A Beginner's—and Expert's—Guide to the Big Bang: Separating Fact from Fiction

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Abstract:
The case for the big bang (creation) event rests on compelling scientific evidence. While there are still astronomers and others who oppose the theory, the reasons for skepticism are primarily metaphysical and theological. This article provides a summary of the accumulated data supporting the big bang—honing in on eight of the most recent and important confirmations—and concludes by noting that the big bang supporting evidences point to the God of the Bible.

Big bang cosmology is an explosive topic. Heated reactions—and bitter resistance—have arisen from opposite directions in the last century but, ironically, for the same type of reasons: religious reasons. One group of big bang opponents includes those who understand the theory's implications, and the other, those who misunderstand them.

People in the first group understand that the big bang denies the notion of an uncreated or self-existent universe. Big bang theory, based on the accumulated data of centuries, points to a supernatural beginning and a purposeful (hence personal), transcendent (beyond the boundaries of space, time, matter, and energy) Beginner. Those who reject the reality of God or the knowability of God would, of course, find such an idea repugnant, an affront to their philosophical worldview. Similarly, it would offend those who want to spell *universe* with a capital *U*, who have been trained to view the universe itself as ultimate reality and as the totality of all that is real. Again, their response is religious.

People in the second group hate the big bang because they mistakenly think it argues *for* rather than *against* a godless theory of

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origins. They associate "big bang" with blind chance. They see it as a random, chaotic, uncaused explosion when it actually represents exactly the opposite. They reject the date it gives for the beginning of the universe, thinking that to acknowledge a few billion years is to discredit the authority of their holy books, whether the Koran, the book of Mormon, or the Bible.[1,2] Understandably, these people either predict the theory's ultimate overthrow or choose to live with a contradiction at the core of their belief system.

Despite opposition from outspoken enemies, the fundamentals of the big bang model, which is actually a cluster of slightly differing models, stands secure. In fact, it stands more firmly than ever with the aid of its most potent and important allies: the facts of nature and the technological marvels that bring them to light, as well as the men and women who pursue and report those facts.[3] The following comments offer a summary of the accumulated data supporting the big bang, giving special attention to eight of the most recent and significant confirmations.

A Problematic Term

The big bang is *not* a big "bang" as most lay people would comprehend the term. This expression conjures up images of bomb blasts or exploding dynamite. Such a "bang" would yield disorder and destruction. In truth, this "bang" represents an immensely powerful yet carefully planned and controlled release of matter, energy, space, and time within the strict confines of very carefully fine-tuned physical constants and laws which govern their behavior and interactions.[4] The power and care this explosion reveals exceeds human potential for design by multiple orders of magnitude.

Why, then, would astronomers retain the term? The simplest answer is that nicknames, for better or for worse, tend to stick. In this case the term came not from proponents of the theory but rather, as one might guess, from a hostile opponent. British astronomer Sir Fred Hoyle coined the expression in the 1950s as an attempt to ridicule the big bang, the up-and-coming challenger to his "steady state" hypothesis.

He objected to any theory that would place the origin, or Cause, of the universe outside the universe itself, hence, to his thinking, outside the realm of scientific inquiry.[5]

For whatever reasons, perhaps because of its simplicity and its catchy alliteration, the term stuck. No one found a more memorable, short-hand label for the "precisely controlled cosmic expansion from an infinitely or near infinitely compact, hot cosmic 'seed,' brought into existence by a Creator who lives beyond the cosmos." The accurate but unwieldy gave way to the wieldy but misleading.

A Multiplicity of Models

The first attempts to describe the big bang universe, as many as a dozen, proved solid in the broad simple strokes but weak in the complex details. So, they have been replaced by more refined models. Scientists are used to this process of proposing and refining theoretical models. News reporters—even textbook writers—sometimes misunderstand, though, and inadvertently misrepresent what is happening.

Reports of the overthrow of the "standard big bang model" illustrate the point. That model, developed in the 1960s, identified matter as the one factor determining the rate at which the universe expands from its starting point. It also assumed that all matter in the universe is ordinary matter, the kind that interacts in familiar ways with gravity and radiation. Subsequent discoveries showed that the situation is much more complex. Matter is just one of the determiners of the expansion rate, and an extraordinary kind of matter (called "exotic" matter) not only exists but more strongly influences the development of the universe than does ordinary matter.

The reported demise of the "standard big bang" led many to view the big bang as fiction rather than fact. On the contrary, the discoveries that contradicted the standard model gave rise to a more robust model, actually a set of models attempting to answer new questions. More than once, as one of these models has been replaced with a more refined variant, news articles heralded the overthrow of *the* big bang theory when they should have specified *a* big bang model.

Currently, cosmologists (those who study the origin and characteristics of the universe) are investigating several dozen newer variations on the big bang theme. Scientists expect still more to arise as technological advances make new data accessible. This proliferation of slightly variant big bang models actually speaks of the vitality and viability of the theory.

It makes sense that the first models proposed were simple and sketchy. The observations at that time, while adequate to support the fundamental principles of the big bang, were insufficient to explore and account for the details. As the evidences have become more numerous and more precise, astronomers have discovered additional details and subtleties, features previously beyond their capability to discern.

New details, of course, mean more accurate "reconstructions" of what actually occurred "in the beginning." Each generation of newer, more detailed big bang models permits researchers to make more accurate predictions of what *should be* discovered with the help of new instruments and techniques.

As each wave of predictions proves true, researchers gain more certainty that they are on the right track, and they gain new material with which to construct more accurate and more intricate models. The testing of these models, in turn, gives rise to a new level of certainty and a new generation of predictions and advances. This process has been ongoing for many decades now, and its successes are documented not only in the technical journals but in newspaper headlines worldwide.

Overview of Big Bang Evidences

Most textbooks currently in use at middle schools, high schools, and colleges describe only three or four evidences supporting big bang cosmology. The short list makes sense to a scientist, who sees no need to reiterate evidences for a roundish earth or for protons and electrons. But scientists who write textbooks may lack an appreciation for the clouds of doubt and confusion still hovering in the minds of non-scientists.

One purpose of this article is to help bridge the gap between the frontiers of science and popular awareness. This purpose, however, can be only partially realized in the scope of a magazine. Space does not permit an explanation or even an adequate description of each discovery supporting the big bang. It does permit two things, however. First, it allows a simple listing of thirty evidences (with one or two primary sources cited and a secondary source that gives an extensive list of other primary sources) demonstrating the breadth and depth of that evidence. Second, it allows for a more detailed description of the most powerful new findings that support a big bang creation event.

Summary List of Evidences for a Big Bang Creation Event

1. Existence and temperature of the cosmic background radiation[6]

Ralph Alpher and Robert Herman calculated in 1948 that cooling from a big bang creation event would yield a faint cosmic background radiation with a current temperature of roughly 5° Kelvin (-455°F).[7] In 1965 Arno Penzias and Robert Wilson detected a cosmic background radiation and determined that its temperature was about 3° Kelvin (-457°F).[8]

2. Black body character of the cosmic background radiation[9]

Differences between the spectrum of the cosmic background radiation and the spectrum expected from a perfect radiator measured to be less than 0.03 percent over the entire range of observed wavelengths.[10] The only possible explanation for such an extremely close fit is that the entire universe must have expanded from an infinitely or near infinitely hot and compact beginning.

3. Cooling rate of the cosmic background radiation[11]

According to the big bang, the older and more expanded the universe becomes, the cooler its cosmic background radiation. Measurements of the cosmic background radiation at distances so great that we are looking back to when the universe was just a half, a quarter, or an eighth of its present age show temperature measures that are hotter than the present 2.726°K by exactly the amount that the big bang theory predicts.[12] That is, astronomers actually witness the universe growing cooler and cooler through time.

4. Temperature uniformity of the cosmic background radiation13

The temperature of the cosmic background radiation varies by no more than one part in ten thousand everywhere astronomers look from one direction in the heavens to another.[14] Such high uniformity can be explained only if the background radiation arises from one extremely hot primordial creation event.

5. Ratio of photons to baryons[15]

The ratio of photons to baryons (protons and neutrons) in the universe exceeds 100,000,000 to 1.[16] This ratio means that the universe is so extremely entropic (efficient in radiating heat and light) it can only be explained as a rapid explosion from an infinitely or nearly infinitely hot, dense state.

6. Temperature fluctuations in the cosmic background radiation[17]

For galaxies and galaxy clusters to form out of a big bang creation event, temperature fluctuations in maps of the cosmic background radiation should measure at a level of about one part in a hundred thousand. The predicted fluctuations were detected at the expected level.[18]

7. Power spectrum of the temperature fluctuations in the cosmic background radiation[19]

For a big bang universe with a geometry suitable for the formation of stars and life supporting planets, the temperature fluctuations in the cosmic background radiation must peak at an angular resolution close to one degree with a few much smaller spikes at other resolutions. In other words, the power spectrum graph will look like a bell curve with a few sub-peaks to the side of the main peak. The Boomerang balloon experiment this past April confirmed this big bang prediction.[20] (See section in this article on deuterium and lithium abundances for another confirmation of this discovery.)

8. Cosmic expansion rate[21]

A big bang creation event implies a universal expansion of the universe from a beginning several billion years ago. The most careful measurements of the velocities of galaxies establish that such a cosmic expansion has been proceeding for the past 14.9 billion years,[22] a cosmic age measure that is consistent with measurements made by other means.[23] (Some of the other measurements are described in the paragraphs to follow.)

9. Stable orbits of stars and planets[24]

Our universe allows stable orbits of planets about stars and of stars about the nuclei of galaxies. Such stable orbits are physically impossible unless the universe is comprised of three very large and rapidly expanding dimensions of space. (An explanation of this proof follows.)

10. Existence of life and humans[25]

Life and humans require a stable star like our sun. However, if the universe cools down too slowly, galaxies trap radiation so effectively as to prevent any fragmentation into stars. If the universe cools too rapidly, no galaxies or stars can condense out of the cosmic gas. If the universe expands too slowly, the universe collapses before solar-type stars reach their stable burning phase. If it expands too rapidly, no galaxies or stars can condense from the general expansion.

11. Abundance of helium in the universe[26]

(explained in the following paragraphs.)

12. Abundance of deuterium (heavy hydrogen) in the universe[27]

(explained in the following paragraphs.)

13. Abundance of lithium in the universe[27]

(explained in the following paragraphs.)

14. Evidences for general relativity[28]

Recent measurements of the theory of general relativity affirm it as the most exhaustively tested and best proven principle in all of physics.[29] The solution to the equations of general relativity demonstrate that the universe must be expanding from a beginning in the finite past.

15. Space-time theorem of general relativity[30]

A mathematical theorem developed by Stephen Hawking and Roger Penrose in 1970 establishes that if the universe contains mass, and if its dynamics are governed by general relativity, then time itself must be finite and must have been created when the universe was created.[31] It proves there must exist a CAUSE responsible for bringing the universe into existence, a cause that exists and operates "transcendently," outside and independent of matter, energy, and all cosmic space-time dimensions.

16. Space energy density measurements[32]

Albert Einstein and Arthur Eddington sought to escape the big bang by altering the theory of relativity to include a cosmic space energy density term (a.k.a. the cosmological constant) and by assigning a particular value to that term. Recently, astronomers determined that indeed a cosmic space energy density term does exist.[33] Its value, however, proves that Einstein's and Eddington's alternative models are incorrect. The measured value actually increases the evidence for the big bang, establishing that the universe will continue to expand at an ever-increasing rate.

17. Ten-dimensional creation calculation[34]

In 1995, a team of scholars led by Andrew Strominger demonstrated that only in a universe framed in ten space-time dimensions, six of which stopped expanding when the universe was a ten millionth of a trillionth of a trillionth of a trillionth of a second old, is it possible for gravity and quantum mechanics to coexist.[35-37] Their demonstration also successfully confirmed both special and general relativity and solved a number of outstanding problems in both particle physics and black hole physics. This finding implies that the big bang and the laws of physics are valid all the way back to the creation event itself.

18. Stellar ages[38]

According to the big bang theory, different types of stars form at different epochs. The colors and surface temperatures of stars tell astronomers how long the stars have been burning. These measured burning times are consistent with the big bang. They also are consistent with all other methods for measuring the time back to the cosmic creation event. (See this article for the latest measurements.)

19. Galaxy ages[39]

According to the big bang theory, nearly all the galaxies in the universe formed early in its history, within about a four billion year window of time. Indeed, astronomers measure the galaxies to be as old as the model predicts.[40]

20. Decrease in galaxy crowding[41]

The big bang predicts that galaxies spread farther and farther apart from one another as the universe expands. Hubble Space Telescope images show that the farther away in the cosmos one looks (and, thus, because of light's finite velocity, the farther back in time) the more closely packed the galaxies are.[42] In fact, looking back to when the universe was but a third of its present age, the Space Telescope images reveal galaxies so tightly packed together that they literally are ripping spiral arms away from one another.

21. Photo album history of the universe[43]

Since the big bang predicts that nearly all the galaxies form at about the same time (see #18), and since galaxies change their appearance significantly as they age, images of portions of the universe at progressively greater and greater distances (and, because of light's finite velocity, farther and farther back in time) can be expected to show dramatic changes in the appearance of the galaxies. Hubble Space Telescope images verify the predicted changes.[44] (For more details see paragraphs to follow.)

22. Ratio of ordinary matter to exotic matter[45]

In a big bang universe, galaxies and stars can develop as suitable life-support sites only if the cosmos exhibits a certain ratio of exotic matter (matter that does not interact well with radiation) to ordinary matter (matter that strongly interacts with radiation). That crucial ratio is roughly five or six to one. Recent measurements reveal such a ratio for the universe.[46]

23. Abundance of beryllium and boron in elderly stars[47]

Long before the first stars form, during the first few minutes after it bursts into existence, the big bang fireball generates tiny amounts of boron and beryllium–that is if, and only if, the universe contains a significant amount of exotic matter. Astronomers have confirmed that primordial boron and beryllium exist in the amounts predicted by the big bang theory and by the measured amount of exotic matter.[48]

24. Numbers of Population I, II, and III stars

(See paragraphs to follow.)

25. Population, locations, and types of black holes and neutron stars.[49]

After many billions of years of star burning, a big bang universe with the right characteristics for life support produces a relatively small population of stellar mass black holes and a larger population of neutron stars. Large galaxies produce supermassive (exceeding a million solar masses) black holes in their central cores. Astronomers, in fact, observe the predicted populations, locations, and types of black holes and neutron stars.[50]

26. Dispersion of star clusters and galaxy clusters[51]

The big bang predicts that as the universe expands, different types of star clusters and galaxy clusters will disperse at specific (and increasing) rates. It also predicts that the densest star clusters hold together, but the stars' orbital velocities about the cluster's center "evolves" toward a predictable randomized condition known as virialization. The virial times depend on the cluster mass and size and on the individual masses of the stars. Astronomers observe the dispersal rates and virial times predicted by the big bang.

27. Number and type of space-time dimensions[52]

A big bang universe of the type so that a site suitable for the support of physical life will be possible must begin with ten rapidly expanding space-time dimensions. At about 10-43 seconds (about a ten millionth of a trillionth of a trillionth of a trillionth of a second) after the creation event six of the ten dimensions must cease expanding while the other four continue to expand at a rapid rate. Several experiments and calculations confirm that we live in such a universe.

28. Masses and flavors of neutrinos[53]

All currently viable big bang models require that the dominant form of matter in the universe be a form of exotic matter called "cold dark matter." Astronomers and physicists already know that neutrinos are very plentiful in the universe and that they are "cold" and "dark." Recent experiments establish that neutrinos oscillate (that is, transform) from one flavor or type to another (the three neutrino flavors are electron, muon, and tau).[54] This oscillation implies that a neutrino particle must have a mass between a few billionths and a millionth of an electron mass. Such a range of masses for the neutrino satisfies the requirement for the viable big bang models.

29. Populations and types of fundamental particles.[55, 56]

In the big bang the rapid cooling of the universe from a near infinitely high temperature and a near infinitely dense state will generate a zoo of different fundamental particles of predictable properties and predictable populations. Particle accelerator experiments which duplicate the temperature and density conditions of the early universe have verified all the types and populations of particles predicted that are within the energy limits of the particle accelerators.

30. Cosmic density of protons and neutrons

(See paragraphs to follow.)

A Big Bang Picture Album

The simplest-to-grasp evidence in support of the big bang comes from pictures. With the help of various imaging devices, one can actually enjoy a kind of time-lapse photo of the big bang. The images show the universe in its various "growing up" stages, much as a time-lapse camera captures the opening of a flower, or as a photo album documents the development of a person from birth onward.

Such an album is made possible by light (or radiation) travel time. Observing a distant galaxy, for example, some 5 billion light-years distant is equivalent to seeing that galaxy 5 billion years ago, when the light now entering an earth-based telescope began its journey through space. In one sense, astronomers can only capture glimpses of the past, not of the present, as they peer out into space.

Thanks to the Keck and Hubble Space Telescopes, astronomers now have a photo history of the universe that covers nearly 14 billion years. It begins when the universe was only about half a billion years old and follows it to "middle age," where it yet remains. The sequence of images [images not available online] presents highlights from this cosmic photo album. Photo (a) shows the universe at the equivalent of infancy, before galaxies exist; (b) depicts the "toddler" stage, when newly-formed galaxies are so tightly packed as to rip the spiral arms off one another; (c) shows the youthful universe, a time when most of the galaxies are still actively generating new stars and galaxy collisions are frequent; and (d) captures the universe's entrance to middle age, a time when nearly all galaxies have ceased forming new stars and galaxy collisions are rare.

Figure X deserves special attention. It captures that moment in cosmic history when light first separated from darkness, before any stars or galaxies existed. It shows us the universe at just 300,000 years of age, only 0.002 percent of its current age.

These images testify that the universe is anything but static. It expanded from a tiny volume and changed according to a predictable pattern as it grew, a big bang pattern. A picture is still worth a thousand words, perhaps more.[57]

Helium abundance matches big bang prediction

The big bang theory says that most of the helium in the universe formed very soon after the creation event. According to the big bang, the universe was infinitely or nearly infinitely hot at the creation moment. As the cosmos expanded, it cooled, much like the combustion chamber in a piston engine.

By the time the universe was one millisecond old it had settled down into a sea of protons and neutrons. The only element in existence at that time was simple hydrogen, described by a single proton. For about 20 seconds, when the universe was a little less than four minutes old, it reached the right temperature for nuclear fusion to occur. At that point, protons and neutrons fused together to form elements heavier than simple hydrogen.

According to the theory, almost exactly one-fourth of the universe's hydrogen, by mass, was converted into helium during that 20-second period. Except for tiny amounts of lithium, beryllium, boron, and deuterium (which is hydrogen with both a proton and a neutron in its nucleus), all other elements that exist in the universe were produced much later, along with a little extra helium, in the nuclear furnaces at the cores of stars.

One of the ways astronomers can test the big bang theory is to measure the amount of helium in objects that are so far away (and, hence, are being viewed so far back in time) that they predate significant stellar burning. A second way is to examine objects in which little stellar burning has ever occurred. That is, astronomers can find and make measurements on relatively nearby objects in which star formation shut down quickly, too quickly to contribute significantly to the total helium abundance.

In 1994 astronomers measured for the first time the abundance of helium in very distant intergalactic gas clouds.[58] These measurements, recently confirmed by additional measurements,[59] revealed the presence of helium in the quantity predicted by the big bang model.

In the last 1999 issue of the *Astrophysical Journal*, a team of American and Ukrainian astronomers published yet another proof for the hot big bang creation event.[60] The six researchers used the Multiple Mirror and Keck telescopes to check the quantity of helium in two of the most heavy-element-deficient galaxies known (blue compact galaxies I Zwicky 18 and SBS 0335-052). They determined that helium comprised 0.2462 ± 0.0015 of the total mass of those galaxies. After subtracting the tiny amount of star-produced helium in the two galaxies, they derived a primordial helium abundance of 0.2452 ± 0.0015, consistent with the findings in distant, ancient objects. This value is so close to the big bang prediction that the team concluded it "strongly supports the standard big bang nucleosynthesis theory."[61]

During the months since that publication was released, Canadian astronomers have refined the data of the American-Ukrainian team.[62] Their correction (based on the elimination of data from hot-star-excited nebulae within the galaxies) yielded a primordial helium abundance 1.5 percent higher and 20 percent more accurate than the first set of figures. The new value is so very close to the theoretically expected value as to be indistinguishable.[63]

Deuterium and lithium abundances match big bang prediction

Whatever quantity of deuterium (heavy hydrogen) and lithium exists today was produced during the first four minutes of creation, the big bang theory tells us. Not all that deuterium and lithium remains, however, for stellar burning gobbles up those elements, rather than producing more. In seeking to measure the abundance of deuterium and lithium and to compare that amount with the amount predicted by the big bang model, astronomers focused again on extremely distant systems, also on nearer systems in which little stellar burning has occurred. With significant help from the Keck telescopes [64-66] and from the "Hubble Deep Field" image (a "picture" assembled from layers upon layers of Hubble Space Telescope exposures to the same part of the sky),[67] five different teams produced measurements.[68, 69] In their words, the deuterium and lithium abundances fit the big bang predictions "extremely well." [70]

Density of protons and neutrons

The big bang theory fails to produce the stars and planets necessary for life and the elements necessary for life unless the cosmic density of baryons (protons and neutrons) takes on a specific value. This value is about four or five percent of the mass density that would be necessary, by itself, to bring the expansion of the universe to an eventual halt, what astronomers refer to as the critical density. Therefore, an obvious test of the big bang would be to see if the baryon density is close to this 4-5 percent of the critical density.

Until recently, the determination of primordial helium, deuterium, or lithium abundances was the only reliable way to get a measure of the density of baryons in the universe. The best results came from the five teams mentioned in the section above. They determined that the cosmic baryon density is equal to 0.04 to 0.05 of the critical density.

During the last year astronomers have developed three new and independent methods for measuring the cosmic baryon density. The most spectacular and accurate of these three new methods comes from the Boomerang maps of the temperature fluctuations in the cosmic background radiation (see the last issue of *Facts for Faith* for details). From the North American test flight of the Boomerang high altitude balloon, the cosmic baryon density was measured at 0.05 of the critical density.[71] The other two methods gave an average value of roughly 0.03.[72-74] These independent confirmations of the cosmic baryon density deduced from primordial helium, deuterium, and lithium abundances give yet more evidence for a big bang creation event.

Cosmic expansion velocity matches big bang prediction

An obvious way to test the big bang is to affirm that the universe is indeed expanding from an infinitesimal volume and to measure the rate of its expansion from the beginning up to the present moment. While this task may seem simple in principle, in practice it is not. Measurements of adequate precision are enormously difficult to make. Only in the last few years have measurements as accurate (or nearly so) as the other big bang proofs become possible.

Five methods (some independent, some slightly dependent) for measuring the cosmic expansion rate have now been developed and applied (see Table 2). The average of the five yields a rate of 64 kilometers per second per megaparsec (a megaparsec = the distance light travels in 3.26 million years). Running the expansion backward at this rate implies that the universe is approximately 14.6 billion years old.

The newly discovered "energy density term" adds another half billion years, suggesting that the universe is about 15.1 billion years old.[75, 76] This figure serves as a confirmation of the model because of its consistency with other age indicators, including the cosmic background radiation, the abundance of various radiometric elements,[77] and the measured ages of the oldest stars (see below).

Table 1: Latest Measurements of the Cosmic Expansion Rate

Astronomers have developed and refined five measuring tools for determining the rate of expansion for the universe, or what they call the "Hubble constant." A megaparsec = the distance light travels in 3.26 million years.

Method	**Hubble Constant Value**
gravitational lensing	66 km/sec/megaparsec[78-82]
Tully-Fisher	61 km/sec/megaparsec[83-86]
cepheid distances to galaxies	62 km/sec/megaparsec[87-90]
type Ia supernovae	61 km/sec/megaparsec[91-94]
geometric distance measures	71 km/sec/megaparsec[95-98]
average of measured values	64 km/sec/megaparsec
age calculation based on average of values	14.6 billion years
correction for energy density term	+0.5 billion years
corrected age calculation	15.1 billion years

Star populations fit big bang scenario

Big bang theory proposes that three distinct generations of stars formed at certain intervals after the creation event. Astronomers creatively refer to these generations as Population III, Population II, and Population I stars. The numbering system seems reversed, since Population III stars are the oldest, but the latter were the last to be discovered and studied; hence, the confusing numbering system.

According to the big bang, Population III stars formed when the universe was barely a half billion years old. By that time, matter had condensed adequately for stars to begin coalescing. However, since the universe had expanded so little as yet, the average density of gases was much higher than today's observed density. Thus, the earliest stars were mostly supergiant stars. Such stars burn up very quickly (astronomically speaking), in less than ten million years. They end with catastrophic explosions, dispersing their ashes throughout the cosmos.

Given the brief burning time and early formation of such stars, big bang theorists conclude that few, if any, Population III stars should still be observable. However, their remains should be. Population III stars leave a distinctive signature of elements in their scattered ashes. This signature is found in all the distant gas clouds of the universe.

Recently, there has emerged evidence that some of the rare low-mass Population III stars may have been found.[99, 100] Their low mass means that they can burn long enough for astronomers to be able to find them today. They have been difficult to detect, though, because they absorb the ashes of the giant Pop IIIs, thus taking on a disguise. Recently, however, stellar physicists have developed tools for distinguishing Population III survivors from the younger Population II stars that form from the ashes of Population III supergiants.[101, 102]

The big bang theory makes three major predictions about Population II stars: 1) this group should be the largest of the star populations, given that it formed when galaxies were young and at their peak star-forming efficiency; 2) they should be more numerous in certain locations, such as globular clusters, where early star formation proceeds most efficiently, and 3) they should come in all sizes, all mass categories from low to high, not favoring one category over another. All three predictions are borne out by astronomers' observations over the last few decades.

The third generation of stars, the Population I stars (including Earth's sun), formed from the scattered ashes of the largest Population II stars. These ashes are easy to distinguish from Population III ashes because they are at least 50 percent richer in heavy elements (those heavier than helium). The gaseous nebulae (or gas clouds) scattered throughout the spiral arms of the Milky Way and gas streams the Milky Way galaxy steals from nearby dwarf galaxies are actually "ash heaps" of giant Population II stars.

The big bang theory says that star formation shut down for the most part shortly after the formation of Population II stars. Thus, most galaxies are devoid, or nearly devoid, of Population I stars. The big bang also says that in the few galaxies where Population I stars do form, the most intense period of star formation was the past few billion years, and the most intense regions of star formation are the densest areas, such as the nuclei and spiral arms. (Some also would have formed in what astronomers call "irregular" galaxies.) All these characteristics have proved true, confirmed by observations.

Does the big bang allow for Population IV stars to form in the future? Yes, it does. But, it predicts that this population should be tiny compared to the other three. Everywhere astronomers look in the universe, they see signs that star formation will soon shut down totally, even in those galaxies still active in forming stars. ("Soon" to an astronomer is not tomorrow or next year but a few billion years hence.) Astronomers anticipate, for example, that the Milky Way galaxy will experience a "brief" burst of star formation when it pulls the Large Magellanic Cloud (its companion galaxy) into its core region some four or five billion years from now. Already the universe is old enough to make such incidents rare.

Oldest stars tell their story

Since the big bang theory indicates when the Population II stars formed—the era when galaxies began to take shape, roughly .5 billion to 1.5 billion years after the creation event—astronomers can test the theory by determining the age of the oldest visible stars. By adding .5 to 1.5 billion years to that age, they can compare the sum with the creation dates suggested by other independent measures.

One difficulty of this seemingly simple test is that stars, like some people, sometimes hide their age well. Stars in dense clusters, however, can be more easily dated than others, and globular clusters appear to comprise the oldest of the Population II stars. Table 3 lists the most accurate dating of globular cluster stars in five different galaxies. It also includes the limit researchers recently placed on the oldest white dwarf stars in Earth's galaxy.

Table 2: Latest Measurements of the Oldest Population II Stars

Star Group Measured Ages (billions of years)
average of all globular clusters in our galaxy 12.9 ± 1.5[103]
47 Tucanae (oldest globular cluster in our galaxy) 14.1 ± 1.0[104]
Large Magellanic Cloud globulars same as for Milky Way[105]
globular cluster in WLM dwarf galaxy 14.8 ±0.06[106]
globular clusters in Fornax dwarf galaxy same as for Milky Way[107]
average of all globulars in our galaxy less than 14.0[108]
oldest white dwarfs in our galaxy more than 12.6[109]
average of all globular clusters in M87 (a supergiant galaxy) 13.0[110]

* average of all results = 13.5 billion years

The numbers indicate that globular clusters formed within a two- to three-billion-year time window, roughly consistent from galaxy to galaxy.[111] If one adds to their ages the years prior to Population II star formation (1 billion ± 0.5 billion years), the derived age fits remarkably well all other methods for determining how long the universe has been expanding from the creation event.

Stability of stars and orbits fits big bang picture

Stable orbits and stable stars are possible *only* in a big bang universe. Their existence ranks among the most clear-cut proofs for the big bang. (Incidentally, life would be impossible unless planets orbit with stability, stars burn with stability, and stars orbit galaxy cores with stability.[112, 113])

Such stability demands gravity, not just any force of gravity, but gravity operating according to the inverse square law. Gravity operating at that level demands three dimensions of space—the big bang universe.

In two dimensions of space, gravity would obey a different law (objects with mass would attract one another in proportion to the inverse of the distance separating them). In four space dimensions, gravity would obey a different law (massive bodies would attract one another in proportion to the inverse of the cube of the distance separating them).

Stability under the influence of gravity in turn demands that the three space dimensions be large (significantly unwound from their original tight curl). Otherwise galaxies would be so close together as to wreak havoc on stellar orbits, and stars would be so close together as to wreak havoc on planets' orbits. When galaxies are too close together, galaxy collisions and close encounters catastrophically disturb stars' orbits. Likewise, when stars are too close together, their mutual gravitational tugs catastrophically disturb the orbits of their planets.

The three dimensions of space must be expanding at a particular rate, as well. A universe that expands too slowly will produce only neutron stars and black holes. A universe that expands too rapidly will produce no stars at all and thus no planets and, of course, no stable orbits.

The simple fact is this: humans do observe that galaxies, stars, and planets exist, and that they exist with adequate stability to allow humans to exist and observe them. This fact, in itself, argues for the big bang, In fact, it argues for a specific subset of big bang models. Even this narrowing and refining of the original theory serves as evidence that the theory is correct.

Apologetics Impact of Big Bang Cosmology

Though the case for the big bang, or "creation event," rests on compelling evidence, the theory still has its critics. Some skepticism may be attributable to the communication gap between scientists and the rest of the world. Some of the evidences are so new that most people have yet to hear of them. Some of the evidences, including the older ones, are so technical that few people understand their significance. The need for better education and clearer communication remains. In fact, it motivates the publication of this article.

However, communication and education gaps explain only some of the skepticism. Spiritual issues are also involved. The few astronomers who still oppose the big bang openly object not on scientific grounds but on personal grounds.

The Fingerprint of God tells the story of astronomers' early reaction to findings that affirmed a cosmic beginning, hence Beginner. Some openly stated their view of the big bang as "philosophically repugnant." For decades they invented one cosmic hypothesis after another in a futile attempt to get around the glaring facts. When all their hypotheses failed the observational tests, many of those astronomers conceded, perhaps reluctantly, the big bang's veracity.

Today, only a handful of astronomers still hold out against the big bang. Their resistence, seems based not on what observations and experiments can test but rather on that which observations and experiments cannot test. Though their articles appear in science journals, they engage in metaphysics rather than in physics, in ideology rather than in science. The supporting evidences clearly point to something more than the "superior reasoning power" Einstein acknowledged or some ill-defined "intelligent Designer." The physical evidence points clearly and consistently to the personal, purposeful God of the Bible.

General relativity theory, which gave rise to the big bang, stipulates that the universe had a beginning, more specifically, a "transcendent" beginning. The space-time theorems of general relativity state that matter, energy, and all the space-time dimensions associated with the universe began in finite time and that the Causal Agent of the universe brings all the matter, energy, and space-time dimensions of the universe into existence from a reality beyond matter, energy, space, and time. An even more powerful theorem developed by Arvind Borde, Alexander Vilenkin, and Alan Guth demonstrates that any universe that expands, on average, throughout its history must possess a space-time beginning attributable to a Causal Agent beyond space and time.[114]

The extreme fine-tuning of big bang parameters essential for life in the universe exceeds by many orders of magnitude the design capabilities of human beings. Further, this fine-tuning is not limited to the universe as a whole, as Stephen Hawking and Leonard Mlodinow claim in their recent best-selling book, The Grand Design. Rather, it is observed on all scales within the universe—including that of our supercluster of galaxies (The Virgo Supercluster), our local galaxy cluster (the Local Group), our galaxy, our solar system, our moon, our planet, our planet's surface—as well as in our planet's life history. Therefore, to say that God is an impersonal entity, as Hawking and others assert, is illogical. Everywhere we look, on all size and complexity scales, we see what physicist Paul Davies sees: "[T]he impression of design is overwhelming."[115] In the words of another renowned physicist, Freeman Dyson, "The more I examine the universe...the more evidence I find that the universe in some sense must have known we were coming."[116]

The significance of these observations and conclusions cannot be avoided. For the universe on all size scales to manifest exquisite design for the specific benefit of human life demands not just any transcendent Causal Agent, but one who possesses immeasurably great power, intellect, and love. No philosophical system or religious teaching in the world, other than the Bible, points to such a Creator. No other system or teaching anticipated by several thousand years all four of the fundamental features of big bang cosmology.

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