# POPCORN:
## Hunting down the differences in population synthesis codes

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## Scientific question

Binary population synthesis codes (BPS codes) enable the entire evolution of a large number of binary systems. BPS codes are aimed for the study of the formation and evolution of astronomical populations, e.g. novae, X-ray binaries and type Ia supernovae. In this research we compare the results of 3 different BPS codes and investigate the importance of the different assumptions in these codes.

## Different BPS codes

For this project different BPS code are compared:

- Binary_c: Based on Hurley et al. (2000, 2002), with updates described in Izzard et al. (2006) and Claeys et al. (in prep.)
- SeBa: Based on Portegies Zwart et al. (1996), with updates described in Nelemans et al. (2001) and Toonen et al. (in prep.)
- Brussels code: Based on Vanbeveren et al. (1998), with updates described in Mennekens et al. (2010)

## Assumptions for the comparison

In order to make the comparison we equalize the assumptions, to compare the inherent differences of the different BPS codes. These assumptions are not necessarily considered to be realistic.

- Conservative mass transfer to all types of stars
- No tides, magnetic braking, wind accretion, eccentricities
- Common envelope evolution prescription: Webbink (1984)
- Same initial distributions (primary mass, mass ratio, separation)

In order to investigate the effect of the differences in the BPS codes, we look at two populations at their time of formation

- Single WD systems with a non-degenerate companion
- Double WD systems

## Conclusion

Different BPS codes give similar results for the formation of binary WDs, when the assumptions are equalized. The differences in their results are not due to numerical differences, but can be explained by differences in the input physics.

## References

[1] Hurley, J. R. et al., 2000, MNRAS, 315, 543
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[3] Izzard, R. G. et al., 2006, A&A, 460, 565
[4] Portegies Zwart, S. F., & Verbunt, F., 1996, A&A, 309, 179
[5] Nelemans, G. et al., 2001, A&A, 368, 939
[6] Vanbeveren, D. et al., 1998, NewA, 3, 443
[7] Mennekens, N. et al., 2010, A&A, 515, A89
[8] Webbink, R. F. 1984, ApJ, 277, 355

## Results

We analyzed the results of and investigated the evolution paths towards the two populations of binary WDs, in order to have a complete -within the limits of this project- overview of the similarities and causes of the differences in the results of the BPS codes.

- Formation of a single WD with a non-degenerate companion:

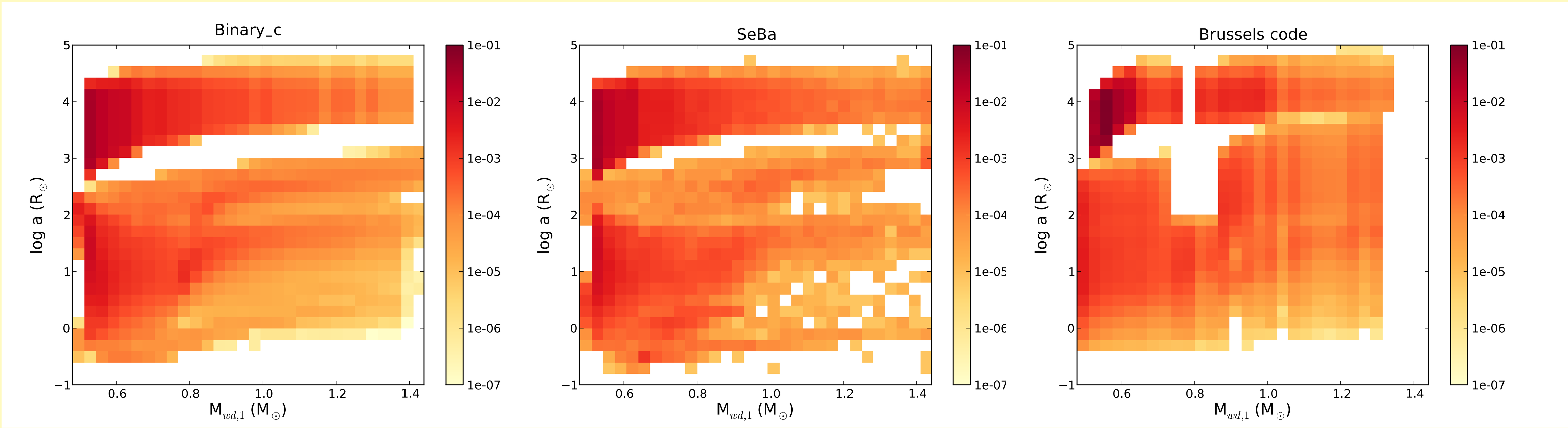


Fig. 1) Mass of the primary WD versus the separation at the moment of formation of the WD, given by the different BPS codes. The numbers of the systems are normalized to the total number of the systems forming 1 WD with a non-degenerate companion.

**Similarities:**

- Percentage of simulated systems forming a single WD system with a non-degenerate companion (for $M_{WD} > 0.48\ M_\odot \Rightarrow$ Binary_c: 33.4%, SeBa: 36.2%, Brussels code: 30.5%)
- $\log a \gtrsim 3$: Non-interacting systems
- $3 \gtrsim \log a \gtrsim 1.5$: Systems resulting from stable mass transfer towards the companion
- $\log a \lesssim 1.5$: Systems resulting from unstable mass transfer

- Formation of a double WD system:

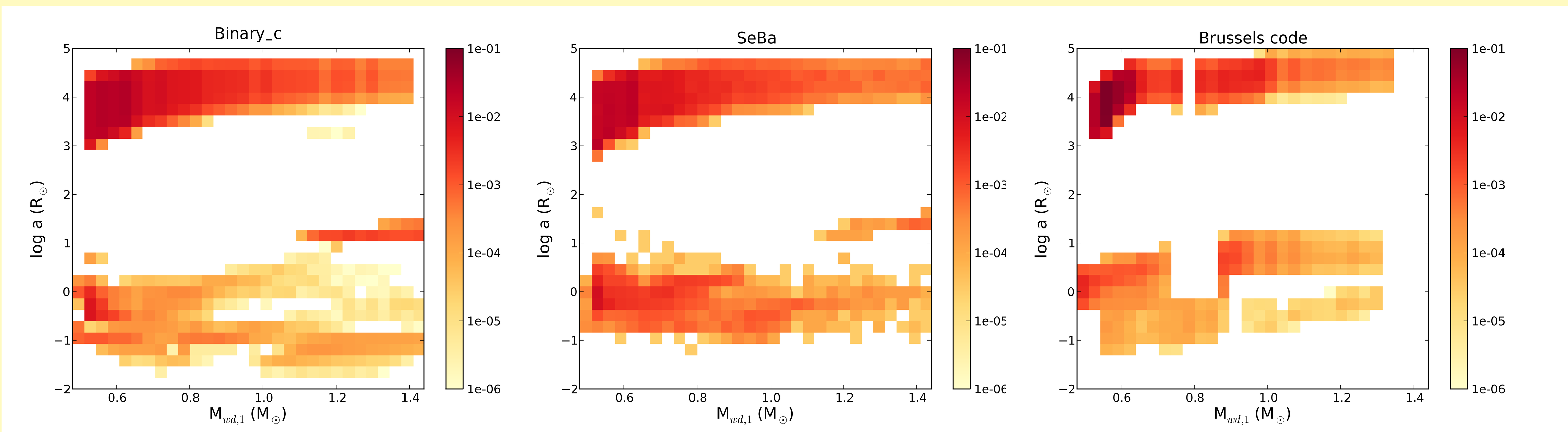


Fig. 2) Mass of the primary WD versus the separation at the moment of formation of the second WD, given by the different BPS codes. The numbers of the systems are normalized to the total number of the systems forming 2 WDs.

**Similarities:**

- Percentage of simulated systems forming a double WD system (for $M_{WD,1,2} > 0.48\ M_\odot \Rightarrow$ Binary_c: 8.8%, SeBa: 9.7%, Brussels code: 14.4%)
- $\log a \gtrsim 3$: Non-interacting systems
- $\log a \sim 1$: Systems resulting from a first mass transfer phase which is unstable and a second phase which is stable (in the results of the BPS codes SeBa and Binary_c)
- $\log a \lesssim 1.5$: Systems resulting from a first mass transfer which can be stable or unstable and a second phase which is unstable

The predicted population of binary WDs (with another WD or a non-degenerate companion) are similar.(see Figs. 1 & 2), but small differences can be noticed. These are due to the differences in the input physics:

- **Initial-final mass relation**: This determines which mass the WD will have when the original star loses its envelope through wind or mass transfer.
- **Stability criterion**: This defines if mass transfer is stable or not and therefore defines the properties of the binary system after mass transfer.
- **Mass transfer rate**: If mass transfer is stable, the exact rate and duration of this phase can affect how the companion star reacts to mass gain.
- **Wind prescription**: Differences in the wind can be in the mass-loss rate, but also the angular momentum that is lost through the wind. Both change the properties of the binary systems at the onset of mass transfer and therefore also after.
- **He star evolution**: He star evolution includes the wind mass loss, the mass transfer rate and the stability criterion of these type of stars, which is yet not well studied. A He-star can have a radius varying by a few orders of magnitude.