PixInsight Workflow

Revision 2.0

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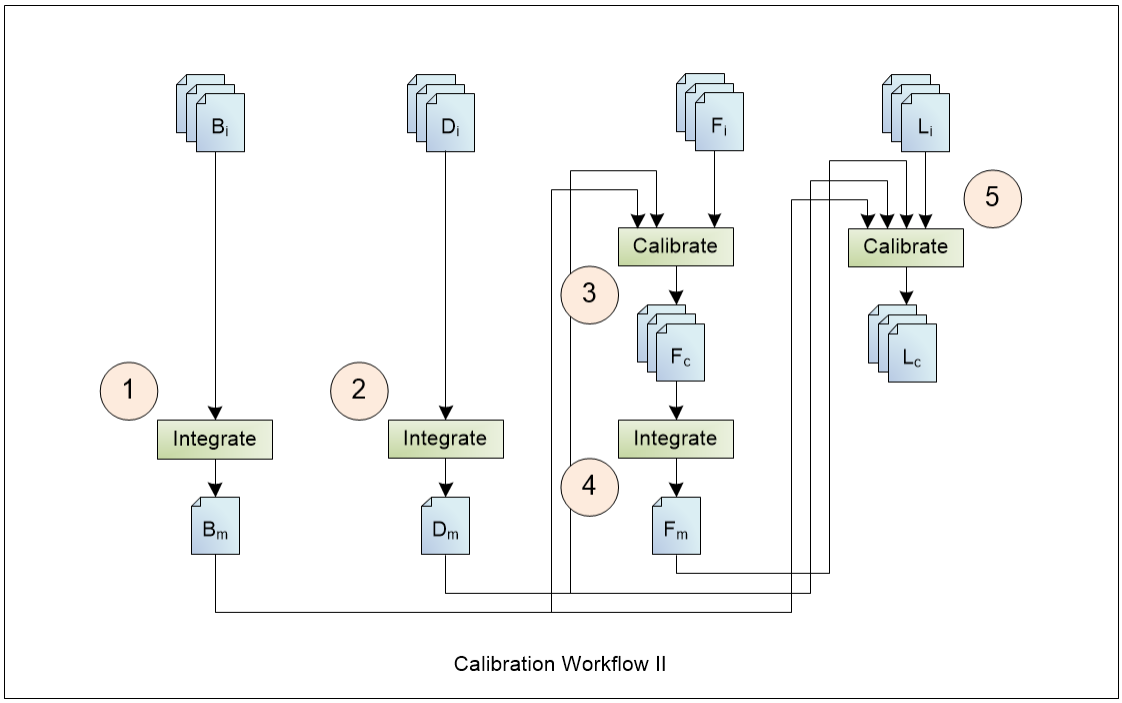
1.2 Calibration Workflow

The overall calibration workflow is shown below. The objective is:

- Create calibration masters for bias, dark and flat
- Calibrate dark with bias
- Calibrate flat with dark and bias
- Remove outliers caused by cosmic ray artifacts from bias, dark and flat
- Calibrate the lights with bias, dark and flat

The calibration of calibration frames can take place either before or after integration. Performing calibration post integration simplifies the process, but means that integration cannot use any kind of scaling within the set of frames.



Because we don't need to do scaling within the set of bias or darks, we just do integration with no pre-calibration, but include outlier rejection to get rid of cosmic rays.

For flats, we may need to account for variations in brightness within the set, so we need to do calibration pre-integration. Integration will also include outlier rejection.

Calibration of lights needs to include calibration of darks with bias, but no calibration of flats, because that will have already happened earlier in the process.

2 Linear Process Steps

2.1 Create Master Calibration Frames

2.1.1 Create Master Dark & Bias

For cleanest results, experimentation may be required to find the best rejection algorithm and parameters.

General recommendations for rejection algorithm:

- Percentile clipping for 3-6 images
- Averaged sigma clipping for 5-10 images
- Sigma clipping, Winsorized clipping or linear fit clipping for >10 images

Winsorized clipping has been shown to work well for large calibration sets.

Starting point for clipping parameters around 3.0 sigma for high pixels. Low parameter is not that important as there tend not to be low side outliers.

Consider creating an experimental stack first with no rejection, and then using the Blink tool to compare the rejected and non-rejected versions to ensure that only outliers (cosmic rays) have been rejected.

ImageIntegration->ImageIntegration

This is purely an image integration task.

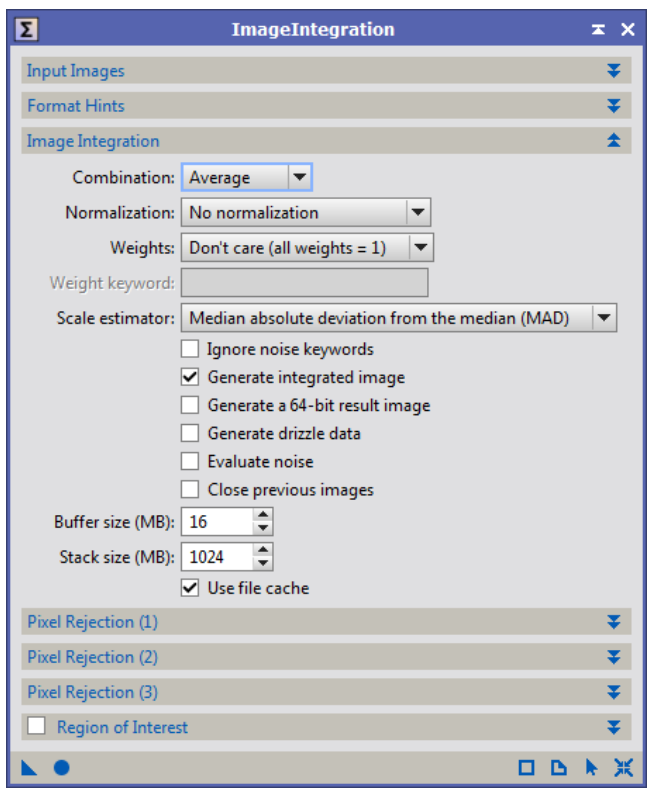
Integration panel:

Average combination

No normalization

Weights don't care

Generate integrated image checked, everything else unchecked



Pixel rejection (1):

Most likely best settings:

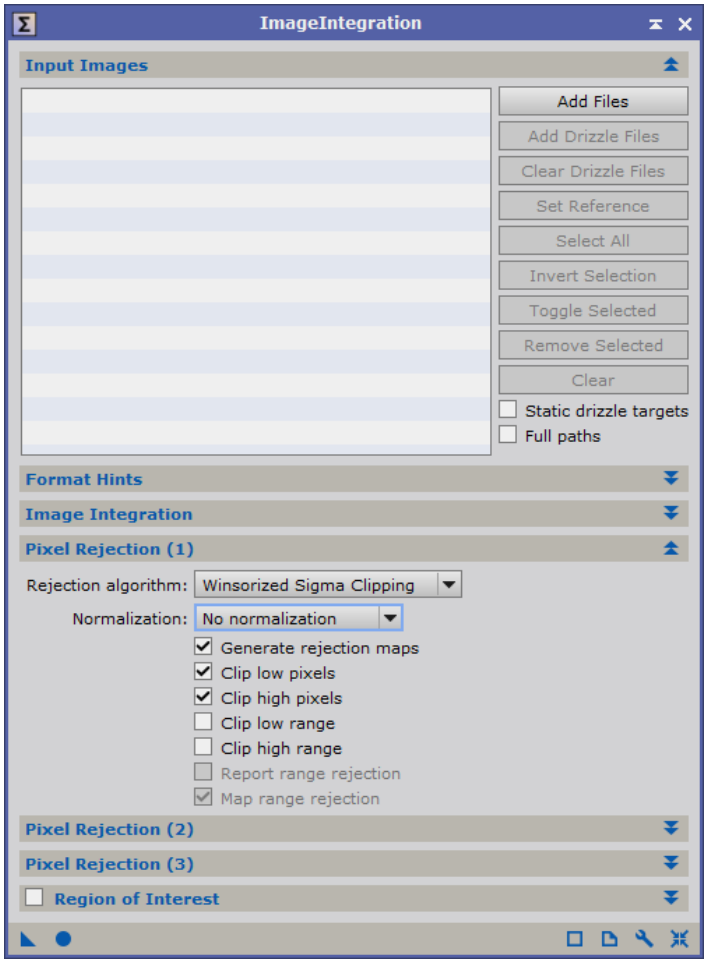
Winsorized sigma clipping
No normalization

Both checked:
Clip low pixels
Clip high pixels

This enables clipping based on the selected statistical rejection algorithm

Both unchecked:
Clip low range
Clip high range

This disables clipping of pixels based on absolute settings of brightness

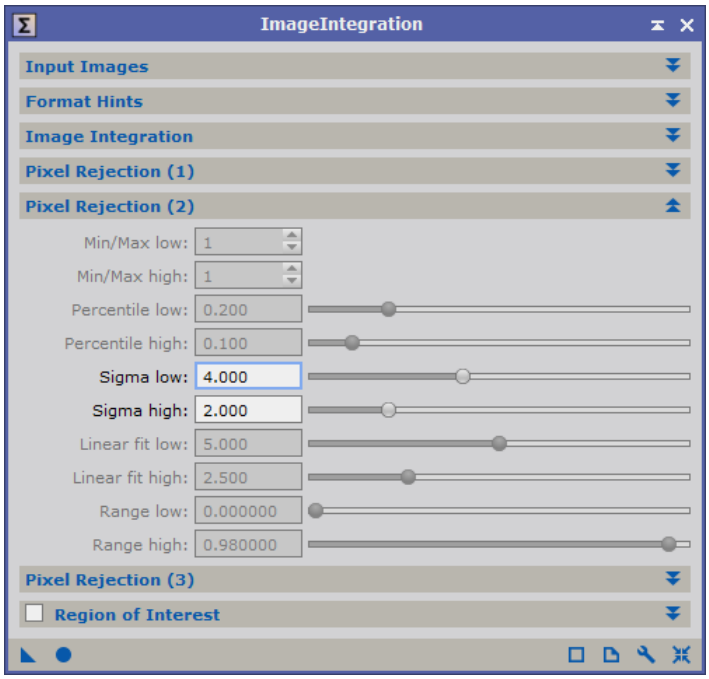


Pixel rejection (2):

Likely best settings:
Sigma low 4.0
Sigma high 3.0

Pixel rejection (3) panel is active only when CCD noise model rejection algorithm is selected

Region of interest should be unchecked



2.1.2 Create Master Flat

2.1.2.1 Calibrate Flats

ImageIntegration->ImageCalibration

Set prefix to Cal- and postfix to blank, check overwrite files

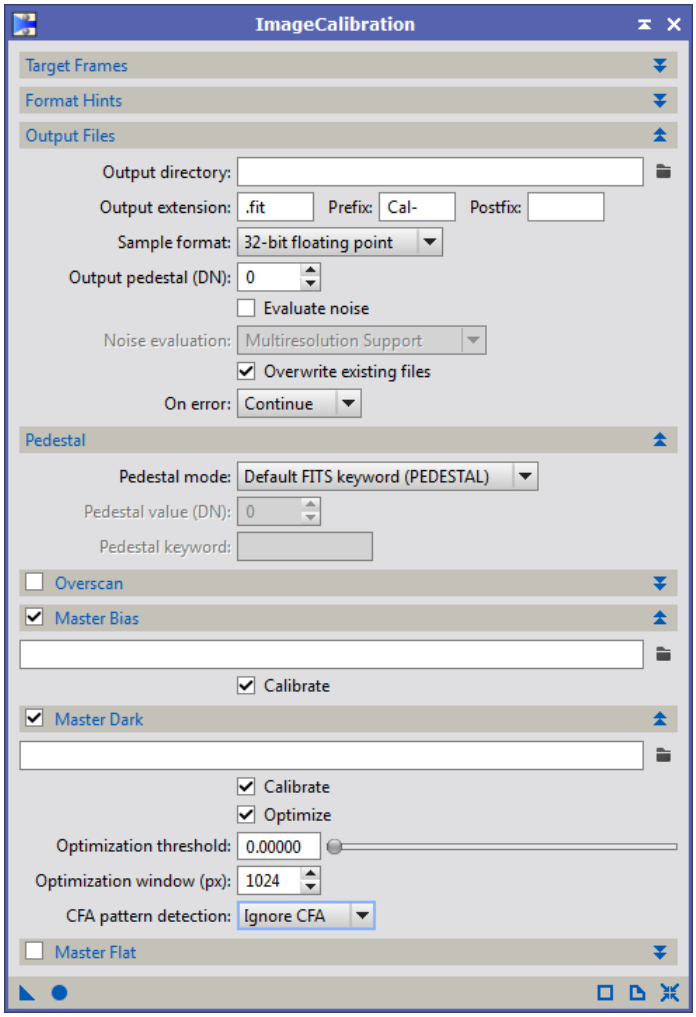
Use bias and dark calibration.

Calibrate box must be checked for master dark, because the dark is just a straight integration with no bias subtraction.

Ensure that optimize is checked for the master dark frame, in order to ensure that the dark frame will be scaled appropriately.

Also set CFA mode to Ignore CFA to disable the CFA detection algorithm.

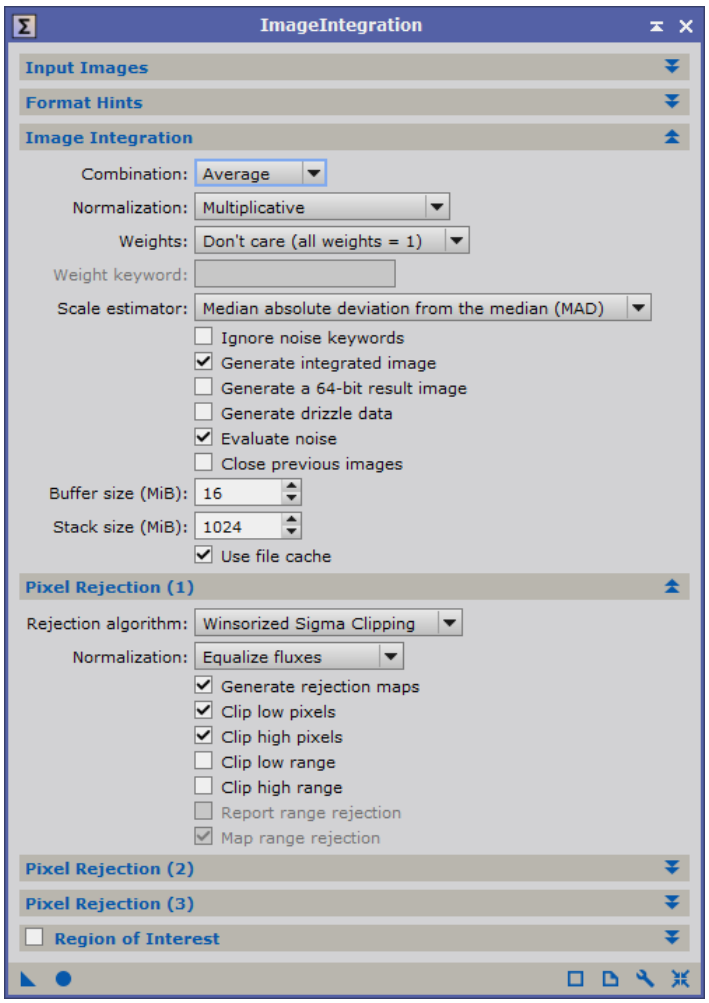
During the calibration process, there may be warning messages saying that no dark has been applied to some of the flats. This is not a problem; it just means that the optimization algorithm has determined that the optimum scaling factor for the dark component is zero.



2.1.2.2 Integrate Flats

ImageIntegration->ImageIntegration

Image Integration panel



Combination: Average

Normalization: Multiplicative

Weights: Don't care

The calibrated flats can be normalized for brightness by using the multiplicative setting.

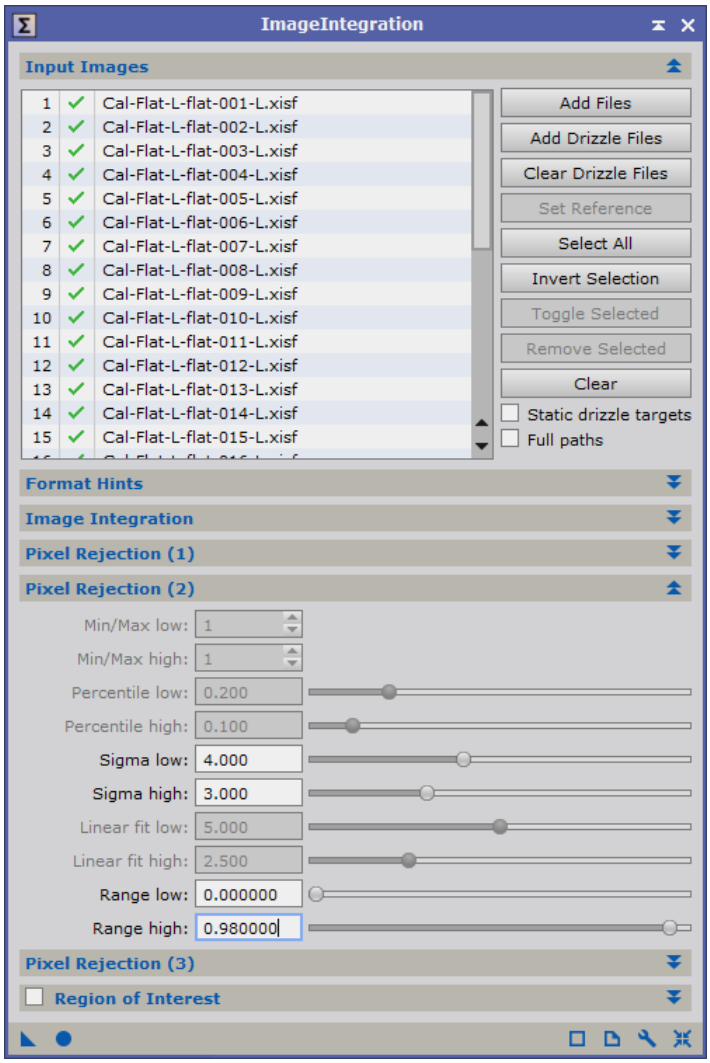
Pixel rejection first panel:

Likely best rejection algorithm is Winsorized sigma clipping, but may be different if the number of frames in the set is small (see earlier notes).

Use Equalize Fluxes setting for normalization. This ensures that the rejection algorithm takes into account the integration normalization.

Pixel Rejection (2)

This will require experimentation to set, dependent on algorithm selected



2.2 Calibration

2.2.1 Calibrate Lights

ImageIntegration->ImageCalibration

Remember to set output directory.

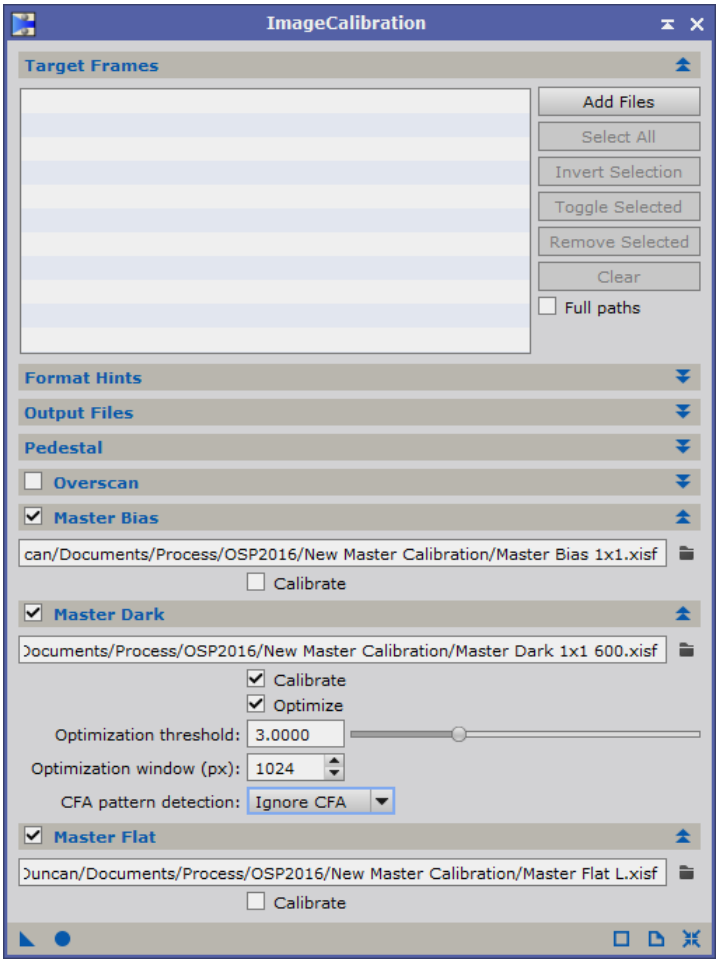
Set prefix to Cal-, suffix blank

Use master bias with no calibration

Use master dark with calibration, optimization, ignore CFA

Use master flat with no calibration

This calibration step must take into account that the bias and dark frames are straight integration with no calibration, but the flat has already been calibrated.

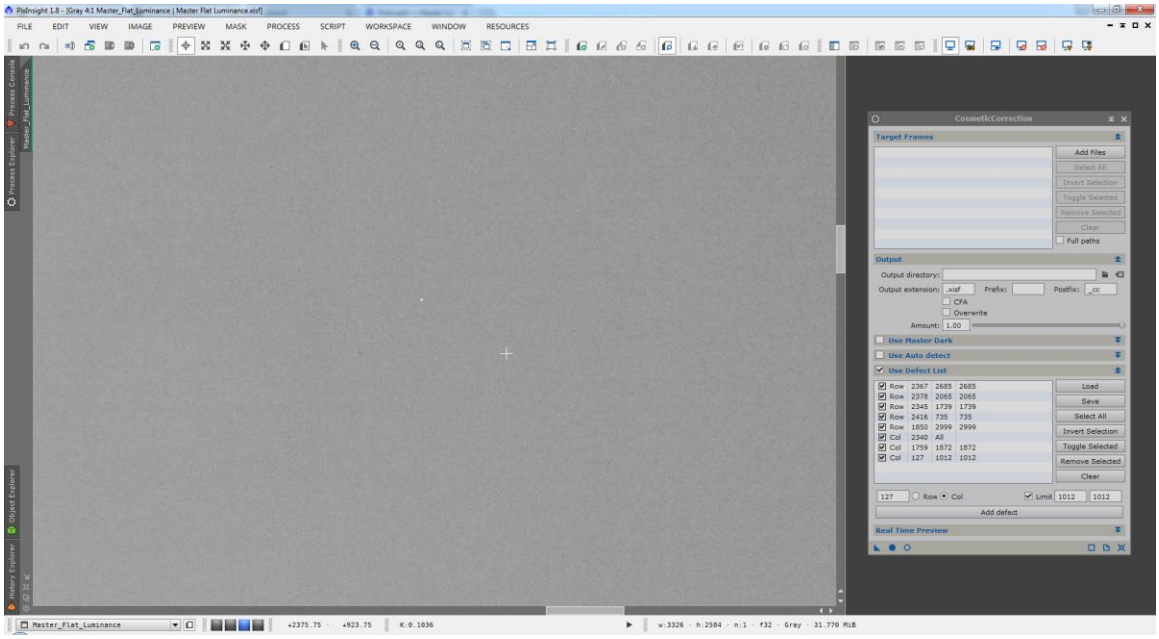


2.3 Cosmetic Correction

2.3.1 Defect List Creation

Open an ***ImageCalibration->CosmeticCorrection*** tool and open the Use Defect List panel.

Locate defective pixels or columns that have escaped calibration by examining a calibrated master flat frame with strong screen stretching and high zoom level.



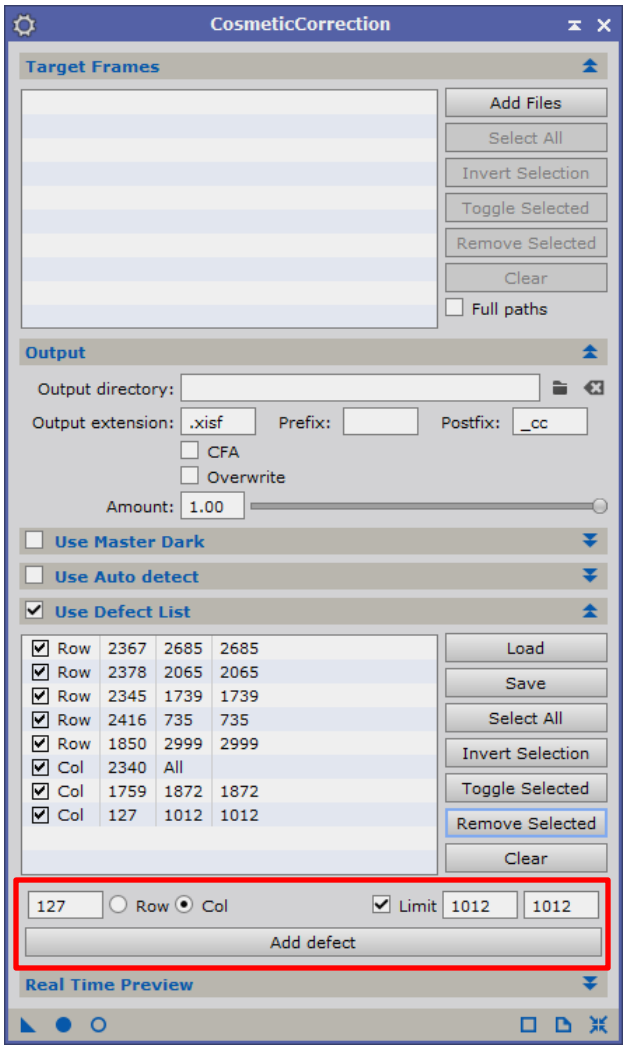
Clicking on a pixel populates the defect fields.

Depending on whether row or column is selected, the text box at left will show the row or column index.

Limit settings when enabled restrict the selection to a single pixel or a range of pixels from the same row or column.

Deselect limit to select an entire row or column.

Click the add defect button to add to the list, and then save for future use.

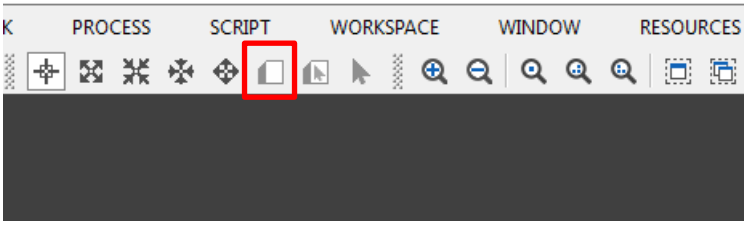


2.3.2 Cosmetic Correction of Light Frames

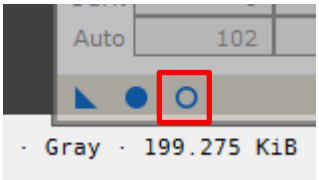
ImageCalibration->CosmeticCorrection

Open image to use as preview

Use “New Preview” button or Alt+N to create new preview window with mouse



Show cosmetic correction preview



Set output directory

Set prefix to CC-, suffix blank

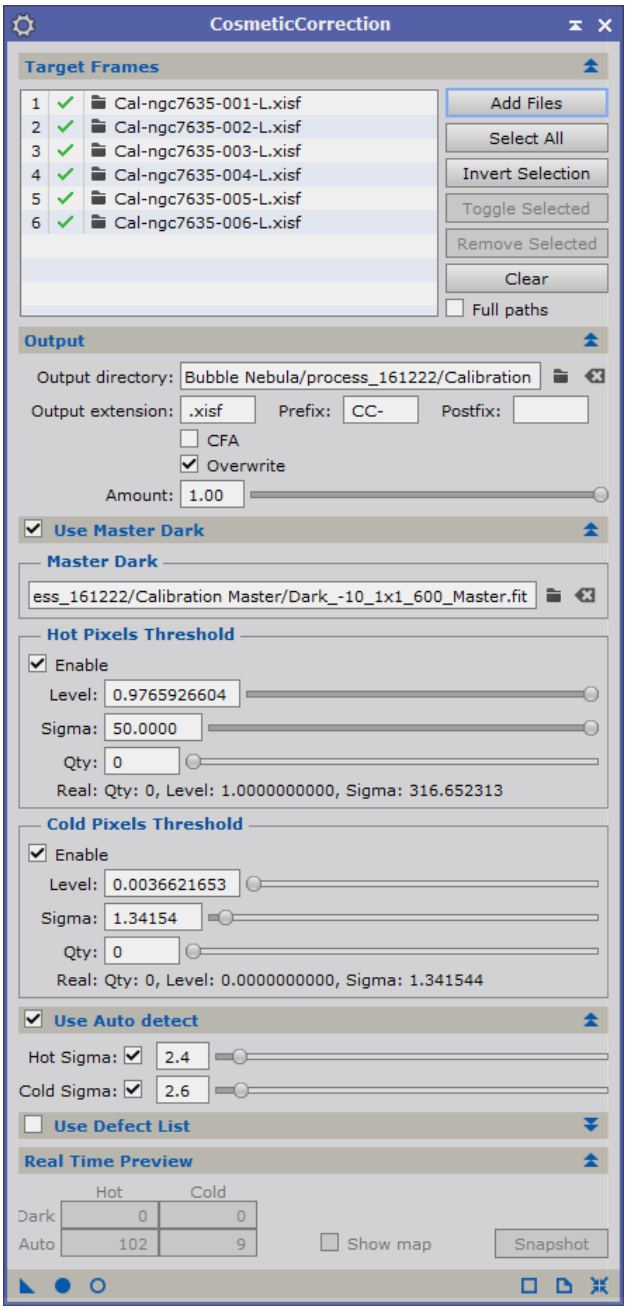
Use master dark, enable hot and cold pixel detection

Use auto-detect

Adjust parameters, checking and unchecking “Show Map” to see effects

Also select and load defect list if previously created.

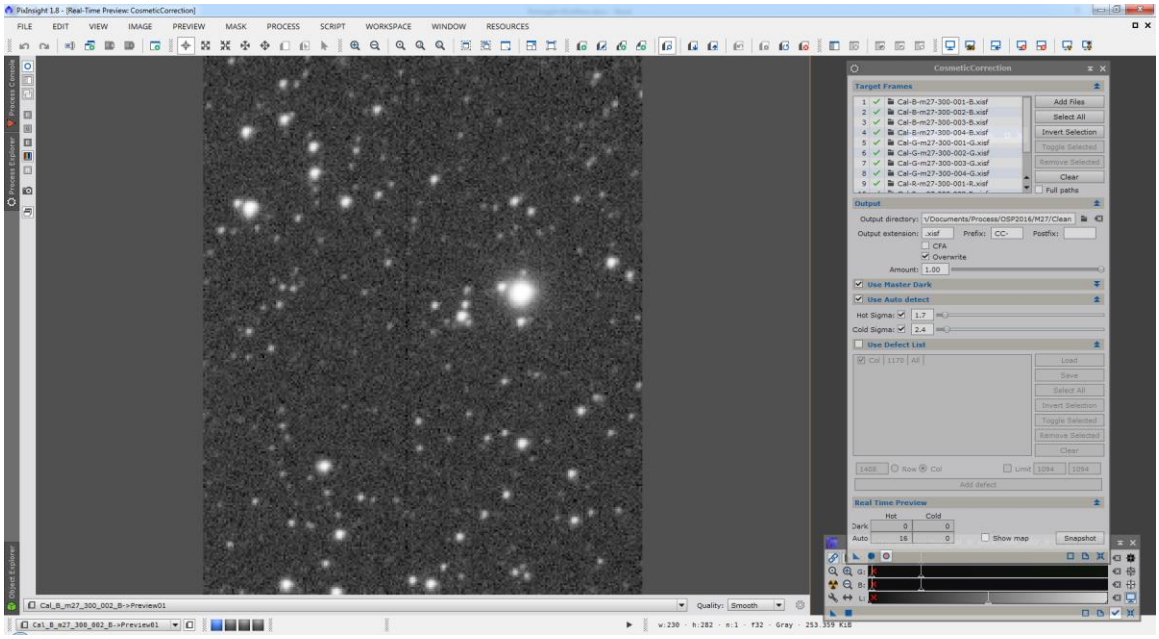
Use process global when done



2.4 Defect List Refinement

2.4.1 Single Frame Defect List Creation

With single frame open, check “Use Defect List” option. Selecting single pixel in the example frame populates coordinates in cosmetic correction “use defect list” panel. Pixel coordinates can be used to identify an entire column or row according to radio button selection, or can be restricted to a partial row or column if the “limit” option is checked. By default, with the “limit” option checked, only a single pixel will be selected. Must click the “add defect” button when done to actually add to the defect list.



2.4.2 Blink Frame Defect List Creation

After initial defect list and cosmetic correction, further refinement can be performed using the

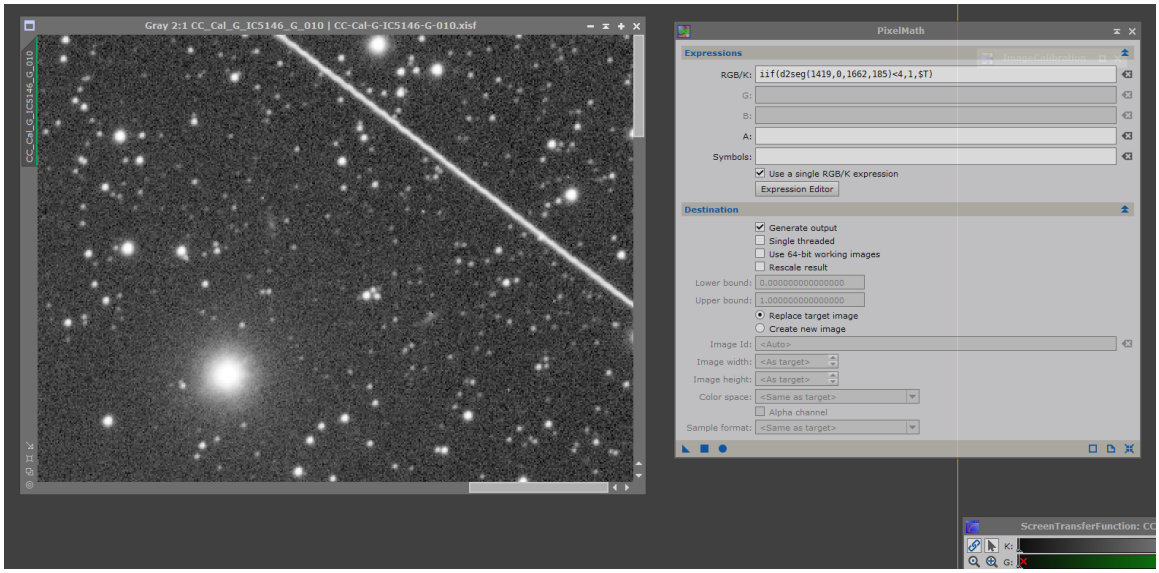
2.5 Satellite Track Removal

Use ***PixelMath->PixelMath*** tool to generate overlay for satellite track forcing all pixels within a specified distance of a specified line segment to 1. This will cause the subsequent integration rejection algorithms to exclude those pixels from the set.

Formula:

```
iif(d2seg(x1, x2, y1, y2) < d, 1, $T)
```

Where (x1, y1) and (x2, y2) are the start and end points of the line respectively and d is the half-width of the line. Start with a d value of 3.



For multiple tracks, the expression needs to be nested:

```
iif(d2seg(x1, x2, y1, y2) < d1, 1, iif(d2seg(x3, x3, y4, y4) < d2, 1, $T))
```

2.6 Registration

2.6.1 Registration Process

ImageRegistration->StarAlignment

Set reference image to best available luminance image

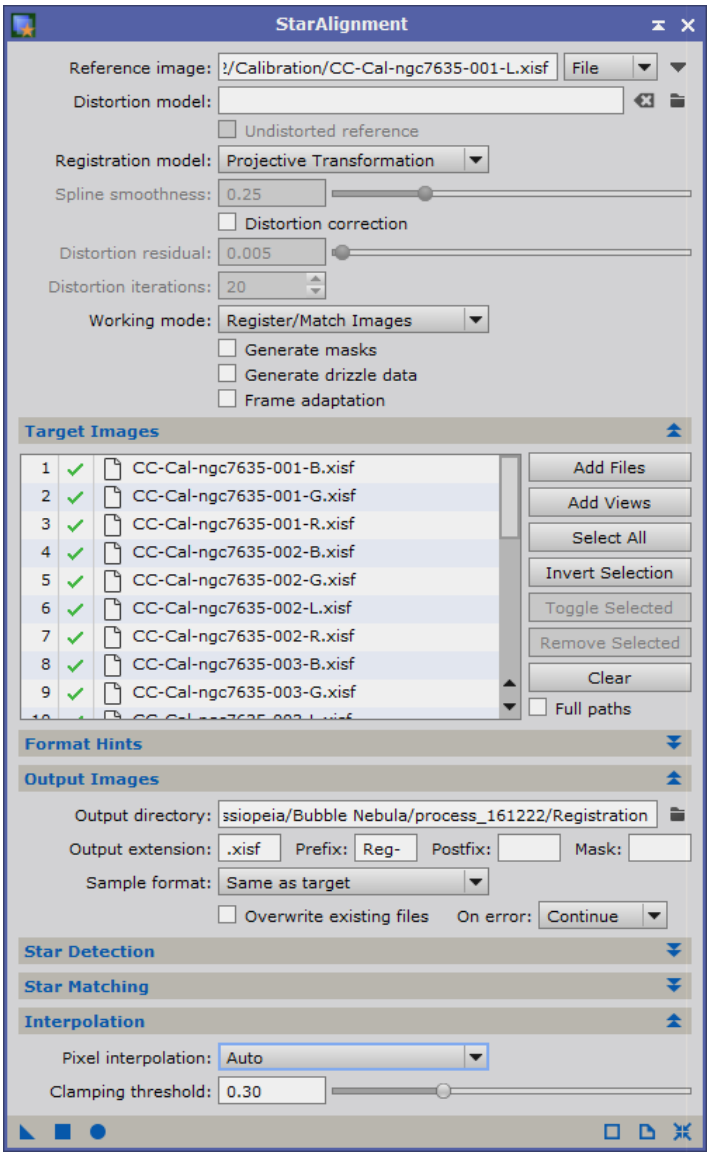
Set target images to remaining calibrated images (all channels)

Create new folder for output directory

Set prefix to Reg-, suffix blank

Check overwrite existing images

Star detection, matching, interpolation set to defaults



2.6.2 Post Registration Cleanup

Copy across reference image to target directory

Note the interpolation method used, specified in process console window

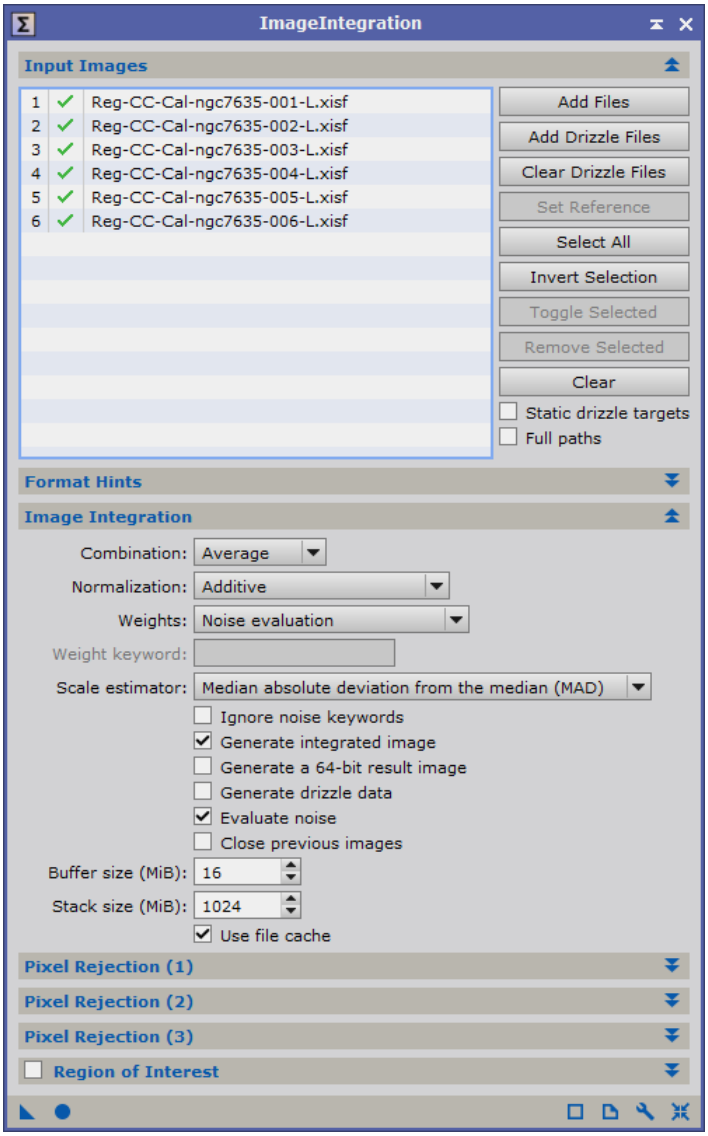
```
scale       : 2.000
scale-X     : 2.000
scale-Y     : 2.000
rotation    :     -0.09 deg
dx          :    -17.03 px
dy          :    -16.30 px
Generating registered image
Homographic Projection / Lanczos-3 interpolation, c=0.30:
Registration successful.
Writing output file: C:/Users/Duncan/Documents/Catalog/Cassiopeia/Bubble Nebula/
process_161222/Registration/Reg-CC-Cal-ngc7635-006-G.xisf
** Warning: Overwriting existing file
Writing image: w=3326 h=2504 n=1 Gray Float32
86 FITS keyword(s) embedded.
```

2.7 Integration

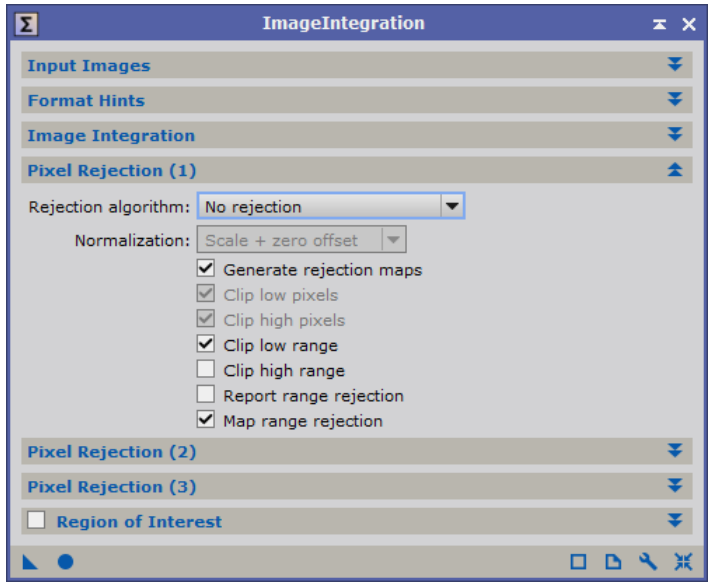
ImageIntegration->ImageIntegration

Add files to input images panel

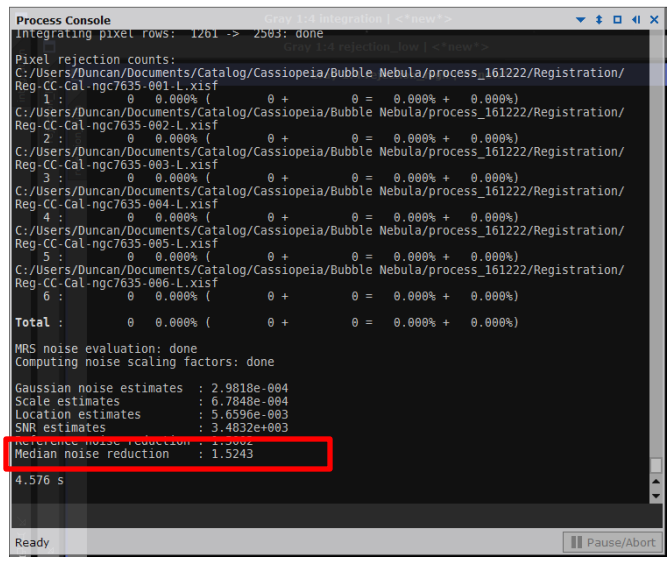
Initial settings:
Combination: Average
Normalization: Additive
Weights: Noise evaluation



Initial run with no rejection algorithm specified in Pixel Rejection (1) panel



Note noise reduction factor (1.5243 shown)



Experiment with different rejection algorithms, checking rejection maps and noise reduction.

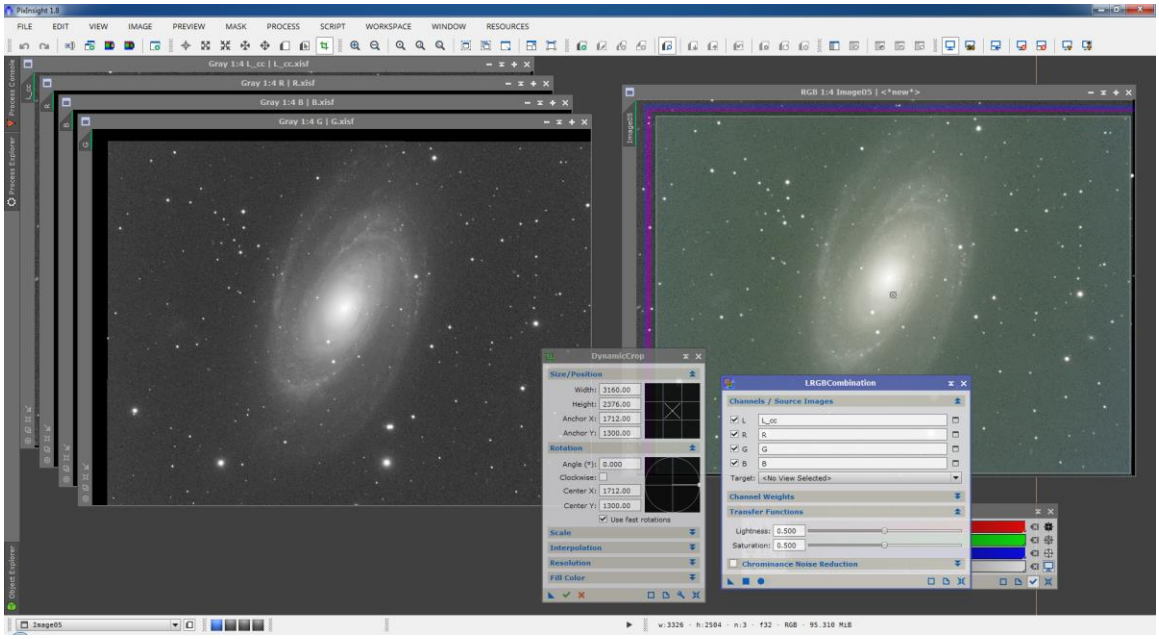
Likely optimum:

- Percentile clipping for 3-6 images
- Averaged sigma clipping for 5-10 images
- Sigma clipping, Winsorized clipping or linear fit clipping for >10 images

2.8 Dynamic Crop

With all four planes open, use ***ColorSpaces->LRGBCombination*** to generate a temporary combined image. With all five images open, open ***Geometry->DynamicCrop***. Select an area in the LRGB image that is covered by all four image planes.

Apply the crop to the four individual color plane images using the new instance icon.



2.9 Linear Noise Reduction (MURE)

Script->Noise Reduction->MureDenoise

Select image

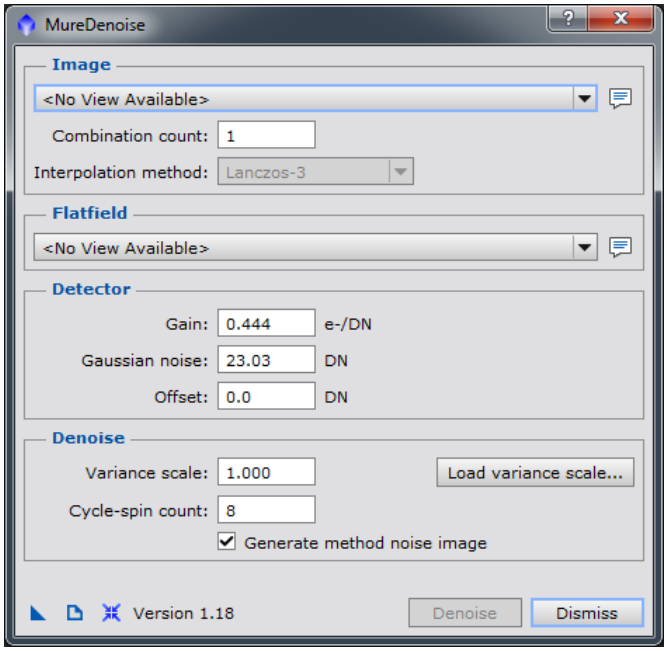
Combination count – set to number of images combined

Interpolation method – set to method used in integration and noted earlier

Gain, Gaussian noise, offset set to parameters below

Variance scale 1.000

Cycle-spin count can be left at 8



Measure gain from EGAIN parameter in FITS header or script ***Image Analysis->FlatSNREstimator***

Measure Gaussian noise using script ***Image Analysis->DarkBiasNoiseEstimator***

Previously measured values:

Gain:	0.444
Gaussian Noise (1x1):	23.61
Gaussian Noise (2x2):	33.73

2.10 RGB Combine

ColorSpaces->LRGBCombination

Uncheck L

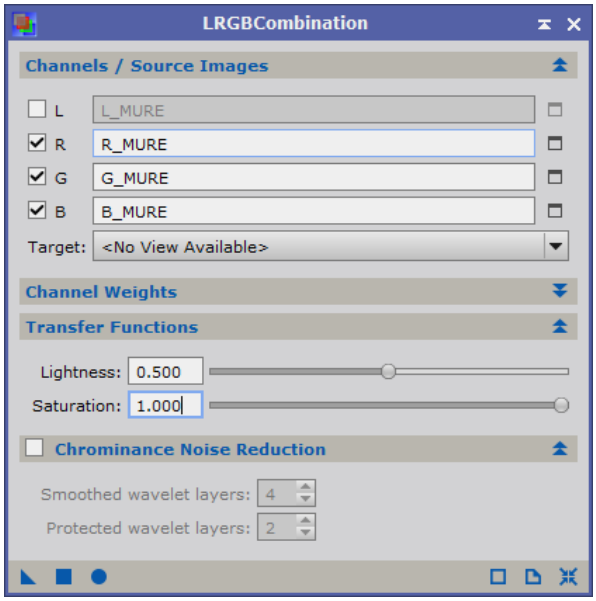
Check R, G, B

Select open images for R, G, B channels

Lightness 0.500

Saturation 1.000

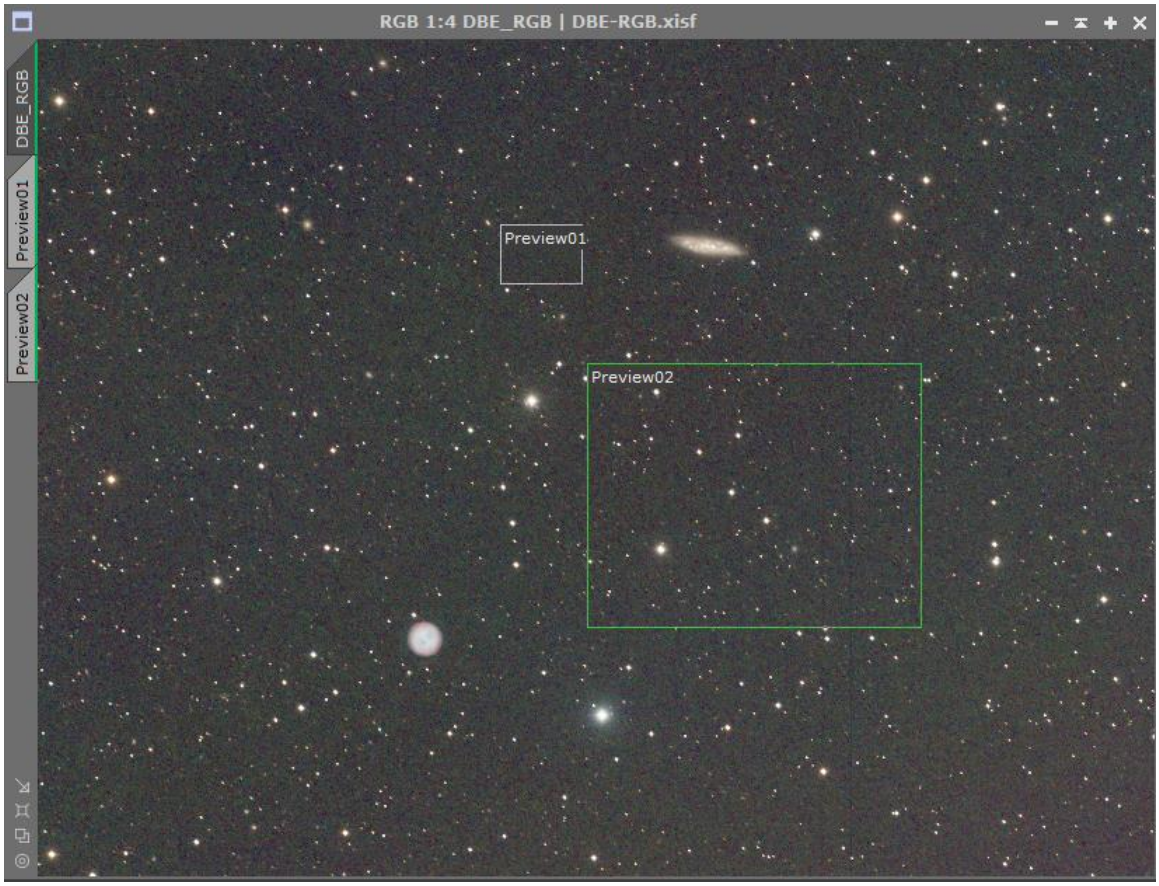
Uncheck chrominance noise reduction



2.11 Color Calibration

2.11.1 Setup

Create two previews (Ctrl-N) in the image. The first should contain only background, and the second should contain either an entire galaxy or a group of stars



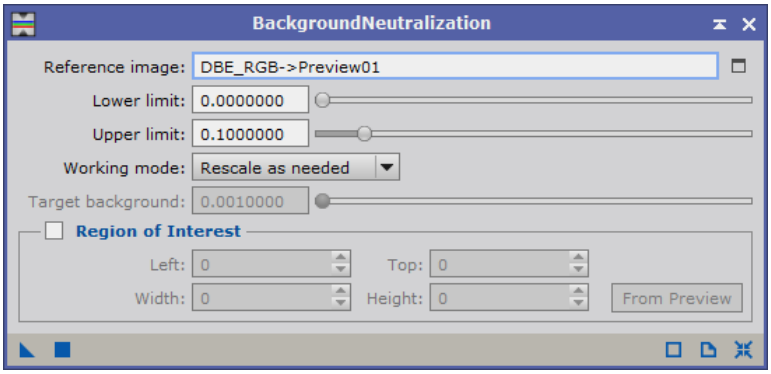
2.11.2 Background Color Correction

Color Calibration->Background Neutralization

Select first preview (containing no stars, just background) as the reference image. This will need to be reselected even if the image name appears correct

Lower limit 0.000

Upper limit 0.100



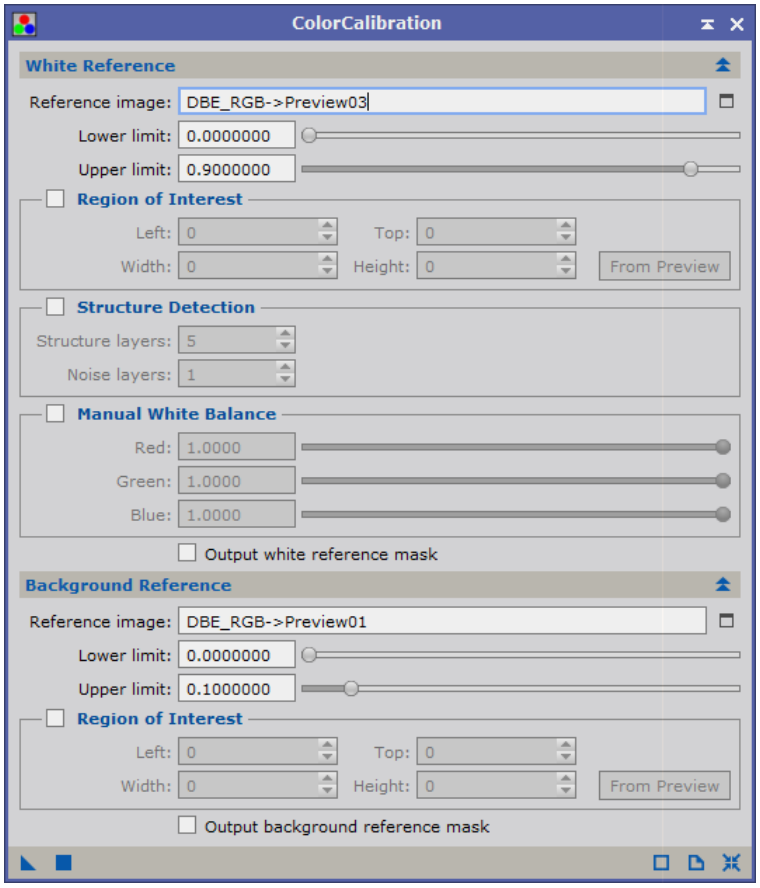
Color Calibration->ColorCalibration

White reference image set to preview containing either stars or entire galaxy.

Stars: check “Structure Detection”. This will assume that a population of stars has a mean white color.

Galaxy: uncheck “Structure Detection”. This will assume that the starlight integrated across a galaxy is white.

Background reference set to preview containing only background.



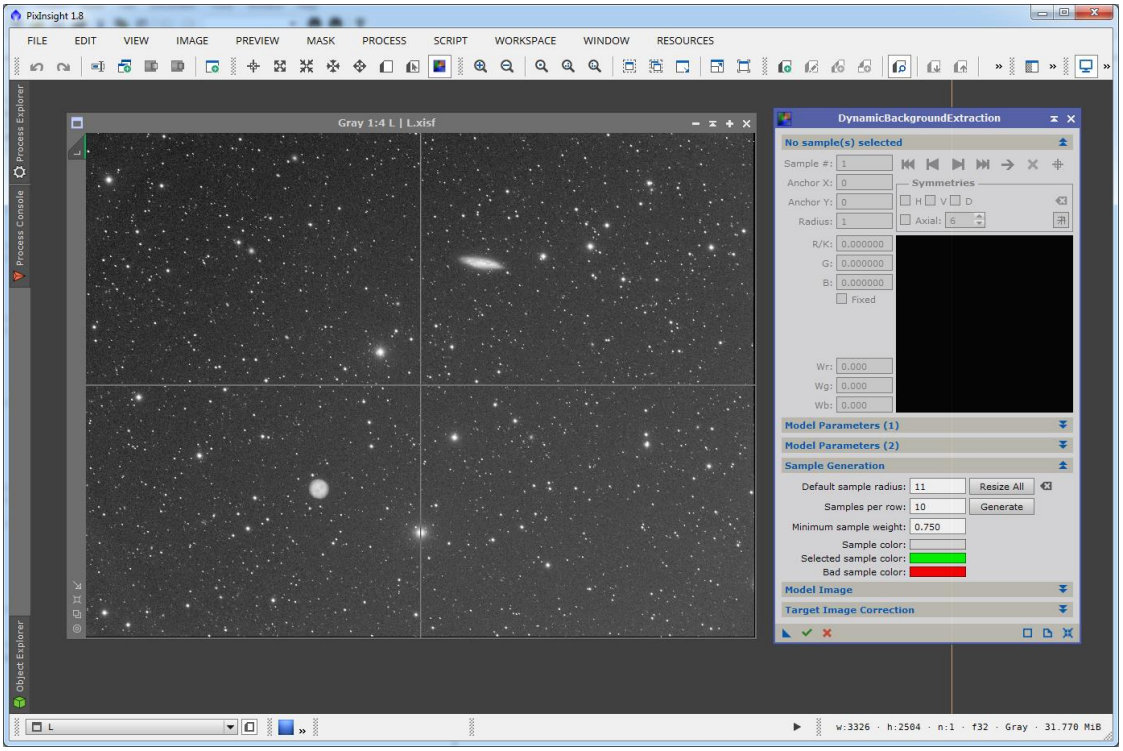
2.12 Background Extraction for Gradient Removal

2.12.1 Option 1: Dynamic Background Extraction

BackgroundModelization->DynamicBackgroundExtraction

Much more sophisticated tool than automatic background extraction, with many configurable parameters, but more steps to make work. Will work on any image.

Open DBE tool, select image (cross will appear in selected image)



Start by resetting everything to defaults to make sure there are no strange settings anywhere.

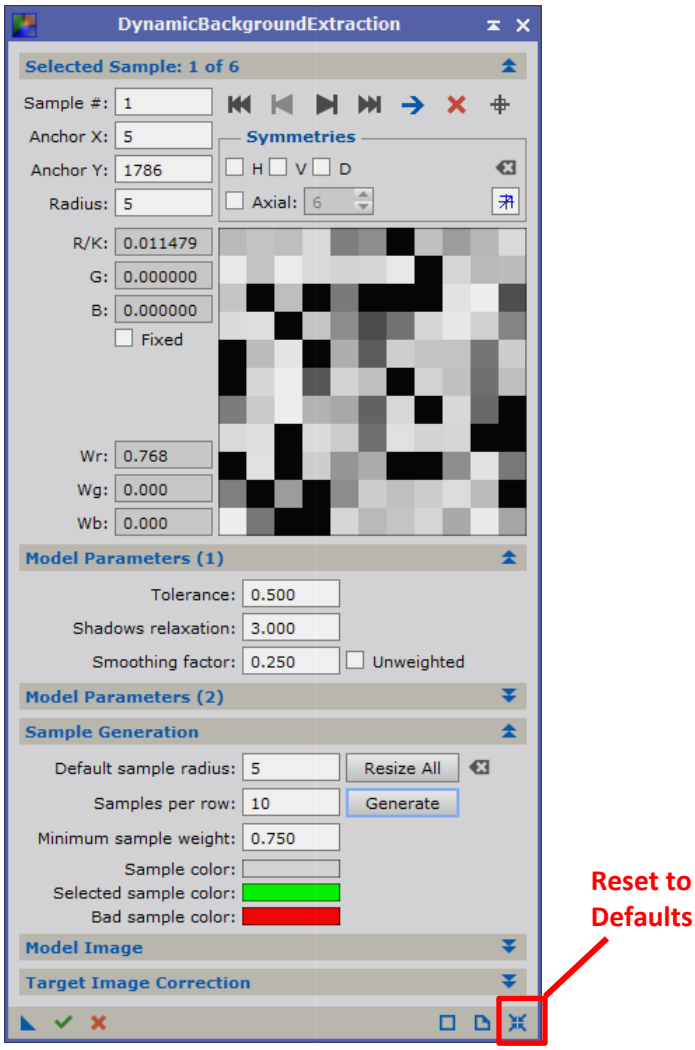
Under “Sample Generation” click “Generate” to create a set of background samples.

Depending on the image and other parameter settings, insufficient samples may be generated.

To increase the number of samples, increase “Tolerance” (under “Model Parameters (1)”) or decrease “Minimum sample weight”. Experimentation will be required.

Any samples shown in the image in red will be excluded from the model. Increase Tolerance setting until the samples turn white.

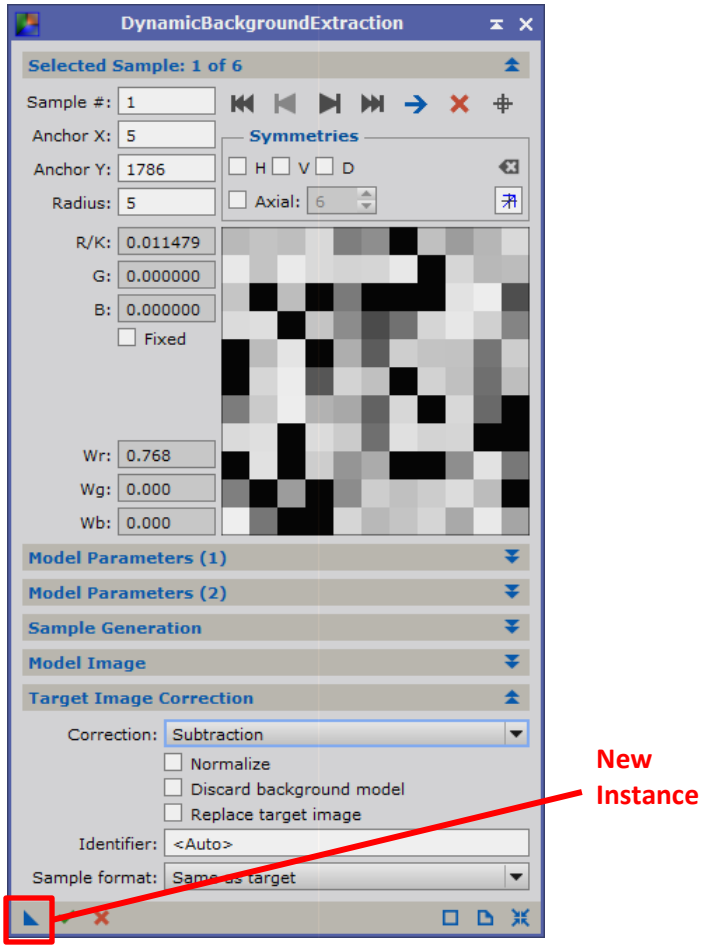
Samples should go all the way to the edges. Delete manually any samples that are in a DSO region as these will distort the background model.



Select type of correction. Typically should use “subtract” for light pollution gradients and “division” for uneven illumination.

After generating and applying DBE on luminance channel, drag the new instance icon to the workspace and rename it.

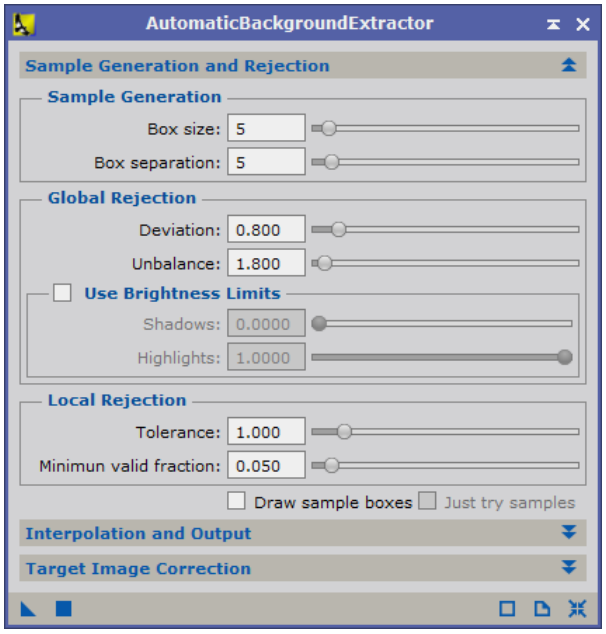
The DBE tool can be closed up, and then later recreated from the saved workspace icon for application to the RGB image.



2.12.2 Option 2: Automatic Background Extraction

BackgroundModelization->AutomaticBackgroundExtractor

ABE with default options can work well on images with large amounts of background and small deep sky objects such as a galaxy field.



There may be benefit from applying DBE followed by ABE.

Experimentation may be required.

2.13 Create Masks

2.13.1 Duplicate Stretched Image Mask

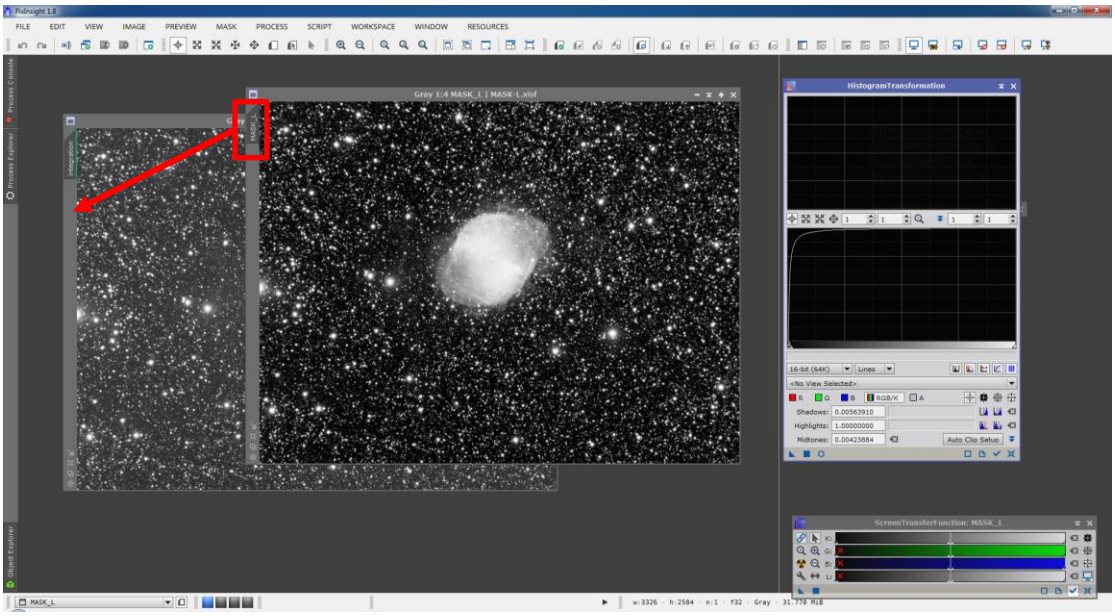
Create a duplicate of the grayscale integrated image using menu command Image->Duplicate.

Adjust the duplicated image using screen transfer function to ensure a black background with high stretch to brighten stars and deep sky objects.

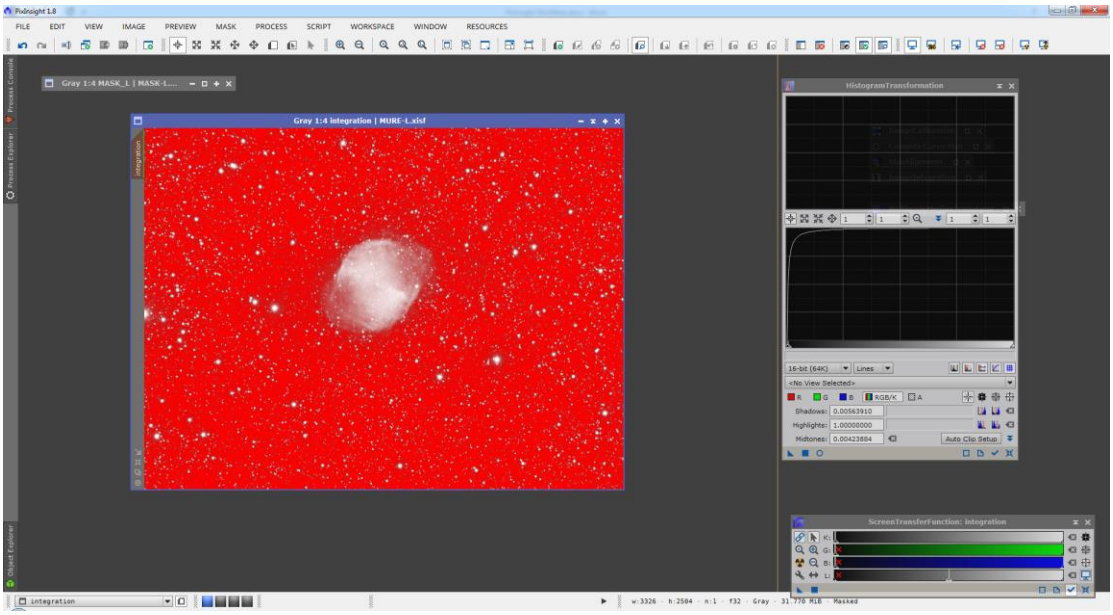
Drag the new instance icon from the screen transfer function to the status bar of an ***Intensity Transformations->HistogramTransformation*** and drag the new instance icon of the histogram transformation onto the duplicate image, as for nonlinear stretch of main images (see section 3.1).

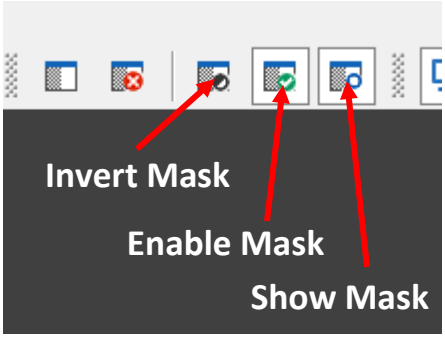
Save the duplicate image as a mask.

For subsequent processes, attach the mask to the main image by dragging the duplicate image tab onto the tab area of the main image.



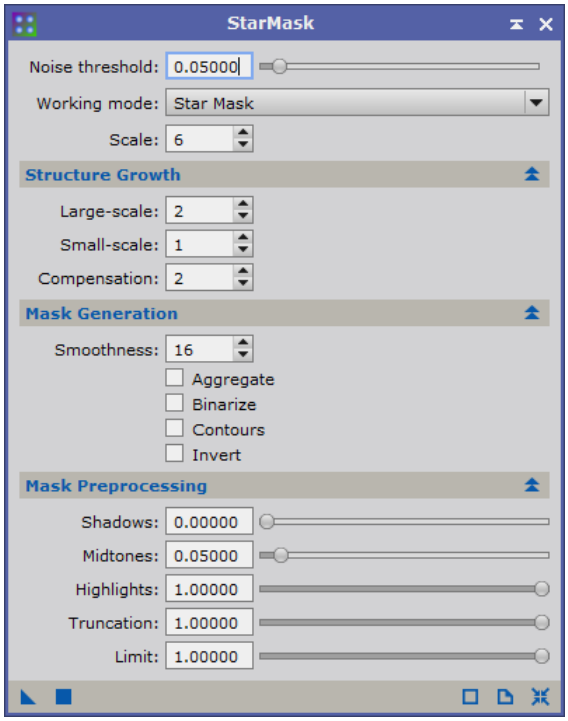
Areas in red are protected.


FILE
EDIT
VIEW
IMAGE
PREVIEW
MASK
PROCESS
SCRIPT
WORKSPACE
WINDOW
RESOURCES
Gray 1:4 integration | MURE-L.xisf
HistogramTransformation
ScreenTransferFunction: integration


Invert Mask
Enable Mask
Show Mask

2.13.2 Star Mask

MaskGeneration->StarMask



Significant experimentation will be required to get good results.

Reducing noise threshold from default value of 0.1 to 0.05 will improve detection of smaller stars.

Set scale to different values to generate star mask for different scale stars. Typical range 4 – 6.

Mask preprocessing will need to be set to apply a stretch to the linear image prior to star structure detection.

Adjusting Midtones slider to 0.05 – 0.10 should be a good starting point.

After generating mask, rename mask by right clicking on image and selecting Identifier…

Name cannot contain spaces.

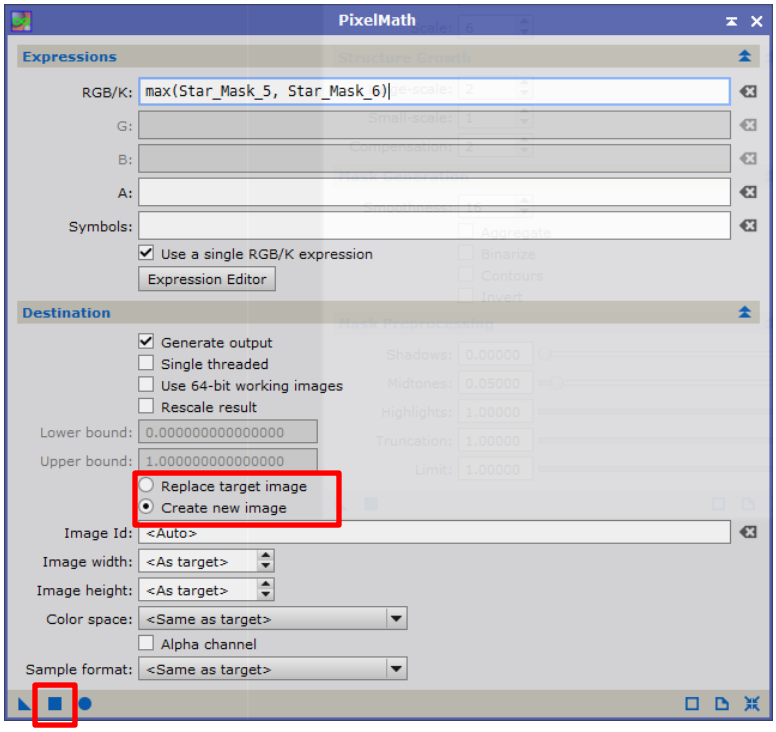
2.13.3 Combine Star Masks

PixelMath->PixelMath

Can use pixel math to combine two masks generated at different scales (or using different methods).

Example here uses max(X,Y) function and renamed mask images.

Select Create New Image radio button and click square apply button to create a new combined mask.

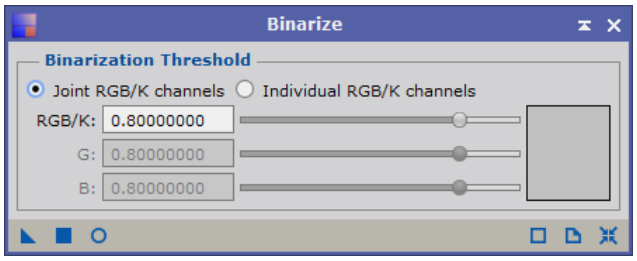


2.14 Deconvolution

2.14.1 Preparation: PSF Function Mask

IntensityTransformations->Binarize

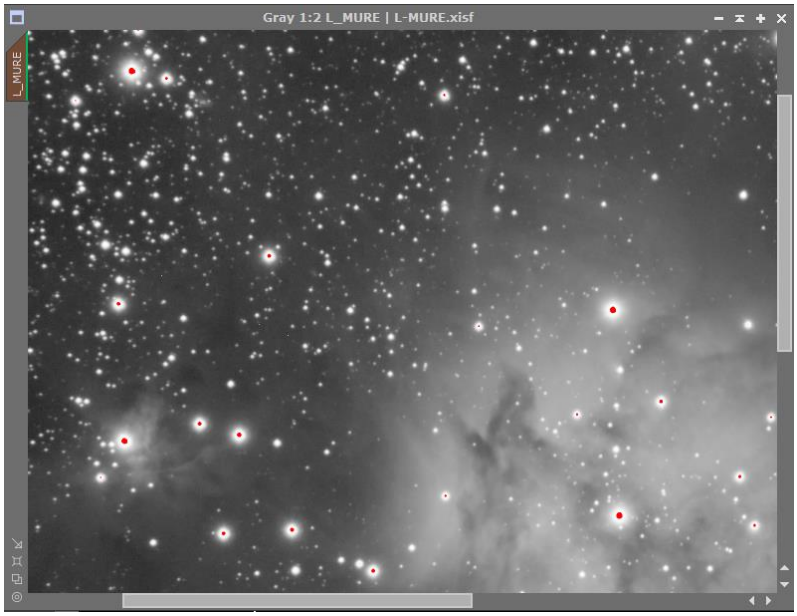
PSF function is generated from a set of non-saturated stars across the image.



In preparation for generating the PSF, create a mask that will identify the saturated stars using the Binarize tool.

Duplicate the luminance image and open the Binarize tool. Set the threshold to a high value such as 0.8 and apply to the duplicated image using the new instance icon.

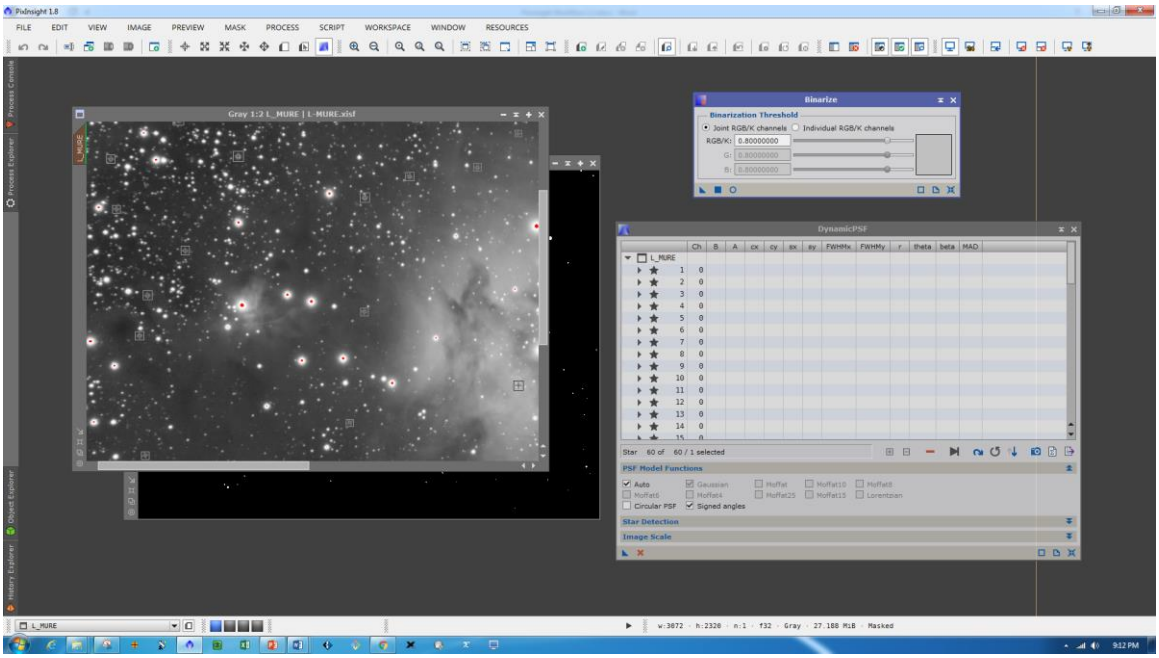
Drag the mask onto the luminance image, show it and invert it to highlight the saturated stars.



2.14.2 Dynamic PSF

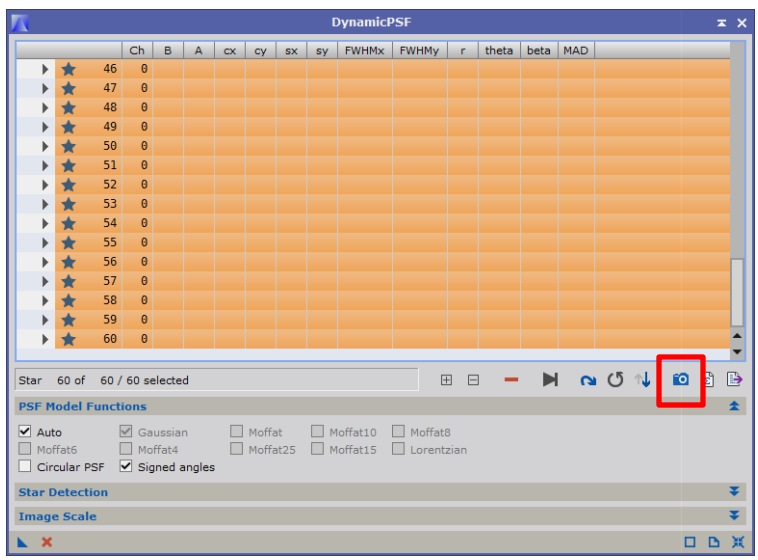
Image->DynamicPSF

Open the dynamic PSF tool and select a set of about 30-40 non-saturated stars from across the image.

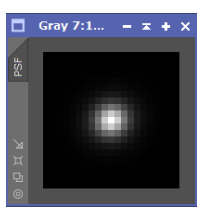


Make sure that all of the stars in the set are selected.

Click on the camera Icon to generate the PSF image.



Rename the generated image.



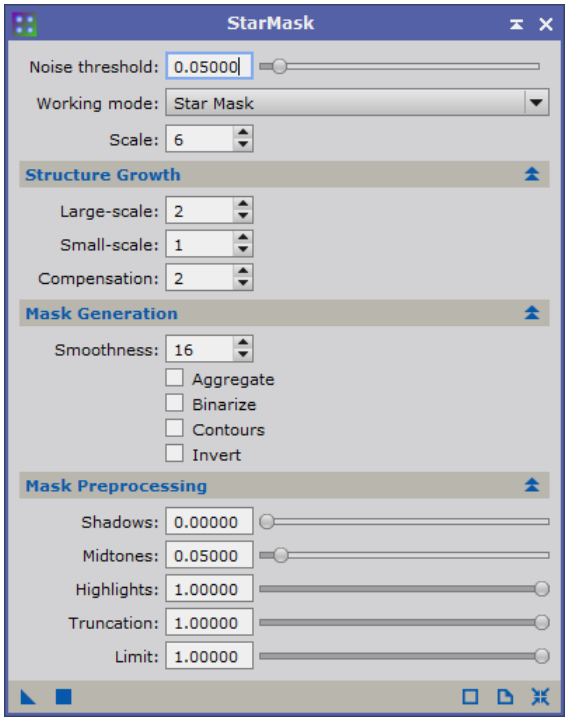
2.14.3 Deringing Mask

MaskGeneration->StarMask

Generate a deringing mask using the star mask tool.

The deringing support mask needs to mask out the brightest stars.

Recommend higher end settings for scale, depending on the image, and may also want to increase the large scale structure growth parameter to ensure that bright stars are fully covered.



2.14.4 Luminance Mask

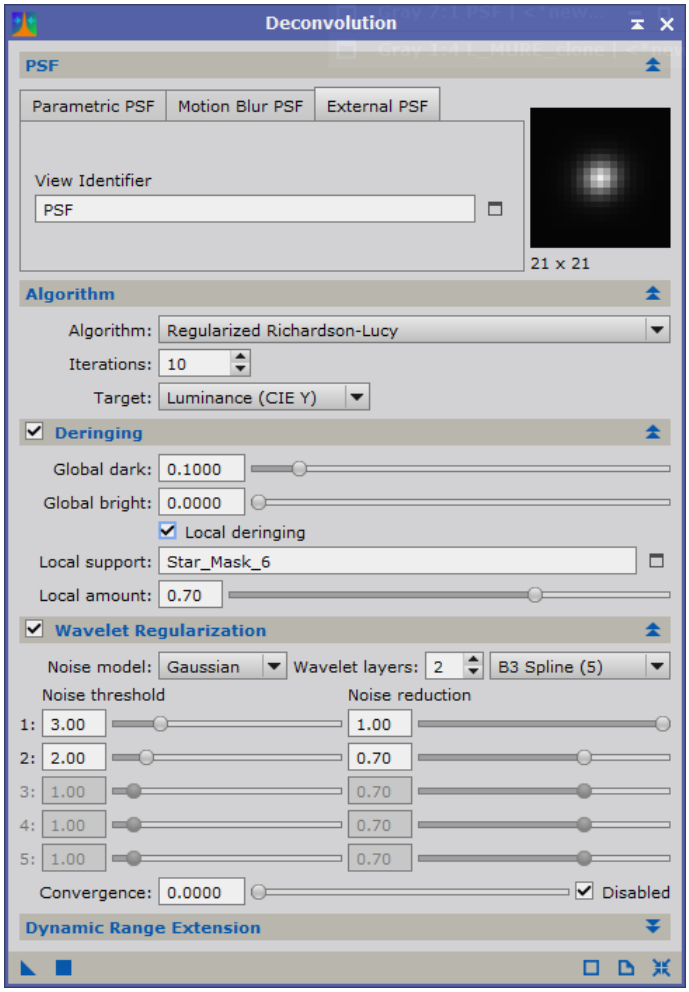
Luminance mask needs to protect the background from deconvolution.

May be possible to use a luminance mask generated earlier.

Generate from a duplicate of the luminance image, using histogram stretch tool. Set black point higher than normal to clip low pixel values.

2.14.5 Deconvolution

Deconvolution->Deconvolution



Apply the just generated luminance mask to the image.

Select the external PSF tab in the PSF panel, and load the previously generated PSF.

In the algorithm panel, start with Regularized Richardson-Lucy algorithm and experiment with others. To start with, set iterations low, but increase to 40 or 50 later.

In the deringing panel, check local deringing and load the deringing mask image as local support.

Very important: the global dark parameter will need adjustment, and the default is usually too high.

Typical values 0.03 – 0.07. When executing, too high a value will result in local divergence warnings (these have very bad consequences). Reduce the global dark parameter if you see this.

2.15 Luminance Fine Tuning

2.15.1 Morphological Transform

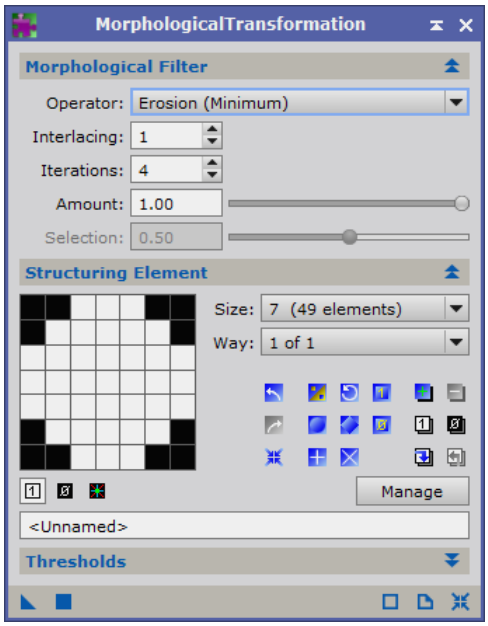
Morphology->MorphologicalTransform

Morphological transform tool can be used to reduce star sizes or correct globally misshapen stars.

Significant experimentation with the iterations and structuring element will be required.

Use a star mask to restrict application to stars only.

A combined star mask that includes generated masks at multiple scales has worked well in many cases.



3 Nonlinear Process Steps

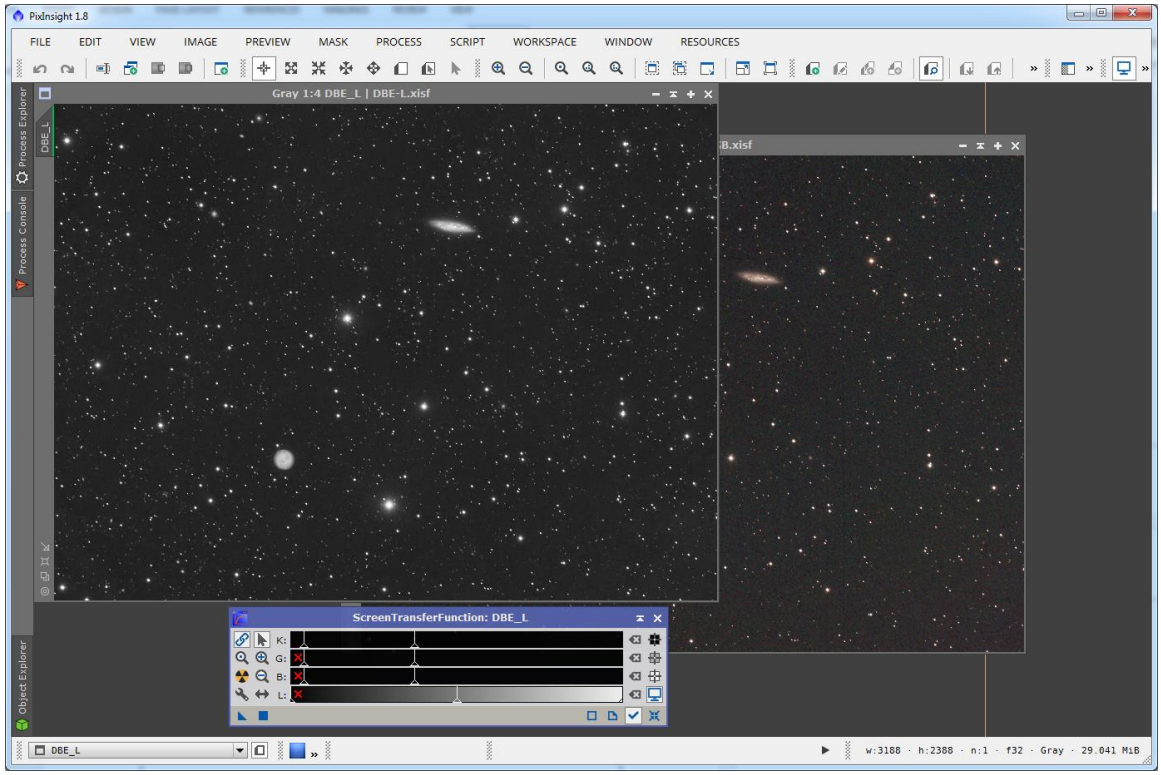
3.1 Histogram Stretch

3.1.1 Screen Transfer Function

Intensity Transformations->ScreenTransferFunction

Use Screen Transfer Function to set intensity separately for RGB and Luminance images.

In particular for images with lots of star background, default STF may be significantly overstretched. Zoom in on luminance setting and reduce stretch if necessary. RGB and L need to have similar stretch.

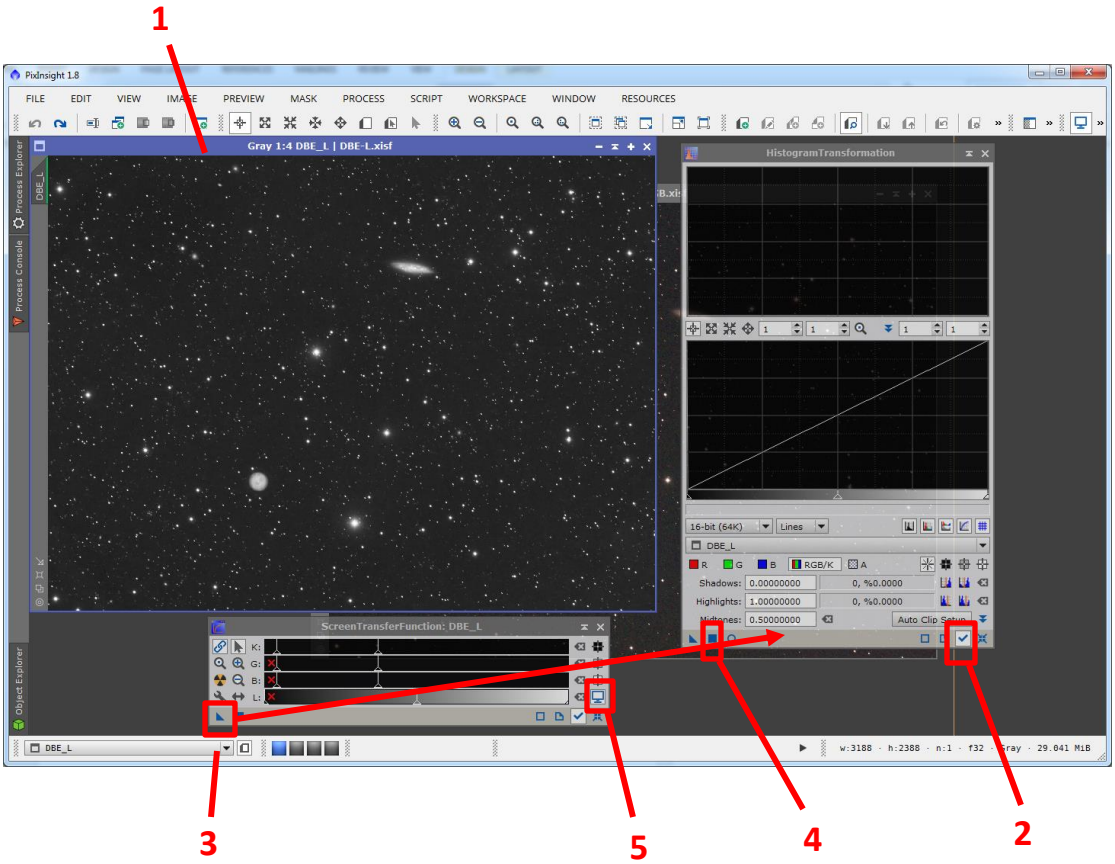


3.1.2 Histogram Transformation

Intensity Transformations->HistogramTransformation

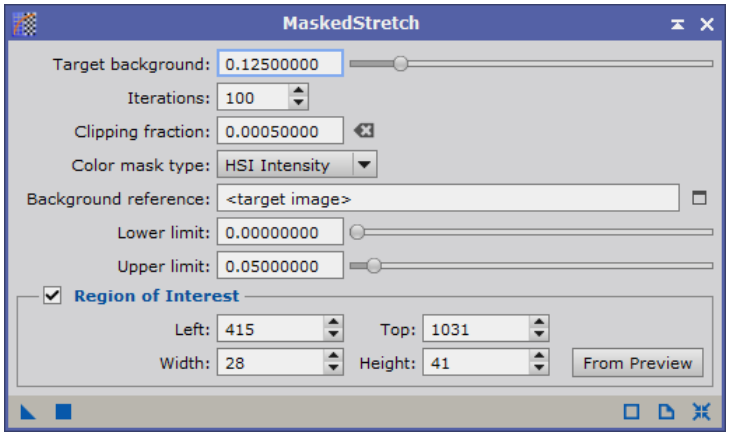
1. Select image
2. Display image histogram data in HistogramTransformation tool
3. Drag STF "New Instance" icon to bottom toolbar of HistogramTransformation
4. Apply histogram transformation (image will turn white)
5. Disable STF visualization

Repeat for RGB and L images. Images are now nonlinear.



3.2 Masked Stretch

IntensityTransformations->MaskedStretch



Alternative stretching method that results in smaller stars due to an iterative algorithm.

Create a preview in the image containing only background.

Check region of interest, and then click the From Preview button, selecting the background preview.

Rest of the parameters can be defaults.

The default target background value of 0.125 should work, but can be experimented with.

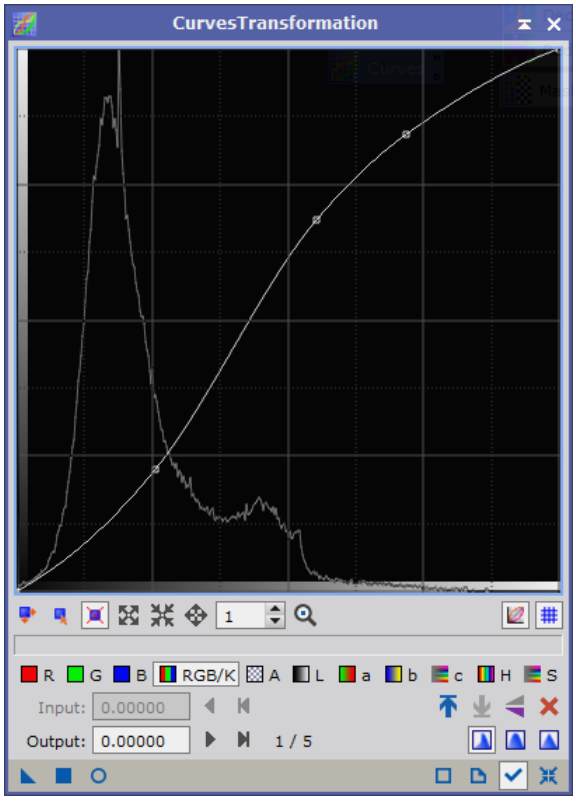
3.3 Curves

IntensityTransformations->CurvesTransformation

Curves transformation can be used post initial stretch to increase contrast in areas of interest.

With image selected, click the track view icon to load the histogram of the target image into the tool.

Clicking and holding the left mouse button over the image shows the corresponding brightness level on the histogram. Use this to identify brightness ranges of interest and boost contrast.



3.4 LRGB Combine

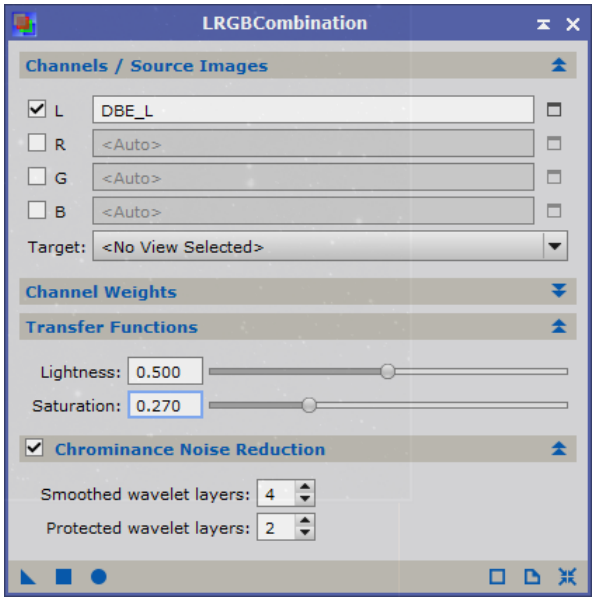
ColorSpaces->LRGBCombination

Start with nonlinear RGB and L images open.

Reset dialog to defaults.

Unselect all planes except "L". In view box, select the open luminance image.

Under "Transfer Functions" saturation will need to be increased by reducing the value. Experimentation will be required, but a value of 0.300 will be a good starting point.



Enable "Chrominance Noise Reduction". Default parameters are usually good.

Apply by dragging "New Instance" icon onto RGB image.