Shedding light on gravitational waves through GPU computing

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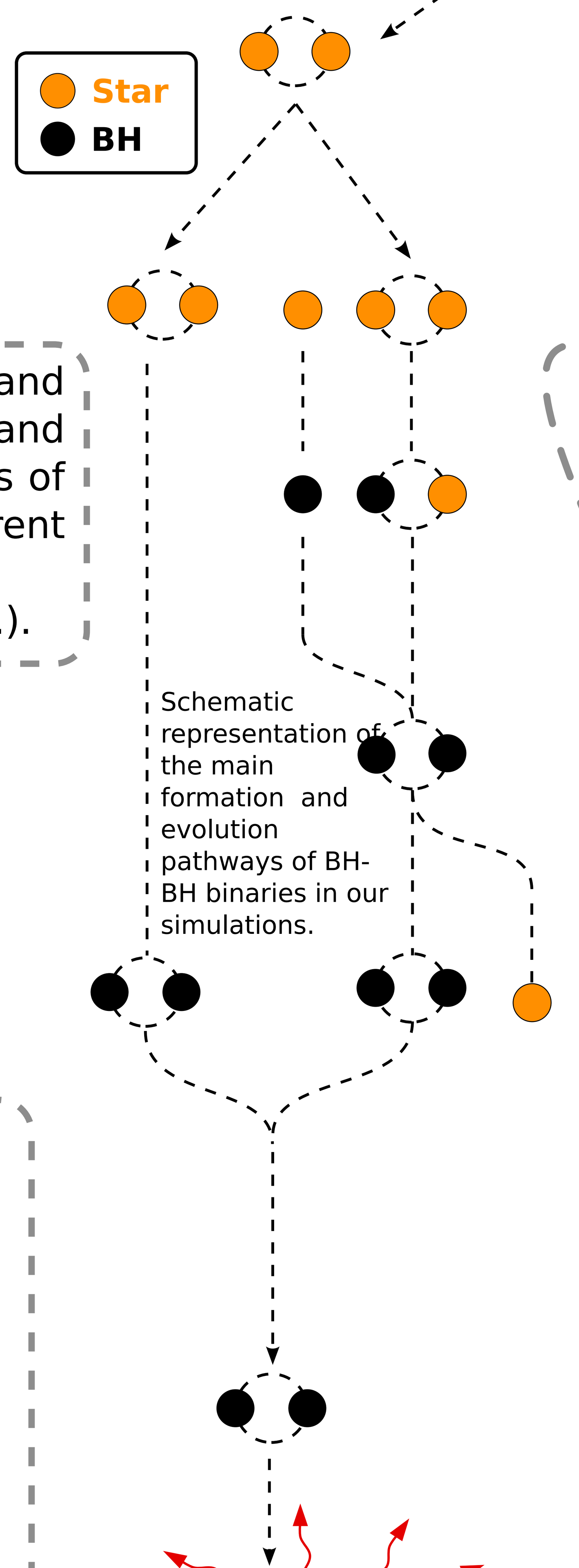
Overview

Mergers of black hole (BH) and neutron star (NS) binaries in dense star clusters are expected to be powerful sources of gravitational waves (GWs).

Environment:
young dense star cluster were stars evolve and dinamically interact

It is extremely important to understand the **dynamical evolution** of BH and NS binaries, and to make predictions of their **merger rate** in different **astrophysical environments** (Ziosi et al. 2014, Ziosi et al. in prep.).

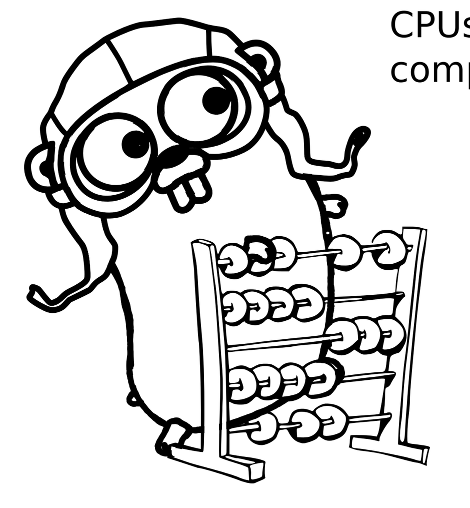
Metallicity is important:
- Heavier BHs form from metal-poor stars
- They tend to form BH-BH binaries at early times
- These binaries are more stable



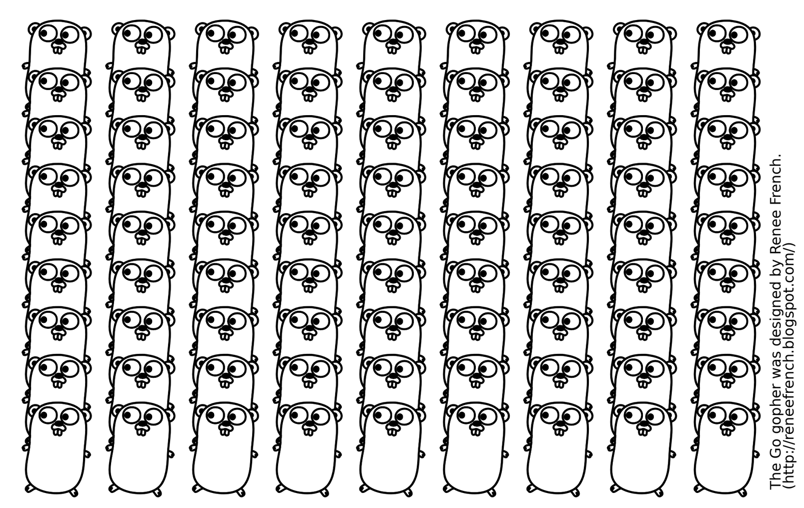
Schematic representation of the main formation and evolution pathways of BH-BH binaries in our simulations.

GPUs

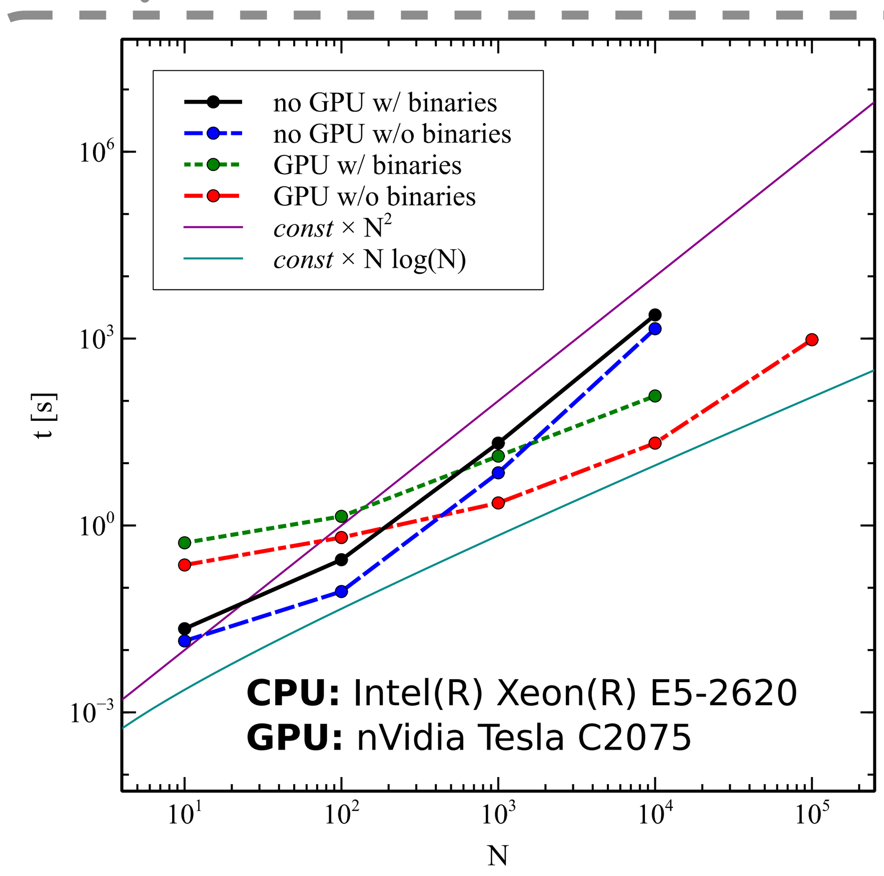
Simulating BH and NS binaries in star clusters is a **challenging task**, because it requires to couple an **accurate integration of dynamics** with advanced **recipes for stellar and binary evolution**. To reach this goal, we make use of **advanced direct-summation N-body codes** (Portegies Zwart et al. 2001, Mapelli et al. 2013), which are well suited to run on graphics processing units (**GPUs**).



CPUs are single complex generic computational tools.



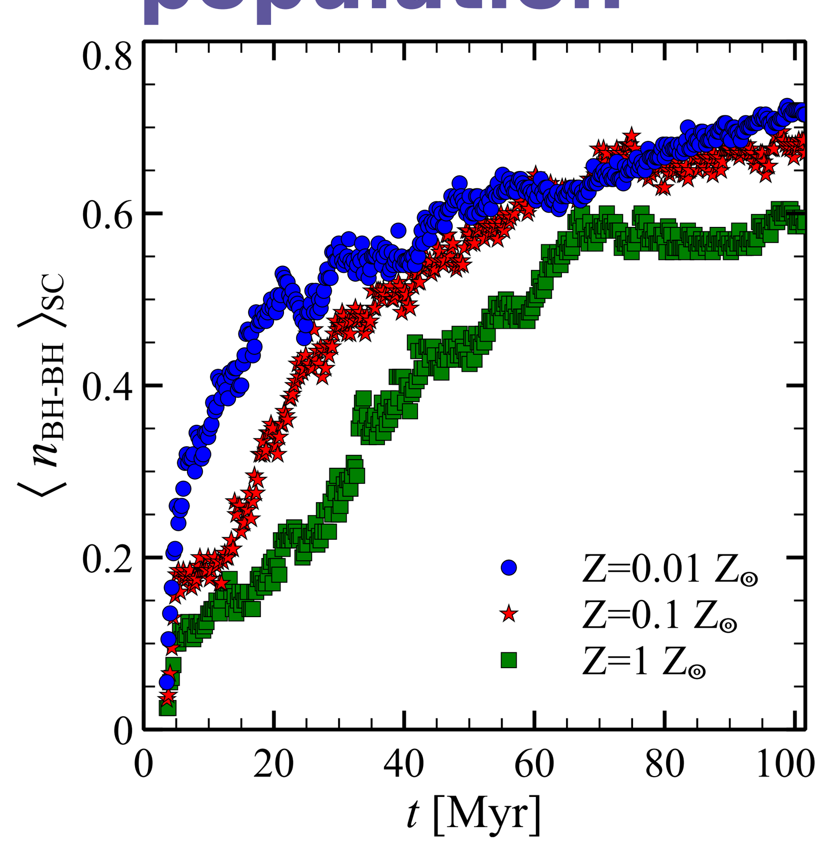
GPUs are a huge set of simple but massive parallel computational units.



GPU are **essential** to run our simulations in reasonable times. Because of the **massive parallel** execution, **gravity computations** can benefit of very large **speed-ups**.

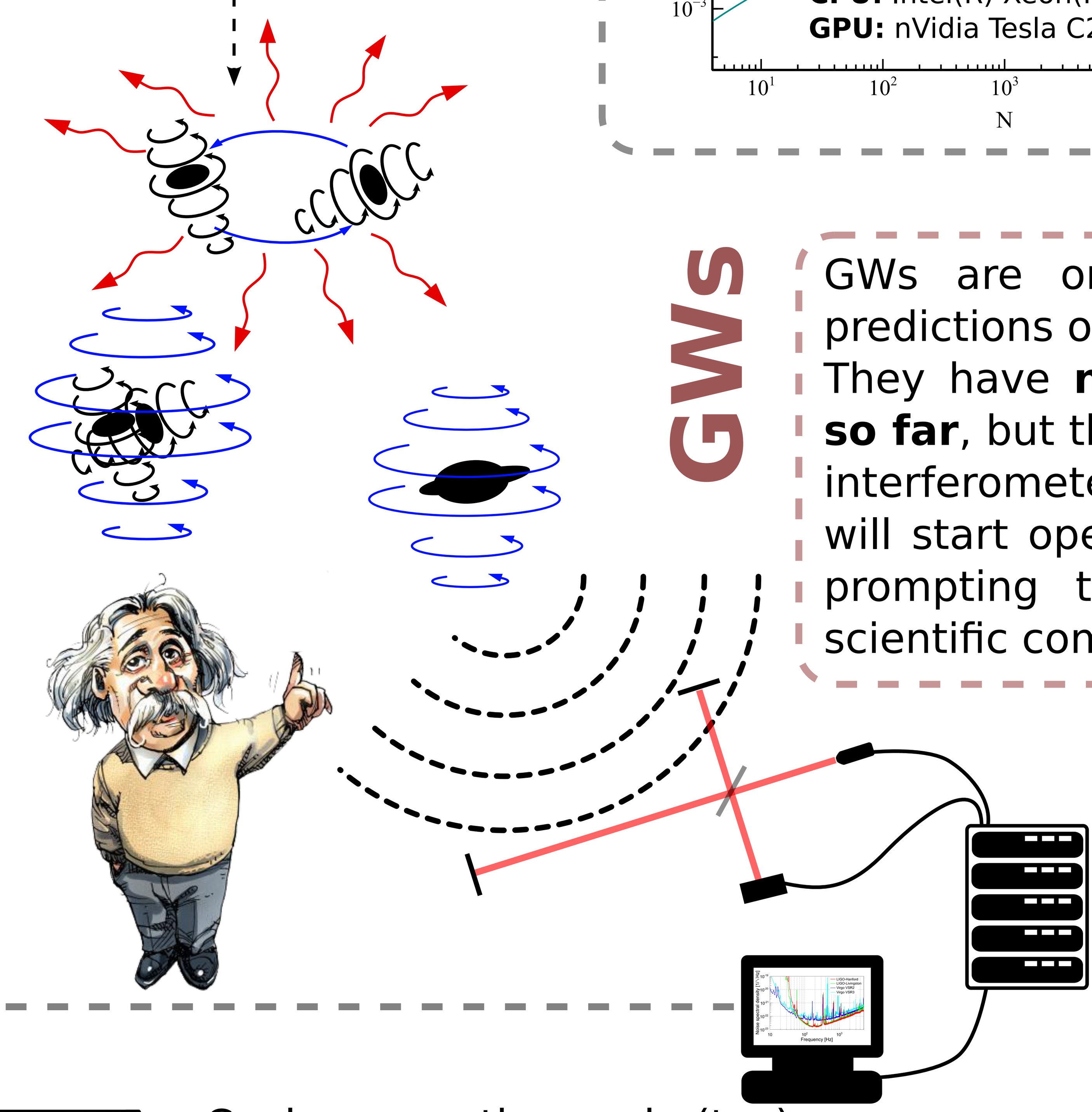
Outcomes

BH binaries population



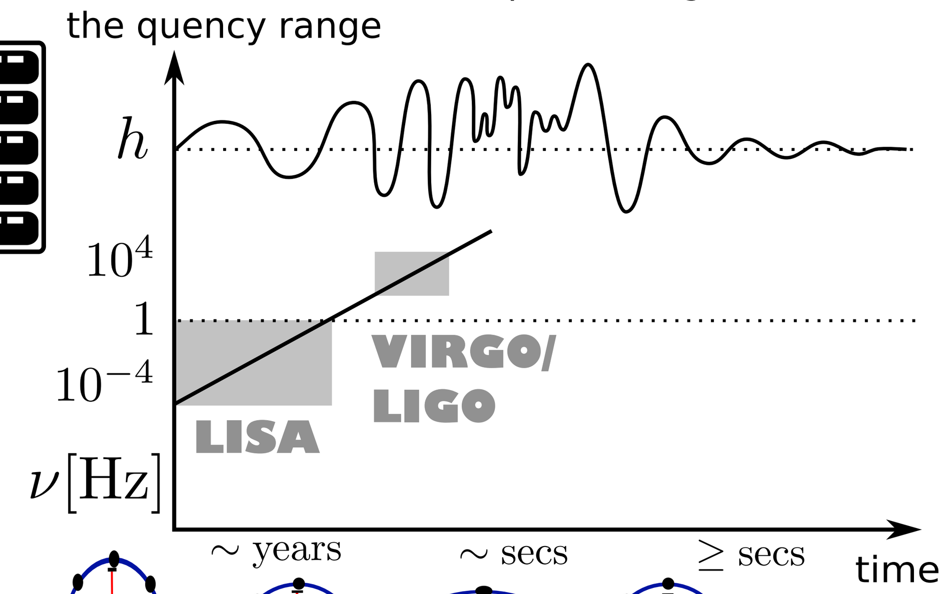
Average number of BH-BH binaries per star cluster as a function of time for different metallicities.

Dynamics is important:
- It enhances the formation of DCOBs: 97% of BH-BH binaries come from exchanges
- It hardens binaries and can modify the eccentricity

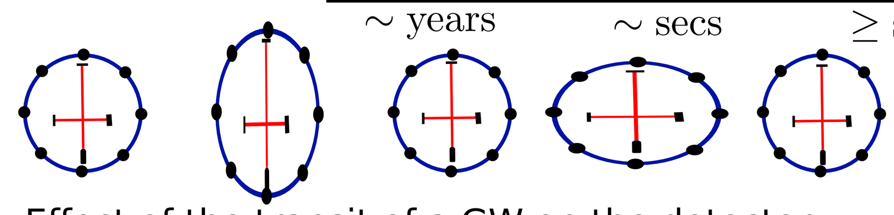


GWs

GWs are one of the most fascinating predictions of Einstein's theory.
They have **not been directly detected so far**, but the new second-generation GW interferometers, Advanced LIGO and Virgo, will start operating in the next two years, prompting the expectations of a large scientific community (Abadie et al. 2010).

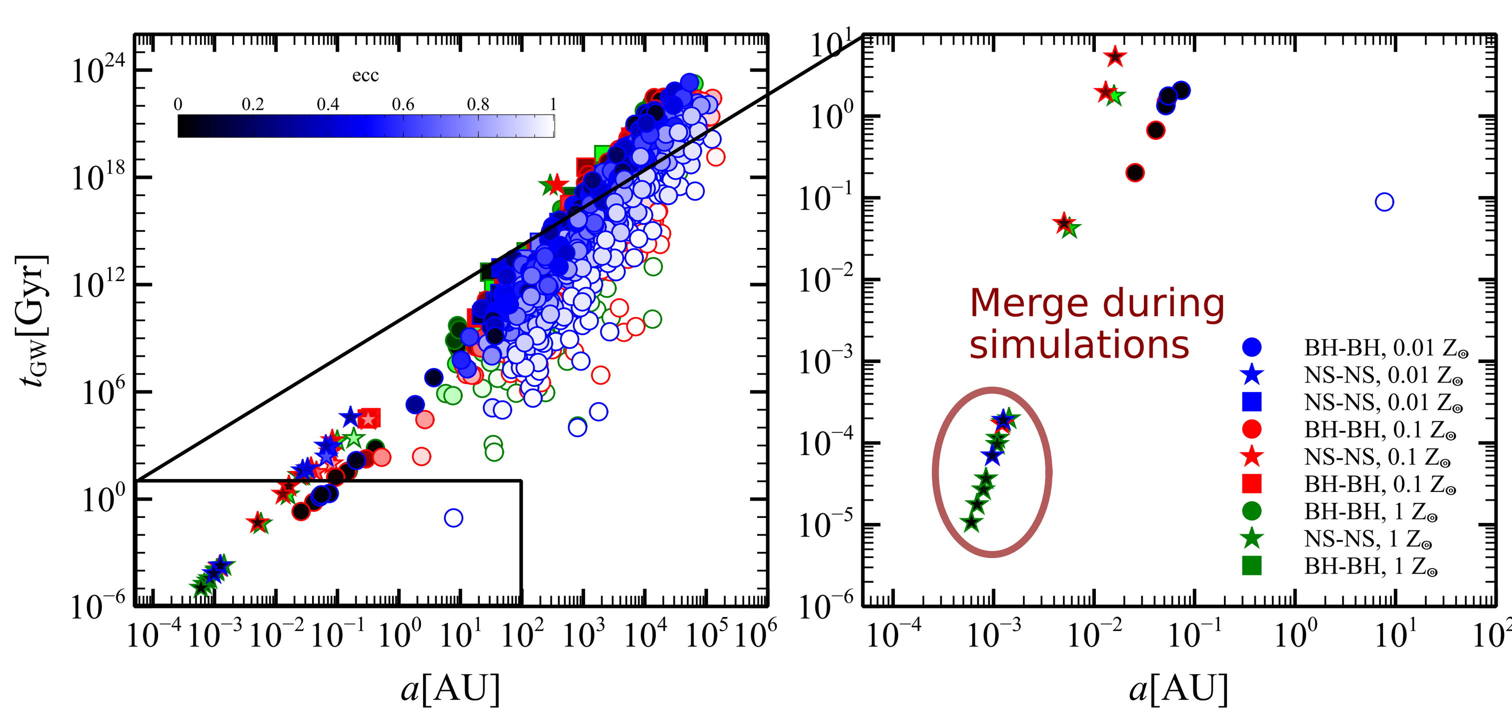


Schematic view of a GW waveform associated to different coalescence phases together with the quency range



Effect of the transit of a GW on the detector.

Coalescence timescale



Coalescence timescale (t_{GW}) as a function of the semi-major axis (a) for BH-BH binaries. The right-hand panel is a zoom of the left-hand panel.

- Coalescence timescale (t_{GW}) is the time a system needs to reach semi-major axis a=0 due to orbital decay by GW emission (Peters 1964)
- 7 DBHs with $t_{GW} < 13$ Gyr (0 for Z=$Z_\odot$)
- 17 DNSs with $t_{GW} < 13$ Gyr
- 11 DNS mergers during the simulations

$\longrightarrow$ over the 600 simulated star clusters

Bibliography

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- Mapelli et al. 2013, MNRAS, 429, 2298
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- Peters P.C., 1964, Phys. Rev., 136, 1224
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