Searching for Life

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AIM:

The intention of this project is to find the area of the Milky Way most likely to contain life outside of Earth. We will plot the probability of life against the distance away from the centre of the Milky Way. The probability of life in any position of the milky way has to take into account a multitude of factors. We will be limiting the factors involved for the sake of making the aim achievable.

INTRODUCTION :

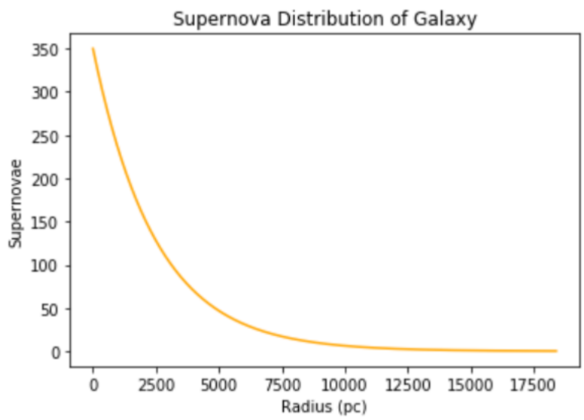
The basis for our research project is the Drake equation proposed by Dr Frank Drake estimates the number of intelligent life in the Milky Way. We used the Drake equation as a guide when deciding on the factors that we will use to determine the probability of life in different regions of the Milky Way.

At the start, rather than using the rate of star formation in the Milky way, as used in the Drake equation, we instead decided to plot the amount of mass at each distance from the centre of the Milky Way and used this to approximate the amount of stars at each distance.
Continuing through the Drake equation, the next two variables used are the fraction of stars with planetary systems and the fraction of those planets with conditions suitable for life. The fraction of sun-like stars in the milky way is 7.5% and the amount of those stars with earth sized planets that receive energy similar to Earth is 11 ± 4%.
For the probability of a planet forming intelligent life and then the probability of that life being able to communicate with us, other than the fact that the stars would have to be around 4 (±1) billion years old to have developed life, we have to estimate in order to take this into account. This is due to Earth being the only known planet currently with intelligent life so the sample size is too small to draw conclusions.
The next thing that drew our attention was factors that would limit the amount of life forming in different areas such as supernovas in areas with a larger amount of stars or a lack of heavy metals that are needed for life.

METHOD:

To begin, we imported all the necessary functions we'd be using from the python libraries. We then began to map the surface density of the Milky Way, starting off with defining some constants we got from our sources (the values of b and n for the bulge mass density were set at 8 and 4). We then used equations found from sources to get the surface mass density of the bulge and the disc, and then used arrays and loops to graph the mass distribution with a point for every parsec (3.26 light year).

We then integrated these curves to get the amount of stellar masses in the galaxy (found to be roughly the accurate number), and we used the number of stars known to exist in the galaxy to scale the map to give us the amount of stars for each radius in the galaxy. Next we used the Drake equation and implemented the constants from it into the mass distribution of the Milky Way (we later discovered that this assumes that all stars are equally likely to have life, this'll come up later). We ended up with two different lists, one for the amount of life in the galaxy, and one for the amount of intelligent species, so we could map them separately [should look the same but with a different scale (set at 0.1% of planets with life producing intelligent life)].



Supernova distribution

After adding the constants we mapped out the distribution of supernovae across the galaxy (through the equation from the sources), and also the metallicity distribution of the galaxy. We then created a function to scale the lifelists by a factor (supernovas), with the factor taken to an exponential. We then used the function to scale with the inverse of supernovas (supernovas make it less likely for life to exist because the gamma rays produced by the supernovas can wipe out life), and with the metallicity across the galaxy. The result seemed obviously off, so we had to re-evaluate our approach at this point. We realised that the approach with metallicity was off as we didn't think about the effect of metallicity on life - when a region's metallicity is too high, it doesn't support life (creates more Hot Jupiters, which destroys inner planets making life less likely), but when it is too low, it also doesn't support life (Earth like planets can't form). We also were looking at all the stars in the galaxy, instead of only looking at Sun-like stars with Earth-like planets, which is what we should be looking at if we want to see where we'd find life we'd be able to recognise. We had to find a new approach to find the Galactic Habitable Zone.

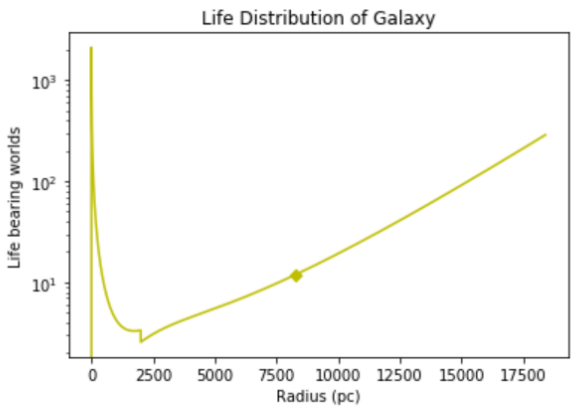
We used the data found in our sources to find how many sun-like stars exist in the galaxy for each metallicity. Unlike the previous data points, where we could use equations to find the values, we couldn't find any equations to find the relationship between the abundance of sun-like stars and metallicity (even though equations appear to be used in the source itself), so all we have to go off are the actual values given in the source. This means we only have 19 values, as opposed to the 18396 we had before. This'll mean the maps will be much less defined than before.

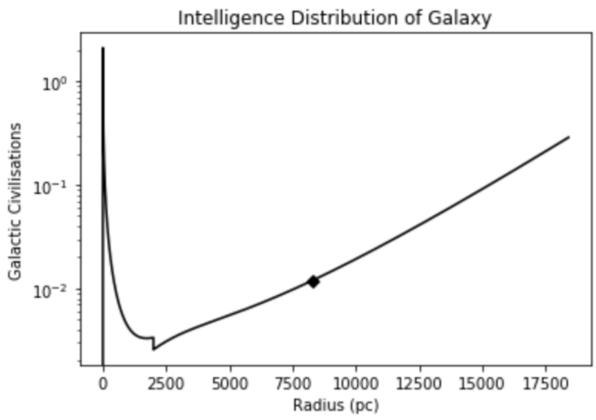
After getting the suns per metallicity, we combined it with the metallicity distribution across the galaxy and scaled to get the distribution of sun-like stars across the galaxy, and then scaled it with the drake equation factors from earlier to get some new life and intelligent life maps. These maps looked much closer to the expected maps with life being most frequent in the middle part of the spiral arms of the Milky Way, but the supernovae were yet to be added in. Once they were, we got an odd bunch of maps which made life appear to be much more common in the edge of the galaxy. If we take the factor to the exponent of -(1/2pi), then it appears vaguely reasonable, but we can't find a good reason why that'd happen, apart from the idea that supernovae weren't as impactful as metallicity, but it still seemed weak.

We then realised that though the method had been able to find how many suns there were for each radius per location from the metallicity, it hadn't actually taken into account how the metallicity itself affected the probability of life. We then used an equation from the sources to find the probability of an Earth-like planet existing for a given radius of the galaxy (points are very rough due to only 19 points of data for each factor). We found what the relative abundance for metallicity Hot Jupiters were, which gave the probability of destroying Earth per metallicity (due to a math error due to the small amount of points, we had to cheat and manually enter the last two points to set them to 1 as it is in the source), giving the probability of harbouring Earths for each metallicity. We then used that to make a map of where all the Earth's were in the galaxy, and then included supernovae, which made the map appear to show that most life existed in the edge of the galaxy once again, even more than with the previous map. We tried to replace the original metallicity with this earthlist, but it gave us nothing.

RESULTS:

In the end we came up with two sets of results the first which is based off of the surface mass distribution in the galaxy but doesn't take into account that each star has a different probability of harboring an Earth-like planet, and the second which is based off of the differing metallicity levels of the galaxy.



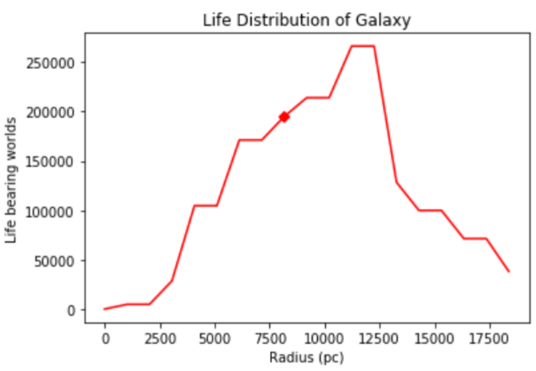


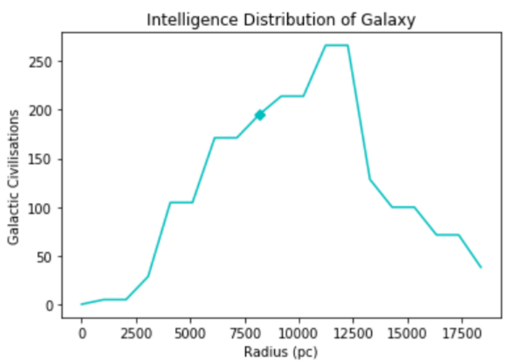
(Fig: 1) (Fig: 2)

(in all plots dot is at the location of our solar system)

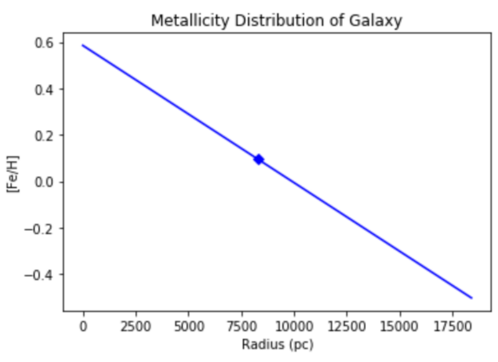
Figure 1 and 2 show the amount of life you should find at each radius from the galactic centre point with the assumption that all stars are equally likely to have an Earth-like planet. They do take supernovae into account however they don't include metallicity. The lack of metallicity as a limiting factor means the graph shows too much life at the edges of the galaxy as well as the centre point. The point shown at ~8000pc is the location of our own solar system in the maps where radius is used.

The difference between Figure 1 and 2 is that we added in a constant for the chance of a life bearing planet having a civilisation (this only changes the scale). The sharp drop off just before 2500 pc is where the bulge ends.



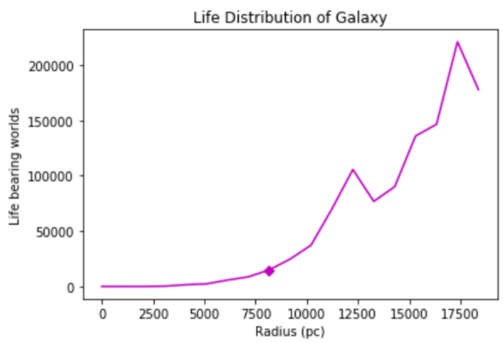


(Fig: 3) (Fig: 4)

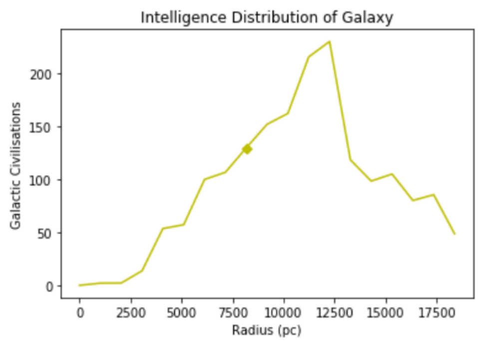


(Fig: 5)

In comparison to figures one and two, Figure 3 and 4 are much more like what we initially expected the plots would look like as the abundance of life is higher halfway out from the centre and lower at both the edges of the galaxy and the centre. These plots all were formed based on the metallicity distribution of the galaxy (Figure 5) and the abundance of suns and Earths per metallicity. Though not all the stars for a radius would have the metallicity (Figure 5 places the sun at roughly 0.1, while in reality it's 0.012), they should all roughly be around it and should average to it. These graphs therefore have all the constants of the Drake equation for all the Earth-like worlds orbiting sun-like stars. However these plots don't take into account supernovae. This may seem to imply that supernovae are not too impactful on the distribution of life, and metallicity is the only factor, but all the studies we've seen mention the importance of supernovae, but don't mention how important supernovae are in comparison to metallicity. If we take this map to be the correct map, what shows is that there should be millions of life bearing worlds in the Milky Way (and any spiral galaxy with a similar or bigger size), and thousands of intelligent civilisations. This might not seem too likely as we haven't yet discovered any life outside of the planet, so maybe the constants of the Drake equation need to be altered, or maybe we just have to look further.



(Fig: 6)



(Fig: 7)

The result of including the effects of supernovae are in Figure 6 and 7. The graphs appear different as we've applied different weights to the effect of supernovas in both (arbitrary). With the Life Distribution, we just divide by supernova, but we get a result showing that life should be most prevalent on the edge of the galaxy. With the Intelligence Distribution, we took the supernova list to the exponential of (1/2pi) - this was chosen we wanted to include the effect of the circumference (2pir), to try and see if it'd make the map look better, but taking it to the exponential seems too arbitrary, so we ignored the results of it. There may be the implication that supernovae are less important than metallicity to the map, but we don't know by how much.

By looking at the gradient of each plot at the point where our solar system is located we can deduce that the best place to start looking for life would be in the direction away from the galactic centre.

One reason for our data being inaccurate is that we had to mesh different equations and data together in order to come out with this result and they may not all agree. One point which we were concerned about was the shape of the galaxy, we weren't sure if all the equations used considered the nature of the galaxy as a 2D disc or just as a 1D line (we suspect this might have affected the supernova data). If we had more time we would have checked through each source in greater detail and figured out how all of them were related and then altered them accordingly (or only used the ones that worked together).

CONCLUSIONS:

We weren't exactly able to get a map including all the constants of the Drake Equation, Metallicity and Supernovae that seemed reasonable for the location of life as we know it in the galaxy, though when ignoring supernovae or giving it a low weighting, we do get a reasonable map of the location of life in the galaxy. We can tell where to look for signs of life - further out from where we are, in the region around 8-12kpc.