

the primordial Spectrum, which could (in principle) be identified as a fingerprint on the temperature distribution of the microwave background.

It remains as a future investigation objective to determine how general the proposed scenario is, for example by considering more general cosmological models like the Bianchi Universes [35]. Clearly, these cosmological frameworks can be reconciled to the isotropic late Universe by the inflationary de-Sitter phase [36], whose associated Spectrum should have a corrected morphology

which is expected to be similar to the one presented here.

ACKNOWLEDGEMENTS

G. B. would like to thank L. Falorsi and S. Segreto for useful insight and discussions. G. B. and A.M. also thank the TAsP Iniziativa specifica of INFN for their support.

-
- [1] G. Montani, M. V. Battisti, R. Benini, and G. Imponente, *Primordial Cosmology* (World Scientific, Singapore, 2009).
 - [2] S. Weinberg, *Gravitation and Cosmology: Principles and Applications of the General Theory of Relativity* (John Wiley and Sons, New York, 1972).
 - [3] E. W. Kolb and M. S. Turner, *The Early Universe* (Taylor and Francis, Boca Raton, 1990).
 - [4] E. M. Lifshitz and I. M. Khalatnikov, *Advances in Physics* **12**, 185 (1963).
 - [5] C. W. Misner, *Phys. Rev. Lett.* **22**, 1071 (1969).
 - [6] V. A. Belinsky, I. M. Khalatnikov, and E. M. Lifshitz, *Advances in Physics* **31**, 639 (1982).
 - [7] S. W. Hawking and R. Penrose, *Proceedings of the Royal Society of London A* **314**, 529 (1970).
 - [8] S. W. Hawking and R. Penrose, *The Nature of Space and Time* (Princeton University Press, Princeton, 1996).
 - [9] C. J. Isham, R. Penrose, and D. W. Sciama, *Quantum gravity; Proceedings of the Oxford Symposium, Harwell, Berks., England, February 15, 16, 1974* (Oxford University Press, Oxford, 1975).
 - [10] R. Benini and G. Montani, *Classical and Quantum Gravity* **24**, 387 (2006).
 - [11] E. Giovannetti and G. Montani, *Physical Review D* **106**, 10.1103/physrevd.106.044053 (2022).
 - [12] A. Ashtekar and P. Singh, *Classical and Quantum Gravity* **28**, 10.1088/0264-9381/28/21/213001 (2011).
 - [13] A. Corichi, T. Vukašinac, and J. A. Zapata, *Physical Review D* **76**, 044016 (2007).
 - [14] G. Barca, E. Giovannetti, and G. Montani, *Universe* **7**, 327 (2021).
 - [15] F. Bombacigno, S. Boudet, G. J. Olmo, and G. Montani, *Physical Review D* **103**, 10.1103/physrevd.103.124031 (2021).
 - [16] G. F. R. Ellis and R. Maartens, *Classical and Quantum Gravity* **21**, 223 (2003).
 - [17] G. F. R. Ellis, J. Murugan, and C. G. Tsagas, *Classical and Quantum Gravity* **21**, 233 (2003).
 - [18] N. Aghanim et al (Planck Collaboration), *Astronomy and Astrophysics* **641**, 92 (2020).
 - [19] N. Aghanim et al (Planck Collaboration), *Astronomy and Astrophysics* **641**, 67 (2020).
 - [20] E. Di Valentino, A. Melchiorri, and J. Silk, *Nature Astronomy* **4**, 10.1038/s41550-019-0906-9 (2019).
 - [21] W. Handley, *Phys. Rev. D* **103**, L041301 (2021).
 - [22] G. Barca, E. Giovannetti, and G. Montani, *International Journal of Geometric Methods in Modern Physics* **19**, 2250097 (2022).
 - [23] V. F. Mukhanov, H. A. Feldman, and R. H. Brandenberger, *Physics Reports* **215**, 203 (1992).
 - [24] G. Montani, C. Mantero, F. Bombacigno, F. Cianfrani, and G. Barca, *Physical Review D* **99**, 063534 (2019).
 - [25] M. V. Battisti, *Physical Review D* **79**, 083506 (2009).
 - [26] M. Maggiore, *Physics Letters B* **304**, 65 (1993).
 - [27] A. Kempf, G. Mangano, and R. B. Mann, *Physical Review D* **52**, 1108 (1995).
 - [28] S. Segreto and G. Montani, preprint (2022).
 - [29] D. Brizuela, C. Kiefer, and M. Krämer, *Physical Review D* **93**, 104035 (2016).
 - [30] H. R. Lewis Jr, *Journal of Mathematical Physics* **9**, 1976 (1968).
 - [31] H. R. Lewis Jr and W. B. Riesenfeld, *Journal of Mathematical Physics* **10**, 1458 (1969).
 - [32] I. Pedrosa, *Physical Review A* **55**, 3219 (1997).
 - [33] J. Martin and R. H. Brandenberger, *Physical Review D* **63**, 123501 (2001).
 - [34] S. S. Seahra, I. A. Brown, G. M. Hossain, and V. Husain, *Journal of Cosmology and Astroparticle Physics* **10**, 020 (2008).
 - [35] G. Montani, M. V. Battisti, R. Benini, and G. Imponente, *International Journal of Modern Physics A* **23**, 10.1142/s0217751x08040275 (2008).
 - [36] A. A. Kirillov and G. Montani, *Phys. Rev. D* **66**, 10.1103/PhysRevD.66.064010 (2002).