

Poster prizes

Congratulations to all!

The jury had a very hard time...

Suspense...

Third prize: Fabio Bernardo & Philipp Schicho

Limits of EFTs at finite temperature for strong phase transitions

Fabio Bernardo¹, Philipp Klose², Philipp Schicho³
¹Université de Genève
²Swiss National Science Foundation
³Universität Amsterdam, ⁴University of Helsinki

Introduction

Phase transitions are violent remaking phenomena that could have occurred in the early stage of the Universe, interests gravitational wave signal. The main parameters from which we can learn about the gravitational signal of these phenomena are a transition temperature T_c and a critical value λ_c of the effective potential $V(\phi)$ (at the zero of the wall velocity). One of the main ingredients to determine these is the Effective Potential $V(\phi)$, in many models, is a scalar field background

$$\text{const} \left(-\frac{1}{2} g^2 |\partial_\mu \phi|^2 \right) + \int d^d x \text{Tr} \left[\partial_\mu \phi^\dagger \partial_\mu \phi + \mu^2 |\phi|^2 + \lambda |\phi|^4 \right] \quad (1)$$

When the temperature is close to its critical value T_c , at which the phase transition occurs, it is possible to identify a hierarchy of scales, which allows the construction of the Effective Field Theory (EFT) and to predict the large scale effects.

First, it is possible to perform a **dimensional reduction** [3], which consists of an expansion around the critical point λ_c and T_c . This expansion leads to the Wilson coefficients of a 3-dimensional theory. Then, it is possible to perform successive EFTs by integrating out additional degrees of freedom. In this process, the theory remains unaffected, but the number of degrees of freedom decreases, even more than in the dimensional reduction.

Model Ad Lagrangian

SETUP A: $\mathcal{L}_{\text{eff}} = \mathcal{L}_{\text{kin}} + \text{perturbations}$
SETUP B: $\mathcal{L}_{\text{eff}} = \mathcal{L}_{\text{kin}} + \text{perturbations}$

Effects of higher-dimensional operators

By considering the effect of higher-dimensional operators:

$$V^{(d)}(\phi) = \frac{1}{2} g^2 \phi^2 + \frac{1}{120} (\partial_\mu \phi)^2 (\lambda \phi^2 + \lambda_2 \phi^4) + \frac{1}{4!} \lambda_3 \phi^6 \quad (2)$$

$$V^{(d+1)}(\phi) = \frac{1}{2} g^2 \phi^2 + \frac{1}{120} (\partial_\mu \phi)^2 (\lambda \phi^2 + \lambda_2 \phi^4) + \frac{1}{4!} \lambda_3 \phi^6 + \frac{1}{5!} \lambda_4 \phi^8 \quad (3)$$

Figure 2 shows the effects of the $d=7$ -operator become relevant for small values of ϵ . The smaller ϵ is, the stronger the corrections.

The limits of the EFT approach

The EFT provides reliable results as long as the main dynamics is encoded in the leading lower-dimensional scenario, while the contributions of higher-dimensional operators are suppressed. If the higher-dimensional operators are dominant, the EFT becomes unreliable. To estimate the validity of the EFT, one needs to compare the temperature T with the scale where the higher-dimensional operators become relevant. Therefore, the EFT is valid only if the thermal scale is too far apart. On the other hand, if the thermal scale is too close to the scale where the higher-dimensional operators are relevant, the EFT becomes unreliable. The EFT breaks down when the thermal scale is comparable to the effects of the higher-dimensional operators. The figure shows the limits of the EFT approach.

Conclusion

The EFT is shown to be robust for strong transitions. Corrections from higher-dimensional operators are taken robust for strong transitions. Corrections from higher-dimensional operators are taken into account for transitions strong enough.

References

[1] Fabio Bernardo, Philipp Klose, and Philipp Schicho, “Limits of EFTs at finite temperature for strong phase transitions,” *JHEP*, vol. 2022, no. 05, p. 055, May 2022. [https://doi.org/10.1007/JHEP05\(2022\)055](https://doi.org/10.1007/JHEP05(2022)055)

[2] Fabio Bernardo, Philipp Klose, and Philipp Schicho, “Bubble nucleation with shifting scale hierarchies,” *JHEP*, vol. 2022, no. 05, p. 056, May 2022. [https://doi.org/10.1007/JHEP05\(2022\)056](https://doi.org/10.1007/JHEP05(2022)056)

[3] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[4] K. G. Wilson and J. B. Kogut, “The Renormalization Group and the燤ean-Field Theory of Strongly Interacting Fermion Systems,” *Phys. Rep.*, vol. 12, no. 3, pp. 75–199, 1974. [https://doi.org/10.1016/0370-1573\(74\)90093-9](https://doi.org/10.1016/0370-1573(74)90093-9)

[5] S. Weinberg, “The Quantum Theory of Fields, Vol. 1: Foundations,” Cambridge University Press, Cambridge, UK, 1995.

[6] M. Lüscher, “Chiral Perturbation Theory,” *Rev. Mod. Phys.*, vol. 54, no. 2, pp. 274–306, 1982. <https://doi.org/10.1103/RevModPhys.54.274>

[7] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[8] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[9] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[10] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[11] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[12] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[13] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[14] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[15] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[16] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[17] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[18] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[19] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[20] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[21] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[22] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[23] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[24] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[25] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[26] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[27] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[28] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[29] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[30] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[31] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[32] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[33] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[34] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[35] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[36] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[37] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[38] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[39] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[40] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[41] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[42] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[43] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[44] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[45] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[46] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[47] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[48] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[49] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[50] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[51] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[52] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[53] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[54] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[55] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[56] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[57] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[58] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[59] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[60] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[61] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[62] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[63] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[64] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[65] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[66] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[67] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[68] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[69] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[70] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[71] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[72] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[73] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. [https://doi.org/10.1016/0550-3213\(85\)90296-7](https://doi.org/10.1016/0550-3213(85)90296-7)

[74] J. Gasser, H. Leutwyler, and E. Poggio, “Chiral Perturbation Theory and the Nucleon Form Factors,” *Nucl. Phys. B*, vol. 250, no. 3, pp. 469–500, 1985. <a href="https://doi.org/10.1016/0550-3213(85)90296-

Suspense...

Second prize: Guglielmo Frittoli

TESTING GRAVITY WITH CROSS-CORRELATIONS OF CMB AND LSS

G. FRITTOLO^{1,2}, G. BENEVENTO^{1,2}, M. MIGLIACCIO^{1,2}, N. BARTOLO^{1,4}

We aim to test gravity models exploring the additional information retained in the cross-correlations of CMB and the Large Scale Structure. In order to describe gravity, we adopt the Effective Field Theory of Dark Energy approach, which encapsulates a general modification of the theory without being bound to a specific model. In this framework, we use the EFTCAMB Boltzmann code to compute theoretical angular power spectra and the Fisher Information Matrix to forecast the ability to constrain cosmological parameters with present and future surveys.

Effective Field Theory (EFT) of Dark Energy

In EFT, a powerful framework that describes dark energy and modified gravity, the action recovers all single-field models in the regime where the slow-roll approximation is applicable. The DE action is written directly in terms of the perturbations of the metric field around a FRW solution:

$$S = \frac{1}{2} \int d^4x \sqrt{-M_0(t)} [(\bar{R} - \bar{R}_0) + \bar{M}_0(t) \bar{R}_0^{(1)} + \bar{M}_0(t) \bar{R}_0^{(2)} + \bar{M}_0(t) \bar{R}_0^{(3)}]$$

Each operator is responsible for distinctive dynamical features in the evolution of the scalar perturbations.

At present, we specialised our study to the case of the Transient Planck Mass (TPM), which is defined by a direct choice of the operator of the EFT action:

Fisher Forecasts (FF)

The information on a vector of cosmological parameter θ_i that can be obtained from a subset M of all the auto and cross-spectra can be estimated via the Fisher Information Matrix F_{ijL} with L the total mode, and the expectation value evaluated at the fiducial values θ_{fid} :

$$F_{ijL} = \frac{\partial^2 \ln(L)}{\partial \theta_i \partial \theta_j} \Big|_{\theta=\theta_{fid}}$$

$(F^{-1})^{ijL} = R_{ijL}$ is the inverse of the diagonal elements reads the i,j marginalized covariance matrix on each parameter.

We include a multiple set of nuisance parameters:

- Gravity bias
- Magnification bias
- Redshift alignment
- Shear bias

We also considered the Fisher matrix for CMB+LSS with a Fisher matrix for Type Ia SNe since they are additive.

EFTCAMB & FF Code

EFTCAMB is an extension of the publicly available Einstein-Boltzmann code EFTCAMB implements the EFT approach, and it allows to:

- Add the linear cosmological perturbations in a model independent fashion.
- Add specific single scalar field DE/NG models as the mapping EFT procedure.
- Perform the full perturbation equations on all linear scales without any numerical approximations.
- Check the stability conditions of perturbations.
- Check the evolution history by choosing a DE equation of state.

We built a Fisher Forecast code in Python!

It interacts directly with EFTCAMB. However, it can accept any spectra from files.

We modified EFTCAMB to include Intrinsic Alignment for the EFT.

- A file for the selection of specific probes (include or exclude probe).
- A file for the selection of the multigauge gauge in which the probe is considered.

Transitional Planck Mass (TPM) Model

To obtain the TPM action we restrict our choice to the set of EFT functions that allow for a constant modification of the gravitational constant. We take the speed of gravitational waves to be constant and equal to the speed of light.

$$s = \left(\frac{dt}{dx} \right)^2 \frac{d[\phi]}{dx} [(1 + \alpha H) + \dot{\alpha} - \dot{\alpha} \Omega^2 \phi^2] = \frac{M_{P0}^2}{M_{P0}^2 + \alpha^2 \phi^2}$$

We consider a modified-gravity model that allows for a phenomenological shift (model as a step-like function) in the effective Planck mass. We can set the EFT-function as:

$$D(x) = \frac{m_p}{2} \left(1 - \text{erf} \left(\frac{\ln(x) - x_0}{\sqrt{2}} \right) \right), \quad c(t) = c_0 = \frac{M_P^2(t)}{3H_0^2 m_p^2}$$

The background evolution of the TPM model fixes $\dot{\alpha}(t)$ and $H(t)$, and can be described through an effective fluid with density and pressure:

$$\rho_{eff} = 2c - 2(1 - 3\ln(H^2(t) + 1)), \quad P_{eff} = 8\pi m_p^2 \left[\dot{\alpha}^2 + \dot{\alpha}^2 \left(\frac{H^2}{H_0^2} + 2 \right) + \dot{\alpha} \left(\frac{H^2}{H_0^2} + 3 \right) \right]$$

The cosmology is parametrized by the 6 ADE parameters. The c_0 parameter is relevant for the evolution at late time, and the 2 parameters describing the shift are relevant for the evolution at early time ($D_0 = c_0 - 3m_p^2$)

Forecasts Results

We consider Planck-like and Euclid-like survey, with a combined CMB+LSS+SN type Ia for future surveys. We can see an improvement on σ_8 and b below, otherwise unmeasurable.

CMB+CMB+SN	1.8	2.5	3.2	4.0	4.4	5.0	5.5	6.1	6.8	7.5	8.1	9.0
CMB+CMB+LSS+SN	2.9	2.6	2.10	1.9	2.3	2.7	3.2	3.9	4.6			
CMB+CMB+LSS	2.4	2.2	2.10	1.8	2.1	1.6	1.6	0.8	4.2			
CMB+CMB+GG	1.8	1.8	2.10	1.3	1.7	1.3	1.9	4.0	2.7			
CMB+CMB+WL	1.4	1.3	2.10	1.2	1.3	1.2	2.5	4.8	2.5			
CMB+GG+CMB+GG	1.2	1.1	1.1	1.0	1.1	1.0	1.7	1.2	3.2			
CMB+WL+CMB+WL	1.5	1.3	1.5	1.1	1.3	1.0	2.3	1.1	1.0			
LSS+CMB+LSS+LSS+SN	1.4	1.1	1.2	1.0	1.1	1.0	2.2	1.6	1.2			
LSS+LSS+LSS	1.8	1.4	2.6	1.9	1.3	1.0	2.3	2.1	1.3			

DATA

EMAIL: guglielmo.frittoli@roma2.inaf.it

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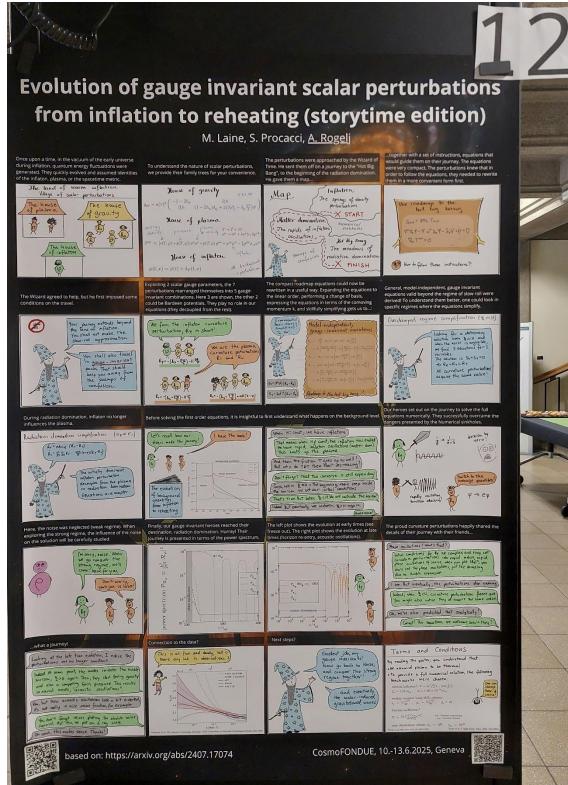
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Congratulations

COSMO Fondue

Suspense...

First prize: Alicia Rogelj



Congratulations!

Thank you for participating!

**Thank you for all the amazing
contributions!**

A big thank you to all!

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Davide Perrone,

Ajith Sampath,

Alica Rogelj,

Stylianios Papadopoulos,

Eloi Andriamihatra Rakoto,

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Omar Darwish

CERN guides:

Fredrik Olof,

Andre Parnefjord,

Davide Perrone,

Elias Waagaard

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Secretaries:

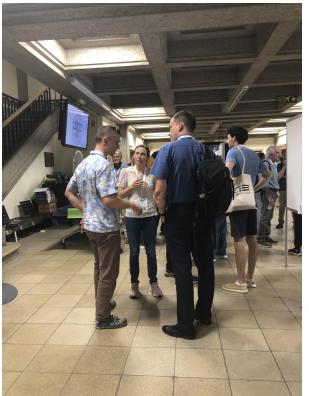
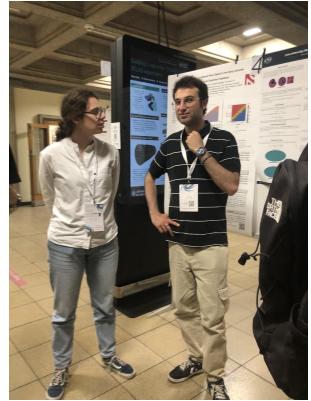
Corinne,
Angela

Technician:

Sandro

A big thank you to all!





COSMOFondue





COSMO *Fondue*



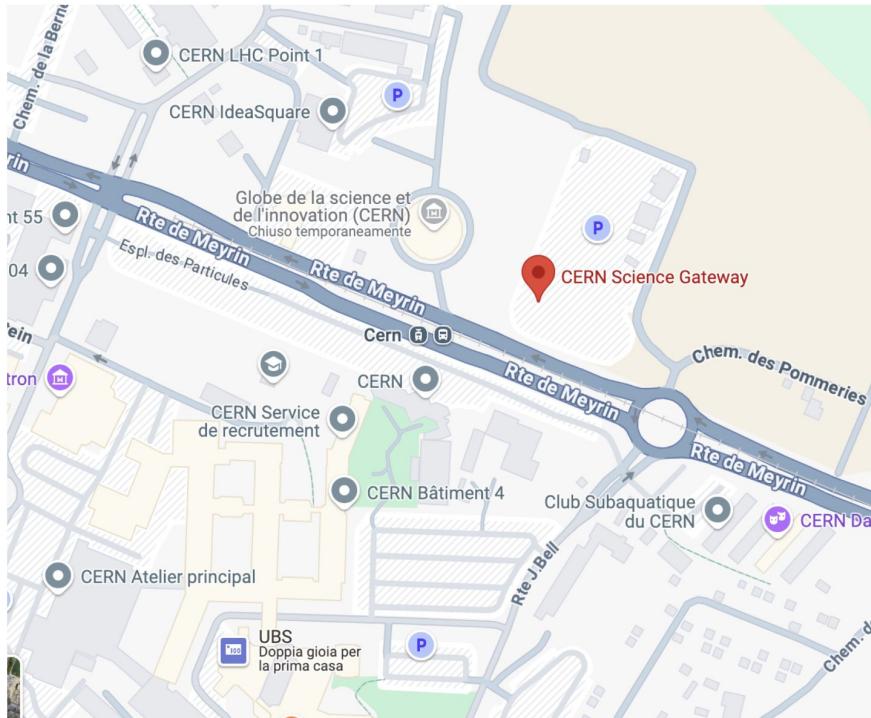


COSMO *Fondue*



CERN tour

Meeting point at the CERN Science Gateway at 2:30pm



14:30 - 15:30 visit of the museum
15:30 - 16:00 collection of visitor badges
16:00 - 18:00 visit of the experimental sites