



GWPAW 2017, Annecy

# Testing the area theorem with gravitational-wave signals

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### The area theorem

Area of a Kerr black hole:

$$A = 8\pi m^2 \left(1 + \sqrt{1 - \chi^2}\right)$$

*"If two black holes coalesce, the area of the final event horizon is greater than the sum of the areas of the initial horizons" \** 



\* Bardeen, Carter, Hawking, Commun. Math. Phys. 31 (1973)

### Gravitational-wave signals



Caltech / MIT / LIGO Lab

### Gravitational-wave signals

#### Inspiral: initial areas





Caltech / MIT / LIGO Lab

### The end of the inspiral

<u>Template</u> Known parameters: "hybrid MECO" \*

#### <u>Data</u>

Unknown parameters: grid of times



\* MC, Nielsen, Lundgren, Capano, Phys. Rev. D95 (2017)

### The end of the inspiral



### **Technical details**

- **Simulated signal**: binary black hole, 40-30 solar masses, no spins
- PyCBC inference: MCMC algorithm for parameter estimation
- PSD representative of first Advanced LIGO run (O1)
- Zero noise realisation
- Tapering function: kaiser window
- Sky location prior based on arrival time difference between detectors

### **Inspiral results**



### **Inspiral results**



### **Inspiral results**



### Initial area

#### $A_1 + A_2 (\times 10^{11}) = 3.29^{+2.01}_{-0.93}$



### The start of the ringdown

<u>Template</u> Ringdown-only waveform (damped sinusoid)

#### <u>Data</u>

Unknown parameters: grid of times



### **Ringdown results**

Share sky location with inspiral, other parameters are completely independent



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Share sky location with inspiral, other parameters are completely independent



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Share sky location with inspiral, other parameters are completely independent



### Final area

#### $A_f$ (×10<sup>11</sup>) = 3.36<sup>+1.28</sup><sub>-1.41</sub>



### **Combined results**



### **Combined results**



### Future work

- Polish some details
- Compare <u>measured</u> change in areas with <u>expected</u> values
- Analyse **GW150914**
- Try different detector sensitivities (O2, design)
- Test performance on simulated signals that violate the area theorem
- Incorporate ringdown quasi-normal modes (for future sensitivities)





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## Thanks for your attention

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