BERKELEY CENTER *for* COSMOLOGICAL PHYSICS

Slicing the Vacuum:
New Ideas for the Dynamical Casimir Effect

Eric Linder

UC Berkeley/LBNL/KASI

based on Good & Linder 1707.03670

YITP-ICG-KASI-NAOC Workshop
7 September 2017

What is Acceleration?

BERKELEY CENTER *for* COSMOLOGICAL PHYSICS

Einstein's Equivalence Principle:
Acceleration = Gravity

QFT/Hawking/Unruh:
Acceleration → Particle Production

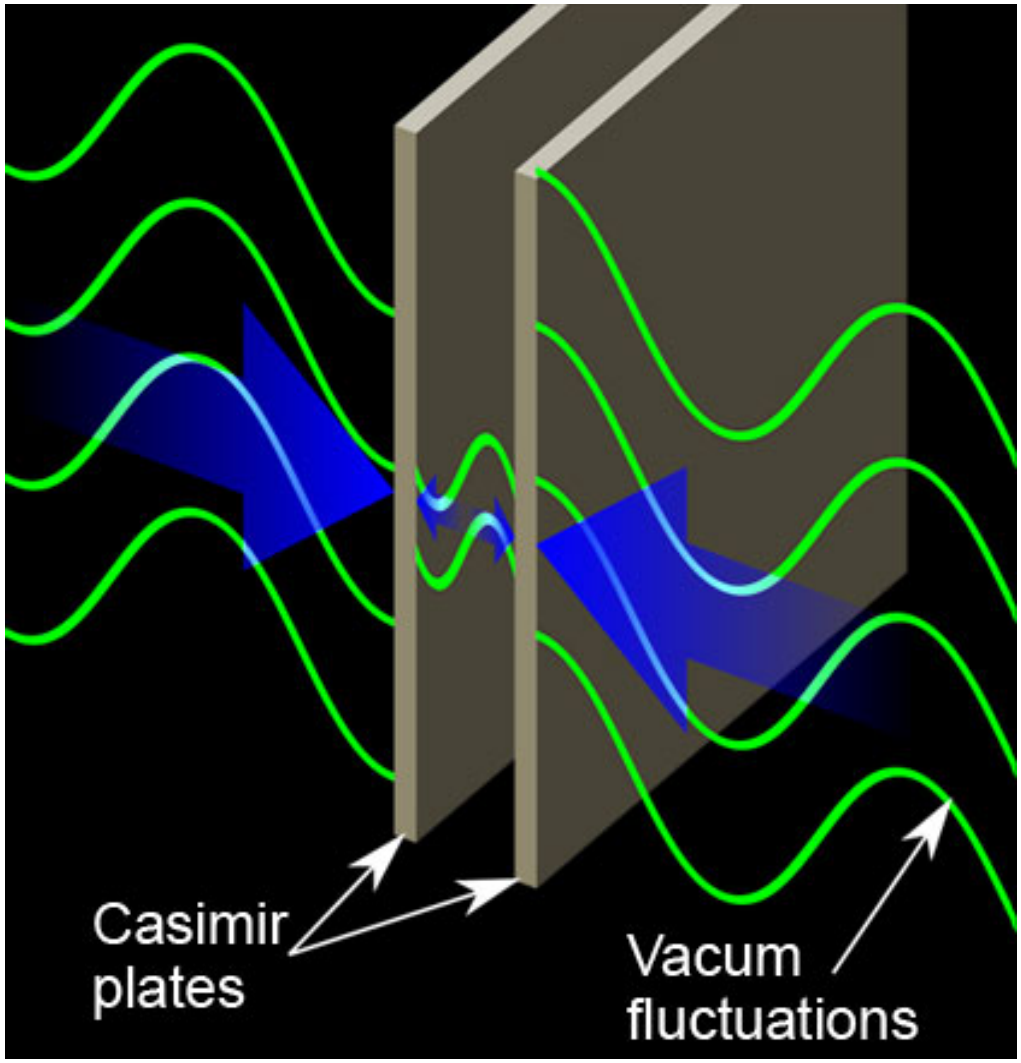
Accelerating Mirrors as analogs of black holes.
Study horizons, information paradox, firewalls.

- **Only 2 finite solutions known (1982, 2013); now 2 new ones (Good & Linder 2017) with analytic Bogolyubov coefficients!**

Accelerating Mirrors as analogs of cosmic acceleration?

Static Casimir Effect

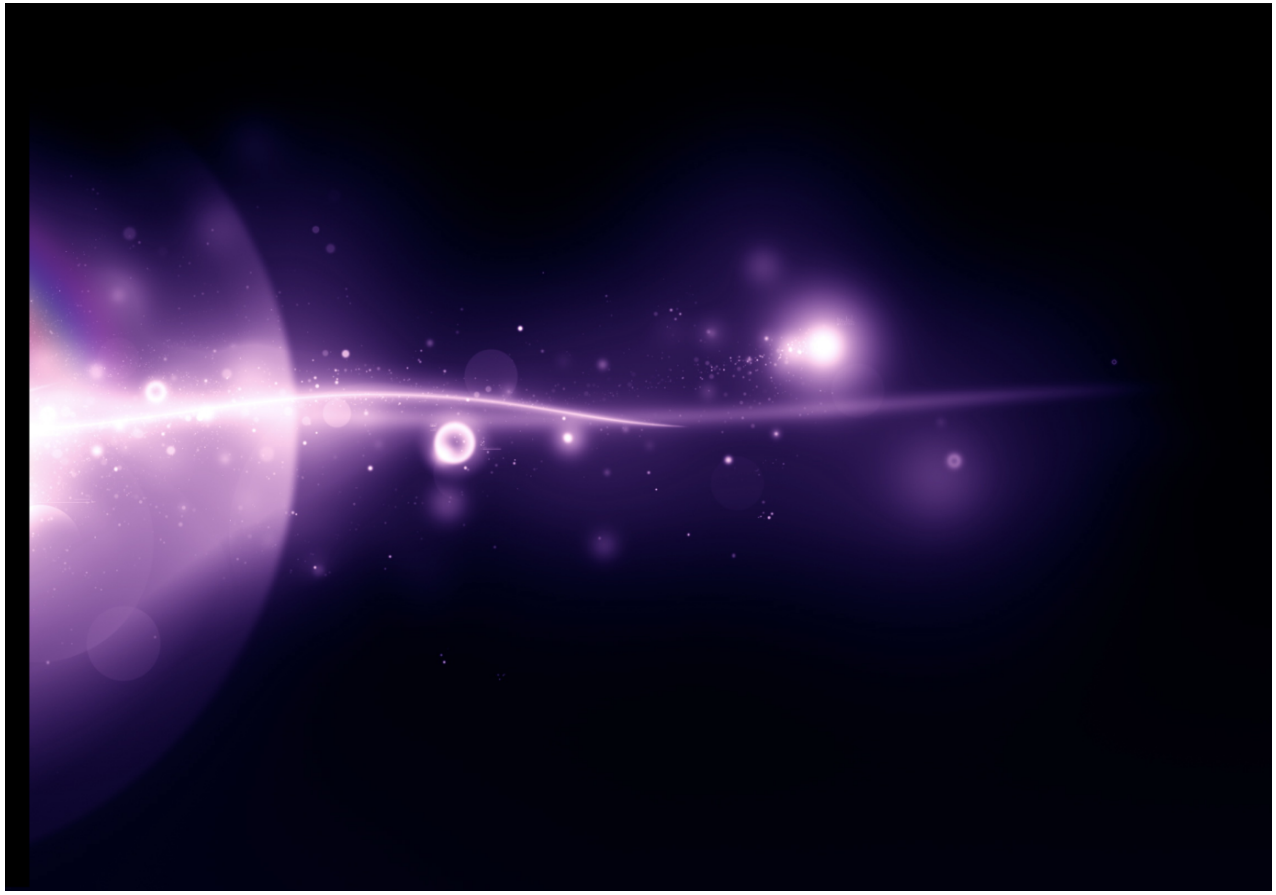
BERKELEY CENTER *for* COSMOLOGICAL PHYSICS



$$\frac{F}{A} = -\frac{\pi^2 \hbar c}{240 a^4}$$

Dynamical Casimir Effect

BERKELEY CENTER *for* COSMOLOGICAL PHYSICS



$$T = \frac{\hbar \kappa}{2\pi c k_B}$$

Reflections on Black Mirrors

BERKELEY CENTER *for* COSMOLOGICAL PHYSICS

$$T = \frac{\hbar c^3}{8\pi k G M} \quad \rightarrow \quad \frac{\kappa}{2\pi}$$

$$T = \frac{\hbar \kappa}{2\pi c k} \quad \rightarrow \quad \frac{\kappa}{2\pi}$$

Hawking, S. W. **"Particle Creation by Black Holes"**, CMP 1975

The Model

BERKELEY CENTER *for* COSMOLOGICAL PHYSICS

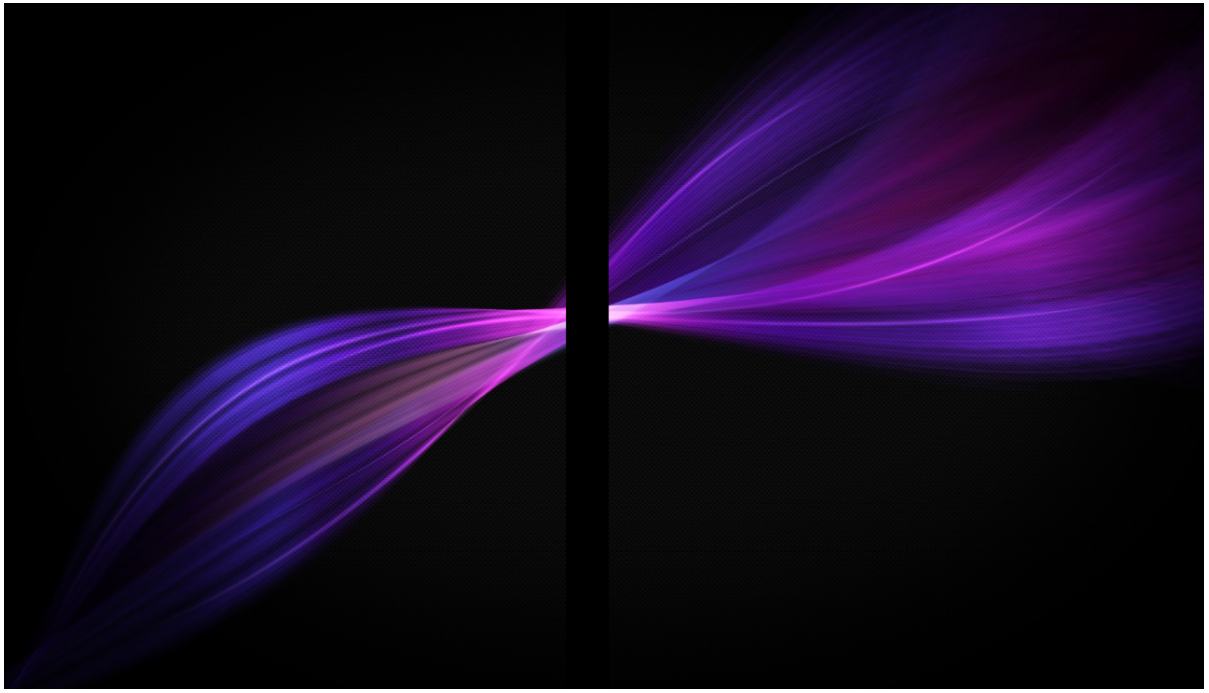
- **Massless Particles**
- **Scalar Field**
- **1+1 Dimensions**
- **Non-interacting**
- **Minimally Coupled**
- **Klein-Gordon Equation**

Davies, P. C. W and S. A. Fulling
"Radiation from Moving Mirrors and Black Holes", PRS 1976

Boundary Conditions

BERKELEY CENTER *for* COSMOLOGICAL PHYSICS

$$\partial_u \partial_v \Phi = 0$$



$$\Phi|_z = 0$$

Entropy, Energy, and Rapidity

BERKELEY CENTER *for* COSMOLOGICAL PHYSICS

$$S(u) = -\frac{1}{6}\eta(u)$$

Entropy is additive, just like (Lorentz) rapidity

$$\tanh\eta = \dot{z}(t)$$

$$F(u) = \frac{1}{12\pi}(\eta'(u)^2 - \eta''(u))$$

$$E = \frac{1}{12\pi}\int_{-\infty}^{\infty}\eta'(u)^2 du$$

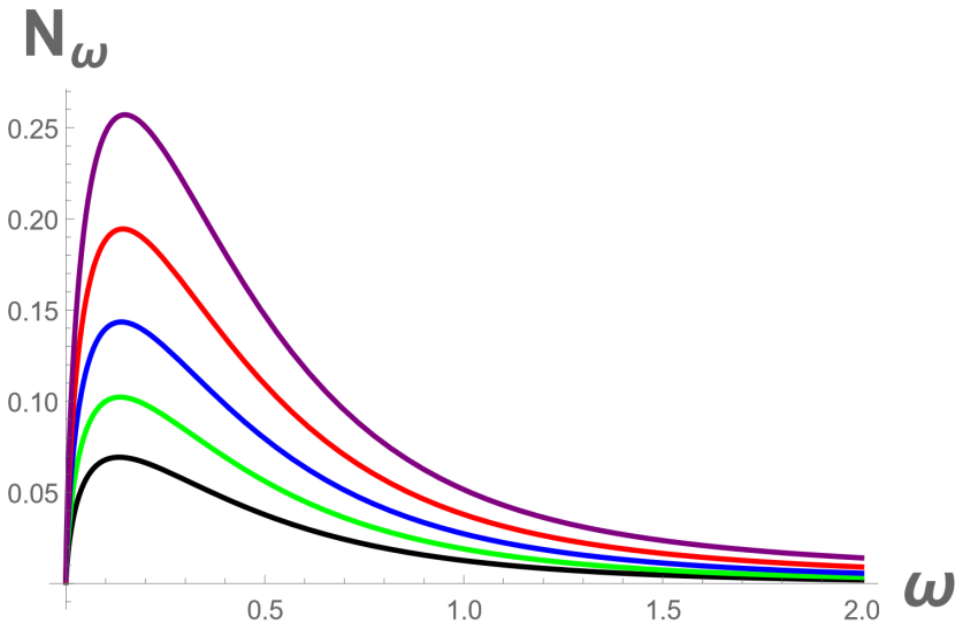
Particles and Spectrum

BERKELEY CENTER for COSMOLOGICAL PHYSICS

$$\beta_{\omega\omega'} = \frac{1}{4\pi\sqrt{\omega\omega'}} \int_{-\infty}^{\infty} dt\; e^{-i\omega_p t + i\omega_n z(t)} \left[\omega_p \dot{z}(t) - \omega_n\right]$$

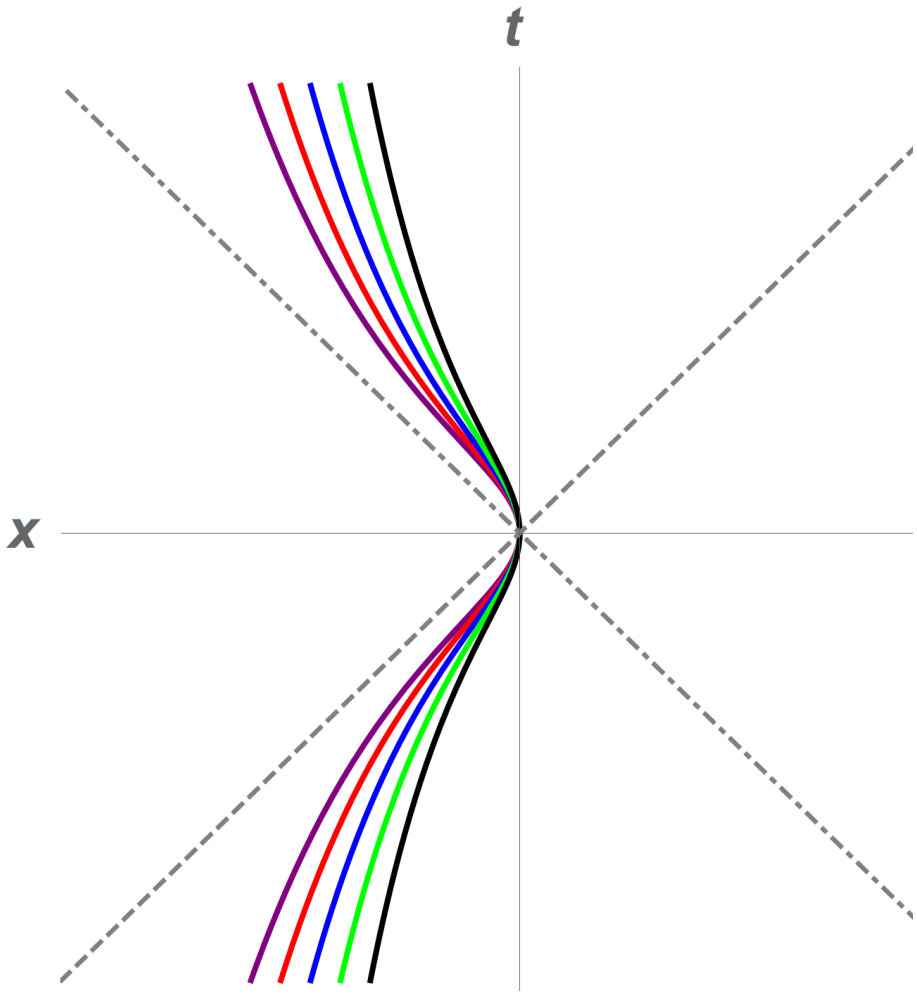
$$N_\omega = \int_0^\infty |\beta_{\omega\omega'}|^2 \, d\omega'$$

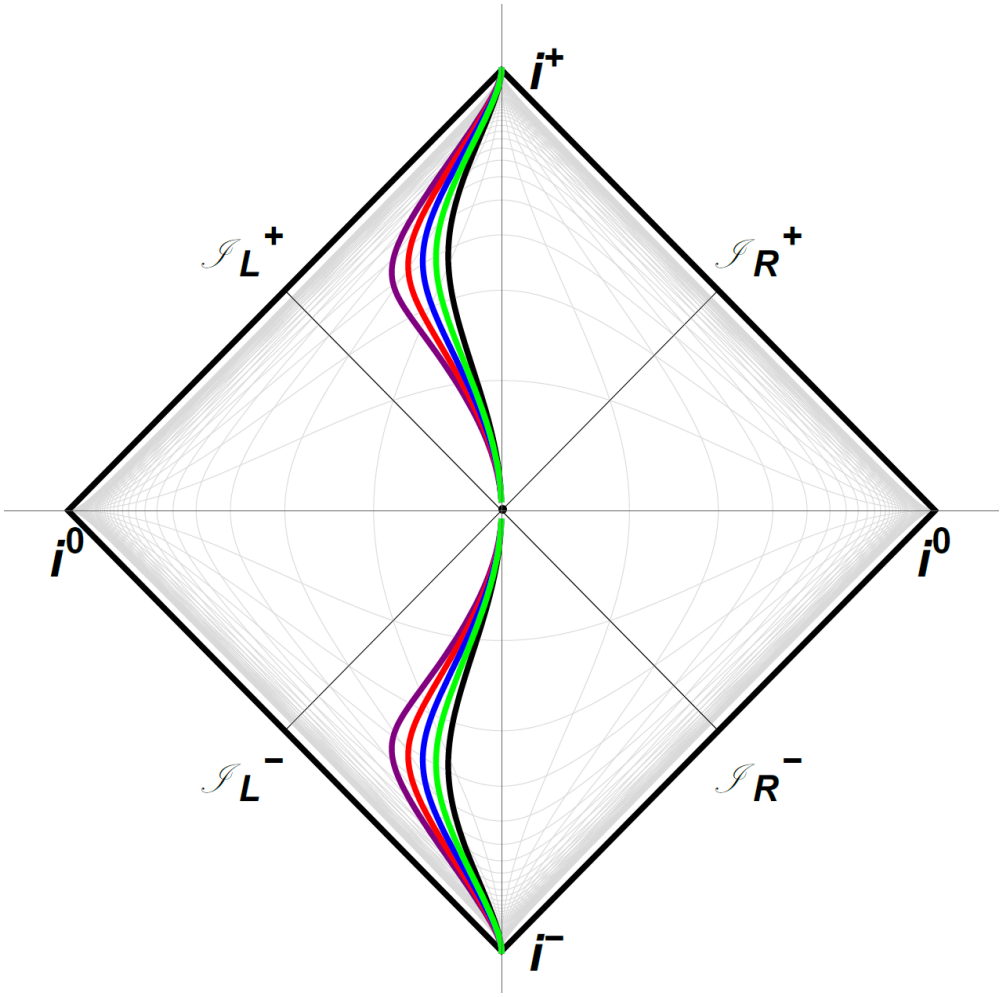
$$N = \int_0^\infty \int_0^\infty |\beta_{\omega\omega'}|^2 \, d\omega \, d\omega'$$



Two New Solutions: 1

BERKELEY CENTER *for* COSMOLOGICAL PHYSICS



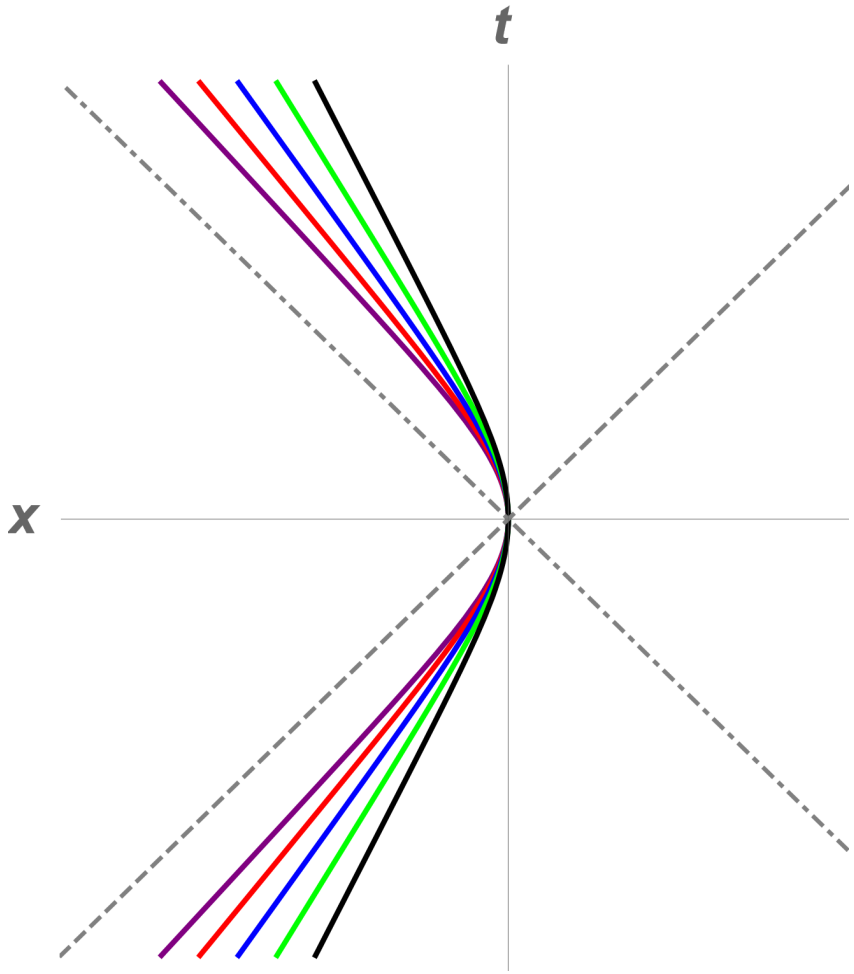


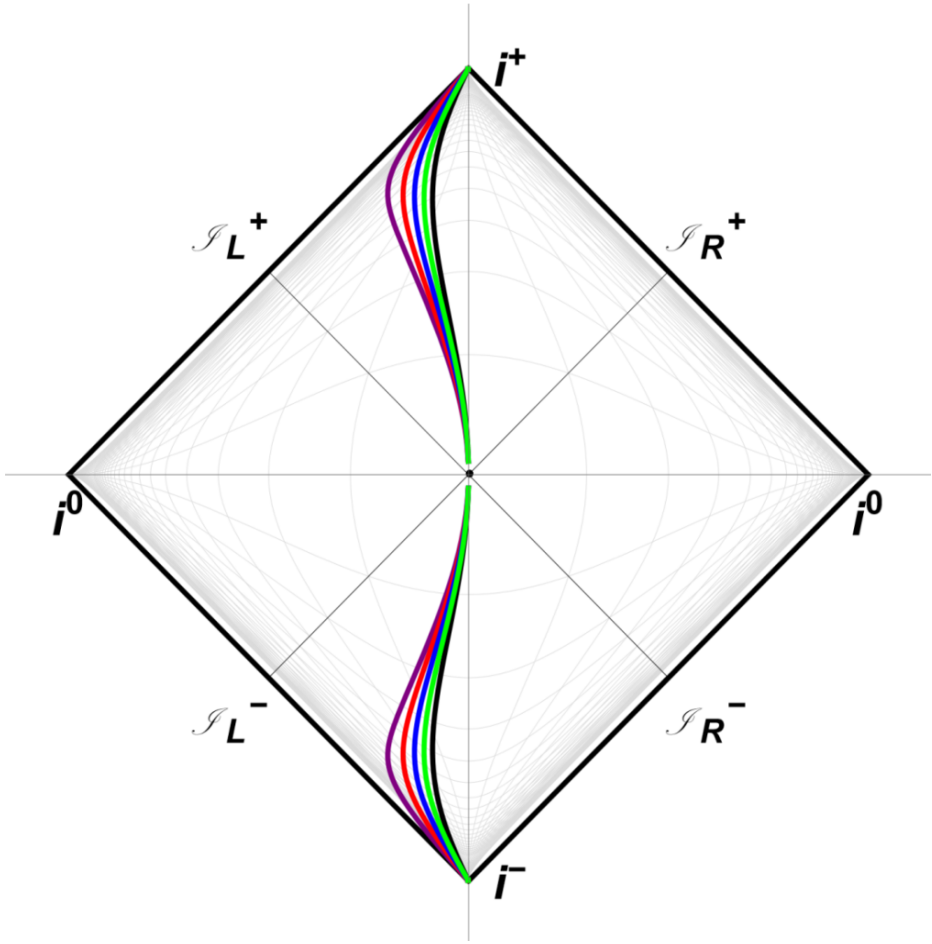
Asymptotic Static:

$$z(t) = -\frac{v}{\kappa}\ln(\kappa^2 t^2 + 1)$$

Two New Solutions: 2

BERKELEY CENTER *for* COSMOLOGICAL PHYSICS





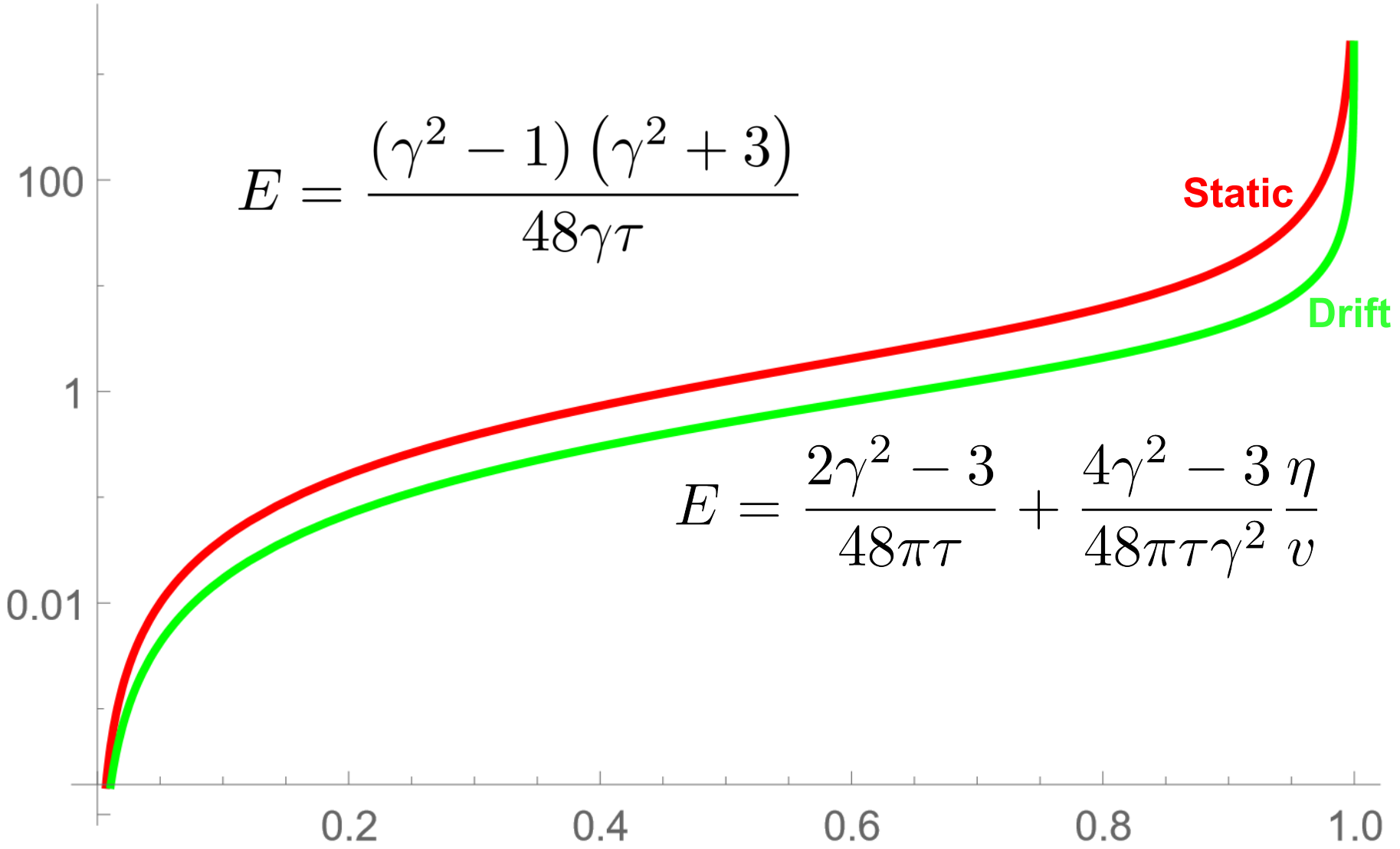
Asymptotic Drift:

$$z(t) = -\frac{v}{\kappa}\,\ln[\cosh \kappa t]$$

Total Energy

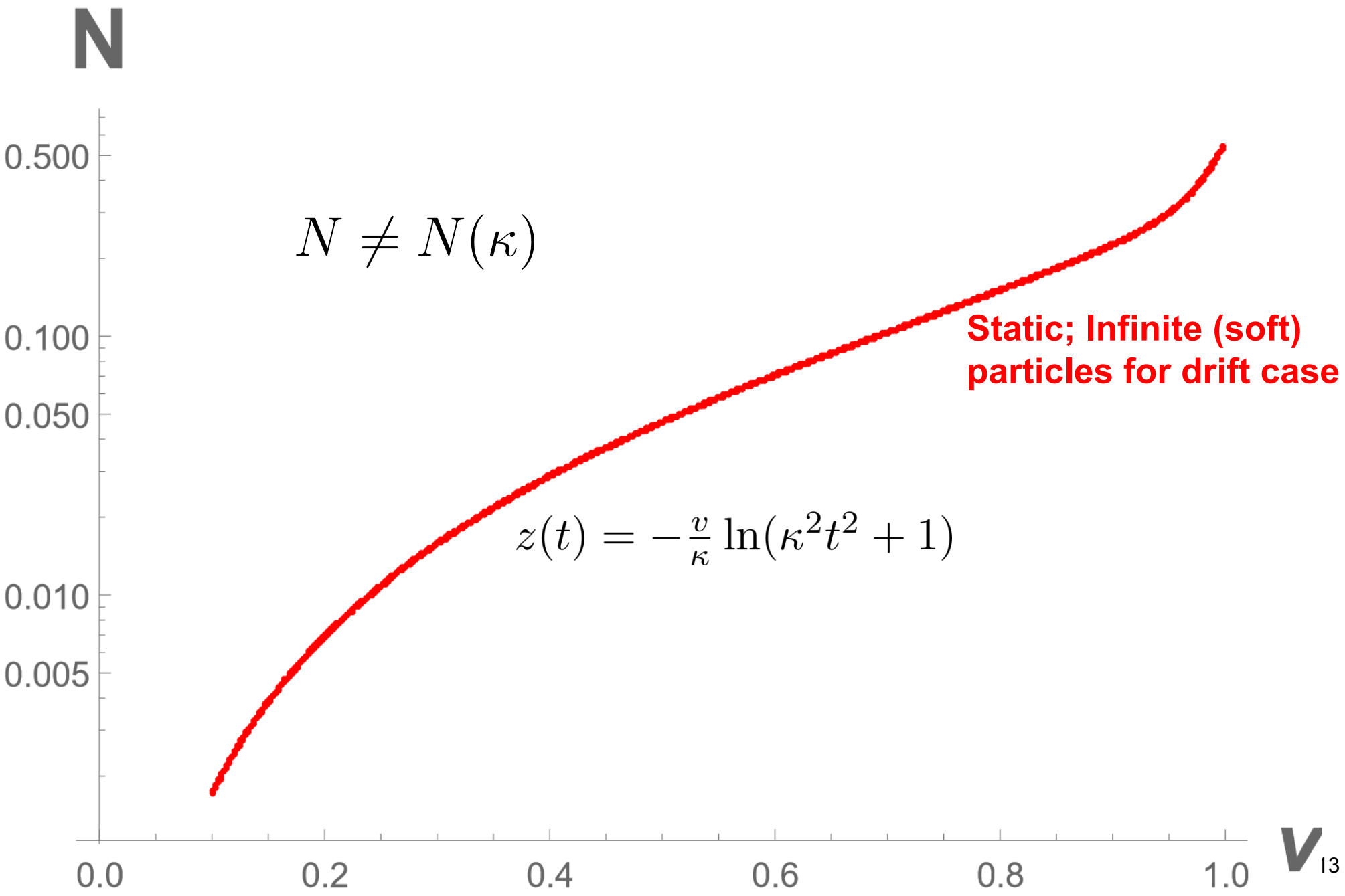
BERKELEY CENTER *for* COSMOLOGICAL PHYSICS

$$v \to 1 \qquad E \to \infty$$



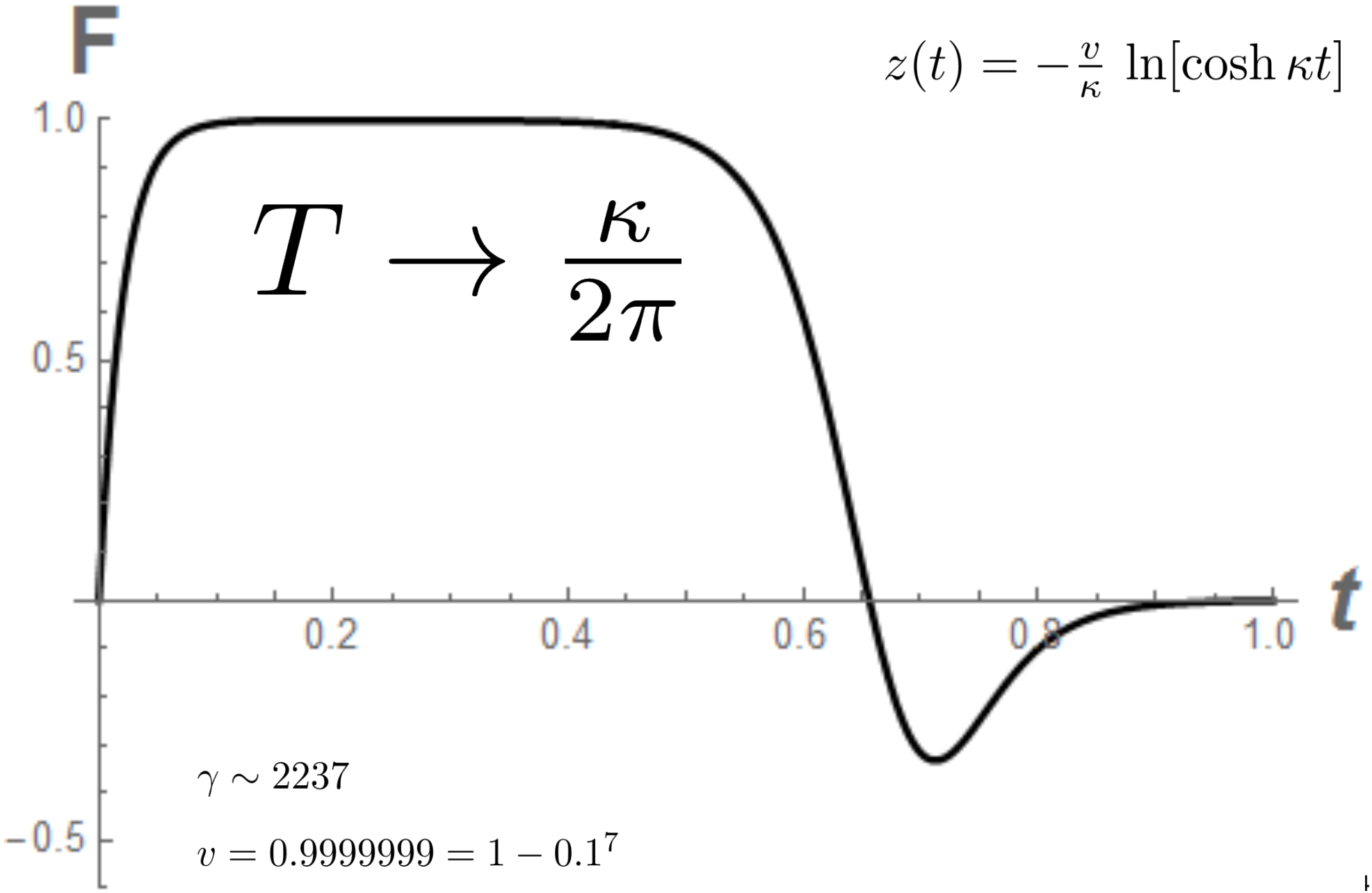
Total Particles

BERKELEY CENTER for COSMOLOGICAL PHYSICS



Thermal Emission

BERKELEY CENTER *for* COSMOLOGICAL PHYSICS



Future

BERKELEY CENTER *for* COSMOLOGICAL PHYSICS

Still much to explore:

Particle nature of thermal emission

Black hole evaporation vs black hole remnant

Analog to cosmic acceleration

Laboratory tests –

1. **Plasma mirrors (accelerated by lasers)**
   Chen & Mourou, PRL 2017
2. **Superconducting resonant circuits**
   Wilson+, Nature 2011