

Problems in Perturbed Coupled Quintessence

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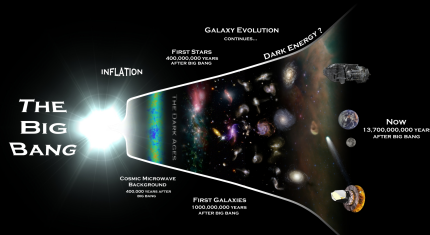
Overview



Overview

- Beyond Lambda - Why Coupled Quintessence?
- Work to date - general perturbation equations, PYESSENCE code
- Results and future work

Beyond Lambda - Why Coupled Quintessence?



Why Coupled Quintessence?

- Late time accelerated expansion - simplest solution: Cosmological Constant, Λ , “Dark Energy?” - problems e.g. coincidence
- Alternatives: scalar field or scalar fields
- Coupled Quintessence: Canonical scalar field(s), ϕ , with potential $V(\phi)$, interacting gravitationally with other components, and through couplings between DE and CDM species - solves problems e.g. coincidence (Quintessence alone), breaking tracking (when Coupled)
- Potential examples: Exponential, $V_0 e^{-\lambda\kappa\phi}$, Freezing, e.g. $M^{4-n}\phi^{-n}$, ($n > 0$), Thawing, e.g. $M^4 \cos^2(\frac{\phi}{f})$, etc., a “potential” glut

Beyond Lambda - Why Coupled Quintessence?

Questions of Coupled Quintessence

- Need a generalised code to test any given coupled quintessence model and allow comparison with observations
- We are developing code, PYESSENCE, to do this
- Background evolution of a model must match observations (CMB, SN data)
- If background satisfies this, is the perturbed model stable (under what range of couplings/no. of fields etc.)?
- If perturbations are stable do they match observations from large scale structure surveys e.g. BOSS, DES, eBOSS, DESI, Euclid?

Work to date - perturbed equations

The key equations

- We perturbed around flat FLRW
- We derived the perturbed equations for multiple CDM fluids and DE fields for first time in full generality, gauge unspecified, allowing for pressure (c.f. 1407.2156 Amendola, Barreiro, Nunes for earlier work)
- Allows us to write completely general code for the community to test wide range of models under differing conditions
- Finished code will allow selection of gauge

Work to date - PYESSENCE code

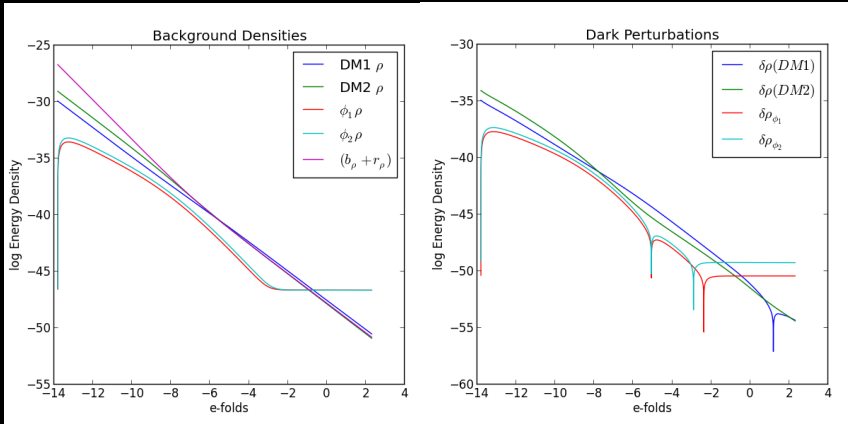
Work to date

- Code designed to step through parameter space of couplings, slopes of potentials, determine region of parameter space for stable perturbations
- First implementation longitudinal gauge
- Code to be used for N fields, M fluids
- Initial testing for 2 fields and 2 fluids
- Also for testing, sum of exponential potential chosen ($V(\phi_1 \dots \phi_n) = M^4 \sum_I e^{-\kappa \lambda_I \phi_I}$) (gives analytical solution for background evolution CDM)

PYSESSENCE code - Work to date

Work to date

- For first time we have plotted evolution of stable perturbations to this 2 fluid, 2 field, sum of exponentials model, for a point in coupling constant space



Results and future work

Results and future work

- Forthcoming paper to present these results in full and release PYESSENCE code for community
- Constrain models through stability
- Constrain models through comparison with LSS surveys (Euclid etc.)

Thank you

Extra Slide - perturbed equations

The key equations

- Perturb metric,

$$ds^2 = -(1 + 2\Phi)dt^2 + 2aB_{,i}dtdx^i + a^2 (\delta_{ij} + 2C_{ij}) dx^i dx^j$$

- Conservation equation:

$$\begin{aligned} \dot{\delta\rho}_\alpha + \left(\frac{\nabla^2 v_\alpha}{a} + \dot{E} - 3\dot{\psi} \right) (\bar{\rho}_\alpha + \bar{P}_\alpha) + 3H(\delta\rho_\alpha + \delta P_\alpha) = \\ -\kappa \sum_I \mathbb{C}_{I\alpha} (\bar{\rho}_\alpha - 3\bar{P}_\alpha) \dot{\delta\phi}_I - \kappa \sum_I \mathbb{C}_{I\alpha} (\delta\rho_\alpha - 3\delta P_\alpha) \dot{\phi}_I \end{aligned}$$

- Field perturbations:

$$\begin{aligned} \ddot{\delta\phi}_I + 3H\dot{\delta\phi}_I + V''\delta\phi_I + (\dot{E} - 3\dot{\psi})\dot{\phi}_I + \frac{k^2}{a^2}\delta\phi_I + \frac{\dot{\phi}_I}{a}k^2B - \dot{\phi}_I\dot{\Phi} + \\ 2V'\Phi - 2\kappa \sum_\alpha \mathbb{C}_{I\alpha} (\bar{\rho} - 3\bar{P})\Phi - \kappa \sum_\alpha \mathbb{C}_{I\alpha} (\delta\rho - 3\delta P) = 0 \end{aligned}$$

- EFEs also derived