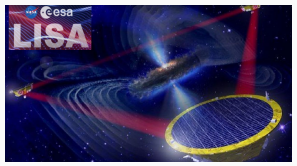

Analytical fits for parameter estimation of inspiralling MBH binaries in LISA

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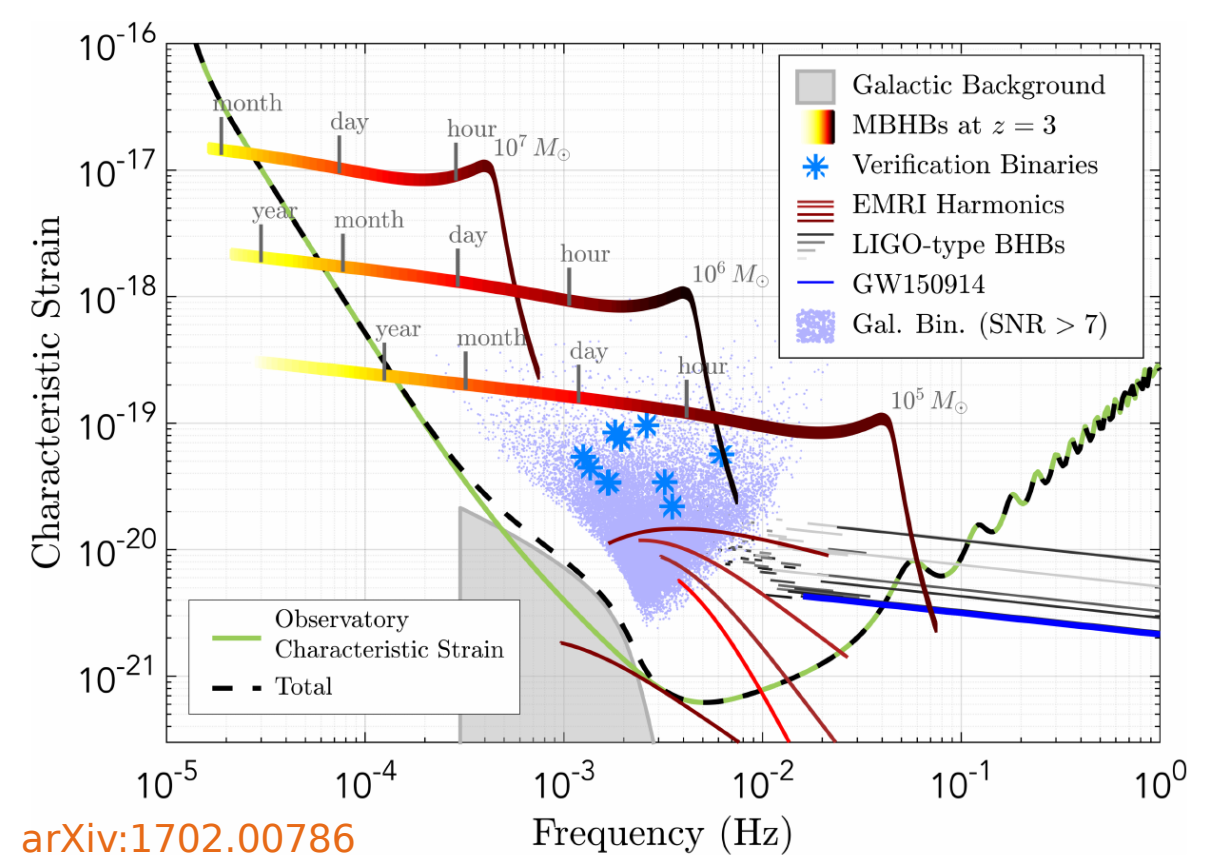
Overview



arXiv:1702.00786

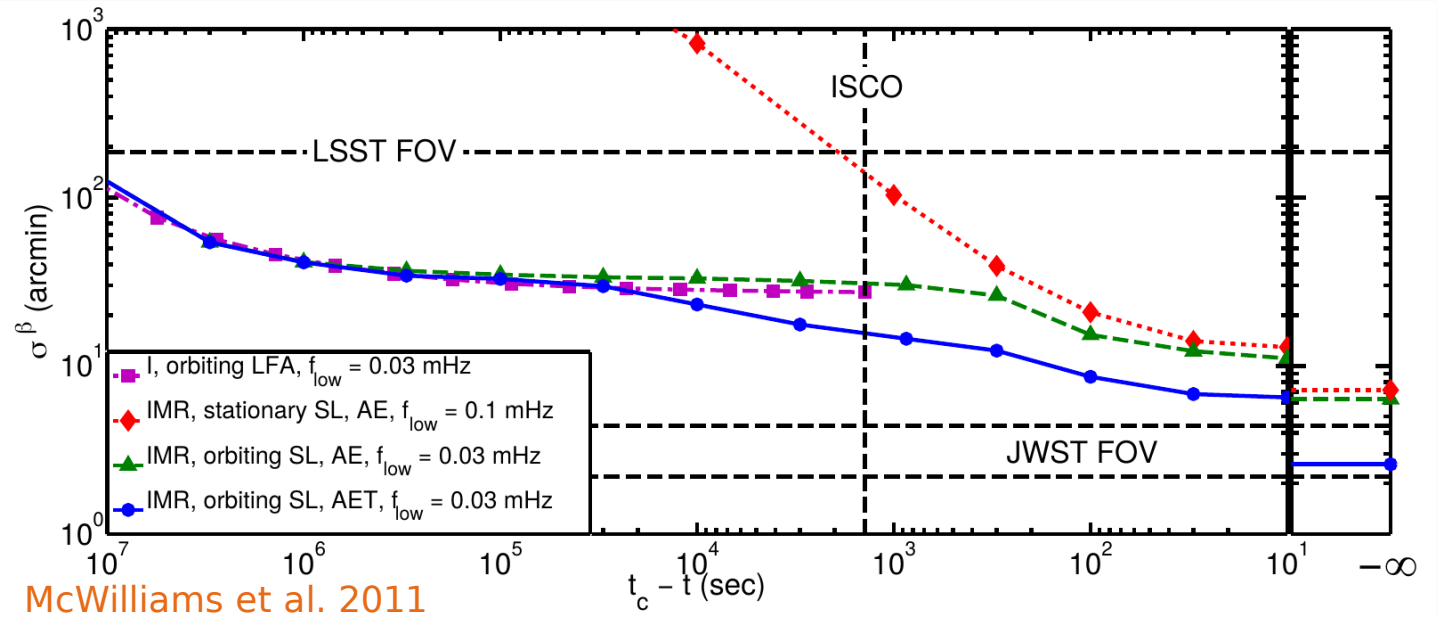
MBHBs are key sources for Multi-Messenger Astrophysics

- Detected weeks prior coalescence $\rightarrow$ early warnings
- Likely occurring in gas-rich environment $\rightarrow$ EM counterparts
- At least $\simeq 10$ events per year expected $\rightarrow$ statistics

Parameter estimation

Science outcomes depends on LISA ability to estimate source parameters

1. **MCMC** (Babak et al.2010, Marsat et al.2020)
   - Bayesian formalism
   - Computational expensive $\rightarrow$ few selected cases
2. **Fisher matrix** (Lang&Hughes 2008, Kocsis et al.2008, Klein et al.2016)
   - Reproduce MCMC results only in the high-SNR limit
   - Computational cheap $\rightarrow$ large parameter space



McWilliams et al. 2011

Main idea

Problems

- old LISA design in past inspiral studies
- Both methods require large set of simulations

Aims (AM et al. 2020, in preparation)

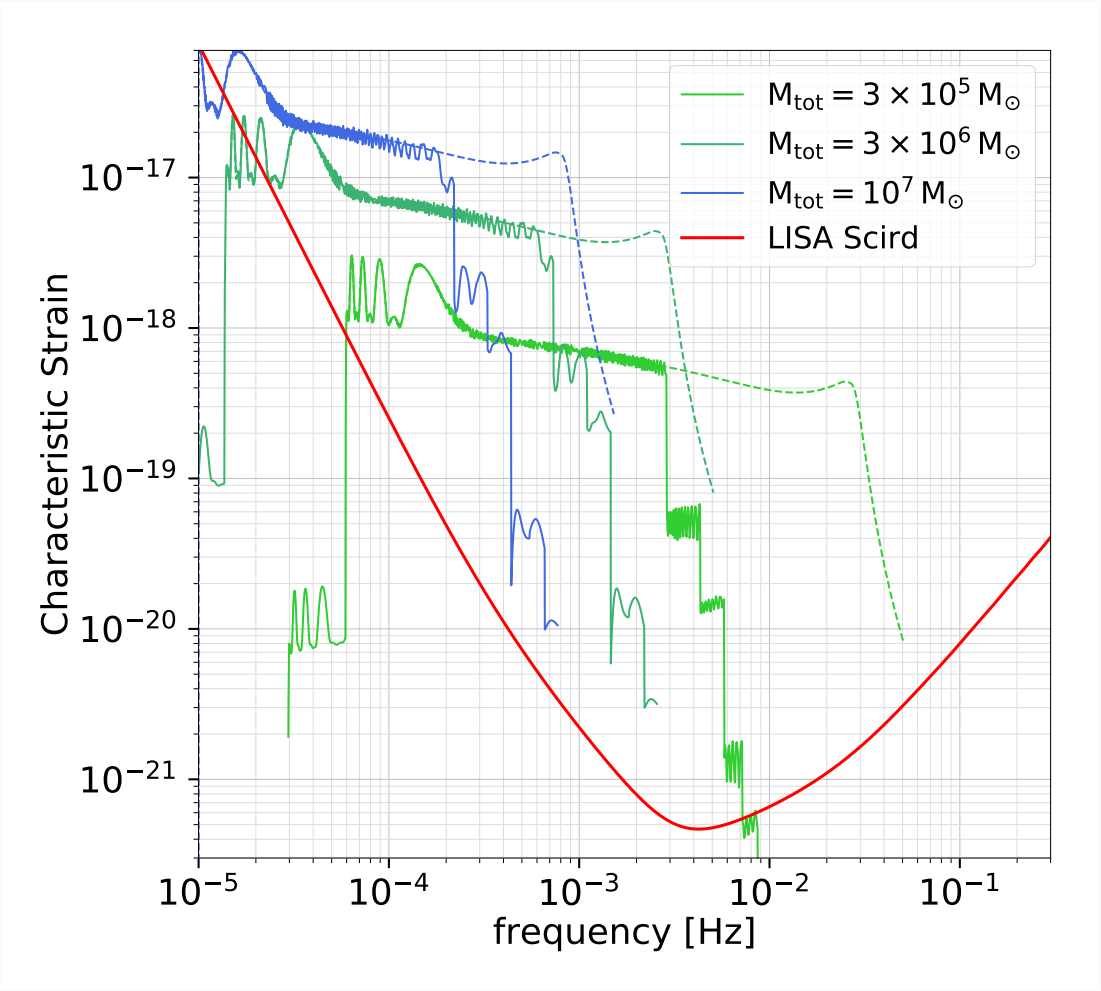
- Performance of current LISA design for *'on the fly'* estimates
- Analytical formulae to describe how parameter estimates improve during the inspiral $\rightarrow \Delta\Omega = \mathcal{F}(\mathrm{t_c}, \mathrm{M_{tot}}, \mathrm{z})$?

Parameter space

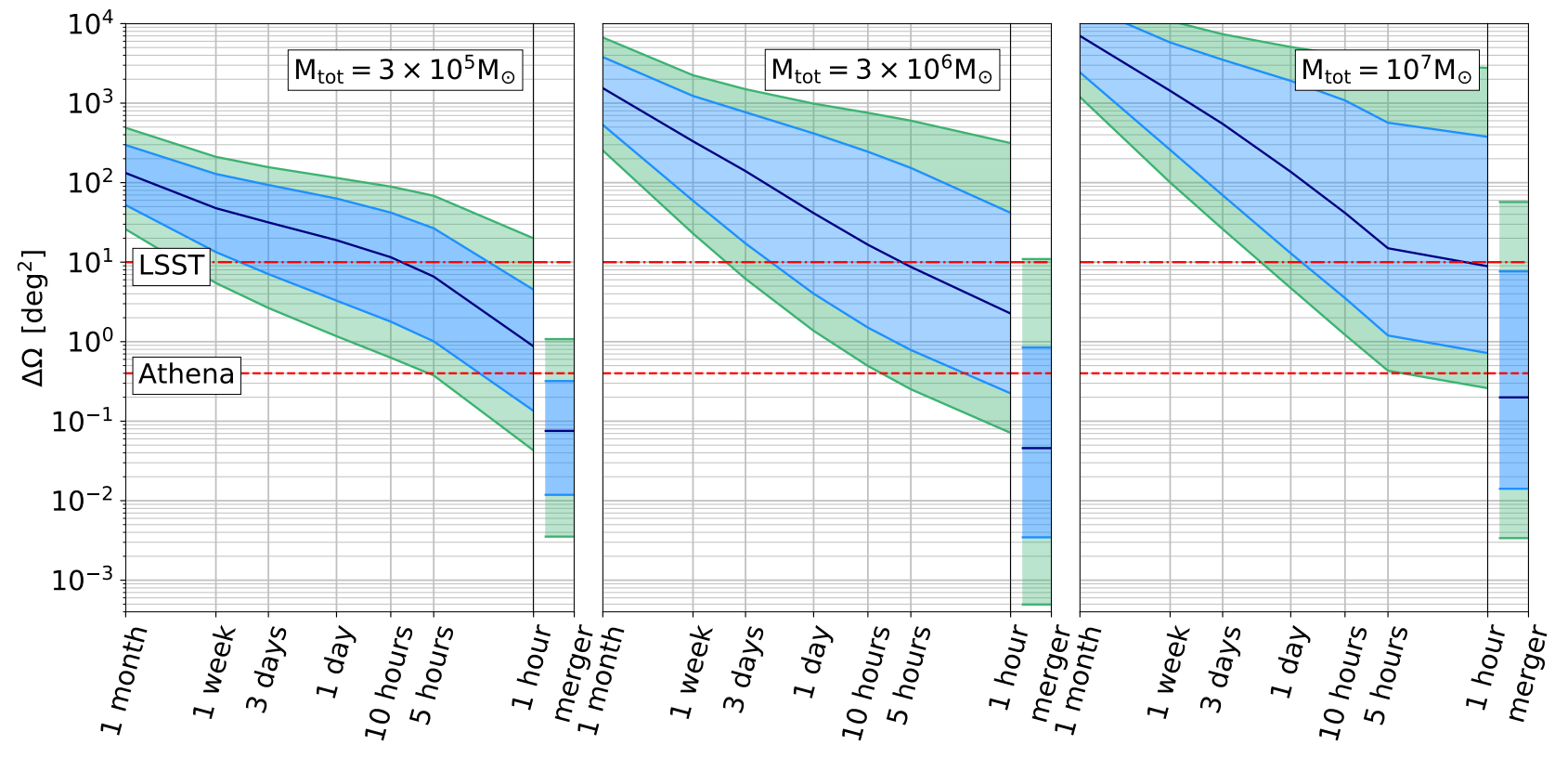
- $\mathrm{M_{tot}} = 10^5, 3\times10^5, 5\times10^5, 7.5\times10^5, 10^6, \ldots, 3\times10^7 \mathrm{M_\odot}$
- $z = 0.1$, 0.3, 0.5, 1, 2, 3, 4
- 1 month, 1 week, 3 days, 1 day, 10 hrs, 5, hrs and 1 hr from merger

Examples of simulated signals

- Fisher matrix with inspiral precessing waveform (Klein et al. 2014)
- PhenomC to rescale $\Delta\Omega$ at merger



Sky position uncertainties at $z = 1$

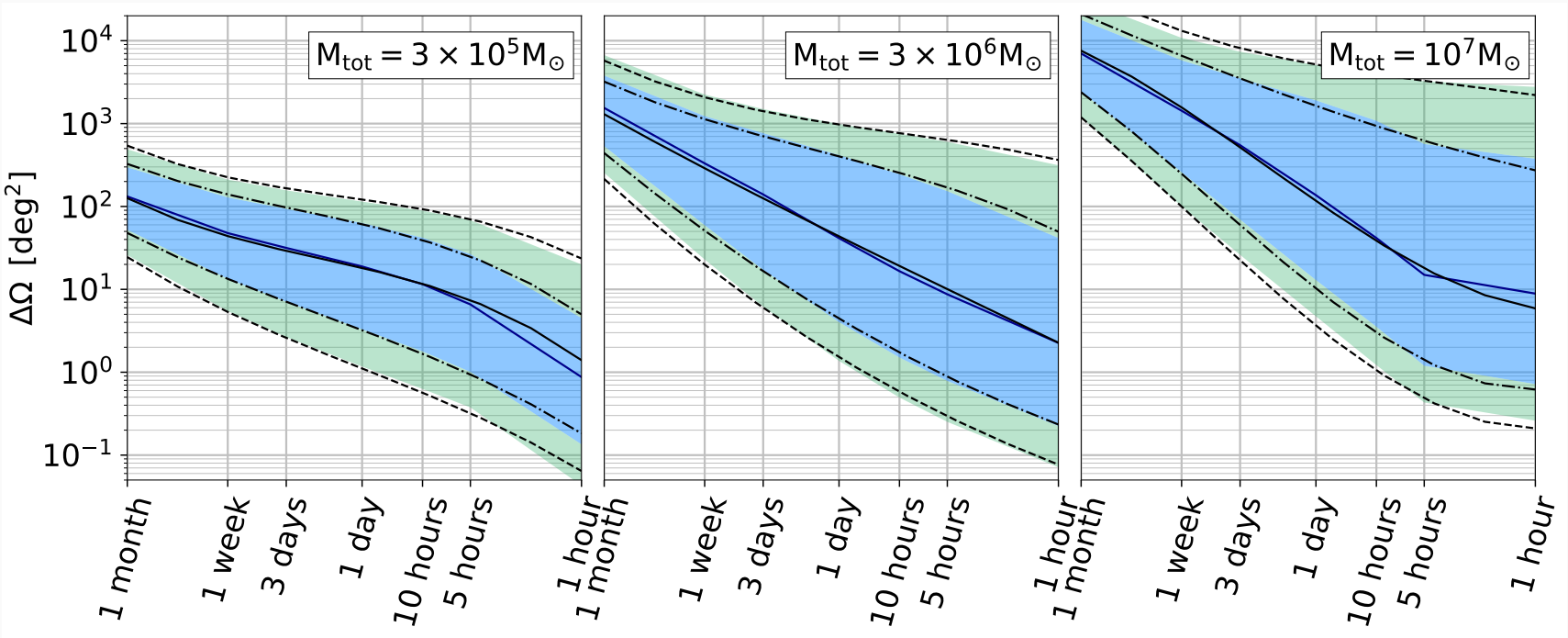


$\Delta\Omega \simeq$ telescope FOV only close to merger $\begin{cases} < 10\,\mathrm{hrs} & \text{LSST} \\ \mathrm{merger} & \text{Athena} \end{cases}$

Large distributions $\rightarrow$ strong dependence from true binary position

Analytical fits

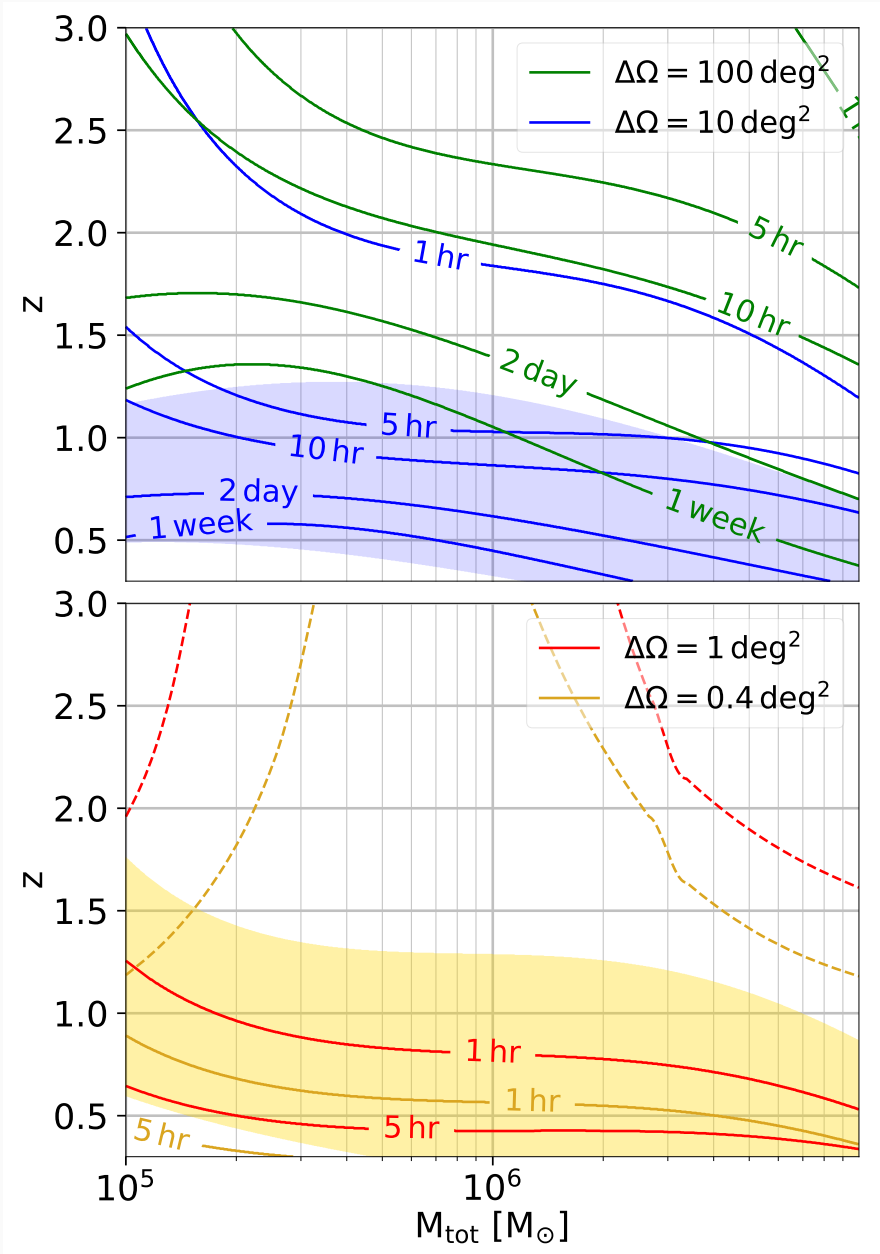
Few input parameters $\rightarrow$ Time left before merger, $\mathrm{M_{tot}}$ and z



Fits for $\begin{cases} \mathrm{M_{tot}} \in [10^5, 10^7]\,\mathrm{M}_\odot \\ z \quad\quad \in [0.3,\, 3] \end{cases}$

Also for luminosity distance, chirp mass and mass-ratio

Time left before merger



For $\mathrm{M_{tot}} = 10^6 \mathrm{M}_\odot$:

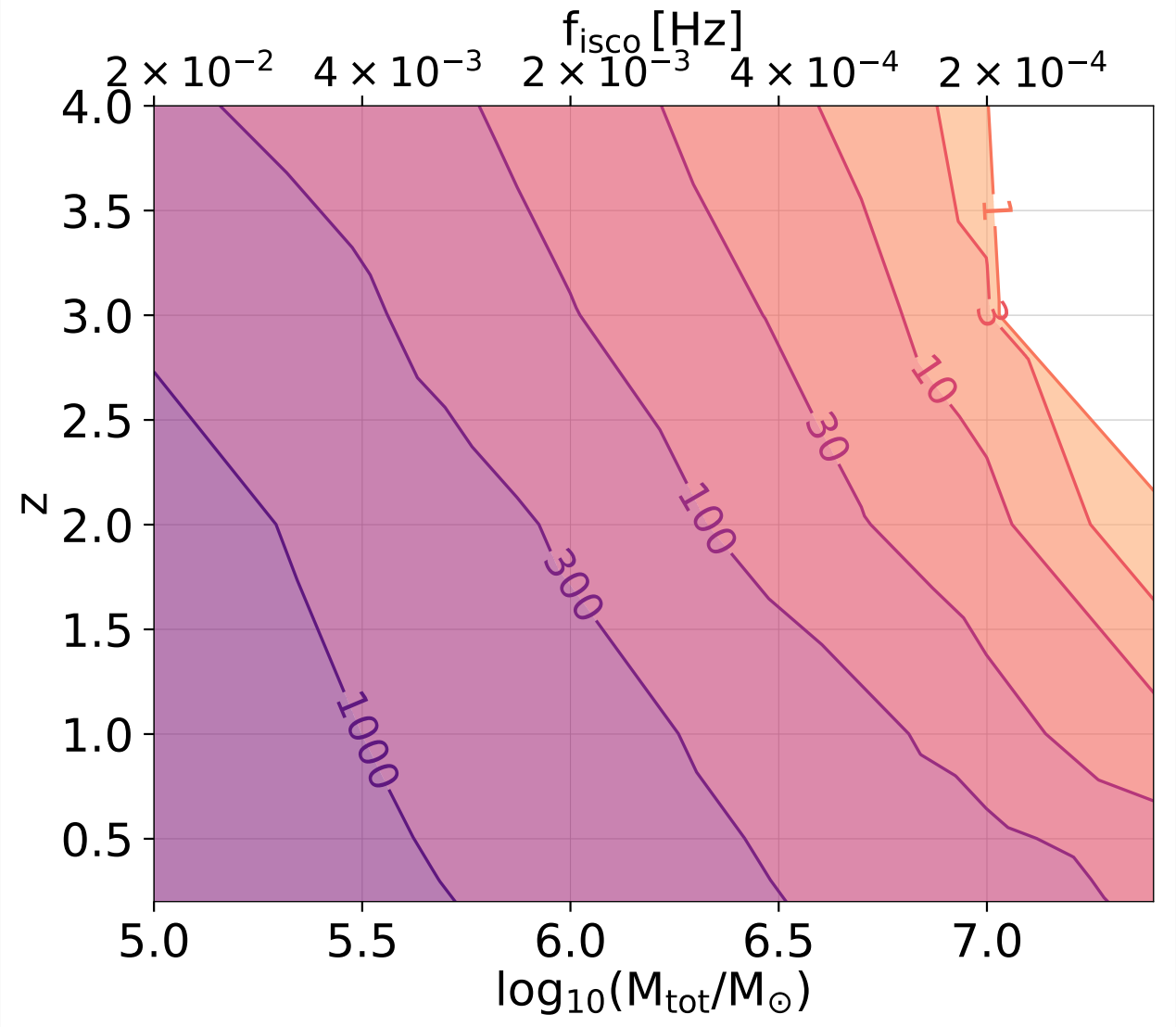
- $10\,\mathrm{deg}^2$ $\begin{cases} 5\,\mathrm{hrs} & \rightarrow z < 1 \\ 1\,\mathrm{week} & \rightarrow z < 0.5 \end{cases}$
- $100\,\mathrm{deg}^2$ $\begin{cases} 5\,\mathrm{hrs} & \rightarrow z \lesssim 2.4 \\ 1\,\mathrm{week} & \rightarrow z < 1 \end{cases}$

For all masses:

- $\Delta\Omega < 1\mathrm{deg}^2$ close to merger
- Large uncertainties

Periodicity

Number of cycles from detection . . .



Conclusions

Parameter estimation 'on the fly' for LISA MBHBs:

- Adopted LISA current design
- Sky localization uncertainties (also for d_L, chirp mass and mass-ratio)
- Sky uncertainties $\simeq$ telescopes FOV only close to merger but large uncertainties
- compare few cases with MCMC simulations (work in progress)

Analytical fits for parameter estimates

- Valid for $\mathrm{M}_{\mathrm{tot}} \in [10^5, 10^7]\,\mathrm{M}_\odot$ and $z \in [0.3, 3]$
- Indepent fits for uncertainties at merger
- fits also for d_L, chirp mass and mass-ratio
- Release data

Thanks