Bright Traversable Wormholes

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Background & Motivation

- The **Casimir effect** is a quantum phenomenon whereby two uncharged parallel plates are pushed together
- This effect is due to **vacuum fluctuations**, as only a discrete number of wavelengths of light can fit in between the plates

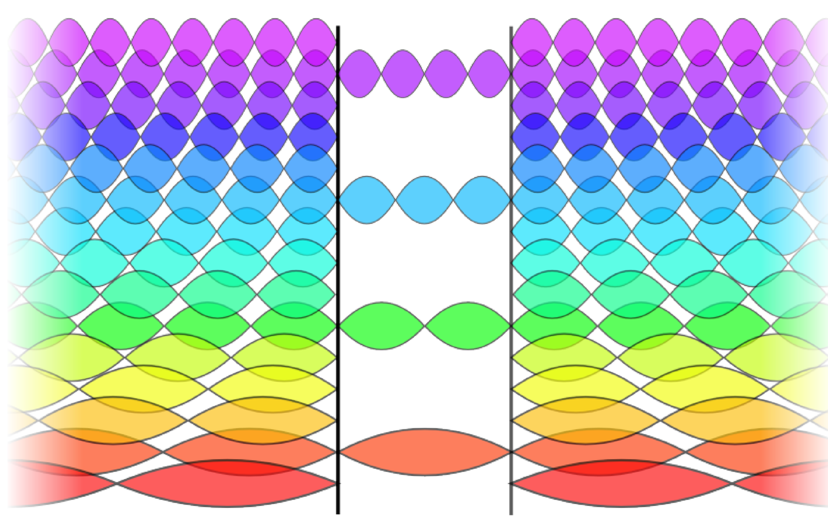

Figure 1: Visualization of the Casimir effect [K. Kingsbury, 2009]. The greater number of light modes outside the plates exert an inward force on the plates

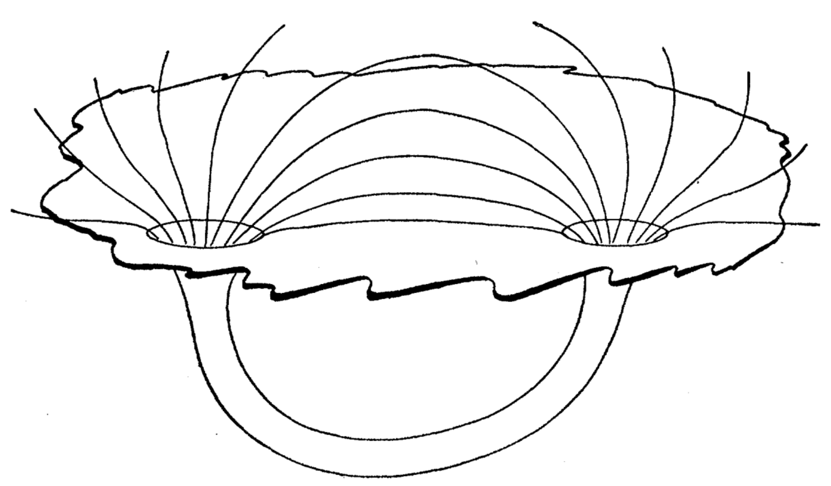

Figure 2: Illustration of a traversable wormhole [J. Wheeler, 1955]

- **Wormholes** are solutions to Einstein's equations that connect two separated regions of spacetime
- **Traversable wormholes** allow a particle to enter from one side and then exit through the other in a finite amount of time

- Certain wormholes become traversable given large enough amounts of **negative energy**
- Recent work inspired by the Casimir effect (c.f. [7]) demonstrates that there exist states of fermionic matter which produce arbitrarily large amounts of negative energy
- The existence of these large amounts of negative energy is important in certain developing models of cosmology

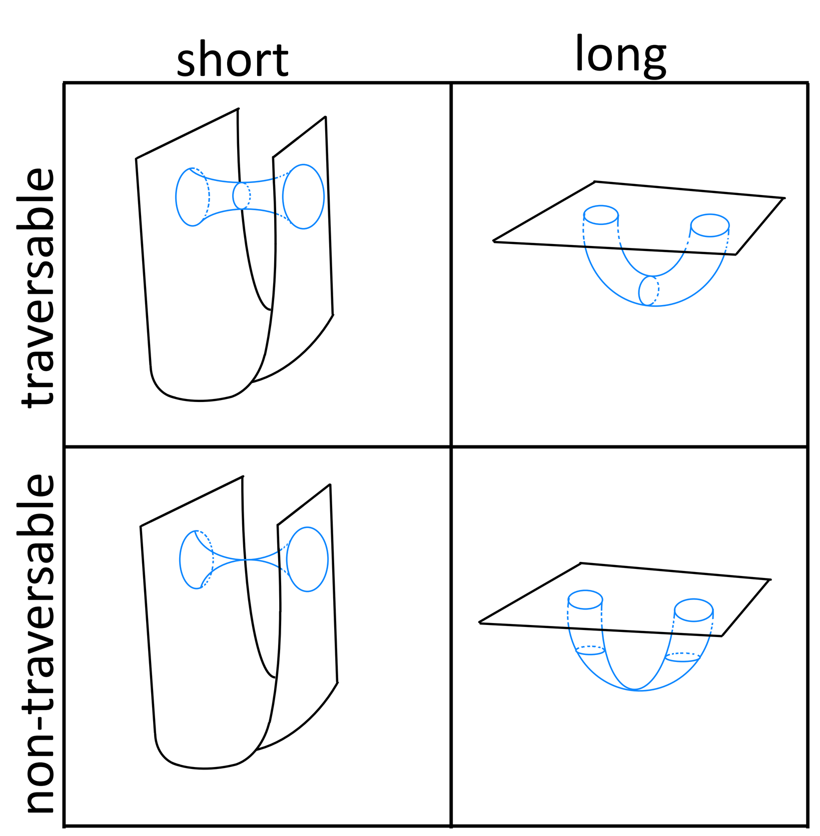

Figure 3: Common types of wormholes

We wish to find other physical systems that produce arbitrarily large amounts of negative energy

Methods & Progress

- Our model is a nearest-neighbor interacting lattice of bosonic harmonic oscillators (e.g., photons):

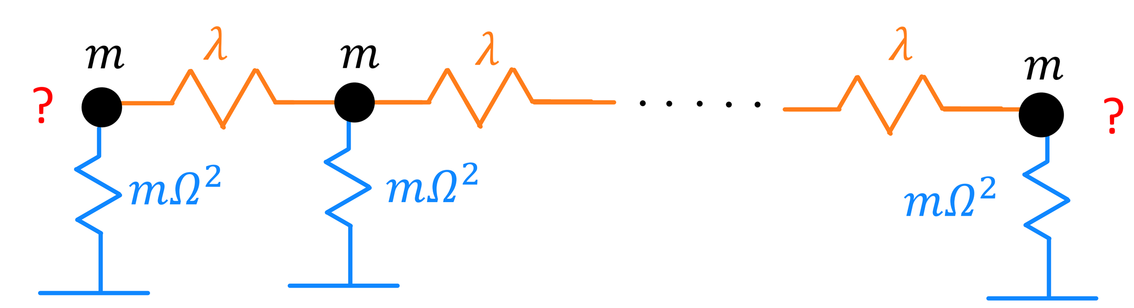

Figure 4: Our model of a bosonic lattice (many masses coupled via springs) with the question marks indicating that we don't specify boundary conditions

$$H = \sum_i \left(\frac{p_i^2}{2m} + \frac{1}{2} m \Omega^2 q_i^2 \right) + \lambda \sum_i (q_i - q_{i-1})^2$$

Goal: Numerically explore the amount of uniform negative energy that can exist on our chain

- We attach a temperature-like parameter to each site of the chain, which we then numerically vary while constraining the energy density to be uniform
- Because we don't specify the boundary conditions, we essentially search over all possible states and boundary conditions in our optimization

- Technically, we use the result that, given a state that fixes the expectation values of some operators, there exists a corresponding entropy-maximizing state with those same expectation values:

$$\rho_{th} = \frac{1}{Z} \exp\left(-\sum_r \beta_r \hat{\varepsilon}_r \right)$$

- The temperature-like variables (β_r) are what we vary given the constraint that the energy densities (ε_r) are uniform in r.

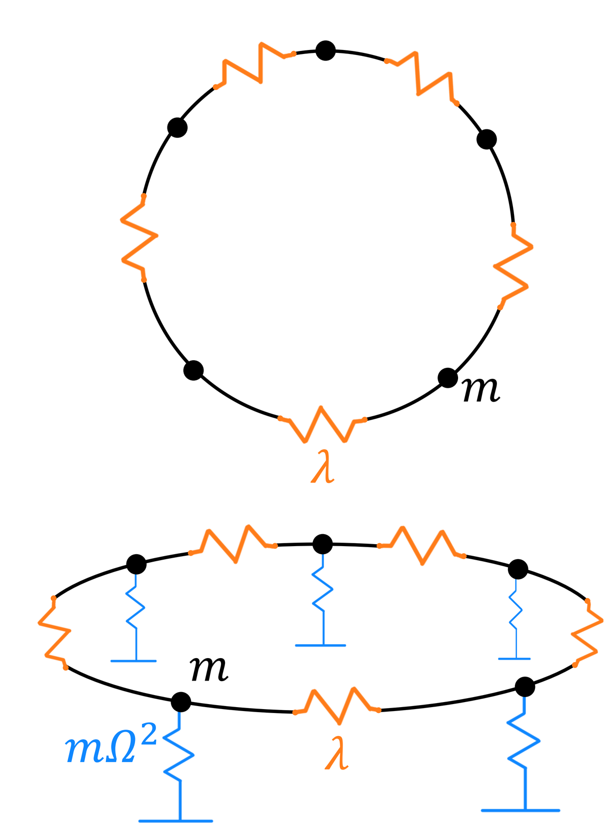

Figure 5: Example of periodic boundary conditions for N=5 (i.e., the end sites are identified) viewed from the top (top) and from the side (bottom)

Outlook

- Numerical analysis is currently underway, and preliminary results suggest that the bulk energy density is roughly uniform, although more robust results are needed
- Next steps:
  - Get numerics running for our bosonic chain
  - Consider higher dimensional lattice realizations
  - Explore properties of the traversable wormholes motivating this project

References

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