Amateur Imaging of the Night-side of Venus

MR Lewis 22/1/2025

Introduction

When Venus is imaged in a narrow band of infra-red light centred around a wavelength of 1010nm, its thick and densely opaque atmosphere becomes partly transparent. Because Venus's surface temperature is ~460°C it also emits significant amounts of radiation in that same region of the electromagnetic spectrum. These two facts, combined with the presence of a window in the Earth's atmosphere matching this same wavelength range, mean that in the planet's unilluminated (night-side) portion it is possible to capture infra-red images of the actual surface. In the right conditions significant amounts of detail can be seen in this thermal night-side image; darker features can be recorded, corresponding to cooler topographical features of higher elevation. Additionally, one can occasionally detect intriguing transient features including darker areas, brighter spots and streaks.

The thermal night-side of Venus is a relatively new target for amateur planetary imagers and the methods used and equipment available are improving with each apparition. Despite these improvements, recording the night-side of Venus is likely to remain a significant challenge, especially obtaining good feature-rich images. Despite the difficulties, if you are familiar with standard planetary imaging and have a telescope of an aperture >250mm, you might be able to capture night-side (NS) features yourself. This section should help you in that quest, giving details of when best to image, what equipment to use, and what capture settings to employ.

Venus Night-side and the Ashen light

Although imaging in these specific infra-red wavelengths might allow you to capture the night-side (NS) of Venus, it is important to remember that you are working in wavelength range which is invisible to the human eye. Venus's Ashen light, reported by experienced observers over many decades, where the night-side of the planet is faintly seen when visually observing the crescent in a nearly dark sky, is a different phenomena. What causes the Ashen light is unknown, but it is certainly not a naked eye view of the hot surface of the planet, as its atmosphere is opaque at these wavelengths. The Ashen light, if real and not an optical artefact, is much more likely to be a phenomena of the Venusian atmosphere rather than a view of the planet's surface.

Venus Night-side - The Challenges

Planetary imagers striving to image Venus's thermal night-side will face an array of familiar and less familiar practical challenges. The main issues generally arise from the fact that the thermal radiation from the night-side is relatively weak and that you are imaging this faint region next to one of the highest surface brightness objects in the sky - the Venus dayside. The dimness of the night-side also means you will need to image with the Sun below the horizon in order not to be overwhelmed with the wash of light from the background sky. The need to minimise this wash of twilit sky and also the problem of the dayside glare, means the best time to image the night-side will be when Venus is a crescent of phase 15%-

35%, and at a time just before sunrise or after sunset. Unfortunately, this does means the planet will then be close to the Sun, as it will be away from maximum elongation (where phase is 50%) and consequently of relatively low altitude. This lower altitude generally means poorer seeing, as you will be then looking through a greater thickness of the Earth's atmosphere.

You can get an idea of some of the challenges in Venus night-side imaging by referring to the plot shown in figure 2. This shows a brightness profile though a Venus night-side image during an optimum imaging period in early September 2023. The line profile used for the plot is shown in figure 1 and starts in the middle of the overexposed dayside, runs across the night-side and finally extends into the background.

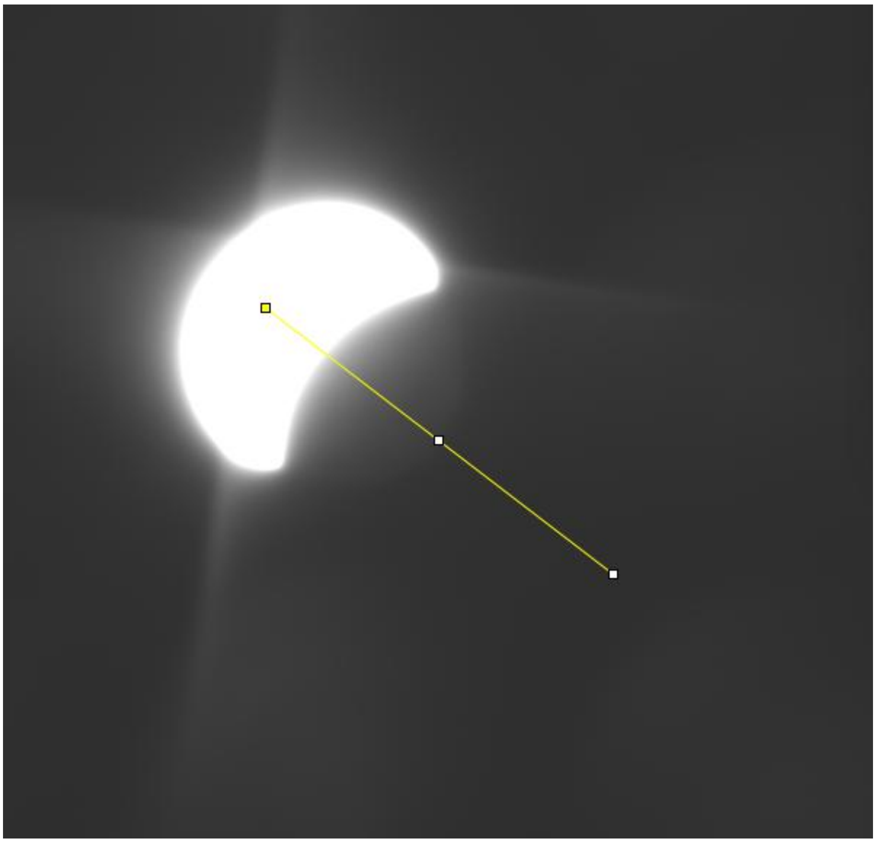


Figure 1. Line profile through an example stacked Venus image from the optimum imaging period in early September 2023.

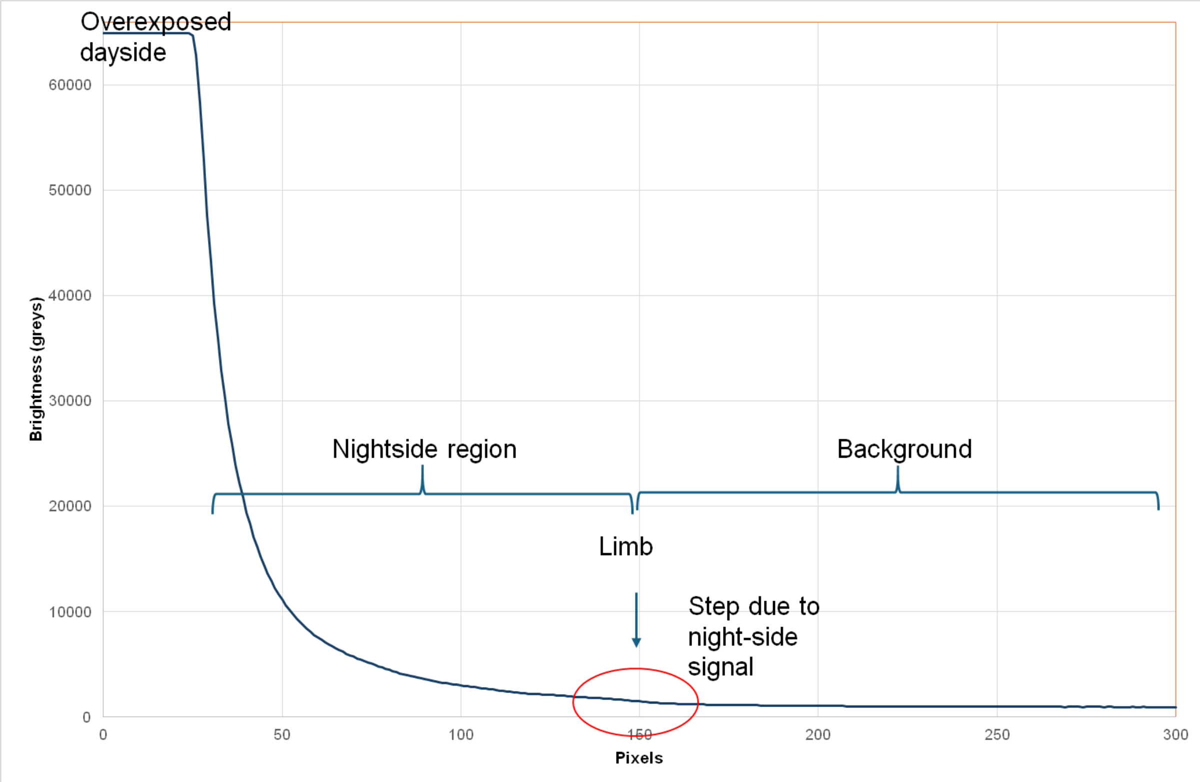


Figure 2. Plot of brightness with position for the line shown in figure 1 during the optimum imaging period, with the crescent at 17%. The night-side signal is the tiny step of 200 grey levels at the limb, circled. This has to be picked out of the background wash whose level is ~1000 grey levels and the glare from the dayside which rapidly rises as you move towards the over-exposed crescent. A third of the way in from the limb (at the 100 pixel position) the glare and the background wash are together at ~3000 grey levels. This means the night-side signal represents just 7% of the total brightness at this location- and even an even smaller fraction even closer to the dayside.

When to attempt Venus night-side imaging

The best periods for Venus night-side attempts are when Venus's phase is between approximately 15% to 35% and the ecliptic makes a steep angle with the horizon - putting the planet higher in a darker sky just before sunrise or just after sunset. For northern hemisphere observers this means evening apparitions when inferior conjunction occurs in spring or early summer and morning apparitions when inferior conjunction occurs in late summer or autumn.

With 5 inferior conjunctions in almost exactly an 8 year period, Venus apparitions go through a repeating cycle. The best apparitions for Northern hemisphere imagers in coming years are given for observers at 52° N in the table below. Altitudes at sunset/sunrise are when the phase is about 25%, approximately one month from inferior conjunction and in the middle of the 15% to 35% phase period:

Optimum NS imaging - Evening	**Altitude of Venus at 25% phase in Evening at sunset**	**Optimum NS imaging -Morning**	**Altitude of Venus at 25% phase in Morning at sunrise**
April-May 2020/28/36/44	31°	Sept. 2023/31/39/47	29°
Feb. 2025/33/41/49	34°	Nov-Dec 2026/34/42/50	26°

Table 1. Good evening and morning apparitions of Venus in coming years from 52°N

Close to inferior conjunction the phase changes rapidly and the window of opportunity is short, with only just over 3 weeks between the 15% and 35% phases. Outside of this window the favourability of the conditions drops-off rapidly. When the phase is too small (<15%), although Venus is large and the dayside glare is less, Venus is much closer to the Sun. This means it is then rather too low in a sufficiently dark sky - leading to poor seeing and very short imaging sessions. At the other extreme with the phase too large (>35%), the glare from the proportionally larger dayside seriously starts to swamp the proportionally smaller night-side, even though it is higher in the sky and the seeing generally better. To further hamper efforts, the planet shrinks, reducing the angular size of surface features.

One's location has a bearing on the exact geometry of the apparition and at lower latitudes, where the ecliptic makes a steeper angle with the horizon, the bottom end may be extended down to a phase of 10% or even lower, as Venus will be higher in a sufficiently dark sky here, helping noticeably with the seeing.

Shot Noise

When imaging the Venus NS at the right time and with the right equipment, the level of detail seen is determined by two main factors - resolution and noise. The best images are well-resolved *and* have low levels of noise.

Resolution depends on factors such as aperture, optical quality, atmospheric seeing effects, scope thermal effects, and optical image scale. However, even if you have great potential resolution, if the image is plagued by noise then the finer detail will be lost. Imaging the NS of Venus is difficult and made easier if you have a proper understanding of how to reduce noise in your images.

In planetary imaging, with its relatively short exposures compared to those in deep sky imaging, the two main types of noise to contend with are read noise and shot noise. Read noise is essentially a fixed level of random signal noise added to each frame, often manifesting itself as lines of noise in the x or y direction. With modern digital video cameras, working at med/high gain, the levels of read noise are relatively low and much more important than read noise is the level of shot noise in images. This shot noise comes from the quantum variation in the number of photons in a signal. If a pixel captures 100 photons, the level of variation (noise) is 10, so the ratio of the signal to the noise (SNR) is 100:10 or 10:1. If 10,000 photons are captured then the level of variation, given as the square root of the number of photons, is 10x higher at 100. In this second case, although the noise is 10x higher, the SNR is now 10,000:100 or 100:1, and so much improved. Thus the SNR can be improved by capturing more photons, so that the signal increases by more than the shot noise.

Venus night-side images can suffer from low SNR because the signal is weak (low photon count). Increasing the effective accumulated exposure time by taking more frames and adding them to the stack will help, as figure 3 shows. SNR improves by the square root of the number of frames stacked. Increase the number of frames by a factor of 4 and the SNR improves by 2x.

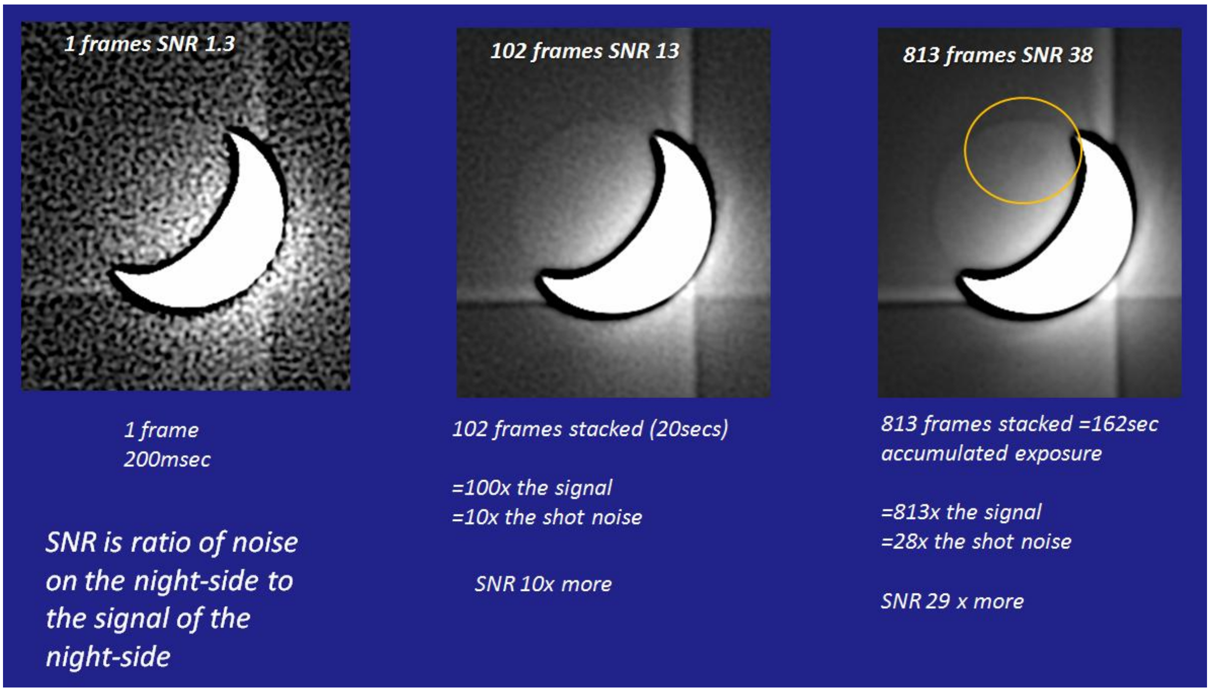


Figure 3. See how SNR improves as more frames are stacked and the effective accumulated exposure time increases. It is only with a 162 sec. accumulated exposure time that thermal signal surface features start to emerge.

Venus NS imaging is particularly challenging in that the main source of the noise is not the variation in the dim signal, which would lead to low SNR anyway, but the two big sources of extraneous infra-red radiation which give a wash of light overlying the faint signal - the twilight wash and the glare from the dayside. These are both generally much larger in magnitude than the NS signal and are problematic as the noise signal from these sources is correspondingly much larger. You can subtract off the average glare or twilight signal from all pixels in the image but the noise from those two culprits is left imprinted on the NS data. It is the same problem that deep sky imagers face with light pollution and hopefully is more clearly explained in figure 4 below. This is from the perspective of twilight wash, but the principle equally applies to the issue of glare.

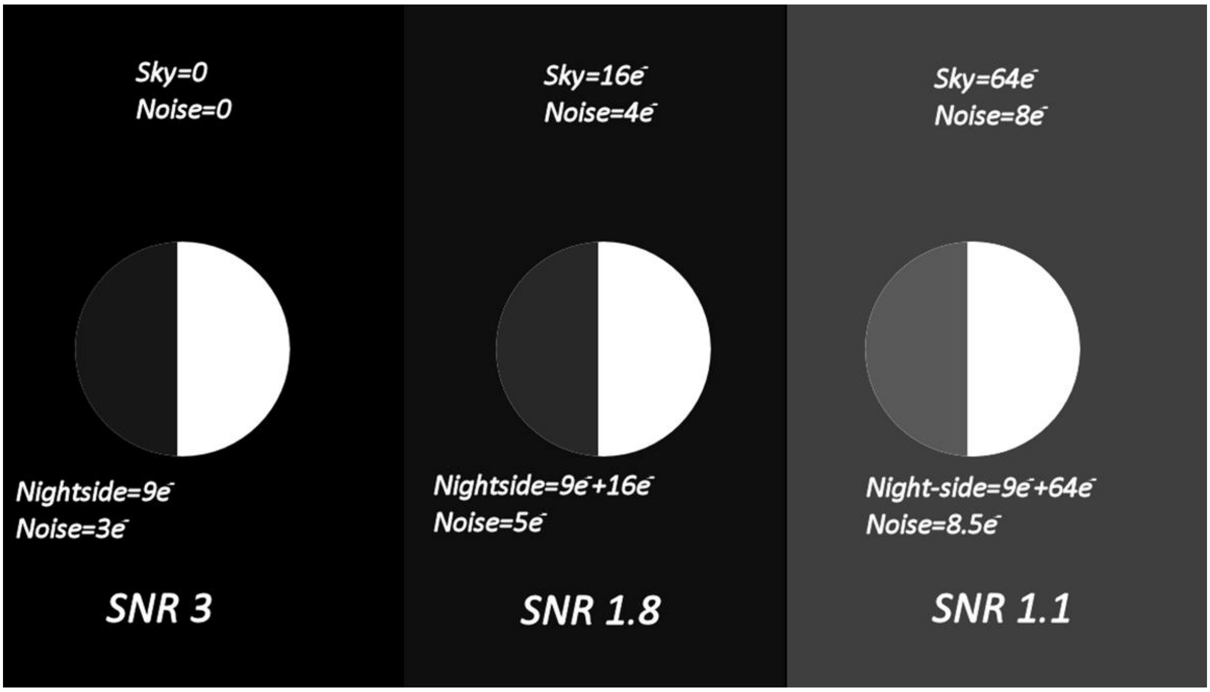


Figure 4. Illustrating the issue of a wash of unwanted light across the object and how it causes the SNR to fall. The twilight wash increases from left to right leaving an increasing shot noise imprint on the precious night-side data. (The night-side noise is the square root of the sum of the base night-side signal and the sky wash signal)

Twilight Wash

In the section on shot noise it was explained how a wash of twilight leaves an imprint of shot noise on the night-side signal. This is why serious night-side imaging needs to be carried out when this +twilight wash is minimal. Figure 5 below plots real measurements of the background sky brightness as a function of the distance that the was Sun below the horizon. It shows that when the Sun is more than 6° below the horizon the sky is about as dark as it gets as far as Venus night-side imaging goes. Clearly the sky does actually darken further if the Sun is lower than 6° below the horizon but this is not apparent on the plot and probably indicates that some portion of the background brightness comes from glare from the dayside, which changes little with solar altitude.

When the Sun is higher than -6° the sky brightness climbs very rapidly so that at -4° the sky brightness is about 10x what it was at -6° and increasingly dominates over glare and other factors.

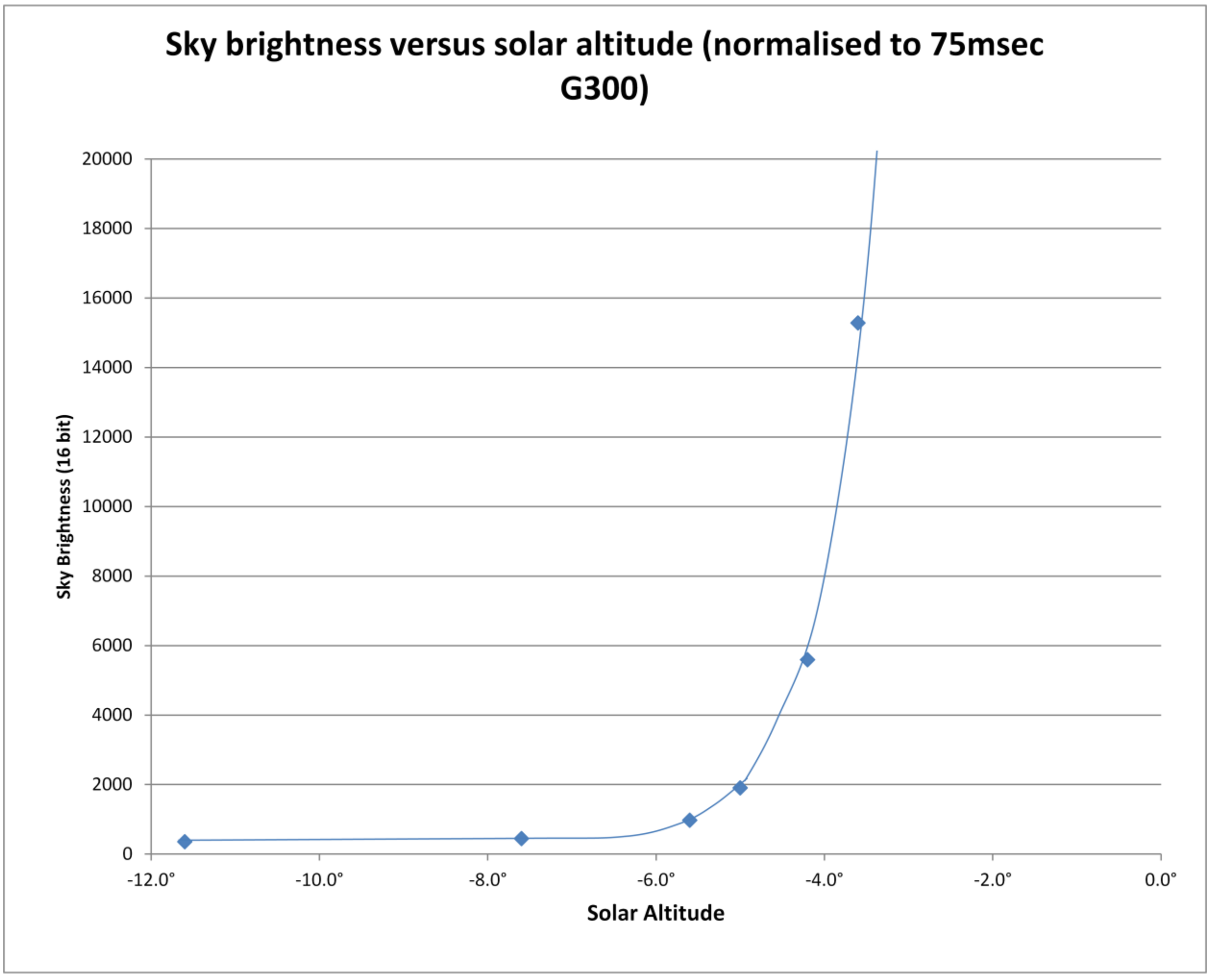
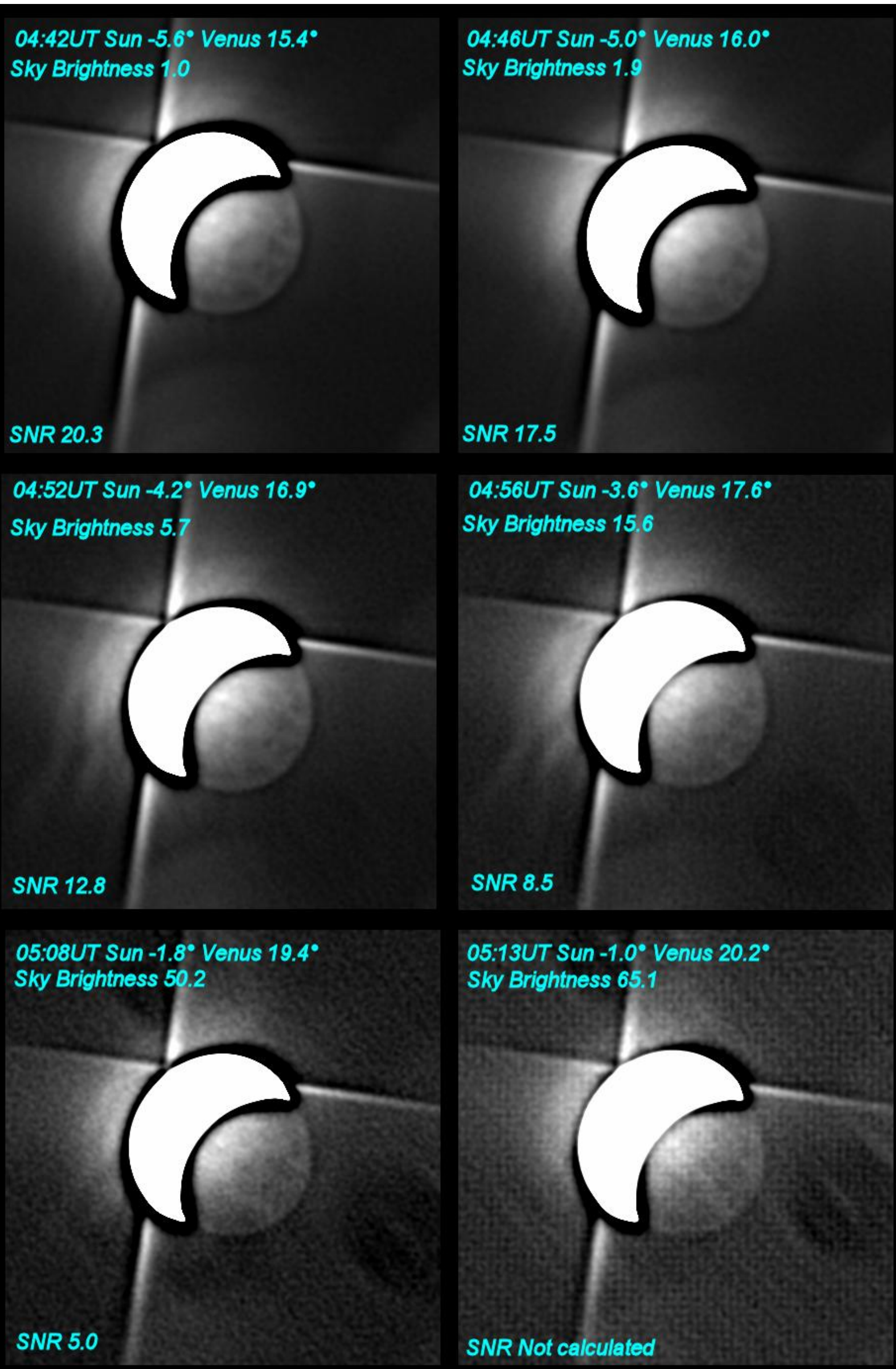


Figure 5. Example plot of background brightness with solar altitude during the good Northern hemisphere apparition in early Sept. 2023. The background brightness increases rapidly when the Sun climbs above -6°.

You can see the impact of sky brightness on image quality in the montage below (figure 6).



Venus Nightside 5th Sept. 2023 - SNR at 31% ref. location versus solar alt.
444mm Dob with Uranus C camera at f4.4. All same wavelet scheme.
Sky brightness from Image J all normalised to 75msec & Gain 300 and brightness at 04:42

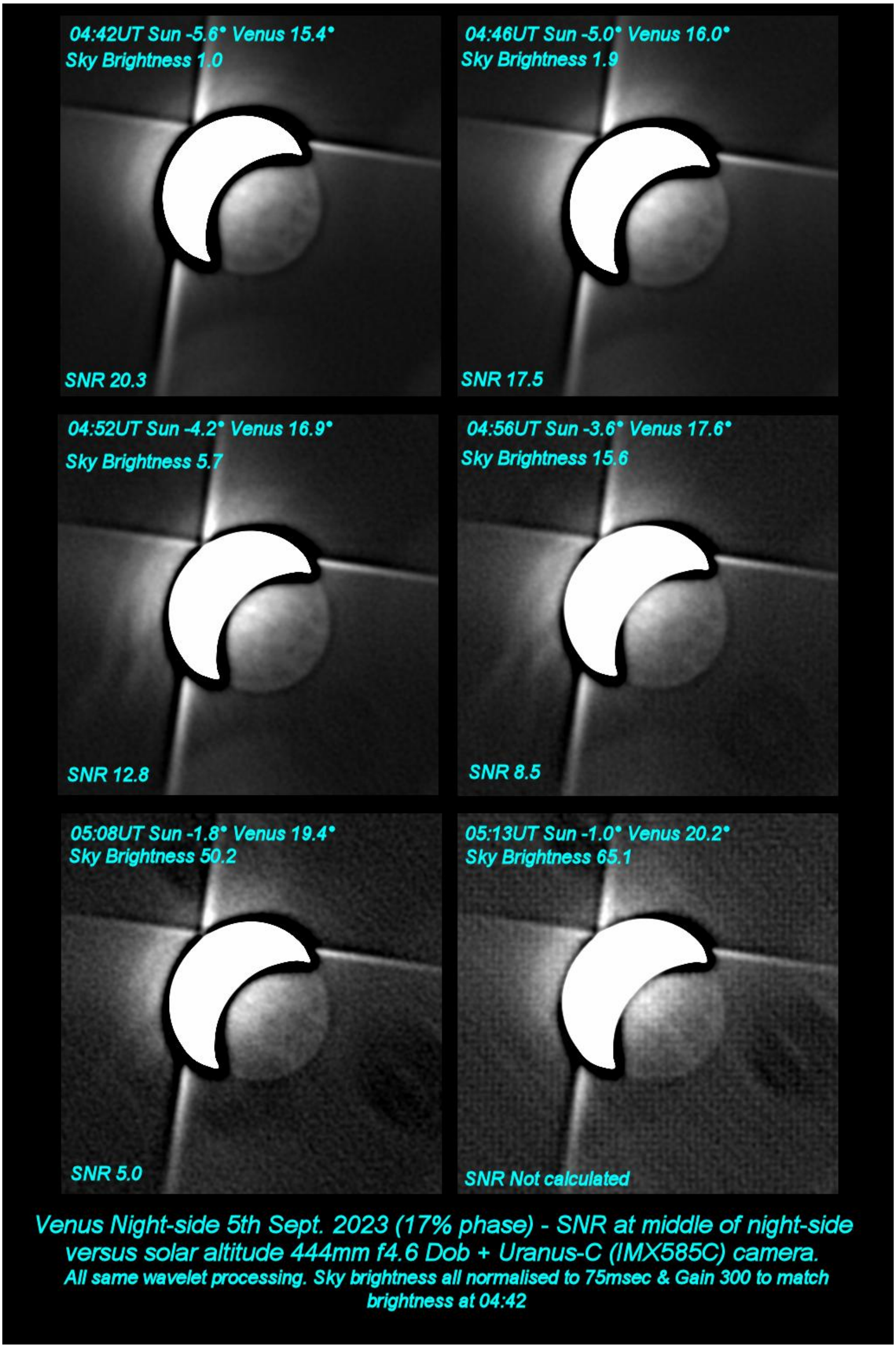


Figure 6. Real-world data showing how the rising brightness of the sky as the session progresses leads to increased shot noise and resulting image deterioration.
Note: At a solar altitude of -1.0° the high sky brightness leads to an 8-pixel weave effect with this IMX585 sensor camera. This is associated with buried metallisation tracking in the sensor becoming evident.

Dayside Glare

In good apparitions, during the optimum imaging period and when the Sun is also more than 6° below the horizon, twilight is reduced and glare from the dayside then becomes the dominant source of shot noise. Glare arises from many sources and the list below is not exhaustive, but the source of the glare is almost invariably light spreading into the night-side region from the much brighter, and immediately adjacent, dayside crescent:

- Atmospheric scatter from aerosols and dust in the atmosphere
- Scatter and reflection from optical surfaces such as mirrors and corrector plates
- Scatter and reflection from surfaces of Barlows and optical reducers, if used
- Scatter and reflection from surfaces of infra-red filters
- Scatter and reflection from coverglass and protection glass in camera
- Scatter within the sensor material
- Diffraction from secondary spider vanes in a Newtonian scope

As you saw in figure 2, the glare increases dramatically as you move across the night-side from the limb towards the dayside crescent. In figure 7 below, line brightness profile data is given for three dates in Sept. 2023 where the phase increased from 17% to 31%. The over-exposed saturated dayside is the plateau at upper left and all the plots are arranged so that the position of the dayside limb is at the left hand axis (0 pixels) for all dates. The individual curves all terminate at the pixel location where the night-side limb is located on that date - the planet clearly shrinking in size as the phase increases.

As the dayside crescent proportionally grows and the night-side proportionally shrinks, the planet also shrinks in angular size. The glare slope near the dayside becomes steeper too. The net result is that the amount of the night-side not so badly affected by the glare, essentially the flattish portion at the bottom of the plot, becomes smaller and smaller. It is this which sets the upper limit of about 35% on the phase. This is approximately the limit at which there is very little night-side which is not on the steep glare slope running up the left hand side of the plot. At 35% any night-side data is hard to process due to the steep slope and is much more affected by the shot noise that the glare imprints on the night-side region.

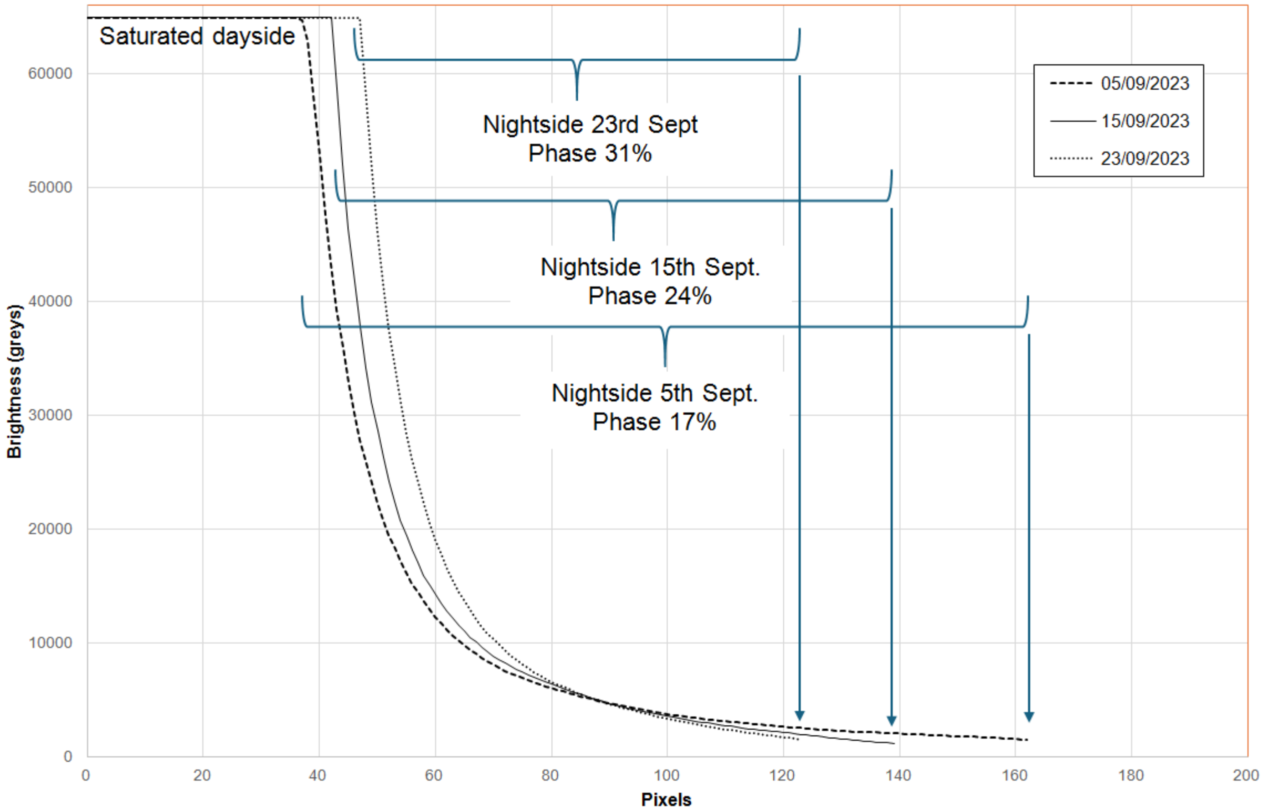


Figure 7. Line profiles across Venus on three days in Sept 2023 when phase increased from 17% to 31%. Curves start on the left at the dayside limb, run across the saturated (overexposed) dayside plateau, then sweep down across the night-side to the night-side limb at the right hand end of each curve. In each case the night-side signal is just about 200 grey levels on the y-axis and most of the signal in the night-side region is glare from the dayside which decreases with distance from the dayside.

Equipment- Aperture, f-ratio and image scale

In the right conditions and with a suitable set-up the night-side should be detectable in small and medium telescopes, but imaging details in the night-side will likely require a scope of at least 250mm. The larger the aperture the smaller the size of the detail and the lower the contrast of the details that can potentially be imaged.

With the night-side so faint, imaging at low f-ratios (<f10) is recommended to increase the surface brightness of the planet and reduce shot noise. The best amateur night-side images have been obtained with large scopes operating at f4 to f7. Large aperture SCTs (280mm - 355mm) which have an inherently high native f-ratio of around f10 can use focal reducers to reduce the effective f-ratio and increase the night-side image surface brightness.

For a given telescope you might imagine that in choosing the most effective f-ratio it was all about image scale and a 300mm f-5 scope with a 2.9um pixel camera would perform the same as a 300mm scope f10 scope with a 5.8um pixel camera[1] as these would have the same brightness per pixel and the same arcsecs/pixel. However, the ghost reflection issue with cameras, described below, complicates things. The dimensionally bigger image on the

[1] This could be a 2.9um pixel camera with 2x2 binning mode applied

chip with the f10 scope *may* mean that the night-side image is partly overlapped by ghost reflection images of the dayside. The f5 scope on the other hand is likely to have better separation between night-side and those nuisance ghost reflections.

The size of Venus on the chip depends on the focal length of the scope, so the bigger the aperture the smaller the f-ratio needs to be to avoid overlaps. This is illustrated in figure 8 which shows a Venus NS image taken with a 508mm scope operating at f11. At this f-ratio the night-side overlapped with a nearby ghost image causing degradation of an otherwise excellent image - at f6 there would have been no overlapping issue as the Venus night-side would have been smaller and the ghost images would have been smaller too - although their separation on the chip would stay the same.

Note that has been observed that the definition of the secondary ghost images increase as the focal ratio increases. This is likely as a result of the narrower cone of light arriving on the sensor surface.

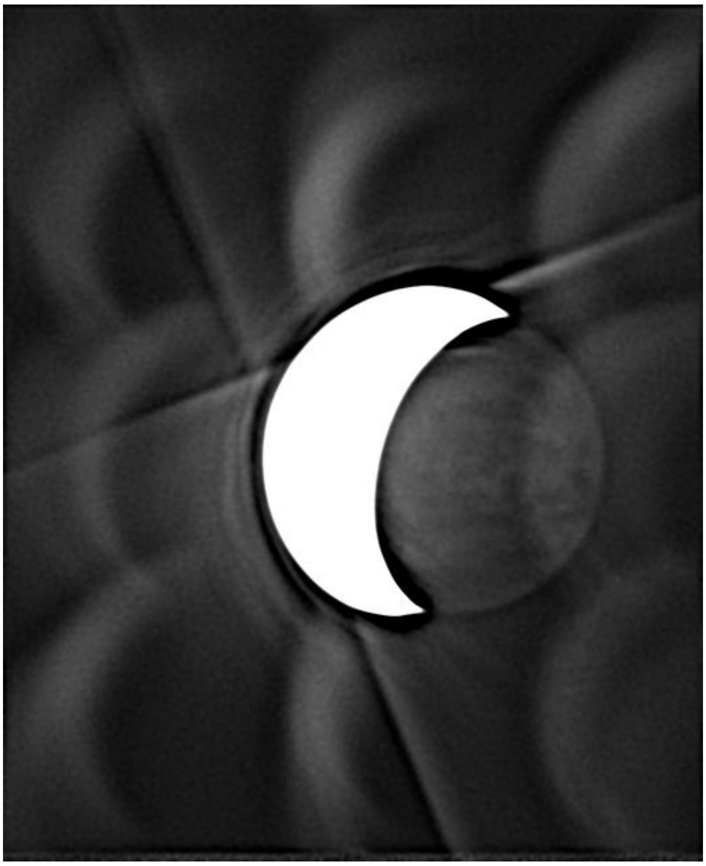


Figure 8. A native f3.3 scope of 508mm aperture was used with a 3.3x Barlow to take this image of the Venus NS. At this image scale, however, the night-side was overlapped by the one of the ghost images of the dayside crescent (image courtesy of Tom Williams and Sophie Paulin)

In normal planetary imaging one would chose an optical set-up best suited to the resolving power of the scope. Generally this is done through matching the camera pixel size with the choice of Barlow or focal reducer so that ~3 pixels or so covers the small resolvable feature that the scope can produce. This is the so-called Nyquist criterion. For planetary imagers the Nyquist criterion is embodied in a simple rule of thumb where you should pick an effective f-ratio for your optical train which, for mono cameras, is 3x to 5x the pixel size in microns[2]. For example a scope with a 2.9um camera would be best operated at f9 to f15 and you would pick your Barlow (or focal reducer) to achieve this.

Venus night-side imaging is not standard planetary imaging however. The 3x to 5x rule of thumb is based on 550nm (green) light, whereas night-side imaging is done at ~1000nm. The rule of thumb needs to be amended for Venus night-side imaging to allow for this much longer wavelength and becomes the recommendation to pick an f-ratio which is 1.6x to 2.8x the pixel size in microns. Thus for the 2.9um pixel example this becomes f4.6 to f8. Large imaging Dobsonians, which are typically f4 to f5, might therefore benefit from a 1.5x Barlow to improve resolution when the seeing is good, as long as that doesn't mean the planet is then so large that the night-side overlapped by dayside secondary images, as just discussed.

Equipment- Cameras & Sensitivity

Traditionally the silicon-based sensors used in digital video cameras used by amateurs for planetary imaging had very low sensitivity in the wavelengths used for Venus night-side imaging. At ~1000nm the quantum efficiency (QE) was typically just 2% to 3%.

A big push by sensor maker, Sony, in the past few years to improve performance in the near IR for machine vision applications, has now produced cameras which, although still relatively low sensitivity at 1000nm, are much better than they were. Cameras are now widely available with QEs of around 15%, dramatically improving SNR and allowing shorter exposures with commensurate reductions in atmospheric smearing of the image (improved seeing).

Equipment- Cameras & Dayside Ghost Reflections

Although good QE at 1000nm is important, there are other considerations which also to be taken into account before picking something suitable for Venus night-side imaging. A key characteristic mentioned earlier is the camera sensor's susceptibility to exhibit multiple ghost reflections of the much brighter and over-exposed dayside.

Figure 9 shows an example of the ghost reflection issue, here with a camera having an IMX178 mono chip.

[2] For colour cameras it is 4x to 7x

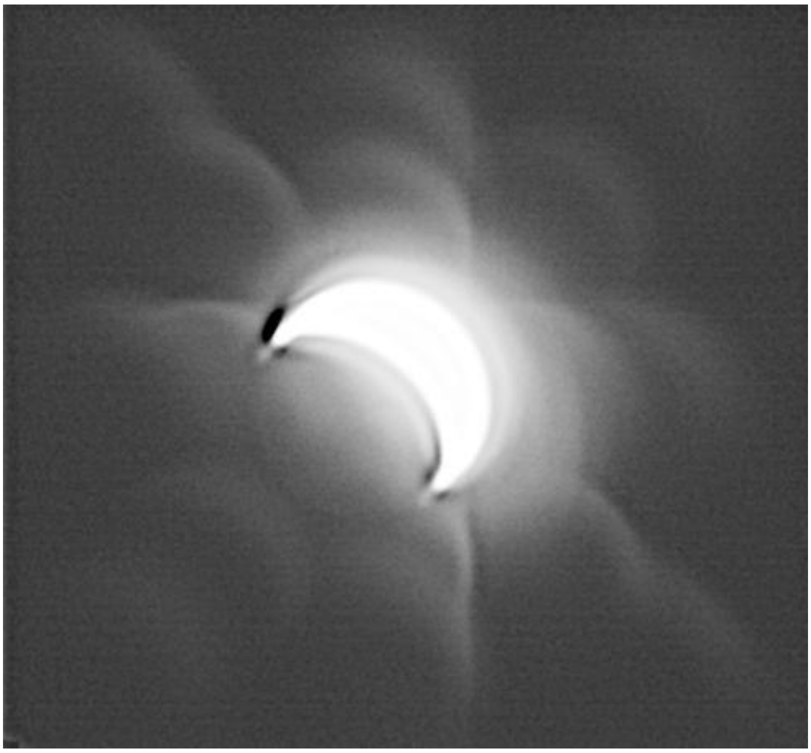


Figure 9. ASI178MM with a Sony IMX178 chip showing multiple ghost reflections of the over-exposed dayside crescent. The ghost reflections are distributed in a geometric pattern over the frame and overlap the faint night-side region (image courtesy of Guntram Lambert).

This ghost reflection issue is caused by the regularity of the metallisation pattern in the chip acting like a diffraction grating and so producing multiple diffraction images of the dayside crescent. These images travel away from the sensor surface, reflect off the top of coverslip attached to the top of the sensor and then travel back to the sensor to interfere with the primary image. These ghost images can obscure and confuse the detail in the night-side portion.

Different cameras are susceptible to different degrees to this issue; the severity likely depending on factors like the sensor coverslip thickness and reflectivity, as well as the sensor metallisation pitch and layout. Figure 10 below shows test images taken through a 1000nm filter on an indoor set-up to mimic the Venus dayside and compare the issue of ghost reflections between different cameras.

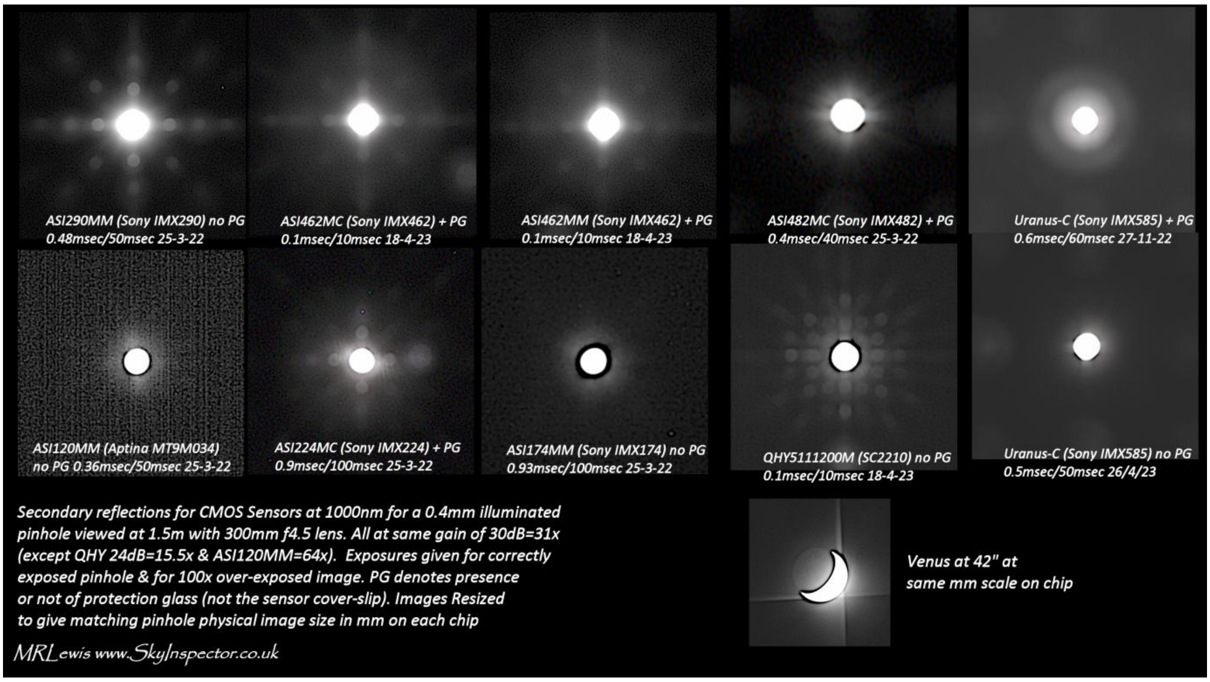


Figure 10. Ghost reflections seen in different popular planetary imaging cameras at 1000nm using a test rig designed to mimic the set-up used in Venus night-side imaging. A 0.4mm pinhole is imaged with a 300mm f4.5 lens at 1.5m and is overexposed 100x. Venus is included at the bottom at the same chip scale for a 444mm f4.6 scope.

There are three approaches that can be taken to tackling this annoying ghost issue:

- Find a camera which inherently exhibits no ghost reflections of any significance
- Find a camera where the pattern of secondary reflections are well-separated and away from the night-side
- Modify the camera to remove the coverslip and by this method eliminate the secondary reflections

There are very few cameras which don't show the secondary reflections. There is the very old ZWO ASI120mm which uses the OnSemi AR0130CS sensor but this has very poor sensitivity at 1000nm and has high read noise. Another candidate is the ZWO ASI174MM which uses the venerable IMX174 chip, but again this has a low IR sensitivity (~2.8% QE at 1000nm). The ASI174mm does have large 5.86um pixels, however, and can produces clean night-side images, as shown in figure 11.

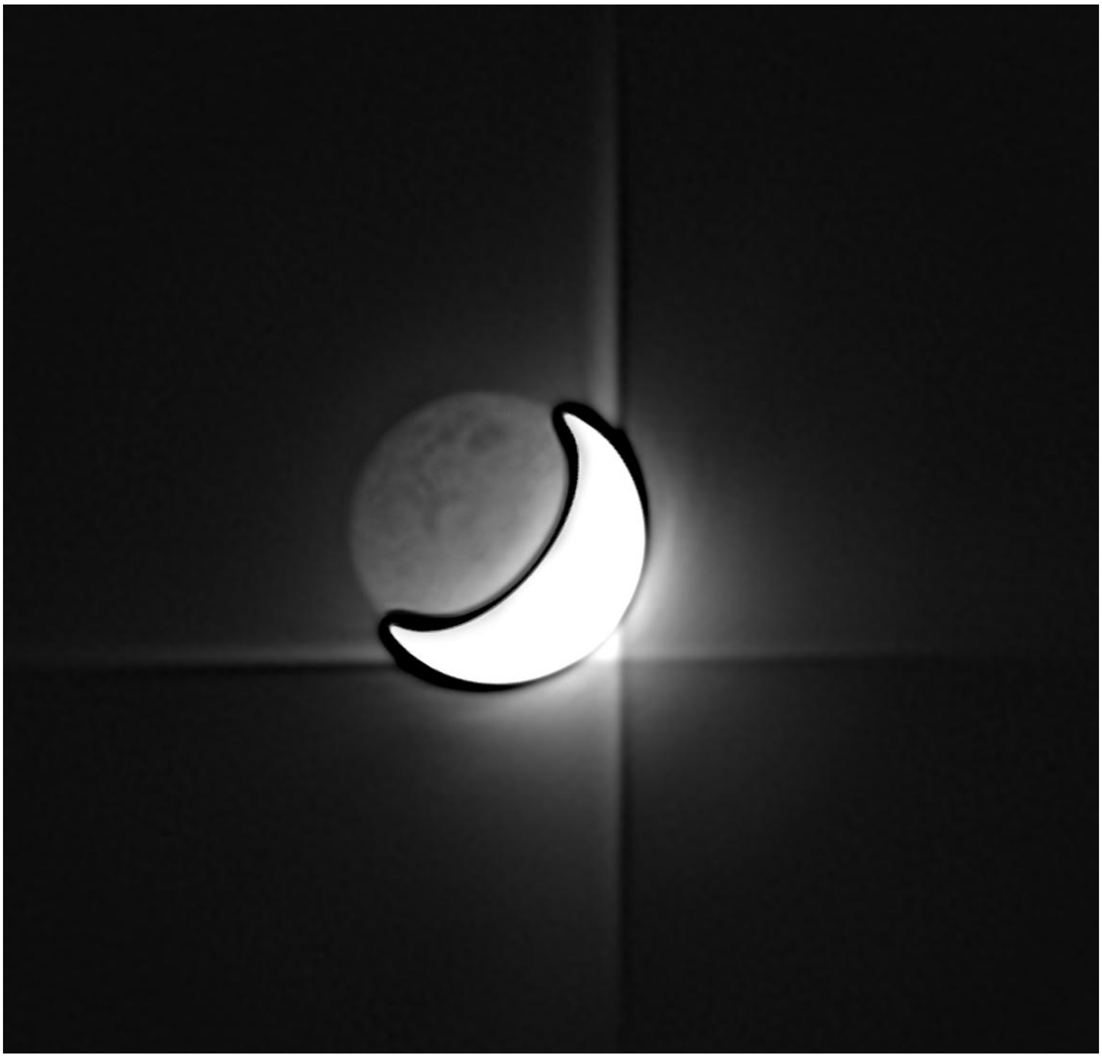


Figure 11. Venus image using an ASI174MM camera and showing significant night-side detail and no ghost reflections. This is data combined in Winjupos from three sessions on separate days in early May 2020.

Other known ghost reflection-free cameras are the FLIR Chameleon3 CM3-U3-31S4M which uses the Sony IMX265 sensor and the FLIR Grasshopper3 GS3-U3-32S4M-C using the Sony Pregius IMX252, both which have 3.45um pixels but which are fairly insensitive at 1000nm. More sensitive is the Lucid Vision Labs Triton TRI051S-MC using a Sony Pregius-S IMX547 sensor and used with some success for NS imaging in 2022, by Anthony Wesley and Phil Miles.

Finding a camera with a sensor which gives widely-spaced ghost reflections is a second approach to this issue. The test image from one such camera is seen in Figure 10 at the right-hand end of middle row. This is the Player One Uranus-C camera with its IMX585 sensor, modified by removing the protection window[3] which sits a short distance in front of the sensor. As of 2024 the Uranus-C is probably the most popular camera for Venus night-side imaging. Other cameras are coming out all the time however, and it is inevitable that a different model will take the 'most-popular' mantle before too long.

The Uranus -C has 2.9um pixels and a QE of about 15% at 1000nm and surprisingly is a colour camera. Like many recent Sony colour chips, when operating at wavelengths above 850nm, the red, green and blue colour filters all become highly transparent and the camera

[3] not to be confused with the coverslip which is attached to the front of the sensor

essentially operates as a mono camera. The Uranus-C can give good clean images of the Venus night-side as long as the planet's image is not too large that the night-side starts to overlap with the ghost dayside images.

As noted earlier, for best operation you will need to open the camera up and remove the protection window as this causes a lot of scatter and glare otherwise. When you remove the protection window it is recommended to leave the black foam filter location ring in place in the camera. The foam ring prevents unwanted light entering through gaps in the camera body and reaching the sensor.

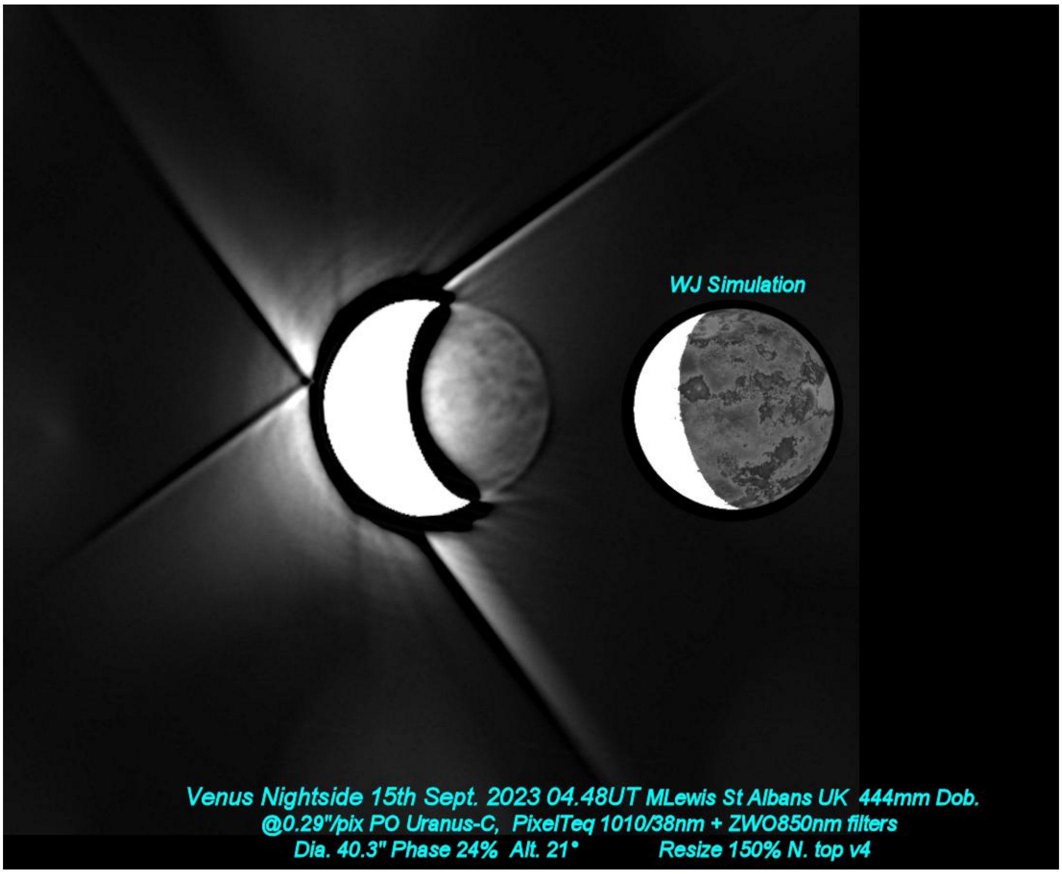


Figure 12. Venus night-side image with a Player One Uranus C camera with the protection glass removed. 444mm scope at f4.6 with PixelTeq 1010/38 filter

Camera Coverslip removal

The third approach to dealing with ghost reflections is to remove the coverslip of the front of the sensor. This is no trivial task, but those that have gone down that path have found the resulting camera completely free of ghost reflections. Removing the coverslip gives much greater freedom on camera choice and image scale but does leave the sensor completely unprotected and vulnerable to dust mote issues as these are much harder to safely remove. The sensor is also potentially subject to deterioration from moisture ingress.

There are two ways to remove the filter. The easiest is to pay Salvo Technologies in the US to remove it from a camera that you supply to them. The cost is about $500 - see: *https://salvoimaging.com/service/cover-glass-removal/* . The other route is to try and remove it yourself. This is a very difficult task requiring patience, courage and a good deal of technical skill. If you are considering going down this route then you are advised to first read notes on the task from António José Saraiva Da Cunha Cidadão on the Groups IO Venus forum. A good place to start is the following message: *https://groups.io/g/VenusImaging/message/1419*

Filters

The key enabling technology that makes it possible to image details in the thermal night-side is the availability of suitable infra-red filters which will pass wavelengths within the narrow bandwidth of light of 960nm to 1030nm, but block wavelengths outside of this. Without such filters, which preferentially select the night-side over the dayside, the night-side would be hopelessly lost in the overwhelmingly bright glare from the dayside. Figure 13 shows the thermal night-side peak on the right-hand side of the plot.

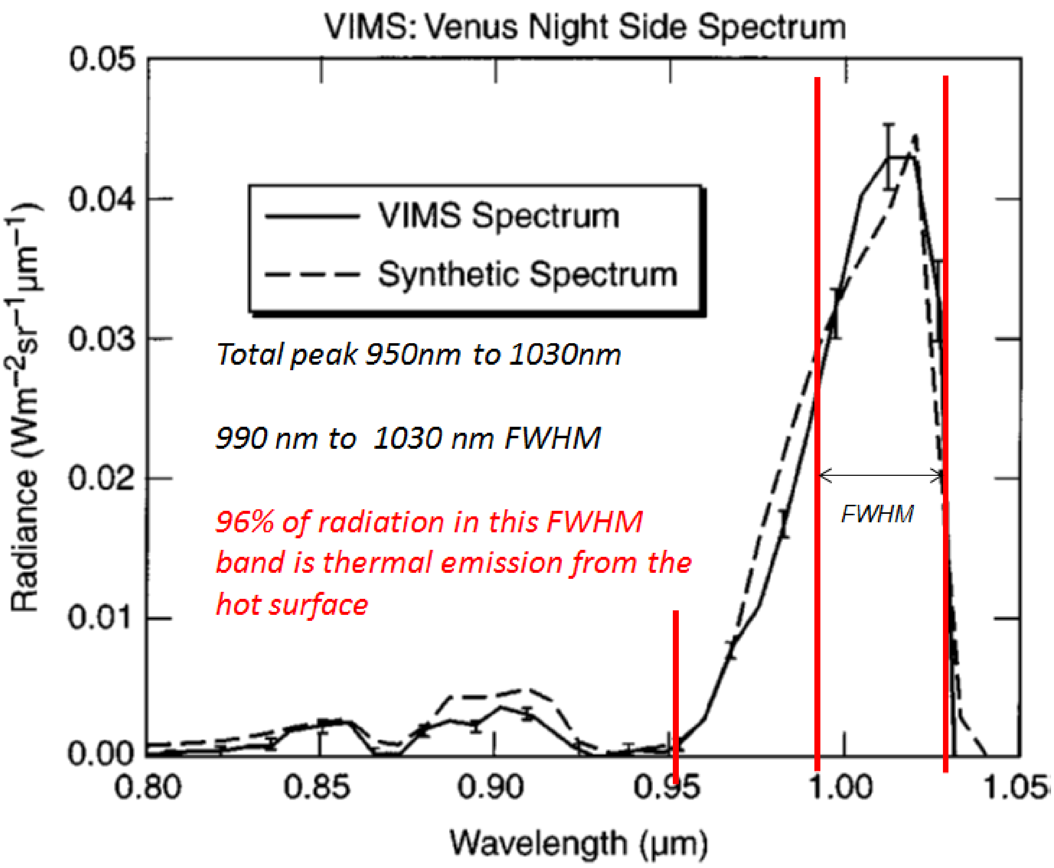


Figure 13. Venus thermal night-side emission peak between 950nm and 1030nm. In the full width half maximum (FWH) region between 990nm and 1030nm, 96% of the radiation is thermal radiation from the hot surface of the planet. In this wavelength range the Earth's atmosphere and the Venusian atmosphere are both essentially transparent. (This base spectrum from 'Detection of Sub-Micron Radiation from the Surface of Venus by Cassini/VIMS', courtesy of Kevin Baines & others)

A number of filters have been used by amateurs for imaging detail in the night-side. These include:

- Edmunds 1000nm narrowband filter with 25nm bandwidth

- Edmunds 1000nm narrowband filter with 50nm bandwidth
- A combination of FELH 1000nm longpass filter with a Semrock 935/170[4] filter to create a filter with a bandpass range from 1000nm to 1020nm
- Torrent Technologies, Optical Filter Shop, Pixelteq 1010nm narrowband filter with 38nm bandwidth

Figure 14 plots the spectrum of the FELH/Semrock combination against the Venus spectrum shown in figure 13. The filter pairing has good discrimination of night-side acceptance versus dayside rejection but does not used all the light available from the night-side. Such a filter pairing has been used very successfully by Wesley and Miles, but is an expensive option.

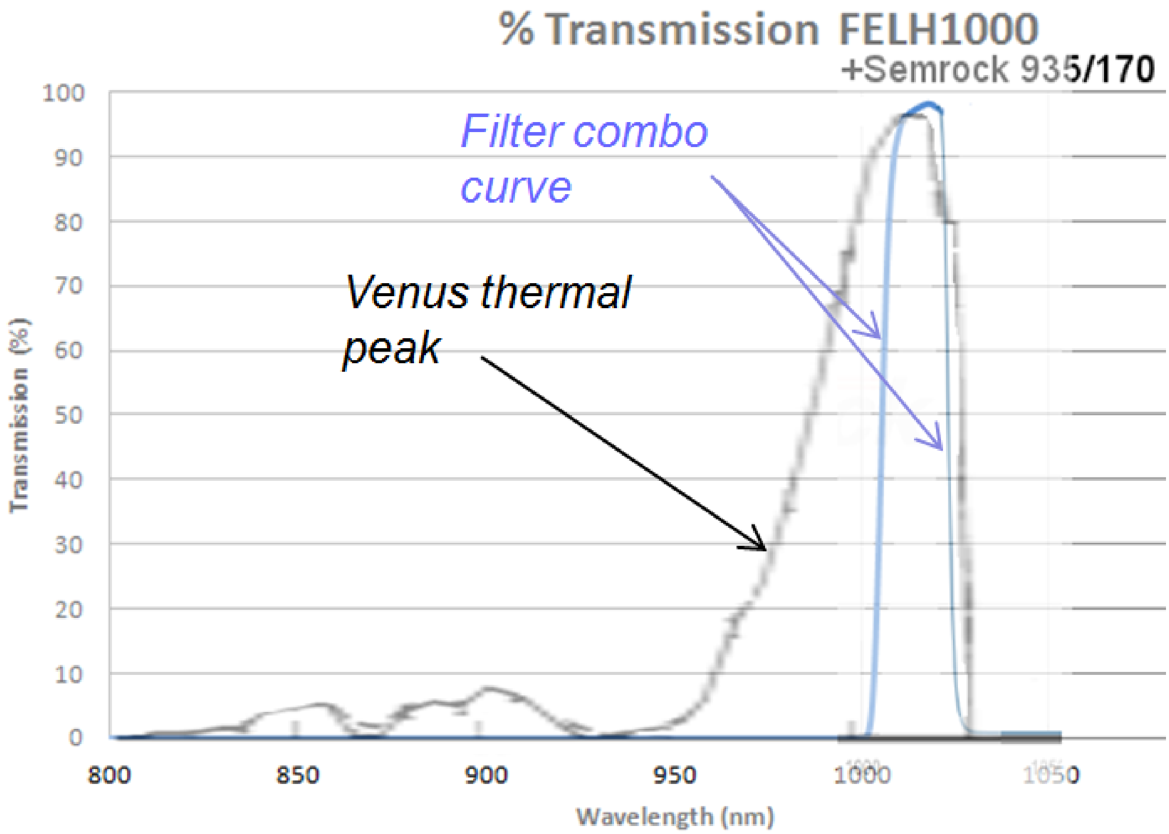


Figure 14. Graph of the FELH1000/Serock 935/170 combination superimposed on the Venus night-side plot.

A lower-cost alternative which uses a wider portion of the Venus night-side plot and which has been very successfully used by a number of imagers is the PixelTeq 1010/38nm filter with a bandpass from 990nm to 1030nm. The transmission spectrum for this is shown in figure 15.

[4] 935nm middle of bandpass and 170nm bandwidth

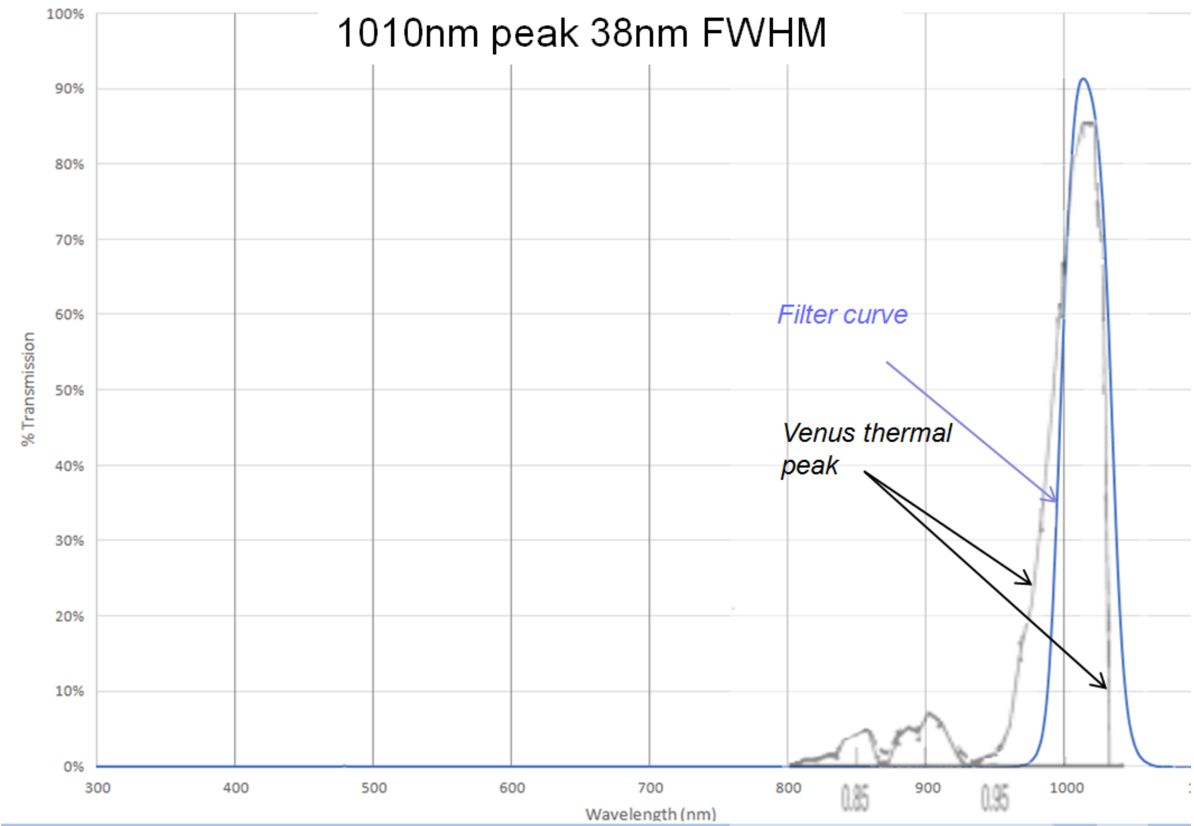


Figure 15. The graph of the PixelTeq 1010/38nm filter superimposed on the Venus night-side plot.

When you buy one of these filters you specify the diameter (typically 25.0mm) and have to mount it yourself in something like an unwanted filter mounting ring. There is a small amount of visible light leakage outside of the specified wavelength range for the PixelTeq and this needs to be blocked by using a second filter in series with it. The ZWO 850nm long-pass filter has been successfully used for this purpose.

Camera settings Gain, Exposure

The camera settings best used for night-side imaging are a matter of individual experimentation as they depend on the particular camera, filter and telescope being used. Traditionally, long exposures of $\geq$200msecs were used as the signal was so faint, but with higher sensitivity cameras and better filters, exposures can now be significantly lower than this. Shorter exposures are less affected by atmospheric smearing but the stack is more affected by read noise, although with modern cameras as long as the gain is kept above about 25dB read noise is low. You can get an idea of the variation in the final image for different gain and exposure settings by studying figure 16. In this set the 25msec images seem to give the clearest view of surface features.

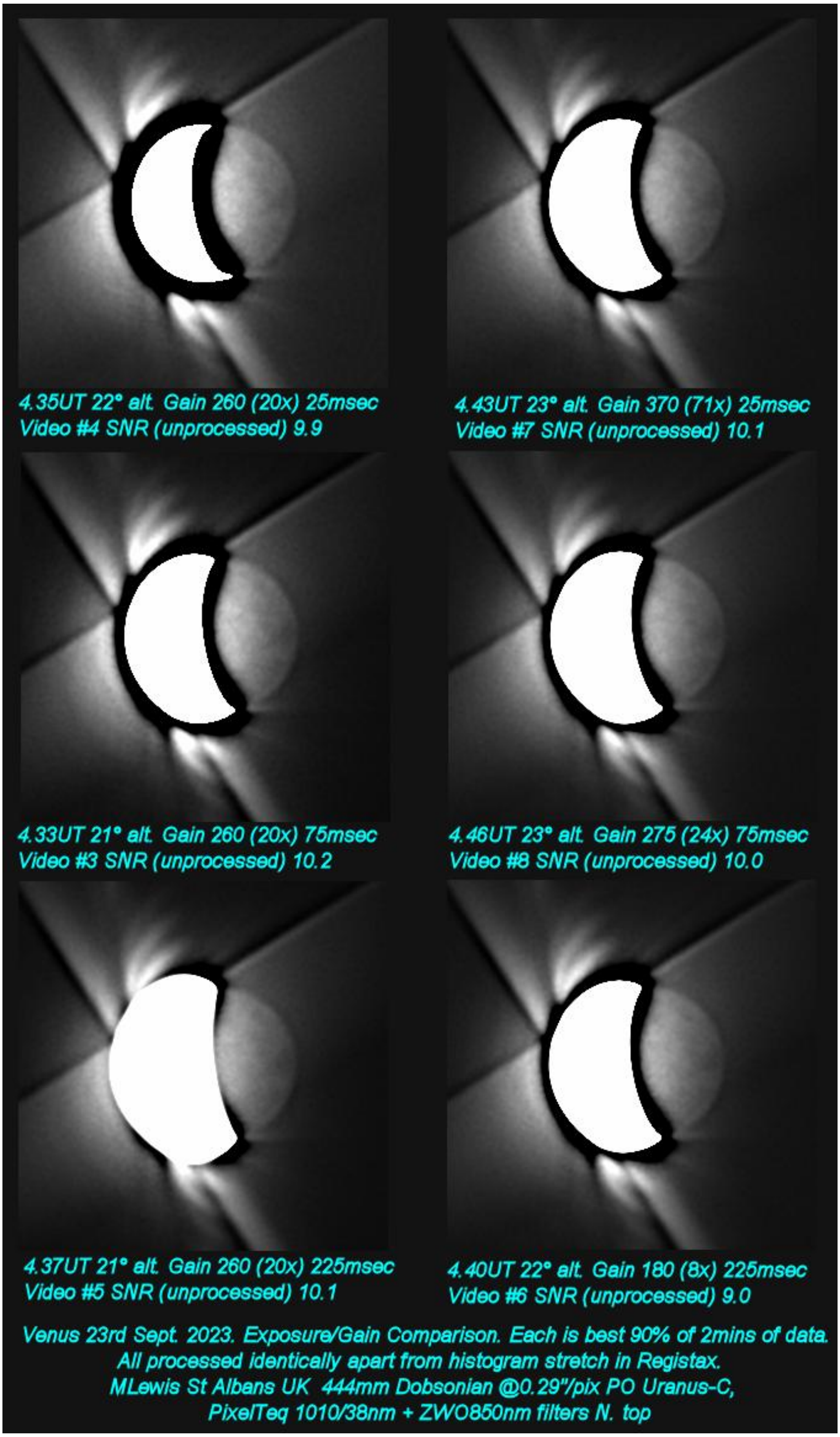


Figure 16. Gain and exposure set with f4.6 scope 444mm aperture with Uranus C camera and PixelTeq 1010/38 filter. All processed near identically apart from histogram stretch parameters. Notice the varying size of the bloated crescent and surrounding black halo which together seem to block the same portion of the night-side

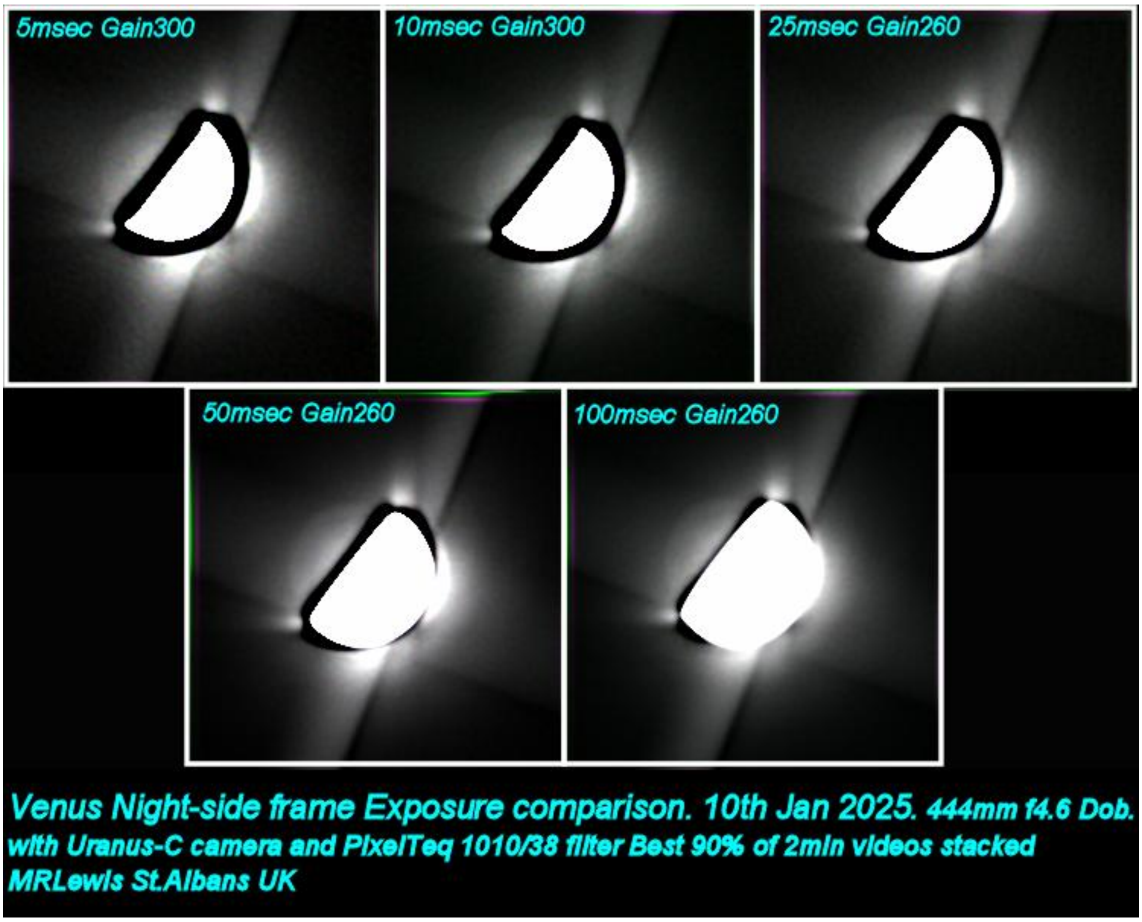


Figure 17. Venus night-side exposure comparison with phase at 51% and exposure times from 5msec to 100msec. All processing similar except the histogram stretch

In figure 17 above, we see how with the most recent low-noise and high-sensitivity cameras, we can use much shorter exposures than have conventionally been used and yet still clearly image the night-side. As the frame exposure time decreases, atmospheric smearing effects will play less of a role, helping with resolution. However, as we see in the montage, the read noise becomes more apparent as we shorten the frame time. The 10msec stack is slightly more noisy than the 25msec stack and the 5msec stack much more so. It may be that with modern cameras and large telescopes, operating at f5 or so, a frame exposure time in the range 10-20msec strikes the optimum balance between noise and seeing.

Camera Bit Depth and Video duration

Although to some extent you can play around with gain and exposure, comparing the different stacked results, one camera setting that you probably want to fix is the bit depth. Changing the camera mode from 8bit to 16bit will increase the bit depth from 256 levels to 4096 levels[5] . Even though the night-side is very faint where normally there might be quantisation errors creeping in with the lower bit depth, there is some discussion about whether 16 bit is strictly necessary, given the gain used and the magnitude of the overlying glare and background wash signal. More experimentation is needed to give a definitive answer on bit depth selection and so for now, as the only downside of 16 bit is a doubling of the data storage requirements, and for Venus night-side imaging those are low anyway, it is easier to leave it enabled.

[5] 16 bit is actually 12bit with 0000 added on the end of the signal string to make the data compatible with byte processing

Gather as much data as you can in 1 to 2 minute videos between the times when Venus is too low (<10°) or the Sun is too high (higher than ~3° *below* the horizon). Although there is no significant rotation of the planet to worry about rotational smearing, in a sky that may be changing brightness, too long a video may have quite a different background brightness at the beginning compared to the end and this may make processing difficult.

Equipment- Focussing

In Venus night-side imaging focusing is easy. Just drop the exposure and focus on the correctly exposed dayside, get that sharp then change the exposure time back to that for the night-side.

Equipment- Secondary vane issues

If imaging the Venus night-side with a Newtonian telescope, the four vanes that hold the secondary mirror in place will introduce four diffraction spikes which will radiate out from the processed image of the over-exposed dayside crescent. You can see examples of these spikes in many of the images accompanying this section as these have all been taken with a 444mm Dobsonian telescope, which of course is a Newtonian design.

If you are unlucky with the orientation of the diffraction spikes relative to the orientation of Venus, one of them may unfortunately pass through the night-side portion. With some Newtonians the head of the scope and the offending vane set can be rotated to rectify the matter, but most will be stuck with the problem.

One possible solution, championed in particular by Chris Hooker, is to change the distribution of the diffraction image by using apodising mask on the offending vane pair. Figure 18 shows an apodising mask on two of the vanes of the 444mm scope, whilst figure 19 shows the situation before and after fitting the mask. The mask cut was from an opaque PET with a foil backing using an XY-plotter/cutter and effectively eliminates the troublesome spike.

Figure 18. Apodising mask consisting of a 30° saw-tooth on 3mm pitch and attached to the two offending vanes of 444mm scope

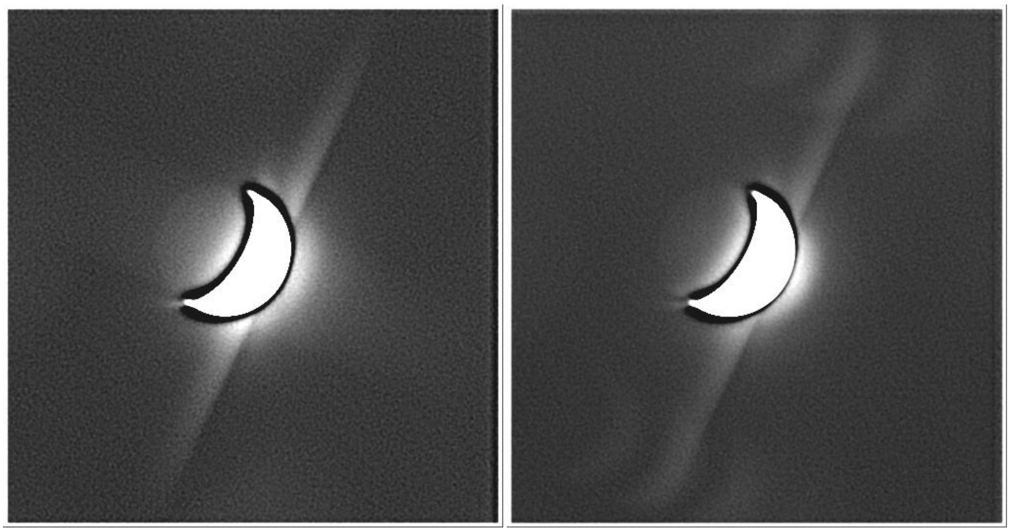


Figure 19. Left: without apodising mask, showing wide diffraction spike passing right through the night-side. Right with the mask shown in figure 18 fitted to one set of vanes - the diffraction spike is changed to become inoffensive secondary images at top right and bottom left.

Processing settings Autostakkert and Registax

Captured videos should be processed in AutoStakkert! to quality sort and stack the frames as for normal planetary imaging. Use a single alignment box around the planet and stack at least 80% of the frames, without any sharpening. Save the stacked image as a tiff or png.

After Autostakkert! processing, Registax can be used to enhance the night-side portion. You will likely need to use completely different wavelet settings to those you would normally employ for planetary imaging, as you need to both suppress the spreading glare from the dayside whilst also bringing out any large real features in the much darker night-side. As a starting point, try using the Registax settings shown in figure 20.

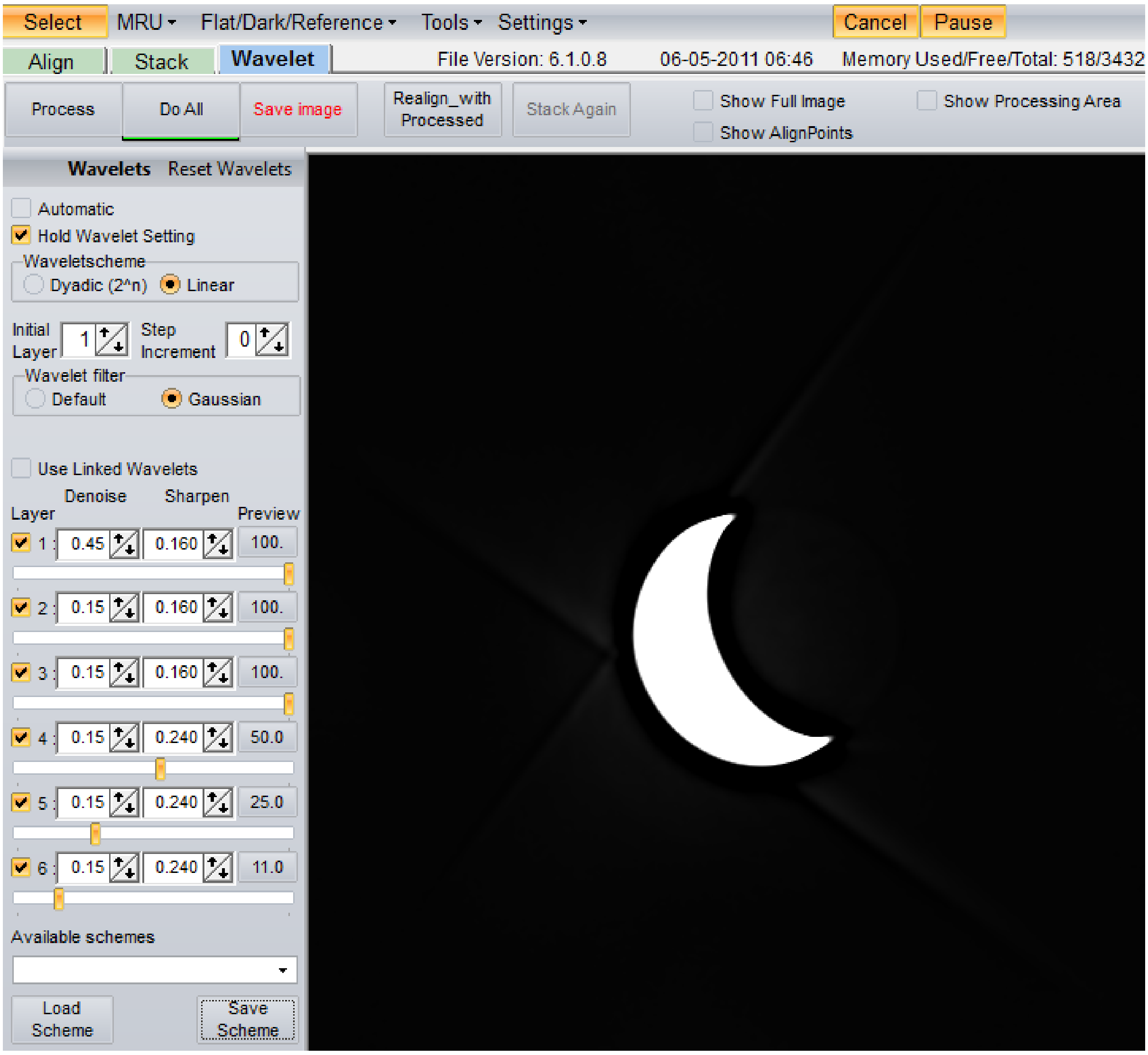


Figure 20. Suggested starting wavelet settings

After wavelets use the histogram stretch to massively increase the brightness of the night-side. This should bring out any large darker features that might be present. Play around with the settings to get the best results but set the lower slider just before the peak and the upper slider just after it, before hitting the 'stretch' button, as shown in figure 21.

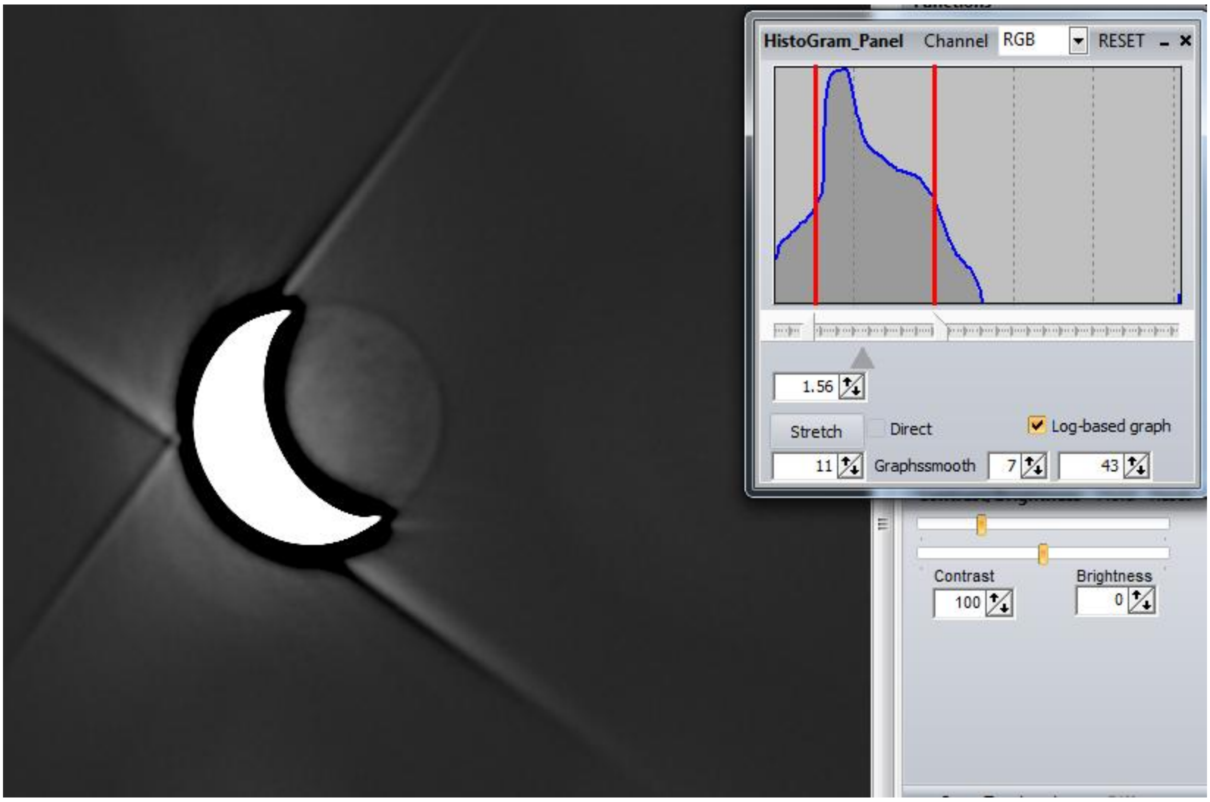


Figure 21. Histogram stretch limit positions at upper and lower ends (red lines) to bring out night-side details in Registax. Set upper and lower limits in the Histogram Panel and then hit the Stretch button.

Repeat the AutoStakkert!/Registax processing for all your capture videos. Once you have good wavelet settings, use the same ones for all your videos but tweak the histogram stretch values according to the exact darkness of the background and the exposure time and gain used for that video.

Processing settings Winjupos

If you have several images all showing the night-side you can stack them very simply by dragging and dropping the set of processed images onto the AutoStakkert! control panel. Set the stack percentage to 100% and stack them with similar alignment box setting as the first time round, to combine the images. Stacking processed images like this will reduce noise and give you the best chance of revealing true surface features. Alternatively you can combine them in the usual way in Winjupos derotate. This is particularly useful if you want to combine images taken a few days apart as this will correct for the slight Venus rotation between sessions.

If you do see some darker features, you can use the Ephemerides feature in the freeware program Winjupos to check if they are likely to be real. Set the planet to Venus and set the Options as shown in figure 22. Pick the *VenusThermalEmission1micron.jpg* as the texture image, use the time/date of your session, then switch to the Graphics tab and tick Unillum. *Surface* to give a simulated thermal map of Venus's night-side based on Magellan planetary probe height data.

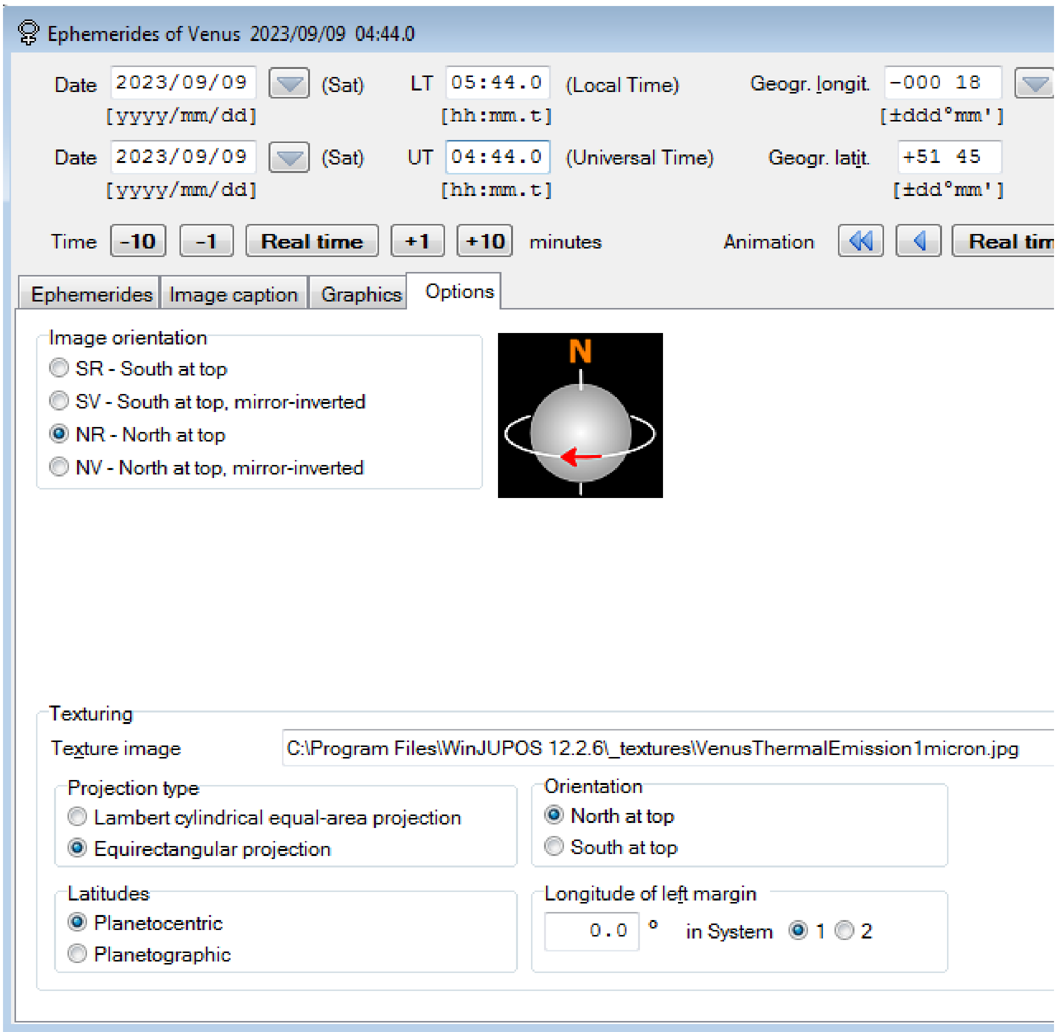


Figure 22. Winjupos Settings for correct Graphics simulation of Venus' night-side

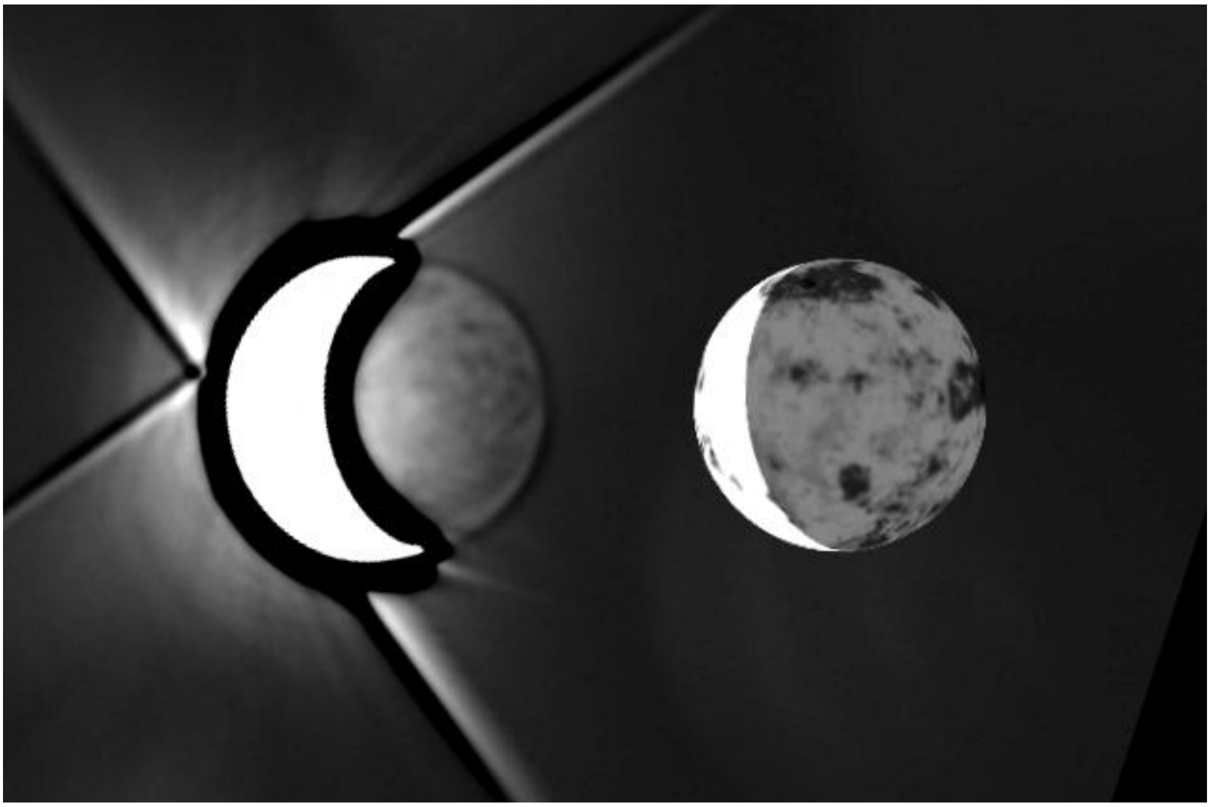


Figure 23. Images combined in Autostakkert!3 then compared with Winjupos simulation, showing multiple matching dark (higher elevation) features

What Features to look out for

Most of the features which good images will show are darker areas which generally relate to higher and cooler areas of the planet's surface, whose topography is well-mapped. Between one day and the next day the central meridian of Venus changes by about 2°, so during the 3weeks of the best part of the apparition, with the phase changing from 15% to 35% (or vice versa), the planet appears to rotate through a total of about 43°, increasing the accessible portion of the night-side during each apparition.

Venus's orbital parameters are such that in 8 years on Earth Venus goes round the Sun almost exactly 13 times and this is almost exactly 12 days on Venus. These facts, combined with the planet's retrograde rotation, lead to the surprising result that at every evening apparition, at the same phase, we see pretty much the same face presented to Earth. The same is true with each morning apparition - at the same phase we see the same face - although this is a different one from the evening face. From the 25% phase in the evening, to the 25% phase in the morning, the central median on Venus changes by about 90°. In figure 24 you can see how all this comes together to give the sort of coverage you might get of the planet for a set of evening sessions and a set of morning sessions. It shows that although a good proportion of the planet can be imaged by Earth-bound amateurs, some areas of the Venusian surface unfortunately remain inaccessible to imagers with normal life-spans!

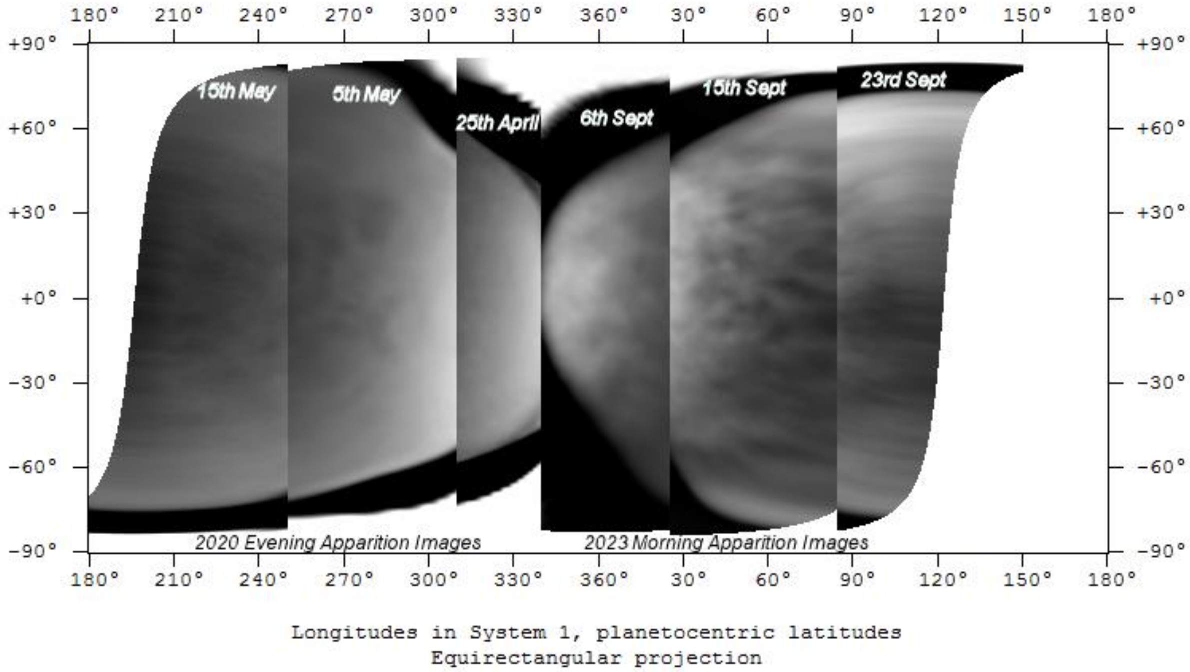


Figure 24. Coverage of Venus's surface for a set of evening sessions in 2020 (left) and a set of morning sessions in 2023 (right)

As well as permanent dark features relating to higher areas of the surface, imagers have also recorded transient features including darker areas which may relate to absorbing cloud as well as more intriguing lighter features such as bright spots and bright streaks.

You can see an example of a transient darker feature in figure 25 below, where a prominent darker region in circled but does not appear on the Winjupos topographical map.

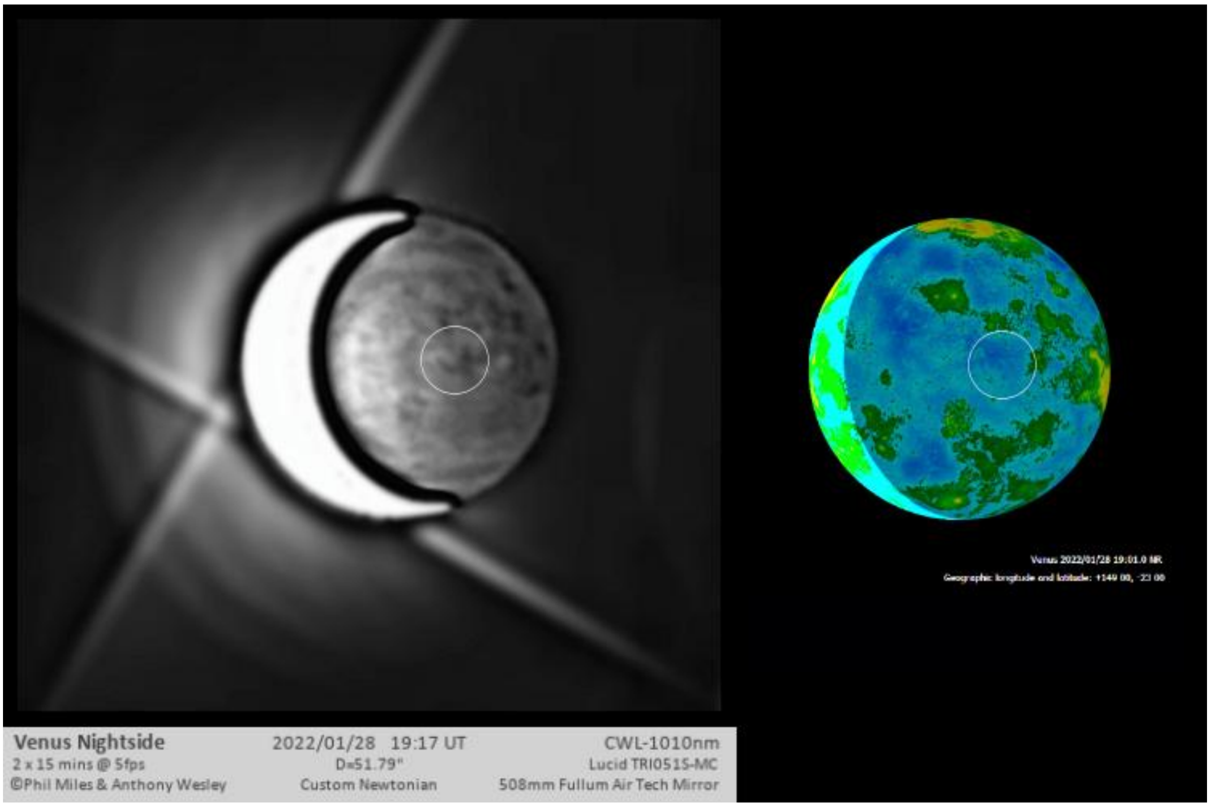


Figure 25. A transient dark feature circled in the excellent Wesley and Miles Venus NS image of 28th Jan 202. The feature is not an area of higher elevation and so is absent on the topographical map on the right.

Persistent non-permanent bright spots have also been regularly recorded, particularly at a location just beyond the western end of Aphrodite. You can see an image of a bright spot at this location near Aphrodite in figure 26.

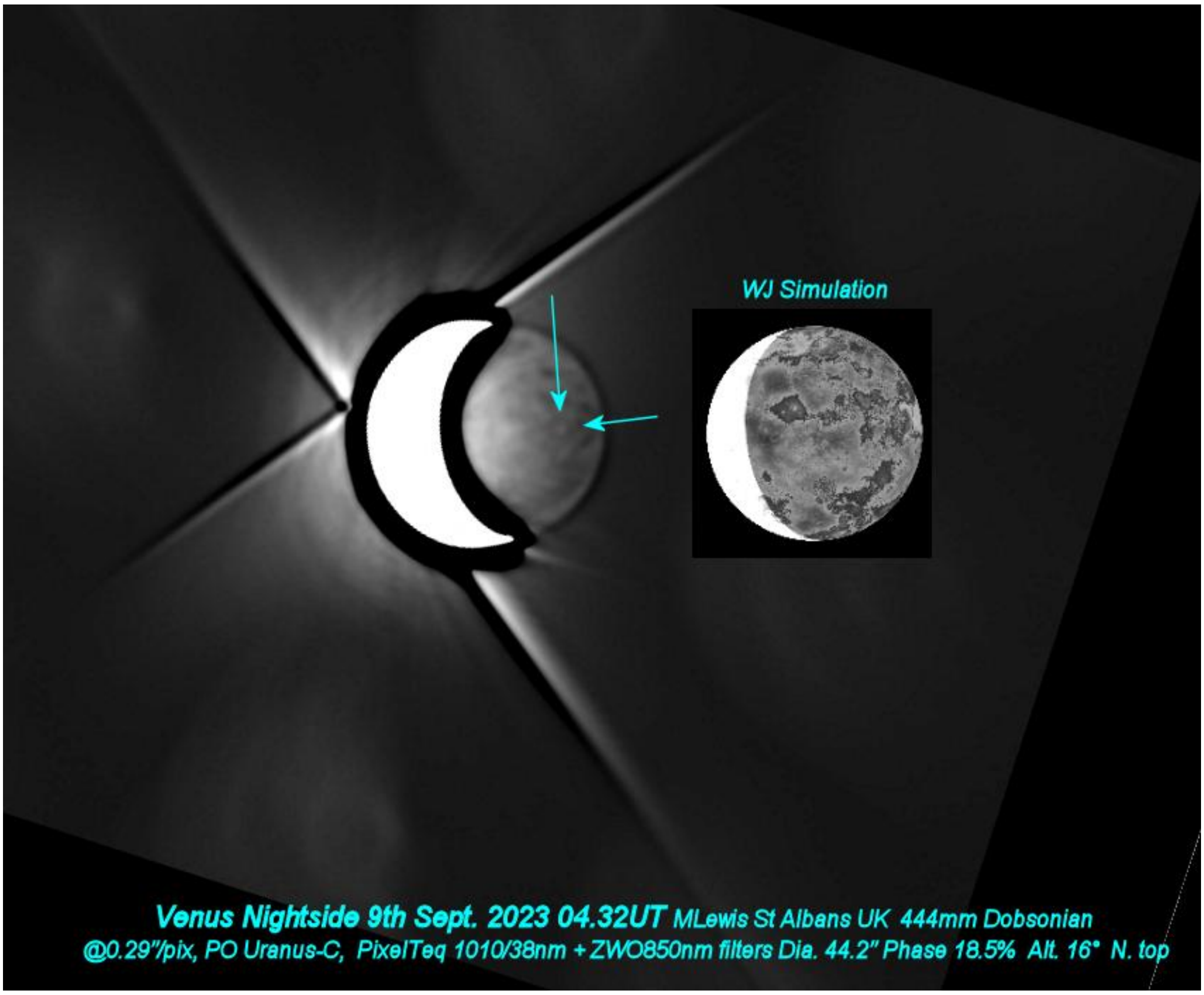


Figure 26. The brighter night-side spot regularly seen at the western end of the Aphrodite feature on 9th September 2023. It was absent in the author's images on 6th and 15th Sept but again seen in Wesley and Miles image on 15th Sept (see figure 28).

Equally mysterious are long brighter streaks which seem to move across the face of the planet. You can see one such streak in figure 27, which *may* have moved to a location further North over a period of few hours, as shown in Wesley and Miles' image, figure 28.

Figure 27. Bright streak in the author's image from 15th Sept 2023 at 04.48UT

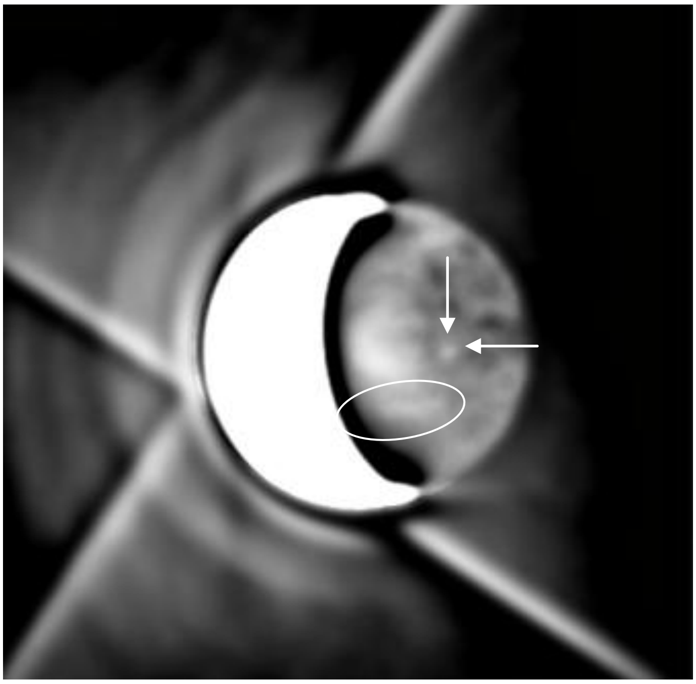


Figure 28. Wesley and Miles' image on 15th Sept. 2023 at 19-23UT showing bright streak some distance north of the streak shown in figure 27. The bright spot arrowed is seen in the image on the 9th Sept (figure 26) but was absent 14 hours earlier (figure 27).

It is hoped further improvements in equipment and methods in coming years, and an increase in popularity of Venus NS imaging, will together lead to an increase in the frequency and quality of images of these transient features. Better data, more closely-spaced in time, enabling study the evolution of these features, will help planetary scientists in understanding what these features really are - atmospheric, volcanic or something else.

Additional Information

Groups IO Venus forum

For more details on capturing and processing Venus night-side images, consider joining the Venus Groups IO forum at https://groups.io/g/VenusImaging. Here you will find much discussion on the latest methods and equipment for imaging the Venusian night-side

Further Reading

- *Anthony Wesley and Phil Miles Venus night-side campaigns:*
  - *2017 http://www.acquerra.au/astro/venus/2017-nightside/*
  - *2022 http://www.acquerra.au/astro/venus/nightside-2022/*
- *'Imaging the Venus night side at 1000nm', BAA Venus and Mercury section newsletter Messenger No. 4 June 2020*
- *'Imaging the Night-side of Venus - 2023 Evening and Morning Apparitions', BAA Venus and Mercury section newsletter Messenger No. 14 March 2024*
- *'Venus Night-side Imaging - Measuring the Signal to Noise Ratio (SNR)', BAA Venus and Mercury section newsletter Messenger No. 15 August 2024*