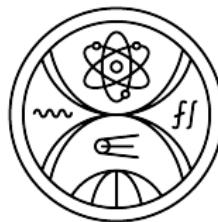


Effects of exotic solid-like matter in the post-inflationary Universe

[arXiv:1905.03544 — arXiv:2302.14480]



Peter Mészáros
Department of Theoretical Physics,
Comenius University, Bratislava



triplet of matter fields ϕ^i

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homogeneity and isotropy \leftarrow glob. rot. & trans. invariance

$$\phi^i \xrightarrow{\text{inv.}} R_j^i \phi^j + T^i \quad \begin{cases} R_j^i - \text{glob. rotations} \\ T^i - \text{glob. translations} \end{cases}$$

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three invariants

$$\mathcal{X} = \text{Tr}(\mathbf{B}), \quad \mathcal{Y} = \frac{\text{Tr}(\mathbf{B}^2)}{(\text{Tr}(\mathbf{B}))^2}, \quad \mathcal{Z} = \frac{\text{Tr}(\mathbf{B}^3)}{(\text{Tr}(\mathbf{B}))^3}, \quad \mathbf{B}^{ij} = g^{\mu\nu} \phi^i_{,\mu} \phi^j_{,\nu}$$

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relaxed configuration

$$\phi^i = \alpha x^i$$

Solid Matter

triplet of matter fields ϕ^i = body coordinates

homogeneity and isotropy \longleftrightarrow glob. rot. & trans. invariance

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B^{ij} = body metric

relaxed configuration

$$\phi^i = \alpha x^i$$

body coordinates \longleftrightarrow comoving coordinates

Solid matter in general relativity

- B. Carter, H. Quintana: *Foundations of General Relativistic High-Pressure Elasticity Theory*, Proc. Roy. Soc. Lond. A **57** 331, (1972)
- M. Bucher, D. N. Spergel: *Is the Dark Matter a Solid?*, Phys. Rev. D **60**, 043505 (1999), [arXiv:astro-ph/9812022]
- M. Karlovini, L. Samuelsson: *Elastic Stars in General Relativity: I. Foundations and Equilibrium Models*, Class. Quant. Grav. **20**, 3613 (2003), [arXiv:gr-qc/0211026]
- A. Gruzinov: *Elastic Inflation*, Phys. Rev. D **70**, 063518 (2004), [arXiv:astro-ph/0404548]
- S. Endlich, A. Nicolis, J. Wang: *Solid Inflation*, JCAP **1310**, 011 (2013), [arXiv:1210.0569]
- V. Balek, M. Škovran: *Effect of radiation-like solid on CMB anisotropies*, Class. Quant. Grav. **32**, 015015 (2015), [arXiv:1402.4434]

Inflation with solid

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solid inflation: $\mathcal{L}_m = F(\mathcal{X}, \mathcal{Y}, \mathcal{Z})$

Mészáros: JCAP 1909, 048 (2019) [arXiv:1905.03544]

solid + scalar field: $\mathcal{L}_m = -\frac{1}{2}g^{\mu\nu}\varphi_{,\mu}\varphi_{,\nu} + F(\varphi, \mathcal{X}, \mathcal{Y}, \mathcal{Z})$

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special solid inflation: $\mathcal{L}_m = -C\mathcal{X}^A$

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slow-roll—

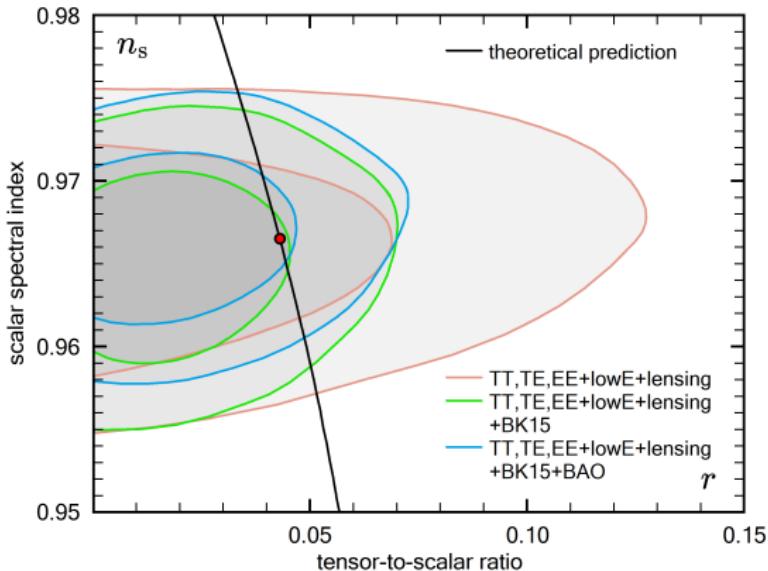
\mathcal{A} $p = \frac{M_{\text{Pl}}}{2} \left(\frac{W_{,\varphi}}{W} \right)^2$	\cdots special solid parameter \cdots scalar field parameter
--	---

Special solid inflation: $\mathcal{L}_m = -\mathcal{C} \mathcal{X}^{\mathcal{A}}$

$$n_S = 1 + \frac{2}{3}(1 + 2\mathcal{A})\mathcal{A} \quad \& \quad r = 16 \left(\frac{1 + 2\mathcal{A}}{3} \right)^{5/2} |\mathcal{A}|$$

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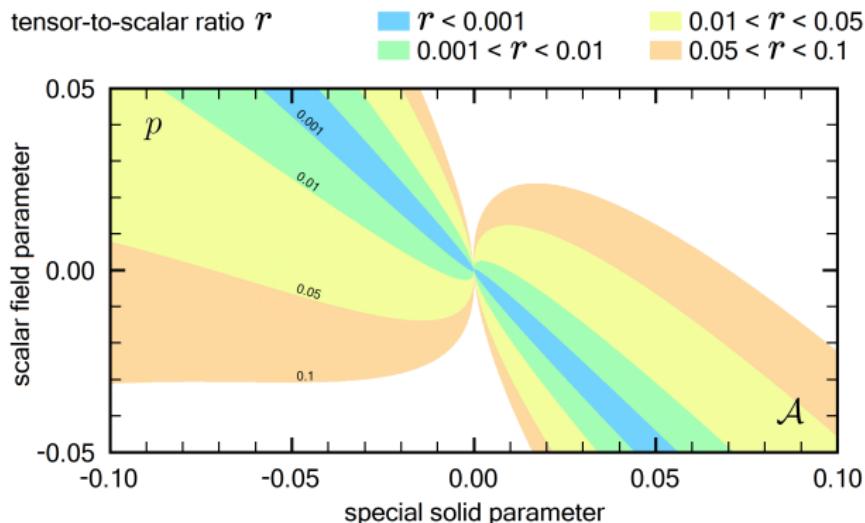
$$\mathcal{A} = -0.05667 \quad \longrightarrow \quad n_S = 0.9665 \quad \& \quad r = 0.04306$$

+ scalar field: $\mathcal{L}_m = -\frac{1}{2}g^{\mu\nu}\varphi_{,\mu}\varphi_{,\nu} - W(\varphi)\mathcal{A}$

$$r = \frac{16(1+2\mathcal{A})^{5/2}(\mathcal{A}+p)^2}{\left|9\sqrt{3}\mathcal{A} + (1+2\mathcal{A})^{5/2}p\right|}$$

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Solid remnant era: $\mathcal{L}_m = -\mathcal{C} \mathcal{X}^{\beta}$

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Solid remnant era: $\mathcal{L}_m = -\mathcal{C} \mathcal{X}^B$

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Solid remnant era: $\mathcal{L}_m = -\mathcal{C} \mathcal{X}^{\mathcal{B}}$

$$w = -1 + \frac{2}{3}\mathcal{B} \quad \longrightarrow \quad \text{ordinary background evolution}$$

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$$\varphi^i = \alpha \left(x^i + \zeta_{,i} + \xi_{\perp i} \right)$$

$$\left\{ \begin{array}{ll} \phi, \psi, \zeta, \delta, \tilde{\mathcal{R}}, \tilde{\xi} & \dots \text{ scalar} \\ S_i, \xi_{\perp i} & \dots \text{ vector} \\ \gamma_{ij} & \dots \text{ tensor} \end{array} \right\} \text{perturbations}$$

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!!! $B \in [-\frac{1}{2}, 11 - 4\sqrt{7}] \longleftrightarrow w \in \left[-\frac{4}{3}, \frac{19 - 8\sqrt{7}}{3} \right], w \leq -0.722\dots$

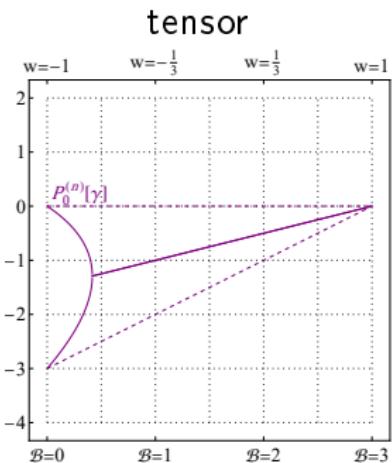
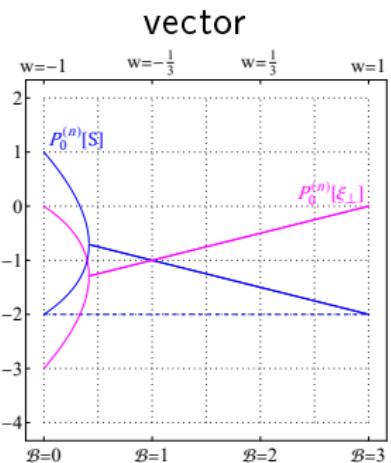
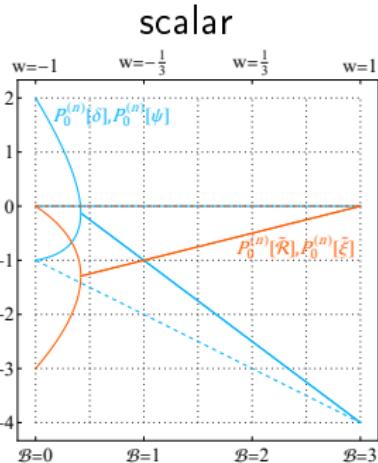
Results

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$$\left(\text{size of } (n)\text{-th mode of } [\chi] \text{ in superhorizon limit} \right) \propto a^{P_0^{(n)}} [\chi]$$

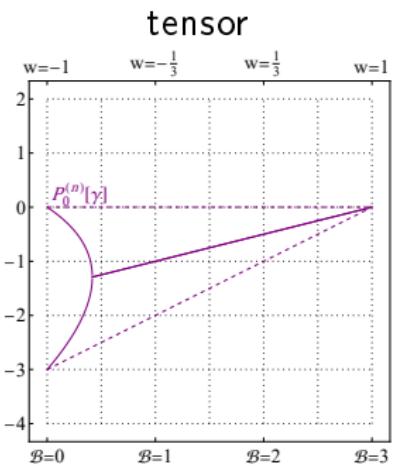
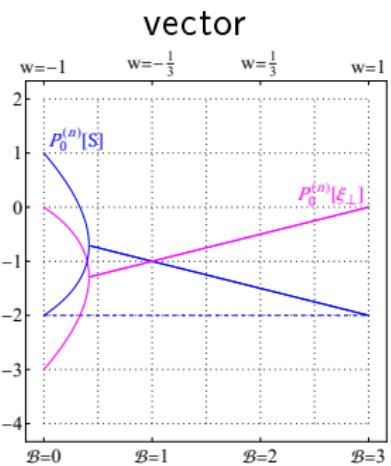
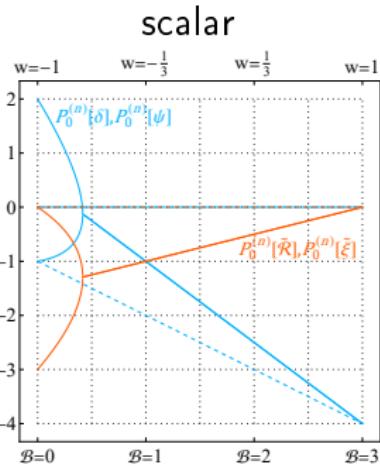
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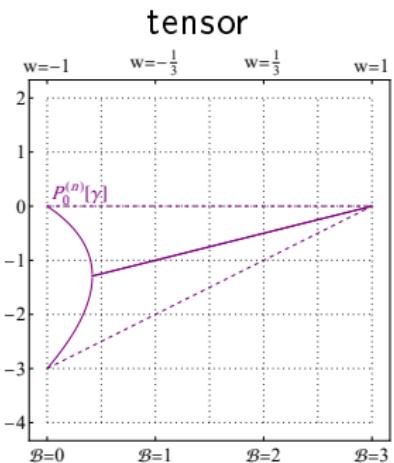
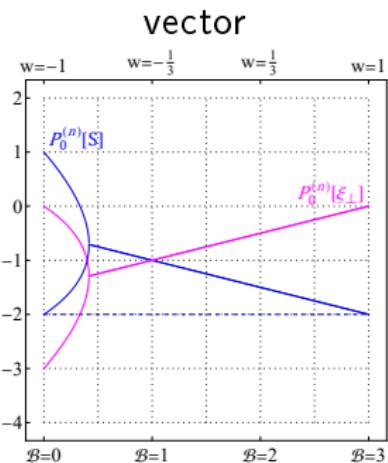
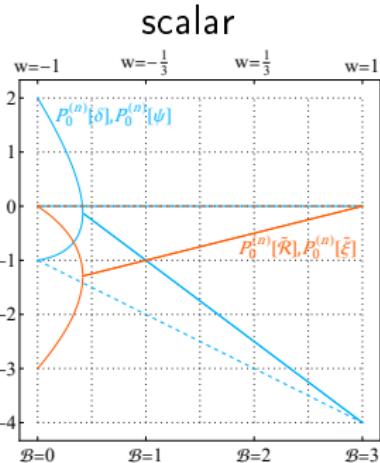


SUMMARY
[2302.14480]

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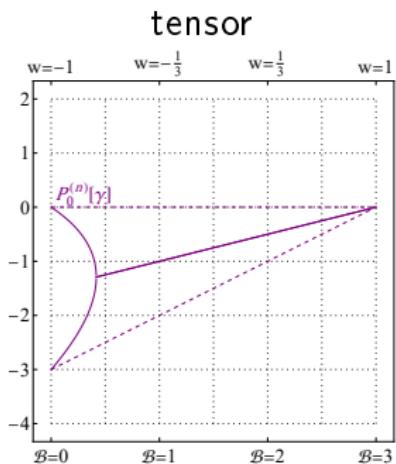
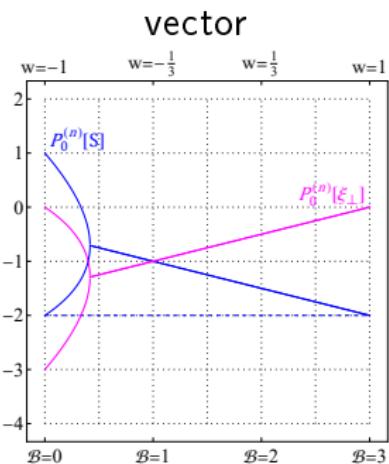
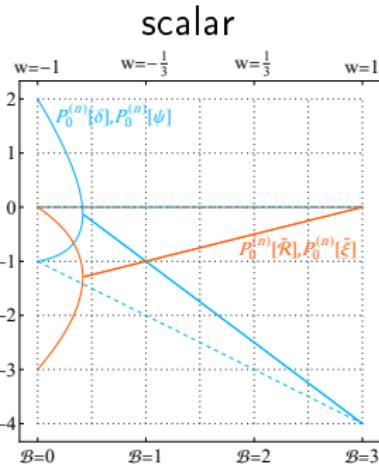


SUMMARY
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$$\left\{ \begin{array}{l} \mathcal{B} \leq 11 - 4\sqrt{7} \leftrightarrow w \leq \frac{19 - 8\sqrt{7}}{3} \doteq -0.722 \end{array} \right.$$

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SUMMARY
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$$\begin{cases} \mathcal{B} \leq 11 - 4\sqrt{7} \leftrightarrow w \leq \frac{19 - 8\sqrt{7}}{3} \doteq -0.722 \\ \text{growth of some superhorizon modes} \end{cases}$$