



Backyard Astrophotography A How-To Story

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2007 June 27

Astrocon 2007

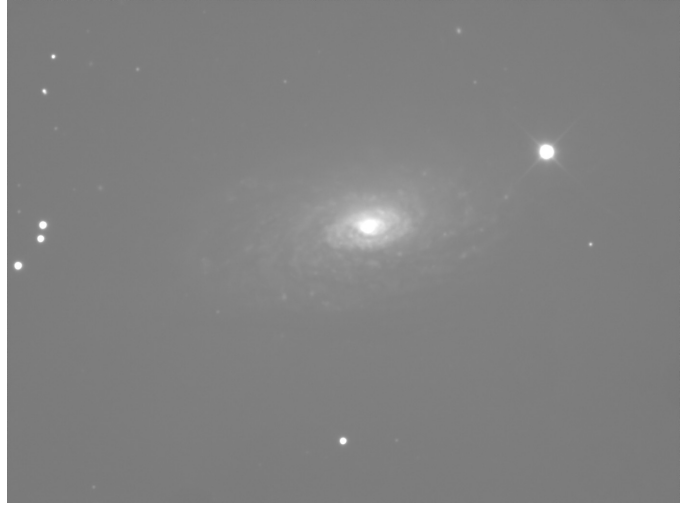
<http://www.princeton.edu/~rvdb>

Why Astrophotography?

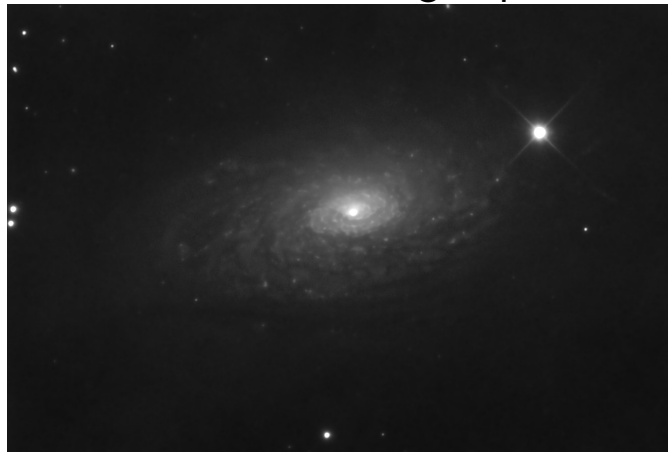
Long Exposures, Permanent Record, Digital Enhancement, Light Pollution!



Visual Experience



Long Exposure



Light Pollution Subtracted

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: 6.45×6.45 microns
- Dimensions: 1392 x 1040
- Quant. Eff.: $\sim 65\%$
- Readout Noise: ~ 7 electrons
- Cooling: $\sim 30^\circ\text{C}$ below ambient
- Download: 3.5 seconds
- Format: 16 bit
- Weight: 350g



Questar: A High-Quality Mount



Questar: \$4,500



Meade ETX-90: \$500

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 H α

Fundamental Principles

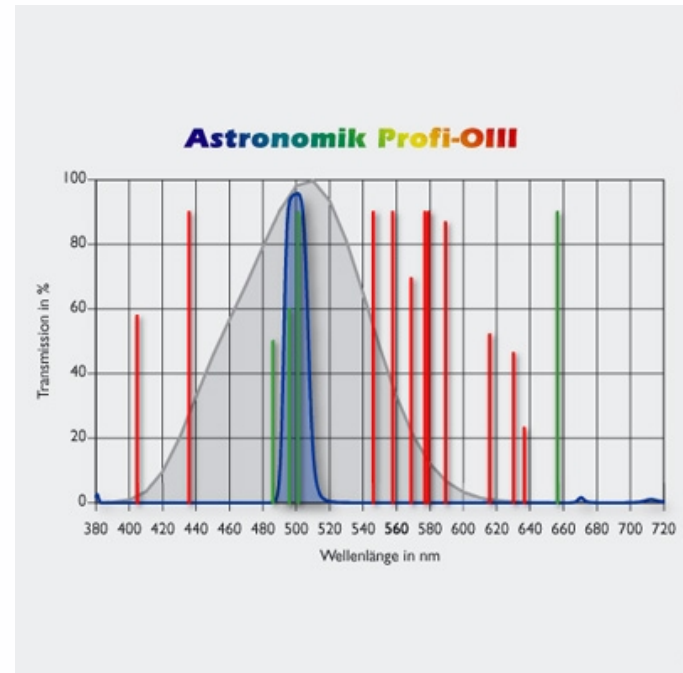
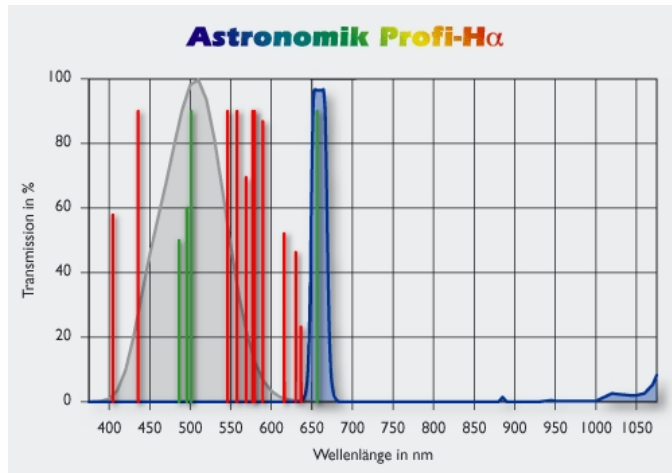
- *Focal length* determines *field of view*
- *F-ratio* determines *exposure time*



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

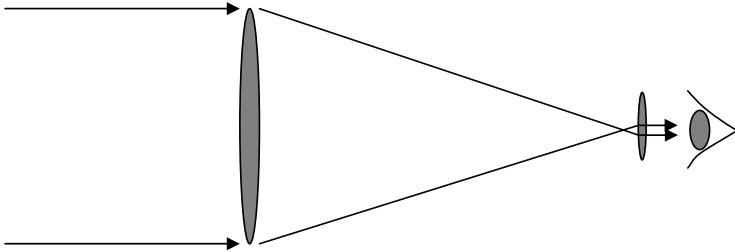
Combating Light Pollution

Narrow-Band Filters



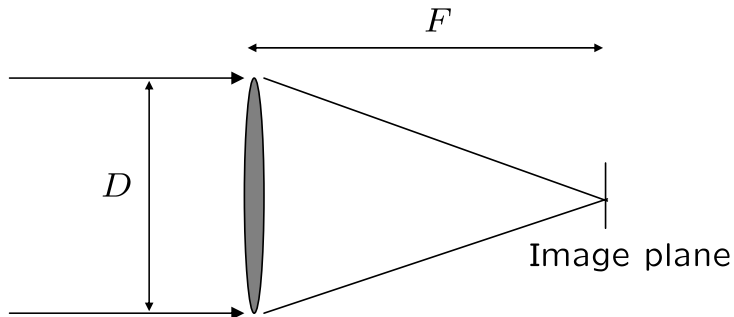
Visual Astronomy vs. Astrophotography

Visual astronomy is complicated.



- *Aperture* determines *photon flux*

Astrophotography is easier!

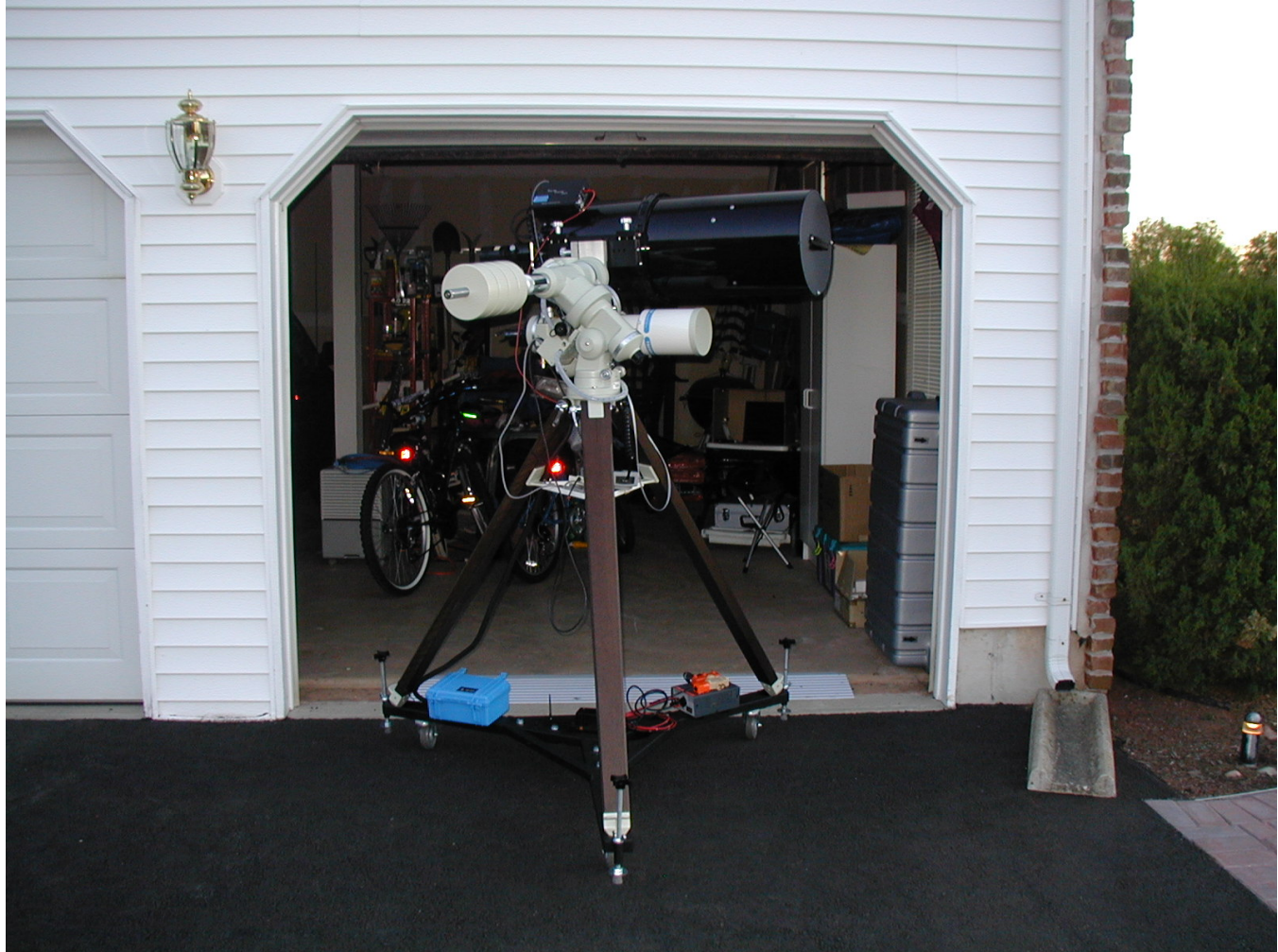


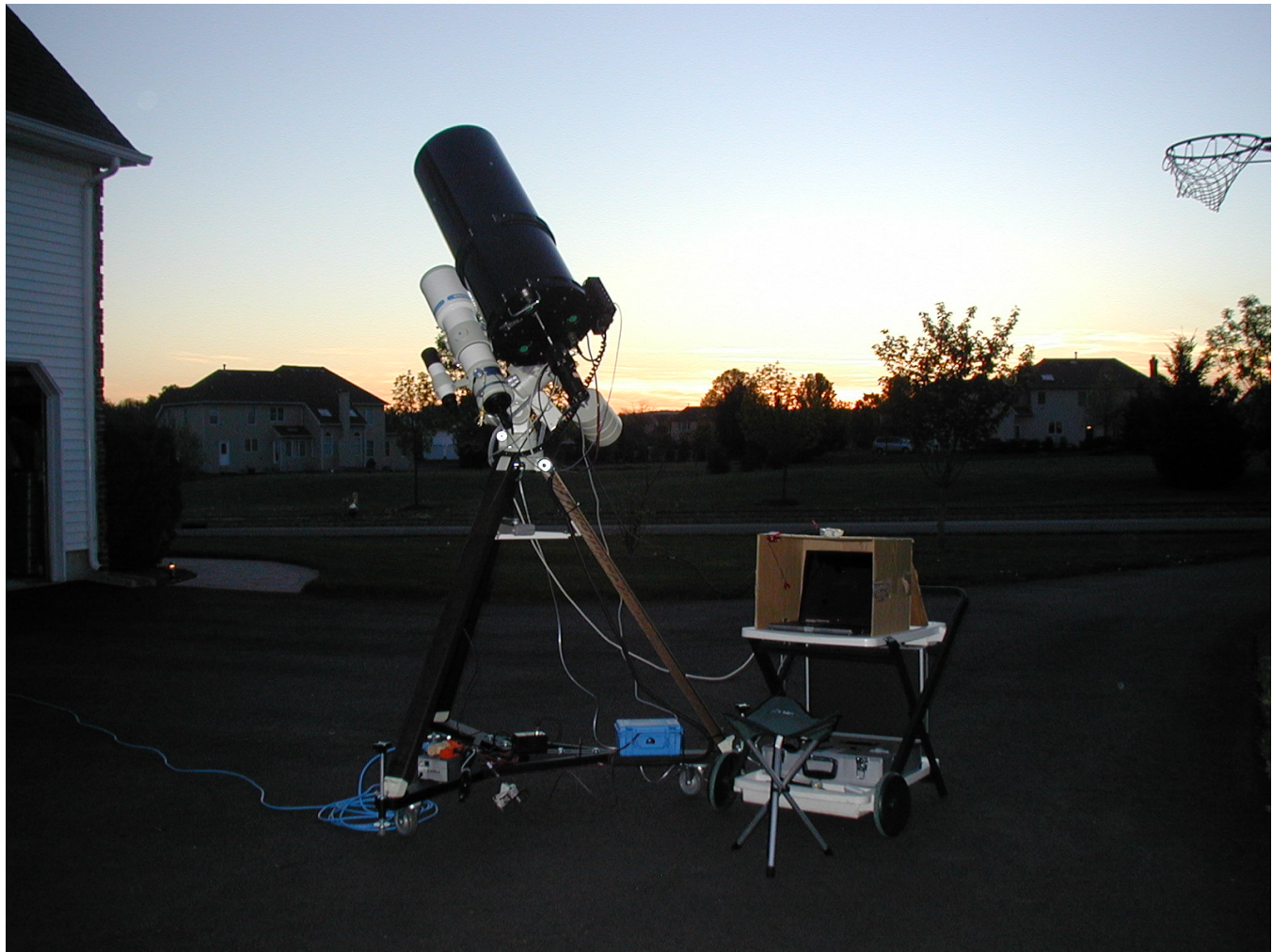
- *Focal length* determines *field of view*
- *F-ratio* determines *exposure time*

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?).
14. Go outside. Pack everything up (15 minutes).

Move equipment outside (3 minutes). Let cool (in parallel).





Polar align (2 minutes).

Equatorial mount!

Zones de saisies utilisateur

Etape 1 : **T.U. SYSTEM**

Etape 2 :

Latitude : 40 d 27 m
Nord+ Sud-

Longitude : 74 d 39 m
Est- Ouest+

Date : 9 / 1 / 2007

Heure T.U. : 20 h 17 m **update**

Etape 3 : **CALCULER**

Affichage des résultats

T.S.L. : 22 h 34 m

T.U. local = T.U. + -298.6 m

hemisphere nord Alpha Polaris

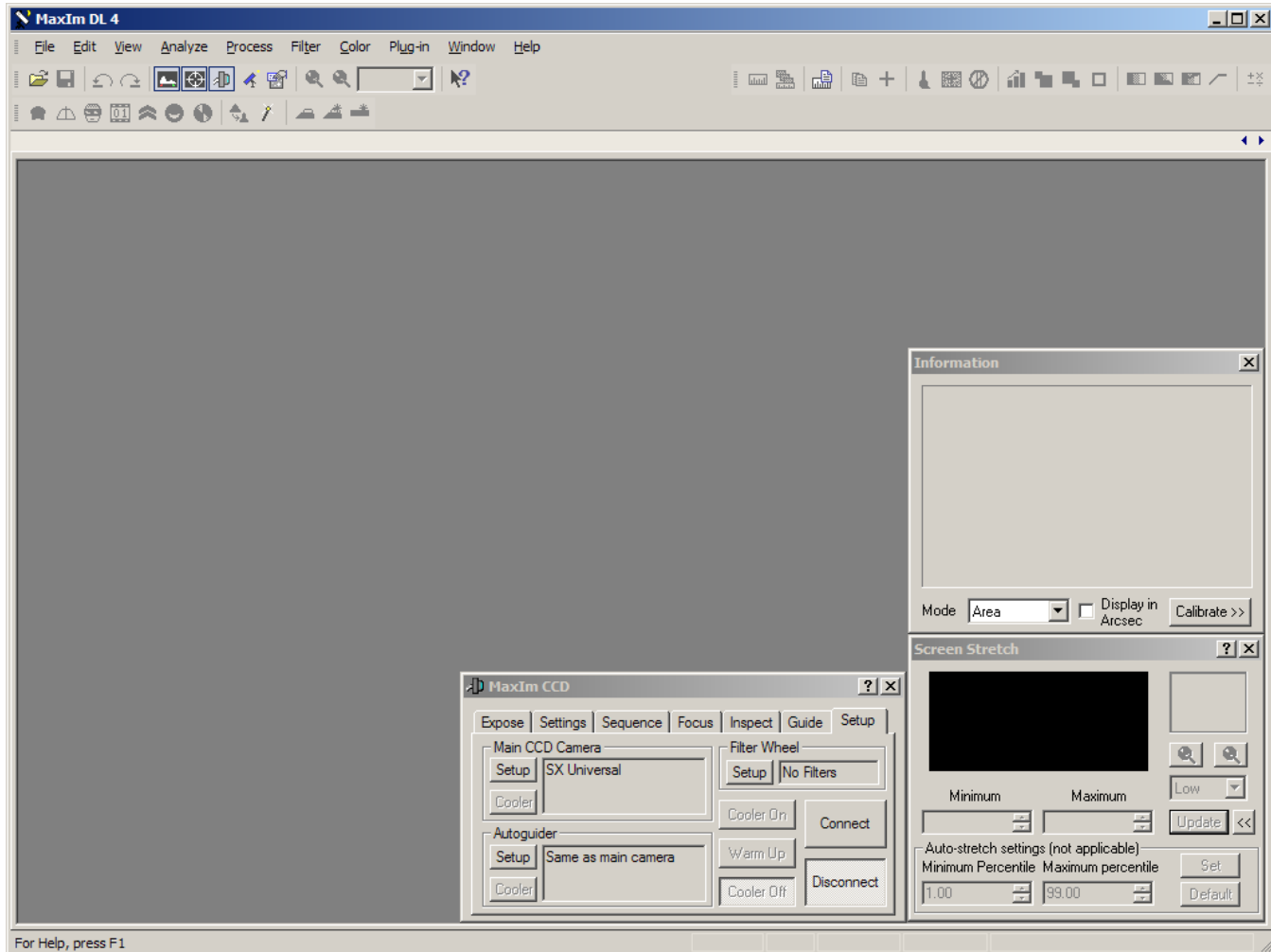
Angle Horaire : 19 h 54 m

Position de l'Etoile Polaire ou de Sigma Octan au moment de votre mise en station avec une monture TAKAHASHI P2-Z, EM-10, NJP, EM-500 : viseur polaire à niveau

PolarisFinder 1.3
OPTIQUE UNTERLINDEN

Done No Calendars

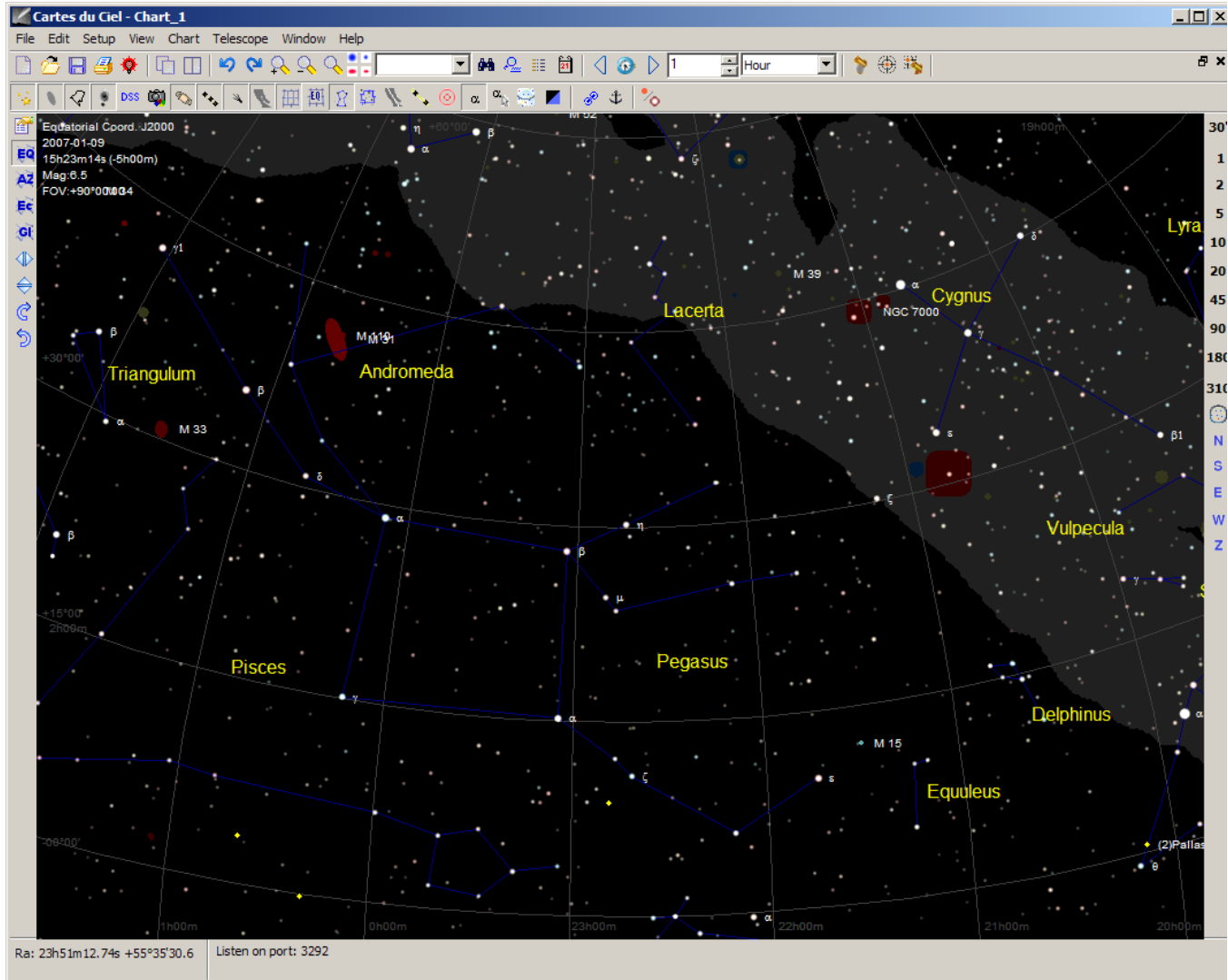
- Manually point at a known star (1 minute).
- Fire up image acquisition software (0 minutes).
- Focus on bright star (3 minutes).



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.

Flats

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.

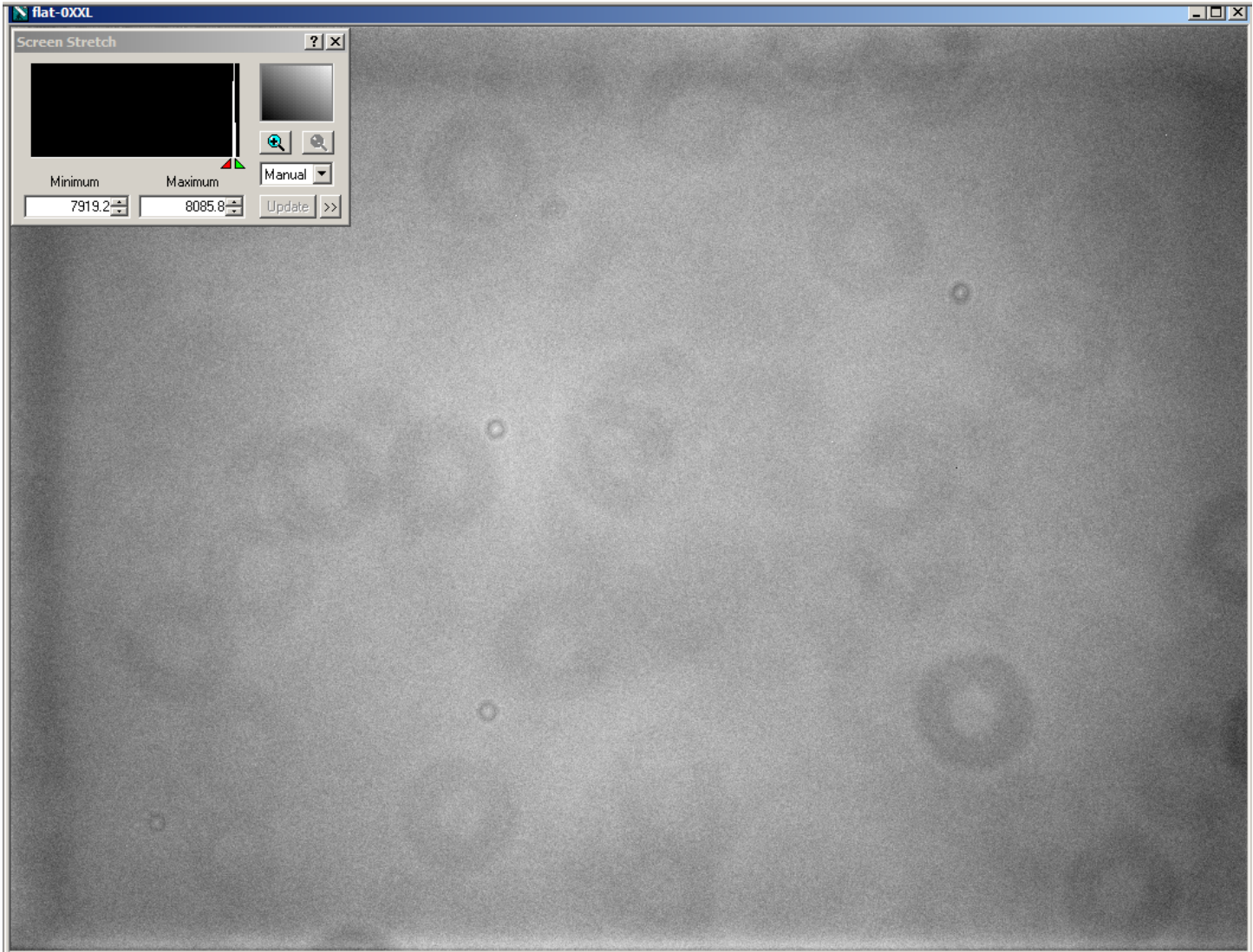
Most CCD chips are small and hence vignetting is usually not a problem.

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

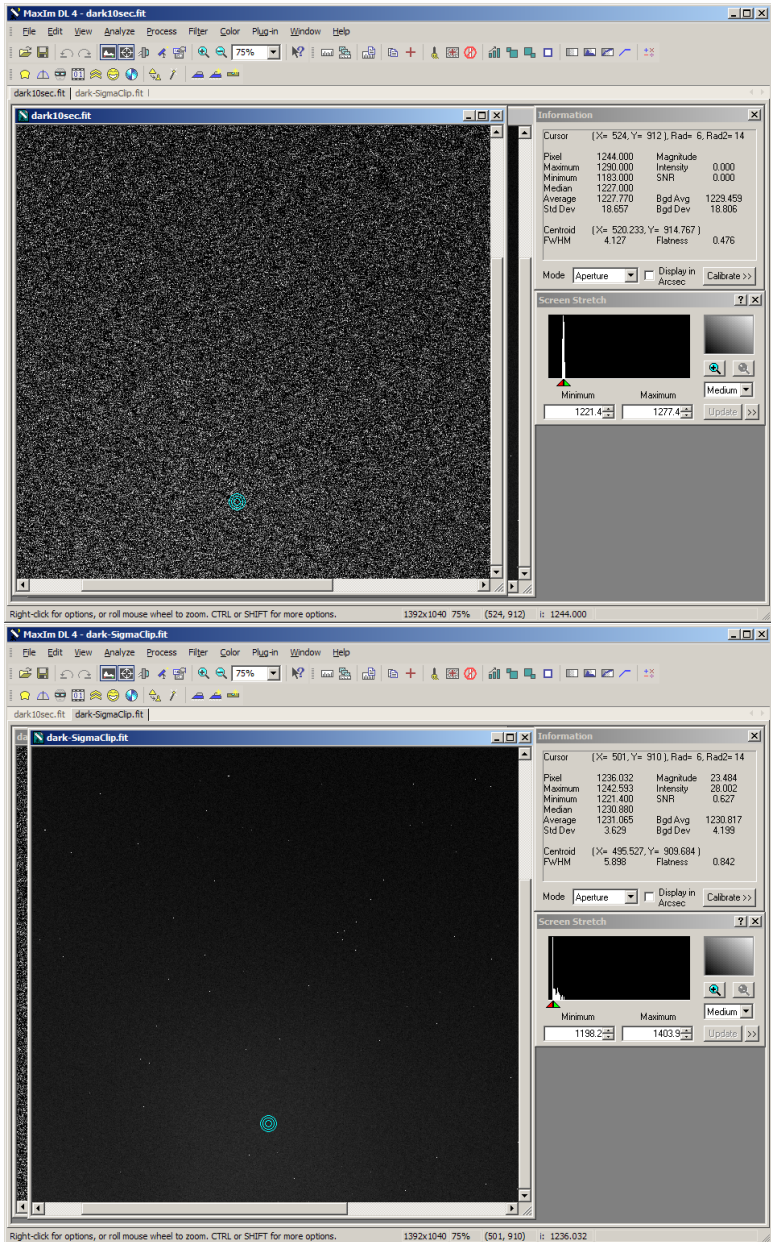
Idea: Take several images of a completely black field (obtained by closing the "shutter" to the camera). Subtract this "dark" image from the "light" images.

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.



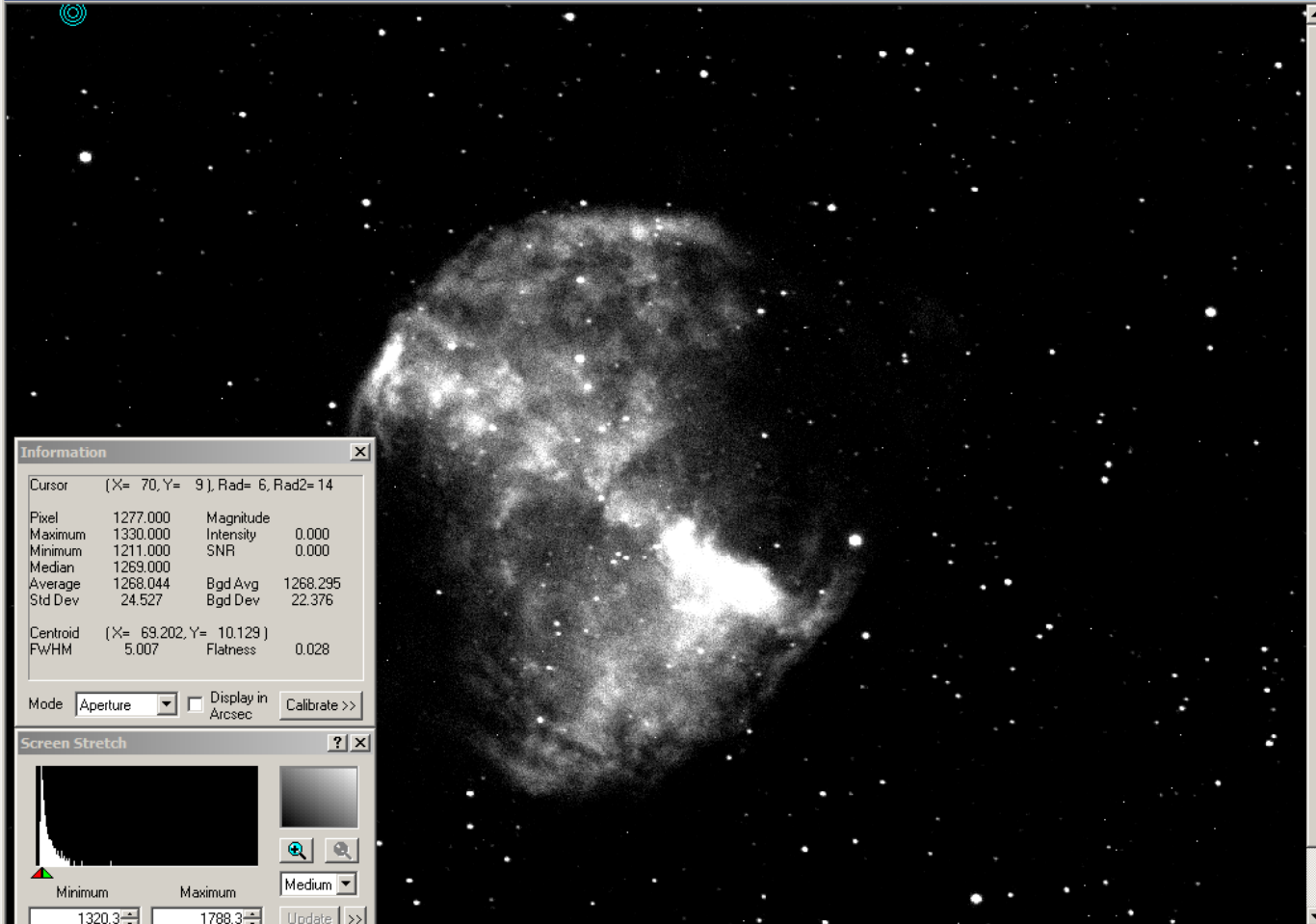
MaxIm DL 4 - m27-044Ha.fit

File Edit View Analyze Process Filter Color Plug-in Window Help

75%

m27-044Ha.fit | m27-039Ha.fit | m27-001Ha.fit | m27-011Ha.fit | m27-010Ha.fit | m27-009Ha.fit | m27-008Ha.fit | m27-007Ha.fit | m27-006Ha.fit | m27-005Ha.fit | m27-003Ha.fit | m27-002Ha.fit | m27-044Ha.fit

m27-044Ha.fit

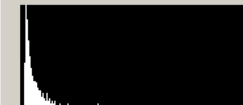


Information

Cursor	[X= 70, Y= 9], Rad= 6, Rad2= 14		
Pixel	1277.000	Magnitude	
Maximum	1330.000	Intensity	0.000
Minimum	1211.000	SNR	0.000
Median	1269.000		
Average	1268.044	Bgd Avg	1268.295
Std Dev	24.527	Bgd Dev	22.376
Centroid	[X= 69.202, Y= 10.129]		
FWHM	5.007	Flatness	0.028

Mode: Aperture Display in Arcsec Calibrate >>

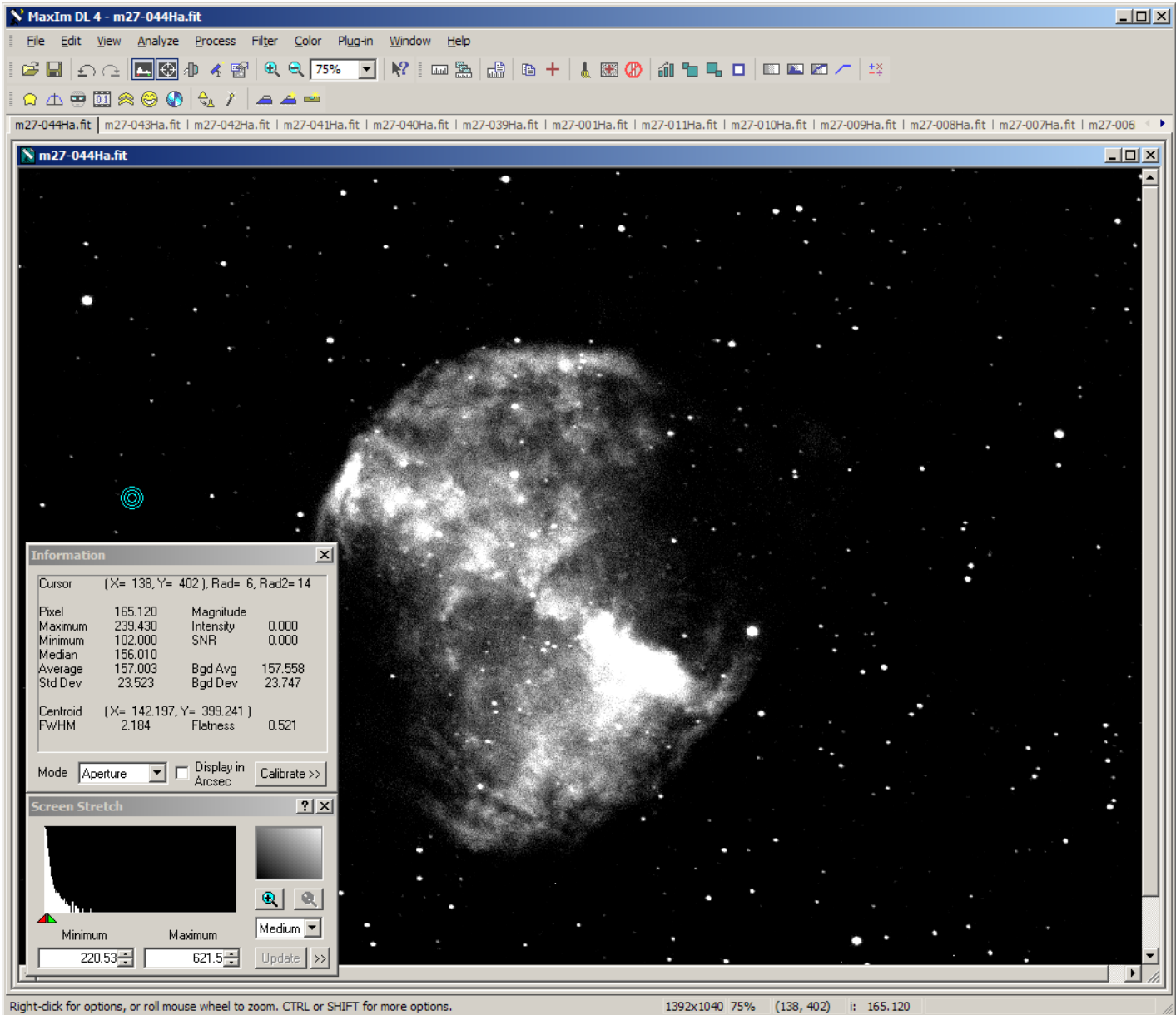
Screen Stretch

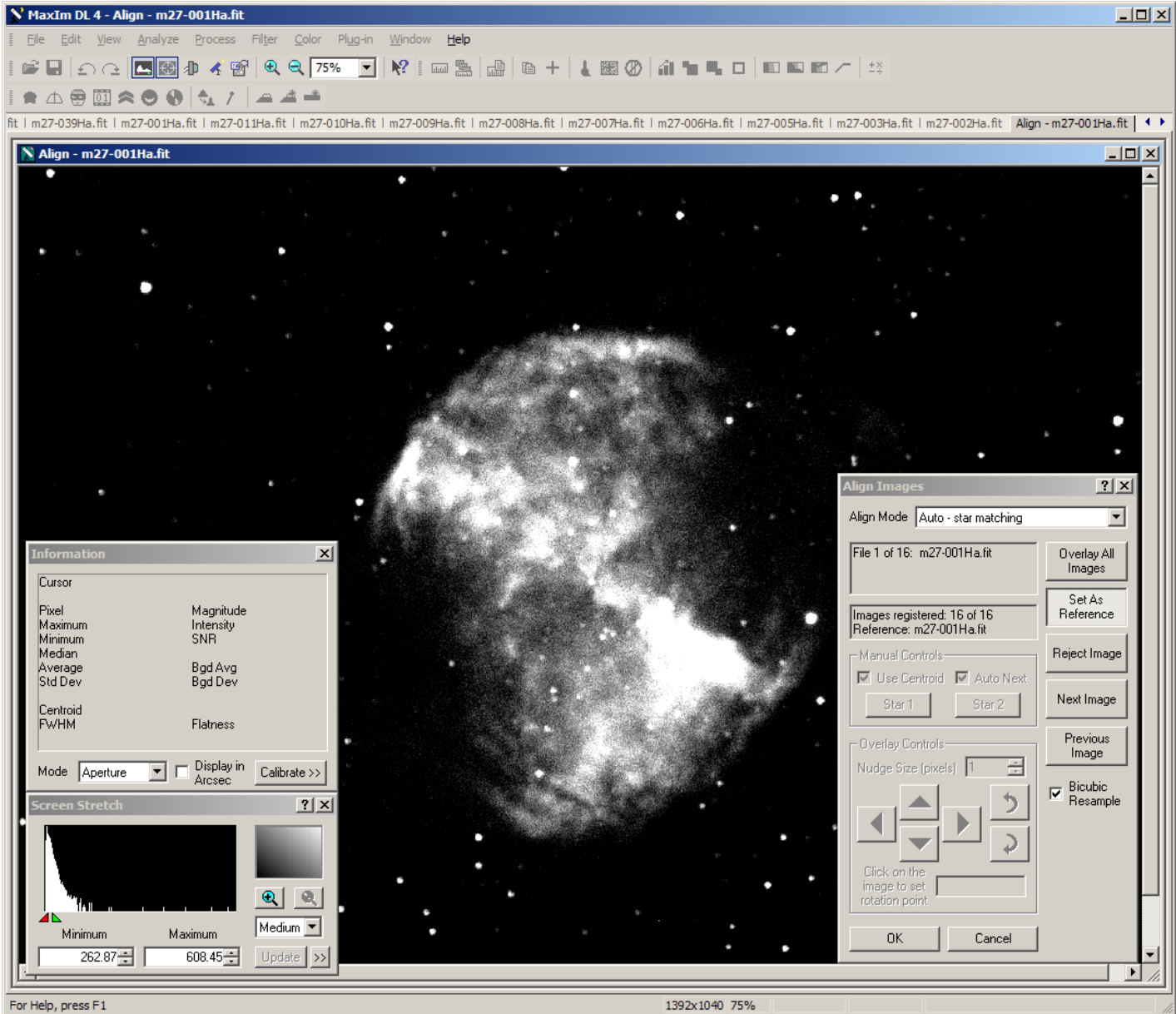


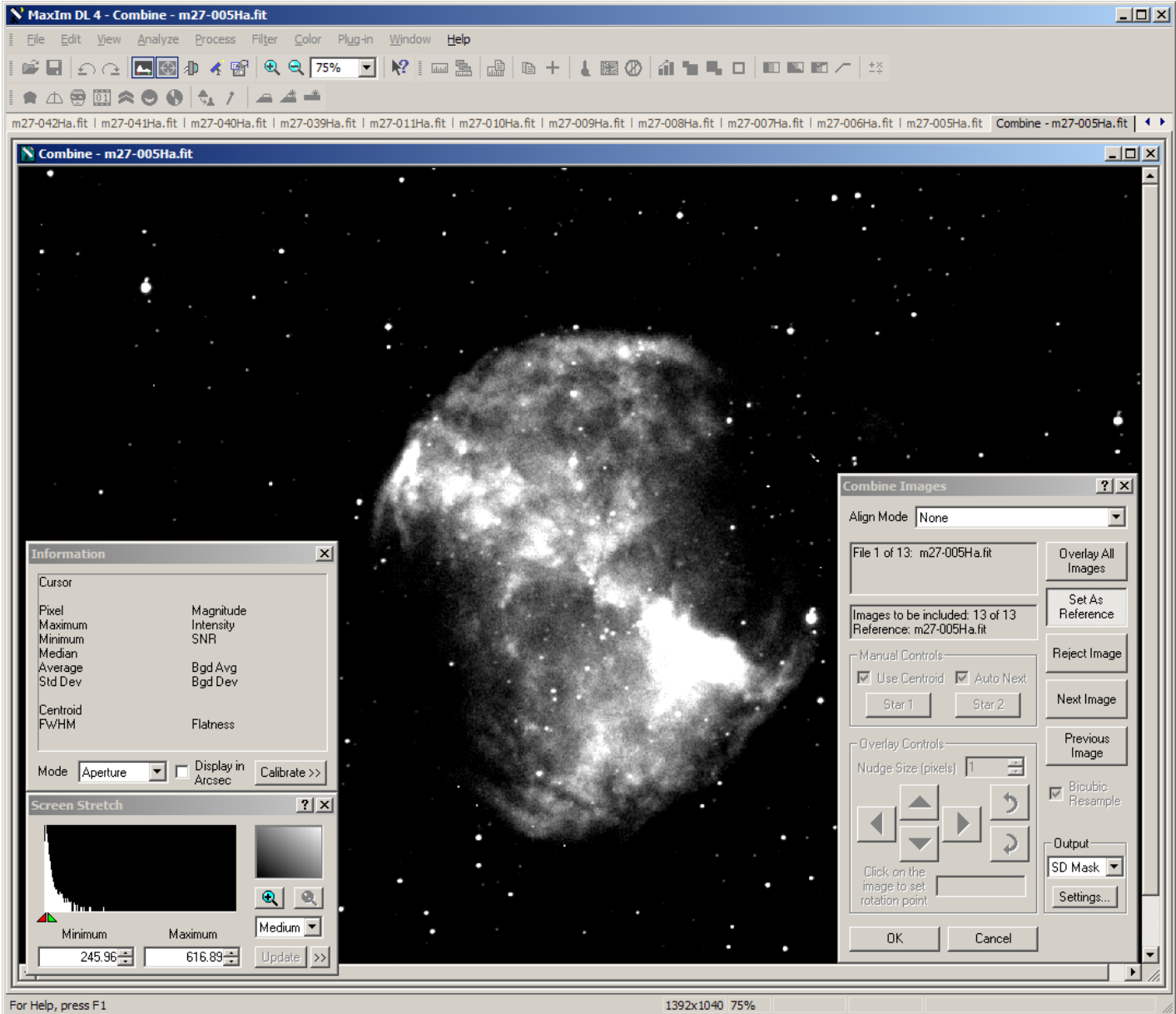
Minimum: 1320.3 Maximum: 1788.3 Medium Update >>

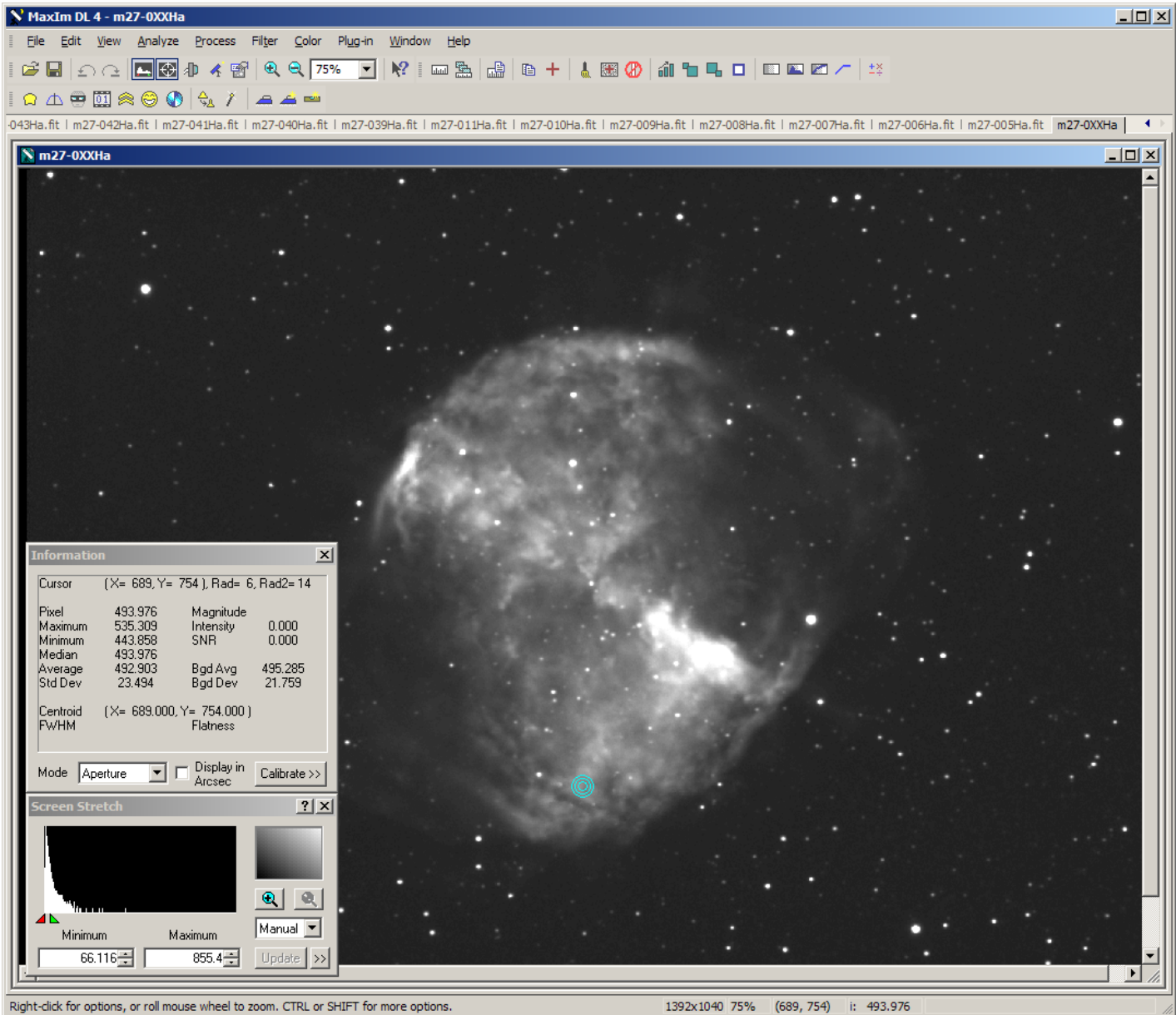
Right-click for options, or roll mouse wheel to zoom. CTRL or SHIFT for more options.

1392x1040 75% (70, 9) i: 1277.000









Right-click for options, or roll mouse wheel to zoom. CTRL or SHIFT for more options.

1392x1040 75% (689, 754) i: 493.976

Color Combining



Left. Red = $H\alpha$.

Right. Green & Blue = O-III.

Bottom. Color.



Sharpening w/ Richardson-Lucy Deconvolution

Before

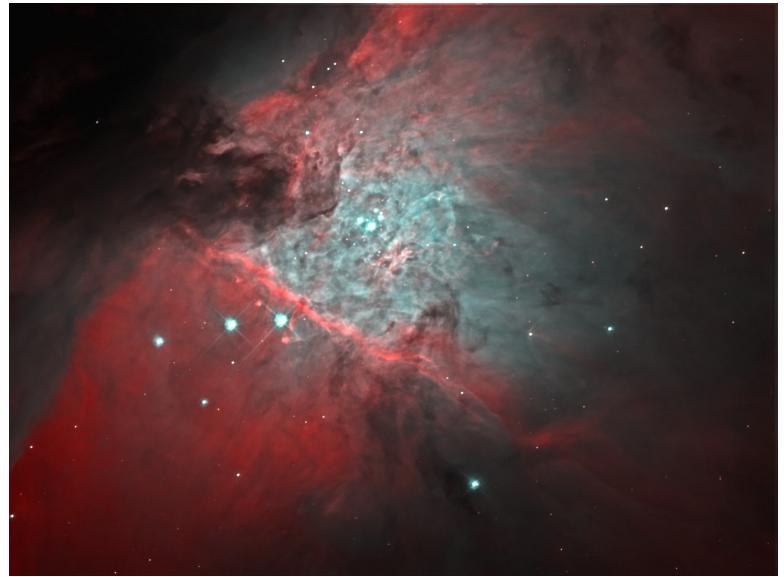


After



http://www.cyanogen.com/products/maxim_extras.htm
http://www.princeton.edu/~rvdb/images/deconv/deconv_MaximDL.html

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.

Backup Slides

Biases