Studies of white dwarfs from Gaia and the Virtual Observatory

F. Jiménez-Esteban et al.

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Studies of WDs from Gaia and the VO

Collaboration

Alberto Rebassa-Mansergas

Santiago Torres

Fran Jiménez-Esteban

Enrique Solano

Raquel Murillo-Ojeda

Patricia Cruz

Ricardo Rizzo

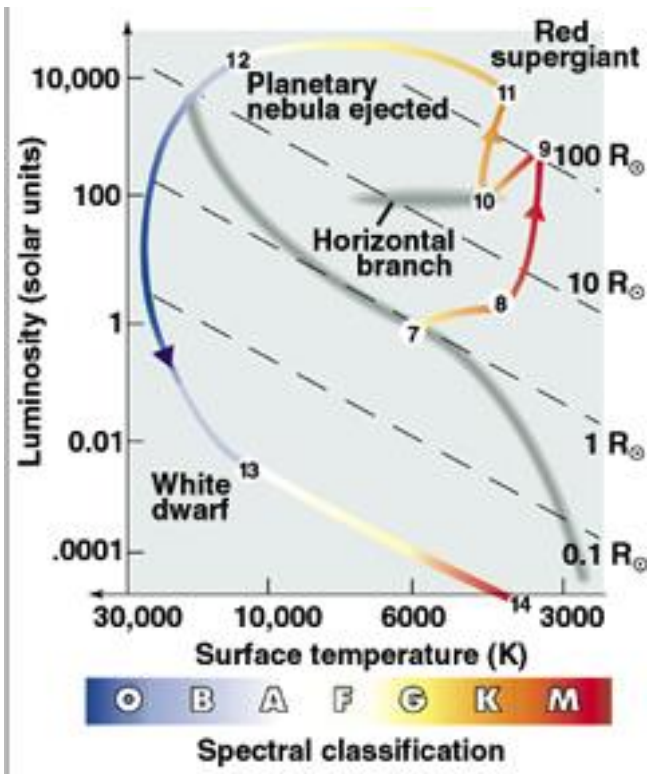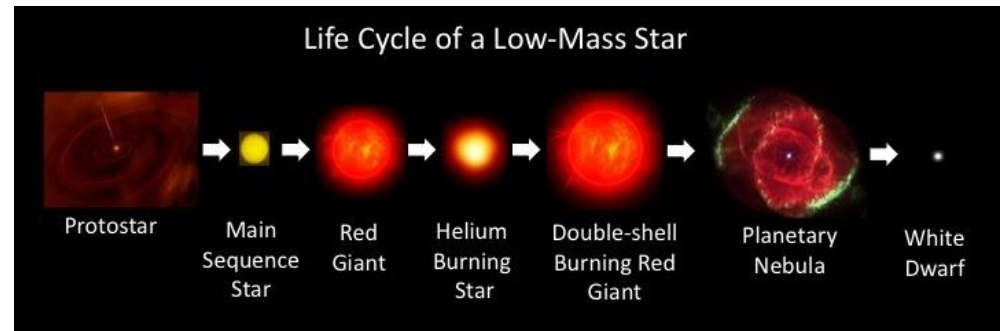**and sporadic collaborations with other researchers**

What is a white dwarf?

Result of stellar evolution of low- and intermediate-mass stars $M_{MS} < 10\ M_{\odot}$

- ~97% of the stars in the MW

- There is not nuclear reactions
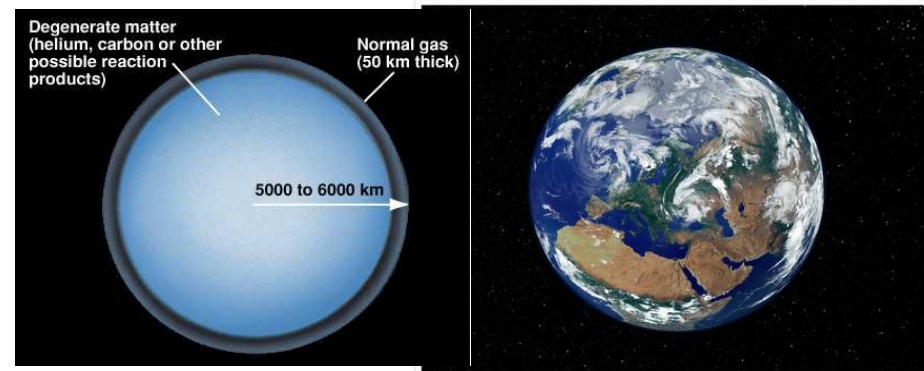
- They just cool and fade

What is a white dwarf?

Structure:

- Electron degenerated core → Chandrasekhar limit M<1.4 M☉
  - He ($<0.45\ M_{\odot}$)
  - CO ($<1.04\ M_{\odot}$)
  - ONe ($>1.04\ M_{\odot}$)

- Thin layer of He 10^{-4}-$10^{-2}\ M_{\odot}$

- Thinner layer of H 10^{-15}-$10^{-4}\ M_{\odot}$

Degenerate matter (helium, carbon or other possible reaction products)

Normal gas (50 km thick)

5000 to 6000 km

They are very small and very dense

A ton of matter compressed into the volume of a grape!

Spectral Classification

- ~80% DA: H lines

- ~20% Non-DA
  - DB: He I lines ~16%
  - DO (He II lines), DC (no lines), DQ (C lines), DZ (Metal lines)

Why to study white dwarf?

- Retain the past history of the Galaxy
  - WD Luminosity Function
  - Population: thin disc, thick disc, and halo

- Study of stellar clusters
  - Age
  - WD cooling process

- Test non-standard physics
  - Variability of the gravitational constant G
  - Existence of exotic particles

- Planet system formation/evolution/survival

Why to use Gaia & VO?

Gaia allows identification of an unprecedented number of WDs:

- Astrometry and photometry for ~12,000 WDs within **100 pc (almost complete volume-limited sample),** and >300,000 in total
- ~100.000 low-resolution spectra of WDs

In order to characterize these sources why need to estimate their **stellar parameters**

VO provided us with the **ideal framework**
- easy and fast access to deep multi-λ photometry → SED
- VO tools to analyse thousands of objects at once: → **VOSA, Topcat, ADQL, Aladin**

→ **GAIA'S HERTZSPRUNG-RUSSELL DIAGRAM**

ESA
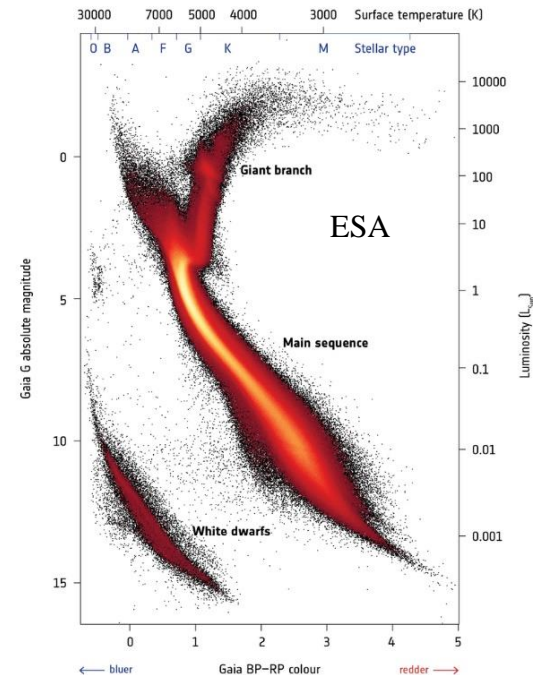
Gaia Collaboration et al. 2018, A&A, 616, A10

Studies of WDs from Gaia and the VO

Block 1: Identification and classification of WDs

Block 2: Studies of Galactic WD population

Block 3: Studies of peculiar WDs

Studies of WDs from Gaia and the VO

Block 1: Identification and classification of WDs

A white dwarf catalogue from *Gaia*-DR2 and the Virtual Observatory

F. M. Jiménez-Esteban,[1,2,3]★ S. Torres,[4,5] A. Rebassa-Mansergas,[4,5] G. Skorobogatov,[4]
E. Solano,[1,2] C. Cantero[4] and C. Rodrigo[1,2]

We published the **first catalogue of 73,221 WDs from Gaia-DR2**
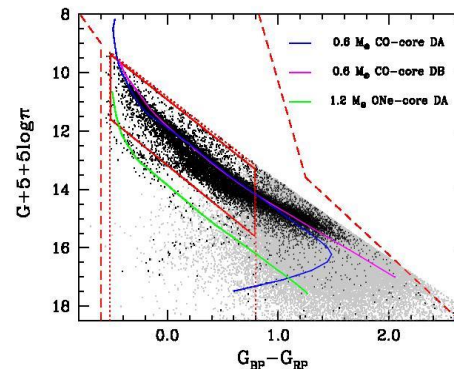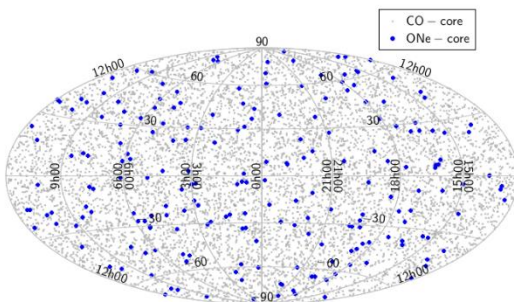
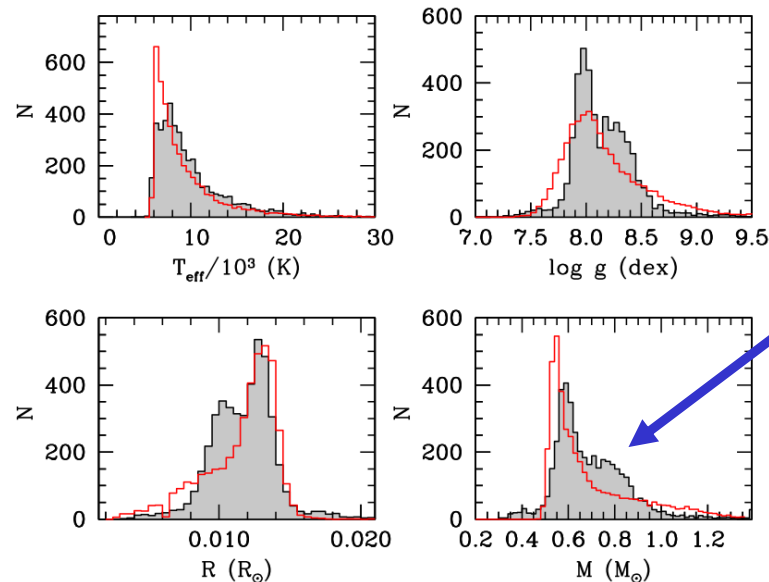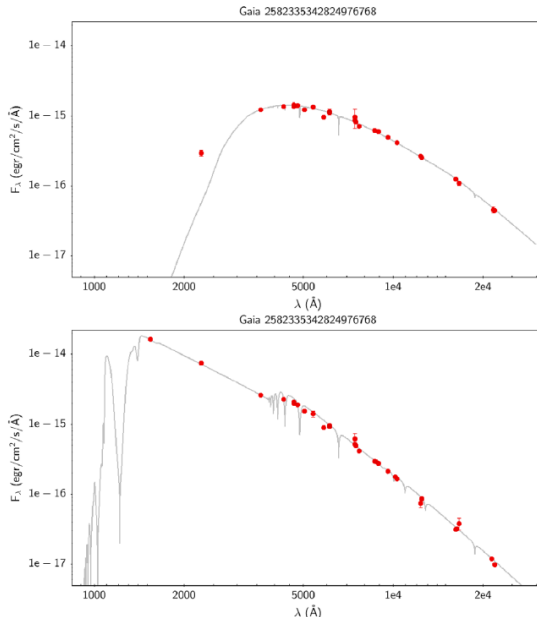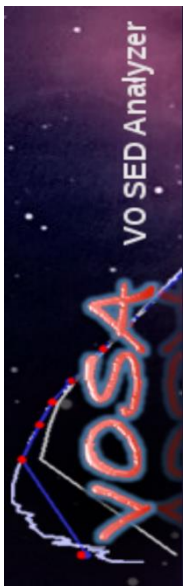Selected in the HR diagram

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Block 1: Identification and classification of WDs

We published the **first catalogue of WDs from Gaia-DR2**

Enhanced with physical parameters from the **VO**:
- Used **VOSA** to build and analyzed their **Spectral Energy Distributions** (SED)
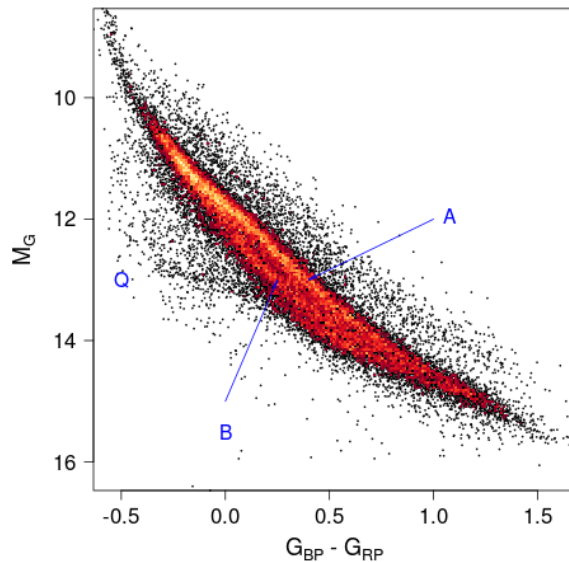- **Photometric database & atmospheric emission models**

Unpredicted

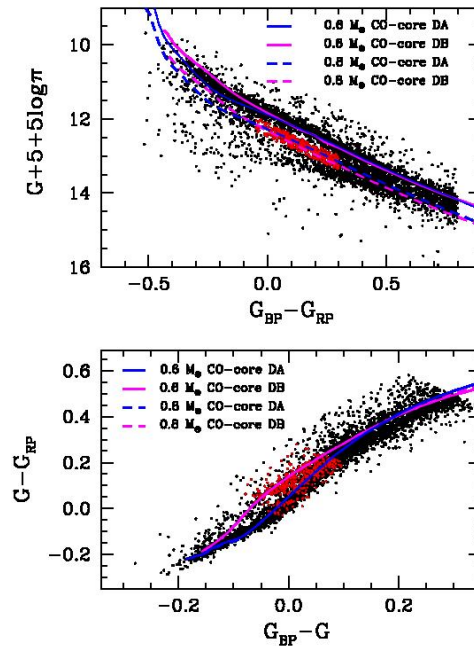fran.jimenez-esteban@cab.inta-csic.es

Block 1: Identification and classification of WDs

We published the **first catalogue of WDs from Gaia-DR2**

We studied the WD sequence bifurcation discovered in the Gaia HR diagram:

Gaia Collaboration et al. 2018, A&A, 616, A10

Discrepancies between DA and DB cannot explain it

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Block 1: Identification and classification of WDs

We were the first in exploiting **Gaia-DR3 BP/RP spectra** to characterize the WD population within 500 pc.

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MNRAS **518**, 5106–5122 (2023)
Advance Access publication 2022 November 23

https://doi.org/10.1093/mnras/stac3382

Spectral classification of the 100 pc white dwarf population from *Gaia*-DR3 and the virtual observatory

F. M. Jiménez-Esteban,[1]★ S. Torres,[2,3] A. Rebassa-Mansergas,[2,3] P. Cruz,[1] R. Murillo-Ojeda,[1] E. Solano,[1] C. Rodrigo[1] and M. E. Camisassa[4]

A&A 677, A159 (2023)
https://doi.org/10.1051/0004-6361/202346977
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Astronomy & Astrophysics

White dwarf spectral type-temperature distribution from *Gaia* DR3 and the Virtual Observatory★

S. Torres[1,2], P. Cruz[3], R. Murillo-Ojeda[3], F. M. Jiménez-Esteban[3], A. Rebassa-Mansergas[1,2], E. Solano[3], M. E. Camisassa[1], R. Raddi[1], and J. Doliguez Le Lourec[4]
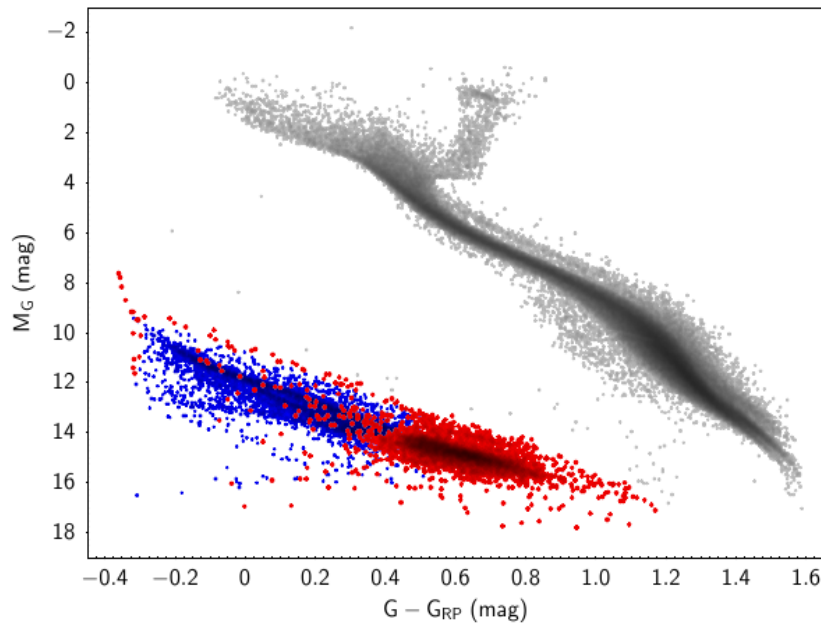
Block 1: Identification and classification of WDs

We extended the previous catalogue with **new identification**, specially in the coolest end of the WD sequence

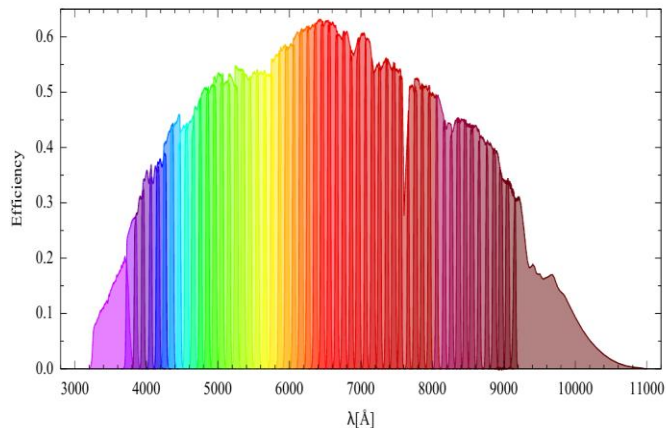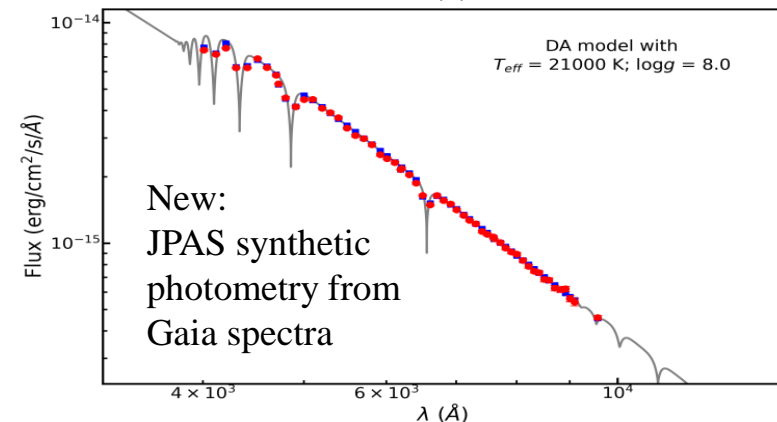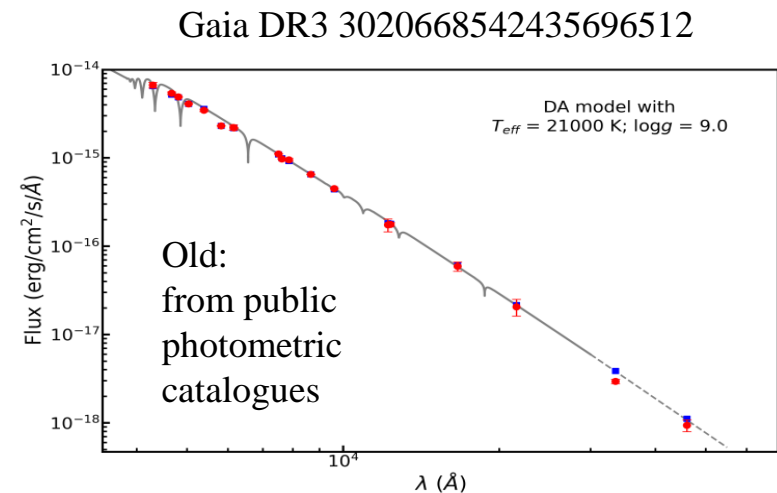Blue: Gaia-DR2 Jiménez-Esteban et al. 2018
Red: Gaia-DR3 new identifications

Block 1: Identification and classification of WDs

We used **GaiaXPy** build the SED with synthetic **JPAS** photometry from **Gaia spectra**.

- 56 narrow-bands
- R ≈ 60 photo-spectra

J-PAS filter system (Bonoli et al. 2021)

Gaia DR3 3020668542435696512

DA model with
T_{eff} = 21000 K; log$g$ = 9.0

Old:
from public
photometric
catalogues

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

New:
JPAS synthetic
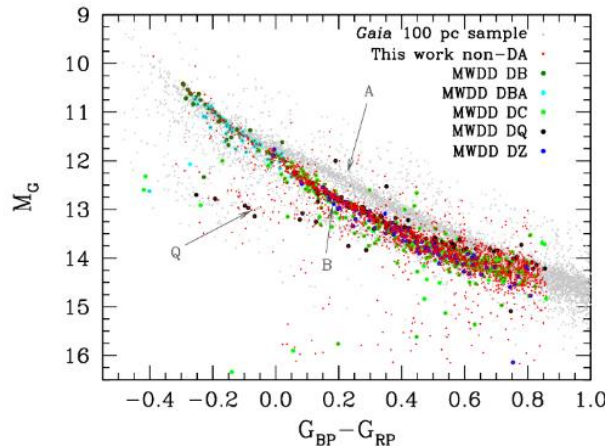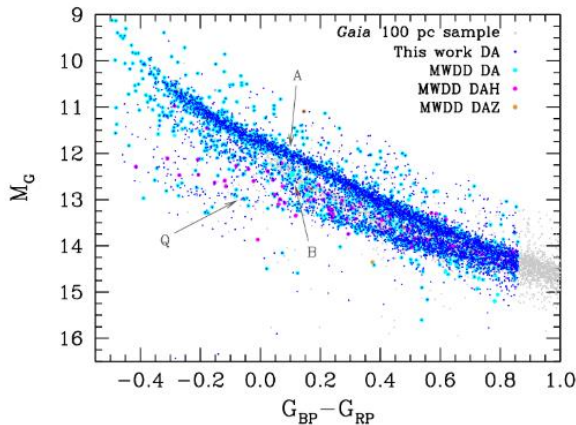photometry from
Gaia spectra

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Block 1: Identification and classification of WDs

We **spectral classified 65,310 WDs** based on the best model fit: DA or non-DA.

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

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

We looked again into the bifurcation of the WD sequence in the Gaia HR diagram

- **A branch:**
  95% DA + 5% non-DA
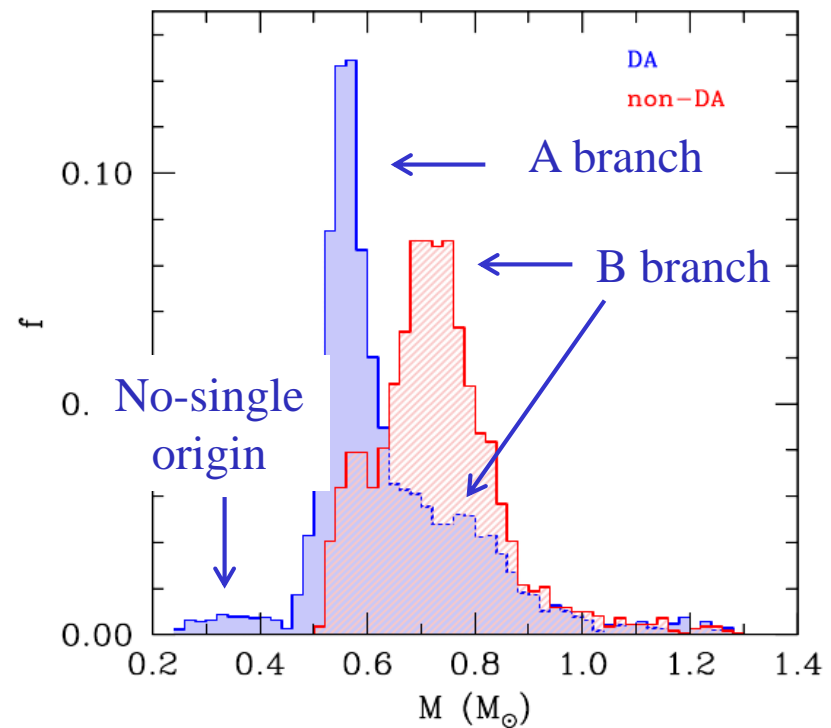
- **B branch:**
  35% DA + 65% non-DA

Block 1: Identification and classification of WDs

We studied the **physical properties** of DAs and non-Das
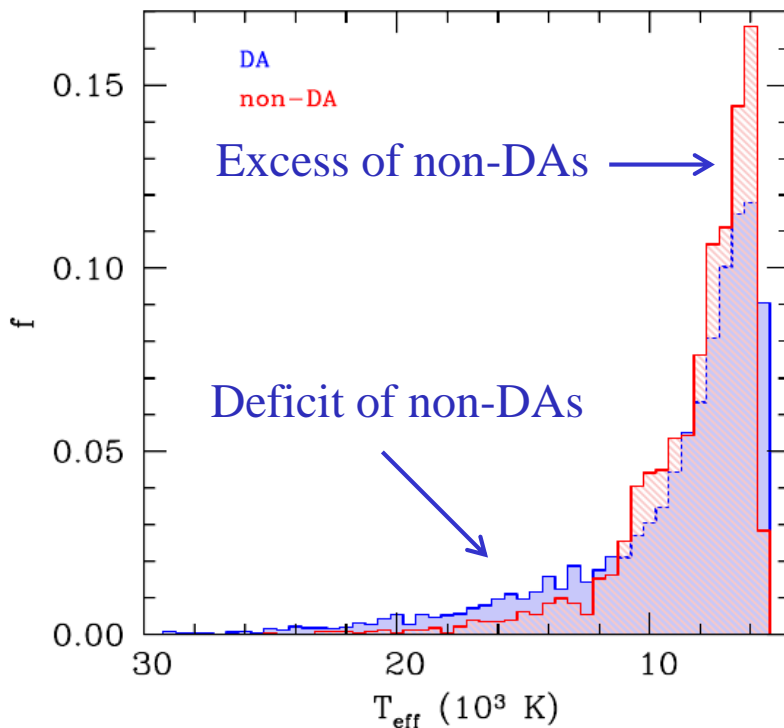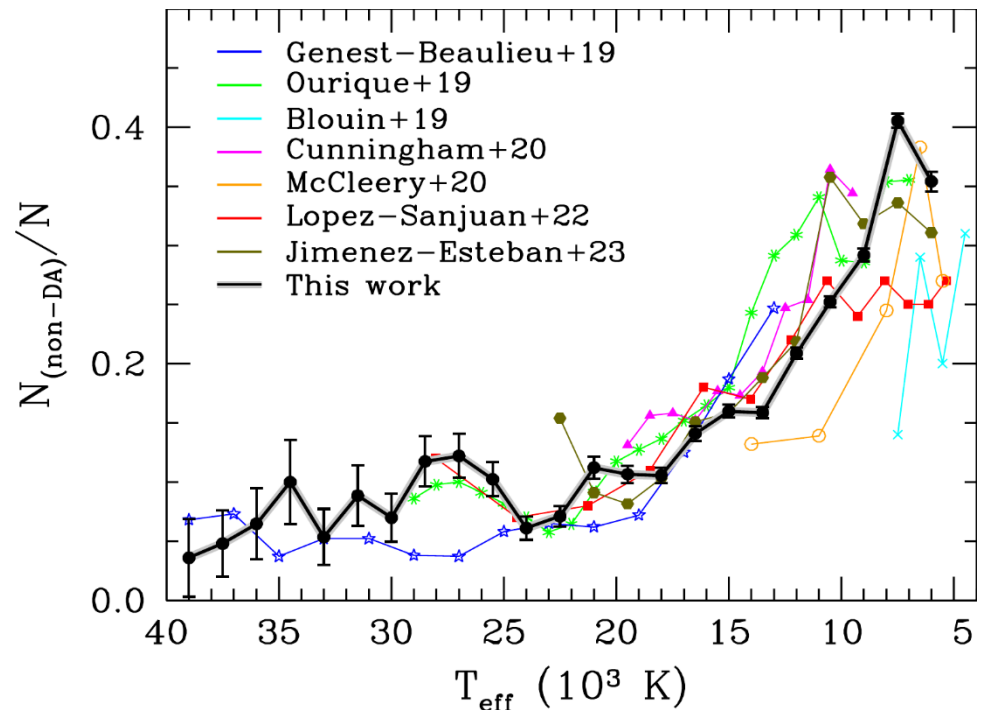
Block 1: Identification and classification of WDs

We study of **the WD spectral evolution** with the largest sample of WDs (34,000 WDs) used so far.

Spectral evolution: the evolution with the effective temperature of the rate of non-DA WDs with respect to the total number of WDs

Block 2: Studies of Galactic WD population

We used **artificial intelligence techniques**, a thorough and robust **population synthesis code**, the **VO**, and the superb **Gaia DR2** astrometry data, to study the different components (thin disk, thick disk, halo) of the Galactic WD population within 100 pc.

Random Forest identification of the thin disc, thick disc, and halo *Gaia*-DR2 white dwarf population

S. Torres,[1,2]★ C. Cantero,[1] A. Rebassa-Mansergas,[1,2] G. Skorobogatov,[1]
F. M. Jiménez-Esteban[3,4] and E. Solano[3,4]

Block 2: Studies of Galactic WD population

We used **artificial intelligence techniques**, a thorough and robust **population synthesis code**, the **VO**, and the superb **Gaia DR2** astrometry data, to study the different components (thin disk, thick disk, halo) of the Galactic WD population within 100 pc.
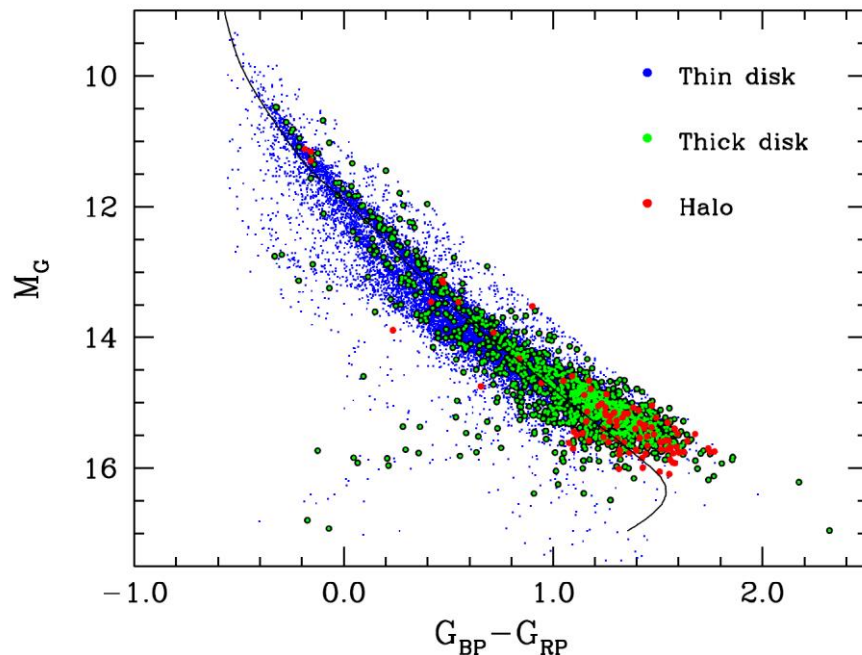
Gaia HR diagram where the three Galactic component sources are shown with different colours:
- **thin disk** in blue: 74% of WDs
- **thick disk** in cyan: 25% of WDs
- **halo** in red: 1% of WDs

Block 2: Studies of Galactic WD population

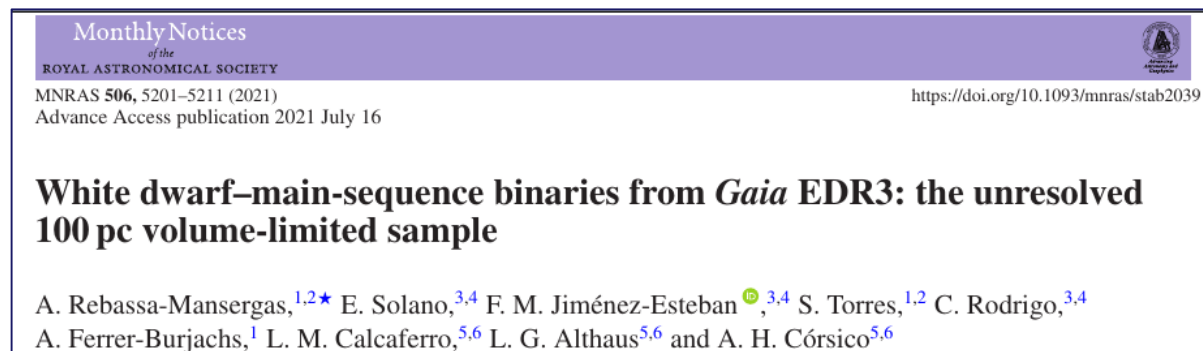We studied the **WD binary population** with in 100 pc, both resolved and unresolved, with the help of **population synthesis code**, the **VO**, and the superb astrometry of **Gaia EDR3**.

A population synthesis fitting of the *Gaia* resolved white dwarf binary population

S. Torres,[1,2]★ P. Canals,[1] F. M. Jiménez-Esteban [○],[3,4] A. Rebassa-Mansergas[1,2] and E. Solano[3,4]

White dwarf–main-sequence binaries from *Gaia* EDR3: the unresolved 100 pc volume-limited sample

A. Rebassa-Mansergas,[1,2]★ E. Solano,[3,4] F. M. Jiménez-Esteban [○],[3,4] S. Torres,[1,2] C. Rodrigo,[3,4] A. Ferrer-Burjachs,[1] L. M. Calcaferro,[5,6] L. G. Althaus[5,6] and A. H. Córsico[5,6]
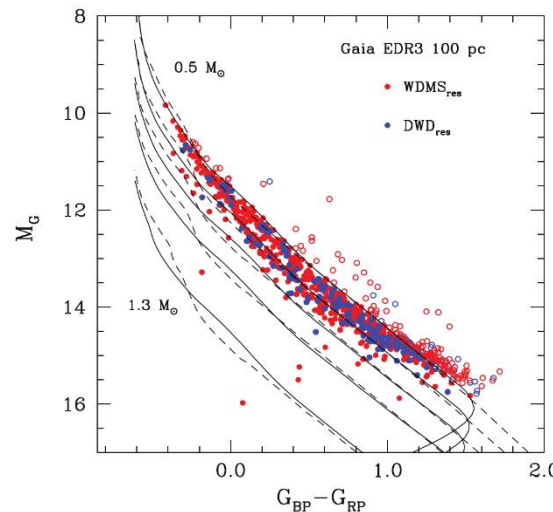
Block 2: Studies of Galactic WD population

Resolved WD binary population with in 100 pc:
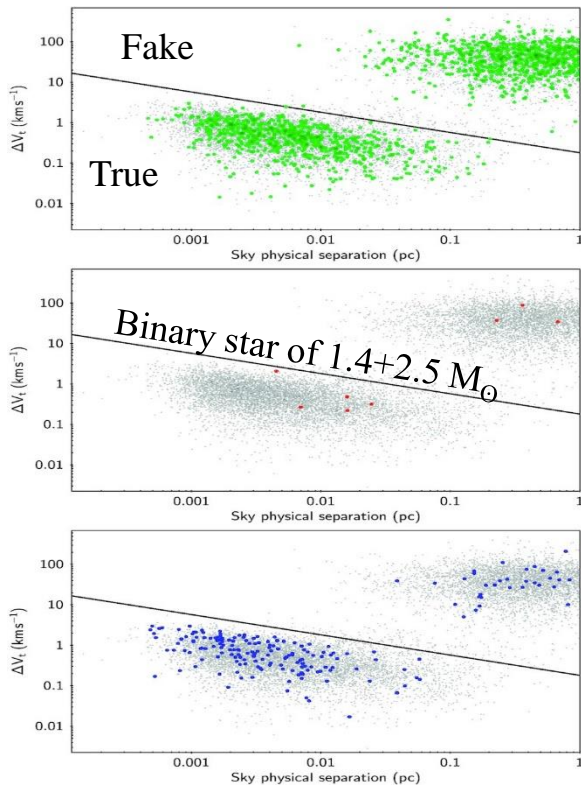
Identification of commoving pairs by **parallax and proper motion**.

- Green: WD+MS → 6.3%
- Red: WD+RG
- Blue: WD+WD → 1.2%

Position in the Gaia HR diagram of the WDs in binary systems:

- WD+MS (red)
- WD+WD (blue)

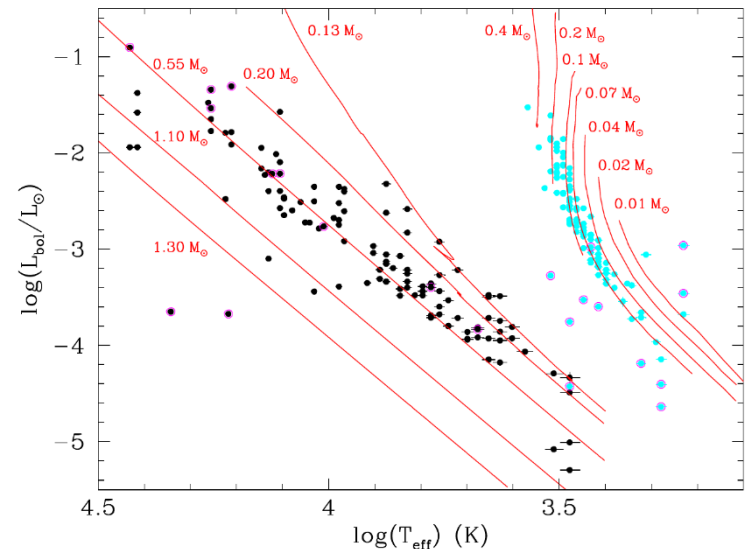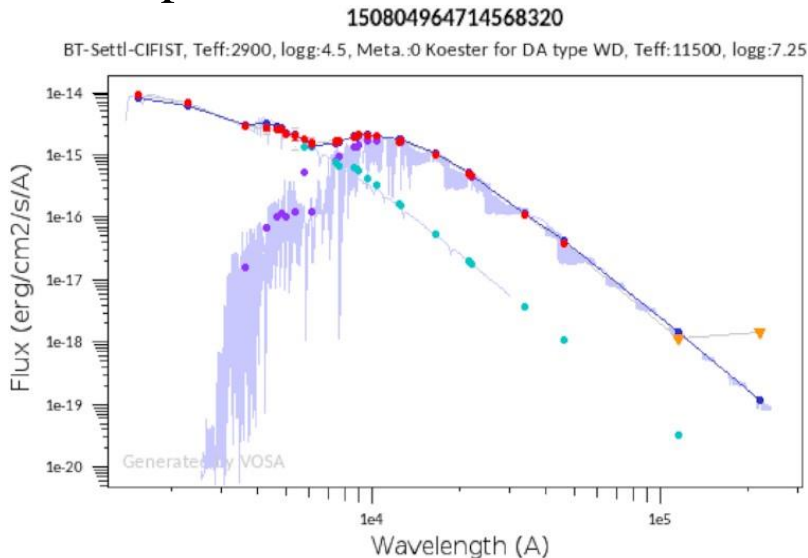fran.jimenez-esteban@cab.inta-csic.es

Block 2: Studies of Galactic WD population

Unresolved WD binary population with in 100 pc:

Identification of unresolved binaries by **composed SED**:

- Red: Observed data
- Cyan: WD model
- Purple: MS model

Luminosity as a function of the T_{eff} for 117 unresolved WD (black) and MS (cyan) binary stars.

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SASP 2025

Block 3: Studies of peculiar WDs

We identified **WDs** showing **infrared excess** emission due to the presence of **circumstellar material or a substellar companion** within 100 pc.

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MNRAS **489**, 3990–4000 (2019)
Advance Access publication 2019 September 2
doi:10.1093/mnras/stz2423

Infrared-excess white dwarfs in the *Gaia* 100 pc sample

A. Rebassa-Mansergas,[1,2]★ E. Solano,[3,4] S. Xu (许偲艺) [⊙],[5] C. Rodrigo,[3,4] F. M. Jiménez-Esteban[3,4] and S. Torres[1,2]

Gaia DR2
- 77 systems
- 68% new discoveries

Astronomy & Astrophysics manuscript no. output
December 8, 2025   ©ESO 2025

Submitted

***Gaia* white dwarfs with infrared excess**

I. The 100 pc catalogue

R. Murillo-Ojeda[1], F. M. Jiménez-Esteban[1], A. Rebassa-Mansergas[2,3], and S. Torres[2,3]

Gaia DR3
- 456 systems
- 77% new discoveries

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Block 3: Studies of peculiar WDs

We identified **WDs** showing **infrared excess** emission due to the presence of **circumstellar material or a substellar companion** within 100 pc.

Gaia DR3: **456** infrared excess WD**, 351** were **new discoveries**
- Optical**: Gaia-XP+JPAS** synthetic photometry
- IR: **VO photometric catalogues**
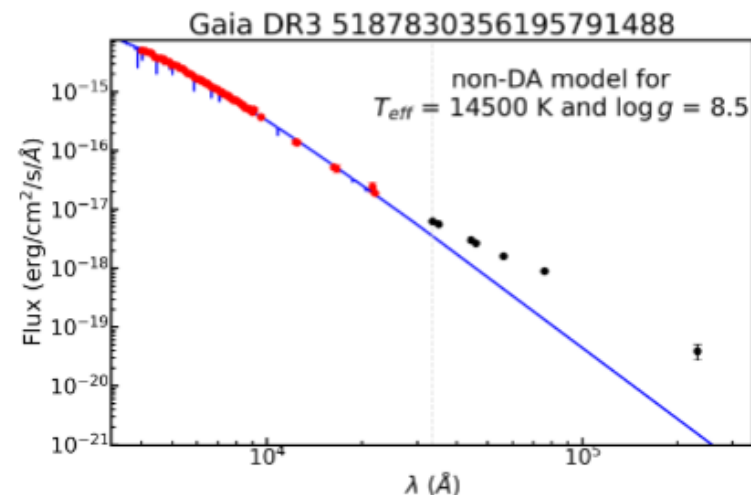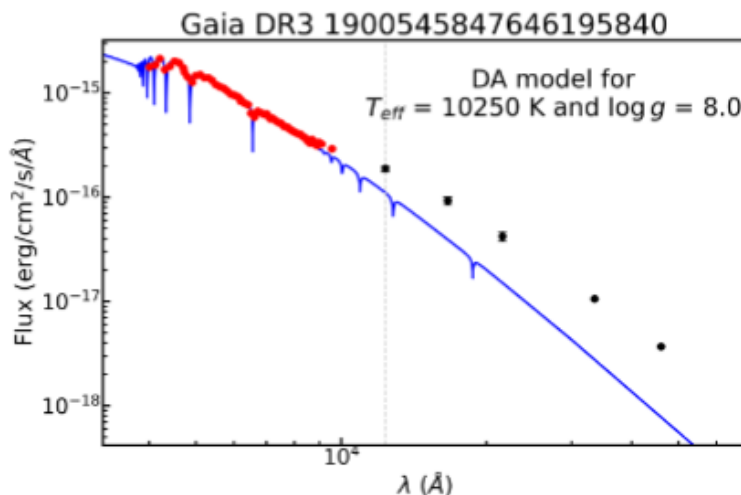- **DA** (H-rich) and **non-DA** (He-rich) atmospheric emission models

SASP 2025
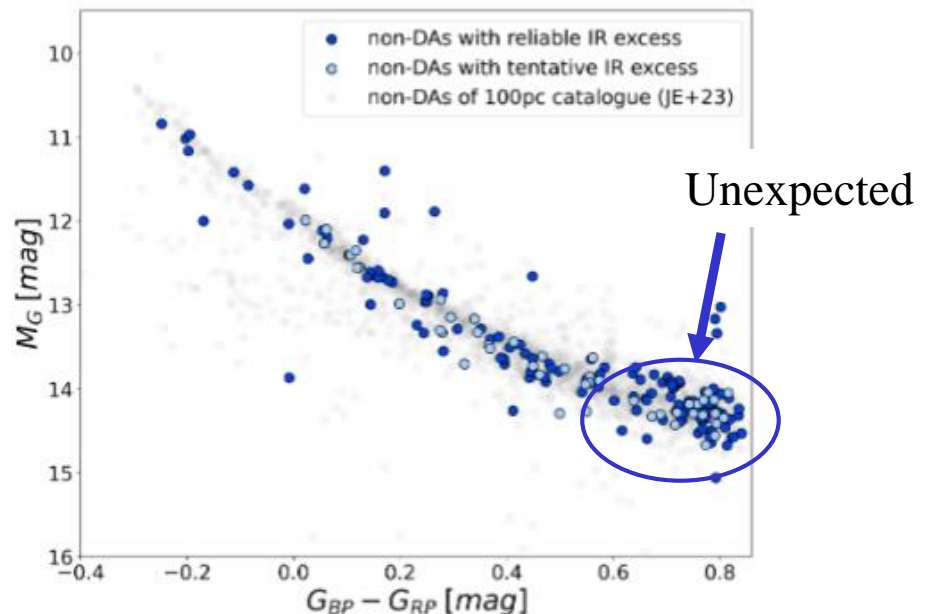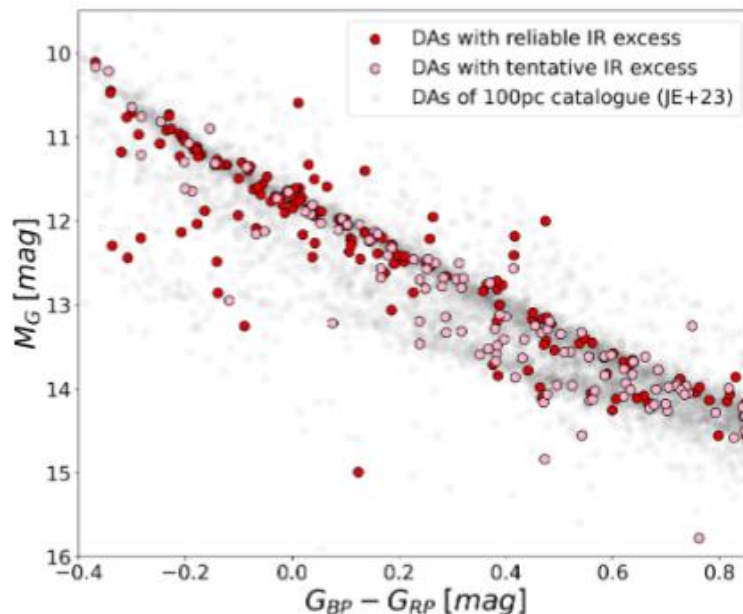
Block 3: Studies of peculiar WDs

We identified **WDs** showing **infrared excess** emission due to the presence of **circumstellar material or a substellar companion** within 100 pc.

Distribution of the systems in the WD cooling sequence

Block 3: Studies of peculiar WDs
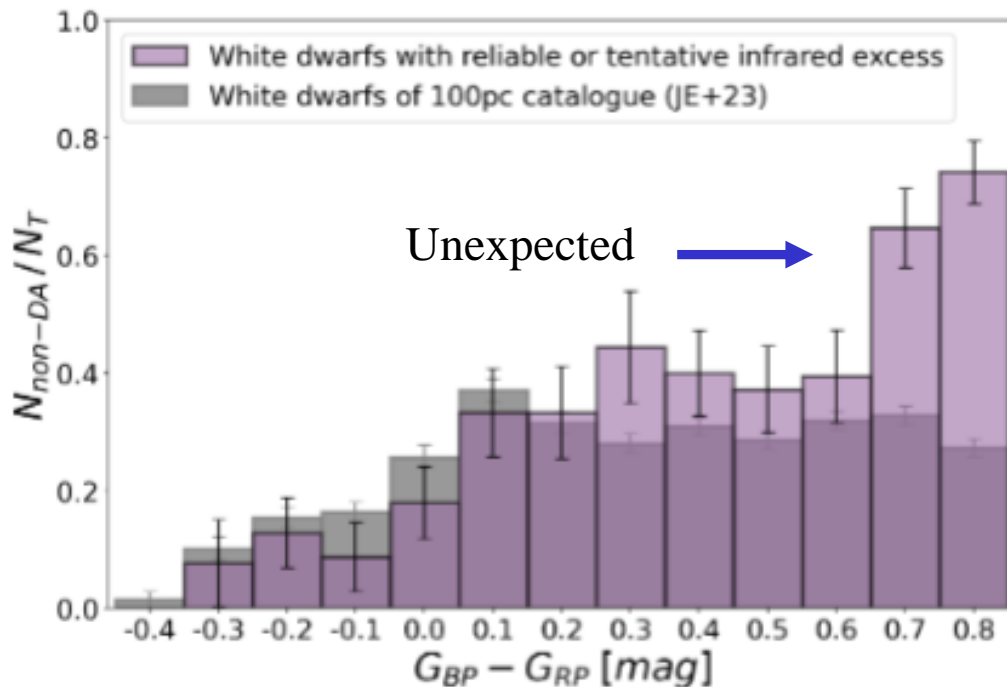
We identified **WDs** showing **infrared excess** emission due to the presence of **circumstellar material or a substellar companion** within 100 pc.

- We study for the first time the rate of non-DA WDs with infrared excess along the cooling sequence

- We estimated that the overall rate of WDs shows infrared excess is 6-9% within 100 pc population

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Block 3: Studies of peculiar WDs

Follow-up spectroscopic observation of the most **interesting sources**.

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© 2022. The Author(s). Published by the American Astronomical Society.
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OPEN ACCESS

Gaia 0007–1605: An Old Triple System with an Inner Brown Dwarf–White Dwarf Binary and an Outer White Dwarf Companion

Alberto Rebassa-Mansergas[1,2], Siyi Xu (许偲艺)[3], Roberto Raddi[1], Anna F. Pala[4], Enrique Solano[5,6], Santiago Torres[1,2], Francisco Jiménez-Esteban[5,6], and Patricia Cruz[5,6]
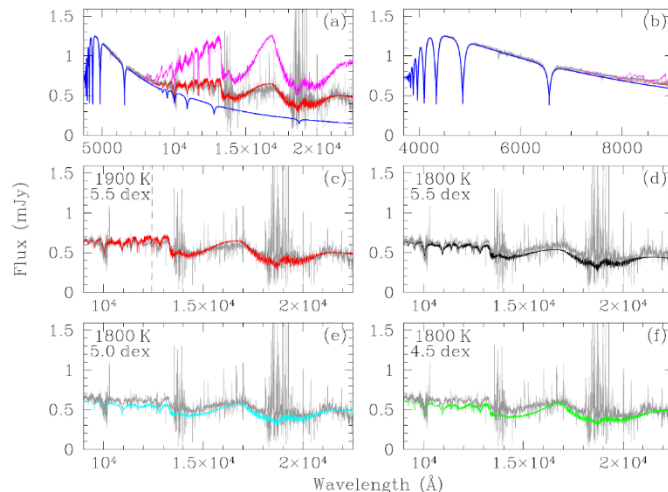
Gaia 0007-1605:
The first inner BD-WD binary of a hierarchical triple system with another WD.

The SVO archive of WDs from Gaia

The catalogues built by our group are publicly available at the SVO archive
http://svocats.cab.inta-csic.es/wdw/

The SVO archive of White Dwarfs from Gaia

The SVO archive of White Dwarfs from Gaia:

Currently, Gaia is making the largest, most precise three-dimensional map of our Galaxy by surveying more than a thousand million stars. Thanks to the superb capabilities of Gaia, an unprecedented number of white dwarfs with excellent both astrometric and photometric measurements is being discovered.

We made use of the Gaia data and the Virtual Observatory to build the following catalogues of white dwarfs:

- A catalogue of 73,221 white dwarfs identified using Gaia-DR2 and the Virtual Observatory (Jiménez-Esteban et al. 2018). This catalogue contains white dwarfs at any distance and provides their physical parameters (Teff, M, R, L, logg).

- A catalogue of 13,732 white dwarfs within 100 pc from Gaia-DR2 (Torres et al 2019). These white dwarfs have been classified as belonging to the thin disk, thick disc, or halo Galactic population.

- A catalogue of 77 white dwarfs with infrared excess from Gaia-DR2 (Rebassa-Mansergas et al., 2019).

- A catalogue of 112 white dwarf and main sequence unresolved binaries at less than 100 pc from Gaia EDR3. (Rebassa-Mansergas et al. 2021).

- A catalogue of 12,718 white dwarfs within 100 pc spectroscopically classified using Gaia-DR3 and the Virtual Observatory (Jiménez-Esteban et al. 2023)

- A catalogue of 57,148 white dwarfs between 100 and 500 pc spectroscopically classified using Gaia-DR3 and the Virtual Observatory (Torres et al. 2023)

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Conclusions

- **Gaia** and the **VO** have demonstrated to be a **pairing of great value**.

- Our collaboration has extensively used this synergy, in combination with **artificial intelligent** algorithms and **population synthesis codes**, **atmospheric emission models**, **photometric data bases,** available through the **VO**, for the study of white dwarf evolution.

Conclusions

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Thanks!!