CCD Astronomy

• CCD imaging is visual astronomy
  – Those well travelled photons arriving from extremely distant objects are collected by the telescope optics and captured by the CCD in the camera
  – The CCD counts those photons at every detector (pixel) and sends the results to a computer
  – The computer processes those results and presents them on its display for your (and other’s) visual enjoyment

• CCD imaging is a magical process
  – Greatly increases the sensitivity of the observer’s eye
  – Brings out color and detail in deep sky objects that can’t be seen any other way
  – Downside – it’s not real time and refinement takes a little effort
What Does it Take?

• Any amateur astronomer can make CCD magic happen
  – It takes is some extra equipment, some specialized software and an understanding of the CCD imaging process

• There are no closely guarded secrets – there are a few key things you need to focus on:
  – Long exposures with a sensitive camera
  – Precise focus
  – Steady tracking equatorial mount
  – Precise polar alignment
  – Good quality optics
CCD Camera = Sensitivity

SBIG ST-8XME Camera and 5 Position Filter Wheel

Sensitivity (QE) Comparison
CCD versus DSLR
CCD Camera = Low Noise

• Active Cooling
  – Fan(s)
  – Thermoelectric
  – Water Assisted

• Controlled Temperature
  – Precise Calibration

• Special Low Noise Circuit Designs
Precise Focusing

NGC0457
The Owl Cluster
Focusing Techniques

• Camera Control SW
  – OK, but not optimal

• Diffraction Grating
  – Bahtinov mask
  – Accurate, inexpensive

• Automation (FocusMax)
  – Motorized focuser
  – Special software
  – Fast, accurate
Accurate Tracking

Accurate Tracking = Round Stars + Sharp Detail

Inaccurate Tracking = Elongated Stars + Motion Blur

M3
Polar Alignment

- Equatorial Mounts are ideal for imaging
  - Rotation on only 1 axis needed to follow an object in the sky
- RA axis must be accurately aligned with Earth’s polar axis
  - A few degrees is adequate for finding objects with go-to feature
  - A few arc minutes is essential for long exposure deep sky imaging
- Polar alignment errors cause the field seen by the camera to rotate as it is tracked
  - Long exposures that track perfectly will still suffer star elongation and motion blur
Mount Tracking Errors

“Typical” Losmandy G11

Upgraded Losmandy G11
Periodic Error Correction
Autoguiding

• Automatically correct mount tracking errors during exposure
  – Employ a second camera (sensor) focused on a relatively bright star and special software
  – Take rapid exposures of the guide star and continuously measure its position on the sensor
  – Send commands to the mount as required to maintain the guide star at the same position on the sensor

• Guide scope method
  – Guide with a second scope and camera on the same mount

• Self-guiding method
  – Guide using a second sensor or camera on the imaging telescope
Self-Guiding Example

M91
CCD Imaging Hardware

- Permanent Pier
- Losmandy G-11 with Gemini
- Celestron C9.25 with Robofocus
- Stellarvue SV90TBV with Digital FeatherTouch
- Optec Pyxis 2” Rotator
- DewBuster and Straps
- USB and USB-Serial Hubs
- MacBook Pro running Windows XP (Bootcamp)
- 12 VDC Converter
My CCD Imaging Equipment
CCD Imaging Software

- CCDNavigator - Target Selection and Session Planning
- CCDSofv5 - Camera Control
- FocusMax - Automated Focusing
- TheSky6 - Planetarium Program
- ASCOM Driver - Telescope Control
- MaxPoint - Pointing Model Refinement
- PinPoint - Plate Solves
- CCDAutoPilot - System Automation
CCD Imaging Process

• Preparation
• Set Up Equipment
• Acquire Image Data (L, R, G, B, Ha, …)
• Acquire Calibration Data (Darks, Flats & Bias)
• Pre-Process Raw Data
  – Create master flats and darks
  – Calibrate image data files
  – Clean up, normalize, align and combine each channel
  – Export one each L (.fits) and LRGB (.tiff) files
• LLRGB Processing in Photoshop
Preparation is Key

• Identify Promising Targets
  – Lots of possible sources
    • Fellow astronomers / astro-photographers
    • Publications, like S&T
    • Web sites
    • Software

• Plan the Session(s) in Detail
  – CCDNavigator + TheSky6 are my tools of choice
    • Frame the object, with guide star on internal chip
    • Optimize target / filter sequence (LRGB stair-step)
    • Tightly integrated with my automation program (CCDAutopilot)
Good Planning Gets Results

Planned

Actual Image

M63
Sunflower Galaxy
Evolution of a CCD Image

IC5067/5070
Pelican Nebula
CCD Imaging with Automation

~ 42 hours of exposure time between 8th and 20th of February 2010
# How much does it cost?

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<thead>
<tr>
<th>Item Description</th>
<th>New</th>
<th>Used</th>
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<tbody>
<tr>
<td>Losmandy G11 with Gemini</td>
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<td>Stellarvue 90mm Refractor</td>
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<td>Moonlite 2.5” Focuser w/ Motor</td>
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<td>RoboFocus System</td>
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<td>Optec Pyxis 2” Rotator</td>
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<td>5-Pos Filter Wheel &amp; Filters</td>
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<td>SBig ST-8XME Camera</td>
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<td><strong>Equipment Total</strong></td>
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How much does it really cost?

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<th>Item Description</th>
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<td>The Sky X</td>
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<td>CCDWare Product Suite</td>
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<td>Photoshop CS5</td>
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<td>Grand Total</td>
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Recommended Resources

• Local Astronomy Club
• Many Good Resources on the Web
  – http://www.skyandtelescope.com/howto/astrophotography
• Many Good Books
  – The New CCD Astronomy, R. Wodaski
  – The NewAstro Zone System for Astro Imaging, R Wodaski
Does the CCD Magic Last?

• I do for me.
• I've been CCD imaging for over six years and still enjoy it immensely.
• I plan to continue in the hobby for many more years.
• I hope others in the club will explore this part of "visual" astronomy, too.

M13
10/1/05
M33
Pinwheel Galaxy