



MONASH
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Distinguishing between stellar and primordial black hole merger events

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Credit: NYU

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MoCA
Monash Centre for Astrophysics

<https://dcc.ligo.org/LIGO-G1700985>

Overview

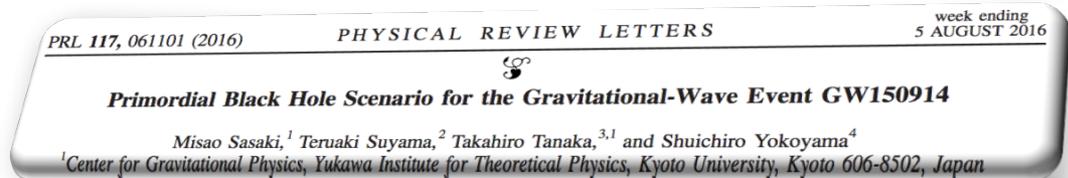
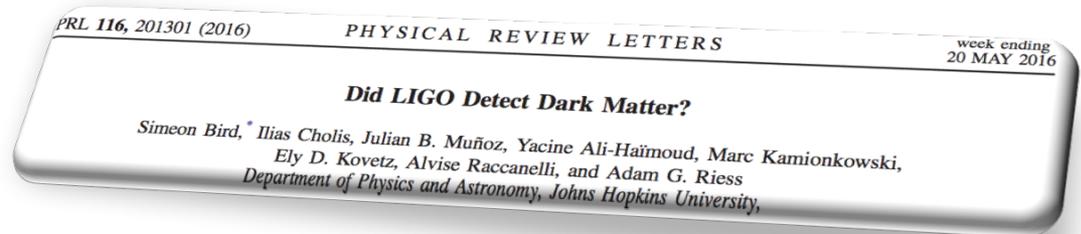
Suggestions that LIGO could have detected relic primordial BHs.

Is it possible to test this hypothesis?

We present preliminary results developing a framework for conclusively testing the primordial scenario.

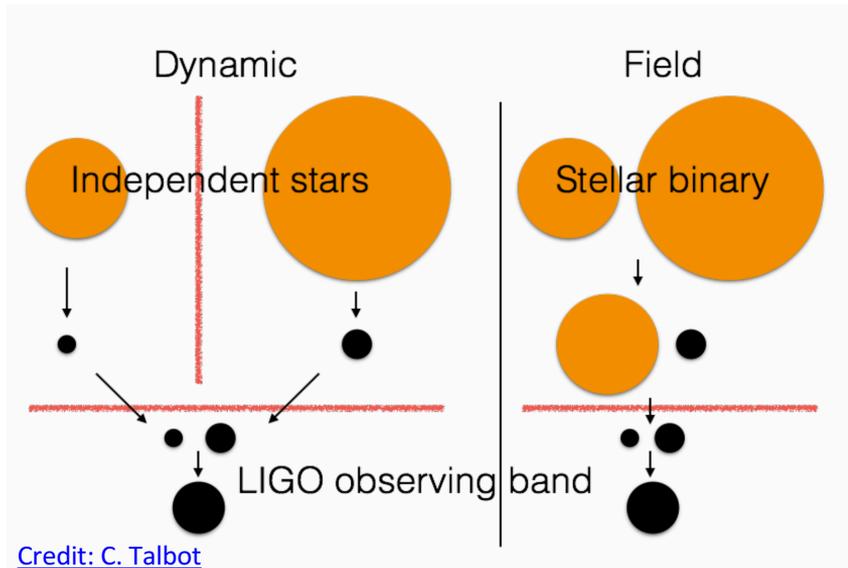
Outline

- Stellar/PBH properties
- Bayesian model selection
- Preliminary results



BBH merger events

Conventional (stellar) models?

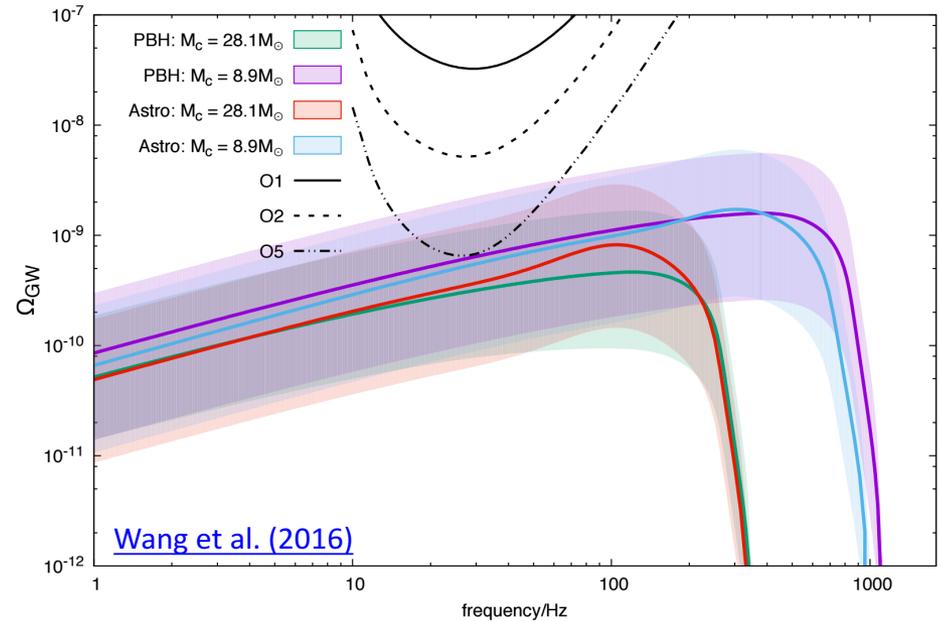
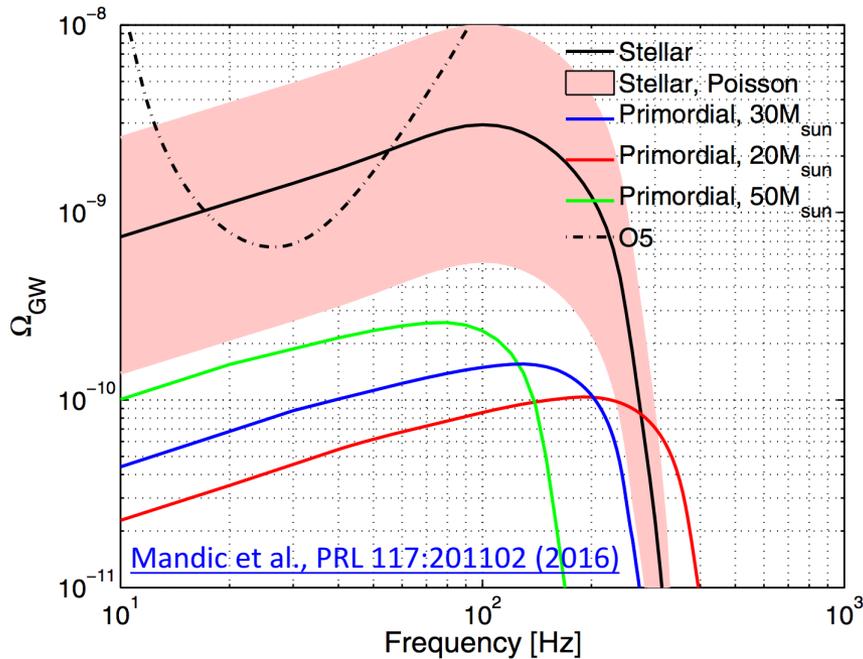


Primordial BHs ?

- PBHs could contribute to DM
- Mass window for PBHs to be DM includes GW150914
 $20M_{\odot} \lesssim M \lesssim 100M_{\odot}$
 - Lower masses are excluded by microlensing surveys
 - Higher masses would disrupt wide binaries

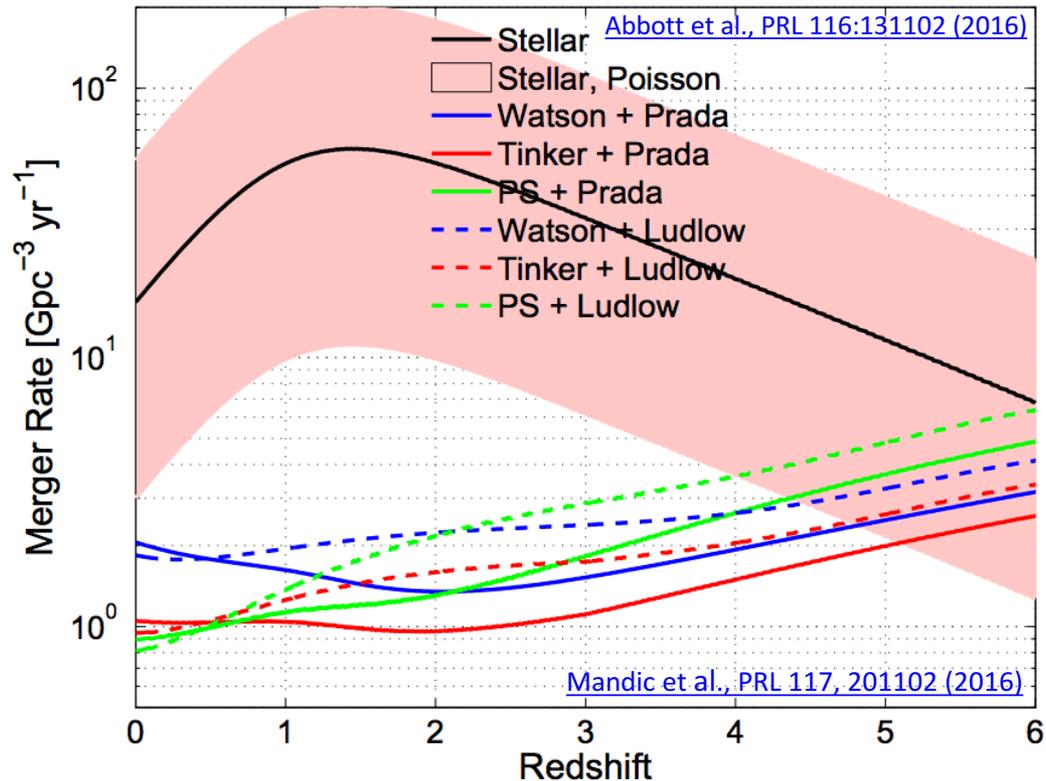
GW backgrounds

- Testing PBH scenario with SGWB not conclusive
 - signal is integrated over redshift
 - Confounding variables: mass, redshift, rate



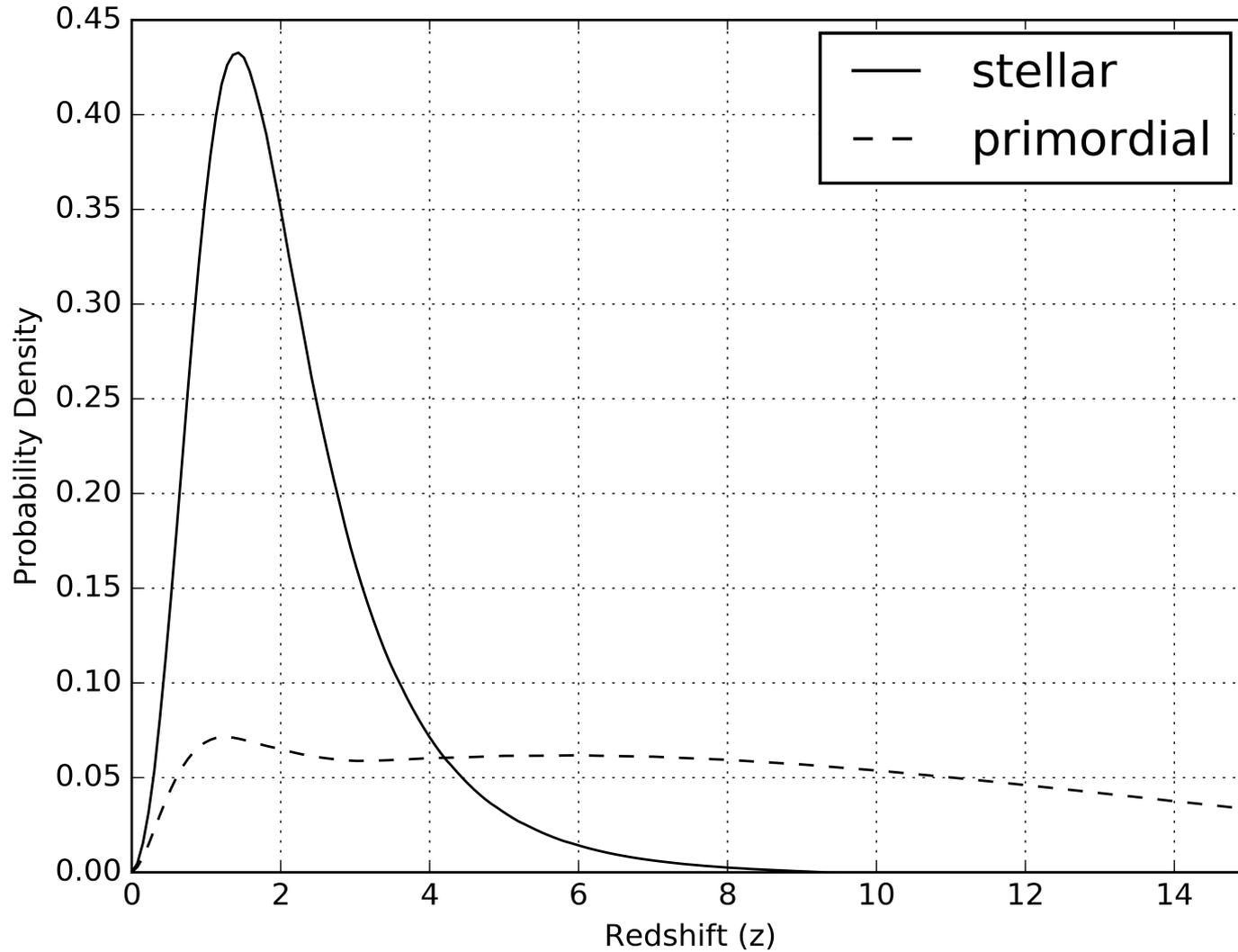
Merger rate

- Is SGWB the best tool for distinguishing between populations?
 - Merger rate integrated over redshift

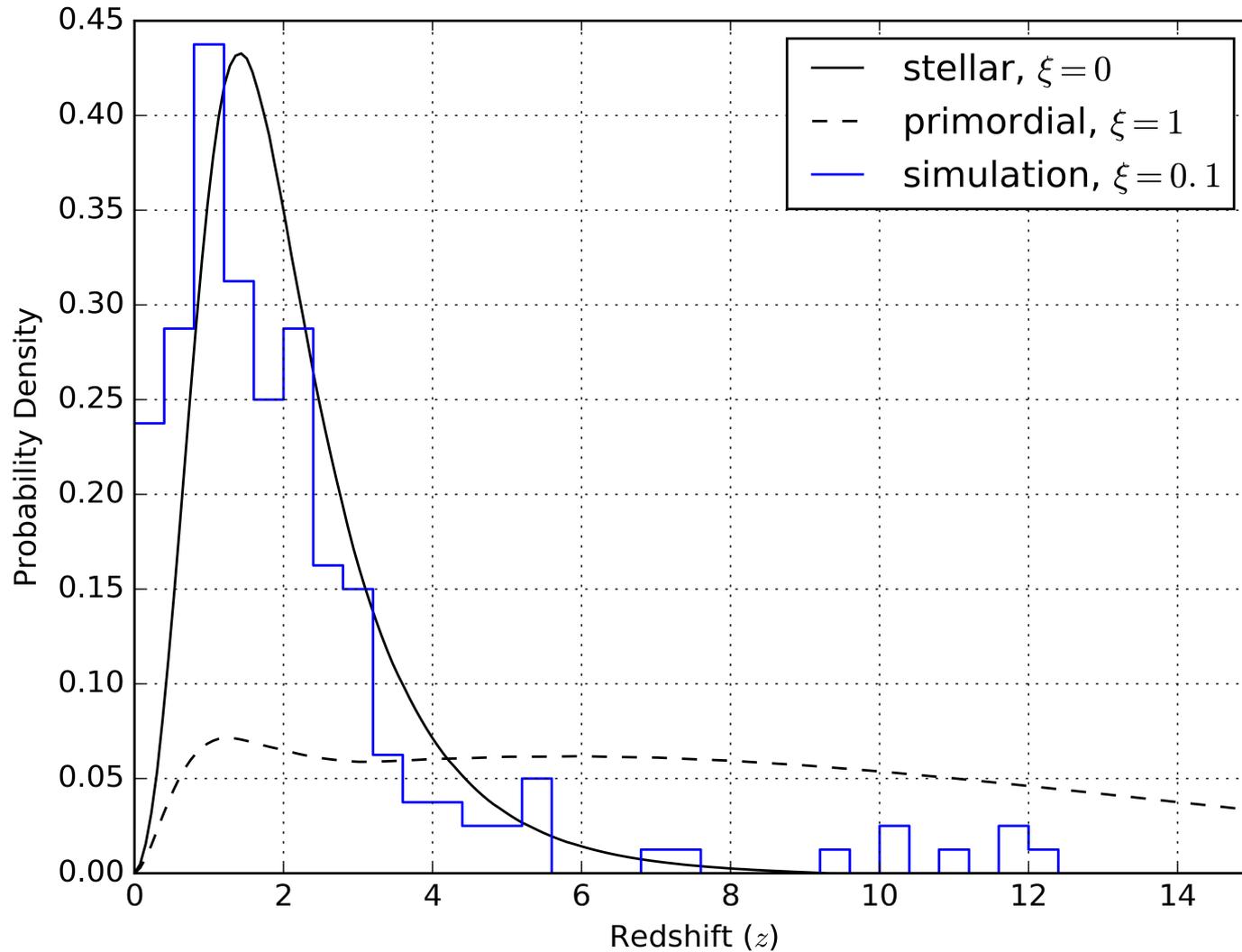


What if we look out to higher redshifts...

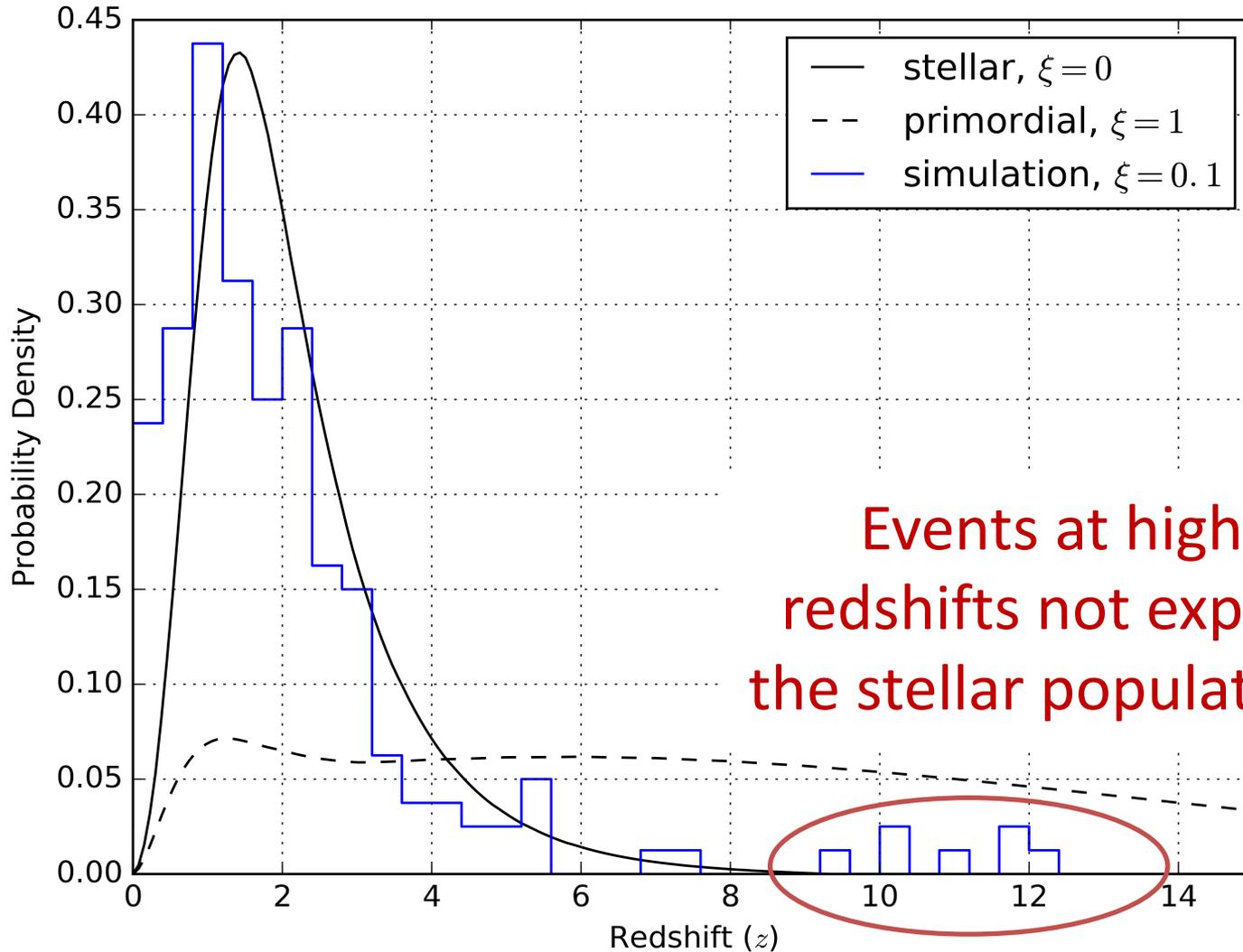
PBH signature



PBH signature



PBH signature



Events at high enough redshifts not expected from the stellar population models!

Model construction

$$\mathcal{L}(d|\xi) = (1 - \xi)\mathcal{L}_*(d) + \xi\mathcal{L}_P(d)$$

Stellar Likelihood

$$\mathcal{L}_*(d)$$

- Likelihood that observed BBH mergers follow the redshift profile based on star formation rates

Primordial likelihood:

$$\mathcal{L}_P(d)$$

- Likelihood that observed BBH mergers follow the PBH merger rate redshift profile based on DM halo concentrations

Bayes factor (Odds ratio)

$$\mathcal{L}(d|\xi) = (1 - \xi)\mathcal{L}_*(d) + \xi\mathcal{L}_P(d)$$

$$\mathcal{B}_{1,0} = \frac{\mathcal{Z}_1}{\mathcal{Z}_0} = \frac{\int d\xi \mathcal{L}(d|\xi)\pi(\xi)}{\int d\xi \mathcal{L}(d|\xi=0)\pi(\xi=0)}$$

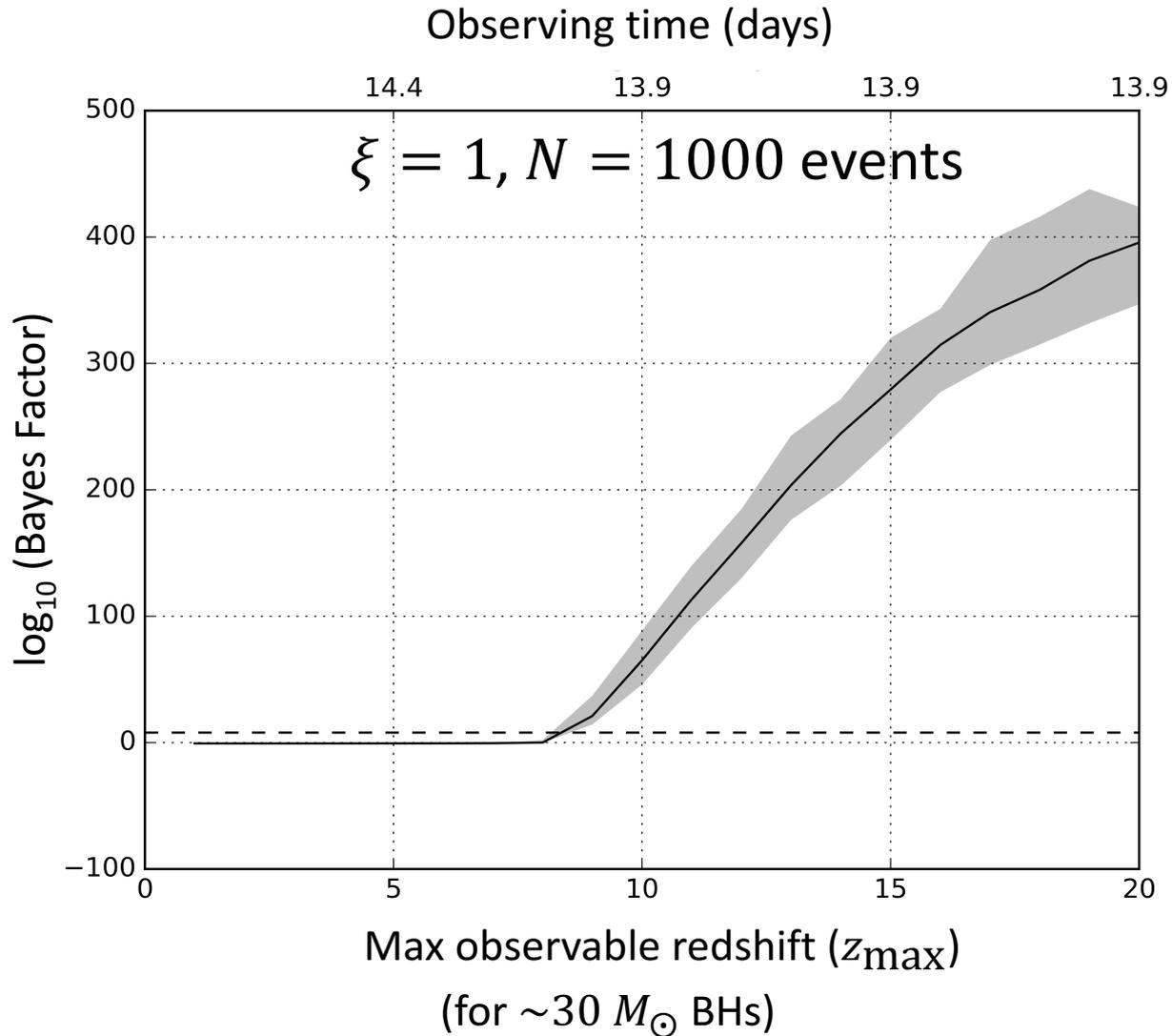
Model 0: $\xi = 0$

Model 1: $\xi \in [0, 1]$

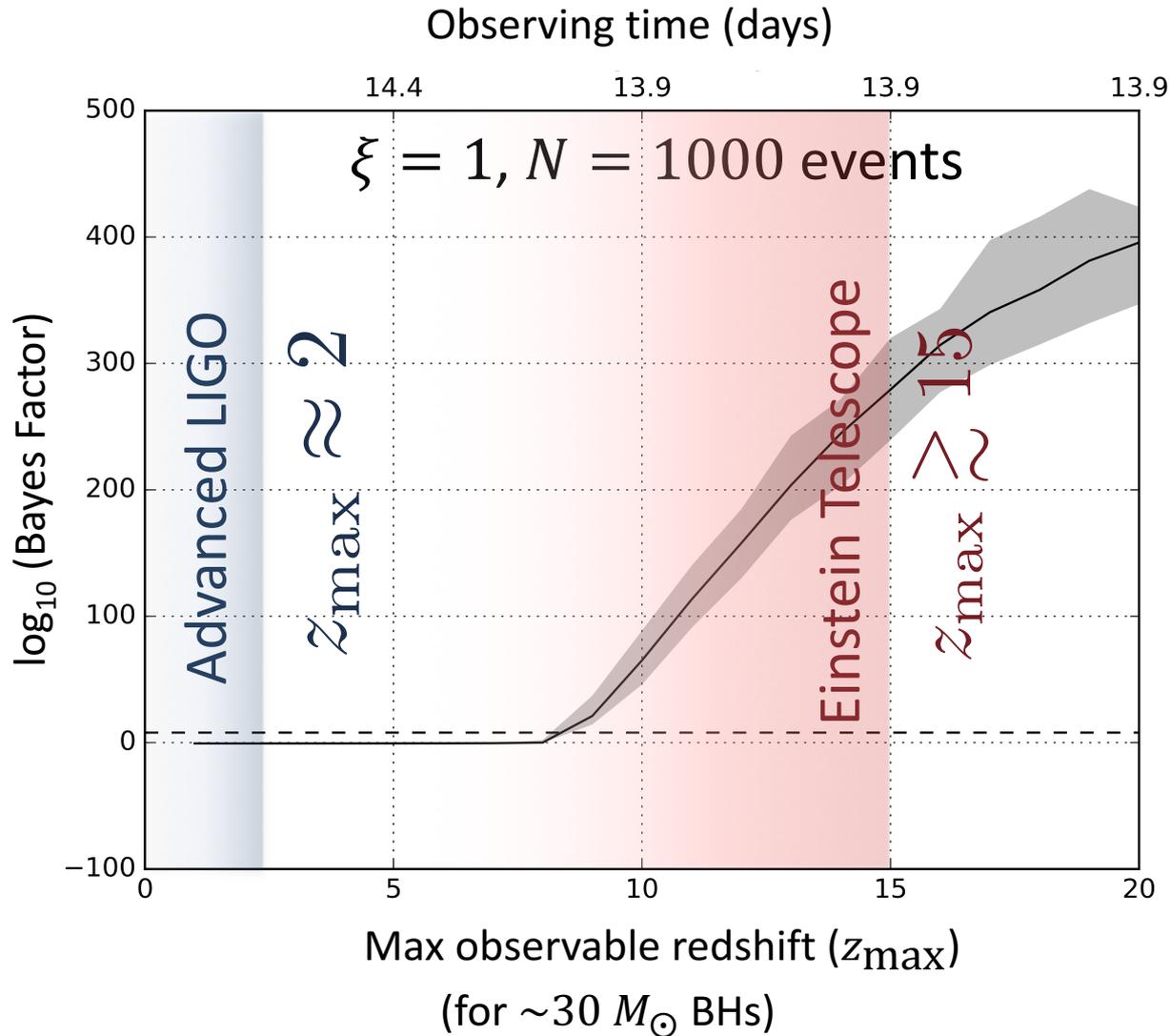
- all BBH mergers follow the redshift profile based on star formation rates

- some fraction of observed BBH mergers follow the PBH merger rate redshift profile

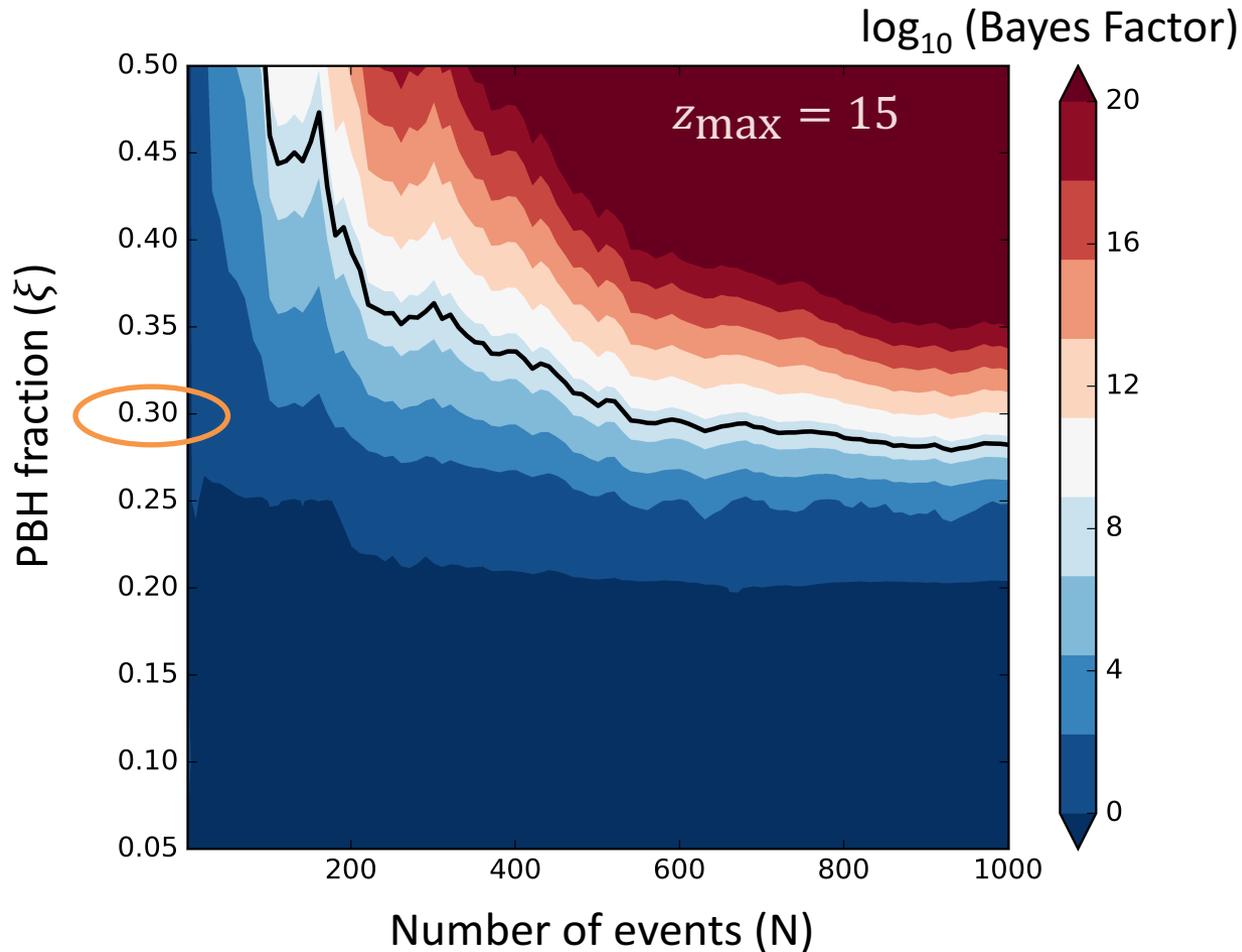
Horizon Redshift



Horizon Redshift

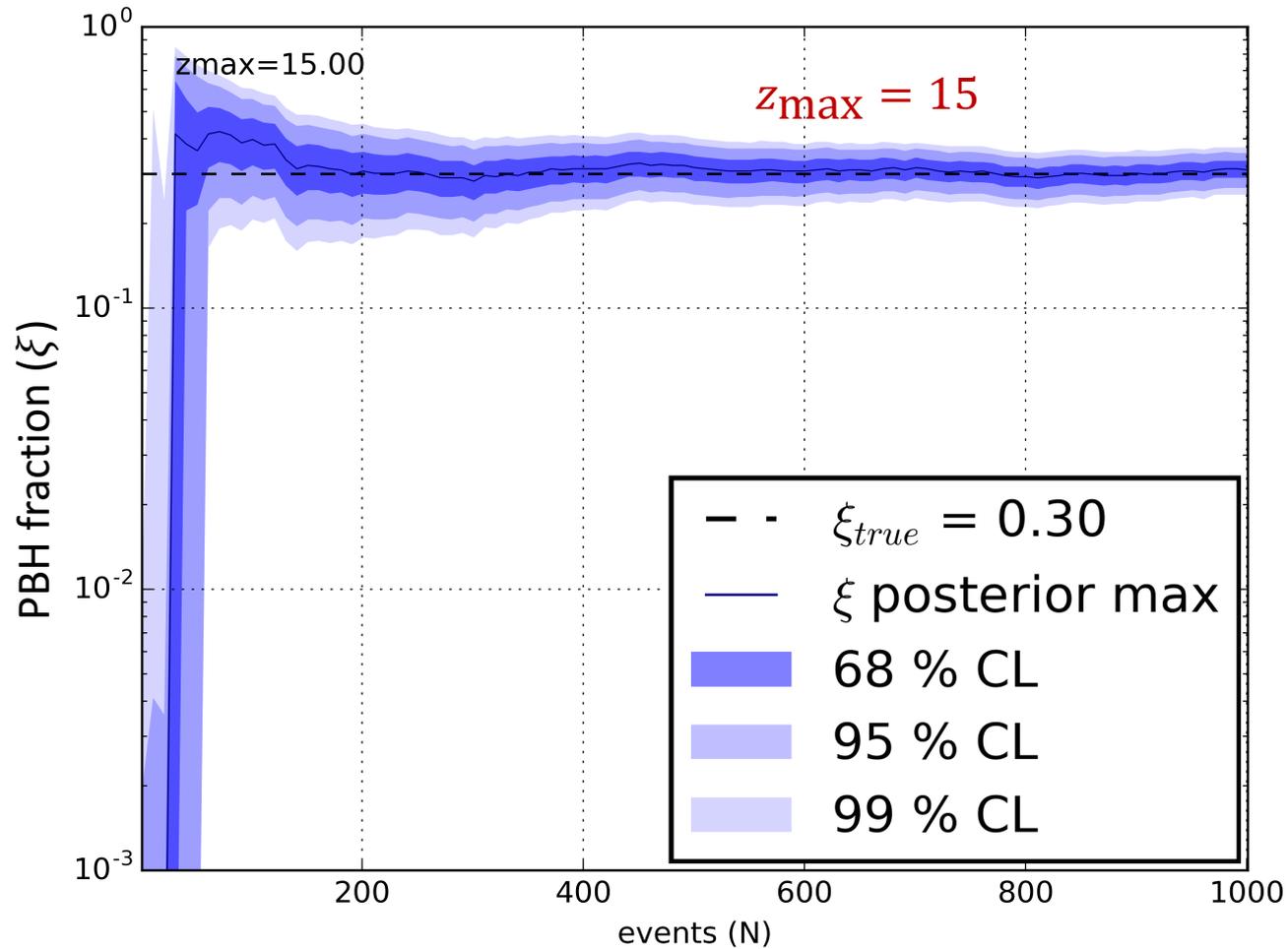


Hypothesis Testing



Distinguish to about $\xi \sim 0.3$ after 1000 events
(only ~ 15 days of ET observation)

Parameter estimation



Summary

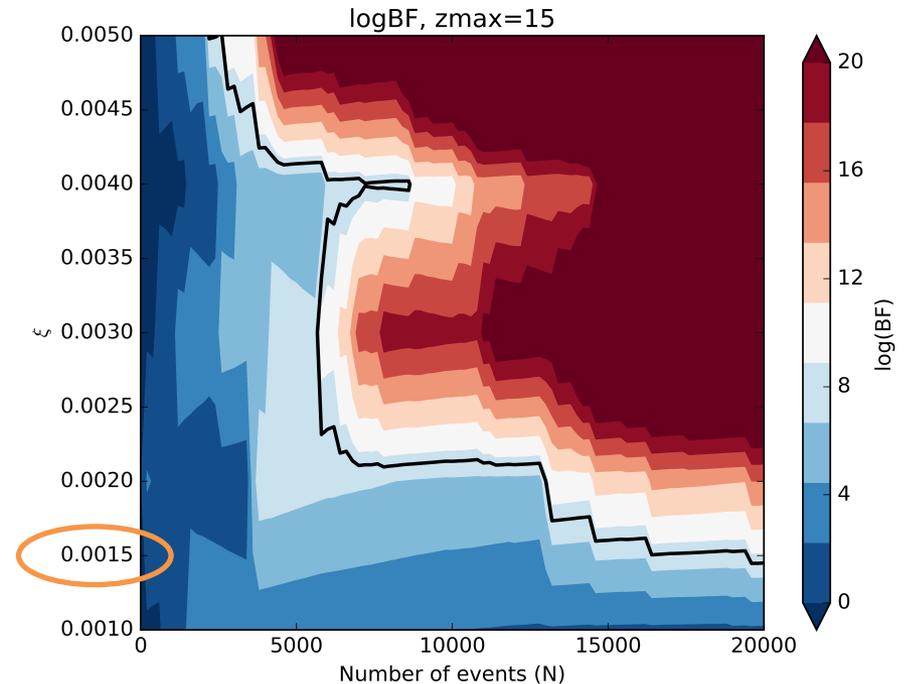
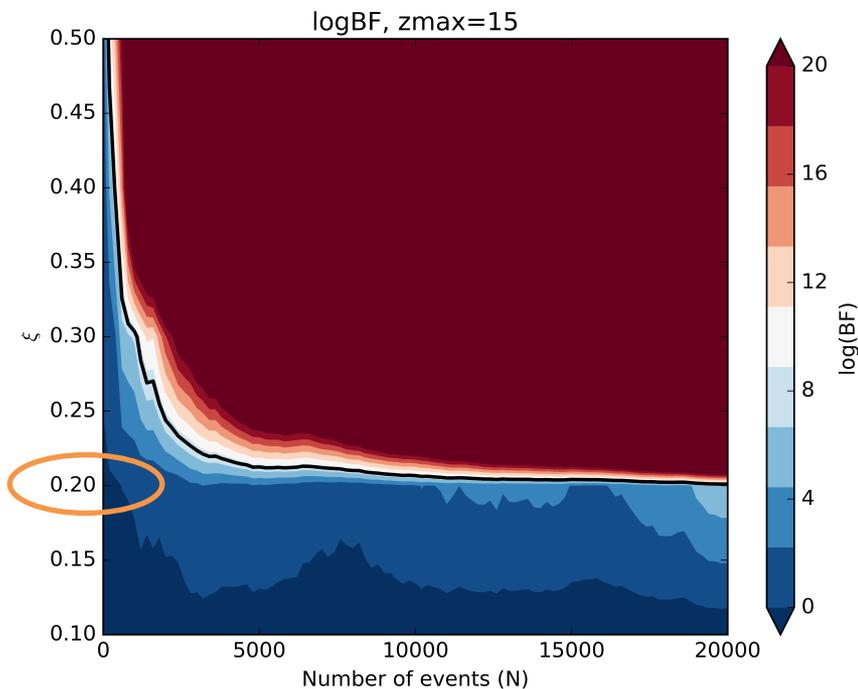
- Investigating what it would take to conclusively test primordial BH hypothesis
- Looking at redshift distribution of ensemble of individual events
 - Preliminary results suggests that 2nd generation measurements will be inconclusive
 - Conclusive results may be possible with 3rd generation detectors like ET

THANK YOU

Hypothesis Testing – 1yr with ET

redshift uncertainty

exact redshift



Minimum discernable ξ limited by redshift uncertainty

Minimum discernable ξ keeps improving with number of events if exact redshift is known