Simulating Dark Matter in the Universe

Daus Carmichael, Sebastian Brumm, Hannah Campbell, Gary Maloncon
Chapman University
Schmid College of Science and Technology

What is Dark Matter?

The answer to this question is that nobody really knows, even though dark matter and dark energy make up the majority of our universe. Dark matter cannot interact with light or radiation, rendering it "invisible." We only know it exists because in theory, the expansion of the universe should be slowing down, but it's speeding up instead. The gravitational behavior of the universe does not align with the amount of matter we've detected inside of it, so we know that there must be other undetectable matter present, causing this behavior.

The Simulation

While there are not enough resources available to us to completely solve the properties of dark matter, we can make our own tools to help. We created a small, very rough simulation of our universe that has several variables that are modifiable. Using this, we can input our hypothesis of dark matter being negative mass and compare the data we get to actual data that has been recorded and released by NASA.

Results

The simulation was run given the initial conditions of Messier 33. The mass and kinematics were found in the paper by Kam, Carigan, Chemin et al. Using the surface density equations for the distribution of luminous mass where calculated and created. The simulation in this context did as expected, The galaxy rapidly expanded in the outer edges where the measured velocity is greater than the expected velocity. The masses will reach a critical point and after reaching, not be held in orbit of the galaxy. The future generations of mass distributions will include dark matter candidates. Only the first simulation was able to finish and all others ran out of computational power.

Going Forward: What Can You Do?

Upon completion of our experiment, further research we may participate in is citizen science. Citizen science is the gathering and analyzing of scientific data by members of the public most often associated with collaborative projects. One of the ways we can accomplish this is with the CREDO Detector App, created as a part of the Cosmic-Ray Extremely Distributed Observatory project. This dark matter focused research was founded in 2016 and offers membership to the program with the goal of more eyes on the sky, to detect cosmic rays and contribute to the discovery of dark matter. Phone cameras are able to detect particle cascades, and this app recognizes and links your data with a web of other citizen scientists who are participating. We intend to continue to contribute our knowledge to the scientific community so that we may one day know the true origin of dark matter.

Our Project

There are a few theories of what dark matter could be, the main one being that it is non-baryonic matter, which is not made up of the same sub-particles as "normal matter". This includes axions, neutrinos, and neutralinos; all of which could make up dark matter. If dark matter is baryonic, then it's theorized that it's found in Massive Compact Halo Objects such as black holes, neutron stars, and brown dwarfs.

Another theory, which we are focusing on in our project, is that dark matter is negative matter that generates negative gravity.

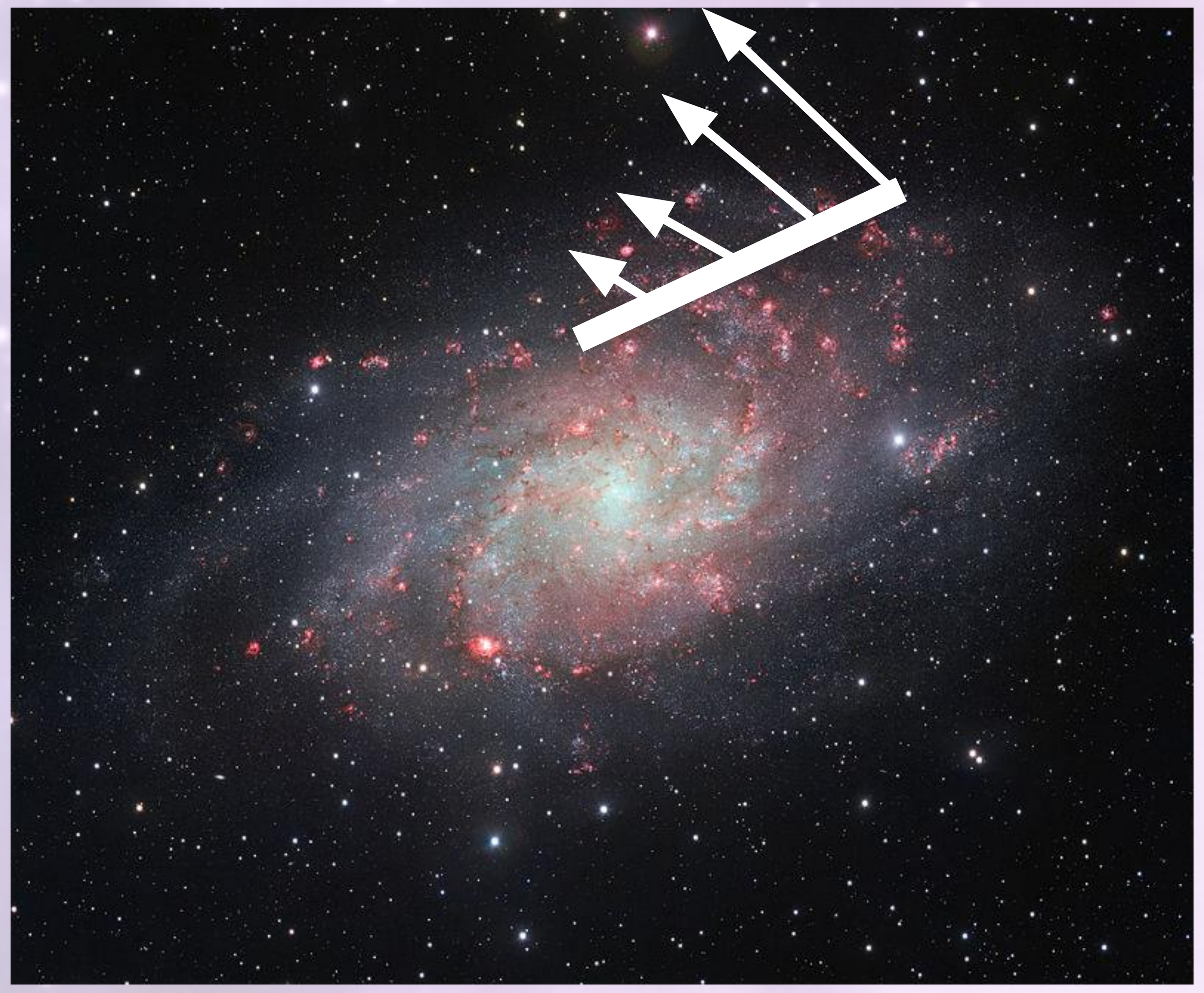


Figure 1

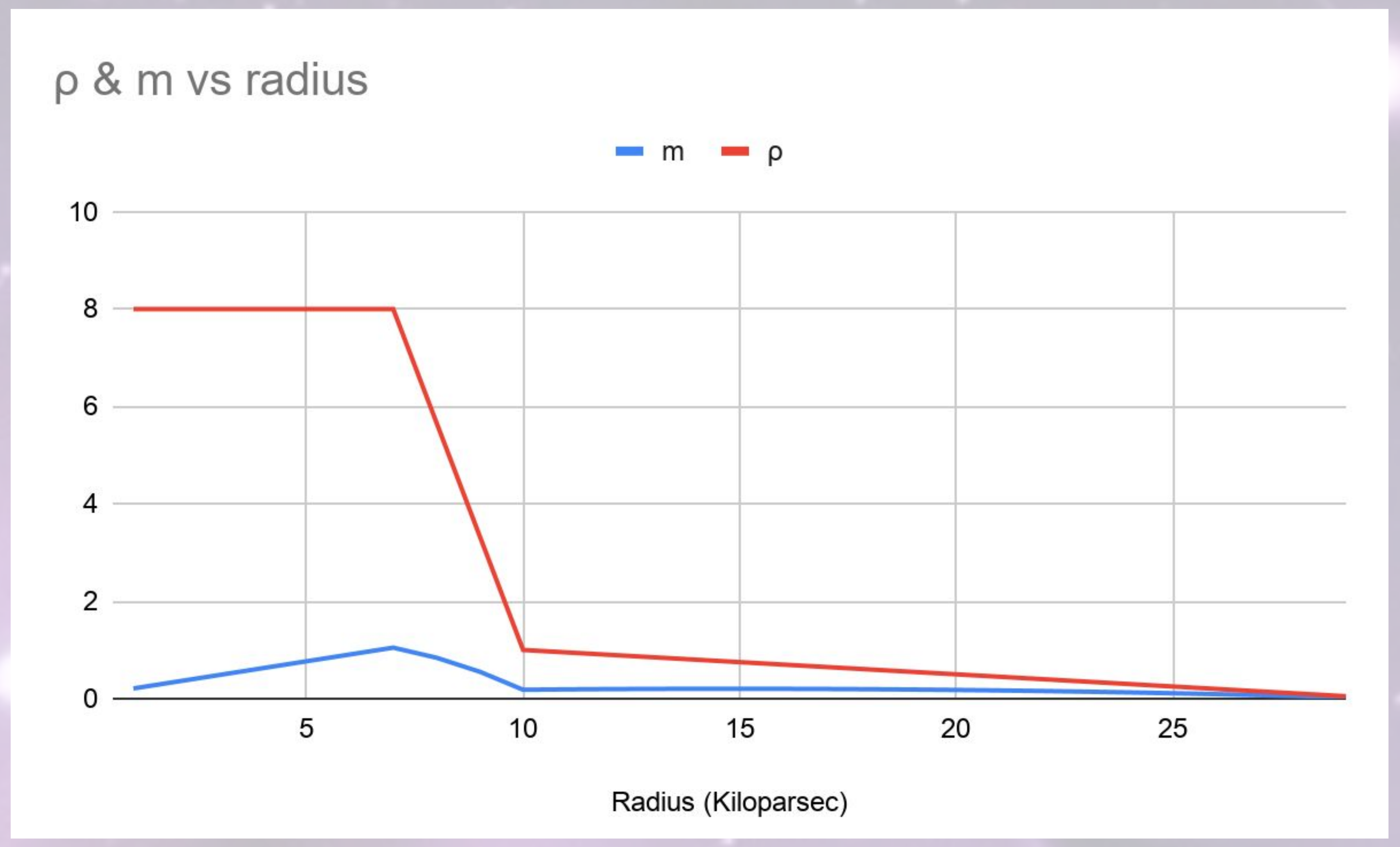
Velocity at various radial distances

These values are the goal of the simulations analysis function to return with. Each point will will have a measurement and for 24 various intervals an average velocity will be given. An ideal candidate, yet to be found, will closely match the expected velocities.

Figure 2

Mass Distributions used in Simulation

The blue line represents the given mass from Messier 33 without dark matter taken into account. The other lines are for various generations of mass. The best candidate is a heavy negative ring at 30 kpsc. This is derived solely in a 1-D expression but was unable to be verified in the simulation. P is surface density, m is mass.



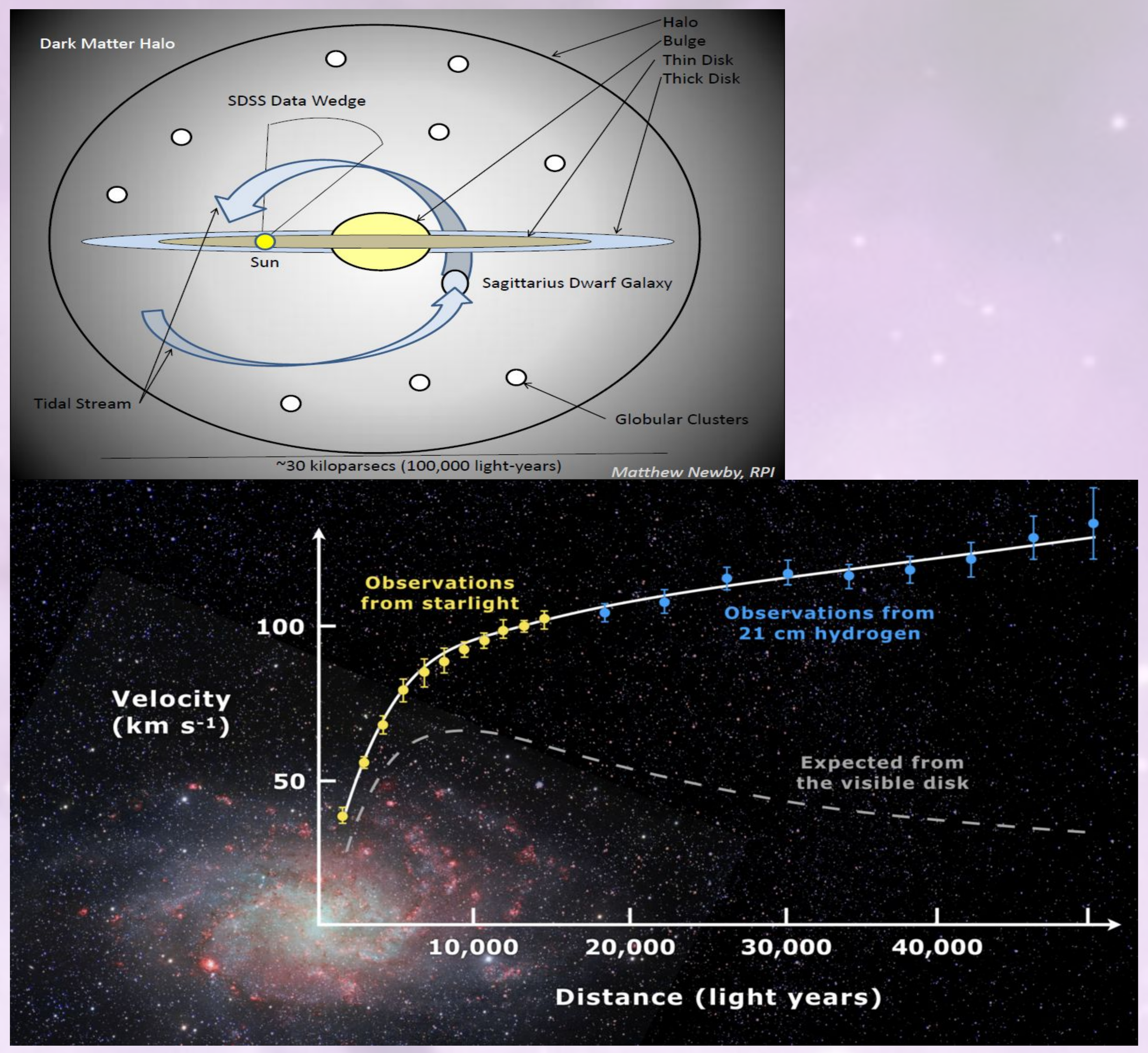


Figure 3 & 4

Dark Matter Halo diagram

The Diagram show that there is a halo surrounding the galaxy comprised of dark matter. We used this model to determine candidates that could apply to this region of space. Figure 4 shows a graph of the expected(dashed line) and measured(solid line) overlayed on the galaxy being measured, Messier 33. This is a different representation of the same data in Figure 1.

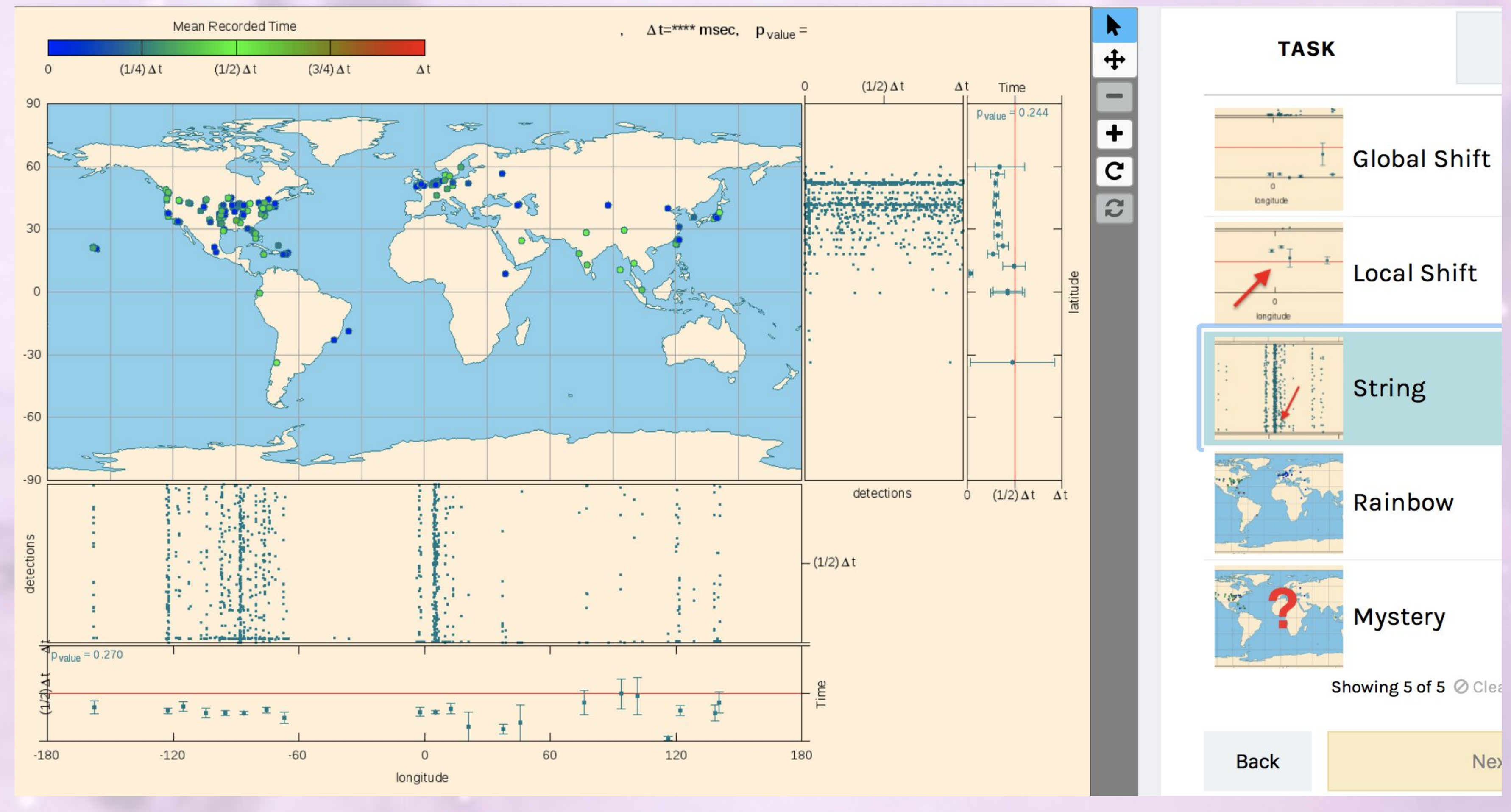


Figure 4

Citizen Science Data Analysis

CREDO's website shows screens of data that the user can help analyze. By identifying certain patterns in the data, the user is helping train computers to recognize these patterns.

References

https://www.zooniverse.org/projects/credo/dark-universe-welcome/classify
https://science.nasa.gov/astrophysics/focus-areas/what-is-dark-energy
https://milkyway.cs.rpi.edu/milkyway/science.php
https://iopscience.iop.org/article/10.3847/1538-3881/aa79f3/pdf
https://en.wikipedia.org/wiki/Galaxy_rotation_curve