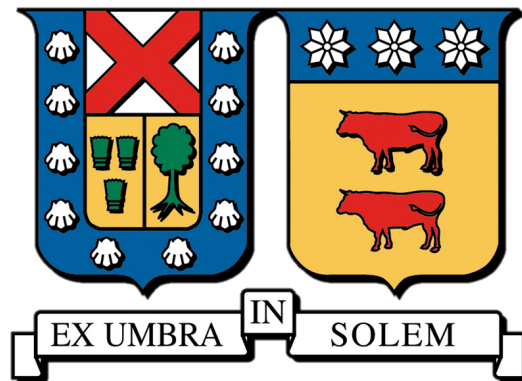


UNIVERSIDAD TÉCNICA FEDERICO SANTA MARÍA

DEPARTAMENTO DE FÍSICA



Predicting the occurrence rate of Jupiter like planets around white
dwarfs I: generating a representative population of progenitor systems

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THESIS TO OBTAIN THE DEGREE OF BACHELOR IN ASTROPHYSICS

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Abstract

The study of exoplanets has seen remarkable advancements since the first discoveries in the early 1990s. This thesis investigates the characteristics and distribution of exoplanets, focusing on the progenitors of white dwarfs (WDs). We highlight the challenges associated with detecting exoplanets around more massive stars due to issues such as reduced radial velocity signals, shallower transit depths, and difficulties in direct imaging. Despite these challenges, significant progress has been made in identifying exoplanets around Sun-like and smaller stars using missions like Kepler, TESS, and JWST.

The central aspect of this research is the creation of a comprehensive dataset, i.e. a representative synthetic population of progenitor stars of white dwarfs including orbiting Jupiter mass planets. This population is generated based on the Initial Mass Function (IMF) [Kroupa \(2001\)](#), assuming a constant star formation rate, and the age-metallicity relation ([Carrillo et al., 2023](#)). The study also incorporates the planet occurrence rate function by [Wolthoff et al. \(2022\)](#) to estimate the likelihood of planet detection based on stellar mass and metallicity.

In the final population of white dwarf progenitors hosting Jupiter mass planets is 6.6 %. Despite being less dominated by low-mass host stars than the full population, most of the planet hosts are still lower mass stars. The population of planet hosts is shifted towards higher metallicity stars and, as a consequence of the age metallicity relation, towards younger ages.

The generated population of white dwarf progenitors forms the base of a population synthesis of Jupiter-mass planets around white dwarfs. To obtain this final goal the obtained samples need to be combined with stellar evolution codes and require to calculate which planets might survive the evolution of the host star into a white dwarf.

Acknowledgments

I am profoundly grateful to Mr. Matthias Schreiber, my advisor, whose unwavering support, insightful guidance, and constant encouragement have been the cornerstone of this thesis. His dedication and expertise have not only shaped this work but have also significantly influenced my academic and personal growth. Mr. Schreiber's mentorship has also inspired me to develop critical thinking and problem-solving skills that will benefit me throughout my career. I feel incredibly fortunate to have had the privilege of working with someone as him. His passion for research and teaching has been a constant source of motivation for me.

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Also, I would like to thank my teachers, especially those who were fully dedicated to my development as an early-stage astrophysicist. Their mentorship and commitment to my growth have played a crucial role in shaping my academic journey and passion for the field.

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Chapter 1

Introduction

1.1 A brief history of exoplanets detections

Have you ever wondered what lies beyond our own solar system? Well, it turns out there are thousands of planets out there that orbit stars other than our Sun! These distant worlds, called exoplanets, come in all shapes and sizes. Some are tiny, while others are massive. They're made up of all sorts of things, and they orbit their stars in some pretty wild ways. Learning about these exoplanets has totally changed the game for astronomers. We're gaining new insights into how planets are formed and how they change over time. And honestly, it's making us rethink some of our old theories about how planets work together in a system.

The first confirmed exoplanet discovery (or in this case, exoplanets) was made in 1992 by [Wolszczan and Frail \(1992\)](#). They detected three planets orbiting the pulsar PSR B1257+12, located approximately 2,300 light-years from Earth. Pulsars are highly magnetized, rotating neutron stars that are the remnants of supernova explosions. The planets were found using precise measurements of the timing of the pulsar's radio pulses, which varied slightly due to the gravitational influence of these planets. This discovery was shocking, because it showed that planets could exist in extreme and very unconventional environments, such as the remnants of dead stars, though it was unclear how such planets could survive or form in the aftermath of a supernova.

While the 1992 discovery marked the first confirmed detection of planets outside of our solar system, it wasn't until 1995 that the discovery by [Mayor and Queloz \(1995\)](#) truly revolutionized the field of exoplanet research. They discovered a planet, 51 Pegasi b, orbiting a Sun-like star, 51 Pegasi, located about 50 light-years from Earth. This planet was detected using the radial velocity method, which measures the "wobble" of a star caused by the gravitational pull of an orbiting planet. This discovery was significant because it demonstrated that planets could be found around stars similar to our Sun, opening the door to the search for Earth-like planets outside our system.

The impact of this discovery was so profound that in 2019, Michel Mayor and Didier Queloz were

awarded the Nobel Prize in Physics for their work. The Nobel Prize recognized their influence in exoplanetary science and acknowledged the pivotal role their discovery played in the advancement of our understanding of planetary systems.

1.2 Newer discoveries and Research updates

In recent years, the field of exoplanet research has made tremendous strides, building from all the previous advances and discoveries made. With newer technology, detection methods and newer projects such as Kepler, TESS, and the James Webb Space Telescope (JWST), scientists have been able to discover thousands of new exoplanets, leading to a deeper understanding of these distant worlds and their potential for life.

The Kepler Space Telescope, launched in 2009 (for details see [Borucki et al., 2010](#)), marked a tremendous impact in exoplanet research. Kepler’s mission was to monitor the brightness of over 150,000 stars within a specific region of the sky. By detecting the subtle dimming of stars caused by planets transiting in front of them, Kepler identified thousands of exoplanets and provided crucial data on the frequency and diversity of planetary systems. This wealth of information has been instrumental in expanding our knowledge of the variety of planetary environments within our galaxy.

Following Kepler, the Transiting Exoplanet Survey Satellite (TESS), launched in 2018 ([Ricker et al., 2014](#)), extended the search for exoplanets to the entire sky. TESS focuses on surveying bright, nearby stars, aiming to discover new exoplanets that are well-suited for detailed follow-up observations. By identifying promising candidates, TESS plays a key role in preparing for in-depth studies.

The James Webb Space Telescope (JWST), which began its mission in 2021 ([Gardner et al., 2006](#)), represents the leader of exoplanetary research. JWST is designed to analyze the atmospheres of exoplanets with unprecedented detail, seeking signs of habitability and potentially life-sustaining conditions. Through its advanced instruments, JWST aims to provide better perspectives into the environmental conditions of planets, enhancing our understanding of the potential for life beyond our solar system.

When examining the masses of stars around which exoplanets are discovered, a significant portion are found orbiting Sun-like stars, known as G-type stars. However, a large number of exoplanets are also detected around M-dwarfs, or red dwarfs, which are smaller and cooler than the Sun. All the stars mentioned, typically have masses always ranging around $1 M_{\odot}$ or less, which it isn’t surprising at first sight, since the most common method to detect exoplanets, is through the radial velocity of the host star, or using the transit method.

Most known exoplanet host stars have masses equal to or less than the Sun. Planets are more

challenging to detect around more massive stars. For more massive stars, radial velocities are smaller and more difficult to measure due to the fewer spectral lines these stars exhibit. Additionally, the depth of transits is shallower because the star’s larger size results in a smaller fraction of light being blocked by a transiting planet. This makes transits harder to detect. Furthermore, direct imaging of planets around these stars is challenging because the stars are brighter, increasing the contrast between the star and the planet, and making the planet more difficult to detect. These factors, combined with the longer life-times of protoplanetary disks around lower mass stars, which allows more time for planets to form, should lead to a higher detection rate of exoplanets around stars that are similar in mass to the Sun or smaller. It is also well known that the majority of Stars in the Milky Way are low mass stars and therefore it is easier to find suitable targets for planet searches.

However, all the above does not necessarily imply that exoplanets are not capable of being formed around stars more massive than the Sun. In fact, [Wolthoff et al. \(2022\)](#) have mainly focus in studying planet occurrence rate around evolved stars more massive than the Sun, which has expanded our knowledge in this type of Exoplanets, and her studies have helped us in developing this project.

1.3 WD Accretion and observed data

When a star like the Sun exhausts its nuclear fuel in the core, it evolves into a red giant and eventually sheds its outer layers, leaving behind a dense core known as a white dwarf. During this process, the gravitational interactions can destabilize the orbits of any remaining planets, asteroids, or comets. These objects can be torn apart by the white dwarf’s gravity, creating a disk of debris around the star. The debris from these disrupted objects can eventually spiral in and be accreted onto the white dwarf’s surface. In fact, observations suggest that a significant fraction of white dwarfs show signs of accreting planetary debris ([Koester et al., 2014](#)). This indicates that the presence of planets and smaller bodies around white dwarf stars should be common, but there’s only one confirmed exoplanet confirmed around a WD, a massive Jupiter-like exoplanet ([Vanderburg et al., 2020](#)) and a few other candidates (not confirmed), such as the one discovered by [Gänsicke et al. \(2019\)](#), which led us to the main questions motivating this thesis. What is the actual population of Exoplanets around WDs? Why haven’t we discovered more candidates if we expect them to be ”common”? This thesis provides the basis towards answering these questions.

Chapter 2

Methods

2.1 Project Overview

The primary objective of this project is to create a comprehensive representative population of stars that could have been progenitors of white dwarfs we observe today, by applying various measured distribution functions such as the initial mass function (IMF), the star formation history of the Galaxy, and a metallicity-age relation. From an initial dataset of stars with random mass we selected a sub-sample that matches the IMF ([Kroupa, 2001](#)). To all these stars we assigned a random age (from 0 to 10 Gyears, based on the age of our Galaxy) assuming a constant star formation rate. We then use the age metallicity relation ([Carrillo et al., 2023](#)) and eventually add an occurrence rate and a orbital period ([Wolthoff et al., 2022](#)).

The generation of a representative population was implemented using the Monte Carlo ensuring that the data is statistically correct, and provides a reliable basis. Last, but not least, Python was used in order to simulate the data, due to its facilities and big amount of libraries it has, but you could use any other programming language if you prefer.

2.2 IMF Function

The Initial Mass Function (IMF) is the cornerstone of stellar astrophysics, referring to the distribution of stellar masses during their formation. It is crucial to galaxy evolution as it affects star formation processes and stellar populations of galaxies. In this work, we adopt an IMF defined by a constant value 0.0121257 and different slopes α for low mass range which comes from [Kroupa \(2001\)](#). Denoting the IMF by $\xi(m) \propto m^{-\alpha}$ where $\xi(m)$ is the number of stars per unit mass bin, m is stellar mass and α represents slope in power-law form that defines IMF. We adopt these values for the IMF in our analysis:

For stellar masses between 0.8 and 1 solar mass ($M_{\odot}$):

$$\xi(m) = 0.0121257 \times m^{-2.7} \quad (2.1)$$

Here, the constant $\xi(m) = 0.0121257$ ensures that the number of stars formed in this mass range is correctly normalized, and the slope $\alpha = 2.7$ describes the steep decline in the number of stars as mass increases within this range.

For stellar masses greater than 1 solar mass ($M_{\odot}$):

$$\xi(m) = 0.0121257 \times m^{-2.3} \quad (2.2)$$

In this mass range, the slope $\alpha = 2.3$ is less steep compared to the previous range, indicating a slower decline in the number of stars with increasing mass.

The constant $\xi(m) = 0.0121257$ ensures that the IMF is properly normalized across the mass ranges considered, taking in count the continuity of the function in the critical masses values in each mass range, following the method outlined in [Kroupa \(2001\)](#).

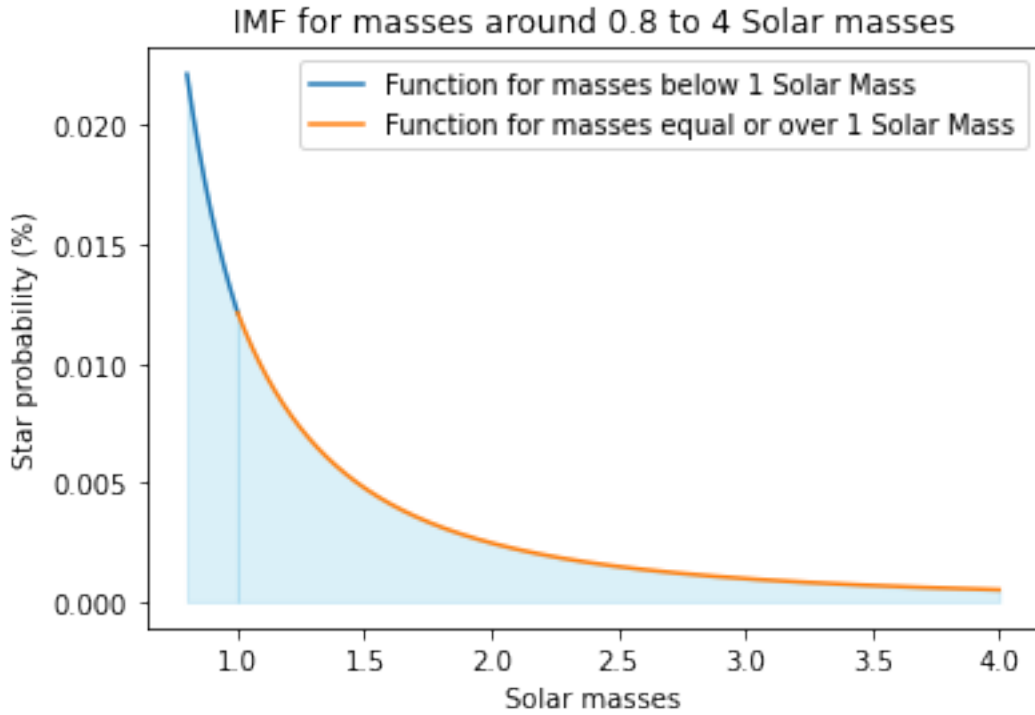


Figure 1: The figure shows the IMF as a continuous curve across the mass range of interest. This curve provides the probability density that stars are forming as a function of mass.

We utilized the IMF feature as a filter in our examination. In our selection, indeed all stars that are out of the IMF function curve should be excluded. This implies our study keeps stars within the range/ inside the curve of the IMF function (the idea is to keep a realistic/expectable result).

Using the IMF curve for selection enables us to further clean up our sample of stars, based on theoretical predictions regarding star formation rates and their mass distribution. Continuity of the IMF function is central to this endeavor, because it ensures it is uninterrupted and that makes complete sense selection threshold across every mass range.

2.3 Stellar age

As we said before, once we have our Stars filtered by the IMF function, we will set a randomized age for each Star (maximum age is that of the thin disk of the Milky Way), assuming a constant star formation rate between 0 and 10 Gyears. This age will be used to use the age-metallicity relation proposed by Carrillo et al. (2023)

2.4 Metallicity Distribution

We used the model presented by Carrillo et al. (2023) to model an age-metallicity relation using the previous ages generated. They reported the mean metallicity ($[\text{Fe}/\text{H}]$) and its dispersion regarding stellar ages of 1 Gyr, 3 Gyr, 5 Gyr, 7Gyr and 9Gyr. The data can be summarized as follows:

Age (Gyr)	Mean $[\text{Fe}/\text{H}]$	Scatter σ
1	0.04	0.17
3	0.03	0.15
5	-0.08	0.14
7	-0.12	0.17
9	-0.32	0.24

Table 2.1: Metallicity data from Carrillo et al. (2023) for different stellar ages.

2.4.1 Assumptions and Interpolation

Taking into count that we are using the Data compiled from the previous "IMF filter", in order to create a continuous metallicity distribution for the range of ages considered, we made the following assumptions:

- **Normal Distribution Assumption:** In the following analysis we assumed that the metallicity distributions at each age can be described by normal distribution. This is an inferred conclusion because it uses the scatter (σ), which tells us how much spread exists around the mean $[\text{Fe}/\text{H}]$ value.

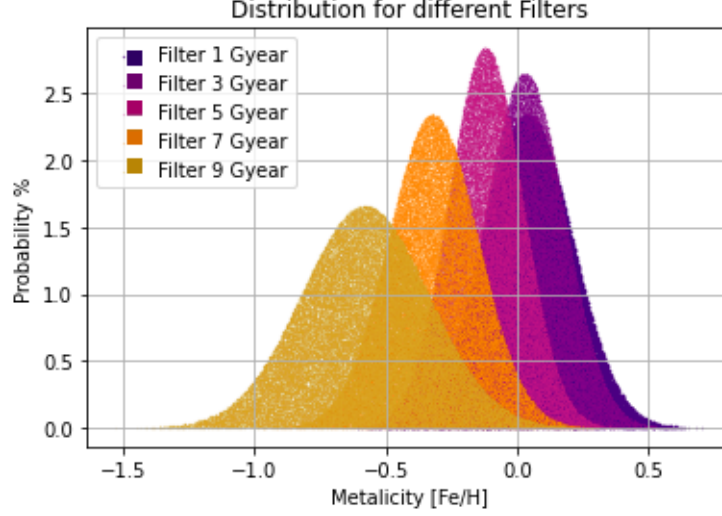


Figure 2: The figure shows the five initial metallicity distributions corresponding to different age ranges. We used data from Andreia Carrillo's paper, applying the given mean $[Fe/H]$ and scatter values for specific ages to create these distributions.

For simplicity, each metallicity distribution is assumed to be a normal distribution. We assigned metallicities to stars in 2 Gyr age bins:

The mean and scatter for 1 Gyr were applied to stars in the 0-2 Gyr range, 3 Gyr values were used for the 2-4 Gyr range, and so on up to 9 Gyr for the 8-10 Gyr range.

In this case, depending on the age of the Star, we created a function for each distribution to evaluate the veracity of the data used with python and make a 2nd filter of the data I'm using.

- **Linear Interpolation:** In order to combine the metallicity data into a single continuous distribution, we used linear interpolation between the age-dependent mean metallicities and scatter values. Another advantage of this approach is that we can simply switch between the discrete age points (1 Gyr, 3 Gyr, 5 Gyr, 7 Gyr, and 9 Gyr) instead only having to deal with five separate distributions.

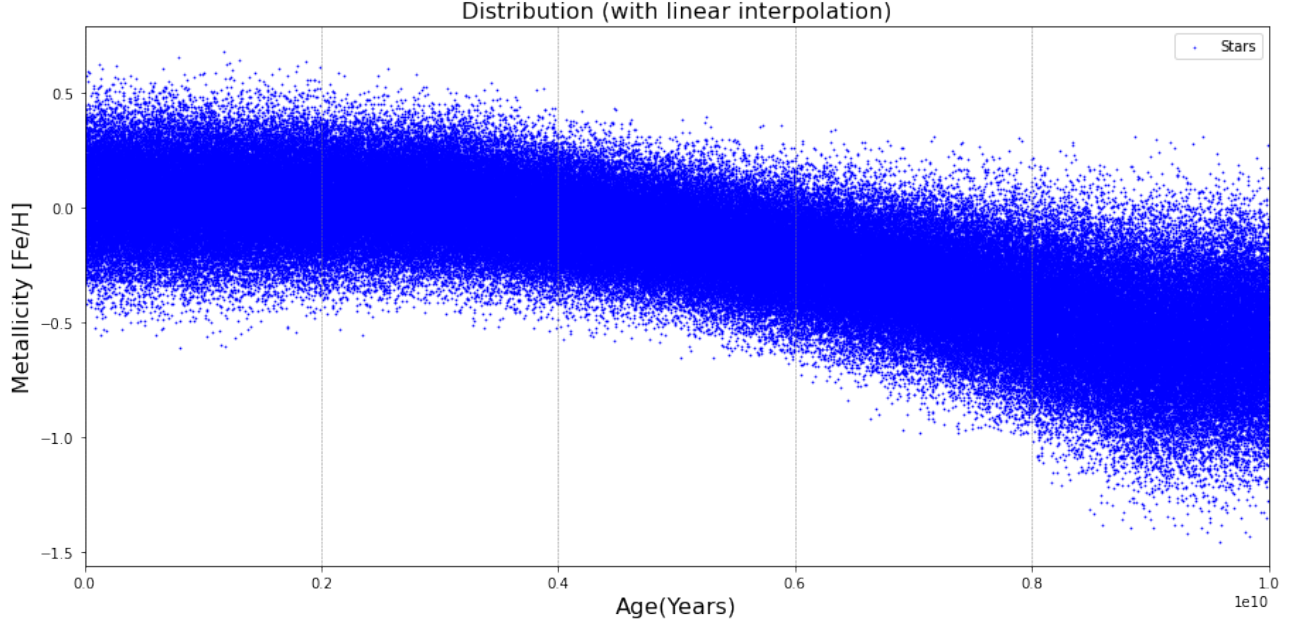


Figure 3: The figure illustrates the result of the linear interpolation applied to the metallicity distributions. You can see how the mean $[Fe/H]$ values and their associated scatter smoothly transition across the entire age spectrum, from 0 Gyr to 10 Gyr.

Instead of discrete steps at 2 Gyr, 4 Gyr, 6 Gyr, etc., the interpolation has created a continuous curve. This smooth progression indicates that the metallicity gradually changes with age, without abrupt jumps between the predefined age intervals. The scatter values also adjust seamlessly, reflecting a little variation in the spread of metallicities as the stellar population ages.

By adopting this approach, we were able to incorporate the age-metallicity relationship into our models in a more refined manner, providing a more accurate representation of the metallicity distribution across the age spectrum considered.

2.5 Planet Occurrence Rate Function

In our analysis, we utilized the planet occurrence rate function derived by [Wolthoff et al. \(2022\)](#) in the paper "Precise Radial Velocities of Giant Stars XVI. Planet Occurrence Rates from the Combined Analysis of the Lick, EXPRESS, and PPPS Giant Star Surveys." This function describes how the rate of planet occurrence depends on stellar mass and metallicity. The function is expressed as:

$$i(x, y) = 0.128 \times \left(\exp \left(-\frac{1}{2} \left(\frac{x - 1.68}{0.7} \right)^2 \right) \right) \times 10^{1.38 \cdot y} \quad (2.3)$$

This model represents the dependence of the occurrence rate on stellar mass and metallicity,

with an exponential distribution in metallicity and a Gaussian distribution in stellar mass where x represents the stellar mass and y represents the metallicity.

We applied this function to estimate the planet occurrence rates across different stellar masses and metallicities in our dataset. By incorporating this function, we accounted for the variations in planet occurrence rates influenced by the intrinsic properties of stars, thus refining our analysis of the stellar population and their potential for hosting planets.

This can be consider the final distribution needed to simulate a population of population WD progenitors hosting a planet.

2.6 Distance/Period

To investigate how the occurrence of planets varies with planetary mass and orbital period, we used a log-normal distribution function as described by [Wolthoff et al. \(2022\)](#). The function is given by Equation 5 in their paper and writes as follows:

$$f_{\text{occ}}(P) = \frac{A}{\sqrt{2\pi}\sigma \cdot \frac{P}{\text{days}}} \exp\left(-\frac{(\log(\frac{P}{\text{days}}) - \mu)^2}{2\sigma^2}\right) \quad (2.4)$$

This fitting allows us to parameterise if planets could survive the evolution of their host star while reaching WD phase, providing valuable insights into the period distribution of exoplanets around WD.

The function calculates the probability density of the orbital period x . It was applied to the range of 80 to 4000 days to model the distribution of planetary orbital periods. This fitting allows us to understand how the occurrence of planets changes with different orbital periods, providing valuable insights into the period distribution of exoplanets around giant stars.

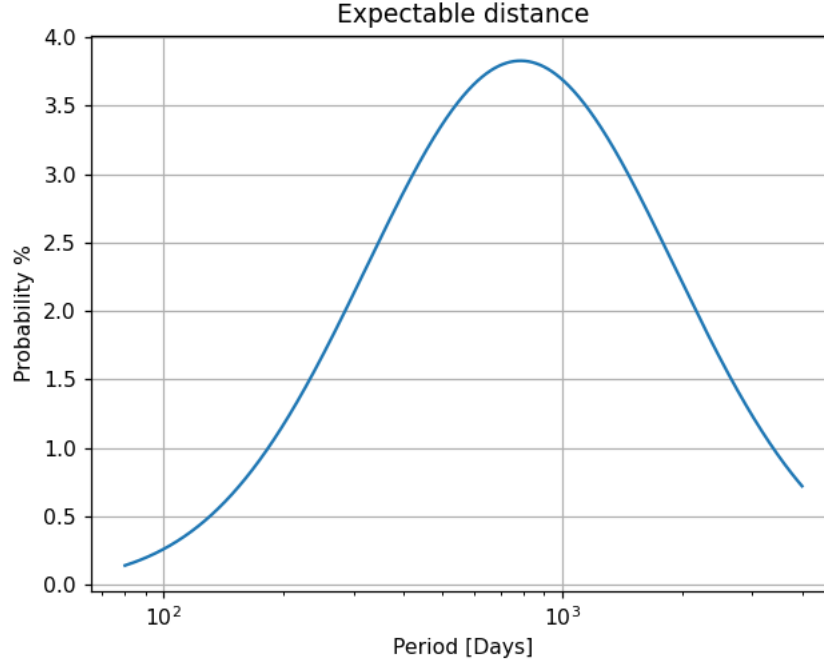


Figure 4: In this figure we can see the Period variation a probability of finding an exoplanet around the WD, where we can clearly see it is more likely expected to be found at around 1000 days.

In this case, we don't expect out of the 80-4000 days range, since the Exoplanet would be too far away (more than 4000 days) or too close (less than 80 days) to its holder, making it unlikely for a planet to survive the star evolution due to various reasons, such as gravitational perturbations, stellar activity and radiation, or in worst cases, making it impossible to track radial velocity of the Planet, since it is required to have a long term measurement (or unfeasible) .

In order to prove this statement, we are also showing an accumulated expectation of the Period of the possible exoplanet holder candidates and its behaviour.

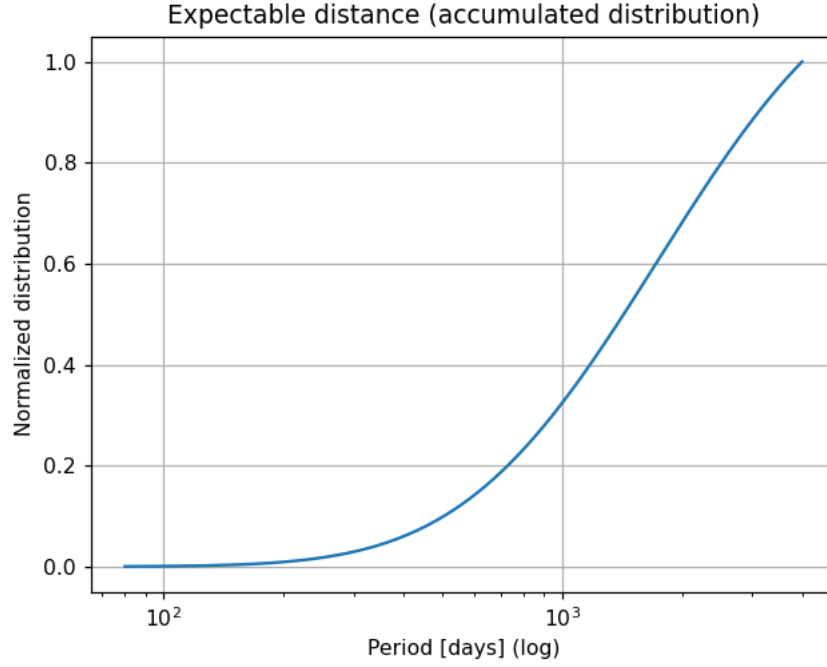


Figure 5: In addition to the log-normal distribution fit, we also analyzed the accumulated distribution of planetary orbital periods. This accumulated distribution represents the cumulative probability that a planet has an orbital period less than or equal to a given value. The accumulated distribution is plotted to visualize how the total number of planets increases with increasing orbital period.

This cumulative distribution provides insights into the distribution of orbital periods across a range of values and helps to assess the proportion of planets with periods within specific ranges. By examining the accumulated distribution, we can better understand the overall distribution pattern of planetary orbital periods and identify any trends or deviations from the expected log-normal behavior. This analysis complements the log-normal fit by providing a broader perspective on the occurrence of planets with different orbital periods. .

Chapter 3

Results

3.1 IMF Function

First of all, we began with the IMF from [Kroupa \(2001\)](#), where we used both the equations [2.1](#) and [2.2](#). We were expecting to lose a very big amount of data due to the nature of it.

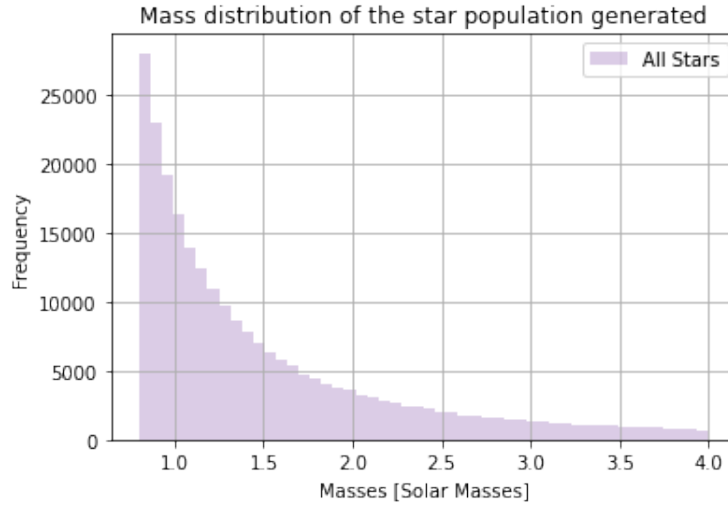


Figure 6: As we expected, due to the IMF function, various Stars where eliminated from our study, were it got reduced to 243617 Stars, our Star Population.

It wasn't a surprise that most of the Stars had very low mass (Most of the stars don't surpass much more than $2 M_{\odot}$), since this is the normal behaviour of the IMF. Since we are looking for WD planet holders, we decided to limit the range of the function between 0.8 and $4 M_{\odot}$.

3.2 Metallicity Distribution

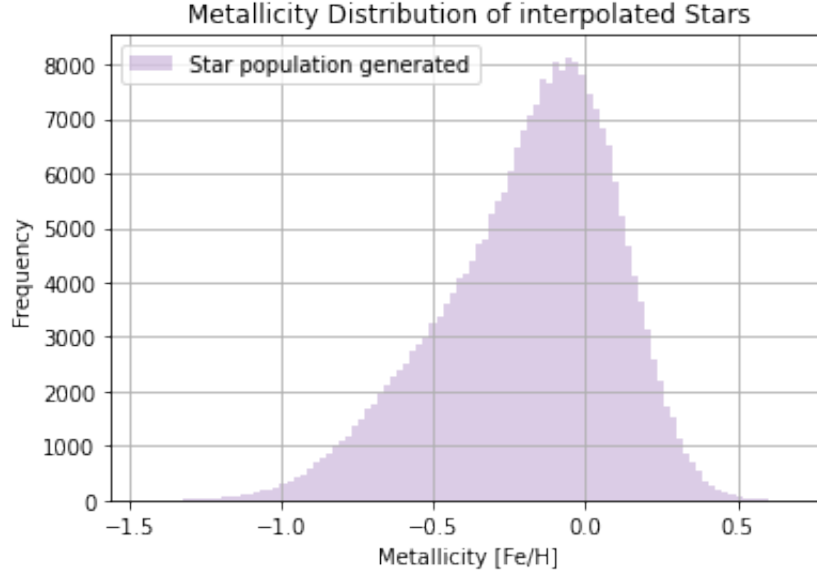


Figure 7: After applying the assumptions and interpolation to the initial metallicity data, the resulting distribution does not perfectly conform to a normal distribution. The final distribution exhibits a mean metallicity of $[Fe/H] = -0.19$ and a scatter (standard deviation) of 0.28 dex.

This distribution reflects the complexity of the underlying stellar population and the variations in metallicity over time. The final distribution provides a realistic representation of the metallicity of the remaining stars, incorporating the detailed nuances captured during the interpolation process. We noticed that majority of the Stars (mean) have a slightly poorer composition compare to the Sun. Since we are looking for WD, it is reasonable to think that the metallicity of the Stars should be poorer. This is because they formed earlier in the universe's history, when there were fewer heavy elements (metals) available.

Now we have a representative proportion of data, we shouldn't have any problems with the continuity of this project. This new Distribution generated represents 100% of our Star Population.

3.3 Planet Rate

3.3.1 Metallicity Variaton

Eventhough the planet rate equation 2.3 showed that richer metallicities should increase the chance of holding an exoplanet, the truth is that because of the distribution showed in Figure 7, Stars with richer metallicities were not neccesarily common.

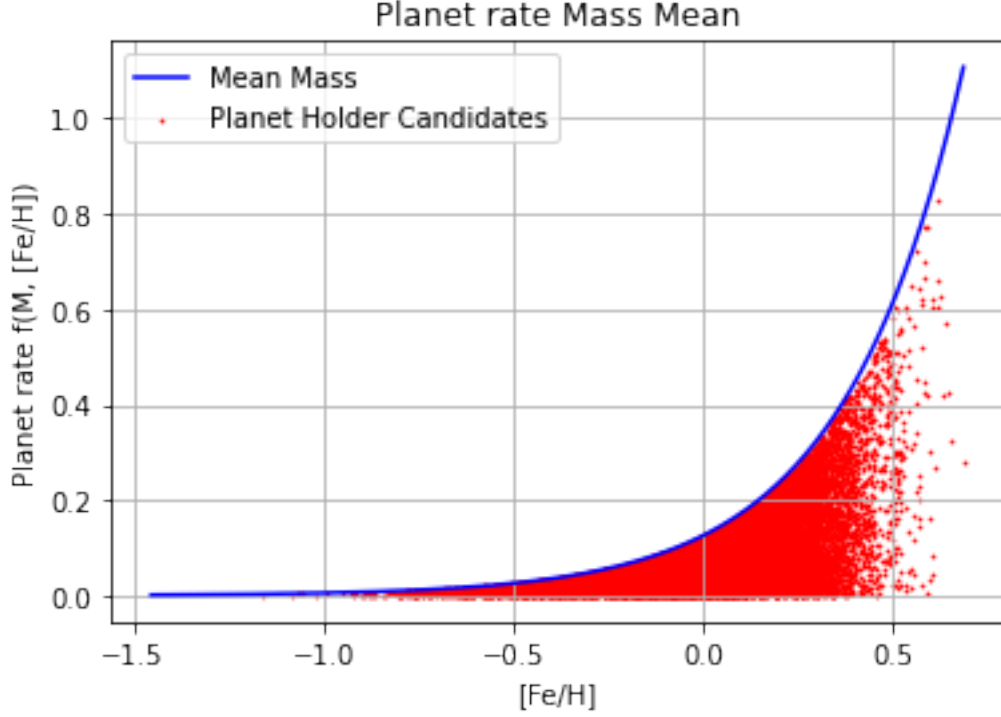


Figure 8: This is a Figure where the Mass of the Stars were established as the mass mean of the data, only making variations to the Metallicity.

We could really see that most of the stars tend to have metallicities around $(-)0.5 - 0.5$ $[\text{Fe}/\text{H}]$, but it is hardly recognisable where the "big" proportion of data is located. We could expect it is around the Metallicity Mean showed in 3.2, but we will show a distribution that will clarify this later.

3.3.2 Mass Variaton

As well as it happened in section 3.3.1, we can clearly see that by establishing a value (in this case the Metallicity Mean) for the planet rate equation, we would expect that the best candidates to planet holder (only taking in count the equation) would be around $1.5-2 M_{\odot}$ (as showed in Figure 9), but due to the previous filters used (in this case the influence of the IMF Function showed in 3.1), most of the planet holder candidates tend to have light masses.

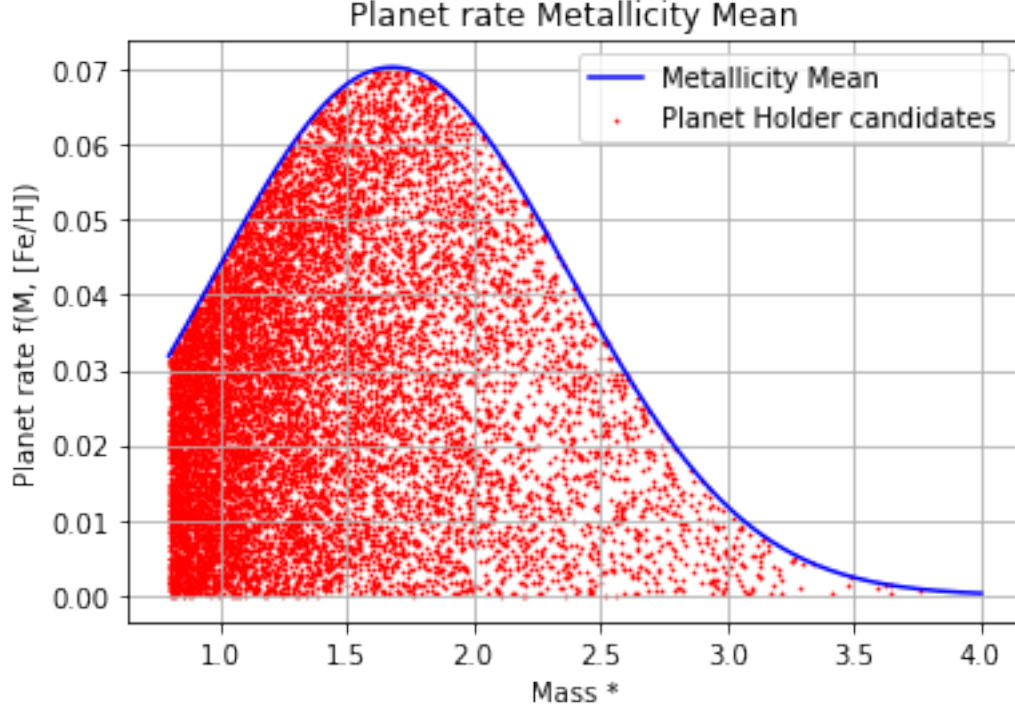


Figure 9: This is a Figure where the Metallicity of the Stars were established as the Metallicity mean of the data, only making variations to the Star Mass.

3.3.3 Planet Rate Distribution

As we showed in the previous subsections, before filtering the Stars with the equation 2.3, we wanted to make sure the behaviour of the function was similar to the one showed in [Wolthoff et al. \(2022\)](#). That is the main reason why we checked both cases where the metallicity and the Mass of the Star were "established". But it is necessary to check the behaviour of planet rate function as a two-dimensional function. This wasn't an easy work, and it is probably the most important part of this project.

A total of 16086 Stars were selected as possible planet holders with the planet rate distribution (6.60% of the Star population generated). We could clearly see in Figure 9 that Stars with Rich metallicities, and masses around $1-2M_{\odot}$ are more likely to survive (at least if we are only taking in count the nature of the planet rate function), but as we can clearly see, most of the Stars are located in the 0 - 0.5 [Fe/H] ratio.

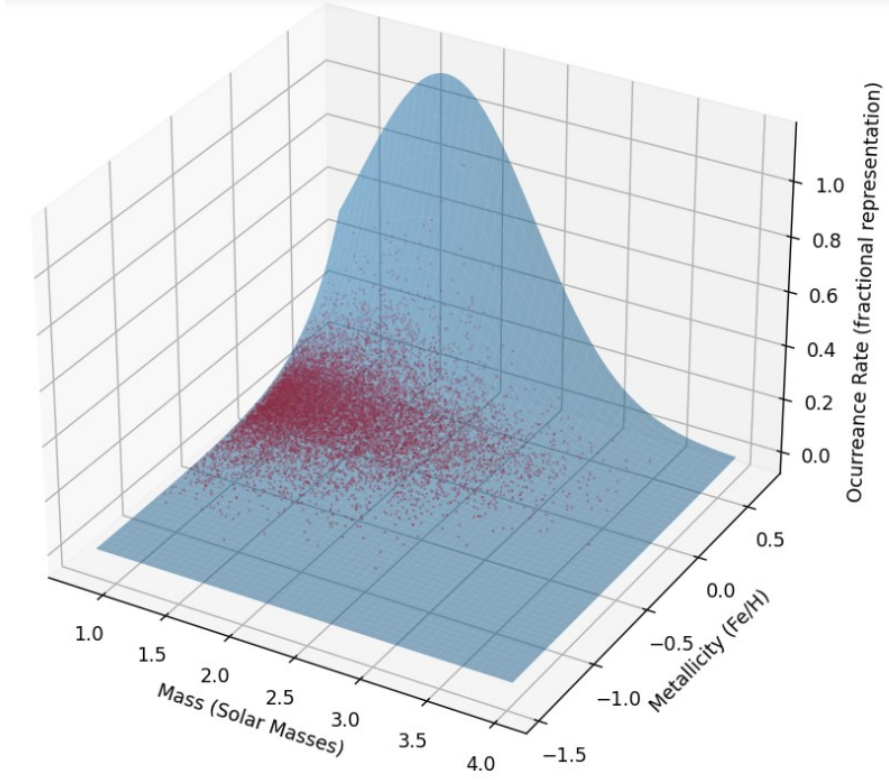


Figure 10: In this Figure we show the behaviour of the function as a two-dimensional function. Blue area represents the function and red dots represent the candidates selected.

In order to have a better view of the candidates selected, we also made a 3D version of the distributions in Figure 11 (mass and metallicity vs occurrence rate), and also a comparison of the mass, metallicity and age with the star population we generated previously (Figures 12, 13 and 14). Now in Figure 11, we can clearly see the survivor candidates clearly tend to have low masses, and high metallicities. This trend is significant as it may suggest that certain stellar characteristics, such as higher metallicity, play a crucial role in the survival and detection of planets. These findings could provide new insights into the processes of planet formation and the evolution of planetary systems, particularly in metal-rich environments.

The updated analysis from figures 12, 13 and 14 are illustrated through comparative Figures that juxtapose the generated star population against the exoplanet holder candidates. The new metallicity mean of the exoplanet holder candidates is now $[\text{Fe}/\text{H}] = 0.014$, with a scatter of 0.22 dex., indicating a slight shift towards higher metallicity values compared to previous iterations.

Additionally, the mass distribution of these candidates now shows a more gradual decrease, reflecting a refined selection process that better captures the characteristics of stars likely to host exoplanets.

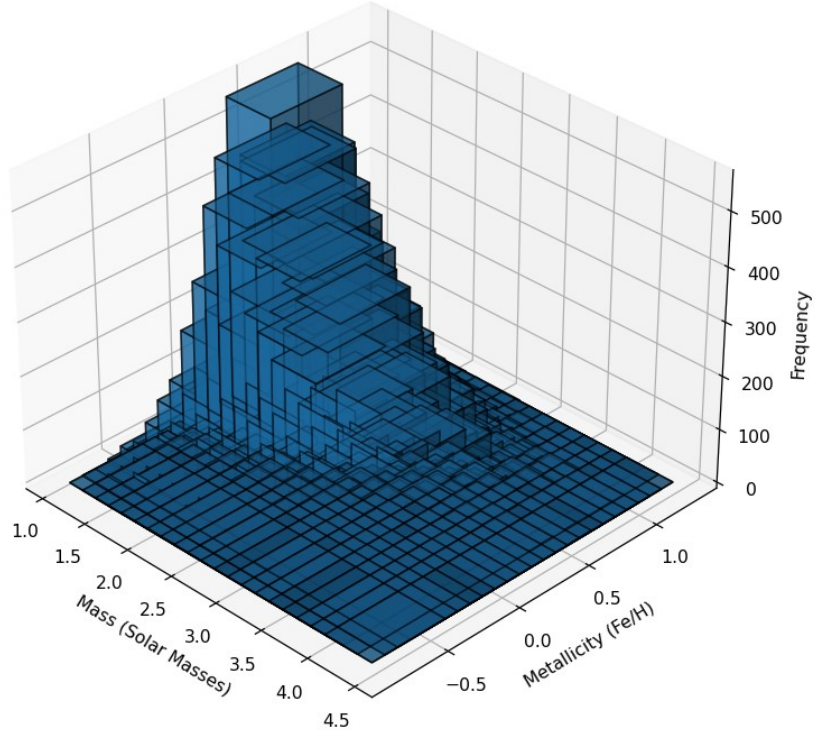
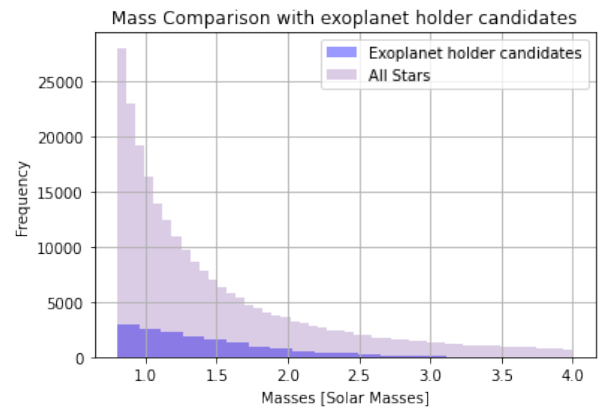
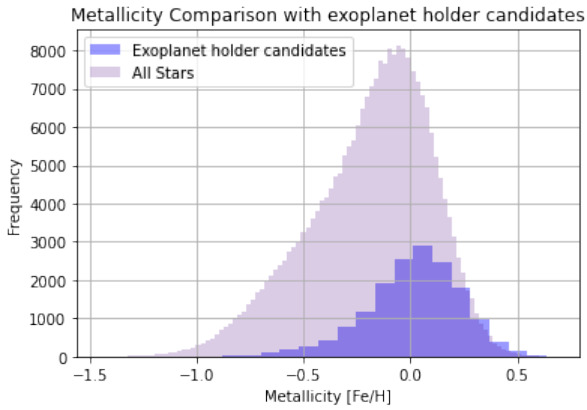


Figure 11: In this Figure we show the behaviour of the distribution of selected candidate stars. There's basically no planet holders in stars with too high Masses. WD progenitors tend to have Metallicities close to the Sun.



Figures 12 and 13: In these figures we can see how both the Mass and Metallicity varied after selecting the exoplanet holder candidates, where we can clearly differentiate how the Metallicity increased, and mass now has a more gradual decrease.

Finally, we can clearly see on Figure 14 how the age of the WD progenitors candidates evolved, tending to be relatively younger, with a slight gradual decrease for older stars.

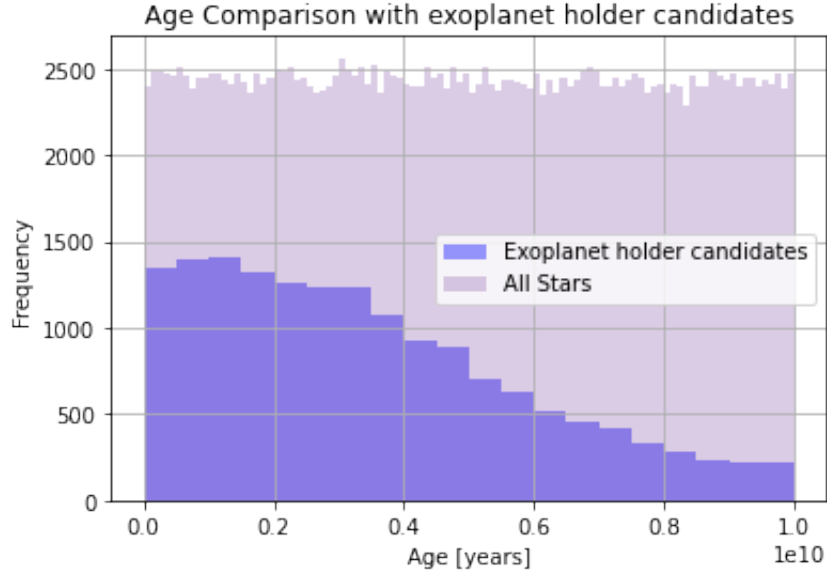


Figure 14: In this figure we can see how both the Age varied after selecting the exoplanet holder candidates. WD progenitors tend to be "young".

3.4 Period Expected

The distribution of exoplanet periods demonstrates a clear trend. The data reveals that exoplanets are most commonly found with periods peaking around 500-1500 days as you can see in figure 15. Beyond this range, the frequency of detected exoplanets decreases gradually. This indicates that while longer-period exoplanets are still present, they become less common as the period increases. This trend aligns with our understanding of planetary formation and detection, where planets with shorter periods are more likely to be observed due to more frequent transits or stronger radial velocity signals.

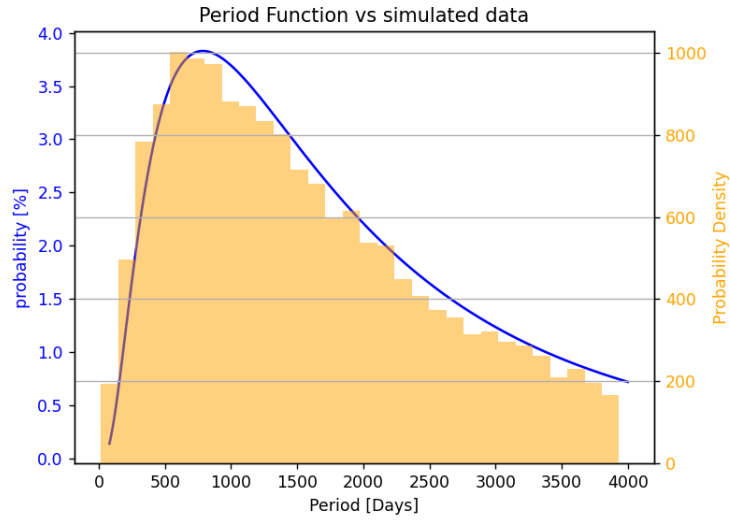


Figure 15: In this figure we can see how the distribution alligns with the function proposed by [Wolthoff et al. \(2022\)](#) with very light "irregularities", which could be explained by the dataset filtered during this project.

Chapter 4

Conclusions

The search for exoplanets around white dwarfs has not yet yielded significant results but it remains uncertain whether planets around white dwarfs are just rare or if we just have not been able to detect those planets. Here we generated representative sample of potential white dwarf progenitor.

We found that around these progenitors 6.6 % host a Jupiter-like planet. The fraction of stars that host planets are shifted towards larger metallicities, larger masses (but still dominated by low-mass stars), and younger ages, compared to the full sample of potential white dwarf progenitors. Given that not all these potential progenitors will survive the evolution of the host star, we expect the 6.6 per cent to be an upper limit of Jupiter-like planets around white dwarfs.

Furthermore, given that a significant fraction of the surviving planets might be relatively old, it will be difficult to detect them.

To test the above hypotheses, in a future work we will evolve all the planet host stars and determine whether the planet survives and thereby construct a representative sample of Jupiter-mass planets around white dwarfs.

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