Measuring Rotation Curves of Spiral Galaxies with DESI

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DARK ENERGY SPECTROSCOPIC INSTRUMENT
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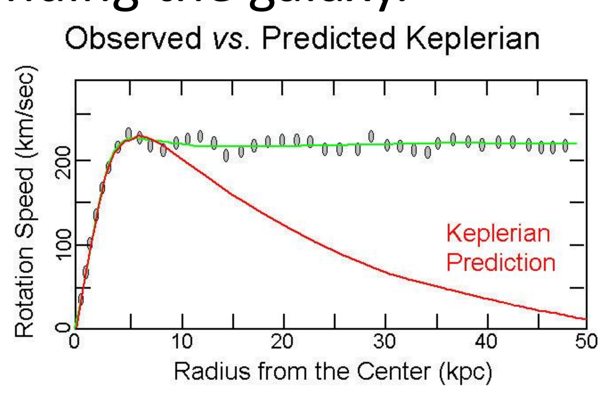
We determine the effects of dark matter on spiral galaxies with the Dark Energy Spectroscopic Instrument. Observations of spiral galaxies show that at larger radii, the rotational velocity does not decrease as expected from Kepler's Laws, but instead plateaus; This is inferred to be a result of dark matter mass surrounding spiral galaxies. We fit rotation curves to the rotational velocity, which enables us to measure the total mass within a galaxy. We use this to determine the relationship between magnitude and total mass for each galaxy, which provides insight into how dark matter varies with luminosity.

Rotation Curves & Dark Matter

The stellar mass in spiral galaxies is not enough to account for the gravitational effects evident in rotation curves [1]. This indicates that more mass we cannot see, known as dark matter, is surrounding the galaxy.

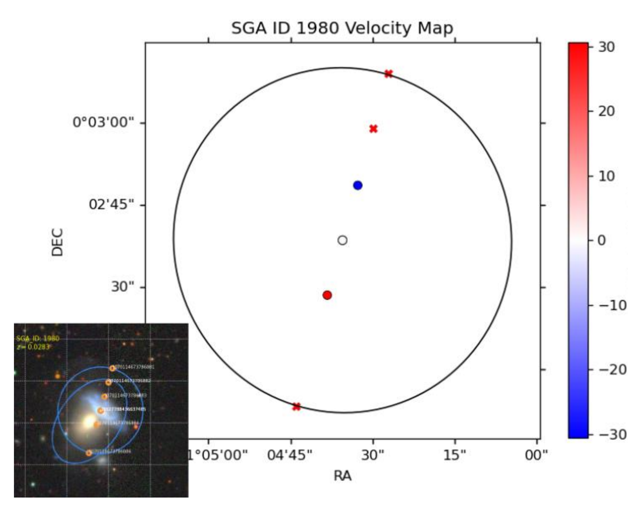


Expected rotation curve of a spiral galaxy based on distribution of stars (red) and example of an observed rotation curve (green) [2].

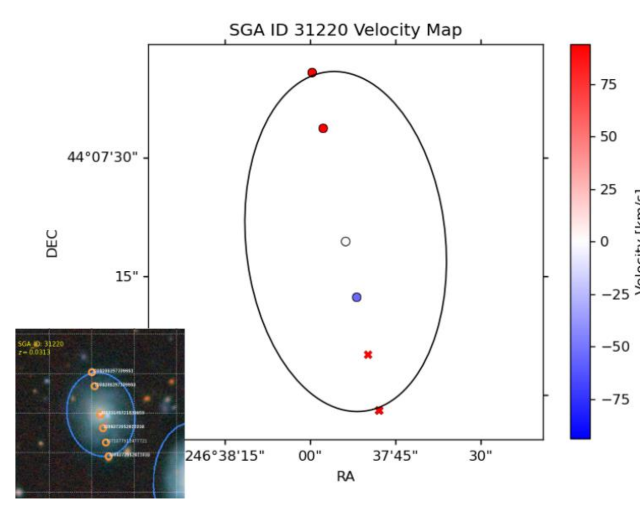
Visually Inspecting Galaxies

The DESI Peculiar Velocity Survey uses the Fundamental Plane and Tully-Fisher relationship to find peculiar velocities [3]. We use redshift data from this survey to calculate the velocities at each target before a 2D velocity map is used to determine viability of targets and galaxies.

A galaxy with at least two non-center target velocities less than or equal to 1000 km/s is considered usable for a velocity curve plot and further analysis. These requirements ensure that there are enough points to fit a curve and that the points used are within the galaxy, avoiding data that may incorporate background noise.



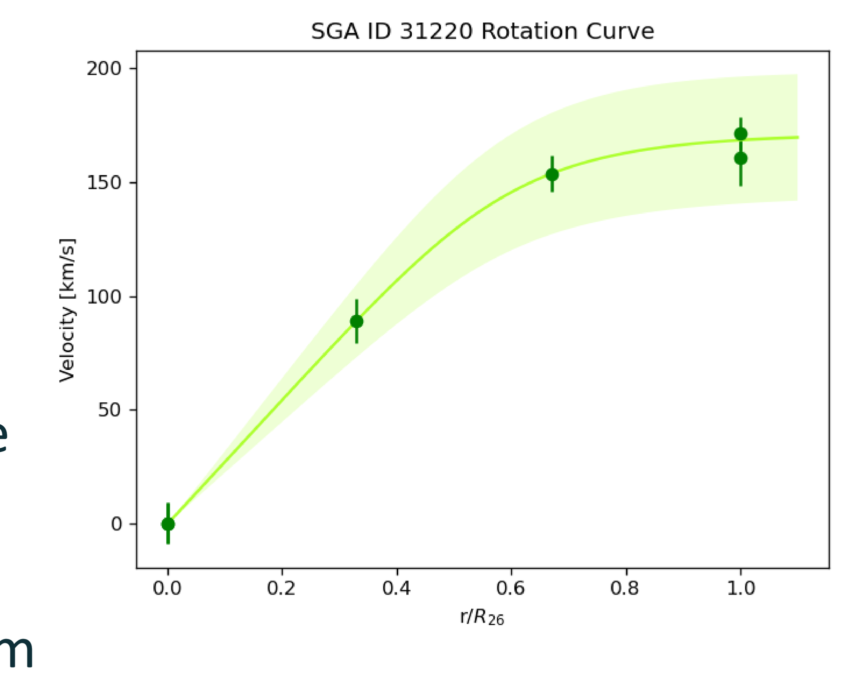
Example of a 2D velocity map with the corresponding galaxy image that did not meet requirements for further analysis.



Example of a 2D velocity map with the corresponding galaxy image that was approved for further analysis.

Fitting Rotation Curves

Fitting the relationship between velocity and distance at different radii within a galaxy demonstrates the velocity curve behavior we would expect from a spiral galaxy with a dark matter mass component.



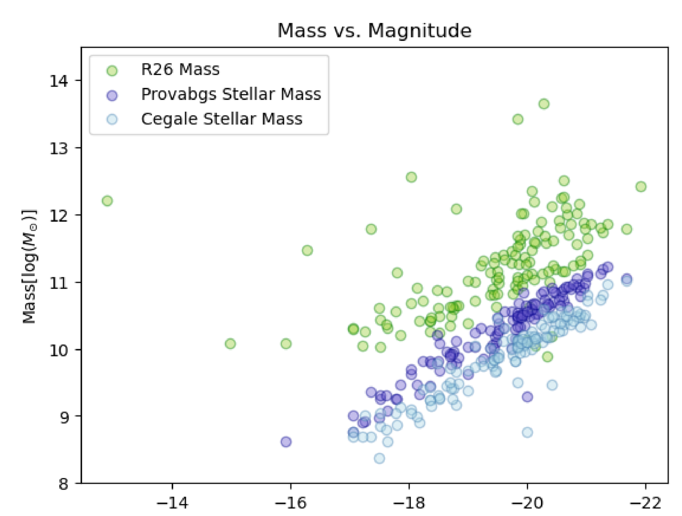
An example of a rotation curve best fit (green) with its corresponding uncertainty range (light green) and data points (dark green).

Analyzing Mass and Magnitude Relationships

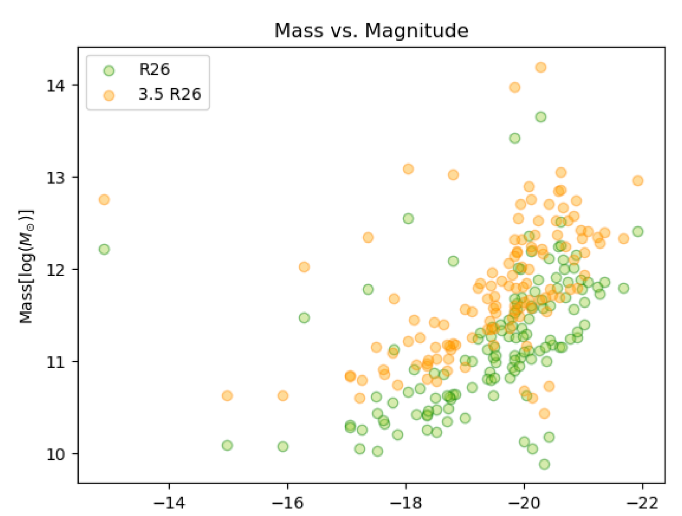
Total masses are calculated using equation 1, where *v* is the rotational velocity. When plotting the relationship between mass within R_{26}, the 26 magnitude isophote in the *r*-band, and magnitude for all of the galaxies in the sample, the relationship demonstrates the expected correlation of mass increasing with luminosity. Plotting with the calculated mass within 3.5 R_{26} shifts the correlation upwards, indicating an increased mass even past the radius at which stellar mass is present. This is what we expect from the plotted rotation curves. Additionally, plotting the stellar mass as a function of magnitude shifts this correlation downward, confirming the expectation that the stellar mass does not fully make up the total mass of a galaxy.

$$M = \frac{v^2 r}{G}$$

Equation 1



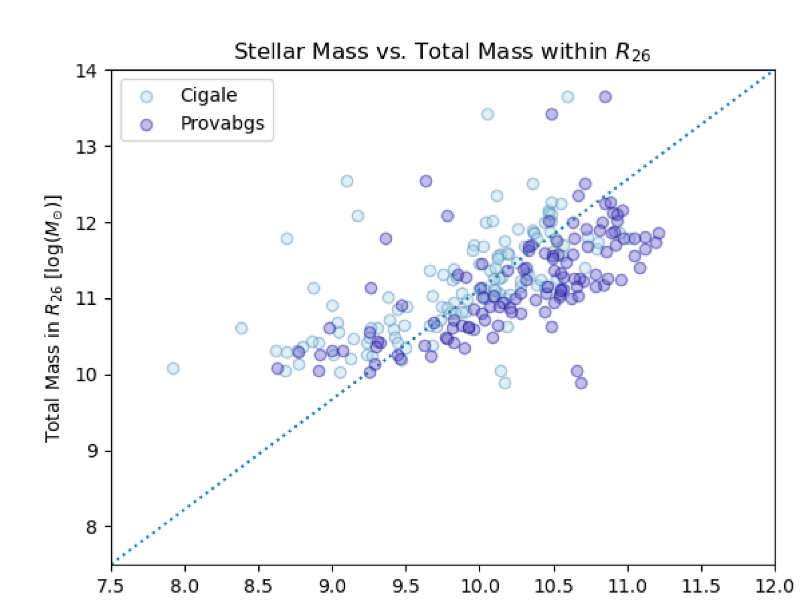
Total mass within R_{26} and stellar mass from two catalogs plotted in relation to magnitude (brightness).



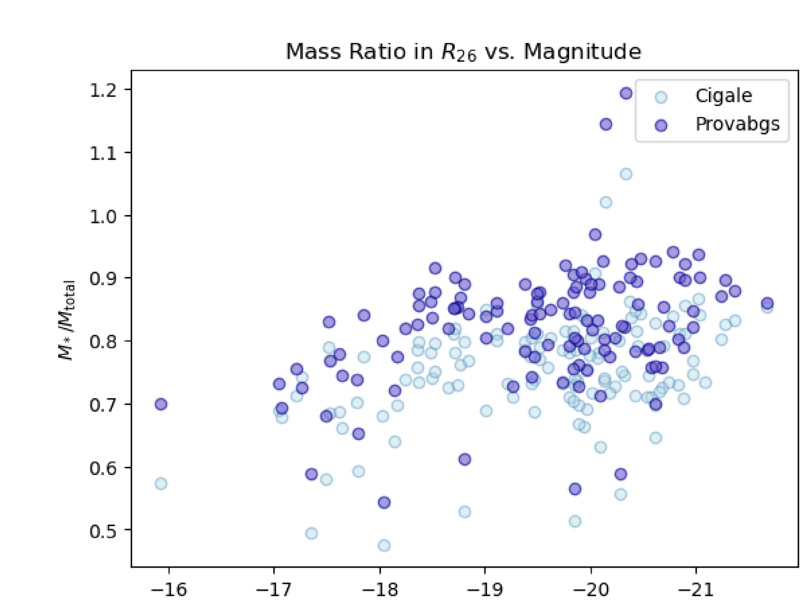
Total mass within 3.5 R_{26} and total mass within 3.5 R_{26} plotted in relation to magnitude (brightness).

Investigating Stellar and Total Mass Relations

Rotation curves of spiral galaxies provide insight into the mass distributions and ratio between stellar mass and total mass. When plotting the relationship between total mass and stellar mass, in general the total mass increases with stellar mass. This data can be further used to determine the ratios of gas to stellar mass, which is useful for measuring star formation rates within galaxies. We can also find the ratio of dark matter mass to stellar mass within these galaxies, which will help quantify the dark matter presence and distribution within the universe.



Total mass within R_{26} plotted as a function of stellar mass from two catalogs.



The ratio of stellar mass to total mass within R_{26} as a function of magnitude.

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