

Questioning Cosmological Superstition

Separating science from myth in our theory of the universe

By Rich Halvorson, degree candidate,
Harvard University Department of Philosophy

Written for Professor Robert P. Kirshner,
Harvard University Department of Astronomy

Abstract

For decades the two aspects of the cosmological principle, isotropy and homogeneity, have been held as inseparable and invaluable foundations for cosmology. As observational evidence has improved, however, it offers empirical support only for the claim of isotropy, and continues to disprove homogeneity even at large multi-galactic scales. In examining the origins of the two principles, we note that isotropy was an ingenious insight that managed to connect a few disparate data points into a helpful and accurate theory. Homogeneity, on the other hand, was considered a necessary correlate to isotropy not for any scientific reason, but because it seemed necessary to make isotropy compatible with a secular view of the universe. As such, homogeneity became a founding principle of cosmology not for scientific merit but as a philosophical perspective preferred by some scientists. This essay argues that this has proven to be unhelpful—and even an outright hindrance—to the advance of cosmological theory. As Stephen Hawking admits, a similar secular bias kept scientists from accepting the big bang theory in spite of much evidence. And, as this paper argues, cosmology may be suffering from yet another case of myth hindering science.

1 Introduction

Upon its completion in the early 1920's, the 100-inch Hooker Telescope was the most powerful tool yet invented to allow astronomers to peer into distant corners of the universe. Constructed at the Mount Wilson Observatory outside Los Angeles, the finishing of the powerful new telescope roughly coincided with the arrival of the young scientist Edwin Hubble. By 1924, Hubble announced that with the new telescope he was able to make accurate observations not

only of features in our own Milky Way galaxy, but also of other previously unknown and unseen distant galaxies.

Hubble began charting the distance of each galaxy he observed, and looking for signs of motion—whether they were moving closer, standing still, or moving away. Based on only a handful of observations, Hubble noticed that the galaxies were all moving away, and that their velocity was always greater with greater distance. Despite the scant data, Hubble went on a hunch to formulate what later came to be known as the Hubble Law, which establishes the velocity-distance relation of galaxies to our own, and accurately describes the expansion of the universe.

Even though the Hubble Law began with a simple insight and a guess, it has now been confirmed over and over in subsequent observations plotting thousands of galaxies.

On the road to scientific progress, researchers must often use insight to make hypotheses while data are scant. Then, armed with a theorem to test, further experiment or exploration can establish whether the hypothesis holds up, if it needs tweaking and revision, or if it was entirely wrong.

The following discussion concerns the Cosmological Principle, which contains two of astronomy's foundational hypotheses. Both of them began as unconfirmed theories or assumptions, and one of which remains so today. Although the first has been confirmed by data, the second remains entirely speculative. Even so, it is broadly assumed by astronomers to be a sound scientific fact and is used as the basis of much research and investigation.

In the absence of confirming data, the assumption is held firmly in place by astronomers' philosophical preferences to see a purposeless and undesigned universe rather than a purposeful and designed one. While scientists should certainly not make a *prima facie* assumption of design, neither should they make one against it. Especially, I argue, when the assumption against design could tempt them to ignore evidence, needlessly complicate their theorems, or slow the advance of scientific knowledge. Instead, honest science must follow the trail of evidence toward the simplest explanation that accounts for all data.

Likening this case to the example of scientists' reluctance to accept the Big Bang Theory (because of its possible theological or philosophical implications), this essay warns of how these unfounded philosophical biases have been—and probably are in this case—a significant hindrance to the advance of scientific knowledge and discovery.

2 The Cosmological Principle

Since cosmology is the study of the origins, development and form of the *cosmos*—that is, the entire observable universe—its foundational propositions are proportionately broad in scope. The Cosmological Principle is the most basic and dearly held tenet of cosmology, and serves as the basis for making progress with new theories of the universe and observational studies of galaxies. In its most current and widely held formulation, the Cosmological Principle consists of two simple propositions:

Cosmological Principle

- (1) The universe is ***isotropic*** – from Earth, the universe looks the same in every direction.
- (2) The universe is ***homogeneous*** – from any other galaxy, the universe would also appear isotropic.

The claim of *isotropy* is made relative to the perspective of the earth, and is an observable and verifiable claim, since we now have the ability to chart and track many other galaxies. It is validated by observations of other galaxies which reveal that all galaxies are moving away, with higher velocities at greater distances. It could have been equally true if all galaxies were moving towards us or if all were dispersed and standing still. The important thing is that we do not observe some galaxies getting closer while others are moving away—they are all moving away with an identical pattern in every direction.¹

The claim of *homogeneity* is that of a generalized isotropy which is not relative to the earth, but relative to observations from any other galaxy. It means that from any galaxy A, all other galaxies in every direction would be moving away in the same red-shifted pattern (ie, velocity increasing with greater distance) that we observe from Earth.

When these two principles were first proposed, they were both relatively speculative. In cosmological practice today, isotropy is the observable and documented phenomenon that distant galaxies are all rushing away from us. Homogeneity, on the other hand, remains a theoretical proposition seeking evidence to show that matter, on average, is distributed evenly throughout the universe and its expansion occurs evenly in every direction.

¹ This excludes a handful of nearby dwarf galaxies, like the Magellanic Clouds, that are in the process of being absorbed into our Milky Way galaxy.

3 Origins

Since the Cosmological Principle was first proposed early in the twentieth century, it has evolved and changed with advances in our abilities to observe distant galaxies.

The original formulation of the Cosmological Principle—which was the version preferred by Einstein—was called the *Perfect Cosmological Principle*.² This version claimed that the universe appears the same in every direction (isotropy), from every location (homogeneity), and at all times (stasis). The third proposition, for a static model, correlated with Einstein’s belief in the *steady state theory* of the universe, which many scientists held at the time. The steady state theory implied that the universe had no beginning. It had certain scientific merits, but was also preferred largely because it avoided the theological implications of a “beginning” of time and the universe.³

Adherence to the steady state theory was eventually—and reluctantly—overcome by evidence for the Big Bang. With the fading of the steady state theory, the tenets of the Cosmological Principle were appropriately whittled from three to two. Now, Alexander Friedmann would formulate the Cosmological Principle essentially as it continues today, with the two basic propositions for isotropy and homogeneity.

In the classic *A Brief History of Time*, Stephen Hawking charts the evolution of cosmology and the Cosmological Principle. He chronicles the origins of the Cosmological Principle, saying, “Friedmann made two very simple assumptions about the universe: that the universe looks identical in whichever direction we look, and that this would also be true if we were observing the universe from anywhere else.”⁴ It is important that Hawking refers to Friedmann’s two postulates as “assumptions,” because at the time they were both radically new and still relatively unsupported by empirical evidence.

At this time, there were a few disparate data points supporting isotropy—that a handful of distant galaxies were all observed to be speeding away in the opposite direction. But isotropy by itself, when combined with the newly christened idea of the Big Bang, held seemingly strange implications.

² This point came to my attention through the writings from an astronomy lecture by Professor Ian Waddington, University of Sussex. (<http://astronomy.sussex.ac.uk/~iw21/ast1/lecture2.pdf>)

³ This claim is discussed further below.

⁴ Stephen Hawking. *A Brief History of Time*. (Bantam 1990) p40.

If the universe began with an explosion, and now everything we observe is quickly receding, we could naturally infer that our galaxy is positioned at the center of the explosion—or that we are at the “center of the universe.” Enter the claim of homogeneity.

The idea of homogeneity came not from observation or evidence, but because it would accommodate the evidence of isotropy while also avoiding the implication that our galaxy is a special place in the universe. Homogeneity is the cosmological extension of the Copernican Principle—which showed that the earth was not the center of the solar system. Therefore, homogeneity was proposed not so much as a scientific postulate, but a philosophical one. It was an affirmation of humility about man’s place in the universe: Man is not at the center of everything.

As Hawking writes of the assumption of homogeneity, “We have no scientific evidence for, or against, this assumption. We believe it only on grounds of modesty.”⁵

This Copernican Principle of modesty is certainly a reasonable assumption, but it is an unnecessary assumption. And, without confirmation, it remains only an assumption. Despite these tenuous grounds for acceptance, however, the principle of homogeneity came to be accepted as one of the most basic tenets of cosmology—and has informed and shaped cosmological inquiry, research and theory for over 50 years.

Some scientists noted the potential dangers of basing serious scientific inquiries on a philosophical assumption. In 1931, Willem de Sitter warned, “It should not be forgotten that all this talk about the universe involves a tremendous extrapolation, which is a very dangerous operation.”⁶ Using caution to approach new theories still lacking evidence leaves Sitter in the camp of objective science.

Einstein and others, however, quickly embraced homogeneity (along with isotropy) as a foregone conclusion and a settled scientific fact. Einstein’s 1933 reaction, which strongly affirmed homogeneity, was not uncommon among leading scientists of the time: “Hubble’s research has, furthermore, shown that these objects [the galaxies] are distributed in space in a statistically uniform fashion, by which the schematic assumption of the theory of a uniform mean density receives experimental confirmation.”⁷ In this statement the phrase “statistically uniform fashion” is the equivalent of homogeneity. Further, many scientists found Friedmann’s

⁵ Hawking, p42.

⁶ P.J.E. Peebles. *Principles of Physical Cosmology*. p14.

mathematical explanation—based on his two assumptions—to be both exciting and compelling, noting that it seemed to coincide with the predictions of the Hubble Law.

In retrospect, de Sitter’s analysis of the situation was more scientifically sound and prudent. Modern cosmologists acknowledge that the theory was not as well supported as Einstein would have liked to believe. Recently, Princeton cosmologist P.J.E. Peebles wrote that Einstein was exaggerating the evidential confirmation: “From an empirical viewpoint de Sitter’s would have been the more sensible position.”⁸

The following section shows how the assumption of isotropy has been confirmed by extensive studies and then discusses various possible interpretations and implications. Then, the essay will move on to discuss the quietly retreating claim of homogeneity in light of a continuing lack of supporting evidence, and burgeoning evidence to the contrary.

4 Isotropy Confirmed

Although isotropy was proposed based on extremely limited evidence, every subsequent study seems to confirm that Hubble’s original insight—and Friedmann’s first assumption—were surprisingly accurate. At present, there are two primary confirmations of the isotropy of the universe: (1) the consistently observed Hubble constant reflects the fact that galaxies are all equally rushing away from us in proportion to their distance; (2) the observed cosmic microwave background (CMB) shows a radio background signal coming toward us equally from all angles. All the evidence we have points to the idea that every direction cosmologists look out into the universe, it will appear the same.

The confirmation of this idea that things will look the same came first from Hubble’s observations of 18 galaxies and his announcement in 1929 that “the red shift of galaxies increase roughly in proportion to the distance from us.”⁹ Repeated observation and confirmation of red shift in distant galaxies, does in fact show Hubble’s conclusion that they are all moving away

⁷ Peebles, p14.

⁸ Peebles, p14.

from us with velocities proportional to their distances. It is quite remarkable, however, that Hubble's theory has been confirmed so thoroughly by repeated observation (and turned into the "Hubble constant") because his original observation was based on such a limited sample of galaxies.

Stephen Weinberg exclaims that Hubble's data leaves him "perplexed" as to how Hubble reached his conclusion. With so few observations "we would not *expect* any neat relation of proportionality between velocity and distance for these 18 galaxies."¹⁰ Hubble's exceptional insight allowed him to successfully predict a proportional relationship between velocity and distance in far-off galaxies.

Now, with heaps of evidence, we have a strong confirmation of Friedmann's first assumption of the Cosmological Principle—that the universe is isotropic. From an earth-bound perspective, galaxies all seem to be rushing away from us at predictable velocities. In every direction we look at galaxies speeding away from us, and they seem to be doing so in uniform fashion.

Stephen Hawking comments that galaxy plotting, and observation of the microwave background, have been "a remarkably accurate confirmation of Friedmann's first assumption."¹¹ New galaxy plots and a growing stock of evidence strongly support the proposition that the universe is isotropic.

⁹ Stephen Weinberg. *The First Three Minutes*. (1993) p21.

¹⁰ Weinberg, p26.

¹¹ Hawking, p41.

5 Homogeneity in Retreat

When homogeneity was originally assumed as a part of the Cosmological Principle, astronomers and cosmologists believed they would easily find homogeneity on small scales.¹² For most of the 1920's, cosmologists assumed that distant stars would be evenly distributed, thus giving a homogeneous appearance to the universe from the level of individual stars. This interpretation of homogeneity is the strongest possible version, since it starts on the level of basic astronomical units—stars and their planetary systems.

In the later 1920's, however, observations with the strongest available telescopes revealed that stars were not moving independently, but were actually grouped together in large clusters—what we now call galaxies. This discovery meant that homogeneity would not occur on the level of individual stars, so cosmologists weakened the assumed level of homogeneity. Now, looking beyond the scale of individual galaxies (1-5 Mpc), they hoped to see a homogeneous distribution.

Subsequent observations showed that galaxies themselves were clustered together. As Robert Oldershaw recounts in his helpful chronology of cosmological homogeneity, “Theoreticians then hypothesized that the small galaxy clusters would be distributed homogeneously at scales of 20 to 30 Mpc.” But in the 1970's, with improving telescopes and data analysis, observational astronomers continued to spot inhomogeneity above 30 Mpc, in “superclusters” at 60 Mpc and above.

With each step to larger scales, the claim of homogeneity became weaker. Through each decade, as observational techniques improved, the evidence continued to disappoint the hopes of cosmologists seeking to confirm the homogeneity hypothesis. But since it was a foundational assumption for much of their research, had been assumed for years, or was necessary to avoid the theological implications of isotropy, the assumption of a homogeneous universe has seldom been questioned—and never *en masse*.¹³

¹² Many thanks to Robert L. Oldershaw, of Amherst College, whose chronology of cosmological homogeneity fills in many of the curious blanks left by other less complete accounts of where the assumption originated, how it developed, and where it is today. See “The Legend of Cosmological Homogeneity,” <http://www.amherst.edu/~rlolders/LOCH.HTM>.

¹³ A few voices of dissent, such as some chronicled by Oldershaw, went so far as to throw out homogeneity altogether. The more common approach, by cosmologists such as Hawking, Peebles and Weinberg, is to acknowledge the lack of evidence but insist that the Copernican Principle of mankind's humility is strong enough to guarantee that homogeneity will eventually be confirmed on some level, even though it continues eluding our progressively improving analyses.

As the evidence continues improving and the criterion for testing homogeneity continues broadening, our current observational limits—large as they are—have found only further confirmation of large-scale inhomogeneity. In some cases, galaxy structures and voids are seen in the 100 to 400 Mpc range—and non-random clustering has been observed at a scale of 1,000 to 2,000 Mpc. Among the largest and best known of these is the “Great Wall” of galaxies, shown to be over 750 million light-years long, 250 million light-years wide, and 20 million light-years thick.

Cosmologist Stephen D. Landy, who participated in one of the largest galactic surveys to date, wrote in *Scientific American*: “On all scales thus far observed by astronomers, galaxies appear to cluster and form intricate structures ... Yet there is a paradox. The clumpiness of galaxies runs contrary to one of the essential tenets of modern cosmology: the cosmological principle.”¹⁴ At every observational level, the data seem to “pull the rug out from under modern cosmology,” says Landy. However, as with any respectable cosmologist, Landy has not given up hope on homogeneity. Landy waxes poetic, theorizing that the choppy galactic distributions can be reconciled with homogeneity if we liken their distribution to “harmonic analysis.”¹⁵

Moving from the original hypothesis that individual stars would be homogeneously distributed, we now observe superclusters of galaxies flowing and moving together in non-homogeneous distributions. Observational astronomers continue to see only inhomogeneity on any scale, however small or large. Yet, the theories of cosmologists continue insisting that the principle of homogeneity is a requisite basis and foundation for us to have any understanding of the universe.

Somehow, even as the definition of a homogeneous cosmos grows weaker and weaker, few if any cosmologists are willing or able to question in writing whether this original assumption—this strictly philosophical assumption—might have been a bad idea from the outset.

Through some combination of intellectual laziness and intellectual dishonesty, the principle of homogeneity continues as a *foundational tenet* of modern cosmology, despite the fact that mountains of data clearly pointing in the opposite direction. Thus, as Oldershaw points out, there is a certain heightening tension between those who gather data (astronomers) and those who are supposed to build coherent theories around the data (cosmologists).

¹⁴ Stephen D. Landy, “Mapping the Universe.” *Scientific American*, June 19, 1999. (<http://www.sciam.com/article.cfm?articleID=0001AA37-92BA-1CD6-B4A8809EC588EEDF>)

6 Cosmology and Mythology

If we hope to understand the persistence of the homogeneity principle despite its tendency to run contrary to all available evidence, we must return to the reason for its origin. When isotropy was postulated, cosmologists considered homogeneity to be a necessary correlate not for scientific, but for philosophical reasons.

The principle of isotropy was suggested by mounting evidence. But, as Hawking explains frankly, the implications of isotropy without homogeneity were simply unacceptable to the philosophical palate of the scientific community:

Now at first sight, all this evidence that the universe looks the same whichever direction we look in might seem to suggest there is something special about our place in the universe. In particular, it might seem that if we observe all other galaxies to be moving away from us, then we must be at the center of the universe. There is, however, an alternate explanation: the universe might look the same in every direction as seen from any other galaxy, too. ... We have no scientific evidence for, or against, this assumption. We believe it only on grounds of modesty: it would be most remarkable if the universe looked the same in every direction around us, but not around other points in the universe!¹⁶

While the *conclusion* that we are not at the center of the universe would certainly be reasonable—and even expected—it is strange to think that we need it as a *premise*. None of the cosmologists quoted and discussed here gives any scientific reason why this must be a starting point for investigation rather than a potential result of investigation.

The fact that the principle of isotropy so perfectly coincides with extensive scientific investigation is probably because it was an insight that accurately connected disparate data points. The fact that the principle of homogeneity so perfectly contradicts extensive scientific investigation is probably because it was a philosophical speculation that originated without reference to any data points.

In science, as in philosophy, the best theory is always the simplest set of postulates that can account for all the data. The assumption of homogeneity was never necessary to account for data, but to accommodate particular philosophical preferences. It was the above quote from Hawking that originally drew me, a philosopher dabbling in the sciences, to investigate this

¹⁵ Ibid.

¹⁶ Hawking, p42.

topic—I was intrigued that such an important scientific postulate could originate without evidence and continue in spite of mounting evidence.

But Hawking is certainly not the only author to discuss this infusion of philosophy into science. In a widely-used undergraduate cosmology textbook called *Universe*, the authors mention that the most intuitive interpretation of the *available data* is jettisoned because it could carry unacceptable implications:

To make progress in cosmology, we must accept certain philosophical assumptions or abandon hope of understanding the nature of the universe. The Hubble law provides a classic example. It could be interpreted to mean that we are at the center of the universe. We reject this interpretation, however, because it violates a cosmological extension of Copernicus’s belief that we do not occupy a special location in space.¹⁷

Why would being at the center—or at the edge—of the cosmos make us “abandon hope of understanding” our universe? These are simply potentially observable facts about our position in the universe. We are never told why this would be such a disastrous conclusion. We could be at the center or the edge, or there may be no center or edge (i.e., homogeneity), but the most important scientific concern should be to find a theory that accounts for the *evidence*, not one that caters to theology—or a lack thereof. Other sources take the philosophical extrapolation even further, claiming, for example, that the most important aspect of Copernicus’ work was not the scientific discovery, but the way he changed man’s place in the universe—removing the “immodesty” imputed by the theologians.¹⁸

7 Steady State Folly

It would seem natural that science is better left in the careful hands of scientists, and philosophy better left between the ears of philosophers. At the very least, when practitioners of either step into the territory of the other, they should be purposeful to acknowledge that they are doing so. As a philosopher, then, my primary goal in this essay is certainly not scientific, but to post a “Keep off the Grass” sign to cosmologists indiscreetly trampling the philosophical lawn—which makes for both poor science and poor philosophy.

¹⁷ William Kaufman and Roger Freedman. *Universe*. (5th ed, 1999) p701.

¹⁸ Internet Biography search for “Copernicus”.

(<http://www.blupete.com/Literature/Biographies/Science/Copernicus.htm>) May 2001.

In an unfortunate irony, advances in cosmological theory have already been delayed for decades by the secular bias of cosmologists. Ideally science would be an objective enterprise influenced by evidence alone, rather than ever being a tool of theology or politics. Although the dangers of making scientists answer to the Church are well established, what goes unacknowledged is that an implied or explicit anti-theistic ideology can be just as harmful to science. After casting aside the shackles of religious ideology, science has been blinded in more recent times by secular ideology. Specifically, evidence for the now ubiquitous Big Bang theory was ignored, suppressed and explained away during the 20th century because of the apparent theistic implications of the theory.

During the mid-twentieth century, despite mounting evidence for the Big Bang, the alternative “steady state theory” gained in popularity among scientists. Steady state theory says that the large-scale appearance of the universe remains the same through time. In 1948, noted scientist Fred Hoyle became the leading advocate of the steady state movement, also known as “continuous creation,” theory, and “according to which the universe had existed for an infinite past time and would continue infinitely into the future.”¹⁹ A steady state universe was considered preferable to a Big Bang universe, since it appeared less likely to involve creation by some deity. Hawking writes that “there were a number of attempts to avoid the conclusion that there had been a big bang.” Scientists were reluctant to accept the evidence for this theory “because it smacks of divine intervention.”²⁰

The steady state theory did not fit the accumulating data, and complicated the theory by requiring extraneous postulates. The steady state theory “avoided the necessity” for a big bang, but it also required scientists to postulate “the continuous creation of matter” between galaxies.²¹ Essentially, continuous creation was one way to reconcile observed expansion with steady state, because it implied that a constant average density could be achieved. Also, the level of matter creation postulated was quite low, perhaps even an undetectable rate.

Still, this implausible postulate warrants repetition: to support steady state theory, scientists were willing to accept the idea that matter was being continuously created from nowhere. Even though this assumption was a direct challenge to experience, intuition and basic

¹⁹ “Professor Sir Fred Hoyle,” by Bernard Lovell, in a memorial tribute in *The Guardian*, August 23, 2001. (<http://www.guardian.co.uk/obituaries/story/0,3604,540961,00.html>)

²⁰ Hawking, p46.

scientific laws about the conservation of matter and energy, it was justified to avoid a conclusion that might appear theistic.

In other words, the proposal that matter is continually created from nothing was preferable to a simpler explanation that might have a secondary implication that time had a beginning, and therefore that God might have started the universe in motion. After further evidence piled up, and especially after Penzias and Wilson discovered the cosmic microwave background in 1965, the steady state theory finally “had to be abandoned.”²²

Hawking chronicles how evidence for the Big Bang was ignored and explained away for decades due to secular biases in the scientific community. It finally became more scientifically palatable with the arrival of variations that appeared less theistic—like the idea of an oscillating universe in a cycle of expansions and contractions. Currently, the Big Bang is the most widely accepted theory of the origin of the universe, while steady state theory is considered highly implausible if not entirely disproved.

Ironically, despite Hawking’s chronicling of how philosophy hindered cosmology for decades, he and others fail to notice that the same secular bias props up the principle of homogeneity in spite of all observed evidence. These are parallel cases of scientific hypotheses formed out of philosophical convenience—with similarly unique tendencies to defy scientific confirmation and require extraneous and exotic postulates.

Just as the steady state theory was preferred to the big bang based on a philosophical idea, the presumption of homogeneity rests primarily on the fear of possible theistic implications. Homogeneity is considered a necessary correlate to isotropy since it precludes the conclusion that there is anything special or unique about our place in the universe. Stephen Weinberg admits that no evidence supports it, but declares the doctrine to be very “satisfying philosophically.”²³

8 Tenuous Conclusions

Since Einstein’s *perfect cosmological principle*, the scope of the cosmological principle has been scaled back from three propositions to two. Then, as observations continued improving,

²¹ Encyclopedia of Astronomy and Astrophysics. Definition for “Steady state theory” (<http://lib.harvard.edu:2523/>) May 2001.

²² Hawking, p48.

²³ Weinberg, p23. I consider the word “admits” to be appropriate here, since philosophically satisfying tenets may have a place in theology or self-help books, but they really have no place becoming regarded as scientific facts, without some sort of scientific evidence.

the proposition of homogeneity has changed from a strong assumption about evenly distributed stars to an as-yet unobserved phenomenon, even at the level of thousands of galaxies.

We have seen that the homogeneity of the universe was posited and accepted as a cosmological fact in large part due to a secular bias in the scientific community. Now, theorists continue to broaden and change the meaning of “homogeneous cosmos” to attempt to maintain the principle despite all observable evidence pointing towards inhomogeneity. Similarly, homogeneity has, through time and custom, become attached to the Big Bang theory as a “necessary correlate.”

The idea of a homogeneous universe is widely considered as a prerequisite for any sort of cosmological investigation or theorizing. Further, as a foundational premise, it influences the way that every other aspect of cosmological theory is developed. As Stephen Landy wrote of homogeneity in *Scientific American*, “Whenever cosmologists discuss the global properties of the universe, such as its mean density, expansion rate and shape, they do so under the auspices of this principle.”²⁴

The lack of evidential basis for homogeneity, then, means that discussions of other basic properties of the universe could be fundamentally shifted if contrary evidence finally brought the assumption of homogeneity into serious doubt.

In one specific example, the currently popular notions of dark matter and dark energy originated, in part, to satisfy the problem of inhomogeneity. Primarily, the exotic and elusive concept of dark matter originated to explain certain gravitational features of galaxy clusters. However, since dark matter and dark energy are now supposed to make up between 90-99% of the matter and energy in the universe, it is also taken as a possible explanation for the lack of observed homogeneity. Dark matter has never been observed, but is presumed to have mass many times larger than all the stars and planets we observe. Therefore, although the matter we observe is inhomogeneous, the much greater quantity of postulated, unobserved matter could likely fit the requirements of homogeneity.

Dark matter, like homogeneity, is a postulate that came into fashion as a result of certain assumptions about the universe. Of course, the observed gravitational effects that primarily led to postulating dark matter are stronger evidences than the foundations for homogeneity.

²⁴ “Mapping the Universe,” Landy.

But as observational astronomers continue to document large scale walls of galaxy clusters and voids, no theory yet postulated can account for all the evidence. One interesting hypothesis could remove the necessity for the dual unobserved phenomena of dark matter and homogeneity. Landy describes this as the “less dense universe” hypothesis: “Most of this decrease in density comes at the expense of exotic dark matter. ... Intriguingly, an underdense universe would also resolve other cosmological conundrums.”²⁵ Indeed, other more recent studies suggest that the dark matter hypothesis may soon unravel, leaving much of the current cosmological theory also in tatters.²⁶

Other scientific investigation has suggested that homogeneity and the Copernican principle are actually two *different* parameters.²⁷ This research suggests that the Copernican principle could be true (that all observers in the universe would see the same degree of isotropy), without homogeneity being true (the universe remains “lumpy”). It was previously assumed that if the Copernican principle were applied, a homogeneous universe would then be a given.

Perhaps the second presupposition of the Cosmological Principle is reasonable and perhaps it is valid, but with major cosmologists in agreement that homogeneity stems from nothing more than a secular philosophical bias, it should be held loosely while maintaining openness to other possible positions. As with the Big Bang, it could be that we will come to adhere to some version of inhomogeneity that fits with secular principles. The belief that we are not at the center of the universe is entirely reasonable; but its reasonableness and plausibility by no means make it a *necessary* scientific presupposition or a starting point for everything else.

It seems, then, that just as science has broken free of the superstitions of the theologians, it has shackled itself into a system of secular superstitions. In the case of the declaring the homogeneity of the universe, they admit that the principle is based on certain philosophical or theological assumptions rather than scientific observation. These assumptions take particular importance because they rely on a particularly secular set of beliefs about man’s place in the universe.

While there is certainly nothing wrong with this set of assumptions, they are no substitute for scientific observation. Neither are they a legitimate basis for establishing scientific fact.

²⁵ Landy. See also, “Inflation in a Low-Density Universe,” by Martin A. Bucher and David N. Spergel; *Scientific American*, January 1999.

²⁶ “Things fall apart,” *Economist*, February 5, 2004.

Hawking, Peebles, Kaufmann, and Freedman all align behind Weinberg's adept phrasing, that the second assumption of the Cosmological Principle is simply "philosophically satisfying." It would be better, one might think, to follow the evidence and data analysis, rather than the philosophically palatable.

While on some still unobserved cosmic scale, homogeneity may turn out to be an ingenious insight (as was isotropy), cosmologists ought to be wary of allowing the desire to see homogeneity (and its philosophical implications) steer cosmological theory off course while the evidence points elsewhere. When evidence is scant, insight is useful for moving forward with bold conjecture and even experimentation, but is unhelpful when it becomes a firm and fixedly held principle lacking evidence.

²⁷ "Does the isotropy of the CMB imply a homogeneous universe?" Chris A. Clarkson and Richard K. Barrett. *Classical Quantum Grav* 16 (1999), 3781-3794. (<http://www.mth.uct.ac.za/~webpages/clarkson/papers/q91202.pdf>).