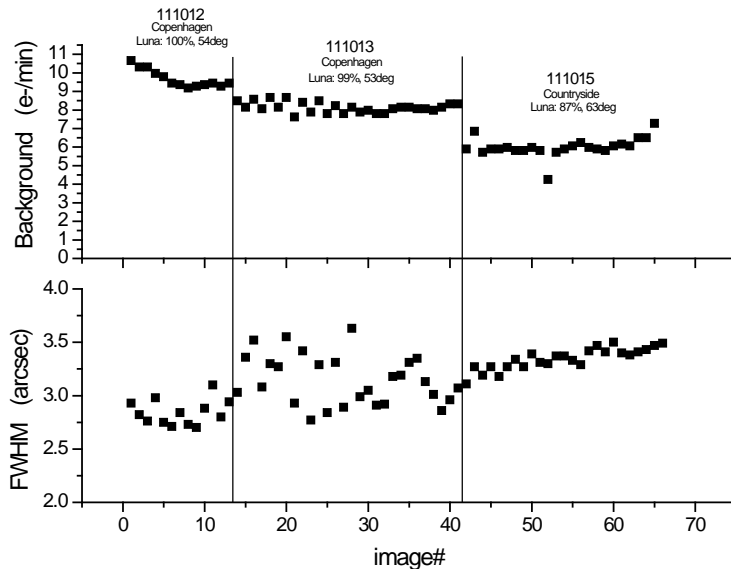


Basic calibration: dark and flat field correction, 2 x hot pixel filtering with 10% threshold, correction of column defects.

Measured all images with CCDInspector (noise rejection=medium). Will first consider the H-alpha data:

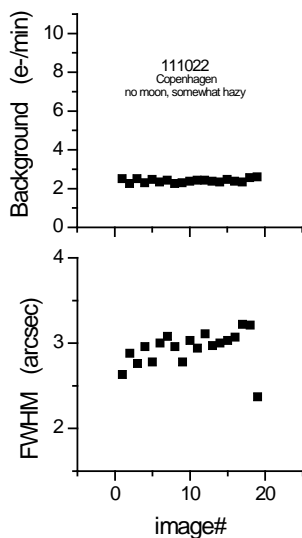


Acquisition was done over three nights, the first two from Copenhagen with a nearly full moon a little over 50deg away while the last night had slightly less moonlight and was done from the countryside. This is evident in the variations of background level. All H-alpha images have a background within 64% of the minimum value, so I do not consider these variations large enough to warrant filtering. The seeing was best on the first night with FWHM down to 2.7", deteriorating over the next days, reaching up to 3.6". Since I have many images to work with I will make three images that range from having optimized sharpness in the bright and midrange regions to optimized SNR in the dim regions. Later on these images will be combined according to brightness so that the final result has optimized sharpness in the bright and midrange regions and optimized SNR in the dim regions.

Before stacking I will explore how the use of bilinear vs. bicubic resampling affects the result. Stacking the sharpest third with bicubic resampling results in FWHM=3.16" while bilinear results in FWHM=3.03" – hence bilinear produces a slightly sharper image. On the other hand, the SNR is ~20% better with bicubic resampling. Based on this I will use bicubic for the dim regions and bilinear for the rest.

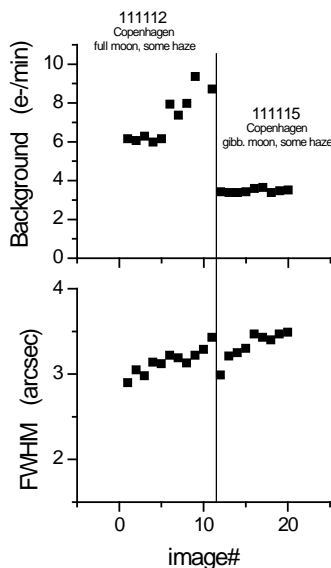
The sharpest 1/3 of the images have a FWHM<2.95", while the sharpest 2/3 have a FWHM<3.27". Using the strategy described above I created three stacked images, using the sharpest third, the sharpest two-thirds and all images, respectively. For some reason the 'all' stack had an offset of 51 ADU compared to the two other stacks – this I corrected. As expected, the stellar peak values then scale according to $1/\text{FWHM}^2$.

I will now proceed with the OIII data, of which there are 19x30minutes worth.



The background flux is much less than with the H-alpha data – no moon was present during these exposures. This is very good since the nebula OIII signal is much dimmer. The FWHM increased steadily from 2.5" to 3.0". In this case I will produce two stacked images, using bilinear and bicubic resampling. Later these will be combined so that bicubic is used in the dim regions.

Next the SII data is processed – here I have 20x30minutes.



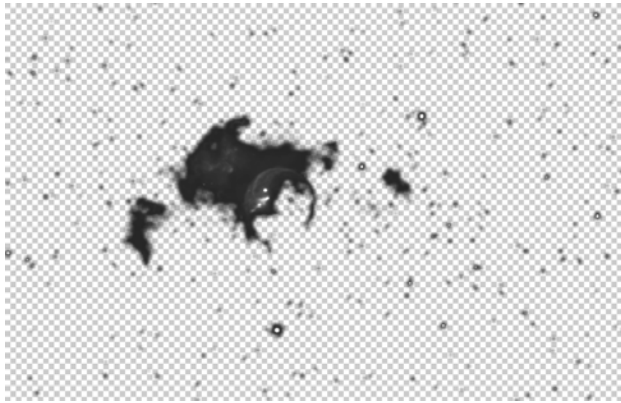
Since the SII nebula signal is weak I choose to discard the last five images from 111112, stacking the rest in two runs – one with bilinear (bright regions) and another with bicubic (dim regions).

Below is a summary of the stacked images produced:

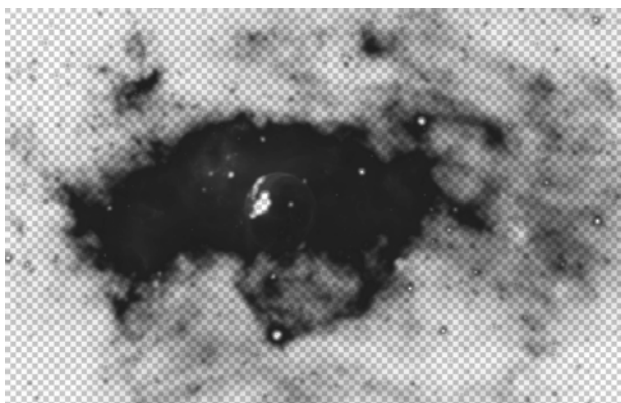
Image File	FWHM	Aspect (%)	SNR (middle region)
NGC7635_Ha-bright.fit	3.04"	5	52
NGC7635_Ha-middle.fit	3.18"	5	69
NGC7635_Ha-dim.fit	3.39"	4	89
NGC7635_OIII-bright.fit	3.12"	2	25
NGC7635_OIII-dim.fit	3.27"	2	34
NGC7635_SII-bright.fit	3.41"	3	44
NGC7635_SII-dim.fit	3.53"	2	55

Is it evident that the intended optimization has succeeded. The images intended for the bright regions have a low FWHM but are noisy in the dim regions, while the opposite is true for the images intended for the dim regions.

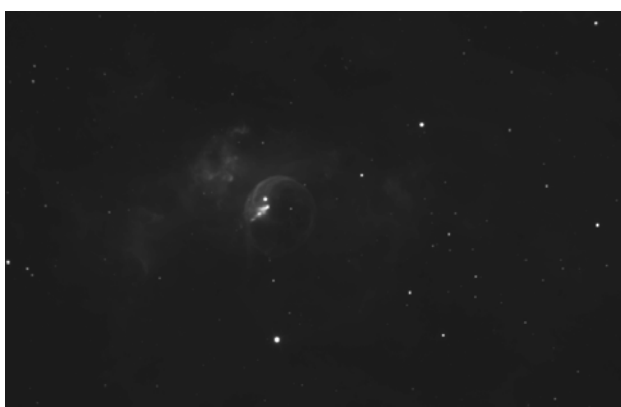
Next step is to combine images for each channel. This will be done in Photoshop, with import done by FITS liberator (all images: black level=0, white level=55000). To see something at all I gave all images an initial level adjustment (input levels: 0,1,16). I then used the color range selection tool to select the bright region in the 'bright' image and the middle region in the 'middle' image. These selections are then stacked onto the 'dim' image as layers:



(bright)



(middle)



(dim)

The image is flattened and saved as a 16-bit TIFF. A similar procedure is carried out for the OIII and SII channels.

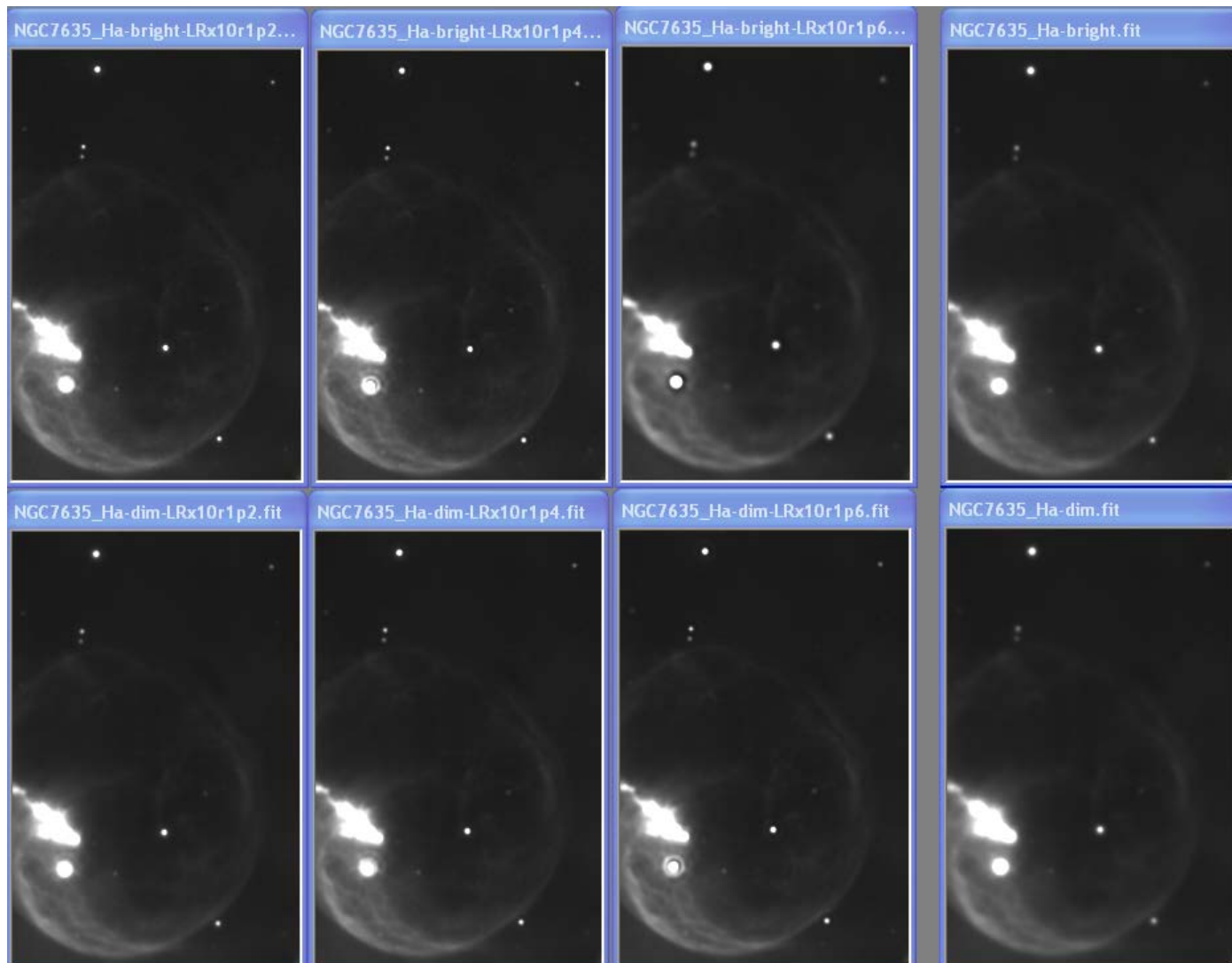
The three narrowband composite images are then aligned using Maxim with the H-alpha channel as reference.

Back in Photoshop a color image is made using the Hubble palette (R: SII, G: H-alpha, B: OIII). Levels and curves are used to bring out the nebula and control the white/black points. Using Annie's Astro Actions I ran several 'reduce star size' on the SII channel since this has the largest FWHM. This reduced the red halos somewhat. Here's a segment of the result so far:

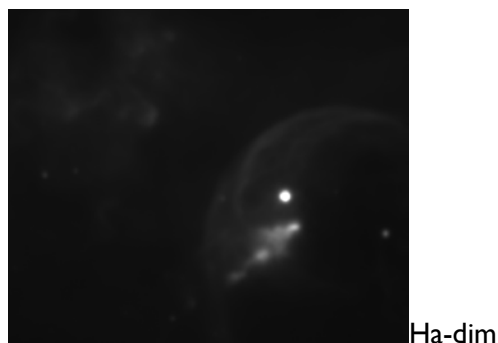


I also had to manually repair some diffraction artifacts around the two brightest stars in the SII and OIII channels.

I wonder whether some deconvolution can improve on the image resolution. Using Maxim I tried Lucy-Richardson deconvolution with various PSF radius values and on both the 'bright' and 'dim' H-alpha images:

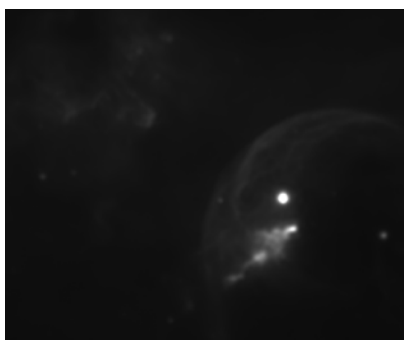


From these images it is clear to me that 1) deconvolution can improve sharpness of nebulous regions but not without creating a ring artifact around brighter stars, 2) no deconvolved 'bright' image can match the best deconvolved 'dim' image – hence: good SNR trumps good FWHM in this game. A way forward could be to deconvolve 'dim' using PSF $r=1.6$ and repair the stellar artifacts using the original image or the RGB data. I did this on all three narrowband channels. Below is shown how the deconvolved data is incorporated into the image:



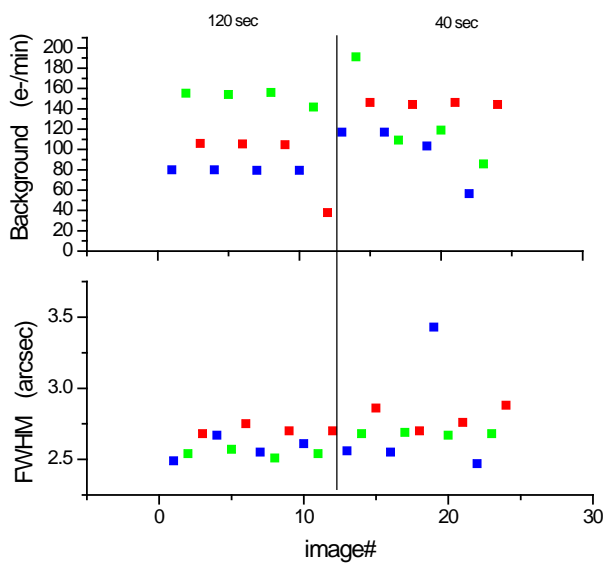


Ha-dim (LRx10, r=1.6), brightest regions selected, non-nebula sections removed



Stack of the above

Time to consider the RGB data:



I will choose to use the 120sec data. First I removed bloom artifacts, then each color-series was stacked with the stacked H-alpha-dim image as reference.

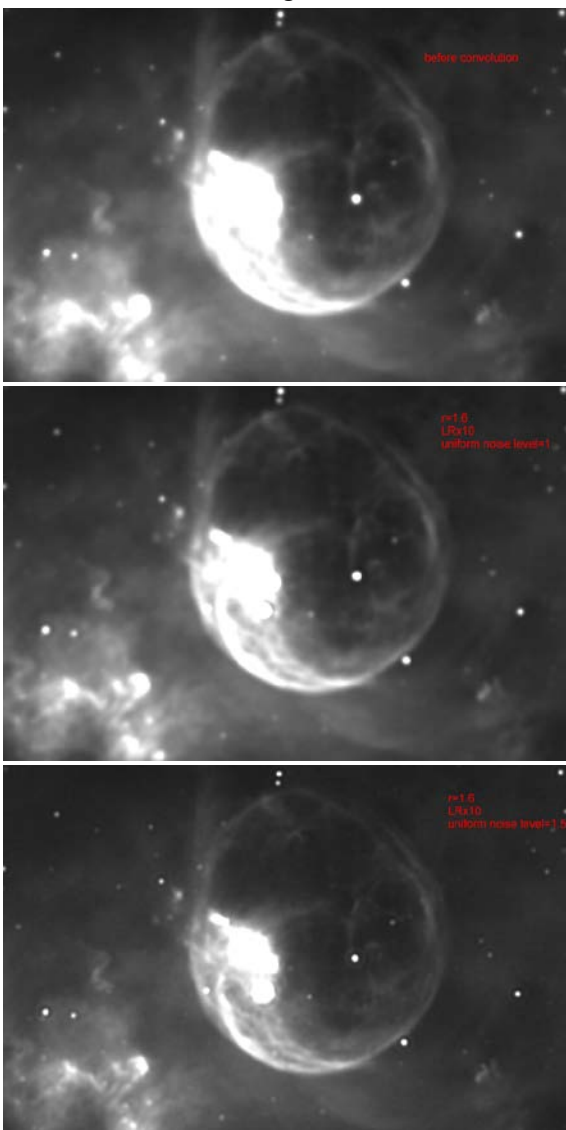
UPS!! Found out that I had deconvoluted on the wrong images, ones that were not aligned to the Ha-channel. Will reprocess:

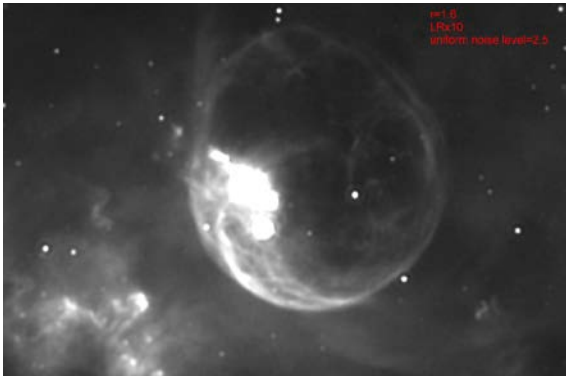
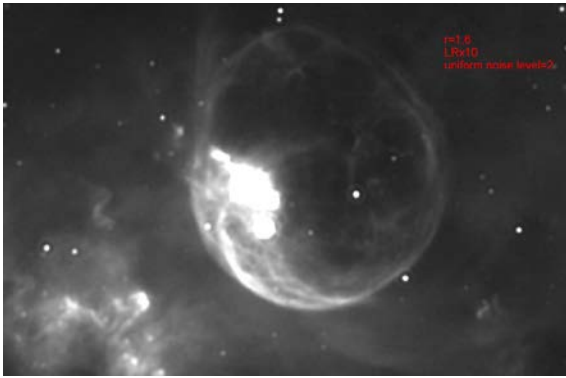
viewed all single images for Ha,OIII,SII in Mira, deleted three worst SII images where nebulosity faded substantially – using all others.

stacked OIII images in Maxim (bicubic, SD combine 2.5, reference Ha-dim), saved as OIII-dim, did LR deconvolution $r=1.6$, $n=10$, saved as OIII-dim-LR

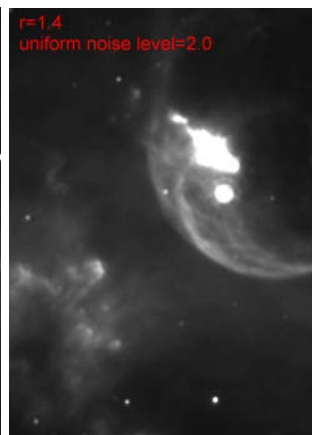
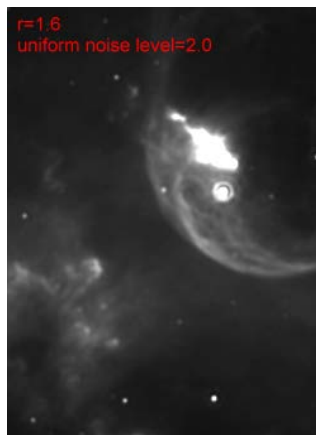
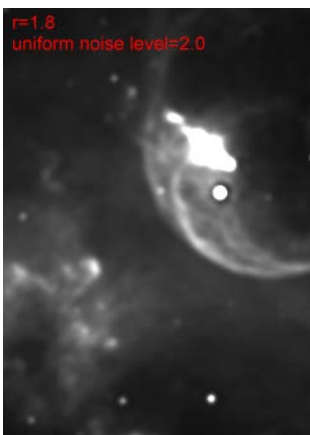
did the same for SII images

On Ha-dim: experimenting with LR deconvolution. Radius is fairly easy and I get $r=1.6$ as last time. I found that it is critical to choose the right 'uniform noise level':

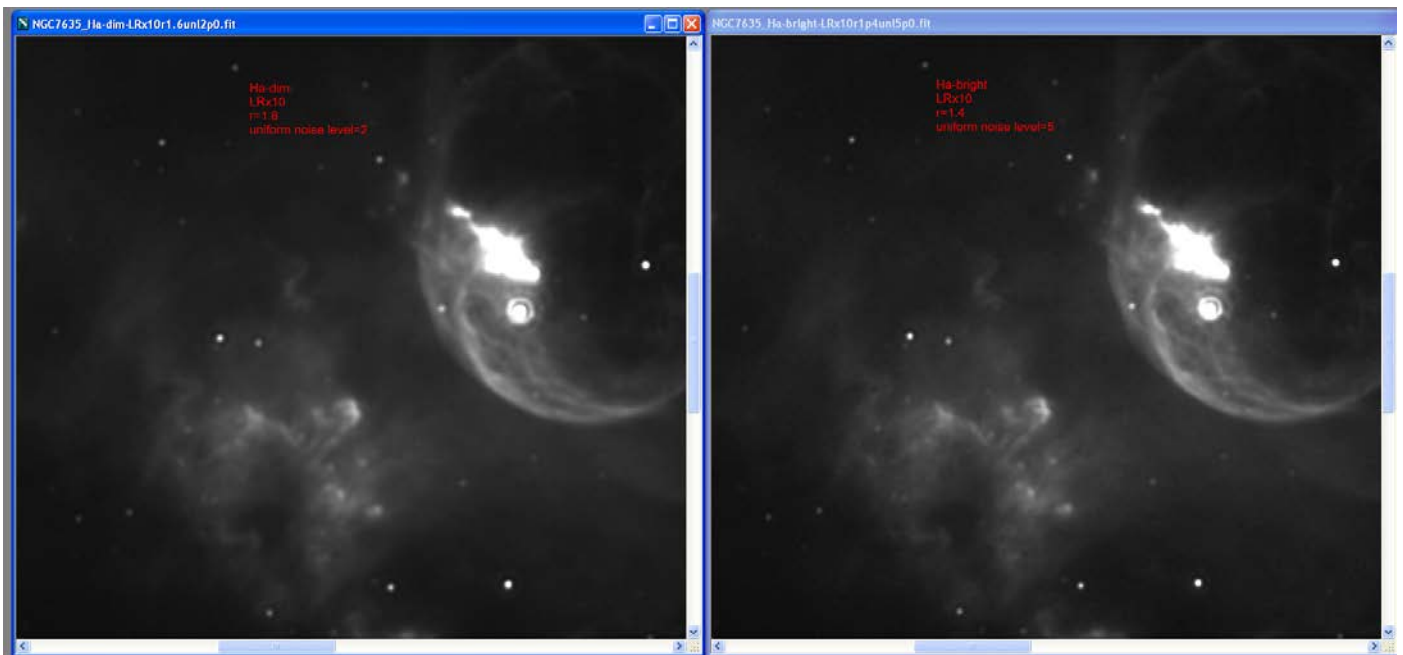




From above I will choose to use 'uniform noise level'=2.0. Re-checking the value for radius:



Hence, for Ha-dim I will use unl=2, r=1.6. If I use these parameters on Ha-bright the result is very bad! This makes sense because the dim and bright images have different noise levels and hence unl and r must be re-optimized. Doing this I get for Ha-bright; unl=5, r=1.4. Below are the two deconvoluted images for -dim and -bright:



I find the noise in the deconvoluted –bright image to be too strong and the sharpness is not sufficiently higher than that in the –dim image to warrant further use.

Importing into PS; levels 0,1,25, levels 0,1,130. Combined bright portions of nebula with the Ha-dim image.

Optimizing LR deconv. on OIII-dim => $r=1.4$, $unl=4$. Importing into PS; levels 0,1,25, levels 0,1,130, levels 0,1,130.

Optimizing LR deconv. on SII-dim => $r=1.4$, $unl=3$. Importing into PS; levels 0,1,25, levels 0,1,130, levels 0,1,130.

Combined into RGB with Hubble palette, adjusted levels and curves for each color channel.

Need to do: color combine in maxim, DDP in maxim, use RGB data for stars, reduce star bloating, reduce noise in dim region

Processing of final version – NGC7635:

Input data: 65×900sec Ha, 19×1800sec OIII, 20×1800sec SII, 4×120sec R, 4×120sec G, 4×120sec B → 36 hours total exposure time

Final image is a Hubble palette narrowband image with RGB data for the stars. Brightest portions of nebula have been sharpened with Lucy-Richardson deconvolution. A synthetic luminance layer is constructed as the sum of all narrowband images. Below is shown an outline of my processing:

