CMB from standard and current-carrying cosmic strings

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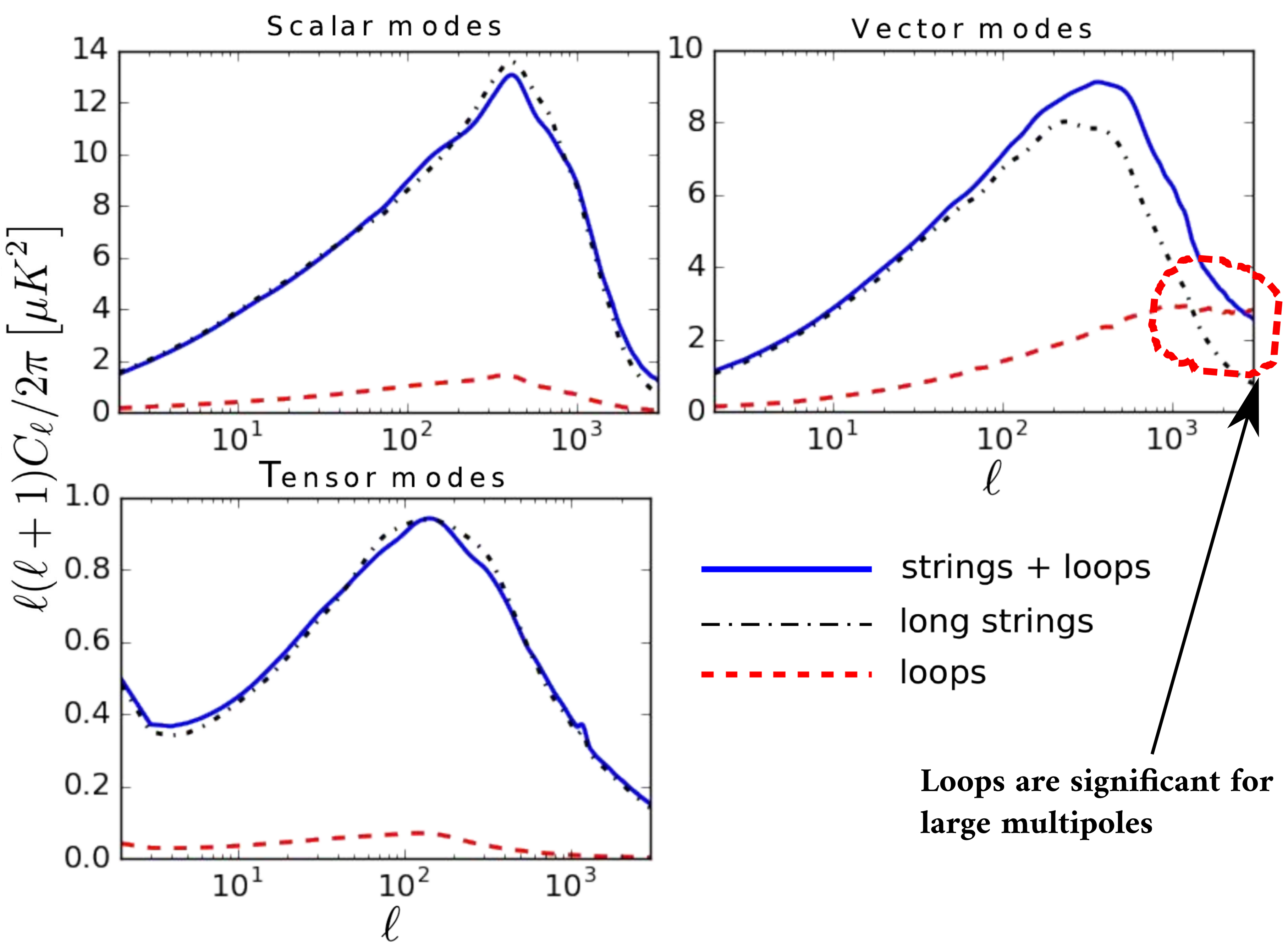
More details in [I.R., L. Sousa, Phys.Rev.D 104 (2021) 2, 023507; e-Print: 2104.08375 [astro-ph.CO]]

More details in [C.J.A.P. Martins, P. Peter, I.R., E.P.S. Shellard e-Print: 2108.03147 [astro-ph.CO]]

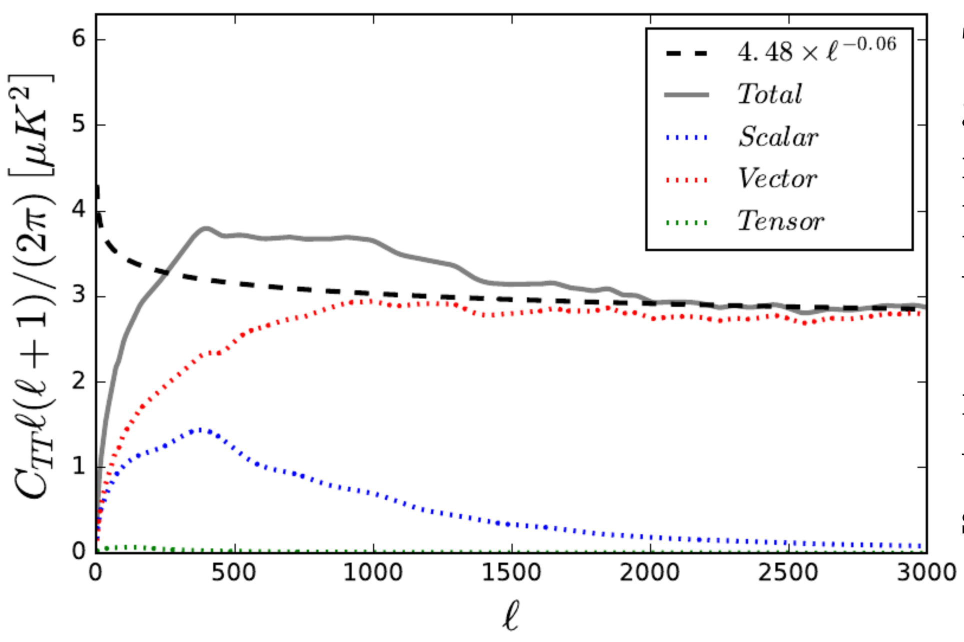
1. CMB anisotropies generated by cosmic string segments and loops

The contribution of cosmic string loops to the Cosmic Microwave Background (CMB) anisotropies can be predicted by extension of the CMBACT code [1], which originally was developed only for straight string segments. It can be acheived by extending the Unconnected Segment Model (USM) to include the contribution of the cosmic string loops created throughout the cosmological evolution of a cosmic string network to the stress-energy tensor.

Main result of loops anisotropies is shown in Figure below, where TT power spectra for scalar and vector modes are plotted as a function of the multipole moments.



We find that the shape of the angular power spectra generated by loops is, in general, similar to that of long strings. However, there is generally an enhancement of the anisotropies on small angular scales. Vector modes produced by loops dominate over those produced by long strings for large multipole moments. The contribution of loops to the CMB anisotropies generated by cosmic string networks may reach a level of 10% for large loops but decreases as the size of loops decreases.



Temperature angular power spectrum generated by cosmic string loops and its scalar, vector, tensor components. For $\ell > 1500$ the total contribution is well approximated by

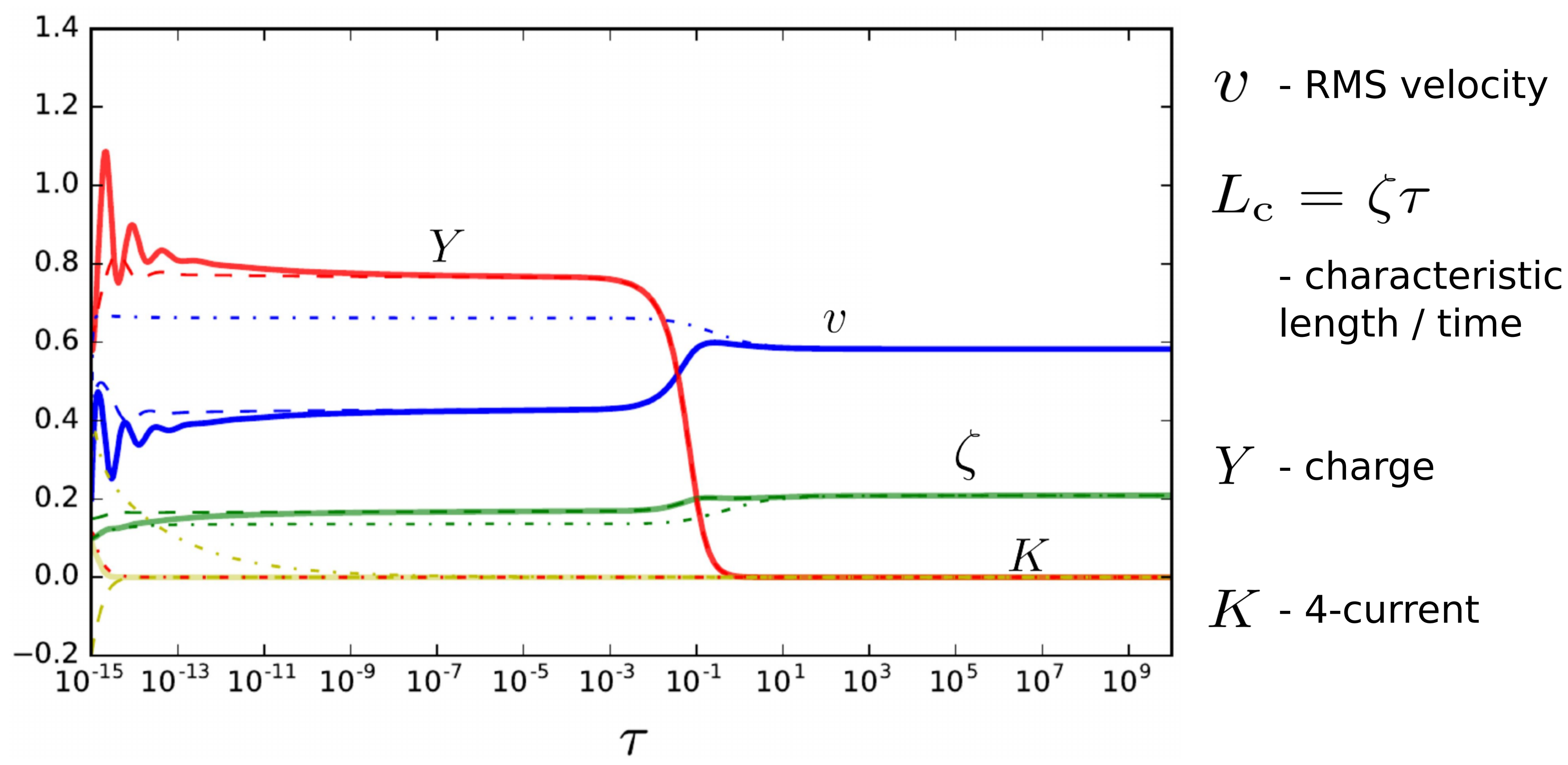
$$C_{TT}\frac{\ell(\ell+1)}{2\pi} \sim \ell^{-0.05},$$

i.e it is almost constant due to the vector contribution, generated by string loops.

2. Evolution of a "linear" current-carrying string network

We apply a recently developed formalism [2] to study the evolution of a current-carrying string network under the simple but generic assumption of a linear equation $F(K) = 1 - \frac{\kappa_0}{2}K$, where K is a 4-current, κ_0 is a positive constant.

We demonstrate that the existence of a scaling solution with non-trivial current depends on the expansion rate of the universe, the initial root mean square current on the string, and the available energy loss mechanisms. We find that the fast expansion rate after radiation-matter equality will tend to rapidly dilute any pre-existing current and the network will evolve towards the standard Nambu-Goto scaling solution (provided there are no external current-generating mechanisms). During the radiation era, current growth is possible provided the initial conditions for the network generate a relatively large current and/or there is significant early string damping. The network can then achieve scaling with a stable non-trivial current, assuming large currents will be regulated by some leakage mechanism. The potential existence of current-carrying string networks in the radiation era, unlike the standard Nambu-Goto networks expected in the matter era. An example of a string network evolution for radiation-matter transition is shown in Figure below:

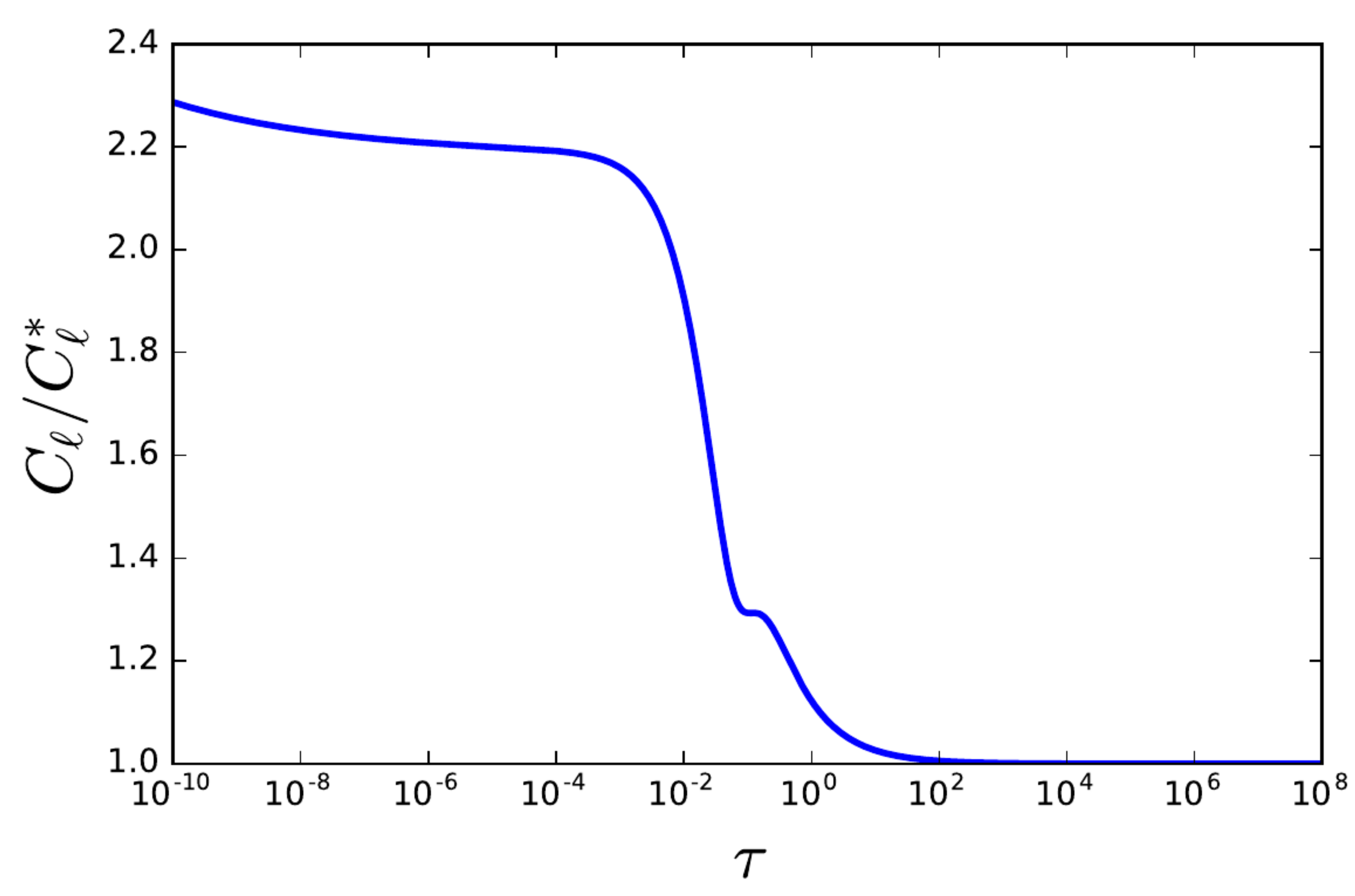


3. CMB for superconducting strings?

Using approximate expression of power spectra for high multipoles [3]

$$C_{1<<\ell} \sim (G\mu_0)^2 \frac{(1+Y)^2 v^4 + (1-Y^2)\, v^2(1-v^2) + (1-Y)^2 (1-v^2)^2 + 3v^2Y^2}{\zeta(1-v^2)}$$

We can estimate how much the standard power spectra C_ℓ is bigger than power spectra C_ℓ^* from a superconducting string network, shown in Figure below



4. Take-home message:

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1) For accurate prediction of angular power spectrum generated by a cosmic string network for high multipoles we need to include loops;
2) Features of cosmic strings, such as currents on string worldsheets, change the CMB anisotropy prediction;
3) Constraints on a superconducting cosmic string tension should take into account change of a string network evolution due to currents presence (strings with currents produce less anisotropies);
4) Particular features, such as possible vorton formation, should be studied in more details to have an accurate prediction of CMB anisotropies generated by strings with non-trivial internal structure.

5. References

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