BIG BANG AND COSMOLOGY

SUMMARY AND PROBLEMS

by Michael Harwood, 2022

The present model for the origin of the universe is the standard Big Bang Model. It is also called the ΛCDM model (cold dark matter with non-zero Lambda Λ). The Lambda in ΛCDM refers to dark energy, which is needed to create a force to explain the accelerating expansion of the universe.

It explains three observations extremely well [i] :

1. The expansion of the universe
2. The 3K background radiation
3. The hydrogen-helium abundance ratio.

And yet, there are a lot of serious problems with the Big Bang theory, a number of of things that it simply cannot explain at all. In spite of this, we still tout the Big Bang model as the explanation of the universe – <u>because there is no better model</u>. When one speaks of the Big Bang and cosmology, it's important to know both the supporting science and the significant holes and flaws with it. On the one hand, one should not speak of it as it it's a done deal and everything is figured out. It's not. On the other hand, one should not pretend that the Big Bang theory is arbitrarily made up with no underpinning of physics and no support from observation. There are specific precise scientific observations that support it.

Part of the direction that cosmology takes is driven by a fanatical antagonism towards Creationism or anything that might imply the existence of some sort of intelligent creator of the universe. It's important to be aware of this bias. Alternative creationist models for the origin of the universe are not well developed. There's a "white hole" model that's interesting, but inchoate.

Supporting Evidence

1. The expansion of the universe.

As we observe galaxies in space, we see that almost all of them are red-shifted. The further away the galaxy is, the greater the red-shift. The most obvious explanation for this is the Doppler effect: thus all galaxies are receding from us. Now why should this be? Because the universe is expanding. There doesn't seem to be any credible alternative explanation for (i) the red shift other than the Doppler effect and receding galaxies, nor for (ii) receding galaxies other than the universe expanding.

If we go back in time, then the galaxies would be closer together. Winding things back even more we get to a point 13 billion years ago when the whole universe is a single point, called a singularity.

Note that the ΛCDM model has trouble pinning down the age of the universe exactly. Various observations give different values for the Hubble constant, changing the age by about 2 billion years.[ii] This is not a huge problem. It's quite hard to figure some of this stuff out.

2. The Cosmic Microwave Background Radiation

If the Big Bang happened, as the universe was denser and more compact the temperature would be higher. It's expanding now and cooling. Looking back in time (which corresponds to looking farther into space), we can see the leftover radiation from the Big Bang. This is now in the microwave range and corresponds to a temperature of 2.73 Kelvin. Our observation of CMB matches the Big Bang predictions exactly.
Note that the CMB radiation is not from the actual instant of the Big Bang, but from the time when the universe had expanded enough so that it became transparent to light. This happened about 370,000 years after the Big Bang when hydrogen atoms finally became stable. We are unable to see anything before this time.

3. The hydrogen-helium abundance ratio.

One second after the Big Bang, as matter formed from energy (E = mc2), protons were favoured over neutrons by a ratio of 6:1. Some neutrons subsequently decayed to protons leading to a ratio of 7:1. When atoms were finally able to form and become stable (between 3 min and 20 min), essentially all of the neutrons were bound up in He-4 nuclei (2p + 2n).[iii] The left over protons formed H nuclei. This ratio of H:He is dependent on the characteristics of the Big Bang. The observations match the predictions of the theory.

Philosophical assumptions

The cosmological principle states that, on large scales, the Universe is **homogeneous** (looks the same at all locations) and **isotropic** (looks the same in all directions).

Cosmological **isotropy** has indeed been observed: the Cosmic Microwave Background radiation, emitted from everywhere in the Universe a few hundred thousand years after the Big Bang, is isotropic to one part in 100,000. In fact, it is so isotropic that it creates a problem called the Horizon problem.

Homogeniety cannot be proven. It is an assumption called the Copernican Principle. It assumes that all locations in the universe are the same. There is no centre. If we were at the centre of the universe, it would look isotropic, but it would not be homogeneous.

Many of the mathematical theories of cosmology are based on the assumptions of isotropy and homogeniety. A non-homogeneous universe would have a different type of Big Bang.

If we happened to be located near the centre of the universe, it would be such an unlikely coincidence that one could reasonably invoke some sort of special creation of the universe by an intelligent being. This is an anathema to modern cosmologists, so this possibility is discarded a priori.

Naturalism is the other philosophical assumption of cosmology. It assumes (though it cannot be proven) that everything we see can be explained by the laws of nature, by science. Naturalism rules out, a priori, any idea that the universe was specifically and carefully created by an intelligent being external to the universe. As we'll see below, this creates some serious problems since there are a number of observations that make an intelligent creator of the universe the most likely conclusion.

Problems with the Big Bang Model

Minor problems[iv]:

1. Nucleosynthesis

   The Big Bang model predicts the relative amounts of H-1, He-3 and He-4, but it has a significant problem with Li-7. Observed abundances of lithium-7 are three times less than expected. This is the "cosmological lithium problem"[v]

2. Red Shift

   There is evidence that the red-shift of quasars is quantized, i.e. exhibits some periodicity. [vi] If true, this would seriously mess up one of the foundations of the Big Bang. It's claimed that quasars are active galactic nuclei (AGN) powered by supermassive black holes. We don't actually know this. It's a hypothesis. Quasars are incredibly far away. There is also the possibility that they are associated with adjacent galaxies which have differing red-shifts. Research into this seems to be relegated to the realm of fringe or crackpot astronomy because of it's association with Creationism. One is not taken seriously if one tries to research something that goes against fundamental Big Bang theory.

   If quasars red-shifts are quantized, one plausible explanation is that they are in concentric rings around us, which means that we are close to the centre of the universe. As mentioned above, this idea is hostile to atheistic explanations of the origin of the universe.

3. Most of the universe is invisible and has never been detected.

   The ΛCDM model requires dark energy, and modern astronomy requires dark matter. These two are invisible and have never been detected.

   This means that the hypothetical composition of the universe is:

   - dark energy: 68-70%
   - dark matter: 25-27%
   - ordinary matter: 5%
     - neutrinos 0.3%
     - elements heavier than helium: 0.01%
   - photons: 0.01%
   - antimatter ?
   - black holes: 0.005%

   According to the best cosmological theories, we have to believe that we can only detect 20% of the matter in the universe and 5% of total constituents of the universe!

4. Age of Galaxies.

If galaxies are as old as we think, spiral galaxies should no longer exist. The arms should all be wound up ending as an elliptical galaxy. The solution to this is some sort of density wave theory that maintains this structure. This just puts off the problem as we have to explain the density wave origins and how they are maintained over aeons.

5. The magnetic monopole problem.

Maxwell's equations (as currently stated) say that magnetic monopoles cannot exist. However, quantum field theory and Grand Unified Theories predict that magnetic monopoles do, in fact, exist.[vii] The Big Bang theory implies that magnetic monopoles should have been formed early in the universe and persisted to today. Not only can we not create them, we cannot find any in the universe. All our magnets are dipoles with N and S poles. This might be more of a problem for QFT or GUT than for cosmology.

★ Significant Problems ★

1. What caused the Big Bang? All events in this universe have a cause, so what triggered this? There's no way to know this.

2. How can space, time, and energy be created? We have no idea. What are they created from? How do you create time (or space or energy) from a situation where there is no time?

3. **Singularities.** What happens in a singularity? The whole universe was in a singularity at $t < 10^{-43}$ s. None of our laws of physics work in singularities. We don't understand them at all.

4. **Initial Entropy.** The Second Law of Thermodynamics says that entropy always increases. (Entropy may roughly be understood to be disorder.) Therefore the Big Bang had to have incredibly low entropy since it's been increasing for 13 billion years.
   Roger Penrose[viii] has estimated the initial entropy of the universe to be 1 in 10^10^123. This is an incredibly large number, far far more than all of the individual particles (protons, neutrons, neutrinos, electrons) that exist in the universe. If I choose one subatomic particle in the universe and mark it some how, out of all of these particles, you then have to pick the correct one in order for the universe to have the right entropy, and you would have to do this a few times in a row. Does this seem likely to happen by chance? An intelligent being designing the universe seems more plausible.

5. **The fine-tuning problem**.[ix] Why are all of the physical constants so precisely set at values that allow atoms, molecules, stars, planets, life?
   The relation between the strength of gravity and the electromagnetic force cannot change by more that 10^{-39} otherwise all stars are either red dwarfs or blue giants … no life. If the strong nuclear force were just 2% greater, then all hydrogen would be converted to helium in the Big Bang. Stars would burn out quickly and there would be no water (since it needs hydrogen). If the proton to electron mass ratio were different, there would be no chemistry. It looks like someone has made the universe in a very specific way so that stars, elements, and life would be possible. Fine tuning is so precise – far more than what I've touched on here – that one cannot believe that it's mere serendipity.

6. **The Antimatter problem.** All our theories and all of our experiments show that when matter is made from energy, exactly the same amount of antimatter is formed. Yet this is not observed in the universe as a whole: there is hardly any antimatter. Why is there more matter than antimatter?

7. **The Horizon Problem.** If we look far out into space, billions of light years away, we see photons with the same temperature, roughly 2.725 degrees Kelvin. If we look in the opposite direction, we find the same thing. But how could this happen? These two regions are separated by distances that are greater than any signal, even light, could have traveled in the time since the Universe was born. There is no way that opposite sides of the universe should have exactly the same temperature. They are too far apart for thermal equilibrium to occur.

8. **Flatness problem.** Why is the universe so flat? Spacetime shows no curvature whatsoever. Out of all the possible positive or negative values for curvature, how did the universe end up with the unlikely choice of 0.000… ?

9. **Dark Energy**. The universe seems to be expanding at an accelerating rate. This deduction is based on the luminosity of type 1 supernovas. They are not as bright as they should be, but the data is very hard to measure. There is also not enough mass for the universe to be flat. The solution to both these problems is something called "dark energy", something that we have no physical evidence for. Dark energy can be abstracted by defining it as a property of space, some type of unknown energy that space has, defined by the cosmological constant Λ. The problem is that (i) Λ is hard to measure (if it even exists), (ii) theoretical values do not match the value that is needed for a flat universe.

10. **Dark matter.** The expanding universe was so uniform that there was not sufficient time to allow galaxies to form, as we observe them today. Yes, that's right: cosmology and the Big Bang cannot explain the formation of galaxies. The other issue is that the rotation of galaxies is fast enough that they should fly apart. There is not enough matter in galaxies to keep them together over long periods of time. The solution to both of these problems is dark matter. This invisible, and so far undetectable, substance has formed clumps in the universe. These clumps attract matter thus permitting the formation of galaxies.
    One could avoid the need for dark matter if one could come up with a modified theory of gravity (Newtonian and perhaps Einsteinian), but so far no one has been able to do this.

Attempted Solutions to these problems

As we've seen, two solutions involve imaginary undetectable substances: **dark matter** and **dark energy**. These explain problems with galaxies and expansion of the universe.

The fine tuning problem is more serious and intractable. The only way to explain it is to postulate **multiverses**, but that is abandoning science altogether. It's illogical and not merely wrong, it's not science at all. It's a belief system like religion.[x] Multiverses might also be able to explain away the initial entropy problem.

There is no solution anywhere to the antimatter problem.

Inflation is the theory that solves flatness problem, horizon problem, monopole problem. (Except that there is some dispute as to whether it solves the flatness problem or not). "Inflation" postulates that after the Big Bang started, it was expanding as normal, but then at 10^{-36} seconds inflation kicked in and the expansion was far faster than the speed of light. The universe grew massively.
At 10^{-32} seconds inflation stopped and disappeared and the universe continued on with its normal expansion.
The monopole problem disappears: we haven't detected any monopoles because the universe has expanded so much that monopoles are now so dispersed that we might never find one. The horizon problem is solved because the universe was in thermal equilibrium and then it had a massive rapid expansion. This allows places which are nowadays distant to still be in thermal equilibrium.

There is a lot of controversy about Inflation. Apparently, you can set whatever parameters you want and then get whatever answer you want. It's not one fixed theory, it's a whole family of theories that can fit any scenario you want. The problem with this sort of flexibility is that it loses all predictive power. While inflation "solves" some problems, it just creates others: what exactly is inflation? What caused it? What made it start at 10^{-36} seconds and what made it stop at 10^{-32} seconds? Where did the massive energy required come from? The very tight time-lines required by the inflation model become another sort of fine tuning that must be explained.

Summary

<table>
<tr><th>Cosmological Problem</th><th colspan="2">Proposed Solution</th></tr>
<tr><td>Galaxy formation</td><td>Dark matter</td><td rowspan="7">most likely to be found
↓
least likely to be found</td></tr>
<tr><td>Accelerating expansion</td><td>Dark energy</td></tr>
<tr><td>Monopole problem</td><td rowspan="3">Inflation</td></tr>
<tr><td>Flatness problem †</td></tr>
<tr><td>Horizon problem †</td></tr>
<tr><td>Fine tuning †
Initial entropy</td><td>Multiverse</td></tr>
<tr><td>Antimatter</td><td>No solution</td></tr>
</table>

† These issues/observations are not actually failures or contradictions in the Big Bang Theory.
The "problem" is that they imply an intelligent being who created this specific universe with these specific characteristics so that stars and life could form.

I should mention that while I have a background in physics, I am not a cosmologist and don't know the math nor the intricacies of the various theories. I've tried to explain the current situation as well as I can, but there may be errors. If so, please let me know so that I can fix them.

M. Harwood

References and Endnotes

i Cosmological Models http://hyperphysics.phy-astr.gsu.edu/hbase/Astro/cosmo.html and MIT's lecture series on cosmology: http://web.mit.edu/8.286/www/lecn18/

ii *"The generally accepted age of the universe is 13.7 billion years, based on a Hubble Constant of 70. Jee's team came up with a Hubble Constant of 82.4, which would put the age of the universe at around 11.4 billion years."*
From: "The universe may be 2 billion years younger than we think" CBC. Sep 12, 2019 https://www.cbc.ca/news/science/universe-younger-1.5281217
Observations from the James Webb telescope in 2022 have suggested that the universe might be 26.7 billion years old! https://academic.oup.com/mnras/article/524/3/3385/7221343

iii https://en.wikipedia.org/wiki/Big_Bang_nucleosynthesis#Neutron%E2%80%93proton_ratio

iv Note: The distinction between major and minor problems is subjective. I'm trying to reflect what one reads in the literature about problems with the Big Bang and Cosmology.

v For more information, start here: https://en.wikipedia.org/wiki/Cosmological_lithium_problem

vi Quasar References:
- https://arxiv.org/abs/2206.11897
- https://www.aanda.org/articles/aa/full_html/2020/11/aa30164-16/aa30164-16.html
- https://link.springer.com/article/10.1023/A:1025457030279
- https://astrobites.org/2022/05/11/missing-link-quasars/

vii An overview of magnetic monopoles: https://royalsocietypublishing.org/doi/10.1098/rsta.2011.0394
Here is an indepth explanation: https://web.mit.edu/8.286/www/lecn18/ln09-euf18.pdf

viii There might be more detailed links on this. http://therationalzealot.blogspot.com/2014/03/roger-penrose-on-entropy-how-did-he.html

ix For more information on fine tuning:
- https://crossexamined.org/fine-tuning-force-strengths-permit-life/
- https://www.cambridge.org/core/journals/publications-of-the-astronomical-society-of-australia/article/finetuning-of-the-universe-for-intelligent-life/222321D5D4B5A4D68A3A97BBE46AEE45#
- https://reasons.org/explore/publications/articles/where-is-the-cosmic-density-fine-tuning

x Dr. Sabine Hossenfelder "Why the multiverse is religion, not science" http://backreaction.blogspot.com/2019/07/why-multiverse-is-religion-not-science.html