

# Astrofoto

## an exercise in monochrome digital astrophotography

### Introduction

Since Ralph and I wrote 'Way Beyond Monochrome', we have both moved over to digital imaging due to different circumstances. In my case, I needed a new challenge: I did not want to do more of the same, as I had for the last 30 years, only this time with a digital camera. It is safe to say that I found a big, new and exciting challenge on my doorstep. Astrophotography. There is not so much of a learning curve as a sheer cliff. Let me explain, by listing out what a good astro photograph requires:

- Each image is aligned to a star, circling overhead every 23h56m, and maintained with a tracking accuracy of 1/12000<sup>th</sup> degree for the duration of a 5-20 minute exposure.
- If a tripod leg sinks by 0.5 mm, it causes an alignment error of 1/35<sup>th</sup> degree
- A single color image may require 20-120 separate images.
- Any single image is mostly featureless black. Typically, all the interesting data occupies just 3% of the tonal range in the deepest shadow.
- My camera operates at about -20°C to reduce thermal noise.
- After image capture, each image has to be precisely aligned (scale, position and rotation) to the others before statistical combination.
- After acquisition, image processing is entirely unique, mostly employing 32-bit data files and highly specialist imaging programs.
- Clear nights in the UK are a precious and rare commodity!
- Stars are the most demanding photographic subject. We instinctively know if a star has a distortion, focus or optical issue.
- An image from a perfect noiseless sensor still has noise, equal to the square root of the signal level.

The full example of this image is one of the practical how-to chapters in my new book "The Astrophotography Manual". That chapter exhibits a full-color image, combining separate



image © Chris Woodhouse. All rights reserved.

monochrome exposures taken through precise narrowband filters to detect ionized sulfur, hydrogen and oxygen which are assigned to red, green and blue (affectionately known as the Hubble palette). On their own, these monochrome files are beautiful and wondrous in their own right. In this simplified “taster”, I have selected the stronger Hydrogen Alpha emission to use as a monochrome example.

The Heart Nebula (IC1805)

This large emission nebula is mostly formed from ionized hydrogen plasma, powered by the radiation from the star cluster (Melotte 15) at its center. Its shape resembles a heart with two ventricles, suggesting its common name. Having said that, a search for “The Heart Nebula” in several planetarium and planning programs surprisingly draws a blank. This object requires a wide field of view of about  $3^\circ \times 2.5^\circ$  degrees to comfortably frame it, mandating a short focal length, around 350 mm and a large sensor. (A large sensor in astrophotographic terms is APS-C or larger.) This image was my first using a new William Optics Star 71, a 5-element refractor. This astrograph has its 5 optical elements in a fixed relationship to each other (not always the case in refractors) and is simply focused onto the sensor,

in the same way that manual focus camera lenses have done so for the last century. Although short focal lengths are less sensitive to tracking errors, they do require precise focus and image registration to ensure a high quality result.

For this image, I acquired 15 20-minute exposures over several nights. Thankfully narrowband filters (typically with a 10 nm or less pass band) block most of the light pollution and are relatively immune to any sky glow from the Moon.

#### Acquisition

In telescope terms, this refractor is tiny and although it uses a rack and pinion focuser, the camera assembly, comprising a motorized filter wheel, shutter and cooled CCD is a heavy load for such a small mechanism and the mechanism can sag. Even a small movement will cause stars to lose focus. To check, I took a trial exposure and ran an analysis program called CCDInspector on it. By looking at star shapes, it confirmed an image tilt of a few arc seconds and a reassuringly flat frame. (An arc second is  $1/3600^{\text{th}}$  degree.) After a small adjustment to the focus mechanism, the tilt halved to a respectable arc second.

Image exposure for narrowband images is subtly different to that taken with normal color filters. Only a few emission nebulas are sufficiently bright to saturate a sensor using exposures under 20 minutes and in most instances exposure is a simple balance between exposure length and the probability of a ruined exposure for some special cause. These exposures were taken over a few nights and at the end of each session, the equipment was dismantled. Even with the short focal length and large(ish) sensor, the framing was tight and I could not afford to crop data due to misalignment between sessions. Thankfully, my image acquisition program, Sequence Generator Pro, uses plate-solving utilities to determine the exact center of an image and issues corrections to the telescope mount to center the image to within 1 pixel of where it was before.

#### Image Calibration

Image calibration is required to get the very best from the sensor and reduces sensor read noise, thermal noise, shot noise, non-linearity's, vignetting, dust spots and statistically registers and combines all the files to form one master file in 32-bit FITS

file format. The calibration process itself requires hundreds of previously acquired exposures, taken in the dark, at different exposure times and with different filters in the optical path and requires a chapter in its own right. Calibration is computationally intensive and astrophotographers use specialist programs to accomplish this. I use PixInsight, written by a bunch of graduates from Valencia University. The clever statistics working behind the scene can remove the effect of cosmic-ray hits, meteors and the 20:20 to London Heathrow.

#### Manipulation Strategies

In the full color image, human interest is supported by interesting structures and contrast in both color and intensity. In monochrome, we focus on tone and texture. Color image processing follows two paths, color and luminance. They are kept entirely separate until the end; many astrophotographs are formed from a highly detailed luminance file, which is combined with a soft, even blurred but saturated color image. It is like working in LAB mode in Photoshop but processing the L and A/B channels separately. In this example, we are just looking at the luminance data, which undergoes some clever mathematical manipulations to enhance detail and undo the effects of diffraction.

#### Sharpen Stars and Remove them

All optical images suffer from convolution: a minuscule point of light is spread by diffraction to a diffuse blob. An image of a star can be analyzed and the effect modeled to form a PSF or point spreading function. Using more maths, an inverse function (deconvolution) is applied to the image to counteract most of the effect. Used selectively this sharpens stars and accentuates detail without making the background noise any worse. Even so, the extreme image stretching that the image requires to make the faint nebulosity come to life also causes stars to grow in size or “bloat”. One-way around this is to remove the stars before image stretching makes them too intrusive. Further software tools in Pix Insight analyze the image mathematically and isolate the stars with a mask. More tools progressively reduce the star size, much in the same way as the dust and scratches filter in Photoshop. With the stars removed, the full image stretching is much easier. (In some places the image contrast is increased by several orders of magnitude and this amplifies image defects and faint signals in equal measure.) Having achieved the desired tonality, the

image structures are enhanced with multi-scale tools. These analyze the image for structures of a defined size and enhance their contrast. (The Nik software plug-ins for Photoshop and Aperture has a structure enhancement feature that appears to be a simpler execution of the same idea.)

After selectively removing noise from the image, using image masks and image scale filters to leave the brighter areas untouched, the stars are added back in, using a technique analogous to Photoshop layers and layer masks. Remember this is only the luminance file... I did say it was a challenge!

*Christopher Woodhouse*

*Multi-Media, Fine-Art Photographer, England, UK  
October 2014*

fig.1 (below) You'll be able to shoot beautiful twilight pictures of the moon, the milky way or planets and constellations with just about any camera on a tripod.



## Astro Photography with a standard DSLR

If you have a digital camera and want to try your luck at astrophotography, but don't really know where to start, this text is for you.

I'll try to give you a little bit of basic information here to get you started. You'll find more in 'Astrophotography' by Chris Woodhouse, if you want to learn more about it.

You can get started taking astronomical pictures with just about any kind of camera, especially if it permits manually setting shutter speed, ISO sensitivity and aperture. You'll be able to shoot beautiful twilight pictures of the Moon, the milky way or and planets or constellations with just about any camera on a tripod (see fig.1).

If you have a telescope, you'll also be able to shoot the Planets, Moon, and even close-ups of craters on the Moon.

To shoot deep-sky objects like galaxies and nebulae, you will need more sophisticated equipment such as a telescope on an equatorial mount to track the stars so you can use the long exposures required for these faint objects. You can use a computerized altazimuth mount to shoot brighter deep-sky objects, but you really need something like a German-equatorial mounting with motor drives on both axes to do any kind of serious long-exposure deep-sky astrophotography.

## Digital Cameras

You can get started taking simple astrophotos, such as of constellations, with almost any kind of digital camera. A tripod helps, and you don't really need or even want even need one of those heavy DSLRs. There are adaptors (so-called 'T' mounts) to attach them to a telescope but they are likely too heavy to keep the telescope balanced easily. In that case, you are better off with a more expensive eye-piece camera, which hooks up right to a computer

First let's go over some fundamental facts and terms about cameras and exposure in general.

### The '500' Rule

In order to avoid star trails, due to the earth's rotation when using common 35mm cameras, the longest exposure should not exceed 500/focal length in seconds. for example: for a 35mm lens 500/35 roughly 15s is the maximum exposure time.

### Exposure guidelines

Very little light is reaching earth from stars and the milky way. Hence, proper exposure is tricky and left to experimentation but start with these values:

**ISO 3200 or higher**

**aperture: between f/1.4-f/2.8**  
and a shutter speed using the '500' rule.

### Starting Points

- Use a camera with manual settings and a tripod
- Use a wide-angle lens with wide-open aperture.
- Use the '500' rule to determine the max exposure time, the highest ISO setting possible and tungsten white balance.



more interesting photograph,previsualize the image and also consider adding something to the foreground of your astrophotograph.

### Exposure Shutter speeds, aperture, sensitivity(ISO)

Except for the moon, the stuff we want to shoot in the night sky is very faint. That means we need to record as much light as we can. Cameras control the light required to take a picture in three basic ways. First, There is a shutter that opens and lets light in to hit the digital sensor in the camera, If we leave the shutter open longer, we record more light.

Shutter speeds run in fractions of a second, usually from around  $1/1,000$  of a second to 1 second at the shortest exposure to 1 or several seconds at the longest. Most Some cameras also have a setting called 'B' for 'bulb' that keeps the shutter open as long as the shutter button is pressed down. Use the '500' rule(previous page)to determine the longest exposure time possible for your focal length.

Second, there is a variable-sized hole, called the aperture or diaphragm, in the camera lens. If we use a larger hole, we let more light in. Aperture settings are labelled in fractions of the focal length such as  $f/2.8$ ,  $f/4$ ,  $f/5.6$ , and  $f/8$ . That,often confusingly means that the smaller the number, the larger the hole in the diaphragm and the more light is recorded. So,  $f/4$

is a bigger aperture than  $f/8$ .

Most cameras also have a way to change their "sensitivity" or 'ISO'. This is a purely electronic setting. You can't really change the sensitivity of the sensor in the camera, but you can adjust a setting called the ISO, which is sort of lika an amplifier. ISOs may run from 100 to 400 in simple cameras, or up to 800, 1600 or 3200 in more expensive cameras. The higher the ISO number, the more the incoming light is amplified

Unfortunately, the noise, or grain, gets worse at the higher ISO settings,so, there is a quality maximum, but let's not worry about that for now.

•To get started, you will have to figure out how to get your camera to use as long a shutter speed as possible, at as wide an aperture as possible, and at as high an ISO as possible. Unfortunately, you will have to consult your camera manual to learn how to do this. Because, every camera handles this a little differently. Your other option is to just dig around in the camera's menus looking for these settings, but sometimes they can be hard to find and not labeled very clearly. No matter hpw you do it,be prepared before your shoot,because it will be a lot harder to find the right setting in dusk or the dark! and a good reason to have a small flash light in your camera bag.

Set the camera on manual exposure if it has that setting. Then set the lens to its widest opening, usually  $f/2.8$  or wider and set the ISO to the highest it will go, usually 400 for simple point and shoot cameras. If the camera doesn't have a manual exposure setting, set it to night mode.

### ?Focus

The next thing you will have to worry about is the focus. Once again, dig through the camera manual, or menus, and see if you can figure out how to turn off the autofocus, and manually focus the camera on infinity (the farthest away that the camera will focus).

For more sophisticated digital cameras like Slurs, you can pre-focus the camera in the daytime on something very far away, and then turn the auto-focus off. If you have a DSLR with a lens that you can manually focus, focus it on infinity and tape it down. Beware; some lenses actually will go past infinity, so you can't always just trust the markings on the lens.

Experiment with this in the daytime. If you have a point and shoot camera, it may have a setting for shooting at infinity and may have some type of icon of mountains to indicate this. Try shooting something very far away to be.

### ??White Balance