
First Telescope
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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 objective lens. 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 Adaption** (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, Nebula 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** – Usually on a glass substrate is used to block specific frequencies of light associated with light pollution the intended result is to increase the contrast between the background and the target object for observation.
- **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 a 50 x 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.

Goals of this class

This class is targeted to new telescope owners, or persons considering purchasing a telescope. Information needed in deciding to purchase a telescope, and how to operate a telescope will be covered in this class. 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 type of class.

Labs are a critical part of this class. If you own a telescope, you will be 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 besides the moon and possibly a few planets (i.e. deep sky photography) is exponentially more complicated and expensive so we will not be covering Deep Sky photography in this class.

Class Structure

Lectures - This course is presented as a set of five lectures each lecture 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 lecture.

Labs – There are five labs generally corresponding to the lectures. While lectures are focused on general concepts and information on telescopes and astronomy, labs are focused on practical application and techniques. New concepts and methods will be covered in the labs so it is vital the student reviews the lab material and completes any exercises before attending the labs so they are prepared to perform task in the labs. 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 space objects that exist outside our solar system but within the Milky Way galaxy such open clusters, 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 a small (actually for most) telescope**.**

What You Will NOT See...

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

That all being said, 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 filters) 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. There are a number of illustrations they provide we will display below. Another website, deepskysketch provides sketches of what to expect from a small to medium size telescopes.

Examples of What You Might See

The Moon

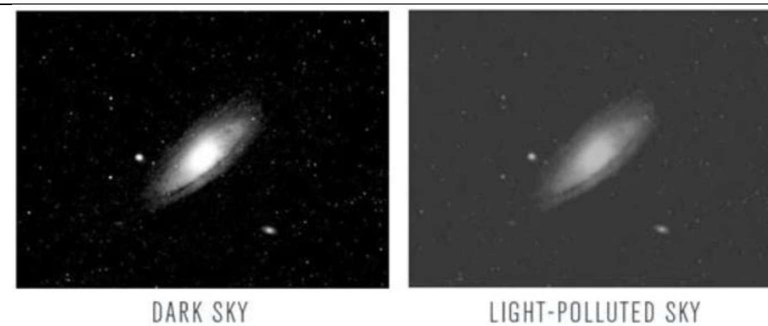
Planets

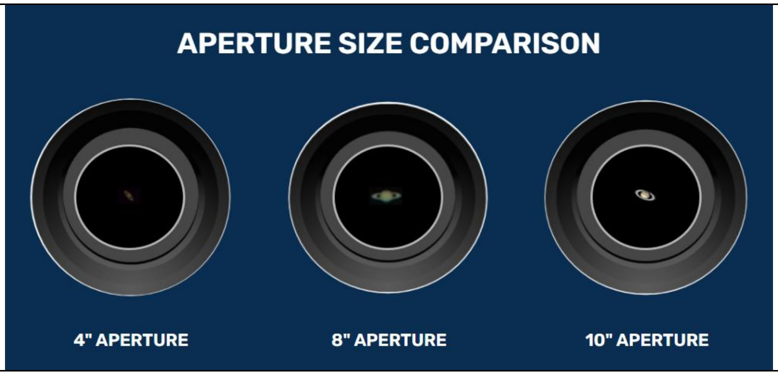
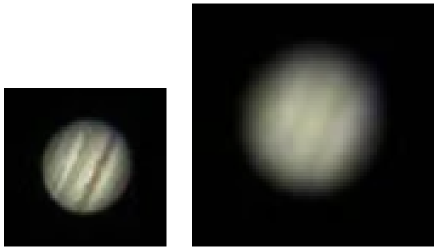
Multiple Star Systems

Bright Deep Sky – Orion Nebula

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.

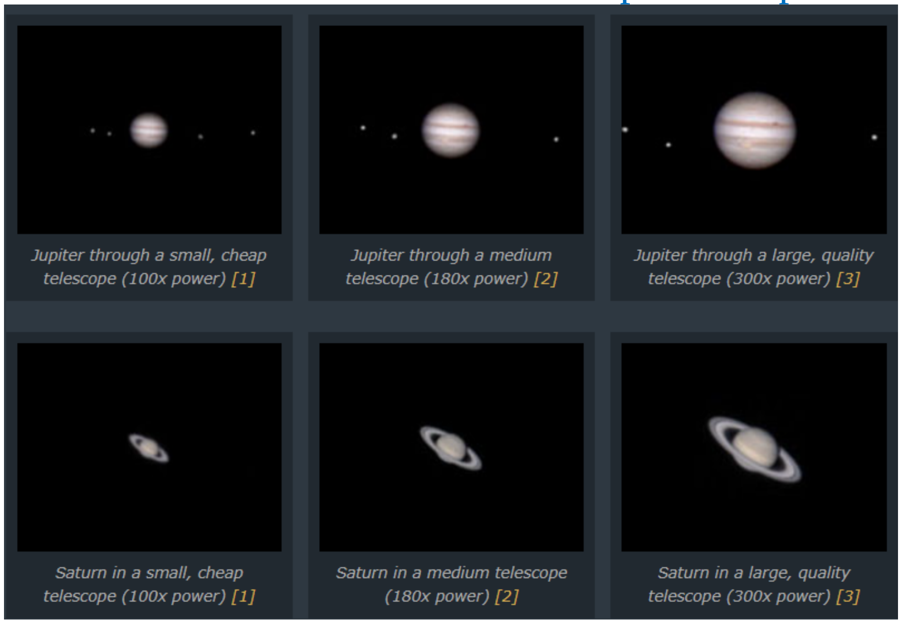
Dark Adaption (aka Night Vision) – Refers to the sensitivity of your eye to dimly lit objects. It is well understood that in a dark environment the eye becomes more sensitive to light being able to see dimmer and dimmer objects as time progresses. This is due to a number of factors including the size of the eye pupil and generation of the protein rhodopsin in the eye. Red light does not impact night vision; this is why red flash lights are used by astronomers and white light is distained. Generally light sensitivity nears its peak after about 30 minutes in the dark. However, this can quickly be lost with even momentary exposer to white light. More details on this topic can be found here.	 Dark Adaption
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 identification of objects and features within the object. 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 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 in the view. 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. $$Magnification = \frac{Telescope\ fl\ (mm)}{Eyepiece\ fl\ (mm)}$$	 Sometime Less is More
Optics – Optical quality including telescope optics and the eyepiece optics can impact the quality of an image. For most high production telescopes, the eyepieces provided with the telescope are of sub-par quality. There are various designs of eyepieces and associated costs. The Plossl design seem 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 adaption and light pollution have little if any impact. On the other hand, for deep sky objects dark adaption, light pollution, and aperture size are top considerations. Interestingly, magnification power is the least of issues for the majority of cases.

All these factors are important, yet even the smallest and lowest cost of telescopes can provide hundreds of hours of enjoyment if you know what type of objects are appropriate for that size scope. The telescope on the cover page was a 4" refractor I purchased in college for $75. I used it extensively for two years before being ready to move on to a larger telescope; a Celestron C-8 purchased for $2,000 that I used for about 25 years before upgrading to a Celestron C-11 that I currently own.

Impact of Aperture Size and Quality Optics



Jupiter through a small, cheap telescope (100x power) [1]

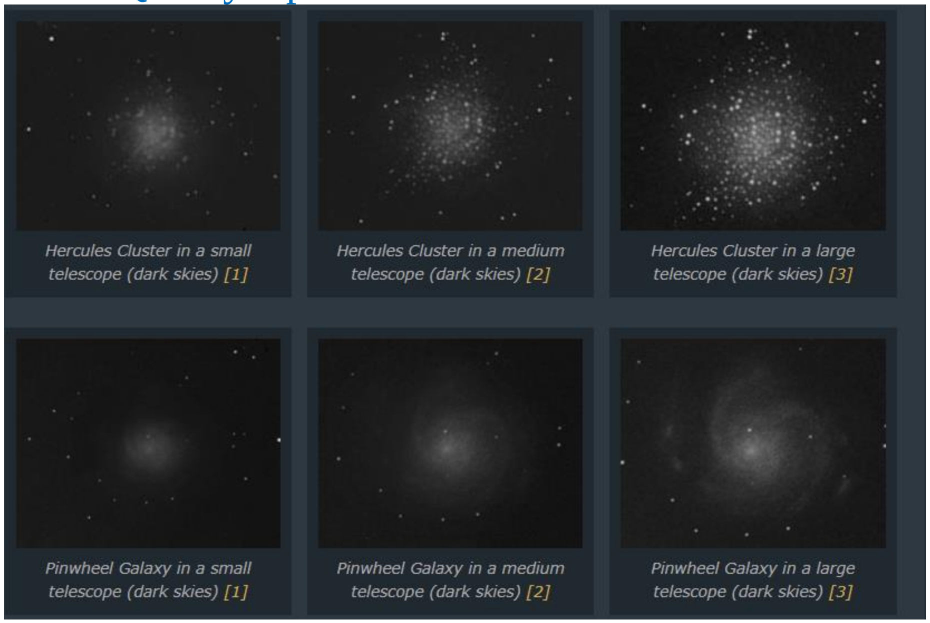
Jupiter through a medium telescope (180x power) [2]

Jupiter through a large, quality telescope (300x power) [3]

Saturn in a small, cheap telescope (100x power) [1]

Saturn in a medium telescope (180x power) [2]

Saturn in a large, quality telescope (300x power) [3]



Hercules Cluster in a small telescope (dark skies) [1]

Hercules Cluster in a medium telescope (dark skies) [2]

Hercules Cluster in a large telescope (dark skies) [3]

Pinwheel Galaxy in a small telescope (dark skies) [1]

Pinwheel Galaxy in a medium telescope (dark skies) [2]

Pinwheel Galaxy in a large telescope (dark skies) [3]

Impact of Light Pollution

Under truly dark skies

Countryside-suburbs area

Light polluted small city

References and Resources

Title	Type	Description
Stellarium Web	Website	Free online Planetarium.
What Can you See with Different Telescopes	Website	Deep-Sky Watch: Excellent article setting expectations for what to expect out of different cost telescopes
Go Astronomy	Website	Go Astronomy is a good general astronomy website
AZ Observing Group	Website	AZ-Observing groups is a great local group 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.
Superstition Mountain Astronomical League	Astronomy Club	Superstition Mountain Astronomical League (SMAL) is located in the East Valley
Astronomical Events for the year	Webpage	ArtCentrics web page listing some of the major astronomical events for the year.
Cloudy Nights	Website	Place where astronomers share ideas get help share photos, advertise very robust and strong astronomy community here.
Dark Adaptation: How It Affects What You Can See	Webpage	Good article detailing how dark adaption works.
Telescope Aperture Explained	Website	Detailed discussion on telescope aperture size and 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:

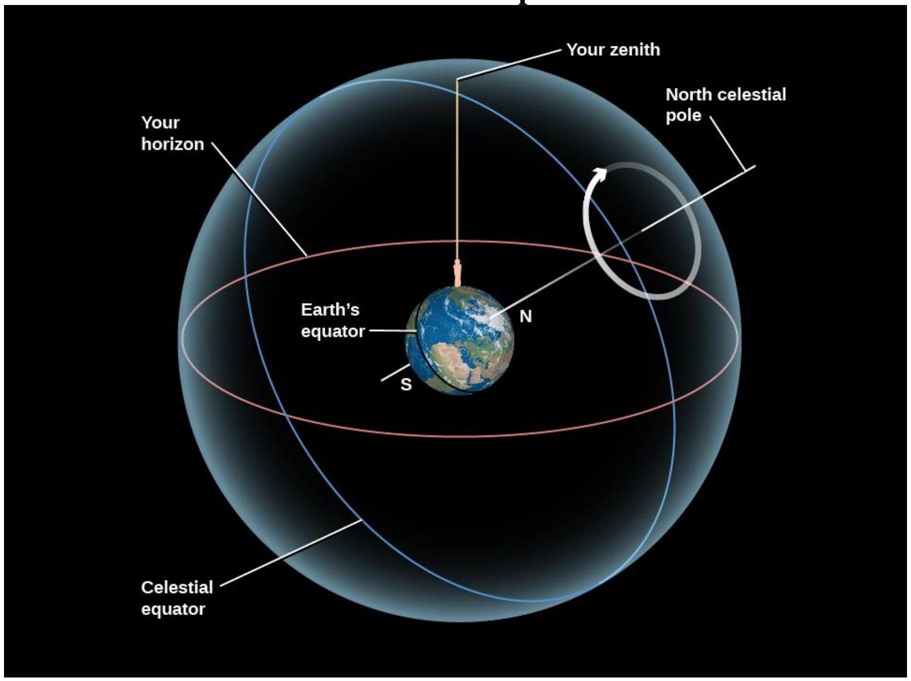
- **Altitude**(Alt) – One of the coordinate values utilized in the Horizontal Coordinate System and is divided into Degrees, Minutes and Seconds ranging from -90° to +90° with 0° representing directly overhead.
- **Azimuth** (Az) **-** One of the coordinate values utilized in the Horizontal Coordinate System and is divided into Degrees, Minutes and Seconds ranging from 0° to 360°.
- **Bortle Scale** (Bottle 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 upon 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 a Relative coordinate system in that the values of Alt/Az depend upon the location and time for the observer.
- **Magnitude** – a measure of the brightness of a star or other astronomical object observed from Earth.
- **Northern 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) - quantifies the apparent brightness or flux density per unit angular area of a spatially extended object such as a galaxy or nebula, or of the night sky background.

Sphere of the Sky

The earth spins like a top with the North Pole roughly aligned to the North Star. This is what gives the illusion of the sun, moon and stars rising in the east and setting in the west. 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 above to see the North Star. The Phoenix Metro area is approximately 33° North, so the North Star is about 33° above the horizon.

The Celestrial Sphere	**The North Celestial Pole**

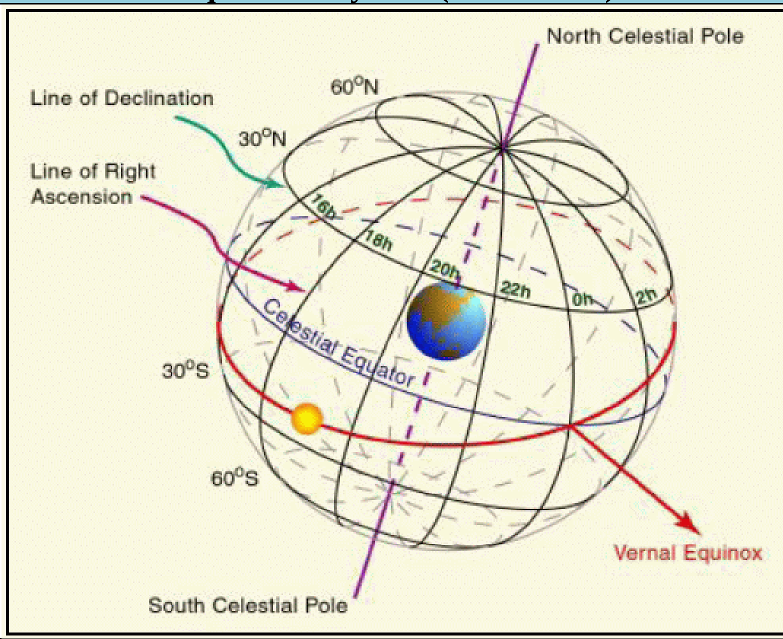
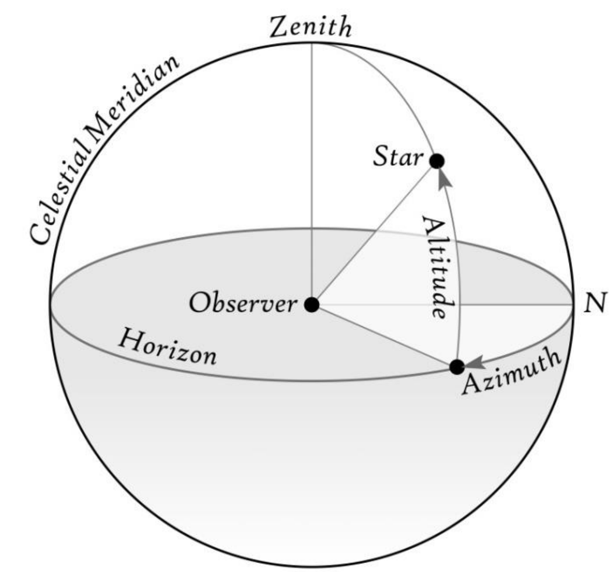


Astronomy Coordinate Systems

There are two primary coordinate systems utilized by Astronomers to locate objects in the sky. These systems are similar to the Longitude and Latitude coordination system that is used to specify a location on the earth. The system you utilize will likely depend on the type of telescope mount you own.

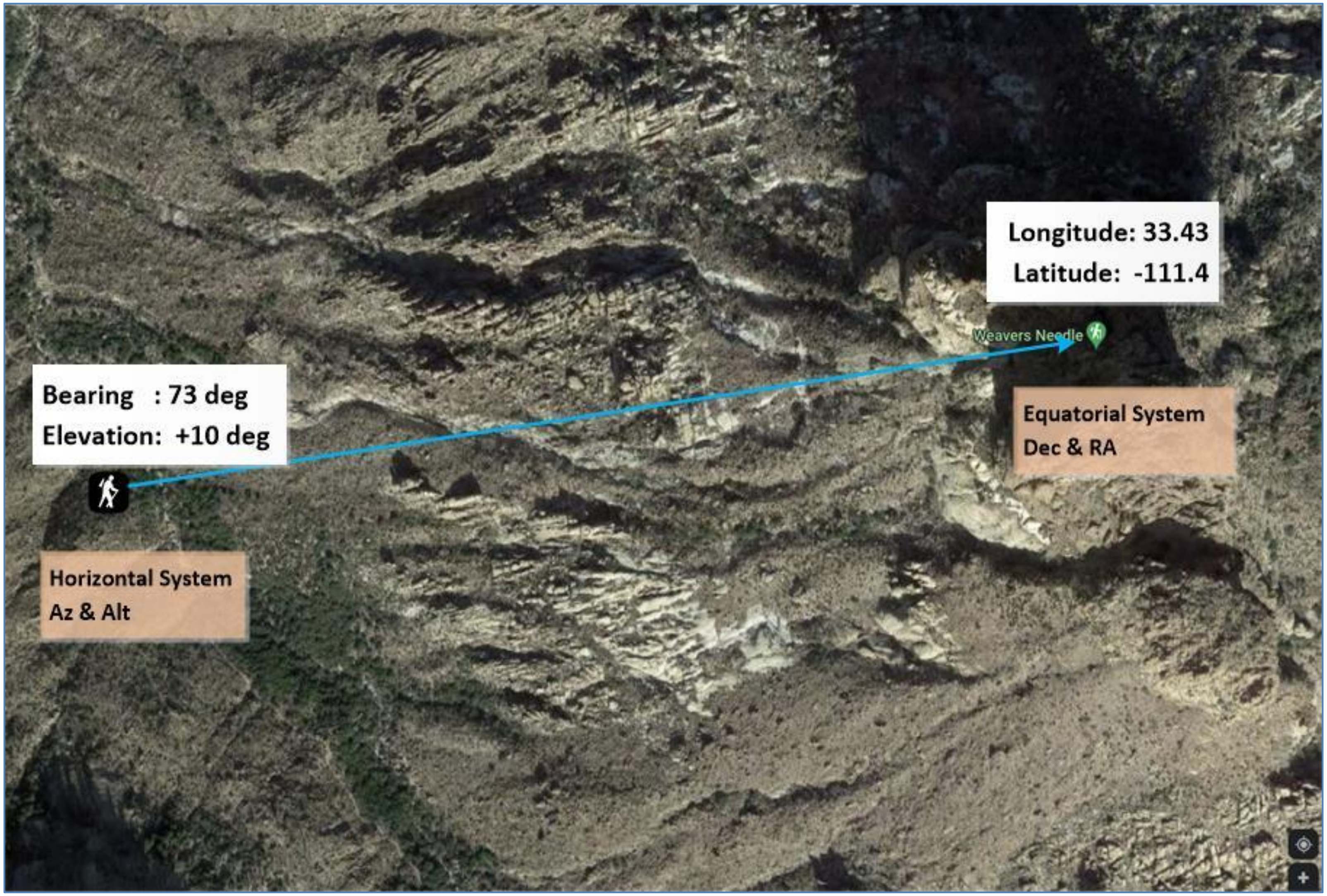
The **Equatorial System** utilizes Right Ascension (**RA**) and Declination (**DEC**) values to locate objects in the sky. Right Ascension units are the same units as a clock; Hours(**h**) Ranging from 0 to 24, Minutes(**m**) ranging from 0 to 60, and Seconds(**s**) ranging from 0 to 60. Declination (DEC) utilizes units of Degrees(°) ranging from -90° to +90°, Minutes(**‘**) ranging from 0 to 60, and Seconds(**“**) ranging from 0 to 60. 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 range from 0° to +90° while the Azimuth values range from 0° to 360° corresponding to compass bearings. This system is relative coordinate system where the values are dependent upon the location and the time for the observer.

<table>
<tr><th>Equatorial System (RA & DEC)</th><th>Horizontal System (Alt & Az)</th></tr>
<tr><td>
</td><td>

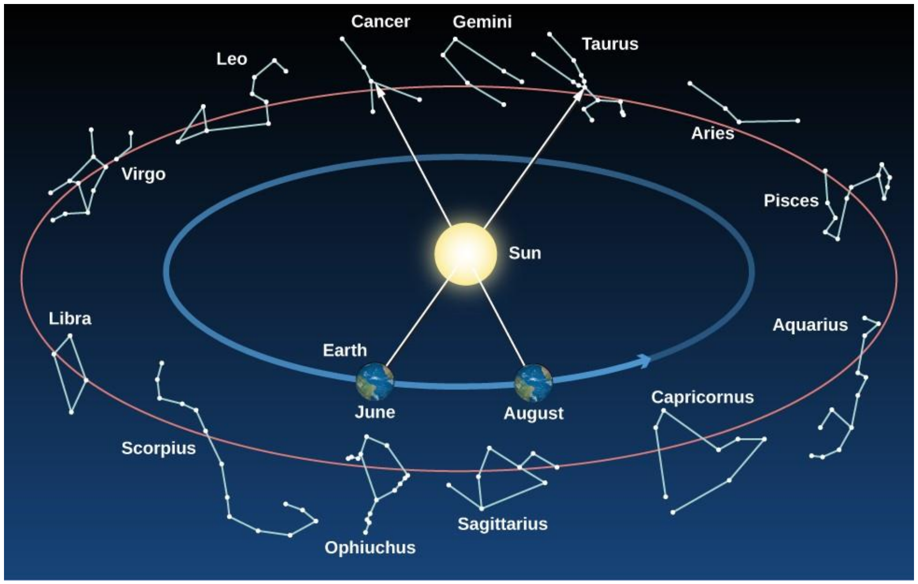
The horizontal coordinate system</td></tr>
</table>

Another way to think of these two systems is making an analogy to the coordinate system used specify locations on earth where the Longitude/Latitude system could be compared to the Equatorial System, both are absolute systems, where specifying the location on a map of an object relative to another location on a map (Bearing and Elevation) is a relative system similar to the Horizontal System.



Constellations and the Seasons

As the earth orbits around the sun the constellations and visible night slowly shifts (about 1° a day). Because of this, the stars rise about 4 minutes earlier every night. The result of this action is that the night sky and constellations slowly change as the seasons progress through the year.

<table>
<tr><th>Constellations in the Seasons</th><th>Star Chart</th></tr>
<tr><td>


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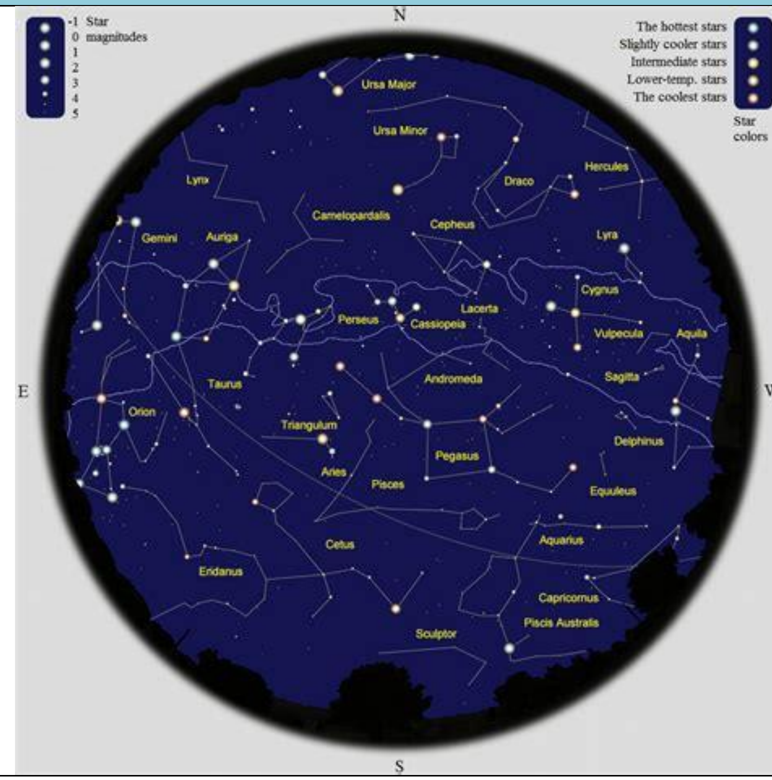
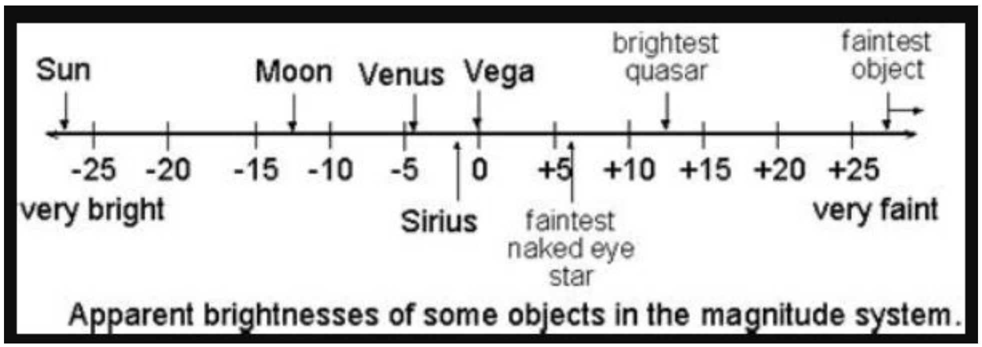
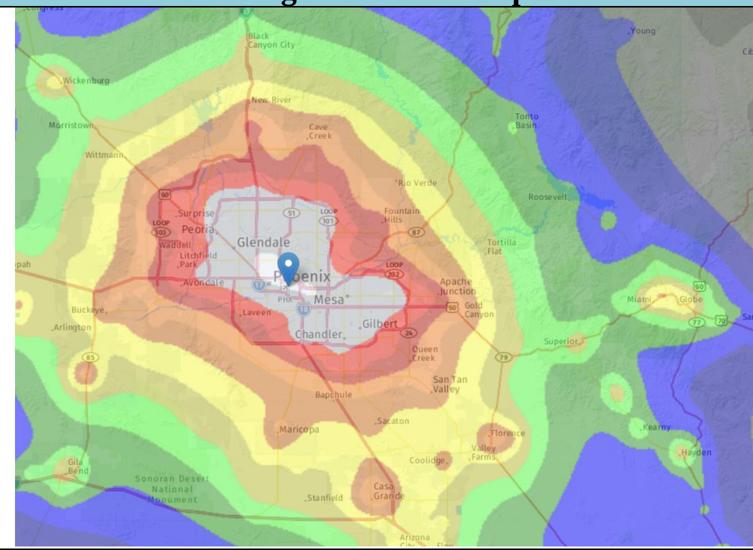


</td></tr>
</table>

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 logarithmic scale; so that a decrease in one unit of magnitude represents a 2.5x increase in brightness. Note, very bright objects such as the Sun and Moon have negative values while dimmer objects such as stars have positive values that increase with the faintness of the star. 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 tend to wash out the dimmer stars resulting in the dimmest stars visible with the naked eye being about magnitude +4.3

The Apparent Magnitude Scale	Light Pollution Map
	

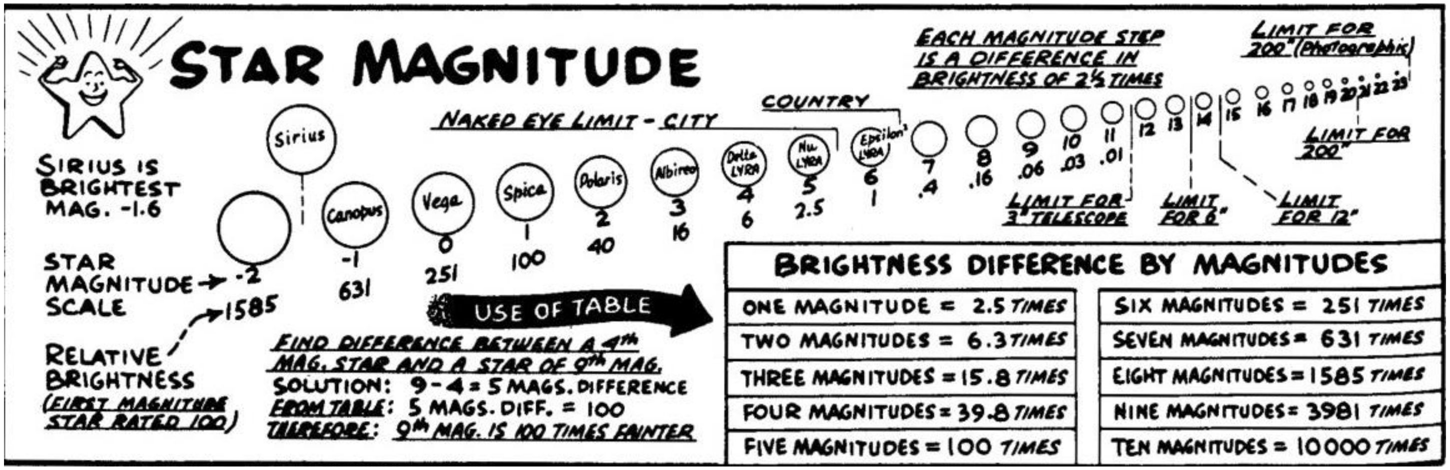
Bortle Scale

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. Its scale ranges from darkest skies possible on earth measuring at 1.0 while bright inner cities measure values of 4.0 to 9.0 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.

Bortle Scale Class	**1.0**	**2.0**	**3.0**	**4.0**	**5.0**	**6.0**	**7.0**	**8.0**	**9.0**
Limiting Magnitude	7.6 – 8.0	7.1 – 7.5	6.6 – 7.0	6.1 – 6.5	5.6-6.0	5.5	5.0	**4.5**	4.0

Surface Brightness

For an object with essentially no size such 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 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 more useful for indicating how easy it will be to view non stellar objects, it isn't highly utilized.



In the images below the total light emitted from both inner squares is the same, you can see the average brightness is much less for the larger object. What's worst is if you added to the simulation light pollution, the background color would change from black to grey 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.

Surface Brightness

Light Pollution

Catalogs

There are quite a few different systems developed by astronomers to classify and identify objects in the sky. The first and most famous catalog system 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 these objects as possible comets. He cataloged over 100 objects. This list is known as Messier Objects 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, nebula, 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 common for the same astronomical object to appear in multiple lists. For instance the Andromeda Galaxy is known by catalog numbers M 31, NGC 244, CGCG 535-17, MCG-7-2-15, 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 and contains 7,840 objects including star clusters, galaxies, and emission nebula.

Index Catalogue of Nebulae and Clusters of Stars (**IC**) – The first major update to the NGC contains 5,386 objects of galaxies, clusters and nebulae.

Principal Galaxies Catalogue (**PGC**) – Published in 1989 is composed of a list of 73,197 galaxies.

Lynds' Catalogue of Dark Nebula (**LDN**) – Published in 1962 a list of dark nebula based on a study of the Palomar Observatory Sky Atlas.

Barnard's List of Dark Nebula (**B**) – A list of 366 dark nebulas.

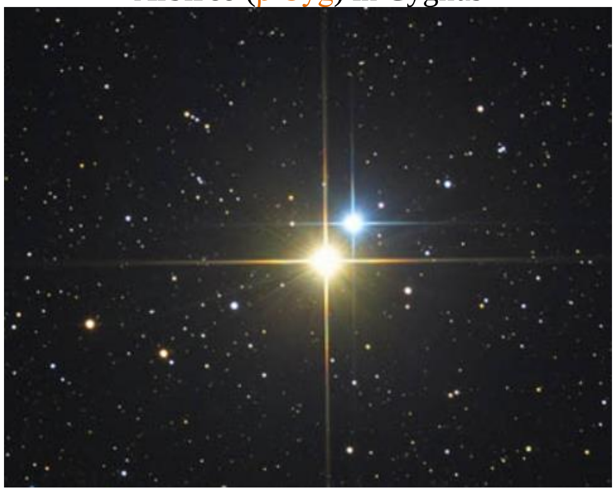
Smithsonian Astrophysical Observatory Star Catalog (**SAO**) - An astrometric star catalogue, created by Smithsonian Institution, a research institute. It was published by the Smithsonian Astrophysical Observatory in 1966 and contains 258,997 stars.

Washington Double Star Catalog (**WDS**) – A list of over 141,743 pairs of double stars maintained at the United States Naval Observatory. The list also includes multiple star systems.

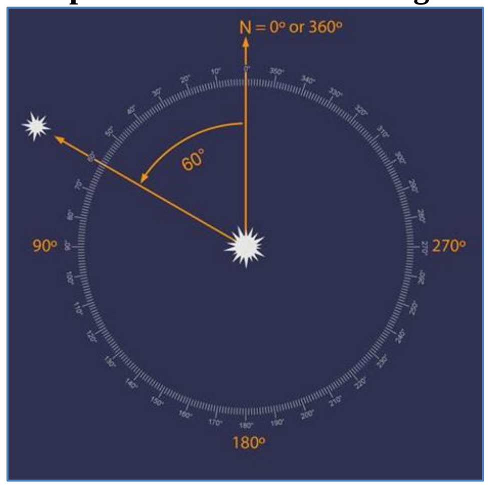
Multiple Star Systems

It is estimated that approximately 50% to 85% of 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 still are many systems in the night sky that can be resolved (separated) by small telescopes.

Albireo (β Cyg) in Cygnus



Separation and Position Angle



Epsilon Lyrae (ε Lyr)
Double-Double Star system in Lyrae

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 theses stars can be more challenging in a bright night sky due to less stars overall being visible to the naked eye for navigation (GoTo mounts neglect this issue).

Two measurements utilized in the study of multiple star systems are the Separation (the apparent distance between stars measured in arc-seconds) and Position Angle (PA) (the location of the secondary star relative to the primary star measured in degrees). There are even a couple of star systems with as many as seven components although these are not visually observable.

Observing multiple star systems generally follows the sequence of utilizing the lowest power eyepiece to locate the system and progressing to higher power magnification to resolve the components of the system.

MINIMUM SEPARATION FOR AN APERTURE

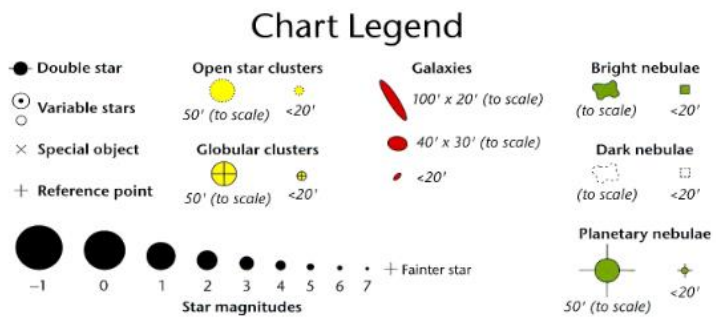
Δm is the difference in magnitude between the primary and secondary stars. The estimated minimum separation for the different apertures is in arcseconds. These estimates are useful only when the primary star is magnitude 6.5 or brighter.

Magnitude difference	60-mm	100-mm	150-mm	200-mm	250-mm
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″

Ref: Double Stars for Small Telescopes by Sissy HAAS (2006)

Reading Star Charts and Atlases

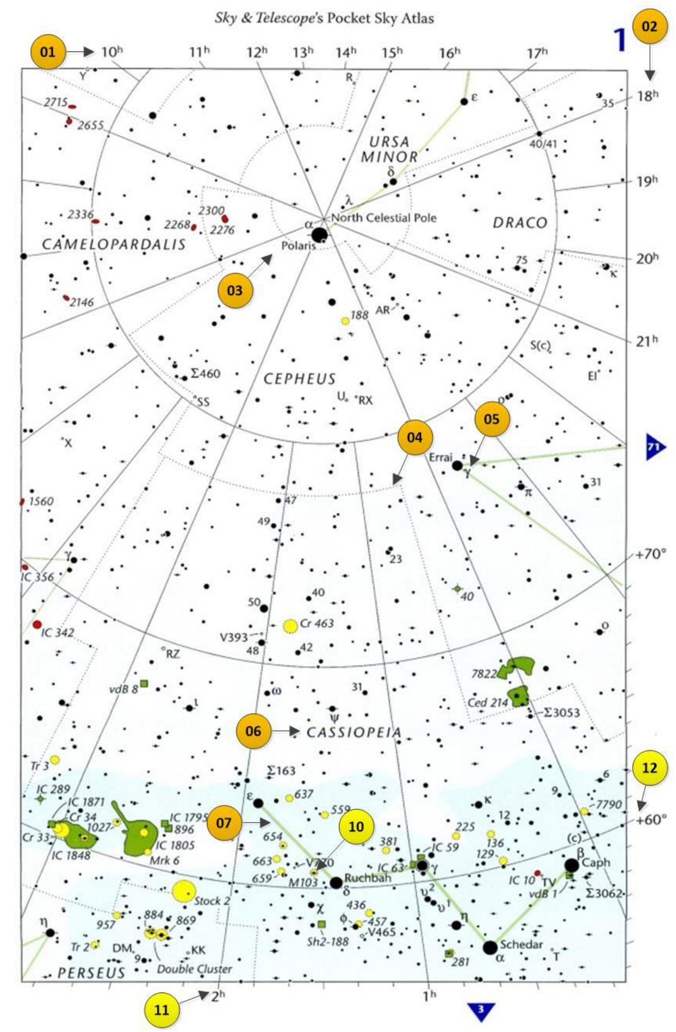
In addition to catalog numbers for the various catalogs we have reviewed you will find a number of features common to most star charts and atlases. Most will label common star names, constellation names, identify double stars, and also identify the major stars in the constellation if not by name with a Greek letter assigned by the German cartographer Johann Bayer in 1603 following the convention of the brightest star in the constellation being labeled the first letter of the Greek alphabet(α) the second brightest the next letter (β) and so on.



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

01. Right Accession (**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

Obtaining RA & DEC values of an item on the chart is accomplished by inspecting the RA scale (**11**), we see that each tick mark represents 10 minutes, while the DEC scale (**12**) represents 1° for each tick mark. Using this chart we can see item **10** is M 103, a small open star cluster located just to the left of the star Ruchbah (δ Cassiopeia) located in the constellation Cassiopeia. We can approximate the RA and DEC of this object to be about RA = 1h 32min with a DEC = 60.5°. Looking up this object online we see its actual real RA/DEC values as being RA = 1hr 33' 23" DEC = 60° 39' 30".

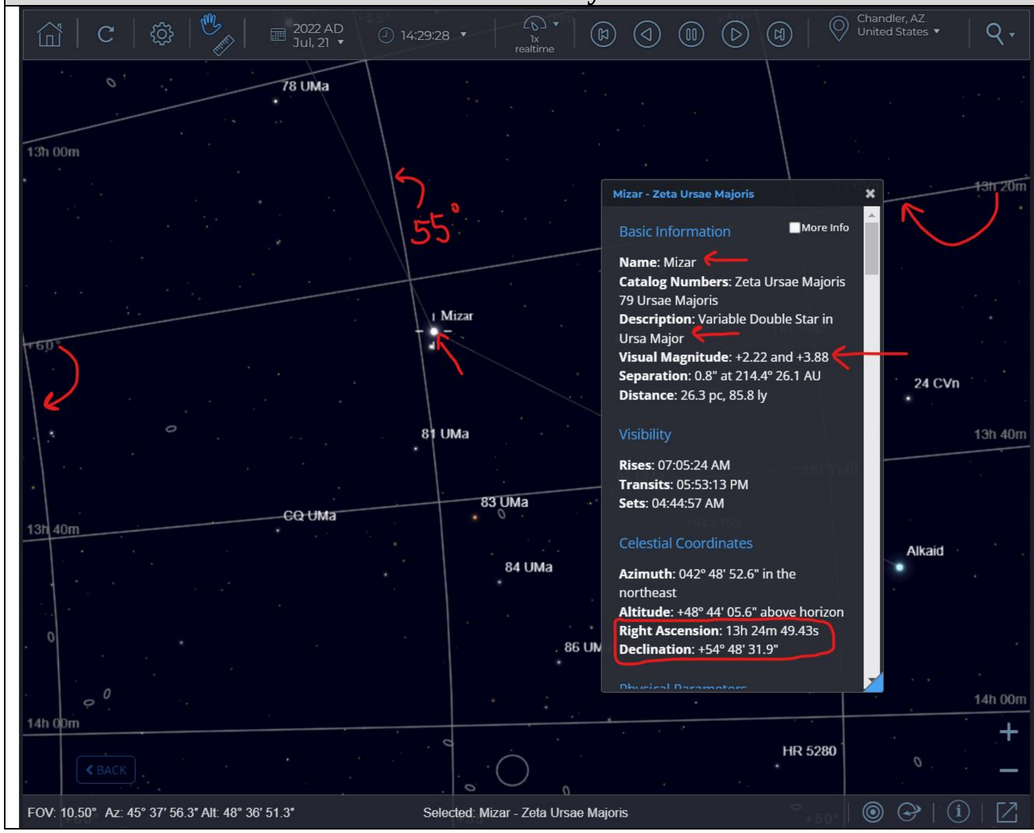


Putting it all Together

Suppose you would like to look at the star Mizar, a bright star located in the constellation [Ursa Major](#) (The Big Dipper) Using either a Star Atlas, or [online application](#) we can see it is located at RA 13h 24m 49.43s and DEC of +54° 48' 31.9". We can also see this is a variable star that indicates the brightness of the star can vary night to night. Mizar has a visual magnitude of +2.2 to +3.88, 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 also provides Azimuth and Altitude (AZ/ALT) coordinates. These values are only valid for the Date/Time and location the person was at when looking up this information.

A great online chart reference for Messier objects, NGC and IC catalogues can be located at [www.freestarcharts.com](#) and [Stellarium Web Online](#).

<table>
<tr><th>Mizar in Astronomy Software</th><th>Mizar in a Star Atlas</th></tr>
<tr><td>


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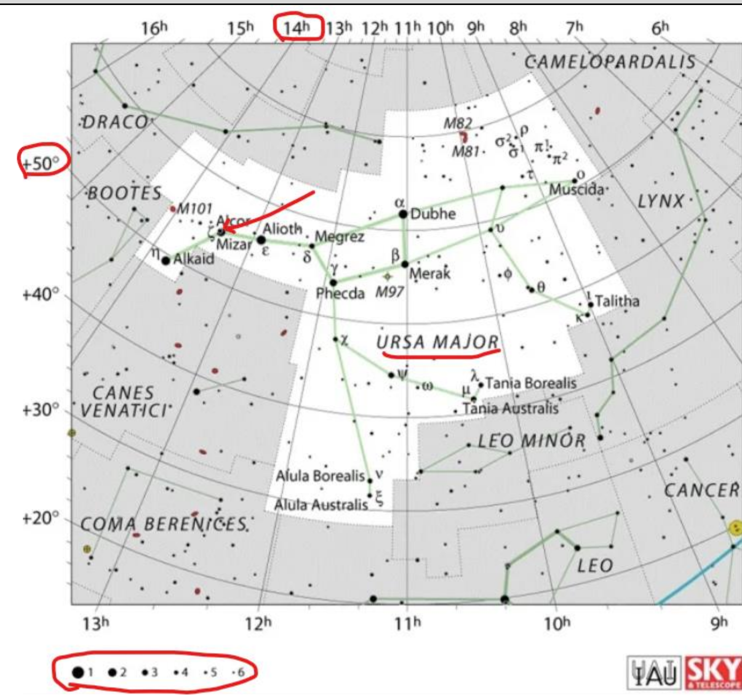


</td></tr>
</table>

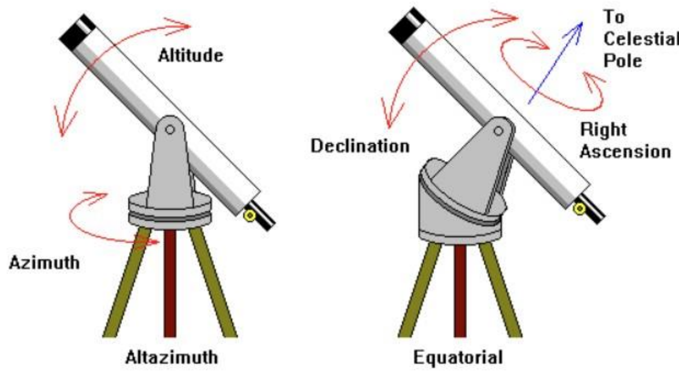
References and Resources

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.
The Live Sky	Website	Highlights objects of interest in the night sky
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 object located in them.
Light Pollution Map	Website	Online map that shows you how the sky is at any location on the planet
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 user to construct a detailed sky map.
Surface Brightness vs Magnitude	Webpage	Detailed discussion on Surface Brightness and the Magnitude system
Free Star Charts.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 axis points to the North Celestial North (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. • Generally unsuitable for Deep-Sky Astrophotography. • 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 sky once located if clock drive is included. • 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 axis to the North Celestial North (NCP).

Single Axis, Dual Axis and GoTo Telescope Drives

Manually locating and tracking an object in your telescope adds another layer of complication especially true 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 increase 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. Usually, the most cost-effective drives can be purchased when purchasing the Optical Tube Assembly (OTA), but the best mounts tend to be third party drives.

- **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 Accession axis and provides basic start tracking.

- **Dual-Axis Telescope Motor Drives** – Provides basic star tracking in addition to control of the telescope in any direction.

- **GoTo Telescope Drives** – Very popular and found on many telescopes. With GoTo drives, after 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 pad and let the computer slew the telescope to the object. 3rd party mounts tend to be quite reliable. Low-cost telescope/mounts can be fickle at best. Initial setup procedure can be challenging to master. If your 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 not really used anymore since the prices of GoTo mounts have dropped so much in price.

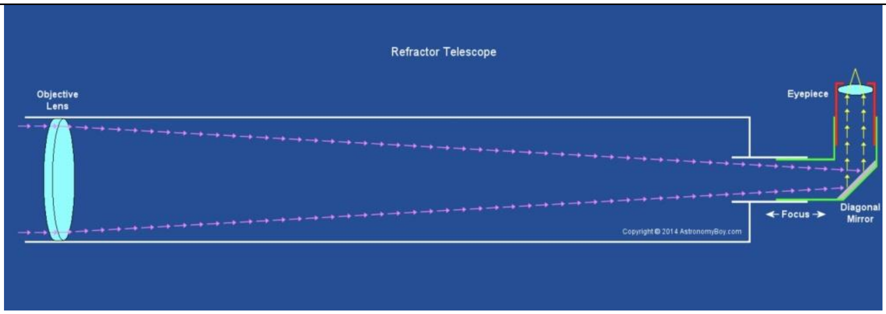
Clock Drive	Alt/Az GoTo Mount	Equatorial GoTo Mount
		

Optical Tube Assembly (OTA)

There are many types of Optical Tube Assembly (OTA) designs; Three of the most popular designed 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.

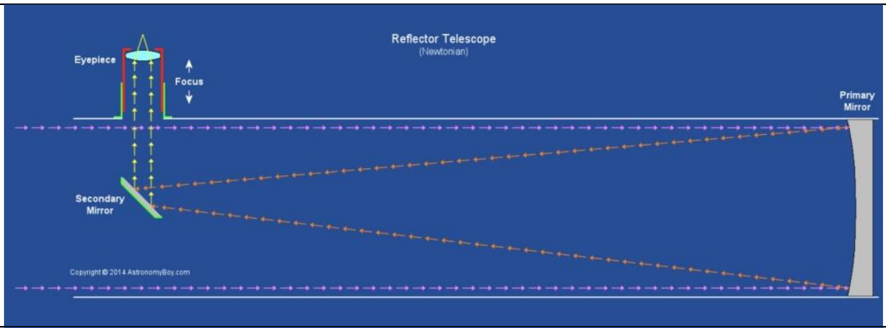
Refractor – A series of lenses are used to collect light.

- 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 aperture size) 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.



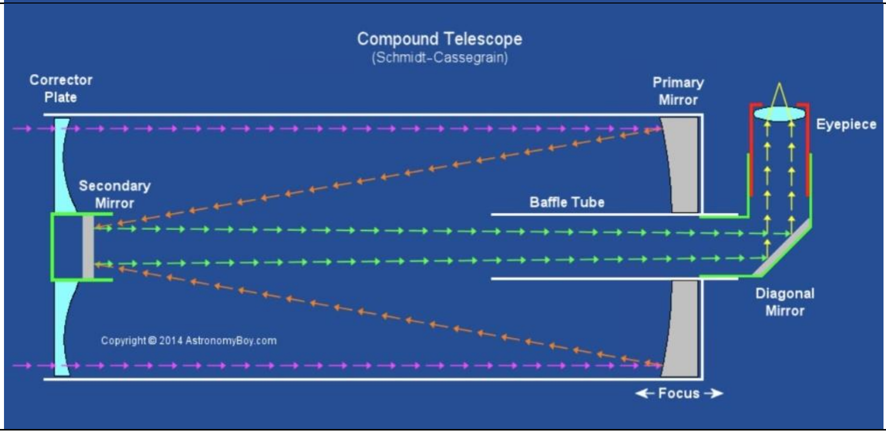
Reflector – A series of mirrors are used to collect light.

- 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: Not conducive to taking photos.



Schmidt-Cassegrain (SCT) AKA Compound Telescopes – 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: Generally, a good multi-purpose design performing well on plants, moon, and deep sky objects.
- Con: Occasional need for collimation.



Many Combinations

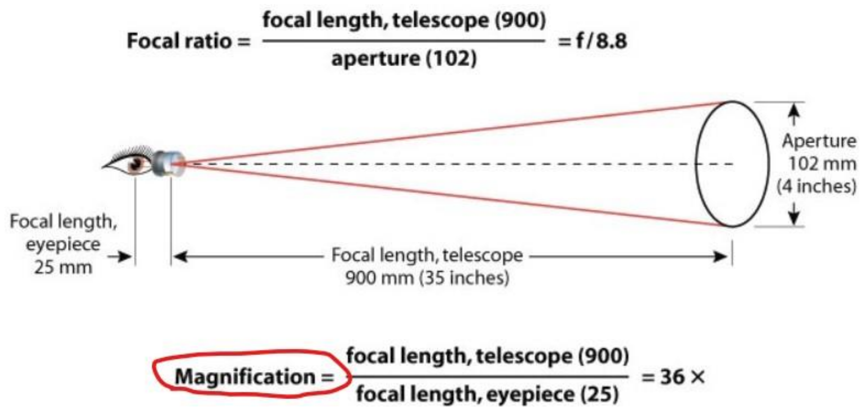
Combinations of Mounts and Optical Tube Assemblies (OTA) are vast. Here are a few examples

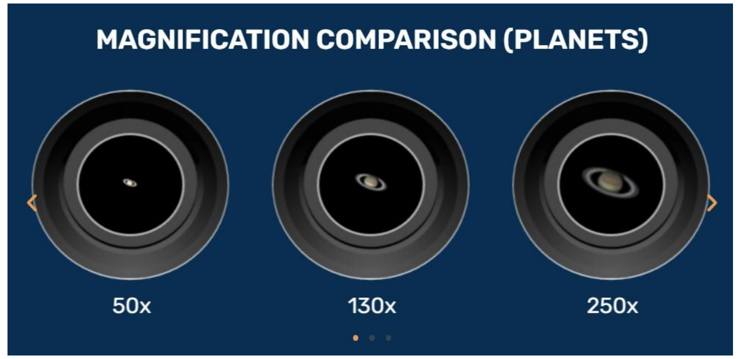
Many Combinations Possible (In no particular order)

 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 manufactures 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, magnification of over 250x is not very useful. Even if you have the same magnification between a small and large telescope, since the large telescope gathers more light, the large telescope will have a brighter image making it easier to see details.

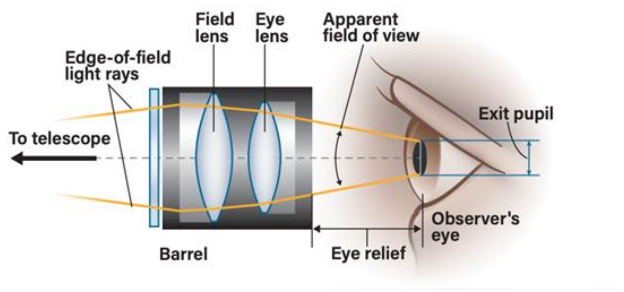




Exit Pupil

Exit pupil is a measure diameter of the cone of light exiting an eyepiece. As a general rule an exit pupil between 2mm – 5mm 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 waste light, while a very small exit pupil can be difficult for viewing. This is while exit pupil should be a consideration when considering purchasing an eyepiece. Exit Pupil calculation can be calculate with the following equations:

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



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

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) Masksutov-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	1.6 mm	61.2x
		4 mm	0.6 mm	122.5x

5.2" (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	27.0x
		8 mm	1.6 mm	81.3x
		4 mm	0.8 mm	163.5x

Finder Scope Alignment

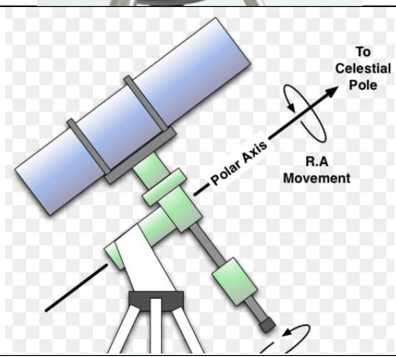
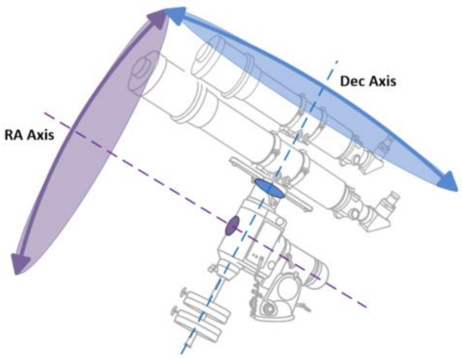
It is critical that the finder scope is aligned with the telescope. The first time you setup your telescope you should probably align the finder scope with the main scope during the day. Put your lowest magnification eyepiece in the telescope and point the main scope to a terrestrial object quite far from the telescope (tree top, 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. Details of alignment vary for various mounts. Information provided below offer a general summary for the type of mount described. Refer to your owners manual for more specific details.

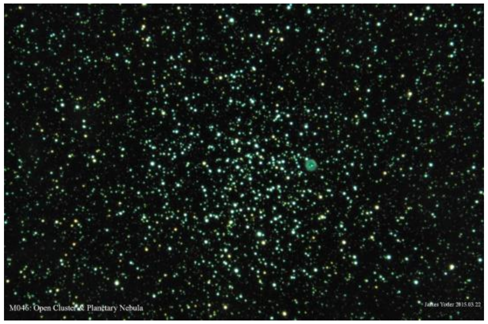
Image 1	Image 2	Description
		**Alt-Az Manual Mounts** – Setup for these mounts is quite minimal. Generally, you just need to make sure the mount is level. Many mounts have a level integrated in them; otherwise, you may have to supply your own. Some may have markings for either the Alt and/or Azimuth axis in these cases you may want to rotate the Azimuth axis to coincide with compass coordinate (ie 0° = North). This will enable you to utilize applications that supply Alt-Az coordinates to locate objects in the sky.

Image 1	Image 2	Description
		**Alt-Az GoTo Mounts** – Level the telescope. Turn on the GoTo computer and follow alignment instructions. Most mounts will have you point to two to three bright stars and to calibrate the mount.
		**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 point the RA axis toward the North Pole, next level the telescope. Adjust the counterweights to balance the telescope. Adjust the RA to match your latitude. Re-adjust the RA Axis to point at the North Celestial Pole (NCP). Many Equatorial mounts have built dedicated NCP scopes to assist in precisely aligning the mount with the Northern Celestial Pole.
		**Equatorial GoTo Mount** – Same basic setup as Equatorial Manual Mount to start with, then turn on GoTo computer and follow alignment procedure. Generally, will 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.



M-46: Open Cluster and Planetary Nebula

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, forming early in its history. Stars in a globular are gravitationally bound to each other.

M-12: Globular Cluster

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.

Galaxies NGC-4631 & NGC-4656

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 disk representing expanding gas from the source star.

NGC-7293: Planetary Nebula

Supernova - A structure that results from 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 shockwave sweeps up along the way.

M-1: Supernova Remnant

Reflection Nebula – Do not create its own light but instead shines 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.

M-45: Open Cluster and Reflection Nebula

Emission Nebula – Are unique in that it shines with its own source of light. Similar, to a planetary nebula, emission nebulae form from ionized gases. Emission nebulae tend to emit a reddish color as a result of the abundance of hydrogen in them.

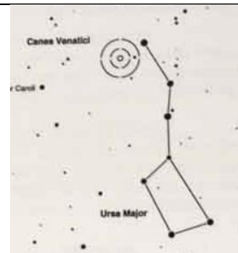
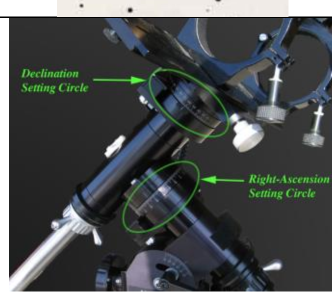
M-20: Emission Nebula

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

B-72: Dark Nebula

Techniques for Finding Objects

There are a number of techniques that can be used to locate astronomical targets, many depend on the telescope mount, some techniques are mount agnostic.

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. In this way the scope is first slewed to the bright star(s) then moving to the next star and continuing until the final star is located and finally the target object is move to. 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 that reference 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 be used also.
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, star atlas, or table of listed bright stars and coordinates. The setting circles are then adjusted to match the coordinates of the star. This ensures your scope setting circle 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:

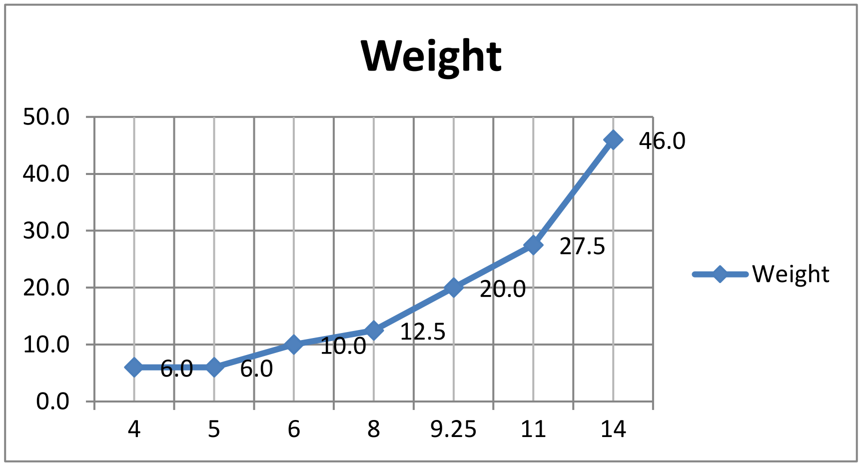
- **Budget** – What is your budget? Also, keep in mind that almost all telescopes will need accessories to make your viewing session pleasurable so don't consider the cost of the scope and mount to be the final cost. We will cover some of these costs in the accessories section.
- **Viewing Targets** – What to you intend on viewing? Larger scopes generally support higher magnification and gather more light making dimmer objects brighter. Observing very bright objects such as the moon and sun do not require large apertures.
- **Portability** – How often to you plan on moving/setting up the scope and where you intend on using it should be considered.
- **Tracking** – Once setup, 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 focus on observing the 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 telescope tend to be about ½ the cost of new ones. Periodically astronomy clubs will have auctions with used telescope 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.

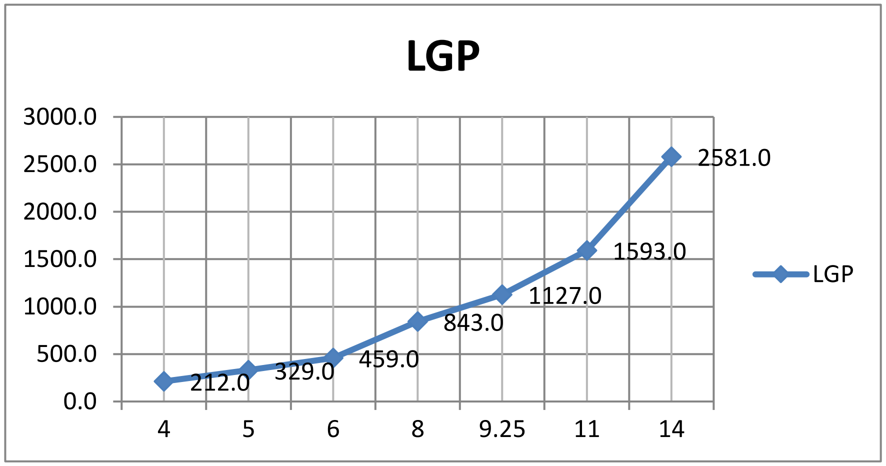
List it out – Make a list of everything you think you may need for your astronomy hobby so you can make an informed decision on what to purchase and how much the bottom-line cost will be. We will show examples of this in at the end of Chapter 4.

A Practical Example: Schmidt-Cassegrain

In addition to factors listed above one must 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	329.0
6	$840	150.0	10.0	459.0
8	$1,350	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	355.5	46.0	2581.0





References and Resources

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	Show you how large an object should appear for a given telescope and eyepiece combination
Telescope Magnification Explained	Website	More information on magnification and how to 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 eyepeices
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, technical know how and help from these guys is great.
AgenaAstro	Vendor	Good website for purchasing various astronomy equipment, located in California, so shipping time is usually quite low.

Chapter 4: Accessories

There are many different accessories you can purchase to help with your observing; some of the most critical include a good Head Lamp, Navigation Reference, Finder Scope and quality Eyepieces.

Headlamp/Flash Light

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 Apertura Astronomers Headlamp is a good fit for astronomy at $25 you may think it is a bit pricy for a headlamp, but believe me it is well built and a great investment.

Navigation and Planning Resources

We are talking about some reference 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 smart phone there is some excellent applications that can be used. I personally use my iPad mostly in the field, but bring a sky atlas as a backup. Below is a list of a few excellent references.

Reference	Media Type	Price Range	Comments
Star Wheel	Print	$15	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 smart phone or iPad I would consider this a must have reference. SkyPortal is a free app from Celestron and a light 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. There are 4 books they create; the best for the beginner is the Bright Telescopic Objects just for small scopes.
Sky Atlas	Digital or Print	$10 - $70	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, for more advanced observers and may be considered redundant if you already have an astronomy application such as SkySafari.

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 of these 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. Other much better cost-effective solutions exist. **I highly recommend using any one of the other options.**
	Reflex Sight Telerad – This is the original zero magnification finder. It is one of the more costly ones at $50 but with features the generally cheaper red dot finders don't have 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 hoping, the technique of hopping from star to star to the target object you wish to observe.
	Red Dot Finder – You can get a red dot finder as cheap as $20 on amazon and you can get them as expensive 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 – $50 dollars 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 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 some, 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 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 at amazon runs for about $25 and has a pigtail that makes it convent 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.

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 you get what you pay for is true, this is especially true for eyepieces. Prices range from as low as $25 to as high as $1,000 for a premium eyepiece. Decent quality ones tend to be in the $40 - $100 range. There are a wide range of types and designs to choose from. Factors such as what object you are viewing, the apparent field of view for the eyepiece, eye relief and exit pupil are a few things to consider when looking for the perfect eyepiece. Looking for the most cost effective yet high-quality performers the Plössl design eyepieces are a good option. Major manufactures 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 manufactures. Other manufactures such as Tele Vue and Baader only create high quality pieces so the concern isn't over the quality but more if it is appropriate for the object you are viewing.

- **Barrel Diameter** – The vast majority of telescopes accommodate 1.25" barrels, while higher cost, larger models will have 2" or even 3" barrel sizes some of the 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 a good eye relief are recommended since it makes 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 no matter how bad your vision is 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 persons with glaucoma.*
- **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. This is determined by the telescope focal length, eyepiece focal length and the diameter of the eyepiece barrow. This number is commonly placed next to the focal length of the eyepiece.
- **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 (i.e. 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 the Barlow lenses typically ranges from 2x to 5x magnification.

How many eye pieces 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 ($50), Celestron 8-24mm Zoom ($100), and Celestron Omni 2x Barlow ($40). This combination will prove effective to whatever you are viewing, be it deep sky galaxy and nebula, the moon or planets. A good wide field, low magnification (ie 40-60mm) should be one of your first purchases since it will likely be the first eyepiece you use in finding an object.

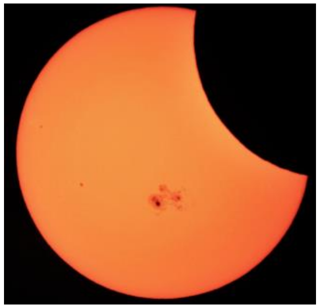
Celestron Omni Plossl series have reasonably priced good quality eyepieces with a wide range of focal lengths and might be a good starting point if you are considering purchasing some eyepieces.

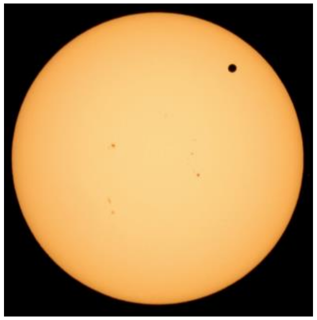
Solar Filter

Most telescopes can be used for observing the sun. A special broad band Mylar film that cuts out over 99.999% of light is placed over the primary aperture. Cost is very reasonable costing between $20 - $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 material required to make your own filter you desire. Solar observation is one hobby that a small telescope may be considered a great fit. With these filters attached to your telescope you can watch the progression of sunspots, observe solar eclipses, and inner planetary transits.


Purchased Solar Filter


Home Made Solar Filter


Solar Eclipse


Venus Transit

Other Filters

Other filters for night observation can help see more detail than you might see without it especially in the city where light pollution can be a real problem. Filters have three major applications 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, ($95) so if there is only one filter you can purchase, make this the one. Filters generally bring subtle improvements to the viewing experience.

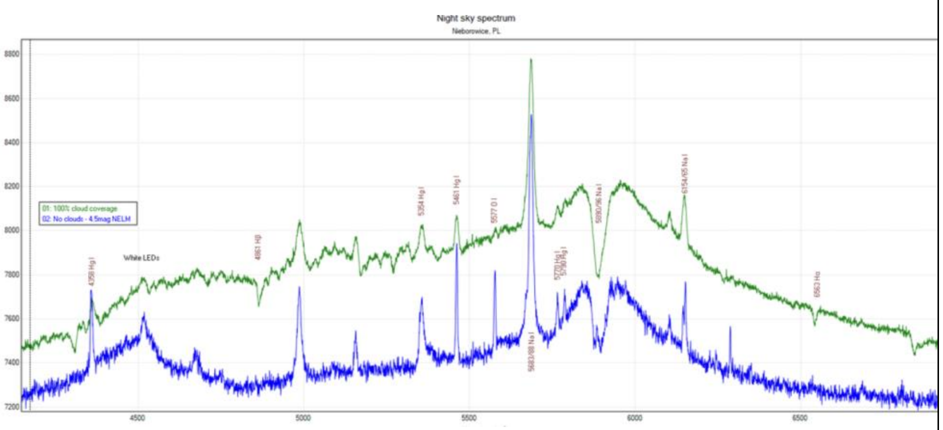
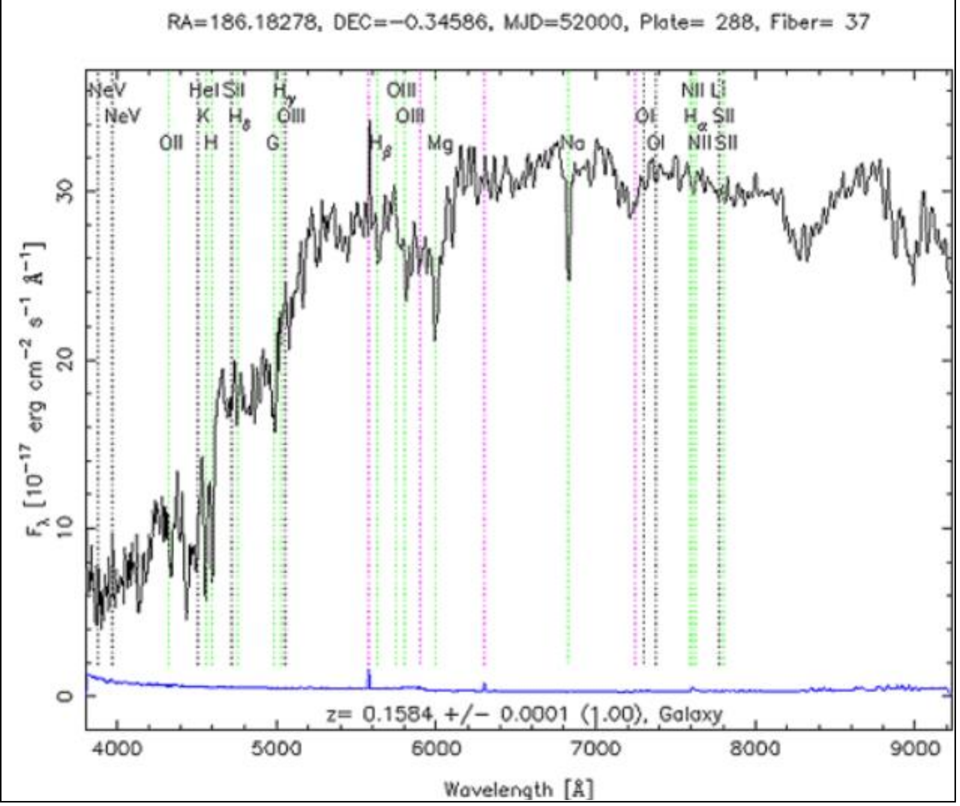
An in-depth discussion on the types of filters and are available for deep-sky observations along with information on what filters to utilize for various deep sky targets can be downloaded from the ArtCentrics Website here: Deep Sky Filters for Visual Observation (PDF)

Object	**Filter Type**	**Cost**	**Comments**
Moon	Polarizing Variable filter	$40	Polarizing filters are among the more popular filters for the moon, but other filters are useful in helping stabilize the image when high magnification is used by cutting down atmospheric interference.
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		Application of color filters to planets is to bring out certain 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.

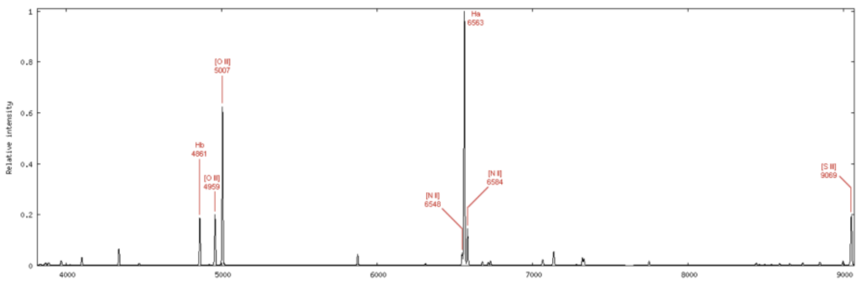
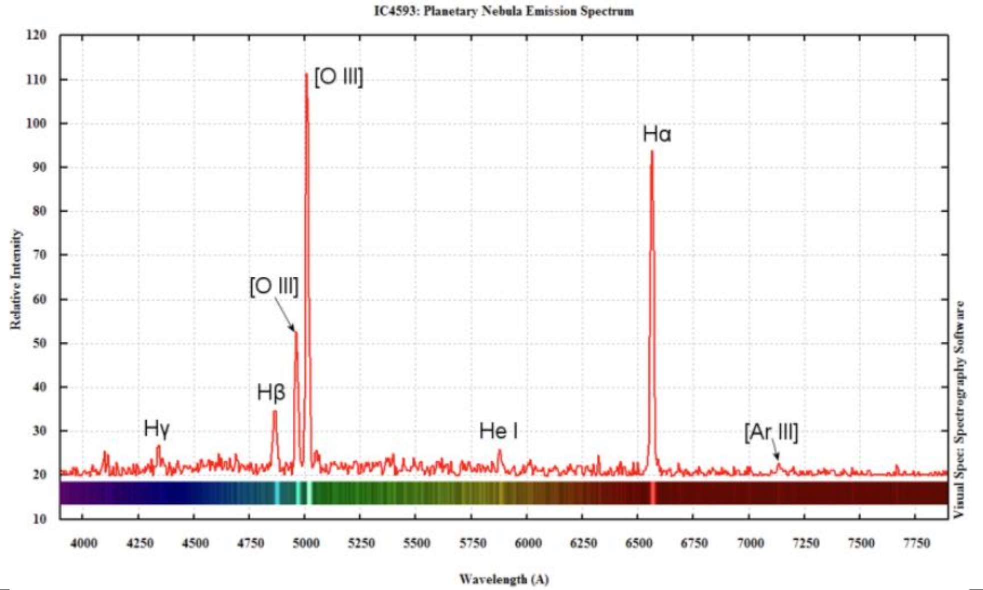
Further Discussion on Filters and Applications

Deciding if a filter is needed, and what 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 cannot be directly compared, but that isn't the point here, what we are interested in is the general shapes of each of the spectrum provided.

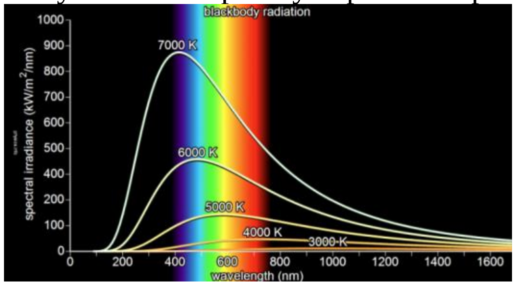
Night Sky Spectrum	Broad Spectrum: Galaxy Spectrum
	

Here we can observe that the night sky (with light pollution) has a broad band spectrum where light is being emitted in all visible wave lengths. Similarly looking at the spectra of a galaxy, it can be classified as having a broad band spectrum. Generally, one can classify Stars, Galaxies, Open Clusters, and Globular Clusters as broad band sources.

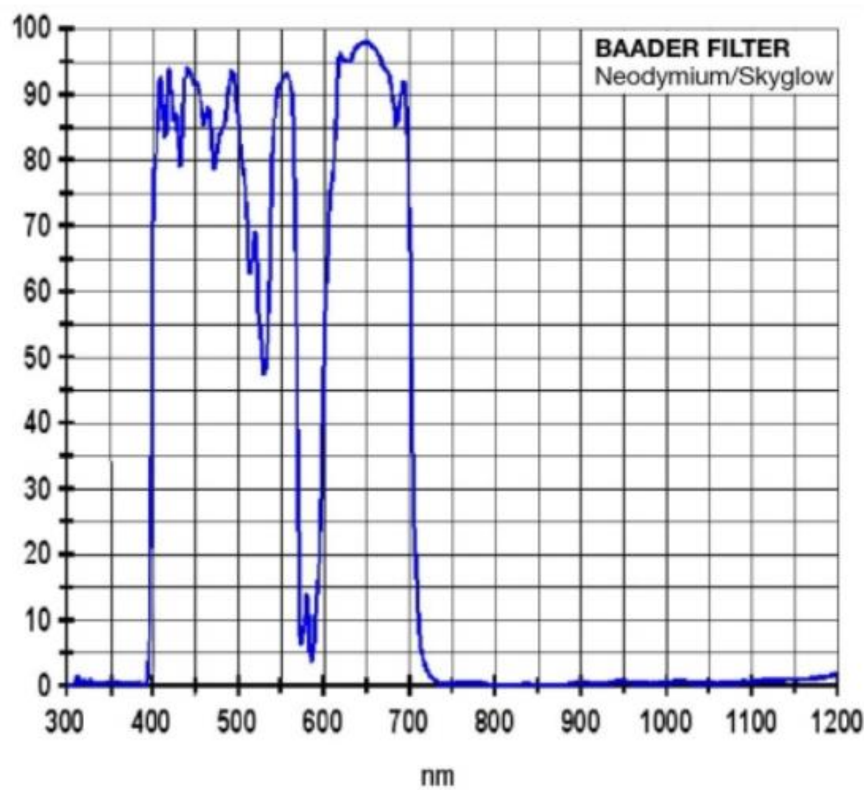
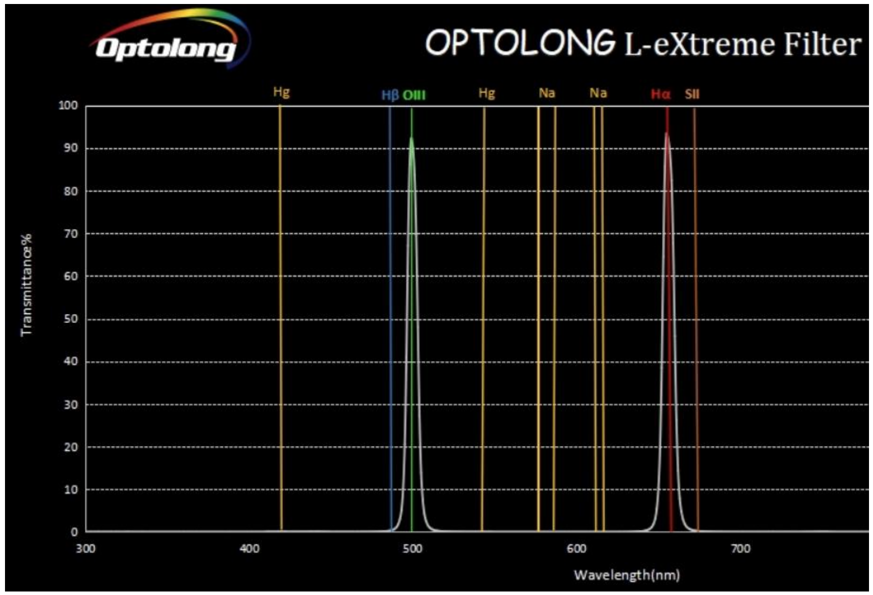
Below are spectra of Emission Nebula. These are loosely defined as cool gas clouds that are emitting light due to a close by energy source. Deep sky objects such as Molecular Gas Clouds (ie Orion nebula), Supernova Remnants (ie Veil Nebula), Planetary Nebula (ie Ring Nebula) emit light mostly in distinct wavelengths. Specifically, Hydrogen alpha, and beta; Oxygen III and Sulfur II. These are classified and narrow band emissions.

<table>
<tr><th>Emission Spectrum: Orion Nebula</th><th>Emission Spectrum: Planetary Nebula</th></tr>
<tr><td>
</td><td>
</td></tr>
</table>

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 temperature. Cool gasses have low energy and only emit light at discrete wavelengths. However, once the gasses start to heat up the electrons associated with them are freed from the individual atoms and begin to emit at all wavelengths. There spectra begin to mimic a black body and have the spectrum of a black body that is completely dependent upon 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 you are attempting to observe, thus providing better contrast for the target object compared to the background. At the very high level we can classify them as either broad band or narrow band filters. Broadband filters take into consideration the spectra associated with light pollution, but are aware of the many wavelengths of light from the deep sky object, so their transmission spectra are rather large. Narrow Band 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 to the object being observed.

Broad Band Filters Transmission Spectra	Narrow Band Filters Transmission Spectra
	

For viewing non gaseous/plasma sources such as 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 in any of these objects, so may be a good filter to have around when observing planets and the moon.

KEY

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

What filters to what Targets?

Targets	**Filter(s)**	**Comments**
Emission Nebula, Planetary Nebula, Super Nova Ruminants	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 nebula.
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 round filter.
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	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 ($95) – An overall good filter should help all of these objects (although it will likely be subtle).
2. #80A Blue Filter ($20) – A low cost and general useful for most planetary and moon viewing.
3. Polarizing Filter ($25) – Good for viewing the moon.
4. Narrow Band Filter ($200) – May help with the narrow band targets.

The Astronomik website has great descriptions of filters they make and what are appropriate applications for each of these filters. This company makes some good filters. Baader and Astronomik are also companies known for their high-quality filters but there are others that make excellent filters.

Celestron GoTo Telescopes with AUX Ports

Mark Lord (mlord@pobox.com) designed and built a great accessory that works with many Celestron GoTo mounts called the HomeBrew Gen 3. It is compatible with CPWI, SkyPortal, SkySafari+/Pro. The HomeBrew contains a GPS ($190 from Celestron), and WIFI ($140 from Celestron) and support for WII Numchuck for telescope control among other features. You can make your own or email Mark and ask him to ship one to you that he created for just over $100. This is a Great Accessory for Celestron GoTo mounts.

Other Accessories

There are 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	$15	Critical for planning your night
Starwheel	Night Sky Star Wheel	Used for seeing what constellations are up	$15	
Headlamp	LED Headlamp	Expensive but best headlamp for Astronomy	$25	Three RED brightness levels
Potable Table	GCI Portable Table	Small portable table for equipment	$40	Larger Table here ($100)
Portable Chair	Alevmoon Portable Stool	Portable Stool	$35	
Dust Bulb	UES Air Blower Bulb	Used for cleaning optics	$10	
Dust Brush	Orion 5830 Ultra Brush	Used for removing dust from optics	$10	
Total			**$150**	

Putting It All Together: Two Examples

Ref: [Best Telescopes/Scope Combos at $200, $500, $100, $2,500, $5,000, $10,000 and $50,000]

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 $1,600. Also keep in mind these are cost 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 114 AZ	4.5" (114mm)Reflector including • Eyepieces: 25mm, 10mm (40x, 100x) • Red Dot Finderscope • Tripod & Alt/Az mount Focal Length: 1000mm Aperture: 114mm Focal Ratio: 9.0	$240	Smartphone can be used to guide you to objects in the sky.
Accessories	Celestron Omni 40mm eyepiece	40mm Plossl Eyepiece = 25x	$50	
Accessories	Celestron Omni 2x Barlow	Barlow lens provides 2x magnification	$40	With eyepieces: 32x, 51x, 128x
Total			**$330**	
With Accessories		All mentioned accessories in first table	**$480**	

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	$900	GoTo mount and tripod Aperture: 150mm Focal Length: 1500mm Focal Ratio: f/10
Accessories	Celestron Omni 40mm eyepiece	40mm Plossl Eyepiece = 37x	$50	18
Accessories	Celestron 8-24mm Zoom	Variable Mag: 62x – 188x	$100	
Accessories	Celestron AC Adapter	Power adapter for telescope mount	$30	
Accessories	Baader Moon & Skyglow Filter	Moon and sky pollution filter	$95	
Total			**$1,275**	
With Accessories	All mentioned accessories	Accessories in first table	**$1,425**	

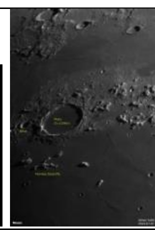
References and Resources

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 setup. This package handles cold weather $95. Must have green laser for night usage, red does not work.
Red Dot Finders	Website	Multiple Choices $19, $23, $40, $50 Generally 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 differ types and what types to utilize 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, skill required for photographing astronomical objects is mostly depended 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 differ.

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 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 the back 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 utilized in Deep Sky photography.
Moon Planets and Bright Deep Sky	 	Difficult	$100 - $500	**Lucky Imaging** is where you place a specialized camera in place of an eyepiece to capture videos or images of planets, 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 a minimal of clock drive, associated guide scope, camera and computer are needed to make adjustments to guiding during the exposure. Specialized cameras are generally utilized for best results and run between $1,000 – $10,000 (Really the sky is the limit here).

Smart Telescopes: New hardware has recently been added to the mix that make 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 are an increasing number of options available, currently the most popular include:

- ZWO Seestar S30 List price = $350
- ZWO Seestar S50 List price = $500
- Celestron Origin List Price = $4,000

Try it before you buy it. East Valley Astronomy Club (EVAC) currently rents out astronomy equipment including the ZWO SeeStar S30 and a planetary imaging kit (Everything supplied but the telescope) to members for $25/week.

Targets for Beginners

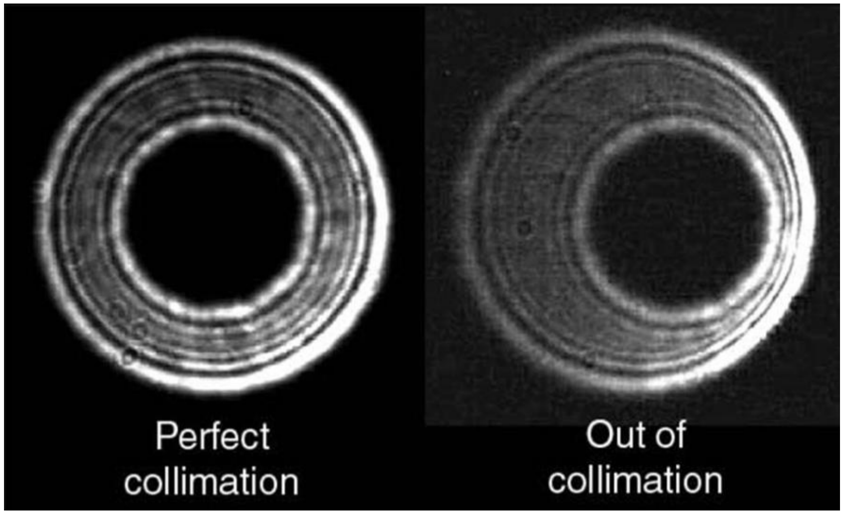
Most amateur astronomers find to have a good observation session they need to make plans on what they will be observing in the evening. An excellent tool to help making your plans is The Sky Live website. It has sections dedicated to the Planets, Comets and Asteroids. the Night Guide section along with the Planetarium will help identify potential targets for the evening and help determine 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 type 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 only cost $1
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 suns orbit each other. Even small telescopes can view many of these. If you really want to dive deep into this topic, here is a PDF download (137 pages) all about Multiple Star Systems, and how to observe them.
Planets	• Jupiter's Moons (iOS) $3.00 • Saturn's Moons (iOS) $3.00	Jupiter, Saturn and possibly Mars are a joy to view in almost all size scopes. One thing I really enjoy is finding out when you can see one of Jupiter's moon shadows go across the surface of the planet (Transit). The iOS application Jupiter's Moon is excellent for making plans on observing Jupiter.
The Sun	• SOHO Observatory • SpaceWeatherLive.com	An inexpensive solar filter can be made for you telescope (<$50) allowing you to view sunspots, eclipses and even transits of planets.
Deep Sky Objects	• 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. Nebula such as the Great Orion Nebula (M-42), a galaxies such as the Andromeda (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 (ie 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 micro fiber towels and/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 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 requiring occasional collimation. Temperature variations and vibrations from moving the telescope are the main causes a telescope to lose collimation. Checking to see if your telescope needs collimation is an easy enough task to perform. Simply center a bright star in center of the field of view and bring it out of focus to form a doughnut shape pattern. If the hole in the pattern is off-centered the telescope is out of collimation. There are a lot of different tools sold to assist for collimation ranging from $15 - $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.



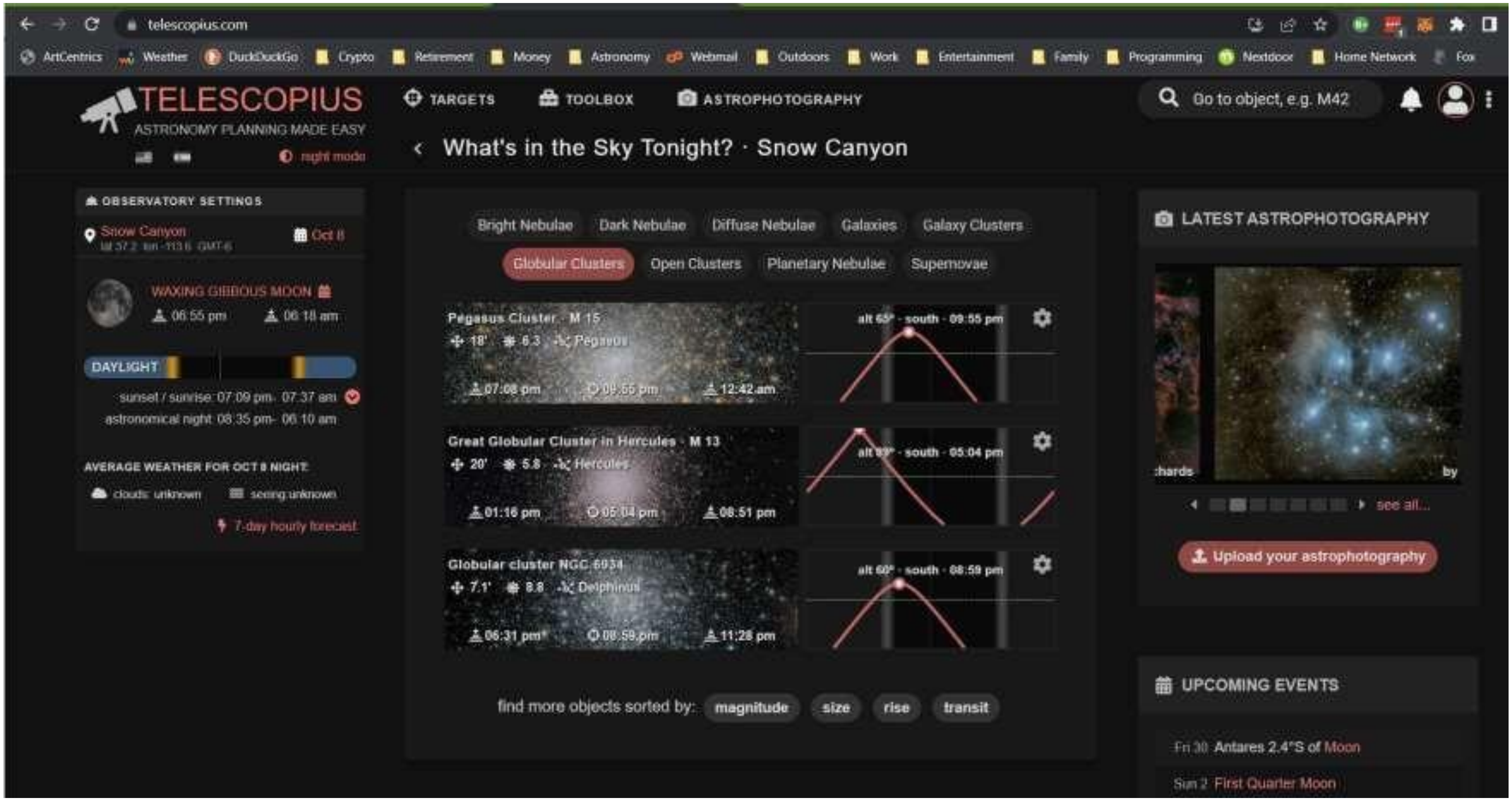
Advanced Session Planning Tools

There are a number of applications available to help assist 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. Price range for the identified programs range from free to over $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
DeepSky Astronomy Software	Free	Windows	• It's Free!	• A little tricky to install • No longer actively supported • Some features do not work • Interface is dated and charts
AstroPlanner	$45	Mac OS X & Windows	• Reasonable price • Flexible • Pretty easy to use • Large list of catalogs • Large selection of user supplied plans that can be downloaded.	• This product is probably the best bang for the buck if you want to spend money on this type of application.
Deep-Sky Planner	$10-$75	Windows, iOS, Android		
SkyTools 4	$100-250	Windows	• Most comprehensive package	• Very Expensive • Fairly complicated

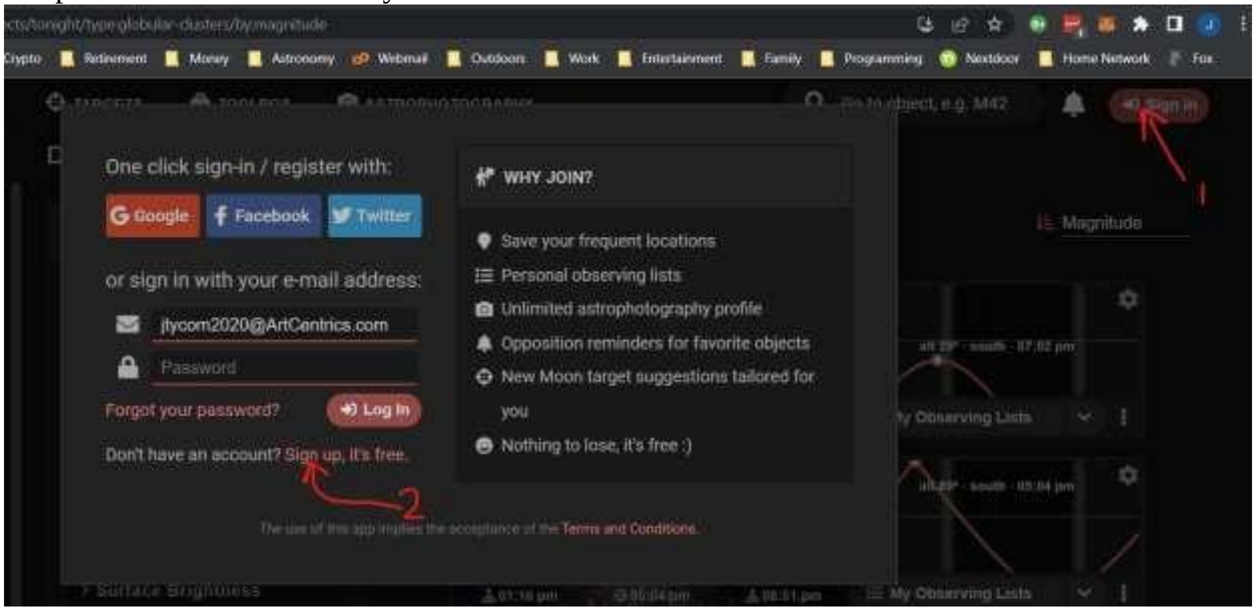
Telescopius

Telescopius is a website mostly focusses on providing information for imaging and planning imaging sessions, but is also a good cheap 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 in the website will always appear much brighter than you should expect to see in your telescope. Indeed, many objects available in this website will be much to dim to view with your telescope, so it is vital you utilize filters to specify Magnitude and Surface Brightness to eliminate those objects that are appropriate for imaging but unavailable for viewing.

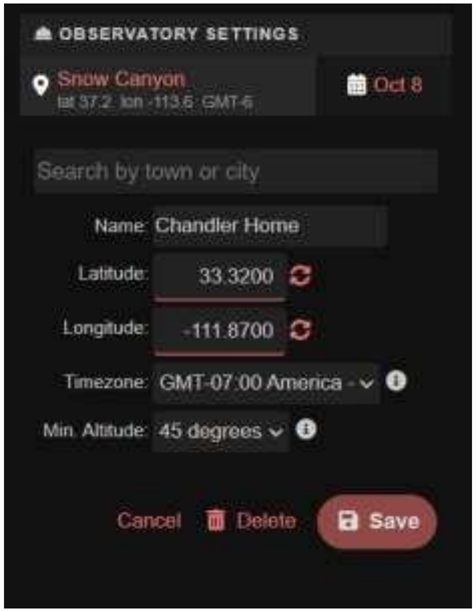


<u>Telescopius Workflow</u>

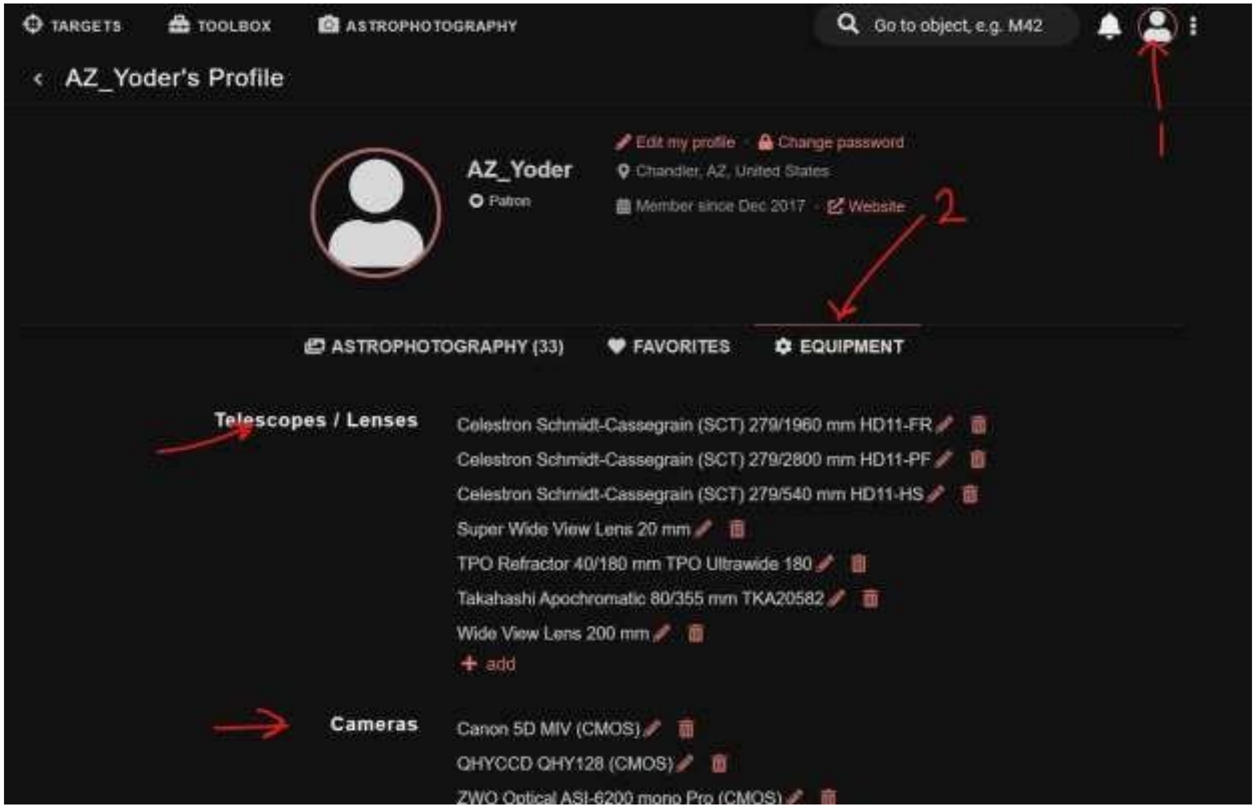
1. First Time Setup – Basic setup information needed for your account.



   a. **Setup 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.

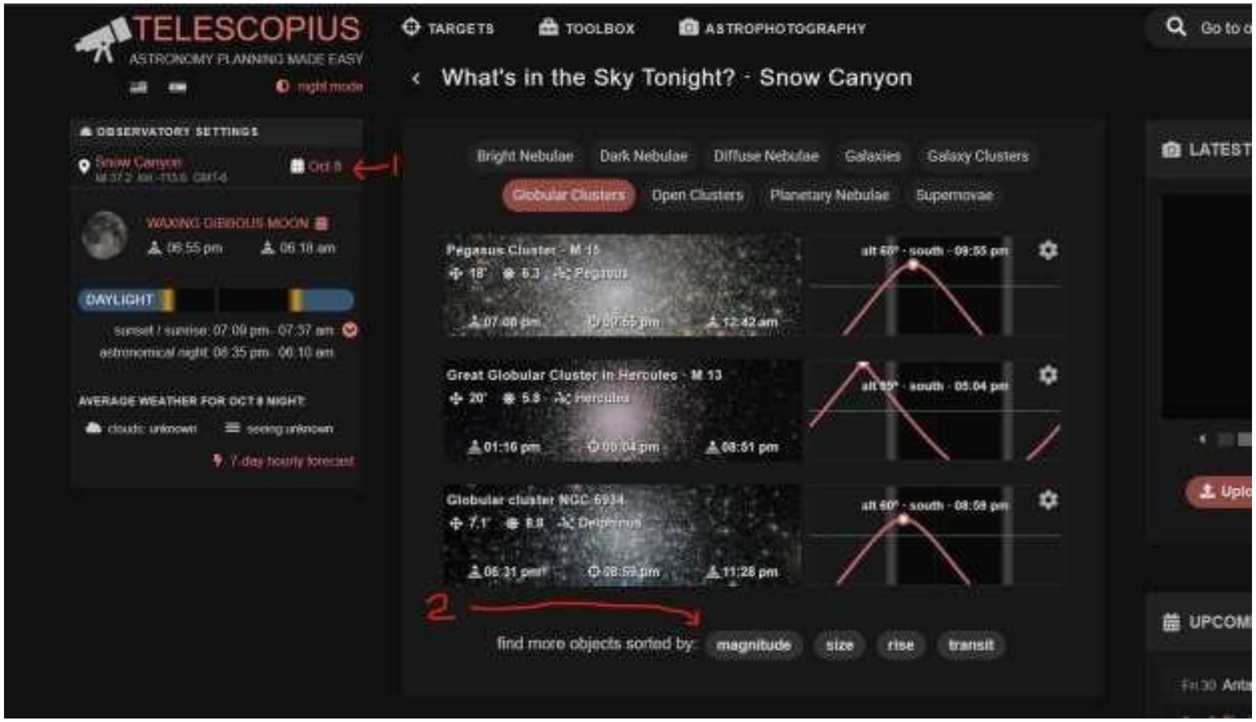


b. **Setup Observatory**: Identify the location of your observing site by selecting the Observatory Settings select the Date of the observation and setup your Observation site. You can also set your Min Altitude for observation (generally I set a min Altitude of 45°).

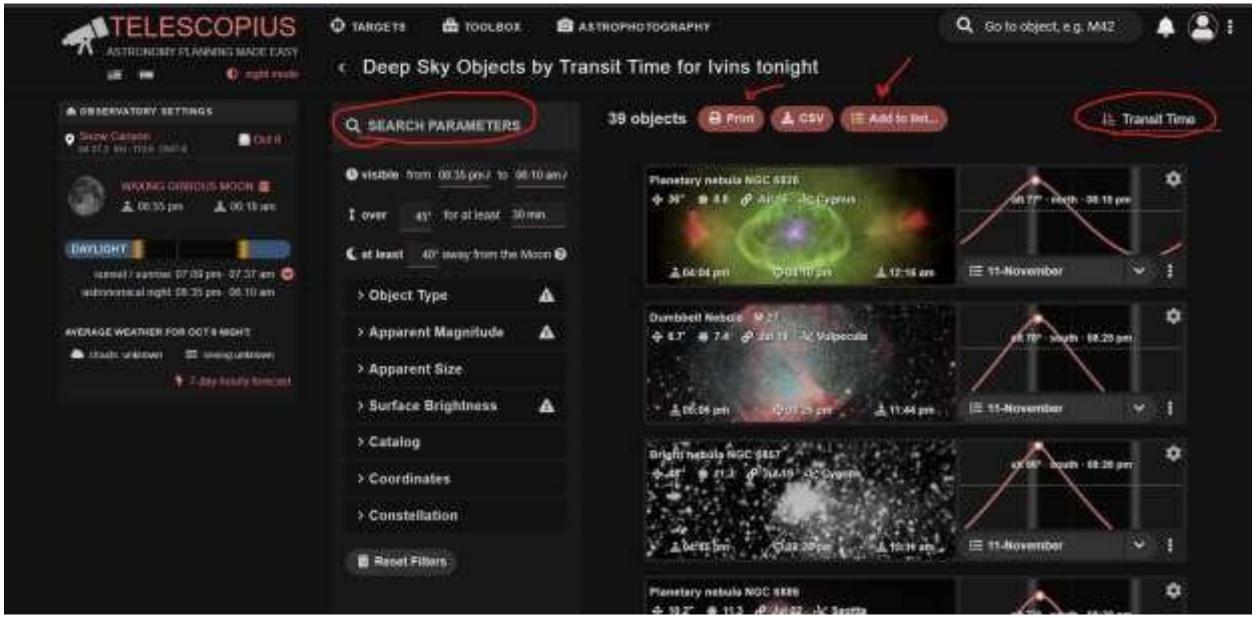


c. **Configure Hardware**: Open your Profile page by selecting the person icon located in the top right of the page. Once this page is open select the Equipment link located just under the profile summary in the main window. Provide hardware equipment specifications including Telescope specs, Mount specs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

2. Generate Observation List



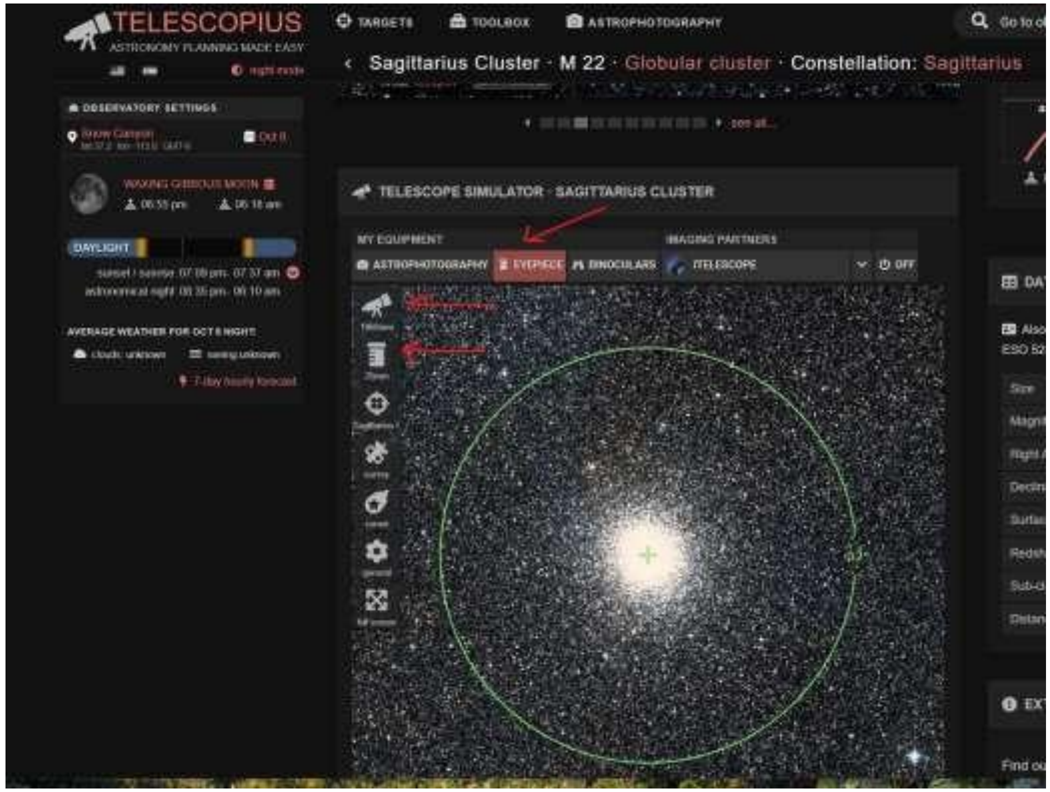
a. **Set the observation Date**: Located under the Observatory Settings on the Left side of the window.



b. **Set Filters**: In the main screen select one of the buttons (Magnitude, size, rise, transit) located to the right of the 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-med telescope in the city.
   i. **Visibility Factors**: Timeframe, Min altitude time, etc.
   ii. **Object Type**: Diffuse Nebula, Galaxies, Galaxy Clutters, 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.



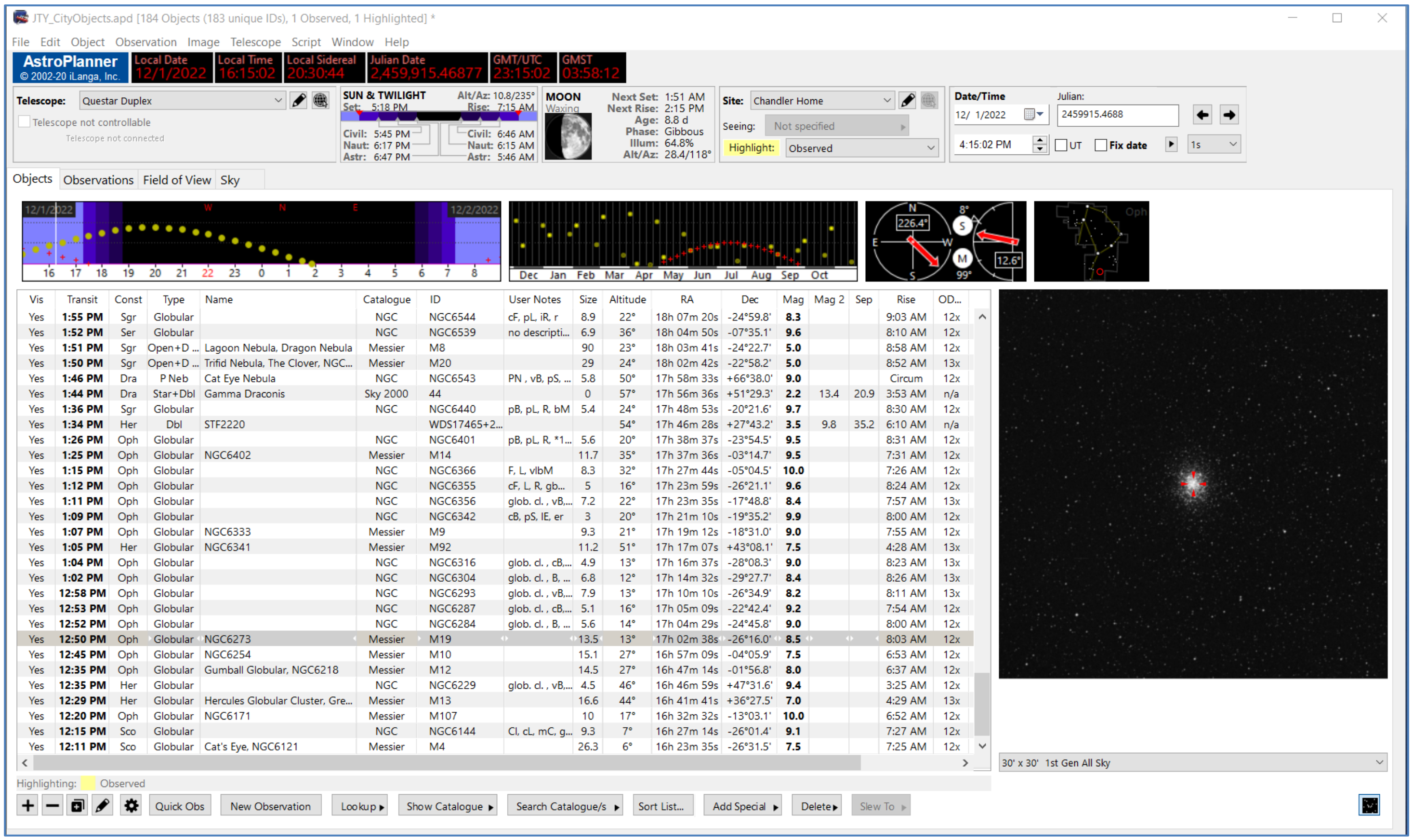
e. **Check it out:** You can take a look at how large the object should appear for your telescope and eyepiece combination by selecting the object in the list and reviewing in the Telescope Simulator. *NOTE: Objects here will always appear much brighter than what you will find in your telescope no matter 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 when equipment specifications have been entered in the application a field of view of targets that represents the size of the target in your eyepiece for your telescope can be reviewed.

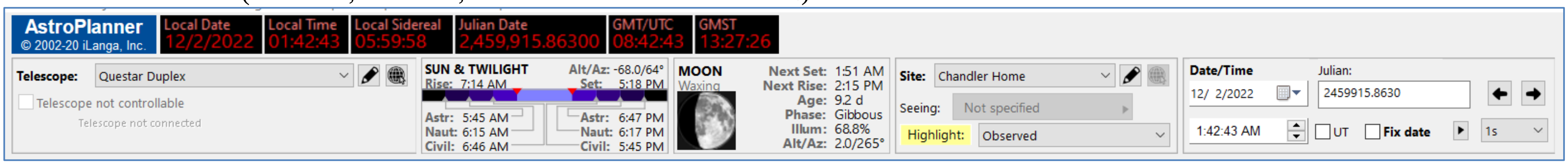
The manual for this application is over 400 pages long, so we can’t possibly cover most aspects of this application but we will cover some of the high-level basics.



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

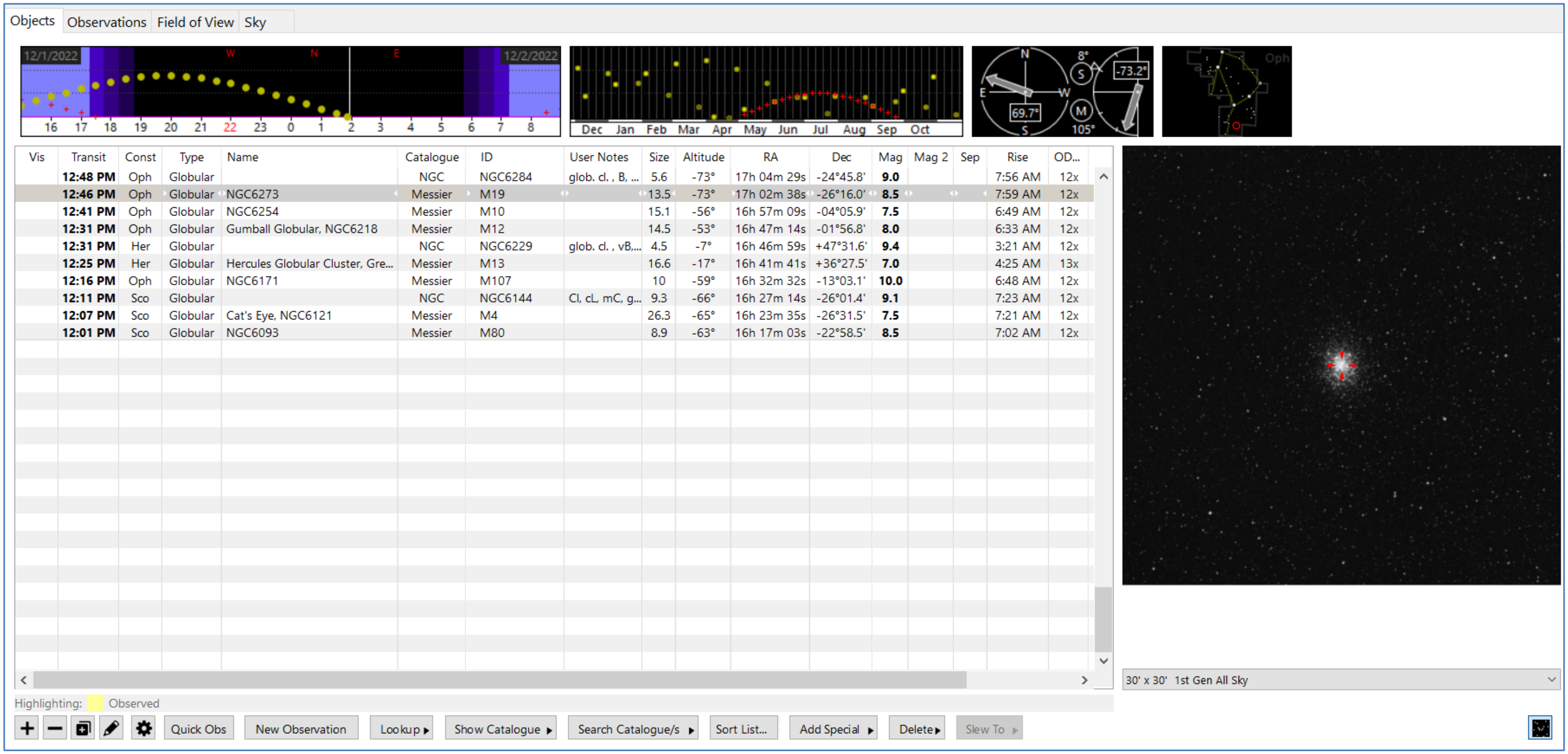
Main Menu
Located at the top of the application is the name of the observation plan that is loaded and immediately below that is the primary menu.

Common information and Settings Section
Information associated with your planned observation session including location, date/time (Fix Date), Telescope Astronomical data including Sun and Moon related data (ie sunrise, moonrise, Astronomical dusk & dawn etc.)

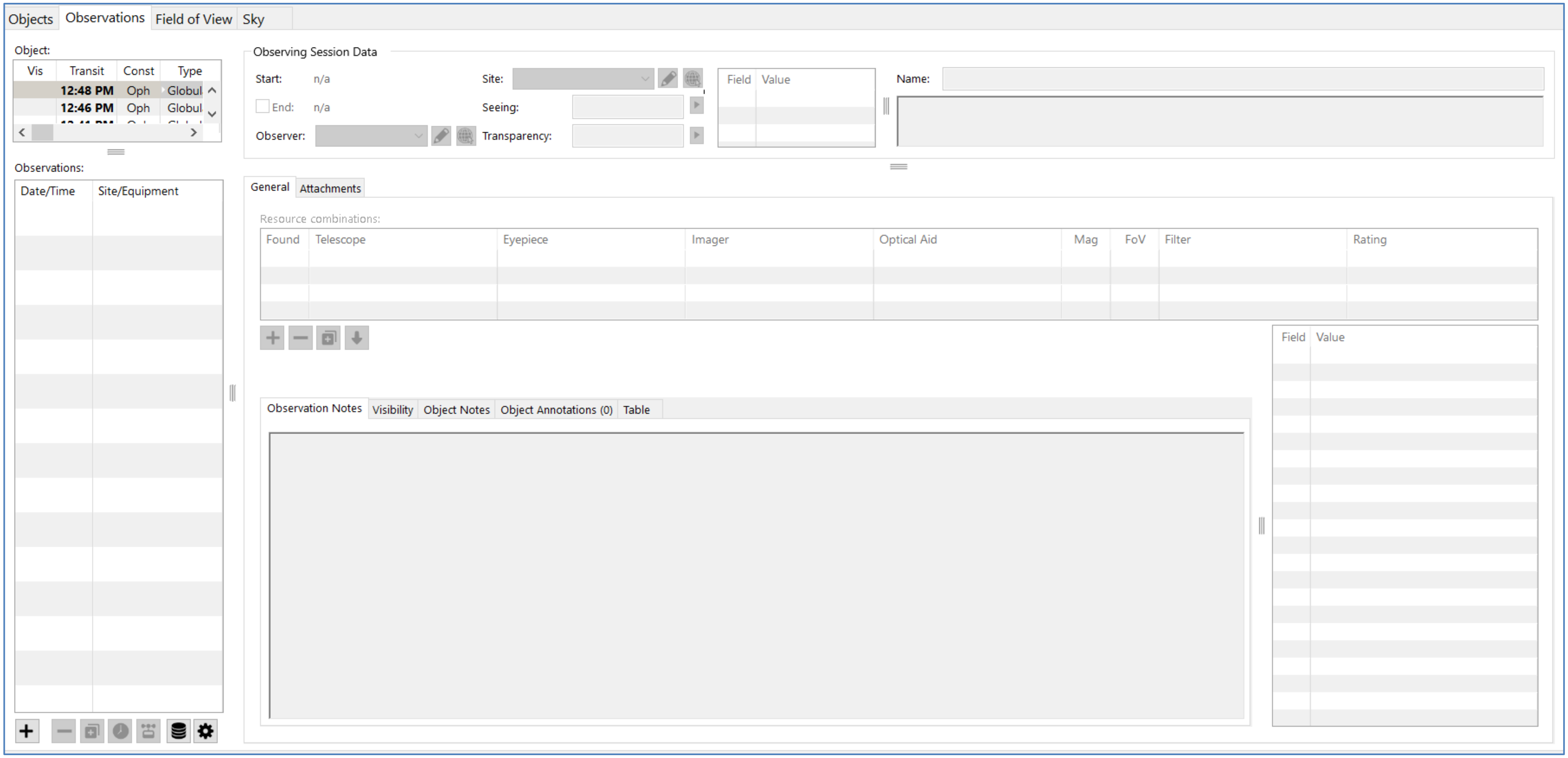


Primary Working Section
Primary Working section consists of four tabs (Objects, Observations, Field of View, Sky) that represent the primary functionality of the application. Each tab has its own unique data/screen associated with it.

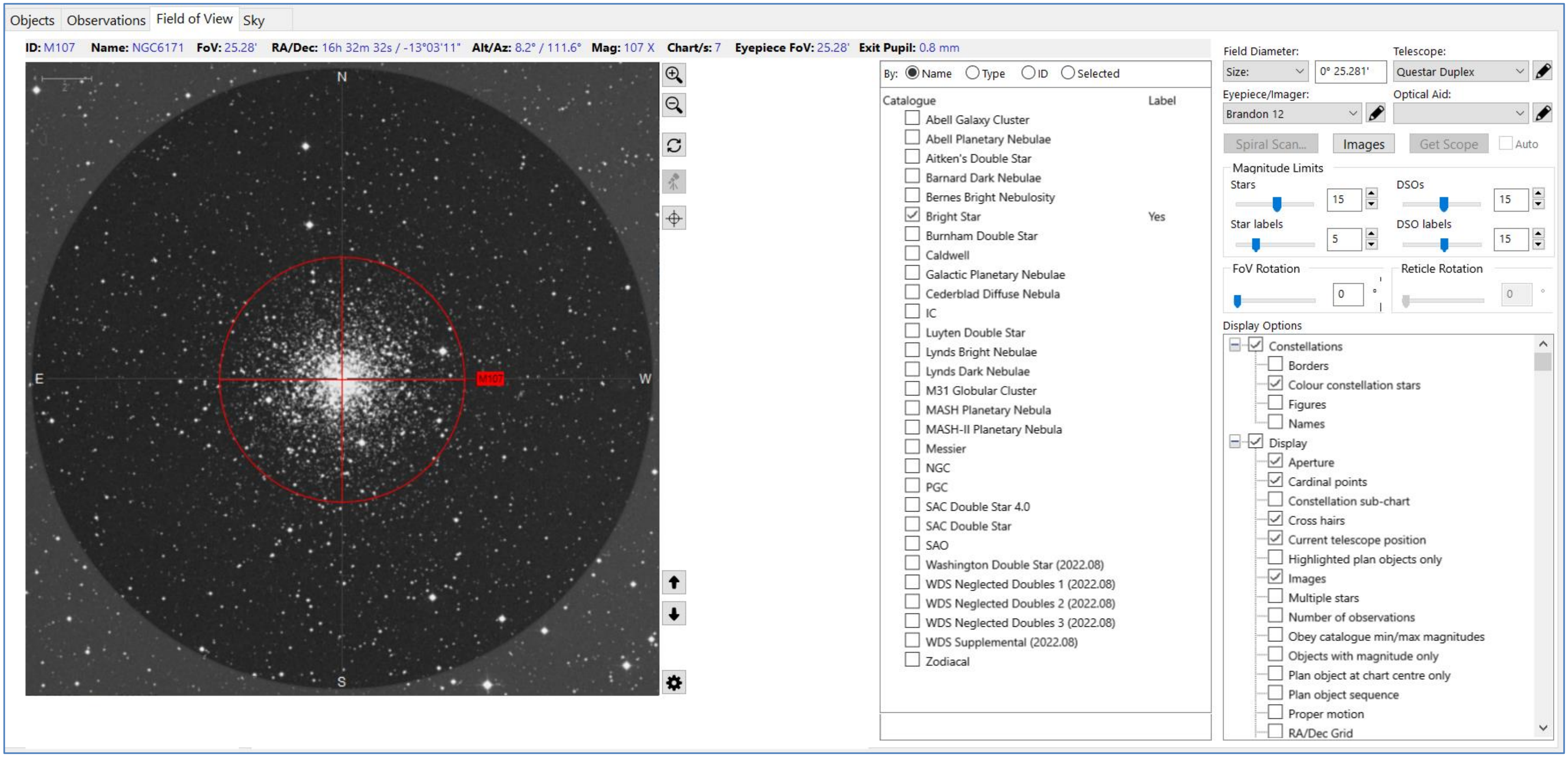
Objects tab – This is where items for observation are displayed. We also use this screen to locate and add additional objects for observation.   The main datagrid contains the list of objects and supporting details on each of the objects for observation.   Selection of any item in the displayed list 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.



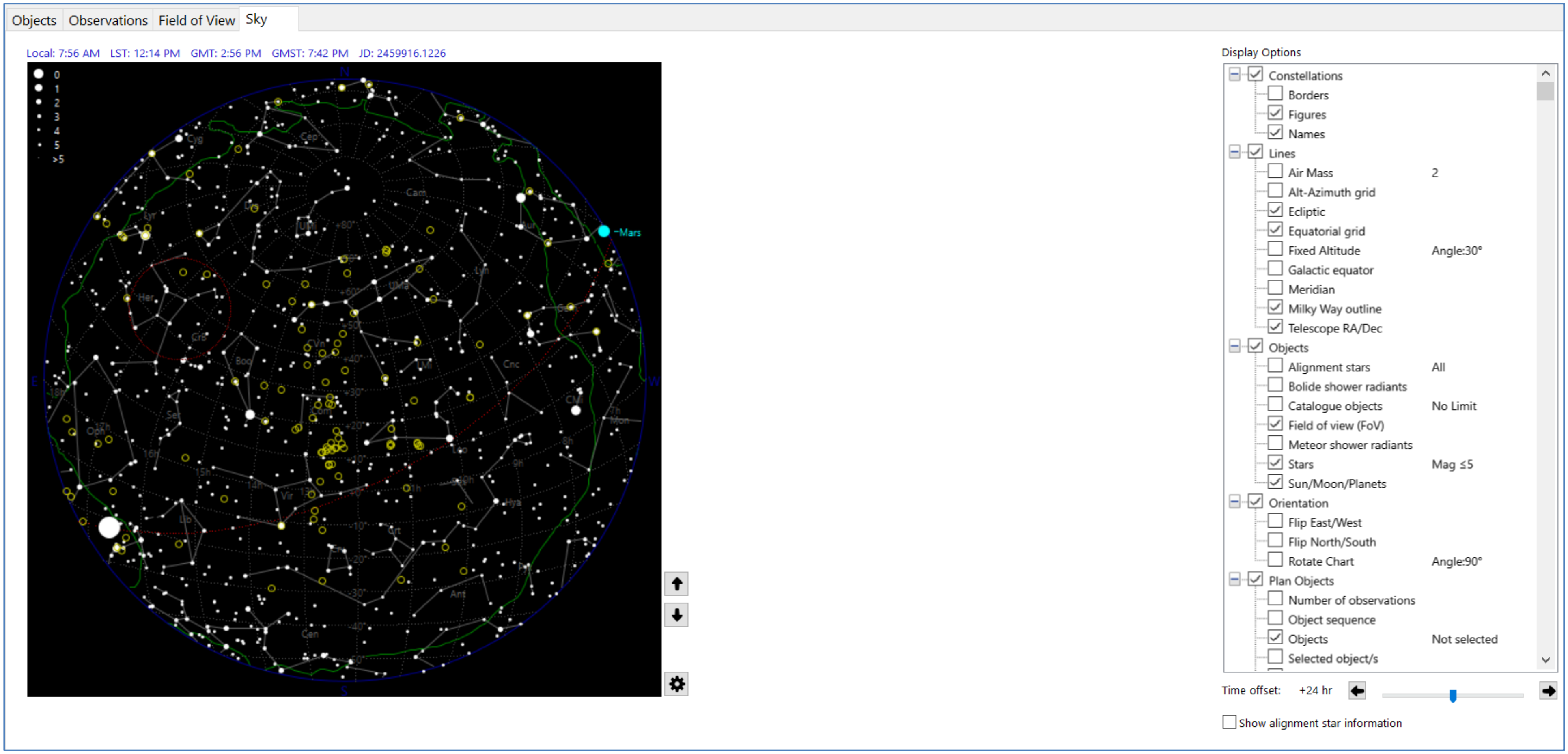
Observations tab – This screen is dedicated to allowing the user to document observations on the target of interest. This screen is very flexible and allows the user to document many details on their observation including location what telescope/eyepiece combination they used, seeing conditions, and even addition of attachments. It should be noted here that this application does have the ability to print observation logs that could be used in the field that can be transferred to the application at a later time if you don't want to take a computer with you in the field.



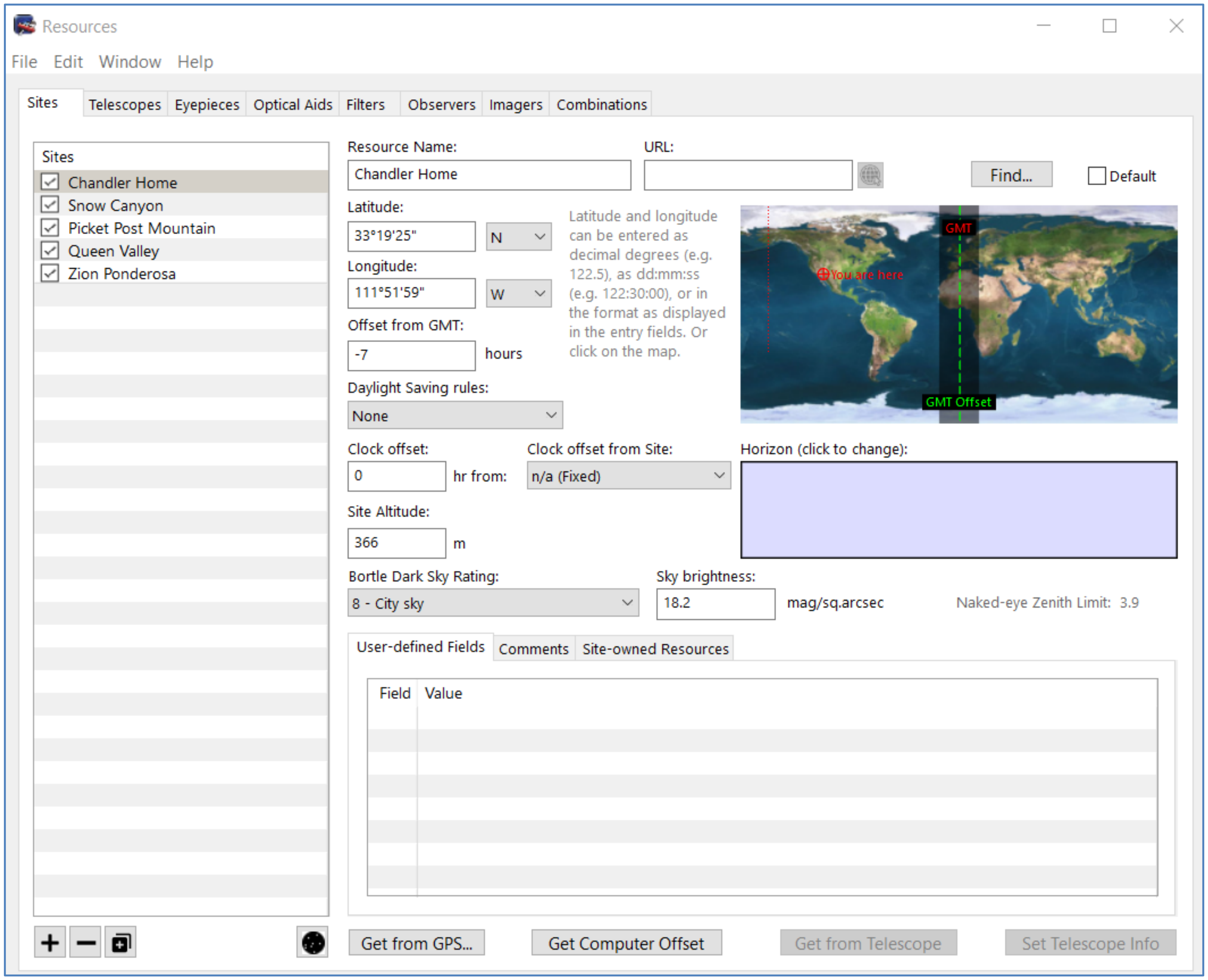
Field of View tab - This screen focuses on presenting the user with a representation of the size an object may appear for a given telescope/eyepiece combination. By updating the Field Diameter field you can view (ie 10°) you can see where the object appears relative to other objects (ie constellations,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



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



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 hardware specifications to provide this information and this may take a while to enter your telescope(s), eyepieces and cameras, 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** |



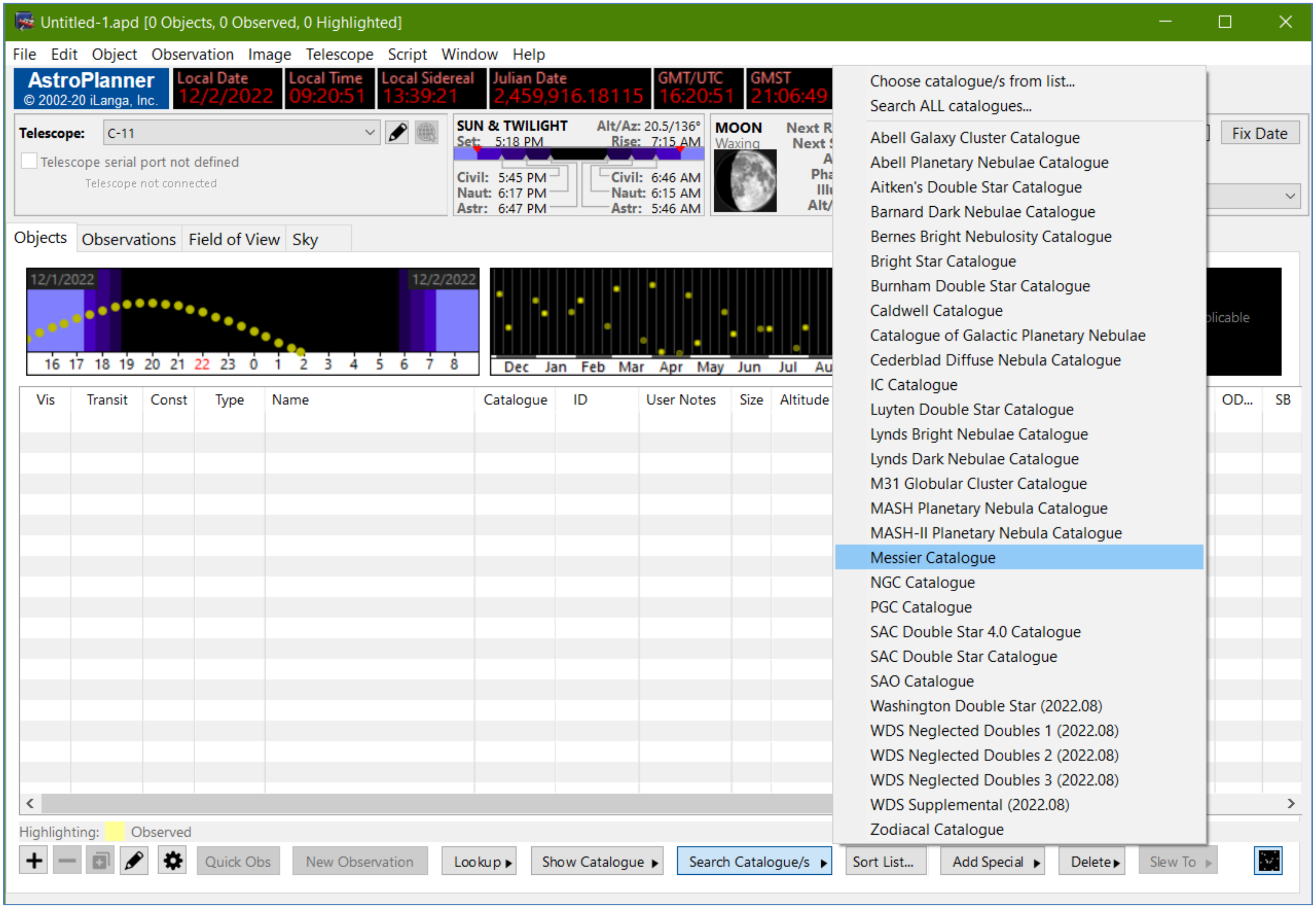
Workflow for Creating a Plan

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:

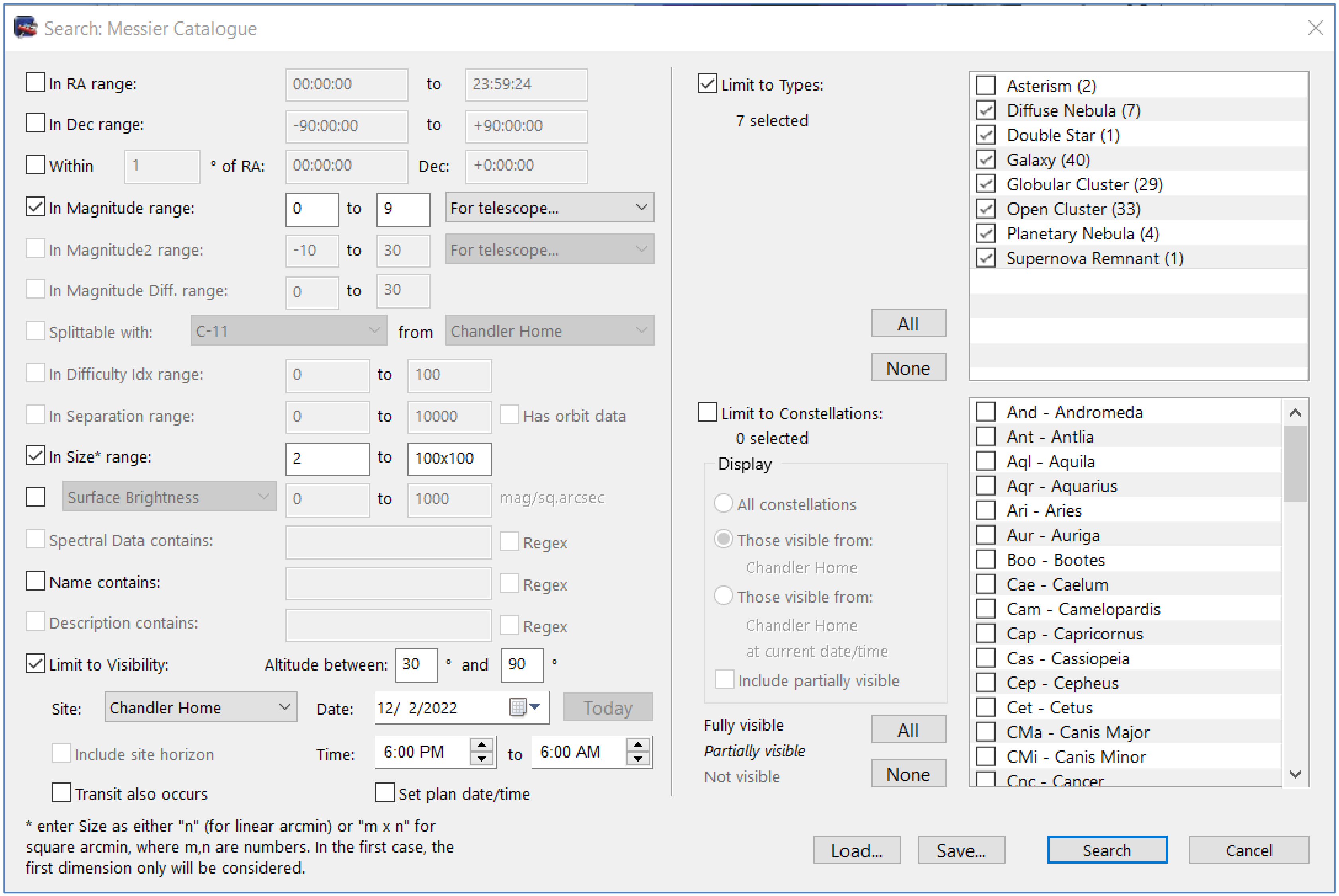
- **Create a New Plan** – Menu selection: | File | New |
- **Add Objects to Plan** – There are multiple paths to adding objects to you plan
  - Browsing a Catalogue - | Object | Open Catalogue/s | Browse and add selected items from one of many catalogs available (ie Messier, IC, NGC, etc.)
  - Search Catalogue/s – Search Catalogue/s button at bottom of screen. Search one of the many catalogs available (ie Messier, IC, NGC, etc).
  - 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 utilized for identify object that you may want to add to your plan (Browsing a Catalogue, Search Catalogue/s button, Add Special button, User Defined Plans), in this example we will utilize the Search Catalog feature on the Messier List catalog.

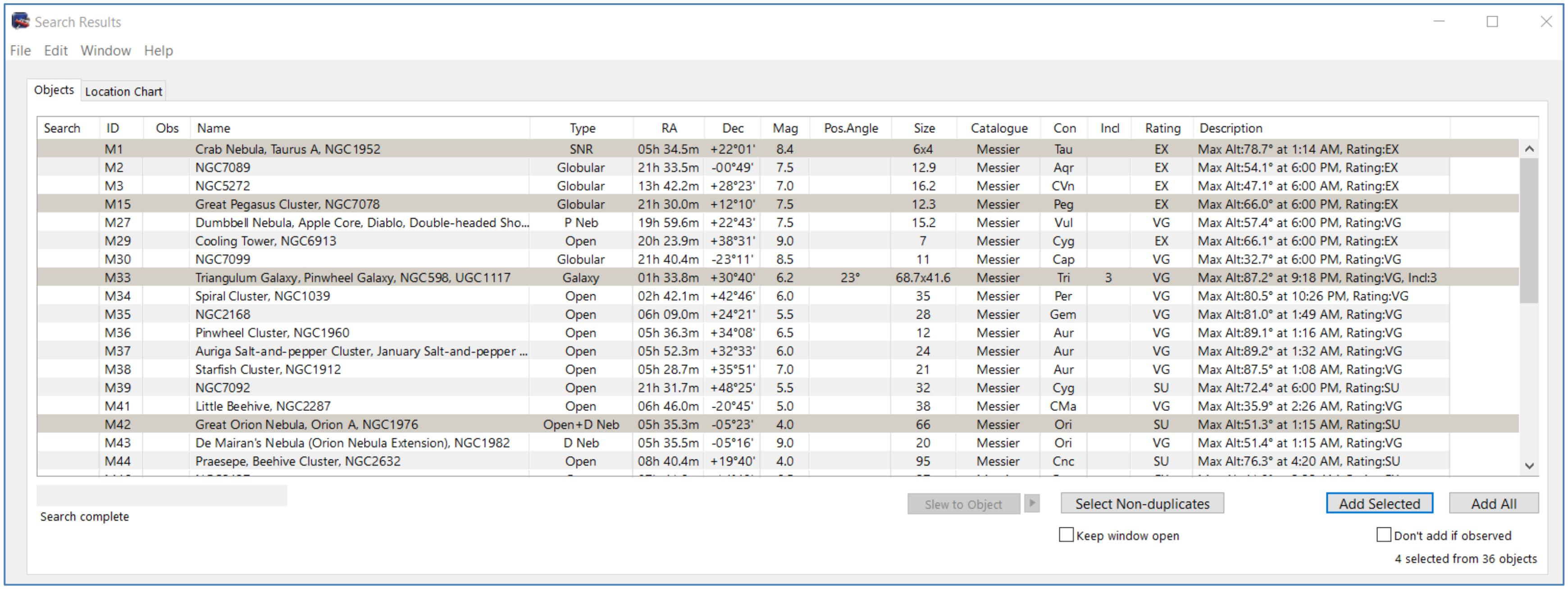
1. Open the Search Catalogue/s screen and select the catalogue you wish to search (Messier Catalogue in this example).



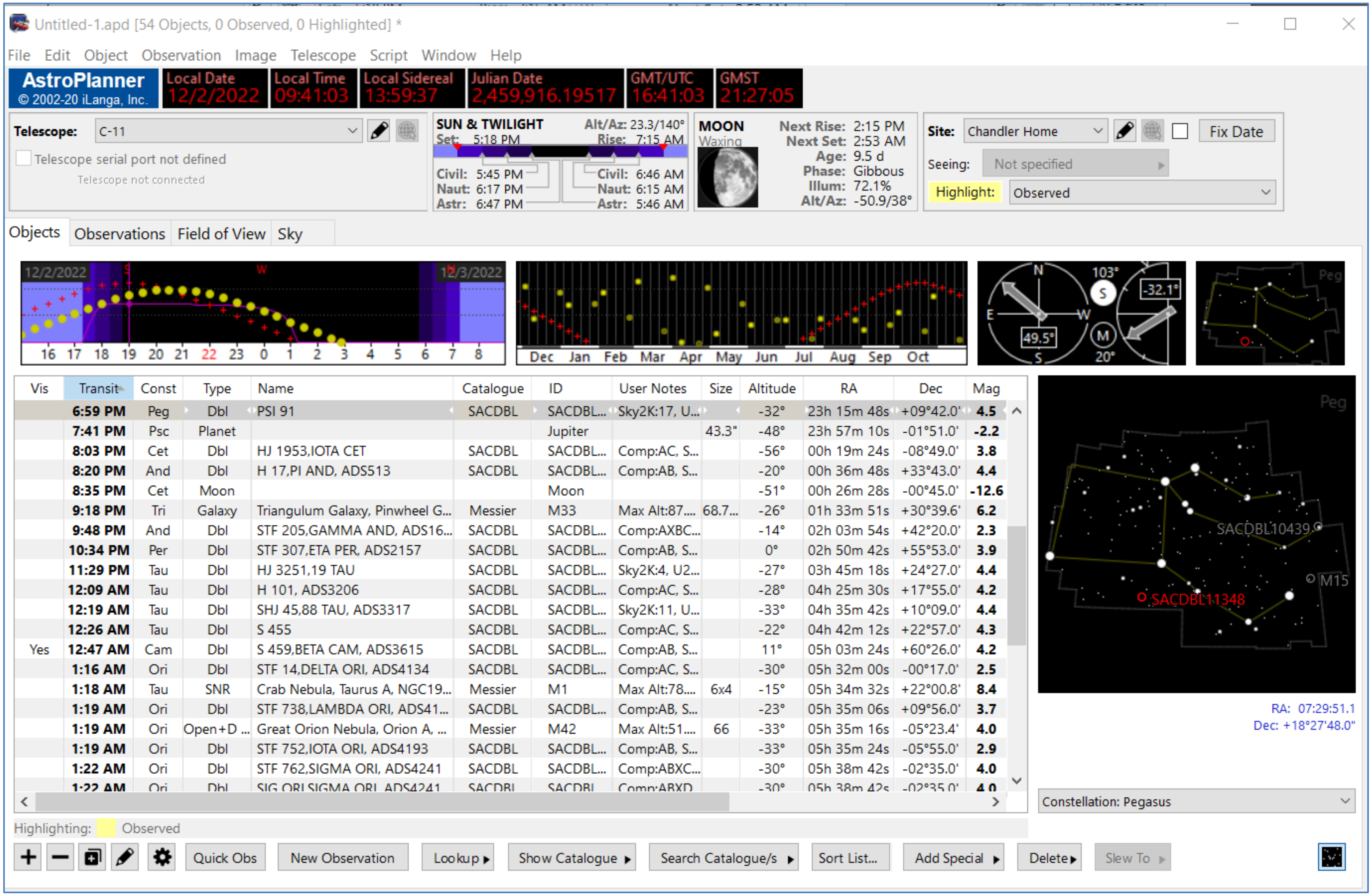
2. Set the filters you want to narrow down the results. Select the Search button once you have set all criteria. A new window with a list of all objects that meet your criteria will be displayed.



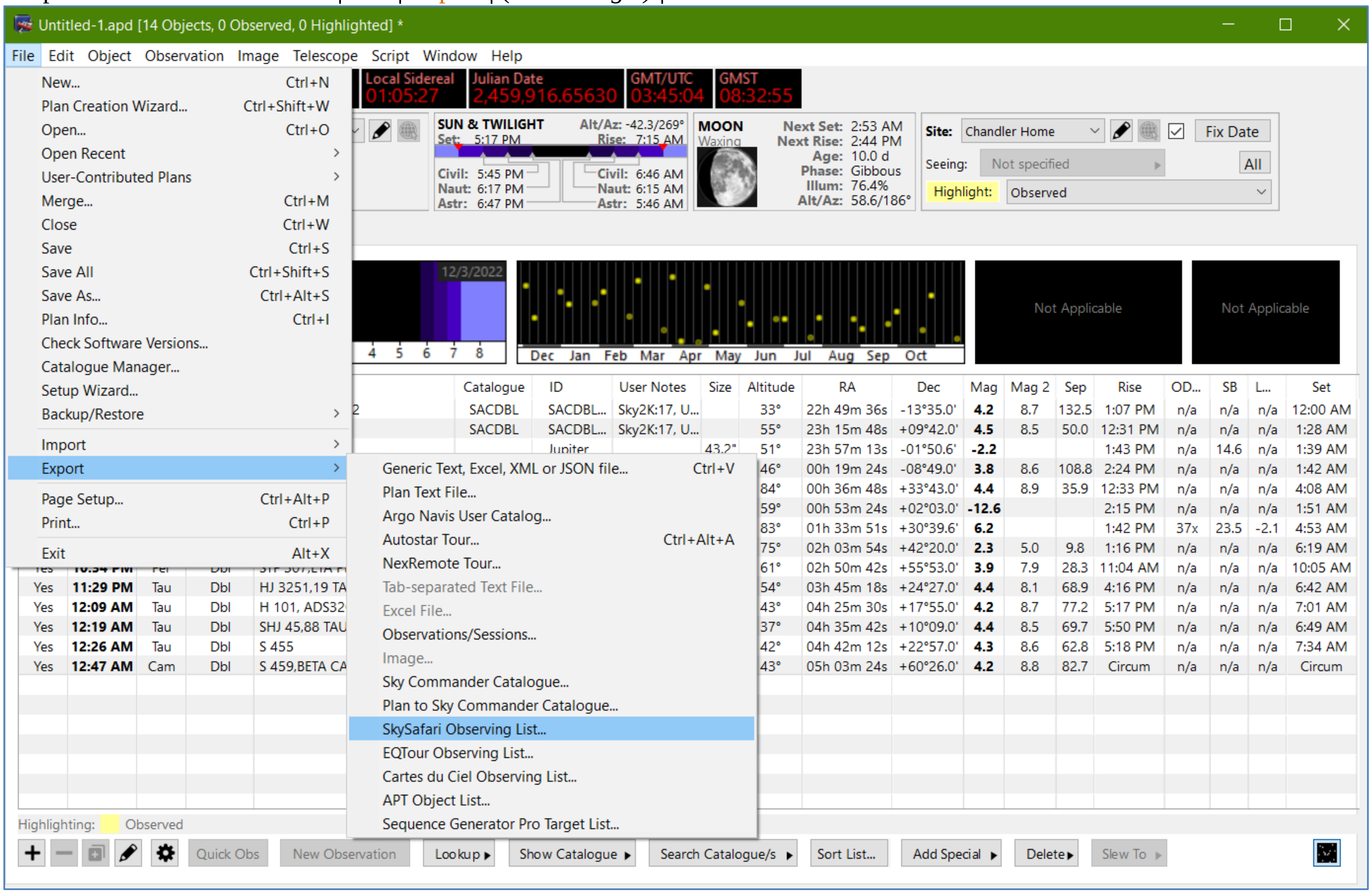
3. Review list, select objects you want to add and select the Add Selected button to transfer the objects to your plan.



4. The selected objects should now appear on you 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 (ie Tranit 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 help when using the AstroPlanner software.

Catalogs and User List – there are many Catalogs and Users 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 | Turn Left at Orion Cosolmagno and Davis |
  - | Book | Deep-Sky Observing With Small Telescopes – Eicher |
  - | Book | Haas-double |
  - | Book | Urban Astronomers 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 in 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 are over a couple of hours outside of your observation session, so if I plan on observing from 8pm – 10pm I would eliminate objects that transit outside of the time of 6pm – 12 midnight
- Type: Eliminate any object types you may not be interested in (ie Asterism, Open clusters, etc)
- Size: Knowing the limitation on how small or large an object you can view for your telescope/eyepiece combination eliminate objects outside of that range.
- Mag: Eliminate any objects to dim to see for your situation, for a small scope in the city, I usually limit this to Magnitude 10 or less
- Double/Multiple Star Systems – Utilize Sep and Mag 2 fields to eliminate systems that can't be resolved by your setup. (ie Sep between 2-150 arc seconds and Mag 2 < 12)
- SB (Surface Brightness) – Many objects will not have SB values associated with them but for those who do, eliminate ones with higher values than you can see for your situation (i.e., 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 what order of observations for the list.

References and Resources

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	Webste	Good website article introducing the Telrad sight.
Telrad Messier List	Website	Online finder charts of Messier List objects for the Telrad.
Telrad Calwell Catalogue	Website	Online finder charts for the Caldwell Catalogue for the Telrad.
Telrad Messier List (printable)	PDF	Printable list of Messier objects with maps
How to Collimate a Dobsonian Telescope	Website	Instructions on Collimating a Dobsonian, but concept applies to all reflector telescopes.
How to Collimate your SCT	Website	How to collimate your Schmidt-Cassegrains Telescope (SCT)
What is Piggyback Astrophotography?	Video	Video explaining technique, shows example photos and discusses equipment.
The Sky Live	Website	Great free online resource describes what objects may be of interest. Also has a good planetarium for planning your observing session.

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 manufactures 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 (ie +/- 10 degrees DEC).
- Center the star in your eyepiece.
- If you have a clock drive turn it off or 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 it will track across into the eyepiece when observing it.
- 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 take 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