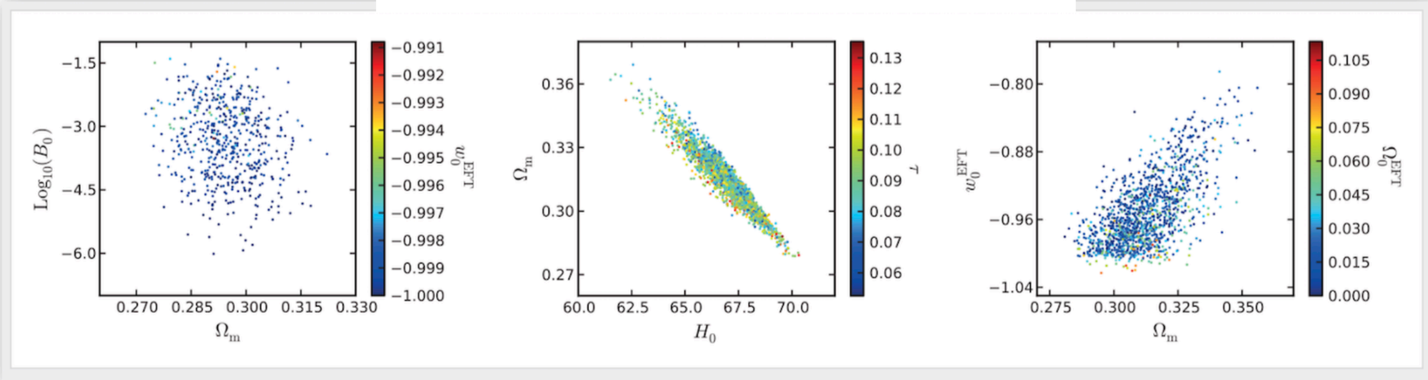
Effective Field Theory with CAMB

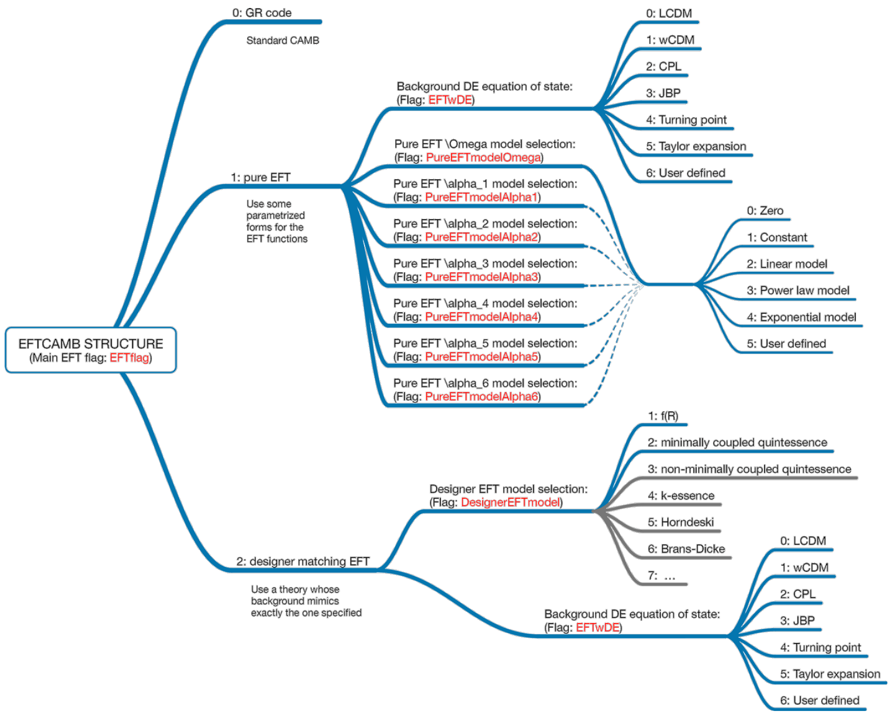
B. Hu, M. Raveri

Google Nederland

N. Frusciante, A. Silvestri

EFTCAMB





- unify description single scalar field DE/MG by using EFT language

- selected by Planck and Euclid

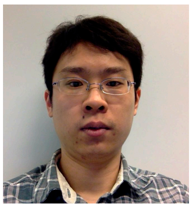
- New release updated with Planck-2015 likelihood is coming soon

Effective field theory approach for dark energy and modified gravity

Bin HU

Instituut-Lorentz for Theoretical Physics, Leiden University;

Web: `http://wwwhome.lorentz.leidenuniv.nl/~hu/codes/`



Abstract

EFTCAMB is a patch of the public Einstein-Boltzmann solver CAMB, which implements the Effective Field Theory approach to cosmic acceleration. The code can be used to investigate the effect of different EFT operators on linear perturbations as well as to study perturbations in any specific DE/MG model that can be cast into EFT framework. To interface EFTCAMB with cosmological data sets, we equipped it with a modified version of CosmoMC, namely EFTCosmoMC, creating a bridge between the EFT parametrization of the dynamics of perturbations and observations. The full package is currently composed by three parts: EFTCAMB (Linear Einstein-Boltzmann solver), EFTCAMB Sources (LSS observables), EFTCosmoMC (Parameter sampler). It has been selected by Planck and Euclid consortium. A new release updated with Planck-2015 likelihood code is coming soon. Please register in our mailing-list we will inform you once the new release is available.

1. FEATURES

- A unified description of Dark Energy & Modified Gravity models:
  - cosmological constant, quintessence, k-essence...
  - f(R), Brans-Dicke theories, Galileon, Horndenski theories...
- Model independent approach to test gravity on cosmological scale:
  - such as Principle Component Analysis for the EFT operators
- Interface with cosmological observations and datasets:
  - CMB data: Planck, WMAP, ACT, SPT, BICEP/KECK Array, ...
  - LSS data: WiggleZ, CFHTLenS, ...
  - BAO and SN data
- Spectra
  - ALL the CMB spectra
  - Lensing potential
  - matter power spectra
- Including modified relativistic effects in the number counts (clusters of galaxies, voids)
  - Redshift distortion
  - Light of sight projection effect

2. EFT FORMULATION

- Single additional scalar field π;
- Cosmological Principle: operators are time-dependent spatial diffeomorphisms invariants;
- $S_m[\chi_i, g_{\mu\nu}]$: Validity of the Weak Equivalence Principle;
- Jordan frame: directly related to observations;
- Model independent framework to address the acceleration issue :
  - Only three background EFT functions: $\{\Omega(t), \Lambda(t), c(t)\}$
  - Linear perturbations $\{M_2^4, \bar{M}_1^3, \bar{M}_2^2, \bar{M}_3^2, \hat{M}^2, m_2^2\}$ + three background EFT functions

Precise *mapping* between EFT functions and most of the single scalar field DE/MG models

3. EFTCAMB

- Patch of CAMB: full perturbative Boltzmann-Einstein equations;
- No approximations: NO quasi-static, NO sub-horizon;
- Complete set of perturbative equations which includes all the second order EFT operators;
- Background expansion histories: ΛCDM, wCDM, CPL;
- **Pure EFT mode**: It allows to study the underlying DE/MG theory through a parametrization of the EFT functions
- **Mapping EFT mode**: It allows implementation of specific single scalar field DE/MG model, buit in: designer-$f(R)$, Hu-Sawicki-$f(R)$, (non-)miniamally coupled quintessence, Hořava models, ...

4. STABILITY OF PERTURBATIONS IN THE DARK SECTOR

Stability check to ensure that the underlying gravitational theory is acceptable.
The general form of the π field equation:

$$A(\tau,k)\,\ddot{\pi} + B(\tau,k)\,\dot{\pi} + C(\tau)\,\pi + k^2\,D(\tau,k)\,\pi + E(\tau,k) = 0$$

$1+\Omega > 0$
Positive Newtonian constant;
$A > 0$
No ghost instabilities;

$c_s^2 \equiv D/A \leq 1$
Subluminal perturbations;
$m_\pi^2 \equiv C/A \geq 0$
Positive mass of the scalar.

5. RESULTS

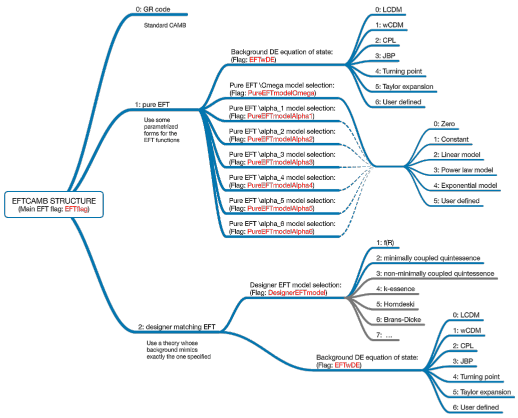
Pure EFT mode examples:

- Power law EFT model: $\Omega(a) = \Omega_0 a^n$;
- CPL background: $w_{\rm DE} = w_0 + w_a(1-a)$;
- Consistently cross the phantom divide $w_{\rm DE} = -1$;

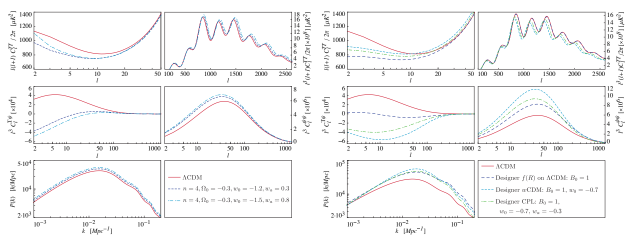
Mapping EFT mode examples:

- Designer $f(R)$ [3] mimicking a ΛCDM, wCDM and CPL background;
- Mapping with the EFT functions:

$$\Lambda = \frac{M_{Pl}^2}{2}(f - Rf_R) \ \ , \ \ c = 0 \ \ , \ \ \Omega = f_R$$



The flow chat of the EFTCAMB v1.1. Blue curves denote for those modules have been implemented, grey for the upcoming ones.



Upper panels: CMB temperature power spectra; *Central panels*: lensing- temperature cross-correlation (left) and the lensing potential power spectra (right); *Lower panels*: total matter power spectra.

6. CONCLUSION

EFTCAMB will be a very useful tool to explore the full dynamics of perturbations in all single field approaches to the phenomenon of cosmic acceleration, providing upcoming surveys such as Euclid with a powerful code to perform both model-dependent and -independent tests of gravity on cosmological scales.

7. MAIN LITERATURE REFERENCES

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