



# Using Stellar Kinematics to Determine the Stellar Population of White Dwarfs in the Milky Way Galaxy

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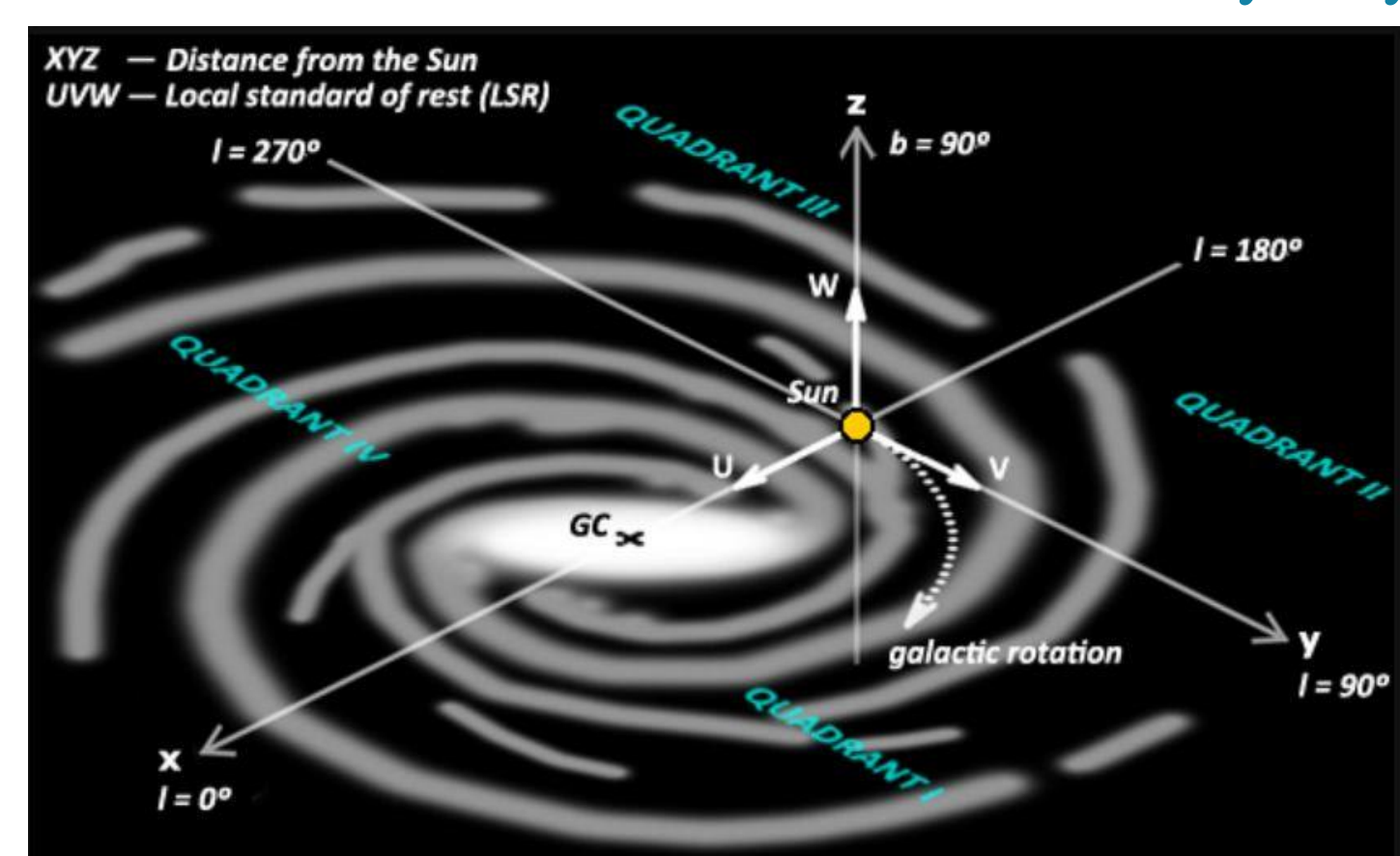
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## Abstract

Within the Milky Way Galaxy there are three different stellar populations that stars can reside in: thick disk, thin disk, and halo. For this research, white dwarfs in the local neighborhood were chosen from the second Gaia data release. Using the white dwarf's proper motion, parallax, and radial velocity, I calculated their three-dimensional velocities (U, V, W). Working with the star's three-dimensional velocities, I have created plots of velocity density distribution, expected gaussian distributions for each population, and determined which white dwarfs are most likely in the thick disk based on their U, V, and W velocities. From these analyses, I was able to create a list of 698 white dwarfs that are most likely thick disk stars. Since white dwarf stars are considered the final evolutionary state, they can be good approximators for the age of the thick disk. These white dwarfs will be used in hierarchical analysis to estimate the age of the thick disk of the Milky Way Galaxy.

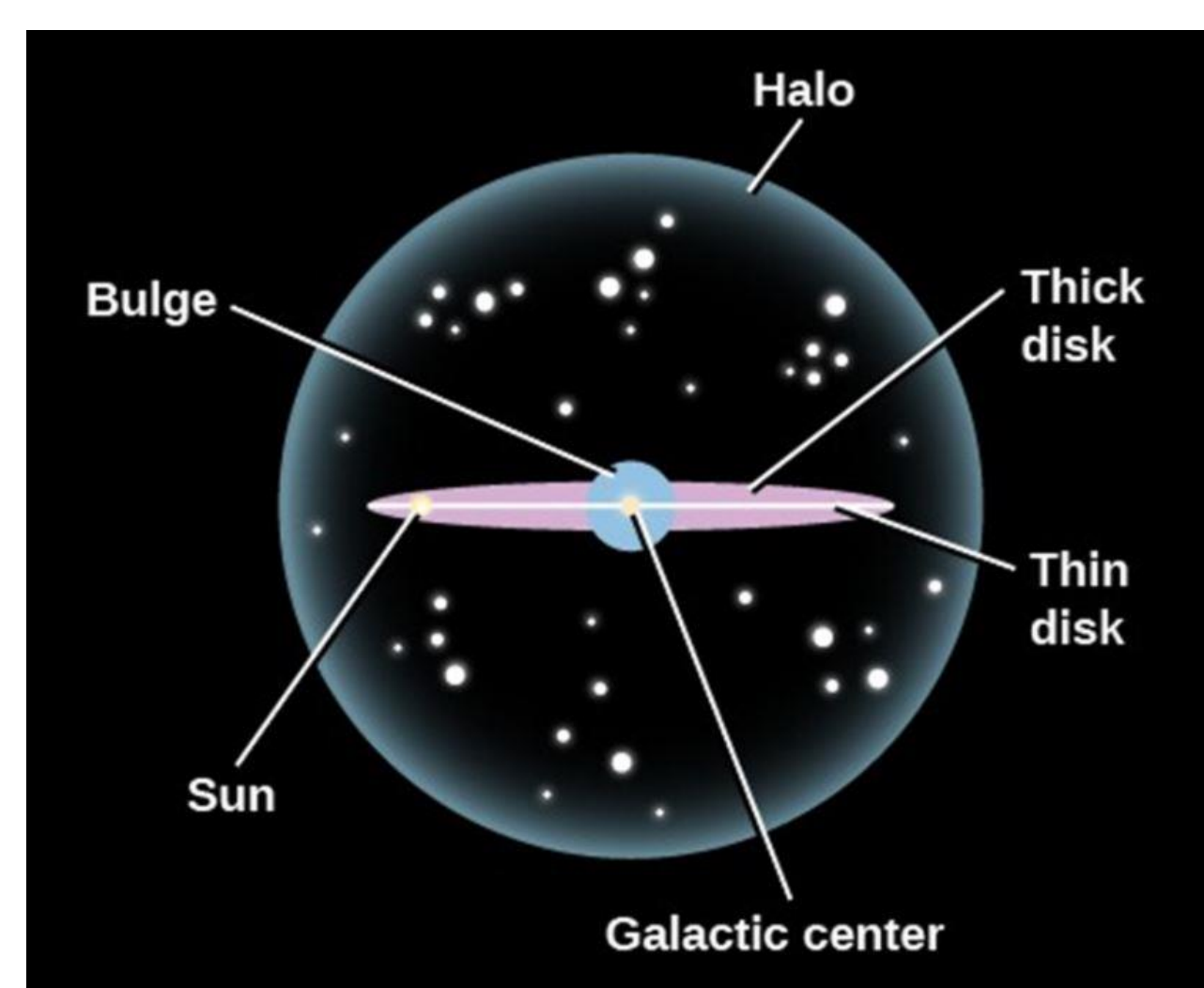
## Introduction

- The age of the stellar populations in the Milky Way can be estimated from multiple methods such as looking at star forming regions in the thin disk, using the cooling times of white dwarfs in the thick disk, and using the age-metallicity relation.
- This research involves using proper motions, parallaxes, and radial velocities of white dwarfs to calculate their three-dimensional velocity components. Probabilities of each velocity component (in each stellar population) were calculated for a list of white dwarfs to help denote which ones were most likely in the thin disk and thick disk of the Milky Way Galaxy.



- Using the Local Standard of Rest (LSR) reference frame to define the three-dimensional velocity components.
  - U is positive in the direction of the Galactic center.
  - V is positive in the direction of galactic rotation.
  - W is positive in the direction of the North Galactic Pole.

- Thin disk has a vertical scale height of about 350 pc. This is the thinnest and youngest stellar population among the three. The estimated age of this population is around 8 to 10 Gyr.
- Thick disk has a vertical scale height of about 1000 pc (1 kpc), and its estimated age is about 10 Gyr.
- Halo is roughly spherical and has a vertical scale height of about 3000 pc (3kpc). This is the oldest stellar population out of the three. The estimated age could range anywhere between 11 and 13 Gyr.



## Methodology & Results

- MATLAB is used to read data files and create a multitude of plots.
- To determine which white dwarfs have a higher probability of being in the thick disk based off their U, V, W velocity components, the probability of being a thick disk star was divided by the probability of being a thin disk star. Three of these calculations were made, one for U, one for V, and one for W. This ratio was plotted against the U, V and W velocity components of each white dwarf.

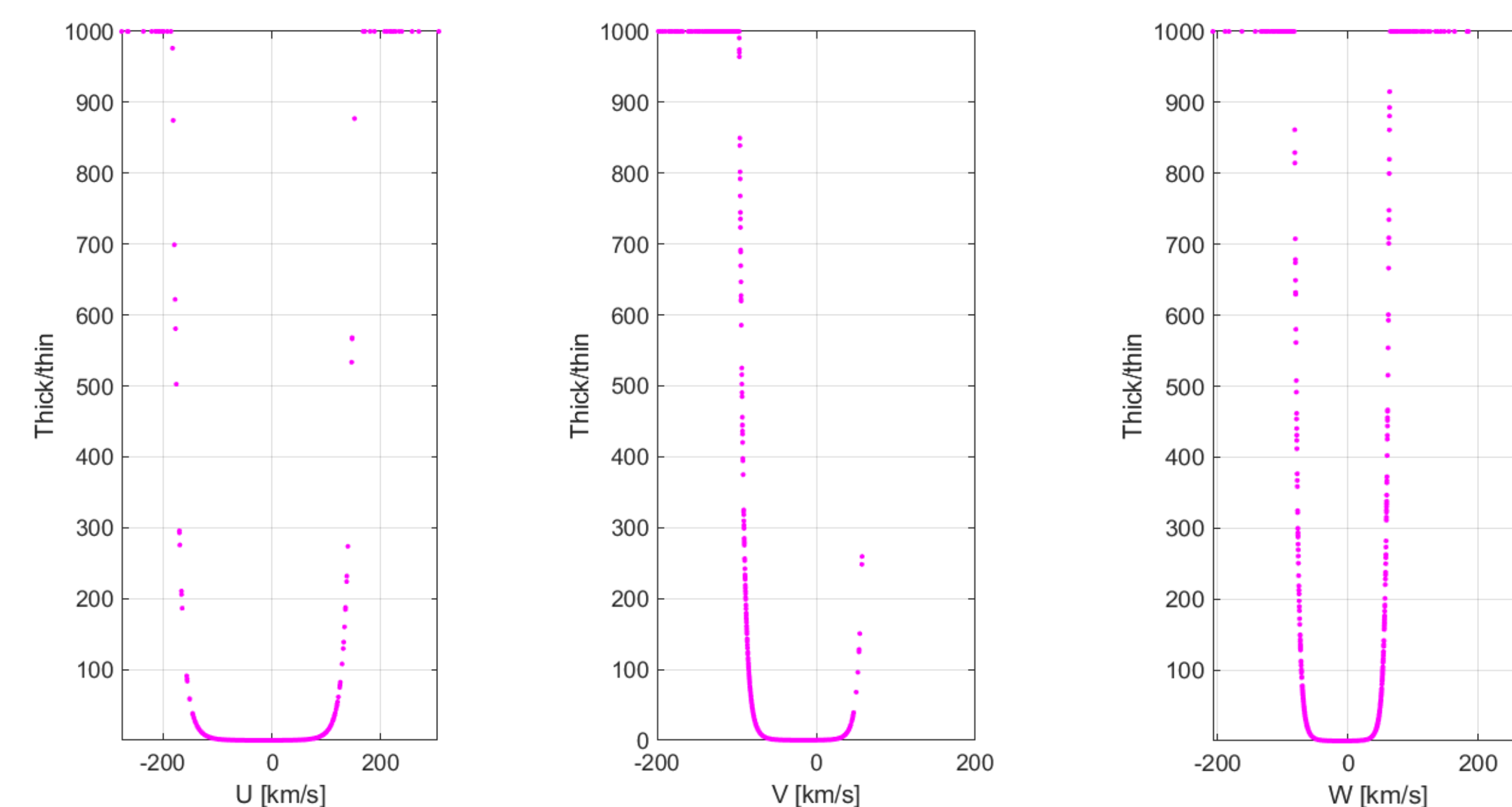


Figure 1: Shows the possible velocity ranges for the thick disk and thin disk stars as well as the higher the ratio, the most likely the star is in the thick disk. For the U velocity component, the white dwarfs in the thick disk have velocities of about  $\pm 180$  km/s. For the V velocity component, the white dwarfs in the thick disk have velocities less than  $-100$  km/s and larger than  $70$  km/s. Lastly, for the W velocity component, the white dwarfs in the thick disk have velocities of less than  $-80$  km/s and larger than  $65$  km/s. Used the three ratio calculations from each of the graphs above to calculate an overall ratio, which determined the possible stellar populations for each white dwarf in the list.

- After separating the white dwarfs into thin and thick disk candidates, these stars were run through a software called BASE-9. This software gave an estimated age for each star, and figure 2 shows an age distribution for a thin disk candidate white dwarf. The distribution peaks around 0.475, so the linear age is around 3 Gyr.

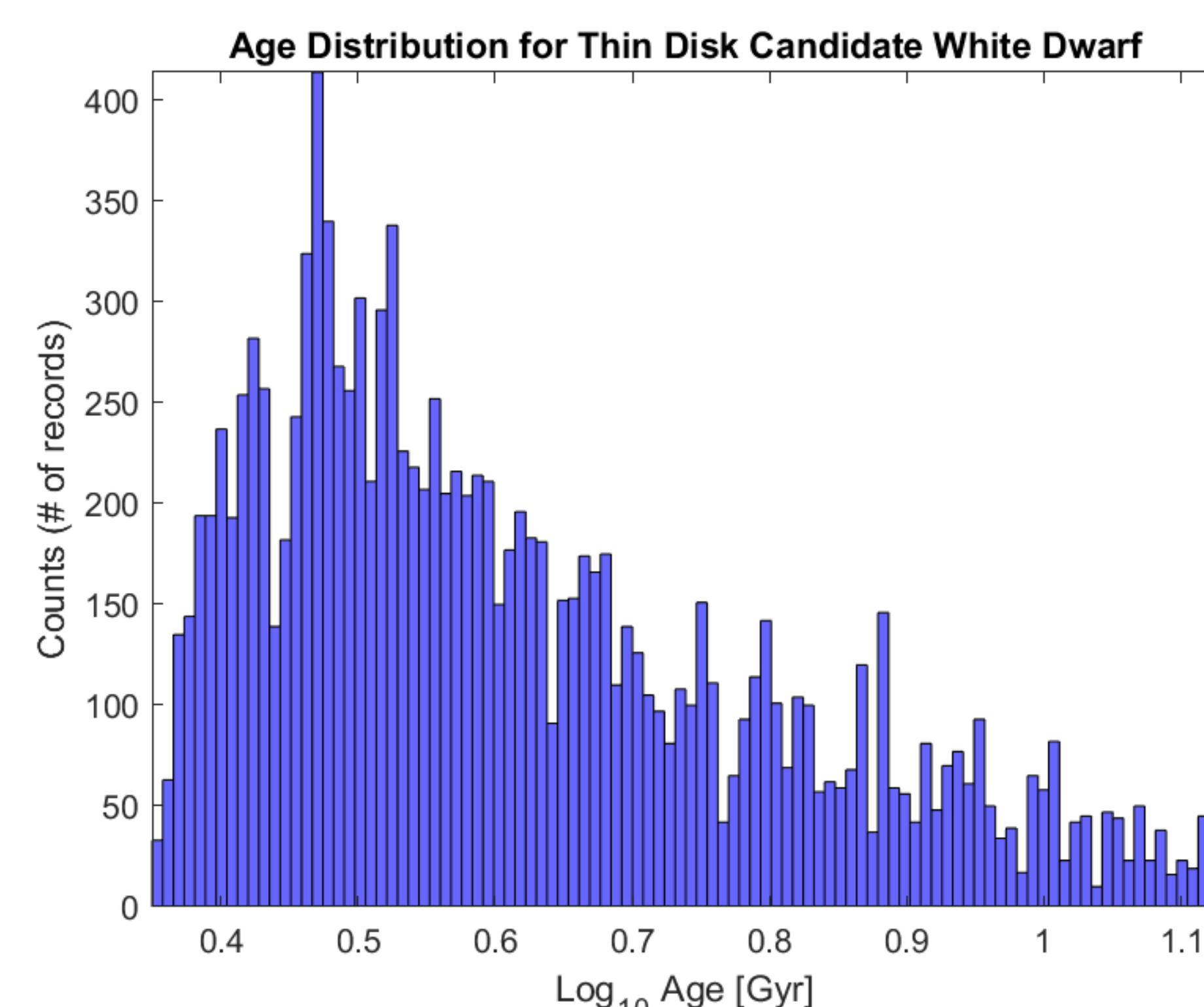


Figure 2: Shows an age distribution for a single white dwarf, which is a possible thin disk candidate. The peak of the distribution is around 3 Gyr. This is not an exact age of the thin disk, since the overall estimated age is the peak in a distribution. This distribution just shows that the method of using U, V, and W velocities is working, and can be applied to a large data set.

## Conclusion

- In figure 1 there is a strong relationship between the velocity components (U, V, W) and the stellar populations (thick and thin disk). These three figures allows the white dwarfs to be categorized by possible thick and thin disk candidates. After the white dwarfs are separated, each stellar population set is run through BASE-9, which gives the age of each star.
- From the most recent results, figure 2, it shows that the method of using white dwarf's three-dimensional velocity components is a reliable method and can roughly estimate the ages of the stellar populations. Each white dwarf is going to have a slightly different age, and the overall age distribution of the thin disk (or thick disk, or halo) will peak at the most probable age.
- Since the age of one white dwarf in the thin disk is a bit younger than expected, I could go back to the U, V, W calculations and include the uncertainties in my calculations to help refine the data.
- Overall, this method has shown good correlations in the plots that I have made and is giving reasonable results of the age of the stellar populations.

## Future Work

- This method has shown to give a decent estimate for the age of a single white dwarf, so The next steps will be applying this method to a larger set of data. This should give an age estimate of a stellar population, such as the thick disk. It could also be applied to the other two stellar populations and can be compared to the expected ages.
- I currently have a list of 304 files, one for each candidate white dwarf of the thick disk. I will combine all the necessary data to create an age distribution plot for the thick disk.
- If the age of the thick disk is obtained, I will send the list of the candidate white dwarfs to a graduate student, who will then run different simulations with different parameters to estimate the age of the thick disk of the Milky Way.
- Could refine the original data set once the third data release from Gaia is out.

## References

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