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Transformation Optics and Models of Spatial Topology

What is the topology and geometry of the spatial universe? This fundamental question in cosmology remains open. Some cosmologists argue that closed 3-manifolds may provide a better fit to observational data than simply connected models. In this talk, I will describe how techniques from transformation optics allow one to physically model harmonic wave propagation on any closed, orientable 3-manifold.

First, I will give an overview of transformation optics. For our purposes, we prove a strengthened form of the Lickorish–Wallace link surgery theorem. Using this, we construct a diffeomorphism from the complement of a smooth link in a closed 3-manifold to a bounded domain in $\mathbb{R}^3$. Pushing forward the spatial metric through this map allows us to construct a metamaterial device whose induced anisotropic conductivity suitably reproduces the Helmholtz dynamics of the original manifold.