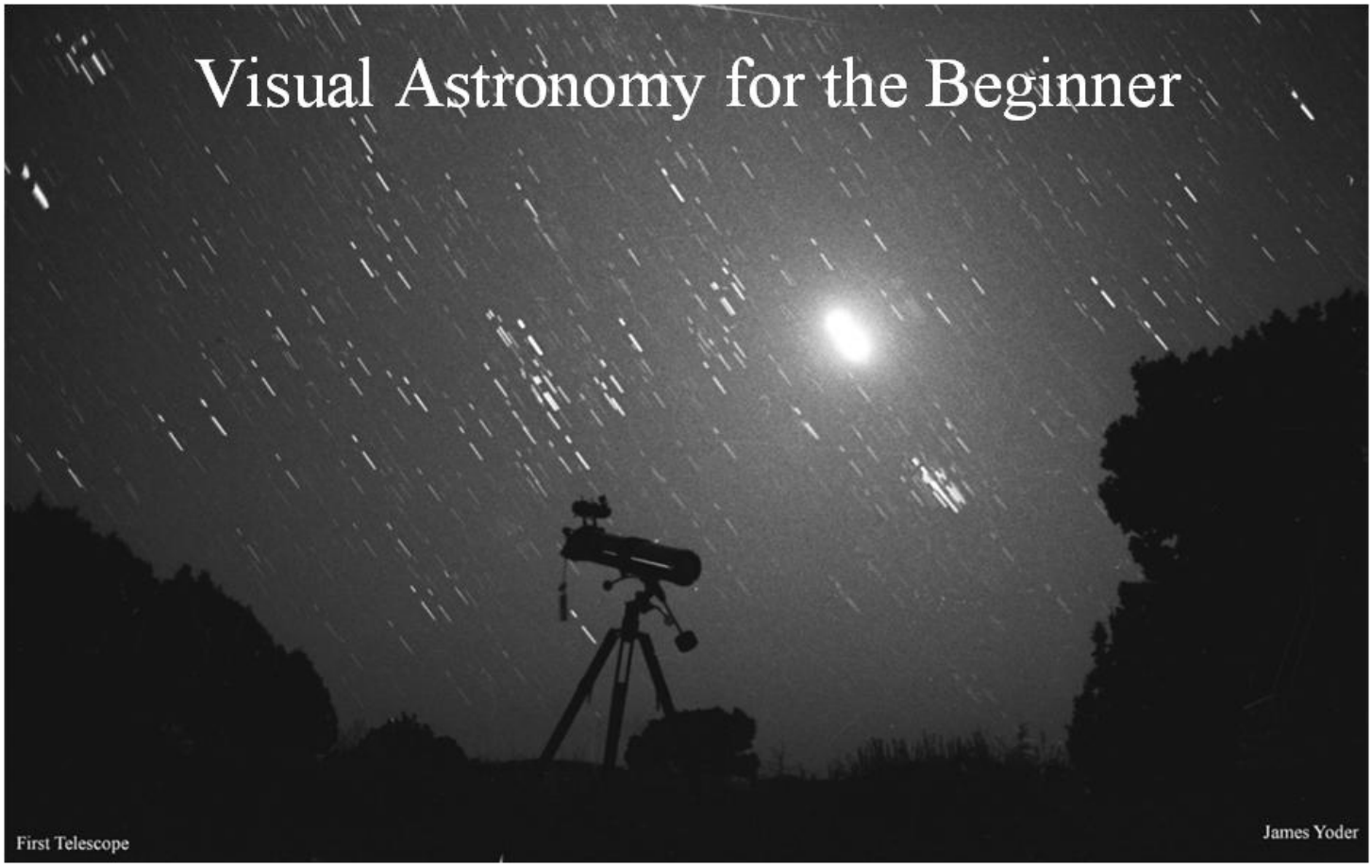
Visual Astronomy for the Beginner



First Telescope

James Yoder

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Chapter 1: Introduction

Terms

Some key terms and concepts that are important to know in this chapter are:

- **Aperture** – The diameter of a telescope's main lens or mirror. For more information, click here.
- **Astronomy** - The scientific study of matter and phenomena in the universe, especially in outer space, including the positions, dimensions, distribution, motion, composition, energy, and evolution of celestial objects.
- **Astrophotography** – Photography of astronomical objects.
- **Dark Adaptation** (aka Night Vision) - The eyes' transition to night vision, in order to see faint objects. Dark adaptation is rapid during the first 5 or 10 minutes after you leave a well-lit room, but full adaptation requires at least a half hour and it can be ruined by a momentary glance at a bright light.
- **Deep Sky Objects** – Objects outside our solar system including galaxies, nebulae and star clusters. For more information, click here.
- **Light Pollution** – Unwanted light that is projected up into the night sky (city lights, flashlights) that significantly impacts the visibility of faint objects in telescopes. For more information, click here.
- **Light Pollution Filters** – Filters, usually on a glass substrate, that block specific wavelengths of light associated with light pollution. The intent is to increase contrast between the background sky and the object being observed.
- **Maximum Usable Magnification** – Indicates the highest degree to which you can enlarge an image before the view starts to become blurry (assuming ideal atmospheric conditions). This can be estimated as 50x the telescope aperture size (in inches).
- **Seeing** - A measure of the atmosphere's stability. Poor seeing makes objects waver or blur when viewed in a telescope at high magnification. The best seeing often occurs on hazy nights, when the sky's transparency is poor.
- **Transparency** - A measure of the atmosphere's clarity; how dark the sky is at night and how blue it is during the day. When transparency is high, you see the most stars. Yet crystal-clear nights with superb transparency often have poor seeing.
- **Magnification** - The magnification power of a telescope essentially indicates the size of an object observed inside the eyepiece relative to the size of that object when observed with the naked eye.
- **Focal Length** - The focal length of a telescope is the distance from the objective lens or mirror to the focal point where the telescope forms an image of an object, usually given in millimeters.

Goals of this class

This class is targeted at new telescope owners, or persons considering purchasing a telescope. This class covers what you need to know to choose a telescope and the skills to operate one. We will cover basics such as understanding the night sky, different types of telescopes, accessories for telescopes and how to use your telescope. This course is both informational and hands-on.

Labs are a critical part of this class. If you own a telescope, you are encouraged to bring it to the lab. Those who have not yet purchased a telescope will have a telescope provided to them (sharing with other class members). To ensure each class member has ample hands-on time on a telescope, the class size will be limited.

Although we will broach the topic of photography with telescopes (Astrophotography), it should be understood that taking photos of anything beyond the Moon and a few bright planets — that is, deep-sky astrophotography — can be far more complicated and expensive and will not be covered in this class.

Class Structure

Lectures – This course is presented as five lectures, each lasting 60–90 minutes. It is recommended that you briefly review the chapter before each class so you can get familiar with the concepts and prepare any questions you may have. Attendance is strongly recommended, but lectures will be recorded and available for viewing at a later time if you are unable to attend or would like to review a previous lecture.

Labs – While lectures are focused on general concepts and information on telescopes and astronomy, labs are focused on practical application and techniques. Please bring a red flashlight to the lab and dress appropriately; it can get cold standing around at night!

Using Other Tools

This class was designed for the budget-conscious astronomer; we try to use references and tools in this class that are free or not very expensive. That being said, there are many other resources, including phone applications, that are very effective and you are welcome to use these if you desire.

What is Astronomy?

Astronomy is a natural science that studies celestial objects and phenomena. A small telescope has the capability of exploring many of these phenomena including objects residing in our solar system: the Sun, the Moon, the major planets, and occasionally comets. Deep sky objects that exist outside our solar system but within the Milky Way galaxy, such as open clusters and globular clusters, can be viewed to a limited extent. Even a few galaxies can be viewed in small telescopes.

Setting Expectations

It is important we set expectations for what you will see when viewing objects in most small- to medium-sized telescopes.

What You Will NOT See...



The Seagull Nebula



The Triangulum Galaxy



The Great Hercules Cluster

Images such as these represent multiple hours of exposure through a moderate-size telescope. By contrast, the human eye can integrate only about a tenth of a second of the image being viewed through the telescope. The number of photons captured by the eye in this length of time is orders of magnitude less than what these images represent. Humans don't perceive color until a certain threshold of light is reached, and this threshold is not met for most deep-sky objects. As a result, most objects will appear to have no color when viewing them through a telescope. However, planets and some stars can exhibit colors. For small scopes, all but the very brightest deep-sky objects will appear as faint fuzzy patches. To make things more challenging, the amount of light pollution at your location may have a serious impact on how things appear.

There are still a large number of objects that are quite thrilling to see even through some of the smallest of telescopes. These objects include the Moon, the Sun (with appropriate filter), the planets Jupiter and Saturn, and even a few very bright deep-sky objects such as the Orion Nebula. There is an excellent article titled What Can You See with Different Telescopes on the Deep-Sky Watch website that discusses this topic. Another website, deepskysketch provides sketches of what to expect for small- to medium-size telescopes.

Examples of What You Might See



The Moon



Planets



Bright Deep Sky – Andromeda Galaxy



Bright Deep Sky – Owl Cluster

Primary Factors Impacting What You Will See

There are a number of factors that have an impact on what you will see when you view an object through a telescope. These are listed in general order of impact, although this order may change if a particular factor is extreme or based on what type of object you are observing.

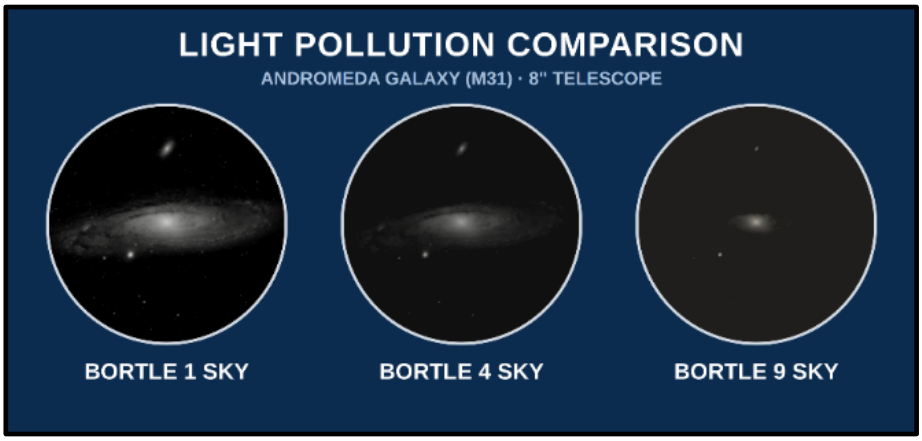


Dark Adaptation (aka Night Vision) – Refers to the sensitivity of your eye to dimly lit objects. In a dark environment the eye becomes more sensitive to light, allowing you to see progressively dimmer objects. This is due to a number of factors including the size of the eye pupil and regeneration of the protein rhodopsin in the eye.

Red light has far less impact on night vision; this is why red flashlights are used by astronomers and white light is disdained.

Generally, light sensitivity nears its peak in 30 to 45 minutes in the dark. However, this can quickly be lost with even momentary exposure to white light.

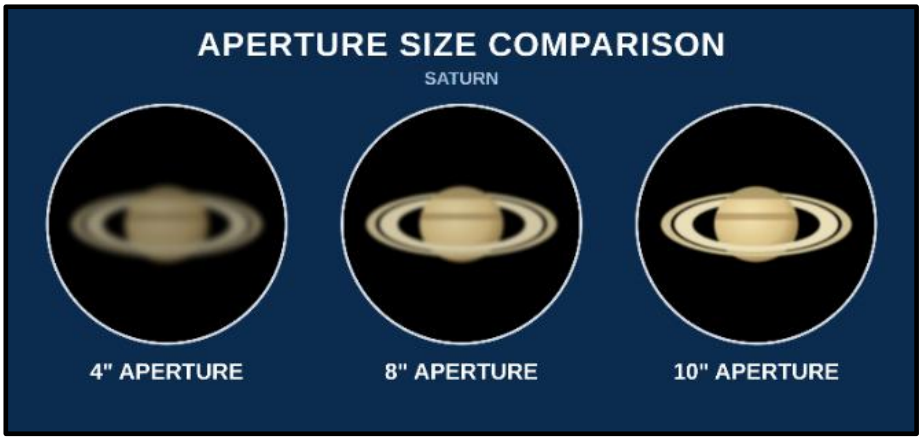
More details on this topic can be found here.



Light Pollution – Any light that makes its way into the night sky increases the background brightness when viewing objects in a telescope. This in turn decreases the difference in brightness between the object you are viewing and the background. The result is a decrease in contrast, making it harder to distinguish objects and features within the object from the background.

Light pollution is commonly expressed using the Bortle Scale.

Unfortunately, the Phoenix metro area has a high level of light pollution. There is not much that can be done to change this, but there are Light Pollution Filters that can sometimes help increase the contrast of some deep-sky objects.



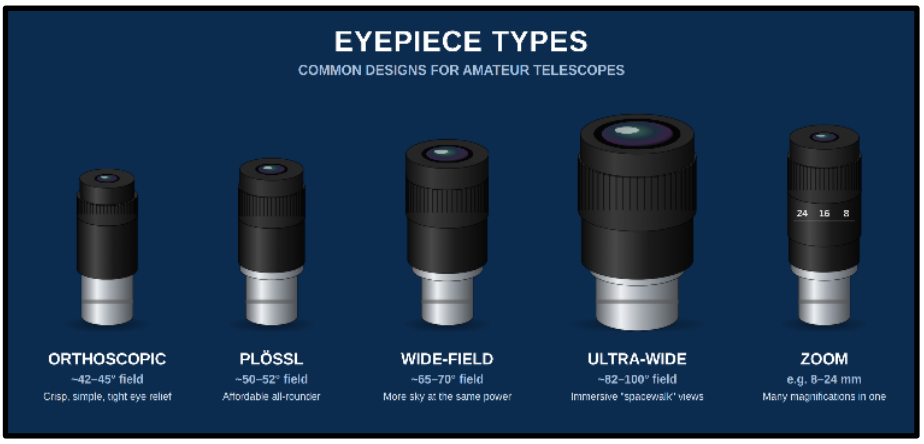
Aperture Size – The aperture is the diameter of a telescope's main lens or mirror. This determines the amount of light that is gathered by the telescope and is directly correlated with how bright a given object may appear when viewed.

With aperture size, generally bigger is better. Aperture also has a direct correlation to the Maximum Usable Magnification (discussed in the Magnification section).



Magnification – Defined as the telescope focal length (mm) divided by the eyepiece focal length (mm). As a rule of thumb, 50x the aperture size (in inches) is the Maximum Usable Magnification for a given telescope. It is important to keep in mind the Maximum Usable Magnification assumes ideal conditions. Atmospheric turbulence (seeing) may limit this value further.

$$Magnification = \frac{Telescope\ fl\ (mm)}{Eyepiece\ fl\ (mm)}$$

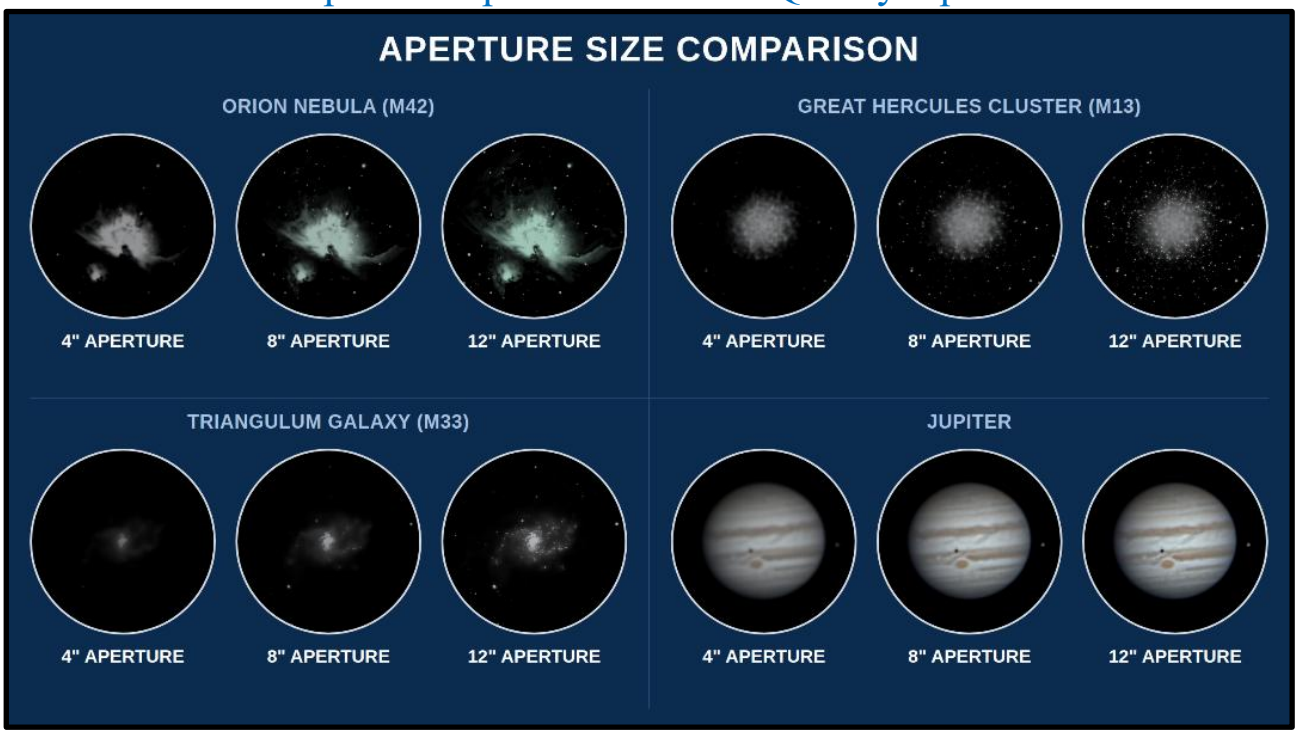


Optics – The quality of both the telescope optics and the eyepiece optics can affect the image. For most mass-produced telescopes, the eyepieces provided with the telescope are of sub-par quality. Eyepieces come in a range of optical designs at a range of prices. The Plössl design seems to provide excellent quality for a reasonable cost for the visual astronomer.

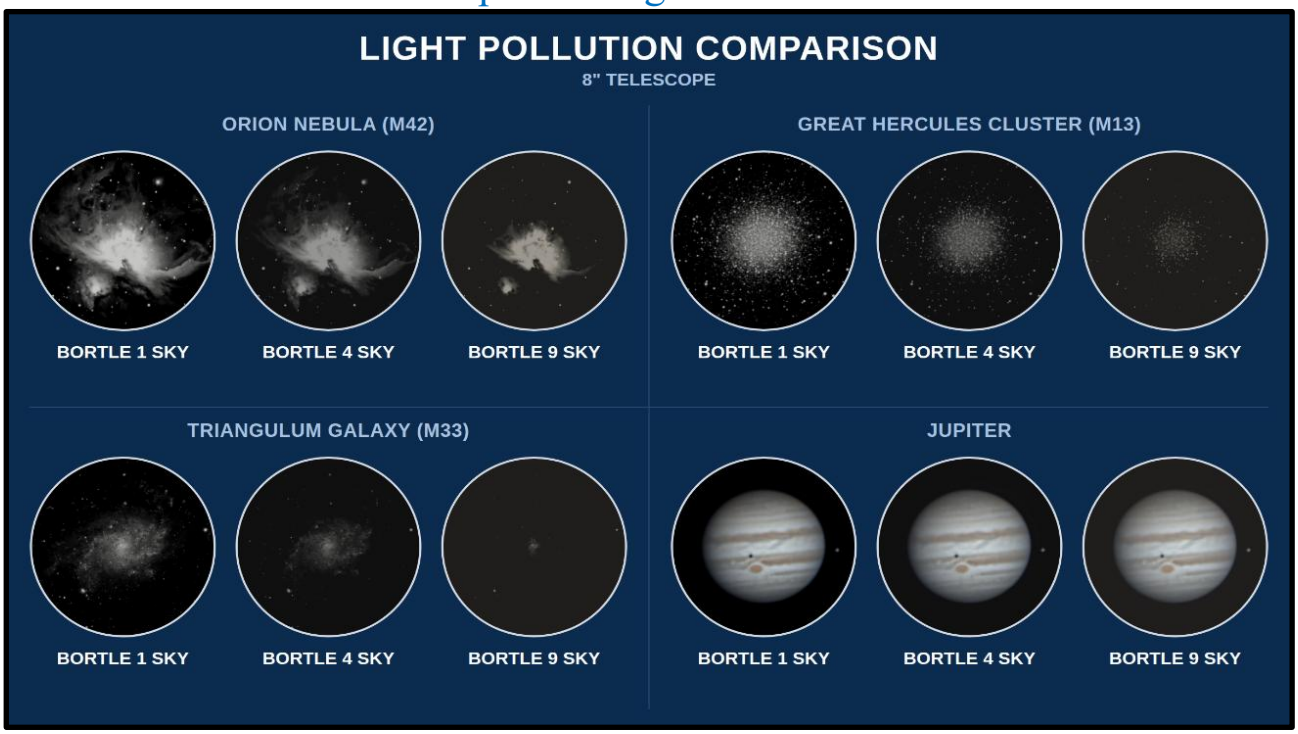
The primary factors impacting your view through a telescope are dependent on the objects you are viewing. For example, if you are observing the Moon or other bright objects such as planets or multiple star systems, dark adaptation and light pollution have little impact. On the other hand, for deep-sky objects, dark adaptation, light pollution, and aperture size are top considerations. Interestingly, magnification is usually the least important factor for the majority of cases.

All these factors are important, yet even the smallest, least expensive telescopes can provide hundreds of hours of enjoyment if you know what type of objects are appropriate for that size scope and have a stable tripod and mount.

Impact of Aperture Size and Quality Optics



Impact of Light Pollution



Resources and References

Title	Type	Description
Stellarium Web	Website	Free online Planetarium.
What Can You See with Different Telescopes	Website	Deep-Sky Watch: Excellent article on what telescopes at different price points can actually show.
Go Astronomy	Website	Go Astronomy is a good general astronomy website.
AZ Observing Group	Website	AZ Observing Group is a great local website covering a range of astronomy-related topics for local astronomers.
East Valley Astronomy Club	Astronomy Club	East Valley Astronomy Club (EVAC) is one of the larger clubs in the Phoenix metro area that meets monthly at the Southeast Regional Library in Gilbert.
Saguaro Astronomy Club	Astronomy Club	Saguaro Astronomy Club (SAC) – Astronomy club in the central Phoenix area.
Astronomical Events for the year	Webpage	ArtCentrics web page listing some of the major astronomical events for the year.
Cloudy Nights	Website	A large, active online astronomy community where members share ideas and photos, ask for advice, and buy and sell equipment.
Dark Adaptation: How It Affects What You Can See	Webpage	Good article detailing how Dark Adaptation works.
Telescope Aperture Explained	Website	Detailed discussion on telescope aperture size and its impact on what you can see.
How to Calculate the Magnification of Any Telescope	Website	Article detailing how to calculate magnification of a telescope/eyepiece combination. Also discusses what useful magnifications are possible.
Astromart	Website	Great place to purchase or sell used astronomy equipment.

Chapter 2: The Night Sky

Terms

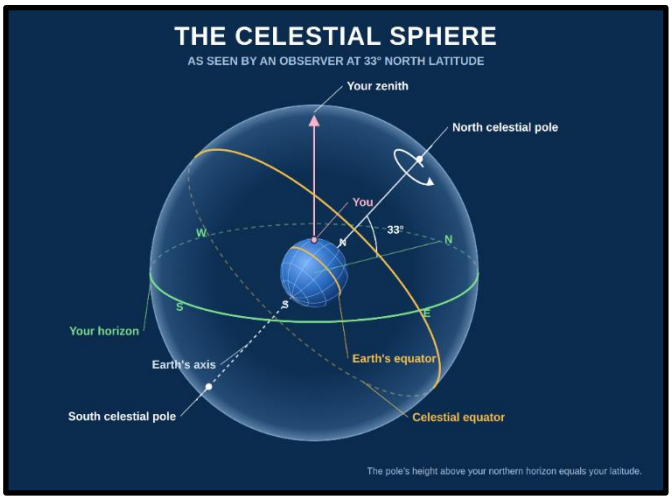
Some key terms and concepts that are important to know in this chapter are:

- **Altitude** (Alt) – One of the coordinate values utilized in the Horizontal Coordinate System and is divided into Degrees, Minutes and Seconds ranging from -90° to +90°: 0° is the horizon, +90° is directly overhead, and negative values are below the horizon.
- **Azimuth** (Az) **-** One of the coordinate values utilized in the Horizontal Coordinate System and is divided into degrees (often with minutes and seconds) ranging from 0° to 360°.
- **Bortle Scale** - A nine-level numeric scale that measures the night sky's brightness of a particular location.
- **Celestial Coordinates** - A grid system for locating things in the sky. It's anchored to the celestial poles (directly above Earth's north and south poles) and the celestial equator (directly above Earth's equator). Declination and right ascension are the celestial equivalents of latitude and longitude.
- **Celestial Sphere** – In astronomy and navigation, the celestial sphere is an abstract sphere that has an arbitrarily large radius and is concentric to Earth. All objects in the sky can be conceived as being projected upon the inner surface of the celestial sphere, which may be centered on Earth or the observer. If centered on the observer, half of the sphere would resemble a hemispherical screen over the observing location.
- **Circumpolar** - Denotes an object near a celestial pole that never dips below the horizon as Earth rotates and thus does not rise or set.
- **Constellation** - A distinctive pattern of stars used informally to organize a part of the sky. There are 88 official constellations, which technically define sections of the sky rather than collections of specific stars.
- **Declination** (DEC) – One of the coordinate values utilized in the Equatorial Coordinate System and is divided into Degrees, Minutes and Seconds ranging from -90° to +90°.
- **Equatorial Coordinate System** - A celestial coordinate system widely used to specify the positions of celestial objects. This is an absolute coordinate system independent of the location and time of the observer.
- **Horizontal Coordinate System** - The horizontal coordinate system, also known as the Alt/Az system, is a method for describing the exact position of objects in the sky, such as planets, the Sun, or the Moon. This is a relative coordinate system in that the values of Alt/Az depend upon the location and time of the observer.
- **Apparent Magnitude** – A measure of how bright an object appears from Earth.
- **North Celestial Pole** (NCP) - The celestial pole above the northern hemisphere; near Polaris.
- **Right Ascension** (RA) – One of the coordinate values utilized in the Equatorial Coordinate System and is divided into Hours, Minutes and Seconds.
- **Surface Brightness** (SB) - How bright an object looks once its light is spread over its apparent area, usually quoted in magnitudes per square arcminute, which is why M33 at magnitude 5.7 is harder to see than a magnitude 8 globular.

Sphere of the Sky

The celestial sphere is an imaginary sphere surrounding Earth onto which the stars, planets, and other celestial objects appear to be projected from our viewpoint. It's a useful model for describing where things are in the sky. The Earth spins like a top with the North Pole roughly aligned to the North Star. This is what produces

the apparent motion of the Sun, Moon and stars. How high off the horizon the North Star appears is dependent on your location on Earth (latitude). At the equator (Latitude = 0°) the North Star is at the horizon, while someone at the North Pole (Latitude = 90°) would have to look straight up to see the North Star. The Phoenix Metro area is approximately 33° North, so the North Star is about 33° above the horizon.



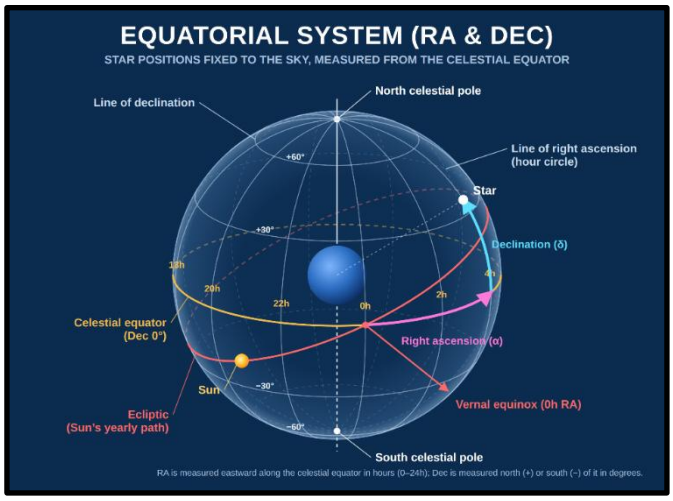


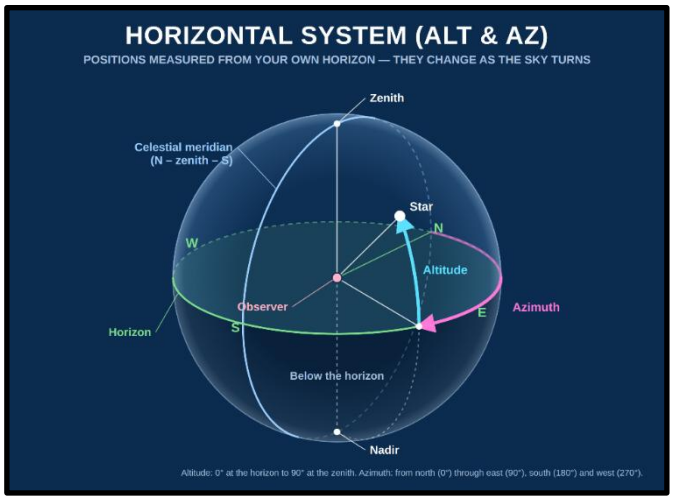
Astronomy Coordinate Systems

There are two primary coordinate systems used by astronomers to locate objects in the sky: the Equatorial System and the Horizontal System. These systems are similar to the systems used in navigation on Earth: latitude/longitude vs. bearing/elevation coordinate systems. The system you utilize will likely depend on the type of telescope mount you own.

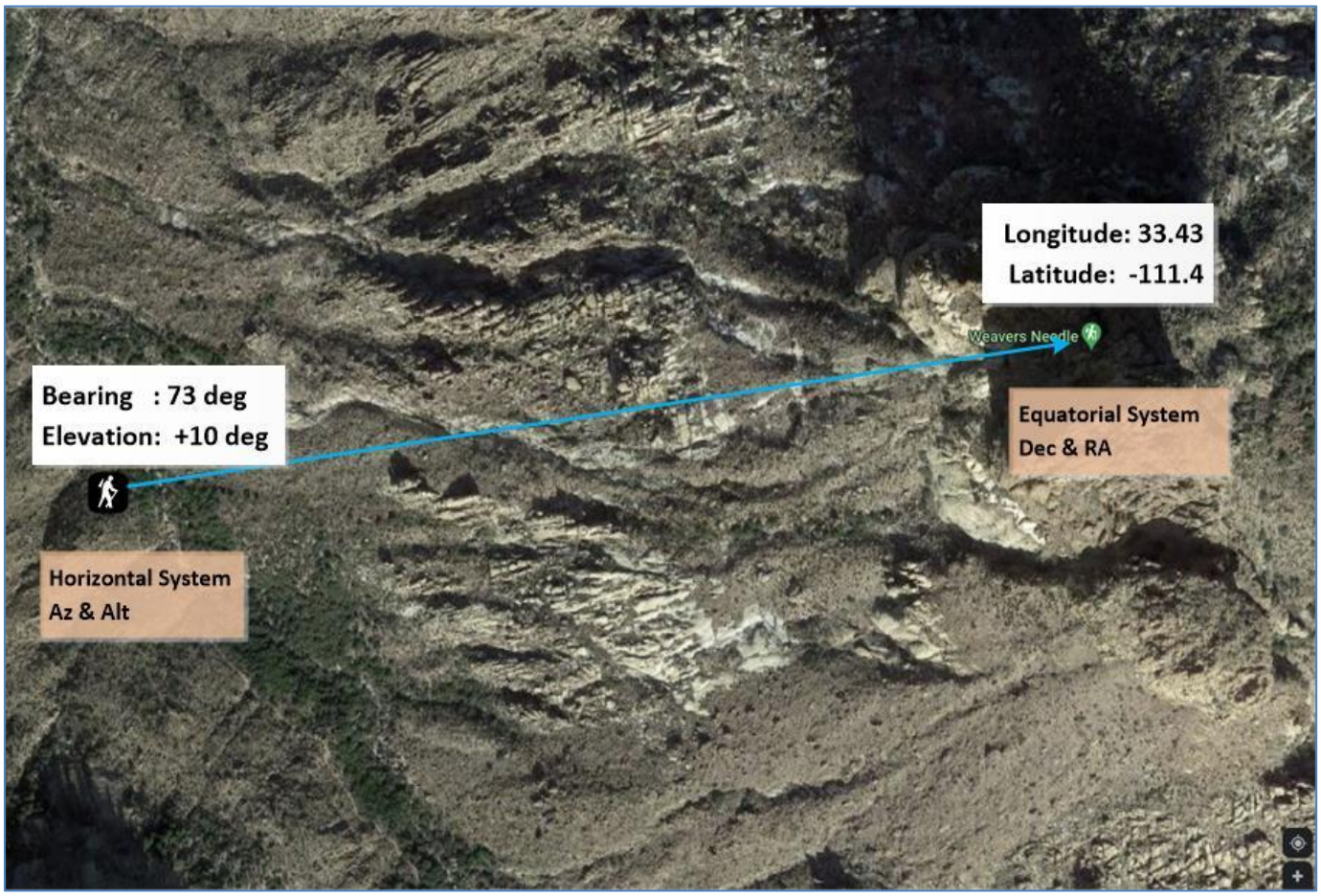
The **Equatorial System** utilizes Right Ascension (**RA**) and Declination (**DEC**) values to locate objects in the sky. Right Ascension units are the same units as a clock; Hours (**h**) ranging from 0 to 23, Minutes (**m**) ranging from 0 to 59, and Seconds (**s**) ranging from 0 to 59. Declination (DEC) utilizes units of Degrees (°) ranging from -90° to +90°, Minutes (') ranging from 0 to 59, and Seconds (") ranging from 0 to 59. This coordinate system is an absolute system; it doesn't matter where on Earth you are located, the RA and DEC values for an object remain the same. Star charts utilize this system.

The **Horizontal System** utilizes Altitude (**Alt**) and Azimuth (**Az**) coordinates to locate objects in the sky. Altitude values for objects above the horizon range from 0° to +90°, while the Azimuth values range from 0° to 360° corresponding to compass bearings. This is a relative coordinate system where the values are dependent upon the location and the time for the observer.



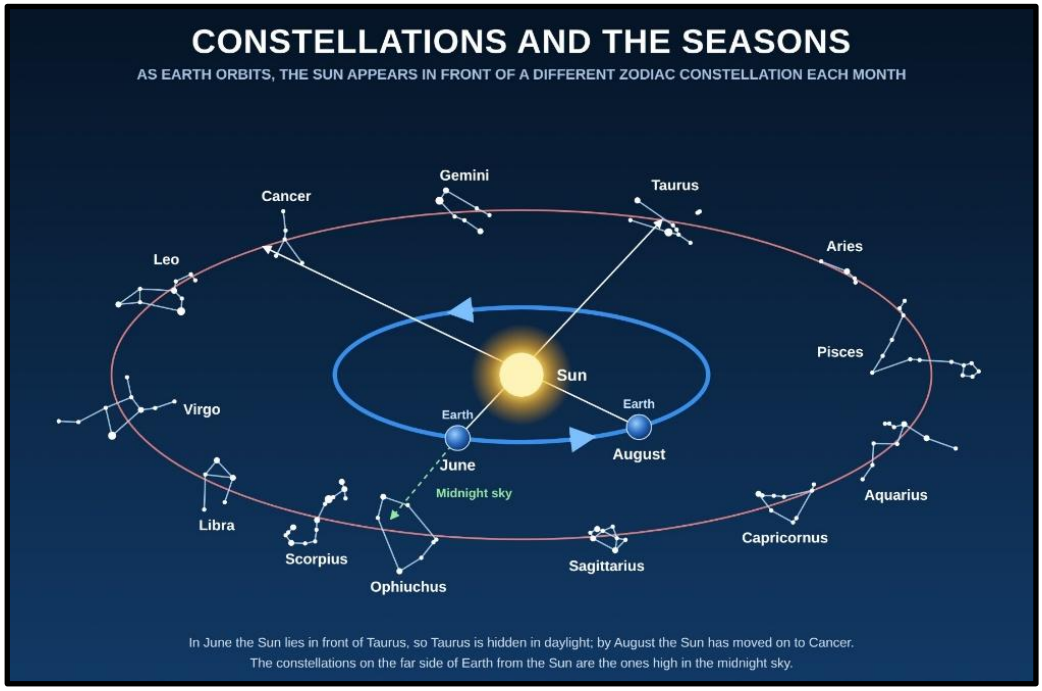


Another way to think of these two systems is by analogy to locations on Earth. Latitude/longitude, like the Equatorial System, is an absolute system. Giving a location by bearing and elevation from where you stand, like the Horizontal System, is a relative system.



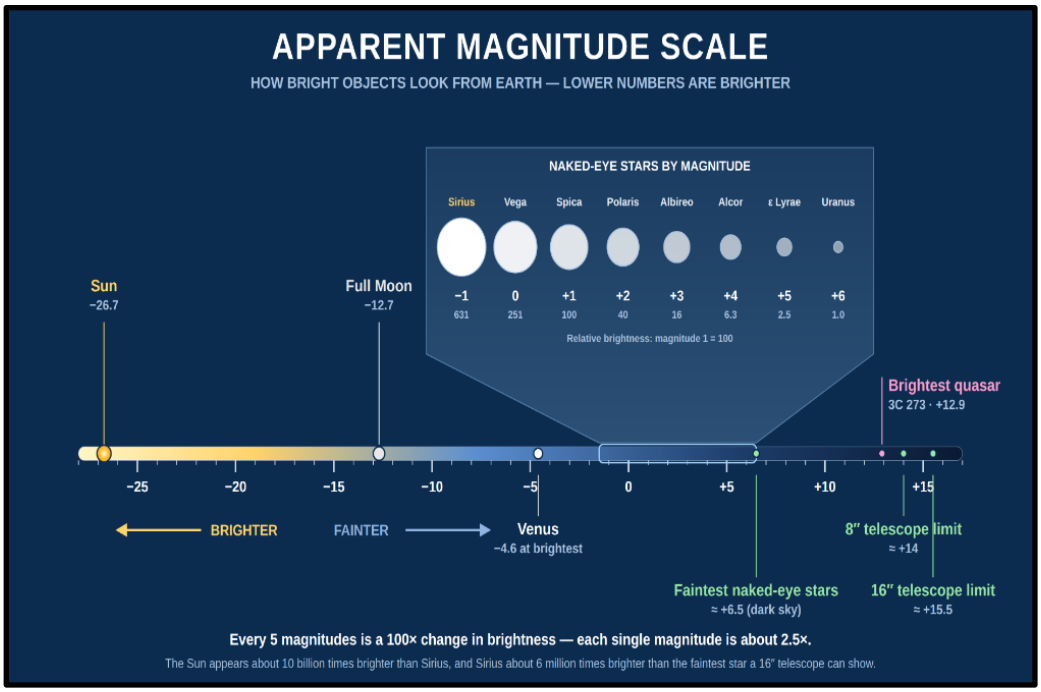
Constellations and the Seasons

As the Earth orbits around the Sun, the constellations and visible night sky slowly shift (about 1° a day). Because of this, the same stars rise about 4 minutes earlier every night. As a result, the night sky and constellations slowly change as the seasons progress through the year.



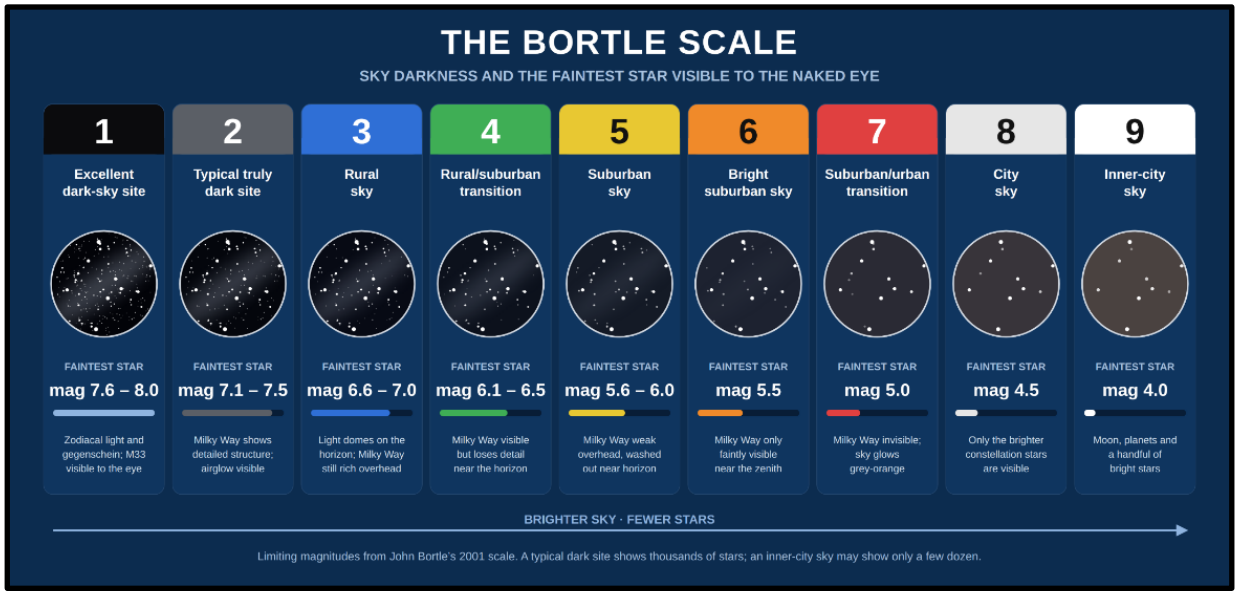
Visual (Apparent) Magnitude

Another system developed by astronomers to indicate how much light from an object is reaching the observer is the **Visual Magnitude** scale. This is a logarithmic scale: a decrease of one magnitude represents about a 2.5x increase in brightness. Note that very bright objects such as the Sun, the Moon, the brightest planets and Sirius have negative values, while fainter objects have positive values that increase with faintness. The faintest stars that can be seen in a dark sky with the naked eye, away from city lights, are about magnitude +6. In a large city such as Phoenix, the city lights wash out the dimmer stars resulting in the dimmest stars visible with the naked eye being about magnitude +4.5.



Bortle Scale

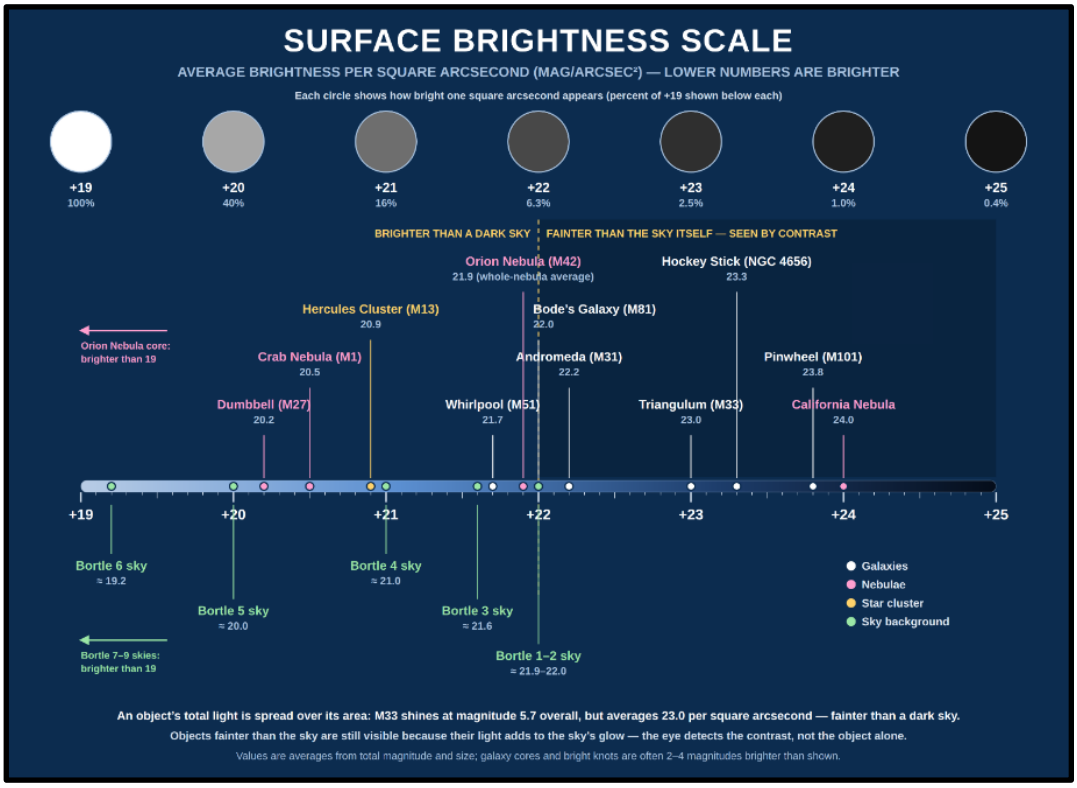
While the Visual Magnitude scale was developed to describe how bright or dim objects in the night sky are, the Bortle Scale was developed to describe the brightness of the night sky. It ranges from Class 1, the darkest skies on Earth, to Class 8 or 9 for bright inner cities, usually corresponding with the population density of the city. This scale is used to describe light pollution and many light pollution maps utilize this scale. The table below can be used to determine what magnitude stars are visible with the naked eye for a given Bortle value.



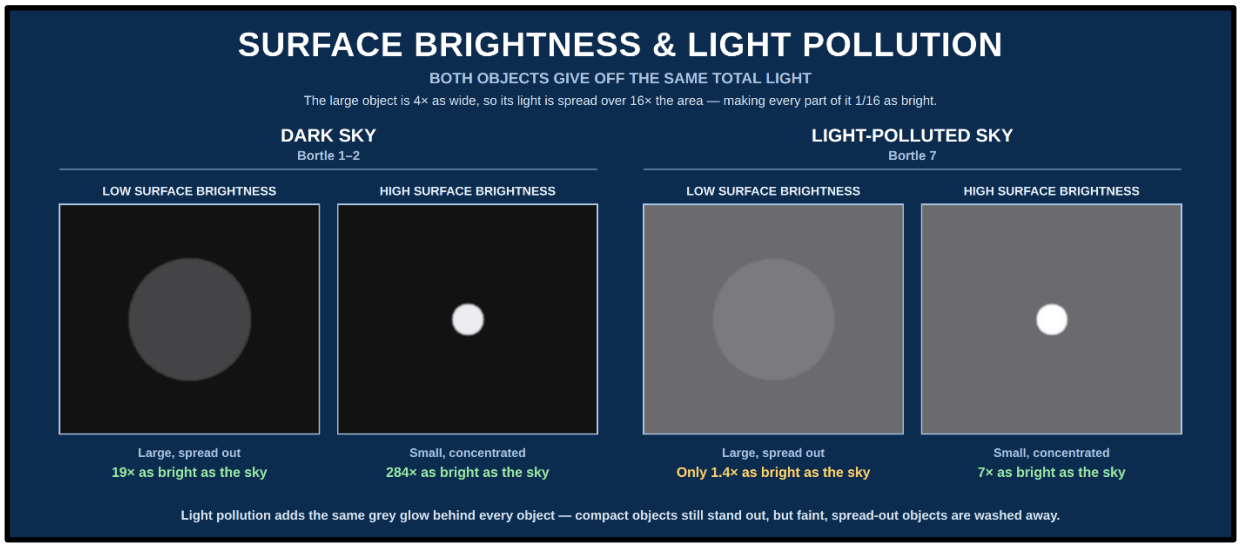
Surface Brightness

For an object with essentially no size such as a star, magnitude is a pretty good indicator of how bright an object may appear to the observer. On the other hand, for an object that has a measurable size such as a

nebula, this number can be a bit deceptive, since the **Surface Brightness** of the object can be considerably lower than the magnitude may indicate. While surface brightness may be more useful for indicating how easy it will be to view non-stellar objects, it isn't widely used.



In the images below, the total light emitted from both inner circles is the same. You can see the average brightness is much less for the larger object. What's worse is that if you added light pollution to the simulation, the background color would change from black to gray depending on how bad the light pollution is, showing how it is much more difficult to view objects with low surface brightness in areas with light pollution.



Catalogs

There are many different systems developed by astronomers to classify and identify objects in the sky. One of the earliest and most famous catalog systems was developed by the astronomer Charles Messier (1730 – 1817). He was a comet hunter who noticed there were fuzzy spots in the sky that didn't change position from night to night (relative to the stars) as comets would. So, he began keeping a record of these objects so he wouldn't mistake them for comets. He cataloged over 100 objects. This list is known as the Messier Catalog and is composed of just about every type of deep-sky object you can find. Other lists are more focused on a particular type of object (multiple star systems, galaxies, nebulae, etc.). Some of the more common catalogs along with a short description are summarized below. Catalogs are listed in general order of popularity. Most likely the Messier (M) and New General Catalogue (NGC) lists are the only ones you will need to worry about.

Note: it is common for the same astronomical object to appear in multiple lists. For instance, the Andromeda Galaxy is known by catalog numbers M 31, NGC 224, CGCG 535-17, MCG+07-02-016, PGC 2557, UGC 454 to name a few, but is generally called by its name or its Messier Number (M 31).

Messier Objects (**M**) – A list of 110 astronomical objects noted by the letter M in front of the number. For example, M 1 is the Crab Nebula. M 13 is the Great Hercules Globular Cluster.

New General Catalogue (**NGC**) – A catalogue of deep-sky objects compiled by John Louis Emil Dreyer in 1888; it contains 7,840 objects including star clusters, galaxies, and emission nebulae.

Index Catalogue of Nebulae and Clusters of Stars (**IC**) – Published as two supplements to the NGC (1895 and 1908), it contains 5,386 galaxies, clusters and nebulae.

Principal Galaxies Catalogue (**PGC**) – Published in 1989, it lists 73,197 galaxies.

Smithsonian Astrophysical Observatory Star Catalog (**SAO**) - An astrometric star catalogue, created by the Smithsonian Institution. It was published by the Smithsonian Astrophysical Observatory in 1966 and contains 258,997 stars.

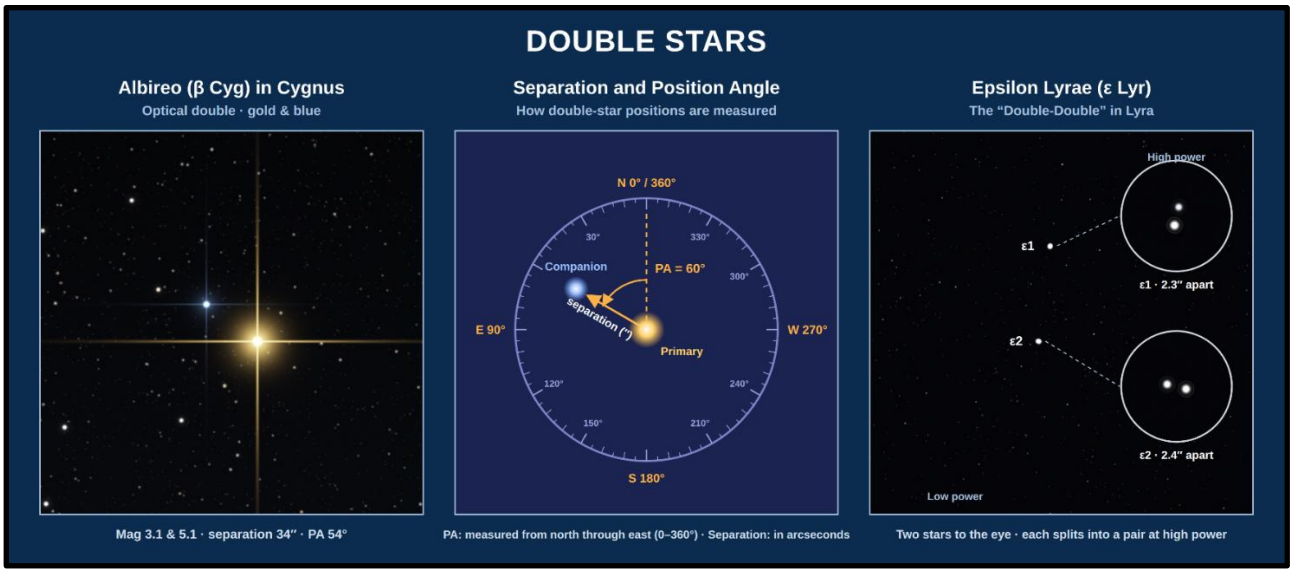
Washington Double Star Catalog (**WDS**) – As of 2026, a list of more than 157,000 pairs of double stars maintained at the United States Naval Observatory. The list also includes multiple star systems.

Lynds' Catalogue of Dark Nebulae (**LDN**) – Published in 1962, this is a list of dark nebulae based on a study of the Palomar Observatory Sky Atlas.

Barnard's List of Dark Nebulae (B) – A list of dark nebulae compiled by E. E. Barnard, first published in 1919 (182 objects) and expanded to 349 objects in 1927.

Multiple Star Systems

It is estimated that over half of the stars in the night sky are actually multiple star systems. These are systems with two or more stars gravitationally bound to each other. Most of these star systems are so far away from us and close to each other that it is not possible to visually identify a separation between them. However, there are still many systems in the night sky that can be resolved (separated) by small telescopes. There are even a couple of star systems with as many as seven components, although no Earth-bound telescope will show you all seven components.



One of the benefits of observing multiple star systems is that they are generally not impacted by light pollution, so this is a perfect hobby for the observer in a big city, even when there is a full Moon. However, navigating and locating these stars can be more challenging in a bright night sky due to fewer stars overall being visible to the naked eye for navigation (GoTo mounts negate this issue).

Two measurements utilized in the study of multiple star systems are the Separation (the apparent distance between stars measured in arcseconds) and Position Angle (PA) (the location of the secondary star relative to the primary star measured in degrees from north through east, where 0° means the companion lies due north of the primary and 90° means it lies due east).

Observing multiple star systems generally follows the sequence of using the lowest-power eyepiece to locate the system and progressing to higher magnification to resolve the components of the system. The table below can help in determining if your telescope will be able to resolve a given star system based on the aperture of the telescope and the magnitude difference (Δm) between the stars in the system.

MINIMUM SEPARATION FOR A GIVEN APERTURE

THE CLOSEST DOUBLE STAR EACH TELESCOPE CAN SPLIT, IN ARCSECONDS (″)

Δm is the magnitude difference between the primary and its companion — the fainter the companion, the wider the gap needed.
Estimates apply when the primary star is magnitude 6.5 or brighter.

MAGNITUDE DIFFERENCE	TELESCOPE APERTURE				
	60 mm (2.4″)	100 mm (3.9″)	150 mm (5.9″)	200 mm (7.9″)	250 mm (9.8″)
Δm 0.0	2.0″	1.2″	0.8″	0.6″	0.5″
Δm 0.5	2.0″	1.2″	0.8″	0.6″	0.5″
Δm 1.0	2.2″	1.3″	0.9″	0.8″	0.6″
Δm 1.5	2.5″	1.4″	1.0″	0.9″	0.7″
Δm 2.0	3.2″	1.9″	1.2″	1.1″	0.9″
Δm 2.5	3.5″	2.0″	1.4″	1.3″	1.1″
Δm 3.0	3.7″	2.3″	1.6″	1.5″	1.3″
Δm 3.5	4.4″	2.4″	1.8″	1.6″	1.5″
Δm 4.0	4.5″	2.6″	2.0″	1.9″	1.6″

Tighter split Wider split needed

Example: each pair of Epsilon Lyrae is about 2.3″ apart with Δm ≈ 1, so a 100 mm (4″) scope can split both in steady air.

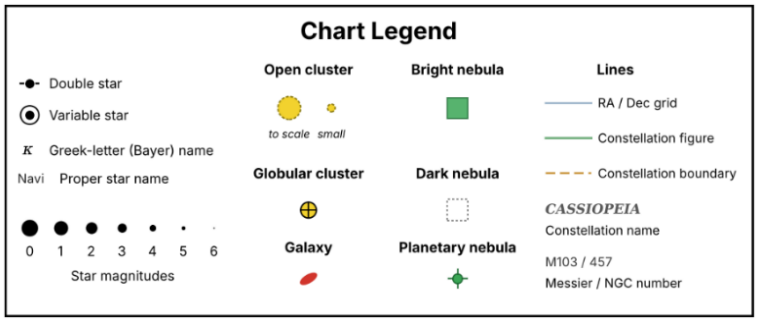
Real-world results also depend on seeing, optical quality and collimation.

Reading Star Charts and Atlases

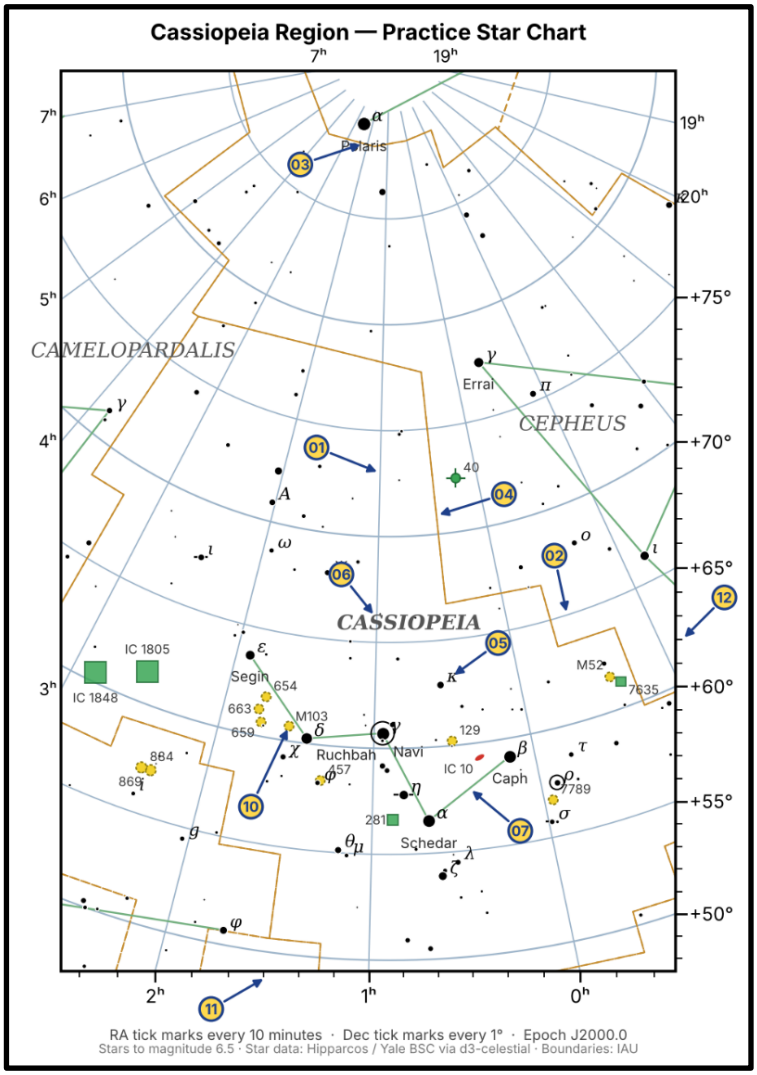
In addition to catalog numbers for the various catalogs we have reviewed, you will find a number of features common to most star charts and atlases. Most will label common star names, constellation names, identify double stars, and also identify the major stars in each constellation. Stars without a common name are labeled with a Greek letter assigned by the German celestial cartographer Johann Bayer in 1603, generally with the brightest star labeled with the first letter of the Greek alphabet (α), the second brightest with the next letter (β), and so on.

In addition to the legend for this particular star chart, take note of the following features:

01. Right Ascension (**RA**) indicator lines.
02. Declination (**DEC**) indicator lines.
03. Star Name
04. Constellation Boundary Line
05. Star Greek Alphabet notation
06. Constellation Name
07. Constellation Lines



To obtain the RA and DEC values of an item on the chart, inspect the RA scale (11), where each tick mark represents 10 minutes, and the DEC scale (12), where each tick mark represents 1°. Using this chart, we can see item **10** is M 103, a small open star cluster located just east of the star Ruchbah (δ Cassiopeiae) located in the constellation Cassiopeia. We can approximate the RA and DEC of this object to be about RA = 1h 32m with a DEC = +60.5°. Looking up this object online we see the actual RA/DEC values as being RA = 1h 33m 23s DEC = 60° 39' 30".

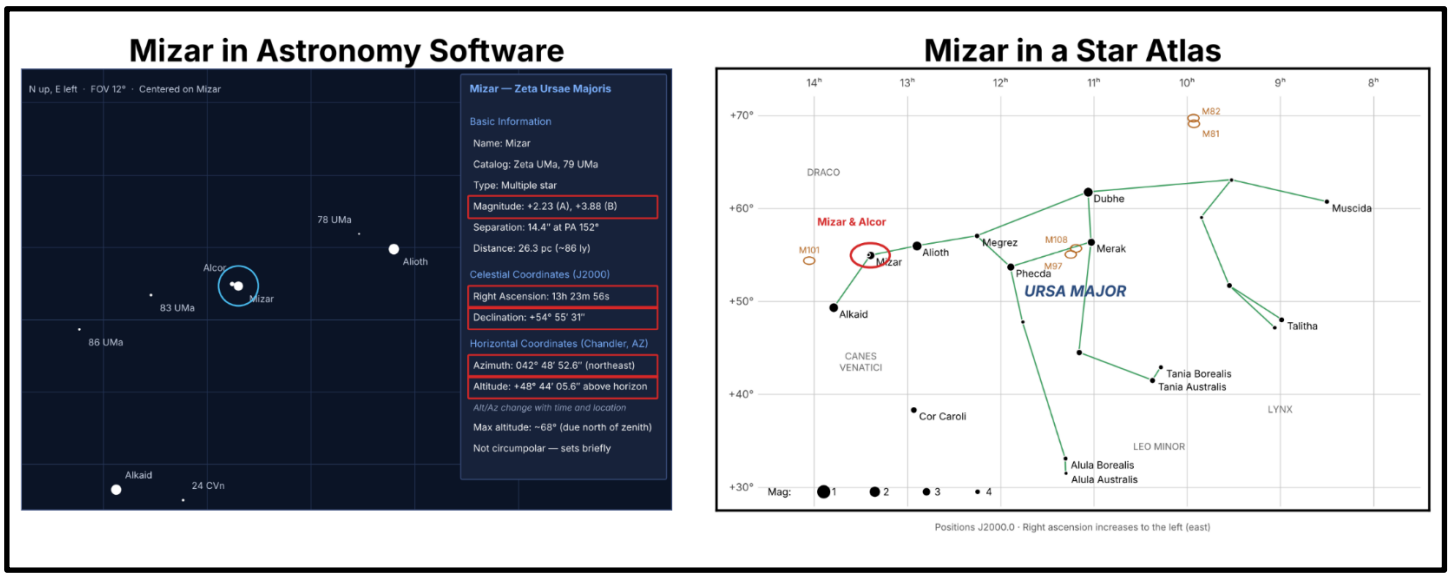


Putting it all Together

Suppose you would like to look at the star Mizar, a bright star in the Big Dipper asterism. Using either a star atlas or an online application we can see it is located at RA 13h 24m 49.43s and DEC of +54° 48’ 31.9”. The software labels Mizar a variable double star, although its brightness does not vary in any way a visual observer would notice. Mizar is a double star with components of visual magnitude +2.2 and +3.9. This is pretty bright, and we should be able to see it even in the Phoenix metro area where the naked eye visual magnitude limit is about +4.5.

Also note how the online software provides Azimuth and Altitude (Alt/Az) coordinates. These values are only valid for the date, time and location set in the software.

A great online chart reference for Messier objects, NGC and IC catalogues can be found at www.freestarcharts.com and Stellarium Web Online.



Resources and References

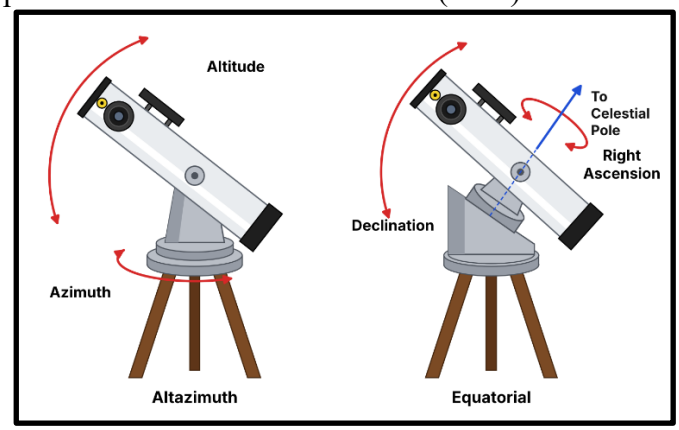
Title	Type	Description
EVAC Double Star Program	Website	100 of the finest double and multiple stars in the sky.
Royal Astronomical Society of Canada Double Star Program	Website	110 double and multiple star targets.
Stellarium Web	Website	Free online Planetarium.
SkySafari	Software	Great software for iOS and Android operating systems to see what’s up, plan your session and much more. There is also a browser-based version of this. Price ranges from $5 - $25 based on features. I use this software extensively when observing.
TheSkyLive	Website	Highlights objects of interest in the night sky.

Title	Type	Description
Planets Visible Tonight	Website	Shows what planets will be up in the night sky and when they are visible.
Constellation Guide	Website	All things about constellations including what is visible, history, charts and more information on constellations, and objects located in them.
Dark Site Finder	Website	Shows sky brightness and light pollution levels for any location.
Bortle Scale	Webpage	Wikipedia: Explanation of the Bortle Scale.
Rate Your Skies	PDF	Use the Bortle Scale along with real-world observation to rate your sky darkness.
Rotating Sky Explorer	Website	An interactive demonstration that introduces the apparent rotation of the sky.
Interactive Sky Chart	Website	Allows users to construct a detailed sky map.
Surface Brightness vs Magnitude	Webpage	Detailed discussion on Surface Brightness and the Magnitude system.
FreeStarCharts.com	Website	Star charts for Messier objects, NGC/IC Catalog objects and some stars.

Chapter 3: Mounts and Telescopes

Mounts

A mount is the structure that holds your telescope. Fundamentally there are two broad types of telescope mounts: **Alt-Azimuth** and **Equatorial**. They are named after the coordinate system they mimic. Alt-Azimuth mounts have an up/down, left/right motion and are quite intuitive to use. Equatorial mounts have a different motion since one of the axes points to the North Celestial Pole (NCP).



Mount Type	Pros	Cons
Alt-Azimuth	• Easy and intuitive to operate • Setup is easy and quick	• Does not follow objects in the sky unless computer controlled. • Not easily used with star charts since star charts are based on the Equatorial system. Applications can eliminate this issue. • Once an object is located, keeping it in the field of view can be a bit more work since there are two axes that need adjustment to follow the object (if you are manually tracking).
Equatorial	• Follows objects in the sky once located if clock drive is engaged. • Relatively easy to follow object if manually tracking the object since only one axis should need adjustment. • Star charts can be easily used with these mounts.	• Motion of mount is not intuitive. • Setup will take longer since you need to point the polar axis to the North Celestial Pole (NCP). • Requires counterweights that must be balanced.

Single Axis, Dual Axis and GoTo Telescope Drives

Manually locating and tracking an object in your telescope adds another layer of complication, especially for deep-sky objects or objects being viewed with high magnification. GoTo mounts potentially make finding objects much easier once the telescope mount has been aligned. Of course, there is an increased cost associated with these types of drives, but prices have dropped considerably over time. Both Equatorial and Alt-Azimuth mounts can be purchased with GoTo drives. The cheapest way to get a drive is usually to buy it bundled with the telescope, but the best-performing mounts are generally third-party units bought separately.

- **Single-Axis Telescope Motor Drives** (aka Clock Drives) – Restricted to Equatorial mounts; these consist of a single motor and drive that attaches to the Right Ascension axis and provides basic star tracking.

- **Dual-Axis Telescope Motor Drives** – Provide basic star tracking in addition to control of the telescope in any direction, but do not locate objects for you.

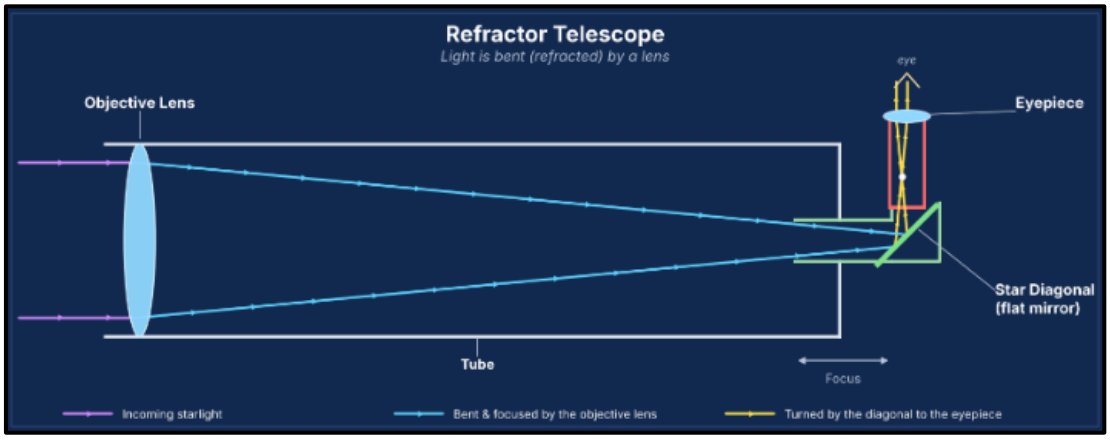
- **GoTo Telescope Drives** – Very popular and found on many telescopes. Require a basic calibration process at the start of a viewing session by pointing to a number of bright stars to orient the computer. Once calibration is complete, enter the object of interest in the hand controller and let the computer slew the telescope to the object. Third-party mounts tend to be quite reliable. Low-cost telescope/mounts can be fickle at best. The initial setup procedure can be challenging to master. If you purchase one of these, make sure you can return it if you can't get it to work as expected.

Single- and Dual-Axis drives tend to be aftermarket modifications and are not really used anymore since the prices of GoTo mounts have dropped so much.

Clock Drive	Alt/Az GoTo Mount	Equatorial GoTo Mount
		

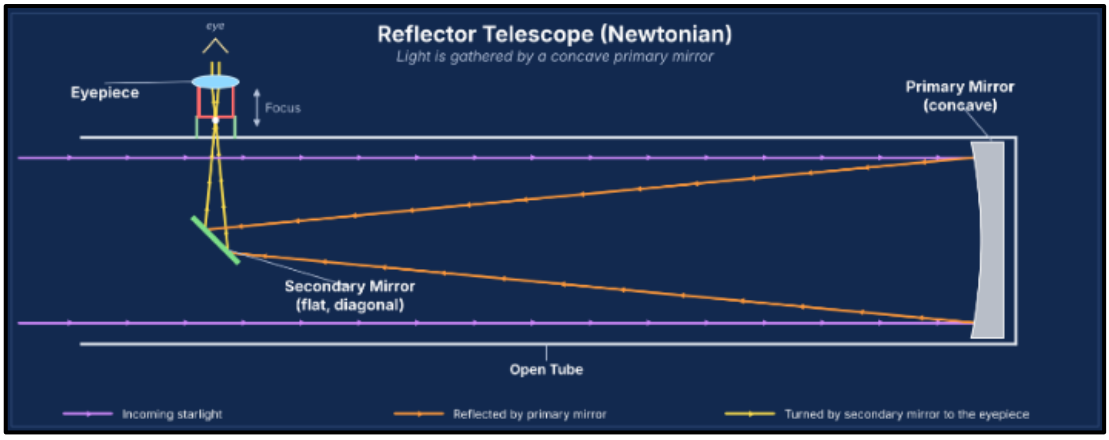
Optical Tube Assembly (OTA)

There are many types of Optical Tube Assembly (OTA) designs. Three of the designs most common in mass-produced telescopes are discussed below. Contrary to popular belief, magnification is not the primary consideration when purchasing a telescope. Build quality and light-gathering power (aperture size) are probably the two most important factors.

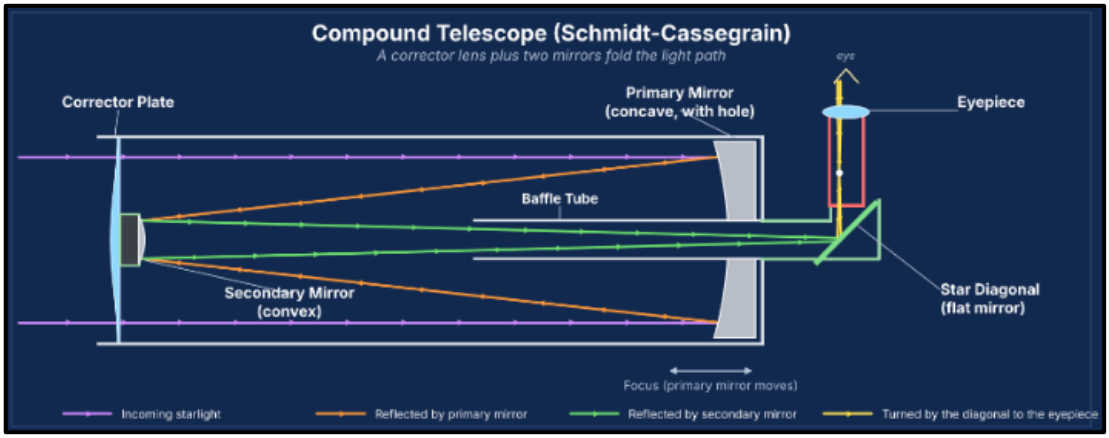


Refractor – Lenses are used to collect light.

- Pro: Excellent design for viewing planets and the Moon (when good optics and design are implemented).
- Pro: No need for collimation
- Con: Cost – a well-designed refractor is the most expensive (per inch of aperture) telescope.
  Con: Not great for most deep-sky viewing since aperture size is so important, and these are limited to about 5" before becoming very expensive.



Reflector – Mirrors are used to collect light.
- Pro: Cost, least expensive (per inch of aperture) telescope.
- Pro: Most cost-effective design for viewing deep-sky objects.
- Con: Not very portable
- Con: Needs collimation on a regular basis for best views.
- Con: Harder to use for photography on basic mounts.



Schmidt-Cassegrain (SCT) AKA Compound Telescopes – A corrector lens and mirrors are used to collect light. Combines advantages of both Refractor and Reflector telescopes. This is a great general-purpose telescope that performs well for deep sky, planetary viewing and imaging.
- Pro: Very portable.
- Pro: A good multi-purpose design performing well on planets, Moon, and deep-sky objects.
- Con: Occasional need for collimation.
- Con: Long cool-down time
- Con: Dew easily forms on the corrector plate (not a real issue in AZ)

Many Combinations

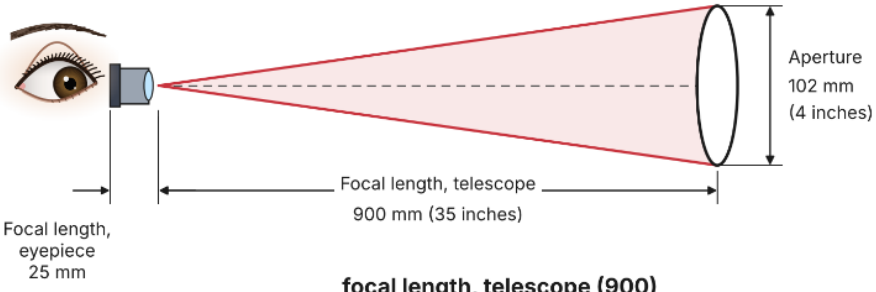
The possible combinations of mounts and Optical Tube Assemblies (OTA) are nearly endless. Here are a few examples.

 Reflector on Tabletop Alt/Az mount	 Reflector on Equatorial Mount (Manual Operation)	 Refractor on Center Balanced Equatorial GoTo Mount	 Schmidt-Cassegrain on Fork Mount with Wedge and Clock Drive
 Schmidt-Cassegrain on Alt/Az GoTo Mount	 Refractor on Alt/Az Mount (Manual Operation)	 Dobsonian telescope and mount (Manual Operation)	 Schmidt-Cassegrain on Alt/Az Fork GoTo Mount

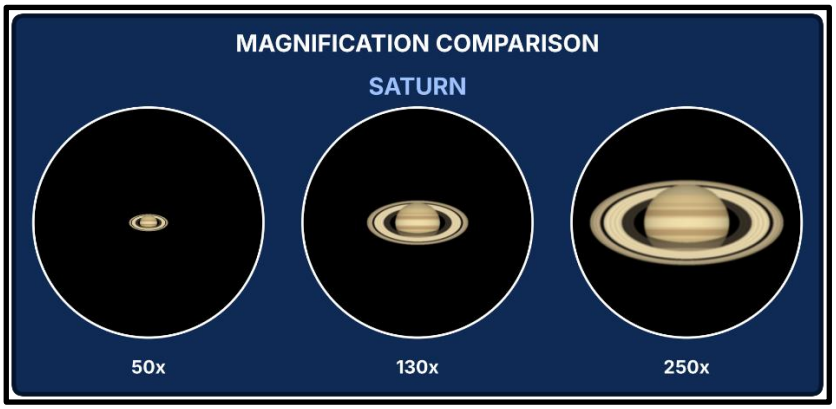
Magnification

Magnification is expressed as a number indicating how large an object appears when viewed through a telescope compared to how large it appears to the unaided eye. Magnification is defined as the Focal Length (mm) of the Optical Tube Assembly (OTA) divided by the Focal Length (mm) of the eyepiece. For a given telescope, the magnification is determined by the eyepiece being used. The eyepieces will have their focal length printed on them, so the magnification is easily calculated. Generally, the maximum useful magnification of a telescope is 50 times the aperture (in inches). It is a common practice for less reputable telescope manufacturers to advertise magnifications for telescopes beyond the useful magnification. Another factor impacting usable magnification is the stability (aka seeing) of the atmosphere. Generally, even for large telescopes, about 250x is often a practical upper limit due to atmospheric turbulence. At the same magnification, the larger telescope gathers more light, so the image is brighter and fine detail is easier to see.

$$\text{Focal ratio} = \frac{\text{focal length, telescope (900)}}{\text{aperture (102)}} = \text{f/8.8}$$

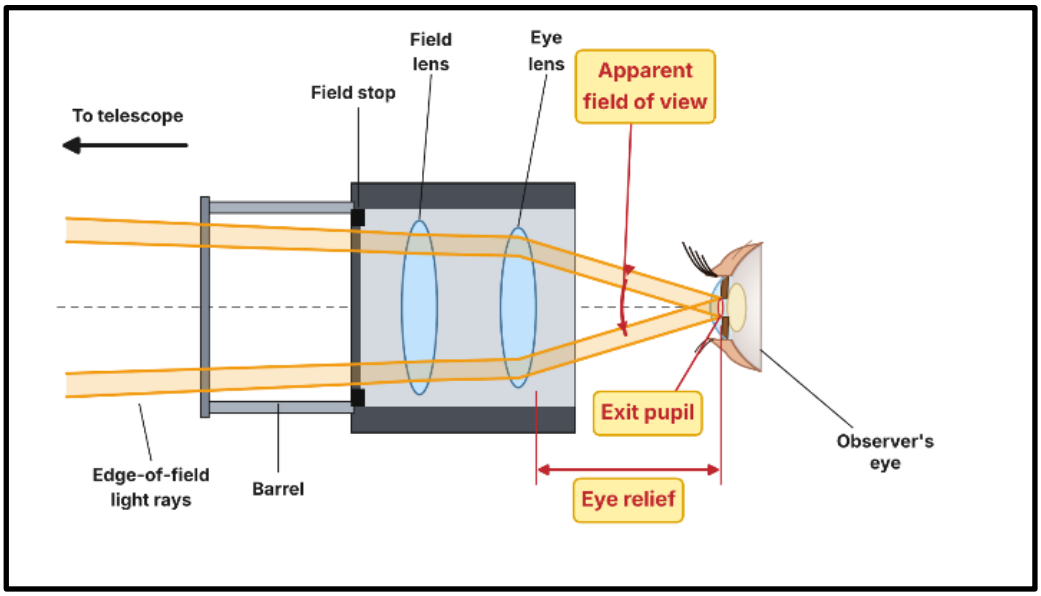


$$\text{Magnification} = \frac{\text{focal length, telescope (900)}}{\text{focal length, eyepiece (25)}} = 36\times$$



Exit Pupil

Exit pupil is a measure of the diameter of the cone of light exiting an eyepiece. As a general rule, an exit pupil between 2 and 5 mm seems to provide the best viewing experience. This is because the average human pupil size ranges from 2 to 7mm. Having an eyepiece with an exit pupil much greater than the observer's pupil wastes light, while a very small exit pupil can be difficult for viewing. This is why exit pupil should be a consideration when purchasing an eyepiece. View these links (1, 2) for more detailed discussions on exit pupil. Exit pupil can be calculated with the following equations:



$$\boldsymbol{ExitPupil} = \frac{Eyepiece\ fl\ (mm)}{Telescope\ FR}$$

$$\boldsymbol{ExitPupil} = \frac{TelescopeAperture\ \ (mm)}{Magnification}$$

6" (150mm) Schmidt-Cassegrain

Telescope FL	Telescope FR	Eyepiece FL	Exit Pupil	Mag
1500mm	**10**	55 mm	5.5 mm	27x
		40 mm	4.0 mm	37x
		24 mm	2.4 mm	63x
		8 mm	0.8 mm	187x

7" (178mm) Maksutov-Cassegrain

Telescope FL	Telescope FR	Eyepiece FL	Exit Pupil	Mag
2670mm	**15**	55mm	3.7mm	48x
		40mm	2.7mm	67x
		24mm	1.6mm	111x
		8mm	0.5mm	334x

2.8" (71mm) Refractor

Telescope FL	Telescope FR	Eyepiece FL	Exit Pupil	Mag
490mm	**6.9**	55 mm	8.0 mm	8.9x
		40 mm	5.8 mm	12.3x
		24 mm	3.5 mm	20.4x
		8 mm	1.2 mm	61.2x
		4 mm	0.6 mm	122.5x

5.1" (130mm) Reflector

Telescope FL	Telescope FR	Eyepiece FL	Exit Pupil	Mag
650mm	**5.0**	~~55 mm~~	11 mm	11.8x
		40 mm	8.0 mm	16.3x
		24 mm	4.8 mm	27.1x
		8 mm	1.6 mm	81.3x
		4 mm	0.8 mm	162.5x

Finder Scope Alignment

It is critical that the finder scope is aligned with the telescope. The first time you set up your telescope, you should probably align the finder scope with the main scope during the day. Put your lowest-magnification eyepiece in the telescope and point the main scope at a terrestrial object quite far from the telescope (treetop, light post, etc.). If you have a clock drive or GoTo mount, do not turn it on. Once you have an object centered in the main scope, go to the finder scope and make adjustments to the finder scope so that the target is in the center of the finder scope. Go back to the telescope and make sure the target is still in the middle of the field of view. Now place a high-magnification eyepiece in the main scope and re-center the target in the main scope. Next, check the finder scope and make any required adjustments to ensure the target is in the center of the finder scope. Re-check the telescope and ensure the target is still centered; if not, re-center and re-check the finder scope. Once the target is centered in both the finder scope and telescope, you have completed your finder scope alignment.

The procedure for Finder Scope Alignment at night is basically the same process, but a bright star or a planet should be used as the target. If you are having trouble locating a target in the main scope, use the Moon as a target if it is up, since it should be fairly easy to locate in the telescope.

Telescope Mount Alignment

The alignment procedure is the process of setting up your telescope so it can locate and track objects in the night sky. The process of alignment is dependent on the type of mount and the accuracy you desire when tracking an object in the sky. Alignment details vary from mount to mount. The information provided below offers a general summary for the type of mount described. Refer to your owner's manual for more specific details.

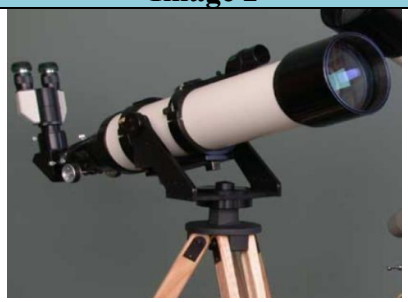
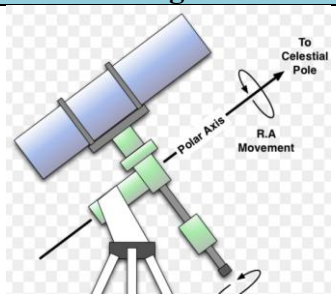
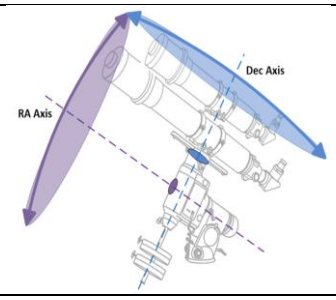
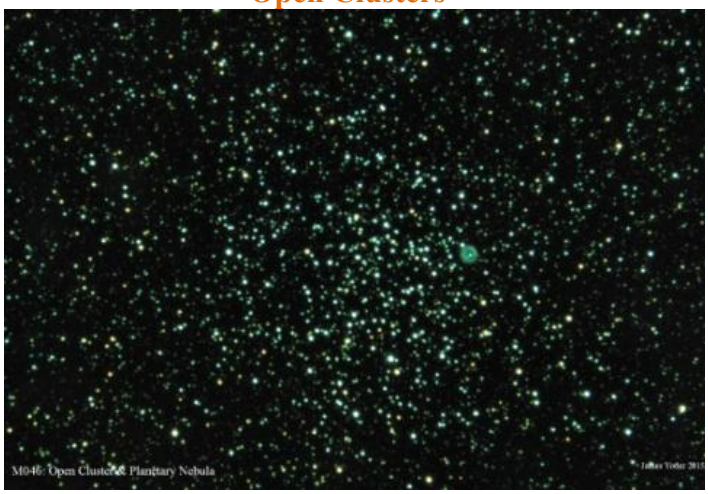
Image 1	Image 2	Description
		**Alt-Az Manual Mounts** – Setup for these mounts is quite minimal. Generally, you just need to make sure the mount is level. Many mounts have a built-in level; otherwise, you may have to supply your own. Some may have markings on the Alt and/or Azimuth axis; in these cases, you may want to rotate the Azimuth axis to coincide with compass coordinates (i.e., 0° = North). This will enable you to use applications that supply Alt-Az coordinates to locate objects in the sky.
		**Alt-Az GoTo Mounts** – Level the telescope. Turn on the GoTo computer and follow alignment instructions. Most mounts will have you point to two or three bright stars to calibrate the mount.

Image 1	Image 2	Description
		**Equatorial Manual Mount** – All Equatorial mounts require polar alignment to ensure the scope tracks objects in one motion. They will also have setting circles associated with each axis (see image). First, level the tripod. Next, set the mount's latitude adjustment to match your latitude (about 33° in the Phoenix area). Point the polar axis toward true north, then adjust the counterweights to balance the telescope. Finally, refine the polar axis so it points at the North Celestial Pole (NCP); note that a compass points to magnetic north (about 10° east of true north in Phoenix), and that Polaris itself sits about two-thirds of a degree from the true pole. Many Equatorial mounts have built-in polar alignment scopes to assist in precisely aligning the mount with the North Celestial Pole.
		**Equatorial GoTo Mount** – Same basic setup as Equatorial Manual Mount to start with, then turn on GoTo computer and follow alignment procedure. It will generally instruct the user to point to two or three bright stars in the sky for alignment procedure.

Deep Sky Objects

Objects that exist outside of our solar system are called Deep Sky Objects. These objects can be classified as follows:

Open Clusters



Young, loosely bound gatherings of stars. The stars in these clusters were born together. They may contain a handful of stars or thousands of stars. You can see many open star clusters with the naked eye.

Globular Clusters



Tightly packed, symmetrical collections of stars. They orbit mostly in the extended stellar halos surrounding most spiral galaxies. Globulars contain some of the oldest stars in a galaxy, having formed early in its history. Stars in a globular are gravitationally bound to each other.

Galaxies



A vast collection of stars in an ocean of space. Galaxies are typically separated from one another by huge distances measured in millions of light-years. A galaxy can contain hundreds of billions of stars and be many thousands of light-years across.

Supernova Remnant



The expanding debris left behind by the explosion of a star. A supernova remnant is held together by an expanding shock wave and consists of ejected material of the star that expands from the explosion and interstellar material the shock wave sweeps up along the way.

Planetary Nebula



Consist of a glowing and expanding shell of gas, ejected from red giant stars late in their lives. Planetary nebulae often appear as rings or disks representing expanding gas from the source star.

Reflection Nebulae



Do not create their own light but instead shine by reflecting the light of nearby stars. Reflection nebulae are created when the energy from a nearby star is insufficient to create an emission nebula but is enough to make the dust visible.

Emission Nebulae



Shine with their own light. Like planetary nebulae, emission nebulae glow because their gas is ionized. Emission nebulae tend to emit a reddish color as a result of the abundance of hydrogen in them.

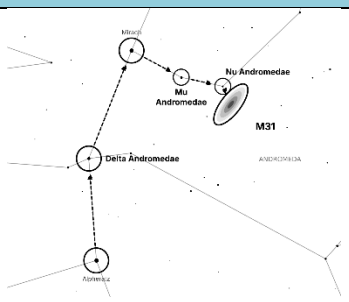
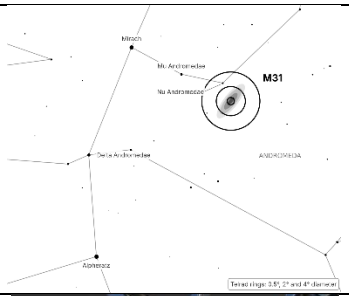
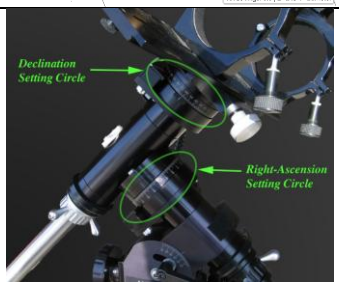
Dark Nebula



A dense collection of gas and dust that obscures visible wavelengths of light, meaning that we are unable to see through it, explaining why they are also called absorption nebulae. Because of this absorption, to us, dark nebulae just look like dark masses blotting out the background stars.

Techniques for Finding Objects

There are a number of techniques that can be used to locate astronomical targets; many depend on the telescope mount, while others work with any mount.

Technique	Mount Type(s)	Image	Description
Star Hopping	Manual Mount		In this technique, a star chart (either online or paper) is used to locate the object of interest, then nearby bright stars are located that will help guide you to the target. The scope is first pointed at a bright starting star, then moved from star to star until the target is reached. The process allows the astronomer to move from an easily identified and located bright star to subsequent dimmer stars closer to the target until finally the target is located.
Telrad Charts	Manual Mount		A variation of Star Hopping, except those references such as SkySpot Finder Charts are used to identify exactly where in the sky the Telrad pointer should be placed for the target of interest. Many software applications support displaying Telrad indicators and can also be used.
Setting Circles	Manual Mount with setting circles		In this technique, a bright star fairly close to the target of interest is located and centered in the scope. The bright star coordinates (either Equatorial or Alt-Az depending on your scope mount) are looked up using software, a star atlas, or a table of bright stars and coordinates. The setting circles are then adjusted to match the coordinates of the star. This ensures your scope setting circles correspond to the celestial sphere. Next, the celestial coordinates of the object you wish to locate are looked up and the telescope is moved to the coordinates using the setting circles you have just adjusted.

Technique	Mount Type(s)	Image	Description
GoTo	GoTo Mounts		Once the initial alignment procedure has been completed on your GoTo mount, you simply punch in the object of interest, and the telescope will slew to the target. Once the telescope has been aligned, this is super-fast and easy. The downside is that you generally won't get to know the night sky.

Putting it all Together

As you can see, there are many factors to consider when purchasing a telescope, and many combinations of OTA and mounts are possible. Some factors to think about before making a purchase include:

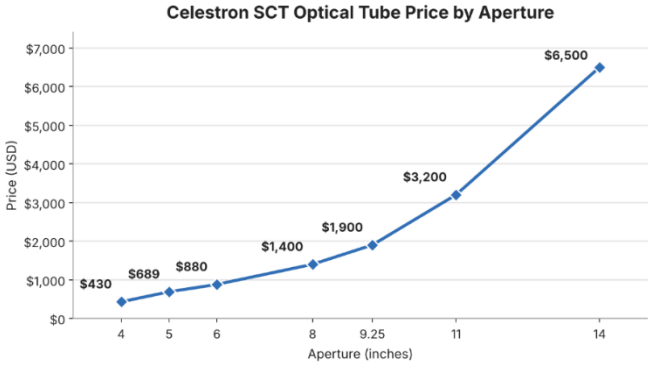
- **Budget** – What is your budget? Also, keep in mind that almost all telescopes will need accessories to make your viewing session pleasurable, so don't consider the cost of the scope and mount to be the final cost. We will cover some of these costs in Chapter 4.
- **Viewing Targets** – What do you intend to view? Larger scopes generally support higher magnification and gather more light, making dimmer objects brighter. Observing very bright objects such as the Moon and Sun does not require large apertures.
- **Portability** – Consider how often you plan to move and set up the scope, and where you intend to use it.
- **Tracking** – Once set up, motorized mounts should track your object, while manual mounts will require you to continually adjust to keep the object in the field of view.
- **GoTo Mounts** – An additional cost, but getting much less expensive, these mounts make finding objects much easier provided you set them up properly at the start of your session. These allow you to spend more time observing objects and less time trying to find them.
- **Complexity** – GoTo mounts can have a steep initial learning curve. Finding objects manually has its own challenges. Try both methods and determine what works best for you.
- **Used or New** – Used telescopes tend to be about half the cost of new ones. Periodically, astronomy clubs will have sales with used telescopes that you can get at a very reasonable cost. The website Astromart also has a large selection of used equipment. East Valley Astronomy Club (EVAC) also has used equipment for sale.

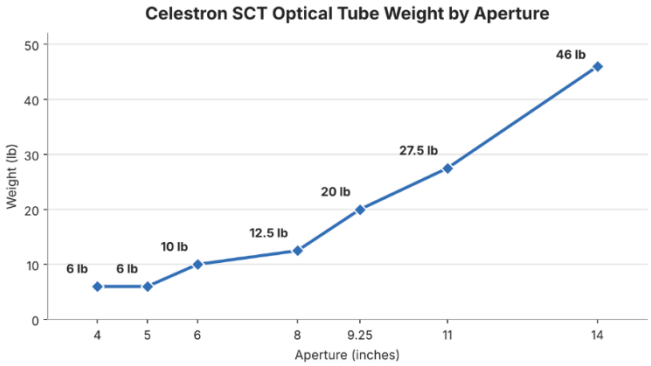
List it out – Make a list of everything you think you may need for your astronomy hobby so you can make an informed decision on what to purchase and how much the bottom-line cost will be. We will show examples of this at the end of Chapter 4.

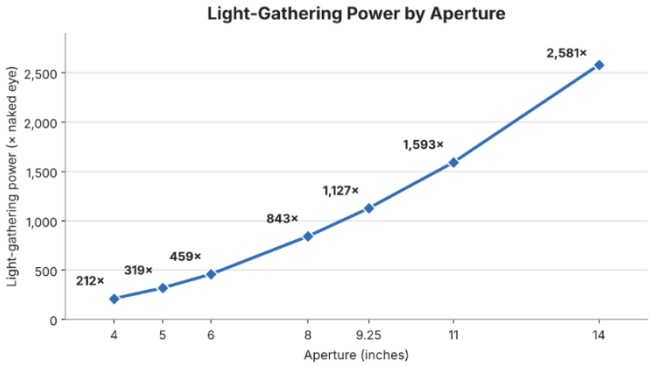
A Practical Example: Schmidt-Cassegrain

In addition to the factors listed above, you must also consider the ease of transport of the telescope. In this example we evaluate some of the primary properties of a Schmidt-Cassegrain Optical Tube Assembly (OTA) (Ref: Celestron Website). Sure, a 14" telescope would be great to have with 2,580 times the light-gathering power of the human eye, but are you going to be able to lug a 46-pound OTA out for viewing?

Size (Inches)	Price	Aperture	Weight	LGP x
4	$430	102.0	6.0	212.0
5	$689	125.0	6.0	318.9
6	$880	150.0	10.0	459.0
8	$1,400	203.2	12.5	843.0
9.25 (Edge)	$1,900	235.0	20.0	1127.0
11	$3,200	279.4	27.5	1593.0
14	$6,500	355.6	46.0	2581.0







Resources and References

Title	Type	Description
EVAC Observing Programs	Website	A number of observing programs offered by East Valley Astronomy Club (EVAC).
Best Telescope For Beginners	Website	Additional information for what telescope to purchase.
Basic Telescope Types	Video	YouTube – OPT, Basic Telescope Types
Telescope Eyepiece Basics	Website	Good detailed article on basic principles for eyepieces, Barlow lenses and other factors.
Field of View Calculator	Website	Shows you how large an object should appear for a given telescope and eyepiece combination

Telescope Magnification Explained	Website	More information on magnification and how it applies to telescopes.
What is an Exit Pupil and why is it important?	Website	Detailed discussion on Exit Pupil related to telescopes/binoculars and eyepieces
A Pupil Primer: How big should a Telescope's exit pupil be?	Website	Factors on exit pupil for consideration in selecting an eyepiece.
Astromart	Website	Great place for getting used equipment. There is a membership fee associated with this website.
Starizona	Vendor	Located in Tucson, this is one of the best locations to purchase higher-end telescopes and associated equipment; their technical know-how and help are excellent.
AgenaAstro	Vendor	Good website for purchasing various astronomy equipment, located in California, so shipping time is usually quite short.

Chapter 4: Accessories

There are many different accessories you can purchase to help with your observing; some of the most critical include a good headlamp, navigation reference, finder scope and quality eyepieces.

Headlamp/Flashlight

Headlamps free up your hands for the various tasks you need to do when observing. White light will ruin your night vision and make other astronomers upset, so make sure you purchase a light with a red filter or red LEDs. Having a light that allows for different levels of brightness is also very helpful. Finding a light that isn't too bright and has the features I have mentioned can be surprisingly difficult. I have found the Celestron Night Vision Headlamp ($18) is a good fit for astronomy.

Navigation and Planning Resources

Listed below are some references to help identify what items you may want to view for the night and where they are located. You can go old school and get a book, atlas or other such material, or if you have an iPad or smartphone, there are some excellent applications that can be used. I personally use my iPad mostly in the field, but bring a sky atlas as a backup.

Reference	Media Type	Price Range	Comments
Star Wheel	Print	$20	Old school, but a great way to see what is up at a glance. Easy to carry and always reliable.
SkySafari	Digital	$5 - $50	Available for iOS and Android systems, this is a great tool to see what may be of interest for viewing for the night. If you have a smartphone or iPad, I would consider this a must-have reference. SkyPortal is a free app from Celestron and a lite version of SkySafari.
SkySpot Books	Print	$18 - $40	This company publishes a number of great field guides that are customized just for the Telrad finder (although you don't have to have one to use these books); they will show you exactly where the object is in reference to the finder bullseye. They also give detailed information on the object. They publish four books; the best for the beginner is the Bright Telescopic Objects just for small scopes.
Sky Atlas	Digital or Print	$10 - $50	This is an atlas of the sky with objects identified in the atlas. You will need to read off the atlas the coordinates of the object you want to observe. Generally better suited to more advanced observers, and may be considered redundant if you already have an astronomy application such as SkySafari.
Star Hopper's Guide to the Universe	PDF	Free	Excellent resource for those who don't have a GoTo telescope and have to star hop to their targets.
Yoder's Constellation Guides	PDF	Free	More than 58 constellation guides, and growing.

Reference	Media Type	Price Range	Comments
A New Catalog of Stellar Richfields for Binoculars	PDF	Free	Great resource for binocular owners.

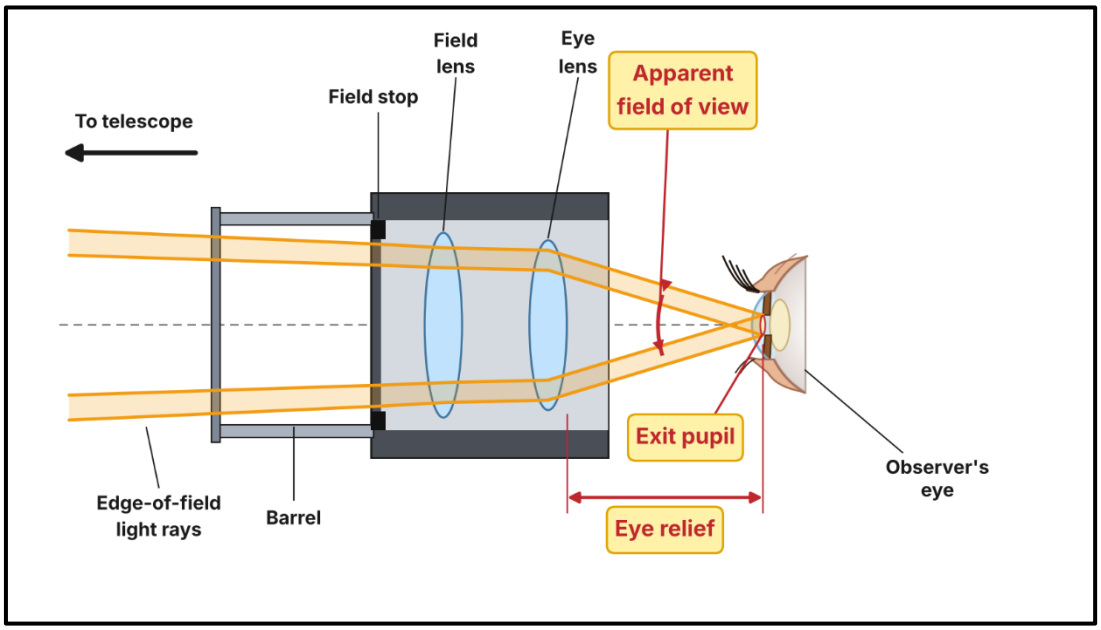
Finder Scopes

A decent finder scope is critical to helping locate objects in the night sky. There are a number of excellent types of devices that can be used as finder scopes.

Finder Scope Type	
	**Optical Finder Scope** – Most optical finders that come with small telescopes (and even some larger scopes) are junk. Unless it has an aperture of 50mm or greater, do yourself a favor and get rid of it. Even 50mm and larger finder scopes can be challenging to use. Better, more cost-effective solutions exist. **I highly recommend using any one of the other options.**
	Reflex Sight Telrad – This is the original zero magnification finder. At about $50 it is one of the more costly ones, but it has features that the cheaper red dot finders lack that will prove helpful if you don't have a GoTo mount. Features such as concentric circles that represent a fixed area in the sky prove very useful when star hopping, the technique of hopping from star to star to the target object you wish to observe.
	Red Dot Finder – Red dot finders range from about $20 on Amazon to as much as $350, depending on the model. If you have a GoTo mount, this is an ideal finder since you will likely only be using it to target a few bright stars when setting up your scope. Expect to pay between $30 and $50 for a good unit. YouTube video on how to align your red dot finder.
	Laser Finder – Units cost about $100 for a decent kit. In many ways these are similar to Red Dot Finders with a few exceptions. With all the other finders, you have to be directly behind the finder for it to work properly. When looking at objects directly overhead, this may mean you have to get on your knees and do some contortions to be positioned properly. Laser finders relax this requirement somewhat, since you don't have to be directly behind the finder to see where it is pointed. Not to mention they just look cool. The downside of many lasers is that you may have to push the button to turn the laser on, and this may be tricky when trying to move the scope at the same time.
	Do-It-Yourself Laser – This laser on Amazon runs about $25 and has a pigtail that makes it convenient for use. Two downsides to this: • You will need to figure out how to mount it to your telescope, and this may involve more cost. • This model generally does not perform well in cold temperatures, although this isn't generally a concern in AZ. On the plus side, it does have adjustments built into the laser for aiming it, so alignment with the telescope is quite easy. Another option for the technically minded is a Laser/Redot finder (Instructions).

Eyepieces

Most telescopes come with at least one eyepiece. If the scope you are purchasing isn't a premium scope, the eyepiece may not be the best quality. For most astronomy equipment the old adage that you get what you pay for holds, and it holds especially for eyepieces. Prices range from as low as $25 to as high as $1,300 for a premium eyepiece. Decent quality ones tend to be in the $40 - $100 range. There is a wide range of types and designs to choose from. Factors such as what object you are viewing, the apparent field of view of the eyepiece, eye relief and exit pupil are a few things to consider when looking for the perfect eyepiece. If you are looking for the most cost-effective yet high-quality performers, the Plössl design eyepieces are a good option. Major manufacturers like Celestron produce a wide range of eyepieces; unfortunately, this includes some poorer-quality eyepieces, so care must be taken when purchasing from some of these manufacturers. Other manufacturers such as Tele Vue and Baader only create high-quality pieces so the question is less about quality than whether it is appropriate for the object you are viewing.



- **Barrel Diameter** – The vast majority of telescopes accommodate 1.25" barrels, while larger, higher-cost models will have 2" or even 3" barrel sizes. Some very low-cost scopes have 0.95" diameter barrels; these telescopes should be avoided.
- **Focal Length (FL)** – This value is measured in millimeters (mm) and typically printed on the eyepiece. The Focal Length (FL) of the eyepiece is what determines the magnification of the object when viewing it through the telescope (see section on magnification).

  Magnification = (FL of telescope) / (FL of eyepiece)
- **Eye Relief** – The distance between the lens of the eyepiece and your eye. Eyepieces with good eye relief are recommended since they make for easier viewing and can be especially important for those who want to wear glasses while viewing objects. It should be pointed out here that if you are near- or far-sighted, you don't need glasses for viewing things through a telescope since you can adjust the focus for your eyes. *Note: this is not the case for astigmatism, which the telescope cannot correct.*
- **Exit Pupil** – The size of the cone of light exiting from an eyepiece. It is important to match the exit pupil to your viewing needs.

Exit Pupil = (FL of eyepiece) / (FR of telescope)

- **Apparent Field of View (AFOV)** – The angular size of the amount of sky you will see through the eyepiece measured in degrees. AFOV is fixed by the eyepiece design and is commonly printed next to the focal length on the eyepiece. The true field of view you actually see is the AFOV divided by the magnification.
- **Parfocal Eyepieces** – These are eyepieces that share the same focus point so that if you change one eyepiece you will not have to refocus the telescope to see the object clearly.
- **Zoom Eyepieces** – These are eyepieces that have variable focal lengths (e.g., 8mm – 24mm) so that you can use one eyepiece for multiple magnification levels. These do tend to be more expensive than fixed FL eyepieces and generally will not perform quite as well as fixed FL eyepieces do, but a good quality zoom eyepiece can perform quite well, and in the long run may save money since it may be used in place of two or three fixed FL eyepieces.
- **Barlow Lenses** – These are add-on tubes that when used with an eyepiece will magnify the image by a set factor. The factor for Barlow lenses typically ranges from 2x to 5x magnification.

How many eyepieces do you need? A combination of a good low-power eyepiece with a decent zoom eyepiece and a 2x Barlow may be a good start. An example of this may be Celestron 40mm Omni Plossl ($55), Celestron 8-24mm Zoom ($110), and Celestron Omni 2x Barlow ($42). This combination will prove effective for whatever you are viewing, be it deep-sky galaxies and nebulae, the Moon or planets. A good wide-field, low-magnification eyepiece (e.g., 40-60mm) should be one of your first purchases since it will likely be the first eyepiece you use in finding an object. SVBONY eyepiece set with 68° ultra wide angle lenses is an excellent beginners set for a very reasonable price, add the Celestron 40mm Omni and you should have a complete set of eyepieces for a reasonable price.

The Celestron Omni Plossl series offers reasonably priced, good-quality eyepieces with a wide range of focal lengths and might be a good starting point if you are considering purchasing some eyepieces.

Solar Filter

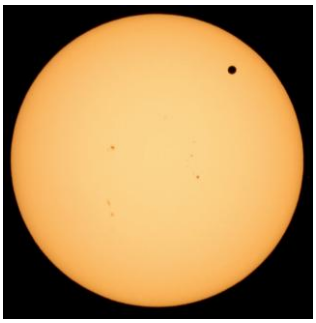
Most telescopes can be used for observing the Sun. A special broadband Mylar film that cuts out over 99.999% of light is placed over the primary
aperture. Cost is very reasonable, between $20 and $50 to make your own filter. Note: it is critical you purchase these filters from a reputable supplier. Both Baader Planetarium and Thousand Oaks Optical are trusted brands that sell excellent filters and the material required to make your own filter. Solar observation is one area where a small telescope is a great fit. With these filters attached to your telescope, you can watch the progression of sunspots, observe solar eclipses, and watch transits of the inner planets.


Purchased Solar Filter


Homemade Solar Filter



Solar Eclipse


Venus Transit

Other Filters

Other filters for night observation can help you see more detail than you might see without them, especially in the city where light pollution can be a real problem. Filters have three major applications (the Moon, deep-sky objects and planets), and there are many choices of filters for each application. The one filter that seems to perform quite well for all three applications (and also astrophotography) is the Baader Neodymium Moon and Skyglow filter ($105), so if there is only one filter you can purchase, make this the one. Filters generally bring subtle improvements to the viewing experience.

An in-depth discussion of the types of filters available for deep-sky observation along with information on what filters to use for various deep-sky targets can be downloaded from the ArtCentrics website here: Deep Sky Filters for Visual Observation (PDF).

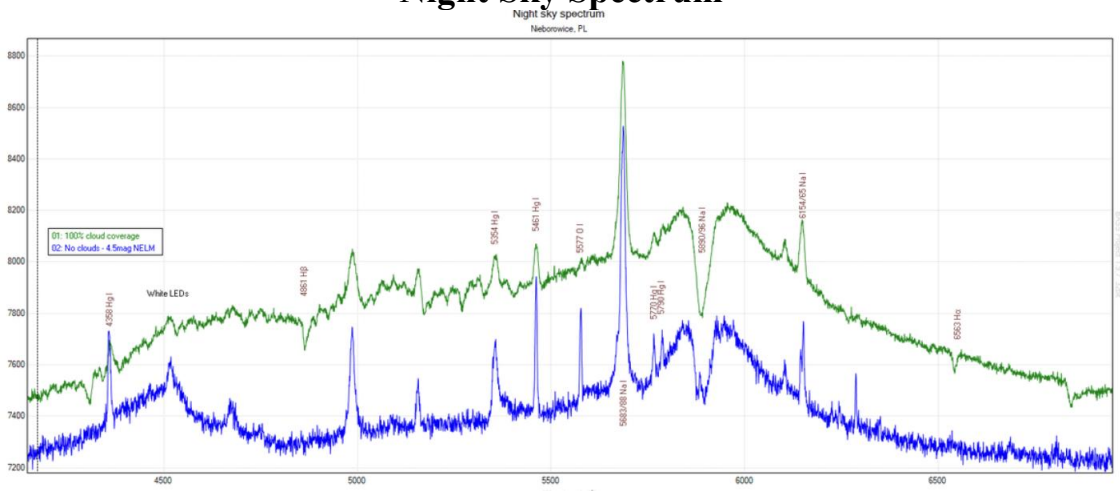
Object	Filter Type	Cost	Comments
Moon	Variable polarizing filter	$43	Polarizing filters are among the more popular filters for the Moon, cut glare and improve contrast when high magnification is used.
Deep Sky	Light Pollution Filter	$30 - $200	The purpose of these filters is to increase the contrast of the object by reducing the unwanted background light from city lights. There are many brands to select from.
Planets	Various color filters		Color filters are used to bring out specific planetary features. A good summary of the various usages of different colors can be found here. Note: #80A Blue and #82A Light Blue provide benefits for all planets, so if you are on a budget, one of these may be a good starting point.

As stated earlier, the Baader Neodymium Moon and Skyglow filter performs well in all of these applications. However, a word of warning: many people are underwhelmed when it comes to filters and how much they help. It may be informative to test some of these out before spending money on them. The East Valley Astronomy Club (EVAC) has a visual filter rental program for members just for this purpose.

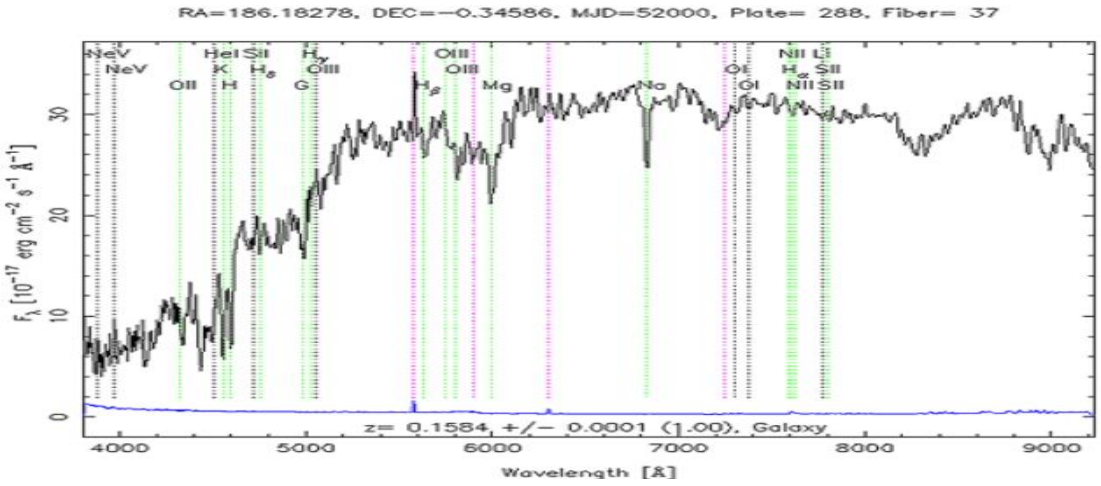
Further Discussion on Filters and Applications

Deciding whether a filter is needed, and which filter is appropriate, depends mainly on how dark your site is and what type of object you are observing. In the images provided below (it should be noted they are not scaled the same, so they cannot be directly compared, but that isn't the point here), what we are interested in is the general shape of each spectrum.

Night Sky Spectrum



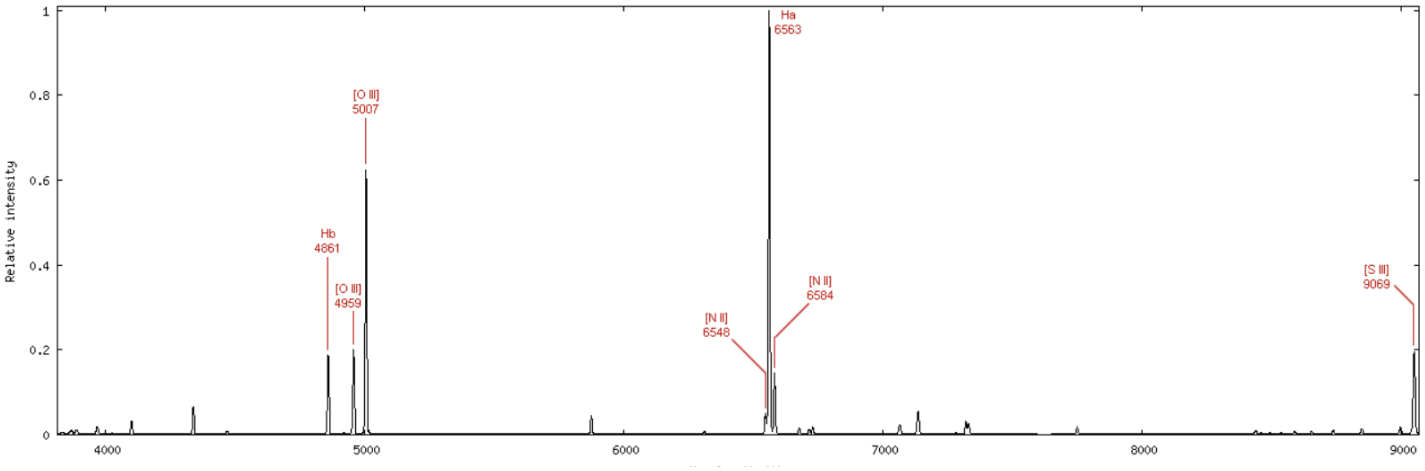
Broad Spectrum: Galaxy Spectrum



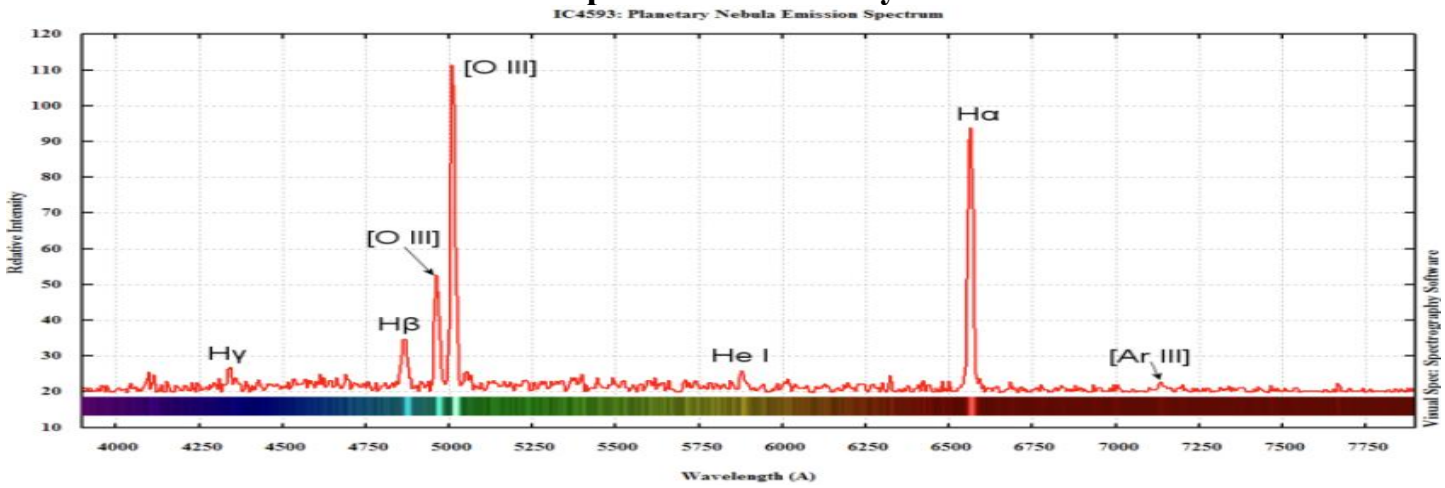
Here we can observe that the night sky (with light pollution) has a broadband spectrum where light is being emitted in all visible wavelengths. Similarly, a galaxy's spectrum can be classified as broadband. Generally, one can classify stars, galaxies, open clusters, and globular clusters as broadband sources.

Below are spectra of emission nebulae. These are loosely defined as clouds of thin gas that glow because a nearby energy source, such as a hot star, ionizes them. Deep sky objects such as H II regions (e.g., the Orion Nebula), supernova remnants (e.g., the Veil Nebula) and planetary nebulae (e.g., the Ring Nebula) emit light mostly at distinct wavelengths: specifically, hydrogen-alpha, hydrogen-beta, oxygen III (OIII) and sulfur II (SII). These are classified as narrowband emissions.

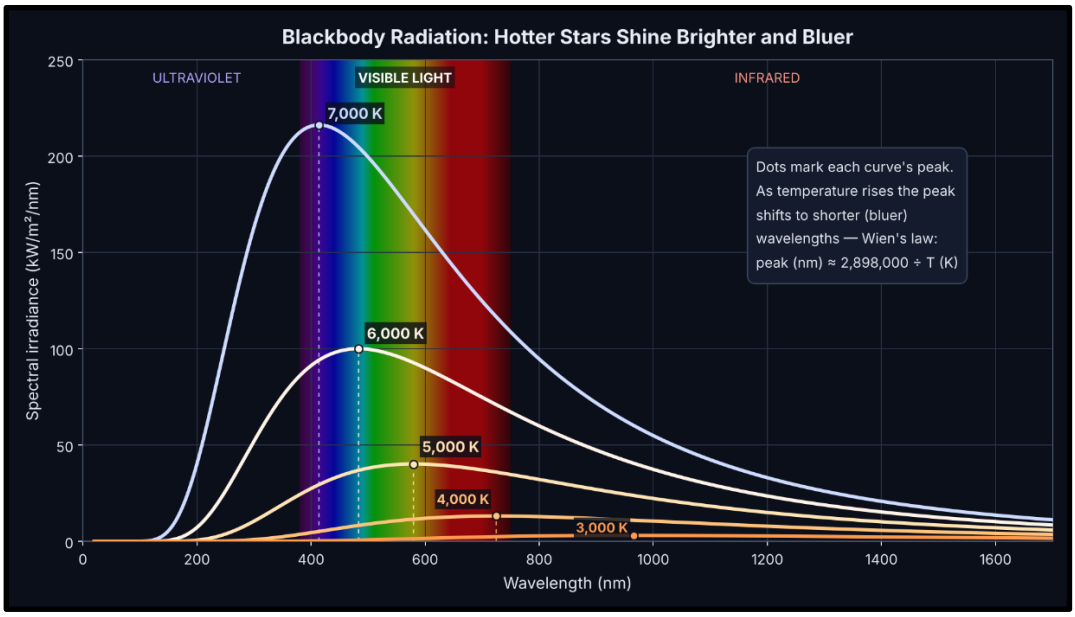
Emission Spectrum: Orion Nebula



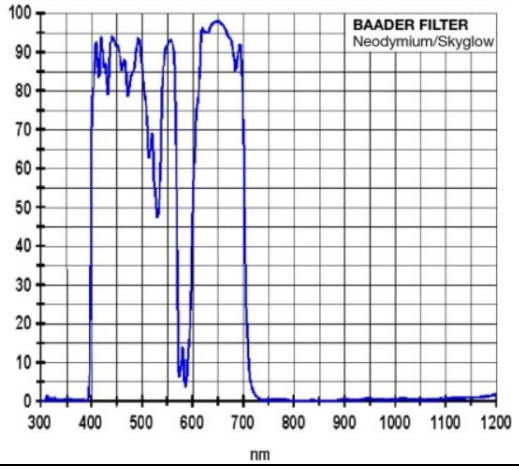
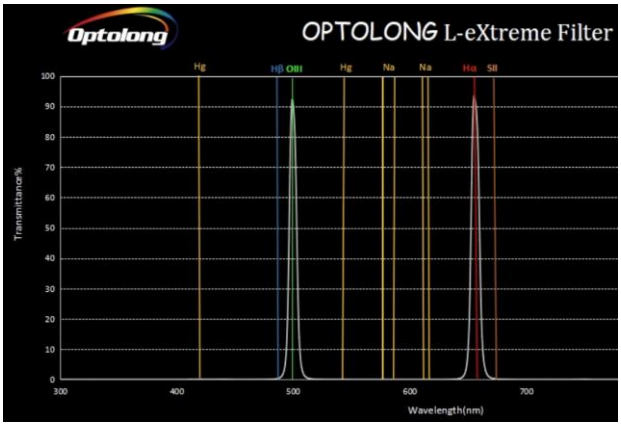
Emission Spectrum: Planetary Nebula



Why do these sources emit light so differently even though they are roughly made of the same stuff: mostly hydrogen and other lower-mass elements? The main reason is density. Thin, low-density gas, even when hot, emits light only at discrete wavelengths set by its atoms. Dense, opaque gas, such as the inside of a star, emits at all wavelengths; its spectrum mimics a black body whose shape depends on temperature.



The purpose of filters in astronomy is to try to minimize light pollution with minimal impact to the light originating from the deep-sky object being observed, thus providing better contrast for the target object compared to the background. At a very high level, we can classify them as either broadband or narrowband filters. Broadband filters block the main wavelengths associated with light pollution while passing the many wavelengths of light from the deep-sky object, so their transmission spectra are rather wide. Narrowband filters, on the other hand, can eliminate almost all wavelengths of light except for the few being emitted by the deep-sky object in question. When utilizing filters, it is vital to use the appropriate filter for the object being observed.

Broad Band Filters Transmission Spectra	Narrow Band Filters Transmission Spectra
	

For viewing reflected-light objects such as the planets and the Moon, basic color filters can be used to bring out certain features of the object. Note the #80A Blue and #82A Light Blue filters below seem to be quite helpful for any of these objects, so either may be a good filter to have around when observing planets and the Moon.

Color Filters for Planetary Observing

Not Useful	Good	Excellent	Probably the Best

Wratten Number and Color	Moon	Mercury	Venus	Mars	Jupiter	Saturn
#8 Light Yellow	With small telescopes			Maria, Dust clouds	Belts	
#11 Yellow-Green				Maria	Belts	Cassini Division
#12 Yellow			Improves contrast	Maria, Atmospheric clouds	Belts, Poles	
#15 Dark Yellow / Amber	Useful	Daylight	Low contrast clouds	Maria, Dust clouds, Polar regions	Belts, Poles, Festoons	
#21 Orange	Very useful	Daylight surface		Surface edge detail	Belts, Red Spot, Festoons	Bands, Poles
#23A Light Red		Daylight, Twilight		Maria and surface, Dust clouds, Polar caps	Blue clouds	Blue clouds
#25 Red		Daylight, Twilight	Upper clouds	Maria, Polar caps	Improves contrast	
#29 Dark Red			Terminator	Maria, Polar caps	Moon transits	Clouds
#38A Dark Blue			Upper clouds	Dust storms, Polar caps, Violet clearing	Belts, Red Spot	Bands, Rings
#47 Violet	Useful		Upper clouds	Clouds and haze above poles		Ring detail
#56 Light Green	Useful		Improves contrast	Dust storms, Polar caps	Red Spot	Bands, Poles
#58 Green	Useful		Improves contrast	Dust storms, Polar caps	Belts	White bands, Poles
#80A Blue	Very useful	Twilight surface	Upper clouds	High clouds, Ice caps	Rills, Festoons, Red Spot	Bands, Poles
#82A Light Blue	Useful	Twilight surface	Upper clouds	Polar caps, Surface	Belt transition	Band transition

Which Filters for Which Targets?

Targets	Filter(s)	Comments
Emission Nebulae, Planetary Nebulae, Supernova Remnants	Narrow Band Filters	In theory, these should really help someone in the city. Of note, the OIII filter is supposed to be particularly useful for planetary nebulae.
Stars, Galaxies, Globular Clusters, Open Clusters	Broad Band Filters	There are many different names for these filters and this can get rather confusing. I personally would just go with the Baader Skyglow if you want to use one; it is a great all-around filter.

Targets	Filter(s)	Comments
Planets	Color Filters	Different colors bring out different details, but #80A Blue filter seems to have wide application across the Moon and all the planets.
Moon	Polarizing Filter/Color Filters	The main goal here is to cut down on the light so details can be viewed.

Do they really work? Every situation is different, and in many situations, you may not notice an obvious difference when using the filters. If I were just getting into this, I would probably prioritize my filter purchases as:

1. Baader Skyglow ($105) – A good all-around filter that should help with all of these objects (although it will likely be subtle).
2. #80A Blue Filter ($20) – Low cost and generally useful for most planetary and Moon viewing.
3. Polarizing Filter ($43) – Good for viewing the Moon.
4. Narrow Band Filter ($200) – May help with the narrowband targets.

The Astronomik website has great descriptions of the filters it makes and the appropriate applications for each. Baader and Astronomik are companies known for their high-quality filters, but there are others that make excellent filters.

Other Accessories

There is a wide range of other accessories that can help make the observation experience enjoyable. I will list a few of my favorites here.

Accessories That Make Life Easier

Item	Make/Model	Considerations	Cost	Comments
Software	SkySafari 7 Plus	Smartphone/iPad/Online Astronomy software	$20	Critical for planning your night
Starwheel	Night Sky Star Wheel	Used for seeing what constellations are up	$20	
Headlamp	LED Headlamp	Best headlamp for astronomy	$20	Three red brightness levels
Portable Table	GCI Portable Table	Small portable table for equipment	$45	Larger tables here ($109, $130)
Portable Chair	Alevmoon Portable Stool	Portable Stool	$30	
Dust Bulb	UES Air Blower Bulb	Used for cleaning optics	$15	
Dust Brush	Orion 5830 Ultra Brush	Used for removing dust from optics	$10	
Dew Shield	Varies by type of telescope	Only needed for refractors and SCTs		

Item	Make/Model	Considerations	Cost	Comments
Ground Cover		Helps keep dust and dirt down		
Knee Pads		Useful if you have to kneel a lot		
Total			**$160**	

Putting It All Together: Two Examples

Provided below is an example of how someone might go about identifying the items they want to purchase and get an idea of the cost involved. The first example is a low-budget example coming in just over $500, while the second would be considered a mid-budget example running about $1,500. Also keep in mind these are costs for new equipment; used equipment may cut this cost considerably.

Lower-Budget Option 4.5" Alt/Az Reflector

Item	Make/Model	Considerations	Cost	Comments
Mount and OTA	Celestron Item #22452 StarSense Explorer LT 114AZ	4.5" (114mm) Reflector including • Eyepieces: 25mm, 10mm (40x, 100x) • Red Dot Finderscope • Tripod & Alt/Az mount Focal Length: 1000mm Aperture: 114mm Focal Ratio: f/8.8	$260	Smartphone can be used to guide you to objects in the sky.
Accessories	Celestron Omni 40mm eyepiece	40mm Plossl Eyepiece = 25x	$55	
Accessories	Celestron Omni 2x Barlow	Barlow lens provides 2x magnification	$42	With eyepieces: 50x, 80x, 200x
Total			**$357**	
With Accessories		All mentioned accessories in first table	**$517**	

Mid-Budget Option 6” Alt/Az Schmidt-Cassegrain with GoTo mount

Item	Make/Model	Considerations	Cost	Comments
Mount and OTA	Celestron NexStar 6SE	6” Schmidt-Cassegrain telescope Included 25mm eyepiece = 60x	$1,200	GoTo mount and tripod Aperture: 150mm Focal Length: 1500mm Focal Ratio: f/10
Accessories	Celestron Omni 40mm eyepiece	40mm Plossl Eyepiece = 37x	$55	18
Accessories	Celestron 8-24mm Zoom	Variable Mag: 62x – 188x	$110	
Accessories	Celestron AC Adapter	Power adapter for telescope mount	$40	
Accessories	Baader Moon & Skyglow Filter	Moon and skyglow (light-pollution) filter	$105	
Total			**$1,510**	
With Accessories	All mentioned accessories	Accessories in first table	**$1,670**	

Resources and References

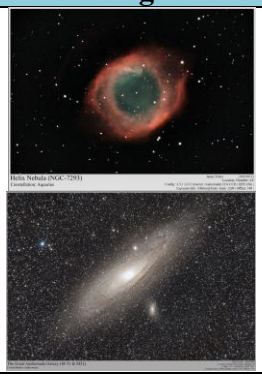
Title	Type	Description
Astronomy Technology Today	Website	Review of astronomy-related equipment – generally high-end equipment here.
Telescope Eyepiece Guide	Website	Good general introduction to eyepieces.
What is Exit Pupil and why is it important?	Webpage	Good explanation of exit pupil and why it should be taken into consideration when purchasing an eyepiece.
Fingerless Mittens	Website	Amazon website: For cold weather
Laser Pointer Finder	Website	Bracket and laser for about $60 (Amazon), and may not handle very cold weather well. Easy to use once set up. This package handles cold weather $95. Must be a green laser for night use; red does not work.
Red Dot Finders	Website	Multiple choices: $19, $23, $40, $50, $65. Generally, you get what you pay for. Telrad is most popular.
Telescope Finders Review	YouTube	General overview of Finders
Deep Sky Filters for Visual Observation	Website	ArtCentrics: Covers concepts on filters for visual observation, the different types and what types to use on the different types of targets.
Filters for Visual Astronomy	Website	Discussion on various filters and how to apply them to visual astronomy
Best Telescope Filter Guide	Website	Rundown of various filters and usages

Chapter 5: Using Your Telescope

Photography

Equipment, cost and skill required for photographing astronomical objects depend mostly on the target object. We break these down into four classifications; each represents a substantial increase in cost and complexity. Estimates and descriptions are general statements; your mileage may vary.

Targets	Images	Complexity	Cost	Description
Moon		Simple	$0 - $200	**Smartphone photography** generally will only work on the brightest objects in the sky. The technique is to place your lowest-power eyepiece in the telescope, focus on the object and then place the phone up to the eyepiece and take an image. This can be quite tricky to do when holding the phone by hand. There are adapters that can attach to the eyepiece that will make this process a bit easier.
Large Deep Sky		Basic	$50 - $300	**Piggyback Photography** is the process of mounting a regular camera on top of a telescope with a drive that tracks the motion of the sky and taking a longer exposure. A camera and equatorial mount are required for this method. This is also a good starting point if you are interested in deep-sky photography since you can use many of the same techniques as used in deep-sky photography.
Moon, Planets and Bright Deep Sky		Difficult	$100 - $500	**Lucky Imaging** is where you replace the eyepiece with a specialized camera to capture videos or images of the planets, the Moon, or even some of the brightest deep-sky objects. By astronomical standards these cameras can be pretty inexpensive ($100 - $500). Post-capture processing techniques are applied to videos or images to get the best results of these targets.

Targets	Images	Complexity	Cost	Description
Deep Sky		Very Difficult	$2,000 – $10,000	**Deep Sky Imaging** is where multiple images of an object are taken during the night(s) and combined into one single image. This technique has many demands. Generally, an equatorial mount with at least a clock drive, plus a guide scope, guide camera and computer to correct the tracking during each exposure, are needed. Specialized cameras are generally used for best results and run between $1,000 – $4,000 (really, the sky is the limit here).

Smart Telescopes: New hardware has recently been added to the mix that makes imaging objects such as the Moon, the Sun, and many deep-sky objects possible (Note: these do not work for planetary imaging since the field of view is so large). Cost is very reasonable, and complexity of using these smart telescopes is minimal compared to normal imaging. There is an increasing number of options available; currently the most popular include:

- ZWO Seestar S30 Pro List price = $700
- ZWO Seestar S50 List price = $550
- ZWO Seestar S50 Pro List Price=$1,000
- Celestron Origin List Price = $4,300
- DwarfLab Draco List Price = $1,600
- PegasusAstro SmartEye List Price = $2,000
- Build your own semi-smart imaging rig = $4,000

Try it before you buy it. East Valley Astronomy Club (EVAC) currently rents out astronomy equipment including the ZWO Seestar S50, Celestron Origin, and a planetary imaging kit (everything supplied but the telescope) to members for $25/week.

Targets for Beginners

Most amateur astronomers find that a good observing session takes some planning, deciding in advance what they will observe that evening. An excellent tool to help make your plans is The Sky Live website. It has sections dedicated to the Planets, Comets and Asteroids. The Night Guide section along with the Planetarium will help identify potential targets for the evening and help determine in what sequence to view them. The website Telescopius is also a great resource for planning your observation and imaging sessions. Provided below is a table listing some of the types of objects that are appropriate for small telescopes.

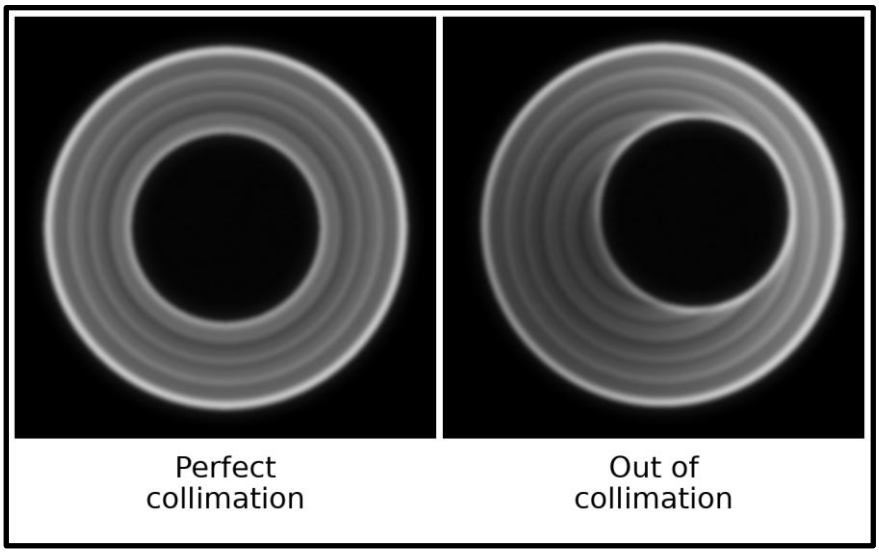
Object Type	Links	Description
The Moon	• The Sky Live: Moon • Moongiant.com • Moon Globe HD (iOS) • MoonMap (Moongiant.com) • Virtual Moon Atlas	This should be your first observation target. No matter how small your scope, the view is sure to please! Moon Globe HD is an excellent iOS application for helping identify features of the Moon and costs only $1.

Object Type	Links	Description
Multiple Star Systems	• Colored Double Stars • Dazzling Double Stars for Compromised Skies • The Best Triple Stars - Ranked • A guide to Double and Multiple Star Systems	Multiple star systems are systems where two or more stars orbit each other. Even small telescopes can view many of these.
Planets		Jupiter, Saturn and possibly Mars are a joy to view in scopes of almost any size. One thing I really enjoy is watching the shadow of one of Jupiter's moons cross the planet's disk (a shadow transit).
The Sun	• SOHO Observatory • SpaceWeatherLive.com	An inexpensive solar filter can be made for your telescope (<$50), allowing you to view sunspots, eclipses and even transits of planets.
Deep Sky Objects	• Yoder's Constellation Guides • Star Hoppers' Guide to the Universe • A New Catalog of Stellar Richfields for Binoculars • 10 Easiest deep-sky objects to see with small telescopes	While most deep-sky objects may not be realistic targets for small scopes, there are a few bright objects that are worth checking out: nebulae such as the Great Orion Nebula (M-42), galaxies such as the Andromeda Galaxy (M-31) and even some globular clusters such as the Great Hercules Cluster (M-13).
More Resources	• 111 Deep-Sky Wonders for Light-Polluted Skies (PDF) • SkySpot: Bright Telescopic Objects ($18)	These are more resources that you might find helpful if looking for objects.

Maintenance

Generally, telescopes require very little maintenance if they are treated properly. This includes storing the telescope in a climate-controlled environment and covering lenses, mirrors and aperture openings when not in use. For telescopes with a lens at the aperture (i.e., refractors and Schmidt-Cassegrains), use a lens brush and air blower bulb at the end of every observing session to remove any dust that may have accumulated.

- **Cleaning optics**, including mirrors and lenses, is fraught with hazards; even when using microfiber towels or lens cleaning wipes, undesired results are typically the outcome. Ideally, you should never let the optics get dirty to begin with. A well-treated telescope can go 10 or more years without having to clean the optics.
- **Collimation** is the process of making sure all components (mirrors/lenses) in the optical path are aligned with each other. Refractors generally do not require collimation, while reflectors and Schmidt-Cassegrains require occasional collimation. Temperature variations and vibrations from moving the telescope are the main causes of a telescope losing collimation. Checking to see if your telescope needs collimation is an easy enough task to perform. Simply center a bright star in the field of view and bring it out of focus to form a doughnut-shaped pattern. If the hole in the pattern is off-center, the telescope is out of collimation. There are a lot of different tools sold to assist with collimation, ranging from $15 to $500; these tools are not needed for visual observations. A simple process of Star Collimation without tools should be sufficient. There are some good videos on both Reflector Collimation and SCT Collimation that go through this process.



Advanced Session Planning Tools

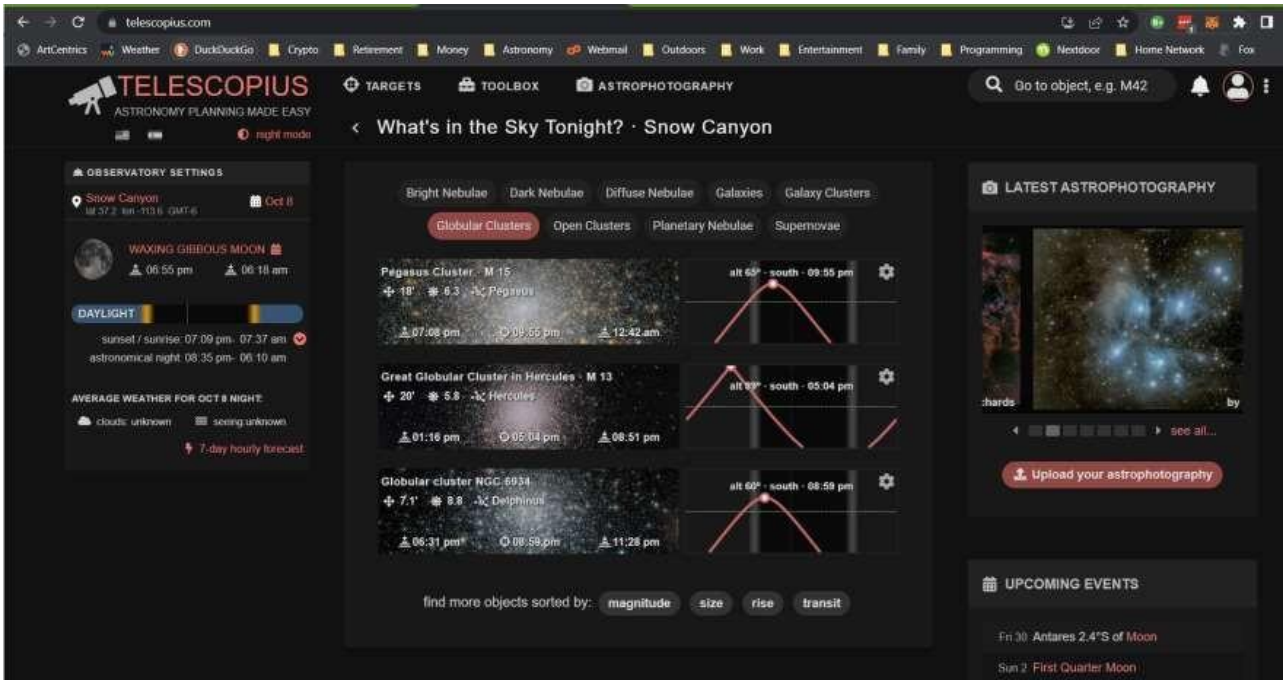
There are a number of applications available to help in planning your observation session. Here we identify some of the features/functionalities that you may want to keep in mind if considering investing in one of these tools. Prices for the programs identified range from free to about $250.

Application	Cost	Operating System	Pros	Cons
Telescopius	Free	Website	• It's Free!	• Designed for imaging, so may have inappropriate targets listed. • Does not include Double/Multiple star systems
AstroPlanner (Best bang for the buck)	$45	macOS & Windows	• Reasonable price • Flexible • Pretty easy to use • Large list of catalogs • Large selection of user supplied plans that can be downloaded.	
Deep-Sky Planner	$10-$75	Windows, iOS, Android		
SkyTools 4	$100-250	Windows	• Most comprehensive package	• Very expensive • Fairly complicated
A New Catalog of Stellar Richfields for Binoculars	Free	N/A – PDF Download	• Free • Great for wide-field binoculars	• Large fields of view, not appropriate for telescopes

Application	Cost	Operating System	Pros	Cons
Star Hopper's Guide to the Universe	Free	N/A – PDF Download	• One of the best resources for star-hoppers. • Many of the most popular deep-sky targets	
Yoder's Constellation Guides	Free	N/A – PDF Download	• Includes pretty much all popular deep-sky targets, multiple star systems, carbon stars and various observing lists. • Newest versions include SkySafari downloads	• In addition to popular targets, includes many obscure targets that require larger apertures and darker skies. • Older versions of guides not as star-hopper-friendly • Not all constellations have been completed.

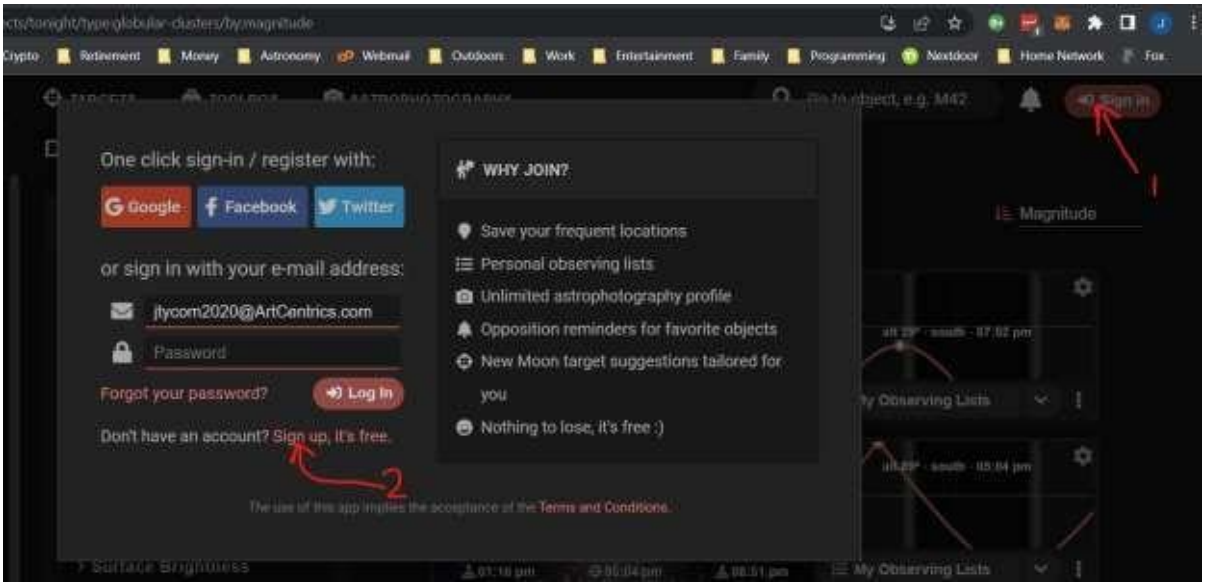
Telescopius

Telescopius is a website that focuses mostly on providing information for imaging and planning imaging sessions, but is also a good free option for planning deep-sky observation sessions. One big issue is that this does not contain double or multiple star systems in its database. The website is mostly focused on imaging, so images and objects presented on the website will always appear much brighter than you should expect to see in your telescope. Indeed, many objects available on this website will be much too dim to view with your telescope, so it is vital you use filters to specify Magnitude and Surface Brightness to eliminate those objects that are appropriate for imaging but not visible in your telescope.

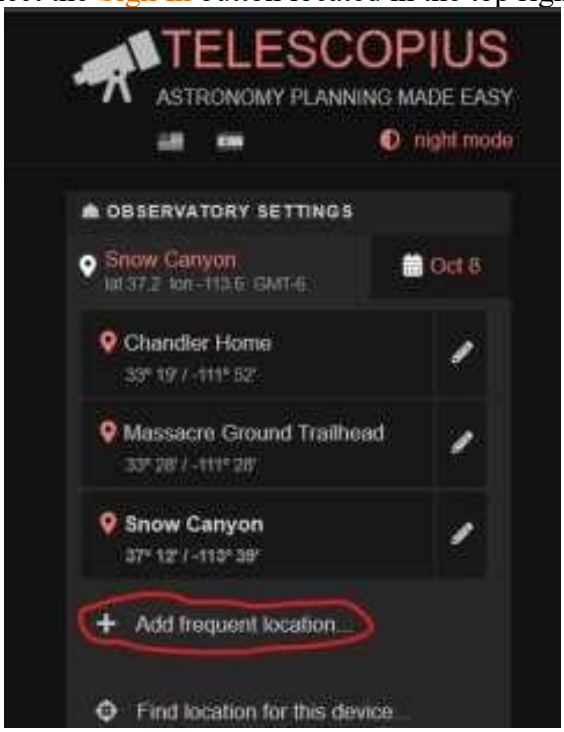


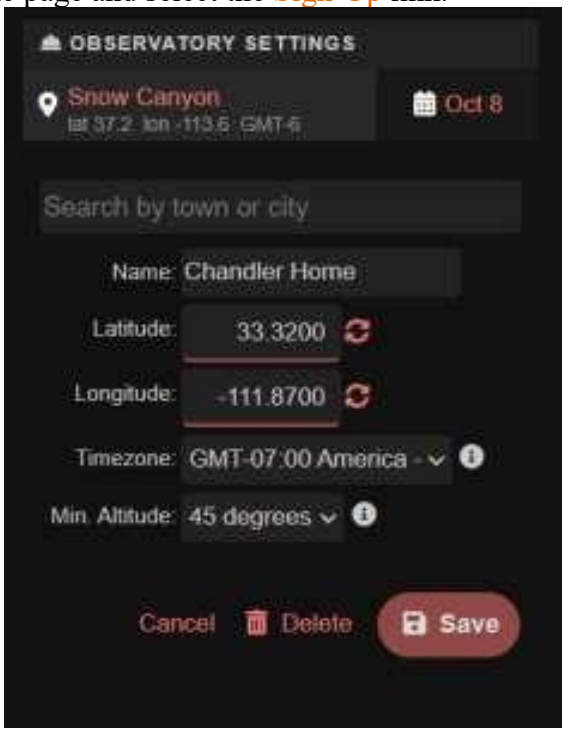
Telescopius Workflow

1. First-Time Setup – Basic setup information needed for your account.

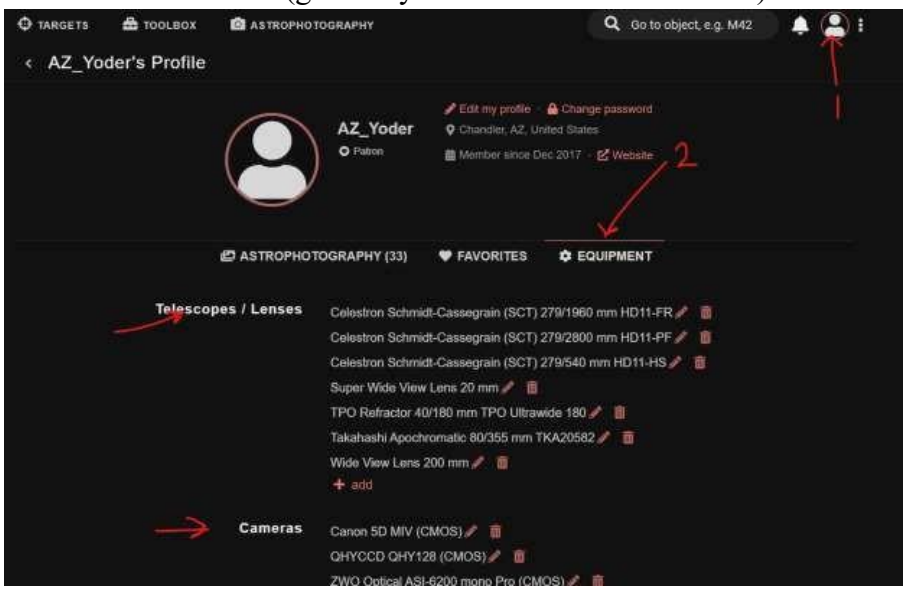


a. **Set Up Account**: This enables you to store your hardware information and create observation lists. Select the Sign In button located in the top right of the page and select the Sign-Up link.



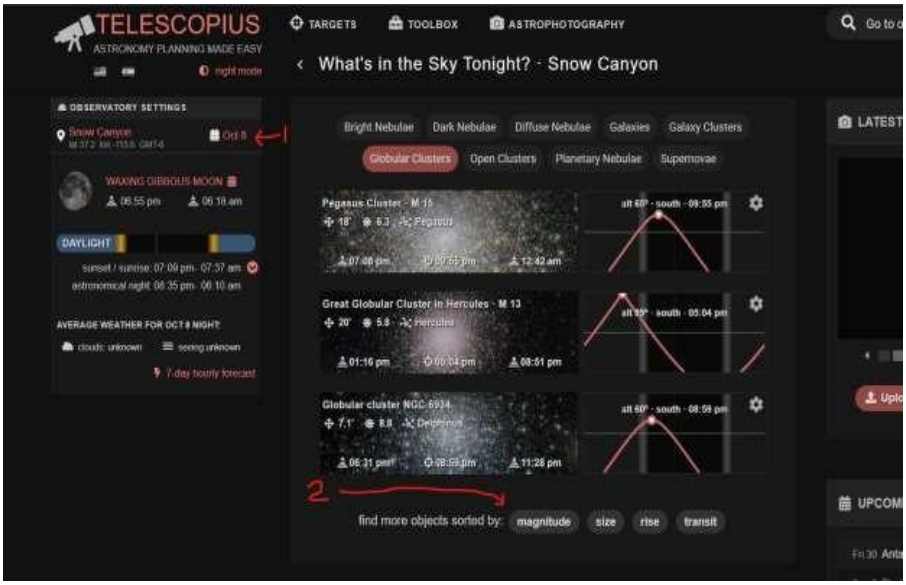


b. **Set Up Observatory:** Identify the location of your observing site by selecting the Observatory Settings, then select the date of the observation and set up your observation site. You can also set your Min Altitude for observation (generally I set a min Altitude of 45°).

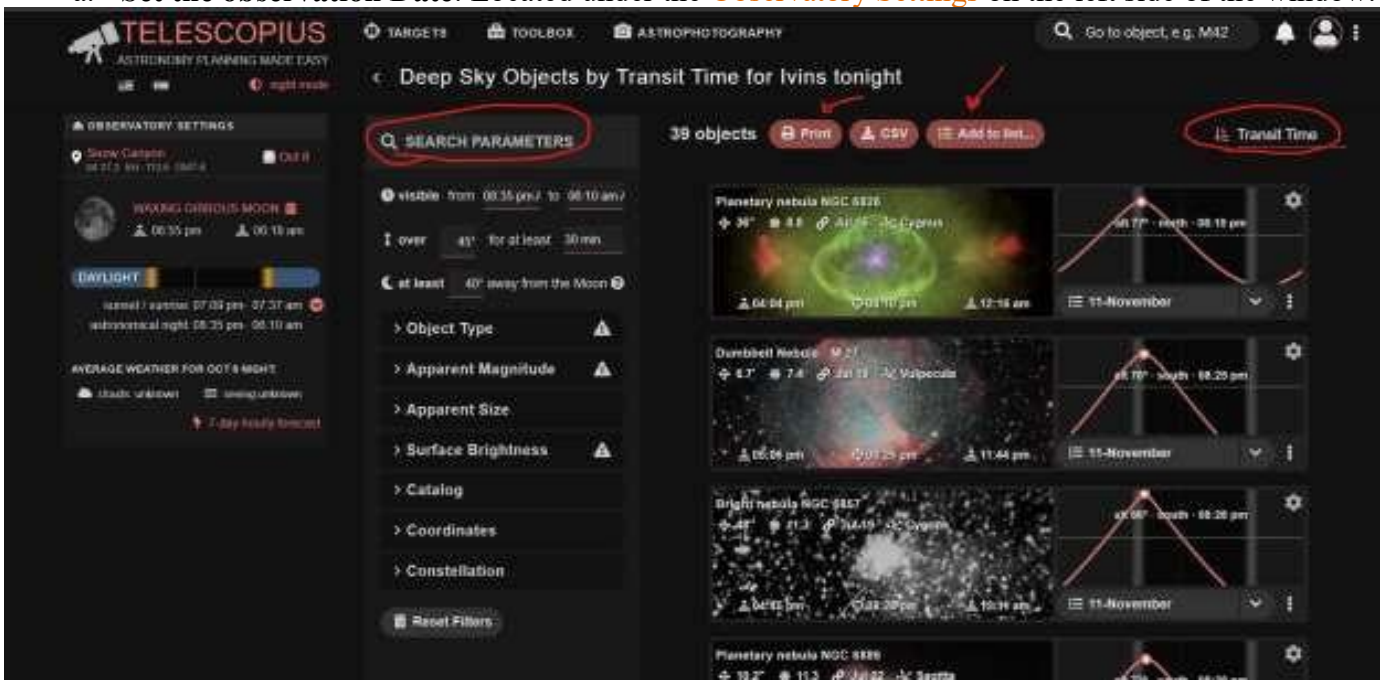


c. **Configure Hardware**: Open your Profile page by selecting the person icon located in the top right of the page. Once this page is open, select the Equipment link located just under the profile summary in the main window. Provide hardware equipment specifications including Telescope specs, Mount specs and Eyepieces.

2. Generate Observation List



a. **Set the observation Date**: Located under the Observatory Settings on the left side of the window.



b. **Set Filters**: In the main screen, select one of the buttons (Magnitude, Size, Rise, Transit) located to the right of "find more objects sorted by:" to access the Search Parameters Page. Here we can specify the various criteria/filters we want. Provided below are some recommendations for a small to medium telescope in the city.
   i. **Visibility Factors**: Timeframe, Min altitude time, etc.
   ii. **Object Type**: Diffuse Nebula, Galaxies, Galaxy Clusters, Globular Clusters, Planetary Nebula, Supernova Remnants. iii. **Apparent Magnitude**: To 11.2
   iv. **Surface Brightness**: To 12

c. **Set Sort Order**: Located at the top right of the main window is the sort order icon. Select Transit Time to order the resulting list according to when the objects will transit.

d. **Add to List or Print Out**: These options are available at the top of the main window.



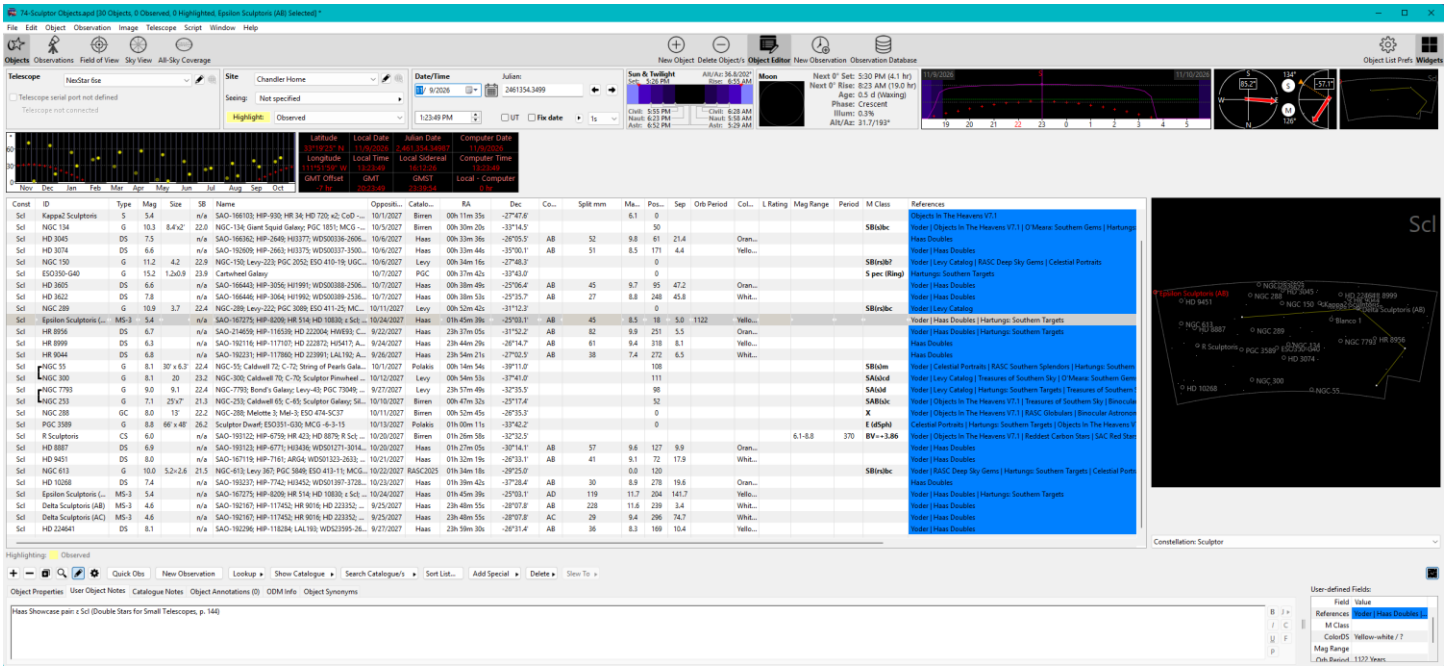
e. **Check it out:** You can take a look at how large the object should appear for your telescope and eyepiece combination by selecting the object in the list and reviewing it in the Telescope Simulator. *NOTE: Objects here will always appear much brighter than what you will find in your telescope no matter how large your telescope is!*

3. **Done**!

AstroPlanner

AstroPlanner is an application for Mac or Windows systems and is an extensive tool that can help plan observation sessions based on your requirements. Extensive catalogs and observing lists are available to download and filter through for your requirements. The application can interface with many GoTo mounts, allowing an automated tour for your viewing session. Observation notes and user image downloads are supported. Images from various catalogs and surveys can be downloaded, and once equipment specifications have been entered, you can review a field-of-view image that shows how large the target will appear in your eyepiece.

The manual for this application is over 400 pages long, so we can't possibly cover every aspect of this application, but we will cover some of the high-level basics.



Primary Components

Some of the main components along with a brief description include:

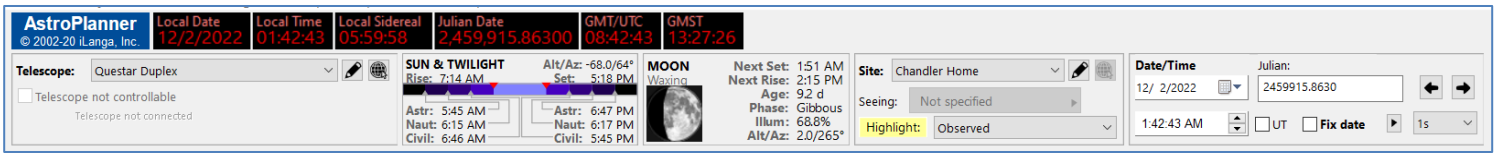
Main Menu

Located at the top of the application is the name of the observation plan that is loaded, and immediately below that is the primary menu.



Common Information and Settings Section

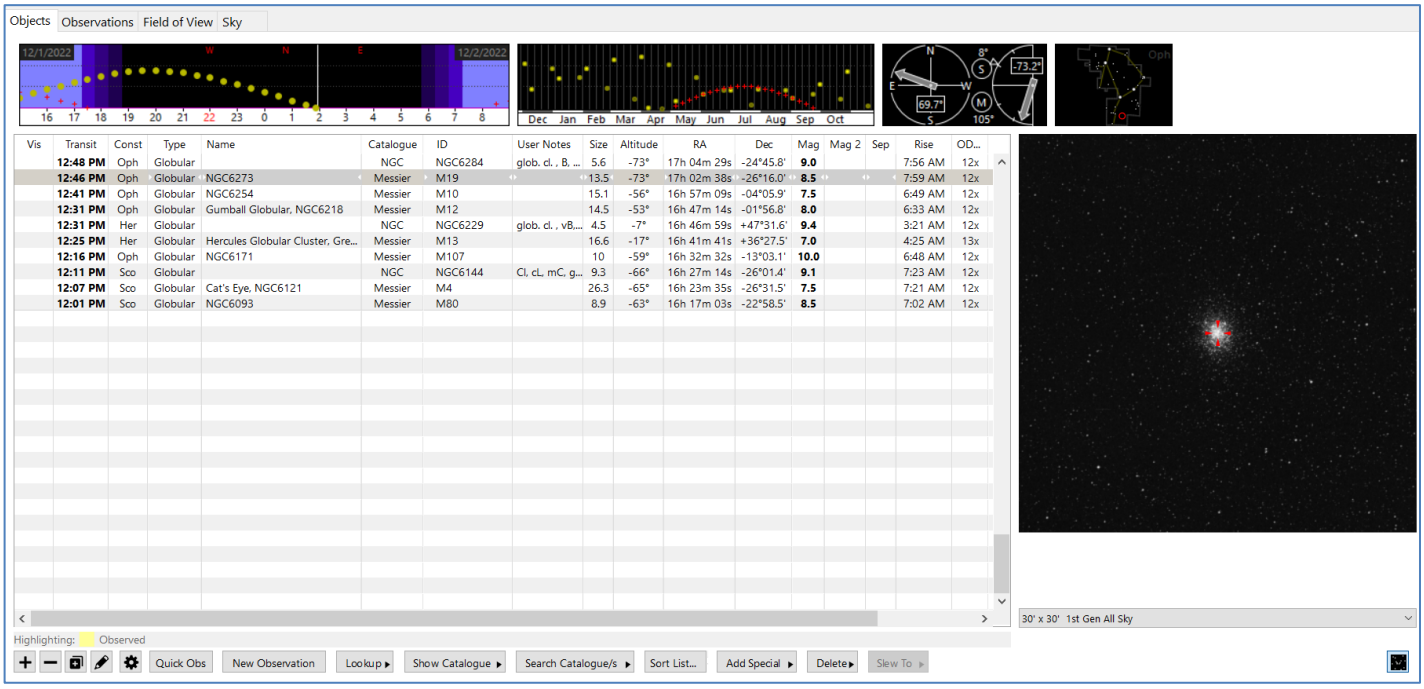
Information associated with your planned observation session including location, date/time (Fix Date), telescope, and astronomical data including Sun- and Moon-related data (e.g., sunrise, moonrise, and astronomical dusk and dawn).



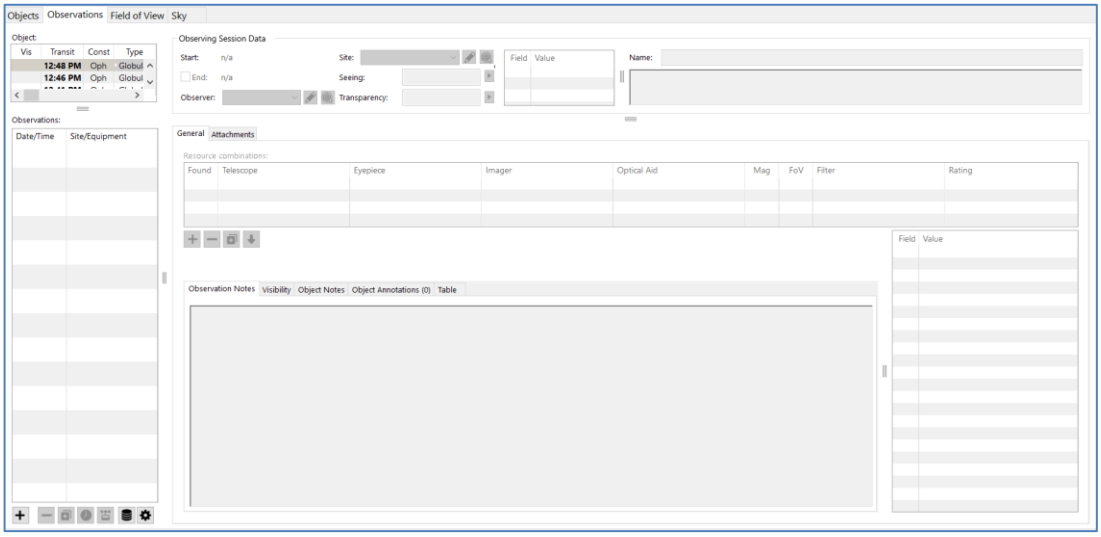
Primary Working Section

The Primary Working section consists of four tabs (Objects, Observations, Field of View, Sky) that represent the primary functionality of the application. Each tab has its own unique data/screen associated with it.

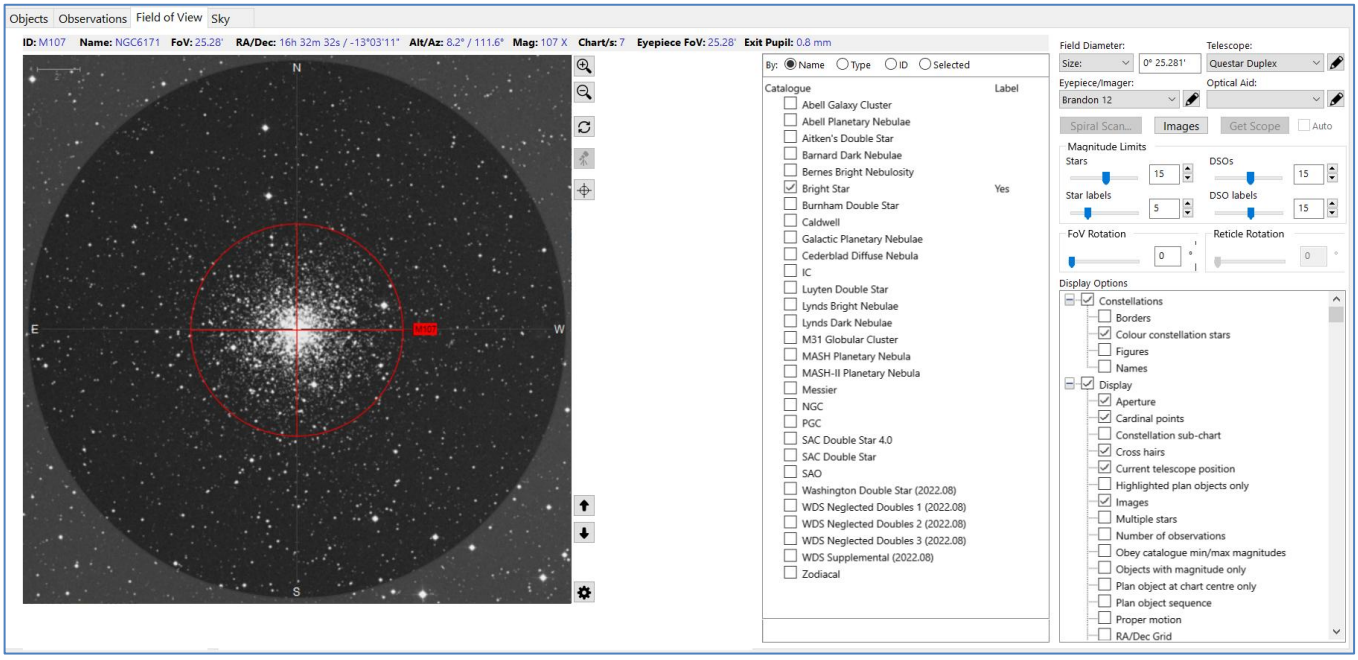
Objects tab – This is where items for observation are displayed. We also use this screen to locate and add additional objects for observation. The main data grid contains the list of objects and supporting details on each of the objects for observation. Selection of any item in the displayed list will update information displayed at the top and left of this tab that includes details such as the elevation of the object through the night, the best season to view it, the Alt/Az of the object and the location of the object in the constellation. If you have downloaded the image of the object from one of the image catalogs, the image will be displayed on the right of the tab.



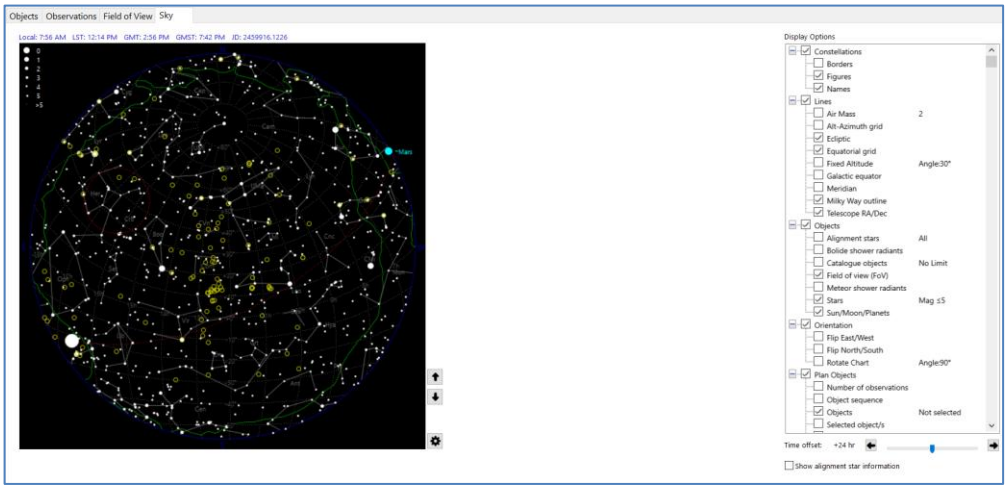
Observations tab – This screen is dedicated to allowing the user to document observations on the target of interest. This screen is very flexible and allows the user to document many details on their observation including location, what telescope/eyepiece combination they used, seeing conditions, and even attachments. This application can also print observation logs for use in the field; your notes can be transferred to the application later if you don't want to take a computer into the field.



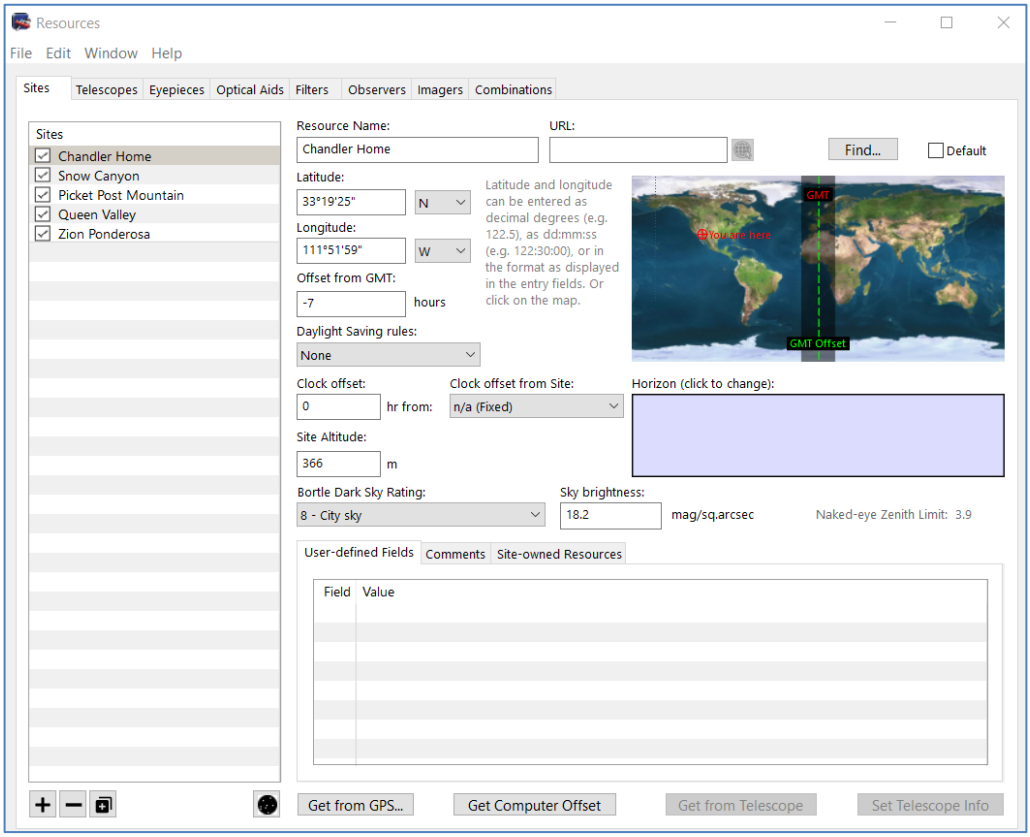
Field of View tab - This screen focuses on presenting the user with a representation of the size an object may appear for a given telescope/eyepiece combination. By updating the Field Diameter field (e.g., 10°), you can see where the object appears relative to other objects (e.g., constellations, other deep-sky objects, stars).



Sky tab – This displays the all-sky chart for the site's location and the current date/time.



Setup Resources – Resources refers to the equipment, observation site(s), camera(s), and other hardware you have in your arsenal. You will need to know your hardware specifications, and entering your telescope(s), eyepieces and cameras may take a while, but once this is complete and saved you won't have to do it again unless your equipment changes. Entering this information is vital to ensure that AstroPlanner can provide you with an accurate representation of what the field of view will look like when observing an object for a given combination of telescope and eyepiece/camera. This pop-up window is accessed via the menu options | **Edit** | **Resources** |



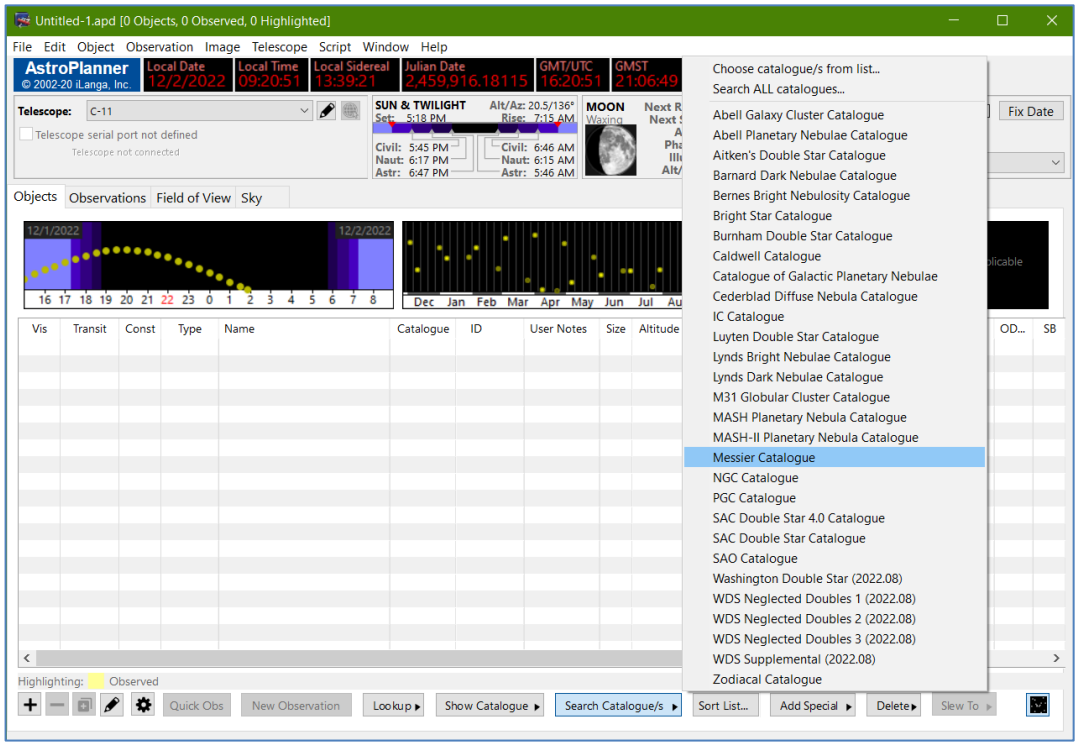
Workflow for Creating a Plan

Now that the primary screens have been reviewed, we are prepared to demonstrate one way you can create an observation plan that fits your specific requirements. This is accomplished by performing the following steps:

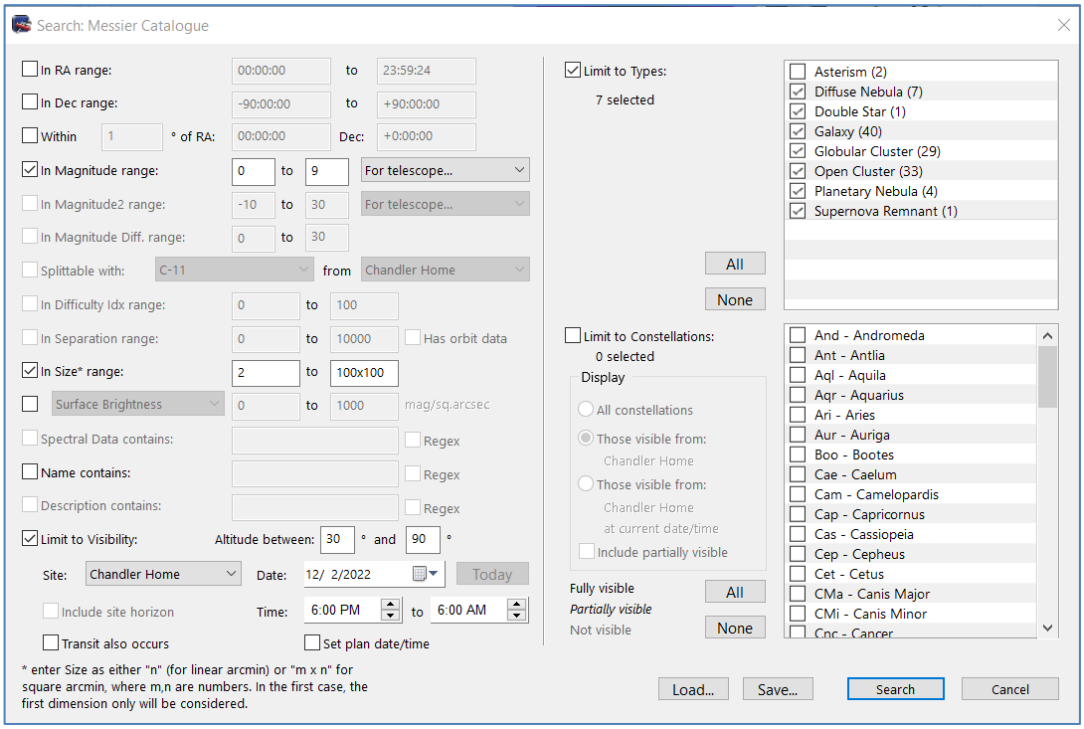
- **Create a New Plan** – Menu selection: | File | New |
- **Add Objects to Plan** – There are multiple paths to adding objects to your plan
  - Browsing a Catalogue - | Object | Open Catalogue/s | Browse and add selected items from one of many catalogs available (e.g., Messier, IC, NGC)
  - Search Catalogue/s – Search Catalogue/s button at bottom of screen. Search one of the many catalogs available (e.g., Messier, IC, NGC).
  - Add Special – Add Special button at bottom of screen. Used for adding planets/sun, comets, etc.
  - User Defined Plans - | File | User-Contributed Plans | Download | Download any of hundreds of plans associated with books, or created by others.
- **Refine Plan** – Make final refinements to narrow down target objects on your list for the specific date/time you plan on viewing the objects.
- **Export/Print Plan** – You can export your viewing plan to many third-party applications or print your plan for reference.

Adding Objects to the Plan – As mentioned earlier, there are a number of processes that can be used to identify objects that you may want to add to your plan (Browsing a Catalogue, Search Catalogue/s button, Add Special button, User-Contributed Plans). In this example, we will use the Search Catalogue/s feature on the Messier catalogue.

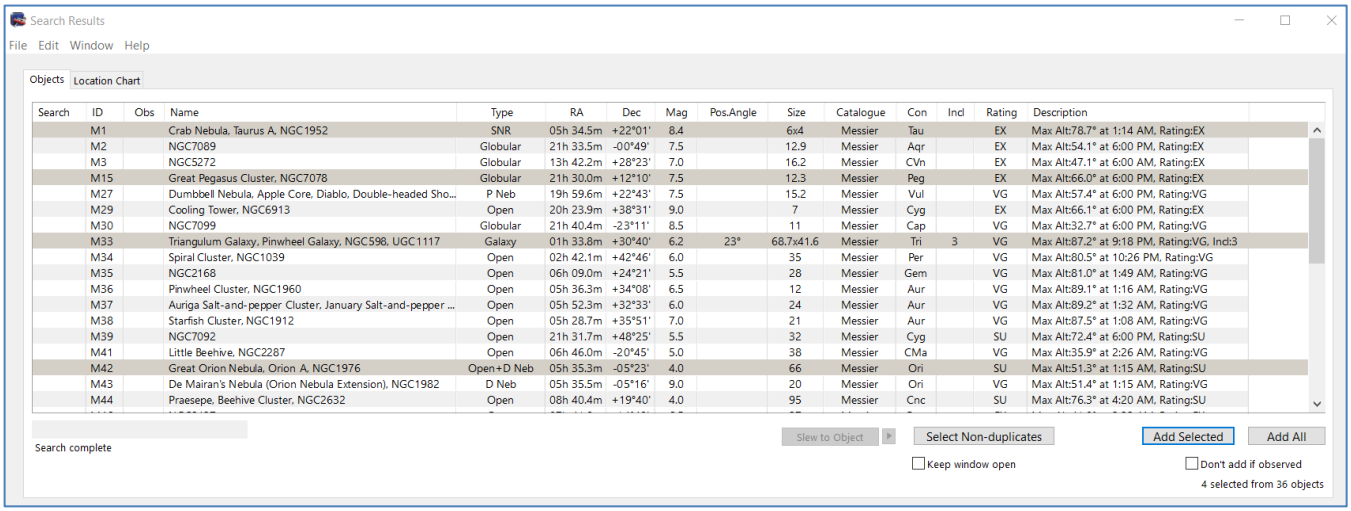
1. Open the Search Catalogue/s screen and select the catalogue you wish to search (Messier Catalogue in this example).



2. Set the filters you want to narrow down the results. Select the Search button once you have set all criteria. A new window with a list of all objects that meet your criteria will be displayed.

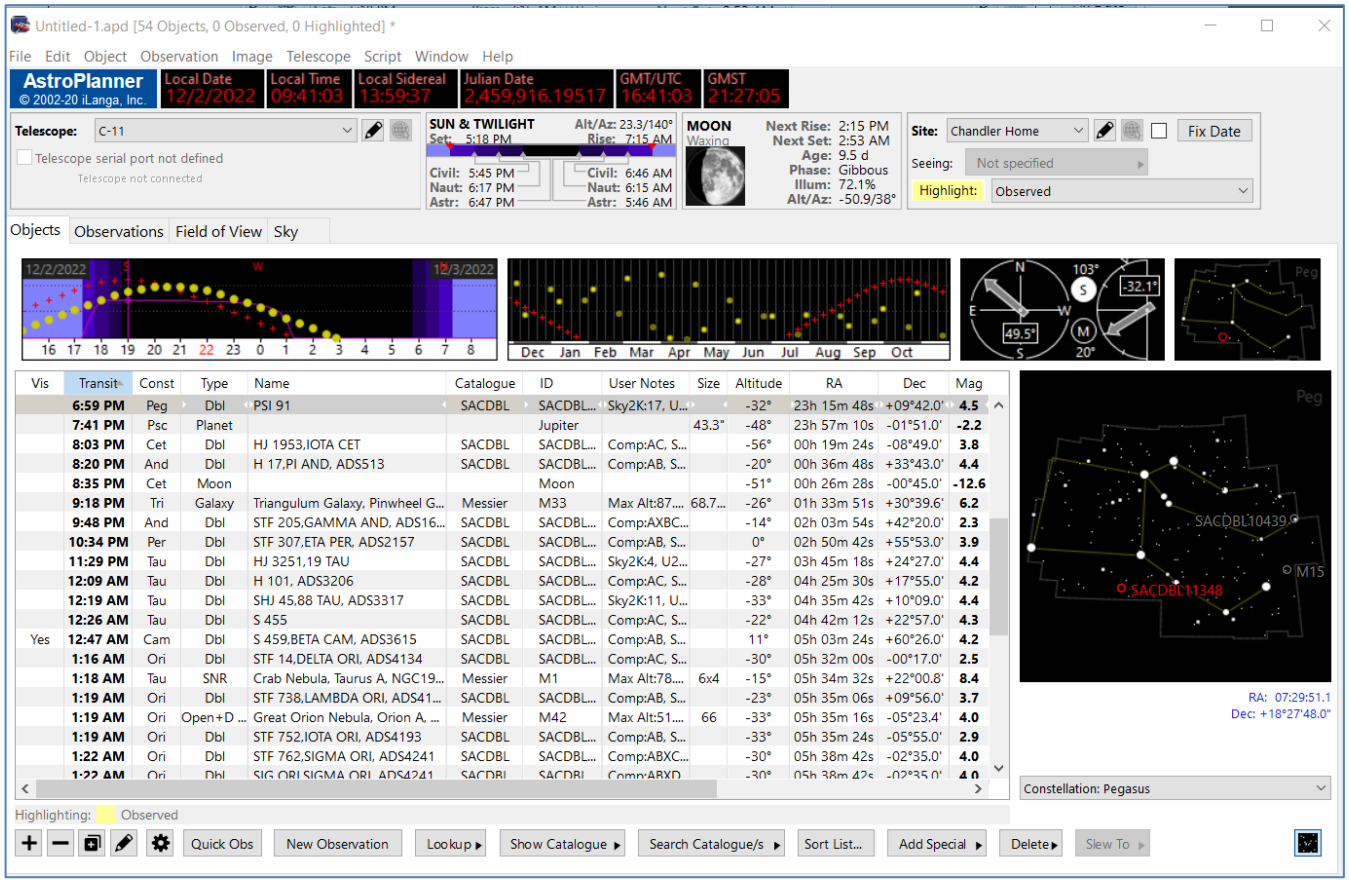


3. Review the list, select the objects you want to add and select the Add Selected button to transfer the objects to your plan.

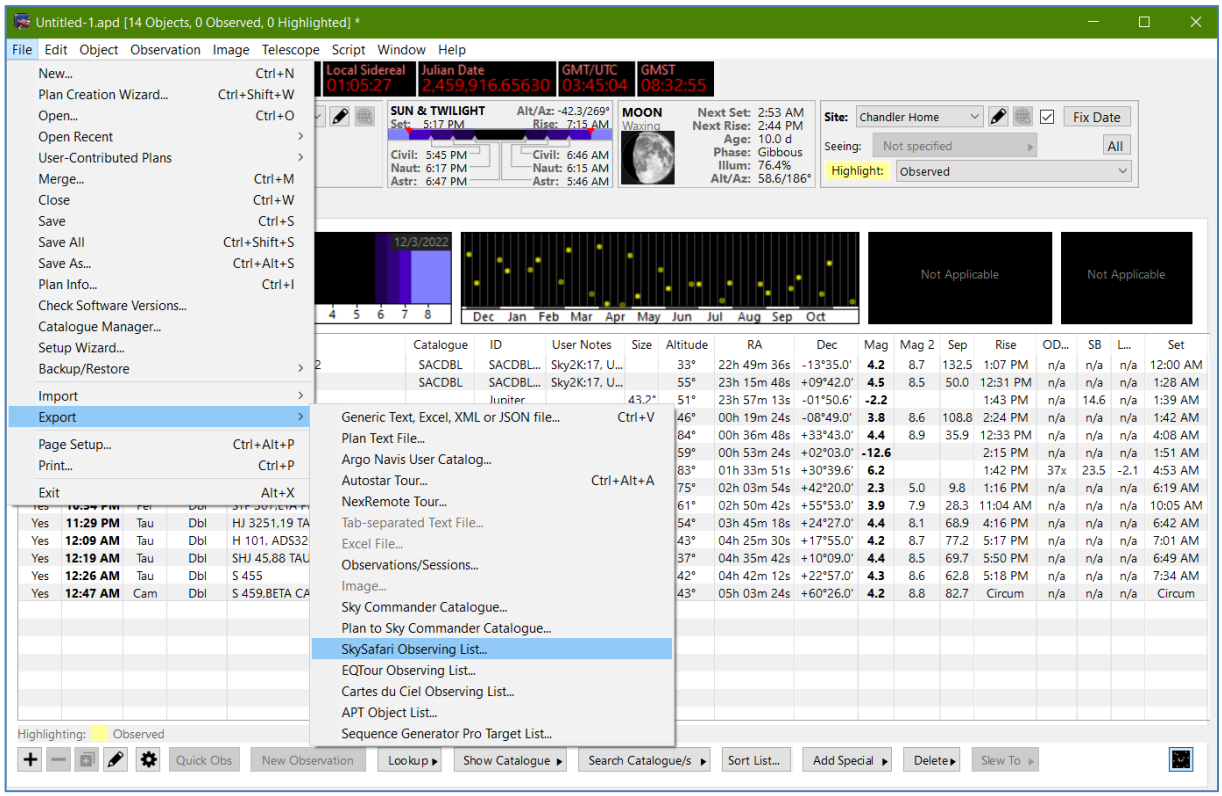


Search	ID	Obs	Name	Type	RA	Dec	Mag	Pos.Angle	Size	Catalogue	Con	Incl	Rating	Description
	M1		Crab Nebula, Taurus A, NGC1952	SNR	05h 34.5m	+22°01'	8.4		6x4	Messier	Tau		EX	Max Alt:78.7° at 1:14 AM, Rating:EX
	M2		NGC7089	Globular	21h 33.5m	-00°49'	7.5		12.9	Messier	Aqr		EX	Max Alt:54.1° at 6:00 PM, Rating:EX
	M3		NGC5272	Globular	13h 42.2m	+28°23'	7.0		16.2	Messier	CVn		EX	Max Alt:47.1° at 6:00 AM, Rating:EX
	M15		Great Pegasus Cluster, NGC7078	Globular	21h 30.0m	+12°10'	7.5		12.3	Messier	Peg		EX	Max Alt:66.0° at 6:00 PM, Rating:EX
	M27		Dumbbell Nebula, Apple Core, Diablo, Double-headed Sho...	P Neb	19h 59.6m	+22°43'	7.5		15.2	Messier	Vul		VG	Max Alt:57.4° at 6:00 PM, Rating:VG
	M29		Cooling Tower, NGC6913	Open	20h 23.9m	+38°31'	9.0		7	Messier	Cyg		EX	Max Alt:66.1° at 6:00 PM, Rating:EX
	M30		NGC7099	Globular	21h 40.4m	-23°11'	8.5		11	Messier	Cap		VG	Max Alt:32.7° at 6:00 PM, Rating:VG
	M33		Triangulum Galaxy, Pinwheel Galaxy, NGC598, UGC1117	Galaxy	01h 33.8m	+30°40'	6.2	23°	68.7x41.6	Messier	Tri	3	VG	Max Alt:87.2° at 9:18 PM, Rating:VG, Incl:3
	M34		Spiral Cluster, NGC1039	Open	02h 42.1m	+42°46'	6.0		35	Messier	Per		VG	Max Alt:80.5° at 10:26 PM, Rating:VG
	M35		NGC2168	Open	06h 09.0m	+24°21'	5.5		28	Messier	Gem		VG	Max Alt:81.0° at 1:49 AM, Rating:VG
	M36		Pinwheel Cluster, NGC1960	Open	05h 36.3m	+34°08'	6.5		12	Messier	Aur		VG	Max Alt:89.1° at 1:16 AM, Rating:VG
	M37		Auriga Salt-and-pepper Cluster, January Salt-and-pepper ...	Open	05h 52.3m	+32°33'	6.0		24	Messier	Aur		VG	Max Alt:89.2° at 1:32 AM, Rating:VG
	M38		Starfish Cluster, NGC1912	Open	05h 28.7m	+35°51'	7.0		21	Messier	Aur		VG	Max Alt:87.5° at 1:08 AM, Rating:VG
	M39		NGC7092	Open	21h 31.7m	+48°25'	5.5		32	Messier	Cyg		SU	Max Alt:72.4° at 6:00 PM, Rating:SU
	M41		Little Beehive, NGC2287	Open	06h 46.0m	-20°45'	5.0		38	Messier	CMa		VG	Max Alt:35.9° at 2:26 AM, Rating:VG
	M42		Great Orion Nebula, Orion A, NGC1976	Open+D Neb	05h 35.3m	-05°23'	4.0		66	Messier	Ori		SU	Max Alt:51.3° at 1:15 AM, Rating:SU
	M43		De Mairan's Nebula (Orion Nebula Extension), NGC1982	D Neb	05h 35.5m	-05°16'	9.0		20	Messier	Ori		VG	Max Alt:51.4° at 1:15 AM, Rating:VG
	M44		Praesepe, Beehive Cluster, NGC2632	Open	08h 40.4m	+19°40'	4.0		95	Messier	Cnc		SU	Max Alt:76.3° at 4:20 AM, Rating:SU

4. The selected objects should now appear on your Plan document. You can now proceed to add more objects from other catalogs, other imaging plans, etc. Further refinement of the list can be completed by sorting columns in this list and removing objects that you may want to eliminate.



5. Organize the list according to how you want to prioritize your viewing by sorting by the column you wish to use to accomplish this (e.g., Transit time). Save the list for future reference, then export or print the list for field use.
    a. Save Plan - menu selection: | File | Save |
    b. Print Plan - menu selection: | File | Print |
    c. Export Plan - menu selection: | File | Export | (*Select target)* |



Further Hints and Tricks using AstroPlanner
Provided below are a few hints/tricks I have found helpful when using the AstroPlanner software.

Catalogs and User List – there are many Catalogs and User-Contributed Plans to select from. Here are some of my favorites (in no particular order):

- Catalogs
  - Messier, IC Catalog, Barnard Dark Nebula Catalogue, NGC Catalogue – Should cover most deep-sky objects
  - SAC Double Star Catalogue – Double Star Systems; there are other double/multiple star catalogs that would work also.
- User-Contributed Plans
  - | Book | City Astronomy- Scagell Book |
  - | Book | Turn Left at Orion – Consolmagno and Davis |
  - | Book | Deep-Sky Observing With Small Telescopes – Eicher |
  - | Book | Haas-double |
  - | Book | The Urban Astronomer's Guide – Mollise |
  - | Magazine | SkyWatch | 2017 Small-Scope Skywatching by James Mullaney |
  - | Other | Multiple | Objects_for_Public_Nights |

Adding Objects to your plan from other plans – If you have objects in another plan (User-Contributed Plan) that you would like to include in a plan that is already open, just select the objects from the second plan, and drag and drop them into your plan.

Narrowing down your list – After acquiring the main list of objects for a plan and then saving the plan, I will further narrow the list based on what my particular needs are for the session I am planning. Before proceeding here, set the date/time of your observation session.

- Transit: Eliminate objects that transit more than a couple of hours outside of your observation session; for example, if I plan on observing from 8pm – 10pm, I would eliminate objects that transit outside of 6pm – midnight.
- Type: Eliminate any object types you may not be interested in (e.g., asterisms, open clusters)
- Size: Knowing how small or large an object your telescope/eyepiece combination can show, eliminate objects outside of that range.
- Mag: Eliminate any objects too dim to see for your situation; for a small scope in the city, I usually limit this to magnitude 10 or brighter.
- Double/Multiple Star Systems – Utilize Sep and Mag 2 fields to eliminate systems that can't be resolved by your setup. (e.g., Sep between 2 and 150 arcseconds and Mag 2 < 12).
- SB (Surface Brightness) – Many objects will not have SB values associated with them but for those that do, eliminate ones with higher values than you can see for your situation (e.g., keep only objects with SB < 22).

Ordering your Observation – Generally, my final sorting on the list before exporting or printing it is on the Transit Time so I can identify the order in which to observe the objects on the list.

Resources and References

Title	Type	Description
Star Hopping 101	Website	Good webpage introducing the Star Hopping technique.
The Setting Circles on your Telescope	Website	Sky & Telescope discussion on setting circles and how to use them.
How to use Digital Setting Circles	Video	Good overview of using setting circles on telescope focused on Equatorial mounts. Presenter concludes setting circles on small telescopes are useless. I disagree: if you use a very low-power eyepiece, you should be able to use them.
Telrad Sight	Website	Good website article introducing the Telrad sight.
Telrad Messier List	Website	Online finder charts of Messier List objects for the Telrad.
Telrad Caldwell Catalogue	Website	Online finder charts for the Caldwell Catalogue for the Telrad.
How to Collimate your SCT	Website	How to collimate your Schmidt-Cassegrain Telescope (SCT)
What is Piggyback Astrophotography?	Video	Video explaining technique, shows example photos and discusses equipment.
The Sky Live	Website	Great free online resource that describes what objects may be of interest. Also has a good planetarium for planning your observing session.

Chapter 6: Observing

Preparing for an Observation Session

It is important to make sure you have everything you need for your observation session; this is especially true when the observation site is located a long distance from home. Nothing is worse than arriving at a site that is a two-hour drive away, only to realize you have forgotten a star diagonal, mount adapter, battery or your eyepieces. Here are three approaches that can help ensure you don't forget any equipment you need.

- **Create a checklist** – Create a list of things you will need and review the checklist as you are packing the gear.
- **Pre-Assemble Everything** – Set up your telescope in your house before packing it to make sure you remember all the hardware you need to observe.
- **Prepack** – Have everything already pre-packed and ready to go anytime.

Listed below is a starter checklist.

Astronomy Checklist

Item	Notes
Optical Tube Assembly (OTA)	The Telescope
Mount, tripod, power supply	
Eyepieces, Diagonal, Finderscope	
Table, Chair, Groundcover	
Headlamp, Observation Guides/List, Log Book, Pen	
Phone/iPad	
Spare Batteries	For headlamp, mount, finderscope, etc.
Spare Jacket	It can get surprisingly chilly at night; always bring a spare jacket just in case.
Dew Shield, Hand Warmers	Winter accessories. Dew shield is rarely needed in desert areas.

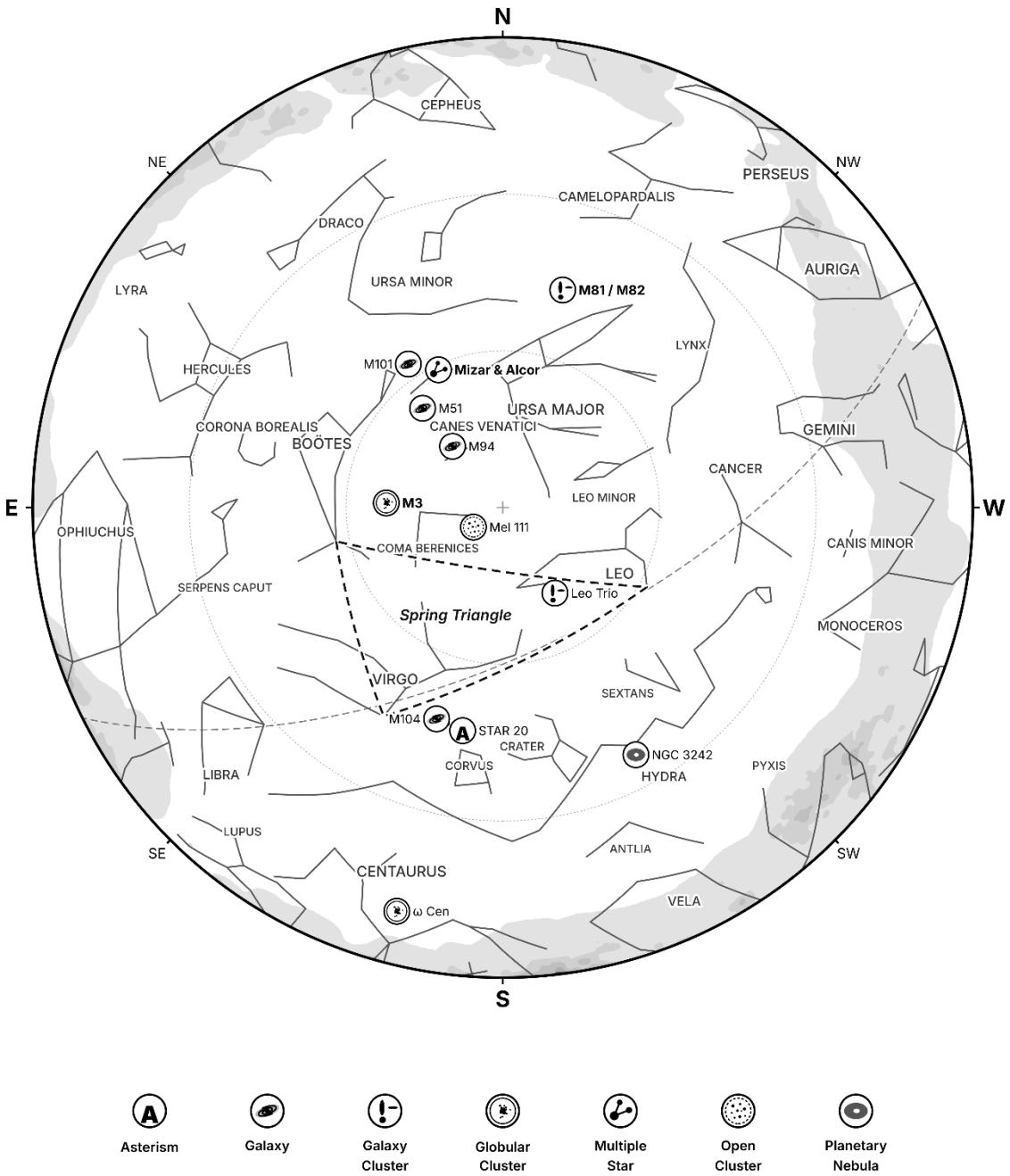
Seasonal Highlights

Listed below are some highlights for each season. Items marked with * in the *Target* column are considered exceptional targets and should not be missed. Selection was based on ease of locating and/or viewing pleasure. Of course, this is a subjective list, and the equipment you have will have a great impact on your viewing experience. Each seasonal list is ordered according to what constellation is best positioned within the season from earliest to latest.

For additional objects for observation, you may want to check out the free PDF book downloads at the ArtCentrics.com website.

Spring (March – May)

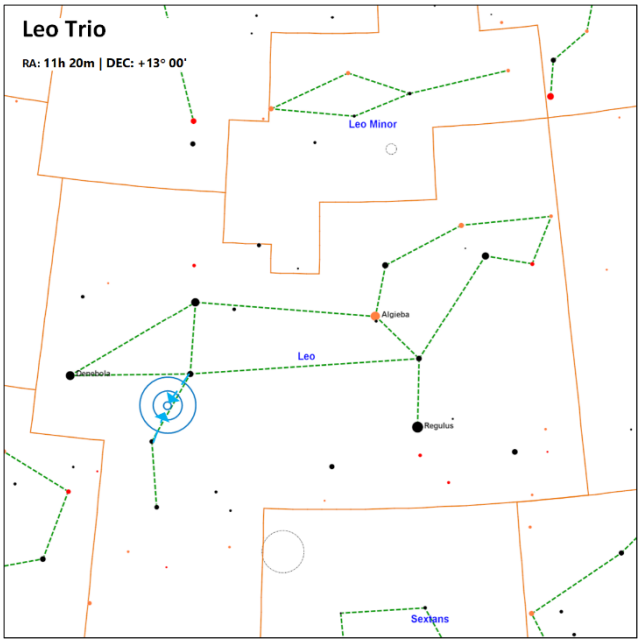
Const	Target (Type)	Size / Sep	Comments
Leo	Leo Trio (G)	45’	M-65, M-66, NGC-3628 group of galaxies in close proximity
Hya	NGC-3242 (PN)	25”	Ghost of Jupiter. A planetary nebula roughly the size of Jupiter.
UMa	*Mizar & Alcor (MS)	715”, 14”	A splendid binocular pair and easily located; a telescope triple; Mizar is a double with 14” separation between stars.
UMa	* M-81, 82 (G)	45’	Bode’s Galaxy & Cigar Galaxy, a pair of galaxies in close proximity.
UMa	M-101 (G)	29x27’	Pinwheel galaxy. Face-on galaxy nearly the size of the full Moon. Large aperture is required to see any details on this object.
Crv	STAR 20 (AS)	15'	Asterism known as the Stargate: a triangle embedded in a triangle.
Com	Mel-111 (OC)	4.5°	Coma Star Cluster. About 40 stars in a 4.5° area.
CVn	*M-3 (GC)	18’	A bright globular cluster with a very dense center.
CVn	M-94 (G)	11x9’	A bright face-on spiral galaxy. Large scopes show some detail in its spiral arms.
CVn	M-51 (G)	11x7’	Whirlpool Galaxy. Two interacting galaxies.
Cen	NGC-5139 (GC)	36'	Only visible for a brief period each year, and very low on the horizon, but a wonderful target to view.
Vir	M-104 (G)	9x4’	Sombrero Galaxy. Visible in small telescopes, with its dark dust band.

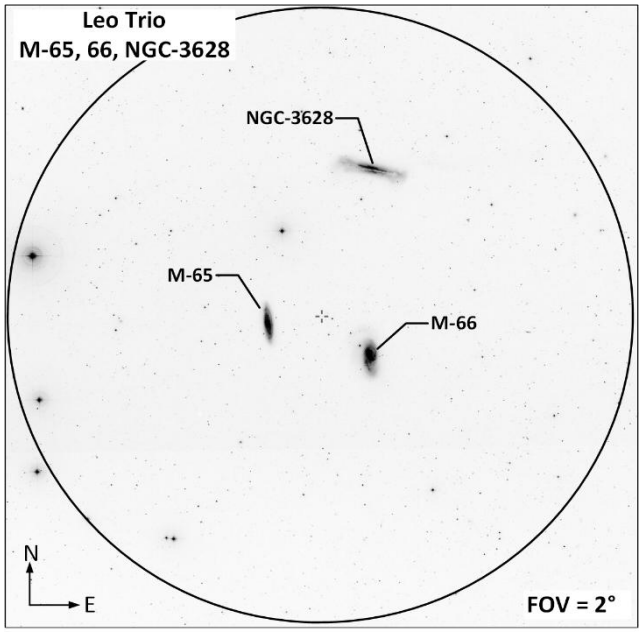

The Spring Sky
Northern hemisphere · latitude 30° N
N
NE
NW
E
W
SE
SW
S
CEPHEUS
PERSEUS
CAMELOPARDALIS
DRACO
AURIGA
URSA MINOR
M81 / M82
LYRA
LYNX
HERCULES
M101
Mizar & Alcor
M51
URSA MAJOR
CANES VENATICI
CORONA BOREALIS
BOÖTES
M94
GEMINI
CANCER
M3
LEO MINOR
Mel 111
OPHIUCHUS
CANIS MINOR
COMA BERENICES
LEO
SERPENS CAPUT
Leo Trio
Spring Triangle
MONOCEROS
VIRGO
SEXTANS
M104
STAR 20
CRATER
NGC 3242
CORVUS
HYDRA
PYXIS
LIBRA
LUPUS
ANTLIA
CENTAURUS
VELA
ω Cen
Asterism
Galaxy
Galaxy Cluster
Globular Cluster
Multiple Star
Open Cluster
Planetary Nebula
Bold labels mark exceptional targets. Hold the chart overhead with the direction you face at the bottom.
Bold dashed lines: seasonal asterism. Fine gray dashes: ecliptic. Dotted circles: 30° and 60° altitude.

Leo Triplet

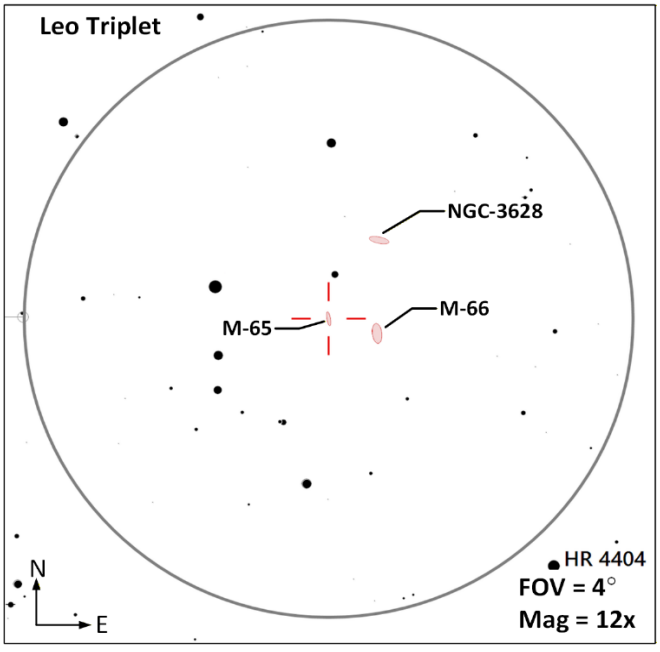
The three galaxies Messier 65, Messier 66 and NGC-3628 make up the Leo Triplet of galaxies and all lie within about 30 arcminutes of each other. This small group of galaxies is located about 41 million light-years away.

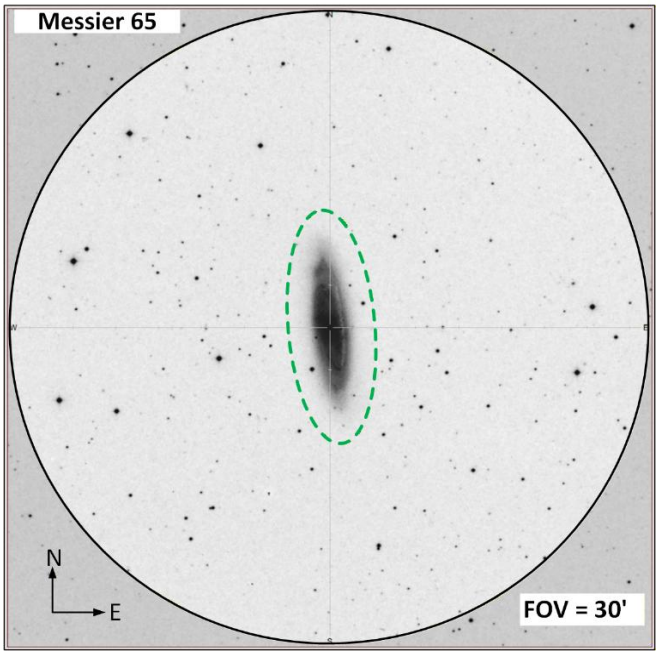
Both M-65 and M-66 should be easily seen with 10x magnification in a good set of binoculars.



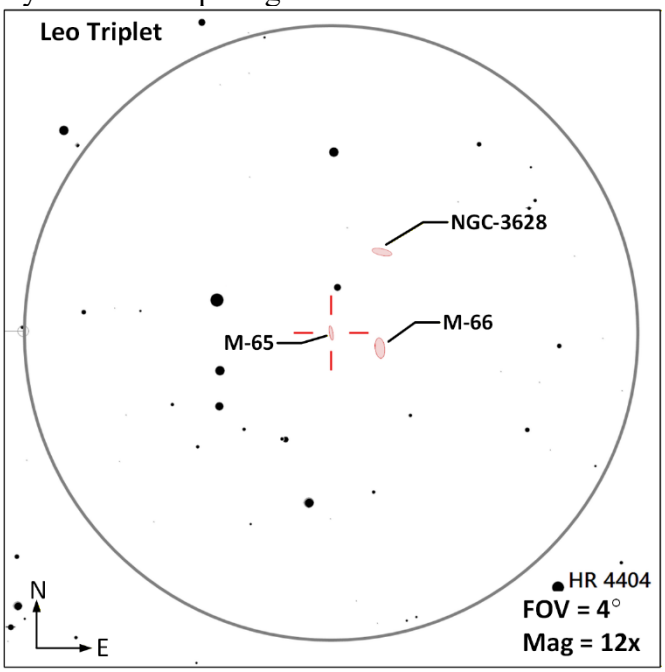


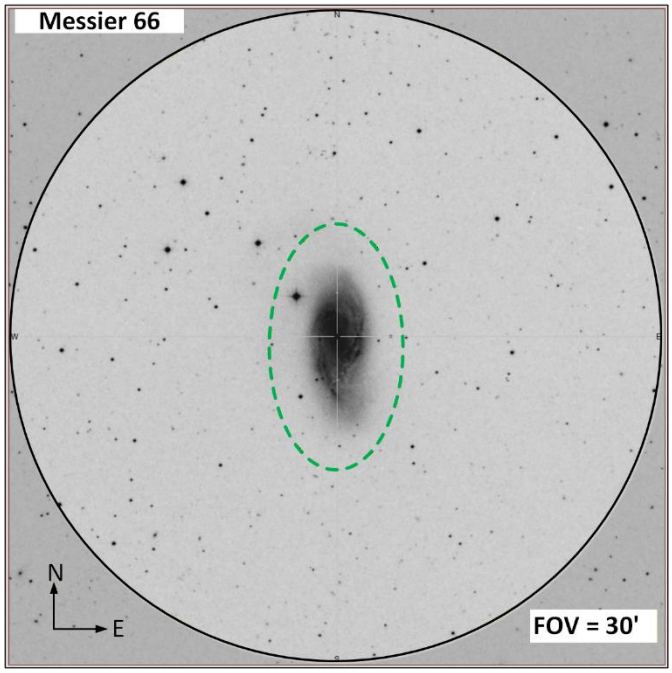
Messier 65 (G | M=9.3 | Size=9.0' x 2.3' | SB=21.2 | MC=SAB(rs)a |) – NGC 3623 is an intermediate spiral galaxy that is highly inclined relative to Earth and is located about 45 million light-years away. A prominent dust lane extending across the side of its disk may be visible in telescopes of moderate aperture.



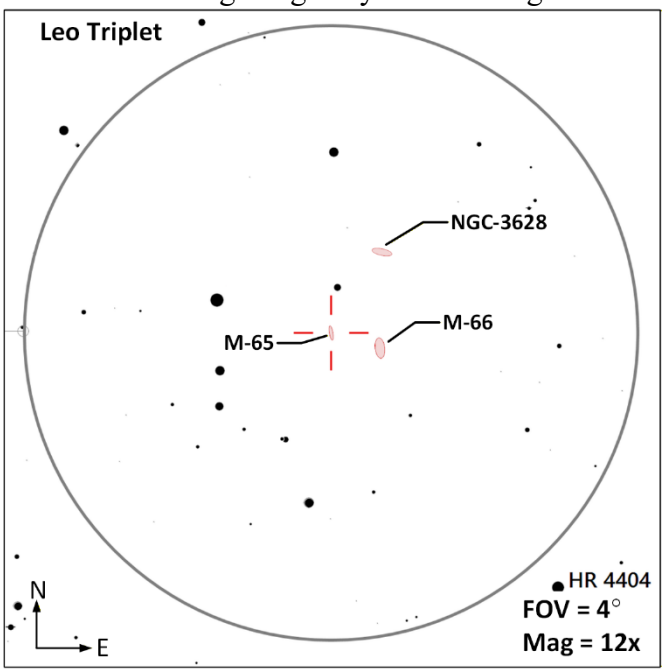


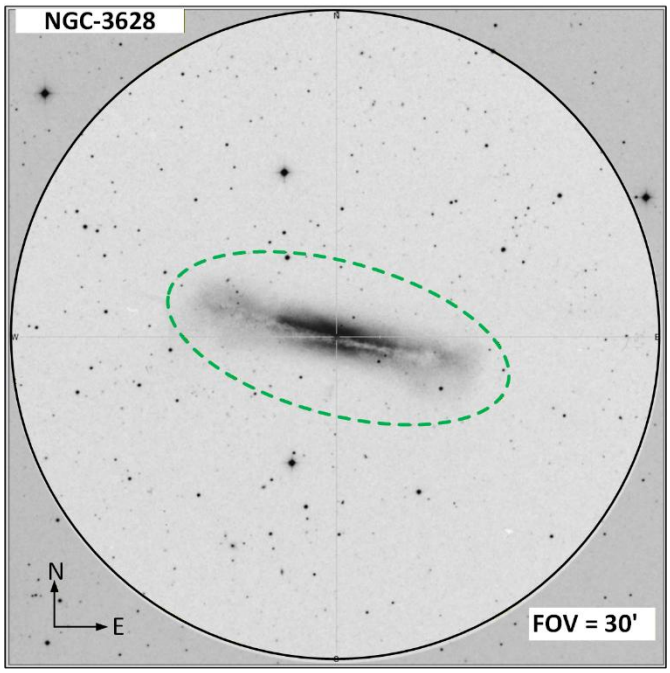
Messier 66 (G | M=8.9 | Size=9.1’ x 4.2’ | SB=21.5 | MC=SAB(s)b |) – NGC 3627 is an intermediate spiral galaxy with a weak bar feature and loosely wound arms and is about 95 thousand light-years across. Close observations may reveal two bright arms looping outward from the nucleus. These arms are among the most easily seen of all spiral galaxies.



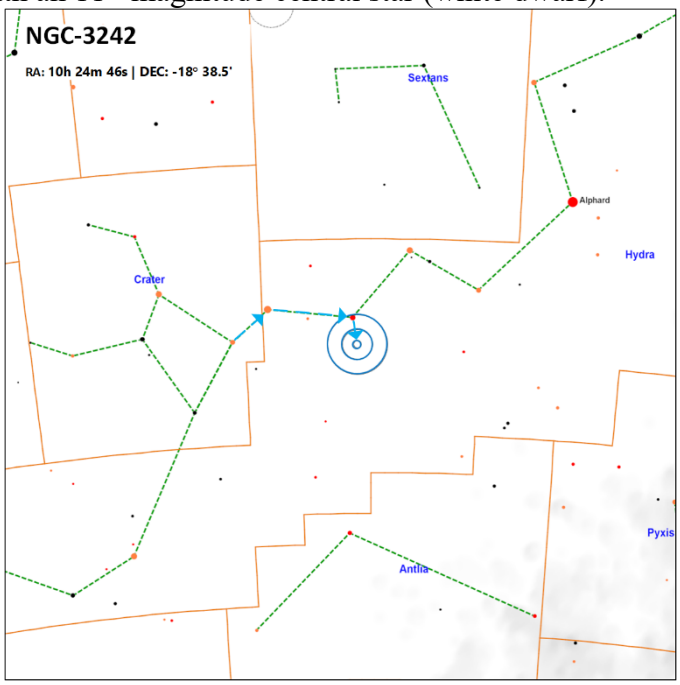


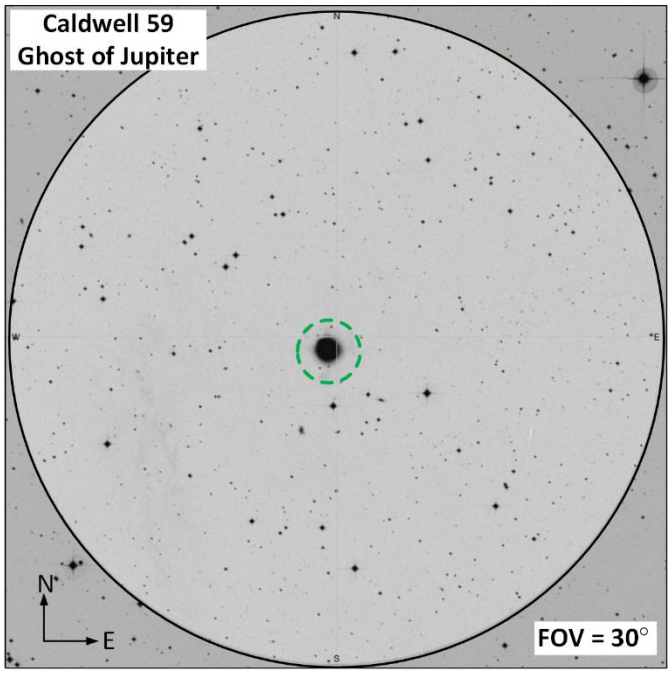
NGC 3628 (G | M=9.5 | Size=14’ x 3.6’ | SB=22.4 | MC=Sab pec |– The Hamburger Galaxy is the faintest of the three galaxies making up the Leo Triplet. This is an edge-on galaxy with a conspicuous equatorial band of dark dust obscuring the galaxy’s central region.



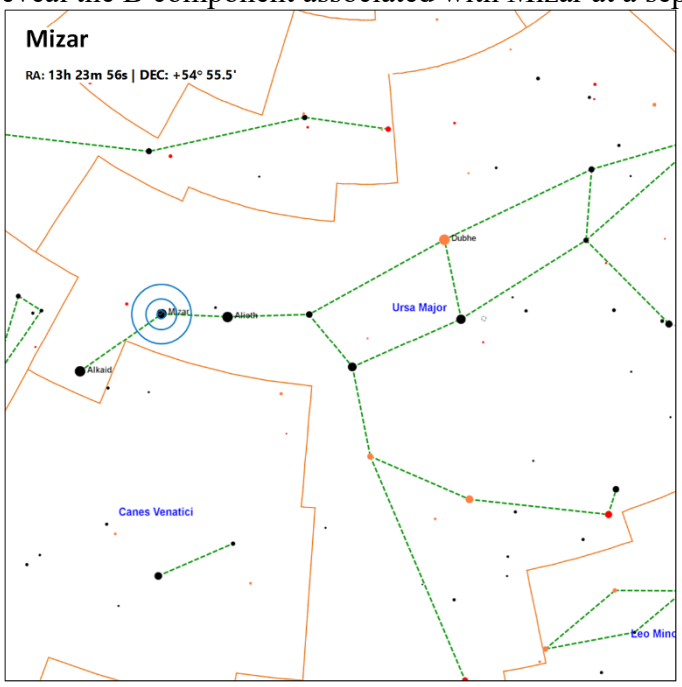


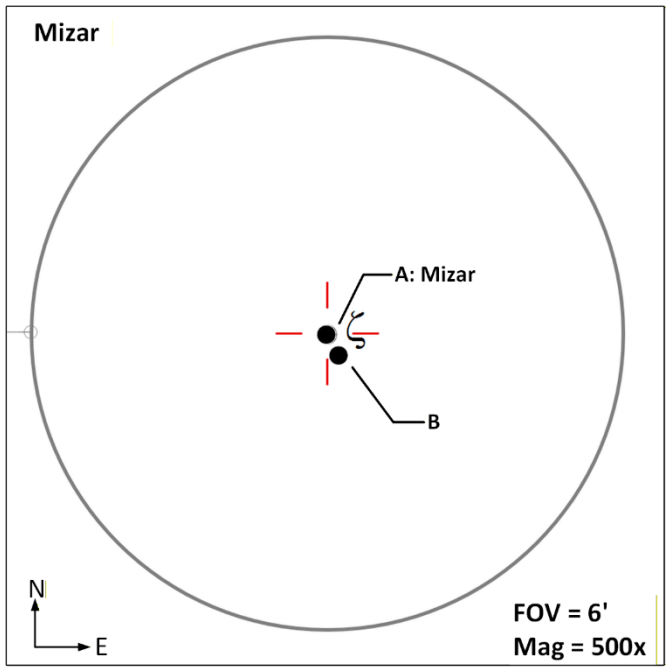
NGC-3242 (PN | Mag=8.6 | Size=25” | SB=24.2 |) – The Ghost of Jupiter Nebula has a similar shape and size to the planet Jupiter and has a bluish-green color. It is located 4,800 ly away and measures 2 ly from end to end, with an 11th magnitude central star (white dwarf).



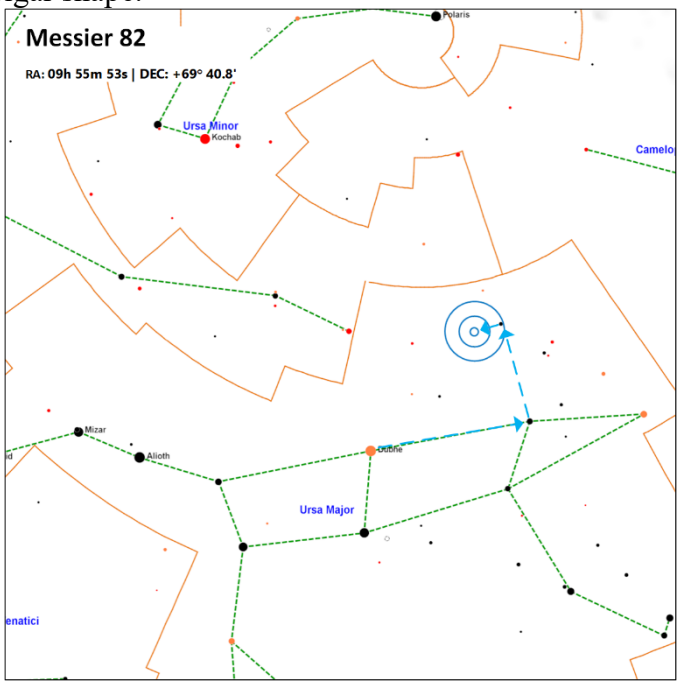


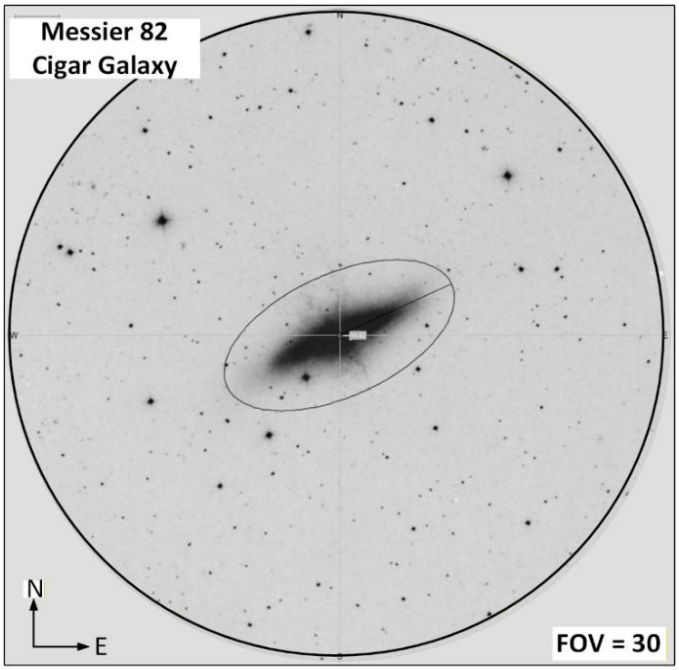
Mizar (MS-3 | **AB** | M=2.2, 3.9 | Sep=14.4” | PA=153° || **AC** | M=2.2, 4.0 | Sep=715.5” | PA=73° |) – Mizar (A component) and Alcor (C component) are a famous double star system. It is uncertain if these two stars are actually physically associated with each other. This is a much-celebrated binocular double, and telescopes will reveal the B component associated with Mizar at a separation of 14”.



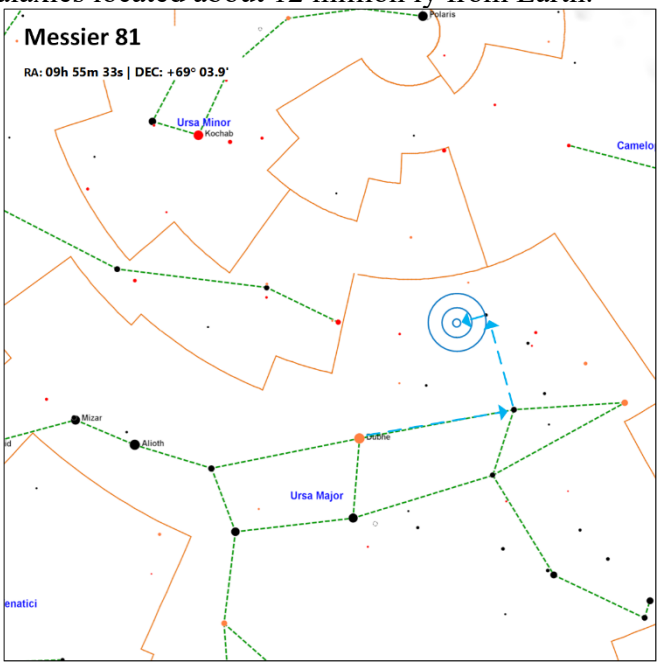


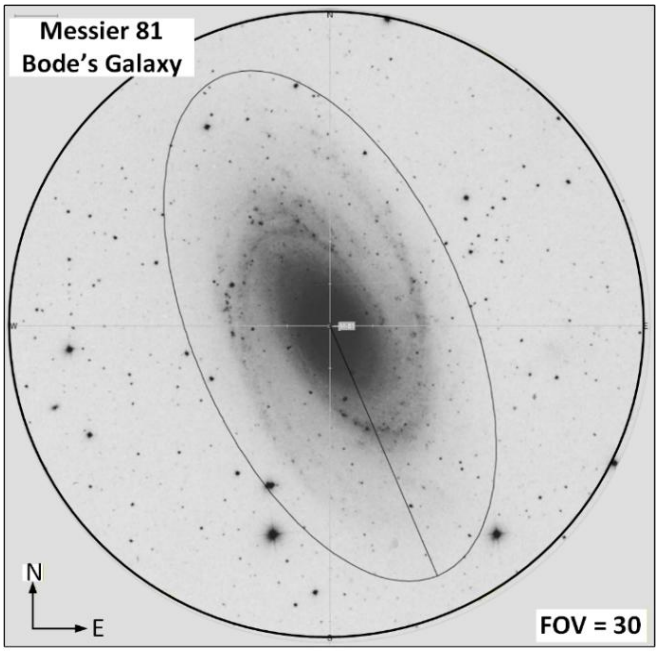
Messier 82 (G | M=8.4 | Size=11'x4' | SB=21.1 | MC= I0 |) – The Cigar Galaxy (NGC-3034) is a starburst galaxy (has exceptionally high star formation). It is suspected that the high star formation is being induced by its interaction with Bode's Galaxy (M-81). When viewed through a telescope, this galaxy does indeed have a cigar shape.



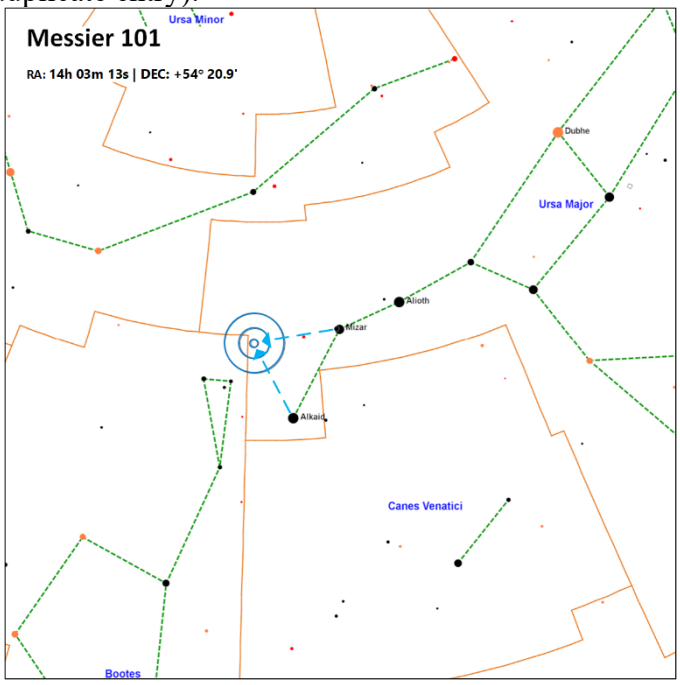


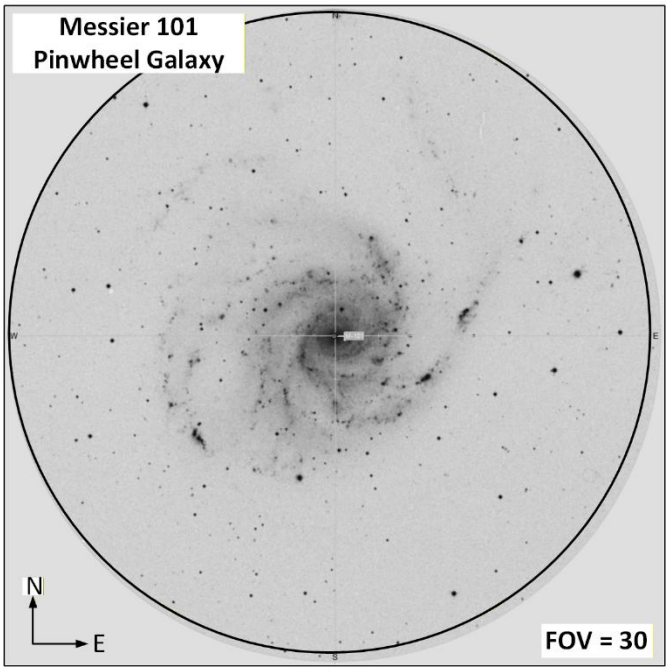
Messier 81 (G | M=6.9 | Size=27'x14' | SB=22.0 | MC= Sab |) – Bode's Galaxy (NGC-3031) is a grand-design spiral galaxy (contains prominent and well-defined spiral arms) 12 million light-years away. This object is quite bright and a great target for small telescopes and binoculars. At low enough power, you should be able to fit both M-81 and M-82 in the same field of view. Both M-81 and M-82 are suspected of interacting with each other. These two galaxies are part of the M-81 group of galaxies composed of about 30 galaxies located about 12 million ly from Earth.



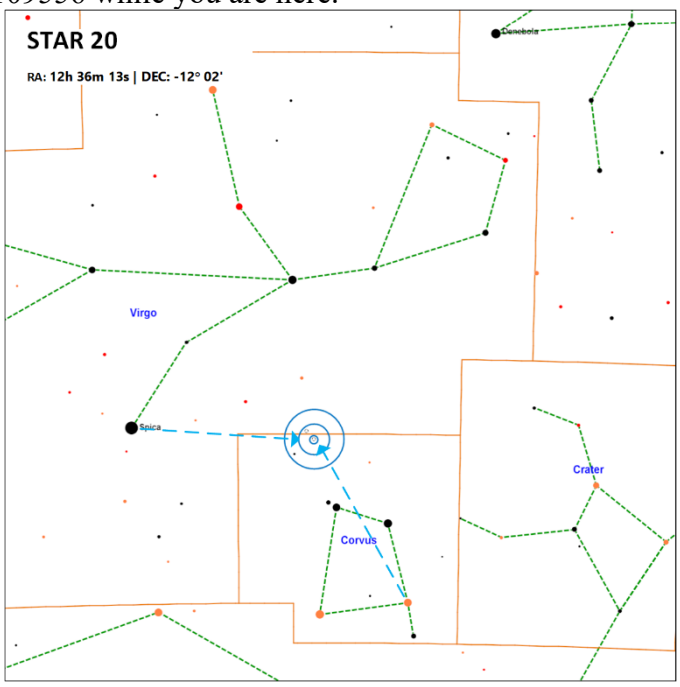


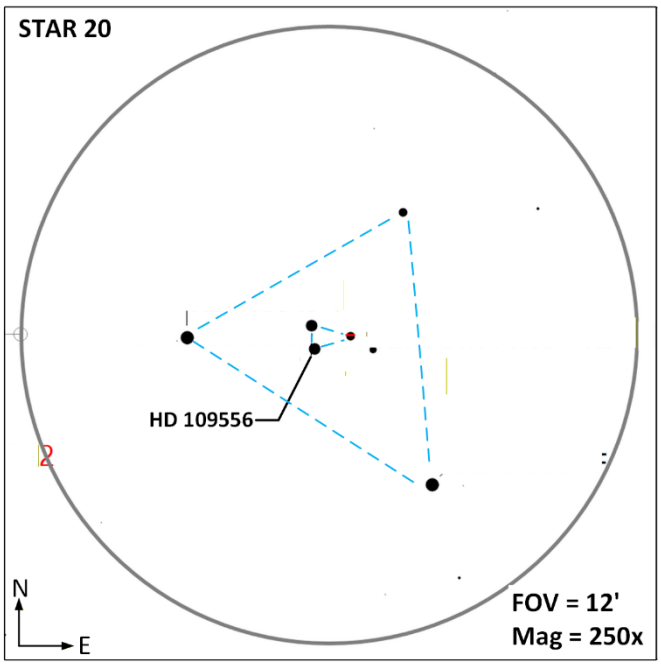
Messier 101 (G | M=7.9 | Size=29'x27' | SB=23.8 | MC=SABc |) – The Pinwheel Galaxy (NGC-5457) is a face-on spiral galaxy located 21 million light-years from Earth. Due to its larger angular diameter in the sky, M-101 has a low surface brightness; darker skies are required to view this object and smaller instruments probably see only the core of this galaxy. It is suspected that this is also the object Messier listed as M-102 (a duplicate entry).





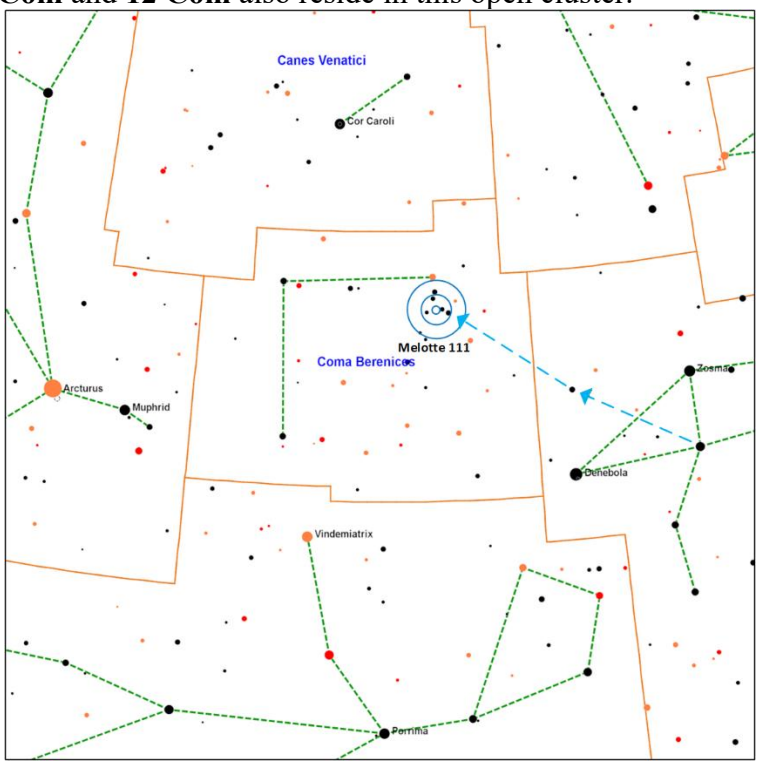
STAR 20 (AS | Stars=6 | Size=15' | Ref Star: STF-1659, SAO-157379, HIP 61449 |) – Stargate, an asterism in the shape of a triangle within a triangle. Best viewed with a telescope. Check out the double star system HD-109556 while you are here.

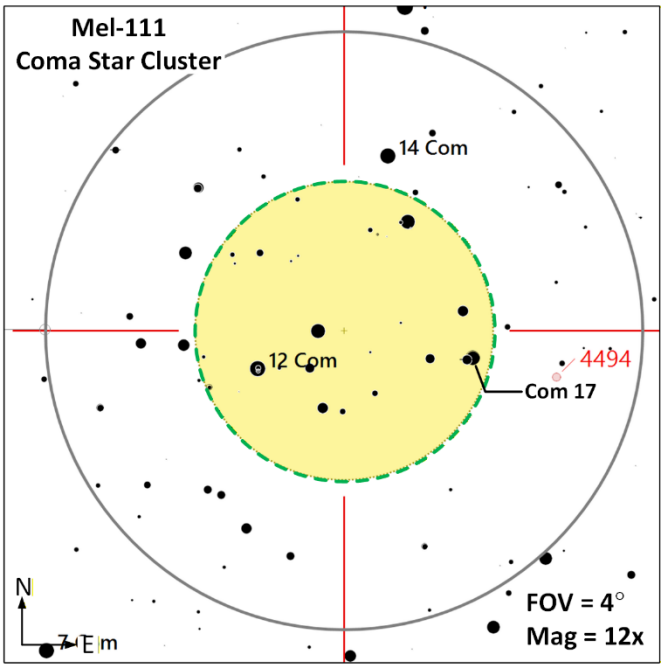


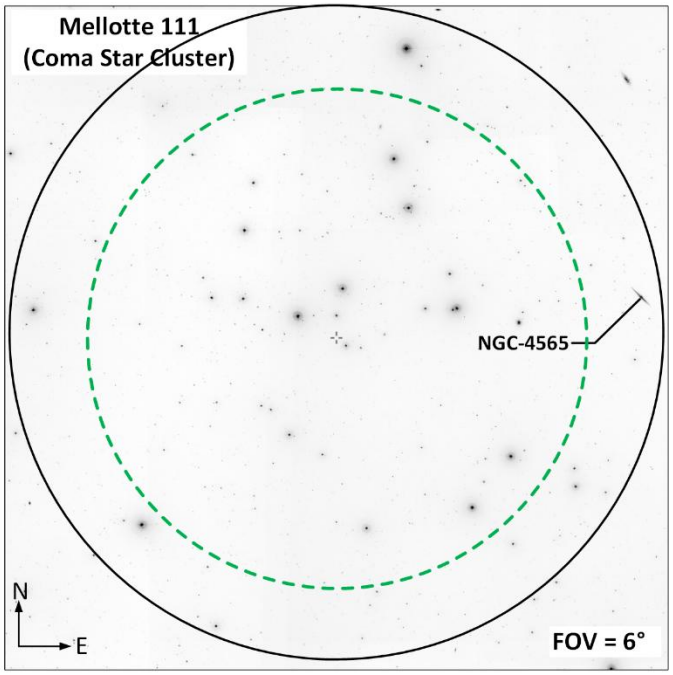


Melotte 111 (OC | M = 1.8 | Size=4.5° | SB=22.6 | MC=III3r |) – The Coma Star Cluster is a close open cluster at a distance of 288 light-years that contains about 40 stars between magnitude 5 and 10 and a dozen brighter than magnitude 6 over an area of about 4.5°. The brighter stars in this open cluster form a "V" shape. The cluster was first cataloged by Ptolemy around 138 AD and is suspected to be about 450 million years old.

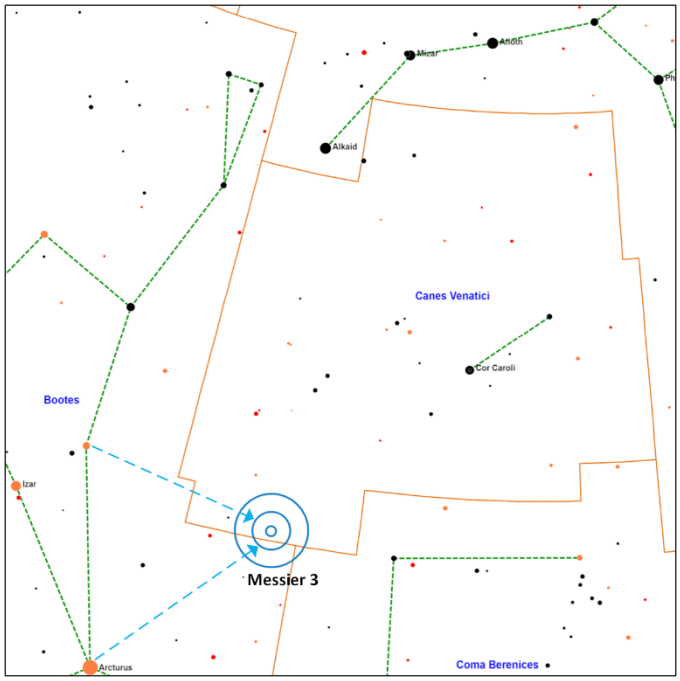
Multiple Star systems **17 Com** and **12 Com** also reside in this open cluster.

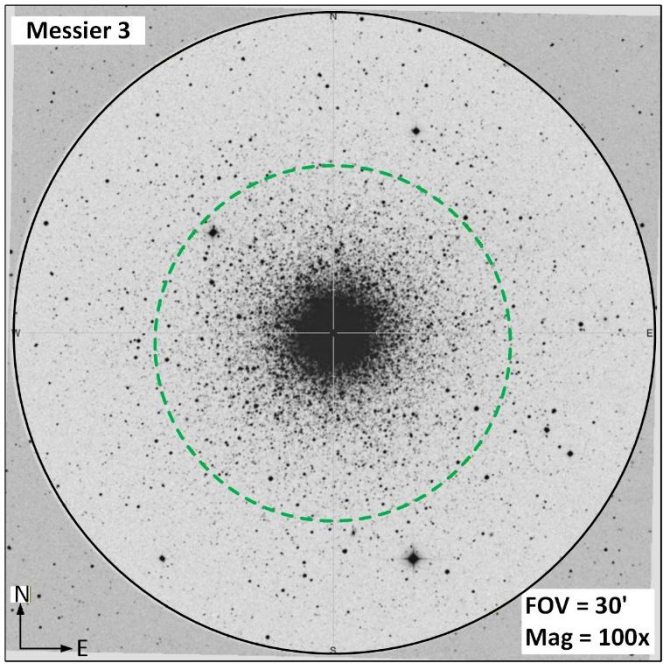




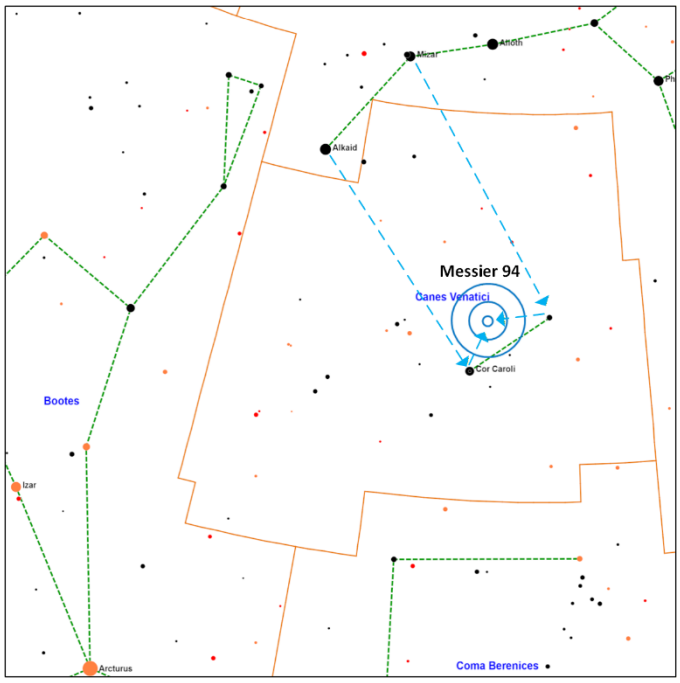


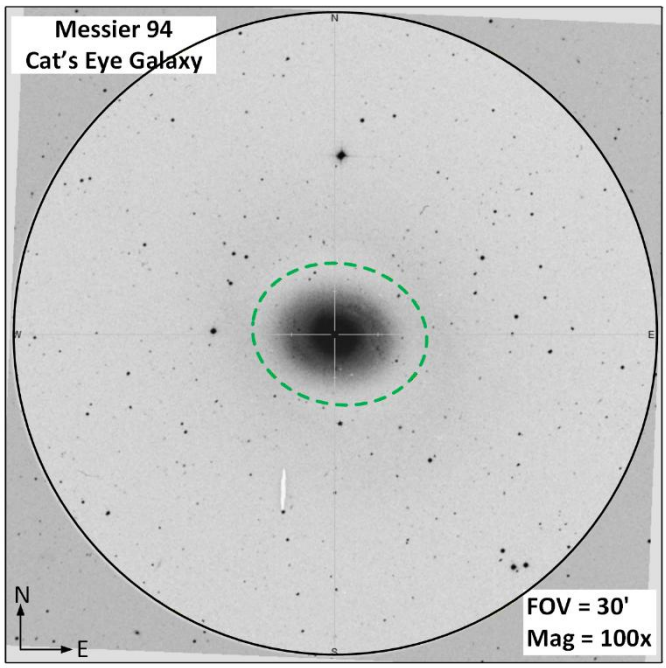
Messier 3 (GC | M=6.4 | Size=18.0' | SB=21.3 | MC= VI |) – NGC-5272 is located 34 thousand light-years away and is one of the largest and brightest globular clusters discovered, containing approximately 500,000 stars. It is estimated to be 11.4 billion years old. Many consider this one of the finest globulars visible in the northern skies.



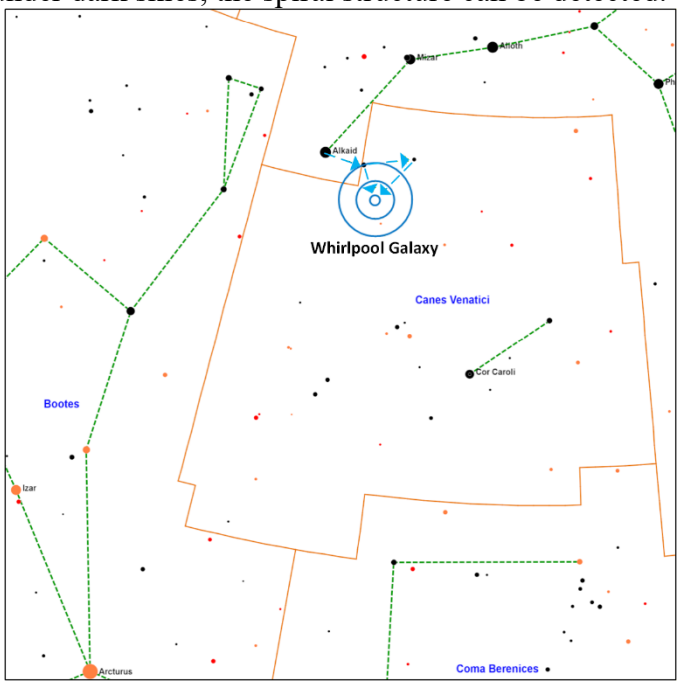


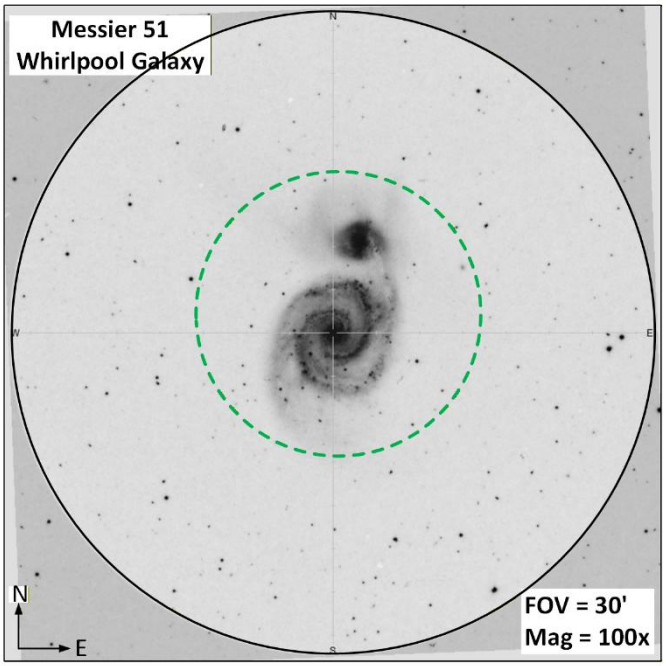
Messier 94 (G | M=8.2 | Size=11.2 x 9.1 | SB=21.8 | MC=Sab |) – The Cat's Eye Galaxy is the most prominent member of the Canes Venatici I Group of galaxies (aka M94 Group) and is located 17 million light-years away. Although described as having a "bar" structure, the bar appears more oval-shaped. The galaxy has two ring structures visible in photographs and contains a supermassive black hole with a mass of 1.6 x 10^7 solar masses.



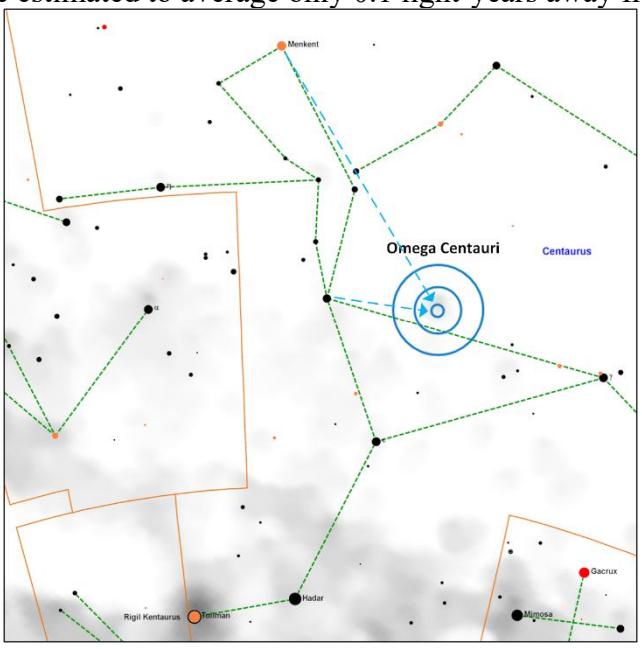


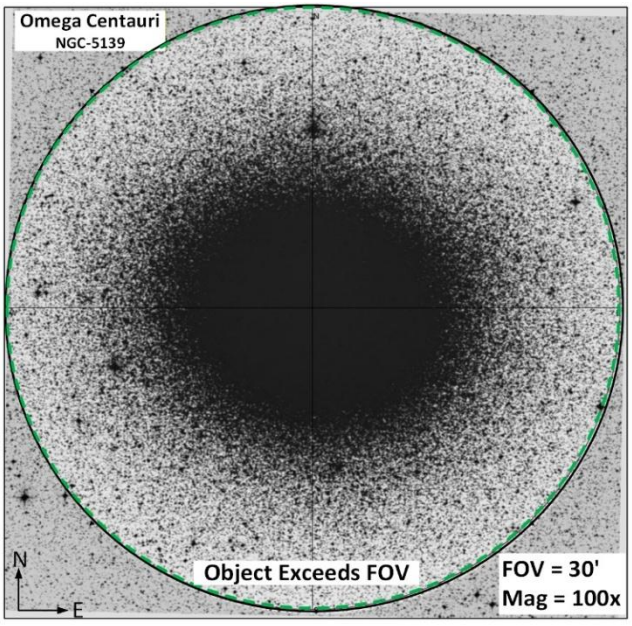
Messier 51 (G | M=8.4 | Size=11.2' x 6.9' | SB=21.7 | MC=Sbc |) – The Whirlpool Galaxy is a face-on grand-design spiral galaxy interacting with dwarf galaxy NGC-5195. Both are located 31 million light-years away. The galaxy pair is easily observed in most telescopes and even binoculars. With a telescope of 150mm (6") under dark skies, the spiral structure can be detected.



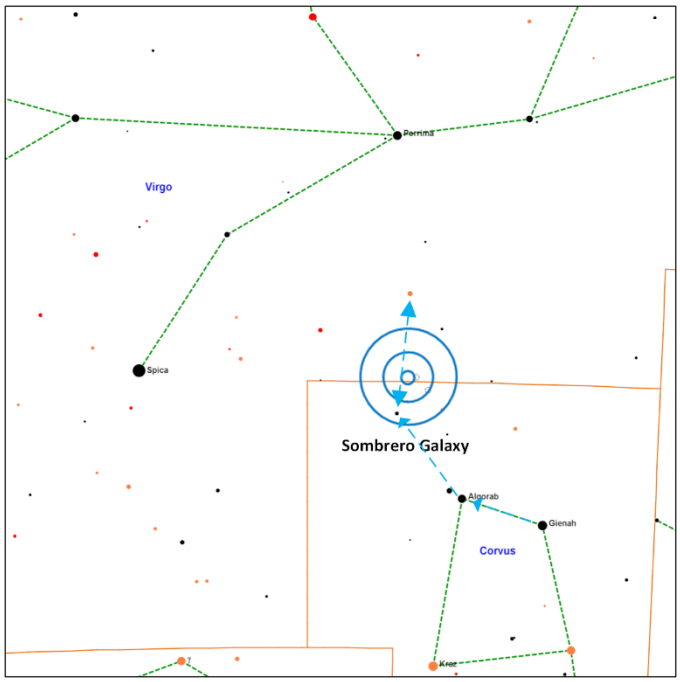


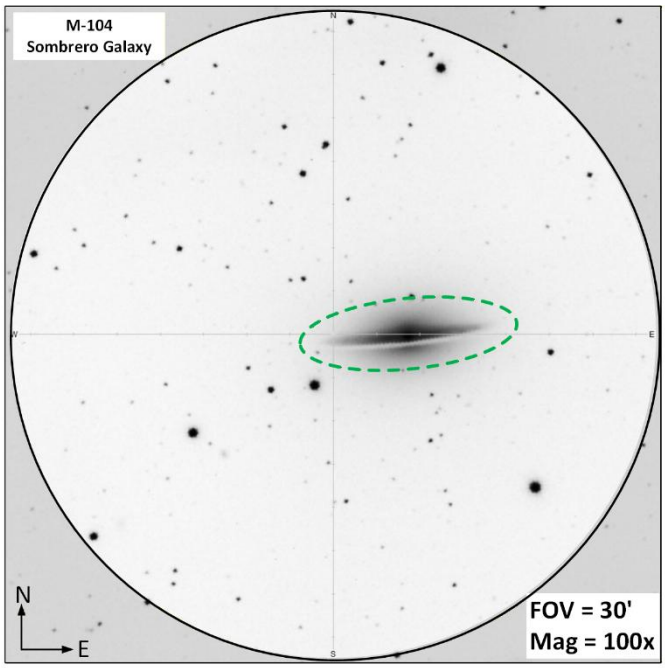
NGC 5139 (GC | M=3.9 | Size=36.3' | SB=20.3 |) – Omega Centauri is the brightest globular cluster in the sky and the largest and most luminous orbiting the Milky Way. It is located 17,100 ly away with a physical diameter of 150 light-years. It is estimated to contain approximately 10 million stars with a combined mass of 4 million solar masses. It is suspected that it is the core remnant of a disrupted dwarf galaxy consumed by our galaxy. Omega Centauri is estimated to be 12 billion years old, and the stars located around the core region are estimated to average only 0.1 light-years away from each other.





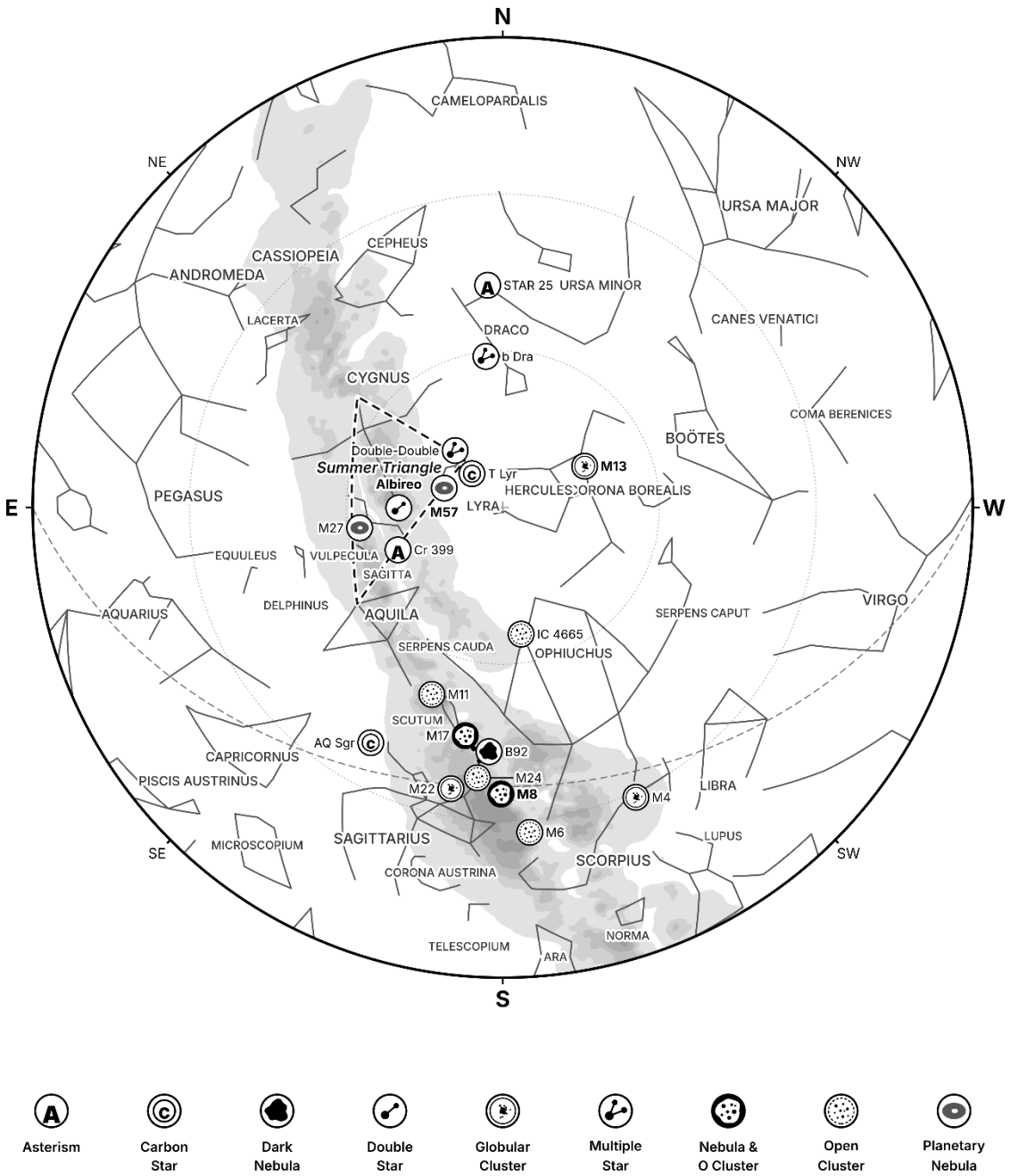
Messier 104 (G | M=8.0 | Size=9’x4’ | SB=20.4 | MC=Sa |) – The Sombrero Galaxy is considered a bright, easy target and is a great target for smaller telescopes. It is also located within 30’ of STAR-21, so both targets should be checked out.



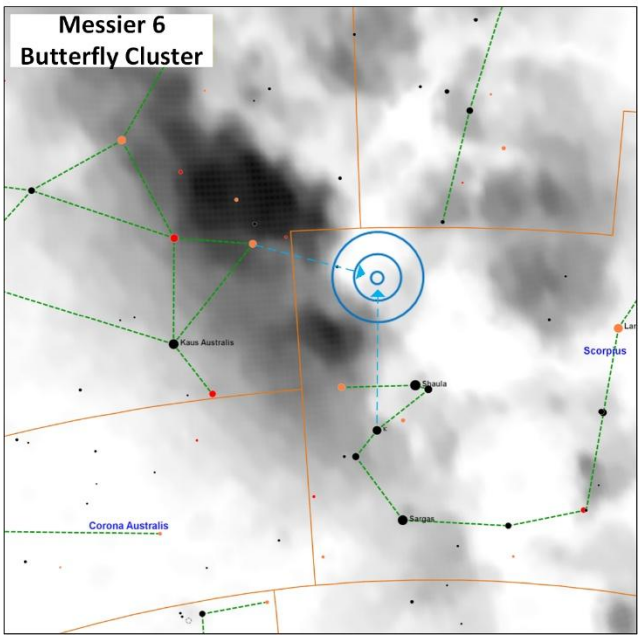


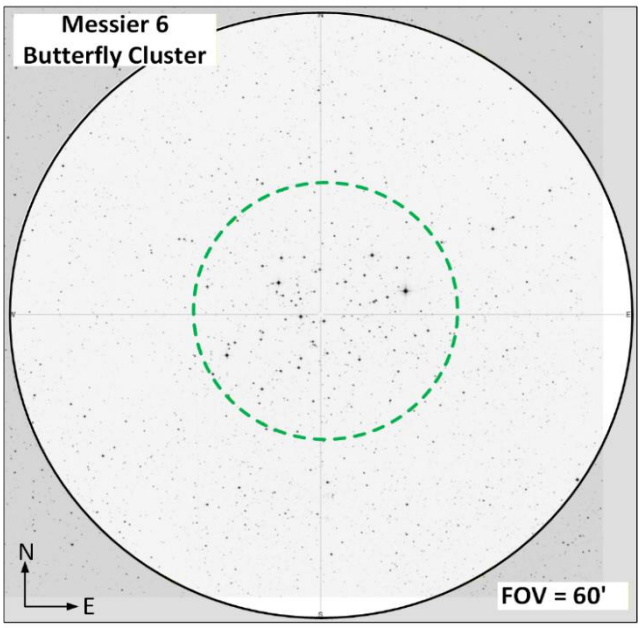
Summer (June – August)

Const	Target (Type)	Size / Sep	Comments
Sco	M-6 (OC)	25’	Butterfly Cluster. Shape does resemble a butterfly.
Sco	M-4 (GC)	26’	Loose globular with row of bright stars going through the middle.
Dra	b Dra (MS-3)		Excellent multiple star system, B is very dim but visible.
Dra	STAR 25 (AS)	10'x20'	Truly a Cassiopeia-shaped asterism! Best viewed with binoculars.
Sgr	B-92, 93 & Jenn's Confluence (DN)		Three items in this field of view; B-92, B-93 and Jenn’s Confluence. Rare case of being able to see a dark nebula.
Sgr	* M-8 (EN, OC)	90x40’	Lagoon Nebula. Large open cluster in nebula.
Oph	IC-4665 (OC)	40’	A large and sprawling open cluster, good for binoculars.
Her	* M-13 (GC)	20’	Hercules Cluster: Best globular cluster in the Northern Hemisphere.
Sct	M-11 (OC)	23’	Wild Duck Cluster. A rich very dense open cluster.
Lyr	T Lyrae (CS)		Bright Red (very red)
Lyr	Double-Double (MS-4)	208"	Celebrated quadruple star system.
Lyr	* M-57 (PN)	1x1’	The Ring Nebula. Bright PN visible even in small telescopes.
Sgr	M-17 (EN, OC)	11’	Swan Nebula. Cluster of bright stars in faint nebulosity.
Sgr	M-22 (GC)	32’	One of the largest, brightest, and most impressive globular clusters in the sky.
Sgr	AQ Sgr (CS)		Bright red, stop-light colored. Excellent!
Sgr	M-24 (Star Cloud)	2x1°	Sagittarius Star Cloud. Great binocular target.
Cyg	*Albireo (DS)	35”	The most celebrated double in the northern hemisphere.
Vul	M-27 (PN)	8x6’	Dumbbell Nebula. A large PN with an hourglass shape.
Vul	CR-399 (OC)	60’	Coathanger Cluster. A great binocular target.

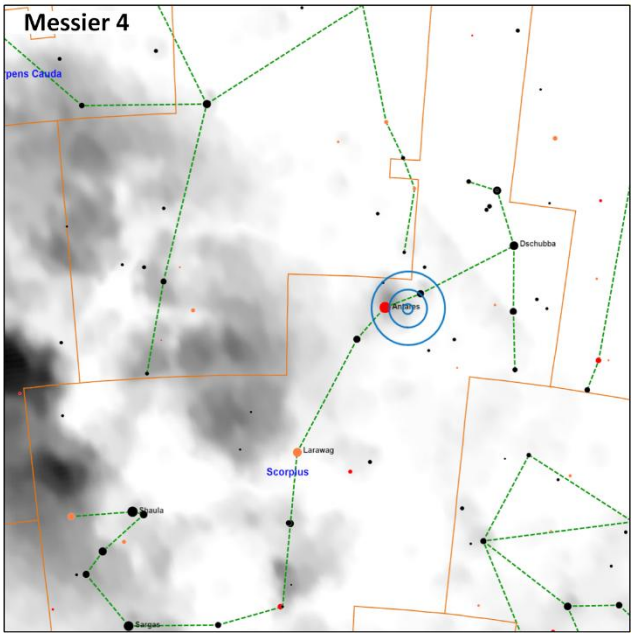

The Summer Sky
Northern hemisphere · latitude 30° N
N
NE
NW
E
W
SE
SW
S
CAMELOPARDALIS
URSA MAJOR
CASSIOPEIA
CEPHEUS
ANDROMEDA
STAR 25 URSA MINOR
LACERTA
CANES VENATICI
DRACO
b Dra
CYGNUS
COMA BERENICES
BOÖTES
Double-Double
Summer Triangle
Albireo
T Lyr
M13
PEGASUS
HERCULES
CORONA BOREALIS
LYRA
M57
M27
EQUULEUS
VULPECULA
Cr 399
SAGITTA
DELPHINUS
AQUILA
SERPENS CAPUT
VIRGO
AQUARIUS
IC 4665
SERPENS CAUDA
OPHIUCHUS
M11
SCUTUM
M17
AQ Sgr
B92
CAPRICORNUS
PISCIS AUSTRINUS
M24
M22
M8
M4
LIBRA
M6
SAGITTARIUS
LUPUS
MICROSCOPIUM
SCORPIUS
CORONA AUSTRINA
NORMA
TELESCOPIUM
ARA
Asterism
Carbon Star
Dark Nebula
Double Star
Globular Cluster
Multiple Star
Nebula & O Cluster
Open Cluster
Planetary Nebula
Bold labels mark exceptional targets. Hold the chart overhead with the direction you face at the bottom.
Bold dashed lines: seasonal asterism. Fine gray dashes: ecliptic. Dotted circles: 30° and 60° altitude.

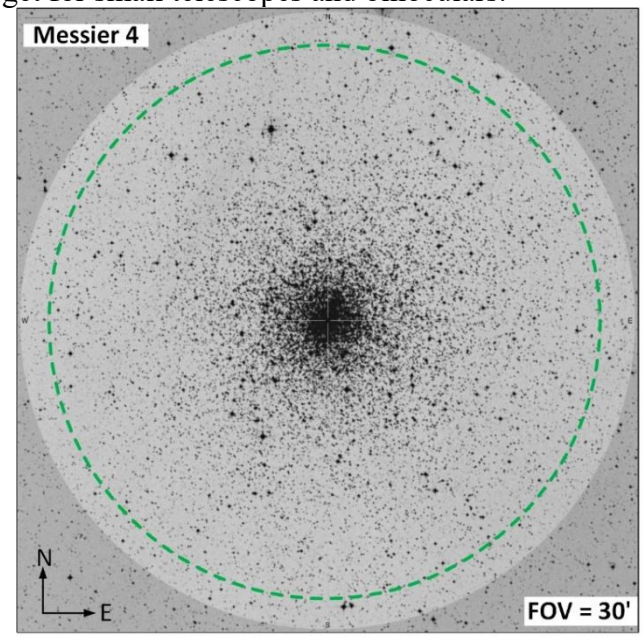
Messier 6 (OC | Mag=4.2 | D=33' | SB=20.4 | MC=II3r |) – The Butterfly Cluster is reported to have a shape like a butterfly. It is suspected that the astronomer Ptolemy may have observed this open cluster in the 2nd century. It is estimated to be located 1,600 light-years away with a diameter of 12 light-years. The cluster is estimated to be 94 million years old. Approximately 120 stars ranging down to magnitude 15 have been identified.



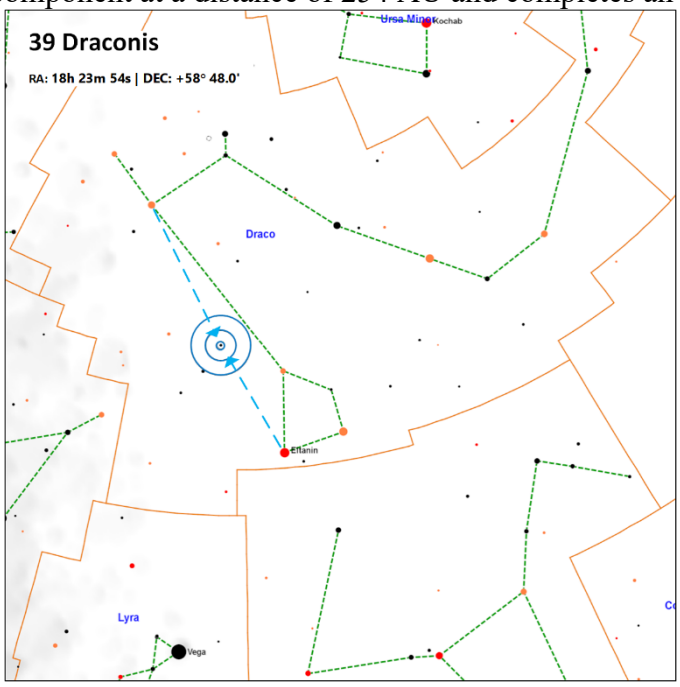


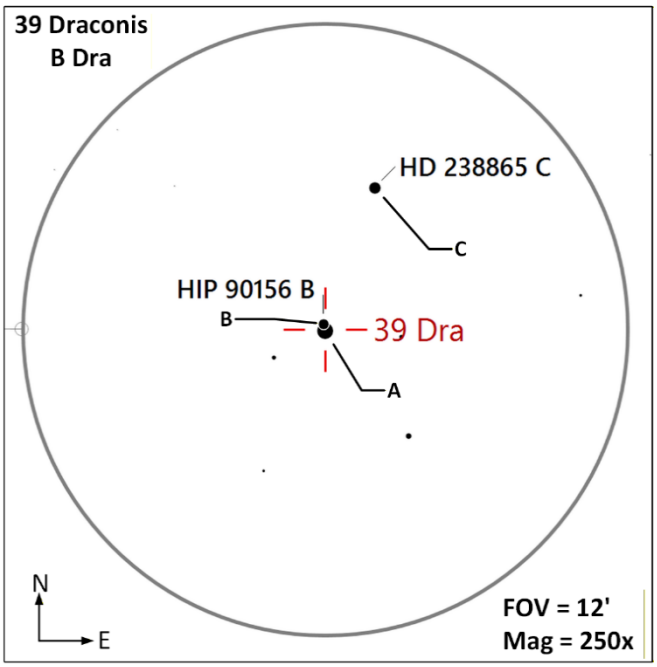
Messier 4 (GC | Mag = 5.6 | Size = 26' | SB = 21.3 | MC=IX |) – One of the closest and brightest globular clusters in the sky, it is positioned only 1.3° west of Antares, so it is also easily located. M4 is estimated to be 7,200 ly from Earth with an estimated age of 12.2 billion years. This was the only globular cluster in which Messier was able to resolve stars, and it is an excellent target for small telescopes and binoculars.



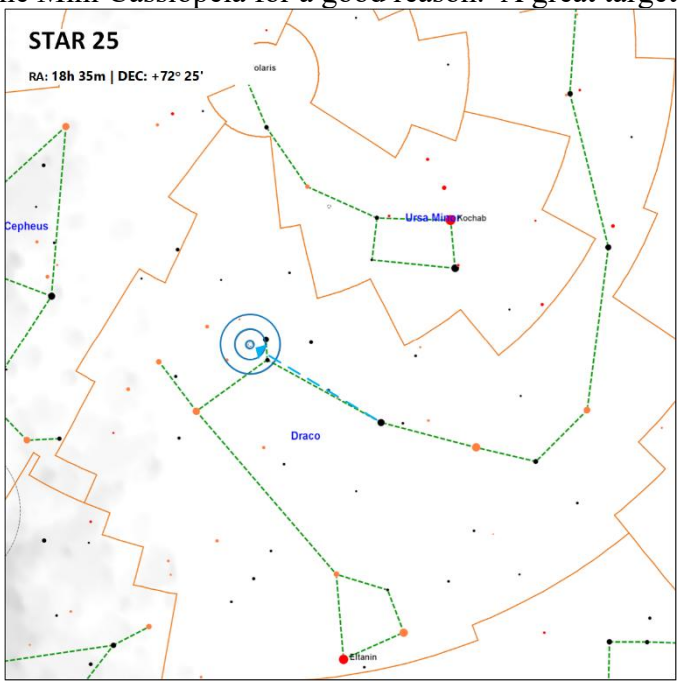


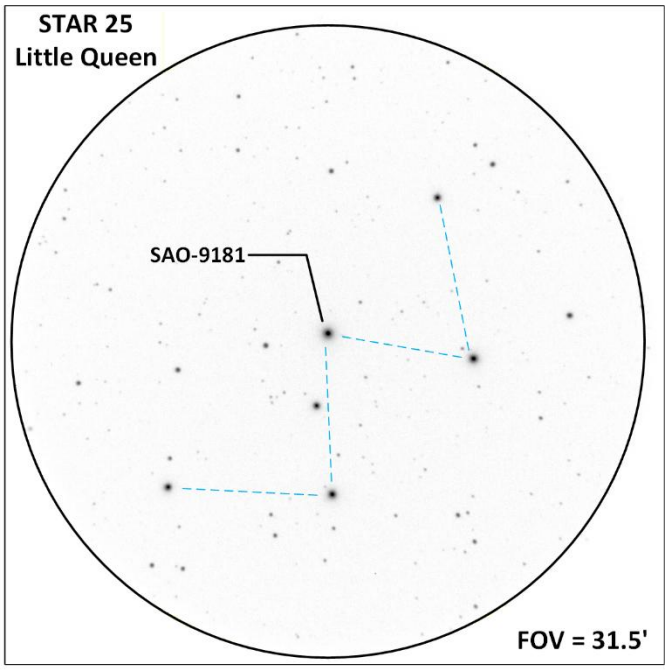
b Draconis (MS-3 **AB** | M=5.1, 8.1 | Sep=3.6” | PA=348° | | **AC** | M=5.1, 8.0 | Sep=89” | PA=19° || **CD** | M=7.0, 11.0 | Sep=198” | PA=68° |) – A triple star system 184 ly from Earth. The B component orbits the A component at a distance of 254 AU and completes an orbit every 4,000 years.



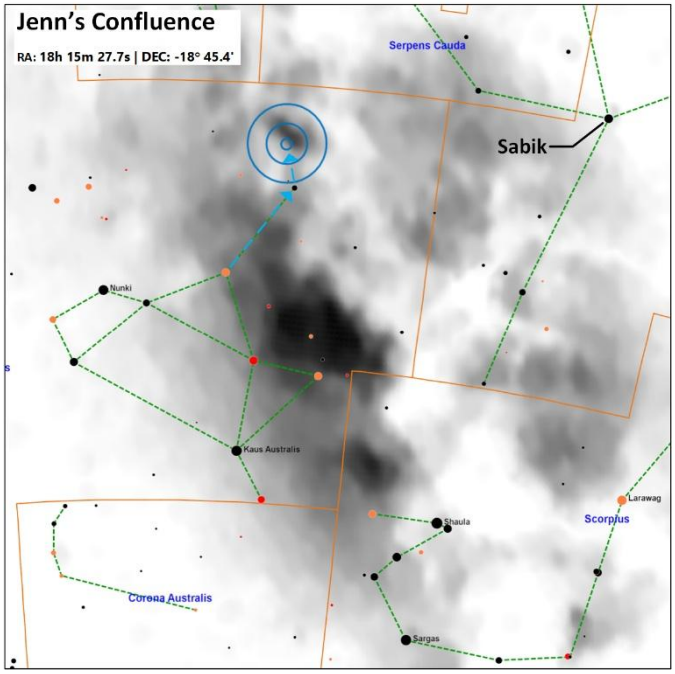


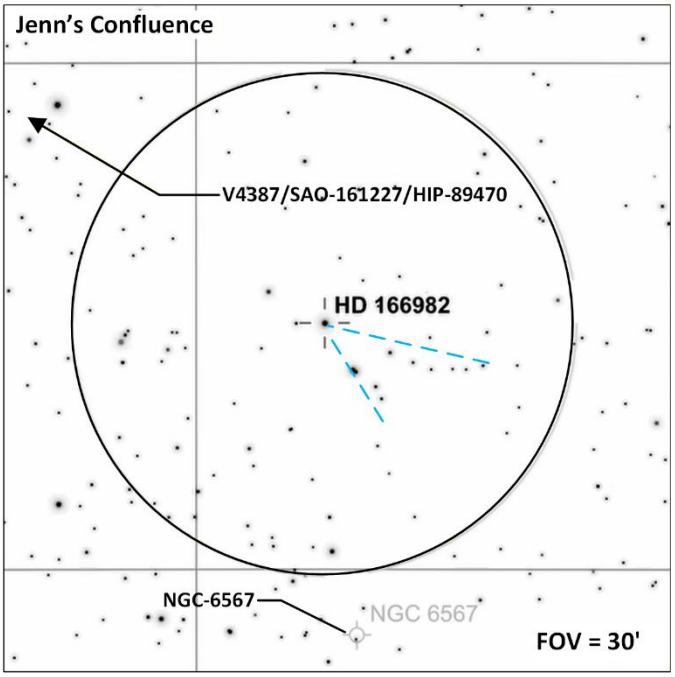
STAR 25 (AS | Size = 10 x 20 | Stars = 6 | Ref Star: SAO-009181/HD 172992) – This asterism is also called the Mini Cassiopeia for a good reason. A great target for binoculars.



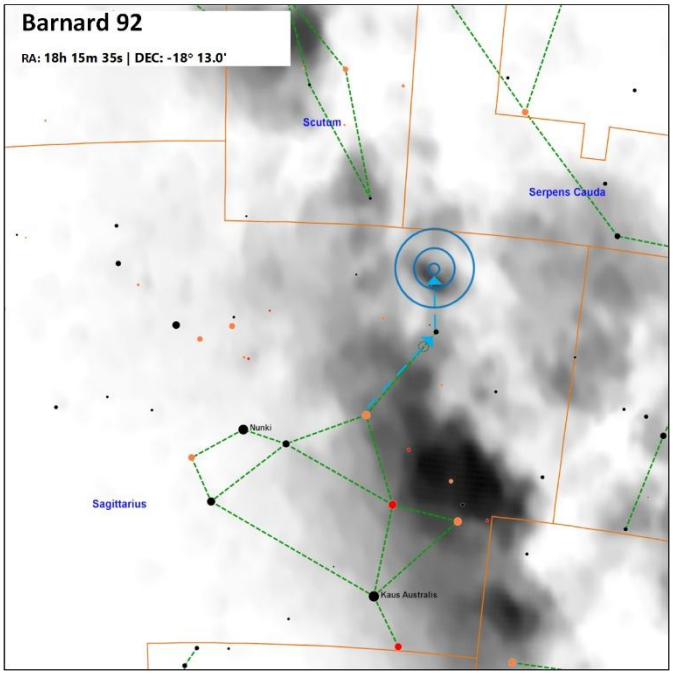


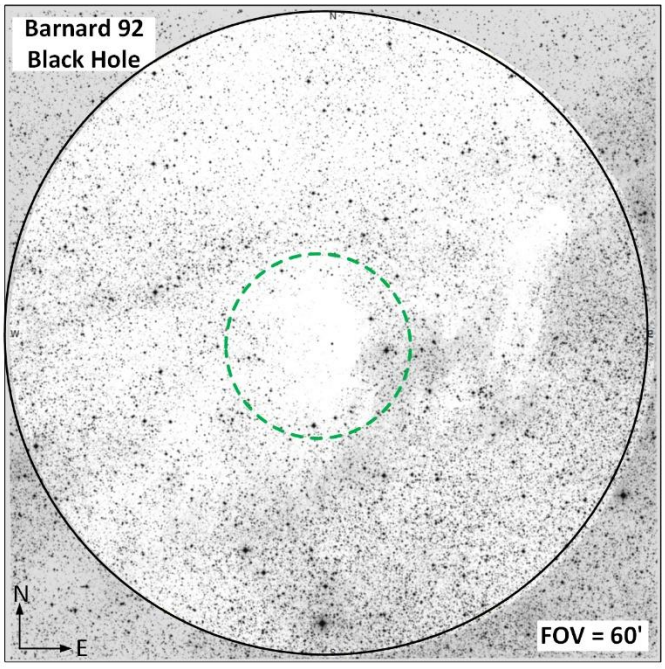
Jenn's Confluence (AS || | Size=15' | Centering Star: HD 166982 |) A merging of two rows of arching stars. Closest star with SAO/HIP number: V4387 Sgr; SAO-161227; HIP-89470. Just about 30' from the asterism.



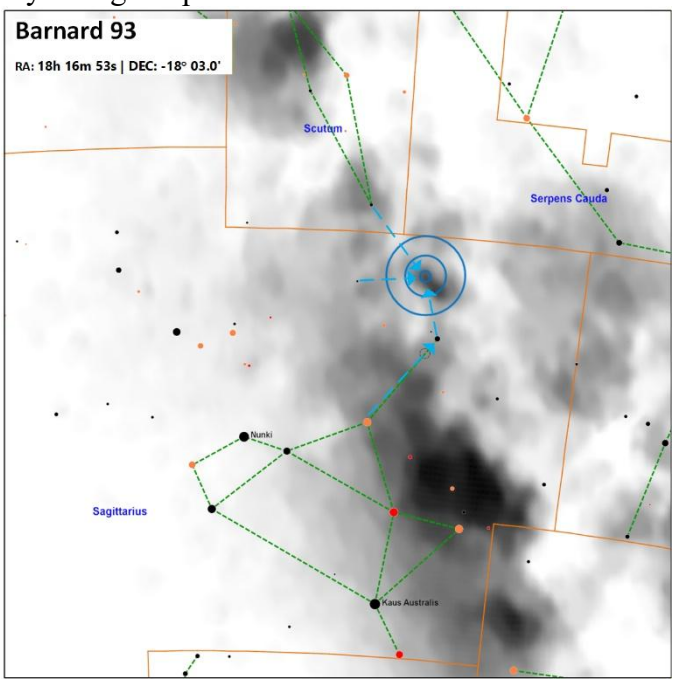


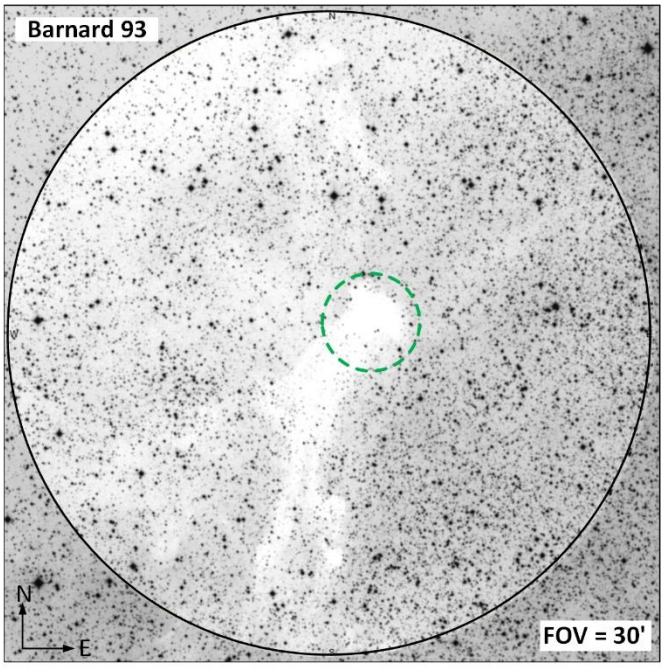
Barnard 92 (DN || | Size=12' | mBortle=4 | mApt=50mm | Opacity=6 |) Catalogued in 1913, B-92 was given the name Black Hole, which is a bit misleading given today's definition of a black hole. B-92 and B93 may be a good pair to view with 7x50 binoculars.



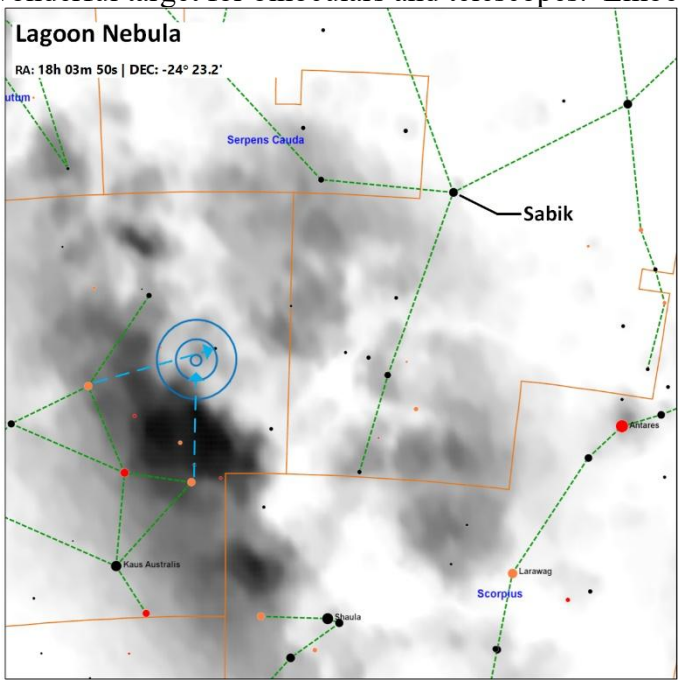


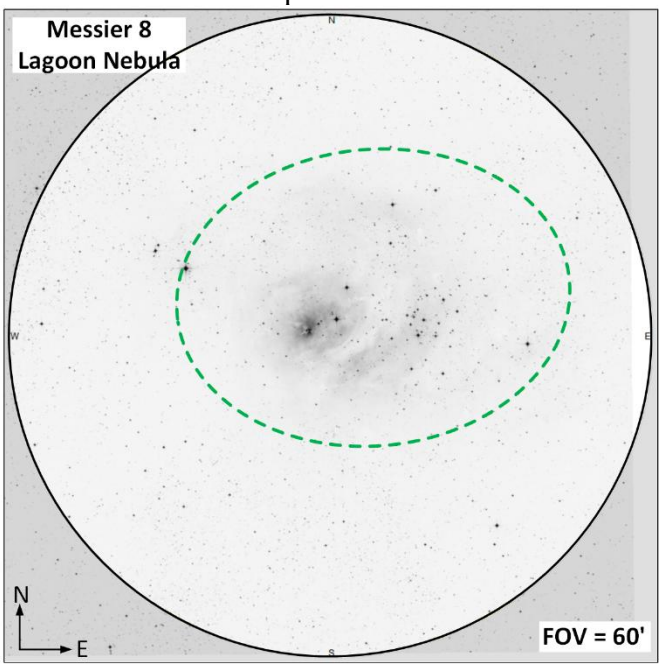
Barnard 93 (DN || | Size=2' | mBortle=4 | mApt=114mm | Opacity=4 |) Another dark nebula. B-92 and B93 may be a good pair of binoculars.



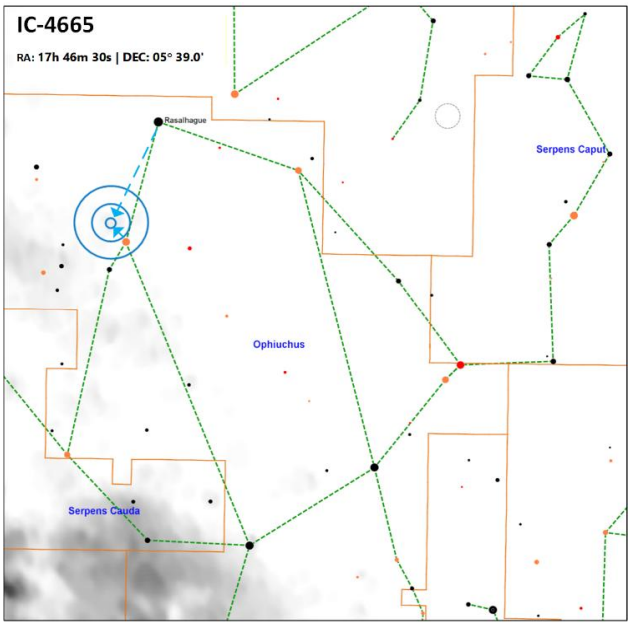


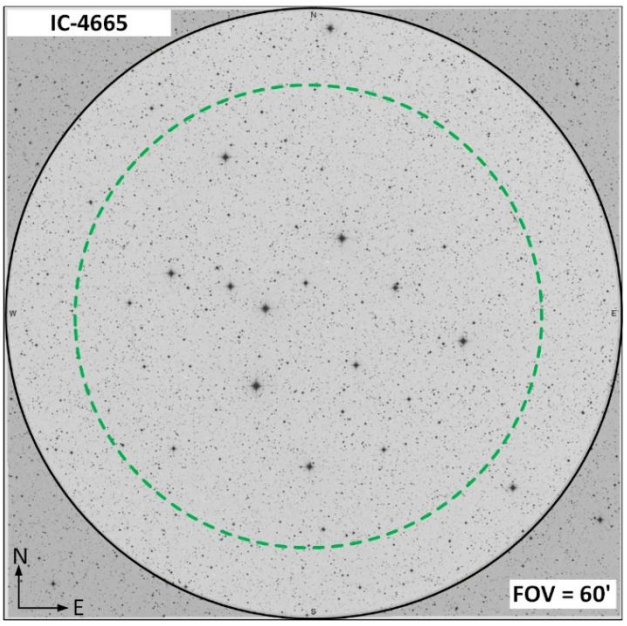
Messier 8 (EN, OC || Mag=5.8 | Size=90'x40' | SB=23.3 |) The Lagoon Nebula is a stellar nursery and wonderful target for binoculars and telescopes. Embedded in the nebula is the open cluster NGC-6530.



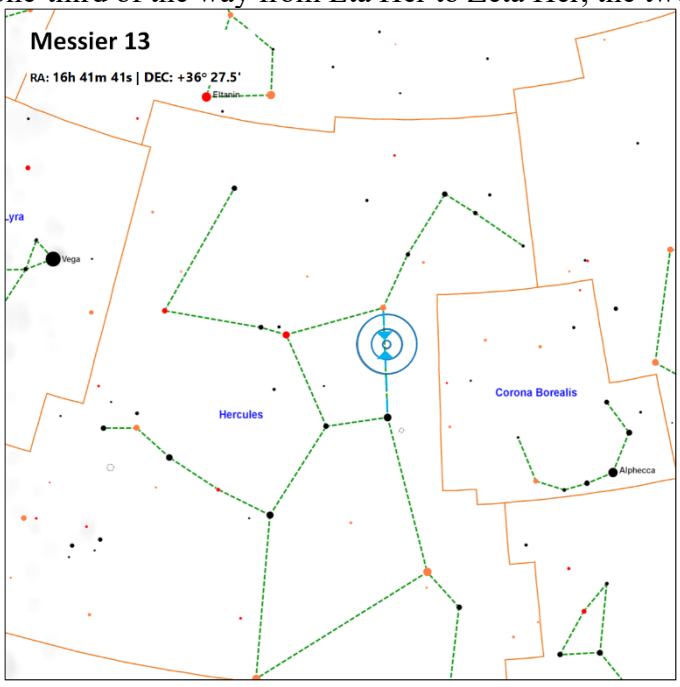


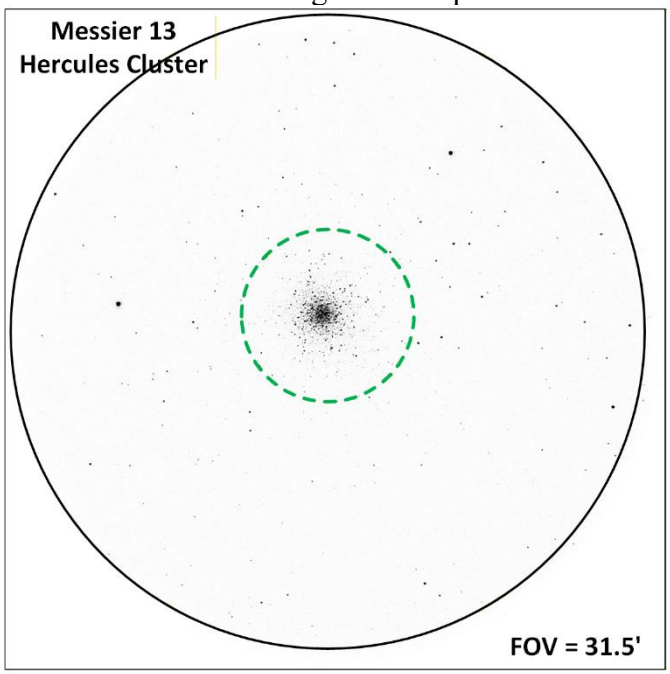
IC 4665 (OC || Mag=4.2 | Size=70' | mBortle=9 | mApt=50mm | MC=III2p |) One of the brighter open clusters that is not listed in the Messier or NGC catalogs. Views through binoculars show a clear cluster while close-up telescope views may have difficulty identifying this as an open cluster. Trumpler class III- Detached cluster with no noticeable concentration, 2- A medium range of brightness between the stars in the cluster, p- Poor clusters with fewer than 50 stars.



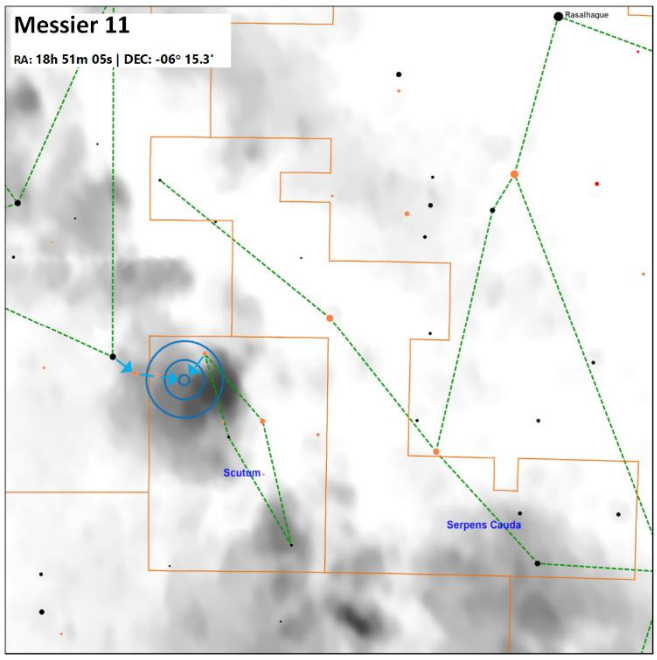


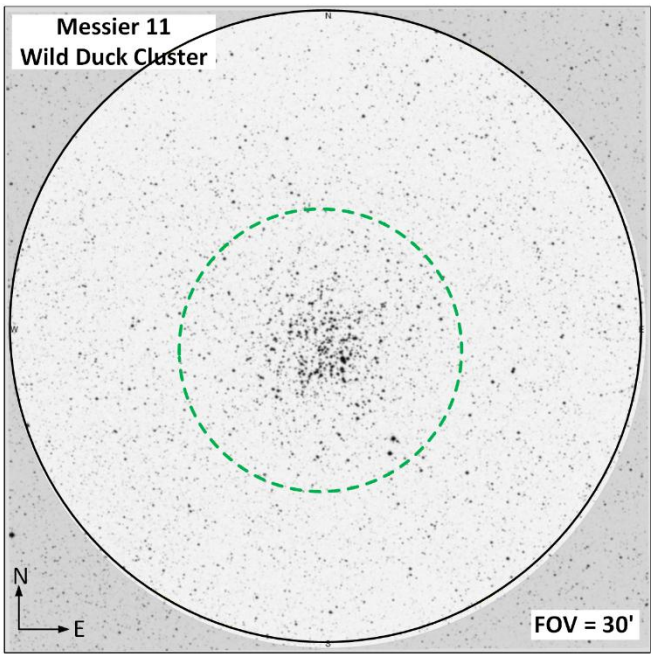
Messier 13 (GC | M = 5.8 | Size = 20' | SB = 21.7 |) – The Great Hercules Cluster is the best globular cluster in the northern hemisphere. This globular is a great target for binoculars and telescopes. It is located about one-third of the way from Eta Her to Zeta Her, the two stars that form the west edge of the square of Hercules.



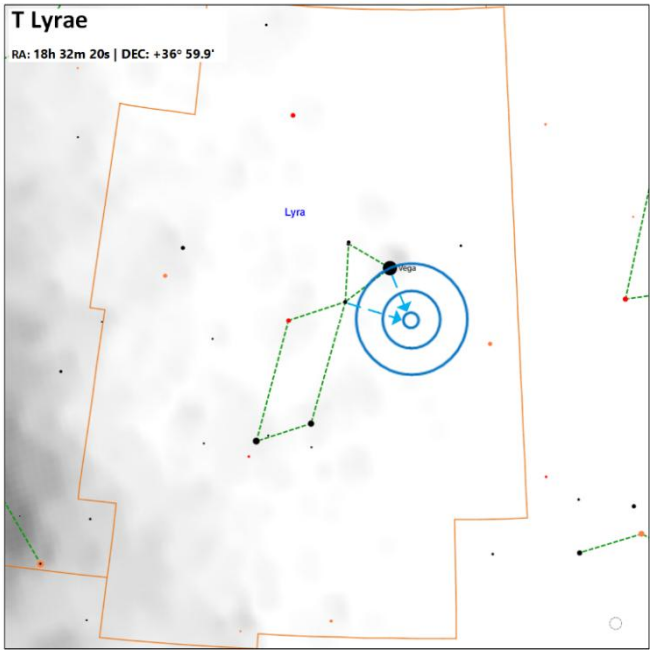


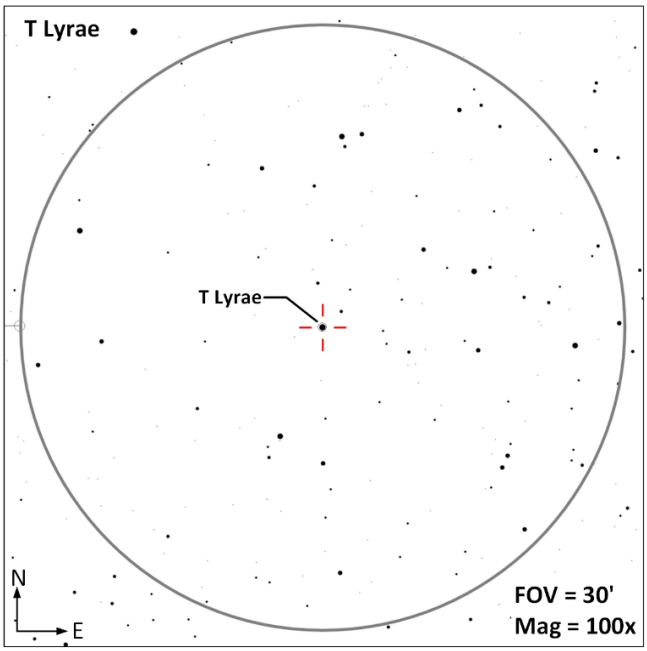
Messier 11 (OC || | Mag=6.3 | Size=14' | SB=20.5 | mBortle=9 | mApt=50mm | MC=II2r |) The Wild Duck Cluster gets its name from the brighter stars forming a triangle which could resemble a flying flock of ducks. M 11 is one of the most massive open clusters known and has an estimated age of 316 million years. The estimated mass of the cluster ranges from 3,700 to 11,000 solar masses. Trumpler class is II- Detached cluster with little central concentration, 2- Medium range of brightness between stars in the cluster, r-Rich cluster with over 100 stars.



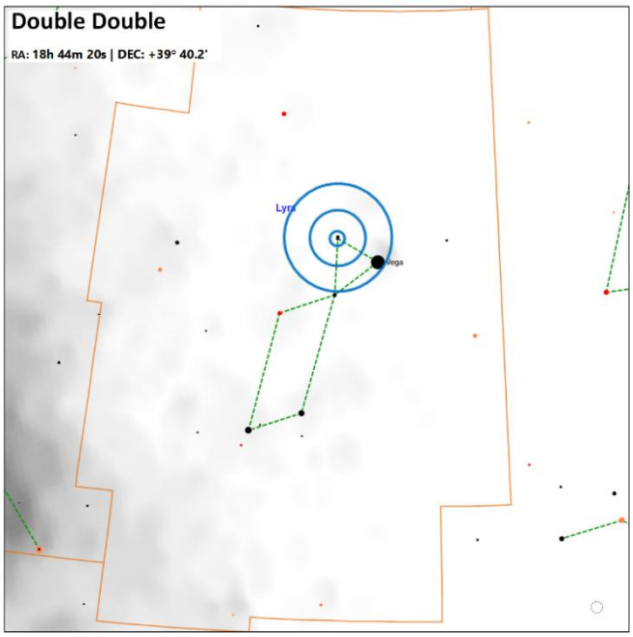


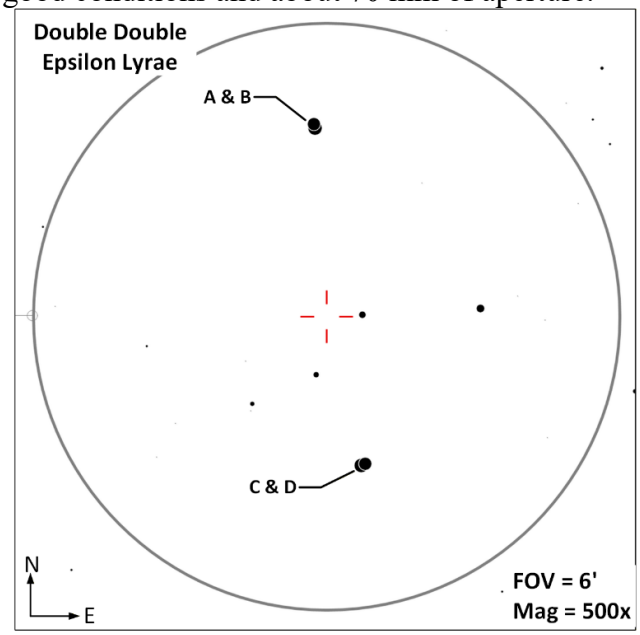
T Lyrae (CS || Magnitude Range= 7.5 to 9.3 | Spec=C8 (C-N) | BV=+5.46 | Color=deep red |) T Lyrae is located 2,346 light-years away, and its BV color index indicates this should be an intensely red star. This is a slow irregular variable with no well-defined period.



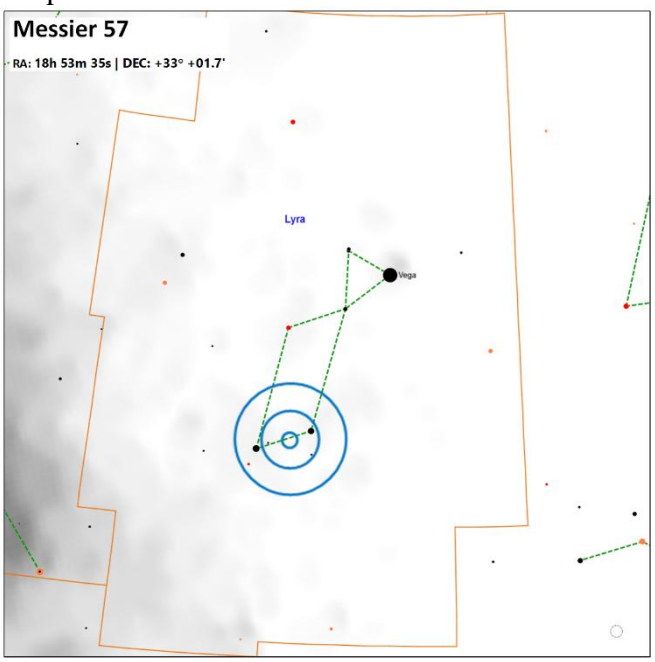


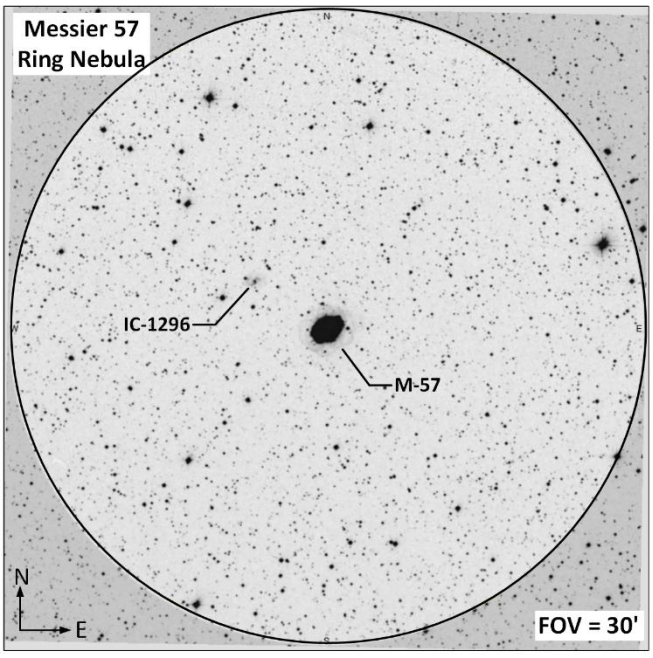
Double Double (MS-4 || **AB, CD** | Mag=4.7,4.6 | Sep=207.9" | PA=171° | mBortle=9 | mApt=50mm | Period=>400,000y | Spec=A3V, A6Vn | Color=white, white || **AB** | Mag=5.15,6.1 | Sep=2.2" | PA=343.5° | mBortle=9 | mApt=70mm | Period=1725y | Spec=A4V, F1V | Color=white, yellow-white || **CD** | Mag=5.2,5.4 | Sep=2.4" | PA=72.9° | mBortle=9 | mApt=70mm | Period=724y | Spec=A8Vn, F0Vn | Color=white, yellow-white |) Epsilon Lyrae is one of the most celebrated quadruple star systems in the northern hemisphere. It is located 162 light-years away. The AB & CD pairs (ε1 and ε2) can be easily separated with binoculars, while splitting each pair into its individual components requires good conditions and about 70 mm of aperture.



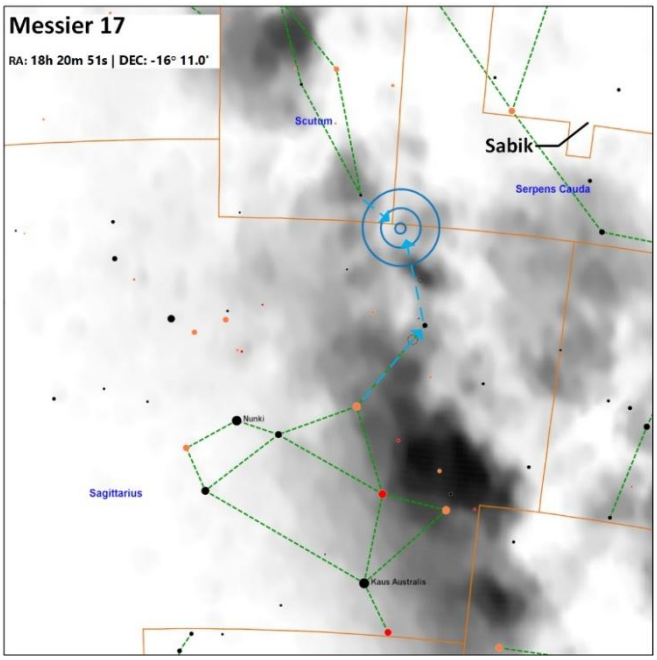


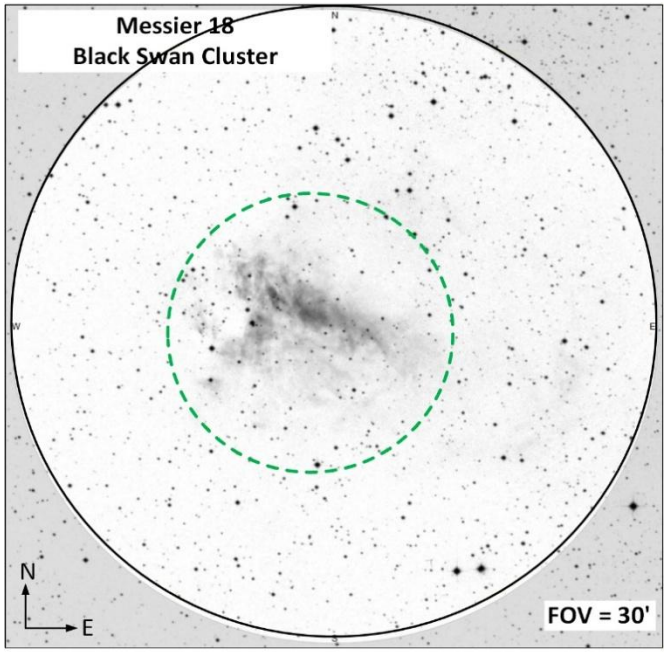
Messier 57 (PN | Mag=8.8 | Size=1.4'x1.0' | SB=17.8 | mBortle=9 | mApt=50mm | MC=Elliptical (ring) |) The Ring Nebula is one of the finer planetary nebulae in the northern hemisphere. It is fairly easy to locate and is best viewed with a telescope of 8" aperture to support higher magnifications. It is estimated the central star responsible for the ring structure shed its outer layers about 7,000 years ago. An aperture of at least 12" would be required to see the central star under ideal conditions.



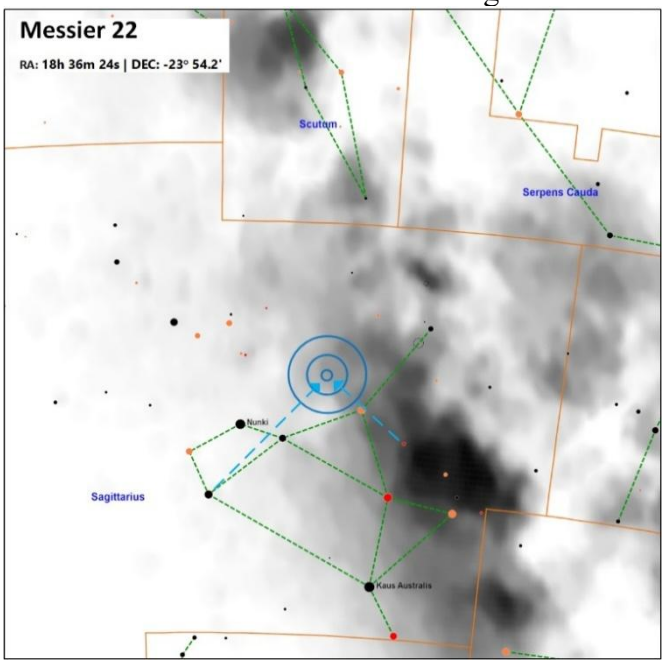


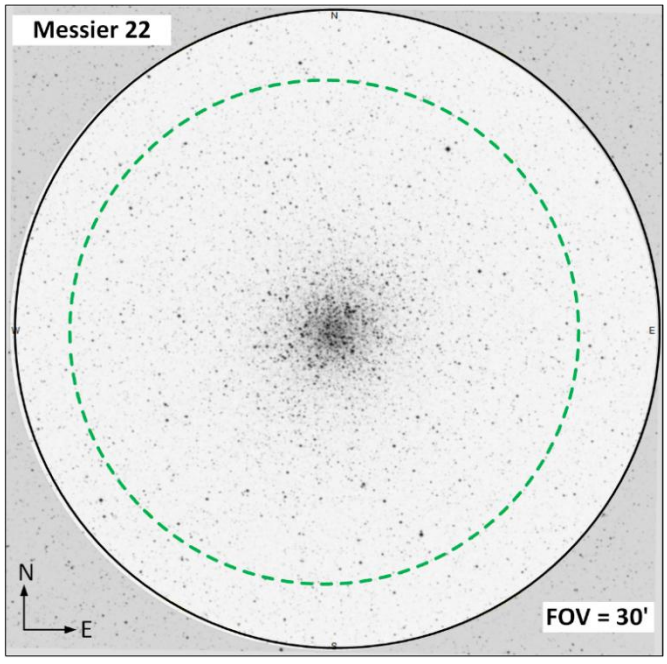
Messier 17 (OC, EN || Mag=6 | Size=11' | SB=19.8 | mBortle=9 | mApt=50mm | MC=III3m n |) The Omega Nebula is an H II region located 5,500 light-years away with a diameter of 40 light-years and an estimated mass of 30,000 solar masses. This is considered one of the brightest and most massive star-forming regions of our galaxy and has a similar geometry to the Orion Nebula except that it is viewed edge-on rather than face-on.



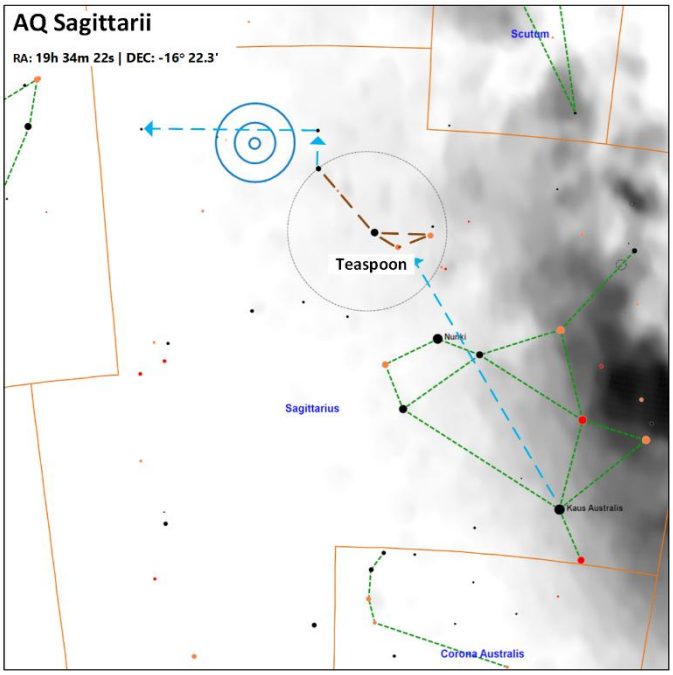


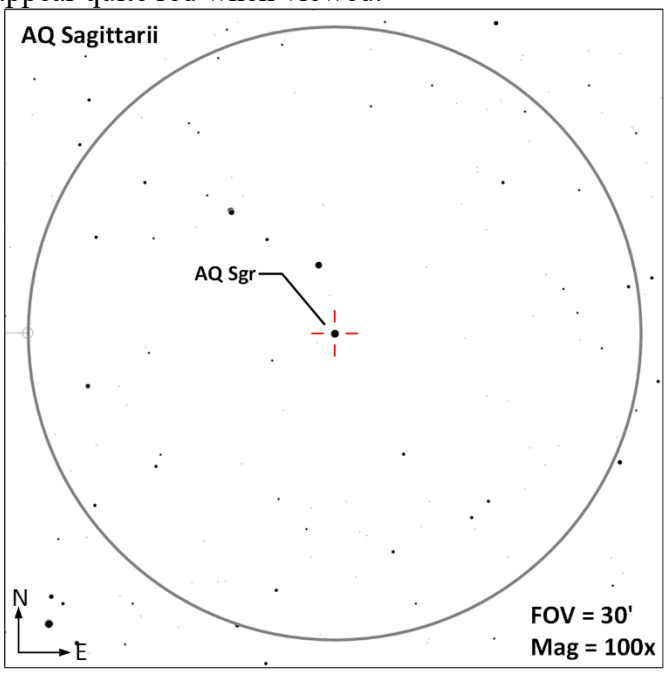
Messier 22 (GC || Mag=5.1 | Size=32' | SB=21.3 | mBortle=9 | mApt=50mm | MC=VII |) The Great Sagittarius Cluster is an elliptical globular cluster near the Galactic Bulge region and is one of the brightest globulars visible in the night sky. M-22 is one of the nearer globular clusters to Earth at 10,600 light-years away and is one of only four globulars of our galaxy known to contain a planetary nebula. An 8" telescope should resolve hundreds of stars in the globular.



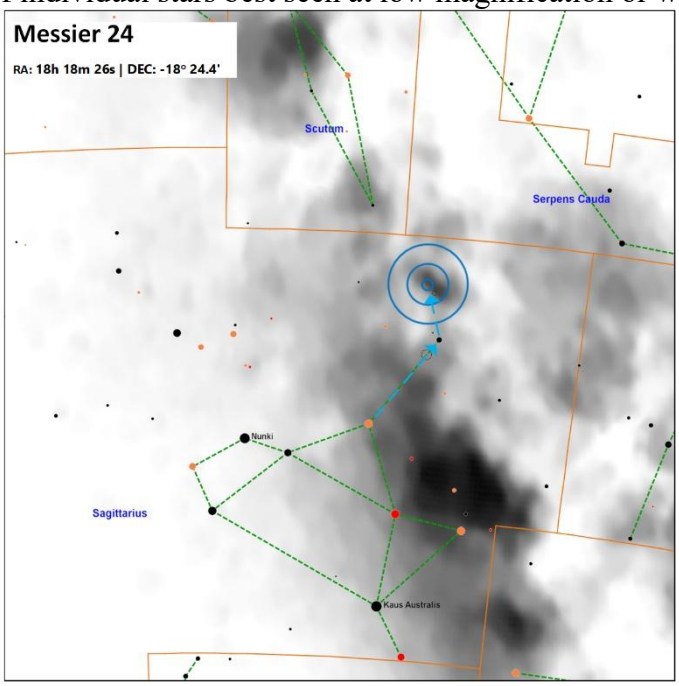


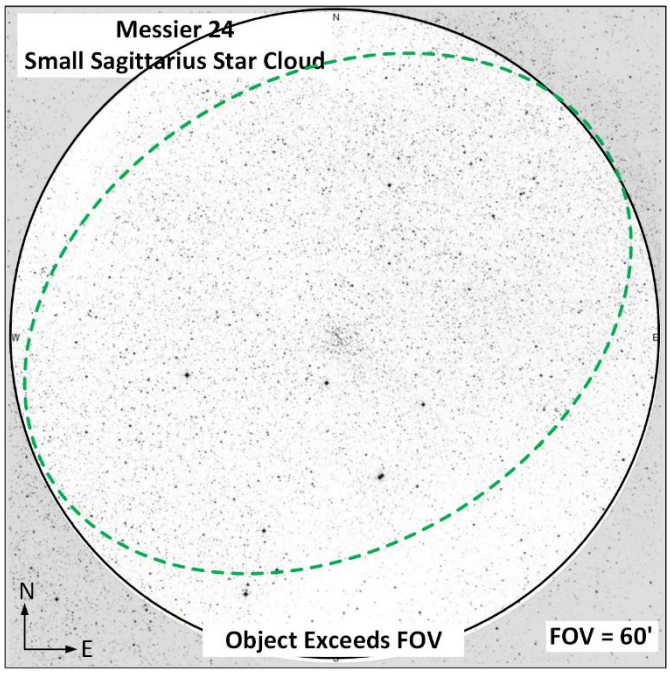
AQ Sagittarii (CS || | Magnitude Range= 6.6 to 8.5 | Period=0.55y | Spec=C7 (N3) | BV=+3.50 | Color=deep red |) Located 1,087 light-years away, this variable star has a magnitude range of 6.6 to 8.5 over a period of 200 days. A B-V color index of +3.5 indicates it should appear quite red when viewed.



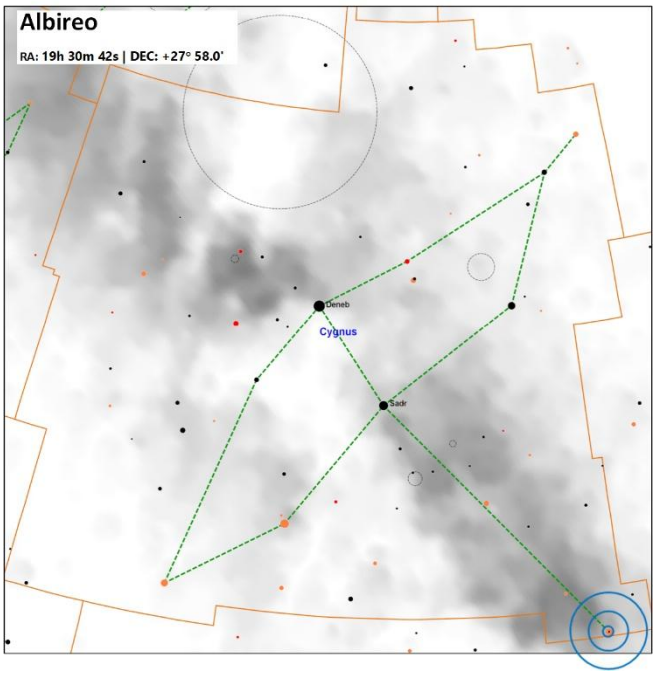


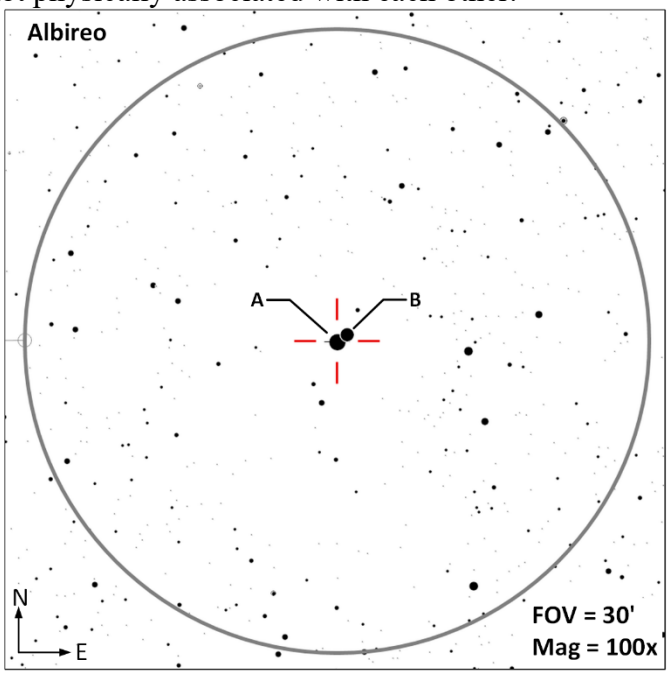
Messier 24 (OC || Mag=4.5 | Size=80'x35' | SB=21.7 | mBortle=9 | mApt=50mm | MC=I1r |) The Small Sagittarius Star Cloud is a star cloud about 600 light-years wide. M-24 is not a distinct open cluster, but a gap in the Great Rift where one can see into deeper regions of the Milky Way galaxy and is a dense concentration of individual stars best seen at low magnification or with binoculars.



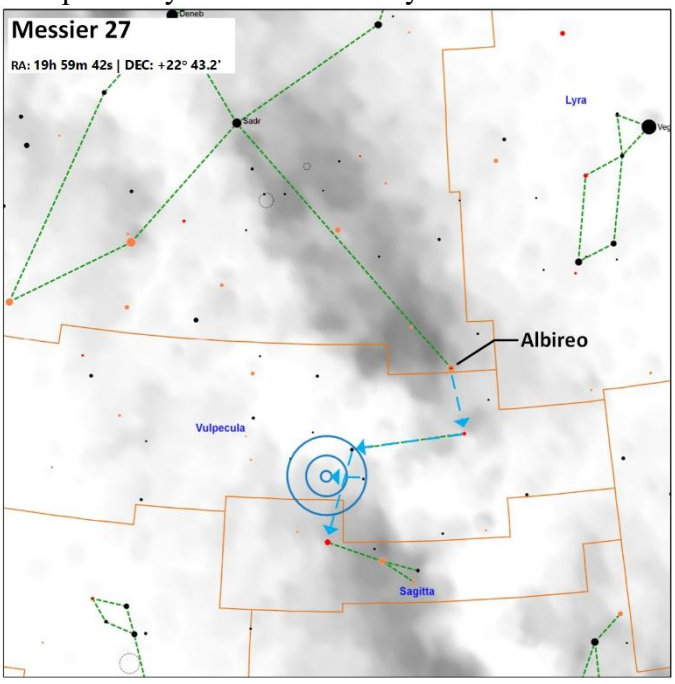


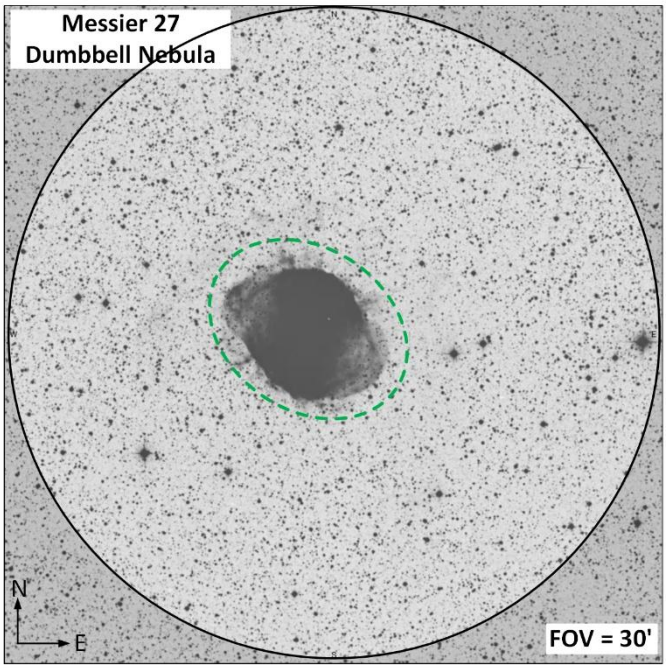
Albireo (DS || **AB** | Mag=3.1,5.1 | Sep=34.4" | PA=54° | mBortle=9 | mApt=50mm | Spec=K3II, B9.5V | Color=yellow-orange, blue-white |) Perhaps the most celebrated double star in the northern sky. A beautiful gold and blue pair of stars easily located and viewed. A delight for binoculars and telescopes. This is probably an optical star system, meaning these stars are not physically associated with each other.



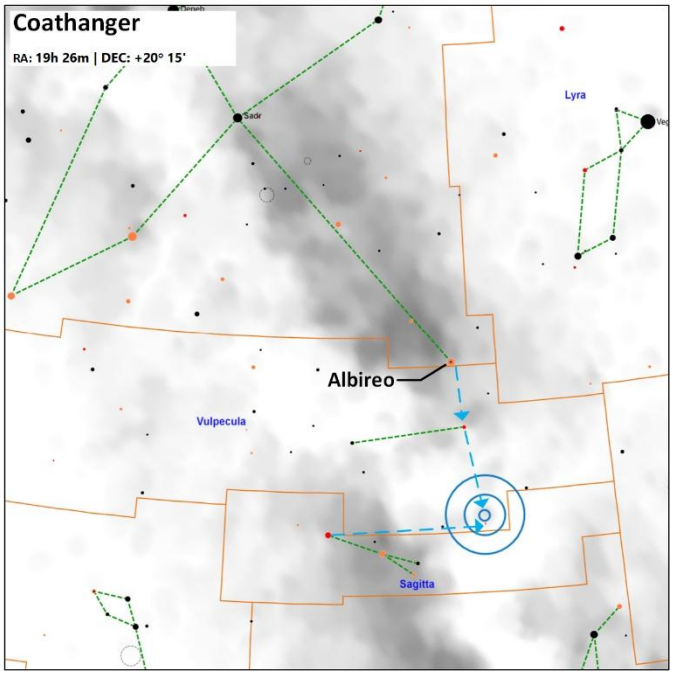


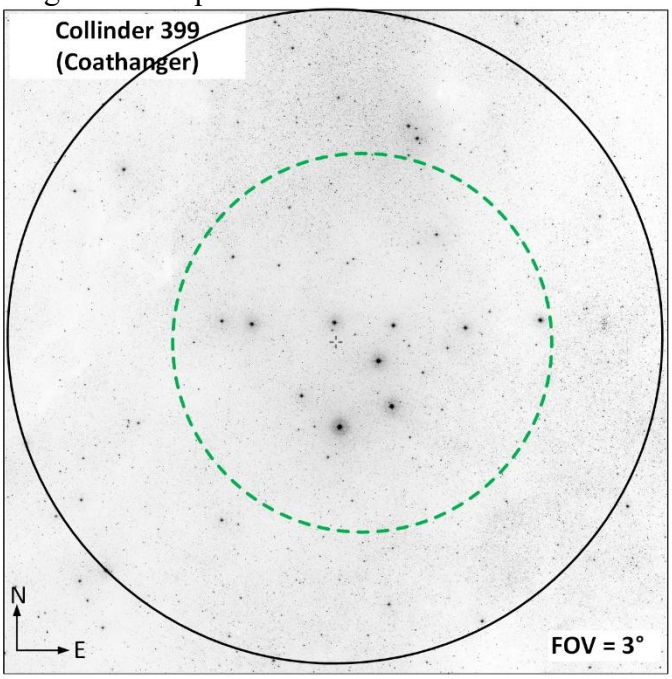
Messier 27 (PN || | Mag=7.4 | Size=8'x6' | SB=20.2 | mApt=200mm |) The Dumbbell Nebula is one of the finest planetary nebulae in the sky and is estimated to be about 1,300 light-years away.





Collinder 399 (AS, OC || Mag=4.0 | Size=60' | SB=21.5 | mBortle=9 | mApt=50mm | MC=III3m |) The Coathanger has been historically classified as an open cluster but recent studies indicate that these stars are not part of an open cluster and so this group of 10 stars forming the outline of a coat hanger is just an asterism. An excellent target for binoculars and wide-field views through a telescope.

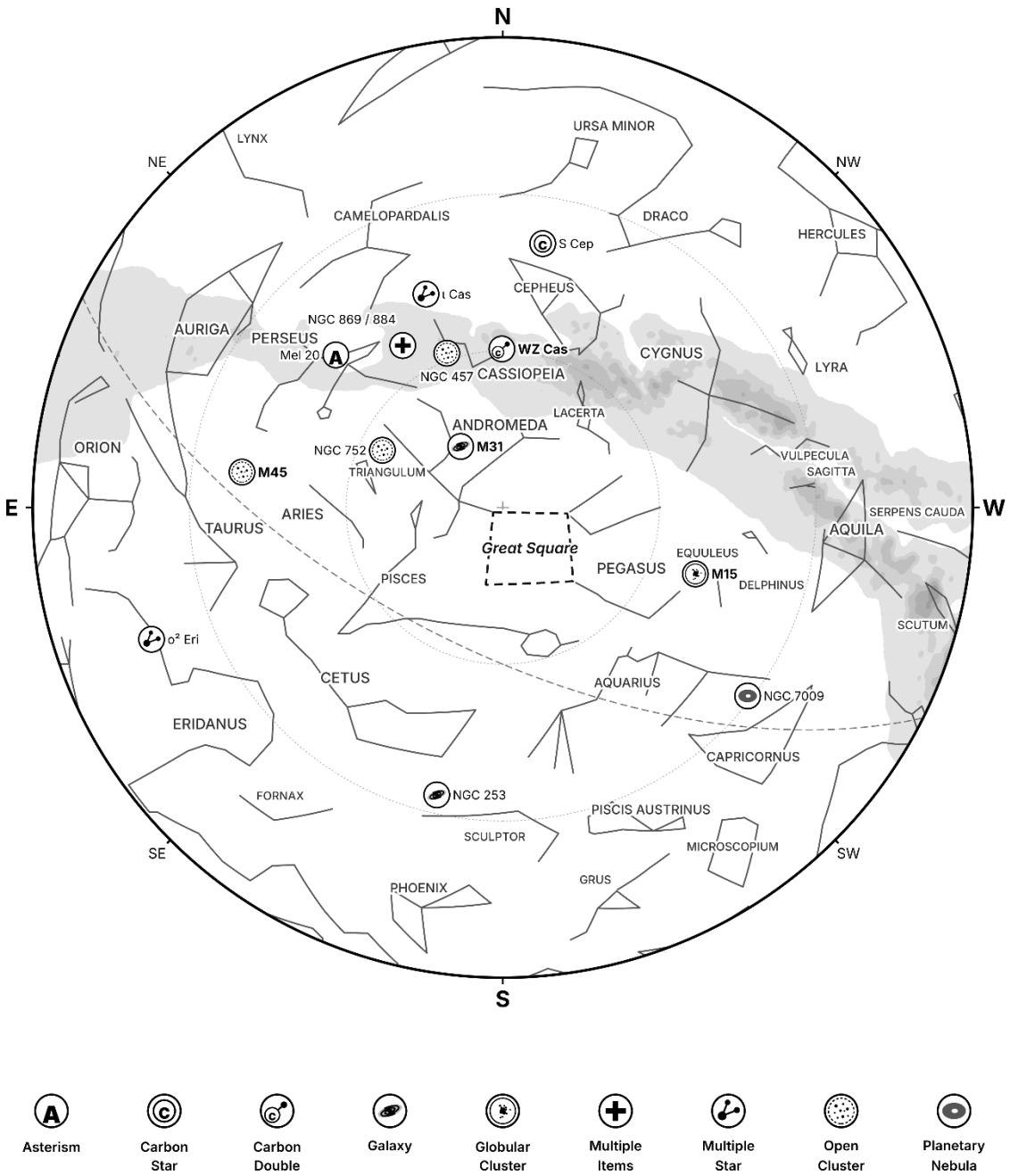




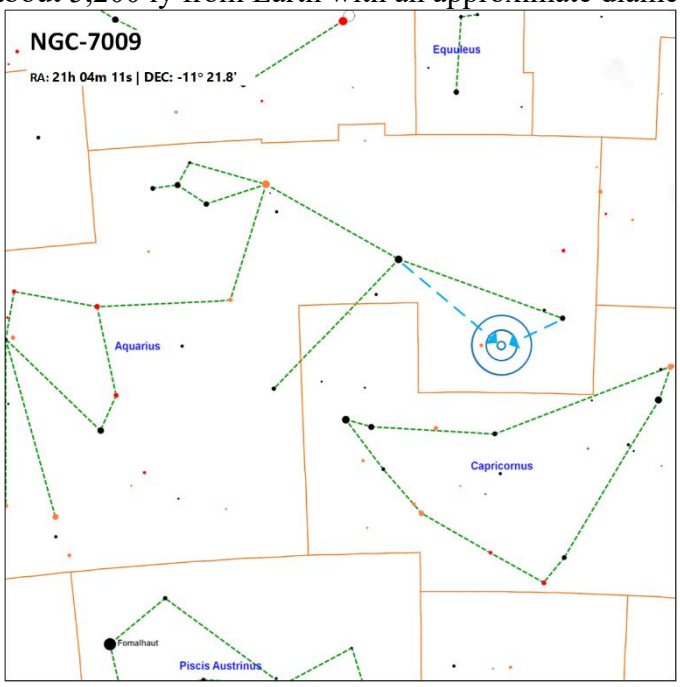
Beginner's Guide to Small Telescopes

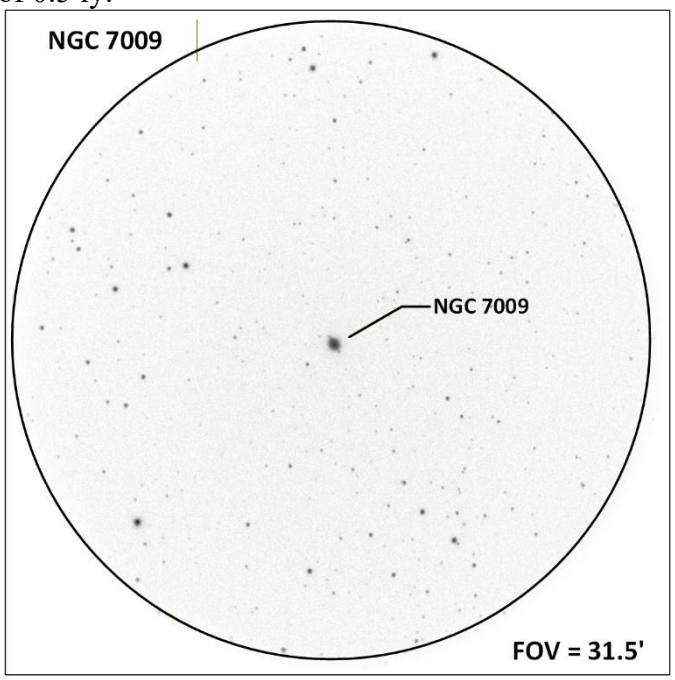
Fall (September – November)

Const	Target (Type)	Size / Sep	Comments
Aqr	NGC-7009 (PN)	41x35”	Saturn Nebula. The PN does have a shape similar to Saturn.
Cep	S Cep (CS)		Carbon star dark orange to red in color.
Peg	*M-15 (GC)	18’	One of the brightest globular clusters in the Northern Hemisphere.
And	NGC-752 (OC)	75’	A large open cluster of some 70 stars covering more than 1 degree of sky. Impressive at low power.
And	*M-31 (G)	3x2°	Andromeda Galaxy: Best galaxy in the Northern Hemisphere
Scl	NGC 253 (G)	27x7’	Silver Coin Galaxy. A nice galaxy with a GC nearby.
Cas	NGC-457 AS)	13’	Owl Cluster – Easily located; Owl with spread wings
Cas	Iota Cas (MS)	7.3”, 2.3”	Triple Star System | Mag 4.6, 6.9, 9.0 | An excellent triple star system
Cas	*WZ Cas (DS)	57”	Red (Carbon Star) and blue pair in field of stars. Beautiful!
Tau	*M-45 (OC)	2°	The Pleiades: Famous large open cluster best seen with binoculars.
Per	NGC 869 & 884 (OC)	30’	Perseus Double Cluster: Excellent binocular target
Per	Melotte 20 (AS)	5°	The Alpha Persei Association. Easily located and a nice binocular target.
Eri	Keid (DS)	83”, 8”	Keid | Triple Star System | Mag 4.4, 9.5, 11.2

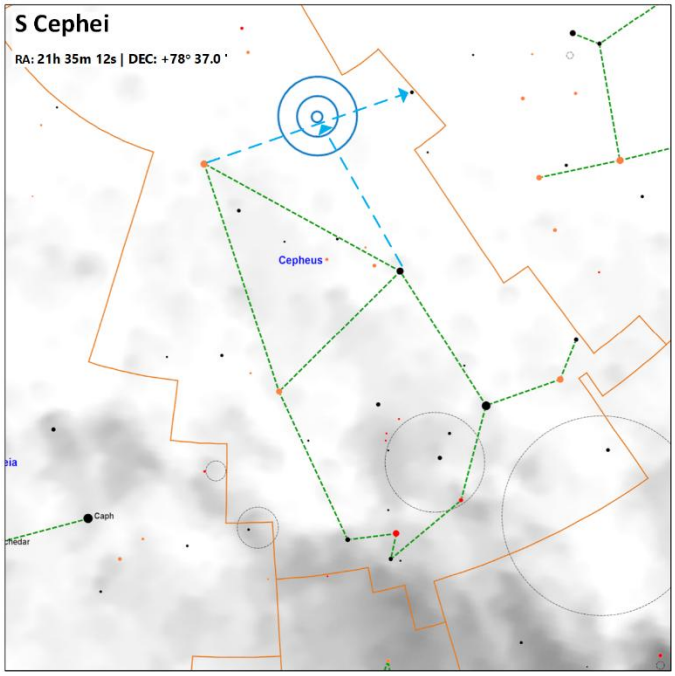

The Autumn Sky
Northern hemisphere · latitude 30° N
N
NE
NW
E
W
SE
SW
S
LYNX
URSA MINOR
CAMELOPARDALIS
DRACO
HERCULES
S Cep
CEPHEUS
ι Cas
NGC 869 / 884
AURIGA
PERSEUS
Mel 20
WZ Cas
NGC 457
CASSIOPEIA
CYGNUS
LYRA
LACERTA
ANDROMEDA
M31
NGC 752
TRIANGULUM
ORION
M45
VULPECULA
SAGITTA
SERPENS CAUDA
ARIES
TAURUS
Great Square
AQUILA
EQUULEUS
PEGASUS
M15
DELPHINUS
PISCES
SCUTUM
o² Eri
CETUS
AQUARIUS
NGC 7009
ERIDANUS
CAPRICORNUS
FORNAX
NGC 253
PISCIS AUSTRINUS
SCULPTOR
MICROSCOPIUM
GRUS
PHOENIX
Asterism
Carbon Star
Carbon Double
Galaxy
Globular Cluster
Multiple Items
Multiple Star
Open Cluster
Planetary Nebula
Bold labels mark exceptional targets. Hold the chart overhead with the direction you face at the bottom.
Bold dashed lines: seasonal asterism. Fine gray dashes: ecliptic. Dotted circles: 30° and 60° altitude.

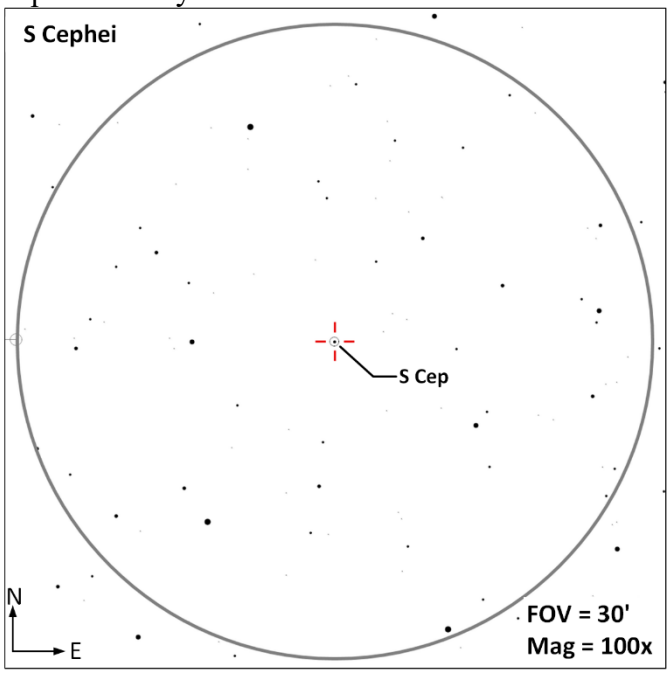
NGC 7009 (PN | M = 8.0 | Size = 0.5’ | SB = 15.1 |) – The Saturn Nebula (also called Caldwell 55) is a planetary nebula that has a shape similar to Saturn when viewed at high magnification. It is estimated to be about 5,200 ly from Earth with an approximate diameter of 0.5 ly.



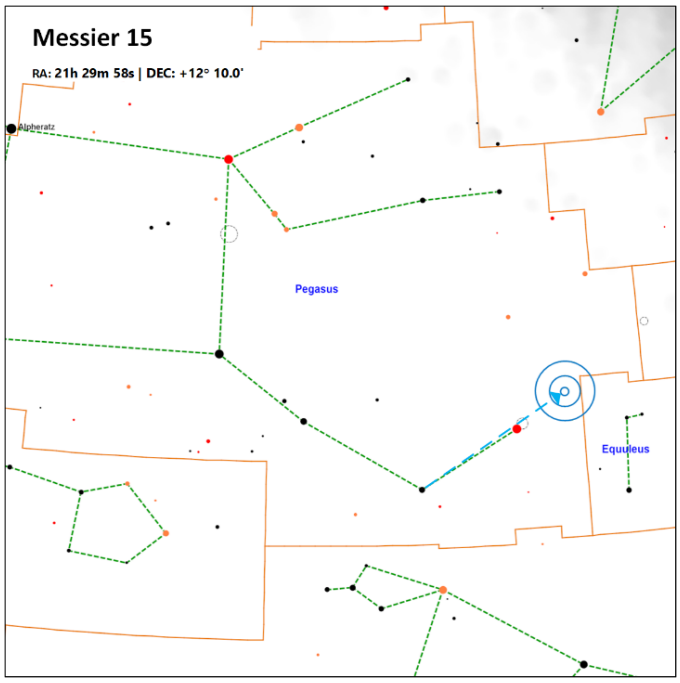


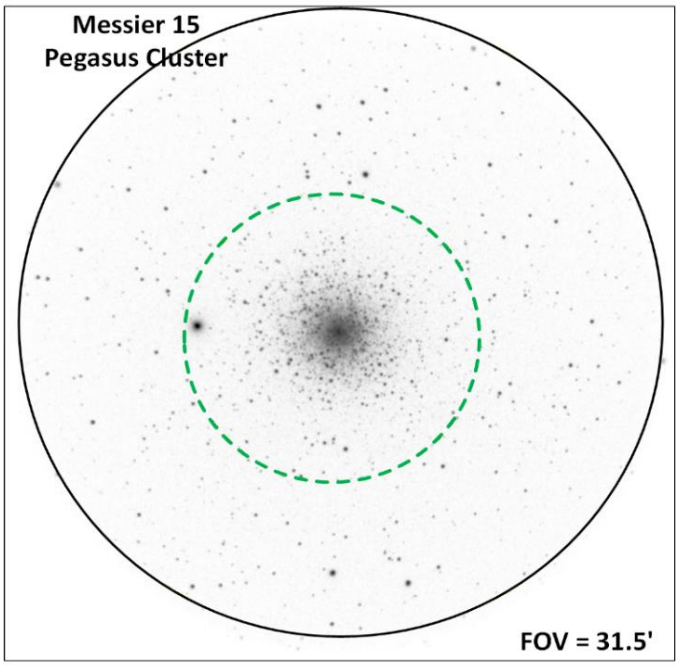
S Cephei (CS || Magnitude Range= 7.4 to 12.9 | Period=1.33y | Spec=C7,4e | BV=+4.45 | Color=deep red |) This carbon star is a Mira-type variable located about 1,590 light-years away and varies greatly in magnitude over a period of 484 days. With a BV index of +4.45, this should appear to be a very red star; however, its color may not be as apparent when the star is in the dimmer part of its cycle.



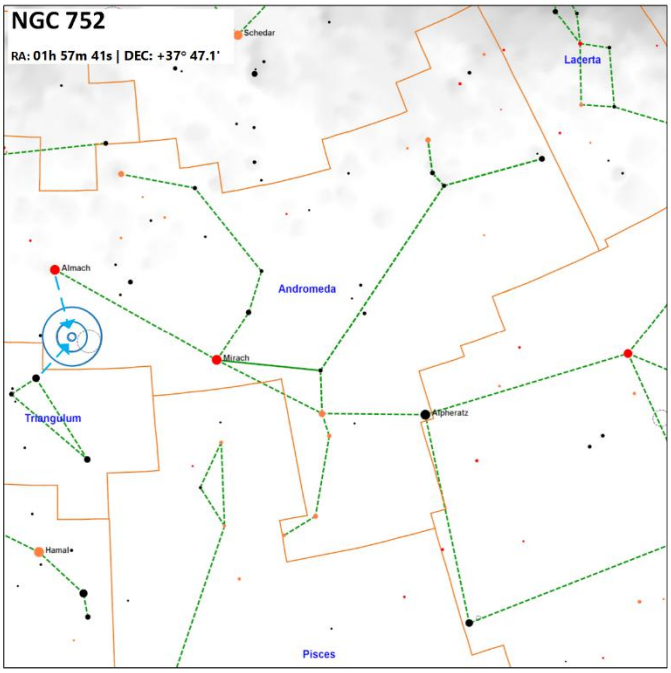


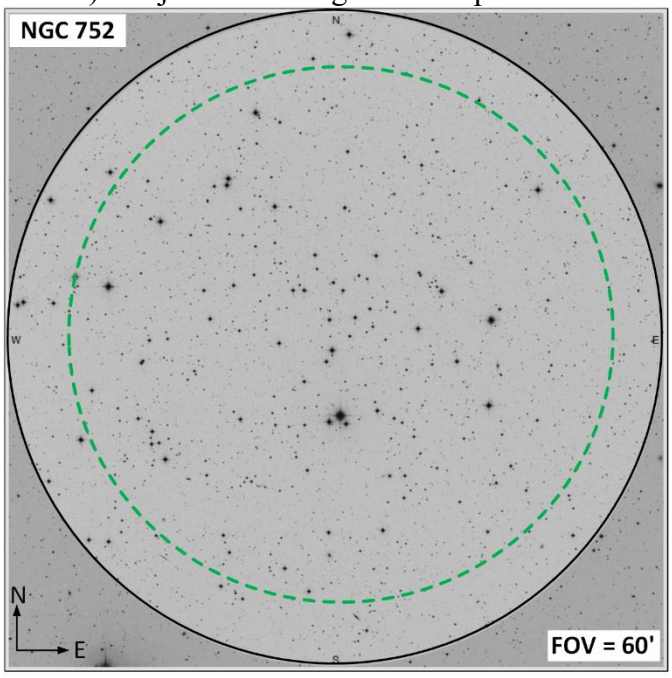
Messier 15 (GC, | M = 6.2 | Size = 18' | SB = 21.6 |) – This bright globular cluster is located about 4° northwest of Enif. It should be fairly easy to star hop to by extending an imaginary line between Biham and Enif that points directly to this object. M 15 is approximately 33,600 ly from our Sun, has a diameter of about 175 ly and contains about 360,000 stars. It is estimated to be 13.2 billion years old making it one of the oldest known globular clusters in our galaxy. Note the dim planetary nebula Pease 1 (see below) located in this Globular Cluster.



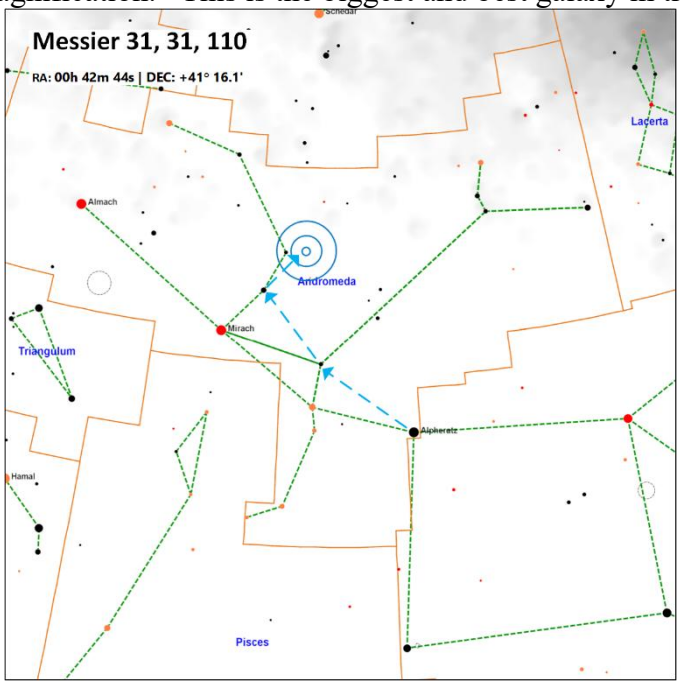


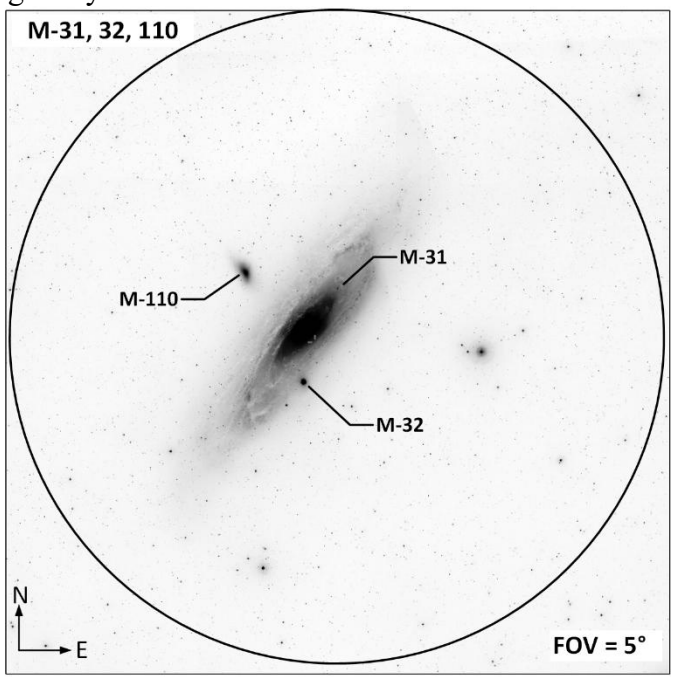
NGC 752 (OC | M = 5.7 | Size = 50' | SB = 22.8 |) – A large collection of 60 to 70 stars over a 50' area. This is an excellent target for binoculars. The star 56 And (see below) lies just on the edge of this open cluster.

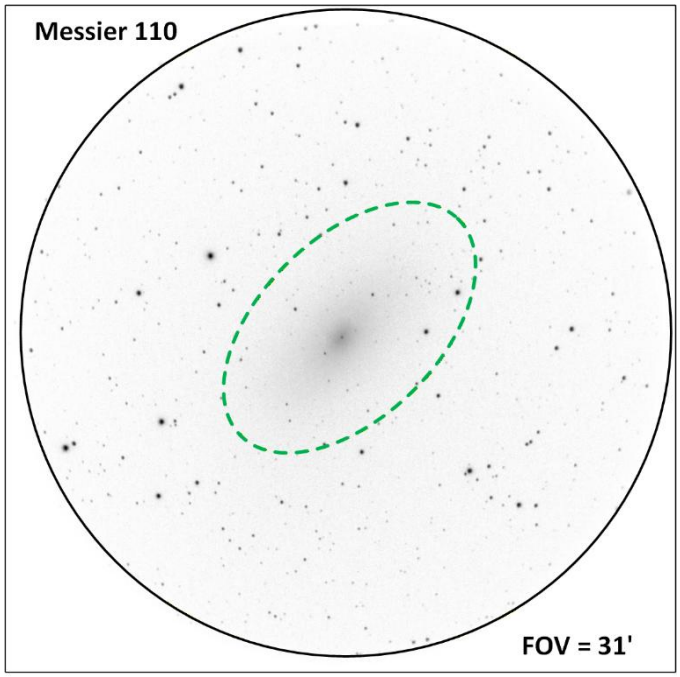


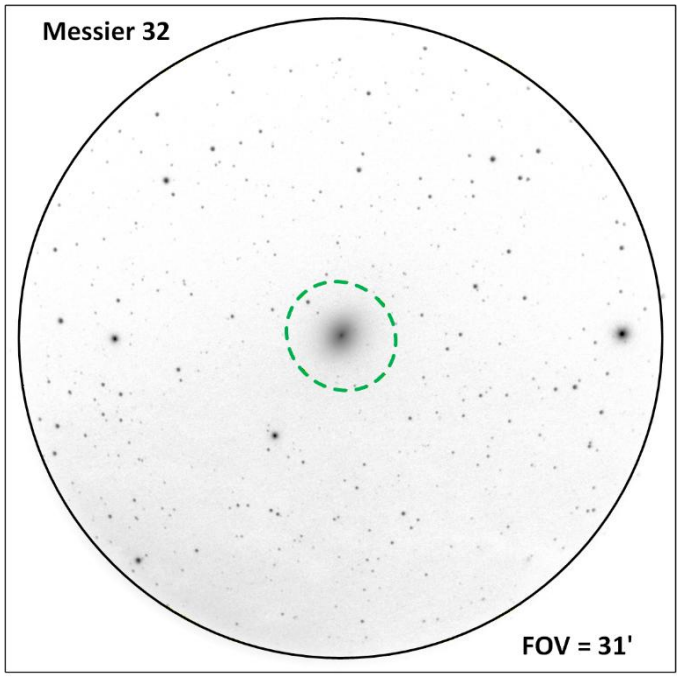


Messier 31, 32, 110 (Galaxies | M-31 | M=4.3 | Size =189.1x61.7' | SB = 23.1 |) – The Andromeda Galaxy is the nearest spiral galaxy to our own. It is located 2.54 million ly from our Sun. Two companion galaxies, M-32 and M-110, can also be identified. These objects are best observed in binoculars or a small telescope with low magnification. This is the biggest and best galaxy in the night sky.

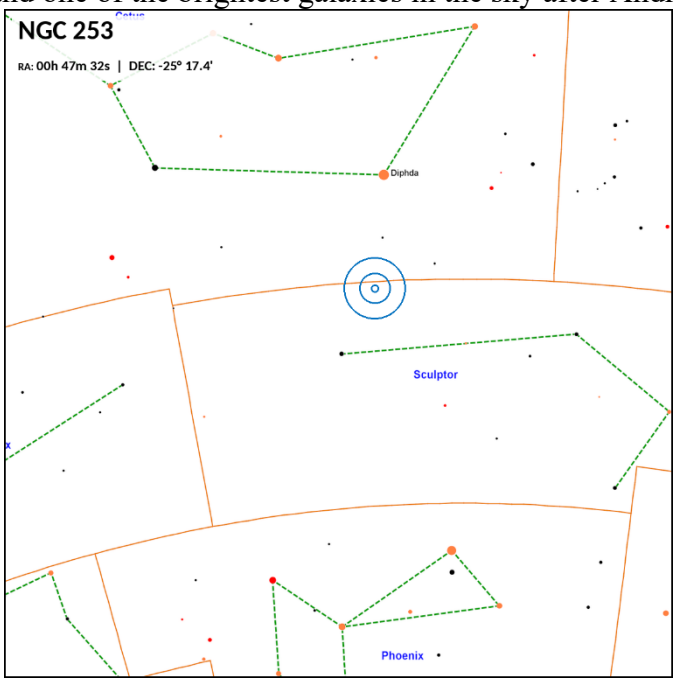


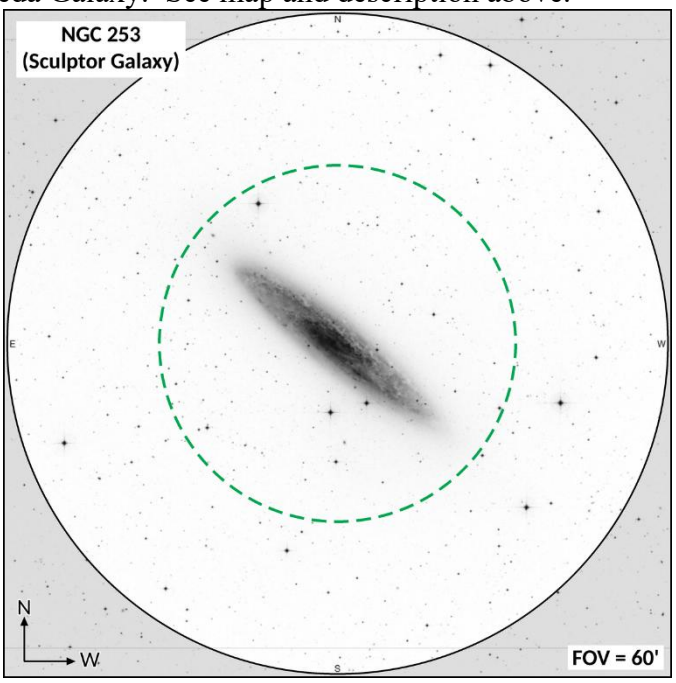




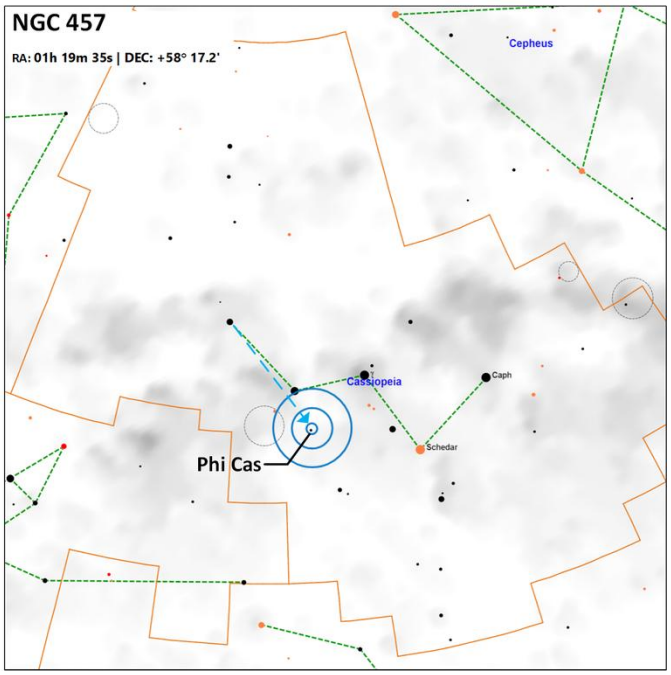


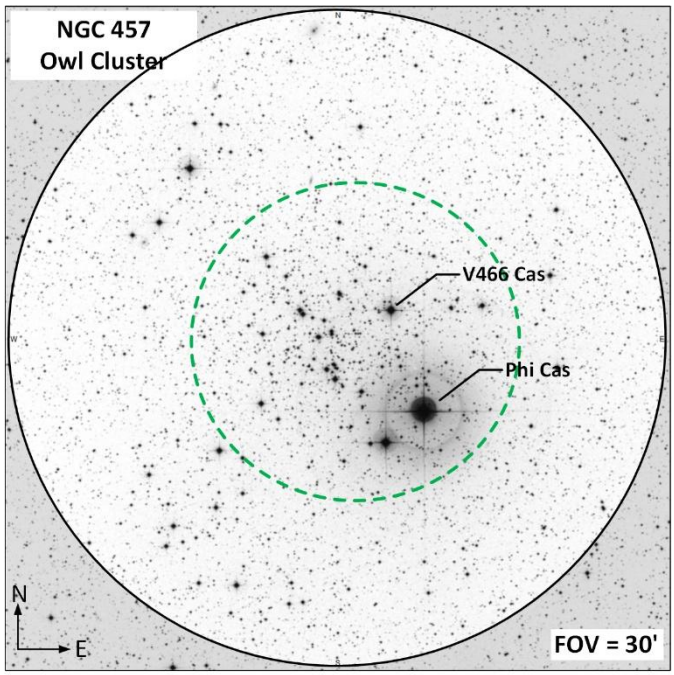
NGC 253 (G || Mag=7.1 | Size=25'x7' | SB=21.3 | mBortle=8 | mApt=50mm | MC=SAB(s)c |) The Sculptor Galaxy is an intermediate spiral galaxy and a starburst galaxy, (undergoing a period of intense star formation) and one of the brightest galaxies in the sky after Andromeda Galaxy. See map and description above.



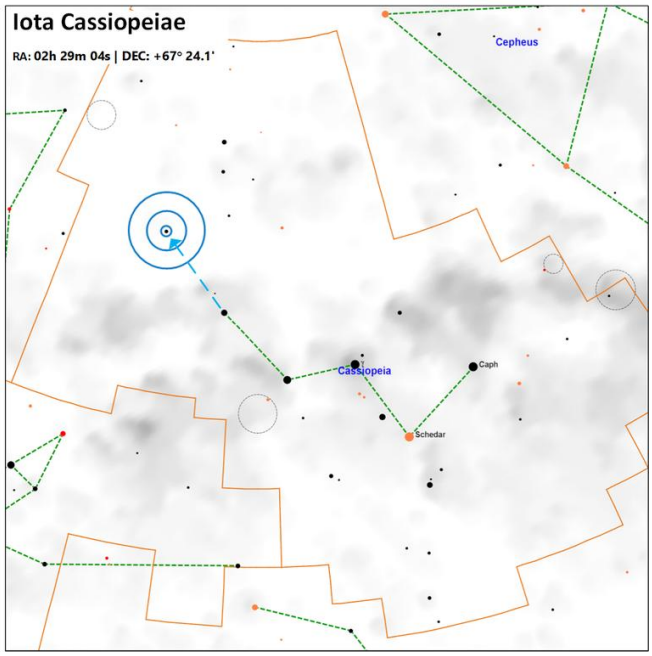


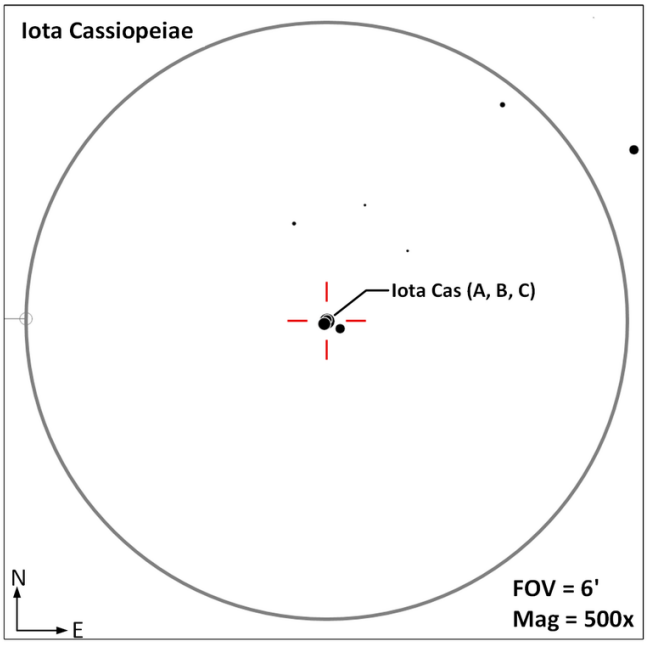
NGC 457 (OC || Mag=6.4 | Size=13' | SB=20.6 | mBortle=9 | mApt=60mm | MC=II3r |) NGC 457 lies about 7,900 light-years away and is roughly 21 million years old; around 60 stars are considered true members. After Phi Cas, the next brightest star in the field is the red supergiant variable V466 Cas, which is treated as a cluster member. This is a favorite open cluster for many astronomers.



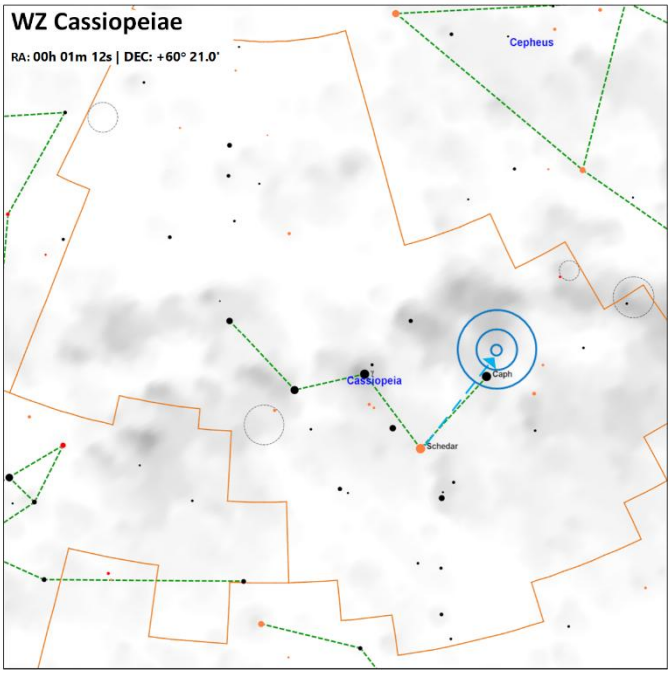


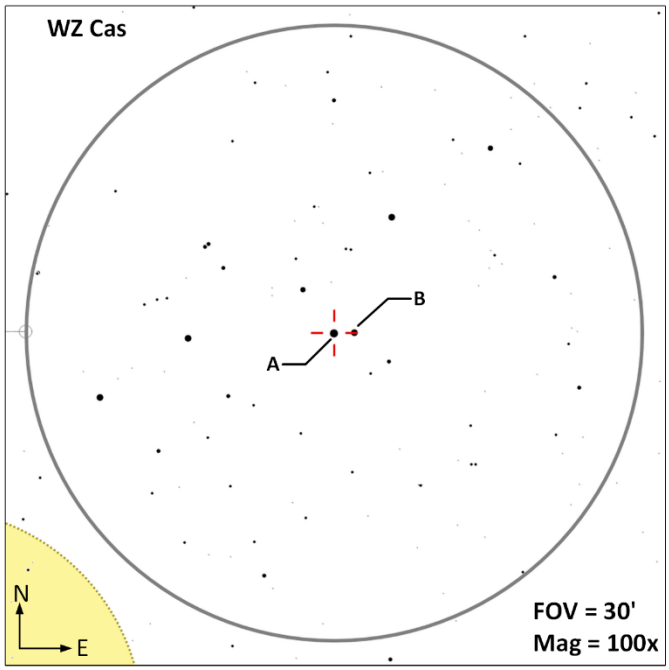
iota Cas (MS-3 || AB | Mag=4.7,6.9 | Sep=3" | PA=231° | mBortle=9 | mApt=60mm | Spec=A5p, F5V | Color=white, yellow-white || BC | Mag=6.9,9.1 | Sep=8.5" | PA=99° | mBortle=9 | mApt=50mm | Spec=F5V, G5 | Color=yellow-white, yellow || AC | Mag=4.7,9.1 | Sep=6.9" | PA=117° | mBortle=9 | mApt=50mm | Spec=A5p, G5 | Color=white, yellow |) A celebrated triple star system consisting of a brilliant white primary star with yellow and blue companions.



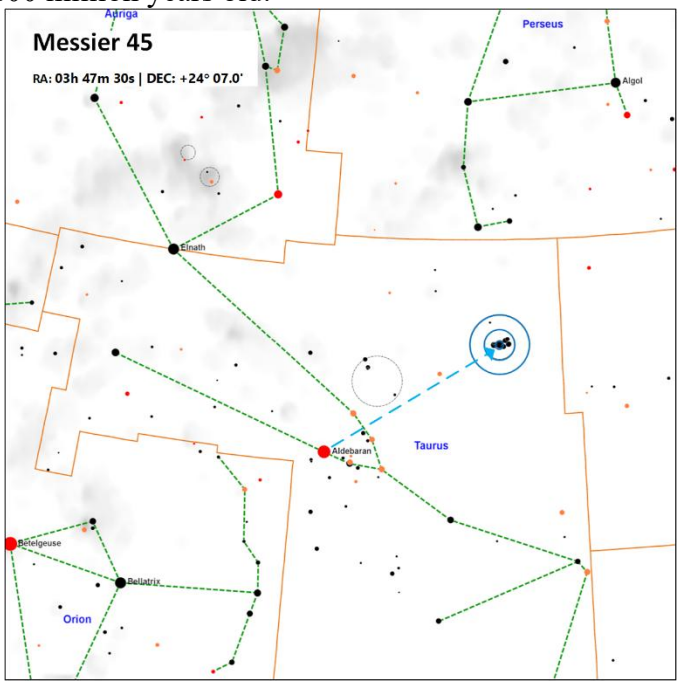


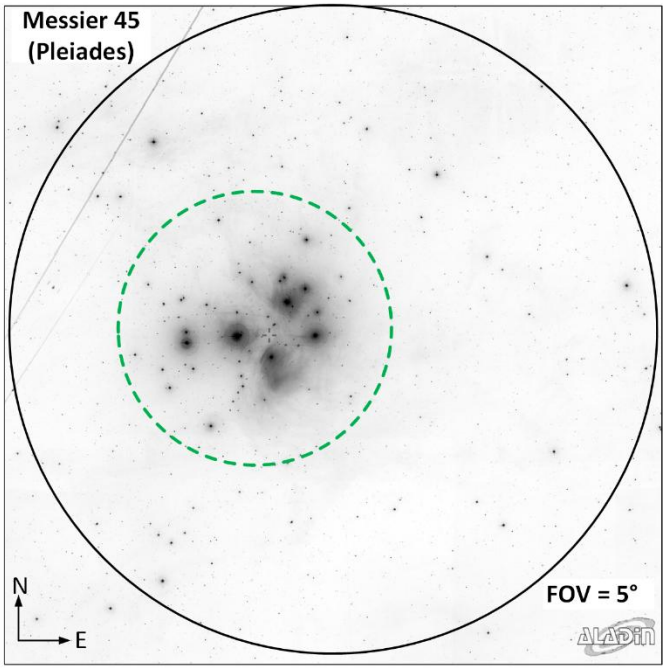
WZ Cas (DS, CS || Magnitude Range= 7.4 to 8.3 | Spec=C9,2JLi, ? | BV=+2.84 | Color=red || **AB** | Mag=7.4, 8.3 | Sep=57.8" | PA=88.8° | mBortle=9 | mApt=50mm | Spec=NIab: p | Color=red, blue |) This ranks in my top 5 favorite doubles. A dark red primary and blue companion in a field of stars. This is an optical double, and sometimes (as with many carbon stars) it can take a few seconds before the red from the primary becomes apparent. A delight to view that should not be missed.



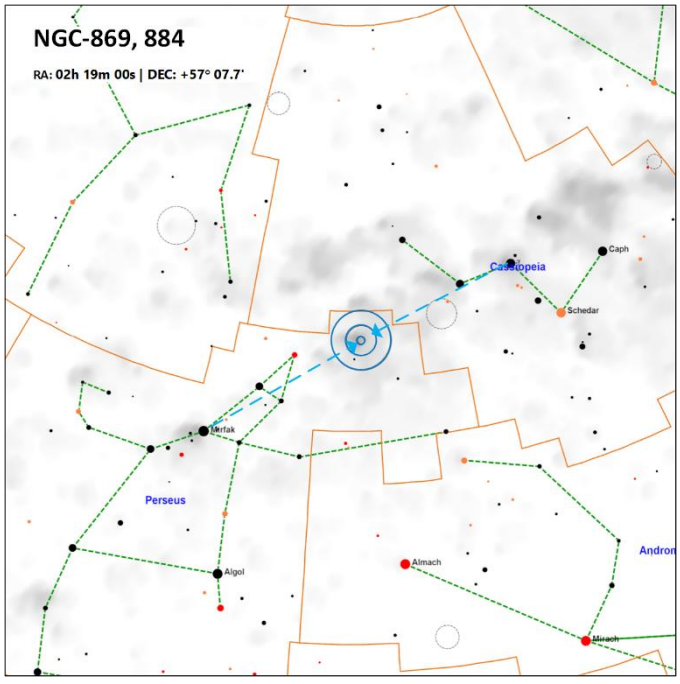


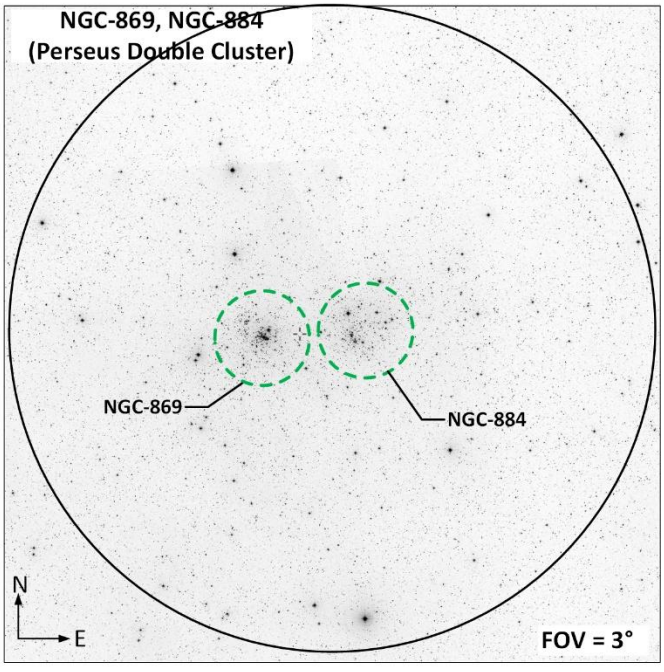
Messier 45 (OC, RN | M=1.6 | Size=2° |SB=29.0 |) – The Pleiades is perhaps the most famous of the open clusters, also known as the Seven Sisters. At a distance of 444 ly, this is one of the closest open clusters to Earth. This cluster also contains a reflection nebula (NGC-1435) noted below. The cluster is estimated to be 100 million years old.



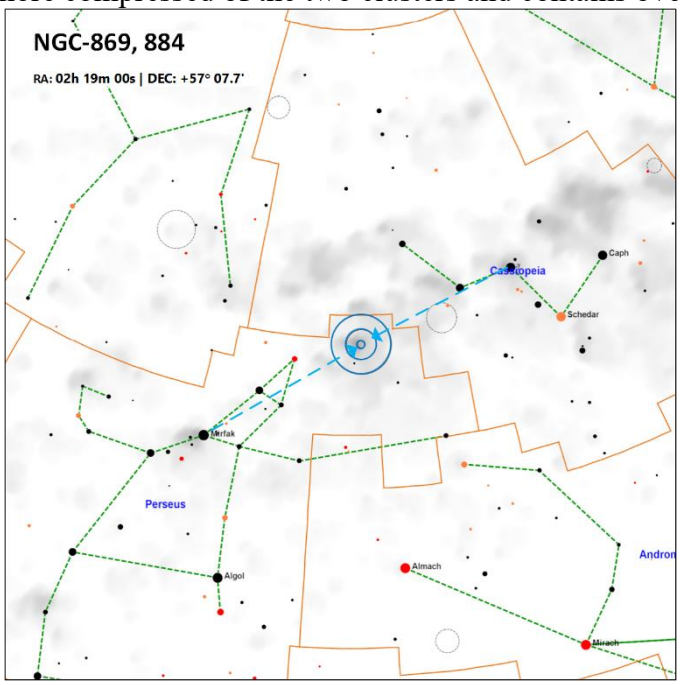


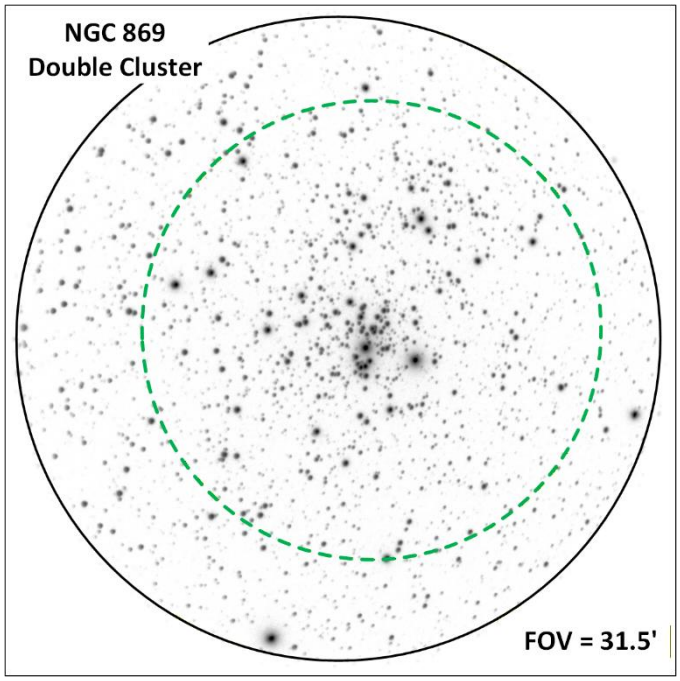
Perseus Double Cluster – Also known as Caldwell 14, this object is made up of NGC-869 and NGC-884. This is an excellent target for binoculars. This cluster was first cataloged by the Greek astronomer Hipparchus in 130 B.C. This should be visible to the naked eye in a dark sky. These clusters have only a few hundred light-years separating them, so they are close companions. More details on NGC-869 and NGC-884 are provided below.



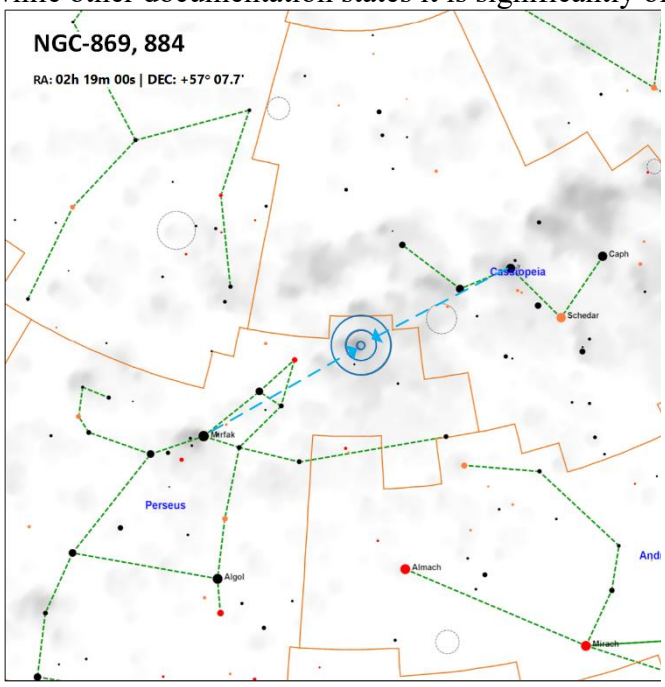


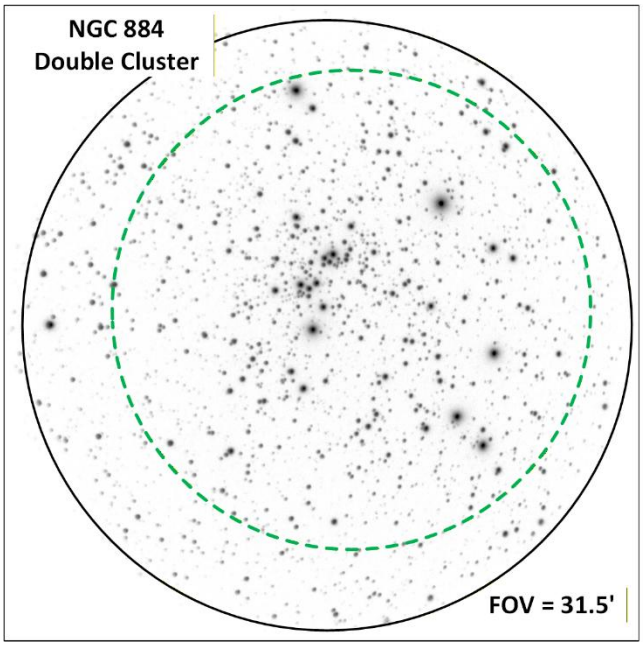
NGC 869 (OC| M=3.7 | Size=30’ | SB=19.8 |)– h Persei is about 7,460ly from Earth and is one of the two clusters known as the “Perseus Double Cluster”. This cluster is estimated to be 14 million years old, is the more compressed of the two clusters and contains over 200 stars.



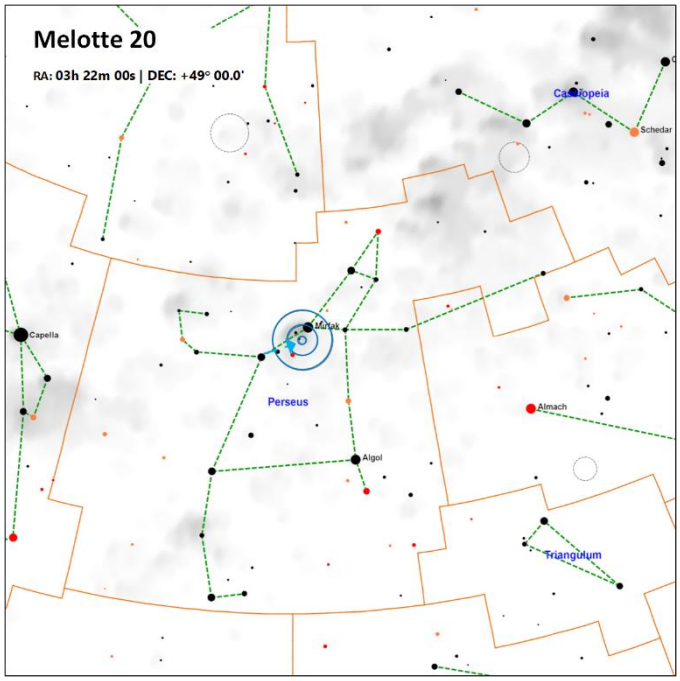


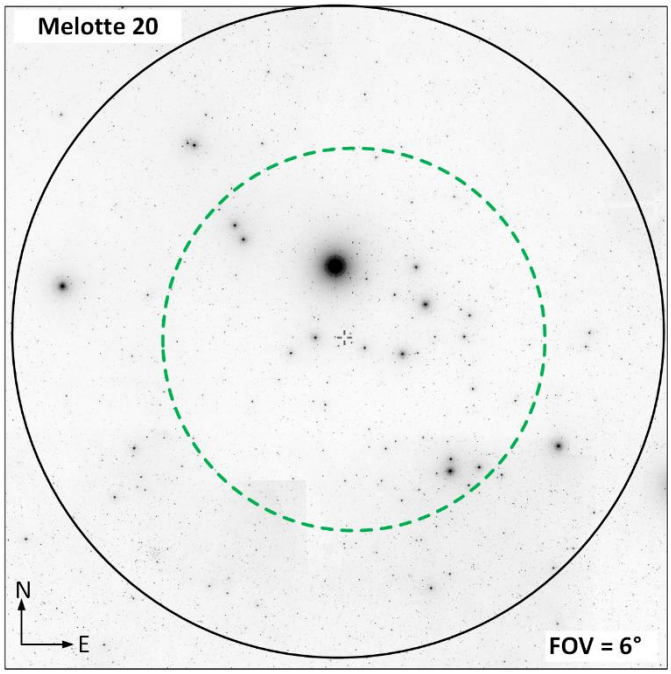
NGC 884 (OC | M=3.8 | Size=30’ | SB= 19.8 |) – Also known as Chi Persei, this is the second open cluster in the Perseus Double Cluster. This cluster is estimated to contain about 150 stars. There is conflicting information as to the age of this cluster: some documentation indicates it is about the same age as NGC-869, while other documentation states it is significantly older.



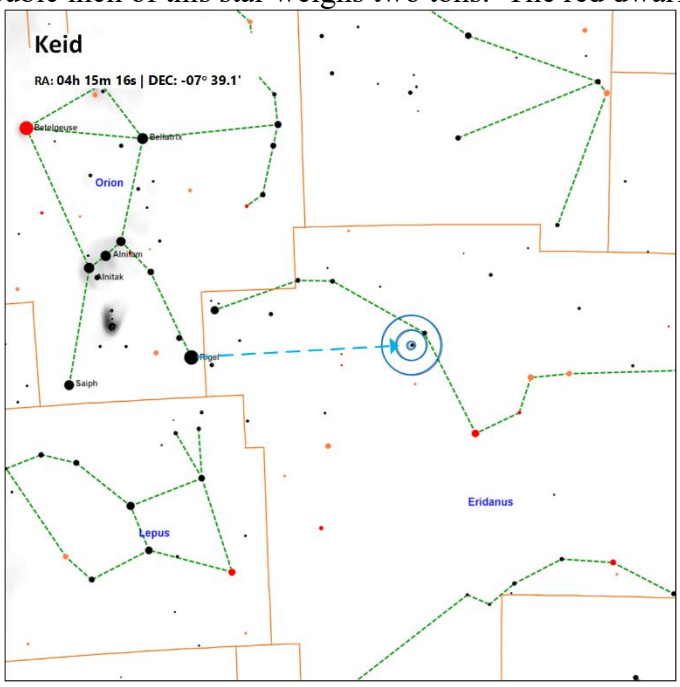


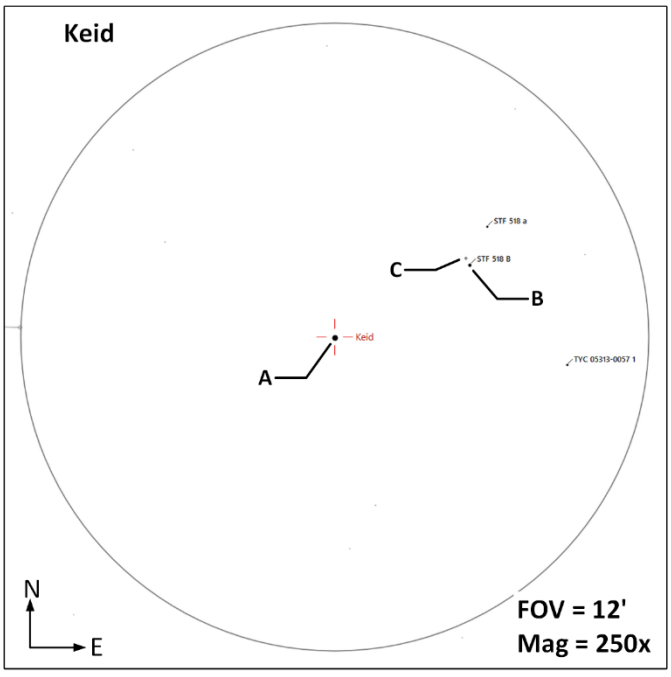
Melotte 20 (OC | M=1.2 | Size=300' | SB= 22.2 |)– The Alpha Persei Cluster is also known as Collinder 39 and visually is a very large cluster indeed. This target is strictly a binocular target. It is about 560 ly from Earth, has a radius of about 11.4 ly and contains 517 members. It is estimated to be about 60 million years old.





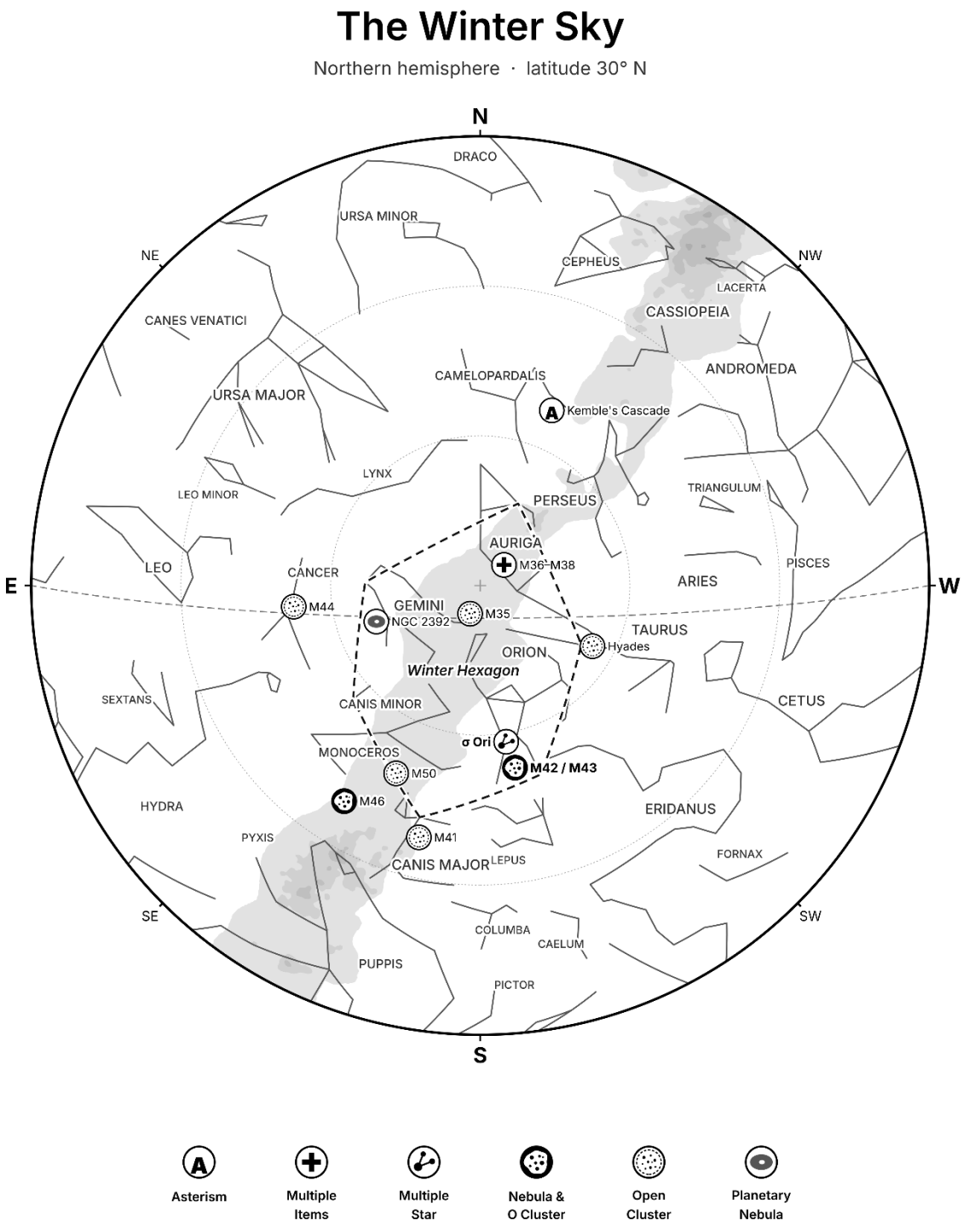
Keid (MS-3 **A, BC** | M=4.4, 9.3 | Sep=83" | PA=102° || **AC** | M=4.4, 11.2 | Sep=78" | PA=98 ° || **BC** | M=9.5, 11.2 | Sep=7.7" | PA=327° |) – The primary is a main-sequence star; the B component is a white dwarf; the C component is a red dwarf. The two dwarfs orbit each other every 248 years. The white dwarf is quite dense; 1 cubic inch of this star weighs two tons. The red dwarf star has 16% of the mass of our Sun.



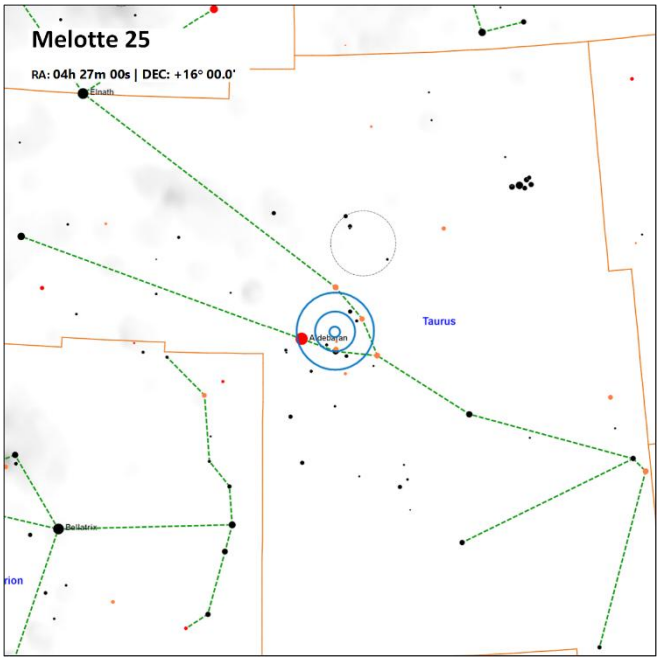


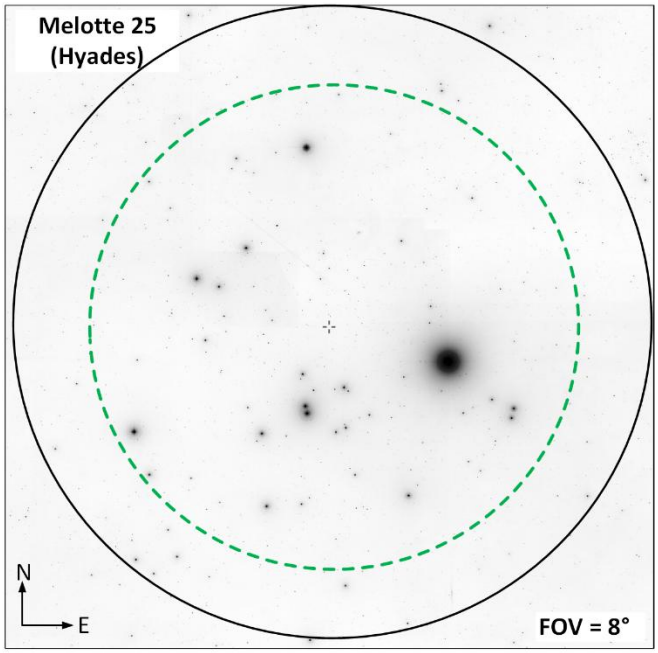
Winter (December – February)

Const	Target (Type)	Size / Sep	Comments
Tau	Mel-25 (OC)	5°	The Hyades. Large open cluster.
Ori	*M 42 & 43 (EN, RN, OC)	65x60’	Orion Nebula: M-42 and M-43 make up the Orion Nebula; the best nebula in the Northern Hemisphere.
Ori	*Sigma Ori (MS)		A Quintuple Star System! Most telescopes can make out 3 or 4 stars in this system. The closest pair is a mere 0.25” apart.
Cam	Kemble’s Cascade (AS)	2.5°	A pretty string of stars stretching for 2.5 degrees and ending with the cluster NGC 1502.
Aur	M 36, 37 & 38 (OC)	12’, 24’, 21’	Pinwheel, Salt and Pepper, Starfish Clusters all in the same area.
CMa	M-41 (OC)	38’	Little Beehive Cluster. Just visible to the naked eye.
Gem	M-35 (OC)	28’	Shoe-Buckle Cluster. A large bright open cluster.
Gem	NGC-2392 (PN)	48”	Clown Face Nebula. Small but bright planetary nebula.
Mon	M-50 (OC)	16’	Heart-shaped Cluster. A bright cluster with various colored stars.
Pup	M-46 (OC, PN)	23’	Open cluster with planetary nebula. Larger aperture may be required to see the planetary nebula.
Cnc	M-44 (OC)	95’	Beehive Cluster. About three times the diameter of the full Moon. Binocular target.

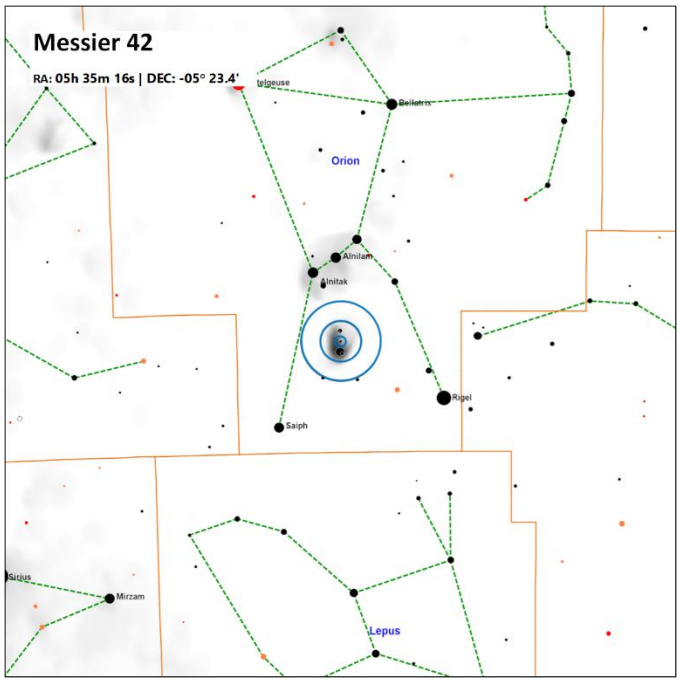

The Winter Sky
Northern hemisphere · latitude 30° N
N
NE
NW
E
W
SE
SW
S
DRACO
URSA MINOR
CEPHEUS
LACERTA
CASSIOPEIA
CANES VENATICI
ANDROMEDA
CAMELOPARDALIS
URSA MAJOR
Kemble's Cascade
LYNX
LEO MINOR
TRIANGULUM
PERSEUS
AURIGA
M36
M38
LEO
CANCER
ARIES
PISCES
M44
GEMINI
NGC 2392
M35
TAURUS
Hyades
ORION
Winter Hexagon
SEXTANS
CANIS MINOR
CETUS
σ Ori
MONOCEROS
M42 / M43
M50
M46
HYDRA
ERIDANUS
PYXIS
M41
CANIS MAJOR
LEPUS
FORNAX
COLUMBA
CAELUM
PUPPIS
PICTOR
Asterism
Multiple Items
Multiple Star
Nebula & O Cluster
Open Cluster
Planetary Nebula
Bold labels mark exceptional targets. Hold the chart overhead with the direction you face at the bottom.
Bold dashed lines: seasonal asterism. Fine gray dashes: ecliptic. Dotted circles: 30° and 60° altitude.

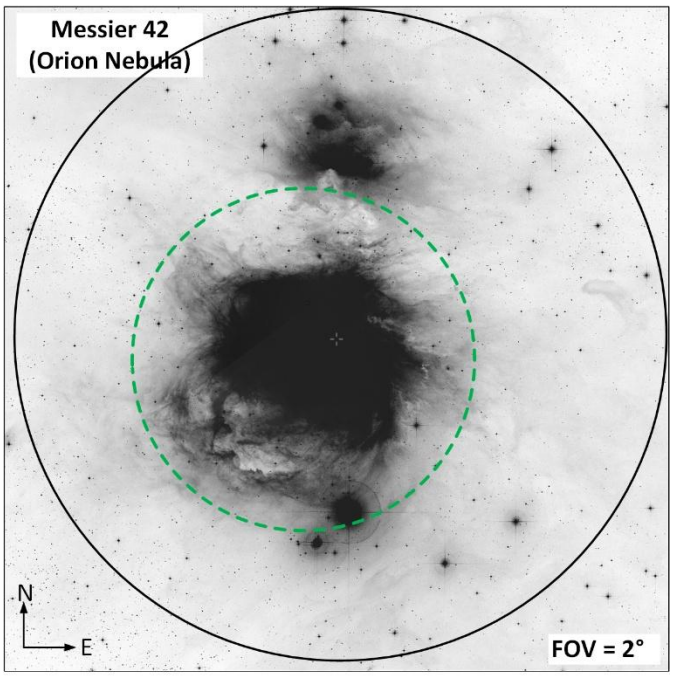
Melotte 25 (OC | M=0.5 | Size=5.5° | SB=21.7 |) – The Hyades is a large open cluster of several hundred stars at a distance of about 152 ly and covers an area of 5.5° in the sky, making up the head of Taurus. Binoculars will be required to view the full cluster. This is a loose cluster of stars.



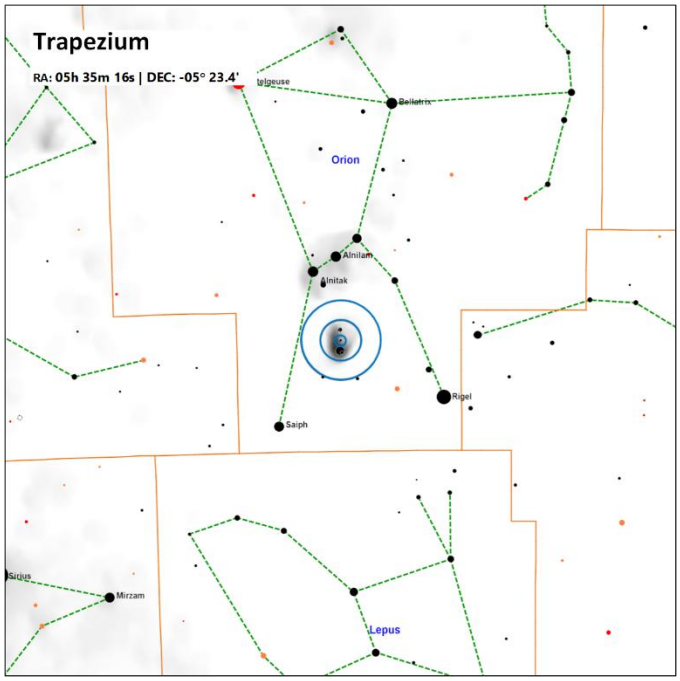


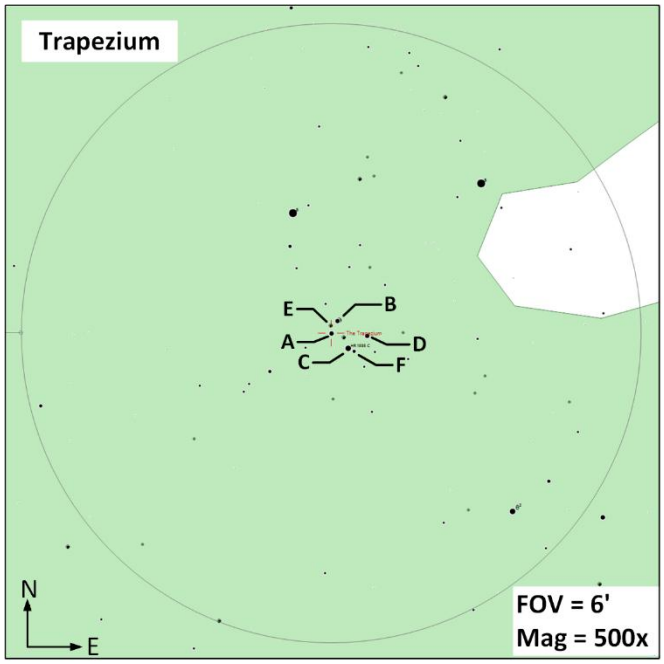
Messier 42 (EN, OC | M=4.0 | Size=65'x60' | SB=21.6 |) – The Orion Nebula is one of the best-known objects in the Northern sky. It is a stellar nursery where stars are forming from a giant gas cloud. Both the gas cloud and some of the newly formed stars are visible even in the smallest of telescopes. The Orion Nebula is estimated to be 25 ly across and to have a mass of about 2,000 solar masses and is about 1,400ly from Earth.

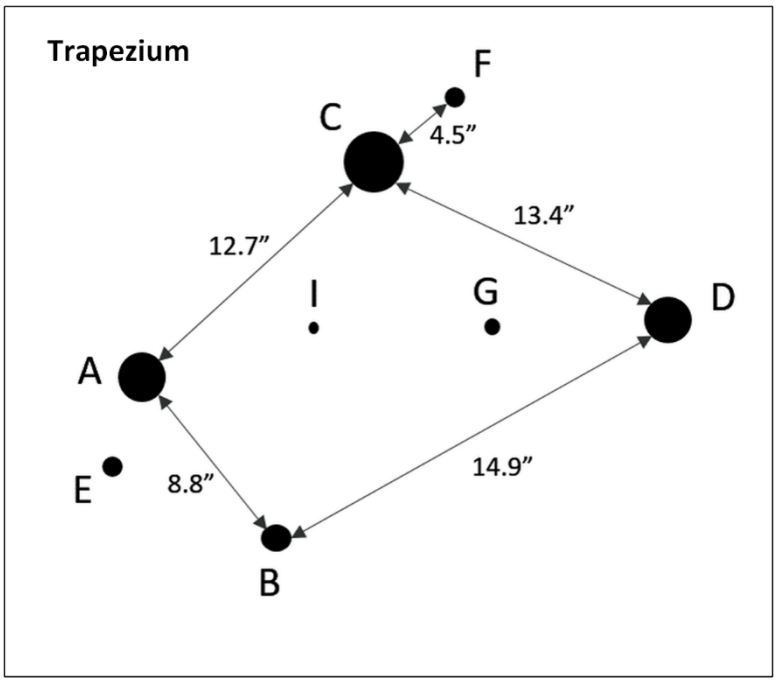




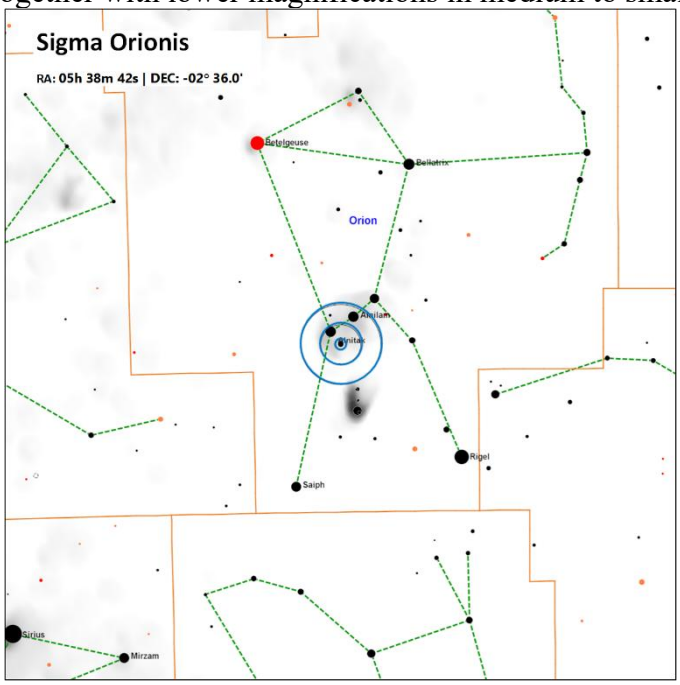
Trapezium (MS, OC AB | M=6.5, 7.5 | Sep=8.8” | PA 32° || AC | M=6.5, 5.1 | Sep=12.8” | PA 132° || AD | M=6.5, 6.4 | Sep=21” | PA 97° || AE | M=6.5, 11.1 | Sep=4.5” | PA 350° || BF | M=7.5, 11.5 | Sep=20” | PA 154° |) – Embedded in the heart of the Orion Nebula, this small cluster of newly formed stars is mostly responsible for energizing the nebula. The Trapezium has often been used to check seeing conditions and telescope optics. The four brightest components (A-D) are usually easily identified while the E & F components test the seeing conditions and optics.

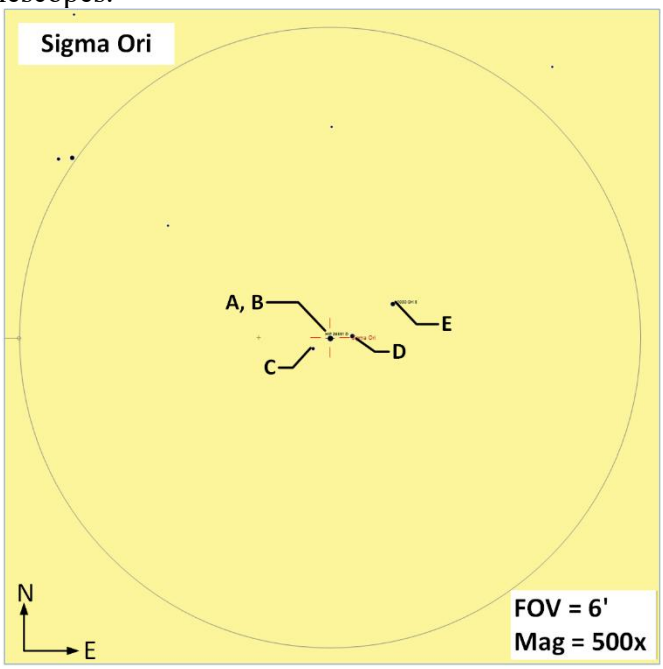




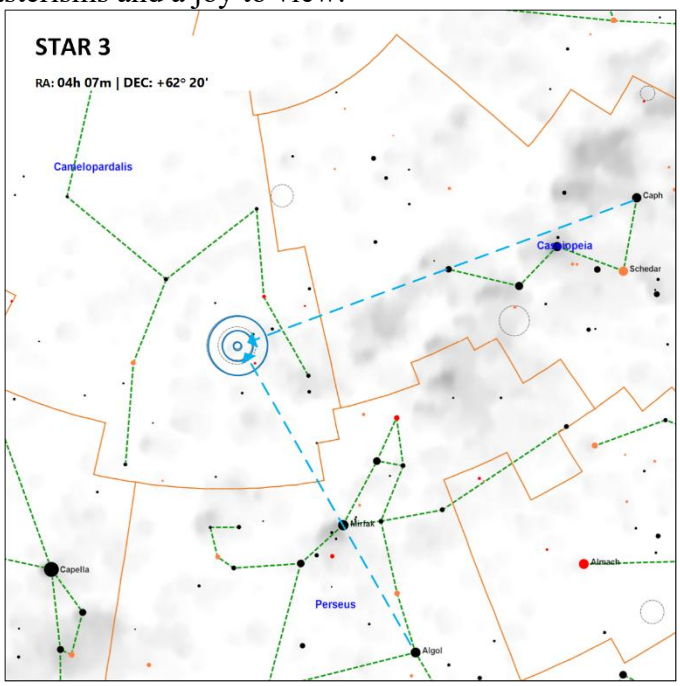


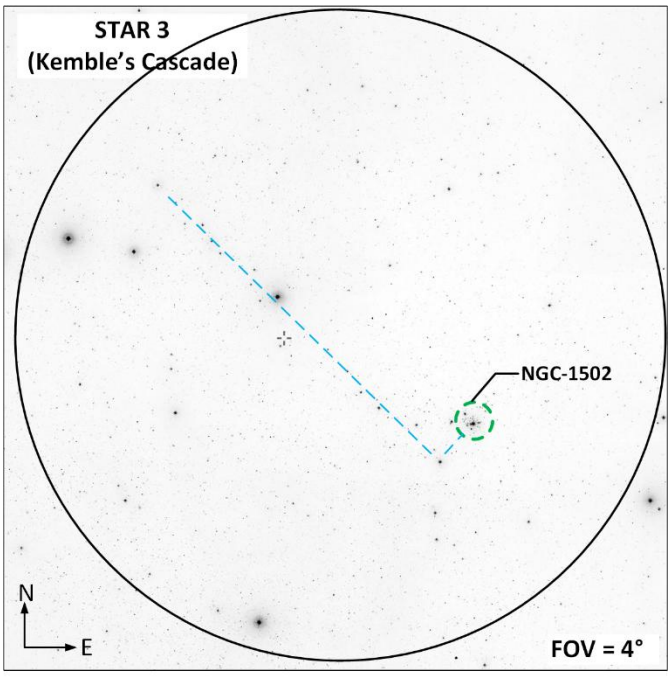
Sigma Orionis (MS-5 **AB/C** | M=4.1, 5.3, 8.8 | Sep=11.4” | PA=239° || **AB/D** | M=4.1, 5.3, 6.6 | Sep=13.5” | PA=84° || **AB/E** | M=4.1, 5.3, 6.3 | Sep=42” | PA=62° |) – This is an exceptional multiple star system composed of four elements. Most of these stars do not seem to be physically associated with each other but may be members of the small Sigma Orionis cluster. NOTE: Sigma Orionis and Struve 761 can be viewed together with lower magnifications in medium to small telescopes.



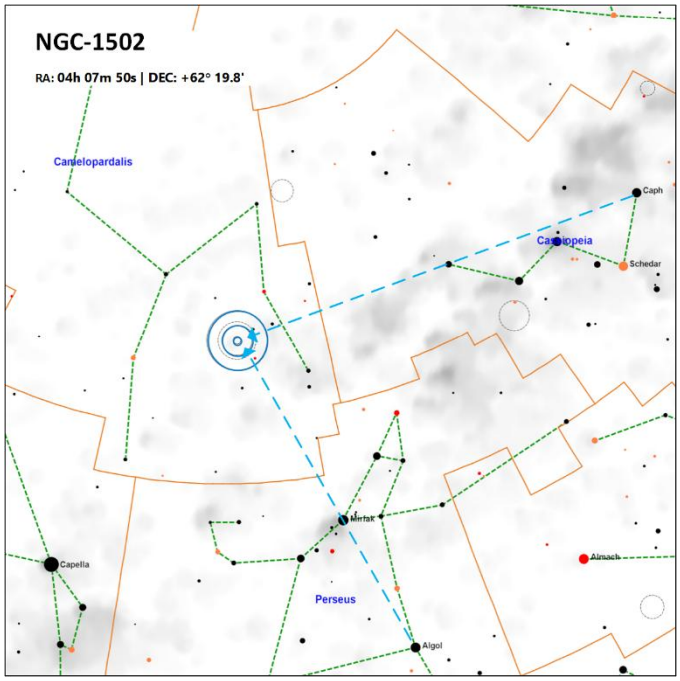


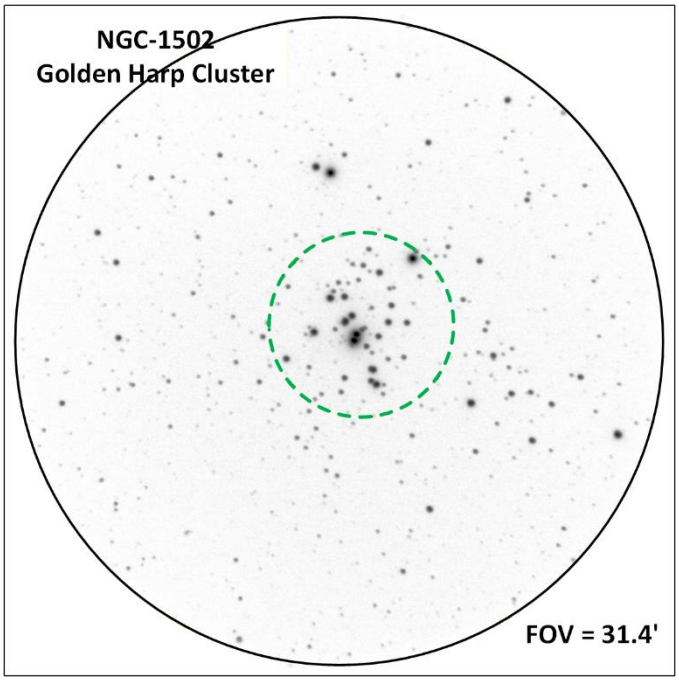
STAR 3 (AS | Size=2.5° | Stars=20) – Kemble’s Cascade is an asterism consisting of about 20 stars over a distance of 3 degrees and ends at the open star cluster NGC-1502. This is one of the more popular binocular asterisms and a joy to view.



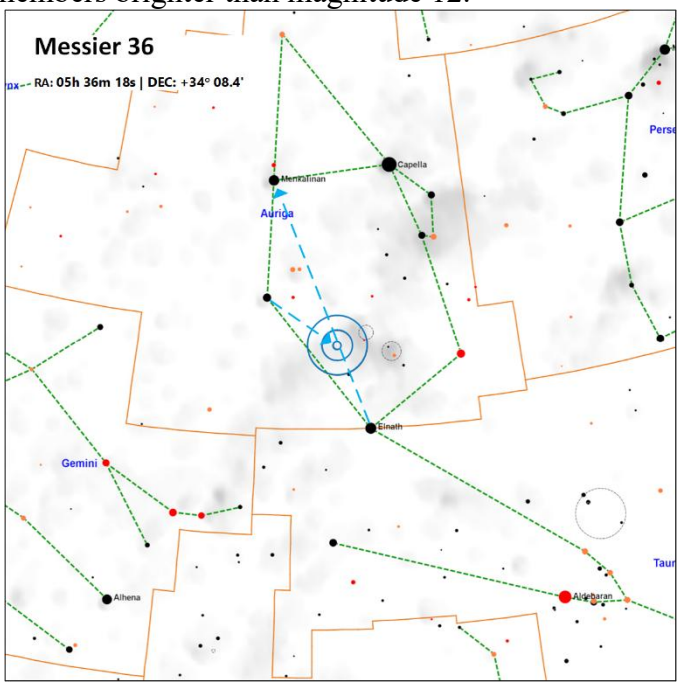


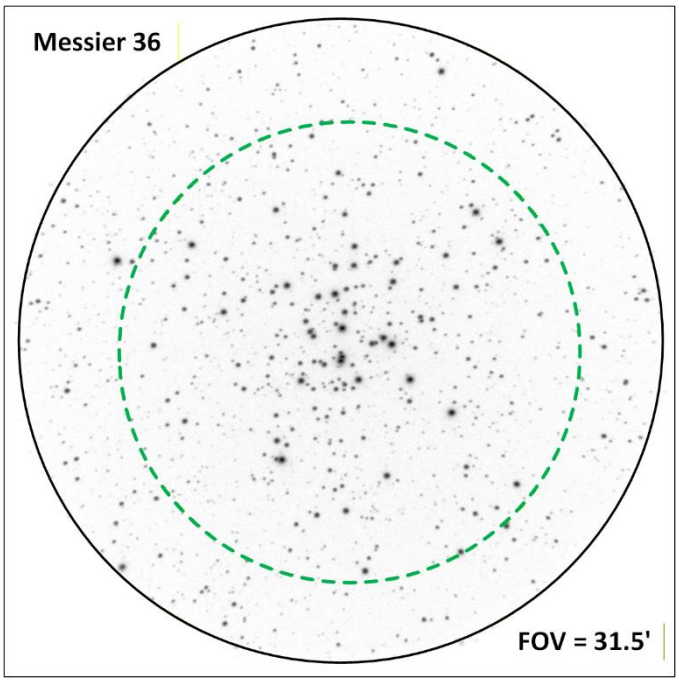
NGC 1502 (OC | M=6.0 | Size=9.7’ | SB=19.6 | Stars=45 |) – Golden Harp Cluster (Collinder 45) is a young open cluster consisting of 45 to 60 stars at a distance of about 3,500 light-years from Earth. This open cluster may be dimly visible to the naked eye in ideal conditions. This open cluster is roughly triangular in shape with the double star STF-485 in the center of the cluster.



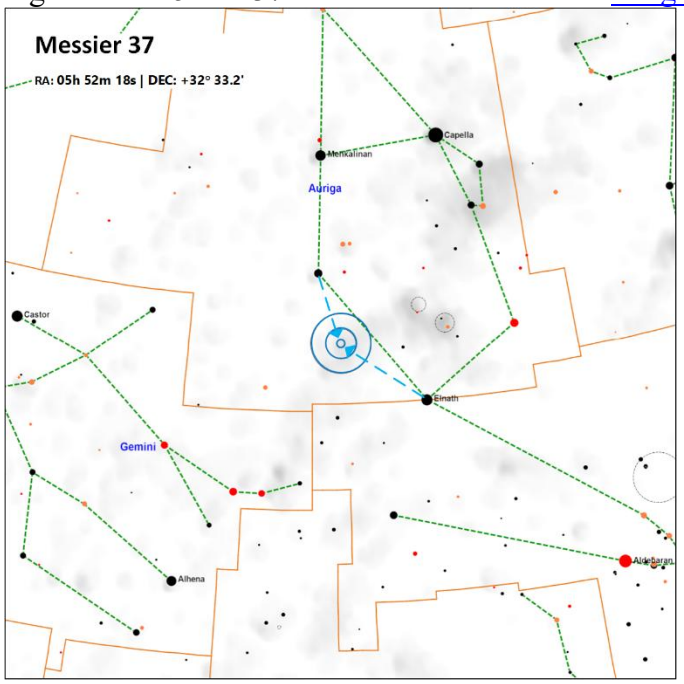


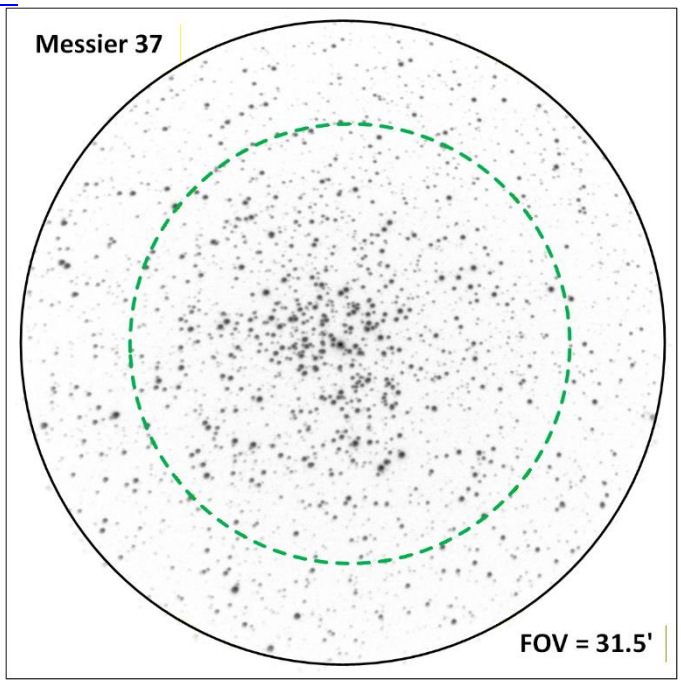
Messier 36 (OC | M=6.3 | Size=12’ | SB=20.3 |) – The Pinwheel Cluster is 4,300 ly from Earth and is estimated to be 25 million years old with a diameter of 14 ly. The cluster contains about 60 members with 30 members brighter than magnitude 12.



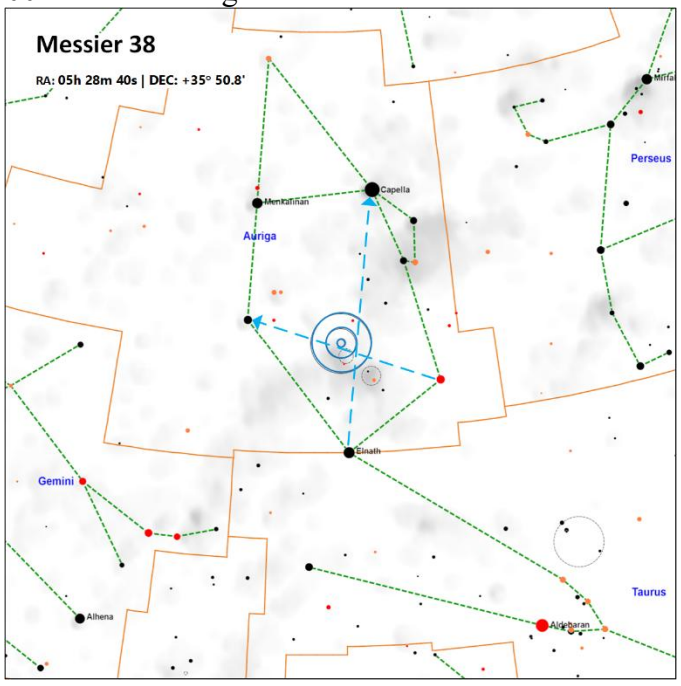


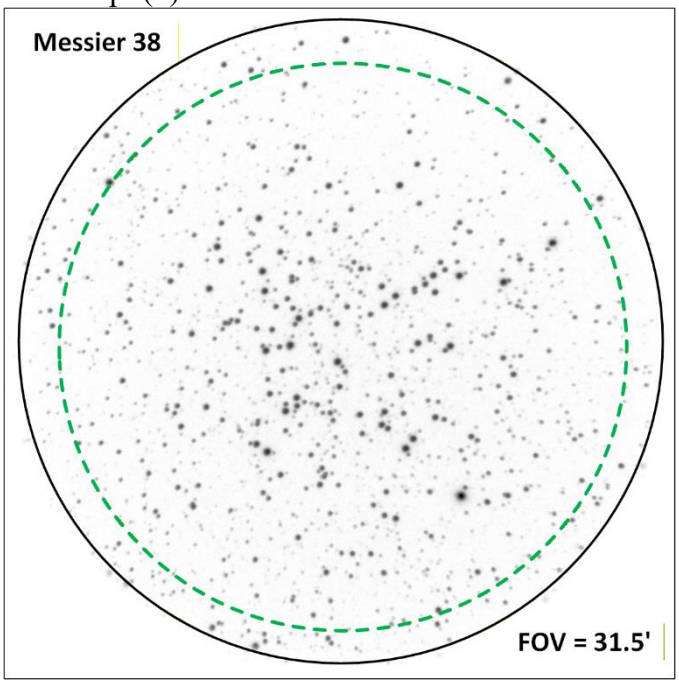
Messier 37 (OC | M=6.2 | Size=24' | SB=21.7 |) – The Salt and Pepper Cluster is located 4,500 ly from Earth and is estimated to be about 475 million years old. The cluster contains over 500 stars with 150 brighter than magnitude 12.5. M-37 contains at least a dozen red giants.



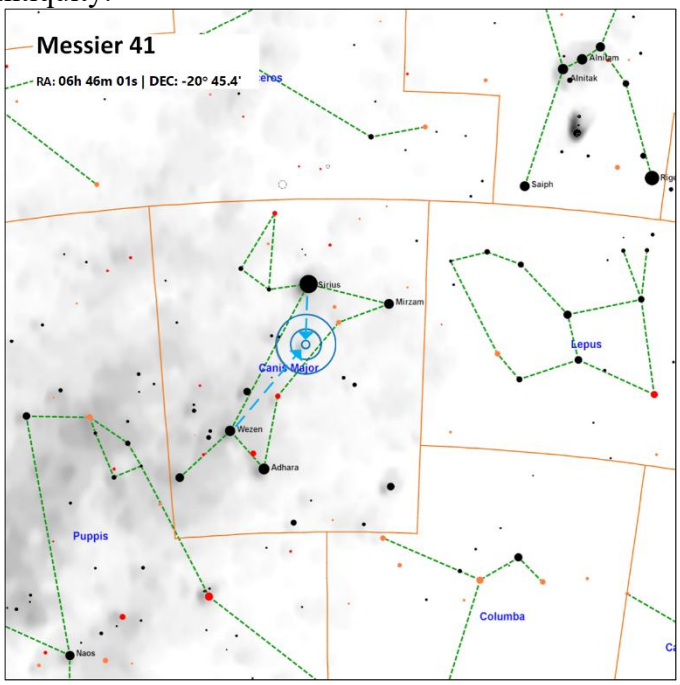


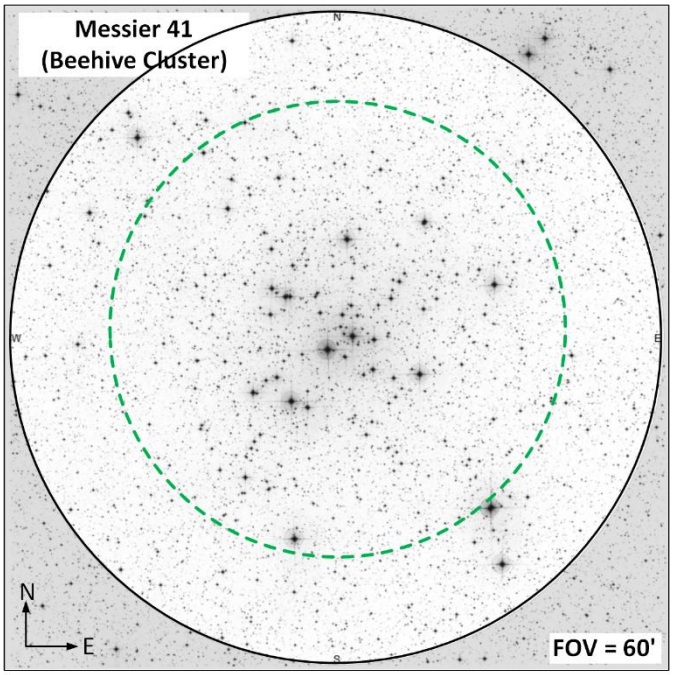
Messier 38 (OC | M=7.4 | Size=21' | SB=22.6 |) – The Starfish Cluster is an open cluster 3,500 ly from Earth and is estimated to be 220 million years old with a diameter of 25 ly. This is a rich cluster that contains over 100 stars. The brightest stars in this cluster form the Greek letter pi (π).



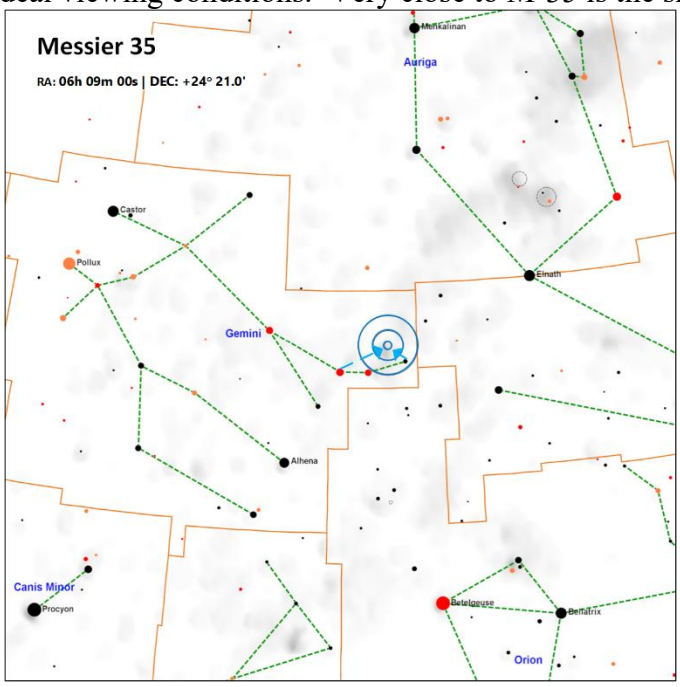


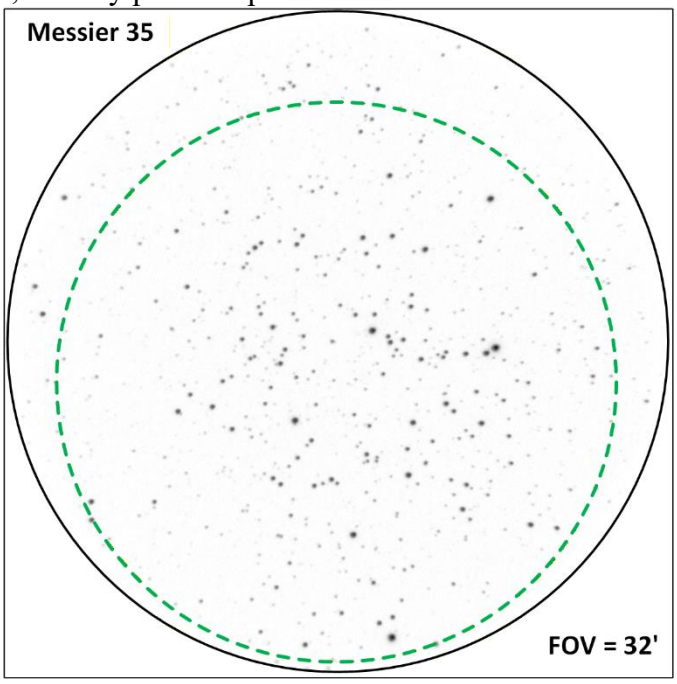
Messier 41 (OC | M=4.5 | Size=38' | SB= 21.5 | Stars=100+ |) – A large bright open cluster that is visible with the naked eye under dark skies. This is one of the best open clusters to observe with binoculars. It is suspected M-41 was identified by Aristotle around 325 B.C. and is the faintest object recorded in classical antiquity.



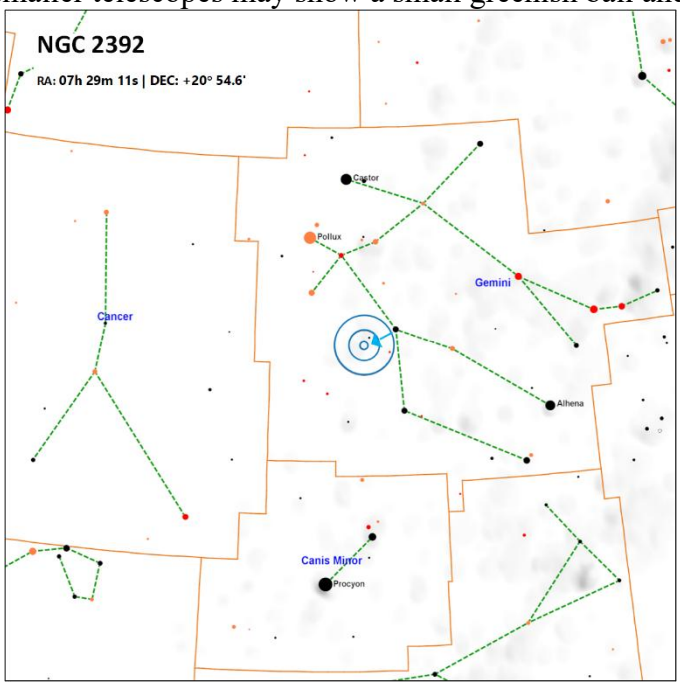


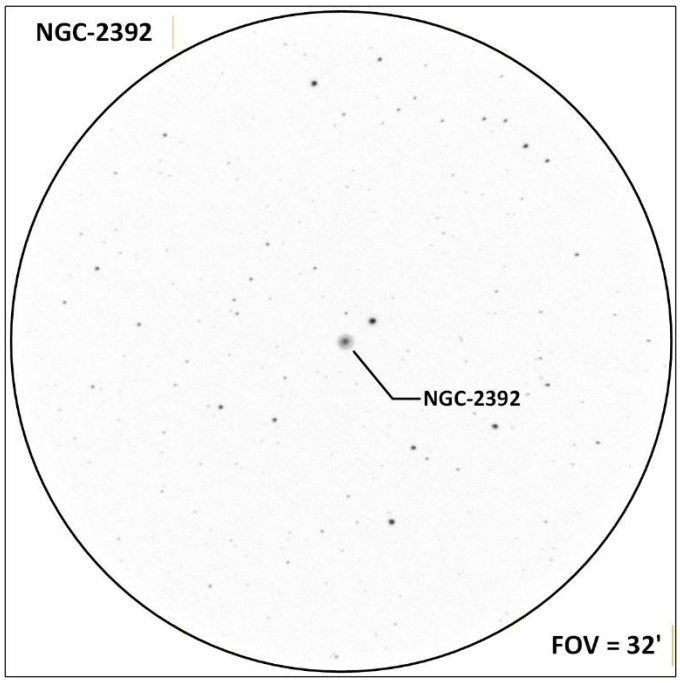
Messier 35 (OC | M=5.3 | Size=28' | SB= 21.2| Stars=120 |) – Many consider M-35 one of the premier open clusters in the northern winter sky. A great binocular target that may even be visible to the naked eye under ideal viewing conditions. Very close to M-35 is the small, densely packed open cluster NGC-2158.



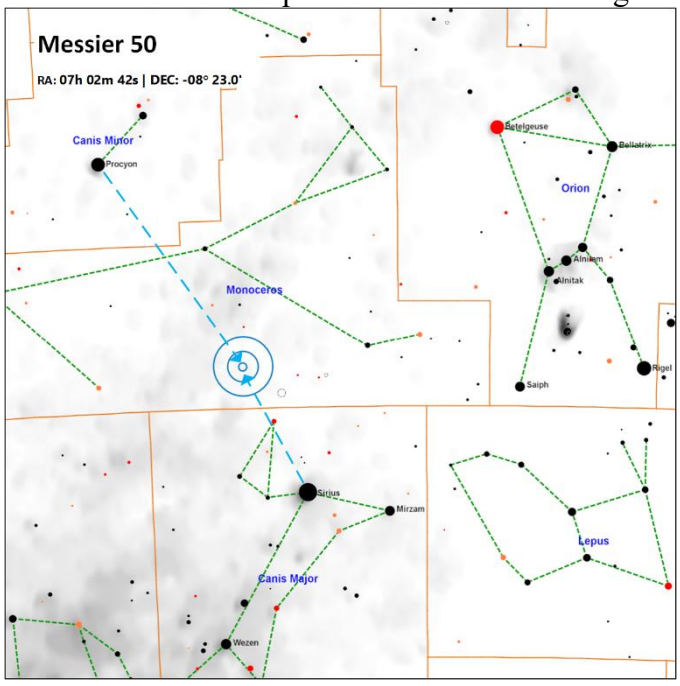


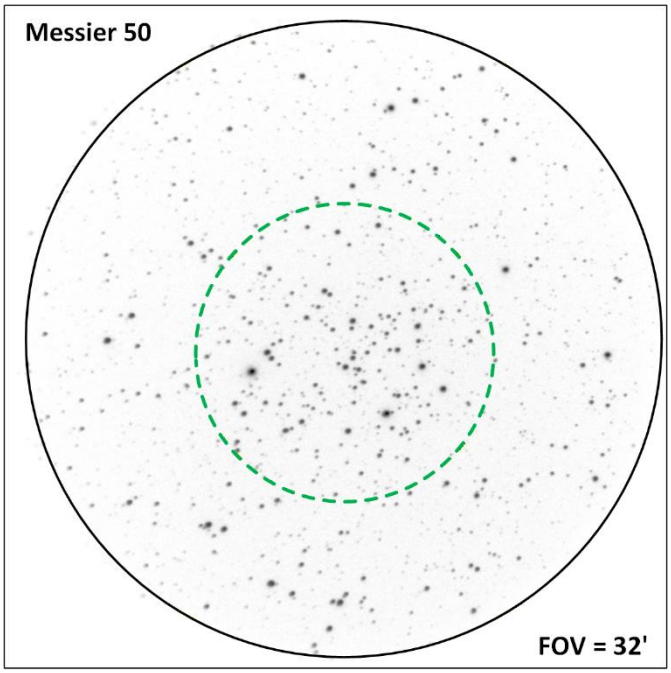
NGC 2392 (PN | M=8.3 | Size=6.4’ | SB=21.0 | Stars=100 |– The Eskimo Nebula is a planetary nebula; smaller telescopes may show a small greenish ball and central star.



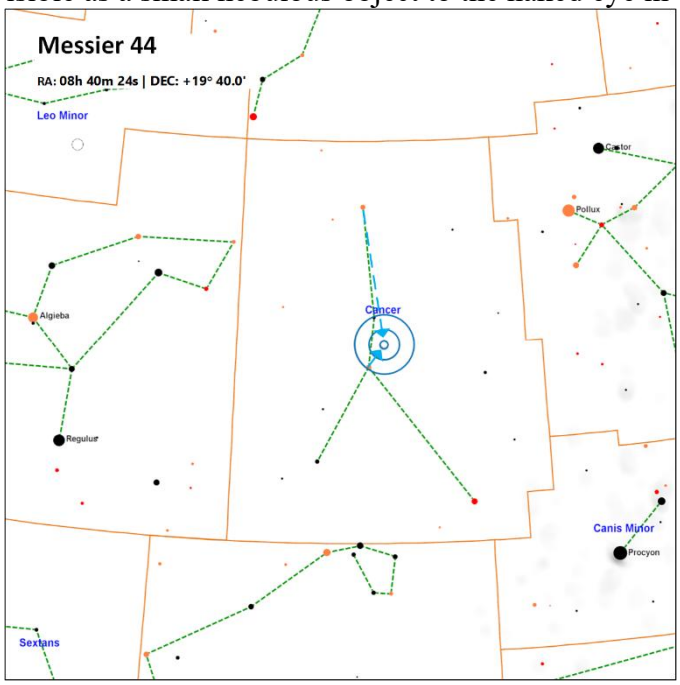


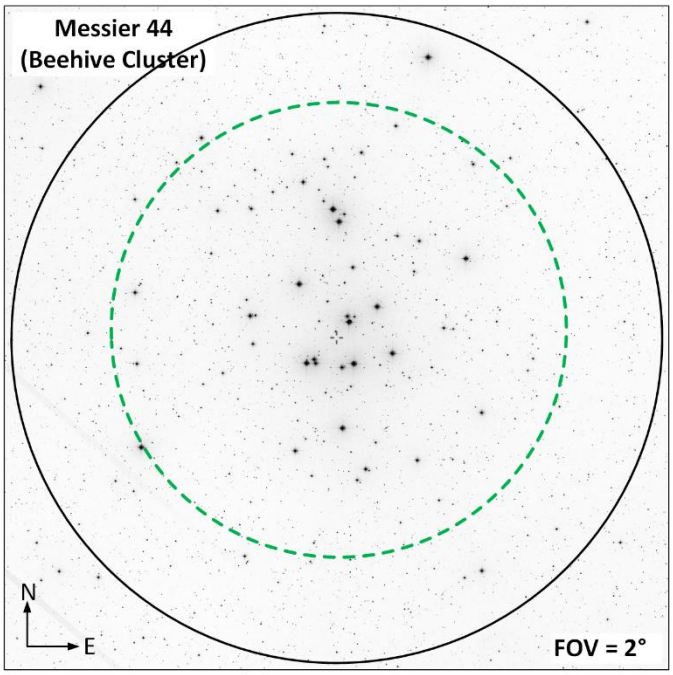
Messier 50 (OC | M=5.9 | Size=16’ | SB=20.5 | Stars= 100 |) – A large cluster containing about 200 stars (100 brighter stars) if you include the immediate area surrounding the official size of the cluster. This cluster is visible in small telescopes and binoculars. A single red giant star stands out in this cluster.





Messier 44 (OC | M=3.7 | Size=95' | SB=22.2 | Stars=40+|) – The Beehive Cluster is one of the nearest open clusters to Earth at a distance of 610 ly. The cluster is an estimated 600 to 700 million years old, is expected to have an overall mass of 500 to 600 solar masses, and contains an estimated 1,000 stars. This cluster is visible as a small nebulous object to the naked eye in dark skies.





Appendix

Measuring Field of View for a Telescope/Eyepiece Combination

Most eyepieces have not only the **Focal Length** (FL) printed on them but also the **Apparent Field of View** (AFOV). Although not all manufacturers provide the **Apparent Field of View** (AFOV) for their eyepieces. This is especially true for lower-cost packages where the telescope comes with a number of eyepieces. If this information is not provided, you can manually measure the field of view and back-calculate the **Apparent Field Of View** (AFOV) for an eyepiece by following the procedure below:

- Locate any star near the celestial equator (within about ±10° of 0° DEC).
- Center the star in your eyepiece.
- If you have a clock drive, turn it off; if you have a computer-controlled drive, disable tracking.
- Using the RA control only, move the star to the edge of the field of view so that it will drift across the field of view, passing through its center.
- Record the number of seconds it takes for the star to travel across the field of view until it is no longer visible in the eyepiece (**Recorded Time**).

$$\boldsymbol{FOV_{Measured}} = \frac{(Recorded\ Time)}{(240)}$$

Where

$FOV_{Measured}$ = Measured Field Of View in units of degrees °
Recorded Time = Time in seconds it takes the star to travel across the field of view

Now we can back-calculate the **Apparent Field Of View** (AFOV) for the eyepiece

$$\boldsymbol{AFOV_{Eyepiece}} = (FOV_{Measured}) \times (\frac{FL_{Telescope}}{FL_{Eyepiece}})$$

Where

$AFOV_{Eyepiece}$ = Calculated Apparent Field of View in units of degrees °
$FOV_{Measured}$ = Measured field of view in units of degrees °
$FL_{Telescope}$ = Focal Length of Telescope in units of millimeters
$FOV_{Measured}$ = Focal Length of Eyepiece in units of millimeters