The Cosmological Flow

Denis Werth† with Lucas Pinol†‡ and Sébastien Renaux-Petel†

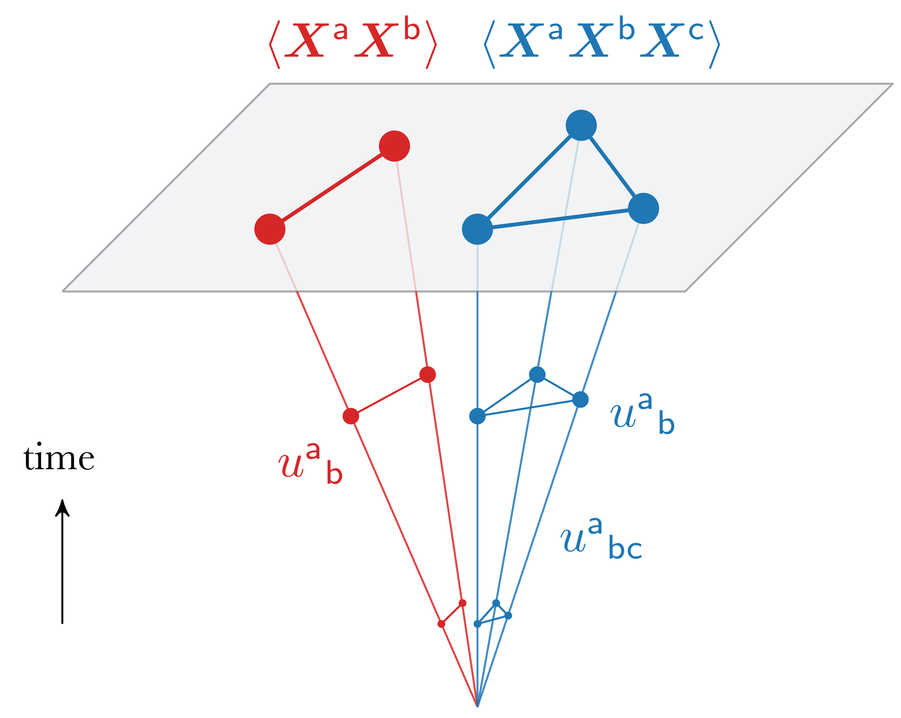
† Institut d'Astrophysique de Paris, Sorbonne Université, CNRS, Paris, F-75014, France
‡ Laboratoire de Physique de l'École Normale Supérieure, Sorbonne Université, Université Paris Cité, CNRS, Paris, F-75005, France

Introduction

Context & Motivation. Cosmological correlators hold the key to high-energy physics as they probe the earliest moments of our Universe. However, even at tree-level, perturbative calculations are limited by technical difficulties. A complete dictionary mapping the landscape of inflationary theories and observable signatures is not yet available, which can lead to a biased interpretation of cosmological data.

New Formalism. We have developed the Cosmological Flow framework to automatically compute tree-level cosmological correlators in any theory.

New Numerical Tool. We have developed an open source Python package that can compute any tree-level two- and three-point correlators in any theory in all kinematic configurations. The code is simple, intuitive and flexible, and provides high-resolution results.



The Cosmological Flow Formalism

Method. Solving universal differential equations in time satisfied by equal-time correlators that dictate their bulk time evolution

Conceptual Advantages

- Equivalent to Schwinger-Keldysh in-in diagrammatic
- Unified approach → no case-specific integrals
- Focuses directly on observable → no mode functions

Practical Advantages

- Calculations performed effortlessly
- Universal equations → automatic procedure
- Real time axis evolution → no UV regulator

Universal Flow Equations.

Phase-space variables in Fourier space

$$\boldsymbol{X}^a \equiv (\varphi^\alpha, \boldsymbol{p}^\beta)$$

$$\frac{\mathrm{d}}{\mathrm{d}t}\langle \boldsymbol{X}^a \boldsymbol{X}^b \rangle = u^a{}_c \langle \boldsymbol{X}^c \boldsymbol{X}^b \rangle + u^b{}_c \langle \boldsymbol{X}^a \boldsymbol{X}^c \rangle$$

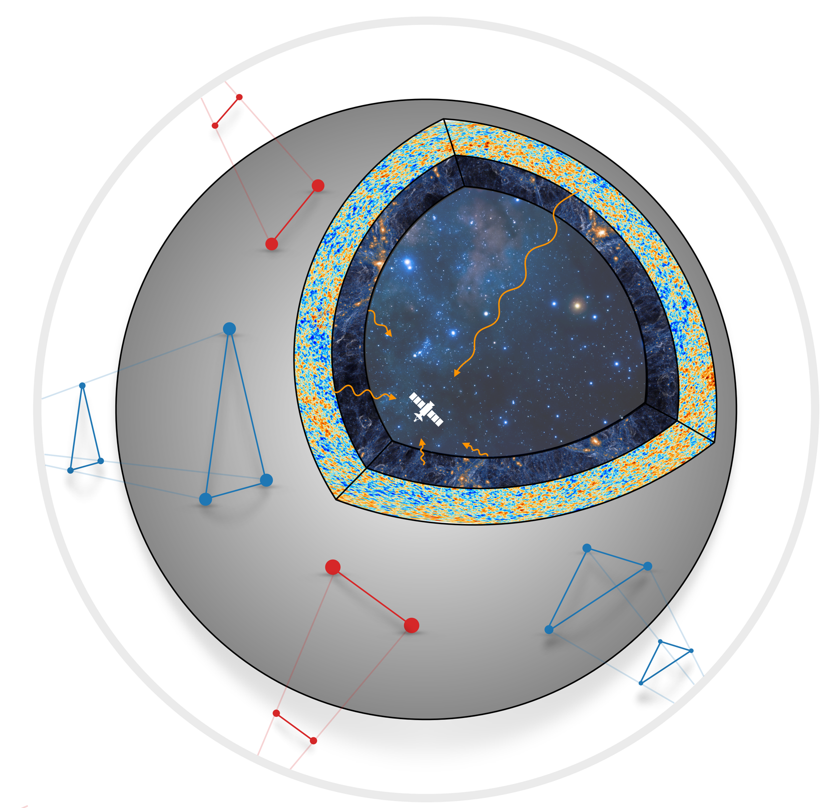
$$\frac{\mathrm{d}}{\mathrm{d}t}\langle \boldsymbol{X}^a \boldsymbol{X}^b \boldsymbol{X}^c \rangle = u^a{}_d \langle \boldsymbol{X}^d \boldsymbol{X}^b \boldsymbol{X}^c \rangle + u^a{}_{de} \langle \boldsymbol{X}^b \boldsymbol{X}^d \rangle \langle \boldsymbol{X}^c \boldsymbol{X}^e \rangle + \text{perms}$$

Entire theory dependence
(Any time/momentum

e.g. $\mathcal{L} = g(t)(\partial_i\varphi)^2\Psi$ implies $u^{\Psi}_{\varphi\varphi} = g(t)\,\boldsymbol{k}_\varphi \cdot \boldsymbol{k}_\varphi$

Initial Conditions. Asymptotically reaching the vacuum state in the infinite past i.e. deep inside the horizon

- Numerical $i\epsilon$-prescription → switching on interactions adiabatically
- Analytical initialisation → massless decoupled approximation



GitHub Repository
user guide & tutorial notebooks

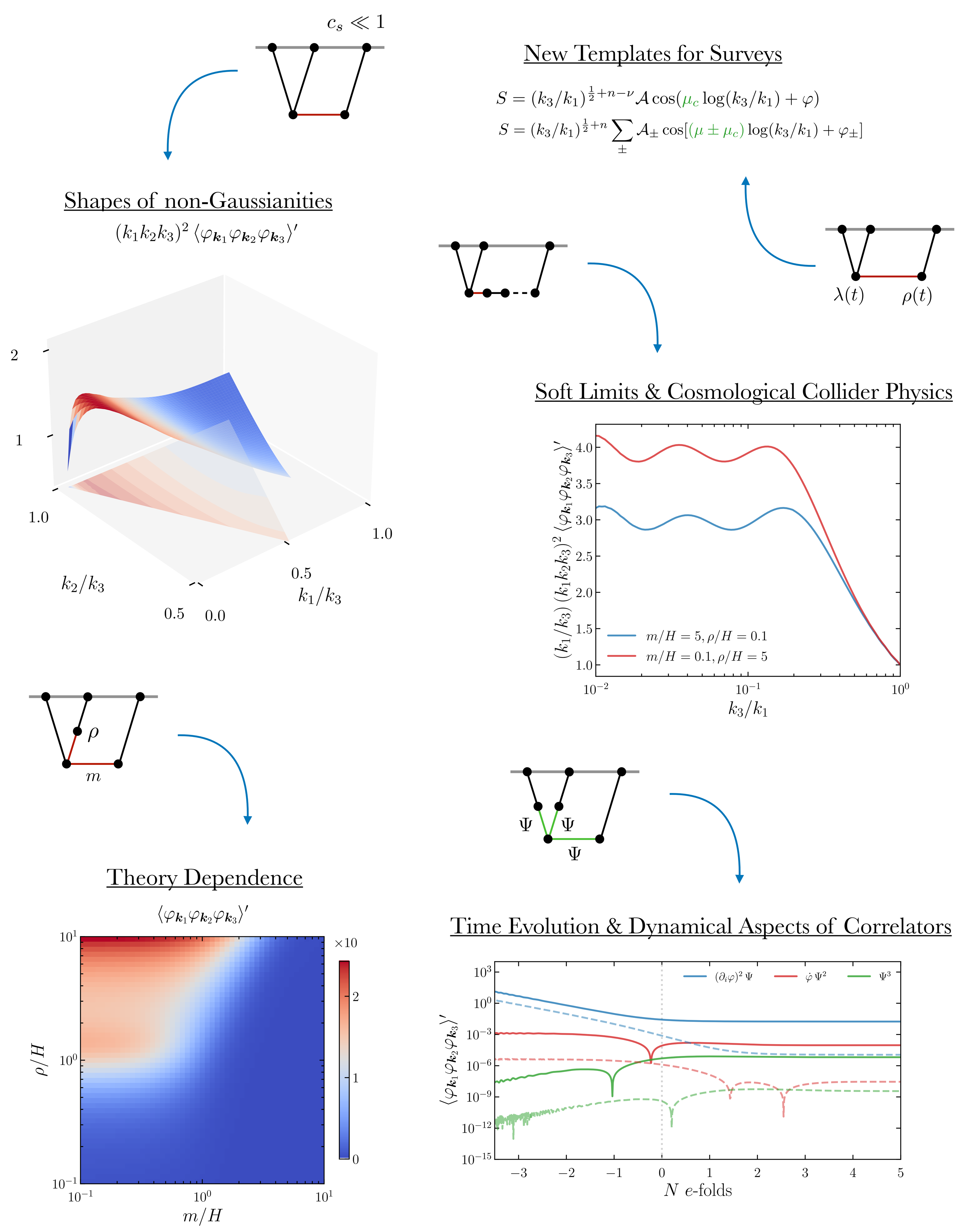
SCAN ME

Python Package for Cosmological Correlators

CosmoFlow.

- Complement analytical computations
- Provide physical intuition when the studying inflationary theories
- Obtain exact results in regimes that were out of reach

Theories	CosmoFlow	Cosmological Correlators
$\mathcal{L}(\varphi^a)$	⟶	$\langle \varphi^a_{\boldsymbol{k}_1} \varphi^b_{\boldsymbol{k}_2} \rangle(t)$, $\langle \varphi^a_{\boldsymbol{k}_1} \varphi^b_{\boldsymbol{k}_2} \varphi^c_{\boldsymbol{k}_3} \rangle(t)$



References

1. "Cosmological Flow of Primordial Correlators" (Short paper)
2. "The Cosmological Flow: A Systematic Approach to Primordial Correlators" (Long paper)
3. "CosmoFlow: Python Package for Cosmological Correlators" (Code paper)