LIGO

NSF

On the feasibility of constraining the neutron star equation of state with advanced gravitational-wave detectors

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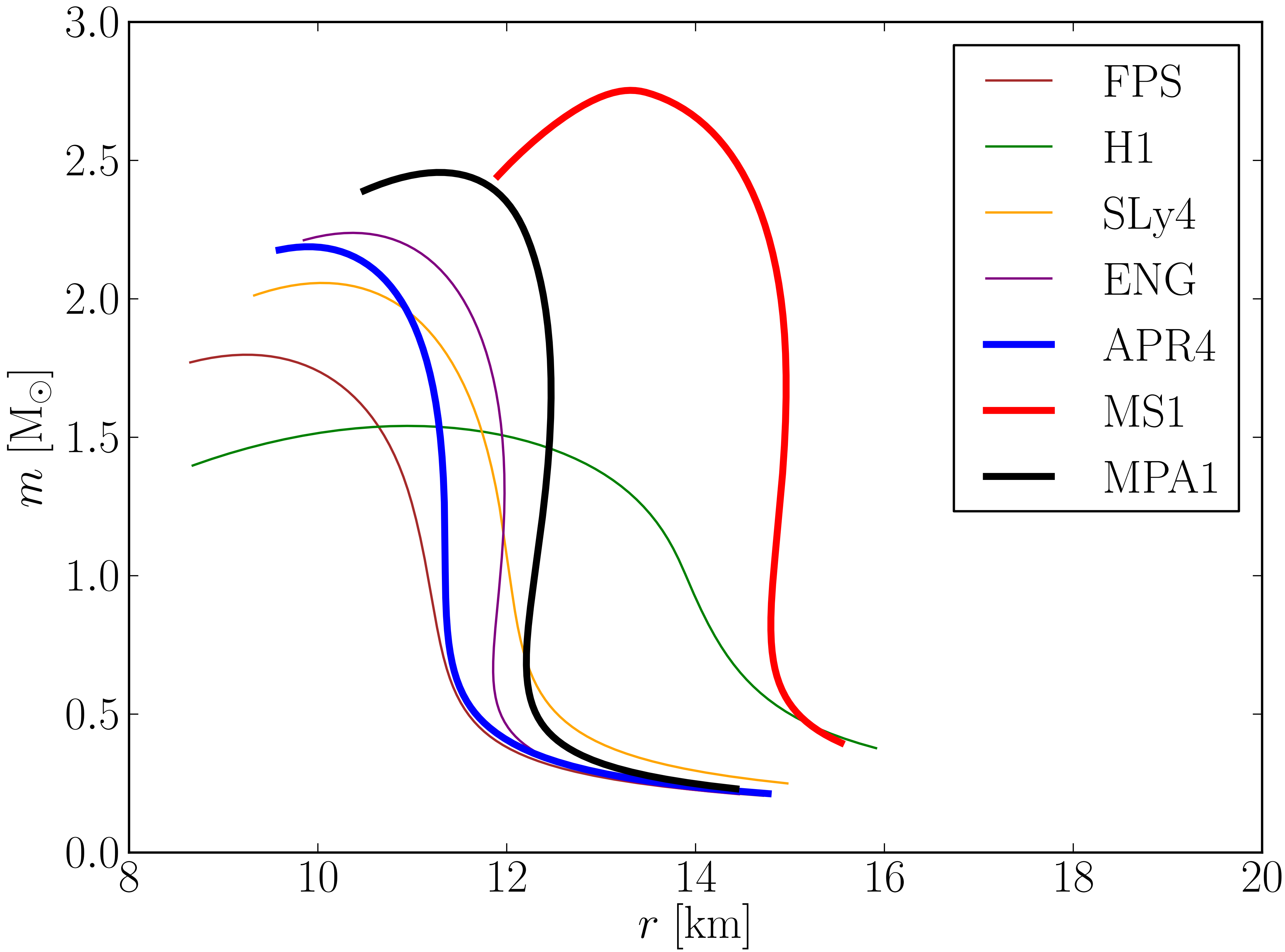
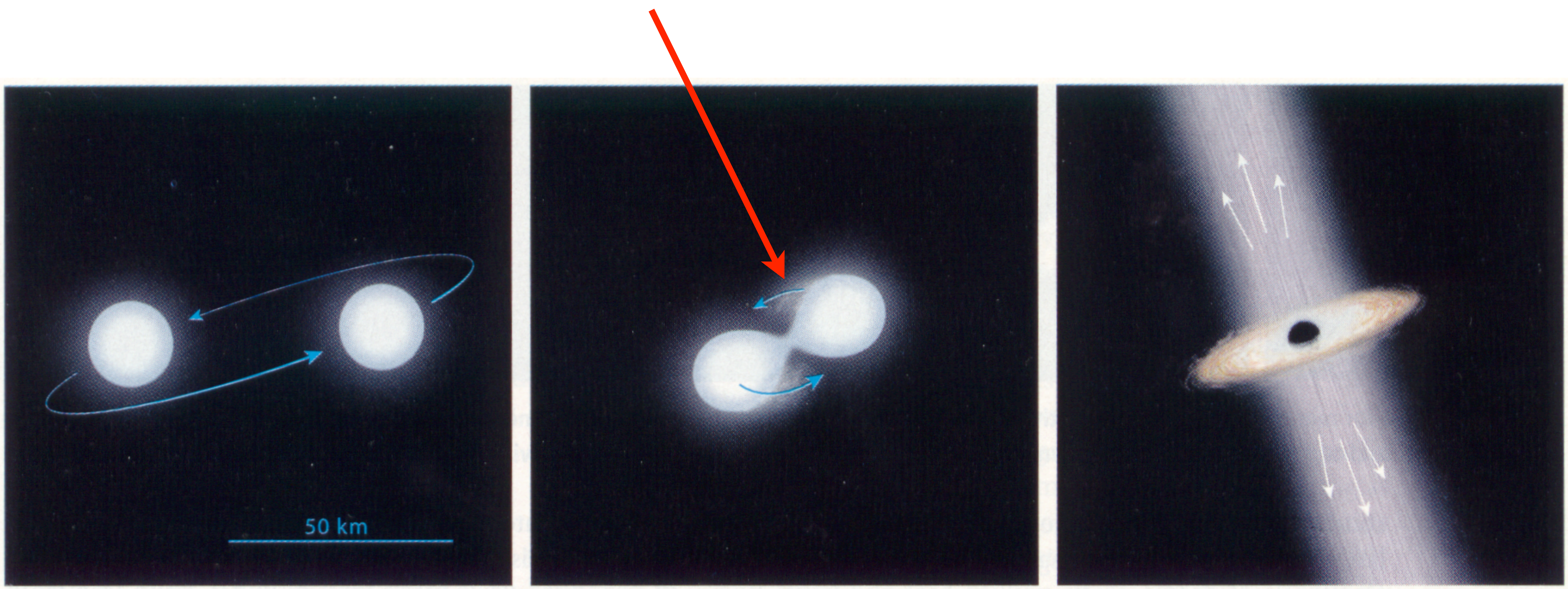
The unknown NS EOS



Tidal effects in BNS systems

- GW detectors can measure mass, but can they measure radius?

$$Q_{ij} = -\lambda \, \mathcal{E}_{ij}$$
$$\hat{\lambda} = \frac{\lambda}{m^5} = \frac{2}{3} k_2 \left(\frac{r}{m}\right)^5$$



http://www.laeff.cab.inta-csic.es/BOOTES/pictures/GRB/image015.png

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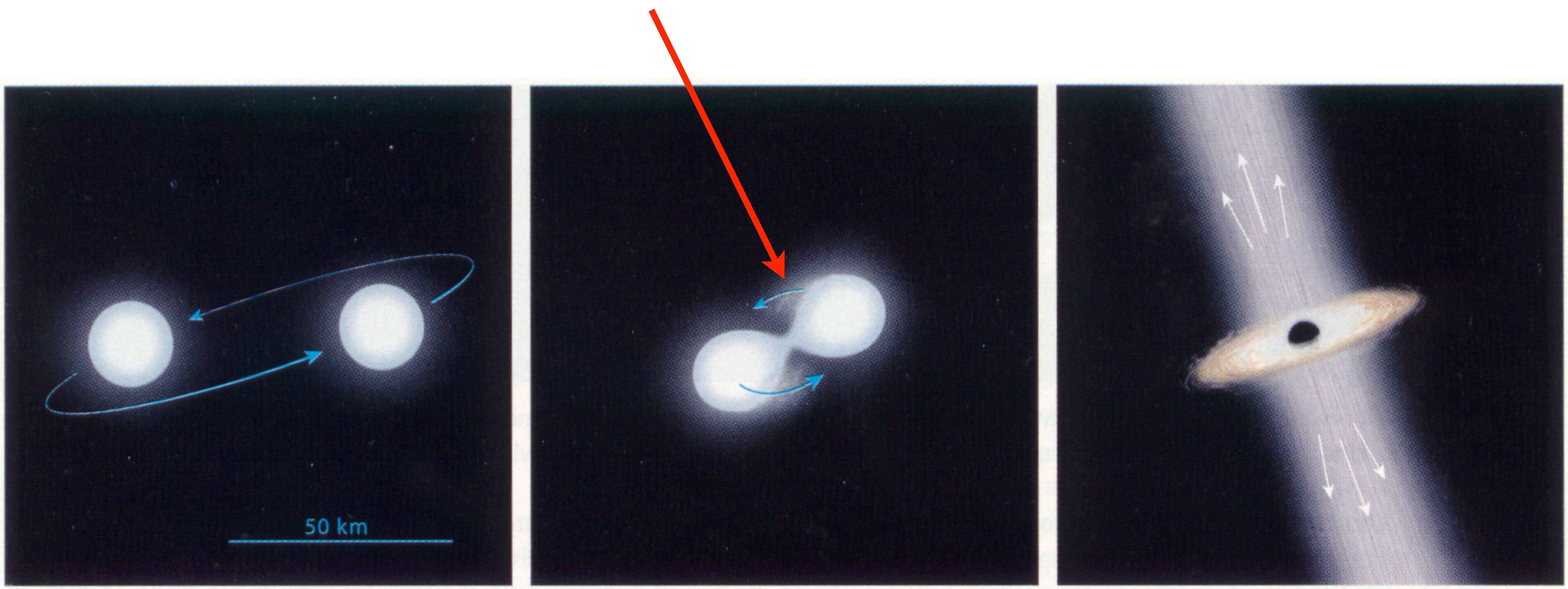

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Tidal effects in BNS systems

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$$\hat{\lambda}^{1/5} \sim r$$

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Post-Newtonian BNS waveform

- In the frequency domain (Taylor F2), the BNS signal is known to 3.5PN order:

$$\tilde{h}(f) = \mathcal{A} f^{-7/6} \exp\left[i\Psi_{3.5}(v)\right]$$
$$v(f) = (\pi M f)^{1/3}$$

$\uparrow$ v^7

Post-Newtonian BNS waveform + tidal corrections

- In the frequency domain (Taylor F2), the BNS signal is known to 3.5PN order:

$$\begin{aligned}\tilde{h}(f) &= \mathcal{A} f^{-7/6} \exp\left(i\left[\Psi_{3.5}(v) + \delta\Psi_{\rm tidal}(v)\right]\right) \\ v(f) &= (\pi M f)^{1/3}\end{aligned}$$

↑ v^7

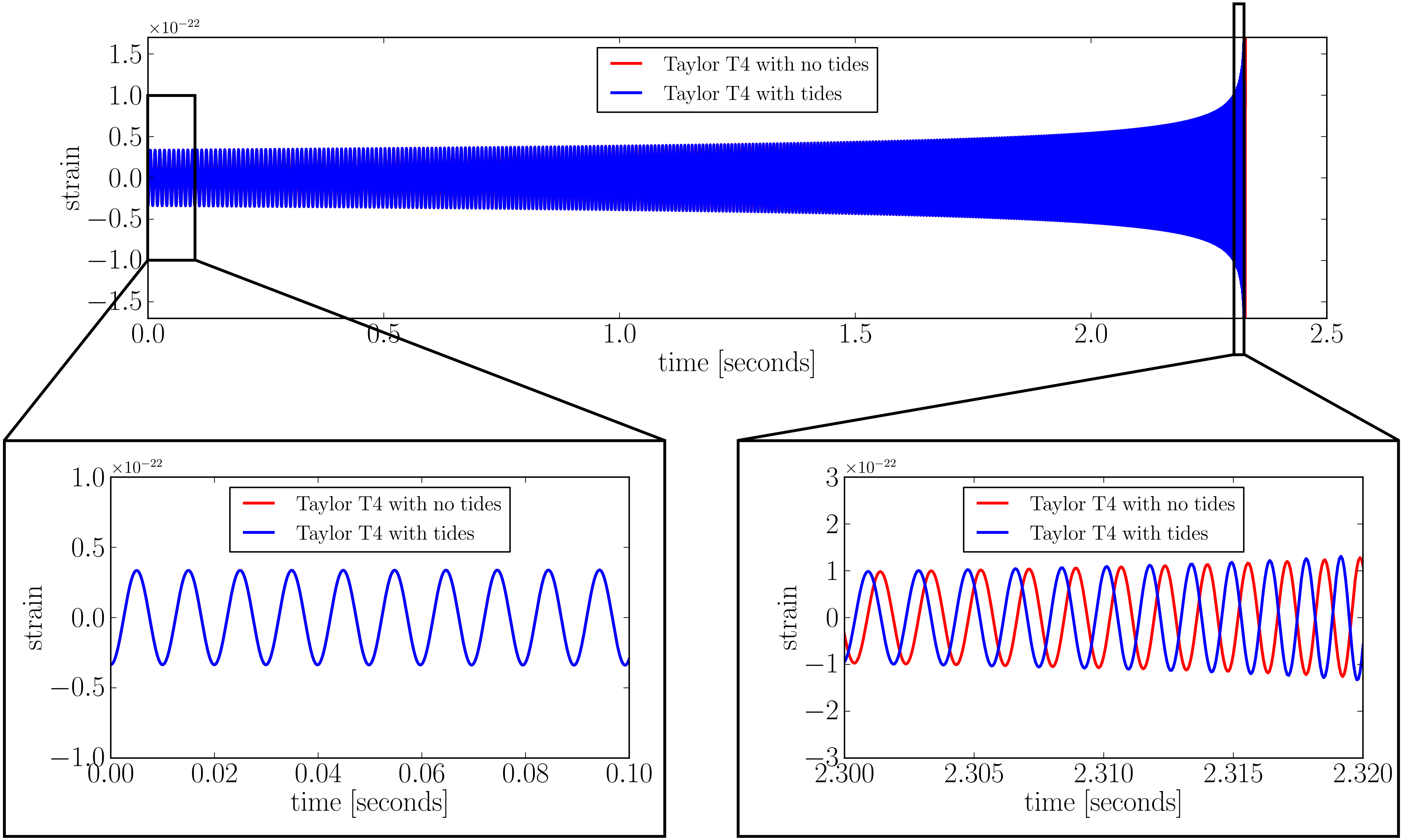
- The leading-order and next-to-leading-order tidal corrections are:

$$\delta\Psi_{\rm tidal} = \frac{3}{128\eta v^5}\left[\left(\frac{39}{2}\tilde{\Lambda}\right) v^{10} + \left(\frac{3115}{64}\tilde{\Lambda} - \frac{659}{364}\sqrt{1-4\eta}\;\delta\tilde{\Lambda}\right) v^{12}\right]$$

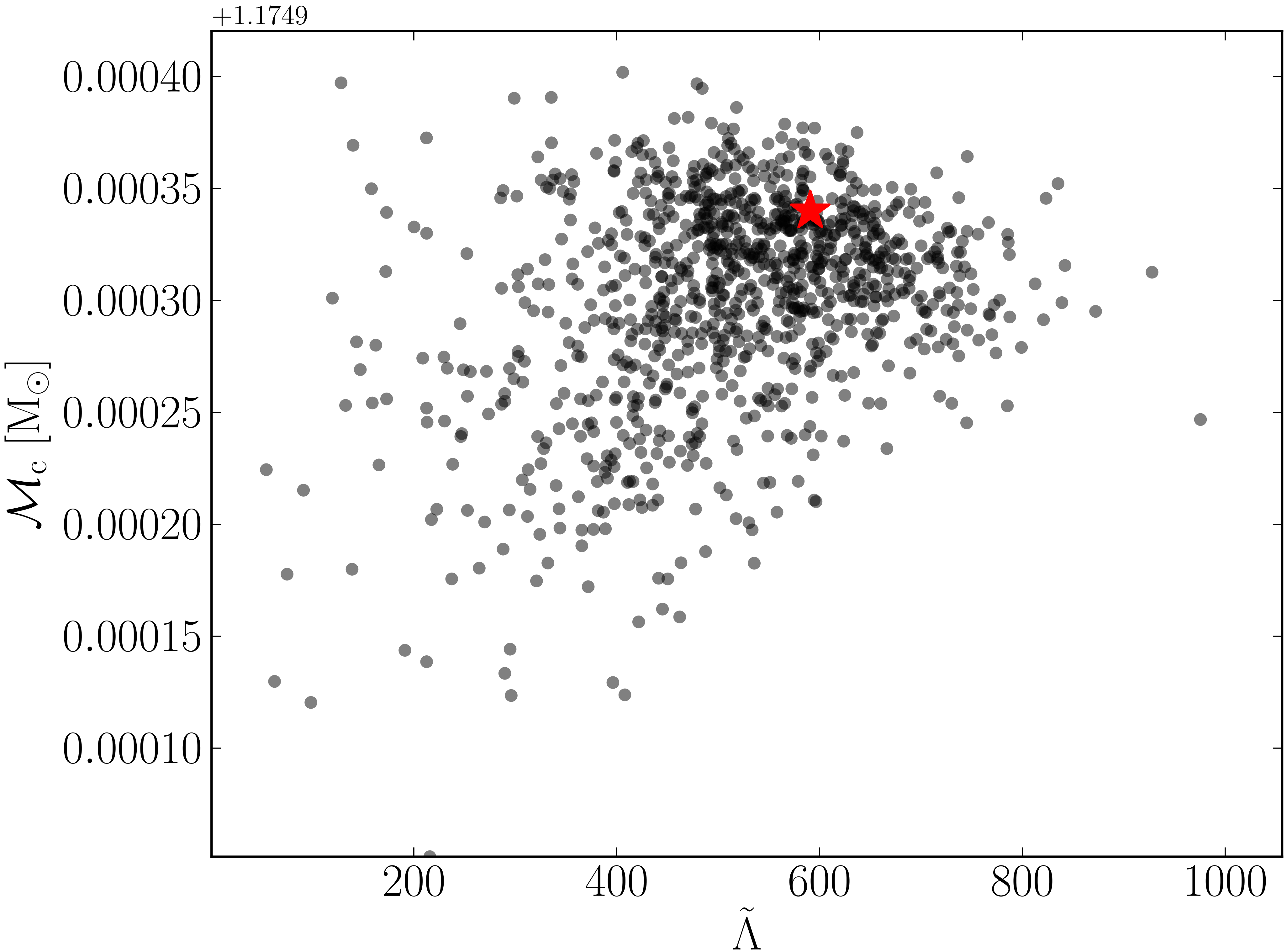
- The parameters $(\tilde{\Lambda}, \delta\tilde{\Lambda})$ are just a linear combination of $(\hat{\lambda}_1, \hat{\lambda}_2)$ with the following property:

$$\tilde{\Lambda}(m_1 = m_2, \hat{\lambda}_1 = \hat{\lambda}_2 = \hat{\lambda}) = \hat{\lambda}$$

Tidal corrections to PN waveforms



Parameter estimation: MCMC



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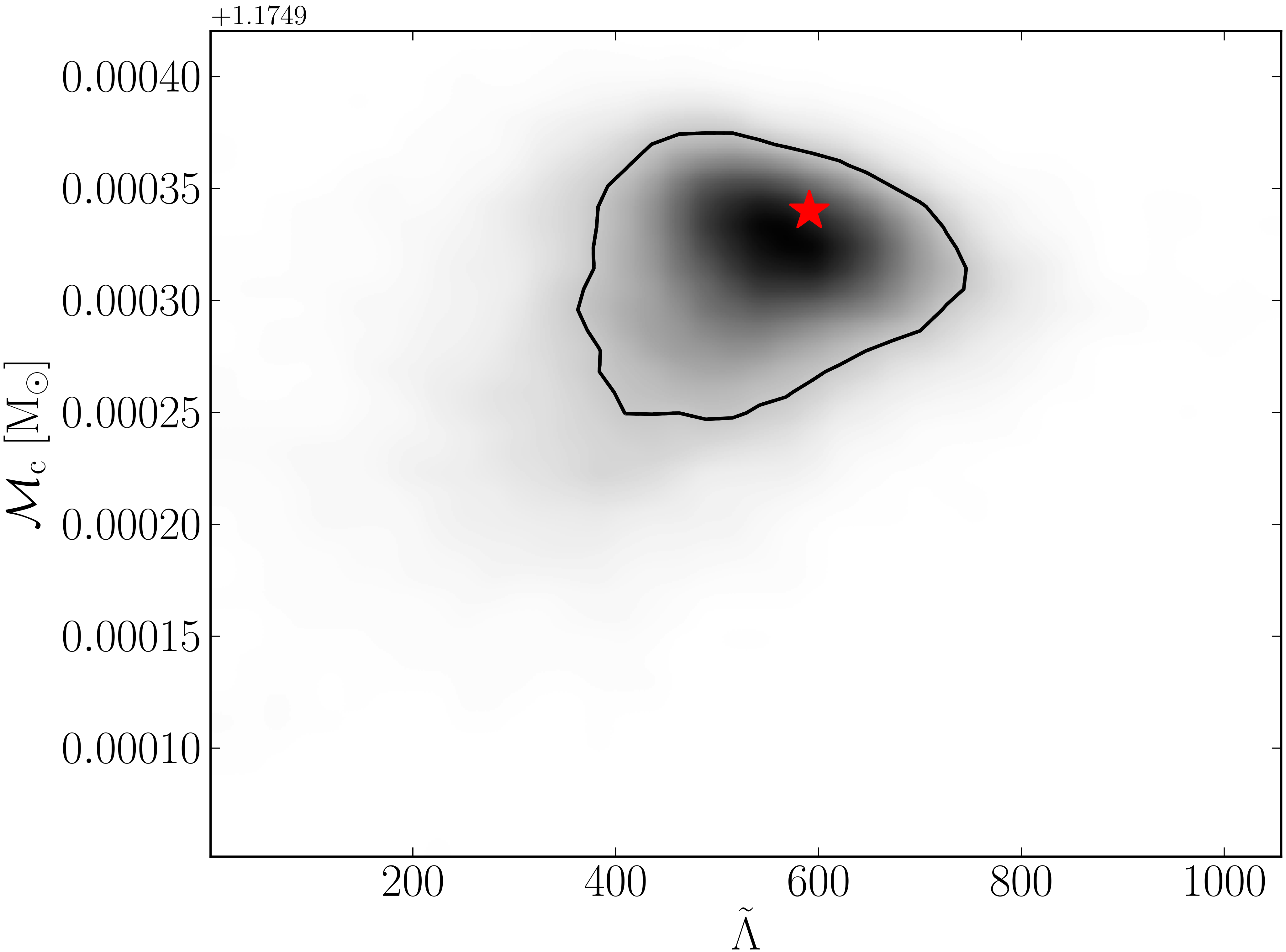
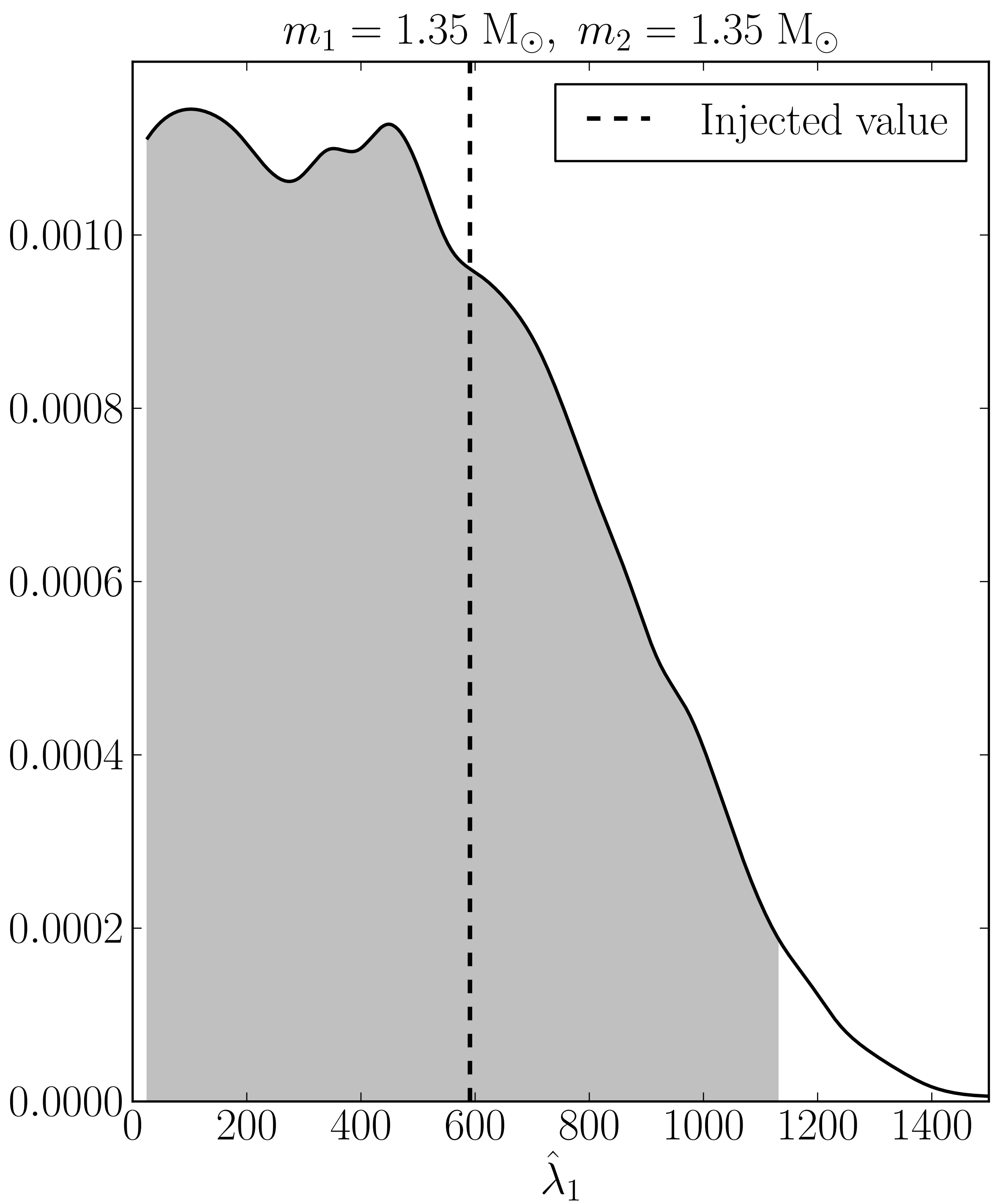
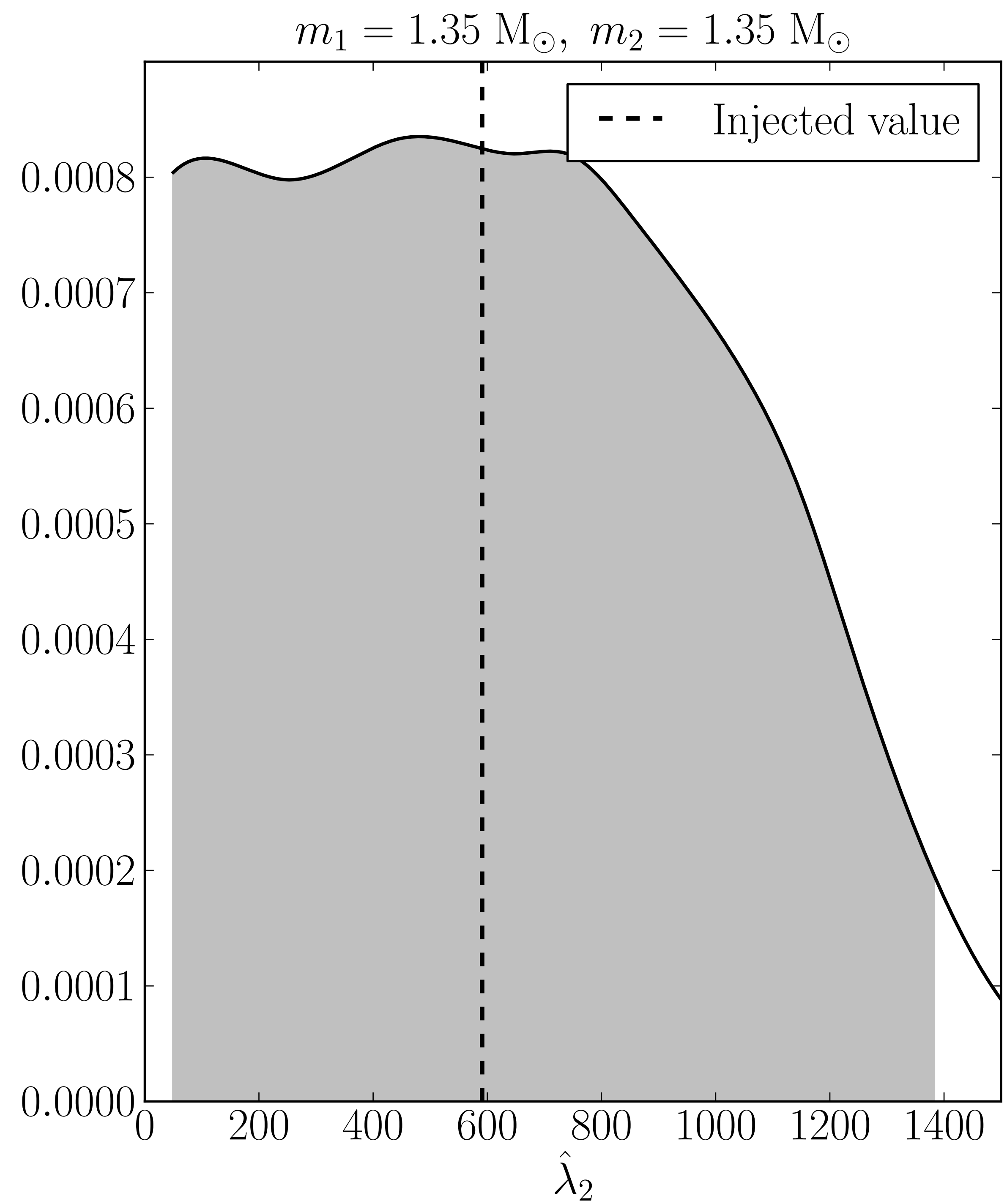
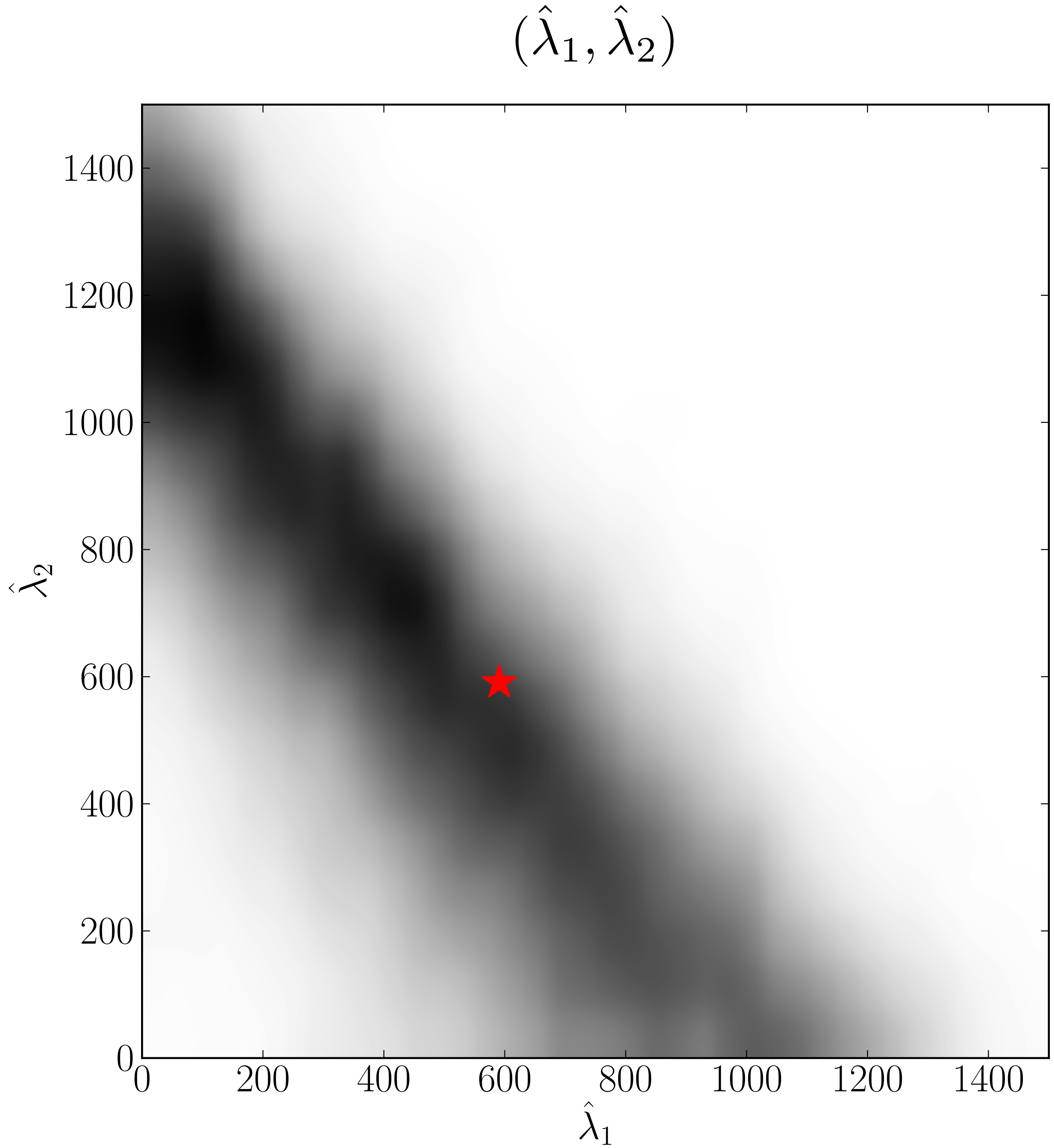


Measuring tidal parameters (Net SNR ~ 30)





Measuring tidal parameters



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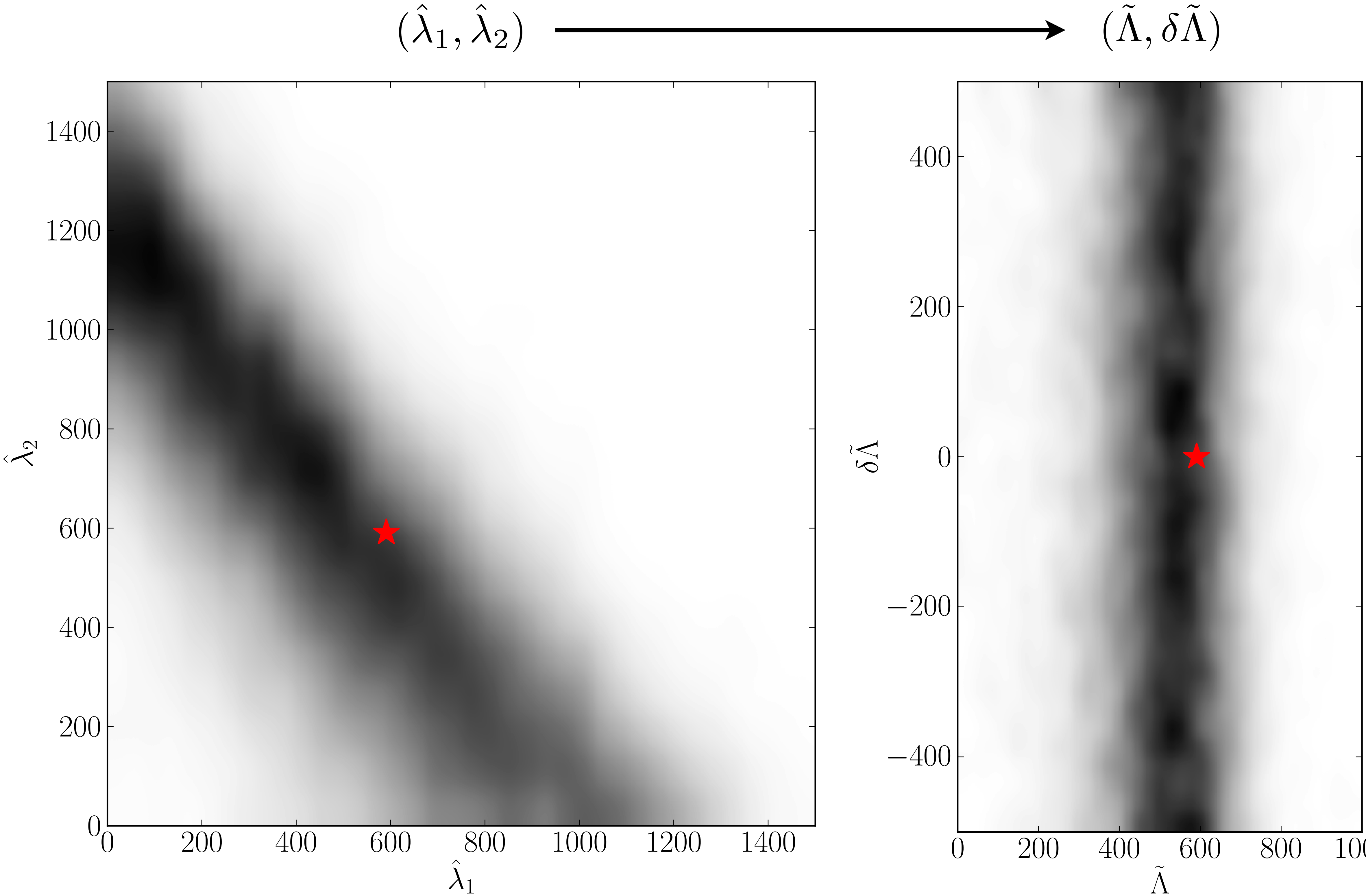

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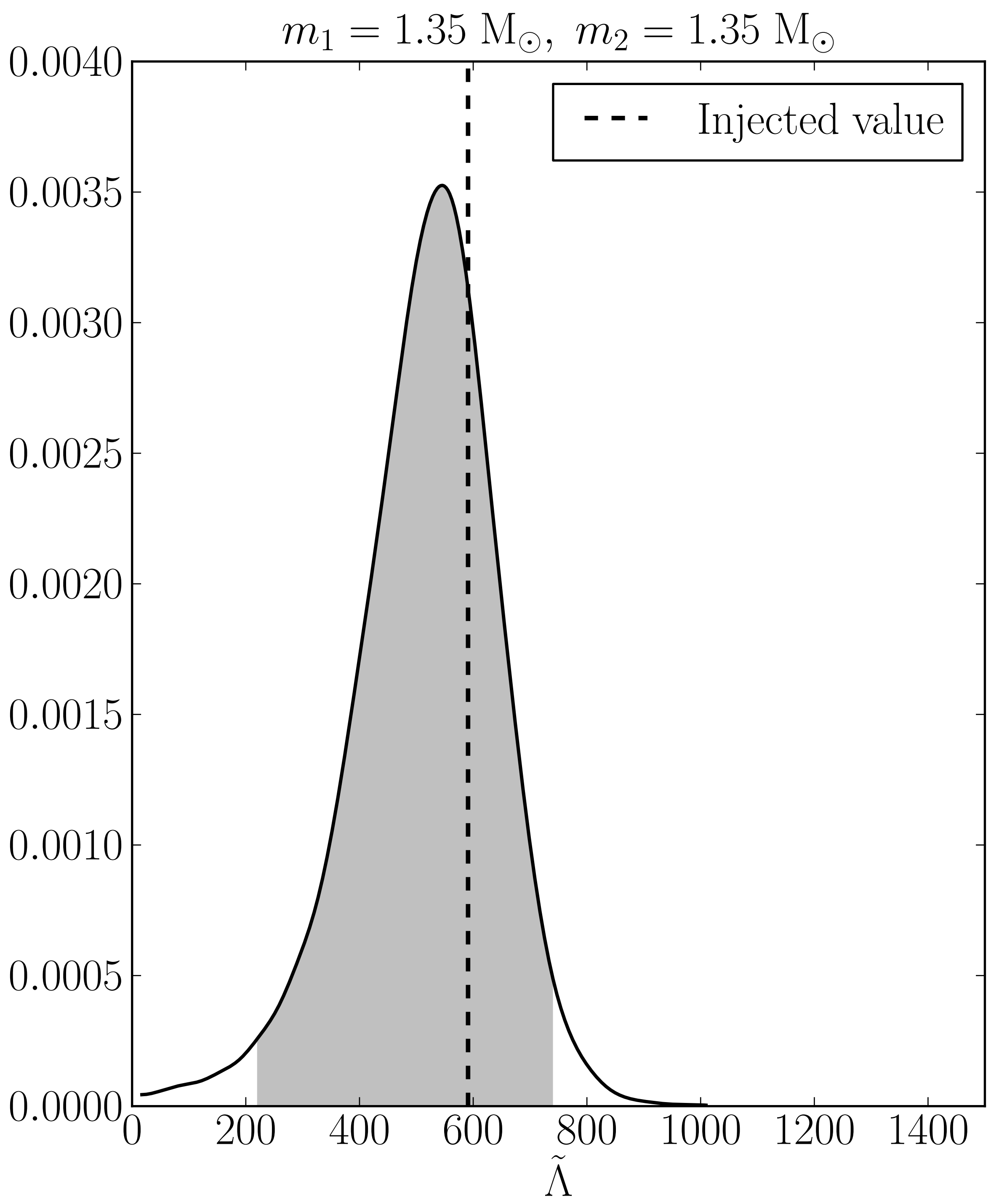

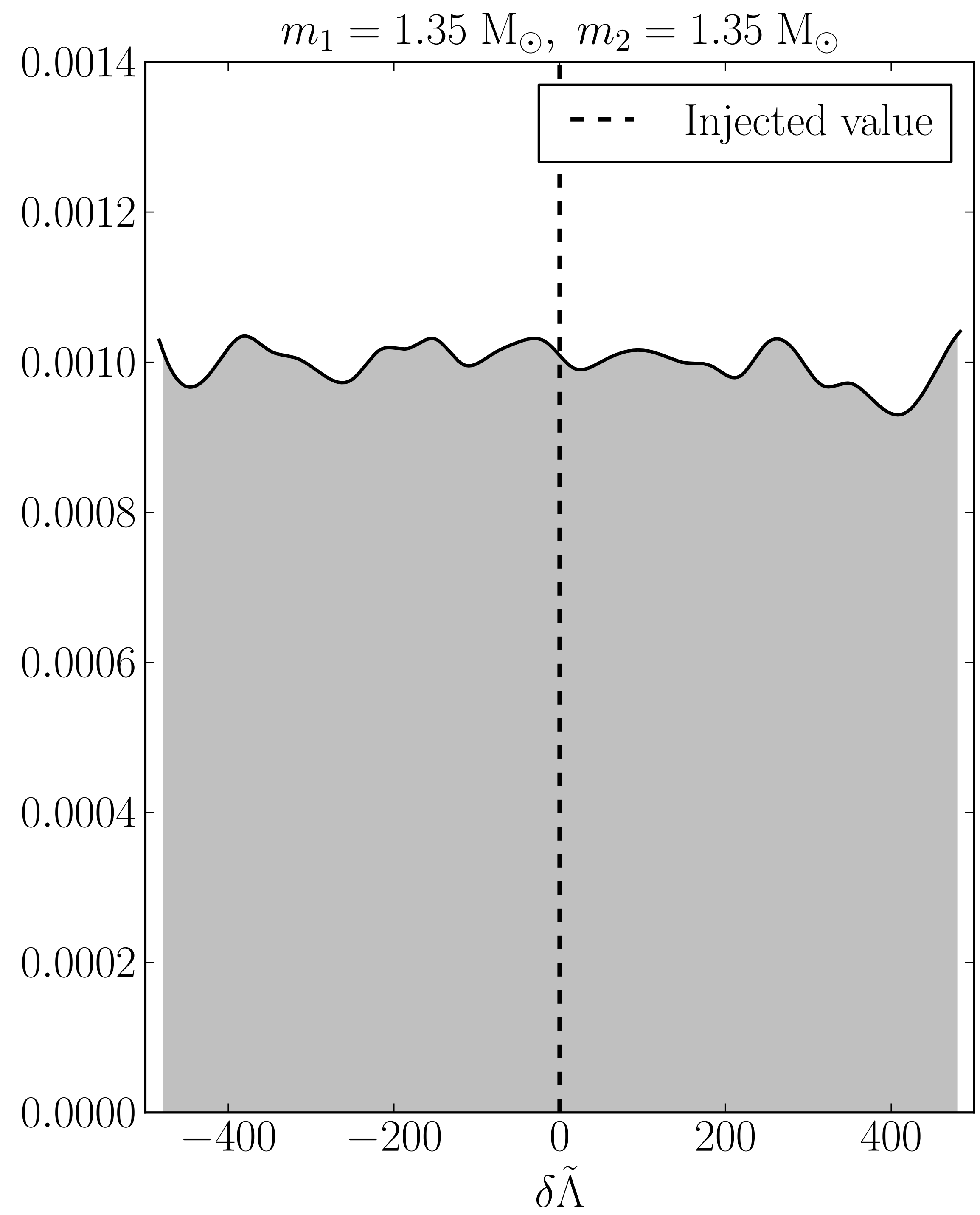

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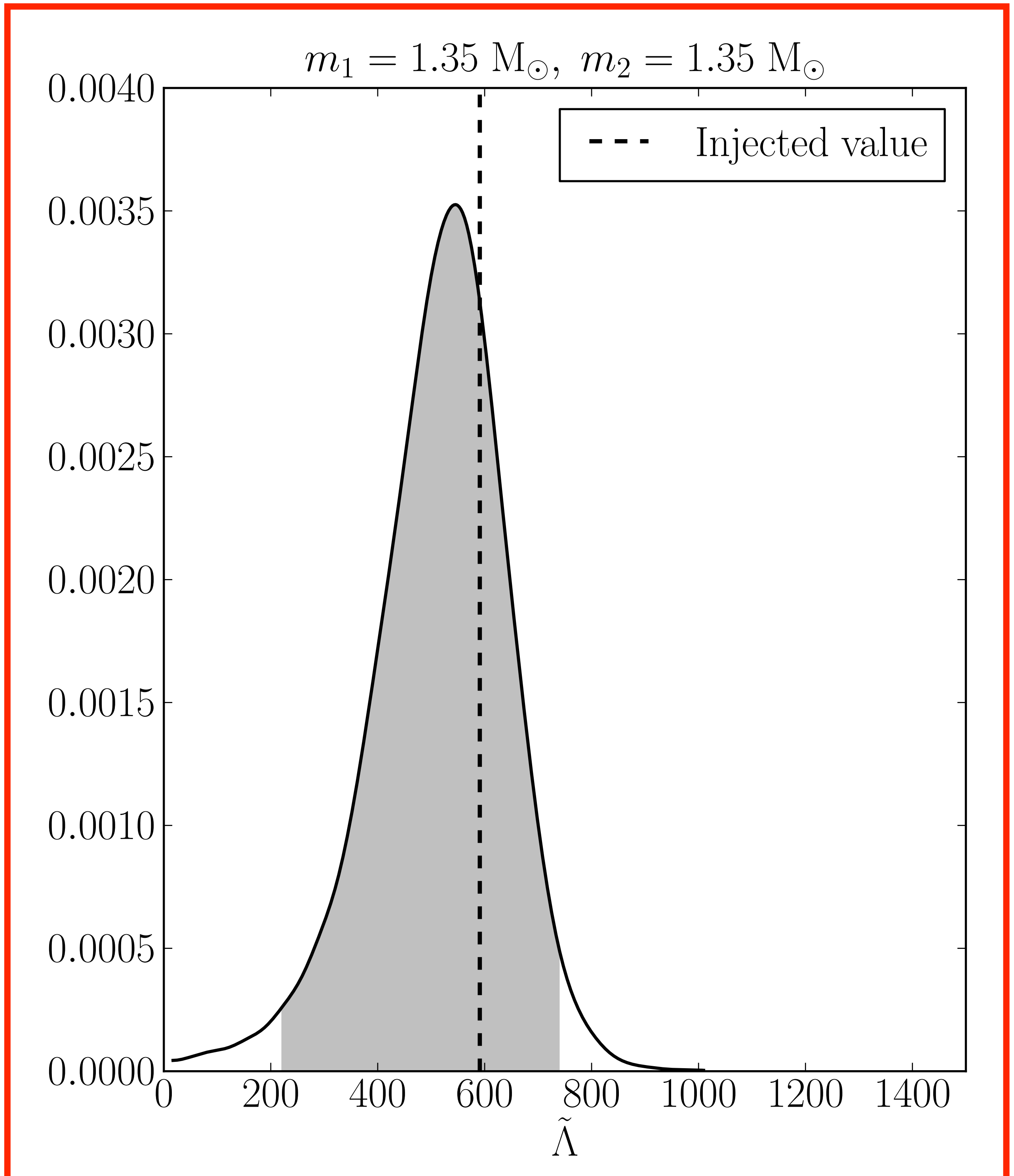
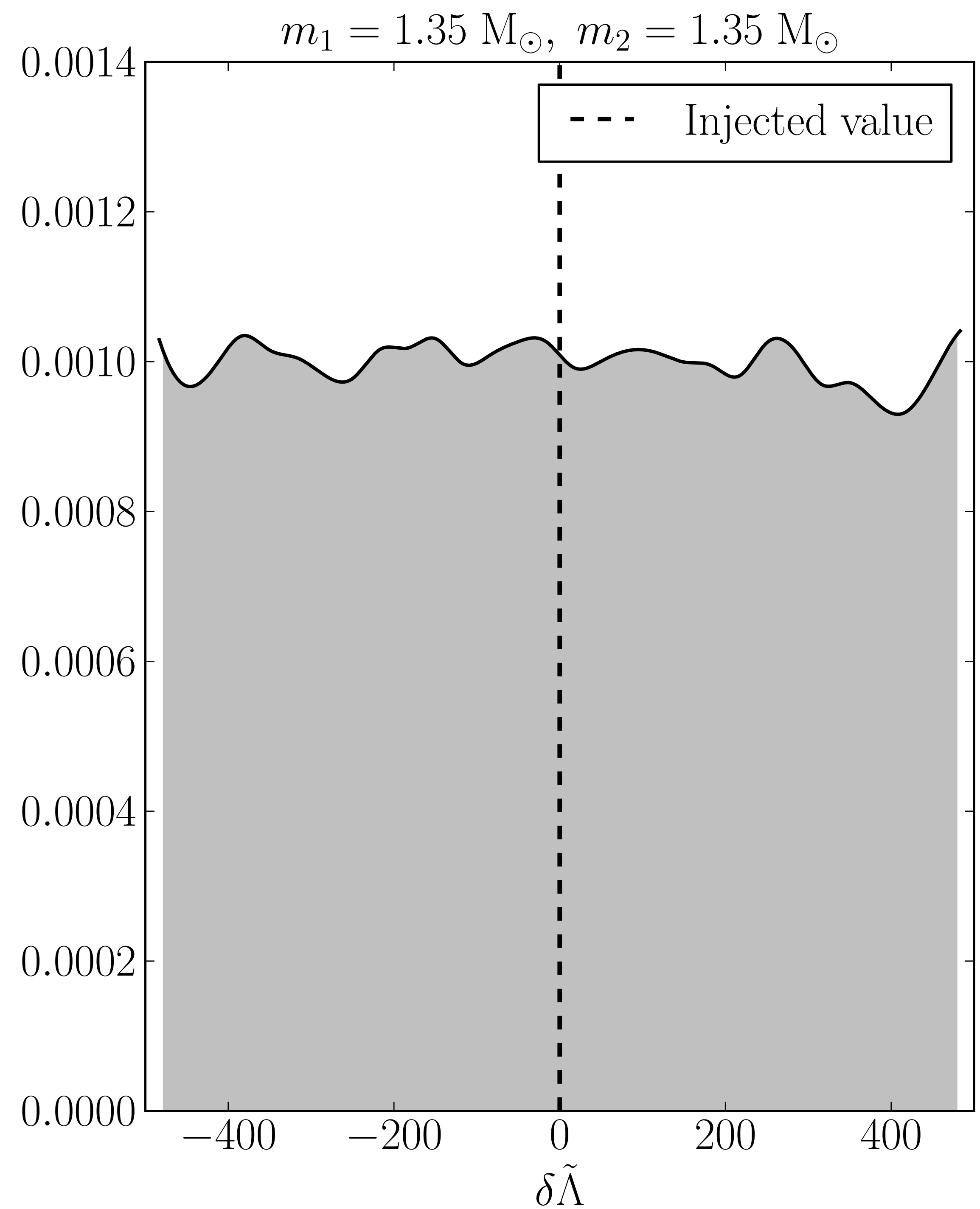
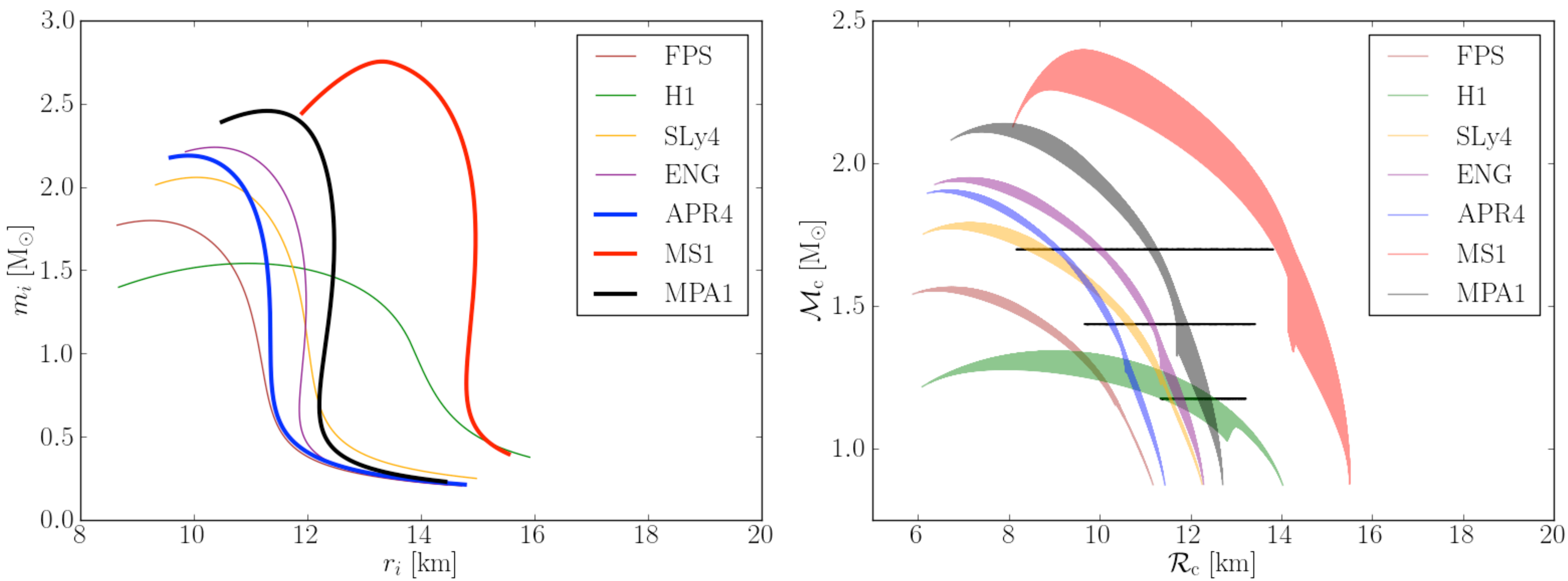




- We define a radius-like parameter: $\mathcal{R}_c = 2\mathcal{M}_c\tilde{\Lambda}^{1/5}$



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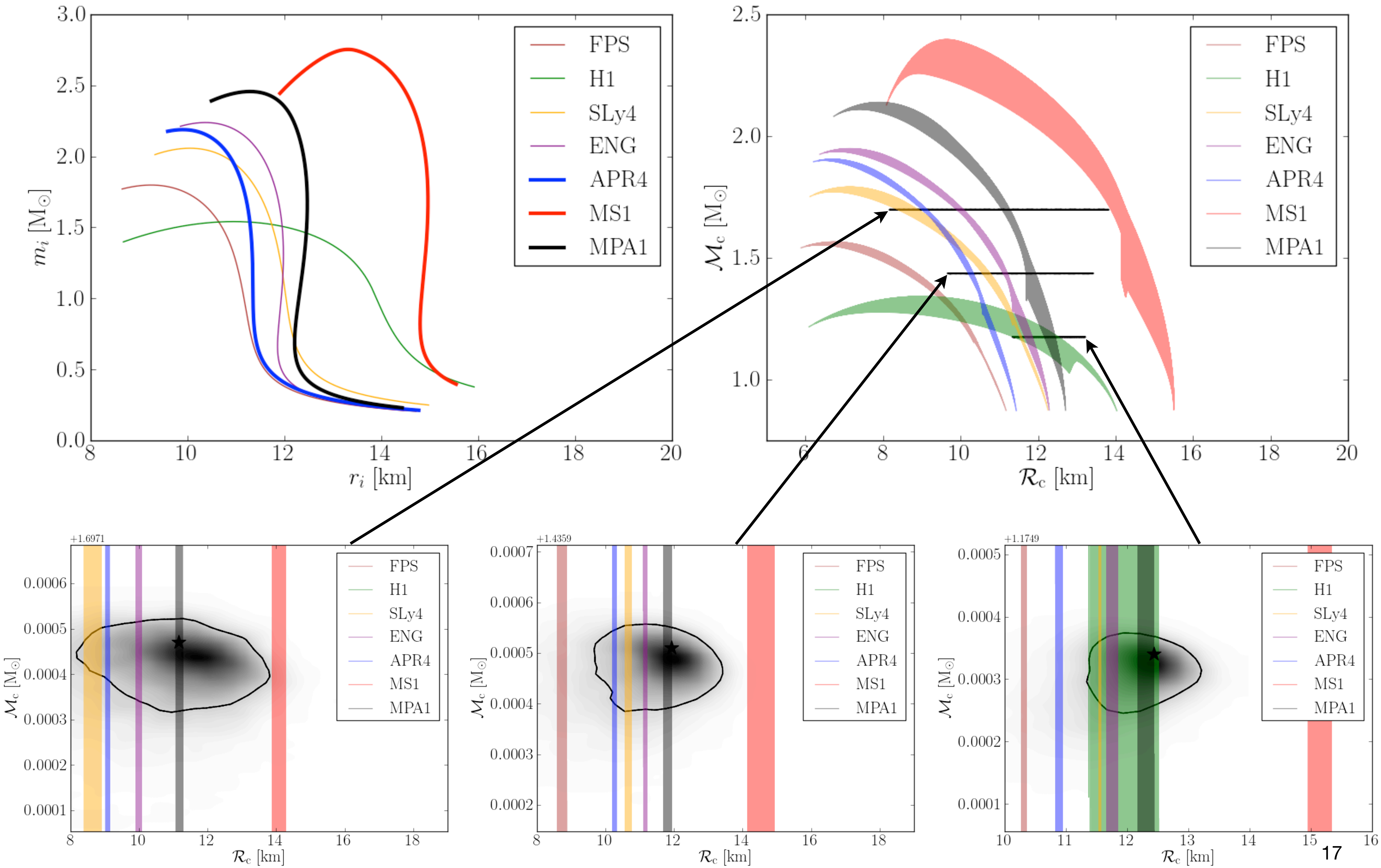
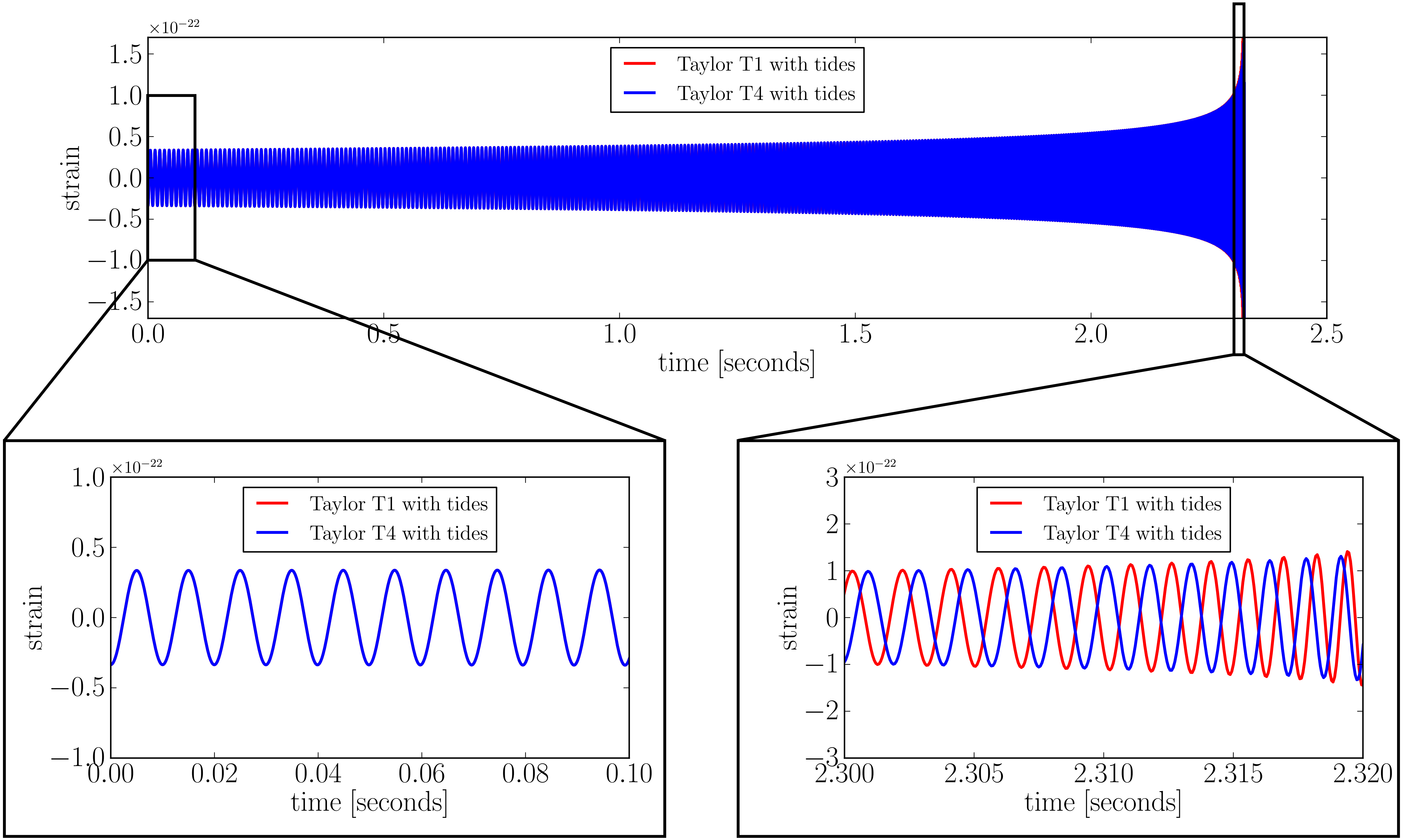
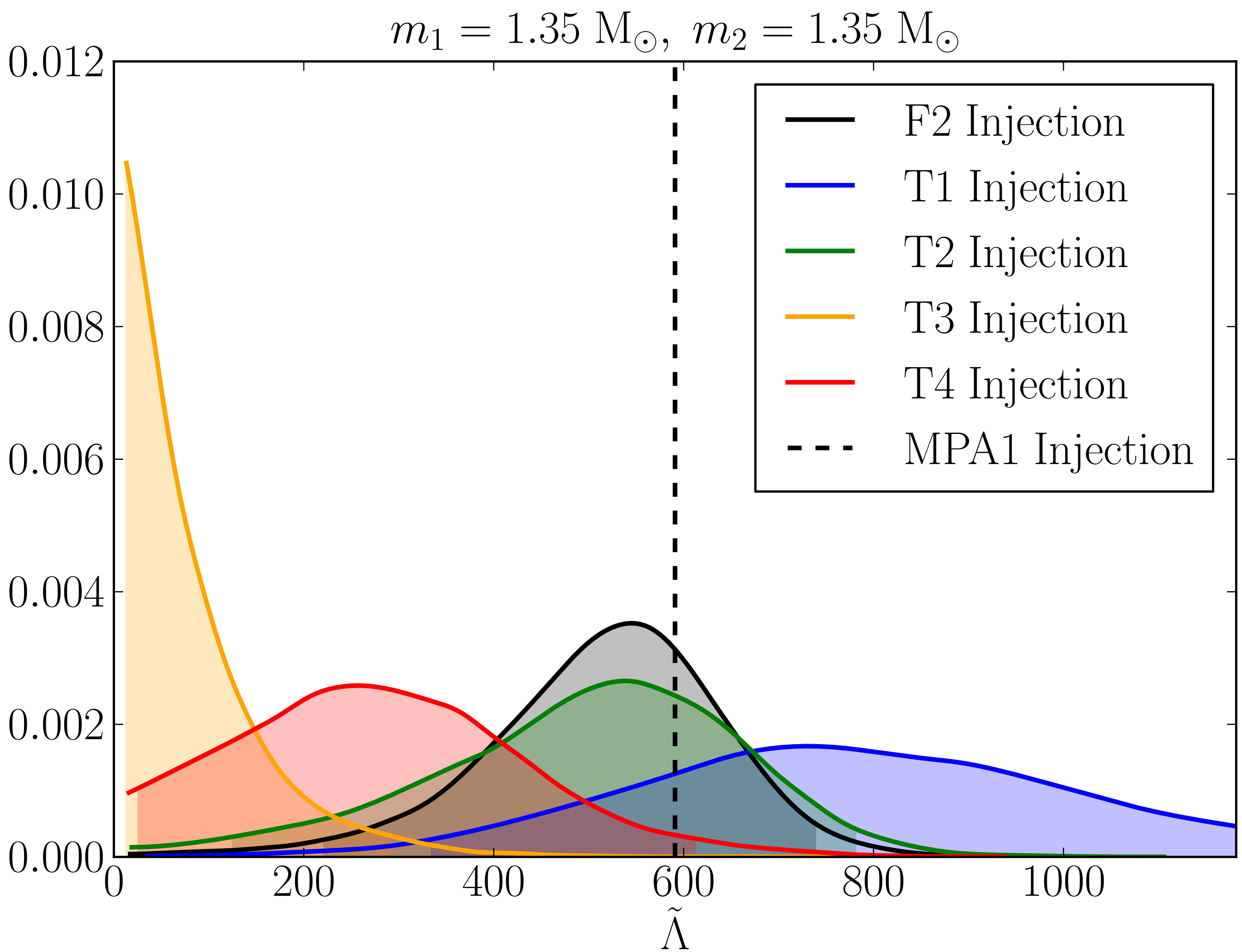


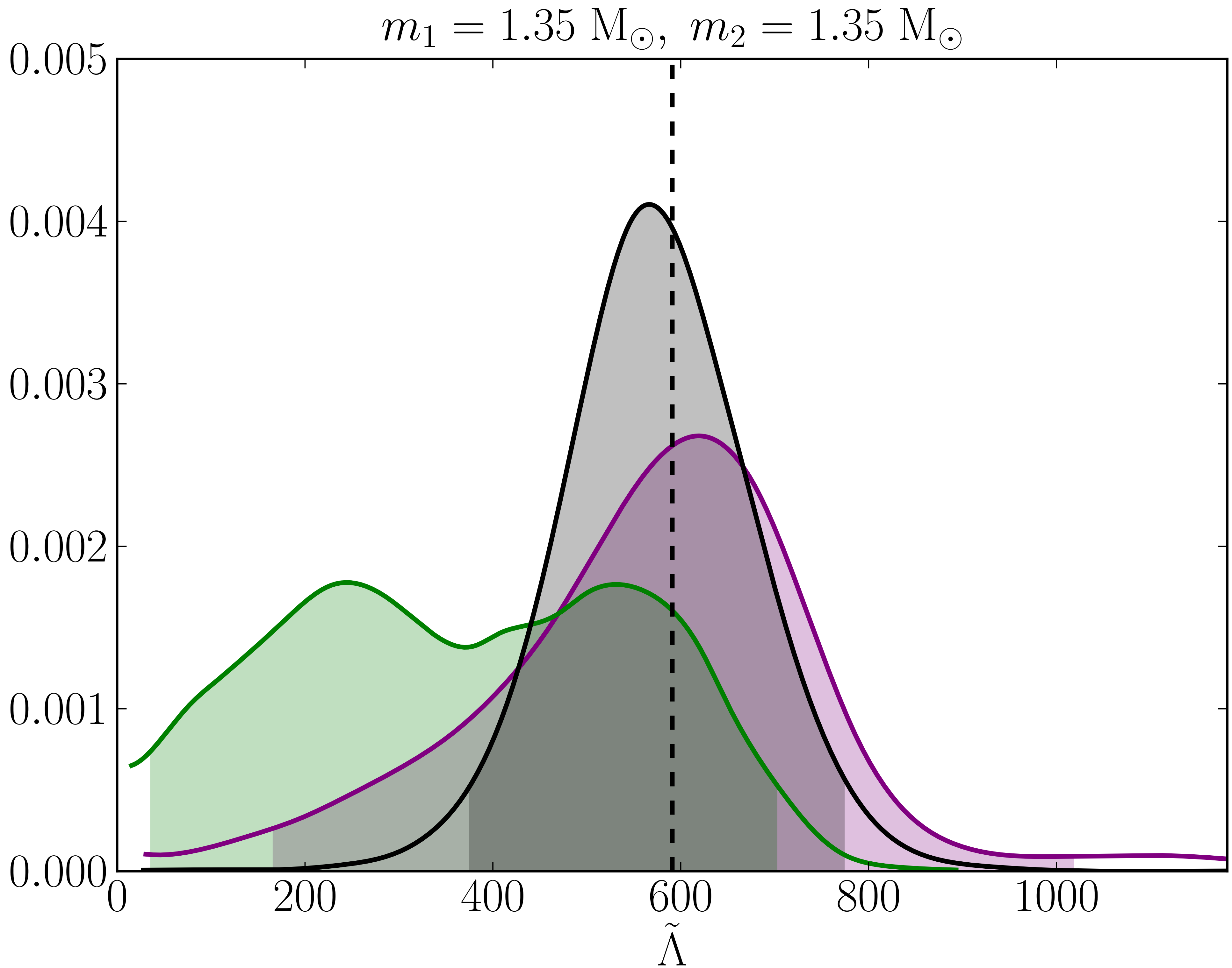
Uncertainty in PN waveforms



Systematic error (waveform uncertainty)



Statistical error (noise realization)



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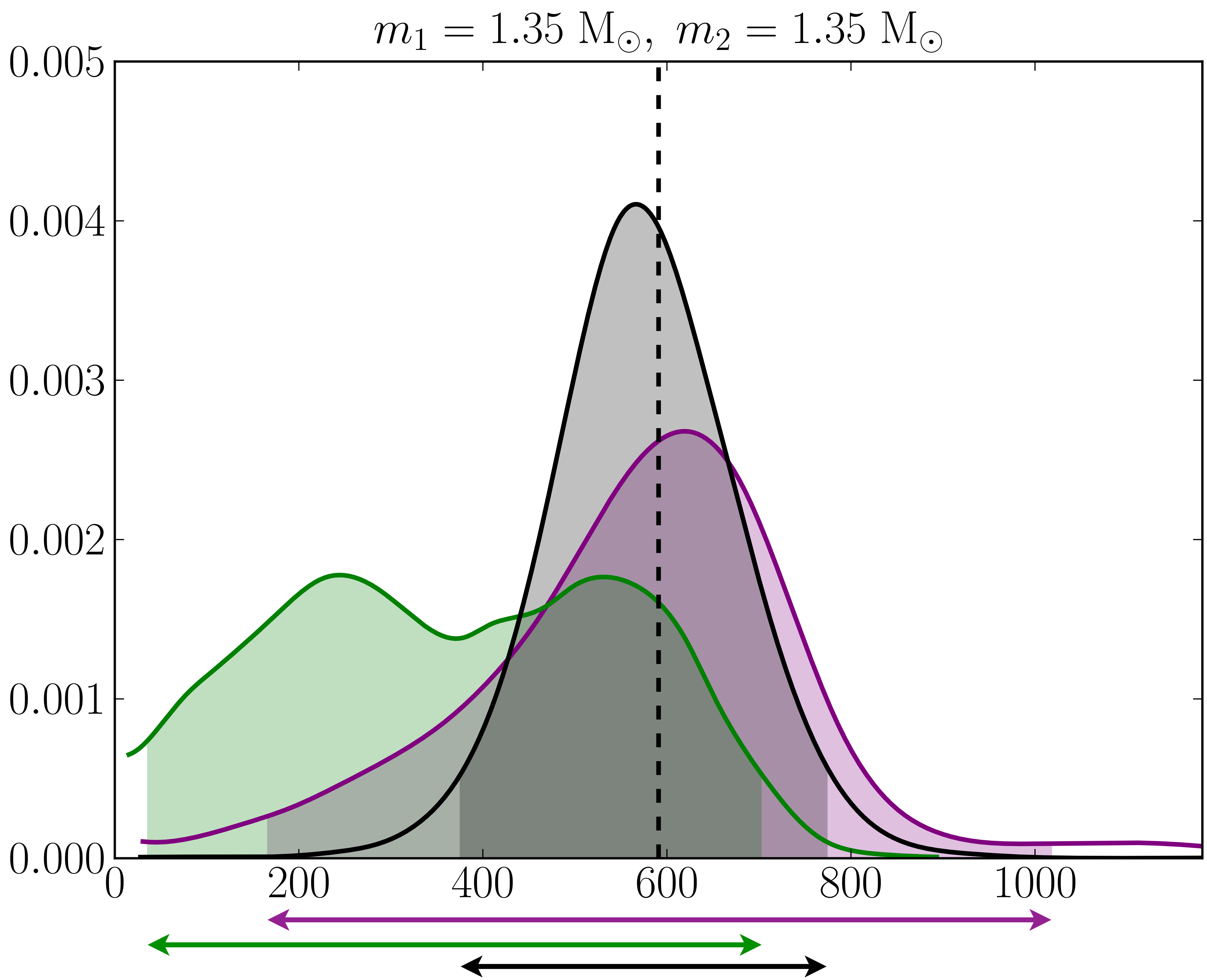

Summary of findings

- Tidal deformability can be measured with advanced detectors
- The NS EOS can be constrained with these measurements
- Statistical error can significantly increase measurement uncertainty
- Systematic error can significantly bias recovery of tidal deformability
- Better waveforms are needed to measure EOS effects
    - NR with matter effects
    - Hybrid/Phenomenological waveforms? Higher PN terms?