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Catalog of Friedmann Universe Models

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1. Abstract

This thesis presents a comprehensive catalog of various Friedmann universe models. It details single and multiple component models, exploring their characteristics, evolution, and significance in cosmology. Through mathematical formulations and graphical representations, the dynamics of different universe configurations are analyzed, providing insights into the fundamental nature of the cosmos.

2. Introduction

The Friedmann equations describe the evolution of the universe under general relativity, providing a framework for understanding cosmological phenomena. This thesis catalogs various models of Friedmann universes, focusing on their physical implications and mathematical formulations [1,2].

3. Single Component Flat Universe Models

3.1. Matter Dominated Universe

The matter dominated universe is characterized by the density parameter:

$$\Omega_m = 1 \Rightarrow \Omega_r = \Omega_\Lambda = \Omega_k = 0$$

The scale factor evolves as:

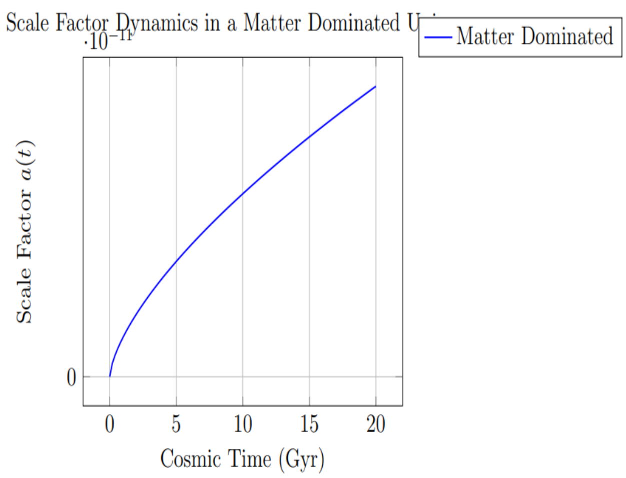
$$a(t) = \left(\frac{3}{2} H_0 t\right)^{2/3}$$

The age of a matter dominated universe can be calculated as:

$$t_0 = \frac{2}{3H_0} = 9.32 \text{ Gyr}$$

3.1.1. Plot

Figure 1: Scale factor evolution for a matter dominated universe. The blue curve shows the evolution of the scale factor over time, indicating a polynomial growth characteristic of matter dominance.



3.2. Radiation Dominated Universe

In a radiation dominated universe, the density parameter is:

$$\Omega_r = 1 \Rightarrow \Omega_m = \Omega_\Lambda = \Omega_k = 0$$

The evolution of the scale factor is given by:

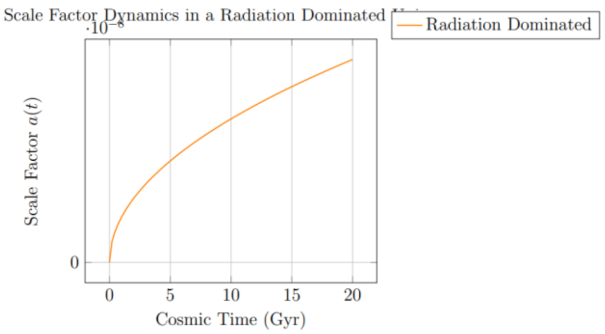
$$a(t) = (2H_0 t)^{1/2}$$

And its age is:

$$t_0 = \frac{1}{2H_0} = 6.99 \text{ Gyr}$$

3.2.1. Plot

Figure 2: Scale factor evolution for a radiation dominated universe. The orange curve illustrates the square root dependence on time, reflecting the rapid expansion in the early universe when radiation was the dominant form of energy.



3.3. Dominated Universe (de Sitter)

For a universe dominated by a cosmological constant:

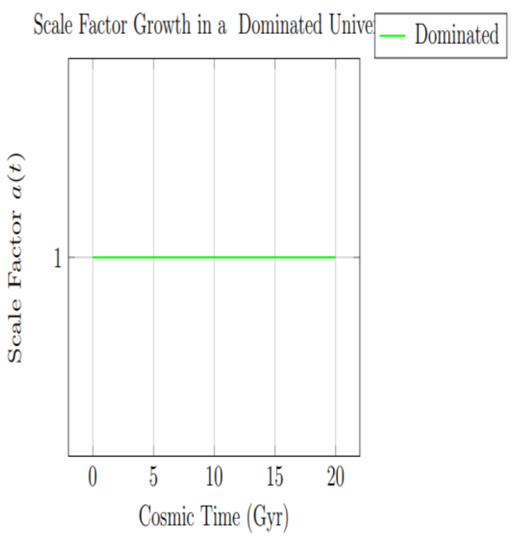
$$\Omega_\Lambda = 1 \Rightarrow \Omega_m = \Omega_r = \Omega_k = 0$$

The scale factor evolves as:

$$a(t) = e^{H_0 t}$$

3.3.1. Plot

Figure 3: Scale factor evolution for a dominated universe. The green curve shows exponential growth, indicative of a universe dominated by dark energy, leading to accelerated expansion.



3.4. Empty Universe

An empty universe is characterized by:

$$\Omega_k = 1 \Rightarrow \Omega_m = \Omega_r = \Omega_\Lambda = 0$$

Its scale factor is described by:

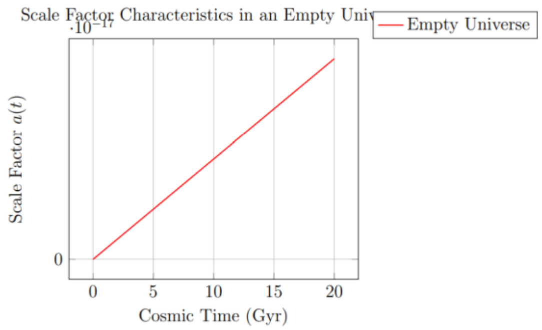
$$a(t) = H_0 t$$

With an age of:

$$t_0 = \frac{1}{H_0} = 13.98 \text{ Gyr}$$

3.4.1. Plot

Figure 4: Scale factor evolution for an empty universe. The red curve displays a linear relationship with time, indicating a universe devoid of matter and radiation.



4. Multiple Component Universe Models

4.1. Matter-Curvature Models

The evolution of the scale factor in matter-curvature models is expressed as:

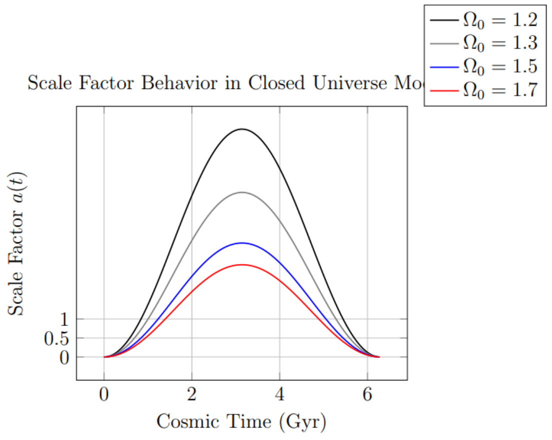
4.1.1. Closed models ($\Omega_0 > 1$)

For closed models, the scale factor evolves as:

$$a(\theta) = \frac{1}{2}\frac{\Omega_0}{\Omega_0 - 1}(1 - \cos\theta)$$

4.1.2. Plot for closed models

Figure 5: Scale factor evolution for closed models. Different curves correspond to various values of Ω_0, illustrating how curvature affects the scale factor and time relationship. Higher Ω_0 values lead to more pronounced oscillatory behavior.



4.1.3. Open models ($\Omega_0 < 1$)

For open models, the scale factor is given by:

$$a(\eta) = \frac{1}{2}\frac{\Omega_0}{1 - \Omega_0}(\cosh\eta - 1)$$

5. Conclusion

This catalog of Friedmann universe models provides a framework for understanding the evolution of the cosmos under different conditions. Each model presents unique insights into the structure and fate of the universe, highlighting the complex interplay of matter, curvature, and cosmological constants.

6. Acknowledgments

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7. References

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2. Lemaitre G. (1927) A homogeneous universe of constant mass and increasing radius. Monthly Notices of the Royal Astronomical Society. 91: 483-490.