Getting Started in Deep Sky Astrophotography

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Topics

- Beginning deep sky astrophotography
- Getting started with minimum frustration
- Data capture
- Data processing

Why astrophotography?

- Go deeper than visual
  - CCD/CMOS more sensitive than human eye (especially to Hydrogen emissions)
- Share with others
- Satisfaction of capturing detail

Human Eye vs. DSLR

Astrophotography Elements

- Data collection - requires precision
  - Equipment
  - Knowledge
  - Practice
- Processing - constantly evolving state of the art

Hurdles, Barriers, Frustrations,
Why some give up

- Dim targets = Long exposures =Tracking errors
- Long exposures = noise
  - Drawing the signal out of the noise
- Tracking errors
  - Polar misalignment
  - Mechanical errors
  - Flexure
- Mount pointing accuracy
  - Field of view
- Error messages, drivers, etc.
- Processing time
  - learning the tools
  - keeping up with advancing state of the art

Equipment

- Mount
- Telescope
- Camera
- Peripherals
  - Guide scope
  - Guide camera
  - Laptop to guide mount and control camera

Mount

- Equatorial
  - Tracks motion of sky as earth rotates
  - Accuracy important
  - Go-to preferred
  - Polar alignment
    - Software – Celestron All-Star, PEM Pro, SkyX T-point
    - Drift Alignment – eyepiece or software assisted
  - Guiding

Camera

- DSLR with live view (CMOS)
  - Economical, used are viable
  - Poor red sensitivity (can be modified)
  - Noisier, harder to noise correct
- CCD
  - More expensive ($2000 and up)
  - Smaller field of view (except very high $$$)
  - Cooled = lower noise & easier to correct
  - Mono or Color
  - Mono
    - Higher efficiency
    - Best narrow band camera
    - Requires filters and wheel
    - More post processing

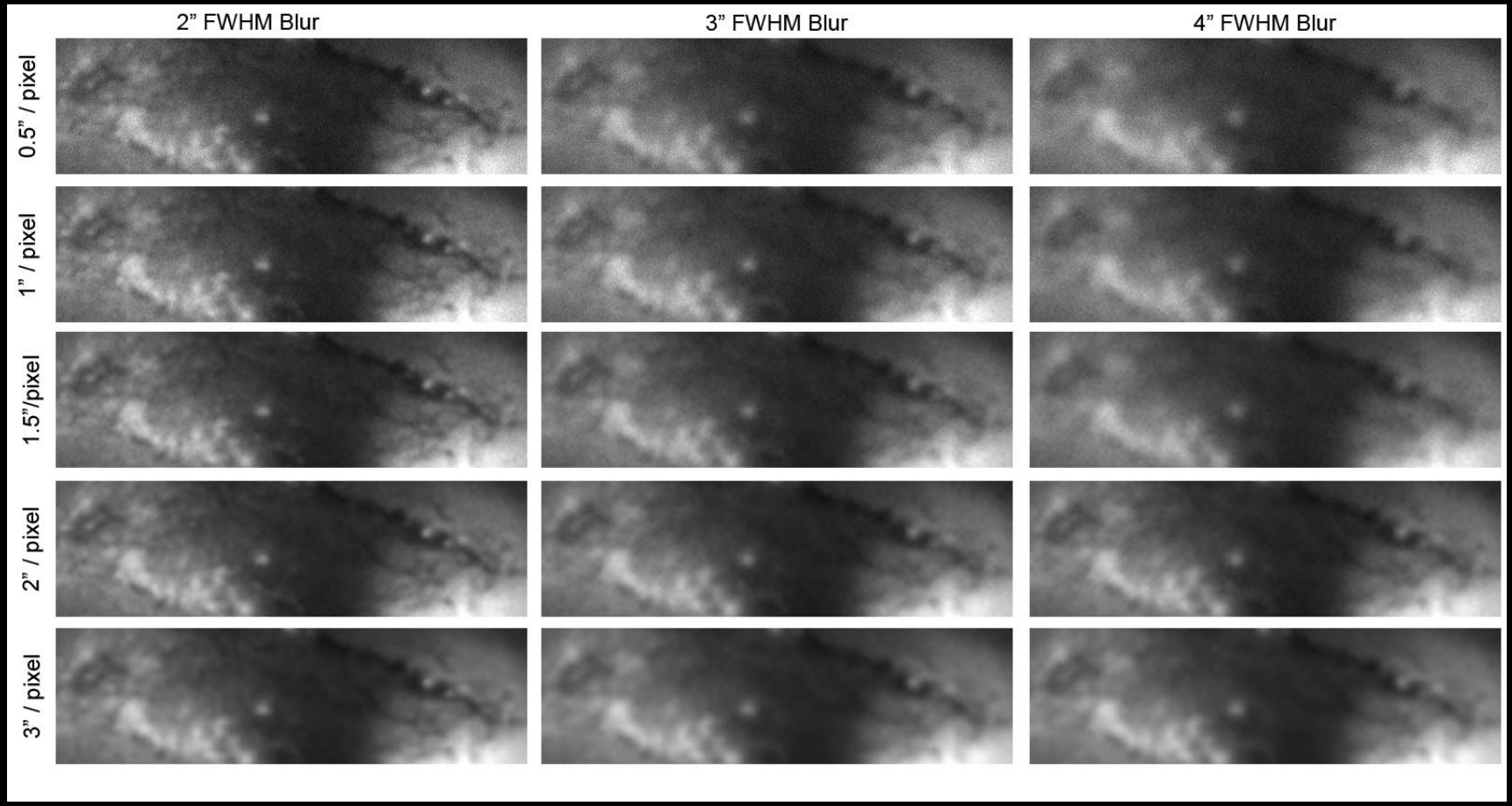
Scopes

- Refractor
  - Fast, available in short focal lengths
  - Subject to color fringing
  - Edge of field distortion
- Reflector
  - Can be fast
  - Needs collimation
  - Edge of field distortion
- Cassegrain
  - Compact
  - Long focal lengths (undesirable)
  - Mirror flop
  - Frequent collimation needed
- Camera Lens
  - Short focal lengths
  - Focus challenges
  - Most expensive per inch

Image Scale – How Much Can You See?

- Image scale in arc-seconds/pixel
  - (206 x pixel size in microns)/focal length in millimeters
  - Micron = micrometer = 0.001 mm
  - Full moon = 1800 arc seconds
- Canon DSLR with 500 mm refractor or 100 mm telephoto lense
  - 206 x 5.2 microns / 500 mm ~ 2 arc seconds per pixel
  - 206 x 5.2 microns / 100 mm ~ 10 arc seconds per pixel
    - About the limit for unguided tracking
- Seeing in Georgia is typically 2 – 4 arc seconds

Image Scale vs. Seeing



Guiding Options

- Guiding scope
  - Easier to learn
  - Small, light weight guide scope
  - Light guide camera
  - Sturdy attachment to main scope or mount
  - Differential flexure
- Off-axis guider
  - Fewer, dimmer guide stars
  - Hard to focus
  - Requires more back focus
  - No differential flexure

Key Points

- Start imaging using *short focal lengths* – about 500 mm
  - Will sacrifice little, if any, detail
  - Larger field of view less susceptible to mount pointing errors
  - Larger pixel scale less sensitive to tracking errors
- Guide errors less than one pixel will not harm end result
  - Mounts with < 2 arc seconds mechanical error cost $9,000 and higher
  - So guiding is essential to deep sky astrophotography

Suggested Starter Imaging Rig

- Mount – Celestron AVX or similar performance
- Refractor, 400 – 600 mm focal length
  - Two speed focuser
  - Doublet with high quality glass or triplet
- Canon DSLR, possibly used
  - Upgrade with spectrum mod in future
- More forgiving
  - Pointing errors
  - Tracking errors

One More Thing: Accessories

- Camera control
  - Remote shutter control
  - Camera control software
    - Backyard EOS – DSLR's
    - Nebulosity
    - Maxim DL
    - The SkyX camera add-on
- Guiding software
  - PHD, PHD2
  - Guide dog
  - Meta guide
  - others
- Battery
- T-ring
- Nose piece
- Bahnitov mask
- Laptop
- Field flattener
- Focal reducer

Celestron AVX, Canon DSLR, Mini guide scope, Nebulosity

Capturing Data

Let’s Go Take Some Pictures!

- Set up as much as you can at home first
- Establish connections to mount, camera, guide camera
  - Trouble shoot driver issues, ASCOM issues etc.
  - Shoot some pictures
  - Focus on a distant object if available
  - Don’t waste your precious dark sky time
- Polar alignment (a topic for another day)
- Focus
- Guider calibration
- What do about that long exposure noise?

Capture Strategy
Maximize Signal to Noise Ratio

- Target signal accumulates faster than noise
- Longer exposures mean more difference between target and noise
- Practical limit on length – tracking, airplanes and other misfortunes
- Statistics are your friend!
  - Wish you'd paid more attention in school?
  - Stack multiple exposures
    - Signal is constant (same place)
    - Noise is random (moves around frame)
    - Averaging cancels noise

How long is enough?

- The number and duration of exposures needed depends on the target brightness, focal ratio, light pollution, transparency and other factors
- Thumb rule: SNR doubles with the square root of the exposure duration
  - Dark sky site, bright galaxy; three hours can produce good results with a DSLR
  - Average emission nebula, narrow band filters; over 20 hours may be needed
- Soooooo: Take lots of data – as long as you can

300 second vs. 900 second exposure

Key Points

- Setup and connect everything possible during daylight. Better yet, before you head to the field
- Take longest exposures gear will allow
- Maximize total image time

Processing

Let’s do something with that data

Processing Steps

- Calibration
  - Remove noise, correct uneven illumination
- Alignment and Stacking
- Enhancements (the Magic)
  - Stretching
  - Color correction
  - Contrast enhancement
  - Noise removal
  - Etc., etc., etc.

Processing Tools

- Perform calibration, alignment, stacking, enhancement
- Budget suite
  - DeepSkyStacker
  - Photoshop Elements
- Traditional high end suite
  - CDDStack
  - Photoshop
  - Registar (mosaic)
- Modern high end suite
  - Pixinsight

Calibration

- Correcting images for:
  - read noise – noise from camera/chip electronics, present in shortest exposures
  - thermal noise (or dark current) - Charge that accumulates over time due to heating of imaging chip
  - uneven illumination – imperfections in the optics, such as dust motes, vignetting, etc.
- Dark frames
  - Contain read noise and thermal noise
  - Match duration to light frames
  - Subtract from each light frame before alignment and stacking
- Flat frames
  - Model imperfections – complex enough to be a separate topic

Alignment and Stacking

- Align all stars perfectly – correct x,y shift and rotation between frames
- Best done by purpose built software

- Stacking
  - Pixel by pixel averaging or outlier rejection to determine correct value at each location on frame
  - Random noise averages out, target signal enhanced

Calibration and stacking comparisons

Raw 15 min frame

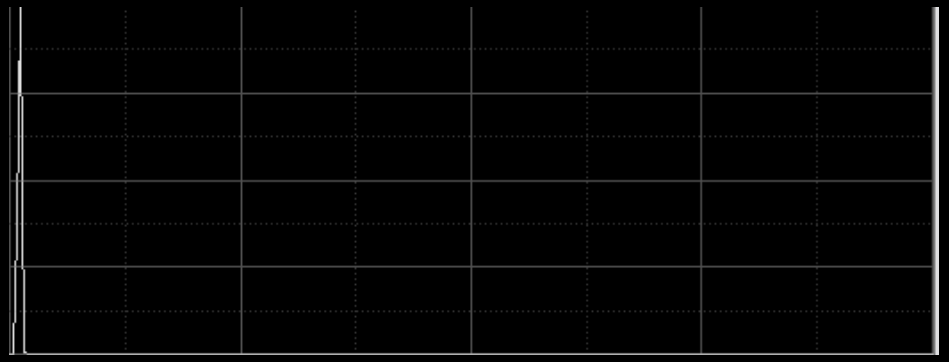
Dark subtracted

Stack of 41 frames

Enhancement - Stretching

- Unstretched data

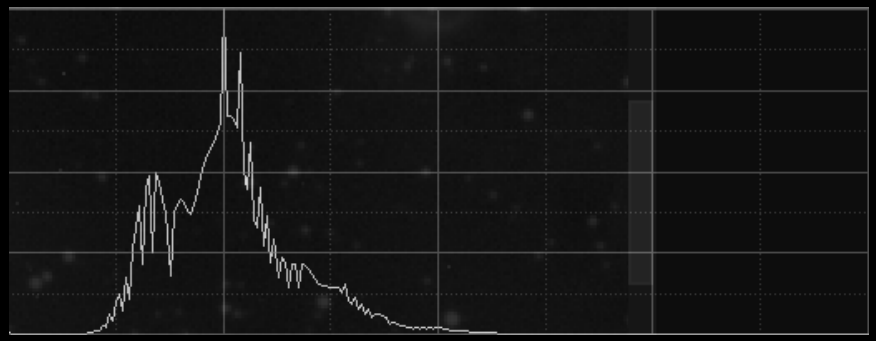
- Intensity distribution
- The Histogram
  - Count of pixels at each intensity level



Enhancement - Stretching

- Stretched data

- Histogram after stretching



More enhancement

- Stretched data

- Enhanced contrast

Which Image is Better?

Key Points

- All workflows start with calibration
  - Start with dark frame subtraction
  - Add flat field and bias as you learn more
- Several stacking algorithm choices (average, median, etc.) are available. Learn which works best in each situation.
- Many other enhancement techniques available. Study online resources.
- Pixinsight being rapidly adopted by many imagers. More features per $ than any other suite.

Good First Targets

Name	Exposure Length	Number of Exposures	Comments
Andromeda Galaxy (M31)	5 minutes	36	Fall target
Orion Nebula (M42)	2 minutes	36	Winter target. High dynamic range. Can be processing challenge. Blending longer exposures yields better results.
Lagoon Nebula (M8)	5 minutes	36	Spring target
M81/M82	5 minutes	36	Up in winter/spring (now!)

Resources

- Pixinsight Resources - http://pixinsight.com.ar/, http://pixinsight.com/forum/index.php
- Google Astro Imaging Channel
- Bill Snyder Astrophotography – good links
- Deep Sky Colors
- Thierry Legault – Astrophotography (book)
- Harry's Astroshed
- Bob Franke
- Neil Fleming

Summary

- Basis for what to do
- Start with short focal lengths
- Guiding highly recommended
- Setup as much during daylight as possible
- Take longest exposures rig will allow
- Maximize total image time

- Calibration – start with dark frames
- Align and stacking multiple frames of the same target
- State of the art is Pixinsight, Photoshop is not gone but fading fast
- Learn a workflow for enhancements
- State of the art constantly improving
  - Many online free resources

Questions?
Want know more?