

DESI and Gravitational Wave Constraints on α -attractor Inflationary Models

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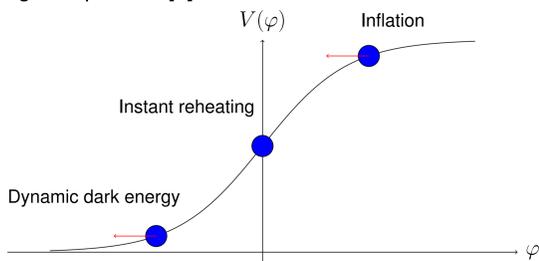
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Alpha attractor quintessential inflation model

The α -attractor quintessential inflation model provides a unified framework for inflation and dynamic dark energy. In α -attractor quintessential inflation model, inflation does not end with an oscillation phase as in conventional reheating scenarios. Instead, the inflaton typically rolls past the flat inflationary plateau into a steep region of the potential, entering a kinetic-energy-dominated (kination or stiff) phase. Since stiff matter redshifts faster than gravitational waves, modes that reenter the horizon during this epoch experience a significant enhancement in their power spectrum $\Omega_{\text{GW}}(k)$ at high frequencies[1].



In this work, we consider the potential $V(\varphi)$ of inflaton φ as

$$V(\varphi) = M^2 e^{\gamma(\tanh(\frac{\varphi}{f_{\text{end}}}) - 1)} - M^2 e^{-2\gamma}, \quad (1)$$

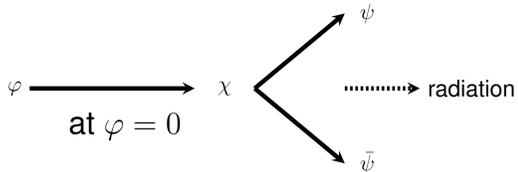
which approaches zero as the field φ rolls toward $-\infty$.

Instant reheating

Following Ref. [4], we consider the Lagrangian density in the preheating epoch

$$\mathcal{L}_m \supset -\frac{1}{2}g^2\phi^2\chi^2 - h\chi\psi\bar{\psi}, \quad (2)$$

where the inflaton is coupled to a heavier particle χ , and χ is in turn coupled to a lighter particle ψ , the reheating process proceeds in two steps. In this case, χ particles are produced through their interaction with the inflaton and subsequently decay into ψ . ψ is assumed to be light and effectively behaves as radiation.



Gravitational wave

Using the spacetime background evolution provided by the α -attractor inflationary model with instant reheating, we compute the primordial gravitational-wave spectrum.

GWs evolve as a radiation component and therefore modify the effective number of neutrino species according to

$$\int_0^\infty d(\log f) h_0^2 \Omega_{\text{GW}}(f) = 5.6 \times 10^{-6} \Delta N_{\text{eff}}. \quad (3)$$

The modification of the effective number of relativistic species, ΔN_{eff} , is tightly constrained by BBN and CMB observations, which in turn imposes a lower bound on the reheating temperature T_{reh} .

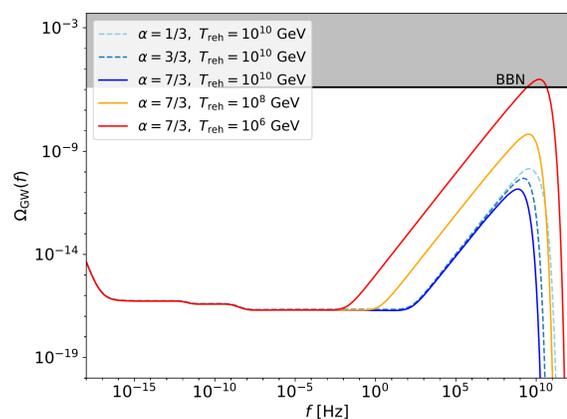


Figure 1: GW power spectrum for different parameters α and reheating temperature T_{reh} .

The scalar spectral index n_s of α -attractor is connected with the scalar potential at the end of inflation V_{end} and reheating temperature T_{reh} via[3]

$$n_s = 1 - \frac{N_*}{2} \quad (4)$$

$$N_* \simeq 61.93 + \ln\left(\frac{V_{\text{end}}^{1/4}}{M_{\text{pl}}}\right) + \frac{1}{3} \ln\left(\frac{V_{\text{end}}^{1/4}}{T_{\text{reh}}}\right), \quad (5)$$

where M_{pl} represent planck mass. The value of n_s lies about 2σ away from the best-fit result obtained from the ACT, Planck, and DESI DR1 constraints [2] when one adopts $N_* \in [50, 60]$. Lowering the reheating temperature can partially alleviate this tension, but not sufficiently to remove it.

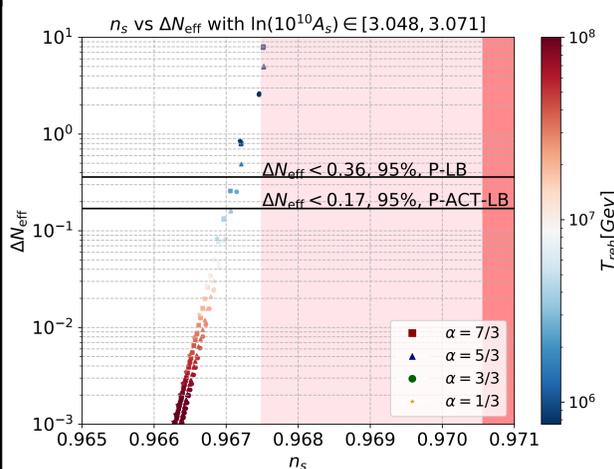


Figure 2: The relationship between the scalar spectral index n_s and the GW-induced modification of the effective number of relativistic species ΔN_{eff} . The pink and red shaded regions denote the 2σ and 1σ confidence intervals of n_s , respectively, obtained from Λ CDM constraints based on P-ACT-LB.

Mcmc result

We constrain the parameters of the α -attractor model, instant reheating parameter g (by fixing $h = 0.01$), together with the standard cosmological parameters H_0 , $\Omega_c h^2$ and $\Omega_b h^2$, using an MCMC analysis by Cobaya. In this MCMC analysis, we combine CMB data from Planck (P), ACT, and ACT lensing (L), BAO measurements from DESI DR2 (B), and supernovae observations from Pantheon+ (S).

The effect of gravitational waves is incorporated by treating them as an additional radiation component, which modifies the effective number of neutrino species N_ν via equation (3).

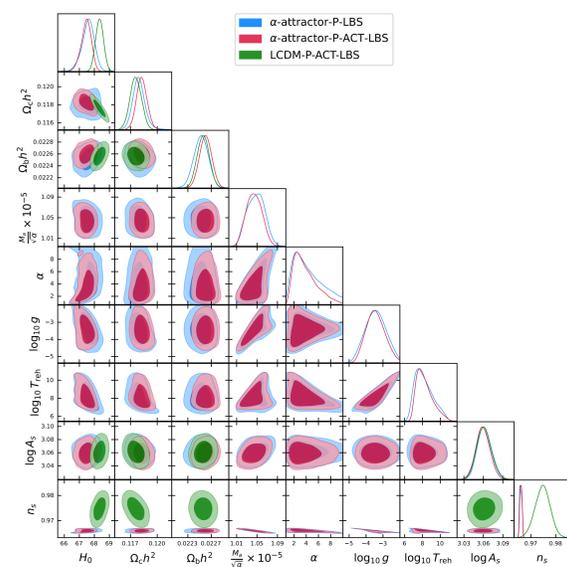


Figure 3: The 63.3% – 95.5% confidence contours for the cosmology parameter of α attractor models and Λ CDM model. n_s , A_s and T_{reh} is also showed for α -attractor model as three derived parameters

Thanks to the DESI data, we obtain a lower bound on α , which in turn yields a lower bound on the tensor-to-scalar ratio and highlights the strong predictive power of the model regarding the amplitude of primordial GWs. Moreover, the CMB bound on N_{eff} imposes a corresponding lower limit on the reheating temperature T_{reh} , further constraining and helping to predict the GW amplitude at high frequencies.

Our result show the gravitational waves predicted by the α -attractor inflationary model are too weak to be detected by current or near-future ground-based and space-based laser-interferometer detectors, but they may be within the reach of next-generation CMB experiments.

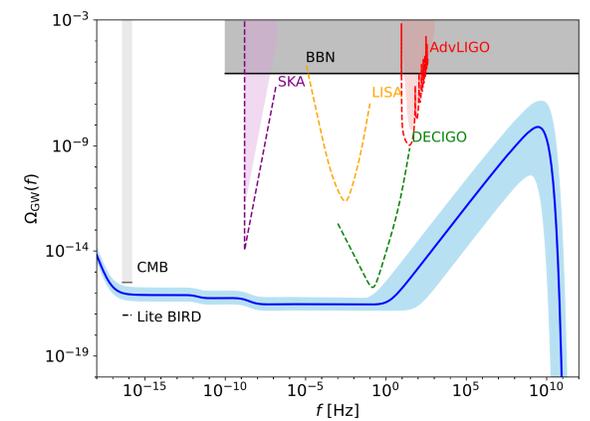


Figure 4: The GW power spectrum come from the best-fit point and 1σ region

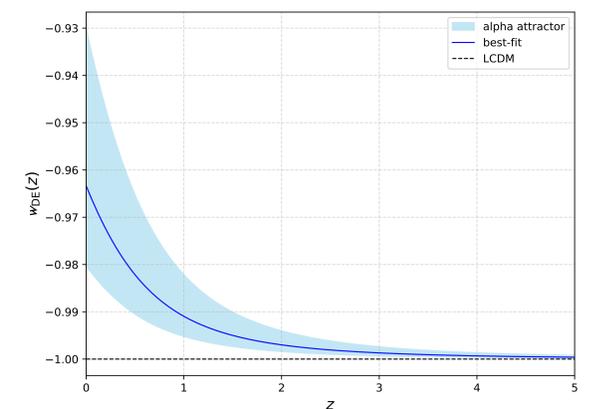


Figure 5: The evolution of dark energy EOS parameter w_{DE} come from the best-fit point and 1σ region

References

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