Looking for Dark Matter in the Rotation Curves of the Hubble Tuning Fork Galaxy Diagram

Abstract:

I will obtain an understanding of galaxy formation through analysis of galaxy rotation curves in spiral, elliptical, and lenticular galaxies while accounting for dark matter. I will research galaxy rotation curves different types of spiral galaxies and investigate different mathematical models of galaxy rotation. Once this basic understanding is achieved I will obtain an understanding of java programming with genetic algorithms. If necessary I will modify the software, to better fit galaxy rotation. If time is available I will see if this process can be done with lenticular galaxies. It is unclear that this technique will work with elliptical galaxies since they are of a different rotation pattern, but this will also be investigated.

Introduction:

Galaxy formation is a rapidly growing area of interest for astrophysicists. It is so interesting because there is so much unknown, which means there is a lot still to discover. It is a very complex study in which many people do not have an understanding of as an undergraduate. In this project I would like to obtain a basic understanding of galaxy rotation curves (J.Q. Feng and C.F. Gallo, 2011) of the galaxies found within the Hubble Tuning Fork galaxy diagram and how to analyze them.

Related Work:

Galaxy rotation curves are a graphical analysis obtained from the magnitude of the orbital velocities of visible stars in a particular galaxy and their radial distance from the galaxies center, typically depicted with a scatter plot. To accurately do this, I must obtain a basic understanding of dark matter and how it affects the observed rotation curve to make it differ from the theoretical rotation curve. In spiral galaxies ordinary matter like stars and planets provide the primary mass. Newton's law of universal gravitation

$$F = G\left(\frac{m_1 m_2}{r^2}\right) \tag{1}$$

and Kepler's orbital laws define how the stars orbit the center of the galaxy. Moving radially outward from the core, the rotation speed increases as more mass is added to the growing volume. Moving further out on the disk, the volume grows but the mass of the ordinary matter does not which should decrease the rotational velocity. During this analysis of the rotation curves there will be a surprising flattening off of the rotation curve which means some mass entity such as dark matter is present. How much dark matter, and how it is distributed will be studied with various model parameters. This model can be created with different tunable parameters that need to be adjusted. If the values appear to be reasonable then it is a good model if they do not then it will need to be readjusted. A simple change-of-parameter model is used with Excel and slider values similar to that used in the University Physics 2 Simple Harmonic Motion lab, but it would be very time consuming and difficult to obtain a desirable result because it is less accurate. Depending on the number of parameters good solutions could be overlooked. There are several different parameters that need to be adjusted to obtain a model containing ordinary matter and dark matter to match the existing rotational curves.

While analyzing spiral galaxy rotation curves, I will implement the use of genetic algorithms, (P. Charbonneau, 1995) and determine if genetic algorithms will work for elliptical and lenticular galaxies. Genetic algorithms are a quick computational approach using evolution through natural selection. They are often used in computer science, artificial intelligence and computer-aided engineering design but not as often in physical sciences. In this project they will be used as a quick but effective approach to solving mathematical equations. Genetic algorithms can be used to search the parameter space, to help fit the model to the data. This parameter space is a set of all possible combinations of values contained in the galaxy. The genetic algorithms is modeled after natural selection, so with manipulations and gene-swapping we are able to evolve solutions that are more vigorous based on chosen fitness criteria. These techniques have been used successfully when searching multiple planet solar systems, determining the period and distance information from a complex radial velocity signal from the planet influences on the host star. To understand and effectively use genetic algorithms I will learn some Java programing and modify some existing programs.

In understanding galaxy rotation curves I need to obtain a theoretical and mathematical understanding (J.Q. Feng and C.F. Gallo). This is one way a spiral galaxy can be illustrated mathematically using the equation

$$V(r) = 1 - e^{\frac{-r}{R_c}} \qquad (2)$$

where V(r) is measured in relation to the maximum orbital velocity V_0, using the parameter R_c as the core of a galaxy. In understanding genetic algorithms, I will need a theoretical and experimental understanding. These techniques will work for spiral galaxies but I need to investigate if it will work for lenticular galaxies. I will not be analyzing elliptical galaxies in this project as they are much more complex.

Materials and Methods:

The materials needed for this project are: LTU laptop, stable internet connection, external hard drive to back up data. Methods use are mathematical analysis with the application of genetic algorithms.

Sustainability:

This project is very sustainable since everything is being done through the use of computers including: file sharing using Google Drive, electronic feedback using PDF Annotator, e-mail and Facebook. Utilizing genetic algorithms also limits resources since I will be doing limited calculations manually on paper.

Budget:

This project will require a budget of $0.00. If I find conferences I would like to present at and would need funding to do so I will put together a budget of expenses needed to attend the conference.

Timeline:

A. Research related journal articles.
B. Investigate current theories on rotation curves with ordinary and dark matter.
C. Research genetic algorithms and uses in astronomy and astrophysics.
D. Modify genetic algorithm programs to search for desired parameters.

E. Obtain databases of radial velocity data sets. This may be possible through networking with astronomers who presented at the 6th Annual Midwest Conference for Undergraduate Women in Physics that Dr. Scott, Jamie MacLennan and I attended in January, 2013.

F. Gather data sets for rotation curves.

G. Run genetic algorithm programs to search for parameters to find best fit.

H. Ideally, present project and conferences.

Key Personnel:

The key personnel in this project are Dr. Scott Schneider and Dane Falberg. Dr. Scott Schneider will be my faculty advisor. Dane Falberg is creating genetic algorithm software which I will be able to modify to fit galaxy rotation. We share resources on Google Drive through a Dr. Scott shared folder.

References

J.Q. Feng and C.F. Gallo, Res. Astron. Astrophys. **11** 1429-1449, 1 (2011).

P. Charbonneau, Astrophys. J. Suppl. Ser. **101** 309-334, 1 (1995).

"I have neither given nor received unauthorized aid in completing this work, nor have I presented someone else's work as my own."

Signature: Signature: Cera Rettig ____________________

Ceré L. Rettig Projected Research