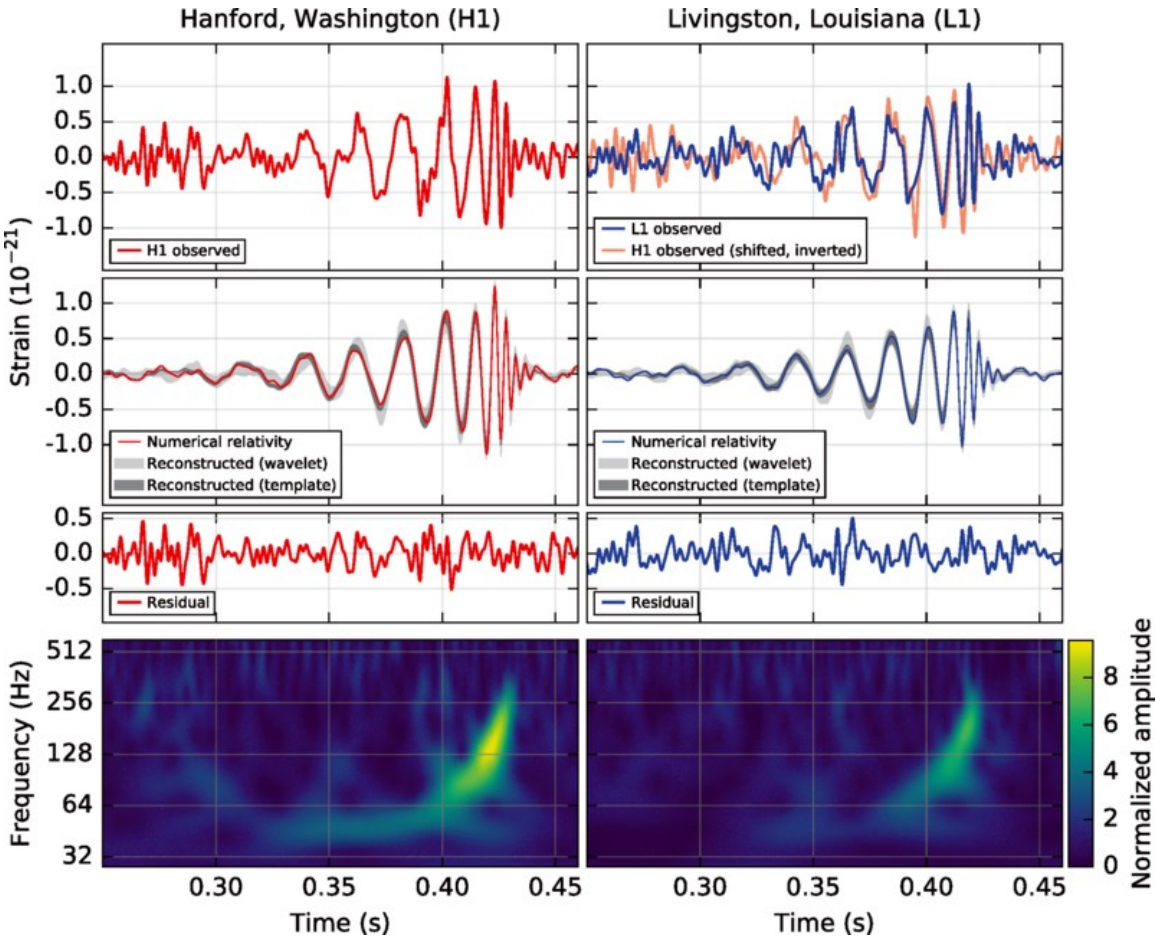
Did LIGO detect dark matter?

Simeon Bird (UCR)

I. Cholis, J. Munoz, Y. Ali-Haimoud, M. Kamionkowski, E. Kovetz, A. Raccanelli, A. Riess

arXiv: 1603.00464
PRL 116 201301

LIGO detected Gravitational Waves

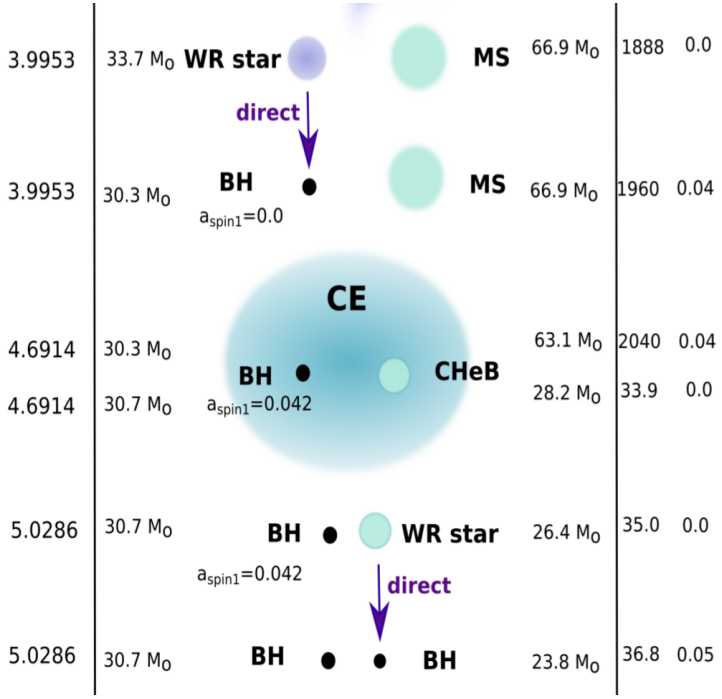


GW signal from two merging 30 solar mass BHs

How did the Black Holes form?

End points of stellar evolution

- Need binary with two heavy stars
- Need misaligned black hole spins

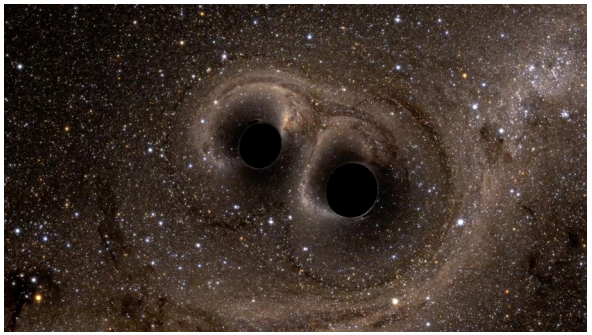


Belczynski, K

How did the Black Holes form?

Black holes from early universe over-density

Primordial Black Hole Dark Matter



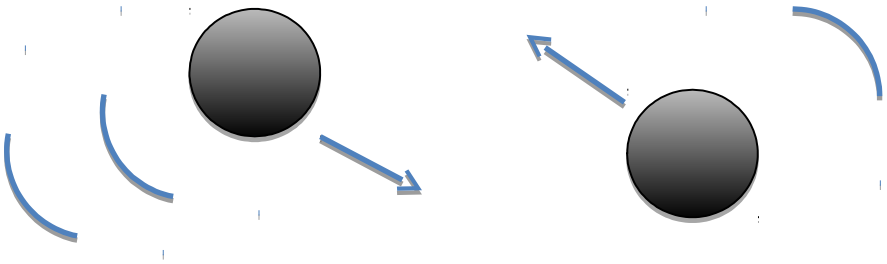
Don’t test this in an accelerator

Does the Merger Rate match LIGO?

Black Holes are all the dark matter

Form halos as for CDM

Gravitational wave emission forms binaries



Cross-Section

$$\sigma = \pi \left(\frac{85\pi}{3}\right)^{2/7} R_{\rm s}^2 \left(\frac{v_{\rm PBH}}{c}\right)^{-18/7}$$

(Quinlan & Shapiro 1989)

PBH velocity ~ halo velocity dispersion

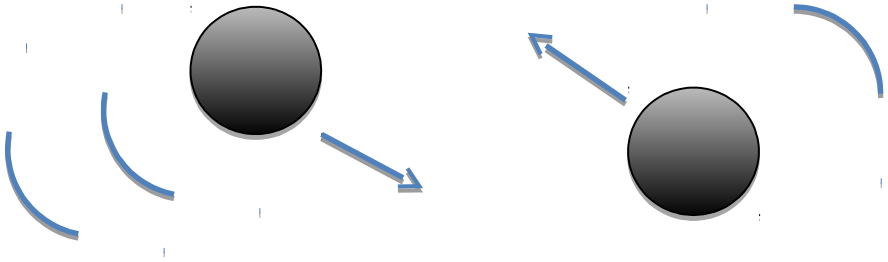
Most mergers in smallest halos

At $M \sim 400 M_\odot$ binaries wide enough that timescale is Hubble time

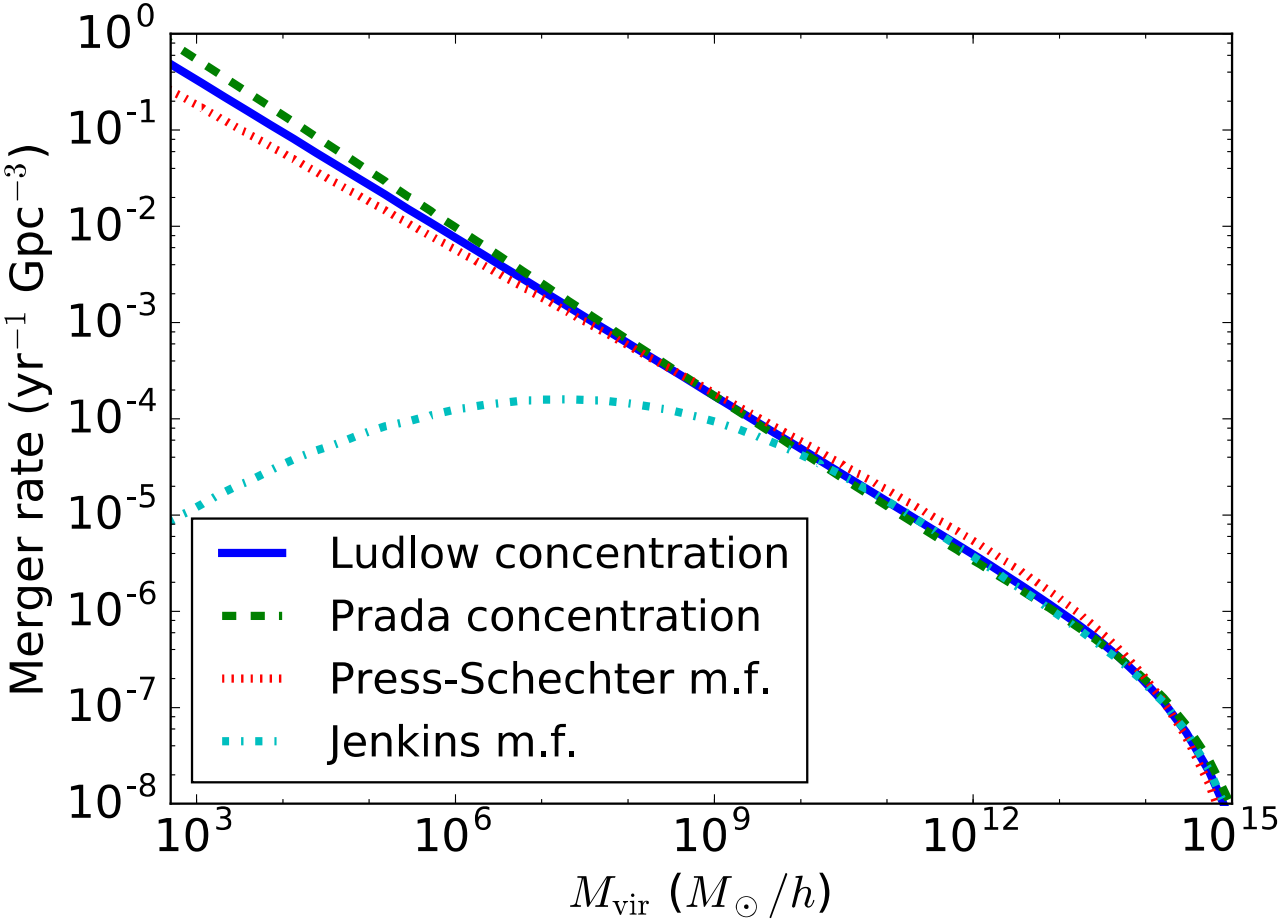
Does the Merger Rate match LIGO?

Binary formation is slow, mergers are fast

Black holes binaries form **today,** distributed as in dark matter halos

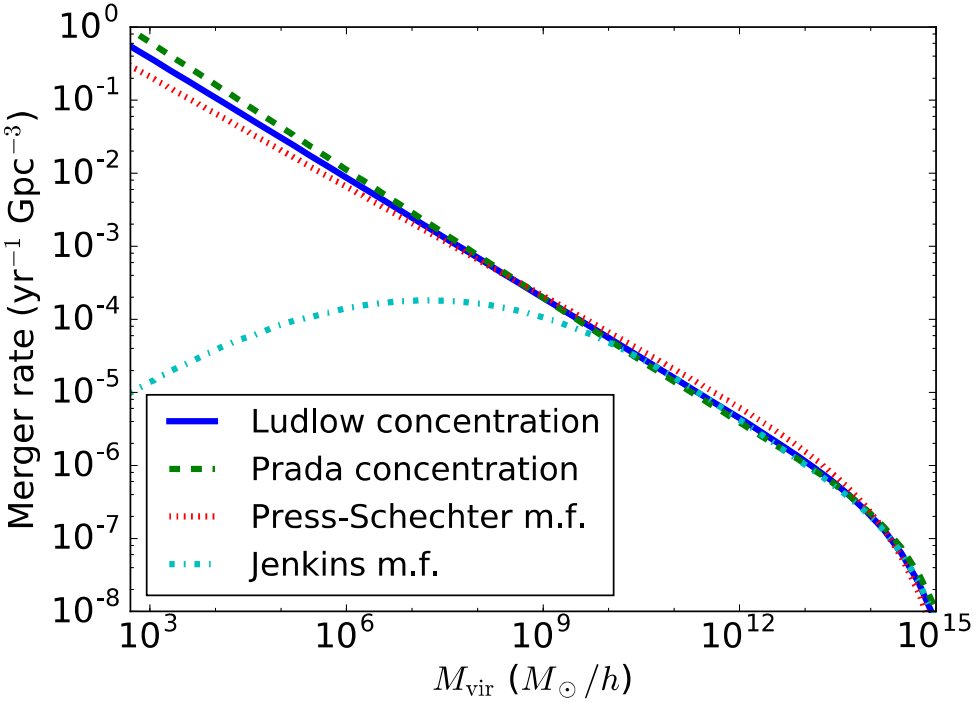


Total Merger Rate



Lines show different dark matter models

Merger Rate



- Integrated: $2\ \mathrm{yr}^{-1}\mathrm{Gpc}^{-3}$
- LIGO: ~~$2 - 53\ \mathrm{yr}^{-1}\mathrm{Gpc}^{-3}$~~

$$0.5 - 12\ \mathrm{yr}^{-1}\mathrm{Gpc}^{-3}$$

Merger Rate

- Total mergers: $2\ \mathrm{yr}^{-1}\mathrm{Gpc}^{-3}$

Very uncertain

This number could have been $10^{\pm 10}$

INTERESTING

Did LIGO Detect Dark Matter?

Possibly.

Are PBHs ruled out?

All masses are ruled out except for 20-80 solar

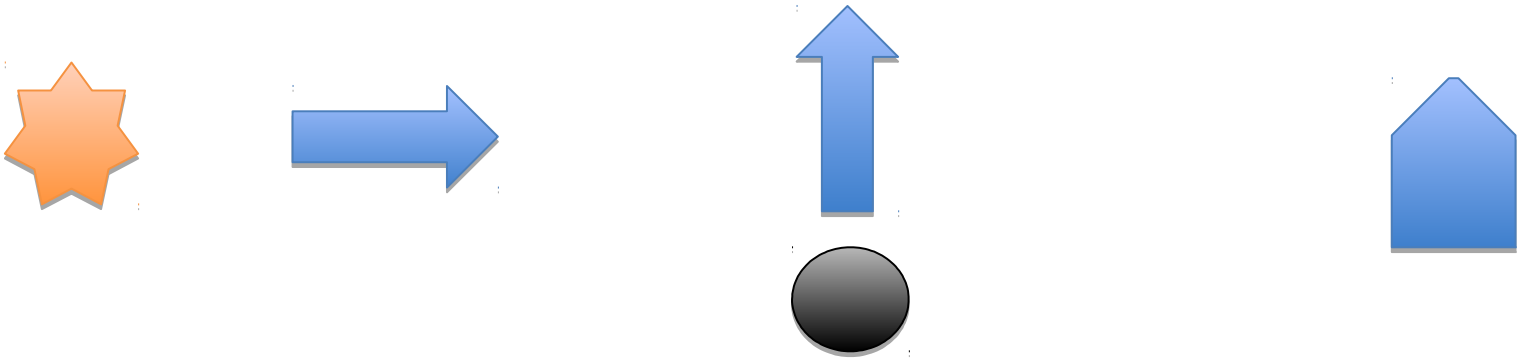
Larger: ruled out by disruption of structures

Smaller: ruled out by micro-lensing

LIGO detection in sole allowed gap

Supernovae Microlensing

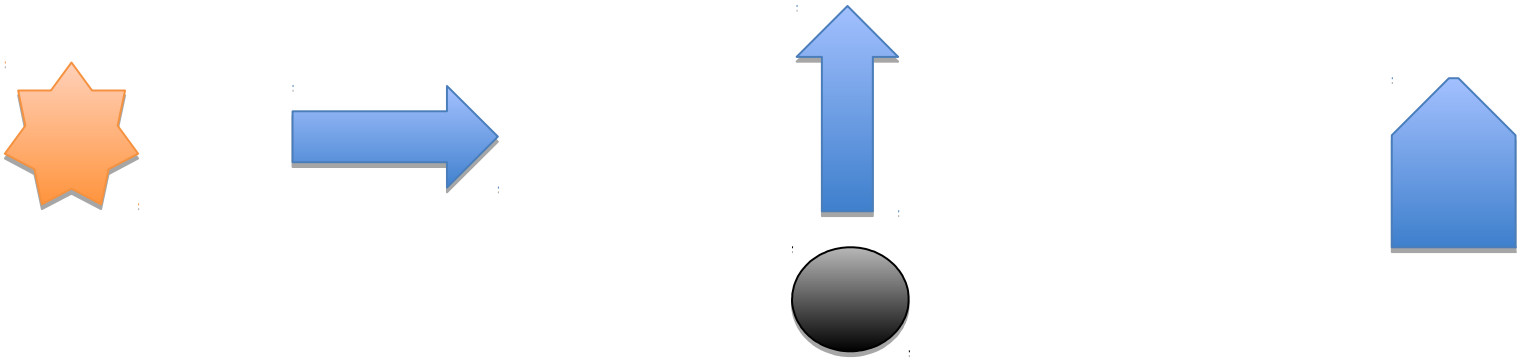
- Non-detection of lensed supernovae (Zumalacarregui & Seljak): ‘No LIGO MACHO’



- PBH < 30 % of dark matter at 2-sigma

Future Microlensing

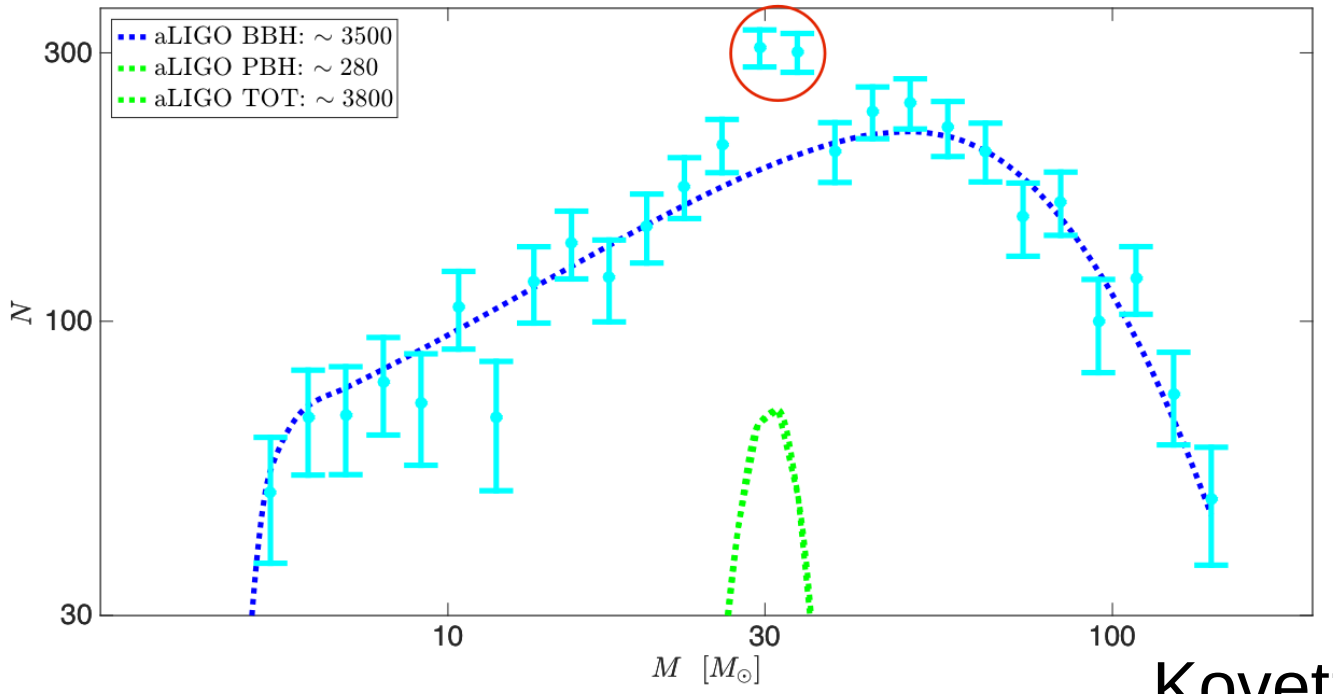
- Large Synoptic Survey Telescope
- 10 year survey images half the sky > 10^3 times



- Forecast PBH fraction < 10^{-4} for $M_{PBH} > 10\ M_{sun}$

Can we test this?

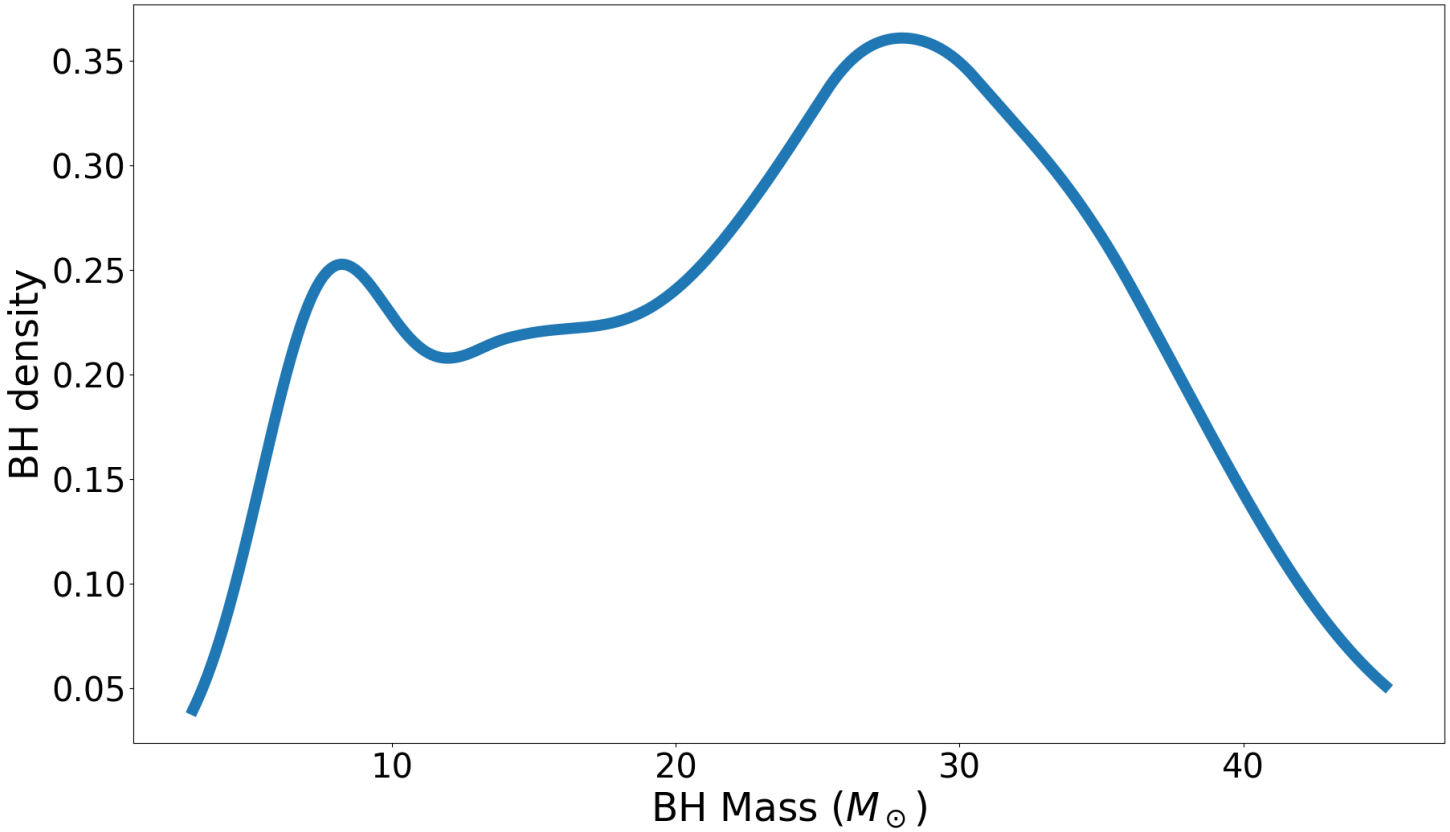
Two populations → mass function bump



Kovetz 2017

No hair theorem means no extra work

Current LIGO BH Mass Function



10% of DM in 30 Solar Mass PBH POSSIBLE

Wait for LSST and more events!

Can We Test This?

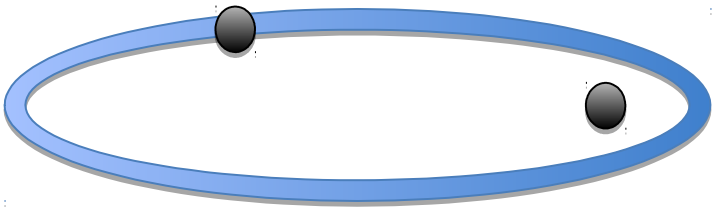
Mergers happen in small halos with no stars

- No EM counterparts
  - But we don’t expect them anyway
- Localized away from galaxy
  - But LIGO’s angular resolution isn’t enough

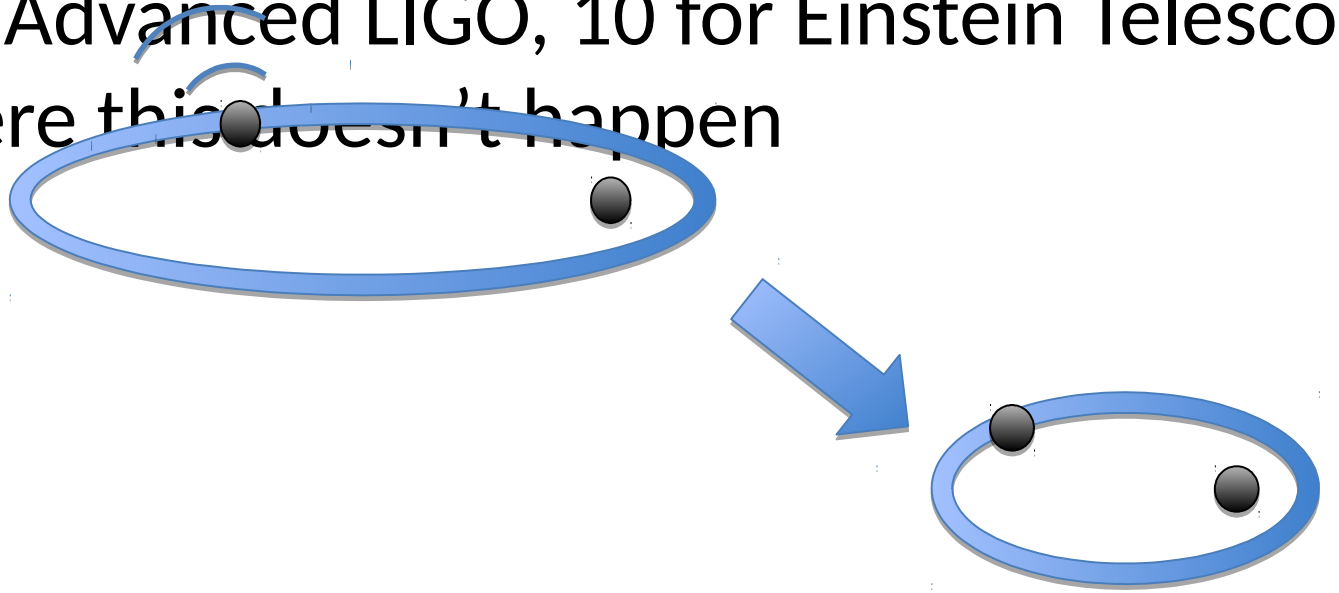
Can We Test This?

Initially Eccentric Binaries:

- Stellar binary orbits are circular
- Dark matter orbits are elliptical
- Our binaries are initially eccentric



Can We Test This?

Initially Eccentric Binaries:

- GW wave emission circularizes quickly:
- 1 in Advanced LIGO, 10 for Einstein Telescope where this doesn't happen