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Lab 6: The Great Debate

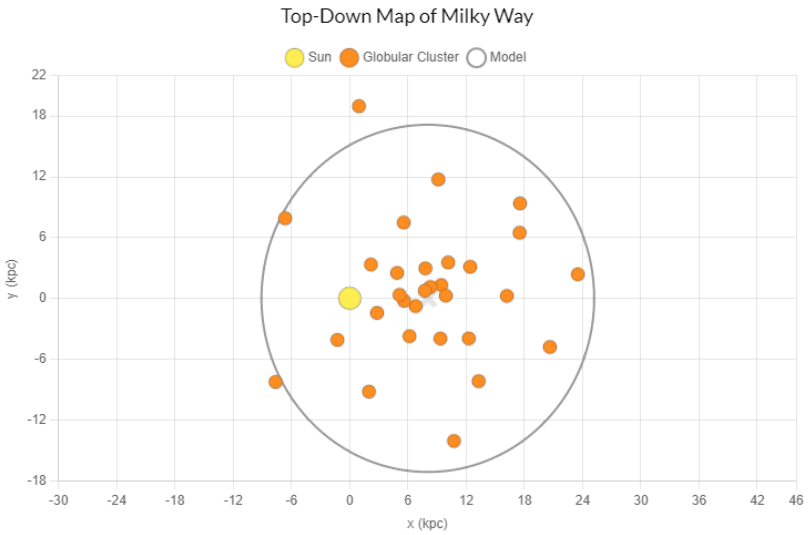
In the context of the historical ‘Great Debate’ (between astronomers Harlow Shapely and Heber Curtis), the goal of this lab was to consider our place in the universe. More specifically, to use variable stars (RR Lyrae in local globular clusters and Cepheid stars in nearby galaxies) to calculate galactic sizes and distances.

Process:

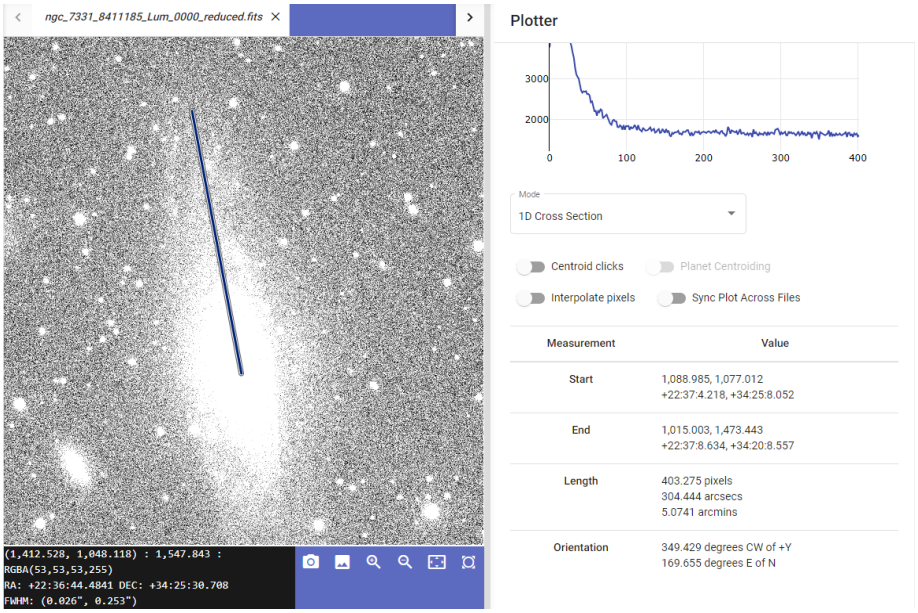
To determine our location (the Solar System) relative to the Milky Way, we tabulated coordinate data and apparent magnitudes of thirty RR Lyrae stars located in globular clusters known to be orbiting the Milky Way galaxy. By calculating their distance, we were able to plot a distribution of these local clusters, which we used to approximate the distance to the galactic center and overall diameter of the galaxy.

To determine whether the Milky Way galaxy is a ‘primary object’ in the universe, or one of countless similar galaxies, we used Skynet telescopes to observe so-called spiral nebulae (M66, M96, NGC 1365, NGC 2935, NGC 7331). Using known values for the periods and apparent magnitudes of Cepheid variable stars within each of those nebulae, we calculated the average absolute magnitude and distance to each. From our telescope observation, we used the Afterglow software to measure the angular diameter of each nebula, which allowed us to calculate the diameters of each target.

Data:



Using this distribution of local globular clusters, we can approximate our distance from the center of the galaxy (about 8 kpc) and the total diameter (around 30 kpc). The outlying clusters lead to a higher error/uncertainty in the diameter calculation, since they are comparatively sparse. With more data points (clusters) we could get a better visualization of the actual boundaries of the distribution and thus the galactic diameter.



Using observation image to measure apparent angular size of NGC 7331. The bottom portion of the disk is harder to see due to the image saturation, so the angular radius was measured instead. Determining the true extent of each galaxy's disk proved our larger source of error, even with careful tuning of saturation levels, using only one image for each 'spiral nebula' made it challenging to find the dimensions necessary. For more accurate calculations, a series of multiple images of the same galaxy could be captured and then use the average angular diameter measured from each.

Table 1: Nearby Galaxies

Spiral Nebula	Cepheid Average Apparent Magnitude (m)	Cepheid Period (days)	Cepheid Average Absolute Magnitude (M)	Spiral Nebula Distance (kpc)	D (Mpc)
M66	24.2	48.300	-6.162	11837.688	11.838
M96	24.6	22.100	-5.208	9171.087	9.171
NGC 1365	25.5	35.200	-5.776	18033.180	18.033
NGC 2935	26.2	60.800	-6.443	33846.140	33.846
NGC 7331	24.5	42.600	-6.009	12665.463	12.665
Spiral Nebula	**Angular diameter (arcmin)**	**Ang. dia (degrees)**	**Spiral Nebula Distance (kpc)**	**Diameter (kpc)**	
M66	9.635	0.161	11837.688	33.178	
M96	7.203	0.120	9171.087	19.216	
NGC 1365	10.8914	0.182	18033.180	57.132	
NGC 2935	4.18	0.070	33846.140	41.154	
NGC 7331	10.1482	0.169	12665.463	37.388	

With the given Cepheid periods and average apparent magnitudes, the diameters and distance to each galaxy were calculated.

Conclusion:

As shown above, using the local globular cluster distribution, we estimated a Milky Way diameter of approximately 30 kpc, with the Solar System situated about 9 kpc from its center. Regarding the ‘Great Debate’, Shapely correctly predicted that the solar system is not at the center of the galaxy. Both astronomers were a bit off in their predictions of the size of the galaxy, but Curtis was correct in assuming the Milky Way *is not* a primary object in the universe, but one of many (countless?) similarly-sized objects. And, with the distances we calculated from our own observations to (relatively) nearby galaxies, it shows the scale of the universe is far beyond what either astronomer had predicted in their time.Curtis did correctly identify that the spiral nebulae they were observing were galaxies in their own right.

Neither party was completely accurate with their predictions, but the Great Debate itself marks a watershed moment in astronomy. Observations made from our tiny rock can be leveraged (with increasing degrees of accuracy) to calculate the scale of the universe and our place in it.