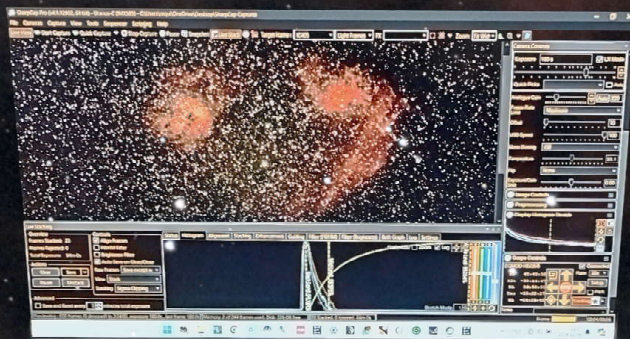


Deepsky for Starters

from a starter...

Electronically **A**ssisted **A**stronomy (Live Viewing)

A lousy weather publication.



Preliminary
Version 1.45, April 22, 2025

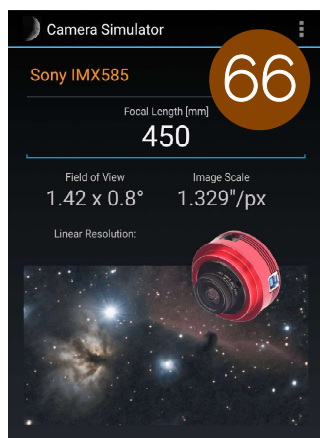


"Rosette Nebula", Caldwell 49 or NGC 2244 in Monoceros.

2022-12-27 12:30 UTC, TS-71SDQ, Kenko LPR II filter, Nikon D5300a (modified), ISO1600, 85 x 120s, no calibration.

Contents

Thanks to advanced capture software EAA/Live Viewing is largely accomplished by replacing the eyepiece with a dedicated CMOS camera connected via USB to a computer running capture software which also controls a mount via a driver interface. Of course, there is a bit more to consider. The essential issues are discussed hereafter.



Foreword	4
Basics	6
Imaging Gear	8
Telescopes	8
Field Power	9
Mounts	10
Camera	11
Telescope	10
Camera Properties	14
Matching	14
Exposure	16
Filters	17
Light Pollution	18
Multi-Band	19
Dual Band, H α	20
Electronic Finder	20
More to Consider	22
Plate Solving	22
FWHM & Image Scale	23
Dark Frames	24
Flat Frames	25
Object Framing	26
Documentation	28
Capture Software	30
Smartscopes	62
Sony Sensors	64



Actual Results

Eagle Nebula	32
Great Orion Nebula	34
Open Cluster M41	35
Lagoon Nebula	36
Dumbbell Nebula	37
Trifid Nebula	38
Western Veil Nebula	39
Messier 78	40
Omega Nebula	41
Pleiades	42
Crab Nebula	43
Wizard Nebula	44
Pacman Nebula	45
Triangulum Galaxy	46
Thor's Helmet	48
Silver Sliver Galaxy	49
Images with 135mm lens	50
Monkey Head Nebula	58
Horsehead Nebula	60
California Nebula	61

Imaging App

† The author's free "Lunar Imaging" App for Android includes camera and telescope simulators, and much more.

This brochure is work in progress and uploaded for feedback, exchange of ideas and experiences. The author is not affiliated with any manufacturer mentioned in this brochure. No liability assumed whatsoever for product specifications. Photos are credited to best knowledge, otherwise own work. Please appreciate that this brochure cannot substitute manuals of the hardware and software referenced to herein.

This booklet is made with a 25-years old version of "Adobe Pagemaker", in other words, not really modern and fancy.

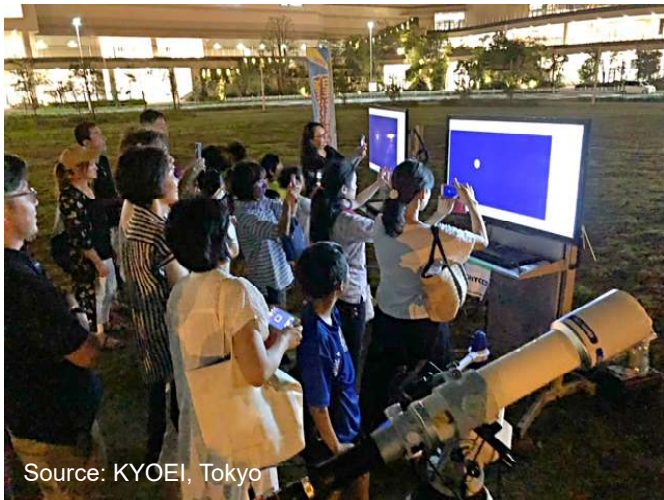
Foreword

Astrophotography is all about compromising.

Astrophotography is an exciting hobby where frustration meets enjoyment. Often "try and error" contribute a lot to learning and experience gathering.

Some people are more inclined to visual observation through the eyepiece, others prefer imaging. EAA is somehow in between. You view a celestial object on a monitor screen which can be shown to an audience while you can save the image as-seen as well as for further processing.

The term "Electronically Assisted Astronomy, EAA", is still disputed but this does not change anything in terms of its typical viewing environment. It is the WYSIWYG in astronomy!



Source: KYOEI, Tokyo

Most objects are invisible through eyepieces under urban or suburban skies. Modern CMOS cameras boost high sensitivity and can thread filters which cut typical wavelengths of unwanted artificial light. So equipped, EAA qualifies for "observing" under unfavorable conditions or moonshine, absence of clouds provided. A view through an eyepiece is basically faint while a color camera will send an image to the screen within a minute. In public outreaches with visual observations, guests will have to line up in front of telescopes and when it is their turn they won't have the patience or time to learn how to view through an eyepiece. EAA eliminates these drawbacks while guests with impaired visual acuity, too, can benefit. Of course, you need to prepare power, fire up a computer and to set up a large monitor for a large audience.

The wider a telescope's aperture the more light it gathers. Always true, but in EAA small telescopes can perform similarly because the highly sensitive camera to some extent will act in place of aperture relieving need for bulky and heavy telescopes. Being less demanding than serious astrophotography, the aim of EAA is to present beautifully looking images, in that a small portable refractor between 50 and 80mm aperture or a 'fast' photo lens will do a great job.

A setup must also include an motorized tracking mount. The lighter the telescope the more affordable and smaller a mount can suffice for the purpose. Most mobile mounts can shoulder payloads up to 5kg, but less will contribute to higher tracking accuracy. High-end "trackers" can be autoguided. Autoguiding is accomplished with a small guide telescope and a small CMOS camera (which cannot be used as imager at the same time).

Most CMOS camera sensors are smaller than APS-C in that a telescope with short focal length will help create a wider field of view which is desirable for most nebulae and other extended objects. Focal reducers provide a wider field and faster focal ratio, but they need to be of superior optical quality if edge distortions (comet-shaped stars) cannot be tolerated.

EAA involves the stacking of single images collected by the optical train, which largely consists of a telescope or photo lens and a dedicated CMOS camera, plus an adapter for mating telescope and camera, possibly also an extension tube to get into focus. Then, via USB, the camera is connected to a controlling computer, such as a laptop, running software which does not only perform capturing and live-stacking but also histogram manipulations plus generation of calibration data. Such a package is the popular SharpCap4 (Pro) which this brochure centers on.

An electric focuser can be extremely useful, but a simple inexpensive "Bahtinov Mask" fitted over the front objective can equally well assist focusing and refocusing if need be.

Essential E

Motorized mount
Telescope o
Dedicated (color
UV/IR c
Camera o
Laptop c
Capture Software,

For large viewing gro

For auto

Small gui
Monochrome
Software for gu



▲ This is 16-years old "Ken", the author's shadow, best friend, son and guardian.

Slow $f/10$ and above telescopes are not really suited for EAA. The best bets for deepsky objects are from $f/4$ to $f/7$ or a fast $f/2$ to $f/4$ photo lens.



▲ Pacific coast in Okinawa in January 2023 on a rare sunny day.

The most commonly used filter type is a light pollution rejection (LPR) filter to minimize the effect of artificial light pollution, such as street lights but also moonlight. Since CMOS cameras are sensitive also in infrared the filter should also block infrared wavelengths to help obtain sharper images.

Often underestimated is the usefulness of a sky atlas or planetarium software. Plate solving (discussed later) helps center an object spot on.

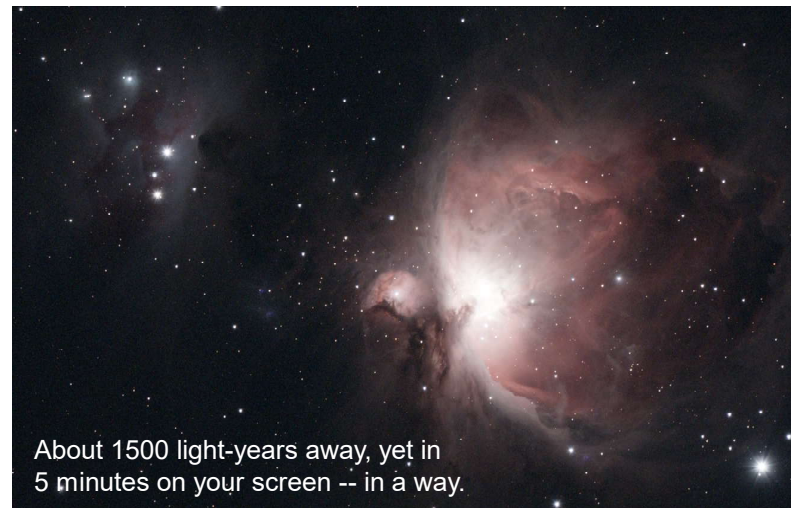
In order to get an image on the screen in shortest possible time the telescope or lens should be 'fast', meaning a low f -number allowing short exposure times, say under 60 seconds at noise-minimized gain. When entertaining an audience, fast appearance of the first light frame of an object will wet more appetite

and interest for more. As live stacking continues, noise will be reduced, more details unveiled and contrast increased. The show is successful when nobody draws a smartphone during ongoing stacking.

Budget and mobility permitting, EAA can also be performed with large telescopes, such as Newtonians with a fast focal ratio of, say, $f/5$, or Schmidt-Cassegrains. The latter have a focal ratio of $f/10$, therefore requiring an optimized focal reducer or a special provision allowing a CMOS camera to be attached directly in place of the secondary mirror. Maktsutov-Cassegrains are not suitable for their slow speed of $f/15$ and slower. Large telescopes are heavy and require a sturdy, mount burdening budget. This brochure concentrates on discussions around small refracting telescopes and photo lenses.

EAA can be highly encouraging. It is such a thrill to see the excitement and joy of children looking at colorful objects surfacing from the depth of space though thousands of light-years away. EAA allows observers to see color and detail that would not register to the eye through an eyepiece. A "live feed" can as well be shared via the internet using live broadcasting website services.

Basically, EAA is possible with a DSLR, however, because of its large sensor a DSLR may be an overkill and also slow down image acquisition. Besides, the popular SharpCap 4 (Pro) capture software is not currently compatible with DSLRs. This might not be necessary anyway.



About 1500 light-years away, yet in 5 minutes on your screen -- in a way.

EAA without a (laptop) computer can be done with a tablet and a WiFi-enabled device with built-in control and stacking software such as the ZWO ASiAir-Plus capable of steering ZWO imaging and autoguide cameras, a mount, focusers, plate solving and more. In any case some sort of monitor, a WiFi-enabled tablet or a smartphone, is essential.

Equipment

t & power supply
r photo lens
r) CMOS camera
ut filter
connector
omputer
ex. SharpCap4 Pro

roups a large monitor

Guiding:

de scope
guide camera
iding, ex. PHD2

Basics

In very simplified terms, Electronically Assisted Astronomy, EAA, replaces the eyepiece with a dedicated CMOS (planetary or deepsky) camera.



EAA is not exactly a new way of imaging. Many years ago, an eyepiece was replaced by a webcam (the legendary *Philips ToUcam* or *Logitech C310HD*, etc). EAA is made easy thanks to recent capture software capable of stacking and basic processing in real time while CMOS cameras advanced rapidly in terms of sensitivity and noise oppression.

Basically, a dedicated astro CMOS camera is connected via USB-3.x to a computer running capture software. The software sets exposure time, gain and other properties and then records a video (for lunar and planetary work) or saves image files (for deepsky objects). When employing for EAA, the capture software stacks light frames in real time and displays the gradually emerging celestial object. When stacking is finished the result is saved as a single file which can then be further processed to taste or as need be. Individual image files can be saved separately for further processing.

Dedicated cameras are housing small image sensors all the way up to full-frame 36mm wide sensors. The Sony IMX585 sensor measures 11.2 x 6.3mm (12.85mm diagonal) with 3840 x 2160 pixels, a fine affordable sensor for entering EAA. Though specified a "planetary" camera, an IMX585 based model is great for EAA as well.

▼ All simulated FOVs with 135mm lens and IMX585 sensor.



FOV with the Rosette Nebula



FOV with the California Nebula

For example, mated with a 135mm primary lens the obtained field of view with an IMX585 is 4.72° x 2.66°, which is just fine for bright popular objects such as the Andromeda Galaxy, Orion Nebula, Rosette Nebula, Pleiades, etc. In this combination each 2.9µm camera pixel subtends 4.43" of sky.

Longer lenses or refractors result into narrower fields which are desirable for, say, star clusters and large galaxies.

The approximate magnification can be obtained by focal length / sensor diagonal. For a 135mm lens and an IMX585-based camera: $135\text{mm} / 12.85\text{mm} = \sim 11\times$.



▲ ZWO ASI585MC



▲ Lens adapter

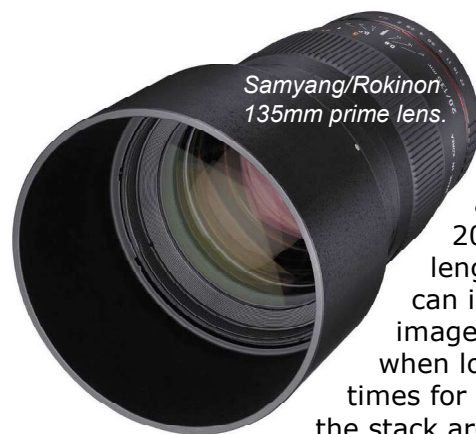


Photo credit Samyang.

Accurate tracking provided, autoguiding is not essential for EAA with an under 200mm focal length lens, but it can improve the image, especially when longer exposure times for each image of the stack are involved.



FOV with the Andromeda Galaxy



FOV with the Orion Nebula

Exposure

Since the Samyang 135mm is a fast f/2 lens short exposure times around a minute will often suffice. Also, a CMOS camera can be operated in binning mode which combines four or more pixels to a single pixel. The advantage is more light being collected relative to noise resulting in shorter exposure times but trading against smaller images and less resolution. Binning is often used for focusing a faint object before the real time show begins. The IMX585 sensor has 2.9µm pixels which is a good choice for a lot of lenses and small telescopes with short focal length.

Efficiency

Quantum efficiency, QE, is the capability of an image sensor to convert incident photons to electrons. QE varies by wavelength and is typically specified in percent relative to maximum. The IMX585 has a favorably high QE of 91% at 600nm (red) visible light.

Filters

Unlike the human eye image sensors are also sensitive to near-infrared. Since certain lenses and telescopes do not focus visible and infrared light in the same focal plane, an infrared cut filter is required for color images while an IR-pass filter blocks visual and passes infrared only.

Color or Monochrome

Obviously, a one-shot-color camera, OSC, is most practical for EAA imaging. Monochrome cameras can be excluded as an object would need to be captured at least three times, namely through three color filters to be combined to a color image. OSCs, which have a color filter (Bayer) mask obstructing the sensor are less sensitive, need longer exposure, are more prone to noise and have a lower resolving power than their monochrome versions, but save the hardware expense for filtering, both in terms of time and budget. Monochrome cameras are more expensive than color cameras simply because manufacturers produce more color sensors. In spite of their weak points a color sensor is the preferred choice for the goals of EAA. Of course, EAA can be done with a monochrome camera but an audience attending an outreach would most likely be stunned by color images.

Full Well or Well Depth

When a bucket is filled up with water it will overflow, so does a sensor pixel when it can hold no further photons. Then signal can spill over to adjacent pixels causing blooming on bright stars. A high "well capacity" achieves a better signal to noise ratio, hence a wider dynamic range. In spite of its small pixel size, the IMX585 sensor has a high well capacity of 47,000e (electrons),

an impressive improvement three times over its predecessor with the same pixel size though out of reach in practical applications.

Noise

Every signal is escorted by noise in that it is desirable to keep noise at a lowest possible level also considering that astrophotography involves collection of low signals from faint objects. Noise in images shows up like graininess in particular over regions of low signal. Noise can be reduced by collecting more light and camera cooling.

Choose a camera with low readout noise which is important for EAA when reading out images with short exposure times between, say, 5 and 30 seconds. The noise characteristics of the IMX585 are excellent for EAA.

Powered Camera Cooling

Basically not required for EAA. Cooled cameras are for serious deepsky work. Planetary cameras are not cooled by default and there are no optional kits for efficient active cooling.



▲ Simple EAA setup comprising a lens, an adapter and a CMOS camera. An autoguider can be added to the top if need be. A computer is required for camera control (and auto-guiding). Of course, this setup can also be used for imaging by saving exposures to files for stacking and further processing in other applications.



The WiFi-enabled **ASiAir Pro** from the ZWO company controls a mount, camera, autoguider and more wirelessly. It also performs live-stacking for EAA. Warmly recommended for cold nights.

Photo credit: ZWO

Imaging Gear

Telescopes



▲ The TS-Optics 71SDQ manufactured by Sharpstar is a fine Ø71mm/450mm quadruplet apochromatic astrograph. Photo credit Sharpstar/Teleskop Service.

Basically any type of telescope (or photo lens) is suitable for Live Stacking, however, for best experience the optics should be “fast”, i.e. have a low f-number/focal ratio in order to obtain fine images with short exposure times at low camera gain which will bring an object onto the monitor quickly and with least noise.

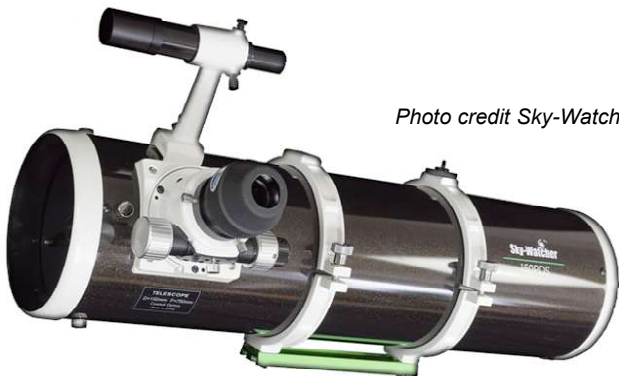


Photo credit Sky-Watcher.

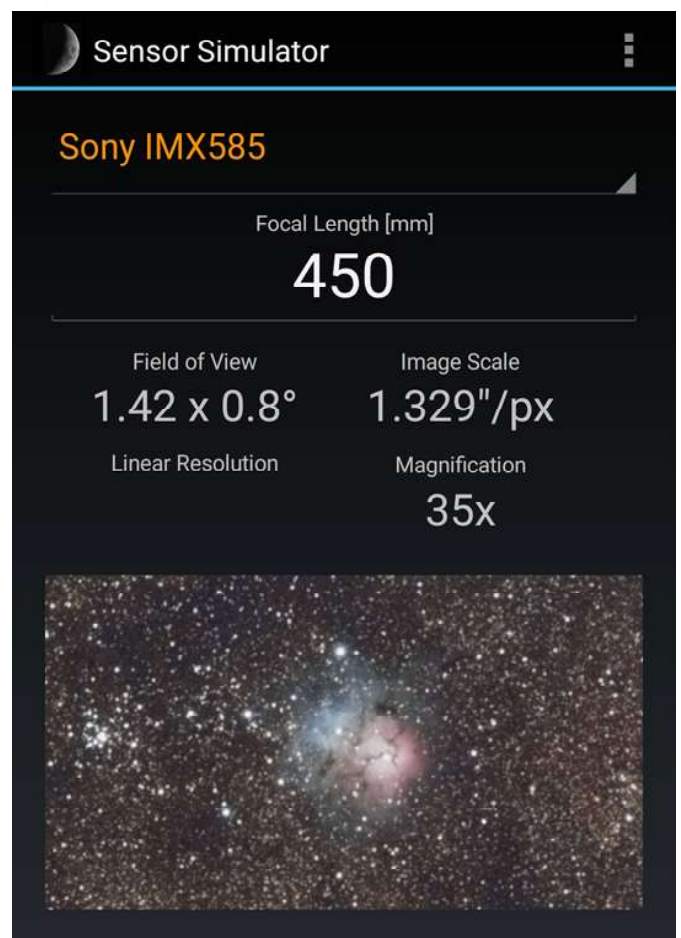
▲ The fine 6” Sky-Watcher Newtonian reflector operates at a fast focal ratio of f/4 or f/5, but the tube assembly weighs over 6kg.

While Newtonian reflecting telescopes are “fast” they are also very heavy demanding a sturdy mount. The best choice is a “fast” refractor telescope or a photo lens.

For example, a quadruplet apochromatic refractor, such as the TS-71SDQ (aperture Ø71mm, focal length 450mm, ratio f/6.3), includes a correction lens which compensates for optical imperfection without the hassle of back focus adjustment which often needs to be exact to a fraction of a millimeter. This eliminates need for an optional flattener/reducer as required for doublets and triplets. Since the flange back of a CMOS camera is typically 12.5 or 17.5mm an extension tube about 80mm long is required to bring an IMX585-based camera into the focus of the TS-71SDQ with short outward focuser travel which will contribute to mechanical stability thus keeping the optical axis straight without tilt.

The field of view is good for most of the popular deepsky objects. The image scale, too, is a fine match for most situations.

With a common 0.5x reducer the focal ratio can be halved to $\sim f/3.2$ while the area of the field of view grows four times. Shorter exposure time and less gain are further benefits. However, budget reducers often introduce unwanted edge aberration and color fringes. Also, for optimal field flattening a reducer typically requires a specific back focus (55mm distance to the sensor plane) which can end up in a hassle with extension tubes and tilt. Also, “the less glass the better”.



▲ A simulated field of view as seen by the IMX585 sensor through a 450mm telescope or lens (Trifid Nebula or Messier 20 in Sagittarius).

The field of view of this combination is almost three lunar disks wide, well framing most nebulae. One sensor pixel subtends 1.33” of sky (image scale) which is a best match for average seeing conditions. The approximate magnification is $450\text{mm}/12.85\text{mm} = \sim 35\times$.*

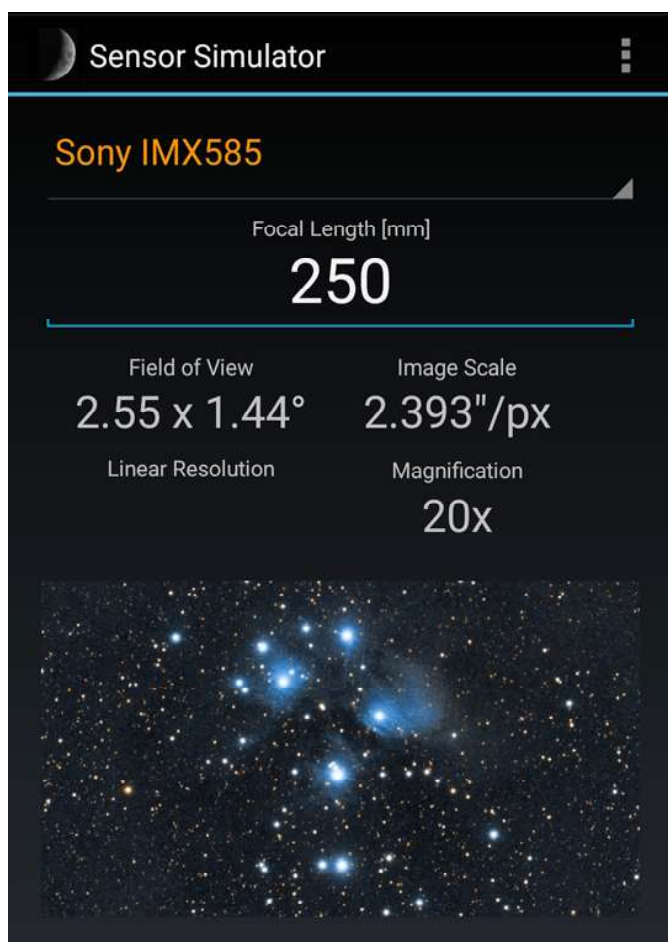
Note that filters are “slowing down” the telescope as no filter transmits 100% light. A light pollution filter, LPR, for instance can turn a native f/6.3 telescope into a f/7 telescope.

* The diagonal size of the IMX585 sensor is 12.85mm.



Photo credit Williams Optics.

Another example for a portable rig is a small 1.8kg "RedCat" from Williams Optics, a fully corrected Petzval design with Ø51mm aperture and 250mm focal length (focal ratio 4.9).



The field of view of a RedCat-IMX585 combination is almost five lunar disks wide, framing most nebulae in a pleasant wide field of space. One sensor pixel subtends 2.4" of sky (image scale) which is a good match for average seeing conditions, including urban. The approximate magnification is $250\text{mm}/12.8\text{ mm} = \sim 20\times$.

A RedCat comes with the bonus of a Bahtinov mask for precise focusing and is threaded for 48mm filters. An extension is required for bringing an IMX585-based camera into focus.

Actually, both refractors are optically too good for merely Live Stacking. Fortunately, the capture software SharpCap4 (Pro) can live stack and save individual 'raw' light frames simultaneously. The so saved image files can be stacked and calibrated in post-processing software such as Siril or Deepsky Stacker. So treated images are of way better quality than live stacks as live stacking algorithms are basically designed for live viewing only.

The major advantage of the TS-71SDQ refractor is its aperture and dual speed focuser.

The advantage of the RedCat is low weight and fast focal ratio. Meanwhile the number of small Petzval refractors is growing in the market.

Both designs eliminate need for adjusting back spacing for a given camera sensor. Once in focus all is well matched and flattened.

Field Power

When imaging on your balcony or in your backyard you would simply roll out an AC extension cord for powering the mount and a computer. An electronically controlled and safe power bank comes in handy in the field. Do not drain the battery of your car.



There are hundreds of power banks in the market in that none of them can be recommended without field-testing. The basic selection criteria are:

1. Should provide power for two nights out
2. Powered by a long-life lithium-ion battery
3. Reliability of electronic components
4. Operating temperature
5. Number of AC, DC and USB outputs
6. Specified charging cycles (life time)
7. Input for solar panel charging
8. Full compliance with safety regulations

In most cases the laptop controlling the rig drains most of the power. A heavy telescope mount drains up to 5A at 12VDC when slewing but less than 1A while tracking.

Portable mounts are often battery powered or have an 12VDC input. Uncooled CMOS cameras are USB powered. The more power and outputs a station provides, the pricier it is. Carefully calculate your power requirement and leave sufficient head margin plus room for future gear.

For an EAA setup a power bank of 256 to 512Wh should suffice, even better, two banks 256Wh each, in case one fails.

Mounts

Alongside steady air and transparent seeing a sturdy and accurately tracking and guiding mount is a guarantor for great EAA images. Here is an example:

One of the latest and most sophisticated portable mounts is Sky-Watcher's WiFi-enabled "Star Adventurer GTi" computerized GoTo equatorial mount.

Doing much more than just a star tracker it is controlled by Sky-Watcher's 'SynScanPro' app for smart-phones or tablets. Compared with previous models, the GTi comes with a sturdier EQ wedge and can be autoguided (with an optional 6-pin RJ12 ST4 cable) in both, right ascension and declination significantly contributing to guiding accuracy and round stars with short focal length optics.

The mount is specified to shoulder up to 5kg payload which is sufficient for DSLRs with (tele)lenses as well as for small aperture refractors. For best tracking accuracy the full load capacity should not be compromised with. Consider 3.5kg the red line for all "5kg mounts" and balance the counter weight well.

The compact mount head itself weighs only 2.9kg, the included tripod weighs 2.6kg, all in all, highly portable.

Any user-provided tripod with a 3/8" screw can be used for this mount.

Not only can the GTi be controlled wirelessly with an app but also directly by a computer via USB. A RJ45 socket is provided for Sky-Watcher's optional SynScan hand control, requiring an optional 8-pin RJ45 cable.

The GTi tracks with simple servo motors, which are **not as precise as stepper motors** even when autoguided. The specified tracking accuracy is 0.35" in RA and 0.44" in declination (optimistic).

Polar alignment is facilitated with a built-in illuminated polar scope or a controlling computer with software capable of plate solving.

The GTi is ASCOM compatible and connects to a computer via USB or remotely over its WiFi network in that it can be controlled with software such as SGP, NINA, APT, EQMOD, GS Server, etc.



Photo credit: Sky-Watcher

A mount like this is a fine choice for people who are new to the hobby, need a simple portable automated EQ mount with full guiding capability and a flat learning curve.

Thanks to its low weight of 1.8kg, for example, the William Optics Redcat II Petzval Apochromat is ideal for sitting on the GTi. EAA is made easy with its 51mm aperture, 250mm focal length and fast f/4.9 focal ratio when combined with an IMX585-class or a higher resolution CMOS camera. Even smaller is the latest MiniCat51 with 178mm focal length operating at f/3.5! The choice is abundant.

The GTi is great for photo lenses or small refractors with a focal length of up to 400mm mated with a CMOS camera or DSLR. It is not suitable for long-exposure deepsky imaging.

The Star Adventurer GTi is more than a star tracker.

USB-B Control, WiFi, GoTo and Autoguiding in RA and Decl supported.

Sky-Watcher EQ-AL55i PRO shoulders more payload

USB-C Control, WiFi, Bluetooth, GoTo and Autoguiding in RA and Decl supported.

This recently introduced mount is designed for a payload of 10kg max. and is an upgrade of the Star Adventurer GTi, while its head weighs only 800 grams more, namely 3.7kg and, as of April 2025, adds about 120 USD to the price tag which includes the tripod.

Though also not achieving sub Arc autoguiding precision, the gears are a bit more precise than those of the SA GTi. The R.A. worm gear is 73.4mm in diameter with 144 teeth, while the DEC worm gear is 51.6mm in diameter with 100 teeth. The worm drives are 11mm in diameter each. *

Else, apart from being sturdier, both mounts are in principle quite similar in terms of electronic control, ports and overall design.



Photo credit: Sky-Watcher

There are dozens of similar mounts out in the market from various manufacturers. A payload of 10kg (7kg in reality) is future-proof. While the SA GTi is great for camera lenses and small refractors, the EQ-AL55i PRO is the safer choice for larger refractors, yes, even for Newtonians up to 6 inches. It is also a great deal since it bundles a sturdy tripod with Ø1.75" legs. The tripod for the SA GTi is optional.

If you are on the fence with both, the EQ-AL55i is the clear winner in particular when considering upgrading imaging gear.

* For comparison, the gear specs of the SA GTi:

R.A. worm gear 180 teeth, 92.5mm diameter. R.A. wheel gear 15.8mm diameter.

Dec worm gear 144 teeth, 73.6mm diameter. Dec wheel gear 10.8mm diameter.

This mount is fairly new in the market, in that, in spite of its attractive features, it may be a good idea to monitor the situation in, for instance, user forums and wait for an update if this is likely to happen, unless it is merely a firmware update.

Camera

Player One's hexagon shaped **CMOS camera** sports a 1/1.2" sensor with a total of 3840 x 2180 pixels (8.3 megapixels), each 2.9µm square, arrayed on an area of 11.2 x 6.3mm. The camera convinces with 91% relative quantum efficiency (QE) and 47k e full-well capacity, a.k.a. "well depth".

Inherent to the large image size at maximum resolution, the transfer rate is 47fps (frames per second). This requires a fast **control computer** with USB-3.x and an SSD disk, but on the other hand, the camera is equipped with 256 megabyte DDR3 buffer memory which smoothes the data transfer to slower computers. At HD resolution (1920 x 1080 pixels) the frame rate reaches speedy 187fps outperforming cameras with native HD-size sensors.

The employed IMX585 sensor is highly responsive to near-infrared, opening gates to additional applications. The sensor has a dynamic range of 88dB in a single exposure.

The Uranus-C also provides DPS (dead pixel suppression) function and incorporates passive cooling. It is free of "Amp-Glow" even after 300 seconds exposure time. Readout noise is below 1e at gain above 250.

With an optional T2 to C-mount adapter and an ultra-wide lens, the Uranus-C is ideal for all-sky monitoring. Its flange distance is 12.5mm for CS lenses. A 5mm thick, Ø25.4mm extension is required for a C lens (flange distance 7.5mm). The IMX585 sensor may be too large for some wide angle C or CS lenses.

Photo credit Player One.

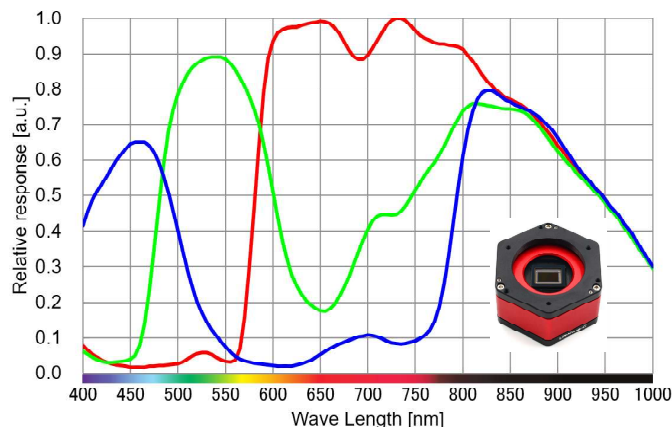


▲ The hexagon-shaped camera body design symbolizes the manufacturer with a high recognition rate. Since February 2025 it is also available in monochrome as Uranus-M which peaks at 650nm, perfect for H-alpha imaging.

▲ The PRO version with active cooling has been released in May 2023. It is the better choice for long exposure times.

Passive Cooling

The camera is equipped with passive cooling which helps keep sensor temperature low though way not as low as active cooling analog to a heat sink glued on a semiconductor chip, such as a CPU. The camera's sensor is contacted with the housing via a thermal conductor pad.



▲ The **relative** infrared response of the IMX585 looks impressive though no absolute curve has been published. Graph source Sony Corporation.

IMX585-powered astro cameras are currently also offered by ZWO, QHY and Svbnony.

In addition, images are cosmetically improved with a Dead Pixel Suppression function, DPS.

Several tests in mid summer revealed that the sensor temperature is 4~5°C above ambient on average, speaking for the welcome efficiency of passive cooling.

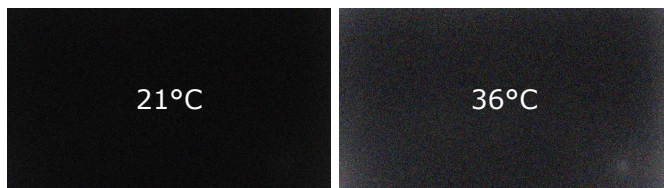
Notwithstanding, the sensor temperature is composed of the influence of ambient and electrical upheating of the sensor chip in that electrically powered active cooling to typically 40°C below ambient can make a tremendous difference in terms of noise and hot pixel suppression.

The images below demonstrate the effect of temperature on noise. Both are 120 seconds exposures at gain 220 (near unity gain).

Eyeing at solar imaging in hot summers, Player One offers an optional air-cool system, ACS, with a magnetic levitation mute fan and a heat sink. A dial controls the speed of the fan.



▲ The external +12VDC powered ACS is designed for planetary and solar cameras to support their native passive cooling. Image courtesy Player One Astronomy.



On a side note, small sensors cool down faster than large sensors.

Characteristics

Of primary interest are the second and fourth plots from the top on the facing page, Readout Noise (RN) and Dynamic Range (DR). RN drops significantly at gain 210 while DR peaks at gain 210 as well ('unity gain'). This indicates that the "starting point" for keeping RN low in 12-bit ADC mode is from gain 210 which also benefits the dynamic range. There is hardly any benefit choosing higher gain, just more saturation issues as dynamic range would decrease with higher gain.

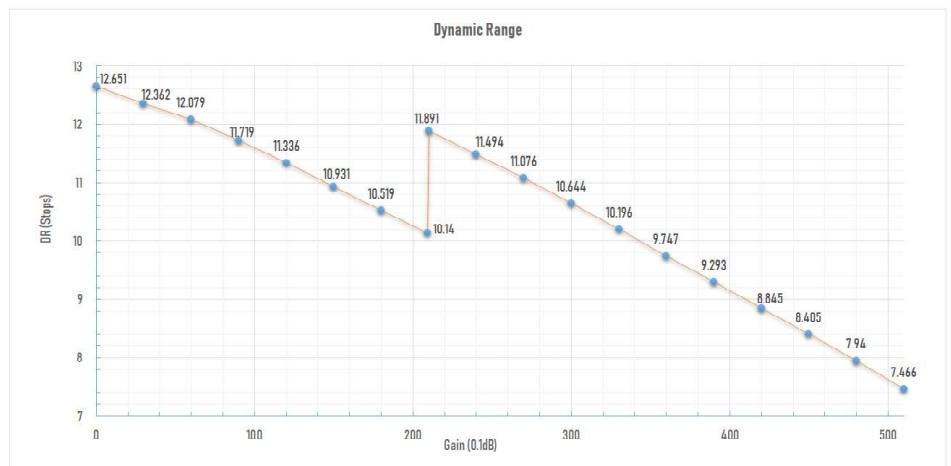
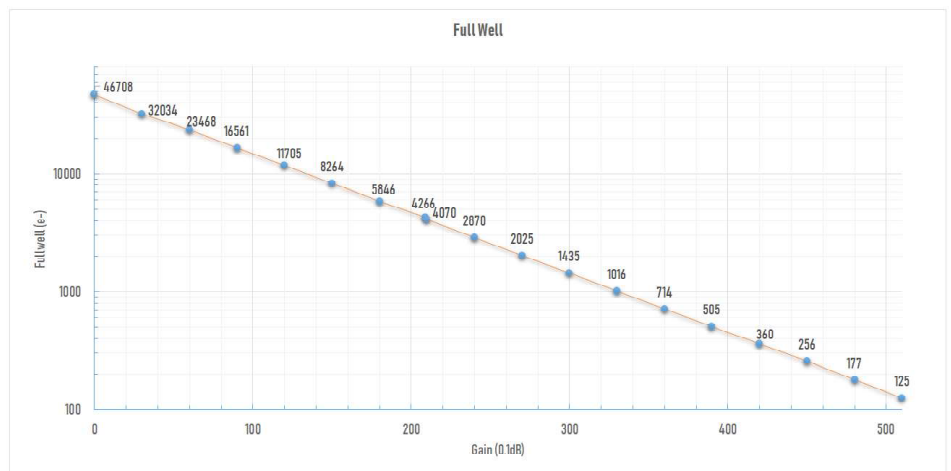
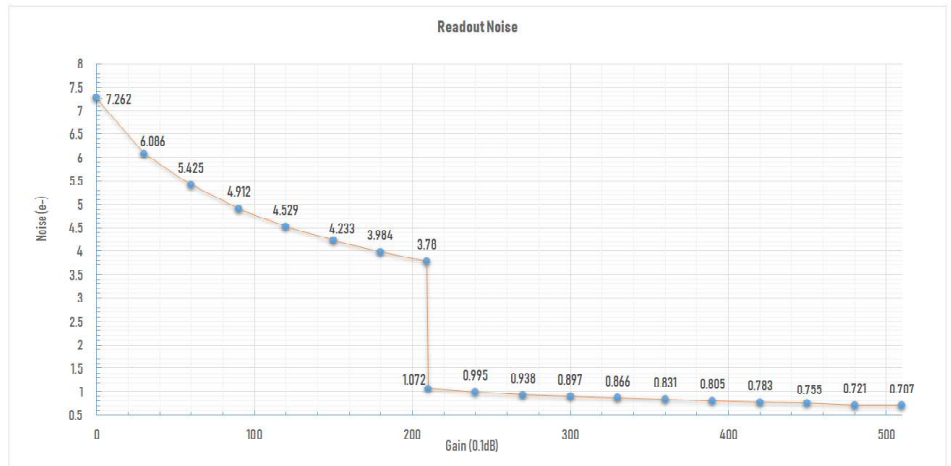
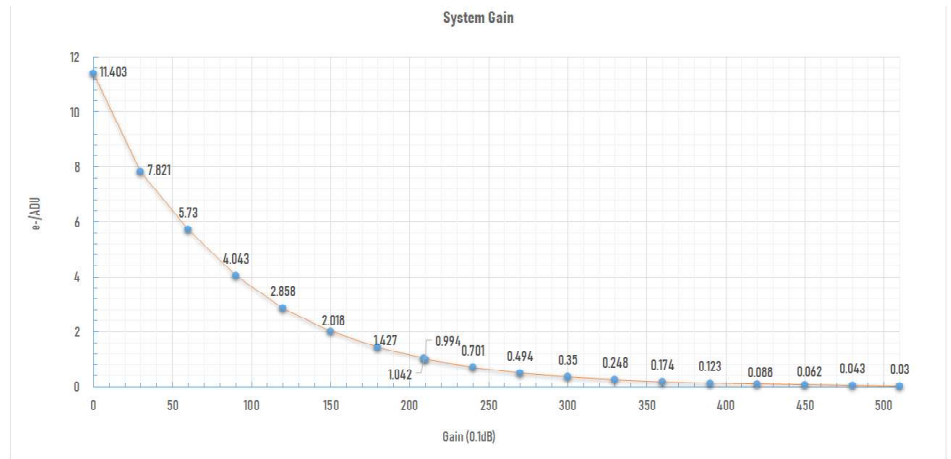
The camera's automatic High Conversion Gain, HCG, function to reduce RN at high gain kicks in at gain 210, too, in that it is a safe choice to set gain to 220 when imaging and adjust exposure time accordingly so as to achieve best exposed light frames. At lower gain the RN starts at 4e- and rises further. This is a real problem for short exposure EAA tasks.

Gain is given in units of 0.1dB in that for instance gain 220 corresponds to 22dB gain.

The maximum full-well capacity won't be reached in practical applications unless readout noise and gain are considered negligible factors.

The analysis result as provided by SharpCap4 Pro is largely in agreement with the graphs on the facing page which is provided by the camera manufacturer. The analysis result attests that a gain near 200 (20dB) is close to the "sweet spot" in terms of dynamic range and readout noise, however, only 10% of the full well is used. S

SharpCap4 Pro test results can differ slightly when repeating tests which is largely related to the uniformity of illumination during the analysis, the more uniform the more accurate the results.



Camera Properties

Matching a Camera

Field of View

The angular part of the sky spanning over the camera sensor. It is a function of image sensor dimension and focal length of the telescope or lens. For extended objects, such as a nebula, a wider field up to 2° (4 lunar diameters) will be needed, while smaller objects, such as galaxies are better framed in a narrow field. The Andromeda galaxy spans over 3°, though.

$$FOV = 2 * \text{Atan}(d[\text{mm}] / 2 * fl[\text{mm}]) * 57.3$$

...where d is the sensor dimension, width, height or diagonal, and fl the effective system focal length. Large objects are best framed with a large sensor and short focal length, vice versa for smaller objects.

Image Scale

The tiny angular fraction of sky which a single pixel covers. Image scale is not that important for EAA but when well matched it can improve image sharpness and detail.

$$ISC = 206.265 * p[\mu\text{m}] / fl[\text{mm}]$$

...where p is the size of a single pixel and fl the effective system focal length. 206265 is the number of arc seconds in a radian. All Sony IMX sensor pixels are square.

Sampling

A sinusoidal signal (star) should be sampled by at least three pixels (in a 3x3 matrix) to make a star, distorted and enlarged by atmospheric seeing, look round. Atmospheric conditions always limit the seeing, say, between 1.5" and 6", which is hard to judge, in that an image scale between 0.5" and 2" is a good approach. If you have a rare good seeing of 2" the best bet is 2"/3 pixels = 0.66" per pixel.

Though merely a rough method, with camera capture or autoguiding software you can focus on a star and measure its FWHM (*Full Width Half Maximum*, see bottom right on facing page) diameter to estimate the seeing condition.

Also, the resolving power of a lens or mirror is limited by its diameter (aperture). For example, the resolving power of a 70mm refractor is 1.6" (Dawes limit), that of a 200mm Schmidt-Cassegrain is 0.57" (minus obstruction from the secondary mirror).

"**Undersampling**" occurs when the image scale is larger, "**oversampling**" when smaller than the smallest feature a telescope can resolve. When too large a star filling only one pixel results into an unwanted block-shaped star without containing any information. When too small, a star will be captured by too many pixels resulting in blurry and soft images. Therefore, undersampling is preferred over oversampling and can even be improved by "drizzling" during the image stacking process. Also, an undersampled image is less prone to guiding errors and image noise on a per-pixel level, but sacrifices detail as the image is softer. Vice-versa applies to oversampling.

Sony IMX585

Focal Length [mm]

450

Field of View

1.42 x 0.8°

Image Scale

1.329"/px

Linear Resolution:



▲ ▼ The author's smartphone app simulates both field of view and image scale for over 75 image sensors in its database.

Sony IMX585

Focal Length [mm]

135

Field of View

4.72 x 2.66°

Image Scale

4.431"/px

Linear Resolution:



▼ ...also for the Moon.

Sony IMX290

Focal Length [mm]

2030

Field of View

0.16 x 0.09°

Image Scale

0.295"/px

Linear Resolution:

0.522 km/px



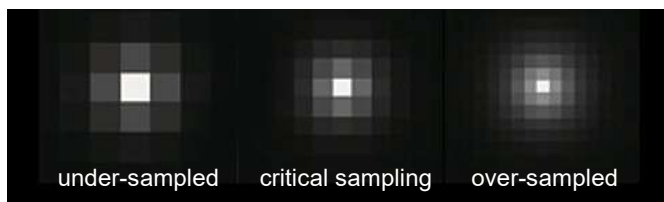
For example, a Ø71mm/450mm refractor with an IMX585-based camera:

field of view = $1.42^\circ \times 0.8^\circ$
image scale = $1.33''/\text{pixel}$

Provided the feature to be resolved is around 4" this combination is just right but demands accurate guiding. At a short focal length of 135mm the image scale is much larger, thus undersampled:

field of view = $4.72^\circ \times 2.66^\circ$
image scale = $4.43''/\text{pixel}$

...in that we need smaller pixels or more focal length. Sensors with the smallest pixels currently available are the IMX178/IMX183 with $2.4\mu\text{m}$ each, the IMX676/IMX678 with $2.0\mu\text{m}$ and IMX715 with $1.45\mu\text{m}$. On a negative note, the smaller the pixels the higher the noise portion and the more dependency on good seeing. Since surfaces such as lunar are linear objects sampling is not that critical but can affect resolution.



The "sweet spot" between undersampling and oversampling is called the "**critical sampling**" which determines the optimal sensor pixel size for a given minimum feature size and focal ratio:

$$Sc = 1.22 * \lambda * fr / n$$

where,

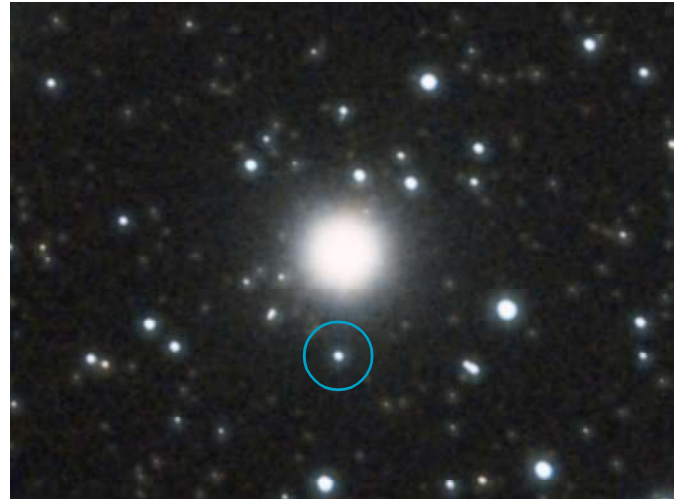
λ = wavelength in microns

fr = focal ratio

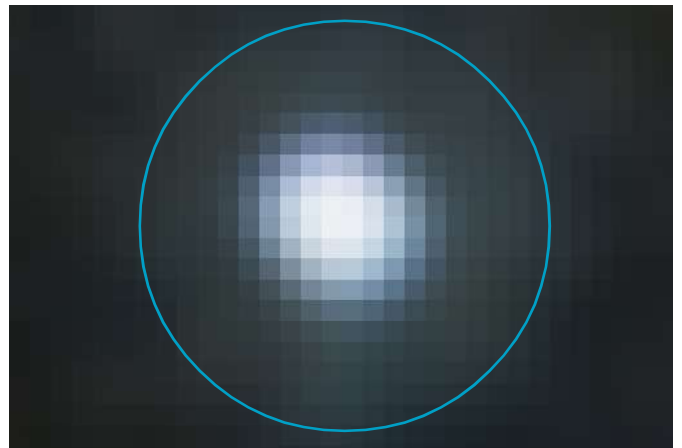
n = typically 3 pixels for sampling the smallest feature at average seeing)

Assuming $\lambda = 0.5\mu\text{m}$ and $n = 3$, then simplified: $Sc = fr/5$ or $fr = Sc * 5$, meaning that critical sampling is achieved roughly with a focal ratio 5 times the pixel size.

Binning is implemented with software by combining four adjacent pixels into a single pixel in 2×2 or larger formation. Since binning quadruples pixel sensitivity it is often used while focusing and framing a target object. With its larger pixels, binning can help compensate for oversampling. Since the number of pixels is reduced to 25%, the image size shrinks accordingly compromising resolution, but providing improved noise performance and dynamic range while sufficing with shorter exposure times.



▲ A star in the famous Double Cluster distorted and enlarged by atmospheric seeing of 4-5". Image scale was $0.63''/\text{pixel}$. Accurate guiding is important.

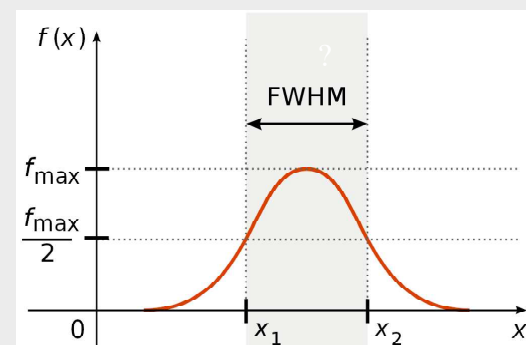


▲ Enlarged view of the encircled star. Celestron C8, 0.63x reducer (fl=1280mm), Nikon D5500 ($3.92\mu\text{m}$ pixels). The image is oversampled but no choice as seeing is the most influential factor.

CONCLUSION: The sampling theory applies best outside the atmosphere.

FWHM (Full Width Half Maximum)

... is a measure in seconds of arc (") for how much a star in relation to seeing spreads over several sensor pixels, that is, for the sharpness of an astronomical image. The width of FWHM spreads out in relation with poor seeing, bad focus, inaccurate guiding or simply dew on the objective lens or mirror.



Graph source: Wikipedia

Exposure

The most important benefit for EAA is a 'fast' telescope with a small focal ratio. Suppose a Ø200mm f/10 SCT produces a pleasing image after 60 seconds. A Ø100mm f/5 refractor can do that irrespective of aperture in...

$$60 \times (5/10)^2 = 60 \times 0.25 = 15 \text{ seconds}$$

In order for this to make sense, the **image scale** comes in. This is the amount of sky in arc seconds which is hitting a single sensor pixel and is calculated as a function of pixel size and focal length by:

$$206.265 \times \text{pixel size } [\mu\text{m}] / \text{focal length } [\text{mm}]$$

Given a camera with 2.9µm pixels in an array of 3840 x 2160 pixels (IMX585), the image scale of an Ø200mm f/10 (fl=2000mm) SCT is 0.295"/pixel. That of a smaller standard Ø100mm f/5 refractor (fl=500mm) is 1.196"/pixel.

The area of sky covered by the 3840 x 2160 pixels sensor is 76.5 x 43.1 arcmin (3297' square) for the refractor and 18.86 x 10.61 arcmin (200' square) for the SCT which is about 1/16th of the area of the refractor.

Twice aperture in diameter results in 4 times the light gathering area. Consequently, the SCT collects 4 times more light but on 1/16th of sky area, therefore requiring 4 times longer exposure than the refractor does.

We may as well adopt the **field of view**, FOV with the IMX585 sensor (11.14 x 6.26mm):

$$2 * \text{Atan}(d [\text{mm}] / 2 * fl [\text{mm}]) * 57.296$$

as a function of sensor size and focal length where d is sensor width, height or diagonal. For the 500mm refractor we obtain 76.56' x 43.07' = 3297 arc min square, for the 2000mm SCT 19.14' x 10.77' = 206' square, which, again, is 1/16th of the area of the refractor.

A 0.5x focal reducer will get the SCT down to f/5, doubling image scale and quadrupling sky area which is still 1/4th that of the refractor, but since the SCT collects 4 times more light, the exposure time is the same. Reducers can cause vignetting and edge aberrations.

Alternatively, you can increase the gain of the camera connected to the slower, but larger SCT. Gain controls the amount of electronic signal amplification. A higher gain produces image signals faster with higher brightness, but also more noise, both of which are equally amplified. In addition comes a lower dynamic range. Every camera has a "sweet spot" gain value that is optimal in terms of noise and dynamic range and should therefore be used in general situations with exposure time adjusted accordingly. Short exposure times are more forgiving in terms of tracking or guiding.

For reference, the frame rates by ROI and color space for the Uranus-C camera (IMX585) connected via USB3 (Speed = 100) at various exposure times. Unlike in the ZWO camera controls, there is no "High Speed Mode" selection (10-bit or 12-bit ADC) in SharpCap for Player One cameras. Some controls are specific to individual camera manufacturers. Frame rate is not related to gain.

3856 x 2180 RAW8

5ms: 46fps
10ms: 46fps
20ms: 46fps
30ms: 33fps
50ms: 20fps

1920 x 1080 RAW8

5ms: **187fps !**
10ms: 99fps
20ms: 50fps
30ms: 33fps
50ms: 20fps

3856 x 2180 RAW16

5ms: 23fps
10ms: 23fps
20ms: 23fps
30ms: 23fps
50ms: 20fps

1920 x 1080 RAW16

5ms: 93fps
10ms: 93fps
20ms: 50fps
30ms: 33fps
50ms: 20fps

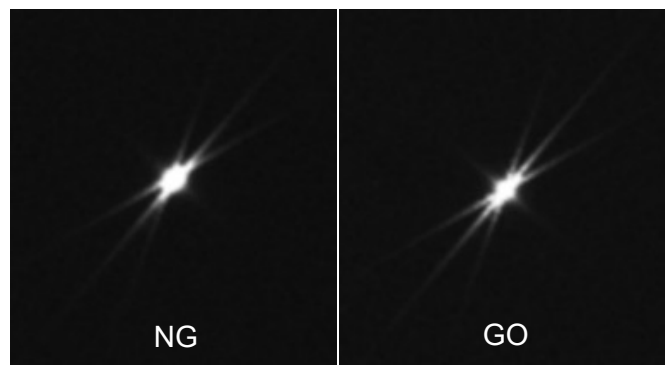
In DSLR terms, for instance, 5ms equal to 1/0.005 seconds = 1/200th second, likewise 40ms equal to 1/0.04 = 1/25th second.

Another choice for obtaining shorter exposure times is pixel binning by the camera control and capture software to mimic four pixels as one in a 2x2 array. This will increase sensitivity and dynamic range, reduce noise level by a factor of 2, but trades 1/4th of image size. Due to the larger and more sensitive pixels, binning and short exposure times helps focus better on faint stars before commencing to stacking or imaging without binning.

Focusing

Precise focusing is as crucial as a clear sky. If no focusing aid at hand aim the view on a bright star field and adjust focus so as the stars are smallest. Then slew back to the target object.

The simplest assistant is a Bahtinov mask placed in front of the aperture. Adjust the focuser until a star looks like on the right picture. The spike in the middle must go through the center of the star. The left picture shows the pattern when out of focus.



Filters

Let's talk a bit about filters for various imaging situations. We need to use filters because most telescopes do not focus all wavelengths on the same focal plane resulting in washed out images due to color aberration. Only reflectors are the exception.

Color Photography

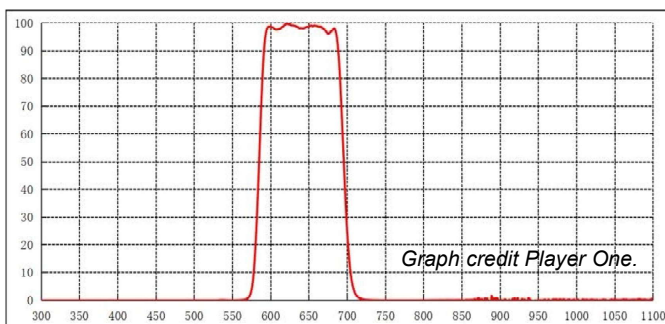
Wide fields, star clusters and galaxies are typical targets for color images because they shine mostly in visual wavelengths. Since a image sensor is sensitive to both, color and infrared, the infrared portion should be screened out to avoid blurry images. This is accomplished with an UV/IR cut filter opening at around 400nm and closing at around 700nm.

Color cameras, OSC, are best suited for EAA. If you own a monochrome camera you will need to capture an object four times, namely through a luminance (can be an IR-cut or an IR-pass), red, green and blue filter each and then merge them to a color image. This is way too complicated and time consuming for EAA, not speaking of extra budget required for filters and filter wheel.

Narrow Band Photography

Nebulae and HII regions are typically peaking at the wavelength of Hydrogen-alpha, $H\alpha$, namely 656nm. Such objects are best captured with a filter passing a window centered on 656nm. This window can be as narrow as 3nm and as wide as 100nm. The narrower the window the more of true $H\alpha$ wavelength is selected, but longer exposure times are required while a wider window passes more light, but also including wavelengths outside $H\alpha$.

Also, the narrower the window the pricier the filter. Though close to red color, a narrowband $H\alpha$ image is usually monochrome. EAA does not demand that much of precision in that an affordable filter with a 100nm window will suffice.



▲ The ERF filter from Player One Astronomy (originally developed for solar work) is basically a filter centered on Hydrogen-Alpha. It is also useful as a Red filter for lunar imaging in monochrome when seeing is favorable.



▲ As a useful accessory for EAA, a mechanical filter wheel helps image the same object through various filters, such as IR-cut, IR-pass and narrow band filters. Programmatically controlled electrical filter wheels do not cause image shifting when rotating for changing filters, but for most purposes, such as EAA, a mechanical type will do, not speaking of budget.

► Indispensable for color imaging, an UV/IR-cut filter blocks unwanted ultraviolet and infrared light and is optimal for EAA in visual color.

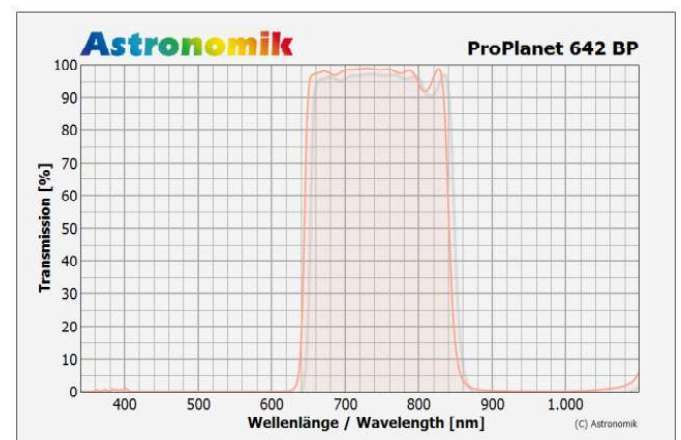


Photo credit Baader Planetarium.

Near-Infrared Photography

Opposite to color imaging, infrared images require a filter which cuts off the visual domain. Infrared pass filters open at 640nm all the way up to 850nm while such images are typically in monochrome. Astronomik's Pro-Planet 642BP has a 200nm spectral window from 642nm to 842nm, blocking the longer infrared. It is also an affordable filter for getting started with imaging $H\alpha$ regions though not centered on $H\alpha$.

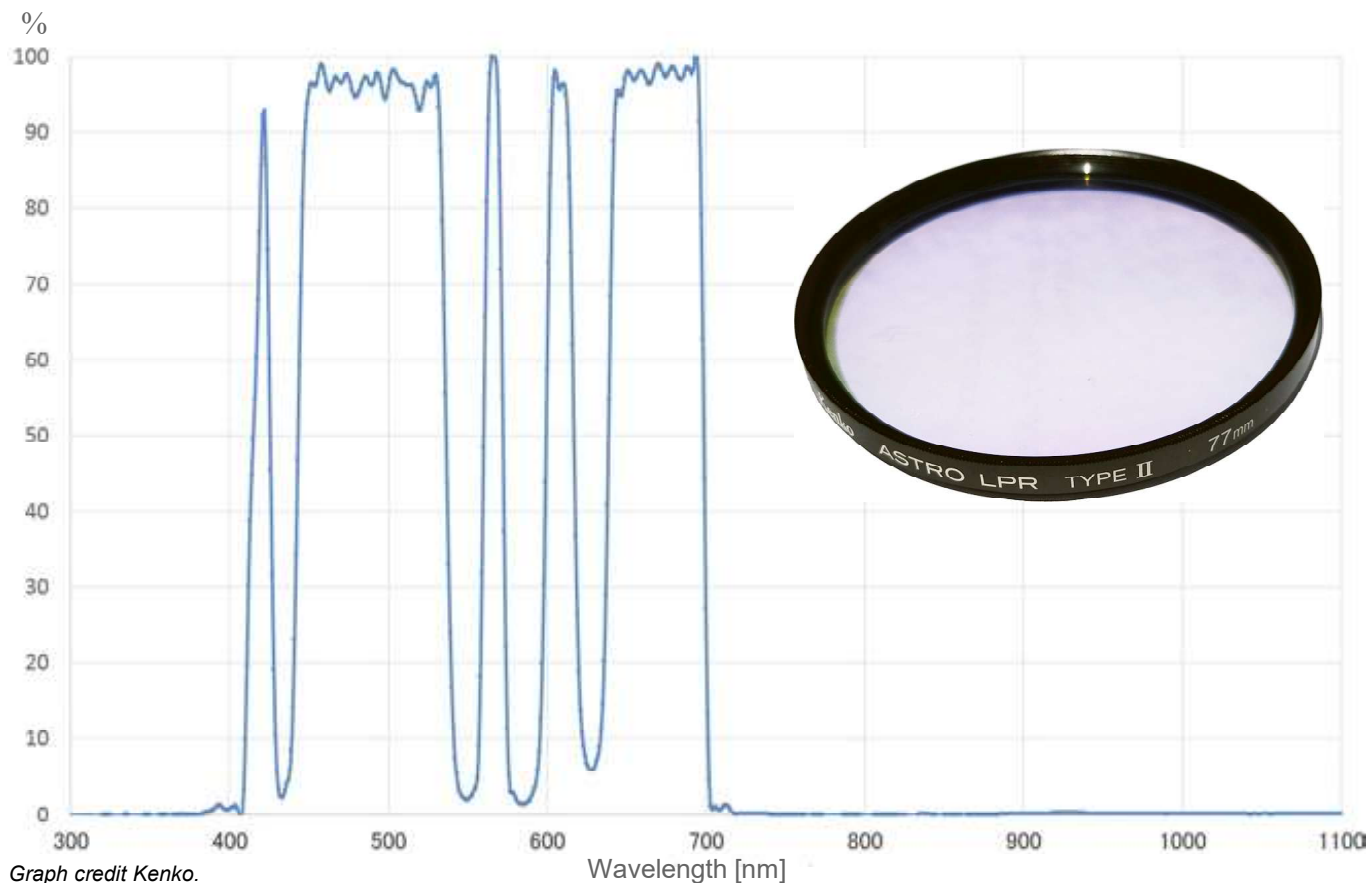
Please appreciate that longer wavelengths can compensate for poor seeing but compromise resolution and detail, in that a 640nm pass is a good bet to start with.



▲ The filter from Astronomik is advertised for planetary and lunar imaging and for Hydrogen-Alpha deepsky objects. Graph credit Astronomik.

CONCLUSION: The first filter to start EAA with is an UV/IR-cut filter for imaging in visual colors. With more experience we can later challenge narrowband and infrared imaging.

Light Pollution Reduction Filters (LPR)



▲ Filter transmission curve of the Kenko Astro LPR II filter.

◀ Photo credit Baader Planetarium.

UV/IR cut filters are typically used for live stacking with a color camera for blocking infrared light, however, they do not block wavelengths of artificial light.



UV/IR-Cut Filter

A Light Pollution Reduction, LPR, 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 **Kenko Astro LPR II** is a LPR filter available in various diameters for threading over photo lenses or small refractors. It blocks ultra-violet, infrared and artificial wavelengths. The filter also passes passes Hydrogen-beta ($H\beta$) and OIII as well as Hydrogen-alpha ($H\alpha$) wavelengths which help obtain more details and contrast in nebulae.

As an the interference type filter it can cause unwanted reflections around bright stars.

Of course, when using this filter over the objective lens any filter threaded in front of the CMOS camera should be removed.



Kenko's "Starry Night" filter is a good light pollution filter but is not suitable for CMOS cameras or modified DSLRs as it leaks near-infrared resulting in smeared blurred reddish images.

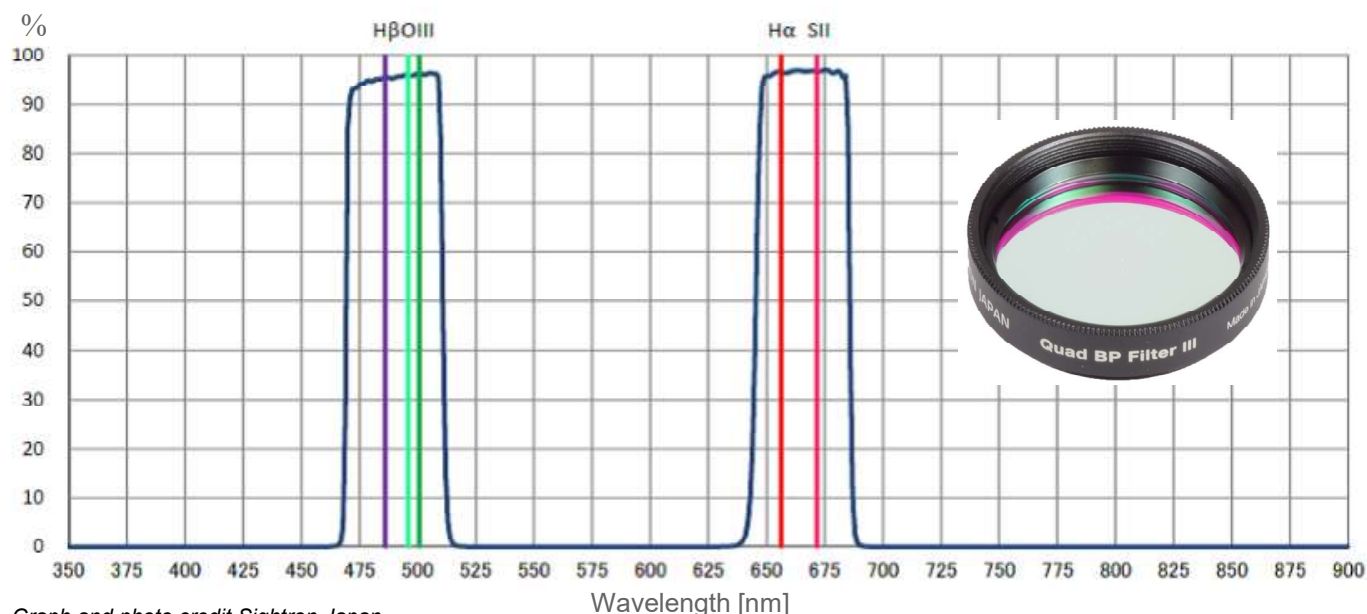


Photo courtesy Kenko.

Please bear in mind that filters are not parfocal even if from the same manufacturer. After every filter change the telescope must be refocused.

A filter should be attached in any case , at least an UV/IR-Cut or LPR filter. Without a filter images can be washed out and stars are depicted larger than desired.

Multiband Filter



Graph and photo credit Sightron Japan..

▲ Filter transmission curve of the Sightron Quad-Band filter.

For example, the Sightron quad-band filter is an interference type filter which passes only the wavelengths around H α , H β , OIII, and SII, which are the four main emission lines of nebulae. The latest version entirely cuts near-infrared up to 1100nm thus preventing halos around bright stars and also effectively cuts the wavelengths of artificial lights such as sodium and mercury sources.

The quad-band filter will render the color of a final image slightly reddish. The color balance can be adjusted using image processing software such as Photoshop or GIMP.

Since the diagonal size of the IMX585 sensor is 12.85mm a 1.25-inch (31.7mm) filter will do without causing vignetting and can be threaded to the camera's nose piece adapter. Larger sensors require the 2-inch (48mm) filter size.

The characteristics of interference type filters vary with the incident angle of light. Brightness and color balance can be uneven when used with wide angle lenses.

Due to the relatively narrow window of the light the Sightron quad-band filter passes (approx. 50nm each slot) exposure times need to be longer as compared with UV/IR-cut or LPR filters. There are quad-band and dual-band filters with even narrower windows of a few nanometers, but they are not suitable for live stacking as it would take too long time until an object emerges on the monitor. Extremely narrow filters are best suited for 'serious' deepsky imaging.

Of course, when threading this quad-band filter in front of the CMOS camera any filter over the objective lens should be removed.

A filter should be attached in any case, at least an UV/IR-Cut or LPR filter. Without a filter images can be washed out and stars are depicted larger than desired.

Test images with IMX585, 60 sec, gain 200.



▲ Single frame without any filter (large stars)

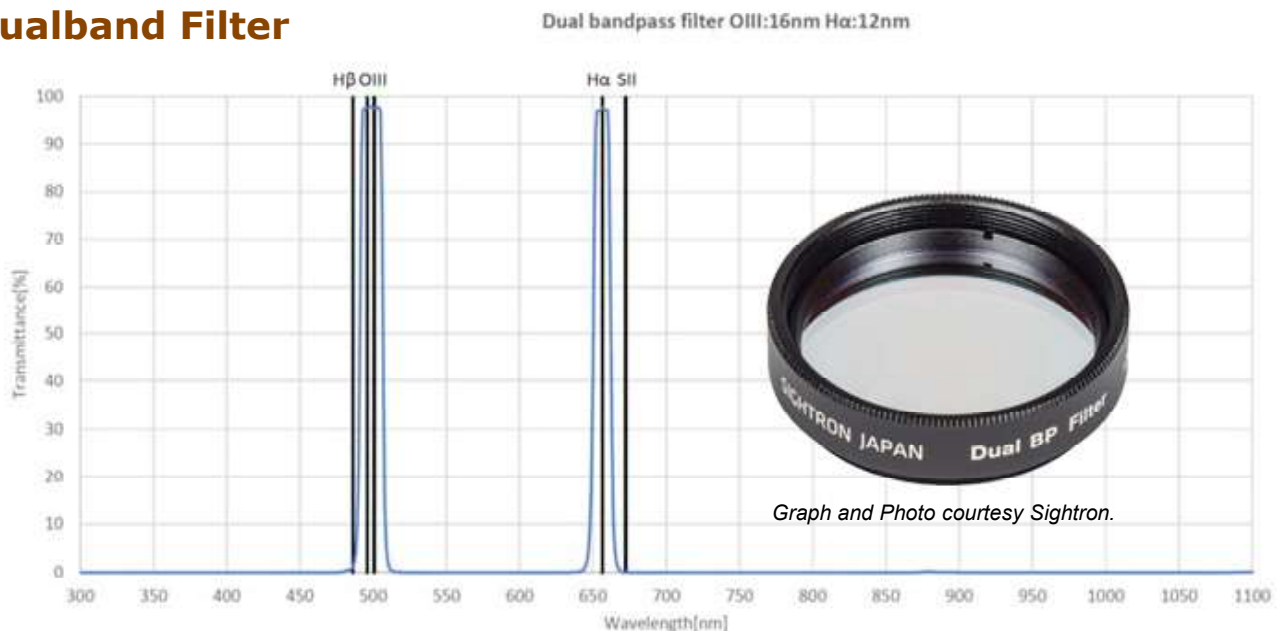


▲ Single frame with UV/IR-Cut filter (smaller stars)



▲ Single frame with Sightron quad band filter (smallest stars)

Dualband Filter



Equally an interference type filter is Sightron's latest Dual-Band filter transmitting H α and OIII only, effectively rejecting artificial and other unwanted light including moonlight. While the Quad-Band passes a window of 50nm, the Dual-Band is much narrower with 16nm and 12nm, respectively requiring a bit more exposure time but in turn unveiling more nebulosity in, say, H α regions as it allows for greater selectivity and precision in isolating unwanted wavelengths. This also results in improved noise performance (SNR).

Yet higher selectivity can be achieved with even narrower filters, such as a filter passing H α only through a window as narrow as 7nm all the way down to 3nm. When imaging in H α only images are usually re-recorded in monochrome and then layer-processed with frames captured in other wavelengths. The narrower a filter the more receptive it is to the light incidence angle especially at fast focal ratios.



Photo courtesy Sightron.

Electronic Finder



▲ A Ø30mm/FL=120mm mini guide scope can do it.
Photo credit ZW Optical.

Provided you are running ASCOM, SharpCap Pro, EQMOD/GS Server and Stellarium on your PC to control a telescope with an attached CMOS camera, SharpCap 4 Pro can take a picture with the CMOS camera and determine the central coordinates by means of its internal plate-solving engine, "SharpSolve". In case the center is off the coordinates of a target object picked in Stellarium it will compute the difference and slew the telescope to the accurate center of the target, eliminating need for conventional star alignment. But what to do, if the camera attached to the telescope is a DSLR which is not supported by SharpCap 4 Pro?

Your autoguide scope can be employed as an **"electronic finder"**. When connected to the autoguide camera and focused, SharpCap 4 Pro will plate-solve and steer the telescope with the DSLR on it to the center of the target. When the target is confirmed on the DSLR monitor or, for faint objects, after a test shot, then simply disconnect the autoguide camera and (re)connect it to the autoguide software, such as PHD2.

Of course, a photo lens mated with an autoguide camera will perform object centering as well, however, a guidescope is usually in the gear box and can be placed onto the main scope in no time.

It is **important** that the optical axes of both, telescope and guidescope (or photo lens) are accurately aligned in parallel, in particular when imaging narrow fields.

Plate solving can be difficult when the focal length of the imaging rig is long and therefore the resulting FOV too narrow or too faint for plate-solving. In such a case plate solving with a small wide field autoguide scope comes in handy.

▼ Be sure to inform SharpCap the focal length of the guide scope in Settings/Plate Solving:

General	Saving	Hardware	Cameras	Filenames	Memory
Plate Solving	Polar Alignment	Guiding	Logging	Startup Scripts	

Plate solve settings:

Select Plate Solving Application:

Astap

After solving from Telescope controls/Solve and Sync Menu:

Sync mount and re-center target

Focal Length of Telescope (should include barlow/reducer adjustments)

☐ Do not use ☐ From ASCOM Mount ☒ Use mm

☒ Always send 8 bit images to the plate solving application

Astap

Path to the Astap.exe (or Astap_cli.exe)

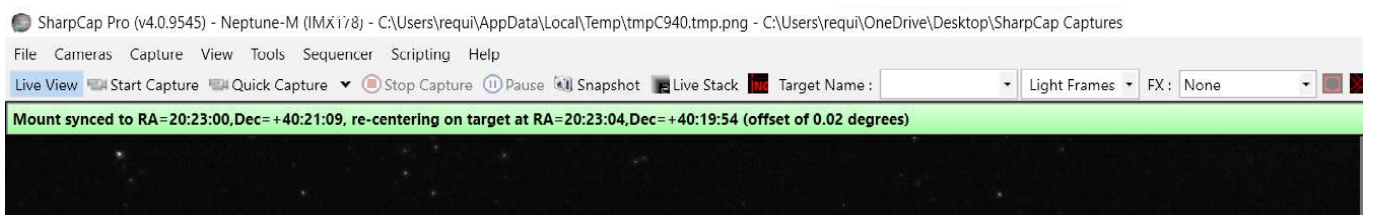
☒ Detect Automatically

c:\Program Files\Astap\Astap.exe

This test was performed with a Ø30mm/FL=120mm mini guidescope and a monochrome Neptune-M camera (IMX178) without filter for maximum light transmission. Exposure 1.7 sec, gain 440.



▲ SharpCap 4 Pro screen after successful plate-solving (the bright star is Altair, no histogram stretch applied).



▲ SharpCap 4 Pro screen head after centering an object.

More to Consider

Plate Solving

When entertaining an audience it is important that everything goes smoothly without letting people wait for results. Please appreciate that you will need to refer to the manuals of each software introduced hereafter for setup and configuration.

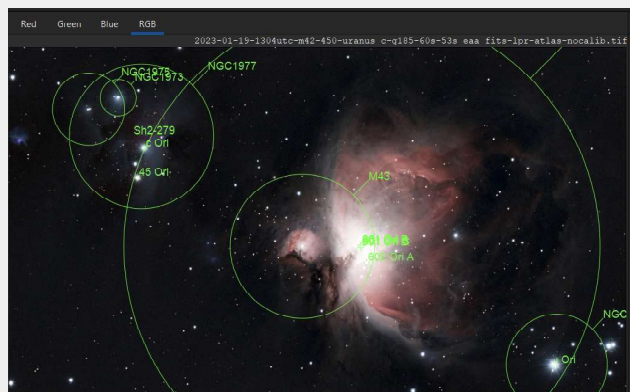
Target objects slewed to are often not centered in the camera's view due to inaccurate mount alignment. Then it will take time to find the target by manually steering the mount which is difficult in particular when the target is faint. Plate solving is the solution.

Since version 4.1.11491.0 SharpCap Pro includes its own plate solving engine including offline star index files with minimum field of views of 0.5° and 0.25° (Settings/Plate Solving/SharpSolve). It is working like a charm and it is fast. SharpCap 4 Pro also needs to be linked to the telescope mount via, for instance, EQMOD or GS Server software which connect to the mount via Wi-Fi or USB eliminating need for a hand control. Note that EQMOD and GS Server software are for SkyWatcher and Orion mounts only and need ASCOM, a software engine developed for standardization of astronomical equipment control. It is a good idea to install the latest version of ASCOM to be prepared for future tasks. ASCOM is somehow an astro operating system.

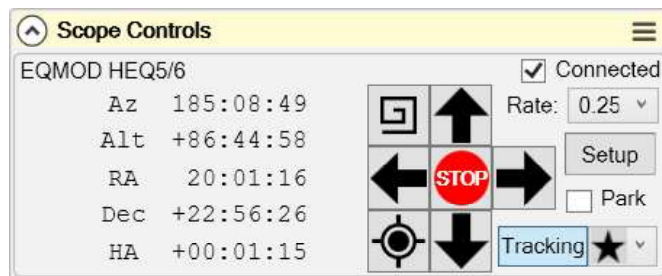
The latest version of SharpCap 4 Pro includes a GoTo database from which to pick an object of interest and have the mount slew to it, then to plate-solve for centering the target if offset and synchronize the mount for further targets. During this fully automated process SharpCap 4 Pro also adjusts camera exposure and gain for best plate-solve results.

Plate Solving Overlay

Some image stacking and processing software, such as 'Siril' and 'PixInsight' can perform plate solving and overlay the data on an image. Stand-alone solutions are for instance 'ASTAP' and 'All Sky Plate Solver'. When online images can also be uploaded to 'astrometry.net' for a plate solved overlay.



▲ Siril's plate solved overlay.



▲ Scope Controls appear in SharpCap Pro when EQMOD or GS Server are detected and running (requires ASCOM).

Alternatively, planetarium software such as Stellarium can be used for picking, slewing and plate-solving in conjunction with SharpCap 4 Pro and EQMOD or GS Server, but camera parameters must be found manually, often by try and error.



Instead of SharpCap Pro there are other software configurations for this task, such as "NINA" which also relies on ASCOM.

Compact control boxes such as ZWO's ASiAir (connects to ZWO cameras only) can handle plate solving and framing tasks merely with a tablet or a smartphone.



PS: This button is for the purpose of centering a planet if not in view of the camera. When kept pressed it spirals the telescope mount around at the current selected slew rate until the planet gets into view and can be centered manually using the direction keys at a slower slew speed. The field of view during planetary imaging is usually a very narrow one in that plate solving will fail due to lack of stars. Spiralling can also be used for centering deepsky objects in wider fields but is less convenient and quite tedious when searching faint nebulae.

FWHM & Image Scale



▲ A magnified star field shows that a digital image is composed of an array of pixels.

As per definition by Astronomy Tools of First Light Optics Ltd., UK, optimal images scales in relation to seeing are:

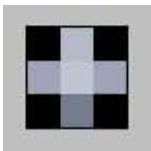
5/5 = Exceptional Seeing	(0.5-1" FWHM)	: 0.17 - 0.5" / pixel.	Reference:
4/5 = Good Seeing	(1-2" FWHM)	: 0.33 - 1.0" / pixel.	https://astronomy.tools/calculators/ccd_suitability
3/5 = Acceptable Seeing	(2-4" FWHM)	: 0.67 - 2.0" / pixel.	
2/5 = Poor Seeing	(4-5" FWHM)	: 1.33 - 2.5" / pixel.	
1/5 = Unacceptable Seeing	(5-6" FWHM)	: 1.67 - 3.0" / pixel.	

The image scale of a given telescope/camera combination is obtained by:

$$206.265 * \text{camera pixel size } [\mu\text{m}] / \text{telescope focal length } [\text{mm}]$$

For example, an IMX585 sensor based camera has 2.9 μm square pixels resulting in an image scale of 1.33" per pixel on a FL = 450mm telescope.

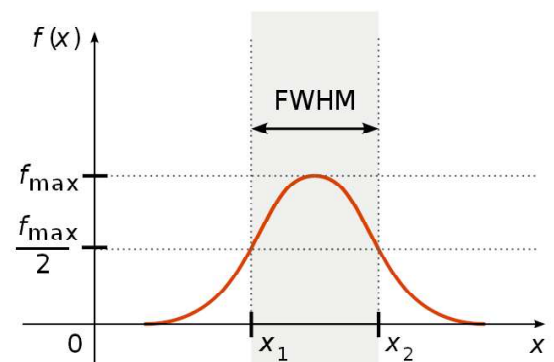
FWHM stands for **F**ull **W**idth (at) **H**alf **M**aximum. It is a measure of the width of a function or a spectrum at half of its maximum value. For example, on a peak-shaped curve, FWHM is the distance between the two points where the curve is half of its peak height. FWHM is used to determine the spectral width of light sources, the duration of pulse waveforms, the resolution of spectrometers, and other phenomena.



In astrophotography, FWHM [in arc-seconds] is a measure of how much a star is dispersed by atmospheric and other influences. Nyquist's theorem suggests that the sampling rate should be twice the frequency

of the analog signal to be sampled. However, a star is best imaged at 1/3 of the analog signal, in that it will always fall on a 3 x 3 pixel matrix for looking near circular. A single pixel cannot contain any information, but brightness only.

FWHM is a measure of the sharpness of an astronomical image based on how much the telescope and atmosphere have smeared a point source, such as a star, over several pixels in the image. The lower the FWHM value halfway up the intensity curve, the pointier the star is and the sharper the image.



Graph source: Wikipedia

Though bright stars spread over a wider area on an image FWHM does not vary with light intensity and maintains the same profile shape. The width of FWHM spreads out in relation with poor seeing, bad focus, inaccurate guiding or simply dew on the objective lens or mirror.

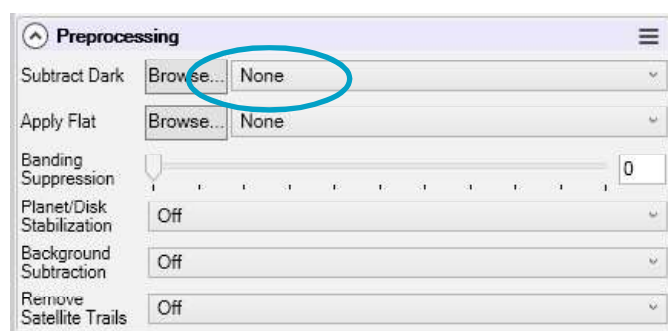
Capture software such as SharpCap Pro measures FWHM during live stacking by which seeing can be estimated. A value of 2 arc seconds or less is widely considered a favorable value for FWHM, but is barely achieved under average sky conditions and also depends on the image scale (focal length and camera pixel size).

Dark Frames

In particular when stacking (or imaging) in summer with an uncooled CMOS camera, "dark frames" are indispensable for obtaining great looking images with an even background. CMOS camera images are always escorted by thermal and electronic noise which can ruin them.

For maximum efficiency a dark file is taken with the same properties (exposure, gain, resolution and ambient temperature) as the light frames used for stacking or saving but with the objective lens covered without light leaks. Naturally, darks are taken immediately prior to live stacking. A so saved master dark file contains the combined noise the camera generates with its current usage properties. SharpCap provides a menu for subtraction of dark frames:

When live stacking, a master dark file can be selected for subtraction from every light frame



being stacked (noise calibration, though the ambient temperature might change during the stacking process). SharpCap Pro will pick the master dark after creation. This will result in a considerably cleaner image stack as most of the noise is cancelled out. Alternatively, several darks can be averaged and saved to a master dark which eventually works more efficiently.

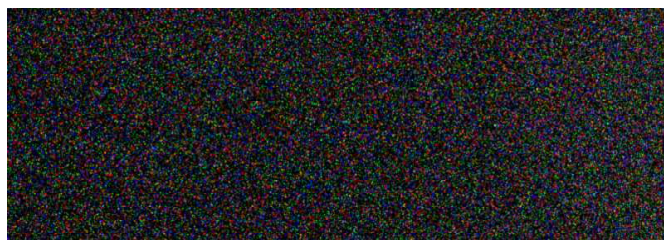
Without calibration the dark noise including hot pixels in red green and blue contaminates the light frame. Though image stacking reduces noise it cannot entirely be removed.

The difference between a single dark and a master is not apparent to the eyeball. Both darks below are excerpts of the bottom right corner of the capture and histogram-stretched to dramatize the noise. This part of a dark is where "amp glow" noise typically occurs but is hardly present in this example, speaking for a quality camera.

Uranus-C (IMX585)

Sensor Temperature = 31.4°C

Exposure = 60 seconds, Gain = 185



▲ Single dark frame



▲ A master dark consisting of 30 averaged dark frames.

In addition to using dark frames, be sure to dither via PHD2 in order to remove "walking noise". This will complete the noise combat with SharpCap Pro which makes it easy to take and employ dark frames.

If you experience vignetting and artifacts of contamination on the sensor then be sure to also take flat frames to calibrate this annoyance away and take the trouble to clean the sensor before using it next time.

▼ Uranus-C (IMX585), 60 seconds at gain 185, sensor 31.4°C.



▲ An uncalibrated single light frame.



▲ A single light frame with dark subtraction.

Flat Frames

Provided the telescope's image circle is wide enough vignetting is no real problem, however a telescope with a contaminated camera sensor can cause quite some harm while making post processing a thankless task. Therefore it is important to take flat frames before or after completion of the exposure. An evenly illuminated white LED sketch board with adjustable brightness is best for flats. Place it over the aperture of the telescope, then, reduce gain to small or zero and adjust exposure time so as the peak in the histogram levels off at around 50%. SharpCap4 Pro calculates exposure and gain automatically before flat capture.

The flat image above from the Newtonian shows a nasty unequal illumination and several "donuts", the latter caused by contamination on the image sensor. Also humidity can assemble on the sensor and ruin an image. A small number of flat frames, say 20, averaged will calibrate these artifacts away resulting in an even image background. Like darks, flats can be preprocessed in SharpCap 4.1 Pro while live stacking. The individual dark and flat files should be saved for post processing in other software.

▼ *This flat frame shows the image sensor's corners as reflected by an interference-type filter over the objective lens of a apochromatic refractor.*



Evidence: top view of the image sensor

Object Framing

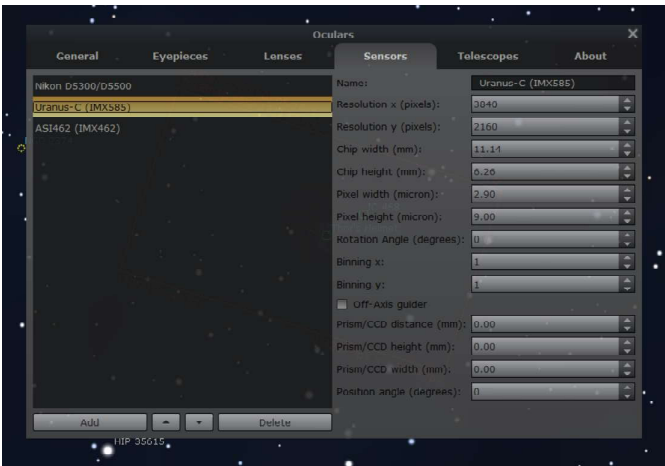
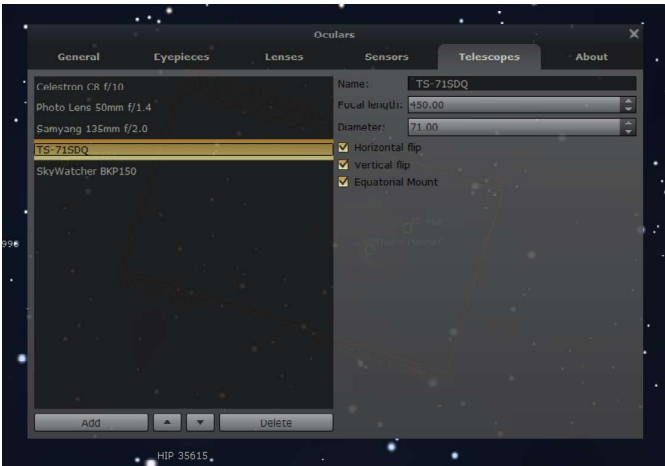


▲ Stellarium 0.20.2 framing screen.

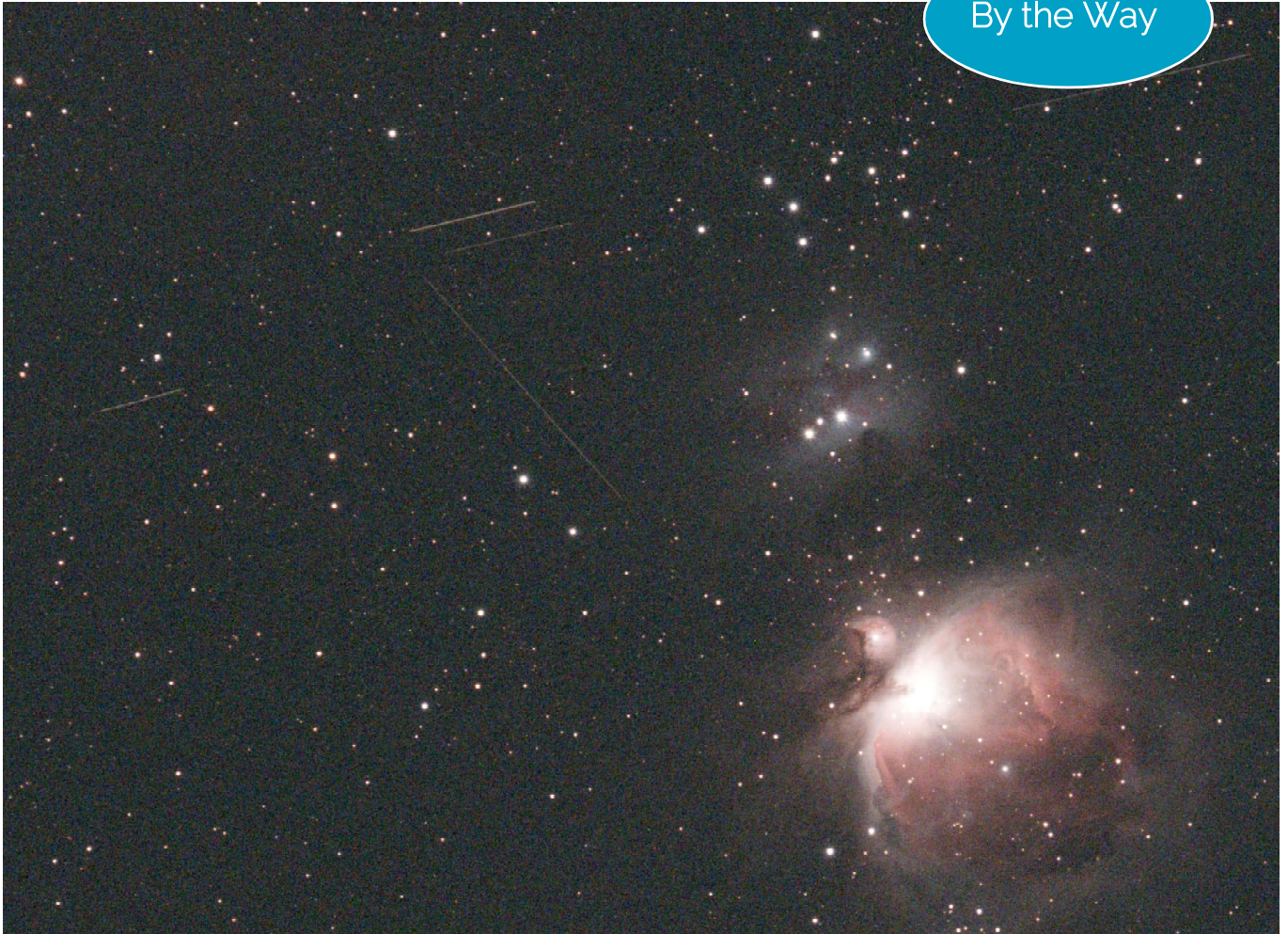
If you have a copy of Stellarium framing a target object is made easy. Enter the parameters of your telescope/lens and camera and select the gear from the box at the top right of the screen. The then appearing rotatable red rectangle shows the portion of the sky you will be imaging including data, such as field of view (FOV), rotation angle, image scale and center coordinates.

The example frames Thor's Helmet with a $\varnothing 71\text{mm}/f\!l\!=\!450\text{mm}$ refractor telescope and an IMX585 camera without barlow or reducer.

Check what your Camera is Seeing before Shooting

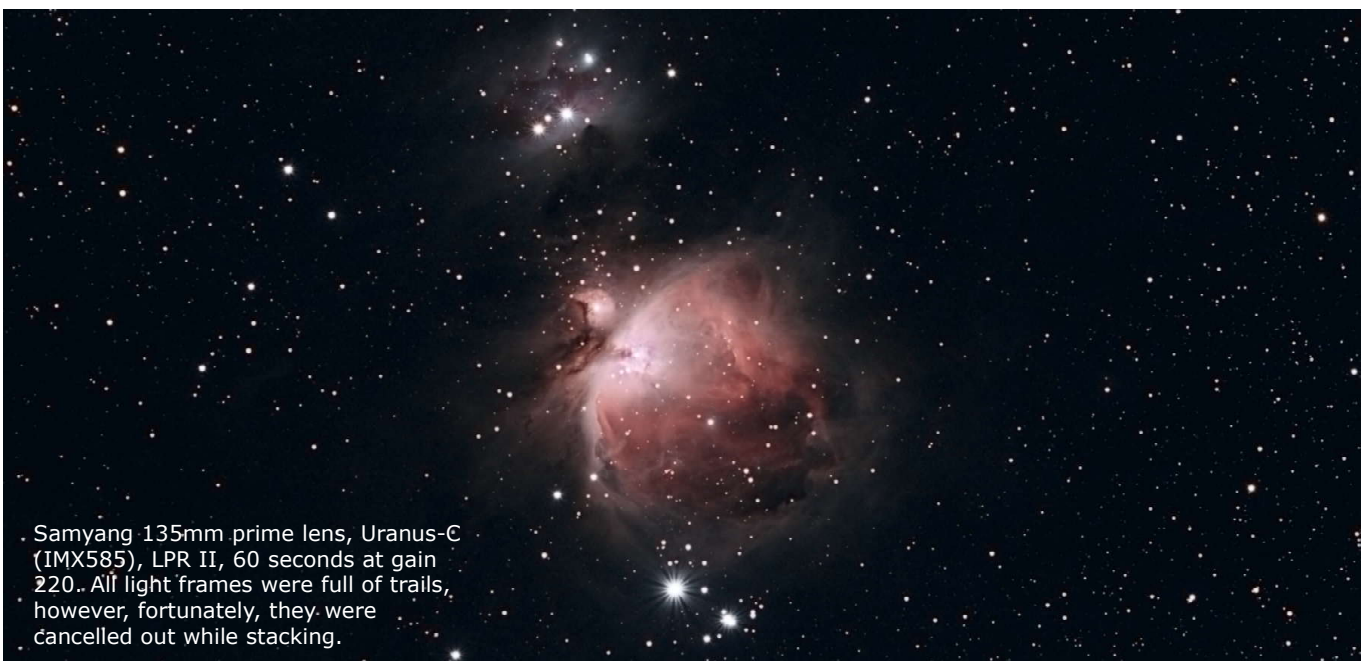


▲ Stellarium's telescope and camera input boxes.



The streaks moving mainly horizontally on this single 60-second exposure are "SpaceX's Starlink" satellites which are traveling at roughly 28,000 km/h on an altitude of 480 km orbiting the Earth approximately every 90 minutes, equalling the orbital period of the ISS. Streaks in vertical direction are meteors of the Geminid shower on December 14, 2023, outnumbered by artificial satellites.

Satellite trails are annoying when imaging deepsky objects with minutes of exposure per frame. Fortunately, most of them are cancelled out when stacking the light frames, however, frames traversed by bright trails such as from airplanes should be thrown off before stacking.



Samyang 135mm prime lens, Uranus-C (IMX585), LPR II, 60 seconds at gain 220. All light frames were full of trails, however, fortunately, they were cancelled out while stacking.

Documentation

Thorough documentation adds value to your images. In addition to tracking your skill progress you can better and faster find or analyze your images. Careful documentation also helps compare, identify and evaluate imaging conditions.

Astrophotos are often collected in Gallery applications which let you swipe through your images forth and back, say, on a tablet, or let you enjoy a slide show.

Photos can also be uploaded to a cloud server but if you are comfortable with web programming you can develop a tailored website to which to upload images and store image data in a database, facilitated with, for instance, PHP scripts and a MySQL database. The database will allow parametric searches, sorting, etc.

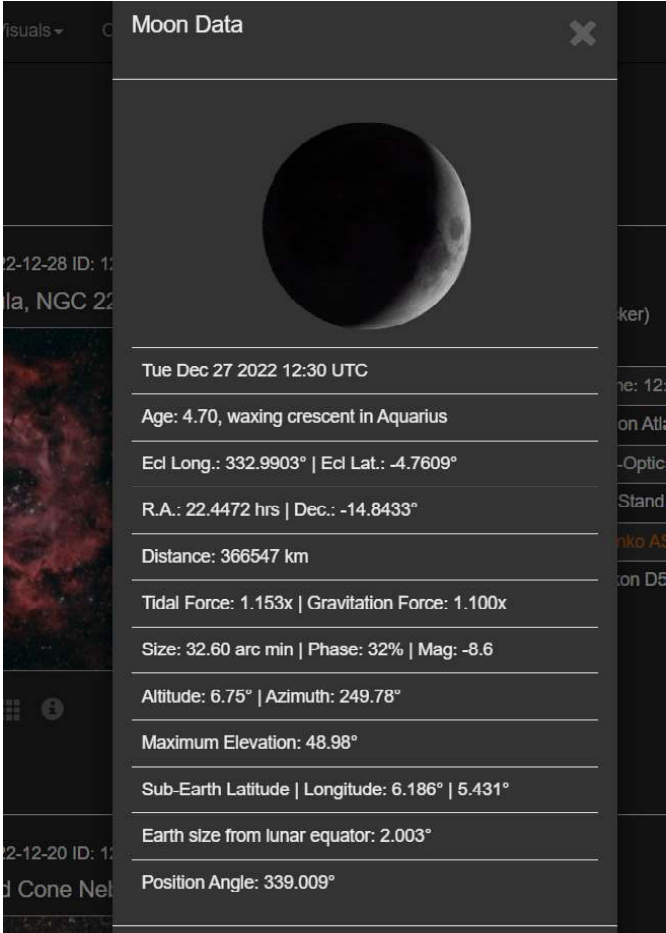
Image file names should contain capture data, coded or readable. The author uses readable file names such as:

```
2023-01-19-1304utc-m42-450mm-uranus_c-g185-60s-53x-lpr-eaa-atlas-aguided-nocalib.png
```

which is like an open book though the file name is a bit long, but in turn conclusive. Data which cannot be derived from the date can be obtained with the help of plate solving, such as rotation angle, central coordinates and an overlay with annotations. Most important data, however, can be calculated using simple equations, such as for **image scale** and **field of view**. Date, time and exposure duration allows you to compute or to have computed lunar data, such as phase and altitude which influence imaging condition especially when not using filters.

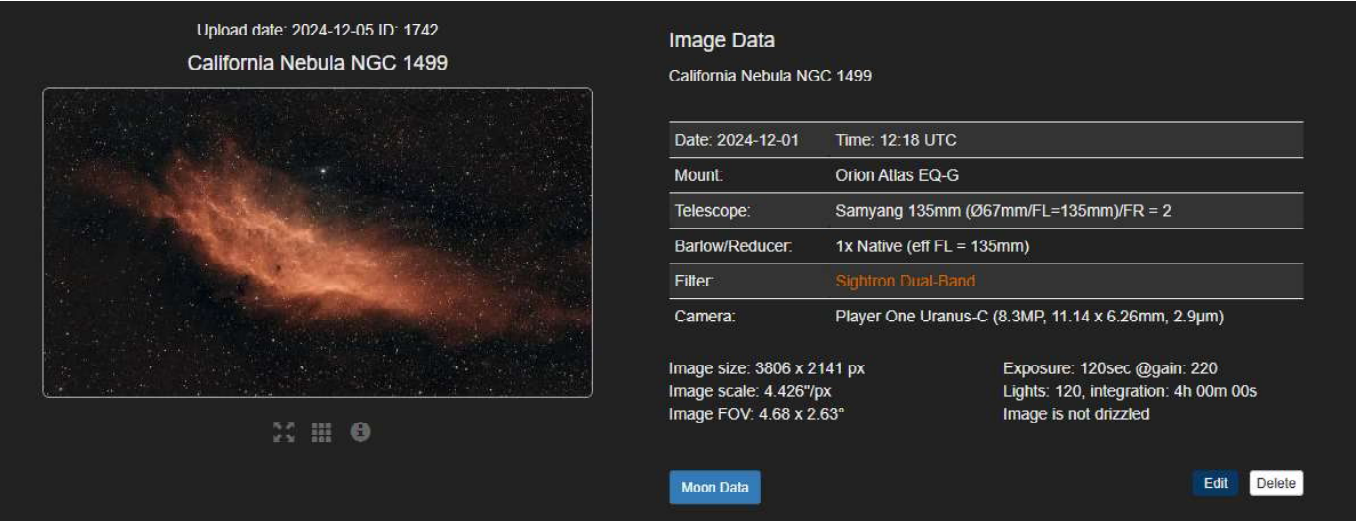
There is much more you can do with your images apart from printing calendars, postcards and wallpapers. For instance, you can author a brochure like this and illustrate it with your own work.

If you are not a web programmer then a popular platform, such as **AstroBin** <https://www.astrobin.com/> is a great place to upload and document your images with descriptions, accompanying image data and share it all with a large international community of astrophotographers of any skill level. You will also make online friends and get heaps of advice from your buddies. AstroBin also includes a member forum where you can discuss imaging techniques, software, equipment as well as issues that burden your heart or simply share the pain of bad seeing.



▲ Example of a pop up for lunar data at date and time of imaging.

▼ Example of a home-brewed website for astro-photos and acquisition data.



When saving images in FITS format with, say, SharpCap or Siril all available information will be written to the header of the FITS file which is an open standard for scientific images, including astronomy. There are various FITS file viewer applications. The screen shots show the scrollable header data as displayed by the ZWO ASI Studio software suite.

BITPIX	-32
number of bits per data pixel	
BSCALE	1.
default scaling factor	
BZERO	0.
offset data range to that of unsigned short	
CCD-TEMP	26.7999992370605
CCD temp in C	
COMMENT	
COMMENT FITS (Flexible Image Transport System) format is defined in 'Astronomy	
COMMENT	
COMMENT and Astrophysics', volume 376, page 359; bibcode: 2001A&A...376..359I	
CTYPE1	'RA---TAN'
Coordinate type for the first axis	
CTYPE2	'DEC--TAN'
Coordinate type for the second axis	
CUNIT1	'deg'
Unit of coordinates	
CUNIT2	'deg'
Unit of coordinates	
DATE	'2023-09-09T01:36:22'
UTC date that FITS file was created	
DATE-OBS	'2023-09-08T19:27:52.943279'
YYYY-MM-DDThh:mm:ss observation start,	
DEC	-4.75220744680848
Image center Declination (deg)	
EQUINOX	2023.68746506641
Equatorial equinox	
EXPEND	2460196.35094698
Exposure end time (standard Julian date)	
EXPSTART	2460196.31102943
Exposure start time (standard Julian date)	
EXPTIME	60.
Exposure time [s]	
EXTEND	T
FITS dataset may contain extensions	

All essential information about the used telescope and camera as well as object and image data are stored ASCII encoded for reference. With this data at hand you can flexibly transport your images for which reason FITS stands for "Flexible Image Transport System".

There are also FITS header editor softwares for correcting or completing data.

FOCALLEN	450.
Camera focal length	
GAIN	200
Camera gain	
COMMENT	
HISTORY .000), additive+scaling normalized input, normalized output, no image we	
COMMENT	
HISTORY TOP-DOWN mirror	
COMMENT	
HISTORY ighting, equalized RGB	
HISTORY mean stacking with wins 3.000 high=3	
IMAGETYP	'Light'
type of image	
INSTRUME	'Uranus-C (IMX585)'
instrument name	
LIVETIME	3300.
Exposure time after deadtime correction	
NAXIS	3
number of data axes	
NAXIS1	3856
length of data axis 1	
NAXIS2	2180
length of data axis 2	
NAXIS3	3
length of data axis 3	
OBJCTDEC	'-04 45 07.000'

OBJCTDEC	'-04 45 07.000'
Image center Declination (dms)	
OBJCTRA	'05 36 22.000'
Image center Right Ascension (hms)	
OBJECT	'Runningman'
Name of the object of interest	
PROGRAM	'Siril v1.2.0-rc1'
Software that created this HDU	
RA	84.0932484125888
Image center Right Ascension (deg)	
ROWORDER	'BOTTOM-UP'
Order of the rows in image array	
SIMPLE	T
file does conform to FITS standard	
SITELAT	Your latitude
[deg] Observation site latitude	
SITELONG	Your longitude
[deg] Observation site longitude	
STACKCNT	55
Stack frames	
XBINNING	1
Camera binning mode	
XPIXSZ	2.9
X pixel size microns	
YBINNING	1
Camera binning mode	
YPIXSZ	2.9
Y pixel size microns	

FITS header as presented by Siril:

SIMPLE	=	T	/ file does conform to FITS standard
BITPIX	=	-32	/ number of bits per data pixel
NAXIS	=	3	/ number of data axes
NAXIS1	=	3856	/ length of data axis 1
NAXIS2	=	2180	/ length of data axis 2
NAXIS3	=	3	/ length of data axis 3
EXTEND	=	T	/ FITS dataset may contain extensions
COMMENT	FITS (Flexible Image Transport System) format is defined in 'Astronomy		
COMMENT	and Astrophysics', volume 376, page 359; bibcode: 2001A&A...376..359H		
BZERO	=	0.	/ offset data range to that of unsigned short
BSCALE	=	1.	/ default scaling factor
ROWORDER	=	'BOTTOM-UP'	/ Order of the rows in image array
INSTRUME	=	'Uranus-C (IMX585)'	/ instrument name
DATE	=	'2023-09-09T01:36:22'	/ UTC date that FITS file was created
DATE-OBS	=	'2023-09-08T19:27:52.943279'	/ YYYY-MM-DDThh:mm:ss observation start,
STACKCNT	=	55	/ Stack frames
EXPTIME	=	60.	/ Exposure time [s]
LIVETIME	=	3300.	/ Exposure time after deadtime correction
EXPSTART	=	2460196.31102943	/ Exposure start time (standard Julian date)
EXPEND	=	2460196.35094698	/ Exposure end time (standard Julian date)
XPIXSZ	=	2.9	/ X pixel size microns
YPIXSZ	=	2.9	/ Y pixel size microns
XBINNING	=	1	/ Camera binning mode
YBINNING	=	1	/ Camera binning mode
FOCALLEN	=	450.	/ Camera focal length
CCD-TEMP	=	26.7999992370605	/ CCD temp in C
IMAGETYP	=	'Light'	/ Type of image
OBJECT	=	'Runningman'	/ Name of the object of interest
GAIN	=	200	/ Camera gain
SITELAT	=	Your latitude	/ [deg] Observation site latitude
SITELONG	=	Your longitude	/ [deg] Observation site longitude
PROGRAM	=	'Siril v1.2.0-rc1'	/ Software that created this HDU
CTYPE1	=	'RA---TAN'	/ Coordinate type for the first axis
CTYPE2	=	'DEC--TAN'	/ Coordinate type for the second axis
CUNIT1	=	'deg'	/ Unit of coordinates
CUNIT2	=	'deg'	/ Unit of coordinates
EQUINOX	=	2023.68746506641	/ Equatorial equinox
OBJCTRA	=	'05 36 22.000'	/ Image center Right Ascension (hms)
OBJCTDEC	=	'-04 45 07.000'	/ Image center Declination (dms)
RA	=	84.0932484125888	/ Image center Right Ascension (deg)
DEC	=	-4.75220744680848	/ Image center Declination (deg)
HISTORY	mean stacking with winsorized sigma clipping rejection (low=3.000 high=3		
HISTORY	.000), additive+scaling normalized input, normalized output, no image we		
HISTORY	ighting, equalized RGB		
HISTORY	TOP-DOWN mirror		
END			

Ready for Action

Altair

Capture Software

The type of software is referred to as "capture software" designed for acquisition and storage of images from a camera with selected properties to a computer via USB. With a rich number of tools the latest versions can perform much more than that, including plate-solving and telescope control.

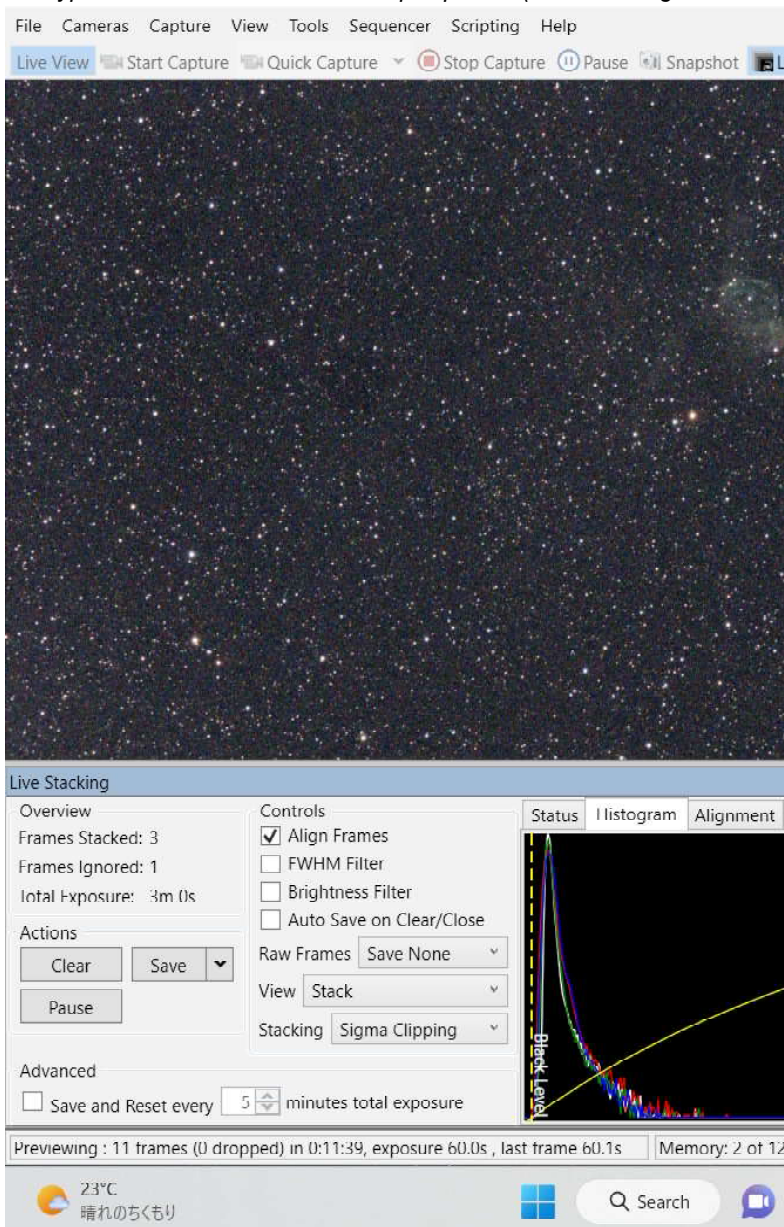
ZWO's **ASISStudio** software suite for Windows supports both planetary and deepsky imaging as well as "live stacking" which is the essential function for EAA. We appreciate that ASISStudio does not connect with cameras other than ZWO's fine range of dedicated CMOS cameras.

SharpCap 4 Pro by AstroSharp Limited is a fully fledged Windows application for most aspects of astronomical imaging and is compatible with cameras from all major manufacturers. SharpCap 4 provides a number of tools to assist improve imaging quality and comfort, including plate solving and polar alignment.

Generic "live stacking" is available in the free version, while the paid version adds "advanced live stacking" which allows image (histogram) processing of an image being stacked. An intuitive user interface contributes to a flat learning curve. SharpCap is accompanied by a detailed user manual, online or PDF, while numerous experienced users have posted videos on YouTube with tips and tricks, odds and evens, success and failure stories.

SharpCap 4 is free, SharpCap 4 Pro is available for 18 USD per year (as of Nov 2024), while its value for serious imaging way exceeds the fee. The manual alone contains over 300 pages.

▼ A typical Live Stack screen in SharpCap4 Pro (here showing the 'Thor'





Milky Way panorama of five panels taken in 2019 and 2021 with a Nikon-D5300 and 28mm lens.

Image Stacking is Averaging, not Adding of Images.

as *Helmet' nebula* in *Canis Major* after three captures).

The screenshot shows the N.I.C.E. software interface. The main window displays a live video feed of a starry sky. On the right side, there is a 'Camera Control Panel' with various settings. Below it is the 'Camera Controls' section, which includes sliders for Exposure (60.0 s), Gain (300), and other parameters. At the bottom, there is an 'Image Controls' section with White Balance settings. A status bar at the bottom indicates '3 Stacked, 1 Ignored, 3m 0s'.

Eagle Nebula, Messier 16

The simple setup for the following test includes an autoguided TS71SDQ quadruplet APO with LPR filter and an Uranus-C (IMX585) camera without filter. Depending on the telescope's back focus distance and focuser travel you may need an extension tube between telescope and camera to get into focus. The target object is the Eagle Nebula, M16 in Serpens. This section provides basic familiarity with the use of SharpCap 4 Pro capture software.

The first attempt with EAA should be experienced painlessly and simply.

Rule #1: Stack when the atmospheric condition is favorable. Thin layers of moving haze can cause halos around stars or ruin the exposures entirely with unwanted background artifacts.

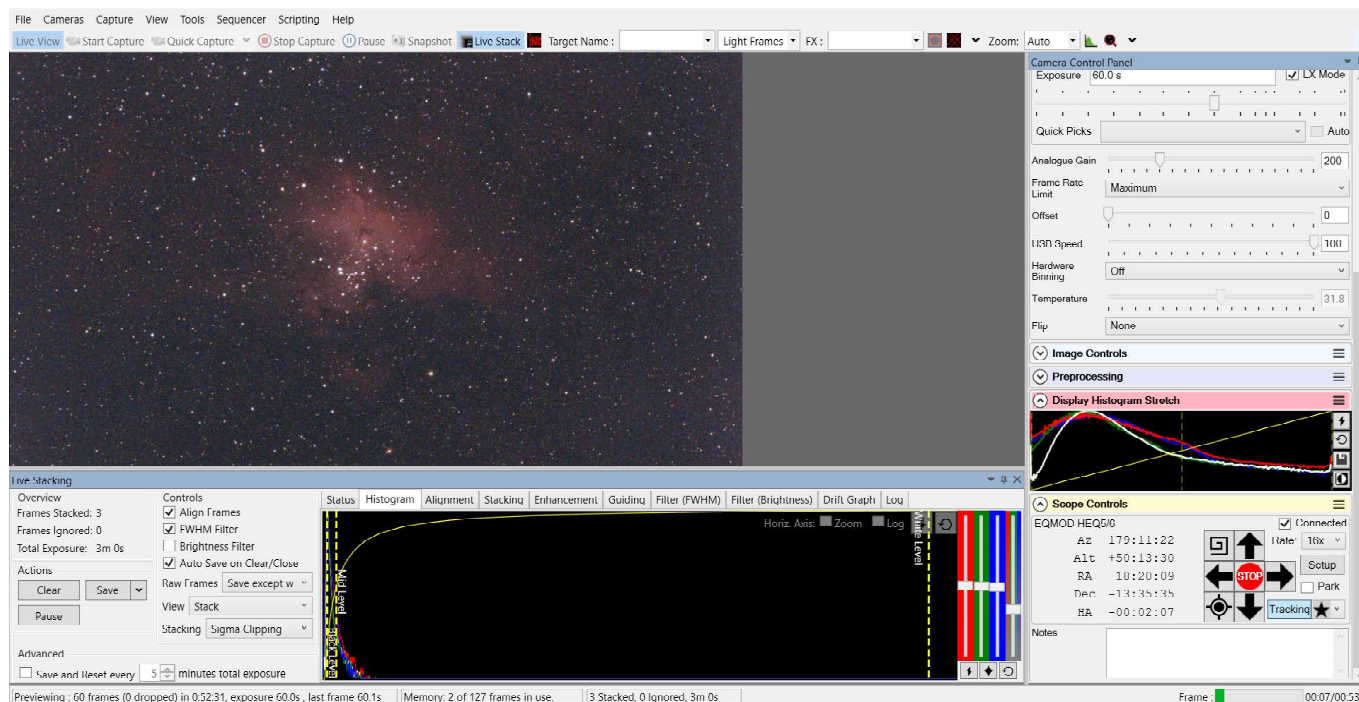
Rule #2: Focus must be pin-point and is the more critical the faster the focal ratio of the lens or telescope. If there are no distinct bright stars in SharpCap's preview field, use binning to increase the camera's sensitivity. If need be, increase gain so that you can see stars in the preview when exposure is around a second. A Bathinov mask will be of great help for focusing.

Rule #3: Make dark and flat frames and dither between light frames.

Rule #4: Use the FWHM filter to avoid stacking "bad" frames with blown out stars etc.

Rule #5: Confirm that all properties are set correctly, such as exposure, gain, ROI and file type.

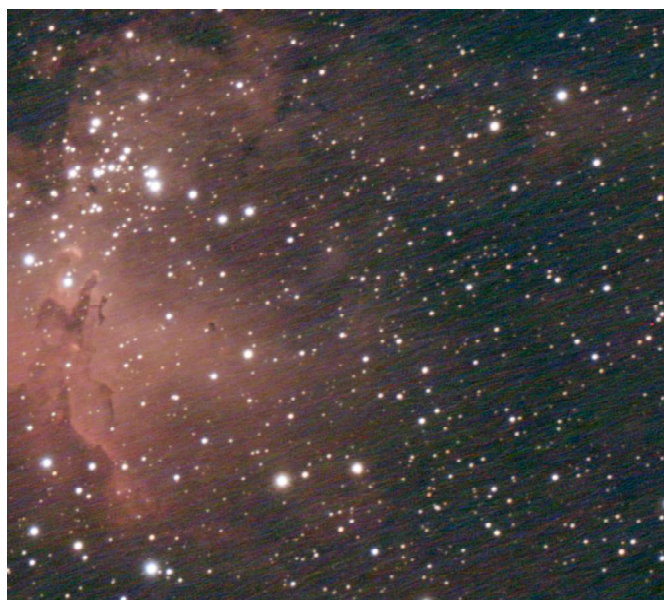
▼ *Live stack after 3 captures.*



Caution: please do not start Live Mode stacking when the main histogram is currently stretched. If so, reset the main histogram and start Live Stacking. You can then adjust the histogram in the Live Stack window to your liking.

You can selectively save light frames in FITS, TIF or PNG while live-stacking (Raw frames/ Save All) for later stacking and processing in other applications.

The appropriate exposure time depends on the "speed" of the lens or telescope. With the f/6.3 APO 60 seconds at gain 200 on the Eagle Nebula are appropriate. The bottom screen snap shows the image after stacking only three light frames without any calibration. You can already figure the faint contours of the Eagle Nebula.



▲ *Example of "Walking Noise". It is better to dither.*



▲ A single frame (60 sec, gain 200).



▲ After 10 light frames stacked.



▲ After 25 light frames stacked.

The three excerpts above demonstrate how noise is gradually cancelled out and details gained by stacking light frames. Of course, it does require more than merely 25 frames to get rid of noise efficiently. Theoretically, noise improvement is calculated as $\text{Sqrt}(\# \text{frames})$. In this example, $\text{Sqrt}(25) = 5x$ improved over a single frame. For reference, a 100x improvement would require 10,000 frames which is not realistic in practical applications.

Further processing and fine-tuning in
Siril and Photoshop.



▲ Messier 16, the Eagle Nebula in Serpens on 2023-08-13 12:17 UTC, stacked in Deepsky Stacker with 20 dark frames and processed in Siril and Photoshop. The result would be quite remarkable with better seeing and hours of integration though the "Pillars of Creation" in the center of the nebula have clearly surfaced in the final image.

About Image Calibration

Dark frames are exposures made with the same exposure time, gain and ambient temperature as the light frames, but with the objective lens covered. Dark frames hold thermal and electronic noise as

well as hot pixels which are subtracted from an image while stacking.

Equally important is "dithering" whereby the telescope mount is randomly shifted by a few pixels in between, say, every 5th light frame. Dithering

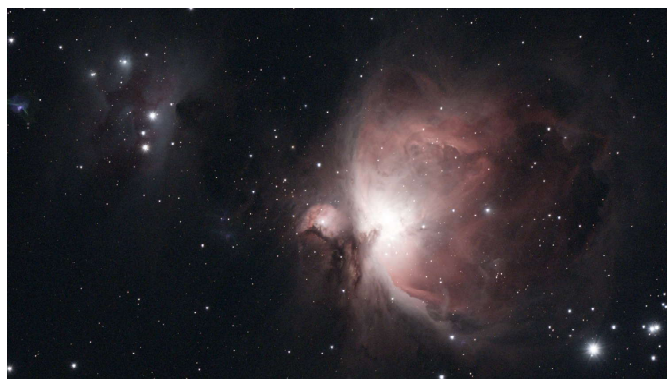
is supported by most capture or guiding software and helps reduce "walking noise" which is hard to come by without sacrificing detail during post processing (image on facing page).



Orion Nebula, Messier 42

This time the target is the bright Orion Nebula, M42. The simple setup for this test again includes an autoguided TS71SDQ quadruplet APO with LPR filter and an Uranus-C (IMX585) camera.

Since the Orion nebula is a bright object it can be marveled by attendees of a star party or other outreaches already after collecting the first frame. Further stacking will reduce noise and unveil more details and enrich contrast. Actually the image was clear after only 5 minutes.



▲ Image after stacking 5 frames.

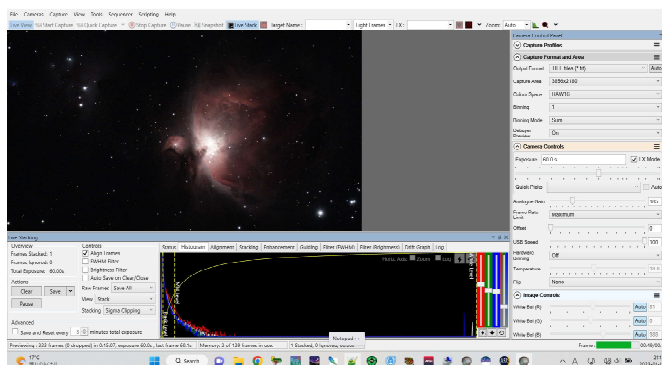
The field of view of the setup was just right to fit the Orion and Running Man nebulae.

The camera gain was set to 210 which is the "sweet spot" of the Uranus-C that keeps readout noise low at maximum possible dynamic range.

The ambient air temperature was 14.5°C, the sensor temperature merely 18.8°C attesting that the camera's passive cooling is effective.

▲ 2023-01-19 13:04 UTC

Final processed image of the Orion nebula, 53 x 60 seconds at gain 185 (4 x 15 seconds exposures blended over the nebula's bright core in Photoshop).



▲ The first frame of the Orion nebula. Bright objects can be viewed in their full glory after only 60 seconds. The rest of the live stacking job is noise cancellation by stacking more frames. Some 1500 light-years away in a minute on-screen!

It is important to pause stacking when clouds are crossing as the image will be contaminated with noise, likely ruined. Use Control/FWMH Filter.



▲ For reference, this image of the Horsehead nebula has been ruined by crossing clouds and haze.



▲ Image saved as seen on SharpCap4 without display stretch.

Open Cluster Messier 41

Telescope: TS-71SDQ (Ø71mm/450mm)
 Camera: Player One's Uranus-C (IMX585)
 Filter: Kenko Astro LPR II
 Exposure: 68 x 15 sec (17min) at gain 185
 Sensor temp: 22.3°C
 Designations: Messier 41
 Magnitude: 4.5 in Canis Major
 Distance: 2,320 ly
 Time stamp: 2023-02-07 13:14:58 UTC

Star clusters like the M41 are easy targets and do not require much exposure time. Gain can be increased as star clusters do not require much dynamic range for looking good. The higher noise level inherent to higher gain can be compensated for with a large number of light frames to stack.

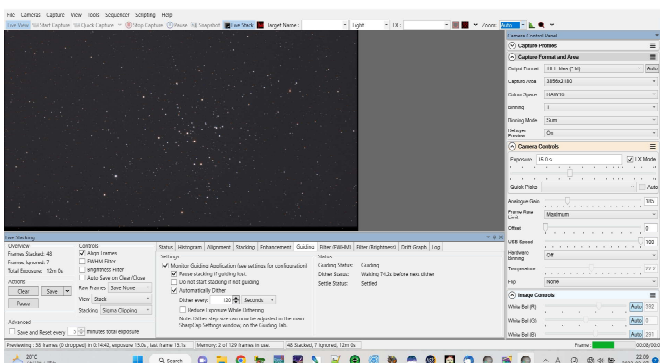
The image at the top is the stack as seen without display stretch. The image at the bottom right is the stack saved by SharpCap, then further processed in Siril and Photoshop. The stretched image stack is contaminated with a number of hot sensor pixels. Next time better with dark frames? Yes, but no big issue for pure EAA purposes though.



▲ Hot (green, red and blue) sensor pixels can be calibrated away with dark frames.



▲ Processed with Siril and Photoshop CS2 from a live stack saved as FITS file by SharpCap Pro.



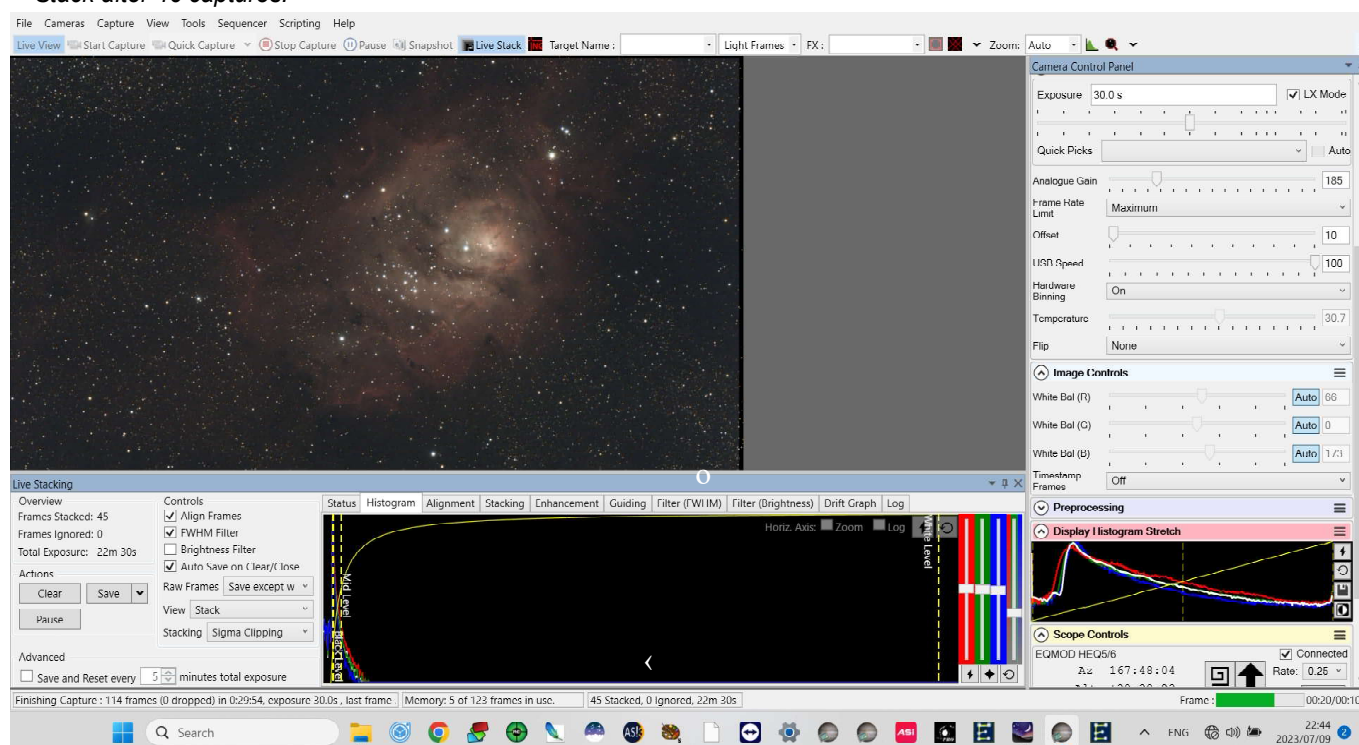


Lagoon Nebula, Messier 8

Telescope: TS-71SDQ (Ø71mm/450mm)
 Camera: Player One Uranus-C (IMX585)
 Filter: Baader UV/IR-Cut CMOS optimized
 Exposure: 243 x 30 sec (2 hrs) at gain 185
 Sensor temp: 31°C (ambient 28°C, 85%RH)
 Designations: Messier 8, Lagoon Nebula
 Magnitude: 4.6 in Sagittarius
 Distance: 4,100 ly
 Image scale: 1.329"/px, width: 1.37°
 Image FOV: 1.37° x 0.77°
 Time stamp: 2023-07-09 13:21 UTC

The image above is not the live stack but composed of individual light frames saved by SharpCap4 Pro in FITS format. The FITS files were stacked in Deepsky Stacker with a master file of 20 dark frames and pre-processed in Siril, then fine tuned in Photoshop. In parallel to live stacking SharpCap supports saving of single light frames for further processing. Note that dark frames zero out hot pixels and noise inherent to warm camera sensors. The image below shows the SharpCap screen after stacking 46 frames. Note the small difference between sensor and ambient temperature.

▼ Stack after 46 captures.





Dumbbell Nebula, Messier 27

Telescope: TS-71SDQ (Ø71mm/450mm)
 Camera: Player One's Uranus-C (IMX585)
 Filter: Baader UV/IR-Cut CMOS optimized
 Exposure: 85 x 30 sec (42 min) at gain 185
 Sensor temp: 30°C (ambient 28°C, 85%RH)
 Designations: Messier 27, Dumbbell Nebula
 Magnitude: 7.4 in Vulpecula
 Distance: 1,360 ly
 Image scale: 1.329"/px, width: 1.34°
 Time stamp: 2023-07-09 15:37 UTC

The image above is not the live stack but composed of individual light frames saved by SharpCap4 Pro in FITS format. The FITS files were stacked in Deepsky Stacker with a master file of 20 dark frames and pre-processed in Siril, then fine tuned in Photoshop. In parallel to live stacking SharpCap allows saving of single light frames for further processing. Note that dark frames zero out hot pixels and noise inherent to warm camera sensors. The image below shows the SharpCap screen after stacking 74 frames. The FOV varies from the previous image of Messier 8, the Lagoon nebula, because it was cropped to different dimensions.

▼ Stack after 74 captures or 37 minutes.



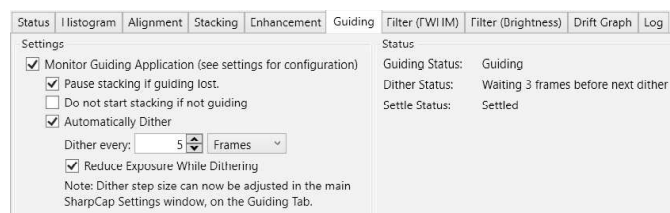
Trifid Nebula, Messier 20

The image above is not the live stack but processed from individual light frames saved by SharpCap4 Pro in FITS format.

The Trifid Nebula is one of the many gems in the Milky Way crossing Sagittarius and a fine target for EAA because of its reddish and blueish colors.

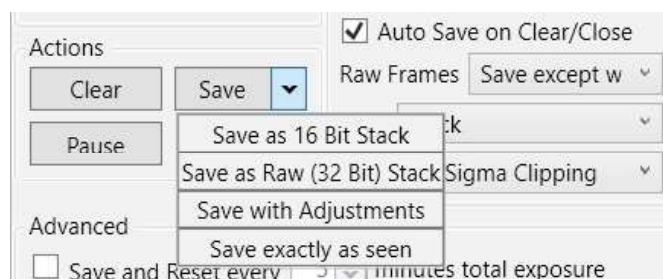
Telescope: TS-71SDQ (Ø71mm/450mm)
 Camera: Player One Uranus-C (IMX585)
 Filter: Kenko Astro LPR II
 Exposure: 116 x 60 sec (116 min), gain 185
 Sensor temp: 31°C (ambient 27°C, 95%RH)
 Designations: Messier 20, NGC 6514, Trifid Nebula
 Magnitude: 6.3 vis in Sagittarius
 Distance: 5,200 ly
 Image scale: 1.329"/px, width: 1.34°
 Time stamp: 2023-08-18 11:02 UTC

Every fifth image has been dithered to cancel out "walking noise" in the background. SharpCap monitors the autoguiding software PHD2 and sends a dither command in selected intervals. Dithering does make a huge difference in addition to dark frames for noise cancellation resulting in a cleaner, even background.



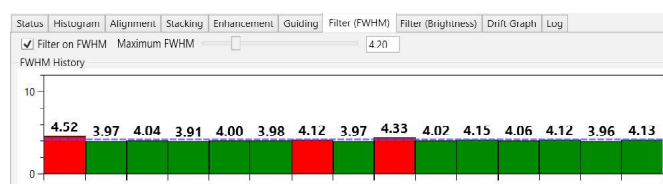
▲ SharpCap's Guiding Monitor connects to PHD2 for dithering and stacking control based on the state of autoguiding.

HINT: The audience can only view the image while it is growing on the screen. Be sure to always save individual light frames for further manipulation in other applications. After final processing you can send or print the image on a post card, perhaps annotated, as a souvenir to all members of the audience. Of course, you may as well save and use the final live stack "exactly as seen".



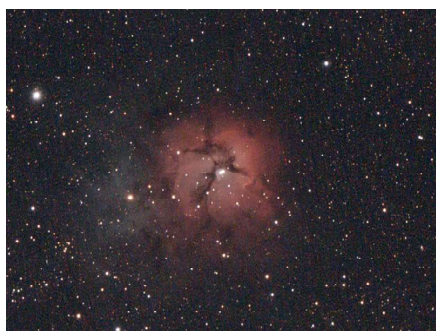
▲ Saving the current stack.

SharpCap's FWHM Filter prevents low quality frames from being stacked. The filter was set to 4.2 which is a generous given the high humidity that night and the low altitude of the nebula. The threshold should be selected with respect to the seeing condition, the lower the stricter. FWHM is also a measure for how much a star is dispersed over sensor pixels as a result of poor seeing or elongated due to inaccurate guiding.

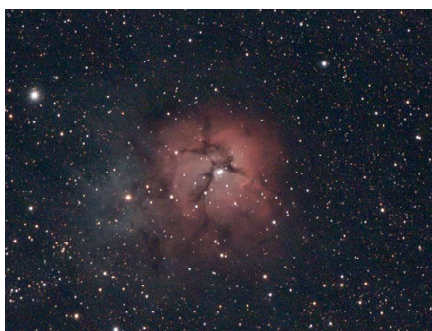


▲ FWHM Filter set to 4.20. The red frames are exempted from stacking.

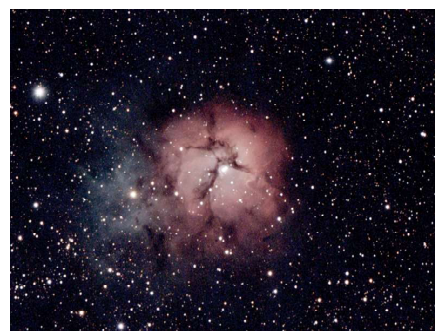
Saved exactly as seen on screen



▲ Stack after 5 captures.



▲ Stack after 25 captures.



▲ Stack after 50 captures.

Western Veil Nebula, NGC 6960



The image above is not the live stack but processed from individual light frames saved by SharpCap4 Pro in FITS format. The capture parameters are the same as used for the Trifid on the facing page.

Telescope: TS-71SDQ (Ø71mm/450mm)
Camera: Player One Uranus-C (IMX585)
Filter: Kenko Astro LPR II
Exposure: 80 x 60 sec (80 min), gain 185
Sensor temp: 31°C (ambient 27°C, 95%RH)
Designations: Caldwell 34, NGC 6960, Western Veil
Magnitude: 6.3 in Cygnus
Distance: 2,500 ly
Image scale: 1.329"/px, width: 1.34°
Time stamp: 2023-08-18 13:31 UTC

Positioned near the zenith during capturing, the average FWHM during live stacking was 3.6 which is not that bad. When imaging in high air humidity a high FWHM value can also signal dew on the objective lens of the telescope as stars disperse.

The Western Veil Nebula in Cygnus, is a supernova remnant consisting of interstellar matter and at visual magnitude 7 it is a faint widespread object, a challenge for EAA demanding good seeing and air transparency. It actually would require hours of integration for fine details and contrast. The excerpt below shows the stack after 10 frames which barely unveils the Veil Nebula. The background exhibits walking noise because the 10-frames-stack has been dithered only once after the 5th frame.



▲ In the center lies the 4.4 magnitude star 52 Cygni.

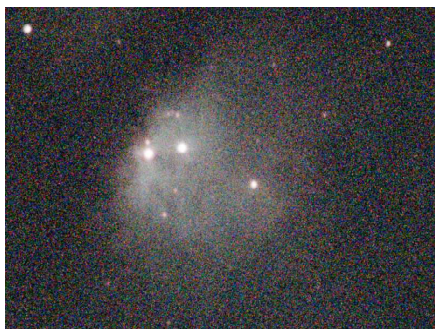


▲ Stacked in Siril using separately saved FITS raw frames.

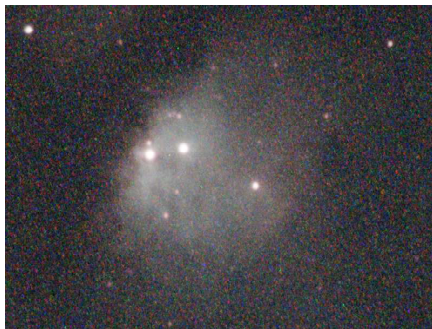
Reflection Nebula, Messier 78

Discovered in 1780, Messier 78 (a.k.a. NGC 2068) is a reflection nebula, a cloud of dust and gas reflecting the light of nearby stars. It is the brightest diffuse reflection nebula in the sky, with an apparent magnitude of 8.3. M78 lies at a distance of some 1,350 light years in Orion and is about 10 light years across or 8' x 6' apparent. M78 is illuminated by the stars HD 38563A and HD 38563B, both of spectral type B2 and have a combined luminosity of about 10,000 times that of the Sun. The M78 cloud contains a cluster of stars that is visible in infrared.

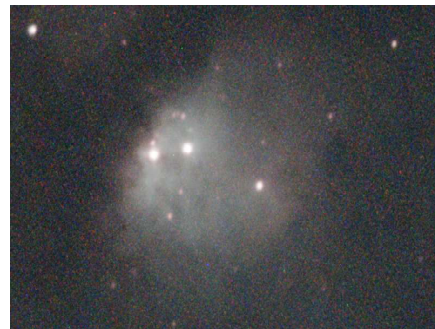
Telescope:	BKP150 (Ø150mm/750mm)
Camera:	Player One Uranus-C (IMX585)
Filter:	Sightron Quad Band
Exposure:	50 x 180 sec, gain 215
Sensor temp:	21°C (ambient 17°C, 77%RH)
Designations:	Messier 78, NGC 2068
Magnitude:	8.3 vis in Orion
Distance:	~1350 ly
Image scale:	0.798"/px, width: 47.85'
Time stamp:	2023-11-19 16:59 UTC



▲ Live stack after 1 capture (3 min).

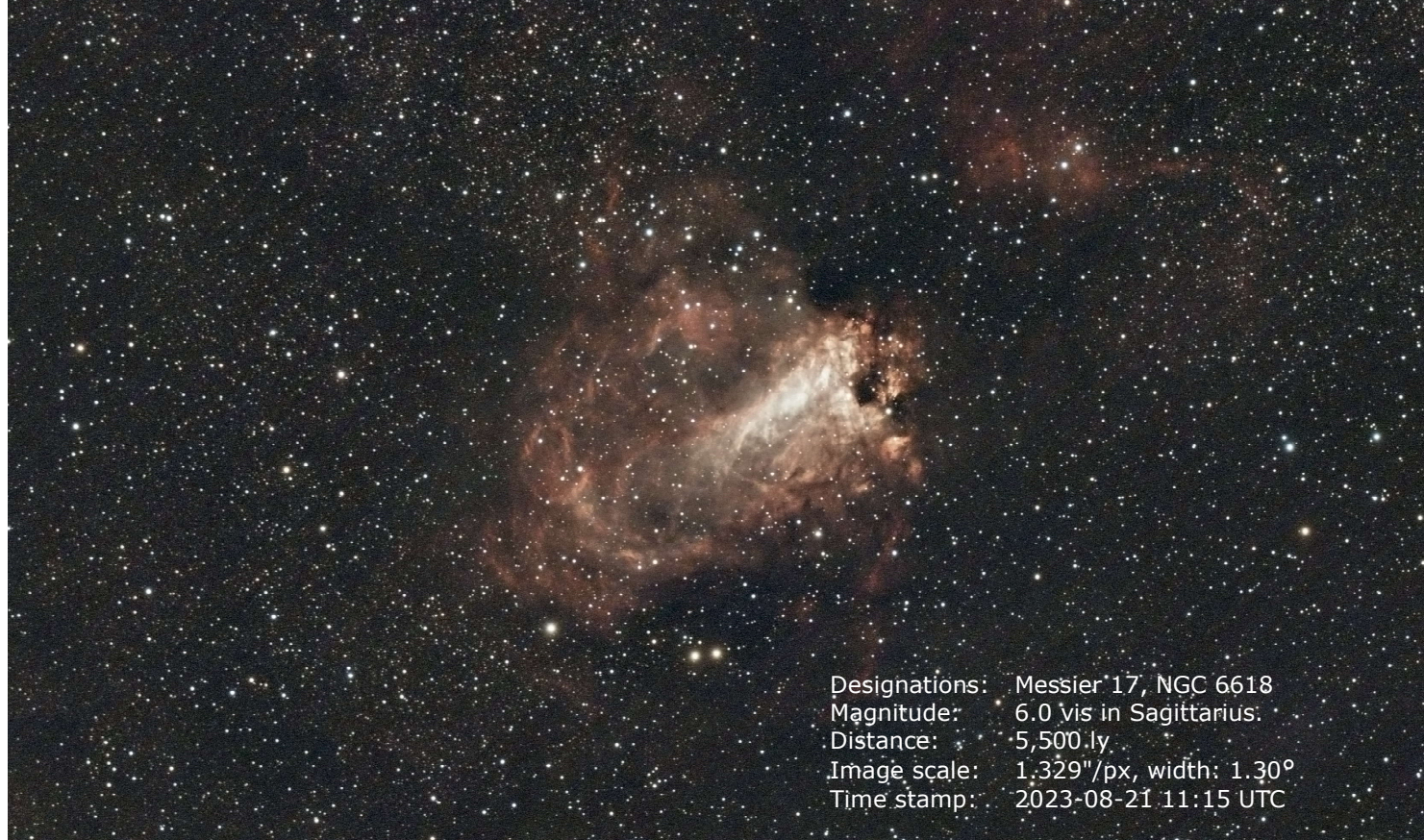


▲ Live stack after 4 captures (12 min).



▲ Live stack after 10 captures (30 min).

Since a quad-band filter was used and owing to the low surface brightness of the object the exposure time was extended to 180 seconds at gain 215 which provides best dynamic range. A coma corrector for the Newtonian was not used. The object appeared immediately with the first frame of 3 minutes in the live view of SharpCap 4.1 Pro without darks subtracted. Darks and flats were taken after the total exposure and processed with the raw FITS images.



Designations: Messier 17, NGC 6618
 Magnitude: 6.0 vis in Sagittarius.
 Distance: 5,500 ly.
 Image scale: 1.329"/px, width: 1.30°
 Time stamp: 2023-08-21 11:15 UTC

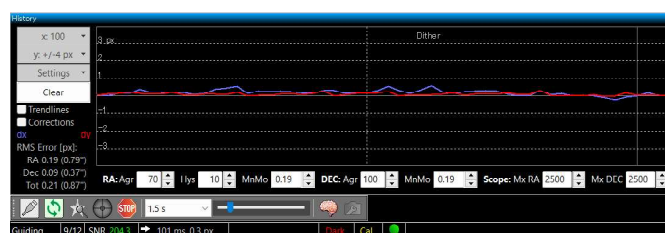
Omega Nebula, Messier 17

The image above is not the live stack but processed from individual light frames saved by SharpCap4 Pro in FITS format.

The Omega or Swan or Lobster nebula is one of the many gems in the Milky Way crossing Sagittarius and a fine target for EAA because of its reddish and white colors.

Gradually learning from previous mistakes this image has been dithered and dark subtracted during live stacking. Unfortunately, on that day crossing white clouds ruined about half of the light frames.

▼ *Live stack after only 3 frames saved as seen on screen.*



▲ *PHD2 guiding history.*

Accurate guiding is crucial. When a guide star is lost or its mass changed due to crossing clouds or haze, then PHD2 pauses guiding and SharpCap pauses stacking but it can still affect the separately saved light frames with trailing or duplicated stars.

SharpCap was set to perform Live Stacking and in parallel saved each raw light frame separately as FITS for later further processing.

In its Live Stack mode SharpCap can communicate with PHD2 for dithering. SharpCap will pause stacking when PHD2 cannot autoguide for any reason. Also, light frames will be skipped in case their FWHM value exceeds a selected threshold. Further, darks have been subtracted while live stacking and saving as FITS.

The use of dithering and dark subtraction is warmly recommended.

The Running Man Nebula

This nebula situated next to the Orion Nebula is a HII region and a bright nebula containing a reflection nebula. It is a fine target for an audience.

Telescope: TS-71SDQ (Ø71mm/450mm)
Camera: Player One Uranus-C (IMX585)
Filter: Baader UV/IR-Cut
Exposure: 55 x 60 sec, gain 200

Designations: NGC 1977, Running Man
Magnitude: 7.0 vis, distance: 1,500 ly
Image scale: 1.329"/px, width: 1.36°
Time stamp: 2023-09-08 19:38 UTC

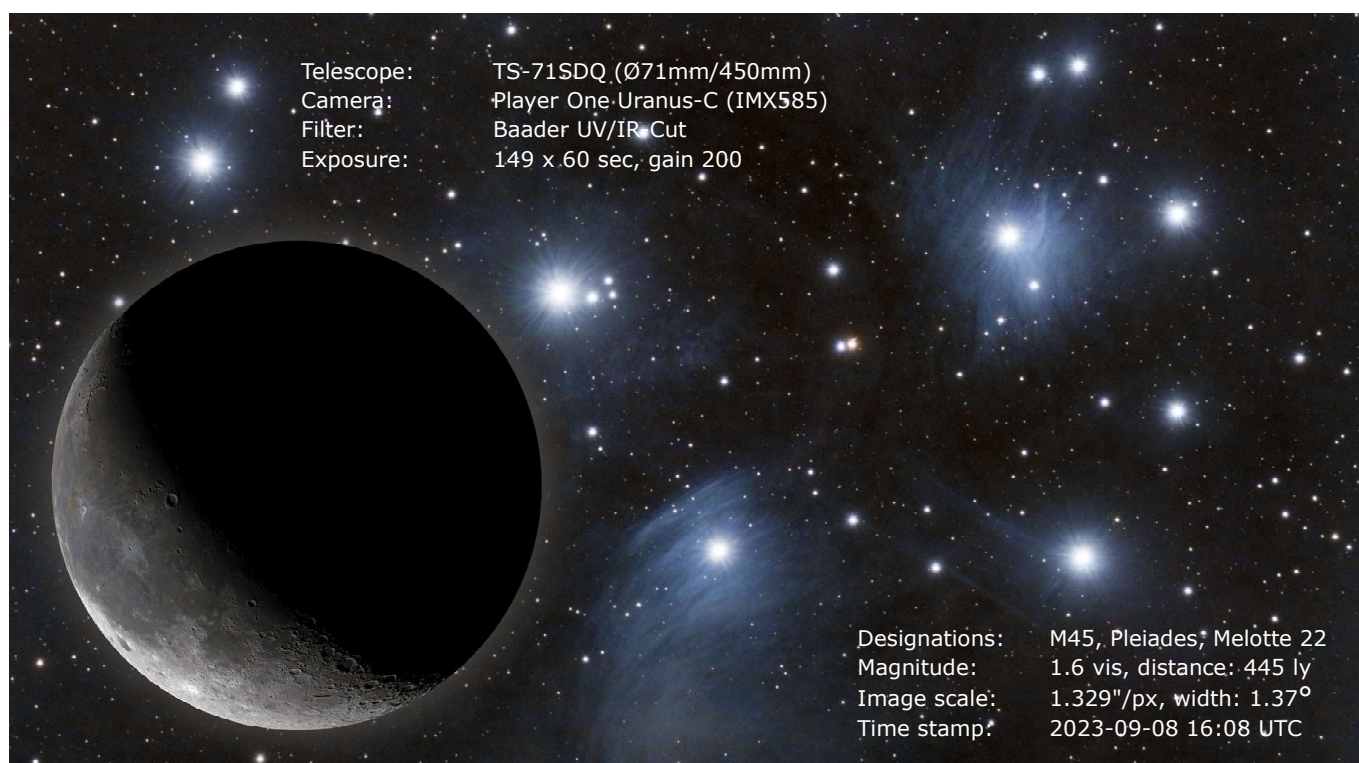
Pleiades, Messier 45



▲ Live stack after 4 captures.

The most famous bright open cluster in Taurus is an exciting target for an audience as it emerges with blue nebulosity already after a few light frames. A further processed image is always better as live stacking does not include background extraction but basic histogram tuning only. At the bottom center nebulosity enshrouds the star Merope.

The Moon taken in the same night at 19:14 UTC with the same telescope, camera and filter is inserted to image scale to depict the apparent sizes. A stack of 600 frames, 5ms at gain 180.



Telescope: TS-71SDQ (Ø71mm/450mm)
Camera: Player One Uranus-C (IMX585)
Filter: Baader UV/IR-Cut
Exposure: 149 x 60 sec, gain 200

Designations: M45, Pleiades, Melotte 22
Magnitude: 1.6 vis, distance: 445 ly
Image scale: 1.329"/px, width: 1.37°
Time stamp: 2023-09-08 16:08 UTC

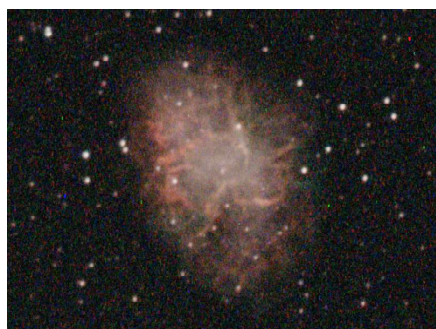


▲ Stacked in Siril using separately saved FITS raw frames.

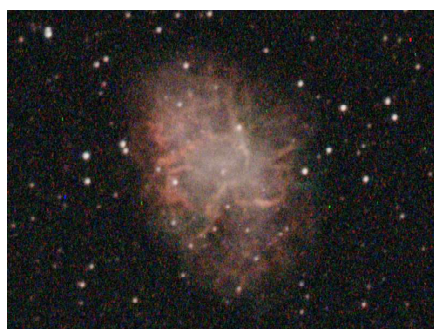
Crab Nebula, Messier 1

The Crab Nebula, Messier 1 in Taurus near the star Zeta Tauri is a supernova remnant which went nova in the year 1054 creating a bright "star" that was visible to the naked eye for almost two years. It is about 11 light years across (7' apparent), is illuminated by two B-class stars and expands at a rate of 1500 km per second. In its center lies a pulsar 28-30 km wide, rotating 30.2 times per second.

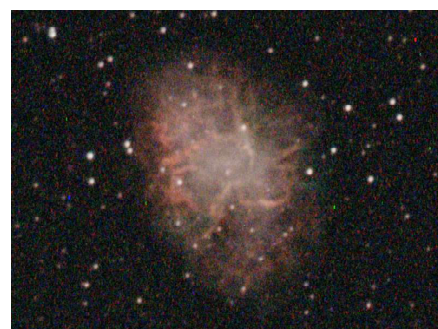
Telescope:	BKP150 (Ø150mm/750mm)
Camera:	Player One Uranus-C (IMX585)
Filter:	Sightron Quad Band
Exposure:	64 x 150 sec, gain 215
Sensor temp:	21°C (ambient 17°C, 77%RH)
Designations:	Messier 1, NGC 1952
Magnitude:	8.5 vis In Taurus
Distance:	~6500 ly
Image scale:	0.798"/px, width: 45.19'
Time stamp:	2023-11-19 14:02 UTC



▲ Live stack after 3 captures (7m30s).



▲ Live stack after 6 captures (15 min).



▲ Live stack after 12 captures (30 min).

Since a quad-band filter was used the exposure time was extended to 150 seconds at gain 215 which provides best dynamic range. A coma corrector for the Newtonian was not used. The object appeared immediately with the first frame of 2.5 minutes in the live view of SharpCap 4.1 Pro without darks subtracted. Darks and flats were taken after the total exposure and processed alongside the raw FITS images (final image above).



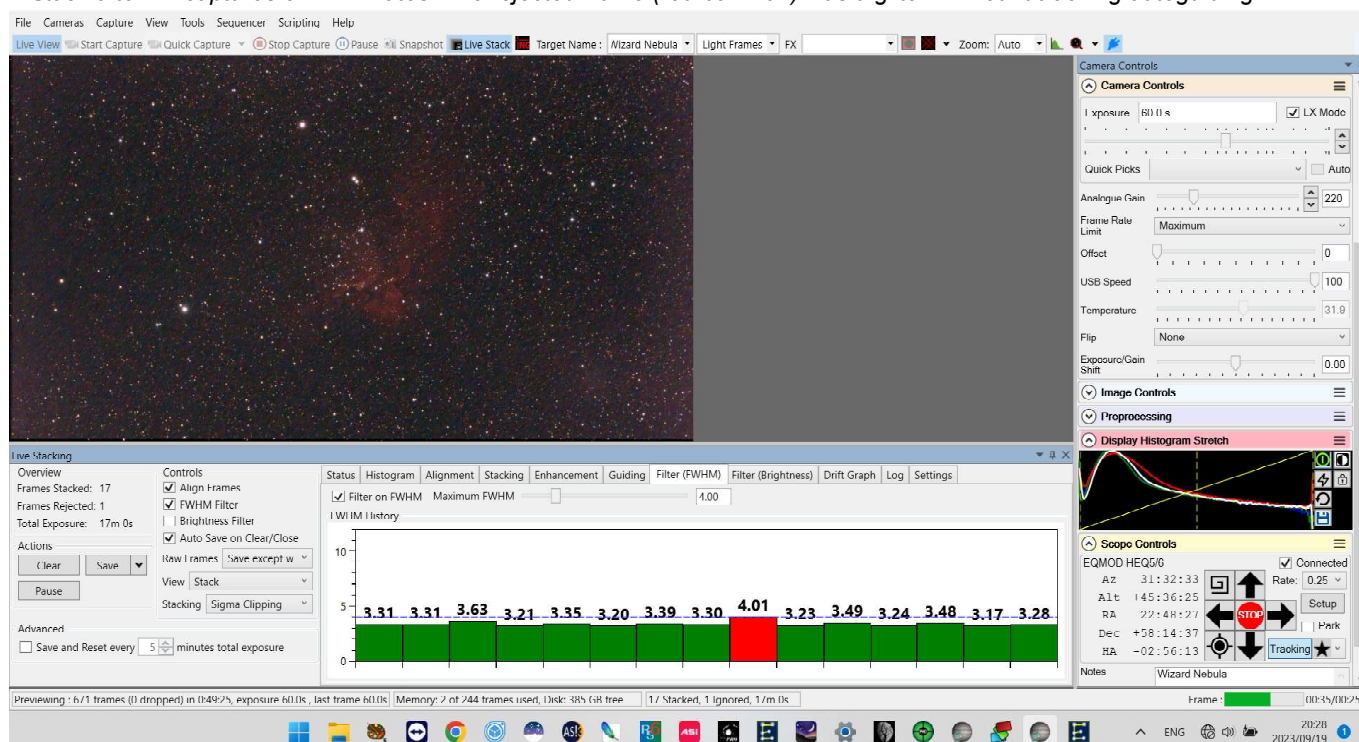
Wizard Nebula, NGC 7380

The impressively looking Wizard Nebula enshrouds the open star cluster NGC 7380 in Cepheus 110 light-years across. In this image the nebula spans about the size of the full moon.

An image processed from separately saved raw FITS files is always of better quality as live stacking algorithms are inferior because they are basically intended for live viewing only. Sharp-Cap Pro allows simple tuning such as histogram stretching and color balancing.

Telescope:	TS-71SDQ (Ø71mm/450mm)
Camera:	Player One Uranus-C (IMX585)
Filter:	Kenko Astro LPR II
Exposure:	138 x 60 sec, gain 220
Sensor temp:	32°C (ambient 27°C, >95%RH)
Designations:	NGC 7380, Sh2-142, Wizard
Magnitude:	7.2 vis in Cepheus
Distance:	8,500 ly
Image scale:	1.329"/px, width: 1.32°
Time stamp:	2023-09-19 11:10 UTC

▼ *Stack after 17 captures or 17 minutes. The rejected frame (red bar 4.01) was a glitch in mount tracking/autoguiding.*





Pacman Nebula, NGC 281

This time exposure time was extended from the usual 60 seconds to 90 seconds at the same gain of 220. One more reason for choosing short exposures is the number of frames you get for image noise reduction. At least 100 are required for a stack to obtain a 10 times improved SNR (theoretically). In spite of identical integration time there is some difference between short exposures and longer exposures. The longer the more details and color contrast. The yellowish and bluish stars in the Pacman image are not post-saturated. The image is a processed stack from raw images captured in Live Stack mode.

table { border: none; }
tr { border-bottom: 1px solid black; }
tr td { padding: 5px 0; }

Telescope:

Camera:

Filter:

Exposure:

Sensor temp:

Designations:

Magnitude:

Distance:

Image scale:

Time stamp:

TS-71SDQ (Ø71mm/450mm)

Player One Uranus-C (IMX585)

Kenko Astro LPR II

139 x 90 sec, gain 220

32°C (ambient 27°C, >95%RH)

NGC 281, IC 11, Pacman Nebula

7.3 vis in Cassiopeia

9,500 ly

1.329"/px, width: 1.35°

2023-09-20 12:23 UTC

▼ A stack of 5 frames or 7.5 minutes (histogram-stretched).



▼ A stack of 55 frames or 1.4 hours (histogram-stretched).





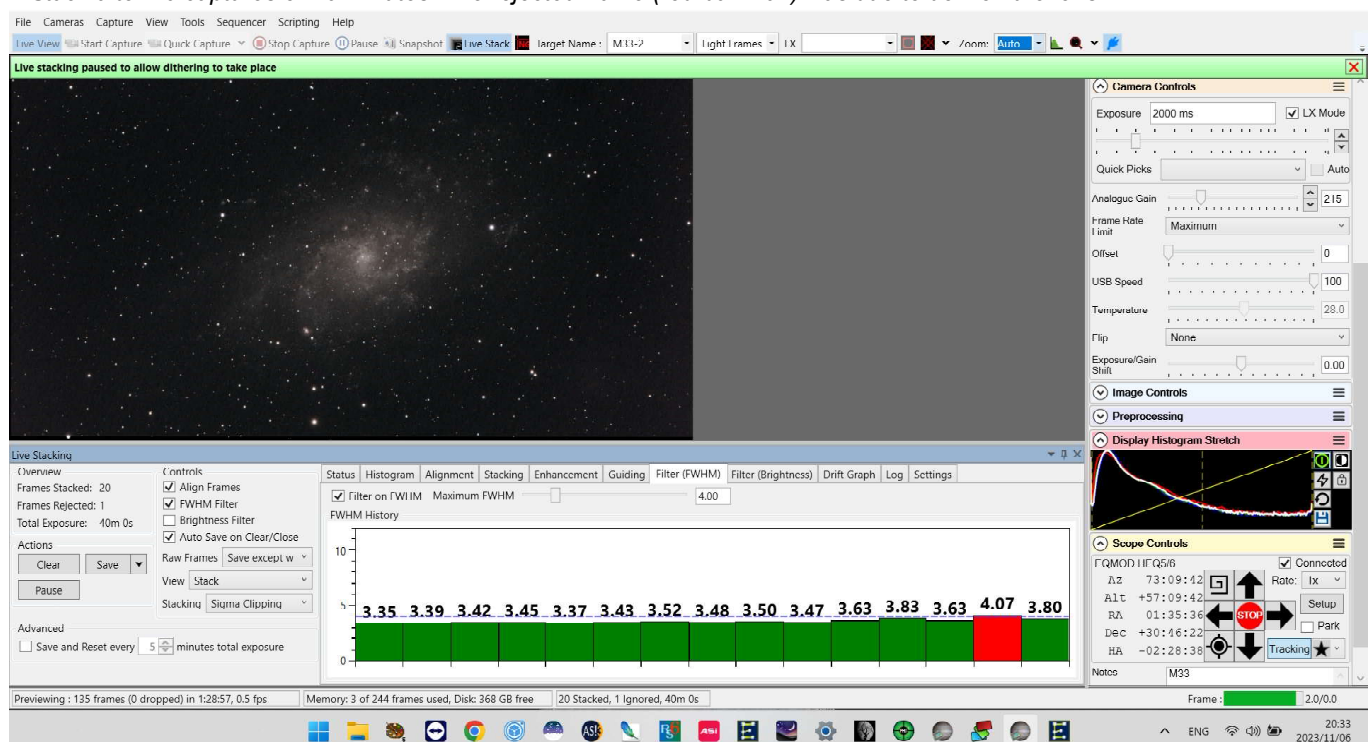
▲ Stacked in Siril using separately saved FITS raw frames..

Triangulum Galaxy, Messier 33

Shining at visual magnitude 5.7 at a distance of 2.75 million light-years away in the small constellation of Triangulum the second-brightest galaxy also cataloged as Messier 33 and dubbed "Triangulum Pinwheel", is 62000 light-years across and contains about 40 billion stars. For imagers on Earth the object extends over 70' × 40' and its outer arms are a challenge requiring long integration time and a transparent, calm atmosphere.

Telescope:	TS-71SDQ (Ø71mm/450mm)
Camera:	Player One Uranus-C (IMX585)
Filter:	Kenko Astro LPR II
Exposure:	87 x 120 sec, gain 215
Sensor temp:	28°C (ambient 23°C, >95%RH)
Designations:	Messier 33
Magnitude:	5.7 vis in Triangulum
Distance:	2.8 mio ly
Image scale:	1.329"/px, width: 1.36°
Time stamp:	2023-11-06 10:53 UTC

▼ Stack after 20 captures or 40 minutes. The rejected frame (red bar 4.07) was due to dew on the lens.





▲ *Stack after 1 capture or 2 minutes.*



▲ *Stack after 5 captures or 10 minutes.*



▲ *Stack after 10 captures or 20 minutes.*



▲ *Stack after 20 captures or 40 minutes.*

The sequence of four screen shots above witnesses that stacking is the key to more details with less noise and increased dynamic range. The effect of stacking is apparent for the eyeball during the first few frames. Subsequent frames will contribute a lot to the final stack but the changes are less apparent like a flattening curve when watching the stacking process live. The image was dithered every five frames with dark frames subtracted while stacking.

Accurate autoguiding is crucial as the field of view is just over a degree with the used telescope and camera. This image was guided with an IMX178 monochrome camera on a Samyang 135mm prime lens operating at f2. This luxury combination results in pinpoint guide stars even when the field has no bright stars. If the intensity and SNR of a guide star is still insufficient, try binning the camera 2 x 2 in PHD2 and have the software select a guide star automatically.



▲ Stacked in Siril using separately saved FITS raw frames.

Thor's Helmet, NGC 2359

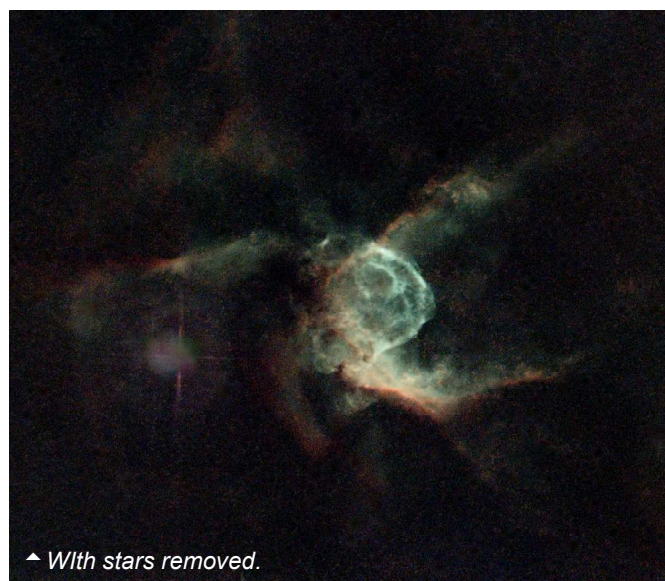
Designated NGC 2359 or Sh2-298, "Thor's Helmet" is a faint 11.4 magnitude emission nebula and HII ionized region some 15000ly away in Canis Major. It spans about 30ly in space and 9' x 6' apparent in the sky. The nebula resembles a bubble with filament structures that have been inflated by a central 50,000°C hot Wolf-Rayet star, HD 56925, which generates strong radiation pressure blowing the outer shells of the nebula into space at 25km/s on average. The bubble is composed of a mixture of material lost by the Wolf-Rayet star in a previous ejection and surrounding interstellar medium. The bubble's mass is estimated to be between 70 and 140 solar.

For this image the Baader 2" MPCC Mark III Coma Corrector was used with extension to the camera to match the 55mm back focus of the corrector, which worked pretty well. The object would require at least another 3 hours integration but unfortunately clouds closed the sky. Anyway, a few structures can be seen inside the bubble portion of the nebula, the brightest star in there being HD 56926 which is the source of energy in the entire nebula.

The image was acquired with SharpCap Pro 4.1 in Live Stack mode. Each light frame was saved in FITS files alongside 10 darks, 20 flats and 26 bias frames (calibration frames) and stacked with 2x drizzle plus star reduction in Siril. Final touches in Photoshop CS2.

Telescope:	BKP150 (Ø150mm/750mm), CC
Camera:	Player One Uranus-C (IMX585)
Filter:	Sightron Quad Band
Exposure:	90 x 120 sec, gain 300
Sensor temp:	20°C (ambient 15°C, 50%RH)
Designations:	NGC 2359, Sh2-298
Magnitude:	11.4 vis in Canis Major
Distance:	~15000 ly
Image scale:	0.798"/px, width: 50.39'
Time stamp:	2024-02-11 10:29 UTC

Light mist in the air and a PM2.5 value of 22µg/m³ which is 4.4 times normal resulting in an average FWHM of poor 5.5".



▲ With stars removed.



▲ Stacked in Siril using separately saved FITS raw frames.

Silver Sliver Galaxy, NGC 891

Telescope: TS71SDQ (Ø71mm/450mm)
 Camera: Player One Uranus-C (IMX585)
 Filter: Kenko Astro LPR II
 Exposure: 222 x 60 sec, gain 220
 Sensor temp: 22°C (ambient 16°C, 77%RH)
 Designations: NGC 891, Caldwell 23
 Magnitude: 10.8 vis in Andromeda
 Distance: ~30 million ly
 Image scale: 1.329"/px, width: 4.6°
 Time stamp: 2023-12-08 11:51 UTC

A small faint edge-on unbarred galaxy which would require a longer focal length for more details but it does look impressive with lots of free space around. Anyhow, the dust lane running along the disk can be clearly distinguished. In terms of luminosity and size, it resembles our Milky Way galaxy if viewed from the same distance and apparent tilt angle.

NGC 891 spans some 125,000 ly in space and only 13.5' x 2.5' apparent in the sky.



▲ Live stack after 1 capture (3 min).



▲ Live stack after 30 captures (90 min).

Images with a 135mm Lens



▲ Pleiades, Messier 45

Telescope: Samyang lens (Ø64mm/135mm)
Camera: Player One Uranus-C (IMX585)
Filter: Kenko Astro LPR II
Exposure: 52 x 120 sec, gain 220
Designations: Messier 45, Melotte 22
Constellation: Taurus
Distance: 444 ly
Image scale: 4.431"/px, width: 4.59°
Time stamp: 2023-12-13 09:59 UTC

▼ Horsehead, IC434

Telescope: Samyang lens (Ø64mm/135mm)
Camera: Player One Uranus-C (IMX585)
Filter: Kenko Astro LPR II
Exposure: 81 x 120 sec, gain 220
Designations: IC 434, Barnard 33
Constellation: Orion
Distance: 1375 ly
Image scale: 4.432"/px, width: 4.64°
Time stamp: 2023-12-13 12:51 UTC

All images stacked in Siril using separately saved FITS raw frames.



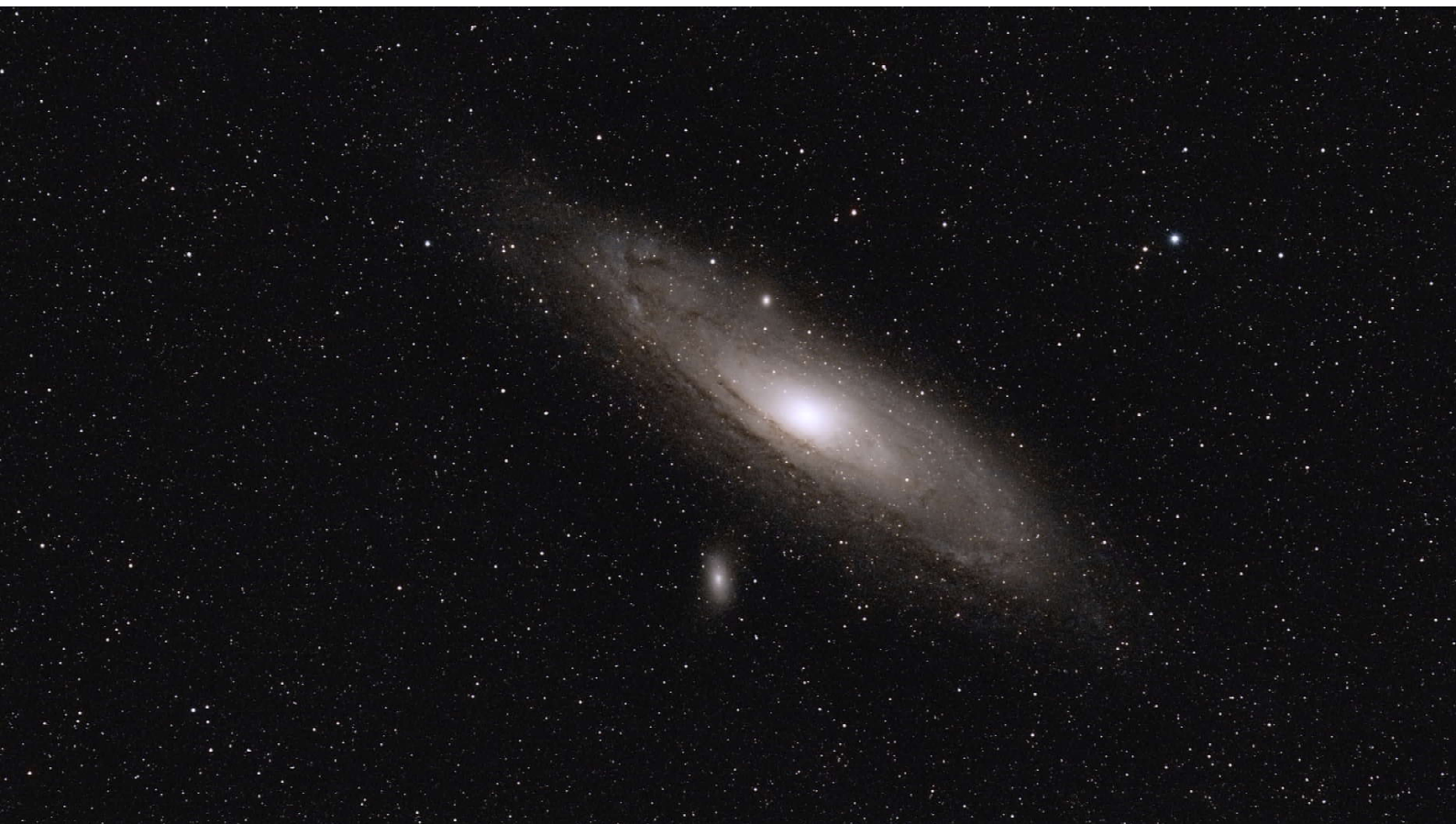


▲ Orion Nebula, Messier 42

Telescope: Samyang lens (Ø64mm/135mm)
Camera: Player One Uranus-C (IMX585)
Filter: Kenko Astro LPR II
Exposure: 180 x 60 sec, gain 220
Designations: M42, NGC 1976, LBN 974
Constellation: Orion
Distance: 1345 ly
Image scale: 4.431"/px, width: 4.59°
Time stamp: 2023-12-14 13:05 UTC

▼ Andromeda Galaxy, Messier 31

Telescope: Samyang lens (Ø64mm/135mm)
Camera: Player One Uranus-C (IMX585)
Filter: Kenko Astro LPR II
Exposure: 37 x 60 sec, gain 220
Designations: M31, NGC 224
Constellation: Andromeda
Distance: 2.5 millllion ly
Image scale: 4.432"/px, width: 4.62°
Time stamp: 2023-12-15 09:33 UTC



Images with 135mm Lens, continued



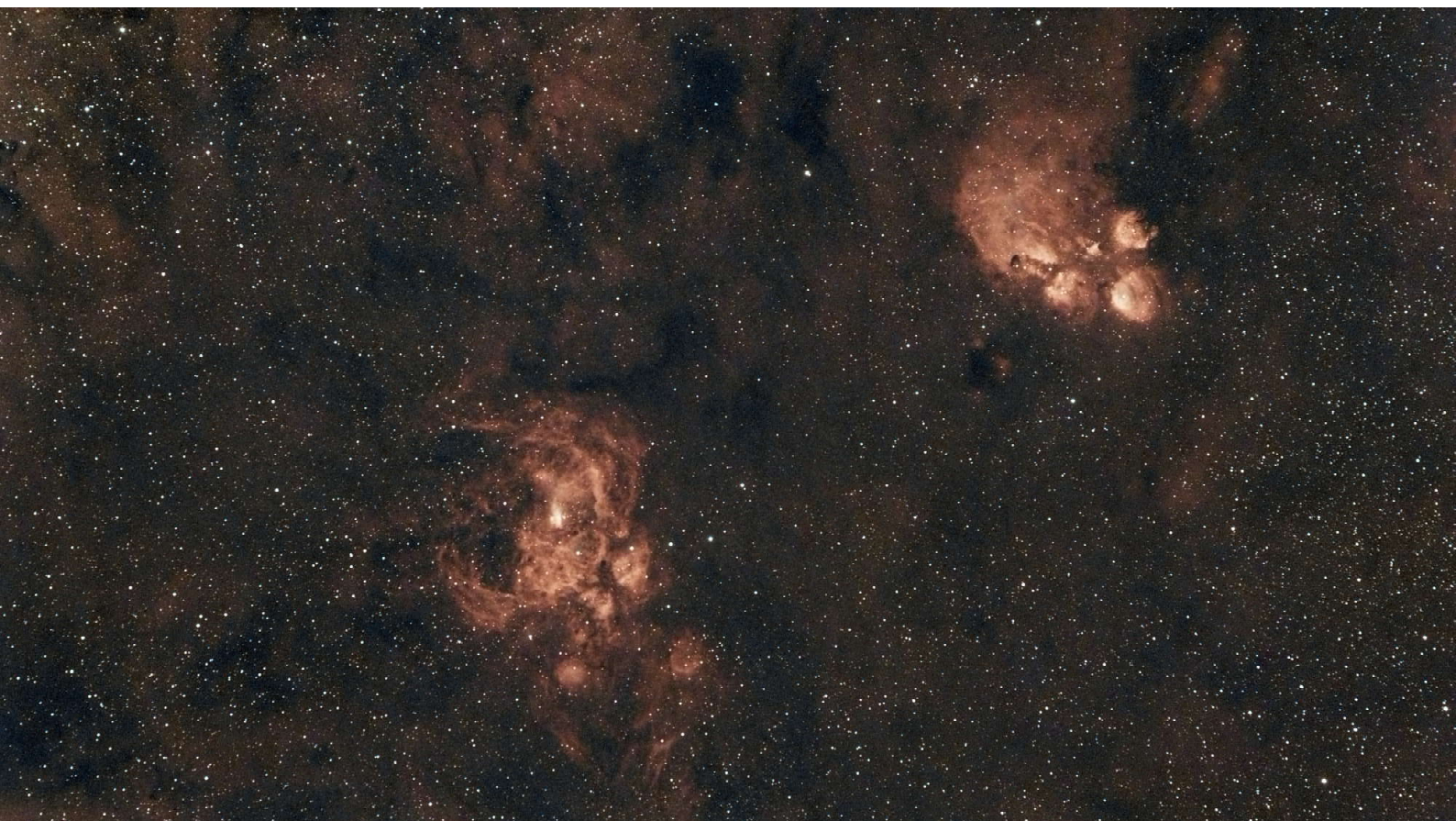
▲ Rosette Nebula, NGC 2244

Telescope: Samyang lens (Ø64mm/135mm)
Camera: Player One Uranus-C (IMX585)
Filter: Kenko Astro LPR II
Exposure: 40 x 120 sec, gain 220
Designations: NGC 2244, Caldwell 49
Constellation: Gemini
Distance: 5200 ly
Image scale: 4.426"/px, width: 4.68°
Time stamp: 2024-01-01 11:58 UTC

▼ Lobster & Cat's Paw Nebulae

Telescope: Samyang lens (Ø64mm/135mm)
Camera: Player One Uranus-C (IMX585)
Filter: Sightron dual-band
Exposure: 129 x 60 sec, gain 220
Designations: NGC 6357 and NGC 6334
Constellation: Scorpius
Distance: 5900 ly and 4400 ly
Image scale: 4.426"/px, width: 4.68°
Time stamp: 2024-08-01 11:34 UTC

All images stacked in Siril using separately saved FITS raw frames.





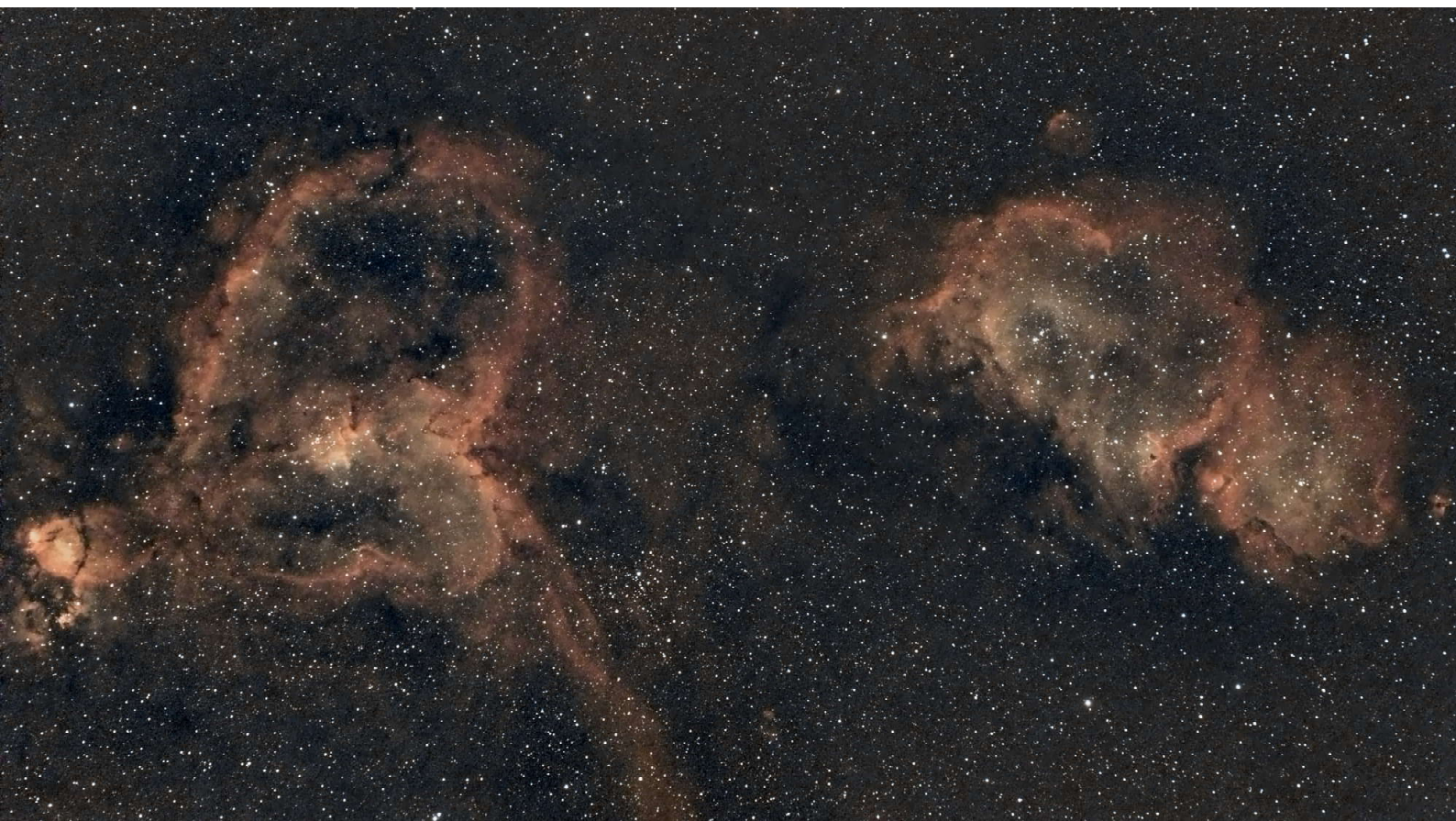
▲ IC 1396, Elephant Trunk

Telescope: Samyang lens (Ø64mm/135mm)
Camera: Player One Uranus-C (IMX585)
Filter: Sightron dual-band
Exposure: 137 x 60 sec, gain 220
Designations: IC 1396
Constellation: Cepheus
Distance: 2400 ly
Image scale: 4.426"/px, width: 4.68°
Time stamp: 2024-08-13 13:00 UTC

▼ Heart & Soul Nebulae

Telescope: Samyang lens (Ø64mm/135mm)
Camera: Player One Uranus-C (IMX585)
Filter: Sightron dual-band
Exposure: 58 x 60 sec, gain 220
Designations: IC 1805 and IC 1848
Constellation: Cassiopeia
Distance: 7500 ly
Image scale: 4.426"/px, width: 4.68°
Time stamp: 2024-11-03 12:33 UTC

All images stacked in Siril using separately saved FITS raw frames.



Images with 135mm Lens, continued



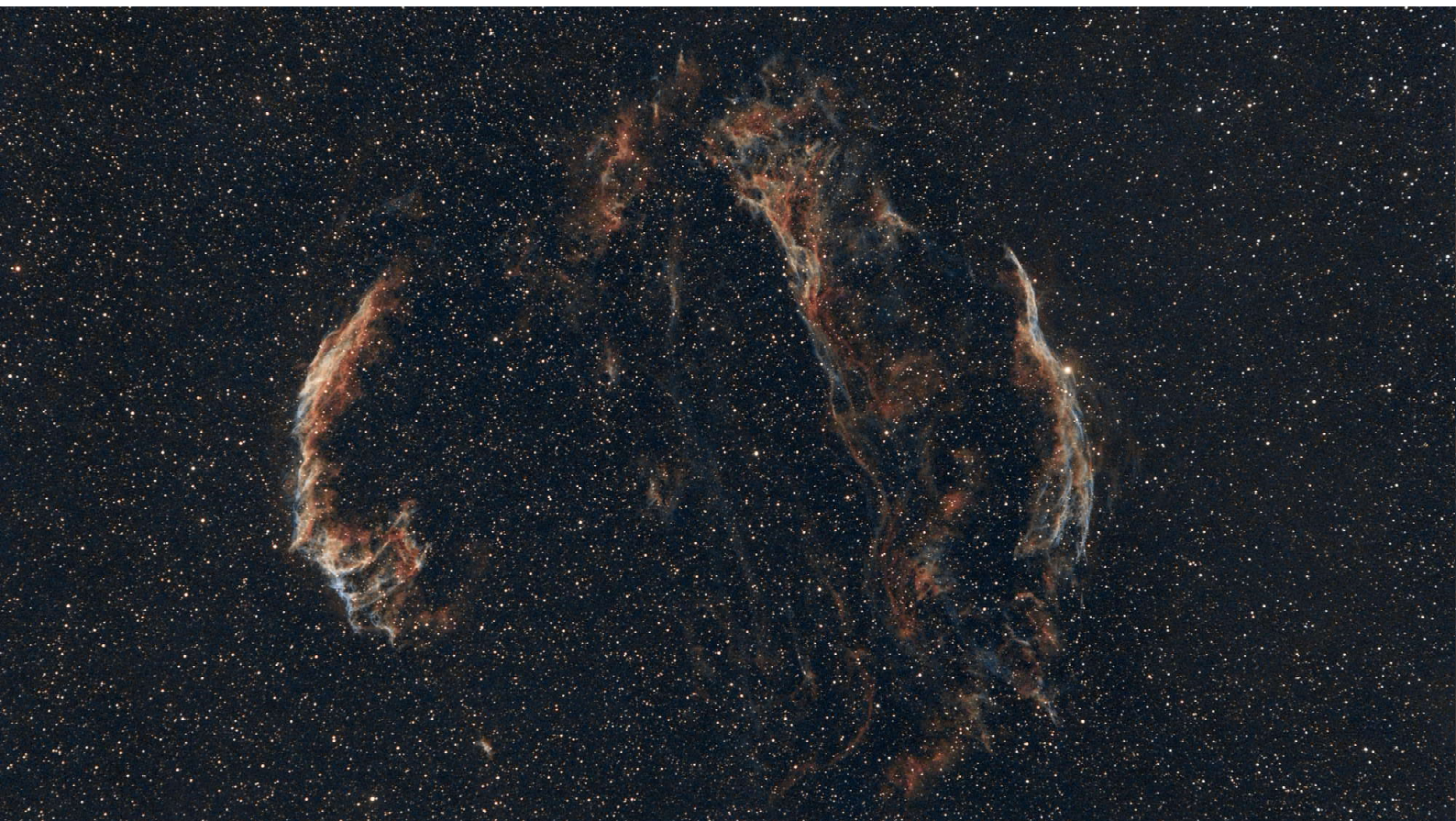
▲ Lagoon Nebula, Messier 8

Telescope: Samyang lens (Ø64mm/135mm)
Camera: Player One Uranus-C (IMX585)
Filter: Kenko Astro LPR II
Exposure: 40 x 120 sec, gain 220
Designations: NGC 2244, Caldwell 49
Constellation: Gemini
Distance: 5200 ly
Image scale: 4.426"/px, width: 4.68°
Time stamp: 2024-08-02 11:30 UTC

▼ Cygnus Loop

Telescope: Samyang lens (Ø64mm/135mm)
Camera: Player One Uranus-C (IMX585)
Filter: Sightron dual-band
Exposure: 219 x 60 sec, gain 220
Designations: NGC 6992 and NGC 6960
Constellation: Cygnus
Distance: 2700 ly
Image scale: 4.426"/px, width: 4.68°
Time stamp: 2024-08-11 11:19 UTC

All images stacked in Siril using separately saved FITS raw frames.





▲ North America Nebula

Telescope: Samyang lens (Ø64mm/135mm)
Camera: Player One Uranus-C (IMX585)
Filter: Sightron dual-band
Exposure: 208 x 60 sec, gain 220
Designations: NGC 7000
Constellation: Cygnus
Distance: 2600 ly
Image scale: 4.426"/px, width: 4.68°
Time stamp: 2024-07-31 11:36 UTC

▼ Sadr Region, Crescent

Telescope: Samyang lens (Ø64mm/135mm)
Camera: Player One Uranus-C (IMX585)
Filter: Sightron dual-band
Exposure: 36 x 60 sec, gain 220
Designations: Crescent Nebula NGC 6888
Constellation: Cygnus
Distance: 5000 ly
Image scale: 4.426"/px, width: 4.68°
Time stamp: 2024-08-12 11:20 UTC

All images stacked in Siril using separately saved FITS raw frames.



Images with 135mm Lens, continued



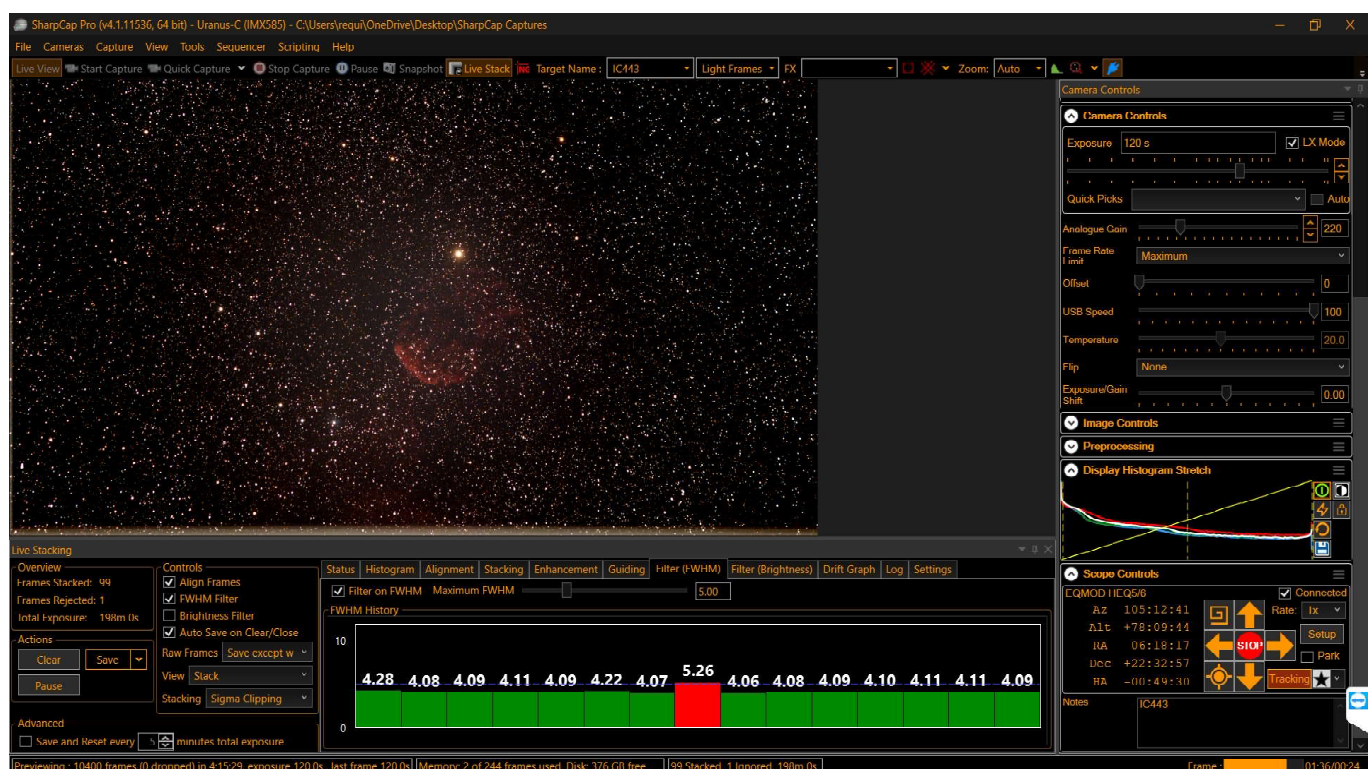
Jellyfish Nebula

Telescope: Samyang lens (Ø64mm/135mm)
Camera: Player One Uranus-C (IMX585)
Filter: Starry Night LPR + UV/IR-Cut
Exposure: 200 x 120 sec, gain 220
Designations: IC 443, Sh2-248
Magnitude: 12 vis in Gemini
Distance: 5000 ly
FWHM: 4.1 average
Image scale: 4.426"/px, width: 4.65°
Time stamp: 2024-01-05 10:35 UTC

Images stacked in Siril using separately saved FITS raw frames.

The Jellyfish nebula is a faint supernova remnant. The images on these pages have been taken simultaneously at different focal lengths and different cameras to showcase the difference between image scales. The resolution of the image on the facing page is theoretically 2.5x higher (4.43/1.8"/px). Both telescopes were saddled on the same mount and aligned in parallel (as accurate as it was).

The red bar on the FWHM graph occurs when you blow off dew with a hair dryer. This frame was automatically discarded from stacking.





▲ Stacked in Siril using separately saved FITS raw frames.

Heart Nebula, IC 1805

Telescope: TS71SDQ (Ø71mm/450mm)
 Camera: Player One Uranus-C (IMX585)
 Filter: Kenko Astro LPR II
 Exposure: 34 x 300 sec, gain 220
 Sensor temp: 25°C (ambient 20°C, 75%RH)
 Designations: NGC 1805, NGC 896
 Magnitude: 6 vis in Cassiopeia
 Distance: 7500 ly
 Image scale: 1.329"/px, width: 1.37°
 Time stamp: 2023-12-10 10:49 UTC

The image zooms in on the heart of the Heart Nebula which spans about 350 ly in space or 150' apparent in the sky. It is also dubbed the "Running Dog Nebula" (the "Running Man Nebula", NGC 1977, lies in Orion).

The excerpts below show the central part of the image which has been dithered every five frames. When the exposure time is long, say 5 minutes, the frequency of dithering should be increased in the interest of faster noise reduction. Long exposures help grab more details but require accurate autoguiding and an unobstructed sky. Throwing off ruined five-minute exposures is a real waste of photons though.

The colors of the stars in the image are bit exaggerated to emphasize the hot, blue stars of the Melotte 15 cluster in the center of the Heart Nebula.

The image shows only a part of the Heart Nebula because the FOV of the telescope/camera combination used is only about 1.42° wide uncropped while the nebula spans more than four full moons.

▼ Live stack after 1 capture (5 min).



▼ Live stack after 6 captures (30 min).





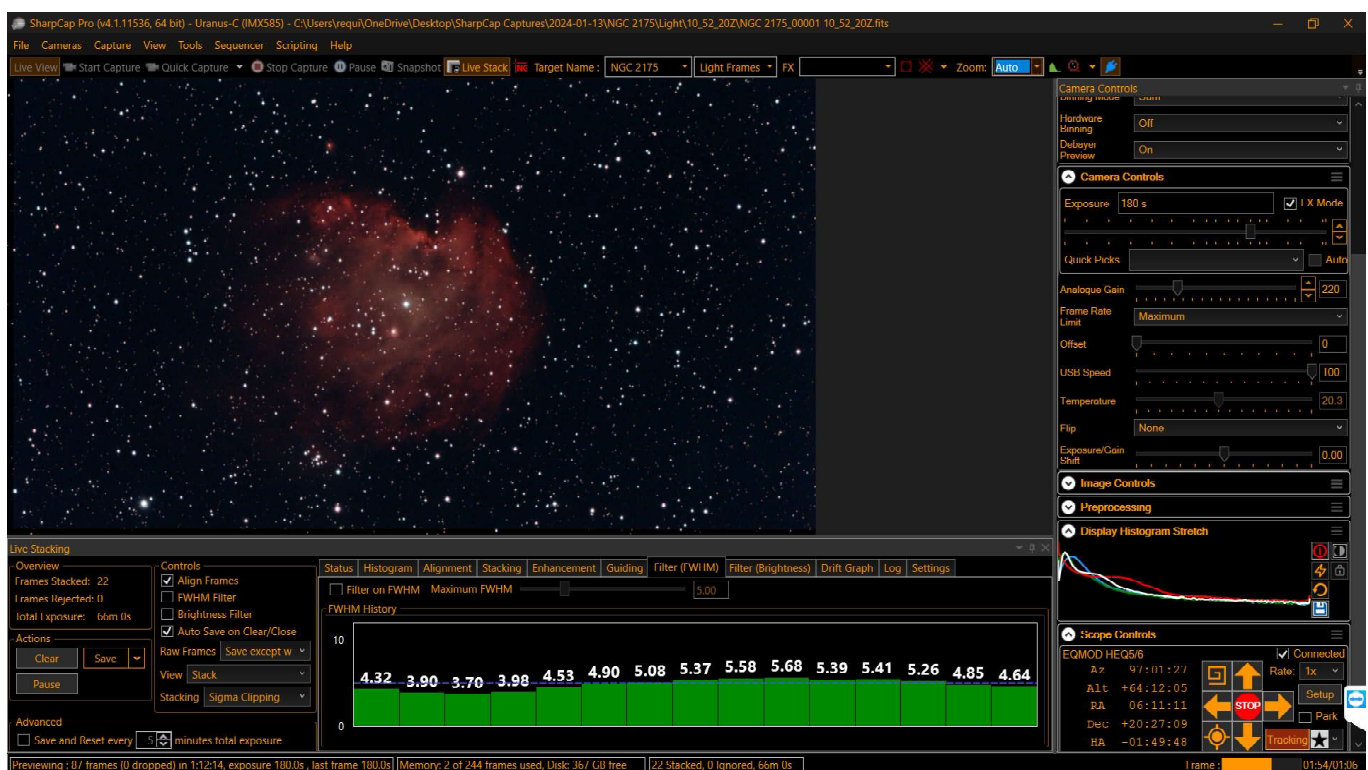
Monkey Head Nebula

Telescope: TS-71SDQ (Ø71mm/450mm)
 Camera: Player One Uranus-C (IMX585)
 Filter: Sightron Quad Band (1.25")
 Exposure: 43 x 180 sec, gain 220
 Designations: NGC 2175
 Magnitude: 6.8 vis in Orion
 Distance: 6400 ly
 FWHM: 4.8 average
 Image scale: 1.329"/px, width: 1.36°
 Time stamp: 2024-01-13 11:14 UTC

Images stacked in Siril using separately saved FITS raw frames.

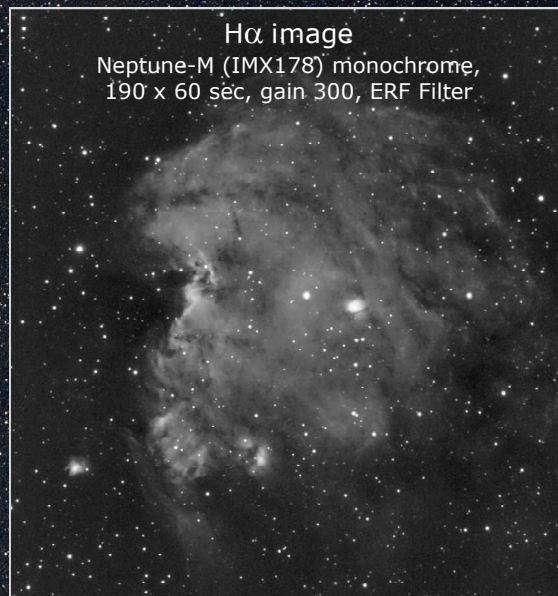
The Monkey Head nebula is a HII region and emission nebula about 40' wide apparent in the sky. The images on these pages have been taken simultaneously at different focal lengths and different cameras. Both telescopes were saddled on the same mount and aligned in parallel. The wide field is centered on the Monkey Head nebula serving as a photographic star chart about 10° tall.

The inset at the top right is a monochrome image taken with the same APO telescope and a Neptune-M (IMX178) camera and Player One's ERF filter abused as H α filter with a 120nm window.



Lower's Nebula

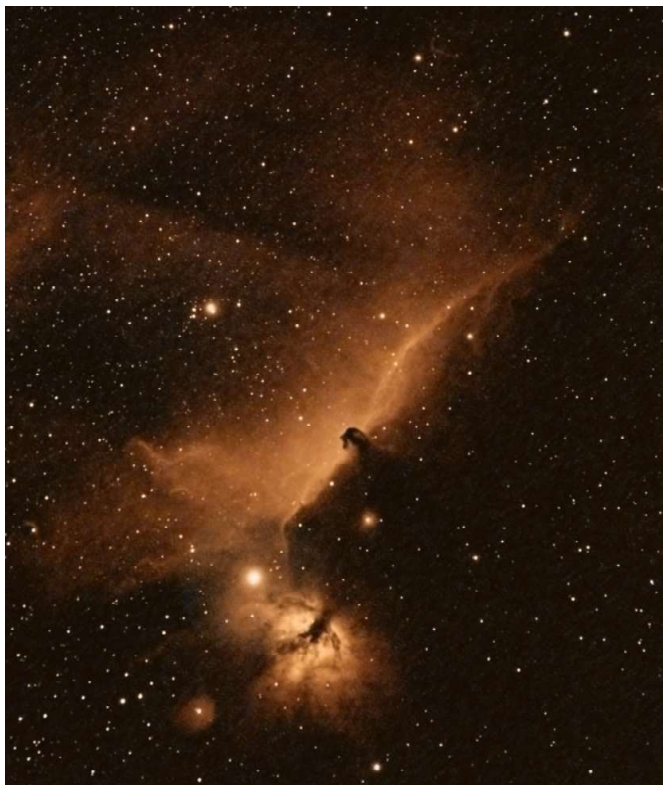
IC 2162



Monkey Head Nebula

Jellyfish Nebula





▲ Stacked in Siril using separately saved FITS raw frames.

Test with IC 434

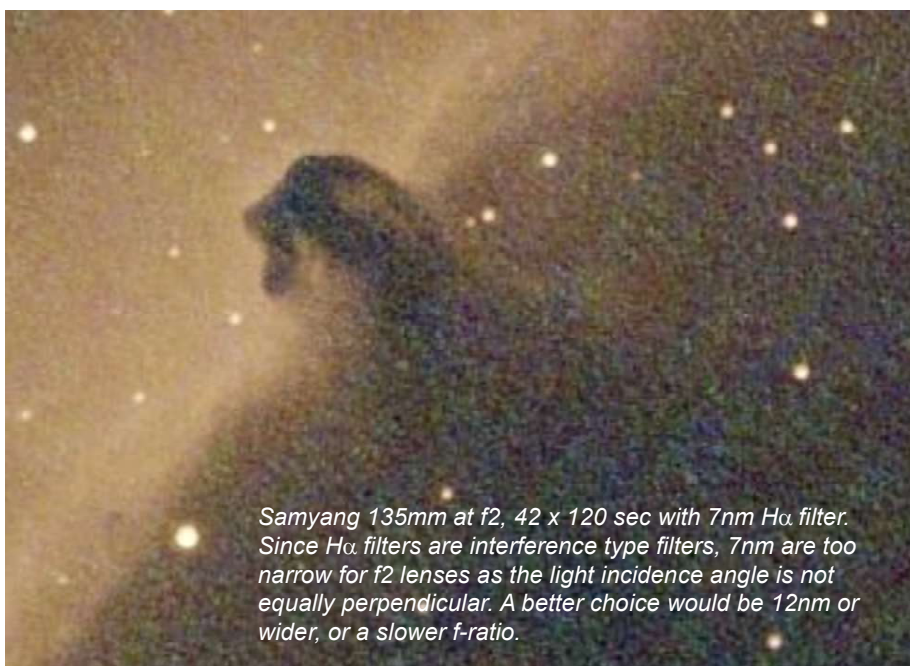
An hydrogen-alpha, $H\alpha$, filter isolates a wavelength which is emitted by most nebula, 656nm through a narrow window, such a 7nm for this test. It requires extended exposure because of the little light the filter passes and is therefore certainly not a good idea for EAA in front of an impatient audience. The color of 656nm is near-infrared and appears so in color images. The best advantage of $H\alpha$ is when imaged with a monochrome camera also because of the higher resolution as compared with a color camera.

Telescope:	Samyang lens (Ø64mm/135mm)
Camera:	Player One Uranus-C (IMX585)
Filter:	Sightron 7nm $H\alpha$ filter
Exposure:	42 x 120 sec, gain 220
Designations:	IC 434, Horsehead, Barnard 33
Distance:	1375 ly in Orion
Time stamp:	2024-12-20 13:43 UTC



$H\alpha$ imaging in Color?

The sensor of a color camera is covered with a color array consisting of four filters, for each physical pixel such as RGGB, one red, two green and one blue. Since the $H\alpha$ wavelength is red the other colors are hardly exposed resulting in primarily green and blue noise which is larger than the light signal (low SNR). Therefore, it is common practice to extract and process the red channel only. Since a color camera has 1/4th the number of red pixels of a monochrome camera, you may need to expose the image about four times longer.



Samyang 135mm at f2, 42 x 120 sec with 7nm $H\alpha$ filter. Since $H\alpha$ filters are interference type filters, 7nm are too narrow for f2 lenses as the light incidence angle is not equally perpendicular. A better choice would be 12nm or wider, or a slower f-ratio.

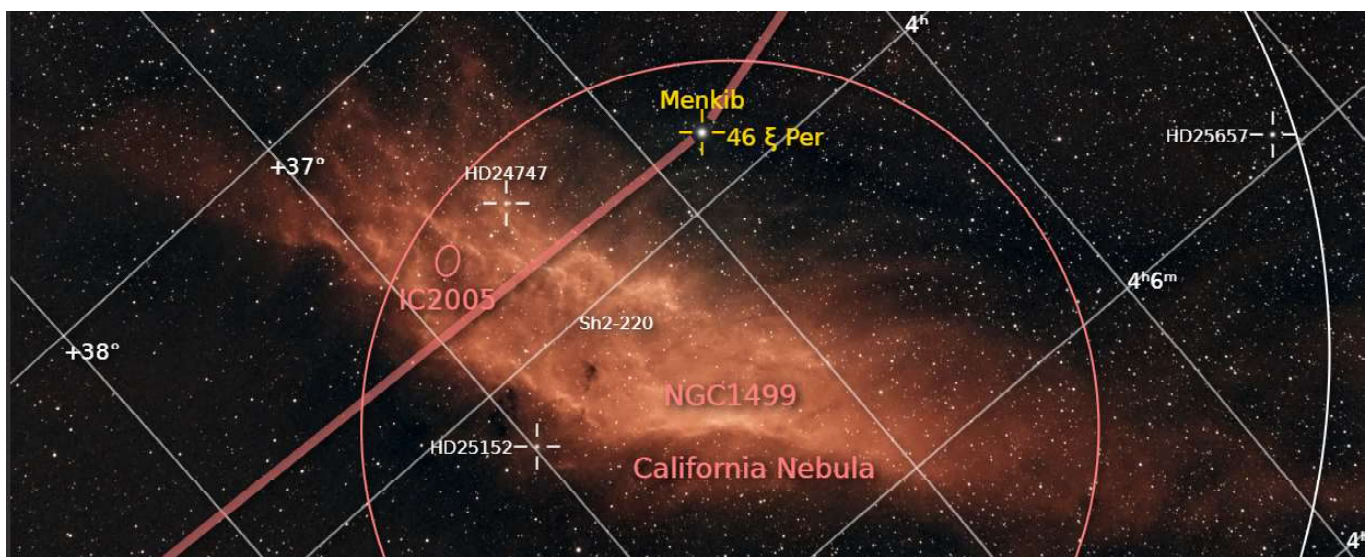


▲ Stacked in Siril using separately saved FITS raw frames.

California Nebula

Telescope: Samyang 135 (Ø64mm/135mm)
 Camera: Player One Uranus-C (IMX585)
 Filter: Sightron dual-band
 Exposure: 120 x 120 sec, gain 220, f/2.0
 Sensor temp: 21°C (ambient 17°C)
 Designations: NGC 1499, Sh2-220
 Magnitude: 6.0 vis in Perseus
 Distance: ~1000 ly
 Image scale: 4.426"/px, width: 4.68°
 Time stamp: 2024-12-01 12:18 UTC

The details in the nebula and an average of FWHM of 3.3" after 4 hours of integration attest favorable seeing condition. The nebula emits abundant $H\alpha$ and $H\beta$ (OIII) wavelengths at 656nm and 486nm, respectively, both of which the dual-band filter formidably captured in spite of the nebula's low surface brightness. Its fluorescence is due to excitation of the $H\beta$ line in the nebula by the nearby prodigiously energetic O7 star, Xi Persei (also known as Menkib in the center of the upper half of the image). The California nebula spans almost 2.5° on the sky and about 45 light-years in actual space. The good quality of this image taken with a photo prime lens demonstrates the importance of a transparent and quiet sky. Also, the right filter unveils most regions of a nebula.



Smartsopes

as of November 2024



EAA Setup
Image credit: KYOEI



Vespera
Image credit: Vaonis



Vespera Pro
Image credit: Vaonis

With **Vaonis' Vespera Pro**, released in April 2024, smart-sopes for EAA will become saloonable in terms of optical quality, imaging resolution and affordability. Alongside apochromatic optics Vaonis previously employed Sony image sensors, such as the IMX178 and the IMX462 which, though specified for planetary imaging, deliver good results with bright popular deepsky objects.

The latest choice for the next-generation model, the Vespera Pro, a



Vespera II
Image credit: Vaonis

In February 2024, **Vaonis** introduced its latest smartscope, the **Vespera II**, on the CP+2024 exhibition in Yokohama, Japan. It employs quadruple apochromatic optics with 50mm aperture and 250mm focal length (f5). What makes this product truly attractive is its color image sensor, a Sony IM585 which, at 250mm focal length, provides a native $2.5^\circ \times 1.4^\circ$ wide field of view ($4.3^\circ \times 2.4^\circ$ or $3.25^\circ \times$

3.25° in mosaic imaging mode), a high dynamic range and sensitivity (QE $\sim 91\%$). The Vespera II is the landmark from which on smartsopes are becoming truly interesting in terms of optical quality, imaging performance and price tag (1700 USD), however and fair enough, all accessories, including table tripod are optional. An optional dual-band filter is offered at around USD 400.

quadruplet $\varnothing 50\text{mm}/250\text{mm}$ APO with S-FPL52 glass, is the IMX676 color sensor, a 7.1mm square chip with 3,536 two-micron pixels on each side (12.5Mp) offering a desirable $1.6^\circ \times 1.6^\circ$ native FOV at 25x magnification, extendable to $2.6^\circ \times 2.6^\circ$. The smartscope contains all functions of a conventional rig, such as telescope, CMOS camera, focuser, tracking motors, WiFi controller with image processing and mount/tripod. The Vespera Pro model carries about the same price tag as all components of a comparable conventional setup (about 3000 USD) which makes it the more attractive. Due to its closed compact design, the camera cannot be swapped. Tracking is in AltAz only which is common to all current smartsopes. The Pro is a compact design with corrected optics and could boost popularity of smartsopes sky-high and space-deep.



ZW Optical, originally a CMOS astro camera manufacturer presented its first line of apochromatic telescopes, among them also a smartscope, the WiFi-enabled "Seestar S50", a triplet Ø50mm/250mm APO mated with an IMX462 color sensor which delivers a $1.3^\circ \times 0.7^\circ$ FOV at 39x magnification. The 3kg light compact design, selling at about 450 USD, sports all functions needed for EAA, including GoTo, tracking and auto-focus.



ZWO Seestar S50
Image credit: ZWO

Since November 2024, ZW Optical accepts pre-orders for its newest Seestar smartscope, the Seestar S30, which is smaller and lighter (1.65kg) than the S50, and selling at about 350

USD. Also smaller, the aperture of the F5 triplet optics with 30mm. The S30 cores the IMX662 image sensor which comes with the same dimensions as the IMX462 but improved in terms of noise characteristics, including HGC mode and higher sensitivity. It is free of amp glow while its larger full-well capacity (3x that of IMX462) helps avoid overexposure and

increase dynamic range. The IMX662 is basically a quarter of the excellent IMX585 image sensor. With its 150mm focal length the S30 provides an image field of $2.14^\circ \times 1.22^\circ$ at 23x magnification which is 1.7 times wider than that of the S50. Naturally the optical resolution of the S30 is inferior (image scale $4''/\text{pixel}$ vs $2.4''/\text{pixel}$ of the S50).



ZWO Seestar S30
Image credit: ZWO

The Seestar S50 has gained high popularity, so will the Seestar S30 as both are highly portable and lots of fun to use.

Another offerer is **Unistellar** who prefers reflecting optics. Current models include the eQuinox 2 (2500 USD range) and eVscope 2 (5000 USD range), both Ø114mm/450mm f4 Newtonians with built-in IMX347 image sensor (7.7Mp). Both WiFi models have their FOV reduced to escape the usual edge distortions inherent to curved mirrors. At 450mm focal length the IMX347 sensor should deliver a $1^\circ \times 0.6^\circ$ FOV at 50x magnification, which is already narrow for large and bright DSOs, but both scopes show merely $0.76^\circ \times 0.57^\circ$ of sky. Unistellar's Odyssey is a Ø85mm/320mm f3.9 Newtonian sporting an IMX715 sensor with $1.45\mu\text{m}$ tiny pixels and selling at 2300 USD or 4000 USD (Pro version).



Unistellar eVscope 2
Image credit: Unistellar



Celestron Origin
Image credit: Celestron

With an impressive 6-inch aperture (41% obstructed) and a RASA design as fast as f2.2 the **Celestron Origin** incorporates an IMX178 color image sensor (FOV $1.27^\circ \times 0.85^\circ$) and is sold at around 4000 USD including essential accessory.

Though there are no 'bad' Sony sensors, the IMX178 is not the latest technology. The IMX585 or IMX676 might be a smarter choice for the high-quality optics. The setup weighs about 19kg and is therefore called an "intelligent home observatory" rather than a portable smartscope.

Some Sony CMOS Camera Sensors

Part Number	Pixel Size	Resolution [px]	Sensor Size	QE	Full-well	ADC
Sony IMX071	4.78µm	4944 x 3284	23.6 x 15.6mm	~50%	46k e-	14-bit
Sony IMX094	4.88µm	7376 x 4928	36 x 24mm	~56%	52k e-	14-bit
Sony IMX128	5.97µm	6032 x 4032	36 x 24mm	~53%	74k e-	14-bit
Sony IMX174	5.86µm	1936 x 1216	11.3 x 7.1mm	~77%	24.8k e-	12-bit
Sony IMX178	2.40µm	3096 x 2080	7.4 x 5mm	~81%	15k e-	14-bit
Sony IMX183	2.40µm	5496 x 3672	13.2 x 8.8mm	~84%	15k e-	12-bit
Sony IMX193	3.76µm	6024 x 4024	22.6 x 15.2mm	~74%	36k e-	14-bit
Sony IMX224	3.75µm	1304 x 976	4.8 x 3.6mm	~75%	19.2k e-	12-bit
Sony IMX249	5.86µm	1920 x 1200	11.3 x 7.1mm	~77%	32k e-	12-bit
Sony IMX290	2.90µm	1936 x 1096	5.6 x 3.2mm	~80%	14.6k e-	12-bit
Sony IMX294	4.63µm	4144 x 2822	19.1 x 13mm	~90%	66k e-	14-bit
Sony IMX347	2.90µm	2712 x 1538	7.86 x 4.46mm	TBA	TBA	12-bit
Sony IMX385	3.75µm	1936 x 1096	7.4 x 4.1mm	~80%	18.7k e-	12-bit
Sony IMX429	4.50µm	1944 x 1472	8.75 x 6.6mm	~79%	25k e-	12-bit
Sony IMX432	9.00µm	1608 x 1104	14.5 x 9.9mm	~79%	97k e-	12-bit
Sony IMX455	3.76µm	9568 x 6380	36 x 24mm	~91%	51.4k e-	16-bit
Sony IMX462	2.90µm	1936 x 1096	5.6 x 3.2mm	~80%	14.6k e-	12-bit
Sony IMX464	2.90µm	2712 x 1538	7.9 x 4.5mm	~90%	12k e-	12-bit
Sony IMX482	5.80µm	1920 x 1080	11.1 x 6.2mm	~85%	51.5k e-	12-bit
Sony IMX492	2.32µm	8192 x 4320	19.1 x 13mm	~90%	66k e-	12-bit
Sony IMX533	3.76µm	3008 x 3008	11.31 x 11.31mm	~91%	73k e-	14-bit
Sony IMX571	3.76µm	6244 x 4168	23.5 x 15.7mm	~91%	50k e-	16-bit
Sony IMX585	2.90µm	3840 x 2160	11.2 x 6.3mm	~91%	47k e-	12-bit
Sony IMX662	2.90µm	1936 x 1100	5.6 x 3.2mm	~91%	37.8k e-	12-bit
Sony IMX664	2.90µm	2704 x 1540	7.4 x 4.5mm	~91%	37.8k e-	12-bit
Sony IMX676	2.00µm	3552 x 3552	7.1 x 7.1mm	~83%	10.66 e-	12-bit
Sony IMX678	2.00µm	3840 x 2160	7.7 x 4.3mm	~91%	38.5k e-	12-bit
Sony IMX715	1.45µm	3840 x 2160	5.6 x 3.2mm	~80%	5.7k e-	12-bit

No liability assumed for sensor specifications, which are subject to change without advanced notice..



By the Way

Off topic, but with its relatively large sensor the Uranus-C is a great camera for lunar color mosaics. The above image is an 8-tile mosaic stitched with MS-ICE and further processed with Photoshop using Curve, High Pass filter, Unsharp Mask and color Saturation under a luminosity layer, the latter step generating a "mineral moon" in saturated colors. The Baader UV/IR-Cut CMOS-optimized filter cuts off infrared. Turmoil, humid air, 20°C ambient temperature, over 70%RH. Captured with SharpCap in raw8 color space, 47fps at full field of view (ROI). Good news, the latest version of SharpCap is capable of live-stacking the moon and planets.

Telescope:	Celestron 8 XLT (Ø203mm/2030mm)
Focuser:	Crayford (optional)
Barlow:	none
Camera:	Player One Uranus-C (IMX585)
Filter:	Baader UV/IR-Cut CMOS optimized
Exposure:	5ms at gain 180
Integration:	600 frames (15%) stacked
Sensor temp:	28°C
Object:	16 days old Moon in Leo
Time stamp:	2023-02-07 14:13 UTC

An often adopted term for imaging the moon and the planets is "lucky imaging". Selected 'good' frames in a recorded video are stacked and further processed, the rest is discarded. It is more like "video astronomy" which is perfectly suited for audiences as the moon can be observed in real time while the camera "flies" over the lunar surface, occasionally catching a bird or an airplane crossing the view within a wink of an eye.

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.

51.6°N | 9.4°W | Alt: 1,840 km



Plato

Crater

Latitude: 51.6°

Longitude: -9.4°

Diameter: 109.0 km

Categories

Crater

Features

Plato



Min Zoom

Max Zoom



Camera Simulator

Sony IMX178

Focal Length [mm]

2030

Field of View

0.21 x 0.14°

Image Scale

0.244"/px

Linear Resolution:

0.432 km/px

Sensor Data

Current lunar angular size is 32.66' (0.544°).

Telescope Simulator

FOV: 0.73°

PARAMETERS

Aperture	203 mm
Focal length	2030 mm
Obstruction	35%
Eyepiece focal length	18 mm
Eyepiece apparent FOV	82°
Barlow/Reducer	1x
Performance Plot	

Optical Performance

Current lunar angular size is 32.66' (0.544°).

▲ The simulator 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 effective 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.

Sony IMX585

Pixel size: 2.9µm
 Sensor size: 11.14 x 6.26 mm
 Diagonal: 12.8 mm
 Total pixels: 8.29 Mp
 Effective pixels: 3840 x 2160
 Diagonal: 4406 pixels
 Aspect ratio (H/W): 0.563

Quantum efficiency: ~91%
 Full-well capacity: 38.8k e
 A/D converter: 12-bit

NOTE:
 Succeeds IMX485

Player One: Uranus-C
 ZWO: ASI585MC
 QHY: QHY5III585C
 Svbnony: SV705C

Close

▲ 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 specified eyepiece. Since 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 performance 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 unsatisfactory 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

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

Lunar Libration Calendar



▲ 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



Sky Photography for Starters



◀ This brochure is not an in-depth tutorial but for the purpose of wetting appetite for sky photography. It concentrates on discussions around small, mobile "grab-and-go" gear, such as a Ø71mm APO refractor, a shelf DSLR, a wide lens and a telephoto lens plus filters, such as an LPR filtering out artificial light. The brochure is illustrated with numerous images acquired with the said gear showing constellations, the Milky Way, wide fields and deepsky objects, the latter taken with a 450mm quadruplet refractor, all with detailed image data.

Download site <https://www.astropical.space/>



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.

<https://www.astropical.space>
<https://www.astrobin.com/users/astropical/>

contact: requio@astropical.space
©2025 Robert Brenner, Okinawa, Japan