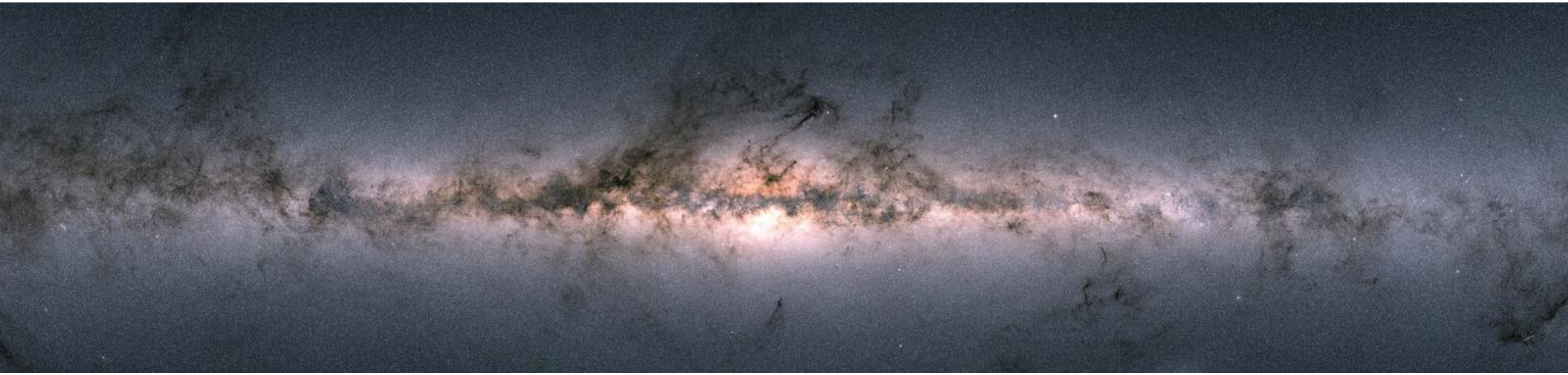
Properties of white dwarfs in a semi-analytic Milky Way model based on Gaia DR3



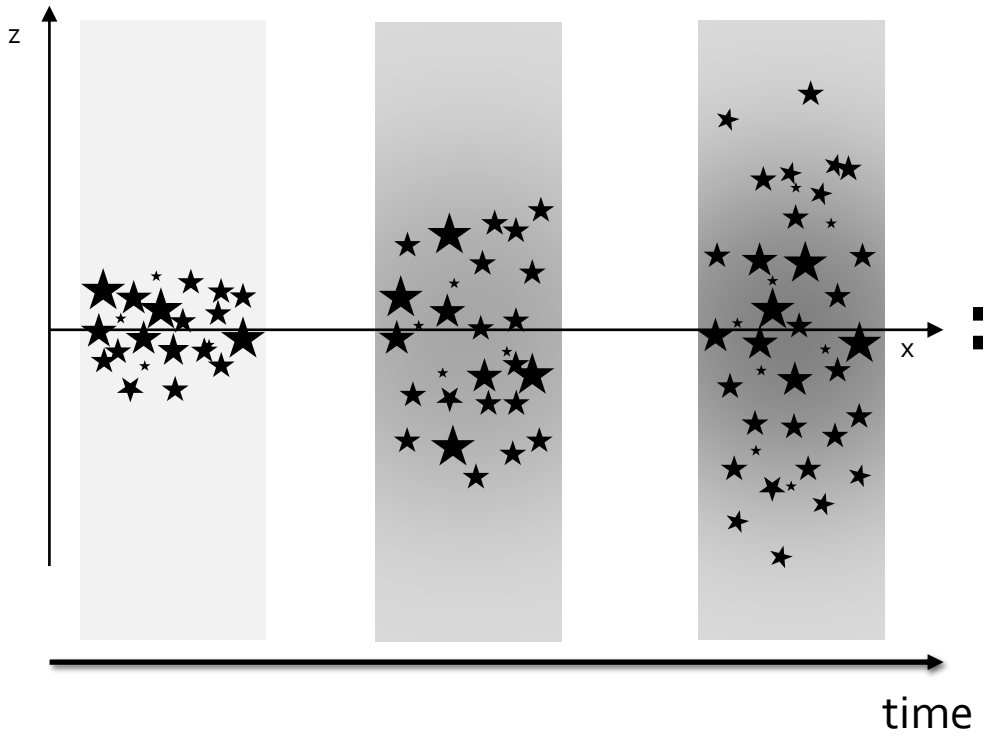
Akash Vani
(Andreas Just, Kseniia Sysoliatina)

ARI, ZAH, Heidelberg University

White Dwarfs from Physics to Astrophysics
KITP, Santa Barbara
17.11.2022

Just-Jahreiß (JJ) model framework

(Just & Jahreiß 2010)



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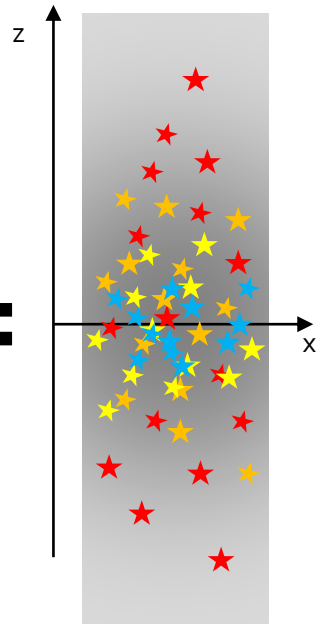
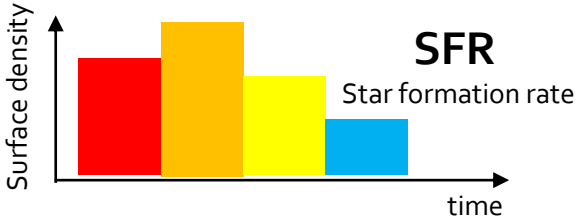
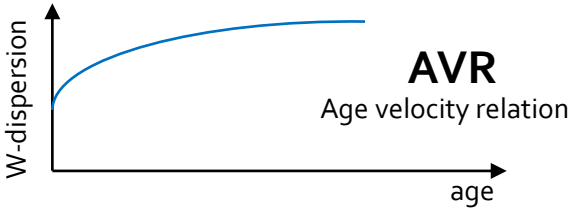
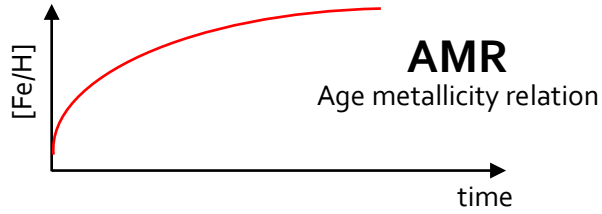
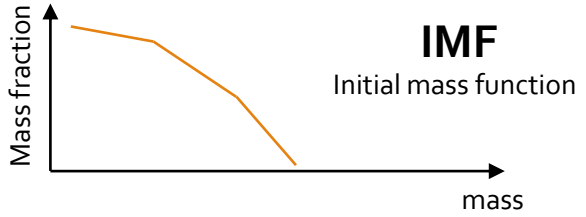


xz-plot today







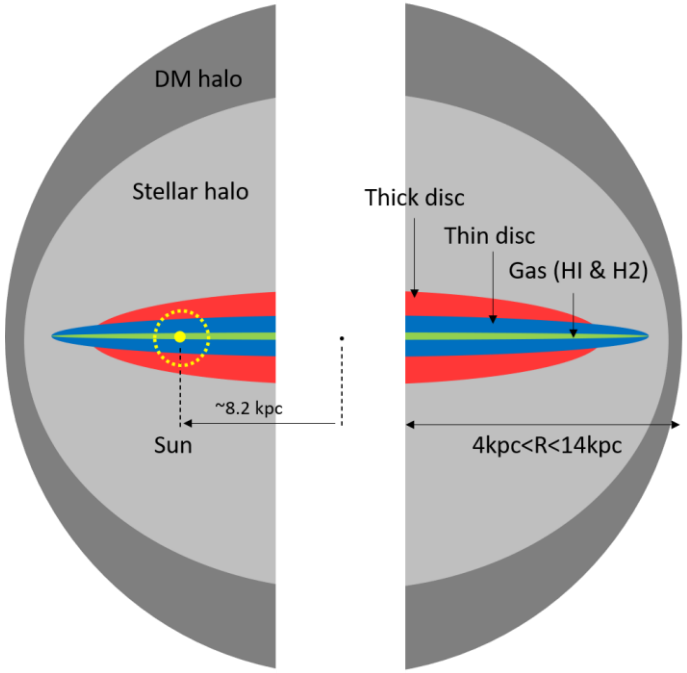


+ Stellar evolution library – **PARSEC**/MIST/BaSTI

JJ model framework

What is it and what does it do?

- **Semi-analytic chemo-dynamic** model (Just & Jahreiß 2010)
- Iteratively solve Poison Boltzmann eq. to form a self-consistent pair of $\{\Phi(z), \rho(z)\}$
- Excellent tool for population synthesis studies



Assumptions of the MW system

- Steady state
- Axisymmetric and plane symmetric
- Flattened
- No explicit radial migration
- Consists of isothermal sub-populations

Limitations

- Not applicable to the Galactic bulge
- Imprecise for very young stellar populations
- Needs to be averaged over large volumes

https://github.com/askenja/jjmodel https://jjmodel.readthedocs.io/ Sysoliatina & Just, A&A 666, A130, 2022

Stellar assemblies setup

(Sysoliatina & Just 2022)

- Global model, 4 kpc < R < 14 kpc
- Local model, **solar neighbourhood** ✔

- **PARSEC**/MIST/BaSTI isochrones of metallicity -2.59 < [Fe/H] < 1.47 (50-Myr time resolution)

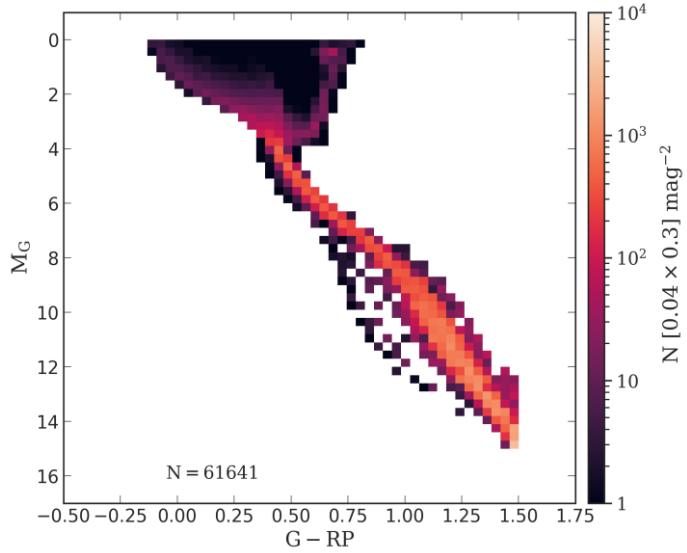
- Populate 3D age-metallicity-mass (=stellar assembly) parameter space
- Number density depends on SFR and IMF

- Deviation in total number of stars based on EDR3:
  - **+0.2 %** against a 25 pc volume (CNS5, Golovin+22)
  - **+2.2 %** against a 60 pc volume (GCNS, Smart+21)

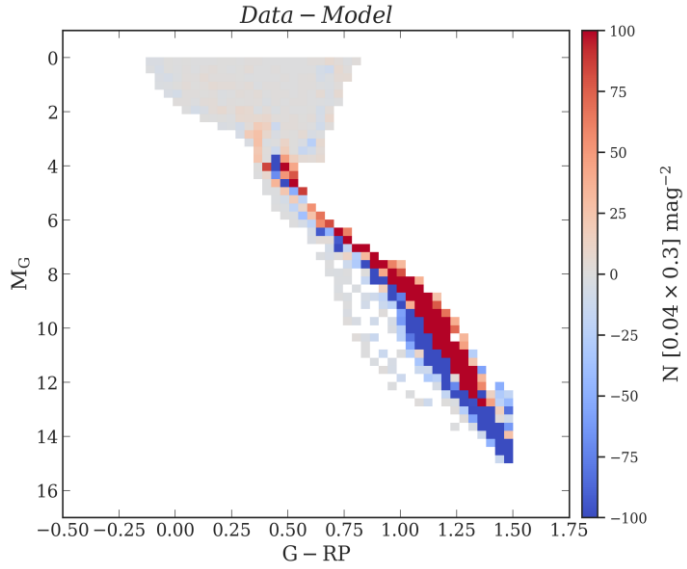
- **Result: A well calibrated model for MS+Giant stars able to make excellent predictions**

- **WDs not included in the JJ model (yet)**

JJ model 60 pc



Difference to Gaia 60 pc sample



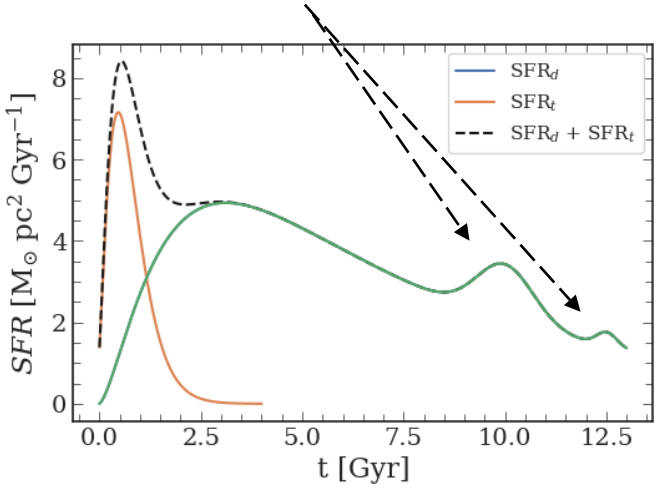
WD stellar assemblies setup

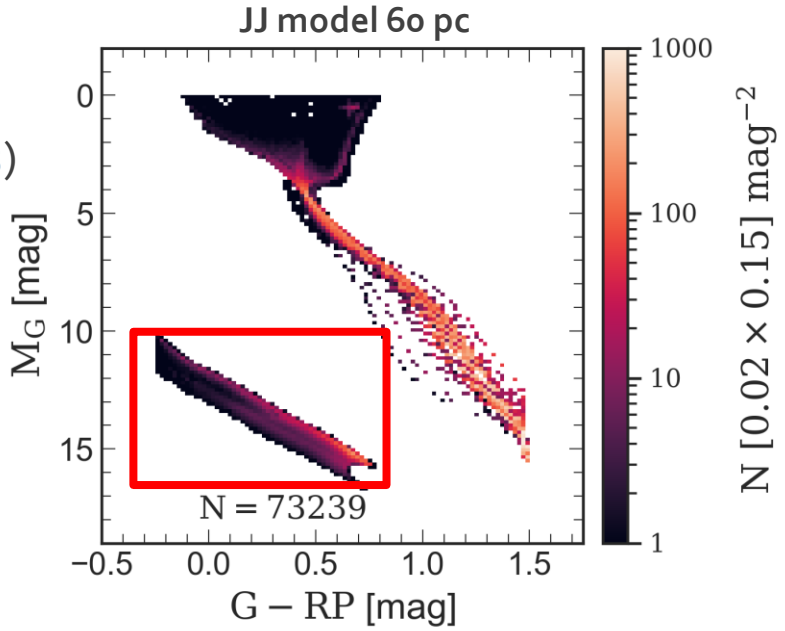
(Vani 22, master's thesis)

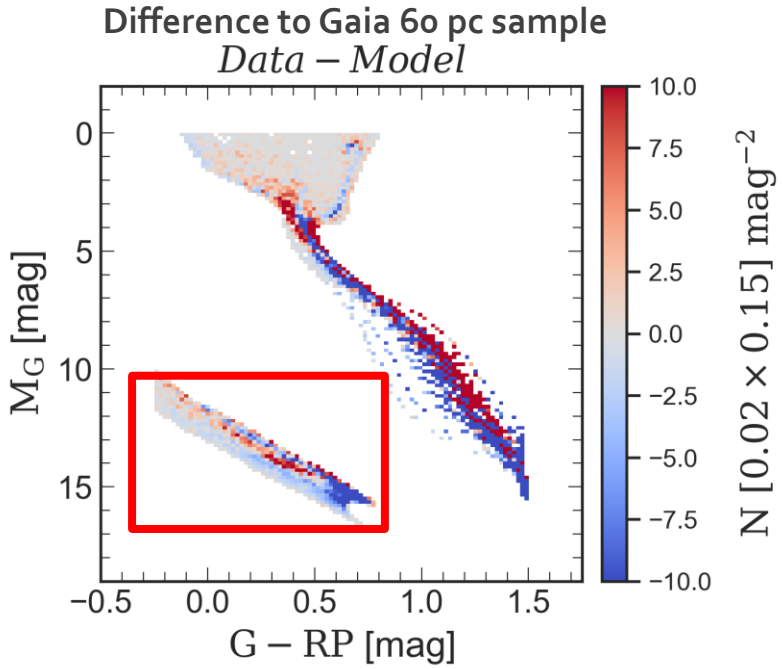
- **BaSTI** WD isochrones of solar metallicity for the whole MS metallicity range with a 50-Myr time resolution (Salaris+22)
- WDs used: **DA carbon oxygen**

Assumptions

- Lifetime of main sequence stars is modelled by a **two slope power law**
- IMF: Modified **4-slope BPL** (Kroupa+93, Sysoliatina & Just 21)
- SFR: Smooth declining continuum with **two SFR bursts** within 4 Gyr (default, Sysoliatina & Just 21)
- IFMR: **Cummings+18**







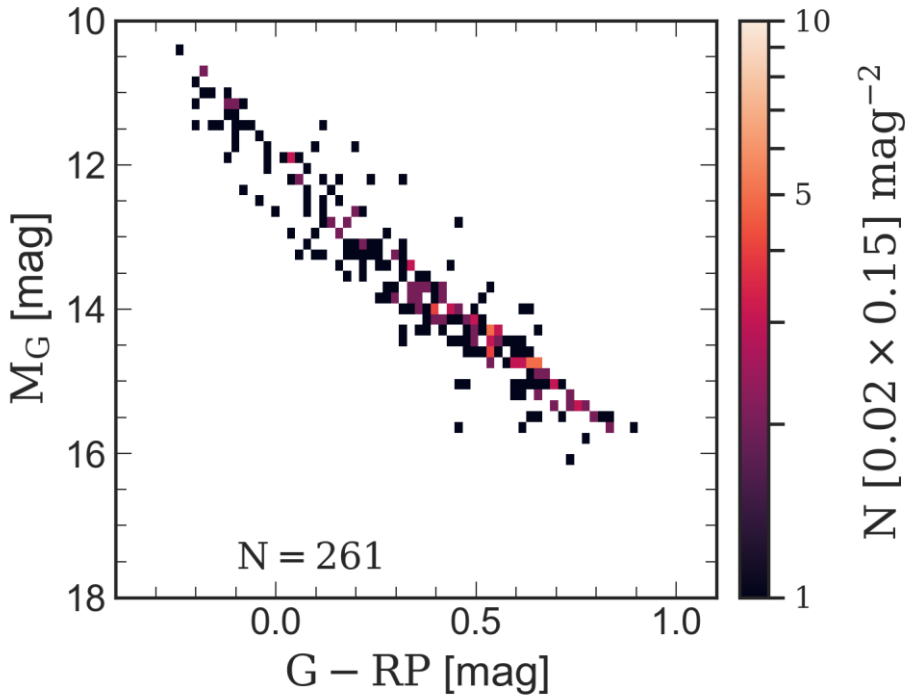
Data selection

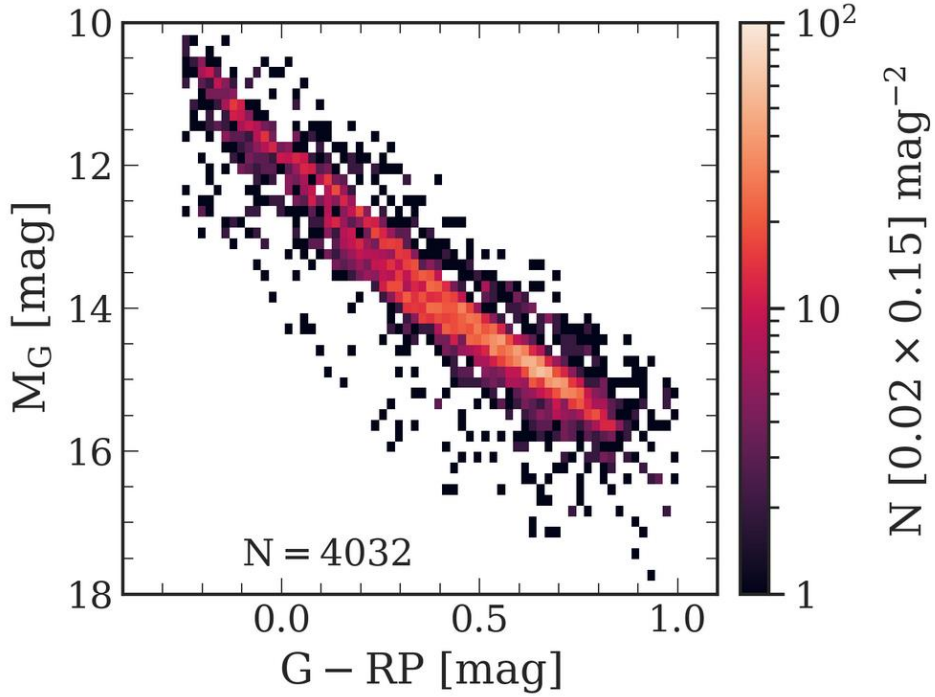
The Fifth Catalogue of Nearby Stars

- CNS5 (Golovin+22): volume limited sample of all stars within **25 pc**
- Also includes a volume complete WD sample

White dwarf 60 pc sample

- WD60 (Vani+22, in prep): **60 pc** volume complete WD sample based on DR3
- Derived using techniques from CNS5

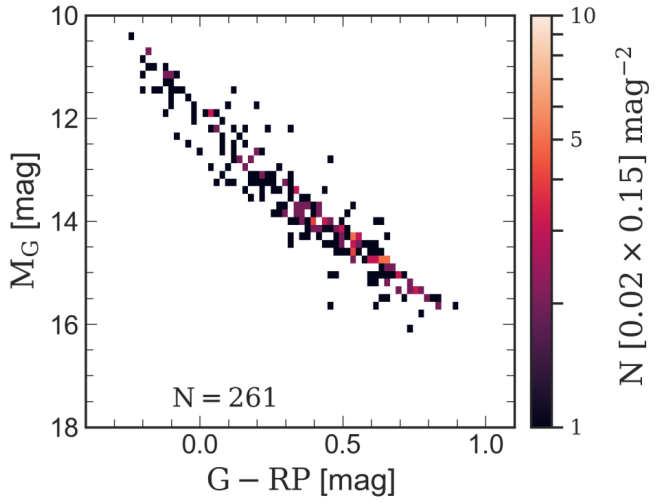




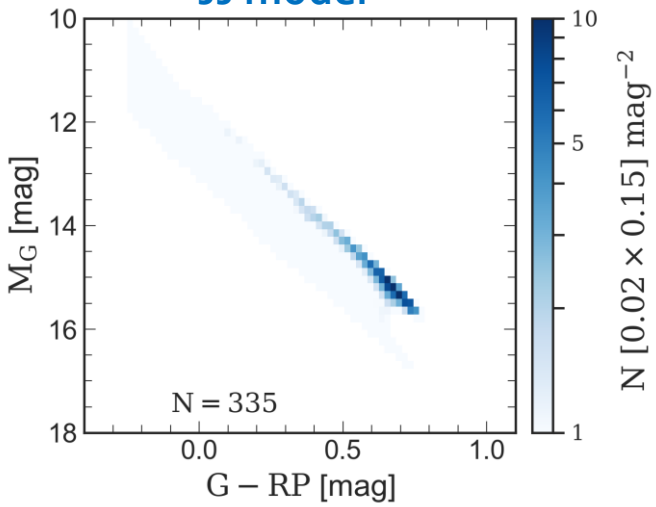
Data to model comparison

CNS5 – Golovin+22

CNS5 (data)

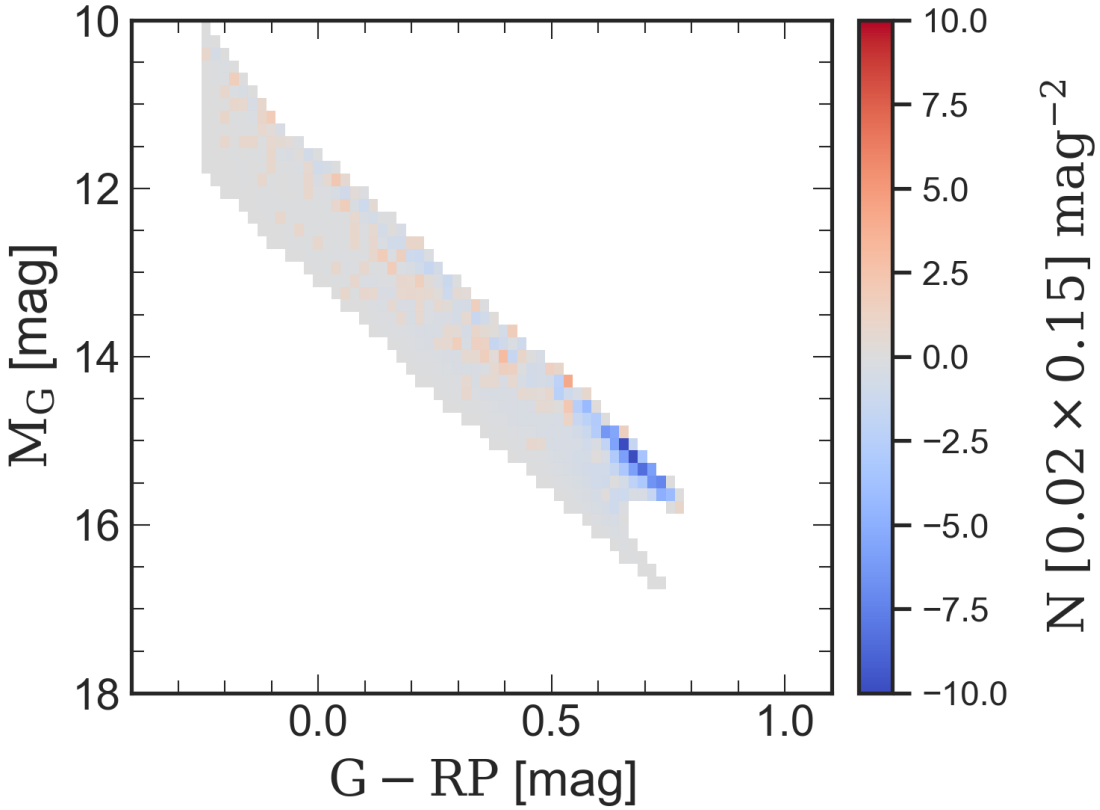


JJ model



Data - Model

CNS5 to JJ model

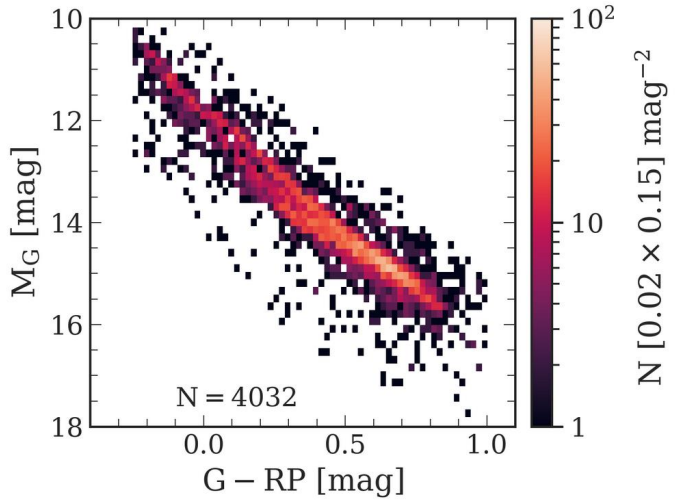


Inconsistency between total number of WDs in 25 pc is **+21 % (overpredicted)**

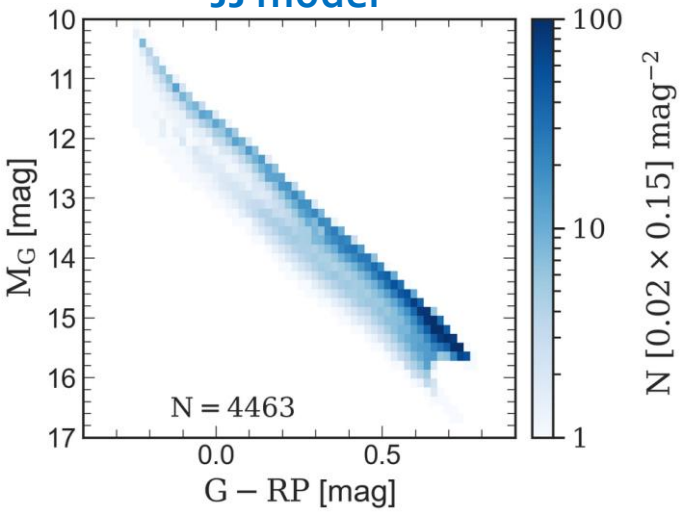
Data to model comparison

WD60 – Vani+22, in prep

WD60 (data)

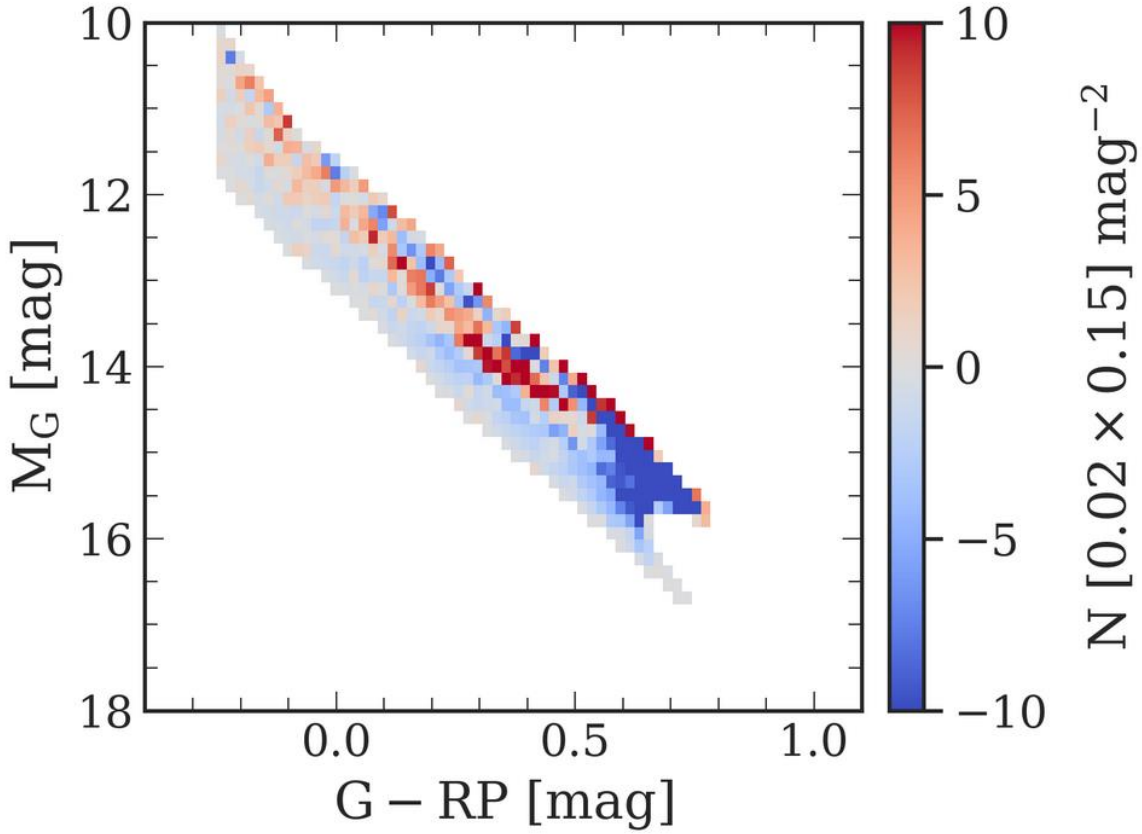


JJ model



Data - Model

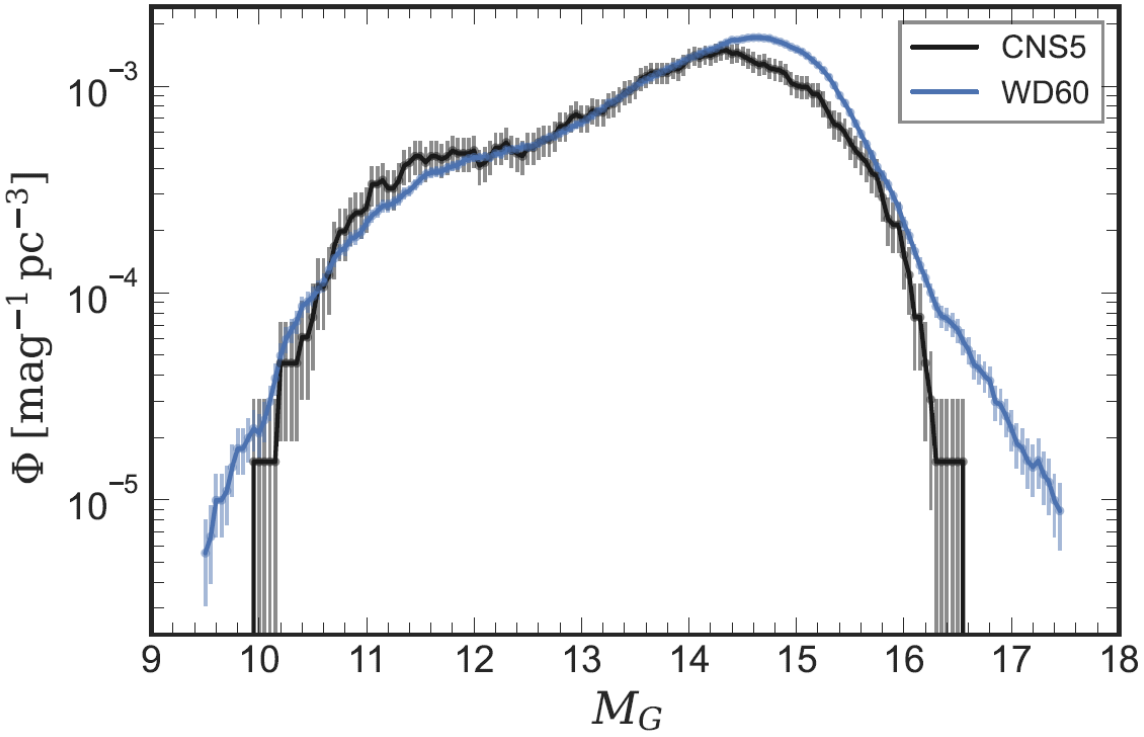
WD60 to JJ model



Inconsistency between total number of WDs in 60 pc is **+10.6 % (overpredicted)**

WDLF: Data and model prediction

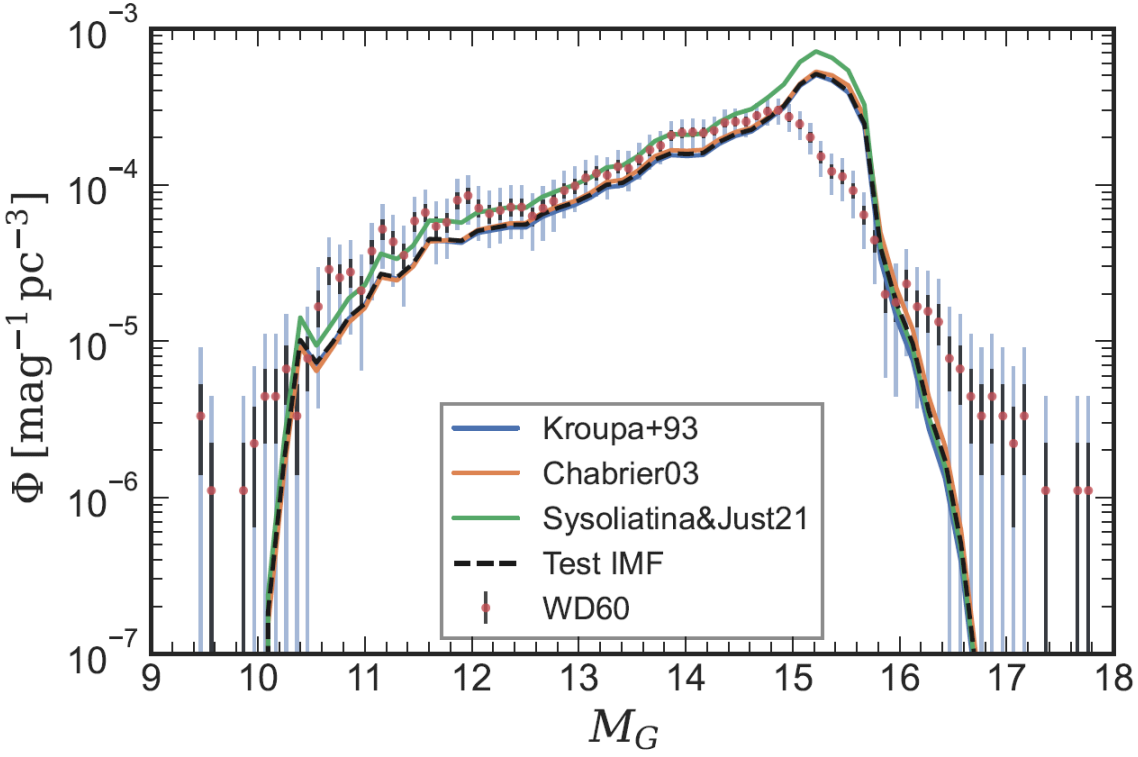
25pc and 60pc sample



Number density of WDs:

- 25pc = (4.03 ± 0.25) × 10^{-3} WDs pc^{-3}
- 60pc = (4.46 ± 0.07) × 10^{-3} WDs pc^{-3}

60pc sample and JJ model prediction with different IMFs

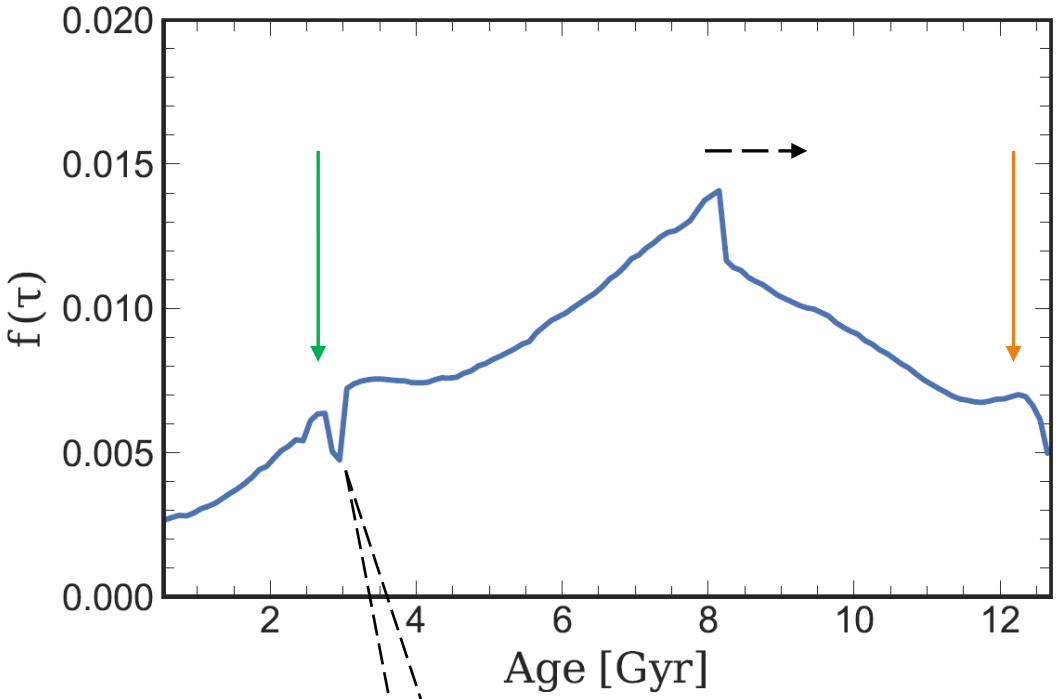


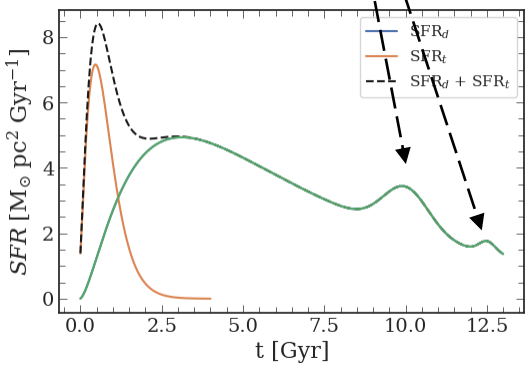
- Choice of IMF (and SFR) affects the number density of all stars
- Low and high mass slope of Kroupa+93 and Chabrier03 is inconsistent with MS+Giant stars

Model prediction

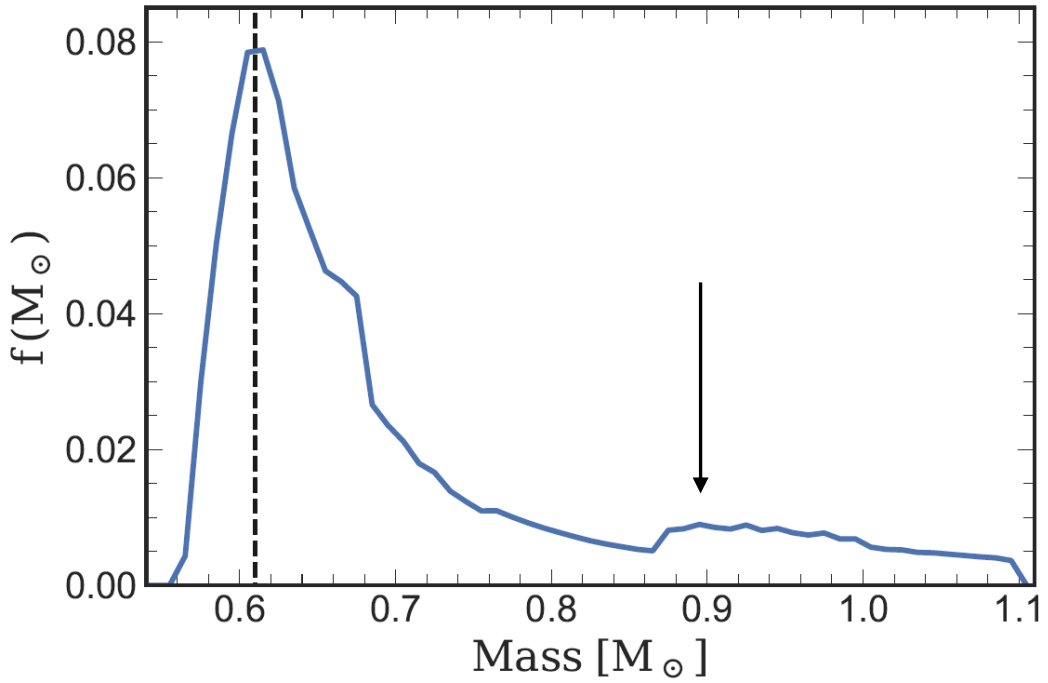
* Calibration required for more precise predictions

Age distribution





Mass distribution

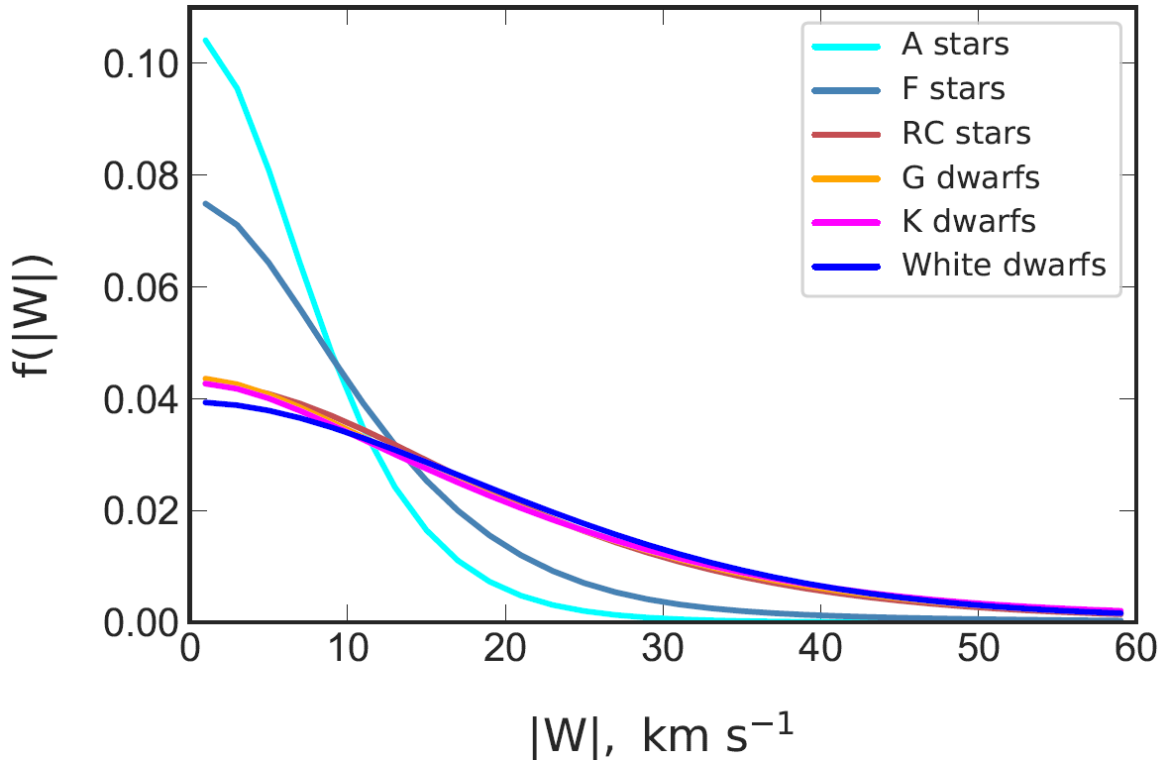


- Mass distribution peaks at **~0.61M⊙**
- Number of WDs in
  - Thin disc **~94.97 %**
  - Thick disc **~4.9 %**
  - Stellar Halo **~0.13 %**

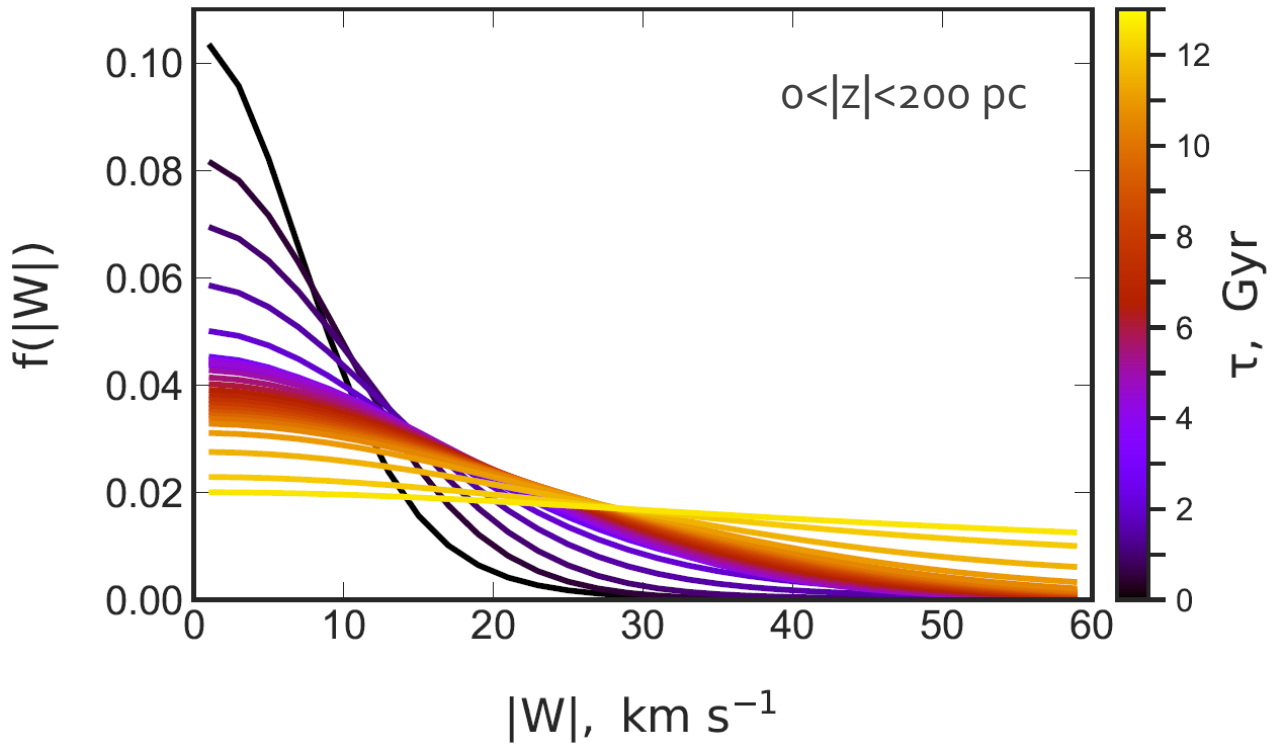
Model prediction

* Calibration required for more precise predictions

Vertical kinematics of different stars

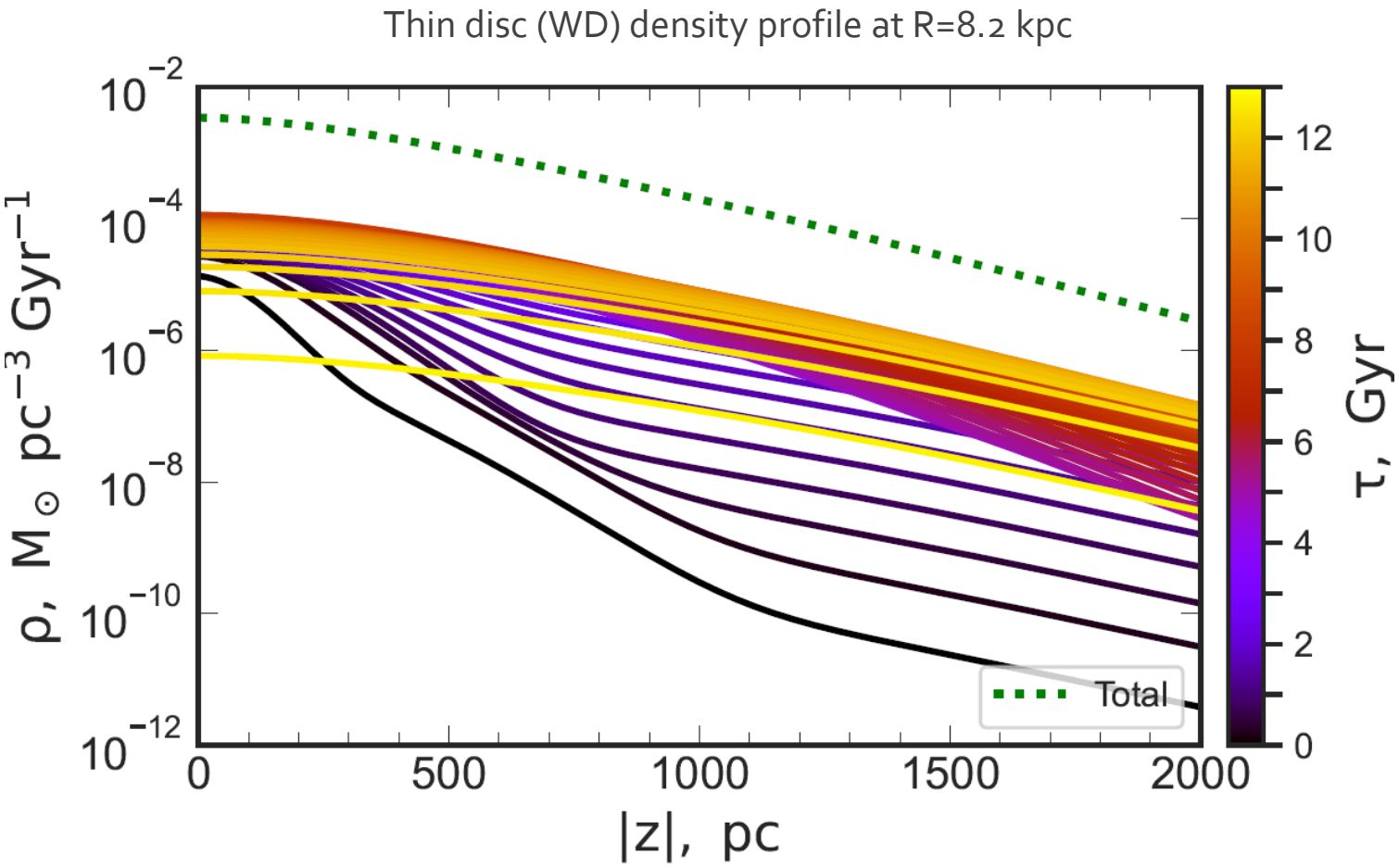


WD Kinematics of total disc and halo



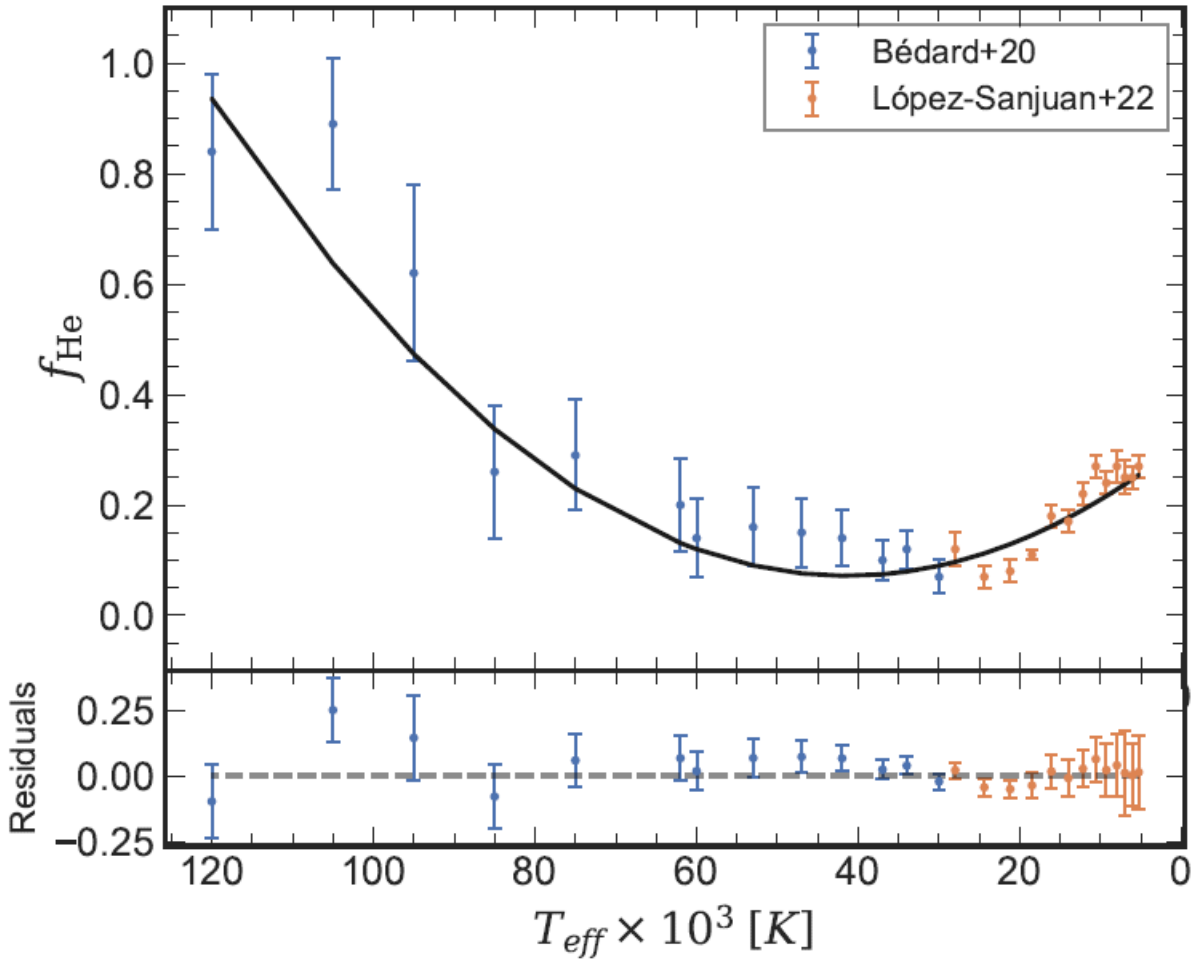
Model prediction

* Calibration required for more precise predictions

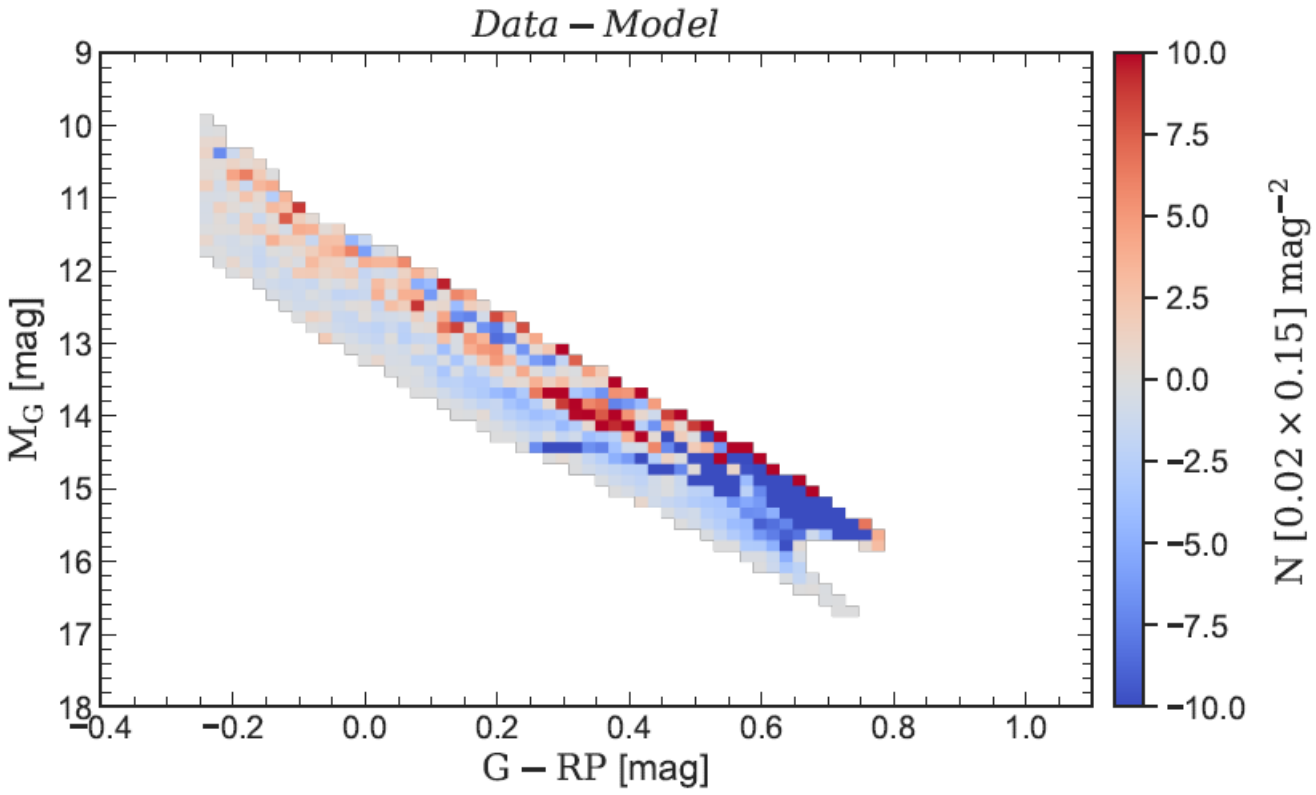


DB WDs ? Work in progress …

Parabolic fit to describe the DB gap



Resulting CMD



*Maximum age of DB WD isochrones is 5.7 Gyr

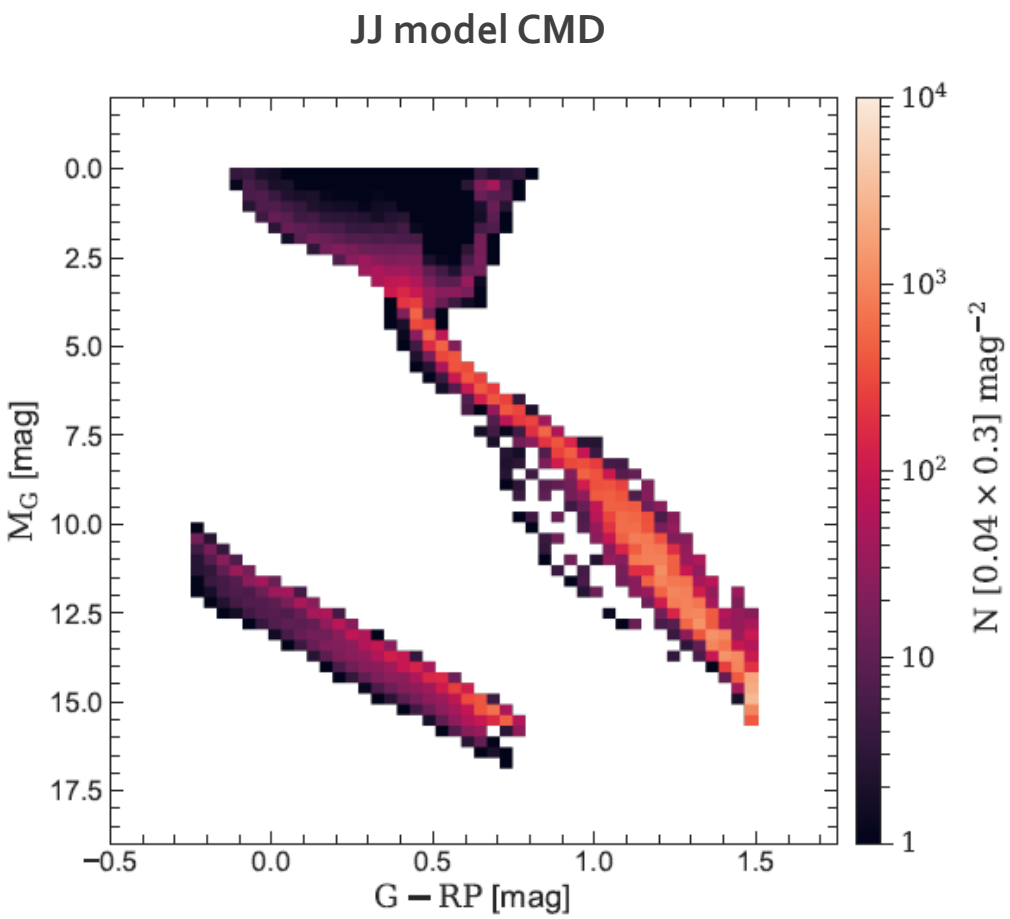
Takeaway…

Conclusion

- JJ model is rigorously calibrated for MS+Giant stars
- Previous assumptions of calibration fails in the presence of WDs
- JJ model predicts more WDs in 60 pc by **~11%**
- IMF slope between ~1 – 8 $M_\odot$ needs to be adapted
- Simultaneous calibration of the IMF and SFR is required in the presence of MS+Giants+WDs

Outlook

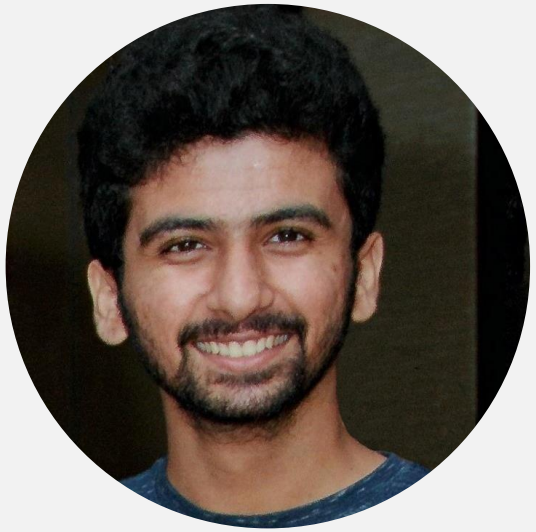
- Include DB and Q branch WDs
- Test different IFMRs and WD models
- Examine the age-mass distribution of WDs



Thank you

Akash Vani

(Currently at MPA, Garching)



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References

JJ model: paper I, paper II, paper III, paper IV, paper V

WD60: Vani+22, in prep

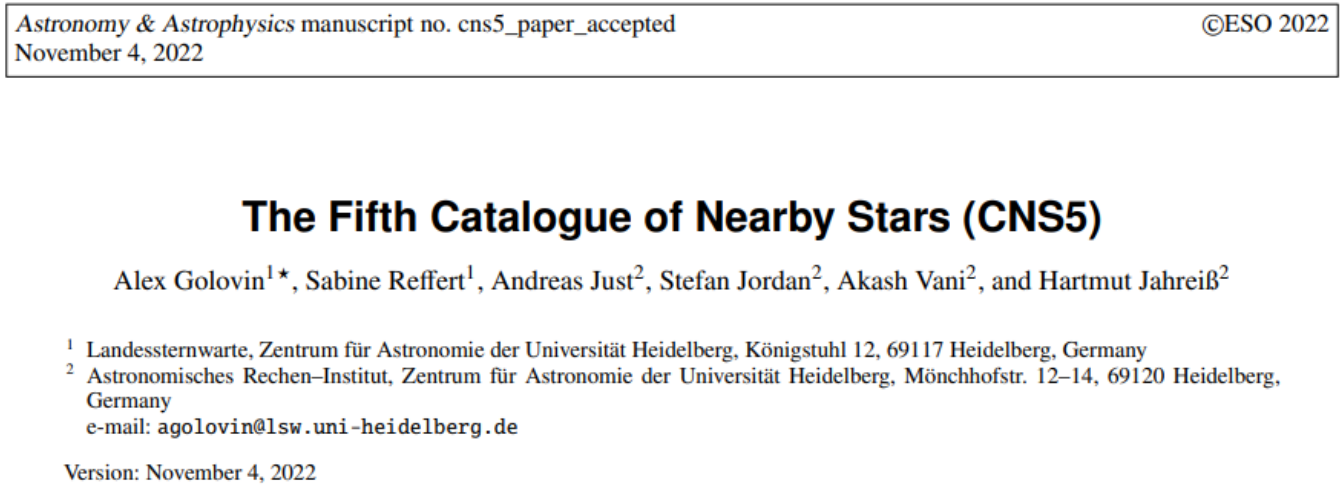
CNS5: Golovin+22

GCNS: Smart+21

PARSEC isochrone: Bressan+12

IFMR: Cummings+18

BaSTI WD isochrones: Salaris+22



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November 4, 2022

The Fifth Catalogue of Nearby Stars (CNS5)

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