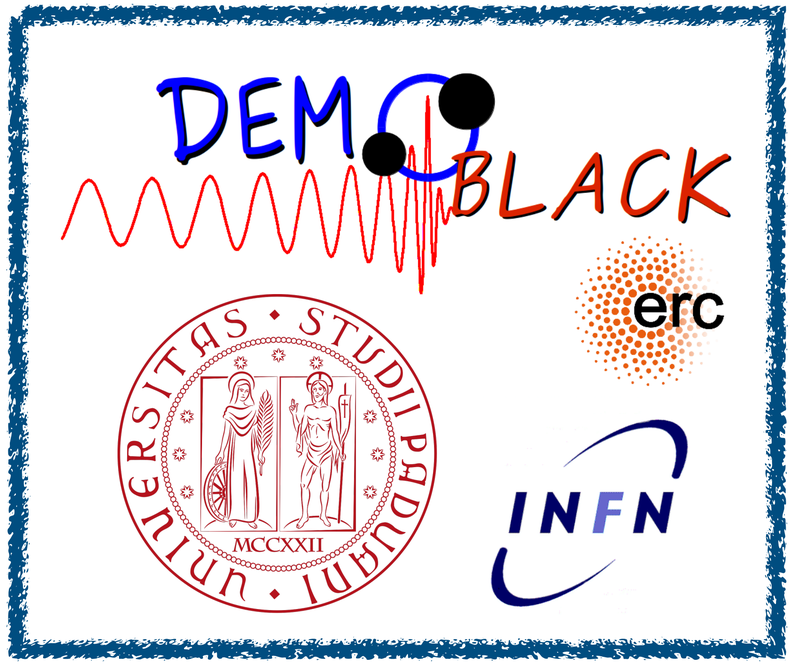
Modelling the host galaxies of binary compact object mergers with observational scaling relations

ArXiv: 2205.05099

Authors: Filippo Santoliquido, Michela Mapelli, M. Celeste Artale and Lumen Boco

Other collaborators: Irina Dvorkin (IAP) and Stanislav Babak (APC)



Quick introduction

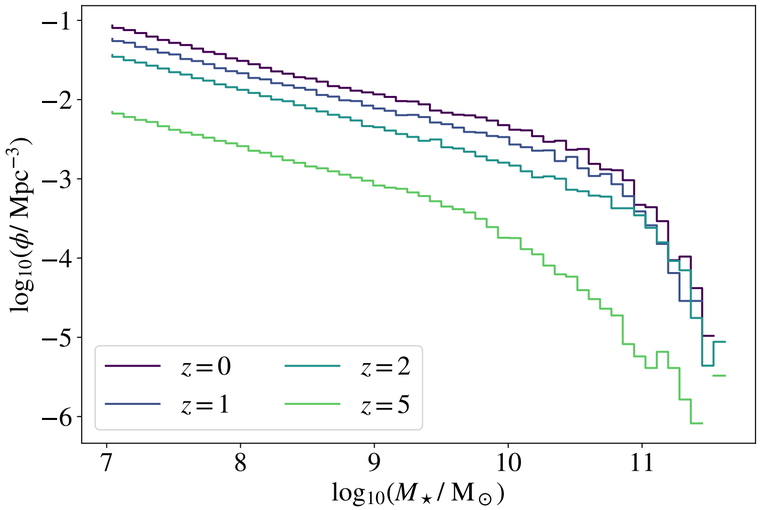
- **Break the title down:** *“Modelling the host galaxies of binary compact object mergers with observational scaling relation”*
- **Goal**: link the properties of compact objects (different astrophysical models) to the properties of galaxies (huge parameter space)
- Host galaxies through cosmological simulations
- Take advantage of **observational properties of galaxies**

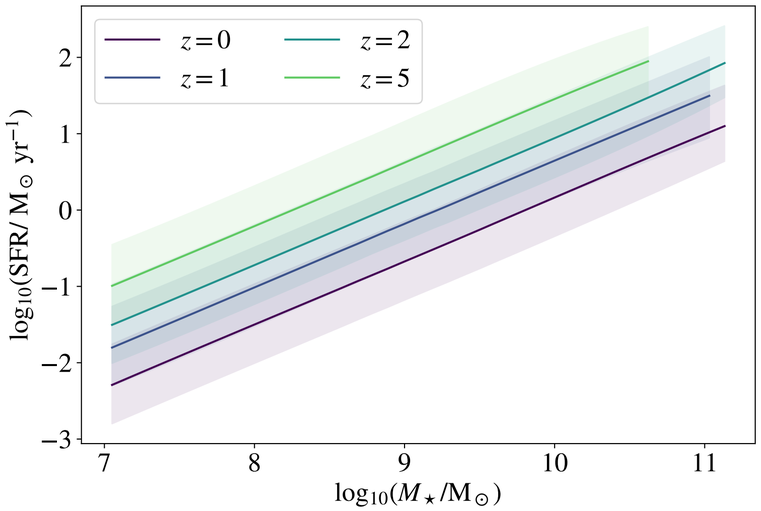
General scheme of `galaxyRate`

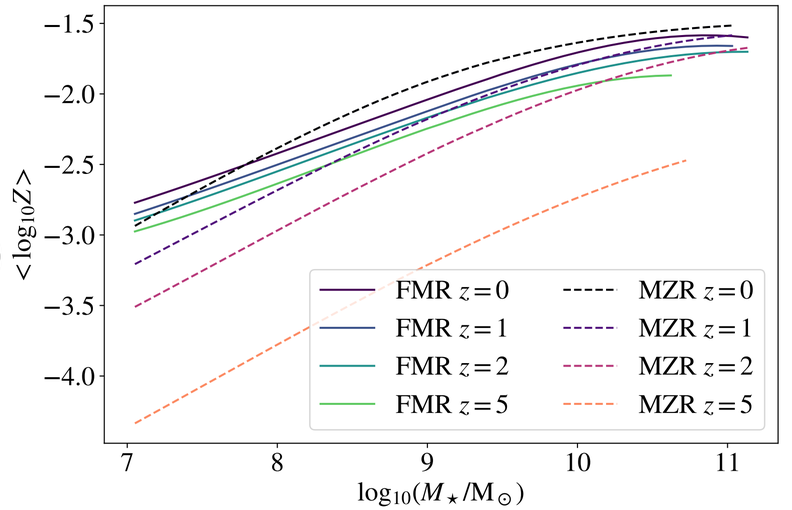
General scheme of galaxyRate

Formation galaxies → Merging compact objects → Host galaxies

We create a population of star-forming galaxies, each of them defined by its **stellar mass**, its **star-formation rate** and its **metallicity**.







Chruslinska et al. 2019

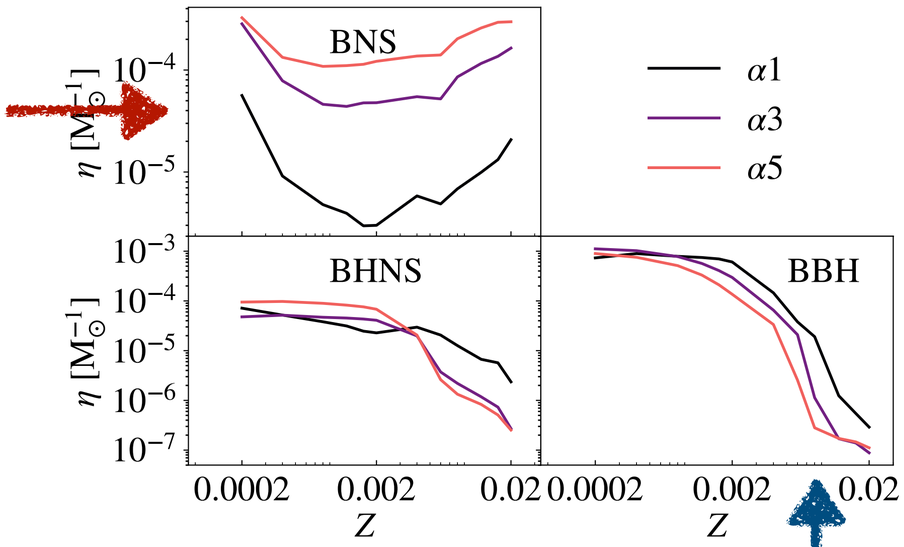
Speagle et al. 2014, Boogaard et al. 2018

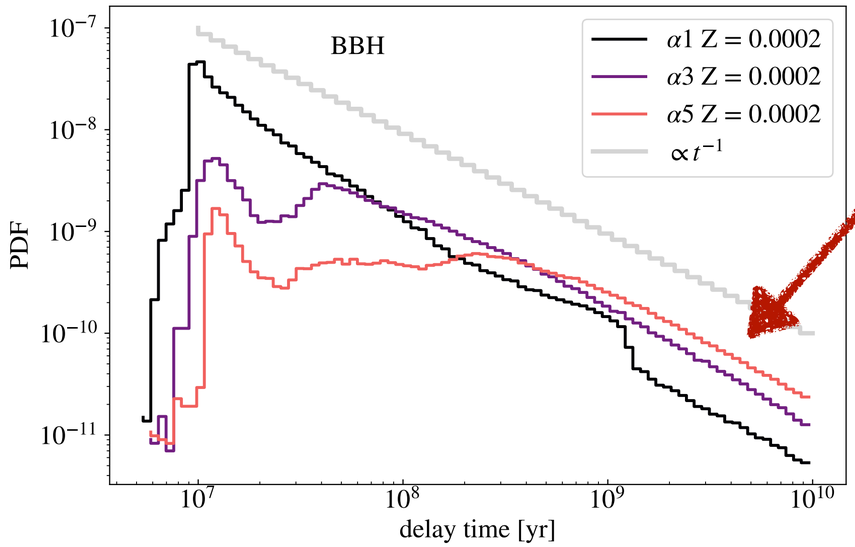
Mannucci et al. 2009, Mannucci et al. 2011

General scheme of galaxyRate

Formation galaxies → Merging compact objects → Host galaxies

Effect of common envelope





Effect of common envelope

Effect of progenitor metallicity

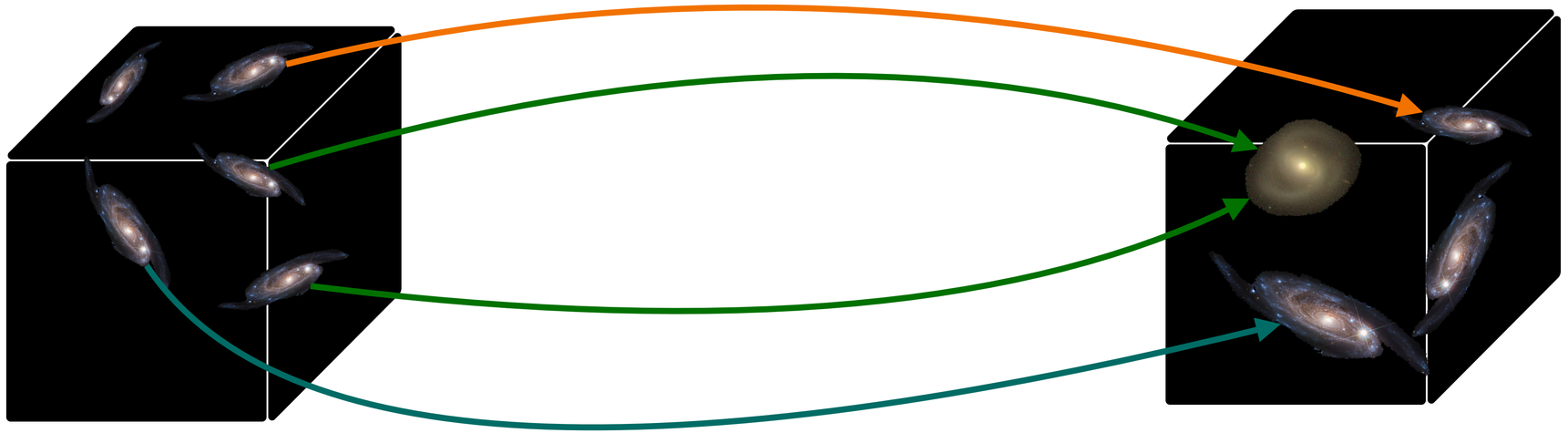
General scheme of galaxyRate

Formation galaxies → Merging compact objects → Host galaxies

From the **merger trees** of the EAGLE cosmological simulation we compute empirically

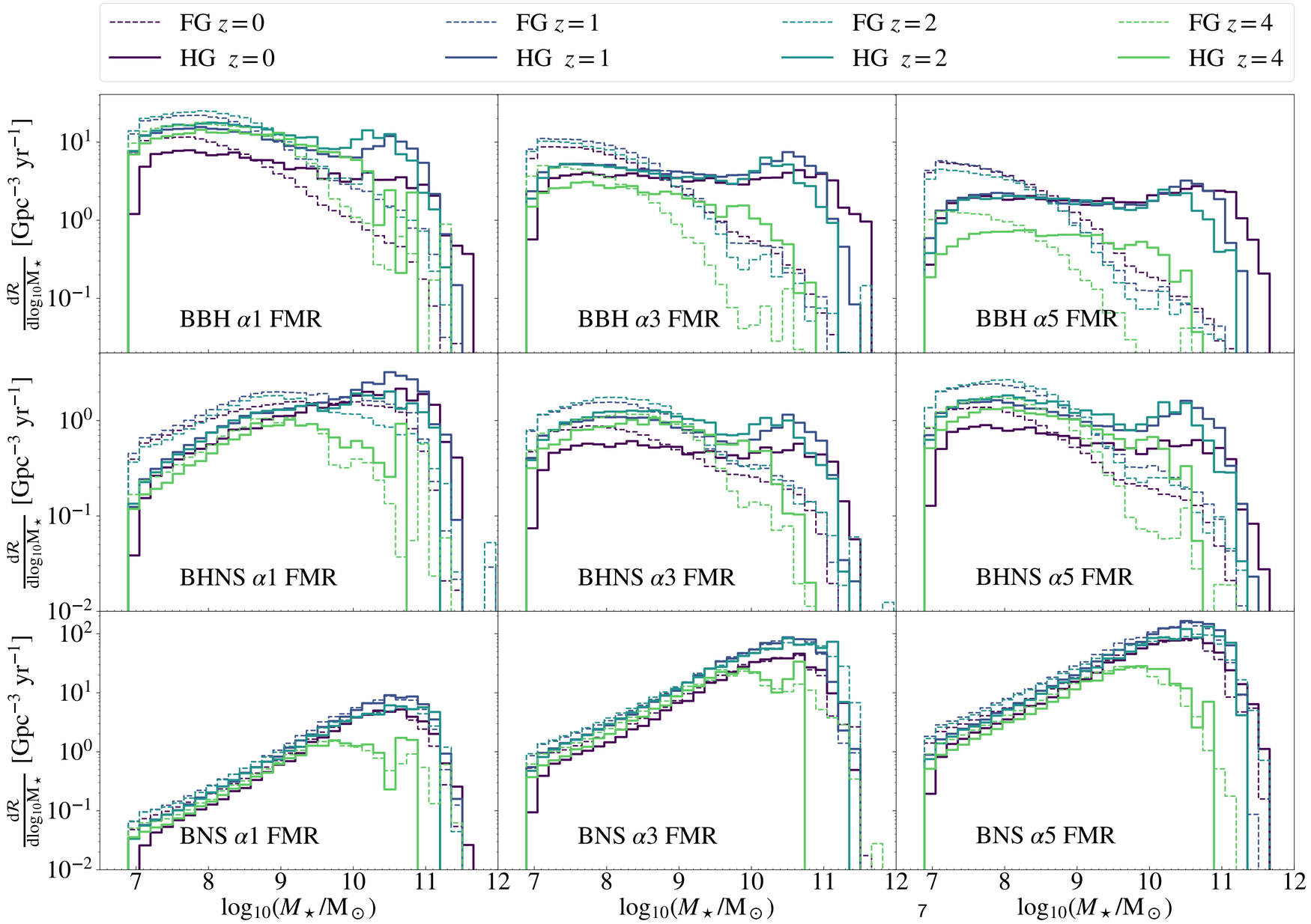
the following conditional probability $p(\mathrm{M}_{host}, \mathrm{SFR}_{host} \,|\, \mathrm{M}_{form}, \mathrm{SFR}_{form}, z_{form}, z_{merg})$.

Universe at z_{form} Universe at z_{merg}



If **multiple** formation galaxies are **linked to the same host galaxy**, their merger rates are **summed together**

Host galaxies of merging compact objects

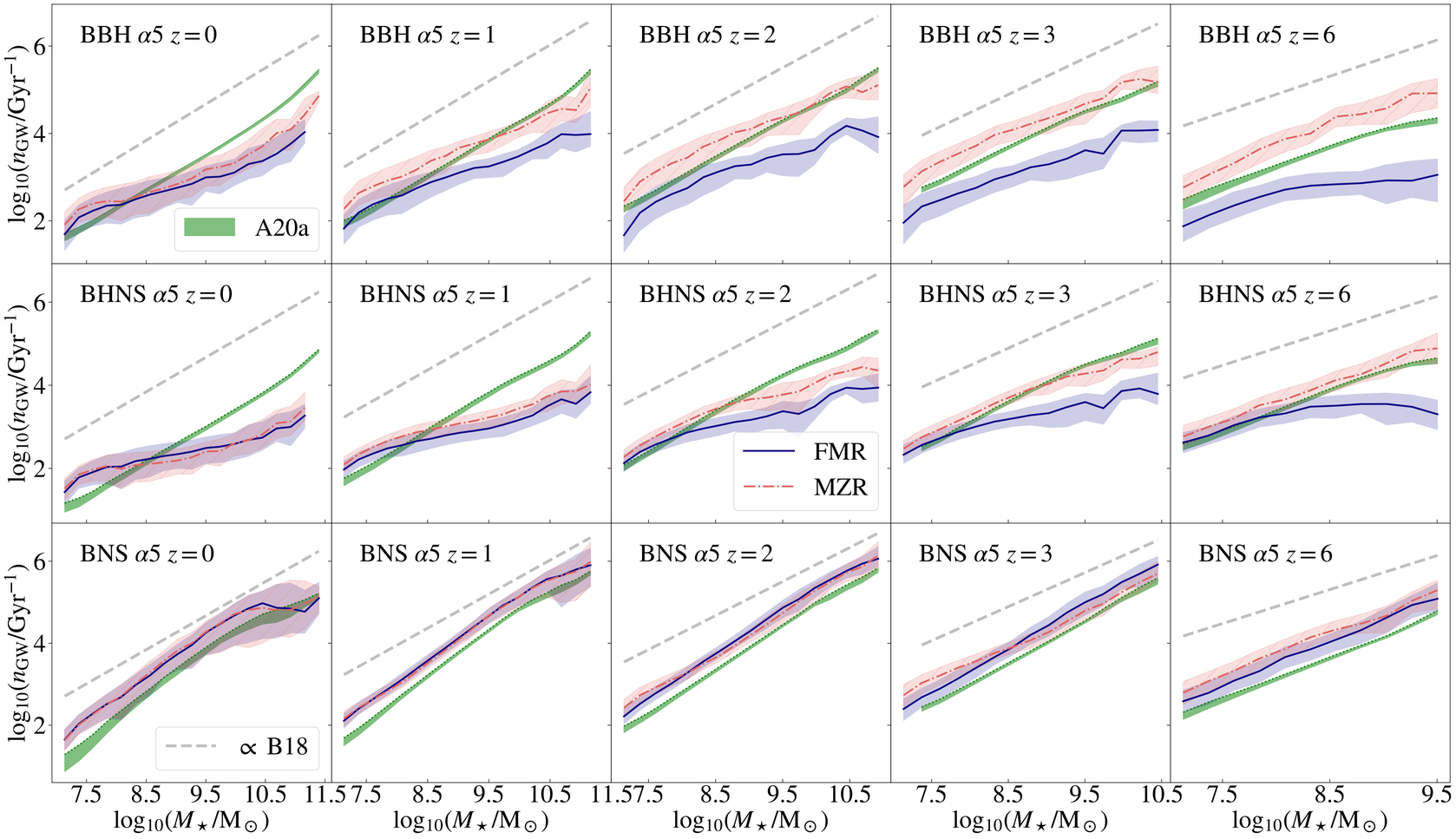


- Here is the **distribution** of merger rate density per **galaxy mass.** We compare the formation galaxy (FG) with the host galaxy (HG)
- Large fraction of **BBHs is hosted** in **low-mass** galaxies
- Contribution of **high-mass** galaxies increases with **increasing** α

Filippo Santoliquido

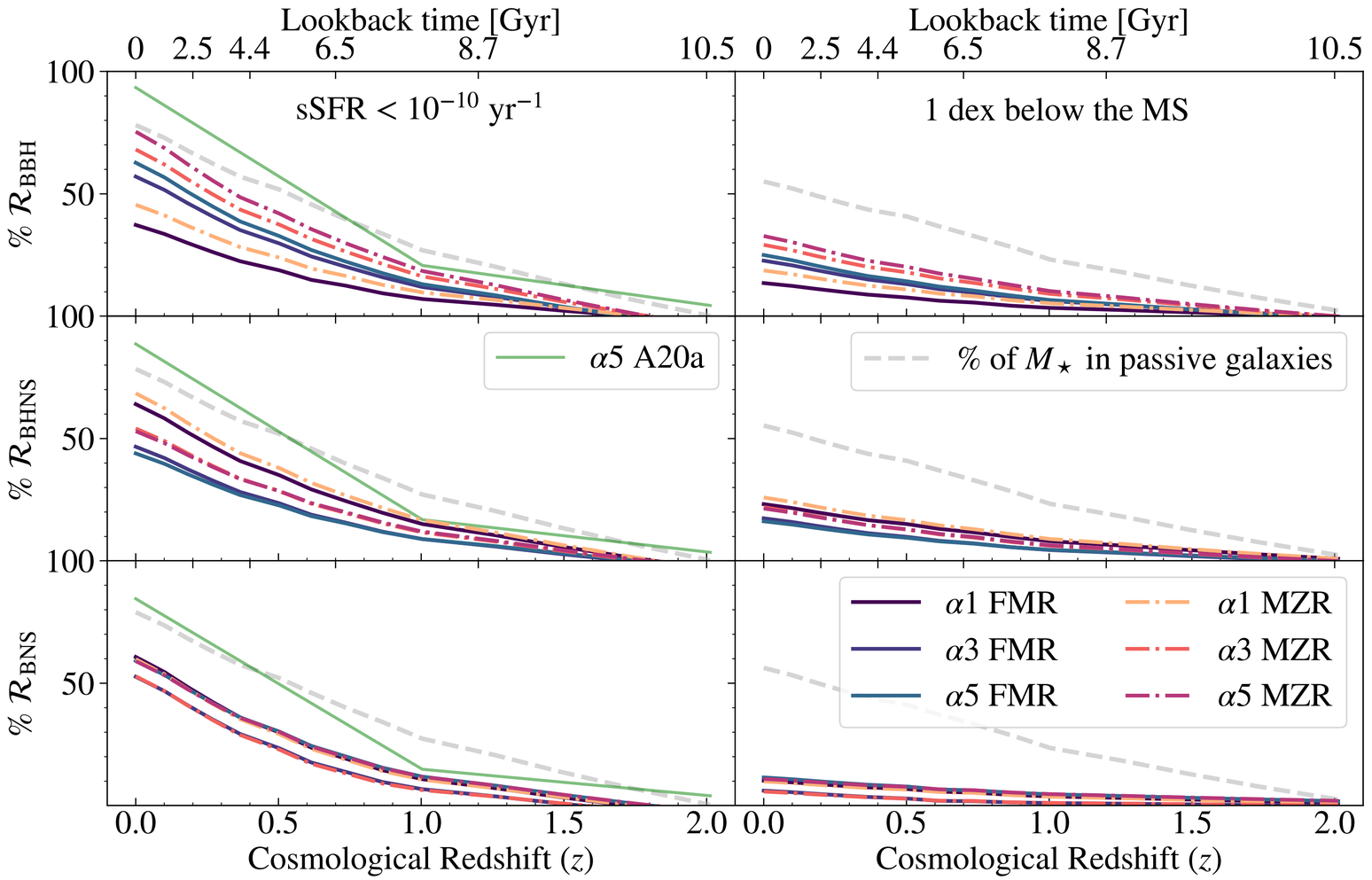
Merger rate per galaxy

- Here we are showing the **merger rate per galaxy** as function of **stellar mass**
- We compare it with results obtained in *Artale et al. 2020* considering EAGLE **cosmological simulation**
- Slope of the correlation of $n_{\rm GW}$ with stellar mass depends on **redshift** and **metallicity evolution** model for BBHs



Passive galaxies

- This plots shows the **mergers hosted by passive galaxies**, showing here two definition of passive galaxies (*Artale et al. 2019*, *Donnari et al. 2021*)
- Percentage of mergers hosted by passive galaxies **increases at decreasing redshift**
- For **BBHs** the percentage of mergers hosted in passive galaxies can changed by a **factor of ~2 depending on the considered model**



Check bibliography

Conclusions

- We **explored the properties** of **host galaxies** for a set of models, varying both the definition of formation galaxies and astrophysical models for binary evolution

---

- A **large fraction** of **BBHs** can merge **in low-mass host galaxies** and this depends on the delay time distribution.
- Strong correlation between the **BNS merger rate per galaxy** ($n_{\rm GW}$) and stellar mass of the host galaxy
- All compact objects have more chances to be hosted in **passive galaxies** if their **delay time distribution is longer**

Conclusions

Check bibliography

- We **explored the properties** of **host galaxies** for a set of models, varying both the definition of formation galaxies and astrophysical models for binary evolution

---

- A **large fraction** of **BBHs** can merge **in low-mass host galaxies** and this depends on the delay time distribution.
- Strong correlation between the **BNS merger rate per galaxy** ($n_{\rm GW}$) and stellar mass of the host galaxy
- All compact objects have more chances to be hosted in **passive galaxies** if their **delay time distribution is longer**

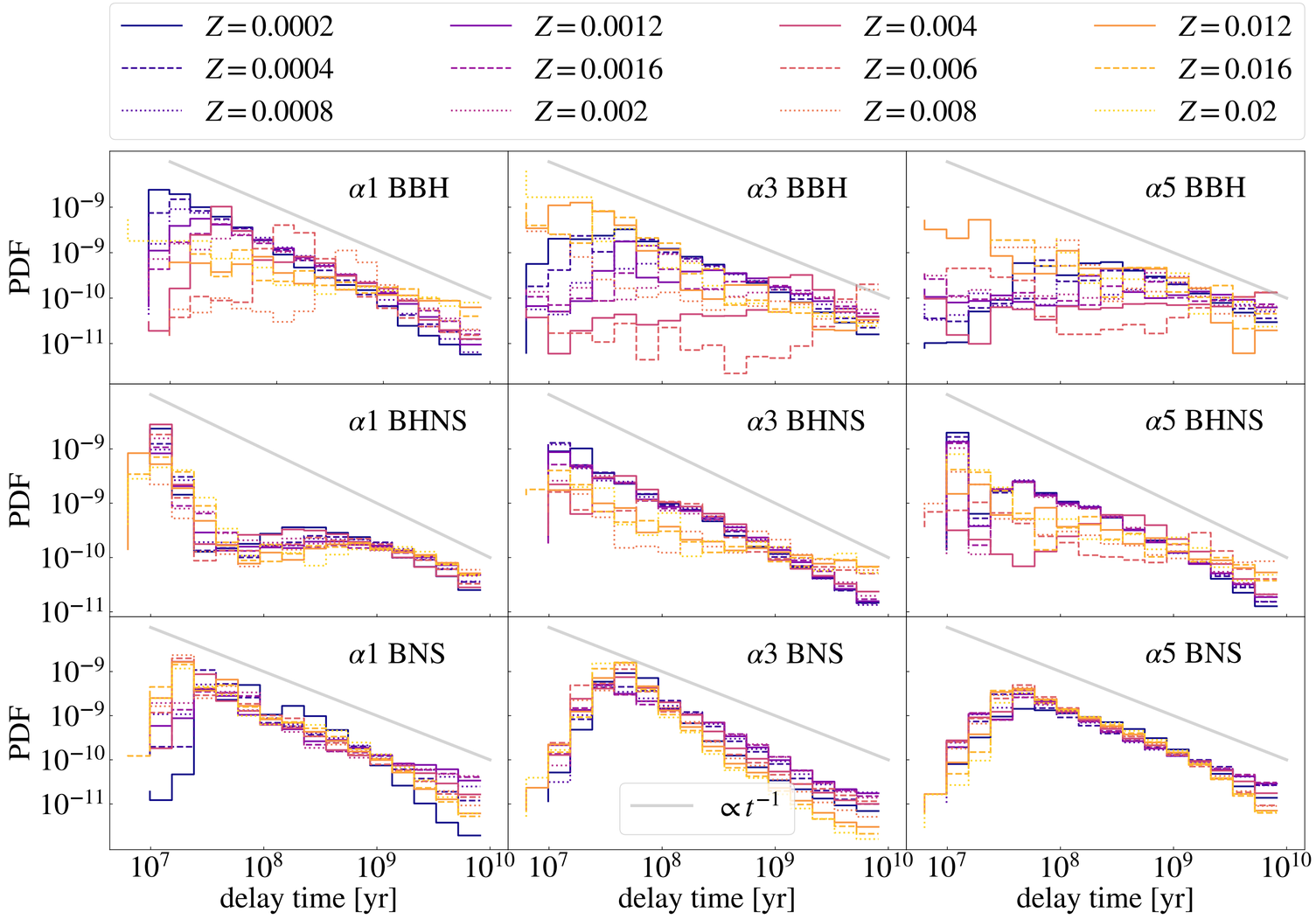
Thank you!

I'm happy to take your questions!

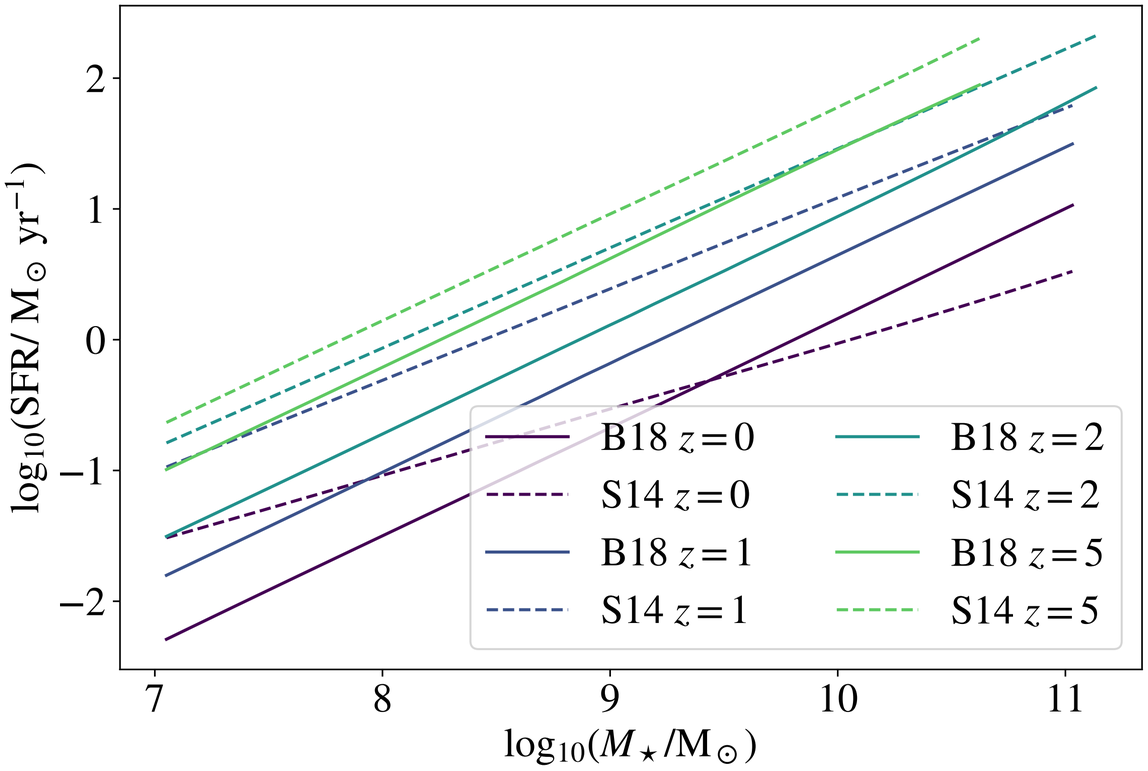
Backup slides

Delay time distribution

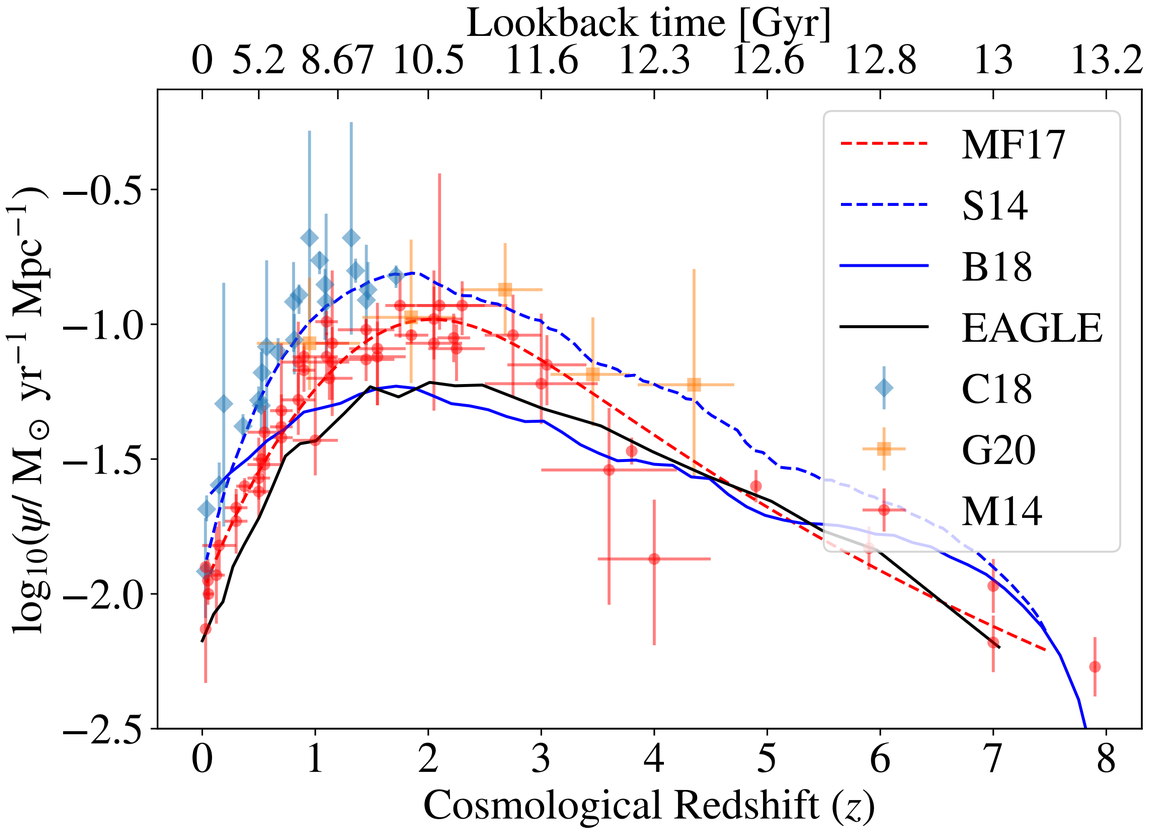
- The figure shows that if $\alpha = 1$ the delay time distribution peaks at shorter delay times than for larger values of α.
- A small value of α implies a more effective shrinking of the progenitor binary during common envelope.
- Figure shows that $\mathrm{d}N/\mathrm{d}t_{\mathrm{del}} \propto t_{\mathrm{del}}^{-1}$ for long delay times.



Different MS

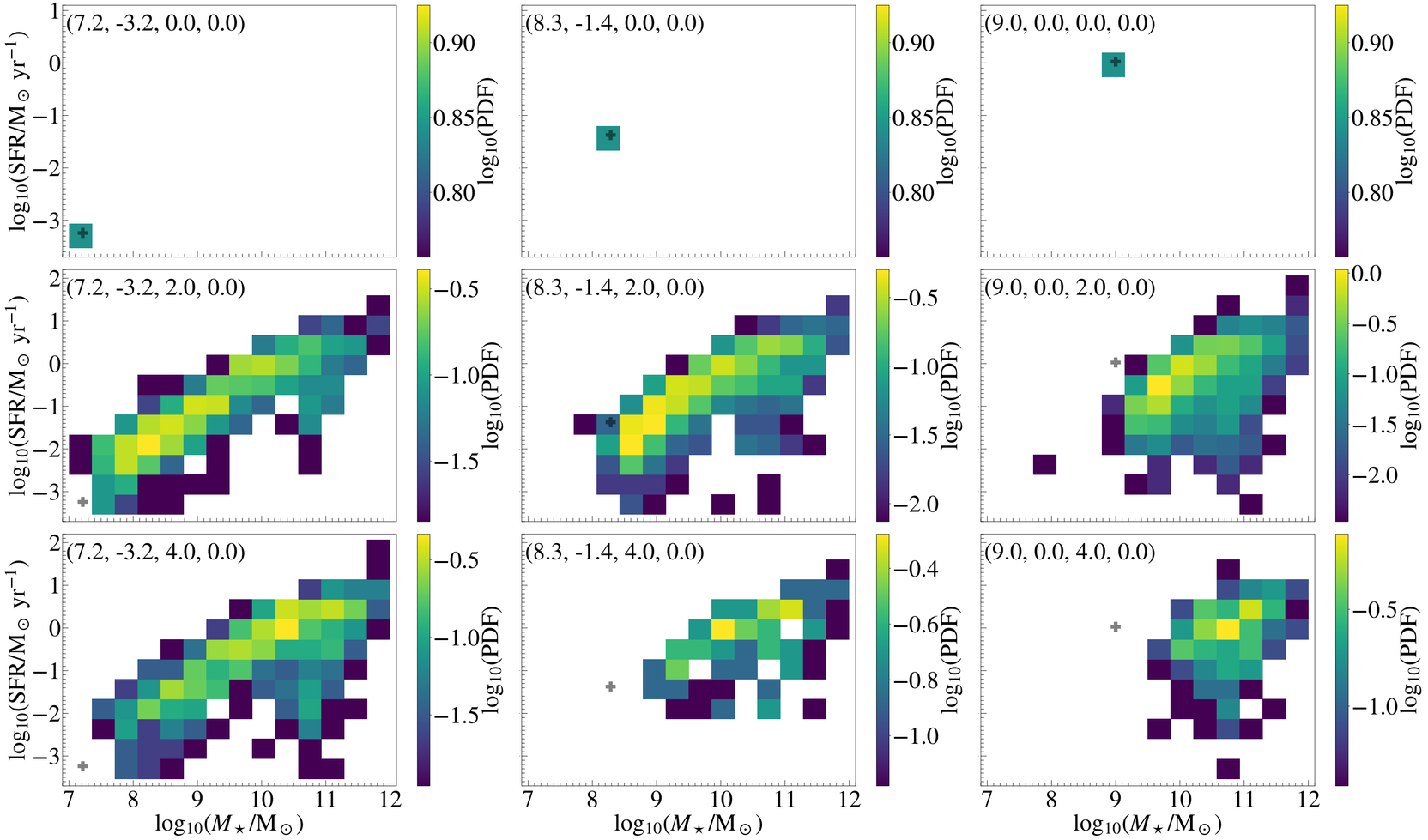


SFRD = GSMF x MS



Conditional Probability

The figure shows some examples of the conditional probability, for various properties of the formation galaxies, annotated at the top of each panel following the order $(\log_{10}(\mathrm{M_{form}/M_\odot}),\ \log_{10}(\mathrm{SFR_{form}/M_\odot yr^{-1}}),\ z_{\mathrm{form}})$



If the formation galaxy has no time to evolve (short delay time), the properties of the host galaxy remain the same (first row) as those of the formation galaxy, while if the formation galaxy has more time to evolve (long delay time) then the host galaxy can be very different from the formation galaxy.