**COMET BAY COLLEGE**

**Physics - Unit 3 & 4 - Task 11**

**Research Topic Validation**

**Name: Total Marks /24**

You are to write a report (introduction, body and conclusion) including the following information. The report is 30 minutes. These are the five articles, of which at least two (2) you were to include in your initial report that has already been handed in. For of these articles are included below.

* What Is the Big Bang Theory? (http://www.space.com/25126-big-bang-theory.html)
* Cosmic Microwave Background: Big Bang Relic Explained (Infographic) (http://www.space.com/20330-cosmic-microwave-background-explained-infographic.html)
* What Came Before the Big Bang? (http://discovermagazine.com/2013/september/13-starting-point)
* The "Big Bang" is just Religion disguised as Science (http://www.whatreallyhappened.com/WRHARTICLES/bang.php)
* Big Bang Theory: Evolution of Our Universe (http://www.universetoday.com/54756/what-is-the-big-bang-theory/)

**Question 1**

What was your research on the big bang theory specifically about;

1. include detail of information (3 marks)
2. specific direction research report was about. (3 marks)
3. detailed scientific language (3 marks)
4. relevance to the big bang theory (3 marks)

**Question 2**

Use three references to prove your discussion was supported.

1. detailed information from your report that was referenced (3 marks)
2. three references. (3 marks)
3. each reference supported your discussion. (6 marks)

Universetoday.com (http://www.universetoday.com/54756/what-is-the-big-bang-theory/)

**Big Bang Theory: Evolution of Our Universe**

*By Matt Williams | December 18, 2015*

How was our Universe created? How did it come to be the seemingly infinite place we know of today? And what will become of it, ages from now? These are the questions that have been puzzling philosophers and scholars since the beginning the time, and led to some pretty wild and interesting theories. Today, the consensus among scientists, astronomers and cosmologists is that the Universe as we know it was created in a massive explosion that not only created the majority of matter, but the physical laws that govern our ever-expanding cosmos. This is known as The Big Bang Theory.

For almost a century, the term has been bandied about by scholars and non-scholars alike. This should come as no surprise, seeing as how it is the most accepted theory of our origins. But what exactly does it mean? How was our Universe conceived in a massive explosion, what proof is there of this, and what does the theory say about the long-term projections for our Universe?

The basics of the Big Bang theory are fairly simple. In short, the Big Bang hypothesis states that all of the current and past matter in the Universe came into existence at the same time, roughly 13.8 billion years ago. At this time, all matter was compacted into a very small ball with infinite density and intense heat called a Singularity. Suddenly, the Singularity began expanding, and the universe as we know it began.

While this is not the only modern theory of how the Universe came into being – for example, there is the Steady State Theory or the Oscillating Universe Theory – it is the most widely accepted and popular. Not only does the model explain the origin of all known matter, the laws of physics, and the large scale structure of the Universe, it also accounts for the expansion of the Universe and a broad range of other phenomena.

**Timeline of the Big Bang Theory**

Working backwards from the current state of the Universe, scientists have theorized that it must have originated at a single point of infinite density and finite time that began to expand. After the initial expansion, the theory maintains that Universe cooled sufficiently to allow the formation of subatomic particles, and later simple atoms. Giant clouds of these primordial elements later coalesced through gravity to form stars and galaxies.

This all began roughly 13.8 billion years ago, and is thus considered to be the age of the universe. Through the testing of theoretical principles, experiments involving particle accelerators and high-energy states, and astronomical studies that have observed the deep universe, scientists have constructed a timeline of events that began with the Big Bang and has led to the current state of cosmic evolution.

However, the earliest times of the Universe – lasting from approximately 10-43 to 10-11 seconds after the Big Bang –  are the subject of extensive speculation. Given that the laws of physics as we know them could not have existed at this time, it is difficult to fathom how the Universe could have been governed. What’s more, experiments that can create the kinds of energies involved have not yet been conducted. Still, many theories prevail as to what took place in this initial instant in time, many of which are compatible.

**Singularity Epoch**

Also known as the Planck Epoch (or Planck Era), this was the earliest known period of the Universe. At this time, all matter was condensed on a single point of infinite density and extreme heat. During this period, it is believed that the quantum effects of gravity dominated physical interactions and that no other physical forces were of equal strength to gravitation.

This Planck period of time extends from point 0 to approximately 10-43 seconds, and is so named because it can only be measured in Planck time. Due to the extreme heat and density of matter, the state of the universe was highly unstable. It thus began to expand and cool, leading to the manifestation of the fundamental forces of physics.

From approximately 10-43 second and 10-36, the universe began to cross transition temperatures. It is here that the fundamental forces that govern the Universe are believed to have began separating from each other. The first step in this was the force of gravitation separating from gauge forces, which account for strong and weak nuclear forces and electromagnetism.

Then, from 10-36 to 10-32 seconds after the Big Bang, the temperature of the universe was low enough (1028 K) that the forces of electromagnetism (strong force) and weak nuclear forces (weak interaction) were able to separate as well, forming two distinct forces.

**Inflation Epoch**

With the creation of the first fundamental forces of the universe, the Inflation Epoch began, lasting from 10-32 seconds in Planck time to an unknown point. Most cosmological models suggest that the Universe at this point was filled homogeneously with a high-energy density, and that the incredibly high temperatures and pressure gave rise to rapid expansion and cooling.

This began at 10-37 seconds, where the phase transition that caused for the separation of forces also led to a period where the universe grew exponentially. It was also at this point in time that baryogenesis occurred, which refers to a hypothetical event where temperatures were so high that the random motions of particles occurred at relativistic speeds.

As a result of this, particle–antiparticle pairs of all kinds were being continuously created and destroyed in collisions, which is believed to have led to the predominance of matter over antimatter in the present universe. After inflation stopped, the universe consisted of a quark–gluon plasma, as well as all other elementary particles. From this point onward, the Universe began to cool and matter coalesced and formed.

**Cooling Epoch**

As the universe continued to decrease in density and temperature, the energy of each particle began to decrease and phase transitions continued until the fundamental forces of physics and elementary particles changed into their present form. Since particle energies would have dropped to values that can be obtained by particle physics experiments, this period onward is subject to less speculation.

For example, scientists believe that about 10-11 seconds after the Big Bang, particle energies dropped considerably. At about 10-6 seconds, quarks and gluons combined to form baryons such as protons and neutrons, and a small excess of quarks over antiquarks led to a small excess of baryons over antibaryons.

Since temperatures were not high enough to create new proton-antiproton pairs (or neutron-anitneutron pairs), mass annihilation immediately followed, leaving just one in 1010 of the original protons and neutrons and none of their antiparticles. A similar process happened at about 1 second after the Big Bang for electrons and positrons. After these annihilations, the remaining protons, neutrons and electrons were no longer moving relativistically and the energy density of the universe was dominated by photons – and to a lesser extent, neutrinos.

A few minutes into the expansion, the period known as Big Bang nucleosynthesis also began. Thanks to temperatures dropping to 1 billion kelvin and the energy densities dropping to about the equivalent of air, neutrons and protons began to combine to form the universe’s first deuterium (a stable isotope of Hydrogen) and helium atoms. However, most of the Universe’s protons remained uncombined as hydrogen nuclei.

After about 379,000 years, electrons combined with these nuclei to form atoms (again, mostly hydrogen), while the radiation decoupled from matter and continued to expand through space, largely unimpeded. This radiation is now known to be what constitutes the Cosmic Microwave Background (CMB), which today is the oldest light in the Universe.

As the CMB expanded, it gradually lost density and energy, and is currently estimated to have a temperature of 2.7260 ± 0.0013 K (-270.424 °C/ -454.763 °F ) and an energy density of 0.25 eV/cm3 (or 4.005×10-14 J/m3; 400–500 photons/cm3). The CMB can be seen in all directions at a distance of roughly 13.8 billion light years, but estimates of its actual distance place it at about 46 billion light years from the center of the Universe.

**Structure Epoch**

Over the course of the several billion years that followed, the slightly denser regions of the almost uniformly distributed matter of the Universe began to become gravitationally attracted to each other. They therefore grew even denser, forming gas clouds, stars, galaxies, and the other astronomical structures that we regularly observe today.

This is what is known as the Structure Epoch, since it was during this time that the modern Universe began to take shape. This consists of visible matter distributed in structures of various sizes, ranging from stars and planets to galaxies, galaxy clusters, and super clusters – where matter is concentrated – that are separated by enormous gulfs containing few galaxies.

The details of this process depend on the amount and type of matter in the universe, with cold dark matter, warm dark matter, hot dark matter, and baryonic matter being the four suggested types. However, the Lambda-Cold Dark Matter model (Lambda-CDM), in which the dark matter particles moved slowly compared to the speed of light, is the considered to be the standard model of Big Bang cosmology, as it best fits the available data.

In this model, cold dark matter is estimated to make up about 23% of the matter/energy of the universe, while baryonic matter makes up about 4.6%. The Lambda refers to the Cosmological Constant, a theory originally proposed by Albert Einstein that attempted to show that the balance of mass-energy in the universe was static. In this case, it is associated with Dark Energy, which served to accelerate the expansion of the universe and keep its large-scale structure largely uniform.

**Long-term Predictions for the Future of the Universe**

Hypothesizing that the Universe had a starting point naturally gives rise to questions about a possible end point. If the Universe began as a tiny point of infinite density that started to expand, does that mean it will continue to expand indefinitely? Or will it one day run out of expansive force, and begin retreating inward until all matter crunches back into a tiny ball?

Answering this question has been a major focus of cosmologists ever since the debate about which model of the Universe was the correct one began. With the acceptance of the Big Bang Theory, but prior to the observation of Dark Energy in the 1990s, cosmologists had come to agree on two scenarios as being the most likely outcomes for our Universe.

In the first, commonly known as the “Big Crunch” scenario, the universe will reach a maximum size and then begin to collapse in on itself. This will only be possible if the mass density of the Universe is greater than the critical density. In other words, as long as the density of matter remains at or above a certain value (1-3 ×10-26 kg of matter per m³), the Universe will eventually contract.

Alternatively, if the density in the universe were equal to or below the critical density, the expansion would slow down but never stop. In this scenario, known as the “Big Freeze”, the Universe would go on until star formation eventually ceased with the consumption of all the interstellar gas in each galaxy. Meanwhile, all existing stars would burn out and become white dwarfs, neutron stars, and black holes.

Very gradually, collisions between these black holes would result in mass accumulating into larger and larger black holes. The average temperature of the universe would approach absolute zero, and black holes would evaporate after emitting the last of their Hawking radiation. Finally, the entropy of the universe would increase to the point where no organized form of energy could be extracted from it (a scenarios known as “heat death”).

Modern observations, which include the existence of Dark Energy and its influence on cosmic expansion, have led to the conclusion that more and more of the currently visible universe will pass beyond our event horizon (i.e. the CMB, the edge of what we can see) and become invisible to us. The eventual result of this is not currently known, but “heat death” is considered a likely end point in this scenario too.

Other explanations of dark energy, called phantom energy theories, suggest that ultimately galaxy clusters, stars, planets, atoms, nuclei, and matter itself will be torn apart by the ever-increasing expansion. This scenario is known as the “Big Rip”, in which the expansion of the Universe itself will eventually be its undoing.

**History of the Big Bang Theory**

The earliest indications of the Big Bang occurred as a result of deep-space observations conducted in the early 20th century. In 1912, American astronomer Vesto Slipher conducted a series of observations of spiral galaxies (which were believed to be nebulae) and measured their Doppler Redshift. In almost all cases, the spiral galaxies were observed to be moving away from our own.

In 1922, Russian cosmologist Alexander Friedmann developed what are known as the Friedmann equations, which were derived from Einstein’s equations for general relativity. Contrary to Einstein’s was advocating at the time with his a Cosmological Constant, Friedmann’s work showed that the universe was likely in a state of expansion.

In 1924, Edwin Hubble’s measurement of the great distance to the nearest spiral nebula showed that these systems were indeed other galaxies. At the same time, Hubble began developing a series of distance indicators using the 100-inch (2.5 m) Hooker telescope at Mount Wilson Observatory. And by 1929, Hubble discovered a correlation between distance and recession velocity – which is now known as Hubble’s law.

And then in 1927, Georges Lemaitre, a Belgian physicist and Roman Catholic priest, independently derived the same results as Friedmann’s equations and proposed that the inferred recession of the galaxies was due to the expansion of the universe. In 1931, he took this further, suggesting that the current expansion of the Universe meant that the father back in time one went, the smaller the Universe would be. At some point in the past, he argued, the entire mass of the universe would have been concentrated into a single point from which the very fabric of space and time originated.

These discoveries triggered a debate between physicists throughout the 1920s and 30s, with the majority advocating that the universe was in a steady state. In this model, new matter is continuously created as the universe expands, thus preserving the uniformity and density of matter over time. Among these scientists, the idea of a Big Bang seemed more theological than scientific, and accusations of bias were made against Lemaitre based on his religious background.

Other theories were advocated during this time as well, such as the Milne Model and the Oscillary Universe model. Both of these theories were based on Einstein’s theory of general relativity (the latter being endorsed by Einstein himself), and held that the universe follows infinite, or indefinite, self-sustaining cycles.

After World War II, the debate came to a head between proponents of the Steady State Model (which had come to be formalized by astronomer Fred Hoyle) and proponents of the Big Bang Theory – which was growing in popularity. Ironically, it was Hoyle who coined the phrase “Big Bang” during a BBC Radio broadcast in March 1949, which was believed by some to be a pejorative dismissal (which Hoyle denied).

Eventually, the observational evidence began to favor Big Bang over Steady State. The discovery and confirmation of the cosmic microwave background radiation in 1965 secured the Big Bang as the best theory of the origin and evolution of the universe. From the late 60s to the 1990s, astronomers and cosmologist made an even better case for the Big Bang by resolving theoretical problems it raised.

These included papers submitted by Stephen Hawking and other physicists that showed that singularities were an inevitable initial condition of general relativity and a Big Bang model of cosmology. In 1981, physicist Alan Guth theorized of a period of rapid cosmic expansion (aka. the “Inflation” Epoch) that resolved other theoretical problems.

The 1990s also saw the rise of Dark Energy as an attempt to resolve outstanding issues in cosmology. In addition to providing an explanation as to the universe’s missing mass (along with Dark Matter, originally proposed in 1932 by Jan Oort), it also provided an explanation as to why the universe is still accelerating, as well as offering a resolution to Einstein’s Cosmological Constant.

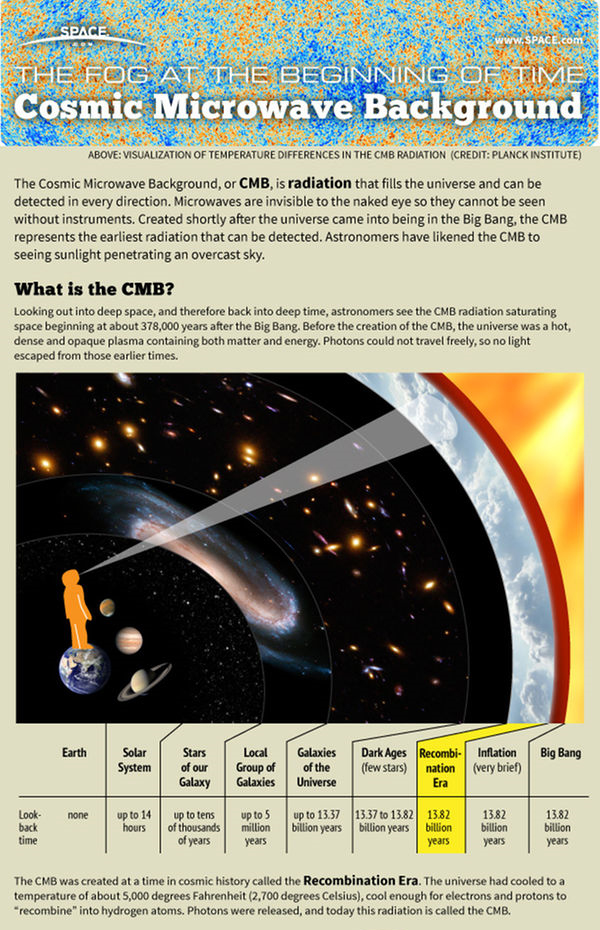
Significant progress was made thanks to advances in telescopes, satellites, and computer simulations, which have allowed astronomers and cosmologists to see more of the universe and gain a better understanding of its true age. The introduction of space telescopes – such as the Cosmic Background Explorer (COBE), the Hubble Space Telescope, Wilkinson Microwave Anisotropy Probe (WMAP) and the Planck Observatory – have also been of immeasurable value.

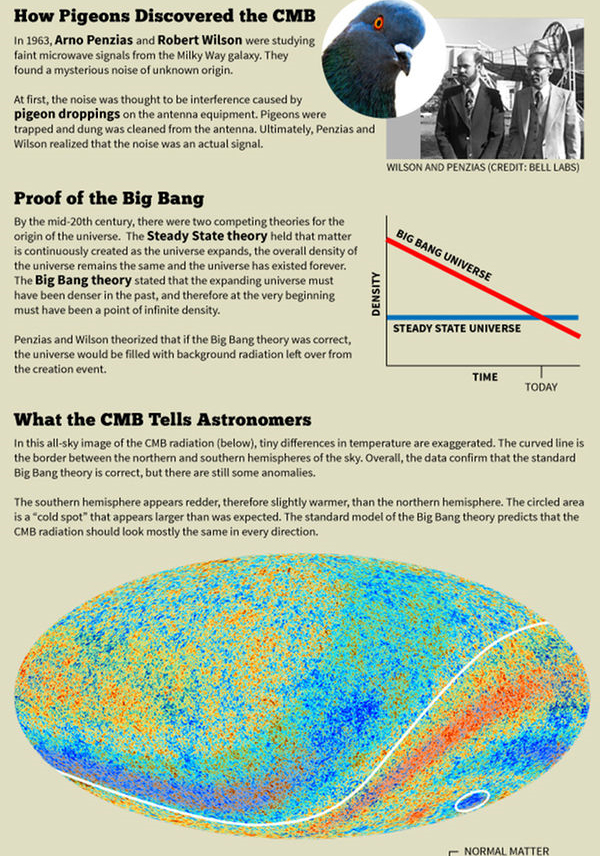
Today, cosmologists have fairly precise and accurate measurements of many of the parameters of the Big Bang Theory model, not to mention the age of the Universe itself. And it all began with the noted observation that massive stellar objects, many light years distant, were slowly moving away from us. And while we still are not sure how it will all end, we do know that on a cosmological scale, that won’t be for a long, LONG time!

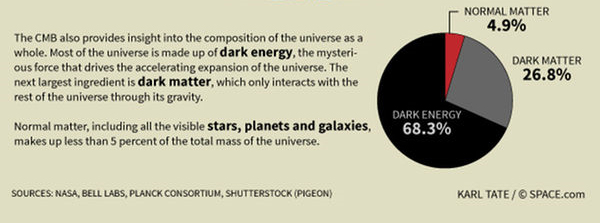
Space.com (http://www.space.com/20330-cosmic-microwave-background-explained-infographic.html)

**Cosmic Microwave Background: Big Bang Relic Explained (Infographic)**

By Karl Tate, SPACE.com Infographics Artist | April 3, 2013 07:33am ET







The CMB radiation tells us the age and composition of the universe and raises new questions that must be answered.

*Credit: Karl Tate, SPACE.com Infographics Artist*

The Cosmic Microwave Background, or CMB, is radiation that fills the universe and can be detected in every direction. Microwaves are invisible to the naked eye so they cannot be seen without instruments. Created shortly after the universe came into being in the Big Bang, the CMB represents the earliest radiation that can be detected. Astronomers have likened the CMB to seeing sunlight penetrating an overcast sky.

Looking out into deep space, and therefore back into deep time, astronomers see the CMB radiation saturating space beginning at about 378,000 years after the Big Bang. Before the creation of the CMB, the universe was a hot, dense and opaque plasma containing both matter and energy. Photons could not travel freely, so no light escaped from those earlier times.

The CMB was created at a time in cosmic history called the Recombination Era. The universe had cooled to a temperature of about 5,000 degrees Fahrenheit (2,700 degrees Celsius), cool enough for electrons and protons to “recombine” into hydrogen atoms. Photons were released, and today this radiation is called the CMB.

In 1963, Arno Penzias and Robert Wilson were studying faint microwave signals from the Milky Way galaxy. They found a mysterious noise of unknown origin.

At first the noise was thought to be interference caused by pigeon droppings on the antenna equipment. Pigeons were trapped and dung was cleaned from the antenna. Ultimately Penzias and Wilson realized that the noise was an actual signal.

By the mid-20th century, there were two competing theories for the origin of the universe.  The Steady State theory held that matter is continuously created as the universe expands, the overall density of the universe remains the same, and the universe has existed forever. The Big Bang theory stated that the expanding universe must have been denser in the past, and therefore at the very beginning must have been a point of infinite density.

Penzias and Wilson theorized that if the Big Bang theory was correct, the universe would be filled with background radiation left over from the creation event.

In an all-sky image of the CMB radiation, the southern hemisphere appears redder, therefore slightly warmer, than the northern hemisphere A "cold spot" in the southern hemisphere appears larger than was expected. The standard model of the Big Bang theory predicts that the CMB radiation should look mostly the same in every direction.

The CMB also provides insight into the composition of the universe as a whole. Most of the universe is made up of dark energy, the mysterious force that drives the accelerating expansion of the universe. The next largest ingredient is dark matter, which only interacts with the rest of the universe through its gravity.

Normal matter, including all the visible stars, planets and galaxies, makes up less than 5 percent of the total mass of the universe.

Discover.com (http://discovermagazine.com/2013/september/13-starting-point)

**What Came Before the Big Bang?**

Cosmologist Alexander Vilenkin believes the Big Bang wasn't a one-off event, but merely one of a series of big bangs creating an endless number of bubble universes.

By [Steve Nadis](http://discovermagazine.com/authors/steve-nadis) Thursday, October 10, 2013

It is cosmology’s most fundamental question: How did the universe begin?

The question presupposes that the universe had an actual starting point, but one might just as well assume the universe always was and always will be. In that case, there would be no beginning whatsoever — just an ever-evolving story of which we’re catching a mere glimpse.

“We have very good evidence that there was a Big Bang, so the universe as we know it almost certainly started some 14 billion years ago. But was that the absolute beginning, or was there something before it?” asks Alexander Vilenkin, a cosmologist at Tufts University near Boston. It seems like the kind of question that can never be truly answered because every time someone proposes a solution, someone else can keep asking the annoying question: What happened before *that*?

But now Vilenkin says he has convincing evidence in hand: The universe had a distinct beginning — though he can’t pinpoint the time. After 35 years of looking backward, he says, he’s found that before our universe there was nothing, nothing at all, not even time itself.

Throughout his career, including the 20-plus years he has directed the Tufts Institute of Cosmology, Vilenkin has issued a series of wild, dazzling ideas, though from the outside he looks neither wild nor dazzling. The 64-year-old professor is soft-spoken, trim and of modest build. He dresses neatly, in neutral, understated tones that don’t draw attention to him.

Despite a low-key manner bordering on subdued, Vilenkin is a creative force who has continually found ways of piercing the fog surrounding some of the densest quandaries imaginable — triumphs that have earned him the respect of scholars worldwide. “Alex is a very original and deep thinker who has made important and profound contributions to our notions about the creation of the universe,” says Stanford cosmologist Andrei Linde.

Yet this brilliant career might never have happened. Born in the Soviet Union in 1949 and raised in the Ukrainian city of Kharkiv, Vilenkin got hooked on cosmology in high school, after reading about the Big Bang in a book by Sir Arthur Eddington. That “obsession” over the universe’s origins, Vilenkin says, “has never left me. I felt that if you could work on this question, which may be the most intriguing one of all, why would you choose to work on anything else?”

As an undergraduate at Kharkiv National University, Vilenkin says he was advised to “do some real physics” rather than pursue his first love, cosmology. Although he was an excellent student, he could not get into any graduate programs in physics because, he suspects, the KGB blacklisted him for refusing to become a government informant. Instead, Vilenkin was forced to take a series of mundane jobs. For a while he taught night school for adults but left that position because his responsibilities included going to the homes of absentees, many of whom were alcoholics, to try and drag them to school — an unenviable task.

He was a night watchman for about a year and a half, including a stint at the Kharkiv Zoo. To protect the animals (which were sometimes hunted for food), he was given a rifle that he didn’t know how to use and fortunately never had to fire. When he had time during those long nights, Vilenkin studied physics, an avocation that included reading the four-volume collected works of Albert Einstein. He got fired from this plum assignment when someone decided — perhaps based on his choice of reading material — that he was overqualified for the task at hand.

With his employment prospects looking bleak, he decided to emigrate to the United States; he figured he’d start out washing dishes while trying to break into academia. But getting out of the Soviet Union required an elaborate plan: Jews like him were allowed to go to Israel in small numbers, determined by a quota, but one had to secure an invitation from Israeli relatives first. Vilenkin had no actual relatives there, so he contacted a friend who knew people in Israel and eventually found someone — a stranger to him — kind enough to write a letter on his behalf.

After the letter arrived, he waited a year for a visa, but it came at great cost. Before Vilenkin and his wife could leave, their parents had to consent to the move. For giving their permission, his wife’s parents lost their laboratory jobs. His father, a university professor, later lost his job, too. The traditional stop en route to Israel was Vienna, but from there Vilenkin, his wife and 1-year-old daughter went to Rome instead, arriving in 1976. They met with the U.S. Consulate in Rome and, after a three-month wait, were finally granted a visa to the U.S.

**Back to the Big Bang**

In fall 1977, Vilenkin took a postdoctoral position at Case Western Reserve, where he was supposed to study the electrical properties of heated metals. Still, he found time on the side to theorize about spinning black holes and their mysterious magnetic fields. A year later, he got his lucky break when Tufts offered him a one-year visiting position. He took a gamble by poring himself into cosmology, an area considered fringe at the time.

That would soon change. In late 1979, a Stanford physics postdoc named Alan Guth offered an explanation for the explosive force behind the Big Bang. Guth’s intellectual leap stemmed from theories in particle physics, which held that at extremely high energies — far higher than could ever be reached in a laboratory — a special state of matter would turn gravity upside down, rendering it a *repulsive* rather than an attractive force.

A patch of space containing a tiny bit of this unusual matter could repel itself so violently as to literally blow up. Guth suggested that a tremendous burst of this sort triggered the Big Bang, swiftly enlarging the universe so much it doubled in size at least 100 times. This exponential growth spurt — called cosmic inflation — was short-lived, however, lasting just a tiny fraction of a second because the repulsive material quickly decayed, leaving behind the more familiar forms of matter and energy that fill the universe today.

The idea simultaneously solved a number of puzzles in cosmology. It explained where the “bang” behind the Big Bang came from and how the cosmos got so big. Rapid inflation in every direction also explained why the universe we now observe is so homogeneous, and why the temperature of the background radiation left over from that primordial blast is uniform, in every patch of the sky, to one part in 100,000. Inflation also revitalized cosmology, giving theorists like Vilenkin plenty to think about — and a bit more respectability to boot.

**The Never-Ending Story**

By 1982, a couple of years after Guth’s breakthrough, Vilenkin had a realization of his own: The process of inflation had to be eternal, meaning that once it started, it never fully stopped. Inflation might end abruptly in one region of space, such as the one we inhabit, but it would continue elsewhere, setting off a never-ending series of big bangs. Each bang would correspond to the birth of a separate “pocket” universe, which might be pictured as an expanding bubble — one of countless bubbles floating around within the “multiverse,” as it’s sometimes called.

As Vilenkin saw it, inflation’s eternal nature stemmed from two competing properties of the cosmic fuel, the gravity-repulsive material that caused the universe to rapidly expand. On the one hand, the material was unstable, much like radioactive substances, and was thus doomed to decay. On the other hand, the material expanded far faster than it decayed, so even though decay might stop inflation in certain regions, runaway growth would continue in others.

As an analogy, Vilenkin suggests a blob of bacteria that wants to keep reproducing and growing, while bacteria-killing antibodies try to curtail that growth. If the bacteria reproduce much faster than they’re destroyed, they will swiftly multiply and spread even though their reproduction may be thwarted in some quarters. Either way you look at it, the net result is that inflation (or bacterial growth) never ends everywhere at once and is always going on in some portion of the multiverse — even as you read this magazine.

To gain a better sense of the phenomenon, Vilenkin teamed up in 1986 with a Tufts graduate student, Mukunda Aryal, on a computer simulation that showed what an eternally inflating universe might look like. In their simulation, inflating regions, or bubbles, started small and steadily grew, while the space between bubbles stretched out as well. Each bubble — representing a mini-universe like ours — was surrounded by smaller bubbles, which were themselves surrounded by even smaller bubble universes, in turn.

**Road to Eternity**

In Vilenkin’s bubbling universe, inflation was, by definition, eternal into the future. Once initiated, it would not stop. But was it also eternal into the past? Was there ever a time when the universe was *not* inflating? And if the universe were always inflating, and always expanding, would that imply that the universe itself was eternal and had no beginning?

To address this question, Vilenkin joined forces with Guth and Long Island University mathematician Arvind Borde. Using a mathematical proof, they argued that any expanding universe like ours had to have a beginning. The thought experiment they posed went like this: Imagine a universe filled with particles. As it steadily expands, the distance between particles grows. It follows that observers sprinkled throughout this expanding universe would be moving away from each other until, eventually, they occupied widely scattered regions of space. If you happened to be one of those observers, the farther an object was from you, the faster it would be moving away.

Now throw into the mix a space traveler moving through space at a fixed speed: He zooms past Earth at 100,000 kilometers per second. But when he reaches the next galaxy, which is moving away from us at, say, 20,000 kilometers per second, he will appear to be moving only 80,000 kilometers per second to observers there. As he continues on his outward journey, the space traveler’s speed will appear smaller and smaller to the observers he passes. Now we’ll run the movie backward. This time, the space traveler’s velocity will appear faster and faster at each successive galaxy.

If we assume inflation is eternal into the past — that it had no beginning — the space traveler will eventually reach and overtake the speed of light. A calculation by Borde, Guth and Vilenkin showed that this would happen in a finite amount of time. But according to the laws of relativity, it is impossible for any massive object to reach the speed of light, let alone exceed it. “This cannot happen,” says Vilenkin. “So when you follow this space traveler’s history back in time, you find that his history must come to an end.”

The fact that the traveler’s journey backward in time hits an impasse means that there’s a problem, from a logical standpoint, with the assumption of an ever-expanding universe upon which this whole scenario is based. The universe, in other words, could not always have been expanding. Its expansion must have had a beginning, and inflation — a particularly explosive form of cosmic expansion — must have had a beginning, too. By this logic, our universe also had a beginning since it was spawned by an inflationary process that is eternal into the future but not the past.

**Something From Nothing**

A universe with a beginning begs the vexing question: Just how did it begin? Vilenkin’s answer is by no means confirmed, and perhaps never can be, but it’s still the best solution he’s heard so far: Maybe our fantastic, glorious universe spontaneously arose from nothing at all. This heretical statement clashes with common sense, which admittedly fails us when talking about the birth of the universe, an event thought to occur at unfathomably high energies. It also flies in the face of the Roman philosopher Lucretius, who argued more than 2,000 years ago that “nothing can be created from nothing.”

Of course, Lucretius had never heard of quantum mechanics and inflationary cosmology, 20th-century fields that contest his bold claim. “We usually say that nothing can be created out of nothing because we think it would violate the law of conservation of energy,” a hallowed principle in physics holding that energy can neither be created nor destroyed, Vilenkin explains. So how could you create a universe with matter in it, where there had been nothing before?

“The way the universe gets around that problem is that gravitational energy is negative,” Vilenkin says. That’s a consequence of the fact, mathematically proven, that the energy of a closed universe is zero: The energy of matter is positive, the energy of gravitation is negative, and they always add up to zero. “Therefore, creating a closed universe out of nothing does not violate any conservation laws.”

Vilenkin’s calculations show that a universe created from nothing is likely to be tiny, indeed — far, far smaller than, say, a proton. Should this minute realm contain just a smattering of repulsive-gravity material, that’s enough to ensure it will ignite the unstoppable process of eternal inflation, leading to the universe we inhabit today. If the theory holds, we owe our existence to the humblest of origins: nothing itself.

One virtue of this picture, if correct, is that the spontaneous creation of our universe gives a definite starting point to things. Time begins at the moment of creation, putting to rest the potentially endless questions about “what happened before that.”

Yet the explanation still leaves a huge mystery unaddressed. Although a universe, in Vilenkin’s scheme, can come from nothing in the sense of there being no space, time or matter, something is in place beforehand — namely the laws of physics. Those laws govern the something-from-nothing moment of creation that gives rise to our universe, and they also govern eternal inflation, which takes over in the first nanosecond of time.

That raises some uncomfortable questions: Where did the laws of physics reside before there was a universe to which they could be applied? Do they exist independently of space or time? “It’s a great mystery as to where the laws of physics came from. We don’t even know how to approach it,” Vilenkin admits. “But before inflation came along, we didn’t even know how to approach the questions that inflation later solved. So who knows, maybe we’ll pass this barrier as well.”

In the Clint Eastwood movie *Magnum Force*, Harry Callahan says, “A man’s got to know his limitations,” but Vilenkin’s work is a testament to pushing past traditional limits. If we persevere in the face of skepticism and doubt, as Vilenkin is often inclined to do, interesting and unexpected ideas may well emerge — just like a universe popping out of nowhere.

Space.com (http://www.space.com/25126-big-bang-theory.html)

**What Is the Big Bang Theory?**

*By Elizabeth Howell, Space.com Contributor | June 22, 2015 09:47pm ET*

The Big Bang Theory is the leading explanation about how the universe began. At its simplest, it talks about the universe as we know it starting with a small singularity, then inflating over the next 13.8 billion years to the cosmos that we know today.

Because current instruments don't allow astronomers to peer back at the universe's birth, much of what we understand about the Big Bang Theory comes from mathematical theory and models. Astronomers can, however, see the "echo" of the expansion through a phenomenon known as the cosmic microwave background.

The phrase "Big Bang Theory" has been popular among astrophysicists for decades, but it hit the mainstream in 2007 when a comedy show with the same name premiered on CBS. The show follows the home and academic life of several researchers (including an astrophysicist).

**The first second, and the birth of light**

In the first second after the universe began, the surrounding temperature was about 10 billion degrees Fahrenheit (5.5 billion Celsius), according to NASA. The cosmos contained a vast array of fundamental particles such as neutrons, electrons and protons. These decayed or combined as the universe got cooler.

This early soup would have been impossible to look at, because light could not carry inside of it. "The free electrons would have caused light (photons) to scatter the way sunlight scatters from the water droplets in clouds," NASA stated. Over time, however, the free electrons met up with nuclei and created neutral atoms. This allowed light to shine through about 380,000 years after the Big Bang.

This early light — sometimes called the "afterglow" of the Big Bang — is more properly known as the cosmic microwave background (CMB). It was first predicted by Ralph Alpher and other scientists in 1948, but was found only by accident almost 20 years later. [Images: Peering Back to the Big Bang & Early Universe]

Arno Penzias and Robert Wilson, both of Bell Telephone Laboratories in Murray Hill, New Jersey, were building a radio receiver in 1965 and picking up higher-than-expected temperatures, according to NASA. At first, they thought the anomaly was due to pigeons and their dung, but even after cleaning up the mess and killing pigeons that tried to roost inside the antenna, the anomaly persisted.

Simultaneously, a Princeton University team (led by Robert Dicke) was trying to find evidence of the CMB, and realized that Penzias and Wilson had stumbled upon it. The teams each published papers in the Astrophysical Journal in 1965.

**Determining the age of the universe**

The cosmic microwave background has been observed on many missions. One of the most famous space-faring missions was NASA's Cosmic Background Explorer (COBE) satellite, which mapped the sky in the 1990s.

Several other missions have followed in COBE's footsteps, such as the BOOMERanG experiment (Balloon Observations of Millimetric Extragalactic Radiation and Geophysics), NASA's Wilkinson Microwave Anisotropy Probe (WMAP) and the European Space Agency's Planck satellite.

Planck's observations, released in 2013, mapped the background in unprecedented detail and revealed that the universe was older than previously thought: 13.82 billion years old, rather than 13.7 billion years old.

The maps give rise to new mysteries, however, such as why the Southern Hemisphere appears slightly redder (warmer) than the Northern Hemisphere. The Big Bang Theory says that the CMB would be mostly the same, no matter where you look.

Examining the CMB also gives astronomers clues as to the composition of the universe. Researchers think most of the cosmos is made up of matter and energy that cannot be "sensed" with conventional instruments, leading to the names dark matter and dark energy. Only 5 percent of the universe is made up of matter such as planets, stars and galaxies.

**Gravitational waves controversy**

While astronomers could see the universe's beginnings, they've also been seeking out proof of its rapid inflation. Theory says that in the first second after the universe was born, our cosmos ballooned faster than the speed of light. That, by the way, does not violate Albert Einstein's speed limit since he said that light is the maximum anything can travel within the universe. That did not apply to the inflation of the universe itself.

In 2014, astronomers said they had found evidence in the CMB concerning "B-modes," a sort of polarization generated as the universe got bigger and created gravitational waves. The team spotted evidence of this using an Antarctic telescope called "Background Imaging of Cosmic Extragalactic Polarization", or BICEP2.

"We're very confident that the signal that we're seeing is real, and it's on the sky," lead researcher John Kovac, of the Harvard-Smithsonian Center for Astrophysics, told Space.com in March 2014.

But by June, the same team said that their findings could have been altered by galactic dust getting in the way of their field of view.

"The basic takeaway has not changed; we have high confidence in our results," Kovac said in a press conference reported by the New York Times. "New information from Planck makes it look like pre-Planckian predictions of dust were too low," he added.

The results from Planck were put online in pre-published form in September. By January 2015, researchers from both teams working together "confirmed that the Bicep signal was mostly, if not all, stardust," the New York Times said in another article.

**Faster inflation, multiverses and charting the start**

The universe is not only expanding, but getting faster as it inflates. This means that with time, nobody will be able to spot other galaxies from Earth, or any other vantage point within our galaxy.

"We will see distant galaxies moving away from us, but their speed is increasing with time," Harvard University astronomer Avi Loeb said in a March 2014 Space.com article.

"So, if you wait long enough, eventually, a distant galaxy will reach the speed of light. What that means is that even light won't be able to bridge the gap that's being opened between that galaxy and us. There's no way for extraterrestrials on that galaxy to communicate with us, to send any signals that will reach us, once their galaxy is moving faster than light relative to us."

Some physicists also suggest that the universe we experience is just one of many. In the "multiverse" model, different universes would coexist with each other like bubbles lying side by side. The theory suggests that in that first big push of inflation, different parts of space-time grew at different rates. This could have carved off different sections — different universes — with potentially different laws of physics.

"It's hard to build models of inflation that don't lead to a multiverse," Alan Guth, a theoretical physicist at the Massachusetts Institute of Technology, said during a news conference in March 2014 concerning the gravitational waves discovery. (Guth is not affiliated with that study.)

"It's not impossible, so I think there's still certainly research that needs to be done. But most models of inflation do lead to a multiverse, and evidence for inflation will be pushing us in the direction of taking [the idea of a] multiverse seriously."

While we can understand how the universe we see came to be, it's possible that the Big Bang was not the first inflationary period the universe experienced. Some scientists believe we live in a cosmos that goes through regular cycles of inflation and deflation, and that we just happen to be living in one of these phases.