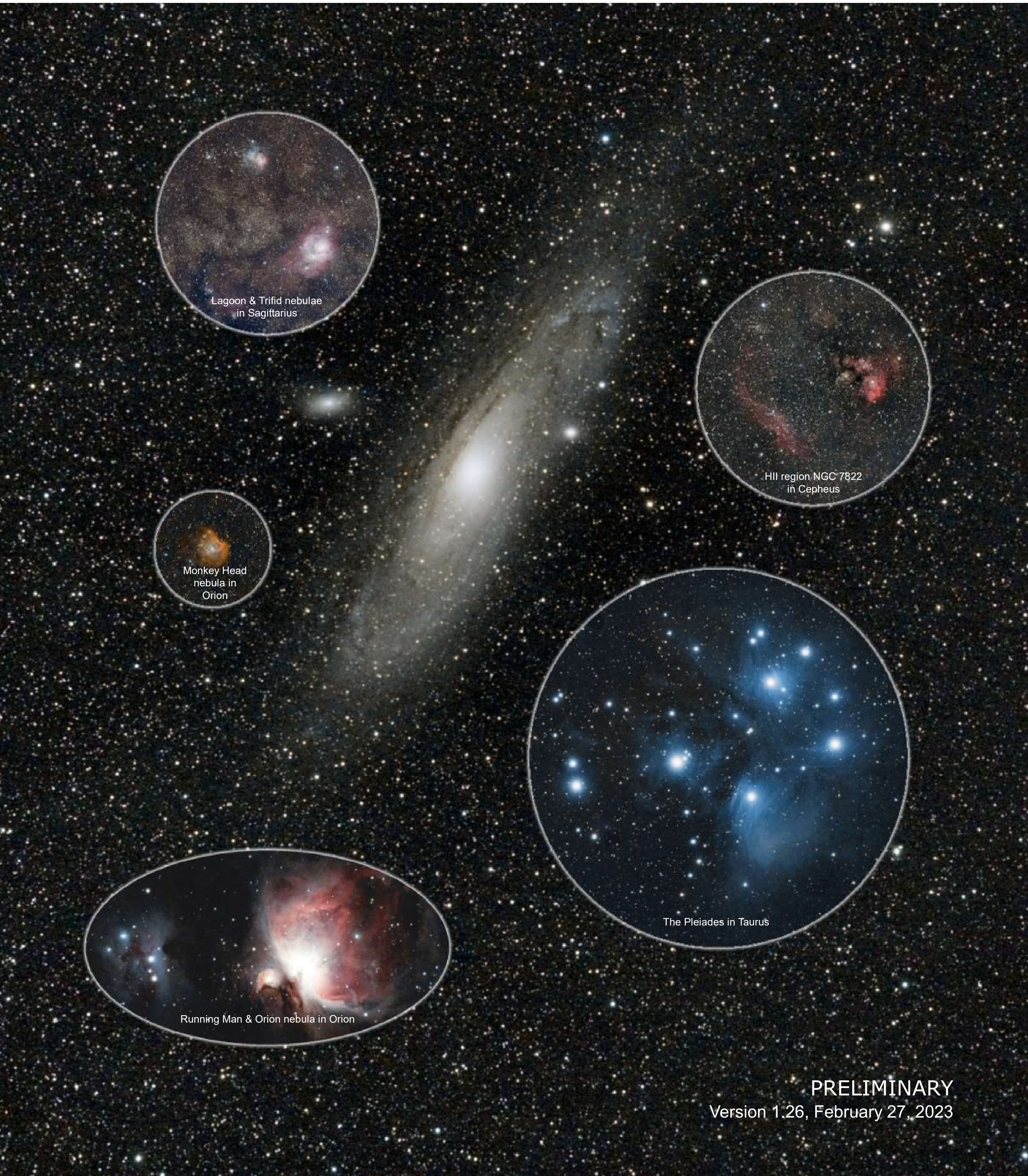
Sky Photography for Starters

Imaging Constellations and the Deepsky with small Lenses and small Telescopes

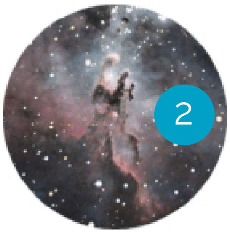
A bad weather publication. Own work ChatGPT-free.



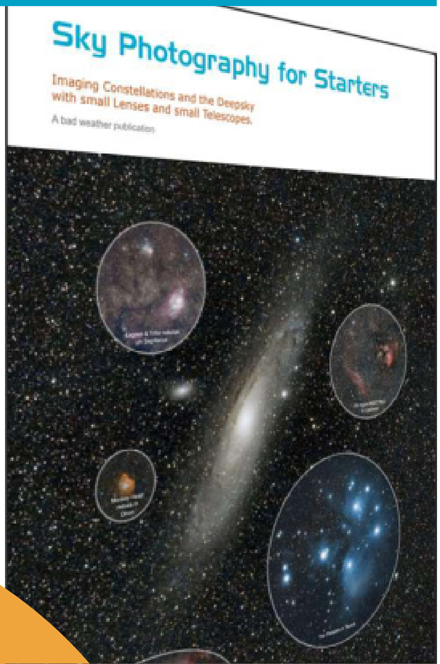
“Pillars of Creation” inside Messier 16, NGC 6611, the Eagle Nebula in Serpens

Contents

Foreword 4
Essential Equipment 6
Constellations with a 50mm lens 10
Milky Way with a 50mm lens 12
Wide Fields with a 135mm lens 14
Deepsky with a 450mm refractor 20



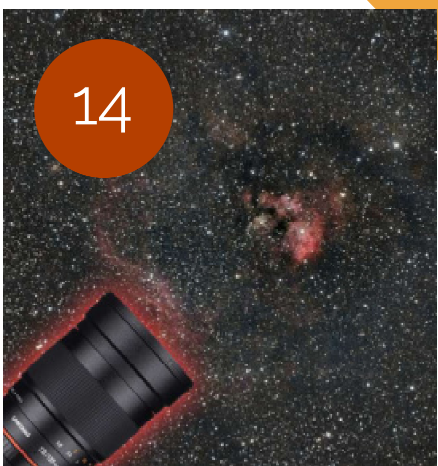
◂ 2021-07-08 14:30 UTC
Celestron 8, 0.63x reducer,
Nikon D5500, ISO1600,
55x120s, no filter, no calibration.



Essential Equipment

Constellations

Milky Way



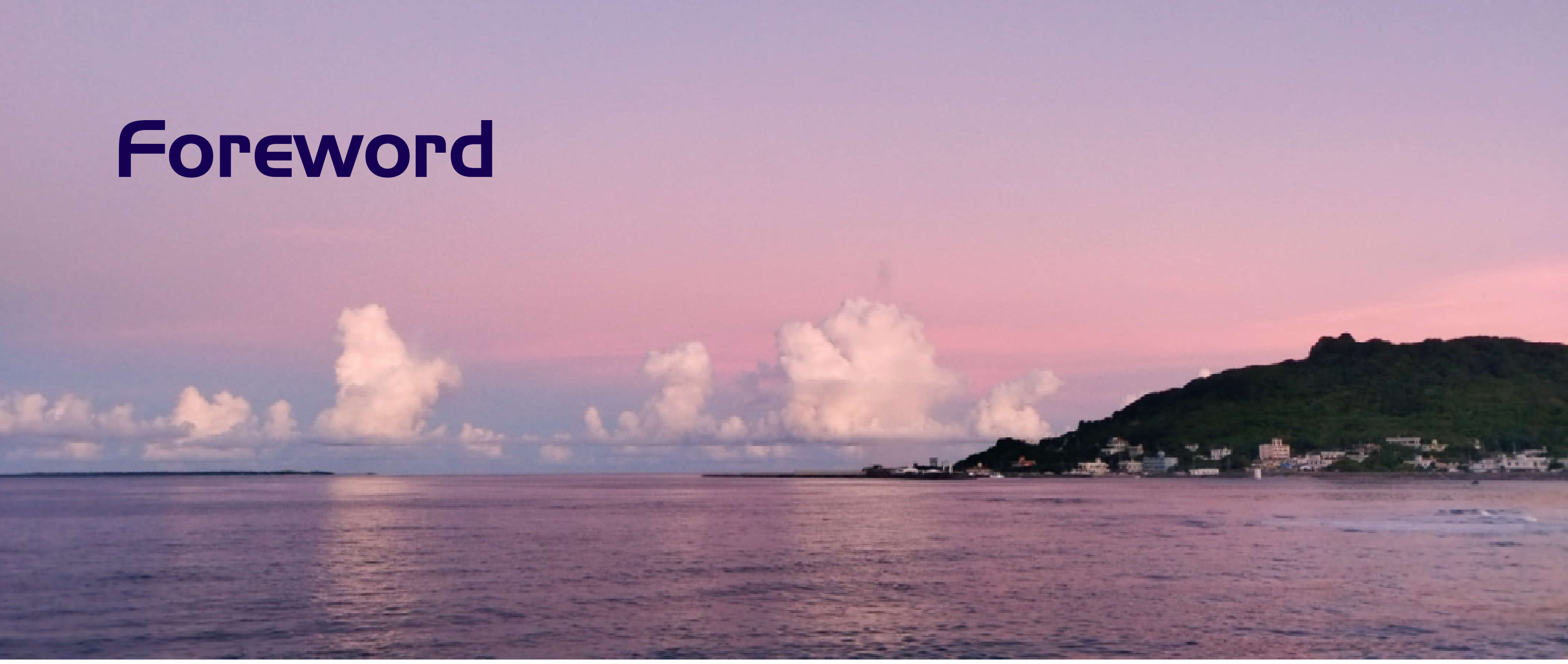
Wide Fields

Deepsky

The author's Imaging App for Android includes camera and telescope simulators, and more.

Imaging App

Foreword



This brochure is not an in-depth tutorial but for the purpose of wetting appetite for sky photography alongside introduction of typical equipment and many examples of sky images taken by the author.

Astrophotography is an exciting, difficult, but rewarding hobby, however, it cannot be enjoyed every day. Apart from work and other priorities, such as a walk with your dog, a clear sky is indispensable. The sky is not necessarily clear just in absense of visible clouds. Often the air is unsteady and humid. High altitude thin veils of clouds are often obstructing the view. A natural enemy is the Moon outshining the rest of the sky. While there are no filters against clouds, moonlight and artificial illumination ('light pollution') can be filtered out to some extend using a Light Pollution Resistance, LPR, filter. Even more efficient are narrowband filters which pass only wavelengths of interest, but this enters the professional zone while costing a little fortune.

This brochure concentrates on small, mobile “grab-and-go” gear, such as a Ø71mm refractor, a shelf DSLR, photo lenses and LPRs. A compact refractor does not need to be calibrated unless dropped. Since astrophotography is solely done in manual mode, the camera and lens can be second-hand products as long as all manual functions are intact. Of course, the telescope, too, may be a used one as optics do not age that quickly while elder optics are still technically up-to-date for sky photography.

"Less is more" does not apply to astrophotography. Imaging involves the capture of as many single light frames as possible. Often crossing clouds interrupt or end an imaging session after a short while. Then the total integration time is often too short for capturing details. While lenses are bright or 'fast' (f1.4 to f2.8), a Ø71mm/fl=450mm refractor (f6.3) requires longer integration times. The more light frames gathered the more detail, contrast and color and the less noise. Faint nebulae often require several hours of integration and a crystal-clear dark sky.

The individual images are processed using stacking software, such as the DeepSky Stacker, which integrates all 'good' images into a single image file (some frames may be obstructed by clouds, distorted by wind gusts or inaccurate tracking, or by crossing air planes and satellites). A stacked file is further processed by software, such as Siril (stacking, background cleaning, histogram stretching, etc.) and finally fine tuned in image processing software, such as Photoshop or GIMP. Most of the basic software is available for free. Professional packages cost several hundred USD.

Cover: **Andromeda Galaxy Messier 31**

Date:	2021-09-02,	Time: 15:30 UTC
Mount:	Orion Atlas EQ-G,	Lens: Samyang 135mm
Filter:	Kenko Starry Night,	Camera: Nikon D5500
Image size:	5700 x 3206 px,	Image scale: 6"/px, FOV: 9.48 x 5.33°
Exposure:	80 x 90 sec, ISO400, stopped at f2.4, integration: 2h 00m	

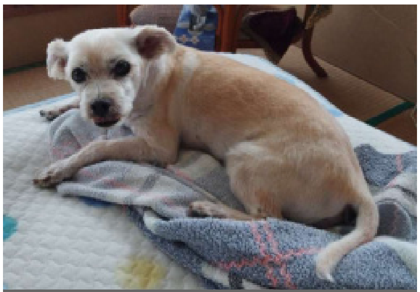
Insets are to image scale.

Image scale = arc sec in a radian * sensor pixel size / focal length
For a Nikon D5500 and a Samyang 135mm prime the image scale is:
`206.265 * 3.92µm / 135mm = 6 arc seconds per pixel`

The Andromeda Galaxy is twice as large as the Milky Way. Moving at a speed of about 400,000 km/hour it will merge with the Milky Way in some 4.5 billion years.

FOV (field of view) = 2 x Atan(sensor size / 2 * focal length) * 57.296
For a Nikon D5500 and a Samyang 135mm prime the FOV is:
`FOV = 2 * Atan(23.6mm / 270mm) * 57.296 = ~10°`

The example is based on horizontal length (width). Sensor size may be horizontal, vertical or in diagonal.



▲This is 14-years old "Ken", the author's shadow, best friend and guardian (when not sleeping).

Please appreciate that the autor introduces equipment he is used to handle, without any endorsement. It is safer and fair to discuss products you are experienced with.

Experience comes with practical use, the more you fail the more you learn. Giving up is no option since you would be missing a lot.

A dark site and favorable meteorological conditions make half the success. The fidelity of images (details, colors) you will achieve strongly depends on size and quality of an objective lens, a prime or a telescope. The larger the aperture the more and the faster light can be gathered. At the end of the day it is a matter of budget. You can faithfully rule out own clumsiness. After a few attempts you will be proud of yourself, perhaps framing your images.

This is a DIY assembly for parallel imaging with a refractor, a telelens and two (used) cameras with intervalometers. A guidescope with CMOS camera is mounted at the left. By means of a ball head another camera can be attached for, say, imaging a constellation while gathering light of a target deepsky object. A few more details are outlined on the following pages.

The Great Orion Nebula, Messier 42

1500ly

Essential Equipment

▲ Date: 2022-02-27 14:00 UTC
Mount: Orion Atlas EQ-G
Telescope: TS71SDQ
Filter: Kenko ASTRO LPR Type II
Camera: Nikon D5300 (modified)
Image size: 5600 x 3150 pixel
Image scale: 1.744"/pixel
Image FOV: 2.71 x 1.53°
Exposure: 30 sec @ISO800
Light frames: 40
Integration: 0h 20m

D5300

TS71SDQ

Telescope Example

The small **TS71SDQ** refractor with Ø71mm aperture and 450mm (f6.3) is a favorable format for popular nebulae and star clusters. Except for the Andromeda and Triangle galaxies its focal length is too short for imaging further galaxies. The quadruplet apochromat sports a built-in flattener and provides outstanding image quality with round corner stars and well corrected colors.

An extension tube for a camera is included. All it needs to connect with a DSLR is a T-ring for the camera brand. So configured the user does not need to care about correct "back focus" which is often a pain in the neck with optional external reducer/flatteners required for doublet (2 lenses) and triplet (3 lenses) refractors. Cheap achromats are prone to unwanted color fringes.

With no plastic parts used in critical places, the TS71SDQ tube weighs 3.2kg including dovetail and tube rings. Numerous mobile mounts can shoulder up to 5kg.

Camera Example

Basically any DSLR will do, but there are a few things that make imaging life easier. The camera should have a APS-C size sensor (23.5 x 15.6mm) and a resolution of 24 megapixels which results in a pixel size of nearly 4µm which is suitable for wide field photography. For comfort in the neck the camera should have a rotatable flip display.

Typical example are the **Nikon D5300/ D5500** and **Canon EOS 90D/EOS kiss**, but there are many other brands in the market. Since the author uses Nikon most descriptions will focus on the Nikon D5300/D5500. A used camera body which is fully intact for manual shooting will do.

You will also need an interval timer (intervalometer) for the camera and a T-ring adapter for mating the camera with the telescope.

◀ *Example of an inexpensive cable intervalometer.*

Honey List

1. A telescope for deepsky and/or a lens for constellations
2. A DSLR with APS-C sized sensor, about 24mp resolution, intervalometer
3. An autoguide scope* with guide camera
4. A sturdy tracking mount for a telescope
5. A mobile tracking mount** for a camera and lens
6. A laptop computer*** for autoguiding

* **Autoguiding** is not required for wide field imaging as accurate tracking will do the trick, but it is not forbidden to autoguide wide fields. It is however essential for imaging deepsky objects with a telescope, such as our TS71SDQ.

▲ Example of a Ø30mm, fl=120mm (f4) small and light-weight guidescope with inserted guide camera.

As a rule of thumb, the focal length of a guide scope should be around one fifth that of the telescope. Monochrome CMOS cameras with small pixels are best suited for autoguiding and the wider the field the better the chance of finding a good guide star. If the camera sports an USB-3 port then it will be fast enough for lunar and planetary imaging with large telescopes, such as the popular Schmidt -or Maktsukov Cassegrains.

▲ Mini guide camera.

Tailored to autoguiding, so called Mini guide cameras are more compact and lighter but often come with a slow USB-2 port which is sufficient for autoguiding though.

** If we limit our activities to compact refractors, a sturdy **equatorial electronic mount** with ability to track and autoguide in both directions (right ascension and declination) and a payload of around 10kg provides sufficient margin for the telescope OTA, camera, autoguider and other gear. In the interest of tracking accuracy, a mount should not be loaded to its full payload capacity, but to about 70% maximum.

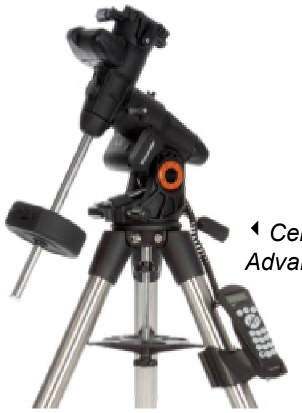
The are plenty of choices. For example, the **iOptron CEM26** (11kg), or the **Sky-Watcher EQ5** (9kg), or the **Celestron Advanced VX** (13.6kg). A sturdy, accurate tracking mount is crucial for sharp sky images with round stars.

Photos of the mounts are not to scale.

▲ iOptron CEM26

▲ Sky-Watcher EQ5

◀ ZWO AM5



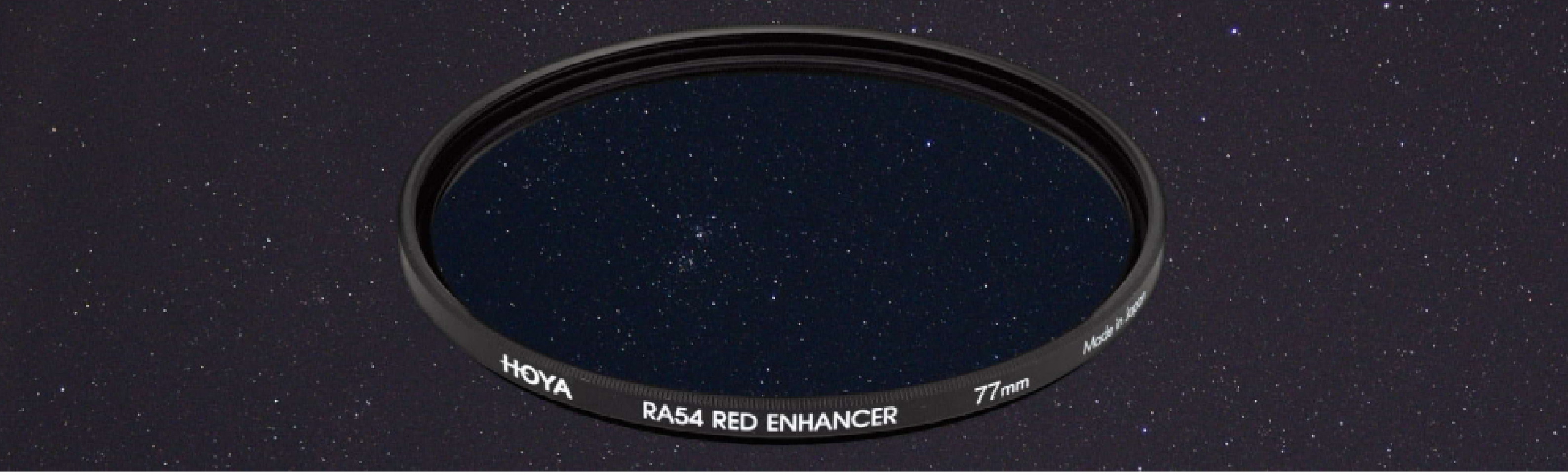
◀ Celestron Advanced VX

Budget permitting, the **ZWO AM5** is a modern mount with strain wave gear and synchronous belt. It is highly accurate and manages up to 13kg payload without counter weight and up to 20kg with.

▼ Star Adventurer

Sky-Watcher's Star Adventurer is an example of a versatile mobile mount with autoguide function for up to 5kg payload. The latest version sports WiFi. Best suited for DSLRs and lenses up to 300mm focal length, ideally with a solid ball head.

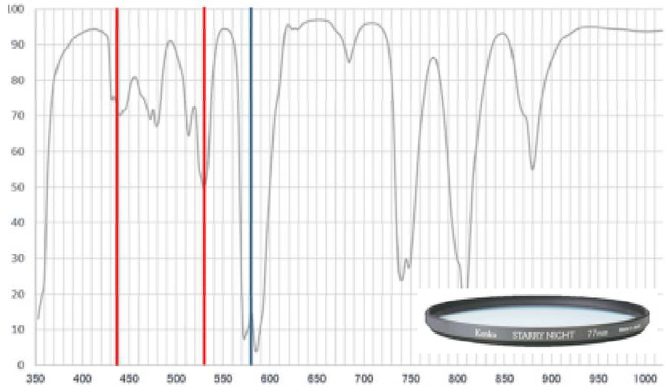
*** Since a DSLR delivers instant gratification a **controlling computer** is not required as image files are stored in the camera's memory card, however, a computer and control software, such as "PHD2" is required for an autoguide camera which is connected to an USB-2 or USB-3 port. Another cable (ST-4) connects the camera with a mount. The software selects a suitable guide star from the camera's field of view and steers a mount should the guide star move away as a result of inaccurate tracking or mechanical errors.

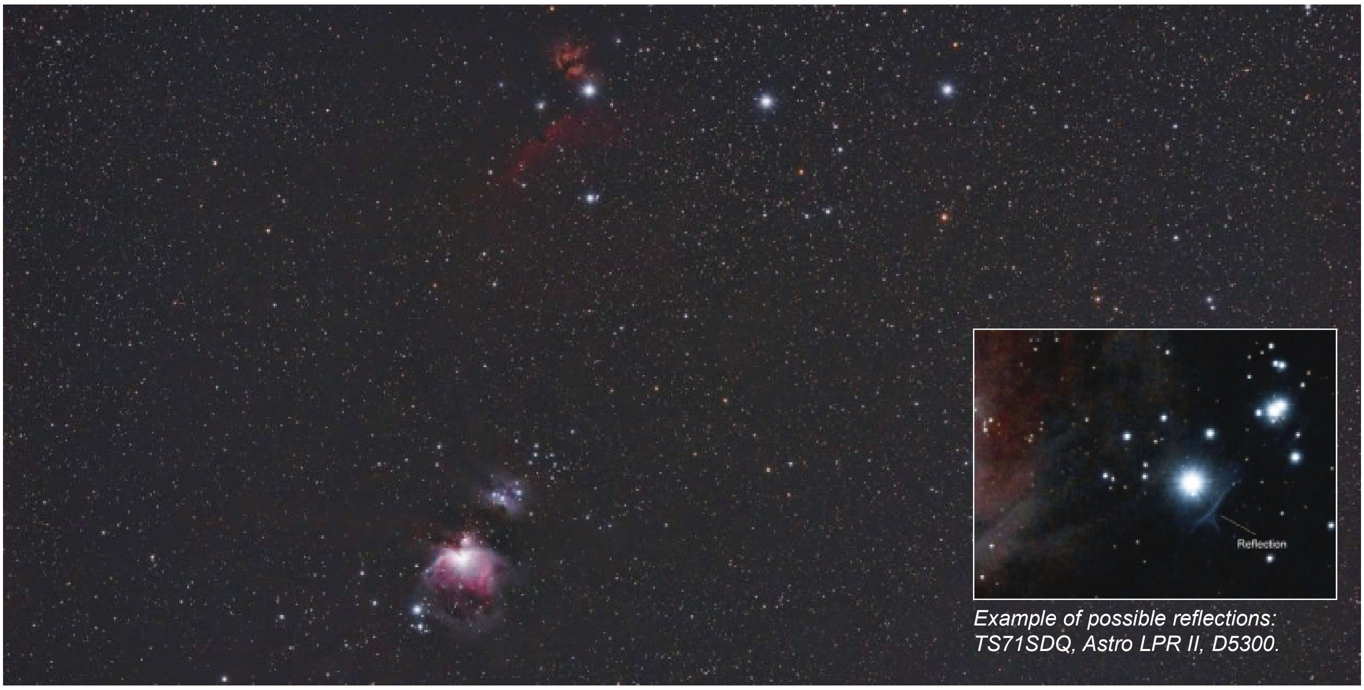


Light Pollution Filter

A Light Pollution Rejection filter helps minimize image gradients and walking noise. It is basically an UV/IR-cut filter but additionally oppressing the typical wavelengths of sodium and mercury city lights.

The author uses the Hoya **RA54 Red Enhancer** for lenses and a Kenko **Starry Night** for the refractor telescope which are essentially the same filters. Like all filters, the LPRs darken the image a little bit (exposure compensation +1/2 stop) because no filter transmits 100% light.

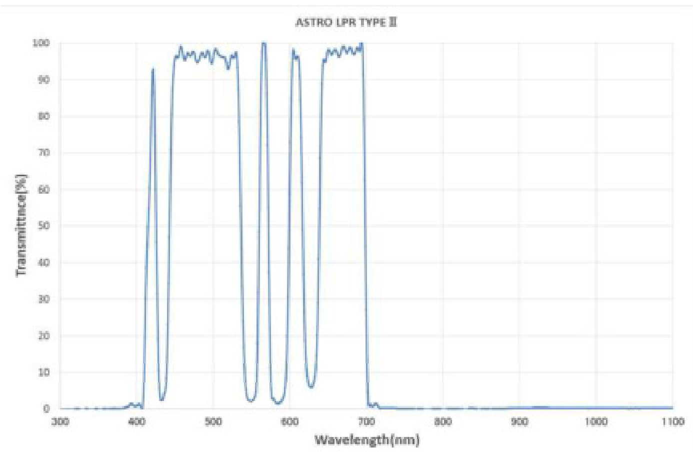




Example of possible reflections: TS71SDQ, Astro LPR II, D5300.

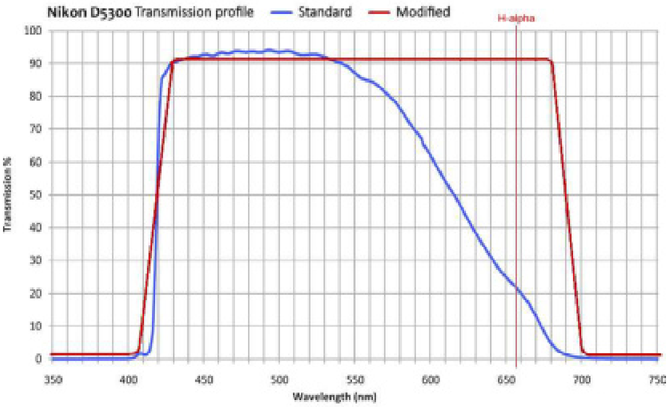
▲ A stack of 88 frames 30 seconds each at ISO800 with the ***Kenko Starry Night*** *filter on a Samyang 135mm telelens stopped at f4 on a Nikon D5500, guided on a Sky-Watcher "StarAdventurer" mobile tracking mount. The horizontal FOV is about 10 degrees.*

Selectively blocking typical light pollution wavelengths, the interference type (can cause reflections on the image) **Kenko Astro LPR Type II** is a further development of "Starry Night". It passes H-beta, OIII as well as H-alpha and is suitable for DSLR cameras with or without infrared filter (see the following chapter).



LPR: *Abbreviation for Light Pollution Resistance*

Filters, such as narrow band filters, can make a huge difference but do cost a little fortune, in that we are using merely an affordable light pollution filter. A shelf DSLR has an infrared cut filter over its image sensor. If removed the camera will have higher acuity for nebulae with narrow band or light pollution filters.



▲ Like all shelf cameras, the Nikon D5300 is not designed with astronomy in mind. While this is no major concern when imaging stars and galaxies, nebulae photographers may not be 100% content. Most nebulae emit in the H-alpha wavelength at 656.28nm. The unmodified D5300 receives just over 20% of this band while a retrofitted camera would receive over 90%, hence about 4.5 times more which makes a notable difference in contrast and detail in nebulae. Please check the internet for 'astro conversion' services.

With a long 200° of rotation the focusing ring has a good touch and feel, smooth and without play while holding its focus well. The lens aperture is Ø67mm, the front filter thread size is the popular Ø77mm, say, for a light pollution filter. In other words, a fine astrophoto lens.

▲ Nikon D5300 and a Samyang 135mm telelens tracked on a Sky-Watcher "StarAdventurer" mobile tracking mount which is capable of autoguiding in a single direction.

Lenses for Wide Fields

With its 135mm focal length, the **Samyang/ Rokina** all-manual telephoto prime provides a desirable 10° horizontal field of view with a crop sensor DSLR (APS-C) and 15° with a full frame sensor for wide field deep space photography. At maximum aperture of f2.0 short exposure times are possible yet without notable edge aberration.

One of its lenses (11 elements, 7 groups) is an extra-low dispersion (ED) element to reduce the impact of chromatic aberrations (color fringes) while full Ultra Multi-Coating (UMC) considerably helps reduce flare and ghosting. The lens comes with bajonet lock for major camera brands.

The **Nikkor 50mm**, f1.4 is a "fast", low-cost standard lens designed for manual mode. The field of view on an APS-C sensor is about 27° x 15° which is well suited for many constellations, though a wider 35mm, 28mm or even a 14mm lens would be favorable for large constellations. The lens threads 52mm filters. With its iris wide open at f1.4 the stars in the image corners get strongly elongated, in that it is recommended to stop the lens at f2.8 or f4.

▲ The iris blades in the lens cause spikes around stars when the iris is not wide open. To avoid spikes wide open the iris and use a stepdown ring, such as a 77mm to 52mm for the Samyang 135mm which has a 77mm filter thread. The resulting f-stop is 135mm/52mm = 2.6.

Constellations with a Wide Lens

Setup

A mobile mount is great for constellation images while auto-guiding is not required (though not forbidden). All we need is a DSLR with a wide lens, say 28mm, 35mm or 50mm. Low-cost lenses should not be used wide open to avoid edge distortions. Too much cropping would be a waste of wide space.

Given the Nikon D5x00 and a standard **50mm f1.4 lens stopped at f2.8** the exposure time is typically 60 seconds at ISO800 or ISO1600, while 100 'good' frames or over 1 hour integration would be nice to obtain, weather permitting. An **LPR** will help improve the result. The dot finder is luxury, while the **ball head** between mount and camera is warmly recommended.

When setting the **intervalometer** make sure to insert 20 to 30 seconds between the shots to allow the sensor to cool down in the interest of less image noise. The internal timer stops at 30 sec.

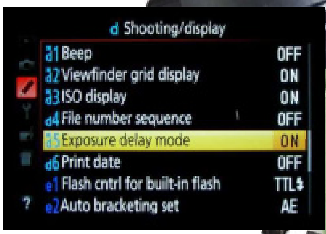
Have the camera save the images in its RAW format. As for white balance, auto or daylight will be fine.

Equally important, make a test shot and check the camera's histogram. The peak should not extend beyond the middle.

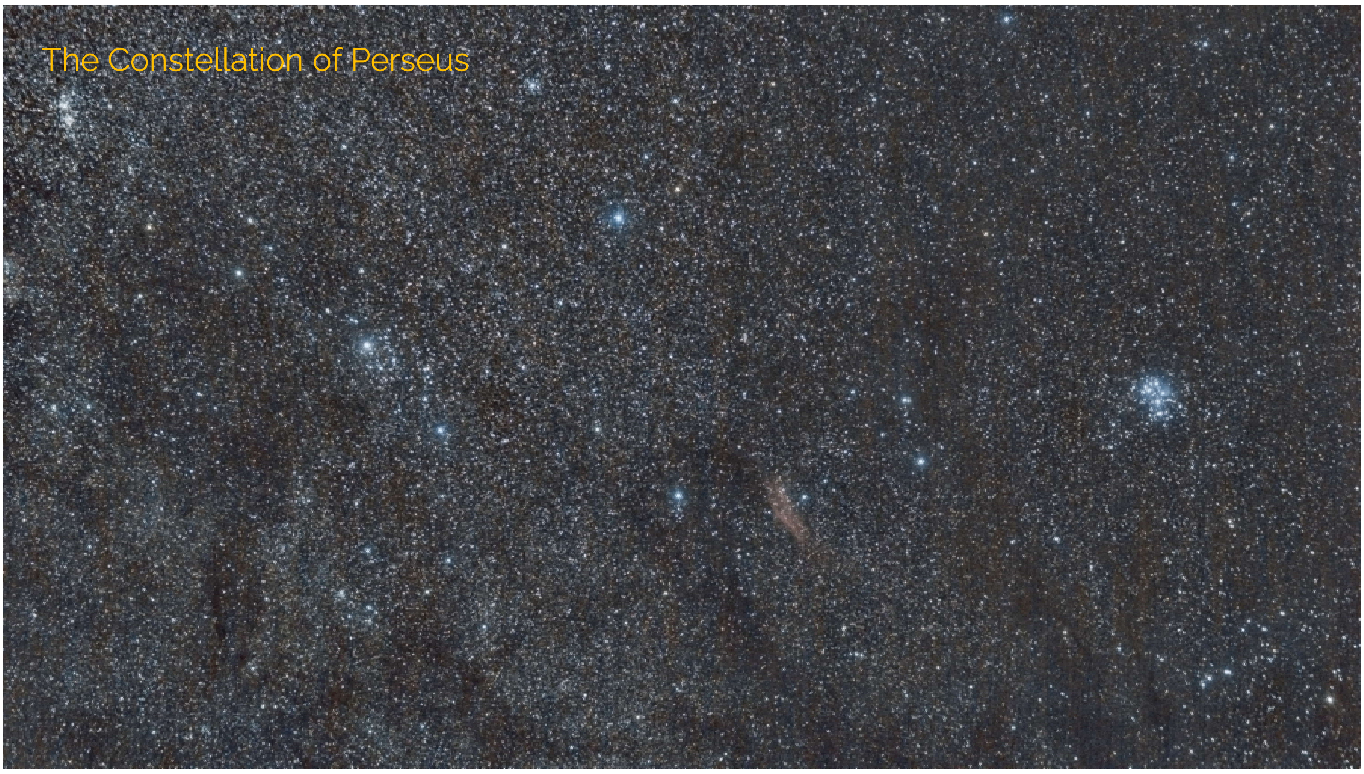
If the camera has an **Exposure Delay Mode**, by all means, activate it to eliminate blurring by shutter shock and mirror flips. Set the camera to Live View to keep the flip mirror up.

Although internal image processing functions are not available in RAW recording mode (they largely apply to the JPEG format), just for safety, disable all noise reduction functions and set sharpness to a low level as too much can amplify image noise.

▲ D5300 with 50mm f1.4 lens on a "Star Adventurer" mobile mount.



▲ Exposure delay mode in the camera settings menu.



Date:	2021-10-01,	Time: 15:30UTC
Mount:	Star Adventurer (tracked)	Lens: Nikkor 28mm
Filter:	Hoya Red Intensifier,	Camera: Nikon D5300
Image:	5800 x 3263 scale: 28.9"/px, FOV: 46.5 x 26.2°	
Exposure:	100 x 60 sec, ISO800, stopped at f4.0, integration: 1h 40m	

Hint: the camera does not write f-number and focal length data to the image file when using a telescope or a manual-only lens.

Date: 2022-11-19, Time: 15:05UTC
Mount: Atlas EQ-G (guided), Lens: Nikkor 50mm
Filter: Hoya Red Intensifier, Camera: Nikon D5500
Image: 6016 x 3384px, scale: 16.2"/px, FOV: 27 x 15.2°
Exposure: 79 x 60 sec, ISO800, stopped at f2.8, integration: 1h 19m

Date: 2022-11-18, Time: 14:42UTC
Mount: Star Adventurer (tracked) Lens: Nikkor 50mm
Filter: Hoya Red Intensifier, Camera: Nikon D5500
Image: 5870 x 3302, scale: 16.2"/px, FOV: 26.4 x 14.8°
Exposure: 60 x 60 sec, ISO1600, stopped at f2.8, integration: 1h 00m

The Milky Way with a Wide Lens

Setup

Wide fields of the Milky Way are best taken with equipment as described for Constellations.

The Earth completes one full rotation in 23 hours 56 minutes and 4.0905 seconds. This period is referred to as a “Sidereal Day”. As a result of Earth's spinning, apparently moving stars draw an arc on long exposure photos.

Mobile mounts, such as the **Vixen Polarie**, compensate for the apparent motion of the sky. This technique is known as "tracking" which avoids star trails. Of course, polar alignment should be as accurate as possible. If so, the tracker can be used with up to 135mm lenses. The wider the lens the more forgiving.

Without tracking the maximum allowable exposure time before stars begin to trail is largely limited by the focal length of the lens.

By rule of thumb:

500 / (focal length * crop factor)

Crop factor is the ratio of a camera sensor to a full frame 35mm sensor, 1.5x for Nikon and 1.6x for Canon APS-C cameras.

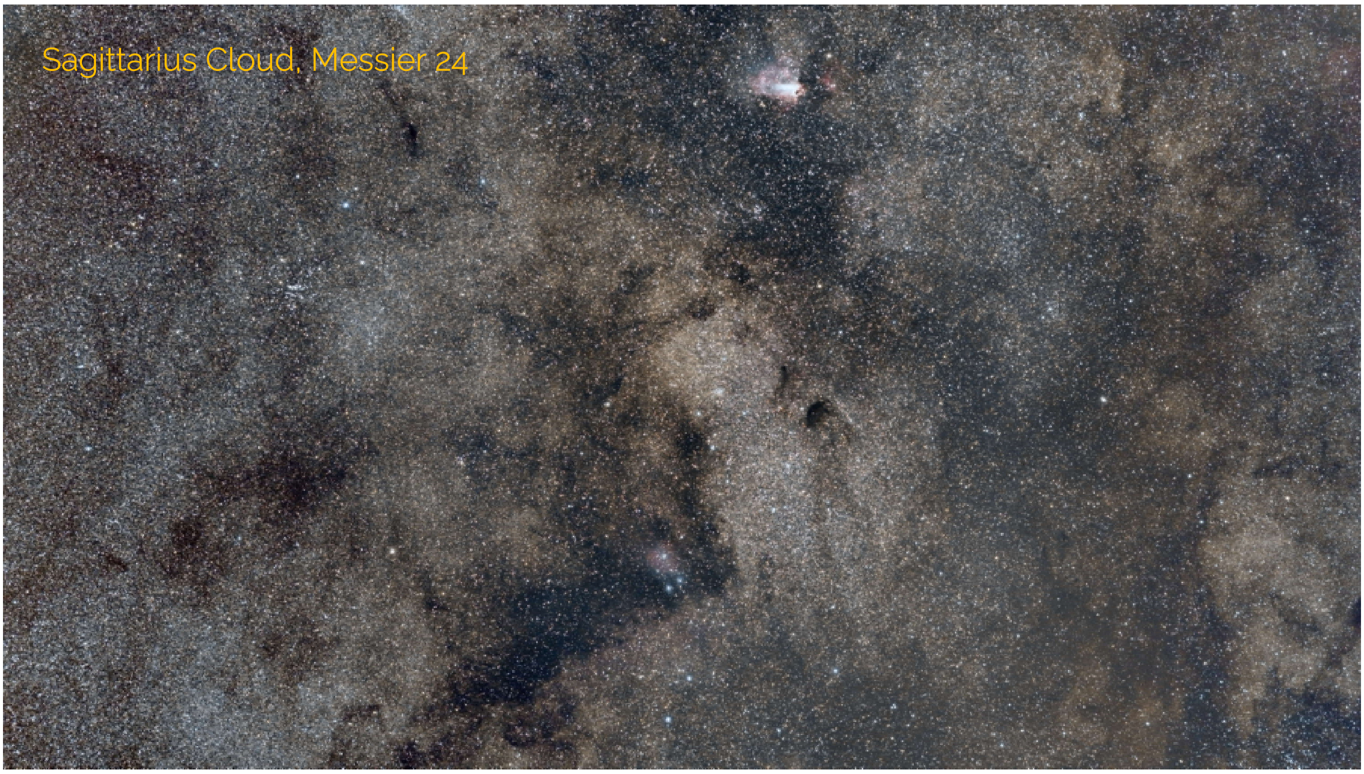
Example: 500 / (1.5 * 28mm) = 12 seconds. If you tolerate a few pixels trailing you can extend the exposure time accordingly.

⏶ A Nikon D5300 with a 28mm lens mounted on Vixen’s Polarie tracker simply with a ball head. The tracker itself sits on a photo tripod with a standard 1/4” screw.

This is a very rough guide. Other factors include sensor pixel size and declination of a star. Trailing is most apparent near the celestial equator.

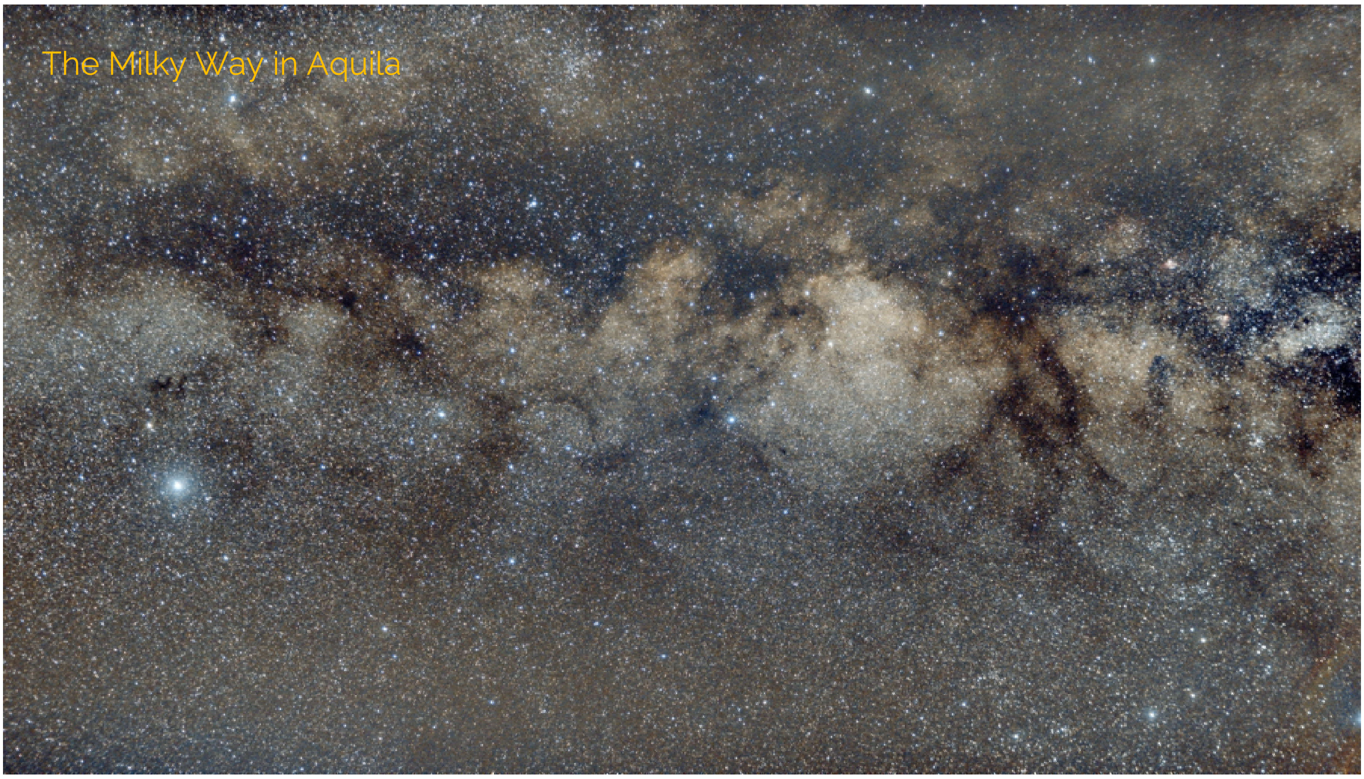
Date:	2019-05-09,	Time: 11:30UTC
Mount:	Vixen Polarie (tracked)	Lens: Nikkor 28mm
Filter:	Hoya Red Intensifier,	Camera: Nikon D5300
Image:	5800 x 3263 scale: 28.9"/px, FOV: 46.5 x 26.2°	
Exposure:	13 x 30 sec, ISO1600, stopped at f2.8, integration: 0h 06m	

Jupiter shining like a beacon in the Milky Way on May 4, 2019. A bit noisy when zooming in though, but this picture was taken with only six minutes integration on a small mobile setup.



Date: 2021-09-02 Time: 11:45UTC
Mount: Orion Atlas EQ-G Lens: Samyang 135mm
Filter: Hoya Red Intensifier, Camera: Nikon D5500
Image: 5800 x 3263 scale: 5.9"/px, FOV: 9.65 x 5.43°
Exposure: 40 x 90 sec, ISO800, stopped at f2.4, integration: 1h 00m

Centered on Messier 24, at the top center lies the Omega Nebula.



Date: 2021-07-15 Time: 13:05UTC
Mount: Star Adventurer (tracked) Lens: Nikkor 28mm
Filter: Hoya Red Intensifier, Camera: Nikon D5300
Image: 5600 x 3175 scale: 28.9"/px, FOV: 44.9 x 25.5°
Exposure: 50 x 30 sec, ISO3200, stopped at f2.8, integration: 0h 25m

The bright star at the left is Altair.

Wide Fields with a 135mm Lens

Setup

The setup, camera settings and caution items are basically the same as for Constellation imaging. Since the focal length of the Samyang/Rokinon prime lens is 135mm the polar alignment of the mount needs to be accurate when tracking. In addition, with the Star Adventurer, autoguiding in right ascension can be applied for increased accuracy, but this will demand a guide scope with a guide camera and require us to connect and fire up a laptop to run guiding software.

A ball head is not crucial but helps frame a target way more easily, but trading against sturdiness. When using a guidescope make sure its optical axis is aligned in parallel to the optical axis of the lens.

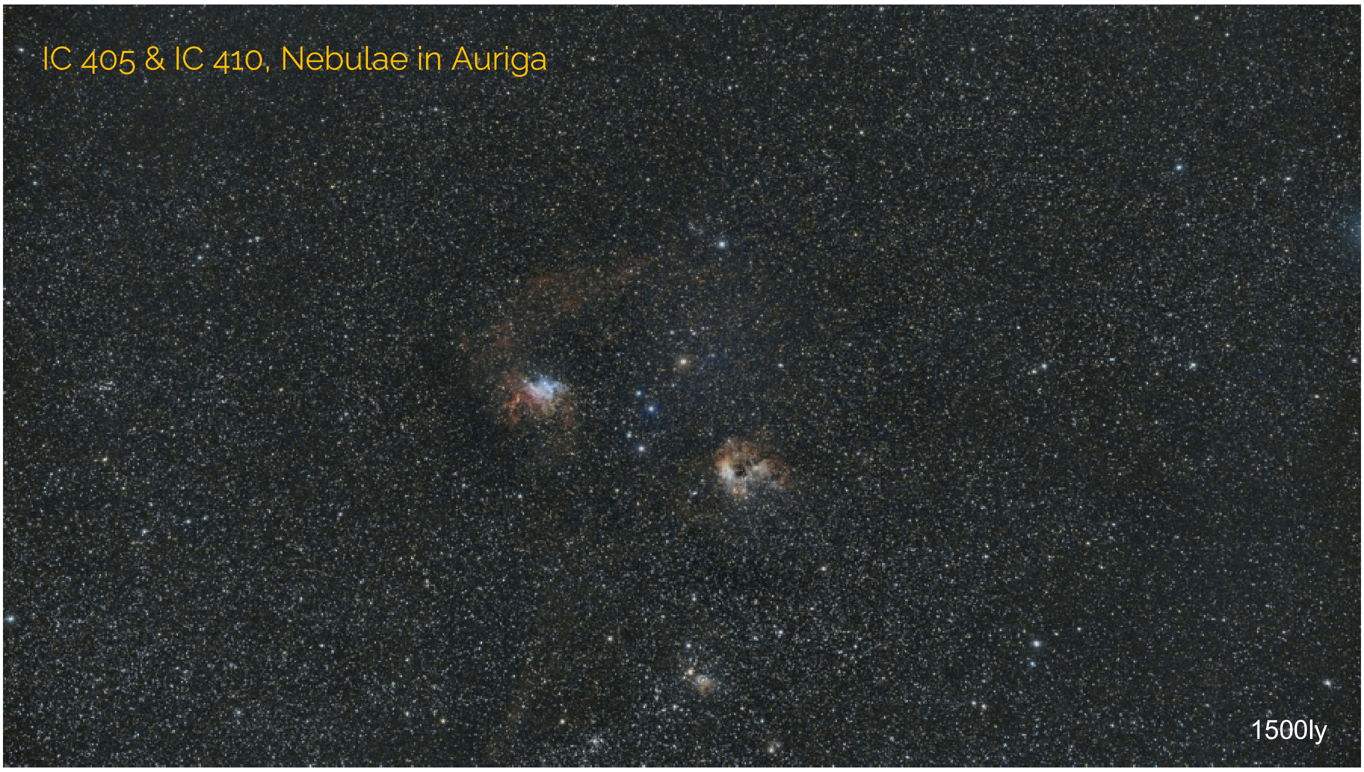
An Ø77mm LPR filter to reduce the impact of light pollution threaded to the lens is warmly recommended.

Since the Samyang/Rokinon is optically well corrected, stars in the utmost image corners will be sharp and round. Consequently you can fully open the lens at f2, though focus-ing is more tricky than when stopped down. When the iris is stopped, say at f2.8 or f4, bright stars will be surrounded by spikes which are inherent to the shape of the iris.

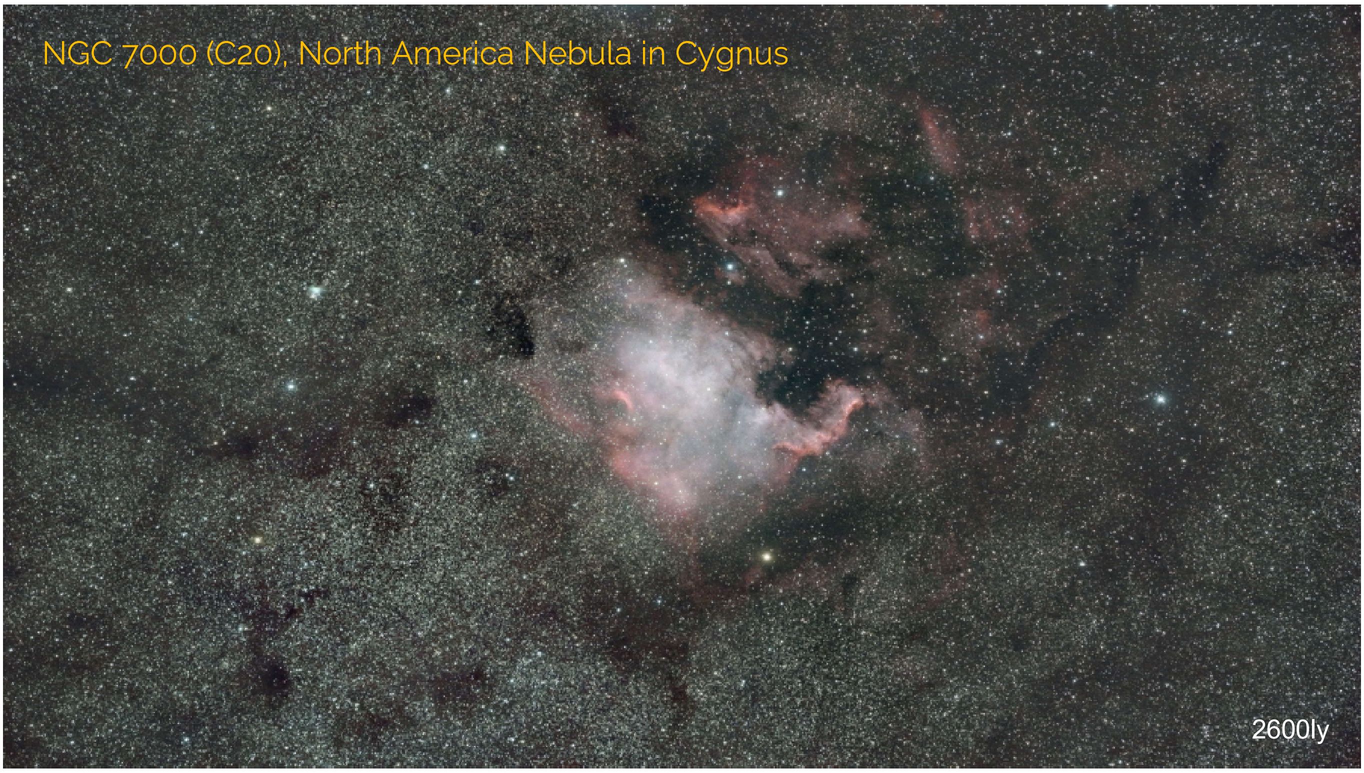
The example shows a D5500 with a Samyang 135mm prime lens and a Ø30mm guidescope with inserted camera mounted on a plate with two 1/4″ screws. The plate itself provides two threads, 1/4″ and 3/8″ in its middle. The alternative and better choice is using a sturdy, accurate equatorial mount which may eliminate need for autoguiding, but it is legitimate to employ :-)

Date:	2021-10-01,	Time: 16:50 UTC
Mount:	Orion Atlas EQ-G,	Lens: Samyang 135mm
Filter:	Kenko Starry Night,	Camera: Nikon D5500
Image:	5800 x 3263 px, scale: 6"/px, FOV: 9.65 x 5.43°	
Exposure:	70 x 90 sec, ISO800, stopped at f2.4, integration: 1h 45m	

Date: 2021-09-03, Time: 15:35 UTC
Mount: Orion Atlas EQ-G, Lens: Samyang 135mm
Filter: Kenko Starry Night, Camera: Nikon D5500
Image: 5800 x 3263 px, scale: 6"/px, FOV: 9.65 x 5.43°
Exposure: 32 x 120 sec, ISO400, stopped at 2.4, integration: 1h 03m

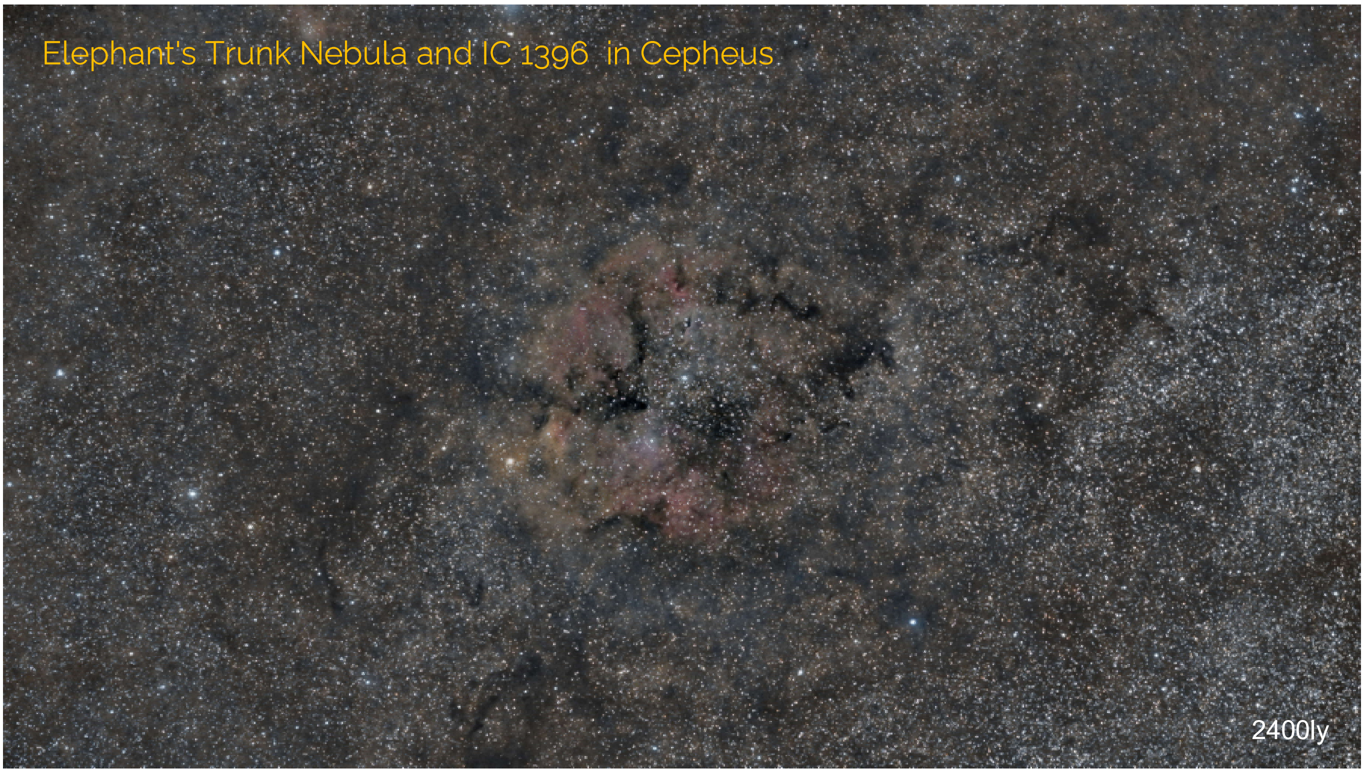


Date: 2021-10-08, Time: 16:30 UTC
Mount: Orion Atlas EQ-G, Lens: Samyang 135mm
Filter: Kenko Starry Night, Camera: Nikon D5500
Image: 5700 x 3206 px, scale: 6"/px, FOV: 9.48 x 5.33°
Exposure: 17 x 45 sec, ISO800, stopped at f2.0, integration: 0h 12m

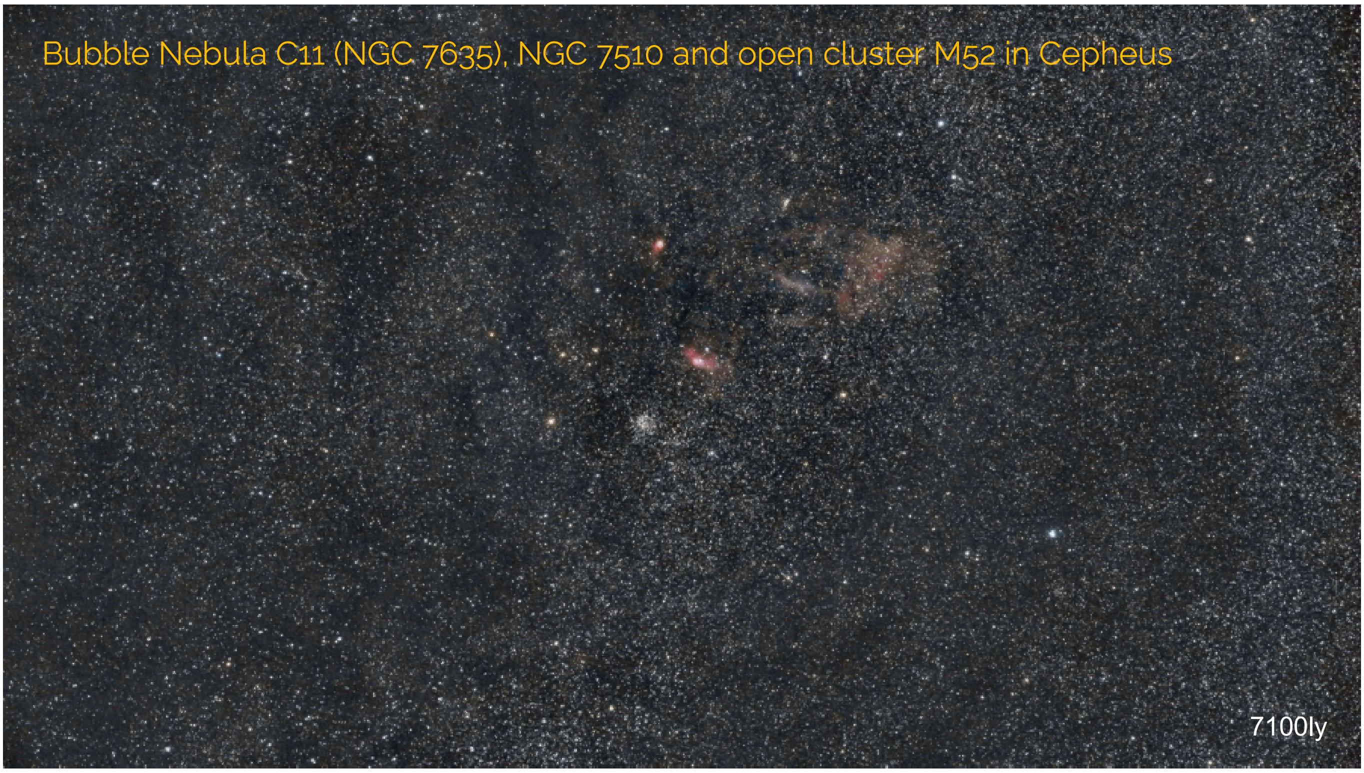


Date:	2022-08-03,	Time: 13:00 UTC
Mount:	Orion Atlas EQ-G,	Lens: Samyang 135mm
Filter:	Kenko Starry Night,	Camera: Nikon D5500
Image:	5780 x 3251 px, scale: 6"/px, FOV: 9.62 x 5.41°	
Exposure:	60 x 90 sec, ISO400, stopped at f2.0, integration: 1h 30m	

Date:	2022-08-04,	Time: 13:25 UTC
Mount:	Orion Atlas EQ-G,	Lens: Samyang 135mm
Filter:	Kenko Starry Night,	Camera: Nikon D5500
Image:	5700 x 3207 px, scale: 6"/px, FOV: 9.48 x 5.34°	
Exposure:	110 x 90 sec, ISO400, stopped at f2.0, integration: 2h 45m	



Date:	2022-09-21,	Time: 11:36UTC
Mount:	Orion Atlas EQ-G,	Lens: Samyang 135mm
Filter:	Kenko Starry Night,	Camera: Nikon D5500
Image:	5800 x 3263 px, scale: 6"/px, FOV: 9.65 x 5.43°	
Exposure:	90 x 90 sec, ISO800, stopped at f2.4, integration: 2h 15m	



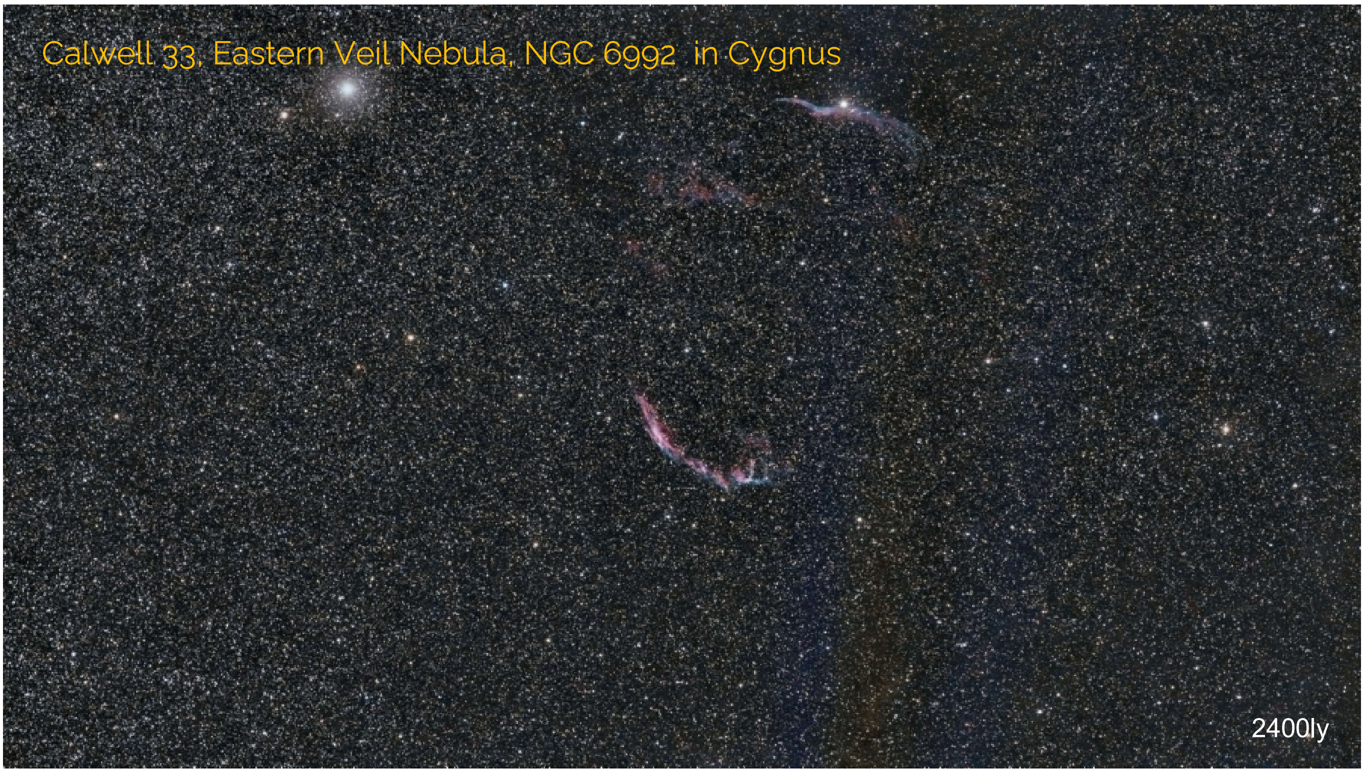
Date:	2022-09-27	Time: 11:33UTC
Mount:	Orion Atlas EQ-G,	Lens: Samyang 135mm
Filter:	Kenko Starry Night,	Camera: Nikon D5500
Image:	5800 x 3262 px, scale: 6"/px, FOV: 9.65 x 5.43°	
Exposure:	28 x 90 sec, ISO800, stopped at f2.4, integration: 0h 42m	

Lagoon (M8) and Trifid (M20) Nebulae in Sagittarius

Date: 2022-08-05, Time: 12:45 UTC
Mount: Orion Atlas EQ-G, Lens: Samyang 135mm
Filter: Kenko Starry Night, Camera: Nikon D5500
Image: 5700 x 3206px, scale: 6"/px, FOV: 9.48 x 5.33°
Exposure: 50 x 90 sec, ISO400, stopped at f2.0, integration: 1h 15m

Eagle (M16) and Omega Nebulae (M17) in Serpens and Sagittarius

Date: 2022-08-30, Time: 12:30 UTC
Mount: Orion Atlas EQ-G, Lens: Samyang 135mm
Filter: Kenko Starry Night, Camera: Nikon D5500
Image: 5739 x 3228px, scale: 6"/px, FOV: 9.55 x 5.37°
Exposure: 30 x 90 sec, ISO800, stopped at f2.4, integration: 0h 45m



Date:	2022-08-20,	Time: 12:54 UTC	
Mount:	Orion Atlas EQ-G,	Lens: Samyang 135mm	
Filter:	Kenko Starry Night,	Camera: Nikon D5500	
Image:	5166 x 2906px, scale: 6"/px, FOV: 8.59 x 4.83°		
Exposure:	23 x 90 sec, ISO800, stopped at f2.8, integration: 0h 34m		

Taken in parallel to the Eastern Veil nebula on page 22.

Date:	2022-12-27,	Time: 12:35 UTC	
Mount:	Orion Atlas EQ-G,	Lens: Samyang 135mm	
Filter:	Kenko Starry Night,	Camera: Nikon D5500	
Image:	5850 x 3291px, scale: 6"/px, FOV: 9.53 x 5.48°		
Exposure:	102 x 90 sec, ISO800, stopped at f2.4, integration: 2h32m		

Taken in parallel to the Rosette nebula on page 23.

Deepsky with an 450mm Apochromat

Setup

Camera settings and related caution items are essentially the same as for Constellation and Wide Field imaging.

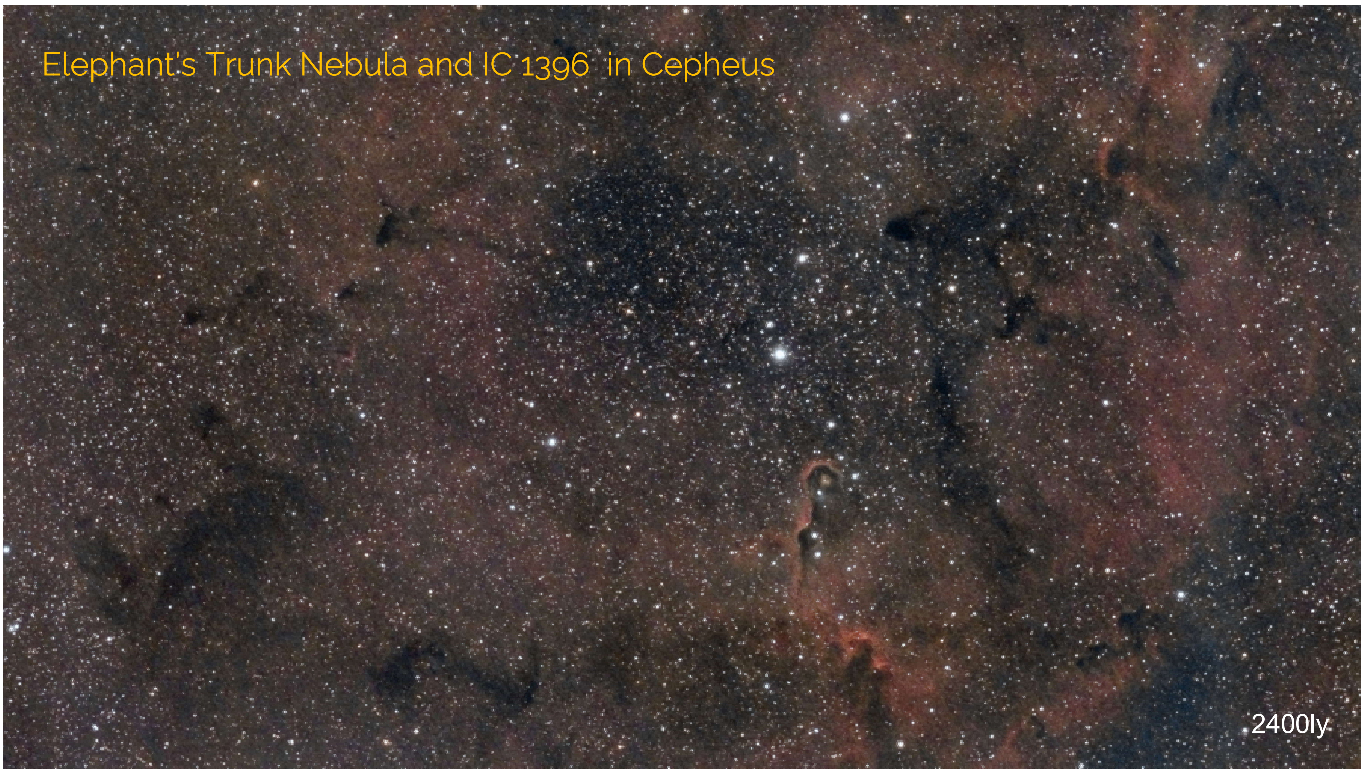
Since the focal length of the refractor is 450mm we need to use an accurate equatorial mount and, for best results, autoguiding. Polar alignment is crucial and must therefore be as precise as possible.

An Ø77mm LPR filter to reduce the impact of light pollution threaded to the lens is warmly recommended.

A dot finder on the camera as pictured or a finder scope are helpful when it comes to aligning the mount and for framing the target.

The example at the top shows a Nikon D5300 DSLR attached to a Ø71mm TS71SDQ quadruplet and a Ø30mm guidescope with inserted guide camera and plugged in intervalometer fixed on an old Orion Atlas EQ-G equatorial mount. A smaller mount would be quite sufficient though.

‣ This photo demonstrates the essential difference between an achromat and an apochromat refractor. In the achromat (Ø80mm/fl=980mm) the star Mizar and Alcor are surrounded by color fringes (left), while the apochromat (TS71SDQ) corrects color fringes most efficiently. In the apochromat the star Mizar can be seen double, not so in the achromat. Both single shots exposed 10 seconds at ISO1600 in prime focus.



Date:	2021-09-21,	Time: 11:27 UTC
Mount:	Orion Atlas EQ-G,	Lens: TS71SDQ
Filter:	Kenko Astro LPR Type II,	Camera: Nikon D5300
Image:	5800 x 3263 px, scale: 1.8"/px, FOV: 2.89 x 1.63°	
Exposure:	49 x 120 sec, ISO1600, integration: 1h 38m	

Considering the slower 'speed' of the TS71SDQ at f6.3 plus LPR filter, a typical exposure time for nebulae is 90 to 120 seconds at ISO1600, depending on the surface brightness of the object. For star clusters 60 to 90 seconds at ISO800 will avoid bloating of stars, but need more integration to gather true star colors. In any case please make a test shot and check the histogram in the camera. The peak should not extend beyond the middle.

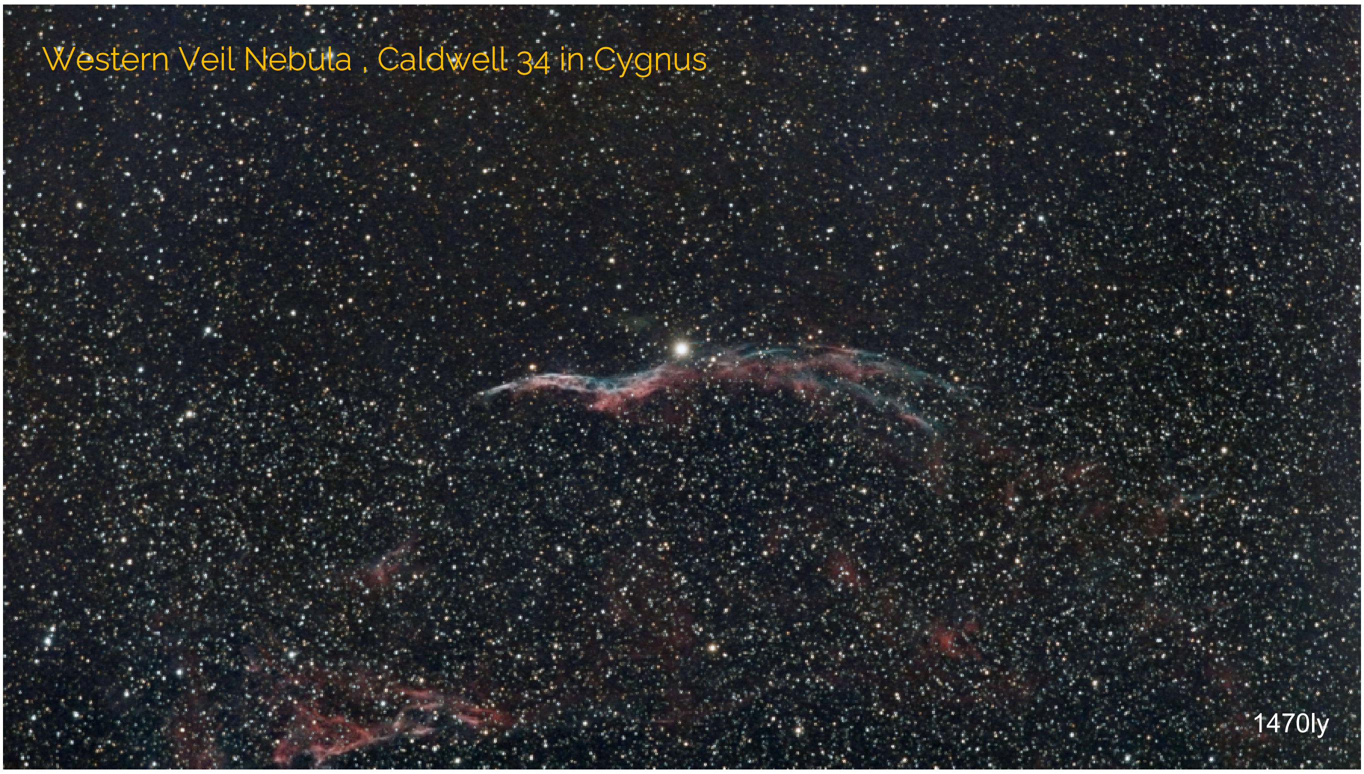
Objects with a bright core, such as the Andromeda galaxy (M31) and the Orion nebula (M42) need special care to avoid oversaturation of its cores. Shorter exposure times, say 30 seconds and a lower ISO compensate for it but need longer integration for the surrounding structures. Making it a bit more complicated, you can take two bunches of images differently exposured and combine them in post-processing.

▾Off topic, but the TS71SDQ produces fine lunar images with a 2x barlow and a CMOS camera or a DSLR. The resolution is limited by the small aperture of the refractor and its short focal length but the quality of the lenses convinces.

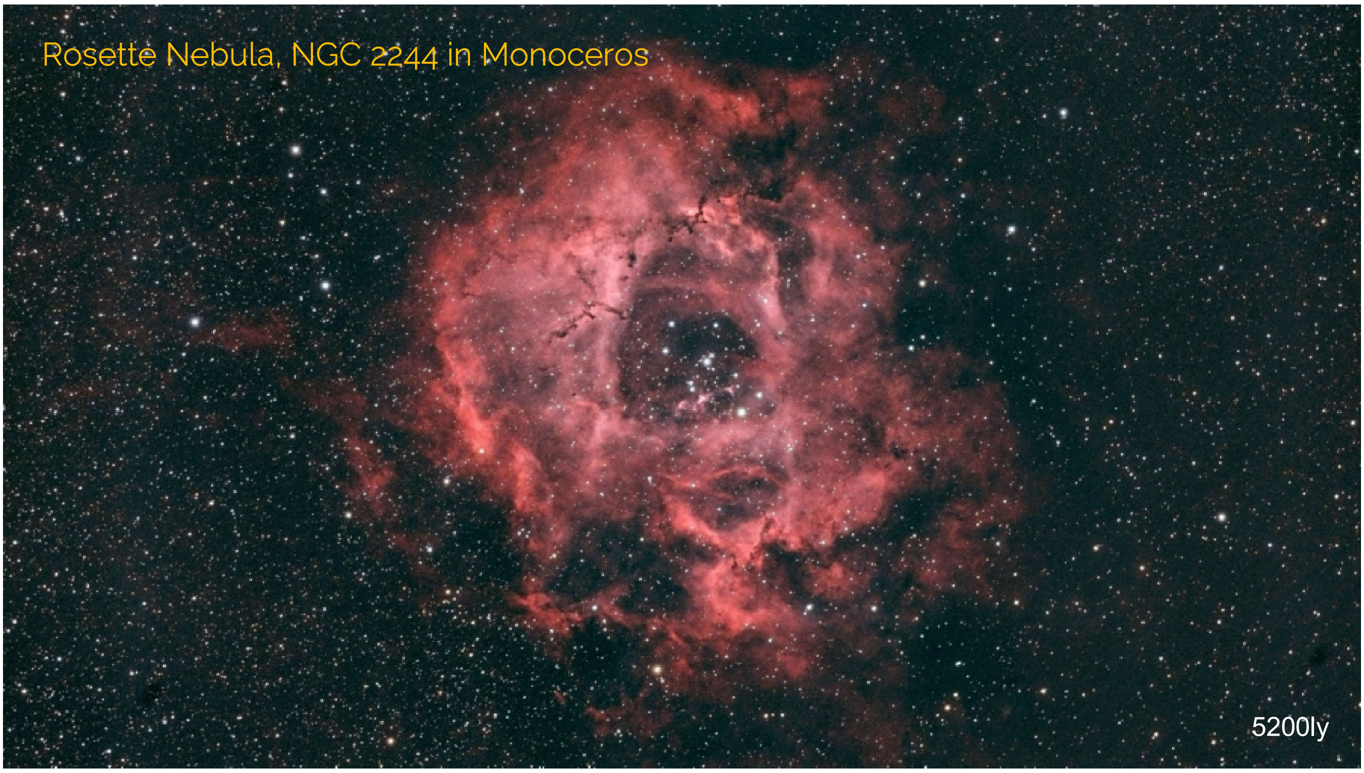
TS71SDQ with 2x barlow and ASI462MC CMOS camera, IR742nm infrared band pass filter, 3.5ms at gain 200, 64fps, 400 stacked frames.

TS71SDQ with Nikon D5300 DSLR, 1/125 second at ISO400, single frame.

Date:	2022-08-20,	Time: 12:54 UTC	
Mount:	Orion Atlas EQ-G,	Lens: TS71SDQ	
Filter:	Kenko Astro LPR Type II,	Camera: Nikon D5300a	
Image:	6016 x 3263 px, scale: 1.8"/px, FOV: 3.0 x 1.69°		
Exposure:	12 x 120 sec, ISO1600, integration: 0h 24m		



Date:	2022-08-29,	Time: 11:20 UTC	
Mount:	Orion Atlas EQ-G,	Lens: TS71SDQ	
Filter:	Kenko Astro LPR Type II,	Camera: Nikon D5300a	
Image:	5800 x 3263 px, scale: 1.8"/px, FOV: 2.89 x 1.63°		
Exposure:	60 x 120 sec, ISO1600, integration: 2h 00m		



Date:	2022-12-27,	Time: 12:30 UTC
Mount:	Orion Atlas EQ-G,	Lens: TS71SDQ
Filter:	Kenko Astro LPR Type II,	Camera: Nikon D5300a
Image:	5800 x 3263 px, scale: 1.8"/px, FOV: 2.89 x 1.63°	
Exposure:	85 x 120 sec, ISO1600, integration: 2h 50m	

Date:	2021-10-31,	Time: 17:50 UTC
Mount:	Orion Atlas EQ-G,	Lens: TS71SDQ
Filter:	Kenko Starry Night,	Camera: Nikon D5500
Image:	5600 x 3150 px, scale: 1.8"/px, FOV: 2.80 x 1.57°	
Exposure:	35 x 180 sec, ISO1600, integration: 1h 45m	

Date:	2022-12-19,	Time: 13:18 UTC
Mount:	Orion Atlas EQ-G,	Lens: TS71SDQ
Filter:	Kenko Astro LPR Type II,	Camera: Nikon D5300a
Image:	5650 x 3178 px, scale: 1.8"/px, FOV: 2.82 x 1.59°	
Exposure:	72 x 120 sec, ISO1600, integration: 2h 23m	

Date:	2021-10-27,	Time: 15:30 UTC
Mount:	Orion Atlas EQ-G,	Lens: TS71SDQ
Filter:	Kenko Starry Night,	Camera: Nikon D5500
Image:	5800 x 3263 px, scale: 1.8"/px, FOV: 2.89 x 1.63°	
Exposure:	65 x 120 sec, ISO800, integration: 2h 09m	

Date: 2021-10-31, Time: 12:30 UTC
Mount: Orion Atlas EQ-G, Lens: TS71SDQ
Filter: Kenko Starry Night, Camera: Nikon D5300
Image: 5600 x 3150 px, scale: 1.8"/px, FOV: 2.8 x 1.57°
Exposure: 55 x 180 sec, ISO1600, integration: 2h 45m

Date: 2021-02-07, Time: 15:30 UTC
Mount: Orion Atlas EQ-G, Lens: TS71SDQ
Filter: Kenko Starry Night, Camera: Nikon D5500
Image: 5400 x 3038 px, scale: 1.8"/px, FOV: 2.7 x 1.52°
Exposure: 38 x 180 sec, ISO800, integration: 1h 53m

Imaging Application

For Android 8+

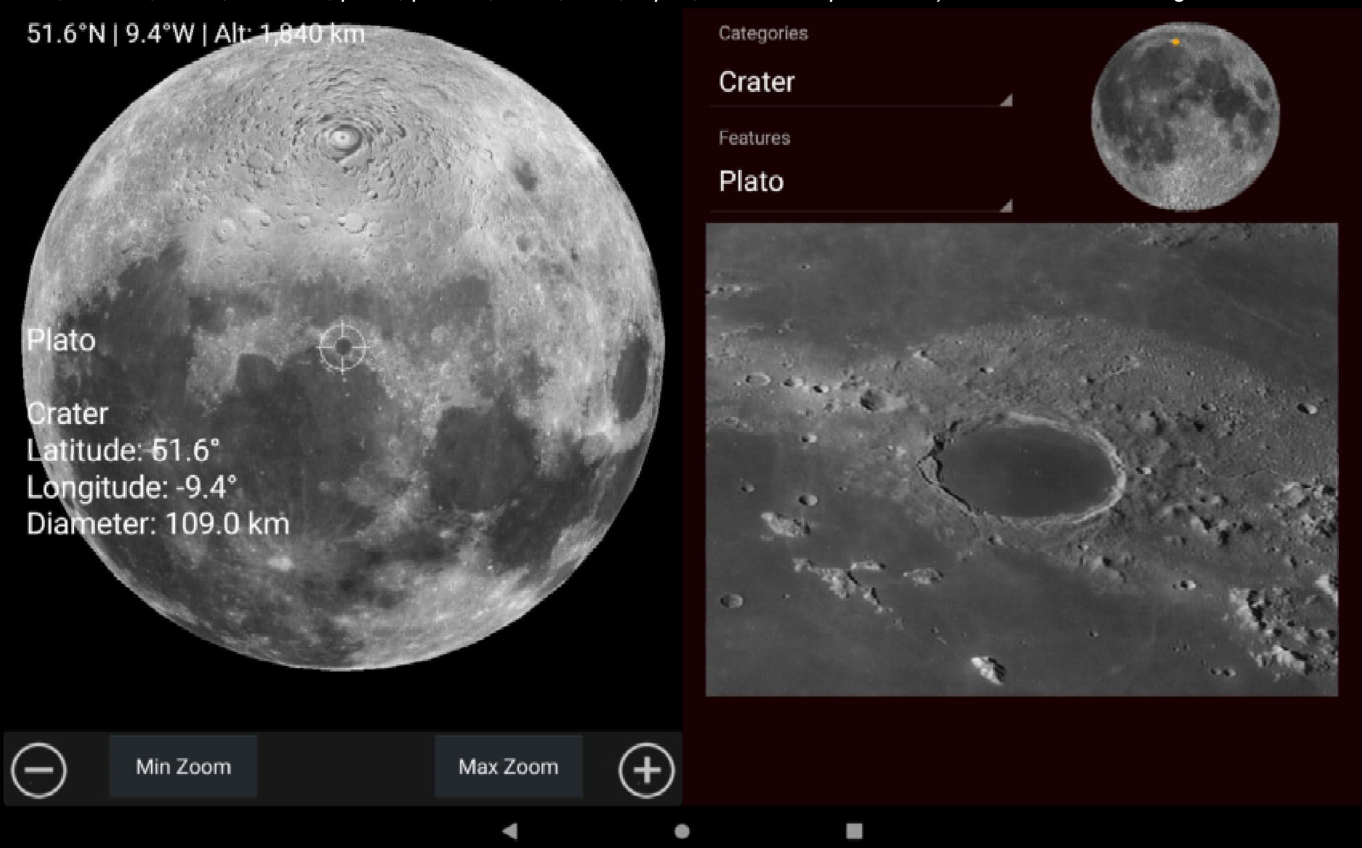
Compatible with Android 8 and higher smartphones and tablets **Lunar Imaging** is a companion for visual Moon observers and imagers alike. It provides abundant lunar information for current and selectable dates, including positional, physical and ephemeris as well as libration data. The phase of the moon is represented by a 3D globe in 8K resolution which can be swiped to change dates by one day back or forth. Its orientation can be toggled between upright and diurnal angles, while the phase shadow can be toggled on and off.

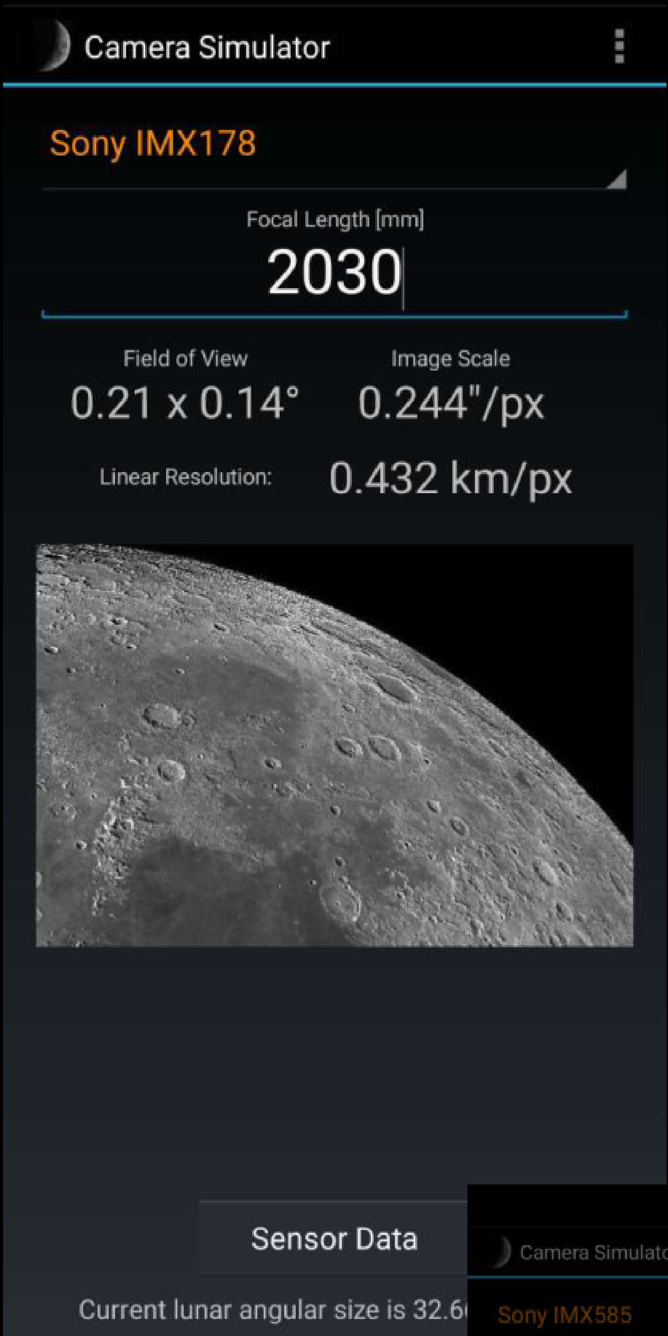
Further menu items include a **Lunar Calendar** and **Lunar Atlas**. The **Camera Simulator** is for imagers, the **Scope Simulator** for visual observers while its **Polar Finder** should please both. **Annual Libration** data is provided in form of a table. An **Observatory Clock** is a time keeper for your observatory. **More information** is made available via online links.

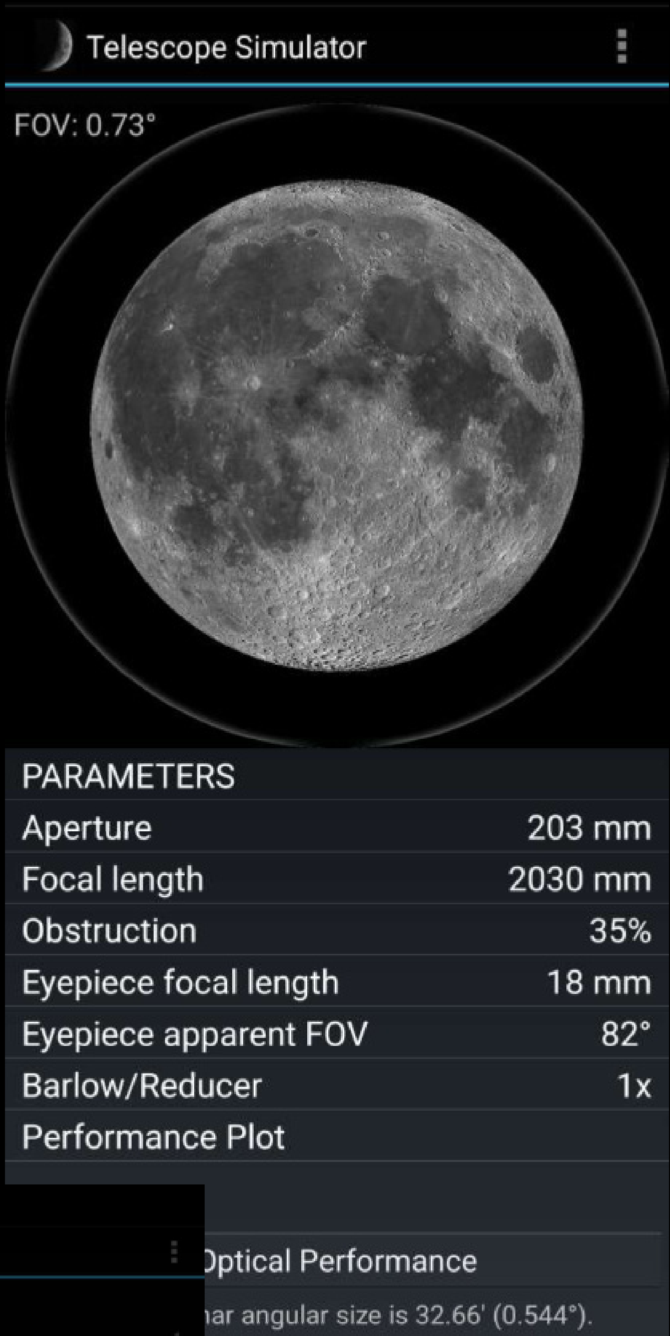
▲ *Lunar information at a glance.*

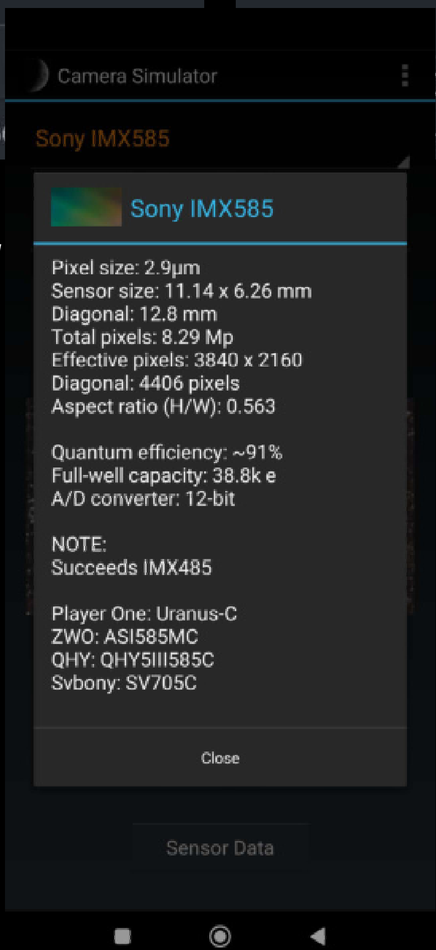
▲ *A few gorgeous gauges for the Moon.*

▼ *The Lunar Atlas contains a rotatable lunar globe and a database of over 550 major lunar features (craters, dorsa, lacus, mare, montes, mons, oceanus, palus, planitia, sinus, rima, rupes, vallis and Apollo sites) half of them with image thumbnails.*









▲ *The simulator does does not take into account atmospheric seeing. Ideally, the image scale should be a third of the seeing but is often unrealistic.*

The **Camera Simulator** helps choose a suitable camera for a given focal length and vice-versa. Pick an image sensor from a dropdown and enter the effectve focal length of your optical system to compute the resulting field of view, FOV, image scale and, for the moon only, the linear resolution. The apparent size of the moon changes with its distance to the Earth and is calculated for real-time for best accuracy. The simulator also has a few deepsky images against which to check the FOV. The data of a selected sensor is also available.

▲ *The aperture of a reflecting telescope is obstructed by its secondary mirror which is accounted for in Optical Performance data.*

The **Telescope Simulator** is for visual observers. Against provision of aperture and focal length as well as focal length and apparent field of view, AFOV, of the eyepiece (ocular) the simulator will provide the true field of view, TFOV, value and the simulated view through the speci-fied eyepiece. Sine the apparent size of the moon changes with its distance to the Earth it is calculated for real-time for best accuracy. The TFOV can also be checked against an image of the southern region of Orion. The overall optical perfor-mance data is also available.

After reading this brochure you may feel that the learning curve is flatter than previously assumed.

Should you think you could loose interest after all, then do not spend too much money on gear. On the other hand, cheap stuff will produce unsatisfatory results ending up in surrender while nobody will buy it second-hand. It is a dance on a rope. Challenge this hobby when you are confident.

Find an astronomy club and join its star parties for a 'test drive' with various telescope types in short time. Do not hesitate to ask questions. The owners will gladly provide you with "first aid", helpful information and a good piece of advice.

More from the author

Right: Almost all about shooting the moon on over 80 richly illustrated pages including numerous images by the author. In PDF format.

Lunar Libration Calendar

Top: An annual table of lunar data with lunar images by the author. It helps track the best dates for moon shooting. PDF 25 pages.

Lunar Imaging

Download site **https://www.astropical.space/**

Excerpt from Lunar Imaging

Celestron C8 XLT

You may wish to look for similarly sized Schmidt-Cassegrain telescopes from Meade, or Maktsutov Cassegrain telescopes from Sky-Watcher and others.

This Schmidt-Cassegrain telescope, SCT, is a real workhorse and an excellent compromise in terms of size, weight and cost. It sports a primary mirror 8 inches across and comes with a convenient grab handle at the back. The primary mirror is f2.0 fast. The secondary mirror magnifies 5x, resulting in a f10 scope with a short tube.

The secondary mirror obstructs the primary by 64mm or 31% in diameter. The overall obstruction is 35% or 10% by area. The tube weighs only 5.7kg and sits comfortably on a medium sized equatorial mount, such as the iOptron CEM28, Orion Sirius, Sky-Watcher EQ5, or similar.

Thanks to its short tube the setup is sturdy and less prone to wind shake. It is a closed optical design in that it can take some time to thermal equilibrium, say an hour before action. In turn, the primary mirror is protected against contamination, while the corrector plate can be easily removed and cleaned. In humid nights the corrector plate will dew up quickly, in that a heater tape is indispensable (or a small hair dryer).

The aluminum optical tube offers 2032mm of focal length and a focal ratio of f/10, which is ideal for lunar and planetary imaging tasks at native focal length with popular CMOS cameras. Of course, the use of reducers to reduce or barlows to extend focal length is possible, but within limitations, such as given by seeing, pixel (image) scale and resolution. As a rule of thumb, going beyond a focal ratio of 5 x camera pixel size will not yield any further resolution. An IMX290 sensor based camera has a pixel size of 2.9µm. Multiplied by 5 = about f/15, in other words, a 1.5x barlow for the C8 would be optimal for close-up imaging but not really more because the theoretical resolution limit of the C8 mirror is 0.56 seconds of arc.

In spite of many improvements over the classic C8, the visual back is still the 1.25" sized with two screws to hold accessories, such as cameras and star diagonals. A modern, sturdy upgrade is the "Baader Clicklock" which accepts 1.25- or 2-inch accessories that can be fastened with a single, well, "rotation clicklock". It should be a standard feature.

An SCT focuses by moving the primary mirror. Since the motion changes the distance of the primary to the secondary mirror, the focal length, too, changes. The closer the mirrors, the longer is the resulting focal length. The nominal back focus is about 127mm from the rear surface of the baffle nut (the focal length of 2032mm is specified for this point). Since the focus travel is very long, extension tubes can be used to manipulate the focal length to a notable extend.

Owing to mirror curvature, a SCT is prone to off-axis aberration that makes stars away from the center look like little comets. Sensors of planetary cameras are usually too small to get into the outward area where aberration occurs, yet adjustment of the optical axis is crucial.

Celestron's standard 0.63x reducer/flattener replaces the visual back for deep sky imaging. Also, a shelf 1.25" reducer, typically 0.5x, can be threaded to a CMOS planetary camera if a wider field at less resolution is wanted.

A rough collimation is made easy with three Philips-head screws on the secondary mirror until a, say, defocused 2nd magnitude star is concentric with identical diffraction patterns on either side of focus. Replacing the three collimation screws, "Bob's Knobs" are thumb screws making collimation even easier without need for a tool.

A truly useful focusing assistant is a dual-speed 10:1 Crayford focuser with 25mm focus travel which threads to the visual back of an SCT. It accepts 1.25" and 2" imaging gear including a Ø48mm filter thread. It provides way finer focusing and is an alternative to the standard visual back or the above introduced "Baader Clicklock" mechansim.

Celestron calls its coating technology 'StarBright XLT', multi-layer mirror coatings and multiple layers of magnesium and hafnium fluoride on the corrector plate. Celestron specifies an overall transmission of 85.3% for their XLT design.

16 Lunar Imaging

About the author

Born in July 1955, the author is a German national living in Japan since late 1996. Formerly a marketing communications manager for a Tokyo-based semiconductor company, he moved to Okinawa as a freelance web developer, now retired and stranded on the island with two wonderful dogs. A life long interested in astronomy, he started with astrophotography in late 2018 initially with a Vixen A80Mf and a DSLR on an old but working Orion Atlas EQ-G mount. His current workhorse is a Celestron C8 XLT telescope. He began with lunar and planetary imaging because persistent cloudy weather does not permit serious deepsky work.

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