A consistency test of GR using different multipoles of gravitational radiation from binary black holes

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Method

- **Gravitational waveform can be decomposed into the two independent polarisations:**

$$\mathrm{h}(t) := \mathrm{h}_{+}(t) - i\mathrm{h}_{\times}(t)$$

- **Alternatively, expand in a basis of spin -2 weighted spherical harmonics:**

$$\mathrm{h}(t;\iota,\phi_0,\lambda) = \sum_{l=2}\sum_{m=-l} \mathcal{Y}^{-2}_{lm}(\iota,\phi_0)\mathrm{h}_{lm}(t,\lambda)$$

$$\lambda = \{M_c, q, t_0, d_L\}$$

- **Split contributions from dominant (2, \pm2) modes, and the subdominant higher-order multipole moments:**

$$\mathrm{h}(t;\iota,\phi_0,\lambda) = \mathcal{Y}^{-2}_{2,\pm 2}(\iota,\phi_0)\mathrm{h}_{2,\pm 2}(t,\lambda) + \sum_{\mathrm{H.O.M}} \mathcal{Y}^{-2}_{lm}(\iota,\phi_0)\mathrm{h}_{lm}(t,\lambda)$$

Method

- **The Test: Check for consistency between estimates of λ, independently measured using the dominant and the sub-dominant modes of the gravitational waveform respectively:**

$$\mathrm{h}(t;\iota,\phi_0,\lambda,\lambda') = \mathcal{Y}^{-2}_{2,\pm2}(\iota,\phi_0)\mathrm{h}_{2,\pm2}(t,\lambda) + \sum \mathcal{Y}^{-2}_{lm}(\iota,\phi_0)\mathrm{h}_{lm}(t,\lambda')$$

H.O.M

λ: PE estimates using dominant (2, \pm 2) modes
λ': PE estimates using subdominant higher-order modes

- **If GR is correct, these two independent estimates would be consistent with each other.**

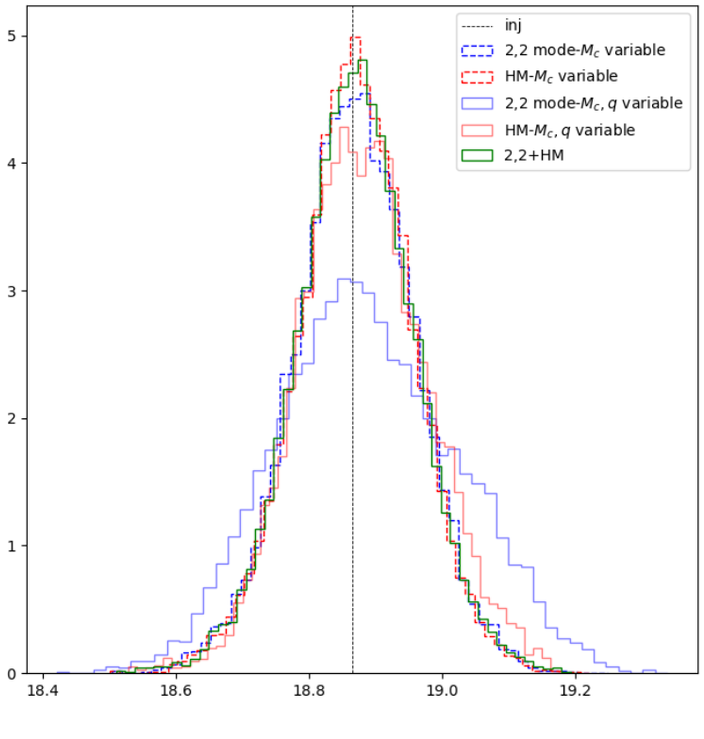
- **Alternatively define: λ' = λ + Δλ**

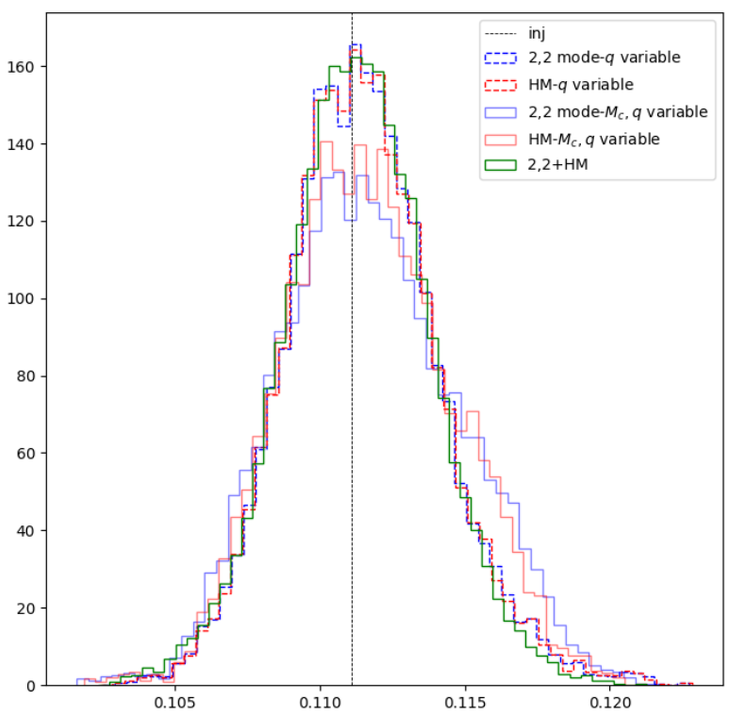
- **If GR is correct p(Δλ) should be consistent with 0.**

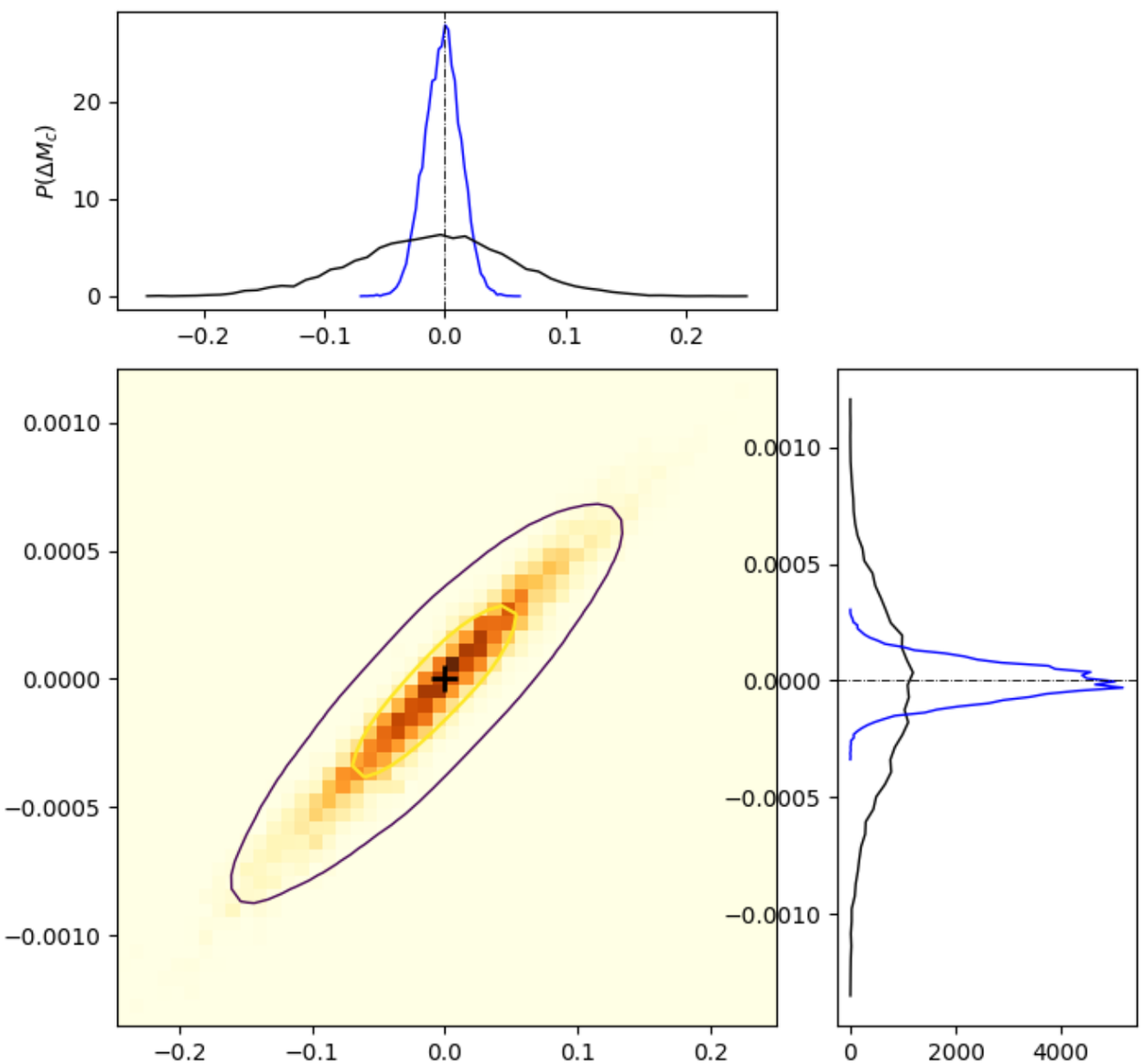
Results

- Analysis:
  - Single IFO PE over λ = {Mc, q}
  - Fixed SNR = 25 (optimally oriented on the sky)
  - Waveform model: higher-order IMR model described in Mehta et al (arxiv:1708.03501, accepted in PRD)
  - Noise PSD: Advanced LIGO ZDHP noise
  - Sampler: emcee

Results

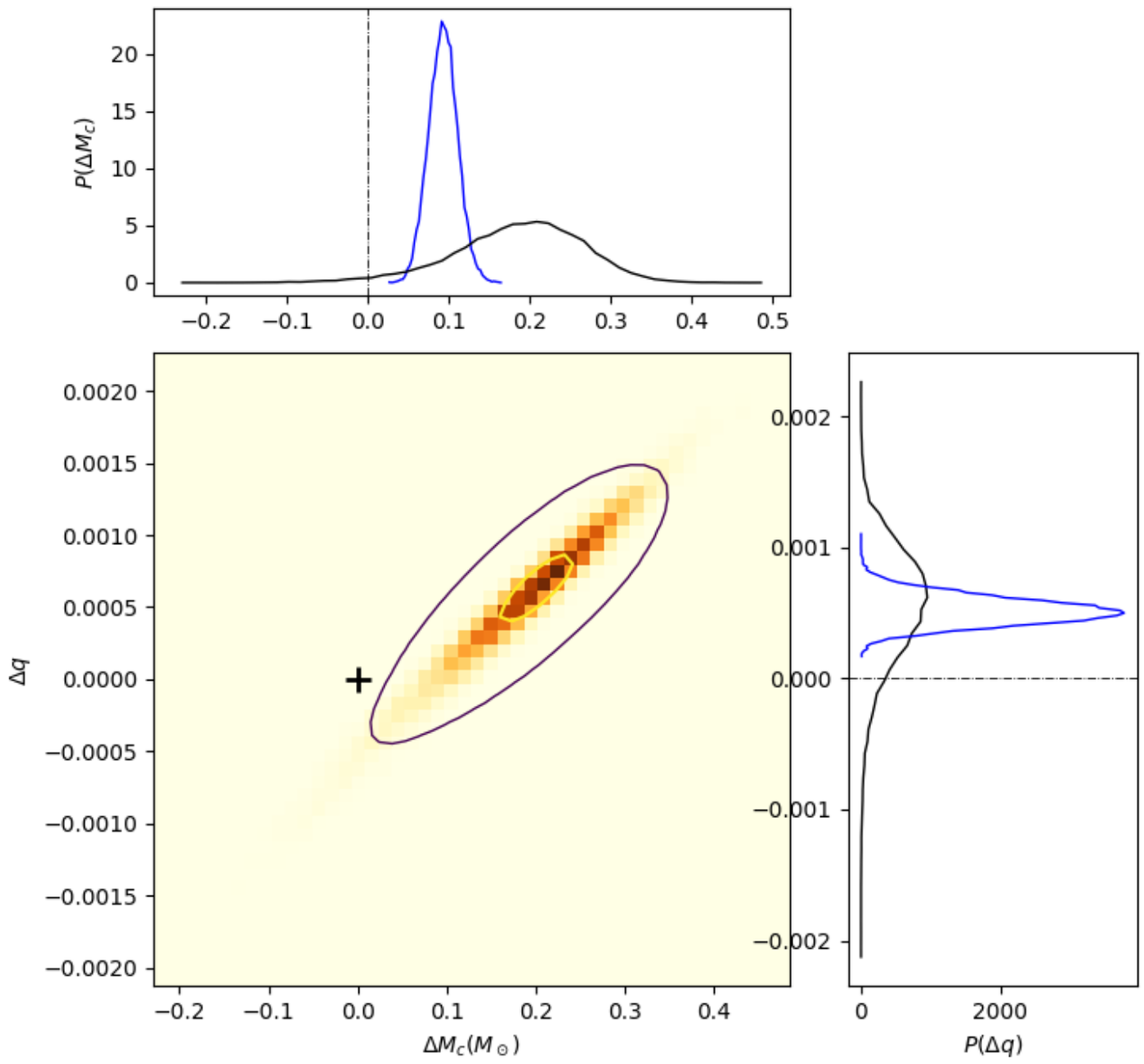

inj
2,2 mode-M_c variable
HM-M_c variable
2,2 mode-M_c, q variable
HM-M_c, q variable
2,2+HM


inj
2,2 mode-q variable
HM-q variable
2,2 mode-M_c, q variable
HM-M_c, q variable
2,2+HM


$P(\Delta M_c)$

Kludge Waveforms

Results


$P(\Delta M_c)$
20
15
10
5
0
−0.2
−0.1
0.0
0.1
0.2
0.3
0.4
0.5
Δq
0.0020
0.0015
0.0010
0.0005
0.0000
−0.0005
−0.0010
−0.0015
−0.0020
$\Delta M_c (M_\odot)$
0.002
0.001
0.000
−0.001
−0.002
0
2000
$P(\Delta q)$