Mimicking Alternatives of Inflation with Interacting Spectator Fields

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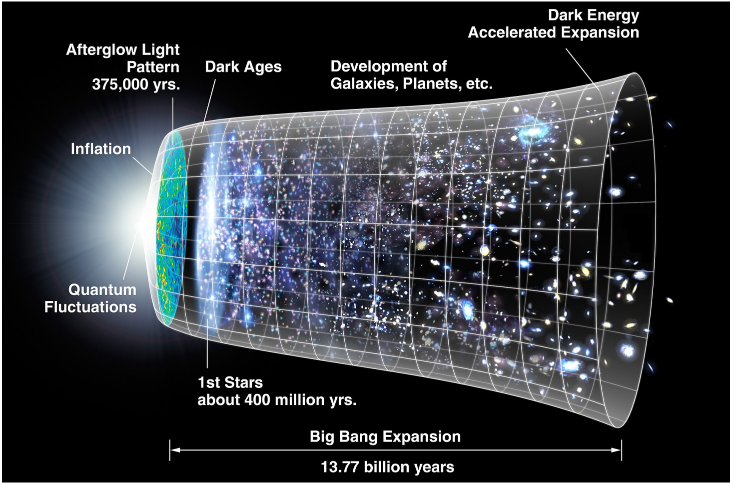
Motivation



[Wikipedia]

Spectral Tilt

- Prediction of minimal inflationary set up (Single Field Slow Roll):

$$\mathcal{P}_{\mathcal{R}} \sim k^{n_s - 1}$$

- Assuming a power-law scale factor:

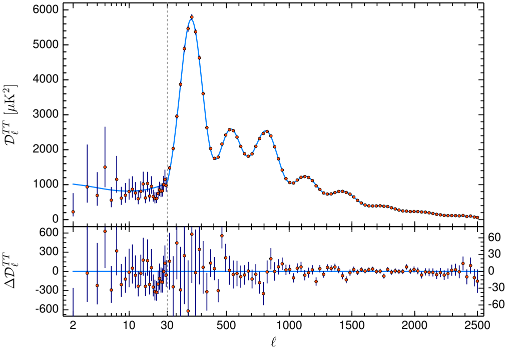
$$a(t) \sim t^p$$

- Resulting spectral tilt:

$$n_s - 1 = 3 - \left| 3 + \frac{2}{p-1} \right| \approx 0$$

- n_s vanishes for $p \gg 1$ (Inflation)
  and $p = 2/3$ (Matter Contraction)

Features in The CMB



- Cosmic Variance limits accuracy at small ℓ.
- Dip at $\ell \approx 30$
- Hint for features in the CMB

[Planck 2018: Constrains on inflation (1807.06211)]

Heavy Fields / Primordial Standard Clock

- Heavy Fields ($m \gg H$) during the primordial epoch oscillate around minimum.
- Oscillation will affect the evolution of the "inflaton".
- Studies on oscillatory features in CMB with $m^2\chi^2$-potential [Primordial Standard Clock, X. Chen et al (1411.2349)].
- Assumes only gravitational interaction between field.
- Can distinguish Inflation and alternatives.

Model

- Introduce non-trivial interaction between fields:

$$\mathcal{L} = \frac{M_{\rm P}^2}{2} R - \frac{1}{2}\omega^2(\chi) g^{\mu\nu}\partial_\mu\phi\partial_\nu\phi - V(\phi) \\ - \frac{1}{2} f^2(\phi) g^{\mu\nu}\partial_\mu\chi\partial_\nu\chi - \frac{1}{2} m^2(\phi)\chi^2$$

- non-canonical kinetic term $\omega(\chi)$ for the "inflaton" ϕ
- non-canonical kinetic term $f(\chi)$ for heavy spectator field χ $+$ non-constant mass term $m(\phi)$
- red terms appear generically in models with non-minimal coupling to gravity

[Guillem Domenech, Javier Rubio, JW (1811.08224)]

Mechanism to Create Features

$$\chi \propto \sqrt{\frac{a^{-3}}{m_{\text{eff}} f^2}} \sin\left(\int m_{\text{eff}}\, dt\right) \qquad \text{with} \qquad m_{\text{eff}} = \frac{m}{f}$$

χ	Spectator field oscillates under the assumption $m_{\text{eff}}/H \gg 1$.
ΔH_{osci}	Spectator field adds an oscillatory corrections to the Hubble parameter.
$\Delta \epsilon_{\text{osci}}$	Also the slow-roll parameter will get a correction.
$\Delta \mathcal{P}_{\mathcal{R}}$	Finally this will lead to oscillatory features in the power spectrum

$$\Delta \mathcal{P}_{\mathcal{R}} \propto \left(\frac{2k}{k_r}\right)^{\nu} \sin\left[C\left(\frac{2k}{k_r}\right)^{\frac{\gamma}{p}} + \theta_r\right]$$

Corrections to the power spectrum

$$\Delta\mathcal{P}_{\mathcal{R}} \propto \left(\frac{2k}{k_r}\right)^{\nu} \sin\left[C\left(\frac{2k}{k_r}\right)^{\frac{\gamma}{p}} + \theta_r\right]$$

- k_r : scale of first oscillation
- Scaling of amplitude: $\nu = -\frac{3}{2} + \frac{1}{2}\frac{\gamma}{p} + \frac{\delta_m - 2\delta_f}{1+\delta_m-\delta_f}$
- Scaling of frequency: $\gamma = \frac{1+p\,\delta_m - p\,\delta_f}{1+\delta_m-\delta_f}$
- Assume constant change in: $\delta_m = \frac{\dot{m}}{Hm}$ and $\delta_f = \frac{\dot{f}}{Hf}$

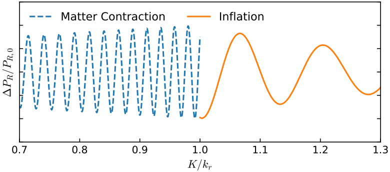
Mimicking a Signal

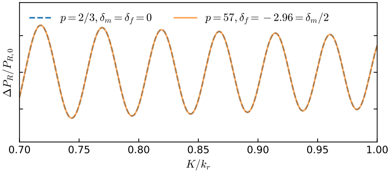
Frequency: $\bar{p} = p/\gamma\,,$ Amplitude: $\nu = -\frac{3}{2} + \frac{1}{2}\frac{1}{\bar{p}} + \frac{\delta_m - 2\delta_f}{1+\delta_m-\delta_f}$

- Use two parameters δ_m and δ_f to fix two observables ν and $\bar{p}$

1) Choose $\delta_m = 2\delta_f$ to cancel additional contribution to ν
2) Choose δ_f such that $\bar{p} = p_{\rm inf}/\gamma = p_{\rm alt}$

Resonance condition: $k = \frac{m}{f} a$





- Constant m and $f = 1$, Resonance directly probes $a(t)$
- Very distinct feature for inflation and alternatives

- m and f depend on time, Resonance probes combination of m, f and a
- Inflation can mimic signal from alternative scenarios

Conclusions

- Time dependent mass makes different signals indistinguishable at the level of the power spectrum.
- Power spectrum is not enough to tell inflation and alternatives apart.
- Need full information (frequency scaling + amplitude scaling) on bispectrum to break degeneracy.