Image acquisition and processing using low budget setups

Oleg Bryzgalov
https://www.flickr.com/photos/olegbr/
http://olegbr.astroclub.kiev.ua/

All of the following is based only on my personal experience.

Probably, someone will disagree, someone will consider all this as “outdated” equipment with unacceptable expenditure of time and resources.

Since I am rather limited in money and much less limited in time and enthusiasm, I describe my approach and my technique on the basis of these resources that I have.

About me

I was born in Ukraine and now I live in the city of Kiev. My profession is a construction engineer, but I have been working in computer technology for the last 28 years. Since I was always very interested in the natural sciences, my children and friends gave me a 50-year anniversary 10-inch telescope-reflector "SkyWatcher". It was exactly 10 years ago and this was the beginning of my passion for astronomy. After several months of visual observations, I began my first steps in astrophotography using a Nikon D80 digital SLR camera, which I had then.

The following year, I bought a QSI-583wsg astronomical black-and-white camera and improved my telescope.

In 2013, I designed and assembled an “astrograph of my dream." The main requirement for it is the high quality of the components, the reasonable size of a small budget.

My way.

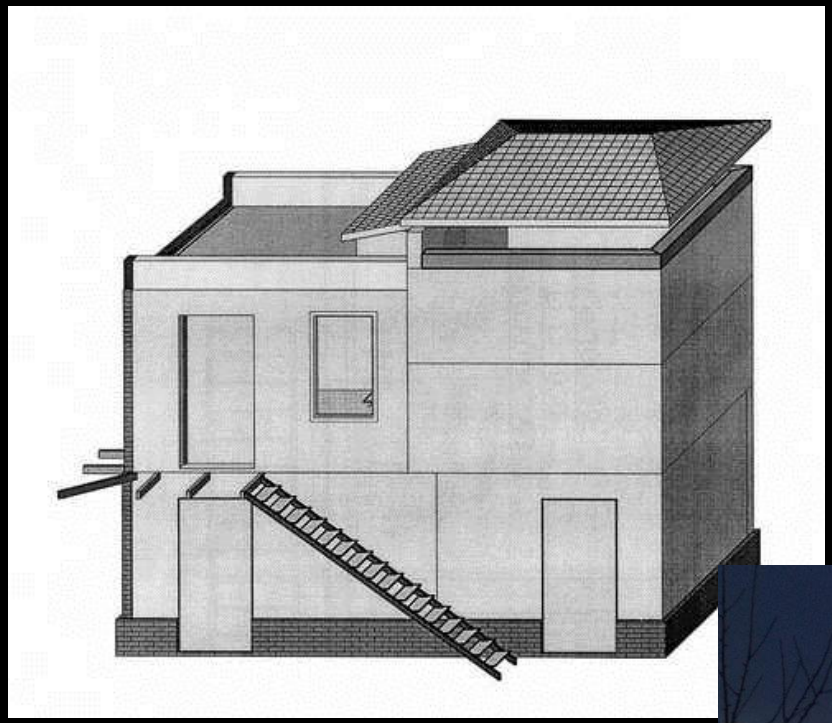
2009 – start visual observations through reflector SkyWatcher 10" in my first "Astro shelter"

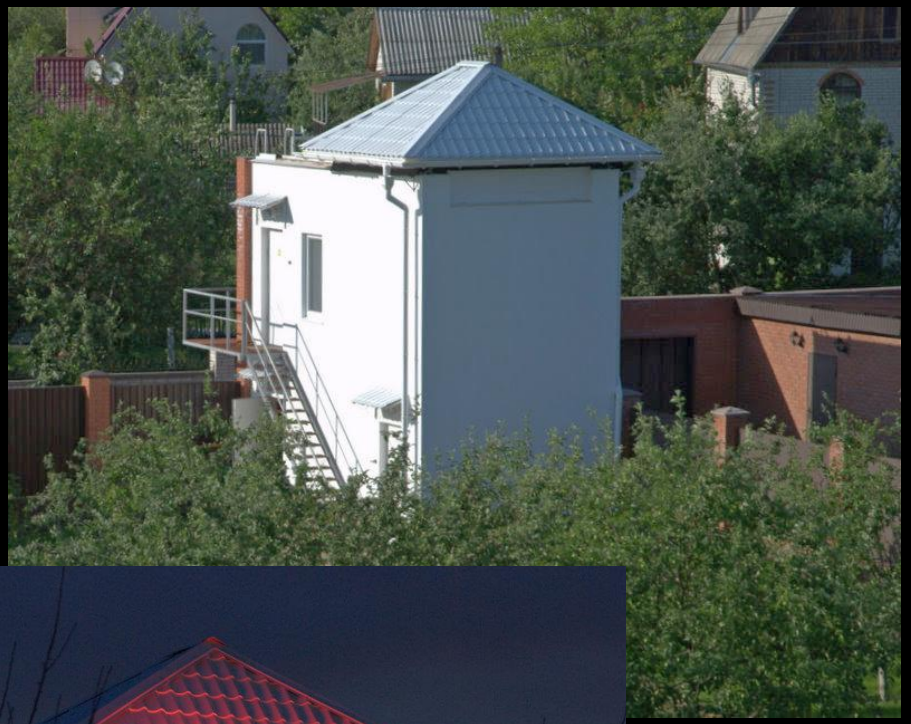
2009 :The first attempts of astrophoto

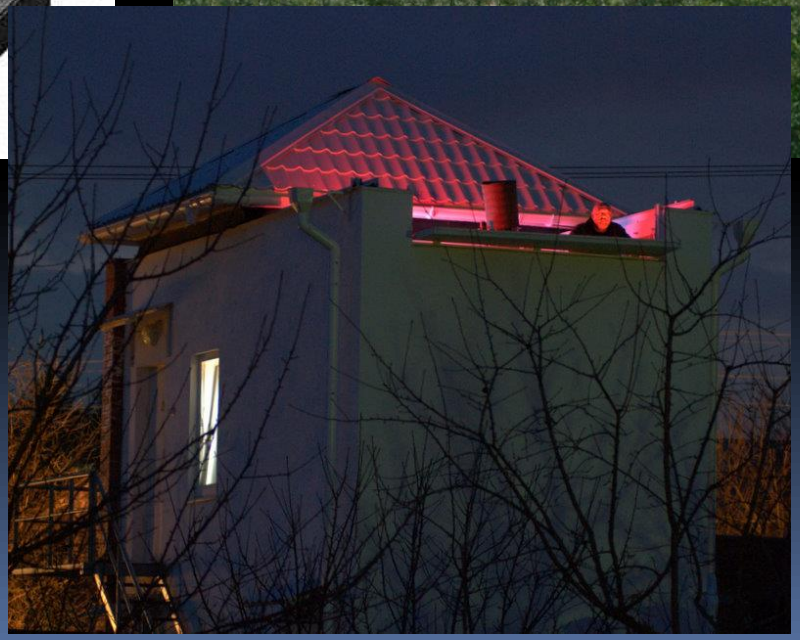
Reflector SkyWatcher 10" with DSLR camera "Nikon D80"

Refractor SkyWatcher ED80

2009: Design and construction my Roll_Off_Roof observatory near Kiev







2009-2010:

-Color CCD camera “Orion StarShoot Pro V2.0

- Mount SkyWatcher EQ-6 Pro

- Homemade guide scope based on the lens "Tair-3“

- Guide camera “Orion StarShoot autoguider

2010-2019.
New stage: cooled CCD camera QSI-583wsg

Filter sets:

2010-2011	Astronomik
2012-2016	Baader Planetarium
2016-2019	Astrodon gen.II

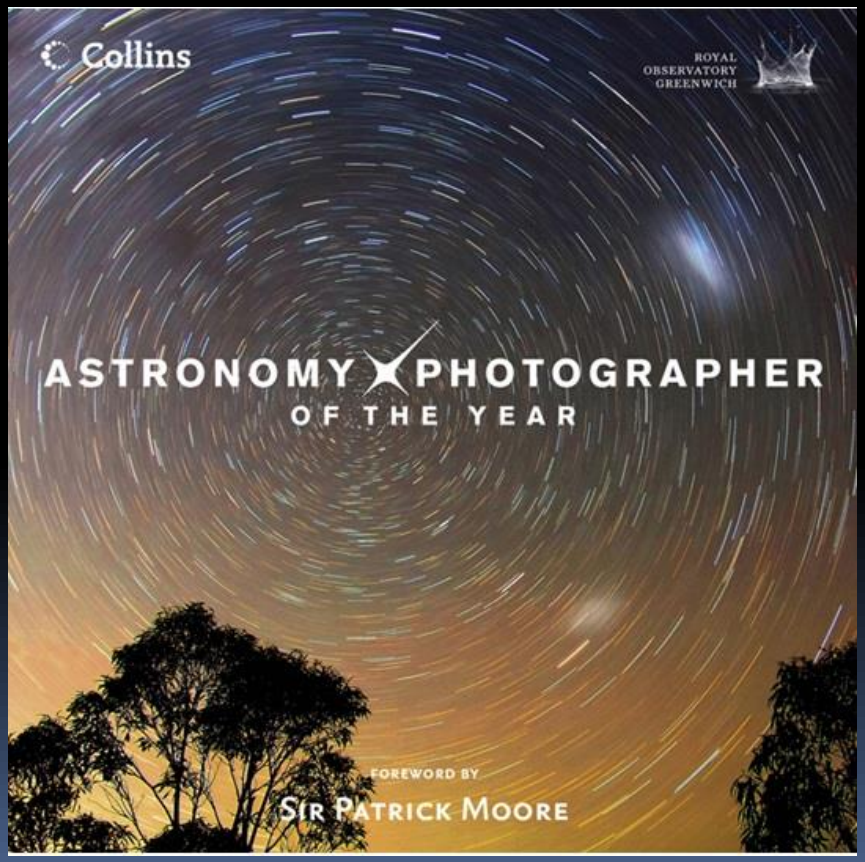
2010: The first attempts to shoot in narrowband filters (HST palette)

NGC 7380

Mel15 (IC1805)

2011 – New mount WS-180 (made in Ukraine).
In this astrograph from "SkyWatcher" only the main mirror and its rim remain.

2011, june. First shot "Ghost of the Cepheus Flare" on a new mount with an upgraded astrograph awarded "Highly Commended" in "Astronomy Photographer Of The Year 2012"



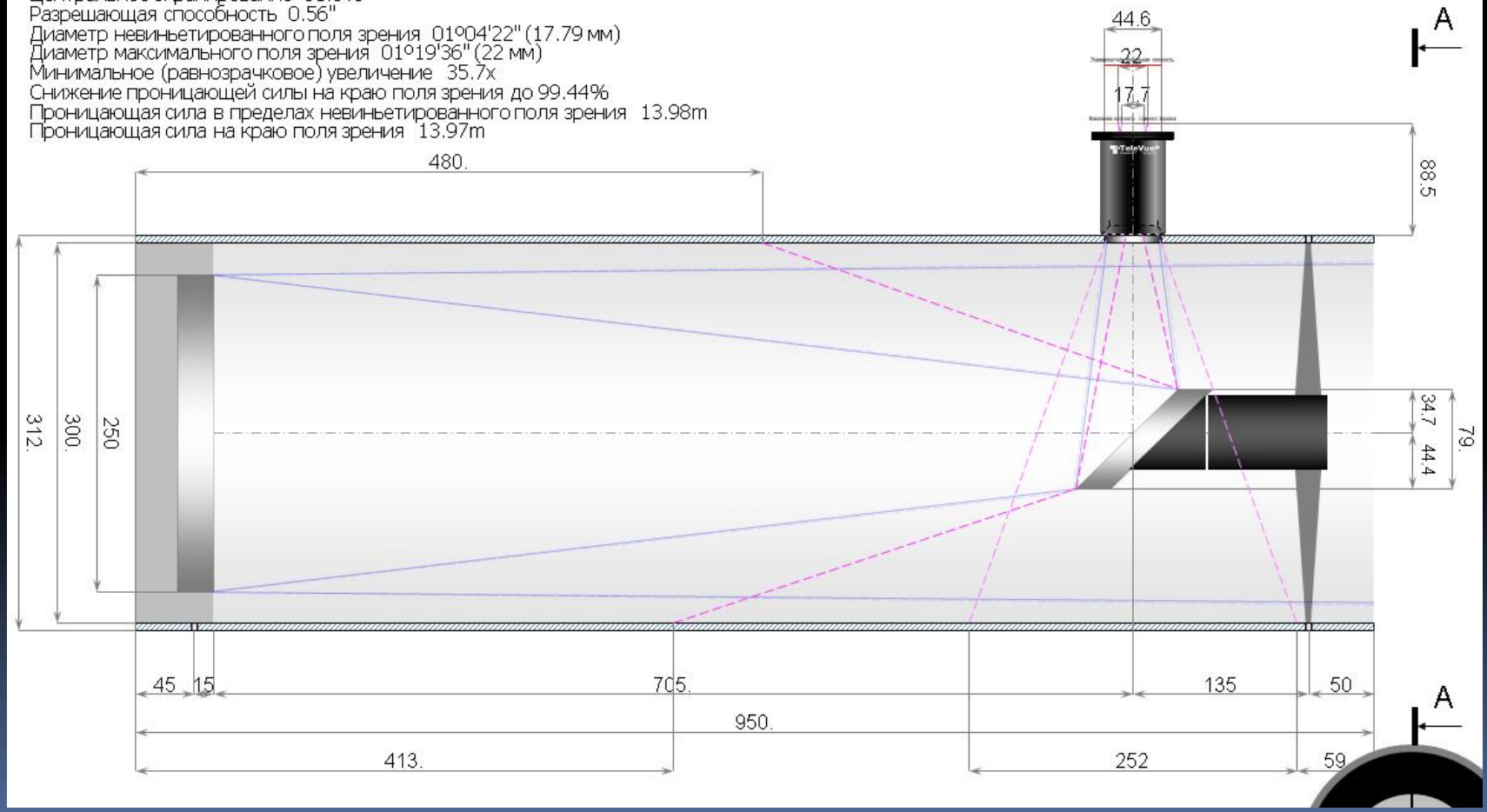
06.06.2012: Unforgettable Venus transit ☺

2013 After upgrading two ready-made reflectors, I decided to design and build a new "telescope of my dream" with the maximum “power / cost” ratio

ASA MIRROR + PARACORR-2 D=250MM, F/3.8

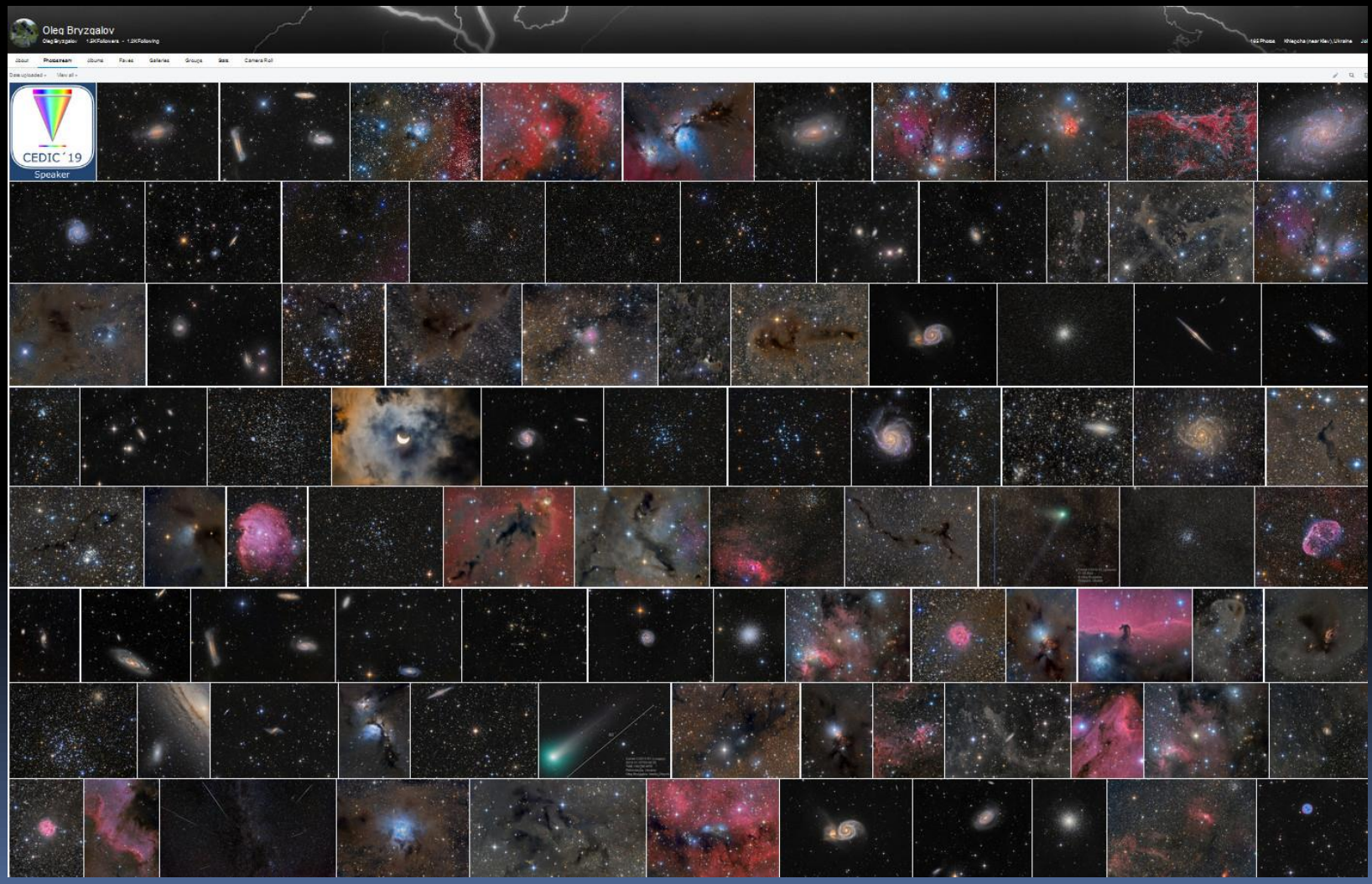
Диаметр главного зеркала 250 мм
Фокусное расстояние главного зеркала 950 мм
Центральное экранирование 31.6%
Разрешающая способность 0.56"
Диаметр невиньетированного поля зрения 01°04'22" (17.79 мм)
Диаметр максимального поля зрения 01°19'36" (22 мм)
Минимальное (равнозрачковое) увеличение 35.7x
Снижение проницающей силы на краю поля зрения до 99.44%
Проницающая сила в пределах невиньетированного поля зрения 13.98m
Проницающая сила на краю поля зрения 13.97m

Telescope layout

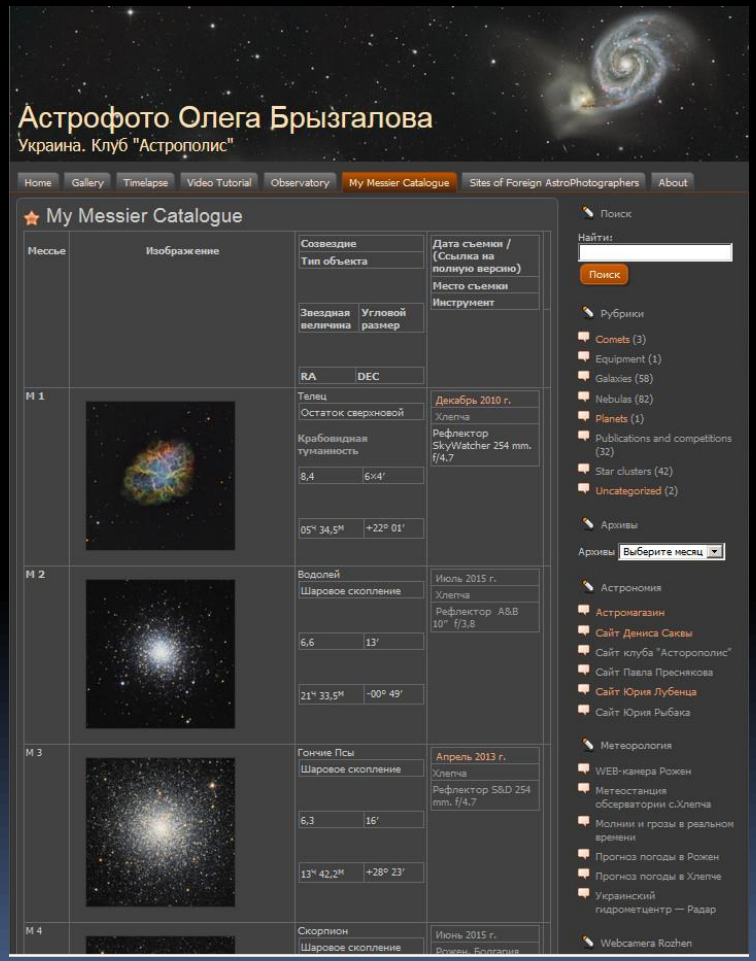


2013: After six months, the astrograph is basically ready.
The first shot in July 2013 - NGC6914 nebula in Cygnus
(carbon tube is still on its way to me)

2013-2019. Seven years of pleasure with a new astrograph.
More than 80 astrophoto published on the site:
(https://www.flickr.com/photos/olegbr)



My personal complete Messier Catalogue.
http://olegbr.astroclub.kiev.ua/?page_id=191



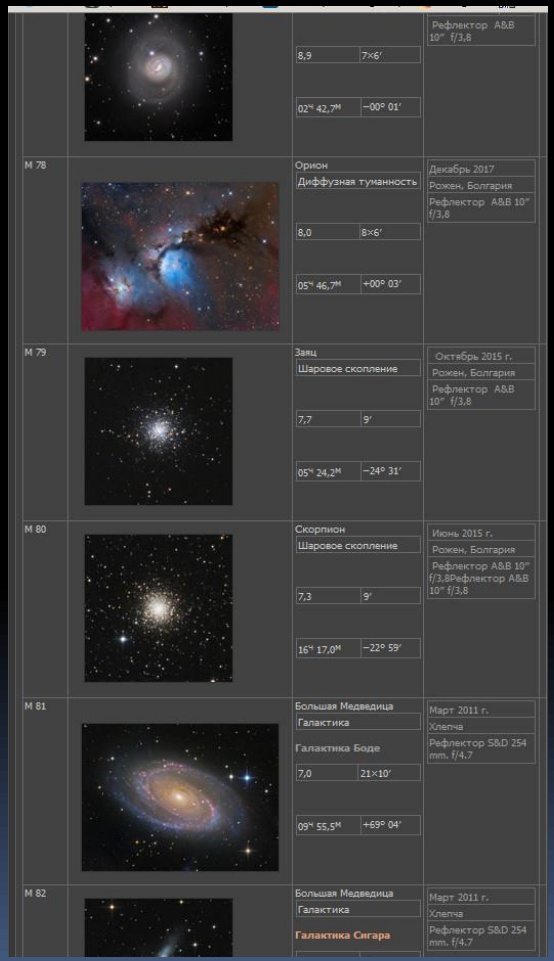
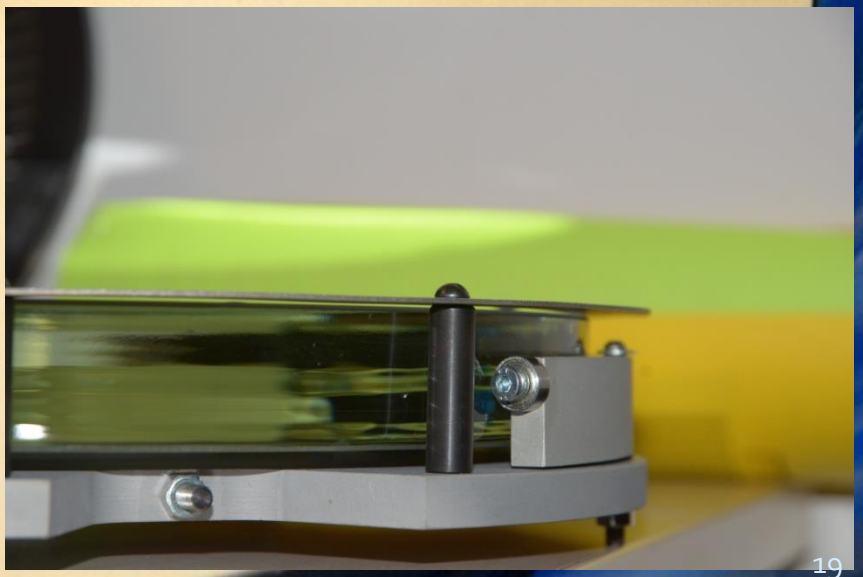


Photo M63 is “Galaxies” category winners of the “Insight Investment Astronomy Photographer of the Year 2017” competition https://www.rmg.co.uk/whats-on/astronomy-photographer-year/galleries/2017/galaxies

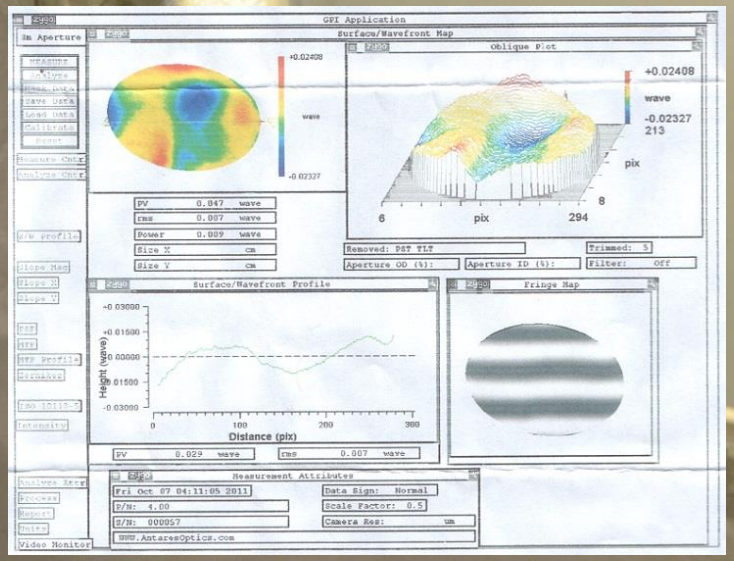
The main components of the “Telescope of my dream"

Main mirror 10“ F/3.8 bought at ASA

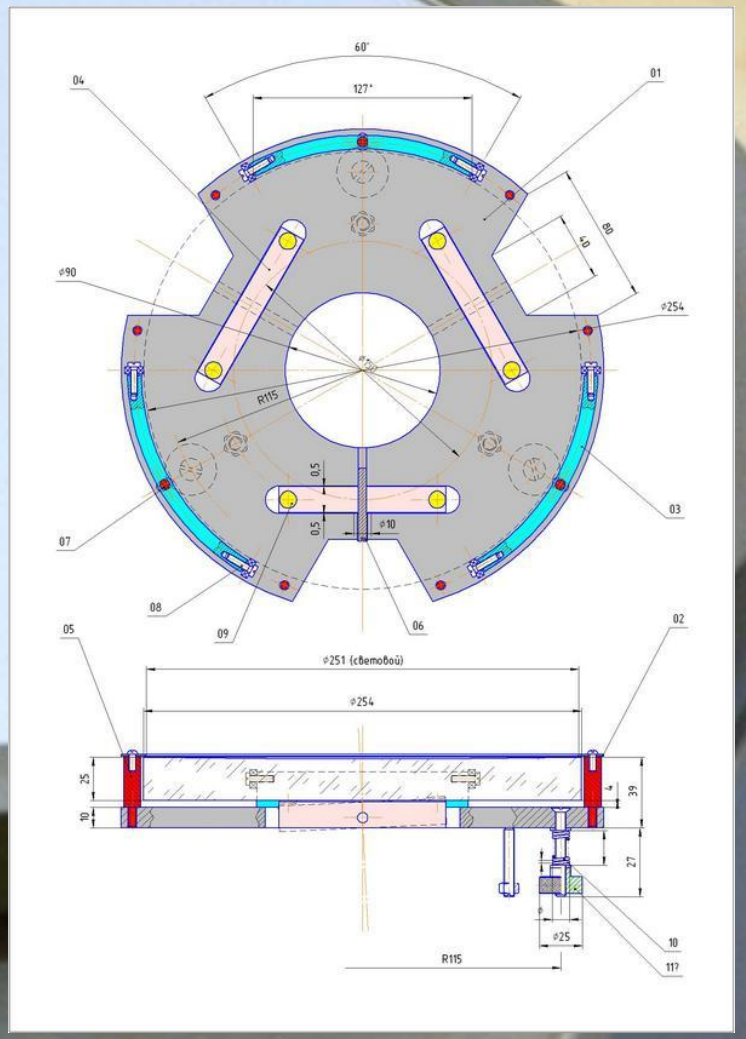
https://www.astrosysteme.com/



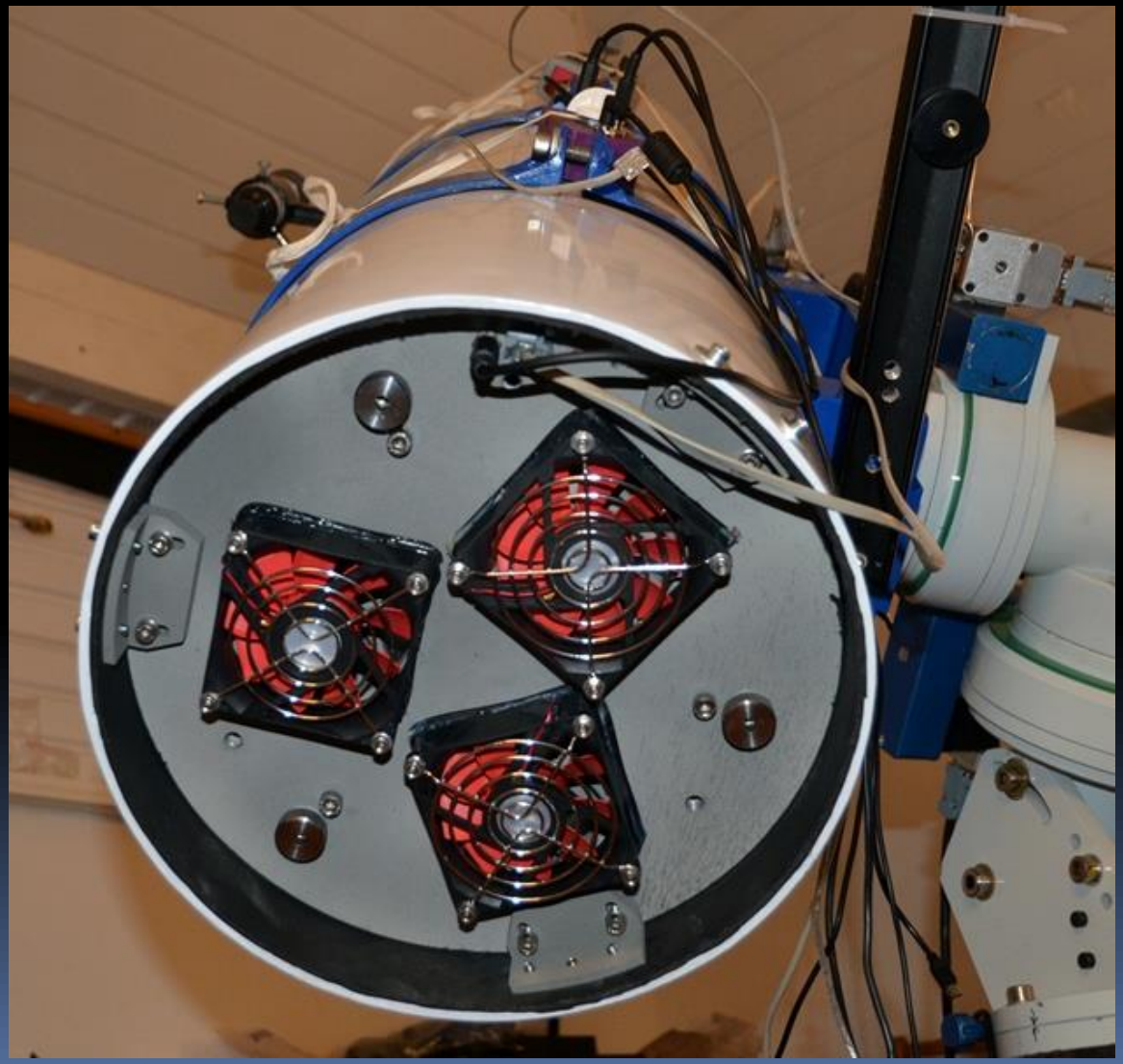
Secondary mirrors (3.1" and 4" (1/20 Wave PW) for different coma-correctors bought in "Antares Optics"
http://www.antaresoptics.com/



The telescope should allow the use of various coma-correctors depending on the camera. The holder of the main mirror should be able to move inside the pipe (like a piston)



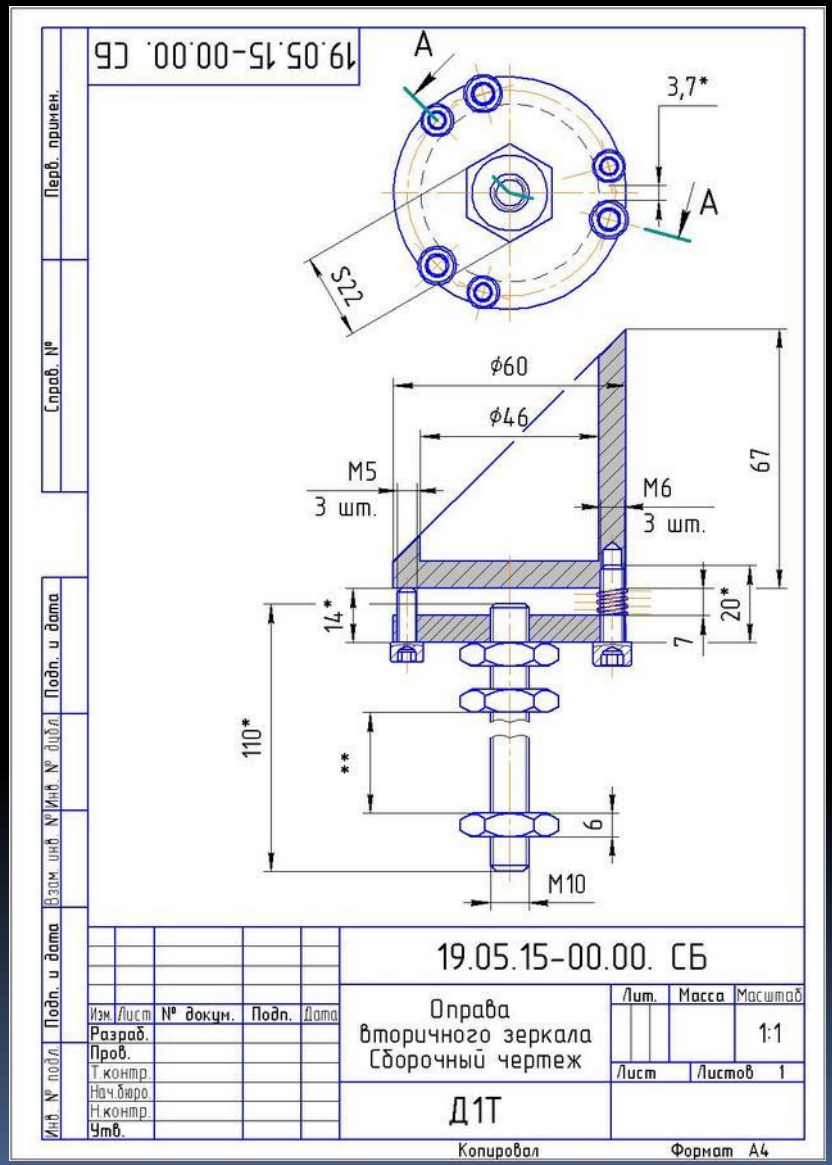
The telescope should allow the use of various coma-correctors depending on the camera. The holder of the main mirror should be able to move inside the tube (like a piston)



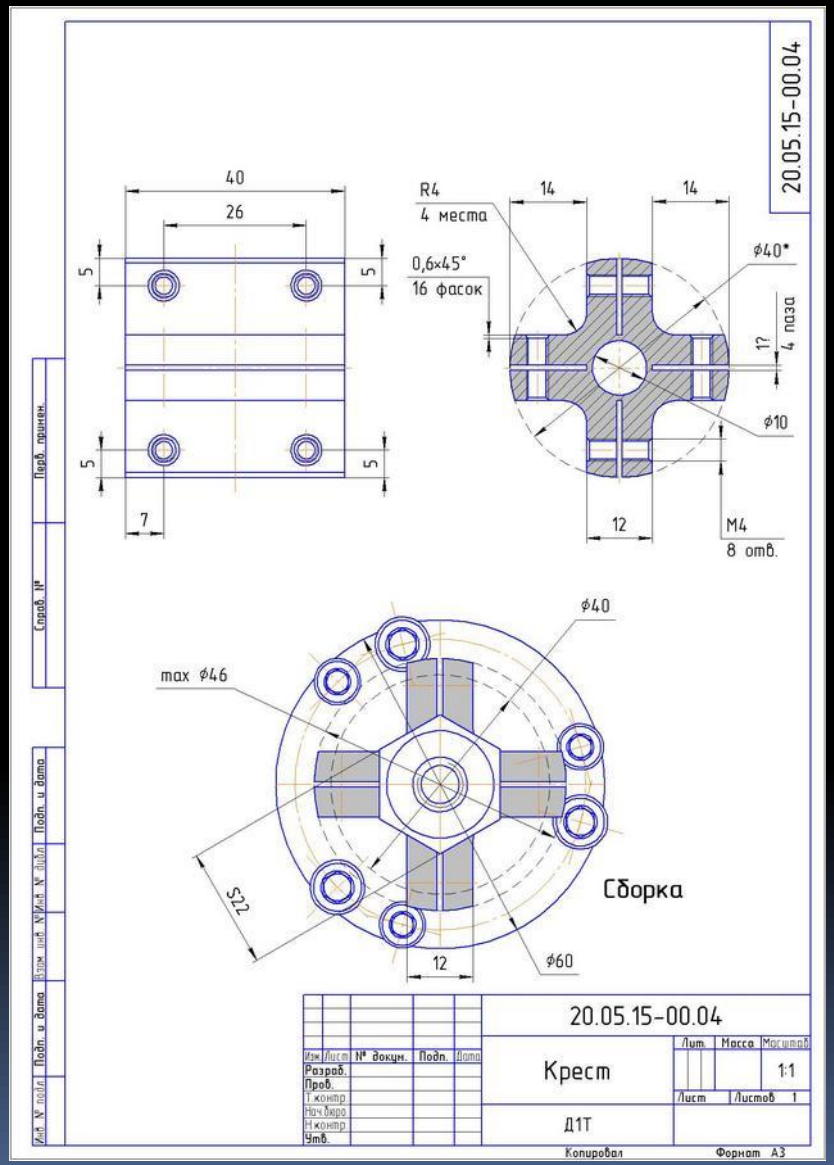
Stepper Motor Focuser “Moonlite” 2.5" http://focuser.com/

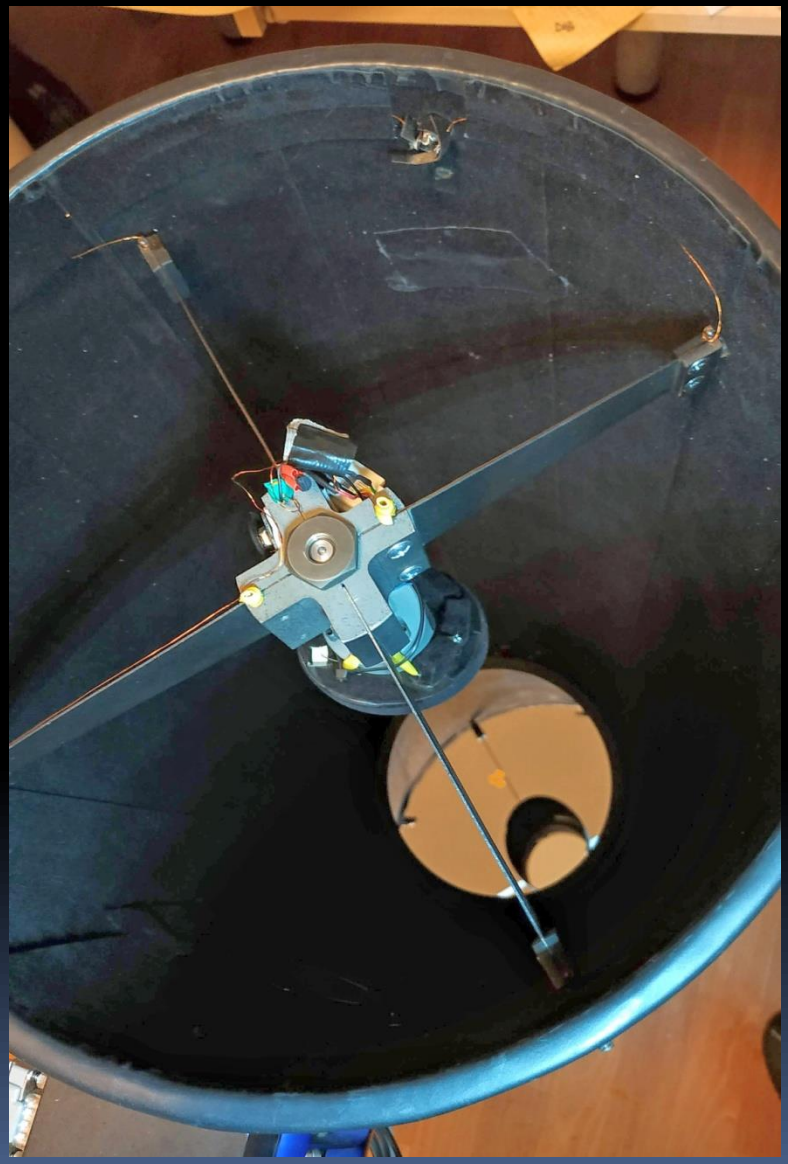
Carbon tube 6 mm thickness and a diameter of 300 mm from Klaus Helmerich http://www.klaushelmi.de/ The tube is plastered outside with a white oracal. Inside - black flock

The secondary mirror holder is made on a CNC machine



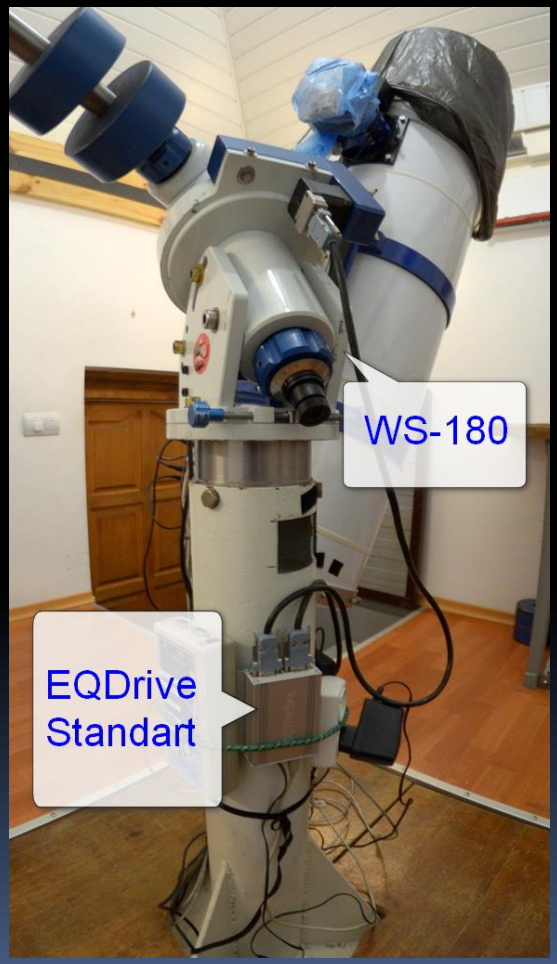
"Spider" for the secondary mirror holder is made on a CNC machine





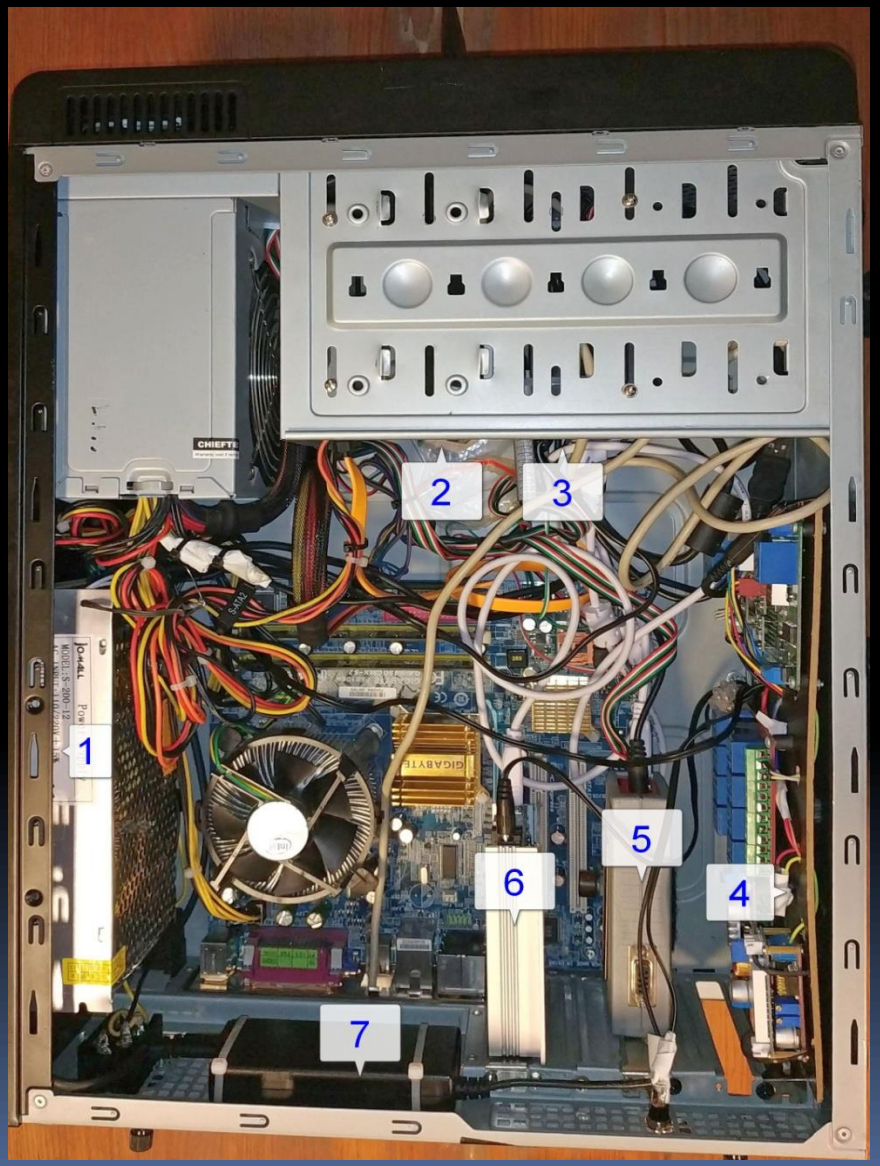
“Made in Ukraine”

WS-180 mount (andriy@lebid.com.ua)
with control system "EQDrive Standart"
ttp://www.eqdrive.com.ua/



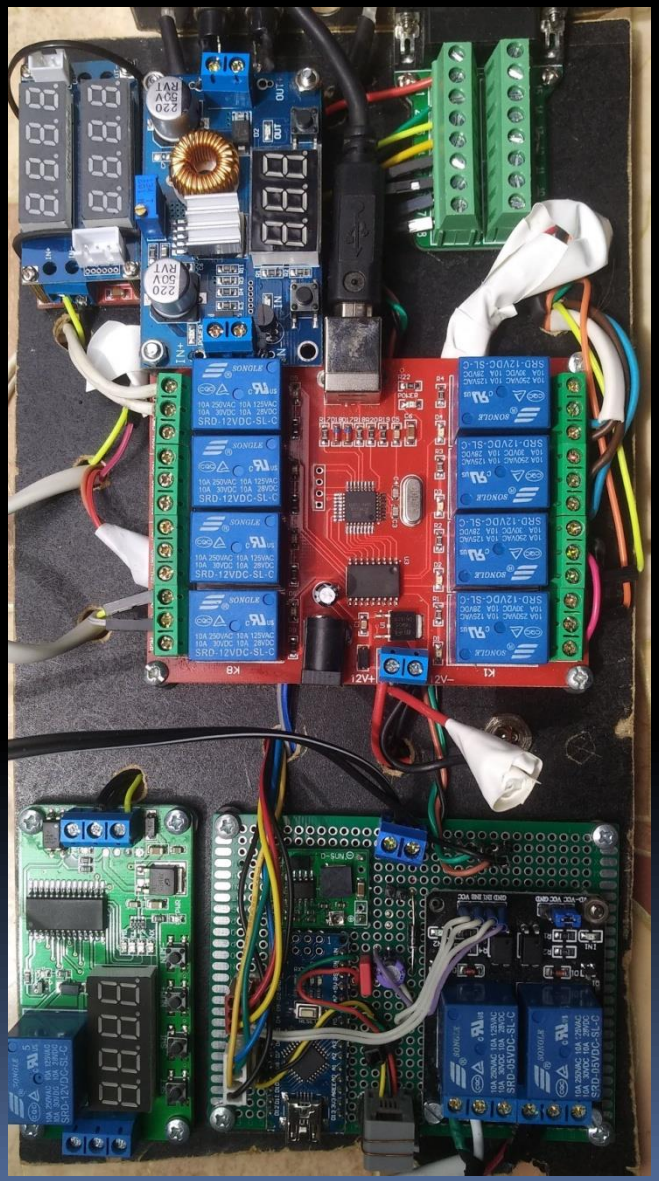
Imaging computer and All-in-One Management System

1. Power supply 12v, 16A
2. Wi-Fi router-repeater
3. USB 2.0 hub
4. Simple remote control power devices
5. Focuser controller
6. EQDrive Standart
7. Main camera power supply



Simple remote control power devices.
Central unit for 8 relays with USB control

- - automatic activation of the heating of the secondary mirror (depending on the temperature difference on the surface of the mirror and the air in the tube)
- - main mirror fan speed control
- - flat-box brightness control
- - camera additional fan speed control
- - switching on the heating of the main and secondary mirrors after the end of the session (to prevent their fogging). Turning off the heating by timer
- - main camera power reset
- - power reset of the control system "EQDrive Standart"



Imaging computer and software:

- Core2Duo E6300, i945
- 4GB RAM, 128GB SSD integrated video

- Software :
- OS: Windows 7 -64
- Imaging: MaximDL
- EQMOD
- CCD Inspector
- Cartes du Ciel
- FocusMax
- Photo processing:
- Pixinsight
- PhotoShop

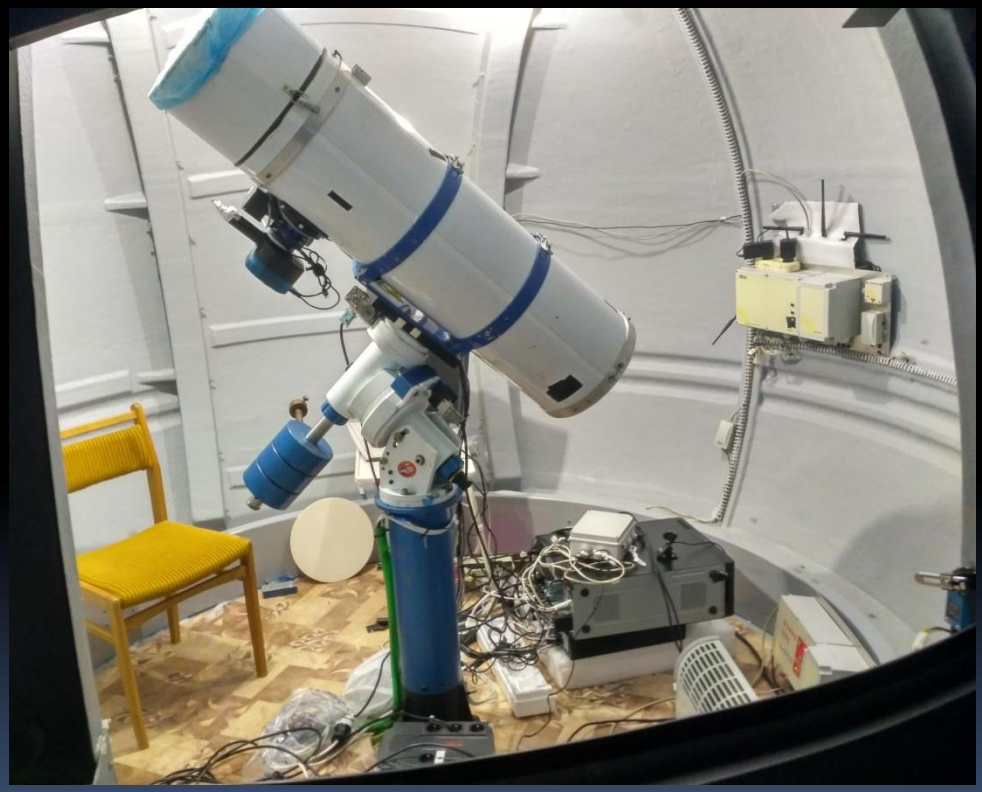
The most important for success

- In my opinion, the qualities that characterize a good astrophotographer:
- - Enthusiasm and continuing interest in this hobby
- - A lot of free time
- - Infinite patience and a desire to use for photographing every night
- - Desire the opportunity to travel to a deserted place under a dark sky
- - Willingness and ability to learn new things
- - Stoically endure setbacks and a critical attitude toward success
- - The desire to spend a lot of sleepless nights, suffering from a cold, damp, mosquito, etc.
- - Sufficient expertise in the areas of: conventional photography, optics, mechanics, electronics, computer software, image processing, etc.

- A place with a suitable astroclimate - to live well in a place with a dark sky, suitable for astrophoto (photo of the my Observatory in Khlepcha)

Have the opportunity to travel for a long time (at least 10 days) with an astronomical tent. My experience is the mountains of Crimea, a village 100 km. from Kiev, mountains of Bulgaria.

Remote access – the best. My little experience of management in the winter of 2017-2018 (my setup in the dome in Bulgaria)



All equipment must be:

- - well designed
- - firmly assembled
- - carefully adjusted
- - it is necessary to achieve absolutely predictable work of all components
- - It is very useful to provide remote access to the setup even when staying near the tent

During the session, careful monitoring of the results obtained.

- - The main key to obtaining a good astrophoto is a sufficient amount of high-quality source images
- My goal is to do no less:
- 25 frames in the L filter with an exposure of 600 - 900 seconds.
- 15 frames in each of the RGB filters with a exposure of 600 seconds (unbinned)
- During the session continuous images quality control using the CCD Inspector.

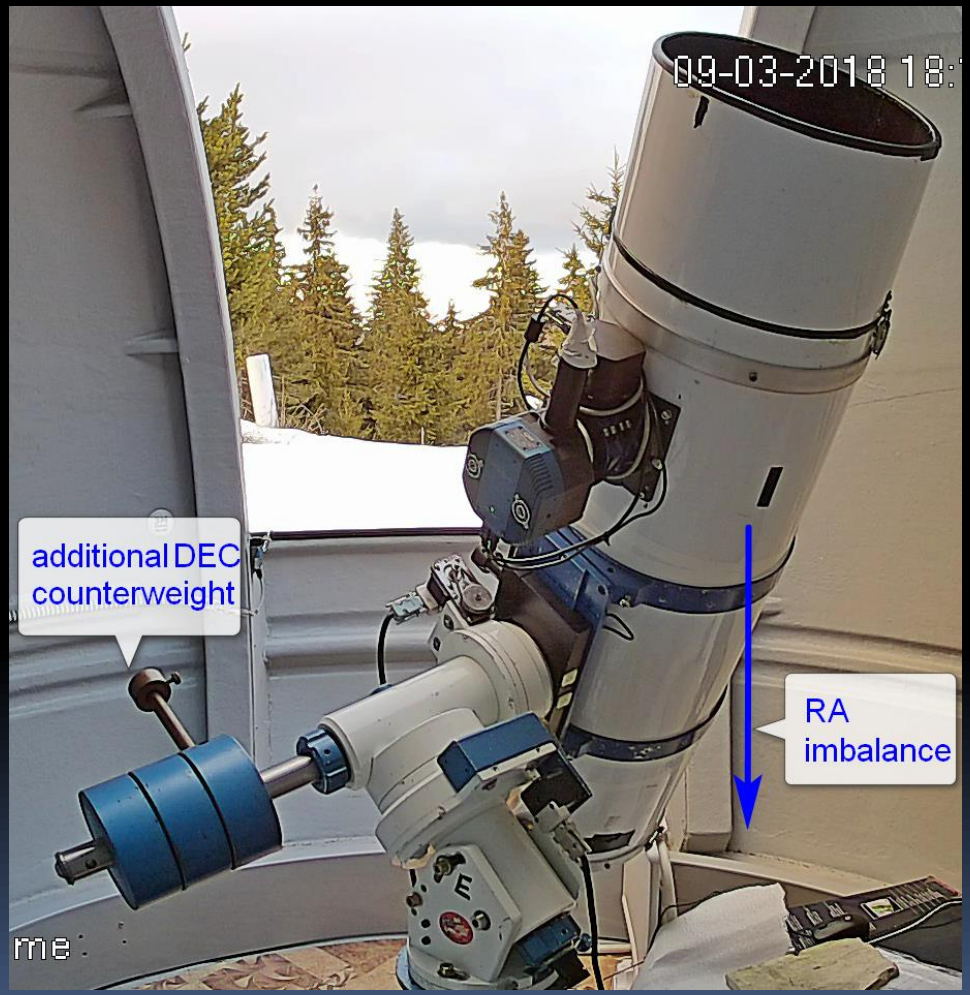
In the process of imaging:

- During each night, I photograph when the pipe is on one side of the meridian without rerun.
- - In the process of shooting, it is very important to ensure compensation of backlash in worm gears along the axes of RA and DEC.
- The "eastern" part of the RA axis setup should be slightly heavier than the "western" part.
- Corrective impulses along the DEC axis should be on the “one side”. To do this, before you start shooting:

a) disable guiding along the DEC axis and determine which way the guide star goes

b) make the tube imbalance along the DEC axis (using additional DEC counterweight) so that the corrective impulses are directed “against” the imbalance

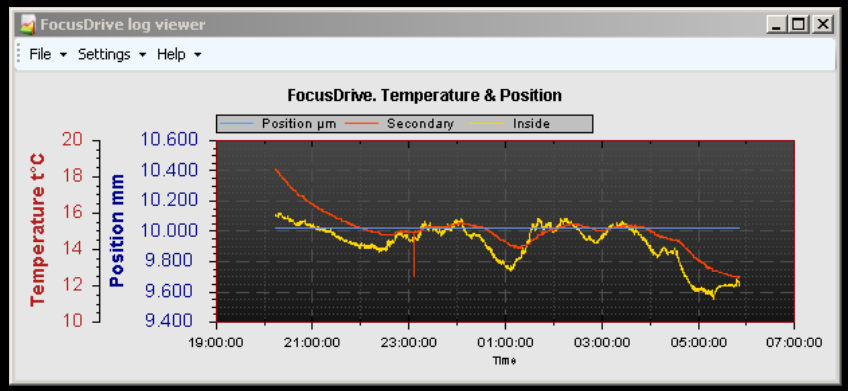
c) enable guiding and control correction impulses using graphics



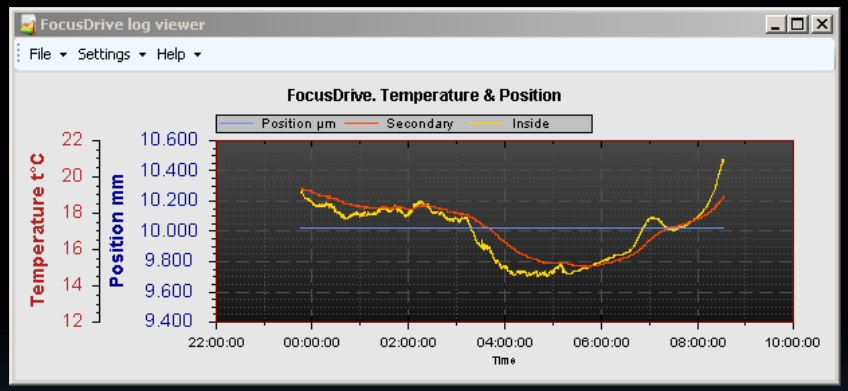
As well as temperature control using sensors in three places (main mirror surface, inside the tube, outside the tube) with recording of logs and plotting in real time

- If in the process of shooting the graph shows a rise in temperature, then this inevitably entails an increase in FWHM!

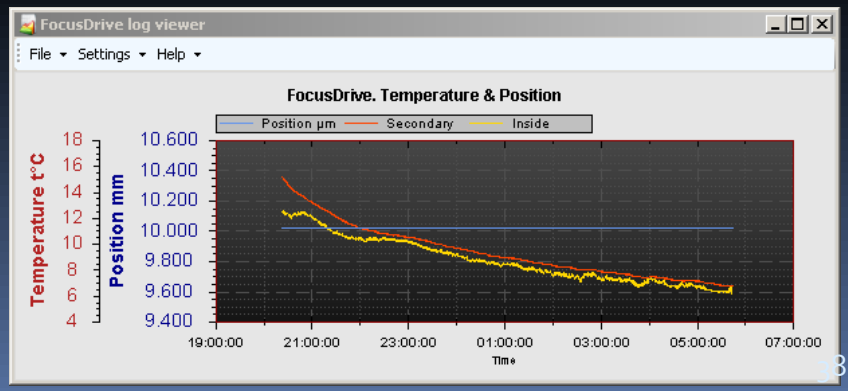
Poorly



It is better



Perfectly



Calibration Images

- Thoroughness and meticulousness in taking calibration images
- I do no less:
- {200 BIAS;
- 25 DARK;
- 25 FLAT for each filter (I use flat-box);
- 25 DARK-FLAT for each exposure FLAT}
- {This is all for each matrix temperature value.}
- As far as possible, refresh the calibration library

Highlights of NGC3521 Galaxy Processing with Pixinsight

Imaged remotely in 3m. the dome in the territory of the observatory Rozhen (mountains in Bulgaria).

imaging period - 20.02.2018 - 14.04.2018,

9 nights.

All lights (L and RGB) are photographed with an exposure of 600 seconds in binning 1

Lights in RGB filters were photographed sequentially (R-G-B, R-G-B etc.) so that when processing I could select a synthetic L channel from each "triad"

Summary table lights and calibration frames

- Total shot: L = 92
- RGB = 30 each
- For 7 nights - the temperature of the matrix is -27°, the last two are -25° (the air temperature has increased)
- Therefore, 2 sets of BIAS and DARK were made (for each temperature of the matrix)
- FLAT and DARK-FLAT were made only at -27 ° matrix temperature

	A	B	C	D	E	F	G	H	I	J
1	Date	CCD temp	BIAS	DARK-600	DARK-Flat	L	R	G	B	Flat
2										
3	20.02	-27	200	25						
4	9.03	-27				16	1	1	1	old
5	16.03	-27	100							50
6	8.04	-27		25			10	10	10	old
7	9.04	-27				27	3	3	3	old
8	11.04	-27					9	9	9	flat1
9	12.04	-27	100		25	22	1	1	1	flat2
10			400	50	25					
11	13.04	-25	42	25		10	4	4	4	flat2
12	14.04	-25	50	25		17	2	2	2	flat2
13			92	50						
14										
15										
16										
17										Hours
18	All					92	30	30	30	30.33333
19										
20	L sum=2.49"									
21	FWHM 1.98"-3.37"									
22	alt: 29-48									

Astrophoto Processing: Part 1

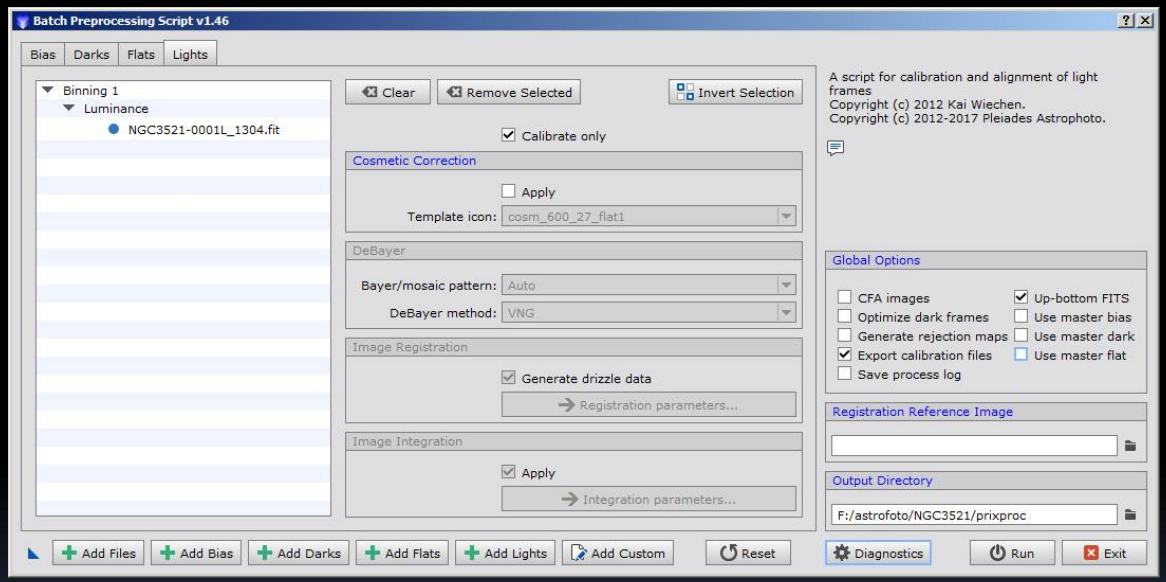
- Part 1 processing - mathematical functions without a creative component. The main task is to do everything neatly and not lose a single reference matrix.
- - calibration with cosmetic correction
- - alignment
- - per channel integration

batch preprocessing for each CCD temperature - in 2 passes each

1 pass - creation of master calibration files and calibration of one light.

1 . If there is a collection of enough fresh "correct" calibration files:
1.1 - DARKs have the same duration and temperature and their quantity is not less than 25
1.2 - BIASs have the same temperature and their quantity is not less than 100
1.3 - FLATs have the same temperature and their quantity is not less than 25
1.4 - each FLAT has DARK for calibration of the same duration and temperature:

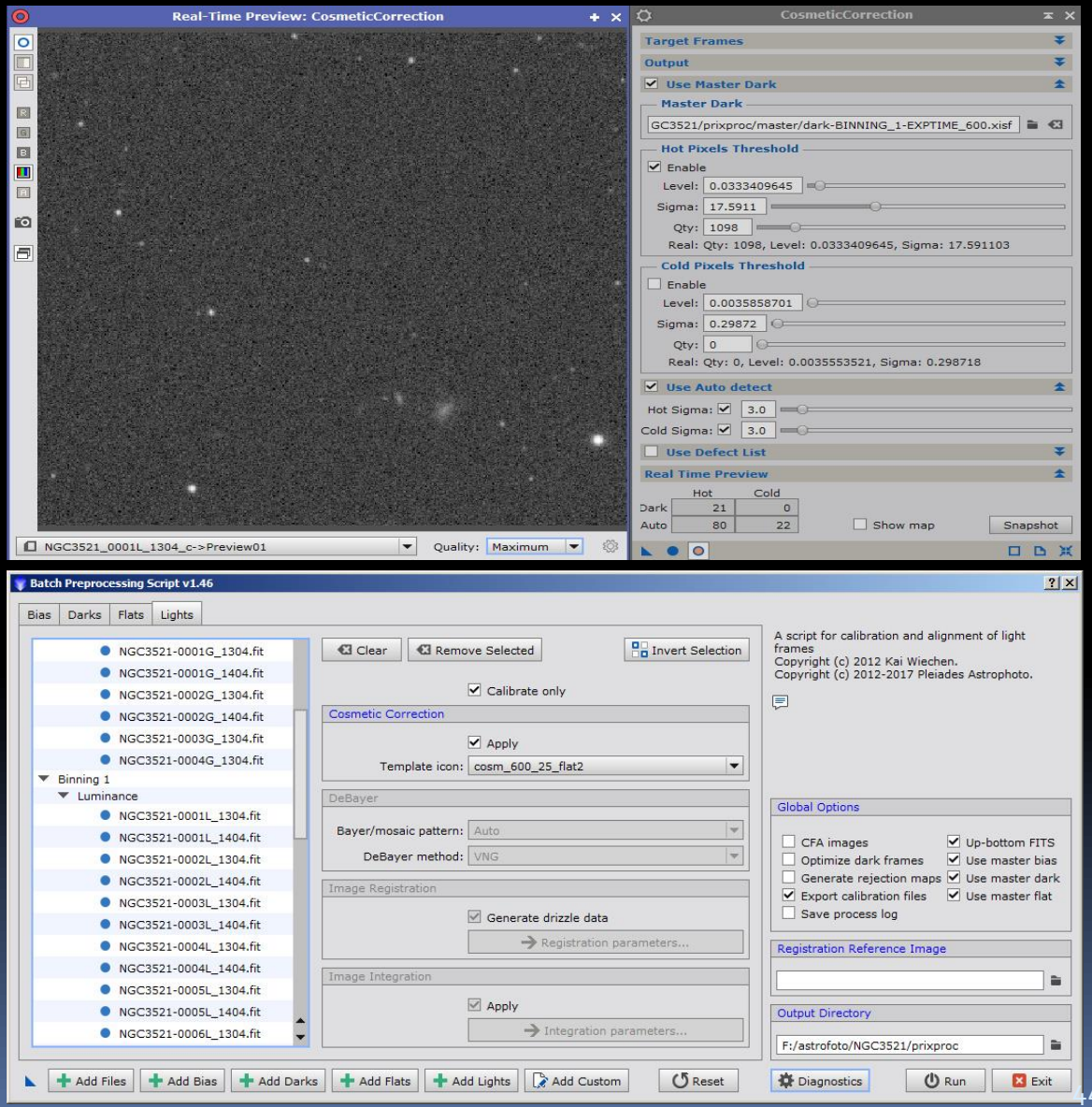
Checkbox “Optimize Dark Frames” is not needed!



Batch preprocessing second pass

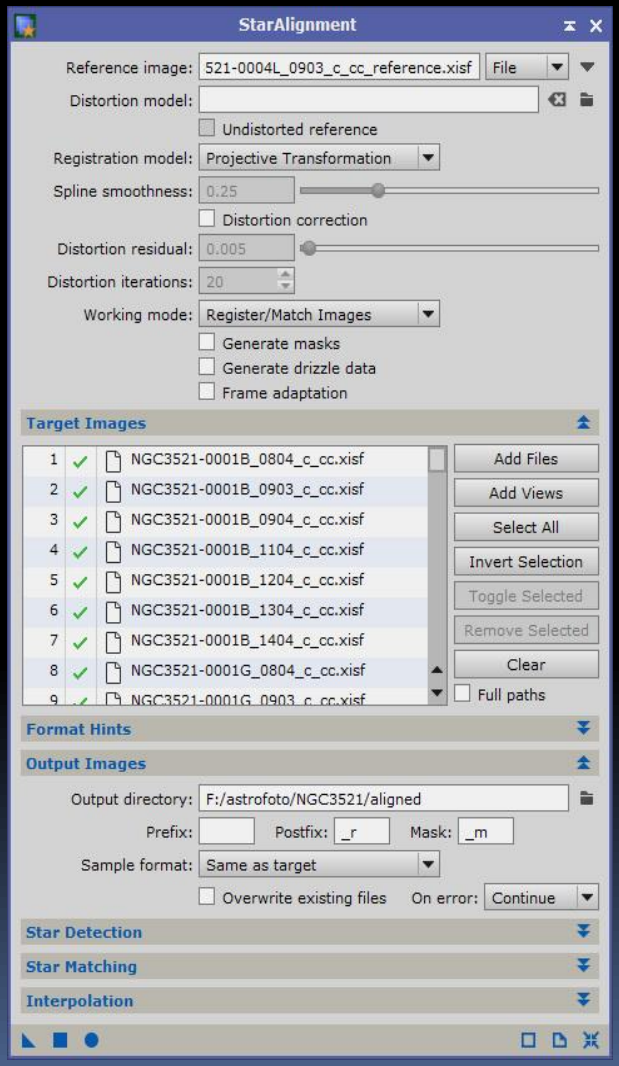
- creating a "Cosmetic correction process" for this single source image using the Real-Time Preview

- 2 pass batch preprocessing for calibration and apply "Cosmetic correction" for all source images



Star Alighnment

Star Alignment with default settings. The reference frame in the L filter is selected using the CCD Inspector to minimize the values of "FWHM" and "Aspect"



Selection of a synthetic L image from each RSL triad

Using synthetic L images from each RGB sum taken in triads in a row (R-G-B - ==> L, R-G-B ==> L etc.)

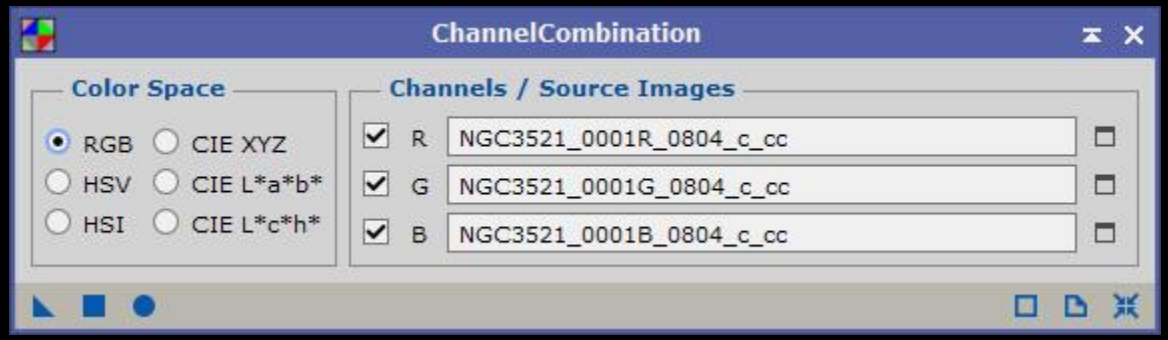
For each "triad", the following are performed sequentially:

- Channel Combination

-Background Neutralisation

- Extract Lightness component (CIE L*)

- saving the resulting gray image to file for using for Image Integration with "true" L



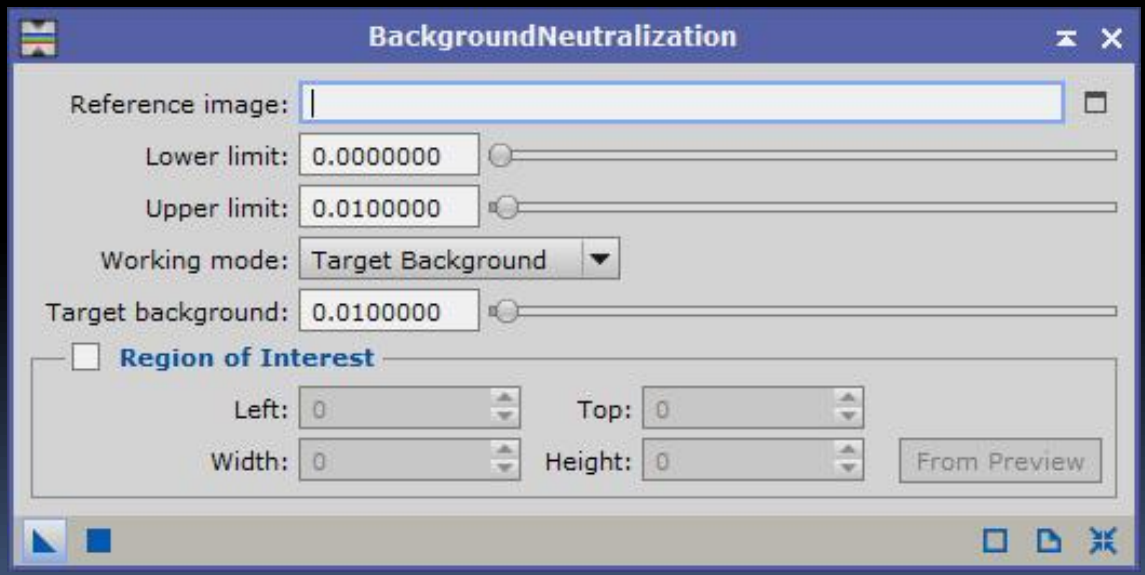


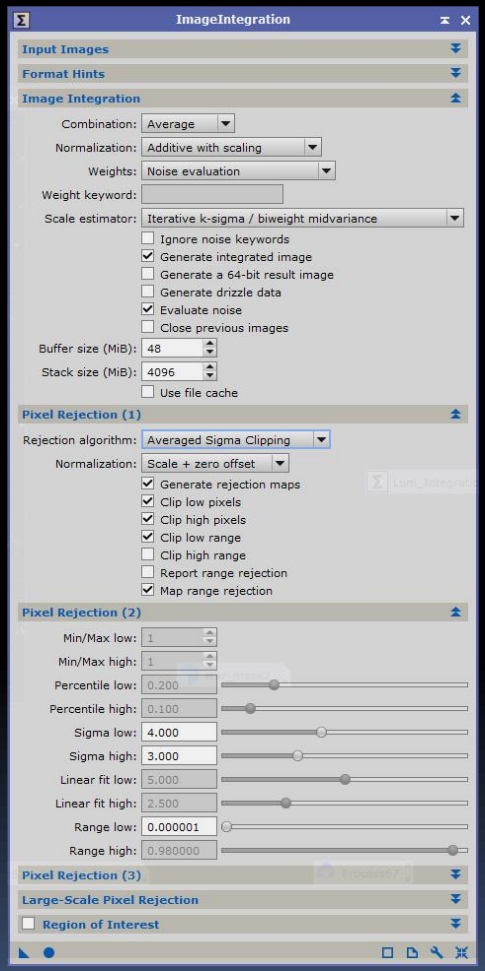
Image Integration: by channels

Sum (L) = 92 * L + 30 * (L fom RGB) = 122 frames

Process parameters are selected based on the minimum value of "Gaussian noise estimates" in the "Process console"

```
MRS noise evaluation: done
Computing noise scaling factors: done

Gaussian noise estimates  : 2.1148e-05
Scale estimates           : 3.7088e-05
Location estimates        : 5.3144e-03
SNR estimates             : 1.2381e+05
Reference noise reduction : 1.5036
Median noise reduction    : 1.8689
```



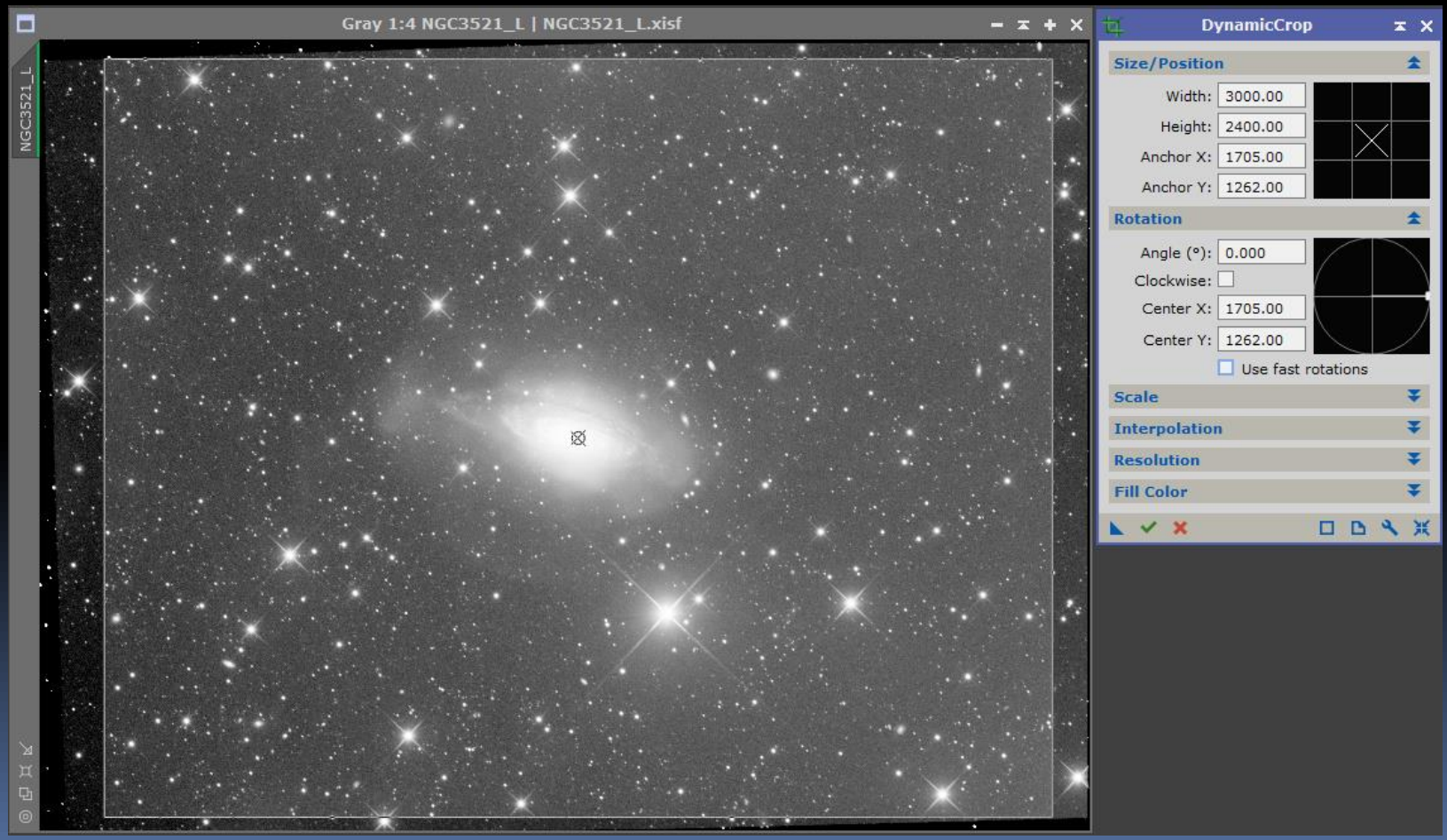
Astrophoto processing: part 2

- The second part of the processing is creative.
- It is performed only if there is inspiration ☺
- I presume that all objects of nature are initially harmonious.
- The aim of an astrophotographer during processing is to preserve this harmony and open it to the audience.

- cropping frame
- removing background gradients
- deconvolution
- noise reduction
- color correction
- nonlinear transformations
- color correction
- color enhancement

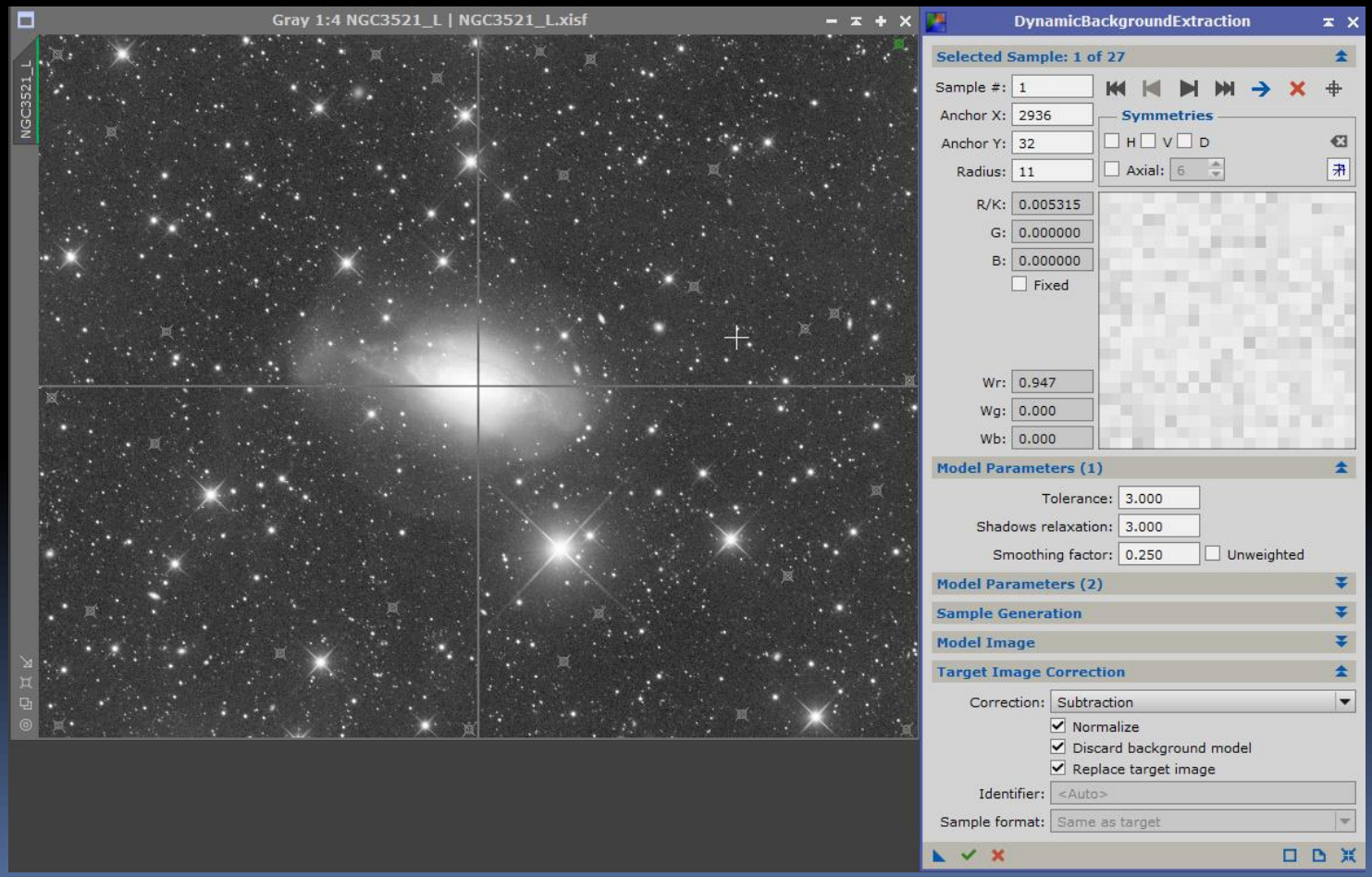
Dynamic crop (all channels)

- Allows you to cut off the effects of different framing at the edges of the frame
- Allows you to adjust the layout and composition of the image.



DBExtraction (all channels)

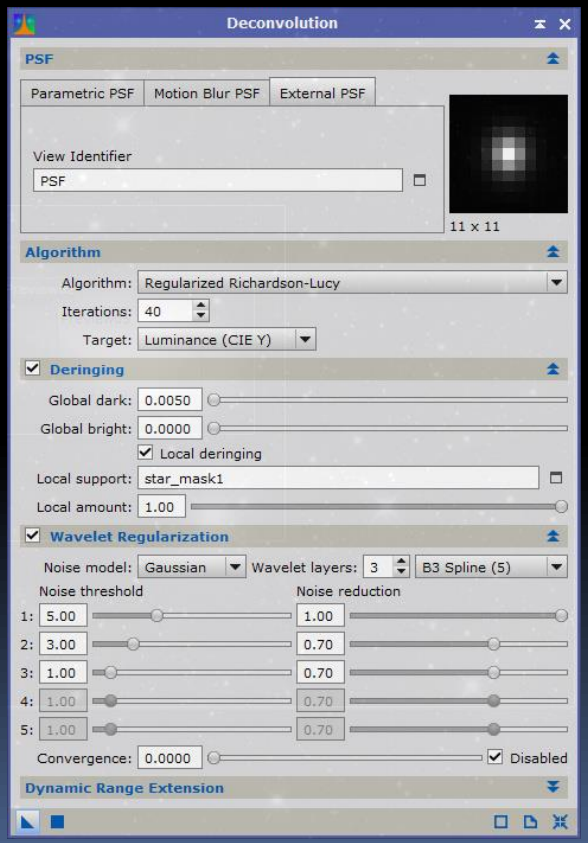
-Aligns background irregularities caused by sky flare and errors in the application of FLAT correction



Deconvolution (only L sum.) Based in **Processing example by Juan Conejero**

https://pixinsight.com/examples/M81M82/index.html

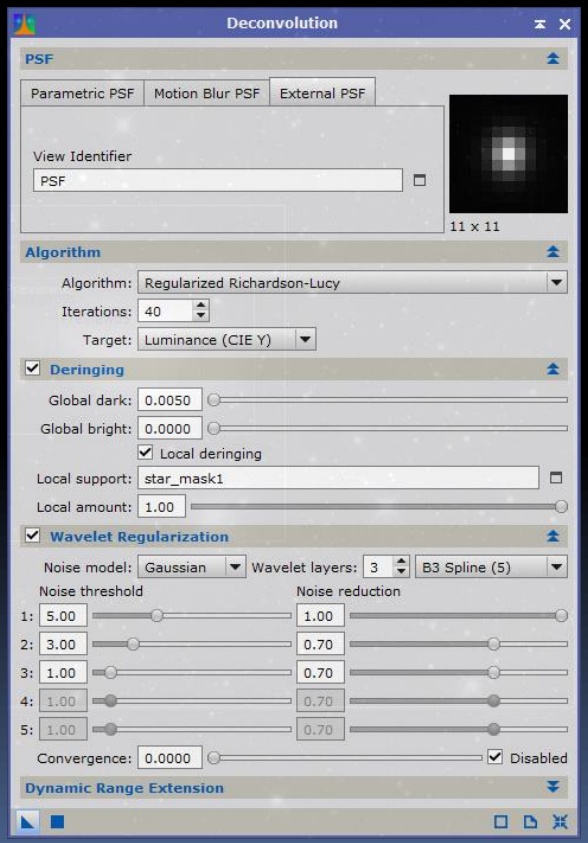
Process



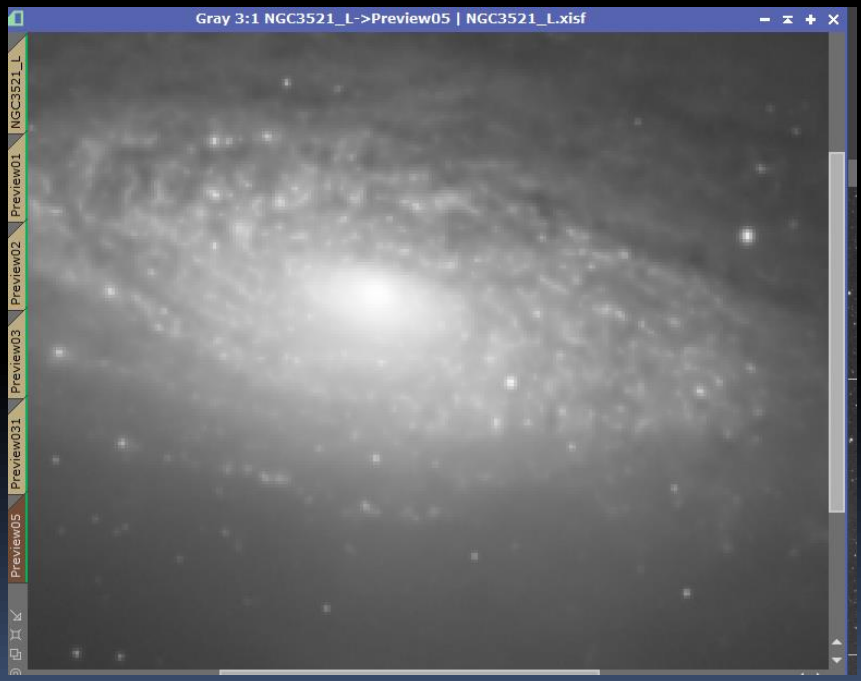
Before

Deconvolution (only L sum.) Based in **Processing example by Juan Conejero**
https://pixinsight.com/examples/M81M82/index.html

Process

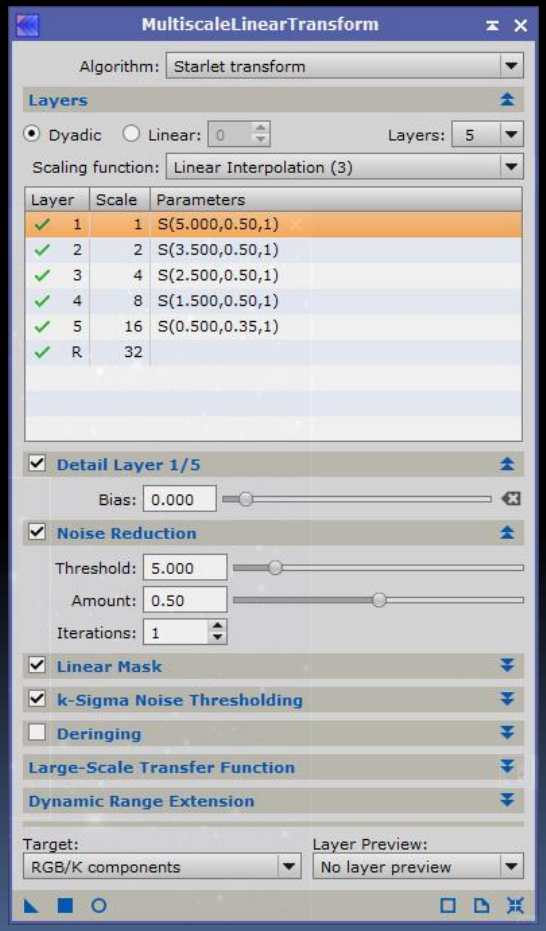


After



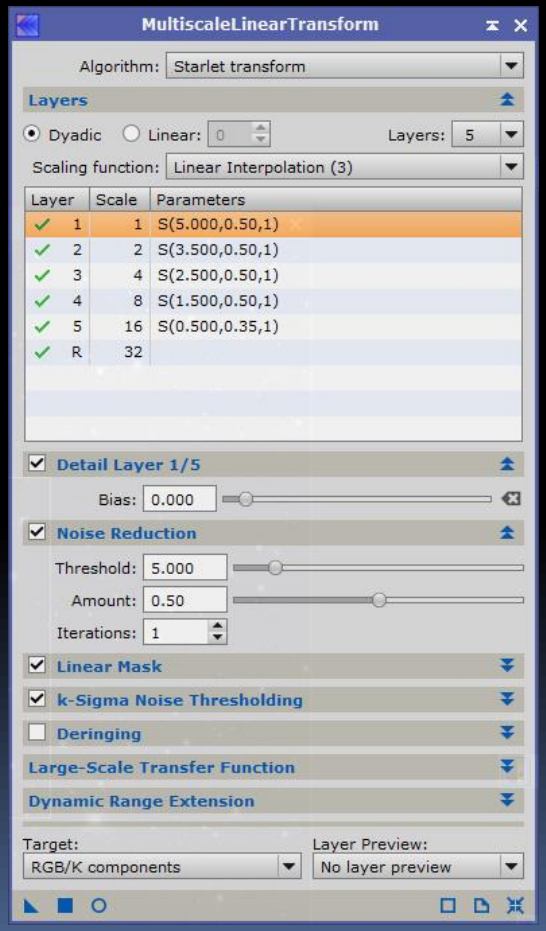
MultiscaleLinearTransform – decreasing background noise

Before MLT

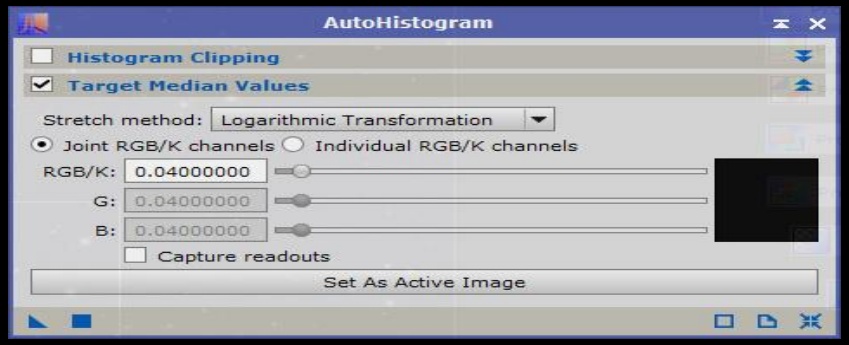


MultiscaleLinearTransform – decreasing background noise

After MLT

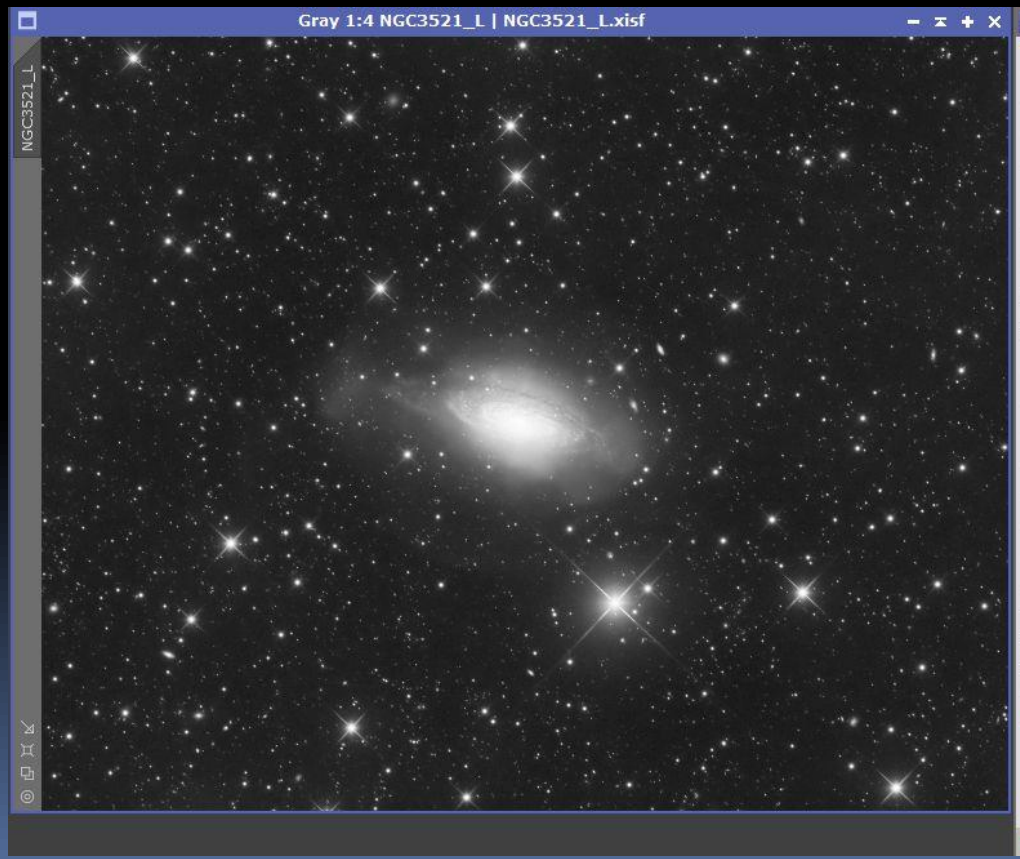


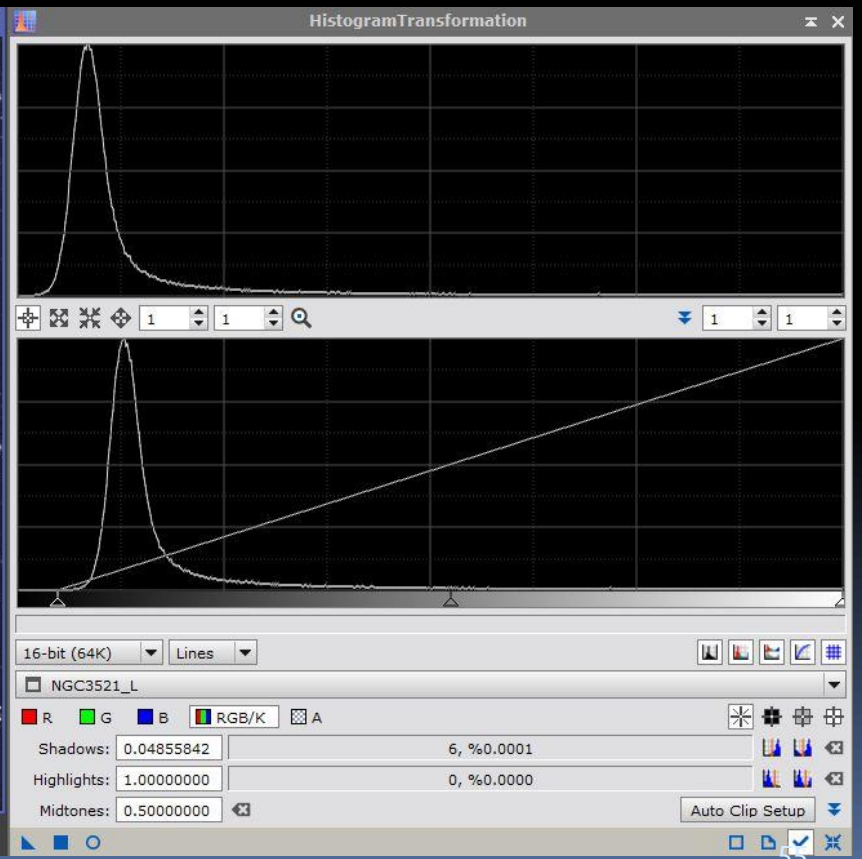
Non-linear Transformation



For two passes:

1. **Autohistogram**
2. **Histogram Transformation**



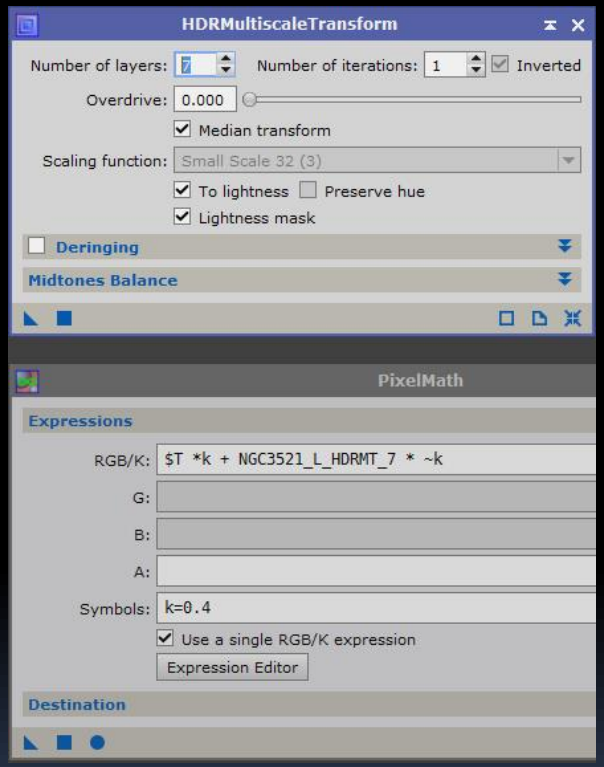


HDR Multiscale Transform for core of galaxy

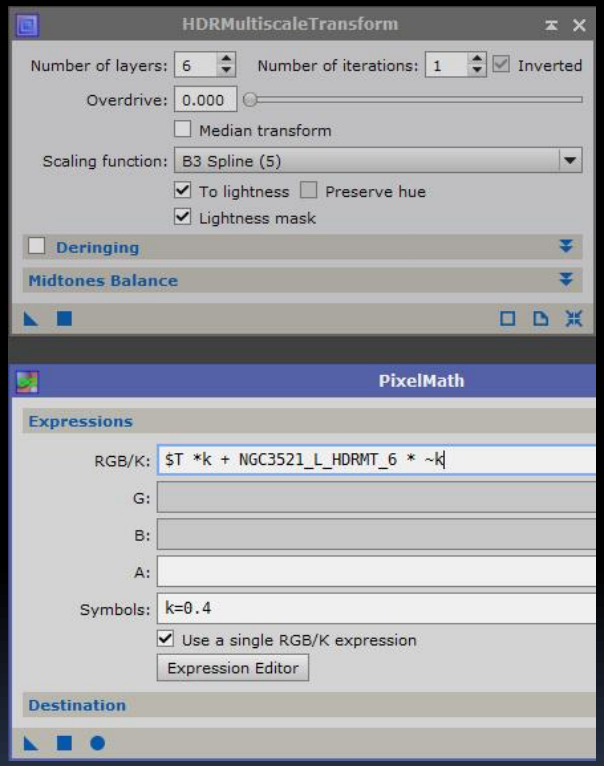
- Original image

Four consecutive iterations of the following algorithm:
- duplicate image
- apply star mask
- apply HDRMT with "Number of layers" from 7 to 4
- apply PixelMath with previous image having k=0.3 -0.4

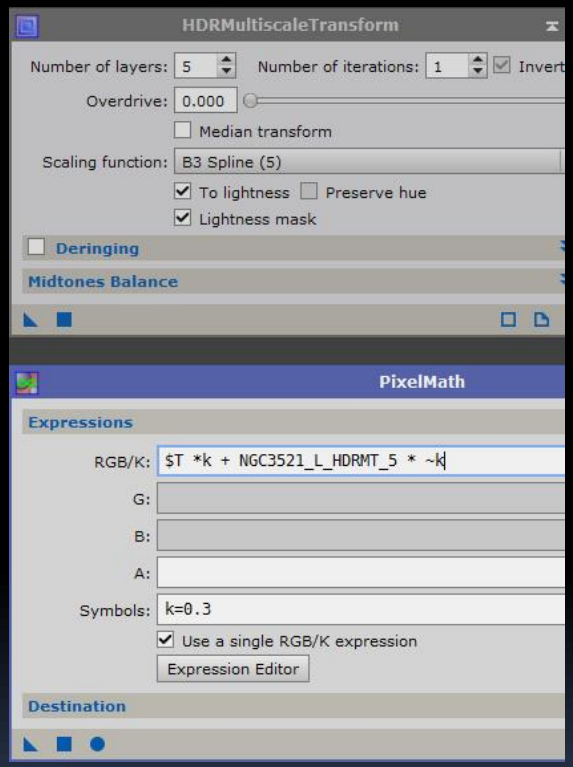
Apply HDRMT – 7 layers



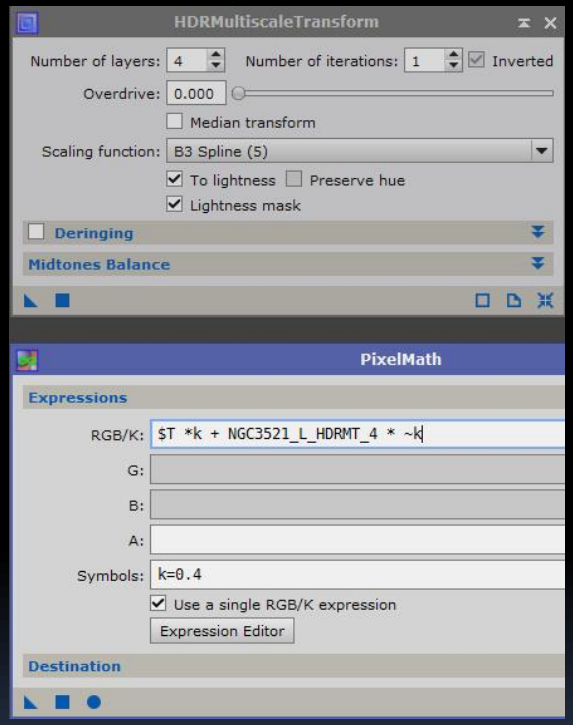
Apply HDRMT – 6 layers



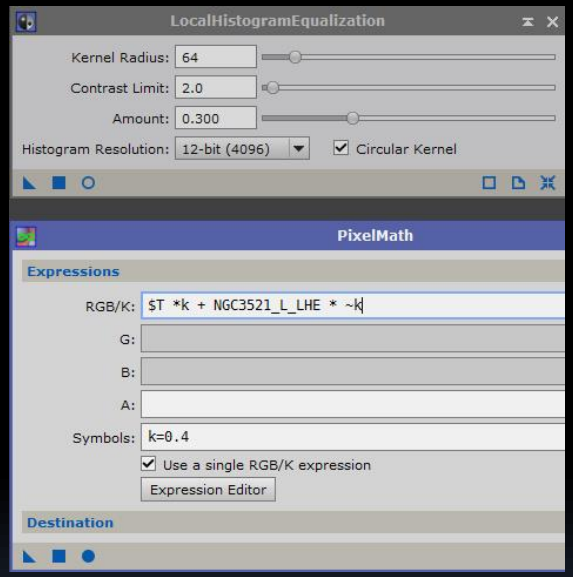
Apply HDRMT – 5 layers



Apply HDRMT – 4 layers

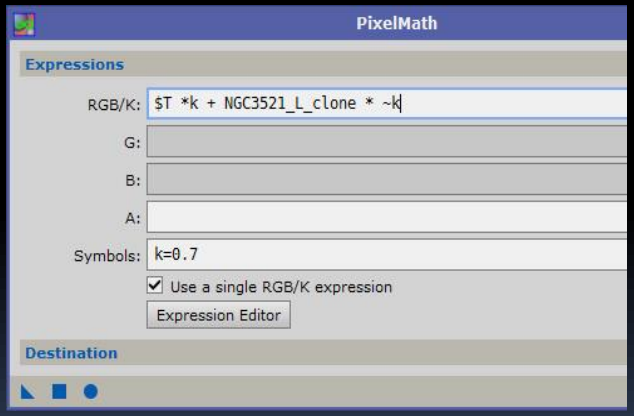


Alpply Local Histogram Ewualization

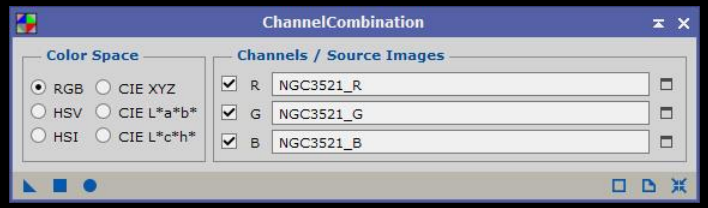


Alpply PixelMath with ORIGINAL image

Final L channel

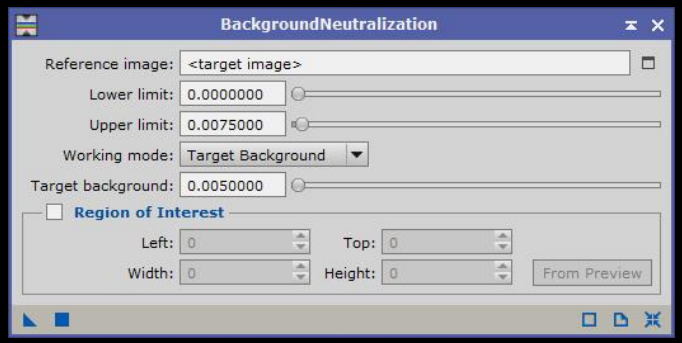


RGB – Channel combination



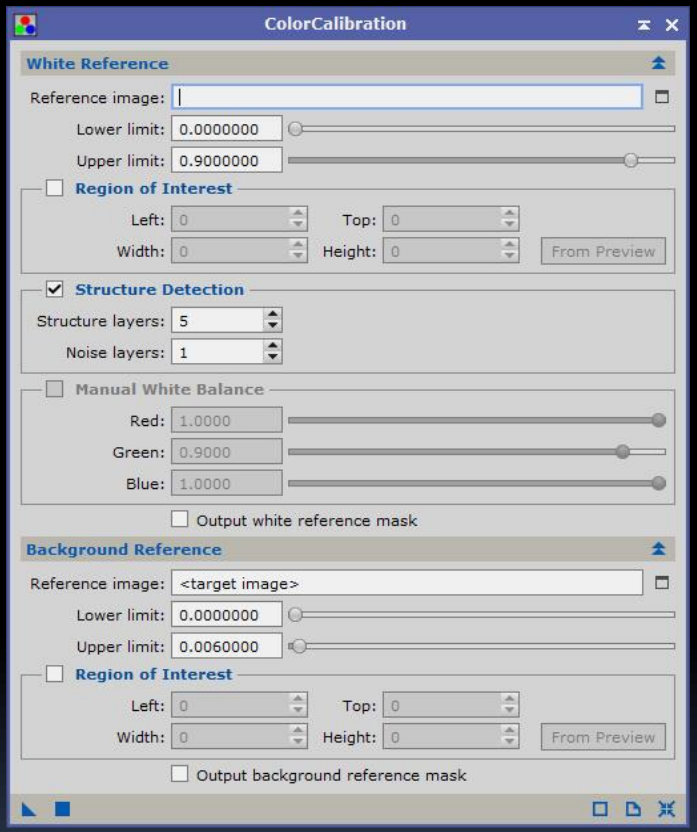
Auto Stretch (STF)

RGB – Background Neutralisation



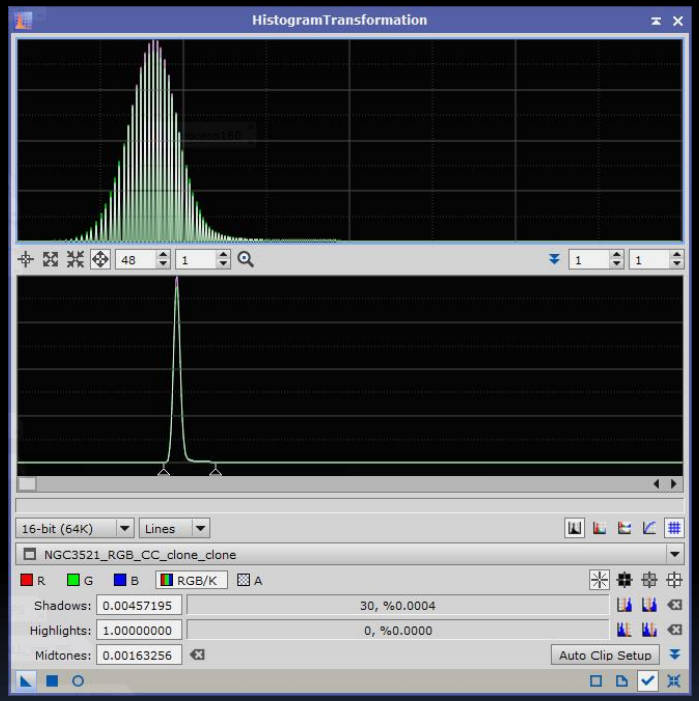
Auto Stretch (STF)

RGB – Color calibration

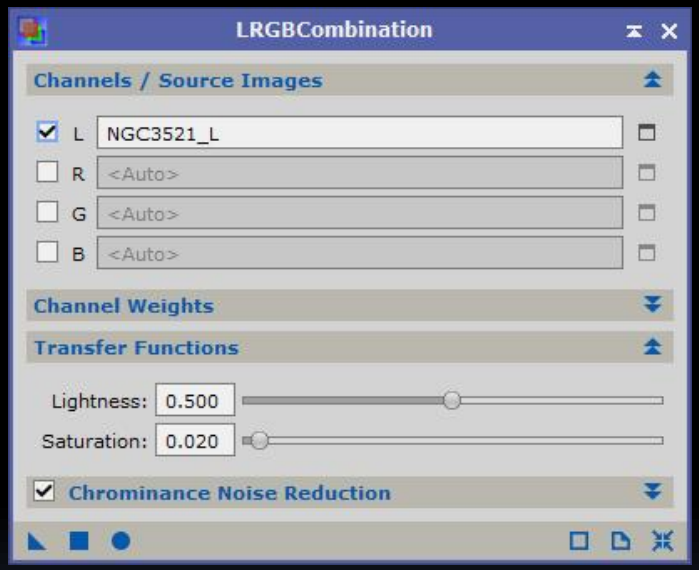


Auto Stretch (STF)

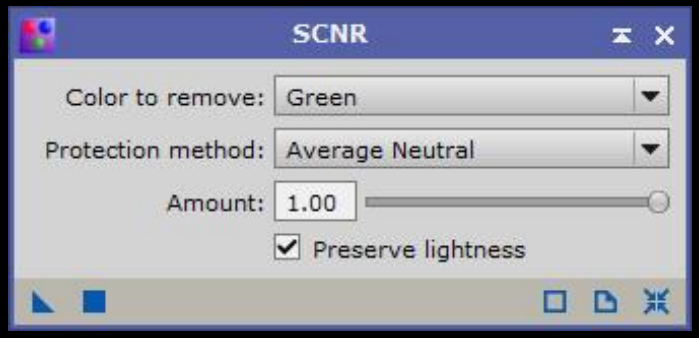
RGB – Histogram Transformation



RGB – LRGB combination

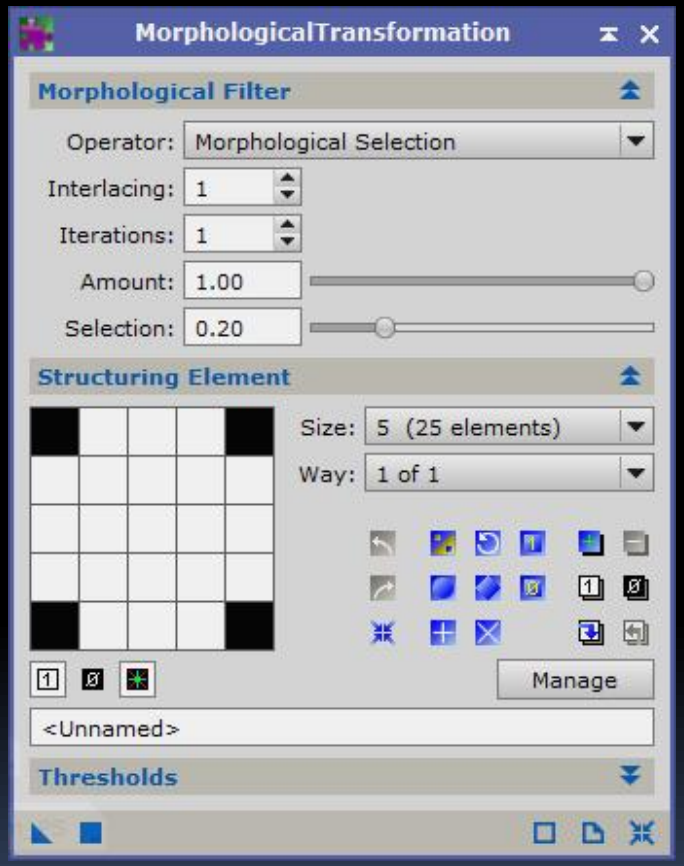


LRGB – reducing green tint



RGB – Rotation

LRGB – Reducing star size



Based in tutorial by [Gerald Wechselberger](http://www.werbeagentur.org/oldwexi/PixInsight/PixInsight.html)
http://www.werbeagentur.org/oldwexi/PixInsight/PixInsight.html

My next dream:

- Mount and telescope from "White Swan Telescopes Company" from Ukraine

- New Direct Drive mount
- Telescope up to 1 m.

Thank you!

Oleg Bryzgalov
http://olegbr.astroclub.kiev.ua/ https://www.flickr.com/photos/olegbr/