The white dwarf population within 100 pc as seen by Gaia-DR3 and the VO

F. Jiménez-Esteban et al.
Spanish Virtual Observatory

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Naples 2022

Spectral classification of the 100 pc white dwarf population from *Gaia*-DR3 and the Virtual Observatory

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[2] *Departament de Física, Universitat Politècnica de Catalunya, c/Esteve Terrades 5, 08860 Castelldefels, Spain*
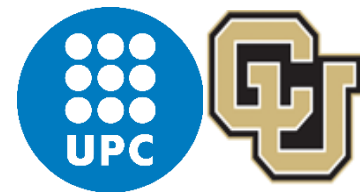[3] *Institut d'Estudis Espacials de Catalunya, Ed. Nexus-201, c/Gran Capità 2-4, 08034 Barcelona, Spain*
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Submitted to MNRAS

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White dwarfs

- Very common: the result of stellar evolution $M_{MS} < 10\ M_\odot$

- Structure
  - Degenerated core: He ($<0.45\ M_\odot$); CO ($<1.05\ M_\odot$); ONe ($>1.05\ M_\odot$)
  - Thin layer of He
  - Even thinner layer of H

- Spectral classification
  - ~80% H rich atmosphere $\rightarrow$ DA
  - ~20% non-DA

- Why WDs?
  - Retain the past history of the Galaxy
  - Study of stellar clusters
  - Test non-standard physics
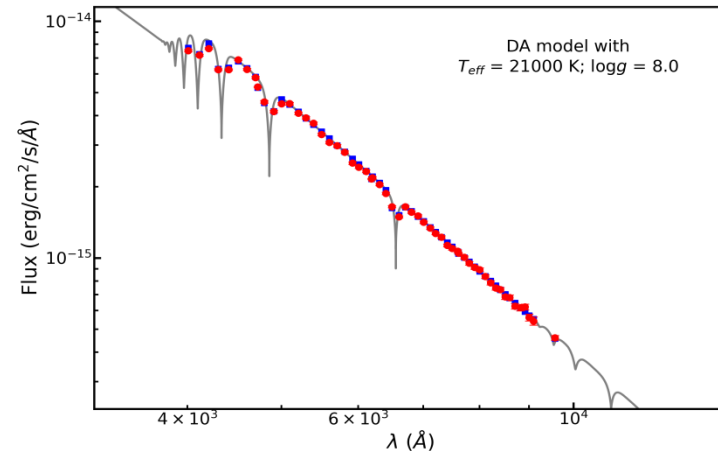
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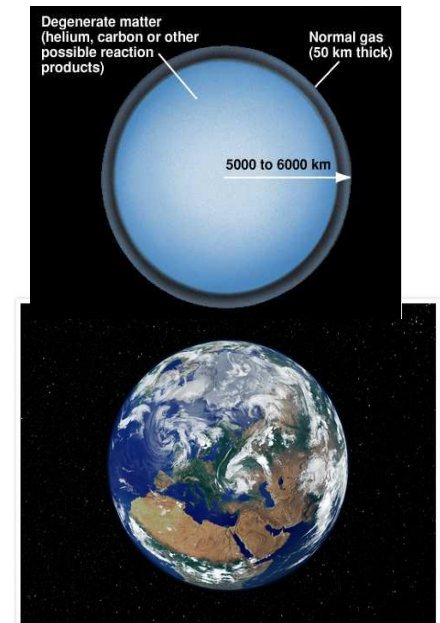
Context

- Gaia-DR3 has provided ~100,000 low-resolution spectra of WDs

- Jiménez-Esteban et al. 2018 → 100 pc WD sample is almost complete

- VOSA allows to analyze thousands of SEDs at a time

Completeness

94% for $\sigma_\pi < 10\%$

G<21 mag
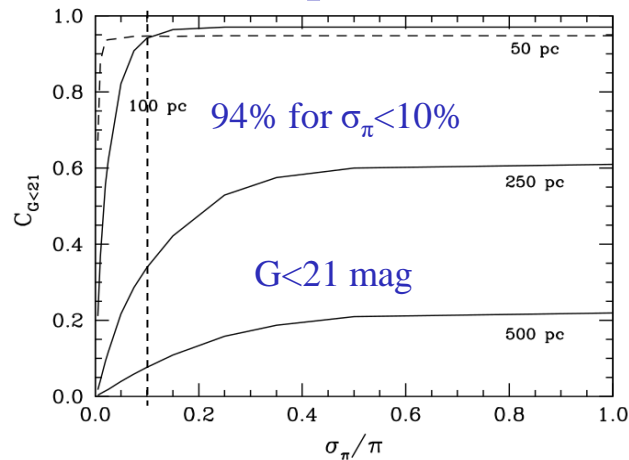
Jiménez-Esteban et al. 2018

Gaia DR3 3020668542435696512

DA model with T_{eff} = 21000 K; log$g$ = 8.0

100 pc WDs spectral classification with Gaia-DR3 & VO
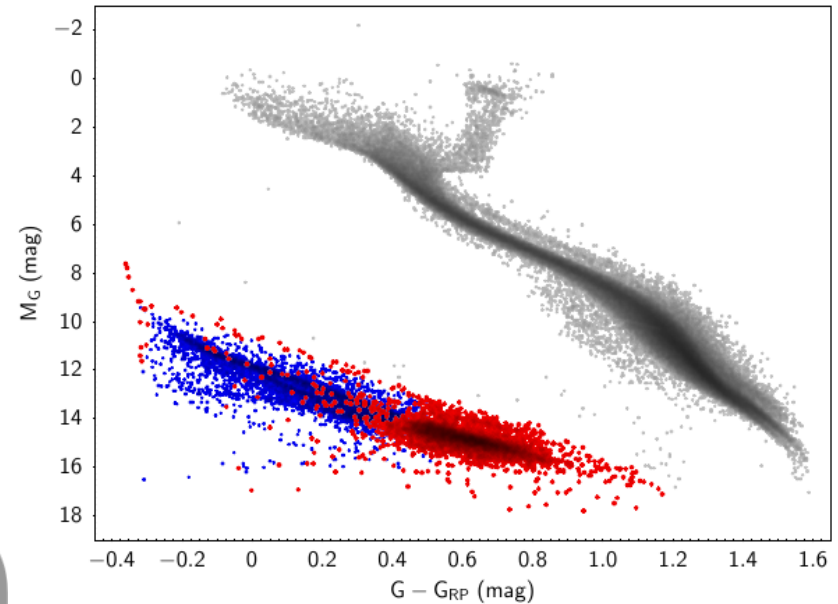
The 100 pc white dwarf sample

We query the *Gaia*-DR3 with these criteria:

- Within 100 pc
  ($\omega - 3\sigma_\omega \geq 10$ mas & $\sigma_\omega < 10\%$)

- Good photometry
  ($\sigma_F < 10\% + 3\sigma$ cut in the C^*)

- Good astrometry
  (RUWE<1.4)

12,737 white dwarfs

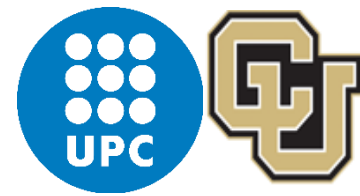Contamination < 0.1%

The 100 pc Gaia DR3 HR diagram

Blue: Jiménez-Esteban et al. 2018
Red: New identifications

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100 pc WDs spectral classification with Gaia-DR3 & VO

Spectral Energy Distributions
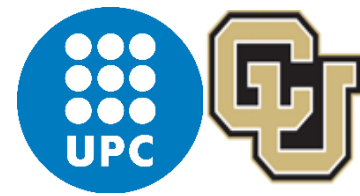
We built 3 sets of SEDs

- From the VO **(VOSA)**
    - Public photometric archives
    - From UV to NIR

- From *Gaia*-DR3 low-resolution spectra
    - Optical
    - J-PAS + GaiaXPy
    - 56 narrow-bands → R ≈ 60 photo-spectra
    - Using all coefficients **(VOSA-GJP)**
    - Using only the relevant coefficients **(VOSA-GJP-trunc)**

Gaia DR3 3020668542435696512
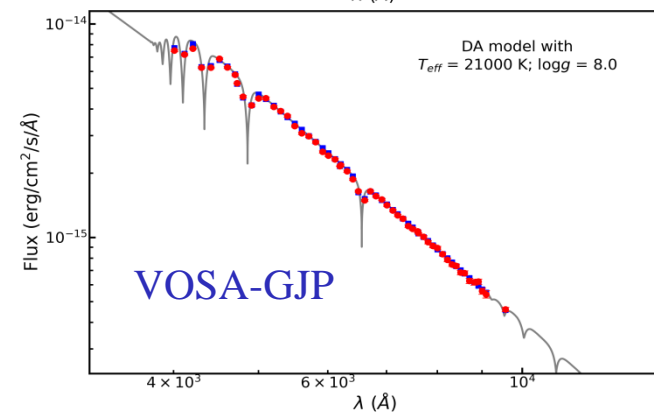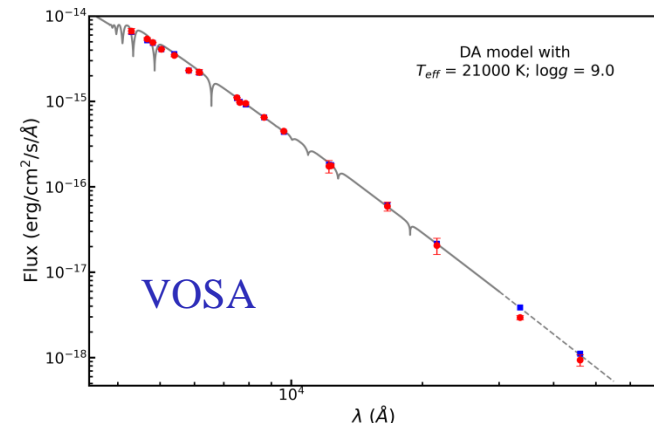
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Spectral Type Classification

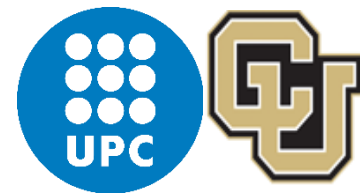We fitted the SEDs to two atmosphere models from Koester:

• Hydrogen-dominated atmosphere → DAs

• Helium-dominated atmosphere → non-DAs

We define a spectral class estimator

$$P_{DA}^i = \frac{1}{2}\left(\frac{\chi^2_{non-DA} - \chi^2_{DA}}{\chi^2_{non-DA} + \chi^2_{DA}} + 1\right)$$ ⟹ $P_{DA}^i \begin{cases} > 0.5 \to DA \\ < 0.5 \to non\text{-}DA \end{cases}$

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Spectral Type Classification

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$$\Longrightarrow \quad P_{DA}^i \begin{cases} > 0.5 \rightarrow DA \\ < 0.5 \rightarrow non\text{-}DA \end{cases}$$

$$T_{eff} > 5{,}500 \text{ K} \iff G_{BP}\text{-}G_{RP} < 0.86$$

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Spectral Type Classification

We studied 6 different estimators:

$$P_{\mathrm{DA}}^{i} = \frac{1}{2}\left(\frac{\chi_{\mathrm{non-DA}}^{2} - \chi_{\mathrm{DA}}^{2}}{\chi_{\mathrm{non-DA}}^{2} + \chi_{\mathrm{DA}}^{2}} + 1\right) \quad \text{(*)}$$

Table 3. Summary of the white dwarf spectral estimator built for the present study.

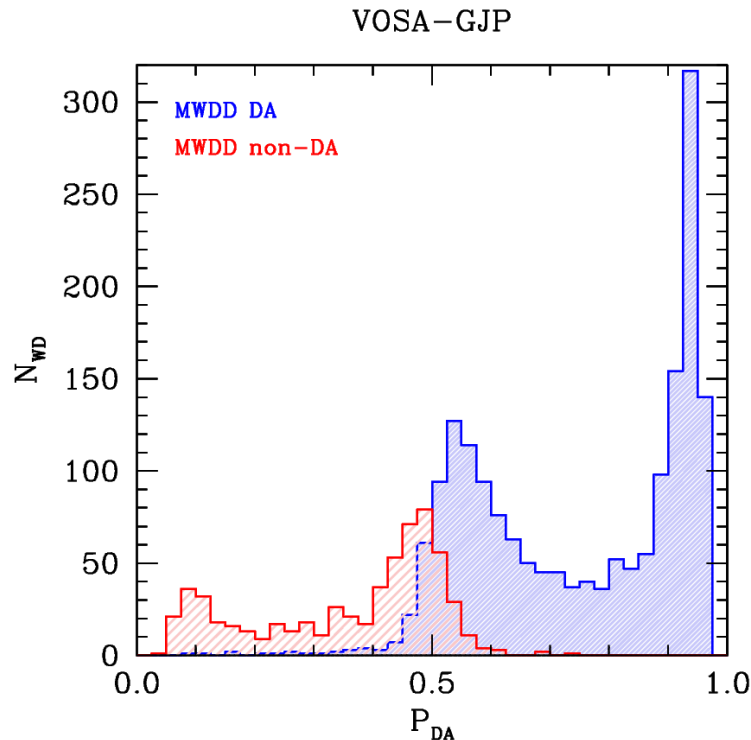| Estimator name	Reference	Atmosphere models	mean number points per SED
VOSA	This work	Pure hydrogen (Koester 2010) **(DA)**	20
		Nearly pure helium H/He= -6 (Koester 2010) **(non-DA)**	
VOSA-GJP	This work	idem	56
VOSA-GJP-trunc	This work	idem	56
GF21-I	Gentile Fusillo et al. (2021)	Pure hydrogen (Tremblay et al. 2011; Kowalski et al. 2010) **(DA)**	3
		Pure helium (Bergeron et al. 2011) **(non-DA)**	
GF21-II	Gentile Fusillo et al. (2021)	Pure hydrogen (Tremblay et al. 2011; Kowalski et al. 2010) **(DA)**	3
		Mixed H/He=-5 (Tremblay et al. 2014; McCleery et al. 2020) **(non-DA)**	
MON22	Gaia Collaboration et al. (2022a) **(Random Forest algorithm)**		60

(*)

100 pc WDs spectral classification with Gaia-DR3 & VO

Spectral Type Classification

Validating sample from Montreal WD Database: 1,786 DAs & 617 non-DAs

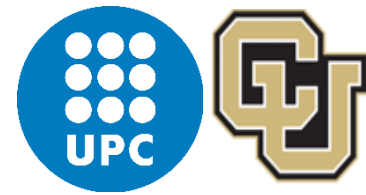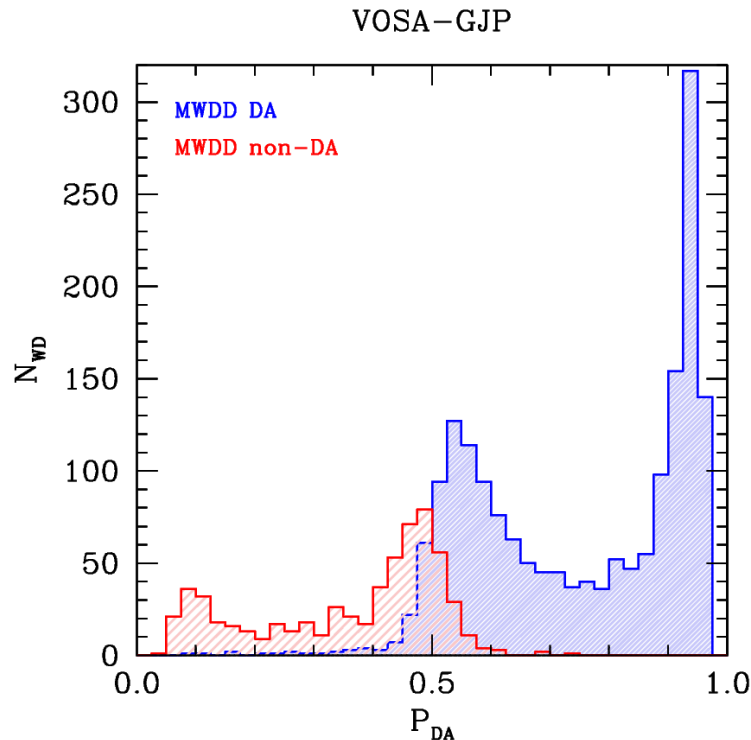VOSA-GJP

MWDD DA
MWDD non-DA

N_{WD} / P_{DA}

30% of 100 pc WDs with T_{eff} > 5,500 K

Table 4. Summary of the performance score, sorted from the highest to the lowest accuracy, for the different estimators under study.

Estimator	Accuracy	F1-Score	Sensitivity	Precision
VOSA-GJP	0.91	0.94	0.94	0.94
VOSA-GJP-trunc	0.88	0.93	0.98	0.88
MON22	0.78	0.85	0.81	0.89
VOSA	0.76	0.84	0.88	0.81
GF21-II	0.70	0.82	0.95	0.72
GF21-I	0.57	0.68	0.64	0.72

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Spectral Type Classification

Validating sample from Montreal WD Database: 1,786 DAs & 617 non-DAs

VOSA–GJP

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GF21-I	0.57	0.68	0.64	0.72

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Properties of DAs and non-DAs 100 pc WD

Using VOSA-GPJ estimator we classified 8,154 WDs
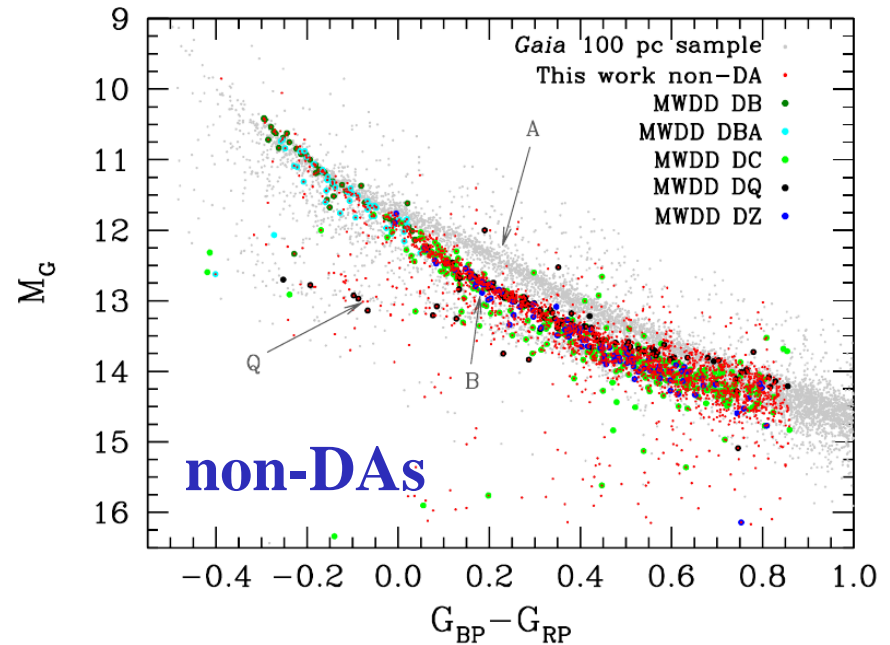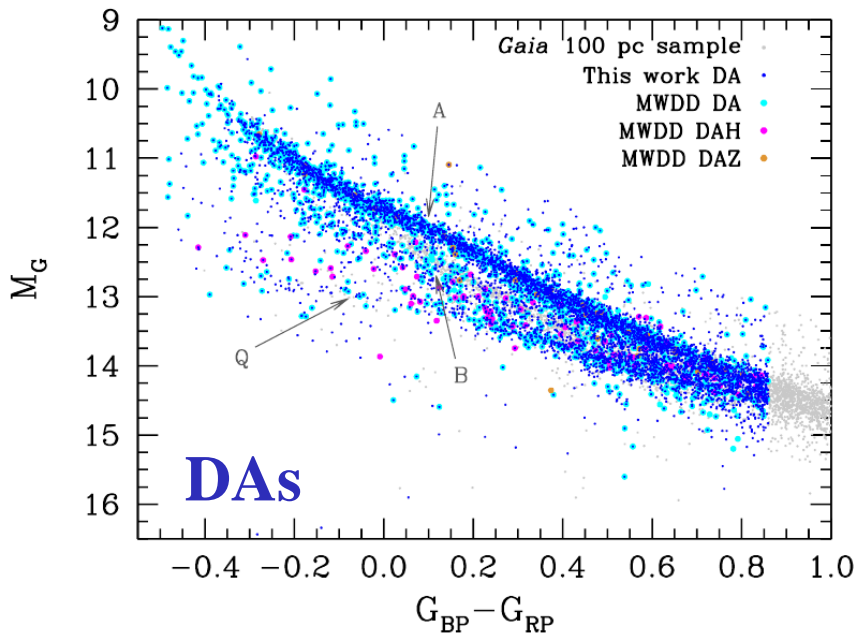
- **99% of the 100 pc WD sample with $T_{eff} > 5,500$ K**

Gaia DR3 HR diagram
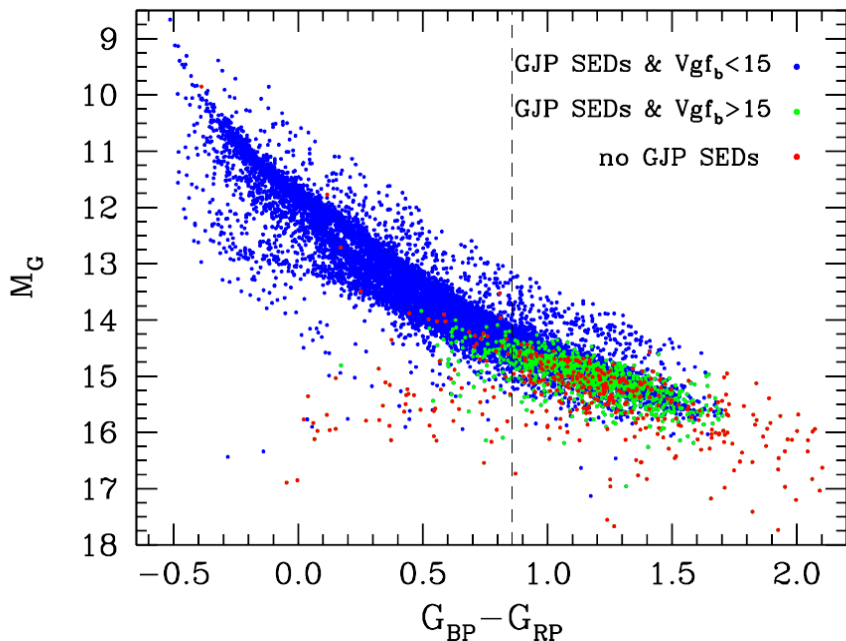
The most complete spectral type classified sample of white dwarfs up-to-date

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100 pc WDs spectral classification with Gaia-DR3 & VO

Properties of DAs and non-DAs 100 pc WD

Gaia DR3 HR diagram

DAs

non-DAs

**A branch:
94% DAs & 6% non-DAs**

**B branch:
35% DAs & 65% non-DAs**

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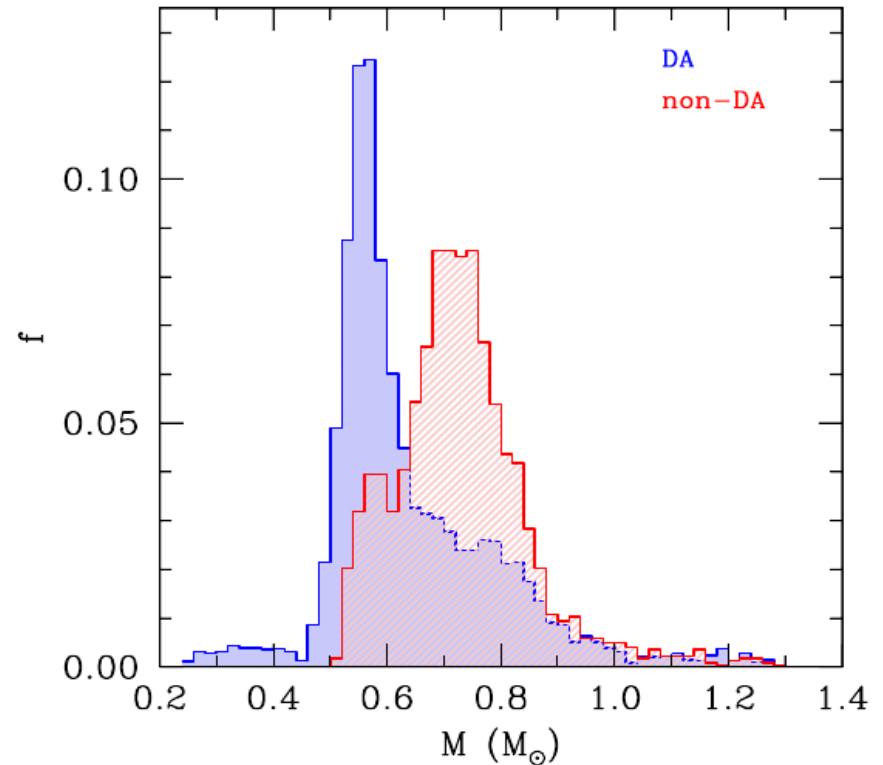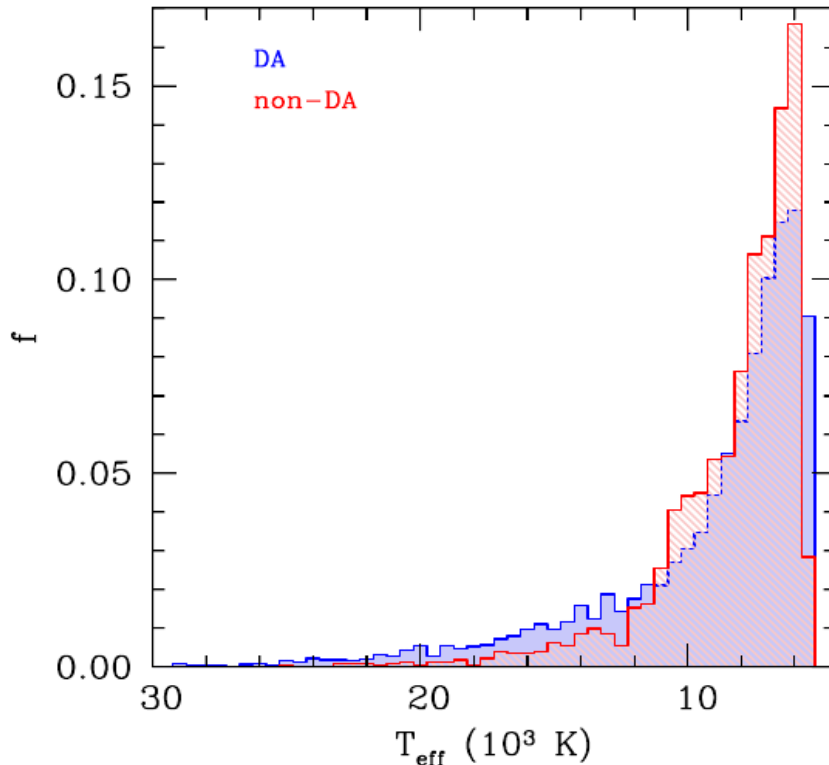
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Properties of DAs and non-DAs 100 pc WD

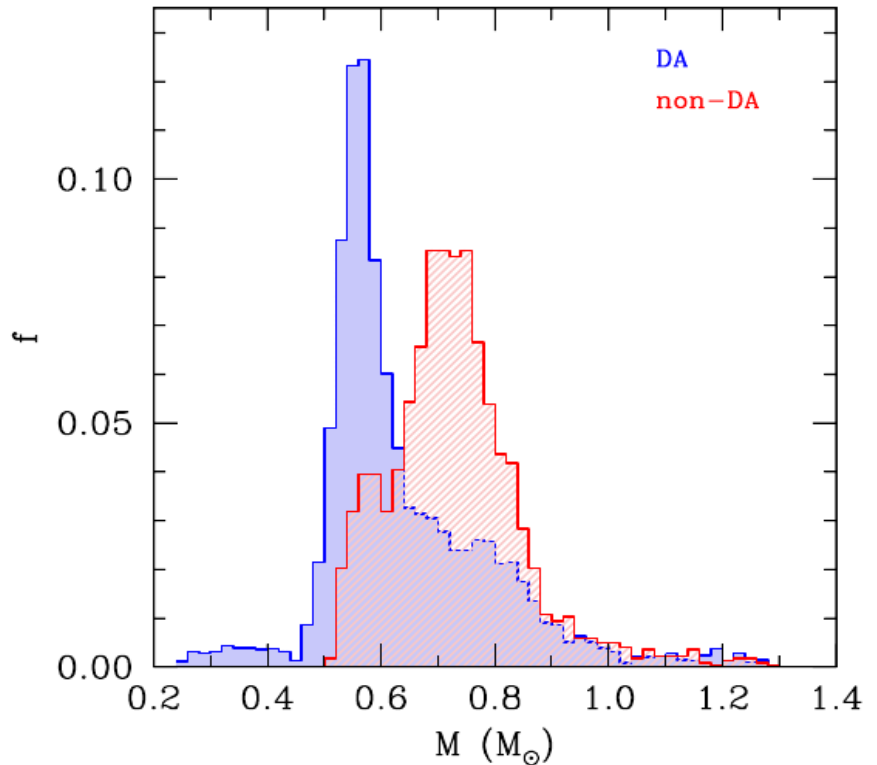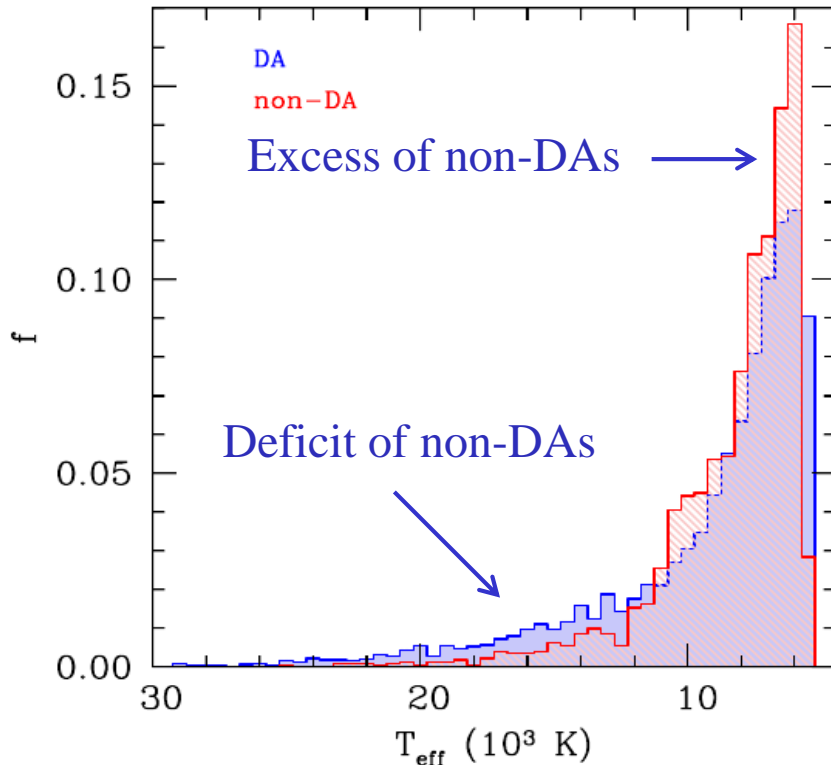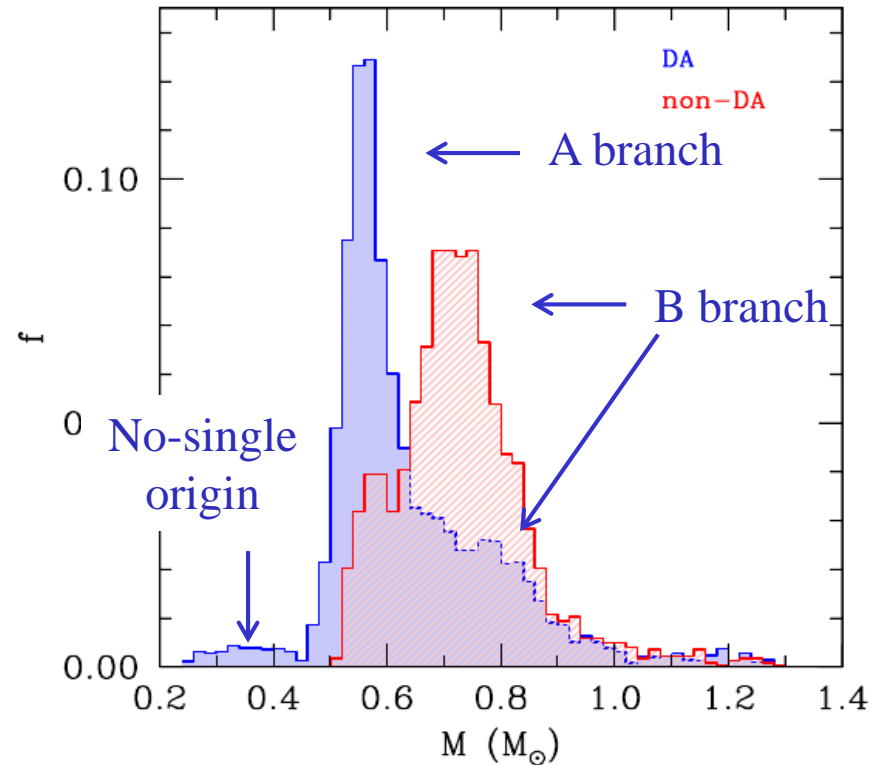## Using evolutionary (La Plata group) + atmosphere (Koester)

Properties of DAs and non-DAs 100 pc WD

Using evolutionary (La Plata group) + atmosphere (Koester)

Excess of non-DAs

Deficit of non-DAs

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Properties of DAs and non-DAs 100 pc WD

Using evolutionary (La Plata group) + atmosphere (Koester)

100 pc WDs spectral classification with Gaia-DR3 & VO

Properties of DAs and non-DAs 100 pc WD

Spectral evolution (fraction of non-DAs)

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100 pc WDs spectral classification with Gaia-DR3 & VO
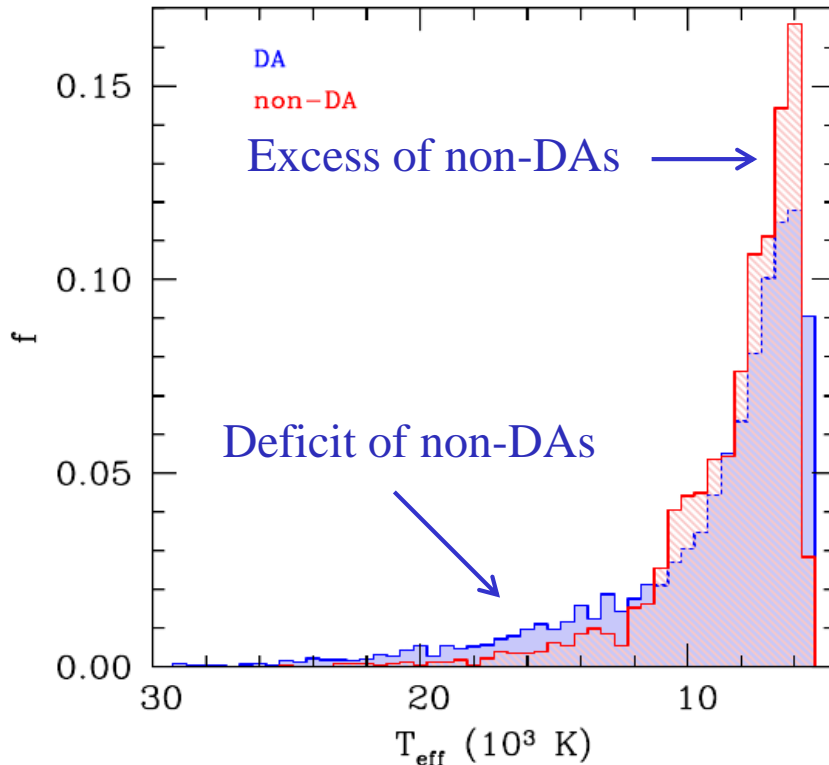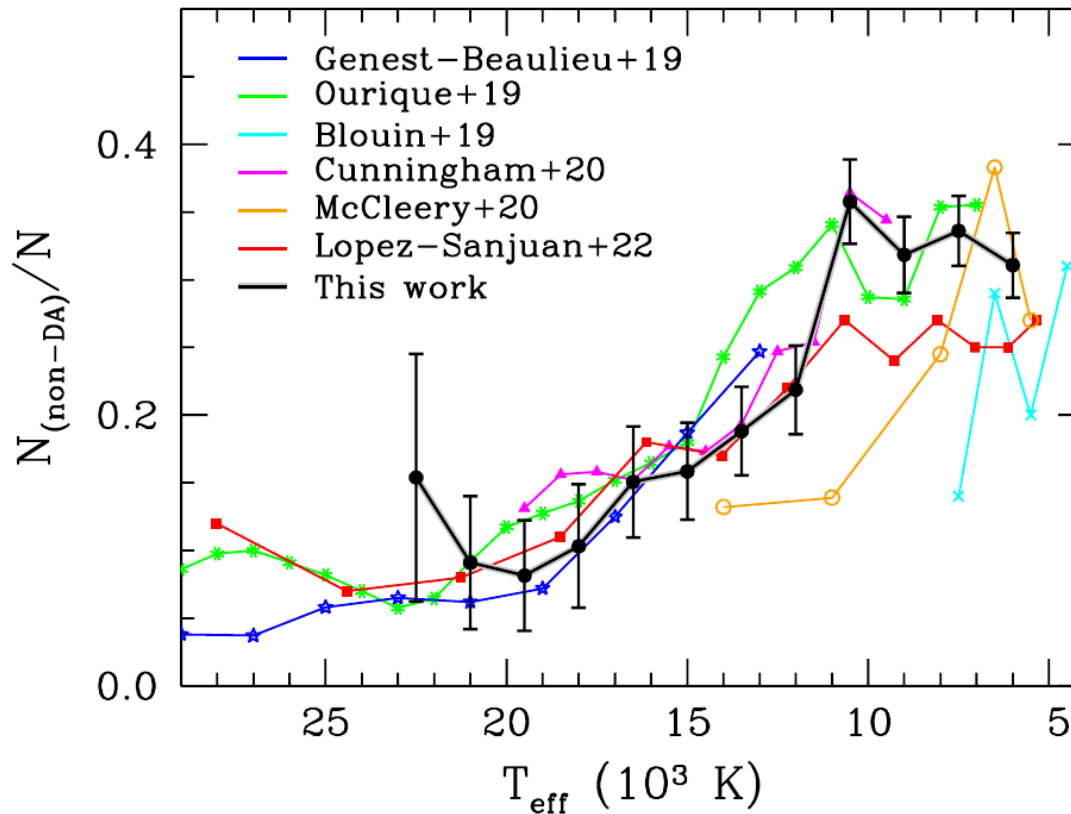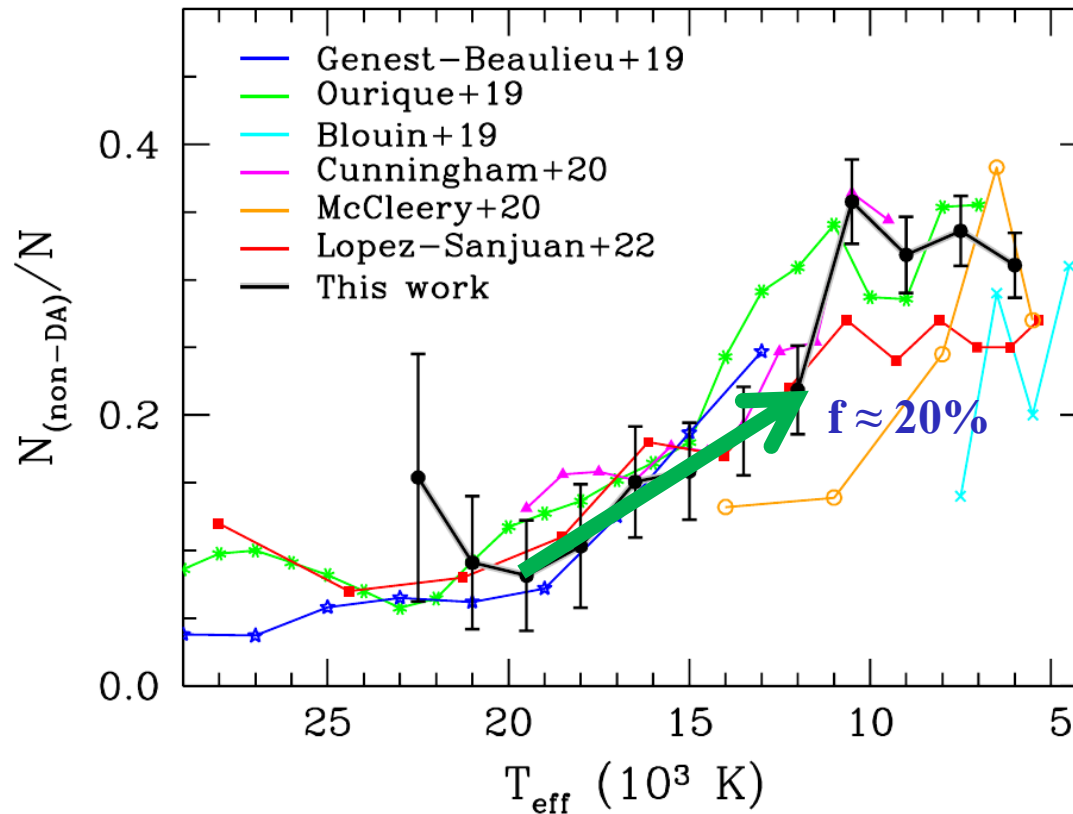
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Properties of DAs and non-DAs 100 pc WD

Spectral evolution (fraction of non-DAs)

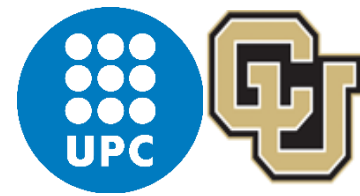# 100 pc WDs spectral classification with Gaia-DR3 & VO

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Properties of DAs and non-DAs 100 pc WD
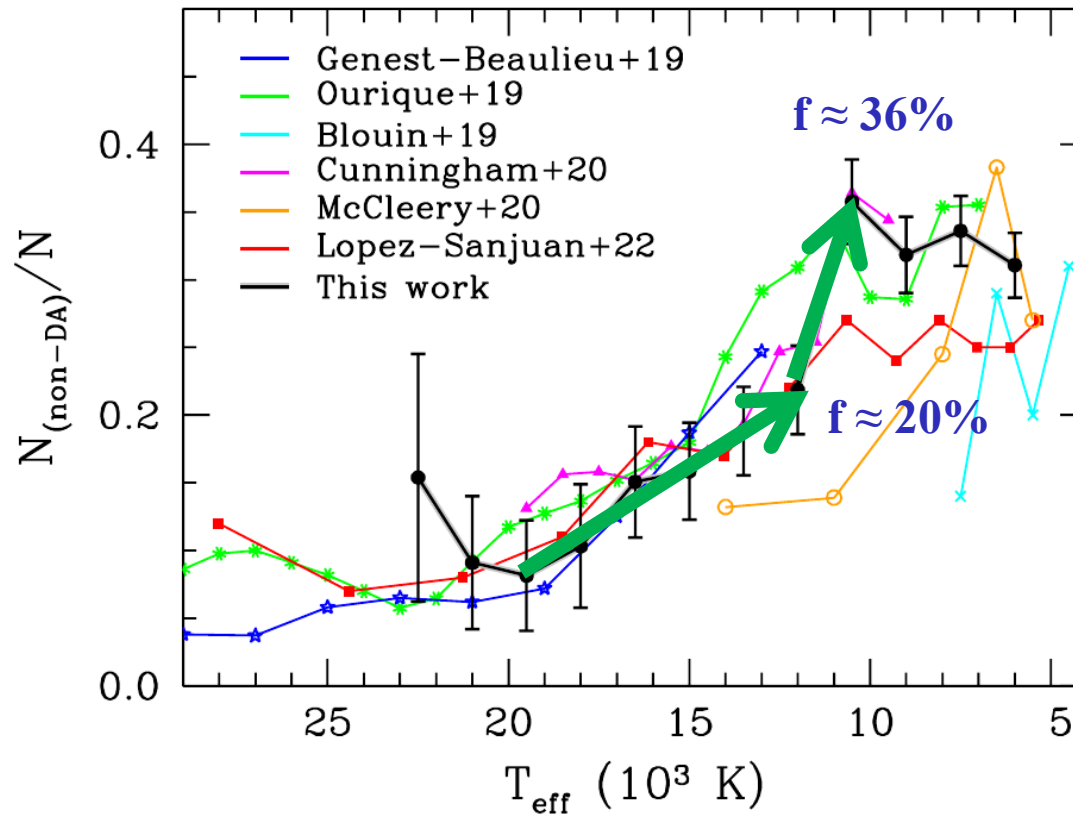
Spectral evolution (fraction of non-DAs)

100 pc WDs spectral classification with Gaia-DR3 & VO

Properties of DAs and non-DAs 100 pc WD

Spectral evolution (fraction of non-DAs)
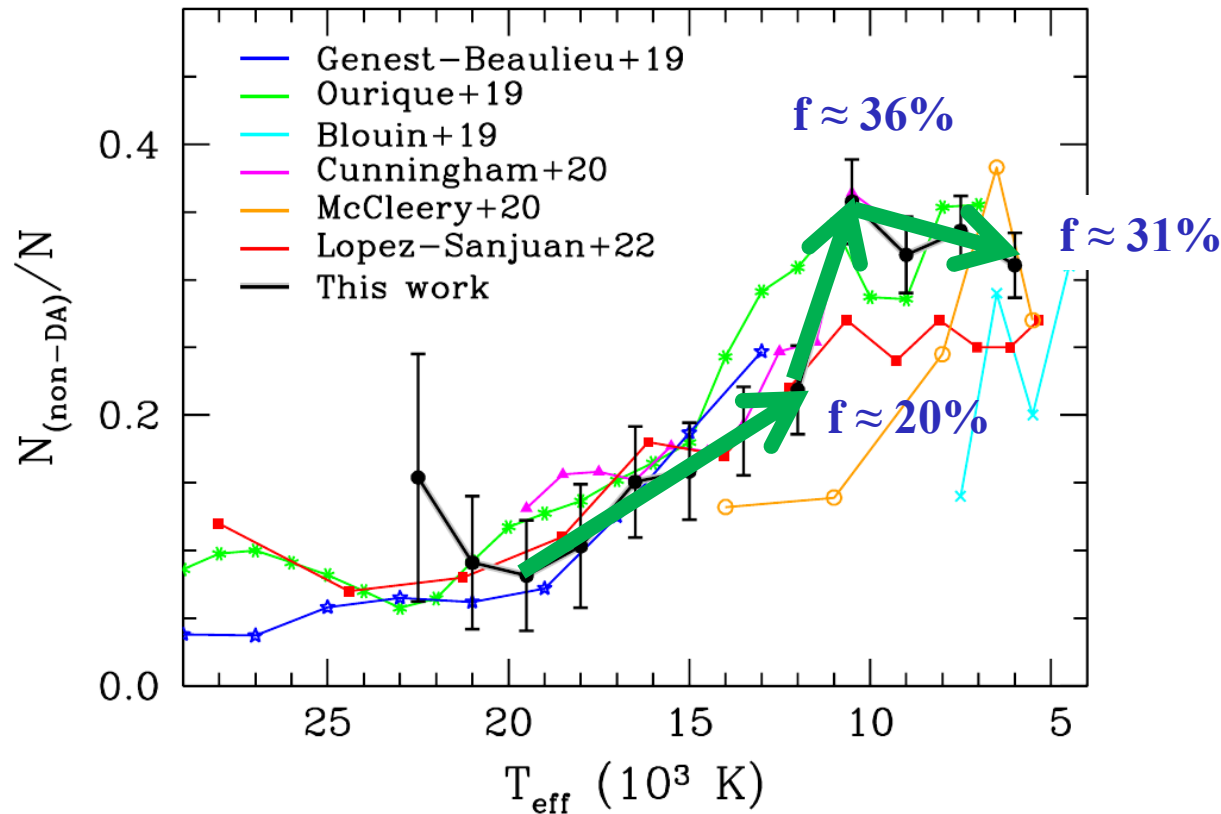
Conclusions

The largest spectral characterization of a nearly-complete volume-limited WD sample:
12,737 WDs within 100 pc: 12,351 have *Gaia*-DR3 spectra: 8154 spectral classified

Estimator from Gaia spectra + J-PAS : accuracy > 90%

DAs & non-DAs distribution in the HR diagram:
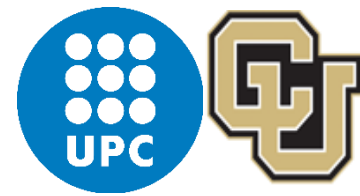A branch: almost all DAs; B branch: non-DAs / DAs ≈ 2/1

DAs & non-DAs stellar parameters:
• Similar T_{eff} distribution
• Bimodality mass distributions: ~0.6 $M_{\odot}$ & ~0.8 $M_{\odot}$
  • Main DA peak at ~0.6 $M_{\odot}$; Main non-DA peak at ~0.8 $M_{\odot}$

Precise spectral evolution

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Thanks!!

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