Image acquisition and processing using low budget setups



Oleg Bryzgalov <u>https://www.flickr.com/photos/olegbr/</u> <u>http://olegbr.astroclub.kiev.ua/</u> 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Probably, someone will disagree, someone will consider all this as "outdated" equipment with unacceptable expenditure of time and resources.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 10inch 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 blackand-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.



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





2009 : The first attempts of astrophoto

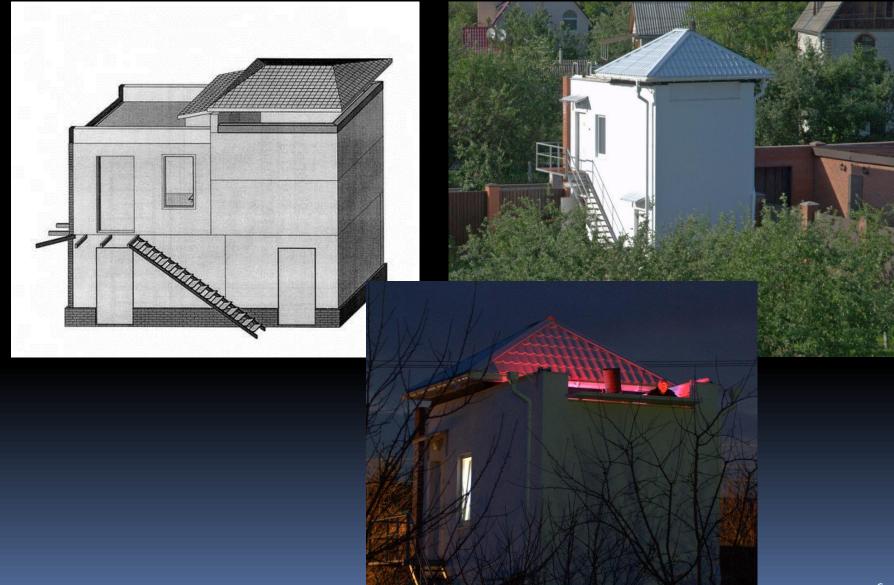
Reflector SkyWatcher 10" with DSLR camera
"Nikon D8o"



Refractor SkyWatcher ED8o



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

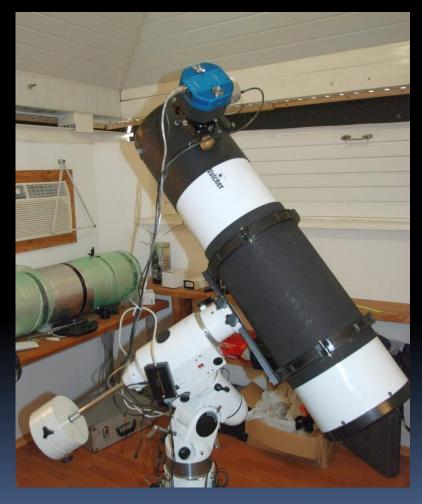


2010-2019. New stage: cooled CCD camera QSI-583wsg

Filter sets: 2010-2011 2012-2016 2016-2019

Astronomik Baader Planetarium Astrodon gen.ll





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

NGC 7380



Mel15 (IC1805)

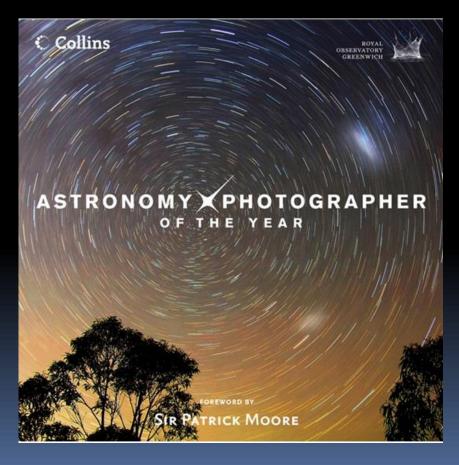


2011 – New mount WS-180 (made in Ukraine). In this astrograph from "SkyWatcher" only the main mirror and its rim remain.

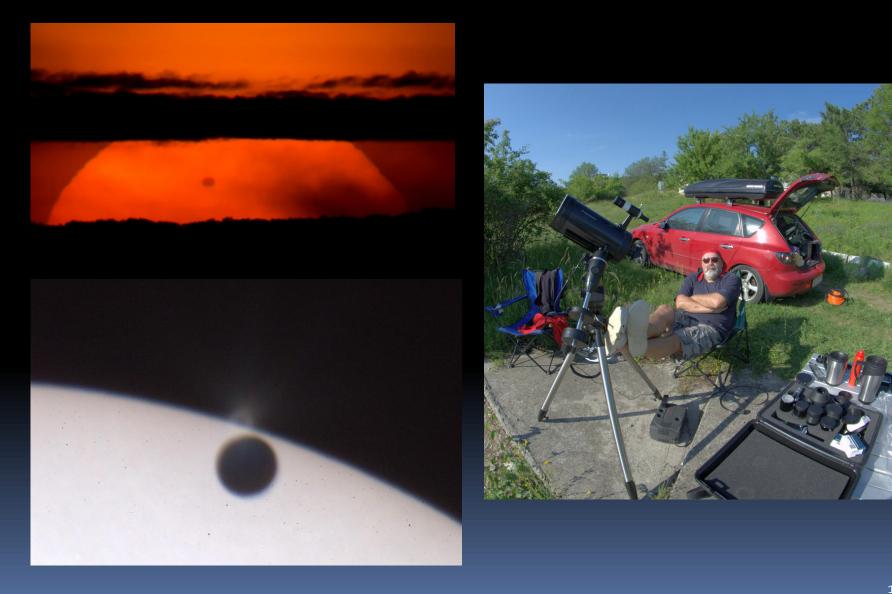


2011, june. First shot "Ghost of the Cepheus Flare" on a new mount with an upgraded astrograph awarded "Highly Commended" in "Astronomy Photographer Of The Year 2012"

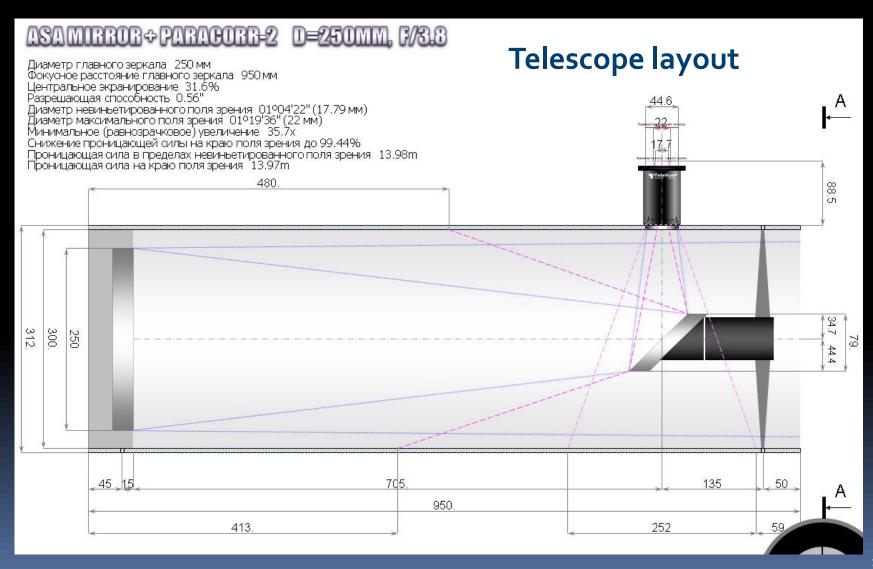




06.06.2012: Unforgettable Venus transit 😊



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



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)

Olea Bryzasłov dwybryski ródniawa - tódniawia zaz Pazersan dona Parel delarie druge das danar	ations were an an an an
na caland - When d-	

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



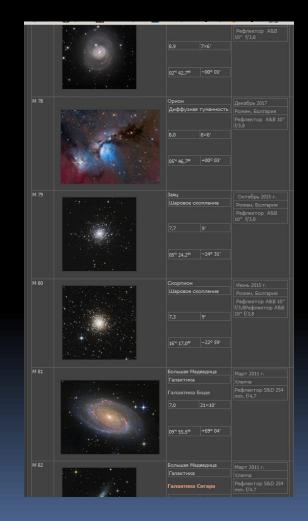


Photo M63 is "Galaxies" category winners of the "Insight Investment Astronomy Photographer of the Year 2017" competition <u>https://www.rmg.co.uk/whats-on/astronomy-</u> <u>photographer-year/galleries/2017/galaxies</u>



The main components of the "Telescope of my dream"

Main mirror 10" F/3.8 bought at ASA https://www.astrosysteme.com/



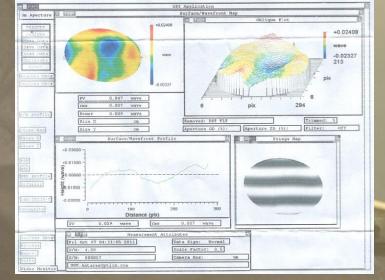
E

Secondary mirrors (3.1" and 4" (1/20 Wave PW) for different coma-correctors bought in "Antares Optics"

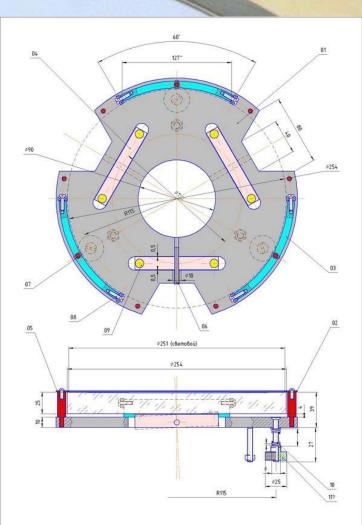
http://www.antaresoptics.com/

ANTARES

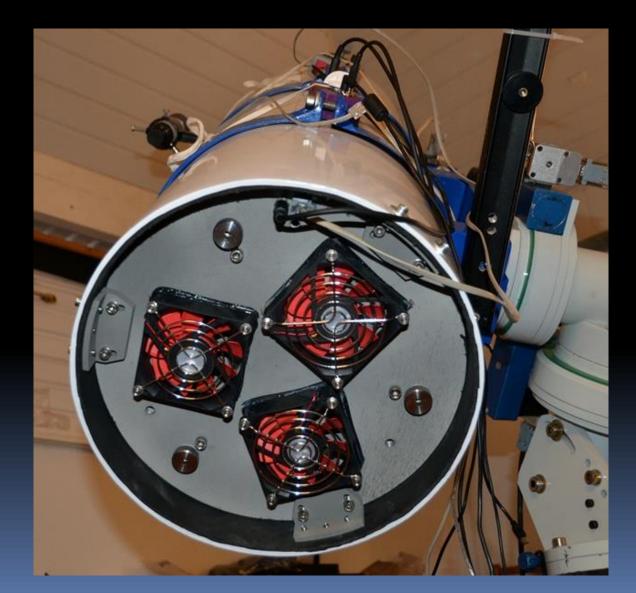
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The telescope should allow the use of various coma-correctors depending on the camera. The holder of the main mirror should be able to move inside the pipe (like a piston)



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 <u>http://focuser.com/</u>





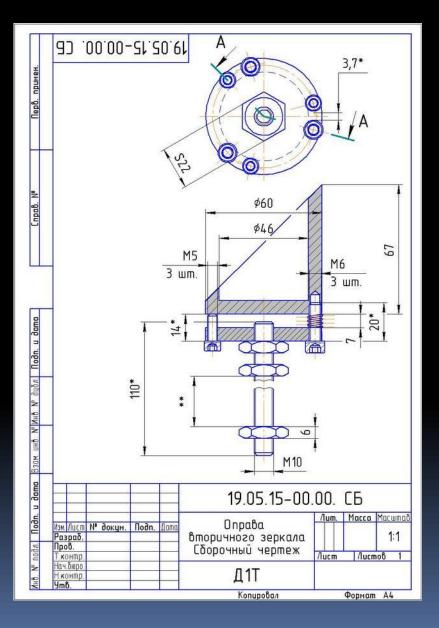
Carbon tube 6 mm thickness and a diameter of 300 mm from Klaus Helmerich http://www.klaushelmi.de/ The tube is plastered outside with a white oracal. Inside - black flock







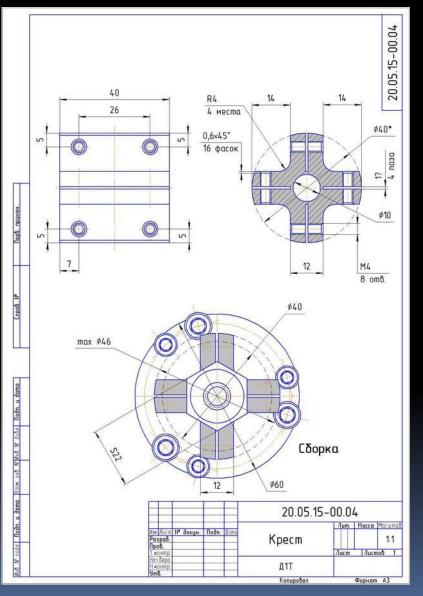
The secondary mirror holder is made on a CNC machine







"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

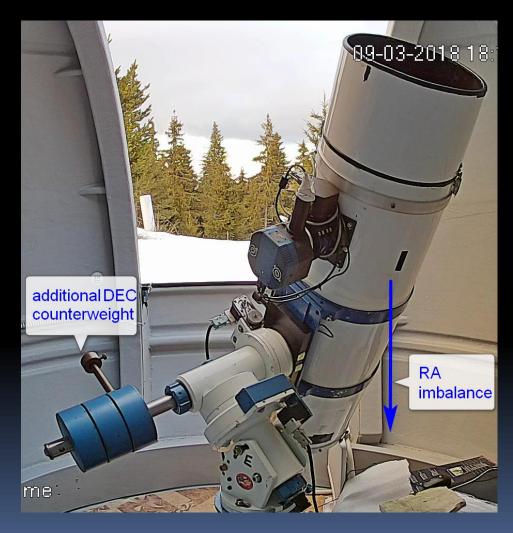


During the session, careful monitoring of the results obtained.

- 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.

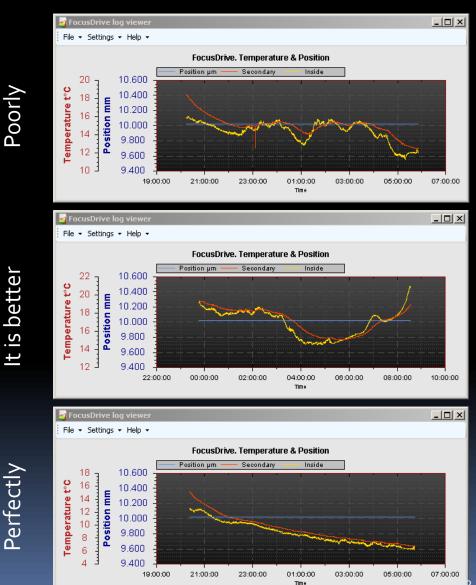
In the process of imaging:

- 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!



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

1	А	В	С	D	E	F	G	Н	1	J
1	Date	CCD temp	BIAS	DARK-600	DARK-Flat	L	R	G	В	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=2.4	9"								
21	FWHM 1.9	8"-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.

 If there is a collection of enough fresh "correct" calibration files:
 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:

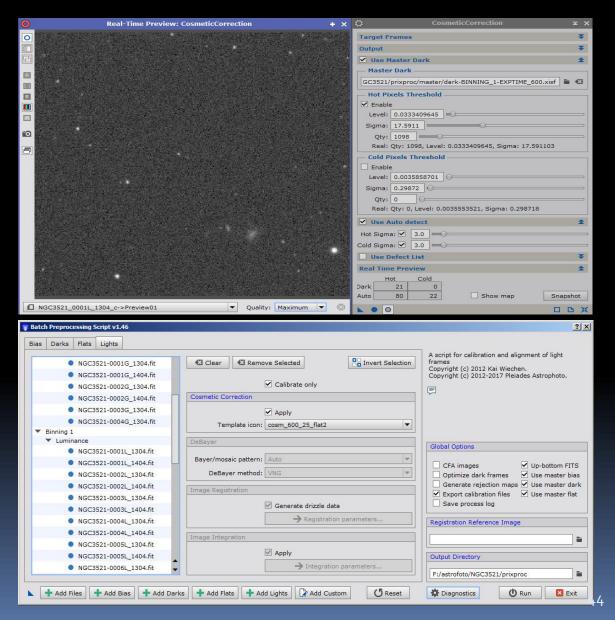
Checkbox "Optimize Dark Frames" is not needed!

Batch Preprocessing Script v1.46 Bias Darks Flats Lights		<u>[2]</u>
 ▼ Binning 1 ▼ Luminance NGC3521-0001L_1304.fit 	Clear Clear Calibrate only Cosmetic Correction Apply Template icon: cosm.600_27_flat1	A script for calibration and alignment of light frames Copyright (c) 2012 Kai Wiechen. Copyright (c) 2012-2017 Pleiades Astrophoto.
	DeBayer Bayer/mosaic pattern: Auto DeBayer method: VNG Image Registration	Global Options CFA images Up-bottom FITS Optimize dark frames Use master bias Generate rejection maps Use master dark Export calibration files Use master flat
	Generate drizzle data Registration parameters Image Integration	Registration Reference Image
+ Add Files + Add Bias + Add Dar	Apply Integration parameters Add Flats Add Lights Add Custom C Reset	Output Directory F:/astrofoto/NGC3521/prixproc

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"

StarAlignment	× ×
Reference image: 521-0004L_0903_c_cc_reference	e.xisf File 🔻 🔻
Distortion model:	43
Undistorted reference	
Registration model: Projective Transformation	
Spline smoothness: 0.25	
Distortion correction	
Distortion residual: 0.005	()
Distortion iterations: 20	20
Working mode: Register/Match Images 🔻	
Generate masks	
Generate drizzle data Frame adaptation	
Target Images	*
	Add Files
1 VGC3521-0001B_0804_c_cc.xisf	
2 V NGC3521-0001B_0903_c_cc.xisf	Add Views
3 ✓ NGC3521-0001B_0904_c_cc.xisf 4 ✓ P NGC3521-0001B 1104 c cc.xisf	Select All
4 ✓ P NGC3521-0001B_1104_c_cc.xisf 5 ✓ P NGC3521-0001B_1204_c_cc.xisf	Invert Selection
6 ✓ [] NGC3521-0001B_1204_c_cc.xisf	Toggle Selected
7 V [] NGC3521-0001B_1404_c_cc.xisf	Remove Selected
8 ✓ [ⁿ NGC3521-0001G_0804_c_cc.xisf	Clear
9 C NGC3521-0001G 0903 c cc.xisf	Full paths
Format Hints	Ŧ
Output Images	\$
Output directory: F:/astrofoto/NGC3521/aligned	
	sk: m
Sample format: Same as target	
	error: Continue 💌
Star Detection	¥
Star Matching	¥
Interpolation	¥

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

-	ChannelCombination		
- Color Space			
● RGB ○ CIE XYZ	R NGC3521_0001R_0804_c_cc		
○ HSV ○ CIE L*a*b*	G NGC3521_0001G_0804_c_cc		
○ HSI ○ CIE L*c*h*	B NGC3521_0001B_0804_c_cc		

H	BackgroundNeutralizatio	m x
Reference image:	ĺ	
Lower limit:	0.0000000	
Upper limit:	0.0100000	
Working mode:	Target Background	
Target background:	0.0100000	
	erest	
Left:	0 🧘 Top: 0	A V
Width:	0 🗘 Height: 0	From Preview

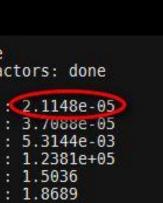
Image Integration: by channels

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



Σ	ImageIntegration	<u> </u>				
Input Images		¥				
Format Hints		Ŧ				
Image Integration	n	*				
Combination:	Average 💌					
Normalization	Additive with scaling					
Weights:	Noise evaluation					
Weight keyword:						
Scale estimator:	Iterative k-sigma / biweight midvariance					
	Ignore noise keywords Generate integrated image					
	Generate a 64-bit result image					
	Generate drizzle data					
	Evaluate noise Close previous images					
Buffer size (MiB):						
Stack size (MiB):						
	Use file cache					
Pixel Rejection (1)	*				
Rejection algorithm:	Averaged Sigma Clipping 💌					
Normalization:	Scale + zero offset 🔻					
	Generate rejection maps					
	Clip low pixels Clip high pixels					
	Clip high pixels Clip low range					
	Clip high range					
	Report range rejection Map range rejection					
Division for the state						
Pixel Rejection (2		-				
Min/Max low:						
Min/Max high:						
Percentile low:						
Percentile high:						
Sigma low:						
Sigma high:						
Linear fit low:						
Linear fit high:						
	0.000001					
Range high:						
Pixel Rejection (3		*				
Large-Scale Pixel		¥				
Region of Inte	rest	¥				
L •	0 0	× ж				

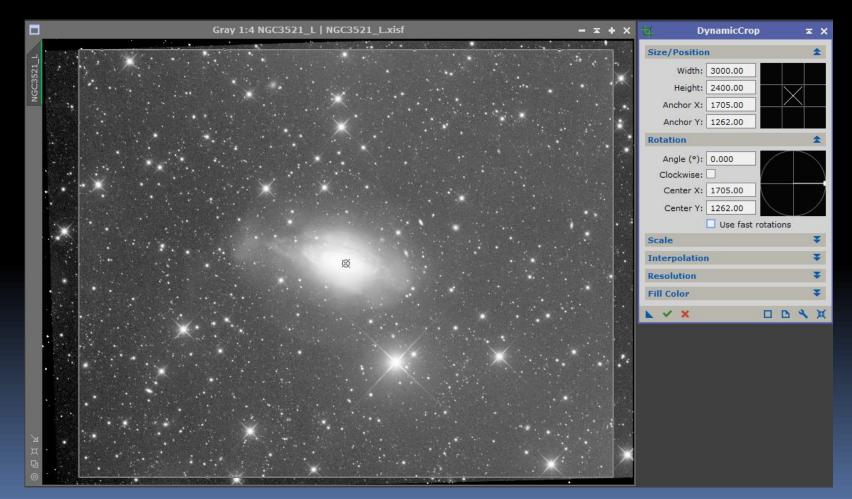
Astrophoto processing: part 2

- The second part of the processing is creative.
- It is performed only if there is inspiration ^(C)
- 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

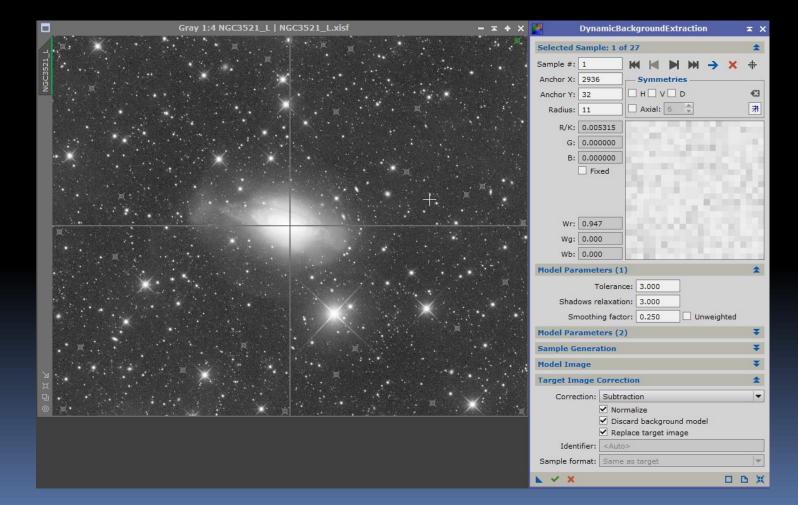
Dynamic crop (all channels)

- 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

Before

<u>*</u>	Decor	volution		x x
PSF				*
Parametric PSF	Motion Blur PSF	External PSF		-
View Identifier				
PSF				
			11 x 11	-
Algorithm				*
Algorithm:	Regularized Richar	dson-Lucy		-
Iterations:	40 🗘			
Target:	Luminance (CIE Y)	•		
Deringing				*
Global dark:	0.0050			
Global bright:	0.0000			3
5	Local deringing			
Local support:				
Local amount:	1.00			=0
✓ Wavelet Reg	ularization			*
	Gaussian 🔻 Wa		B3 Spline (5)	•
Noise threshold		Noise reductio	n	
	0	1.00		-0
2: 3.00		0.70		
4: 1.00				
4: 1.00		0.70		
Convergence:	0.0000	0.70	Disa	blad
Dynamic Range			Ulsa	T
	Extension			
				×

Process



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

	Decor	volution		× ×
PSF				\$
Parametric PSF	Motion Blur PSF	External PSF	-	
View Identifier				
PSF				COLUMN COL
			11 x 1	1
Algorithm				±
Algorithm:	Regularized Richar	dson-Lucy		-
Iterations:	40 🗘			
Target:	Luminance (CIE Y)	•		
Deringing				\$
Global dark:	0.0050 0			
Global bright:	0.0000			
	Local deringing			
Local support:	star_mask1			
Local amount:	1.00		-	0
✓ Wavelet Reg	ularization			*
Noise model:	Gaussian 💌 Wa	velet layers: 3	B3 Spline	(5) 💌
Noise threshold		Noise reductio	on	
1: 5.00	0	1.00		
2: 3.00		0.70		
3: 1.00 =		0.70	(
4: 1.00		0.70		
5: 1.00		0.70		
Convergence:	0.0000			 Disabled
Dynamic Range	Extension			¥

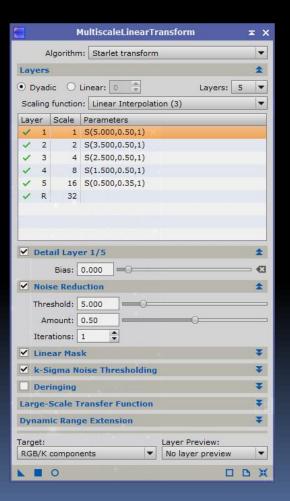
Process

After



MultiscaleLinearTransform - decreasing backround noise

Before MLT

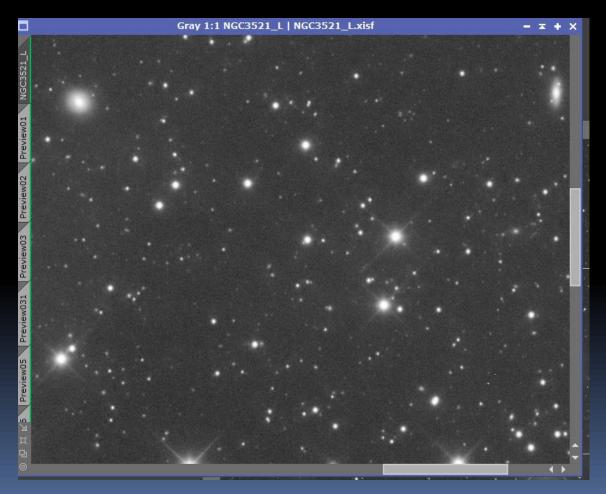




MultiscaleLinearTransform – decreasing backround noise

After MLT

X	MultiscaleLinearTra	ansform	×
Algorithn	n: Starlet transform		-
Layers			\$
• Dyadic O	Linear: 0 🌻	Layers: 5	•
Scaling function	n: Linear Interpolatio	on (3)	-
Laver Scale	Parameters		
✓ 1 1	S(5.000,0.50,1)		
✓ 2 2	S(3.500,0.50,1)		
✓ 3 4	S(2.500,0.50,1)		
✓ 4 8	S(1.500,0.50,1)		
✓ 5 16	S(0.500,0.35,1)		
🗸 R 32			
Detail Lay Bias: Bias: Threshold: Amount: Iterations:	0.000 - sction 5.000 - 0.50 -		
Linear Mas	sk		¥
🖌 k-Sigma N	oise Thresholding		¥
Deringing			¥
Large-Scale T	ransfer Function		Ŧ
Dynamic Rang	je Extension		¥
Target: RGB/K compon	ents 💌	Layer Preview: No layer preview	•
N 0			DX

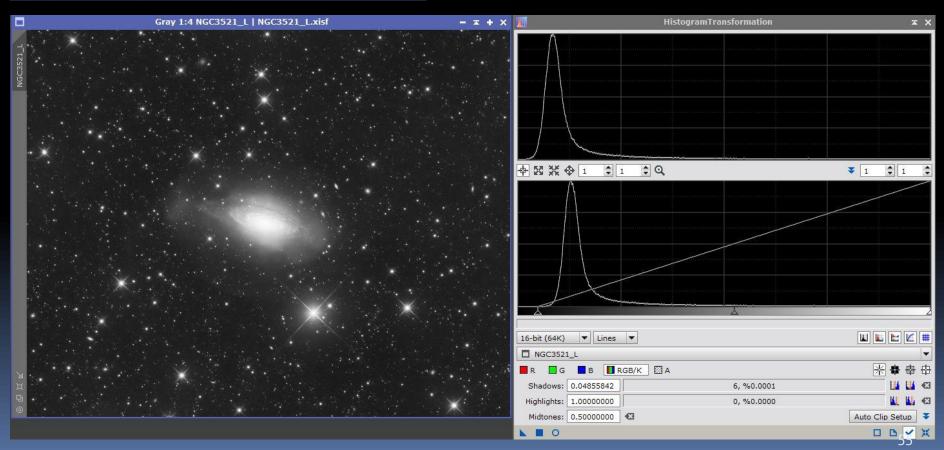


Non-linear Transformation

	AutoHistogram	× ×
Histo	gram Clipping	¥
Targe	et Median Values	*
Stretch r	method: Logarithmic Transformation 💌	
• Joint R	GB/K channels 🔘 Individual RGB/K channels	
RGB/K:	0.04000000 =	
G:	0.04000000	
в:	0.04000000	
	Capture readouts	
	Set As Active Image	

For two passes:

- 1. Autohistogram
- 2. Histogram Transformation

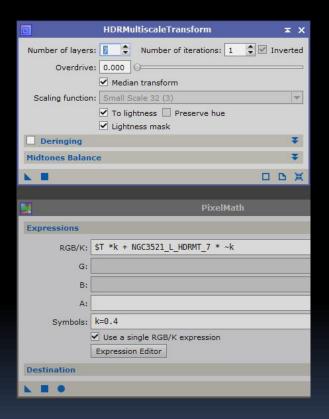


HDR Multiscale Transform for core of galaxy Original image

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

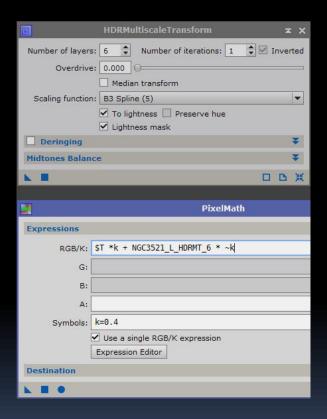


Apply HDRMT - 7 layers



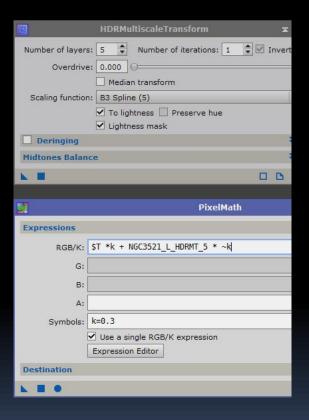


Apply HDRMT - 6 layers



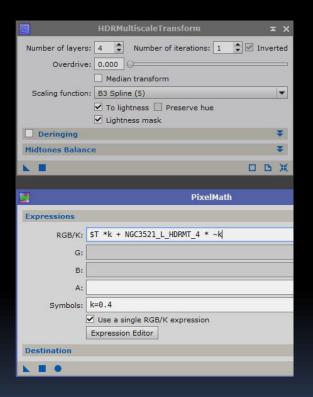


Apply HDRMT - 5 layers





Apply HDRMT - 4 layers





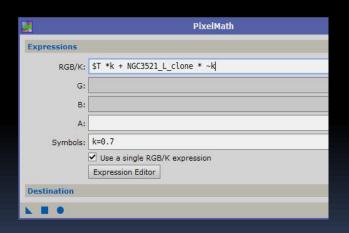
Alpply Local Histogram Ewualization

	LocalHistogramEqualization	жX
Kernel Radius:	64	
Contrast Limit:	2.0	
Amount:	0.300	
Histogram Resolution:	12-bit (4096) 💌 🗹 Circular Kernel	
N 0	0 1	з ж
3	PixelMath	
Expressions		
RGB/K: \$T	*k + NGC3521_L_LHE * ~k	
G:		
в:		
A:		
Symbols: k=0	0.4	
V u	Ise a single RGB/K expression	
Ext	pression Editor	
Destination		



Alpply PixelMath with ORIGINAL image

Final L channel





RGB - Channel combination

*	≖ X		
- Color Space	- Chan	nels / Source Images	
● RGB ○ CIE XYZ	🗹 R	NGC3521_R	
○ HSV ○ CIE L*a*b*	🗹 G	NGC3521_G	
○ HSI ○ CIE L*c*h*	🗹 в	NGC3521_B	



Auto Stretch (STF)

RGB - Background Neutralisation

×	BackgroundNeutralization 🗶 🗶	×
Reference image:	<target image=""></target>	1
Lower limit:	0.0000000	
Upper limit:	0.0075000	
Working mode:	Target Background 💌	
Target background:	0.0050000	
Region of Int	erest	1
Left:	0 🗘 Top: 0	
Width:	0 + Height: 0 From Preview	
		×



Auto Stretch (STF)

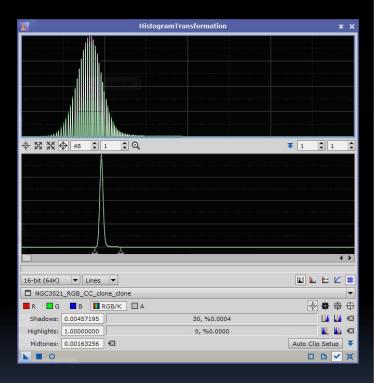
RGB - Color calibration

	ColorCalibration	≭ ×
White Reference		\$
Reference image:	Ì	
Lower limit:	0.0000000	
Upper limit:	0.9000000	
	nterest	
Left:	0 🗘 Top: 0 🌩	
Width:	0 🗘 Height: 0 🌩	From Preview
- Structure D	etection	
Structure layers:	5 🗘	
Noise layers:	1	
— 🗌 Manual Whi	te Balance	
Red:	1.0000	
Green:	0.9000	
Blue:	1.0000	
	Output white reference mask	
Background Refe	rence	\$
Reference image:	<target image=""></target>	
Lower limit:	0.0000000	
Upper limit:	0.0060000	
Region of I	nterest	
Left:	0 🗘 Top: 0 🗘	
Width:	0 🗘 Height: 0 🌩	From Preview
1	Output background reference mask	



Auto Stretch (STF)

RGB - Histogram Transformation





RGB - LRGB combination





LRGB - reducing green tint



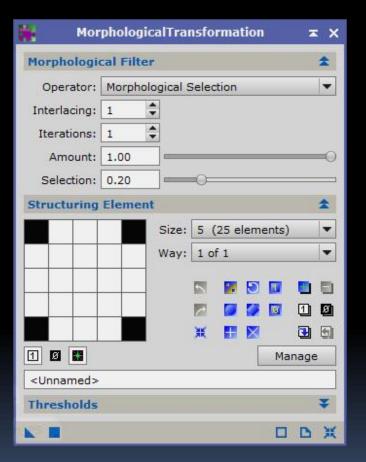


RGB - Rotation





LRGB - Reducing star size



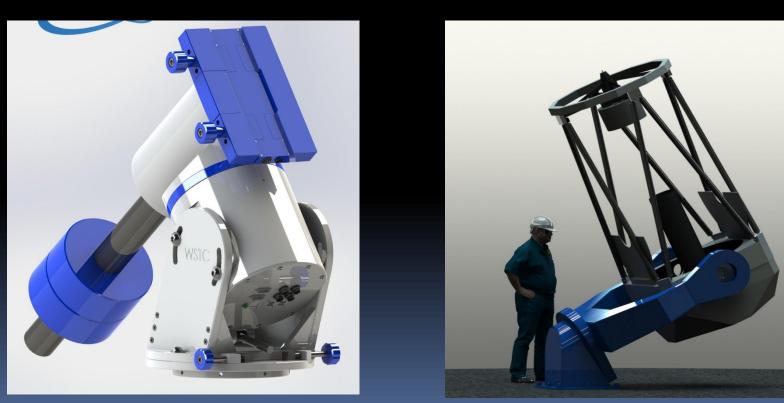


Based in tutorial by <u>Gerald Wechselberger</u> <u>http://www.werbeagentur.org/oldwexi/PixInsight/PixInsight.html</u>

My next dream:

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

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



Thank you!

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https://www.flickr.com/photos/olegbr/

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