BOUNCING COSMOLOGY FROM LQC WITH EKPYROTIC AND MATTER FIELDS

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In collaboration with Mateo Pascual Gomez-Cuétara and Francesca Vidotto

MATTER BOUNCE IN LQC

Wilson-Ewing (2013)

Matter content: perfect fluid

$$\mathcal{H}_m = \frac{p_\psi^2}{2v} + vV(\psi)\,, \qquad V(\psi) = \frac{V_0}{\cosh^2(A\psi)}$$ Mielczarek (2009)

Modified Friedmann equations

$$H^2 = \frac{8\pi G}{3}\rho\left(1 - \frac{\rho}{\rho_{crit}}\right)$$

Equation of state $w = 0 \implies$ scale-invariant scalar power spectrum...

MATTER BOUNCE IN LQC

Wilson-Ewing (2013)

Equation of state $w \lesssim 0 \implies$ almost scale-invariant scalar/tensor power spectra...

BUT

Equation of state $w \lesssim 0 \implies$ amplitude very small !

$$\rho_c \approx 10^{-9} \rho_{pl}$$

Unlikely... (+ anisotropies)

MATTER–EKPYROTIC BOUNCE

Li, Saini, Singh (2020)

Ekpyrotic scalar field + constant dust component

$$\mathcal{H}_m = \frac{p_\phi^2}{2v} + vU(\phi) + \rho_{\text{dust}} v \,, \qquad U(\phi) = \frac{-2U_0}{e^{-\alpha\phi} + e^{\beta\alpha\phi}}$$ Cai et al (2014)

Scalar index $\approx 1 \implies$ needs refinement

MATTER–EKPYROTIC BOUNCE WITH TWO FIELDS

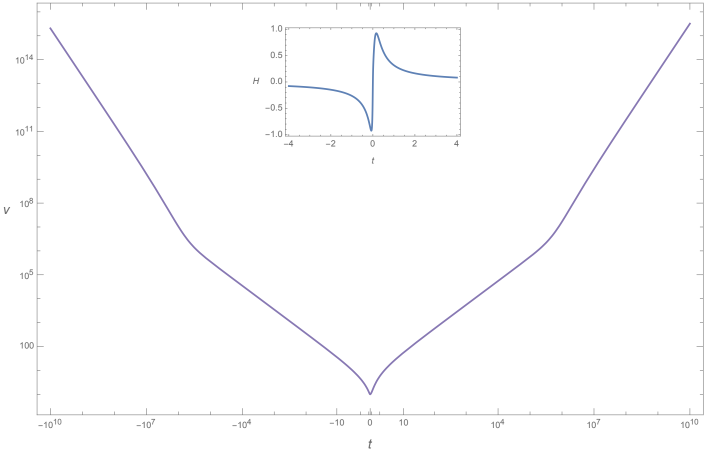
Current work!

Ekpyrotic scalar field + matter field with $w < 0$

$$\mathcal{H}_m = \frac{p_\phi^2}{2v} + vU(\phi) + \frac{p_\psi^2}{2v} + vV(\psi)\,, \qquad V(\psi) = \frac{V_0}{\cosh^2(A\psi)}$$

Mielczarek (2009)

BACKGROUND DYNAMICS



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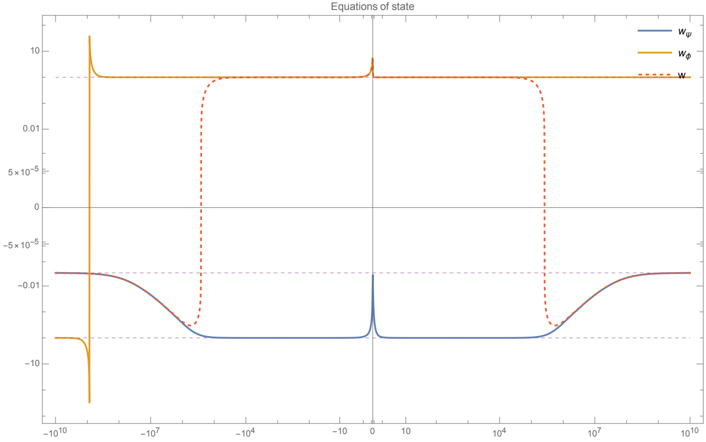

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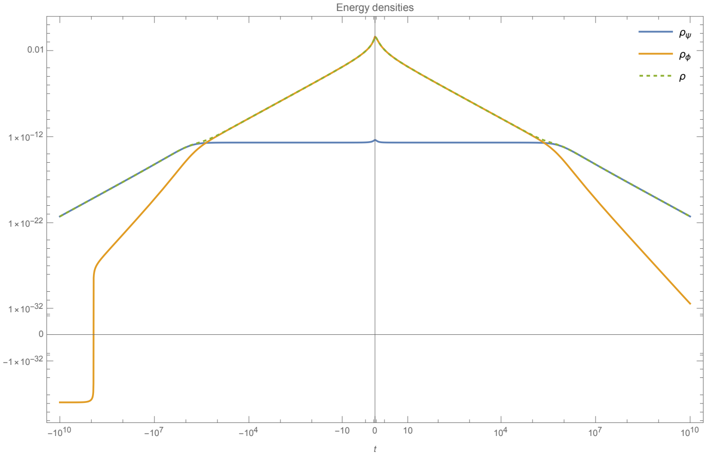

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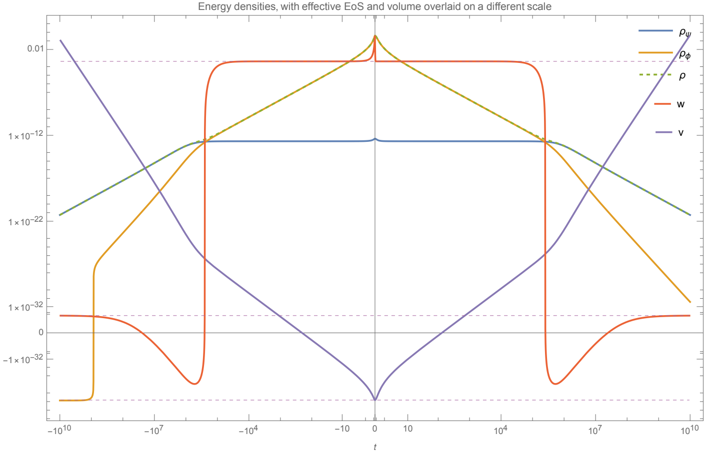

DRESSED METRIC FOR 2 FIELDS

Langlois (1994)

Dynamics in second-order Hamiltonian

$$H^{(2)} = \int \mathrm{d}^3x \left(N\mathcal{H}^{(2)} + N^i \mathcal{H}_i^{(2)} \right)$$

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M. Pascual (2024 to come!)

Gauge-invariant variables

$$\mathcal{Q}_\phi = M_p \left[\delta\phi + \frac{1}{\kappa a} \frac{p_\phi}{\pi_a} (3\gamma_1 - \gamma_2) \right] , \qquad \text{switch } \phi \to \psi \text{ for matter fluid .} \qquad (1)$$

PERTURBATIONS

M. Pascual (2024 to come!)

Linearly perturbed Klein-Gordon equation

$$\ddot{\mathcal{Q}}_i + 3H\dot{\mathcal{Q}}_i + k^2\mathcal{Q}_i + \sum_j \Omega_{ij}\mathcal{Q}_j = 0 \, .$$

with

$$\Omega_{ij} = 3\kappa\frac{p_i p_j}{a^6} - 9(1+\delta_{ij})\frac{p_i p_j}{a^8\pi_a^2}\sum_k p_k^2 - 6\frac{1}{a\pi_a}\left(p_i\frac{\partial U_j}{\partial j} + p_j\frac{\partial U_i}{\partial i}\right) + \frac{\partial^2 U_i}{\partial i^2}\delta_{ij} \, .$$

DRESSED METRIC FOR 2 FIELDS

Quantum gravity corrections (Li, Saini, Singh (2020))

$$\frac{1}{\pi_a^2} \to \frac{16\pi^2 G^2 \gamma^2 \lambda^2}{9a^4 \sin^2(\lambda b)}, \tag{2}$$

$$\frac{1}{\pi_a} \to \frac{-4\pi G \gamma \lambda \cos(\lambda b)}{3a^2 \sin(\lambda b)}. \tag{3}$$

WHAT'S NEXT?

- Power spectra through all phases
- Comparison with numerical solution
- Amplitude of entropic contributions
- Tensor power spectra

Ultimately: use this model to study dark matter! (Francesca's & Mateo's talks!)