ASTROPHYSICAL POPULATIONS WITH EINSTEIN TELESCOPE

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WHERE WE STAND: MASS SPECTRUM

Masses in the Stellar Graveyard
in Solar Masses

- first unequal masses
- Massive BHs
- Lower mass gap object
- BNS masses differ from MW

O3a
Observed mass spectrum
- Peak 35-40 Msun
- Decrease >60 Msun
- Cutoff <8 Msun

LVC: GWTC-2 populations paper

A. Lamberts-M. Mapelli
Astrophysical populations with ET
WHERE WE STAND: FORMATION CHANNELS

- Isolated binary evolution (including chemically homogeneous evolution)
- Young star clusters
- Globular clusters
- Others: AGN disks, triples, nuclear star clusters
WHERE WE STAND: REDSHIFT EVOLUTION

Merger rate density of BBHs from GWTC2

First measurement for BBHs:
$z$-evolution consistent with evolution of star formation rate

Not sensitive enough for BNS $z$-evolution
WHERE WE STAND: REDSHIFT EVOLUTION

Klencki+18: different binary models

Models: **Major uncertainties**, owing to formation channels and star formation/metallicity model

2G detectors will partially solve the question
WHERE WE STAND: SPINS

- Some systems have mis(anti)-aligned: challenge for binary channel
- Some systems have precession
- Some systems have non-zero aligned spin

=> (at least) two formation channels?

Hard to model properly (angular momentum transfer, Belczynski+20)
THE EINSTEIN TELESCOPE REVOLUTION

A world of new possibilities, much beyond what Virgo/LIGO/KAGRA will do

Discovery/understanding based on

- **Intrinsic properties (mass, spin)**
- **Environmental properties (redshift, localisation)**
INTRINSIC: BBH MASS SPECTRUM

1 BBH merger every 15 minutes (10^6/yr)

Confirmation/contours of lower mass gap? (may be found by 2G)

PISN mass gap (and z-evolution?):
(Woosley 2017, 2019; Belczynski et al. 2016; Spera & MM 2017;
Giacobbo et al. 2018; Marchant et al. 2018, 2019, 2020;
Stevenson et al. 2019; MM et al. 2020; Farmer et al. 2019, 2020;
Farrell et al. 2020; Costa et al. 2020; Tanikawa et al. 2020)
Sub-solar mass black-hole: smoking gun for primordial BH

Intermediate mass black holes:
Mass spectrum, z evolution

-> formation channels
**INTRINSIC: BNS UP TO Z~2**

**Neijssel+19**

- Preferred model
- Barrett et al. (2018) MSSFR
- Furlong et al. (2015) Single
- Ma et al. (2015)

**Santoliquido+20**

- $R_{BNS}(z)$ [Gpc$^{-3}$ yr$^{-1}$]
- $\psi$ [$M_\odot$ Mpc$^{-3}$ yr$^{-1}$]

BNS: Limited impact of metallicity on BNS merger rate

Delay time $<>$ star formation rate (well known by $\sim$2035)

$->$ constraints on common envelope
ENVIRONMENT: MASS(Z), SPIN(Z)

BBH: Very different predictions from different models: combination of evolution channels and star formation/metallicity evolution

$\rightarrow$ strong constraining power or degeneracies?

Mapelli+19

Antonini+16
ENVIRONMENT: BNS HOST GALAXIES

BNS mergers to $z \sim 2$: peak of star formation

If EM counterpart is found (needs good sky localisation and/or multi band follow-up facilities)

- Much larger sample than LIGO/Virgo: “preferred” environments? (galaxy type vs merger properties, localisation of the merger…)

- Connection to GRB/kilonova physics (impact of ET less clear)

Adhikari+20

Small delay time”: star forming galaxies
Long delay time: massive galaxies

A. Lamberts-M. Mapelli

Astrophysical populations with ET
ENVIRONMENT: BBH HOSTS

Do (some) BBH mergers have EM counterparts? (needs good localisation: with 3G network, or multi band GW)

Statistical association with galaxy catalogs: types of host galaxies? AGN? (needs good sky localisation)

BBH mergers as a tracer of large scale structure: cosmological parameters, bias factor at higher z than most EM surveys

BBH mergers as standard candles? BHs with M>45Msun seem rare (PISN gap?) -> use BBH “maximal GW luminosity” as a standard candle?
BBH mergers well into the “dark ages”: probes of individual “first stars” (EM telescopes give probe of population)

Reionisation: start? end?

Very low metallicity environments
LOCAL GROUP: CORE-COLLAPSE SUPERNOVAE

New class of sources

Major uncertainties on GWs from CCSN models

Most energetic model: <20 kpc by 2G, 200 kpc by ET

![Detection Efficiency vs Distance (kpc)](image)

- He3.5
- s18
- ET

**Powell+19**
THE ET REVOLUTION

A million BBH mergers/year, BNS mergers up to $z \sim 2$

Very large sample of intrinsic source parameters (spins, masses):
- Formation channels?
- IMBHs?
- Mass gaps?
- Primordial black holes?

Environmental parameters: redshift, (statistical) determination of host galaxy:
- First stars & cosmic reionisation?
- Do BBHs have EM counterparts?
- Host galaxies vs time vs merger properties?
- Large scale structure beyond EM methods?