THE BIG BOUNCE



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REVIEW OF THE BIG BANG

- Occurred ~14 billion years ago
- Universe was an extremely small, hot, and dense point
- As the universe grows, it creates spacetime
- Energy from The Big Bang is spread out over time
- Temperature of the universe decreases
- Universe has a "flat" shape

REVIEW OF SHAPES

- Flat geometry
- Open geometry
- Closed geometry

In the case of The Big Bounce the important shape is closed.

Figure 1: Shapes of the Universe

REVIEW OF THE BIG CRUNCH

- Universe is expanding (inflation)
- BC theory proposes gravity force will eventually reverse this
- This reversal would cause universe to contract back into singularity
- Current observations show expansion is accelerating, makes BC unlikely

Figure 2: What Could Happen to Our Universe: Big Bounce

CRUNCH

CLICKER: FOR THE UNIVERSE'S FATE TO RESULT IN A "BIG BOUNCE", WHAT SHAPE DOES THE UNIVERSE NEED TO BE?

- (a) Closed
- (b) Open
- (c) Flat
- (d) Banana Shaped

WHAT IS THE BIG BOUNCE?

- Alternative cosmological model to the Big Bang Theory, one of many cyclic models of the universe
- Universe undergoes a cycle of expansion and contraction
- The universe is created and eventually destroyed, creating a new universe - the process repeats eternally
- Similar to the Big Crunch, followed by the Big Bang, followed by the Big Crunch, and so forth
- Current iteration of universe is just one of a series of infinite iterations

WHAT IS THE BIG BOUNCE? CONT.

- Time is potentially infinite no true beginning or end
- Universe has a minimum size and maximum density, both are finite
- Behaviour of subatomic objects changes as density approaches the maximum
- May cause physical constants to vary near the very end of a contraction phase
- Quantum effects (as in loop quantum cosmology) stop the universe from collapsing into a singularity

ORIGIN/HISTORY OF THE BIG BOUNCE

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Figure 3: Most Beautiful Surviving Mayan Pyramids

 "endless cosmic cycles" idea traced back to many ancient civilizations

- Notably Chinese, Mayan, Greek, and Hindu
- "Big Bounce" could be thought of as a modern-take seen through the lens of mathematics, and scientific inquiry

ORIGIN/HISTORY OF BIG BOUNCE THEORY

- Big Bounce initially proposed in 1922 by Alexander Friedmann
- "Friedmann's equations" explored universe's evolution, including possibility of "Big Crunch", followed by "Big Bang" (leading to Big Bounce)
- briefly considered by Albert Einstein in 1931, and others in field



Figure 4: Wikipedia: Alexander Friedmann

ORIGIN/HISTORY OF BIG BOUNCE THEORY

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Figure 5: Albert Einstein Institute: Anna Ijjaas

- Big Bounce has largely been disregarded as the Big Bang Theory is more testable/accepted
 - However, recent work in 2020 (still underway) by Anna Ijjaas focuses on designing computer simulations to simulate Big Bounce to determine what residual evidence could be observed/measured to disprove, or prove theory

EVIDENCE

FRIEDMANN'S EQUATIONS

$$\begin{split} \boxed{\left(\frac{\dot{a}\left(t\right)}{a\left(t\right)}\right)^{2} = \frac{8\pi G}{3}\rho\left(t\right) - \frac{\kappa c^{2}}{a^{2}\left(t\right)} + \frac{\Lambda c^{2}}{3}}{\frac{\lambda c^{2}}{a\left(t\right)}}} \\ \frac{\ddot{a}\left(t\right)}{a\left(t\right)} = -\frac{4\pi G}{3}\left(\rho\left(t\right) + \frac{3p\left(t\right)}{c^{2}}\right) + \frac{\Lambda c^{2}}{3}}{\frac{\lambda c^{2}}{3}} \end{split}$$

Figure 6: The Friedmann Equations Explained: A Complete Guide

- Describes how different types of spacetimes or universes behave based on their matter, radiation, and energy content
- LHS focuses on how the 'grid' of universe (how we measure a square lightyear) changes with time (signified by a(t)); à(t) and ä (t) are the first and second derivative!
 - If universe is assumed to be "matter-dominated", and closed in equations? → **Big Crunch**

IJJAAS'S COMPUTER SIMULATIONS



Figure 7: Albert Einstein Institute: Asking The Most Fundamental Questions About The Universe

CLICKER: WHAT THREE CONTENT COMPONENTS CONTRIBUTE TO RESULTS GIVEN BY THE FRIEDMANN EQUATIONS?

- (a) Dark Matter, Free Radicals, Energy
- (b) Strong-Force, Gravity, Electromagnetism
- (c) Matter, Radiation, Energy
- (d) Hakuna-Matata, Radical, E=mc-squared

LOOP QUANTUM COSMOLOGY (LQC)

- based on Loop Quantum Gravity (LQG), which quantizes space-time itself, suggesting that space-time has a discrete structure at very small scales.
- LQC predicts that at extremely high densities, quantum gravitational effects will prevent the collapse of the universe into a singularity. (bojowald, 2005)
- As the universe contracts and reaches a very small size, quantum gravity effects come into play, and instead of a singularity, a **bounce** occurs. (Ashtekar, 2009, pg 16.)

CONTRADICTING EVIDENCE

- Universe seems to be expanding and Accelerating Very likely to be headed towards Big Freeze or even Big Rip
- Cosmic Microwave Background
- Lack of Observable Signatures from Previous Cycles

CLICKER: HOW LIKELY DO YOU FEEL THE BIG BOUNCE IS?

- (a) Yes 100% believe in it
- (b) It might be possible
- (c) not likely
- (d) don't think it is possible at all

CONCLUSION

- The Big Bounce Theory is a fascinating cosmological concept that sees the eventual fate of the universe not as grim, and depressing, but rather as one of many infinite cycles.
- It is unfortunately entirely speculatory at present, as any evidence is either contradictory, or not provable as of yet.
- Until proper evidence, and testable experiments present themselves: The Big Bang Theory, and the Big Freeze/Rip will remain as the leading hypotheses of the definitive origin, and eventual fate of the universe.



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IMAGE REFERENCES

Figure 1: Shapes of the Universe. Retrieved from: <u>https://www.sciencefocus.com/space/what-shape-is-the-universe</u>

Figure 2: What Could Happen to Our Universe: Big Bounce https://dragallur.wordpress.com/2015/09/17/what-could-happen-to-our-universe-big-bounce

Figure 3: Most Beautiful Surviving Mayan Pyramids https://historylists.org/architecture/5-most-beautiful-surviving-mayan-pyramids.html

Figure 4: Wikipedia: Alexander Friedmann https://en.wikipedia.org/wiki/Alexander_Friedmann

Figure 5: The Friedmann Equations Explained: A Complete Guide <u>https://profoundphysics.com/the-friedmann-equations-explained-a-complete-guide</u>

Figure 6: Albert Einstein Institute: New Initiative to Explore Origin and Future of Universe <u>https://www.aei.mpg.de/69996/new-initiative-to-explore-the-origin-and-future-of-the-universe</u> Figure 7: Albert Einstein Institute: Asking The Most Fundamental Questions About The Universe https://www.aei.mpg.de/27266/asking-the-most-fundamental-questions-about-the-universe