Chapter 2: The Big Bang Myth

In 1905, Albert Einstein published papers that resolved long-standing problems in three distinct fields of physical study: materials science (the work function), thermodynamics (Brownian motion), and electrodynamics (the Special Theory of Relativity). These three papers radically affected scientists' view of the nature of reality, and built a bridge between the very large and very small objects of their study.

In 2005, during the centennial of Einstein's "anno mirabilis" (miracle year), Lawrence Livermore National Laboratory hosted a series of presentations that surveyed the current state of physics, and peered forward for clues as to where the next set of revolutionary ideas might lead us.

In the intervening 100 years, Einstein himself had created the reigning theory of cosmology (the theory of the universe), General Relativity, which relates the structure of space and time to the distribution of matter. Through the insights of Planck, Rutherford and others, Quantum Mechanics – the physics of the infinitesimally small – had been fertilized, and then developed. As the theories evolved and became established, others, such as Dirac and Feynman, worked towards their integration, producing Quantum Field Theory.

Belying the obscure terminology and historically marginal personalities (the exception being Einstein himself), these developments exploded from the laboratories and into our lives. The atomic and hydrogen bombs forever altered the calculations of warfare, shifting the focus of geopolitical competition from combat to economics. Quantum Theory led to advancements in our understanding of solids, stimulating the development of the digital microprocessor. That technology has radically improved our lives, increasing productivity and supporting automated information processing that catalyzed the growth of the service sector to dominance in modern economies. These are only the most prominent among a myriad of improvements derived from the achievements of the theorists working at the beginning of the 20th century.

As might have been expected, the presenters at LLNL's series spoke with confidence about the future. Work done in the period since 1990 appears to have brought within their grasp the crowning ambition of physics: a unified theory of everything. A means for joining the equations of General Relativity and Quantum Mechanics was being methodically elaborated. Starting as the Grand Unified Theory, progress was blocked until physicists decided to reconsider the very nature of particles themselves. The resulting construct, String Theory, appeared to resolve the difficulties that had frustrated Einstein in the final years of his life.

The laboratory used to test these theories is the universe itself. By scanning the cosmos for unusual structures and monitoring the behavior of dying stars, physicists rely upon the hugeness of the universe to produce those very rare events that relate the incomprehensibly small to the mind-bogglingly large. Many of the talks described the challenges of designing, constructing, deploying and operating astonishingly expensive "needle in the haystack" detectors.

Amidst all this celebration, two discordant notes were struck. The first was a talk by Les Rosenbaum that noted how the march of physics is progressing as a Moore's law of *human irrelevancy*. In modern physics, more and more rapidly we seem to matter less and less. While the observation was somewhat tongue-in-cheek, this progression has an inevitable cultural impact. If we serve no significant purpose in the grand scheme of things, what meaning can life hold beyond personal gratification - whether through hedonism, the inevitably manipulative search for glory, or some combination of the two?

The second was a talk by the National Science Foundation's Assistant Director for Physics Research. The talk was a call to radicalism. The reigning theory was struggling to explain recent observations. The difficulties were disturbing enough that he asked the audience to bring forth "crazy ideas".

How the Big Bang Started

Einstein completed his work on the General Theory of Relativity in the period between the two World Wars. One of the predictions of the theory was that light was affected by gravity. A relatively easy way to test this prediction was to measure the angle formed by light coming from two stars: First when they were in an unoccupied part of the sky, and then when there was a massive object between them. If the angles were different, Einstein's theory would be upheld. Unfortunately, the sun is the only object in our skies sufficient to cause a measurable change in the angle. This meant that the second observation had to be made during a total eclipse of the sun.

The public imagination was captured when an international team of scientists, representing many of the nations in conflict during World War I, set sail into the South Pacific to make the necessary measurements. Their confirmation of the theory created a great reverence for Einstein's genius.

With this popular success under its belt, scientists began to look for other means of testing Einstein's General Theory. An obscure aspect of the theory concerned the affect of invisible energy on the evolution of the universe. The "cosmological constant", which Einstein latter lamented as a theoretical superfluity, would cause space to appear to shrink or grow over time due to the pressure it created. This was of great interest, as the assumption from ancient times was that the stars were fixed with respect to each other. (In fact, it was to explain this assumption that the constant was introduced to the theory.)

The task of testing these predictions was taken up by the astronomers. It turns out that certain types of stars can be recognized by the mix of colors they emit. The power of these "standard candles" does not vary much, so by measuring their brightness at the Earth astronomers can estimate how far away they are.

Edwin Hubble conducted one of the most extensive early studies of this type, measuring the spectra and brightness of standard candles outside of our galaxy. The measurements produced an astonishing discovery: in every direction the astronomers looked, the incoming light appeared to have "lost" energy on the way to the Earth.

Now, in Einstein's theory, there are only two ways such a "loss" can occur. When light is moving away from a large mass, it loses energy as it climbs against gravity into open space (in the same way as a thrown ball loses energy before falling back to Earth). However, this should affect all stars equally, whether near or far.

Alternatively, stars moving rapidly away from the Earth trail light behind them, causing a shift to lower frequencies similar to the shift that is heard in the pitch of a car's horn when it passes us. Lower frequencies of light have lower energy. By implication, it appeared that all the galaxies in the universe are moving away from ours!

Now a theologian might interpret this as a response to human iniquity (i.e. – the rest of the universe saying, "There goes the neighborhood!"). Hubble, following Einstein and Lemaitre, took a more prosaic view: during an explosion, every particle appears to be moving away from its nearest neighbors. This is because faster particles race to the outside of the expanding mass, trailed by the next fastest, which are in turn faster than those behind them. Standing on an outwardly moving particle, neighboring particles always seem to be getting farther away.

Carrying the analogy to its logical initiation, that mass of the universe was once concentrated in a single place, before being flung outwards in an enormous explosion.

The reason Einstein disliked the Cosmological Constant, however, was because if it existed, it must have a cause. The properties of that cause would be of singular importance to physics, and would probably *cause the constant to change over time*. A constant that changes over time? This oxymoron carries over into further areas of the theory: if there is something filling the empty space between galaxies, might it not steal energy from light as it passes?

The Universe Chills Out

When we set off an explosion on earth, gravity always drags the projectiles back to the ground. To the astronomers, this led to an obvious question: was the original explosion powerful enough that the galaxies would continue to move apart forever, or would they eventually turn around and fall back to the center?

The astronomers realized that the best way to answer this question was to measure how fast the expansion of the universe was slowing down. An accurate determination required the development of new measurement techniques, and advances in our understanding of stars. This work revealed stronger kinds of standard candles that could be used to extend their studies to greater and greater distances. Since light arriving from distant sources takes a long time to get to the Earth, those studies also peered back into the early history of the universe.

The conclusion was astonishing. It appeared that the mass involved in the initial explosion was exactly enough to cause the expansion of the universe to coast to a stop.

Physicists hate serendipity. They don't respect a resort to a mystical hand. The fundamental laws had to contain an explanation for these results.

A possible answer came when particle physicists, led by Alan Guth, began to ponder the conditions that would have existed at the heart of the exploding mass. Obviously, the mass must have been influenced by extremely powerful repulsive forces. In particle physics, those forces could only be created by very intense fields, which generally dissipate by producing matter. Simultaneously (in one way of describing it) the reduction of the tension in the fields (including light) caused them to slow down. You can think of this as analogous to the way a violin string vibrates more slowly when it is loosened. Because it then took longer for light to travel from one place to another, this slowing caused the matter contained in the cooling bubble to *appear* further apart.

The astonishing conclusion of this analysis was that, if the Big Bang had occurred, the slowing of light occurred so dramatically that our universe **is right now** contained in a cool bubble about which the original explosion is still raging. So, whether the explosion occurred or not is actually a moot point: as long as the superheated conditions existed, universes would be formed in an "Expansive Cool".

While this sounds like a hellishly uncomfortable situation, it does satisfy the scientists' desire for theoretical closure. They were left with a single hypothesis (the Universe Was Started from a Superheated Something), which, when elaborated by the known laws of physics, explained all of the available observations of the history of the universe.

Except…except…. if matter comes from the fields, and the fields fill space uniformly, shouldn't stars fill the entire universe? Put the other way around, how did galaxies form? It turns out they can't unless there's some other mechanism that causes clumps in the structure of space. Worse, we actually observe that galaxies aren't uniformly distributed. They gather in clusters, and those clusters seem to be bunched on the surface of extremely large voids. This kind of distribution is even more difficult to explain.

And this is where the trouble arose that caused the NSF representative to call for "crazy" ideas. Despite a decade of trying, theorists had been unable to define a theory of particles and fields that could produce galaxies and their observed distribution. And as they have looked harder, things just keep getting worse.

Rather than pursuing those issues now, let's look back to the characteristics of myth. Myth is likely to arise when students of nature possess theory insufficient to explain their observations (Type I Myth). Nobody ever saw the Big Bang (or, if they had, they couldn't have survived to tell the story). Nobody has ever stood next to a distant galaxy and measured the speed of its stars. Finally, the theoretical interpretation of Hubble's observations was prejudiced by temporary cultural fascination with Einstein's theoretical work (Type III Myth), which led scientists to overlook other possible explanations.

So, given these uncertainties, what the *bleep* do we know anyways?