Phys-4200 Final Project

Valeria Pena

Cal State LA

May 2019

1 Optimization: Minimizing Travel Time

1.1 Introduction

Optimization in Physics is part of Classical Mechanics; although, it can be used as a tool in other fields of Physics. Some of the exercises that one approaches in Classical Mechanics regarding optimization, is how to minimize the time or distance to reach a certain point. In upper division Classical Mechanics, optimization is approached using the Lagrangian and Hamiltonian which I will get into more detail in the theory section. Furthermore, optimization is used to maximize or minimize the efficiency of time, distance, power, capacitance, volume, etc.

1.2 Theory

Optimization as a concept or theory is too complex. Optimization is more of a mathematical discipline that can easily be used in any field like, Physics, Engineering, Economics and so on. Optimization what it does is that it maximize or minimize a function relative to a situation. As I mentioned previously, in Classical Mechanics optimization is a recurring topic and as you approach an upper division Classical Mechanics class the method of solving these optimization problems changes. Lagrangian Multiplier and the Hamiltonian are the new technique used to solve optimization problems. Usually what we try to optimize is a path or a system. The Lagrangian states that when you try to optimize time, the shortest distance is not the way to to go.

1.3 Experiment

I use the path that is shown in figure 1 to minimize the time traveled. By using geometry, I found an equation for the time swimming and the time running,//

$$T_s = y/3 \tag{1}$$

$$T_r = x/8 \tag{2}$$

Where $y = \sqrt{(6-x)^2 + 4}$ and x is the unknown.The function for the total time is

$$T(x) = x/8 + \sqrt{((6-x)^2 + 4))}/3 \tag{3}$$

Using scipy.optimization.fmin I was able to find the minimum time that it would take to reach the Island and that is 1.37 hours.

1.4 Figure

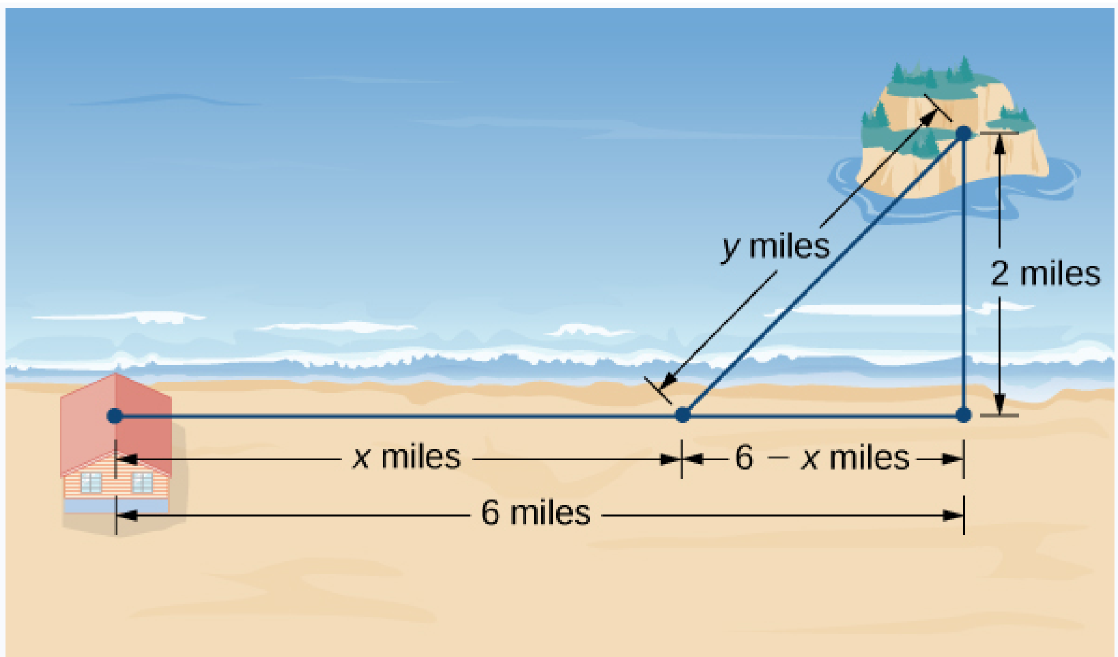

Figure 1:

1.5 Conclusion

Optimization is a mathematical method that is commonly used in different fields as a means to minimize or maximize. In physics, we use the Lagrangian Multiplier and the Hamiltonian to optimize the a path or system. Furthermore, the python's scipy.optimize is a great tool to solve optimization problems like the particle in the box from Quantum Mechanics.

2 Project 2: Nucleosynthesis

2.1 Introduction

Nucleosynthesis is the process in which new and heavier elements are produced from precursor lighter elements, primarily protons, and neutrons. A minute after the Big Bang, all the anti-matter had been destroyed by annihilation with matter. What it was left of the matter was in the form of electrons, protons, and neutrons. As time passed by, the temperature of the Universe dropped and the protons and neutrons were allowed to undergo fusion to form heavier a nuclei.
Big Bang nucleosynthesis is confined to the first few minutes of the Universe. At this stage, the Universe was still hot to be part of the fission process. In this process, the first chemical elements were formed: hydrogen, helium and some traces of lithium.
In the second stage of the nucleosynthesis process in the Universe, stars took responsibility for the nucleosynthesis of elements beyond helium known as "metal" by astronomers. They are known as "metals" because of their heavier atomic mass although, not all these elements categorize as metals today.
Some of the major types of nucleosynthesis are Big Bang nucleosynthesis, Stellar nucleosynthesis, Explosive nucleosynthesis, Cosmic ray spallation, and Neutron star collision. Each of this nucleosynthesis contributed to the majority of the population of elements in the Periodic Table of Elements. There are some other elements in the periodic table that were produced by radioactivity.

2.2 Theory

The process of nucleosynthesis started in the early stage of the Universe when it was very dense and hot. This was after Baryogenesis were matter became more abundant than anti-matter. As the Universe expanded, the temperature of the Universe dropped sufficiently, stables protons and neutrons were formed. The number of protons in this stage of the Universe was greater than the number of neutrons since their higher mass resulted in the spontaneous decay of neutrons to protons. After the BNN, most matter was hydrogen, helium-4, deuterium, helium-3 and some traces of lithium-7[1].
The rest of the atoms were made in the stars by nucleosynthesis. Nuclear reactions occur in the core of stars giving them the energy to shine. There are several nuclear reaction processes that take place in the stellar nucleosynthesis like triple alpha, s-process, proton-proton chain, CNO cycle and fusion. As a result of the fusion of hydrogen and helium, carbon, nitrogen, oxygen, iron, cobalt, and nickel were produced. Most of these elements end up trapped in the interstellar medium when giant stars enter the red phase.
ses are responsible for the production of nuclei with an atomic mass that is beyond 250. Neutron star Merging and Explosive Nucleosynthesis are main sources of the r-processes [2]. R-processes require large neutron fluxes that are associated with catastrophic events like the ones in Neutron Star Merging and Exploding stars.

2.3 Experiment

To analyze the processes that contributed the most to the population of elements in the Universe, I used Pandas. Pandas is built on top of Numpy and is an incredible tool for data analysis.I imported a data table[1] that contained all the ratios of elements that are contributed to different Nucleosynthesis processes. From the table, I chose the data for each process that contributed the most the production of elements and also to the production of the lightest elements in the periodic table.
From the plots below, we can see that in the BBN process, only three elemets were produced as spected, hydrogen, helium and a small portion of lithium. In between the Explosive nucleosynthesis and Low-Mass Dying Stars processes, a significant portion of the elements that we know today were produced. Furthermore, in the Low-Mass Dying Stars, light elements are also produced, along with heavier elements.

2.4 Figure

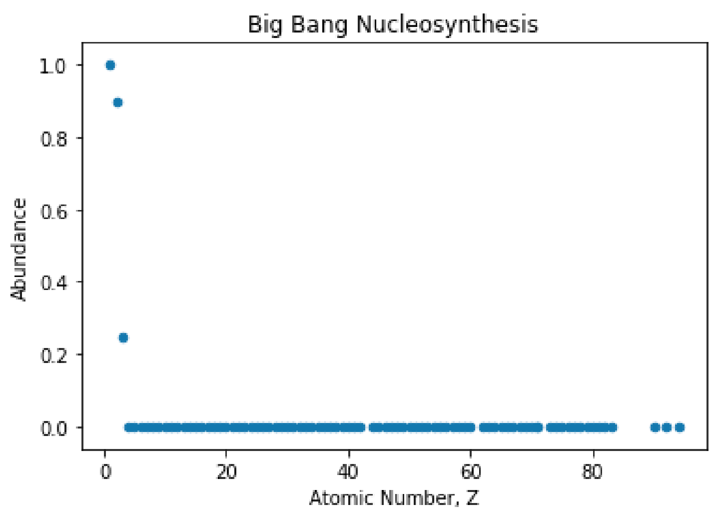

Figure 2: Ration of abundant elements after BNN, Hydrogen, Helium and Lithium.

2.5 Conclusion

Nucleosynthesis has two major eras of new element creation in the Universe. The first era is the being the Big Bang nucleosynthesis where light elements were produced within the first 20 minutes of the Universe existence. The second era is the Stellar nucleosynthesis which lasted for about a billion years. In the Stellar nucleosynthesis heavier elements known as "metals" by Astronomers

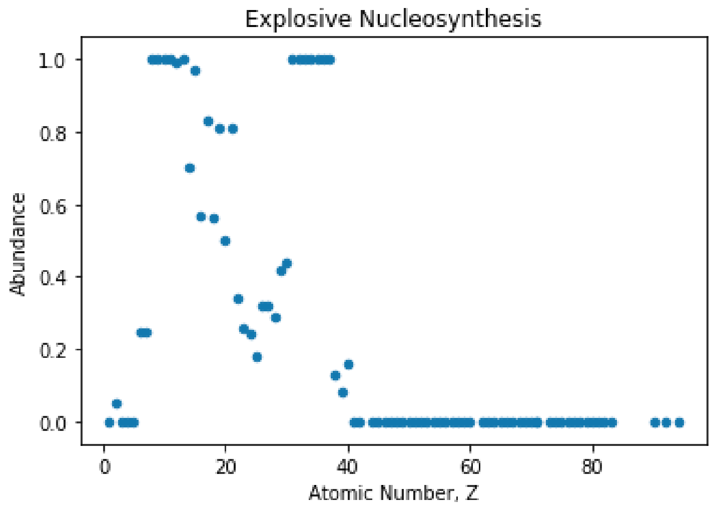

Figure 3: Elements produced after the process of Explosive Nucleosynthesis.

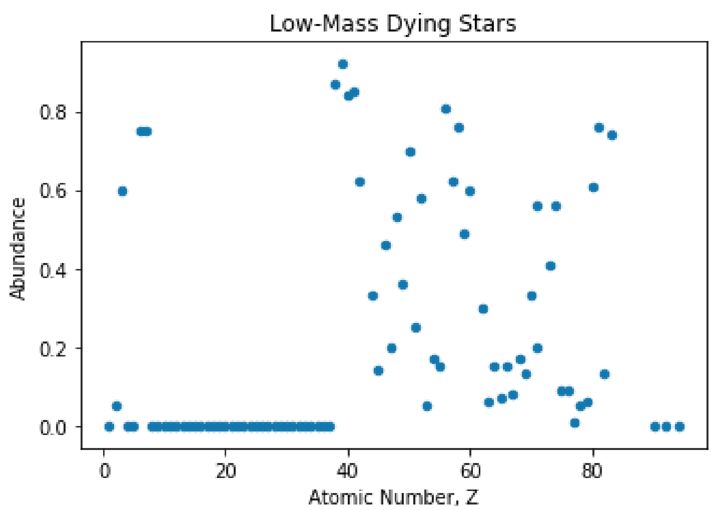

Figure 4: Ratio of abundant elements after Nucleosynthesis of Low-Mass Dying Stars

were produced. The population of the periodic table as seen in figure 5, comes mainly from the Explosive nucleosynthesis and the Low-Mass Dying Star processes. The population of the periodic table is a process that took billions of years to complete. Although, stellar nucleosynthesis is a process that still continuous but is not too noticeable since it is really slow.

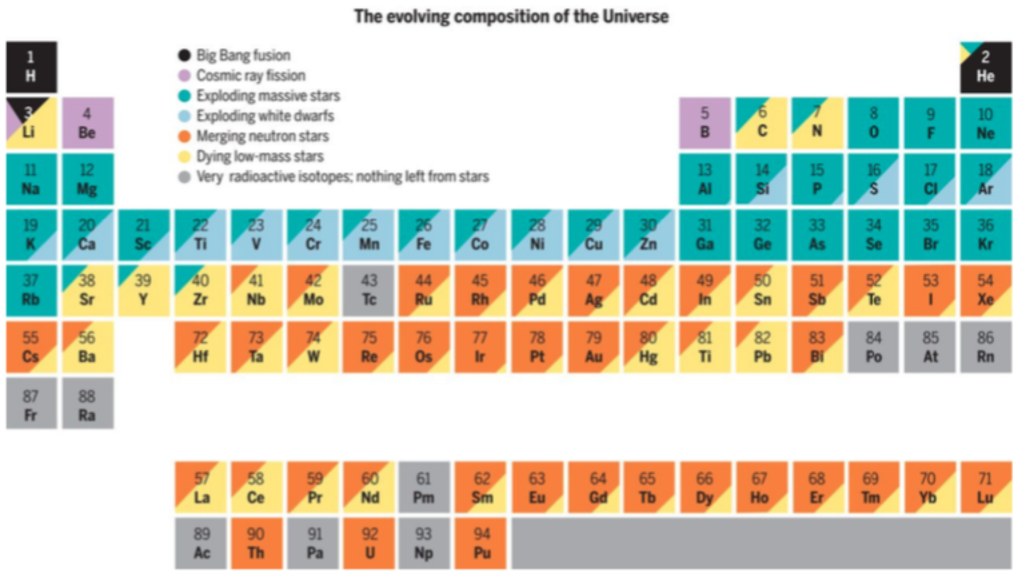

Figure 5: The periodic table of elements shows the origin of most of the elements that we have in our Solar system [1]

References

[1] Jennifer A. Johnson. Populating the periodic table: Nucleosynthesis of the elements. *Science*, 363(6426):474–478, 2019.

[2] N. Langer, J. Fliegner, A. Heger, and S. E. Wòosley. Nucleosynthesis in rotating massive stars. *Nuclear Physics A*, 621(1-2):457–466, 1997.