This is a document that details my initial work with the Daystar Quantum SE solar H-alpha filter. I have received invaluable advice from the Yahoo Daystar Group (http://tech.groups.yahoo.com/group/daystarfilters/) and Jen Winters from Daystar.

Section 1 – First light and comparison with a Coronado SM60 filter. Discovered problems!

This is a comparison of the solar H-alpha filters Coronado SM60 and Daystar Quantum SE. The focus of these tests has been on high-resolution imaging and in this respect I expected the Daystar filter to be a clear winner since it can work at apertures larger than the 60mm of Coronado filter. In addition, the Daystar filter has a more narrow band pass (0.5Å vs. 0.7Å) and should thus also yield better contrast. This extra performance comes at a price: 6000USD for the Daystar filter versus 2500USD for the Coronado filter plus a more complicated usage.

However, as the following account will show my expectations did not materialize; the Coronado filter yielded superior images! I also saw this difference visually. The reason for this is unclear at this time of writing: is my Daystar filter defective, did I use it incorrectly, or what?! Read on, and see what I did.

Great care has been taken to use both filters under near-optimal conditions, on the same equipment and on nearly the same time and target. Only raw images are presented here. Before showing the comparison solar images I will describe the equipment configurations in detail so that any people wiser than myself might have a chance of spotting a problem.

The site is on a concrete pier overlooking a large body of water in the direction of the sun. The tests were carried out at 7am-9am local time with the sun altitude ranging from 26-43 degrees. The weather: no clouds, not hazy, weak wind coming from across the water.
The setup consists of a Borg 100ED refractor with a heavy duty helical focuser mounted on a Takahashi EM-10 mount. The camera is a Lumenera Skynyx 2-2M connected via USB to a laptop. The Daystar filter was set to 6562.8Å and the Coronado tilt plate was set to no tilt. Focusing was done manually for each configuration.

Front end closeup with Daystar ERF 4” filter:

Front end closeup with Coronado SM60 filter:

Daystar Quantum SE with 5x Televue Powermate:

Two threaded spacer tubes are on the back of the focuser, then the 5x powermate followed by the Daystar filter and finally the camera. The camera and Daystar are connected with a T-thread to 1.25” adapter. All-in-all a pretty long and heavy setup, however the telescope was easy enough to balance on the mount. This setup resulted in f/32 and had a theoretical resolution of 1.6". At a binning of 2x2 the camera image scale was 0.56"/pixel hence oversampling the resolution by a factor of 2.9.

Daystar Quantum SE with 4x Televue Powermate:

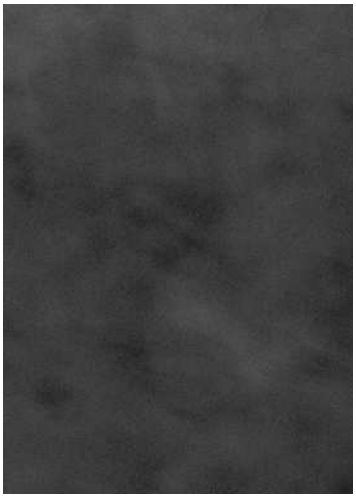
Similar to previous setup, expect that now three threaded spacer tubes are used. This setup resulted in f/26, somewhat faster than the recommended f/30. At a binning of 2x2 the camera image scale was 0.70"/pixel hence oversampling the resolution by a factor of 2.3.

Coronado SM60/BF10 with 1.8x Televue Barlow:

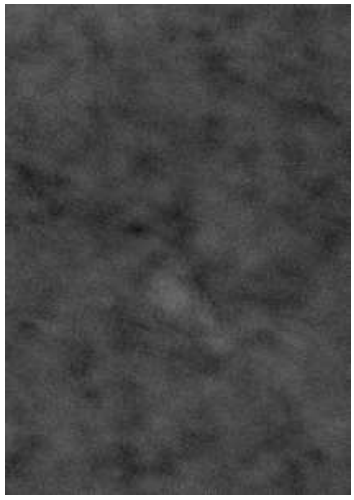
(note: Barlow is missing in the photo above; it was inserted between the camera and the BF10 diagonal). With the 60mm aperture of the front end filter the theoretical resolution is 2.7”. With no binning the camera image scale was 0.79”/pixel giving an oversampling of 3.4.

See the following page for a comparison of how these configurations worked!

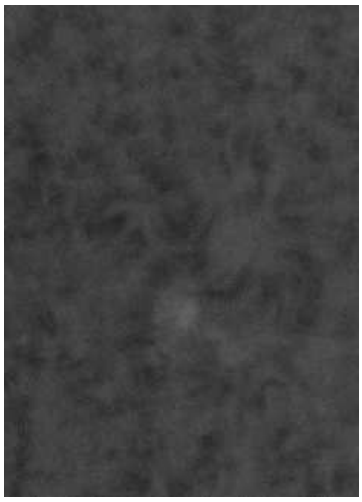
The images below are crops of single frame images with no processing applied. They show identical solar features and are reproduced at the same scale and orientation. Camera settings for gain, exposure time (in milliseconds) and contrast are shown below each image.



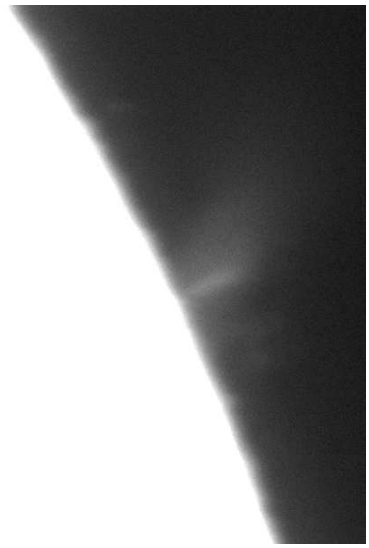
Daystar, 5x powermate
gain1, exptime3.0, contrast1.4



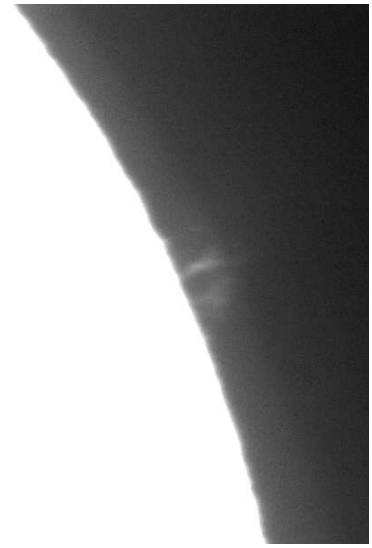
Daystar, 4x powermate
gain1, exptime1.7ms, contrast2.3



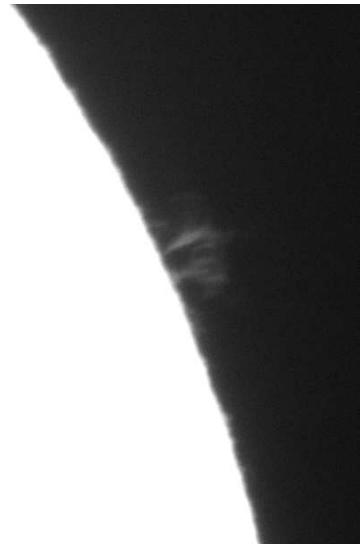
Coronado, 1.8x barlow
gain1, exptime5.1ms, contrast1.9



Daystar, 5x powermate
gain8.9, exptime4.9, contrast1



Daystar, 4x powermate
gain7.5, exptime3.2ms, contrast1



Coronado, 1.8x barlow
gain6.7, exptime11ms, contrast1

(link to images above in slightly higher quality: www.leif.org/mikael/solarcomp.jpg)

The refractor objective was not very well collimated. The camera contrast setting differs slightly among the photosphere images, which I regret at this time. However, during later experiments I confirmed that these issues are irrelevant for the overall conclusion that there is something seriously wrong with the Daystar views. Visual use of the Daystar/Coronado also confirmed this.

It is very clear that the Coronado images are MUCH better than what I could achieve with the Daystar. Furthermore, the Daystar images were considerably worse with the 5x versus that 4x powermate. I suspect there is some hint in this fact.

Section 2 – Help and advice from Daystar and the Yahoo group:

Help and advice from Daystar and the Yahoo group. Only selected posts (sometimes just excerpts) are shown here. A direct link to the full message post as well as the author name is given for each.

http://tech.groups.yahoo.com/group/daystarfilters/message/3440 (John Hicks)
'Try an 8" long extension tube following the Daystar filter. I had the same problem with my old 0.5 A University Daystar. The Powermates produce an extreme cone of light which the Daystar hates. If you extend the focal point out another 8 inches it will help to eliminate the off-axis wave problem, increase magnification slightly and of course overweigh the tailpiece of your telescope. ..... You can make a perfect extension tube following your Daystar with an old Celestron Telextender tube which has a T-thread on one end. You have to cut another INTERNAL T-thread in the other end to accept your camera (Skynyx)'

http://tech.groups.yahoo.com/group/daystarfilters/message/3445 (Eric Roel)
'Powermates act as a Barlow/telecentric system, due to the design (positive lens in front). Many have used it with success. I have the 2.5x, the 4X and the 5X Powermates, I have tried them all but don´t get near the result of the dedicated 2X Barlow + Telecentric lens system'

http://tech.groups.yahoo.com/group/daystarfilters/message/3446 (Jack Mosevich)
I have a 0.5 Ang Universty Daystar and have had the same experience as Eric. Poor results with the 4X Powermate but great results with the 2X Barlow and Telecentric unit from Astro Physics.

http://tech.groups.yahoo.com/group/daystarfilters/message/3452 (John Hicks)
You might still be able to get an Astrophysics unit like mine, but Baader will be as good or better. Notice that little item "the Extension tube" - without that your images are mush. Too bad Daystar doesn't tell you all about this. It took me twenty years to discover that an extension tube is everything you need. Longer the better.

http://tech.groups.yahoo.com/group/daystarfilters/message/3455 (Gradimir Petrovic)
my opinion is that there is not much difference between telecentric units (AP, Baader Pl.) and TV Powermates. They do the same job, first increase focal length with a negative Barlow and afterwards create a parallel beam with an additional lens. The factor of amplification is depending on negative focal length of the Barlow lens and placement of the second lens or eyepiece behind it.
The well known AP telecentric system uses AP convertible Barlow lens as first element with negative fl of 127mm. This is published by AP.
Unfortunately TeleVue does not publish this value for their Powermates. It has been told to me by Al that this is an intellectual capital of TV and not published. By the way at same talk with Al he told me that he is using Powermates himself for solar observation with his Ha filter.
Some figuring and measurement by myself led me to the calculated value of negative fl of 53.8mm for the Powermate 4x, the only one I own.
Ok so far, now to the math. The best source for such information is the excellent book for amateur astronomers (and maybe professionals?) written by Rutten & van Venrooij, "Telescope Optics", definitive worth the spent money!
Here are the variables and formulas:
Fb = negative focal length of Barlow lens
Fo = focal length of objective
Fc = focal length of combined system (lens and Barlow or target focal length)

d1 = distance from orig. focal point of optics to the Barlow lens
d2 = distance from the Barlow lens and new / resulting focal point
Ab = amplification factor of Barlow lens
Now to the formulas:
*Fc = Fo * Fb / (Fb - d1), Ab = Fc / Fo = Fb / (Fb - d1), d2 = Ab * d1*
That's all what you need to calculate everything with Barlows, amplification and distances of the system!
Example given:
You have an nice Zeiss APQ 100/f10 and AP telecentric system and like to extend the focal length for solar observing with 100mm ERF (unobstructed) from f10 to f30.
Values and result: (Fo=1000mm, Fc=3000mm, Fb=-127mm, Ab=3 leads to d1 = -84.6mm and d2 = -254mm).
That means you have to place the Barlow lens at (1000mm - 84.6mm =) 915.3mm from main objective and your new focal point will be exactly at (915.3mm + 254mm =) 1169.3mm. Or in other words, distance between the Barlow lens and new focal point at f30 is (254mm - 84.5mm =) 169.33mm or 6.66 in.
Adding extra extensions between Barlow lens and telecentric lens/filter means increasing the fl (and focal ratio) of the system, that simple. But do the math yourself.
Hope did not made any errors here and this simple formulas allow you to better understand what are you doing and allow you to predict positions of the setup much better.
If there is any stray light in the system this should be visible with the ep resulting no longer in a dark background around the sun.

http://tech.groups.yahoo.com/group/daystarfilters/message/3457 (Michael O'Connell)
I did up a spreadsheet based on your calcs. http://www.astroshot.com/Solar/Telecentric.xls

http://tech.groups.yahoo.com/group/daystarfilters/message/3458 (Jack Mosevich)
Very interesting. But still, I have both the 4X powermate and 2X AP Barlow and telecentric unit and the Barlow-Telecentric configuration is clearly superior. Why? I don't know.

http://tech.groups.yahoo.com/group/daystarfilters/message/3461 (Gradimir Petrovic)
completely agree that each telecentric system has some kind of sweet spot amplification and it seems to be 3 times for AP combo. .....
Because the second lens in the TC system is used to create parallel beams from the Barlow output which itself are converging with an angle, it need some expectation at which angle are the beams coming in from Barlow lens and therefore each TC seems to have a ZEMAX calculated 'sweet spot' of magnification.
That's also the reason that Baader Pl. newer TC systems are designed either for two or four times of amplification and there is not only one systems which fits all.
There is of course some amount of amplification around the sweet spot which also work well but if the amplification goes beyond the beam design, e.g. using extension tubes to push AP combo to 4 or 5 times amplification the resulting beam exiting second lens does no longer consist of parallel beams.
Regarding the TV Powermates I'm a little bit skeptic looking at Powermate 5x showing possibility to work with amplification of 5 to 8 times without any degradation?! Therefore I assume it's maybe not the optimal solution for Ha use.
All other Powermates seem to be much more restricitive with their amplification factors and therefore also more usable for Ha work. Assume they are 'optically' optimized to create a parallel beams exactly at the nominated amp. factors.

And agree with you that with today's fast refractors it's really a problem to get into f30 ratios. Most of my refractors are all very fast between f5 and f7 and that means a lot of amplification for f30. The one which would work perfectly with orig. f10 from Zeiss has unfortunately a helical focuser from the 90-ies not constructed for such loads produced by TC, large mirror, filter and big ep's getting into 3kg weight area. So either stop down to get into 3 to 4 times amplification or use a dedicated non APO slow lens (Ha/Solar view is almost monochromatic light and no need for APO lenses) but spend an excellent heavy focuser which do not shift anything and allow easy and exact focusing.

http://tech.groups.yahoo.com/group/daystarfilters/message/3463 (Gradimir Petrovic)
My experience is exactly as yours but I can't give you clear answer why. The Powermate 4x works but is maybe all purpose design not specialized for solar work as the AP telecentric combo is and also the newer Baader Pl. TC's. The latest units from Baader Pl. are clearly optimized for Ha wavelengths from ray tracing and coating perspective and advertised that way.
Bear in mind that the whole Barlow and correcting lens in the Powermates are only about one inch apart to create such compact unit (also great but maybe with some limitations?) and therefore the Barlow part has much more curved lenses then other longer and 'relaxed' TC designs to achieve high amplifications.

From private communications:

Lars Spatzek (in Danish):
'Hvis du graver dybt i tråde i Cloudynights, så vil du se flere diskutioner omkring telecentriske systemer til de bagmonterede solfiltre. Der er ingen tvivl om, at Baaders system er det bedste og forøvrigt er det Baader, der leverer til AF.
TeleVue er et problem, når vi når over 3x modellerne - så er de ikke "rigtige" telecentriske mere, men opfører sig som en mellemting mellem en Barlow og et telecentrisk system. Der findes også forklaringer på dette på nettet.
.....
Jeg kan ikke forstå, at dit filter ikke leverer et fornuftigt resultat. Den skal være signifikant bedre en Coronadoen. Flemming har jo også et Daystar filter, som jeg personligt mener slet ikke levet op til specifikationerne. Det skræmmer mig faktisk en del, da en direkte sammenligning mellem foreningens og Flemmings filter gav et resultat, der helt klart gør KAF filteret til en langt bedre filter - og så med en bredere båndbredde. Der mangler primært kontrast i billedet .... Problemet kan kun ligge hos Daystar. Også mit eget filter løber om hjørner med Flemmings.'

Daystar Filters Service Dept., Jen Winters:
'1: Is your glass used in the ERF the clear glass with a coating that changes color just a little when it is tilted or is it colored glass? - Back in 2007, we had some ERF glass made in this clear style with a UV/IR coating from a supplier who claimed it was 1/4 wave but it was not anywhere close to this in accuracy. If you have a Clear glass window like this, We should get you a new Colored glass ERF. I would cover that under warranty.
2: I do not recommend the 5X powermate. It is not telecentric and causes some big problems with wing shift and vignetting. I see that to reach F/30, you needed the 5X. ....
So for best performance, I think next time, try reducing your aperture down a little with the 4X Powermate to reach F/30. That is 90mm.'

Eric Roel:
'.... I would go for the Baader Telecentric, it is made with the sun in mind, has special coatings. As for the ERF, mine are red colored glasses, they work perfectly. I believe Baader makes the best ERF (cool type) but are expensive. In my setup also use a 2" Baader IR/UV blocker filter screwed to the first extension before the Barlow and the Telecentric, this protects the DayStar etalon and makes its life longer (takes heat and UV radiation off before it gets to the DayStar filter.)'

Daystar Filters Service Dept., Jen Winters:
'For my opinion on barlows: I prefer the 4X powermate. We have done a lot of tests on telecentricity. This is our most important concern. Any lack of telecentricity causes a change in wavelength of the filter. I have not tested the Astrophysics barlows, but I do know that the 4X and 2X were specifically designed for the DayStar application by Al Nagler. They are so close in telecentricty that the magnification does not change when the position of the barlow changes.

You only need an extender tube with the 4X as you require to reach focus. The one best piece of advice is to keep the extension BEFORE the barlow - not AFTER. This will reduce the overall length needed for focus. Those who use a diagonal, for example, should put the barlow AFTER the diagonal. I see that you do not use one - that is ok. But if you did, you would want to apply the Diagonal FIRST and the Powermate AFTER; with the DayStar and camera last.'

From the comments shown above I have extracted these essential pieces of information relevant for my problems:

x5 powermate is not suitable for Daystar work
my ERF may be flawed
put in a large separation between the powermate and QuantumSE filter
Baader telecentrics are more optimized for solar H-alpha work than the Televue powermate.

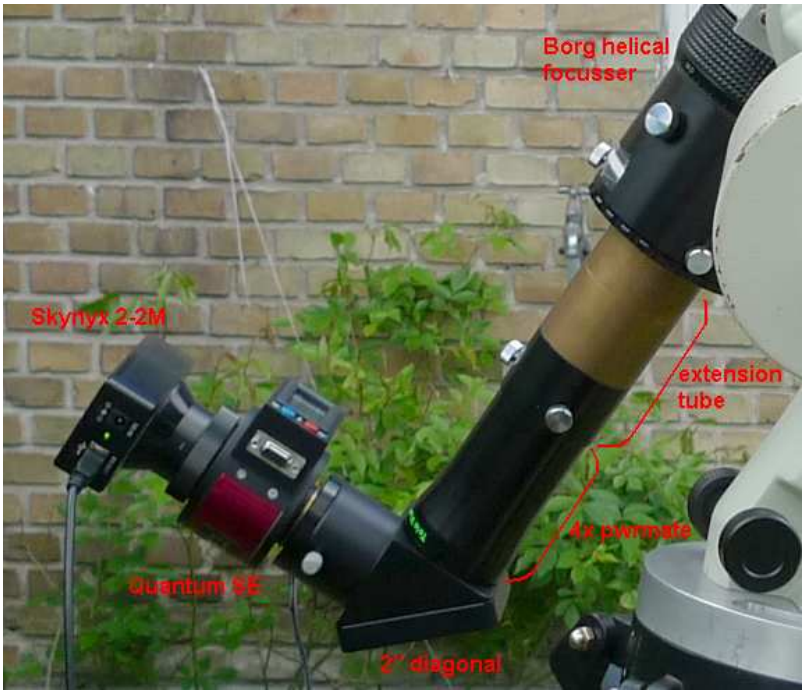
In my next outing under the Sun I will try out the first three suggestions; the fourth will have to wait.

Section 3: Another try – based on help from friends

Based on the advice detailed in the previous section I will try again; this time:

- *not* using the x5 powermate since it is not suitable for Daystar work
- specifically test whether my ERF is flawed
- put in a larger separation between the 4x Powermate and QuantumSE filter (a 2" diagonal is all I could arrange right now)
- use a 85mm front aperture to ensure that my system is not faster than f/30

Here's an overview of the rear and front ends of my setup:

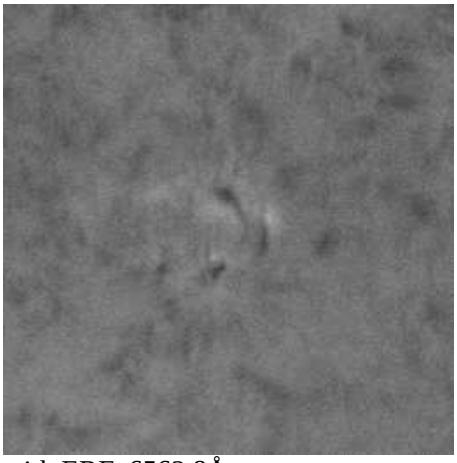


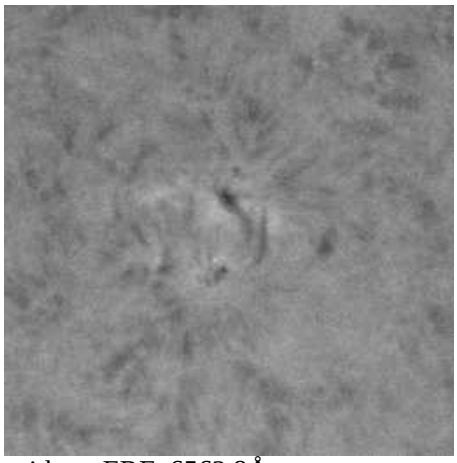
All following tests were conducted at the same focus position and with 2ms exposure time. The camera gain setting was adjusted to yield a common signal level. Prominence images were acquired with a contrast=1, gain=8.4 while photosphere images had contrast=2, gain=1.9. For each test I acquired 500 images, then selected the best frame using Registax and cropped to select a small region of interest. No image processing has been applied.


with ERF, 6562.8Å


without ERF, 6562.8Å

The improvement in sharpness is quite clear! Let's see what the effect is when imaging the photosphere:

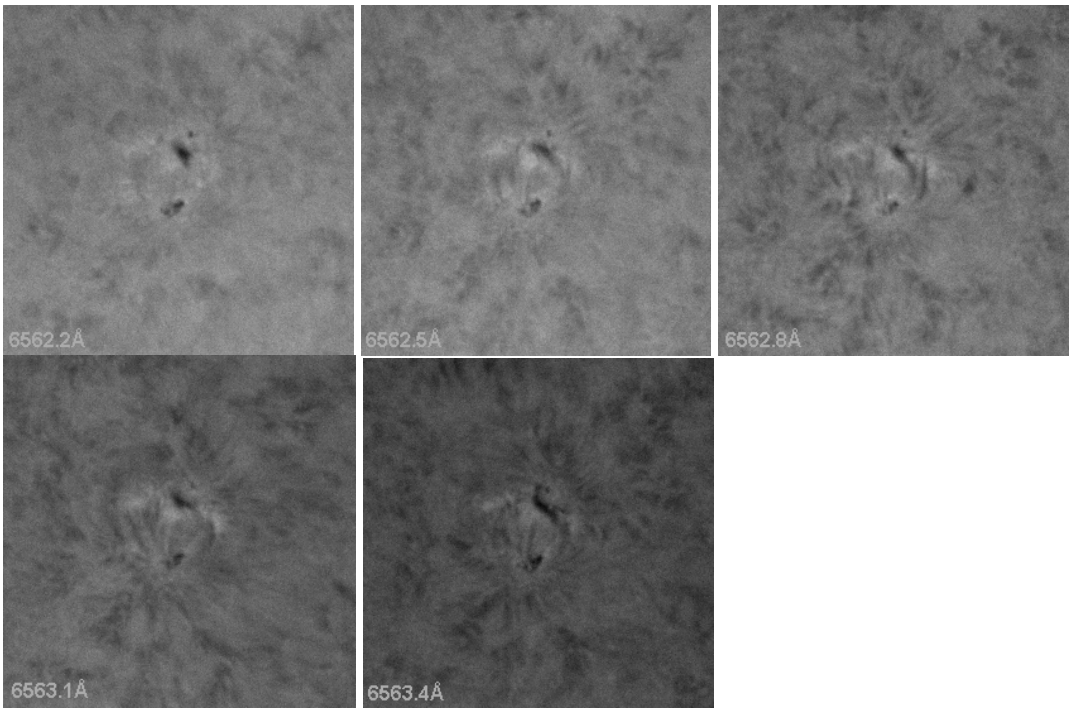

with ERF, 6562.8Å


without ERF, 6562.8Å

Again, a very dramatic improvement is achieved when removing the ERF. Hence, my ERF is flawed as Jen Winters suggested!

I did not make a back-to-back comparison of the effect of having a larger distance between the Powermate and the Daystar filter, hence I cannot say how important this is. However, comparing my images with the ERF to those of my first session the results now seem better.

I also tried detuning the Quantum SE, waiting six minutes for the filter to settle (I was in a hurry!):



The contrast on the longer wavelength side of 6562.8Å seems higher than on the shorter wavelength side. This seems odd to me, but I cannot conclude whether this is an indication of problems with the Quantum SE filter. Can someone help with an opinion?

I have now sent both the ERF and the Quantum SE filters back to Daystar for repair. The former will be exchanged with an optic that does not suffer from poor surface quality and the latter will be checked for problems.