



UNIVERSITAT POLITÈCNICA
DE CATALUNYA
BARCELONATECH



CENTRO DE ASTROBIOLOGÍA
ASOCIADO AL NASA ASTROBIOLOGY INSTITUTE



Monthly Notices

of the
ROYAL ASTRONOMICAL SOCIETY



MNRAS **480**, 4505–4518 (2018)
Advance Access publication 2018 August 6

doi:10.1093/mnras/sty2120

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. Cantero⁴ and C. Rodrigo^{1,2}

¹*Departamento de Astrofísica, Centro de Astrobiología (CSIC-INTA), ESAC Campus, Camino Bajo del Castillo s/n, E-28692 Villanueva de la Cañada, Spain*

²*Spanish Virtual Observatory, E-28692 Villanueva de la Cañada, Spain*

³*Suffolk University, Madrid Campus, C/ de la Viña 3, E-28003 Madrid, Spain*

⁴*Departament de Física, Universitat Politècnica de Catalunya, c/ Esteve Terrades 5, E-08860 Castelldefels, Spain*

⁵*Institut d'Estudis Espacials de Catalunya, Ed. Nexus-201, c/ Gran Capitán 2-4, E-08034 Barcelona, Spain*

Accepted 2018 July 16. in original form 2018 June 28

F. Jiménez-Esteban et al.

CAB / SVO (INTA-CSIC)

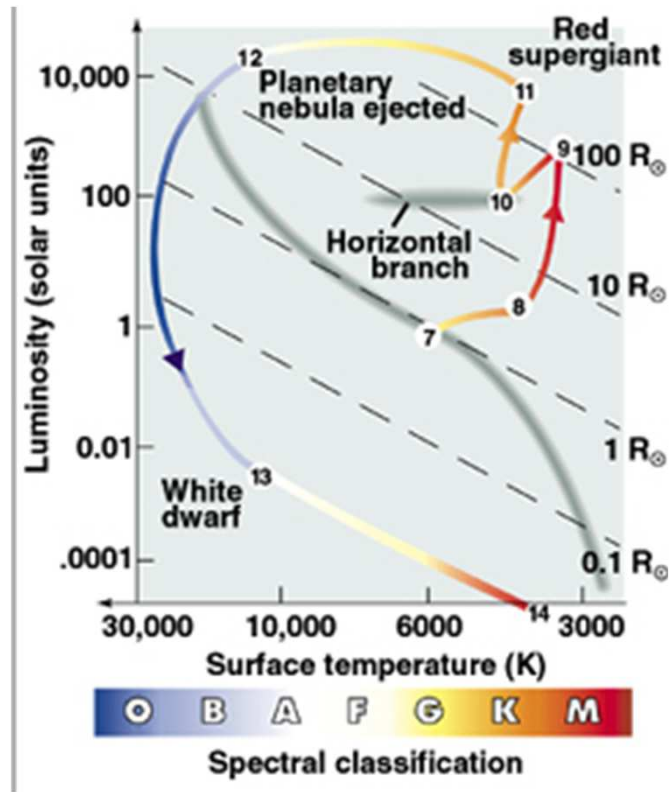


A White Dwarf catalogue from Gaia-DR2 and the VO

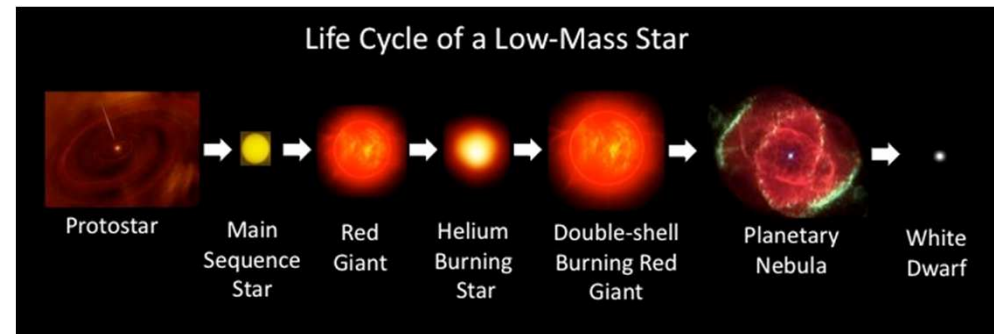


White dwarfs

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

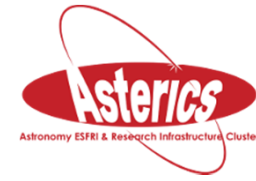


- ~97% of the stars in the MW
- There is not nuclear reactions
- They just cool and fade





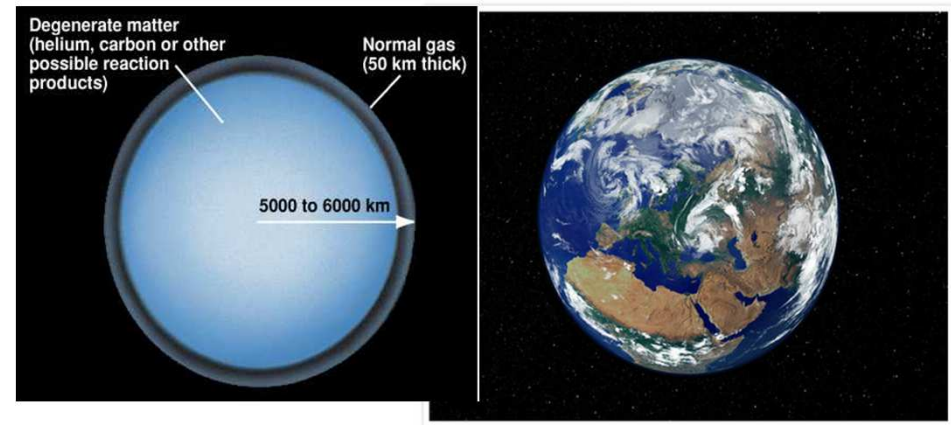
A White Dwarf catalogue from Gaia-DR2 and the VO



White dwarfs

Structure:

- Electron degenerated core \rightarrow Chandrasekhar limit $M < 1.4 M_{\odot}$
 - 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} - $10^{-4} M_{\odot}$



Spectral Classification

- ~80% DA: H lines
- ~20% Non-DA
 - DB: He I lines ~16%
 - DO (He II lines), DC (continuum)...

They are very small and very dense

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



A White Dwarf catalogue from Gaia-DR2 and the VO



White dwarfs - Why?

- 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 no-standard physics
 - Variability of the gravitational constant G
 - Existence of exotic particles



A White Dwarf catalogue from Gaia-DR2 and the VO



White dwarfs – Gaia & VO

- Gaia theoretically provides us with an unprecedented number of WDs
 - 12,000 up to 100 pc
 - 400,000 up to 400 pc
- We also need to estimate their stellar parameters
- VO provided us with the ideal framework
 - easy and fast access to multi- λ deep photometry \rightarrow SED
 - VO tools permit the study of thousands of objects at once \rightarrow VOSA & Topcat



A White Dwarf catalogue from Gaia-DR2 and the VO



Search methodology

Population Synthesis Code

- Monte Carlo based
- Salpeter-like IMF
- Three galactic population
 - Thin disc, thick disc, Halo (80:15:5)
- 80% DA & 20% non-DA
- Cooling sequences $f(M, z, \text{SpTy})$
- WDs space density $4.8 \times 10^{-3} \text{ pc}^{-3}$
- Gaia astrometric and photometric errors

(See paper for details and references)

Completeness

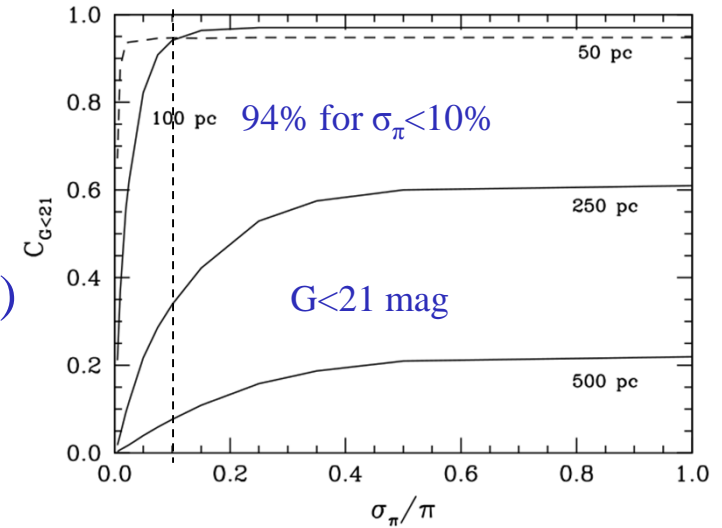


Table 1. Completeness estimate of the white dwarf population for different volume samples after cumulatively applying our three selection cuts. See text for details.

Selection cut	50 pc	100 pc	250 pc	500 pc
$G < 21$	0.95	0.97	0.61	0.22
$\sigma_\pi/\pi < 0.1$	0.95	0.94	0.34	0.08
$6,000 \text{ K} < T_{\text{eff}} < 80,000 \text{ K}$	0.43	0.44	0.27	0.04



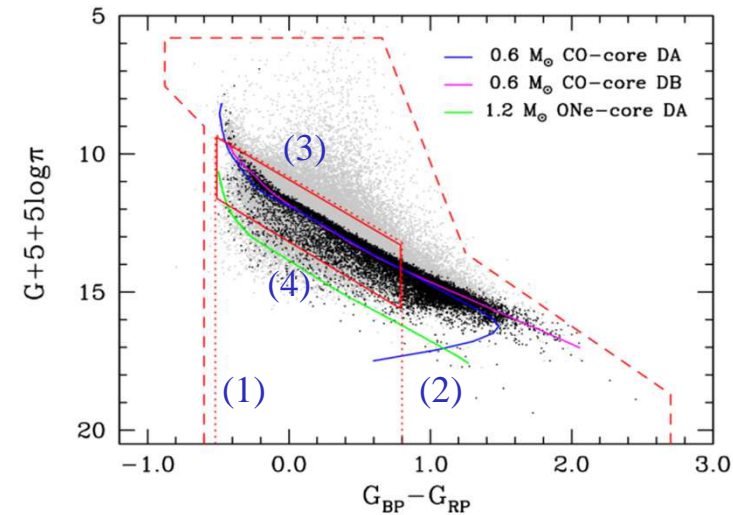
A White Dwarf catalogue from Gaia-DR2 and the VO



Search methodology

With the Population Synthesis Code we defined the search criteria:

- $\sigma_{\pi} < 10\%$
- $6,000 \text{ K (2)} < T_{\text{eff}} < 80,000 \text{ K (1)}$
- CO-core between (3) & (4)
- ONe-core below (4)



Evans et al. (2018) & Lindegren et al. (2018)

- $\sigma(F_{\text{BP}}) \text{ \& } \sigma(F_{\text{BR}}) < 10\%$
- $\text{phot_bp_rp_excess_factor} < 1.3 + 0.06 \times (G_{\text{BP}} - G_{\text{RP}})^2$

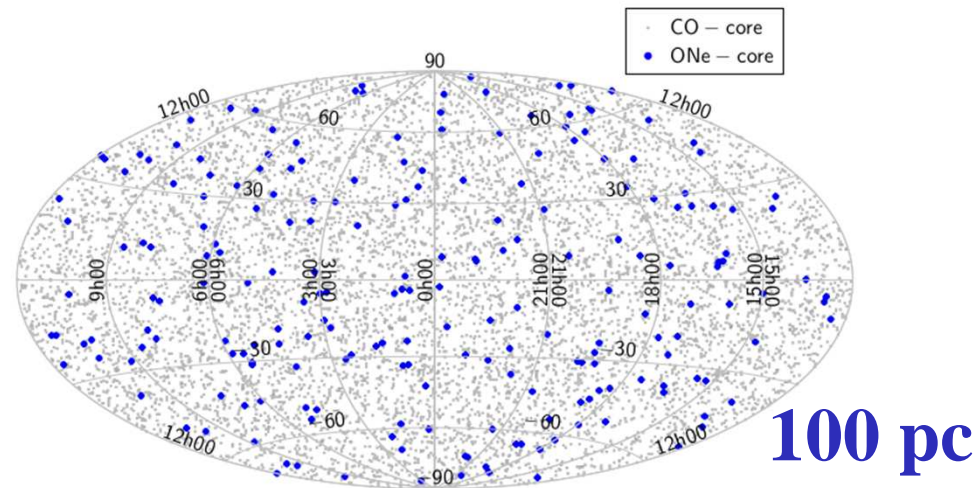


A White Dwarf catalogue from Gaia-DR2 and the VO



The Gaia WD catalogue

- 72,178 CO-core and 1,043 ONe-core WDs
- 8,343 CO-core and 211 ONe-core are within 100 pc
 - **The most complete volume-limited sample to date**
 - WD spatial density of $(4.9 \pm 0.4) \times 10^{-3} \text{ pc}^{-3}$
- Very low (< 1%) contamination (sdBs & CVs)



Equatorial coordinates



A White Dwarf catalogue from Gaia-DR2 and the VO



The Gaia WD catalogue

Available online at the SVO <http://svo2.cab.inta-csic.es/vocats/v2/wdw/>

The SVO archive of White Dwarfs from Gaia

Home | Data retrieval | News | Documentation | Coverage Map | Credits | Help-desk

RA (?) DEC (?) Radius (?) Search Reset (The number of displayed columns depends on the chosen verbosity)
 180 0 180 50 results default verb. (Maximum Search Radius allowed: 180 degrees)

Don't use coordinates as search criterion

Hide additional search fields

Magnitude ranges (?) Color ranges (?)

parallax (?) distance (?)
 pmra (?) pmdec (?)
 Teff (?) logg_VOSA (?)
 Flot (?) Lbol (?)
 Logg (?) R (?)
 M (?)

First 50 results shown (73221 found)

RA (deg)	DEC (deg)	RA (hh:mm:ss)	DEC (hh:mm:ss)	▲ Source ID (?)	parallax (mas)	distance (?)	pmra (?) (mas/year)	pmdec (?) (mas/year)	G_mag (?) (mag)	Gbp_mag (?) (mag)	Grp
103.192038	55.981497	06:52:46.09	55:58:53.39	1000142959474643584	12.924119708791885	77.37470888015146	50.35989443866363	-3.413677659153346	16.892885	16.891329	
102.540236	55.601797	06:50:09.66	55:36:06.47	1000151923070005376	6.256014450951032	159.84617808035614	-9.866363742660104	3.717968461627811	18.850864	18.818426	
103.066186	56.760250	06:52:15.88	56:45:36.90	100028228917483136	6.408127095157198	156.0518362308588	-0.7475928980776859	-8.331014811042937	19.31645	19.324858	
105.039641	56.210701	07:00:09.51	56:12:38.52	100038422926099592	4.169243716753708	239.85165366601032	5.271623545732469	-31.22570575763519	19.017124	18.960796	
104.952692	56.851048	06:59:48.65	56:51:03.77	100047150297099520	14.50294516598468	68.95151216219226	18.320386059819565	-149.10233412198946	18.30079	18.47752	
104.985080	57.830884	06:59:56.42	57:49:51.18	1000634986632549376	6.518173461838995	153.41721202336132	-87.76192600712409	-87.386980810569	20.022451	20.323235	
104.711707	58.092567	06:58:50.81	58:05:33.24	10006430989826064512	6.607957633262839	151.33268938745084	-41.17970385259191	-51.6633898446528	19.188395	19.367556	
104.059739	57.000209	06:56:14.34	57:00:00.75	1000654988295741056	14.998762899126724	66.67216534626488	21.140774906352213	-144.5313664624724	18.418156	18.739996	
103.832808	57.465809	06:55:19.87	57:27:56.91	1000705698973877376	7.481778954856684	133.6580537061537	-30.686209806955382	-53.50464662721546	19.34035	19.42411	
103.209924	57.832138	06:52:50.38	57:49:55.70	1000765038242361088	3.449939794543392	289.8601307713726	-0.6721048164510852	0.06409440474731193	17.90094	17.698368	
101.839302	56.771060	06:46:33.43	56:46:15.81	1000977381425618816	4.0730813491389	245.5143695822204	-9.204908252833047	-39.5997664970425	19.20522	19.247318	
100.136149	57.645965	06:40:32.68	57:38:45.47	1001351318458520960	16.54806058001788	60.43004224963501	-61.45643786000048	-221.35288291584098	18.037228	18.308426	
99.760667	58.280763	06:39:02.61	58:16:50.75	1001410348487980928	3.348275074867906	298.66124424645416	2.8079381806657095	-23.33942288736276	18.276653	18.115606	
99.159915	58.321054	06:36:38.38	58:19:15.80	1001457799287600640	5.287464482511811	189.12656591972979	28.59593059564919	9.458002053607549	18.796843	18.84181	
102.273932	57.501254	06:49:05.74	57:30:04.52	1001488757411973504	4.955784769280527	201.78438866003827	7.239870609564642	-20.065273813643124	18.27944	18.264198	
101.689551	58.086398	06:46:45.49	58:05:11.03	1001545210461761920	7.88133958134656	176.88197759669772	-27.654179425783205	-73.97442934487937	18.409833	18.474898	



A White Dwarf catalogue from Gaia-DR2 and the VO

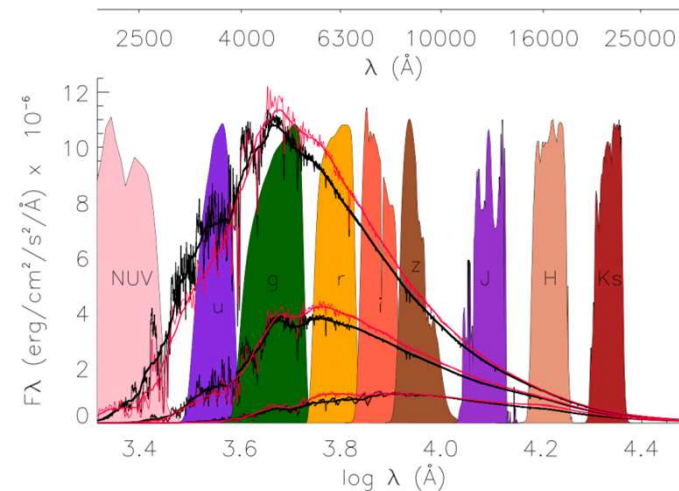


VOSA characterization of the catalogue



<http://svo2.cab.inta-csic.es/theory/vosa/>

- Designed and built by the SVO
- Determine physical parameters (T_{eff} , L , M , Age) from SED fitting
- Built the SEDs from 37 VO catalogues (UV-FIR) and user photometry
- Fit observational SEDs with 26 grids of theoretical spectra





A White Dwarf catalogue from Gaia-DR2 and the VO



VOSA characterization of the catalogue

- Used VOSA to:
 - built the SEDs from VO (UV-NIR)
 - Fit to DA white dwarf model spectra (Koester 2010)
 - T_{eff} and L for $\sim 91\%$ of sources
- $L = 4\pi R^2 \sigma T^4 \rightarrow R$
- Logg & M from evolutionary sequences (Renedo et al. 2010)

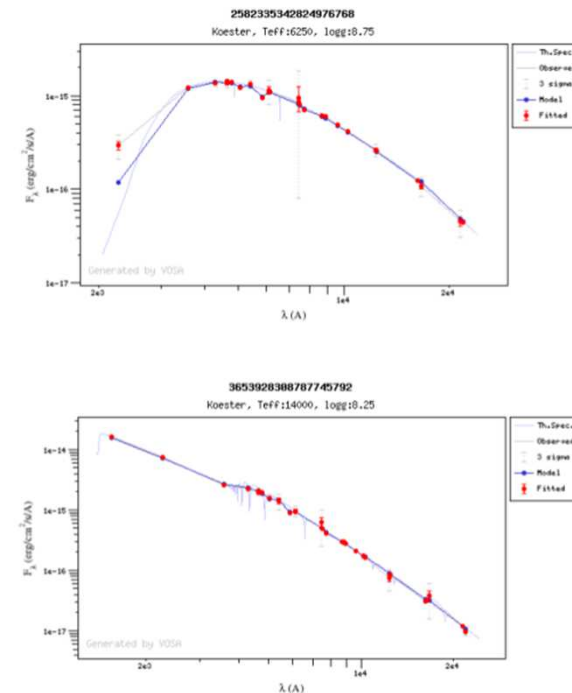


Figure 8. Examples of observational SEDs and their fit to the synthetic spectra done by VOSA for two of our white dwarfs. The observational photometric points are shown in red joint by gray lines, blue dots joint by blue lines are the synthetic photometry, and the cyan line corresponds to the theoretical model.

High reliable estimate of physical parameter for $\sim 59\%$

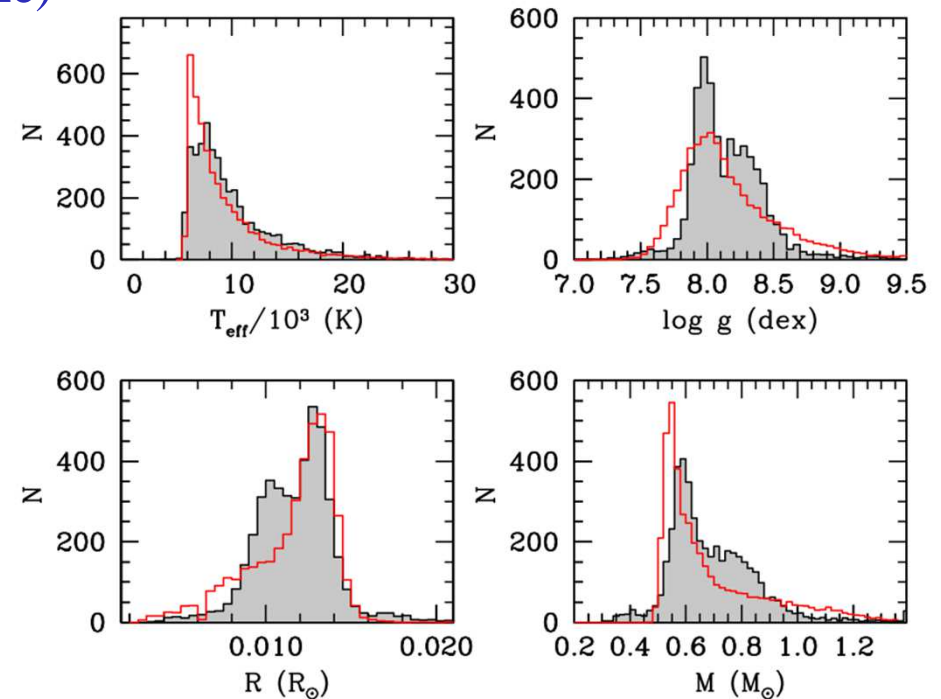


A White Dwarf catalogue from Gaia-DR2 and the VO



Physical parameters (100 pc)

- Concentration at $T_{\text{eff}} \sim 8,000$ K (first time)
 - Lack $T_{\text{eff}} < 8,000$ K
Due to selection and/or bad fit
- **Bimodal-like** distribution for R , $\log g$, M
 - Not predicted
- Unexpected high mass population
 - $\sim 0.8 M_{\odot}$ - $0.010 R_{\odot}$ - 8.3 dex
 - Binary mergers
 - A recent burst of star formation
 - Initial-to-final mass relationship
- Small fraction of He-core
 - $\sim 0.45 M_{\odot}$ - $0.017 R_{\odot}$ - 7.6 dex





A White Dwarf catalogue from Gaia-DR2 and the VO



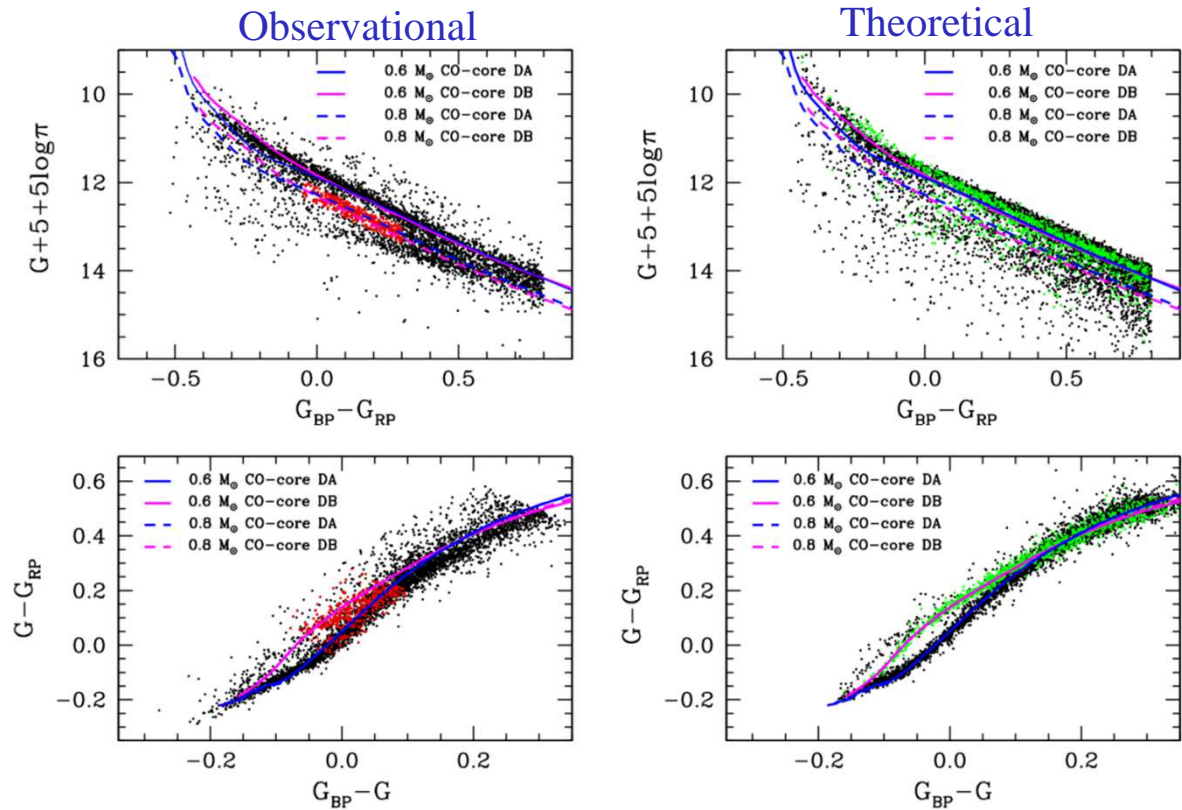
The WDs HR diagram (100 pc)

Good agreement with our model of the Galactic

Bifurcation:

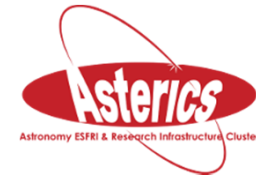
- $0.0 < G_{BP} - G_{RP} < 0.3$
- more massive objects.
- Not explained by DA/DB

30 – 40 % of DB





A White Dwarf catalogue from Gaia-DR2 and the VO



Conclusions

- **The largest white dwarf catalogue to date (>73,000)**
 - 8,343 CO-core and 212 ONe-core within 100pc
 - **Most complete volume-limited sample WDs up to date**
 - WD spatial density of $(4.9 \pm 0.4) \times 10^{-3} \text{ pc}^{-3}$
 - Contamination < 1% (sdBs & WD)
 - Reliable physical parameters for ~59%
- We demonstrated the majority of **WDs in the solar neighbourhood are cool**
- We identified **bimodal-like distributions of R , $\log g$ and M**
- **Bifurcation $0.0 < G_{\text{BP}} - G_{\text{RP}} < 0.3$**
 - more massive objects $\rightarrow \sim 0.8 M_{\odot}$ peak
 - discrepancies between **DA** and **DB cannot explain it**



*A White Dwarf catalogue from
Gaia-DR2 and the VO*



Thanks!!