason to expect that Mars is, like Earth, the abode of life. Mars and Earth began with basically identical conditions, and were assembled from the same nebular matter, including a rich load of organics. To suggest that Mars is devoid of life while next door to Earth's diverse, voracious, and rugged biosphere, is to propose that life on Earth is a "miraculous" and isolated aberration on the Cosmos. Earth appears instead, to be rather typical of a rocky planet in the "Goldilocks zone" of the Sun, sharing this zone with a twin sister, Venus, and of course, Mars. To make this argument complete, orbiting the very closest neighboring star Proxima Centauri, is the exoplanet Proxima b, almost identical in size and projected surface temperature as Earth. So Earth is basically a "common pebble" in the Cosmos.

The Verdict of "no life" from the JPL Viking life experiments a half-Century before, given hindsight and a mountain of new data from Mars and Earth, now appears to be the product of academic caution and confusion rather than bold investigation. The final official verdict of "inconclusive" is understandable given what was known then, but in the present, in the author's opinion, this verdict is no longer defensible. Life, past and present , is found on Mars.

Accordingly, we now have stunning evidence strongly supportive of a verdict of "life" from the JPL Viking experiments. Mars has organics in its soil and breathes seasonally, just as the Earth biosphere does, betraying microbial activity, both photosynthetic and anerobic.

One always wishes for more data, before coming to a conclusion. All scientific discoveries, especially the great ones, must be made initially based on incomplete data. That is how life and even science actually functions: probabilistically. Humans must make decisions based on incomplete data every day, some of which involve life and death. They do this by consciously or unconsciously calculating : "what are the odds?" Copernicus, and his classical Greek inspiration, Aristophanes, could not leave the Earth and observe the movement of the planets from above the ecliptic. Yet they proposed Earth moves around the Sun like the other planets, despite how upsetting this was to the 'powers that be' at the time. Even centuries later, it was found that adding more "epicycles" to the Geocentric model could explain the observations of the planets. It was not until Newton that the Copernican Model was fully accepted. Copernicus had "played the odds" and won.

In the case of biology, the richness of organic chemistry guarantees that any chemical compound, normally associated with life on Earth, can also be synthesized abiotically in a test tube, by some process, no matter how Byzantine. However, Occam's Razor must be considered, since finding organics at numerous sites, over a eons of time, implies extreme complexity. Therefore, the widespread fortuitous geochemical organo-synthesis events required for the abiotic explanation for the numerous findings of organic matter seems unlikely compared to widespread microbial activity. Thus, the rich tapestry of microbial life seen on Earth, makes biologic processes appear to be the most likely answer to the questions provoked by strange new chemical data we have from Mars. In the face of such data on Mars, life is now the simplest and most defensible explanation for what we observe there.

By extension, if life is now discovered on Mars, it is now discovered in the stars. Thus, if human science is to break the bonds of intellectual paralysis, we must awaken to a new, Second Copernican Revolution, and advance boldly into a New Living Cosmos.

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