Journal of Modern Physics, 2026, 17(5), 536-551
https://www.scirp.org/journal/jmp
ISSN Online: 2153-120X
ISSN Print: 2153-1196

A Critical Look at the DESI Analysis Methodology

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How to cite this paper: Botke, J.C. (2026) A Critical Look at the DESI Analysis Methodology. *Journal of Modern Physics*, **17**, 536-551.
https://doi.org/10.4236/jmp.2026.175025

Received: February 18, 2026
Accepted: May 22, 2026
Published: May 25, 2026

Abstract

In this note, we show that the methodology used by the DESI collaboration and others for extracting cosmological parameters from 2-point galaxy correlations is fundamentally flawed. The problem with that method is that it is based on the use of a fiducial cosmology to determine the comoving coordinates of galaxies, which are then used to fix parameters, but the method is circular and is guaranteed to return the fiducial parameters as the optimal solution, no matter what model or set of parameters is used. We also point out several arguments against the existence of baryonic acoustic oscillations on large scales, and a significant problem with the FRW model when the latter is used to investigate events at the time of recombination.

Keywords

Cosmology, Galaxy Correlations, Hubble Constant, Dark Energy, Cosmological Constant

1. Introduction

One of the long-standing problems of cosmology is the disparity between the values of the Hubble constant determined by the standard-candle, distance-ladder approach and the baryonic acoustic oscillation (BAO) approach [1]-[4]. The BAO authors claim that their results support the standard model of cosmology, but the distance ladder authors claim the same thing, and both can't be right since the respective values of the Hubble constant differ by a considerable amount. In this paper, we are concerned with the BAO 2-point galaxy correlation approach which builds on the fact that there is a peak in the correlation distribution at a distance of ~150 Mpc [2] [5]. The current interpretation of this peak is that it is a result of density concentrations induced by BAO in the matter content of the universe at the time of recombination [5] [6]. What we will show is that, first, there are significant problems with the whole idea of BAO on the scale needed to explain the correlation peak, and second, while the peak is real enough, the method used to extract cosmological parameters from it is flawed with no way that it can be fixed.

Before getting to those topics, we will first discuss dark energy. A primary goal of the DESI program (the DE in DESI stands for dark energy) is to determine the origin of dark energy and the value of the cosmological constant. In the next section, we will show that our new model of cosmology provides a full explanation of both, including a formula for the cosmological constant whose value matches the currently accepted Planck value. Following that somewhat off-topic excursion, in the remaining sections, we will point out a number of problems with the BAO model and with the standard 2-point correlation analysis methodology. Because of these problems, the 2-point correlation determinations of cosmological parameters, such as the Hubble constant, are meaningless.

2. Dark Energy and the Cosmological Constant

The idea of a cosmological constant has been around for a long time, but the lack of knowledge about its origin and value didn't acquire any urgency until the discovery of the accelerated expansion of the universe [7]. At that point, within the context of the FRW model of cosmology, a cosmological constant became necessary to account for the expansion. One of the failings of the FRW model of cosmology is that it does not predict its existence or its value, so it had to be introduced as an *ad hoc* addition. That is where things stood for about 20 years, but recent DESI results [2] [5] hint that dark energy varies with time, which creates a problem if one believes that dark energy and the constant are just different names for the same thing. The problem is that the covariant derivative of the cosmological constant term in Einstein's equations, $\Lambda g_{\mu\nu}$, must vanish, and this will only happen if Λ is a constant. This means that one cannot simply substitute $\Lambda \to \Lambda(t)$, either directly or in the form of a time-varying equation-of-state, in the FRW solution to represent time-varying dark energy. Since the cosmological constant is considered to be a vacuum phenomenon, the logical extension is to think of dark energy as another name for time-varying vacuum energy. With that interpretation, the cosmological constant drops to a secondary role as the value or limit of dark energy at some particular point in time. But this now creates a fatal problem for the FRW model because the only property the vacuum has is its curvature, so if the vacuum energy varies with time, so must the curvature. But with time-varying curvature, the FRW metric with its constant curvature no longer represents the actual universe.

Our new model of cosmology, on the other hand, begins with the ideas that the curvature of spacetime varies with time, and that the self-interaction of vacuum energy requires that the vacuum energy and pressure must be included in the energy-momentum (EM) tensor on the RHS of Einstein's equations, which puts us exactly in the position we just described. We found the exact solution of the resulting equations, and among the results are formulas for the time-varying vacuum energy and pressure [8] [9]. Both have non-zero values at infinite time, but their sum, which is the total energy, vanishes at infinite time, and has a present-day value that is within a factor of 3 of the accepted current value of dark energy.

The formula for the scaling is (the parameters are explained [8])

$$a(ct) = a_* \left(\frac{ct}{ct_0}\right)^{\gamma_*} e^{\frac{ct}{ct_0}c_1} \tag{1}$$

and from this, we have

$$H(t) = \frac{\gamma_*}{t} + \frac{c_1}{t_0}. \tag{2}$$

Clearly, the model predicts the present-day accelerated expansion. The parameter values are $\gamma_* = 0.5$, and with $H_0 = 73$, $c_1 = 0.53$. These are the only two parameters of our model.

The formulas for the energy and pressure are

$$\rho_{vac}c^2[ct] = \frac{3}{\kappa(ct_0)^2}\left(\frac{c_1^2}{(1-\gamma_h)^2} + \left(\frac{2c_1\bar{k}_0}{\gamma_h}\right)\frac{ct_0}{ct} + \bar{k}_0\left(1 + \bar{k}_0\frac{(1-\gamma_h)^2}{\gamma_h^2}\right)\frac{(ct_0)^2}{(ct)^2}\right) \tag{3a}$$

$$p_{vac}[ct] = \frac{-3}{\kappa(ct_0)^2}\left(\frac{c_1^2}{(1-\gamma_h)^2} + \left(\frac{2c_1\bar{k}_0}{\gamma_h}\right)\frac{ct_0}{ct} + \bar{k}_0\left(1 - \frac{2}{3\gamma_h} + \bar{k}_0\frac{(1-\gamma_h)^2}{\gamma_h^2}\right)\frac{(ct_0)^2}{(ct)^2}\right). \tag{3b}$$

In these formulas, $\bar{k}_0 = 1/8$ and $\gamma_h = 1/3$, which are also explained in [8].

With respect to a cosmological constant, our original EM tensor does not contain such a constant, but if we replace the original energy and densities with variables that vanish at infinite time,

$$\bar{\rho}_{vac}c^2 = \rho_{vac}c^2 - \rho_\infty c^2 \tag{4a}$$

$$\bar{p}_{vac} = p_{vac} + \rho_\infty c^2, \tag{4b}$$

the EM tensor becomes

$$\boldsymbol{T}^{\mu\nu} = \left(\bar{\rho}_{vac}c^2(ct) + \bar{p}_{vac}(ct)\right)\delta_0^\mu\delta_0^\nu + \left(\bar{p}_{vac}(ct) - \rho_\infty c^2\right)\boldsymbol{g}^{\mu\nu} \tag{5}$$

which has now acquired a cosmological constant whose value is

$$\frac{3}{\kappa(ct_0)^2}\frac{c_1^2}{(1-\gamma_h)^2} = 5.33\times10^{-10}\ \mathrm{J\cdot m^{-3}}. \tag{6}$$

The Planck value is $\rho c^2_{Planck} = 5.36\times10^{-10}\ \mathrm{J\cdot m^{-3}}$ [10] which is the same.

The DESI hint about a time variation of dark energy is expressed in terms of a simple *ad hoc* formula, $w(z) = w_0 + w_a(1 - a(z)/a_0)$ where $w(z) = p(z)/\rho c^2(z)$ is the dark energy equation-of-state (EOS) and w_0, w_a are supposed to be constants [2] [5]. Although the notion of an EOS does not appear in our new model, it is a simple matter to compute the ratio of the formulas of Equations (3) and (4). The result is shown in **Figure 1**. Both ratios approach 1 as $t \to \infty$ and neither crosses into the so-called phantom region. Our prediction of the other parameter, $w_a = (w(z) - w_0)/(1 - a(z)/a_0)$ is also shown in the figure, and it is clearly not constant.

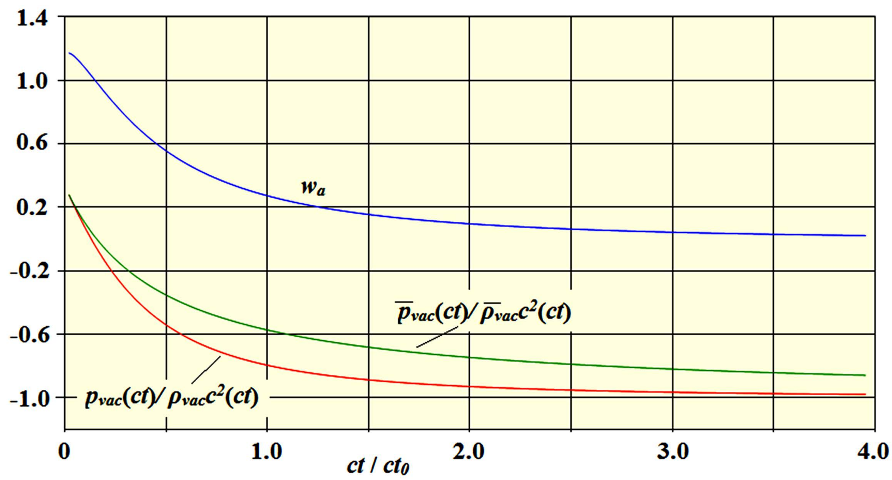

Figure 1. Vacuum EOS.

Our value for the parameter $w_0 = -0.79$ is the value of the EOS at the present day, and so is a constant. Neither DESI nor others pin down values for either of the parameters, so we can't make a direct comparison, but w_0 is thought to be negative with a magnitude somewhat larger than our value. The possible values of w_a range from 0.6 to −1.2 or so, with the latter value favored when w_0 is equal to our value.

The net result is that the FRW EOS does not agree with our solution, but our result is an exact solution of Einstein's equations, whereas, with time-varying vacuum energy, FRW is no longer even a valid model.

3. BAO

Baryonic acoustic oscillations (BAO) are another idea that has been around for a long time, and many observable phenomena have been attributed to such waves, but the fact remains that the BAO are entirely a hypothetical concept without any direct observational basis. In order for any theory to be considered valid, it must be both sufficient and necessary. The only BAO "observable" is the so-called sound horizon, $r_d \sim 150\,\text{Mpc}$, but that same dimension is characteristic of the cosmic web, so any model that can account for the cosmic web without BAO proves that, while BAO might be sufficient, it is certainly not necessary. In spite of its general acceptance, there is nothing in the BAO catalogue of effects that can't be explained by other cosmological models such as ours [11] [12].

We will now present several arguments that show that the idea is unworkable on the large scales necessary to explain, for example, the origin of cosmic structures, or the temperature anisotropies and polarization of the CMB.

BAO emerged from a perturbation approach to Einstein's equations in which the perturbations were small adjustments to the homogeneous FRW background field equations. The idea is that the coupled photon, electron, and proton fluid that filled the universe before recombination supported sound waves that moved away from perturbation sources. Eventually, at the time of recombination, the sound waves dissipated, leaving behind matter density highs and lows that supposedly created the temperature anisotropies and polarization of the CMB, as well as seeding the later formation of structures by gravitational accretion.

We will now establish a few numerical values that will be referred to later. The average present-day size of superclusters is around $4.4\times10^{24}\,\mathrm{m}$. Since superclusters are too large to be affected by gravitation, we can scale their size to the time of recombination ($z = 1100$) to find that a characteristic length was about 10^{21} m. The formula for the apparent angular size of some structure at t_{rec} is given in terms of its present-day size by $\theta = l_{sc}(t_0)/(r_{trec}a_0)(180/\pi)$ [8] where r_{rec} is the (constant) comoving coordinate of the structure. Using the FRW formula for the coordinate [13], we find in the FRW case, an angle of 0.57˚, whereas in our new model, the angle is 1.0˚. We also know that the CMB temperature anisotropies also have a characteristic angular size of 1˚, so these together place a consistent constraint on the sound horizon length if the BAO are going to be responsible for their existence.

There are, however, many problems with that idea. The perturbation model imagines a wave emerging from a source at the time of nucleosynthesis, which was later received at some distant region of space at the time of recombination. The first problem is that there would not have been just one source, so each such target point would receive waves from sources distributed over a sphere with a radius determined by the sound speed and the time of recombination. Comparing the surface area of that sphere with the maximum size of a coherent source at the time of nucleosynthesis, $c\times1\,\mathrm{s}$, we find a count on the order of 10^{23} sources. That might be an overestimate, but probably not by much. A necessary part of the BAO idea is that a BAO wave detected by an observer at the time of recombination would define a direction, because otherwise, there would not be any notion of a horizon. While that would naturally arise from waves emitted by a single source, with the extreme count of sources that would actually have existed, no net direction could have existed, and the basis of the BAO explanation of the CMB polarization falls apart (See e.g. [14]).

If we consider another point some distance away from our first point, it too would have received waves from all directions but from a different set of uncorrelated sources, so the resulting distribution would be an uncorrelated stochastic process. There is just no way that the waves from all those sources could add up to a net wave at any such point, and an even greater impossibility is that all these waves from uncorrelated sources could add up to a blueprint for the cosmic web whose characteristic length is given by the size of superclusters.

The next problem is the assumed existence of the gravitational forces necessary for the formation of sound waves. The idea is that in over-dense regions, gravity will pull the matter together. The resulting increase in the scattering rate would raise the temperature, causing in turn, a pressure which would eventually reverse the infall. The resulting pressure gradient would drive matter away from the high-density regions into the low-density regions, where gravitational attraction would again build up a pressure gradient, but in the opposite direction. The result would be a sound wave.

The problem is that while it might work on small scales, it cannot work on scales large enough to explain cosmic structures or the CMB anisotropies. In [15], we used Newton's law to follow the evolution of spherical structures of various sizes[1]. In this case, Newton's law is perfectly adequate because GR corrections are only necessary for extreme densities or extreme dimensions, and by the end of nucleosynthesis, neither of those limits applied. The evolution of the surface is given by

$$\ddot{R}(t) = -\frac{GM_{eff}(t)}{R(t)^2} + R_0 f_s\left(-\gamma_* + \left(\gamma_* + c_1\frac{t}{t_0}\right)^2\right)\frac{a(t)}{a_0}\frac{1}{t^2} \tag{7}$$

which includes both Newtonian gravity and the expansion of the universe. This model is quite simple, but because it includes the two major influences acting on any enclosed ball of matter, it is also quite likely to be correct. The details of the model are described in the reference. In **Figure 2**, we show the predicted evolution of the Milky Way from the end of nucleosynthesis up to $t_G = 10^{16}$ s, the generally accepted time of galaxy formation.

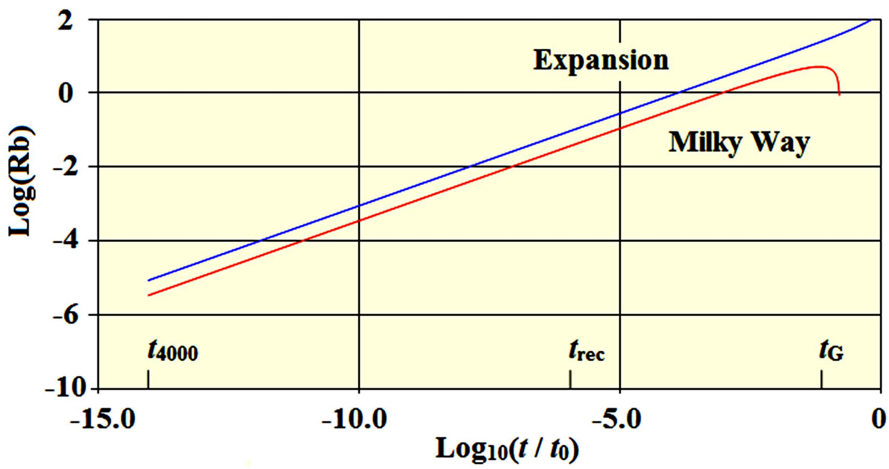

Figure 2. Evolution of the milky way.

The red line shows the evolution of the Milky Way, and the blue line shows the evolution of a point of the surface resulting from just the scaling, *i.e.*, without gravity. Comparing the two curves, we see that gravity did not have any influence on the expansion until well after the time of recombination.

When the model is applied to the evolution of galaxy clusters, the curves are the

[1]In our new model of cosmology, all cosmic structures came into existence during an event that marked the beginning of nucleosynthesis. In this model, accretion played no role. Instead, they were defined by an imprint established in the vacuum during the initial Planck-era inflation, and began with their final masses, but with sizes much larger than their final sizes. Refer to [16] for the details.

same up until times close to t_G. When applied to the evolution of structures with initial sizes on the order of 1 lightyear to represent stars, the results indicated that on those scales, gravitation would be significant even before $t = t_{rec}$, but we also show in [15] that, according to Jean's model of star formation, early stars could not form before $t = t_G$. because the temperature of the cosmic matter gas was too high.

We find then that on scales the size of galaxies or larger, particles were moving apart far too rapidly for pressure forces to exist. The universe might have been filled with small sound wave bubbles, but these would not have become organized on the large scales needed to explain the 1˚ size of structures at the time of recombination.

A third problem is that, in order for BAO to have had any effect during recombination on 1˚ scales, the BAO length scale would have had to match the size of superclusters at that epoch, and that constraint is highly model dependent. Given any model, the time of recombination is found by working backwards from the present, starting with the present-day CMB temperature. The BAO/sound horizon length scale, on the other hand, depends on the time interval between nucleosynthesis and recombination working forward. This makes the BAO model highly dependent on the exact time of recombination in relation to the age of the universe, which, in turn, is fixed by the details of the expansion scaling.

For an estimate, we can find the recombination time going forward using $c_s \approx c/\sqrt{3}$. We noted earlier that the characteristic length needs to be on the order of 10^{21} m. This gives a time of $t_{rec} = 10^{21}\,\text{m}/c_s = 5.8\times10^{12}\,\text{s}$. Next, using the FRW formula [13] for the cosmic time,

$$t_{trec} = \frac{1}{H_0}\int_{z_{trec}}^{\infty} \mathrm{d}z' \frac{1}{(1+z')\sqrt{\Omega_m (1+z')^3 + \Omega_\Lambda}} \tag{8}$$

we find $t_{rec} = 1.5\times10^{13}\,\text{s}$, so, with the FRW model, the two values are reasonably consistent.

Our new model, on the other hand, predicts a time of recombination of $t_{rec} = 1.0\times10^{12}\,\text{s}$ which is about an order of magnitude earlier than the FRW estimate. At that time, the sound horizon length scale would have only been about 5% of the needed 1˚ length scale, so assuming our new model is correct, BAO could not have had anything to do with the origin of the cosmic web even if such waves did exist. The superclusters still need to be explained, and our new model does present such an explanation [9] [15] [16].

Next, we will consider the look-back time. The FRW formula [13] to a source with redshift *z*. is given by

$$t_0 - t_{lb} = \frac{1}{H_0}\int_0^{z} \mathrm{d}z' \frac{1}{(1+z')\sqrt{\Omega_m (1+z')^3 + \Omega_\Lambda}} \tag{9}$$

In **Figure 3**, we show the look-back time for $\Omega_m = 0.3$, $\Omega_\Lambda = 0.7$, and $z_{trec} = 1100$ for a range of Hubble constants

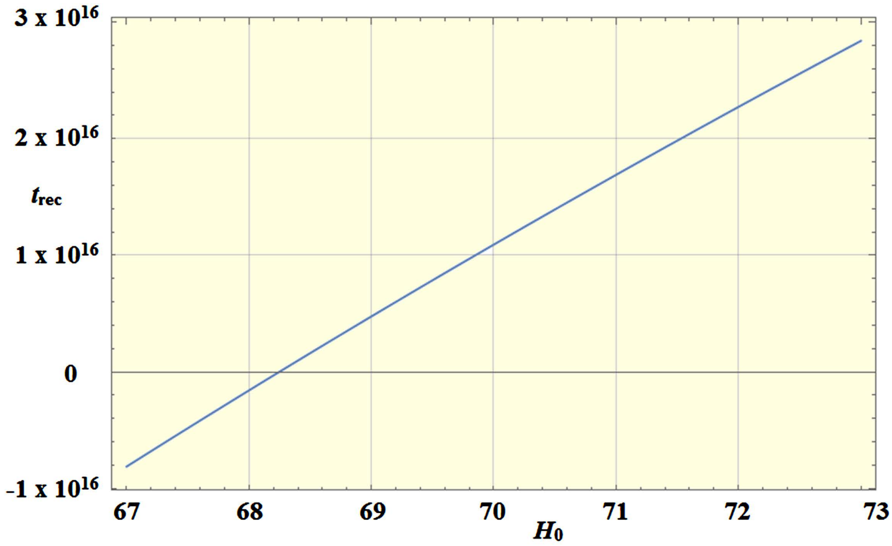

Figure 3. FRW look-back time versus Hubble constant.

The first thing we notice is that for $H_0 = 73$, the look-back time is not even remotely the same as the BAO time of recombination. This means that the *structure* of the FRW model, with the above parameters, forbids that value of the Hubble constant when dealing with events at the time of recombination.

The next thing to notice is that for $H_0 < 68.3$, the look-back time is negative, which again indicates a structural failing of the FRW model since the look-back time should not be negative for any reasonable value of the Hubble constant, and that cutoff value is greater than the Planck determination for the constant.

After rearranging Equation (9), we solve for the Hubble constant for a range of look-back times and for three values of z_{trec}. In **Figure 4**, we show the results.

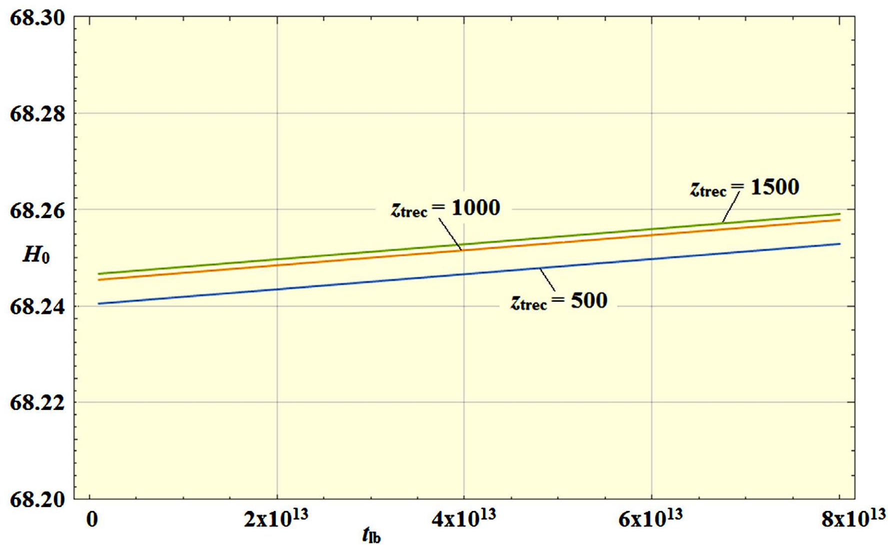

Figure 4. Hubble constant versus look-back time for 3 values of redshift.

The FRW model prediction is that the Hubble constant is essentially a constant, independent of either the look-back time or the redshift. We also see that the predicted value is close to the Planck value, and since the Planck analysis is based on the FRW model, this is no surprise. For recombination times corresponding to the BAO estimates, the only value that FRW will allow is $H_0 \approx 68.25$, and it completely rejects a value of 73, again for the above set of density parameters.

Moving on, a fourth BAO issue is with the anisotropy energy budget, which we discuss in [11].

The conclusion is that a BAO origin of cosmic structures and CMB anisotropies and polarization on the 1° scale of superclusters is just not possible.

4. Two-Point Galaxy Density Correlations

The two-point correlation function is a statistical measure defined in terms of the distance between all pairs of galaxies, and it has been known for some time that there is a bump in the correlations at a separation of ≈ 150 Mpc [17]. The BAO idea is that the sound waves created variations in the distribution of matter, and that the higher density regions were later responsible for the formation of galaxies by accretion. Given that idea, the density distribution of galaxies should peak at the BAO sound horizon distance. As we discussed in the previous section, however, there are a number of reasons why the BAO scheme is unworkable.

In our view, the correlation distance of ≈ 150 Mpc is simply a reflection of the cosmic web, with the peak being fixed by the average size of superclusters and large voids. To test this idea, we created a simple simulation of the cosmic web [9] starting with an initially regular cubic grid, which we then distorted with random relocations of the endpoints. We then populated each of the edges with a large number of randomly located member galaxies on a scale of 10% of the characteristic supercluster dimension. We next calculated the 2-point galaxy correlations for a number of random number sets and obtained the results shown in **Figure 5**. The curves don't match the observed correlations exactly, which isn't surprising given the simplicity of the model, but the peak is in the right place, and its magnitude is reasonable.

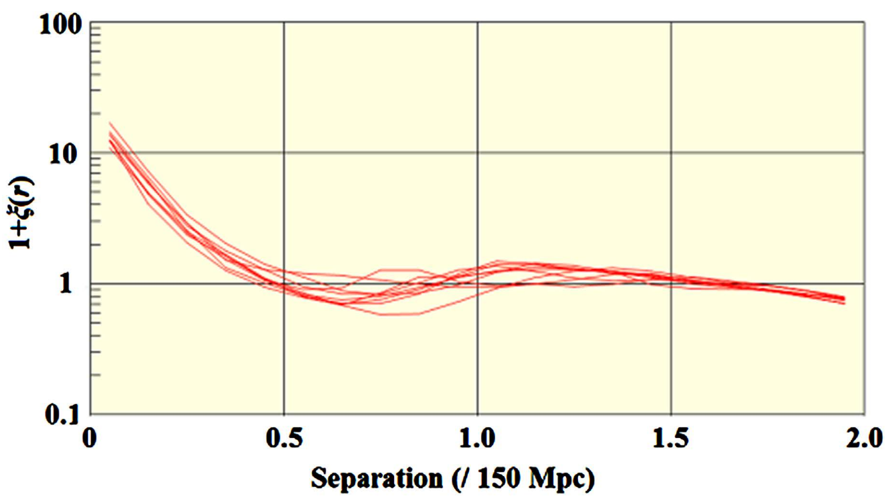

Figure 5. Simulation of 2-point galaxy correlations.

The BAO advocates would say that superclusters are a result of the BAO, but that would require a cooperation between the huge number of original BAO sources if they were to account for the web. Given the limitation of imposed by causality at the time of nucleosynthesis, that idea is impossible.

5. Cosmological Model Parameter Determination.

We will now get to the main topic of this paper. The main reason for having any interest in the length scale of the correlation peak, whatever its origin, is the idea that it could be used to constrain parameters of cosmological models. What we will now show is that that idea doesn't work.

The 2-point galaxy correlation is a manifestation of the actual locations of galaxies in space which we denote by their comoving coordinates, which, leaving aside peculiar velocities, do not change with time. The crux of the problem is that we have no way of actually measuring comoving coordinates outside our local region of space.

Close in, parallax measurements can be used, but beyond their range, the closest we come to actual distance measurements comes from the distance ladder approach, which is based on the idea of standard candles (see references in [12]). The ladder approach has been implemented in a number of independent ways, and these all give results that are in good agreement for redshifts out to $z \approx 1$ or a little larger. These methods are defined in terms of redshifts instead of comoving coordinates, so they still don't nail down comoving coordinates directly, but for a limited range of redshifts, all reasonable models will give the same results, so we can consider those comoving coordinates to be known with some accuracy. A key point, however, is that these determinations are a consequence of some set of cosmological parameters rather than being direct measurements.

For redshifts larger than $z \sim 1$ the standard candle-based measurements become more difficult with consequent larger error bars, and that brings us to the correlation peak method because the redshift measurements used in that method do not become ever more difficult with increasing distance.

As noted above, the 2-point galaxy correlation distance is a comoving coordinate phenomenon. Leaving aside peculiar velocities, all galaxies are at rest in comoving coordinate space, and since their positions don't change over time, neither do the actual 2-point comoving correlations. Since on large scales, the universe is generally thought to be homogeneous and isotropic, determinations of the correlations from any observation point during any epoch should return the same result. A corollary to this is that nothing bearing on time or location can be extracted from the correlation length, even though the locations must be known to determine the correlations.

To extract parameters, the idea is to measure the galaxy correlations across the sky and compare the results with the "known" BAO-induced correlation length using simple formulas from the FRW model. *The problem is that what is measured are redshifts*, *but what are needed are comoving coordinates because it is the* *coordinates that express the correlations*.

All studies, such as the ongoing DESI collaboration effort, begin by building large catalogues of galaxy positions in which their locations are specified in terms of 2 angles and a redshift. To get around the comoving coordinate problem, all studies next convert the measured redshifts into comoving radial coordinates using some fiducial cosmology (See e.g. [18]). In the DESI case, the fiducial model is a flat universe with $\Omega_m = 0.3$ and $H_0 \approx 67.3$ with all other studies using similar, if not identical, fiducial models. The result is a map of the universe that becomes the basis for further analysis. For example, from this map, the power spectrum, $P(k)$ and various forms of the correlation function, denoted by $P(r) = n(1+\xi(r))$ are determined. One then develops some model that is meant to represent the actual universe, which one then compares to the fiducial cosmology in various ways, such as by the use of the Alcock-Paczynski dilation parameters,

$$\alpha_{\parallel} = \frac{H^{fid}(z)r_d^{fid}}{H(z)r_d}, \quad \alpha_{\perp} = \frac{D_A(z)r_d^{fid}}{D_A^{fid}(z)r_d} \tag{10}$$

If the fiducial cosmology matches the true cosmology, then $\alpha_{\parallel} = \alpha_{\perp} = 1$ which is supposed to validate the model.

The problem is that the map upon which the "actual' analysis is based is *not* reality. It is, instead, a "*user-created*" *map*.

Assuming that a reasonable model is used, the resulting map will be a fairly accurate representation of the comoving coordinates of the galaxies, but w*e have no way of knowing it*. It would be perfectly adequate for many purposes, but as a starting point for fixing cosmological parameters, it fails completely because all one is doing is comparing one model with another.

It is important to understand that our following analysis is general. It is not specific to any particular cosmological model or dataset, nor is it concerned with the size of the errors that result from the use of the fiducial cosmology methodology. The DESI analysis pipeline is very detailed and complex, but that is irrelevant. We are only concerned with the fact that the distribution of galaxies used as the basis for the measurements is user-created. The error is not a matter of numerical accuracy, it is a matter of a fundamental, and unfixable, shortcoming of the method.

What follows has the nature of a mathematical proof rather than a systematic error analysis. We will work through the steps used to determine the characteristic distance of the correlation peak. We start with a large catalogue of galaxies, and for each, we convert from redshift to comoving coordinate using

$$r_i = F(z_i; p_k) \tag{11}$$

where $F(z_i; p_k)$ represents some fiducial model with parameters p_k. (We will assume that the galaxies are sufficiently distant that we can ignore peculiar velocities other than our own.) The result is a "user-created" comoving coordinate map of the sky. These coordinates may or may not match the actual coordinates *which* *are unknown*.

From this point onward, the usual procedure is to consider the radial and transverse directions separately. According to the FRW model, in the radial direction, the coordinate distance between any two galaxies with the same angular coordinates is given by [5] [13].

$$\Delta r_{\parallel} = \frac{c}{a_0} \frac{\Delta z}{H(z)} \tag{12}$$

(We note that this formula is specific to the FRW model. It is not true in general.) In terms of our function *F*, the coordinate difference between galaxies i and j, is

$$r_i - r_j = F(z_i; p_k) - F(z_j; p_k) \tag{13}$$

We next search the catalogue for pairs of galaxies that form a peak in our "user-created" comoving coordinate space. The actual correlation length will generally be different from our "user-created" length, but probably not by very much. Having identified those galaxy pairs, we now revert to redshift space, again using our model, but with adjustable parameters q_k. For each galaxy, the redshift is then by the inverse formula,

$$z_i = F^{-1}(r_i; q_k) \tag{14}$$

so the redshift difference is given by

$$\Delta z = z_i - z_j = F^{-1}(r_i; q_k) - F^{-1}(r_j; q_k). \tag{15}$$

Substituting for the original coordinates r_i and r_j, we have

$$\Delta z = F^{-1}(F(z_i; p_k); q_k) - F^{-1}(F(z_j; p_k); q_k) \tag{16}$$

But with $q_k = p_k$, this is an identity. It is true for any fiducial model whatsoever with any set of parameters. The actual correlation length is never part of the process, nor can it be because we have no way of measuring comoving coordinates. The point is that the "actual" universe is user-created with built-in parameters fixed by the fiducial cosmology.

We can make the same point in a slightly different way that might help to visualize the issue. Starting again with Equation (11), the fiducial cosmology is used to create a comoving map of the galaxies. The resulting map has a 2-point galaxy correlation peak whose characteristic length is a function of the parameters, p_k. Let us suppose that galaxies *m* and *n* happen to be separated by exactly the correlation length, $l_c = r_m - r_n$.

We now analyze the map with a generally different model,

$$r_i' = G(z_i; q_k). \tag{17}$$

The same two galaxies represent the correlation length regardless of the analysis model, so we have

$$l_c = G(z_m; q_k) - G(z_n; q_k) \tag{18}$$

We now ask, what set of parameters will satisfy this condition? If G happened to be our original model, then by definition, the solution would be $q_k = p_k$. With a different analysis model, the q_k will generally have somewhat different definitions, so the relationship between q_k and p_k will not be one-to-one. Nevertheless, the two models should agree about the value of derived cosmological parameters such as H_0 because *that value was built into the map by the fiducial model*.

We next ask what happens if the fiducial model is changed? Let's say the value of H_0 is changed to H_0'. Again, the fiducial model builds a comoving coordinate map that will have a different correlation length, possibly represented by a different pair m', n'. We now perform the analysis with model *G*, and this time we should obtain the value H_0' since that is again the value built in by the fiducial model. Thus, we see that the analysis parameters will always track whatever parameters were used to create the comoving coordinates map in the first place.

The process is circular.

A similar argument based on the transverse direction formula,

$$\Delta r_{\perp} = \frac{a_0}{1+z} r\theta \tag{19}$$

for the angular case will end up in the same situation.

The DESI collaboration has gone to great pains to test all aspects of their analysis.

One such that would seem to be relevant to this discussion is a test to determine the sensitivity of the DESI methodology to variation of the fiducial model [19]. The method was to create a mock universe using the Plank solution parameters, and then to run through their pipeline with several secondary models to check on the sensitivity of the results to the details of those secondary cosmologies. What they found was that with a few exceptions, the resulting errors were small. But that analysis is totally beside the point because it is just comparing one model with another. The fundamental problem which they don't address, is that their so-called actual universe is just one more mock cosmology and no amount of mitigation is going to change that fact.

We will now make two points about the reported results. First, we show in **Figure 6**, the calculated comoving coordinates and scaling for our new model and the FRW model, both with $H_0 = 73$ over the relevant redshift range. Also, although we won't show it here, the luminosity distance curves again with $H_0 = 73$ are identical for $z \le 1$ and are not far apart for somewhat larger values of redshift [12]. We see that the curves are not far apart.

We now show in **Figure 7** the familiar plot of the reduced Hubble parameter versus redshift. The data points are from [20]-[25]. We show 3 curves: the FRW model with two values of the Hubble constant, and our new model with $H_0 = 73$.

Even though, as we saw, the FRW and new model coordinates and scaling are similar, there is a considerable difference between the FRW and our new model predictions for the reduced Hubble parameter. Thus, one cannot assume that because some properties of two (nonlinear) models are similar, that all properties will be similar.

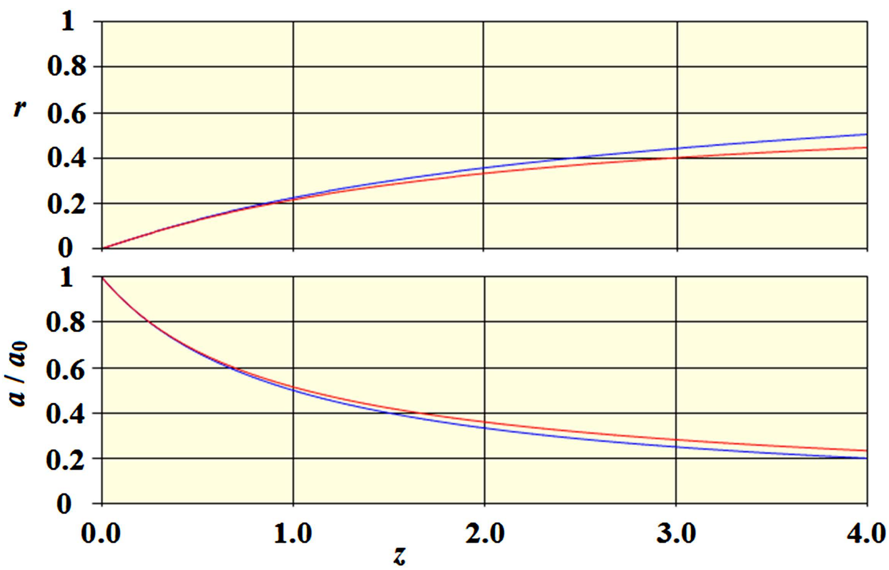

Figure 6. Comparison of our new model and the FRW model for $H_0 = 73$. The FRW curves are shown in blue.

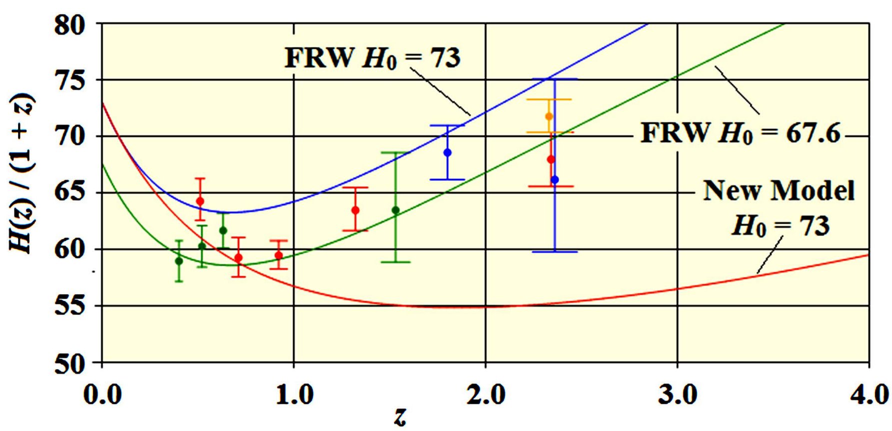

Figure 7. Reduced Hubble parameter.

The main point, however, is that the data points of Figure 5 are all grouped along the FRW curve with $H_0 = 67.6$. The reason is that *all the studies use the same fiducial cosmology with a Hubble constant of 67.6 or a value close to it*. As expected, the predicted Hubble constant is the same as the input fiducial constant.

There is, of course, a simple test of this analysis. All that is needed is for the DESI analysis group to run an analysis with the fiducial model Hubble constant changed to 73, together with necessary changes to the density parameters. Our contention is that, with that change, the data points will then align with the FRW 73 curve instead of the 67 curve.

6. Conclusion

We have pointed out a number of shortcomings of the BAO model and have presented a proof that the analysis method used to extract cosmic model parameters from the 2-point galaxy correlation peak is fundamentally flawed. The consequence is that correlation peak determination of the Hubble constant is circular, and hence meaningless. Our expectation is that, if DESI uses a fiducial FRW cosmology with $H_0 = 73$, their analysis will result in a value that is close to 73. We also showed that the recent determination that dark energy varies with time invalidates the FRW metric upon which all FRW model results are based.

Data Availability

Data sharing not applicable—no new data generated.

Declaration of AI Use

No AI-assisted technologies were used in the development of this article.

Code Availability Statement

This manuscript has no associated code/software.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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