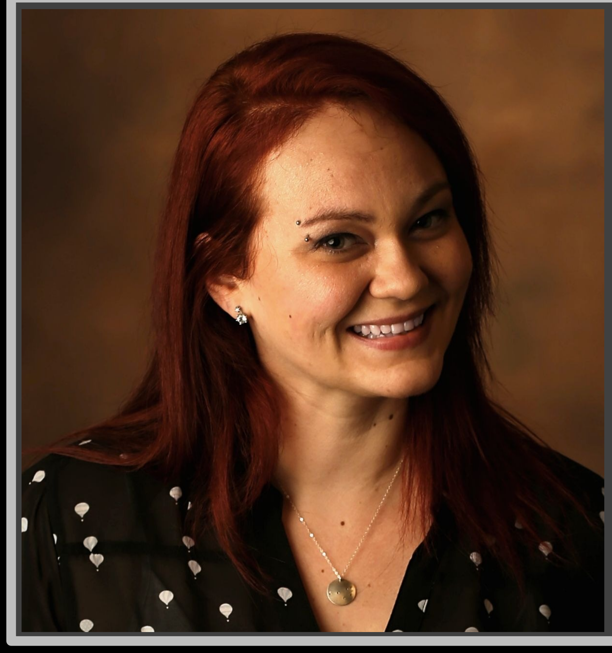

Behind the Curtain: Revealing the effect of sub-grid models on supermassive black hole merger rates for LISA

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FISK-VANDERBILT Master's-to-Ph.D. BRIDGE PROGRAM

MORE REALISTIC PARAMTERS FOR MERGING SIMULATIONS

BEGIN WITH EXISTING SIMULATION

↓

MODEL REALISTIC BH MERGER TIME

↓

LET BH GROWTH CONTINUE DURING THE INFALL

↓

ADD GW RECOIL

↓

FIND NEW BH POPULATION

We aim to understand the effect that more realistic sub-grid physical models have on supermassive black hole merger rates. Using a cosmological zoom-in simulation of black hole formation as a testbed, we add in the often neglected effects of dynamical friction, 3-body scattering, and gravitational wave inspiral times to correct the actual time of merger, allow the black holes to continue their growth as they sink together, and model the effect of gravitational wave recoil as well. This suite of experiments will allow us to dissect the importance of the hidden assumptions in black hole evolution within current semi-analytic models and cosmological simulations, and explore the interplay between these sub-grid physical assumptions.

TIME DELAY FOR MERGING BLACK HOLES

We test our technique using 34 seed black hole mergers from Dunn et al. 2018, taking into account the dynamical friction, 3-body scattering and gravitational wave decay timescales. Although the dynamical friction and gravitational wave timescales are clear-cut (see below), the 3-body scattering timescale is currently not well-defined; we adopt a uniform distribution between 10 Myr and 3 Gyr, bracketing the results from high resolution direct n-body simulations of 3-body scattering in non-spherical galaxy models (e.g. Khan et al. 2014). During the inspiral time, we allow the secondary black hole to grow by Eddington-limited accretion.

$$t_{df} = \frac{v^3}{4\pi G M_{BH2} ln(\Lambda)\rho}$$

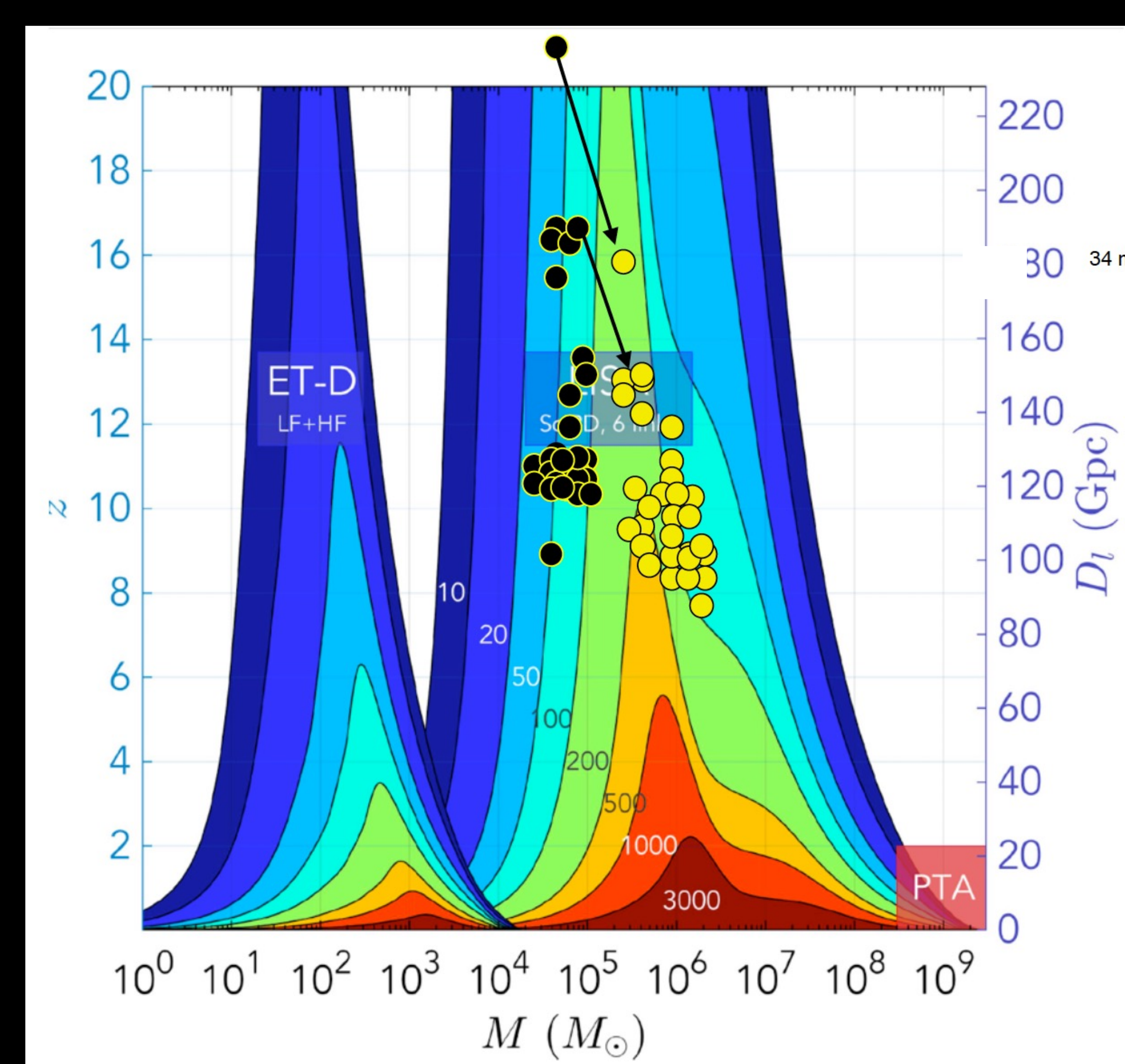
$$t_{merge} = t_{df} + t_{3body} + t_{gw}$$

$$t_{gw} = \frac{5}{256} * \frac{c^5}{G^3} * \frac{a^4}{M_{BH1} M_{BH2} (M_{BH1} + M_{BH2})}$$

$$M_{edd} = M_{BH2} * e^{\frac{t_{merge}\alpha}{t_{sal^{-1}}}} + M_{BH2}$$

LOUDER, MORE MASSIVE BH

WATERFALL PLOT



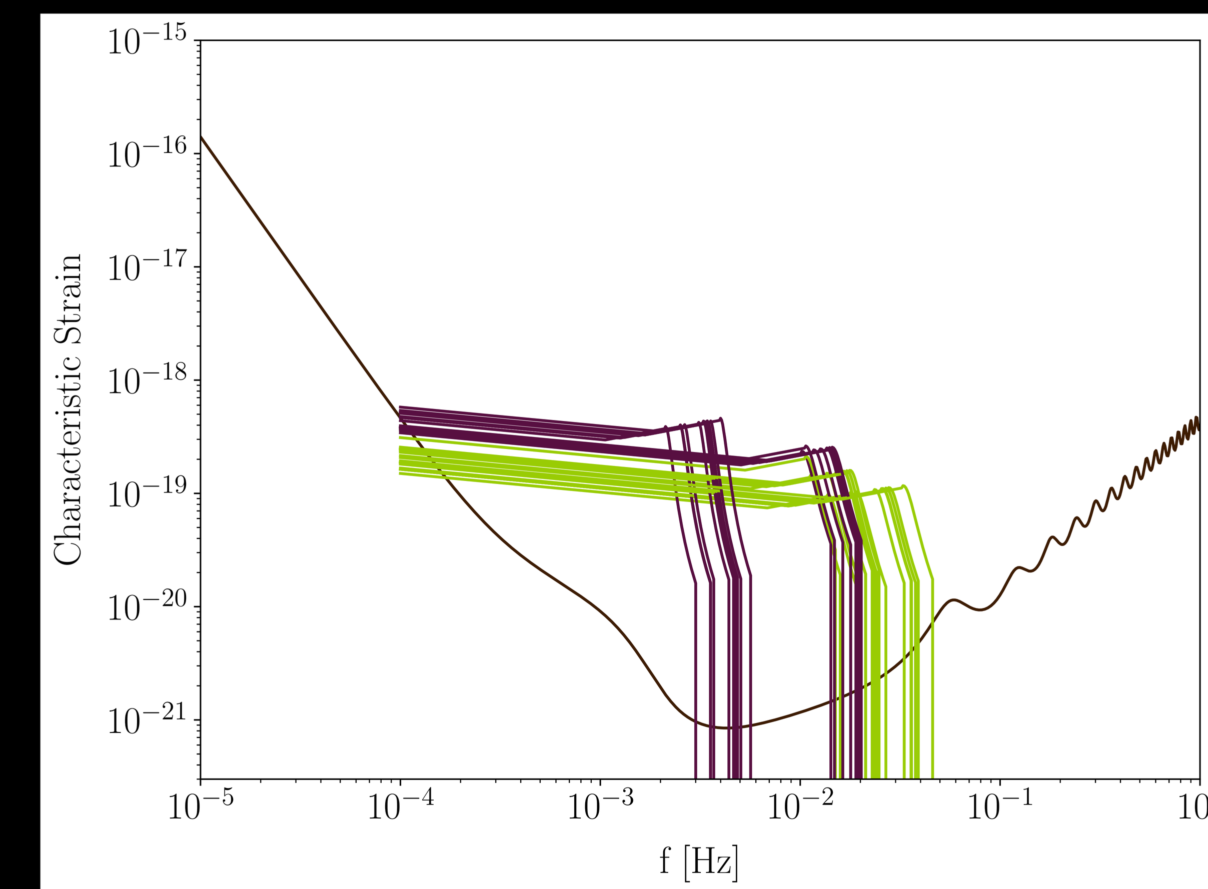
$$M_{chirp} = \frac{(M_{BH1} M_{BH2})^{3/5}}{(M_{BH1} + M_{BH2})^{1/5}}$$

$$h_{pure} = \frac{8\pi^{2/3}}{10^{1/2}} * \frac{G^{5/3} M_{chirp}^{5/3}}{c^4 z} * f^{2/3}$$

$$n = \frac{5}{96\pi^{8/3}} * \frac{c^5}{G^{5/3} M_{chirp}^{5/3}} * f^{5/3}$$

$$h_{char} = h_{pure} * n^{1/2}$$

CHARACTERISTIC STRAIN



FUTURE WORK & IMPLICATIONS FOR LISA

Now that our modeling technique has been tested and verified, we plan to implement this method on larger cosmological hydrodynamic simulations, such as MassiveBlack and Illustris TNG. By correcting the current simulations with more realistic supermassive black hole merger timescales, as well as adding in secondary SMBH growth rates and gravitational wave recoil, we will have a more accurate estimate of the black hole demographics to fold into future LISA predictions.

REFERENCES

Dunn et al, 2018

Khan et al, 2014