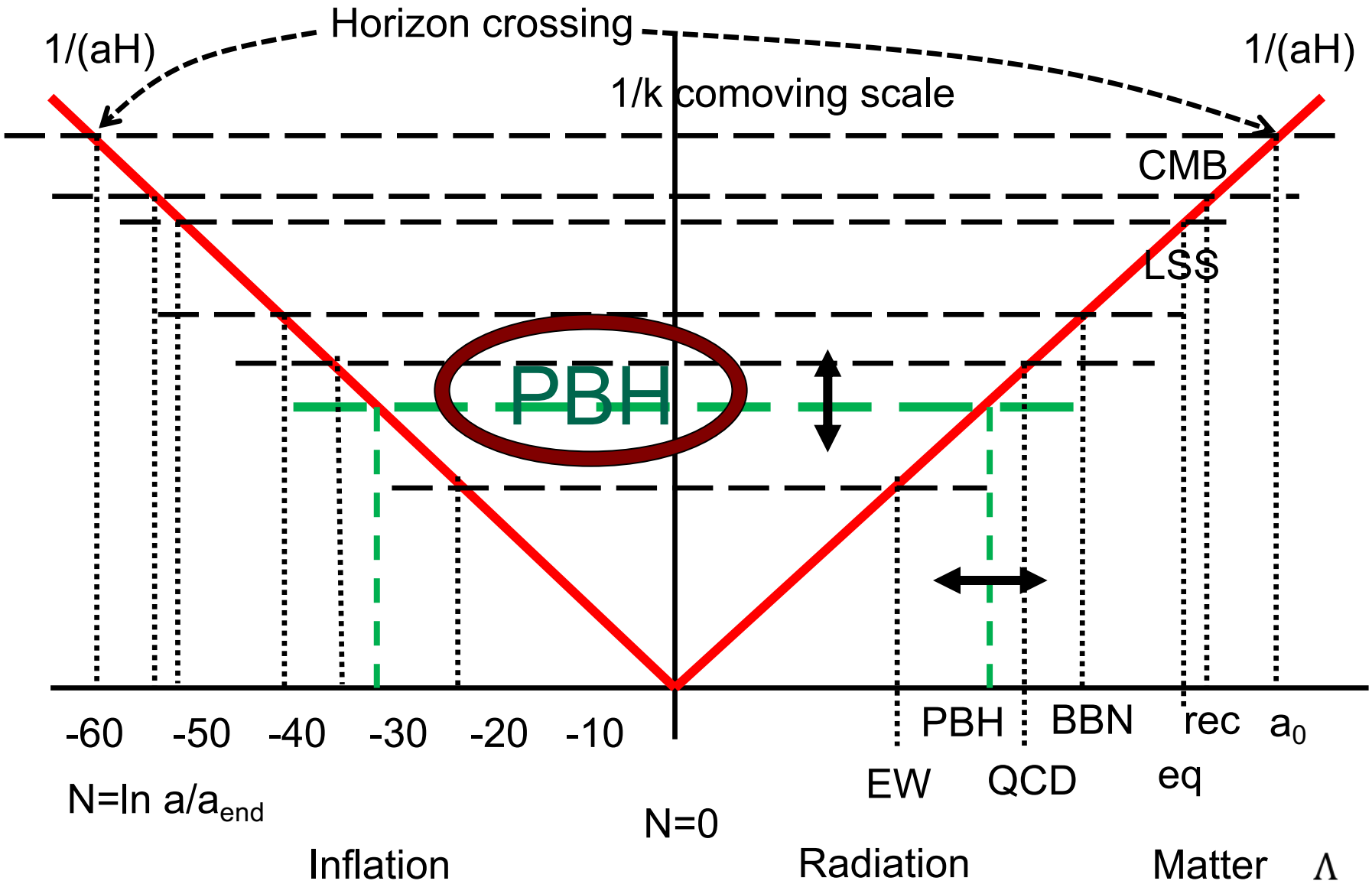
Have we detected Primordial Black Holes at LIGO-Virgo?

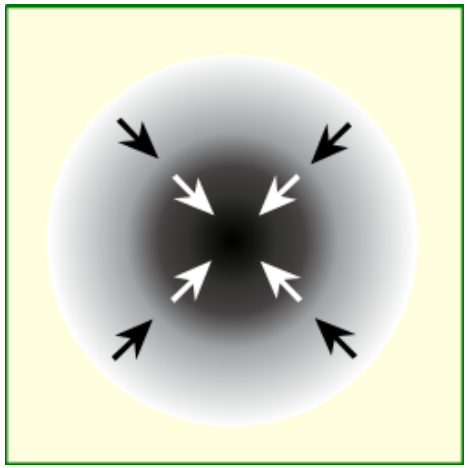
LVEM Zoom Meeting, 22nd October 2019

Juan García-Bellido
IFT-UAM/CSIC Madrid

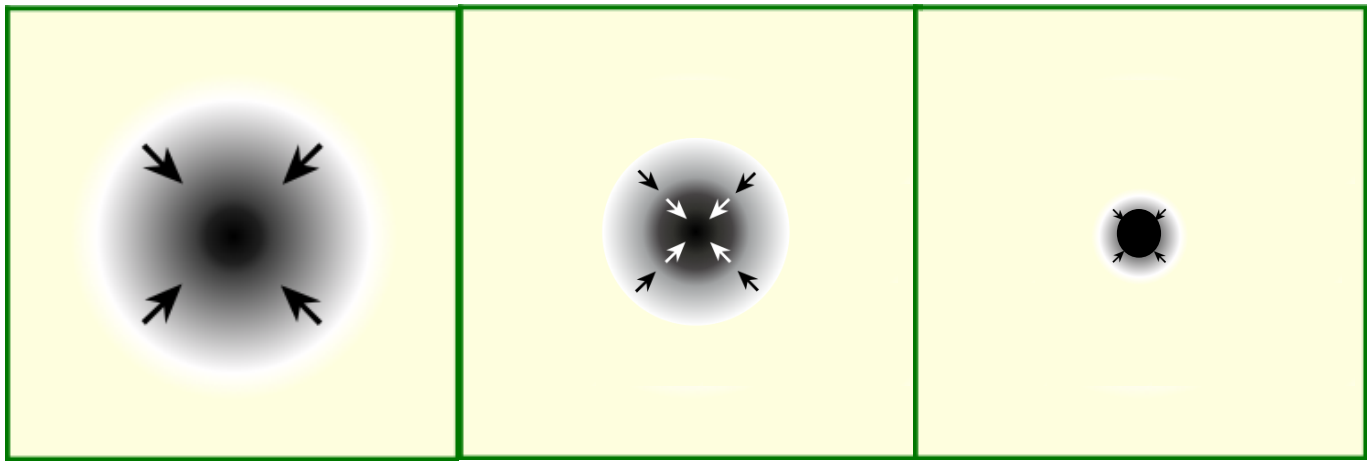
Inflation


Horizon crossing
1/(aH)
1/(aH)
1/k comoving scale
CMB
LSS
PBH
-60
-50
-40
-30
-20
-10
PBH
BBN
rec
a_0
EW
QCD
eq
N=ln a/a_{end}
N=0
Inflation
Radiation
Matter
Λ

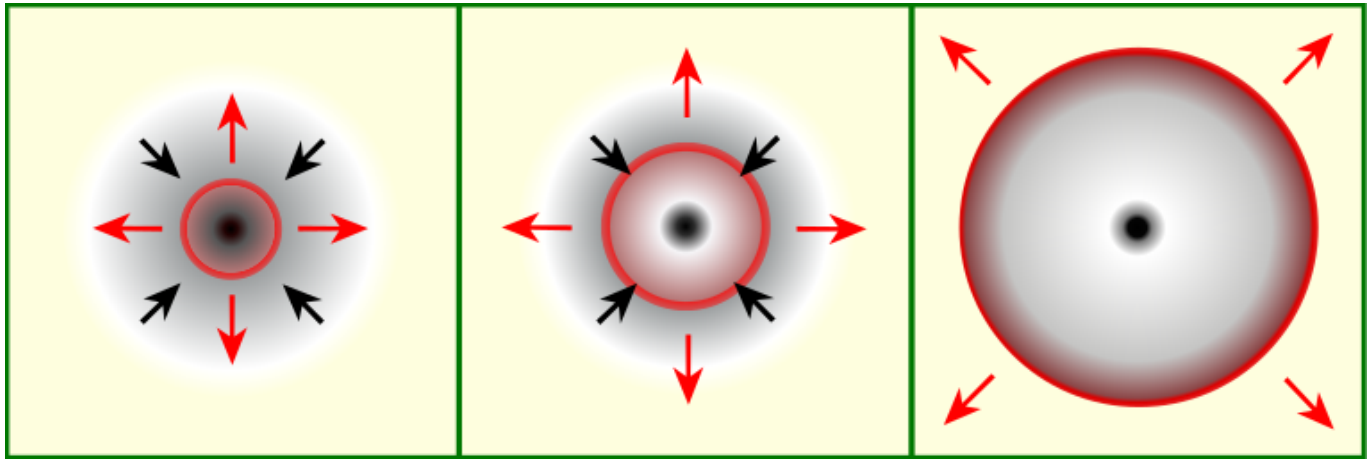
Gravitational Collapse



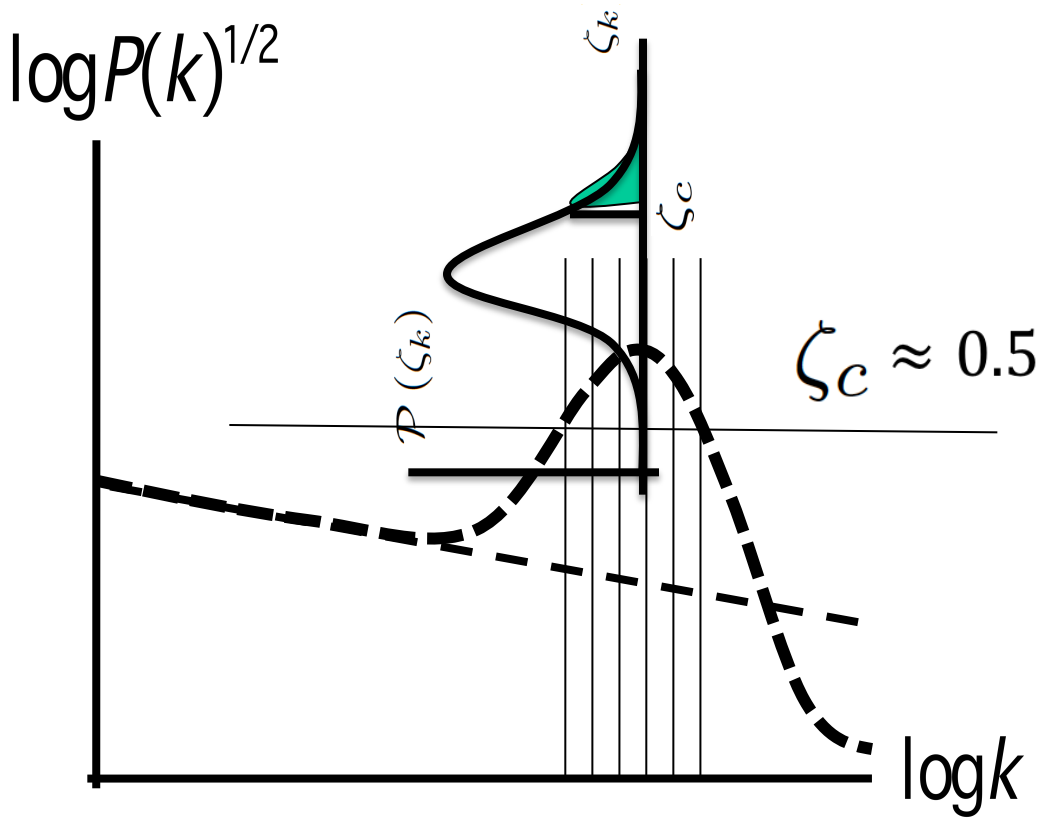
Gravity wins

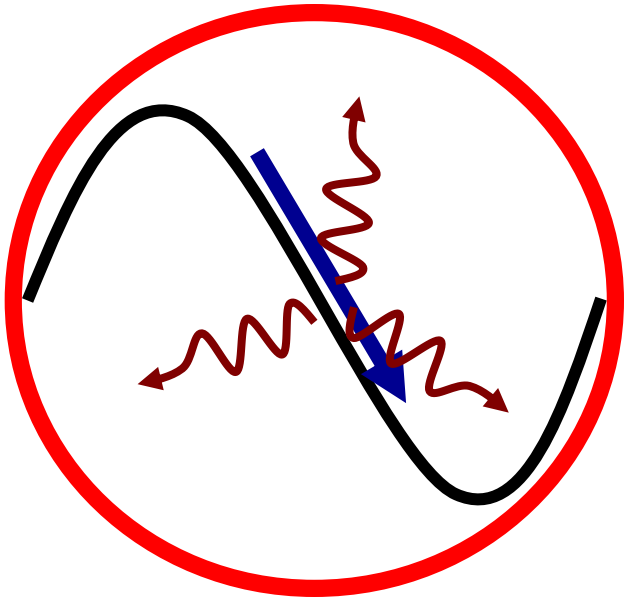


Radiation wins



Gravitational Collapse of PBH

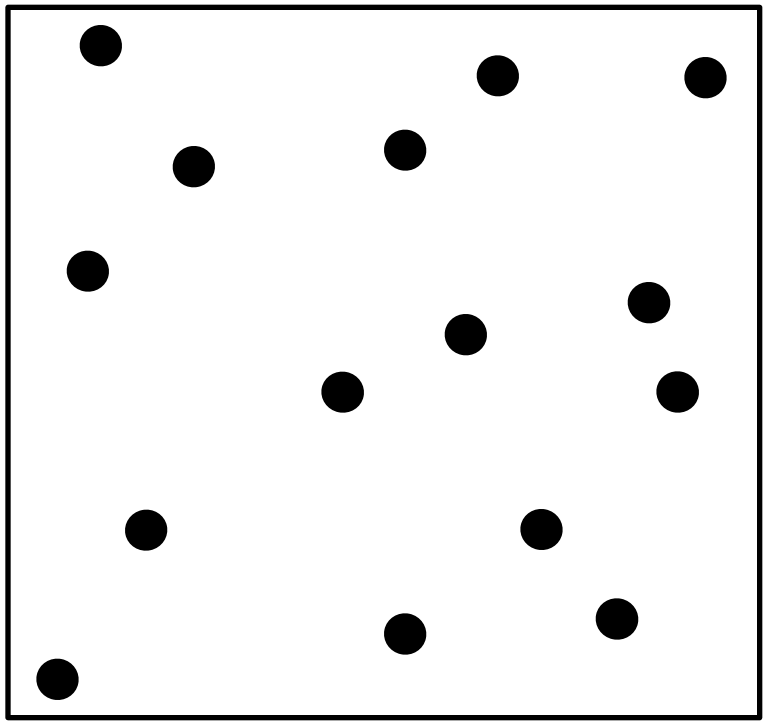




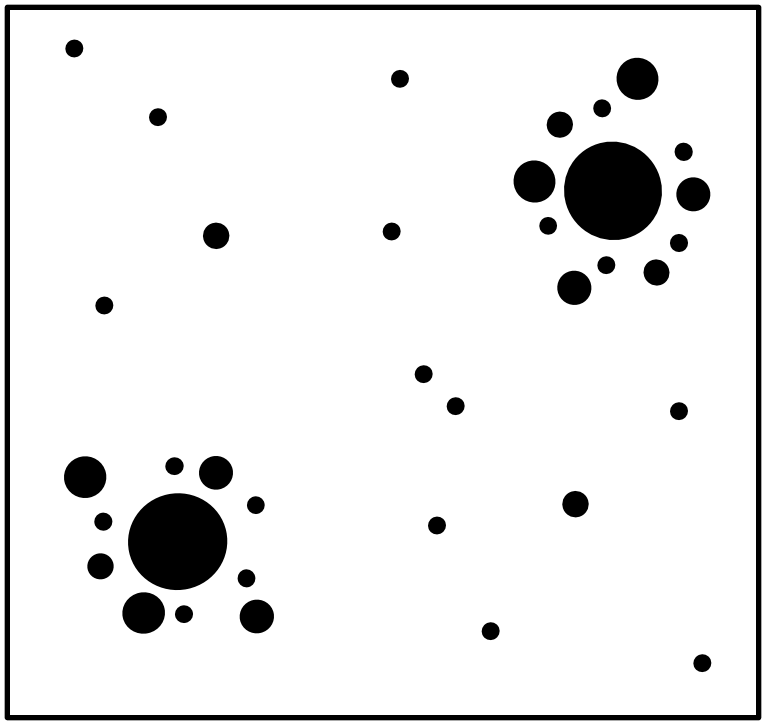
$$M_{PBH} \approx 30 M_{\odot}\, e^{2(N-36)}$$

Inflationary predictions

- Wide mass distribution
- Clusters of PBH: N_{cl} ~100-1000 , comoving size ~1mpc



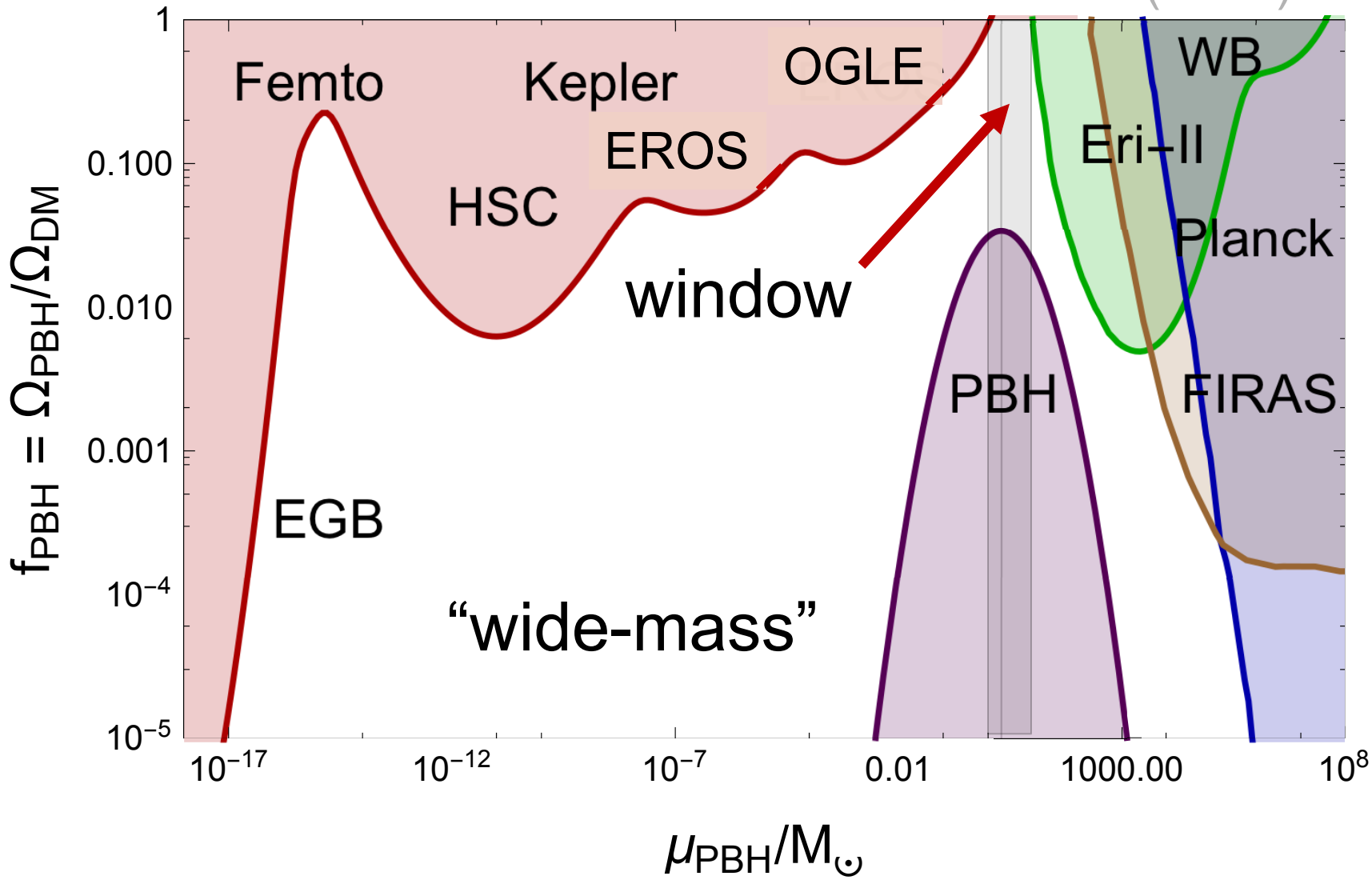
uniform single-mass
is already ruled out



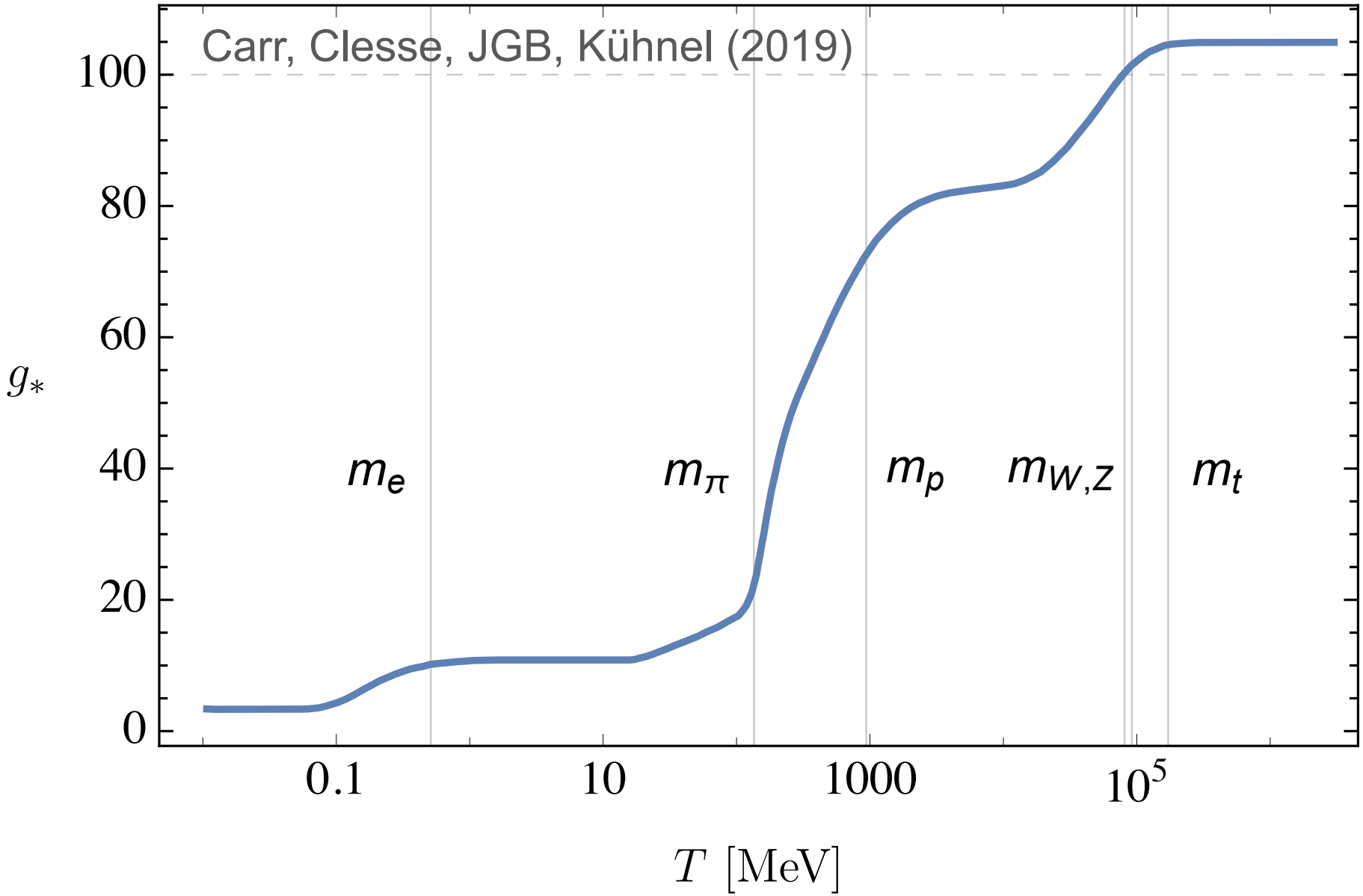
clustered wide-mass
is still viable

PBH constraints

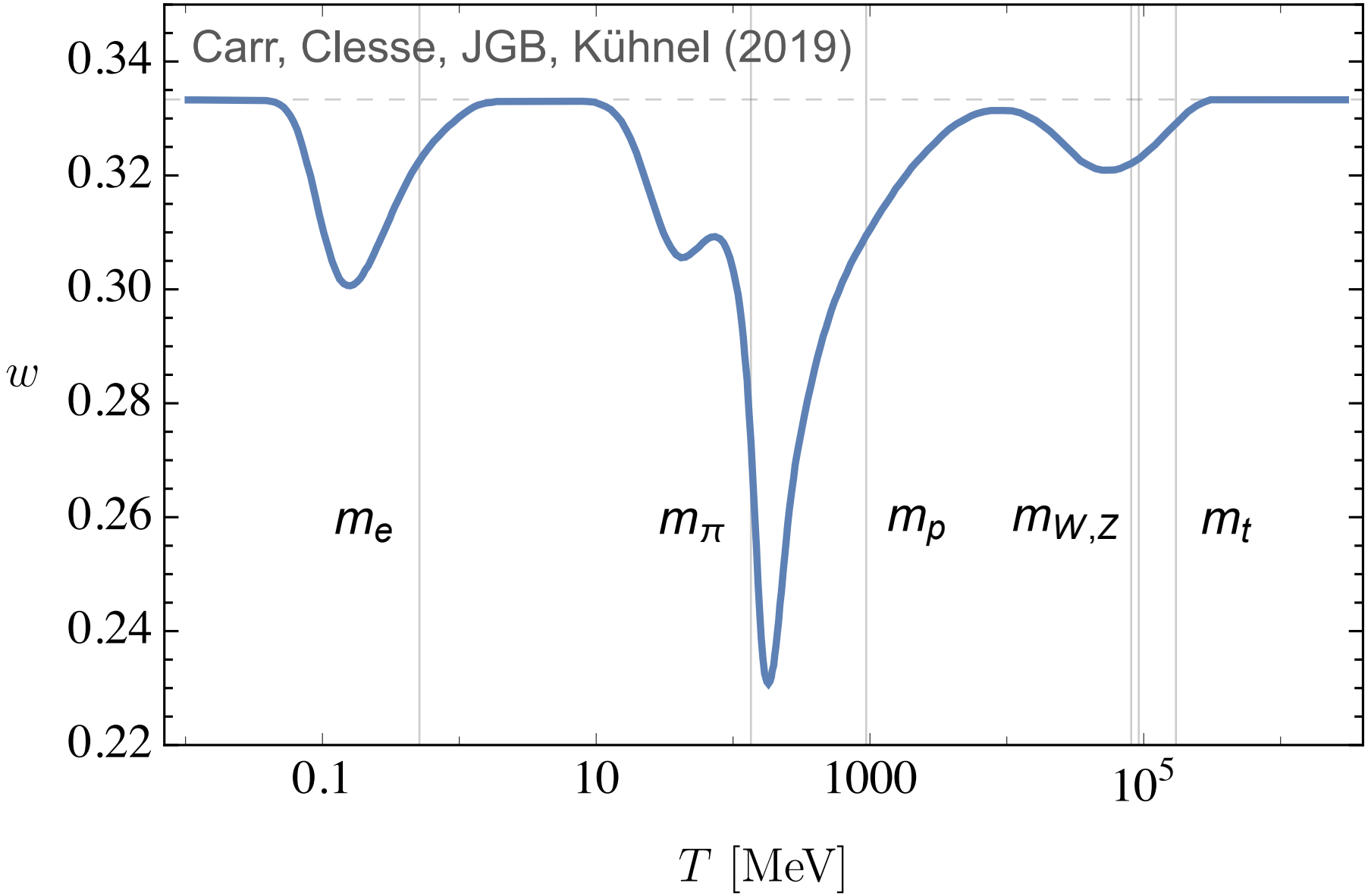
JGB & Clesse (2017)



Thermal history of the universe

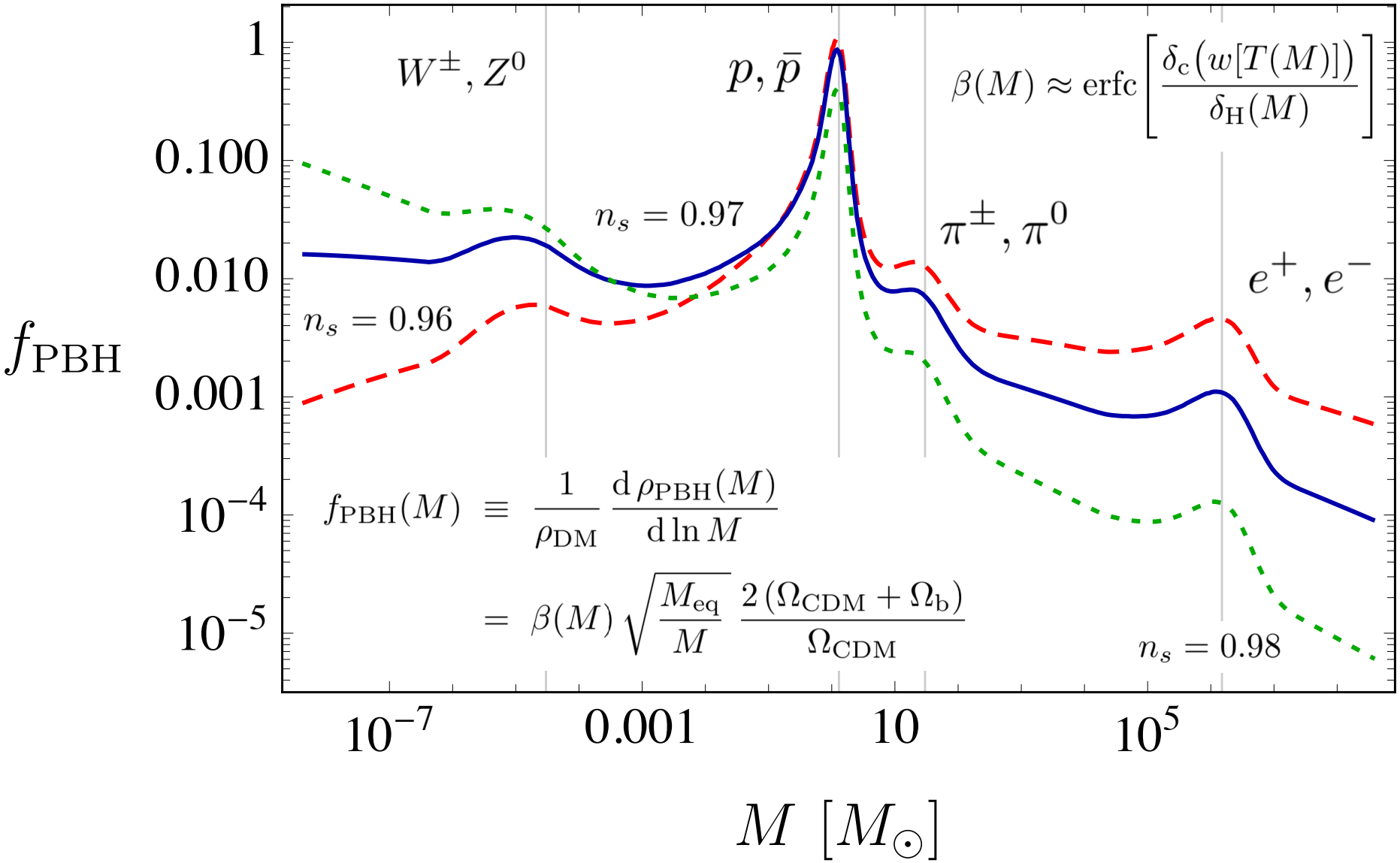


Thermal history of the universe

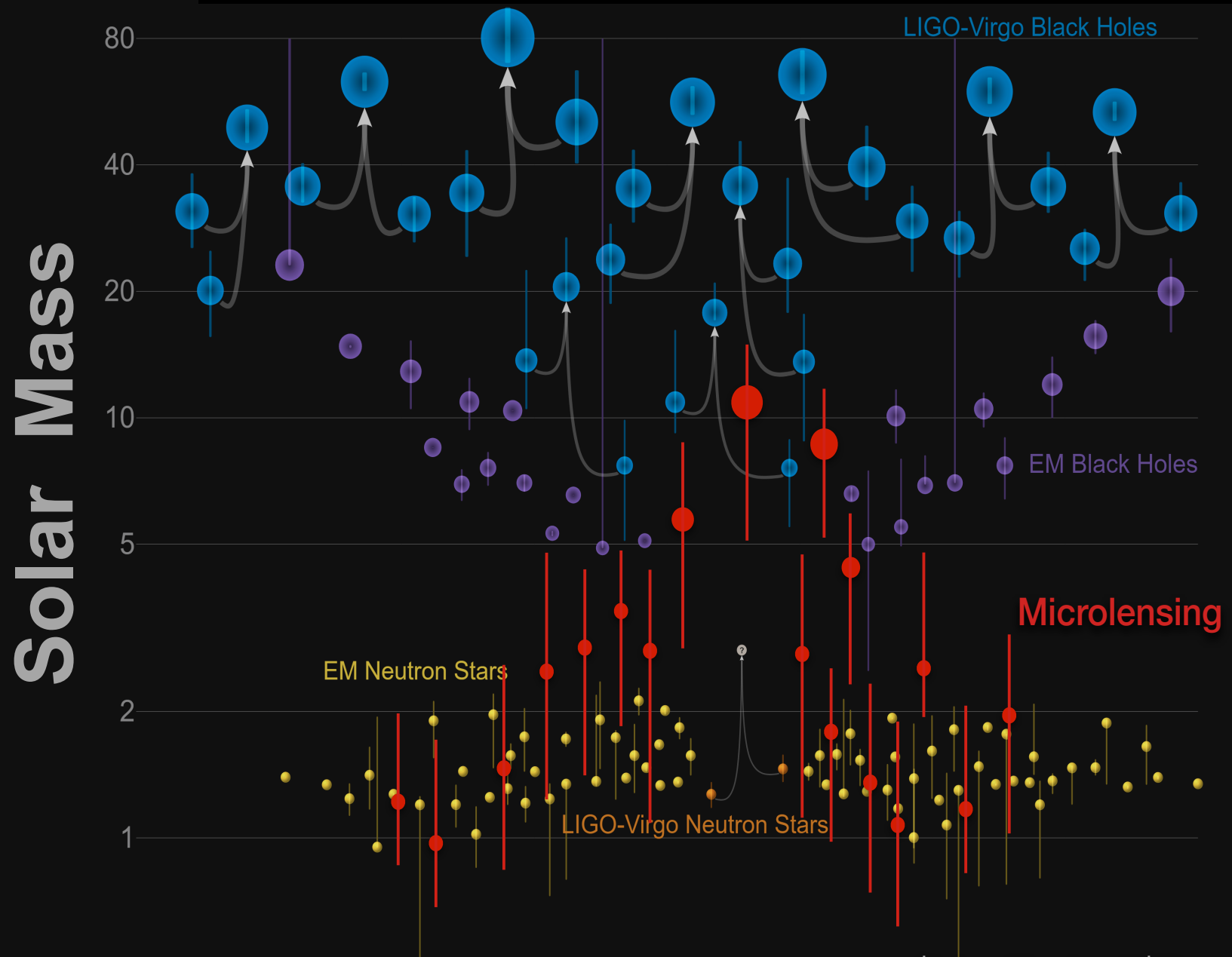


Predictions for PBH mass spectrum

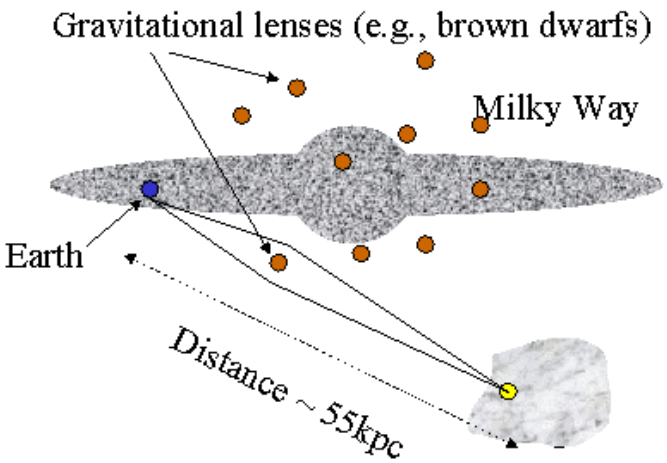
Carr, Clesse, JGB, Kühnel (2019)



Black Holes and Neutron Stars



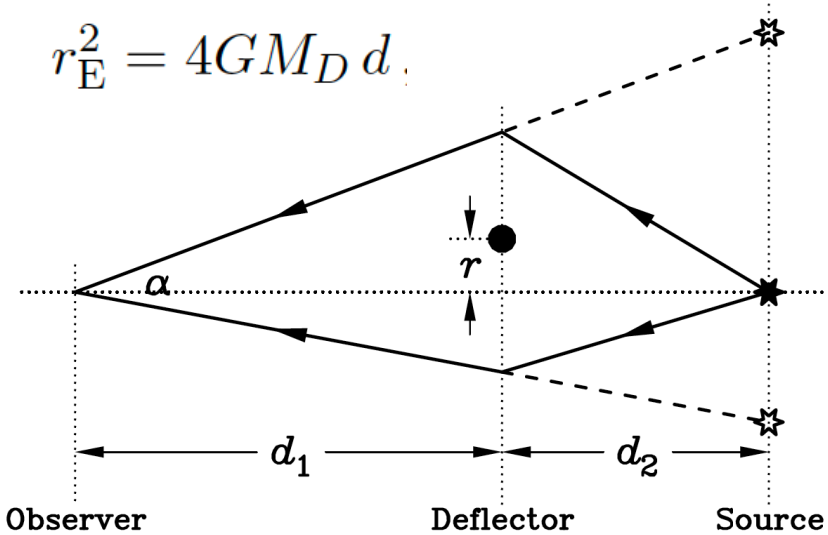
Microlensing Events



$$A = \frac{2+u^2}{u\sqrt{4+u^2}} \qquad u = \frac{r}{r_E} \quad \text{amplification}$$

$$\overline{Dt} = \frac{r_E}{v} = \frac{\sqrt{4GM_D d}}{v} \quad \text{average } \frac{1}{2} \text{ crossing}$$

$$r_E^2 = 4GM_D\, d$$



$$d = \frac{d_1 d_2}{d_1 + d_2}$$

$M_D = 100\,M_\odot$ => $\overline{Dt} = 4$ years

$M_D = 10\,M_\odot$ => $\overline{Dt} = 1.23$ years

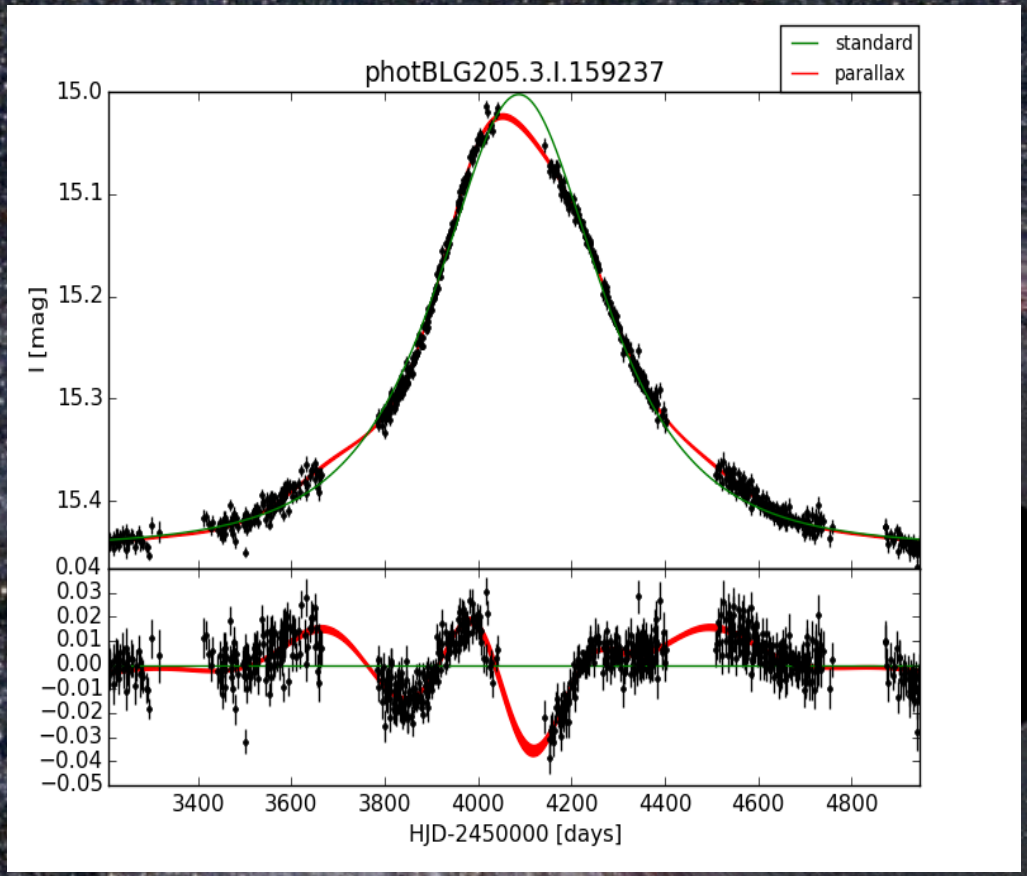
$M_D = 1\,M_\odot$ => $\overline{Dt} = 5$ months

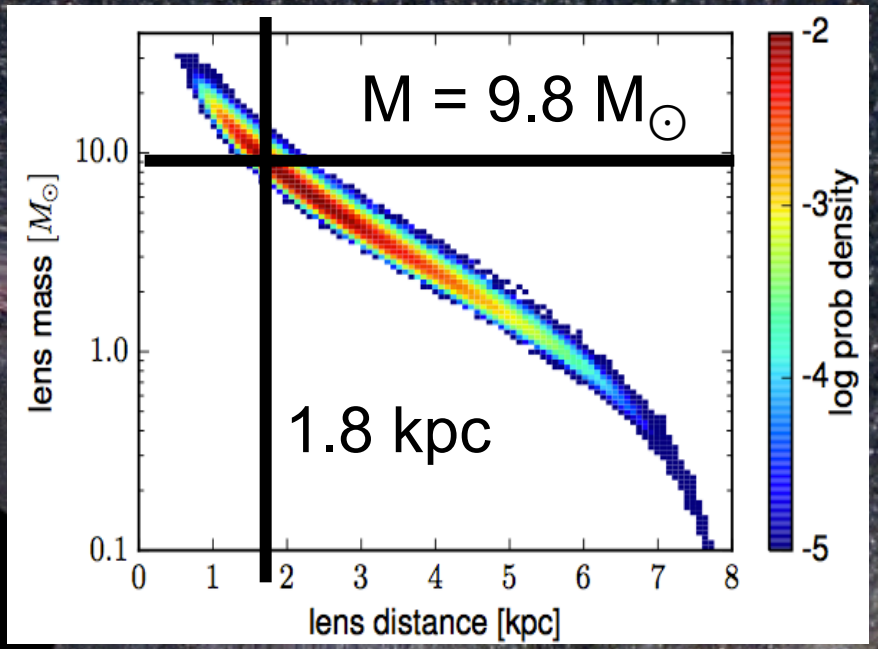
$M_D = 0.1\,M_\odot$ => $\overline{Dt} = 1.5$ months

$M_D = 0.01\,M_\odot$ => $\overline{Dt} = 2$ weeks

OGLE3-UL-PAR-02 - candidate BH

Wyrzykowski (2016)



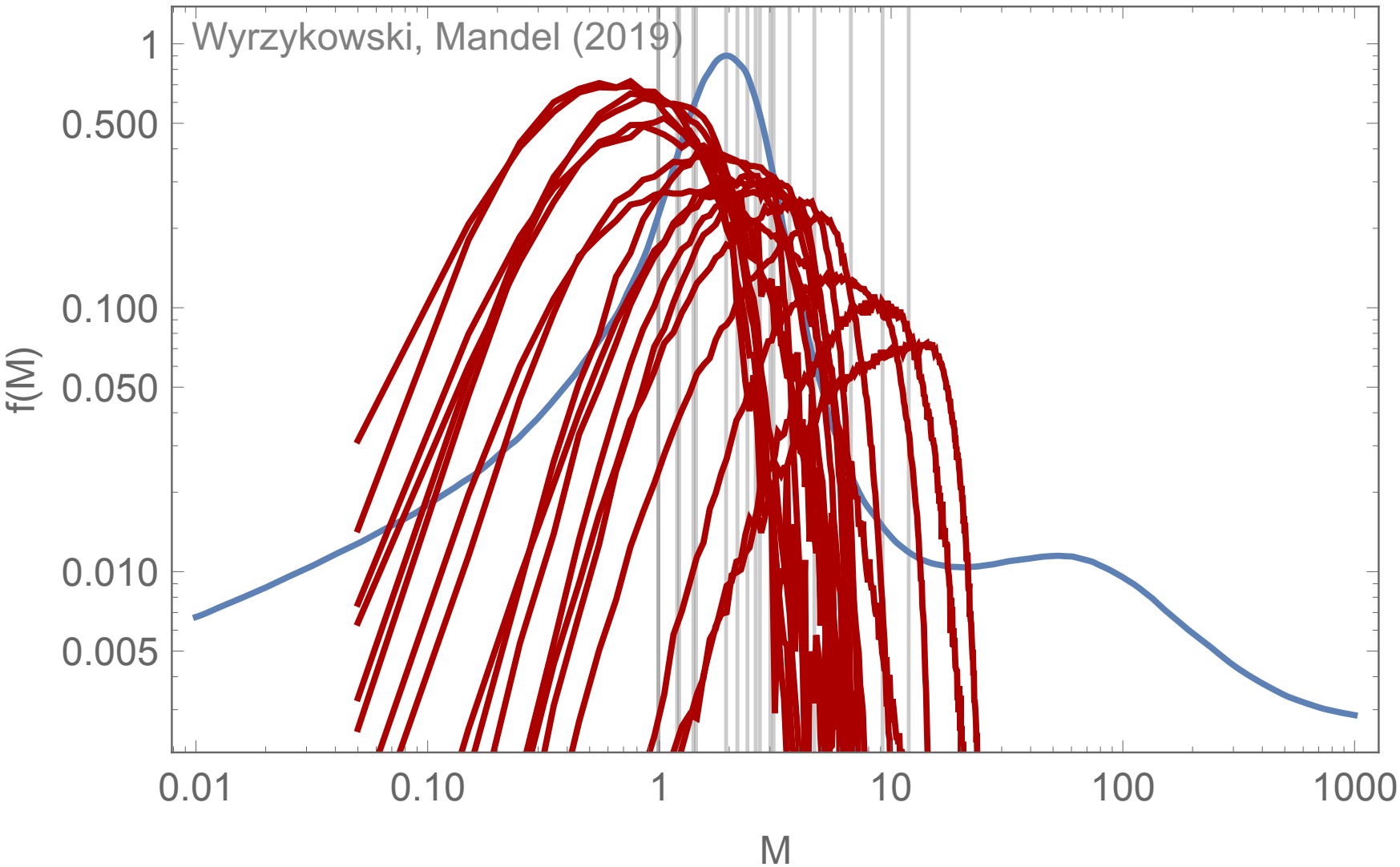


OGLE photometry
from 2001-2008
and microlensing model

Mass, Distance (degenerated estimate)

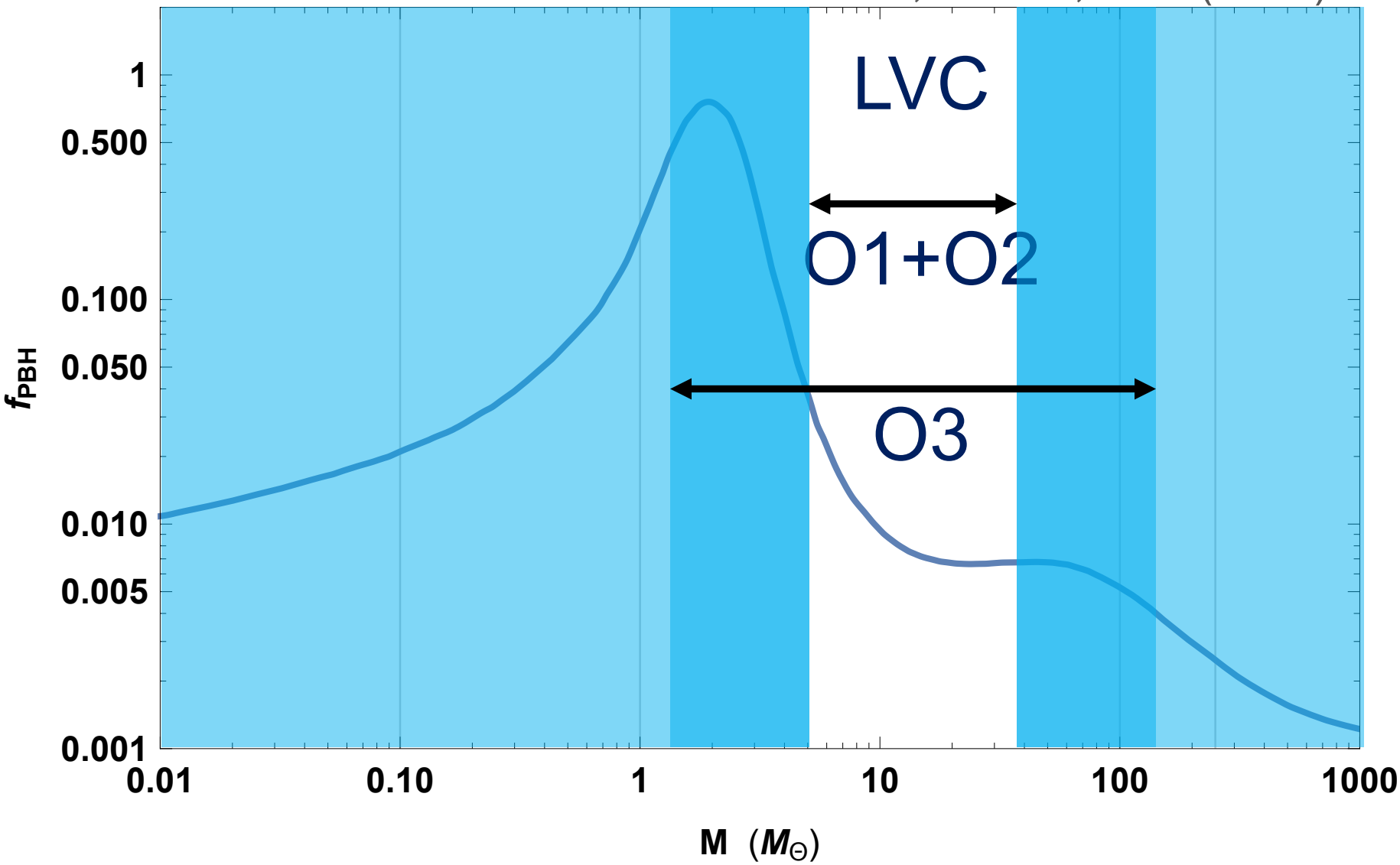
OGLE-GAIA microlensing events

Carr, Clesse, JGB, Kühnel (2019)

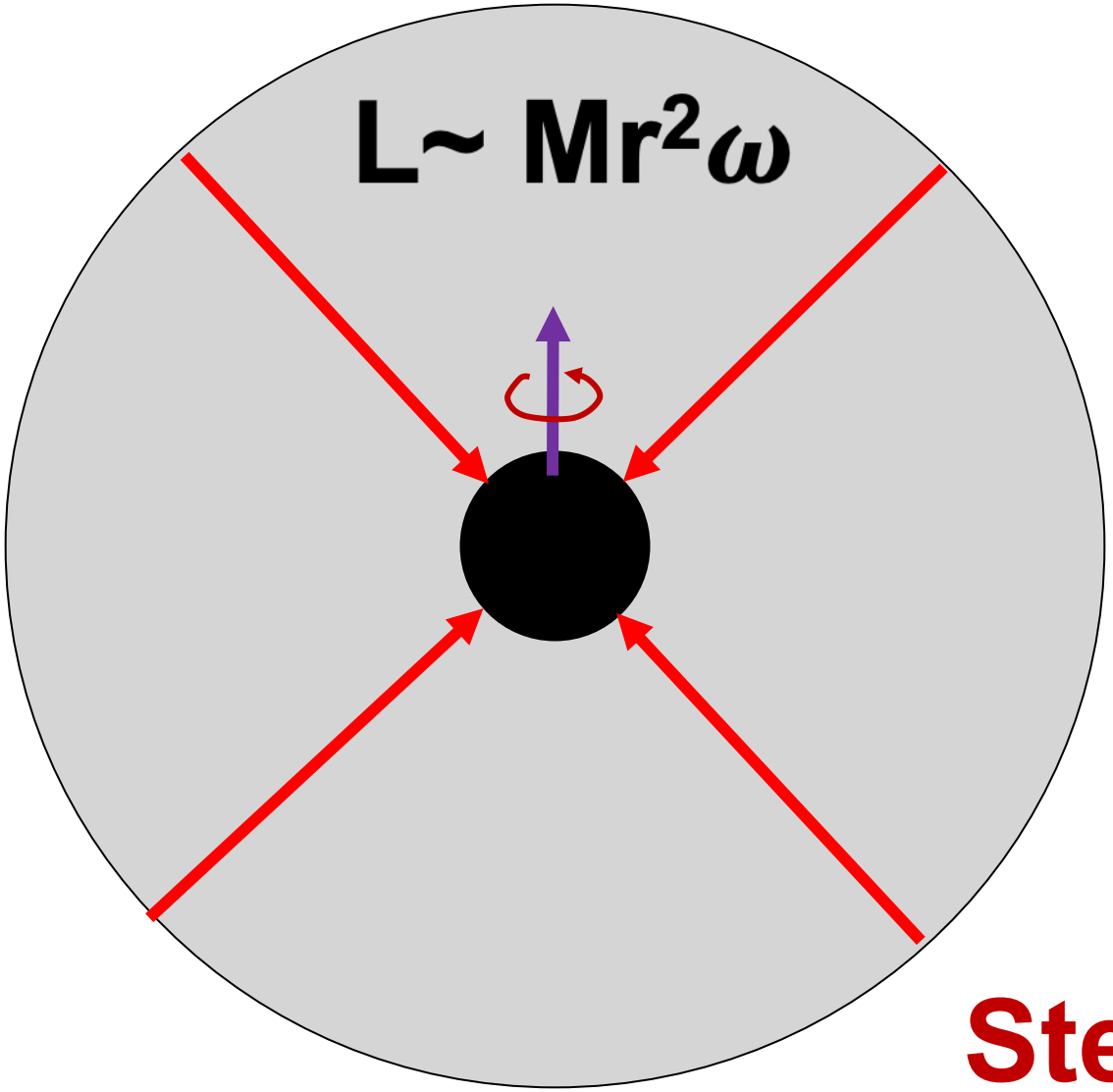


Predictions for PBH mass spectrum

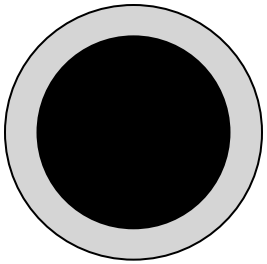
Carr, Clesse, JGB (2019)



PBH are ~ spinless



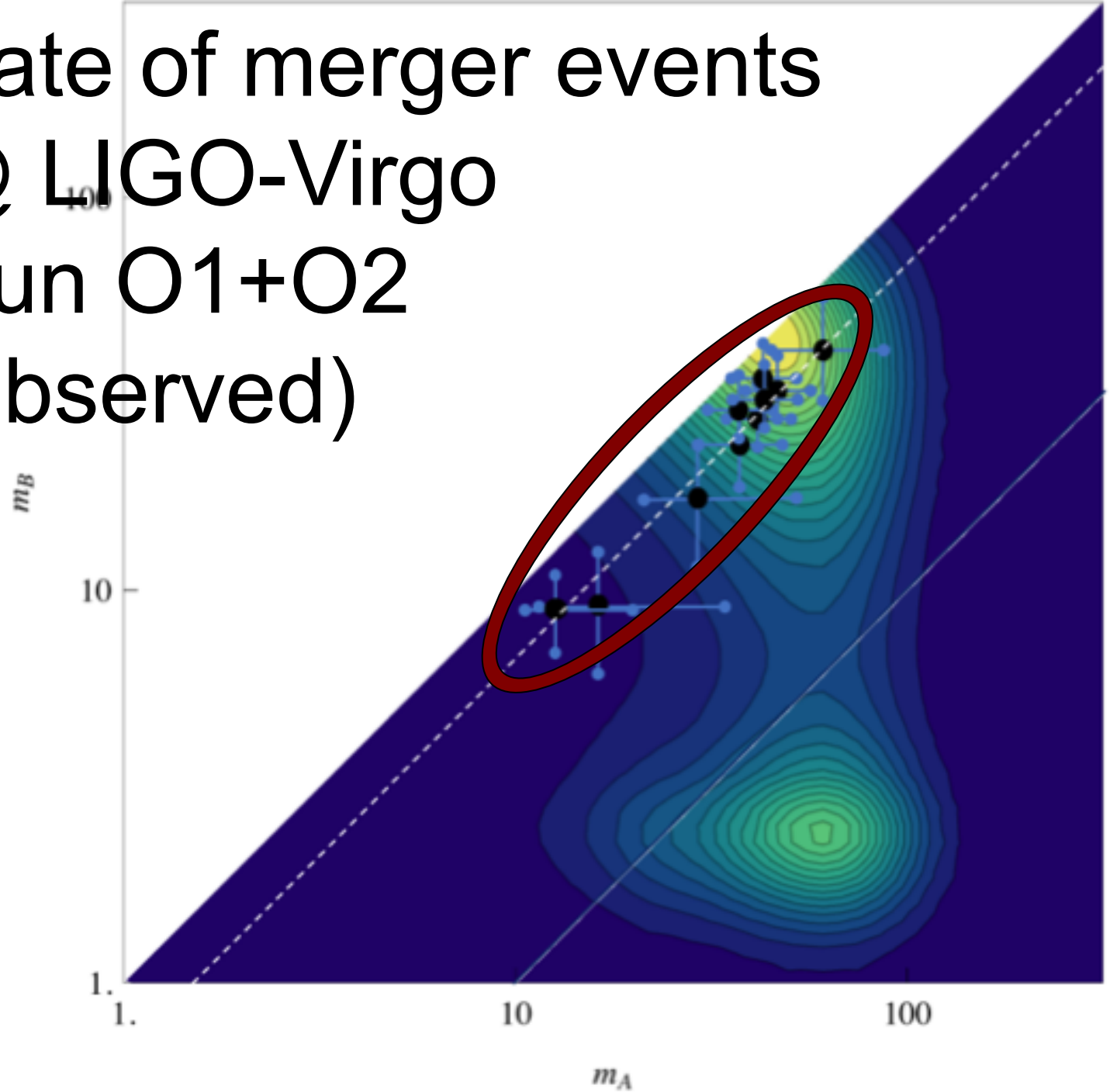
Primordial BH



= Mass

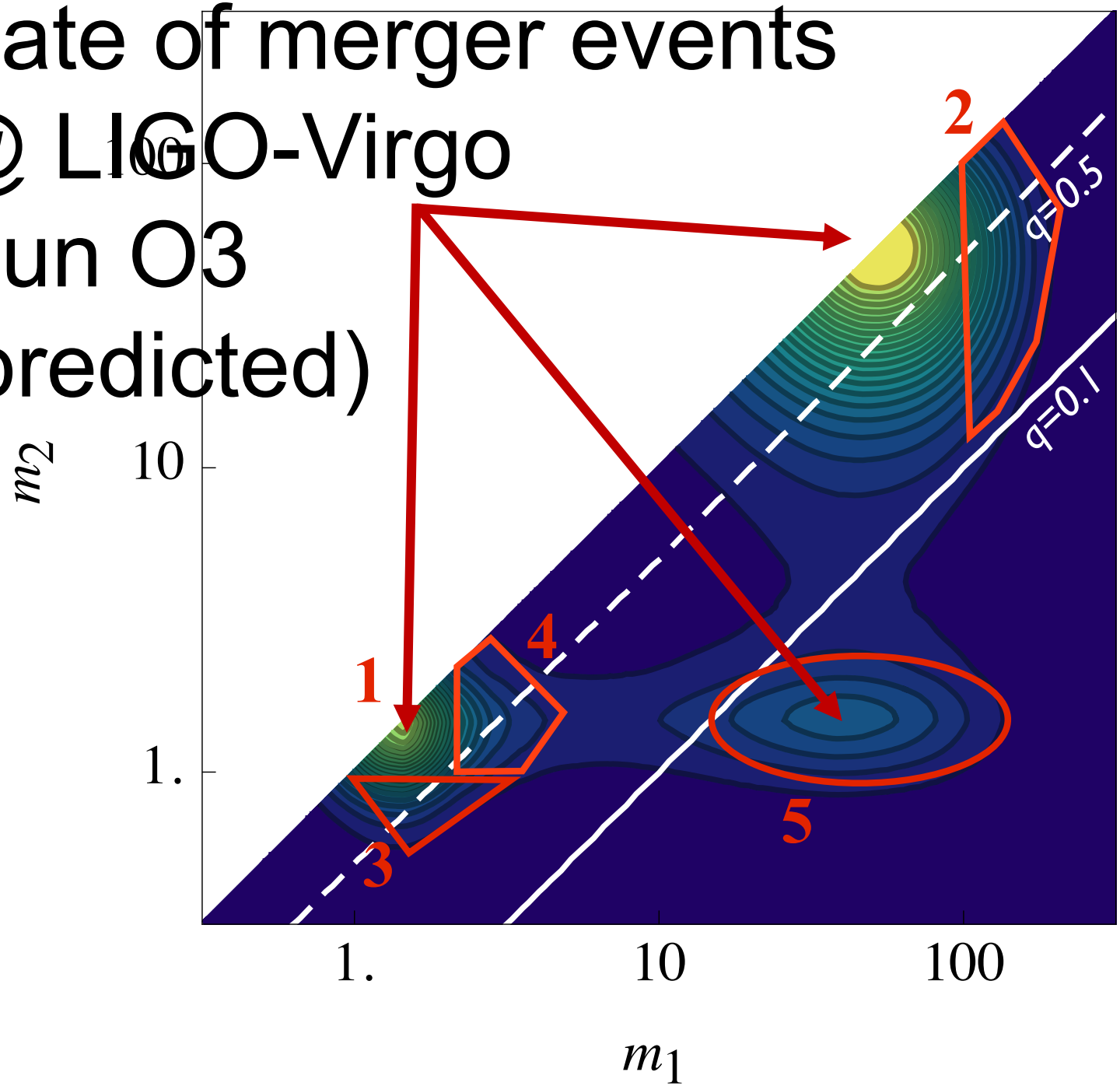
Stellar BH

Rate of merger events @ LIGO-Virgo Run O1+O2 (observed)



Carr, Clesse, JGB, Kühnel (2019)

Rate of merger events @ LIGO-Virgo Run O3 (predicted)



Carr, Clesse, JGB, Kühnel (2019)