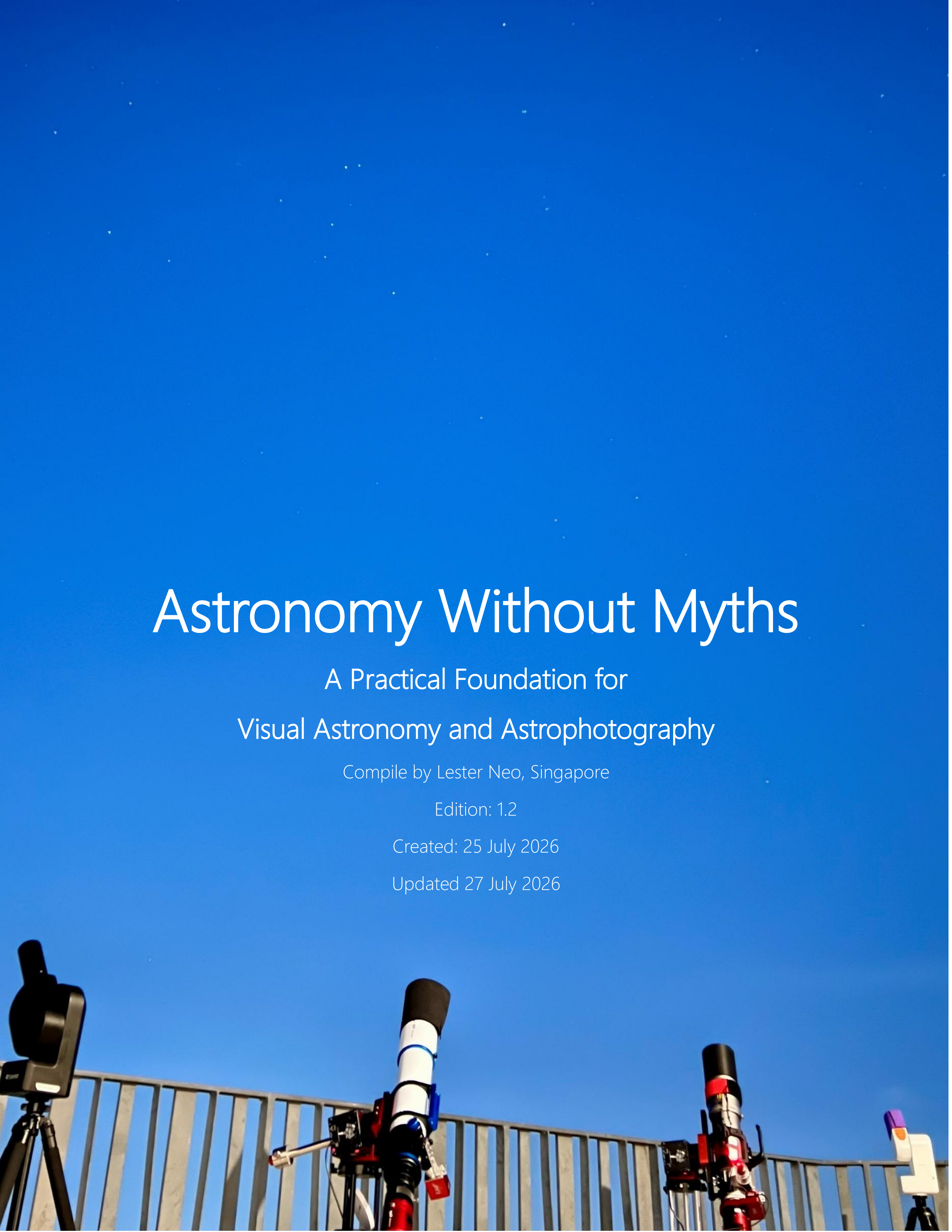

Astronomy Without Myths

A Practical Foundation for Visual Astronomy and Astrophotography

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Preface

This document is structured as a **"Foundation First"** guide rather than a traditional astronomy textbook. The biggest problem with most beginner resources is that they either oversimplify ("bigger telescope = better") or dive too deeply into physics before readers even understand what they're trying to achieve.

Instead, this guide aims to build a **correct mental model**. Once readers have the right way of thinking, every future topic—from buying a telescope to processing astro photos—becomes much easier.

Astronomy is a system, not a specification.

Every observation or astrophotography is shaped by the interaction of the sky, the atmosphere, the equipment, the observer, and the processing workflow. No single parameter - whether aperture, Bortle class, focal ratio, or sensor size - determines success on its own.

This philosophy gives beginners a durable framework for understanding astronomy. Rather than memorizing rules or chasing myths, they learn to evaluate trade-offs, ask the right questions, and make informed decisions as they progress. It creates a much stronger foundation than focusing on isolated facts, preparing readers to advance into both visual astronomy and astrophotography with confidence.

Quick Note to Readers

This document is a compilation of the astrophotography knowledge and practical experience I have gained since 2023. It is built upon thousands of hours spent imaging under Singapore's heavily light-polluted skies, followed by countless hours calibrating, stacking, and post-processing the data into the final images. Almost all of the photographs featured in this guide are my own work.

The text in this document has been edited with the assistance of ChatGPT, while some illustrations were created using Google Gemini. Although every effort has been made to ensure accuracy, both human and AI-generated content may contain errors. If you spot anything that can be improved or corrected, I would sincerely appreciate your feedback.

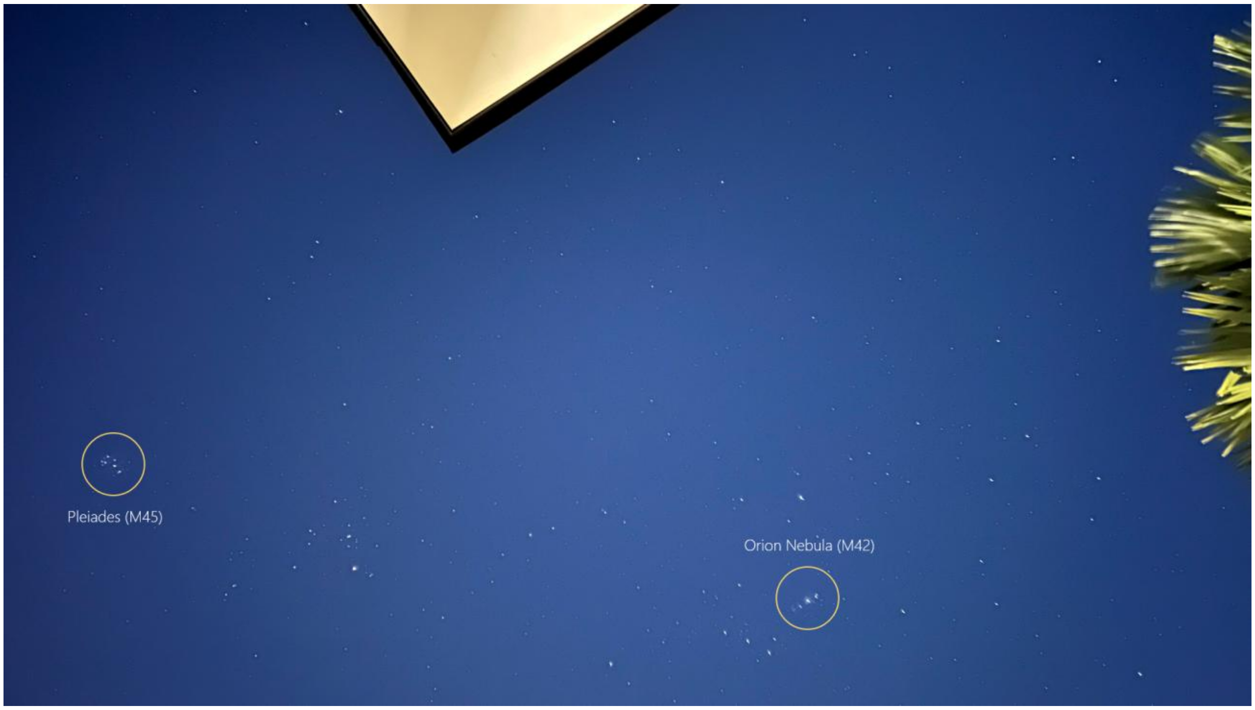
What Astronomy Really Is

Astronomy is the study of the universe through observation. It helps us understand the Sun, the Moon, the planets, the stars, galaxies, and everything beyond Earth.

Unlike many sciences, astronomers cannot travel to the objects they study. Instead, they learn by observing the light that reaches us from space.

Astronomy is not just about looking through a telescope. It is about understanding what you are seeing and discovering how the universe works.

You do not need expensive equipment to begin. Your eyes, your curiosity, and a clear night sky are enough to start learning.



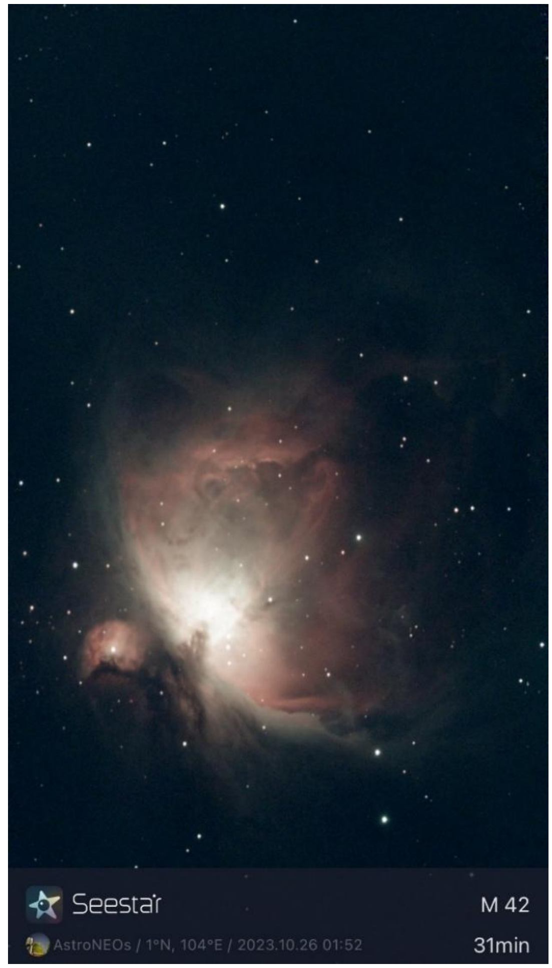
Some people enjoy observing the night sky with their eyes or binoculars. Others use telescopes or cameras to reveal objects too faint for human vision. Both are forms of astronomy.

Throughout this guide, you will learn the basic ideas that make astronomy easier to understand. With a strong foundation, you will be better prepared for both visual astronomy and astrophotography.

Astronomy is not about owning the biggest telescope.
It is about understanding the universe.

Visual Astronomy vs Astrophotography

Visual astronomy *is observing the night sky with your eyes, binoculars, or a telescope. It lets you experience celestial objects as they appear in real time.*



Astrophotography *uses a camera to capture images of the night sky. By collecting light over a longer period, cameras can reveal details and colours that are too faint for our eyes to see.*

Neither is better than the other. They simply offer different ways to enjoy astronomy. Many astronomers enjoy both.

Visual astronomy focuses on the experience of observing, while astrophotography focuses on recording and revealing what cannot be seen by the eye alone.

Visual astronomy lets you see the universe.
Astrophotography lets you reveal more of it.

Amateur vs Professional Astronomy

Professional *astronomers study the universe as their career. They often work at universities, observatories, or research institutions, using advanced telescopes and scientific instruments to conduct research.*

Amateur *astronomers explore the night sky as a hobby. They observe, learn, and share their passion with others using equipment that ranges from the naked eye to personal telescopes and cameras.*

This wide-field image of the Eagle Nebula was taken at the National Science Foundation's 0.9-meter telescope on Kitt Peak with the NOAO Mosaic CCD camera. ***Credit:*** *T.A.Rector (NRAO/AUI/NSF and NOIRLab/NSF/AURA) and B.A.Wolpa (NOIRLab/NSF/AURA)*

The Eagle Nebula (M16) *captured from the edge of Punggol Town, Singapore using a* ***91mm/609mm apochromatic refractor*** *and an* ***ASI585MC AIR*** *camera. Even under Singapore's heavily light-polluted skies, the iconic* ***Pillars of Creation*** *are visible with remarkable detail, showcasing the capabilities of a well-optimized amateur setup.*

The main difference is not the equipment they use, but their purpose. Professionals conduct scientific research, while amateurs observe and explore for enjoyment, education, or personal discovery.

Astronomy is for everyone. Curiosity matters more than your job title.

Why Astronomy Is Different from Daytime Photography

Daytime photography captures objects that are bright and close to us. In astronomy, the subjects are extremely faint and incredibly far away.

Because so little light reaches Earth, astronomical images often require long exposures or many images stacked together to reveal hidden details.

Unlike daytime photography, the Earth's rotation, weather, atmospheric conditions, and light pollution all have a significant impact on the final result.

Success in astrophotography is not just about having a good camera. It also depends on the sky, the equipment, and the techniques used to collect and process light.

Understanding the Night Sky

The night sky is constantly changing. Stars rise in the east and set in the west, different constellations appear throughout the year, and the Moon changes its position and phase every night. These changes are caused by the movement of the Earth, not the stars.

The Earth rotates once every 24 hours. This makes the Sun, Moon, planets, and stars appear to move across the sky from east to west.

At the same time, the Earth orbits the Sun once every year. As our position changes throughout the year, we see different parts of the universe in different seasons. This is why some constellations and deep-sky objects are only visible during certain months.

The planets also move across the sky because they orbit the Sun at different speeds and distances. Unlike the stars, their positions slowly change from night to night.

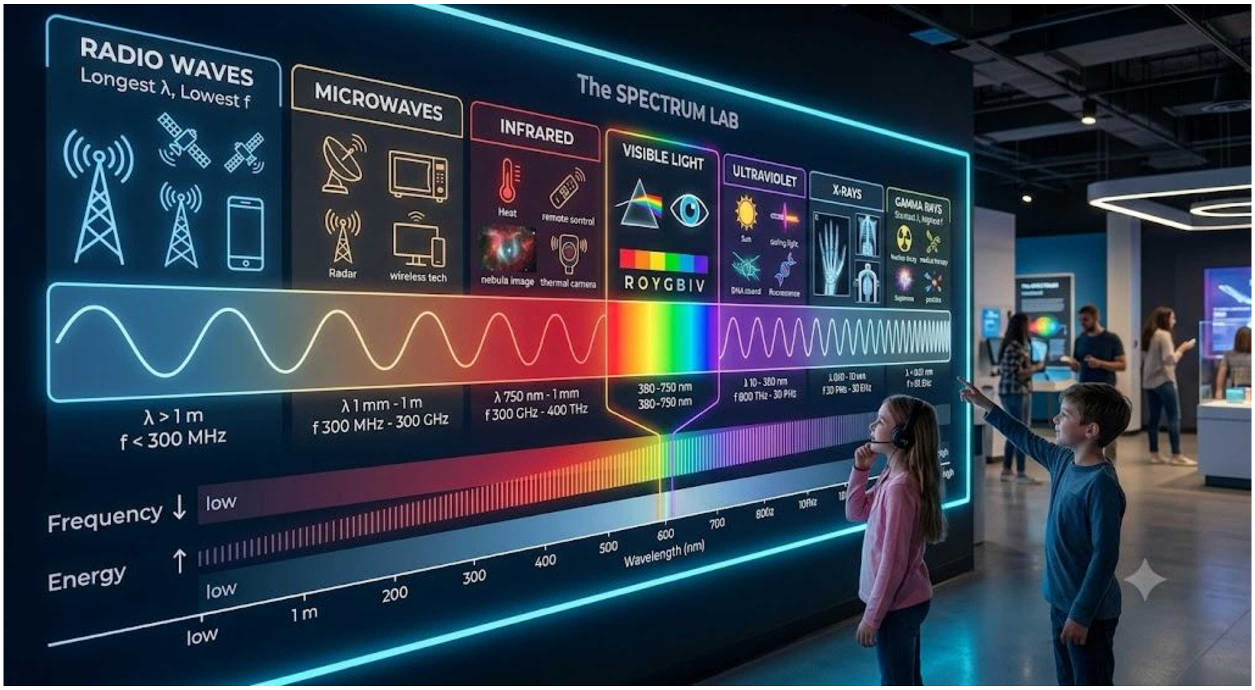
Understanding these simple movements helps you predict where celestial objects will appear and when they are best observed.

The night sky is always changing—not because the stars are moving around us, but because the Earth is moving beneath them.

Understanding Light

Light is the foundation of astronomy. Almost everything we know about the universe comes from studying the light that reaches Earth.

Light carries valuable information. It tells us how bright an object is, how far away it may be, how hot it is, what it is made of, and even whether it is moving towards or away from us.



Our eyes can only see a small part of the light that exists. Many celestial objects also emit infrared, ultraviolet, radio waves, X-rays, and other forms of light that are invisible to us. Modern cameras and scientific instruments can detect some of these invisible wavelengths, revealing details our eyes cannot see.

A telescope does not create light or magnify the universe into existence. Its main job is to collect more light. The more useful light we collect, the more information we can observe and record.

Light Pollution

Light pollution is unwanted artificial light that brightens the night sky. It comes from street lights, buildings, homes, and other human-made light sources.

A brighter sky reduces the **contrast** between celestial objects and the background sky. This makes faint stars, nebulae, and galaxies harder to see or photograph.

Light pollution does not affect every target equally. Bright objects like the Moon, planets, and many star clusters can still be observed even from cities. Fainter deep-sky objects benefit from darker skies.

Omega Centauri Globular Cluster taken from Singapore's Bortle 9 sky.

Omega Centauri Globular Cluster taken from Bortle 4 sky in Kampung Sisek, Mersing, Johor, Malaysia.

While **darker skies** are an advantage, they **are not the only factor**. Atmospheric transparency, seeing conditions, target altitude, and your equipment also play important roles.

Do not judge a night by its Bortle class alone. A clear and stable sky in a city may produce better results than a hazy night under much darker skies.

Transparency

Transparency describes how clear the atmosphere is and how easily light from space can pass through it.

A transparent sky allows more light from stars, nebulae, and galaxies to reach your eyes or camera. A poor transparency night can make the sky appear dull, even when there is little light pollution.

Bortle 4 – Poor transparency due to mist and thin high clouds.

Bortle 6 - Average transparency is a common challenge in rural areas due to higher atmospheric moisture.

Bortle 9 – Cloudless and good transparency is the ideal condition for astrophotography.

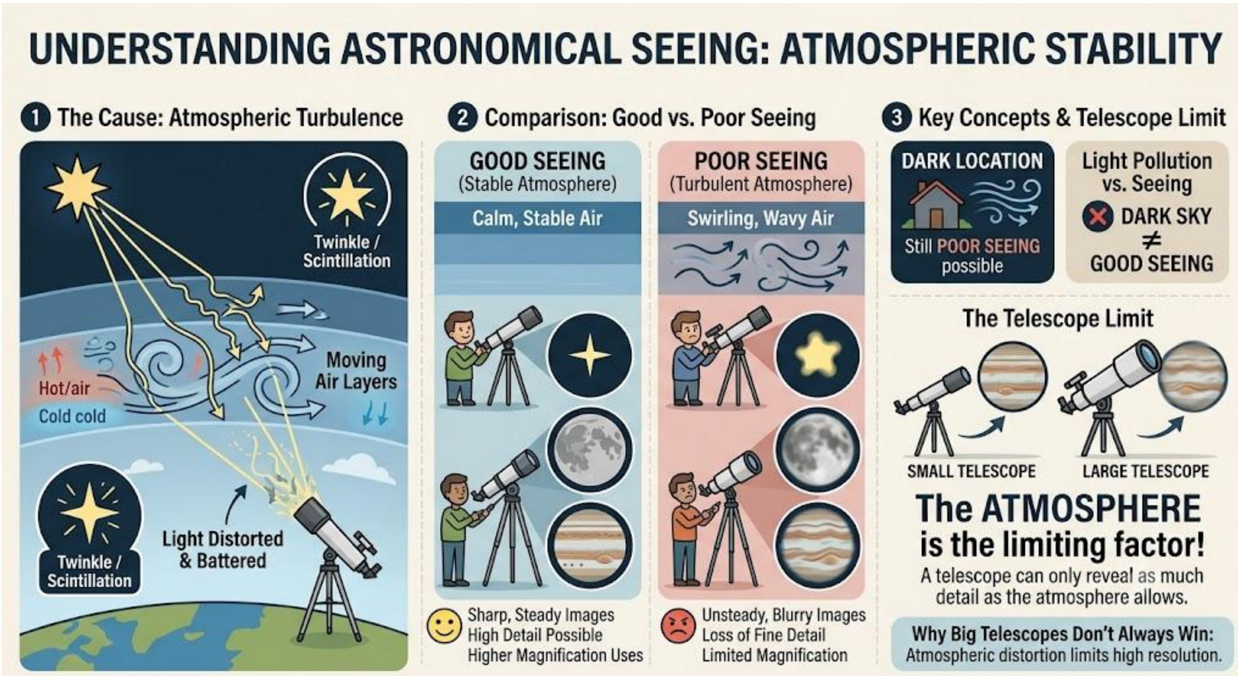
Transparency is affected by many factors, including, humidity and haze, thin clouds, smoke and dust, air pollution and moisture in the atmosphere.

Good transparency is especially important for deep-sky objects because they are often very faint. A darker location does not always guarantee better results if the atmosphere is unclear.

For astrophotography, a clear and transparent night can make a significant difference. More useful light reaches your camera, improving contrast and revealing finer details.

Seeing

Seeing describes the stability of the atmosphere and how much it affects the sharpness of what we observe.



When light from stars and planets travels through Earth's atmosphere, it passes through layers of moving air. These movements can bend and distort the light, causing stars to twinkle and making planets appear blurry.

Good seeing means the atmosphere is calm and stable. Fine details, especially on the Moon and planets, become sharper and easier to observe.

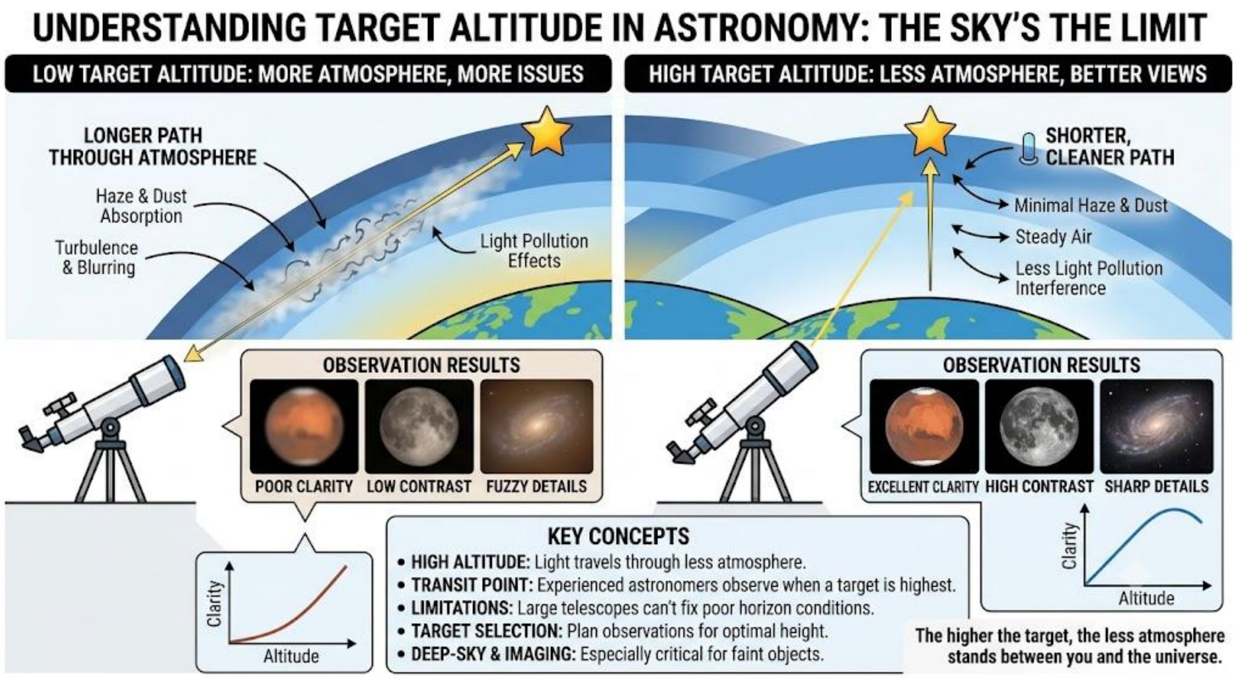
Poor seeing causes images to appear unsteady, reducing the amount of detail that telescopes and cameras can capture. This is especially noticeable when using longer focal lengths or high magnification.

Unlike light pollution, seeing is not improved simply by travelling to a darker location. A dark sky can still have poor seeing if the atmosphere is turbulent.

Understanding seeing helps explain why a larger telescope or higher magnification does not always produce better results. The atmosphere can become the limiting factor.

Target Altitude

Target altitude refers to how high an object appears above the horizon when we observe it in the sky.



When a celestial object is higher in the sky, its light passes through less atmosphere, producing sharper images, better contrast, and improved astrophotography.

Experienced astronomers therefore plan their observations when a target reaches its optimal altitude—typically between 40° and 70° above the horizon. At these elevations, atmospheric effects are minimized, tracking accuracy is improved, and the finest details can be captured.

For multi-night projects, capture at similar altitudes and times to ensure more consistent data for easier stacking. Even the largest telescope cannot overcome the image degradation caused by observing too close to the horizon.

Notice the higher you go, the darker the background is from this photo?

Moonlight

The Moon is one of the brightest objects in the night sky. Although it does not create light pollution, its reflected sunlight brightens the sky background, reducing the contrast of faint deep-sky objects such as nebulae and galaxies. The brighter the Moon, the more difficult it becomes to capture weak details.

The Moon's effect depends on **its phase, altitude, and angular distance** from your target. A full Moon high in the sky can brighten almost the entire sky, while a thin crescent Moon near the horizon has much less impact.

Best Ways to Avoid Moonlight

The simplest solution is to image during the **New Moon**, when the Moon is absent from the night sky. This provides the darkest skies and the highest contrast for faint deep-sky objects.

If imaging during moonlit nights is unavoidable:

- **Image in the opposite direction of the Moon.** The farther your target is from the Moon, the darker the sky background. Aim for at least **40° separation**, with **60–90° or more** being ideal. The greater the angular distance between the Moon and your target, the better the image contrast.
- **Choose targets high in the sky (40°–70° altitude).** This reduces atmospheric scattering and improves image quality.
- **Wait for the Moon to set**, or begin imaging before it rises.
- **Avoid shooting near the horizon**, where moonlight is scattered more strongly by moisture, haze, and atmospheric particles.
- **Use narrowband filters** (3–7 nm) for emission nebulae. These filters reject most moonlight while passing only the emission lines from hydrogen and oxygen, making them highly effective even during bright Moon phases.
- **Avoid faint broadband targets** such as galaxies and reflection nebulae during bright moonlight, as these are affected much more than emission nebulae.

Aperture

Aperture is the diameter of a telescope's main optical element, such as the lens or mirror. It determines how much light the telescope can collect and how much detail it can potentially reveal.

A larger aperture collects more light, allowing you to observe fainter objects and resolve finer details. This is especially useful when viewing planets, distant galaxies, and faint nebulae.

However, aperture is not the only factor that determines the quality of an observation or image. The atmosphere, telescope design, tracking accuracy, camera, sky conditions, and observing techniques all play important roles.

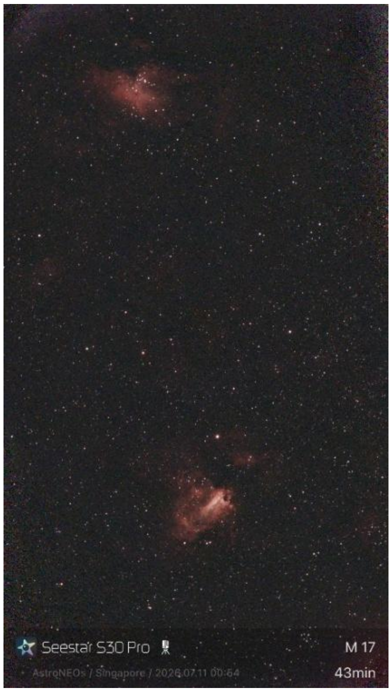
A larger telescope under poor sky conditions may perform worse than a smaller telescope under excellent conditions. More aperture also often means greater size, weight, cost, and setup requirements.

The best telescope is not always the largest one. It is the one that matches your goals, your observing conditions, and how you want to enjoy astronomy.

Aperture provides potential.
The sky and technique determine what you can actually achieve.

Focal Length

Focal length is the distance between a telescope's optical system and the point where light is brought into focus. In simple terms, it determines **how large an object appears** and how much of the sky you can capture in an image.



160mm Focal Length - ***Wider Field of View, Less Detail***
A shorter focal length provides a wider field of view, making it ideal for capturing large objects such as expansive nebulae, large galaxies, and rich star fields. The trade-off is lower image scale, resulting in less visible detail on smaller objects.

250mm Focal Length- ***Balanced Field of View and Detail***
A 250mm focal length offers a good balance between field of view and image scale. It is well suited for medium-sized nebulae, larger galaxies, and star clusters, capturing more detail than 160mm while still framing relatively large celestial objects.

609mm Focal Length - ***Higher Detail with a Narrower Field of View***
A 609mm focal length provides a significant increase in image scale, revealing much finer details in galaxies, planetary nebulae, globular clusters, and smaller emission nebulae. While the field of view is narrower than 250mm, it offers an excellent balance between resolution and framing for deep-sky astrophotography.

Longer focal lengths demand greater tracking accuracy, precise focusing, better guiding, and steadier atmospheric conditions. They **increase image scale, not image quality**—how good the final image still depends on the optics, camera, sky conditions, and data quality.

Focal length determines how you see the universe—not how good your image will be.

Focal Ratio

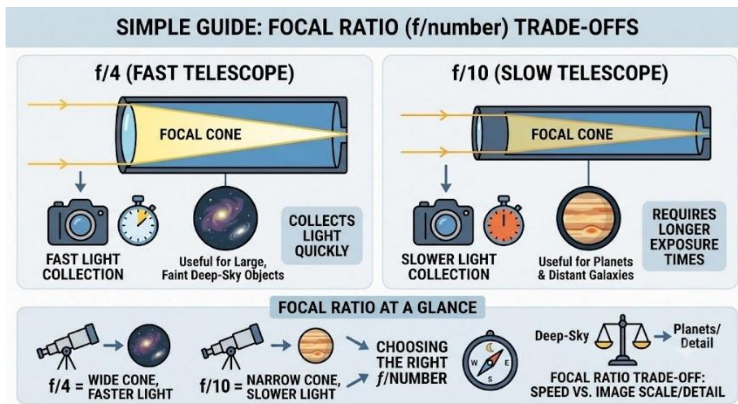
Focal ratio describes the relationship between a telescope's aperture and focal length. It is commonly written as **f/number**, such as f/4, f/6.7, or f/10.

In simple terms, focal ratio affects how quickly a telescope collects light and how the image appears.

A lower focal ratio, such as f/4, is considered a **faster telescope**. It collects light more quickly and is often useful for capturing large, faint deep-sky objects in a shorter amount of time.

A higher focal ratio, such as f/10, is considered a **slower telescope**. It usually requires longer exposure times but can provide a larger image scale when combined with a suitable focal length.

However, a faster telescope is not always better. Lower focal ratios can be more demanding in terms of focusing, optical design, and image correction. Slower systems may offer advantages such as easier handling and better suitability for certain targets.



Focal ratio should always be considered together with aperture, focal length, camera, sky conditions, and the target being observed.

A common beginner mistake is to think that a faster telescope automatically produces better images. In reality, it is a trade-off between speed, image scale, optical performance, and practicality.

Focal ratio determines how efficiently light is collected,
but the best choice depends on what you want to observe.

Mounts

A telescope mount is the system that supports and moves the telescope. It is one of the most important parts of an astronomy setup because it determines how easily and accurately you can observe or capture images.

A good telescope on a poor mount will struggle, while a smaller telescope on a stable mount can often perform much better.

There are two common types of mounts:

Alt-Azimuth Mount (Alt-Az)

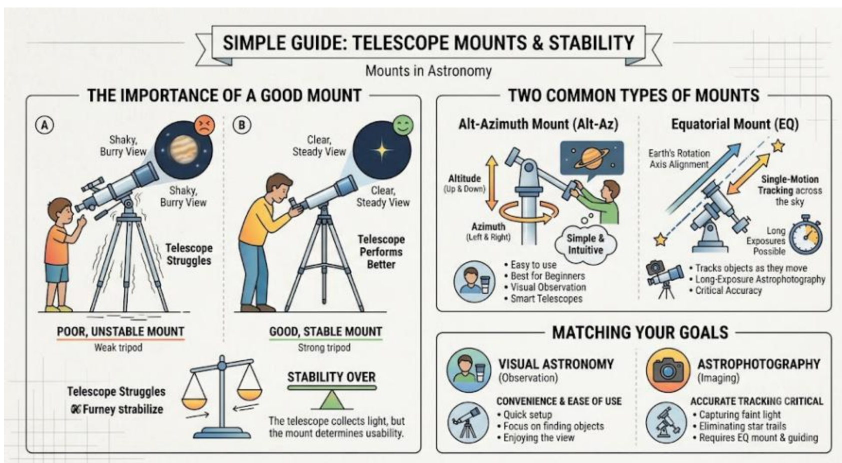
An Alt-Az mount moves the telescope up and down (altitude) and left and right (azimuth). It is simple to use and ideal for beginners, visual observation, and many automated smart telescopes.

Equatorial Mount (EQ)

An equatorial mount is aligned with Earth's rotation axis. It allows the telescope to follow objects across the sky with a single tracking motion, making it especially useful for long-exposure astrophotography.

For visual astronomy, convenience and ease of use are often the most important factors.

For astrophotography, accurate tracking becomes critical because cameras collect light over long periods.



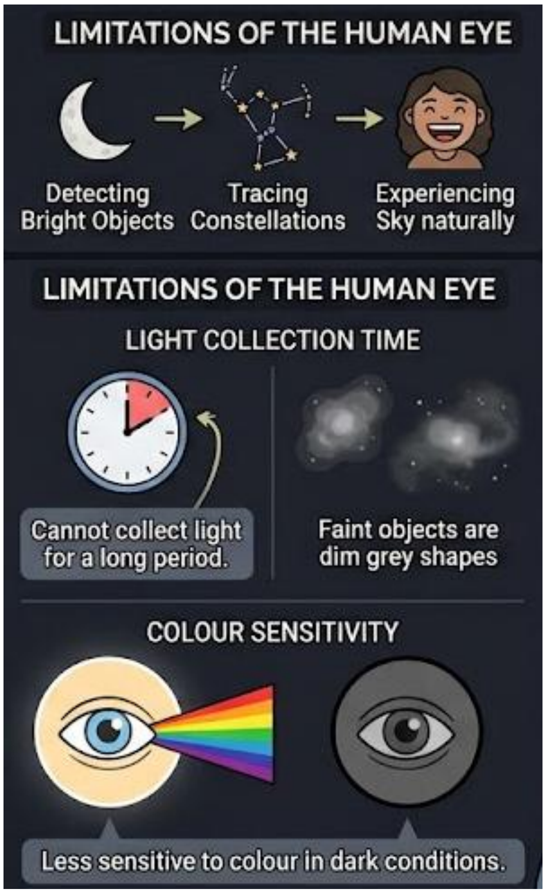
A larger telescope does not automatically produce better results if the mount cannot support it properly. Stability, tracking accuracy, and ease of operation are often more important than size alone.

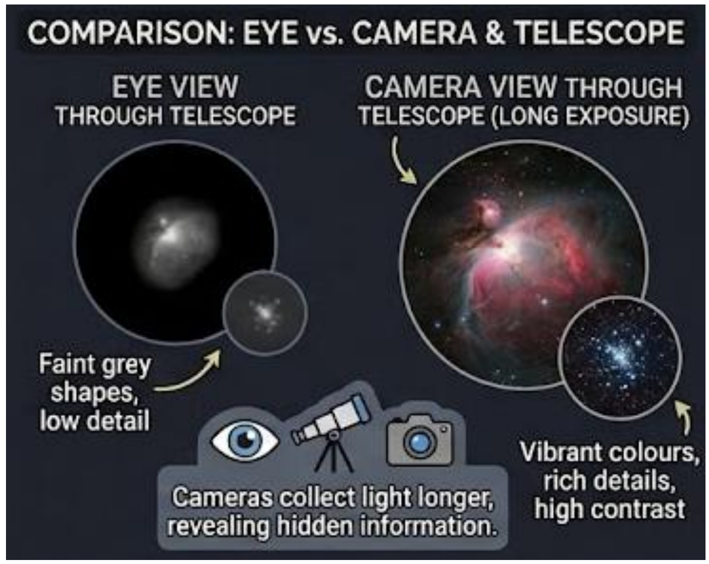
The telescope collects the light,
but the mount determines how well you can use it.

Your Eyes

Your eyes are your first astronomical instrument. Long before telescopes existed, humans studied the universe simply by looking at the night sky.

The human eye is excellent at detecting bright objects such as the Moon, planets, and many stars. It allows us to experience the sky naturally and understand the patterns and movements of celestial objects.





However, our eyes have limitations. They cannot collect light for a long time, and many faint objects such as nebulae and distant galaxies are too dim to see clearly. Our eyes are also less sensitive to colours in very dark conditions.

This is why many deep-sky objects appear as faint grey shapes through a telescope, even though photographs show beautiful colours and details. Cameras can collect light over a much longer period, revealing information that our eyes cannot detect.

Your eyes show you the universe.
Telescopes and cameras help you see more of it.

Cameras

A camera is a tool that allows us to capture and record the light from the universe.

Unlike our eyes, which can only observe light for a short moment, cameras can collect light over many seconds, minutes, or even hours. This allows them to reveal faint details that are invisible to us.

Astrophotography is not simply taking a picture of the sky. It is the process of carefully collecting weak signals from distant objects and combining them to create a clearer image.

Several factors affect the quality of an astronomical image, including:

- The amount of light collected
- Exposure time
- Camera sensitivity
- Focus accuracy
- Tracking stability
- Sky conditions

Many astrophotographers take multiple images and combine them through a process called stacking. This improves signal and reduces noise, allowing more details to be revealed.

A more expensive camera does not always guarantee better results. The camera must work together with the telescope, mount, target, and observing conditions.

A camera does not make the universe brighter.
It gives us more time to collect its hidden light.

Filters

Filters are tools used in astronomy to control which wavelengths of light reach your eyes or camera.

Different celestial objects emit different types of light. By allowing certain wavelengths to pass while reducing others, filters can improve contrast and reveal details that may otherwise be difficult to see. For astrophotography, filters can help cameras capture specific wavelengths of light from faint objects.

Broadband Filters *reduce the effects of artificial light pollution and improve image contrast, making them especially useful in urban areas. They are best suited for imaging galaxies, reflection nebulae, dark nebulae, and star clusters while preserving natural star colours.*

Narrowband Filters *allow only specific wavelengths emitted by hydrogen (Hα), oxygen (O III), and sulphur (S II) to pass through. They are ideal for imaging emission nebulae, supernova remnants, and planetary nebulae. The result is higher-contrast nebulae with finer details, while stars appear dimmer and less prominent.*

However, filters are not a solution for every situation. They cannot completely remove light pollution or replace good sky conditions, proper exposure, and good imaging techniques.

The best results come from understanding what a filter does and when it is useful.

A filter does not create more light.
It helps you separate useful light from unwanted light.

The Moon

The Moon is often the first object people observe through a telescope, and it remains one of the most rewarding targets for beginners and experienced astronomers alike.

Although it appears close to Earth, the Moon is a world with its own landscape of mountains, valleys, craters, and ancient impact marks. Its surface details can be observed even with a small telescope or binoculars.

The **Moon does not produce its own light**. It shines because it reflects sunlight back to Earth. As it orbits our planet, the amount of sunlight reflecting toward us changes, creating the different phases of the Moon.

The Moon is also an excellent introduction to astronomy because it is bright, easy to locate, and changes noticeably from night to night. Observing the Moon helps beginners learn how telescopes work, how light behaves, and how celestial objects move.

For astrophotography, the Moon is very different from faint deep-sky objects. It is extremely bright and requires short exposures rather than long image captures.

The Moon is our closest neighbour in space and the perfect first step into astronomy.

Planets

Planets are among the most fascinating objects to observe because they are worlds within our own solar system. Unlike stars, planets do not produce their own light. They appear bright because they reflect sunlight.

Planetary observation is different from deep-sky observation. Planets are relatively bright but appear small, so they require good optics, accurate focusing, stable tracking, and good atmospheric conditions to reveal fine details.

A larger telescope can provide more potential detail, but **the atmosphere often becomes the limiting factor**. Even the best equipment cannot overcome poor seeing conditions.

Planetary imaging usually uses short exposures and many individual frames. These frames are then combined to reduce atmospheric distortion and enhance details.

Unlike faint nebulae and galaxies, planets can often be observed successfully even from light-polluted cities. Their brightness makes them excellent targets for beginners.

Planetary imaging requires long focal lengths to increase image scale, large apertures to reveal fine surface details, and high-speed video capture to overcome atmospheric turbulence. *Only a few planets are suitable imaging targets due to their size, brightness, and visible features:*

- ***Jupiter*** *– Excellent target with cloud bands, Great Red Spot, and four Galilean moons.*
- ***Saturn*** *– Excellent target with its iconic rings and atmospheric bands.*
- ***Mars*** *– Best around opposition, revealing polar caps and surface markings.*
- ***Venus*** *– Bright and easy to capture, showing phases and cloud patterns (UV filter required for details).*
- ***Uranus*** *– Possible with larger telescopes; mainly shows a small disk and subtle colour.*
- ***Neptune*** *– Very challenging; requires large aperture and excellent conditions.*

Mercury *is rarely imaged due to its low altitude near the Sun, while* ***Earth's Moon*** *remains the easiest and most rewarding high-resolution target.*

Star Clusters

Star clusters are groups of stars that are held together by gravity. They are among the easiest and most beautiful objects to observe, making them excellent targets for beginners.

Open Clusters
Open clusters contain hundreds or thousands of relatively young stars. They are usually found within our own galaxy and often appear as bright groups of stars spread across the sky.

Globular Clusters
Globular clusters contain hundreds of thousands or even millions of older stars packed closely together. They appear as dense, round collections of stars and are often found around the outer regions of galaxies.

Unlike nebulae and galaxies, many star clusters are bright enough to be observed even from areas with light pollution. They can be enjoyed with the naked eye, binoculars, or a small telescope.

Star clusters are also excellent astrophotography targets because they contain many bright stars and do not usually require extremely long exposures.

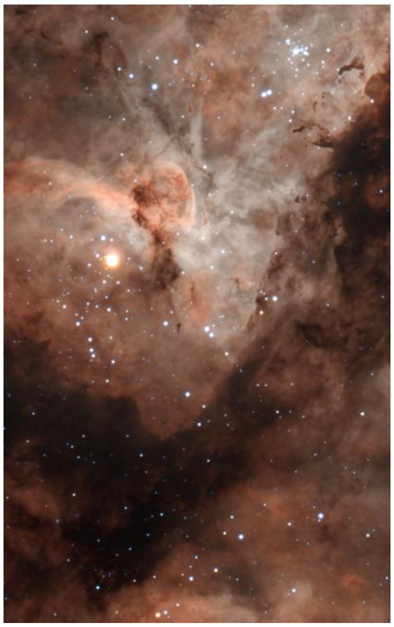
Studying star clusters helps us understand how stars form, evolve, and how galaxies are structured.

Star clusters are collections of stars that reveal the history and evolution of our galaxy.

Nebulae

Nebulae are large clouds of gas and dust found throughout space. They are some of the most beautiful and popular targets in astronomy and astrophotography.

Many nebulae are regions where new stars are being born. As young stars form, their energy can illuminate the surrounding gas, creating colourful clouds of glowing material.



Emission Nebulae
Emission nebulae are glowing clouds of ionised hydrogen gas illuminated by the intense radiation from nearby young, massive stars. They are among the brightest and most colourful deep-sky objects, making them popular targets for astrophotography.
Examples: *Orion Nebula (M42), Lagoon Nebula (M8), Eagle Nebula (M16), Omega Nebula (M17).*

Reflection Nebulae
Reflection nebulae are clouds of dust that shine by reflecting the light of nearby stars. Unlike emission nebulae, they do not produce their own light and often appear blue because dust scatters blue light more efficiently.
Examples: *Iris Nebula (NGC 7023), M78, Witch Head Nebula (IC 2118).*

Dark Nebulae
Dark nebulae are dense clouds of gas and dust that block the light from stars and nebulae behind them. They appear as dark silhouettes against the brighter background of the Milky Way and are important regions where new stars can form.
Examples: *Horsehead Nebula (Barnard 33), Pipe Nebula, Coalsack Nebula.*

Nebulae are often much fainter than the Moon, planets, and star clusters. They usually require darker skies, longer exposure times, sensitive cameras, and careful processing to reveal their details.

Other Types of Nebulae

Besides the familiar **emission, reflection, and dark nebulae**, there are several other fascinating types of nebulae. Although they are all classified as nebulae, they differ in how they are formed and what they represent in the life cycle of stars.

Molecular Cloud Complexes

Molecular cloud complexes are vast clouds of gas and dust where new stars are born. They often contain emission, reflection, and dark nebulae, making them some of the largest star-forming regions in our galaxy.

Examples: *Orion Molecular Cloud, Rho Ophiuchi Cloud Complex, Taurus Molecular Cloud.*

Planetary Nebulae

Planetary nebulae are expanding shells of glowing gas ejected by dying Sun-like stars. Despite their name, they have nothing to do with planets. They are usually small, colourful, and rich in oxygen and hydrogen emissions.

Examples: *Ring Nebula (M57), Dumbbell Nebula (M27), Helix Nebula (NGC 7293).*

Supernova Remnants

Supernova remnants are the expanding remains of massive stars that exploded as supernovae. These clouds of gas and dust are rich in intricate filaments and are popular targets for narrowband astrophotography.

Examples: *Veil Nebula, Crab Nebula (M1), Simeis 147.*

Nebulae remind us that space is not empty. It is filled with vast clouds of material where stars are born, evolve, and shape the future of galaxies.

Nebulae are cosmic nurseries and time capsules, revealing the ongoing story of stars.

Galaxies

Galaxies are enormous collections of stars, gas, dust, and dark matter held together by gravity. Our home galaxy, the Milky Way, is just one of billions of galaxies in the universe.

Unlike planets and nebulae within our own galaxy, most galaxies are extremely far away. Even the closest large galaxies are millions of light-years from Earth, making them some of the most challenging objects for beginners to observe.

Spiral Galaxies
Spiral galaxies are large collections of stars, gas, and dust arranged in a rotating disk with distinctive spiral arms extending from the center. These arms are active regions where new stars are often formed, making many spiral galaxies appear bright and colourful.
Examples: *Andromeda Galaxy (M31), Whirlpool Galaxy (M51), Triangulum Galaxy (M33).*

Elliptical Galaxies
Elliptical galaxies are large collections of stars with smooth, rounded shapes and little visible structure. Unlike spiral galaxies, they contain very little gas and dust, resulting in fewer new stars being formed. They are often dominated by older, redder stars.
Examples: *M87, M49, M60.*

Irregular Galaxies
Irregular galaxies have no clear spiral or elliptical structure, often appearing distorted or chaotic in shape. Their unusual forms are commonly caused by gravitational interactions, collisions with other galaxies, or intense bursts of star formation.
Examples: *Large Magellanic Cloud (LMC), Small Magellanic Cloud (SMC), IC 10.*

Galaxies are usually faint because their light is spread over a very large area. Observing or photographing them requires good sky conditions, accurate tracking, and careful techniques.

Unlike bright planets or star clusters, galaxies often appear as faint patches of light through a telescope. However, astrophotography can reveal their structure, colours, and details that are beyond human vision.

Every galaxy is a universe of its own—a vast collection of stars telling the story of cosmic evolution.

Why Great Images Take Time

Astrophotography is different from normal photography because most objects in space are extremely faint. Their light may have travelled thousands, millions, or even billions of years before reaching us.

A single exposure often captures only a small amount of this weak signal, hidden by noise. By taking many images and stacking them together, astrophotographers can increase useful detail while reducing noise.

***Single 10s** exposure raw sub, unstacked, unprocessed.*

***930 x 10s** subs stacked together, not post processed*

***9,533 x 10s** subs stacked together and post processed*

The quality of an astro image depends on:

- Exposure time – how much light is collected
- Number of images – more data improves signal quality
- Sky conditions – darker skies improve contrast
- Tracking accuracy – keeps stars sharp
- Processing – reveals hidden details

Great astro photographs are built over time through careful data collection, stacking, and processing. Faint nebulosity requires many exposures to gather more signal, reveal details, and produce a cleaner image.

Great astro photos are not created by capturing more light instantly,
but by patiently collecting more light over time.

Why Processing Matters

An astro photograph is not finished when the camera captures the light. Processing reveals the hidden information within the image by improving contrast, reducing noise, and bringing out faint details.

Processing does not create details that are not there. It reveals information already captured in the data. However, good processing cannot fully fix poor data caused by bad focus, tracking errors, clouds or unsuitable conditions.

Calibrated & Stacked
Example of a stacked image produced by calibrating and stacking 455 high-quality 120-second exposures. The combined data reveals more detail, improves signal quality, and reduces noise compared to a single exposure.

Starless Stretching
Separating stars and nebulosity allows independent processing, enabling better background extraction and revealing faint nebula details without affecting the stars.

Combine, Adjust & Touch-ups
The final stage combines stars and nebulosity, balances colours, and fine-tunes contrast and sharpness for a polished final image.

The best astro photographs come from careful planning, dedicated quality data collection, and thoughtful stacking & post processing.

Processing does not create the universe in your image.
It reveals what your camera has already captured.

There Is No Perfect Equipment

Astronomy equipment is designed with different strengths and limitations. There is no single telescope, camera, or setup that is perfect for every situation.

A wide-field telescope is excellent for capturing large nebulae and star fields, while a longer focal length telescope is better suited for smaller objects such as galaxies and planets.

A larger telescope can collect more light and reveal more detail, but it may also be heavier, more expensive, and more difficult to transport and operate.

A faster telescope can collect light more quickly, but it may require more careful focusing and better optical control. A slower telescope may take longer exposures but can be easier to manage.

The best equipment depends on many factors:

- What objects you want to observe or photograph
- Where you observe from
- How much time you have
- Your experience level
- Your budget and practical needs

Many beginners focus too much on specifications such as aperture, focal length, or camera size. In reality, great results come from how the entire system works together.

Smart telescopes like the Seestar series and Dwarf (around S$500–S$1,000) offer beginners an easy way to explore the universe without the complexity of a traditional S$5,000+ astrophotography setup.

The best setup is not always the biggest or most expensive — it is the one that matches your goals and keeps you exploring.

There is no perfect equipment—only the equipment that is right for you.

Choosing the Right Telescope: Optimal Aperture and Focal Length for General Sky Conditions

Selecting a telescope is not simply about choosing the largest aperture or longest focal length. The ideal setup depends on **sky quality, atmospheric conditions, imaging goals, and target size**. A larger telescope can provide greater resolution and light-gathering ability, but its performance is limited by the atmosphere. Under poor seeing conditions, a smaller telescope may produce sharper and more consistent results.

The optimal telescope depends on four main factors:

1. **Atmospheric seeing** (air turbulence)
2. **Transparency** (humidity, haze, dust)
3. **Light pollution**
4. **Target type** (wide nebulae, galaxies, planets, etc.)

Here's how it varies by location:

Sky Condition	Optimal Aperture	Optimal Focal Length
Singapore (humid, **Bortle 8–9**, average seeing)	80–150 mm	600–1,000 mm
Typical suburban skies	80–200 mm	600–1,200 mm
Dark rural skies (**Bortle 2–4**)	100–250 mm	800–1,500 mm
Observatory sites (Chile, Atacama, Mauna Kea)	150–400+ mm	1,000–3,000+ mm

Optimal Aperture: 80–200 mm

For most amateur astrophotographers worldwide, an aperture between 80 mm and 200 mm provides the best balance between performance, cost, and practicality.

- 80–120 mm: Excellent all-round choice. Ideal for wide-field nebulae, galaxies, and beginners. Provides stable performance even under average skies.
- 120–150 mm: A strong upgrade range, offering better light gathering and resolution while remaining manageable.
- 150–200 mm: Suitable for experienced users and darker skies, providing more detail on smaller galaxies and nebulae when atmospheric conditions allow.

Beyond 200 mm, the potential gains become increasingly dependent on excellent seeing, stable weather, and high-quality equipment. Larger apertures are especially valuable for planetary imaging and premium dark-sky locations.

Optimal Focal Length: 400–1,500 mm

For deep-sky astrophotography, a focal length between 400 mm and 1,500 mm covers the majority of popular targets.

- 400–700 mm: The most versatile range. Excellent for large nebulae, galaxies, and star fields while remaining forgiving of tracking and atmospheric issues.
- 700–1,000 mm: A sweet spot for many imagers, providing more image scale for galaxies and smaller deep-sky objects without excessive sensitivity to seeing.
- 1,000–1,500 mm: Better suited for experienced astrophotographers using accurate mounts and imaging from locations with good atmospheric stability.

Beyond 1,500 mm, atmospheric turbulence and tracking precision become increasingly challenging, and the improvement depends heavily on excellent skies.

Recommended General-Purpose Setup

Parameter	Recommended Range
Aperture	80–200 mm
Focal Length	400–1,500 mm
Focal Ratio	f/4 – f/7

Key Principle

Aperture determines the telescope's potential, but the atmosphere determines the results.

A large telescope under poor seeing may not outperform a smaller telescope under excellent skies. The best setup is one that matches your local environment, imaging targets, and experience level.

For most amateur astronomers worldwide, an **80–150 mm telescope with a 400–1,000 mm focal length** represents the ideal balance of image quality, versatility, and reliability. Larger apertures and longer focal lengths become increasingly rewarding as sky quality improves.

Myth: Bigger Aperture Always Wins

Reality: Everything Depends on the Weakest Link

A larger aperture telescope can collect more light and has the potential to reveal more detail. However, it does not automatically produce better results in every situation.

Astronomy is a system where every part must work together. The final result depends on many factors, including:

- Sky conditions
- Atmospheric stability
- Telescope quality
- Mount accuracy
- Camera capability
- Focusing accuracy
- Image processing techniques

A large telescope under poor conditions may perform worse than a smaller telescope under excellent conditions. For example, a very large telescope cannot overcome cloudy skies, poor seeing, inaccurate tracking, or bad focus.

Aperture provides potential, but it does not guarantee success. The **weakest part** of the system often **determines the final result**.

For beginners, understanding this prevents the common mistake of chasing the largest telescope without considering whether it matches their observing location, experience, and goals.

Aperture opens the door to more possibilities,
but the entire system determines what you can achieve.

Myth: Lower Bortle Always Produces Better Images

Reality: Transparency and Seeing Can Outweigh Bortle Differences

A darker sky is an advantage in astronomy because it reduces the brightness of the background sky and improves contrast. However, the Bortle scale is only one measure of observing conditions.

A lower Bortle class does not always guarantee better results. Other factors, especially **transparency** and **seeing**, can have a major impact on the final image.

A dark location with haze, humidity, smoke, or unstable air may produce worse results than a brighter location with clear, stable conditions.

For deep-sky astrophotography, transparency determines how much useful light from distant objects reaches your camera. **For high-resolution imaging of planets and small objects, seeing** determines how much fine detail can be captured.

Other factors also matter:

- Target altitude above the horizon
- Moon position
- Light direction
- Exposure time
- Equipment capability
- Image processing techniques

A city sky will always have limitations, but excellent planning and technique can still produce impressive results. Likewise, a **remote dark site does not guarantee a great image if atmospheric conditions are poor**.

The best results come from understanding the complete environment, not just chasing the lowest Bortle number.

Dark skies help, but clear and stable skies reveal more.

Myth: More Expensive Telescope Equals Better Images

Reality: Mount, Tracking, Conditions, and Processing Often Matter More

A more expensive telescope usually offers better optical quality, larger aperture, or more advanced features. However, the telescope alone does not determine the quality of an astronomical image.

Astrophotography is a complete system where every component plays an important role. A high-end telescope cannot perform well if the mount is unstable, tracking is inaccurate, or the sky conditions are poor.

Important factors include:

- Mount and tracking accuracy – keeps stars sharp during long exposures
- Sky conditions – determine how much useful light can be captured
- Focus accuracy – affects the sharpness of every detail
- Camera performance – determines how efficiently light is recorded
- Processing techniques – reveals the information hidden in the data

A modest telescope with excellent tracking, good conditions, and careful processing can often produce better images than a premium telescope used without proper preparation.

The goal is not to own the most expensive equipment. The goal is to build a balanced system that matches your targets, environment, and experience.

Great astrophotography comes from a well-balanced system,
not the most expensive telescope.

Myth: Long Focal Length Produces Better Images

Reality: Only If the Atmosphere Supports It

A longer focal length makes objects appear larger and provides a finer image scale. This can be useful for small targets such as planets, distant galaxies, and compact nebulae.

However, a longer focal length also makes the entire system more demanding. It requires more accurate tracking, better focusing, higher optical quality, and more stable atmospheric conditions.

The **atmosphere is often the limiting factor**. Even with a powerful telescope, turbulent air can blur fine details and prevent the system from reaching its full potential.

A shorter focal length telescope can sometimes produce better images because it is more forgiving, captures wider areas of the sky, and is less affected by tracking errors and atmospheric turbulence.

The ideal focal length depends on:

- The size of the target
- The camera sensor
- Pixel scale
- Sky conditions
- Tracking capability

A larger image is not always a better image. The goal is to capture the right amount of detail that the conditions allow.

Focal length increases magnification,
but the atmosphere decides how much detail you can actually see.

Myth: You Need Perfect Skies

Reality: Excellent Images Are Possible from Cities

Dark skies are valuable for astronomy, especially when observing or photographing faint deep-sky objects. However, perfect conditions are not required to enjoy astronomy or create impressive images.

Modern equipment, advanced cameras, filters, and image processing techniques have made **astrophotography possible even from heavily light-polluted areas**.

Urban astrophotography has its own challenges, including:

- Brighter sky background
- Reduced contrast
- More difficulty capturing faint details

However, many objects can still be successfully photographed from cities, including:

- The Moon
- Planets
- Bright star clusters
- Many nebulae
- Some galaxies

Success depends on choosing suitable targets, planning carefully, collecting enough quality data, and processing the image properly.

A dark location provides an advantage, but it is not the only path to great results. **Understanding your environment and working within its limitations** is often more important than waiting for perfect conditions.

Great astrophotography is not about having perfect skies.
It is about making the most of the skies you have.

Myth: Fast Telescopes Are Always Superior

Reality: They Have Advantages and Compromises

A fast telescope has a lower focal ratio, such as f/2.8 or f/4, and can collect light more quickly compared to a slower telescope with the same aperture. This makes it attractive for astrophotography, especially when capturing faint deep-sky objects.

However, faster does not always mean better. A faster system often comes with additional challenges such as demanding focusing accuracy, greater sensitivity to optical imperfections, stronger requirements for image correction and more difficulty controlling stars across the image field.

For most deep-sky astrophotography, f/4 to f/7 provides the best balance between light-gathering speed, image quality, and practicality.

Range	Notes
f/2 – f/4	Very fast systems ideal for wide-field nebulae and large deep-sky objects. Requires good optical correction and processing skills.
f/4 – f/6	The sweet spot for most astrophotographers, offering excellent signal collection with manageable exposure times.
f/6 – f/7.5	Slower but often provides excellent sharpness and optical performance, suitable for galaxies and smaller targets.
f/10+	Mainly used for planetary imaging where image scale and resolution are more important than light-gathering speed.

Target-Based Recommendations

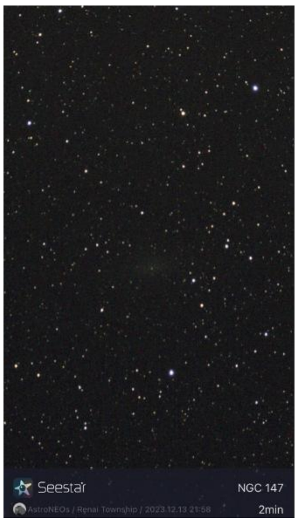
- Large nebulae and star fields: f/2.8 – f/5
- Galaxies and smaller deep-sky objects: f/5 – f/7
- Planetary imaging: f/10 – f/20+ with high-speed video capture

A faster telescope is not always better. The ideal focal ratio balances light collection, optical quality, target size, and sky conditions.

Myth: Stacking Fixes Everything

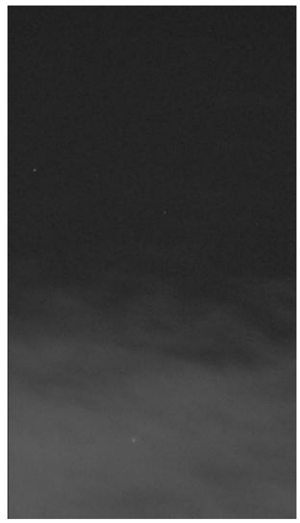
Reality: Poor Data Remains Poor Data

Stacking is one of the most powerful techniques in astrophotography. By combining multiple exposures, it improves signal quality, reduces noise, and reveals faint details that are often hidden in a single image. However, stacking cannot fix poor-quality data. If individual sub-exposures suffer from issues such as:

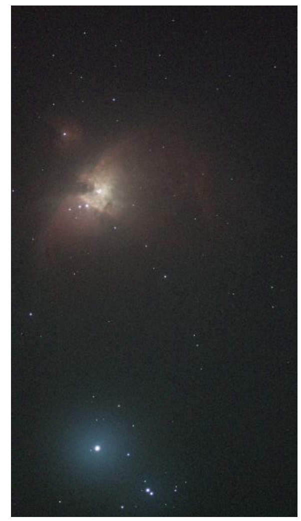


Poor focus can occur when significant temperature changes cause the telescope's optics to shift focus, resulting in bloated and less-defined stars. Regular refocusing throughout the imaging session helps maintain sharp stars and preserve fine details in the final image.

Severe light pollution from cities, airports, ports, nearby artificial lights, moonlight, or low-altitude horizons can create strong gradients across the stacked image, making background correction and processing more difficult.



Cloud-contaminated images are among the worst sources of poor data. Partial cloud cover and thin high clouds can reduce contrast, distort colours, and degrade the final stacked image. Always remove cloud-affected subs before stacking.



Low-quality data can result from poor seeing, reduced transparency, humid air, haze, or even dew forming on optics. These conditions can compromise an entire imaging session. Always monitor and predict sky conditions to maximise the quality of your data collection.

stacking will simply combine these problems together in the final stacked image.

Great astrophotography begins with collecting good data. Careful planning, accurate focusing, stable tracking, appropriate exposure settings, and favourable sky conditions are the foundation of a successful image.

Stacking reveals good data. It cannot rescue data that was never captured.

Putting Everything Together

Astronomy is not about finding one perfect piece of equipment or one perfect condition. It is about understanding how different factors work together.

A successful observation or astrophotography is the result of many connected elements:

- The **sky** determines how much information is available.
- The **equipment** determines how efficiently that information can be collected.
- The **technique** determines how well the data is captured.
- The **processing** determines how effectively the hidden details are revealed.

No single factor can guarantee success.

A large telescope cannot overcome poor weather.
A dark sky cannot compensate for poor focus.
An expensive camera cannot replace good planning.
Advanced processing cannot recover information that was never captured.

Instead of chasing one specification, astronomers learn to balance the entire system.

A useful way to think about image quality is:

Image Quality = Equipment × Sky Conditions × Technique × Processing

If any one factor is weak, it limits the final result. Improving the weakest area often creates a bigger improvement than simply upgrading equipment.

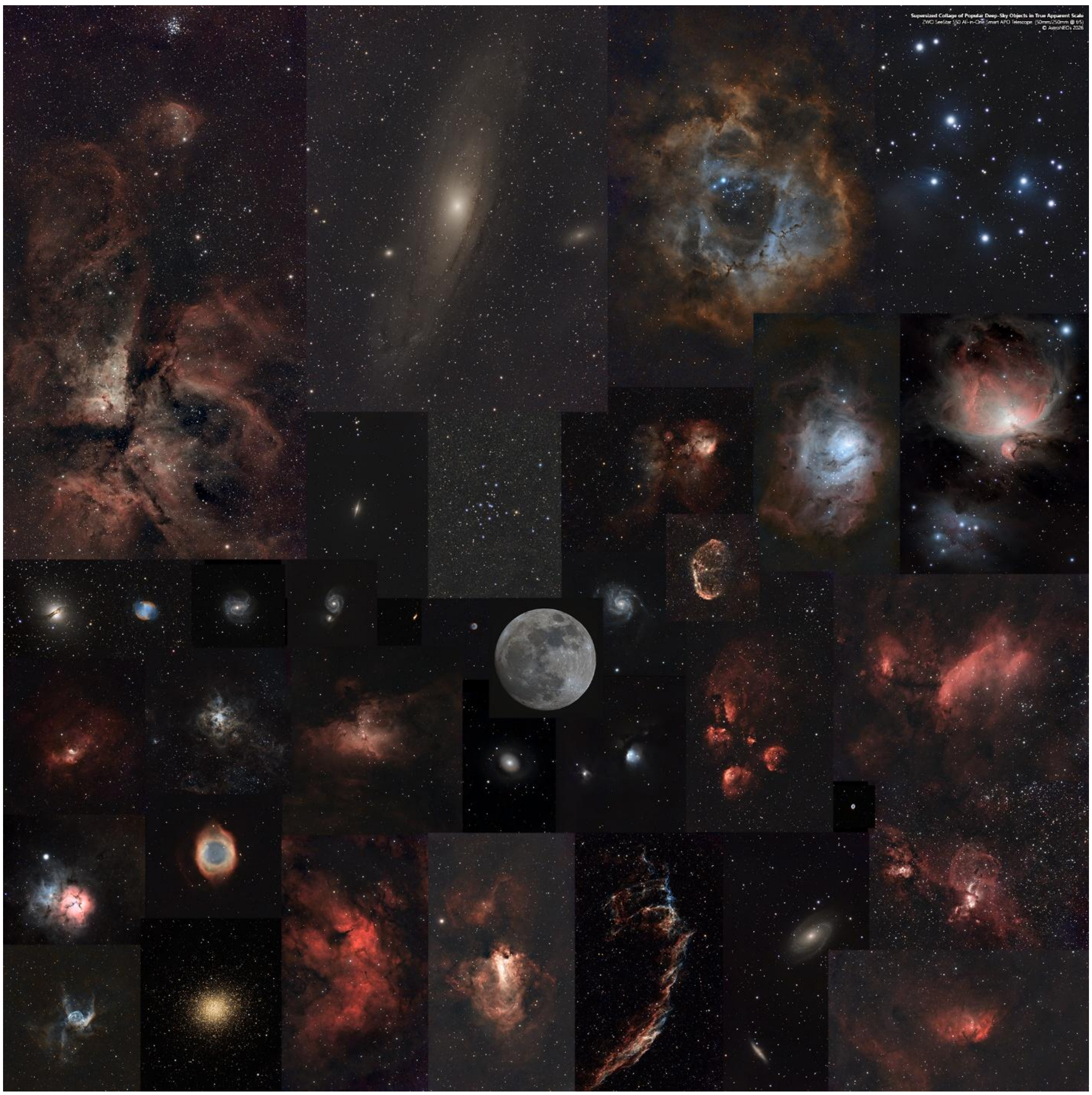
For example:

- A beginner with a modest telescope under clear skies and good technique can produce excellent results.
- A premium telescope under poor conditions may struggle to perform.
- A well-planned imaging session can outperform a more expensive setup used without preparation.

The most successful astronomers are not those who own the biggest equipment. They are those who understand the relationship between the target, the environment, and the tools they use.

Astronomy is a journey of continuous learning. As your understanding improves, you will make better decisions about what to observe, what equipment to use, and how to capture the universe.

Astronomy is a system, not a specification. The best results come from making every part work together.



This mosaic showcases various deep-sky objects (DSOs) in their true apparent sizes, all captured with the Seestar S50.

Glossary of Common Astronomy Terms

Astronomy - The scientific study of objects and events beyond Earth, including stars, planets, galaxies, and the universe.

Astrophotography - The practice of photographing objects in space. It uses cameras, telescopes, and image processing to reveal details that are too faint for our eyes to see.

Aperture - The diameter of a telescope's main lens or mirror. A larger aperture collects more light and can potentially reveal more detail.

Bortle Scale - A nine-level scale used to describe the brightness of the night sky caused by light pollution. Lower numbers represent darker skies.

Celestial Object - Any natural object found in space, such as stars, planets, moons, asteroids, nebulae, and galaxies.

Deep-Sky Object (DSO) - Objects outside our solar system, such as nebulae, star clusters, and galaxies.

Exposure - The amount of time a camera collects light. Longer exposures allow more faint details to be recorded.

Field of View (FOV) - The amount of sky visible through a telescope or camera system. A wider field of view captures larger areas of the sky.

Focal Length - The distance between a telescope's optical system and the point where light is focused. It determines image scale and field of view.

Focal Ratio - The relationship between a telescope's aperture and focal length, expressed as an f-number (such as f/4 or f/10). It affects light-gathering speed and imaging characteristics.

Galaxy - A massive collection of stars, gas, dust, and dark matter held together by gravity. Our home galaxy is the Milky Way.

Light Pollution - Artificial light that brightens the night sky and reduces the visibility of faint astronomical objects.

Light-Year - The distance light travels in one year. It is used to describe distances between stars and galaxies.

Magnification - How much larger an object appears through a telescope compared to viewing it with the naked eye.

Nebula - A large cloud of gas and dust in space. Some nebulae are regions where new stars are forming.

Narrowband Filter - A filter that allows only specific wavelengths of light to pass through. It is commonly used to capture emission nebulae.

Pixel Scale - The amount of sky covered by each pixel of a camera image. It affects the level of detail that can be recorded.

Seeing - The stability of Earth's atmosphere. Good seeing allows sharper views, especially for planets and high-resolution imaging.

Signal-to-Noise Ratio (SNR) - The amount of useful information compared to unwanted noise in an image. Higher SNR usually results in cleaner and more detailed images.

Stacking - Combining multiple images together to improve signal quality and reduce noise.

Star Cluster - A group of stars held together by gravity. The two main types are open clusters and globular clusters.

Telescope - An optical instrument that collects and focuses light to observe distant objects.

Transparency - The clarity of the atmosphere and how easily light from space can pass through it.

Tracking - The movement of a telescope mount to follow objects as Earth rotates, keeping them centred during observation or photography.

My Recent Astrophotography Projects