### Compact Binaries in O2 and beyond

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Single events: e.g. GW170817



## Combining Events

- Inference from multiple events about parameters affecting all events, e.g.
  - Common parameters: Tests of General Relativity, Neutron Star EOS
  - Population parameters: Rate, BH mass function, spin distributions, ...
- Selection effects are important!







## Hierarchical Models

 Goal: Extract information about some population parameter γ from N detected events with data d and nuisance parameters θ



• 
$$p(\gamma|N, \{d_1, d_2, ...\}) \propto p(\gamma|I)p(N|\gamma) \prod_i^N p(d_i|\gamma, \text{detection})$$





## Selection effects

- In general, the number of detected sources N can be affected by the source properties
  - e.g. Large masses -> larger distances
- We are interested in the astrophysical distribution not the observed distribution
  - Must account for selection effects!

$$p(N|\gamma) = p(N|\hat{N})p(\hat{N}|\gamma) = \frac{\hat{N}(\gamma)^N e^{-\hat{N}(\gamma)}}{N!}$$

Poisson statistics on observed number *N* 

$$\hat{N} = \int \frac{\partial^k \hat{N}(\gamma)}{\partial \vec{\theta}} d\vec{\theta}$$
$$= \int \frac{\partial^k N_{astro}(\gamma)}{\partial \vec{\theta}} p(\text{detection}|\theta) d\theta$$

Observed distribution is astrophysical distribution filtered by detection probability





## Where are we now?







- 01: 3 BBHs
- O2: 7 BBHs, 1 BNS







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### Mass distribution







### Spins I



• effective spins ~0: are BBHs non-spinning or just not aligned?



LVC, arXiv:1811.12907 U



## Spins II



Colours: posterior White: Prior

 Better sensitivity required to measure in-plane spins for objects like these we are seeing



LVC, arXiv:1811.12907 🕎 of



### Spins III



Π



## Spin tilt distribution?



- Combining events does not yield big returns
- Subject to selection effects!



LVC, arXiv:1811.12940





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# Digging into noise

- As detections increase, less conservative criteria for using events?
- Decrease thresholds to meet computationa requirements rather than ensure low FAR
- Use catalogues with <100% purity</li>

![](_page_16_Picture_4.jpeg)

![](_page_16_Picture_5.jpeg)

![](_page_16_Picture_6.jpeg)

## Digging into noise

![](_page_17_Figure_1.jpeg)

Gaebel+ 2018

LSC

![](_page_17_Picture_3.jpeg)

## What is needed?

- Single-event / smoking guns
  - Sensitivity: design, A+, 3G
  - Multimessenger: localisation improvement
  - Waveform modeling: control of systematics
- Combined event science
  - Sensitivity (for number of events)
  - Control of systematics: w.f. errors in common to all events can be fatal in producing biases
  - Understanding of selection function (from real search pipelines)
  - Galaxy catalogues to enable statistical correlations
- Cosmology, populations
  - Degeneracy between mass distribution, rate evolution over time, cosmology
  - Global fit for universe of compact binaries

![](_page_18_Picture_13.jpeg)

![](_page_18_Picture_14.jpeg)