The Big Bang

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Notes Outlines

- Theories of the Universe
  - Static Universe
- What is the Big Bang Theory
- What is the evidence supporting Big Bang Theory

☒ Static Universe ☒

- A **static universe**, also referred to as a "stationary" or "Einstein" universe, is a model in which space is neither expanding nor contracting
  - This was Albert Einstein's preferred theory of the universe… Until Hubble found that the universe is expanding (through redshift), thus disproving the Static Universe Model
    - Einstein described his cosmological model as his "biggest blunder"

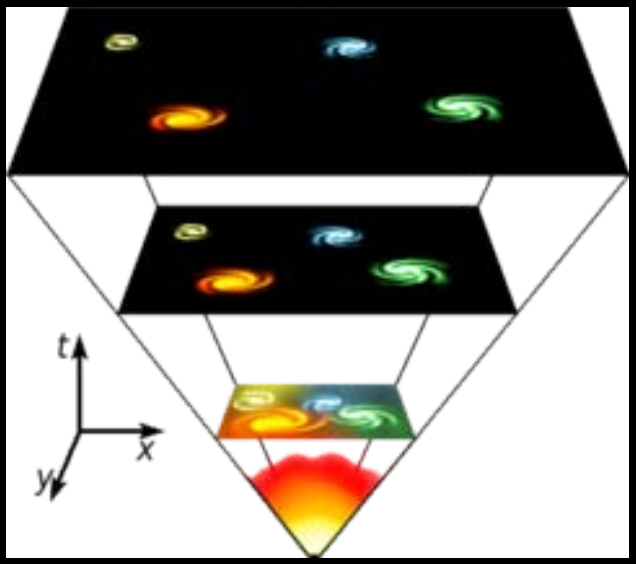
☒ Steady State Theory ☒

- the **Steady State theory** (also known as the **Infinite Universe theory** or **continuous creation**) purports a model of the universe that describes a universe in which new matter is continuously created as the universe expands
  - The steady state model is now largely discredited, as the observational evidence points to a Big Bang-type cosmology and a finite age of the universe.

✓ Big Bang Theory ✓

- **Big Bang Theory – The Basics**
  - The Universe initially existed in a single super hot, super dense point (a singularity)
  - The universe rapidly expanded (The Big Bang)
  - The universe is still expanding
  - This happened about 13.75 billion years ago
    - So… That's how old the universe is!

The Big Bang Theory is **well tested** and is generally accepted as the Standard Cosmological Model of the Universe



The Universe, according to BBT

- **The Early Universe - Aka -The Primordial Fireball**
  - Early Universe was small, dense, and hot things happened quickly
  - Only elementary particles (protons, neutrons, electrons) at this point
    - But not atoms yet, because things were moving so quickly!
  - The Universe quickly cools and expands, ushering in the next age…

The Universe, according to BBT

- **The Radiation Era**
  - For the next 500,000 years, electromagnetic radiation (light) was the most important thing
  - This universe was opaque, milky
  - The universe continued to expand and cool… eventually electrons slowed down enough to be attracted to the protons and atoms and the next age began…

The Universe, according to BBT

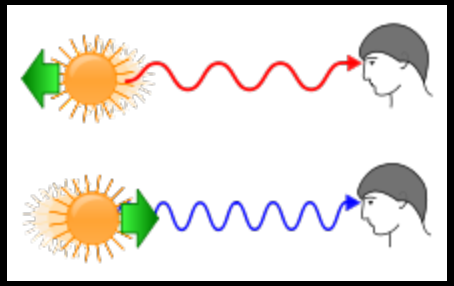
- **The Matter Era**
  - Electrons slowed down enough to be able to combine with protons to form Hydrogen (the most abundant element in the universe)
  - At this point the universe "clears up" and light is able to permeate the universe
    - light that had been trapped by free electrons escaped when the electrons combined with protons to form hydrogen.
    - This produced the **Cosmic Microwave Background Radiation (CMBR)**
  - We are still in the Matter Era of the universe

Evidence Supporting Big Bang Theory: The Expanding Universe

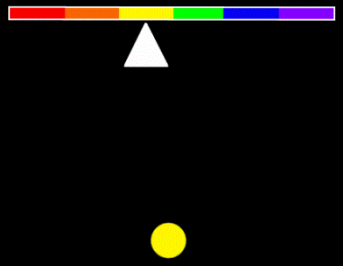
- According to BBT, the Universe is expanding…
  - In the 1920's Edwin Hubble discovered that no matter which direction he looked into space, distant galaxies appeared to be moving away from us.
    - Hubble observed that the spectrum lines coming from distant galaxies was "Redshifted"

Evidence Supporting Big Bang Theory: The Expanding Universe

- **Redshift -** A shift in the wavelength of light towards the red end of the spectrum of light (increase wavelength) as an object (star or galaxy) moves away from an observer

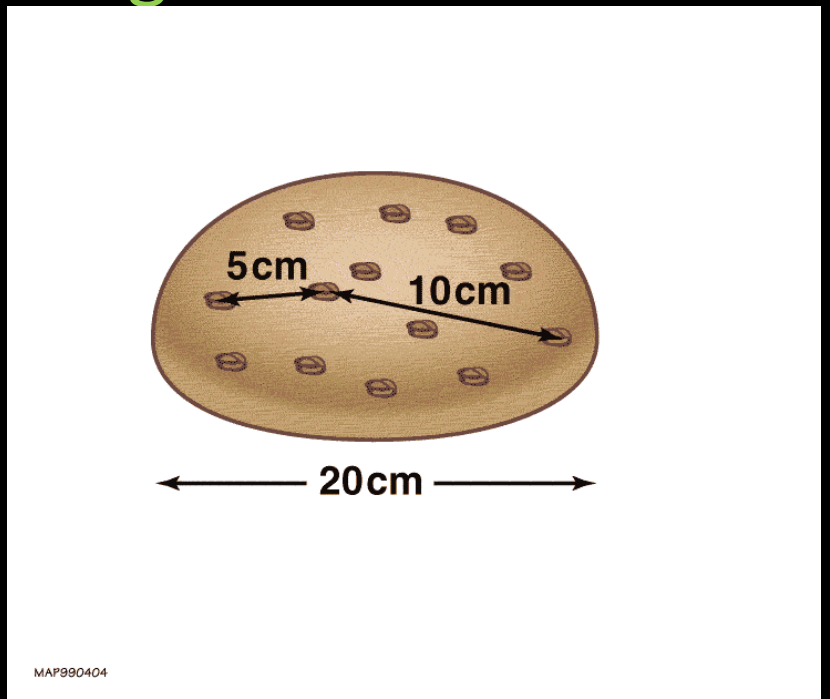


- Blueshift – shift in the wavelength towards blue when an object moves towards the observer



Evidence Supporting Big Bang Theory: The Expanding Universe

- So Hubble found that most galaxies around us are redshifted… that must mean that all galaxies are moving apart… that must mean that space itself is expanding!!!
- Like raisin bread
  - Raisins are galaxies
  - Dough is space/universe



Evidence Supporting Big Bang Theory: Elemental Composition

- Scientists have determined, through spectroscopy, that our universe is made of mostly the elements hydrogen and helium (the lightest elements)
  - These elements were created by a process called Nucleosynthesis – the production of atomic nuclei
    - This started about three minutes after the Big Bang occurred and lasted for another 14 minutes
    - Because the universe expanded rapidly, only the elements hydrogen, helium, (and some lithium) were able to be created in any large quantities before conditions were unfavorable to any additional nucleosynthesis

Evidence Supporting Big Bang Theory: Elemental Composition

- So the prevalence of Hydrogen and Helium in our Universe can be explained by the physics of an expanding universe (Big Bang Theory)
- But what about all the other elements?
  - Heavier elements are created by Nucleosynthesis in stars
    - Including the Carbon that is the prevalent atom in living things

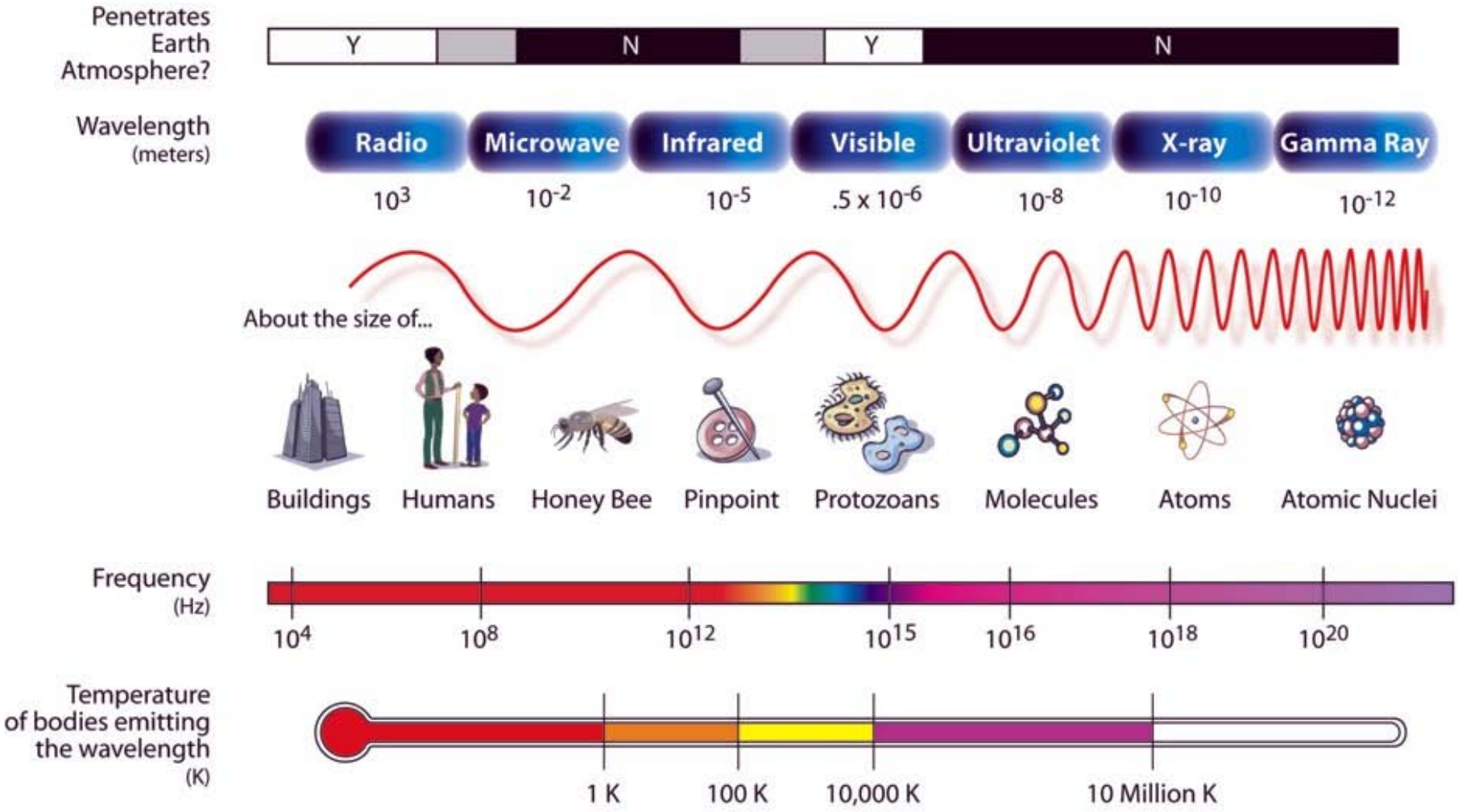
Evidence Supporting Big Bang Theory: Cosmic Microwave Background Radiation (CMBR)

- CMBR was discovered in 1965 in New Jersey by Arno Penzias and Robert Wilson.
- They discovered a "hum" that was present day or night, no matter which direction they pointed their antenna
  - They thought at one point this hum may be caused by pigeon droppings on their antenna
- Instead they found this microwave radiation
  - Both received the Nobel Prize for Physics in 1978

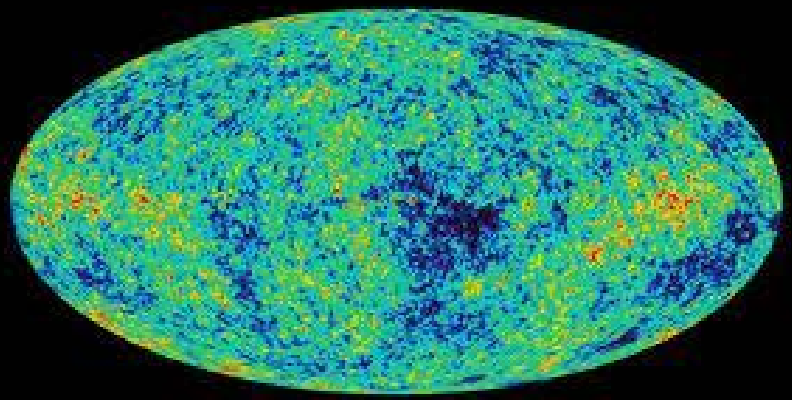
Evidence Supporting Big Bang Theory: Cosmic Microwave Background Radiation (CMBR)

- Cosmic Microwave Radiation started its life in the radiation era, as photons of light.
- When the universe "cleared" this light started propogating through the universe
- The "light" (radiation) has been travelling ever since, and as the universe expands, the wavelength of the waves elongates
- CMB been elongating for over 13 billion years, and now is in the microwave range of the Electromagnetic spectrum

THE ELECTROMAGNETIC SPECTRUM



Evidence Supporting Big Bang Theory: Cosmic Microwave Background Radiation (CMBR)



- This map of CMBR taken by the WMAP (NASA Program)
- CMBR that is measured here is consistent with what CMBR should look like if the universe started out as dense plasma and expanded rapidly (the Big Bang)
- Thus, CMBR supports the Big Bang Theory

Evidence Supporting Big Bang Theory: Age of Stars

- If the estimate for the age of the universe is correct, then there shouldn't be any stars over 13.5 billion years
  - Since scientists believe the first stars formed about 200 million years after the big bang
- And… We don't find any stars older than that!