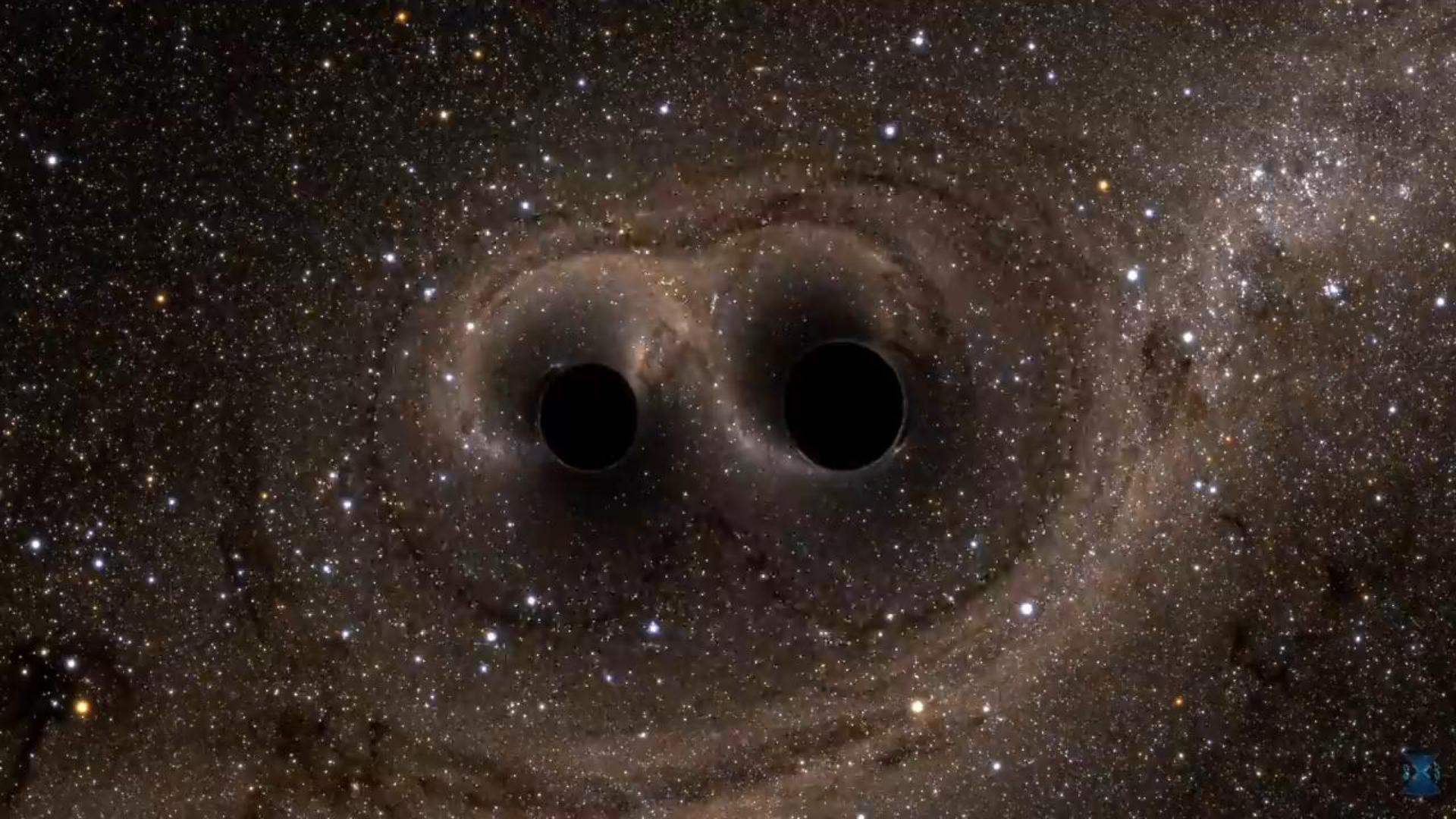
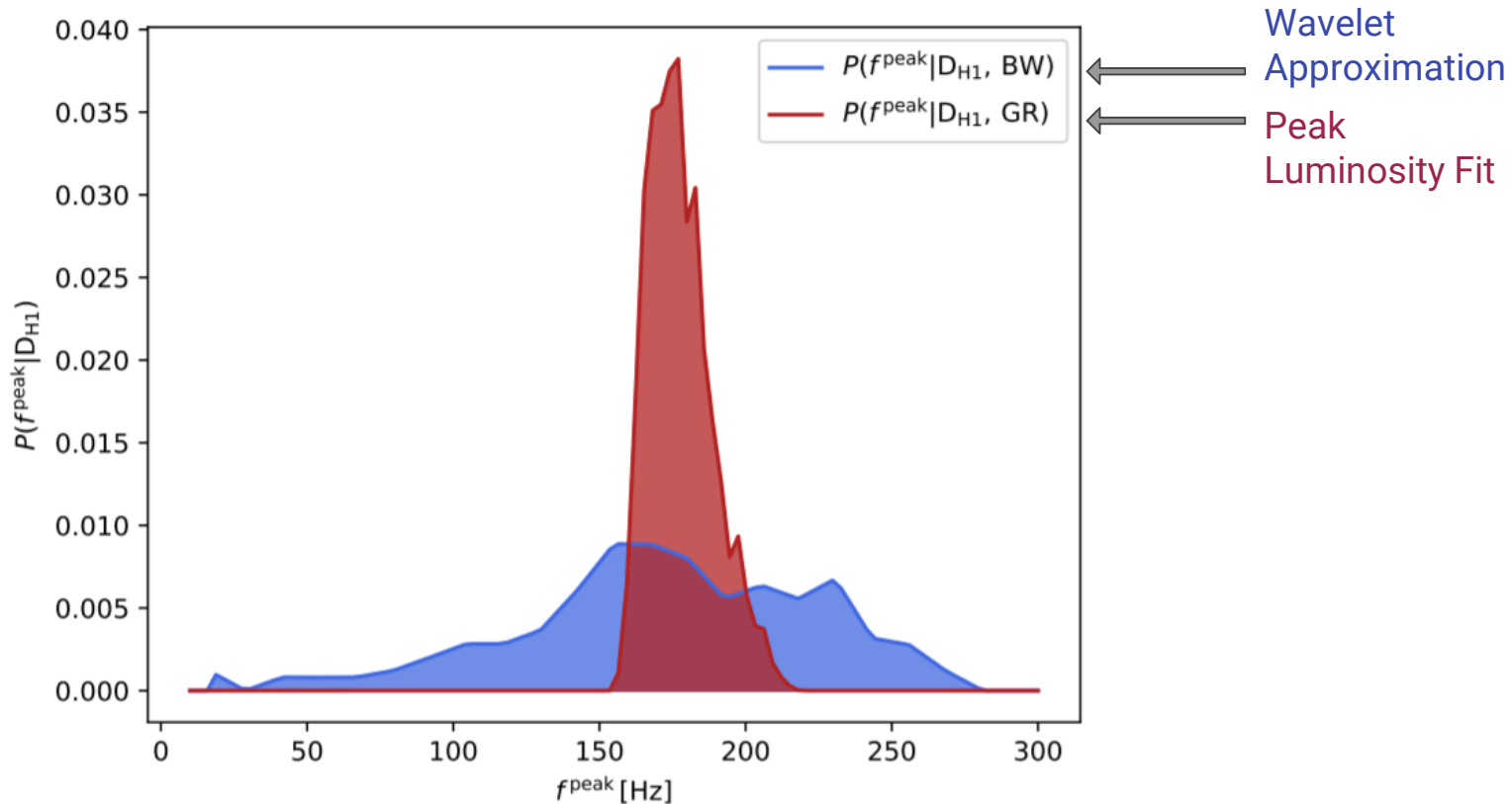


Data-driven modeling of peak luminosity of black hole mergers

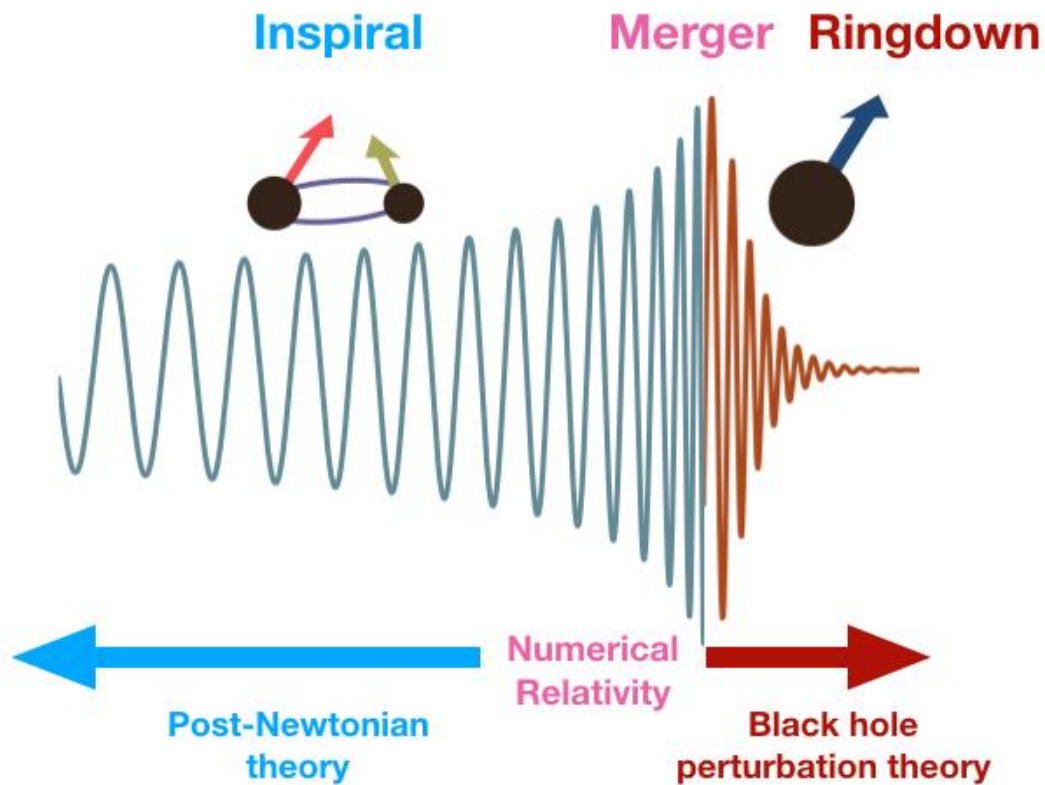
Afura Taylor | TAPIR | Mentor: Dr. Vijay Varma



Testing General Relativity (GR)



Waveform Calculation



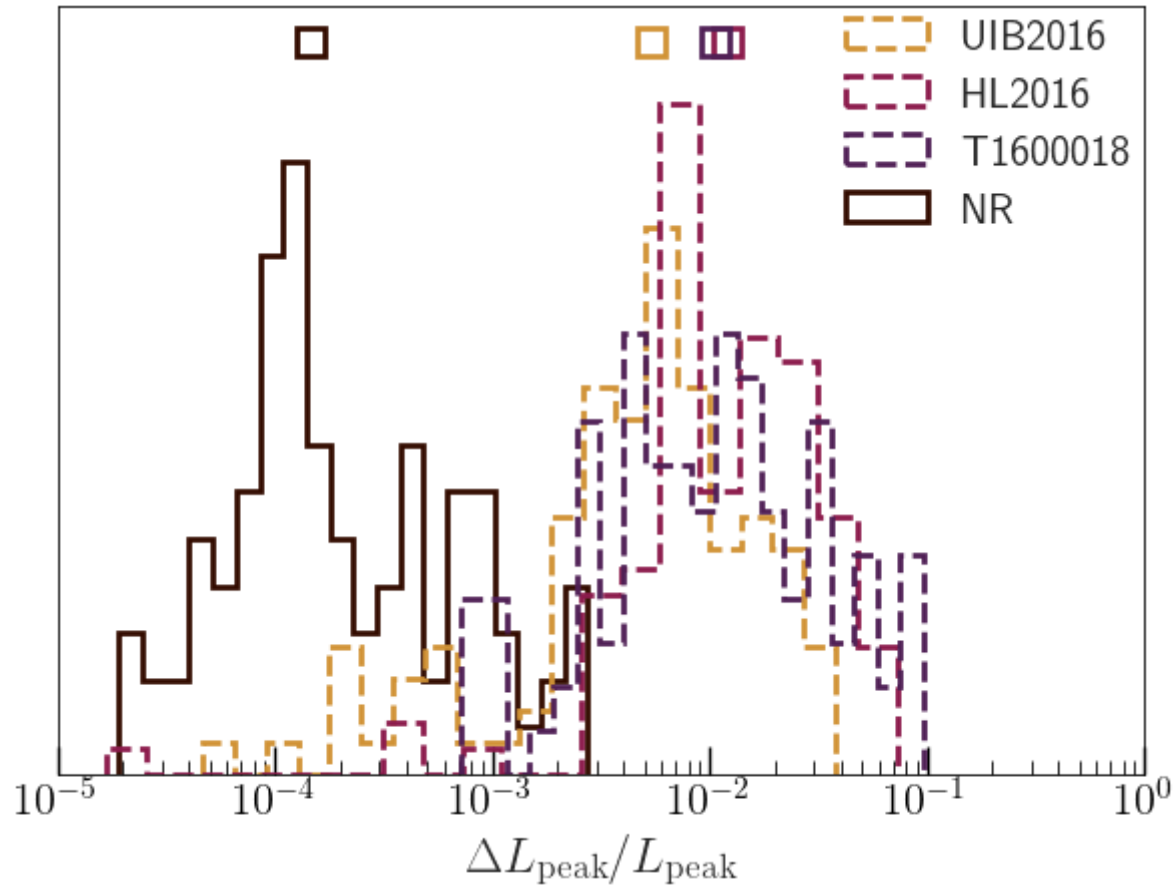
Peak Luminosity

$$L_{\text{peak}} = \max_t \lim_{r \rightarrow \infty} \frac{r^2}{16\pi} \sum_{\ell=2}^{\ell_{\text{max}}} \sum_{m=-\ell}^{+\ell} |\dot{h}_{\ell m}(t)|^2$$

which utilizes....

$$h(t, \iota, \varphi_0) = \sum_{\ell=2}^{\infty} \sum_{m=-\ell}^{\ell} h_{\ell m}(t) {}_{-2}Y_{\ell m}(\iota, \varphi_0)$$

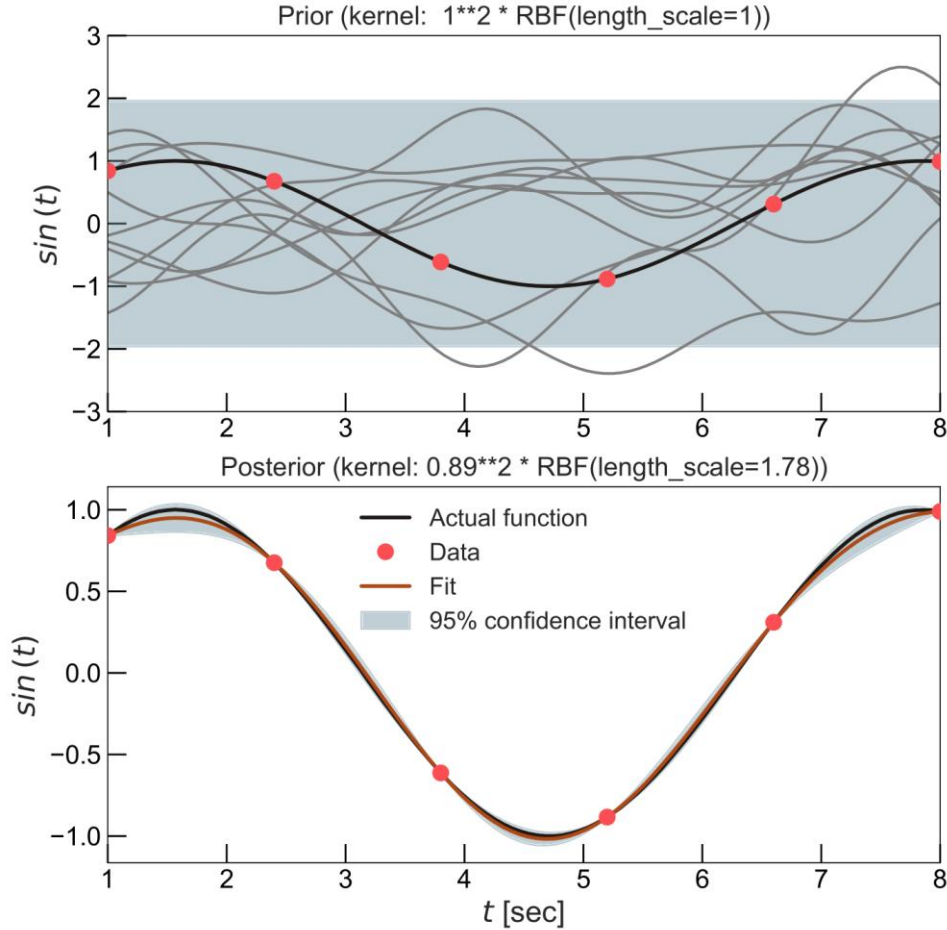
NR Simulations Compared to Current Models



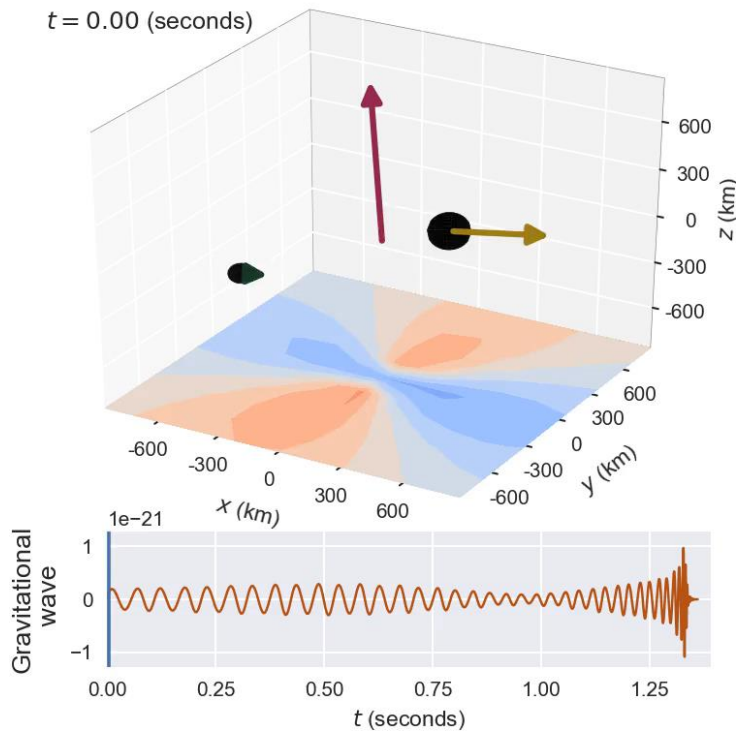
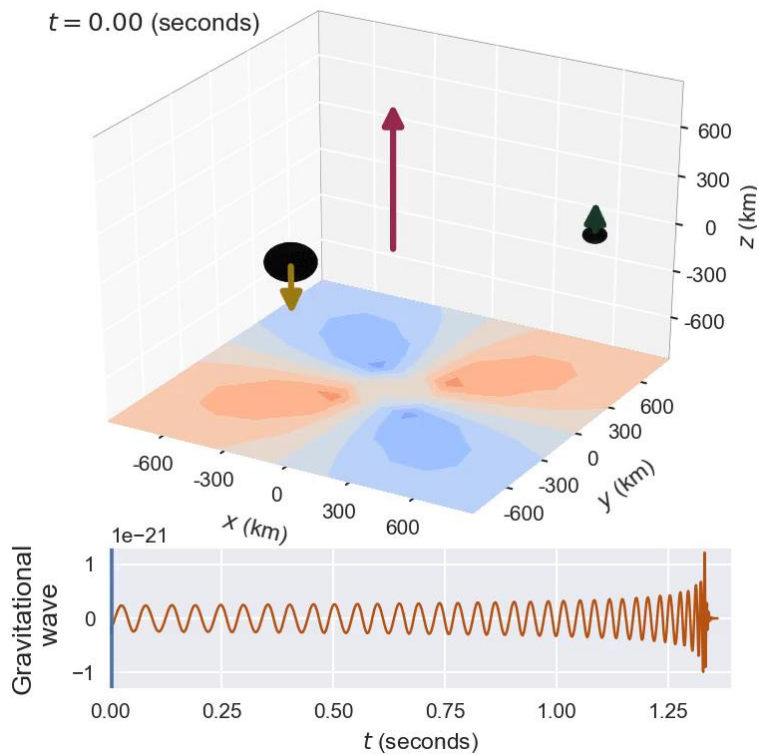
Current Approach: Phenomenological Fits

$$\begin{aligned} L'_{\text{peak}}(\eta, \widehat{S}, \Delta\chi) &= a_5\eta^5 + a_4\eta^4 + a_3\eta^3 + a_2\eta^2 + a_1\eta + a_0 \\ &+ \frac{0.107b_2\widehat{S}^2(f_{22}\eta^2 + f_{21}\eta + f_{20}) + 0.465b_1\widehat{S}(f_{12}\eta^2 + f_{11}\eta + f_{10}) + \widehat{S}^4(f_{42}\eta^2 + f_{41}\eta + f_{40}) + \widehat{S}^3(f_{32}\eta^2 + f_{31}\eta + f_{30})}{-0.328b_4\widehat{S}(f_{62}\eta^2 + f_{61}\eta + f_{60}) + \widehat{S}^2(f_{72}\eta^2 + f_{70}) + 1.0} \\ &+ d_{20}\eta^3(\chi_1 - \chi_2)^2 + d_{10}\sqrt{1 - 4\eta\eta^3}(\chi_1 - \chi_2) + d_{30}\sqrt{1 - 4\eta\eta^3}\widehat{S}(\chi_1 - \chi_2). \end{aligned}$$

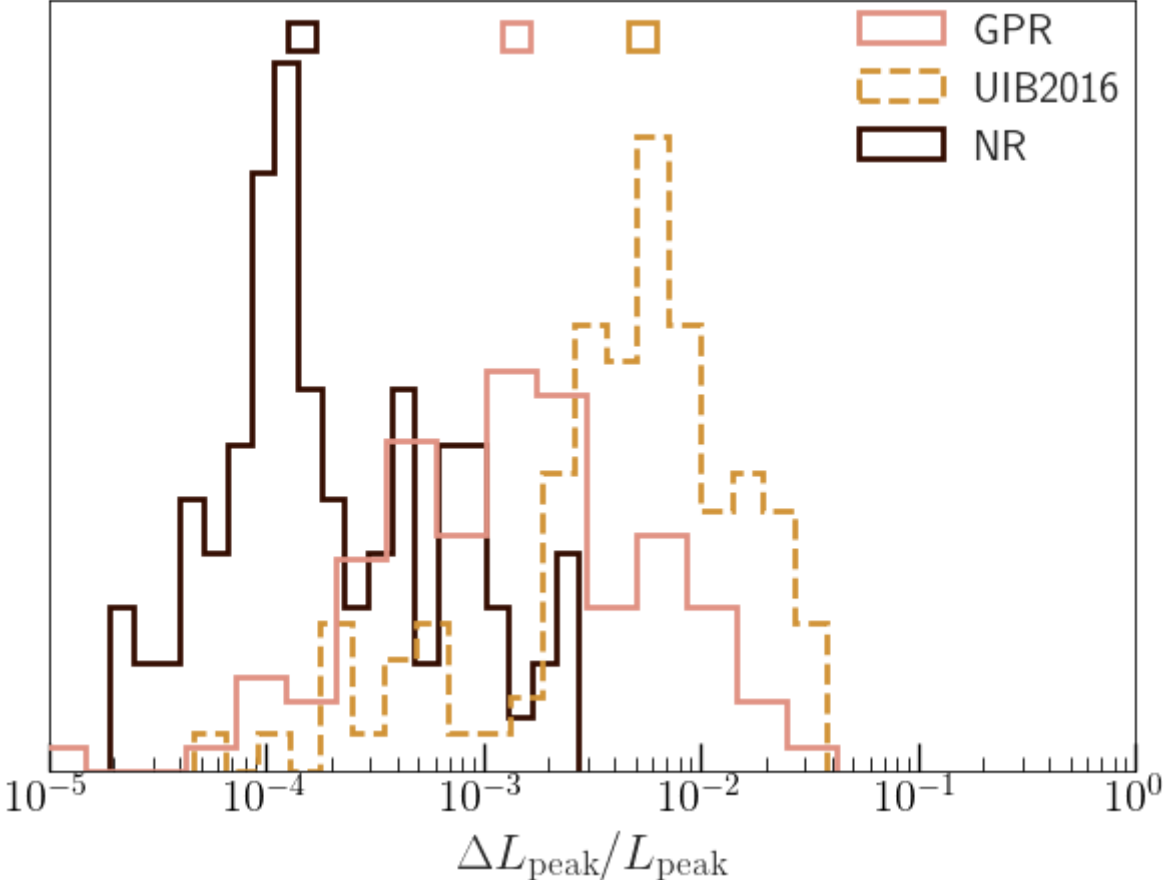
Gaussian Process Regression (GPR)



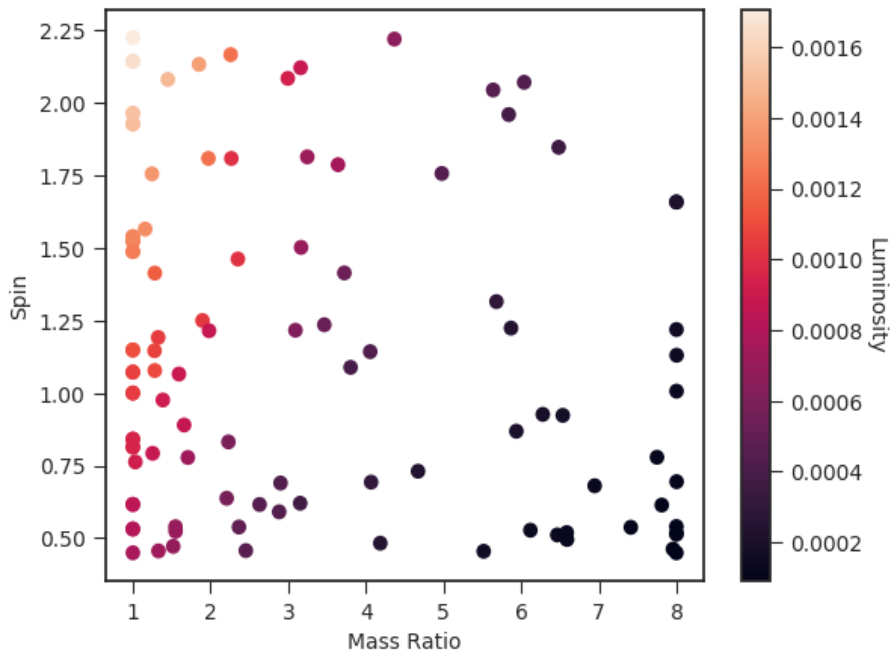
Aligned and Precessing BBH Models



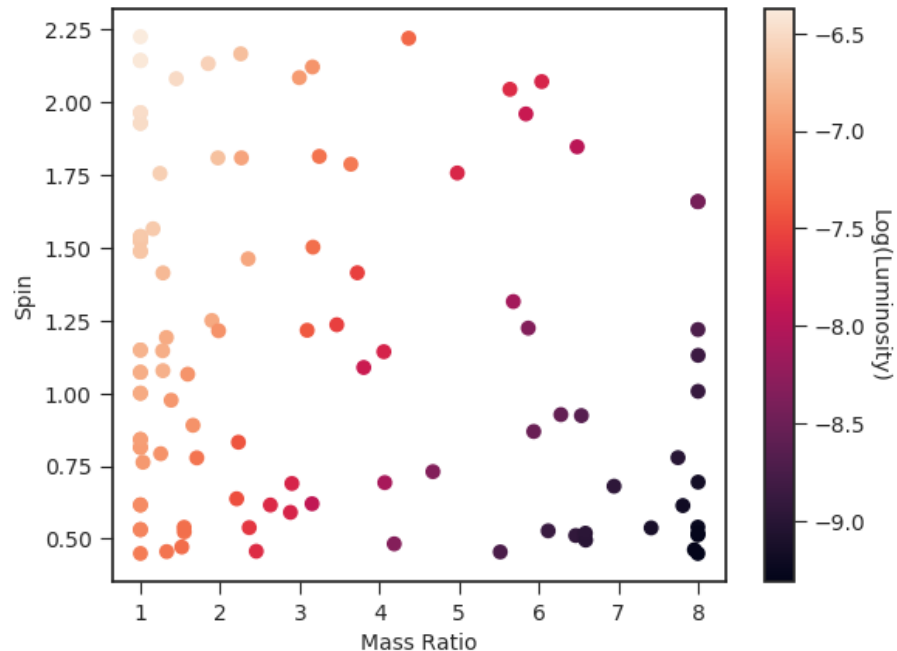
Results: Aligned System



Smoothing the Parameter Space

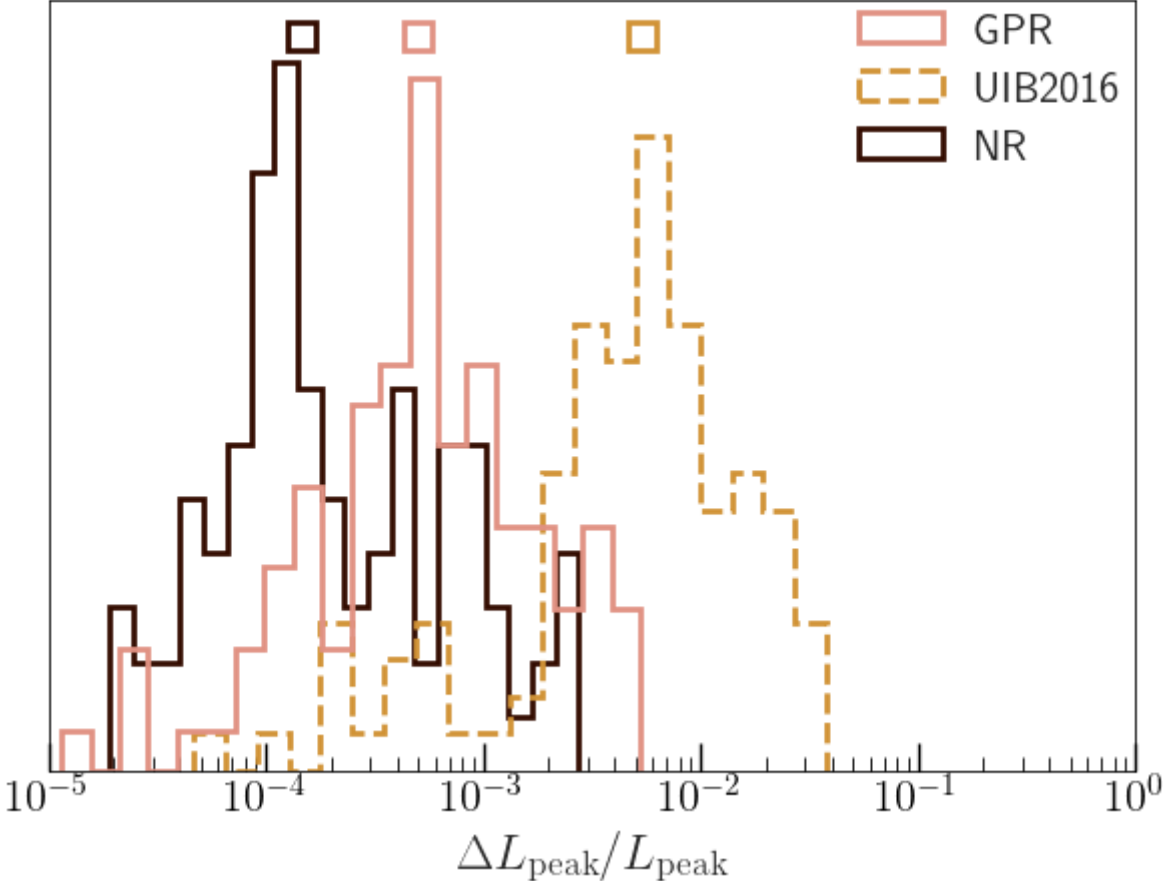


Fitting to L_{peak}

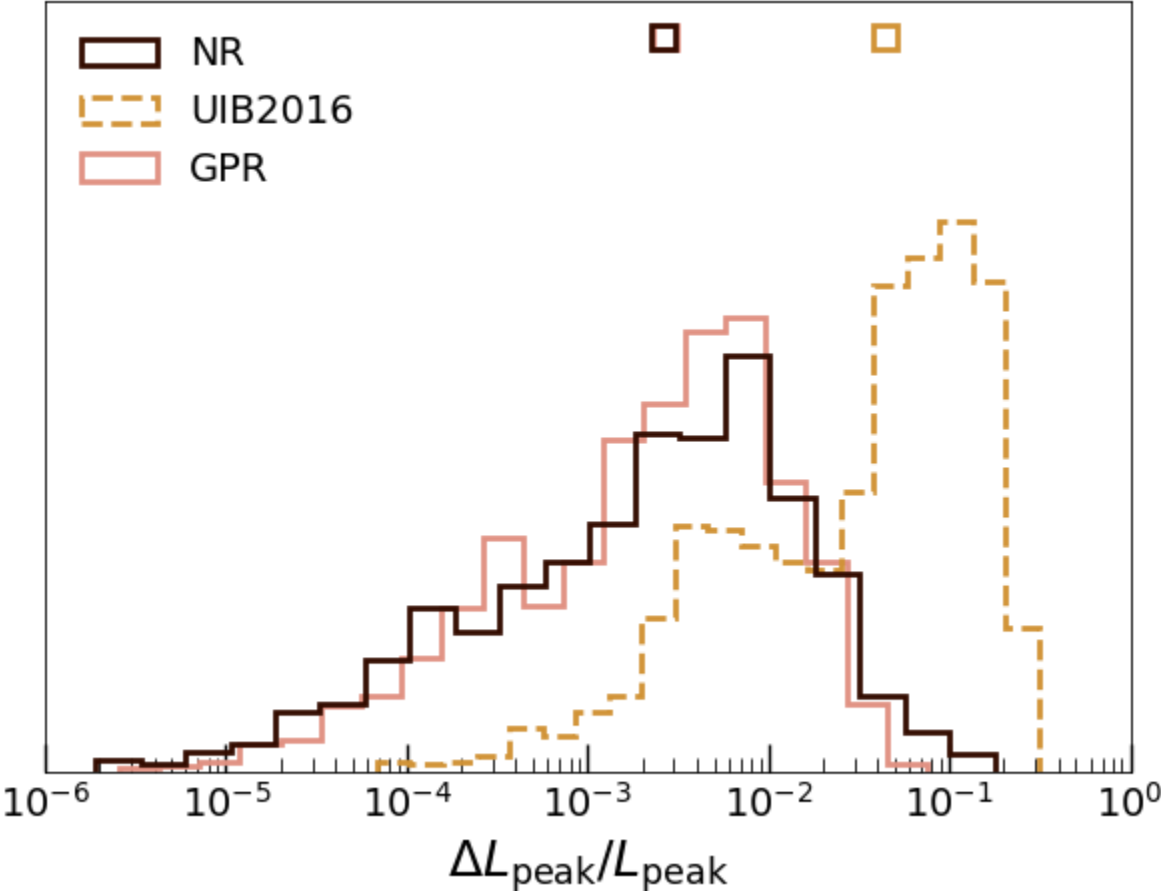


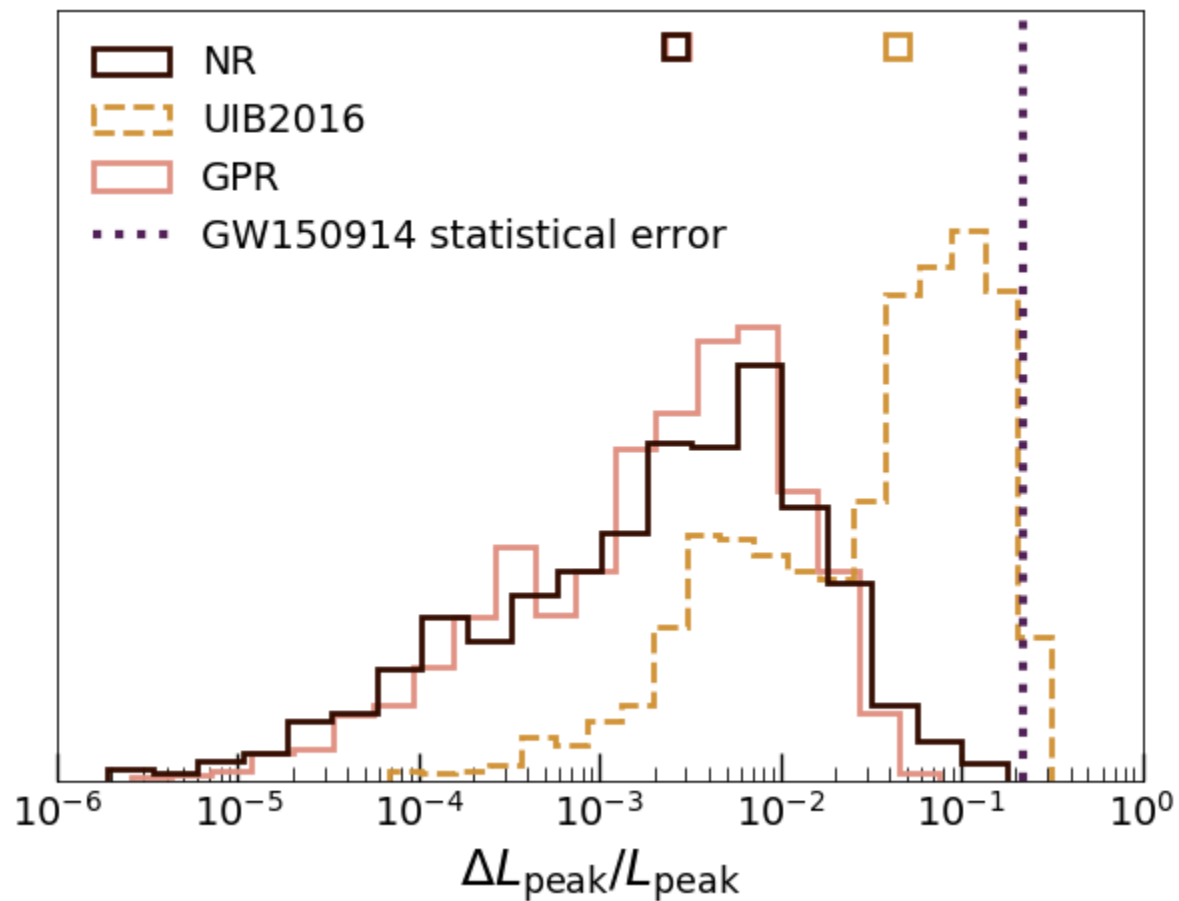
Fitting to $\log(L_{peak})$

Results: Aligned System, Smoothed Parameter Space

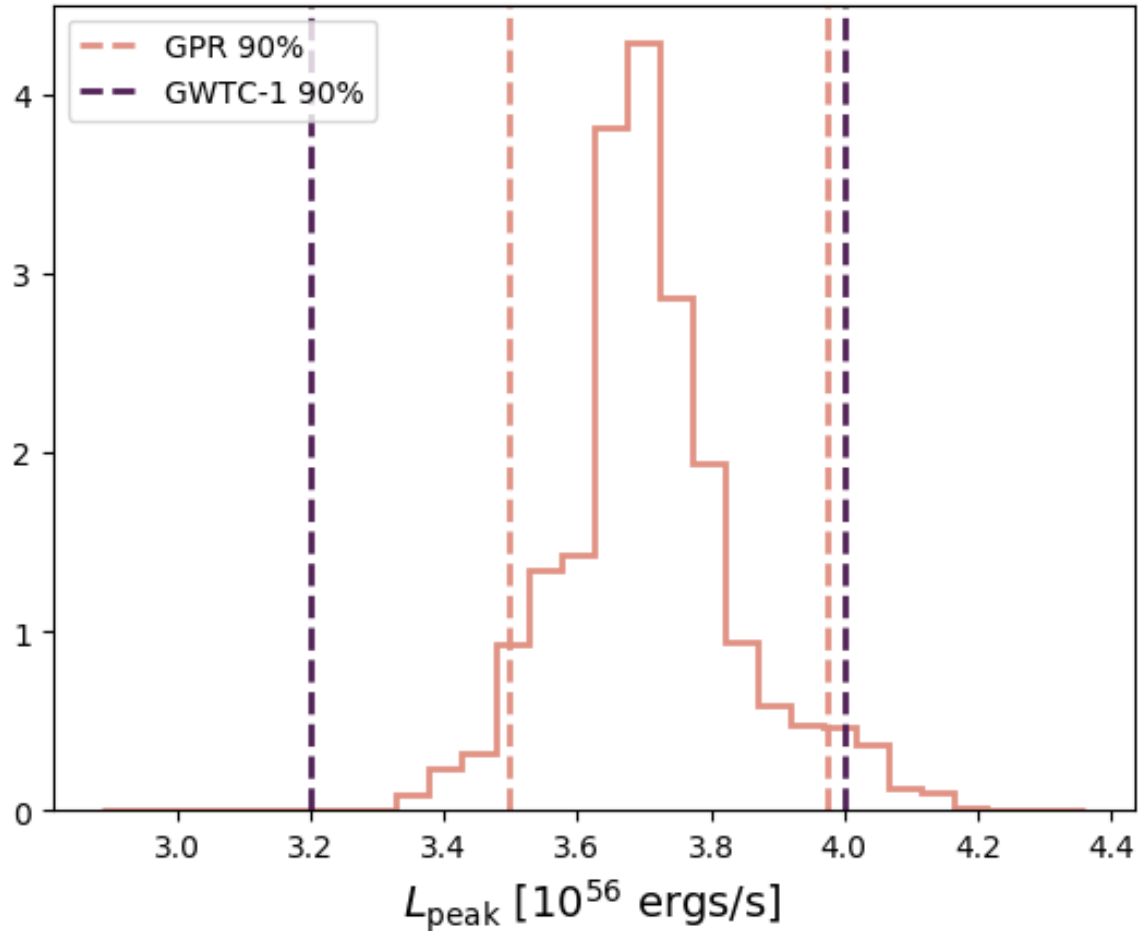


Results: Preprocessing System



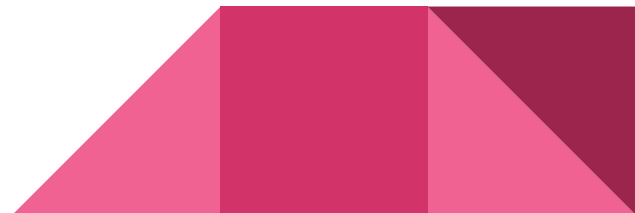


GW150914 Peak Luminosity Calculation



Summary

- **Order of magnitude increase of accuracy** in peak luminosity model
 - GPR vs current models
- Error of current models comparable to the statistical error of peak luminosity of GW150914
- **Possible improvement in peak luminosity measurement of GW150914**
- Future Work:
 - Create surrogate models for other “peak” values
 - Run on all GWTC-1 catalog events



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Vijay Varma

Mark Scheel, Saul Teukolsky

NSF

LIGO Lab



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