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



alexander.jenkins@kcl.ac.uk

20 February 2019 1 / 13

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:

$$egin{aligned} arOmega_{\mathsf{gw}}(f, oldsymbol{\hat{n}}) &= rac{1}{
ho_{\mathsf{c}}}rac{\mathsf{d}^{3}
ho_{\mathsf{gw}}}{\mathsf{d}(\mathsf{ln}\,f)\mathsf{d}^{2}oldsymbol{\hat{n}}} \ &\lesssim 10^{-8} \end{aligned}$$



20 February 2019 2 / 13

Angular power spectrum



CMB

$$C_\ell = \int \mathrm{d}^2 \hat{oldsymbol{n}} P_\ell(\cos heta) \left< \delta T_\gamma \delta T_\gamma \right>$$

SGWB

$$\mathcal{C}_{\ell} = \int \mathrm{d}^2 \hat{\boldsymbol{n}} \mathcal{P}_{\ell}(\cos heta) \left< \delta arOmega_{\mathsf{gw}} \delta arOmega_{\mathsf{gw}}
ight>$$



▲□▶ ▲□▶ ▲□▶ ▲□▶ ▲□ ● ● ●

alexander.jenkins@kcl.ac.uk

20 February 2019 3 / 13

1) The Stochastic Gravitational-Wave Background

2 Cosmic Strings

3 Compact Binary Coalescences



500



《曰》 《部》 《문》 《문》

Cosmic string network



• $\approx 1 \text{ long string} \rightarrow \text{many loops}$ • string tension

$${\cal G}\mu = rac{{\sf mass}}{{\sf length}} \sim \, {\cal T}_{{\sf SSB}}^2$$

イロト イボト イヨト イヨト



Э

20 February 2019

500

4 / 13

Loop GW emission: cusps and kinks





20 February 2019 5 / 13

ONDON

500

Cosmic string SGWB



- $G\mu = 10^{-12} 10^{-20}$
- $\odot \ \rightarrow \ {\cal T}_{\rm SSB} \sim 10^{13} \text{--} 10^9 \, \text{GeV}$
- ${\color{black} \bullet } \hspace{0.1 in } \rightarrow {\color{black} \mathsf{below}} \hspace{0.1 in \mathsf{GUT}} \hspace{0.1 in \mathsf{scale}} \hspace{0.1 in \mathsf{but}} \hspace{0.1 in \mathsf{well}} \hspace{0.1 in \mathsf{above}} \hspace{0.1 in \mathsf{EW}} \hspace{0.1 in \mathsf{scale}} \hspace{0.1 in \mathsf{cale}} \hspace{0.1 in \mathsf{cale}}$



イロト イ理ト イヨト イヨト



500

Э

1) The Stochastic Gravitational-Wave Background

2 Cosmic Strings

3 Compact Binary Coalescences



Compact binary SGWB





- get galaxies from simulation
- calculate rate for each galaxy
- $\bullet \ \text{superimpose} \to \mathsf{SGWB} \ \mathsf{map}$

< 口 > < 同 >



500

3

20 February 2019 7 / 13

alexander.jenkins@kcl.ac.uk

Cosmic star formation history



CBC population models



input from LIGO/Virgo:

- local rate
- mass distribution

 $p(m_1) \propto m_1^{-lpha_m}$ $p(m_2) = ext{uniform}$ $m_{ ext{min}} < m_2 < m_1 < m_{ ext{max}}$



20 February 2019

200

9 / 13

Compact binary SGWB





500

《曰》《曰》《臣》《臣》

20 February 2019 11 / 13

Э



alexander.jenkins@kcl.ac.uk

20 February 2019 11 / 13





alexander.jenkins@kcl.ac.uk

20 February 2019 11 / 13





Shot noise in the angular power spectrum



bias term

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

scales with observation time

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

• removing foreground sources can help



200

alexander.jenkins@kcl.ac.uk

20 February 2019 12 / 13

Summary and outlook

- GW background anisotropies are important
- \bullet 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



13 / 13

→ Ξ → < Ξ →</p>

20 February 2019