Snowmass2021 Letter of Interest: Primordial Nongaussianities and the Consistency Relations for Large Scale Structure

Maximilian H. Abitbol,[1] Paolo Creminelli,[2] Angelo Esposito,[3] Garrett Goon,[4] Kurt Hinterbichler,[5] Lam Hui,[6] Austin Joyce,[7] Alex Kehagias,[8] Justin Khoury,[9] Marco Marinucci,[10] Takahiro Nishimichi,[11] Enrico Pajer,[12] Massimo Pietroni,[10] Roman Scoccimarro,[13] and Patrick Valageas[14]

[1] *Department of Physics, University of Oxford, Keble Road, Oxford, UK OX1 3RH*
[2] *Abdus Salam International Centre for Theoretical Physics Strada Costiera 11, 34151, Trieste, Italy*
[3] *Theoretical Particle Physics Laboratory (LPTP), Institute of Physics, EPFL, 1015 Lausanne, Switzerland*
[4] *Department of Physics, Carnegie Mellon University, 5000 Forbes Ave, Pittsburgh, PA 15217, USA*
[5] *CERCA, Department of Physics, Case Western Reserve University, 10900 Euclid Ave, Cleveland, OH 44106*
[6] *Department of Physics, Center for Theoretical Physics, Columbia University, 538W 120th Street, New York, NY, 10027, USA*
[7] *Institute of Physics, University of Amsterdam, Amsterdam, 1098 XH, The Netherlands*
[8] *Physics Division, National Technical University of Athens 15780 Zografou Campus, Athens, Greece*
[9] *Center for Particle Cosmology, Department of Physics and Astronomy, University of Pennsylvania, 209 South 33rd St., Philadelphia, PA 19104*
[10] *Dipartimento di Scienze Matematiche, Fisiche ed Informatiche dell'Università di Parma, Parco Area delle Scienze 7/a, I-43124, Parma, Italy*
[11] *Center for Gravitational Physics, Yukawa Institute for Theoretical Physics, Kyoto University, Kyoto 606-8502, Japan*
[12] *Department of Applied Mathematics and Theoretical Physics, Centre for Mathematical Sciences, University of Cambridge, Wilberforce Road, Cambridge CB3 0WA, UK*
[13] *Center for Cosmology and Particle Physics, Department of Physics, New York University, NY 10003, New York, USA*
[14] *IPhT, CEA Saclay, 91191 Gif-sur-Yvette, France*

Contact Information

Submitter name and institution: Angelo Esposito, École Polytechnique Fédérale de Lausanne
Contact email: angelo.esposito@epfl.ch

Thematic Areas

- (CF04) Cosmic Frontier: Dark Energy and Cosmic Acceleration: the Modern Universe
- (CF05) Cosmic Frontier: Dark Energy and Cosmic Acceleration: Cosmic Dawn and Before
- (TF09) Theory Frontier: Astro-particle Physics & Cosmology

Letter of Interest

The question about the initial conditions of our Universe is one of the central ones in modern cosmology, and it is yet unanswered. Several efforts have tried for decades to determine whether primordial fluctuations are consistent with what is expected from single-field inflation or if additional light degrees of freedom played any role, or, even more radically, if some other mechanism was at work.

In the standard approach to this problem one only considers linear or mildly nonlinear data (i.e. at large enough scales), where theoretical predictions are reliable—see e.g. [1] for a review. Data in the fully nonlinear regime (say with momentum $k \gtrsim 0.2\ h/\text{Mpc}$ for large scale structure) are typically discarded, despite the fact that they are copious and measured with high precision.

A possible way to employ such fully nonlinear data is through the so-called "consistency relations". First pointed out by Maldacena in the context of inflation with single clock initial conditions [2], and later studied in great detail (see e.g. [3–15]), they are exact identities between different correlators. In particular, they connect the N-point correlator of a given observable in the sky (temperature, matter density, etc.), to the $(N+1)$-point correlator in the limit where the additional leg has momentum soft compared to the others (the so-called "squeezed" limit).

Of particular relevance is the development of consistency relations for large scale structures (see e.g. [16–27]), which have been shown to be potentially crucial in determining, for example, large scale halo bias [28] and growth rate [29] in a model independent way. Crucially, the same consistency relations apply to biased tracers as well [30, 31] with important consequences for real observational data.

The validity of consistency relations for fully nonlinear data has been verified in [32], using N-body simulations for the matter density. In the same work it was also shown that applying consistency relations to the squeezed limit of the bispectrum it is possible to determine whether or not the initial conditions for the matter fluctuations are consistent with single-field inflation.

The road towards a realistic application of consistency relations to future observations is still rather long, but a successful program in this direction has the potential of substantially improving our constraints on primordial non-gaussianities by including nonlinear data.

With this Letter of Interest we encourage the discussion on the topic, and the synergy of this proposal with future white papers dedicated to large scale structures and primordial non-gaussianities.

[1] F. Bernardeau, S. Colombi, E. Gaztanaga, and R. Scoccimarro, Phys. Rept. **367**, 1 (2002), arXiv:astro-ph/0112551 [astro-ph].
[2] J. M. Maldacena, JHEP **05**, 013, arXiv:astro-ph/0210603 [astro-ph].
[3] S. Weinberg, Phys. Rev. D **67**, 123504 (2003), arXiv:astro-ph/0302326.
[4] P. Creminelli, J. Norea, and M. Simonović, JCAP **1207**, 052, arXiv:1203.4595 [hep-th].
[5] S. Endlich, B. Horn, A. Nicolis, and J. Wang, Phys. Rev. D **90**, 063506 (2014), arXiv:1307.8114 [hep-th].
[6] K. Hinterbichler, L. Hui, and J. Khoury, JCAP **1401**, 039, arXiv:1304.5527 [hep-th].
[7] V. Assassi, D. Baumann, and D. Green, JCAP **11**, 047, arXiv:1204.4207 [hep-th].
[8] A. Kehagias and A. Riotto, Nucl. Phys. B **864**, 492 (2012), arXiv:1205.1523 [hep-th].
[9] W. D. Goldberger, L. Hui, and A. Nicolis, Phys. Rev. **D87**, 103520 (2013), arXiv:1303.1193 [hep-th].
[10] L. Hui, A. Joyce, and S. S. Wong, JCAP **02**, 060, arXiv:1811.05951 [hep-th].
[11] E. Pajer, F. Schmidt, and M. Zaldarriaga, Phys. Rev. D **88**, 083502 (2013), arXiv:1305.0824 [astro-ph.CO].
[12] B. Finelli, G. Goon, E. Pajer, and L. Santoni, Phys. Rev. D **97**, 063531 (2018), arXiv:1711.03737 [hep-th].
[13] E. Pajer and S. Jazayeri, JCAP **03**, 013, arXiv:1710.02177 [astro-ph.CO].
[14] G. Cabass, E. Pajer, and D. van der Woude, JCAP **08**, 050, arXiv:1805.08775 [astro-ph.CO].
[15] S. Jazayeri, E. Pajer, and D. van der Woude, JCAP **06**, 011, arXiv:1902.09020 [hep-th].
[16] A. Kehagias and A. Riotto, Nucl. Phys. **B873**, 514 (2013), arXiv:1302.0130 [astro-ph.CO].
[17] M. Peloso and M. Pietroni, JCAP **1305**, 031, arXiv:1302.0223 [astro-ph.CO].
[18] P. Creminelli, J. Noreña, M. Simonović, and F. Vernizzi, JCAP **12**, 025, arXiv:1309.3557 [astro-ph.CO].
[19] P. Creminelli, J. Gleyzes, M. Simonović, and F. Vernizzi, JCAP **02**, 051, arXiv:1311.0290 [astro-ph.CO].
[20] P. Creminelli, J. Gleyzes, L. Hui, M. Simonović, and F. Vernizzi, JCAP **06**, 009, arXiv:1312.6074 [astro-ph.CO].
[21] M. Peloso and M. Pietroni, JCAP **04**, 011, arXiv:1310.7915 [astro-ph.CO].
[22] B. Horn, L. Hui, and X. Xiao, JCAP **1409** (09), 044, arXiv:1406.0842 [hep-th].
[23] T. Nishimichi and P. Valageas, Phys. Rev. **D90**, 023546 (2014), arXiv:1402.3293 [astro-ph.CO].
[24] C. Wagner, F. Schmidt, C.-T. Chiang, and E. Komatsu, JCAP **08**, 042, arXiv:1503.03487 [astro-ph.CO].
[25] M. Biagetti, T. Lazeyras, T. Baldauf, V. Desjacques, and F. Schmidt, Mon. Not. Roy. Astron. Soc. **468**, 3277 (2017), arXiv:1611.04901 [astro-ph.CO].
[26] P. Valageas, A. Taruya, and T. Nishimichi, Phys. Rev. **D95**, 023504 (2017), arXiv:1610.00993 [astro-ph.CO].
[27] G. Cabass, E. Pajer, and F. Schmidt, JCAP **09**, 003, arXiv:1804.07295 [astro-ph.CO].
[28] M. Marinucci, T. Nishimichi, and M. Pietroni, Phys. Rev. D **100**, 123537 (2019), arXiv:1907.09866 [astro-ph.CO].
[29] M. Marinucci, T. Nishimichi, and M. Pietroni, JCAP **07**, 054, arXiv:2005.09574 [astro-ph.CO].
[30] A. Kehagias, J. Norea, H. Perrier, and A. Riotto, Nucl. Phys. **B883**, 83 (2014), arXiv:1311.0786 [astro-ph.CO].
[31] A. Kehagias, A. Moradinezhad Dizgah, J. Norea, H. Perrier, and A. Riotto, JCAP **1508** (08), 018, arXiv:1503.04467 [astro-ph.CO].
[32] A. Esposito, L. Hui, and R. Scoccimarro, Phys. Rev. D **100**, 043536 (2019), arXiv:1905.11423 [astro-ph.CO].