God and the Multiverse

November 4, 2012. A Universe with a Beginning
St. John in the Wilderness
Introduction

Sessions

- **Nov 4**: Introduction. A Universe with a Beginning
- **Nov 11**: A Multiverse with a Beginning
- **Nov 18**: A Universe Finely Tuned for Life
- **Nov 25**: An Orderly, Rational, Comprehensible, Beautiful Universe. Conclusions.
Primary References

1. A Universe with a Beginning

Almighty and everlasting God, you made the universe with all its marvelous order, its atoms, worlds, and galaxies, and the infinite complexity of living creatures: Grant that, as we probe the mysteries of your creation, we may come to know you more truly, and more surely fulfill our role in your eternal purpose; in the name of Jesus Christ our Lord.

Book of Common Prayer, page 827. For Knowledge of God’s Creation
Introduction
Introduction

Goals

- To show how discoveries in modern astronomy and cosmology are:
  - compatible with a belief in a creator God,
  - can be most rationally explained by a creator God who deliberately created a universe — or multiverse — that would be fruitful of life.
Introduction

Reasons for This Study

- As Christians we are commanded to love the Lord Our God with all our heart, all our soul, and all our mind
  - We must, in another words, fully engage our minds in loving God, and that includes the tasks of strengthening our faith and trust in God using our minds.
- We live in an increasingly secular world, and “naturalism” is an increasingly common viewpoint among many intellectuals.
  - **naturalism** = the view nothing exists except matter and the physical world.
  - As Christians, we must be equipped to “defend the faith” against naturalism.
- We should also be ready to defend science – one of the greatest of human adventures – because many in the public, seeing a close link between science and naturalism (a link often promulgated by scientists themselves), are quick to reject science, perceiving science as an enemy to faith.
Introduction

Week 1: A Universe with a Beginning

- (1) Principle of Sufficient Reason: events in this world don't just “happen” out of the blue. They occur because of a reason or a cause.
- (2) “From nothing, comes nothing.”
- (3) Observational cosmology has firmly established, from multiple lines of evidence, that our universe began 13.7 billion year ago in an event called “The Big Bang.”
  - there appears to be clear past limit to physical reality
- (1) + (2) + (3) imply some “First Cause” for the Universe, a "First Cause" not of this world.
Introduction

**Week 2: A Multiverse with a Beginning**

- There is not a shred of observational evidence for any physical reality beyond the universe that began with the Big Bang.
- There are however some physical theories:
  - some very accepted theories (inflation theory) because they explain important observations in this universe,
  - some unproven, often quite speculative theories (string theory, M-theory) held in high regard in the physics community because of what is hoped they will accomplish,
- that allow for “other” universes or “alternative” universes, not directly observable from our own.
Week 2: A Multiverse with a Beginning

Our observable Universe + these unobservable “other” universes = The “Multiverse.”

We will discuss how:
- the second law of thermodynamics +/-
- the Borde-Vilenkin-Guth Theorem

imply that even the “Multiverse” must have a beginning.

Therefore even a “Multiverse” also requires a “First Cause.”
Week 3: A Universe Finely Tuned for Life

The laws of physics appear to be incredibly fine-tuned to produce a Universe fruitful of life.

- The universe appears to be a "put-up job."

Possible explanations:

- The Universe is designed by a creator God who deliberately wanted a universe that would be fruitful of life, *or*
- There is a Multiverse consisting of an unimaginably enormous array of universes of wildly varying properties, the vast majority sterile, without stars or any possibility of life, at least one of which (ours) happens to contain, by random chance, the properties required for life.

Analogy: Hamlet. Possible explanations:

- A book written by a human author, *or*
- There is an unimaginably enormous array of books filled with random letters, one of which (the one in our hands) contains by random chance the text of Hamlet

Principle of Ockham’s Razor: an author, or a creator, designer God, would be the preferred, more economic explanation.
Introduction

**Week 4: An Orderly, Rational, Comprehensible, Beautiful Universe**

- Why is there any order at all, why not just chaos?
- Where do the laws of physics come from? [or] Where do the “meta-laws” of the Multiverse come from?
- What gives “fire” to the law of physics; what gives palpable “reality” to the potentiality they describe?
- Why should the laws of physics that lead to a universe fruitful of life and of conscious, intelligent beings (ourselves) also be laws that those conscious intelligent beings:
  - can comprehend?
  - find to be aesthetically beautiful?
- Science and cosmology offer no explanations to these questions.
Where We Are in the Known Universe
Where We Are
13.7 Billion Years From the Big Bang

- City of White Bear Lake
- State of Minnesota
- Country The United States of America
- Planet Earth
- The Solar System
- The Orion Spur of the Sagittarius Spiral Arm
- The Milky Way Galaxy
- The Local Group of Galaxies
- The Local Supercluster of Galaxies
- The Known Universe
Where We Are

Planet Earth

- Diameter: 7,930 miles
- Circumference: 24,900 miles (= 1/7 light-second)
- 93 million miles from the sun (= 8 light-minutes)
The Earth is one of eight planets orbiting a star called “The Sun”
Where We Are
Solar System
Where We Are
Solar System

- Sun is a “G2V main sequence” star
  - 109 times the diameter of the Earth
  - surface temperature: 5800 degrees
  - surface color: yellow
  - lifespan: about 10 billion years
Where We Are
Our Sun Among the Stars

- Stars group in discrete areas in a plot of star brightness vs color.
- A star will spend most of its life on the “Main Sequence.”
Where We Are

Our Sun Among the Stars

- The brightest, largest stars on the Main Sequence are blue, live a few million years, and die.
- The faintest, smallest stars on the Main Sequence are red, can live hundreds of billions of years before dying.
- The sun, a yellow star, will live about 10 billion years, then evolve rapidly to become a red giant and finally a white dwarf star surrounded by a planetary nebula.
The sun has another 5 billion years or so before becoming a red giant.

(However, in another 0.5 to 1 billion years, the Sun will brighten enough as part of its natural aging on the Main Sequence to boil away the oceans).
The Sun is one of about 100 billion stars (roughly the number of grains of sand in cubic yard of sand) in the Milky Way Galaxy.
Where We Are

Milky Way Galaxy among Galaxies

- Four main types of large galaxies:
  - Elliptical (E galaxies)
  - Lenticular galaxies (SO galaxies)
  - Spiral galaxies
    - Normal or S-shaped spirals (S)
    - Barred spirals (SB)
  - Magellanic Irregulars (Im, IBm)

- Two types of dwarf galaxies
  - Dwarf Spheroidal galaxies
  - Dwarf Irregular galaxies
Where We Are
Milky Way Galaxy among Galaxies

Normal or S-shaped Spiral Galaxies (S)

Barred Spiral Galaxies (SB)
The Milky Way is a giant barred spiral galaxy (SBc).
- Sun lies about 25,000 light-years from our galaxy's center, in the Orion Spur of the Sagittarius Spiral Arm of the Galaxy.
- Sun orbits once around the galaxy center about once every 240 million years.
- If the Earth’s orbit were the size of a pinhead, our galaxy would span the United States.

Structure of the Milky Way, determined from observations by the Spitzer Space Telescope.
Where We Are
Milky Way Galaxy
Where We Are

Milky Way Galaxy

- Our Milky Way Galaxy has several satellite galaxies that orbit it like moons. Most are dwarf galaxies. Largest and most notable are:
  - The Magellanic spiral galaxy (SBm) “The Large Magellanic Cloud”
  - The Magellanic irregular galaxy (IBm) “The Small Magellanic Cloud”
Where We Are

Milky Way Galaxy

- The Magellanic spiral galaxy (SBm) "The Large Magellanic Cloud," a satellite of the Milky Way Galaxy, 180,000 light years away.
The Milky Way belongs to a small group of some 30 galaxies, called “Local Group of Galaxies”.

It and the Great Galaxy in Andromeda M31, another giant spiral galaxy, dominate the Local Group.
Where We Are

Local Group of Galaxies

- The Great Galaxy in Andromeda M31, 2.4 million light years away.
- (optical and infrared images)
Galaxy groups like the Local Group of Galaxies seem to form filaments and tendrils in a web-like structure.

Where these filaments and tendrils intersect, a central galaxy cluster forms – a “hub” or “city” of galaxies – with tendrils and filaments of galaxy groups (~”towns”) extending outwards as its “suburbs.”

- The entire “metropolis” as a whole = a supercluster of galaxies

The central cluster (“city”) of the Local Supercluster (“the local metropolis”) is the Virgo Cluster of Galaxies.

- The center of the Virgo Cluster is marked by the giant elliptical galaxy M87, about 55 million light-years away.
Where We Are

The Local Supercluster
Where We Are

The Local Supercluster – Sculptor Group

NGC 300, spiral galaxy in the nearby Sculptor Group of Galaxies, 3.9 million light-years away
Where We Are

The Local Supercluster – Sculptor Group

NGC 253, spiral galaxy in the nearby Sculptor Group of Galaxies, 9.8 million light-years away.
M81, “signature” galaxy of the nearby M81 Galaxy Group, 4.6 million light-years away
Where We Are

The Local Supercluster – Virgo Cluster

M87, giant elliptical galaxy near the center of the Virgo Cluster of Galaxies (the central cluster of the Local Supercluster of Galaxies), 55 million light-years away.
Where We Are

The Local Supercluster–Virgo Cluster

M81, "signature" galaxy of the nearby M81 Galaxy Group, 4.6 million light-years away

Virgo Cluster of Galaxies
If the distance between our Local Group of Galaxies (our “suburban town”) and the Virgo Cluster (the central city of our “local metropolis” = the Local Supercluster) was the distance between White Bear Lake and St. Paul, then the width of the known universe would equal the distance between us and Japan.
Traditional Arguments for God’s Existence
Arguments for God’s Existence

*a posteriori* versus *a priori*

- Traditional arguments for the existence of God divide into two main groups: *a posteriori* and *a priori* arguments.
  - *a posteriori* arguments: based on premises that can be known only by experiencing the world.
    - for example, the so called *a posteriori* “Cosmological Argument” is based on the idea of causation: in our experience of this world, every event seems to have a cause.
  - *a priori* arguments: based on premises that can be known to be true independently of our experience of this world, through reason alone.
Arguments for God’s Existence

*a posteriori* arguments

- Two most famous *a posteriori* arguments:
  - 1. “Cosmological Argument”:
    - things don't just pop out of nothing. One thing depends on another before it.
    - Furthermore, you just can’t have “one thing depending on another before it” going back in time forever.
    - So there must be some ultimate, very powerful “First Cause” = God.
    - we will be discussing the Cosmological Argument today and next week.
  - 2. “Teleological Argument”:
    - The world exhibits intelligent purpose or order.
    - Therefore there must be / probably is a divine intelligence, a supreme designer.
    - We will be discussing the Teleological Argument in session 3.
Arguments for God’s Existence

*a priori* arguments

- **“Ontological Argument”**:  
  - One of the most remarkable arguments for God ever made.  
  - First set forth by Anselm (1033-1109), Archbishop of Canterbury.  
  - Has continued to puzzle and fascinate philosophers ever since.

Seal of Anselm of Canterbury
Arguments for God’s Existence

*a priori* arguments

- **“Ontological Argument”:**
  - Basic argument:
    - “God” = that Being which is the greatest, the most perfect Being that we can conceive of.
    - It is greater, it is “more” perfect to exist in reality than to exist only in the mind.
    - Therefore God – defined as the greatest, most perfect being we can conceive – must exist in reality.
  - Is this linguistic sleight of hand? Or a profound insight inherent in and unique to the concept of “God”?
  - We will be discussing the Ontological Argument in sessions 3 and 4.
Arguments for God’s Existence

Cosmological Argument

- All versions of the “Cosmological Argument” begin with the observation (= it is *a posteriori* argument) that:
  - the universe exists.
  - everything in it appears to be “contingent” (= depending on something *beyond itself* for its existence).
- That “something else” for the universe must be
  - logically prior to / before the universe.
  - the reason for the existence of the universe.
- God is that “something else.”
Arguments for God’s Existence

Cosmological Argument

- A Formal Statement (The “second way” of St. Thomas Aquinas, 1224-1274, based on the idea of causation)
  - 1. Everything we see in this world is caused.
  - 2. Nothing can be the cause of itself.
  - 3. There cannot be an infinite regress of causes.

Therefore:

- 4. There must exist an uncaused first cause not of this world
- 5. The word God means “uncaused first cause not of this world”.
- 6. Therefore, God exists.
Arguments for God’s Existence

Cosmological Argument

- Premise 1: “Everything we see in this world is caused.”
  - We generally believe that every event has a cause that explains why the event happened.
- Premise 2: “Nothing can be the cause of itself.”
  - Nothing can cause itself to come into existence (*causa sui*), for it would have to exist before it caused anything at all.
  - And nonexistent things have no power to cause anything!
Arguments for God’s Existence

Cosmological Argument

- Premise 3: “There cannot be an infinite regress of causes.”
  - This is the premise generally said to be the downfall of the Cosmological Argument.
  - As Scottish philosopher David Hume (1711-1776) noted, there is nothing logically impossible with the idea of an infinite regress causes.
  - There are an infinite regress of numbers, so why not an infinite regress of causes?

David Hume
Arguments for God’s Existence

Cosmological Argument

- Premise 3: “There cannot be an infinite regress of causes.”
  
  However, if science tells us that the universe has a *beginning*, that there is a *physical limit in time to the universe*, then an infinite regress of causes, one thing causing another before it, backwards through an infinity of time, is impossible.

- Proof that the universe has a *beginning* would remove this primary objection against the Cosmological Argument.
The Big Bang

The View of the Universe 100 Years Ago

At the beginning of the 20th century, most scientists were convinced the universe was eternal in time. It had existed forever, and would exist forever.

- In Newtonian physics, it was natural to assume that time goes on forever just as numbers go on forever, from minus infinity to positive infinity.
- The First law of Thermodynamics -- the “principle of conservation of energy” -- showed energy could not be created or destroyed.
- The conservation of mass – discovered by 19th century chemists – showed the total mass of chemical reactants could not change.
1914: Vesto Melvin Slipher reported at the American Astronomical Society convention in Evanston, Illinois a remarkable new finding: all of the galaxies that he had studied, about a dozen, were receding from the earth at fantastic speeds, some up to 2 million miles an hour.

By 1925, Slipher had studied forty-five galaxies; almost all were receding from the earth at fantastic speeds.
The Big Bang
Receding Galaxies

- **1929:** Edwin Powell Hubble (a lawyer turned astronomer) and Milton Humason (a mule-train driver and janitor turned astronomer), using the new 100 inch telescope at Mt. Wilson observatory, confirmed Slipher's findings, and in addition reported two additional remarkable findings:

  - The galaxies were incredibly far way; they could not be nebulae in the Milky Way, but were themselves independent and vast ensembles of billions of stars, like the Milky Way.
  - The further away the galaxy was, the faster it was receding from us. The Universe appeared to be *expanding*. 
The Big Bang

Receding Galaxies

- The further away the galaxy was, the faster it was receding from us. The Universe appeared to be expanding.

Graph from Hubble and Humason’s paper 1929
The further away the galaxy was, the faster it was receding from us. The Universe appeared to be expanding.
The Big Bang

The General Theory of Relativity

- In the meantime ...
- **1916**: Albert Einstein published the General Theory of Relativity, a new theory of gravity that replaced Isaac Newton’s theory.
- Einstein's theory showed that space-time was a single flexible fabric, a fabric that would bend and quiver in response to the matter and energy that moved around on it:

  (curvature or flexing of space-time) was proportional to
  (distribution of matter, energy, pressure in space and time)
Einstein realized that:
- not only could the fabric of space-time bend and stretch and quiver in one particular place, but that the whole of space, the entire universe, could stretch like an expanding balloon, or shrink like a collapsing balloon.
- Indeed, not only could the entire universe be expanding or collapsing, but it had to be either expanding or collapsing. His equations could not describe a “static” universe.
Einstein did not want to believe what his theory was telling him.
- In 1916, Einstein could have predicted the expansion of the universe
- But he wanted to believe in a static, eternal universe.
- So in 1917, Einstein modified his equations and added a term “the cosmological constant” so the equations of General Relativity could describe a static, unchanging, eternal universe.
  - (Aside: in 1930, English astrophysicist Arthur Stanley Eddington, 1882 - 1944 showed that even with Einstein's new cosmological constant, the equations still would not describe a static universe)
The Big Bang
Friedmann and Lemaitre

1922: Alexander Friedmann, a Russian meteorologist and mathematician, published solutions to Einstein's equations that described an expanding universe filled with matter.

- Einstein in turn published a proof that Friedmann's solutions were wrong.
- But shortly afterward, Einstein had to retract it, finding an error in his proof.
The Big Bang
Friedmann and Lemaitre

1927: Georges Lemaitre, a Belgian physicist and Jesuit priest:
- Independently published solutions to Einstein’s equations that described an expanding universe filled with matter.
- Correlated his solutions with the findings of Slipher, Hubble and Humason that galaxies were receding from us.
- Suggested the universe was expanding, and that all the matter in the universe was originally concentrated into an incredibly dense “primeval atom” that had “exploded” to produce the world we see.
The Big Bang
Einstein Admits Universe Not Static

- **1930**: Einstein finally admitted “New observations by Hubble and Humason concerning the red shifts of distant nebulae [i.e., galaxies] make it appear likely that the general structure of the Universe is not static.”

- **1931**: Einstein wrote English astrophysicist Arthur Eddington: “The notion of a beginning is repugnant to me. . . . I simply do not believe that the present order of things started off with a bang . . . the expanding Universe is preposterous. . . incredible . . . it leaves me cold.”

Albert Einstein
Most physicists and astronomers also remained unconvinced of a “Big Bang.”

They were philosophically committed to the “Strong Cosmological Principle:”

- There is nothing special about where we live in the universe, and
- there is nothing special about when we live in the universe.
- The universe is uniform and homogeneous throughout both space and time.

There were also, at least initially, problems with the timeline:

- Extrapolating back to the “Big Bang,” at the current speed of expansion suggested the universe was younger than some of the stars and star clusters in it.
1948: Hermann Bondi, Thomas Gold, and Fred Hoyle (who had derisively coined the term “Big Bang”) proposed the so-called Steady State Theory:

- the universe had existed for an infinite time and had always been expanding just as we now see it.
- a “creation field” pervaded the universe, a field in which matter was being continuously created to make up for the thinning out due to the cosmic expansion.

1959: a survey of leading American astronomers and physicists found that two-thirds of them still believed that the universe had no beginning.
1948: Ralph Alpher and Robert Herman, working with George Gamow, realized that if there had been a “Big Bang,” then shortly after the “Big Bang,” the entire universe must have been intensely, inconceivably hot.

- One second after the Big Bang, for example, the density of matter throughout the entire universe would be several thousand times the density of lead, and the temperature about 10 billion degrees centigrade.
  - The entire universe was an incandescent inferno.
- (Aside: recall in the Genesis account of creation, light was created on the “first Day,” while the sun and stars were not made until later, on the “fourth Day.”)
The Big Bang
The Cosmic Microwave Background

- As the universe expanded, this intense, hot primordial radiation pervading the entire universe cooled, becoming fainter, “red-shifting” to longer and longer wavelengths.
  - Matter also cooled, forming stars, galaxies, and planets
- In the present universe, billions of years after the Big Bang, the red-shifted primordial radiation would no longer be in the form of “visible light” but in the form of microwaves.
- Gamow, Alpher, and Herman predicted this microwave “cosmic microwave background radiation,” (as it is now called) should exist and theoretically be detectable.
- Findings from this paper were apparently forgotten.
The Big Bang

The Cosmic Microwave Background

- **Mid-1960s:** A group at Princeton led by Robert H. Dicke, Jim Peebles, and David Wilkinson, independently realized that if there had been a “Big Bang,” then a “cosmic microwave background radiation,” should pervade the universe and be detectable.

- They were still trying to build a microwave antennae to detect it in **1965** when Robert Dicke took a call from an astronomer Arno Penzias at Bells Labs in nearby New Jersey.
The Big Bang

The Cosmic Microwave Background

- Arno Penzias and Robert Wilson, two radio astronomers at Bell Labs had been trying to get rid of a persistent “static” in a microwave satellite antenna they had built.
  - Originally they thought there was some problem with their microwave antennae.
  - But after trying nearly everything and still being unable to get rid of the static, they heard about a preprint on the Princeton work.
  - After talking to Penzias, Dicke immediately sent Penzias and Wilson a copy of their preprint predicting a Cosmic Microwave background.
  - “The rest is history.”
- The detection of the primordial radiation of the Cosmic Microwave Background made the “Big Bang” nearly irrefutable.
- **1978:** Penzias and Wilson were awarded the Nobel Prize for Physics for their discovery.
The “Hubble Parameter” relates the speed a galaxy is moving away from us because of the expansion of the universe, with its distance from us:

\[
\text{(recession speed of a galaxy)} = \text{Hubble Parameter} \times \text{(distance to the galaxy)}
\]

- The bigger the Hubble Parameter, the faster the expansion of the universe.
- The smaller the Hubble Parameter, the slower, the more leisurely the expansion of the universe.

Graph from Hubble and Humason’s paper 1929. The “Hubble Parameter” is the slope of the line in the plot of recession speed versus distance.
The Big Bang
The Search for the Hubble Parameter

- Scientists reasoned the “Hubble parameter” would change with time:
  - In the young universe, the universe would be expanding fastest.
  - As the universe aged, the expansion speed would slow down (= “decelerate”) because of the continued, inexorable pull of gravity from all the matter in the universe.
The Big Bang

The Big Question

- The Big Question:
  - (1) Was the speed of expansion slowing down (="decelerating") "fast enough" that eventually the expansion would halt, and then the universe would begin to contract, ultimately leading to a "Big Crunch"?
    - Implied the total density of matter in the universe was large enough for gravity to overcome the expansion from the Big Bang.
  - (2) Or was the speed of expansion slowing down ("decelerating") so slowly, so leisurely, that the expansion would never completely stop, and the universe would expand forever, albeit at an increasingly slower and slower rate?
    - Implied the total density of matter in the universe was not large enough for gravity to overcome the expansion from the Big Bang.
Answering this Big Question was a key NASA project for the last decades of the 20th century and one of the justifications for the Hubble Space Telescope.

Answering it required careful measurements of the distances and speeds of recession of many galaxies.

The “standard candle” of the Type Ia supernova ultimately played a key role in measuring distances.
Type Ia supernova: cataclysmic explosion of a white dwarf star feeding on material from an adjacent star.
In 1998, two international teams of researchers, working independently:
- High-z Supernova Search Team (HZT), and
- the Supernova Cosmology Project (SCP)
announced identical answers to the Big Question.
Their results were completely unexpected, and shocked the world of physics.
Scientists had expected:

- In the young universe, the universe would be expanding fastest.
- As the universe aged, the expansion speed would slow down (= “decelerate”) because of the continued, inexorable pull of gravity from all the matter in the universe.
- The only question was **what was the amount of deceleration?** Would there be a **Big Crunch** or not?
The Big Bang
The Big Question

- **1998:** High-z Supernova Search Team (HZT) and the Supernova Cosmology Project (SCP) both showed:
  - 4 to 5 billion years ago, the expansion speed stopped *decelerating*, and instead began to *accelerate*.
  - *Implication:* 4 to 5 billion years ago, some previously unknown anti-gravity force, an anti-gravity force that pervades the entire universe, grew strong enough to overcome the continued, inexorable pull of gravity from all the matter in the universe, and ever since has caused the universe to expand at increasingly faster and faster rate.
The Big Bang

Dark Energy

- This anti-gravity force is now called “Dark Energy”
  - We now know “Dark Energy” currently makes up 75% of the energy in the universe.
  - The universe is currently doubling in size every 10 billion years.
  - The nature of “Dark Energy” remains a mystery.

- 2011: the leaders of the High-z Supernova Search Team (HZT) and the Supernova Cosmology Project (SCP) received the Nobel Prize in Physics for the discovery of the accelerating universe and Dark Energy.
The Big Bang

The Concordance Model

Detailed investigations and modeling of the Cosmic Microwave Background – measured in exquisite detail by the Wilkinson (one of those Princeton researchers scooped by Penzias and Wilson) Anisotrophy Probe (WMAP satellite) – have led to a “concordance model” of the universe since the Big Bang.

WMAP map of tiny fluctuations in the cosmic microwave background (one part in 10,000) present 380,000 years after the Big Bang. These tiny fluctuations were the seeds for future stars and galaxies.
The Big Bang

The Concordance Model

- The Big Bang occurred 13.7 billion years ago (plus / minus 0.13 billion years)
- \(10^{-36}\) seconds after the Big Bang: temperature \(10^{+28}\), density \(10^{+73}\) tons /cc. A rapid expansion of the universe was launched by a mechanism called “inflation,” causing the universe to be flat and very homogeneous.
- \(10^{-34}\) seconds after the Big Bang: inflation ended, and the energy of the inflation transformed into an immensely hot broth of every kind of subatomic particle.
  - The universe continued to expand at a much slower rate. As the universe expanded, its temperature and density continued to go down.
The Big Bang
The Concordance Model

- **One minute after the Big Bang:** the temperature and density throughout the entire universe had “cooled” to the conditions of the interior of a star. For the next 5 minutes temperatures remained high enough for hydrogen to fuse to some helium and a tad of lithium.
The Big Bang

The Concordance Model

- **380,000 years after the Big Bang**: the entire universe had cooled to the surface temperature of a red dwarf star (3000 degrees). Electrons paired up with nuclei to form atoms for the first time, allowing ambient light (photons) to traveled unimpeded for the first time.
  - Previously freely roving electrons scattered the light photons every which way.
  - The Cosmic Microwave Background is a snapshot of these newly unimpeded photons, a snapshot of the universe 380,000 years after the Big Bang.
  - To a human observer, the entire universe would have been glowing with the deep, beautiful red of a sunset.
The Big Bang

5 to 200 million years after the Big Bang: The Dark Age. The energy of photons in the universe had cooled to infrared wavelengths.

- The universe for the first time would have looked dark to a human observer.

200 million years after the Big Bang: first stars formed.

1 to 2 billions years after the Big Bang: first infant galaxies formed.

2 to 3 billion years after the Big Bang: peak of star birth and peak in “quasar” production (= supermassive black holes).
The Big Bang

The Concordance Model

- **6 billion years after the Big Bang**: first galaxy clusters formed.
- **7 billion years after the Big Bang**: Dark Energy became strong enough to overcome gravity. Expansion of the universe began to *accelerate*.
- **8 billion years after the Big Bang**: first modern spiral galaxies like the Milky Way formed.
- **9.1 billion years after the Big Bang**: Sun and Earth formed.
The Big Bang
The Concordance Model

**Today:** energy of the universe:
- ~5% in form of “normal” matter
- ~20% in form of an unknown type of matter that is impervious to electromagnetism, that interacts only through gravity and the “Weak force:” “Dark Matter”
  - Nature of “Dark Matter” unknown.
- ~75% in the form of “Dark Energy”
  - Nature of “Dark Energy” unknown.
Summary
Summary

Cosmological Argument

- The traditional “Cosmological Argument” for the existence of God says:
  - 1. Everything we see in this world is caused.
  - 2. Nothing can be the cause of itself.
  - 3. There cannot be an infinite regress of causes.

Therefore:

- 4. There must exist an uncaused first cause not of this world
- 5. The word God means “uncaused first cause not of this world”.
- 6. Therefore, God exists.

- Philosophy courses routinely note this argument fails because of premise 3, “There cannot be an infinite regress of causes.”
However the Big Bang proves that premise 3 is in fact correct. There cannot be an infinite regress of causes, for the universe is finite in time; it has a beginning.

Therefore the traditional “Cosmological Argument” for the existence of God (defined as the “uncaused first cause, not of this world”) does work to prove the existence of God.
But Was the Big Bang the Beginning?

- The Big Bang is the beginning of our known Universe.
- But is the Big Bang really the beginning of all of physical reality?
  - Could there have been another physical reality, another “universe” that gave rise to our universe?
  - And could there be other universes, separate from our own?
- There is currently not a shred of observational evidence for any other universe.
Summary
But Was the Big Bang the Beginning?

- But:
  - because of a persistent philosophical preference (bias?) for an eternal universe among cosmologists, and
  - because *it is the job of a scientist* to try to find “natural” explanations for whatever mystery they can,

- Many cosmologists have explored the possibility that there is “Multiverse” of many universes out there, that our universe is but a recent sprout of a “Multiverse.”
Summary

But Was the Big Bang the Beginning?
Next Time:
A Multiverse with a Beginning