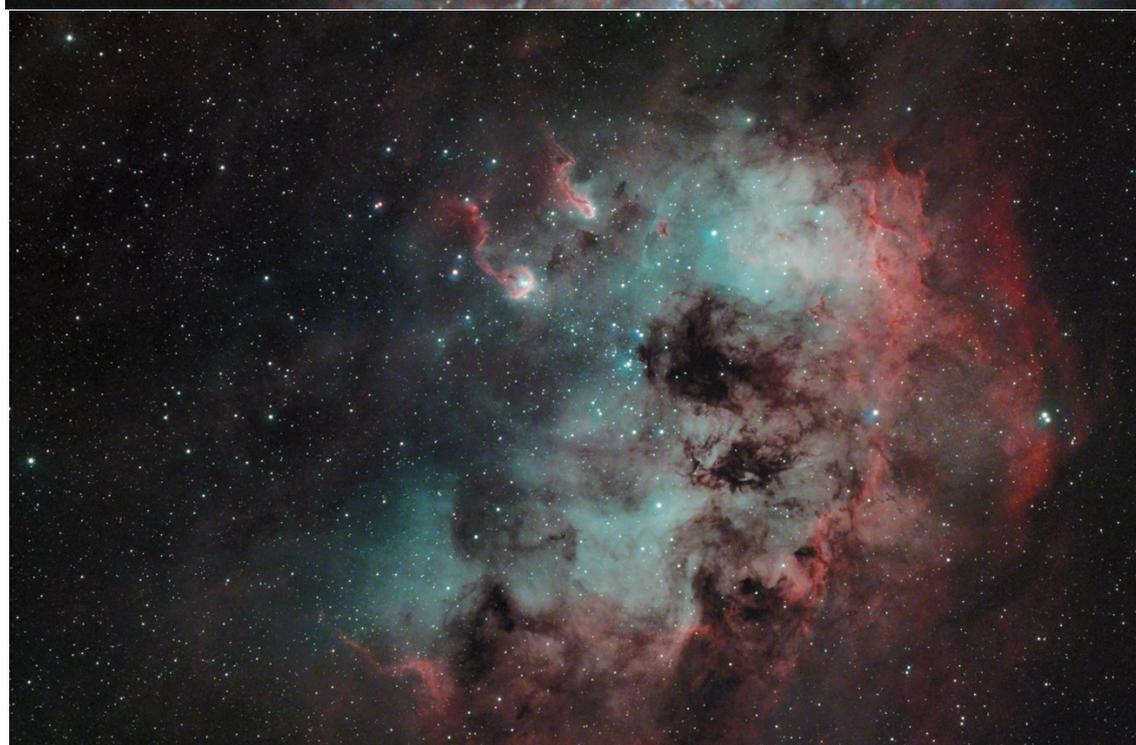
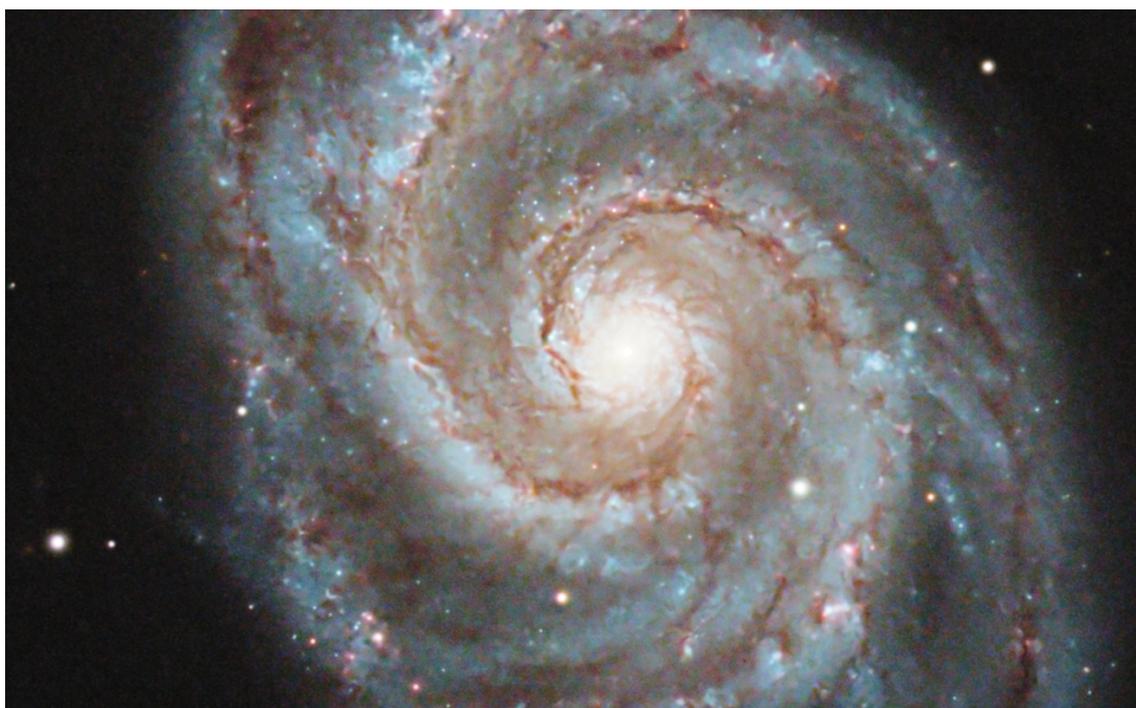


# PixInsight – One Shot Colour Camera Image Processing

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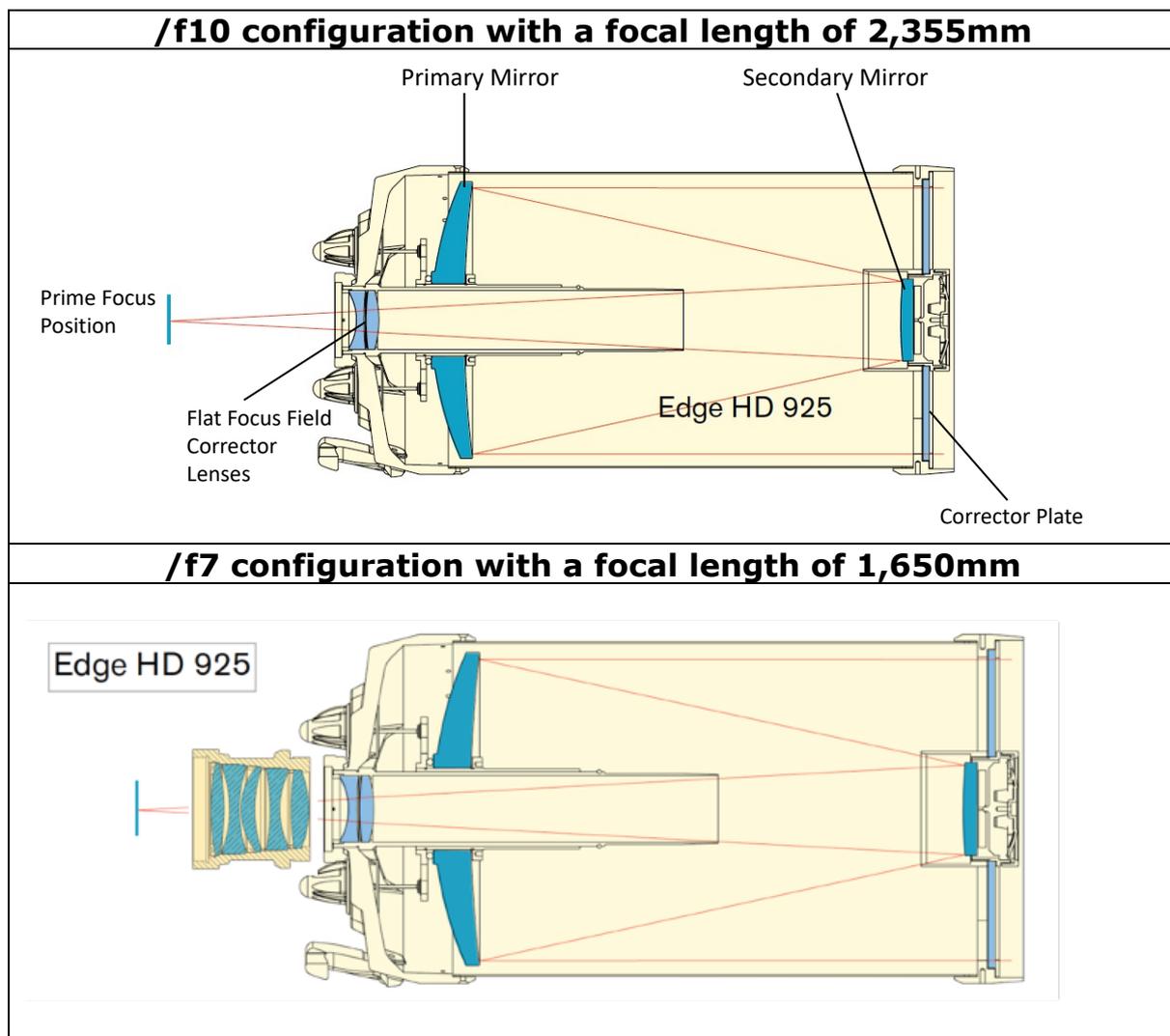
Workshop February 2024

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## The Imaging System used to Capture the Images

The telescope is a 235mm aperture (9.25") Edge HD astrograph quality **Schmitt Cassegrain Telescope (SCT)** telescope that produces a flat focus field with a 42mm diameter circle. This OTA has been designed specifically for astrophotography. A key component of its quality optics are the field corrector lenses within the OTA that create a flat focus field. The scope is used in one of two configurations:



A **QHY268C** 'one-shot colour' (OSC) camera was used to take the images.



### Camera Specifications

CMOS Sensor	SONY IMX571 C
Sensor size	APS-C 23.5x15.7 mm
Pixel size	3.76µm x 3.76µm
Effective Pixel Area (includes overscan and optic black areas)	6280 x 4210
Effective Pixel Area of Image	6252 x 4176
Full well capacity	75ke- or above in extended full well mode
Binning	1x1, 2x2, 3x3, 4x4
A/D Sample Depth	Native 16-bit (0-65,535)

### QHY268C Image Scale and Field of View with the 9.25 EdgeHD

Image scale can be calculated using the formula:

$$\text{Image Scale (arcsec/pixel)} = 206.265 * \text{Pixel Size}(\mu) / \text{Focal Length (mm)}$$

Telescope Focal Length	QHY268C Binning	Image Scale (Arcsec/pixel)	Field of View (Arcmin)
1,650mm /f7	1x1	0.468	48.7 x 32.6
2,355mm /f10	1x1	0.329	34.3 x 22.9

### Pixel Size and Resolution for PixInsight Plate Solving

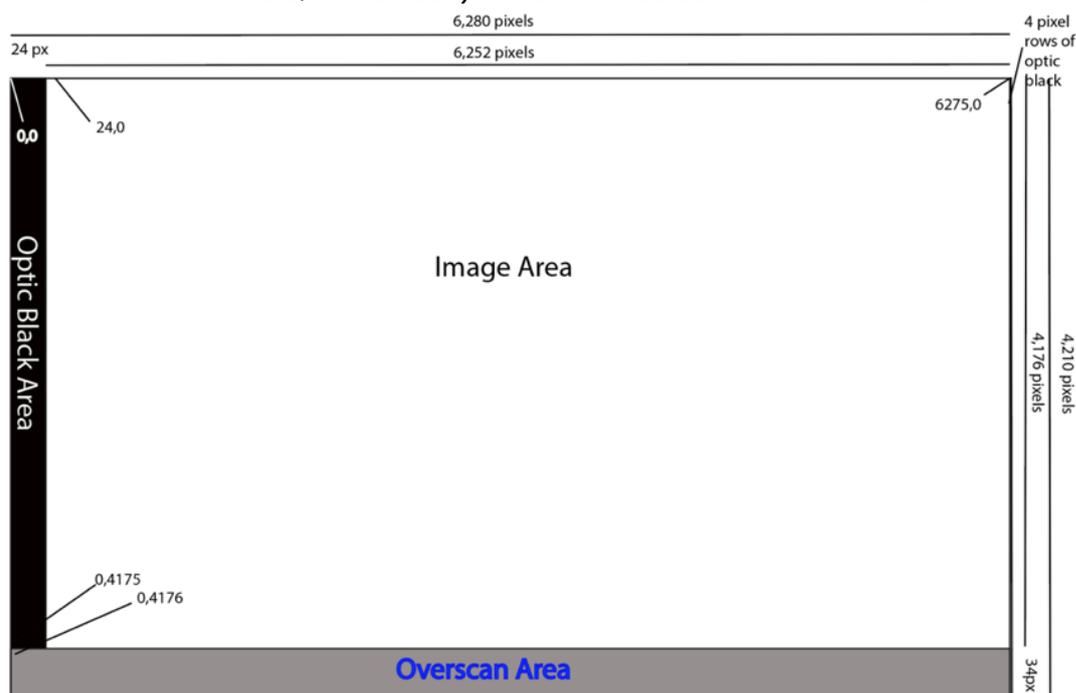
Broadband Image Debayered using VNG Algorithm QHY268C Camera with 9.25 EdgeHD				
Focal Length	1,650mm		2,350mm	
	Pixel Size mm	Resolution Arcsec/pixel	Pixel Size mm	Resolution Arcsec/pixel
Bin 1x1	3.76	0.468	3.76	0.329
Debayer VNG	3.76	0.468	3.76	0.329
Drizzle x2	1.88	0.234	1.88	0.165

Narrowband Image Debayered using Super Pixel Algorithm QHY268C Camera with 9.25 EdgeHD				
Focal Length	1,650mm		2,350mm	
	Pixel Size mm	Resolution Arcsec/pixel	Pixel Size mm	Resolution Arcsec/pixel
Bin 1x1	3.76	0.468	3.76	0.329
Debayer Super Pixel	7.52	0.936	7.52	0.658
Drizzle x2	3.76	0.468	3.76	0.329
Drizzle x4	1.88	0.234	1.88	0.165

## Calibration of QHY268C Images

The on-chip calibration circuitry of the QHY268C Sony IMX571 CMOS sensor may cause a bias-drift of the whole captured image, when that image is bright. Some CMOS sensors also suffer bias-drift due to thermal instability in some of their circuits but this is not the case for the IMX571. The bias-drift will vary from image to image. The bias-drift may cause calibration errors when subtracting a master-bias or master-dark calibration frame from a flat-field image or the actual light images.

*The QHY268C Sony IMX571 CMOS Sensor Architecture*



In order to correct for bias-drift during image calibration, the QHY268C CMOS sensor includes an optic-black area, which is the first 24-pixel columns along the left-hand edge of the sensor (and a further 4-pixel columns on the right-hand edge remain completely black) and an overscan area, which is the bottom 34-pixel rows of the sensor. No light reaches the optic black or overscan pixels.

The **optic black** area receives no light but exposes for the same length of time as the image area. It is the equivalent of a dark frame of 100,224 pixels.

The **overscan** area receives no light or any exposure but does receive the bias and read current. It is the equivalent of a bias frame of 213,384 pixels.

### Sensor mapping

- The individual pixels on the sensor are mapped as x-y coordinates. The top left pixel is (0,0). It is important to note that counting of pixels begins at 0, not 1.
- The optic-black area covers the first 24 columns of pixels. As pixel counting starts at 0, the first 24 columns are columns 0-23.
- The 4 columns of black on the right hand side of the sensor start at 6275,0.
- The first column of the image-area is therefore column 24, and the top left pixel of the image area is co-ordinate (24,0). The image-area is 6,252 pixels wide and 4,176 pixels high.

- As we start counting pixels from 0, the bottom row of the image will be row 4,175. This means that the overscan-area starts at row 4,176. The top-left pixel of the overscan-area is (0, 4176). The overscan-area is 6,276 pixels wide and 34 pixels high.

It is important to remember that no light falls on either the overscan or optic black areas. The difference between the two is that: the optic black exposes for the same time as the image, effectively is a dark or thermal frame; while the overscan only exposures when the image is read, effectively is a bias frame.

#### Analysis of Overscan Area

The analysis of the overscan area indicates that there is some light spillage, on a flat frame, from the image area into the first row of the overscan area. There is no light spillage into the following 33-rows. It is recommended that the first row is not used therefore in calculating the residual bias in the image.

#### Analysis of Optic Black Area

The analysis of the optic black area indicated that there was no light spillage, on a flat frame, into the optic black area.

#### Analysis of a 600s Image

An 600s image was acquired of M81, with the camera TEC set to -20°C. The camera was set to Extended-Full-Well mode at gain-15. This provides a gain of 1ADU=1e<sup>-</sup>.

#### Overscan Area

The average value of the pixels in the overscan area was in effect 0.00ADU with a standard deviation of 0.6ADU. The maximum pixel value was 52ADU. 99% of the pixels had a value of 0.00. (It is only if the 0.00 values are ignored, that the mean pixel value increases to 4.6ADU with a standard deviation of 5.5ADU. The clipped standard deviation is consistent with the read noise quoted for the camera at the gain setting.)

The sensors calibration circuitry appears to have removed the read and bias current from the image.

#### Optic Black Area

The optic black area had a mean pixel value of 0.2ADU with a standard deviation of 8.3ADU. The maximum pixel value was 1,858ADU. (If the 0.00 values are ignored, that the mean pixel value increases to 18.8ADU with a standard deviation of 87.0ADU.)

#### The Image Area

The image area itself has a mean pixel value of 63.5ADU, a standard deviation of 202.9 and a maximum pixel value of 65,534.

#### 36x600s Master Dark

When the image area of a master dark created from the integration of 36x600s darks, the mean pixel value is 1.10ADU, the standard deviation is 42.0ADU and the maximum pixel value is 50,572ADU.

The optic black area of a single 600s image has a lower average pixel value than the master dark image area and is less noisy.

#### Using PixInsight Calibration Process with Optic-Black and Overscan

The 4-pixel rows of true-black on the right-hand side of the sensor will be ignored in the following process and will be cropped away as part of the calibration process.

<input checked="" type="checkbox"/> <b>Overscan</b>				
Image region:	24	0	6252	4176
<input checked="" type="checkbox"/> <b>Overscan #1</b>				
Source region:	0	4177	6276	33
Target region:	0	0	6276	4176
<input checked="" type="checkbox"/> <b>Overscan #2</b>				
Source region:	0	0	23	4176
Target region:	24	0	6252	4176

**Image Region: 24, 0, 6252, 4176**

The image region defines the image area that will be cropped to once the calibration is completed (x,y coordinate of top-left pixel 24,0; 6252 pixels wide; 4176 pixels deep).

**Overscan #1**

**Source Region: 0, 4177, 6276, 33**

**Target Region: 0, 0, 6276, 4176**

Overscan #1 takes the average bias value from the overscan area and subtracts it from both the optic-dark and image area. This is a bias calibration of the optic-dark and image areas correcting for any bias drift created by the sensor's calibration circuits. The first row of the overscan area has been ignored to remove any risk of light spillage from the image area impacting on the average overscan value.

**Overscan #2**

**Source Region: 0, 0, 23, 4176**

**Target Region: 24, 0, 6252, 4176**

Overscan #2 takes the average value from the optic dark area (that has already been calibrated for bias in the overscan#1 step) and subtracts it from the image area. This is a dark/thermal calibration for the image area. The last column of the optic-black area has been ignored to remove any risk of light spillage from the image area impacting on the average optic black-value.

This approach would be used to initially calibrate the flat frames before integrating them to create a master flat. In this case, no dark-flats would be required to calibrate the flats.

## M51 & NGC5195

Discovered by Charles Messier in 1773, M51 is located 31 million light-years from Earth in the constellation Canes Venatici. It has an apparent magnitude of 8.4 and can be spotted with a small telescope most easily during May. The Whirlpool galaxy's beautiful face-on view and closeness to Earth allow astronomers to study a classic spiral galaxy's structure and star-forming processes.



Some astronomers think that the Whirlpool's arms are particularly prominent because of the effects of a close encounter with NGC 5195, the small, yellowish galaxy at the outermost tip of one of the arms. The compact galaxy appears to be tugging on the arm, the tidal forces from which trigger new star formation. Hubble's clear view shows that NGC 5195 is passing behind M51. The small galaxy has been gliding past the Whirlpool for hundreds of millions of years.



These images were captured in April 2022 using the 9.25 EdgeHD telescope in /f10 fl 2,350mm configuration.

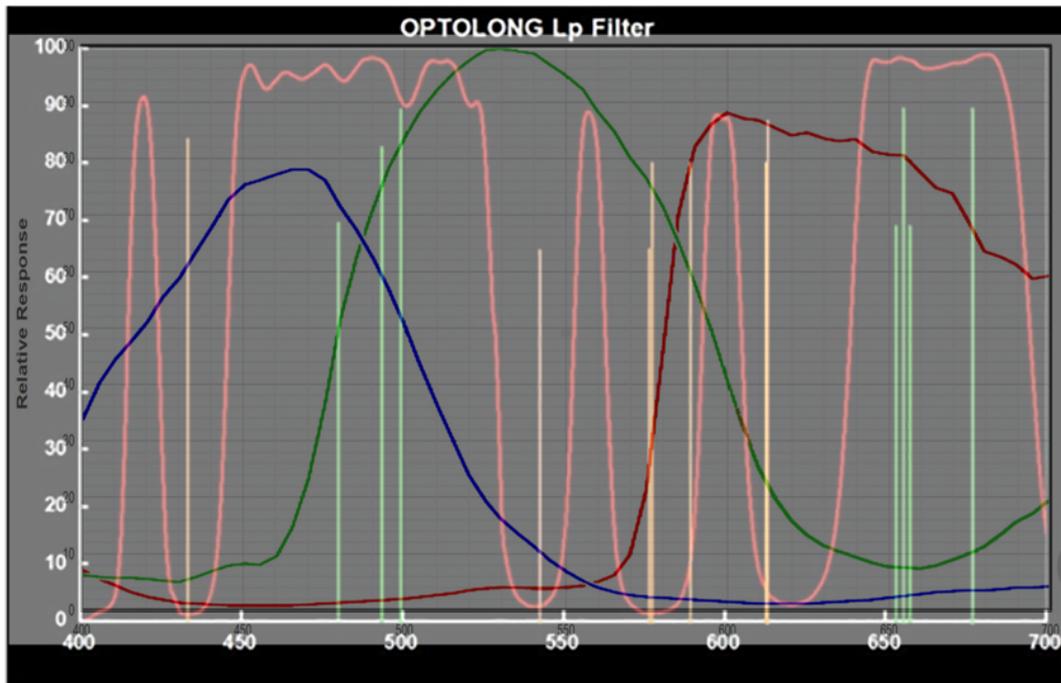
The images were taken using the QHY268C camera and an Optolong L-Pro filter.

**The Optolong L-Pro filter** is a luminous filter that provides IR and UV cut-off for the camera. The QHY268C sensor window has anti-reflection coating only so that the user can control wavelength cut-off for imaging.

The chart below shows the relative quantum efficiency of the blue, green and red pixels of the CMOS sensor at different wavelengths of light.

Superimposed on the sensor quantum efficiency plots (spectral response) is the transmission efficiency of the Optolong L-Pro filter. The filter transmits at all wavelengths associated with astronomical imaging but blocks wavelengths associated with light pollution. The filter has the effect in optimal conditions of reducing the sky flux reaching the sensor to create conditions like a 'darker' sky.

## Optolong L-Pro Filter Transmission vs IMX571 Spectral Response



A set of calibrated and integrated linear red, green and blue images are provided. Each image has been integrated from 26 ten-minute light frames. The images have not been further processed in any way beyond calibration and integration.

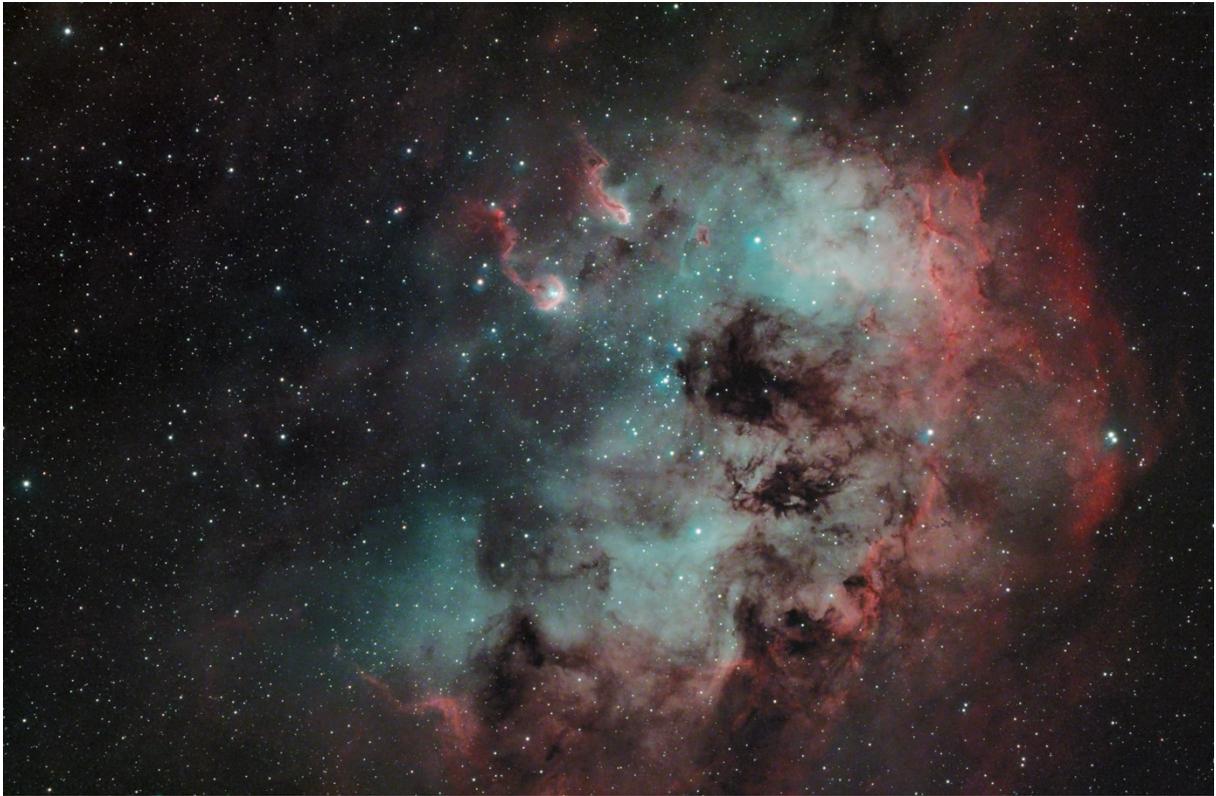
Process/Script	Workshop Manual Page	Notes
Image Calibration	12	Overscan for bias and dark
Cosmetic Correction	16	
DeBayer	16	Use VNG algorithm for RGB images. Use SuperPixel algorithm for narrowband images. Camera is RGGB matrix
Sub-Frame Selector	18	Select highest quality image as reference.  Reject poor quality images (star count)
Blink	17	Visually inspect selected sub-frames. Correct/reject poor quality images.
Satelight trail correction	63	PixelMath

<b>Process/Script</b>	<b>Workshop Manual Page</b>	<b>Notes</b>
RGB Channel Extraction	19	<Script><Batch><Batch Channel Extraction>
Star Alignment	20	Tick 'Generate Drizzle Data'
Image Integration	22	Tick 'Generate Drizzle Data'
Drizzle Integration	23	Save individual R, G and B images
<b>NOTE: Prepared integrated R, G and B images provided</b>		
Dynamic Crop R, G & B	24	Remove edge artefacts
GraXpert R, G & B	25	<Script><Toolbox><GraXpert>
BlurXterminator R, G & B	27	'Correct Only' to each of R, G and B
Image Integration R, G & B -> L	23	Create synthetic luminance image L
MLT R, G & B	26	Linear noise reduction applied to R, G and B
Channel Combination R, G & B -> RGB	26	Create RGB image
BlurXterminator L & RGB	27	Stellar and non-stellar adjustments
Plate Solve RGB	30	<Script><Image Analysis><Image Solver> Pixel Size = 1.88 Resolution = 0.165
Spectrophotometric Colour Calibration RGB	31	Correct colour calibration and background neutralization.
StarNet2 L & RGB	36	For each of RGB and L images separate stars from galaxy.
<b>NOTE: Prepared 'only' stars and 'only' galaxy images provided</b>		

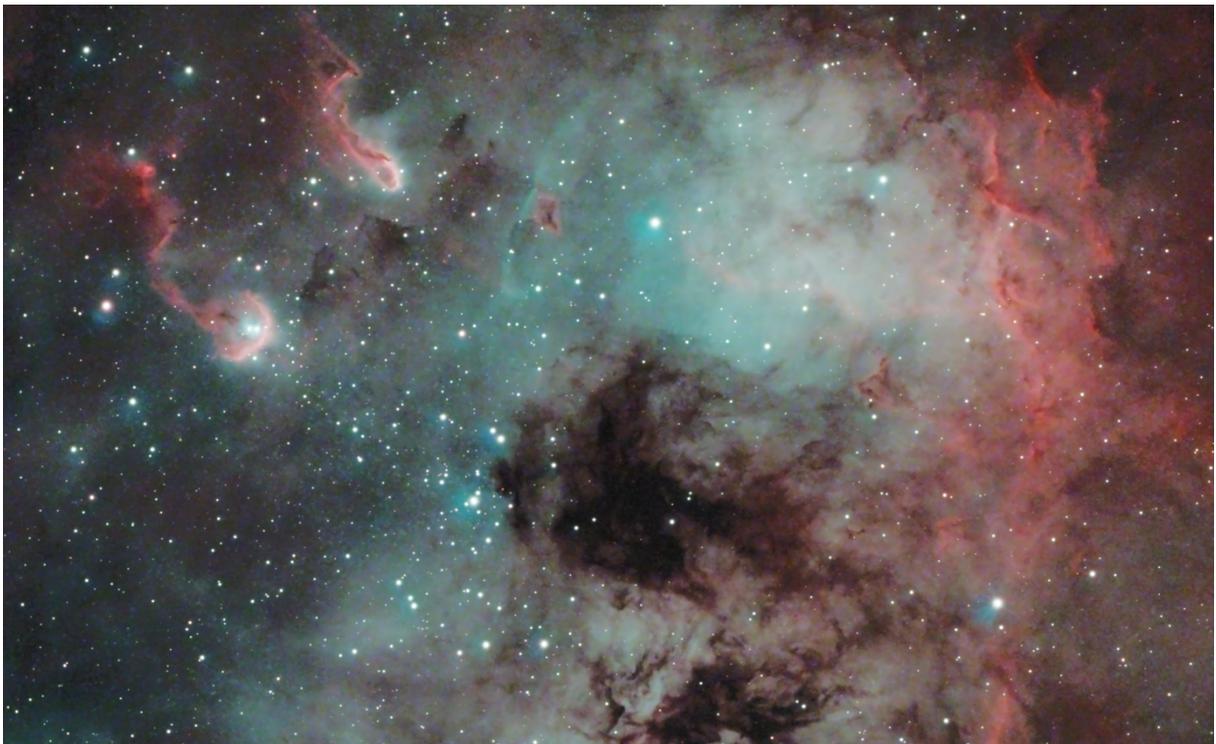
<b>Process/Script</b>	<b>Workshop Manual Page</b>	<b>Notes</b>
<b>Create the non-linear galaxy image.</b>		
Histogram Transformation	37	Create Luminous Mask
Histogram Transformation L(galaxy) & RGB(galaxy)	50	Non-linear stretch
ACDNR or TGVDnoise L(galaxy) & RGB(galaxy)	51	Noise Reduction
Colour Saturation RGB(galaxy)	54	Enhance colour without changing colour balance.
Local Histogram Equalisation or MMT L(galaxy)	52	Selective sharpening
L RGB (galaxy) Combination: Linear Fit; Channel Combination; LRGB Combination	55	Combine the L and RGB galaxy images to create a single LRGB image.
<b>Create the non-linear stars image</b>		
Histogram Transformation RGB(stars)	50	Non-linear stretch
Colour Saturation RGB(stars)	54	Enhance colour without changing colour balance.
<b>Combine the galaxy and stars image to complete the process</b>		
PixelMaths	58	Create a completed image.

## IC410 & NGC1893

The Tadpole Nebula (IC 410) is an H II region located approximately 12,400 light-years away in the northern constellation [Auriga](#). The nebula is more than 100 light-years across.



The star cluster NGC 1893 is embedded within the Tadpole Nebula. The estimated age of the stars of NGC 1893 is about 4 million years.



IC 410 was named the Tadpole Nebula because it hosts tadpole-shaped dark dust clouds that appear as if they were swimming toward the center of the nebula. The tadpoles of IC 410 are gas globules, small dense knots of dust and gas that give birth to young stars. They are composed of denser and cooler dust and gas.

Stretching about 10 light-years across, these dense structures bear a resemblance to the better-known [Pillars of Creation](#) in the [Eagle Nebula](#) (Messier 16). Their heads are marked by bright ridges of ionized gas. The tails of the tadpoles point away from the core of NGC 1893 because of the radiation pressure and strong stellar winds from the young stars in the cluster. The tadpoles are sites of ongoing star formation.

Images taken on 12<sup>th</sup>, 13<sup>th</sup> and 20<sup>th</sup> January 2022. The 9.25 EdgeHD was used in the /f7 fl 1,650mm) configuration.

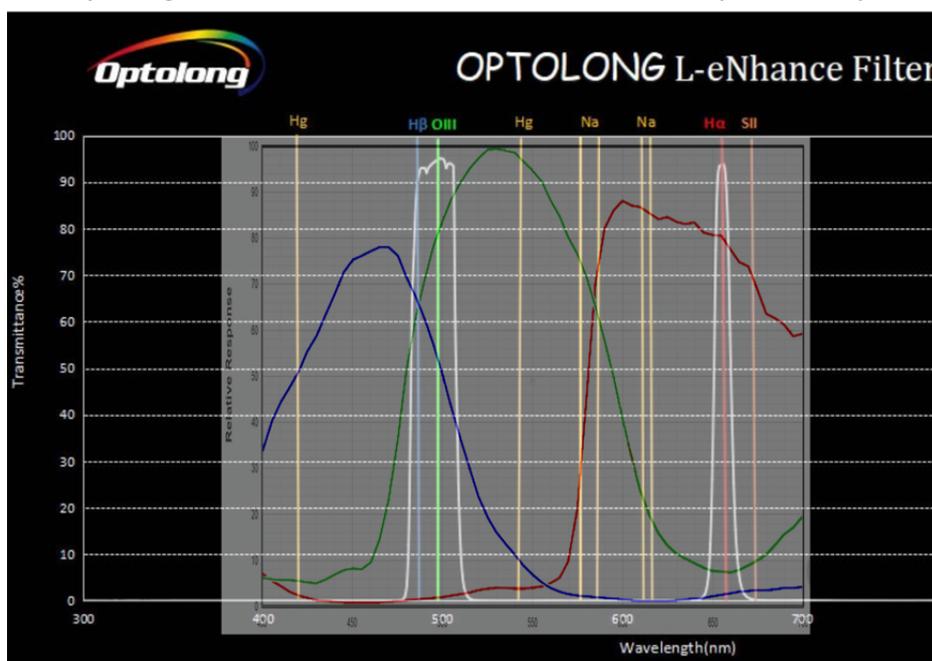
A master flat frame, for calibration, was created using 100 individual flat frames that were calibrated for bias and dark current.

The images were recorded using the QHY 268C camera and an Optolong L-eNhanse optical filter.

**The Optolong L-eNhanse filter** is a tri-band filter. It only transmits light at two wavelengths. One transmission band is centred on 650nm, the wavelength of H $\alpha$  emissions. The second transmission band is centred on 500nm, the wavelength of Oiii and H $\beta$  emissions.

The Optolong L-eNhanse filter is used to image emission nebula. H $\alpha$  emission will be captured exclusively in the red channel of the captured image. Oiii emission will be captured in both the blue and green channels of the captured image.

Optolong L-eNhanse Filter Transmission vs IMX571 Spectral Response



A full set of the RAW light frames captured on the night and the calibration flat frame is provided.