Binary compact objects across cosmic history

Alessandro Ballone

on behalf of the DEMOBLACK Team:

Michela Mapelli (PI), M. Celeste Artale, Yann Bouffanais, Ugo N. Di Carlo, Nicola Giacobbo, Enrico Montanari, Mario Pasquato, Sara Rastello, Filippo Santoliquido, Mario Spera

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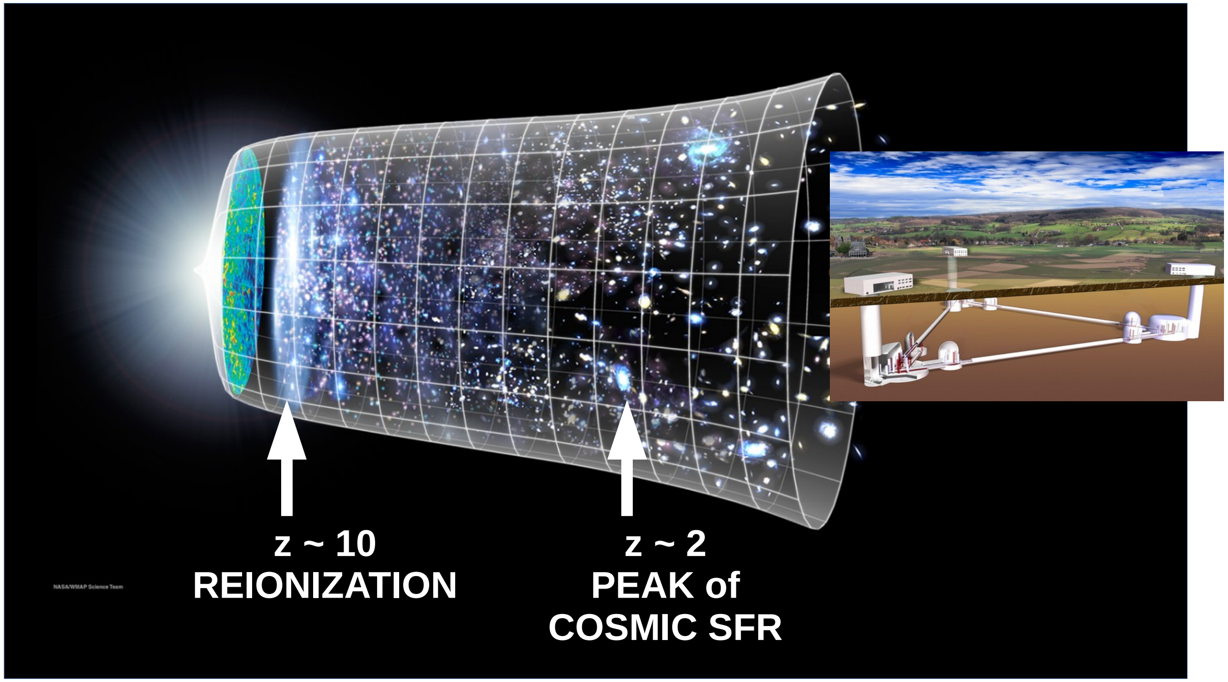
1. Einstein telescope (ET) & compact binaries

ET will observe binary black holes (BBHs) up to $z \geq 10$
binary neutron stars (BNSs) up to $z \geq 2$



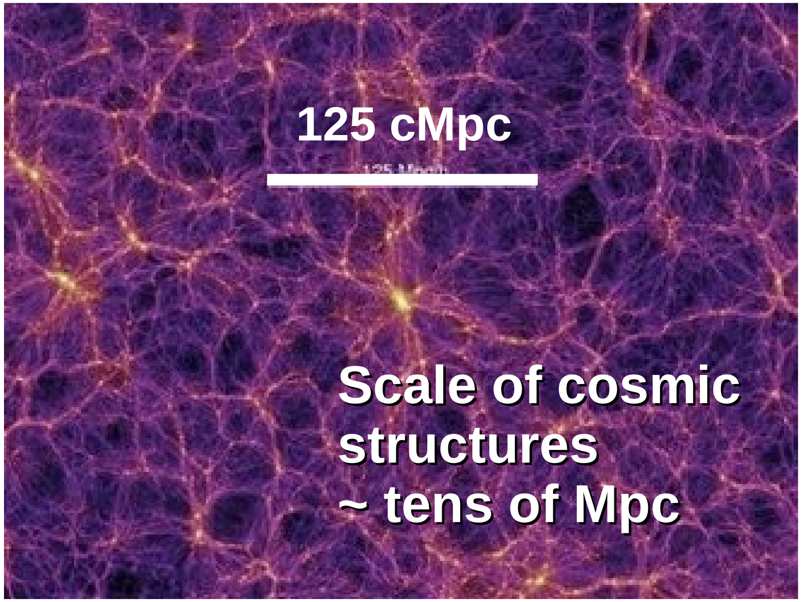
WHY IS IT IMPORTANT?
WHAT KIND OF SCIENCE CAN WE MAKE WITH THIS?

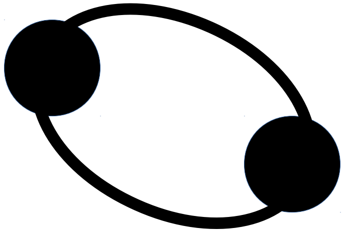
LET'S TRY TO MAKE PREDICTIONS..

1. Einstein telescope (ET) & compact binaries

Predict BBH and BNS evolution across cosmic time

CHALLENGING TASK:
*** humongous physical range**





Scale of a BH binary < AU

1. Einstein telescope (ET) & compact binaries

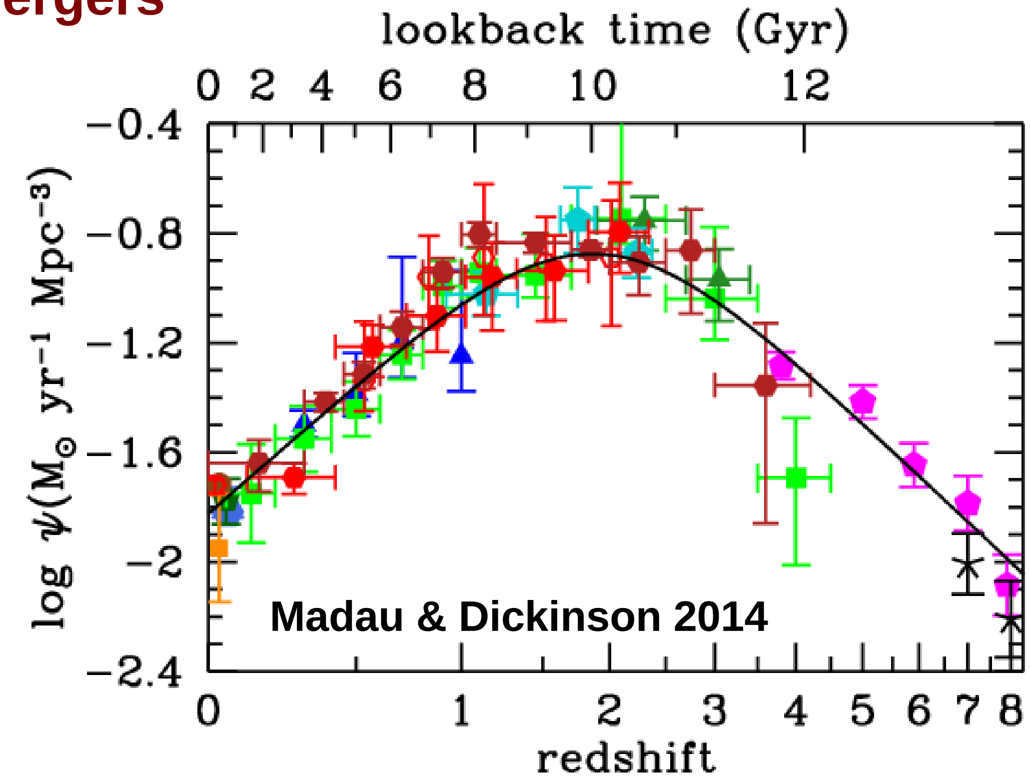
Predict BBH and BNS evolution across cosmic time

CHALLENGING TASK:

*** humongous physical range**

*** account for cosmic SFR**

affects mainly number of mergers



1. Einstein telescope (ET) & compact binaries

Predict BBH and BNS evolution across cosmic time

CHALLENGING TASK:

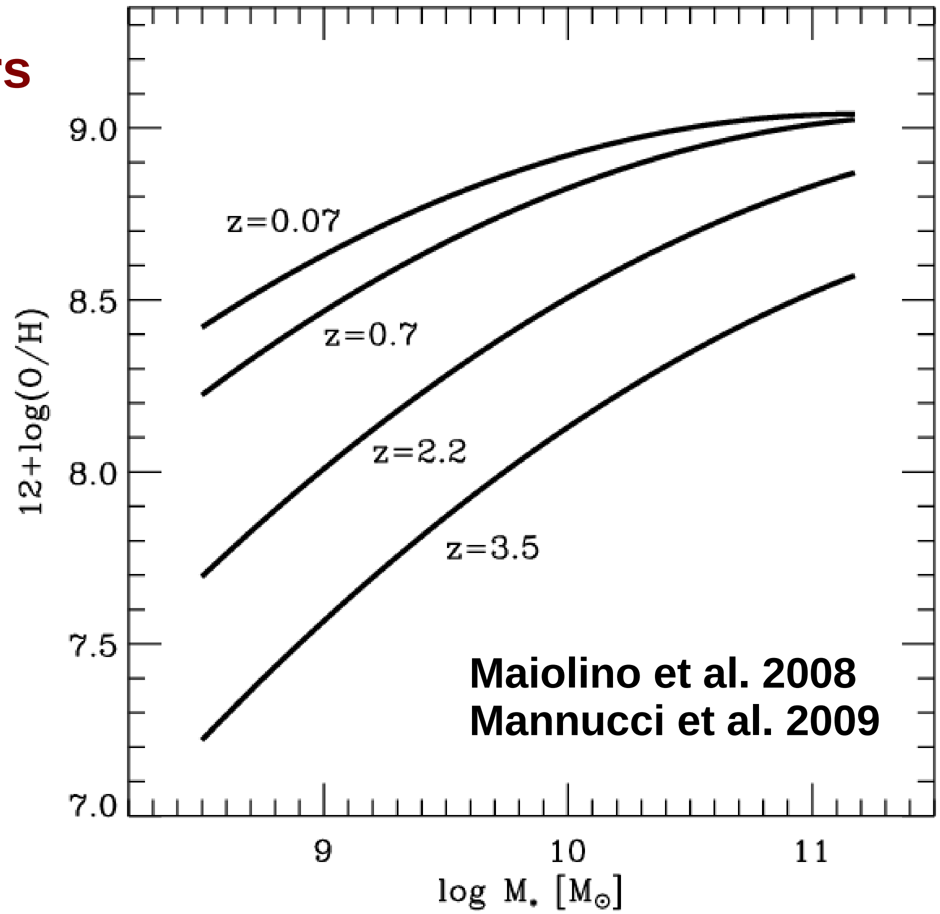
*** humongous physical range**

*** account for cosmic SFR**

affects mainly number of mergers

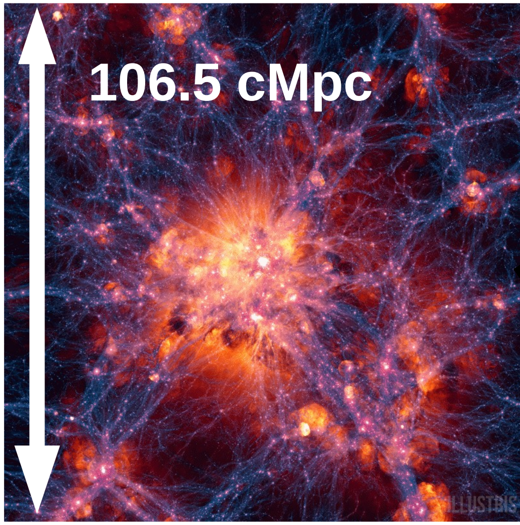
*** account for metallicity**

affects number of mergers and properties of merging systems

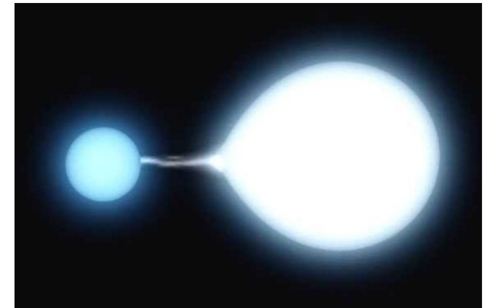


1. Einstein telescope (ET) & compact binaries

Cosmological simulation
(e.g. Illustris, Vogelsberger+ 2014)



Pop. synthesis of isolated binaries
(Giacobbo, MM, Spera 2018)

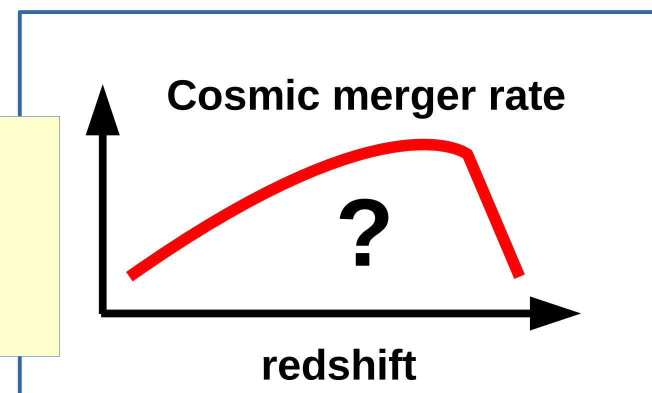


star formation and metallicity in galaxies

catalogues of isolated compact binaries

Monte Carlo code
to plant compact binaries in galaxies

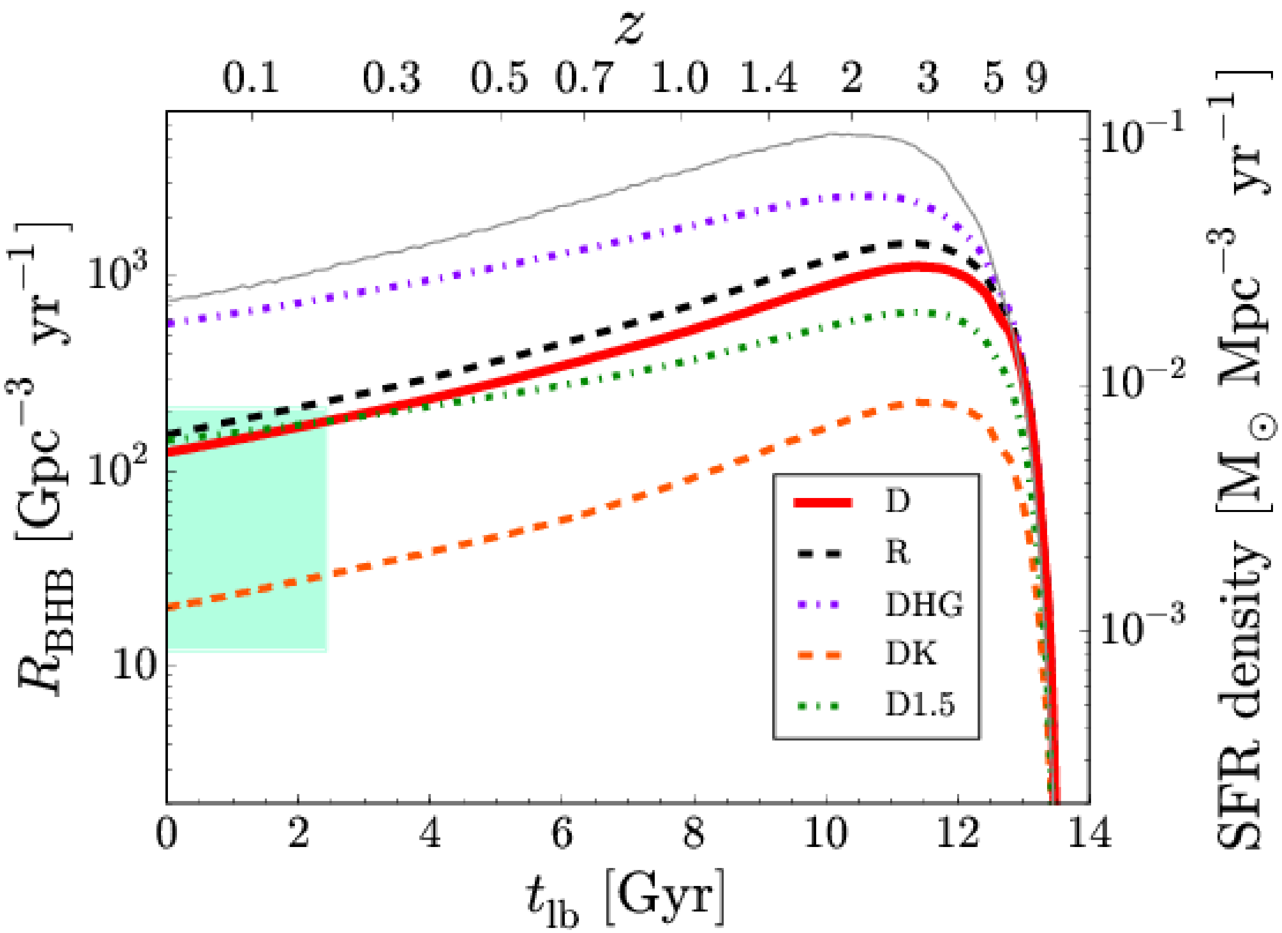
Cosmic merger rate & binary properties



2. BBH merger rate density

Same SFR and Z evolution

Colors: different binary evolution models
(common envelope, supernova kicks, supernova model)



Mapelli et al. 2017

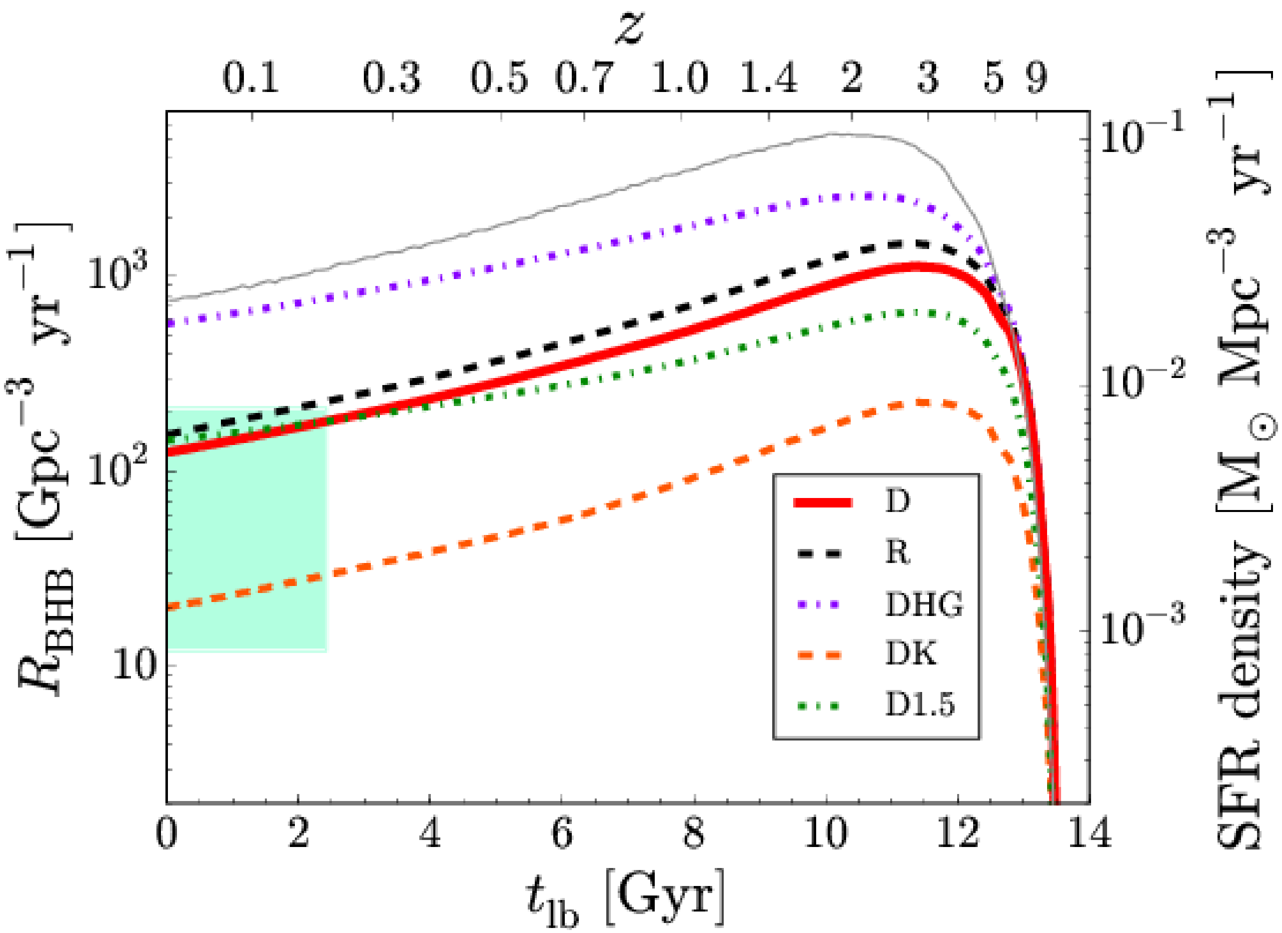
- **BBH merger rate scales with cosmic SFR density**
- **Peak at z ~ 3 – 4 because of metallicity**
- **Rate changes wildly with assumed binary evolution model**
- **If BHs do not come from stars (PRIMORDIAL BLACK HOLES, Carr + 2016) the rate has no reason to scale with cosmic SFR**

2. BBH merger rate density

Same SFR and Z evolution

Colors: different binary evolution models

(common envelope, supernova kicks, supernova model)



TAKE HOME MESSAGE:

Measuring BBH merger rate evolution with redshift allows

*** to distinguish stellar BHs from primordial BHs**

*** to constrain stellar binary evolution processes (now huge uncertainty)**

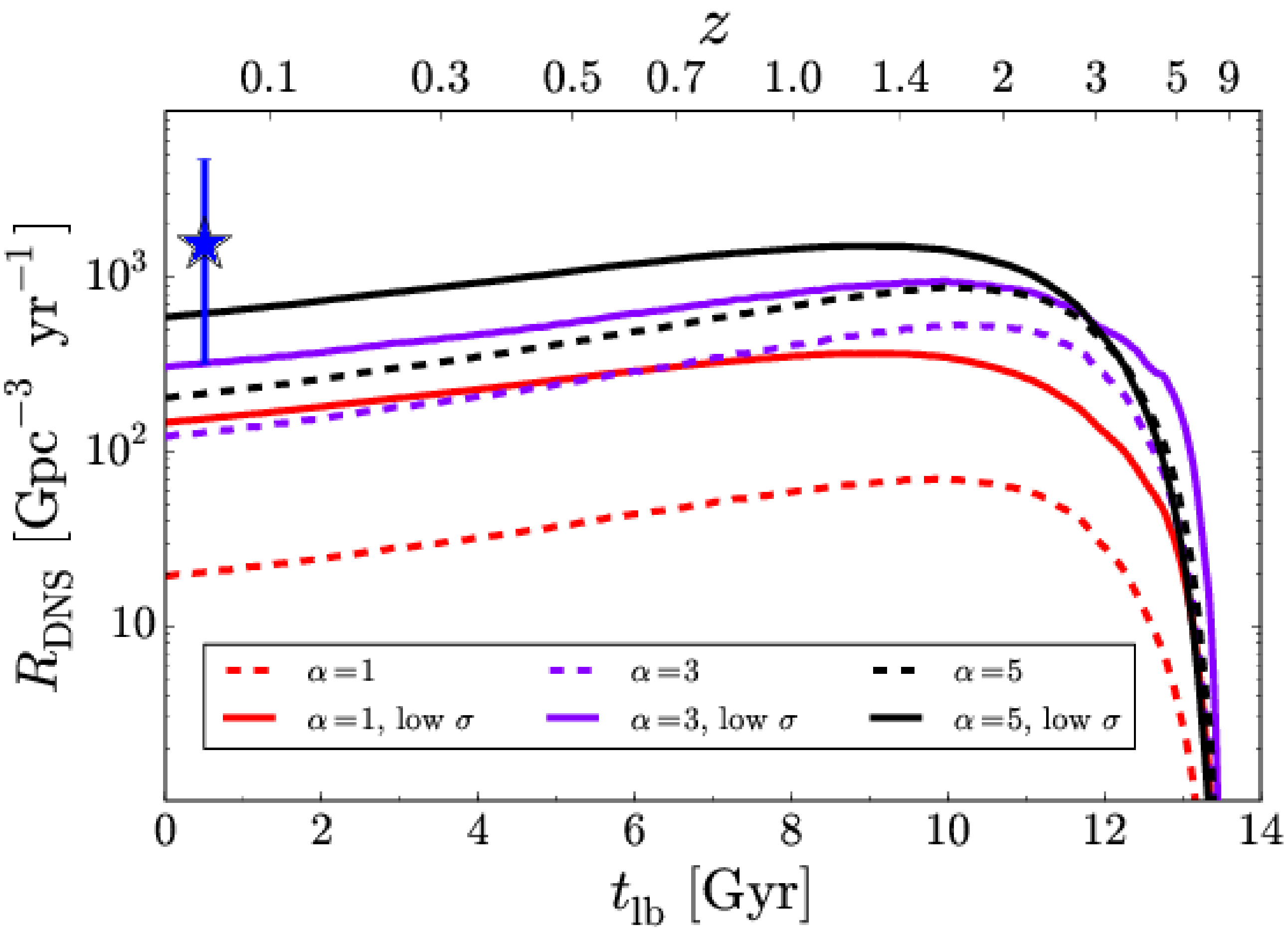
*** to understand when first BHs (primordial BHs or BHs from PopIII) formed: we might detect the first BHs before we observe the first stars**

3. BNS merger rate density

Same SFR and Z evolution

Colors: different binary evolution models

(common envelope, supernova kicks, supernova model)



Mapelli & Giacobbo 2018

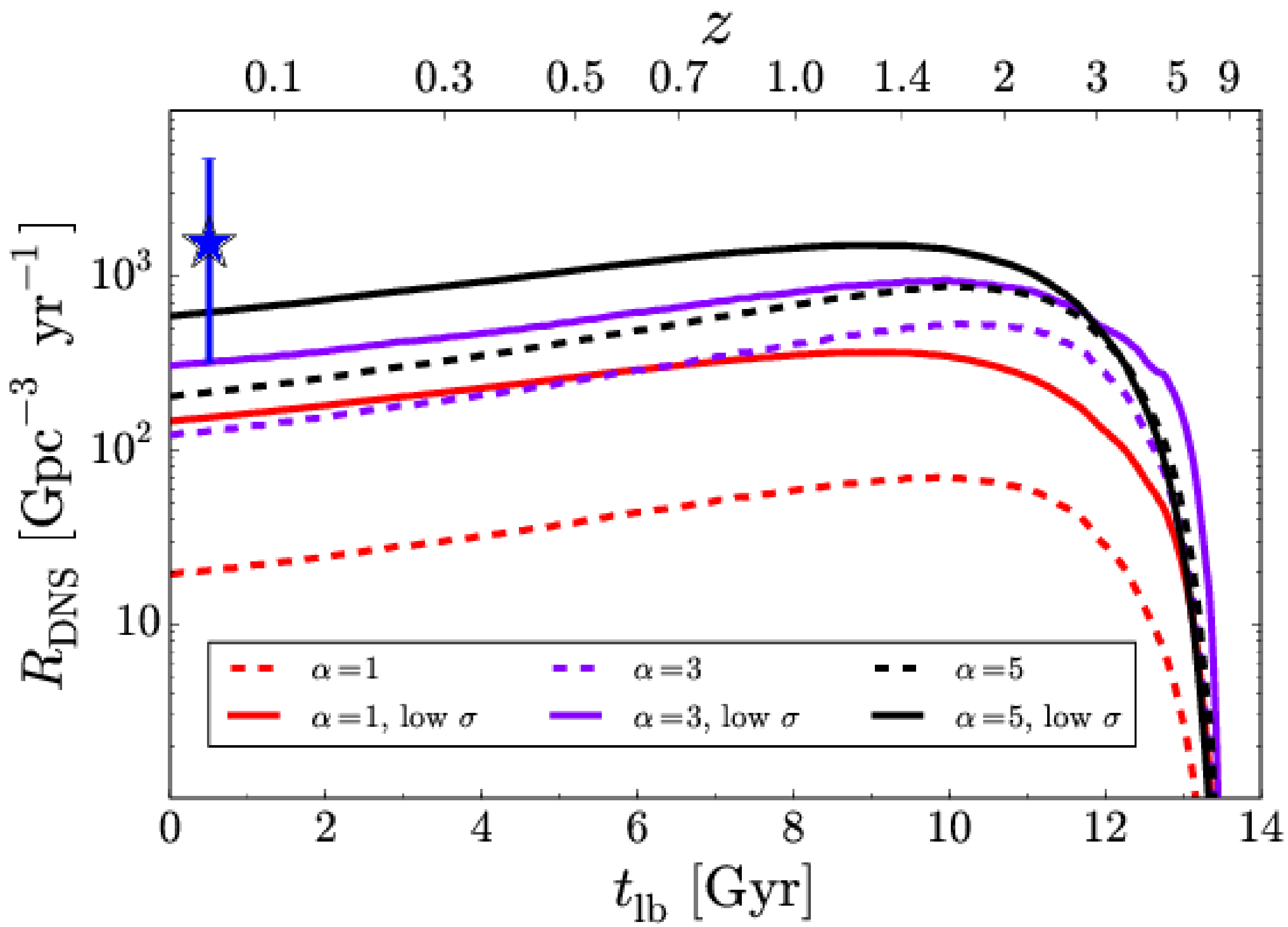
- **BNS merger rate scales with cosmic SFR density**
- **Peak at z ~ 2 (no dependence on metallicity)**
- **BNSs are independent TRACERS of COSMIC SFR**

3. BNS merger rate density

Same SFR and Z evolution

Colors: different binary evolution models

(common envelope, supernova kicks, supernova model)



TAKE HOME MESSAGE:

Measuring BNS merger rate evolution allows

*** to constrain stellar binary evolution processes (now huge uncertainty)**

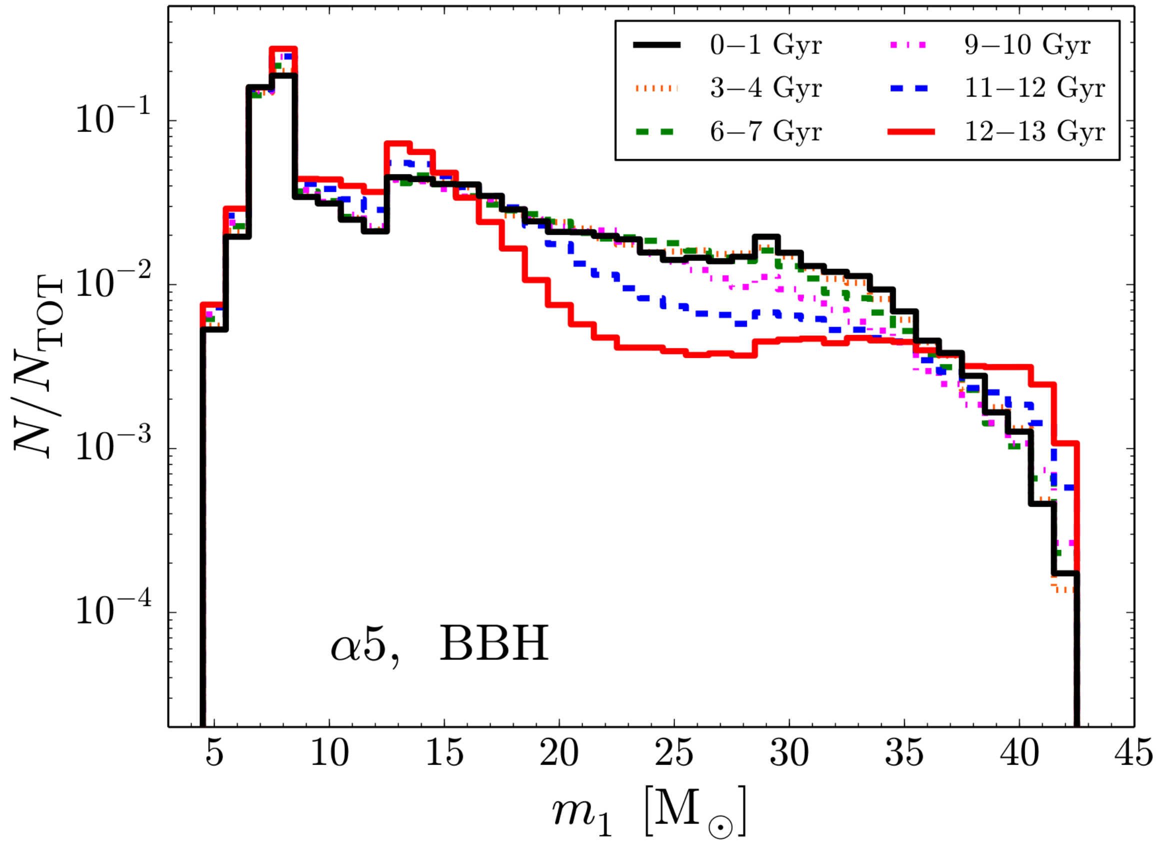
*** to obtain INDEPENDENT estimate of cosmic SFR**

4. Black hole (BH) mass evolution

Mass of
BBHs merging < 1 Gyr ago

BBHs merging 11 – 12 Gyr ago

BBHs merging 12 – 13 Gyr ago



Mapelli et al. 2019

*** BH mass does not change significantly with redshift in our models**

WHY? Metal-poor stars are 3 orders of magnitude more efficient than metal-rich stars in producing merging BBHs

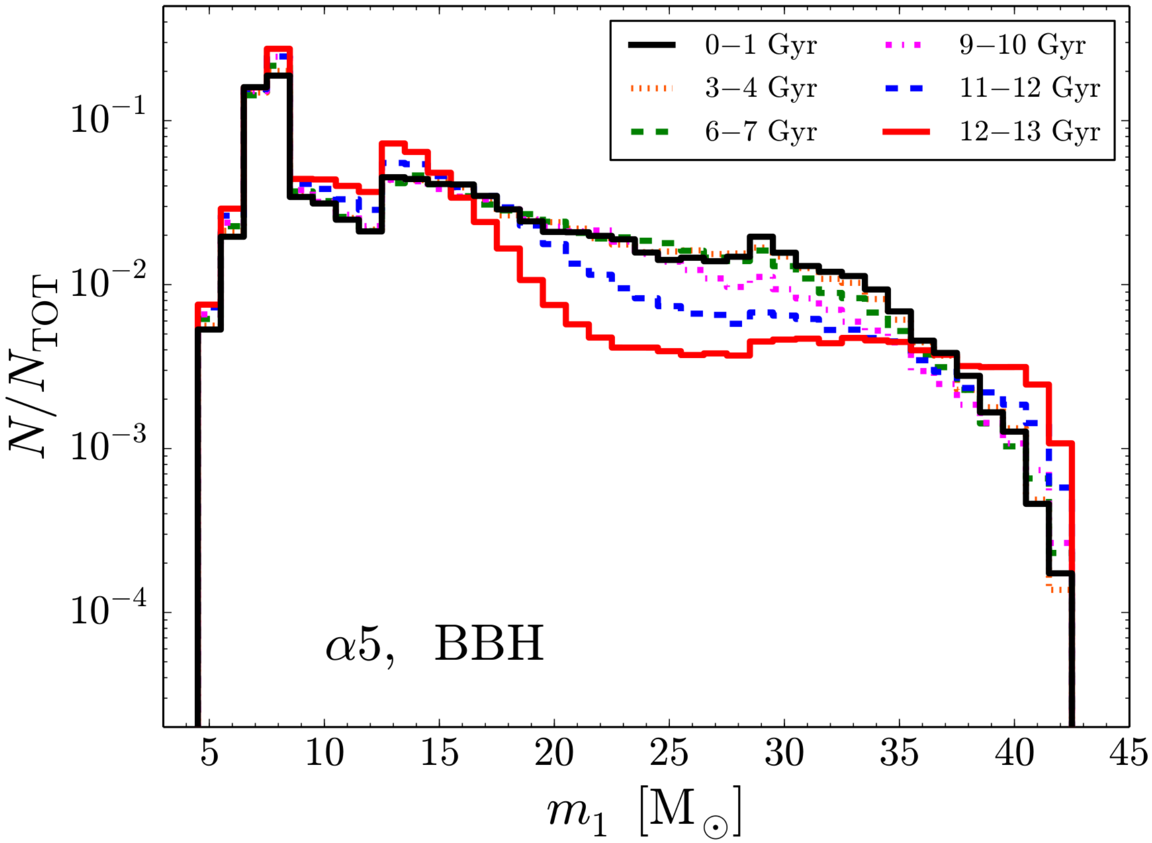
→ Whatever redshift we look at, we see mostly low metallicity BBHs

4. Black hole (BH) mass evolution

Mass of
BBHs merging < 1 Gyr ago

BBHs merging 11 – 12 Gyr ago

BBHs merging 12 – 13 Gyr ago

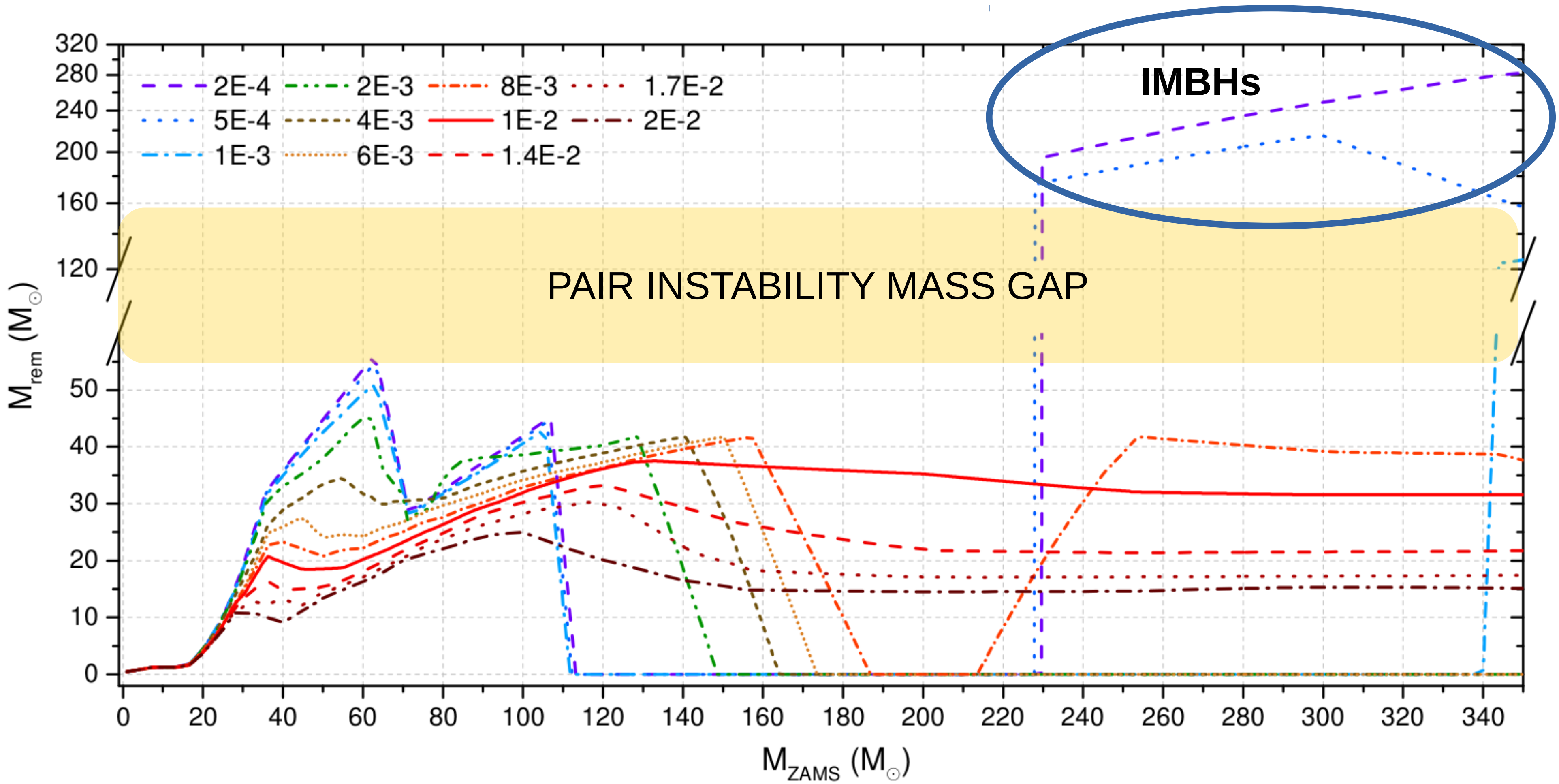


Mapelli et al. 2019

TAKE HOME MESSAGE:

Measuring BBH mass evolution with redshift is the ONLY WAY to VALIDATE our theories on stellar BH mass spectrum

5. Intermediate mass black holes (IMBHs)?

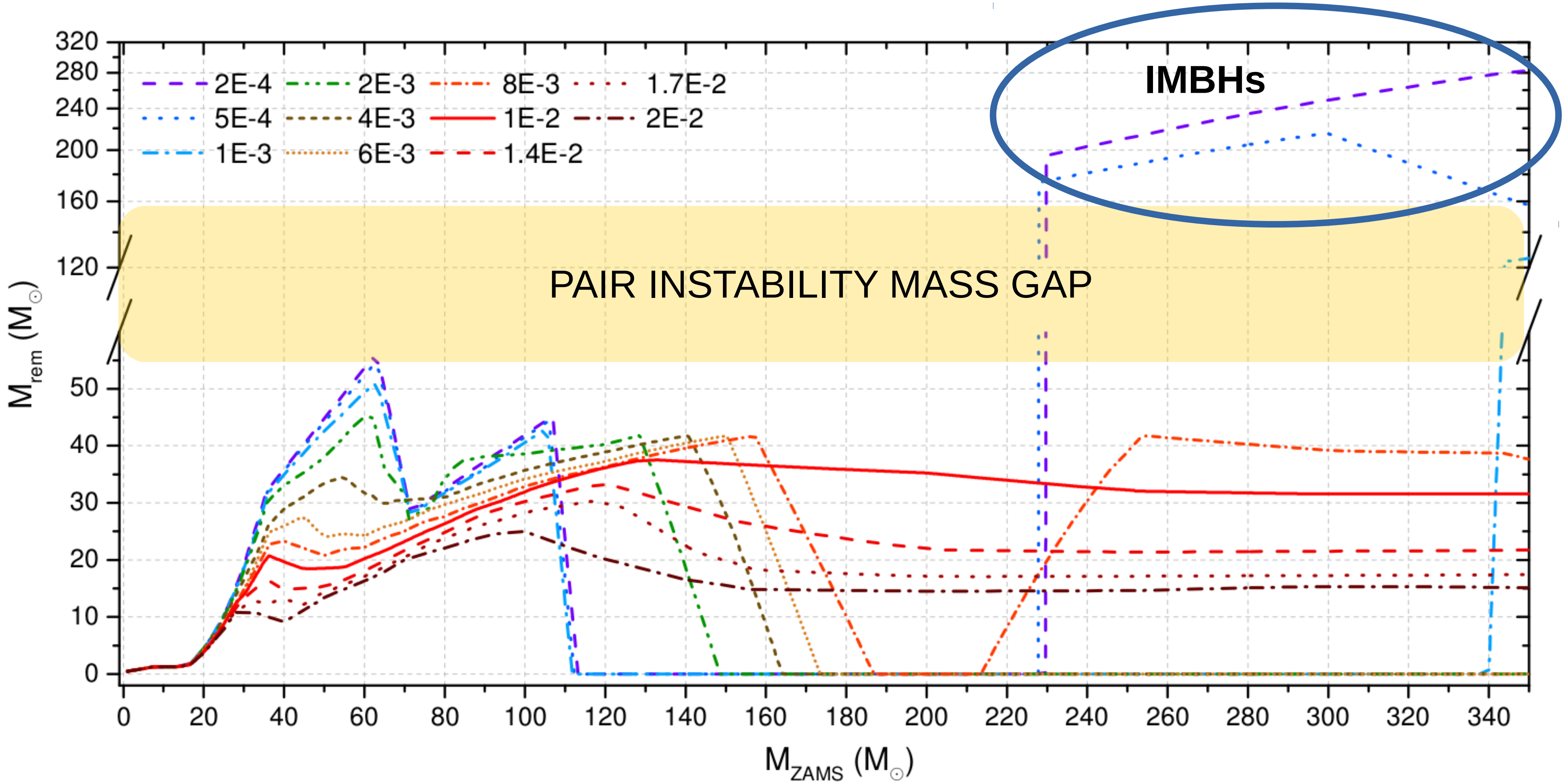


Spera & Mapelli 2017

We expect IMBHs (mass > 200 M⊙) at Z< 0.001 (pop II – pop III stars)

ET will have much higher sensitivities at lower frequencies (<u>higher merger masses</u>) wrt LIGO/VIRGO!

5. Intermediate mass black holes (IMBHs)?



Spera & Mapelli 2017

TAKE HOME MESSAGE:

*** Better probe the pair instability mass gap**

*** Detection of IMBHs at z ~ 10, crucial for seeds of super-massive BHs**

SUMMARY:

* **BBH merger rate evolution with redshift (eg Mapelli et al. 2017):**
  - distinguish stellar BHs from primordial BHs
  - constrain stellar / binary evolution processes
  - understand when first BHs formed:
    we might detect the first BHs before we observe the first stars

* **BNS merger rate evolution with redshift (eg Mapelli & Giacobbo 2018):**
  - constrain stellar binary evolution processes
  - independent estimate of cosmic SFR

* **BH mass evolution with redshift (eg Mapelli et al. 2019):**
  - validate BH formation theories (impact of metallicity on BHs, pair instability gap)
  - look for intermediate-mass BHs

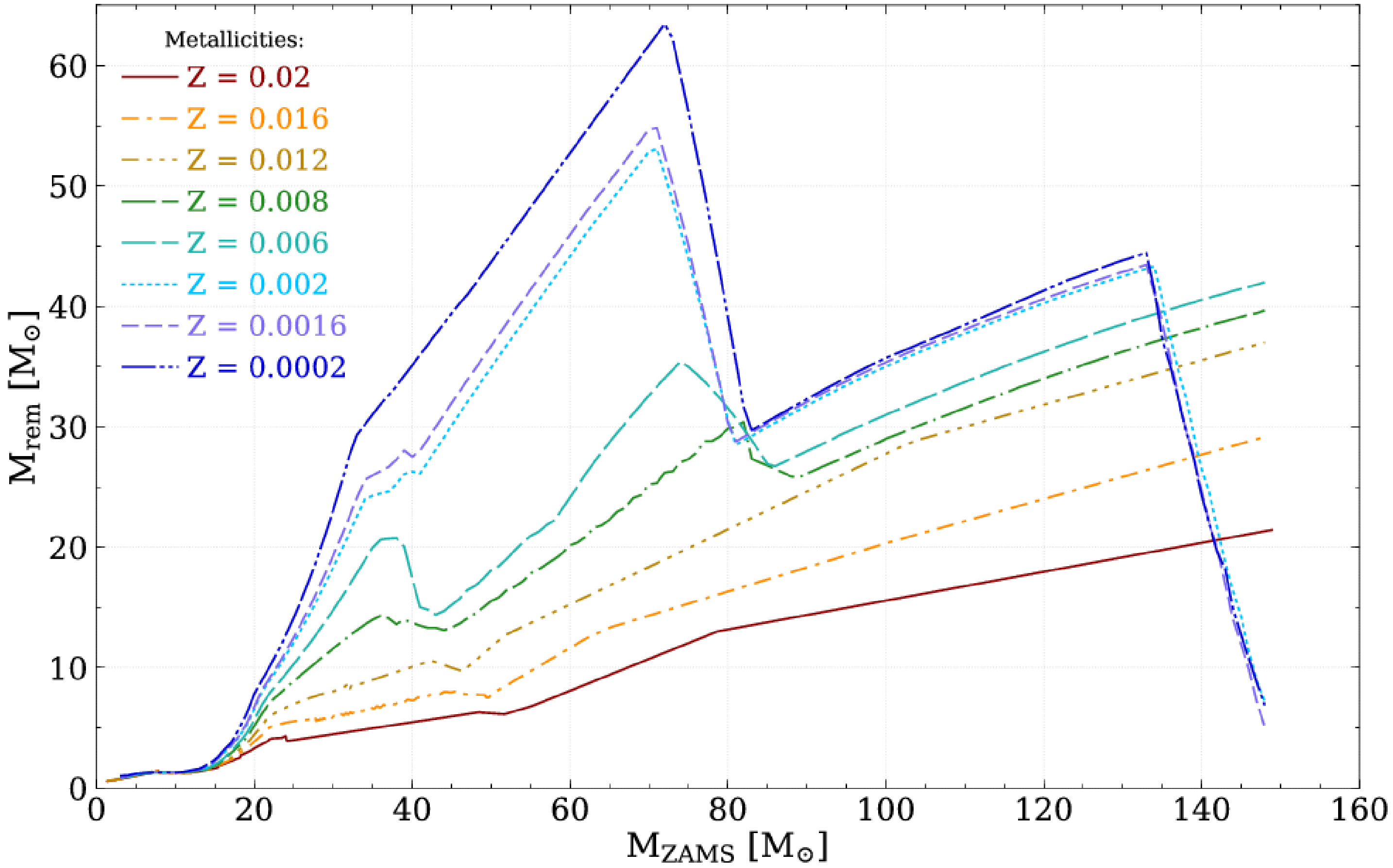
THANK YOU

Pop. Synthesis models:

MOBSE code (Giacobbo, MM, Spera 2018):

up-to-date stellar winds + supernova prescriptions

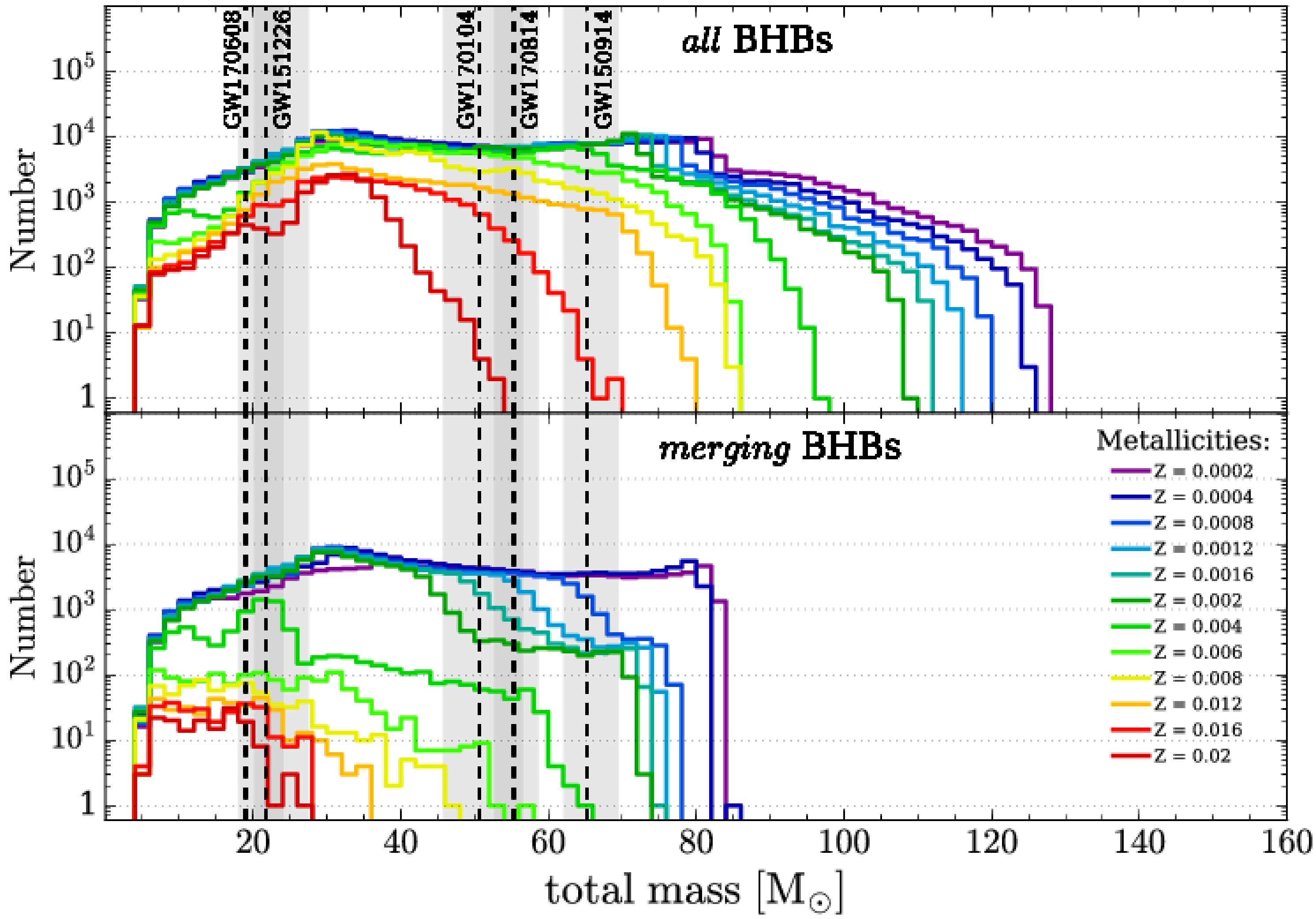
(electron capture, core collapse, direct collapse, pair instability and pulsational pair instability)



Giacobbo, MM & Spera 2018; see also MM+ (2009, 2010, 2013); Spera + 2015; Spera & MM 2017; Giacobbo & MM (2018a, 2018b); MM+ 2017; MM & Giacobbo 2018

Pop. Synthesis models:

Metal-poor stars more efficient than metal-rich in producing merging BBHs



Giacobbo & Mapelli 2018