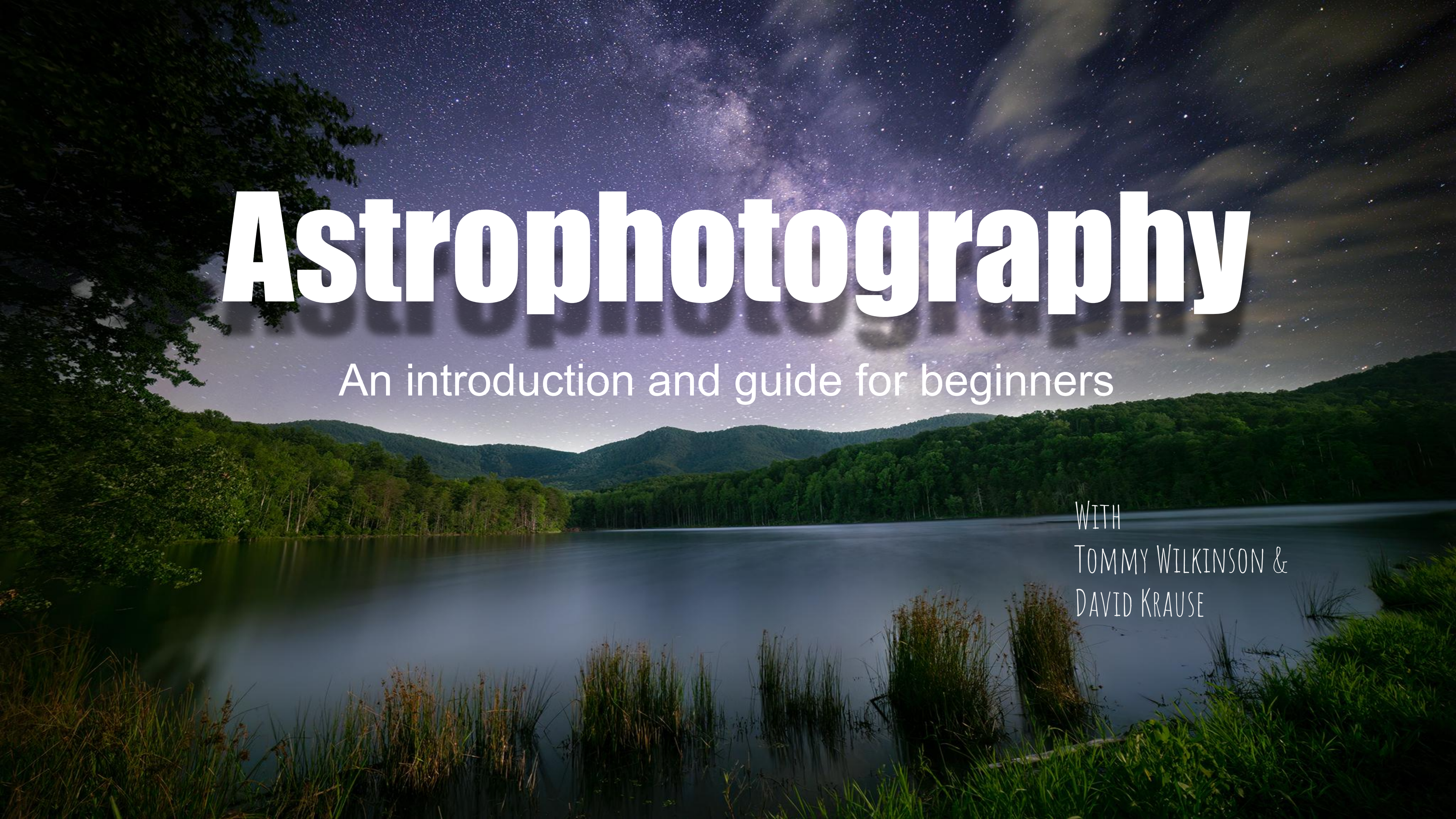


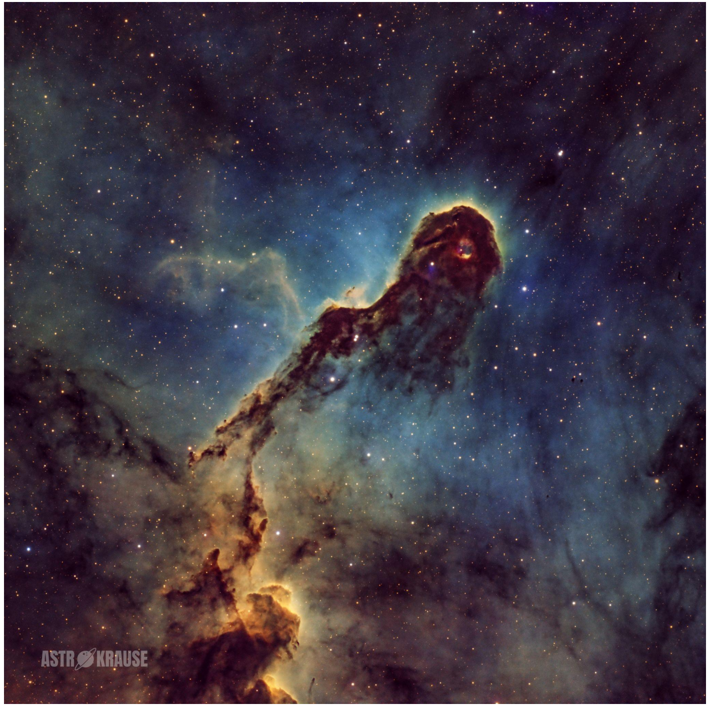
Astrophotography

An introduction and guide for beginners

With
Tommy Wilkinson &
David Krause

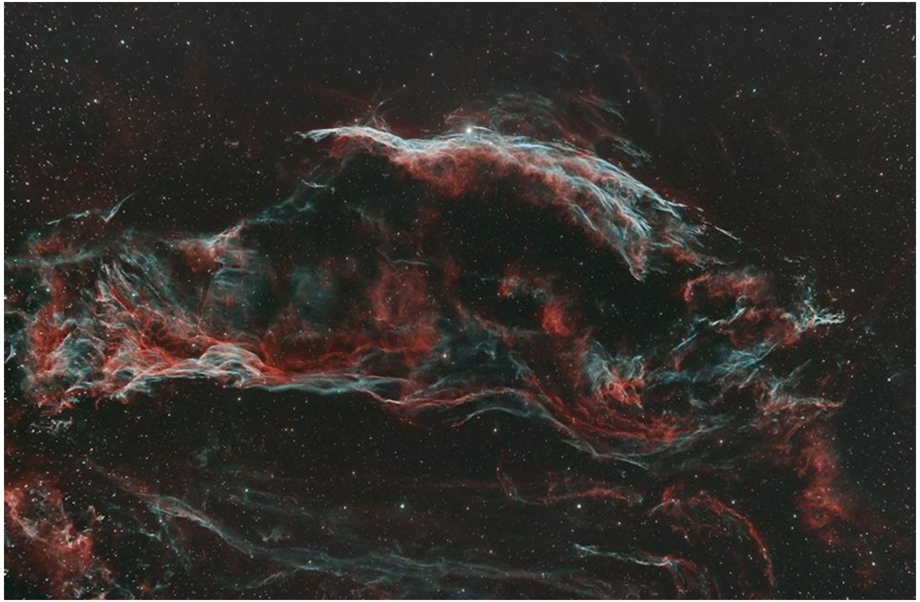
Photos Taken

Whirlpool Galaxy by Tommy



Elephant’s Trunk Nebula by David

Photos Taken



Western Veil Nebula (Witch’s Broom) by Tommy

Horsehead and Orion Nebula by David

Photos Taken

Flaming Star Nebula by Tommy

Pillars of Creation by David

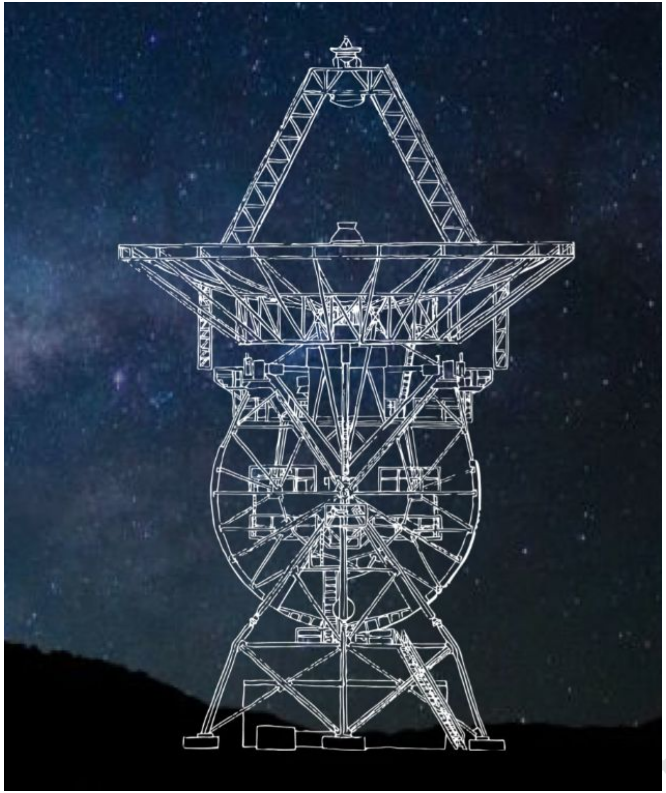
Photos Taken

Tulip Nebula by Tommy

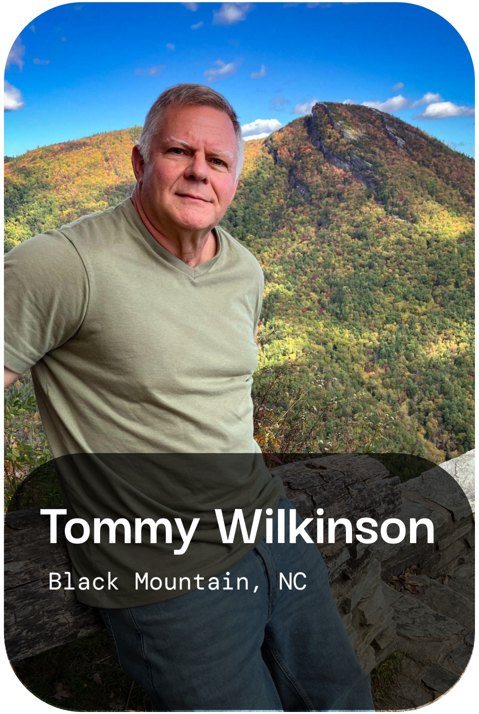
Pinwheel Galaxy by David

Agenda

- ❖ Introduction
  - ➢ Get to know us
  - ➢ What you can expect from this course
  - ➢ Defining astrophotography
- ❖ Part one - Morning Session
  - ➢ Anatomy of an astrophotography system
  - ➢ Connecting equipment
  - ➢ Data acquisition
- ❖ Part two - Afternoon Session
  - ➢ Image processing
  - ➢ Image processing workshop
  - ➢ Conclusion
- ❖ Imaging session - After Sunset
  - ➢ Here at PARI or remote



Get To Know Us - Tommy

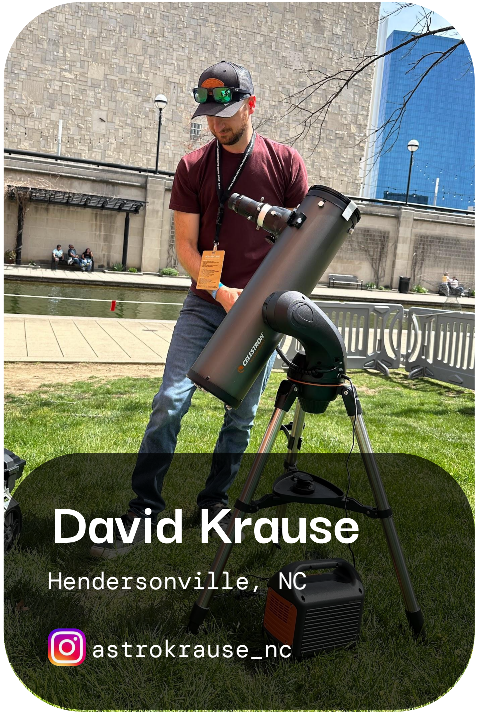


Tommy grew up in a rural dark sky area and has lived in Georgia, Washington State, Virginia, and North Carolina. For the past eight years he and his wife have lived in Black Mountain, NC.

Several years ago, he began taking horrible deep sky photos with his IPhone and telescope. Ultimately, that positioned him on the event horizon where he was pulled into the black hole of astrophotography.

Currently, he serves as president of the Astronomy Club of Asheville.

Get To Know Us - David



David grew up in Connecticut and after obtaining his degree from UCONN in 2011, he moved to Florida before moving to North Carolina in 2021. David currently lives in Hendersonville, NC with his wife and two children.

In 2022, his wife bought him a telescope… for fun. After placing his cell phone on the eyepiece to take a picture of the moon, his journey of astrophotography started.

He currently works in the aviation industry for Collins Aerospace.

Imaging setups:

- ❖ Mono: AT130 telescope, EQ6 mount, Poseidon M-Pro camera
- ❖ OSC: Celestron 8SE telescope, AM3 mount, Risingcam 2600 camera
- ❖ Swapout: Redcat71 telescope for wide-field imaging

His primary focus with astrophotography is imaging deep-sky objects such as galaxies, nebulae, and star clusters. He also likes to image planets, the moon, and sometimes the sun.

What to Expect

- ❖ This course is designed as an introduction and guideline for beginner astrophotographers
- ❖ There is a lot of information, most of it is to provide awareness
- ❖ We will not go too in depth on any one topic, equipment, process, etc…
- ❖ These slides are meant to be used as a reference point for you on your astrophotography journey
- ❖ The image processing workshop will be more of a hands-on experience
- ❖ We will provide data for you to practice processing
- ❖ Please hold questions until the end of each section

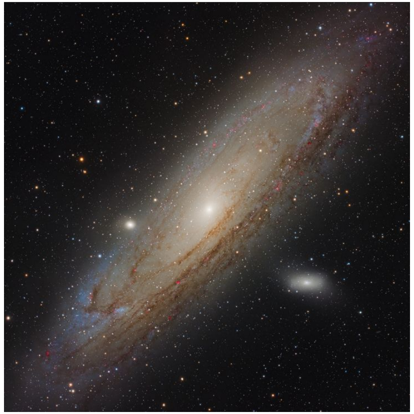
What Is Astrophotography?

It is simply *photography involving astronomical objects and events*

Primary types of astrophotography:

Milky Way / Landscape

Deep Sky Objects (DSO)



Planetary

Solar / Lunar

The Fight for Signal

We are taking pictures of very dark and faint objects, a single picture will not contain enough signal to generate a quality image. This is why we need to take many pictures and stack them together: to increase the SNR!

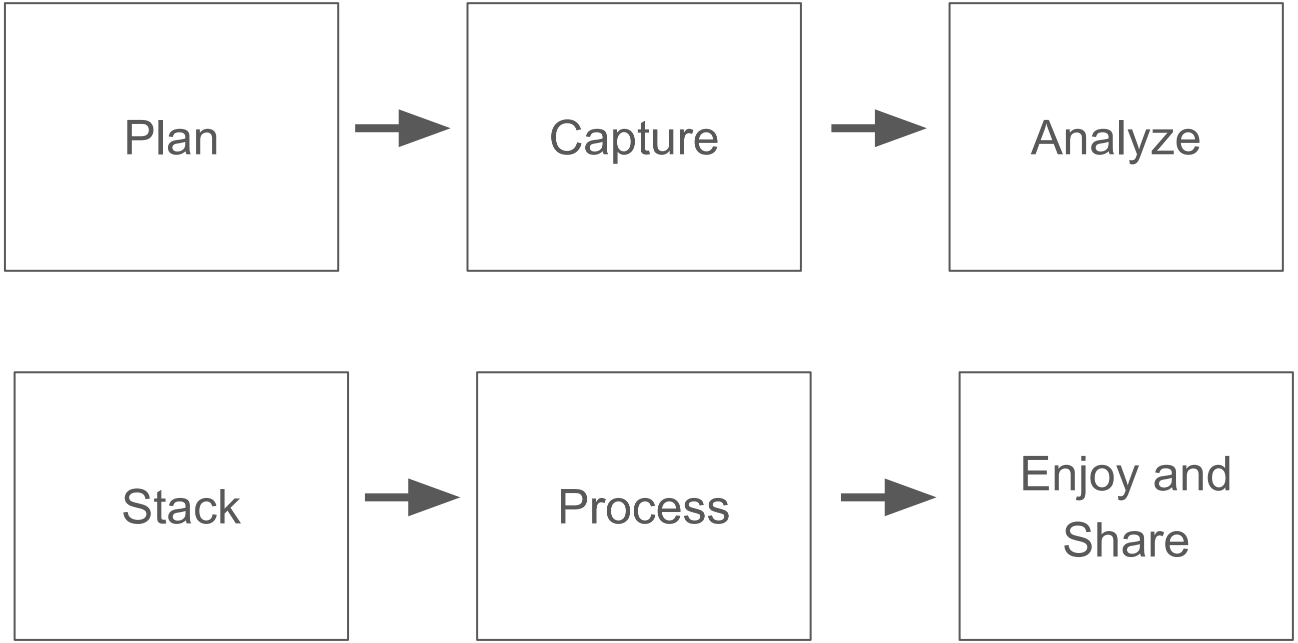
Signal-to-Noise Ratio (SNR)

- ❖ A measure of how clear and strong the image of a celestial object (the signal) is compared to the random, unwanted information (noise) captured by the camera
- ❖ A high SNR means the celestial object's details are prominent and easy to see, while a low SNR indicates that the noise is overwhelming the signal, making the image difficult to interpret and reducing its quality

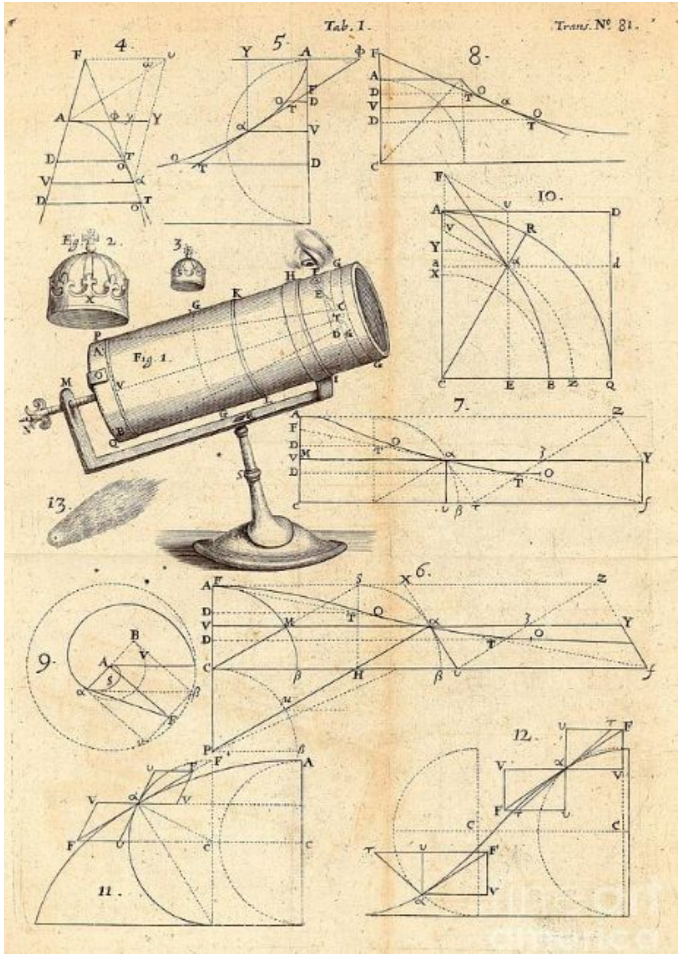
One 300-second exposure (5 min total)

123 stacked 300-second exposures (10 hr total)

Macro-Level Process: DSO



Part One: Image Capture



Anatomy of an Astrophotography System

Anatomy of an Astro Rig

Telescope

Dew Straps

USB Hub

Mini PC

Mount

Powerbox / Dew Controller (on other side)

Guide Scope

Guide Camera

Electronic Focuser

Camera

Filter Wheel & Filters

Telescopes

Telescopes - Common Terms

- **Types**: reflector, refractor
- **Sub-types**: newtonian, dobsonian, doublet/triplet refractor, petzval refractor, SCT, RC, RASA, etc…
- **Aperture** – the diameter of a telescope's primary mirror/lens
- **Focal length** – the distance from the objective lens or mirror to where the image forms
- **Focal ratio or (f/number)** – the photographic speed of a telescope's optics; the ratio of the optical tube's focal length to the diameter of the camera or eyepiece. Equation: Focal ratio = focal length / aperture
- **Resolution/resolving power** – the ability of an optical tube to distinguish small or closely adjacent objects. A telescope's aperture determines its maximum resolution
- **Collimation** – the proper alignment of the optical elements in a telescope, which is critical for achieving the best possible views
- **Coma** – a spherical aberration caused by photons striking a plane off-axis. When an image suffers from coma, stars appear as little, off-axis, comet-shaped blobs that point inwards towards the center of the field and get bigger as you look towards the edge of the field of view
- **Field curvature** – a visual defect that occurs when objects or stars scattered in a field of view of a telescope do not come into focus on the same flat plane. An image that suffers from field curvature will have pinpoint stars at the center of the frame, but out-of-focus stars at the edges.

Telescopes - Newtonian

- Type: Reflector
- Pros
  - The cheapest by aperture size (can get a larger telescope for cheaper)
  - Typically fast (f/4 to f/8)
  - Less susceptible to dew
  - Reasonably compact and portable
- Cons
  - Subject to coma, requires “coma corrector”
  - Requires regular collimation
- Imaging
  - Great for visual, but not the best imaging telescope for beginners; can introduce more complications compared to other telescopes

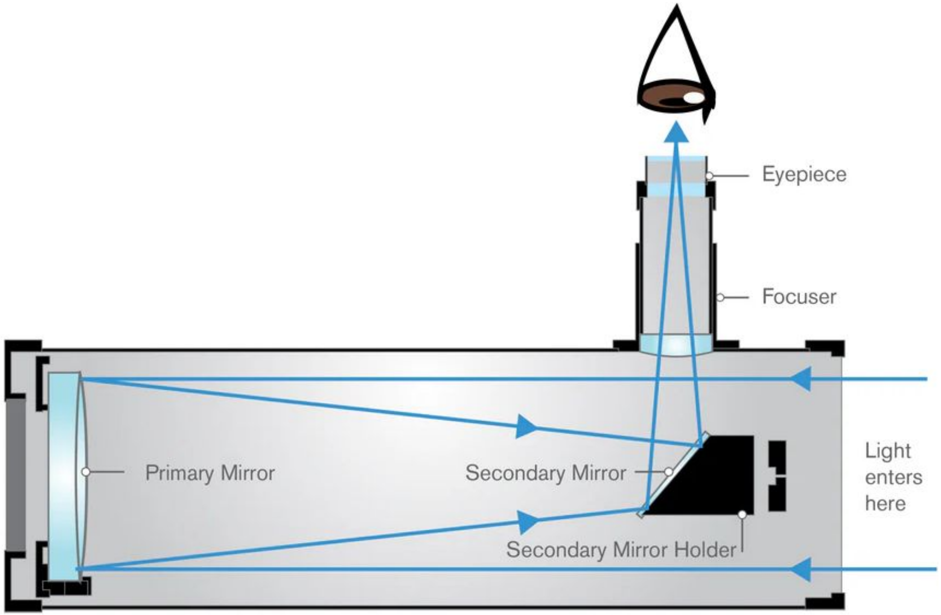


*Diagram by Celestron

Telescopes - SCT (Schmidt-Cassegrain)

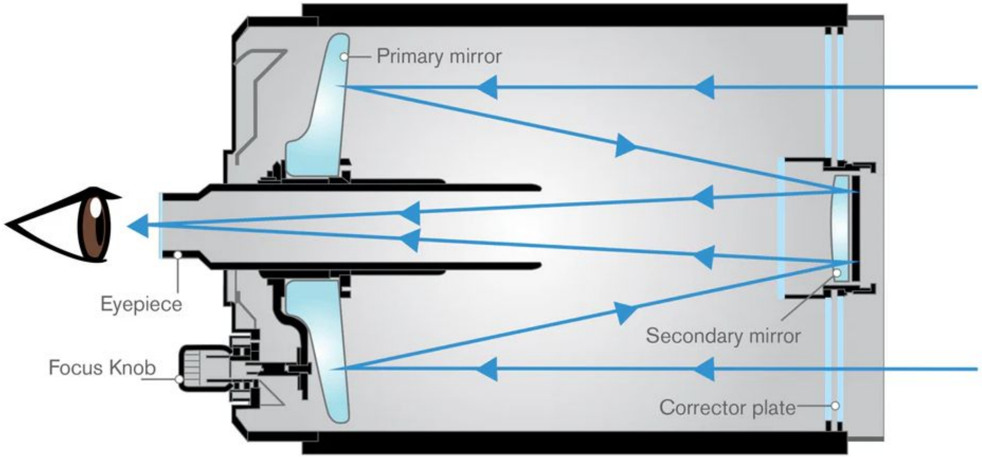
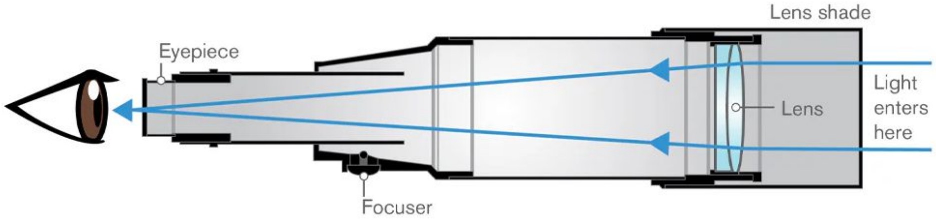


*Diagram by Celestron

- Type: Reflector
- Pros
  - Reasonably priced, less expensive than equivalent aperture refractors
  - Most versatile type of telescope
  - Compact and portable for aperture/focal length
- Cons
  - Can be slow, typically f/10
  - More susceptible to dew
  - Can be subject to coma, may require “coma corrector”
  - Requires regular collimation
  - Requires “cooldown”
  - Subject to “mirror flop”
- Imaging
  - Can use for imaging, just expect complications
  - Excellent for planetary/lunar imaging
  - Most economical option for small targets requiring longer focal lengths

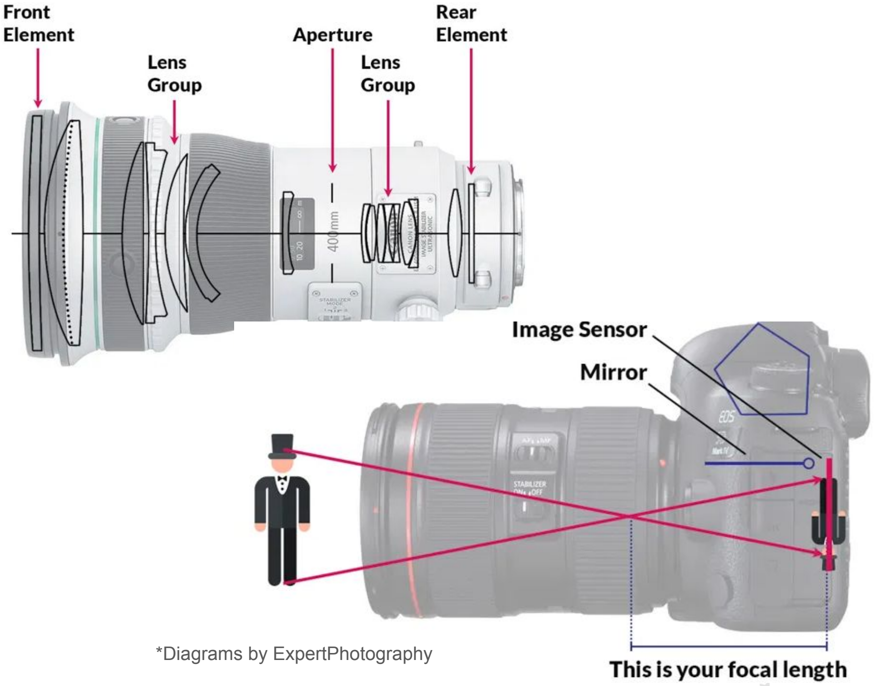
Telescopes - Refractor

- ❖ Type: Refractor
- ❖ Pros
  - ➢ Easy to use and reliable due to the simplicity of design
  - ➢ Lower focal ratios
  - ➢ High contrast images with no secondary mirror obstruction
  - ➢ Objective lens is permanently mounted and aligned—fixed collimation
- ❖ Cons
  - ➢ Most expensive by aperture size
  - ➢ Heaviest by aperture size
  - ➢ Subject to field curvature, may require “field flattener”
- ❖ Imaging
  - ➢ Should use a triplet, preferably apochromatic
  - ➢ Personal favorite, best suited for imaging, especially small refractors for beginners



Telescopes - Camera Lens

- Type: Refractor
- Pros
  - All the pros of a refractor telescope
  - You may already have one!
  - Cheaper than a telescope
  - Extremely portable
- Cons
  - Limited to a very wide-field
  - Some can cost more than a telescope
- Imaging
  - Great for very wide-field shots, especially the Milky Way, but very limiting for resolving detailed space objects



*Diagrams by ExpertPhotography

Telescopes - Smart Telescope

- Type: Refractor
- Pros
  - All-in-one imaging telescopes that includes: telescope, tracking capability, and camera & filters
  - Some like the ZWO Seestar S50 are very affordable
  - Portable
  - Great for beginners who don’t want to go “too deep”
- Cons
  - Typically limited to wider fields of view
  - Limited quality compared to traditional astrophotography rig
- Imaging
  - Great for beginners and community astronomy

ZWO Seestar S50

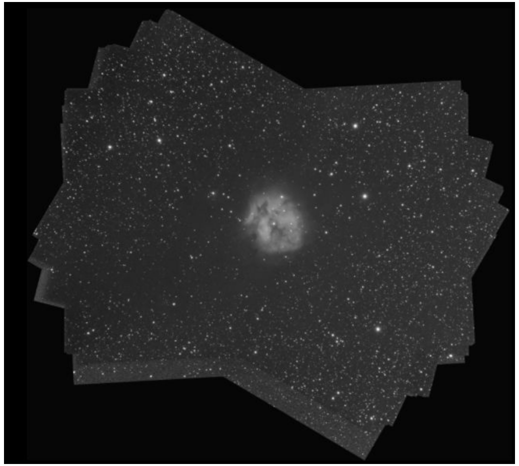
Mounts

Mounts - Tripods

Normal photography tripods

- ❖ Pros
  - ➢ Provides stabilization for DSLR camera photography
  - ➢ Great for Milky Way shots
- ❖ Cons
  - ➢ No usable for imaging with a telescope
- ❖ Imaging
  - ➢ For Milky Way or very wide-field imaging with DSLRs, you can use a normal tripod with exposures up to 30 seconds without noticing star trails

Mounts - Altitude-Azimuth (Alt-Az) (motorized)



Field rotation from alt-az mounts

Alt-Az mount

A simple two-axis mount for supporting and pointing a telescope in altitude (the vertical axis) and azimuth (the horizontal axis)

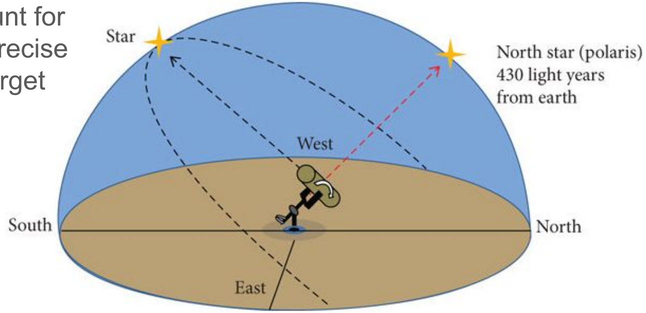
- ❖ Pros
  - ➢ Can track objects automatically over time
  - ➢ Usually has a “go-to” option that can find targets after star alignment
  - ➢ Least expensive motorized mount
  - ➢ Typically comes with medium size telescopes for viewing (i.e Celestron go-to mounts)
- ❖ Cons
  - ➢ Won’t keep orientation of target; causes field rotation
  - ➢ Tend to not be as precise as equatorial mounts
- ❖ Imaging
  - ➢ Great for planetary, lunar, & solar imaging

Mounts - Equatorial (EQ) (motorized)

Equatorial mount (EQ)

A type of telescope base that compensates for Earth's rotation by having its right ascension axis rotate parallel to the Earth's axis

- Pros
  - Tend to be more precise
  - Usually has a “go-to” option that can find targets after polar & star alignment
  - Keeps target orientation throughout night
- Cons
  - Requires polar alignment
  - May require balancing using counterweights
  - Most expensive type of mount
- Imaging
  - Probably the most common/appropriate mount for astrophotography; they usually have more precise tracking, payload capacity, and consistent target orientation



Mounts - Strainwave

Strainwave mounts

A type of equatorial mount that uses a strain wave (or harmonic) drive for its gearing mechanism, allowing for a more compact, lightweight, and robust design compared to traditional equatorial mounts that use worm gears.

- Pros
  - Same as regular EQ mounts
  - Does not require counterweights
  - Lightweight & portable
  - Can convert to alt-az mode
- Cons
  - Slightly more expensive by payload capacity
- Imaging
  - Highly recommend!

Cameras


POSEIDON-M PRO

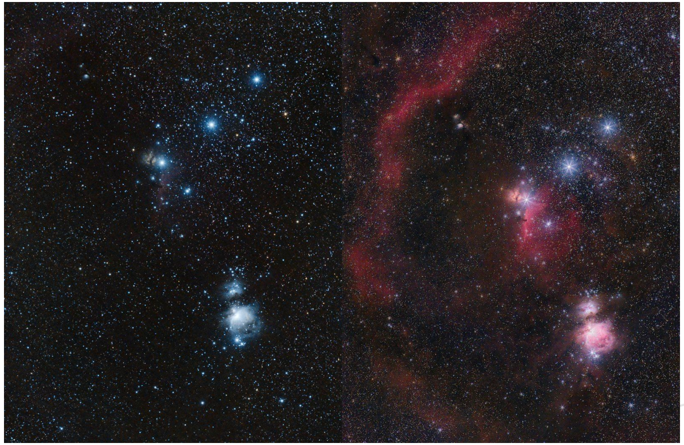

Canon
EOS
2000D
CANON ZOOM LENS EF-S 18-55mm 1:3.5-5.6 III
Φ58mm

Cameras - Digital (common)

Digital Single Lens Reflex Camera (DSLR) & Mirrorless Digital Camera

an electronic device that captures images by converting light into digital data using an electronic sensor, instead of film. These digital files can be stored on a memory card, viewed on a screen, and easily shared or printed. Digital cameras replace traditional film with a digital image sensor, such as a CCD or CMOS sensor, to record information.

- ❖ Pros
  - ➢ You may already have one!
  - ➢ Comes with a lot of options/adjustable settings
  - ➢ Does not require a computer to operate
  - ➢ Pictures stored directly on camera
- ❖ Cons
  - ➢ Likely has IR filter built-in that filters out hydrogen commonly found in space images
  - ➢ Not cooled, therefore subject to “amp glow”
  - ➢ Costs are comparable to dedicated astro cameras
- ❖ Imaging
  - ➢ Use it if you have it! But would recommend upgrading to a dedicated astro camera if that’s an option



With built-in IR filter | Without built-in IR filter

Cameras - Understanding Amp Glow

Amp Glow

“Glow” present on an image that is caused by heat generated by sensor operation

- ❖ Uncooled cameras will generate amp glow, but it can be mitigated by calibration frames
  - ➢ This requires you to generate “dark frames” where you take a picture of the same exposure length as the normal image but with the telescope/lens cover on
- ❖ Cooled cameras cool the digital sensor nullifying amp glow

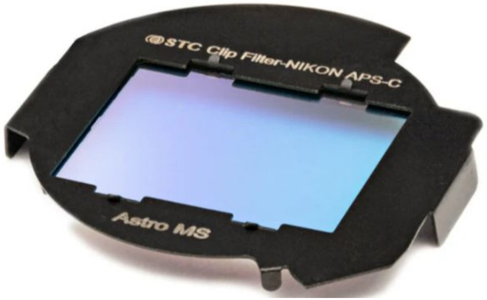
Cameras - Dedicated Astro

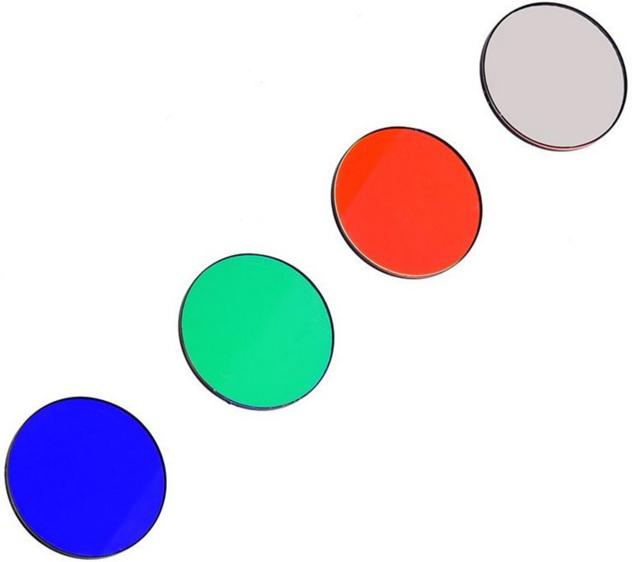
Astronomy Camera (Astro Cam)

A specialized digital camera designed to capture images of astronomical objects and phenomena using a telescope or on its own, often requiring external software and a computer for control and image storage.

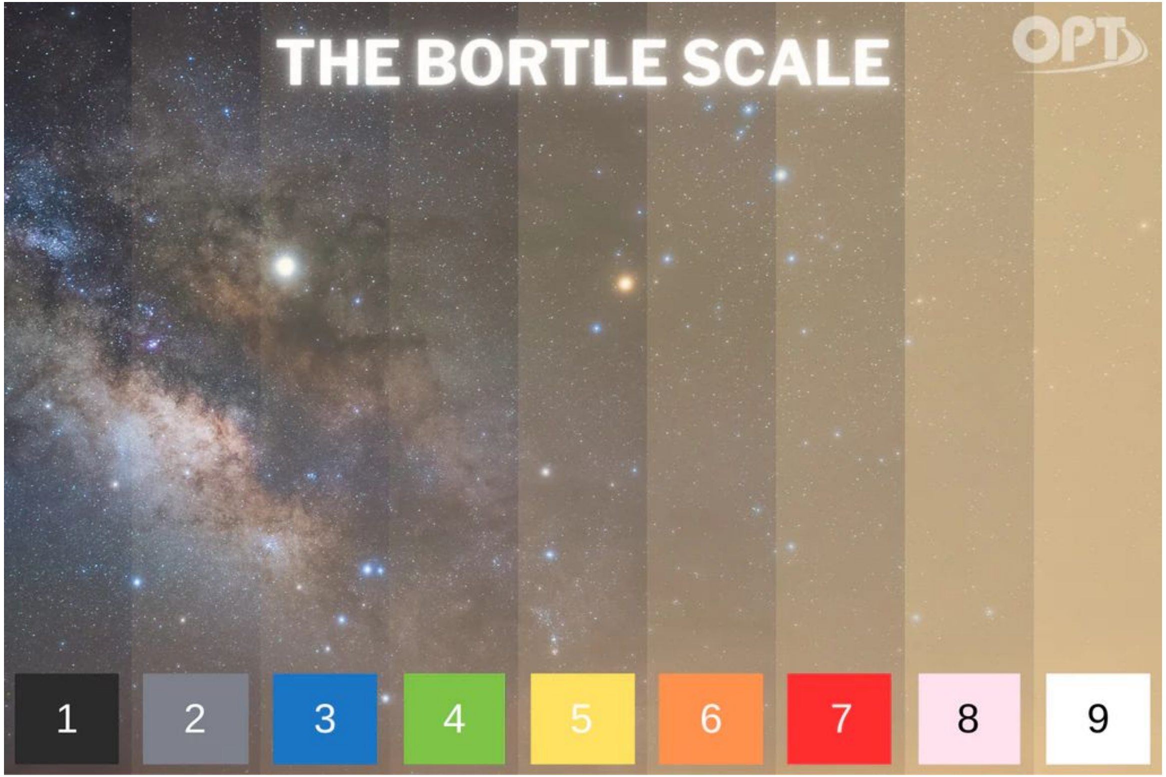
- Pros
  - Can capture IR spectrum required for hydrogen
  - Cooled, therefore mitigates “amp glow”
  - Typically more customizable gain (ISO) options
  - Comes as One-Shot Color (OSC) or Monochrome
- Cons
  - Realistically only usable for astronomy
  - Requires computer and software to operate
- Imaging
  - Astro cams are best-suited for imaging, as the name implies

Filters





Filters - Light Pollution & Bortle Scale



The **Bortle Scale** is a nine-level numeric scale that measures the night sky's brightness of a particular location. It characterizes the observability of celestial objects, taking into account the interference caused by light pollution.

- Bortle Scale 1: Excellent Dark-Sky Site
- Bortle Scale 2: Typically Truly Dark Site
- Bortle Scale 3: Rural Sky
- Bortle Scale 4: Rural/Suburban Transition
- Bortle Scale 5: Suburban Sky
- Bortle Scale 6: Bright Suburban Sky
- Bortle Scale 7: Suburban/Urban Transition
- Bortle Scale 8: City Sky
- Bortle Scale 9: Inner-City Sky

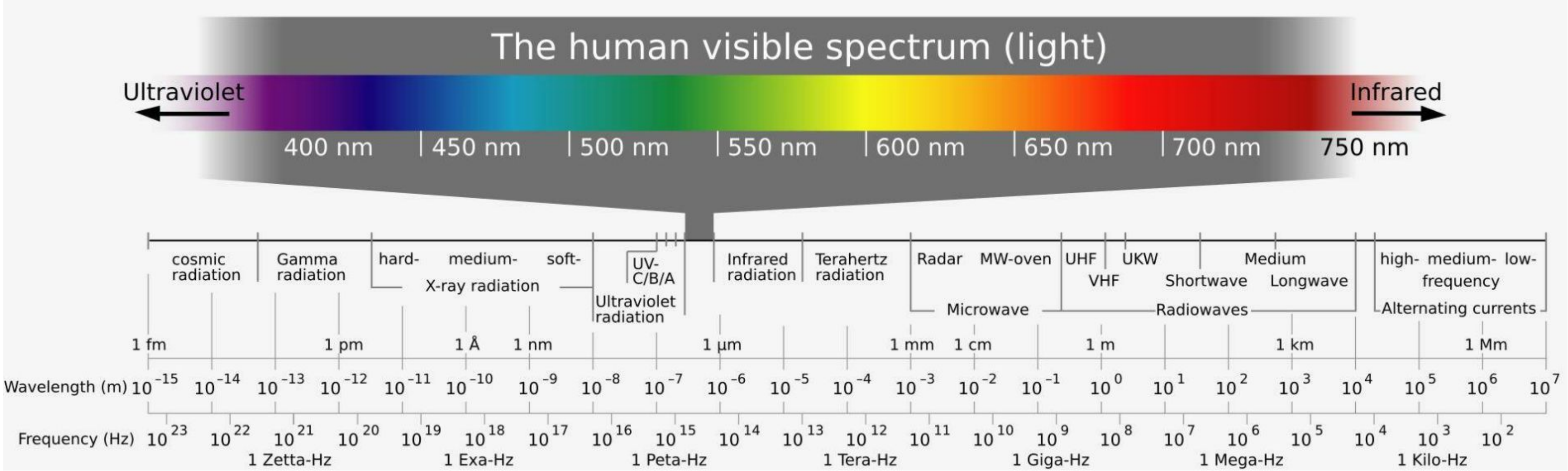
Filters - Light Pollution Filters

Light Pollution Filters

Specialized optical filters that blocks specific wavelengths of artificial light, such as the yellow and orange emissions from sodium-vapor streetlights, to increase the contrast and visibility of deep-sky objects like nebulae and galaxies.

- ❖ Pros
  - ➢ Capture details you would otherwise miss due to light pollution
  - ➢ Relatively inexpensive (as filters go)
  - ➢ Can be used on all types of cameras
- ❖ Cons
  - ➢ Doesn’t entirely negate effects of light pollution
  - ➢ Can distort colors
- ❖ Imaging
  - ➢ Light pollution filters can be particularly helpful if living in high Bortle scale locations or if street/neighborhood lights are an issue. However, nothing compares to a non light-polluted dark sky!

Filters - Broadband vs Narrowband



Broadband refers to the entire human visible spectrum comprised of the three primary colors: red, green, and blue; each covering a third of the visible spectrum. Objects captured/colored in this way represent “true color” images which can be done by color cameras, using RGB-specific pixels in their sensors, or by monochrome cameras using RGB filters.

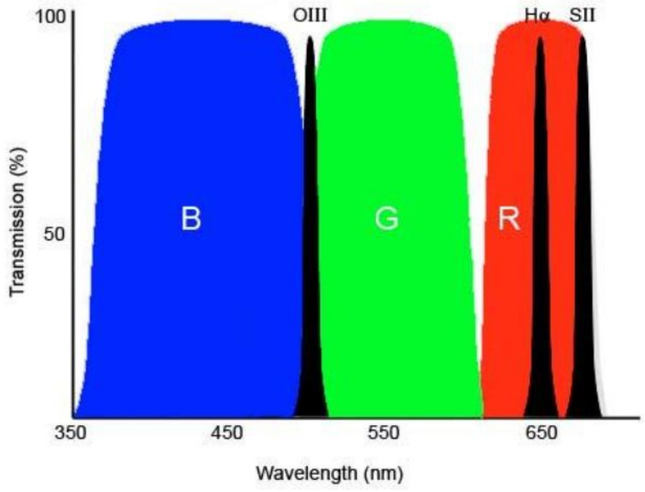
Filters - Broadband vs Narrowband

Narrowband is the capture of very small and specific parts of the spectrum in an attempt to obtain only the prevalent light an object is comprised of.

Common astrophotography targets captured in narrowband are emission nebulae, which are made up of ionized gases emitting their own light. The three most common narrowband elements captured are:

- ❖ Sulfur (SII)
- ❖ Hydrogen (Ha)
- ❖ Oxygen (OIII)

<u>You can go for both broadband and narrowband targets with any type of camera, what matters most is the filter!</u>



Filters - Narrowband filters

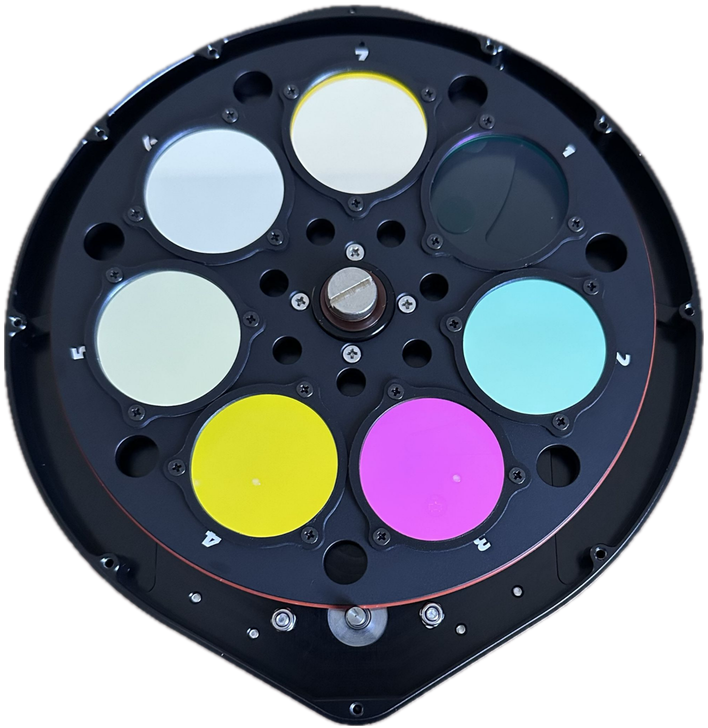
Narrowband filters for OSC (color) cameras

Typically known as “dual” or “tri” band filters, these filters can be used over you color camera to capture only narrowband data. For example, they’ll only allow Ha and Oiii data to hit the camera sensor allowing for significantly more detail on the target without drowning the sensor with broadband data. If you want to image emission nebulae successfully, narrowband filters are required.

Filters - Monochrome filters

Color filters are required by monochrome cameras as they can only image in black/white.

Monochrome cameras produce better results (signal to noise) because every pixel on the sensor is dedicated to the filter being used whereas the pixels on a color camera are split three ways: red, green, and blue. Note that color cameras are of increasingly better quality these days and can produce nearly identical results as monochrome cameras to the average eye.



Luminance, Red, Green, Blue, Sulfur, Hydrogen, and Oxygen Antlia Filters inside a PlayerOne filter wheel

Filters - Filter Drawers/Wheels

There are several ways to utilize filters. Some can be screwed onto some part of the image train of your rig, but most imagers end up using two of the following methods:

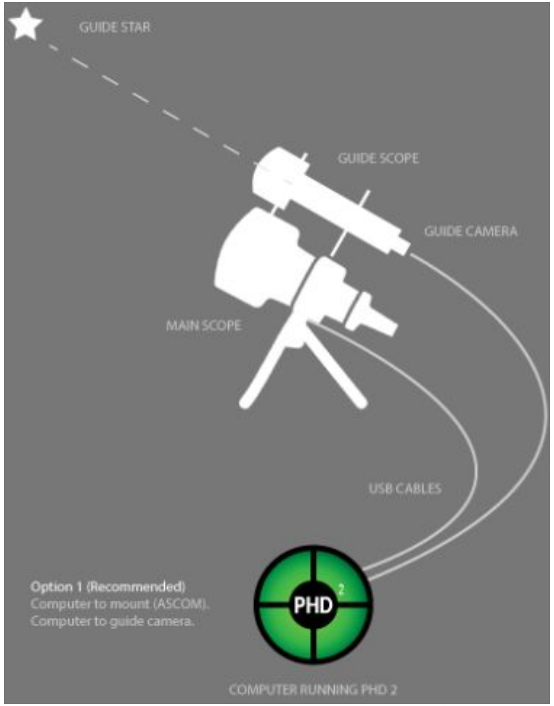
Filter wheels - usually electronic, they allow for switching between filters without touching anything

Filter drawers - allows for the easy swap of filters without taking apart the entire image train

Guide Equipment

Guide Equipment - Why Guide?

Guiding (a.k.a. autoguiding) is the process of using a *secondary* camera and software to monitor a guide star and send corrective commands to a telescope mount to counteract errors in its tracking of celestial objects. This feedback system ensures that stars remain perfectly still in the frame, allowing for much longer exposure times without star trails, which is essential for capturing clear images of deep-sky objects.



<u>Guiding is important because mounts don't track perfectly!</u>

Short focal length telescopes and short exposures may not need guiding if a high-quality mount is used to track the night sky, however the higher the focal length and the longer the exposure, the more guiding is necessary regardless of mount quality.

Guide Equipment - Guide camera

Guide Cameras are a small, dedicated cameras attached to guide telescopes or off-axis guiders used to monitor a celestial object and send correction commands to the telescope mount, ensuring the mount precisely tracks targets during long exposures.

- ❖ They’re typically inexpensive, relative to other astrophotography equipment
- ❖ Best if monochrome to ensure maximum signal-to-noise ratio
- ❖ Some can double as a planetary or all-sky camera
- ❖ Most common software used for guiding is PHD2
    - ➢ Both the mount and the guide camera are connected through this software
    - ➢ Automatic corrections will be sent to the mount based on the guide information analyzed by PHD2

Guide Equipment - Guide scope

A **Guide Scope** is a smaller, secondary telescope with its own dedicated camera that attaches to the main imaging telescope.

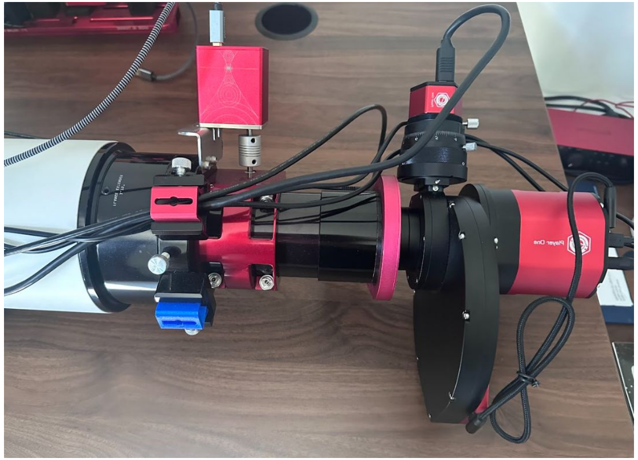
Typically, a guide scope around quarter of the focal length of the primary scope is sufficient. Most guiding software allows for a range of focal lengths to work.

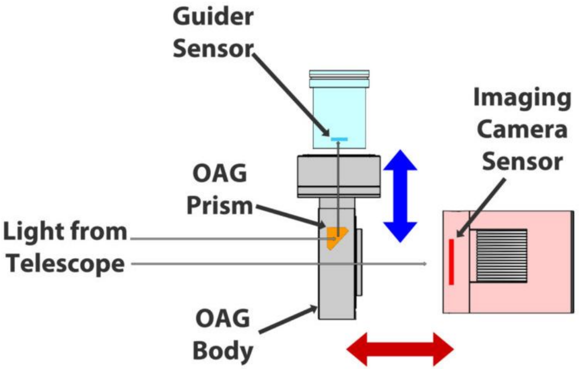
- ❖ Pros
  - ➢ Relatively inexpensive
  - ➢ Straightforward setup
  - ➢ Focus and imaging is separate from primary scope
- ❖ Cons
  - ➢ Not ideal for larger focal lengths (SCT's)
  - ➢ Guide scope is susceptible to dew
- ❖ Imaging
  - ➢ Recommend beginners to use guide scopes. It's the most straightforward option and less susceptible to complications

Guide Equipment - Off-axis guider (OAG)

an **Off-Axis Guider (OAG)** is a device with a small prism that diverts a portion of the light from your main telescope's optical path to a separate guide camera, enabling high-precision autoguiding without needing a secondary guide scope.

- ❖ Pros
  - ➢ Offers more precise guiding than a guide scope
  - ➢ No need to mount guide scope on telescope
  - ➢ Relatively inexpensive
- ❖ Cons
  - ➢ Prone to initial setup complications (less straightforward than using a guide scope)
  - ➢ Can be difficult finding guide stars at higher focal lengths and f-ratios
  - ➢ Will need to recalibrate guiding software every time camera is rotated (unless an electronic rotator is used)
- ❖ Imaging
  - ➢ Perfect for more seasoned imagers and higher focal lengths. OAG technology is ultimately superior to guide scopes





Other Accessories

Auto-Focuser

An **Auto-Focuser** or **Electronic Automatic Focuser (EAF)** is a motorized device that attaches to a telescope to control the focus with extreme precision through a computer or other control device, eliminating the need for manual adjustment.

If you plan to automate imaging to have a rig running all night long, you will find it beneficial to use an auto-focuser.

Primary influences of focus change:

- As the ambient **temperature** drops overnight, the materials of your camera or telescope contract, which shifts the focal plane. This means an initial focus setting might not remain sharp as the night progresses.
- Adding **filters** or filters in a filter wheel can change the optical path, effectively shifting the focal plane and requiring a readjustment of the focus.
- **Atmospheric changes**, primarily due to altitude of targets; the Earth's atmosphere is constantly changing, and its density and refractive index can fluctuate, causing a perceived shift in focus.

Rotator

A **Rotator** is a device that rotates the camera and imaging train around the telescope's optical axis. It’s fits into the imaging train like an extra spacer. A rotator can also be motorized for remote or automated adjustment and can help find better guide stars.

A rotator isn’t necessary as most modern telescopes for imaging come with one built in.

Reducers/Flatteners/Coma Correctors

A telescope **field flattener** is an optical accessory that corrects field curvature and other distortions in astrophotography images, resulting in a flat focal plane and sharper, more detailed photos across the entire field of view.

- *Most refractors, apart from Petzval's, require a field flattener for perfect looking stars throughout the image.*

A telescope **coma corrector** reduces or eliminates coma, an optical aberration that distorts star shapes, making them appear comet-like or egg-shaped, especially at the edges of the field of view.

- *Some reflectors require a coma corrector for perfect looking stars throughout the image.*

A telescope **reducer** decreases a telescope's focal length, effectively shortening the light path to create a wider field of view and faster f-ratio.

- *Reducers aren't necessary, however they can make a telescope significantly "faster". They are often combined with flatteners or coma correctors as a one-stop solution.*

Other Accessories - Dew

Dew shields

Dew shields are cylindrical accessories for telescopes and cameras that attaches to the front to prevent dew and frost from forming on the lens or optical element by trapping warmer air and reducing heat loss to the cold night sky.

Dew heaters

Dew heaters are low-wattage, flexible electric heating strips used in astrophotography to prevent moisture from condensing on telescope optics or camera lenses. They typically require a **dew controller** to operate.

You will likely need both!

Other Accessories - Power

Power box

A **power box** is a central hub that consolidates power distribution and control for multiple astrophotography devices, like cameras, mounts, and dew heaters, into a single, organized unit. With these, you'll only have to "power" the power box, everything else is plugged into the power box.

Recommended as they double as dew controllers and USB hubs!

Power bank

A **power bank** is a portable, high-capacity battery designed to power essential astronomical equipment like telescope mounts, cameras, and computers for extended periods, especially at remote dark sky locations where AC power is unavailable.

Only necessary if you will not have access to AC power.

Control Computer

Between the camera, guide camera, mount, autofocuser, dew heaters, and other accessories, you will need a way to connect, manage, and control all of them.

There are some great options out there that include using a regular laptop, a mini-PC attached to your rig, or something like the ASIAir which is an all-in-one solution perfect for beginners.

Control Computer - Laptop

A common **laptop** can be used to control all of your equipment fairly easily.

- Pros
  - You may already have one
  - Can be fairly inexpensive, does not need to be a powerful system
  - Can use whatever software you want to control rig
- Cons
  - Must be left outside with the telescope
  - Requires different source of power than other accessories
  - Requires own setup of software
- Imaging
  - Most start with a basic laptop to manage their astrophotography rig, however leaving a laptop outside all night is not ideal

Control Computer - Mini PC

A **mini-PC** is really small computer (small as a cell phone) that runs like a normal computer.

- Pros
  - Can be controlled remotely!
  - Small enough to be attached permanently to rig
  - Plenty of USB ports to connect all equipment
  - Runs off 12V power
  - Can be fairly inexpensive, does not need to be a powerful system
  - Can use whatever software you want to control rig
- Cons
  - Requires own setup of software
- Imaging
  - Great for imaging, especially if you want greater control/customization over equipment

Control Computer - Smart Controllers

Smart Controllers are compact, wireless computing devices that acts as the central command hub for an entire astrophotography rig.

- ❖ Pros
  - ➢ A mini-PC designed for astrophotography
  - ➢ Can double as a powerbox/dew controller
  - ➢ Software is already installed (typically the software of the brand you bought the controller from)
- ❖ Cons
  - ➢ The software is already installed, therefore not customizable
  - ➢ Typically only connects within same-brand equipment
- ❖ Imaging
  - ➢ Smart controllers are fantastic for beginners, in fact would highly recommend unless you like computers, but they lack customization often desired as you gain more experience

Break Time

Connecting Equipment

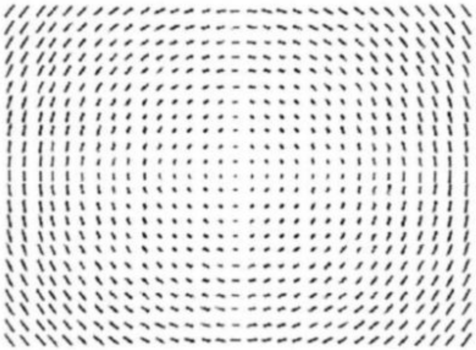
Connecting Equipment - Camera to telescope

Virtually all modern *digital cameras* can be attached to essentially all modern telescopes using **t-adapters,** which connect to the camera where the lens normally would. The opposite end contains threads that allow you to screw the camera directly onto a telescope.

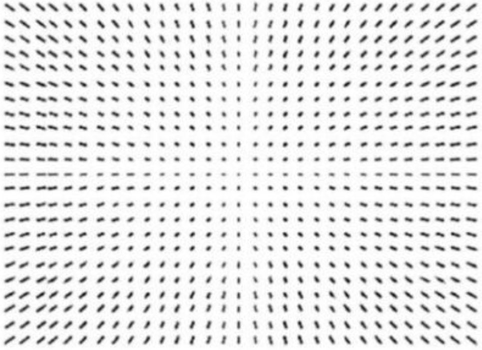
All *astro cameras* already have threads on the frontal interface to allow direct connections to a telescope.

Connecting Equipment - Back Focus

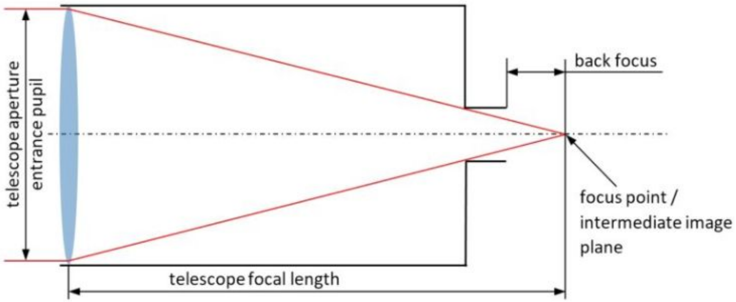
Back focus is the fixed, required distance from the final optical component (like a reducer, coma corrector, or Barlow lens) to the camera's sensor plane that ensures the optics function as designed, preventing image distortions like curvature. It is a crucial optical distance that must be achieved with components like spacers and filter wheels after adding corrective optics to an imaging train.



Too much space between camera and scope



Not enough space between camera and scope



Spacers can help provide the proper back focus distance required by your equipment.

Connecting Equipment - Imaging Train

An **image train** is the complete assembly of optical and electronic components arranged in order from the light-gathering telescope to the image sensor, where the light is recorded.

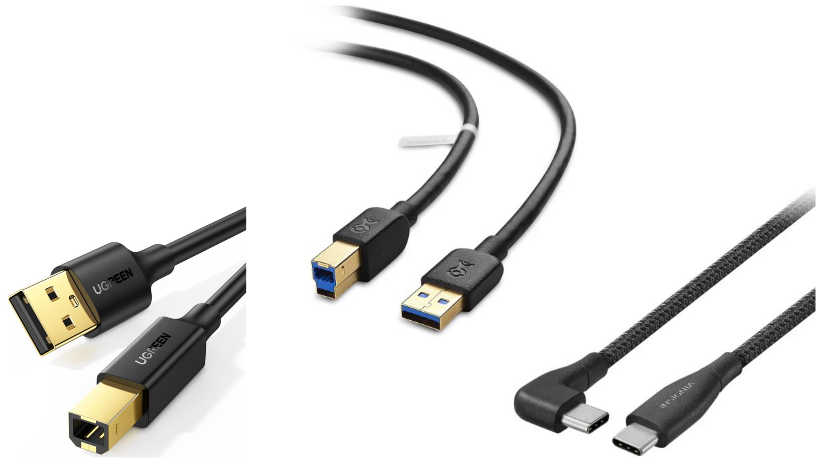
- ❖ Filters via filter drawer or wheel should be right against the camera if possible
- ❖ Reducers, correctors, and flatteners should be right against the telescope
    - ➢ Since back focus is determined by a specific amount of space between the camera sensor and the final optical component of the telescope, you want to “fill the space” between the two with other equipment such as OAG’s and filter wheels or simply spacers to reach the required back focus distance

Camera > Filter Wheel > OAG > Spacer > Rotator > Spacer > Flattener > Telescope

Required back focus in this setup is 88mm

Connecting Equipment - Common Cables

Many different types of cables are used for astrophotography, it all depends on your equipment. But they can be put into two broad categories: **connectivity** and **power** cables.

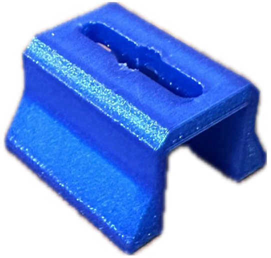


USB cables are used to connect equipment to each other and the computer. They connect cameras, mounts, focusers, filter wheels, rotators, computers, etc. Each piece of equipment may require a different type of USB cable, so be sure to check the compatibility of equipment to cables.

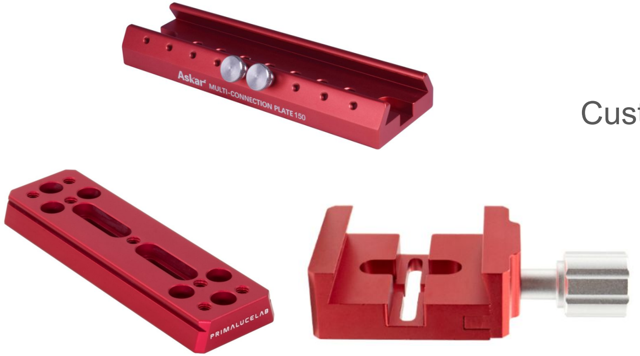
Virtually all astrophotography gear is powered via DC 12V power. You can use AC adapters, however most find it beneficial to consolidate the power source via a power box that is fixed on the rig or telescope itself.

Connecting Equipment - Attaching Accessories

There are multiple ways to attach accessories such as power boxes, mini-PCs, and guide scopes to your rig.

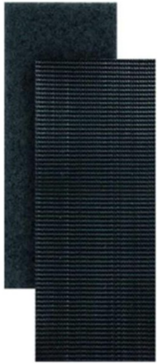


Custom 3D printed pieces



Mounting plates and brackets

Custom manufactured pieces



Velcro!

Data Acquisition: Taking Pictures

What Equipment Should You Start With?

Use what you have!

- ❖ You'd be surprised what you can image with just a cell phone and a small telescope

Consider your goals vs your budget

- ❖ Learning
- ❖ Versatility
- ❖ Investing in gear now to scale up later

Start small

- ❖ Small setups are very forgiving in terms of tracking errors, guiding, image issues, etc.
- ❖ You can get great results with relatively inexpensive gear; a lot of targets are fairly large!
  - ➢ Telescope: wide-field refractor (e.g. Askar FRA300)
  - ➢ Mount: light-weight, low capacity (e.g. Sky-Watcher Star Adventurer 2i Pro)
  - ➢ Camera: color camera (e.g. ZWO ASI294MC)
  - ➢ Guide scope *not* OAG (e.g. WO UniGuide 32mm)
  - ➢ Guide camera: lowest cost (e.g. ZWO ASI120MM Mini)
  - ➢ Control computer: plug and play (e.g. ZWO ASIAir)
- ❖ Can spend more time focusing on the processing
- ❖ Or get a smart telescope like the SeeStar

David's first "real" rig

A Few Things To Consider

Know your limitations

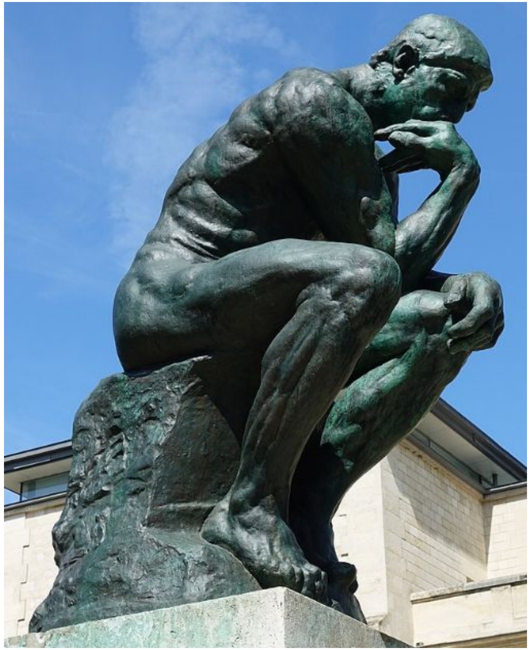
- ❖ Average weather conditions of the region
  - ➢ *Summer in Western NC can be discouraging for imaging
- ❖ Light pollution
  - ➢ Consider light pollution filters if in a brighter Bortle scale area or highly illuminated neighborhood
- ❖ Access to open skies
  - ➢ Imaging from home is ideal but there are alternatives
- ❖ Weight of gear
  - ➢ Setup and takedown of gear can be taxing
- ❖ Expect a lot of troubleshooting and frustration
  - ➢ Occam’s Razor
  - ➢ Start small and slow

Automation is ideal

- ❖ It is possible to fully automate your rig to take images all night long
- ❖ Requires software, can be monitored from indoors
- ❖ Sleep while your rig images!

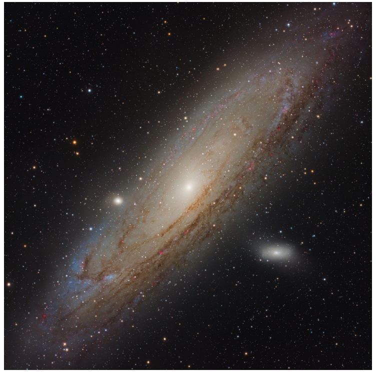
Remote imaging is an option

- ❖ Can send your own rig to a remotely operated site
- ❖ Can use already set up remote telescopes, just pay for the data



Picking Targets

Common types of astrophotography Deep Sky Objects (DSOs)



Galaxies

- ❖ Primarily imaged in broadband
- ❖ Majority of galaxies are found during “galaxy season” which is essentially spring.

Nebulae

- ❖ Two primary types
  - ➢ Emission, imaged in narrowband
  - ➢ Reflection, imaged in broadband
- ❖ Can be found anytime outside of galaxy season

Planetary Nebulae

- ❖ Can be imaged in either broadband or narrowband
- ❖ Can be found anytime throughout the year
- ❖ Typically very small targets

Clusters / Asterisms

- ❖ Imaged in broadband
- ❖ Can be found anytime throughout the year
- ❖ Often accompany other targets

Picking Targets

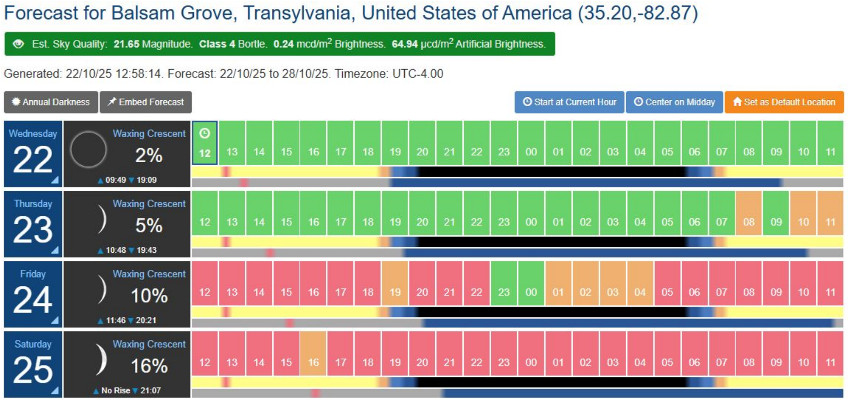
How to choose targets

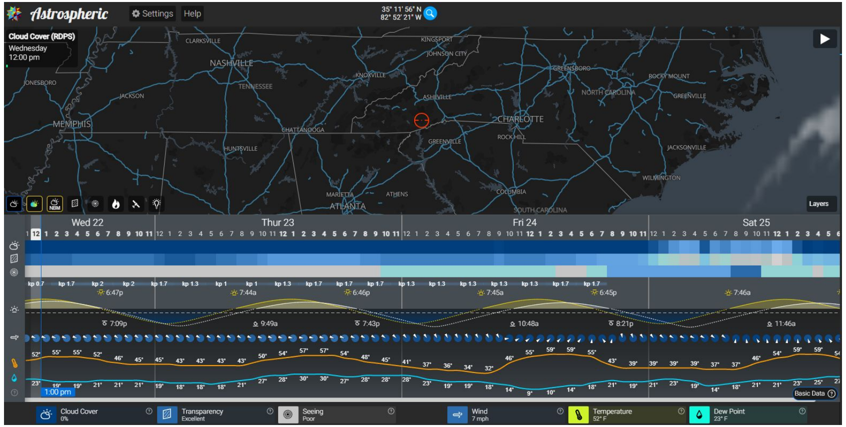
- ❖ Planetarium software
  - ➢ Stellarium, Sky Safari, etc.
  - ➢ Can search the night sky by your coordinates and time
- ❖ Telescopius
  - ➢ Free website to help find astrophotography targets
  - ➢ Telescope simulator to help frame targets
  - ➢ Highly recommend!
- ❖ Forums
  - ➢ CloudyNights, AstroBin, etc.

When to image a target - common rules of thumb

- ❖ Only image targets above 30 degrees altitude
- ❖ Try to get at least **three** hours of total data on a target before processing
- ❖ Image broadband when moon is less than 50% full
- ❖ Image narrowband when moon is more than 50% full
- ❖ Typically not advisable to image during full moon

Weather & conditions





- ❖ Sources for determining weather and conditions
  - ➢ Clear Outside
    - ■ Free website and app
  - ➢ Astrospheric
    - ■ Free website and app that has a subscription version that contains more data and consolidated forecasting
- ❖ Transparency
  - ➢ *the clarity and purity of the atmosphere, determining how much light from celestial objects can pass through it to reach your camera.*
  - ➢ High transparency allows you to see fainter stars and more subtle details in deep-sky objects because less light is absorbed or scattered by atmospheric components like dust, haze, humidity, and aerosols.
- ❖ Seeing
  - ➢ *the stability and clarity of the Earth's atmosphere, which causes light from celestial objects to appear blurred, distorted, or twinkling due to atmospheric turbulence.*
  - ➢ Good seeing results in sharp, stable images of celestial bodies, while poor seeing, often caused by turbulence from wind or the jet stream, leads to fuzzy or unstable images with a loss of fine detail.

Mount alignment & tracking

Alt-Az mounts

- ❖ Alignment usually performed by manually slewing to 2 or 3 prominent stars already recorded in mounts database

EQ mounts

- ❖ Requires polar alignment which is performed by pointing the mount precisely at the north star
  - ➢ Can be done manually through the use of a polar scope, which is sometimes built-in to the mount
    - ■ Requires the mount to be in light-of-sight of the north star
    - ■ This is an obnoxious process if don’t have an observatory as it will need to be done every time you image
  - ➢ Can be done with assistance from software: triangulate the position of the mount by recognizing the stars in an image
    - ■ Best way to polar align, but requires use of software

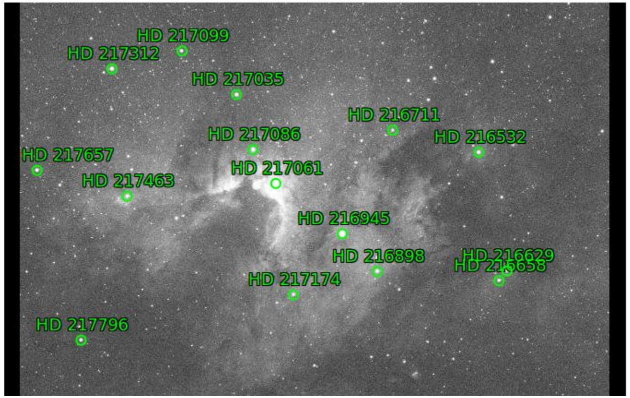
Tracking rate: Sidereal

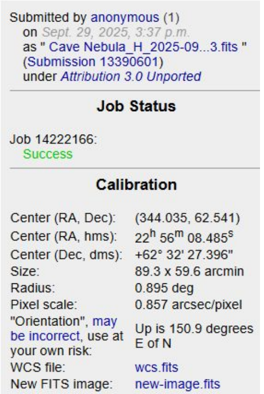
- ❖ This is the standard and most commonly used tracking rate for deep-sky astrophotography
  - ➢ The sidereal day is the time it takes for the Earth to rotate once relative to the distant stars, which is 23 hours, 56 minutes, and 4 seconds
  - ➢ Using a mount set to the sidereal rate compensates for the Earth's rotation, making the stars appear motionless in your long-exposure photographs
  - ➢ This setting allows you to capture sharp, "pinpoint" stars and detailed deep-sky objects, such as nebulae and galaxies, without creating star trails

Mount alignment & tracking

Plate-solving

- Identifying the coordinates of an image by analyzing the stars in the image
  - Can be performed by software to assist in many tasks for astrophotography including: polar alignment (without the need to see the north star) and slewing to a target perfectly.
  - Can “inform” the mount what it’s currently pointing at



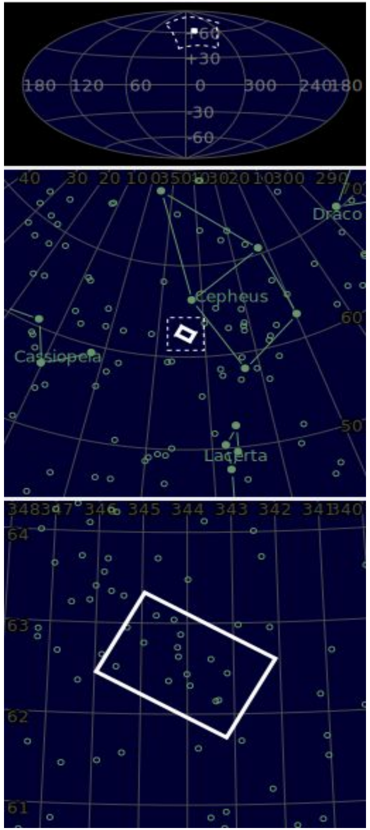

Submitted by anonymous (1)
on Sept. 29, 2025, 3:37 p.m.
as " Cave Nebula_H_2025-09...3.fits "
(Submission 13390601)
under Attribution 3.0 Unported

Job Status

Job 14222166:
Success

Calibration

Center (RA, Dec):	(344.035, 62.541)
Center (RA, hms):	$22^h\ 56^m\ 08.485^s$
Center (Dec, dms):	+62° 32' 27.396"
Size:	89.3 x 59.6 arcmin
Radius:	0.895 deg
Pixel scale:	0.857 arcsec/pixel
"Orientation", may be incorrect, use at your own risk:	Up is 150.9 degrees E of N
WCS file:	wcs.fits
New FITS image:	new-image.fits

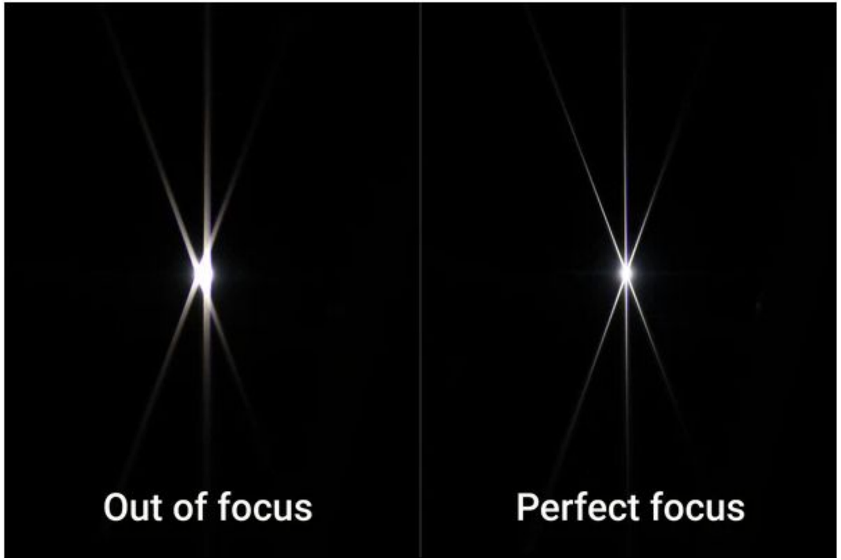


Focus

Manual Focus

- Simply adjust the focuser until the stars are as small as possible, however this is prone to inaccuracy
- Highly recommend using a *Bhatinov Mask*
  - A mask placed over the front of a telescope that creates three distinct diffraction spikes from a bright star. For perfect focus, these spikes must form a symmetrical pattern with a central line bisecting a cross; any offset indicates the telescope is out of focus.

Bhatinov Mask

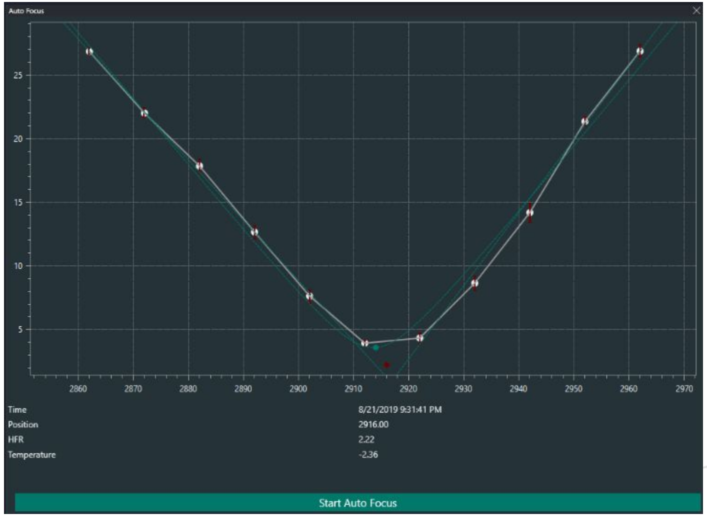


Focus

Auto-Focus

- Remember, most optical assemblies will suffer from focus shift throughout the night whether it be because of temperature shift or other causes such as switching between filters
- With a focus motor and software, you can perform an automated analysis to determine the optimal focus of the telescope. This analysis takes a series of images at different focus intervals to determine the focus point with the smallest star sizes

Focus Motor



Auto-focus analysis performed in N.I.N.A.

Taking pictures - The Fight for Signal

Signal-to-Noise Ratio (SNR)

- ❖ A measure of how clear and strong the image of a celestial object (the signal) is compared to the random, unwanted information (noise) captured by the camera
- ❖ A high SNR means the celestial object's details are prominent and easy to see, while a low SNR indicates that the noise is overwhelming the signal, making the image difficult to interpret and reducing its quality

One 300-second exposure (5 min total)

Since we are taking pictures of very dark and faint objects, a single picture will not contain enough signal to generate a quality image. This is why we need to take many pictures and stack them together: to increase the SNR!

123 stacked 300-second exposures (10 hr total)

Taking pictures - Camera settings

File type

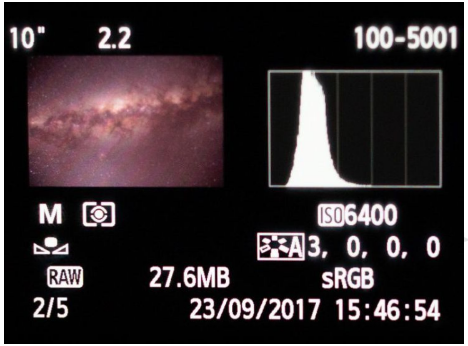
- ➢ For digital cameras, make sure to save images in RAW format for optimal processing of data
- ➢ For astro-cams, FITS formatting is most common

ISO/gain

- ➢ The higher the gain, the brighter the image, the lower the dynamic range, and more noise
- ➢ The lower the gain, the darker the image, the higher the dynamic range, and less noise
- ➢ For digital cameras, try setting ISO at 1600
- ➢ For astro-cams, refer to manufacturer specs for optimal gain

Exposure time

- ➢ ISO/gain used, light pollution, type of target, etc. will affect the amount of exposure time you may need, which may be anywhere from 10 seconds to 5 minutes with adequate tracking
- ➢ *Expose as long as your equipment allows without stair trails or oversaturating pixels*
- ➢ Check your histogram!
    - ■ Ideally want the peak of your histogram to be as close to the middle as possible or at least past the 1/3rd mark from the left
    - ■ Do not want to clip black or white: underexposed will leave pure black pixels, overexposed will “blow out” stars by creating pure white pixels
- ➢ Remember, try to obtain at least **three hours** of total integration time before processing



Calibration frames

Calibrations frames are are separate images taken to identify and remove unwanted information—like electronic noise, sensor imperfections, and dust—from your main "light" images of celestial targets. Each type corrects a specific kind of artifact, allowing you to create a cleaner, high-quality final image of the night sky. There are four primary types with the first two as most important:

- Dark Frames
  - Eliminates the electronic and thermal noise of the sensor, including "hot pixels". They are taken with the lens cap on, at the same exposure time, ISO/gain, and temperature as the light frames.
- Flat Frames
  - Corrects for vignetting (darkening around the edges of the image) and dust or dirt on your optics. They are images of a uniformly illuminated surface, like a white t-shirt, and must be taken with the same focus and configuration as your light frames.
- Bias Frames
  - Eliminates the "read noise" of the camera sensor. They are very short exposures (usually less than a second) taken with the lens cap on.
- Dark Flat Frames
  - Similar to darks but are used to correct the noise in the flats themselves. They are taken with the same exposure settings as your flat frames but with the lens cap on.

You'll want to create about 20 of each frame, typically the morning after an imaging session.
The frames will be stacked together, like light frames, to create Master calibration frames.

Calibration frames - Dark Frames

Dark Frames

- ❖ Eliminates the electronic and thermal noise of the sensor, including "hot pixels"
- ❖ They are taken with the lens cap on with the same settings as the Light frames (temp, gain, etc.)

Calibration frames - Flat Frames

Flat Frames

- ❖ Corrects for vignetting (darkening around the edges of the image) and dust or dirt on your optics. They are images of a uniformly illuminated surface and must be taken with the same focus and configuration as your light frames
- ❖ Methods include putting a white t-shirt over the front of the telescope or pointing the telescope at the early-morning blue sky
- ❖ Exposure length can vary because they are taken at an exposure length where the peak of the histogram is around 50%. All other camera settings should be the same as the Light frames (temp, gain, etc.)

Calibration frames - Bias Frames

Bias Frames

- ❖ Eliminates the read noise of the camera sensor, also known as dark fixed-pattern noise, a pattern that is the result of the manufacturing process
- ❖ They are very short exposures taken with the lens cap on. Exposure time doesn’t matter, hence why it can be less than a second, but all other camera settings should be the same as the Light frames (temp, gain, etc.)

Calibration frames - DSLR v CMOS

DSLR	Flats	Darks
WHEN	The morning after your imaging session	Directly after your imaging session is over
WHY	Removes dust motes, vignetting, and other irregularities within the imaging train	(Not Required) Reduces noise and hot pixels
SETTINGS	- Keep ISO, focus, and camera orientation the same as your light frames. - Expose until histogram is 1/2 to 1/3 from the left	Keep ISO, temperature, and exposure length the same as your light frames
HOW	- Cover aperture with a white T-shirt - Point telescope towards the sky - Experiment with exposure lengths (1/2 to 1/3 from left)	Cover aperture with dust cap and continue exposures as you were with your light frames (15-50 darks).
DO NOTS	- Do not adjust focus before taking flat frames - Do not adjust camera orientation before taking flat frames - Do not change ISO settings	-Do not wait until the next night to take darks - Do not adjust ISO or exposure time before taking darks.

CMOS	Flats	Darks
WHEN	The morning after your imaging session	Directly after your imaging session is over
WHY	Removes dust motes, vignetting, and other irregularities within the imaging train	Removes amp glow and reduces noise
SETTINGS	Keep Gain/Offset, focus and camera orientation equal to light frames Expose for 15k-30k ADU	Keep gain/offset, temperature, and exposure length equal to your light frames
HOW	- Cover aperture with a white T-shirt - Point telescope towards the sky - Experiment with exposure lengths (15k-30k ADU)	- Keep dust cap on camera - Set Camera in a cool/dark place -Begin creating dark libary with desired settings
DO NOTS	Do not adjust focus before taking flat frames Do not adjust camera orientation before taking flat frames Do not change gain/offset settings	- Do not adjust ISO or exposure time before taking darks.

Image Capture Software

Image capture software is a computer program that controls astronomical cameras and related equipment, allowing users to automate exposure sequences, frame and focus celestial objects, and manage the acquisition of image data for deep-sky and planetary imaging.

Sequence Generator Pro
- by -
Main Sequence Software

N.I.N.A.

ZWO ASIAIR

Astro Photography Tool

Image Capture Software

Nighttime Imaging 'N' Astronomy

N.I.N.A: free, open-source software created by astrophotographers for astrophotographers.

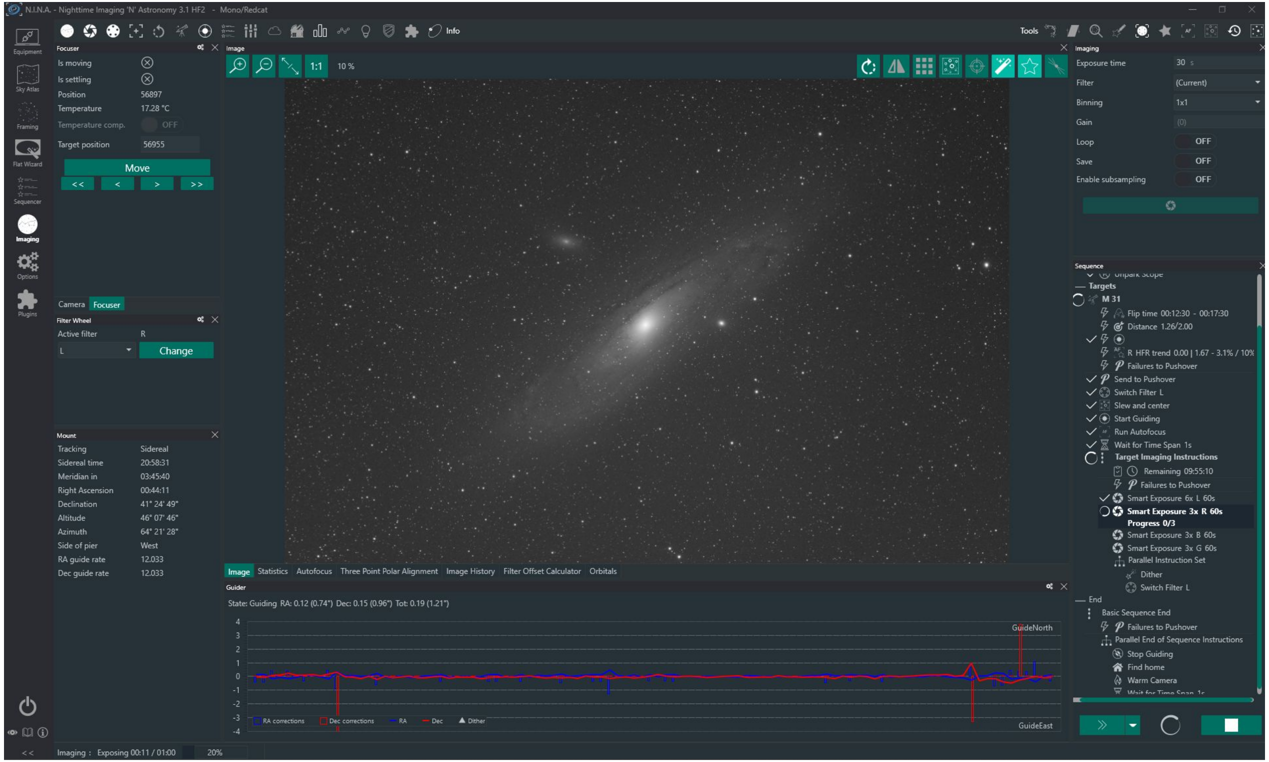
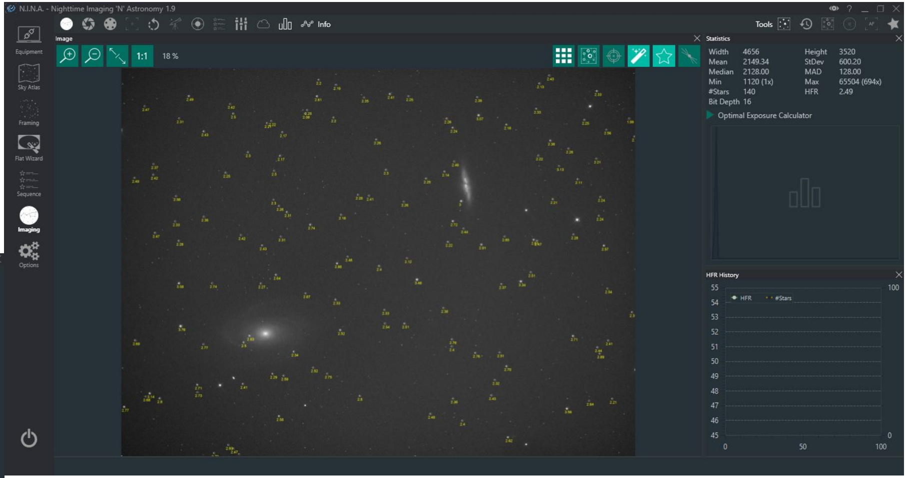
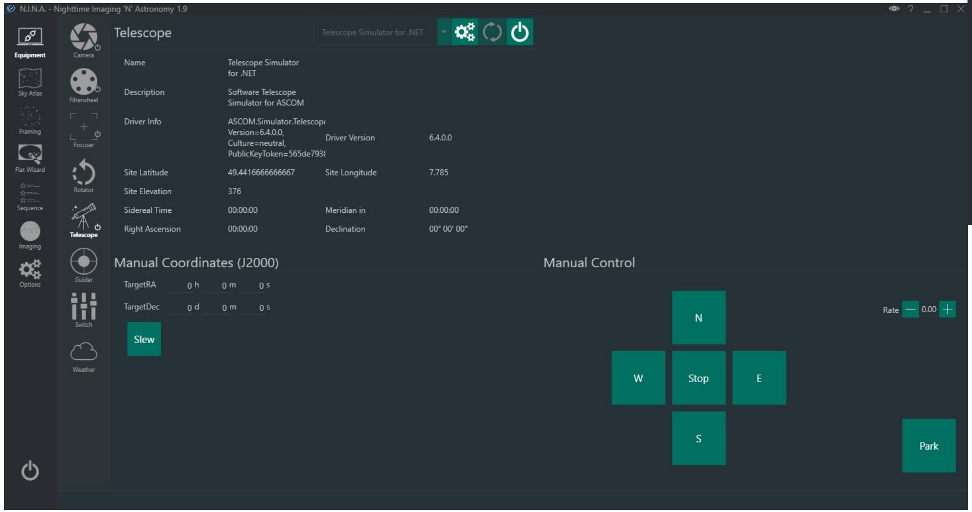


Image Capture Software

Nighttime Imaging 'N' Astronomy

- Can **control all/any equipment** that can be connected to a computer
  - Camera, telescope, filter wheel, focuser, guider, etc.





- **Image Recognition**
  - Statistics calculation for each frame
  - Automatic stretch for a good preview of data
  - Star Detection with Half Flux Radius calculation
  - Exposure time recommendations

Image Capture Software

Nighttime Imaging 'N' Astronomy

- **Sequencing - for beginners**
  - ➢ Set up sequences for multiple targets
  - ➢ Specify various exposure times, number of exposures, filters and more
  - ➢ Automatic target framing using platesolving
  - ➢ Automatic focus after a set of conditions

- **Advanced Sequencer**
  - ➢ Take full control over your equipment
  - ➢ A wide array of instructions to program a sequence
  - ➢ Loop for various conditions
  - ➢ Trigger specific actions when certain events occur
  - ➢ Schedule and plan ahead of time with reusable templates

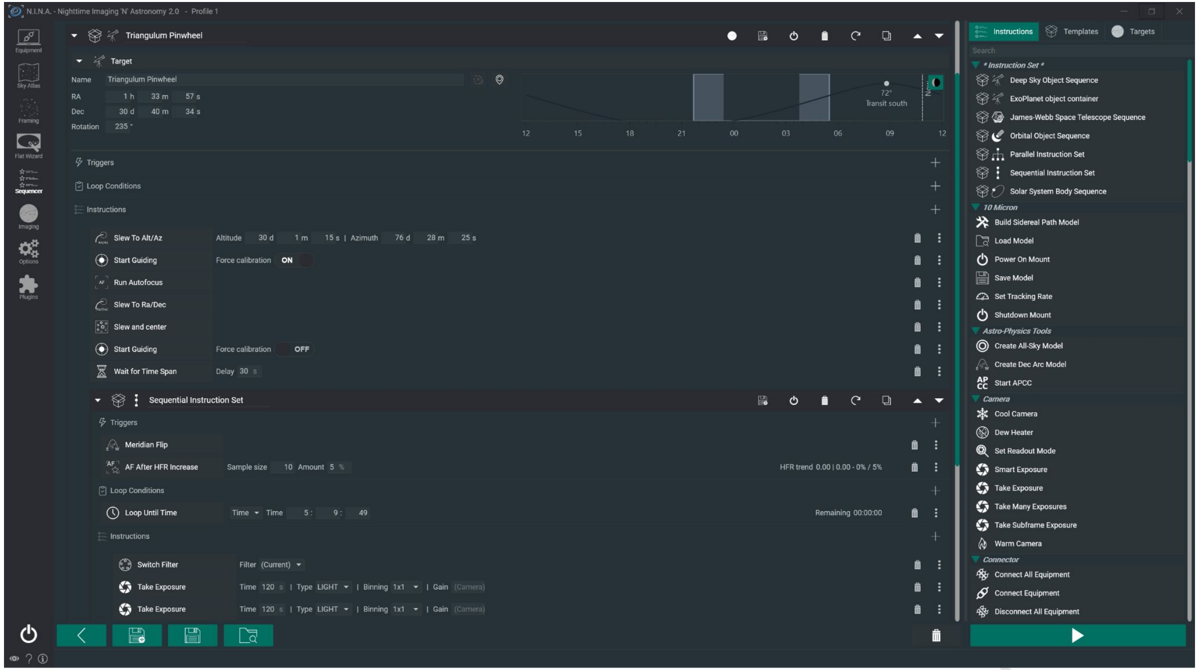
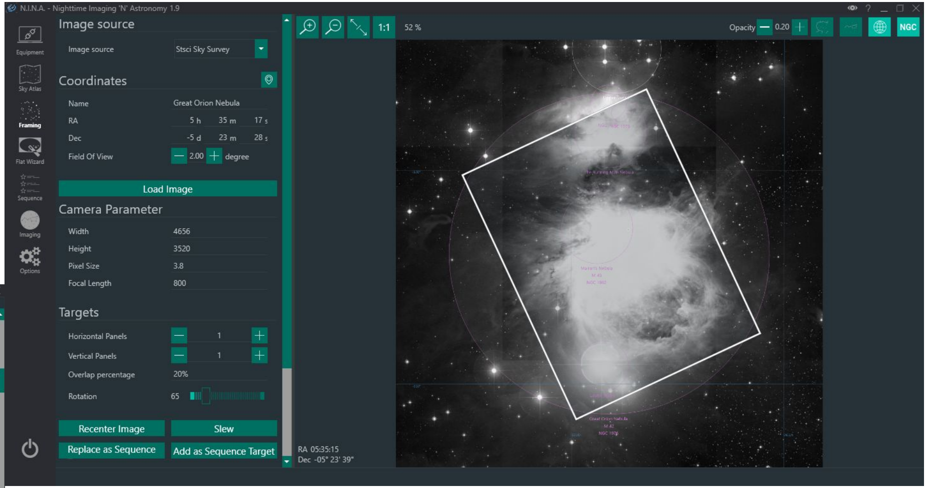
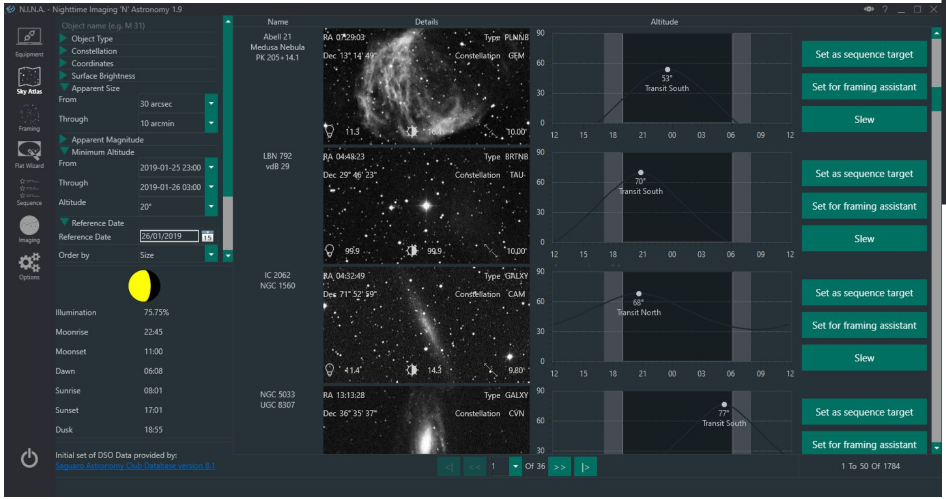


Image Capture Software

Nighttime Imaging 'N' Astronomy



- **Sky Atlas**
  - Detailed Atlas for over 10000 Deep Sky Objects
  - Advanced filtering to get just the Deep Sky Objects that are relevant for you
  - Altitude charts for each object based on your location

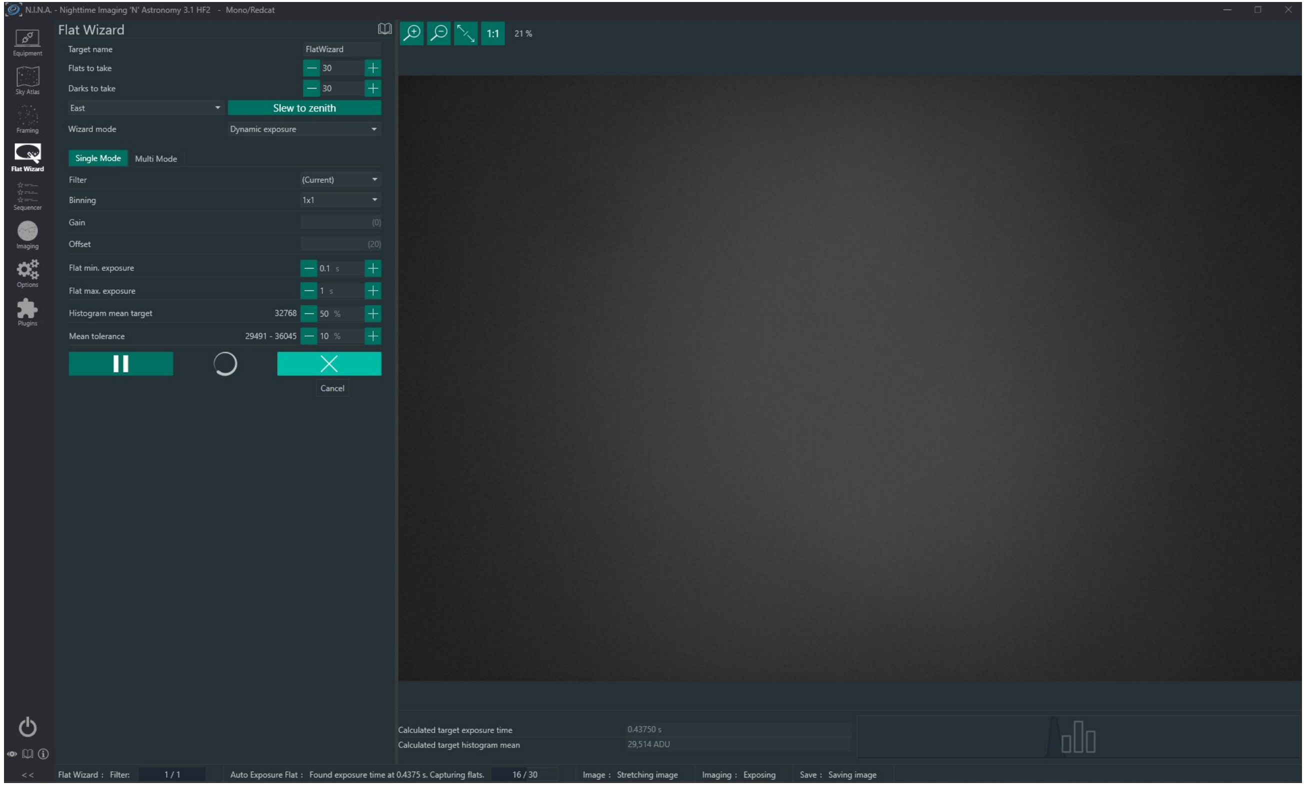


- **Framing Assistant**
  - Various Sky Surveys to pull data from for framing
  - Get a preview of your Field of View
  - Drag the preview for a precise position for framing

Image Capture Software

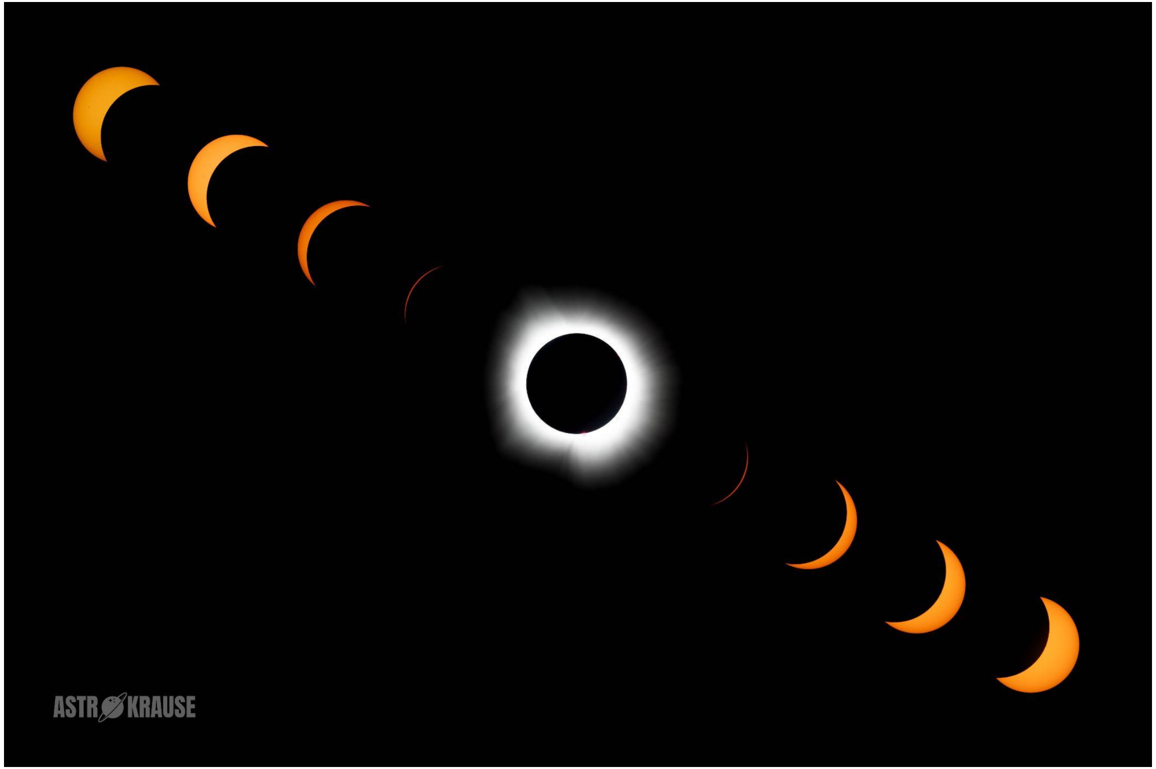
Nighttime Imaging 'N' Astronomy

Flat Wizard to help you easily take perfect flats!



Questions?

Extra Photos

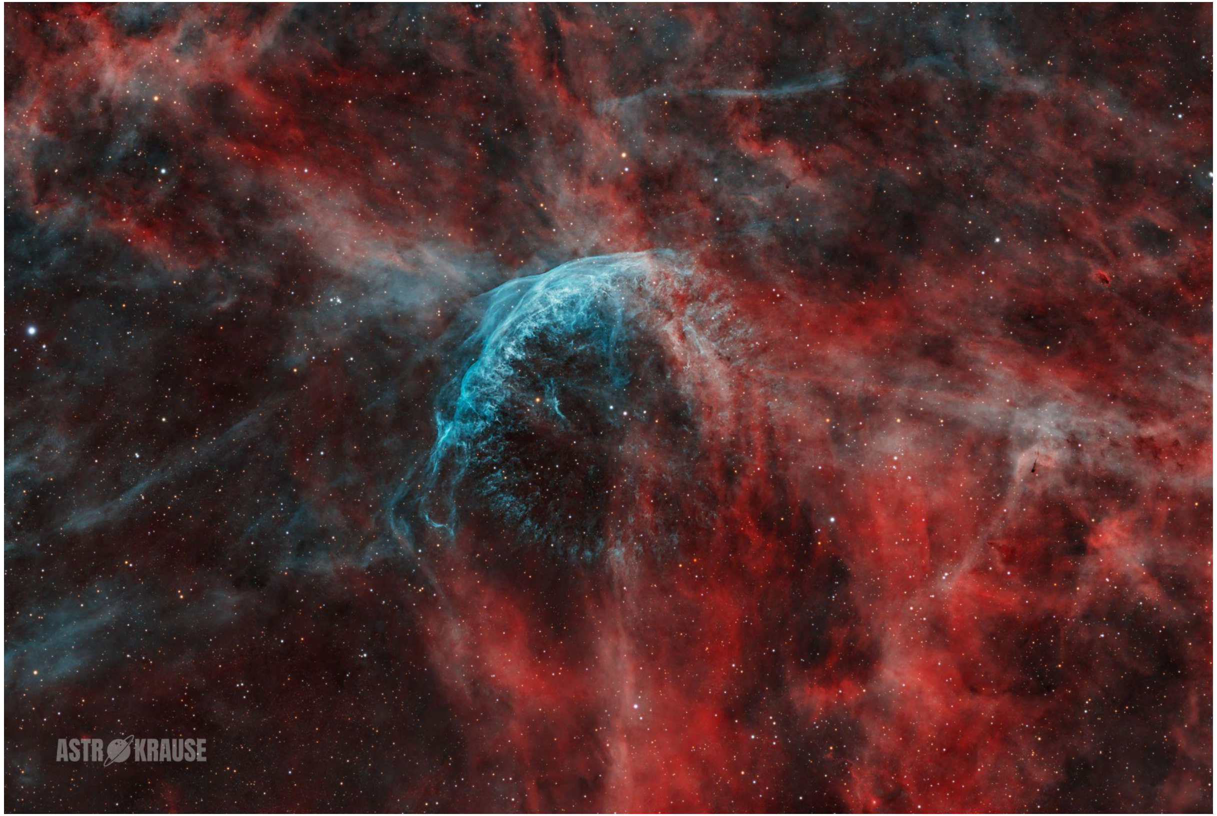


Total Solar Eclipse - April 2024

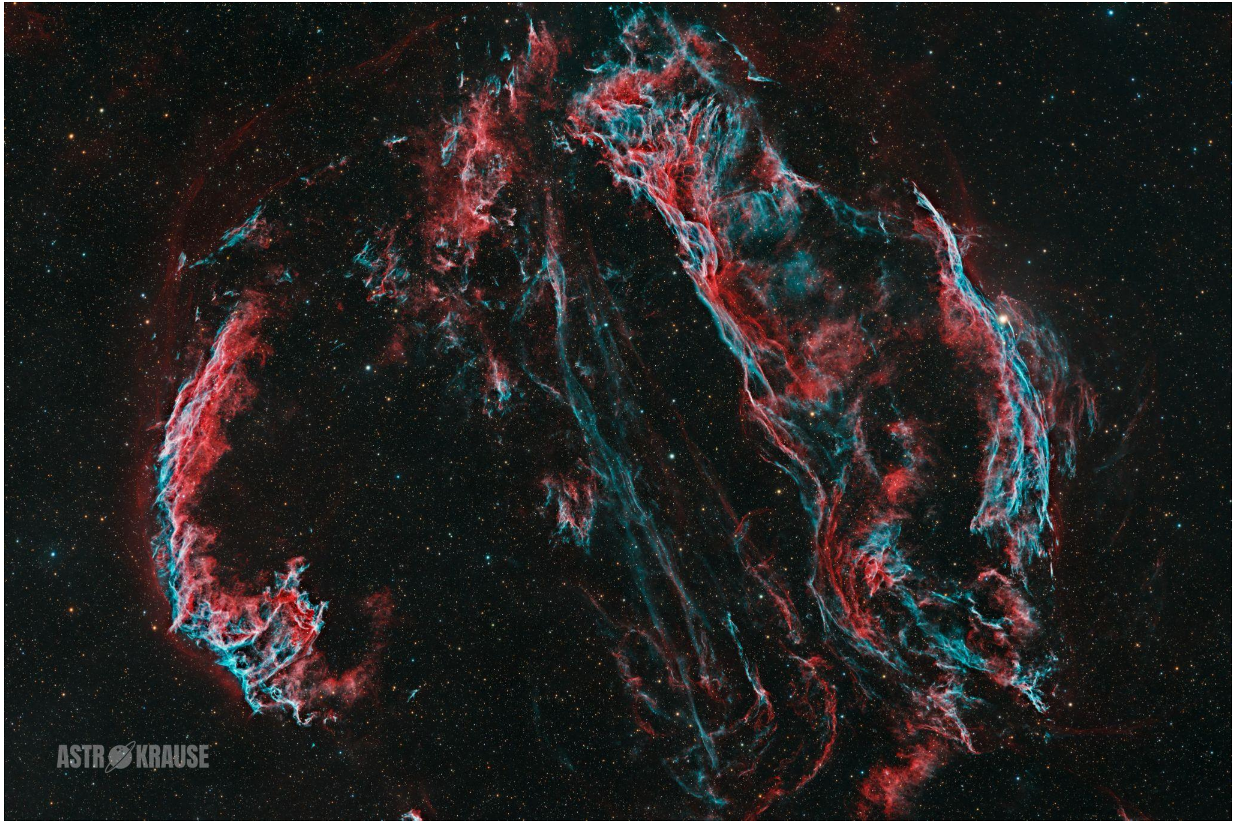
Extra Photos

Extra Photos

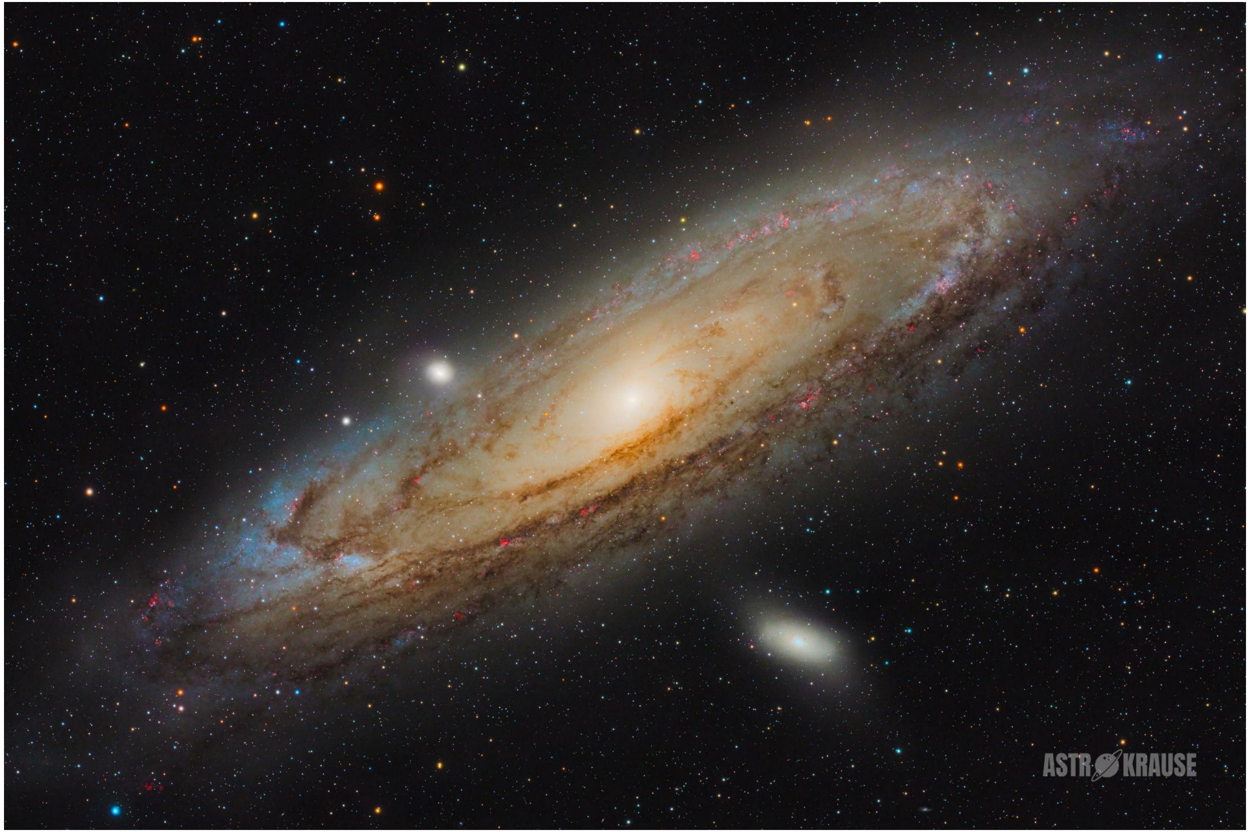
Extra Photos



Extra Photos



Extra Photos



Extra Photos

Extra Photos

Extra Photos

This is really the end now