Cosmology Research Summary (Spring 2019):
(Research advisor: Dr. Sharmanthie Fernando)

  In this research I looked at how the density and radiation pressure of the universe varied with time. I used Mathematica to plot these variables against time. The equations I used were from the paper *The Van Der Waals Fluid and Its Role in Cosmology (*Jantsch*).*

  First, I had to decide what geometry of the universe I was going to assume. There can be 3 different types of geometry, k, of the universe. If $k = 0$, then the geometry of the universe is flat, so Euclidean geometry operates under normal rules; if $k > 0$ the universe is spherical and closed; and if $k < 0$ the universe is open and hyperbolic. I assumed a flat universe, so our k value was 0 (Liddle).

  I used the Friedmann equation to relate the density (ρ), and curvature (k): $\left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G}{\rho} - \frac{k}{a^2}$, where a is the scale factor, and tells us how physical separation grows over time. I used a scale factor of $a(t) = Ae^{\frac{t}{3}},$ where A is some constant; I chose 1. The $\left(\frac{\dot{a}}{a}\right)$ term is referred to as Hubble's parameter, also a function of time. G is newtons gravitational constant, and ρ is the density of the material of the universe (Jantsch, Liddle).

  I used the fluid equation to determine how the density of the material of the universe was changing with time, $\dot{\rho} + 3\frac{\dot{a}}{a}\left(\rho + \frac{p}{c^2}\right)$. Where $\dot{\rho}$ represents the time derivative of density, ρ represents density, and p represents pressure. We can find $\dot{\rho}$ by assuming that there is a unique pressure associated with each density, this is known as the equation of state: $p = p(\rho)$. For my model I used the following equation of state: $p = -3\rho^2$. After I plotted these in Mathematica, I found that the density and pressure varied with time accordingly. The pressure of the material went up, and the density of the material of the universe went down as time went on (Jantsch, Liddle). I presented this research during the Spring Semester of 2019 at NKU's Celebration of Student Research and Creativity; I also presented it during the Fall Semester of 2019, at Kentucky Academy of Science's (KAS) annual conference.