Filippo Santoliquido - GWMess2021 Conference - April 1, 2021

The cosmic Merger Rate Density of compact binaries

Impact of star formation rate, metallicity, binary evolution and different formation channels.

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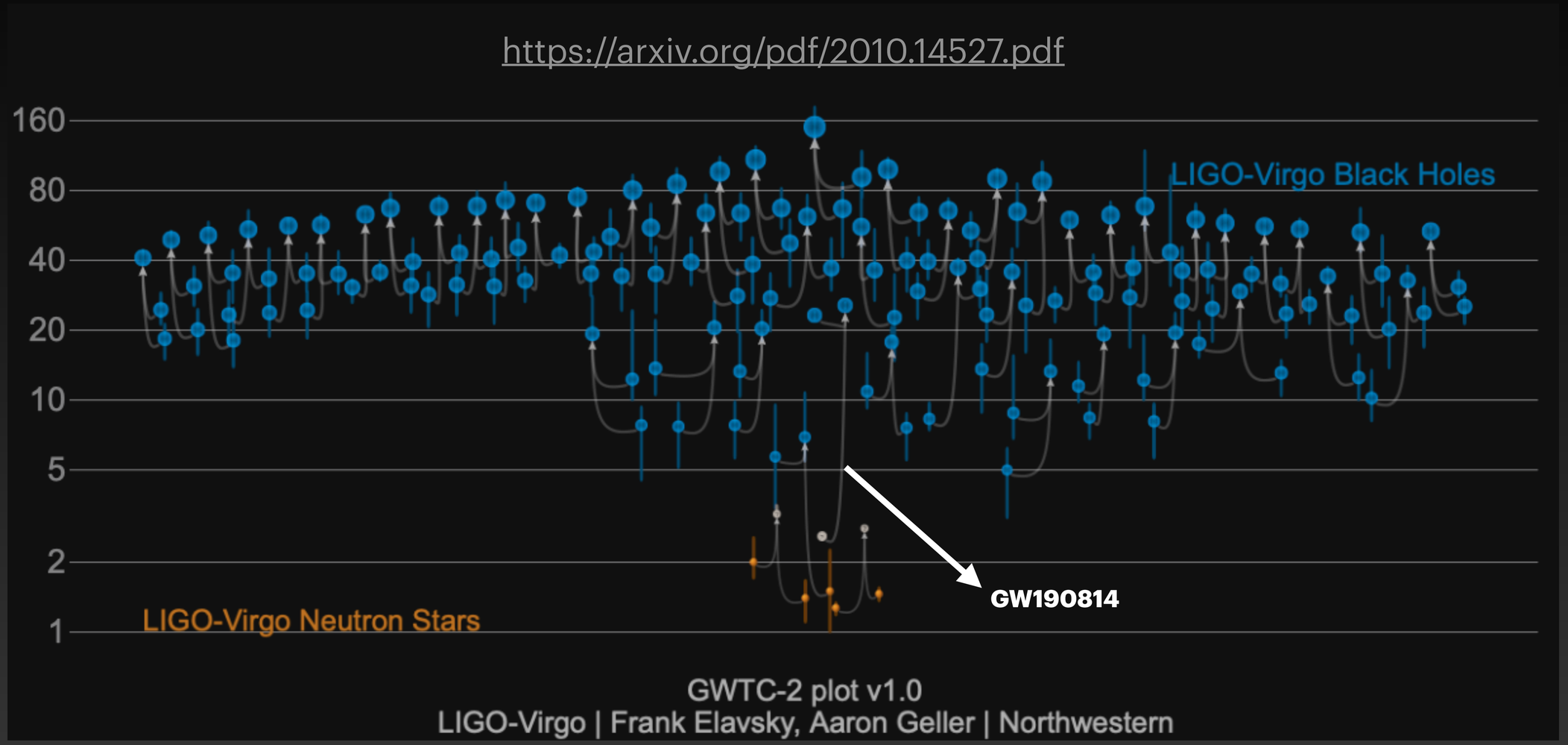
Co-supervisor: Nicola Giacobbo, Yann Bouffanais

2021 GW catalog: O1 + O2 + O3a

https://arxiv.org/pdf/2010.14527.pdf



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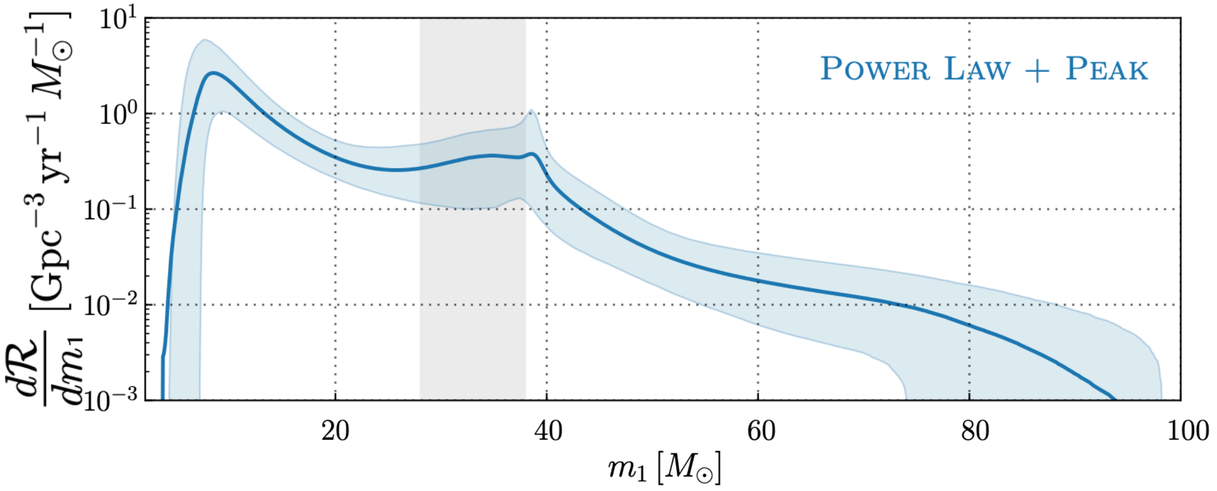
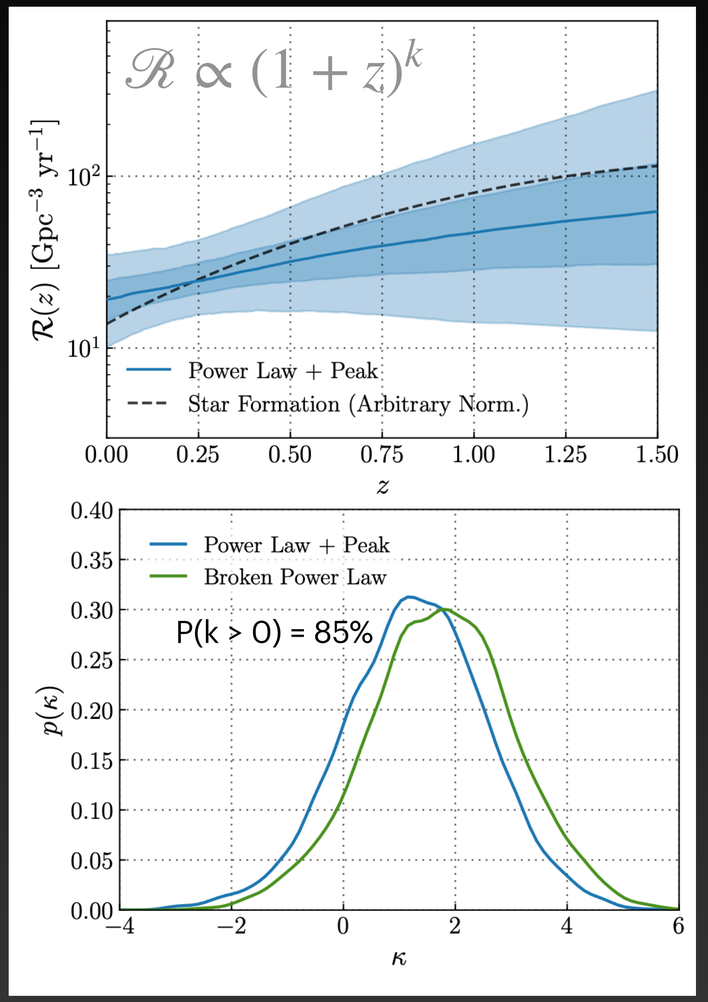
Merger Rate Density inferred from GW observations

https://arxiv.org/pdf/2010.14533.pdf

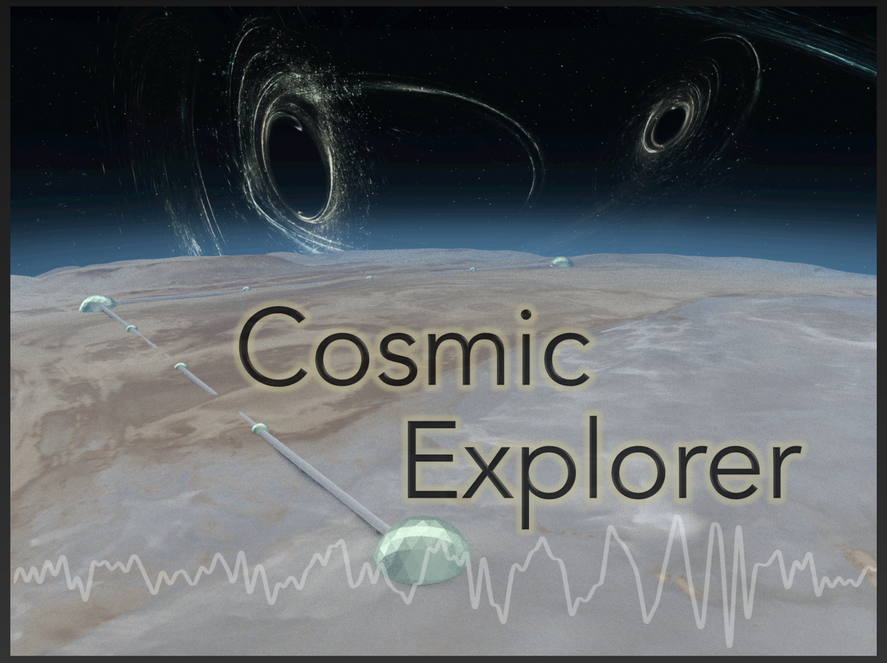


$$\mathcal{R}_{\rm BBH} = 23.9^{+14.9}_{-8.6}\,{\rm Gpc}^{-3}\,{\rm yr}^{-1}$$

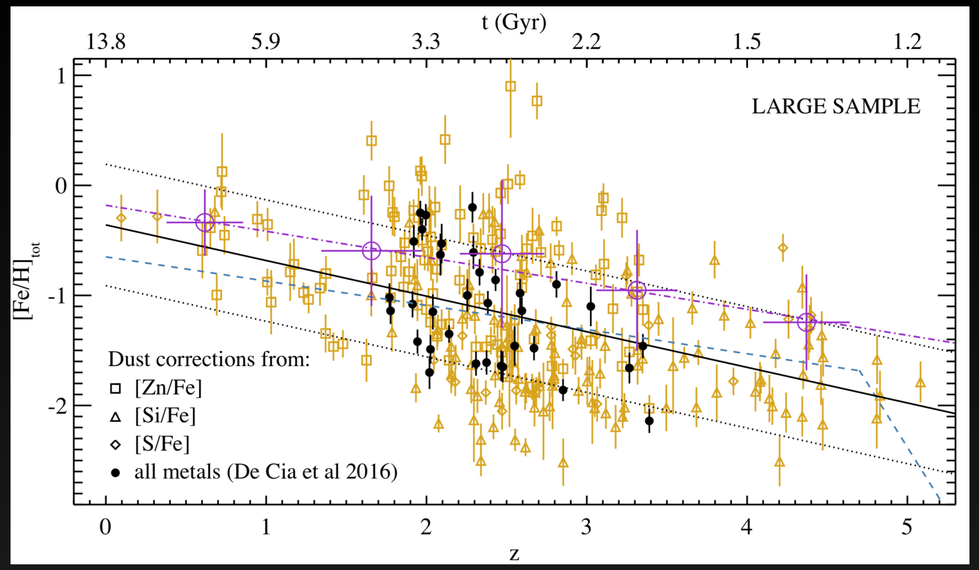


Future instruments

- Europe will build the **Einstein Telescope**, while the US are planning the **Cosmic Explorer**
- These are the so called third generation observatories
- They will be able to detect mergers at $z > 10$ for BBHs and $z < 2$ for BNSs (*Punturo et al. 2010*, *Reitze et al. 2019*, *Kalogera et al. 2019*, *Maggiore et al. 2020*)
- Thus, this is the right time to create the theoretical background of the merger rate density evolution

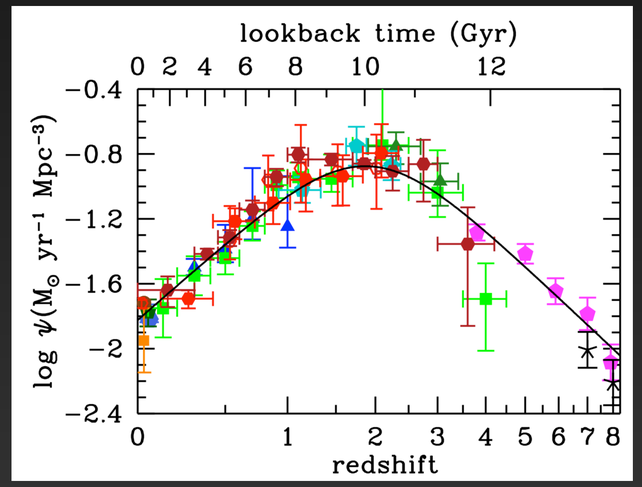


The model



De Cia et al. 2018,
Gallazzi et al. 2008

Madau & Fragos, 2017



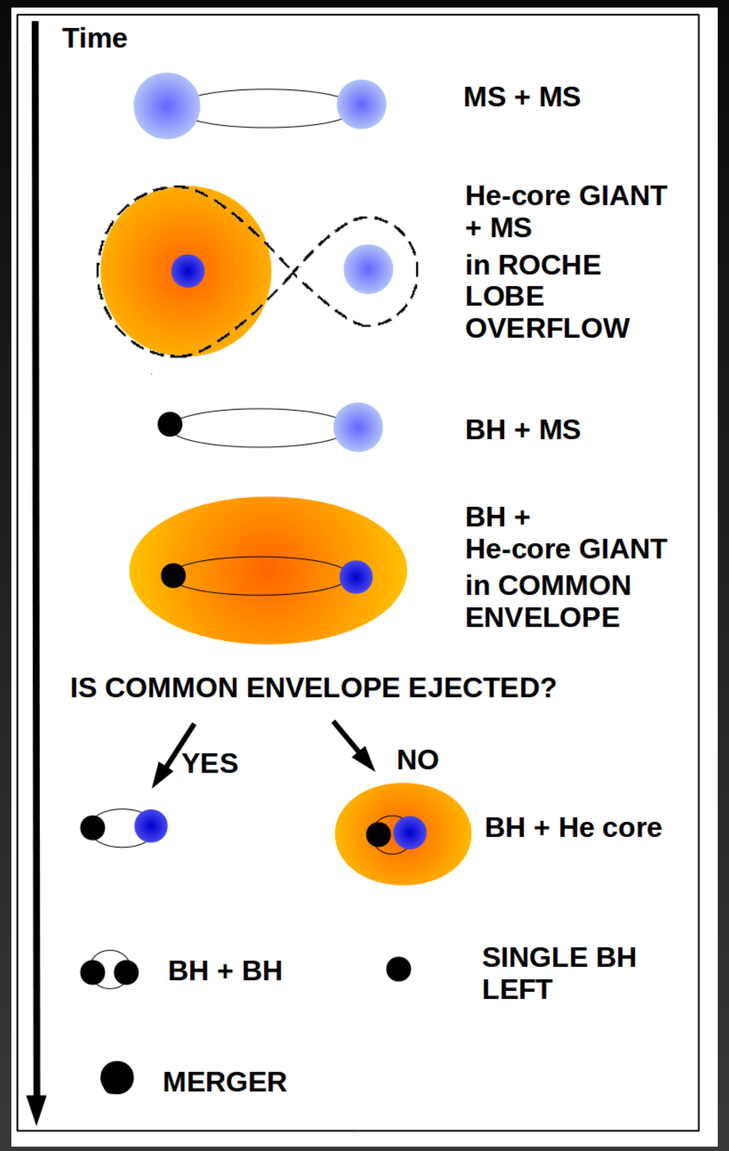
COSMORATE

Merging CB catalogues
(Dynamical or Isolated)

Cosmic merger rate density

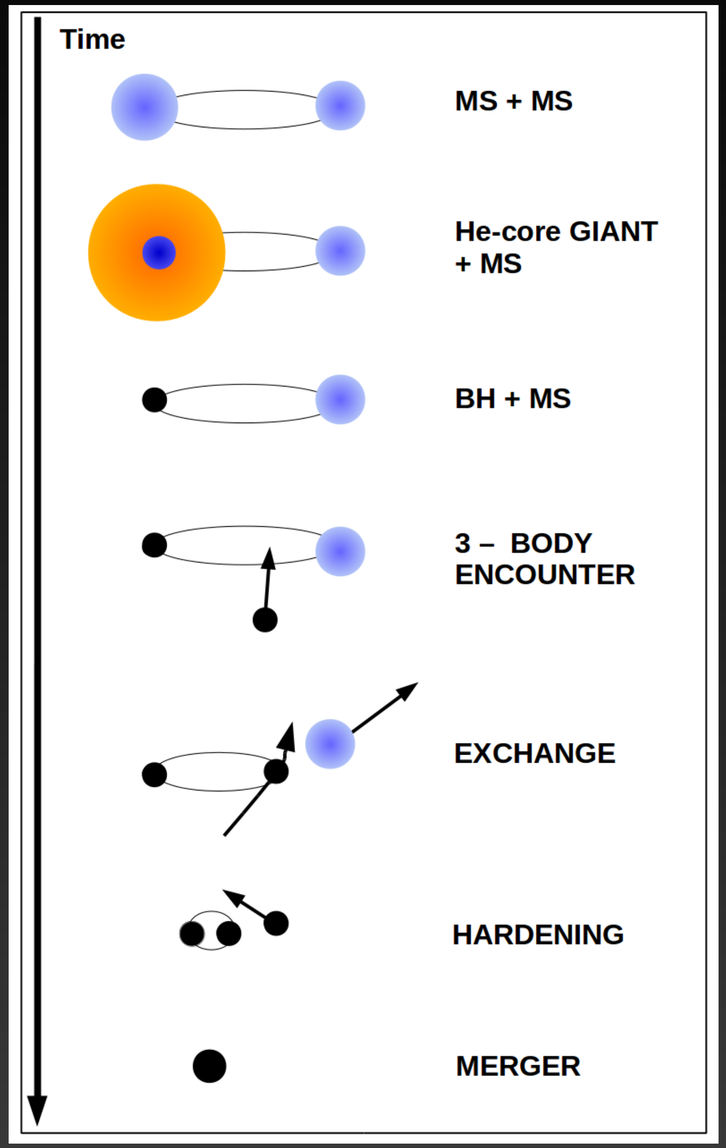
Giacobbo and Mapelli, 2018,
Di Carlo et al. 2020 and
Rastello et al. 2020

Two formation channels



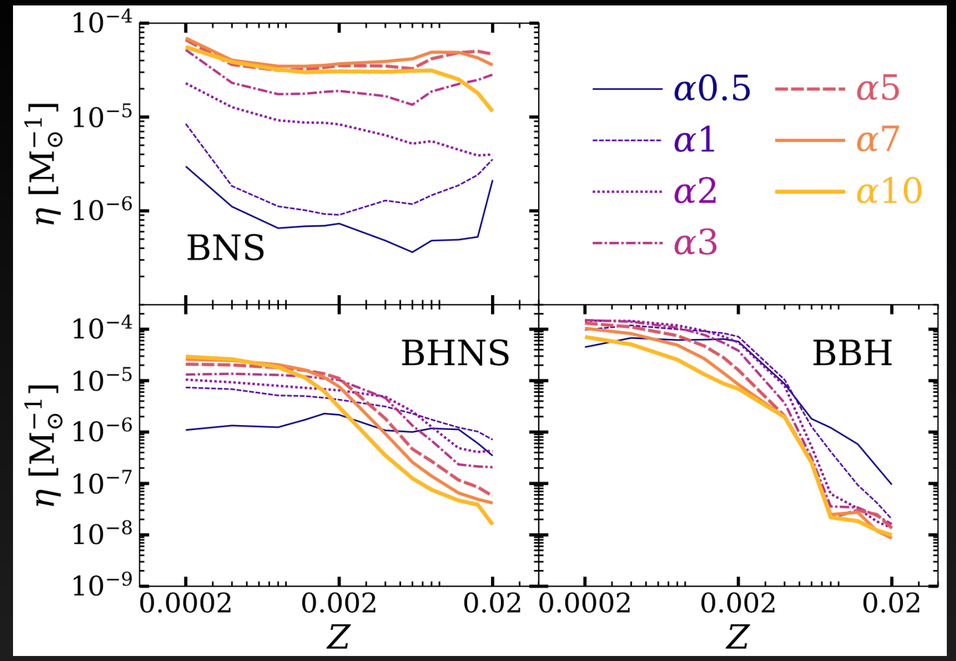
Isolated binaries have been investigated through population synthesis (MOBSE, *Giacobbo and Mapelli, 2018*)

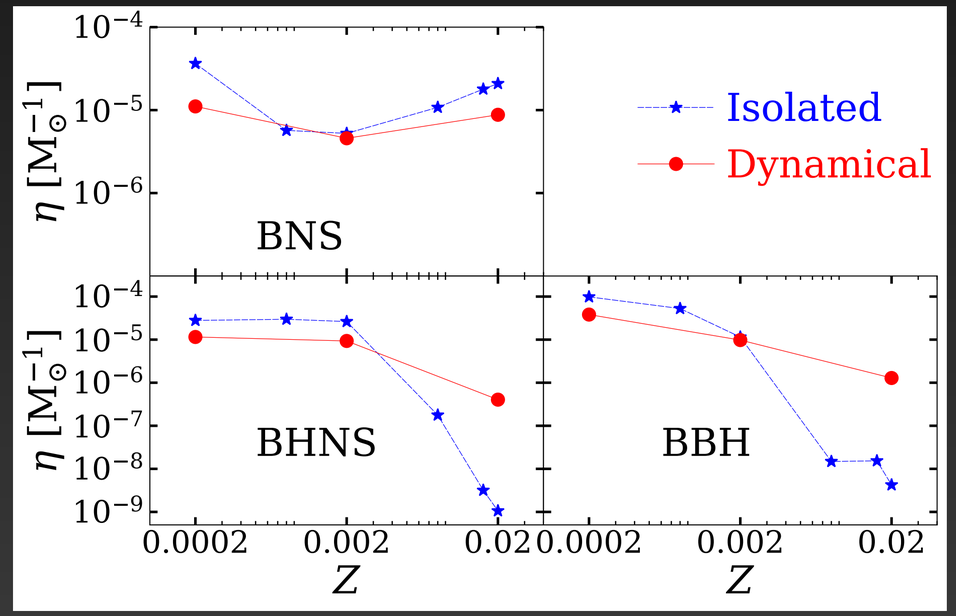
Dynamical binaries have been investigated through direct N-body simulation of young star clusters (*Di Carlo et al. 2020* and *Rastello et al. 2020*)



The merger efficiency

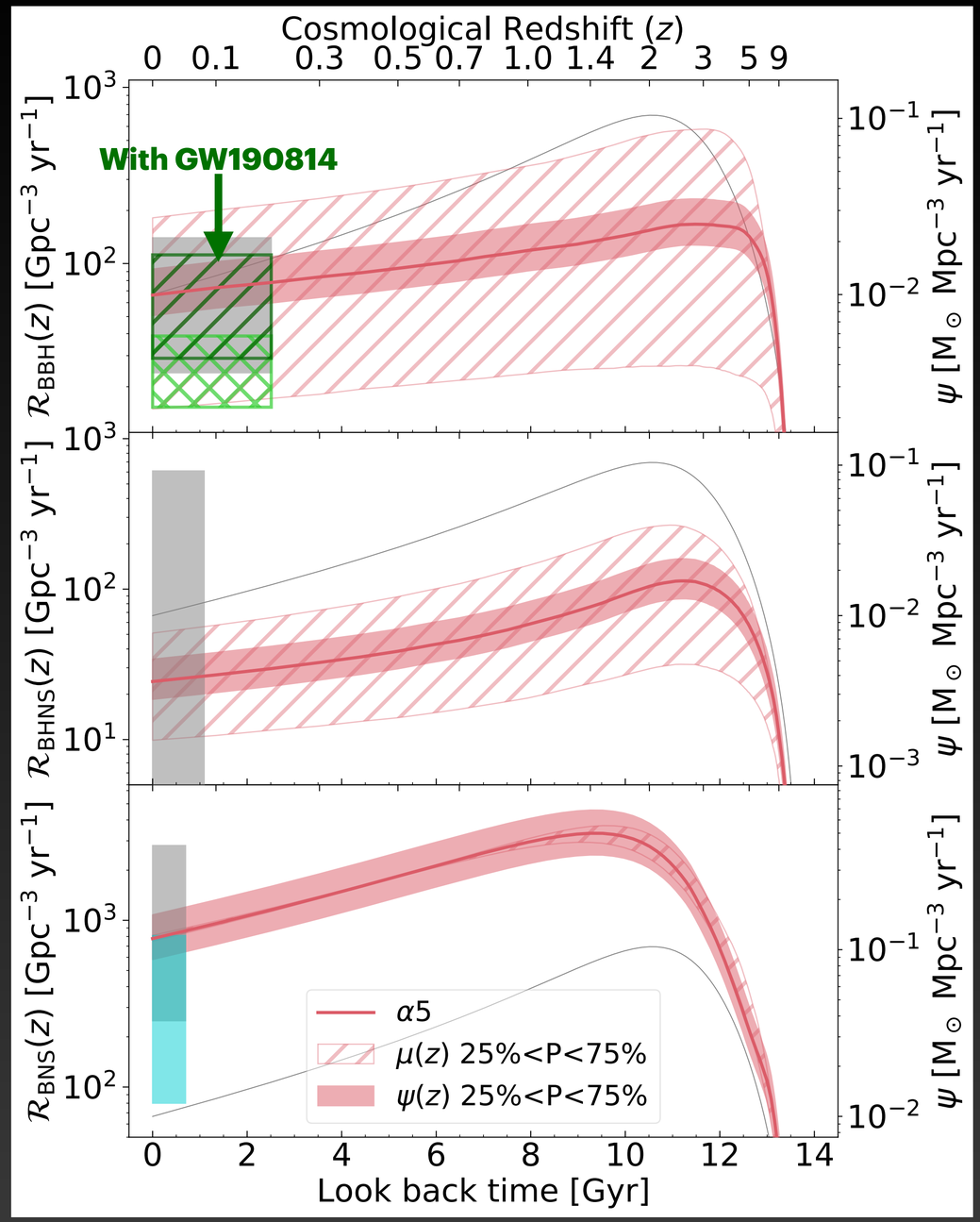
- This quantity gives us an idea of the impact of progenitor's metallicity on the merger rate density, in different scenarios
- The most interesting feature belongs to those binary which host a BH: the merger efficiency decreases by orders of magnitudes with increasing metallicity





Result: uncertainty estimation

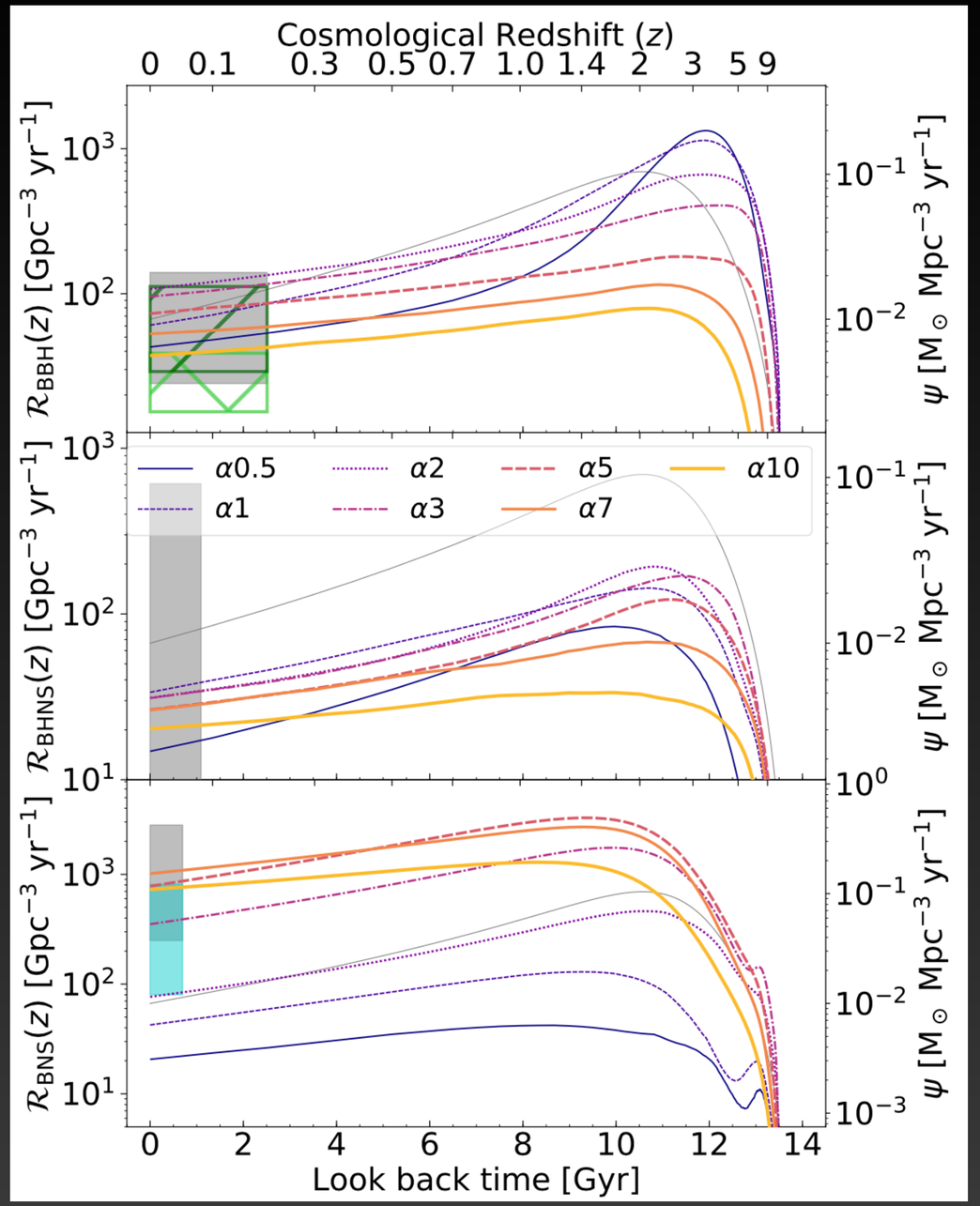
- Here we show an estimation of the uncertainty given by observed cosmological quantities
- $R_{BBH}(z)$ and $R_{BHNS}(z)$ are heavily affected by uncertainties on metallicity evolution.
- In contrast, the uncertainty on $R_{BNS}(z)$ is much smaller and is dominated by the SFR.



Result: impact of α_{CE}

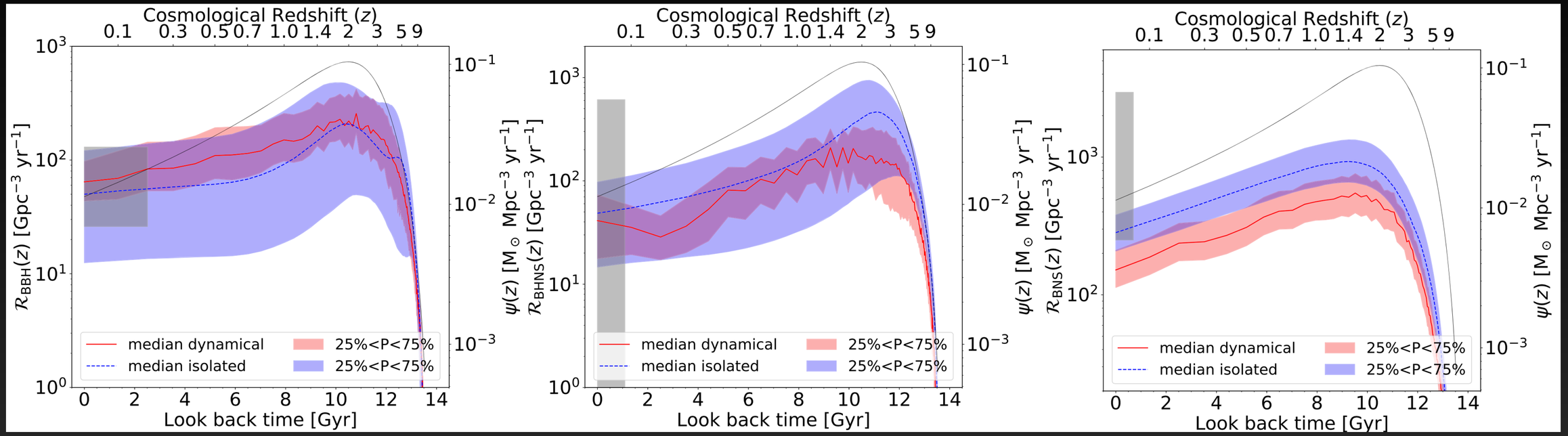
Santoliquido+2021

- We explored the parameter space with the isolated formation channel
- The BNS merger rate density is up to two orders of magnitude higher for large values of α_{CE} than for low values.
- In the local Universe, $\mathcal{R}_{BBH}(z)$ changes by a factor of 2–3 if we vary α_{CE}.



Result: two formation channels

Santoliquido+2020



- The dynamical BBH merger rate is higher than the isolated BBH merger rate between $z = 0$ and $z \sim 4$
- The MRD of dynamical BHNSs is always consistent with that of isolated BHNSs, within the estimated uncertainties
- The MRD of dynamical BNSs is a factor of ~2 lower than that of isolated BNSs, as dynamics suppress the formation of relatively low-mass binaries.

Conclusions

- The number of GW detections continuously increases and thus the astrophysical interpretation of this results is now needed more than ever before
- I developed a model that evaluates the cosmic merger rate density starting from a population of compact binaries.
- We’ve seen that details on binary evolution and cosmological quantities yield a great amount of uncertainty
- We also evaluate the merger rate density for the dynamical formation channel, and we saw that it is much less sensitive to metallicity than isolated binaries

Thanks a lot for the attention!
I’m happy to take your questions