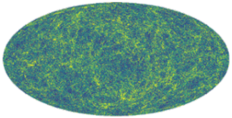
Anisotropies in the Stochastic Gravitational-Wave Background

Alexander C. Jenkins
King's College London

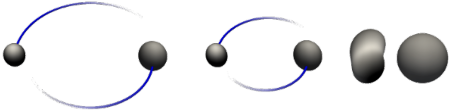
Based on:
ACJ & Sakellariadou, *PRD* 2018, arXiv:1802.06046
ACJ, Sakellariadou, Regimbau, & Slezak, *PRD* 2018, arXiv:1806.01718
ACJ, O'Shaughnessy, Sakellariadou, & Wysocki, arXiv:1810:03435
ACJ & Sakellariadou, arXiv:1902.xxxxx

1. The Stochastic Gravitational-Wave Background

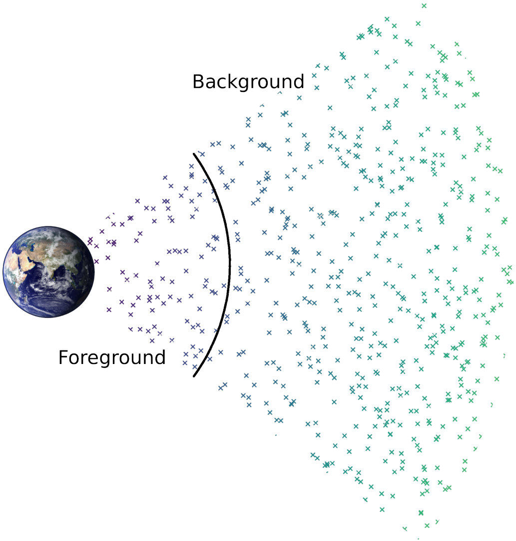


2. Cosmic Strings

3. Compact Binary Coalescences



Stochastic gravitational-wave background (SGWB)



- faint/numerous sources
- astrophysical and cosmological
- incoherent, persistent, correlated
- GW density parameter:

$$\Omega_{\mathrm{gw}}(f, \hat{\boldsymbol{n}}) = \frac{1}{\rho_{\mathrm{c}}} \frac{\mathrm{d}^3 \rho_{\mathrm{gw}}}{\mathrm{d}(\ln f) \mathrm{d}^2 \hat{\boldsymbol{n}}}$$

$$\lesssim 10^{-8}$$

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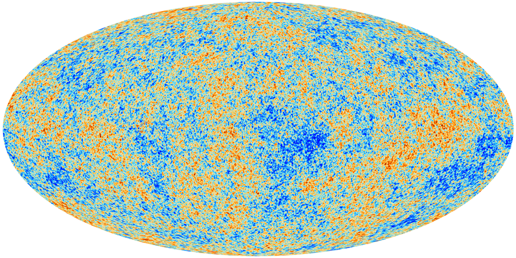
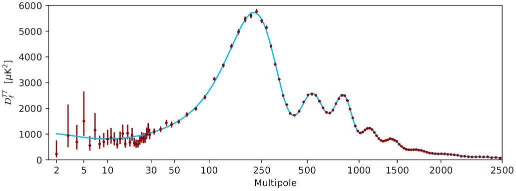
Angular power spectrum





- CMB

$$C_\ell = \int \mathrm{d}^2\hat{\boldsymbol{n}} P_\ell(\cos\theta) \left\langle \delta T_\gamma \delta T_\gamma \right\rangle$$

- SGWB

$$C_\ell = \int \mathrm{d}^2\hat{\boldsymbol{n}} P_\ell(\cos\theta) \left\langle \delta \Omega_{\mathrm{gw}} \delta \Omega_{\mathrm{gw}} \right\rangle$$

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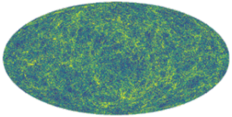
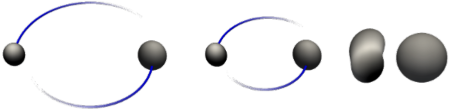
1 The Stochastic Gravitational-Wave Background

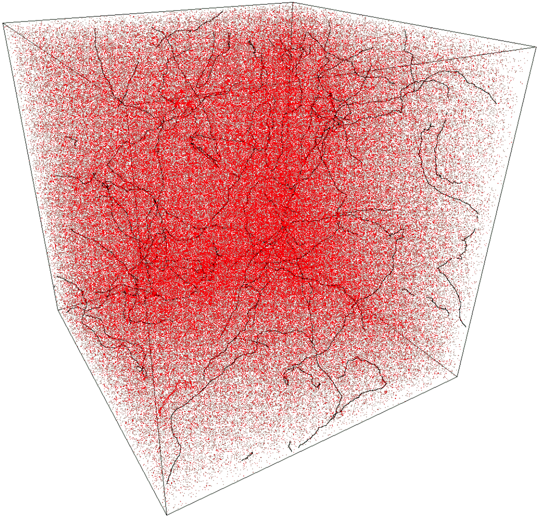


2 Cosmic Strings

3 Compact Binary Coalescences



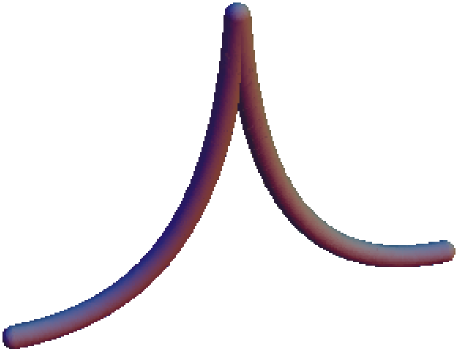
Cosmic string network

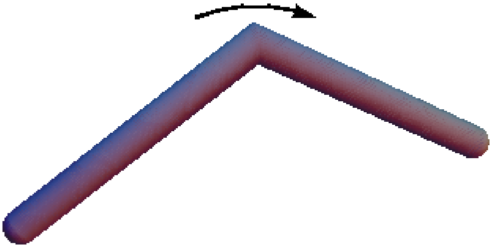


- ≈ 1 long string $\rightarrow$ many loops
- string tension

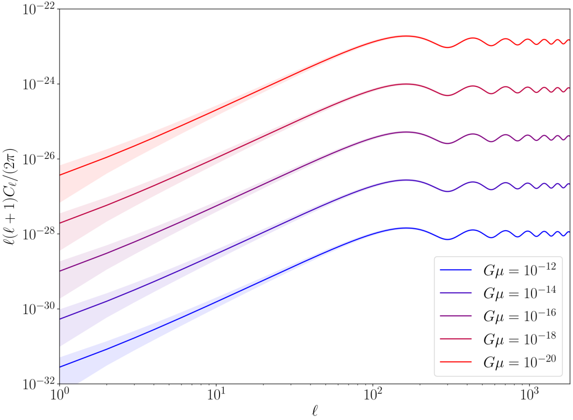
$$G\mu = \frac{\text{mass}}{\text{length}} \sim T_{\text{SSB}}^2$$

Loop GW emission: cusps and kinks

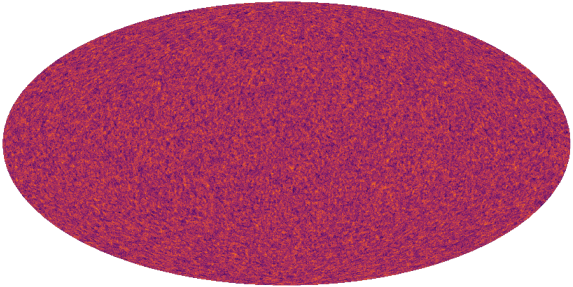




Cosmic string SGWB



- $G\mu = 10^{-12}$–10^{-20}
- $\rightarrow\ T_{\mathrm{SSB}} \sim 10^{13}$–$10^{9}$ GeV
- $\rightarrow$ below GUT scale but well above EW scale



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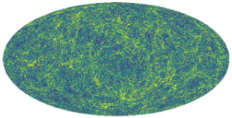

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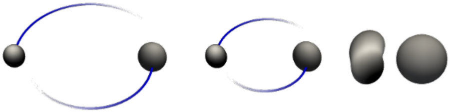
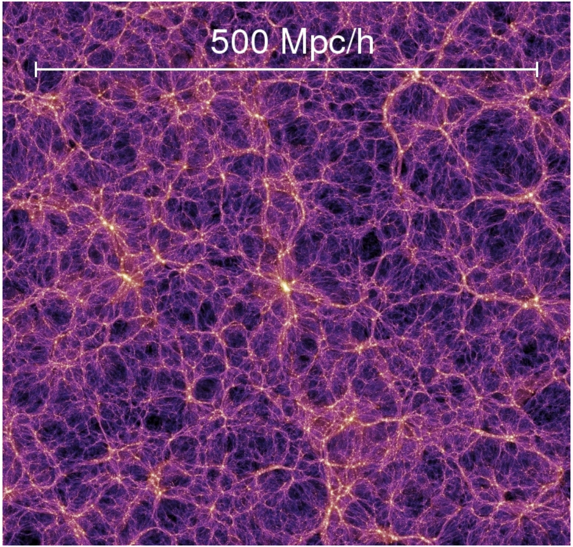
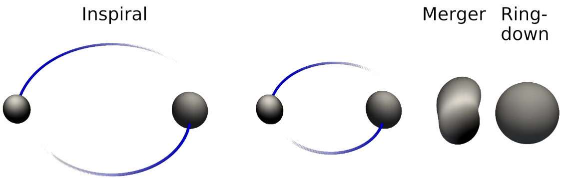


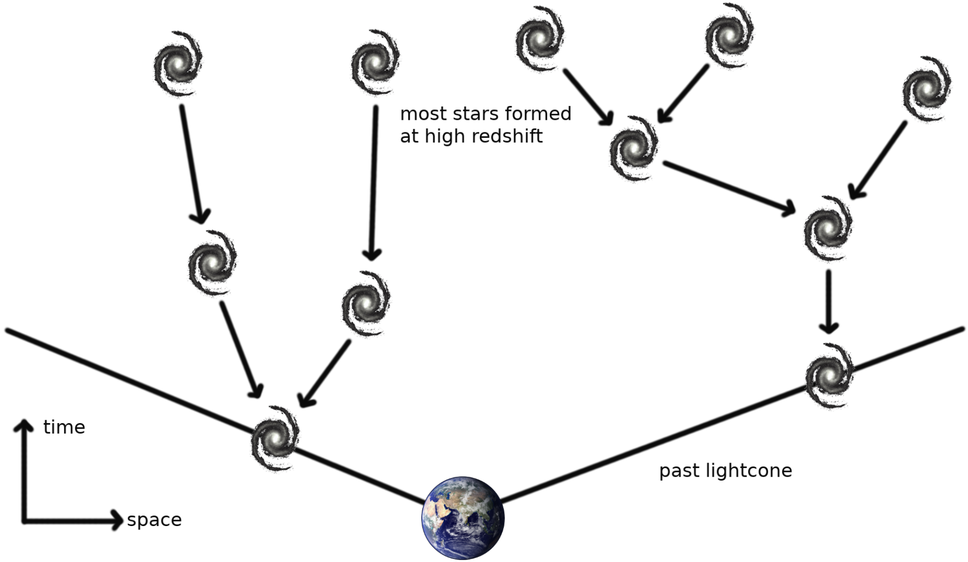
Compact binary SGWB



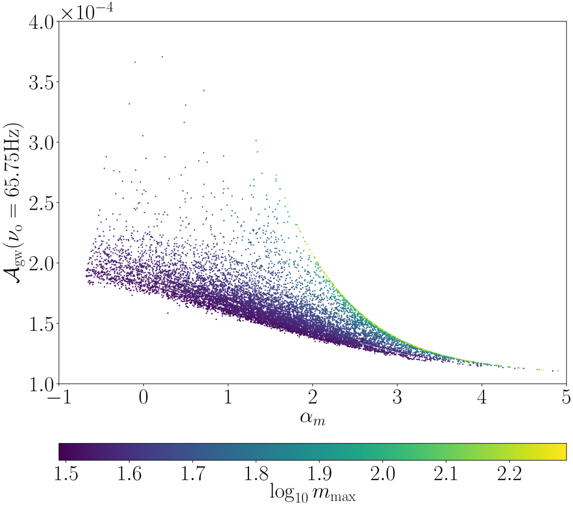


- get galaxies from simulation
- calculate rate for each galaxy
- superimpose $\rightarrow$ SGWB map

Cosmic star formation history



CBC population models



input from LIGO/Virgo:

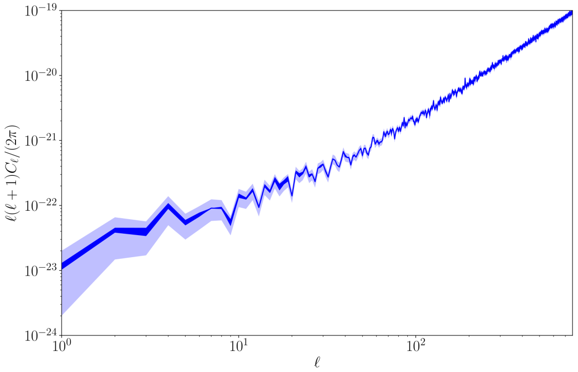
- local rate
- mass distribution

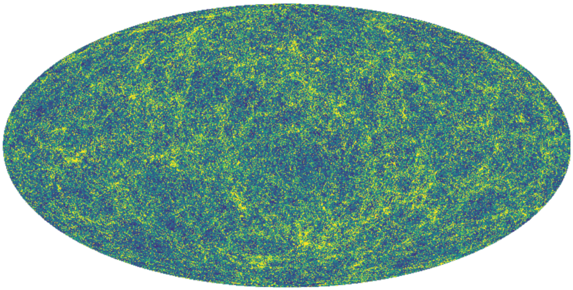
$$p(m_1) \propto m_1^{-\alpha_m}$$

$$p(m_2) = \text{uniform}$$

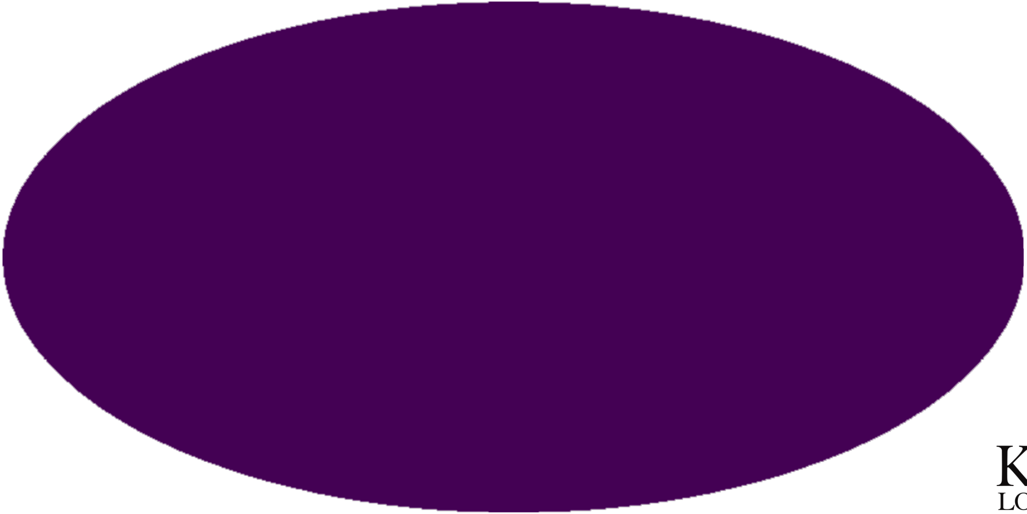
$$m_{\min} \leq m_2 \leq m_1 \leq m_{\max}$$

Compact binary SGWB





Finite sources $\rightarrow$ shot noise



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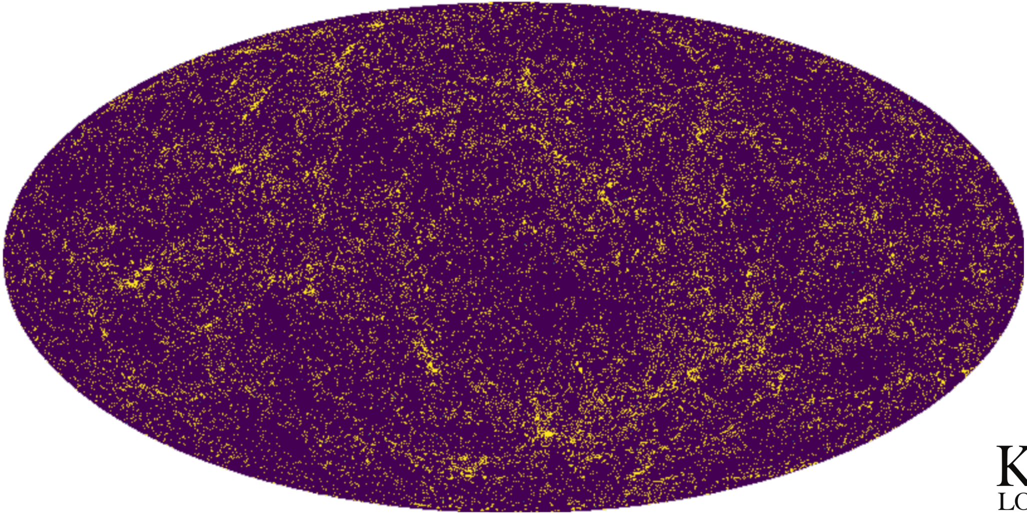

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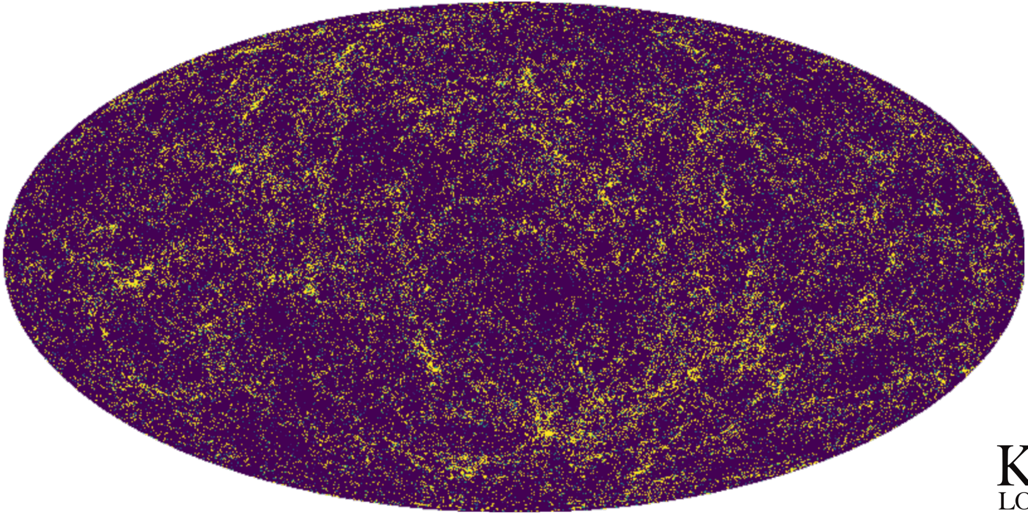

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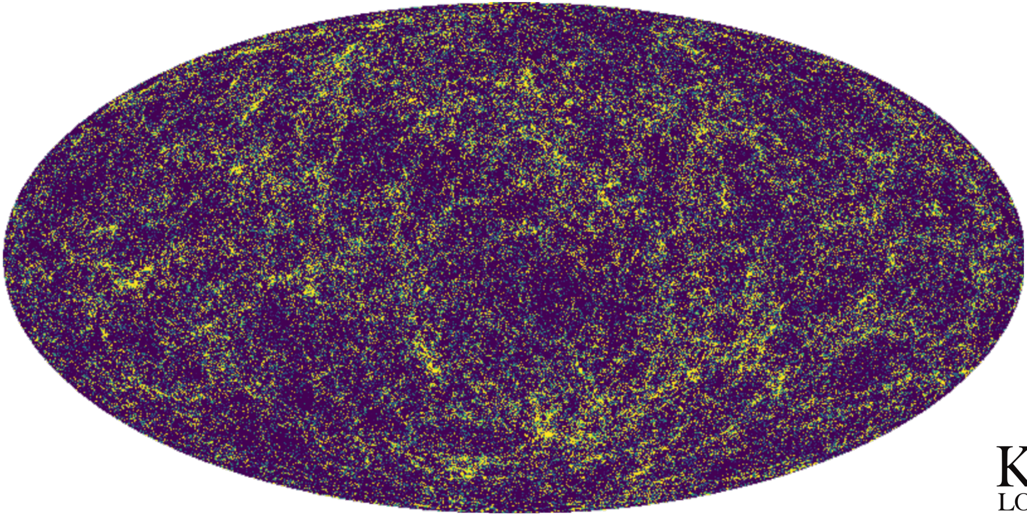

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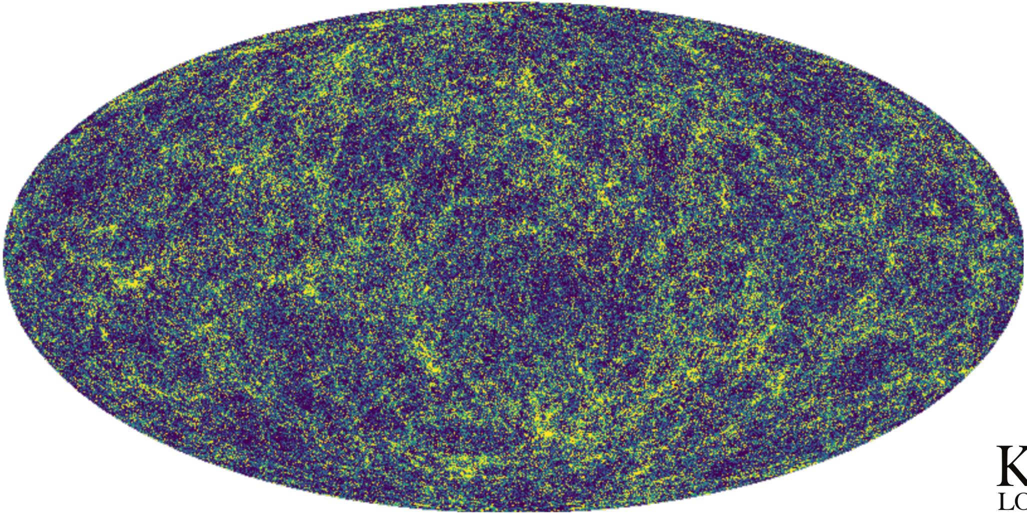

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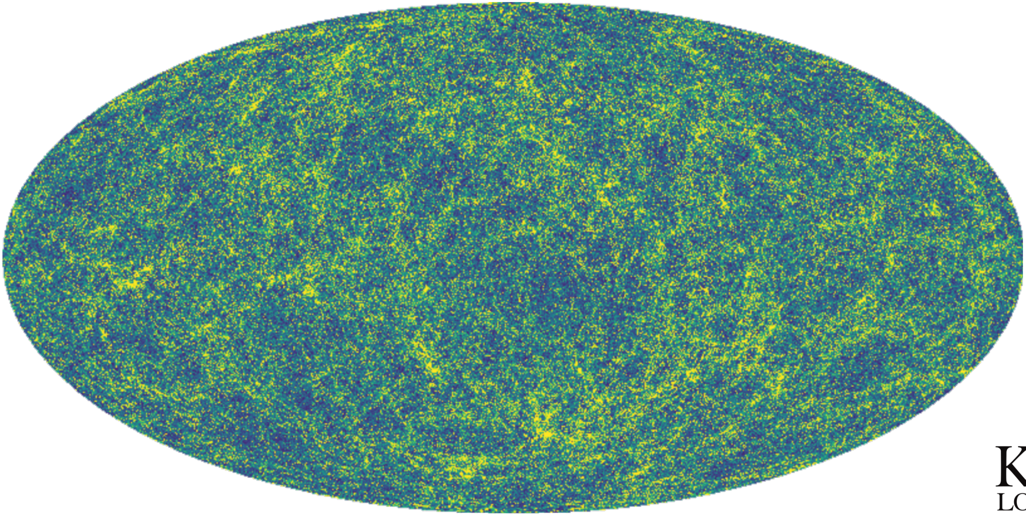
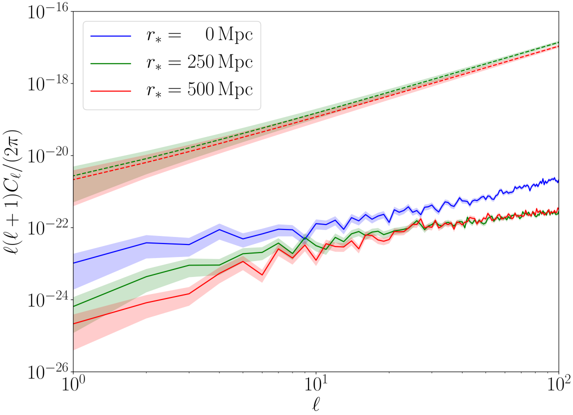


Shot noise in the angular power spectrum



- bias term

$$C_\ell = C_\ell^{\mathsf{LSS}} + \mathcal{B}$$

- scales with observation time

$$\mathcal{B} \propto 1/T_{\mathsf{obs}}$$

- removing foreground sources can help

Summary and outlook

- GW background anisotropies are important
- interesting phenomenology for cosmic strings ($\rightarrow$ BSM physics)
- compact binaries
  - new frontier for large-scale structure ($\rightarrow$ cosmology)
  - robust to population uncertainties
  - challenging to dig beneath shot noise