Spectral distortions in a multifield inflation model

Raúl Henríquez Ortiz
Universidad de El Salvador

November 4, 2024

Content

Content

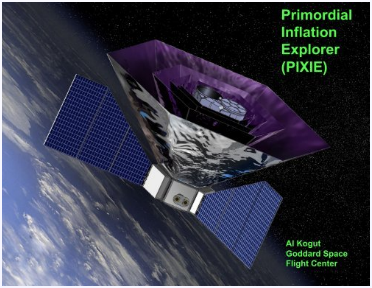
Content

Motivation

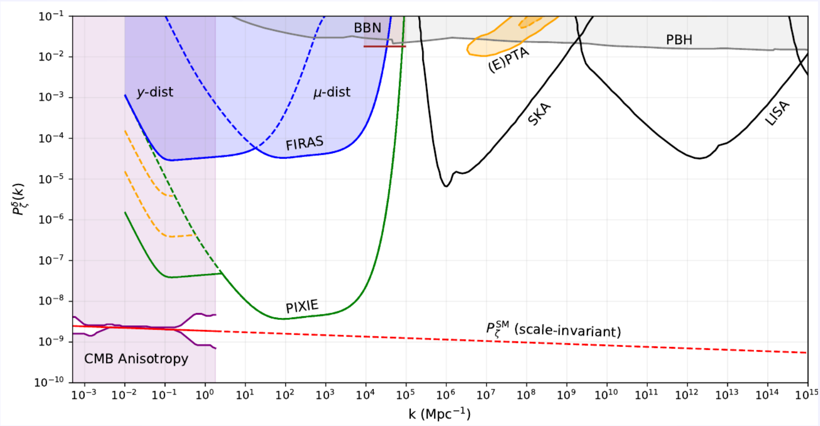
- Inflation scenario solves the flatness problem and answering the question why the Universe looks Homogeneous and Isotropic in large scales.
- Some cosmological problem have been approached by CMB spectral distortions (SD). SDs have not been measured to date, but were tightly constrained by COBE/FIRAS to be $|\mu| \leq 9 \times 10^{-5}$ and $|y| \leq 1.5 \times 10^{-5}$ (95% C.L.).

Motivation

- New experimental missions, such as the Primordial Inflation Explorer (PIXIE) and its upgraded version Super-PIXIE, will soon explore SDs with new and improved resolution.



Motivation

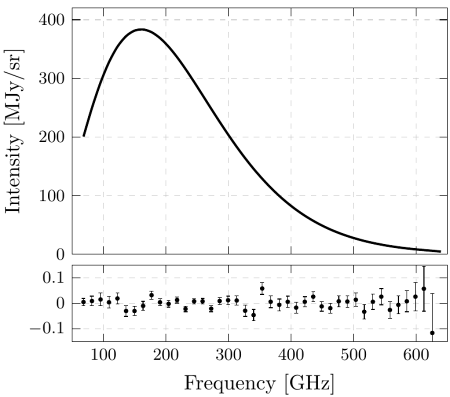

BBN
PBH
(E)PTA
y-dist
μ-dist
SKA
LISA
FIRAS
PIXIE
P_ζ^{SM} (scale-invariant)
CMB Anisotropy
$P_\zeta^\delta(k)$
k (Mpc^{-1})

Cosmic Microwave Background (CMB)

The CMB radiation is a consequence of the thermal equilibrium that was established by photons at Universe early

$$I_0(\nu) = \frac{2h\nu^3}{c^2}\frac{1}{e^{h\nu/kT_0} - 1}$$

$$T_0 = 2.7260 \pm 0.0013 \text{ K},$$



Spectral distortions

- In early Universe, photons and baryons are tightly coupled, behaving as a single fluid close to thermal equilibrium.
- Energy injection into the photon-baryon fluid can disrupt thermal equilibrium, causing small departures from the blackbody distribution. These deviations are known as spectral distortions (SDs) and are sensitive to any energy injected into the CMB.

J. Chluba *et al.*, 2012

Spectral distortions

The total CMB radiation is modelated as

$$I(z,x) = I_0(x) + \Delta I(z,x)\,, \tag{1}$$

where $I_0(x)$ is the distribution function of the black body with a temperature T_0 and $\Delta I(z,x)$ is the total contribution of SDs.

Spectral distortions

The total distortion of the photon intensity spectrum can be modeling (at first order) in terms of the ΔT temperature shift, y, r and μ distortions

$$\Delta I(z,x) \;=\; \int_z^\infty dz'\, G_{\rm th}(x,z,z')\frac{dQ(z')/dz'}{\rho_{\gamma(z')}}\,, \qquad (2)$$

$G_{\rm th}(x,z,z')$ inclued all photon-baryon interactions, this is parametrizated by the branching ration shapes function $\mathcal{J}_a(z')$ (with $a = \{T, y, \mu\}$)

$$G_{\rm th}(x,0,z') \;=\; \mathcal{G}(x)\mathcal{J}_T(z')+\mathcal{Y}(x)\mathcal{J}_y(z')+\mathcal{M}(x)\mathcal{J}_\mu(z')+R(x,z')\,.$$

Spectral distortions

The factor $\rho_\gamma^{-1} dQ(z')/dz'$ quantifies the energy release caused by the dissipation of primordial acoustic modes and encodes all the evolution of the radiation field for some initial

$$\frac{1}{\rho_\gamma}\frac{dQ}{dz} = 4A^2 \int_{k_{\min}}^{\infty} \frac{k^4 dk}{2\pi^2} P_{\mathcal{R}}(k) \left[\partial_z k_D^{-2}\right] e^{-2k^2/k_D^2} . \qquad (3)$$

Where $P_{\mathcal{R}}(k)$ is the primordial scalar power spectrum.

Multifield inflationary scenario

The Multifield inflationary scenario studied was a Hybrid version of the α-attractor model, which result from supergravity. In the canonically normalized bases, the potential is

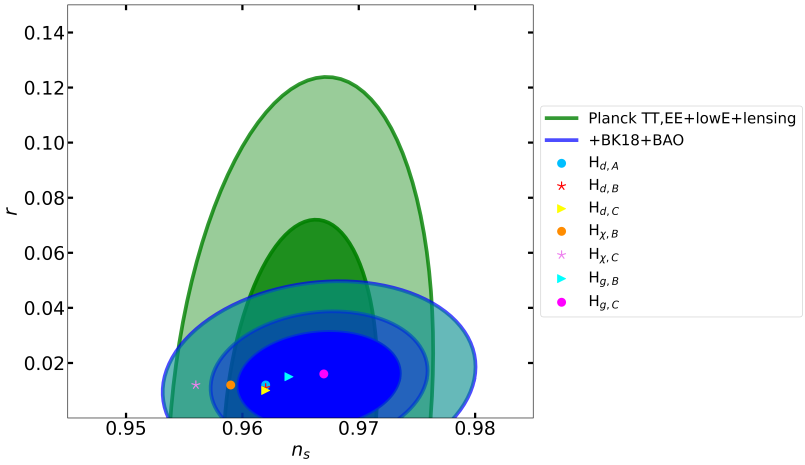
$$V(\phi, \chi) = M^2 \left[\frac{(\chi^2 - \chi_0^2)^2}{4\chi_0^2} + 3\alpha(m^2 + g^2\chi^2) \tanh^2\left(\frac{\phi}{\sqrt{6}\alpha}\right) + d\chi \right] .$$

Metodology

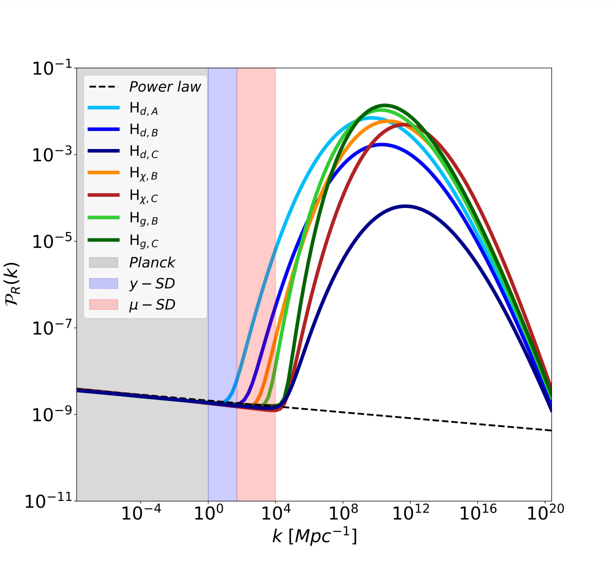
Point	d	χ_0	g	n_s	r
$\mathrm{H}_{d,\mathrm{A}}$	-5×10^{-6}	2.5	0.8	0.962	0.012
$\mathrm{H}_{d,\mathrm{B}}$	-10^{-6}	2.5	0.8	0.962	0.011
$\mathrm{H}_{d,\mathrm{C}}$	-5×10^{-5}	2.5	0.8	0.962	0.010
$\mathrm{H}_{\chi,\mathrm{B}}$	-5×10^{-6}	2.4	0.8	0.959	0.012
$\mathrm{H}_{\chi,\mathrm{C}}$	-5×10^{-6}	2.3	0.8	0.956	0.012
$\mathrm{H}_{g,\mathrm{B}}$	-5×10^{-6}	2.5	1.0	0.964	0.015
$\mathrm{H}_{g,\mathrm{C}}$	-5×10^{-6}	2.5	1.2	0.967	0.016

Table: Sample points for the hybrid attractor mode, and their associated predictions for the CMB observables. $M = 1.47\times10^{-5}$, $\alpha = 1$ and $m = 0.3$.

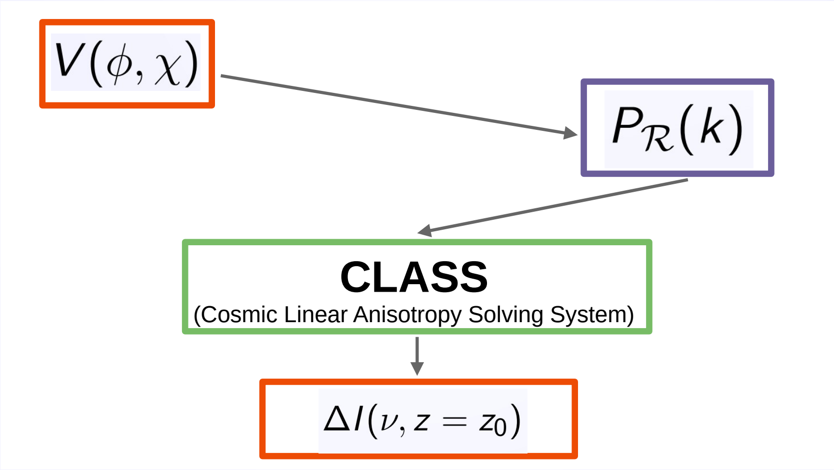
Metodology


0.14
0.12
0.10
0.08
0.06
0.04
0.02
r
0.95
0.96
0.97
0.98
n_s
Planck TT,EE+lowE+lensing
+BK18+BAO
$H_{d,A}$
$H_{d,B}$
$H_{d,C}$
$H_{\chi,B}$
$H_{\chi,C}$
$H_{g,B}$
$H_{g,C}$

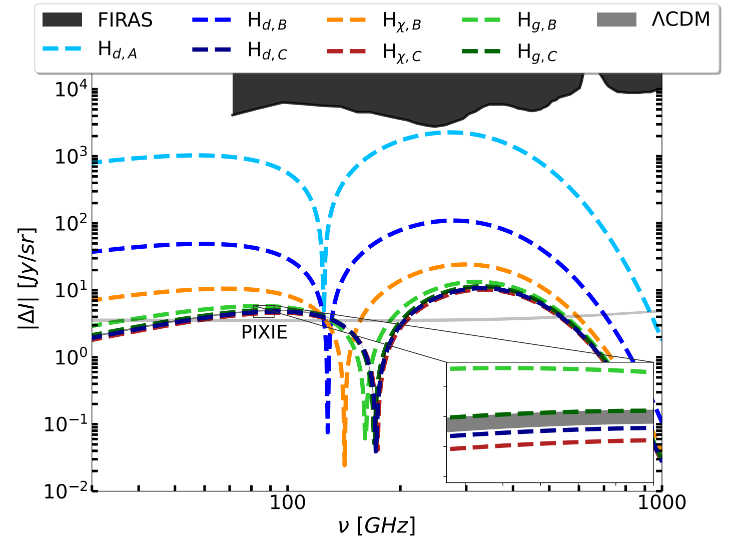
Metodology


Power law
$H_{d,A}$
$H_{d,B}$
$H_{d,C}$
$H_{\chi,B}$
$H_{\chi,C}$
$H_{g,B}$
$H_{g,C}$
Planck
$y-SD$
$\mu-SD$
$\mathcal{P}_R(k)$
10^{-1}
10^{-3}
10^{-5}
10^{-7}
10^{-9}
10^{-11}
10^{-4}
10^{0}
10^{4}
10^{8}
10^{12}
10^{16}
10^{20}
$k\ [Mpc^{-1}]$

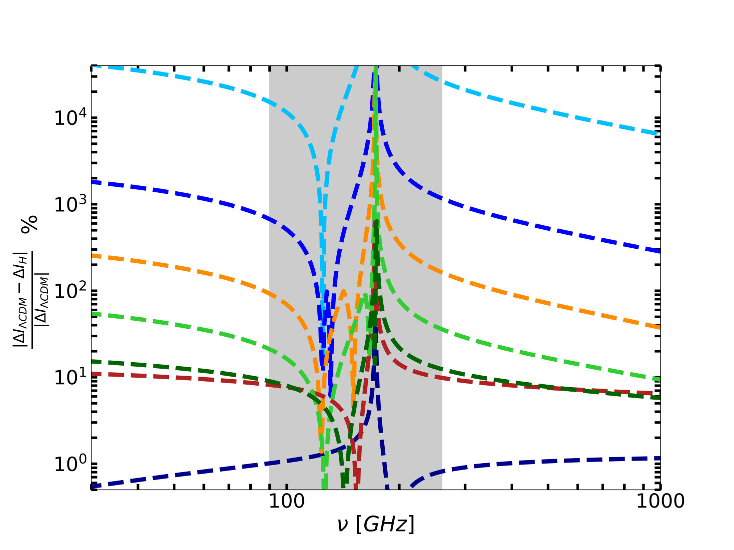
Metodology


$V(\phi, \chi)$
$P_{\mathcal{R}}(k)$
CLASS
(Cosmic Linear Anisotropy Solving System)
$\Delta I(\nu, z = z_0)$

Results


FIRAS
$H_{d,A}$
$H_{d,B}$
$H_{d,C}$
$H_{\chi,B}$
$H_{\chi,C}$
$H_{g,B}$
$H_{g,C}$
ΛCDM
10^4
10^3
10^2
10^1
10^0
10^{-1}
10^{-2}
$|\Delta I|\ [Jy/sr]$
PIXIE
100
1000
$\nu\ [GHz]$

Results


10^4
10^3
10^2
10^1
10^0
$\frac{|\Delta I_{\Lambda CDM} - \Delta I_H|}{|\Delta I_{\Lambda CDM}|}$ %
100
1000
ν [GHz]

- The $H_{d,A}$ scenario a differs by 4×10^4 % from the fiducial power-law scenario.
- The $H_{d,C}$ and $H_{\chi,B}$ scenarios were 1000 % and 100 % respectively, compared to the power-law scenario.
- The other models are approximately the same as the power-law scenario.
- These results were published in JCAP 04 (2024) 090 (`arxiv.org/pdf/2310.13071`).

¡Thanks!