Zac Macintyre

Panspermia and Abiogenesis on the Possibility of Life

Abstract

For this project I was interested in modeling different forms of abiogenesis and seeing how this process coupled with panspermia affects life production. Using Poisson distributions, I was able to model abiogenesis and panspermia with varying levels of success. The results indicate that if the abiogenesis process takes anywhere under 50 trillion years, then it is probable life has been created on other planets. Additionally, if abiogenesis takes under 5 billion years, it is probable humans will find life if we have the detection capabilities. This paper has room for expansion within the simulations. Most models were scaled down from ideal because of the computational complexity they took to run. This is where further exploration can happen.

Introduction

Naturally, many of us our curious about how life was created, and if there is other life out there. It makes sense, humans are a curious organism, and there does not seem to be a problem too big for us to tackle, given enough time and resources. The most popular theory for how life was created is abiogenesis. Abiogenesis is the theory in the evolution of early life on earth: organic molecules and subsequent simple life forms first originated from inorganic substances (Meriam Webster Dictionary). However, there is another theory, panspermia. Panspermia is the theory that life on the earth originated from microorganisms or chemical precursors of life present in outer space and able to initiate life on reaching a suitable environment (google dictionary). This theory of life is less known amongst the laymen, but has some academic support. In this paper, I investigate how you might model these processes, and given different modeling criteria I explore the life generating process and possibility of life elsewhere.

Model Basics

The problem with modeling life creation is there is no available data how life started. As previously stated, they are theories not facts. With that being said most events happening or not happening can be modeled, and this is no different. For this paper, I assumed that both processes can be modeled using a Poisson distribution.

$$\Pr(X \mid t,\tau) = e^{-t/\tau} \frac{t/\tau^{X}}{X!}$$

X = number of successes in time interval t

T = time interval

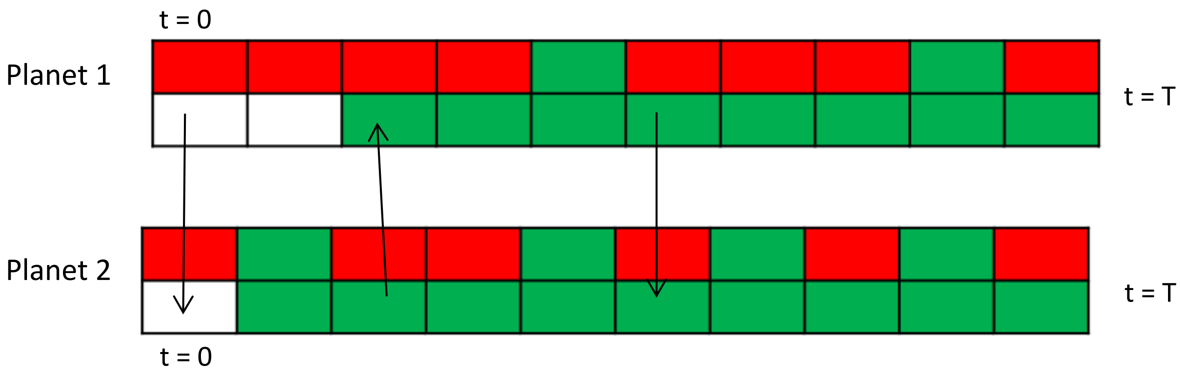
τ = mean time scale to pick the lock

The Poisson distribution has a couple of key characteristics which make it useful in modeling events. First it gives the probability of X successes happening in a given time frame. Second, τ gives an average time for an event happening which allows me to give different time scales for how slow or fast I think the abiogenesis or panspermia process takes. Third, and maybe most importantly it has a memoryless property. In words this means that whatever happened in one interval has no effect on any future intervals. This is useful because when modeling it doesn't matter what happened up until time t and t doesn't affect anything after itself. Overall, a Poisson distribution is an appropriate model for panspermia and abiogenesis.

Now, to frame the model. I have made the total time T take on the value of 5 billion years. You can think of it in one of two ways. First way, a planet has been around for 5 billion years. What are the chances it has had a life generating event? Second way, a planet has 5 billion years left before it is destroyed. What are the chances it will be inhabited? In both scenarios we model the same events, the difference is perspective. I looked at it through the lens of the 5 billion years have passed.

As for the actual abiogenesis process, I will use a Poisson distribution as previously stated. The output of the Poisson will be the probability I feed into a binomial distribution. This will output will be either life was created (a success) or life was not created (a failure). Looking at the figure below you can get an idea of how the process works. I split T up into N parts and use the Poisson distribution to get a probability P. From there I treat each segment in N as random binomial variable, and simulate it using P as the probability input. Additionally, I worked under the assumption of that once life started (a green value in the top row), life will be there until time T. The bottom row represents life being present or absent.

Now, on to the panspermia model process. For this process at least 2 planets are needed, as the sending of foreign debris happens between the planets in the system. For this I used the same abiogenesis process and then added on a panspermia Poisson process. This worked exactly like abiogenesis, each segment in N had a probability to send debris and it would send whatever was going on at the time. For example, if planet 1 had life, and it sent debris to planet 2, the debris would have life. Additionally, if life was being carried by debris, then life would be created on the planet it went to. You can see this in the example below. Life on planet 1 starts before an abiogenesis event because a successful panspermia event happens first.



Methodologies:

I went after this problem in two different ways. The first method used Monte Carlo simulations and showed results that I was not expecting. This led me to my second method, which models a real-life scenario. Finally, I added a 3rd method that was more of exploring the panspermia process and how it affects methods 1 and 2. All. The parts helped me understand this problem in different ways, and led to unique and interesting conclusion.

Method 1

For my first method I was interested in running a Monte Carlo Simulation to see the probabilities of life generation events. Using the above frame work I set T = 5 billion years and then varied τ between 50 million and 50 Trillion years. Additionally, I ran the simulation 10,000 times and broke T into 50,000 intervals. For the first part of this simulation, I used a 1 planet model and a 2-planet model without panspermia. I thought these were good numbers to get a robust and stable estimation of the processes. All of this can be seen in the chart below.

	1 Planet	**2 Planets**
Tau	**% of times Inhabited by T**	**% of times system Inhabited by T**
50 Million	1.0	1.0
500 Million	1.0	1.0
5 Billion	0.6306	.874
50 Billion	0.1001	0.179
500 Billion	0.0078	0.022

5 Trillion	0.0011	0.003
50 Trillion	0.0	0.0002

I found these results to be rather interesting. To start, if we were to assume that tau is less than 5 billion years, then life occurs rather often. I think this is interesting because the universe is 14 billion years old, and that would almost certainly mean other life is out there. Even, if we increased our assumption, that it takes 50 billion years, it still holds that life is most likely out there due to the vast size of the universe. As, tau increases after that the probability gets smaller and smaller until it is near 0. For the 1 planet model I did not have any life generating events when tau was 50 trillion. This is interesting that in over 10,000 samples split into 50,000 trials that not one event happened. The 2-planet model, however, did have life during that process. These findings are pretty remarkable to the implication of other life.

For the next part of my simulations, I ran tests to see how often panspermia starts life earlier on a planet. For this I used the Poisson distribution to model panspermia. The tau for that I kept constant, and the probability was 63%. I thought this was a fair value, as earth gets hit with around an estimated 500 meteorites every year (Planetary Science Institute). That number is about 2 a day, and the time periods in my model are on the thousands of years. So, I reasoned that having panspermia occur a little over 50% of the time made sense. The results of my model are in the table below.

Tau	50 Mil	500 Mil	5 Bil	50 Bil	500 Bil	5 Tril	50 Tril
% life start earlier	1.0	1.0	0.7	0.20	0.0	0.0	0.0

For this table tau is the abiogenesis process, as just stated the panspermia is fixed. Again, these results are pretty interesting. When the abiogenesis process happens at above a 10% rate (from 1st chart), there is almost guaranteed to be some cases in which panspermia speeds up the life creation. Yet, as abiogenesis gets less and less likely, than panspermia appears to play no affect. A word of caution is that this simulation process takes a lot of computing power, and I could not run it very many times. So, there is room for improvement on these numbers. Nonetheless, it is still somewhat telling of what actually goes on.

Method 2

The results from my first method piqued my interest to create a process for randomly sampling for life. I thought of it as a real-life event. Meaning, if us, as humans, checked planets for life. This process is complicated, and there are a few assumptions. First, humans that can check for life is a very small sliver of time. The sampling I did represented that we could theoretically be in any sliver. Second, if there is life, it might not be noticeable, but I assumed if present we could detect it. My final assumption was that was life was created, it was present for the entire time T that was left. With all this being said I created a method to model this process. To do this I created just one sample of a 1 planet model, a 2-planet model and a 2-planet model with panspermia. For each model I created 500,000 time periods within T = 5 billion, so each time slot was equal to 10,000 years. I then randomly sampled 100 of these time periods to see if we saw life. I made the sampling process small because of the assumptions above. To counteract how broad they were, the 100 samples represent humanity randomly being placed. The results are in the table below.

	1 Planet	**2 Planets**	**2 planets With panspermia**
Tau	**% of observations with life**	**% of observations with life**	**% of observations with life**
50 Million	.93	1.0	1.0
500 Million	.97	0.97	0.99
5 Billion	0.4	0.96	0.51
50 Billion	0.39	0.0	0.0
500 Billion	0.0	0.0	0.0
5 Trillion	0.0	0.0	0.0
50 Trillion	0.0	0.0	0.0

These results follow a similar trend as previous results. If the abiogenesis process takes 5 billion years or less, than the discovery of life is highly probable. As we get further past 5 billion years, in this simulation we never find life. The reason for that is the life generating event is very unlikely, and taking just 100 random samples makes it even less likely humans would stumble upon life.

Method 3

This method was more focused on how panspermia plays into a larger simulation. For this I varied panspermia and abiogenesis to see how they interact with each other. In the previous models, there was a bigger emphasis on the abiogenesis process than the panspermia. This model had both, and the results are in the chart below. For each entry in the chart, I ran the simulation 100 times. The model had 10 planets that could randomly trade with any other planet in the system at various panspermia probabilities. The panspermia process was slightly different than the others because there were so many more planets. The probability of transferring also affected the probability of how many planets were involved. Meaning, that at higher probabilities more planets were randomly selected to send debris than at lower probabilities. So, each time step could have anywhere from 0-10 planets sending debris. Again, the planet choice was a factor of the panspermia probability.

In a system with 10 planets with varying panspermia and abiogenesis			
	Slow Abiogenesis Tau >> T	**Modest Abiogenesis Tau ~ T**	**Fast Abiogenesis Tau << T**
Slow Panspermia Tau >> T	S = 0.0 W = 0.0 A = 0.0	S = 1.0 W = 6.44 A = 0.01	S = 1.0 W = 10 A = 1.0
Modest Panspermia Tau ~ T	S = 0.0 W = 0.0 A = 0.00	S = 1.0 W = 7.73 A = 0.13	S = 1.0 W = 10 A = 1.0
Fast Panspermia Tau << T	S = 0.0 W = 0.0 A = 0.0	S = 1.0 W = 8.58 A = 0.25	S = 1.0 W = 10 A = 1.0

S = % of simulations where the **system** became inhabited by time T
W = mean % of **worlds** that became inhabited by time T
A = % of simulations where **all worlds** became inhabited by time T
Simulated 100 times

The chart above further proves some of our findings from before. For one, it shows that when abiogenesis is average to fast the probability for life is high. Additionally, the chart shows how panspermia is important in transferring life. In the modest abiogenesis case, panspermia increases the number of worlds inhabited by 1 in each step. This finding is exciting because as stated before astronomical debris hitting a planet is a really common event. While panspermia cannot be seen in the fast abiogenesis model, we know it is there from the panspermia process in methodology 1. Furthermore, I think there is reason to be hopeful, that if given more time and computing power we would see results in the slow abiogenesis model. Panspermia affects the other 2, so it is a reasonable assumption to expect it to play some role in the slow abiogenesis process.

Conclusion

It might seem simple to model life creation events using just a Poisson Distribution, but a Poisson is a perfect way to model events happening or not. The model does not care about any of the intricate details of the event, for it treats everything as how many times it happened. On a grand scale most events can be thought of as occurring or not, and that's why Poissons are so popular. With that being said, the results of this paper are very interesting. If your prior beliefs make you think abiogenesis should occur at least once in 5 billion years, there is a lot of reason to think life should be out there. Even if you believe that it takes 50 trillion years, we saw at least one instance of life in the 2-planet model, and the universe has millions of times more than 2 planets. Overall, your beliefs will influence how you think about life in the universe, but hopefully soon we can scientifically narrow down what we believe tau to be in the abiogenesis model. This will have resounding effects on the probability of life in the universe. The final word being abiogenesis is the main driver of life, but it is with some certainty that panspermia will speed up the process spreading life no matter how slow abiogenesis is.