

Non-Gaussian signatures arising from warm inflation driven by geometric tachyon

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Abstract. In a warm inflationary scenario, the initial seeds of density perturbation arise from thermal fluctuations of the inflaton field. These fluctuations in principle have Gaussian distribution. In a Gaussian distribution the density perturbation can be expressed as the two point correlation function. Thus if in an inflationary model the density perturbation is expressed as correlation function of order higher than two, these fluctuations are non-Gaussian in nature. A simple inflationary model containing single scalar field, slow roll, canonical kinetic term and vacuum initial state can produce a tiny amount of non-Gaussianity which are very small to be detected by any experiment. Non-Gaussianity can also arise in inflationary models containing multiple scalar fields. For an inflationary scenario with single scalar field, non-Gaussianity can be expressed in terms of bi-spectrum however for multi field Inflation, it is expressed in terms of trispectrum etc. In this piece of work, the warm inflationary scenario, driven by a D3 brane due to the presence of a stack of k coincident NS 5 branes is considered and the non-Gaussian effects in such an inflationary scenario has been analysed by measuring the bispectrum of the gravitational field fluctuations generated during the warm inflation in strong dissipative regime. The bi-spectrum of the Inflation is expressed in terms of the parameter f_{NL} and it is seen that the value of f_{NL} parameter lies well within the limit observed by WMAP7.

1. Introduction

Cosmic inflation refers to a period of accelerated expansion in the very early universe which was proposed more than three decades ago as a solution to the horizon and flatness problems [1]. It provides the causal interpretation of the observed anisotropy in cosmic microwave background and origin of distribution of large scale structure [2]. The scalar field which is the source of inflation is termed as inflaton. The standard inflationary scenario comprises of two varieties-cold inflation and warm inflation [3].

The cold inflationary scenario contains two regimes: slow roll and reheating epochs whereas warm inflation is an alternative form of inflation where there is no reheating epoch [4]. The basic idea of warm inflation is that the inflaton is coupled to several other scalar fields in inflationary epoch and it decays into lighter scalar fields and viscosity is generated in this process. Warm inflation ends when the universe stops inflating and it smoothly enters into the radiation dominated epoch.

In warm inflation, the density fluctuation arises from thermal fluctuations which could play a dominant roll in large scale structure formation. To a good approximation, these fluctuations have a Gaussian distribution and produces a nearly scale invariant spectrum. This means that the density perturbations have no correlation higher than second order in real and Fourier



space. The simple inflationary model containing single scalar field, slow roll, canonical kinetic term and vacuum initial state can produce a tiny amount of non-Gaussianity which are too small to be detectable in present day experiments [5]. The non-Gaussianity arising in an inflationary scenario can be expressed in terms of the bi-spectrum [6, 7], trispectrum etc [8] and they can be measured in the distribution of cosmic microwave background fluctuations [9, 10]. Other scenarios such as the multiple-field inflation models can also give ideas about non-Gaussianity measurements [11].

In the last decade, there have been many attempts to describe successful models of inflation driven by scalar fields motivated from String Theory. Tachyon field associated with unstable D-brane is one such scalar field which may be responsible for driving inflation in the early phase of universe [12, 13]. When one considers a D3 brane in the background of k coincident NS 5 brane, the system gives rise to a unstable tachyonic field termed as *Geometric Tachyon*. We have investigated the warm inflationary scenario driven by this geometric tachyonic field and found that non-Gaussian signals predicted from this model lies well within the range predicted by WMAP7 [14, 15].

In section 2, the non-Gaussianity measurement for an warm inflationary scenario is discussed and in section 3, the non-Gaussianity for geometric tachyon case has been analysed.

2. Non-Gaussianity and warm inflation

The equation of motion for the zero mode of the scalar field ϕ in general has the form

$$\frac{d\phi}{dt} = -\frac{1}{\Gamma} \frac{dV}{d\phi} \quad (1)$$

In order to study the non-Gaussianity, one needs to obtain the three point correlation function of the density perturbation or the bispectrum. For this reason, we need to study the fluctuation of the tachyon field $\delta\phi(x, t)$. It is assumed that they are small and the full tachyon field can be expressed as $\phi(x, t) = \phi_0(t) + \delta\phi(x, t)$, where ϕ_0 is the homogeneous background field. Now for measuring the bi-spectrum, the equation of motion needs to be considered up to second order fluctuations

$$\delta\phi = \delta_1\phi + \delta_2\phi \quad (2)$$

It is often very useful to express these quantities in momentum space. From equation (1), the equations of motion for first and second order perturbation can be found out [16], the solution of which are of the form

$$\delta_1\phi(k, t) = A(k, t - t_{n-1}) \int_{t_{n-1}}^t dt' \frac{\eta(k, t')}{\Gamma} A^{-1}(k, t' - t_{n-1}) + A(k, t - t_{n-1}) \delta\phi_1(ke^{-H(t_n - t_{n-1})}, t_{n-1}) \quad (3)$$

and

$$\begin{aligned} \delta_2\phi(k, t) &= A(k, t - t_{n-1}) \int_{t_{n-1}}^t dt' B(k, t') \left[\frac{dp^3}{(2\pi)^3} \delta_1\phi(p, t') \delta_1\phi(k - p, t') \right] A^{-1}(k, t' - t_{n-1}) \\ &+ A(k, t - t_{n-1}) \delta_2\phi(ke^{-H(t_n - t_{n-1})}, t_{n-1}) \end{aligned} \quad (4)$$

where,

$$A(k, t) = \exp \left[- \int_{t_0}^t \left(\frac{k^2 V(\phi_0(t'))}{\Gamma} + \frac{V''(\phi_0(t'))}{\Gamma} \right) dt' \right] \quad (5)$$

$$B(k, t) = - \frac{2V'(\phi_0(t))k^2 + V'''(\phi_0(t))}{\Gamma} \quad (6)$$

In both these equations, the second term symbolises the memory terms within the Hubble time which leads the mechanism of freeze out [16]. From the definition of freeze out, for $k \geq k_F$ the memory terms damp away within a Hubble time and for $k \leq k_F$ they do not damp. To satisfy this fact, a quantity called the freeze out momentum k_F can be defined with the condition

$$\frac{V(\phi_0)k^2 + V''(\phi_0)}{\Gamma H} > 1 \quad (7)$$

For warm inflation, $V''(\phi_0) < \Gamma H$ and hence k_F can be defined as

$$k_F = \sqrt{\frac{\Gamma H}{V(\phi_0)}} \quad (8)$$

By using the solutions (3) and (4), the three-point correlation function of the fluctuations before the end of inflation (when $t = t_{60}$) can be computed. As this scenario designates single field inflationary mechanism, so, the three-point correlation function defined in this picture is called the bi-spectrum. In the freeze-out region ($k > k_F$) using the approximation $A \simeq 1$ and $B(k, t) \approx B(k_F, t_F)$, the three point correlation function or the bi-spectrum can be computed and from this expression one can determine the f_{NL} parameter as

$$f_{\text{NL}} = -\frac{5}{3} \left(\frac{\dot{\phi}}{H} \right) \left[\frac{1}{H} \ln \left(\frac{k_F}{H} \right) \right] \left(\frac{V'''(\phi_0(t_F)) + 2k_F^2 V'(\phi_0(t_F))}{\Gamma} \right) \quad (9)$$

As f_{NL} is the measure of non-Gaussianity and so, for an inflationary model, one needs to find out the expression of f_{NL} parameter, the value of which decides whether non-Gaussianity arises in this model or not.

3. Non-Gaussianity arising in geometric tachyon model

When the one dimensional motion of a Dp-brane inside a ring of NS 5-branes is considered, the radiation field becomes tachyonic [15] and this arrangement is termed as Geometric Tachyon. The potential under this configuration of the geometric tachyon field is given by

$$V(\phi) = V_0 \cos \left(\frac{\phi}{\sqrt{k} l_s^2} \right), \quad V_0 = \frac{\tau_3 R}{\sqrt{k} l_s^2}. \quad (10)$$

with the condition

$$\sqrt{k} l_s \geq R \quad (11)$$

where k is the number of NS5 branes in the ring of radius R and l_s is the string length scale.

We restrict ourselves in the region of high-dissipation where, $\Gamma \gg 3HV$ i.e. $r = \gamma/(3HV) \gg 1$. Using the slow-roll approximation, the number of e-foldings, $N = \ln a$, a being the scale factor then becomes

$$N = \int H dt = - \int \frac{3H^2 r V(\phi)}{V'(\phi)} d\phi = p[y - y_f]. \quad (12)$$

where $y = \cos(\phi/\sqrt{k}l_s^2)$, $x = (\phi/\sqrt{k}l_s^2)$ and p is a dimensionless parameter introduced via $p = V_0/(4d)$ and d is another parameter in this scenario, which is a combination of the radiation temperature T_γ and the Stephan-Boltzmann constant σ . From the condition of the end of inflation and also, using the fact that one needs $N \sim 60$ before the end of inflation, we can get an expression of y by a suitable choice of the parameter p . By choosing $p = 10^2$, the initial value of y comes out to be $y = 0.60500025$.

For this case, the potential in terms of x is written as $V(x) = \cos(x) = y$ and so, f_{NL} in strong dissipative regime can be written as

$$f_{\text{NL}} = \frac{5}{3p^2 V(x)^{\frac{3}{2}} V'(x)} \frac{4V(x)V'(x)^3 + 7V(x)^2 V'(x)V''(x) + V(x)^3 V'''(x)}{V(x)^{\frac{3}{2}} V'(x)^2} \quad (13)$$

$$+ 2\sqrt{V(x)V'(x)p} \log \left[\frac{\sqrt{3}\sqrt{V'(x)^2}}{2\sqrt{d}} \right]$$

$$= \frac{10 \left[\frac{2}{y^2} + \frac{p}{y} - \frac{4}{1-y^2} \right] \log \left[\frac{\sqrt{3}\sqrt{1-y^2}}{2\sqrt{d}} \right]}{3p^2} \quad (14)$$

When $p = 100$, $x = .60500025$, $d = 10^{-12} M_p^4$, f_{NL} becomes 0.736917 which is well within the bound observed by WMAP7.

4. Conclusion

In this work, it is predicted that non-Gaussian signals in the density spectrum of the scalar field can arise in the warm tachyonic inflationary scenario driven by geometric tachyon. As non-Gaussianity is generally measured in terms of the f_{NL} parameter of the bi-spectrum, we have estimated the value of f_{NL} in this model. It is seen that its value lies well within the limit predicted by WMAP7 for the range of model parameters.

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