Setting Parameters in the EFT Structure

There are two methods to set parameters in the EFT structure:

1. Case-by-Case Definition

This method is suitable for specific models and functions in the structure. Parameters have physical significance within their corresponding models.

Exact examples will also be provided in the examples folder, so we only list their names here. For several specific models, we also list their corrresponding reference papers. *Please add the citation when you use these models.*

- Flag for different w_{DE} parametrizations (LCDM, wCDM, CPL, JBL, Taylor or TurningPoint) in PureEFTmodel (**EFTflag**=1): **EFTwDE**.
  - **EFTwDE** = 0 -> $w_{DE} = -1$
  - **EFTwDE** = 1 -> $w_{DE} = w_0$
  - **EFTwDE** = 2 -> $w_{DE} = w_0 + w_a(1-a)$
  - **EFTwDE** = 3 -> $w_{DE} = w_0 + w_a(1-a)a^{(n-1)}$
  - **EFTwDE** = 4 -> $w_{DE} = w_0 + w_a(a_t - a)^2$
  - **EFTwDE** = 5 -> $w_{DE} = w_0 + w_a a + \frac{1}{2} w_2 a^2 + \frac{1}{6} w_3 a^3$
  - **EFTwDE** equals from 6 to 11 share the same logic of specifying functions decribed below, see **Specifying Functions** for more details.

  The parameters above can be fixed with the flags:
  - w_0->**EFTw0** , w_a->**EFTwa** , n->**EFTwn**, a_t->**EFTwat** , w_2->**EFTw2** , w_3->**EFTw3**

  The flags for parametrizations of PureEFTmodel functions:
  - **PureEFTmodelOmega**, **PureEFTmodelGamma1**, **PureEFTmodelGamma2**,**PureEFTmodelGamma3**, **PureEFTmodelGamma4**, **PureEFTmodelGamma5**, **PureEFTmodelGamma6**.

  And their function names:
  - **EFTOmega**,**EFTGamma1**,**EFTGamma2**,**EFTGamma3**,**EFTGamma4**,**EFTGamma5**,**EFTGamma6**

- Flags and Parameter names of **AltParEFTmodel** (**EFTflag**=2):
  - **AltParEFTmodel** = 1:
    - Flags for different w_{DE} parametrizations: **RPHwDE**.
      So the parameter names are the same with **EFTwDE**, except changing ***"EFT"*** instead of ***"RPH"***.
    - Flags for parametrizations of RPH functions:
      RPHalphaMmodel/RPHmassPmodel, RPHkineticitymodel, RPHbraidingmodel, RPHtensormodel.
      (Parametrizations name rule see the text below.)
      Their function names are **RPHalphaM, RPHmassP, RPHkineticity, RPHbraiding, RPHtenso** and Latex format are $\alpha^{\mathrm{M}}, \tilde{M}, \alpha^{\mathrm{K}}, \alpha^{\mathrm{B}}, \alpha^{\mathrm{T}}$, respectively.

  - **AltParEFTmodel** = 2
    - Flags: **OLLambdamodel, OLOmegamodel, OLGamma1model, OLGamma2model, OLGamma3model**
    - Names: **OLLambda, OLOmega, OLGamma1, OLGamma2, OLGamma3**
    - Latex format: $\tilde{\lambda}, \Omega, \gamma_1, \gamma_2, \gamma_3$

  - **AltParEFTmodel** = 3
    - Flags: **OLLambdamodel, OLmassPmodel, OLkineticitymodel, OLbraidingmodel, OLtensormodel**
    - Names: **OLLambda, OLmass, OLkineticity, OLbraiding, OLtensor**
    - Latex format: $\tilde{\lambda}, \tilde{M}, \alpha^{\mathrm{K}}, \alpha^{\mathrm{B}}, \alpha^{\mathrm{T}}$

  - **AltParEFTmodel** = 4
    Flag for different w_{DE} parametrizations: **EFTwDE**.
    Reference Paper:
    - [1] Albuquerque, I. S., Frusciante, N., Pace, F., and Schimd, C., “Spherical collapse and halo abundance in shift-symmetric Galileon theory”, *Physical Review D*, vol. 109, no. 2, Art. no. 023535, APS, 2024. doi:10.1103/PhysRevD.109.023535.

- Flags and Parameter names of designer mapping EFT (**EFTflag**=3):
  MappingEFTmodel

- **MappingEFTmodel** = 1: f(R)

  Needed parameters:

  - Names: **EFTB0**
  - Latex format: B_0

  The parametrizations of wDE is similar with PureEFT case, with the prefix ***"EFT"***.

- **MappingEFTmodel** = 3: Freezing Gravity

  Reference Paper:

  - [1]Yao, Z., Ye, G., and Silvestri, A., "A General Model for Dark Energy Crossing the Phantom Divide", *arXiv e-prints*, Art. no. arXiv:2508.01378, 2025. doi:10.48550/arXiv.2508.01378.

- Flags and Parameter names of full EFT mapping (**EFTflag**=4): **FullMappingEFTmodel**

  - **FullMappingEFTmodel** = 1: Horava

    Needed parameters:

    - Names: **Horava_eta, Horava_xi, Horava_lambda** (if **HoravaSolarSystem** = 1, then **Horava_xi** is not needed)
    - Latex format: $\eta_{\mathrm{Hořava}}, \lambda_{\mathrm{Hořava}}, \xi_{\mathrm{Hořava}}$

    Reference Paper:

    - [1] Frusciante, N., Raveri, M., Vernieri, D., Hu, B., and Silvestri, A., "Hořava Gravity in the Effective Field Theory formalism: From cosmology to observational constraints", *Physics of the Dark Universe*, vol. 13, pp. 7–24, 2016. doi:10.1016/j.dark.2016.03.002.
    - [2] Frusciante, N. and Benetti, M., "Cosmological constraints on Hořava gravity revised in light of GW170817 and GRB170817A and the degeneracy with massive neutrinos", *Physical Review D*, vol. 103, no. 10, Art. no. 104060, APS, 2021. doi:10.1103/PhysRevD.103.104060.

  - **FullMappingEFTmodel** = 2: Acoustic Dark Energy (ADE)

    Needed parameters:

    - Names: **cs2, Log_ac, f_ac, p, wf**
    - Latex format: $c_s^2, \log(a_c), f(a_c), p, w_f$

  - **FullMappingEFTmodel** = 3: K-mouflage

    Needed parameters:

    - Names: **alphaU, gammaU, m, eps2_0, gammaA**
    - Latex format: $\alpha_U, \gamma_U, m, \epsilon_{2,0}, \gamma_A$

Reference Paper:

- [1] Benevento, G., “K-mouflage imprints on cosmological observables and data constraints”, *Journal of Cosmology and Astroparticle Physics*, vol. 2019, no. 5, Art. no. 027, IOP, 2019. doi:10.1088/1475-7516/2019/05/027.

- **FullMappingEFTmodel** = 4: Quintessence

  There are two flags within Quintessence model: **potential_model** and **drag_initial_conditions**.

  - **potential_model** select the parametrization model for the quintessence potential.

- **FullMappingEFTmodel** = 5: Beyond Horndeski

  Needed parameters:

  - Names: **Beyond_Horndeski_x10, Beyond_Horndeski_x30, Beyond_Horndeski_x40**
  - Latex format: $x_1^0, \ \ x_3^0, \ \ x_4^0$

  Reference Paper:

  - [1] Peirone, S., Benevento, G., Frusciante, N., and Tsujikawa, S., “Cosmological constraints and phenomenology of a beyond-Horndeski model”, *Physical Review D*, vol. 100, no. 6, Art. no. 063509, APS, 2019. doi:10.1103/PhysRevD.100.063509.

- **FullMappingEFTmodel** = 6: Scaling Cubic Galileon

  Needed parameters:

  - Names: **Scaling_Cubic_A, Scaling_Cubic_beta1, Scaling_Cubic_beta2, Scaling_Cubic_lambda**
  - Latex format: $A, \beta_1, \beta_2, \lambda$

  Reference Paper:

  - [1] Albuquerque, I. S., Frusciante, N., and Martinelli, M., “Constraining cosmological scaling solutions of a Galileon field”, *Physical Review D*, vol. 105, no. 4, Art. no. 044056, APS, 2022. doi:10.1103/PhysRevD.105.044056.

- **FullMappingEFTmodel** = 7: Extended Galileon

  Reference Paper:

  - [1]Frusciante, N., Peirone, S., Atayde, L., and De Felice, A., “Phenomenology of the generalized cubic covariant Galileon model and cosmological bounds”, *Physical Review D*, vol. 101, no. 6, Art. no. 064001, APS, 2020. doi:10.1103/PhysRevD.101.064001..

- Flags and Parameter names of Horndeski Module (**EFTflag**=5):

  This module allows the user to work directly with any covariant Lagrangian belonging to the Horndeski class. You can map your own theory within Horndeski Gravity with the coeffcients. Here we show the usages of Early Dark Energy and Thawling Gravity as two examples in the *example_notebooks* file.

Reference Paper:

- [1]Ye, G., Martinelli, M., Hu, B., and Silvestri, A., “Hints of Nonminimally Coupled Gravity in DESI 2024 Baryon Acoustic Oscillation Measurements”, *Physical Review Letters*, vol. 134, no. 18, Art. no. 181002, APS, 2025. doi:10.1103/PhysRevLett.134.181002..
- [2]Ye, G., “Bridge the Cosmological Tensions with Thawing Gravity”, *arXiv e-prints*, Art. no. arXiv:2411.11743, 2024. doi:10.48550/arXiv.2411.11743.

2. Default Definition

If there is no specific definition for the model, a default name will be used. This name is constructed as "Function name" + index, where "Function name" is defined in the model flag, and the index ranges from 0 to $N-1$, where N is the number of parameters. The LaTeX format will be: $\mathrm{FunctionName}_{\mathrm{index}}$.

Specifying functions

In the flowchart, you will notice several functions labeled with *Specifying Functions*. We have implemented a number of parametrization methods within EFTCAMB. The functions can now be defined as both functions of the scale factor and the DE energy fraction Ω_{DE}. For Horndeski modual, the Horndeski functions can also be defines as functions of scaler field ϕ. The flag numbers and corresponding parameter names are listed here. Still, if there is no specific definition for a parameter name, the default definition will be used.

We use Ω in pureEFT as an example

Flags for specifying Ω: **PureEFTmodelOmega**

- Zero: **PureEFTmodelOmega** = 0 -> $\Omega(a) = 0$

- Constant: **PureEFTmodelOmega** = 1 -> $\Omega(a) = \Omega_0$

- Linear: **PureEFTmodelOmega** = 2 -> $\Omega(a) = \Omega_0 a$

- Power Law: **PureEFTmodelOmega** = 3 -> $\Omega(a) = \Omega_0 a^s$.
  Parameter Names: Ω_0-> **EFTOmega0** , s -> **EFTOmegaExp**.
  Latex format label: (Ω_0, Ω_n).

- Exponential: **PureEFTmodelOmega** = 4 -> $\Omega(a) = \exp(\Omega_0 a^s) - 1$.
  Parameter Names: Ω_0-> **EFTOmega0** , s -> **EFTOmegaExp**.
  Latex format label: (Ω_0, Ω_n).

- Taylor series: **PureEFTmodelOmega** = 5 -> $\Omega(a) = \sum_{i=0}^{n} \Omega_n (a - a_0)^n$.
  EFTOmega_Taylor_order define the order and **EFTOmegaa0** define the expansion time.
  Names of the other parameters: Default defination.

- Pade series: **PureEFTmodelOmega** = 6 -> $\Omega(a) = \frac{\sum_{i=0}^{n} \Omega_{\mathrm{up,n}}(a-a_0)^n}{1+\sum_{i=1}^{m} \Omega_{\mathrm{down,m}}(a-a_0)^m}$
  EFTOmega_Pade_order_N and **EFTOmega_Pade_order_D** define the order on the numerator and denominator. **EFTOmegaa0** define the expansion time.
  Names of other parameters: Default defination with FunctionName+N for numerator and FunctionName+D for denominator.

- Fourier: **PureEFTmodelOmega** = 7 -> $\Omega(a) = a_0 + \sum_{i=1}^{n} cos[2\pi n(a - a_p)] + \sum_{i=1}^{m} sin[2\pi m(a - a_p)]$
  EFTOmega_Fourier_order_cos and **EFTOmega_Fourier_order_sin** define the order for cos and sin.
  EFTOmega_a0 define the expansion time. **EFTOmega_phase** define the phase.
  Names of other parameters: Default defination with FunctionName+_a for numerator and FunctionName+_b for denominator.

- Steplog: **PureEFTmodelOmega** = 8 -> $\Omega(a) = \frac{(v_2-v_1)log\frac{a}{a_{\mathrm{T}}}}{2\delta\sqrt{1+(\frac{log\frac{a}{a_{\mathrm{T}}}}{\delta})^2}} + \frac{v_1+v_2}{2}$
  Names of the parameters: **EFTOmega_v1, EFTOmega_v2, EFTOmega_at, EFTOmega_delta**

- Spline: **PureEFTmodelOmega** = 9
  Spline interpolation is a method used to construct a smooth curve that passes through a given set of data points. Here we implement the cubic and fifth-order splines for non-parametrizations of the functions you want to specify.
  EFTOmega_Spline_Pixels defines the number N of chosen pixels.

Name of the parameters: **EFTOmegaxn,n∈{1,N}** are the scale coordinates, **EFTOmegavn,n∈{1,N}** are their values.
Notes: [1] Spline x coordinate must be increasing. [2] N to be at least 6.

- Spline5: **PureEFTmodelOmega** = 10
  Fifth order spline.

- Exponential_Parametrization_2_1D: **PureEFTmodelOmega** = 11 -> $\Omega(a) = \Omega_0 e^{-sa}$.
  The other parametrization method of exponential.
  Names of the parameters: Default defination