

Messier Marathon

ASTR142, May 11, 2025

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Abstract

In this project, our group attempted the Messier Marathon; the marathon is an observational challenge to locate as many Messier objects as possible in a single night. Using calculated rise, set, and peak times for each object, we created a detailed observing plan for April 27. Over the course of the night, we successfully observed and imaged 64 Messier objects. The raw images were processed and calibrated on CCDStack, resulting in high-contrast grayscale images. We then created two chronological and categorical tables with observation descriptions and classifications.

Introduction

The Messier Catalog was compiled by Charles Messier in 1781. The catalog includes 110 of the brightest objects visible from the northern hemisphere, including but not limited to: stellar clusters, gaseous nebulae, and galaxies. The catalog has now become an observation hunt for eager amateur astronomers. Each spring, in the late weeks of March and early April, all 110 objects become visible in one night. This brought to the Messier Marathon. Our group was tasked with attempting to observe as many Messier objects as possible in a single night using the Mees telescope and CCD imaging.

Planning

To successfully attempt the Messier Marathon, our group had to prepare in advance the plan for the entire night such that we would get the most out of our observation. With such a small window between sunset and sunrise, multiple factors were considered when making our observation order. This included the rise/set time of objects, declination at planned observing time, size of slew from previous object, and peak time.

Before we could put together our observing order, we had to calculate the rise, set, and peak times of each object. To begin, on a google sheet, we made a list of all 110 Messier objects and looked up their right ascensions (RA) and declinations (Dec) to add to the list, then converted them to decimal (hours and degrees).

We then used the fact that an object reaches its highest point in the sky when the local sidereal time (LST) is equal to its RA, such that,

$$LST = RA \xrightarrow{\text{yields}} \Delta LST = LST - RA$$

We then calculated the LST at midnight for April 27 at Mees Observatory and subtracted this from each object's RA to get the peak time. This peak time is when the object is best placed for observation and was highly considered in the ordering process.

To determine when the object would rise and set, we calculated its hour angle (HA) when it reaches a minimum altitude. Since the telescope cannot go past a certain zenith, this value is 30 degrees for us on observing night. We calculated the total time the object spends above the horizon, which corresponds to $2HA$, such that,

$$t = 2HA = 2\arccos\left(\frac{0.5 - \sin\delta\sin\lambda}{\cos\delta\cos\lambda}\right)\left(\frac{1}{15}\right)$$

We then used the following formulas to compute rise and set times with respect to the peak, such that,

$$Rise\ time = 24 + (Peak - HA)$$

$$Set\ time = 24 + (Peak + HA)$$

After applying this process to all objects, we now had everything we needed to determine our observing order. We started by omitting any objects whose altitude was less than 30 degrees and rose and set outside of the observation time, therefore making them unobservable.

We now have a list of all observable objects. The list was now carefully gone through and organized such that we prioritized getting in objects that either set right after observing begins or rise right before we are done observing; these objects went at the very start and end of our list. From here we focused on limiting large slews between objects and getting objects as close to their peak times as possible. Slews were made a greater priority as centering the telescope too much takes a great deal of time out of our observing.

Lastly, we went through each object and labeled their classification found online along with any objects we found to be circumpolar. Our final list was composed of 74 objects, but it is to be noted that 9 of them turned out to be too close to sunrise/set and were as a result unobservable.

Observations

On Observing night, the telescope set up began 45 minutes before the sun began setting. We began by accessing the remote desktop connected to Mees Observatory. This would allow us to control the telescope from B&L 203H. Once we had access to the desktop, we launched the applications needed for the night: TCSGalil, for initializing the telescope and later to slew the telescope between images, TheSky X, software used to take the images with Mees, Firefox, and Excel, to calculate the slew entered TCSGalil between images. Once we connected the software to the camera and telescope, and confirmed the weather conditions were suitable for observing, we started by turning on the camera in TheSky X and waiting till the temperature reached -20 degrees C. After the temperature was confirmed, we set the camera to the appropriate conditions to take our flat fields in 1x1 binning and saved them to our file for the night. Once this was done, we followed a multi-step process to set up the telescope including centering it at the zenith (using the scales visible from the cameras on FireFox), followed by using TCSGalil to align the telescope's right ascension with the actual sidereal time, and then check that equatorial track rate was set for the desired hemisphere. At approximately 8:20PM the sun fully set, and the outside cameras switched to grayscale, allowing us to remove the dust cover using FireFox.

The telescope was initialized by slewing to a 0-3 magnitude star near Zenith and taking a test picture of it with a filter, binning, and exposure time of Luminance, 2x2, and 2 seconds. Once the image appeared on the monitor and after turning on the crosshairs, the Excel program was used to align the star to the center of the image. This was an important process since this step was performed many times throughout the night to center objects in the marathon after large slews. To align the object the mouse is placed in the center of the object you want to center; the pixel coordinates are then noted and entered into the spreadsheet that calculator the RA and Declination needed to slew the telescope in TCSGalil (accounting for direction East/West and

North/South). Once slewing is completed, another picture is taken to confirm the object is correctly centered.

Next, the telescope was focused. This was done by finding a different, fainter star around our guide star (around magnitude 10~11). Once a star was found with a low enough magnitude, an image was taken using 30-second exposure. Using TCS Galil a rectangular subframe was drawn around the star in the image, and focus tools were used to get a list of half-flux diameters and maximum pixel values. It's important to always set the focus to 4500 first and then adjust from there. From the conditions of the night, our calculated initial focus for step 18 was 4100. From there we went down in increments of 50 where at 3900 we saw a large change in the maximum pixel value and then confirmed that it was the correct focus by performing two more focuses. Once we confirmed that 3900 was the correct estimate, we calculated our final Focus value of 3902 and $HFD = 6.52$ at a temperature of 48 degrees C. The half flux diameter was then multiplied by 0.448 arcsec/pixel and was recorded as the night's Seeing, 2.92 arcseconds.

Following this, we were able to begin our observations; at 9:14PM the first object, M38 was observed. Throughout the observing process, we observed open clusters, globular clusters, spiral galaxies, elliptical galaxies, lenticular galaxies, starburst galaxies, planetary nebulae, reflection nebulae, and double stars. All clusters and our one double star Messier object (M40) was all taken in a series of 3 pictures with exposure times of 30 seconds. The images of spiral, elliptical, and lenticular galaxies were in a series of 3-5 pictures (varied with time permitted for that object to stay on track with schedule) with exposure times of 60 seconds. The one planetary nebula was taken in a series of 10 pictures with 30-second exposure, and the other two were in a series of 5 pictures with 60-second exposures. One reflection nebula was taken in a series of 10

pictures with 60-second exposures, and the other was taken in a series of 8 pictures with 60-second exposures. These larger series were taken as time permitted throughout the marathon.

All objects had test images taken before their series to check that the object was correct and centered. These images were not saved to our file and are not included in this report. Each object was also checked to see that (a) its altitude was above 30 degrees before imaging (any further can damage the telescope) and (b) not taking images too close to Polaris to protect the telescope and images.

By approximately 5:10AM, we successfully imaged 64/110 Messier objects putting an end to our observation.

Processing

Following observations, we now had approximately 250 images of our 64 Messier objects collected. While the images calibrated further in the time after the series is taken, the final photo saved to the drive is still hard to see on the greyscale. To have the best possible grayscale images for our analysis, the following procedure was carried out in CCDStack.

We began by remotely accessing the Astro Desktop and CCDStack from our personal computers. Once that was completed and CCDStack was opened it was time to upload and organize all our images. We began by creating a master flat field from our flat-field images. This step corrected the pixel sensitivity variations across our stack of photos. We used the *Dark/Bias Subtract Each Flat* and selected Master Bias with 1×1 binning which follows the settings mentioned earlier in the report. Following this, we combined all our images with the sigma-reject mean. The master flat, together with the master dark and bias frames, was then applied to

calibrate all the raw images for all the objects. This first part was completed on one computer as only one master flat needs to be created.

After creating and implementing the master flat, we removed hot and cold pixels that cleared up the image once using sigma-rejection. Now we could open sets of images by their object and adjust the series accordingly for that object. Once an object's images were selected for the stack, we began by selecting 6-8 reference stars that were easily identifiable on the picture guides to align all the series images with each other. Since the images were taken in such a short time from each other, the alignment wasn't very far off. Once that was completed, we normalized the stack by selecting the background (darker background region of the image away from the object) and highlight (brightest part of Messier object); this adjusts the over exposure and brightness of the images. Following this, Poisson sigma reject and interpolate rejected pixels are applied to all images in the stack. Sigma reject removes pixels that do not match and interpolate reject "takes the surrounding" and fills those pixels with the average of the surroundings. This helps clear up the image and brings focus to the object. Now the images are ready to be saved with a suffix, RegNormFix; these are our adjusted images before taking the mean of them all.

Once the RegNormFix images are saved to the file, the mean of the stack is taken creating one final image that will be used for final adjustments, and of course, in this report. The mean image is then saved to a subfolder "Mean" in the project, where all the final images are kept as a collection.

This process was then repeated for all 64 objects and was split evenly amongst the group. Once all images were made into means, it was time to adjust the settings of the images to get the best final image possible. The Messier objects were once again split amongst group members and Adjust Display was used to "beautify" the images. We found that lowering gamma could help

clear the image while keeping it bright, and that for each image a balance of DDP and Background was best to adjust the darkness of the background without over/underexposing the objects. Maximum was found not to have a very big role unless major saturation adjustments were needed.

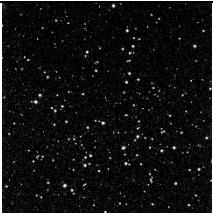
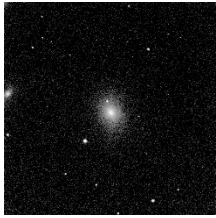
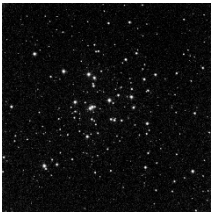
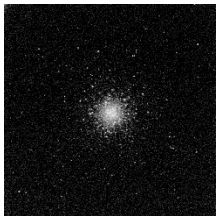
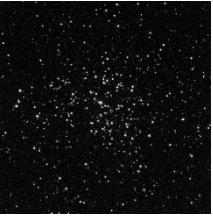
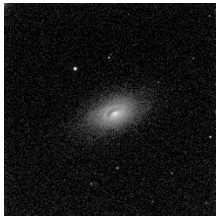
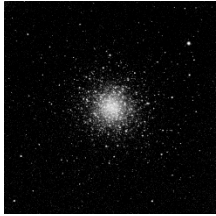
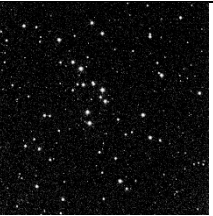
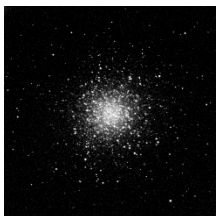
Once everyone finished going through their set of images and everyone compared/checked with each other, we were ready to save our final images as TIFF 16-bit scaled.

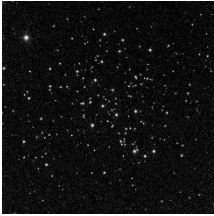
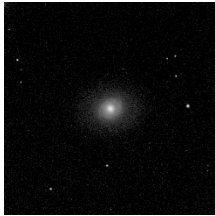
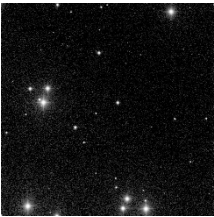
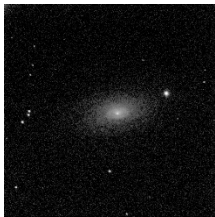
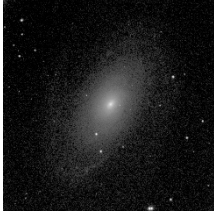
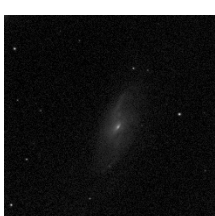
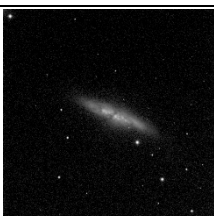
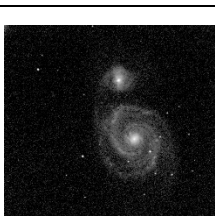
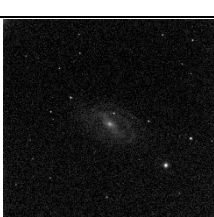
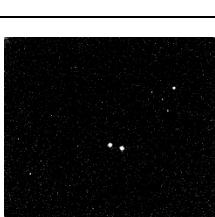
Analysis

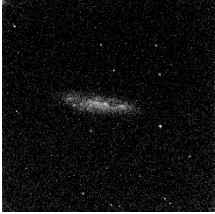
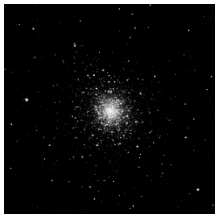
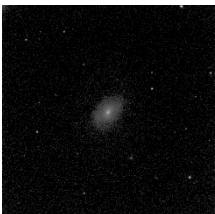
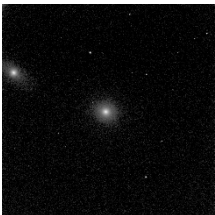
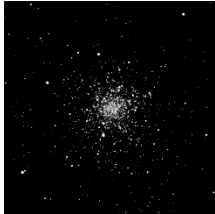
We created two different tables to analyze our observed Messier objects. The first table documented was ordered to match our observing order. This table included the object's classification and if it was a galaxy, its estimated Hubble type. Estimating Hubble types allowed us to identify galaxies based on features we learned in class including bulge size, arms, and ISM/star formation.

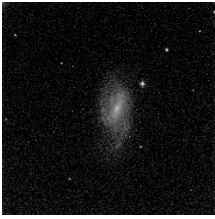
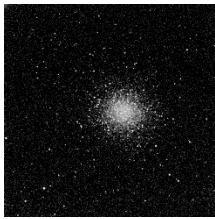
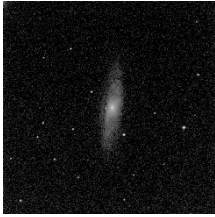
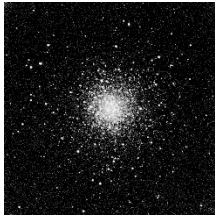
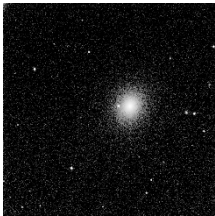
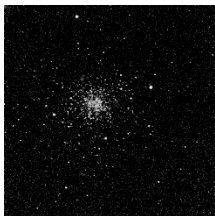
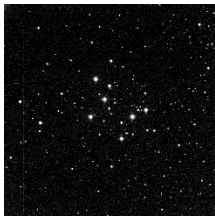
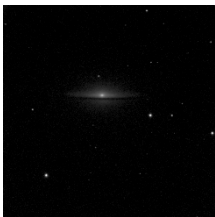
For the second table, we took our observed objects but rather than ordering them by observing order, they were organized into their classification types (open clusters, globular clusters, nebulae, spiral galaxies, etc). This format revealed trends in brightness and angular size; for example, open clusters were often large, spaced out and bright, while Globular clusters were generally compact in the center, appearing much brighter in the images. Elliptical galaxies appeared fainter, and had less visible structure compared to the spiral galaxies that tended to be brighter with visible arms and bulges. Planetary nebulae were among the smallest and faintest objects we took images of; this explains why it took longer to adjust the display settings for

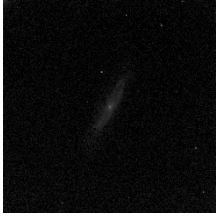
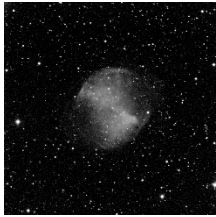
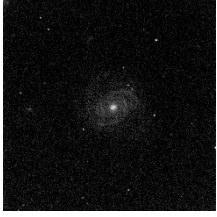
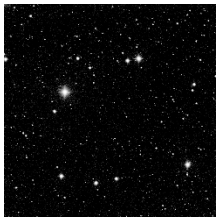
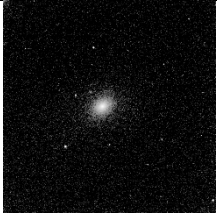
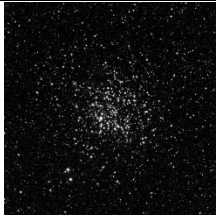
nebulars when editing the images in CCDStack. We saw many trends that we learned about in class, and they matched well with our current understanding of the various objects. Below are our two tables of 64 objects:

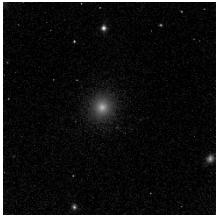
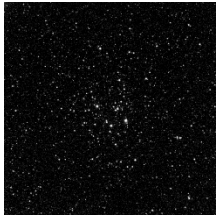
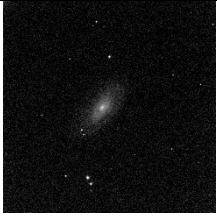
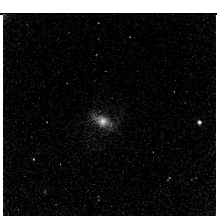
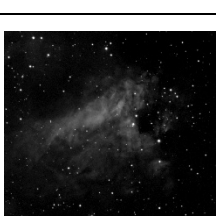
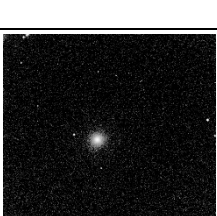
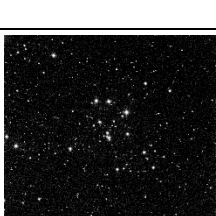
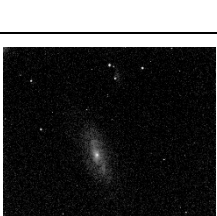
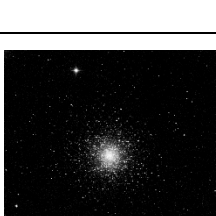
#	Object	Image	Description	#	Object	Image	Description
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2	M_03 6		Open Cluster	35	M_05 3		Globular Cluster
3	M_03 7		Open Cluster	36	M_06 4		Barred Spiral Galaxy SBa(rs)
4	M_03 5		Open Cluster	37	M_00 3		Globular Cluster
5	M_04 8		Open Cluster	38	M_01 3		Globular Cluster

6	M_06 7		Open Cluster	39	M_09 4		Barred Spiral Galaxy SBab(r)
7	M_04 4		Spiral Galaxy Sb	40	M_06 3		Spiral Galaxy Sbc
8	M_08 1		Barred Spiral Galaxy SBc	41	M_10 6		Barred Spiral Galaxy SBbc(s)
9	M_08 2		Starburst Galaxy Irr I	42	M_05 1		Spiral Galaxy Sbc
10	M_10 9		Barred Spiral Galaxy SBbc	43	M_04 0		Double Star

11	M_10 8		Barred Spiral Galaxy SBb	44	M_10 1		Spiral Galaxy SBcd(rs)
12	M_09 7		Planetary Nebula	45	M_10 2 (NGC 5866)		Lenticular Galaxy S0
13	M_09 5		Barred Spiral Galaxy SBab(rs)	46	M_09 2		Globular Cluster
14	M_09 6		Barred Spiral Galaxy SBb(s)	47	M_00 5		Globular Cluster
15	M_10 5		Elliptical Galaxy E1	48	M_01 2		Globular Cluster

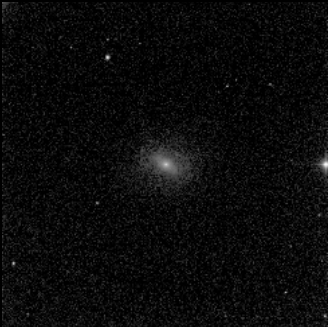
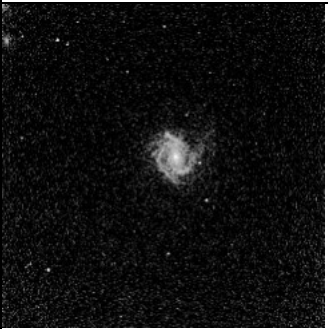
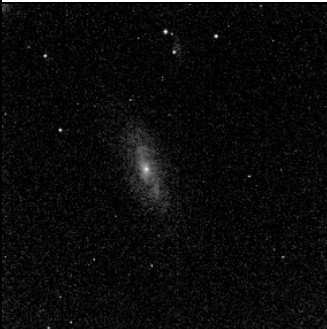
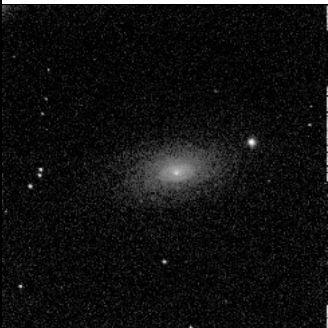
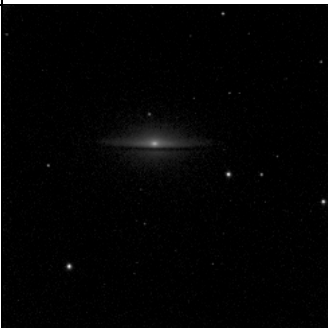
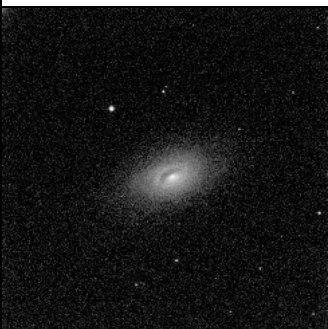
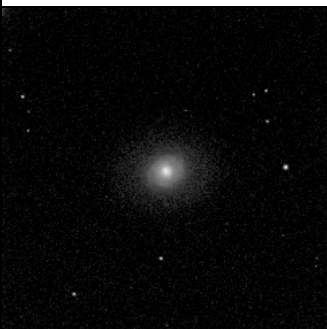
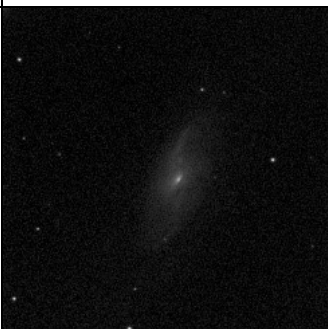
16	M_06 6		Barred Spiral Galaxy SBb(s)	49	M_01 4		Globular Cluster
17	M_06 5		Barred Spiral Galaxy SBa(rs)	50	M_01 0		Globular Cluster
18	M_04 9		Elliptical Galaxy E2	51	M_10 7		Globular Cluster
19	M_06 1		Barred Spiral Galaxy Type: SBbc(rs)	52	M_02 9		Open Cluster
20	M_10 4		Spiral Galaxy Sa	53	M_05 7		Planetary Nebula

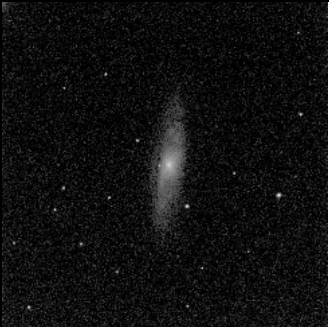
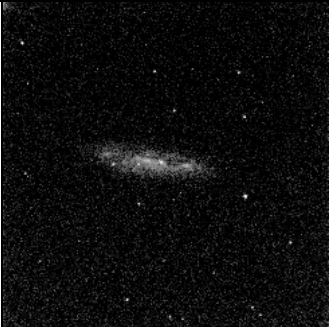
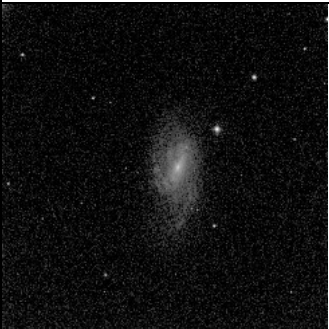
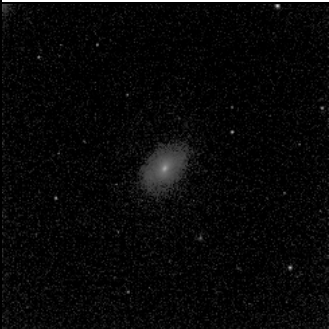
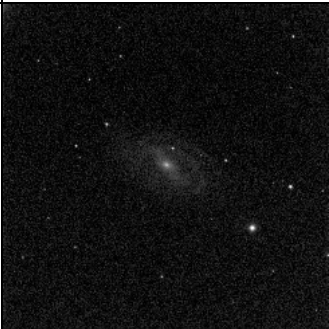
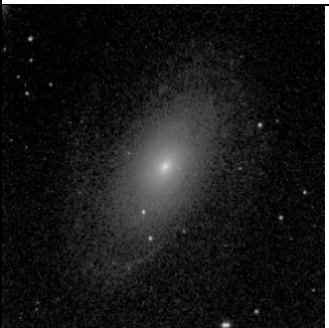
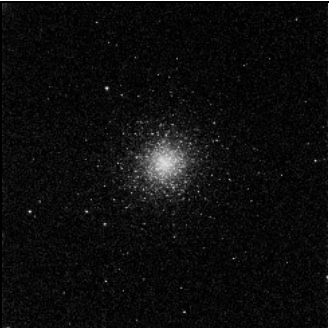
21	M_09 8		Spiral Galaxy SBab(s)	54	M_05 6		Globular Cluster
22	M_09 9		Spiral Galaxy Sc	55	M_02 7		Planetary Nebula
23	M_10 0		Barred Spiral Galaxy SBbc(s)	56	M_07 1		Globular Cluster
24	M_08 4		Lenticular/Elliptical Galaxy E1	57	M_03 9		Open Cluster
25	M_08 6		Lenticular/Elliptical Galaxy E3	58	M_01 1		Open Cluster

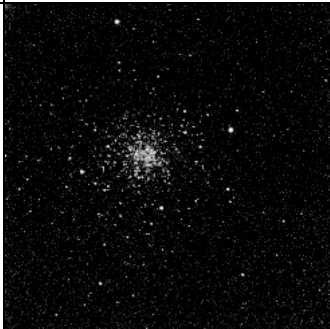
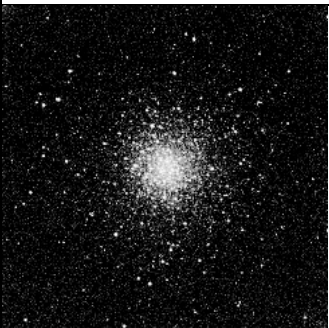
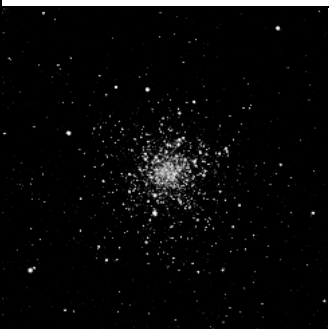
26	M_08 7		Elliptical Galaxy E0	59	M_02 6		Open Cluster
27	M_08 8		Spiral Galaxy Sb	60	M_01 6		Emission nebula with cluster
28	M_09 1		Barred Spiral Galaxy SBb	61	M_01 7		Emission nebula with cluster
29	M_08 9		Elliptical Galaxy E0	62	M_01 8		Open Cluster
30	M_09 0		Barred Spiral Galaxy SBb(rs)	63	M_01 5		Globular Cluster

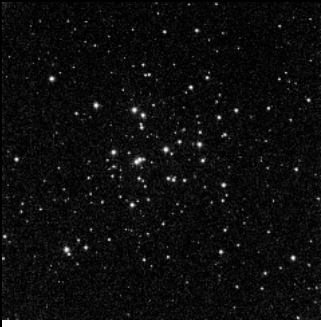
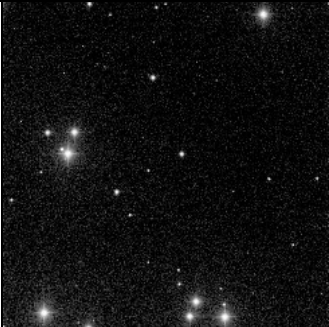
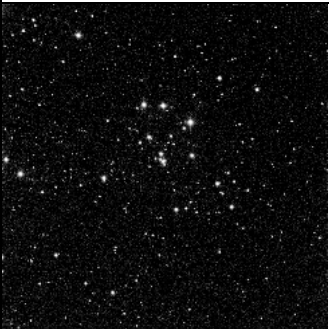
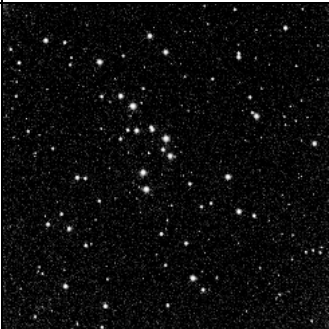
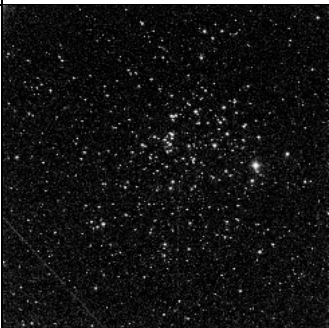
31	M_05 8	A black and white photograph of a barred spiral galaxy, showing a bright central bar and several distinct spiral arms.	Barred Spiral Galaxy SBb(rs)	64	M_05 2	A black and white photograph of an open star cluster, showing a dense collection of individual stars of varying brightness.	Open Cluster
32	M_05 9	A black and white photograph of an elliptical galaxy, showing a smooth, elongated light distribution.	Elliptical Galaxy E2	65	M_00 2	A black and white photograph of a globular cluster, showing a very dense, spherical collection of stars.	Globular Cluster
33	M_06 0	A black and white photograph of an elliptical galaxy, showing a smooth, elongated light distribution.	Elliptical Galaxy E2				

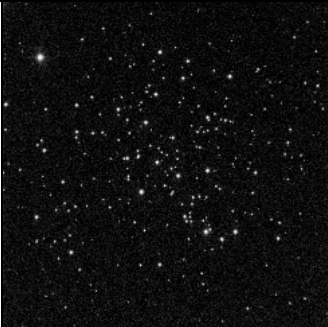
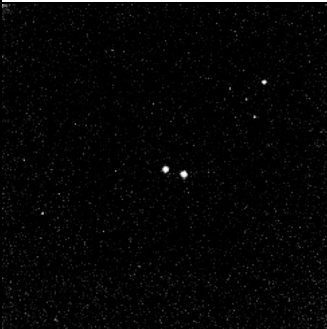
Spiral Galaxies							
M_051	A black and white photograph of a face-on spiral galaxy with a bright central bulge and well-defined spiral arms.	M_082 (Irregular)	A black and white photograph of a face-on spiral galaxy, showing a central core and several spiral arms.	M_099	A black and white photograph of a face-on spiral galaxy, showing a central core and several spiral arms.		

M_058		M_088		M_100	
M_061		M_090		M_101	
M_063		M_091		M_104	
M_064		M_094		M_106	

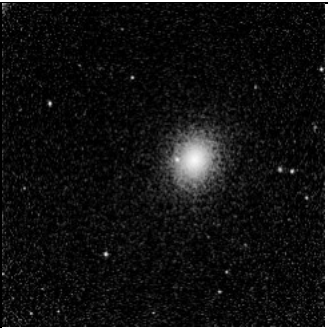
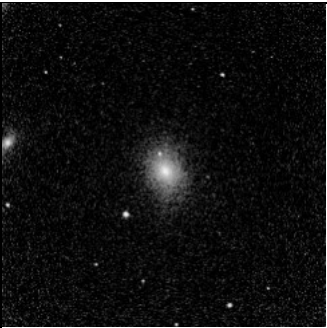
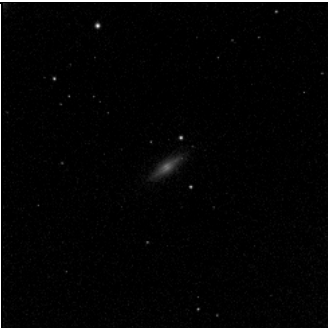
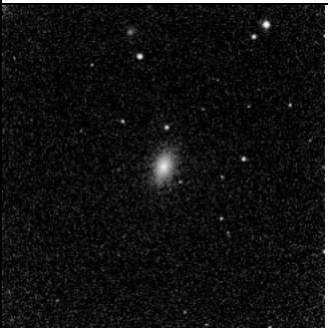
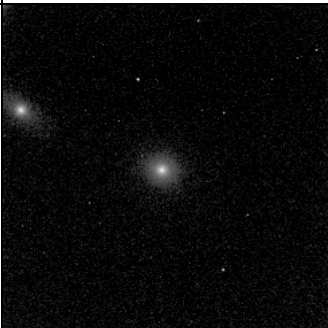
M_065		M_095		M_108	
M_066		M_096		M_109	
M_081		M_098			
Globular Clusters					
M_002		M_013		M_071	

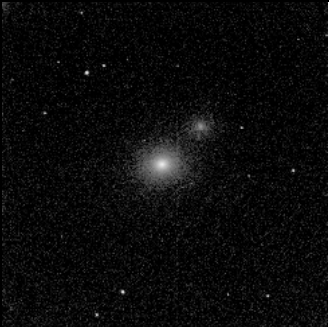
M_003		M_014		M_092	
M_005		M_015		M_107	
M_010		M_053			
M_012		M_056			
Open Clusters/ Double Star					

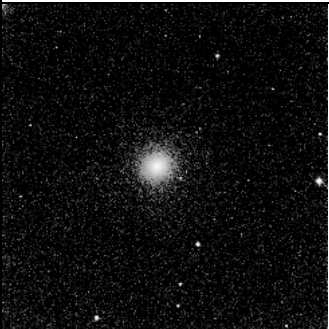
M_011		M_036		M_044	
M_018		M_037		M_048	
M_026		M_038		M_052	

M_029		M_039		M_067	
M_035		M_040 (double star)			

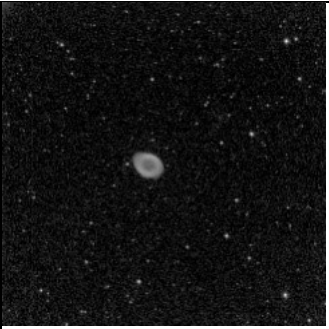
Elliptical/Lenticular Galaxies

M_049		M_085		M_102 (NGC 5866)	
M_059		M_086		M_105	

M_060		M_087			
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M_084		M_089			
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Planetary Nebulae

M_027		M_057		M_097	
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H2 Regions/ Reflection Nebulae

M_016		M_017			

Conclusion

Although we were not able to capture all 110 objects, our group successfully imaged 64/110 Messier objects throughout the night. The project helped us develop our skills with the telescope, applying astronomical calculations outside of homework and recitations, and processing our raw images in CCD. If we were to do the Messier Marathon again, we would aim to optimize our observing sequence further—perhaps accounting better for how late we will start, so that we don't fall behind in time at certain points and have more time for greater series and time to adjust slews. We hope with such adjustments we could get more objects the next time around.