

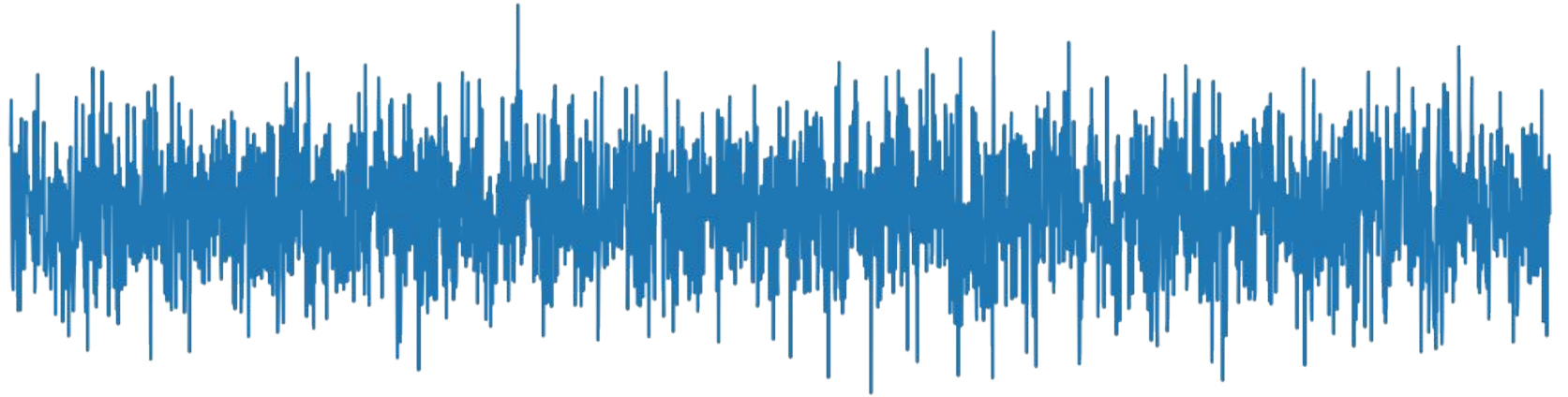


Gravitational Waves Data Analysis (for CBC)

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Why data analysis?



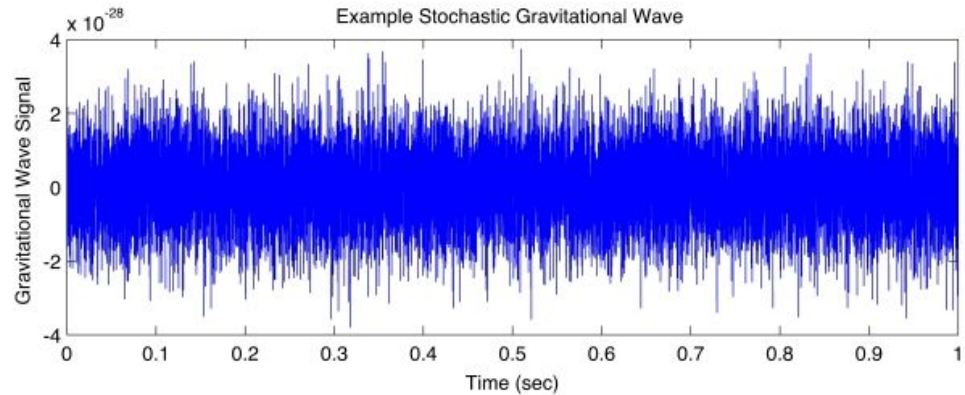


Questions:

1. Is there a signal in the data?
2. Which type of signal was detected?
3. Given one (or more) signal, what are the physical implications?

Possible sources

- Burst
- Compact Binaries
- Continuous waves
- Stochastic





Questions (for CBC):

1. Is there a signal in the data?

GW Searches

2. Which type of signal was detected?

Parameter Estimation

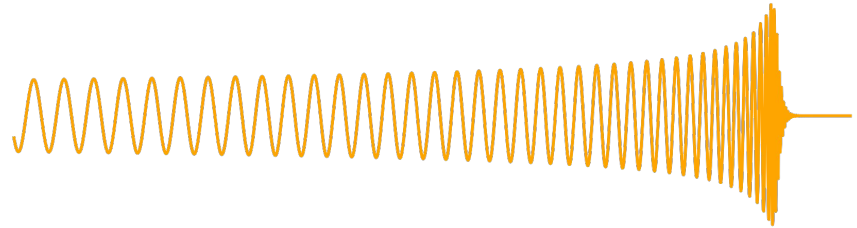
3. Given one (or more) signal, what are the physical implications?

Population, Tests of GR, Fundamental Physics, Cosmology...

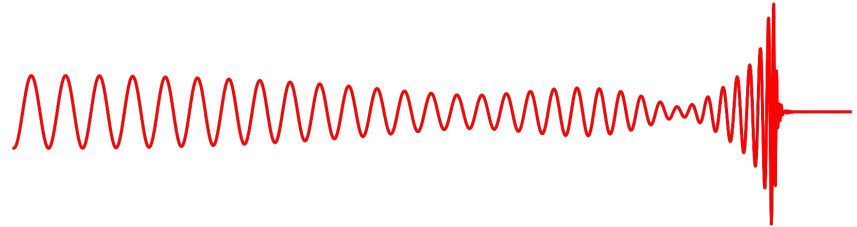


Prerequisite: Waveforms

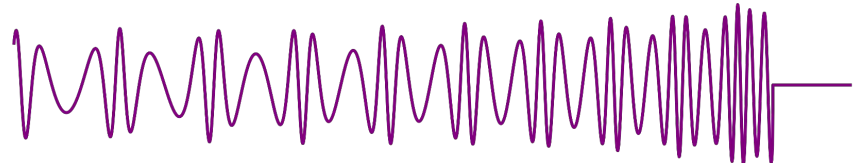
m_1, m_2, s_1, s_2



m_1, m_2, s_1, s_2



m_1, m_2, s_1, s_2



Wa

$$\begin{aligned} \phi(t) = & -\frac{1}{\nu} \Theta^{5/8} \left\{ 1 + \left(\frac{3715}{8064} + \frac{55}{96} \nu \right) \Theta^{-1/4} - \frac{3}{4} \pi \Theta^{-3/8} \right. \\ & + \left(\frac{9275495}{14450688} + \frac{284875}{258048} \nu + \frac{1855}{2048} \nu^2 \right) \Theta^{-1/2} \\ & + \left(-\frac{38645}{172032} + \frac{65}{2048} \nu \right) \pi \Theta^{-5/8} \log \left(\frac{\Theta}{\Theta_0} \right) \\ & \left. + \left[\frac{831032450749357}{576825222758} - \frac{53}{2} - \frac{107}{448} \log \left(\frac{\Theta}{256} \right) \right] \right\} \end{aligned}$$

$$R_{\alpha\beta} - \frac{1}{2} R g_{\alpha\beta} = 8\pi T_{\alpha\beta}$$


$$\begin{aligned} & + \frac{1835008}{17} \nu - \frac{141769}{516096} \nu^2 \left. \right\} \pi \Theta^{-7/8} \\ & + \mathcal{O} \left(\frac{1}{c^8} \right) \left. \right\}, \end{aligned}$$

(5.260)

Speed is crucial!

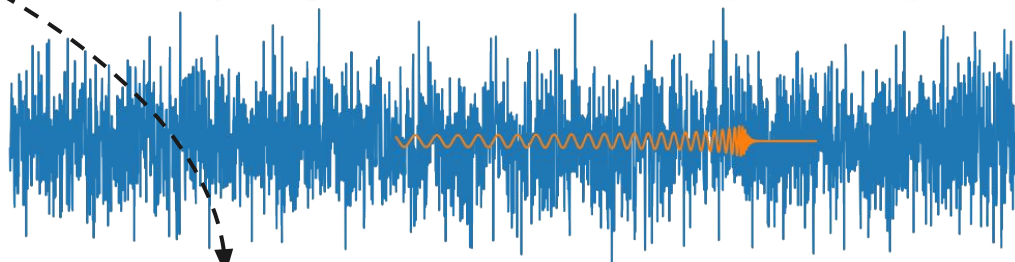
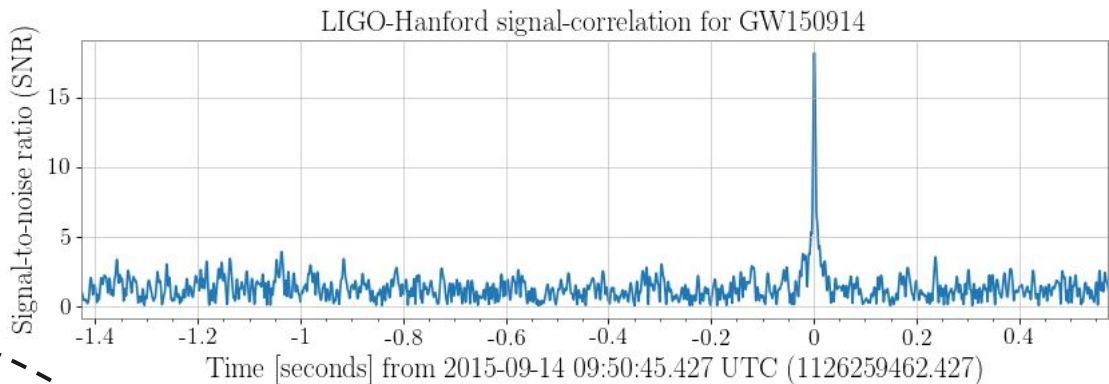
 RINGDOWN



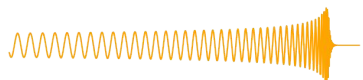
Searches



Template bank



Template

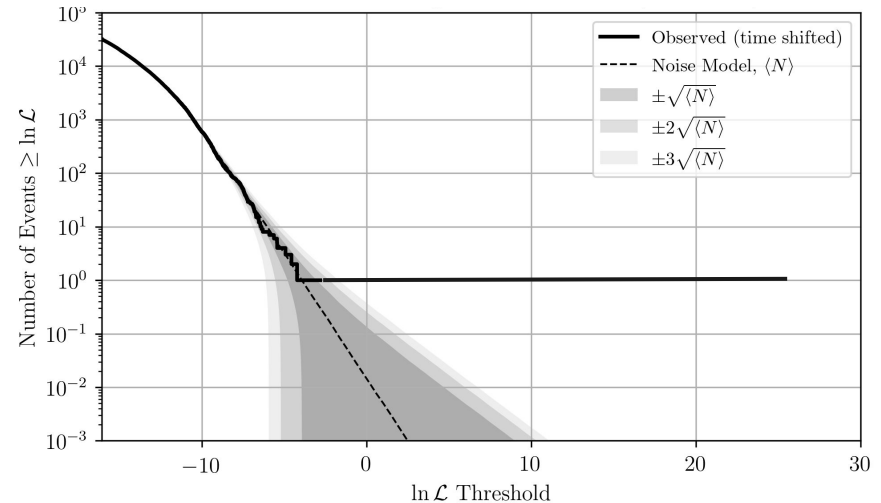


Searches - bis

Assign a likelihood to each trigger

$$\mathcal{L} = \frac{p(\text{trigger}|\text{signal})}{p(\text{trigger}|\text{noise})}$$

How often a given \mathcal{L} value is measured by chance?





Parameter Estimation

Question

What is the best simulated signal that matches the data?

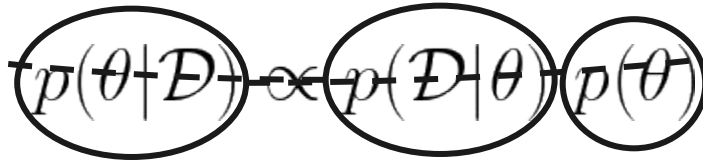
Solution

Trial and error



Parameter Estimation - recipe

- Take many WFs
- Compute how “similar” they are to the data
- Aggregate the results (i.e. measure CBC parameters)



A diagram illustrating the Bayesian inference equation. It consists of three circles arranged horizontally, connected by a central infinity symbol (\propto). The leftmost circle contains the expression $p(\theta | \mathcal{D})$, the middle circle contains $p(\mathcal{D} | \theta)$, and the rightmost circle contains $p(\theta)$. A dashed arrow originates from the right side of the $p(\theta)$ circle, loops around the top and left sides of the list of steps, and points to the 'Take many WFs' step. Another dashed arrow originates from the right side of the $p(\mathcal{D} | \theta)$ circle, loops around the top and right sides of the list, and points to the 'Aggregate the results' step.

$$p(\theta | \mathcal{D}) \propto p(\mathcal{D} | \theta) p(\theta)$$

Posterior Likelihood Prior



Parameter Estimation - *evidence*

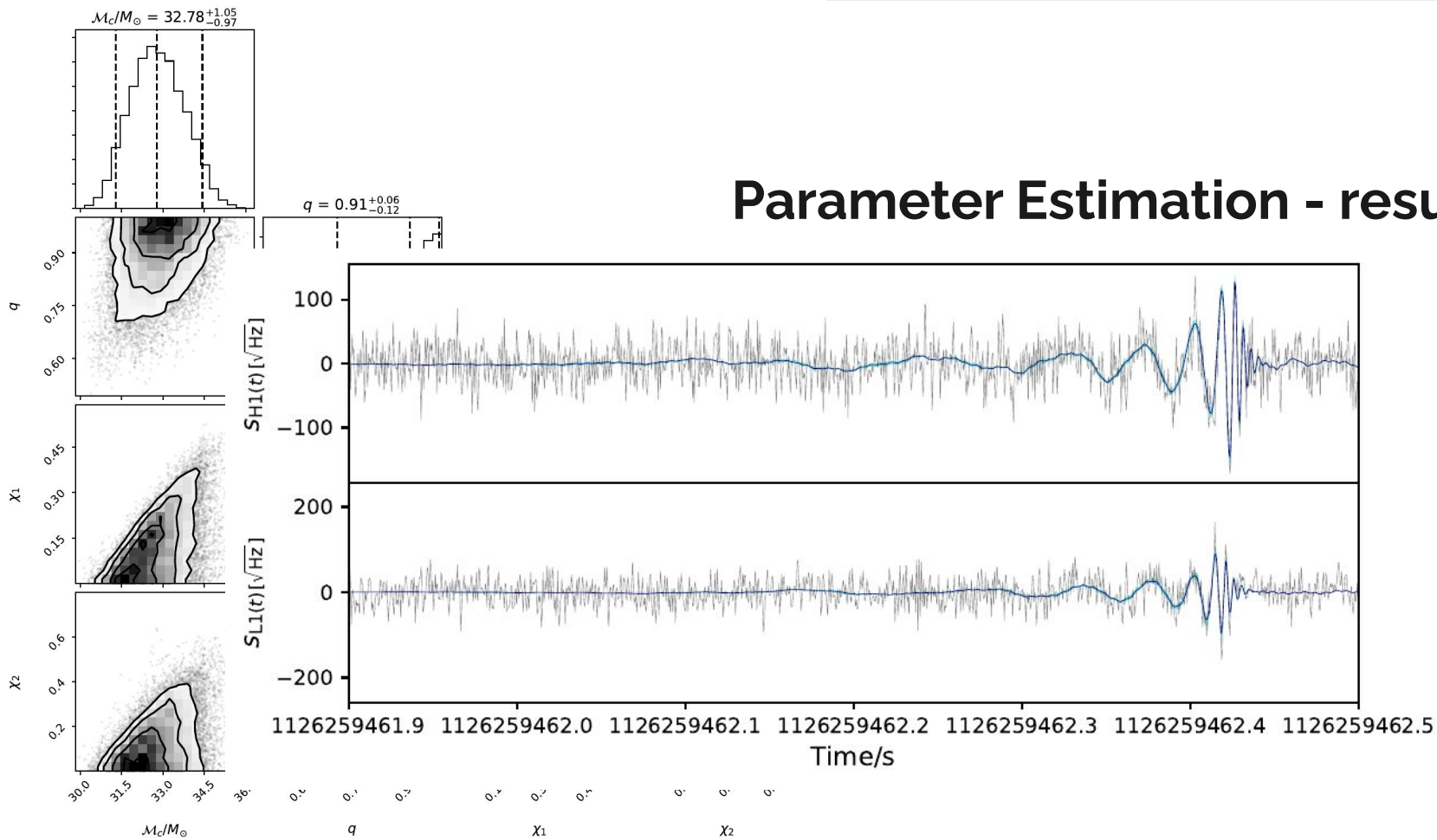
$$p(\mathcal{D}) = \int d^D \theta \, p(\mathcal{D}|\theta)p(\theta)$$

$$p(\mathcal{D}|\text{model})$$

Bayes Factor

$$\frac{p(\mathcal{D}|\text{model}_1)}{p(\mathcal{D}|\text{model}_2)}$$

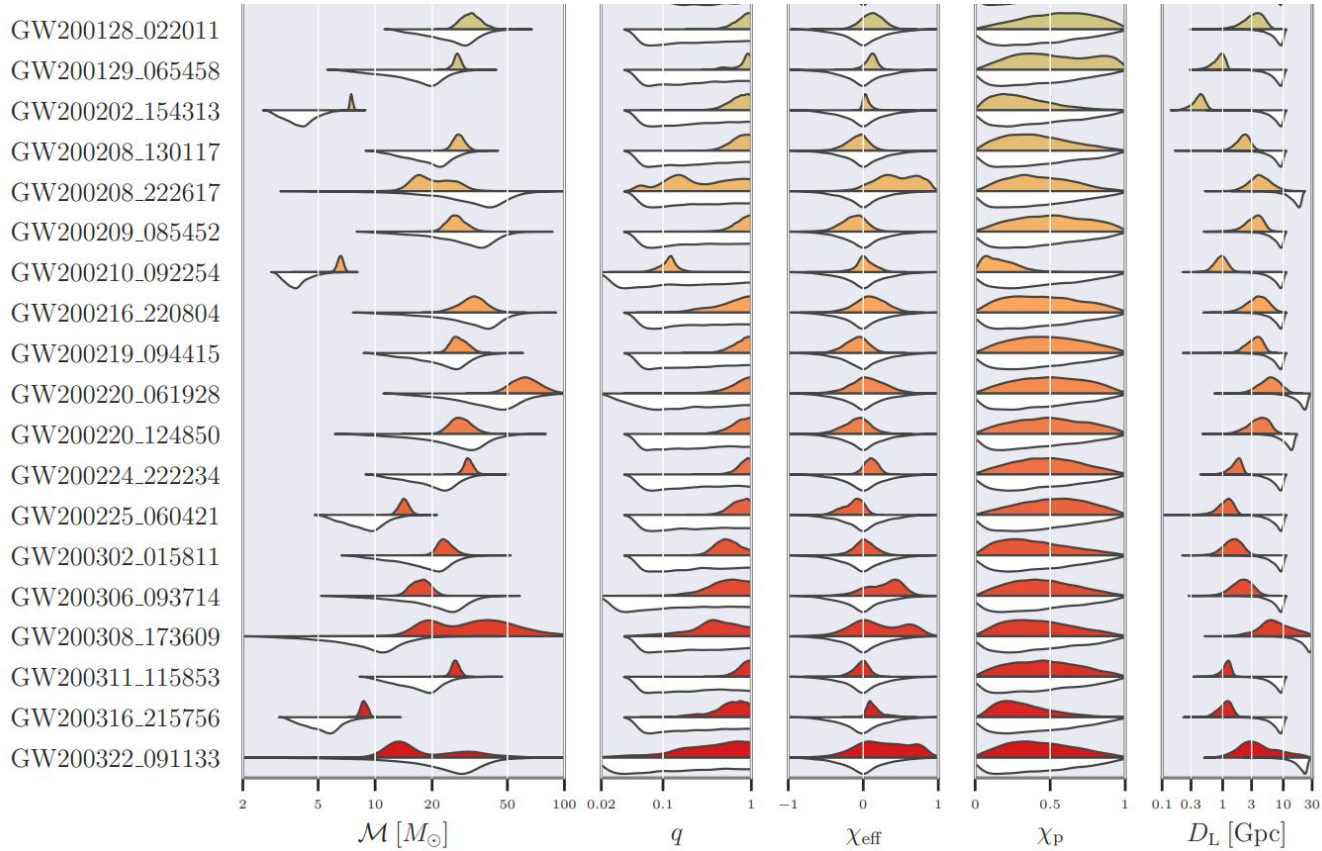
Parameter Estimation - results





A catalogue

Thicker =
more likely true value





A now it comes the nice part...

- Population studies
- Tests of GR
- Neutron Star Equation of State
- Cosmology
- Lensing
- ...



Questions (for CBC):

1. Is there a signal in the data?

Matched filtering

2. Which type of signal was detected?

Bayesian Parameter Estimation

3. Given one (or more) signal, what are the physical implications?

Sooooooo many

Thank you :D