

# Solar Photography with a Coronado PST

## The Coronado PST



Figure 1. The Coronado PST

The Coronado Personal Solar Telescope (or PST, Figure 1), is a small telescope designed for viewing the sun in hydrogen alpha light at a wavelength of 656.3nm, with a band width of order  $\sim 0.1\text{nm}$ . This degree of selectivity in wavelength is provided by an optical device called an etalon, which in the PST is tunable to a small degree (via a tuning ring around the telescope tube)<sup>1</sup>. The PST presents the amateur astronomer with detailed views of the sun's surface, showing filaments, prominences, plages, flares etc. However, while the PST is a great telescope for visual use, it is difficult to use photographically on account of its unusual optical characteristics. Without a special effort, attempts to photograph the fascinating details that a PST provides can be disappointing. This note [1] is intended to help a novice obtain images like Figure 2 below.

This image is a superposition of two copies of the same photograph. The one in the background has been stretched to reveal the otherwise faint prominences on the sun's limb, while the one in the foreground is a normally processed image showing the details on the sun's surface.

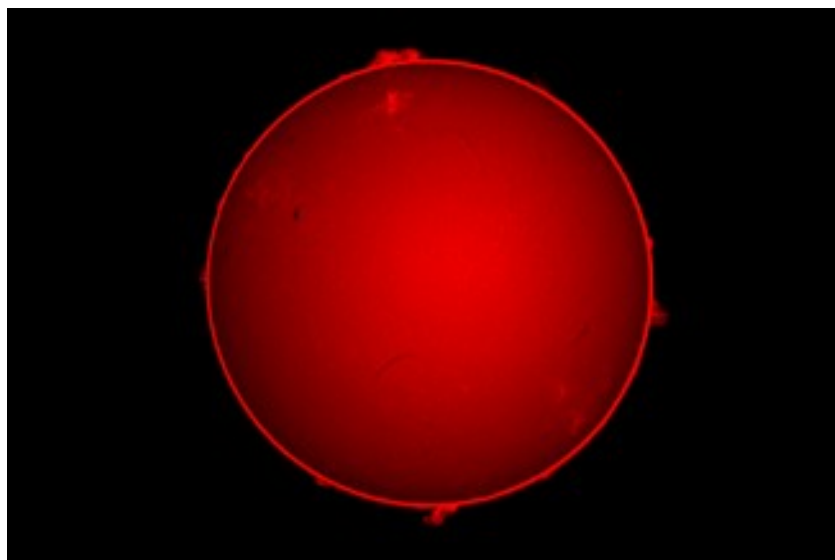


Figure 2. The sun on 20<sup>th</sup> May 2023

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<sup>1</sup> Its original purpose is to correct the etalon for changes in atmospheric pressure.

## Equipment Required

The Coronado PST should be mounted on a photographic tripod. A mechanism for tracking the sun across the sky is not essential, since the shots will have a short exposure. But since keeping the sun central in the image turns out to be important (see below), it is an advantage to use tracking to avoid having to re-centre the image for every shot. On the other hand re-centring isn't difficult and, without a tracking mount, not aligning an equatorial mount beforehand saves time.

Almost any DSLR camera will do, but the higher the pixel number the better. My camera is a Nikon D3100 (4,608×3,072 pixels) is used in prime-focus mode without any camera lenses as such. However, it is essential to incorporate a x2 Barlow lens in the optical train, because the unaided PST isn't able to project an image onto the camera sensor unaided. In my set-up I have taken the lens from a x2 Barlow and screwed it into the 1 inch long nose-piece of a Meade basic camera adaptor (1¼ inch diameter) which connects to my camera via a T-ring (see Figure 3). The nose-piece slots directly into the PST eyepiece tube.

Note that it is possible to rotate the camera in the eyepiece tube. So if you want to keep a consistent camera orientation for all your shots, you need to set aligning marks on the nose-piece and the eyepiece tube. Then, if you later need to work out the orientation of the sun's polar axis in the image, it will be possible. (If you require this for serious work it is best to mount your PST equatorially rather than use alt-az, which is generally agnostic with regard to telescope orientation.)



Figure 3. The camera and nose-piece (with Barlow lens)

One last essential is a cable release (or equivalent) so the shots can be taken free of vibration. Motion blur can destroy the surface detail in the sun's image irrecoverably.

## Preparation

Before stepping out to photograph the sun it's a good idea to check out how the sun is likely to be performing that day. I generally look at the SOHO website [2] which shows the sun in H- $\alpha$  on that day. It can be quite motivational to do so, particularly if there is something spectacular going on. The next step is to take a good look at the sky. Clouds of any kind are bad news for solar photography, but if they are broken, drifting clouds, a viable session is still possible, if you wait for breaks in the cloud cover. High, slow moving, hazy clouds are a great frustration. One thing that it is difficult with a PST is getting good focus on the sun though the camera, and a hazy view does no

favours, either with focussing or later post-processing. Clear views are really essential in my experience.

## **Setting Up**

Setting up is reasonably easy – not much more difficult than setting up a camera and tripod. If you are a novice, start with a suitable eyepiece in place, rather than the camera, because it is easier to get the telescope-plus-eyepiece working than the telescope-plus-camera. Later, with more experience, you can go straight to the camera.

Some practice is required getting the sun into the narrow field of view of the PST, but there is a nice little sun viewer on the PST that helps you home in on the sun when you are reasonably close. To get to that point you need to look at the shadow of the telescope on the ground or perhaps an adjacent wall, to ensure it casts its minimum shadow. When it does the sun should appear in the sun viewer. (With familiarity, you can get good at this.) If you have the official PST sun shade (which is an optional extra), you can watch the shadow of the telescope tube on the front of the sun shade and when it disappears down the telescope hole, the PST is properly pointing at the sun, which then appears in the sun viewer.

Looking though the PST you should now find that the sun appears in the camera viewfinder or eyepiece (whatever you are using at the time), but with my PST, the sun being central in the viewer doesn't mean it is central in the camera/eyepiece and a degree of adjustment is required. After a while you'll get used to this small disparity and correct for it without thinking using the telescope mount, but you need to be aware of it initially. Take note that getting the sun's image into the exact centre of the field of view of the camera/eyepiece is important. The view off-centre is strongly vignetted, and away from centrality the sun's images vignetting will cause a shadow across the sun's image, which is difficult to remove when processing later. If your mount is not driven the sun will keep slipping into the shadow - so be aware.

## **Getting Focused**

Getting the sun's image perfectly focussed on the camera sensor is the most tricky part of PST solar photography and this is where potentially much frustration resides. So let's start with eyepiece focussing.

Getting focus with an eyepiece is relatively simple. Firstly you should set the etalon tuning ring at the middle of its range. (It does not play a major role in focus acquisition, it is principally for refinement. So you want to be able to adjust it forward or back when best focus has been achieved using the focus knob.) Next, with the sun's image in the centre of the eyepiece, turn the focus knob either clockwise or anticlockwise and note what this does to the sun's image. When the image is out of focus (as it most probably is when you are starting up) the sun's image will appear larger than it would be when focussed. If the image decreases in size, you are turning the focus knob in the right direction, if it increases you must reverse the direction of turn. Continue until you pass slightly through the minimum image size and then reverse back carefully to the true focus. At this stage the outline of the sun should appear sharp (possibly with prominences) and the sun's surface should show the anticipated features – filaments, plages, granulation, flares, sunspots etc. Some fine

tuning may be applied by carefully turning the tuning ring of the etalon, which will cause hidden features to jump into view.

Getting focus with a camera is, in principle, the same as for an eyepiece. However, if the image is viewed through the camera viewfinder, I have found that the reticule in the viewfinder, normally an aid to focus, is an obstacle to getting a clear view of the sun. (Hopefully this will not be such a problem with all cameras.) It is reasonably easy to get the sun's image to its minimum size and thereby obtain a sharp outline of the sun's disk, but features on the surface may be hard to make out. Adjusting the etalon is not very revealing in this case as when using the eyepiece and isn't so helpful in making out detail. However, with practice and persistence, it is quite possible to get a clear enough view to be sure that a photograph will capture something of significance.

Alternatively, if you focus using an eyepiece first and obtain a sharp image, you can then remove the eyepiece and, replacing it with the camera, bring the image back into focus in the camera viewfinder with the focus knob of the PST, slowly turning in a direction that causes the sun's image to shrink to a minimum size (as before). This approach helps because once you know the correct direction of turn and have a good idea of what to expect when focus is achieved, you can home in on the best focus quite quickly. This approach helped me a great deal when starting out.

For cameras like the Nikon D3100 there is also the possibility of using *Live View* to assist with focussing<sup>2</sup>. Selecting this option means an image of the sun appears (enlarged) on the camera's LCD monitor and this can be used to obtain focus. For this to be successful, you must cover your head and camera with a dark cloth (and put on your glasses if you normally need them!). An extension of this idea is to connect the camera to a computer and use camera control software to bring up the image of the sun on a much larger monitor. On linux computers this option is provided by the software `gphoto2+gkam` [3] and on windows by the `digiCamControl` program [4], both of which are free to use.

Whichever option is taken to get camera focus, once achieved you can go back to using an eyepiece and, keeping the PST settings fixed, use a locking ring to fix the eyepiece at the correct position in the eyepiece tube for both eyepiece and camera to be in focus. The ring-locked eyepiece may then be used on later occasions to find best camera focus quickly. This is a long-established trick readers will no doubt be familiar with in other contexts. However, it is not in this instance completely foolproof, since the etalon is sensitive to environmental conditions (temperature and pressure) and focus will change slightly between sessions. But it is nevertheless a substantial help.

## **Taking Photographs**

My usual procedure is to take 5 identical shots of the sun in quick succession, allowing camera shake to settle for a second or two between shots. My method is to stack these shots later to reduce image noise - see below. Since I most frequently use an alt-az mount, the quick succession of shots will mean I don't have to rotate any images in stacking. All my shots are taken with a cable release to minimize vibration. Since I don't use a tracking mount, I try to make sure that the sun is accurately centred in the image and check between shots (when being conscientious).

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<sup>2</sup> Unfortunately for me, the Nikon D3100 closes live view after 30 seconds, which is somewhat annoying!

All my shots are taken in RAW format (i.e. as NEF files for Nikon or CR2 for Canon, for example) so I can retain maximum bit depth (12 bits in my case) in the colour channels. This is useful if any kind of brightness or colour stretching is needed in post-processing (and it always is). I use ISO 100 to minimise the camera noise and I see no need to go higher - the sun being bright enough to keep exposure times small. The exposure times I use range from 1/15s to 1/10s. These seem to be good for my D3100, but for your camera you may need to experiment a bit. I find I must stretch these images when processing, but if I use longer exposures instead I often find the surface details are blurred (presumably by motion, since I am without a tracker) and often the surface ends up overexposed. From which all I get is a red disk from which no details can be extracted. This may not be an issue for you, but longer exposures do run the risk of the fine details 'washing out'. As a rule, if you can't see limb darkening on your shots of the sun, you are probably missing some or all of the surface details too.

## Processing the Photographs

I make no great claims for my approach, but I am reasonably content with it and it may help you to get started. So in that spirit, here goes.

I use the image editor known as GIMP for my image processing [5]. GIMP is free and I am a supporter of free software. GIMP is very versatile and I have written plug-ins to automate most of the procedures I shall describe here [6]. I work in 16 bit colour depth, though the camera initially yields only 12 bits of colour.

The main issue I have found in working with PST solar images is that it is easy to lose the surface detail in any operation that alters the brightness or contrast. This is what I term 'washing out'. There is a delicate balance to be struck between brightness and contrast so care is needed.

So these are my steps:

**Step 1.** All my shots are converted from RAW format to 16-bit PPM format using the free program DCRAW [7] by Dave Coffin. In command mode this is done using the command:

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dcraw -v -w -o 0 -q 3 -4 imagefile.NEF
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PPM is a simple, uncompressed format that is quick and easy to handle with GIMP. I store such image files in a non-lossy compressed form using gzip. That's a personal choice, since overall I find PPM with compression faster to handle than PNG files.

**Step 2.** My shots at 1/15s and 1/10s exposure are somewhat dark, so my first act is to brighten them by a factor of 4 or 5. My procedure is equivalent to stacking 4 or 5 copies of the same image using the *Addition* blending mode. (I have written a plug-in that does this by multiplication.) Do not over-brighten or surface detail will wash out.

**Step 3.** If the features on the sun are not sufficiently clear at this stage, the shots are then processed using GIMP's *Brightness-Contrast*. This is only used to tweak the *contrast* slightly (leaving *brightness* alone) so that the sun's surface features stand out a little more. If I overdo this, the limb darkening effects hide the image detail, so take care.

**Step 4.** Now all the images of the sun taken with the same exposure are stacked. Since the number of shots in the stack is only of order 5, I do this by hand. In GIMP the shots are loaded up as separate layers in the same image and then shifted individually to ensure complete overlap with the bottom layer of the stack. The trick to this is first to make all layers invisible except the bottom layer, set at 100% opacity, and the one being aligned with it (the 'moving layer'), which is set to 50% opacity. Next, the moving layer is shifted using click and drag (for coarse adjustment) and keyboard arrows (for fine adjustment) until overlap of the two sun images is as exact as can be made. I zoom in to help with this. Then the moving layer is made invisible and the next layer to be aligned is selected, set visible, and assigned 50% opacity, and the process is repeated for all 4 moving layers. Finally all the layers are made visible with their opacities set to 100%, 50%, 33.3%, 25% and 20%<sup>3</sup>, respectively from the bottom layer up to the top and then merged using *Image Flatten*.

**Step 5.** At this stage the flattened image (which consists of a single layer) may need a little brightening. If so the layer is duplicated in the layer stack and the duplicate (on top of the original in the stack) is given a small opacity (say 10%) and its blending mode set to *Addition*. The opacity setting may be altered to get the right degree of brightening, which must avoid any washing out of the surface features. When the right brightness is achieved, the image is flattened. As an option a small contrast adjustment (using *Brightness-Contrast*) may be made, but usually I find this unnecessary.

**Step 6.** Now the image may be sharpened. I use something called *Smart-Sharpener* for this purpose, which sharpens edges but leaves everything else unsharpened, and so can be used repeatedly. (I have a plug-in for the purpose.) But GIMP's *Unsharp Mask* is acceptable provided it is not used too many times.

**Step 7.** The image can now be exported as a PPM file (or BMP if you prefer) and stored in a non-lossy compressed file. A JPG version is handy for showing others what you have done. GIMP can produce any of these.

## References

[1] Available from: <https://stargazy.weebly.com/essays-in-science.html>

[2] <https://soho.nascom.nasa.gov/data/realtime-images.html>

[3] See essay: *Astrophotography and Linux* on web page [1] above.

[4] digiCamControl, available from: <https://digidcamcontrol.com/>

[5] GIMP, available from: <https://www.gimp.org/>

[6] *PiAstro for GIMP*, available from: <https://stargazy.weebly.com/pyastro-for-gimp.html>

[7] Dcraw, available from: <https://www.softpedia.com/get/Multimedia/Graphic/Image-Convertors/dcraw.shtml>

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3 For 4 layers stop at 25%.

