Scalar perturbations from inflation in the presence of gauge fields

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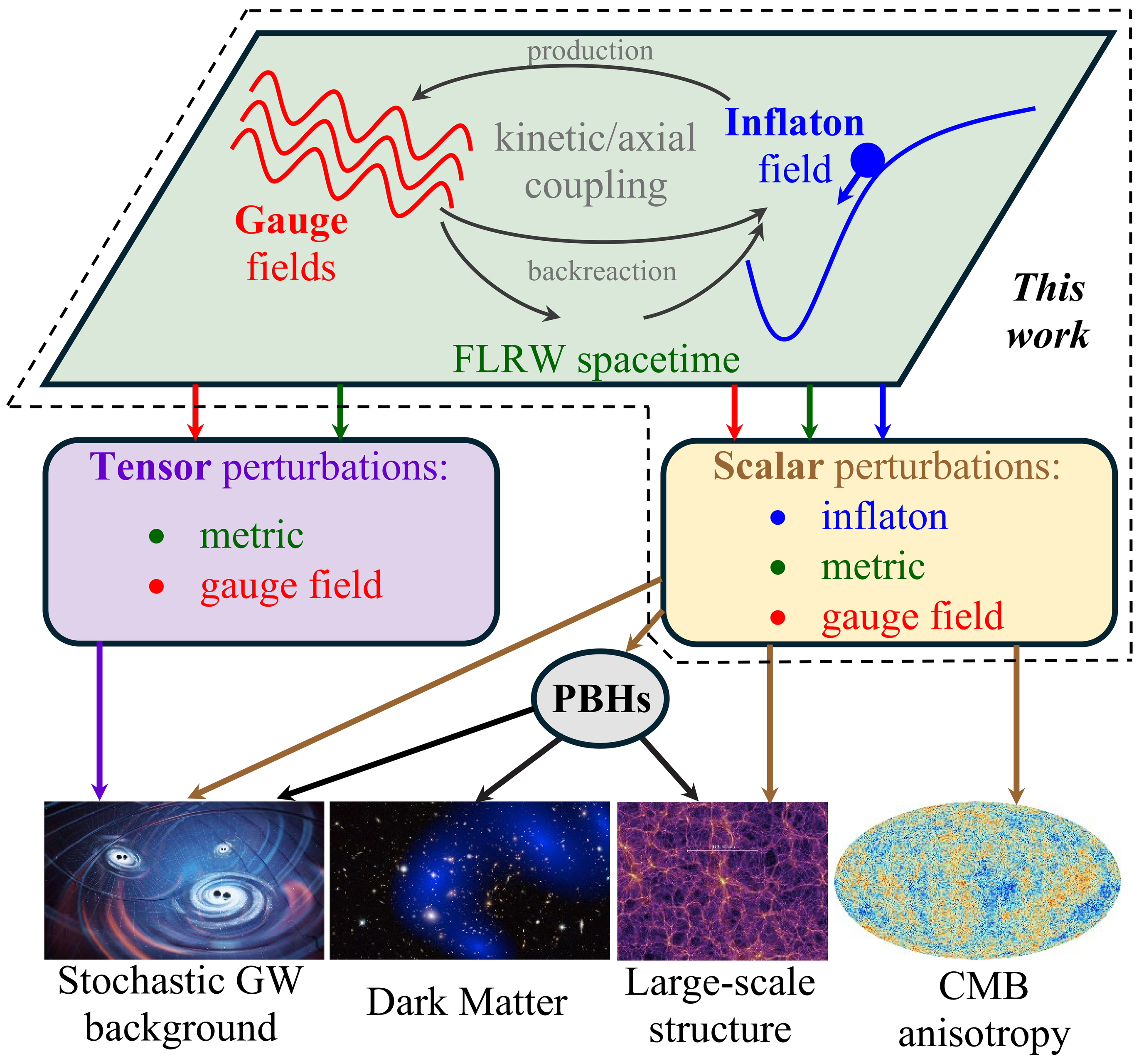
1. Introduction

Inflation is an important pillar of the standard model of cosmology, ΛCDM. The main role played by this period of very rapid expansion before the hot Big Bang is that it leads to the amplification of *vacuum fluctuations* of the inflaton field and of the metric. This mechanism for the generation of cosmological perturbations is supported by observations of the cosmic microwave background and of the cosmological large-scale structure. In the simplest models of inflation, the scalar fluctuations generated during inflation are very close to Gaussian, which is in good agreement with observations. Thus far, no *primordial non-Gaussianities* have been observed, and inflation is characterized purely by the *primordial power spectrum* of scalar perturbations. Clearly, the detection of primordial non-Gaussianity would open a new window to study the physics of inflation, making it an extremely important observable. Processes during inflation that may lead to a measurable non-Gaussianity are, therefore, of great interest.



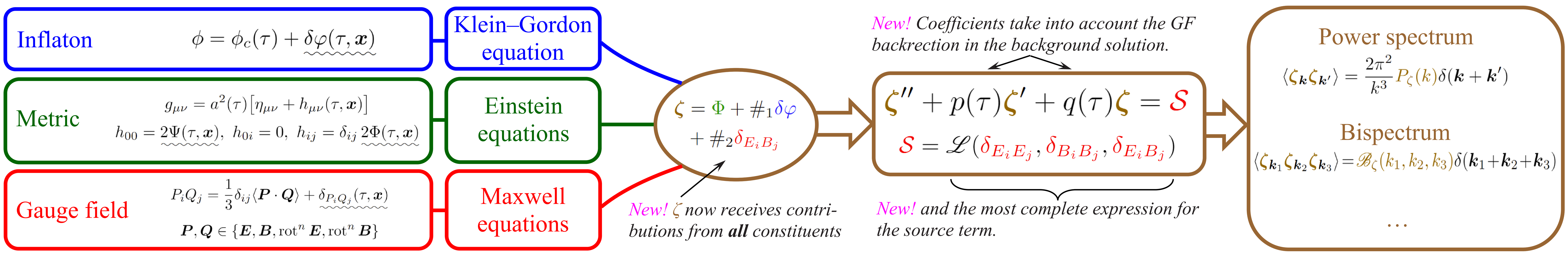
Credit: O. Shmahalo, D. Harvey, R. Massey, H. Ebeling,J.-P. Kneib, Millenium Simulation Project, NASA, ESA, Planck Collaboration

Another subject of great interest is the origin of *magnetic fields* in cosmology which have been observed on all scales: from stars and galaxies to clusters and cosmic voids. Such fields are difficult to generate in the late stages of the evolution of the Universe. Their large coherence length and filling fraction point to a primordial origin, presumably through processes during inflation.

The production of gauge fields during inflation leads to *new sources* of cosmological perturbations. The slow roll of the inflaton amplifies the gauge fields, which in turn produce scalar fluctuations. These additional cosmological perturbations are *statistically independent* from the vacuum perturbations of the inflaton and can be *highly non-Gaussian*. Hence, for any scenario of inflation where gauge fields are generated, it is very important to keep track of the effect of these new source terms on the generation of scalar perturbations. Potentially, they can yield an additional contribution of perturbations which are both, non-Gaussian and, in general, not scale invariant. These properties are observable and can be used to constrain inflationary models that involve the production of gauge fields.

2. Model and methods

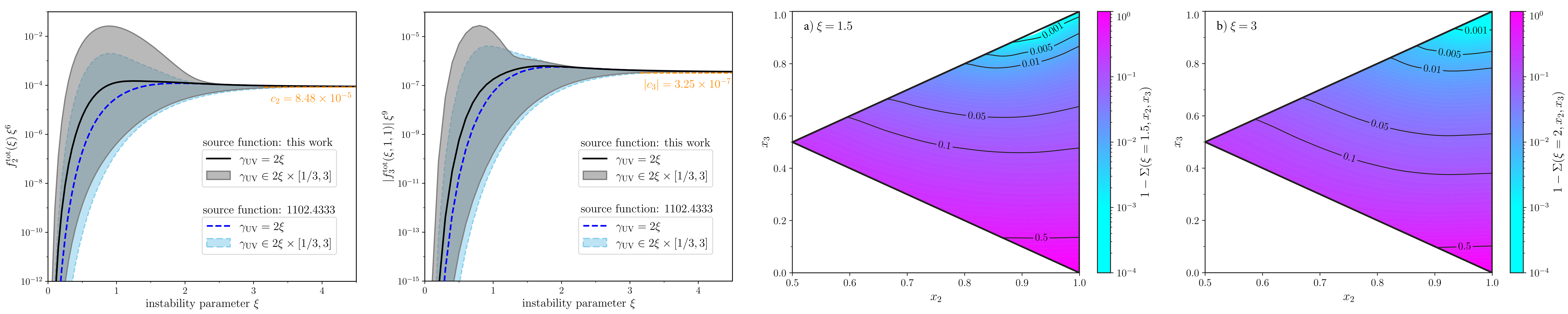
$$S=\int d^4x\sqrt{-g}\Big[-\frac{M_{\rm P}^2}{2}R+\frac{1}{2}g^{\mu\nu}\partial_\mu\phi\partial_\nu\phi-V(\phi)-\frac{1}{4}I_1(\phi)F_{\mu\nu}F^{\mu\nu}-\frac{1}{4}I_2(\phi)F_{\mu\nu}\tilde{F}^{\mu\nu}\Big]$$



3. Application: Axion inflation without backreaction

Model: $I_1(\phi)=0\,,\quad I_2(\phi)=\frac{\alpha}{f}\phi\,.$ Assumptions: $\langle\boldsymbol{E}^2\rangle\approx 0,\ \langle\boldsymbol{B}^2\rangle\approx 0,\ \langle\boldsymbol{E}\cdot\boldsymbol{B}\rangle\approx 0\,,\quad H=\frac{\dot a}{a}={\rm const}\,,\quad \xi\equiv\frac{\alpha\dot\phi_c}{2fH}={\rm const}\,.$

$$P_\zeta^{(\rm ind.)}(k)=e^{4\pi\xi}\Big(\frac{H^2}{2\pi|\dot\phi_c|}\Big)^4 f_2(\xi)\,,\quad \mathcal{B}_\zeta(k,k,k)=\frac{9}{10}(2\pi)^{\frac{5}{2}}\Big(\frac{H^2}{2\pi|\dot\phi_c|}\Big)^6\frac{e^{6\pi\xi}}{k^6}f_3(\xi,1,1)\,,\quad \mathcal{B}_\zeta(k_1,k_2,k_3)=\mathcal{B}_\zeta(k_1,k_1,k_1)\frac{1}{x_2^2x_3^2}\Sigma(\xi,x_2,x_3)\,,\quad x_{2,3}=\frac{k_{2,3}}{k_1}\,.$$



4. Conclusions

1. In Ref. [1] we study how Abelian-gauge-field production during inflation affects scalar perturbations in the case when the gauge field interacts with the inflaton directly (by means of generic kinetic and axial couplings) and via gravity.
2. For the axion inflation without backreaction: (i) The effect of including metric perturbations is small for values of the gauge-field production parameter $\xi>3$. This is in agreement with the previous results in the literature [2]. (ii) However, in the region of smaller values, $\xi\lesssim 2$, our new results exhibit order-of-unity deviations when compared to previous results.
3. We plan to study the regime of strong gauge-field backreaction in future works.

References

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[2] N. Barnaby, R. Namba, and M. Peloso, *J. Cosmol. Astropart. Phys.* **04** (2011) 009 arXiv:1102.4333 [astro-ph.CO].