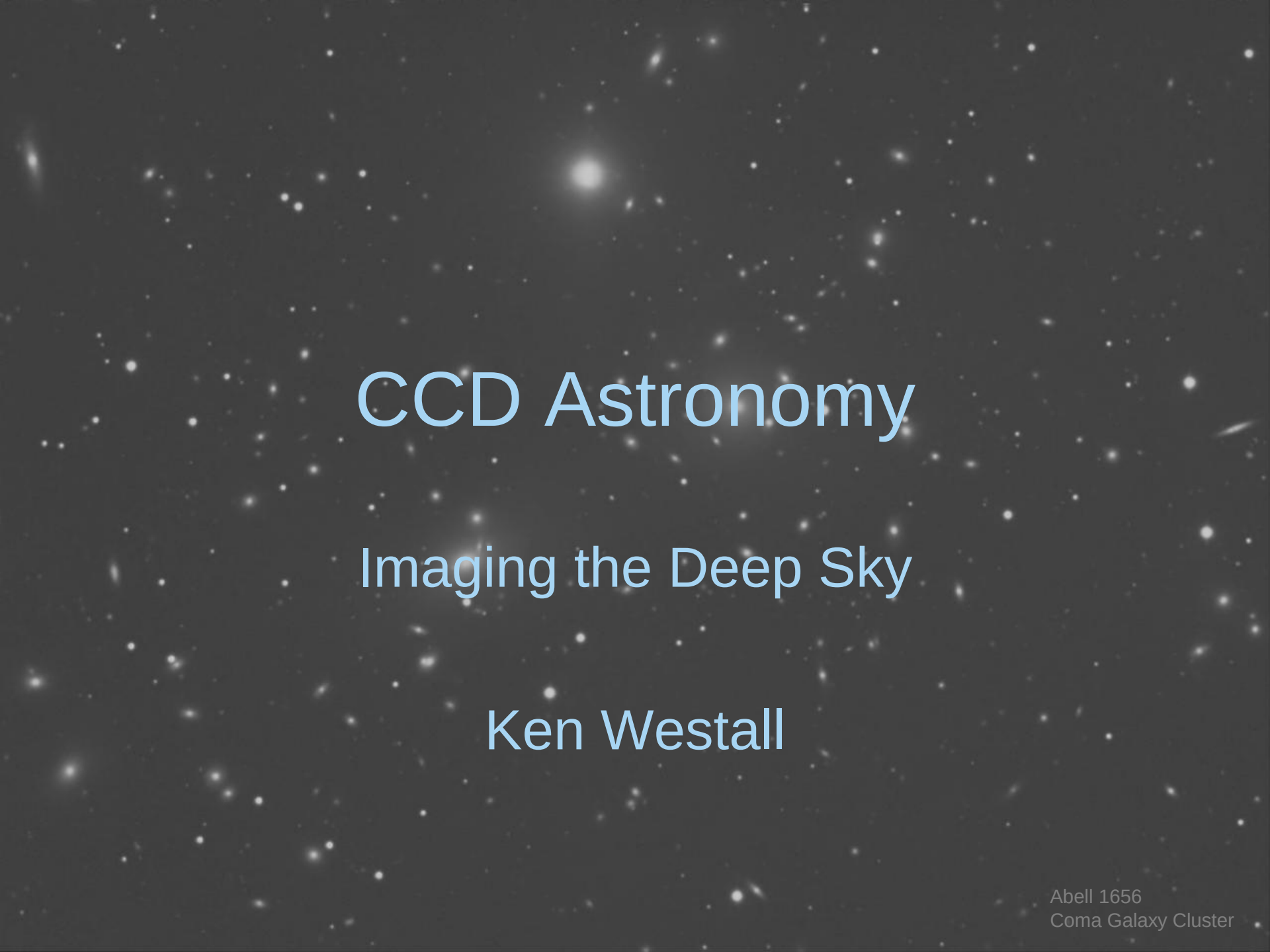
CCD Astronomy

Imaging the Deep Sky

Ken Westall

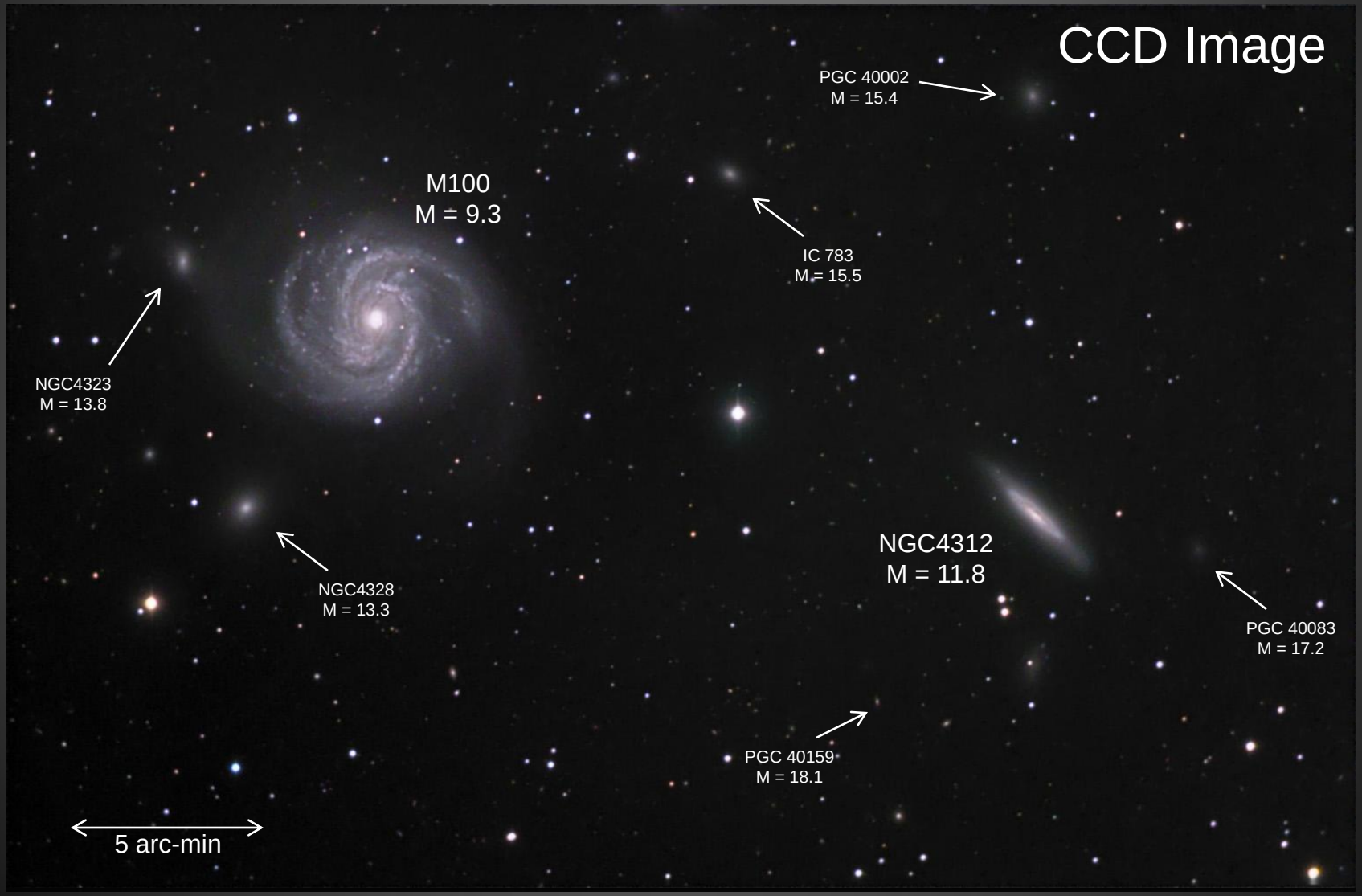


Abell 1656
Coma Galaxy Cluster

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

CCD Magic

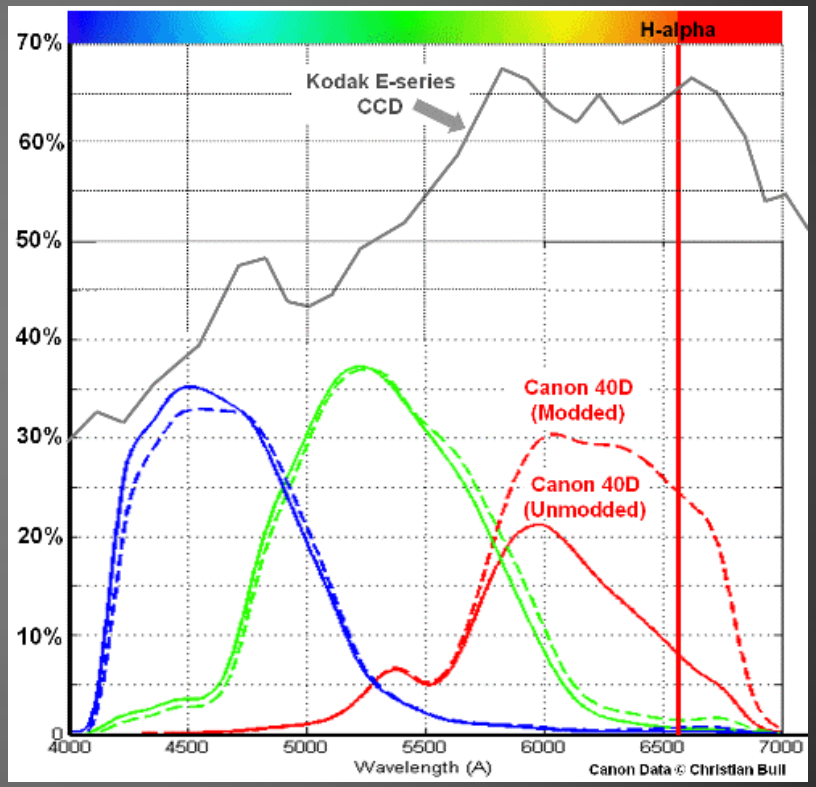

CCD Image
PGC 40002
M = 15.4
M100
M = 9.3
IC 783
M = 15.5
NGC4323
M = 13.8
NGC4328
M = 13.3
NGC4312
M = 11.8
PGC 40083
M = 17.2
PGC 40159
M = 18.1
5 arc-min

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

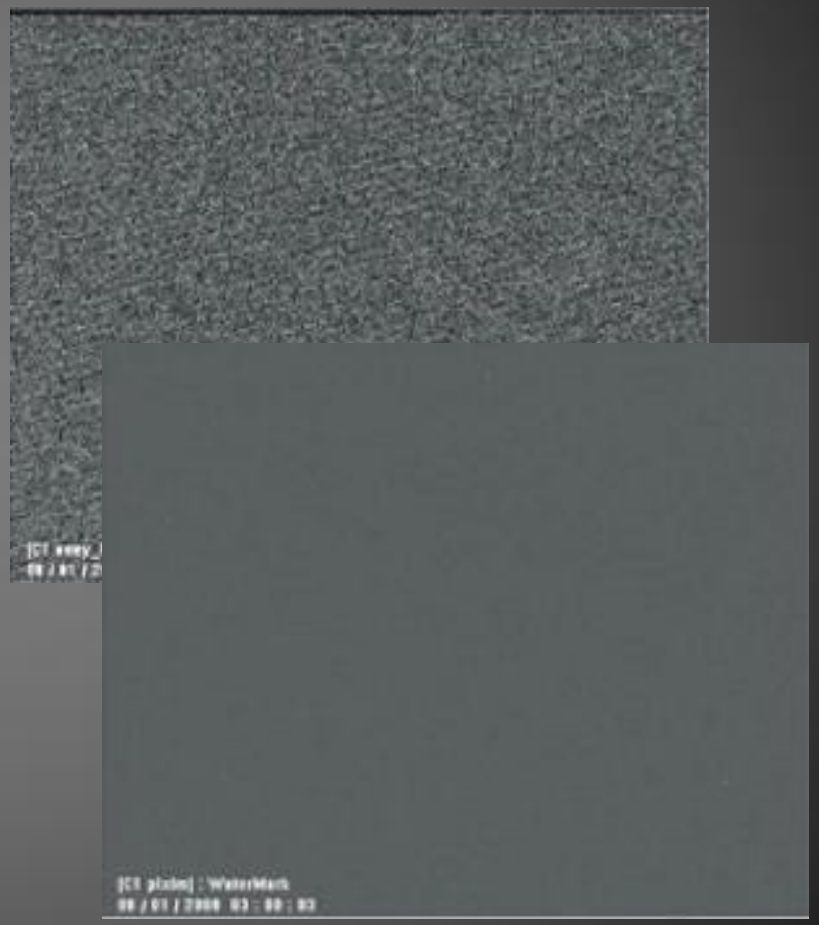
SBIG ST-8XME Camera
and 5 Position Filter Wheel



Sensitivity (QE) Comparison
CCD versus DSLR

CCD Camera = Low Noise

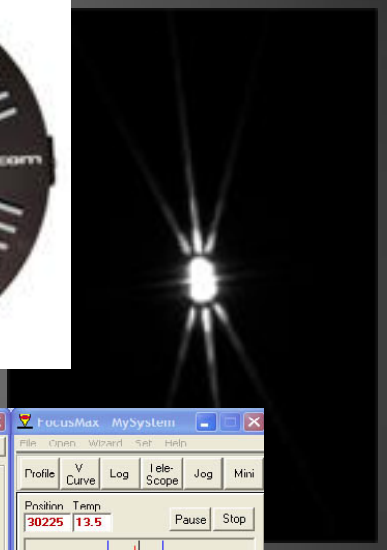
- Active Cooling
  - Fan(s)
  - Thermoelectric
  - Water Assisted
- Controlled Temperature
  - Precise Calibration
- Special Low Noise Circuit Designs

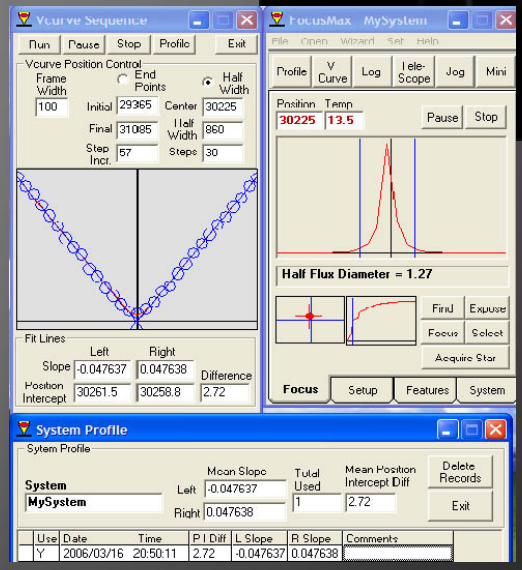


Precise Focusing

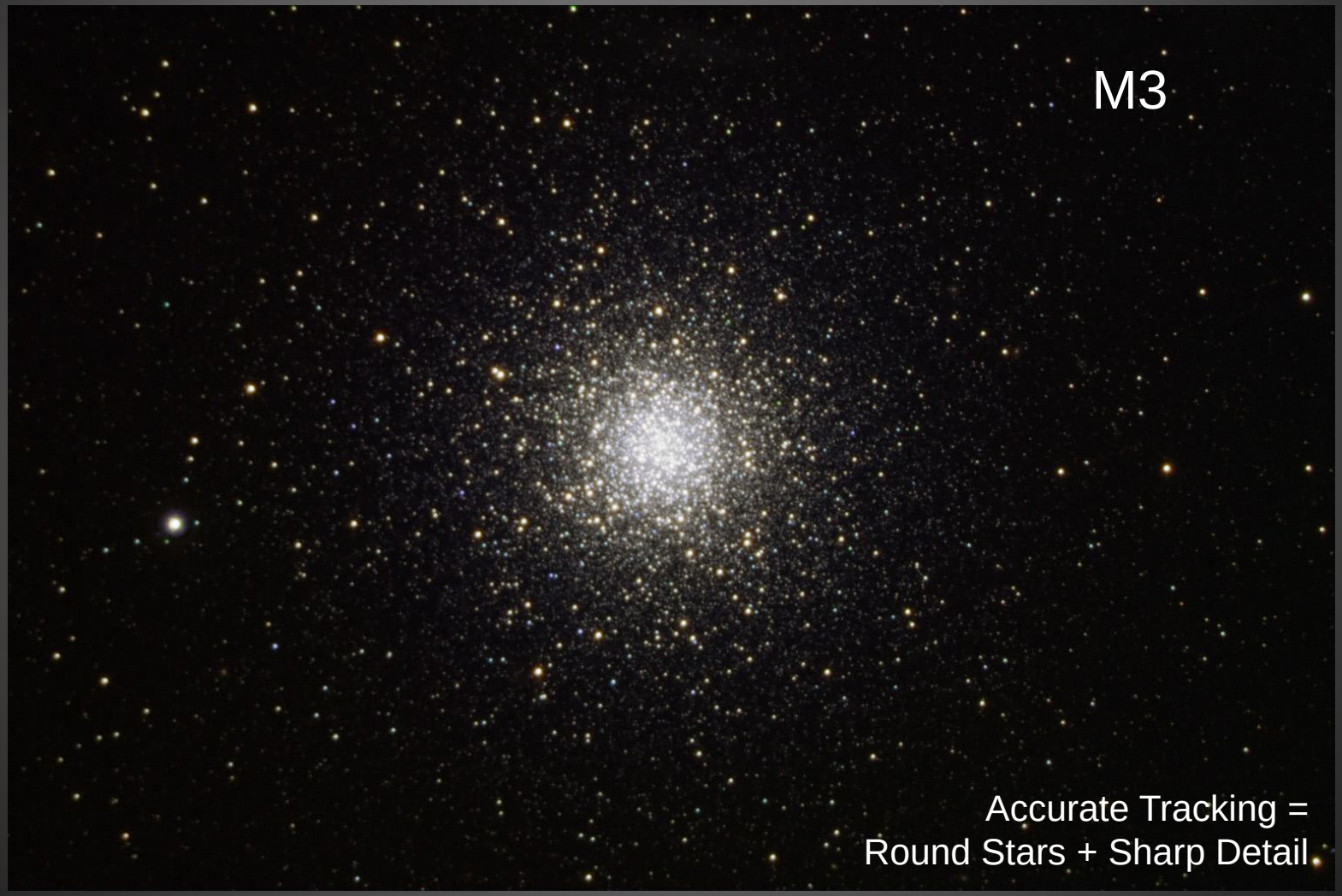
Focusing Techniques

- Camera Control SW
  - OK, but not optimal
- Diffraction Grating
  - Bahtinov mask
  - Accurate, inexpensive
- Automation (FocusMax)
  - Motorized focuser
  - Special software
  - Fast, accurate



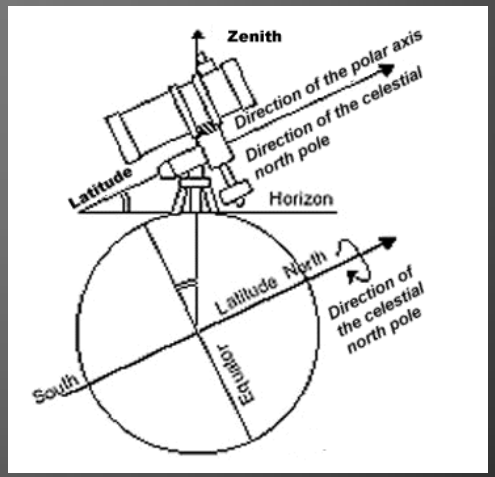


Accurate Tracking

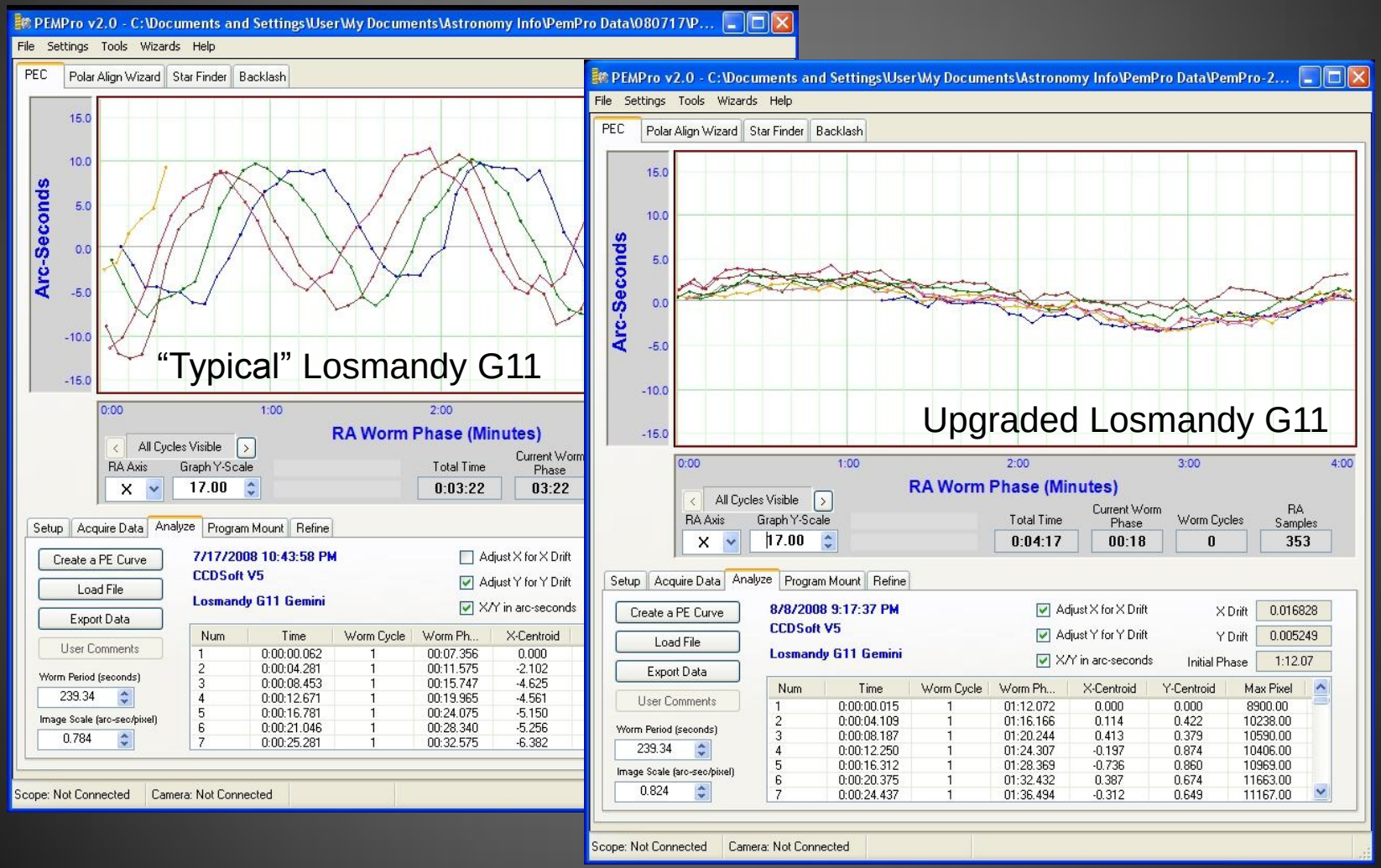


Polar Alignment

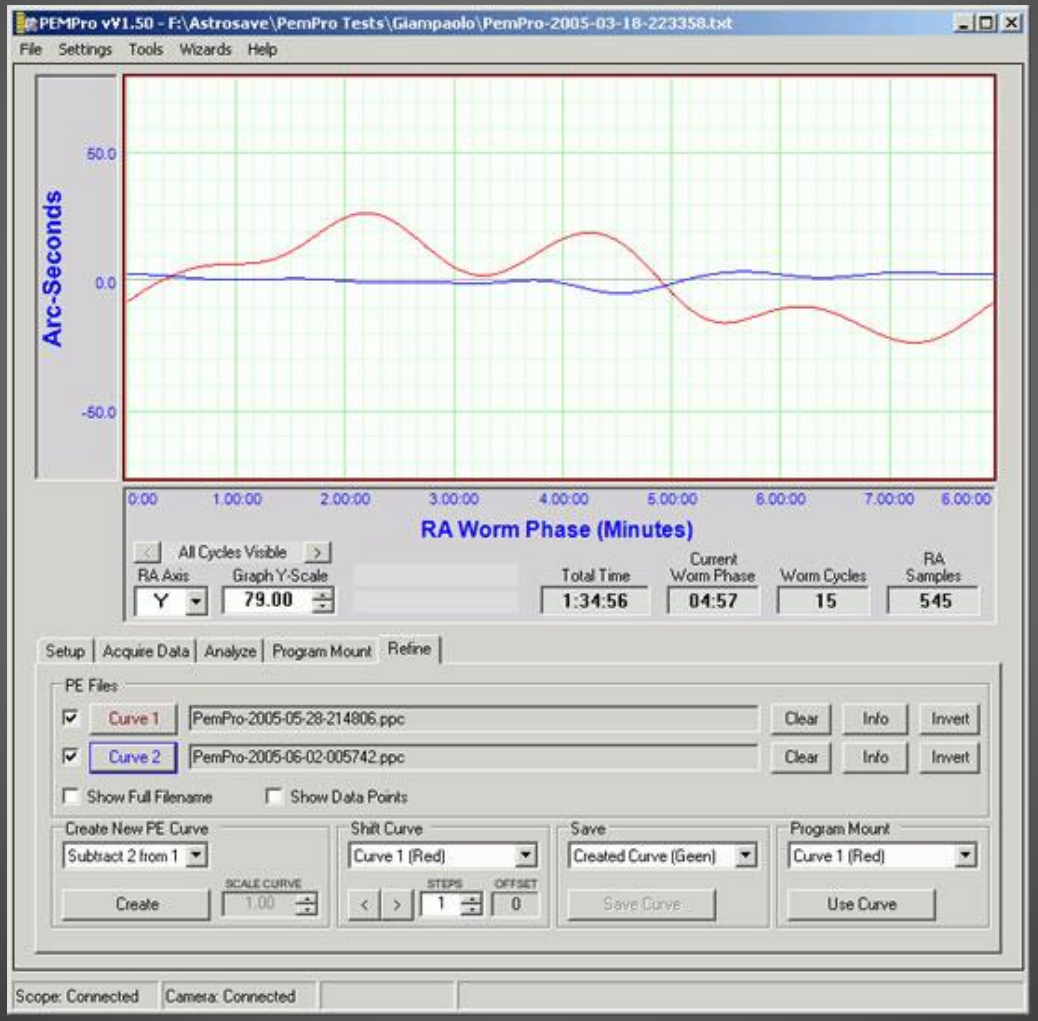
- Equatorial Mounts are ideal for imaging
  - Rotation on only 1 axis needed to follow an object in the sky
- RA axis must be accurately aligned with Earth's polar axis
  - A few degrees is adequate for finding objects with go-to feature
  - A few arc minutes is essential for long exposure deep sky imaging
- 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

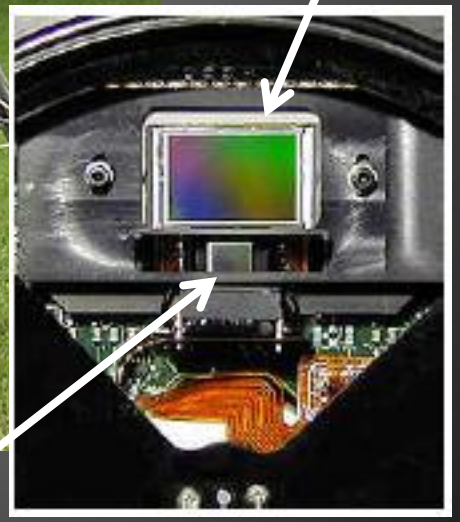


Periodic Error Correction



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



SBIG ST-8XME Camera

Self-Guiding Example

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
- CCDSoft v5 - Camera Control
- FocusMax - Automated Focusing
- TheSky6 - Planetarium Program
- ASCOM Driver - Telescope Control
- MaxPoint - Pointing Model Refinement
- PinPoint - Plate Solves
- CCDAutoPilot - System Automation

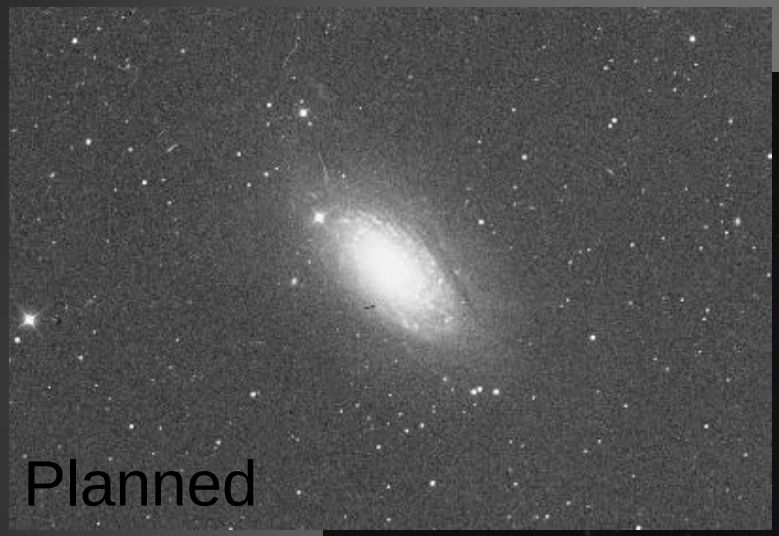
CCD Imaging Process

- 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



M63
Sunflower Galaxy

Evolution of a CCD Image

CCD Imaging with Automation

~ 42 hours of exposure time between 8th and 20th of February 2010

How much does it cost?

Item Description	New	Used
Losmandy G11 with Gemini	3500	2650
Stellarvue 90mm Refractor	1995	1395
Moonlite 2.5” Focuser w/ Motor	535	375
RoboFocus System	345	250
Optec Pyxis 2” Rotator	925	500
5-Pos Filter Wheel & Filters	885	650
SBIG ST-8XME Camera	2495	1895
Equipment Total	10680	7715

How much does it really cost?

Item Description	Cost
Equipment Total	7715 – 10680
The Sky X	349
CCDWare Product Suite	730
Photoshop CS5	610
Astronomy Tools PS Action Set	22
Neat Image PS Plug-in	80
Software Total	1791
Grand Total	9506 – 12471

Recommended Resources

- Local Astronomy Club
- Many Good Resources on the Web
  - http://www.skyandtelescope.com/howto/astrophotography
  - http://en.wikipedia.org/wiki/Digital_camera_astrophotography
- Many Good Books
  - The New CCD Astronomy, R. Wodaski
  - The NewAstro Zone System for Astro Imaging, R Wodaski

Does the CCD Magic Last?

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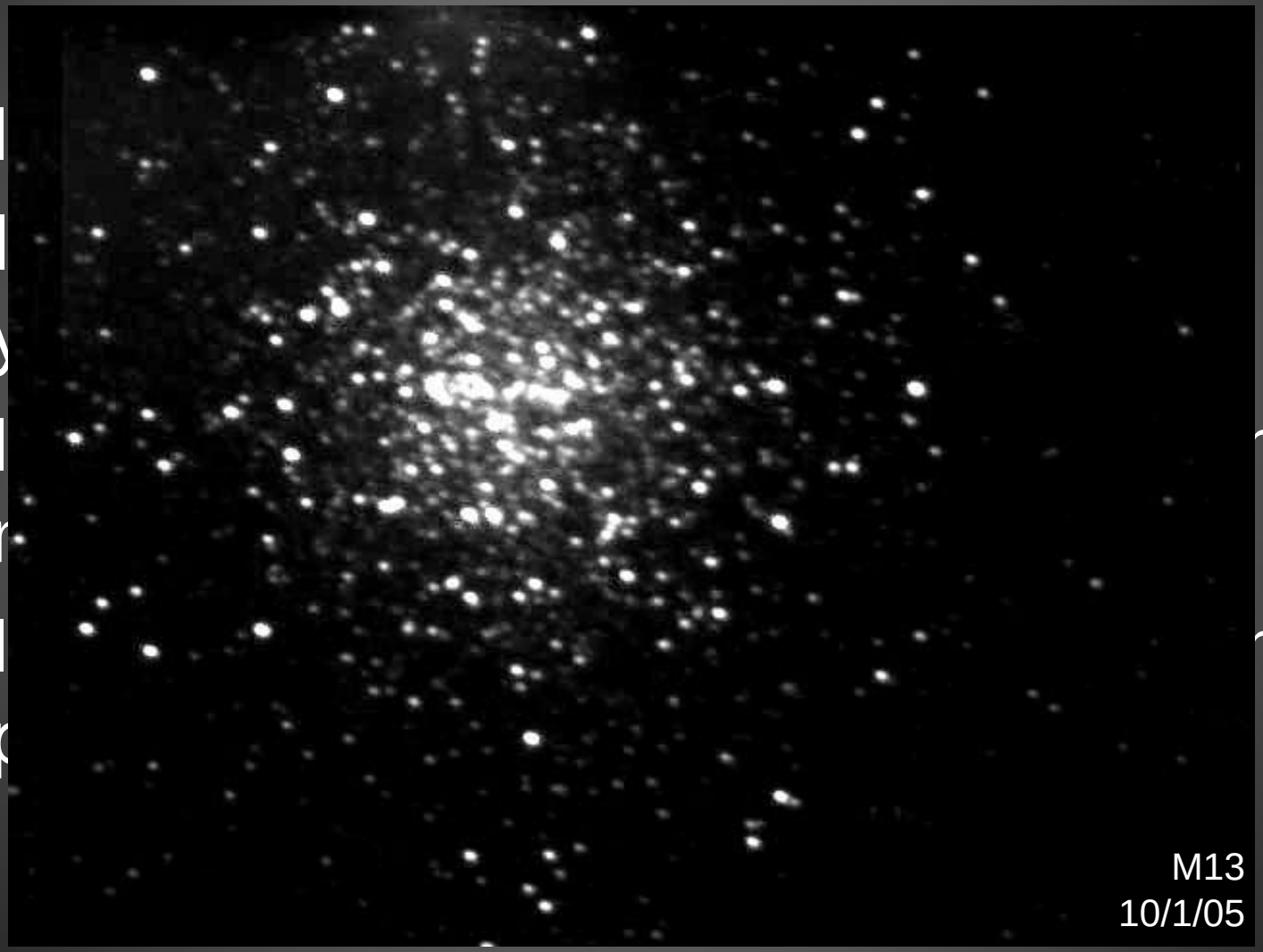


M33
Pinwheel Galaxy