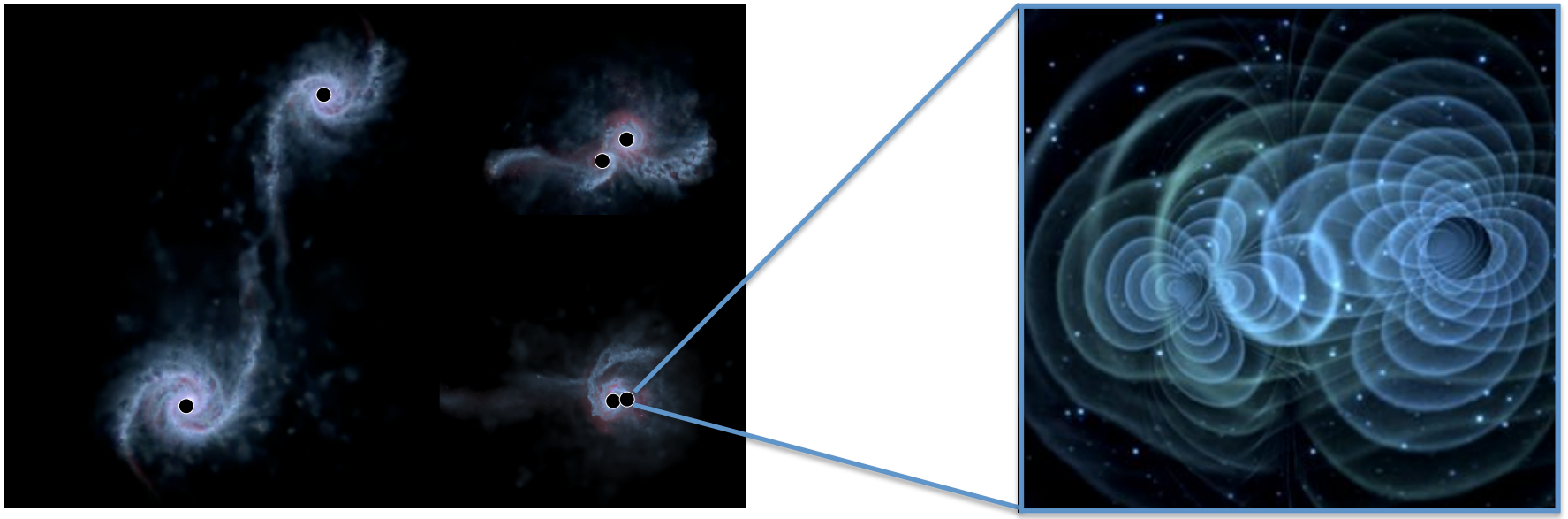
LISA sources



Marta Volonteri
Institut d'Astrophysique de Paris

LISA sources

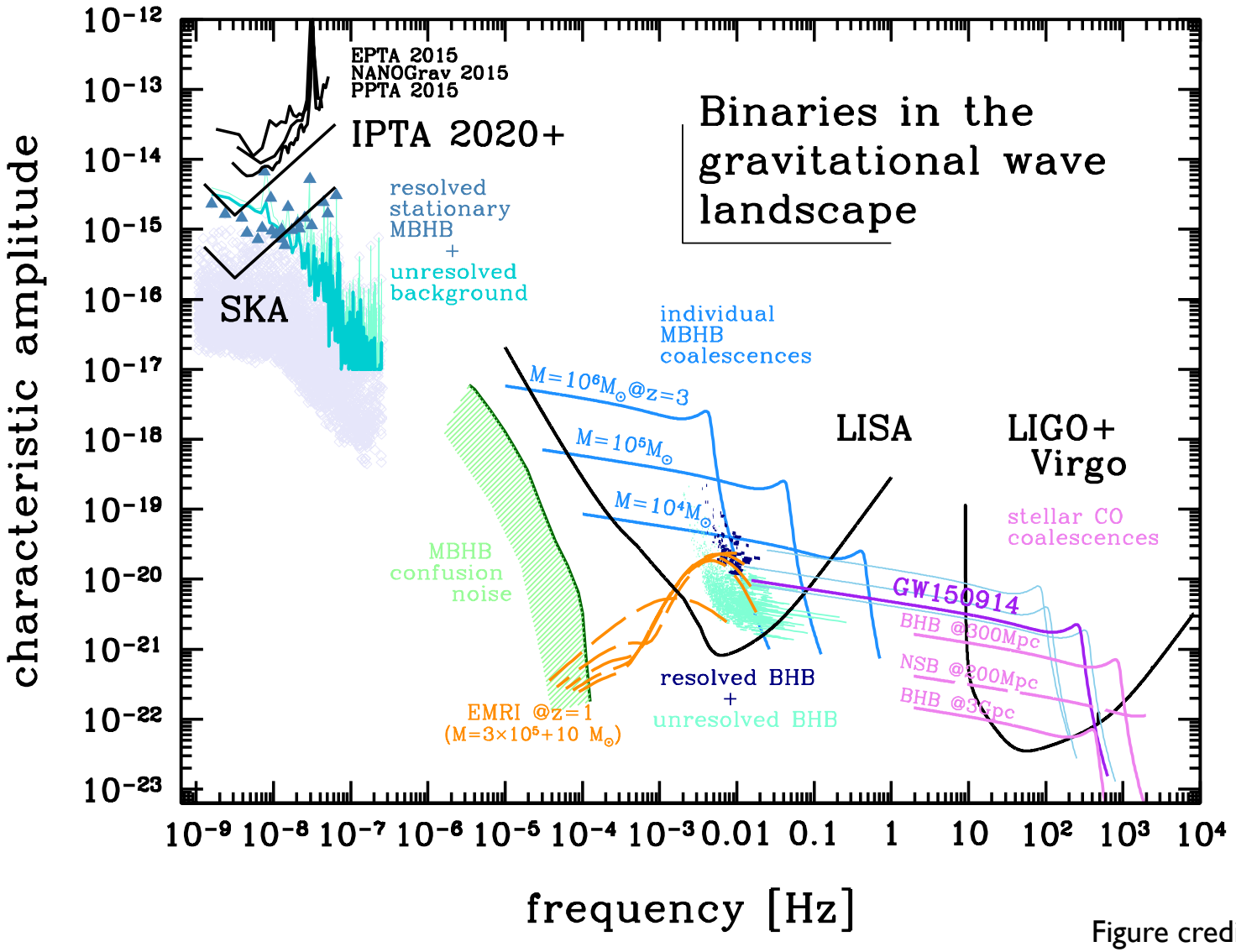
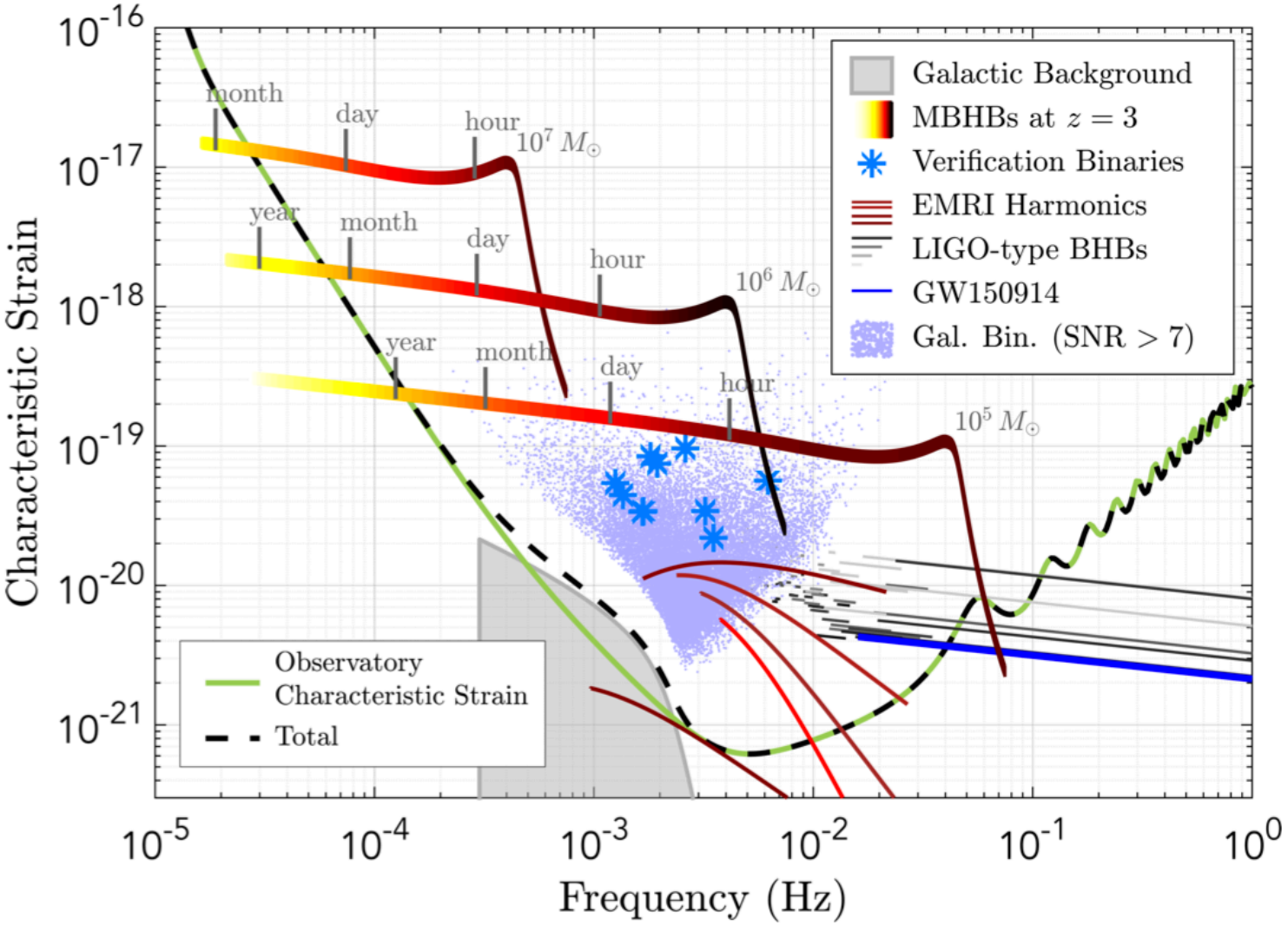
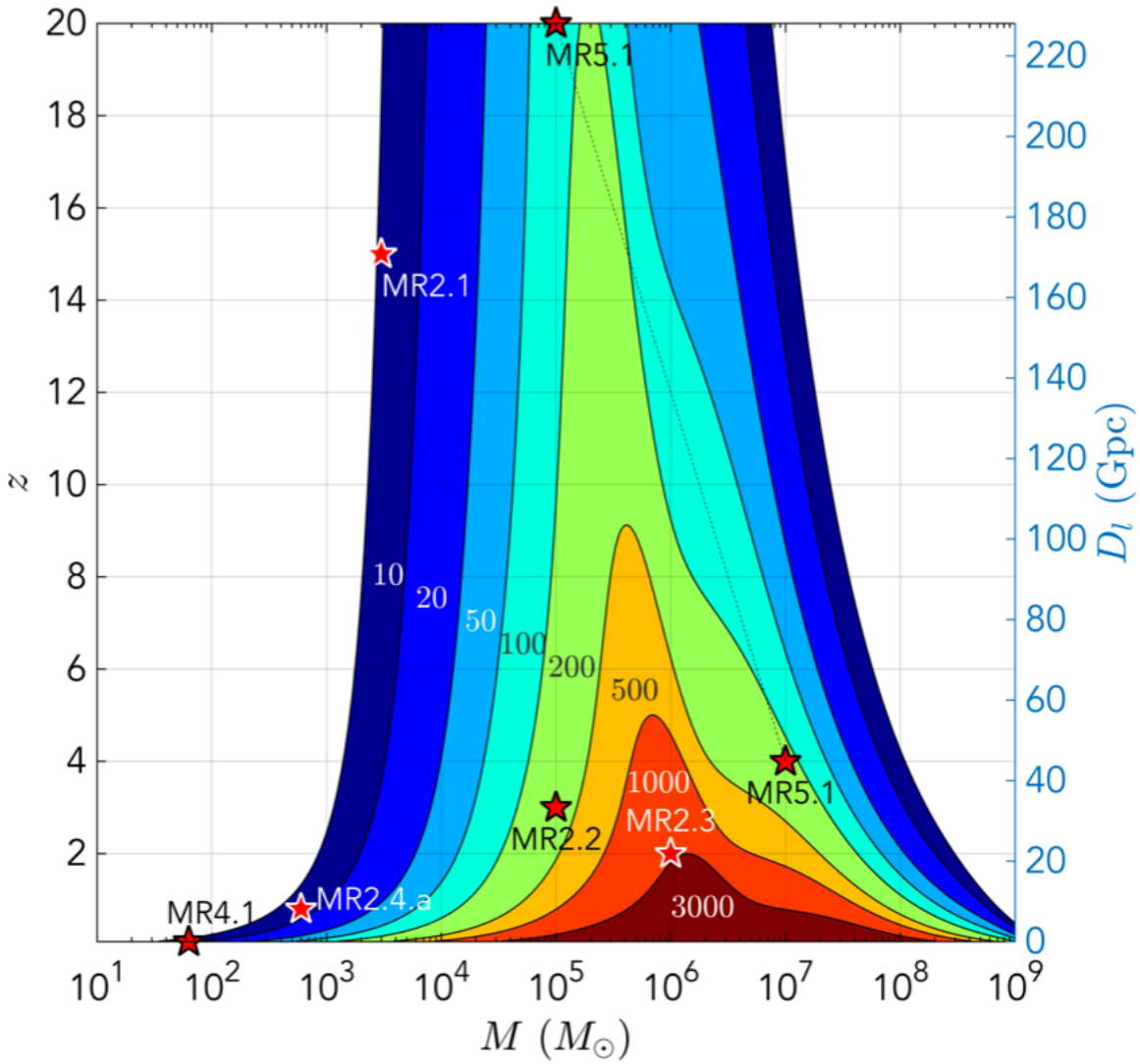


Figure credit: Alberto Sesana

LISA sources



LISA sources



MR2.1 Search for seed black holes at cosmic dawn

MR2.2 Black hole growth over cosmic history

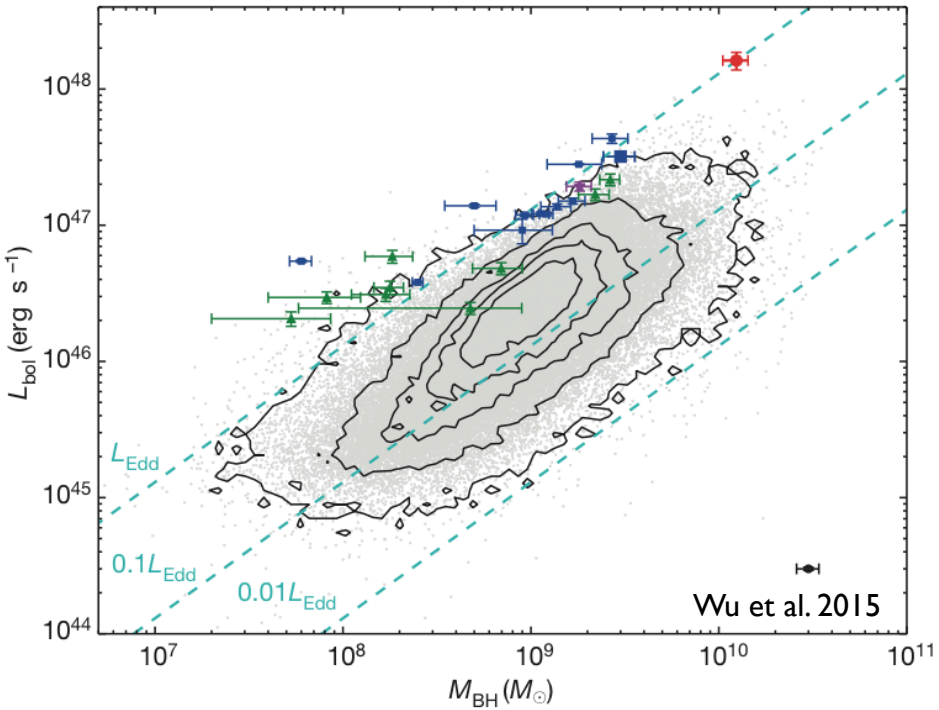
MR2.3 Mergers of MW-like BHs

MR2.4a Detection of intermediate-mass BHs

MR4.1 LIGO-type BHs

MR 5.1 Tests of GW with ringdown signals

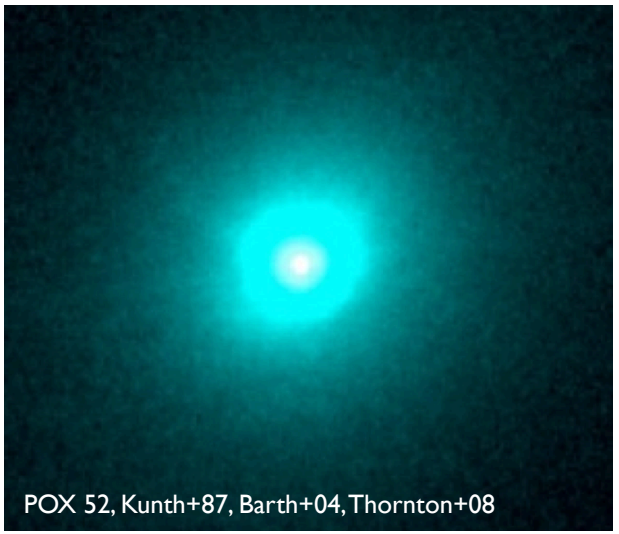
Massive black holes in the Universe



Powering quasars as luminous as L~10^{11}-10^{13} L_{sun}

The engines are accreting black holes with masses up to several billions of M_{sun}

… and down to < 10^{5} M_{sun} in faint AGN



Massive black holes as GW emitters

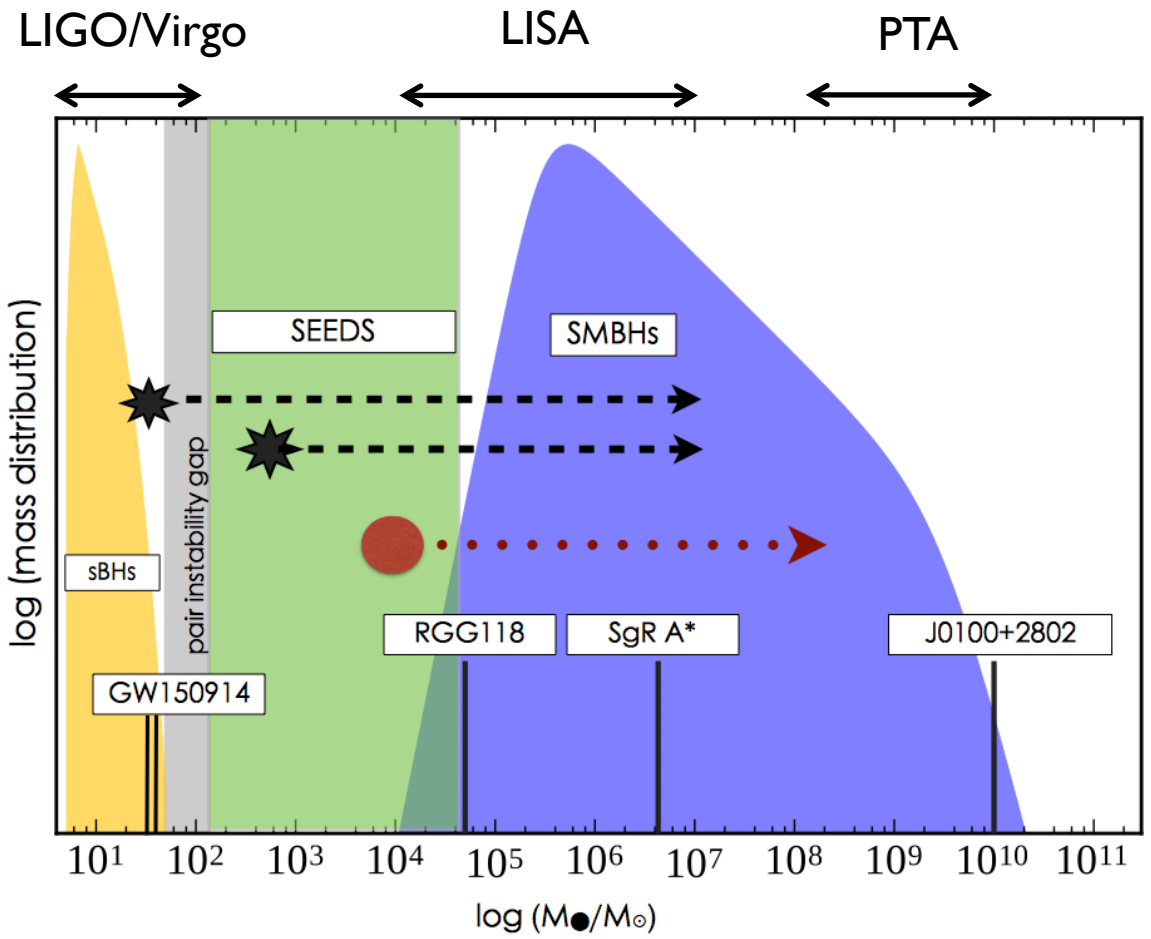
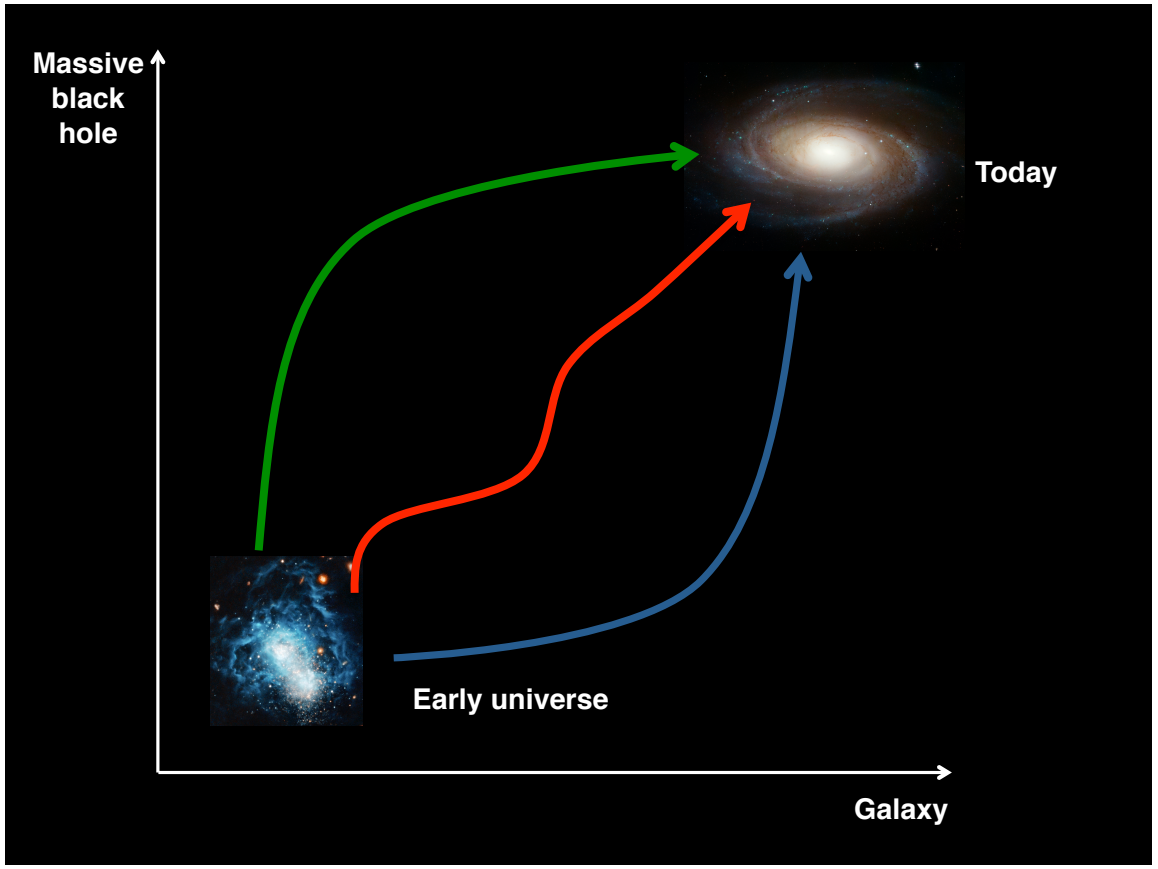


Figure credit: Monica Colpi

Massive black holes in galaxies

Massive black holes should naturally grow along with galaxies through accretion and MBH-MBH mergers and influence the galaxy through feedback



Massive black hole mergers and GWs

How many galaxies host MBHs

➔ when, where, how they form

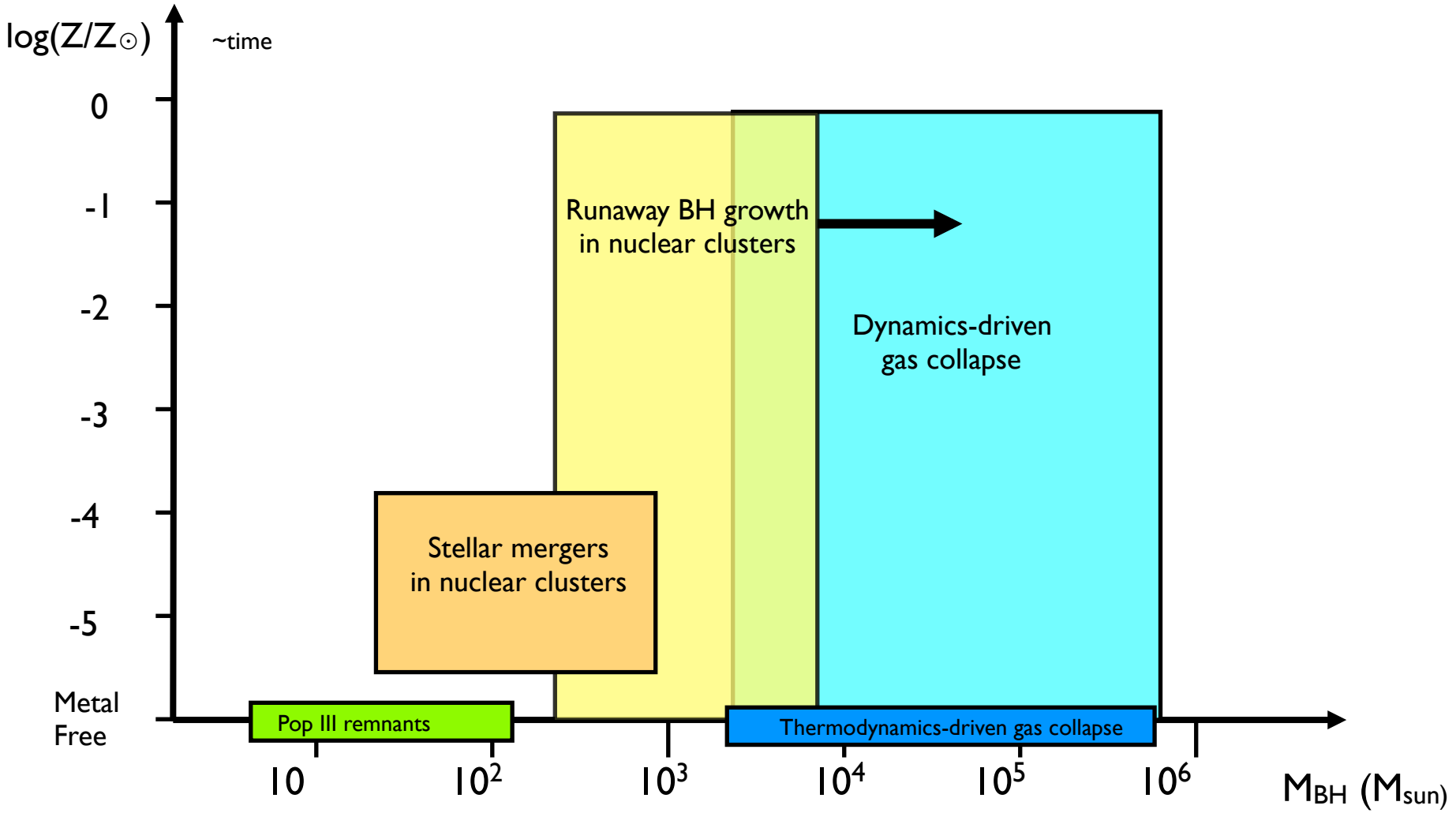
How long it takes for MBHs to merge in halo/ galaxy merger

➔dynamics of MBHs in mergers

How MBHs grow in mass over time

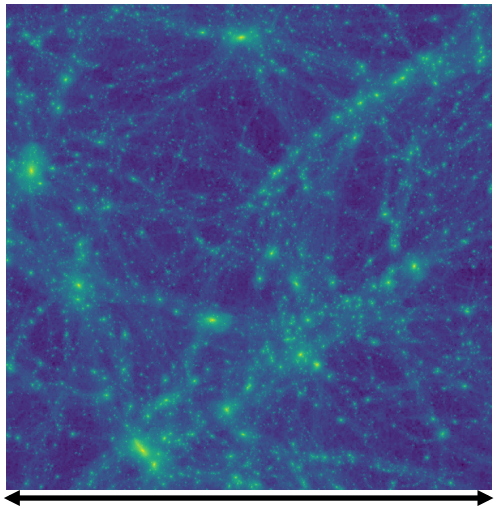
➔accretion vs MBH-MBH mergers

Massive black hole formation



Common ⟶ Rare

The journey of two black holes

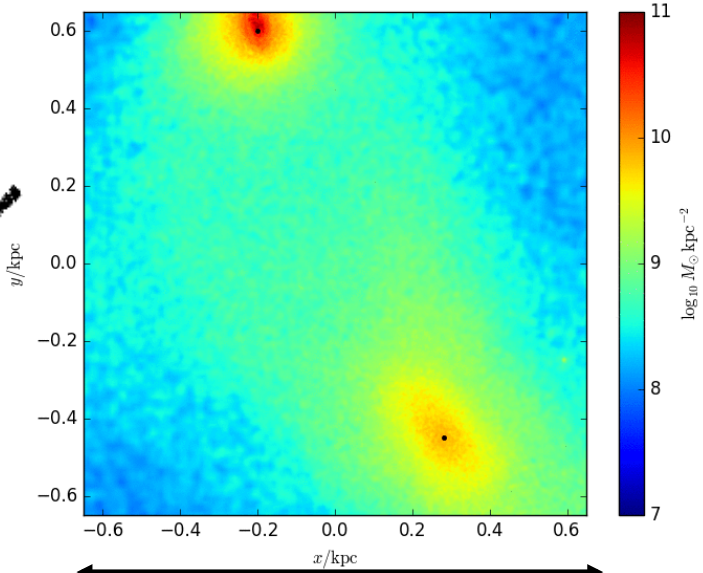


~100 Mpc (cosmology)

Gravity

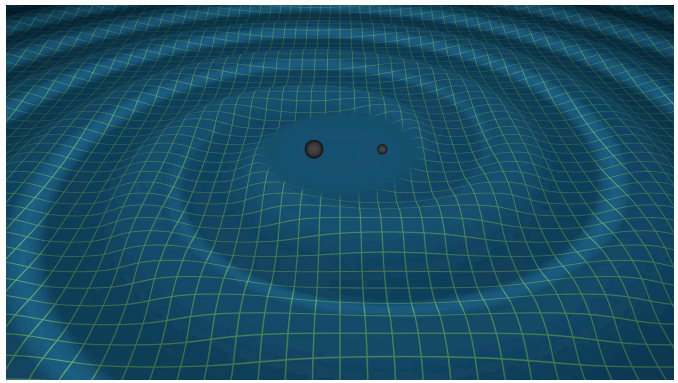
~100 kpc -1 kpc (galaxy mergers)

Dynamical Friction



~1 kpc-1pc (binary formation)

Gas torques?
Stellar scattering?
Last pc problem

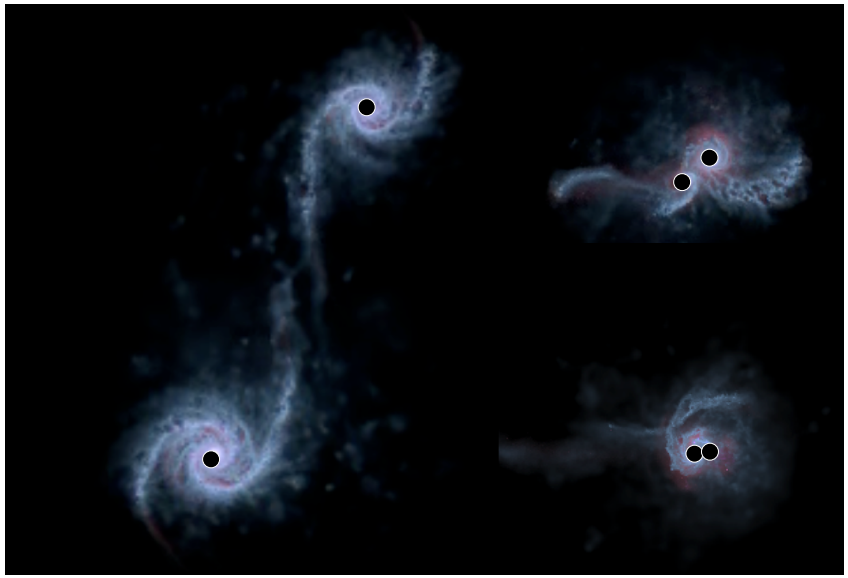


~1 millipc(BH merger)

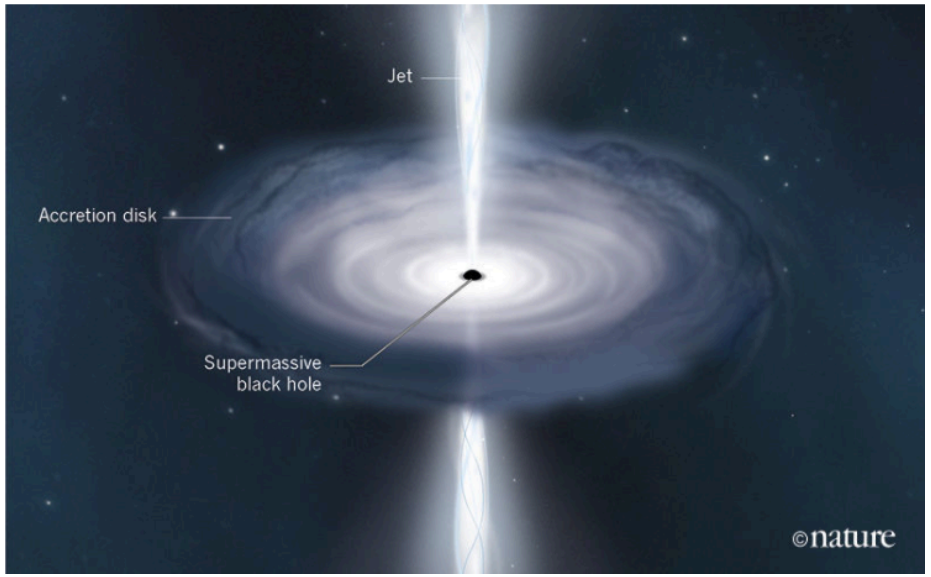
Courtesy of Hugo Pfister

The growth of black holes

MBH-MBH mergers vs gas accretion



Total mass density in MBHs in the Universe is almost constant with time



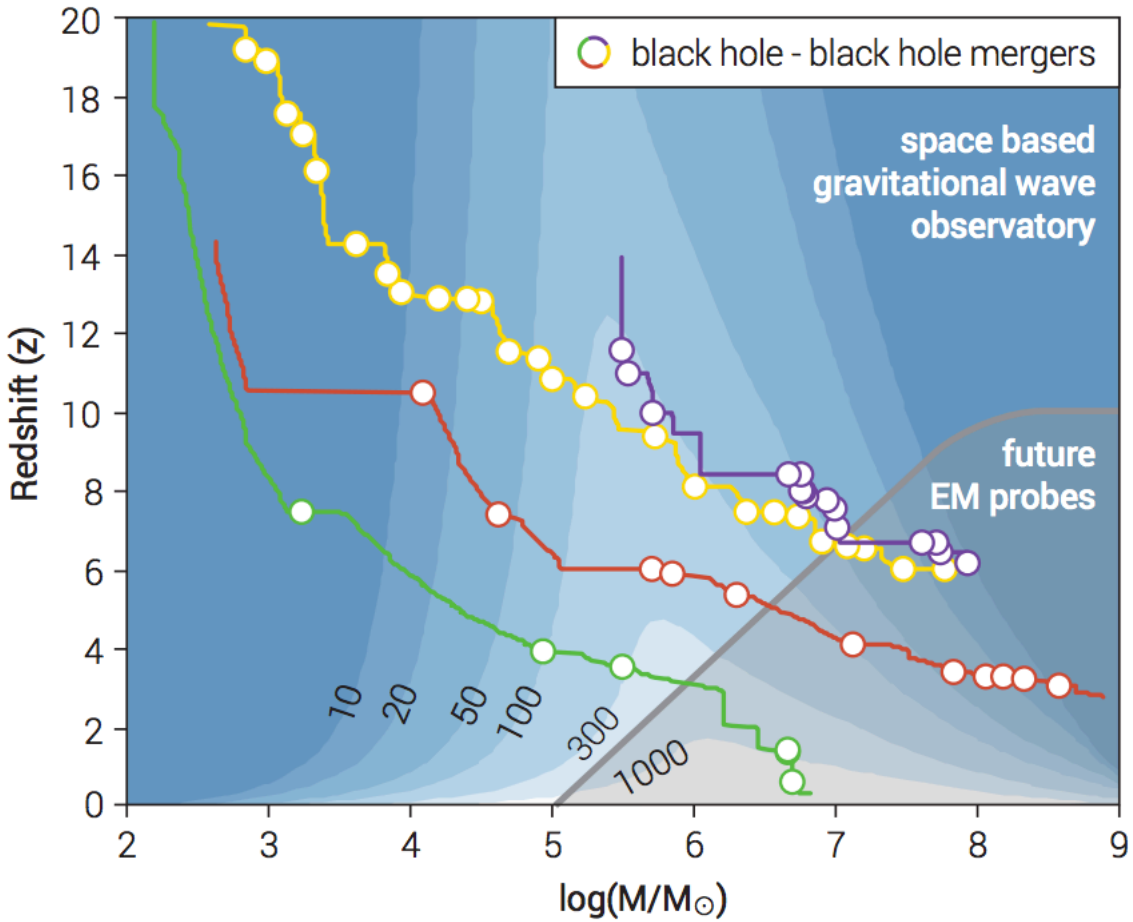
Total mass density in MBHs in the Universe increases with time

Yu & Tremaine 2002

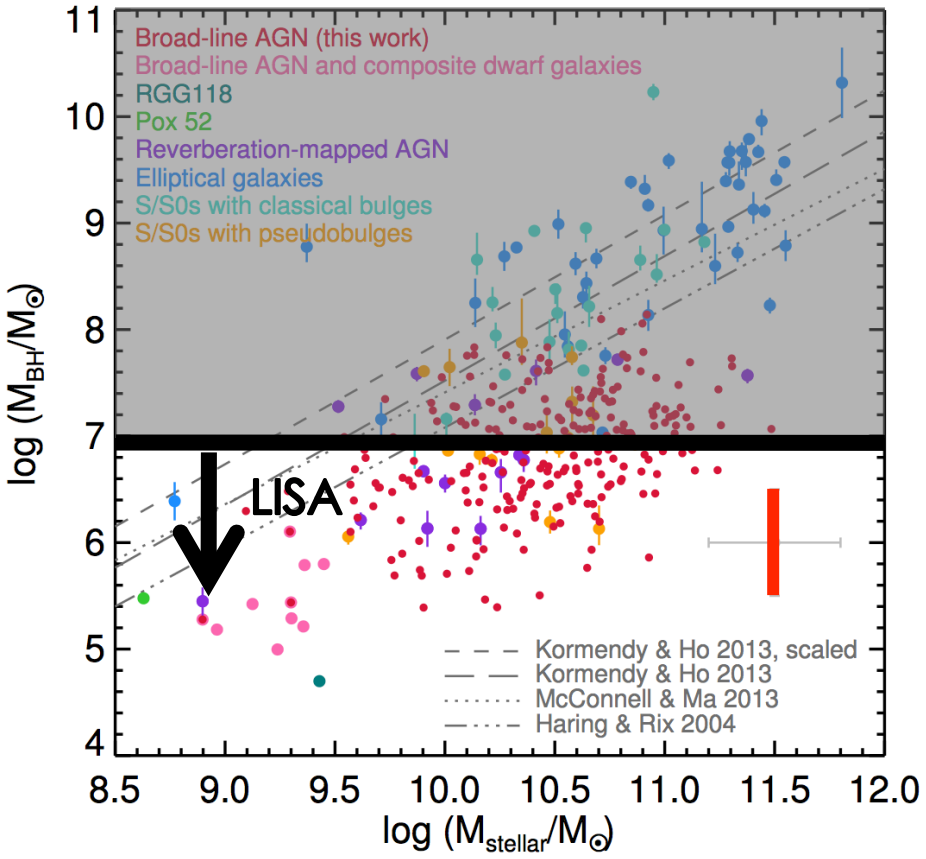
Massive black holes and gravitational waves

MBHs grow along with galaxies through accretion and MBH-MBH mergers

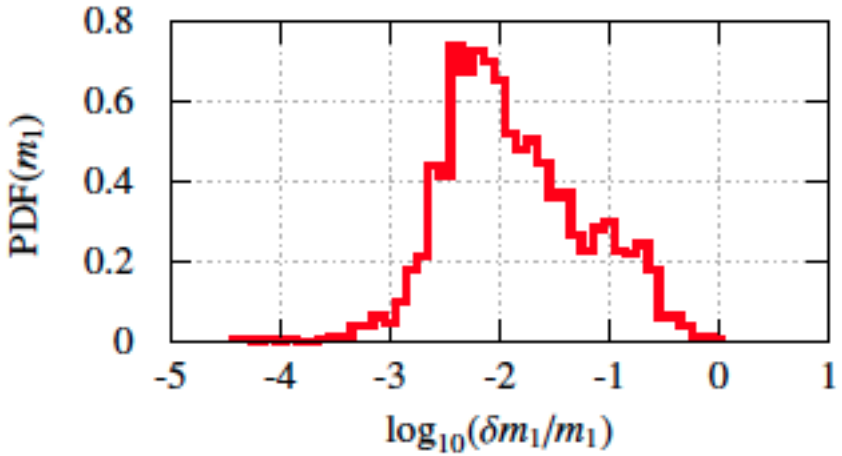
Over time they sweep the LISA band, and if sufficiently massive, they become emitters for Pulsar Timing Array experiments



What can GWs do for MBHs?



MBHs in a range
hard to probe otherwise



Provide exquisite
measurement of mass
(and spin)

What can GWs do for MBHs?

What can we infer about the black hole population from the full set of events observed by LISA?

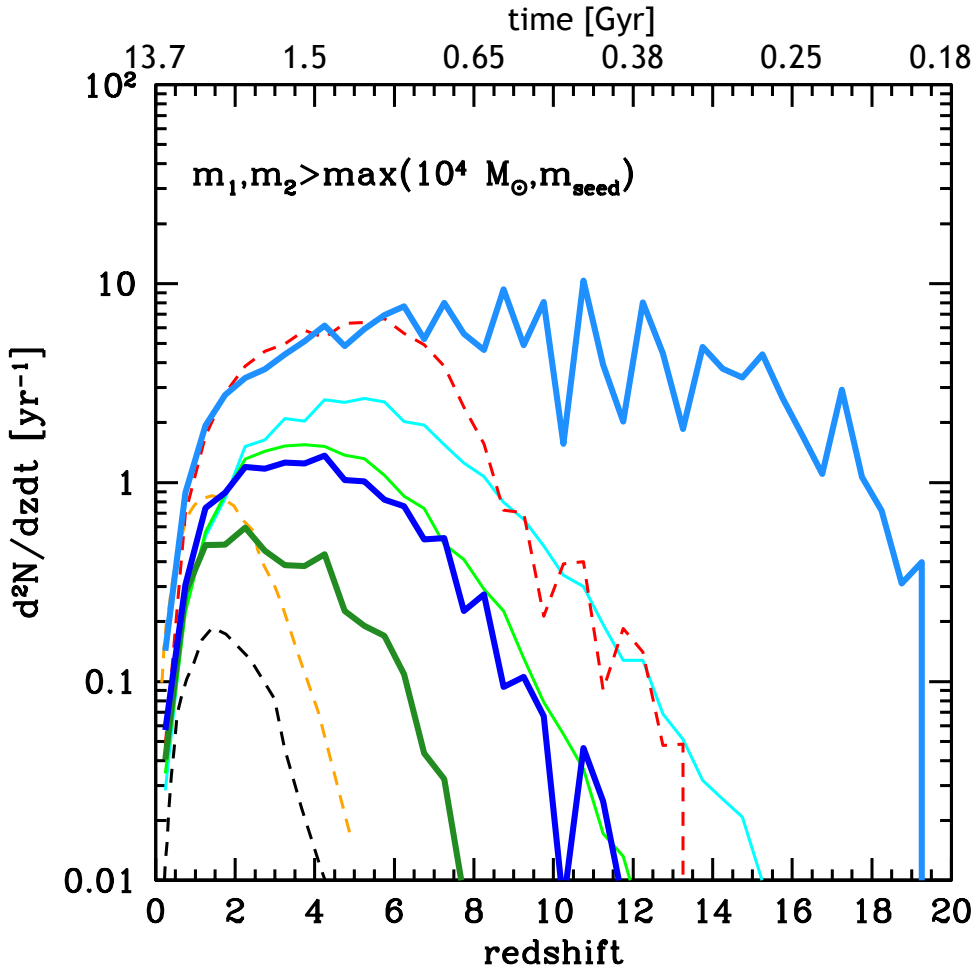
Use observed distribution of source parameters to compare with models. Which model provides the better explanation of the data?

Arun+2008,Sesana, Gair, Berti, MV 2011; Sesana 2008, 13; Ravi+2012,15; Kulier+14; McWilliams+14

Search the mock datastream with model distributions (masses, mass ratios and redshifts)

We can extract information about more complex MBH formation and growth histories by using models we understand well

LISA pseudo merger rate



SAMs:

Barausse+ (Mh>10^5-10^6 Msun)

MV, Sesana+ (Mh>10^5-10^6 Msun)

cyan, light blue, blue: large BH seeds

light green, dark green: small BH seeds

SIMs:

Salcido+ (Eagle, Mh>1.4e10 Msun)

Blecha+ (Illustris, Mh>1.4e11 Msun)

Tremmel+ (Romulus, Mh>3.5e8 Msun)

Number of mergers per year: between 1 and 80

Summary

MBHs in merging galaxies have along journey: beginning to end, it takes between 1 and 10 Gyr with large uncertainties

Full "merger rate" predictions still have large uncertainties – be careful when you pick a merger rate!

Turning this around, GWs are a unique way of probing MBH evolution

- Best and cleanest way to find the first MBHs!
- Will know about MBH dynamics!