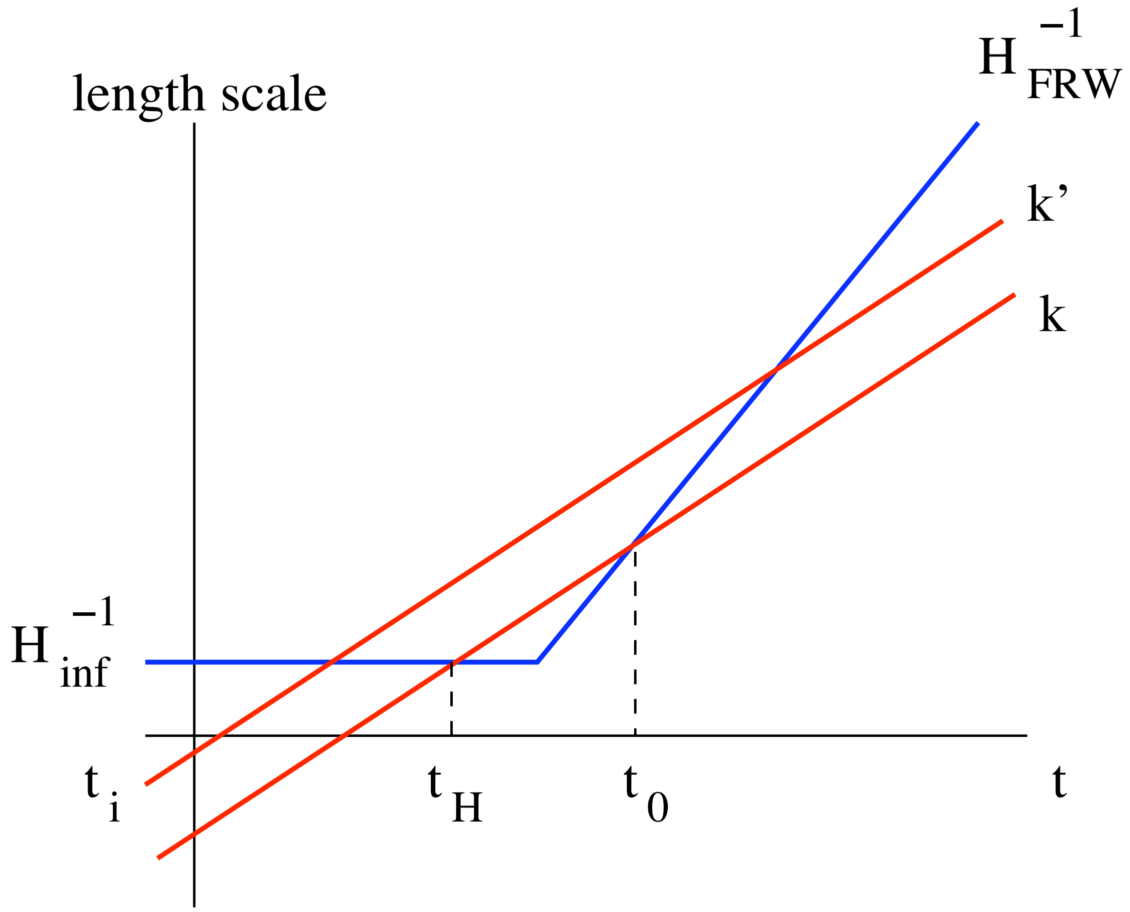
Island Universes

an alternate cosmological model

Tanmay Vachaspati

Inflationary Cosmology

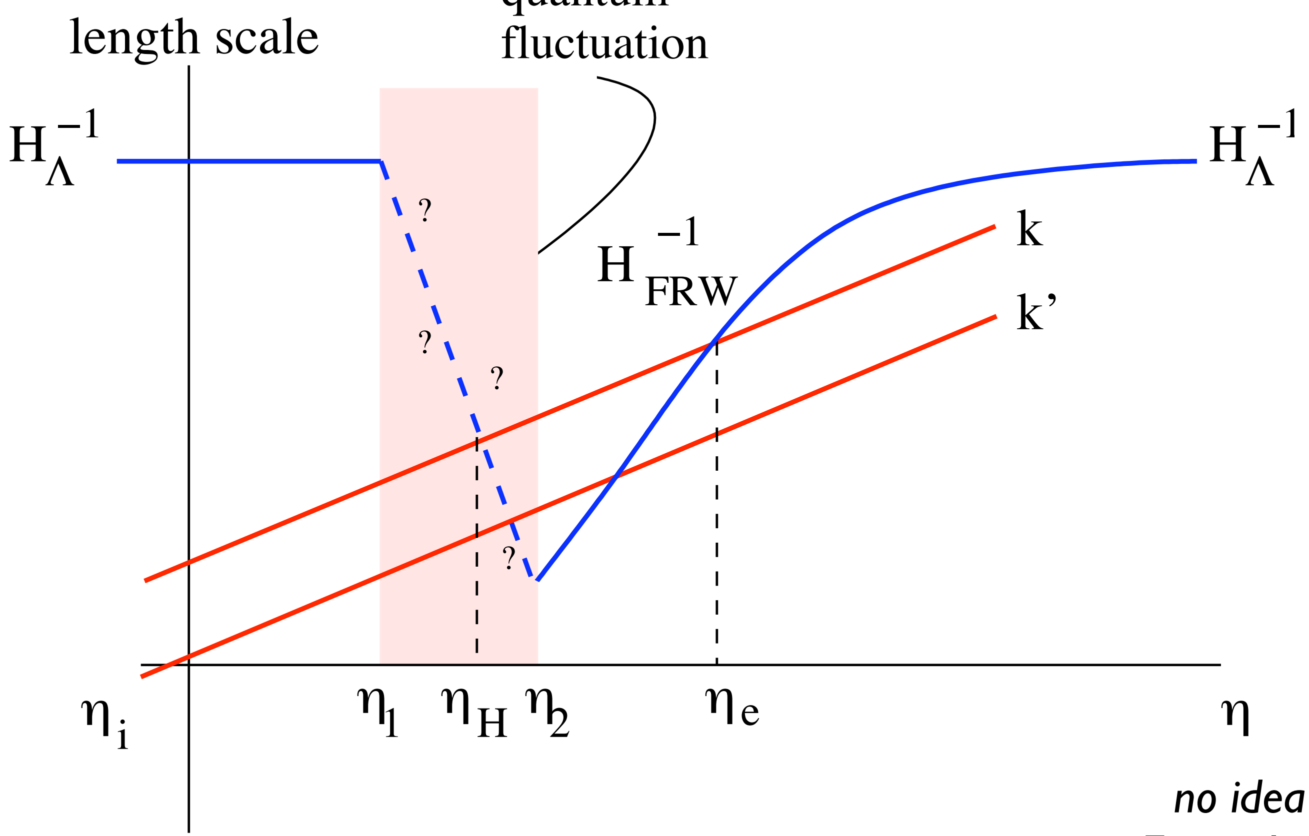


Guth


matter island
Lambda sea

Island cosmology

Sourish Dutta & TV



no idea is an island unto itself

Eternal inflation: Vilenkin; Linde

Recycling universe: Garriga and Vilenkin

Time symmetry: Carroll and Chen

Entropy: Dyson, Kleban and Susskind

Steady State: Bondi and Gold; Hoyle

Ekpyrotic: Khoury, Ovrut and Steinhardt

Quantum fluctuations

Decrease in Hubble length scale possible only if the Null Energy Condition (NEC) is violated.

$N^\mu N^\nu T_{\mu\nu} < 0$ or $\rho + p < 0$

Therefore quantum fluctuation needs to violate NEC.

Eternal inflation: Borde, Vilenkin

de Sitter space

$$\langle 0|N^\mu N^\nu \hat{T}_{\mu\nu}|0\rangle = 0$$

$$\langle 0|(N^\mu N^\nu \hat{T}_{\mu\nu})^2|0\rangle > 0$$

NEC violations

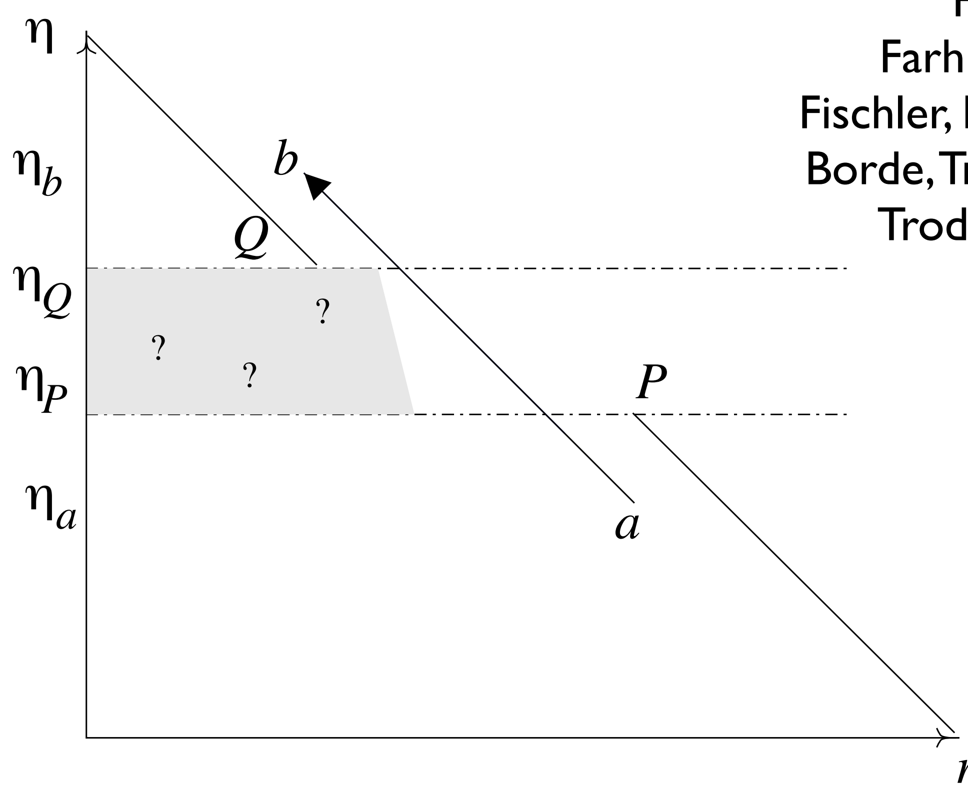
$$\hat{T}_{\mu\nu}|0\rangle = \sum[(\ldots)a_l a_k^\dagger + (\ldots)a_l^\dagger a_k^\dagger]\,|0\rangle$$
$$= \sum[(\ldots)|0\rangle + (\ldots)|2;k,l\rangle]$$

$$\hat{O}_W^{\rm ren} \equiv \int d^4x\sqrt{-g}\,W\,(x;R,T)\,N^\mu N^\nu \hat{T}_{\mu\nu}^{\rm ren}$$

$$O_{\rm rms}^2 \equiv \langle 0|(\hat{O}_W^{\rm ren})^2|0\rangle \sim H_\Lambda^8$$

Guth, Vachaspati, Winitzki

NEC violation: extent (R,T)

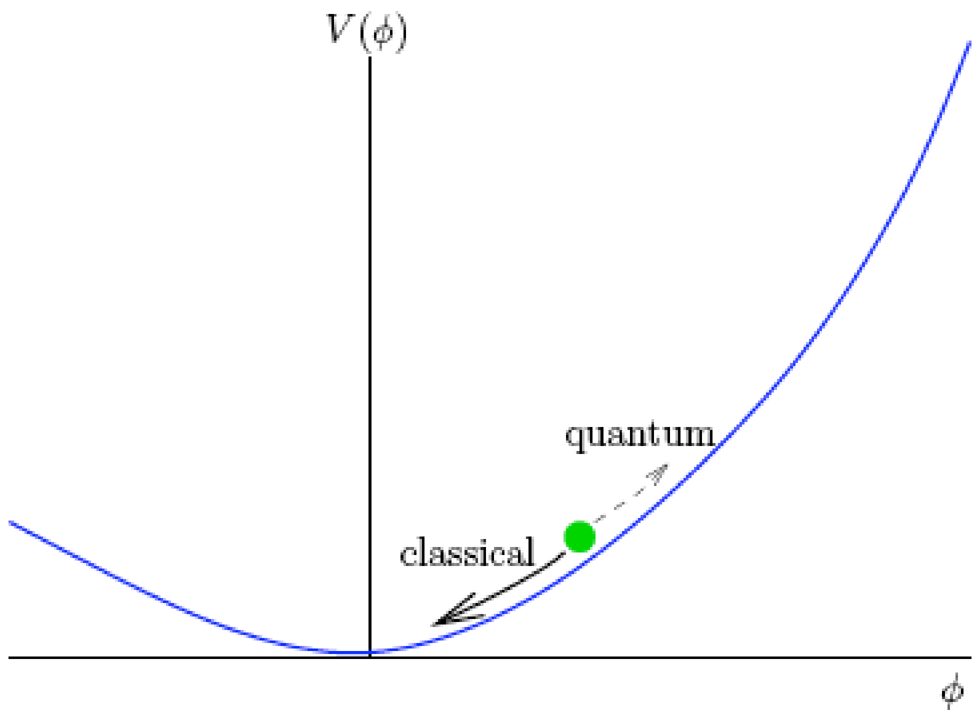


Context
Farhi and Guth;
Farhi, Guth and Guven;
Fischler, Morgan and Polchinski;
Borde, Trodden and Vachaspati;
Trodden and Vachaspati

$$R > H_i^{-1}\ ,\quad T \to 0$$

"sudden approximation"

Backreaction



Semiclassical gravity: $$G_{\mu\nu} = 8\pi G \langle \hat{T}^{\rm ren}_{\mu\nu} \rangle$$

... blind to rms NEC violations in de Sitter space

Backreaction: working hypothesis

$$\rho = \Lambda\ , \quad w = -1\ , \quad \eta < \eta_f$$

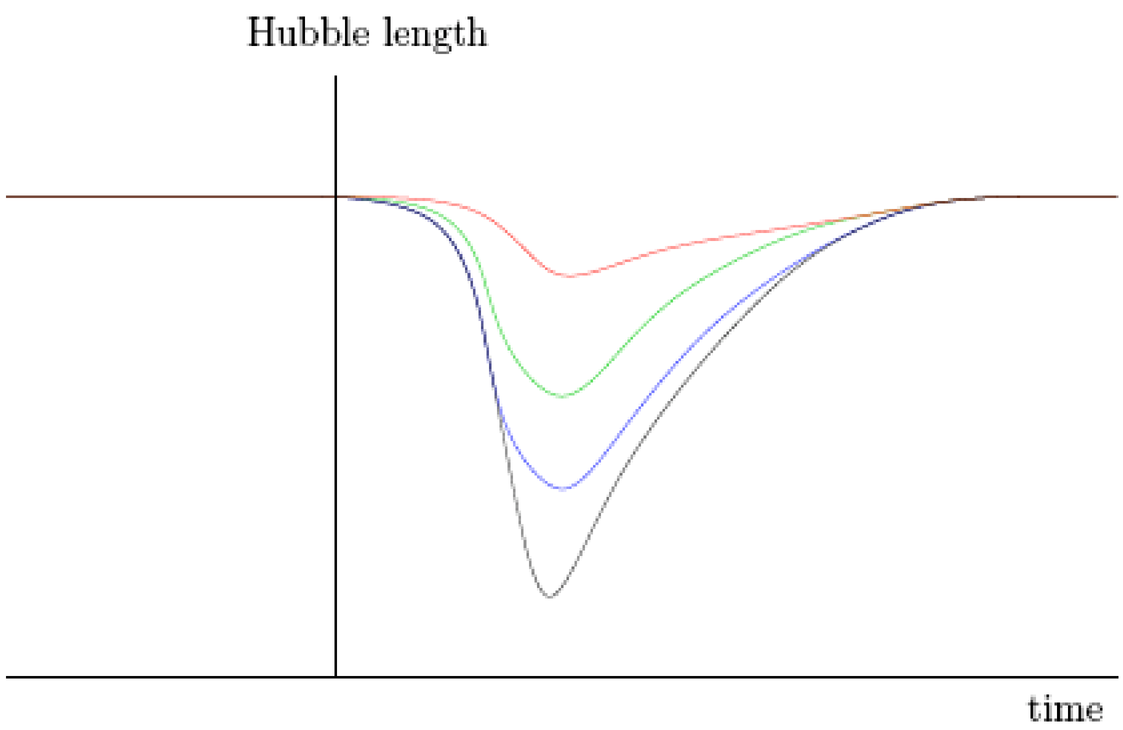
$$\rho = \rho_{\mathrm{FRW}}\ , \quad w = +\frac{1}{3}\ , \quad \eta > \eta_f$$

$$H^2 = \frac{8\pi G}{3}\rho$$ as in eternal inflation

Note: density needs to be positive even when NEC is violated.

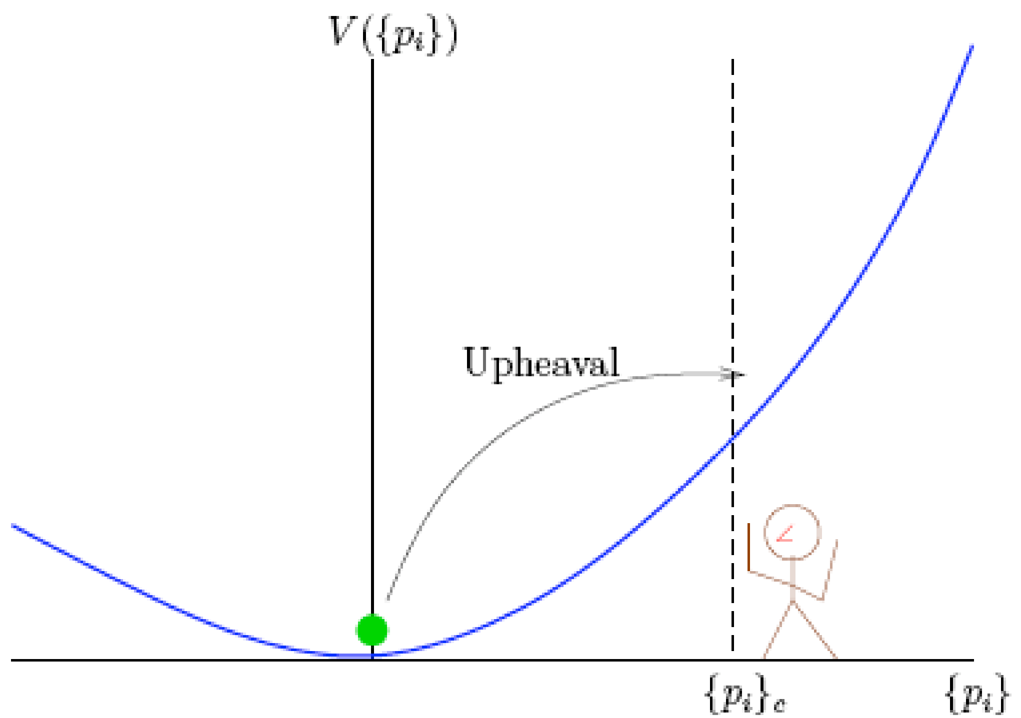
No spatial curvature: not a de Sitter invariant process;
continual expansion in FRW equation

NEC violation: amplitude



Habitable islands

Assumption: a "critical universe"



Critical parameter = baryon number?

Is baryogenesis critical?

Dai, Matsuo, Starkman, Vachaspati

NEC violation: sources

Scalar field

$$\hat{\rho} \;=\; \frac{1}{2}\dot{\phi}^2 + \frac{1}{2}(\boldsymbol{\nabla}\phi)^2 + V(\phi)$$

$$\hat{p} \;=\; \frac{1}{2}\dot{\phi}^2 - \frac{1}{6}(\boldsymbol{\nabla}\phi)^2 - V(\phi)$$

$$\hat{\rho} + \hat{p} = \dot{\phi}^2 + \frac{(\boldsymbol{\nabla}\phi)^2}{3}$$

Photon field

$$\hat{\rho} = \frac{1}{2}(\mathbf{E}^2 + \mathbf{B}^2)$$

$$\hat{p} = \frac{1}{6}(\mathbf{E}^2 + \mathbf{B}^2) = \frac{1}{3}\hat{\rho} \qquad \hat{\rho} + \hat{p} = \frac{4}{3}\hat{\rho}$$

More sources

Higgs, W, Z, etc.

Perturbation spectrum

Sudden approximation

Scalar field *not directly coupled* to NEC violating field

Mukhanov variable $$v_k(\eta) \equiv a(\eta)\chi_k(\eta)$$

Solve before and after $$v_k'' + \left(k^2 - \frac{a''}{a}\right)v_k = 0$$

Match $$v_k(\eta) \approx \frac{-i}{\sqrt{2k}} \frac{1}{(k\eta_f)^2} \frac{H_f}{H_\Lambda} \sin(k\eta)$$

Power spectrum $$\mathcal{P}_\chi(k, \eta_k) \approx \frac{H_\Lambda^2}{4\pi^2}$$

Density fluctuations

Scalar field *directly coupled* to NEC violating field

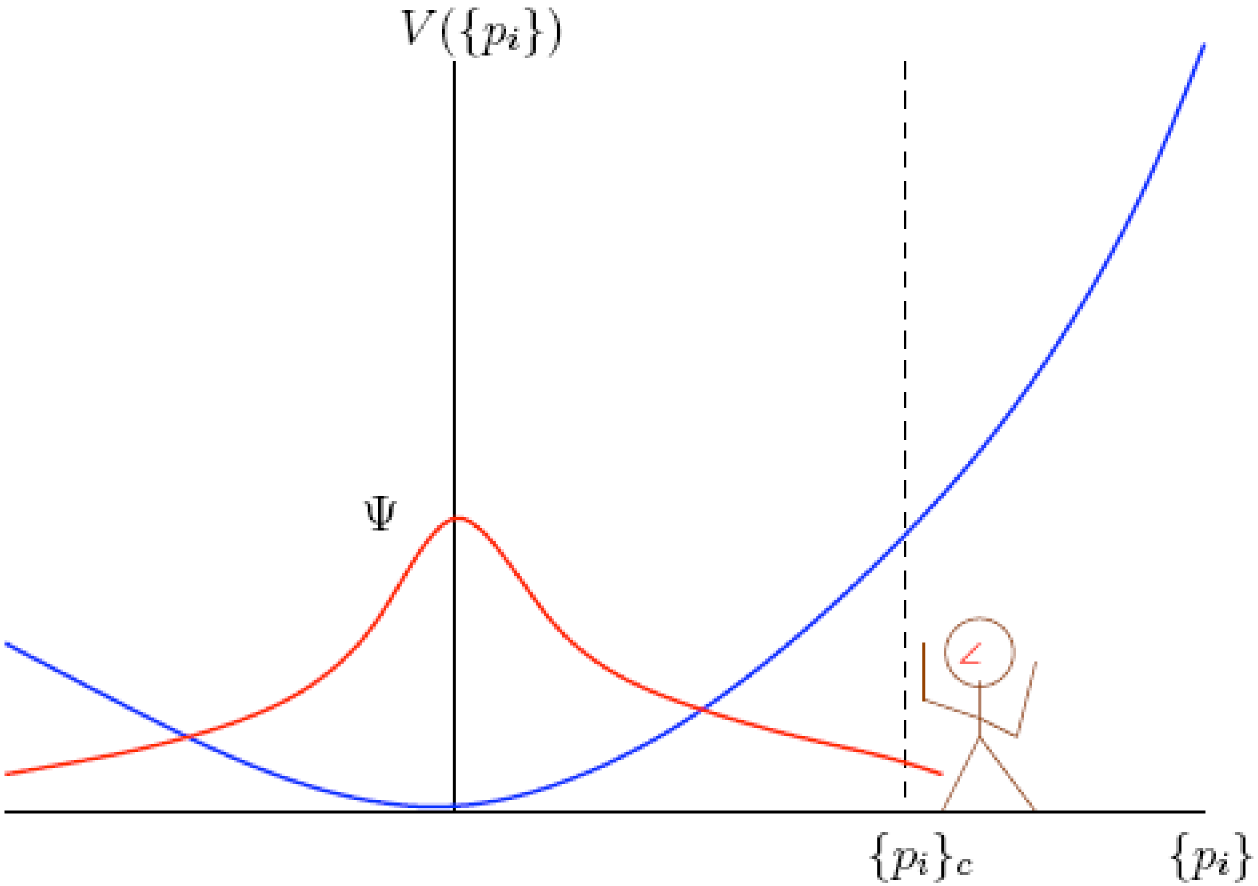
Assume *classical* phantom cosmology

Y. Piao
S. Dutta

Result:

Density fluctuations are also scale invariant with amplitude given by the Hubble scale at the end of the NEC violating fluctuation

Density fluctuations: quantum calculation

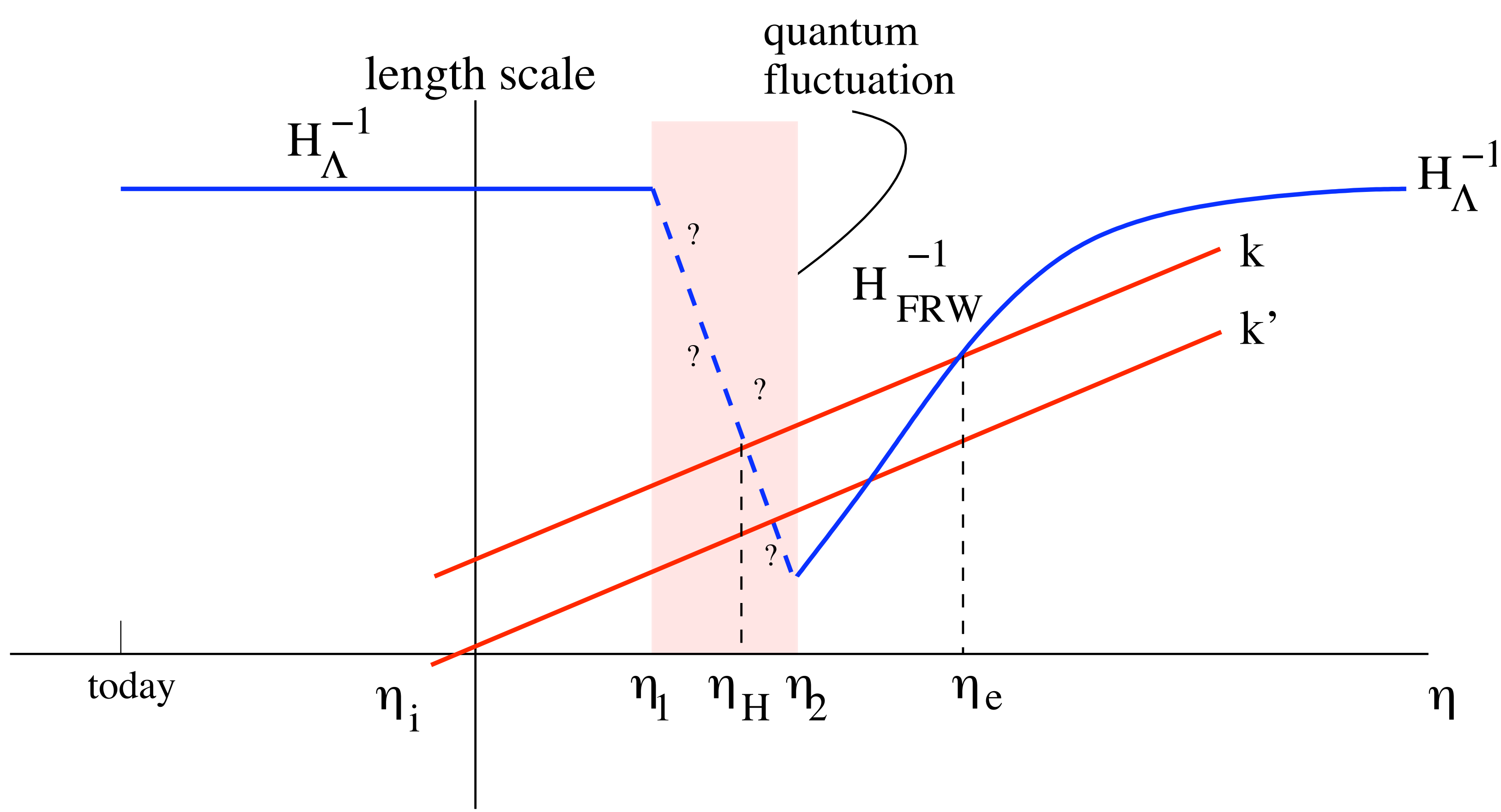


Similar to fluctuations produced during tunneling.

Vachaspati and Vilenkin

The future

not with a crunch, nor with a whimper



Island Cosmology

- Input: cosmological constant plus inevitable quantum processes
- Eternal/semi-eternal
- Cyclic: *the future is our past*
- Scale invariant but tiny tensor perturbations
- Density perturbations (promising based on classical calculations)
