The rate of compact binary coalescences from LIGO observations

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on behalf of the LIGO Scientific Collaboration

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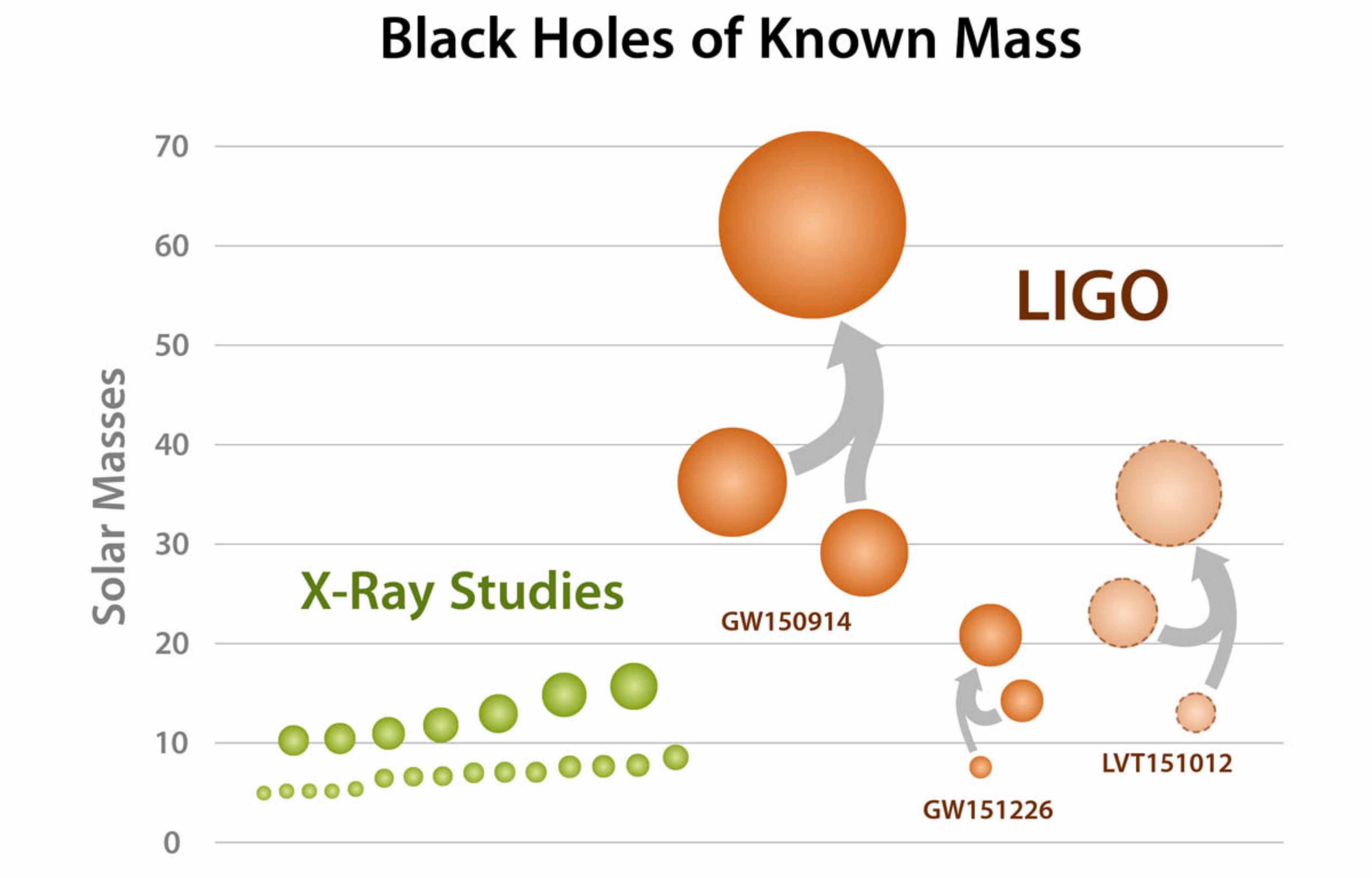
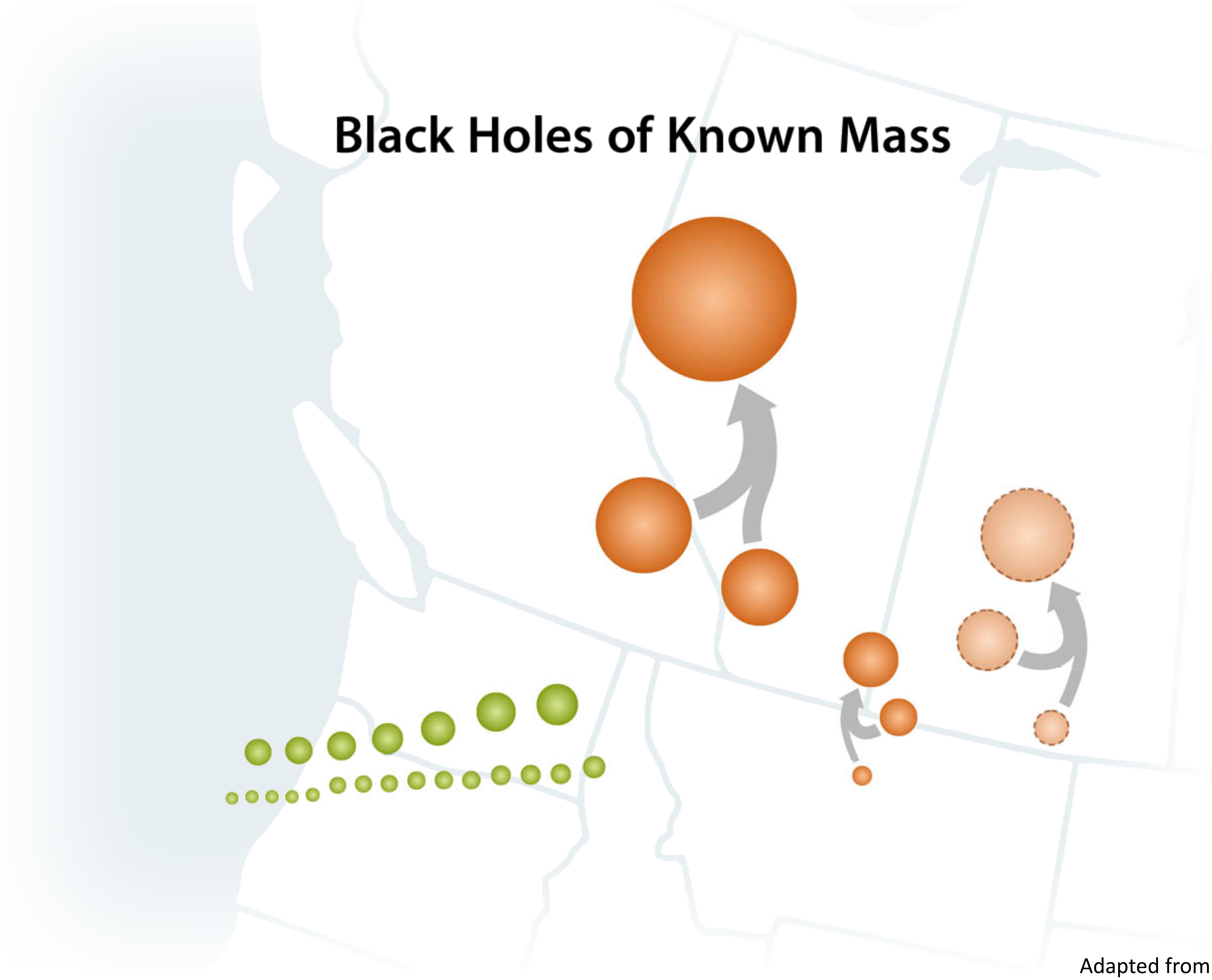
LIGO-G1601425



Credit: T. Hurt

Black Holes of Known Mass



Adapted from T. Hurt

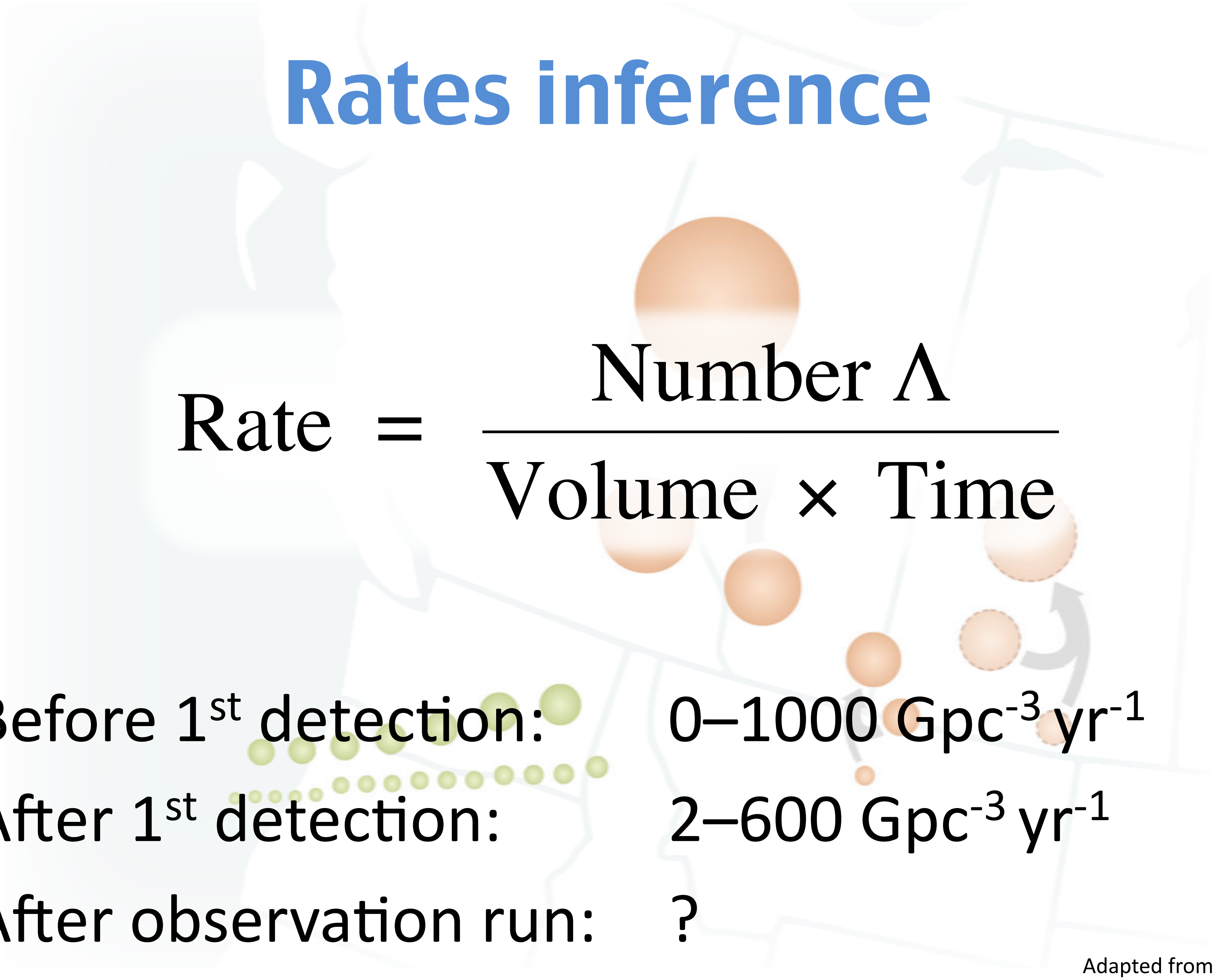
Rates inference

$$\text{Rate} = \frac{\text{Number } \Lambda}{\text{Volume} \times \text{Time}}$$

Before 1st detection: 0–1000 $\text{Gpc}^{-3}\,\text{yr}^{-1}$

After 1st detection: 2–600 $\text{Gpc}^{-3}\,\text{yr}^{-1}$

After observation run: ?



Adapted from T. Hurt

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- Pipeline analyzes coincident data, computes set of triggers
- Trigger is weighted by its "significance"

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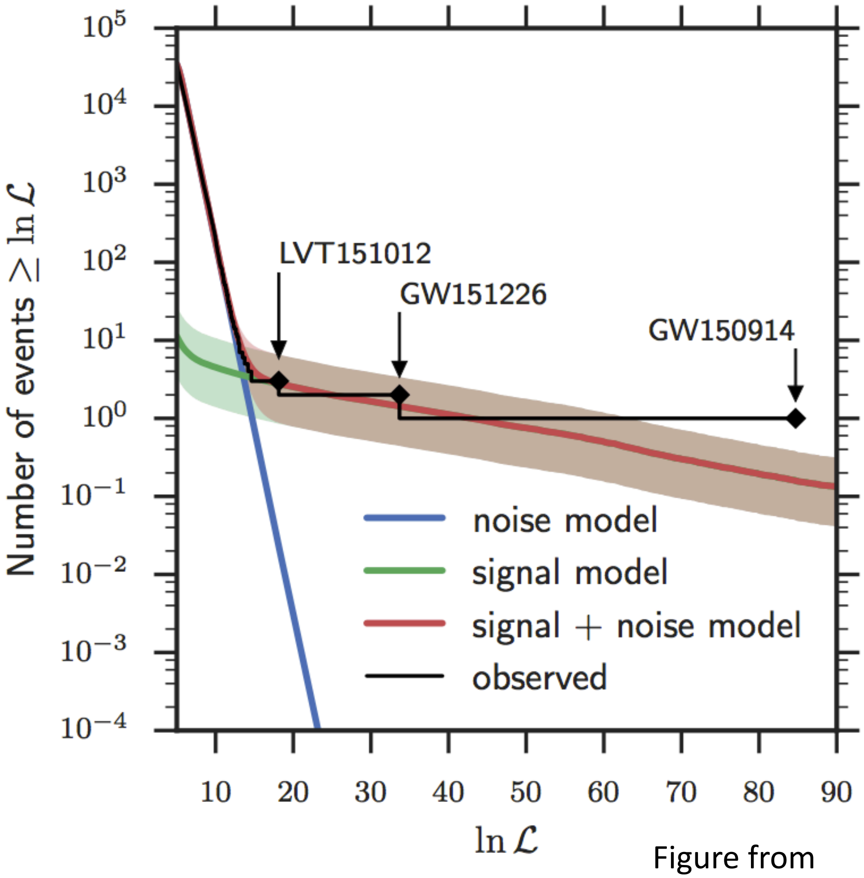

Figure from LIGO-P1600088

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- Pipeline analyzes coincident data, computes set of triggers
- Trigger is weighted by its "significance"
- Λ_i: Mean number of triggers for type i

$$\underset{\text{terrestrial}}{\Lambda_0}, \underbrace{\Lambda_1, \Lambda_2, \Lambda_3}_{\text{astrophysical}}$$

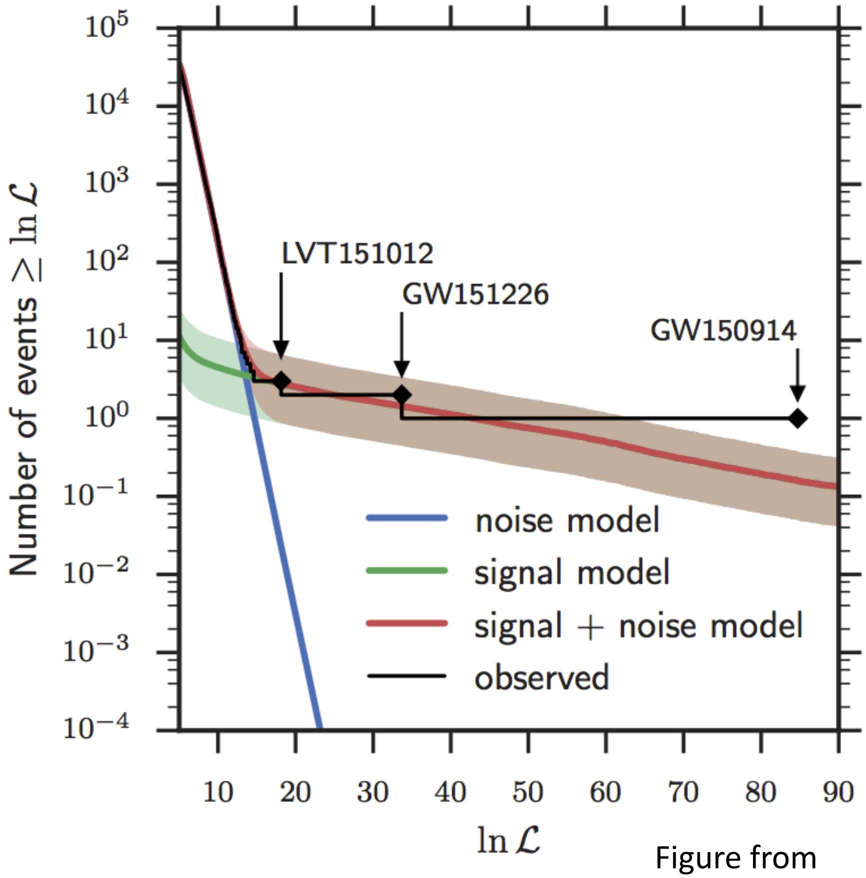

Figure from LIGO-P1600088

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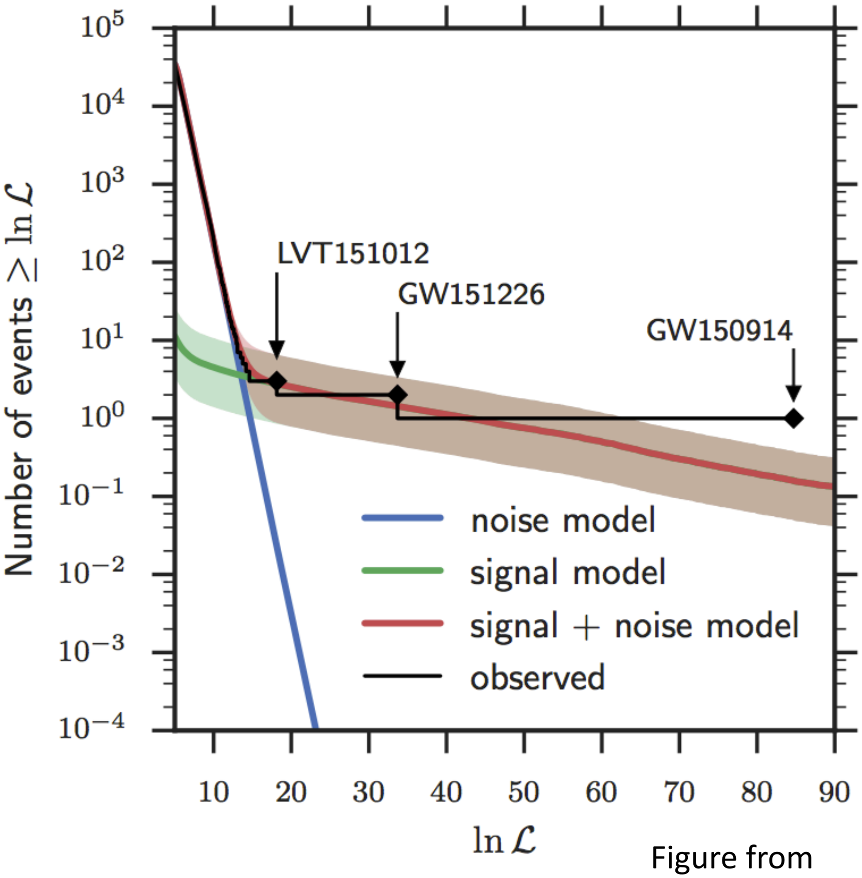

Figure from LIGO-P1600088

$\boxed{\text{Probability of } \Lambda_i \text{ after seeing data}}$ ∝ **Likelihood of our data, given Λ_i** × **What we think about Λ_i**

Rates inference

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terrestrial

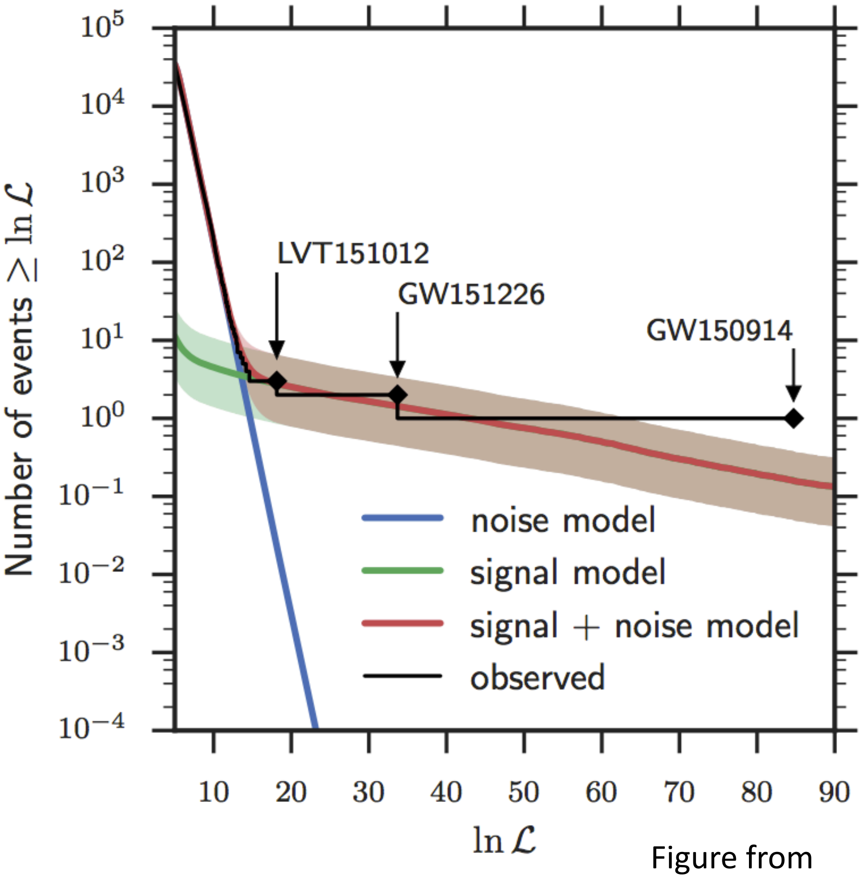


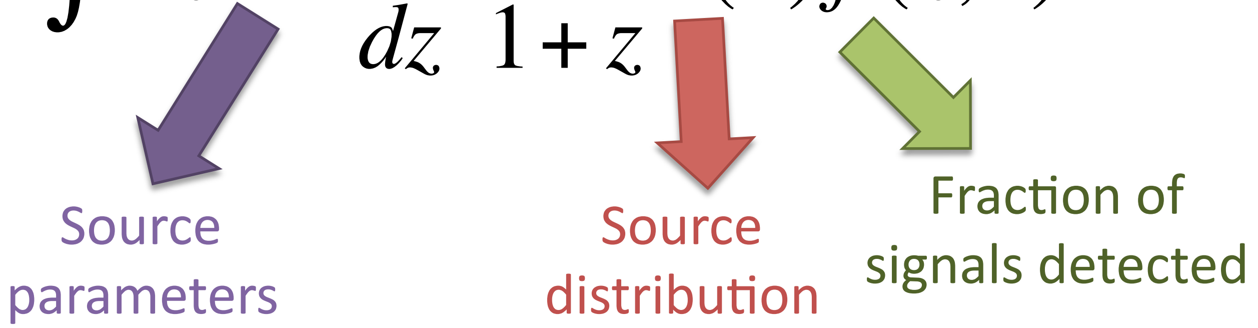
Figure from LIGO-P1600088

$$\boxed{P(\Lambda_0,\Lambda_1,\Lambda_2 \mid \text{data})} \propto \mathcal{L}(\text{data} \mid \Lambda_0,\Lambda_1,\Lambda_2) \times \Pi(\Lambda_0,\Lambda_1,\Lambda_2)$$

Rates inference

$$\text{Rate} = \frac{\text{Number } \Lambda}{\boxed{\text{Volume} \times \text{Time}}}$$

$$\langle VT \rangle = T \int dz d\theta \frac{dV_c}{dz} \frac{1}{1+z} s(\theta) f(z,\theta)$$



Source parameters

Source distribution

Fraction of signals detected

$$\langle VT \rangle = T \int dz d\theta \frac{dV_c}{dz} \frac{1}{1+z} \boxed{s(\theta)} f(z,\theta)$$

$$s(\theta) = \delta(\theta)$$

Independent types of BBH signals

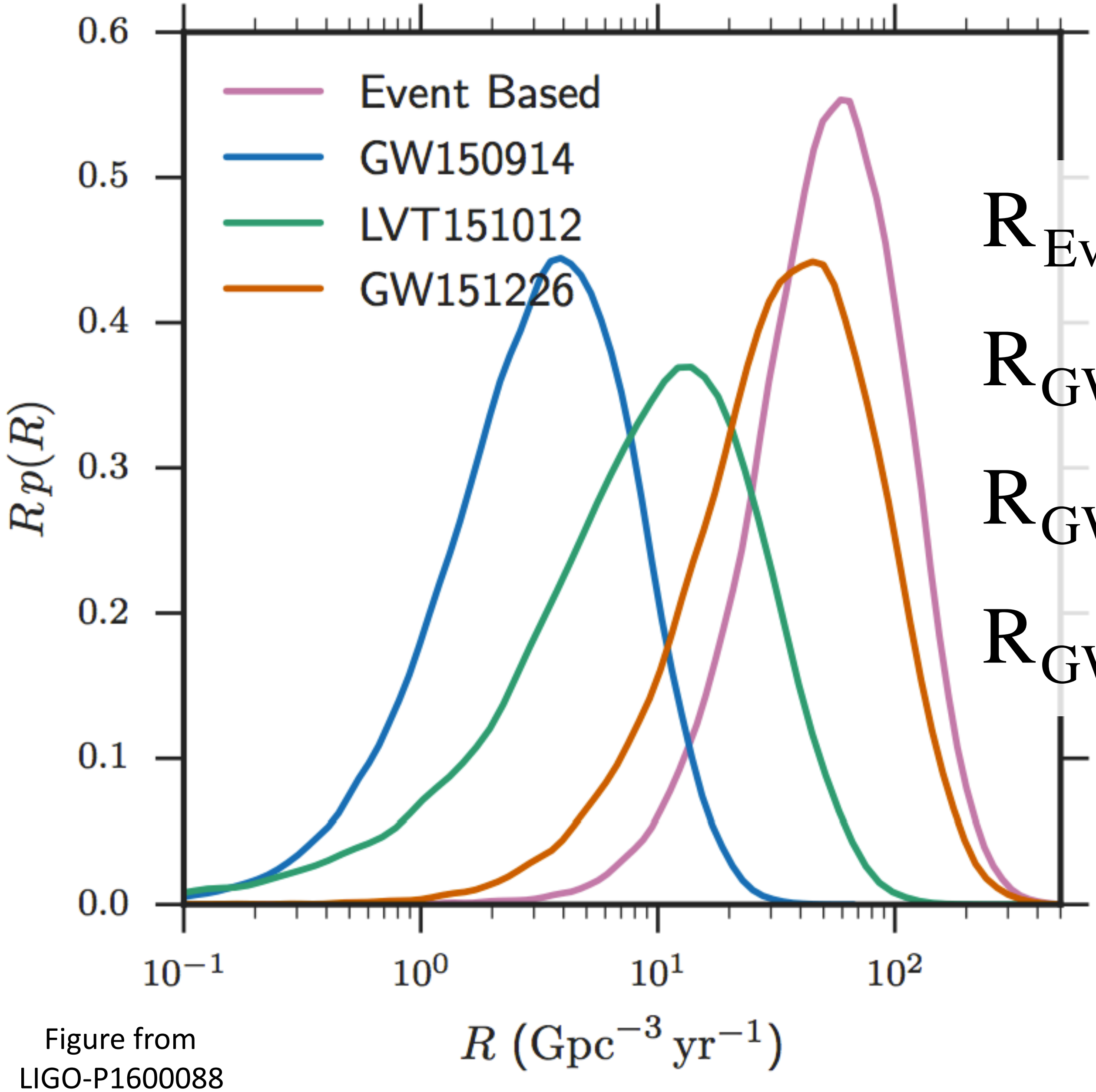
$$s(\theta) \sim \frac{1}{m_1} \frac{1}{m_2}$$

Flat in log(mass) distribution

$$s(\theta) \sim m_1^{-2.35}$$

Power law mass distribution,
m_2 flat in m_2/m_1

Inject signals into data, run through analysis pipeline to estimate integral



$$R_{\text{Event Based}} = 55^{+99}_{-41}$$

$$R_{\text{GW150914}} = 3.4^{+8.6}_{-2.8}$$

$$R_{\text{GW151012}} = 9.4^{+30.4}_{-8.7}$$

$$R_{\text{GW151226}} = 37^{+92}_{-31}$$

Figure from
LIGO-P1600088

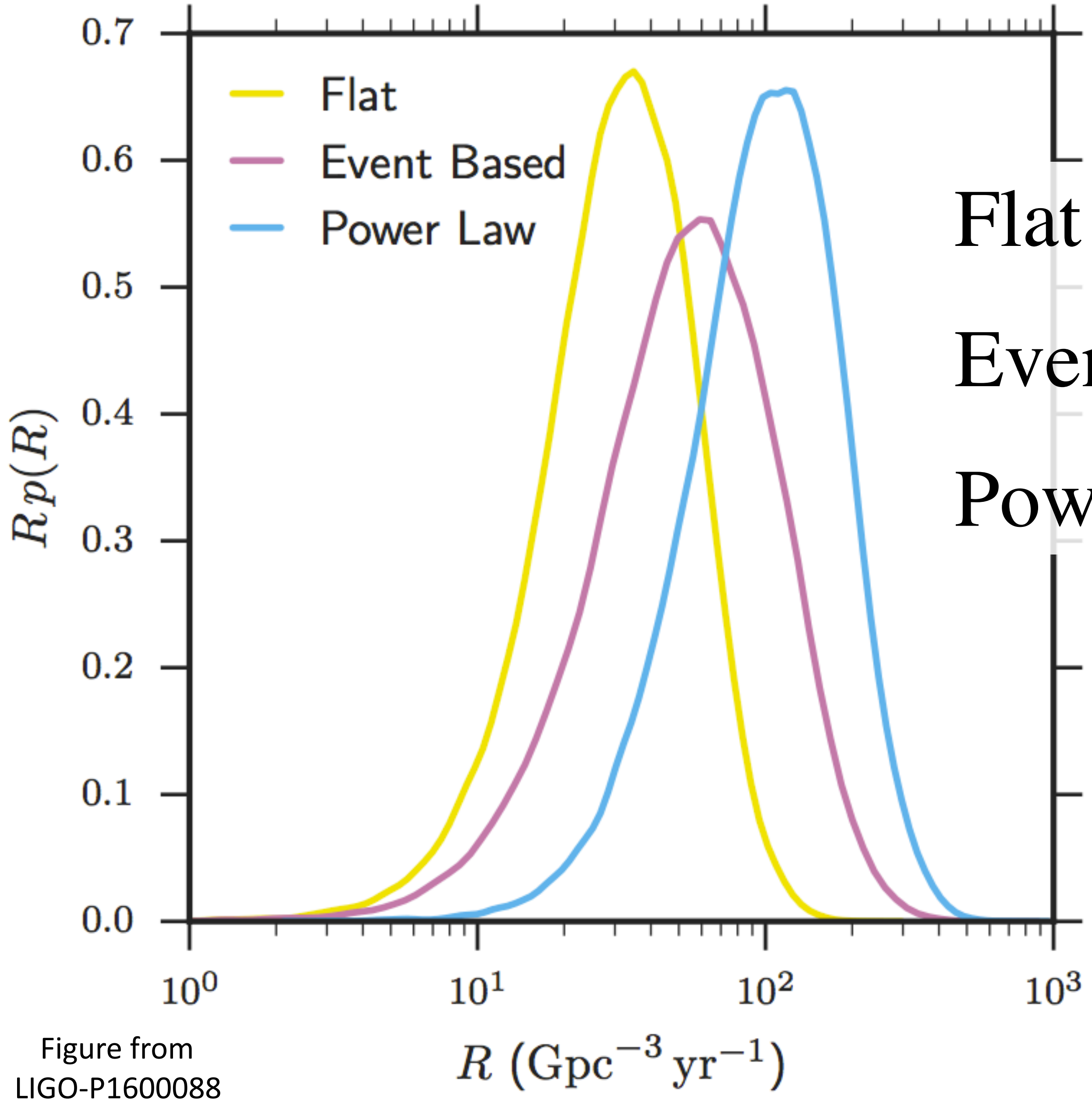


Figure from
LIGO-P1600088

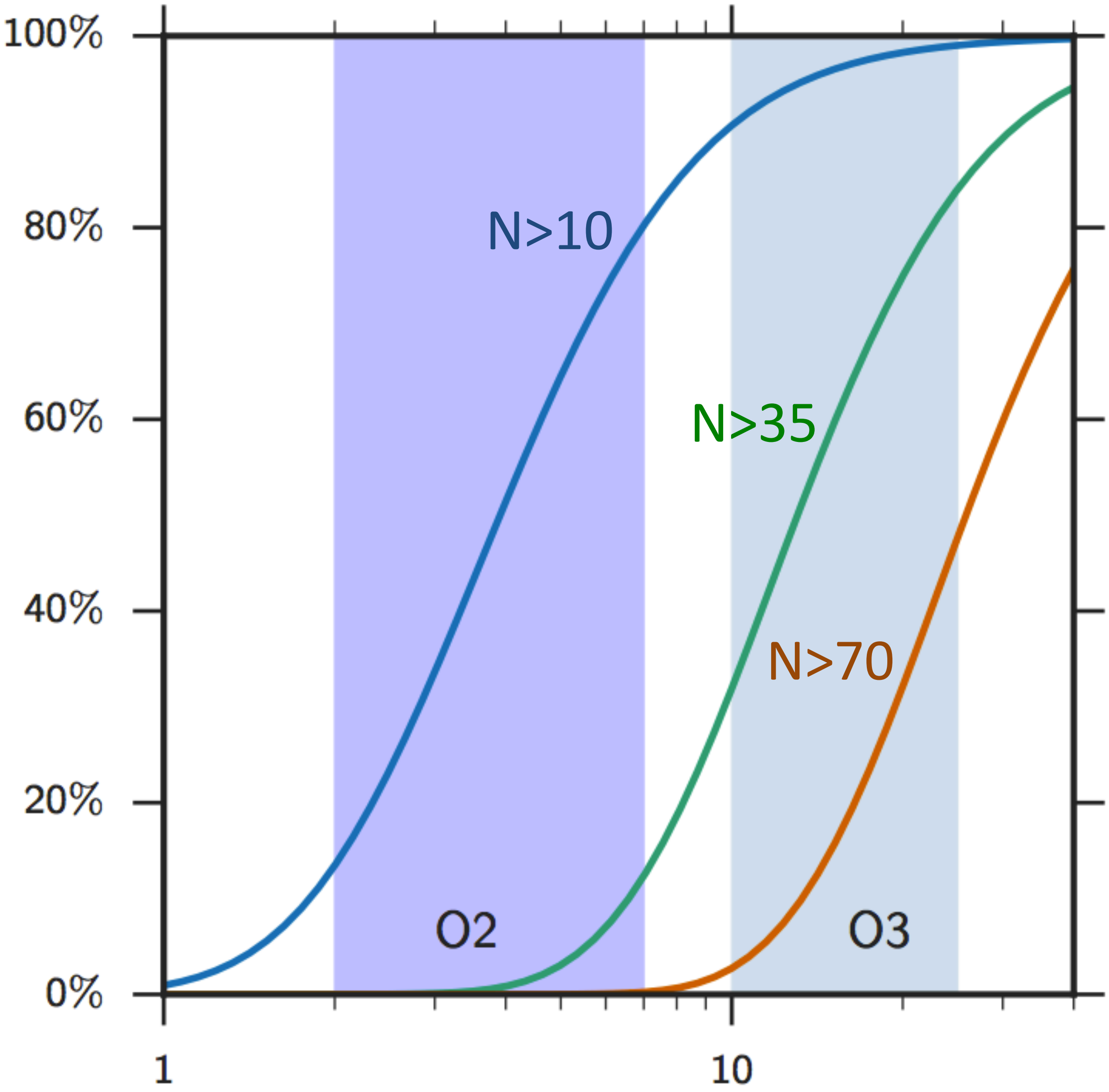
Flat = 30^{+43}_{-21}

Event Based = 55^{+99}_{-41}

Power Law = 99^{+138}_{-70}

9–240
Gpc^{-3} yr^{-1}

Probability of observing N highly significant events



Increase in spacetime volume relative to O1

Figure from LIGO-P1600088

Summary

- **Merger rate:**
  9–240 $\mathrm{Gpc}^{-3}\mathrm{yr}^{-1}$
  (0 is ruled out!)
- Estimate observations of ~10 significant events by end of O2
- https://papers.ligo.org
  "Binary Black Hole Mergers in the First Advanced LIGO Observing Run"
  - LIGO-P1600088

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