Cordes cosmiques, ondes gravitationnelles et abondance des vortons

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[0]Based on 1903.06685, 2009.00334 and 2010.04620

Cosmic strings[3]

1D topological defects

- Cosmic strings are 1D topological defects that may appear after a symmetry breaking phase transition
- After the phase transition the field falls into the new vacuum manifold $\mathcal{M}$
- Strings arise if $\mathcal{M}$ is not simply connected: there exist some closed paths on the vacuum manifold cannot be shrunk to a point
- Strings are expected to form in most models of spontaneous symmetry breaking [1](some having currents)

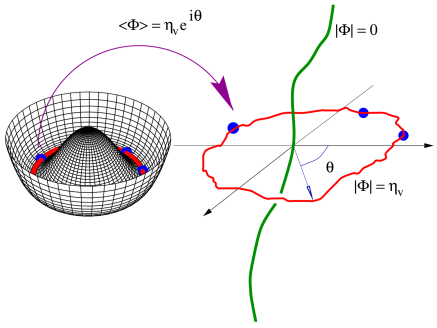


Figure: String formation in the "Mexican hat" potential $V(|\phi|)^2$

[1] Jeannerot, Rocher, and Sakellariadou 2003.
[2] Ringeval 2010.
[3] Kibble 1976.

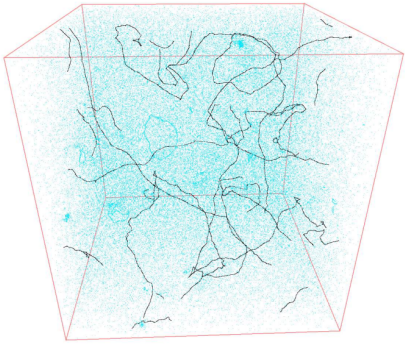
Cosmic string loops

The loop production function

- Infinite strings are stretched by the expansion of the Universe
- They intersect each other and produce loops
- These loops decay by emitting gravitational waves
- The production of non-self intersecting loops is studied through numerical simulations and remains a matter of debate.
- We model the loop production function as[4]

$$t^5 \mathcal{P}(\ell, t) = C \left(\frac{\ell}{t} \right)^{2\chi - 3}$$

- LRS[5]: $\chi_{\mathrm{rad}} = 0.2$, $\chi_{\mathrm{mat}} = 0.295$
- BOS[6]: $\chi_{\mathrm{rad}} = 0.5$, $\chi_{\mathrm{mat}} = 0.655$

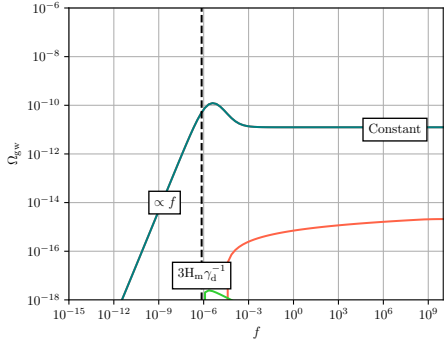


[6] Polchinski 2007.
[6] Lorenz, Ringeval, and Sakellariadou 2010.
[6] Blanco-Pillado, Olum, and Shlaer 2014.

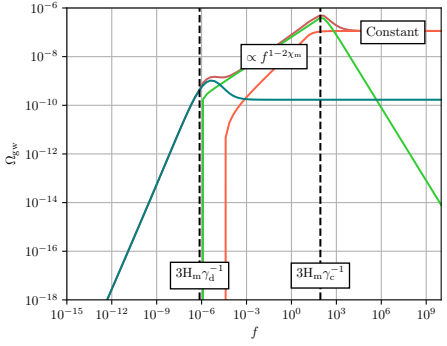
Production of gravitational waves

The stochastic background

- Loops emit bursts of gravitational waves that are looked for in LIGO/Virgo
- The uncorrelated sum of all the GW signals constitutes a Stochastic Background of GW.



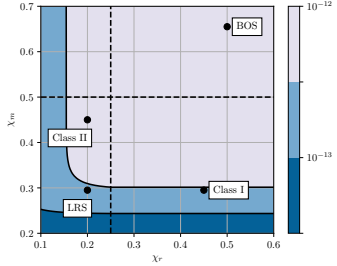
(a) BOS: $\chi_{\mathrm{rad}} = 0.5$, $\chi_{\mathrm{mat}} = 0.655$



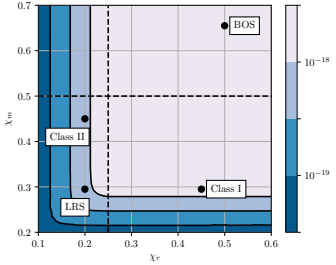
(b) LRS: $\chi_{\mathrm{rad}} = 0.2$, $\chi_{\mathrm{mat}} = 0.295$

A multi-frequency analysis

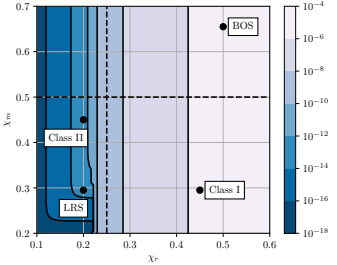
Probing the parameter space



(a) PTA, sensitivity of $\Omega_{\rm GW} = 10^{-12}$ taken at $f = 2 \times 10^{-9}$ Hz



(b) LISA, sensitivity of $\Omega_{\rm GW} = 10^{-13}$ taken at $f = 10^{-2}$ Hz



(c) LIGO/Virgo, sensitivity of $\Omega_{\rm GW} = 10^{-7}$ taken at $f = 20$ Hz

Figure: PA

- In some theories, a current can condense on cosmic strings
- This current carries angular momentum and can, in some cases, prevent the loops from collapsing
- These stable loops of current carrying cosmic string are called **vortons**.
- We consider strings formed at one energy scale and subsequently carry a current in a secondary phase transition

$$\mathcal{R} \equiv \lambda\sqrt{\mu}$$

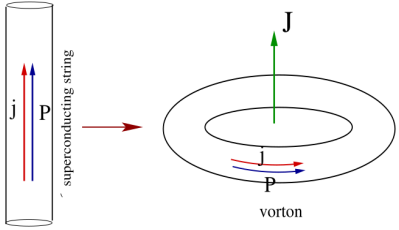


Figure: A closed string with a current[7]

[7] Radu and Volkov 2008.

The abundance of vortons

Contribution to the dark matter content

- A loop is characterized by its proper length ℓ and a quantum number N
- At a length $\ell_0 = N/\sqrt{\mu}$, the loop stops shrinking and becomes a vorton
- The loop number density is the solution of a continuity equation with

$$\frac{\mathrm{d}\ell}{\mathrm{d}t} = -\Gamma G\mu\Theta(\ell - \ell_0) \qquad (1)$$

- The energy density of the vortons scales like matter

$$\Omega_{\mathrm{vortons}} \equiv \frac{8\pi G}{3H_0^2} \int \mu\ell \frac{\mathrm{d}\mathcal{N}}{\mathrm{d}\ell}_{\mathrm{vortons}} (\ell, t_0)\, \mathrm{d}\ell$$

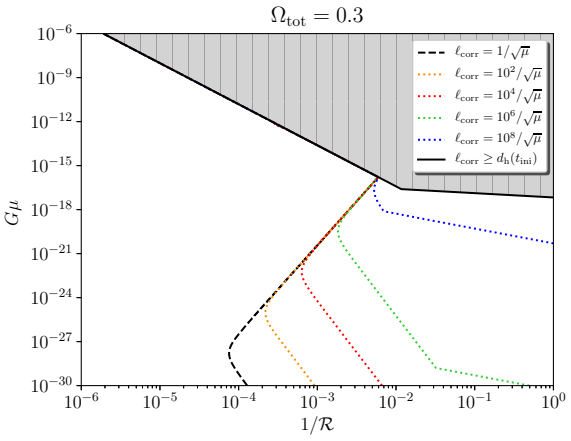


Figure: PA, P. Peter, C. Ringeval and D. Steer 2020

Conclusion

Summary

- Cosmic strings are a general prediction of most symmetry-breaking models
- **Gravitational wave astronomy** is one of the most promising technique to probe for cosmic strings.
- LISA will probe cosmic strings with tension $G\mu \geq 10^{-17}$, with little dependence on the precise cosmic string model
- Currents can condense on the cosmic strings and make them superconducting
- Stable configuration of current carrying loops: **vortons**, can contribute to the **Dark Matter** content of the Universe