Quantum field corrections to the cosmological free-streaming

Topics

- Quantum fields in curved spacetime
- Quantum statistical mechanics
- Robertson Walker Friedman spacetime

Based on:

- D. R. and F. Becattini: Class. Quant. Grav. 40 (2023) 17, 175007
- D. R. and F. Becattini: In preparation

daniele.roselli@unifi.it

Fluid in an expanding universe

RWF metric; $ds^2 = dt^2 - a^2(t)\left(dx^2 + dy^2 + dz^2\right)$

Perfect fluid; $T^{\mu\nu} = (\epsilon + p)u^\mu u^\nu - p g^{\mu\nu}$

energy density

pressure

Classical free-streaming

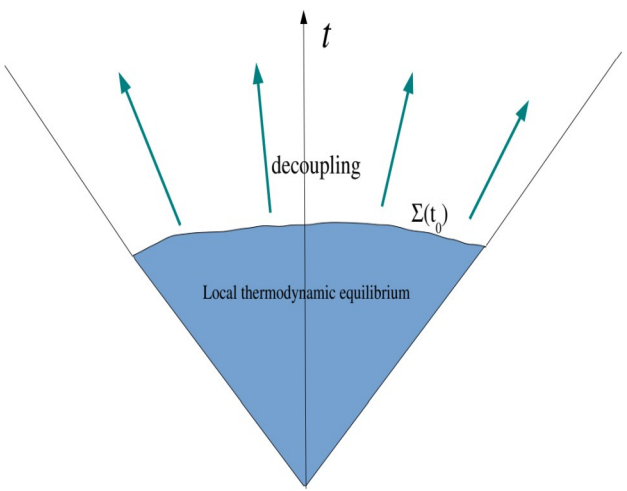
Boltzmann approach

$\epsilon \propto mN\, a^{-3}(t)$

$p \propto a^{-5}(t)$

Equation of state

$W = \frac{p}{\epsilon}, \quad W \geq 0$



Quantum theory

★ State of local thermodynamic equilibrium → LTE density operator

$\hat{\rho} = Z^{-1} \exp\left[-\hat{H}(t_0)/T(t_0)\right]$

$\left\langle \widehat{T_{\mu\nu}} \right\rangle = Tr\left[\hat{\rho}\,\widehat{T_{\mu\nu}}\right] - \left\langle 0 \middle| \widehat{T_{\mu\nu}} \middle| 0 \right\rangle$

depends on a(t) and its derivatives

★ Matter as a quantum field → $\hat{\phi} = \int d^3k \left(\hat{a}_k v_k e^{i\omega_k t} + c.c\right), \quad v''_k + \Omega_k^2 v_k = 0$

Free equation

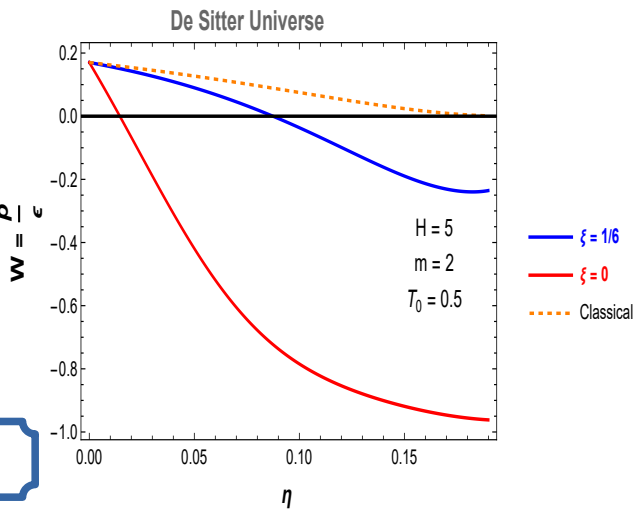
Quantum effects

- Energy density is enanched
- Pressure can become negative

Caveat

$H \gg m$

$H(t_0) \gg \sqrt{mT(t_0)}$



Finanziato dall'Unione europea
NextGenerationEU

Ministero dell'Università e della Ricerca

Italiadomani
PIANO NAZIONALE DI RIPRESA E RESILIENZA

UNIVERSITÀ DEGLI STUDI FIRENZE

Mauro Giliberti

PhD student at Università degli Studi di Firenze

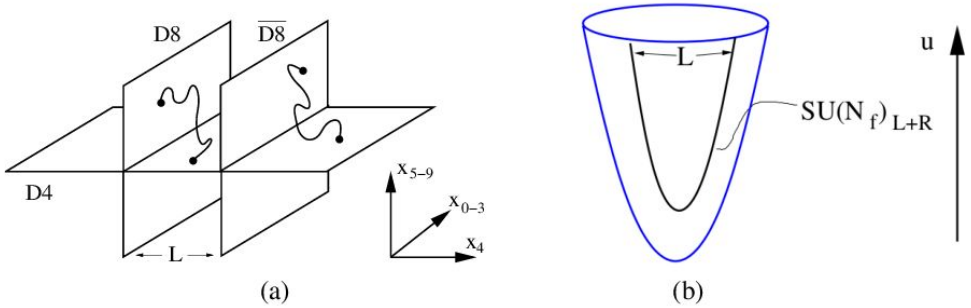
New Frontiers in Theoretical Physics

Numerical Study of Bubble Dynamics in Holographic Vacuum Decay

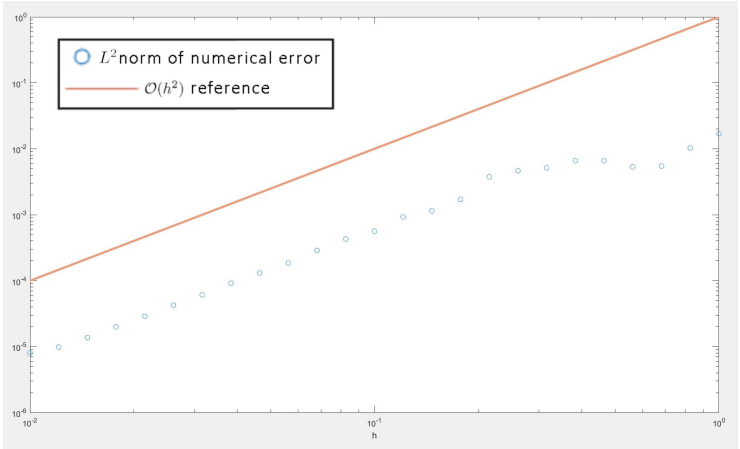
Finanziato dall'Unione europea NextGenerationEU
Ministero dell'Università e della Ricerca
Italiadomani PIANO NAZIONALE DI RIPRESA E RESILIENZA
UNIVERSITÀ DEGLI STUDI FIRENZE

Cosmological phase transition: chiral bubble nucleation with MATLAB

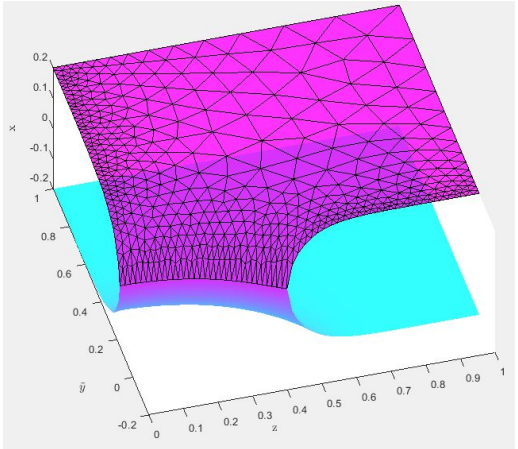
Holographic theory of **branes**: Witten-Sakai-Sugimoto model



Tests of **numerical** methods



Bubble transition profile

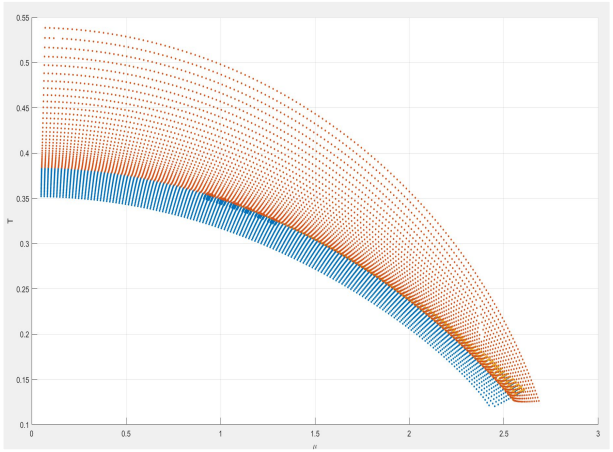
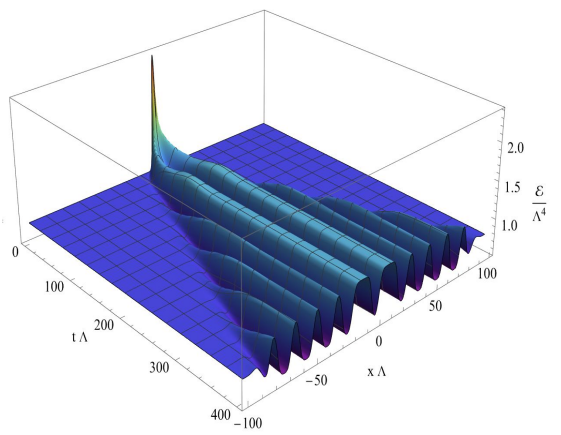


Astrophysical phase transition: finite-density bubble evolution with Julia

Holographic theory of metric-scalar-gauge

$$\mathcal{L} = \frac{1}{2\kappa^2}\left[R - \frac{f(\phi)}{4}F_{\mu\nu}^2 - \frac{1}{2}(\partial\phi)^2 - V(\phi)\right]$$

Finite-density **phase diagram**



Bubble **evolution** dynamics