MODELING THE EXPECTED ROTATION CURVE OF THE MILKY WAY GALAXY WITHOUT DARK MATTER

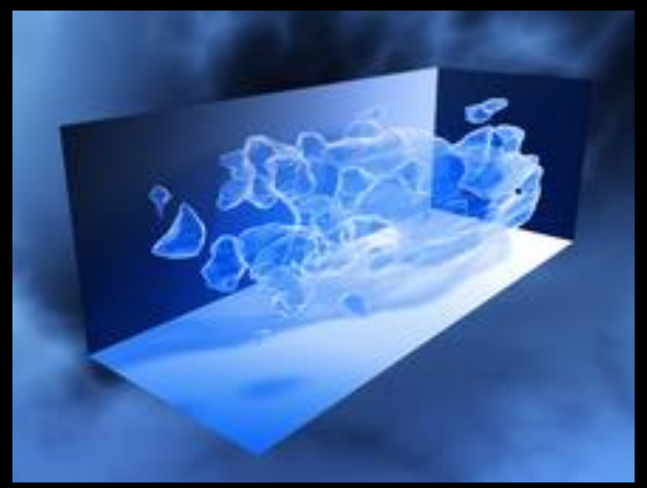
TATIANA DAVIDSON BAJANDAS

ABSTRACT

I constructed a model of the rotation of the galaxy using a simple bulge model. This model yields the curve expected without the gravitational effects of dark matter. Two mathematical models were used, one for the rotation of an object inside the bulge of the galaxy and one of an object outside of it. Distinctly lower rotational speeds for objects with large radii are observed, an attribute which conflicts with collected data, strongly supporting the existence of dark matter in the outer reaches of our galaxy.

WHAT IS DARK MATTER?

Matter that does not interact with the electromagnetic field, making it "invisible." It's composition is yet unknown. Candidates include WIMPs, MACHOs, and axions. It makes up 27% of the galaxy. [6]

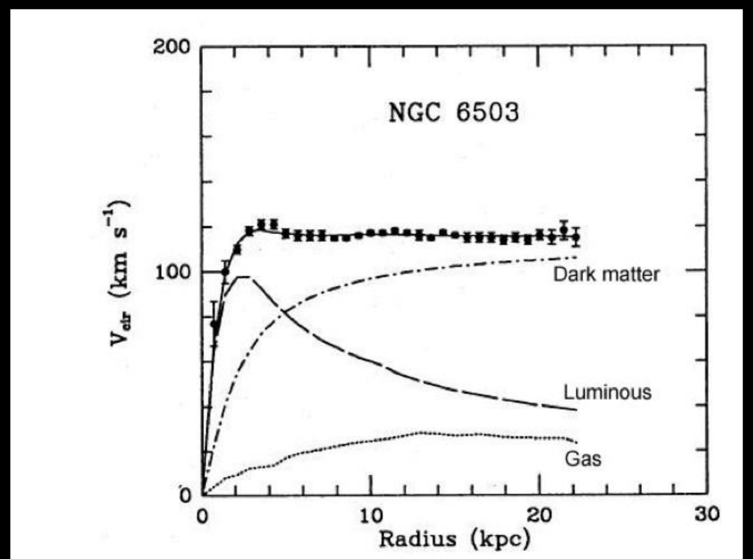


"Hubble Maps the Cosmic Web of "Clumpy" Dark Matter in 3-D" (Press release). NASA. 7 January 2007.

WHAT DOES A FLAT ROTATION CURVE MEAN?

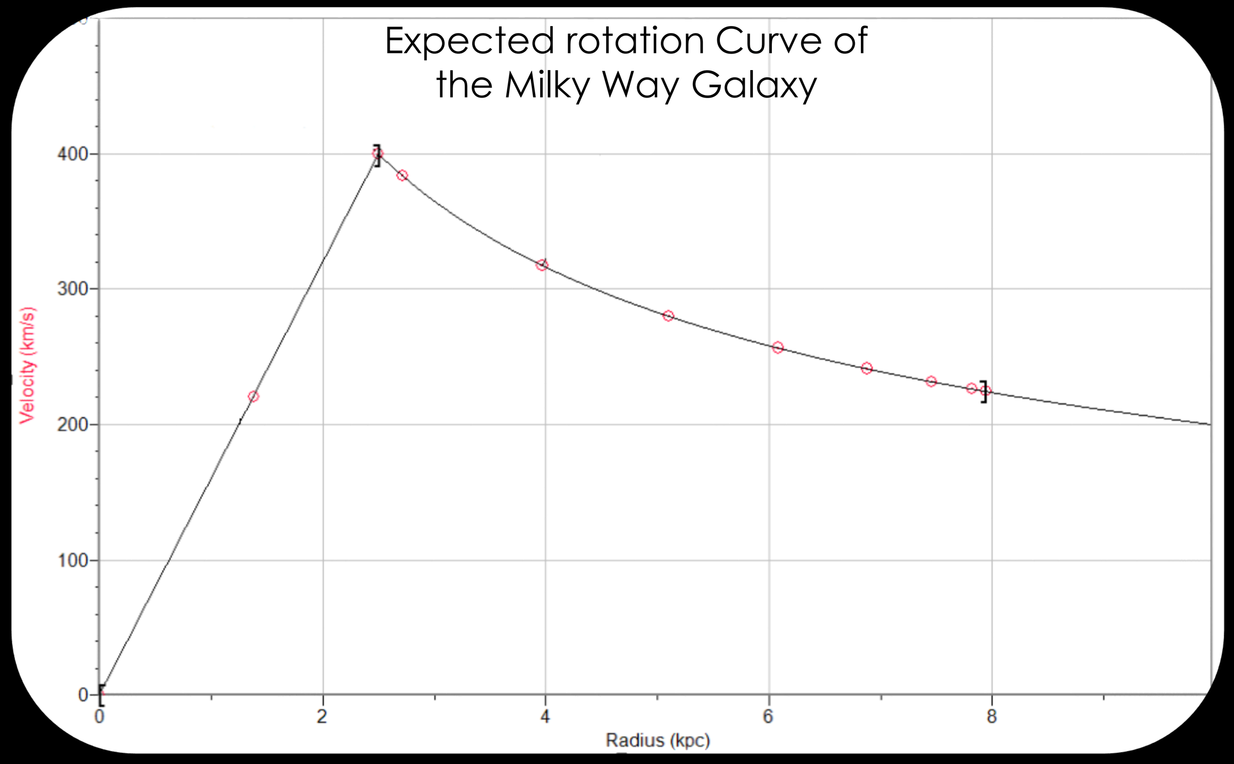
Indicates more mass in the galaxy exerting a gravitational force

Expected rotation curve (luminous curve) shows the speeds at which objects would rotate without that extra mass (dark matter) [5]



K.G. Begeman, A.H. Broels, R.H. Sanders. 1991. Mon.Not.RAS 249, 523.

RESULTS



MATHEMATICAL MODEL – WITHIN THE BULGE

Use a ratio expression to find an expression for the bulge section

$$m = DV$$

$$\frac{m_{bulge\ section}}{M_{entire\ bulge}} = \frac{V_{bulge\ section}}{V_{entire\ bulge}}$$

$$m_{bulge\ section} = \frac{\frac{4}{3}\pi r^3}{\frac{4}{3}\pi R^3} \times M_{entire\ bulge}$$

$$m_{bulge\ section} = \frac{r^3}{R^3} \times M_{entire\ bulge}$$

Plug in this expression for the mass of the bulge into $\frac{GmM}{r^2}$*, where m is mass of the star and M is mass of the bulge section, and get:*

$$\frac{Gm_{star}\left(\frac{M_{entire\ bulge} \times r^3}{R^3}\right)}{r^2} = \frac{m_{star} \times v^2}{r}$$

$$GM_{entire\ bulge} \times r^2 = v^2$$

$$\boxed{v = \sqrt{\frac{GM_{entire\ bulge}}{R^3}} \times r}$$

MATHEMATICAL MODEL – OUTSIDE THE BULGE

$$\sum F = ma$$

$$\sum F = \frac{mv^2}{r}$$

$$\frac{GmM}{r^2} = \frac{mv^2}{r}$$

$$v^2 = \frac{GM}{r}$$

$$\boxed{v = \sqrt{\frac{GM}{r}}}$$

Functions of the Model

Using a bulge radius (R) of 2.5 kpc, the model predicts rotation of objects with r < R as a linear function

$$v = 159.8r$$

For objects with r > R, object rotation is predicted by the function

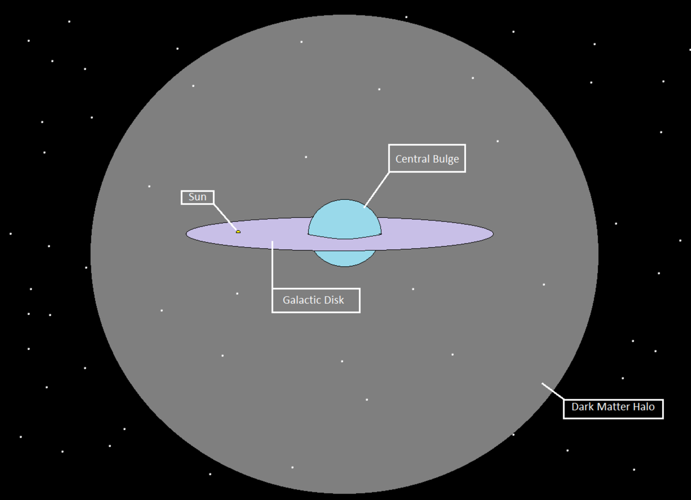
$$v = 632.418 \times r^{-0.5}$$

EXPLANATION OF MODELS

- For objects inside the radius of the bulge, a proportionality method is used comparing a sphere created using the radius of the given object and the whole bulge sphere
- For objects outside of the bulge, Newton's shell theorem can be used to treat the sphere as a single point mass

IMPLICATIONS

The difference in rotational speeds at large radii indicates that at these large radii there is a gravitational force accounted for by dark matter. The large radii at which this phenomena occurs indicates that the dark matter likely exists in a halo at the edges of the galaxy [1]



REFERENCES AND ACKNOWLEDGMENTS

References:

1. Kent, S. M. "Galactic structure from the spacelab infrared telescope. III-A dynamical model for the Milky Way bulge." *The Astrophysical Journal* 387 (1992): 181-188.
2. Merrifield, Michael R. "The rotation curve of the Milky Way to 2.5 R0 from the thickness of the HI layer." *The Astronomical Journal* 103 (1992): 1552-1563.
3. Trimble, Virginia. "Existence and nature of dark matter in the universe."*Annual review of astronomy and astrophysics* 25 (1987): 425-472.
4. Eisenhauer, F., R. Schdel, R. Genzel, T. Ott, M. Tecza, R. Abuter, A. Eckart, and T. Alexander. "A Geometric Determination of the Distance to the Galactic Center." *ApJ ApJL The Astrophysical Journal* 597.2 (2003): n. pag. Web.
5. K.G. Begeman, A.H. Broels, R.H Sanders. 1991. Mon. Not. RAS 249, 523
6. "Dark Energy, Dark Matter." Dark Energy, Dark Matter - NASA Science. National Aeronautics and Space Administration, 5 June 2015. Web. 15 June 2016.

Acknowledgments

Thank you to the following people and institutions for providing me the opportunity and resources I received this summer to conduct this research:

- Dr. Morris Swartz
- Mr. Martz
- Mr. Smith
- Quarknet
- Johns Hopkins University Physics Department
- Richard Montgomery High School