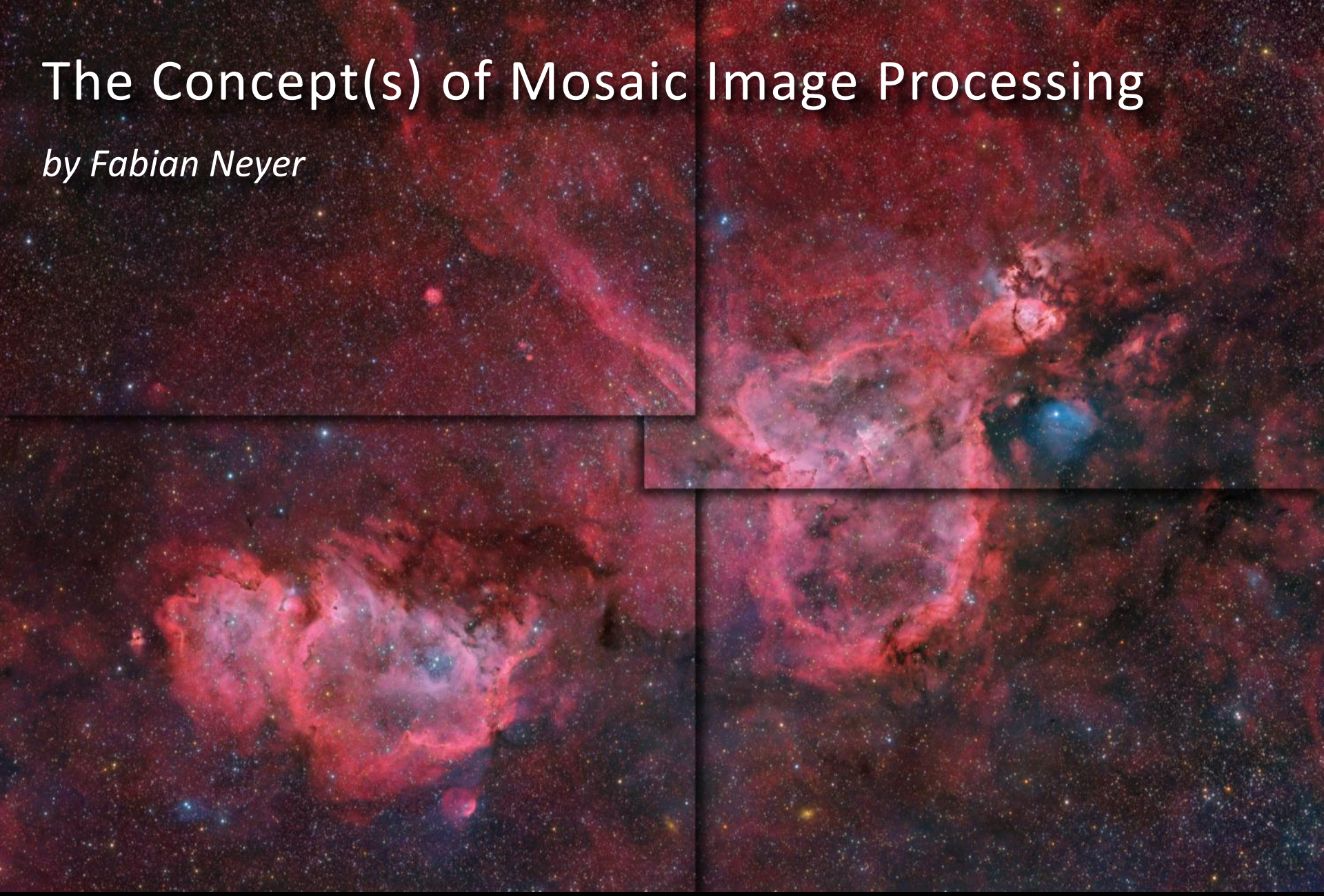
# The Concept(s) of Mosaic Image Processing

*by Fabian Neyer*



NEAIC 2012

April 27, 2012
Suffern, NY

# My Background


2010/11, STL11k, Borg101

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2010/11, STL11k, Borg101

# Why a Mosaic Image?

# Why a Mosaic Image

> One way to get high resolution

> High quality print-outs

> Increase your field of view

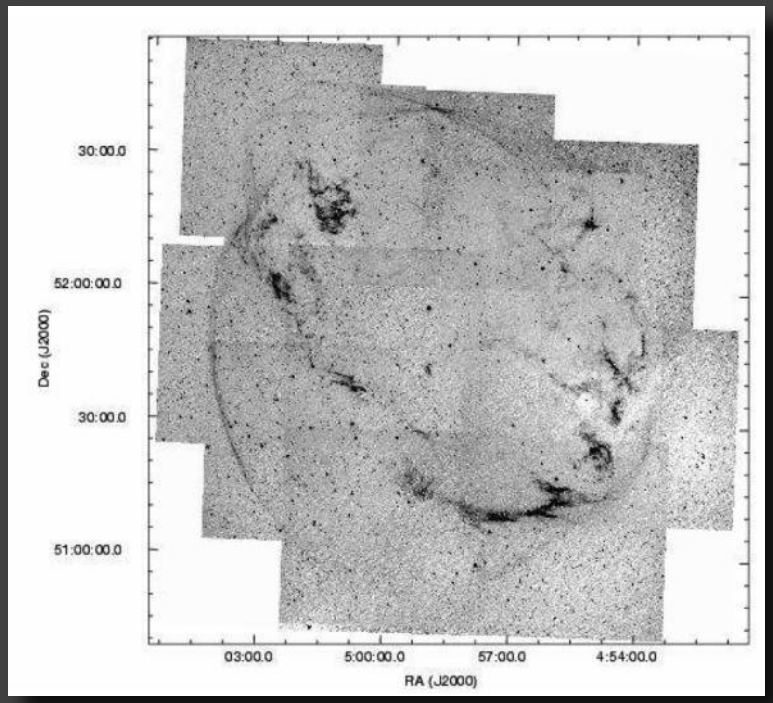
> Get rid of tracking errors

> Challenging? New adventure?

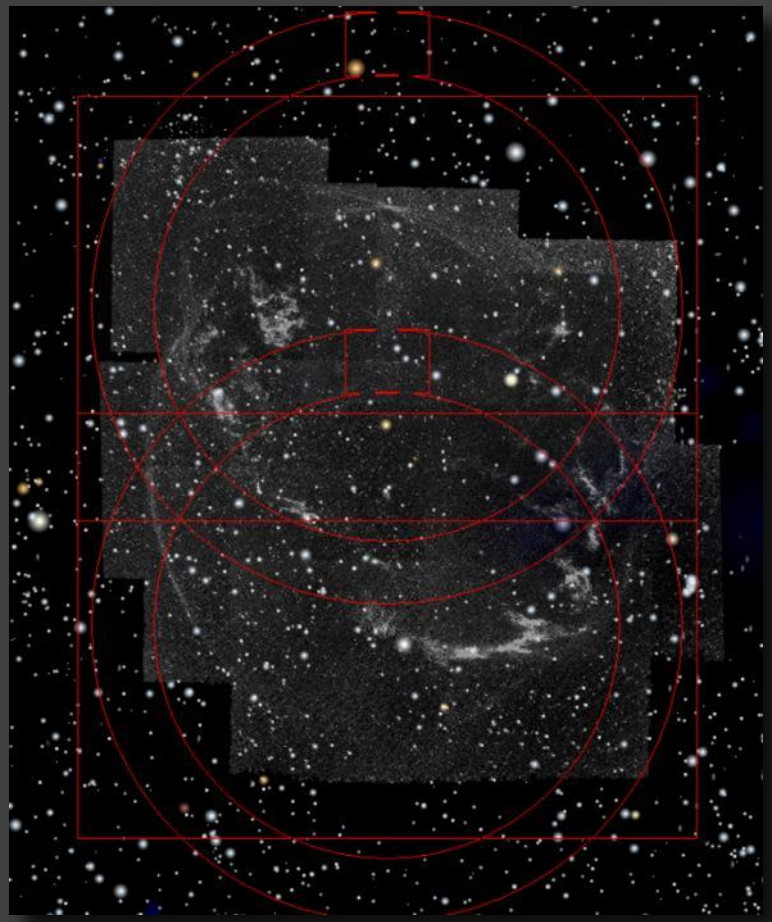
# Requirements

> Know your target for accurate planning and execution

G156.2+5.7

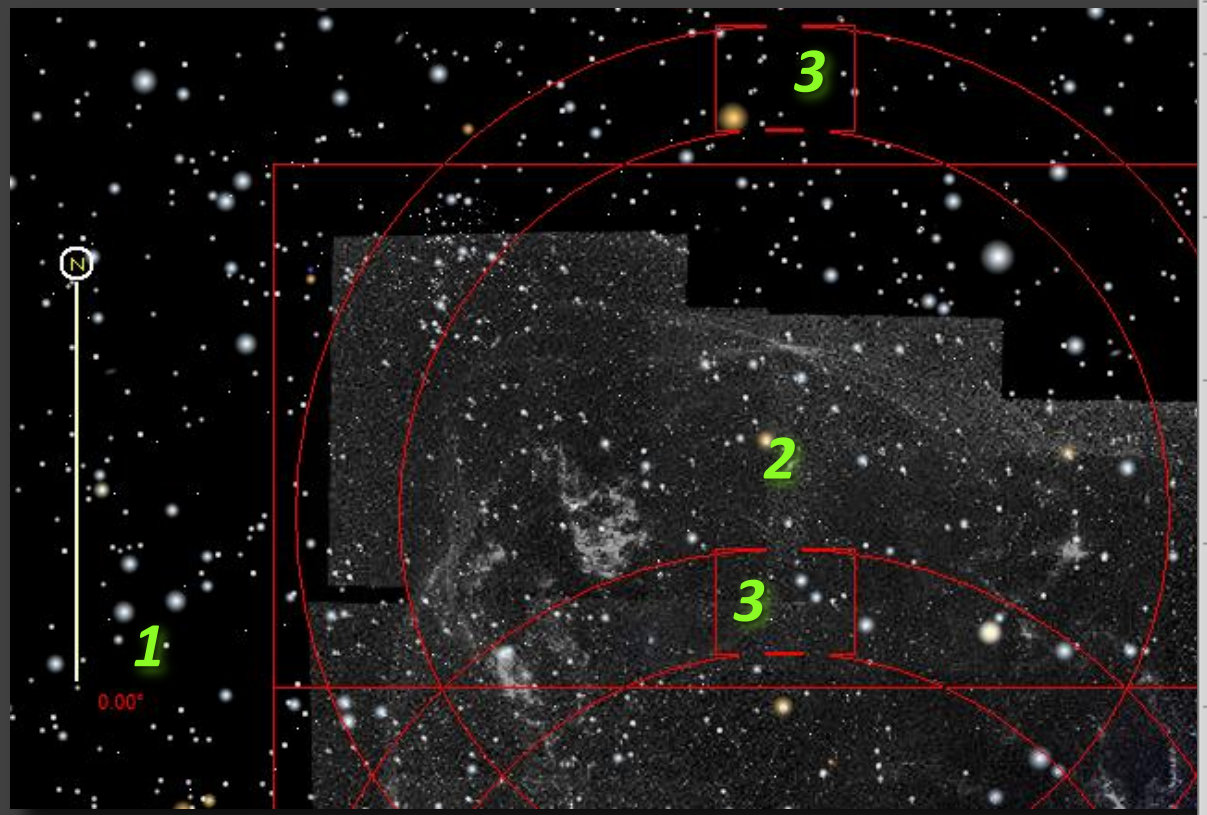


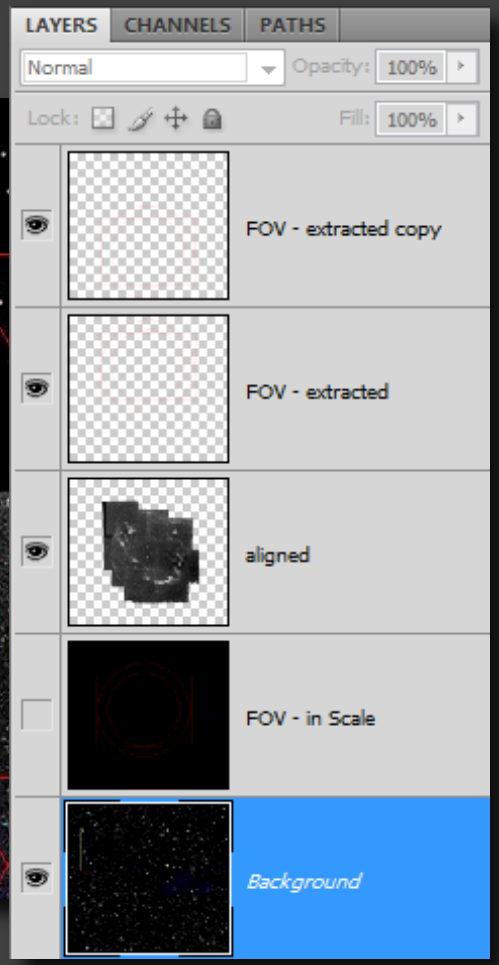

Christopher L. Gerardy & Robert A. Fesen
Royal Astronomical Society, 2007



# Requirements

> Define (1) Orientation, (2) central Coordinates, (3) Guidestars



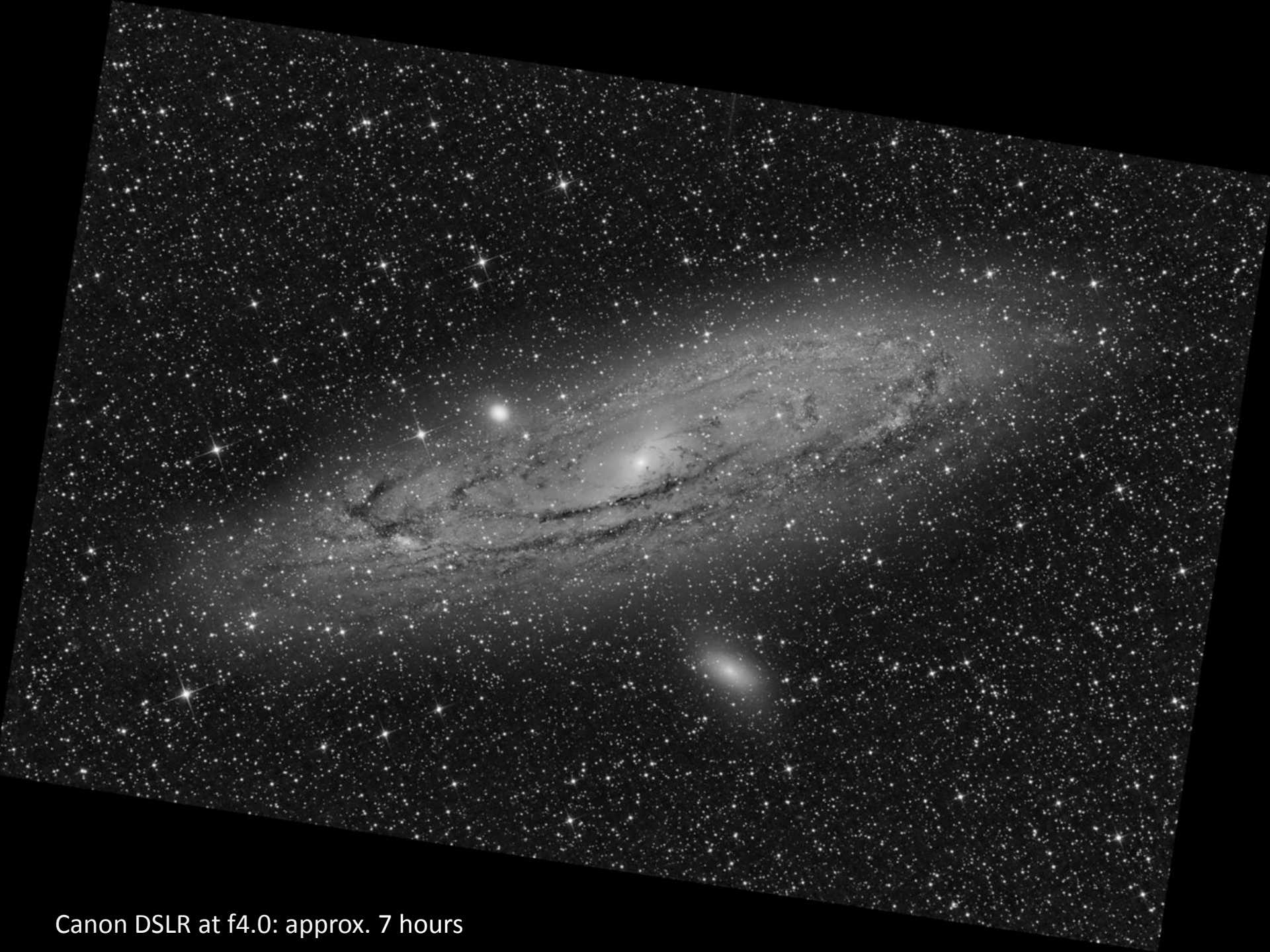




*Have a look here:*
*http://www.robgendlerastropics.com/Compositions.html*

# How many images to take

> Number of light frames:

- Sky quality
- Optical speed
- Camera sensitivity
- Target image depth



Canon DSLR at f4.0: approx. 7 hours

STL11000M at f5.7: approx. 23 hours

# How many images to take

> Number of light frames:

- Sky quality
- Optical speed
- Camera sensitivity
- Target image depth

> As many flats and darks as lights

> About 40 Bias frames

Example: 4-frame LRGB mosaic,
16 light frames per channel and FOV

→ Lights: 4x4x16 = 256
→ Total: 600-800

# Image Alignment

# Merging concepts

Most accurate OR fastest way to build a mosaic?

Two concepts:

(1) Build each mosaic part separately

→ merging afterwards
→ multiple image interpolations

(2) Use a 'Global Reference Image' (GRI)

→ image alignment to GRI
→ stack each part as usual
→ direct merging, i.e. without another interpolation

# Each mosaic part separately

> What most people do – most intuitive…?

> For every mosaic part:

→ Chose a local reference image and do alignment

→ Stack each channel with appropriate rejection routine

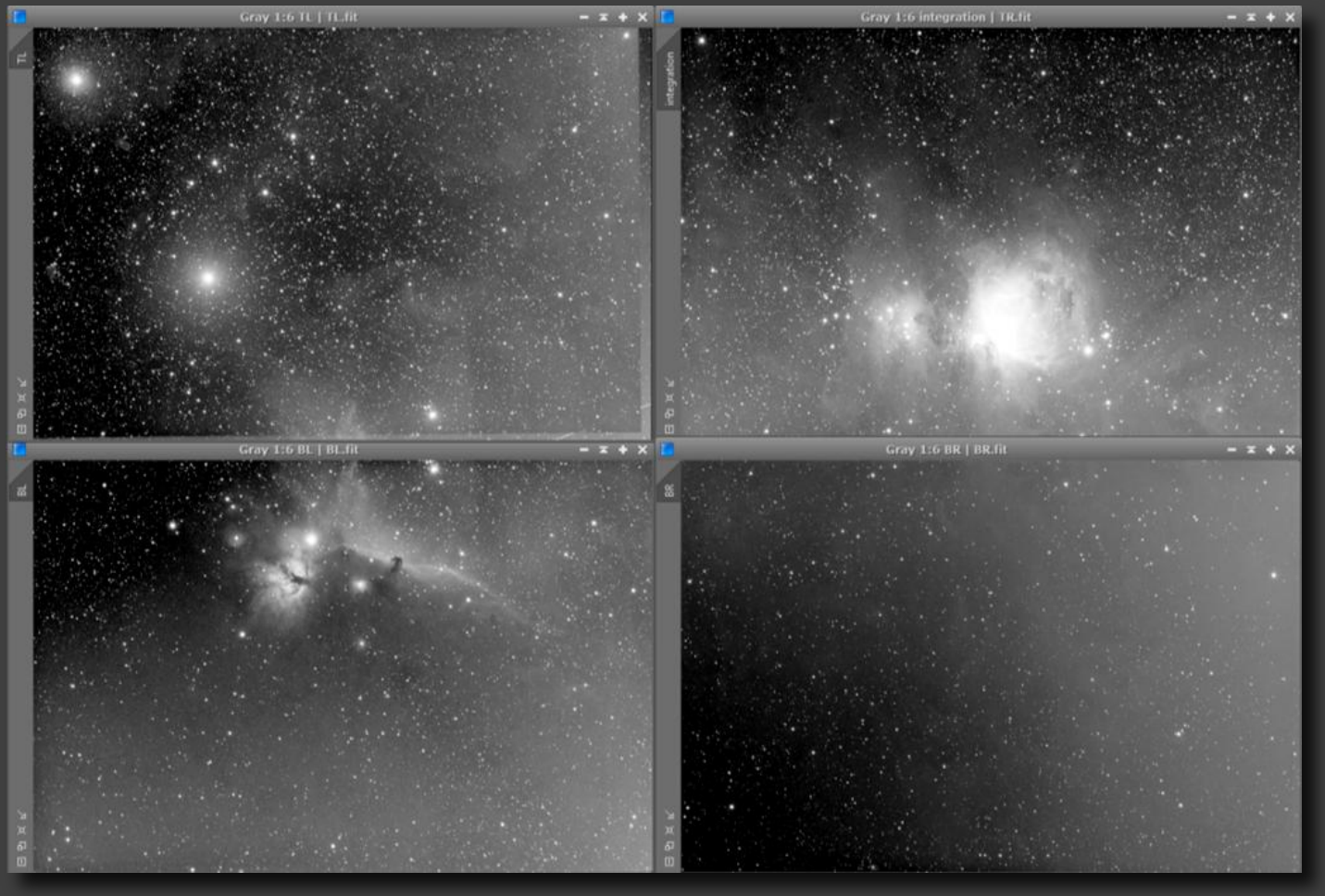
> e.g. 4-frame LRGB mosaic → 4x4 image stacks

> Remove Gradients and/or flatfield calibration errors

→ Critical step to obtain good mosaics

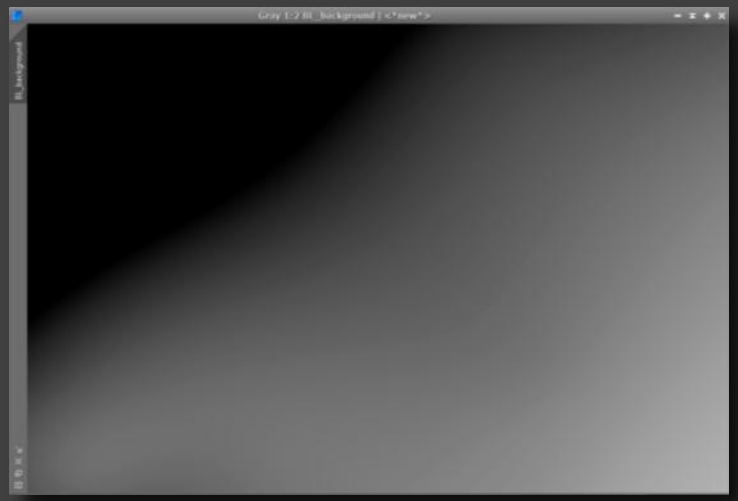
→ Spend enough time here

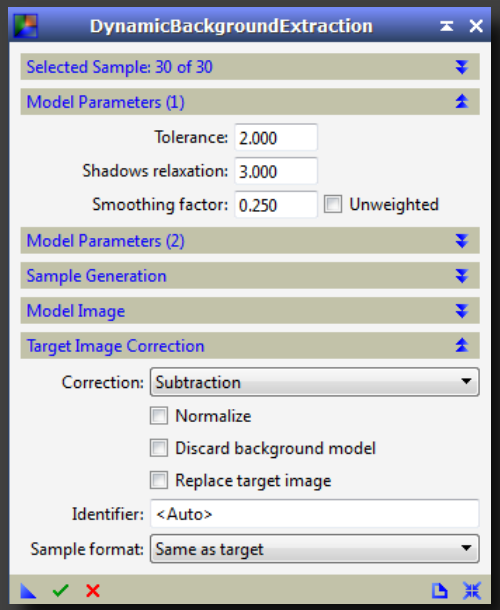
# Correct Gradient & Illumination errors




Gradients due to light pollution, errors in flat field correction, …

# Correct Gradient & Illumination errors



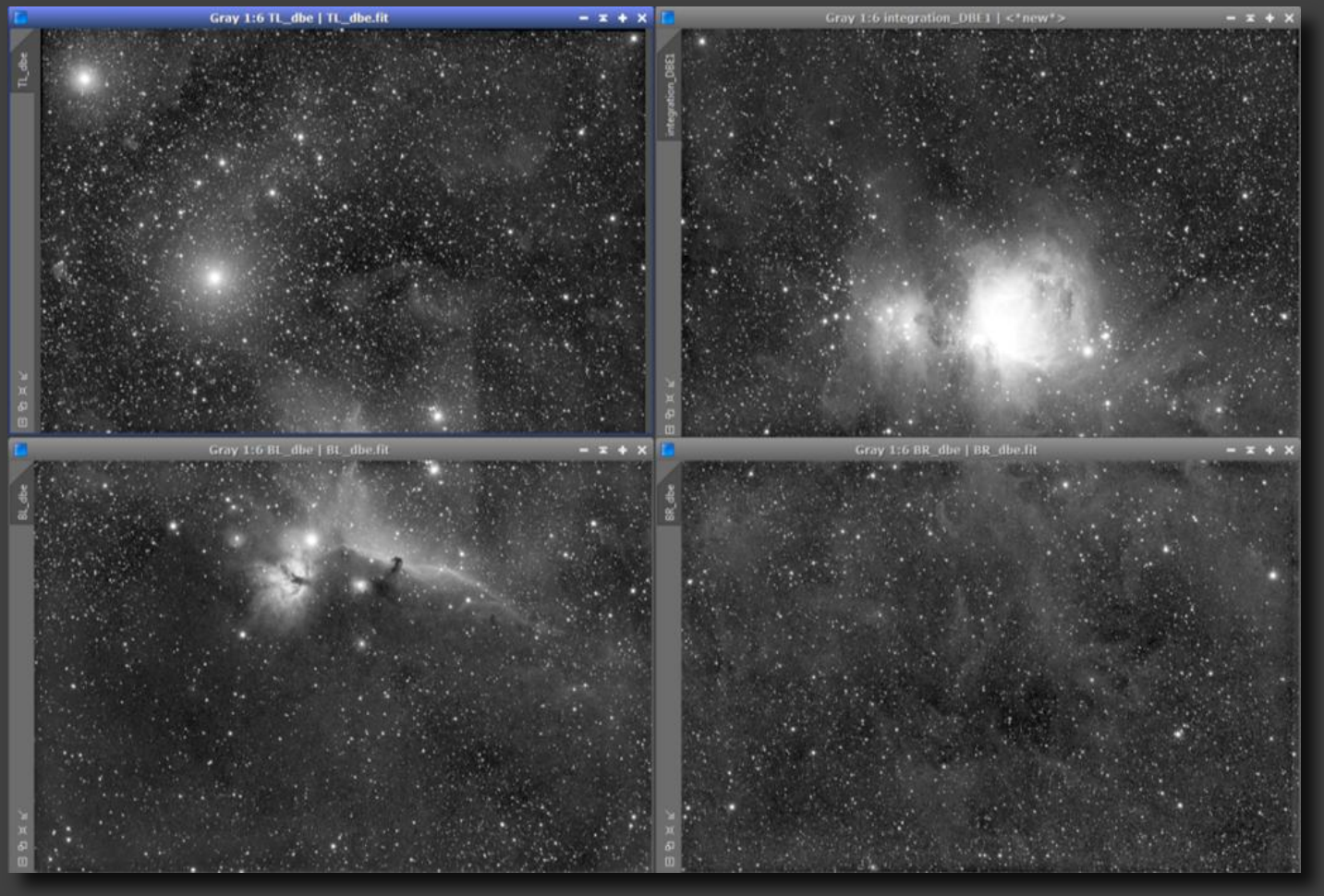



> PIXINSIGHT is very efficient

> Play with different sample positions and model configuration

> Always check background model

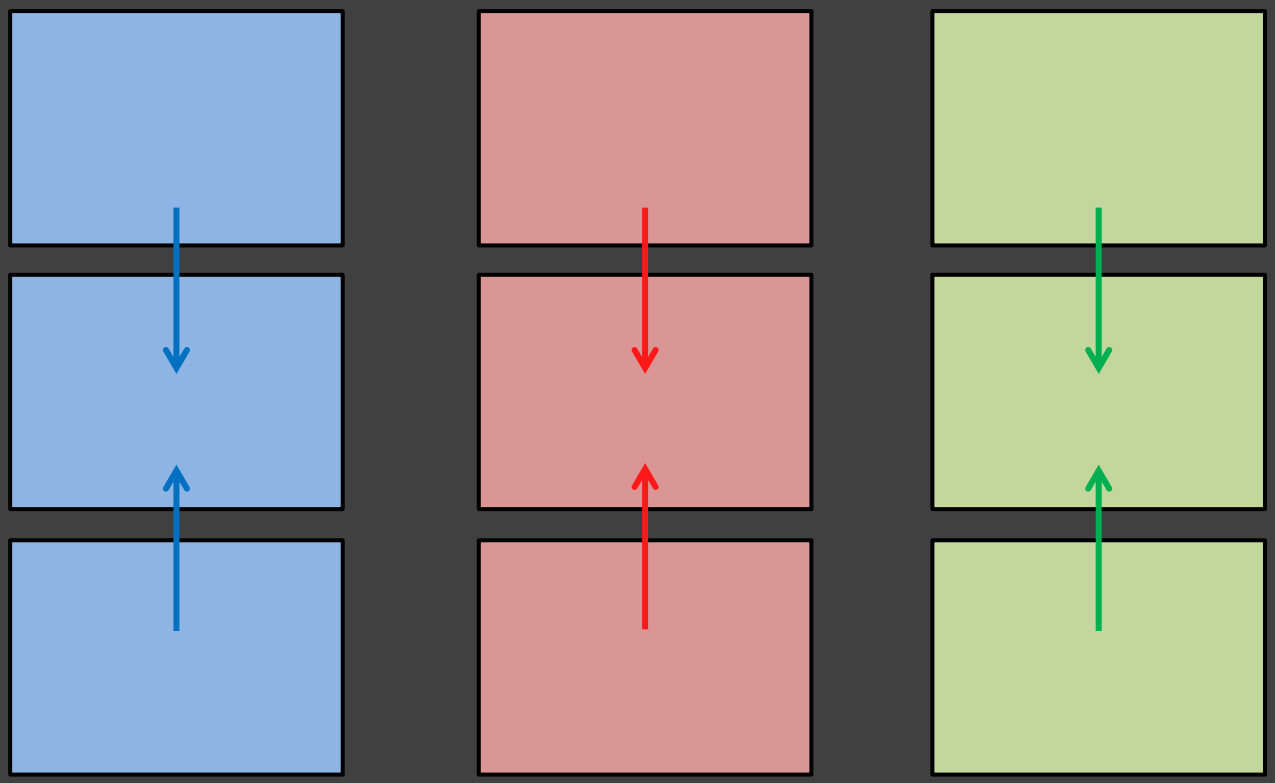
# Correct Gradient & Illumination errors




Something we can work with

# Merge mosaic parts

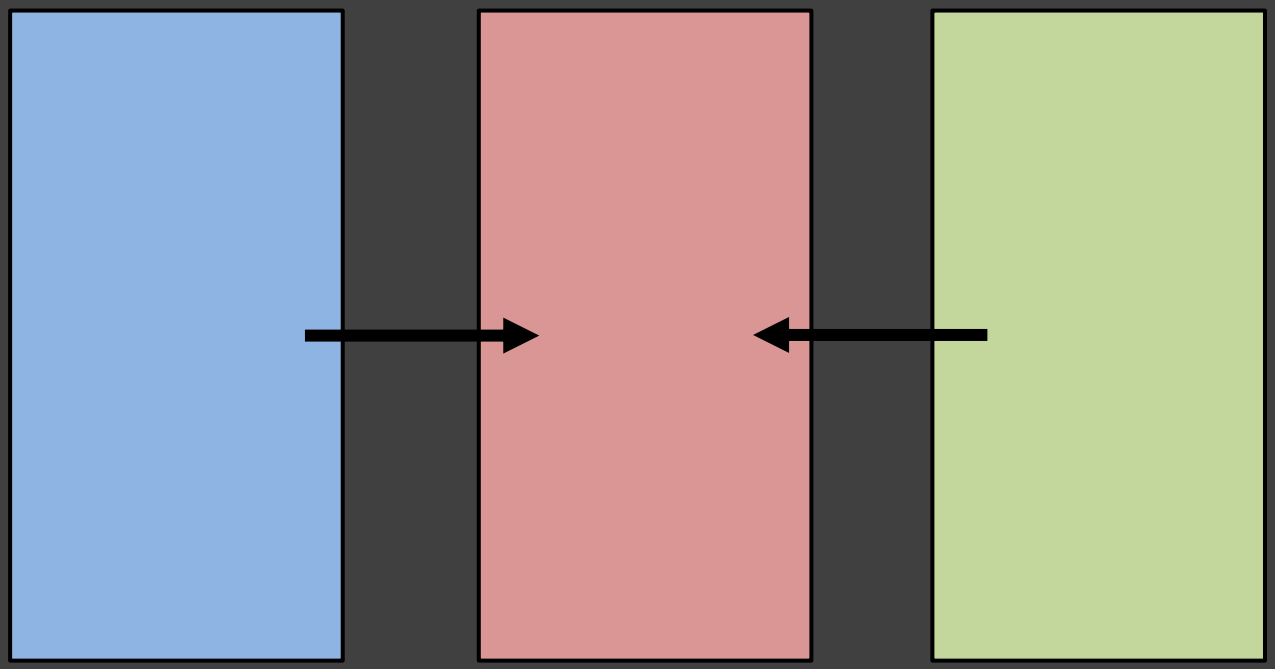
> Create a mosaic by aligning components stepwise such that it minimizes possible distortion errors



f.e. 3x3 mosaic

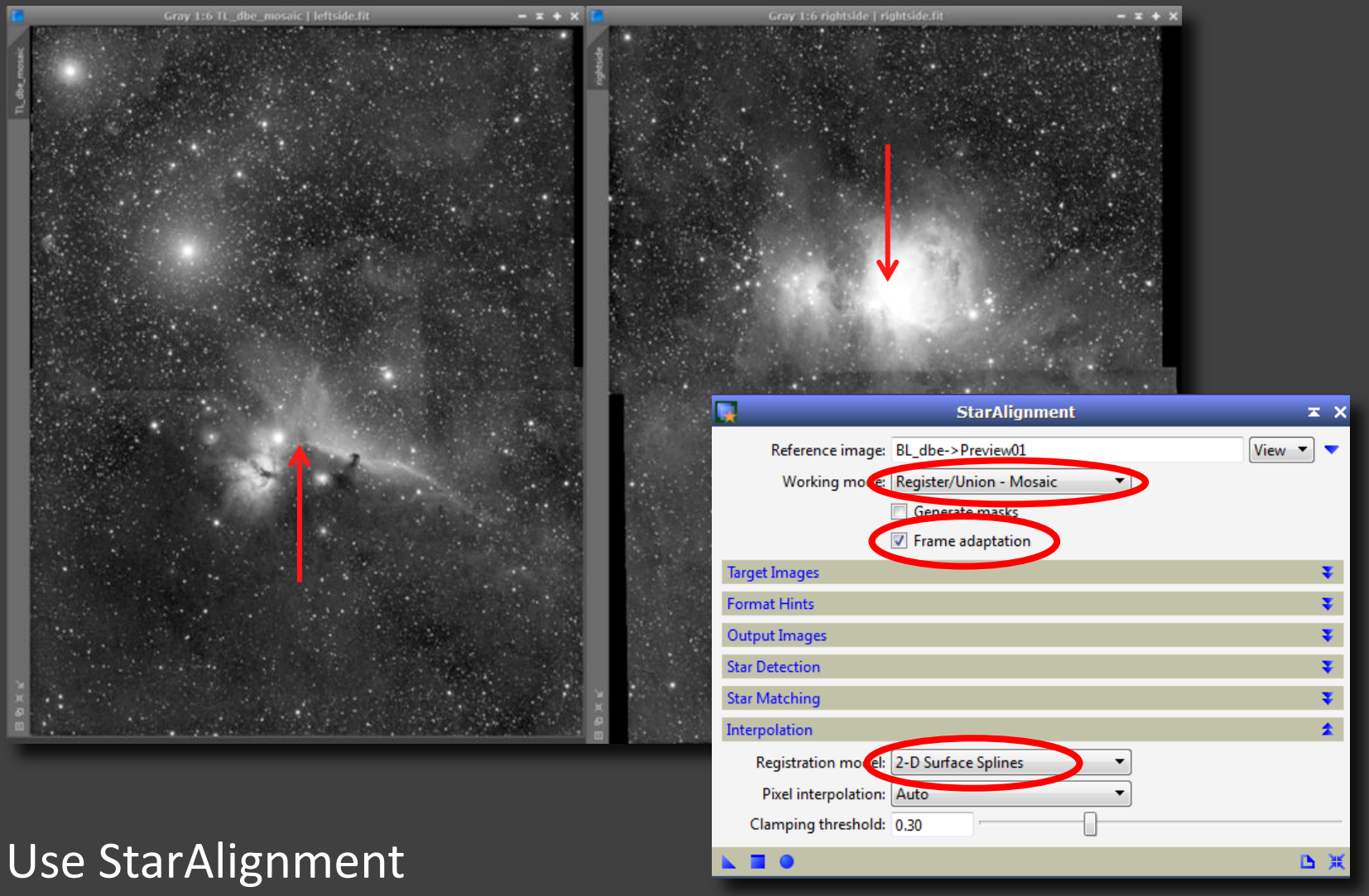
# Merge mosaic parts

> Create a mosaic by aligning components stepwise such that it minimizes possible distortion errors



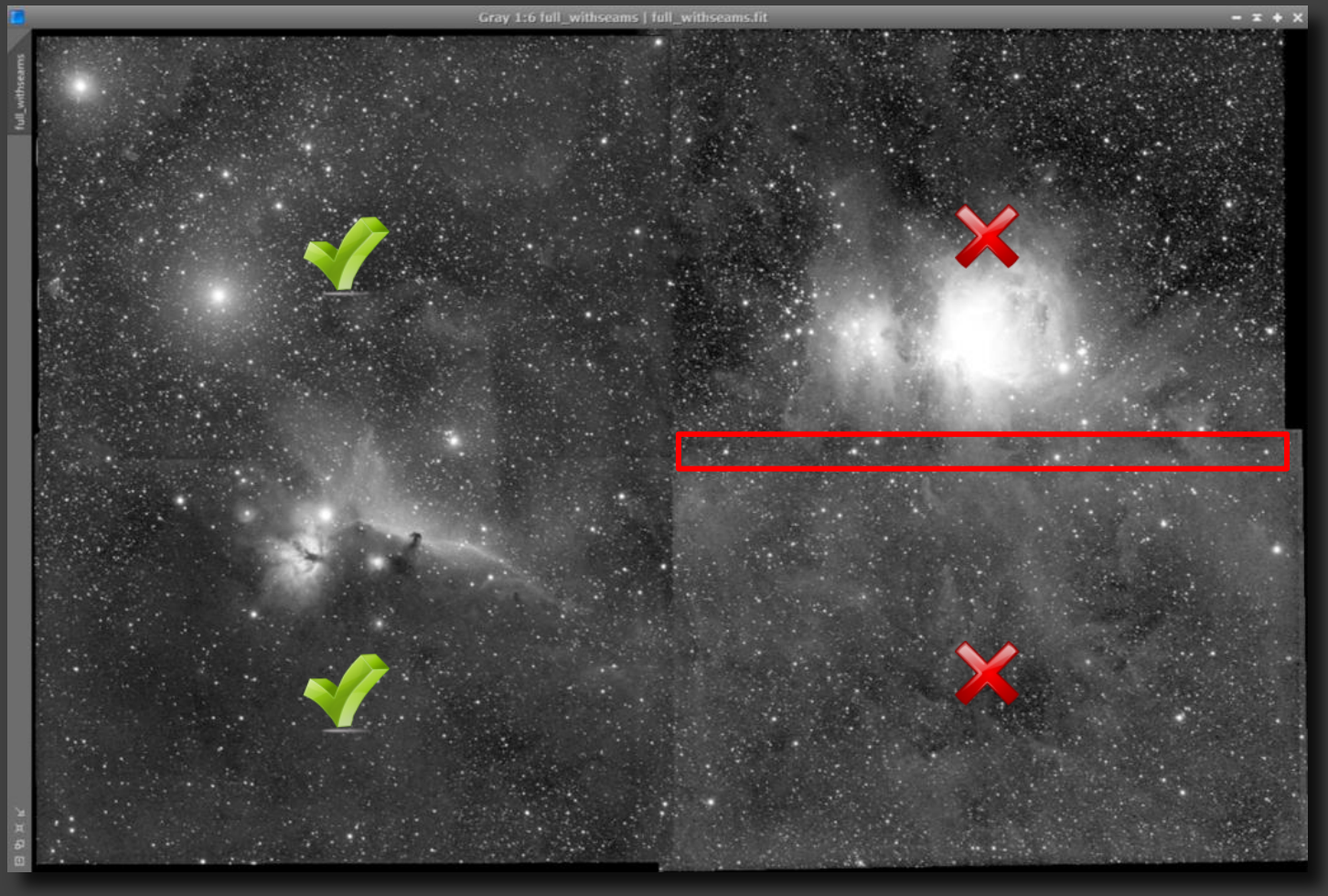
f.e. 3x3 mosaic

# Create Sub-mosaic images




Use StarAlignment

# Create total mosaic




> Overlap is very small → Frame Adaption based on very small region
> Still some errors in the background model…?

# Create total mosaic

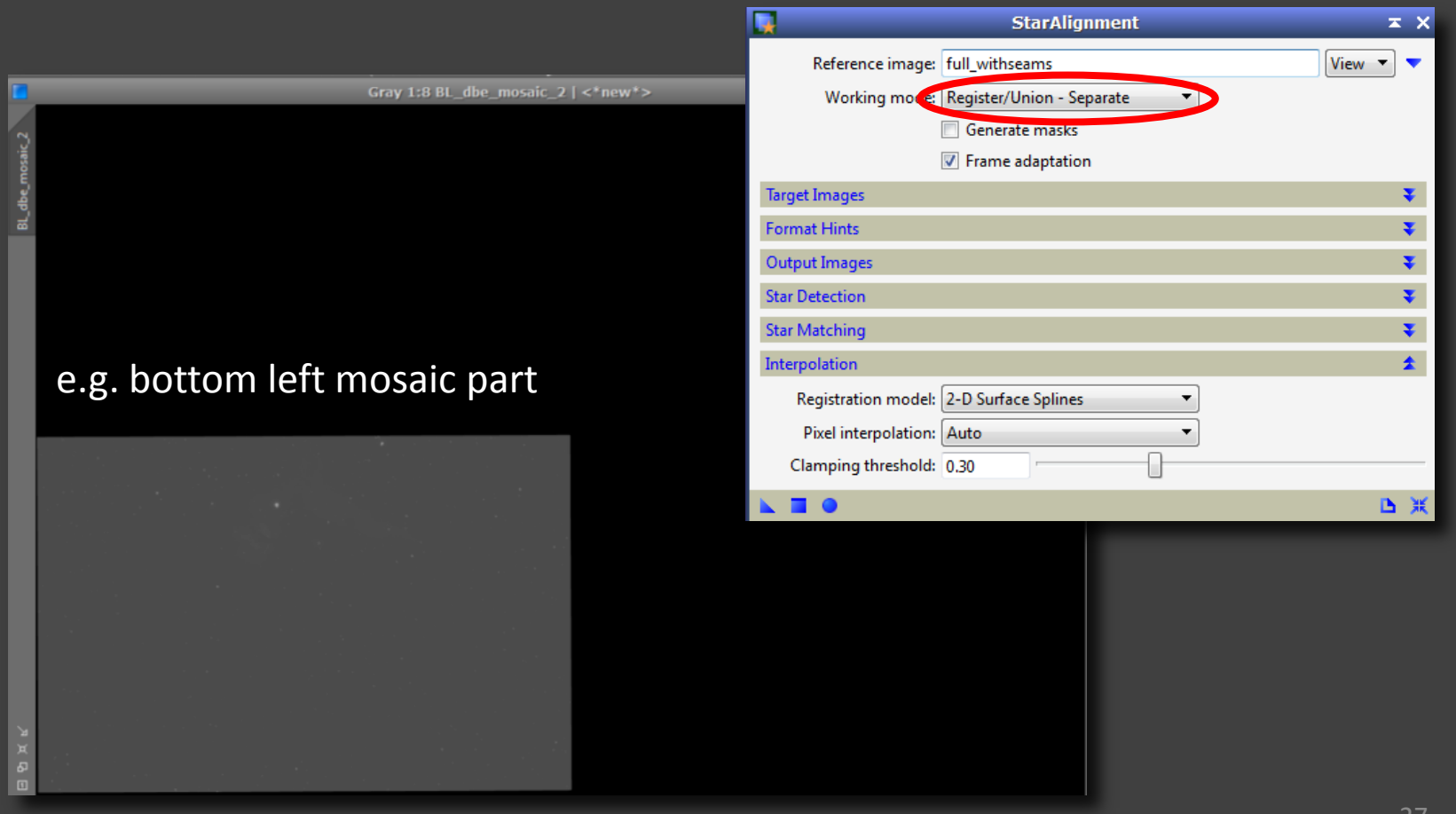

Using a slightly different Background Model
→ Could be further improved

# Create total mosaic

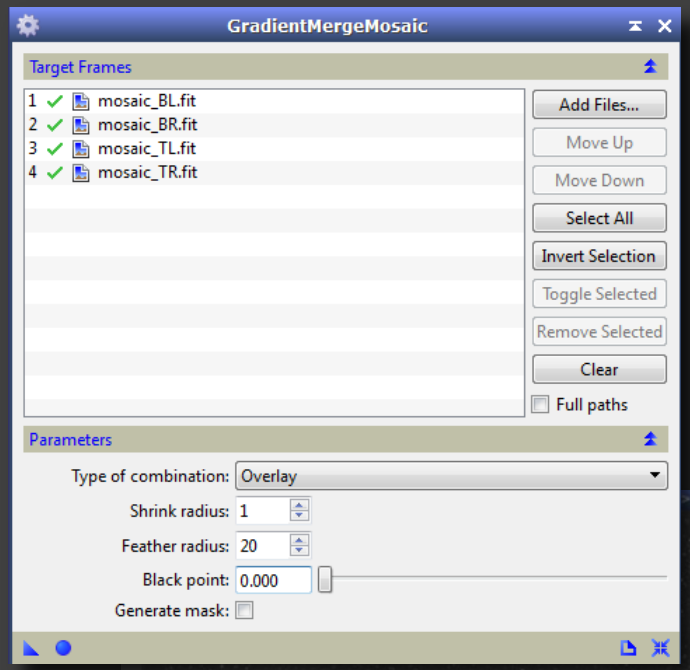
> Use created mosaic to again align all parts

→ Use 'Separate' mode to save mosaic parts individually

→ As reference: mosaic image with seams



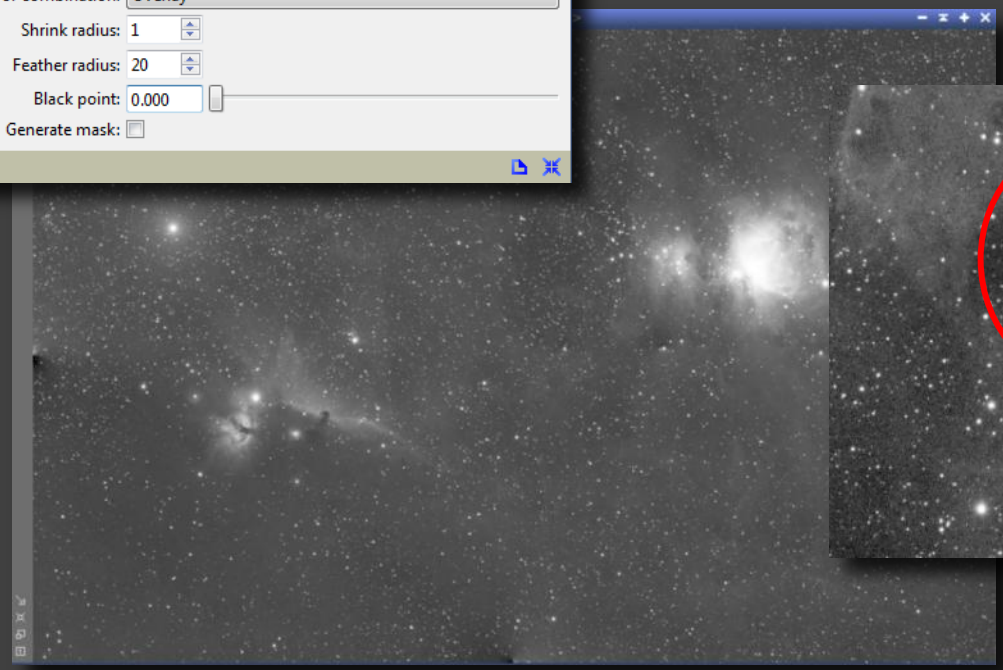
# Seamless Mosaic Transitions with PixInsight




GradientMergeMosaic Tool

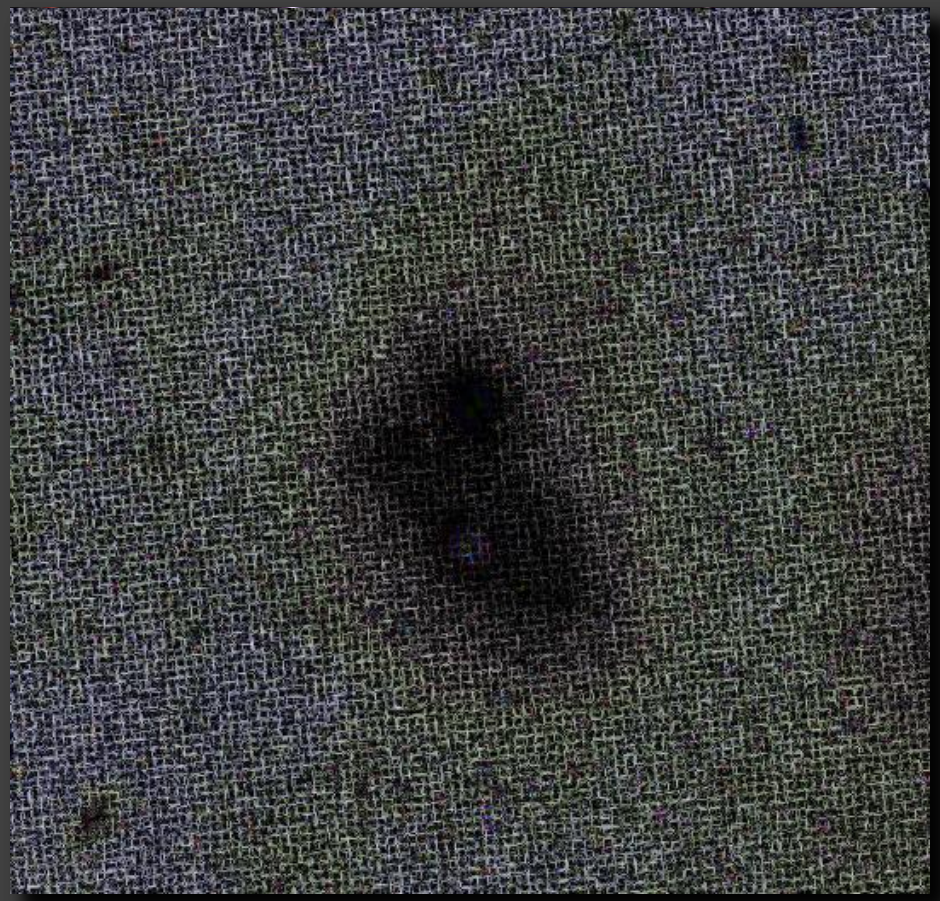
> Load separately aligned mosaic parts from previous step

> Play around with Shrink – and Feather radius



# Seamless Mosaic Transitions with PixInsight

# What image alignment means



= abs(Image1 – Image2)

Image1 = original

Image2 = 2 x Lanczos-3 interpolation

→ Every pixel interpolation produces noise!

Keep the number of image interpolations as low as possible!

# Other Concept: Use a Global Reference Image

My definition:

Global Reference Image:
"An image that provides the information of star locations over the entire field of a mosaic"

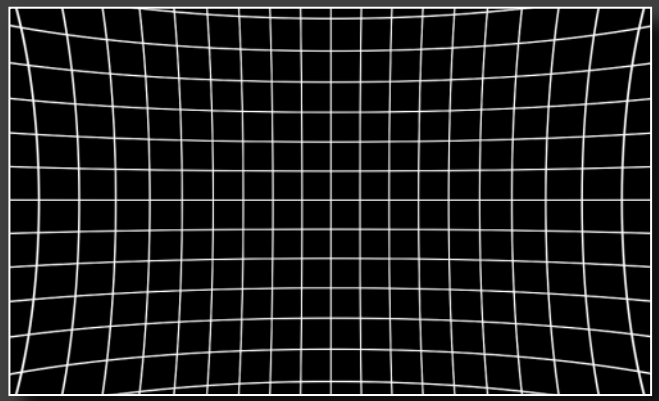
> One image alignment, hence one interpolation

> Possibility to create 'flat' images

> A step closer to be accurate

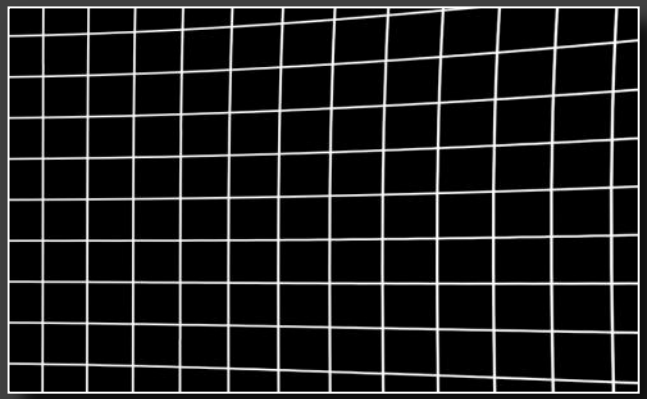
# The Reference Image

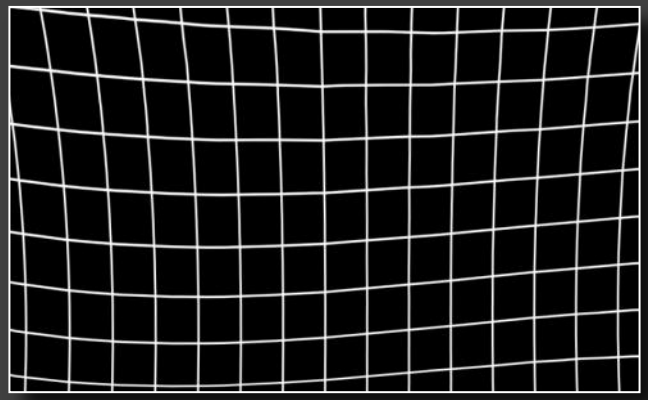
> What makes it non-trivial: Field Distortion



symmetric lens distortion

e.g. one side sensor tip





complicated mixture

# Different types of Reference Images

## (1) Sky-chart, other (low resolution) wide-field image

+ very easy to produce
- does not correct field distortion (may make it even worse)
- usually not accurate enough

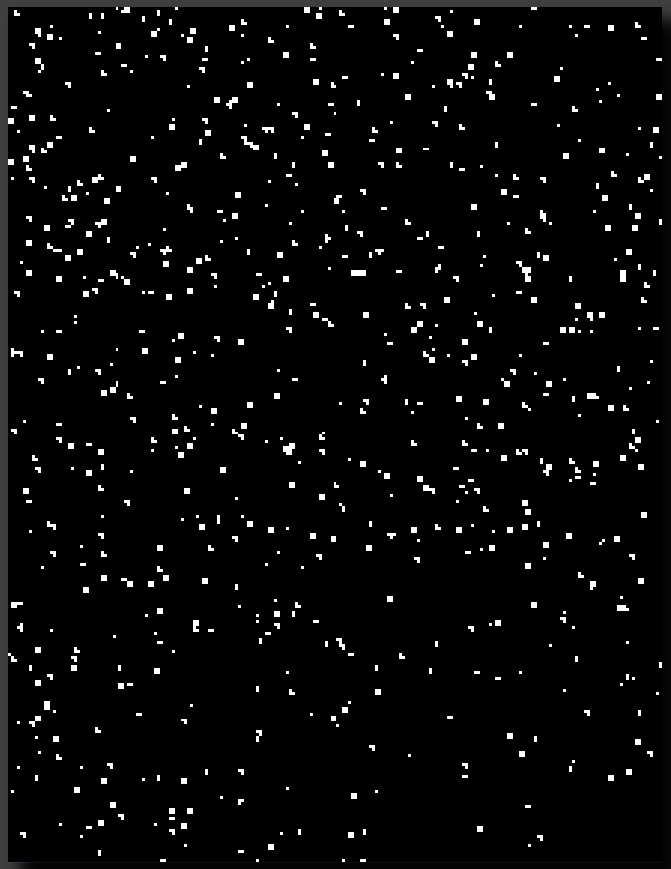
## (2) Star reference catalogue

+ easily available nowadays
+ perfectly corrects distortion
- not every software can handle this

## (3) Subset of own images

+ no other data needed
+ straight forward approach
+ suitable for very big mosaics (FOV)
- problem of field distortions remains

# Star Reference Catalogue – PIXINSIGHT



Generate your starfield:

> Enter center position of FOV,
Date of image capture (Epoch)

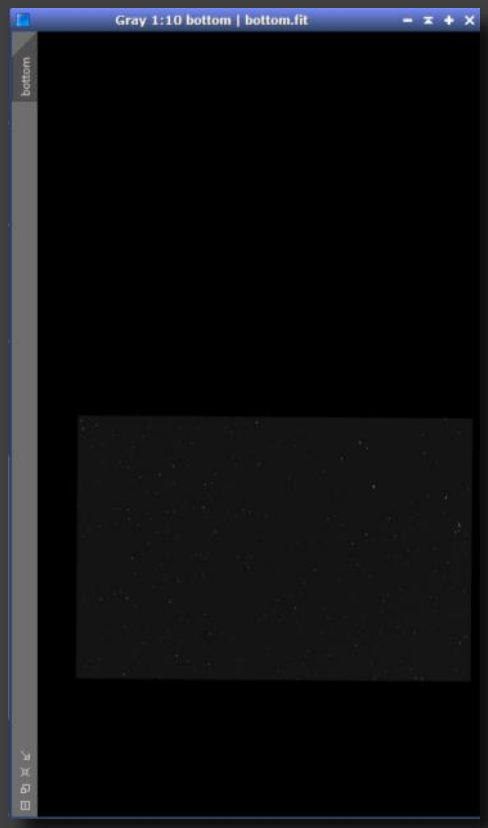
> Use Gnomic projection

> Insert your focal length, pixel size, and the approximate width/height of your mosaic in terms of image pixels

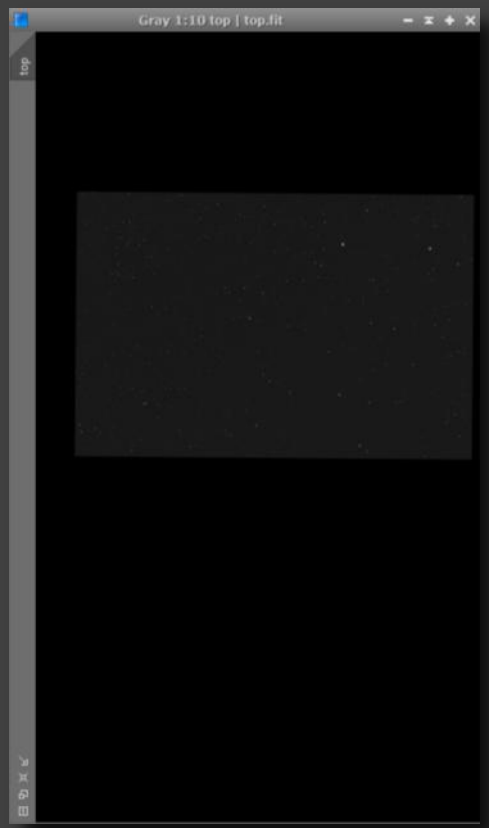
Chose 'Sensor width' and 'Sensor height' such that all parts of your mosaic are completely within the star field created by StarGenerator

→ Orientation does not matter at the moment

# Exact framing of the starfield




Bottom part of mosaic



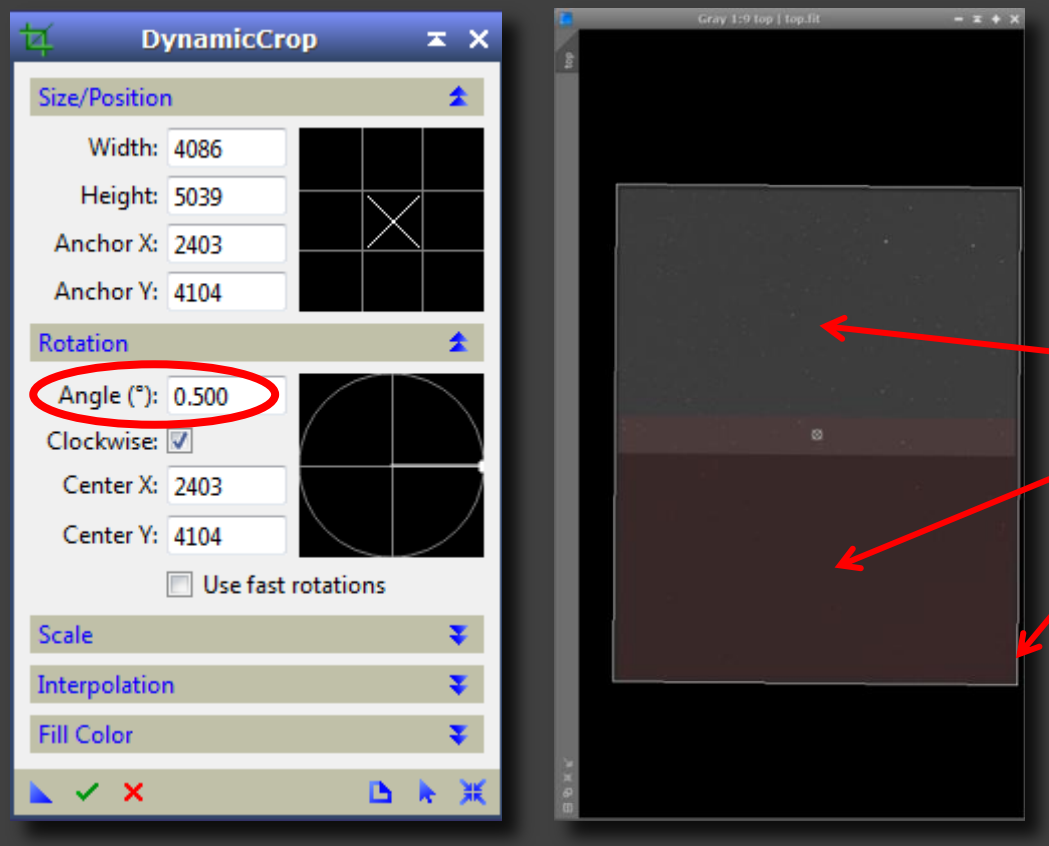

Top part of mosaic

Align one image of each FOV to starfield

Use StarAlignments default values except:

2-D Surface Splines for Registration model

# Exact framing of starfield




One image of each part of the mosaic is aligned:

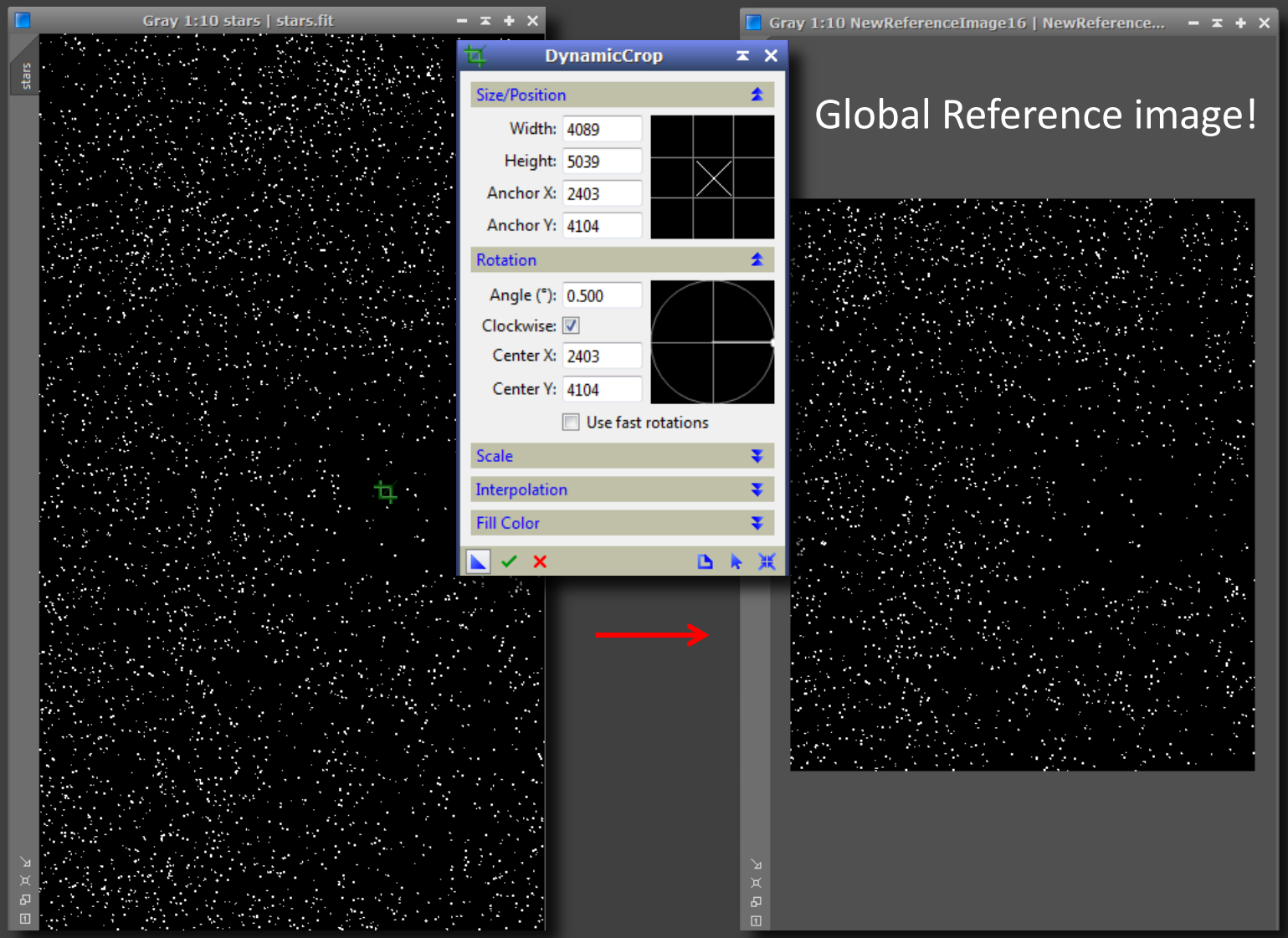
Top part of mosaic

Bottom part overlaid as mask

'DynamicCrop' preview

For larger mosaics:
Combine aligned frames using GradientMergeMosaic or PixelMath

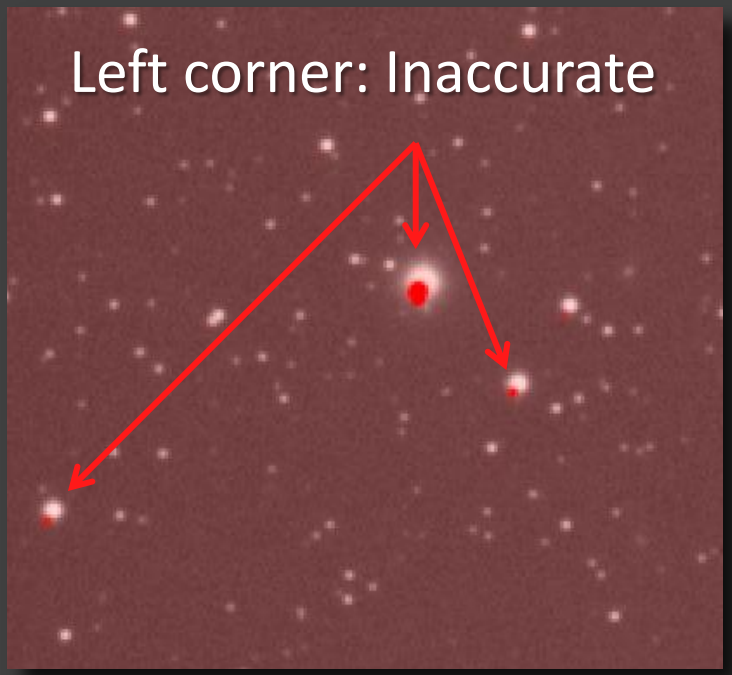
# Exact framing of starfield

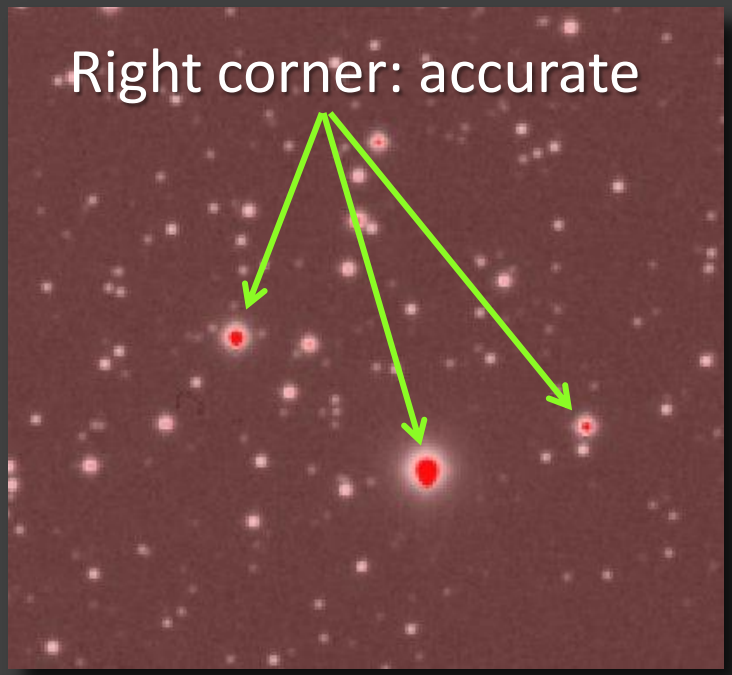


# Aligning this dataset with PIXINSIGHT

> Limitation: Ability to correct field distortion

→ Overlapping zone will not always match accurately




> PixInsight is ***not yet*** ready to deal with any kind of distortion

# Can we solve this?

> Use software which can deal with such distortions

→ REGISTAR

> REGISTAR has limitations:

- No 32bit support
- Stores absolute translation in separate *.rsm files
- Interpolation algorithm not today's state-of-the-art

> Although outdated, REGISTAR still provides the most accurate solution for registering distorted images

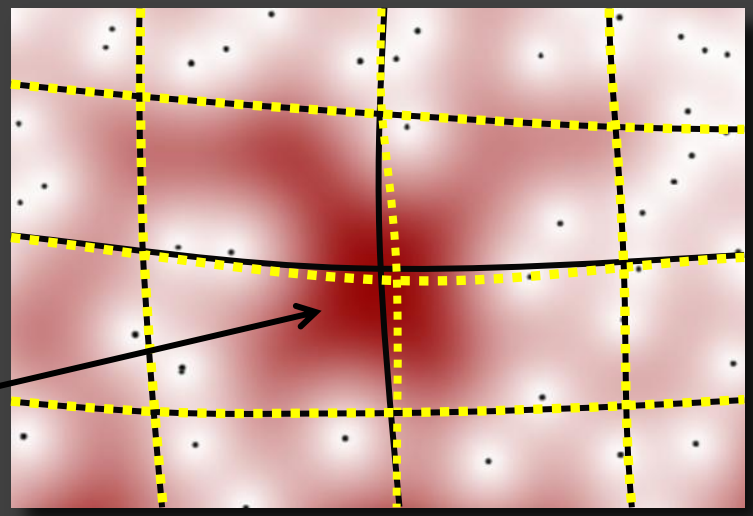
(at least until 27.04.2012)

UPDATE: PixInsight now corrects for all distortions too!

# A Reference Image for REGISTAR

> Use Star Catalogue starfield as Reference Image


+ Easy and fast construction
+ No distortion
- May suffer from bad star coverage
- Increased degree of freedom in alignment



Badly bounded
→ Possible error source

Star nearby  No Star nearby

# A Reference Image for REGISTAR

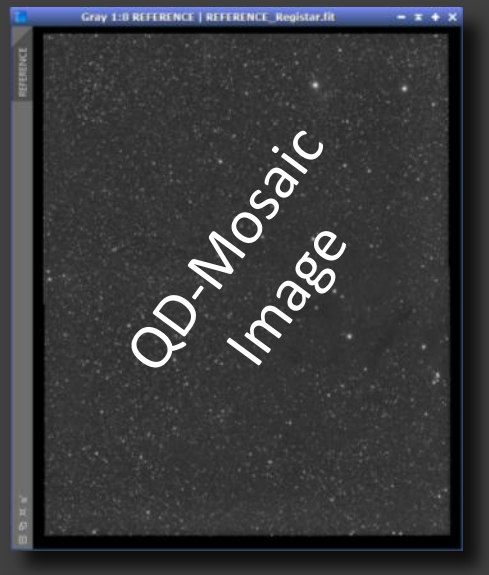
> Use Star Catalogue starfield as Reference Image

> Enhance using subset of your mosaic frames


Not always necessary

May fill gabs in star catalogue starfield

Helps to make alignment more robust with REGISTAR



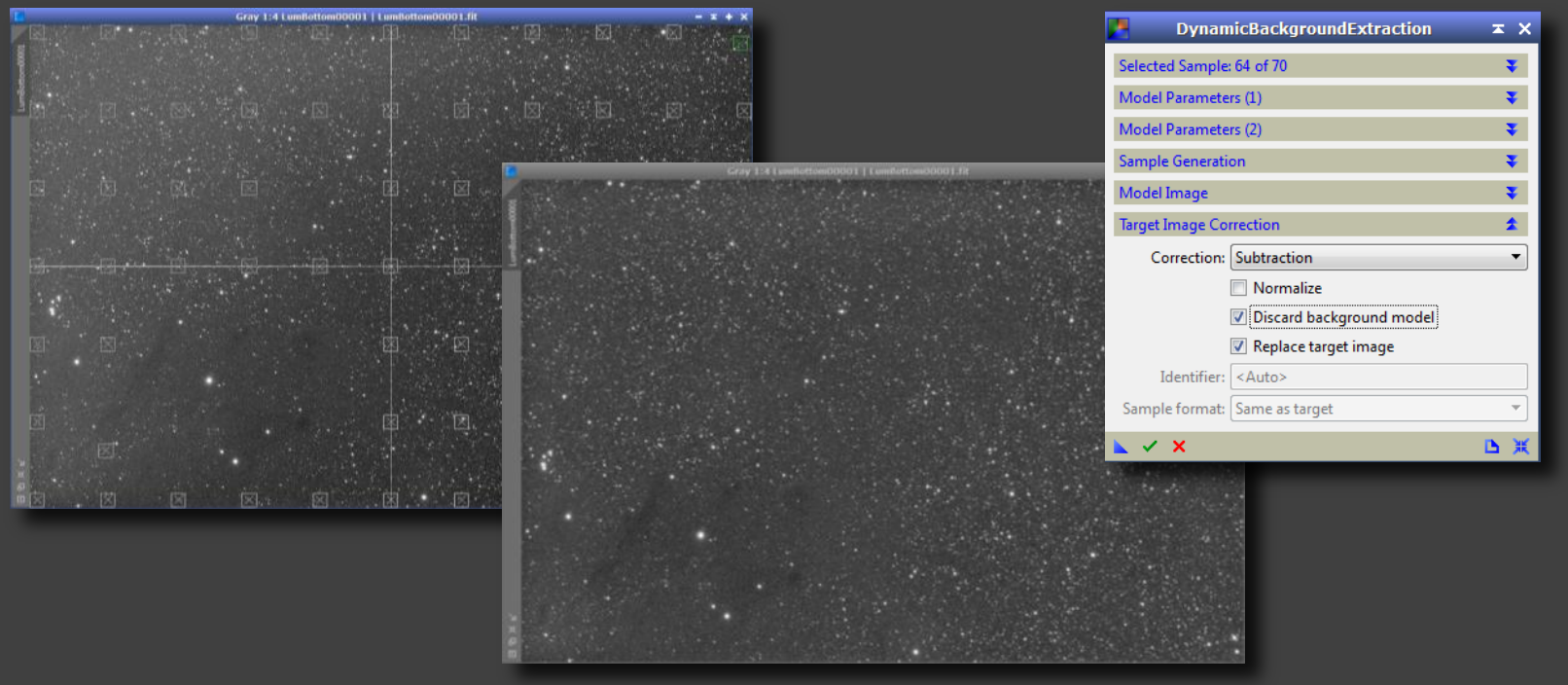

QD = Quick & Dirty

# A Reference Image for REGISTAR

> Use Star Catalogue starfield as Reference Image

> Enhance using subset of your mosaic frames

→ Use highest quality frames (no satellite trails, etc…)
→ Roughly remove gradients (Dynamic Background Extraction)




→ Save in 16 bit (although it hurts a bit…)

# A Reference Image for REGISTAR

> Use Star Catalogue starfield as Reference Image

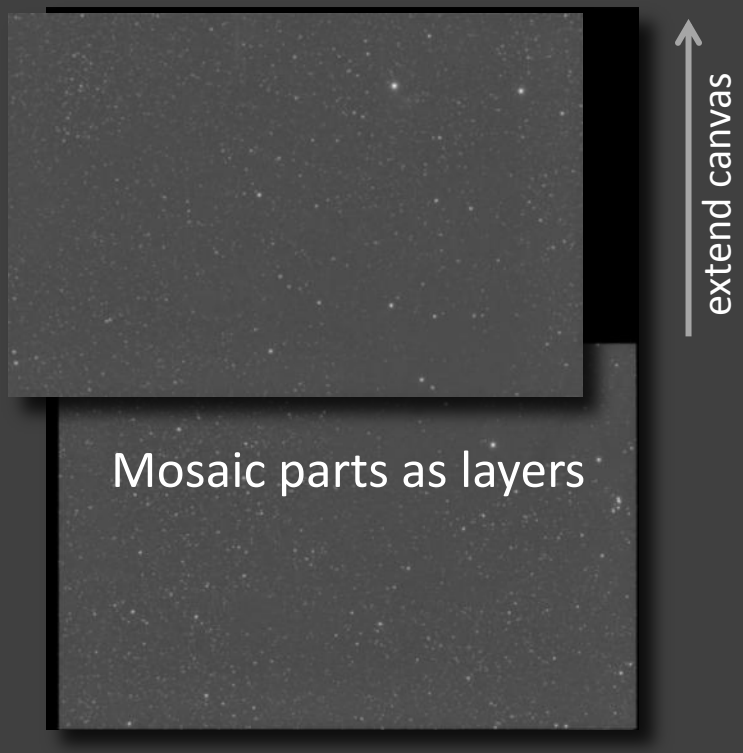
> Enhance using subset of your mosaic frames

→ Use highest quality frames (no satellite trails, etc…)
→ Roughly remove gradients (Dynamic Background Extraction
→ With REGISTAR align these to the starfield (Star Catalogue)
→ Merge aligned images
→ This is your enhanced Reference Image

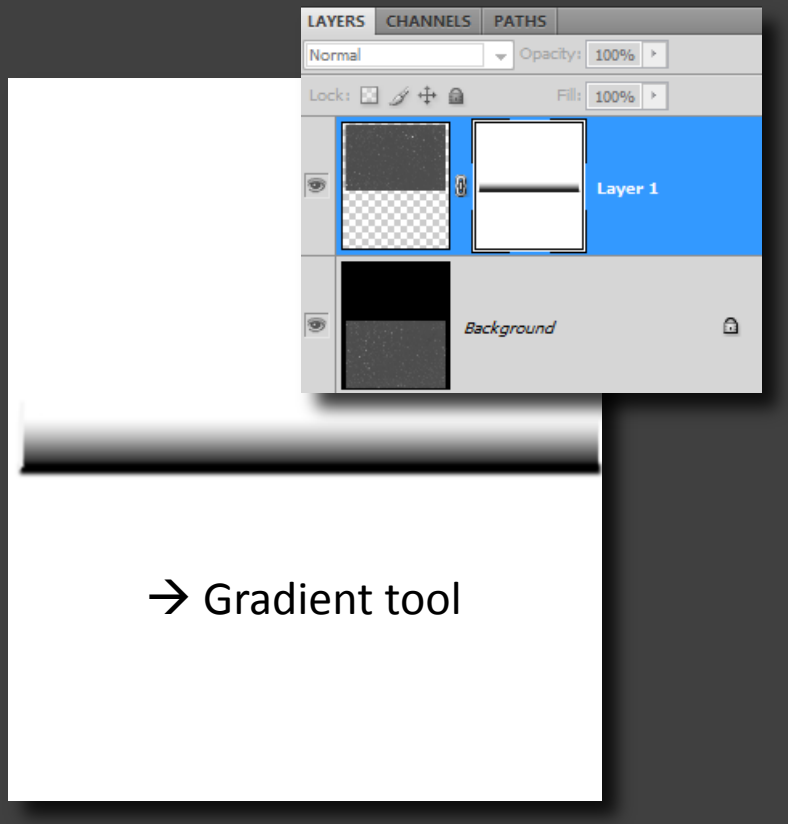
→ How to merge mosaic parts from REGISTAR?

# Merge aligned mosaic parts

## > With PHOTOSHOP




extend canvas




Use 'Move tool' to place top part into correct position

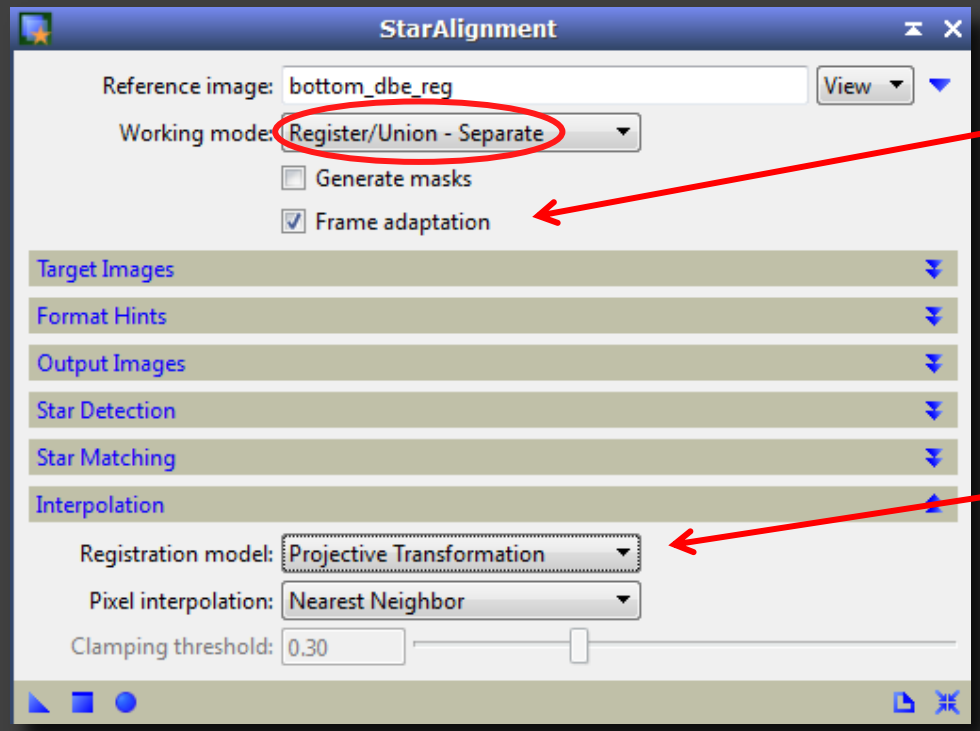
→ Compensate what is written in REGISTAR's *.rsm files

Gradient mask in overlapping region

# Merge aligned mosaic parts

## > With PixInsight

We have to find relative translation first



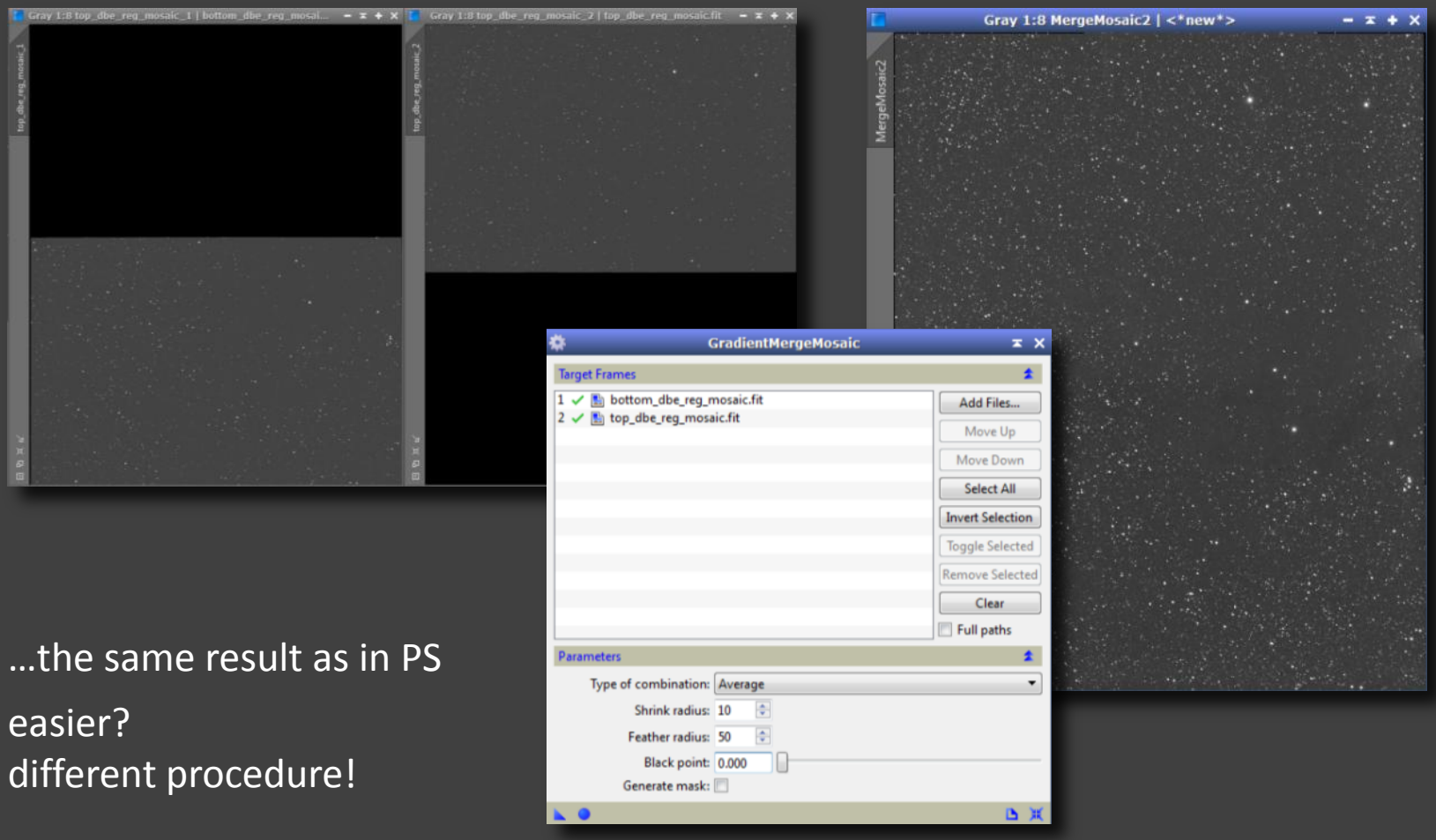

Check 'Frame adaption' to correct for offset and scale differences

→ What you have do manually in PS

Nearest Neighbor:
No image interpolation!

# Merge aligned mosaic parts

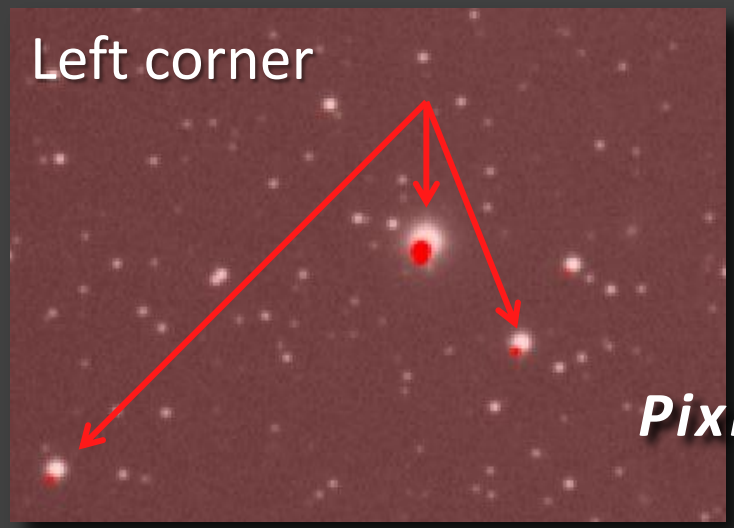
> GradientMergeMosaic Tool for seamless transitions

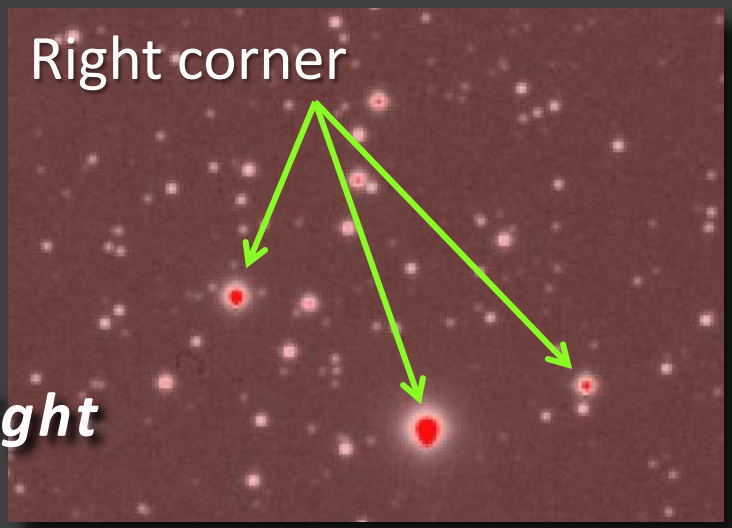



...the same result as in PS

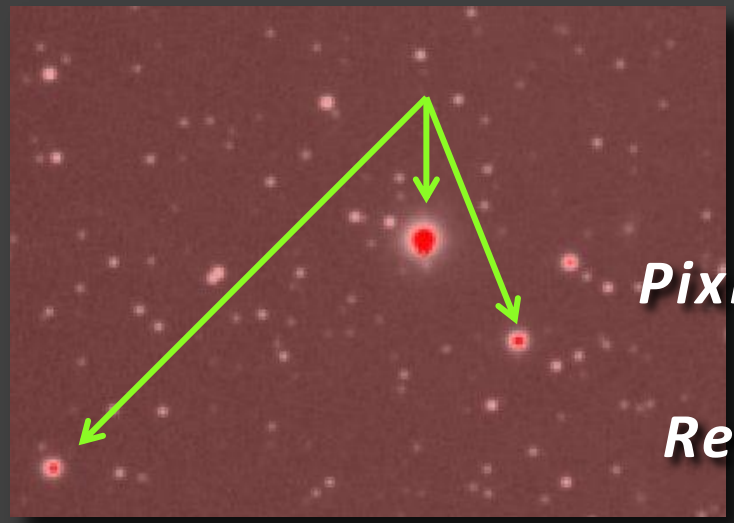
easier?
different procedure!

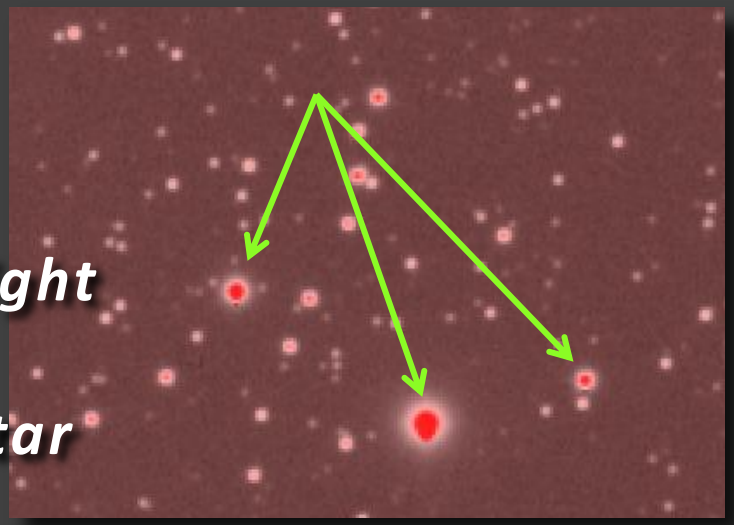
# Advantage of including REGISTAR




***PixInsight***





***PixInsight***
***&***
***Registar***

# Worth the effort?

> Remember: Result obtained with only ‘one’ interpolation

> Arguments:

- PIXINSIGHT uses a better interpolation routine than REGISTAR
- Two (or more) image interpolations not too much ?
- Switch between 32bit and 16bit files ?
- Better stick with one single software ?
- Does PIXINSIGHT fully correct field distortion ?
- Perfect star match over entire FOV ?

It’s up to you!

# Other software?

> THELI = package for the automated reduction of astronomical imaging data

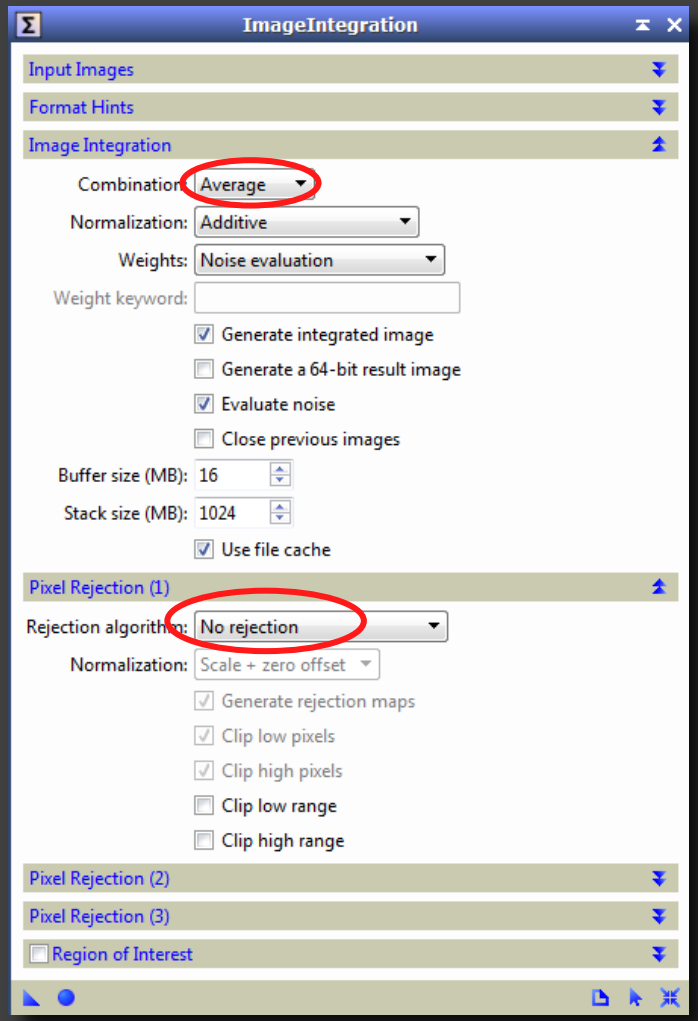
- Developed at University Bonn, Mischa Schirmer et al.
- Powerful software tool running on LINUX
- Freeware!

- Trial and Error in the beginning
- Uses various online star reference catalogues
- Easy color calibration once the image is referenced

# Stacking

# ImageIntegration Settings

> Check what maximum SNR increase is possible




Combination method 'Average'

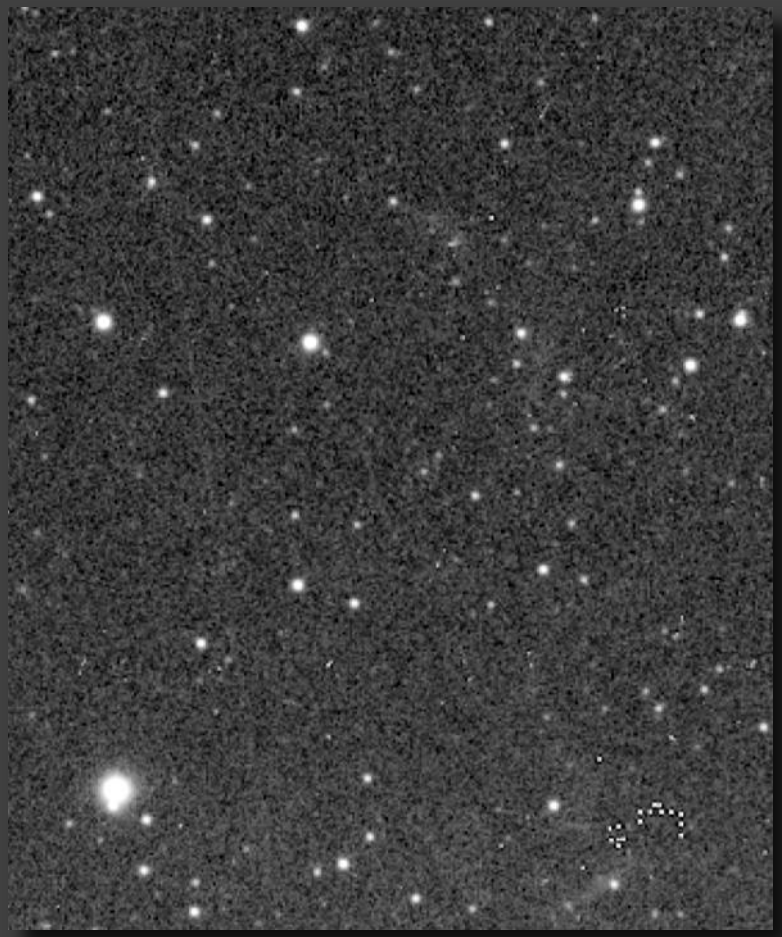
No Pixel rejection is applied at this stage!

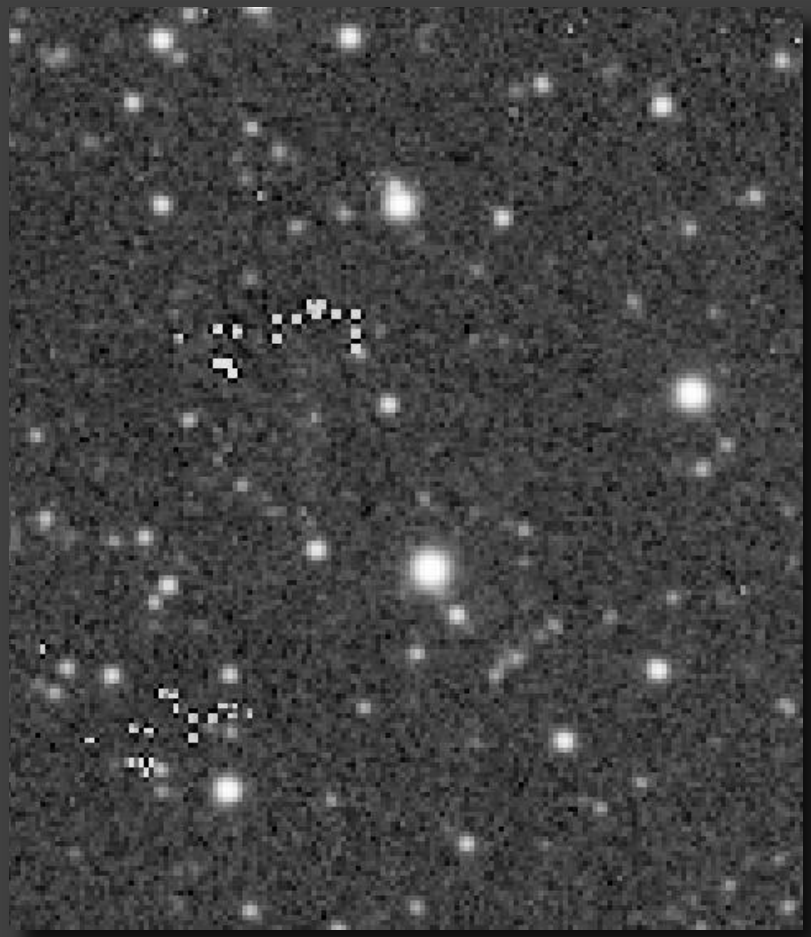
Console output:

```
Gaussian noise estimates:
σ_ε = 7.698e-004

Reference SNR increments:
Δσ_ε0 = 3.7014

Average SNR increments:
Δσ_ε = 3.7947
```

# ImageIntegration Settings

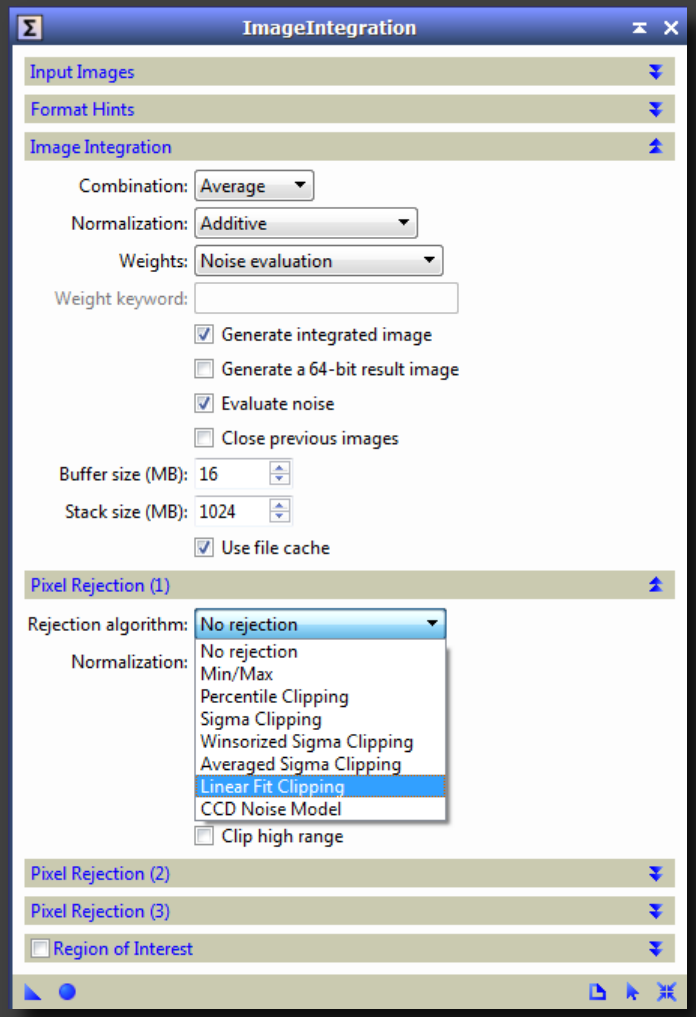
The result:





# Remove outliers

> Choose appropriate rejection algorithm

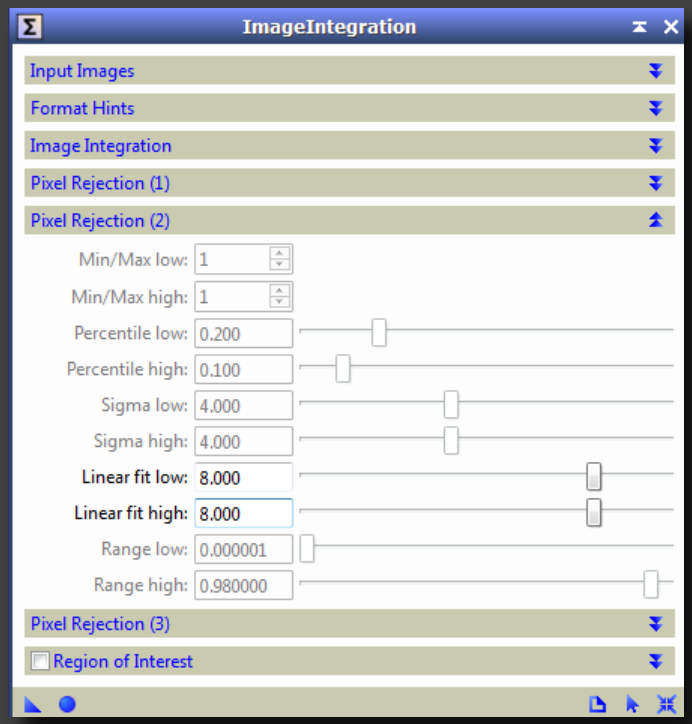



Rule of thumb:

| # images | Rejection algorithm |
|---|---|
| - | Min/Max |
| 3-6 | Percentile Clipping |
| 5-10 | Averaged Sigma Clipping |
| >10 | Sigma Clipping |
| >10 | Winsorized Sigma Clipping |
| >18 | Linear Fit Clipping |
| - | CCD Noise Model |

# Remove outliers

> Start at high Pixel Rejection tolerance



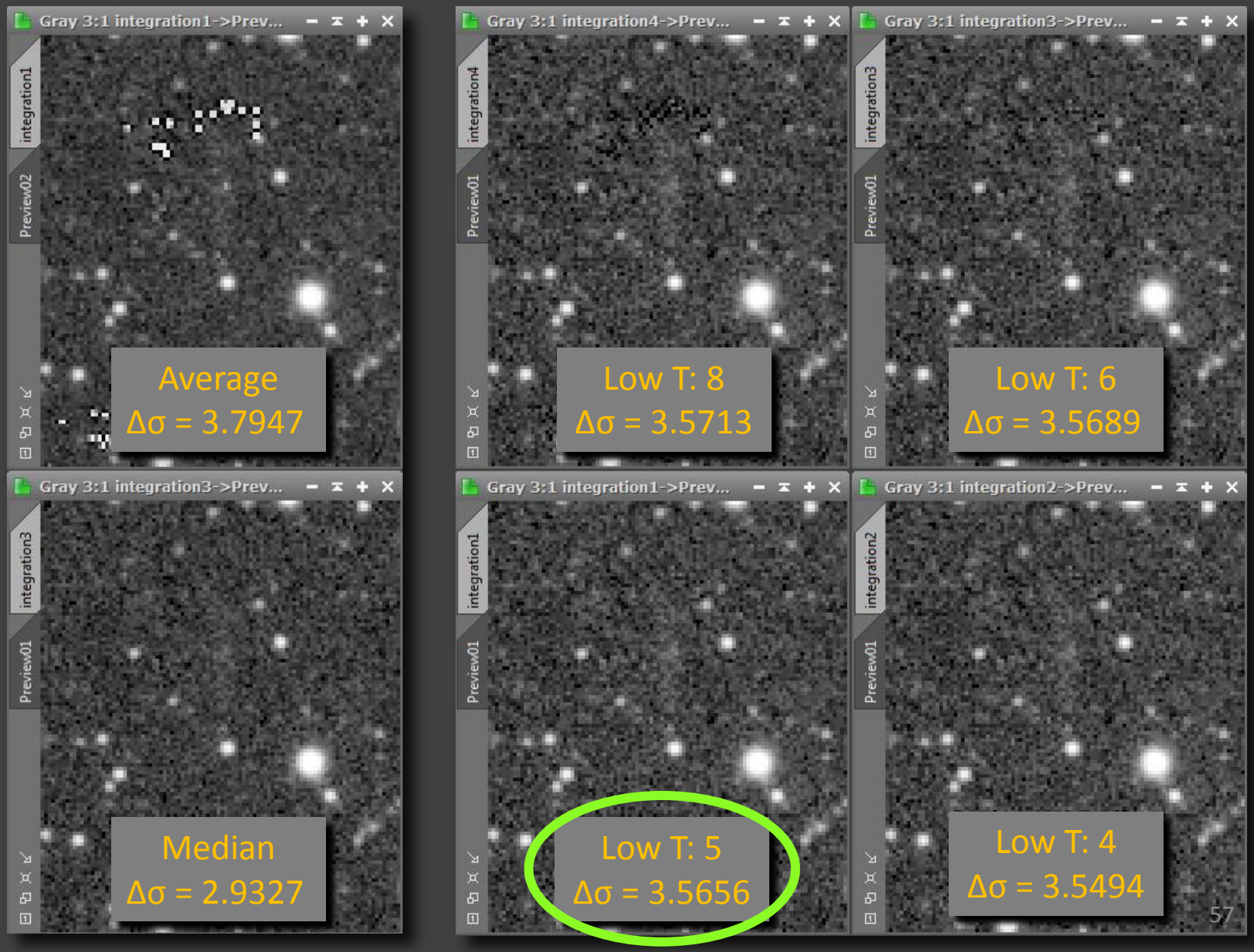

High tolerance values are closer to the result obtained with simple averaging

→ The smaller the rejection tolerance value, the lower the SNR

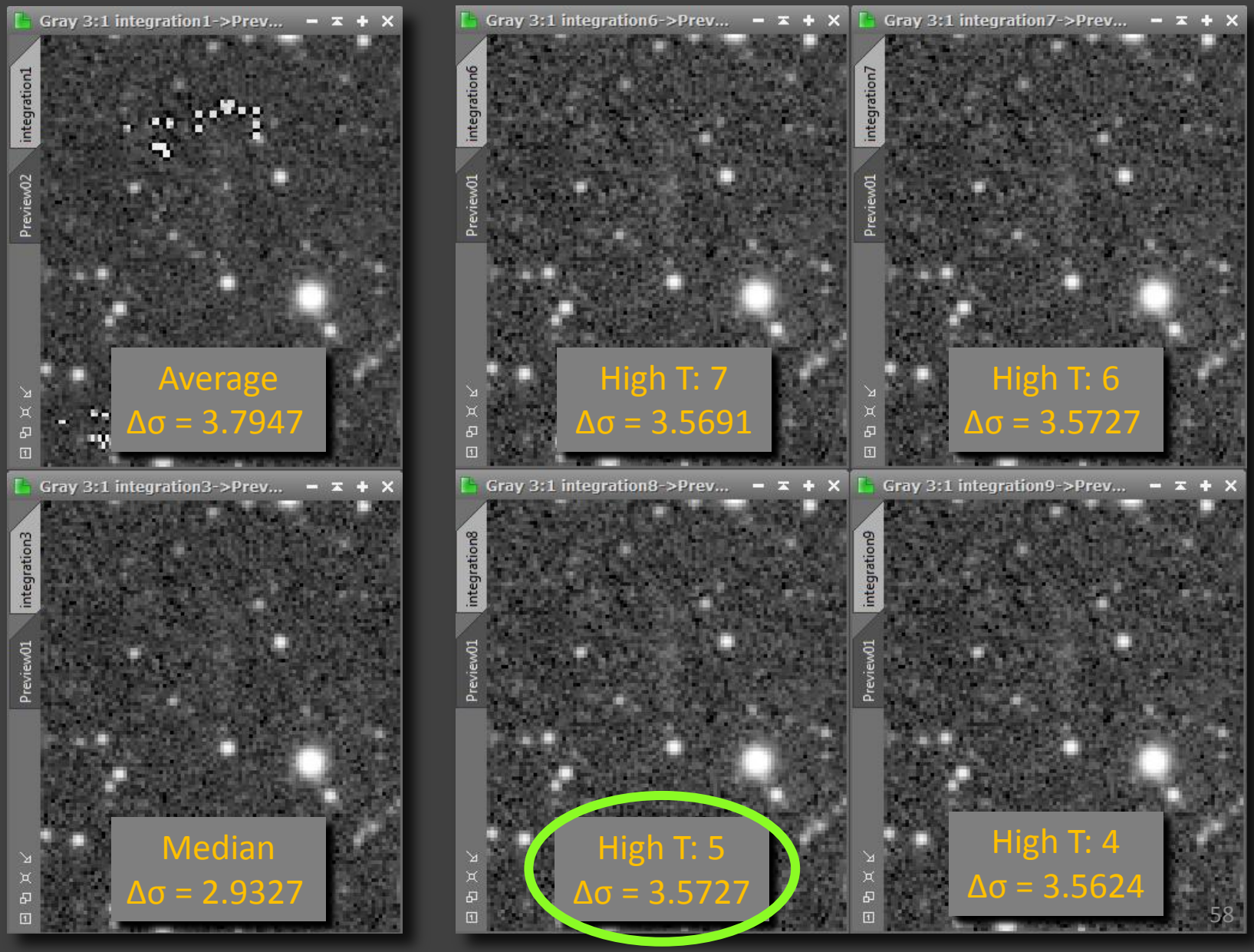
> Iteratively lower the rejection tolerance value

> Check integrated image and rejection maps

# Adjust lower rejection tolerance



# Adjust upper rejection tolerance



# Color Calibration

# What method?

> A number of color calibration method exists

→ B-V calibration (e.g. with eXcalibrator using Aladin, THELI)
→ G2V calibration (not recommended)
→ Maximizing available information, i.e. white is not defined by a specific spectral type (PIXINSIGHT)

> Actually color calibration is a philosophy

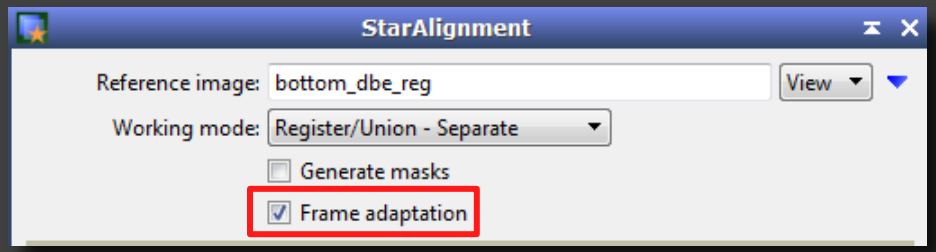
> What's important:
Do it at the right stage of image processing

# When to apply color calibration

> Your images must be in the linear stage

> Doing mosaics: For each filtered image stack, mosaic parts must linearly match

> In PIXINSIGHT




> In PHOTOSHOP

..not available..

# Workflow summary (1)

Image Calibration

Align each mosaic part separately

Aligning Concept 1

Stack aligned images

for each channel

Align and linearly adjust mosaic parts

Merge total mosaics

Combine RGB

Color Calibration for total mosaic

for each mosaic part

Combine RGB

Color Calibration

Align mosaic parts

Merge total mosaic

# Workflow summary (2)

Optimal case if REGISTAR is not needed
→ All in PIXINSIGHT

Image Calibration

Build Global Reference Image

Align all images to GRI

Stack aligned images

Possible method without PIXINSIGHT

Aligning Concept 2

for each channel

Linearly adjust mosaic parts

Merge total mosaics

Combine RGB

Color Calibration for total mosaic

for each mosaic part

Combine RGB

Color calibration

Merge mosaic parts

# Final ingredients

> Experiment with different software packages

> Think about the consequences of possible methods

> Choose one you like the most

> Do not hurry in post-processing

What's most important:

## Processing your data should be fun!

Thank you!

# List of useful Links

- Planning Compositions and Finding Guidestars
  *http://www.robgendlerastropics.com/Compositions.html*

- PTLens (corrects distortion/vignetting,… of camera lenses)
  *http://epaperpress.com/ptlens*

- PIXINSIGHT forum (very active and a great resource to get help)
  *http://pixinsight.com/forum*

- *THELI, free software package running on LINUX*
  *http://astro.uni-bonn.de/~theli/gui/download.html*

- *Personal Homepage*
  *http://www.starpointing.com*