# Reconstructing the Milky Way Star Formation History from Its White Dwarfs

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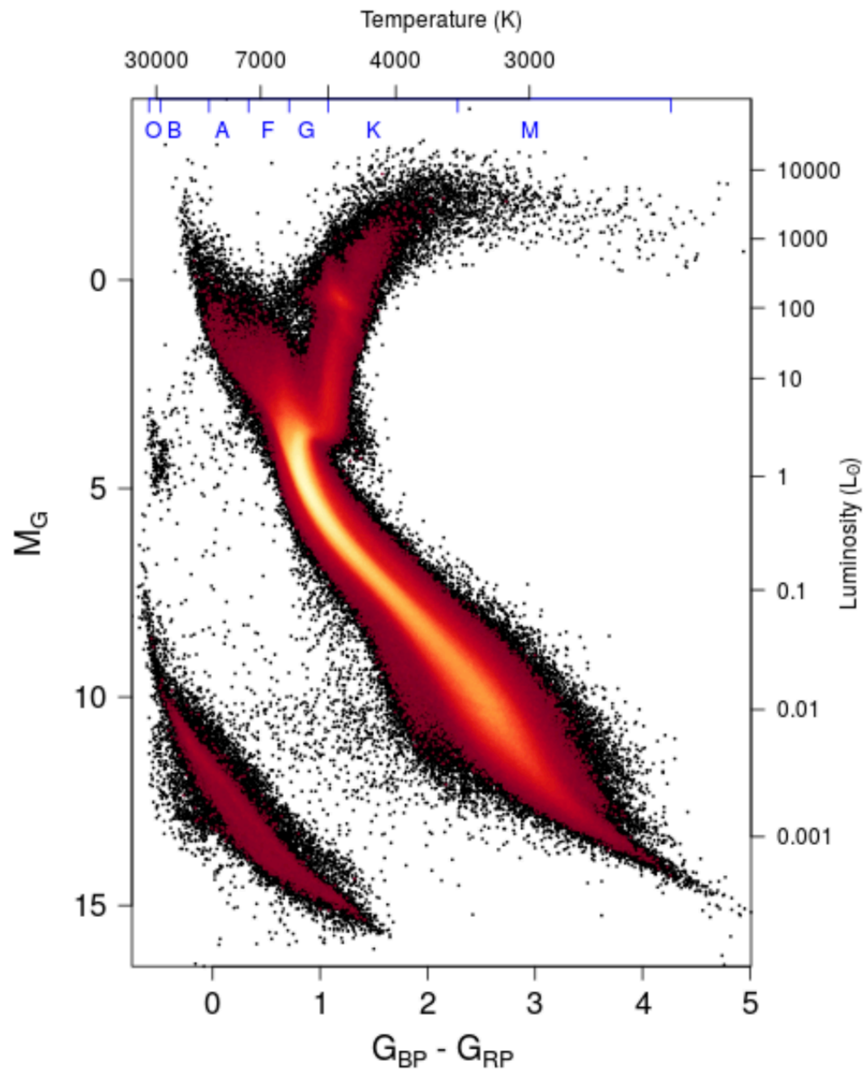
# White Dwarfs and Stellar Evolution

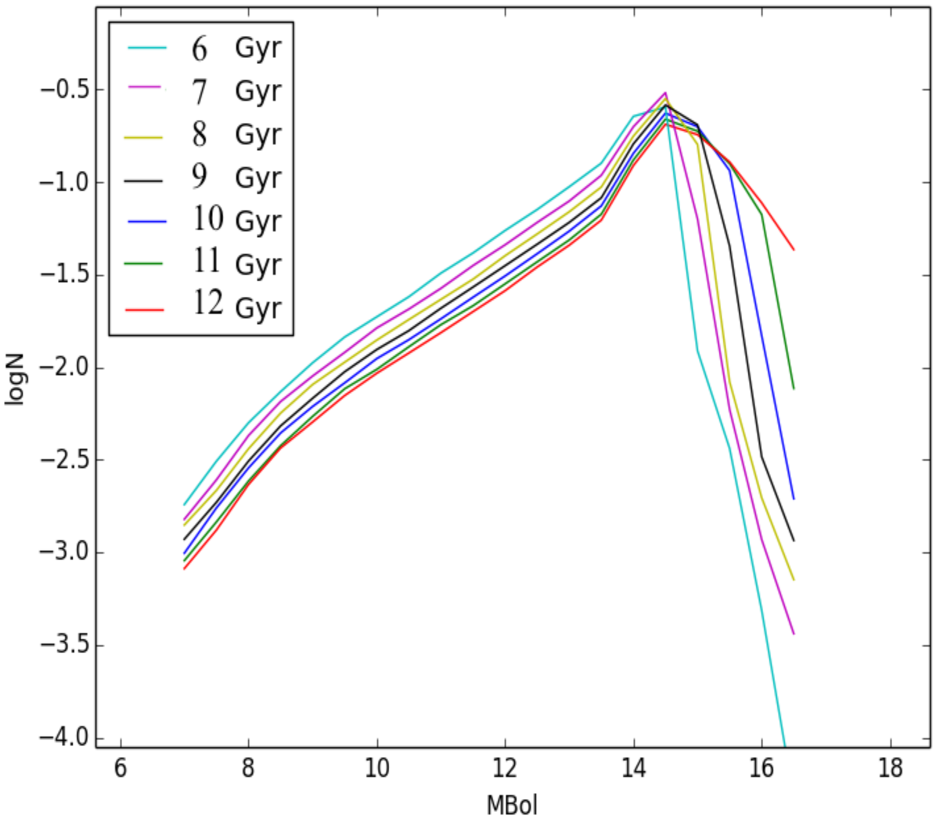
- White dwarfs are the remnants of stars with $M_i \lesssim 8\ M_{\odot}$
- This comprises ~98% of all stars
- Their evolution is dominated by a cooling sequence
- Their ubiquitous and long lived nature makes them ideal probes of the evolution of a stellar population



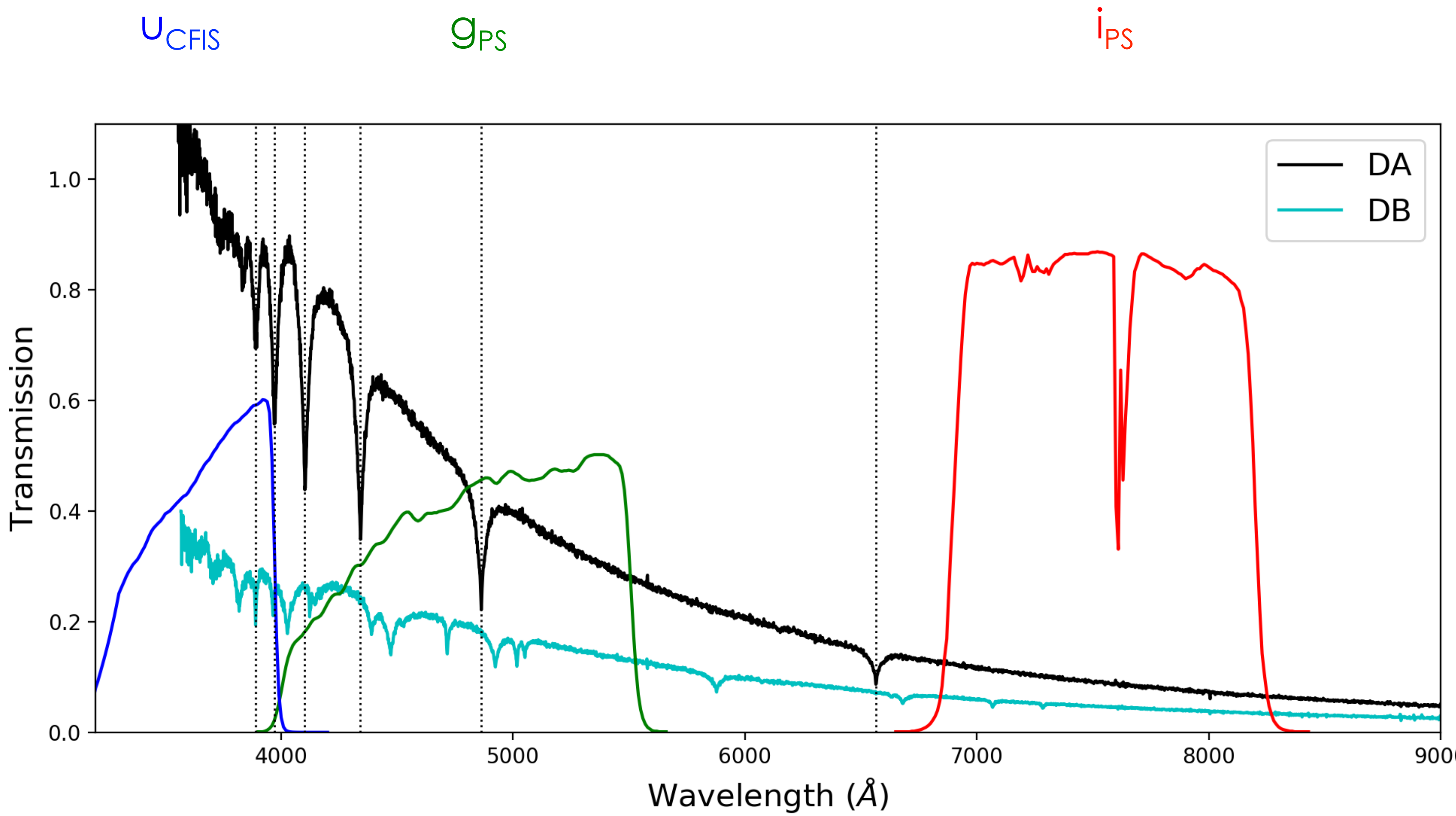

Gaia Collaboration (2018)

# White Dwarfs as Cosmochromometers

- A turn-off in the luminosity function represents the age
- The WDLF also contains information regarding the star formation history
- Our goal is to determine the star formation history of the Milky Way components using white dwarfs
- We do this by modeling the Milky Way's white dwarf population and comparing to observations



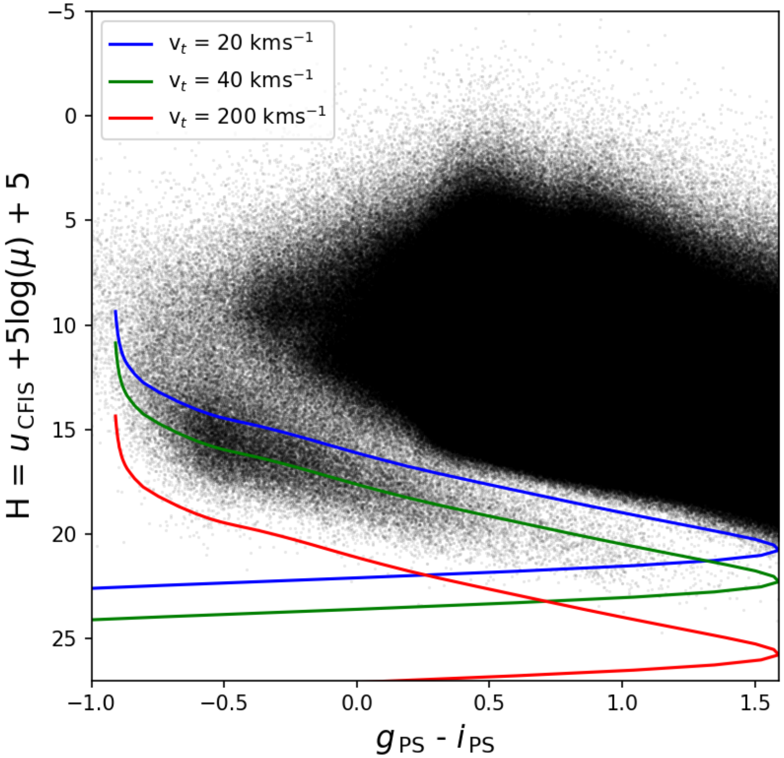
# Why CFIS-u?

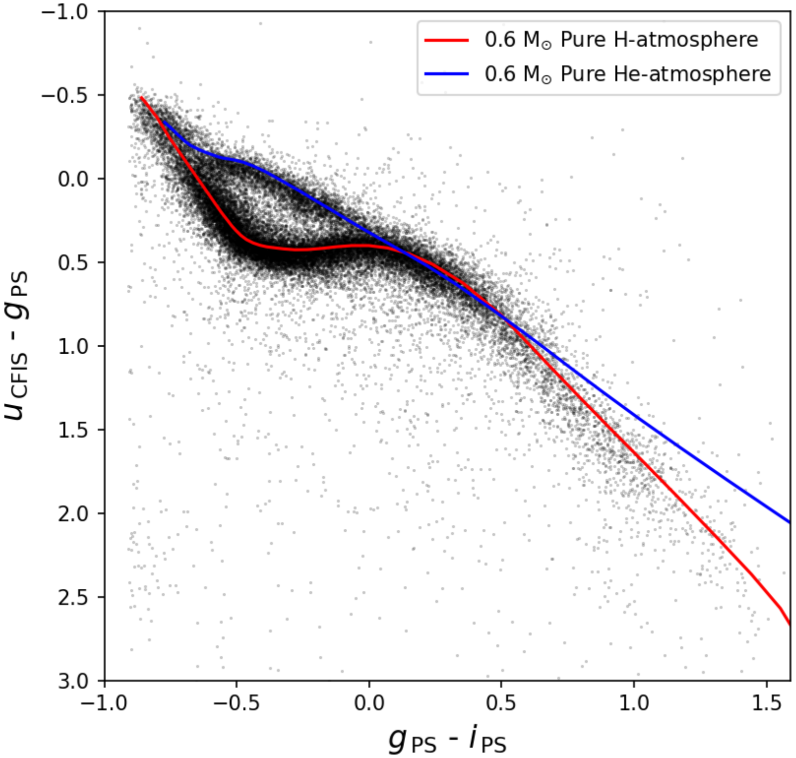


u CFIS
g PS
i PS
DA
DB
Transmission
Wavelength (Å)
0.0
0.2
0.4
0.6
0.8
1.0
4000
5000
6000
7000
8000
9000

# The Data

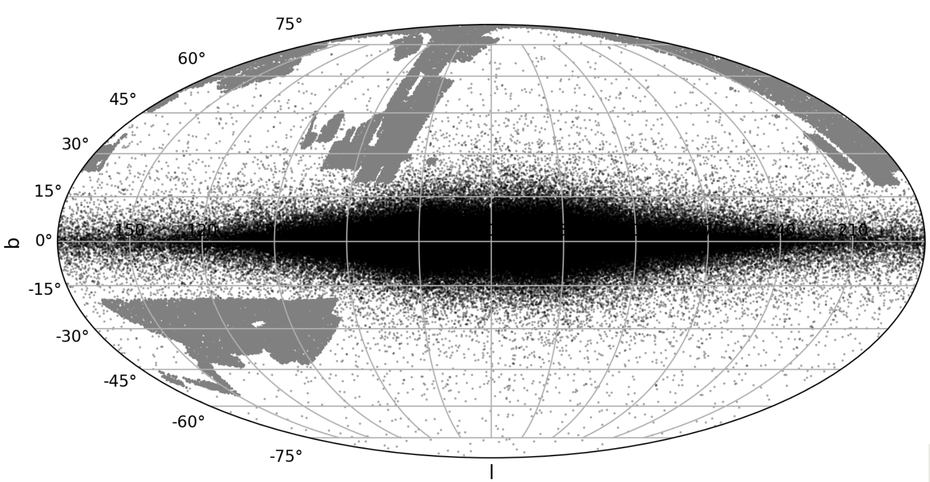
- We combine CFIS, PS1, and Gaia DR2 to select 29,322 white dwarf candidates
- Thus, we are limited in area by CFIS, and in magnitude by Gaia

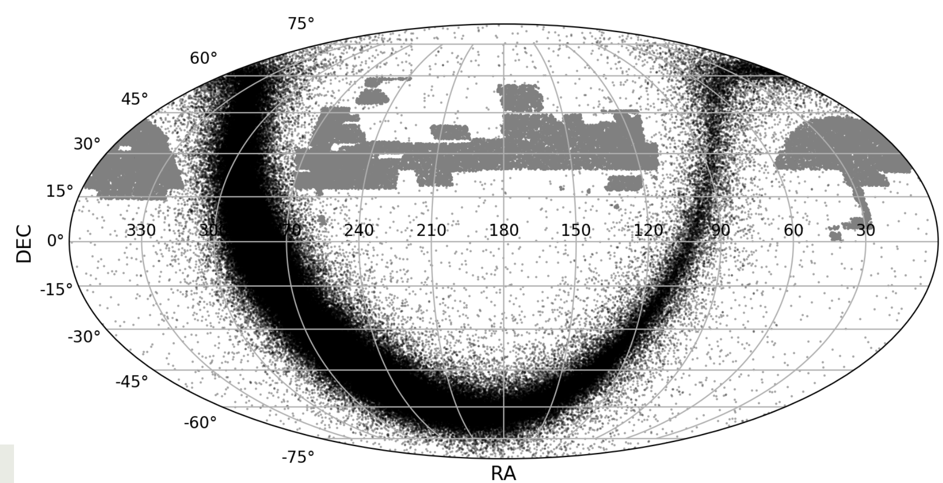


# The Model

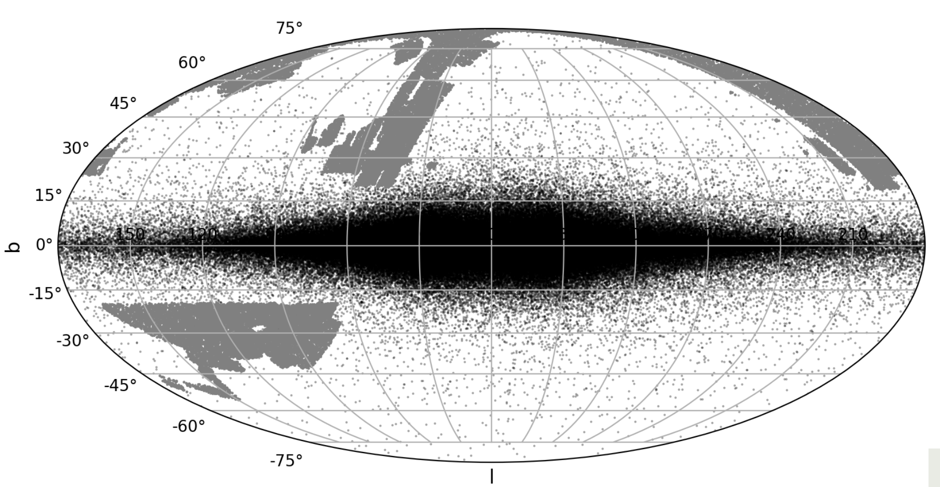
- Modeling the Milky Way requires a few assumptions:
  - We assume a 3-component Milky Way: a halo, a thick disk, and a thin disk
  - [Fe/H] = +0.0, -0.7, -1.5 dex
  - Kroupa Initial Mass Function

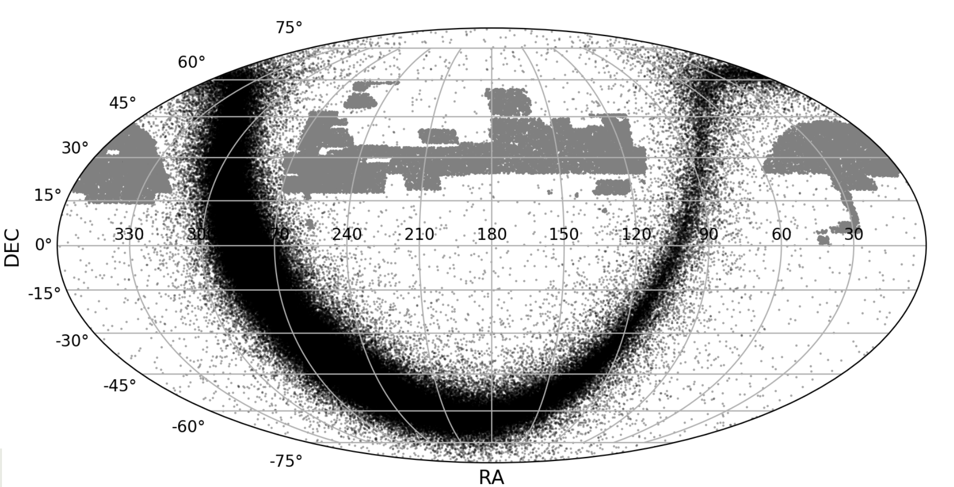


# The Model

- Modeling the Milky Way requires a few assumptions:
  - Pre-white dwarf lifetimes from Hurley et al. (2000)
  - Velocity Ellipsoids from Robin et al. (2014)
  - Initial-to-Final mass relation from Kalirai et al. (2008)



# Model Outline

Generate Stars → Select White Dwarfs → Apply Observational Constraints

**Generate Stars**

- Position — ra, dec, d
- Mass — $M_i$
- Lifetime — $\tau$
- Proper Motion — $\mu$
- Formation Age — $t_0$

**Select White Dwarfs**

- Mass — $M_{WD}$
- Cooling Age — $\tau_{WD}$
- Photometry — $m_i$
- Atmospheric Type

**Apply Observational Constraints**

- Survey Area
- Completeness
- Selection Effects

# Fitting Routine

- We parameterize the star formation history using skewed normal distributions

$$f(x) = \frac{2}{\omega}\phi\left(\frac{x-\xi}{\omega}\right)\Phi\left(\alpha\left(\frac{x-\xi}{\omega}\right)\right)$$

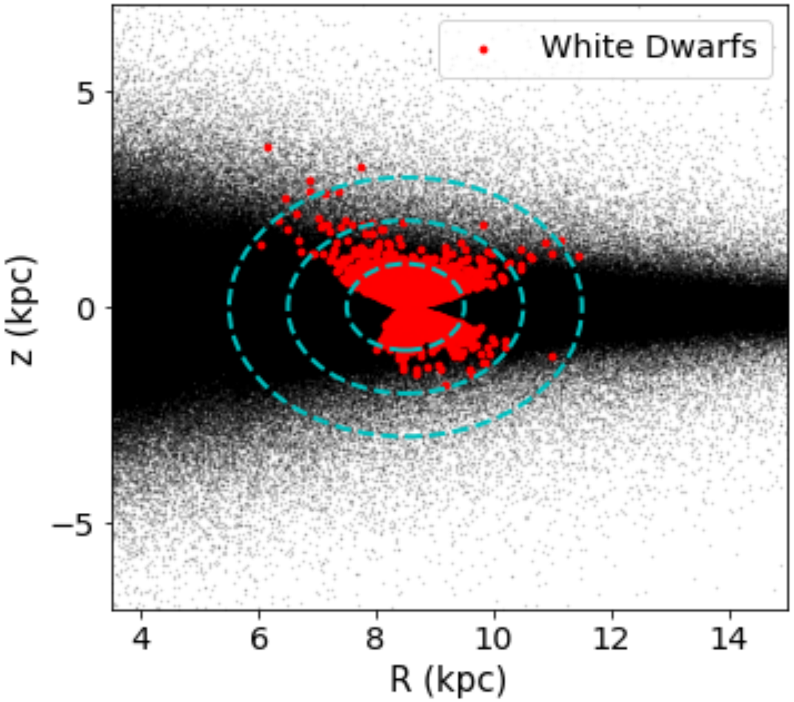
- We also fit for the He/H-atmosphere ratio

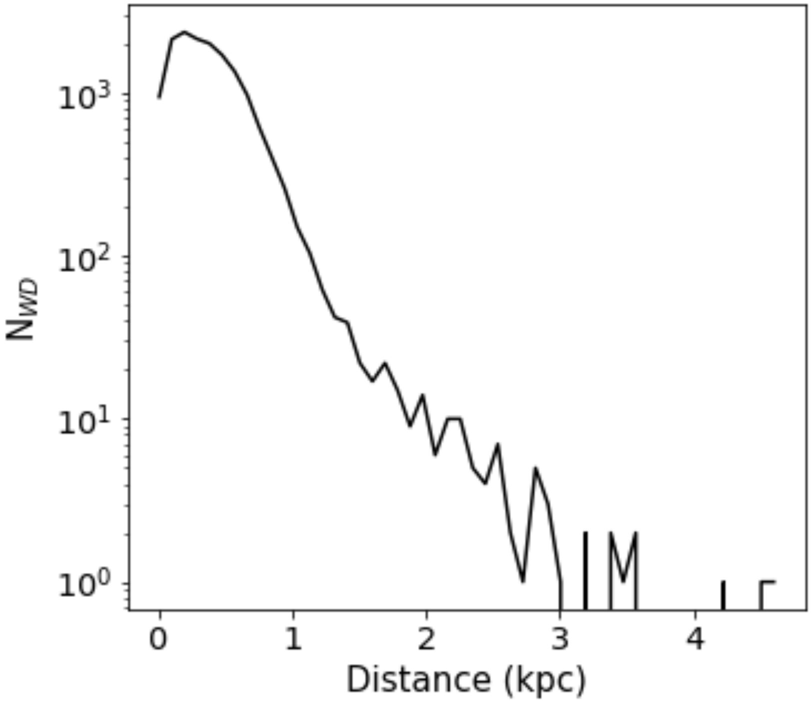
- This results in 13 parameters

- We employ *astroABC*, a python based implementation of an Approximate Bayesian MCMC algorithm, to estimate the PDFs

# Our Sample, in context

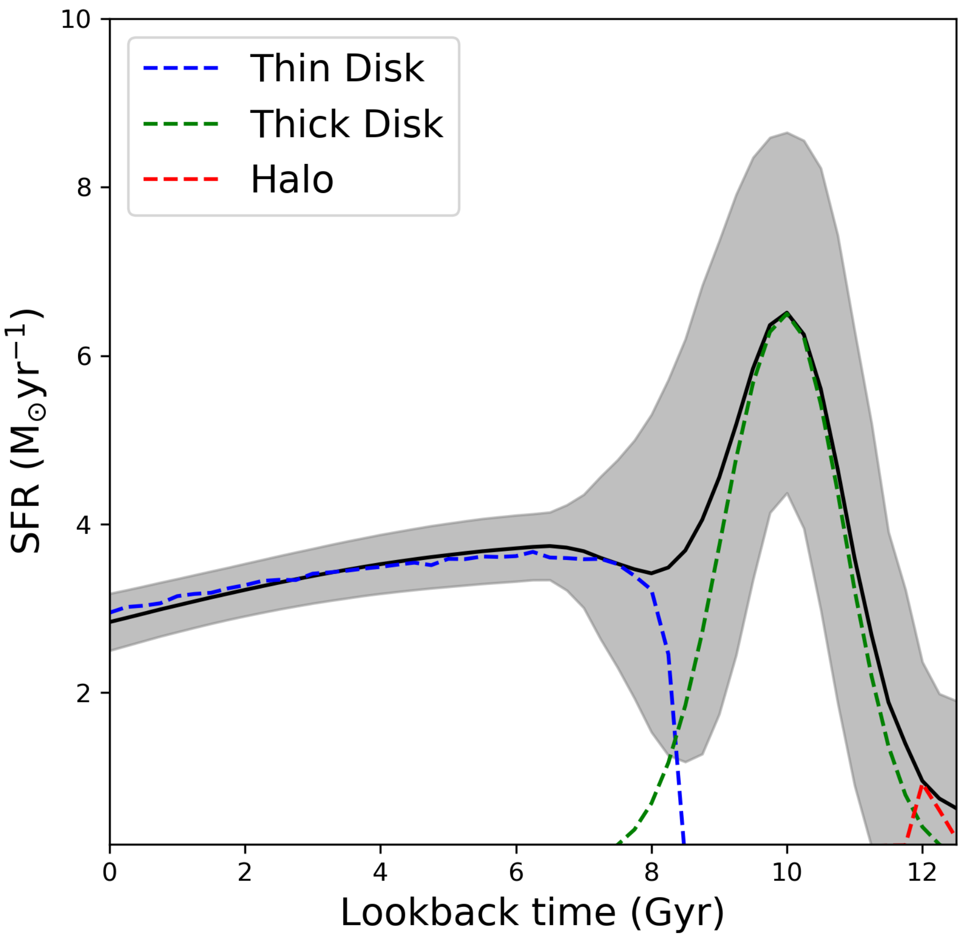
- 96% of our sample is located within 1 kpc, with a median of 388 pc
- It is thus, representative of the Solar neighbourhood



# Results: Star Formation History

- Our star formation history turns on at 12.3 ± 0.4 Gyr
- Peaks at 10.3 ± 0.4 Gyr at a rate of 6.5 ± 2.1 $M_{\odot} yr^{-1}$
- This is followed by a slow decline over the following 9 Gyr



# Results

- Our data results in peak SFR of:

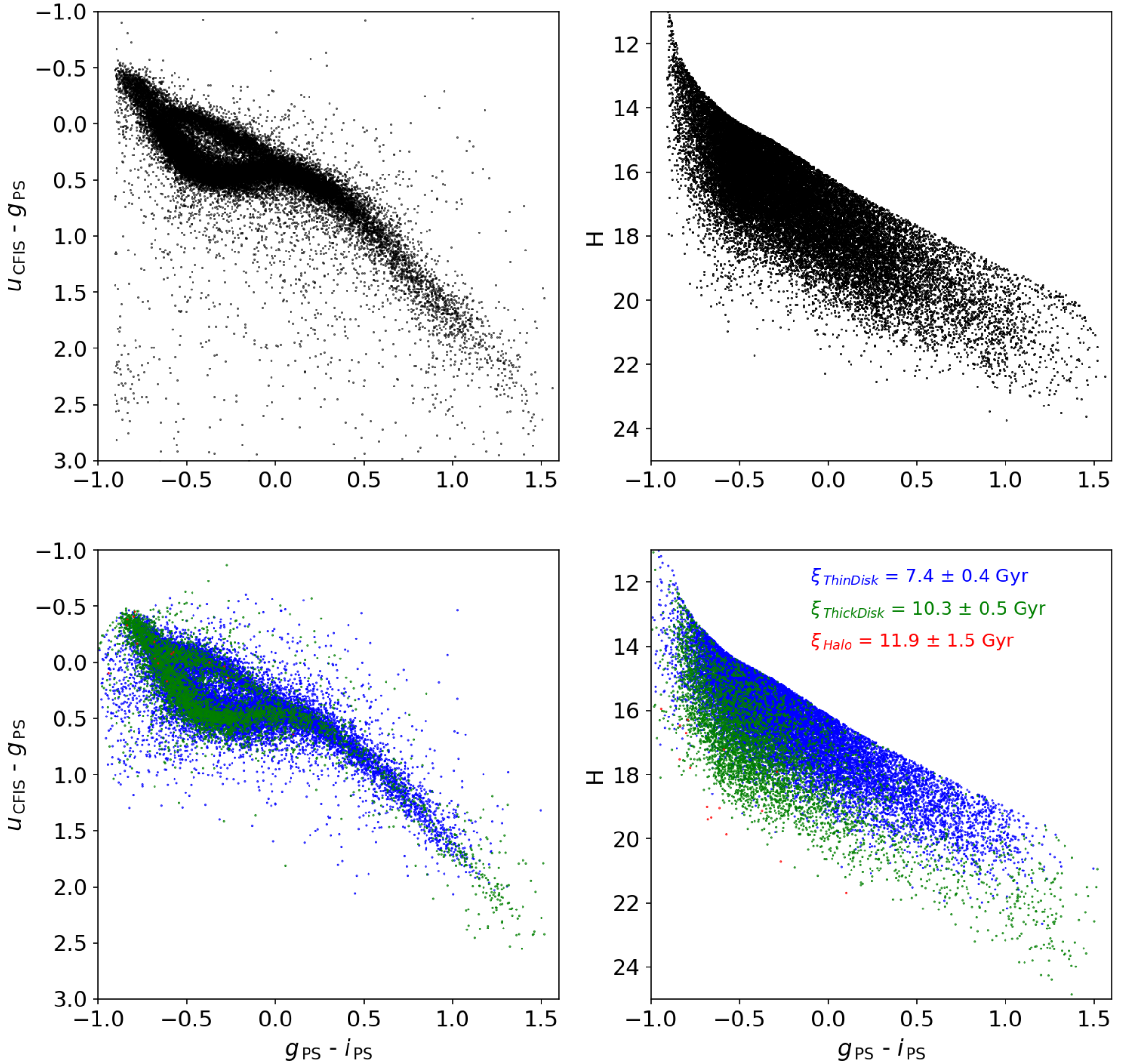
  Thin Disk: 7.4 ± 0.4 Gyr

  Thick Disk: 10.3 ± 0.5 Gyr

  Halo: 11.9 ± 1.5 Gyr

- The thin/thick disk/halo contribute 77/19/4 % respectively

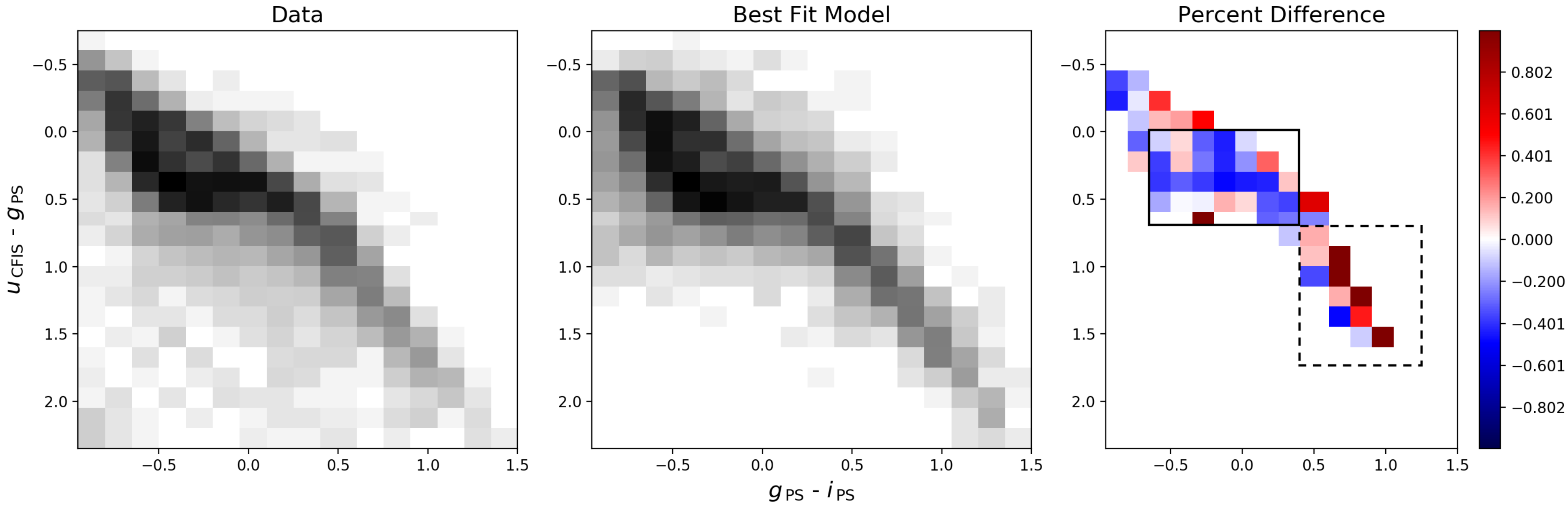
- The He-fraction was found to be 20 ± 3 %



# Revisiting our Assumptions

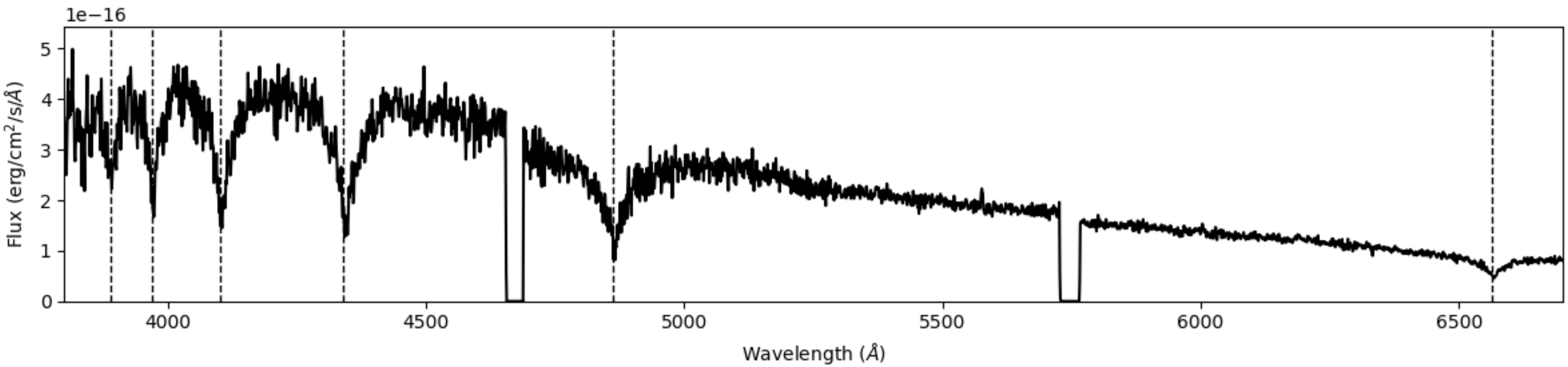
- Our parameterized star formation history assumed a unimodal function

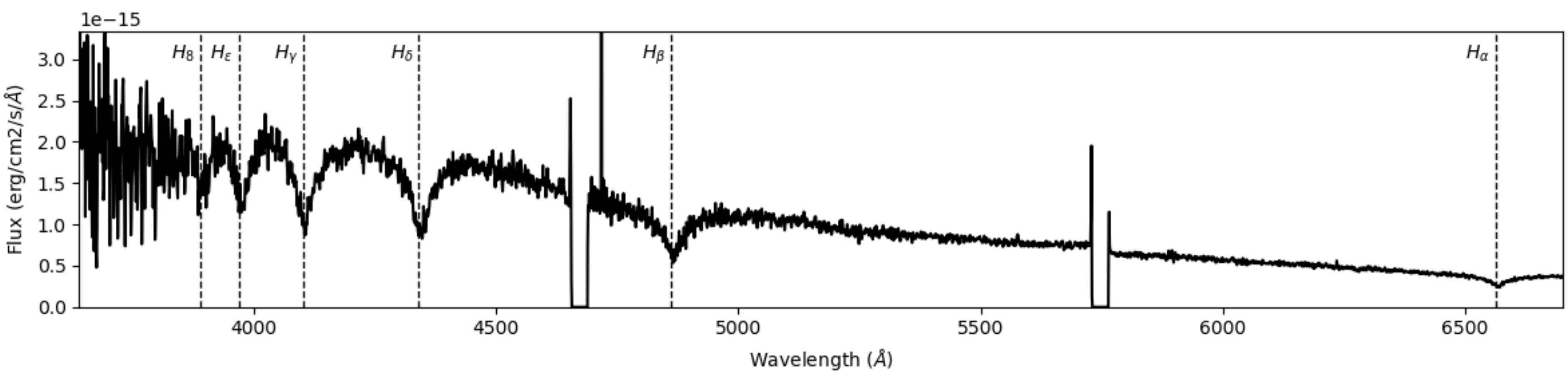
- The residuals between the model and the data suggest slight variations at 3 and 6 Gyr



# A look Ahead: The Halo

- Gemini 2019A PI program to measure the age distribution

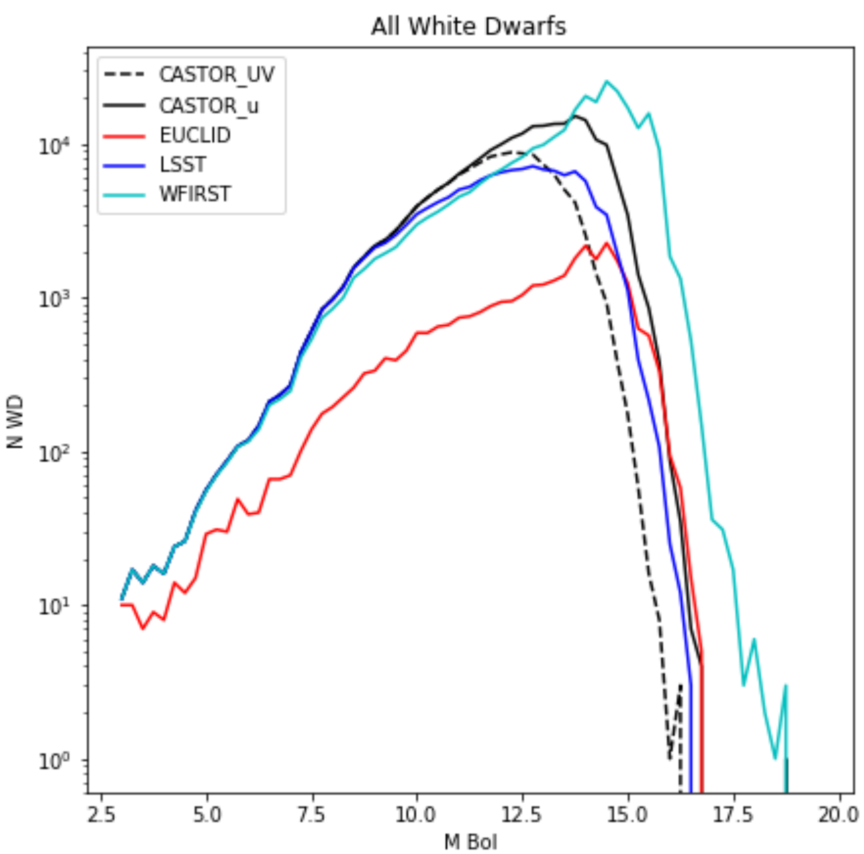


# A look Ahead: Future Surveys

- Ultimately, deeper proper motions will significantly improve this analysis

- Upcoming surveys like WFIRST, LSST, and CASTOR have the opportunity to provide unprecedented proper motion catalogs, on the order of $10^6$ white dwarfs



# Summary

- We have used photometric data from the Canada-France Imaging Survey, Pan-STARRS DR1, and proper motions from Gaia DR2 to select a sample of 29,323 white dwarfs
- A model was constructed to simulate the Milky Way white dwarf population while simultaneously applying observational constraints
- By parameterizing the star formation history we found the best-fit values for the Milky Way
- Small fluctuations at 3 and 6 Gyr can be seen in the residuals suggesting small variations from our functional forms