DEEP-SKY IMAGING

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Astrophotography is one, if not the most interesting and challenging fields of amateur astronomy. It is the appealing concept of recording the images of deep-sky objects at distances so great that the light left the object long before the formation of our planet.

I have been interested in astronomy for more than 40 years and like most amateur astronomers I began with Emulsion-based photography. Star trails are a good starting point for beginners, followed by unguided images of the constellations using different emulsions and lenses. Then comes guided images, and I soon realized that an observatory and a fixed mounting were a must to achieve good astrophotographs. I tried many different emulsions such as Kodak spectroscopic films (103a-E, 103a-F, 103a-O), hypersensitized Kodak 2415 as well as several colour films for imaging the moon and planets. At this stage I built several telescopes that were housed in two different observatories. Most of the images were obtained with two Newtonian reflectors (300mm f/7.1 and 222mm f/5.8). Both had German equatorial mountings equipped with high precision gears in both axes. Good results were obtained with these instruments, but imaging galaxies and nebulae (my main targets) meant that I had to perform long exposures of several minutes or even hours. I had to overcome all the problems that arise when dealing with this (bad polar alignment, flexure of the guide scope, bad guidance...). Eventually good results were obtained using emulsions but progress was slow and not many different objects were imaged.

Enter the CCD revolution and digital astrophotography. CCD cameras have been available to amateur astronomers since the late 80's with the introduction of the SBIG ST-4. CCD detectors have high quantum efficiency (they can record up to 90% of the photons that strike them, and even more in professional systems) and exhibit a very good linearity (their output is almost directly proportional to the number of incident photons- there is no reciprocity failure as found in long exposure emulsion based astrophotography). This means that images of deep-sky objects can be obtained in a few minutes and the output can be processed using standard image processing techniques.

Several different types of CCD cameras are now available. Many considerations have to be taken into account when deciding which camera is the most adequate for your specific work. In 1994 I bought a HI-SIS22 CCD camera equipped with the KAF-0400 chip. It has 768x512 pixels, 9x9 microns, which provides a 6.9 X 4.6 mm photosensitive area. I bought the version with an anti-blooming system (KAF-400L) because I was interested in obtaining results with near photographic quality (this means that sensitivity is reduced by about 30%, not a very high price to pay). This chip is of the Multi-Pinned Phase type meaning that the dark current will be 10 times weaker than other CCD's. The actual noise level amounts to only 12 electrons. A 14-bit analog-to-digital converter produces images with 16,384 intensity levels. In 1998/99 a ST7 CCD camera a MX916 CCD camera and an Audine CCD camera were added.

I also bought a C14 equipped with a fixed pier and a Byers retrofit in 1989. I used this instrument and a Mead 2045 mounted piggyback for Deep-Sky CCD imaging with excellent results. The accuracy of the Byers drive was very high. It consisted of an ultra-precision 230mm 359-tooth gear with virtually no detectable periodic error (less than 3 arc seconds). The original C14 drive showed very erratic tracking with typical periodic errors of up to 120 arc seconds meaning that long exposures required constant corrections. Thanks to the installation of the Byers retrofit CCD imaging was easily achieved with a minimum guiding effort.

In 2005 I acquired a Paramount ME german equatorial mount that was installed on Pier Tech 1 telescope Pier.

Most of my recent deep-sky images are obtained with two apochromatic refractors (TMB152 F/7.9 & AP130 F/6) and two SBIG STL11000 CCD cameras (Figure 1).

Figure 1- Paramount ME, TMB152 F/7.9, AP130 F/6, SBIG STL11000M (Class 1), SBIG STL1000M (Class 2)

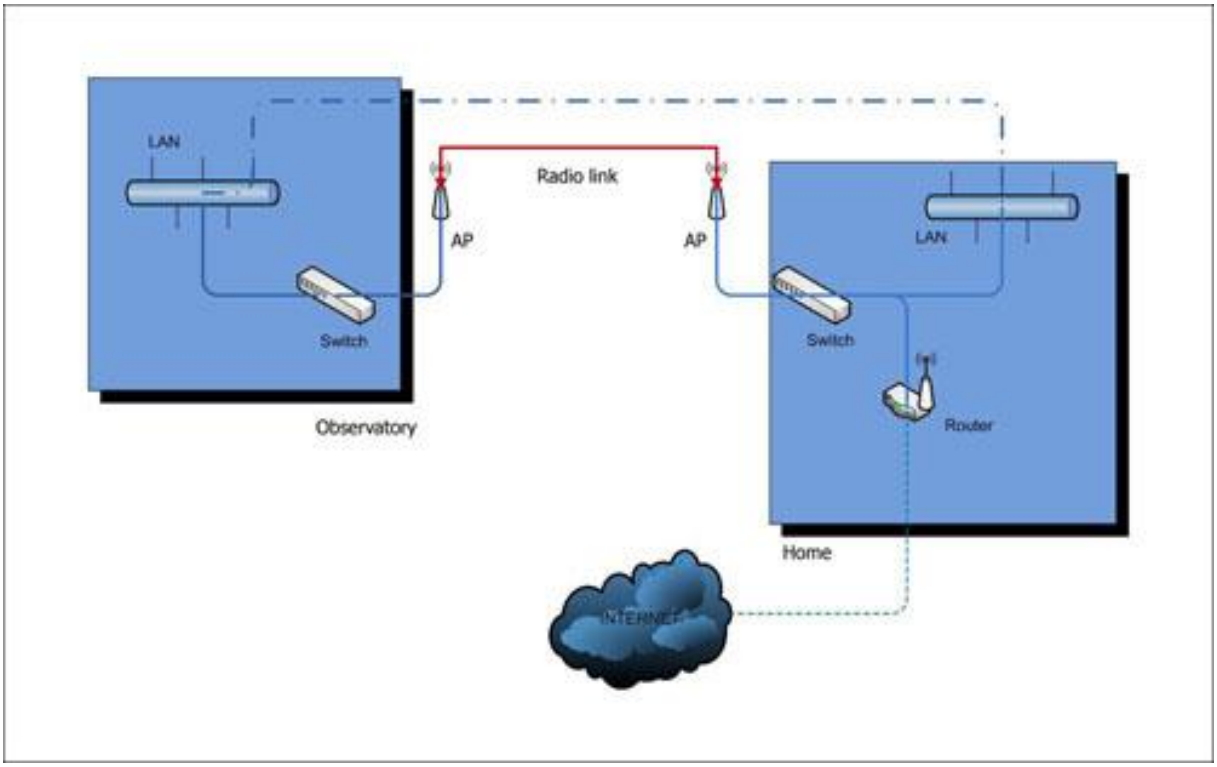

Figure 2 – Wi-Fi connection

The Paramount ME robotic equatorial mount has many interesting features:

- Integrated Electronic Control Panel
- Instruments payloads up to 68 kg
- Multi-port instruments, input panel to run all sorts of equipment
- Telescope serial and USB (MKS 4000) ports
- CCD camera power
- Two auxiliary serial ports
- Parallel port

- Focuser port
- Autoguider input port
- Two additional auxiliary power ports
- Large conduit to run additional cables through the mount
- Easily removable panel to access fuses, and electronic switches for Flash RAM control system software upgrades
- Research-grade 11.45-inch right ascension and 7.45-inch declination gears drive the Paramount. The right ascension gears guaranteed to have 5 arc seconds or less peak-to-peak periodic error.

This imaging setup is installed in a roll-off-rook observatory and can be controlled via a Wi-Fi connection (Figure 2).

The SBIG STL11000 are controlled with the Maxim DL software. The new version of this programme has many acquisition and images processing features:

New Equipment Control Features

- Camera and ASCOM equipment is now multithreaded for smoother operation
- Automatic observatory shutdown sequence with user-settable triggers and sequencing
- Automated pier flipping with guide star reacquisition
- ASCOM Switch Control - remotely operate switches in your observatory
- Observatory webcam integration
- Davis weather station support - display status, update FITS headers
- Boltwood Cloud Sensor integration - display status, update FITS headers, protect observatory
- Improved autoguider performance
- Multi-star autoguiding
- Support for SBIG differential autoguider
- Support for single or dual axis dithering
- Hide unused Observatory window tabs
- Simulated telescope park option
- Bookmark locations in the sky

New Processing and Analysis Features

- Quick Colour display for RAW images - see approximate colours before performing Colour Conversion (debayer)
- Narrowband image blending tool - stack arbitrary numbers of planes with either realistic or false colours
- Multispectral photometry
- Photometry includes astrometric or automatic star matching for automatic target identification
- Perform batch photometry on thousands of images including multiple targets
- PinPoint V6 support - all sky searching, new catalogues
- PinPoint is now "modeless" for easy application to multiple images
- Flatten background can now save and load profiles - apply the same profile to multiple images
- Completely redesigned calibration wizard for quick and easy calibration setup
- New options and other improvements for existing image processing commands

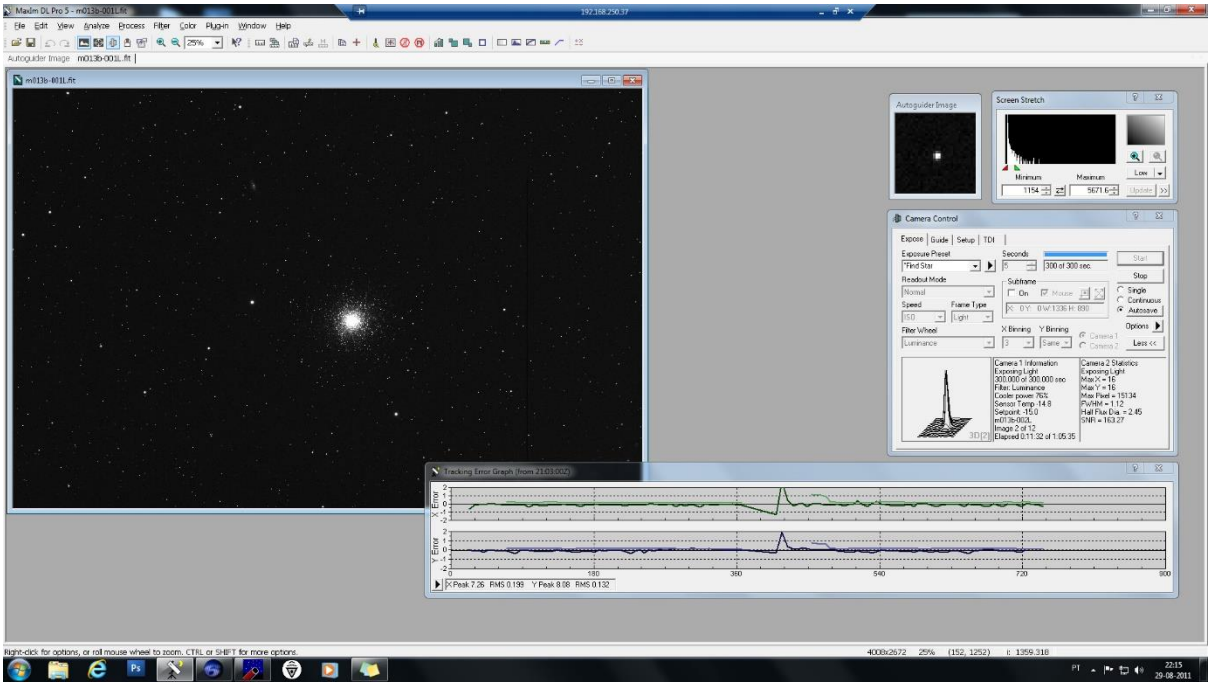

Figure 3 – Screenshot Maxim DL (Wi-Fi connection)

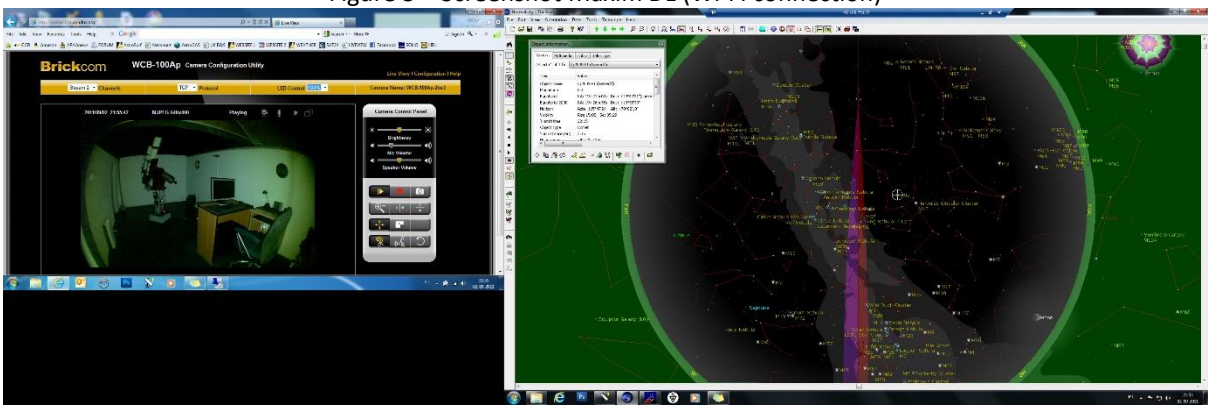

Figure 4 – Screenshot, The Sky 5.0 + IP camera (Wi-Fi connection)

Figure 5 – Screenshot, IP camera (Wi-Fi connection)

The image processing flow I follow in most of my Deep-Sky imaging sessions is described below:

LUMINANCE AND H-ALPHA PROCESSING FLOW

- Acquire deep-sky images (Maxim DL)

Calibrate, align and combine CCD images (Maxim DL)

- Calibrate raw images
- Use manual (2 stars) or automatic alignment operations (Auto correlation or Auto star matching)
- Use Median, SDMask or Sigma Clip for all combination operations
- Perform a DDP-style stretch on the combined image (Don't do any sharpening as part of DDP). This is accomplished by selecting the "user" kernel filter, and setting the filter coefficients to 1.0 in the centre, and zeros elsewhere). DDP with a small sharpening can also be used with good results (FFT Low-Pass, Custom 25 a 35% Cut-off)
- Save the image (FITS format IEEE Float)

Final Processing (Photoshop)

- Load the FITS DDP-stretched image into Photoshop (using Fits Liberator)
- Use Curves to adjust contrast and brightness
- Save the final 16-bit TIF file
- Convert to 8-bit and save JPG file

LLRGB PROCESSING FLOW

- Acquire deep-sky images

Calibrate, Align and Combine CCD images (Maxim DL)

- Calibrate raw images
- Do any star de-blooming repair prior to alignment and combination (non antiblooming CCD cameras)
- Combine images for each channel (L, R, G, and B) (use SDMask for Luminance and Median Sum for RGB files, use manual or automatic alignment operations)
- Perform colour balancing for each colour channel (*e.g.* SBIG ST-10XE RGB= 1.0, 1.1, 1.9)
- Combine the images into an LRGB image in Maxim DL
- Perform a DDP stretch on the Luminance image
- Perform a DDP stretch on the LRGB image
- Boost colour saturation after DDP if needed (save in 16-bit TIFF format)

Final Processing (Photoshop)

- Load the Luminance FITS DDP-stretched image into Photoshop (using Fits Liberator)
- Use Shadow & Highlight (30:50:10, 50:50:10) or Levelizer plugin (Starizona Photoshop Plugin Package)
- Use Curves to adjust contrast and brightness
- Use (if necessary) Neat Image Photoshop plug-in to remove grain
- Load the LRGB 16-bit TIFF file
- Align L and LRGB images

- Combine L and LRGB images (LLRGB) (Change the blend mode to "luminosity", change the opacity to ~50%, Flatten image)

DEEP-SKY IMAGE PROCESSING (MODIFIED DSLR Cameras)

- Acquire deep-sky images (DSLR images)

Calibrate, Align and Combine CCD images (Maxim DL)

- Save images as RAW files
- Calibrate RAW images
- Convert RAW images to colour in Maxim DL (COLOR MENU - Convert Colour: AUTO background level, COLOR SCALING, Red - 75%, Green - 125%, Blue - 125%)
- Align images in Maxim DL (manual 2 stars or automatic alignment)
- Combine images in Maxim DL (*e.g.* SDMask)
- Save result in 16-bit TIFF files (no compression)
- Perform a DDP-style stretch
- Save the image (FITS format 16-bit) (no compression)

Final Processing (Photoshop)

- Load 16-bit TIF DDP stretch file in Photoshop
- Use Curves to adjust contrast and brightness
- Save the final 16-bit TIF file (no compression)
- Convert to 8-bit and save JPG file (no compression)
- Save in TIFF or JPG format

Figure 6- NGC7000/IC5070 region (two-pane MOSAIC). 180min+160min (20min sub-integrations). AP130 F/6, FF, STL11000M. Astrodon (6nm), self-guided, SDmask, DDP, Paramount ME. Processed with Maxim DL and Photoshop

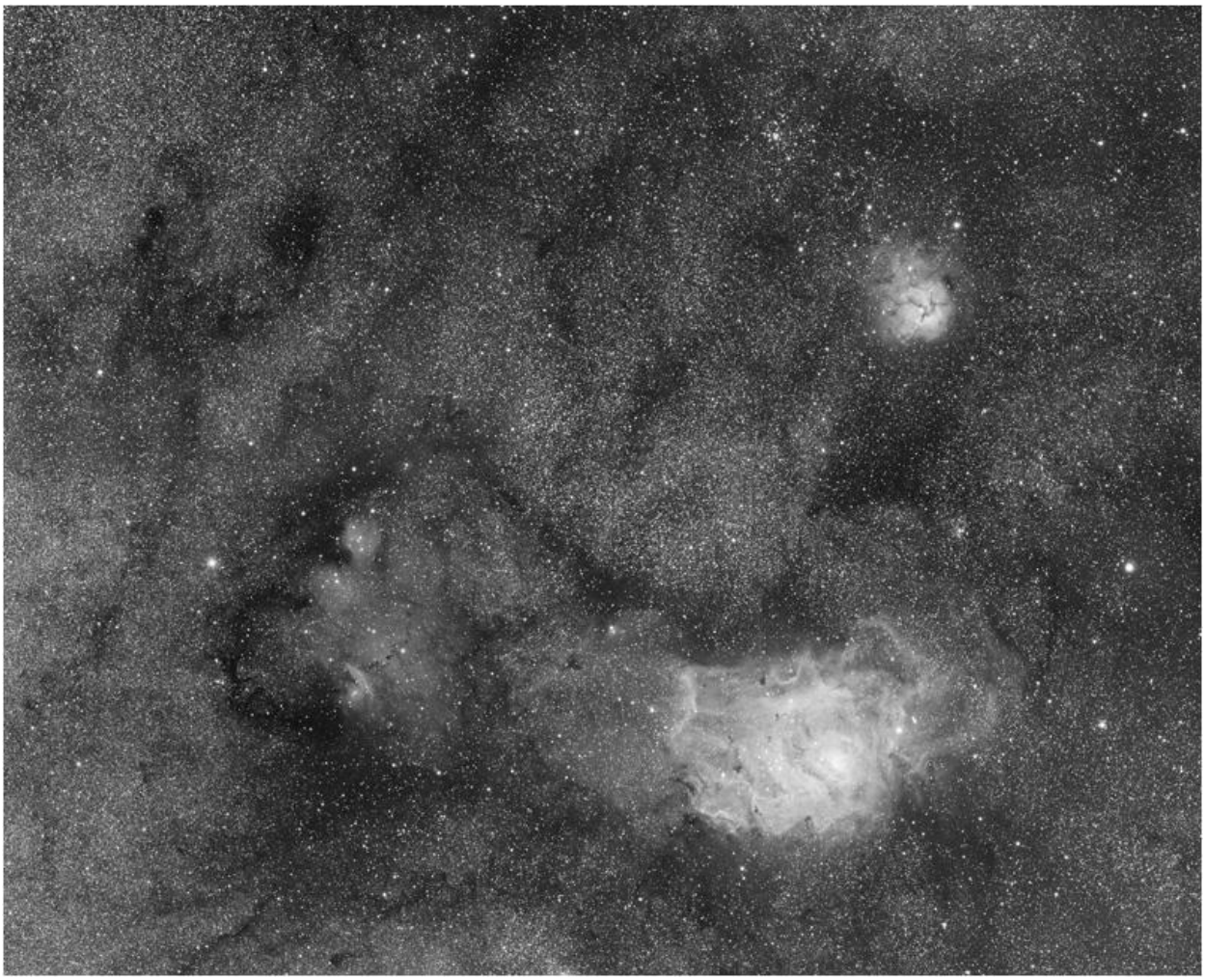

Figure 7- M008/M020 region (four-pane MOSAIC). 80min X 4 (10min sub-integrations). AP130 F/6, FF, STL11000M. Astrodon (6nm), self-guided, SDmask, DDP, Paramount ME. Processed with Maxim DL and Photoshop

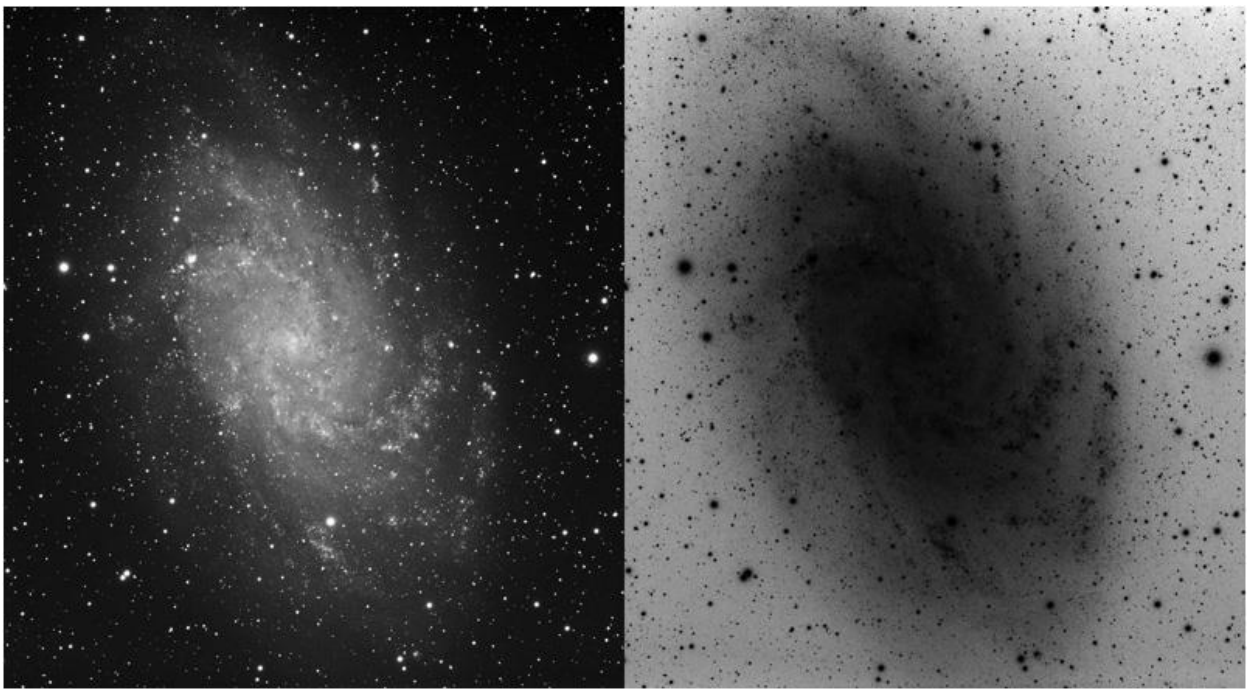

Figure 8- M033. 240min (24x10min). TMB152 F/7.9, FF, STL11000M, self-guided, Median, DDP, Paramount ME. Processed with Maxim DL and Photoshop

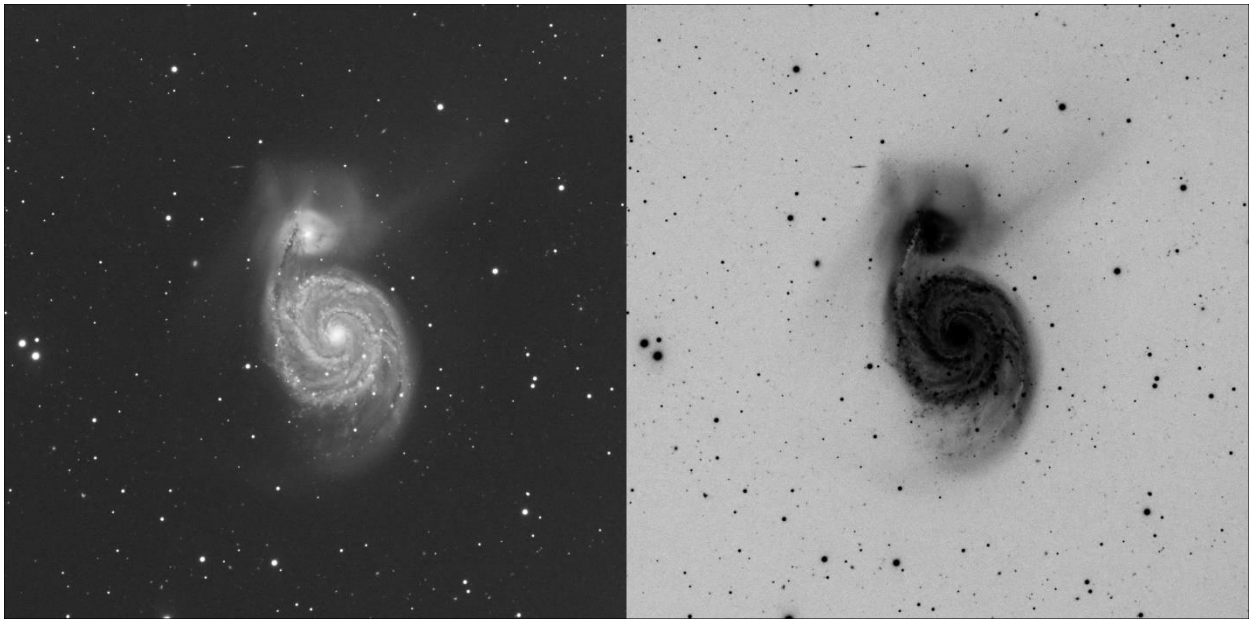

Figure 9 - M051. 265min (53x5min). TMB 152mm F/8, ST10-XE, self-guided, SDMask, DDP, Paramount ME. Processed with Maxim DL and Photoshop

Figure 10- M84/M86. 180min (18x10min). TMB 152mm F/8, STL11002M, self-guided, Median, DDP, Paramount ME. Processed with Maxim DL and Photoshop

Figure 11 – M51 & M13 (LLRGB). TMB 152mm F/8, ST-10XE, self-guided, Paramount ME.

Figure 12- M42. FS128 F/8.1, modified Canon 350D (Baader filter), 800ISO, 25x30s, SDMask, DDP. Processed with Maxim DL and Photoshop CS3.