Constraining the Mass of NGC 4258 with Satellite Galaxies

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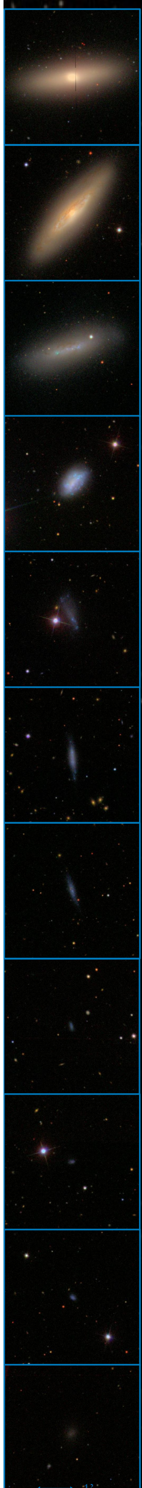


I. ABSTRACT

We combine spectroscopic observations from the APO 3.5-meter telescope with SDSS spectra to conduct a survey of satellite galaxies around the nearby spiral NGC 4258. Of the 28 observed objects, 17 appear to be members of the system. Using the projected line-of-sight velocities of the satellite galaxies and a Jeans equation approximation, we constrain the total mass of NGC 4258 to within 50%. Further observations are expected to yield around 20 more satellite velocity measurements.

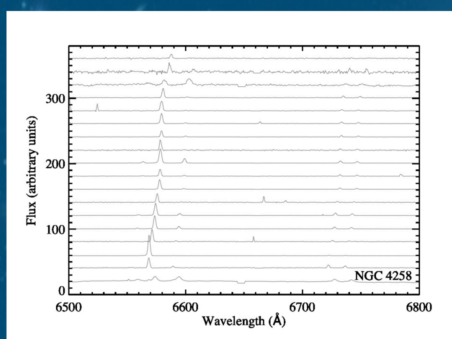
II. INTRODUCTION

The nature of dark matter remains one of the most pressing scientific mysteries of the modern era. Galaxy formation theories call for all galaxies to be embedded in massive extended dark matter halos. Ideally, we would use thousands to millions of tracer particles to map the dynamical environment around galaxies to constrain the properties of dark matter. Reality limits us to using only the dynamical tracers which are luminous enough to actually be observed. Extended HI disks have been the traditional dynamical tracer for dark matter halos. However, the gas disks of most galaxies do not extend far enough to probe the entire halo (i.e, rotation curves are flat). Other common dynamical tracers include globular clusters, planetary nebula, and satellite galaxies. Of these, satellite galaxies are the brightest, and extend to the largest radii. Unfortunately, most galaxies have only a handful of detected satellite systems.

Kim et al. (2010) present a catalog of 20 probable satellite galaxies of NGC 4258 based on deep CFHT wide field photometry. This sample of satellite galaxies represents the richest source of dynamical tracers at large radii for a single galaxy outside the Local Group. In addition to the Kim et al. (2010) sample, a simple query of the SDSS database recovers at least a dozen more potential targets, many with spectroscopy already complete. We expand the Kim et al. (2010) catalog here.

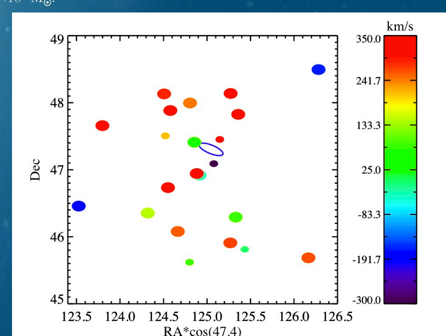
III. DATA ANALYSIS

We determined that 17 of the 28 observed objects maintain redshifts within 800 km/s of NGC 4258, indicating that they are satellites. Five targets had much larger redshifts, signifying that they were background galaxies, and 6 did not have emission lines to deduce redshifts from. SDSS provided us with an additional 5 redshifts, increasing the total to 22. Redshifts were found by fitting several emission lines with Gaussians for both red and blue spectra. Redshifts obtained from the red channel were used for the mass estimate because the error was smaller than the blue. However, the redshifts of both red and blue channels agree. Hα served as the chief indicator, but the SII doublet and the NII doublet helped limit the error in most cases. Below are the 17 red spectra from the satellites of NGC 4258 observed with the APO 3.5-meter telescope, as well as the host galaxy.



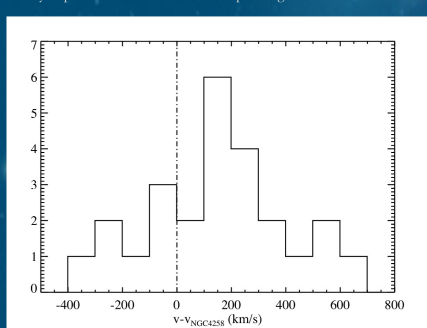
IV. INITIAL RESULTS

Redshifts were converted to line-of-sight velocities relative to the host galaxy. A graphical representation of these galaxies as they appear in the sky is shown below. Red color indicates the satellite is moving away from the host; blue indicates the satellite is moving towards the host. The blue oval marks the size and location of NGC 4258. Satellites observed at APO are large circles, while satellite redshifts taken from SDSS are small circles. We then use the method described in Watkins et al. (2010) to approximate the mass of the galaxy. Since we only have 18 tracer satellites, we expect the uncertainty in our derived mass to be ~50%. This method does not necessitate proper motions, so we prescribe a projected radius for each satellite instead. The mass that we derive enclosed in a radius of 260 kpc is $6\times10^{12} M_{\odot}$.



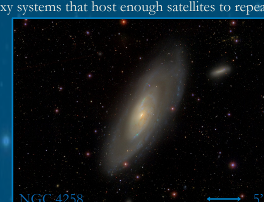
V. FINAL RESULTS

The initial mass derived for NGC 4258 seems quite large when compared to estimates of the Milky Way, especially since the two galaxies have similar rotational velocities, (V_{rot} of NGC 4258 is 208 km/s). We must take into consideration the unfortunate occurrence that some of our supposed satellites are not gravitationally bound to the system. Displaying the velocities as a histogram (below) makes it very obvious that there is an overabundance of satellites with velocities in the 150-250 km/s range. When we only include the satellites that are within 200 km/s of NGC 4258, we instead calculate the mass enclosed within 230 kpc to be $1.3\times10^{12} M_{\odot}$. This value is in much better agreement with halo masses of similar systems, like the Milky and M31. Consequently, our revised mass is only derived from 8 satellite systems, implying we have little, if any, statistical certainty in our result. However, this does not render our project or methods ineffective, as there are still 20 to 40 potential satellites cataloged in the SDSS database and Kim et al. 2011 imaging which have not yet been spectroscopically observed. Such observations should significantly improve our estimate and corresponding error.



VI. CONCLUSION

We calculate the halo mass of NGC 4258 to be $1.3\times10^{12} M_{\odot}$ out to a radius of 230 kpc, which loosely agrees with masses of other galaxies like the Milky Way and M31. This result can only be derived if 8 of the original 22 believed satellites which have velocities within ±200 km/s are used as tracers. Otherwise, the total mass is found to be $6\times10^{12} M_{\odot}$ within a radius of 260 kpc when all 22 satellites are used. Additional potential satellites listed in the SDSS database will be spectroscopically observed in the future to further solidify our estimate. By searching the SDSS database, we believe we can find other galaxy systems that host enough satellites to repeat this technique.



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