High Resolution Astrophotography

AIC 2009

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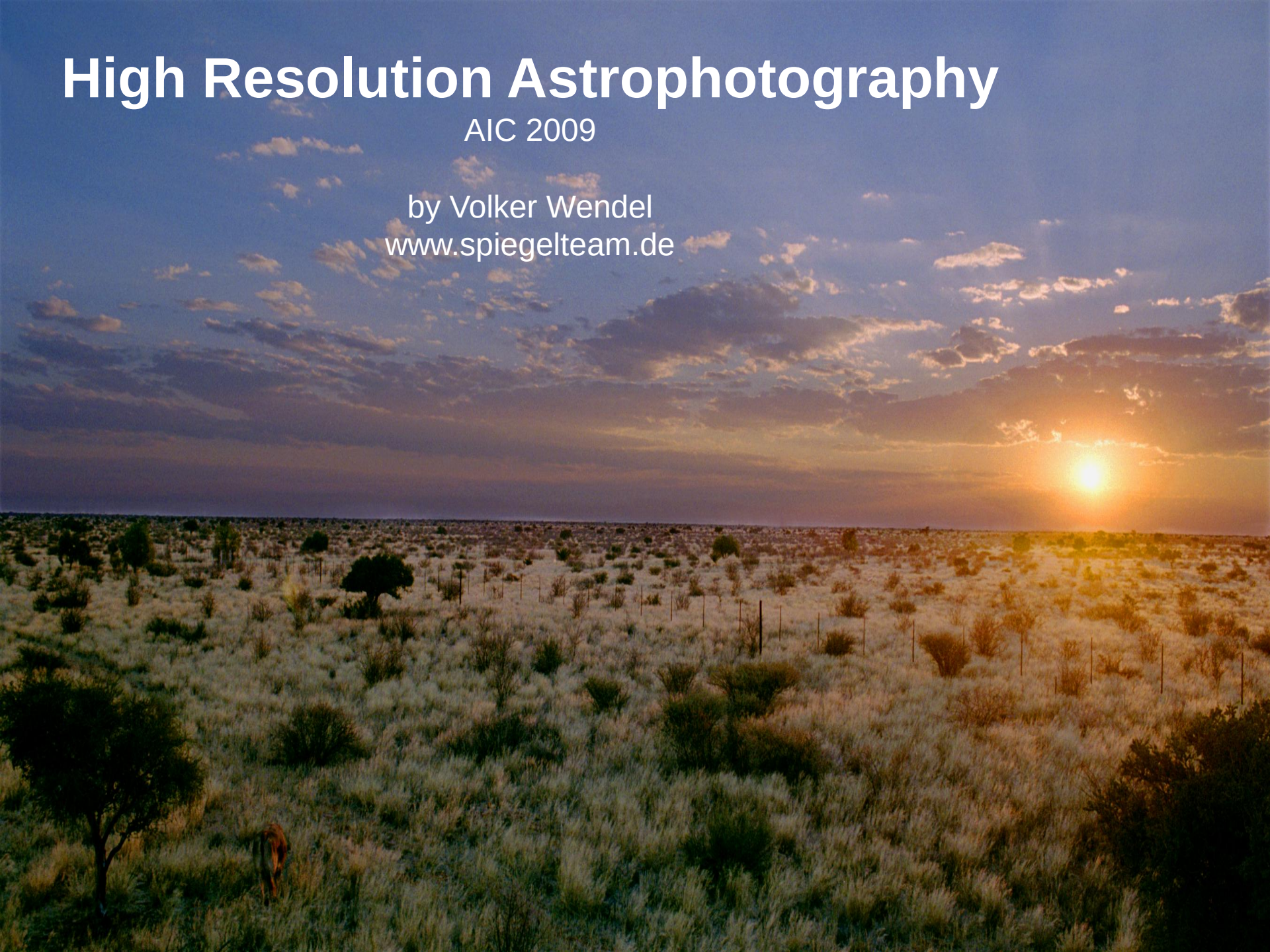
www.spiegelteam.de

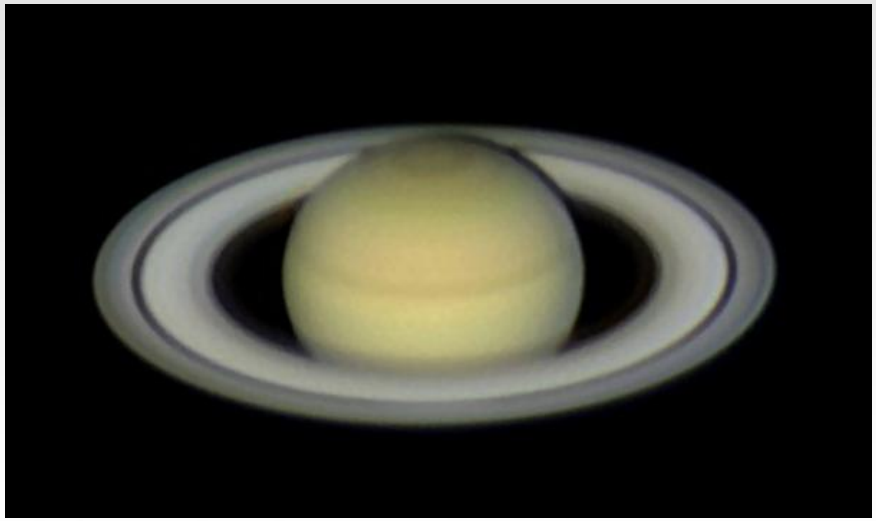


Content:

I. Some theoretical thoughts
II. What helps when starting High Resolution Imaging
III. High Resolution Image Processing

We are looking for smallest details, but we should separate between Deep-Sky Imaging with single exposures >10 seconds and planetary imaging with sub-second exposures.

Image of Saturn and Eskimo Nebula, both at fl = 6000mm



Some theoretical thoughts

- usually we are talking about focal lenghts >2000mm
- a pixel sampling that matches the best possible seeing conditions at your observing site is needed
- roughly spoken: pixel sampling multiplied by 3 should match best seeing conditions

example: best possible seeing in the last four years in my backyard was 1,6“ FWHM so my telescope and CCD-camera setup should give me a sampling of about 1,6/3=0.53“

my reality: 15“-Newtonian with a special made APO-barlow lens gives me a focal lenght of about 3000mm.ST10XME in use, pixel size 6,8my

Formula to calculate pixel sampling

$$\frac{\text{pixelsize (mm)}}{\text{focal length (mm)}} \times 57{,}3 \times 3600$$

In my example:

$$\frac{0{,}068 \text{ mm}}{3000 \text{ mm}} \times 57{,}3 \times 3600 = 0{,}45\text{“ per pixel}$$

$\Rightarrow$ perfect match for seeing conditions up to (0,45“ x 3 =) 1,35“

$\Rightarrow$ in about 95% not needed but able to get the maximum in best nights in my backyard

Urban observing sites have most of the time seeing conditions not better than 2“, remote sites can give you seeing conditions next to 1“ so you should be prepared for your given situation.

maximum seeing condition	pixel size	focal lenght needed
2“	6,8my	~2100mm
2“	9my	~2750mm
1“	6,8my	~4200mm
1“	9my	~5500mm
0,5“	6,8my	~7500mm
0,5“	9my	~10000mm

Maximum Telescope Resolution

(interesting for Planetary imaging)

Rayleigh 116/d = max. resolution in arcsec. (d = telescope aperature in mm)

Results using this formular:

100 mm	200 mm	400 mm	800 mm	5000 mm
1,16“	0,58“	0,29“	0,15“	0,023“

Sparrow 70/d = max. resolution in arcsec. (d = telescope aperature in mm)

Results using this formular:

100 mm	200 mm	400 mm	800 mm	5000 mm
0,7“	0,35“	0,17“	0,09“	0,014“

=> not realistic for Deep-Sky Imaging but for Planetary Imaging with perfect optics

Planetary Imaging

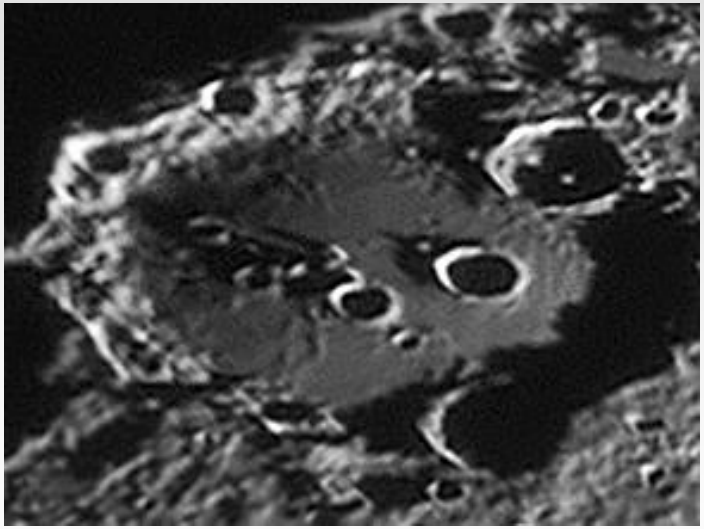
-modern noise free video cameras are the best way to go for lucky imaging

-telescope setups should have such a long focal lenght so that you are able to get your maximum resolution out of the telescope, see the sparrow and pixel sampling formula shown before

-Sparrows extreme resolution formula seems to be realistic!

Clavius with the best lucky shot out of the ST10 and a webcam shot:

15“ at 3000mm



12“ at 6000mm

My backyard observatory with the 15“-Newtonian in my backyard, mag 5.5 skies

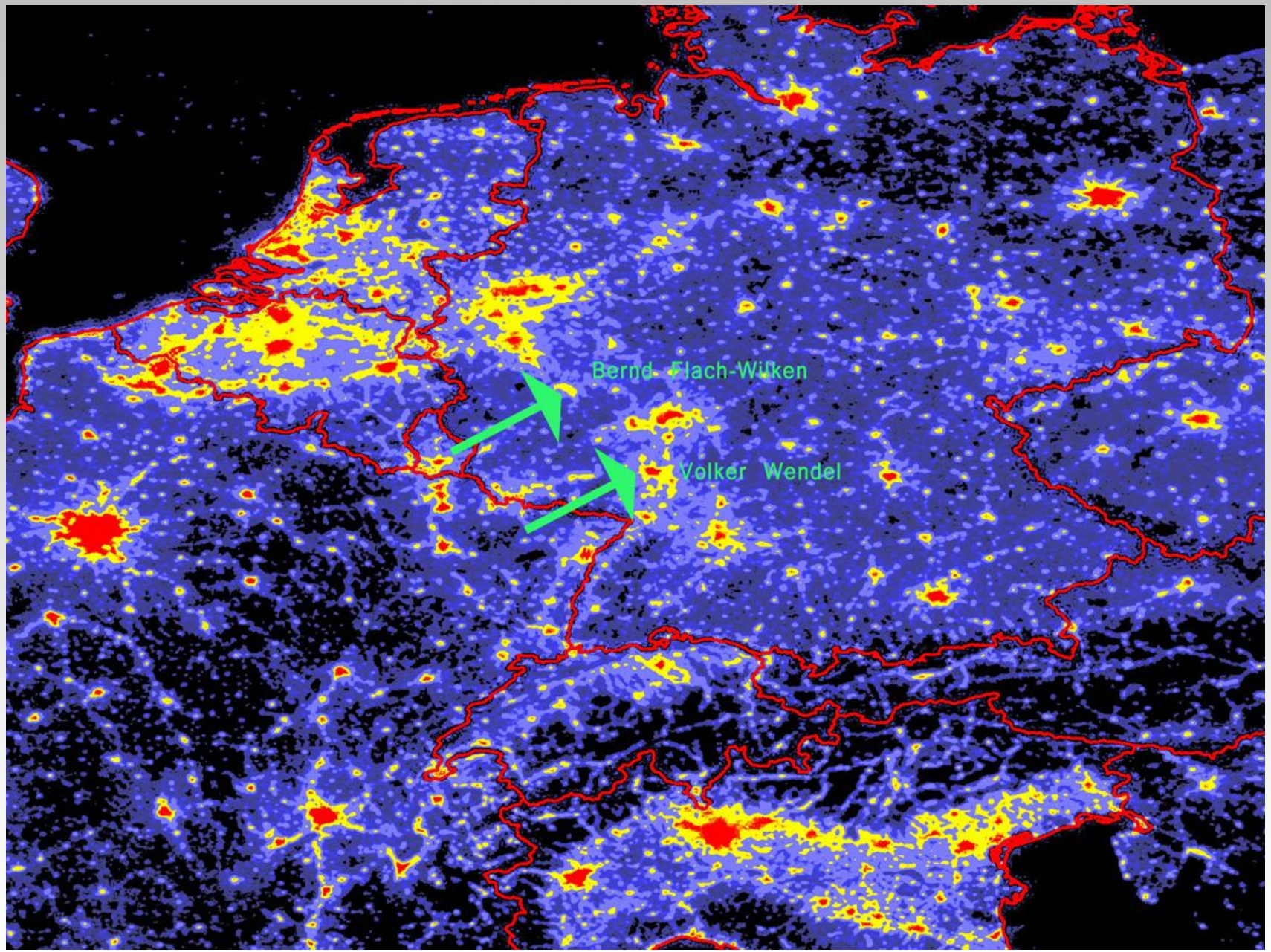
Telescopes used :

12“-Schiefspiegler
fl= 6000mm
Bernd Flach-Wilken

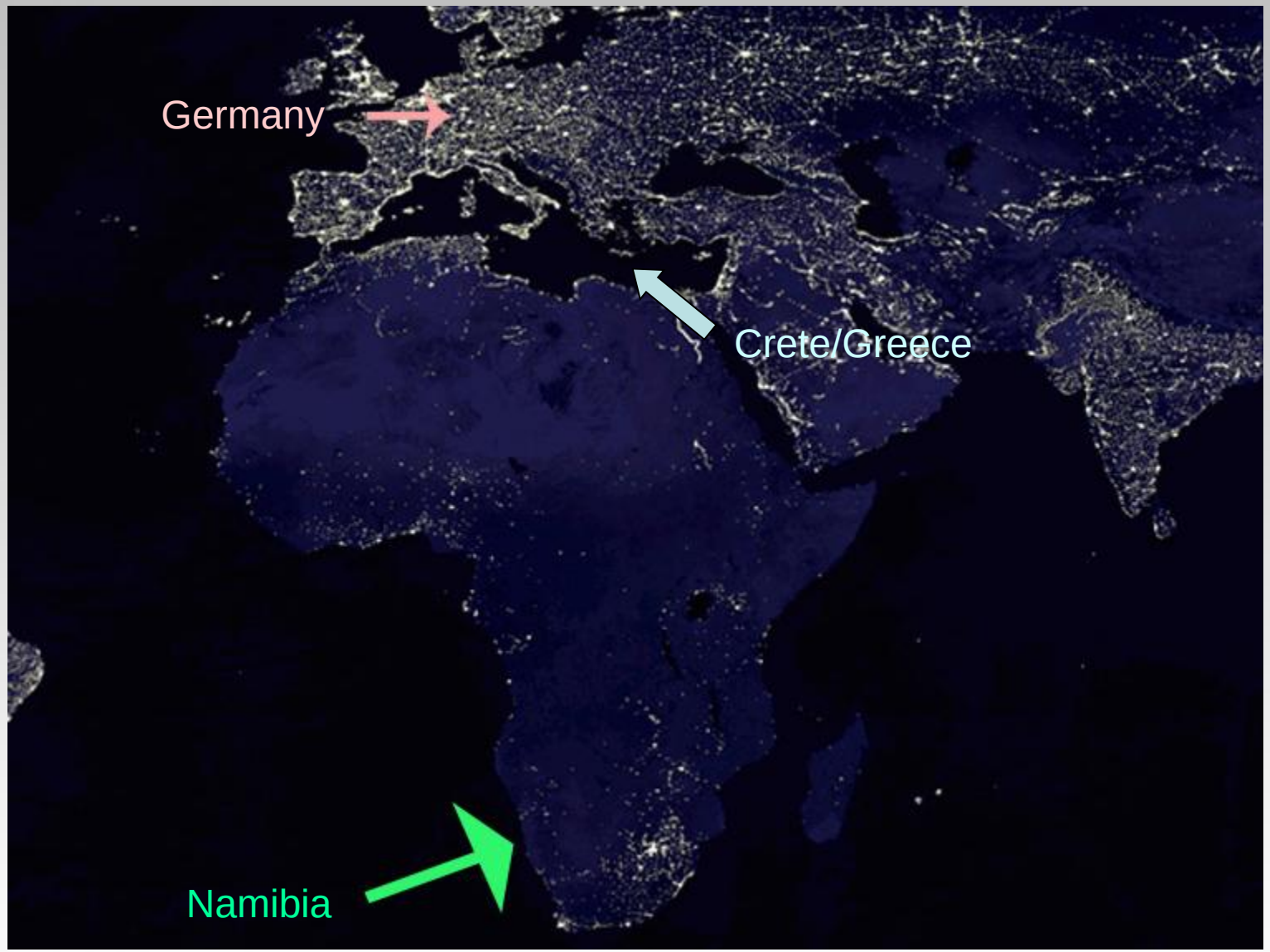
16“-Hypergraph
fl= 3200mm
Bernd Flach-Wilken

24“-Hypergraph
fl= 4800mm
Capella-Observatory

Where does the Spiegelteam shoot from? Germany and…

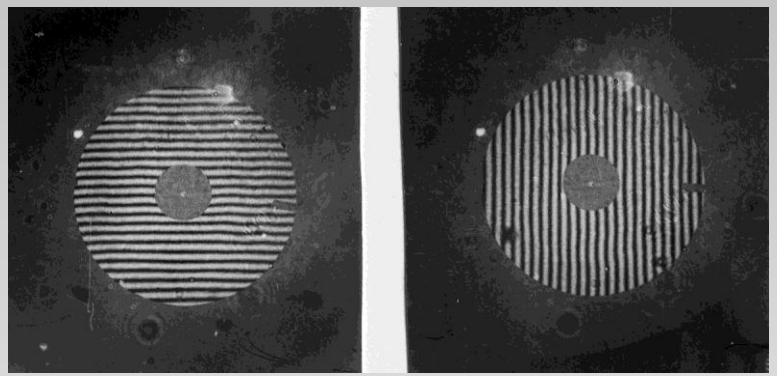


…Namibia and in cooperation with the Capella-Observatory team from Crete/Greece!



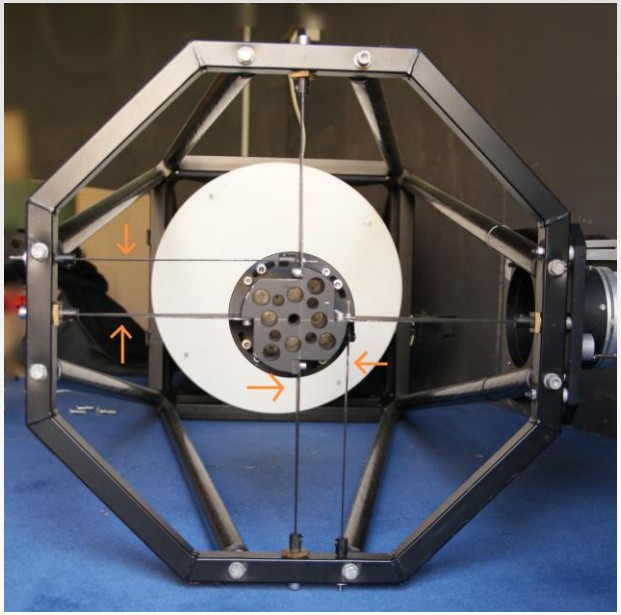
What helps to get the best out of your telescope setup (1)?

- use perfect mirrors (including secondary!) or lenses for highest contrast



- try to get the best collimation possible

- try to make your telescope as collimation stable as possible (very useful when remotely operating)



What helps to get the best out of your telescope setup (2)?

- try to have perfect guiding (for example with AO-Systems)
- try to hold perfect focus the whole night

- try to shoot luminance when your object is near it´s highest position because of seeing

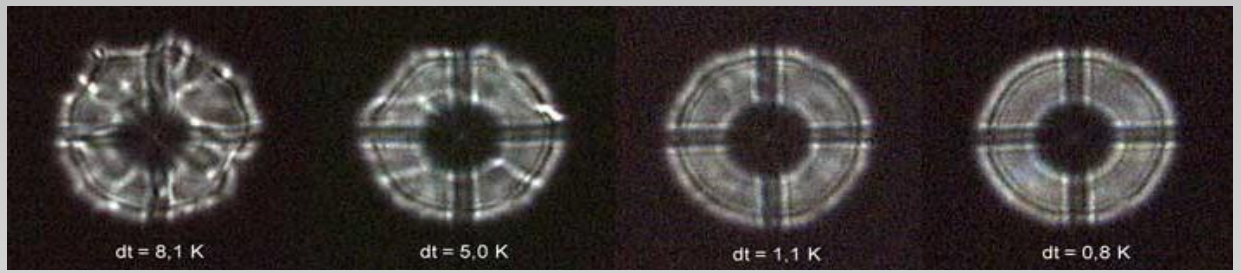
What helps to get the best out of your telescope setup (3)?

• cool down your tube (and your dome) before starting imaging

example:

(source J.S.Schlimmer

www.epsylon-lyrae.de)



• optimize your local system

Long focal lenght = small FOV
=> build mosaics for larger objects

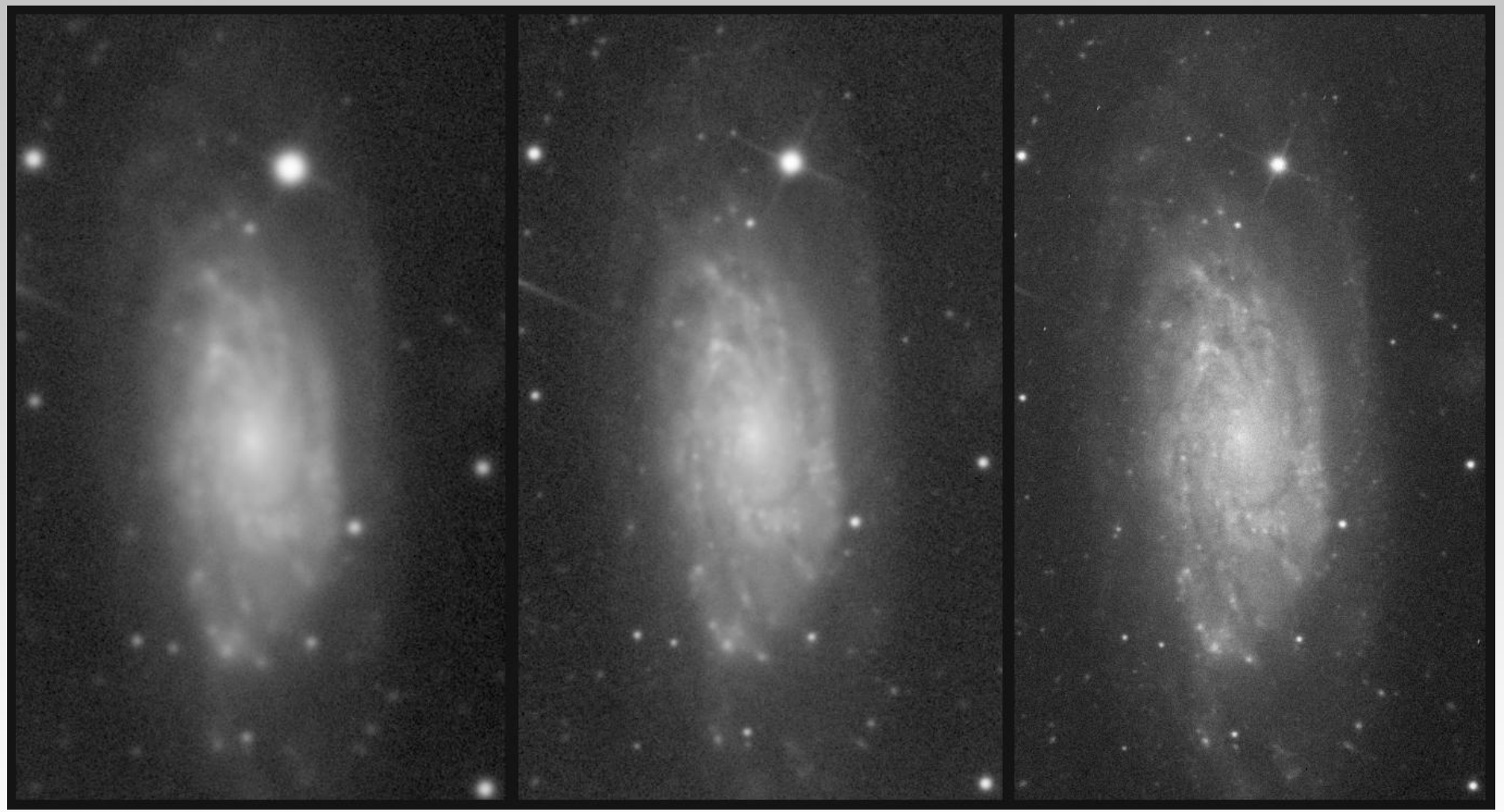
M33

(1800mm, STL11k, two frames)

…or buy larger chips => but be sure, your optics are able to get a nearly coma free field, large chips are not everything!

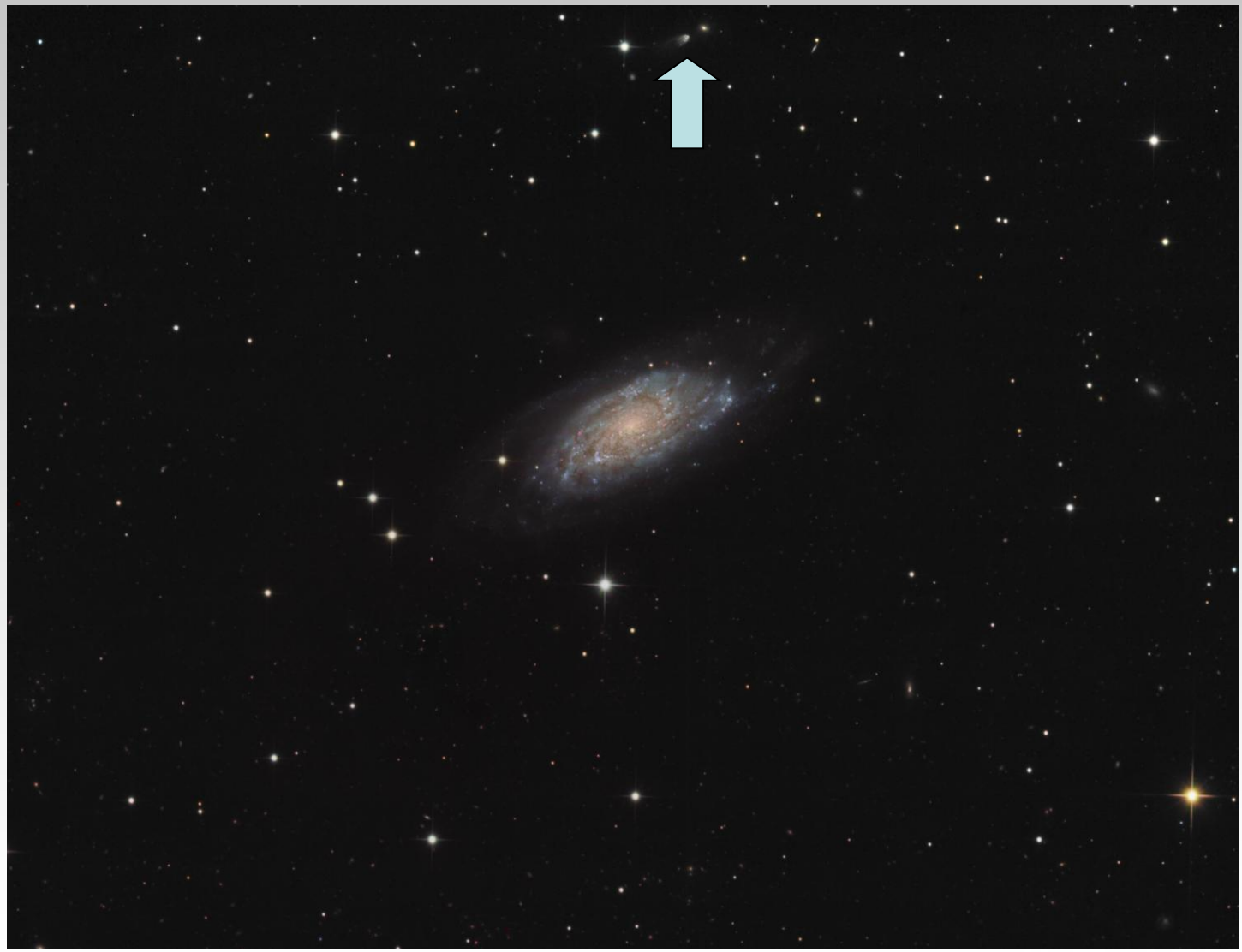
Seeing is everything - example of different seeing conditons

NGC 6015 @ 3“ NGC 6015 @ 1,9“ NGC 6015 @ 1,3“



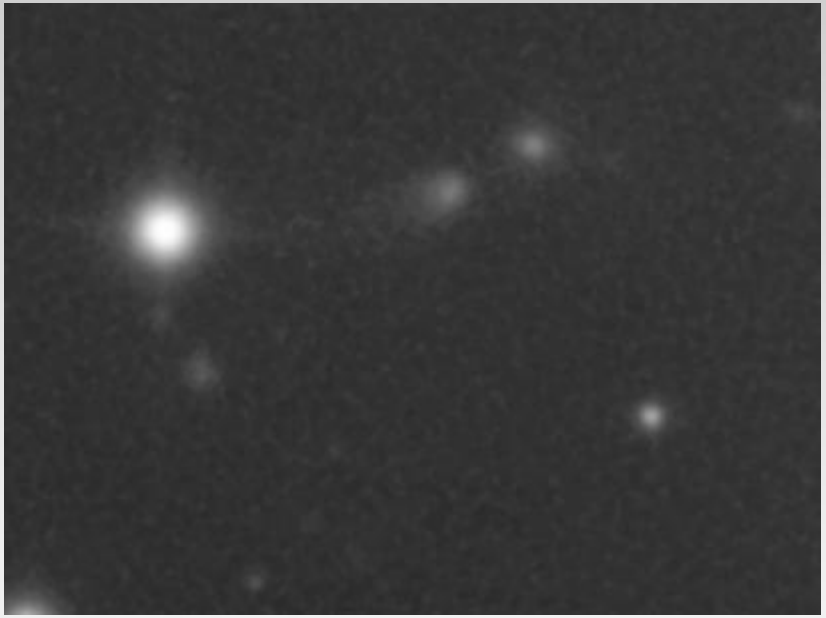
Second example of different seeing conditons

NGC 6015 with an irregular galaxy:



Second example of different seeing conditons

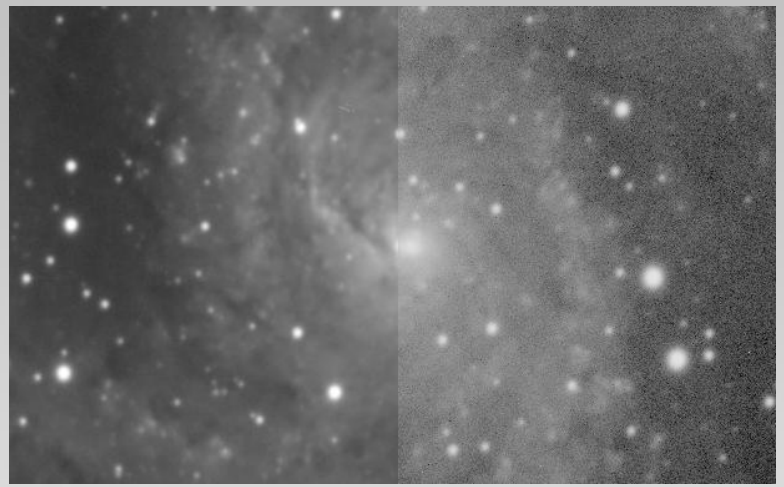
Seeing animation of a irregular galaxy next to NGC 6015 in the finally processed image:

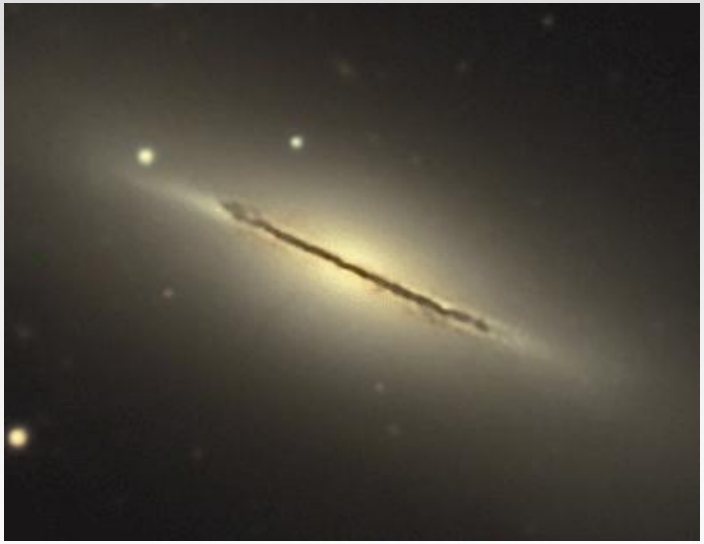


What helps in image processing to get the maximum?

-try to get the best S/N ratio

NGC6946:
left side 16x600s
right side 1x600s





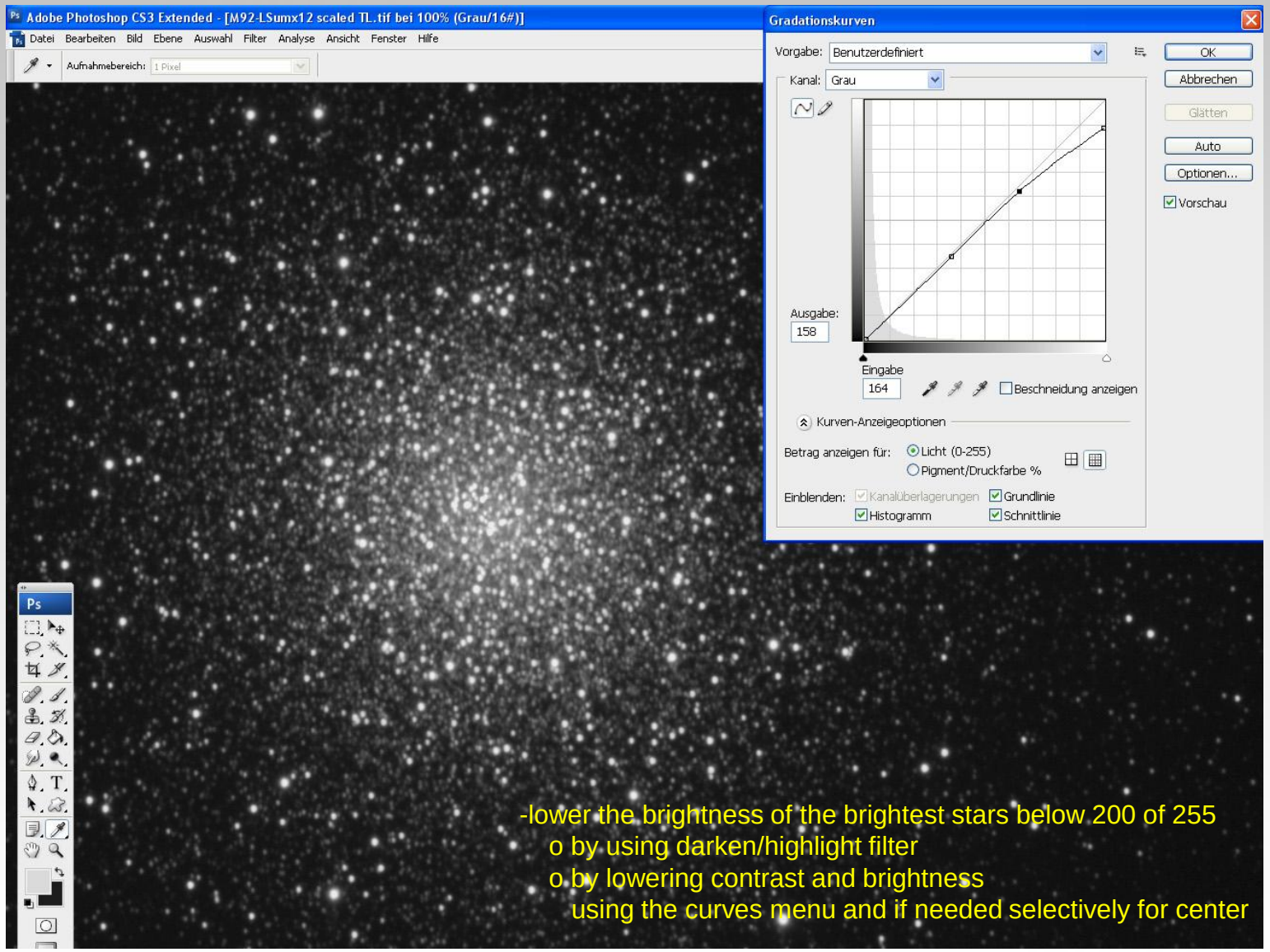
- concentrate your processing on the Luminance master to get the sharpest result

- use deconvolutions and other contrast enhancing techniques

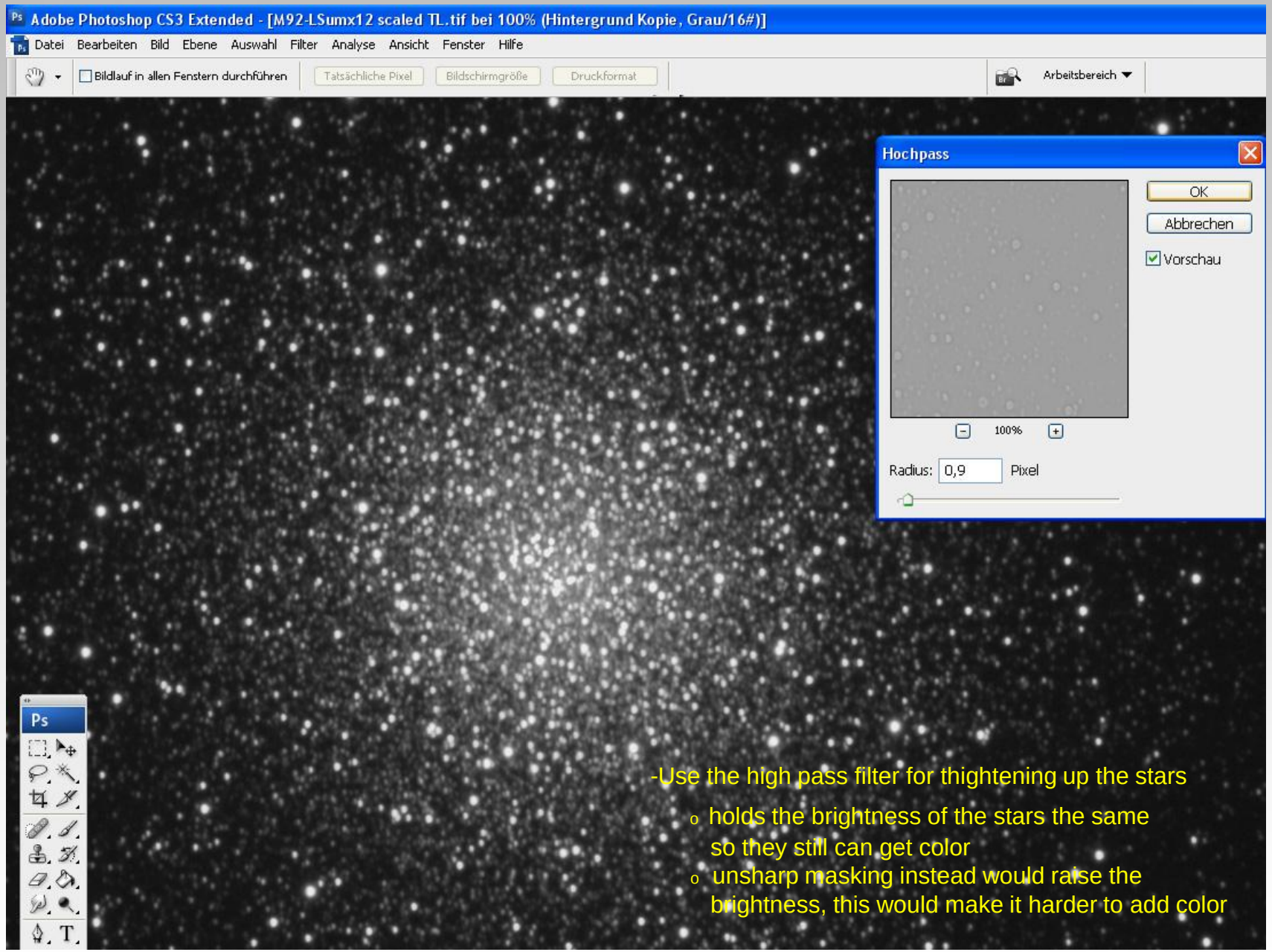
- do not overcook your images using to much of it => artefacts destroy a good image

High Resolution Image Processing

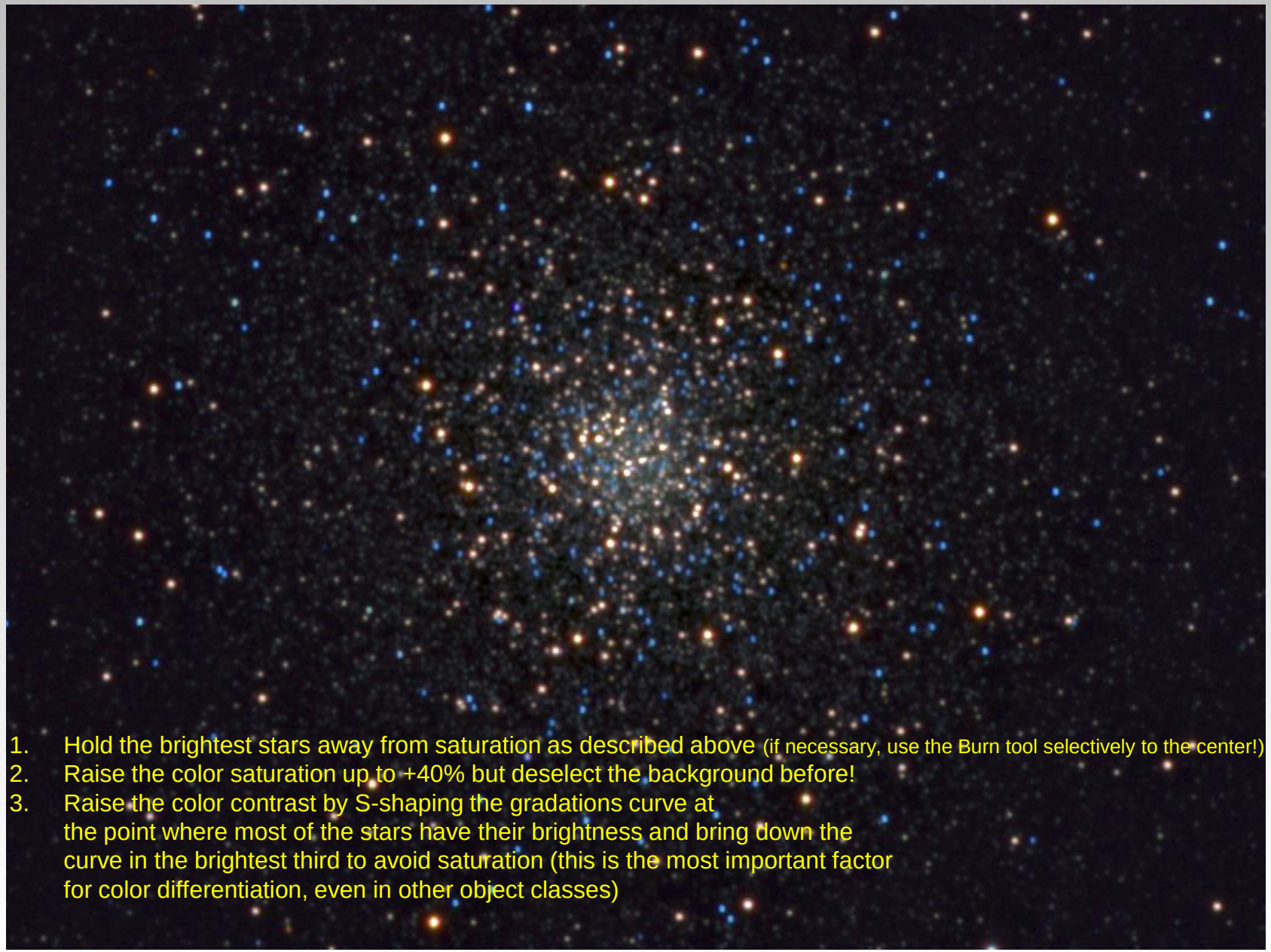
Globular clusters: many bright star near saturation, how to get colors in the image?



Globular clusters: how to tighten up the stars without oversharpening them?



Star clusters: how to get good color saturation and differentiation?



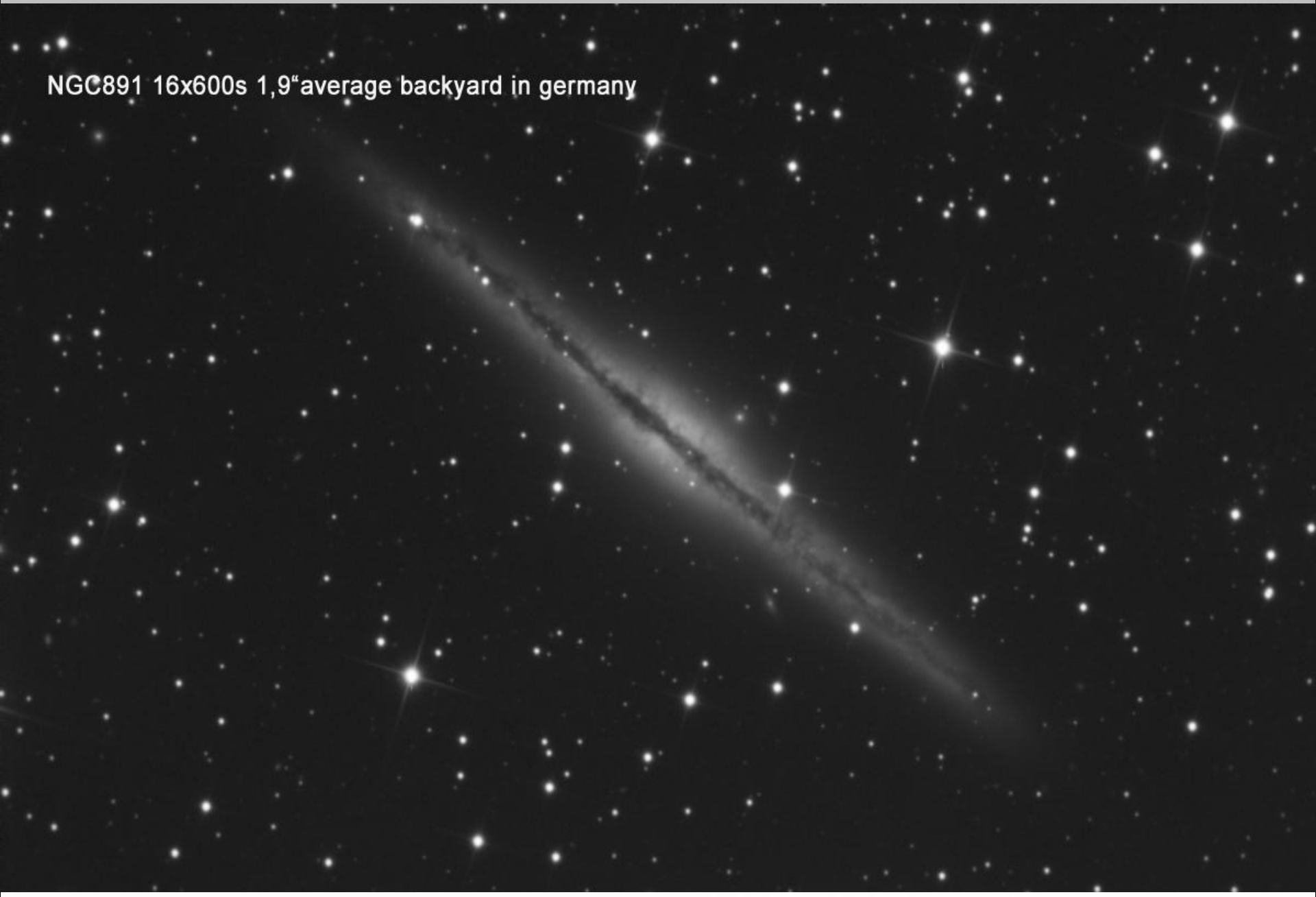
1. Hold the brightest stars away from saturation as described above (if necessary, use the Burn tool selectively to the center!)
2. Raise the color saturation up to +40% but deselect the background before!
3. Raise the color contrast by S-shaping the gradations curve at the point where most of the stars have their brightness and bring down the curve in the brightest third to avoid saturation (this is the most important factor for color differentiation, even in other object classes)

Final LRGB of M92 (in coop with Capella-Observatory team)

⇒as for bright objects, think about shooting them as a straight RGB!

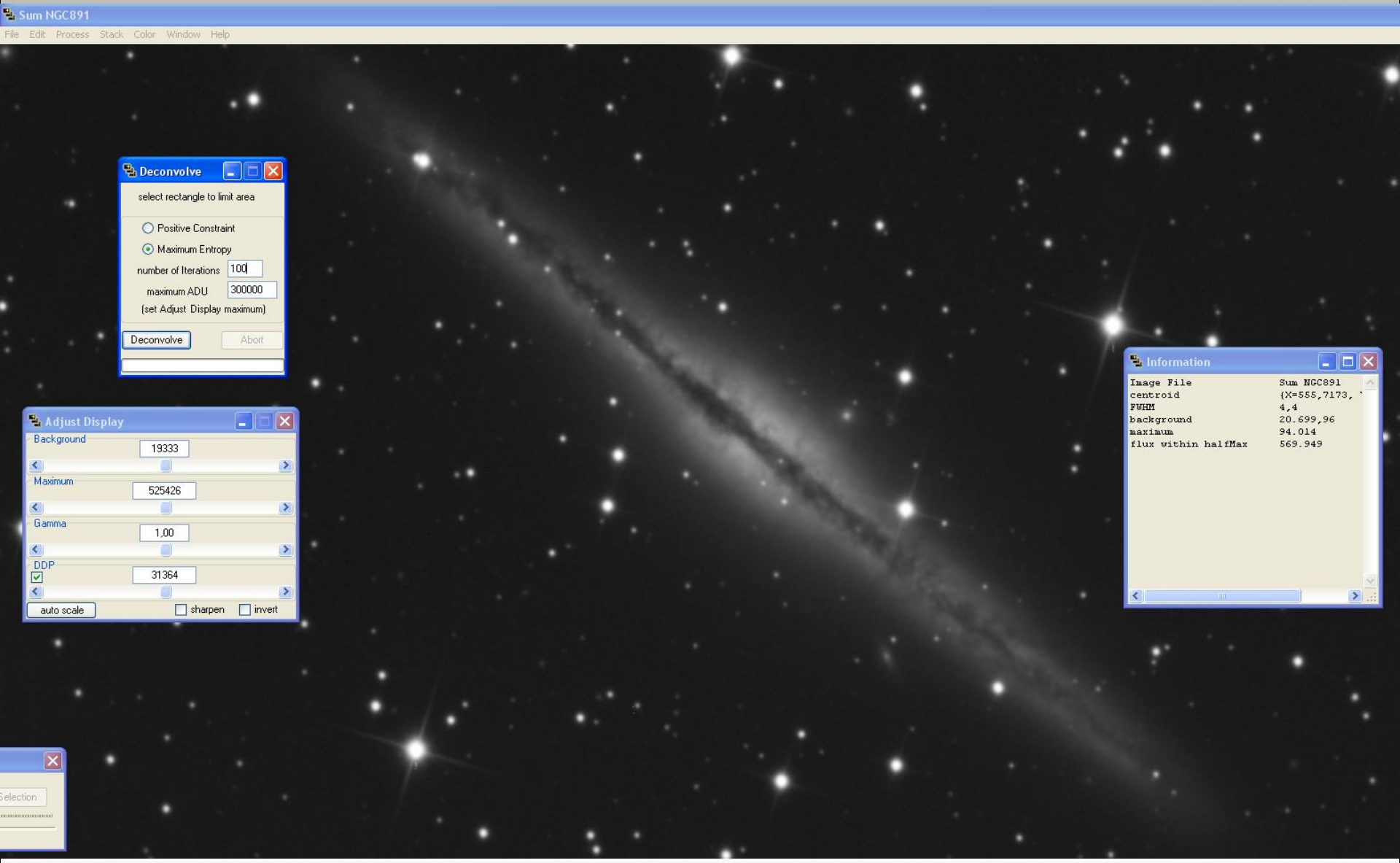
(this helps to avoid saturating stars and gives high color saturation)

Galaxies, PN´s, Nebula: what can we do to let them look „high res“?



=> this image is reduced in CCDStack by using a flat, darks etc and saved as „16bit scaled data“ avoiding saturation in the object and clipping in the background

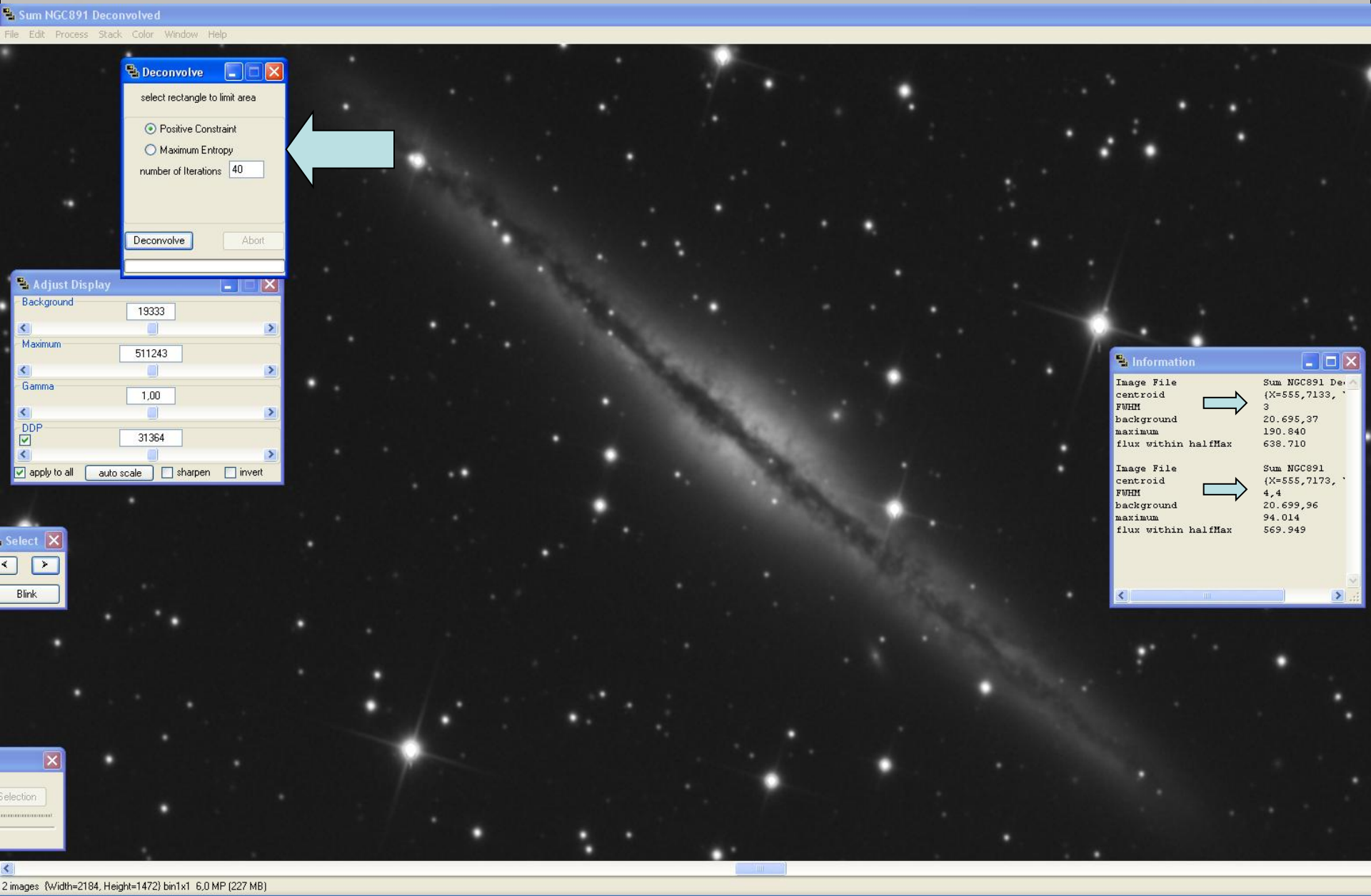
Deconvolution (1)



CCDStack at the beginning:

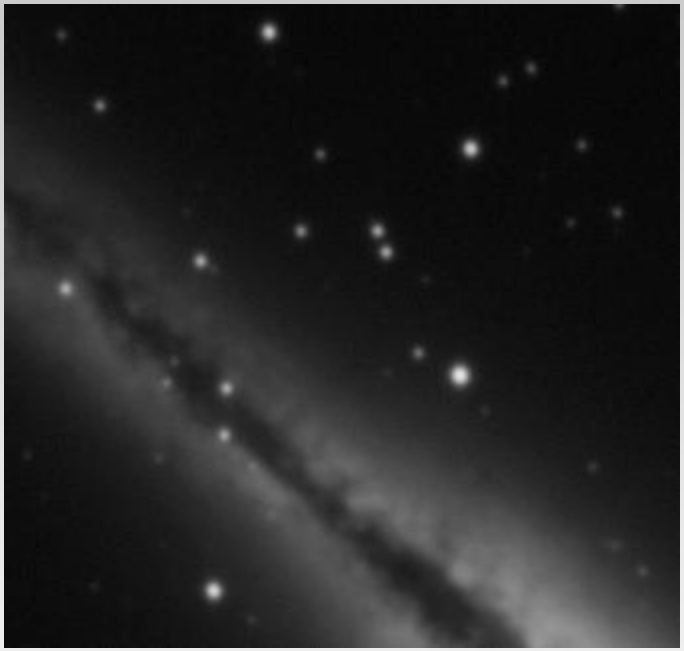
- Use „Maximum Entropy“ in a soft way to get small details and a smoother background (or directly use „Positive Constraint“)
- Hold the original raw file the same contrast to copy the original stars for a star repair later on
- Use a lower „maximum ADU“ number as suggested by CCDStack to make the deconvolution more aggressive

Deconvolution (2)

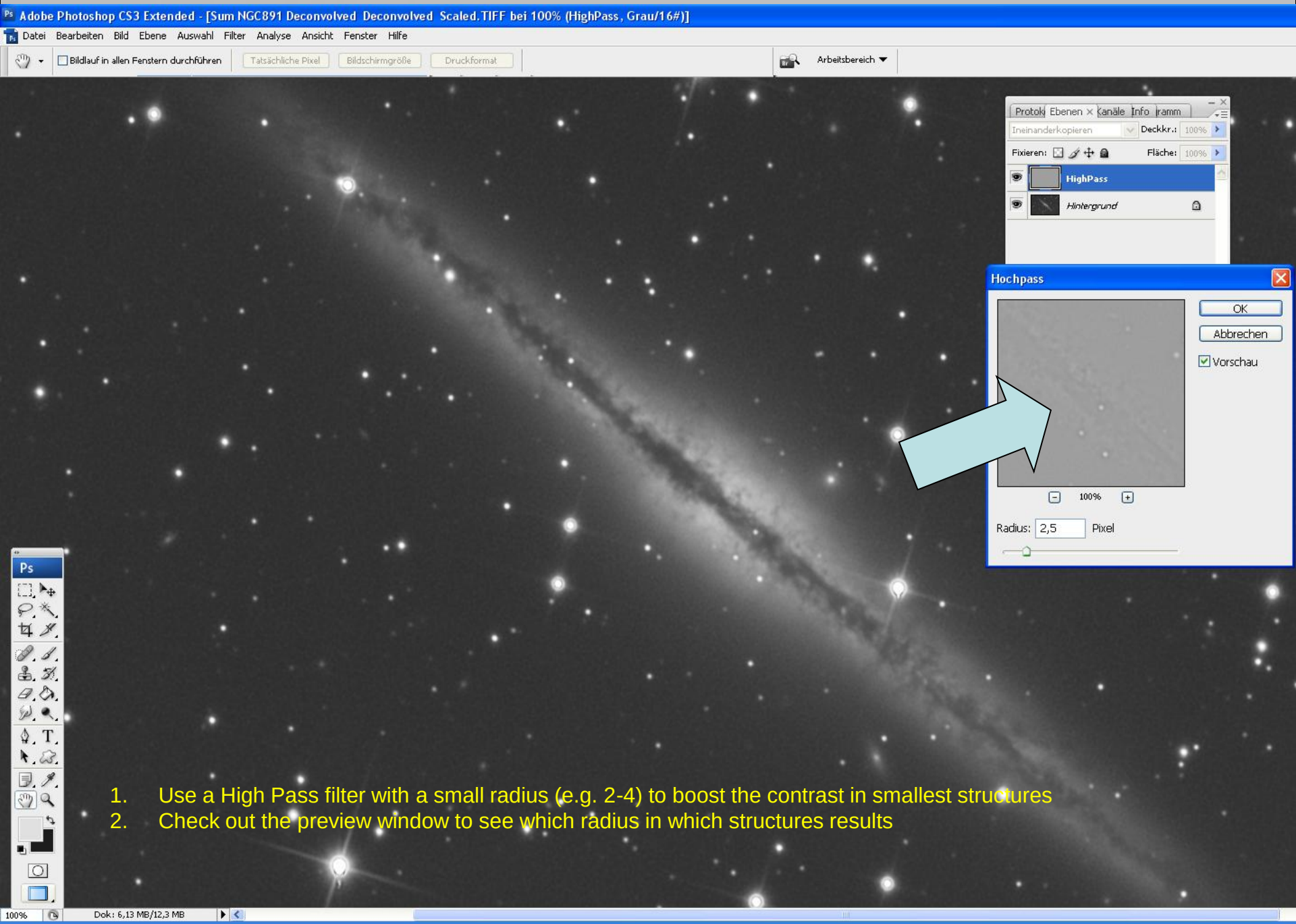


Use Positive Constraint in a mild way as a 2nd deconvolution step (here the stars where reduced from FHWM 4.4 to 3 in the first step)

Animation of raw file, Maximum Entropy and finally Positive Constraint deconvolution

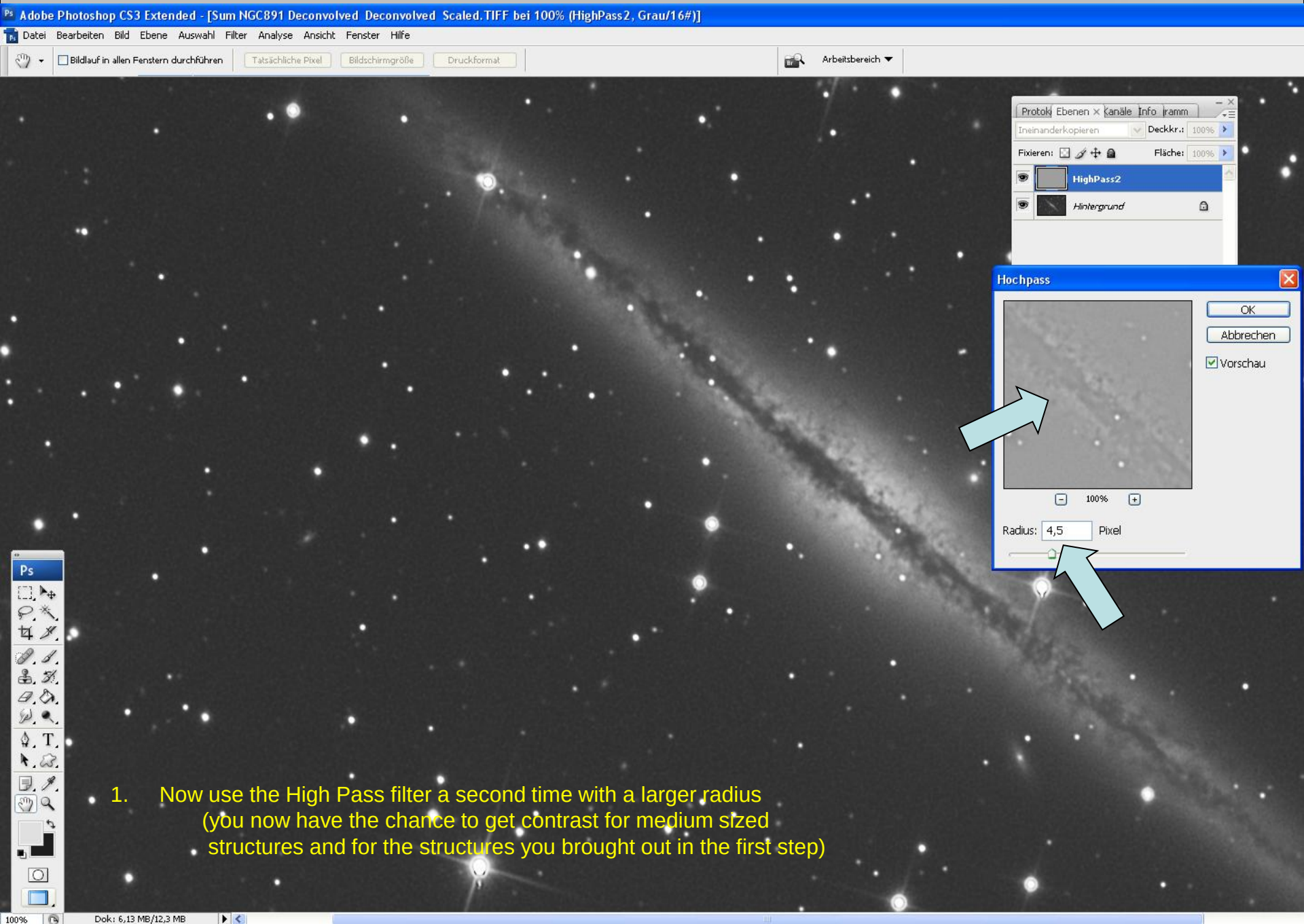


High Pass filtering (1)

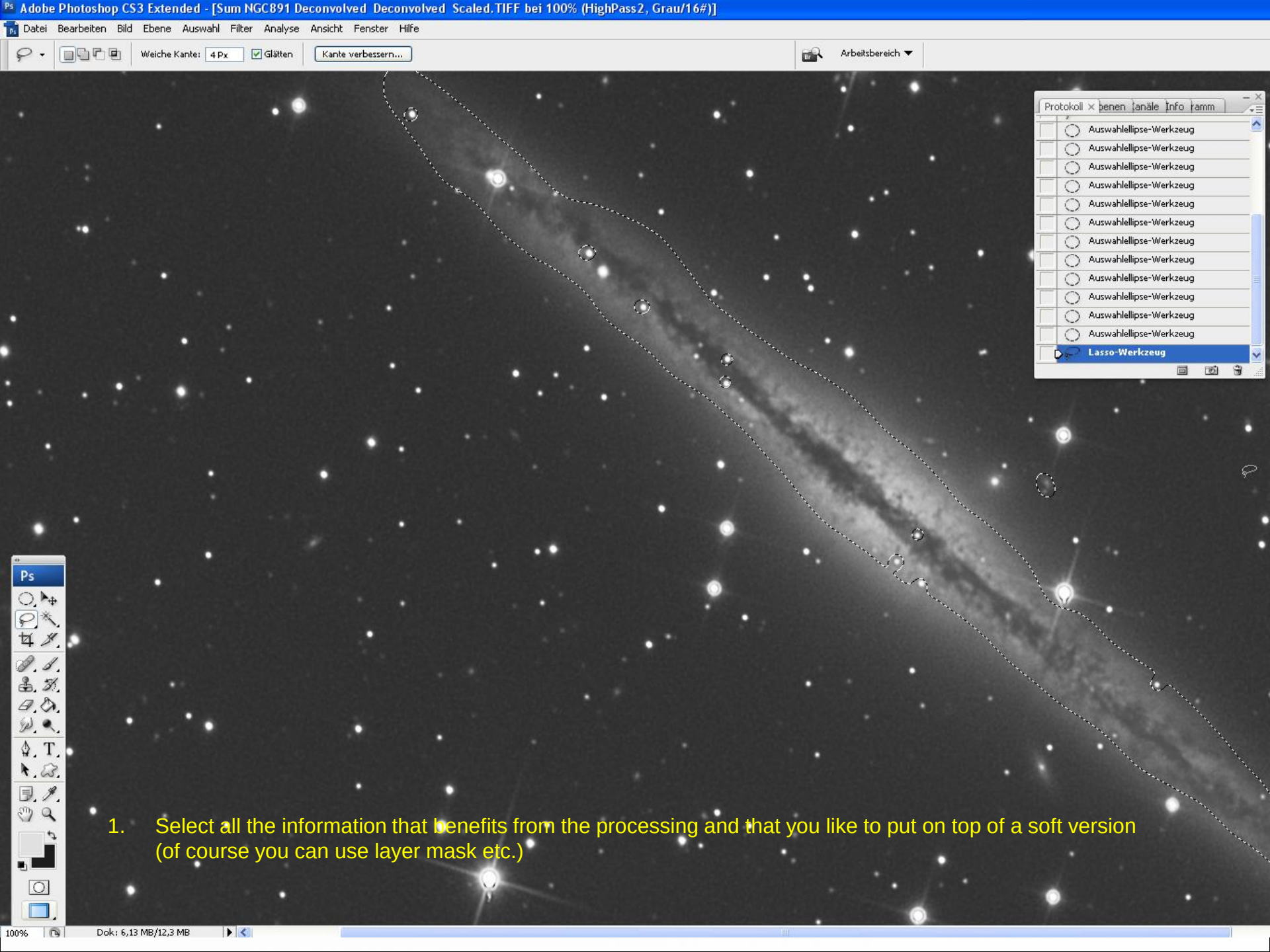


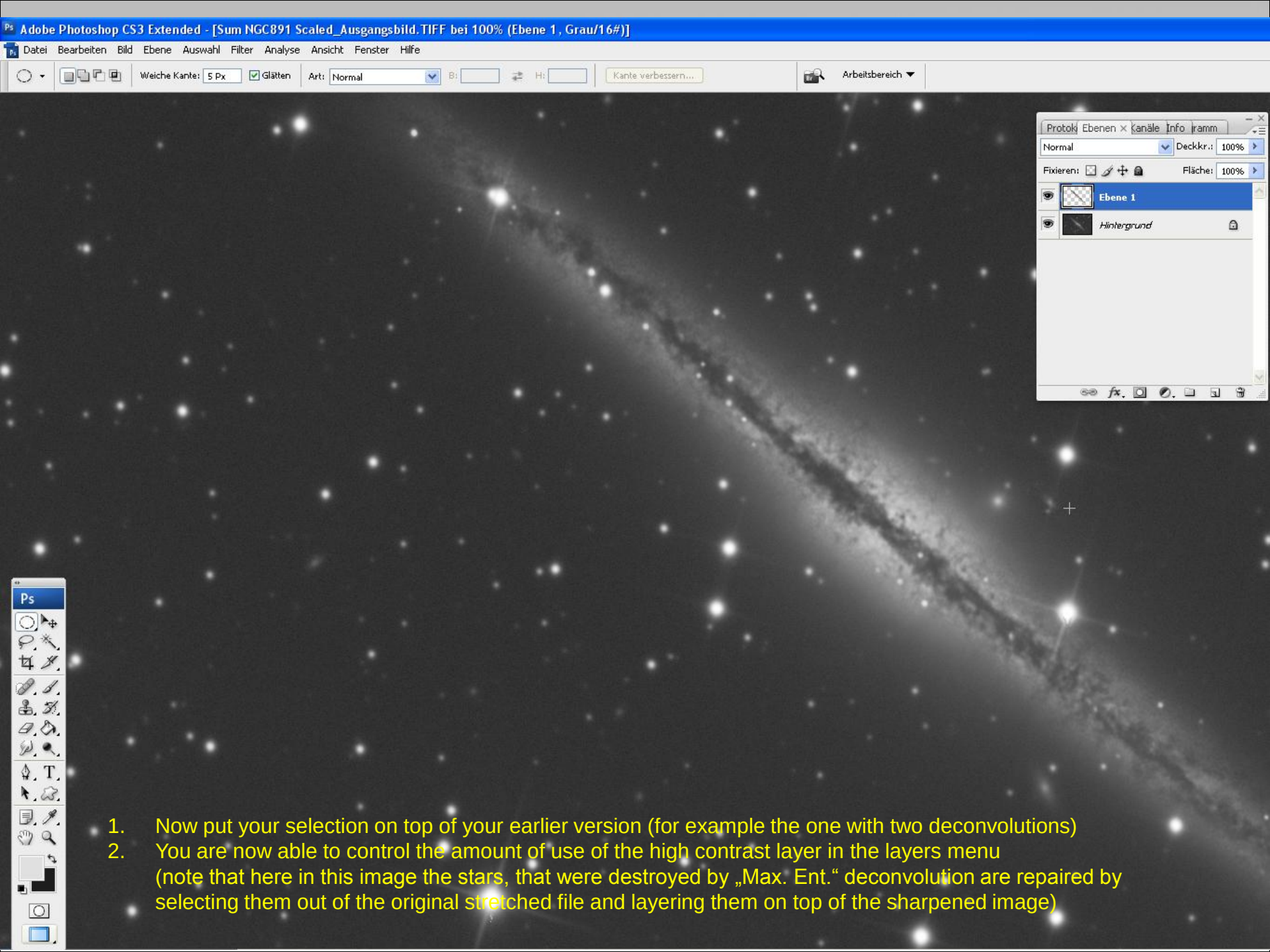
1. Use a High Pass filter with a small radius (e.g. 2-4) to boost the contrast in smallest structures
2. Check out the preview window to see which radius in which structures results

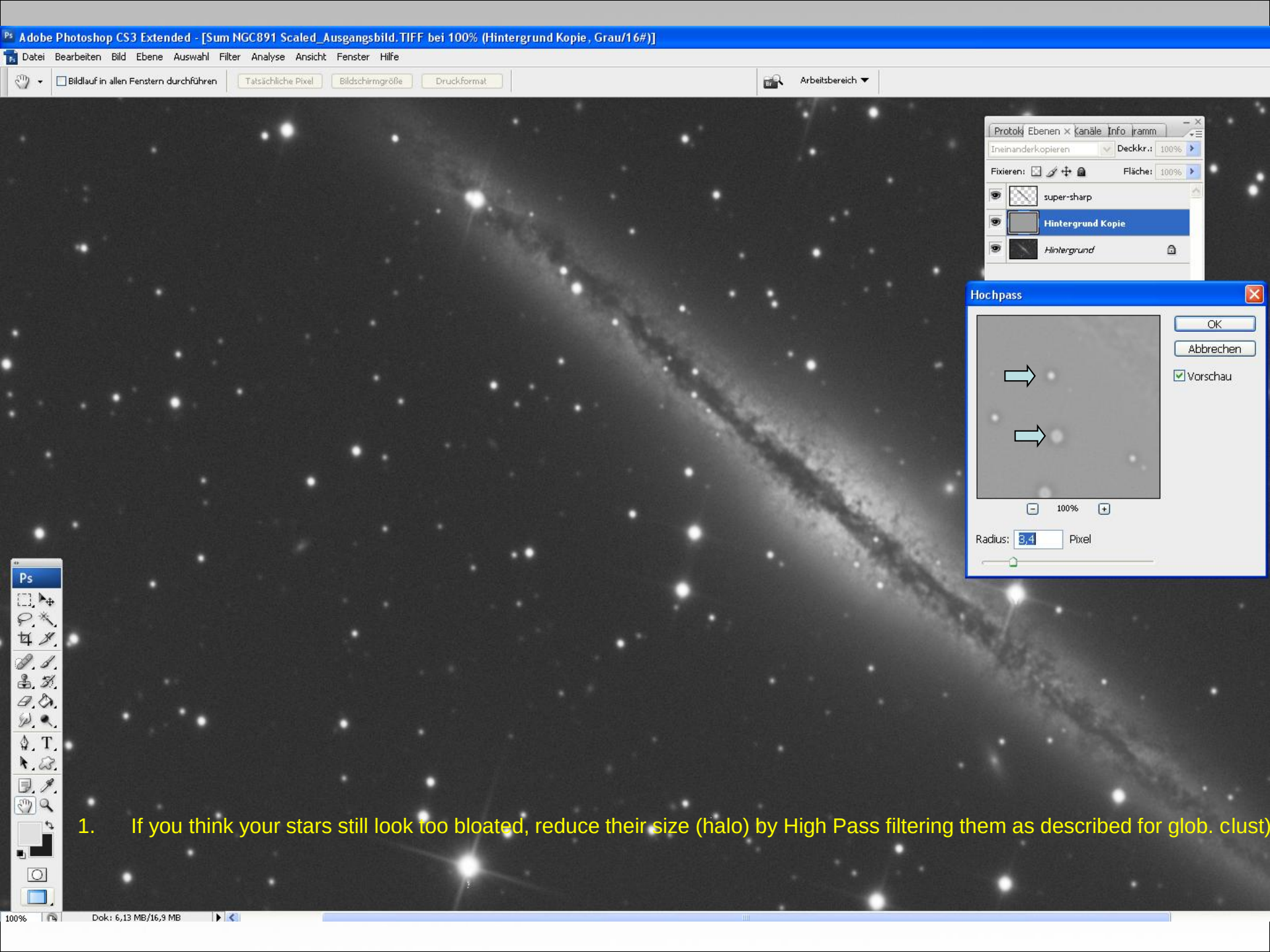
High Pass filtering (2)



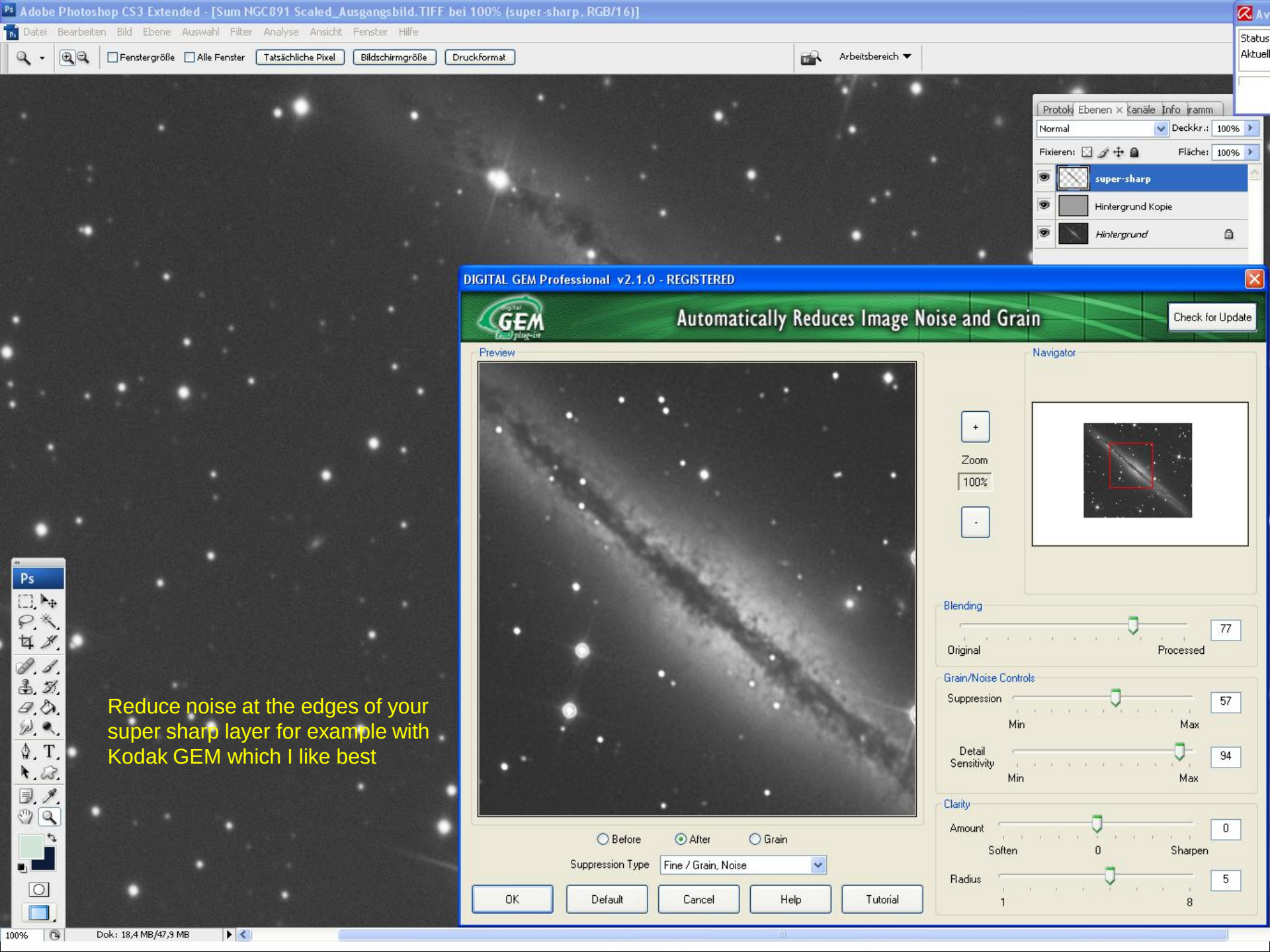
1. Now use the High Pass filter a second time with a larger radius (you now have the chance to get contrast for medium sized structures and for the structures you brought out in the first step)


Adobe Photoshop CS3 Extended - [Sum NGC891 Deconvolved Deconvolved Scaled.TIFF bei 100% (HighPass2, Grau/16#)]
Datei Bearbeiten Bild Ebene Auswahl Filter Analyse Ansicht Fenster Hilfe
Weiche Kante: 4 Px
Glätten
Kante verbessern...
Arbeitsbereich
Protokoll
Auswahlellipse-Werkzeug
Lasso-Werkzeug
Dok: 6,13 MB/12,3 MB
1. Select all the information that benefits from the processing and that you like to put on top of a soft version (of course you can use layer mask etc.)

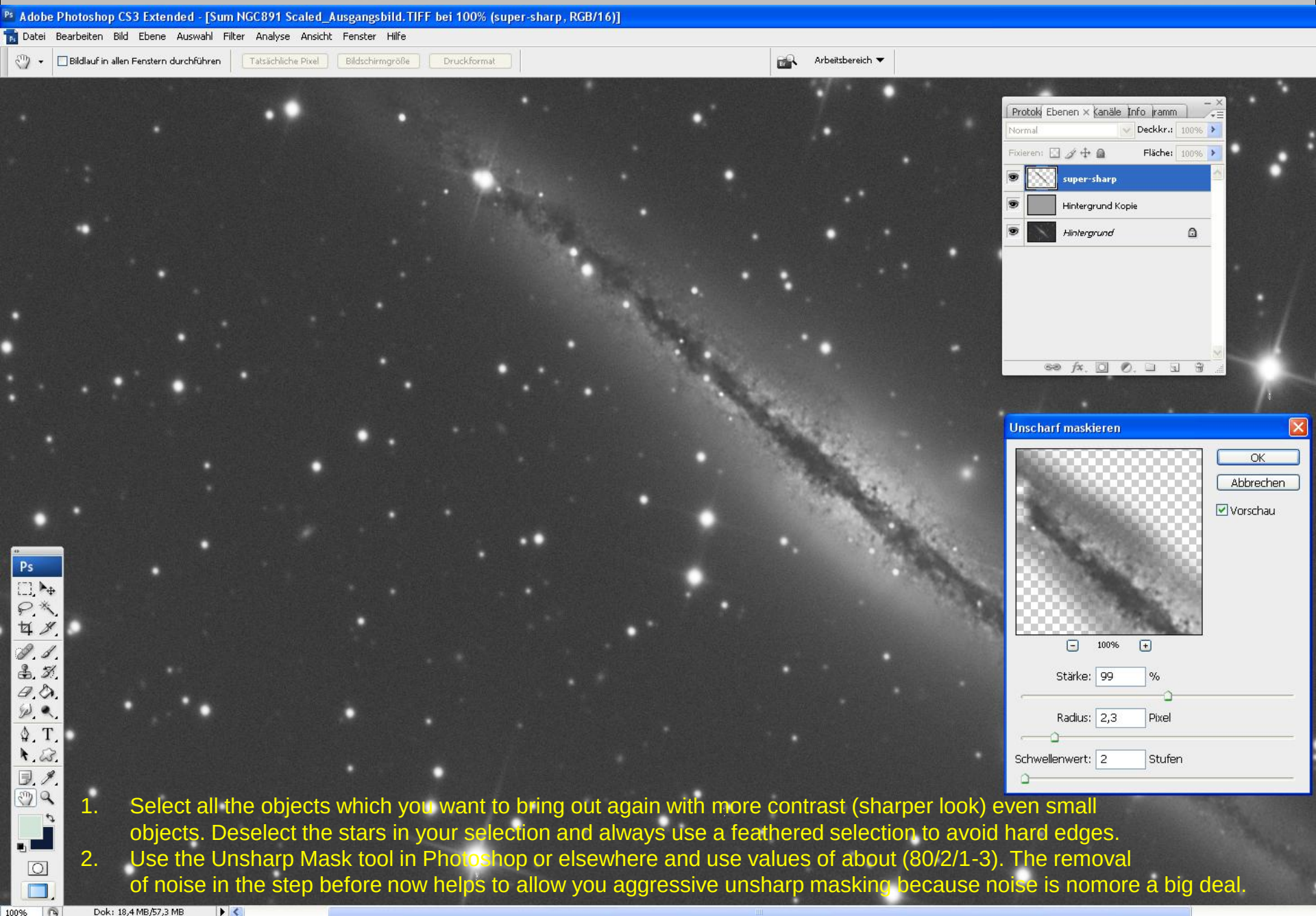

Adobe Photoshop CS3 Extended - [Sum NGC891 Scaled_Ausgangsbild.TIFF bei 100% (Ebene 1, Grau/16#)]
Datei Bearbeiten Bild Ebene Auswahl Filter Analyse Ansicht Fenster Hilfe
Weiche Kante: 5 Px
Glätten
Art: Normal
Kante verbessern...
Arbeitsbereich
Protok Ebenen Kanäle Info Iramm
Normal
Deckkr.: 100%
Fixieren:
Fläche: 100%
Ebene 1
Hintergrund
1. Now put your selection on top of your earlier version (for example the one with two deconvolutions)
2. You are now able to control the amount of use of the high contrast layer in the layers menu
(note that here in this image the stars, that were destroyed by „Max. Ent.“ deconvolution are repaired by selecting them out of the original stretched file and layering them on top of the sharpened image)



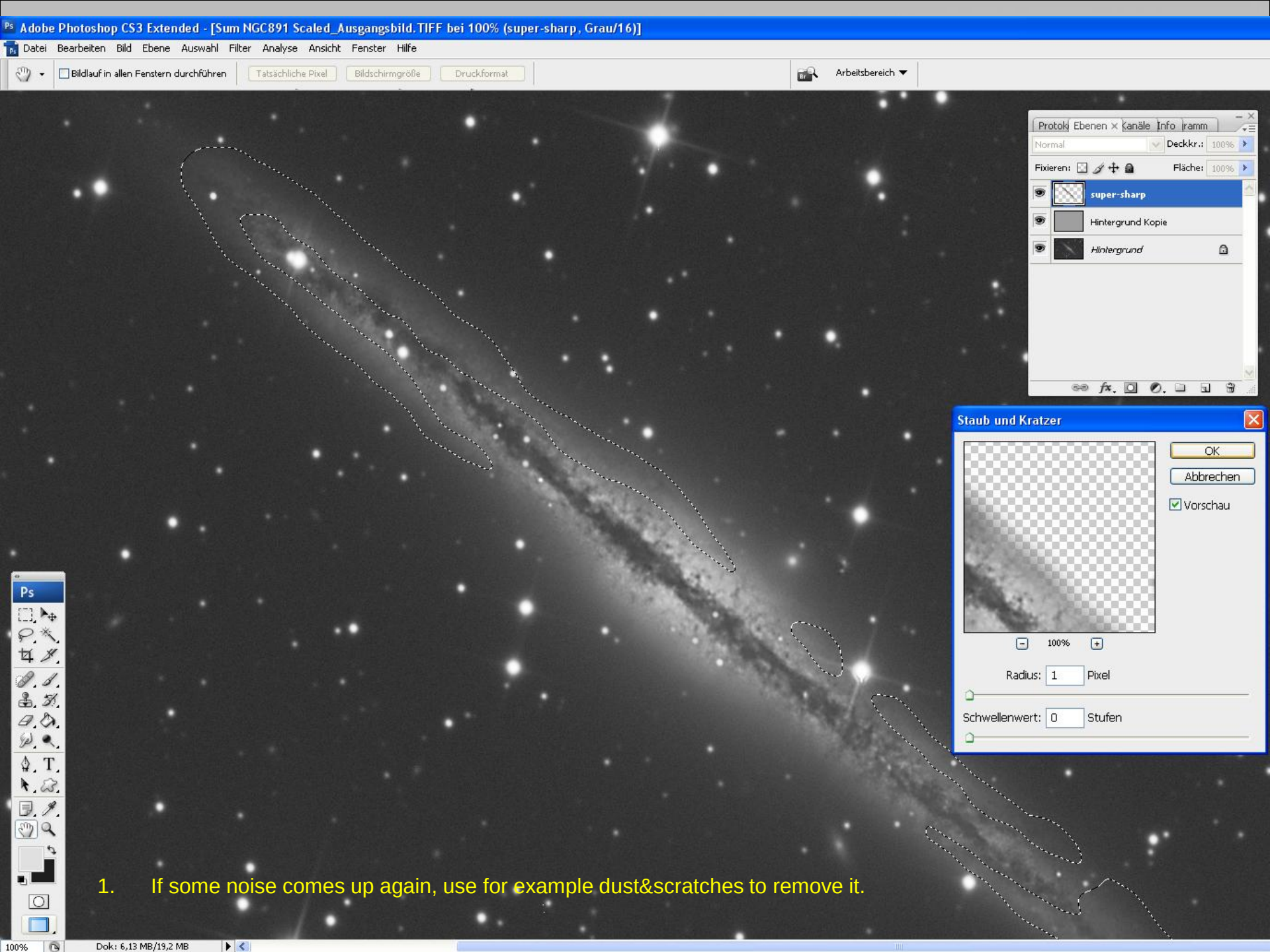
1. If you think your stars still look too bloated, reduce their size (halo) by High Pass filtering them as described for glob. clust)


Adobe Photoshop CS3 Extended - [Sum NGC891 Scaled_Ausgangsbild.TIFF bei 100% (super-sharp, RGB/16)]
Datei Bearbeiten Bild Ebene Auswahl Filter Analyse Ansicht Fenster Hilfe
Fenstergröße
Alle Fenster
Tatsächliche Pixel
Bildschirmgröße
Druckformat
Arbeitsbereich
Protok Ebenen Kanäle Info
Normal
Deckkr.: 100%
Fixieren:
Fläche: 100%
super-sharp
Hintergrund Kopie
Hintergrund
DIGITAL GEM Professional v2.1.0 - REGISTERED
Automatically Reduces Image Noise and Grain
Check for Update
Preview
Navigator
Zoom
100%
Blending
77
Original
Processed
Grain/Noise Controls
Suppression
57
Min
Max
Detail Sensitivity
94
Min
Max
Clarity
Amount
0
Soften
0
Sharpen
Radius
5
1
8
Before
After
Grain
Suppression Type
Fine / Grain, Noise
OK
Default
Cancel
Help
Tutorial
Reduce noise at the edges of your super sharp layer for example with Kodak GEM which I like best
100%
Dok: 18,4 MB/47,9 MB

Unsharp masking



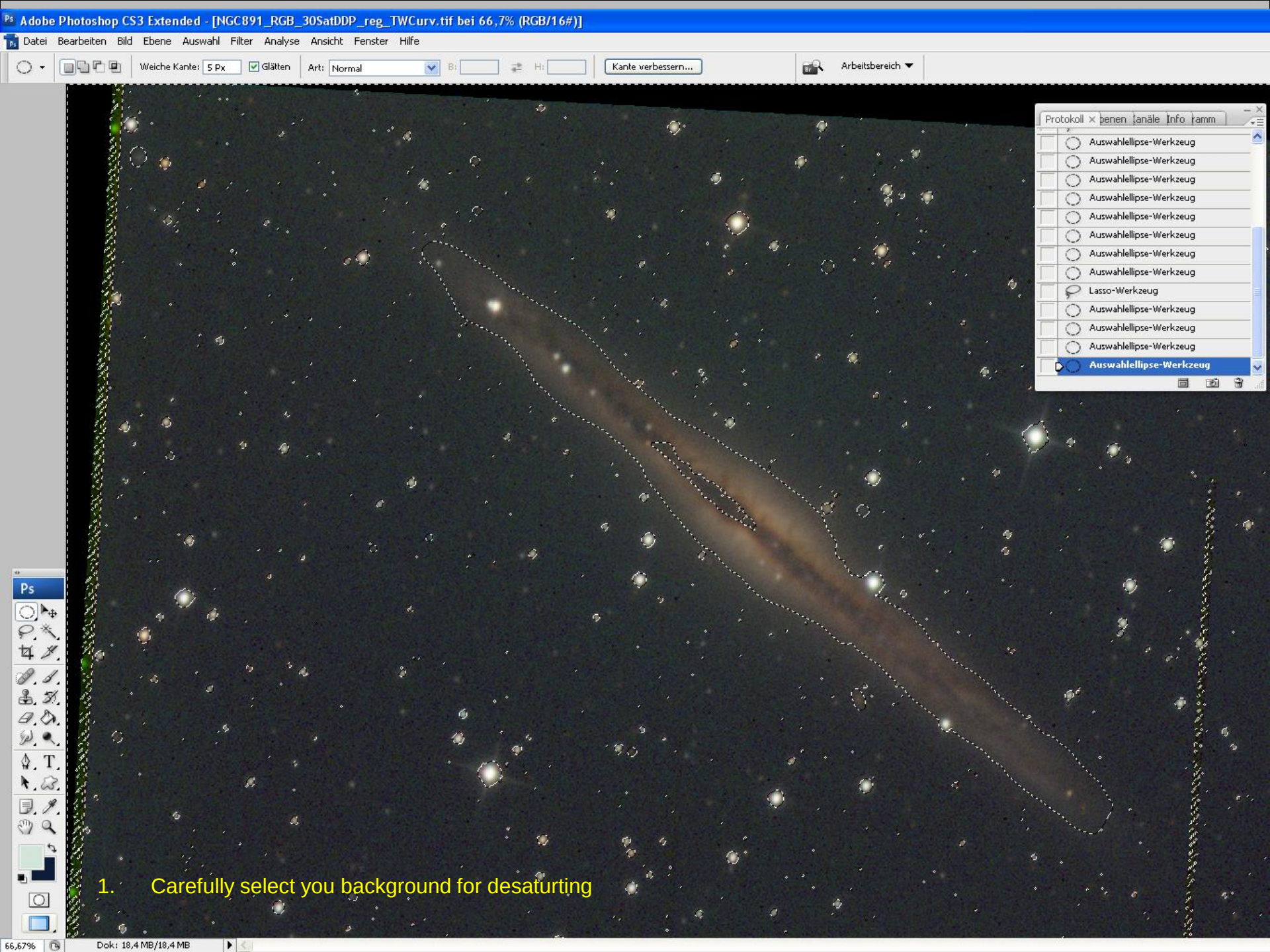
1. Select all the objects which you want to bring out again with more contrast (sharper look) even small objects. Deselect the stars in your selection and always use a feathered selection to avoid hard edges.
2. Use the Unsharp Mask tool in Photoshop or elsewhere and use values of about (80/2/1-3). The removal of noise in the step before now helps to allow you aggressive unsharp masking because noise is nomore a big deal.

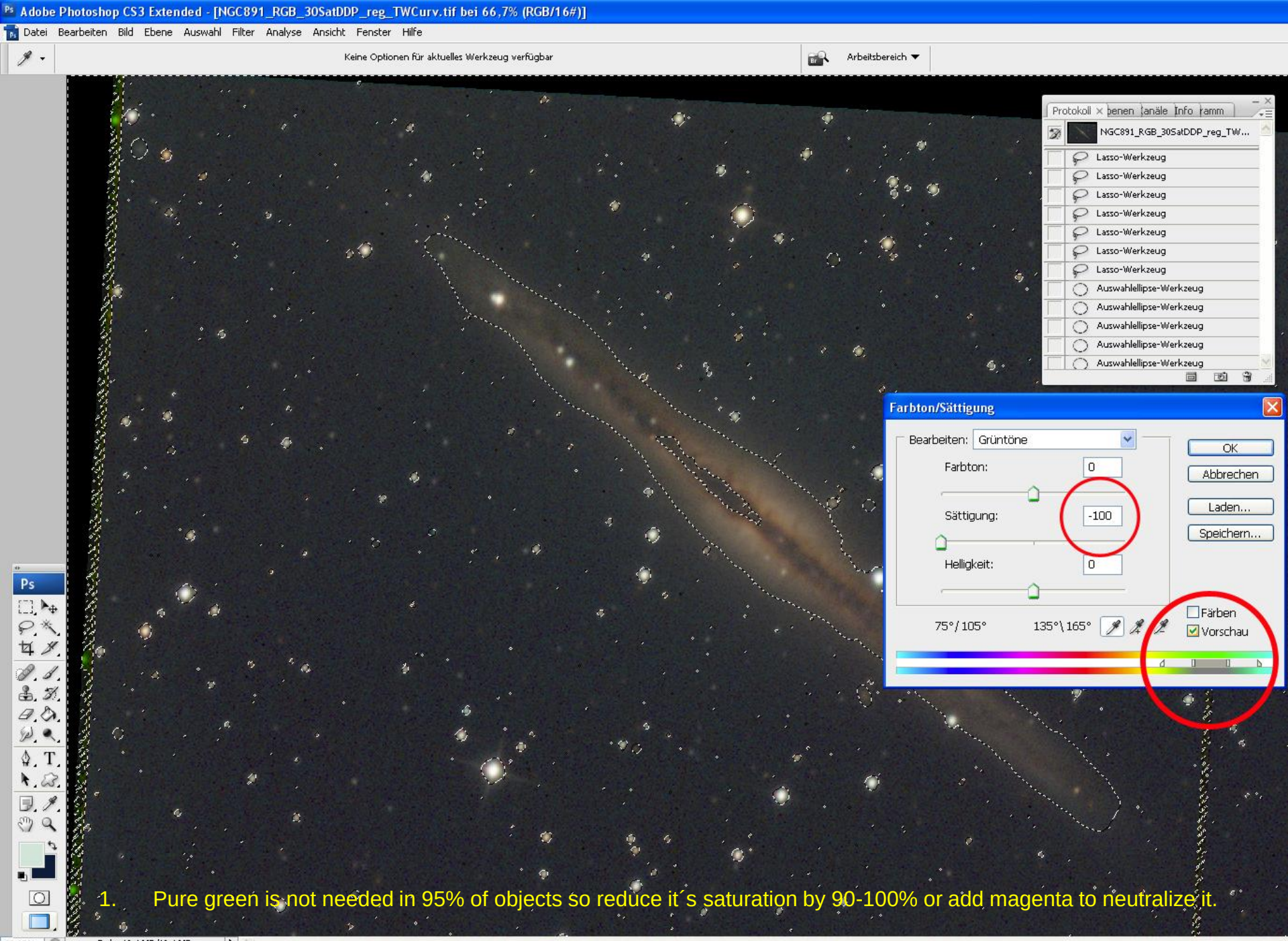


1. If some noise comes up again, use for example dust&scratches to remove it.

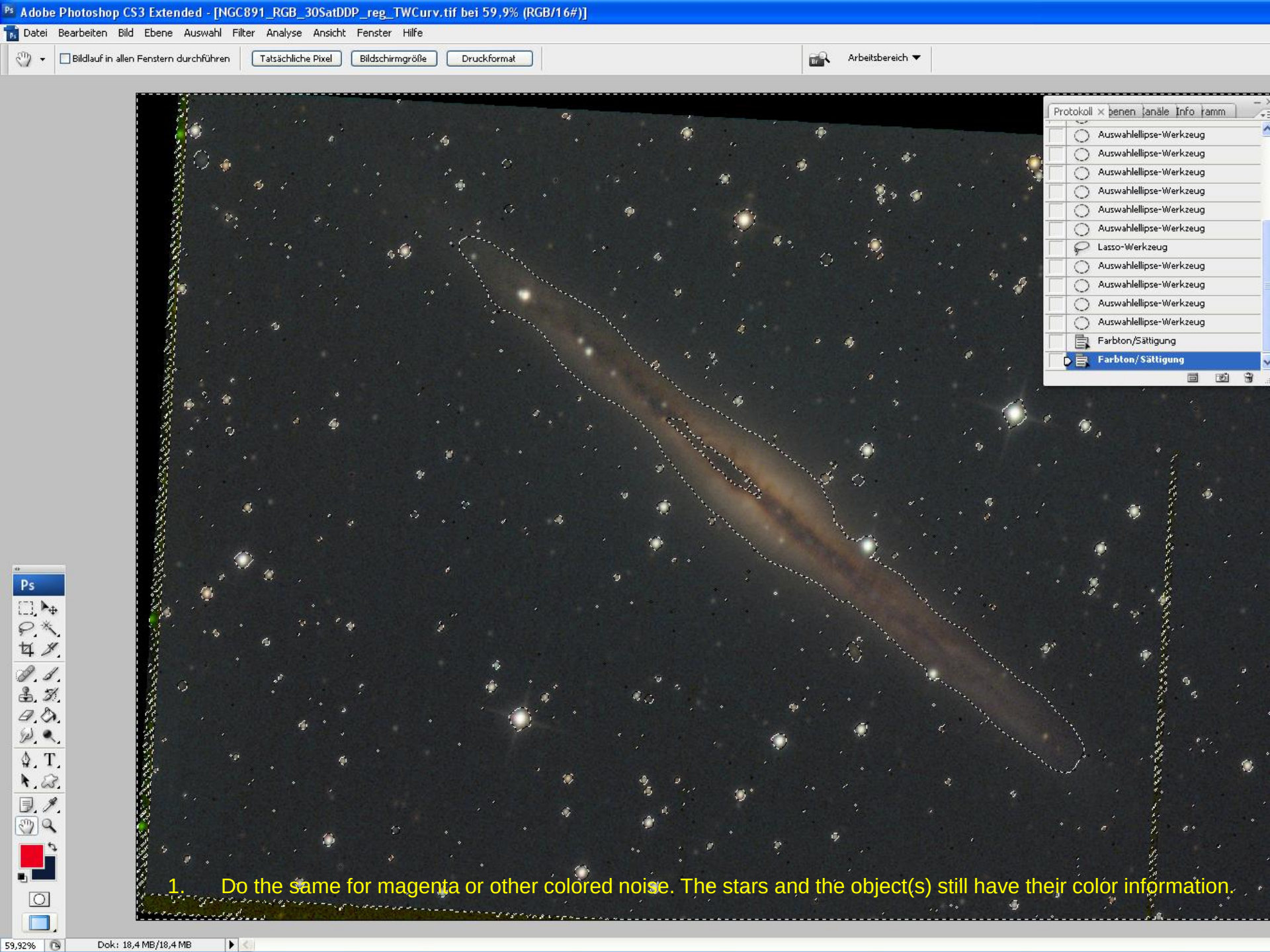
NGC 891 compare raw and processed Luminance

Working on color files made under urban conditions

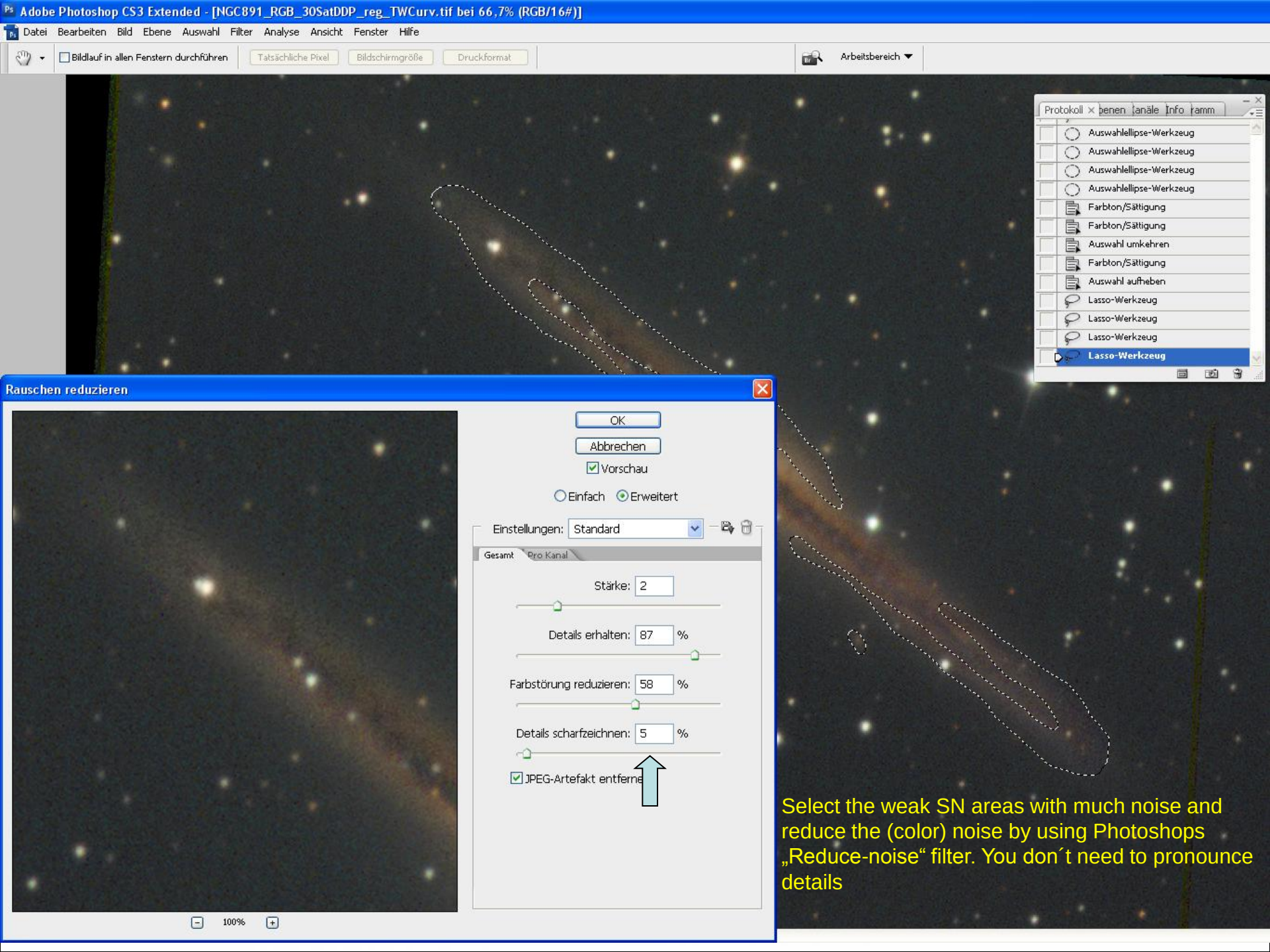

Adobe Photoshop CS3 Extended - [NGC891_RGB_30SatDDP_reg_TWCurv.tif bei 66,7% (RGB/16#)]
Datei Bearbeiten Bild Ebene Auswahl Filter Analyse Ansicht Fenster Hilfe
Weiche Kante: 5 Px
Glätten
Art: Normal
Kante verbessern...
Arbeitsbereich
Protokoll
Auswahlellipse-Werkzeug
Lasso-Werkzeug
Auswahlellipse-Werkzeug
1. Carefully select you background for desaturting
66,67%
Dok: 18,4 MB/18,4 MB

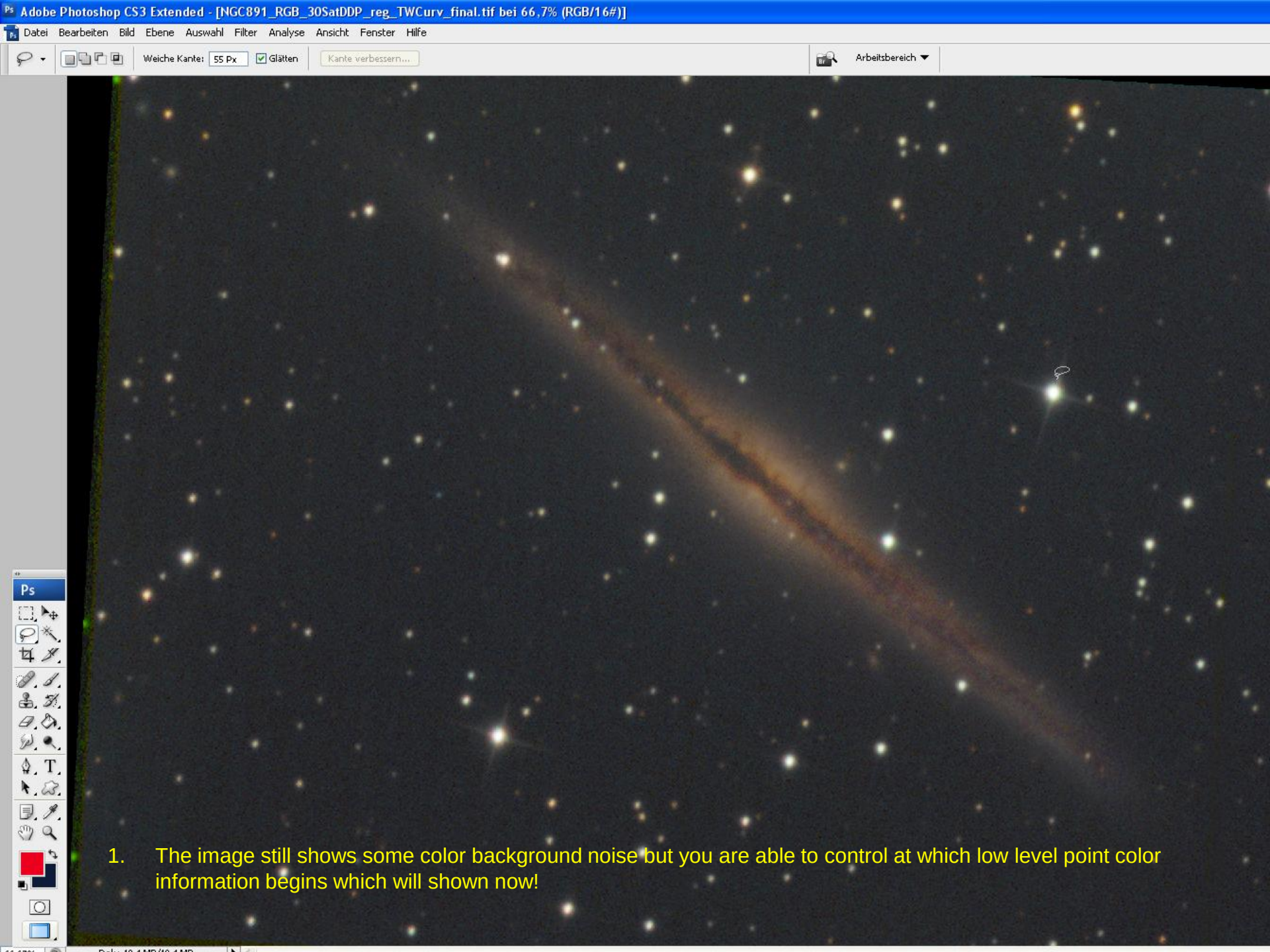


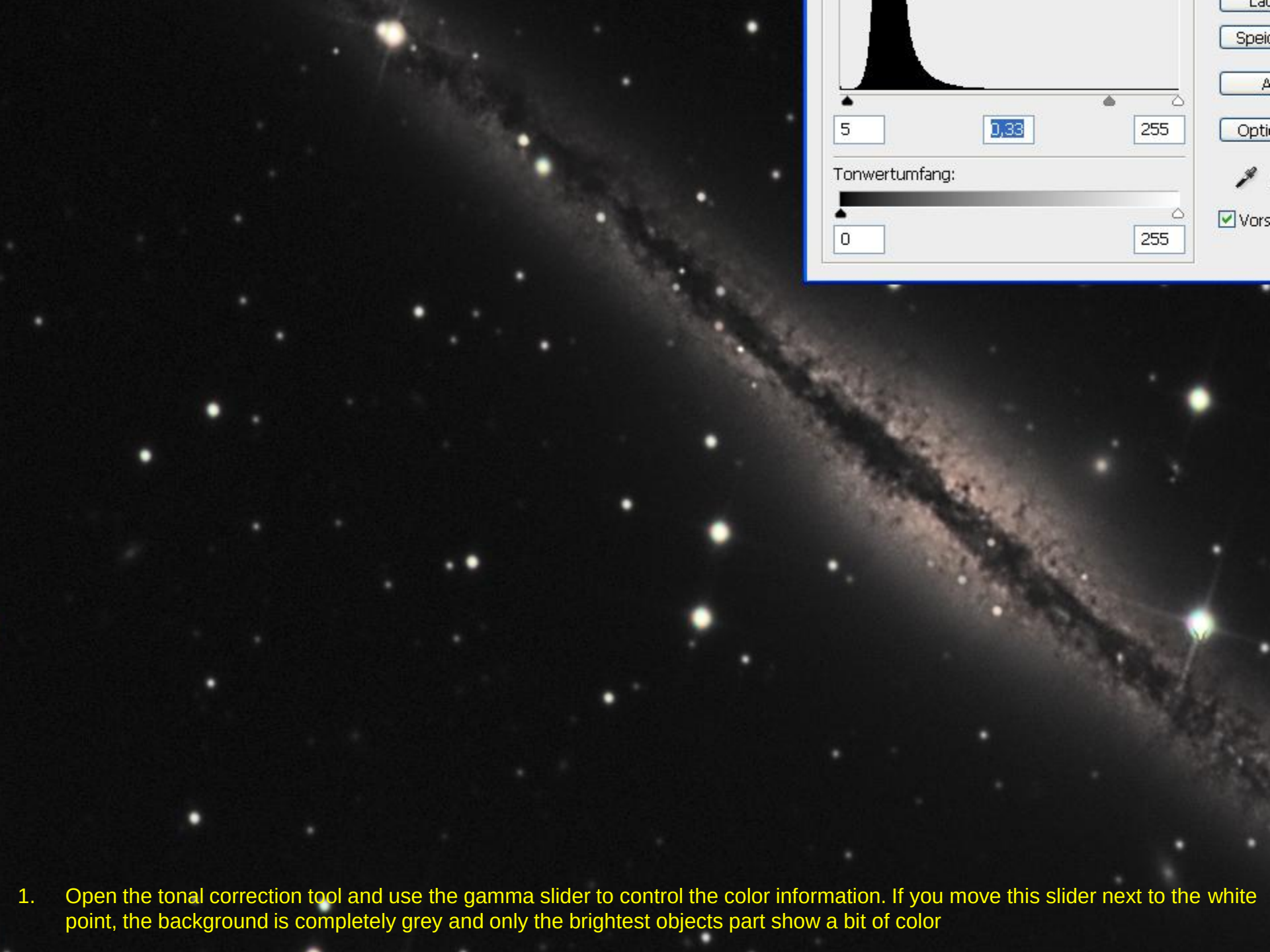
1. Pure green is not needed in 95% of objects so reduce it´s saturation by 90-100% or add magenta to neutralize it.



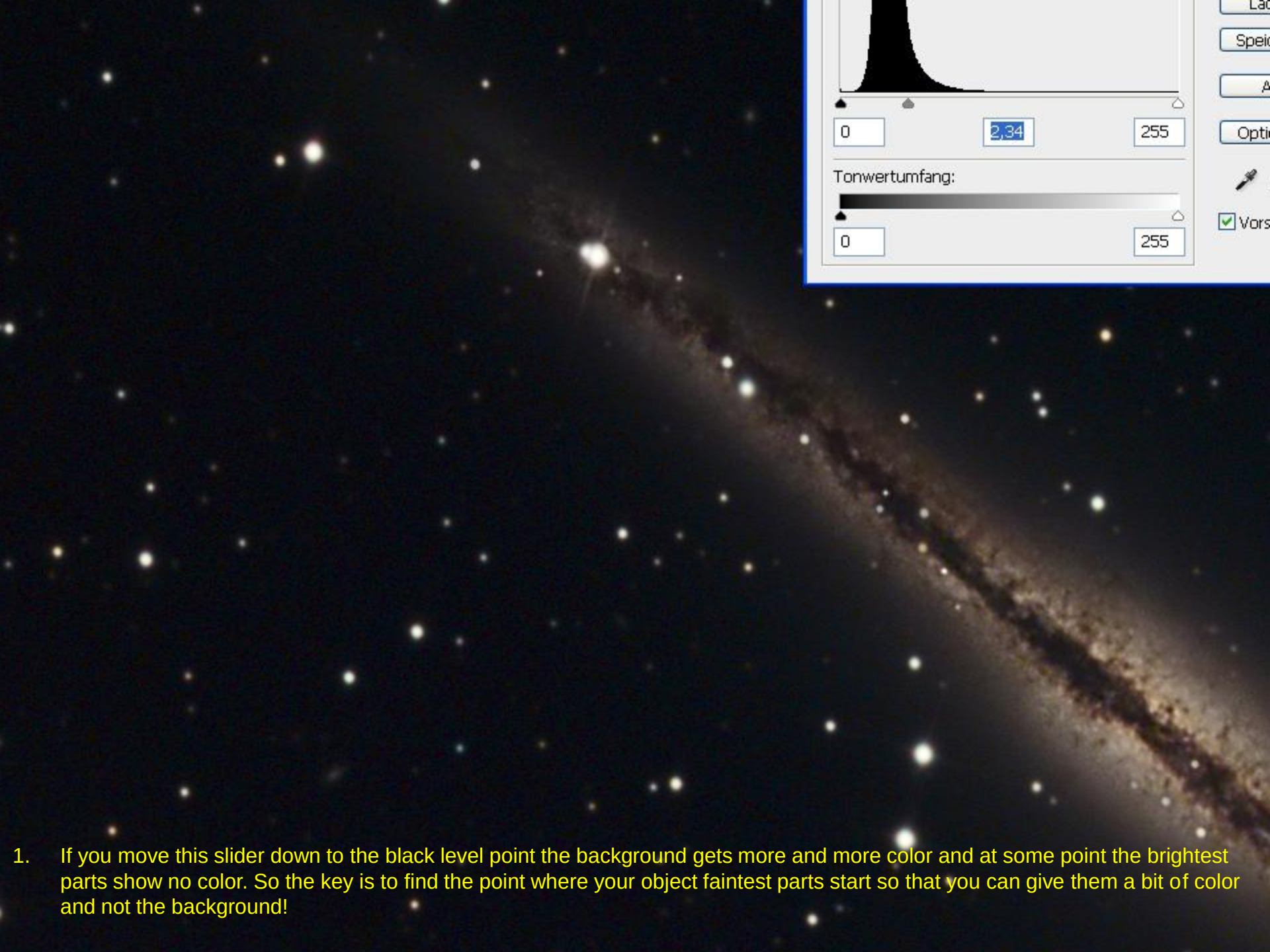
1. Do the same for magenta or other colored noise. The stars and the object(s) still have their color information.


Adobe Photoshop CS3 Extended - [NGC891_RGB_30SatDDP_reg_TWCurv.tif bei 66,7% (RGB/16#)]
Datei Bearbeiten Bild Ebene Auswahl Filter Analyse Ansicht Fenster Hilfe
Bildlauf in allen Fenstern durchführen
Tatsächliche Pixel
Bildschirmgröße
Druckformat
Arbeitsbereich
Protokoll
Auswahlellipse-Werkzeug
Auswahlellipse-Werkzeug
Auswahlellipse-Werkzeug
Auswahlellipse-Werkzeug
Farbton/Sättigung
Farbton/Sättigung
Auswahl umkehren
Farbton/Sättigung
Auswahl aufheben
Lasso-Werkzeug
Lasso-Werkzeug
Lasso-Werkzeug
Lasso-Werkzeug
Rauschen reduzieren
OK
Abbrechen
Vorschau
Einfach
Erweitert
Einstellungen: Standard
Gesamt
Pro Kanal
Stärke: 2
Details erhalten: 87 %
Farbstörung reduzieren: 58 %
Details scharfzeichnen: 5 %
JPEG-Artefakt entferne
100%
Select the weak SN areas with much noise and reduce the (color) noise by using Photoshops „Reduce-noise“ filter. You don´t need to pronounce details


Adobe Photoshop CS3 Extended - [NGC891_RGB_30SatDDP_reg_TWCurv_final.tif bei 66,7% (RGB/16#)]
Datei Bearbeiten Bild Ebene Auswahl Filter Analyse Ansicht Fenster Hilfe
Weiche Kante: 55 Px
Glätten
Kante verbessern...
Arbeitsbereich
1. The image still shows some color background noise but you are able to control at which low level point color information begins which will shown now!



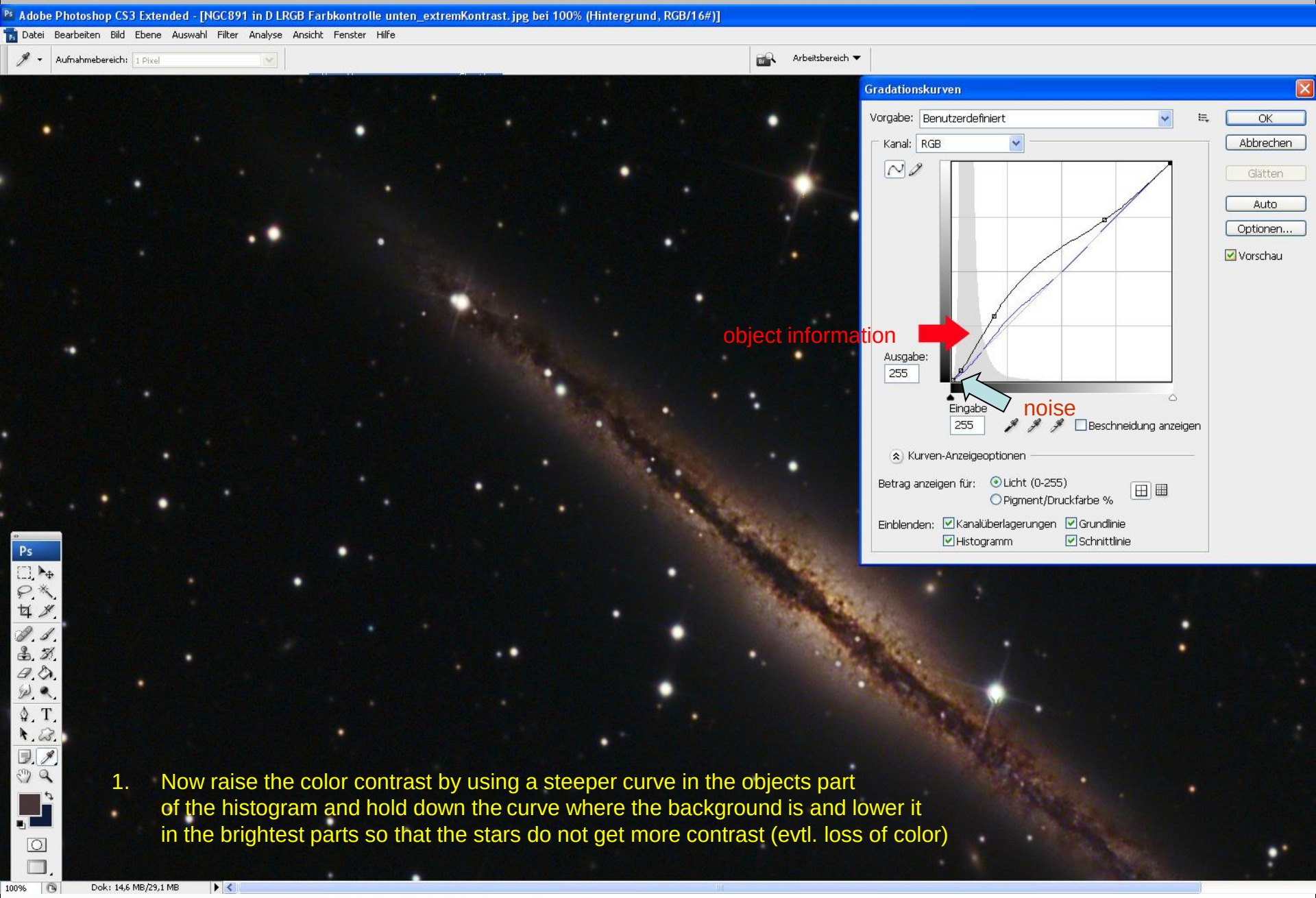
1. Open the tonal correction tool and use the gamma slider to control the color information. If you move this slider next to the white point, the background is completely grey and only the brightest objects part show a bit of color



1. If you move this slider down to the black level point the background gets more and more color and at some point the brightest parts show no color. So the key is to find the point where your object faintest parts start so that you can give them a bit of color and not the background!

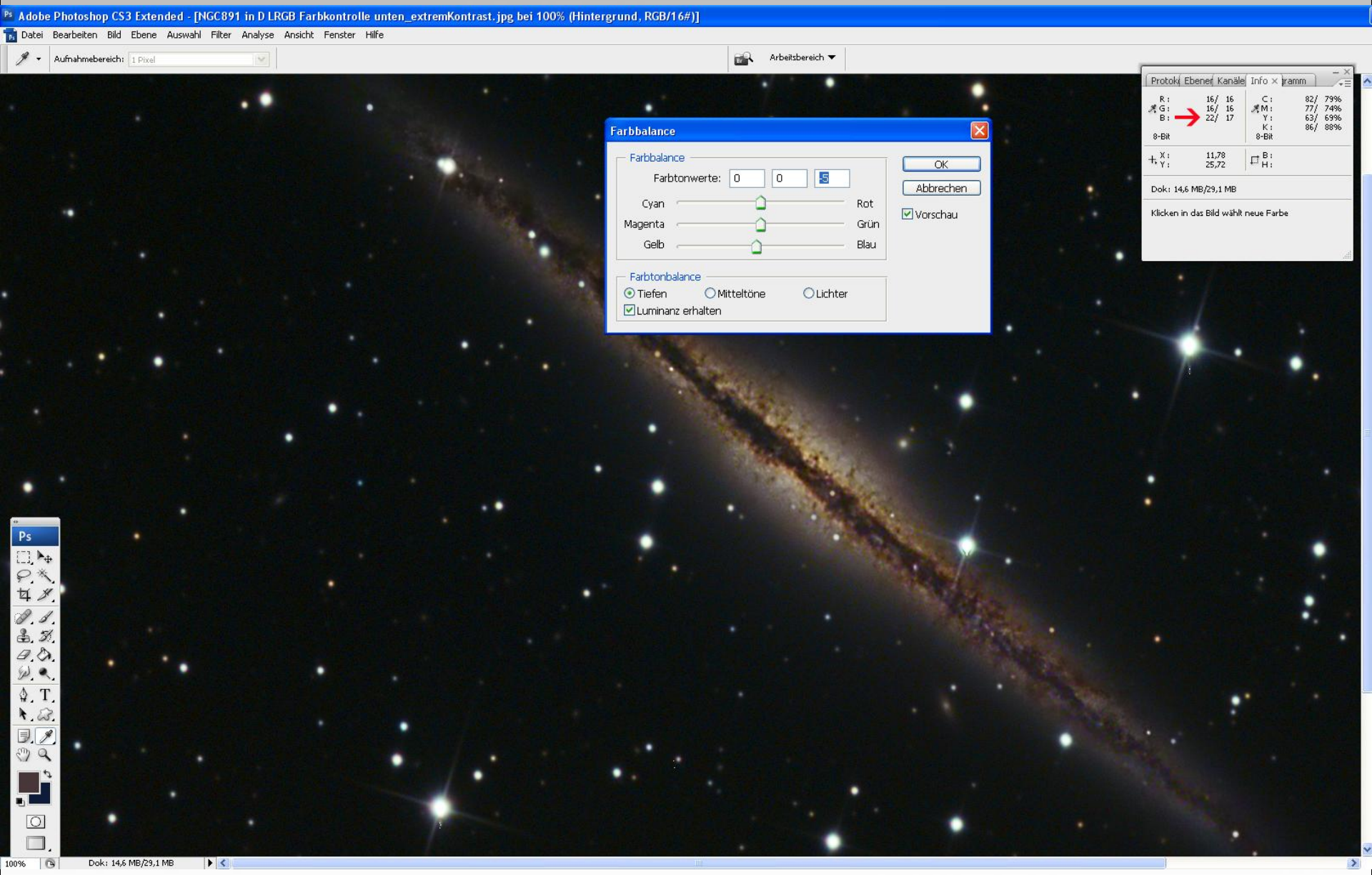
1. If you are not sure move the gamma slider, click ok and raise the contrast to an extreme point so that you can easily check out if your background got color. If that´s the case go back in your protocol and move the gamma slider more to the white point.

Color contrast boost (1)

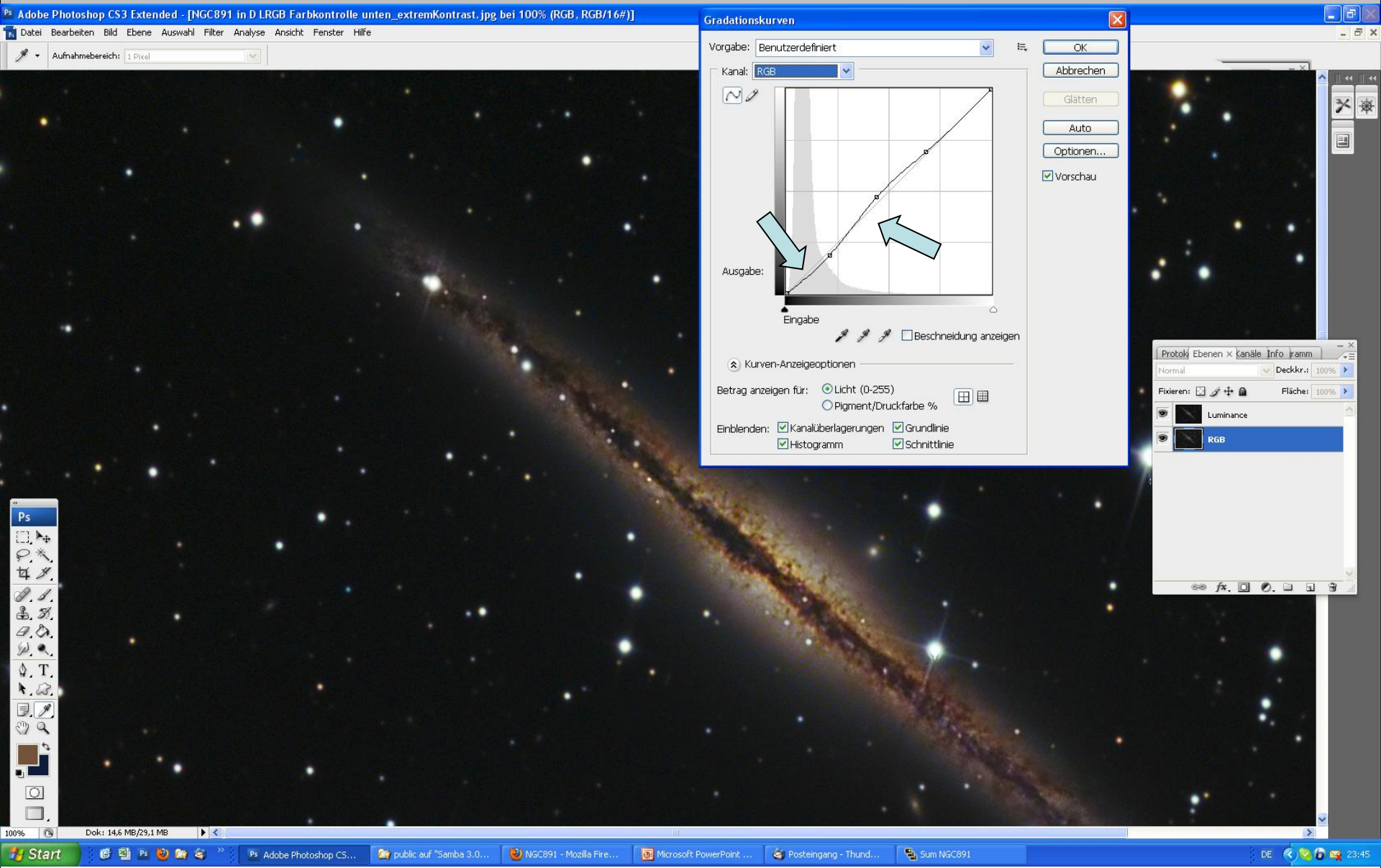


1. Now raise the color contrast by using a steeper curve in the objects part of the histogram and hold down the curve where the background is and lower it in the brightest parts so that the stars do not get more contrast (evtl. loss of color)

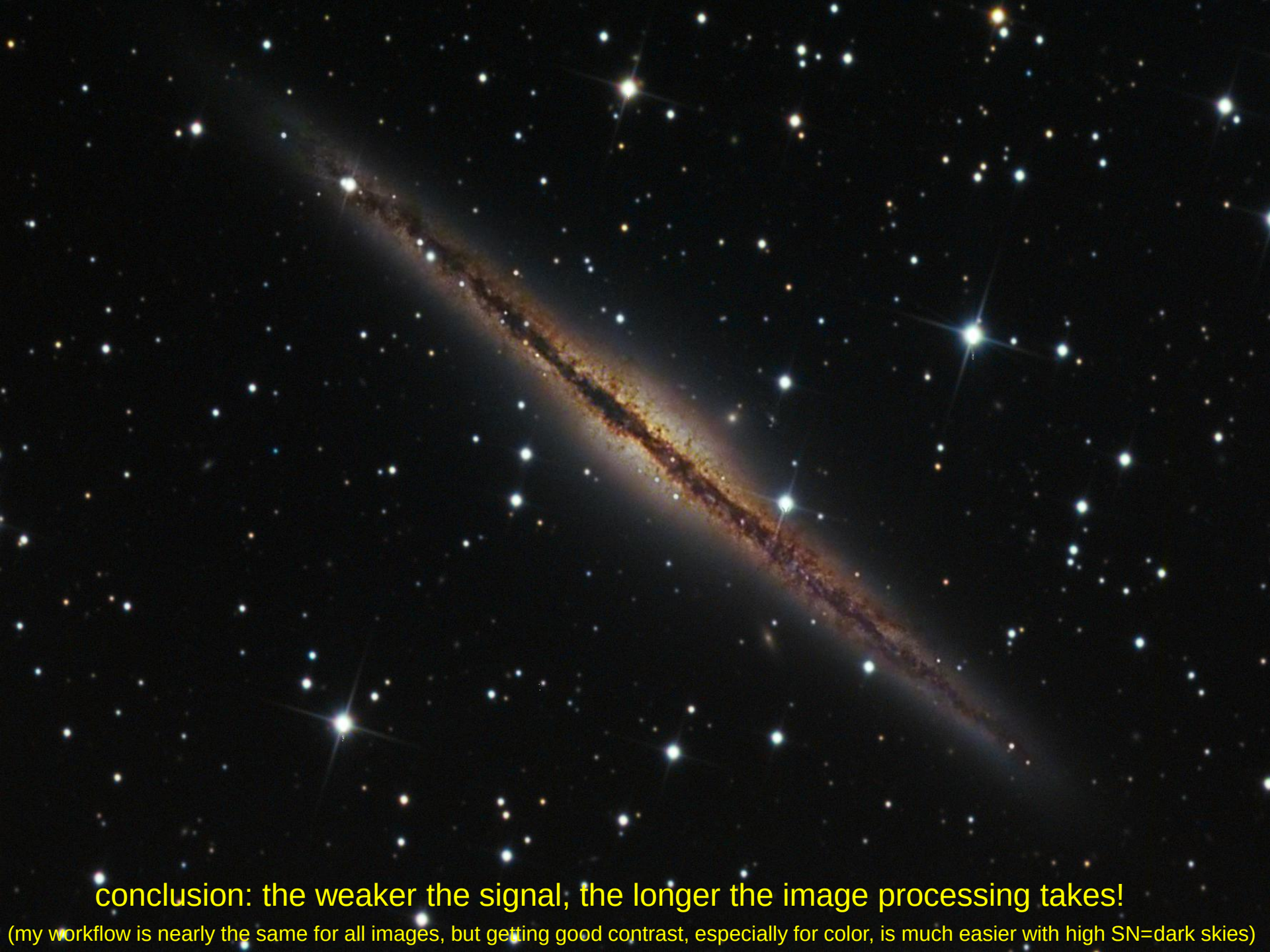
Color correction of background



Color contrast boost (2)

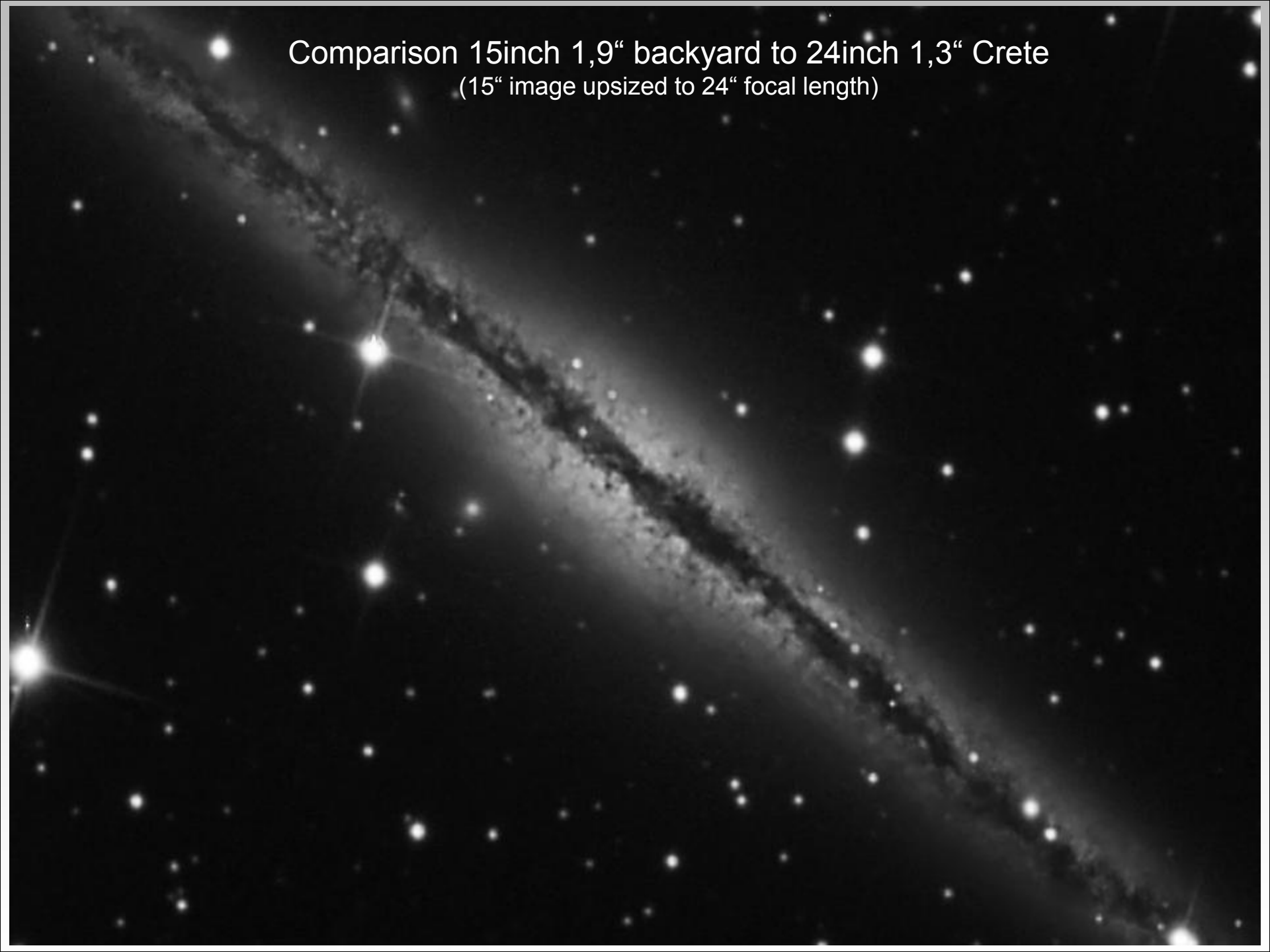


If needed, raise again the color contrast of your object in an LRGB and lower the contrast of faint or background inform. to avoid noise

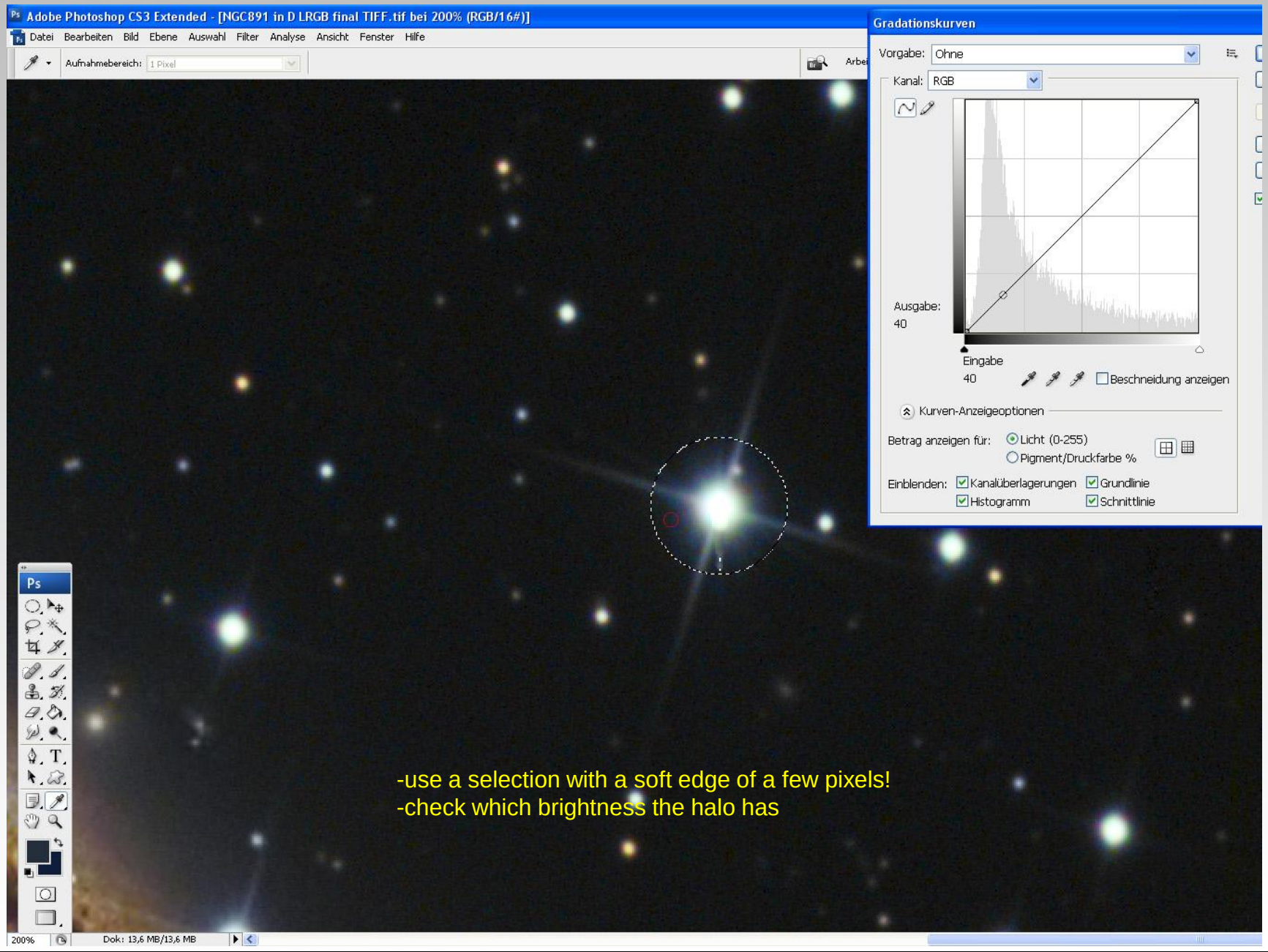


conclusion: the weaker the signal, the longer the image processing takes!

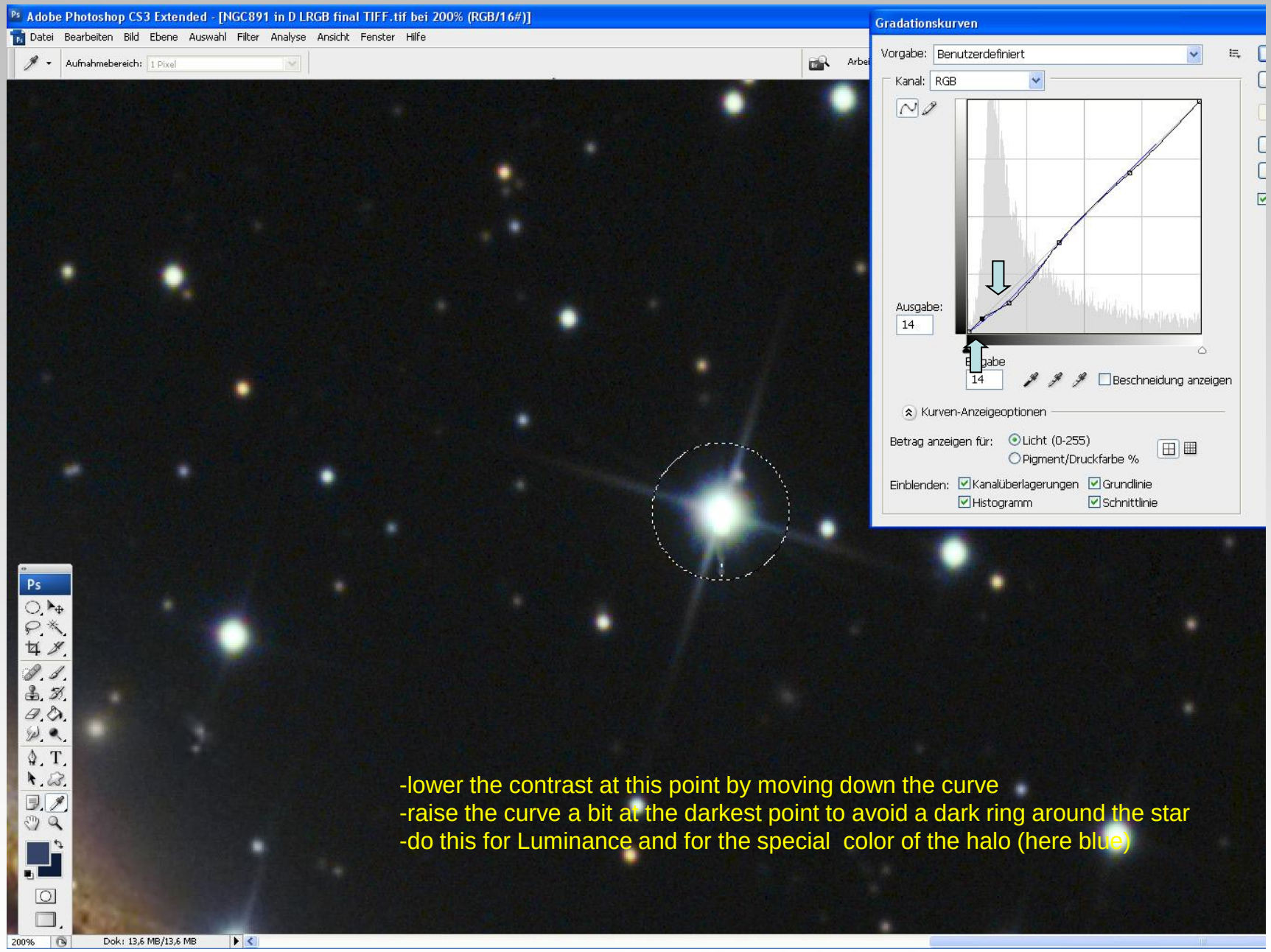
(my workflow is nearly the same for all images, but getting good contrast, especially for color, is much easier with high SN=dark skies)


Comparison 15inch 1,9“ backyard to 24inch 1,3“ Crete
(15“ image upsized to 24“ focal length)

Reduce star halos 1:



Reduce star halos 2:



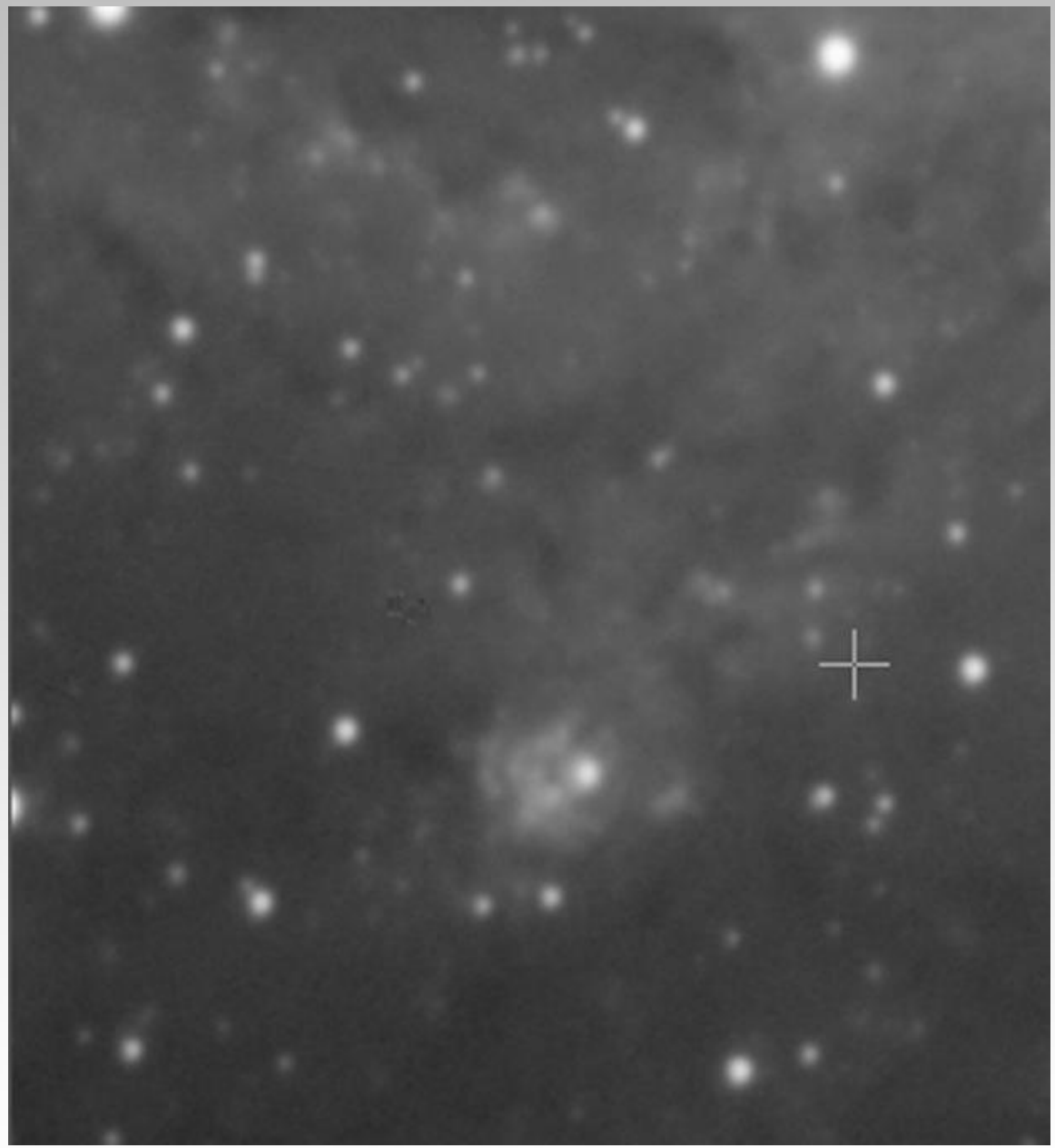
-lower the contrast at this point by moving down the curve
-raise the curve a bit at the darkest point to avoid a dark ring around the star
-do this for Luminance and for the special color of the halo (here blue)

Reduce star halos 3:

-reduce the unnatural colors by lowering the saturation of these colors (here cyan and green)
-if needed use the Curves again using a smaller selection around the star
-if needed use the radial Gauss filter
-add some noise back so that the star noise fits to the background noise
-use the minimum filter as a personal taste for a star size reduction

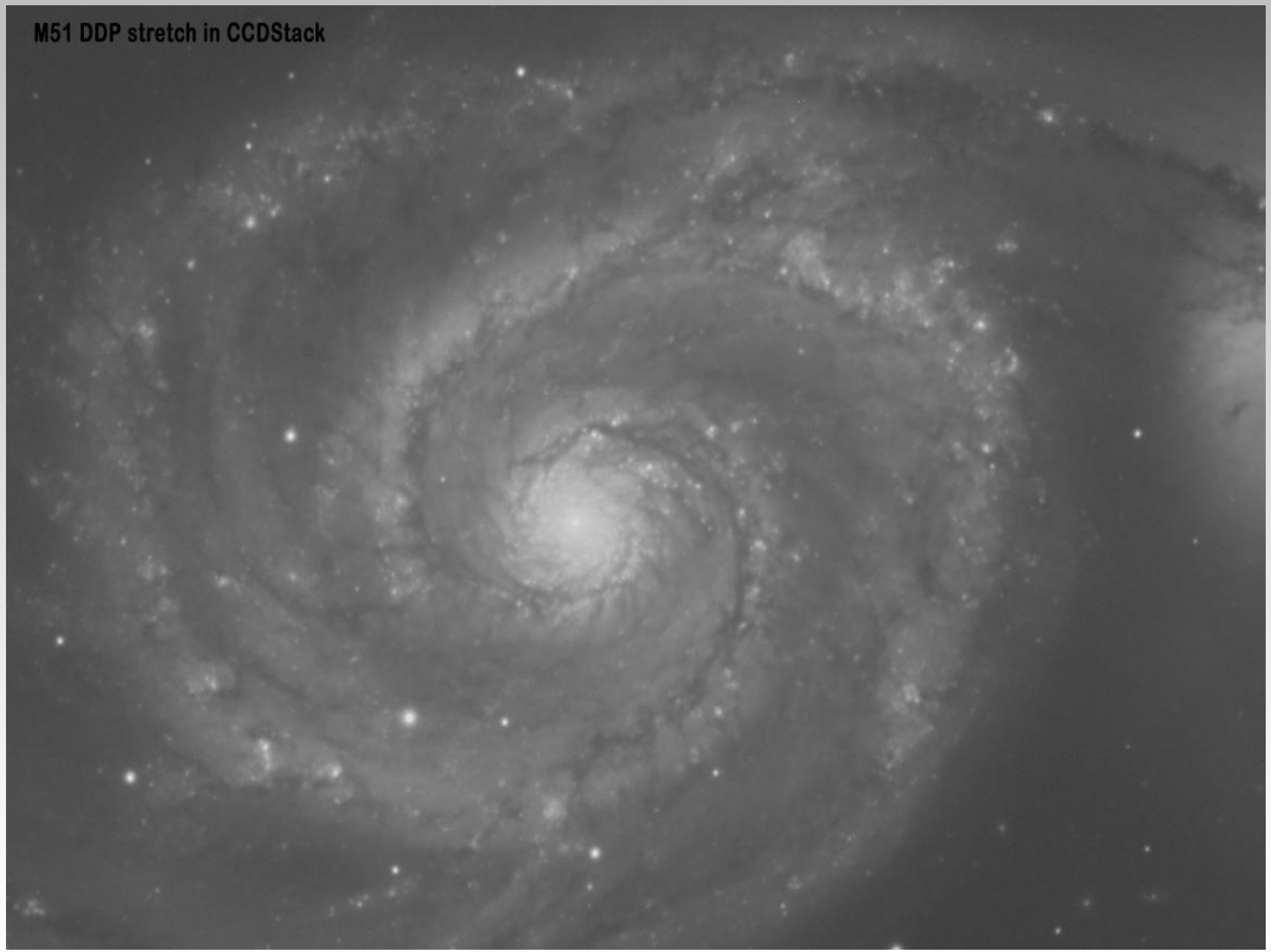
NGC6946, backyard image, 2,1“ (how to get contrast and detail):

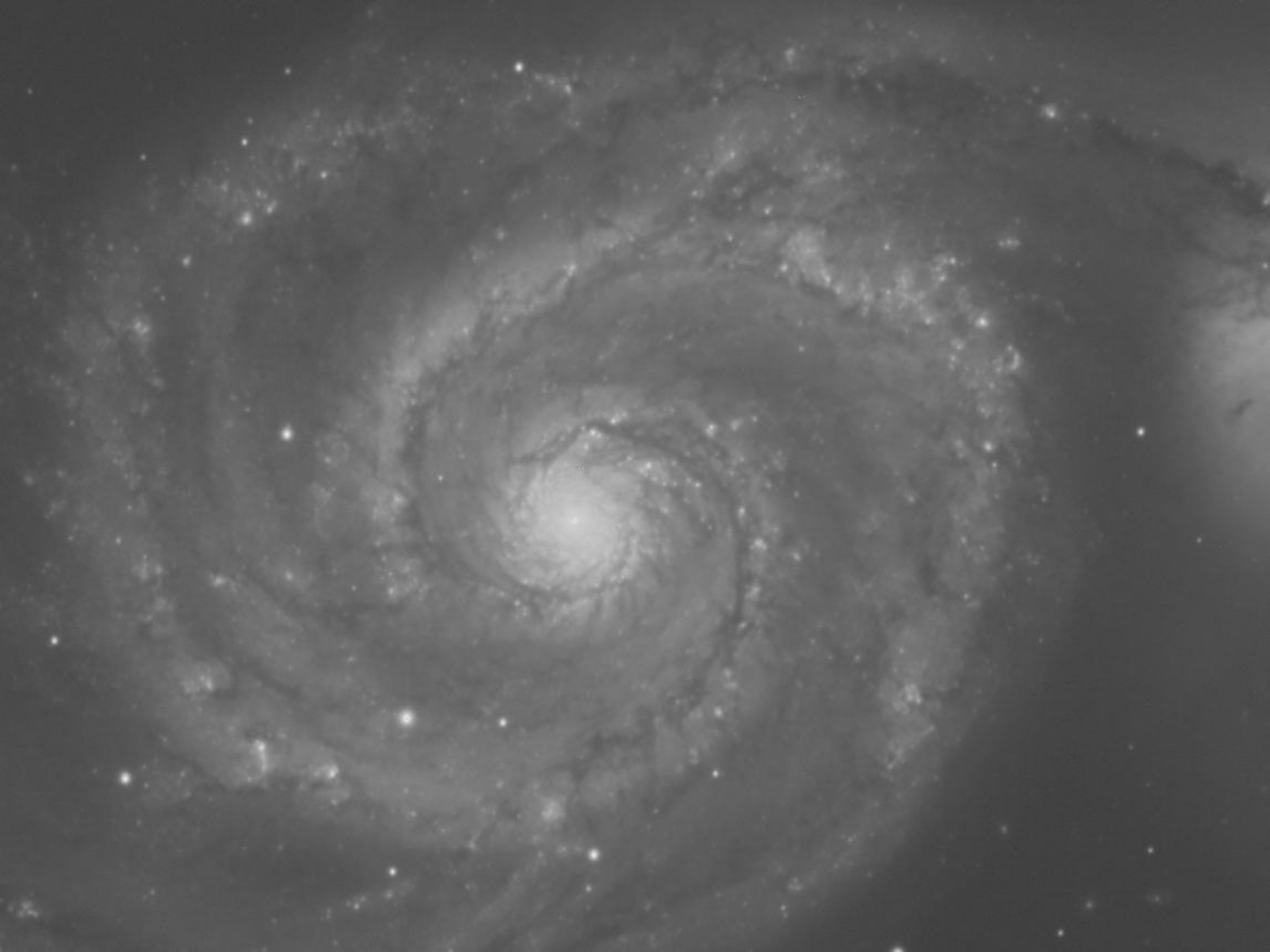
1. Stretched raw data
2. Deconvolution using PixInsight
3. High Pass filtering in Photoshop
4. Unsharp masking with small amount and a large radius
5. Kodak GEM for noise reduction



The center of M51 (how to get contrast and detail):

(the data of this image was aquired by the Capella observatory team www.capella-observatory.com)



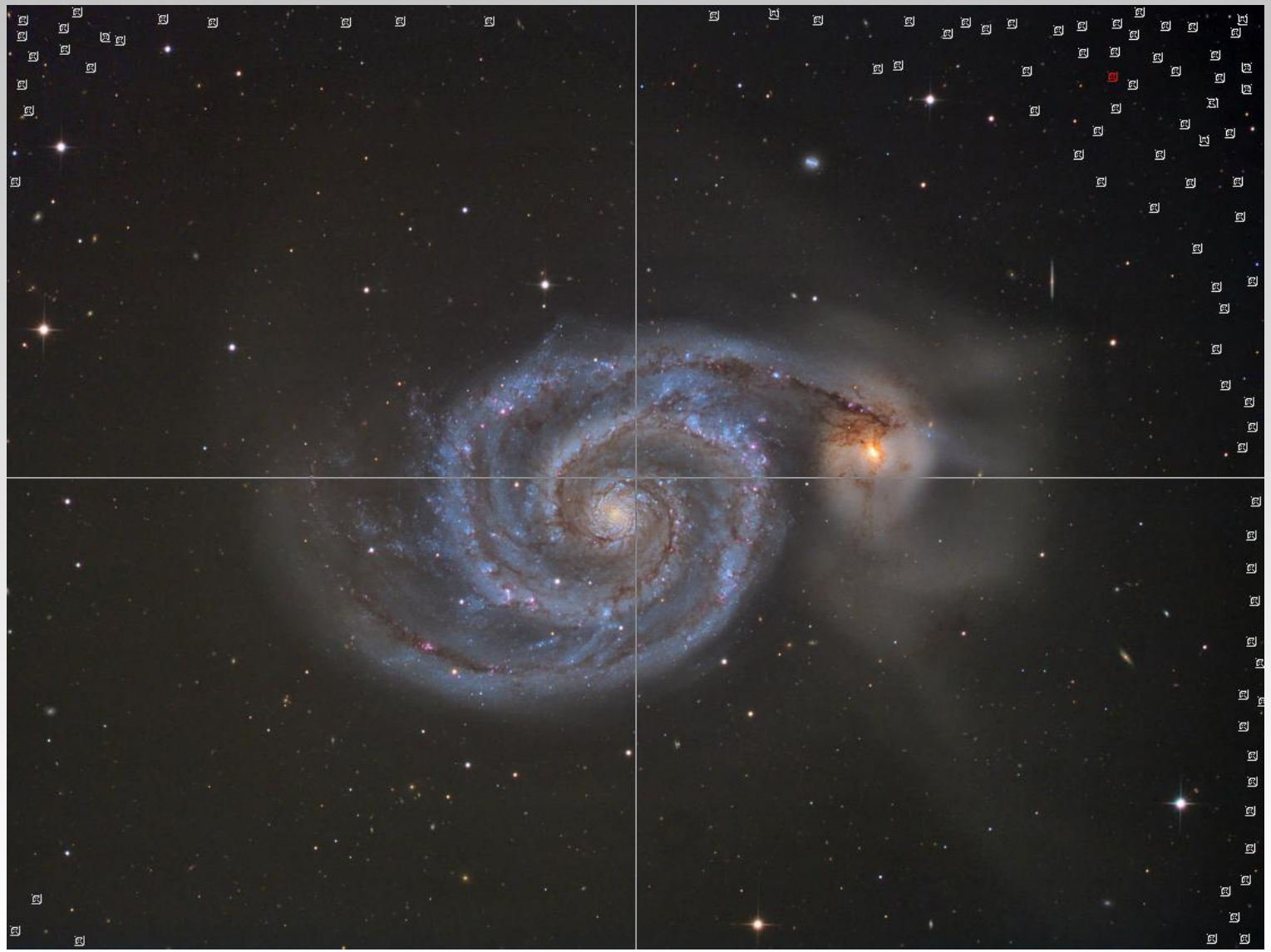


Synthetic flats using PixInsight (1) (www.plejades-astrophoto.com)

M51 with obviously visible vignetting:

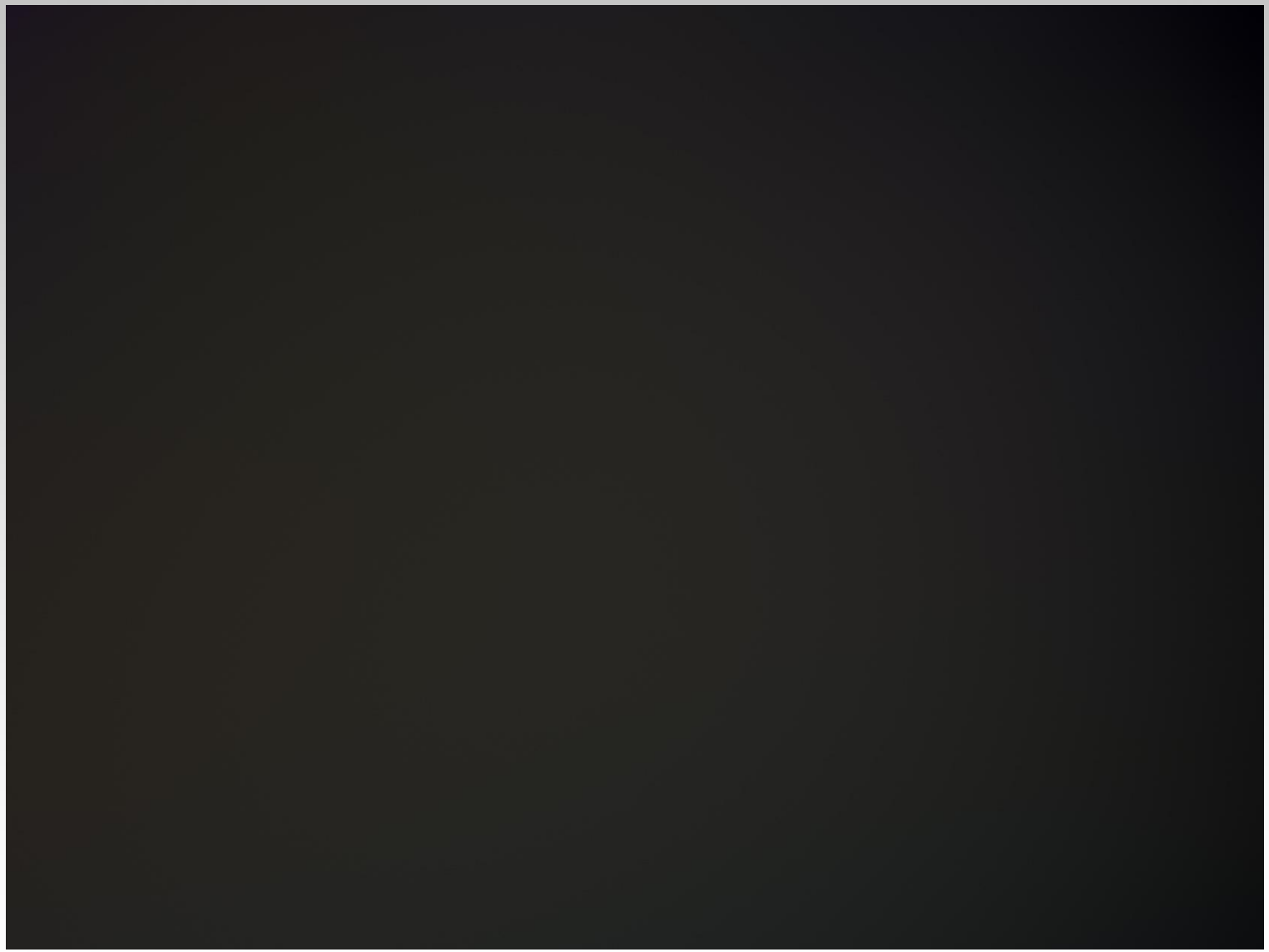
Synthetic flats using PixInsight (2)

Open image in freeware PixInsight LE, use the Dynamic Background Extractor (DBE):



Synthetic flats using PixInsight (3)

Create the mask:

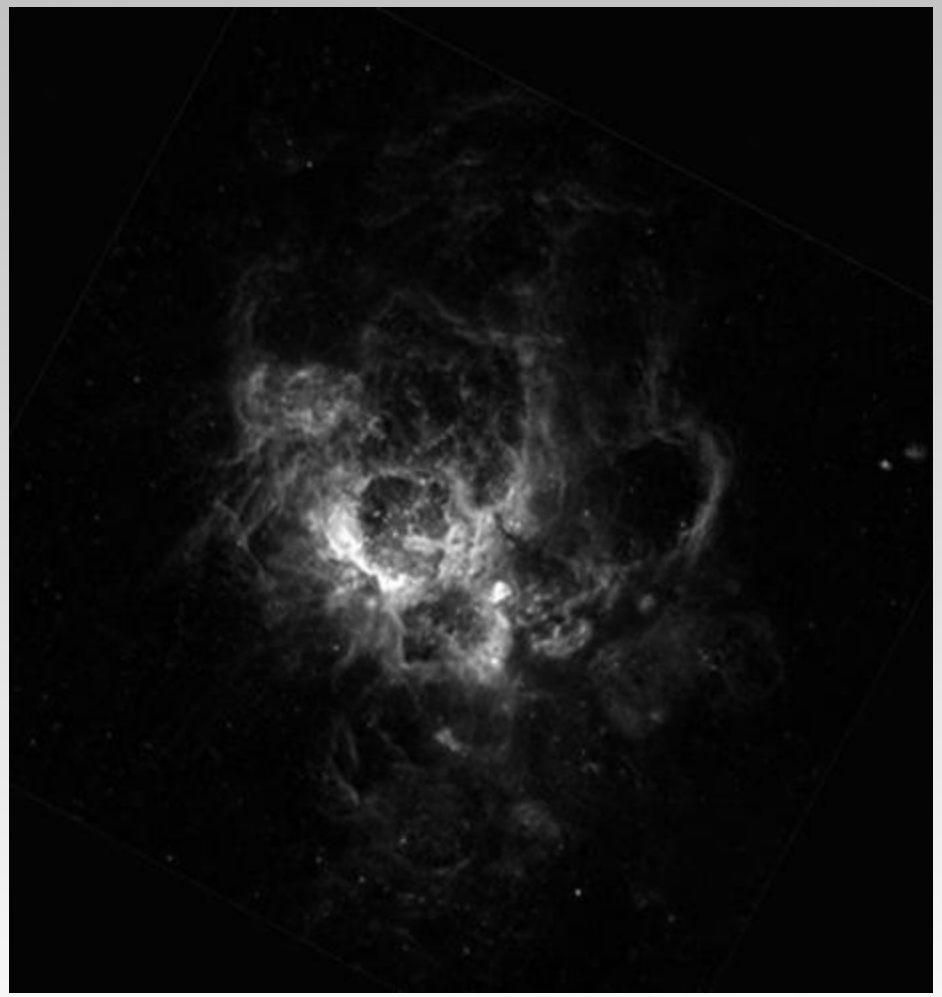


Synthetic flats using PixInsight (4)

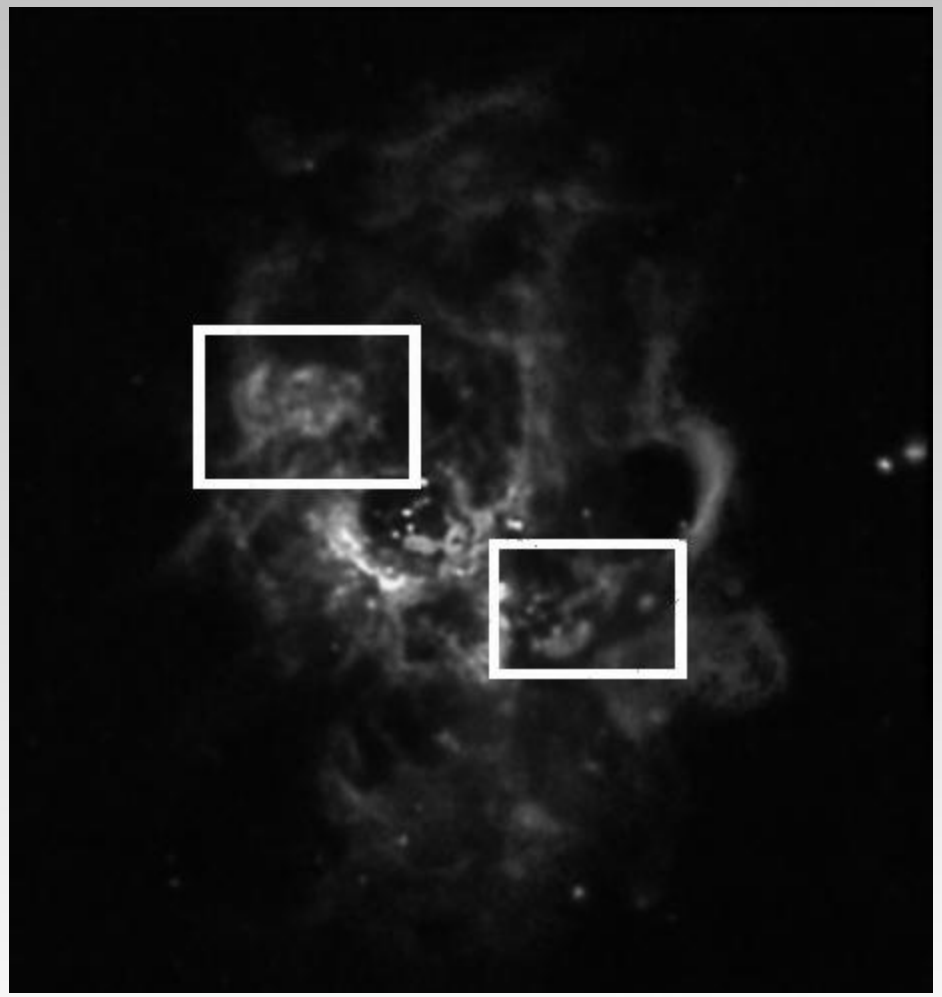
Use Pixel Math and substract the mask from the Original:

What´s possible compared with the Hubble telescope?

(NGC 604 image with about 1,1“ made with 24“ Ganymed)

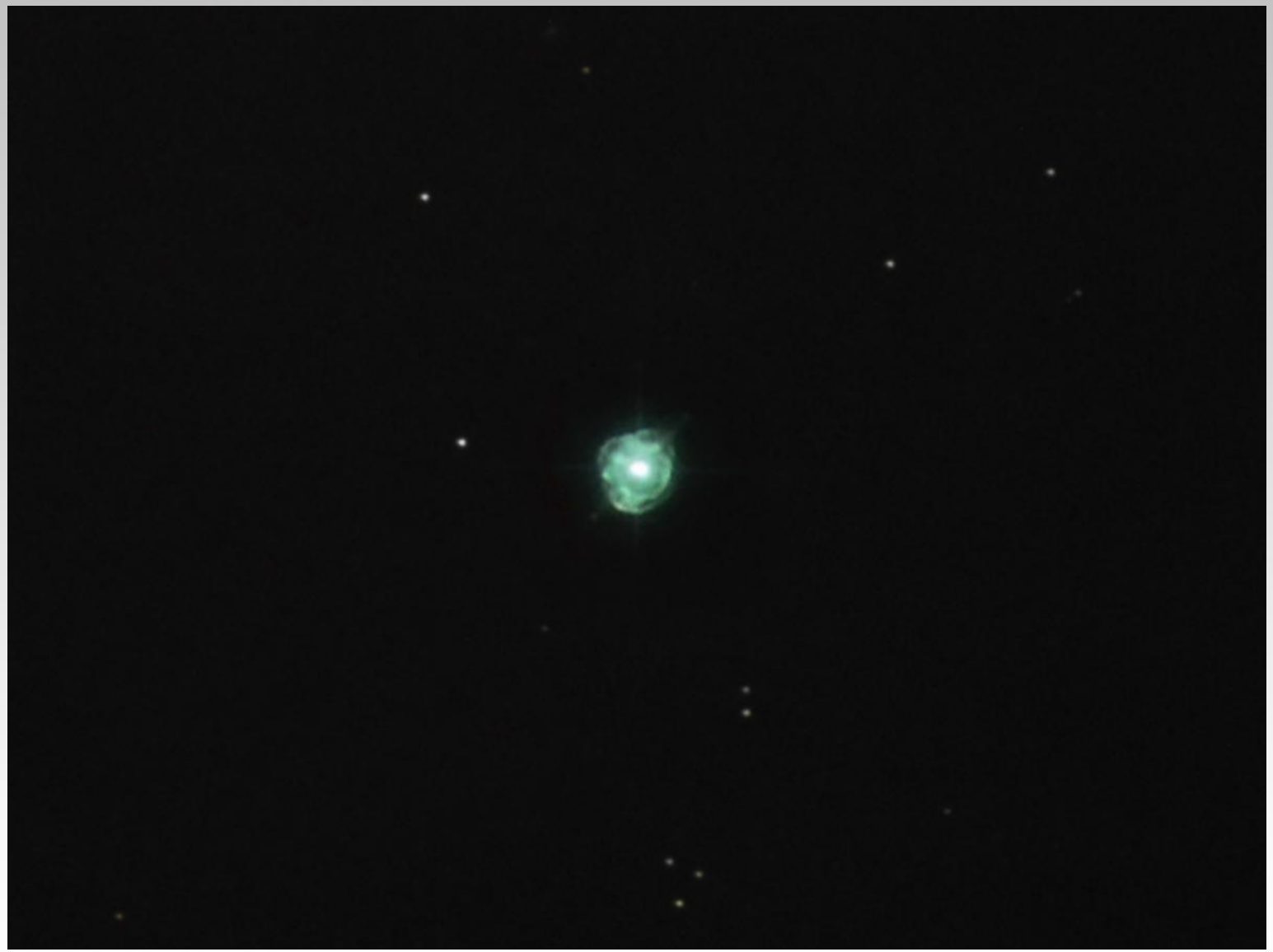


What´s possible compared with Hubble telescopes?



IC 4593 in Hercules (diameter 17“)

(best seeing so far in Crete – about 0,8“ FWHM)



IC 4593 upscaled to the Hubble image

What´s the future for amateur astrophotographers? Active optics???

Thanks for your attention!