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Gregory Phipps, "A Literary Reading of the Big Bang Theory": 38-51

The Narratives and Metaphor of the Balloonverse: A Literary Reading of the Big Bang Theory

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In contemporary astrophysics and cosmology, the Big Bang Theory has acquired wide acceptance as an explanation for the origins of the universe. Notwithstanding the firm evidence supporting it, the mere notion of the Big Bang remains one of the most perplexing cornerstones of modern scientific knowledge. According to the theory, the universe emerged at a specific moment in time as an unfathomably small, dense, and super-heated point, which subsequently expanded at a rate faster than the speed of light. A number of scientists have taken up the challenge of describing the Big Bang to wider audiences, writing books about the beginnings of the universe. Accommodating general readers, these works tend to adopt narrative approaches, placing mathematics in the background while making use of literary elements like metaphors. The purpose of this article is to undertake a literary analysis of several books written by scientists that narrate the Big Bang and the earliest moments of the universe. These books include recent titles like Christophe Galfard's *The Universe in Your Hand*, Dan Hooper's *At the Edge of Time*, Mark Kidger's *Cosmological Enigmas*, Lisa Randall's *Dark Matter and the Dinosaurs*, Stephen Barr's *Modern Physics and Ancient Faith*, and Neil deGrasse Tyson and Donald Goldsmith's *Origins*.

The article has two goals. First, it seeks to identify some of the recurring narrative components in scientific accounts of the Big Bang, especially those that appear in representations of the timeframe extending between the Planck era and the start of nucleosynthesis (from 10^{-43} seconds to a few minutes after the Big Bang). The article further explores one of the most persistent themes in narrative depictions of this timeframe, the transition from chaos to stability. Moreover, within this theme, I analyze how authors use the metaphor of a balloon as a structuring device to guide readers through the transition. The balloon helps clarify what is arguably the most bizarre segment of the transition, the inflationary epoch which spanned between 10^{-36} and 10^{-32} seconds after the Big Bang, but it also provides readers with an easily-graspable image that illustrates the basic form of the universe, both immediately after the Big Bang and also today. The ubiquity and consistency of the balloon metaphor across popular science books attests to its increasing role as a central paradigm for demarcating the structures of the universe. Yet as most of the scientific authors who deploy the metaphor acknowledge, the balloon has intrinsic limitations as an explanatory trope for the inflationary epoch and the form of the universe. Rather than dismissing these limitations, I consider how they supply material for a literary understanding of contemporary scientific knowledge about the universe. Thus, the second goal of the article is to open up the underlying implications of the balloon metaphor to explore the different ways it reflects theories about the structures of the universe. A literary analysis demonstrates that the associations and limitations of the balloon metaphor frame key scientific questions about the universe while also providing avenues to more experimental speculations about the makeup of the cosmos and the possibility that there might be regions and dimensions that are inaccessible to humanity. Ultimately, it is the limitations and veiled connotations of the metaphoric

"Balloonverse" (as astrophysicist Lisa Randall calls it) that add some of the most revealing and fruitful dimensions to this tropological model of the universe.

The first section of the article investigates some of the key issues involved in humanities-based readings of scientific commentaries on the Big Bang. This section situates the article in the context of scholarship that explores the use of metaphors and other literary tropes in scientific discourse before proceeding to a consideration of the challenges scientists face when narrating the origins of the universe. The second section overviews one of the paramount thematic concerns in these narratives, the transition from chaos to order. In the third section, I analyze what is arguably the most mystifying aspect of this transition, the inflationary epoch, focusing on scientific authors' reliance on the balloon metaphor to explain this event. Finally, the last section capitalizes on some of the limitations and associations of the balloon metaphor to provide an imaginative reading of the structural form of the universe and humanity's place within it.

Reading the Big Bang in the Humanities

As recently as the 1960s, three different theories about the overarching structures of the universe were vying for attention, but the accretion of evidence and the lack of serious challenges to key indicators (including the expansion of the universe and the cosmological red shift) have solidified the place of the Big Bang Theory. As has been well-documented, the early acceptance of the Big Bang Theory was greeted with enthusiasm among some theologians, partly because the first proponent of the theory, Georges Lemaître, was a Catholic priest, but also because, as Lawrence Krauss mentions, the theory suggests our universe had a beginning, and a "beginning implies creation" (4). Contemporary scholars continue to locate interconnections between the Big Bang Theory and theological narratives about the origins of existence, but investigations that build on other branches of the humanities are quite rare (Ekeberg 124-25; Rolnick 109; Gleiser 297; Weinberg 13; Vincie 40; Pitts 677; Polkinghorne 64). There seems to be an implicit assumption in scholarship that any counterpoint to the facts and equations delineated in cosmology and astrophysics should revolve around subjects excluded from scientific dialogue, such as faith. Put another way, science addresses the question of how the universe came into existence, whereas other, ostensibly "softer" disciplines tackle the ethereal question of why it came into existence.

At present, science has no established perspective on the latter question, not least because faith-based theories have failed to yield any valid predictions or repeatable experiments. Krauss summarizes this distinction, stating, "You can choose to view the Big Bang as suggestive of a creator if you feel the need . . . But such a metaphysical speculation is independent of the physical validity of the Big Bang itself and is irrelevant to our understanding of it" (6). However, this distinction does not (or should not) exclude humanities-based examinations of the Big Bang Theory that avoid questions of faith or why the universe exists. Yet to an extent such exclusions remain in place, perhaps due to a broad-reaching elevation of numbers and formulae over words in scientific circles. As one example, Neil deGrasse Tyson writes, "I have never been a big fan of philosophy as applied to the physical sciences in the 20th (+21st) century. I have found common arguments to be based more on word usage and word meaning rather than on ideas, and so have found the discussions to be largely useless to the progress of science – a domain where ideas matter more than words" (108). The casual bifurcation of "ideas" and "words," while startling, is representative of underlying assumptions among astrophysicists and cosmologists:

whereas they deal with verifiable ideas, philosophers, theologians, and other scholars in the humanities deal with faith-based wordplay.

One further purpose of this article is to reinstate the importance of words to scientific understandings of the Big Bang, not to launch conjectures about why the universe exists, but to provide a literary interpretation of the way the Big Bang is portrayed in contemporary cosmological and astrophysical narratives. By "narratives" I mean primarily the various books cosmologists and astrophysicists have written for general audiences about the origins of the universe in recent years. On the one hand, that these works are narratives in no way compromises the basic idea that the Big Bang Theory is centred on scientific evidence. Working on the (probably accurate) assumption that their readers will not understand the mathematics and physics at the core of the theory, the authors of these books write narratives so that they can reach their target audiences.

On the other hand, a combination of the overwhelming scientific evidence favouring the Big Bang Theory and the outright difficulty of grasping its implications and visualizing it as a tangible phenomenon frames the use of narratives in these works. With regard to the evidence, one of the frequently neglected aspects of the Big Bang Theory is the novelty of the consensus surrounding it. As Mark Kidger writes, "The current monopoly of scientific opinion for such a fundamental part of the whole basis of astronomy is unusual; normally there are several competing theories, even if one has a substantial majority of support in the scientific community" (154). This peculiarity forms a point of separation between commentaries about the Big Bang and explications of other, more controversial subjects (such as string theory or multidimensionality). The challenge scientific authors face when writing books about the Big Bang for general audiences is not one of proof but of description and representation. So too, for my purposes, a literary reading of these books focuses less on the science behind the Big Bang than on the fraught process of narrating, constructing, and portraying it as a comprehensible event. As I address below, this process is teeming with challenges for scientists due to the sheer extremity of the Big Bang. Put simply, scientific accounts of this event exceed all common-sense perceptions of reality. In popular science works, narratives and also a single metaphor – that of a balloon – are the tools authors call upon to guide readers through this difficult-to-fathom theory.

Previous scholars have studied the use of narratives in general and metaphors in particular in scientific discourses, examining their utility in making complicated ideas accessible and also the role they play in "producing knowledge" (Baake and Bernhardt 56) and "modeling reality" (Christidou, Dimopoulos, and Koulaidis 348). One reason to study narrative constructions of scientific ideas is that the majority of non-experts only encounter these ideas in narrative form, whether through mainstream media, documentaries, or popular science books (Dahlstrom 13614). Metaphors form essential components within these narratives because they help concretize abstract ideas. At the same time, metaphors are often embedded within the very production of scientific knowledge, encapsulating key concepts. As one example, Vasilia Christidou, Kostas Dimopoulos, and Vasilis Koulaidis write that, "in order to describe light, physics introduces two alternative metaphors, wave and particle" (348). Indeed, in his 2018 book *Photons*, Klaus Hentschel asserts that the constituent parts of light, photons, "are neither particles nor waves even though both of these concepts may help us to understand their behavior in certain experiments" (170). The scientific conception of photons as wave-particle dualities amounts to a metaphor that frames how they appear to behave in experiments. The metaphor is ultimately the most efficacious way of depicting the behaviour of entities that, to a degree, elude human perception, even as they saturate our lives.

Metaphors are especially useful for portraying either microscopic or macroscopic phenomena that exceed the typical range of human perception (Taylor and Dewsbury; Nieberta and Gropengiesser), but they also carry inherent risks and limitations. For instance, metaphors can inadvertently serve to maintain outmoded scientific paradigms (Taylor and Dewsbury) and they can also flatten out the nuances in specific topics or problems (Hellsten 16). These risks are all the more acute due to the often-blurry distinctions between metaphors that are ingrained in scientific understandings of concepts (such as the wave-particle duality) and those that rest on tradition and expediency. For example, the metaphor I consider in this article, the Balloonverse, is, at bottom, an imperfect figurative model of the inflationary epoch, but it is so ubiquitous in popular science texts that it has emerged, arguably, as the chief paradigm for narrating and understanding this epoch.

The challenges scientific authors face when narrating the Big Bang may be more daunting than in any other subject in cosmology or astrophysics. For one thing, the Big Bang collapses together the microscopic and the macroscopic. Tyson and Donald Goldsmith describe the first moment after the Big Bang, the Planck era, as a period in which the "large was small" and a "shotgun wedding" occurred between "quantum mechanics (the science of the small) and general relativity (the science of the large)" (39). Popular science authors frequently draw upon everyday objects to capture cosmic scales in size, which can range from the tiniest elementary particles to the vast distances between galaxies, but such comparisons founder when applied to the first moments after the Big Bang because, in its inception, the universe was both very small and all-encompassing. Another challenge science authors face is the general lack of verifiable information about the conditions in the universe during and immediately after the Big Bang. Dan Hooper asserts that, while knowledge of what has happened in the universe since the 380,000-year boundary is "based on a rich array of observations and measurements" (4), the "universe's first seconds and fractions of a second" are shrouded in "impenetrable layers of energy, distance, and time" (5). If popular science authors rely on metaphors when narrating the Big Bang, it is in part because figurative language must fill in some of the gaps in evidence and knowledge.

Taken together, these challenges touch upon a wider issue, namely that the scientific description of the originary moments of the universe defies common-sense perception. According to the evidence, at the moment of its appearance, the entire universe was compressed into an infinitesimally small space. Tyson and Goldsmith write, "a hypothetical observer situated anywhere in the universe during the Planck era could see no farther than 3×10^{-35} meter" (38). The temperature could have been as high as 10^{32} kelvin and the universe may have had a density that, as Brian Greene states, eludes any description, however figurative: "the whole of the known universe fit within a Planck-sized nugget, yielding a density so great that it strains one's ability to find a fitting metaphor or an enlightening analogy: the density of the universe at the Planck time was simply *colossal*" (350). The question of why the universe exists might lead to outlandish and unprovable speculations, but the definitive answer of how it exists is no less outlandish for being accurate. It is the task of narratives about the Big Bang to tell the story of a theory that, at first blush, appears far-fetched and utterly bizarre.

From Chaos to Order: Narrating the Beginning of the Universe

Different popular science books adopt their own approaches to presenting the Big Bang as a describable event, but one recurring strategy – and theme – is to play up the chaos of the very early universe while setting it against the order that soon asserted itself. According to this theme, the instant after the universe emerged represented a moment of calamitous and haphazard disorder, but fortunately structure made its appearance soon enough. Tyson and Goldsmith's 2004 book *Origins* captures this arc well. They write, "We may happily report that our daily lives remain wholly devoid of extreme physics," before proffering examples of what such physics might produce: "suddenly losing all your electrons," "having every atom in your body fly apart," ("That would be bad," they add), or feeling your body "bounce randomly from wall to wall until you're jack-in-the-boxed out the window" (34). Tyson and Goldsmith conclude this list by stating, "back in the early minutes of the universe that kind of stuff happened all the time" (35). They return to this theme when describing the Planck era. After telling readers "Not to worry . . . as far as daily life goes" about the conditions during which the "universe was smaller and hotter than ever thereafter" (38-39), Tyson and Goldsmith chart a trajectory towards the moments when, due to expansion and cooling, the universe began to assume a more orderly form. As is typical, their boundary for this progression is a couple of minutes, at which point a "particle soup of hydrogen nuclei, helium nuclei, electrons and photons" was established that would persist for another 380,000 years (43), but they also repeatedly invoke a ballast that provides guidance through this tempestuous progression, Albert Einstein's famous formula $E = mc^2$. As they mention earlier, this formula is the foundation that equips scientists to "establish a new form of common sense, an altered intuition about how matter behaves, and how physical laws describe its behavior, at extremes of temperature, density, and pressure" (35). In the early parts of *Origins*, $E = mc^2$ operates as a paragon of predictability and order amid the roiling tumult of the first few minutes of existence.

Other authors of narratives about the Big Bang also treat $E = mc^2$ as a sort of lynchpin of stability, though they adopt different narratological approaches to tracking a transition from the chaos of the first moments of the universe to the emergence of order and structure (Hasinger 40-41; Ekeberg 126-27; Ostriker and Mitton 104). One technique is to emphasize a parallel between the development of order following the Big Bang and the increasing durability of scientific knowledge about the universe. Hooper, for example, opens his 2019 book *At the Edge of Time* by sketching a distinction between the "mystery" of the earliest moments of the universe and scientists' "confident" assessment of how it has evolved since "a few hundred thousand years after the Big Bang." Deploying terms like "weird," "[e]xotic," "mind-bogglingly," and "cosmic mysteries," Hooper underscores the irregularity of the very early universe: "All we know for sure is that our newborn universe had little in common with anything that exists in our world today . . . Almost everything we know about physics could have been different during this first instant of time" (1-5). Hooper draws upon the lack of firm information about the first seconds of the universe to accentuate its chaotic character. In Hooper's treatment, the universe after the 380,000-year barrier, by contrast, embodies a more logical and tepid structure that both informs and reflects scientists' knowledge of its evolution.

Other authors have fashioned creative approaches to exploring the first moments of the universe, producing similar images of chaos, extreme conditions, and even danger, which stand against the portraits of order they use to describe the later universe. In his 2015 book *The Universe in Your Hand*, Christophe Galfard sketches a figurative journey back in time, envisaging the reader being transported into the first seconds of the existent universe. For the majority of the "journey," Galfard limits himself to describing the changing surroundings, but his language becomes more dramatic as the reader approaches the Big Bang: "as time keeps rewinding, as the universe continues to shrink, as the energy density rises, everything gets more and more violent . . . Nothing you know or imagine would stand such crushing and shearing power . . . you are now surrounded by an unimaginable inferno" (240). The journey reaches a point of collapse at which "All the known fields are gone" and "The notions of space and time you've used until now do not apply any more." The terminal point is the Planck era, beyond which there is nothing logical or observable: "With no time, no space, with no spacetime, you cannot travel any more. Travel does not actually make any sense in such circumstances" (244). Having brought his narrative journey to a "wall impenetrable not to light, but to modern knowledge," Galfard, like Hooper, conflates the absence of definitive information about the universe at its inception with its extreme and turbulent state during this moment. He writes, "There, our universe becomes a mystery in which twenty-first-century sciences, beliefs and philosophy are intertwined" (245), reinforcing the assumption that disciplines based in the humanities (packaged vaguely as "beliefs and philosophy") only enter the discussion when verifiable ideas are absent.

Other authors like Stephen Hawking (122) and Günther Hasinger (1) have invoked images of chaos and even destruction when describing conditions immediately after the Big Bang, buttressing this thematic through line. From a practical standpoint, this theme speaks to the difficulty of comprehending the early stages of the universe while also serving as a reminder that the Big Bang Theory appeared radical and drastic when it was first introduced. On a more literary level, these narratives create imagery that provides a suitably dramatic backdrop to the moment when existence as we know it began. There is an excitement to the Big Bang that may be absent from other theories since discarded on scientific grounds (particularly the steady-state theory). Moreover, the Big Bang Theory suggests that the universe began *in media res*, in a frenzy of radiation and density, governed by what Tyson and Goldsmith call "extreme physics." Again, there is no indication as to why the universe began in this form, which is another way of saying science does not know what happened prior to the Big Bang. In literary terms, humanity has an incomplete text – a narrative that commences inexplicably with an overwhelming show of chaotic power. Popular science books often revel in this cosmic fury, but they also tend to show an eagerness to introduce structure and reliable information. Einstein's $E = mc^2$ formula provides one foundation for order, but as I consider in the next section, popular science books also call upon a recurring metaphor as a structuring device when narrating the beginning of the universe.

Watching the Universe Blow Up: Narrating the Inflationary Epoch

In most popular science depictions, the universe commenced suddenly with a haphazard burst of power and energy. Due in part to the presumed density of the universe as well as the interchangeability of the microscopic and macroscopic at the beginning of time, authors generally struggle to provide grounding points of comparison for readers when describing this moment. Another difficulty is the lack of firm information about the state of the universe in its first instants. There is no way to duplicate the Plank era in a laboratory setting, so scientists remain uncertain of the composition or structure of the universe at this moment. During the Planck era, the universe was, apparently, extraordinarily dense and hot, but it is impossible to say which particles (if any) existed within it. In most popular science accounts, one of the principal moments of transition towards some semblance of structure was the inflationary epoch, during which the universe transformed from a miniscule nugget into an expansive plasma bath, effectively separating the microscopic and the macroscopic. Time and again, scientific authors invoke the same metaphor to help explain the inflationary epoch – that of a balloon. Unlike the wave-particle duality, the balloon is not yet embedded in scientific understandings of a specific concept, but authors use it with such consistency that it has become the definitive metaphor for detailing the inflationary epoch. What is more, it is frequently the first metaphor these authors call upon when outlining a movement from chaos to order. In this sense, the metaphor of the balloon serves as one of the paramount devices for sketching the form of the universe, not just in its earliest stages but also today. The irony is that the inflationary epoch is itself one of the most difficult concepts to grasp in studies of the Big Bang. This difficulty is reflected in the productive ambiguities and limitations of the balloon metaphor.

The inflationary epoch is said to have occurred between 10^{-36} and 10^{-32} seconds after the Big Bang. According to the available evidence, this epoch commenced after gravity separated from the other fundamental forces (the remaining three, electromagnetism and the strong and weak nuclear forces, were still unified) and was defined by what Galfard calls an "unimaginable rate" of expansion in the universe (243). Hooper avers that this is the moment in the history of the universe when "things got really weird," as the universe "grew in volume by an incredible factor of 10^{75} within a span of only 10^{-32} second" (1-2). The universe went from being miniscule to sizeable almost instantaneously. Randall mentions that the monstrous rate of expansion is a necessary factor for understanding the structure of the universe: "The inflationary Universe's extremely rapid expansion explains the Universe's enormity, uniformity, and flatness. The Universe is enormous because it grew exponentially – in very little time it became very big" (49). One of the challenges involved in depicting this inflation is that it happened at a rate far in excess of the speed of light, though as Hasinger explains, this is not a contradiction within theories of general relativity (44). Another, even broader issue involves the difficulty of articulating the idea that space itself expanded in this manner.

The metaphoric representation of the universe as an expanding balloon is a strategy that popular science books use repeatedly to explain the inflationary epoch and, by extension, the basic structural form of the universe today. In his 2007 book *Cosmological Enigmas*, Kidger concedes that "The concept of inflation is extremely difficult to visualize. Basically it is not a physical expansion of the Universe but rather a rapid growth of its entire fabric." The distinction is not wholly clear, but Kidger calls upon the balloon analogy to clarify his explanation:

> Imagine that you are a flat being living on the surface of a balloon on which you have a grid marked in centimeters. As the balloon is inflated, everything on the surface expands, including your grid. You do not feel that you have moved because you are growing at the same rate as everything else, and your centimeter scale appears not to have changed, but to someone viewing from outside, everything on the surface of the balloon has increased dramatically in size. (213)

Hasinger utilizes the same analogy to describe the inflationary epoch as an explanation for the "fine tuning" of the very early universe:

> Imagine a small, shriveled balloon, which obviously has a rough, curved surface. When you inflate this balloon, all its wrinkles smooth out as it stretches. If you blow up this balloon until it is as big as Earth, then you will not be able to see the slightest curvature on its surface – it has become absolutely flat for all human recognition. Because inflation blows up the tiny primordial universe by a gigantic factor, it simultaneously makes it absolutely flat. (45)

In both of these examples, the authors call upon the familiar, benign image of a balloon to delineate how the universe underwent its hyper-accelerated inflation just instants after its birth. Of notable importance in both examples is the focus on perspective and surface, which serves to draw imaginative distinctions between occupying the universe and viewing it from the outside.

Randall introduces the memorable concept of a "Balloonverse" (37) in her 2015 book *Dark Matter and the Dinosaurs* to describe how she addresses the perplexities of the inflationary epoch and the expansion of the universe, but she also identifies shortcomings in the analogy. Randall writes, "I am frequently asked, 'If the Universe is expanding, what is it expanding into?' The answer is that it is not expanding into anything. Space itself grows. If you imagine the universe as the surface of a balloon, the balloon itself stretches" (36-37). For Randall, the Balloonverse forms a crucial metaphor for describing the transition from the Planck era to the inflationary epoch. She follows the pattern of other physicists in outlining a trajectory from a chaotic and mysterious beginning to a more ordered structure, but she compresses the timescale, asserting that by the 10^{-36}-second mark the early evolution of the universe had become "simple, predictable, and understandable," mainly because by this point the universe was "filled with matter and radiation that was uniform and isotropic – the same at all places and in all directions" (36). Her analysis further underlines the aptness of the balloon as a metaphor while also gesturing towards its limitations: "Our analogy isn't perfect since the surface of the balloon is only two-dimensional and does in fact expand into three-dimensional space. The analogy works only if you imagine that the balloon's surface is all there is – it is space itself" (37). Charles Lineweaver and Tamara Davis make a similar point when speaking about cosmic inflation as an overarching concept:

> The expansion of our universe is much like the inflation of a balloon . . . This balloon analogy should not be stretched too far. From our point of view outside the balloon, the expansion of the curved two-dimensional rubber is possible only because it is embedded in three-dimensional space. Within the third dimension, the balloon has a center, and its surface expands into the surrounding air as it inflates. (37-38)

For Randall and Lineweaver and Davis, part of the trouble with the analogy is that readers will probably be inclined to view the balloon externally, seeing it as an object inflating in front of them into three-dimensional space.

Stephen Barr's 2003 book *Modern Physics and Ancient Faith* is another work that explores the challenges involved in imagining the balloon inflating as a pure surface, but Barr also points towards some of the useful questions that arise from the limitations of the metaphor. Speaking about the history behind the discovery of cosmic inflation, Barr writes that, "What Einstein realized is that not only could the fabric of space-time bend and stretch in one locality, but that the whole of space, the entire universe indeed, could stretch like an expanding balloon." Barr then supplies a roadmap for this analogy that touches upon the demands of visualizing it: "In this balloon analogy, one is not supposed to be thinking of the air or space inside the balloon (or outside the balloon, for that matter). It is the elastic sheet of the balloon itself that is supposed to represent the space of our universe, and physical objects are . . . like little spots of paint on the balloon's surface." Barr also invokes the problem of dimensions, acknowledging, "Of course, the balloon is only a two-dimensional sheet, while the space of our universe, which it is supposed to represent, is three-dimensional." This point leads Barr to extend the analogy to address some inquiries about the overall makeup of the universe, which I return to below:

> One might ask whether there is anything about the real universe that corresponds to the air or volume inside – or outside – the balloon. That is, is our three-dimensional universe embedded in some higher dimensional space, just as the two-dimensional sheet of the balloon is contained in the air around it? No, not at least in the standard cosmological theory. It is not easy, but one is supposed to imagine just the surface of the balloon *without* imagining the inside and outside of it. (40)

Concluding on a similar note to Hasinger, Randall, and Lineweaver and Davis, Barr emphasizes that the analogy of the balloon posits a surface with nothing either above or below it.

The figure of the balloon forms a tropological thread that traverses multiple works, elucidating the inflationary epoch as well as ideas pertaining to the ongoing inflation of the universe. Other authors who make use of the balloon metaphor when describing inflation include Fred Adams and Greg Laughlin (13), Jim Baggott (115-16), Charles Seife (179), Carlo Rovelli (175), Roger Penrose (61), Galfard (98), Rolnick (125), Hawking (46), Hooper (40), and Tyson and Goldsmith (85). What are the literary implications of the balloon metaphor? Also, how does this metaphor work in concert with the theme of transitions in the early universe from chaos to order? The balloon supplies a metaphor that helps organize one of the most bewildering stages in the larger transition, but it also generates paradoxes concerning dimensionality and the difference between being in the universe (occupying the surface of the balloon) and either finding a place outside of it (floating above the surface) or occupying some nether region within it (standing inside of the balloon). For now, the latter two possibilities appear to be physically impossible, hence the necessity of imagining, in Randall's words, that the "balloon's surface is all there is." One could say that the balloon is simply the best figurative example the authors of these books have at their disposal, but the consistent problem of envisioning the universe as a balloon points to another level of interpretation that coalesces on a literary level. In this interpretation, the significance of the balloon as a metaphor unspools not merely through the intentions of scientific authors but also through some of its flaws and unexpected implications.

An Imaginative Reading of the Balloonverse

The figure of the balloon clarifies the difficult concept of the inflationary epoch, but in order to reflect modern scientific knowledge, the metaphor posits the surface of a balloon in isolation, with no air inside of it and nothing surrounding it. This is an unavoidable limitation in the image, but it also provides material that can help unpack its implications. Again, scientists tend to regard the balloon as a flawed model instead of an essential component in theories of inflation, but the ever-increasing entrenchment of this metaphor in popular science has galvanized a portrait of the universe that stretches across many texts. The metaphor has become the defining picture of a uniform, flat, and expanding universe. Examining this metaphor from an imaginative standpoint casts light on the way its associations and limitations both reflect and frame current scientific understandings of the cosmos.

Among other things, the metaphor suggests that everything in the universe occupies the same surface and that each point on this surface is basically the same as every other. As far as science knows, there is no interior or exterior realm that corresponds to the "air" inside or outside of the balloon. Relatedly, there is no centre to the universe – no inner sanctum lurking beneath the "surface." In fact, insofar as there is a centre to the universe, it is found everywhere because the universe is enormous, uniform, and flat. As Krauss remarks, in the context of inflation, "either *every place* is the center of the universe, or *no place* is" (14). The Balloonverse creates the impression that everything that has ever existed or will ever exist is plastered across the same surface.

From the standpoint of modern cosmology, the universe contains nothing but its surface, but is there any hope that humanity could in some way locate a territory beyond this surface? That is, could there actually be an inner or outer realm in addition to the surface we experience and observe? According to current accounts, the universe is flat, so if these realms exist, they are concealed from scientific observation. What happens, however, if an author imagines that the metaphor of the balloon is fundamentally accurate? That is to say, what if I build on Barr's question regarding "whether there is anything about the real universe that corresponds to the air or volume inside – or outside – the balloon" (40) by imagining that a balloon encapsulates symbolically the basic form and workings of the universe? This is an imaginative experiment that reads the limitations of the metaphor as symptomatic of both existing scientific knowledge about the universe and the possibility of further discoveries. The experiment visualizes some of the conundrums involved in open-ended topics like the multiverse and multidimensionality, bringing a different angle to scientific narratives about the early universe.

In this experiment, the rubbery, elastic surface of the balloon represents everything in the universe that humanity has ever observed or detected, including itself. Large, concentrated distributions of mass and energy (planets, stars, and galaxies, for example) bend the surface, forming dimples and depressions. Below is a vast, hidden region that exerts ongoing pressure on the surface, causing it to expand continuously, to the point that it appears flat to any observer located on said surface. This region corresponds to the air inside of the balloon. Above the surface is another region of indeterminate size, the space into which the universe is expanding – though again, because this region is undetected, observers conclude that the surface "is not expanding into anything" (Randall 37). The regions below and above the surface are composed of an analogous matter (symbolically, air), which is profoundly different from the matter that makes up the surface (symbolically, rubber). Yet the surface of the Balloonverse may be permeable. There could be tears and rips scattered about, caused by hyper-intense concentrations of mass and energy in small areas, through which "air" can escape. These tears and rips would correspond to black holes and maybe even wormholes. However, it is also possible that the surface is so pliable and elastic that it simply does not rip. Rather, a high concentration of mass and energy in a small region causes the surface to bend downward like a stretchy texture weighed down by a ball bearing. What might appear to be a hole is in fact a very long, thin concavity, a protracted tunnel to nowhere that snakes through the nether region below the surface. In this case, there is no direct contact between the material of the surface and the mysterious substance that fills the internal and external regions, though they do have an influence on each other.

This imaginative rethinking of the Balloonverse reflects questions about the structures of the universe and humanity's spatial position within it. As with speculative inquiries about multidimensionality and the multiverse, the questions lack answers, so it is their implications that come to the foreground. For instance, what picture emerges if I imagine that this invented Balloonverse is one of many universes, which are all nestled inside one another like Matryoshka dolls? Above and beneath the "air" that composes the outer and inner regions of our universe are the layered surfaces of other universes. This possibility calls to mind a curious image of a valve at the centre of existence that generates successive big bangs, fuelling the pressure that keeps the concentric spheres growing. Another possibility is that there is only one "sphere" that represents all of spacetime, and our universe is merely a bubble that grew out of the surface of that sphere. Perhaps some kind of transition involving one of the aforementioned holes or concavities on the surface caused an air pocket to swell rapidly, inflating into a balloon that has extended far above the larger sphere. The balloon has reached an enormous size, but once the pressure is relieved, it will start (and maybe already has started) to deflate and sink back down to the surface, rejoining its parent sphere. The dimensions of the main sphere are unknown and probably unknowable.

The imaginative experiment also portrays the latest consensus in astrophysics and cosmology about the limits of the universe. If there is an outside region above the surface of the universe and an underworld region inside of it, they are perfectly hidden, because all science can detect for the moment is the surface. Such regions may be possible, but there is no indication of how humanity can extricate itself from the surface, not least because materially everything we know is a part of that surface. Furthermore, if these regions exist in the same way that air exists inside and outside of a balloon, they must be absolutely gargantuan, making it unlikely that humanity could travel through them in a productive manner, assuming science could detect them in the first place. In theory, for example, people may be able find a way to enter one of the holes or concavities on the surface, but the connected tunnel would cover an enormous distance, and it would be unclear if it actually leads anywhere. So too, embarking on an interstellar journey to the limits of the universe would not equip travellers to discover a region beyond the surface; rather, this journey would be like tracing an interminable line across the surface of a balloon, searching for an edge that does not exist. Therefore, one thing this imaginative rethinking of the Balloonverse fails to do is make regions beyond the surface appear more accessible; instead, it emphasizes the daunting size of the parts that make up the Balloonverse.

Conclusion

The metaphor of the Balloonverse carries limitations and paradoxes, but they are productive insofar as they illuminate some of the underlying implications of current scientific knowledge about the evolution and form of the universe. What are these implications? For me, there are two major ones, which together form a useful contrast. The first is that, if the rubbery surface of the balloon is viewed as the equivalent of everything that is perceivable or detectable in the universe, then this suggests that there is an elemental sameness to an incredibly diverse array of things. This one surface contains entities ranging from neutrinos to black holes, not to mention manifestations of the universe ranging from its tiny, dense state in the Planck era to its current, sprawling 13.8-billion-year-old form. The upshot is that the Balloonverse metaphor indicates that humanity may have no discernible way of seeing beyond the surface. After all, this one surface is already stocked with things and events that science struggles to understand, perceive, or even picture. How, then, could it begin to comprehend things or events that are made of an entirely different "substance"? In effect, by hinting that all the observable things in the universe belong to the same surface, the metaphor implies that those things which correspond to the air must be profoundly and radically different from anything humanity has ever encountered or even imagined.

The second implication is that, if there are hidden regions or dimensions that correspond to the air inside and outside of the balloon, they should have an impact on the surface, even if humanity has no way of encountering them. In fact, although the Balloonverse is, first and foremost, a metaphor, it does intersect on these grounds with some of the most pressing unanswered questions in contemporary astrophysics and cosmology. In particular, the Balloonverse offers a salient perspective on the mystery of dark matter and dark energy. According to estimates, approximately 68% of the universe is composed of dark energy and 27% of it is made up of dark matter, accounting for 95% of the universe's total content. Humanity is aware of dark matter and dark energy due to the influence they exert (on the shapes of galaxies, for instance), but it has been unable to identify them in any direct manner.

Speaking figuratively, dark matter and dark energy are viable candidates for the "air" inside and outside of the balloon because they are abundant, they influence the "surface," and yet they are, as yet, undetectable. In fact, the metaphor of the Balloonverse emblematizes the fruitlessness of the search for dark matter and dark energy up to this point. If dark matter and dark energy are analogous to the air inside and outside of the balloon, then it makes sense that humanity is able to witness them only through the impact they produce on the surface – that is, on the matter and energy that compose our perceivable context. Just as the air is a different substance from the rubber sheet, dark matter and dark energy may be elementally different from anything composed of, for instance, subatomic particles (electrons, quarks, etc.). Needless to say, the Balloonverse does not prohibit further advances in scientific knowledge about dark matter and dark energy. Rather, like a good metaphor, it knits together different threads in the thing it represents, binding them into a multilayered and flexible image. In the end, the Balloonverse is an ideal metaphor not because it captures the proven form of the universe but because it captures both scientific knowledge about the universe as well as ongoing gaps in this knowledge.

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