Cosmological Avatars of the Landscape II: 
CMB and LSS Signatures

R. Holman
Department of Physics, Carnegie Mellon University, Pittsburgh PA 15213, USA

L. Mersini-Houghton
Department of Physics and Astronomy, UNC-Chapel Hill, NC, 27599-3255, USA

T. Takahashi
Department of Physics, Saga University, Saga 840-8502, Japan

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This is the second paper in the series that confronts predictions of a model of the landscape with cosmological observations. We show here how the modifications of the Friedmann equation due to the decohering effects of long wavelength modes on the wavefunction of the Universe defined on the landscape leave unique signatures on the CMB spectra and large scale structure (LSS). We show that the effect of the string corrections is to suppress $\sigma_8$ and the CMB $T\,T$ spectrum at large angles, thereby bringing WMAP and SDSS data for $\sigma_8$ into agreement.

We find interesting features imprinted on the matter power spectrum $P(k)$: power is suppressed at large scales indicating the possibility of primordial voids competing with the ISW effect. Furthermore, power is enhanced at structure and substructure scales, $k \simeq 10^{-2-0.5}\,h\,\text{Mpc}^{-1}$. Our smoking gun for discriminating this proposal from others with similar CMB and LSS predictions come from correlations between cosmic shear and temperature anisotropies, which here indicate a noninflationary channel of contribution to LSS, with unique ringing features of nonlocal entanglement displayed at structure and substructure scales.

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I. INTRODUCTION

While finding a dynamical reason for why certain initial conditions for the Universe were preferred over others would be a major step forward in our understanding of Nature, such a proposal must also be falsifiable. In previous work [1, 2], we have argued that the quantum dynamics of gravity acting on the string landscape, treated as the configuration space of initial conditions [3, 4], could in fact show why the initial conditions for high scale inflation are natural.

In the previous paper of this series (hereafter referred to as paper I) [7], we showed how tracing out long wavelength modes of metric and matter field fluctuations could decohere the wavefunction of the Universe, defined on this configuration space. This results in both inducing a highly nonlocal entanglement between our horizon patch with others as well as giving rise to corrections to the Friedmann equation. We then used these cosmological effects to bracket the scale of SUSY breaking $b$ which appears as one of the parameters determining the size of the nonlocality of entanglement. The SUSY breaking bounds were derived by requiring that constraints on the flatness of the modified inflaton potential and the amount of density perturbations be satisfied when the quantum gravity corrections are taken into account.

The backreaction effects that modify the Friedmann equations during inflation (essentially correcting the potential) will also modify the power spectrum. These modifications affect a number of cosmological observables, such as the CMB temperature anisotropy (the $T\,T$ spectrum), large scale structure (LSS), the creation and statistics of voids as well as running of the scalar spectral index $n_s$. We discuss these in detail in Sec. III. In particular, we find a natural explanation for the disagreement between SDSS and WMAP data on the low value of $\sigma_8$ and for the observed low $l$ anomaly in the CMB (temperature anisotropies) $T\,T$—spectrum observed both by COBE [8] as well as by WMAP [9]. We then turn to a discussion of how the backreaction effects may contribute with a negative density contrast that gives rise to the creation of primordial voids in Sec. III. We also show how the effects we find here can be distinguished from other effects predicted by other models of quantum gravity. The main tool we use to do this is the cross-correlation $C_{l\,T\,L}$ of temperature ($T$) with the lensing potential of cosmic shear ($L$).

We collect all of our results and discuss their regimes of validity in Sec. IV and then conclude.

II. QUANTUM EFFECTS OF THE LANDSCAPE

For completeness, we recall some of the basic relations found in paper I. As in paper I, we follow Ref. [10] and use the following inflaton potential

$$V(\phi) = V_0 \exp \left( -\frac{\lambda \phi}{M_p} \right). \quad (2.1)$$

While this potential can appear in supergravity based models of inflation, we use it more for illustrative purposes, due to its
simplicity. Our results will hold generically for any inflaton potential.

After including the backreaction due to the long wavelength modes being traced out, the effective Friedmann equation was shown to be [7]:

\[ H^2 = \frac{1}{3M_p^2} \left[ V(\phi) + \frac{1}{2} \left( \frac{V(\phi)}{3M_p^2} \right)^2 F(b,V) \right] = \frac{V_{\text{eff}}}{3M_p^2} \] (2.2)

where

\[ F(b,V) = \frac{3}{2} \left( 2 + m^2 M_p^2 \right) \log \left( \frac{b^2 M_p^2}{V} \right) - \frac{1}{2} \left( 1 + \frac{m^2}{b^2} \right) \exp \left( -3b^2 M_p^2 \right). \] (2.3)

We have taken \( 8\pi G_N = M_p^{-2} \) and the scale of the nonlocal entanglement is given by the interference length \( L_1 \), derived in [7].

\[ L_1^2 = \frac{a}{H} \left( \frac{m^2}{3H} + H \right) \ln \left( \frac{b}{H} \right) - \frac{m^2 H}{6} \left( \frac{b^2}{b} - \frac{1}{H^2} \right). \] (2.4)

The primordial power spectrum is estimated from

\[ P_R = \frac{1}{7\pi^2 M_p^4} \frac{V^3_{\text{eff}}}{V^2_{\text{eff}}} \] (2.5)

For the initial potential, given in Eq. (2.1), we have

\[ p_R^0 = \frac{1}{7\pi^2 M_p^4} \frac{V_0}{\lambda^2 M_p^2} \] (2.6)

The scalar spectral index before modifications is given by \( n_s - 1 = -\lambda^2 \). Modifications in the Friedmann equation result in a running of the spectral index \( n_s = n_s^0 + \delta n_s \), as we describe below.

The solution for the inflaton field in the presence of the corrected potential is given by:

\[ \phi = \lambda M_p \left[ 1 + \frac{1}{2} \frac{1}{3M_p^2} \left( \frac{V_0}{3M_p^2} \right) \right] \times \left\{ 3 \left( 2 + \frac{m^2 M_p^2}{V_0} \right) \log \left( \frac{b}{\sqrt{3M_p^2/V_0}} \right) - \frac{1}{2} \left( 1 + \frac{m^2}{b^2} \right) e^{-3M_p^2 b^2/V_0} \right\}^{-1} \log \left( \frac{k}{k_{\text{ref}}} \right) \] (2.7)

where \( k_{\text{ref}} \simeq (4000 \text{ Mpc})^{-1} \).

Define \( 3M_p^2 F(b,V) = \sigma(b,\phi) \) and denote the energy correction \( V^2/\sigma = f(b,V) \). The modified Friedmann equation can then be written as

\[ 3M_p^2 H^2 = V + f(b,V) \] (2.8)

An important fact is that \( f(b,V) \) is a negative function, so that the new Friedmann equation only makes sense in the regime where \( V + f(b,V) > 0 \).

We are now prepared to examine the effects of this modification on large scale structure and the CMB.

### III. Signatures of the Landscape on CMB and LSS

Armed with our modified Friedmann equation and power spectrum, we are now ready to compute the corrections to the CMB power spectrum and to Large Scale Structure (LSS).

In Fig. [1] we show the results obtained using CMBFAST [11] with the modification in the primordial spectrum of Eq. (2.2) for \( b \simeq 10^{-5}M_p \). For comparison, we also plot the case with \( \Lambda \)CDM and data from WMAP3 [9]. For the plot, we fixed the parameters for the inflaton potential as \( \lambda = 0.1 \) and \( V_0 = 8.0 \times 10^{-8} M_p^4 \) and \( 1.0 \times 10^{-8} M_p^4 \) for \( b = 4.0 \times 10^9 \text{ GeV} \) and \( 3.8 \times 10^9 \text{ GeV} \) respectively. The cosmological parameters are taken to be \( \Omega_m h^2 = 0.12, \Omega_b h^2 = 0.023, h = 0.79, \tau = 0.091 \) and \( n_s = 0.99 \) for LCDM models. For the cases with our model, we varied them slightly to fit the spectrum to WMAP3 data around the acoustic peaks.

It can be seen from Fig. that power at low \( l \) is suppressed compared to the concordance LCDM model.

Consistency with the Einstein equations in deriving the primordial spectrum requires that we include the pressure corrections corresponding to the energy modification Eq. (2.2). This correction directly contributes to the velocity of the inflaton field \( \phi \) and therefore to the running of the scalar index \( n_s \) as discussed further below. The pressure contribution from the correction term for the inflaton with energy density \( \rho \approx V \) is

\[ p_f = (p + \frac{df(b,V)}{d\rho} - f(b,V) \] (3.1)

Including this modification into the expression for the primordial spectrum and replacing the field solutions, Eq. (2.7), in \( P_R \) in order to obtain \( P_R \) as a function of the wavenumber \( k \) we get

\[ P_R = \frac{1}{7\pi^2 M_p^4} \left( \frac{V_0(1 + V_0/2\sigma)^3}{\lambda^2 M_p^2} \right) g(b,\phi) \simeq \left( \frac{k}{k_{\text{ref}}} \right)^{n_s - 1}. \] (3.2)

where

\[ g(b,\phi) = \left( 1 + 4\pi \left( \frac{f(b,V) + p_f}{M_p^2 H^2} \right) \right)^{-2} \simeq \left( \frac{k}{k_{\text{ref}}} \right)^{8n_s}. \] (3.3)

For the parameter choice described above the maximum power is roughly on scale 180 Mpc. The modified \( P_R \) is an increasing function of \( k \) for small scales and a decreasing function at large scales. This gives rise to a suppression of power on quadrupole scales and a running of the spectral index \( n_s \). The spectrum tilts a little to the blue on large scales and has a slight running towards red in small scales for some parameter sets. This feature can be seen in Fig. [1] in particular, for the case with \( b = 4.0 \times 10^9 \text{ GeV} \). Now let us look at these effects in more detail.

#### A. Suppressed \( \sigma_8 \)

As seen from the figure, the suppression around the quadrupole results in a 30% decrease on the rms amplitude
The running of the spectral index $\delta n_s$, as a function of $k$ can now be estimated by replacing $\phi \approx -V'_\text{eff}/3H$ and using the solution for $\phi$ in Eq. (27). The expression is very long and not particularly illuminating so instead of writing it here we can just describe the relevant features. The maximum running is at low wavenumbers, the result of which is a suppression of the $TT$-spectrum at low multipoles, Fig. 1. The reason for this is that the correction term in the Friedman equation has its maximum effect at the onset of inflation when $V \approx \sigma(b,V)$, and therefore the inflaton slow-roll is disturbed near the scales corresponding to the first few e-foldings. This results in suppressed power at these scales. As $V$ decreases during inflation the correction term is redhifted away. The overall running tends towards the blue at low multipoles and towards the red at higher multipoles.

Unlike the models in Refs. [10, 12] the correction terms that modify the Friedmann equation, and therefore the energy and length cutoff scales $\sigma(b,V,L_1(b,V))$ in our model are dynamical. By this we mean that their scale of influence changes with $k$ since due the interlocking of $b$ and $V$ contained in $\sigma(b,V)$, the ratio $b^2/V(\phi)$ changes as $\phi$ rolls down its potential. This results in three different regimes for the slow-roll of inflaton and generation of perturbations. At the onset of inflation, the two energy terms in $H^2$ are comparable thus the amplitude of perturbations and $TT$ power is suppressed around the quadrupole. The dominant contribution in the interference length comes from the exponential term, which as we mentioned before, arises from tunneling to and from other patches.

When $k_{18}$ leaves the horizon, the inflaton potential $V/M_p^2$ becomes comparable to $b^2$ and thus the energy in the correlation term dominates over the logarithmic term. This results in a discontinuity of $\delta n_s$ around $k_{20}$ which suppresses the perturbations of $k \approx 18 − 20$, corresponding to the scale $140 − 180$ Mpc today. This discontinuity is important for structure formation features as discussed below.

A second discontinuity occurs around $k_{40}$ towards the end of inflation where $V$ has dropped so much that the exponential term in $\sigma(b,V)$ is nearly zero and the energy correction is dominated by the log term. Furthermore, as $V$ drops below $b^2$, the log term and $f(b,V)$ change sign from negative to positive energy corrections, which creates a jump discontinuity at $k \approx 40$ for $n_s$ and thus another suppressed perturbation around $k_{40}$.

1 Here the notation $k_{18}$ means that the scale which exits the horizon 18 e-folds after the onset of inflation.
a scale which at present is deep into the scales relevant for substructure formation.

C. LSS, Voids and the Axis of Evil

We described above the effect of the dynamic modification term on the background potential. Until $k = 40$, this modification is negative and the correction to $\Phi$ lowers structure there. Thus we have a perturbation channel originating from the entanglement modification term which produces inhomogeneous, non-gaussian and nonadiabatic anisotropies $\delta \Phi / \Phi^0$ that are superimposed on the gaussian perturbations generated by the inflaton potential $V$ (cf. Eq. 3.4).

The present day Newtonian background potential can be estimated from Eq. (3.4) through the expression $\Phi(r,z) = (1 + z)G(z)\Phi(r,0)$ where $G(z)$ is the growth factor of structure and $r, z$ are the physical comoving distances and redshifts respectively. It should be noted that the correction term here is scale dependent since it involves a coupling of the $b, V$ channels for the highly nonlocal entanglement with size $L_1 \gg r_H$. Since most of the matter in our universe is made of dark matter we can view the above modification to the background Newtonian potential as a perturbation on dark matter, denoted by $(\delta \rho / \rho)_1$ in the previous section, but of arising due to quantum entanglement, as opposed to having an inflationary origin.

In Fig. 2 we plot the matter power spectrum calculated with CMBFAST with the modifications in our model. For comparison we also plot the results of the LCDM model as well as the SDSS data [13]. Here the parameters for the inflaton potential are taken as $\lambda = 0.1$ and $V_0 = 8.0 \times 10^{-8} M_\odot^2$. We varied the overall normalization slightly to fit the data by using the uncertainty of the bias.

As can be seen from Fig. 2 for the matter power spectrum $P(k)$, the negative contribution from the modification of the energy density during inflation, which takes its maximum value at large scales results in less structure at very large scales in our model compared to the concordance cosmology LCDM. This is due to the negative correction in Eq. (3.4) which gives rise to a negative density contrast denoted above by $\delta f < 0$ being superimposed on the positive background potential thereby resulting in damped structure formation and the creation of primordial voids at those large scales. We discussed above how the correction to the quadrupole amplitude which damps power on these scales also produces the first void at around $k \simeq 1$, when evolved to present times, resulting also in a compensation of the ISW effect of dark energy. This void is unaffected by the nonlinear physics of the subsequent structure growth since it is located at low multipoles where the potential is nearly constant. According to Inoue and Silk [14], a void-induced quadrupole of any size can explain the two cold spots observed by SDSS [13] in the sky at $(\Delta T / T)_{\text{quad}} < 0$ and the alignment of quadrupole with octupole along the preferred axis which here is the direction that joins the two voids at 60 degrees on the sky, namely the axis of evil. We refer the reader to Ref. [14] for the details of this calculation.

We expect the second void to form at the first discontinuity in the kinetic term $\phi, V_\text{eff}'$ corresponding to scales $k = 20$ or

![FIG. 2: Matter power spectra for the same values of $b$ as Fig.1, described in Section III. For comparison, the case with $\Lambda$CDM (solid line) and the data from SDSS are also plotted. Top panel shows $P(k)$ for several orders of $k$, middle panel is the same as the top panel except the range of $k$ to look at the scales seen by SDSS and bottom panel shows $kP(k)$.]
about 200 Mpc at redshifts $z \sim 1$. This void would correspond to an angle less than a degree in the sky today, which may be related to the unusual cold spot observed in the southern hemisphere, as discussed in Ref. [13]. However, a deeper understanding of this point requires dealing with the nonlinear growth of structure at these scales. It is unclear to us whether these structures will persist after nonlinear evolution to the present epoch.

Although the second discontinuity would suppress the background perturbations at around $k = 40$, it would not produce voids now the superimposed nonadiabatic perturbation from the modification term has a positive density contrast, which serves to enhance structure formation rather than suppress it (Fig. 2).

Fig. 2 confirms that power is indeed suppressed compared to LCDM at large scales. However, unlike in the LCDM situation, it is enhanced at structure and substructure scales. As far as the linear theory is concerned, $P(k)$ in our model is in closer agreement with the SDSS data than the conventional $LCDM$ model. For $k < 0.09 \, h/\text{Mpc}$, nonlinear evolution can alter the matter power spectrum. Thus our model may have implications for the nonlinear evolution of structure. We would like to emphasize here that we have no room to change the parameters $b, V$ in order to fit the data shown in Fig. 2 since the effect is derived from a highly nontrivial and nonlocal term that couples $b, V$.

D. Cosmic Shear and its Correlation with Temperature Anisotropies, $C_{TT}$

How can we distinguish our model from other models that might predict suppression of power at low $l$? This crucial issue was addressed in [16] with the result that the best tool to use to discriminate between models is the prediction for the cross-correlation between the $TT$ and the cosmic shear $LL$ lensing potential which traces out the large scale structure of the universe. Doing this gives us a direct comparison between the sources that seed both types of perturbations. The standard picture of the generation of fluctuations in inflationary cosmologies provide only one source, the primordial spectrum, for seeding both CMB and LSS and therefore predicts a correlation of order one on large scales. On the other hand, models with input from quantum gravity/string theory will likely provide additional sources for perturbations or gravitational potential independent of the primordial spectrum since they could contain more degrees of freedom. Therefore the $TL$ correlation would reflect this input of new physical degrees of freedom by predicting a correlation different from one and with unique features on it which are used to identify the model.

We follow the approach of [16] in calculating the cross-correlation fluctuations $C_{TT}^{TL}$ between shear and temperature. Fig. 3 shows our results for this cross-correlation. In the figure, we take $b = 4.0 \times 10^9$ and $3.6 \times 10^9 \, \text{GeV}$ as an example. Other parameters are taken as $\lambda = 0.1$ and $V_0 = 1.2 \times 10^{-8} M_p^2$. The fact that our modification of the Friedmann equation comes as it does, i.e. from entanglement effects between our horizon patch and others gives rise to some interesting and potentially unique features which we display in Figs. 3 and 4.

At large scales (low multipoles) we can see that the cross correlation of our model has essentially the same shape what would come from a LCDM model but with a suppressed amplitude. The reason for this is that at those scales near the onset of inflation, the correction cutoff scale $\sigma(b, k)$ (which is obtained by substituting Eq. 2.7 into the definition of $\sigma(b, \phi)$) is nearly a constant and the overall effect of its negative energy contribution is to slightly suppress $TT$ spectrum, Fig. 3. The most interesting and distinct features can be found at shorter scales $180 < l < 700$ as shown in Fig. 4. We see that around $l \approx 200$ the correlation $C_{TT}^{TL}$ dips by about three orders of magnitude, with a ringing effect at structure formation scales and another dip in power at substructure scale, with ringing in between. The damping of this correlation means that much of the contribution to LSS is not coming from the primordial inflationary channel at those scales but from the correction term to the Newtonian potential given by $\sigma(b, k)$. We believe that these features correspond to the discontinuity found in the spectral index at around $k = 20$, $k = 40$ which arises from the changing in the dynamics of $\sigma(b, k)$. The ringing between them comes from Fourier transforming the two sharp features in $k$ space into $l$ space. These dips and ringing at structure scales are a result of the enhancement of power at these scales originating from the channel of the nonlocal entanglement. As we discussed above, the first one near $l \approx 180$ may be correlated to the void appearing at the same scale, while the second damping originates from the potential modification term switching from negative to positive thereby going through a discontinuity at around $k = 40$, Fig. 4. These features may be distinguishable by future surveys.

![FIG. 3: Cross correlation between lensing and temperature are plotted. We assumed $b = 4.0 \times 10^9$ (dash-line) GeV and $3.6 \times 10^9$ GeV (dot-line) in this figure. For comparison, the case with LCDM (solid-line) is also plotted.](image-url)
IV. A SMOKING GUN FOR THE LANDSCAPE?

Much of the current discussion about string theory is centered around the question of whether any theory with a landscape of vacua as well populated as that of string theory could ever be predictive. Perhaps all we can do is look for correlations between various observables in each of the vacua of the landscape and make a very restricted set of “predictions” from these correlations. This is a rather bleak view of the future of physics, and one we do not share.

What we have shown in this work as well as its prequel is that, while we freely admit that the detailed behavior of the string landscape is still unknown, it is not out of the realm of possibility that we might be able to detect “smoking-gun” effects from it on the sky. In particular, the effects of the dynamics of quantum gravity, and in particular, those due to nonlocal entanglements between our horizon patch and others, could modify the Friedmann equation and hence other cosmological observables and these modifications could be amenable to present or near future observations.

Let us summarize our results in more detail.

In paper I [7] we showed that the requirement of having a sufficiently flat inflationary potential after the modifications to the Friedmann equation are taken into account, coupled with the known value of the CMB quadrupole placed stringent bounds on the energy scale related to the structure of vacua in the non-SUSY part of the landscape. In our picture, this is the SUSY breaking scale, and we find that it has to be significantly larger (five to eight orders of magnitude larger) than studies of the hierarchy problem would have required. The LHC will be able to test this statement soon, once again showing the tight interconnectivity between particle physics and cosmology.

Besides the tight bound on SUSY breaking scale, we find many interesting and perhaps unique clues imprinted on the CMB and on large scale structure.

We have shown here how the negative, scale-dependent, energy correction in the modified Friedman equation suppresses the temperature anisotropy spectrum at large angles, Fig. 1 which could help explain the observed suppression of power in the $TT$-spectrum by WMAP and COBE. The second and the third peak seem to also be mildly sensitive to the SUSY breaking scale $b$ and to the scale of the nonlocal entanglement $L_1$. As we have explained in the text this is related to the enhancement of power Fig. 2 at structure and substructure scales and the scale-dependent modifications to the background Newtonian potential given by Eq. (4.4) which act as a source for the $TT$-spectrum.

The matter power spectrum is given in Fig. 2 and the modulation at scales after the last scattering shows up there too, although it is a small effect. However, as can be seen from Fig. 3 there are definite imprints on $P(k)$ with their origin in the correlations to the Newtonian potential coming from the quantum gravitational entanglement. The correction to the background Newtonian potential coming from the entanglement of our universe with superhorizon fluctuations of our infatation patch and others leaves a definite imprint by damping structure at large scales and enhancing it at structure and substructure scale. As far as the linear theory is concerned, these corrections bring the matter power spectrum into much better agreement than LCDM with the data from the recent result of SDSS [13]. This also suggests that it may have implications for nonlinear modeling.

The effects we find here also provide a natural mechanism for creating primordial voids only at relevant scales $k \gtrsim 1$ and $k \lesssim 20$. These effects come from the potential correction of the non-Gaussian nonadiabatic superhorizon fluctuations being superimposed on the background potential of the gaussian perturbations thereby giving rise to a negative density contrast $\delta_\ell < 0$ at certain scales discussed above. The implications of this superimposition are twofold: It induces a running in the scalar spectral index $n_s$ as calculated above, $n_s = n_s^0 + \delta n_s$, which is in agreement with the WMAP data [9] and; it creates voids at large scales where the background and correction terms are comparable.

We showed in paper I [7] that the anisotropy scale contributing to the spectrum is bound to be at least 100 times greater than the horizon radius namely $10^{-10} M_p < b < 10^{-8} M_p$, corresponding to roughly the first $10^4$ e-foldings for GUT inflation. In terms of energies this stretches to about 18 e-foldings. This corresponds to primordial voids being created at $k \approx 1$ or $50-60$ degrees, (causally disconnected part), in the sky or roughly at $\ell \lesssim 10$. Following the calculation done by Inoue and Silk [14] at the present epoch, the angle $\theta$ is given by the ratio of the size $r_\ell$ to the distance $d$: $\sin \theta = w = ar_\ell/d$. Their estimate shows that for voids with $w \approx 0.9$, $r_\ell \approx 10h/10$ they agree with the SDSS findings of the observed two cold spots in the sky. As we have shown here the first voids are formed at $k \approx 1, \theta \approx 60$ which is in agreement with the SDSS findings. Thus the void induced quadrupole suppression may explain the two observed cold spots since $\Delta T/T \simeq \delta \Phi/\Phi$.

The anticorrelation between the negative and positive density contrasts at low $\ell$ ($\ell < 10$) shows itself as an alignment...
between the quadrupole/octetpole with more power concentrated along this direction [17,18] as shown in [14] i.e. a preferred direction along the correlation where the angular momentum dispersion is a maximum. The preferred direction is the line parallel to the vector connecting the centers of the voids located at 60 degrees. The superhorizon potential fluctuation related to the quadrupole scale acts as a gradient field with the quadrupole direction as the preferred axis. A more careful treatment of this issue requires a more detailed calculation of the evolution of the negative density contrasts, especially for the other voids located at $k = 20$, as well as the generation of the sky maps for this model. This is beyond the scope of this paper.

Our smoking gun which uniquely identifies the CMB and LSS signatures of this model, comes from cross-correlating cosmic shear with temperature anisotropies. As discussed in [16] this cross-correlation compares the sources that seed the lensing potential which maps large scale structure and the source that seed CMB anisotropies. In the case of conventional inflation that source should be the primordial spectrum $P_R$ and be the same for both CMB and LSS. Therefore a conventional cosmology predicts a correlation of order one. What we find here instead is that only the correlation is not close to one, see Fig. [thereby demonstrating the existence of non-inflationary channels contributing to structure, but that there are unique and rather interesting features in this spectrum at structure and substructure scales which soon will be observed by the PLANCK mission. This unique features come from the highly notrivial expression of the nonlocal entanglement contained in $F(b,V), L_1$. We can describe it physically by noting that the discontinuities induced on the scalar spectral index $n_s$ show as the dips in Fig. [when Fourier transformed from $k$ space to $l$-space, these together with the scale-dependent corrections on the Newtonian potential $\delta_f = \delta\Phi/\Phi^0$ show as ringing in the correlation for scales shorter after the surface of the last scattering. These are clearly very definite signatures that can be looked for by future surveys.

The main lesson to be taken from this, admittedly speculative, treatment of the dynamics of the landscape is that there are concrete calculations that can be done and concrete predictions that can be made. We certainly do not argue that our results are exactly how the landscape behaves. Rather, there are interesting possibilities that may be robust enough to survive a more detailed analysis of the landscape. When a more detailed theory of the quantum gravity in the early universe is known, as we have demonstrated here, its astrophysical imprints may be within reach of observation in the cosmological arena.

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