Population synthesis study of the *Gaia* binary white dwarf population within 100 pc

1. Introduction and motivation
2. Population synthesis simulator
3. The *Gaia*-DR2 sample
4. Results
5. Conclusions

2. Motivation

- Binary population of white dwarfs (WD+WD; WD+MS): supernovae progenitors, binary evolutionary models (common-envelope episode), CV's, etc, etc.

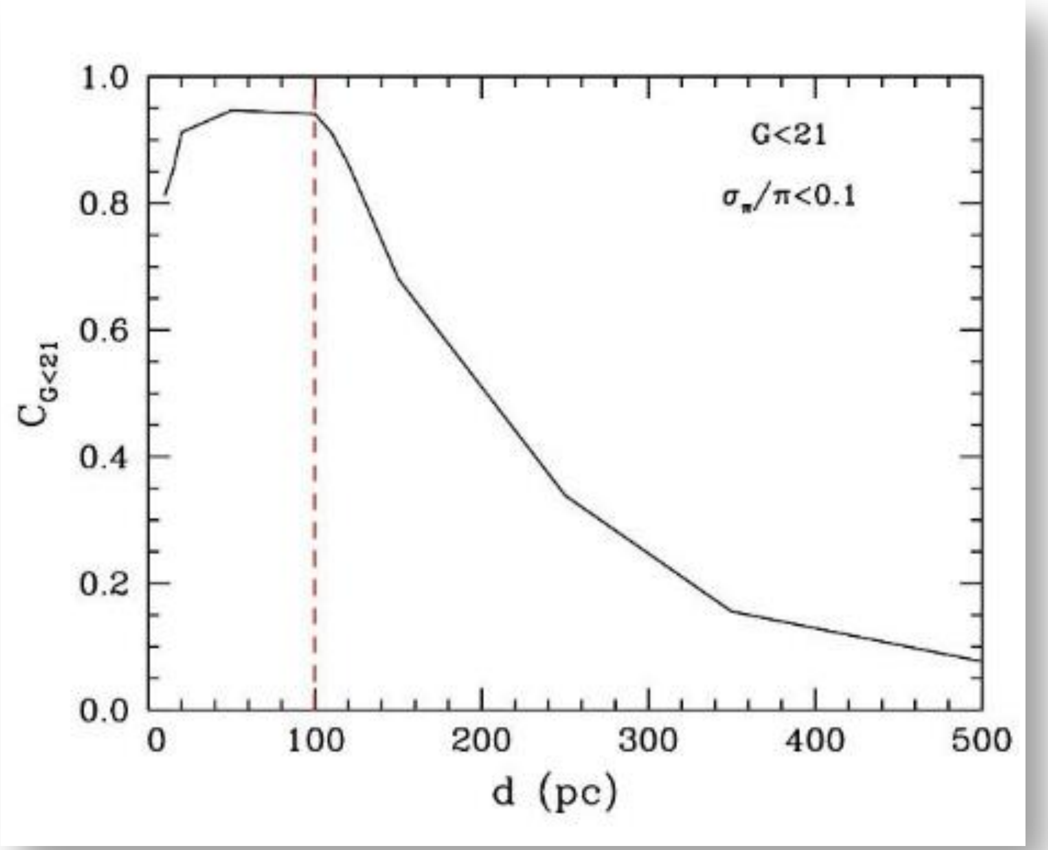
- *Gaia* has provided an unprecedented wealth of information of astrometric and photometric quality

- In particular, nearly 260,000 WDs (Fusillo et al. 2018); within 200 pc El-Badry & Rix (2018) found >3,000 WDMS and nearly 400 DWD.

- Population synthesis approach requires complete samples or a perfectly knowledge of all selection criteria and observational biases.

2. Motivation

- How far can we built a complete sample?
  - 100 pc
  - Jiménez-Esteban et al. (2018) show that the 100 pc simple is the largest complete simple available to *Gaia*
  - Statistically significant improvement: ~18000 WDs in 100 pc; ~100 in 20 pc



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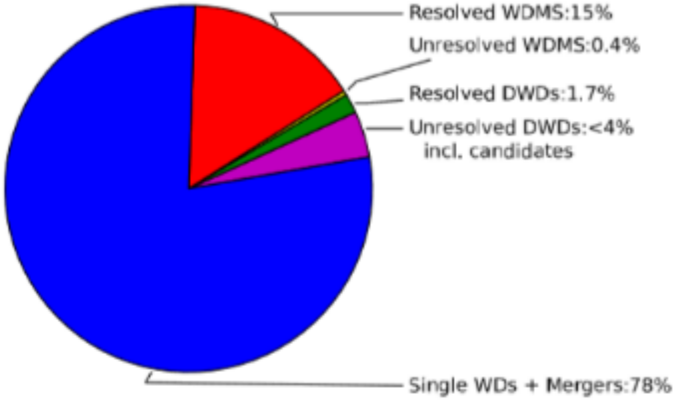
2. Motivation

- Toonen et al. (2017) in a thorough population synthesis study analyzed the % of the different subpopulations (WDMS/DWD, resolved/unresolved) of the 20 pc sample

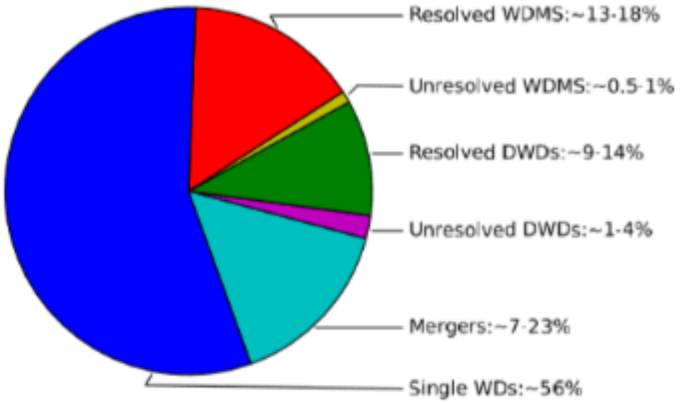
- General good agreement except for resolved DWDs:
  observed 1.7% .vs.predicted 9-14%

- Theoretical/observational 'failures'? Local inhomogeneities? (~110 WDs in 20 pc)

- What happen in the 100 pc sample?



(a) Observed



(b) Predicted

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Santiago Torres

in collaboration with

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2. Population synthesis simulator

- Robust code based on Monte Carlo techniques for the single and binary population

SINGLES

- Since two decades ago widely used in the study of the Galactic components (thin and thick disk, halo, bulge) and globular and open clusters.
- Update self-consistent cooling sequences (La Plata group): DA/DB, He/CO/ONe, Z=0.01/0.001

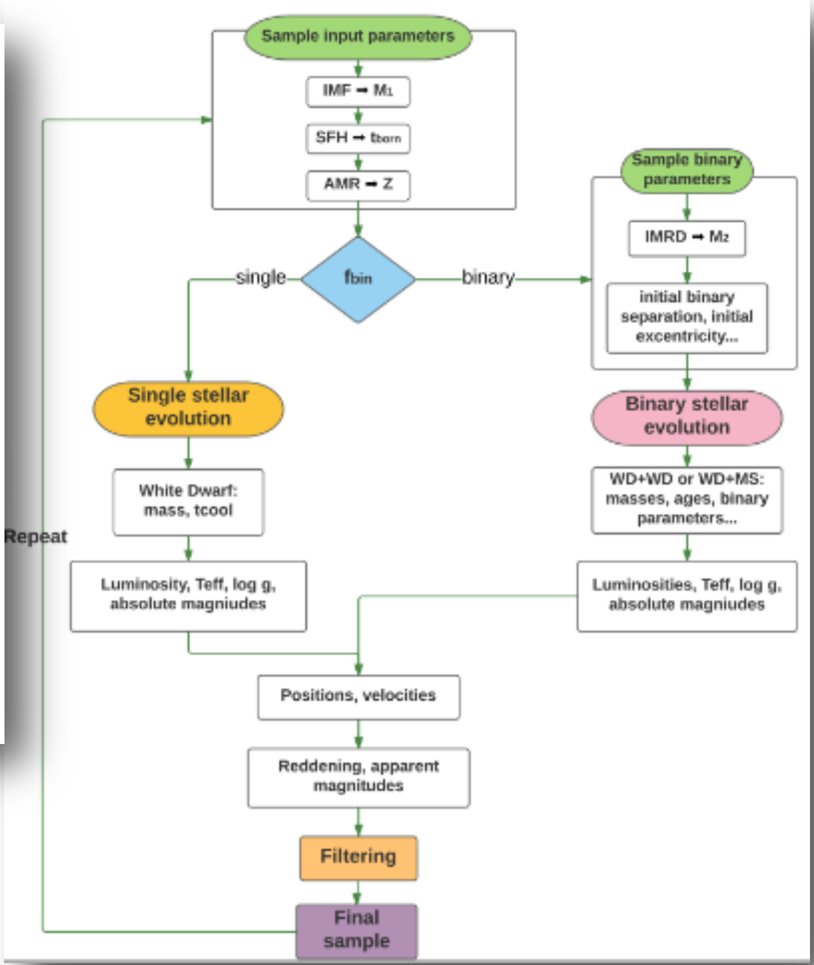
BINARIES

- Based on stellar evolutionary code (BSE) of Hurley et al. (2002).
- Improvements added: common envelope phase model following considering different binding energies of the donor.
- Tidal effects (circularization and synchronization) and wind mass-loss have been taken into account.
- Angular momentum losses due to magnetic braking and gravitational radiation were also considered (Schreiber et al. 2003).

2. Population synthesis simulator

Single inputs:

- IMF
- SFR
- Metallicity
- IFMR
- Three Galactic component model: thin:thick:halo, 80:15:5



Binary inputs:

- Those of the single model

+

- Binary fraction f_{bin}
- n(q)
- Initial separation
- Eccentricity distribution
- Common Envelope treatment
- Stellar winds
- …

○ Highly non-linear (nearly chaotic) system

3. The *Gaia* –DR2 sample

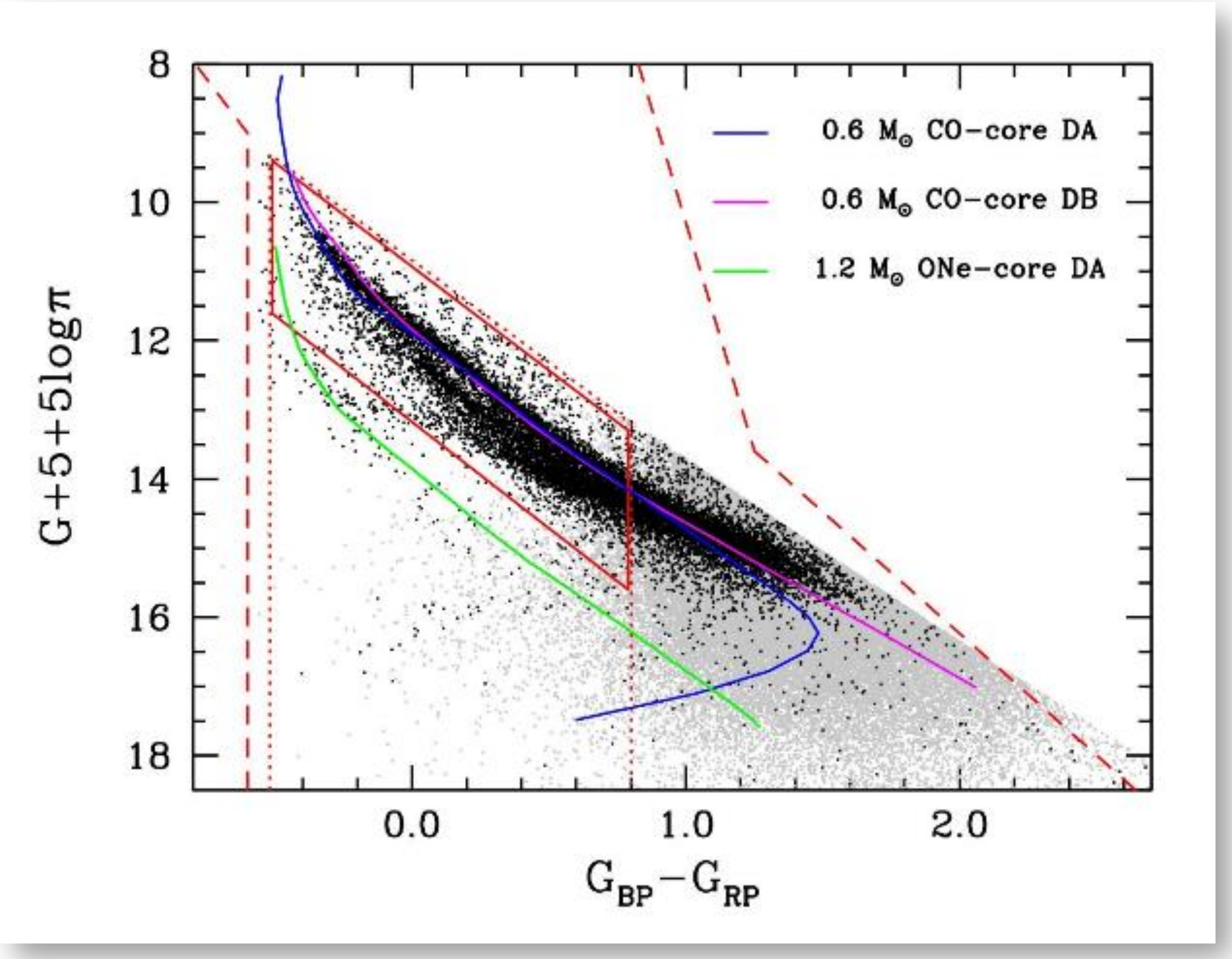
○ General Criteria:

- $G<21$ mag
- $\Pi > 10$ mas (d <100 pc)
- $\sigma_\pi < 10\%$
- σ (FBP) & σ (FBR) < 10%
- $\varepsilon < 1.3+0.06\times(G_{BP}-G_{RP})^2$
- $H_G = G + 5 \log \ + 5 > 3.02\times(G_{BP}-G_{RP}) + 11.95$

○ Subsample:

- $-0.52 < G_{BP} - G_{RP} < 0.8$

(6,000 K< T_{eff}< 80,000 K)



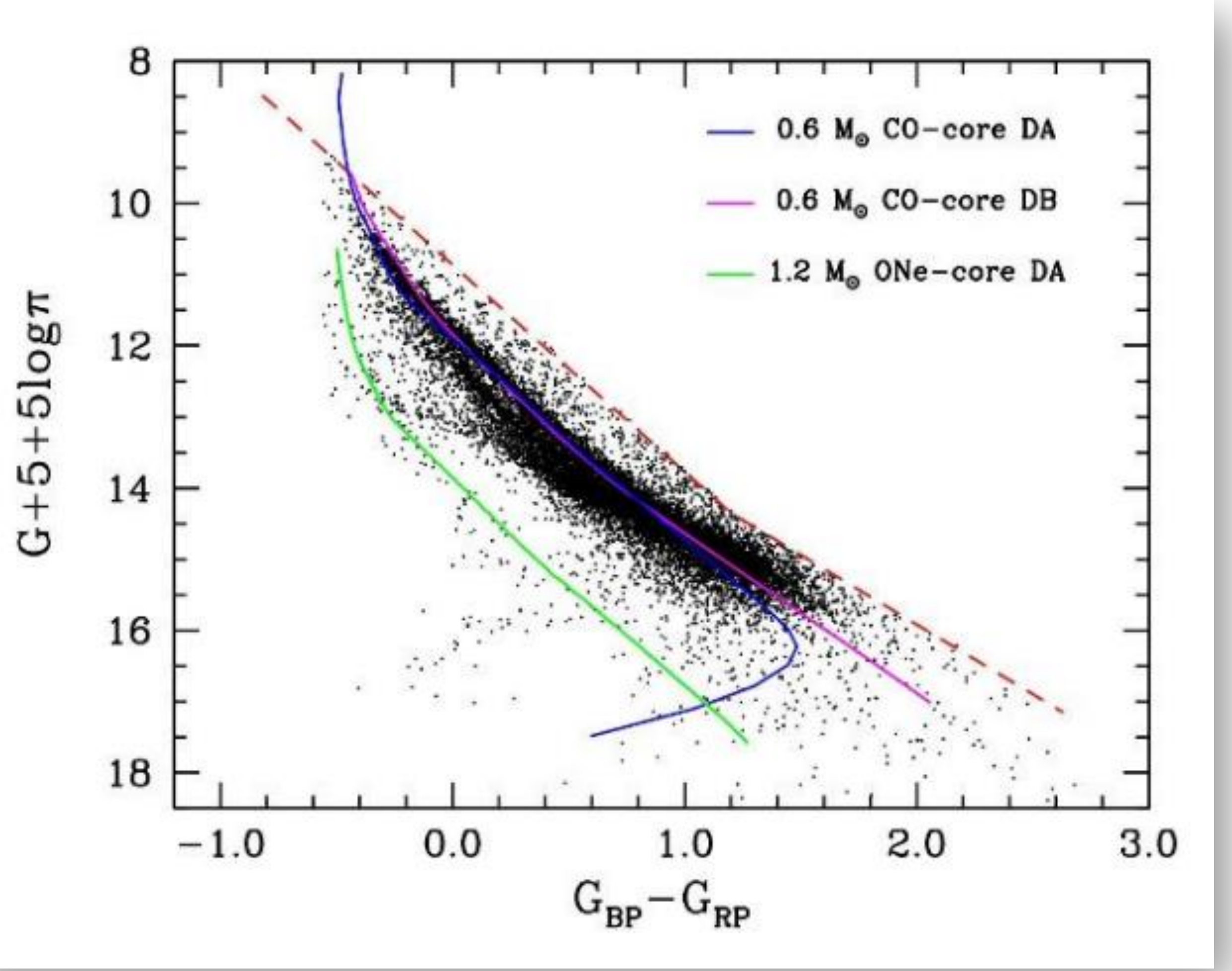
3. The *Gaia* –DR2 sample

- Clean sample:

- Number of objects: 13732

- Completeness estimate

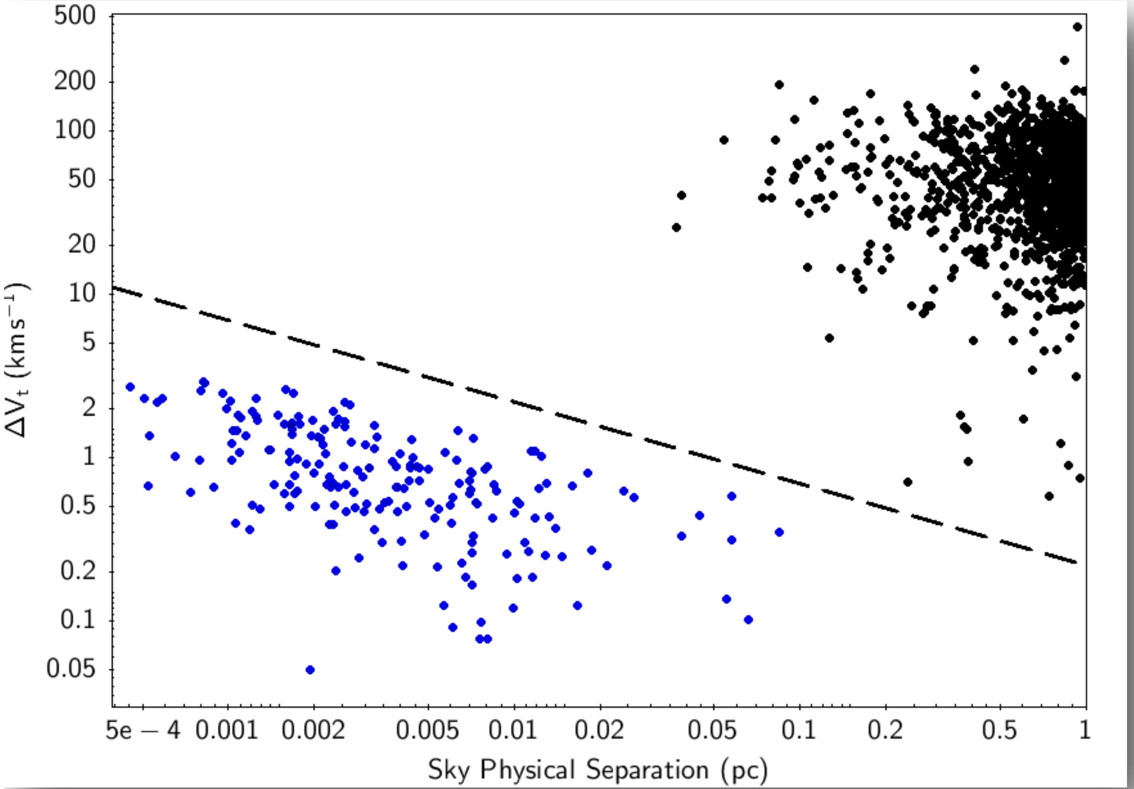
  - White dwarf space density of $4.9\pm0.4\times10^{-3}$ pc^{-3} (Jimenez-Esteban et al. 2018) 100 pc =>20525
  - $4.49\pm0.38\times10^{-3}$ pc^{-3} (Hollands et al. 2018) 20 pc=>
  - Our sample 67-73%



3. The *Gaia* –DR2 sample

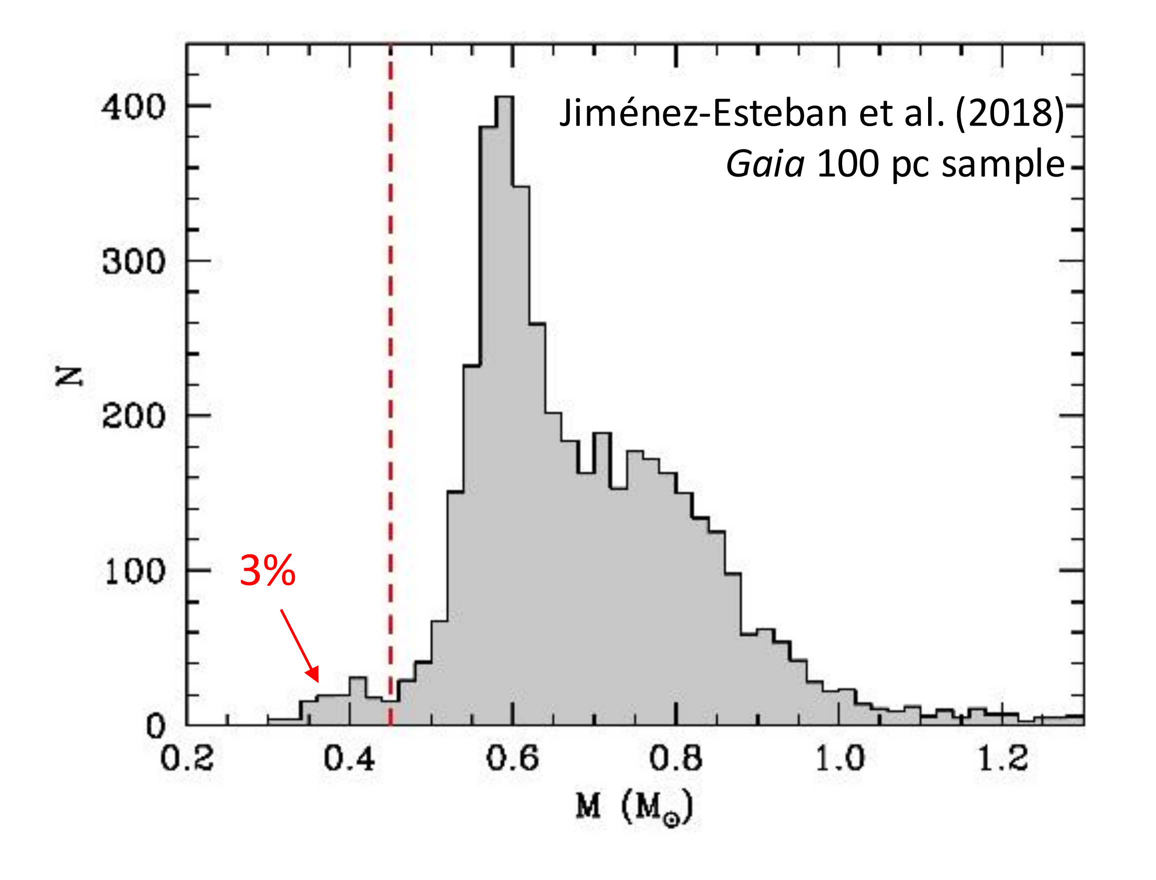
- Identification of comoving pairs

- Based on proper motions and parallaxes
- Separations < 1 pc
- From our initial simple of 13732 objects, there are 1286 candidates
- Those with difference in tangential velocity below $1.4+1.4M_{\odot}$ limit: 194
- 1.4% DWD resolved systems
- 1.7% for the 20 pc simple (Toonen et al. 2017)
- 1.38%; 180 objects <100 pc
- (El Badry et al. 2018)



3. The *Gaia* –DR2 sample

- Fraction of low mass WDs
  - 128 objects with $M<0.45M_{\odot}$
  - This implies a 3% of low mass WDs:
  - Overluminous objects, DWDs?
  - He-core WD in resolved/unresolved systems?



3. The *Gaia* –DR2 sample

- Summary:
  - 100 pc sample: 13732 objects
  - Reasonable high Completeness 67-73%
  - Observed fractions:
    - 1.4% Resolved DWD
    - 7.0% Resolved WDMS
    - 3% ‘low mass’ WDs

4. Results

- **Reference model**: fb=0.5; n(q)=1; Sep=lognormal; α_{IMF}=-2.35

Model	f_b	$n(q)$	Sep	α_{IMF}	DWD res	WDMS res
1	0.5	1	*lognorm*	-2.35	8.7	9.7
2	0.5	q	*lognorm*	-2.35	10.7	7.8
3	0.5	q^{-1}	*lognorm*	-2.35	5.8	12.6
4	0.4	1	*lognorm*	-2.35	7.0	7.2
5	0.4	q	*lognorm*	-2.35	8.5	6.2
6	0.4	q^{-1}	*lognorm*	-2.35	4.6	9.8
7	0.4	q^{-1}	*lognorm*	-2.15	5.5	10.8
8	0.4	q^{-1}	*lognorm*	-2.55	3.9	8.7

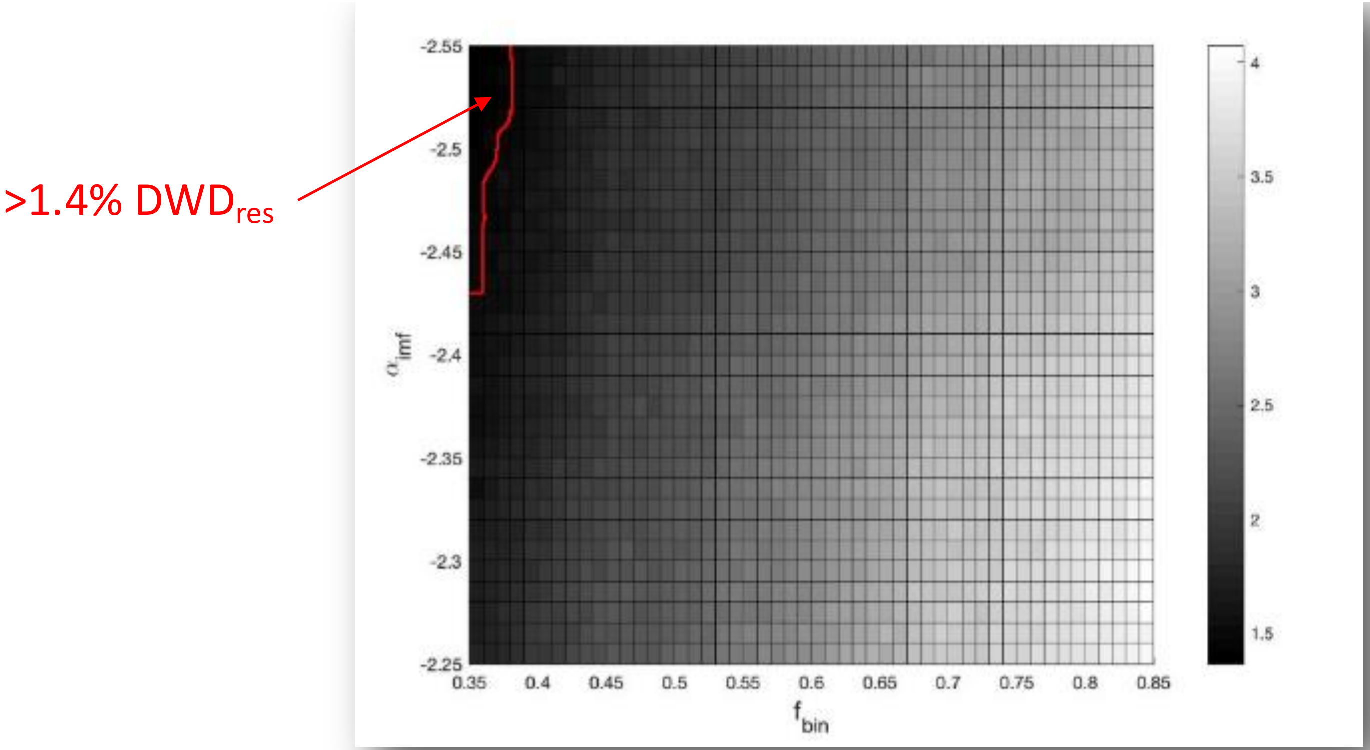
Model	f_b	$n(q)$	Sep	α_{IMF}	DWD res	WDMS res
9	0.4	q^{-1}	BPL	-2.35	1.8	3.8
10	0.4	q^{-1}	BPL	-2.55	1.5	3.4
11	0.4	q^{-1}	BPL	-2.15	2.1	4.3
12	0.5	q^{-1}	BPL	-2.35	2.3	4.7
13	0.5	q^{-1}	BPL	-2.15	2.6	5.3
14	0.5	q^{-1}	BPL	-2.55	2.0	4.2
15	0.5	1	BPL	-2.35	3.4	3.7
16	0.4	1	BPL	-2.35	2.7	2.7

- Lognorm separation models produce % DWD res >3.9%; too high
- n(q)=q^{-1} models have lower % DWD res and higher % WDMS res
- BPL separartion seem closer to observed values

- **Fine-tuning model**: fb=free; n(q)=q^{-1}; Sep=BPL; α_{IMF}=free

4. Results

- % resolved DWD

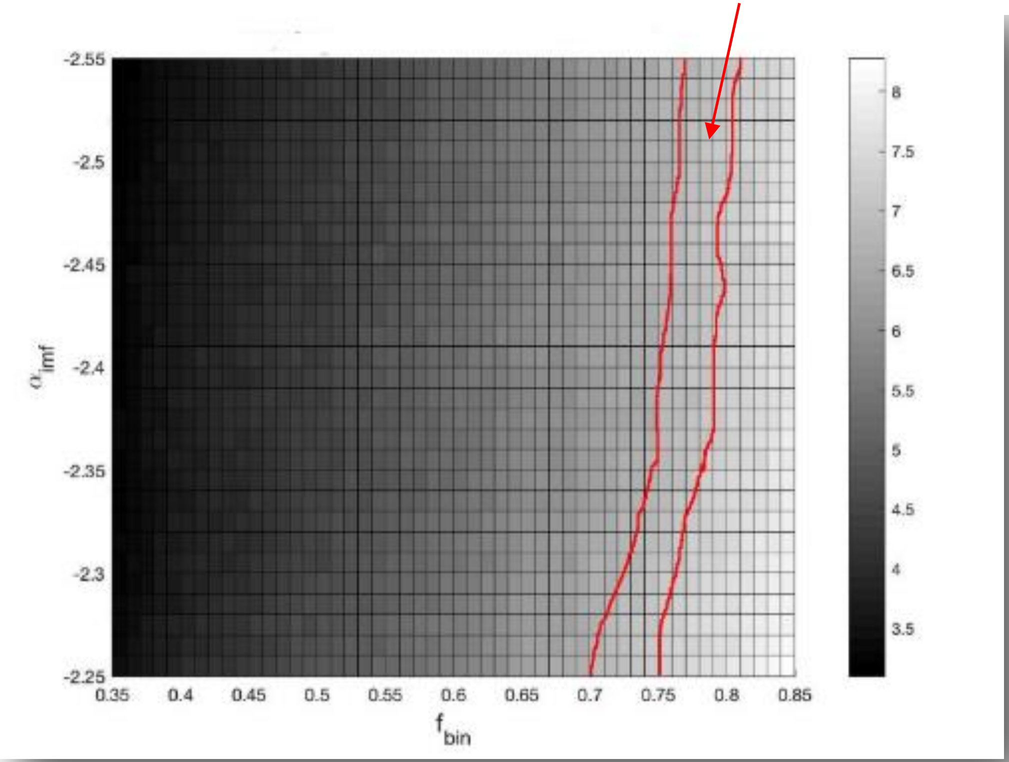


- Observed values for low f_{bin}=0.35-0.4 and steep IMF slopes α_{IMF}=-2.45-2.55

4. Results

- % resolved WDMS

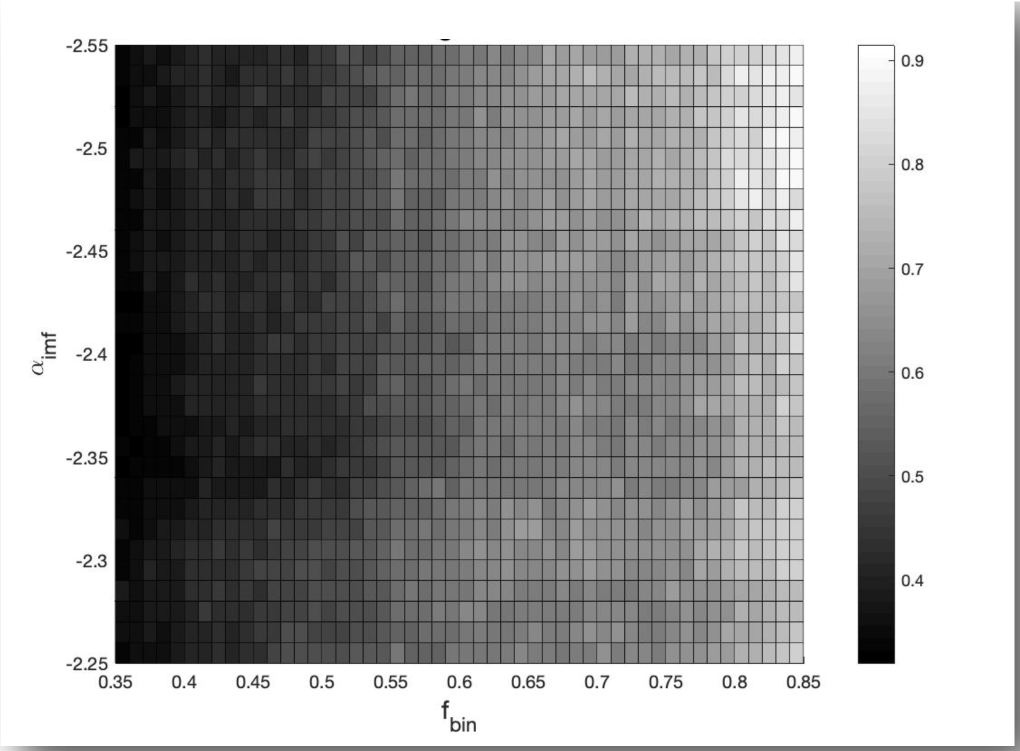
$7.0 \pm 0.2\%$ $WDMS_{res}$



- Observed values for high f_{bin}=0.7-0.8 regardless of α_{IMF}

4. Results

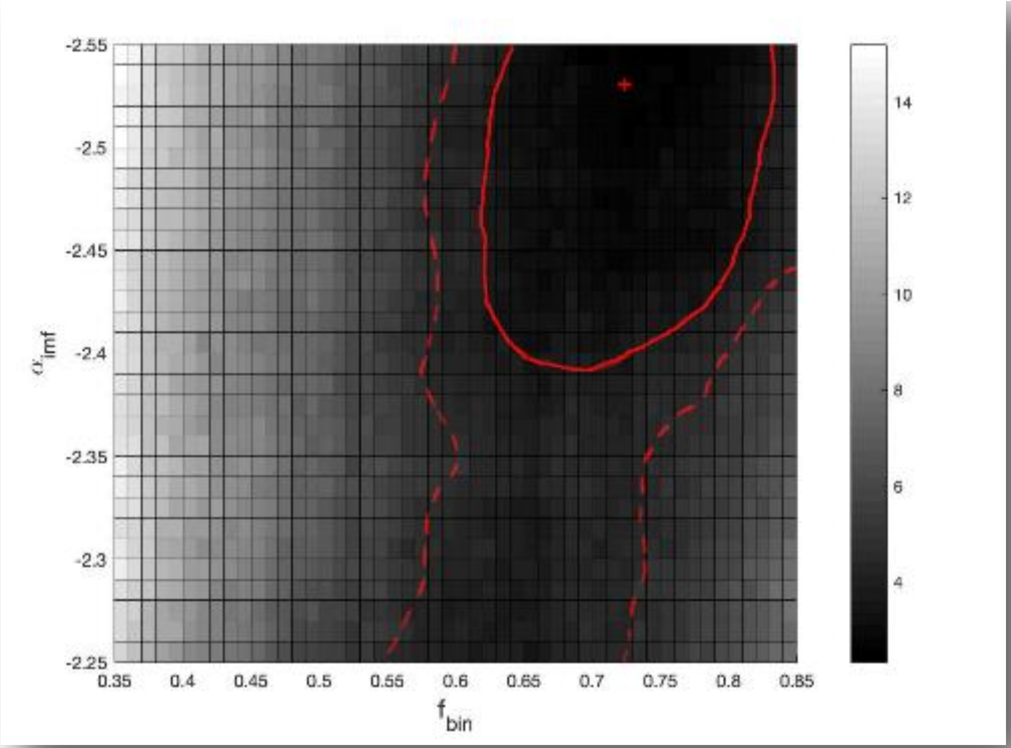
- % HeWD



- %HeWD highest values ~1% are far from estimated 3% low mass WDs
- This 3% shall be unresolved DWD

4. Results

- D-estimator: $D=\sqrt{[(\%DWD_{res}-1.4)^2+(\%MSWD_{res}-7.0)^2]}$



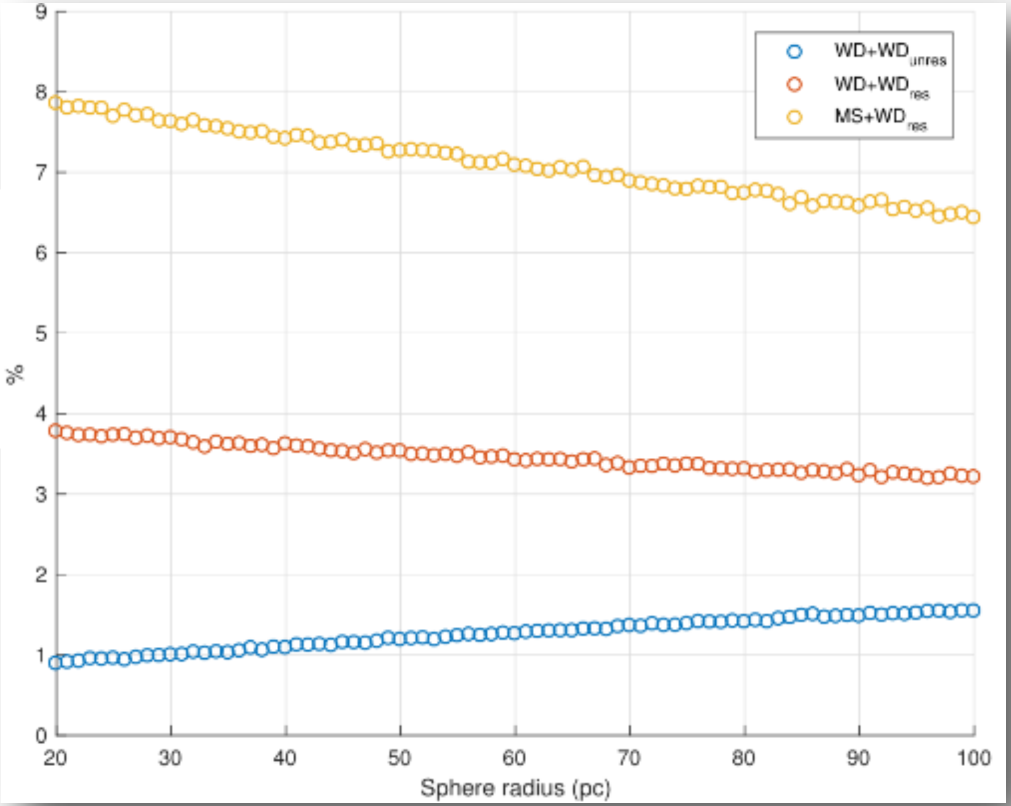
- Best-fit:
  $f_{bin}=0.72$ &
  $\alpha_{IMF}=-2.53$
- 1σ level:
  $f_{bin}=\sim0.62-0.8$ &
  $\alpha_{IMF}=-2.4-2.55$
- 2σ level:
  $f_{bin}=\sim0.58-0.8$ regardless of α_{IMF}

- % for the best-fit model:
  - 2.86% DWD_{res}; 6.35% $WDMS_{res}$; 1.51% DWD_{unres} ; 0.30% HeWD
  - Final binary fraction ~15%

4. Results

- % as a function of the simple size

20 pc sample:
3.7 % DWD_{res}
8.3 % $MSWD_{res}$
0.8 % DWD_{unres}



100 pc sample:
2.9 % DWD_{res}
6.4 % $MSWD_{res}$
1.5 % DWD_{unres}

5. Conclusions

- The *Gaia*-DR2 catalogue up to 100 pc represents the larger complete (volume-limited) sample to date
- We analyzed the % of the different subpopulations: DWD, MSWD, resolved and unresolved
- Our population synthesis analysis reveals that:
  - Best-fit: f_{bin}=0.72; $n(q)=q^{-1}$; Sep=BPL; α_{IMF}=-2.53
  - 1σ level: f_{bin}=~0.62-0.8 & α_{IMF}=-2.4-2.55
  - 2σ level: f_{bin}=~0.58-0.8 regardless of α_{IMF}
- Closer to observed values:
  - Best-fit model: 2.9% DWD_{res}; 6.4% $WDMS_{res}$; 1.5% DWD_{unres} ; 1% HeWD
  - Observed values: 1.4% DWD_{res}; 7.0% $WDMS_{res}$; 3% 'low mass' WDs
- Large fraction of mergers >30%

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