What I Wish Someone Had Told Me About Telescopes


I have been interested in astronomy ever since I was a kid, but never really pursued it until recently. If you are interested in the story of my journey learning telescope astronomy click here. Otherwise, please read on to see my technical notes on this subject.

Contents

Image Quality Progression

Here is a progression of images of M31 and M42 taken as I improved my equipment and skills. In each case you can see the difference the changes made and understand why the technical points in the rest of the document are so important for taking good astrophotography images. **CLICK IMAGES TO ENLARGE**.

Jan 8 2023, Bought Askar FMA180 scope, CG-4 mount with tracking motors

CG-4 mount w/Celestron tracking motors, FMA180 scope, No filter, 2 stacks, 30sec, gain 252

This was my first “real” deep space image of any real value. I had been using my C8 and was really excited to use the FMA180. Technically this is dim, out of focus, with a poor black background.

Jan 17 2024, Bought RedCat 71 scope and some basic filters

CG4 mount tracking broken, RedCat 71 scope, SVBONY UHC, 1 stack, 5.0sec, gain 252

I had been reading about what a great scope the RedCat 71 was. However, when I got it my CG4 tracking motors broke down so I could only get this quick image which is very poor.

Jan 18 2024, Bought AM5 mount – Bad polar alignment - clouds and NO auto-focus

AM5 mount, RedCat 71 scope, M31, no filter, 30.0s, gain 252

I got my new AM5 mount which is amazing, but I couldn't get it focused manually with the clouds and consequently also had very poor polar alignment.

Jan 19 2024, Bought ZWO EAF, Good polar alignment, EAF working but VERY cloudy

AM5 mount, RedCat 71 scope, M31, no filter, 5.0s, gain 252

With the new Electronic Auto Focus (EAF) focusing became a snap – even in clouds. However, it was so cloudy that I gave up trying to get a good shot.

Jan 23 2024, Great conditions, Good polar alignment, EAF working

AM5 mount, RedCat 71 scope, M42, SVBONY UHC, 3 stacks, 180.0s, gain 0

I finally got great conditions and was able to do some stacking with longer exposures which came out pretty good. However, the background is still too light and the details are kind of “fuzzy”

Jan 25 2024, Great conditions

AM5 mount, RedCat 71 scope, M31, SVBONY UHC, 5 stacks, 300.0s, gain 252

Jan 27 2024, Bought Optolong L-Pro UHC filter, Great conditions

AM5 mount, RedCat 71 scope, M42, Optolong L-Pro UHC, 3 stacks, 180.0s, gain 0

The L-Pro filter made a noticable improvement over my SVBONY UHC because it is more wideband. This makes the background better and gives some more detail on the objects.

Jan 28 2024, learned how to use Calibration Frames, mixed thin and heavy clouds

AM5 mount, RedCat 71 scope, M42, Optolong L-Pro UHC, 13 stacks, 10.0s, gain 450

Note how stacking removed the thin clouds on the left, but left and orange “smudge” on the right where the heavier clouds were slowly being blown in. Prior to stacking the entire picture was a “foggy” mess. You can’t see it here too much but the calibration frames make a big difference in later images.

Jan 29 2024, Bought ASI120Mini tracking camera, Great conditions, PERFECT PA (0.0”)

AM5 mount, RedCat 71 scope, M42, Optolong L-Pro UHC, 2 stacks, 1800.0s, gain 0

I finally started using a guide scope which allowed me to extend the exposure time to be 10x longer. This allows much more detail to be captured. The guide scope keeps the tracking on target while the mount is moving and prevents the alignment from fading over time and blurring the image.

Also, you can see the difference that the calibration frames did in cleaning up the background noise.

This picture looks about perfect to me and is the culmination of understanding all of the techniques described in this document.

Feb 12 2024, Bought PixInsight and Learned how to Construct Mosaics

Learning PixInsight was a lot of work, but I’m glad I did it as it is an amazing program and allows you to do so many more things with your images. Here you can see a 2x2 mosaic of M42 showing a much larger field of view than would be possible with my telescope and camera alone.

Feb 16 2024, Bought ASI533MC Astronomy Camera

My ASI585MC camera worked great on a handful of the brighter deep sky objects (M42, Andromeda, etc.) but was mediocre to horrible on dimmer DSOs. It looks to me like the ASI585 is good for objects with magnitude 4.5 or brighter. After struggling unsuccessfully for days to capture the Triangulum galaxy, I finally gave up and decided to purchase a better deep sky camera.

It came down to a choice between the ASI533MC and the ASI294MC. I finally decided on the ASI533MC because it was a little less expensive, it was recommended by a friend, and it had no amp glow. The ASI294MC has larger pixels and a deeper well capacity which would have been nice, but I am also thinking of eventually getting a full frame camera like the ASI2600MC so I didn't want to spend too much on what I'm considering a middle-of-the-road camera.

After about a week of setup I was able to get the following snapshot of M42. This is a single 1000 second shot (not stacked) click on it to see it full size. Note the frame is now square as the 533MC has a square sensor (vs the 585MC that has a rectangular sensor) which allows you to see more of the object in a single shot.

Mar 3 2024, Bought Solar Filter for FMA180 Telescope

See the Solar Observation section – I was able to start taking videos of the sun which was quite fun actually using my telescope during the day time!

Mar 5 2024, Bought Sky Quality Meter (SQM)

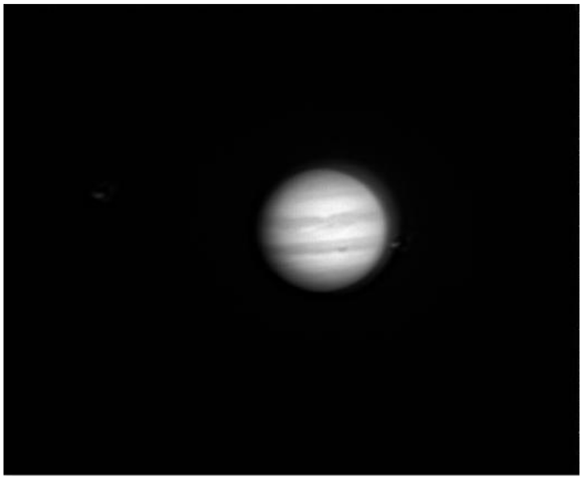
See the Sky Conditions section – I am now able to determine the actual amount of light pollution at my viewing site and make the necessary corrections.

Mar 7 2024, Bought C8 Dew Shield and Started Using Guide Camera on C8

After measuring the light pollution in my area and realizing that views looking straight up were quite good, but looking lower on the horizon suffered from noticeably higher light pollution, I decided to add a dew shield to my C8 (see picture below.) This should eliminate quite a bit of city light pollution.

Additionally, I had been using my C8 without a guide scope. I had figured that my exposure times were very low because I was using the C8 for planetary observation – where I was looking at bright objects with low exposure times. However, I noticed significant image jitter when taking video of Jupiter. Adding the guide scope dramatically reduced this jitter.

You can see the improvement in the left image below (with guide scope and dew shield) compared to the image taken a few days before on the right. You can even see two of the moons on the left and there is much more detail.



Both of these images were processed using only ASIStudio using the following camera settings. The videos were stacked and then the contrast was adjusted up.

```
[ZWO ASI585MC]
Bin = 1
Capture Area Size = 640 * 480
Colour Format = RAW8
Exposure = 0.012 Sec
Flip = None
Gain = 250
StartX = 1600
StartY = 840
Temperature = 20.3 C
Bayer = RG
White Balance (B) = 88
White Balance (R) = 45
Duration=123 Sec
```

```
[ZWO ASI585MC]
Bin = 1
Capture Area Size = 640 * 480
Colour Format = RAW8
Exposure = 0.002 Sec
Flip = None
Gain = 255
StartX = 1600
StartY = 840
Temperature = 27.3 C
Bayer = RG
White Balance (B) = 88
White Balance (R) = 45
Duration=60 Sec
```

It's kind of hard to see in these small clips, but if you click on the images to see the full size, you will notice that the level of detail in the left image is significantly higher. On the right image I had to turn the exposure time very low to reduce the blurring effect of the camera shaking (due to lack of guiding.) This made it much dimmer – no planets are visible

Nov 15 2024, Bought Celestron C11 EdgeHD Telescope

My father passed away in May and I had to put astronomy aside for many months but now that things are calming down, I have started working on it again. I purchased the C11 to try and get better planetary images and have just gotten it setup, but need to do lots more work. However here is an early un-processed shot of Jupiter showing the red spot in the top left.

Telescope Types

Here's how to pick a scope in a nutshell: $ - beginner, just curious, $$ - serious or doing photography, $$$ - professional photographer.

Telescope Characteristics

The following lists the major characteristics that distinguish one telescope from another.

Aperture

Larger aperture (diameter of the lens/mirror) translates to higher resolution per camera pixel. This will enable you to zoom in more, get more detail, and is defined as a lower Dawes Limit value.

Focal Length

Larger focal length translates into the ability to provide more magnification, and consequentially smaller fields of view.

F-Ratio

Smaller f-ratio translates into shorter exposure times required for photography and the ability to see dimmer objects both in photography and visual observation.

Optic Quality

High quality optics (the mirrors and lenses) make the difference between an average image and a professional image. As a beginner you would probably stay away from high quality optics because of the large price difference. However, as you progress and have decided that you truly enjoy astronomy, then you should consider only buying high quality optics.

Flat Field

Flat field scopes are prized for photography (see this section for more details) but are generally more expensive.

Refractors

Use lenses to focus the light rays to your eye/camera. These are prone to chromatic aberration. These are typically better for lower F settings (important in photography) and wider field of view – that is they are better when you only need a little magnification to see a very large object (like a galaxy or nebula.)

Typically, you can buy the same telescope configuration in either APO or Petzval designs, and you will typically pay about double for the Petzval. But if you are a beginner and don't care about getting everything perfect, you can save a lot of money by getting APO scopes.

Basic - $

Basic beginner scopes.

Apochromat (APO) - $$

These improve significantly on the chromatic aberration of Basic scopes – for full details see Wikipedia. Back focus is an issue for these scopes to get focus at the edge of the field.

Petzval Flat Field - $$$

These eliminate field curvature thus eliminating the back focus requirement to ensure the entire image is in focus – for full detail see Wikipedia.

Reflectors

Use mirrors to focus the light rays to your eye/camera. These are immune to chromatic aberration. These are typically better for high F settings and narrower field of view – that is they are better when you need lots of magnification to see a small object (like a planet or a star.)

For a variety of reasons (described in this document) SCT reflectors are the most difficult reflectors to use, but of course they pack a lot of power in a small package so it is a trade-off. Just make sure you understand these issues before you decide which reflector to buy.

Basic - $

Cheap and great if you just want to look at the moon now and then.

Average Quality - $$

Better, you can get good planet shots, but may run into issues photographing and getting distortion around the edges of the image.

HD Quality - $$$

These incorporate a field flattener specific designed to optimize this specific scope so as to eliminate the field curvature issues that are important in astro-photography.

SCT Focusing Issues

SCTs are different from other reflectors (ex: Newtonian) in that the primary mirror moves to focus. This causes a number of issues for SCTs when focusing. For more details, please refer to the following section of this document: SCT Focusing Issues.

Important Math to Understand

There are numerous good articles about this on the internet, I would recommend reading Pixel Size and Critical Sampling.

Image Scale

Image scale describes the angle subtended by a single pixel on your camera sensor. In other words, it describes what portion of the visible sky light falls onto each pixel.

The sky is broken into the normal 360 degrees (only 180 degrees of which are visible from any point on the earth.) Each degree is then broken down into 60' (minutes – denoted by '), and each minute is further broken down into 60" (seconds – denoted by ").

$$\theta = 206 * \frac{S}{L}$$

Where:

- θ is the image scale (in ")
- S is the camera sensor pixel size (in µm)
- L is the telescope focal length (in mm)

So, for example, using a C8 telescope (L = 2032mm) and an ASI585MC camera (S = 2.9 µm) would result in the image scale (θ) of each pixel being 0.2940".

Note that image scale is affected by Binning because it increases the physical pixel size programmatically. The examples in this section assume binning = 1 (off.)

Field of View (FOV)

Once you understand image scale, FOV is easy. The field of view of the camera sensor is simply the image scale multiplied by the number of horizontal/vertical pixels on the camera sensor.

Using the example described in the Image Scale section the ASI585MC sensor has 3840x2160 pixels in the sensor which yields the following field of view for this equipment:

$$FOVx = 0.2940 * 3840 = 1{,}128.94\text{" (or } 1{,}128.94\text{"}/3600 \ = \ 0.31\ degrees$$

$$FOVy = 0.2940 * 2160 = 635.03\text{" (or } 635.03\text{"}/3600 \ = \ 0.18\ degrees$$

So, using a C8 telescope with an ASI585MC camera you would be able to take picture of the sky that is 0.31 x 0.18 degrees wide.

For examples of FOV please refer to the Field of View Examples section.

Critical Sampling

This is the art of getting your telescope and camera matched to get the best picture possible. The way to calculate the ideal relationship between pixel size, focal ratio, and wavelength is:

$$S = 1.22 * \lambda * \frac{F}{N}$$

Where:

- S is the camera sensor pixel size (in µm)
- λ is the light wavelength (in µm) of concern
- F is the telescope focal ratio (the F number)
- N is #of pixels covering smallest feature scope can resolve (basically current viewing conditions)
    - 5 = perfect clear dark skies (where you can see details down to 1”)
    - 4 = good skies (where you can see details down to around 2”)
    - 3 = average skies (where you can see details down to 3”)
    - 2 = overcast (where you can see details down to 4”)
    - 1 = heavy clouds (where you can only see details over 4”)

Simplifying the equation for average skies (N = 3) and normal visible light (λ = 500nm) you get the following which says to achieve critical sampling you should use a pixel size equal to your telescope focal ratio divided by 5.

$$S = \frac{F}{5}$$

So, if you are using a C8 scope (F = 10) your critical sampling pixel size would be 2µm. If you are using an ASI585MC (S = 2.9µm) camera, this means that you are under-sampling - because your actual pixel size is larger than the ideal pixel size for this scope and you are losing detail in the picture. Essentially the scope is providing detail that your camera is unable to capture.

Under-sampling is bad on small objects that provide a lot of detail (planets, sun, moon, and some smaller planetary nebulae and galaxies. However, under-sampling is generally not an issue on larger targets where you are trying to capture a large field of view on a large dramatic object where tiny detail does not matter.

Over-sampling is the opposite problem where your camera is providing more detail than your scope can deliver. Over-sampling is always bad because it increases noise (decreasing your signal to noise ratio) and it makes your images larger with no benefit.

Spreadsheet Calculating Values

I created a spreadsheet that automatically calculates all of the values described above, and suggests binning values and shows the binning effect. The top section is useful to see how different F# scopes react to different conditions.

Focal Length Increment
0.5
Focal Length Start
1

Spectrum of Interest
Wavelength (um)
0.5

Telescope

Aperture (mm)	Focal Length	Focal Ratio
71	348	4.901408451

Camera

Pixel Diameter (um)	Xres	Yres
2.9	3840	2160

Atmospheric Conditions
#pixels/smallest feature
3
Min Image Scale (arc")
3

General Telescope Values for a Range of Telescope Focal Ratios

Focal Ratio	Critical Sampling Pixel diameter (um)	Equipment Image Scale (arc ")	Suggested Bin	Equipment Bin Image Scale	Field of View (degrees) X	Field of View (degrees) Y	Field of View BINNED X	Field of View BINNED Y
1	0.20	8.41	1	8.41	8.98	5.05	8.98	5.05
1.5	0.31	5.61	1	5.61	5.98	3.37	5.98	3.37
2	0.41	4.21	1	4.21	4.49	2.52	4.49	2.52
2.5	0.51	3.37	1	3.37	3.59	2.02	3.59	2.02
3	0.61	2.80	1	2.80	2.99	1.68	2.99	1.68
3.5	0.71	2.40	1	2.40	2.56	1.44	2.56	1.44
4	0.81	2.10	2	4.21	2.24	1.26	4.49	2.52
4.5	0.92	1.87	2	3.74	1.99	1.12	3.99	2.24
5	1.02	1.68	2	3.37	1.80	1.01	3.59	2.02
5.5	1.12	1.53	2	3.06	1.63	0.92	3.26	1.84
6	1.22	1.40	3	4.21	1.50	0.84	4.49	2.52
6.5	1.32	1.29	3	3.88	1.38	0.78	4.14	2.33
7	1.42	1.20	3	3.61	1.28	0.72	3.85	2.16
7.5	1.53	1.12	4	4.49	1.20	0.67	4.79	2.69
8	1.63	1.05	4	4.21	1.12	0.63	4.49	2.52
8.5	1.73	0.99	4	3.96	1.06	0.59	4.22	2.38
9	1.83	0.93	4	3.74	1.00	0.56	3.99	2.24
9.5	1.93	0.89	5	4.43	0.94	0.53	4.72	2.66
10	2.03	0.84	5	4.21	0.90	0.50	4.49	2.52
10.5	2.14	0.80	5	4.01	0.85	0.48	4.27	2.40
11	2.24	0.76	5	3.82	0.82	0.46	4.08	2.29
11.5	2.34	0.73	6	4.39	0.78	0.44	4.68	2.63
12	2.44	0.70	6	4.21	0.75	0.42	4.49	2.52
12.5	2.54	0.67	6	4.04	0.72	0.40	4.31	2.42
13	2.64	0.65	6	3.88	0.69	0.39	4.14	2.33
13.5	2.75	0.62	7	4.36	0.66	0.37	4.65	2.62
14	2.85	0.60	7	4.21	0.64	0.36	4.49	2.52

Over-sampling (physical pixel is SMALLER than critical value)
Under-sampling (phyical pixel is LARGER than critical value)
Binning recommended (image scale is LESS than current conditions all
Currently selected scope range(s)

IMPORTANT!
Ideally you want "Equipment Image Scale"
(or "Equipment Bin Image Scale" if binning) to match
Atmospheric Conditions "Min Image Scale"

If "Equipment Image Scale" > "Min Image Scale" you are losing details
If "Equipment Image Scale" < "Min Image Scale" you are over-sampling and intro

The bottom portion is more practical and shows values specifically for the scope and camera that you have specified (in this case a Redcat 71 with and ASI585MC camera) in different viewing conditions.

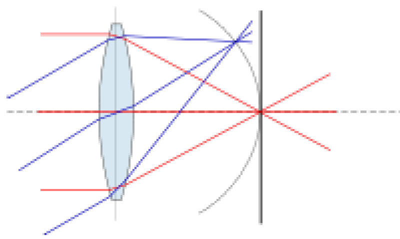
Specific Telescope values for ALL Atmospheric Conditions

#pix/feat	Min Image Scale (arc")		Critical Sampling Pixel diameter (um)	Image Scale (arc ")	Suggested Bin	Bin Image Scale	Field of View (degrees) X	Field of View (degrees) Y	Field of View BINNED X	Field of View BINNED Y
5	1	Perfect Skies	0.60	1.72	1	1.72	1.83	1.03	1.83	1.03
4	2		0.75	1.72	1	1.72	1.83	1.03	1.83	1.03
3	3	Average Skies	1.00	1.72	2	3.43	1.83	1.03	3.66	2.06
2	4		1.49	1.72	3	5.15	1.83	1.03	5.49	3.09
1	5	Heavy Clouds Pollution Etc	2.99	1.72	4	6.87	1.83	1.03	7.32	4.12

You can get a copy of this spreadsheet by clicking on this link.

Field Curvature

See Petzval field curvature - Wikipedia for full details. The image of what you are looking at through the telescope comes into focus at a point somewhere behind the back of the telescope. The image, or "field", however is typically not "flat" as can be seen in the picture below.



This curvature is inversely proportional to lens aperture (larger aperture has less curvature.)

This is a problem when taking pictures with a camera – because it has a flat sensor element – and may cause the pixels around the edges of the picture to be out of focus. This is not a problem looking at something with your eye, because the back of your eye is also curved and can compensate for the focal differences.

Certain types of telescopes do not suffer from field curvature – most notably Petzval Refractors. This is because the entire lens assembly moves as you adjust focus, as opposed to only part of the lens assembly in most other telescopes. If you use one of these you don't have to worry about field curvature.

Back Focus

Telescopes usually compensate for field curvature with special lenses that produce a “flat” field. The problem is that this “flat” field only exists at an exact distance behind the telescope back. This distance is specified as the “back focus” distance.

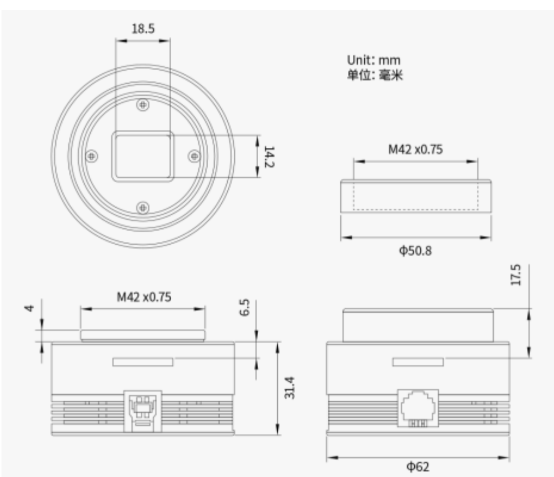
By using spacers between the back of your telescope and your camera, you can position the camera in such a way that the sensor element is exactly where the telescope produces a “flat” field image, thus ensuring that your images will be in focus all the way across the camera sensor. Here is an excellent article explaining this process.

When Does This Matter

It only matters if you are using a camera.

It only matters if your camera uses a “full field” sensor – that is to say that the sensor element is physically large enough to capture “all” of the light from the telescope. Typically, this only occurs in the larger, more expensive professional cameras. Most entry level cameras have a sensor that is smaller than the beam of light from the telescope.

For example, the ZWO ASI585 has a sensor that is 18.5x14.2mm, resulting in a “diagonal” measurement of 12.84mm. Telescope beams are typically 1.5” (38.1mm), 2” (50.8mm) or larger. So, even with the smallest beam (38.1mm) the 12.84mm sensor diagonal comes nowhere near the curved edges of the beam.



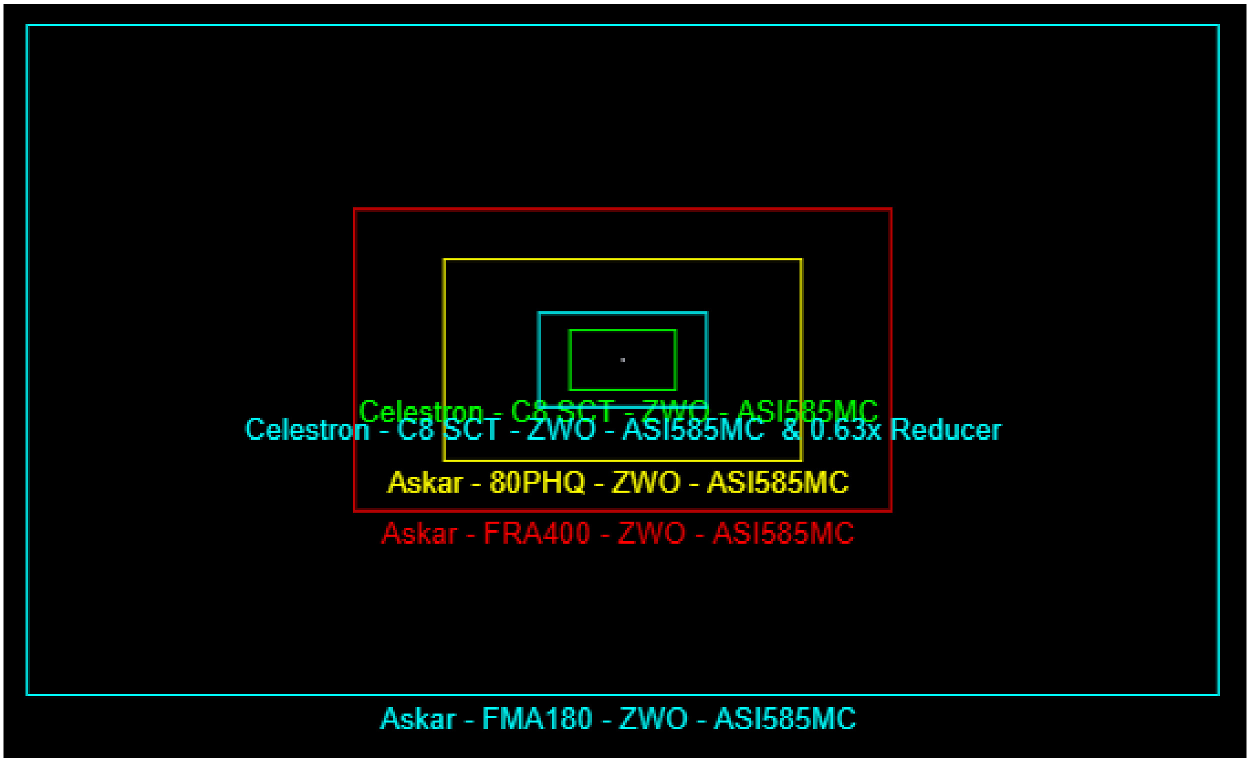
So, if you are using this type of camera setup you really don’t have to worry about back focus – you only need to make sure your camera is not so far away that it is out of the practical focuser range and you will get good pictures.

And after reading many astronomy threads, it also becomes apparent that many non-perfectionists just don’t care if the picture is slightly blurry around the edges. You could also just crop the edges out with a photo editor as well if they don’t contain required image data.

Field of View Examples

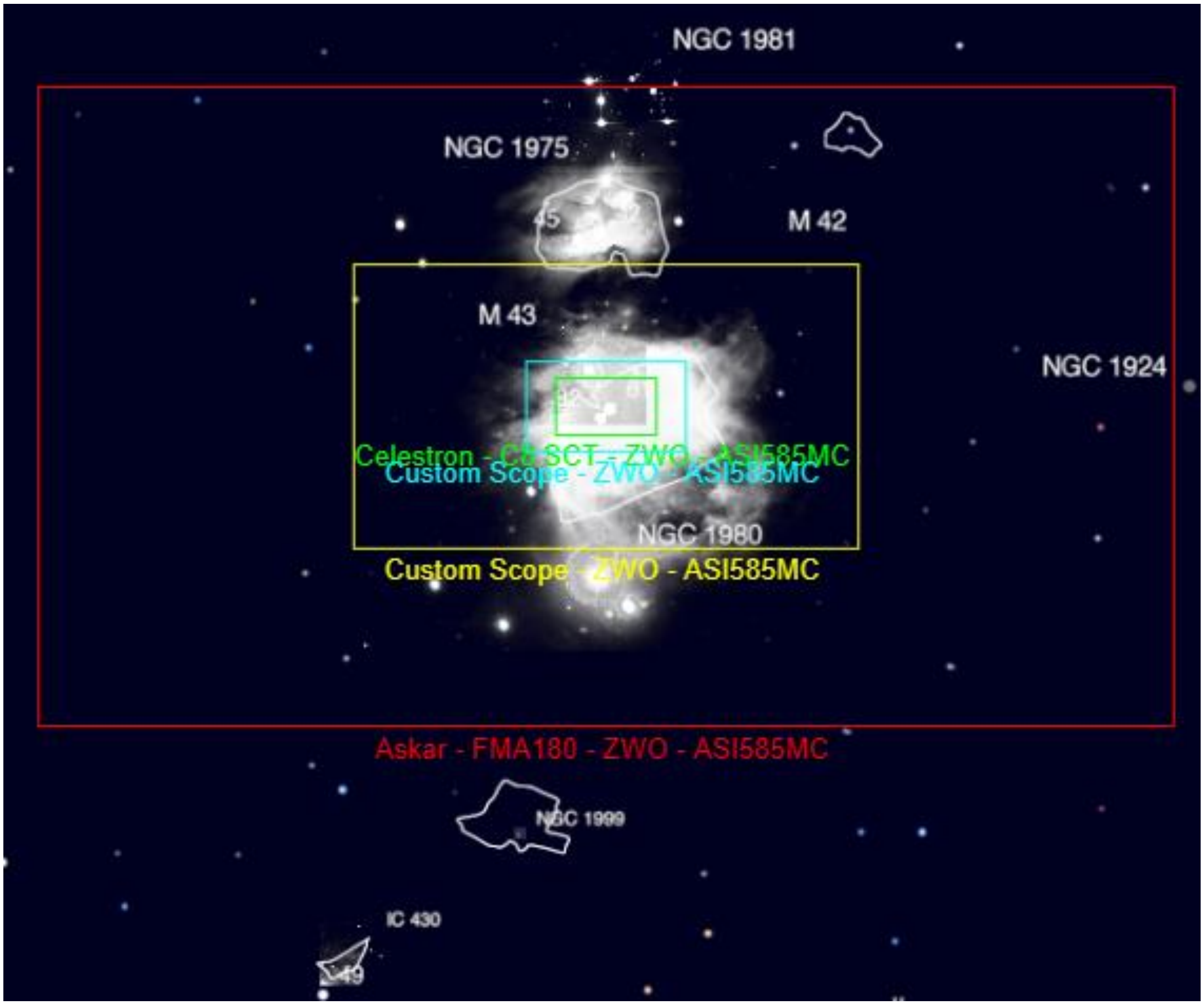
Field of View is what you will actually see on your telescope camera or eyepiece and it depends on the equipment you are using. Here is an excellent website tool that allows you to see the image change as you alter your equipment. For a description of how the math for this works, please refer to the Important Math section.

The following shows what the tool describes for 5 different telescope configurations. As can be seen, using the FMA180 configuration the object will only appear as a tiny dot in the middle of a large field. Clearly the FMA180 is not a good choice, and the Celestron C8 SCT would be much better as it would provide a more detailed image.



Wide field of view (ex: FMA180) is important when viewing large objects like galaxies, and narrow field of view (Celestron C8 SCT) is important for viewing small distant objects like planets and stars.

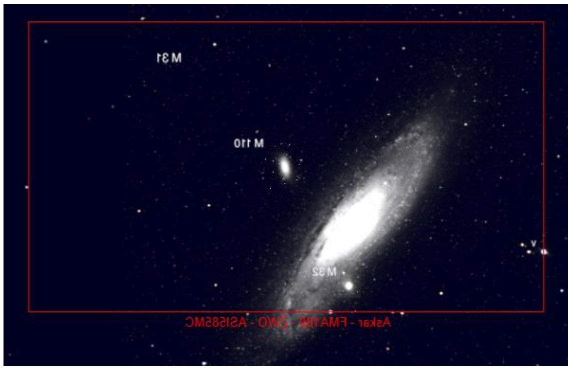
The following illustrates the benefit of a wide field of view telescope like the Askar FMA180 on very large objects. This view would be impossible to capture with the narrower field of view Celestron C8 SCT.



This is an excellent tool to see if the telescope you are thinking of buying will actually help you see the astronomical objects you really care about.

It is important to note that the telescope "F" number is NOT the only factor when determining field of view – the aperture is also important. Two telescopes with matching "F" numbers will show different results if they have different apertures – the larger aperture will have a narrower field of view because it provides more magnification.

IMPORTANT – this tool uses images taken by the best telescopes in the world so what you see with your camera will likely be MUCH worse. The tool is intended to show you the field of view of different telescope configurations and NOT to show you what you will ACTUALLY see. To illustrate this point, here is what the tool shows for my telescope configuration viewing the Andromeda galaxy (left) and what I actually see through my telescope (right.)




My image was a 5-minute exposure on a tracking mount with an average color camera. Doubtless a higher quality camera with longer exposure times would have produced a larger image. What I am seeing in my image is the very bright core of the galaxy – and not the dimmer outlying arms. The result is that my image appears to be smaller, and not quite as exciting as the image on the left – which was probably taken with the Hubble space telescope.

For a full JPG file of my shot of the Andromeda galaxy above click here.

I later found the following video which shows taking photographs of deep space nebula using my exact same camera (ZWO ASI585MC) with very good results.

ADC

For more information on Atmospheric Dispersion Correctors, please follow this link: ADC.

Cameras

For more information on astronomy cameras and their use, please follow this link: Cameras.

Filters

Filters come into play generally when you get involved in more advanced astro-photography. They are in no way essential when you are getting started. To read more about filters, please follow this link: Filters.

Focusing

Focusing is the process of adjusting the optical path to obtain the best possible image.

If you are even remotely interested in getting good quality pictures you will want to understand this process fully. Due to the extensive nature of this topic, it has been moved to its own document.

For more information see the following document: Telescope Focus

Mounts

Mounts are used to support the telescope, and in some cases to allow it to track celestial objects as they move through the sky.

For more information about mounts see the following document: Mounts

Plate Solving

Plate Solving is the process of your controller figuring out where your telescope is actually pointing.

If you want to avoid hours and hours of frustration you will want to fully understand this process.

For more information see the following document: Plate Solving

Telescope Controllers

You will need some sort of controller to tie all of your equipment together and control its operation and record your images. There are many options:

1. Dedicated Controller (ex: ASIAir)
2. Using a computer/laptop/tablet with various 3rd party software

I started out with the ASIAir controller because it was simplest to get started. This was mainly because it is a closed ecosystem and everything is taken care of by this one device – and you don't have to do lots of research into how to make each feature work.

However, this also has its drawbacks: you can't use non-ZWO equipment, some of the features don't work so well when you get more advanced, the processor is not that fast, etc. So, you may outgrow the dedicated controller over time and switch to something more custom.

Guide Scopes

A guide scope is needed ONLY for astrophotography, and ONLY when you are taking exposures over about 2 minutes, and ONLY if your mount supports computer-controlled tracking.

Its purpose is to provide feedback to the mount tracking software so that minor corrections can be made to keep the telescope pointing at its objective. This is necessary because over long periods of time, small errors in the mount motor gearing accumulate and can cause substantial blurring of your image.

Here is a good article on the subject (link to article) which I have summarized on this page.

The guide scope focal length should be roughly 1/3 of the telescope focal length.

Mounting the guide scope on top of the telescope tube (picture below left) can introduce “flexure” issue – where the guide scope and telescope end up pointing to slightly different areas. The ZWO ASI120MM Mini along with the ZWO 30mm f/4 Mini Guide Scope is an excellent choice for non-OAG setups.

Using an Off Axis Guide (OAG) scope (picture below right) is much more reliable because it eliminates flexure and it is able to view the exact same light path that is going to your primary camera.


However, the OAG only gets to see a sliver of the optical image on the outside of the visual circle so it is much more difficult to find a guide star, and without a field flattener those stars are not as sharp. You must also get the OAG camera focus to match your main camera which takes some work. The OAG setup is also more costly.

For more information about OAG, please follow this link: Baader OAG.

Different Approaches to Getting Quality Images

I've been trying to frame everything with no post processing which is why it is so difficult and requires so many different cameras and telescopes. After investigating post-processing I have come up with the following conclusions about how to go about getting good images.

You need to make the philosophical choice of which road you want to go down early on in your astronomy voyage to avoid wasting either a lot of time or money.

Little to No Post-Processing

This is what I'd call the completely "honest" picture approach – where the picture reflects exactly what you saw in your camera. This could also be called "old school" photography as this is what was done before computers became widespread.

This approach is MUCH less complicated, but MUCH more expensive as you have to buy lots of different telescopes, lenses, and cameras. And it is very difficult to get extremely wide-angle shots like the Milky Way.

Lots of Post-Processing

This is the less "honest" approach where the final image is not exactly what you saw in your camera, but has been touched up or altered in some way to make it more esthetically pleasing.

A quality high resolution camera and post processing could allow you almost the same flexibility as the "No Post-Processing" approach with much less hardware cost - i.e. one camera and one scope. The camera "Area Of Interest" feature becomes important in this mode so you are not wasting memory and bandwidth when taking images of objects much smaller than your camera max resolution.

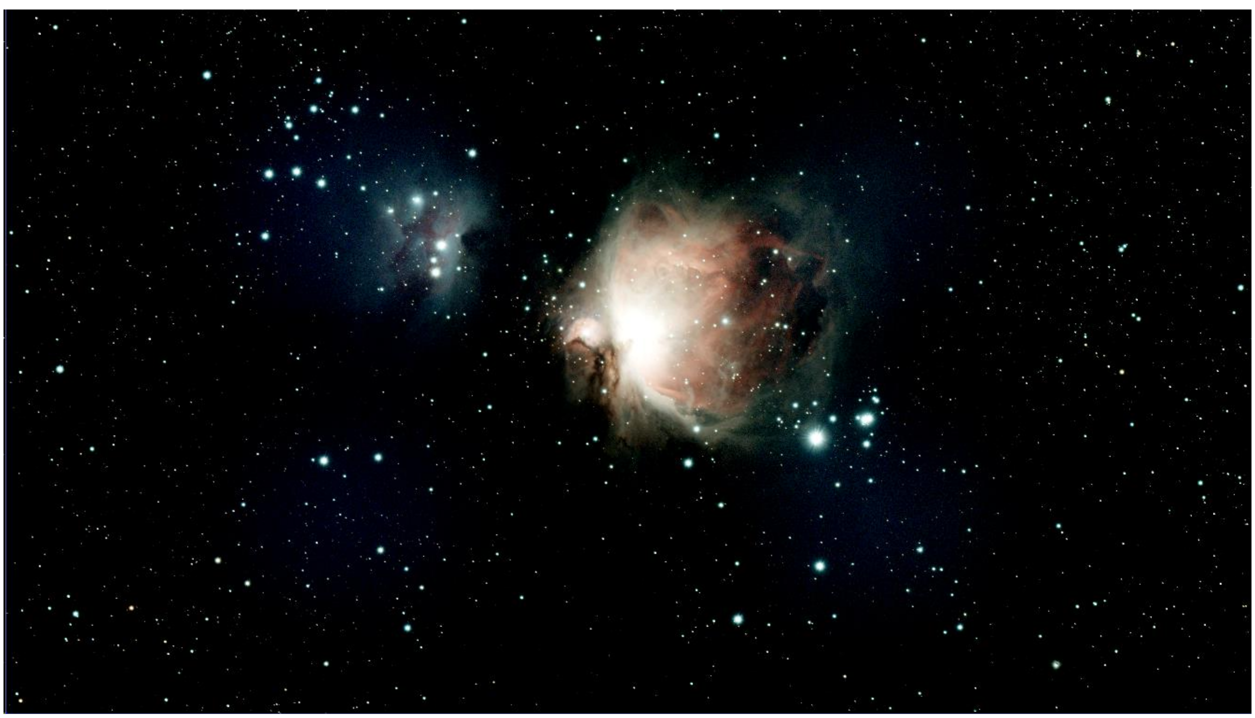
This approach requires that you use Mosaics to "stitch" together lots of small images when creating a wide angle shot. There are many programs that help you do the "stitching" work and in some cases completely automate the work. However, after reading many reviews it seems that the real-world consensus is that automatic Mosaic stitching may be a pipe dream in all but the simplest cases. In which case powerful post processing software and a large commitment of your time is a must if you do Mosaics.

This approach is much cheaper cost-wise as good post-processing software is only a few hundred dollars, but has an EXTREMELY steep learning curve. Some estimates are that it will take you many months before you can use the post-processing tools effectively.

For an in-depth look at post-processing please refer to the Post-Processing document.

The following illustrates what you can do with mosaics. Both images are captured using a Redcat71 and ASI585MC. The first image is a single shot from the camera, and the second is a mosaic composed of 4 overlapping (30% overlap) shots (2nd shot has histogram adjustments.)

You can see how a wider field of view can be achieved with mosaics without any additional hardware (more telescopes) cost.



Solar Observation

Solar observation is different from stellar in many ways:

1. Since it is done during the day, you cannot perform a typical polar alignment.
2. While auto-focus might work, it is really pretty easy to focus manually.
3. Since the sun is extremely bright:
    a. You need to protect your telescope with a solar filter.
    b. You will always use the shortest exposure time possible.
    c. You must not look at the sun with your bare eyes.
    d. You don't need a large aperture telescope and can use a smaller telescope.
    e. You have to be careful not to overheat the telescope and camera internals.
        i. You need to monitor the camera sensor temperature and abort your session when the temperature gets too high. You will see it rising constantly during your session.
4. Since the sun moves at a different rate than the stars you need to change the mount tracking speed to use "solar" (rather than "stellar".)

Special Equipment

To do this requires some extra equipment as pictured below.

First of all, you will need the BuckeyeStargazer Sun Finder (mounted on top of the telescope above.) It seems odd to need a tool to "find" the sun, but since you can't look at the sun, the only way to align the scope is to use the suns image on backscreen cross hairs.

Then you will need a solar filter that is properly sized for your telescope. Since I'm using an Askar FMA180 I chose the Spectrum Telescope Glass Solar Filter: 2.75" Cell Inside Diameter # ST275G. Note that there are cheaper "film" solar filters, but I feel much more comfortable with a real glass filter as the films can crease, tear and develop pin holes that can damage your equipment. You can see the (silver) solar filter attached to the front of the telescope in the image above.

Steps to Record Video of the Sun

Here are the steps that I used to setup the equipment for solar observation. There may be better ways to do this, but this worked pretty well for me.

1. Setup your mount.
    a. If the elevation is not already set from stellar observation set this up for your location.
    b. Point the mount as close to north as you can – don't worry if you are a little bit off.
    c. Change your mount tracking setting from "stellar" to "solar".
    d. Use your mount guiding controls to have it move to the "Sun" and start tracking. Wait for it to complete.
    e. Look in the "Sun Finder" and see where the bright dot is located. If it is not in the center (and it probably isn't), then manually shift your tripod legs around little by little until the bright spot is in the center of the "Sun Finder". You may also have to adjust your elevation slightly.
2. Fine Tuning
    a. Center the sun in the camera frame
        i. Take a picture of the sun.
        ii. If it is not in the center of your frame you will need to adjust the mount slightly – this is best done with the hand controller in "slow" mode – so that the sun moves to the center of the frame.
        iii. Keep taking pictures and moving the mount until the sun is roughly in the middle of the camera frame.
    b. Focus the sun
        i. Take a picture of the sun.
        ii. Move the telescope focus a bit (roughly 5% of full travel.)
        iii. Take another picture and check to see if it is in focus yet – you should see a sharp disk with sun spots on it when it is in focus.
        iv. Keep repeating these steps until you get the sun in focus. If you are seeing the sun disk shrinking as you make each adjustment, then you know you are going in the right direction. When you see it start to grow, you know you went too far.
3. Take Pictures
    a. Normal pictures are the same as normal star pictures.
    b. Typically, you will want to take video of the sun and here the extra things to know.
        i. On my ASI585MC camera, there is a "fine tuning" control below the start/stop control which allows you to fine tune the exposure time as well as the red/blue white balance. You should play with these until the sun image looks good.
        ii. Taking the video on my ASIAIR was pretty straightforward except for the following.
            1. I used the default MPEG setting and it said it saved it but I couldn't find any recorded video. It turns out that MPEG is saved to your phone, and AVI is saved to the ASIAIR storage. So, using AVI works better for me.

Example Video and Notes

Here is an example video that I recorded – this was my first successful video which just happened to have an airplane fly in front of the sun and I left it as it seemed amusing!

Video of the Sun

This is only a getting started section and there is much more that can be done for solar observation including: specialized telescopes, filters, etc.

Sky Conditions

I finally broke down and purchased a Sky Quality Meter (Unihedron SQM-L) to see what my actual observation conditions were in my back yard. Here are the results of my observations.

- For about 40 minutes after sunset SQM is 17.83 or lower (Bortle 9) which is pretty bad.
- 50 minutes after sunset SQM rises to around 18.11-18.26 (Bortle 7) which is OK.
- If I take the reading inside a 2' tube pointing up, it rises to 21.05-21.40 (Bortle 3-4) which is quite good for city observations.

This now explains why I am getting much better images with my Redcat 71 (which has a shield tube that extends about 6" past the front lens) than my Celestron C8 (which has no shield tube, and a much larger aperture.)

I got a dew shield for my C8 (even though I don't have a dew issue) and I think this has made an improvement to the image quality – see Image Quality Progression section.