Backyard Astrophotography
A How-To Story

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2007 June 27

Astrocon 2007

http://www.princeton.edu/~rvdb
Why Astrophotography?

Long Exposures, Permanent Record, Digital Enhancement, Light Pollution!
Some Pictures
Equipment

In order of IMPORTANCE...

1. Mount

2. Camera
   Computer
   Software

3. Telescope (OTA)

NOTE: This talk is about *deep sky* astrophotography.
For imaging the moon and the planets, the issues are different.
Astronomical CCD camera

- Pixel size: $6.45 \times 6.45$ microns
- Dimensions: 1392 x 1040
- Quant. Eff.: $\sim 65\%$
- Readout Noise: $\sim 7$ electrons
- Cooling: $\sim 30^\circ\text{C}$ below ambient
- Download: 3.5 seconds
- Format: 16 bit
- Weight: 350g
Questar: A High-Quality Mount

Optically: comparable.

Mechanically: a world of a difference.
Example

**OTA:** 200mm f/3.5 Vivitar lens ($30)
**Mount:** Questar
**Camera:** Starlight Express SXV-H9
**Filter:** Dichroic Hα

**Fundamental Principles**

- *Focal length* determines *field of view*
- *F-ratio* determines *exposure time*

Total exposure time = 156 mins. Field of view = 2.5°.
Combatting Light Pollution

Narrow-Band Filters

Graphs showing transmission in % vs. wavelength (nm) for Astronomik Profi-Hα and Astronomik Profi-OIII filters.
Visual Astronomy vs. Astrophotography

Visual astronomy is complicated.

- **Aperture** determines *photon flux*

Astrophotography is easier!

- **Focal length** determines *field of view*
- **F-ratio** determines *exposure time*
Image Acquisition

1. Move equipment outside (3 minutes). Let cool (in parallel).
2. Polar align (2 minutes).
3. Manually point at a known star (1 minute).
4. Fire up MaximDL, my image acquisition software (0 minutes).
5. Focus on bright star (3 minutes).
6. Center star in image (1 minute).
7. Fire up Cartes du Ciel, my computer’s planetarium program (0 minutes).
8. Sync on star (1 minute).
9. GoTo desired target (1 minute).
10. Center (1 minute).
11. Select guide star. Calibrate and start guider (5 minutes).
12. Initialize imaging sequence (1 minute).
13. Go inside (1 minute), watch TV (10 minutes), sleep (hours?).
Move equipment outside (3 minutes). Let cool (in parallel).
Polar align (2 minutes).

Equatorial mount!
Manually point at a known star (1 minute).
Fire up image acquisition software (0 minutes).
Focus on bright star (3 minutes).
Center star in image (1 minute).
Fire up computer's planetarium program (0 minutes).
Sync on star (1 minute).
GoTo desired target (1 minute).

Center (1 minute).

Select guide star. Calibrate and start guider (5 minutes).
Here there be dragons!

Initialize imaging sequence (1 minute).
Go inside (1 minute), watch TV (10 minutes), sleep (hours?).

Me watching TV.

Go outside. Pack everything up (15 minutes).
Image Processing

- Calibrate (flats, darks, etc.).
- Align.
- Stack.
- Color combine.
- Enhance.
Idea: Take an image of a uniformly illuminated field (such as the side of a wall). Use this "flat" image to normalize (by division) the pixel brightness of the actual image.

Flats correct for vignetting and dust donuts.

Most CCD chips are small and hence vignetting is usually not a problem.

Dust donuts can be avoided by removing the dust!

Until I get a CCD camera with a much larger chip, I normally don’t do flats.

EXCEPTION: Broadband images with light pollution (i.e., galaxies, globulars, etc.).
Darks

Idea: Take several images of a completely black field (obtained by closing the "shutter" to the camera). Subtract this "dark" image from the "light" images.

Darks correct for dead, warm, and hot pixels as well as "heat" photons.

Most CCD chips are cooled and hence heat glow is not a significant problem.

Newer CCD cameras have better "dark".

Dead, warm, and hot pixels are better handled by software.
Color Combining

**Left.** Red = $H\alpha$.

**Right.** Green & Blue = O-III.

**Bottom.** Color.
Sharpening w/ Richardson-Lucy Deconvolution

Before

After

http://www.cyanogen.com/products/maxim_extras.htm
Digital Development: Being Gentle vs. Overprocessing

Left. Log stretch.
Right. Digital development.
Bottom. Half & Half.
Some More Pictures
Final Suggestions

**OTA.** Low f-ratio, flat field.

**Mount.** Equatorial, low periodic error, controllable, stable.

**Camera.** Cooled, b&w, low noise.

**Filters.** ESSENTIAL. Dichroic. H$\alpha$, O-III, R,G,B.

**Computer.** Laptop.

**Software.**

**Image Acquisition.** MaximDL or AstroArt.

**Planetarium.** CartesDuCiel or TheSky.

**Image Processing.** MaximDL or AstroArt. Maybe Photoshop.
Biases