Lecture 4

September 28, 2017

CCD’s and Observing
News

• Note there are a few changes in lab assignments.

• Lab 2
  – Observing is completed.
  – Lab 2 is now due October 5.

• Lab 3
  – Observing starts tomorrow evening. Show up whether cloudy or clear.
  – Lab sessions start at 7:00 and 9:00 PM.
  – Due October 12

• Rutgers Astronomical Society (RAS)
  – help with public observing nights (observing tonight!)
News

• Lab 3
  – Observing starts tomorrow evening. Show up whether cloudy or clear.
  – Lab sessions start at 7:00 and 9:00 PM.
  – Due October 12.
CCD Imaging Detectors

• Charge Coupled Device: convert photons of light to electric charges.
  – Manipulation and detection of electric charges is well advanced (electronics).
  – Signals easily digitized for analysis by computers.

• Detector of choice in the near infrared, visible, and ultraviolet regions of the electromagnetic spectrum.
  – Have good quantum efficiency (50 – 80%), excellent linearity, and large dynamic range (∼20,000)
SBIG STL1100m CCD Camera

- Contains two CCDs
  - 4008 x 2672 pixels main imager
  - 680 x 500 pixels guide imager
Focusing the CCD

• We focus the telescope on the CCD by moving the secondary mirror.
  – Controls are on the observing panel.
  – Mirror position is shown on the display above the panel (turn on with the green power button).
  • Don’t push the yellow “zero” button.
Focusing the CCD camera is done by moving the position of the secondary mirror with these controls.

The position of the secondary is shown by this readout. Turn it on with the green button. Do NOT push the yellow button.
Focusing the CCD

- We focus the telescope on the CCD by moving the secondary mirror.
  - Controls are on the observing panel.
  - Mirror position is shown on the display above the panel (turn on with the green power button).
    - Don’t push the yellow “zero” button.
  - Be careful not to use saturated images to determine the focus.
  - Best focus will be around 0.000 mm, value increases by about 0.100 mm for every 5 C decrease in temperature.
Sequence of 7 images spaced by 0.05 mm in mirror position.
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Focusing the CCD

• Use RUPhAst and its aperture photometry tool (p key or left-mouse-button) to measure the full-width at half-maximum (FWHM) of stellar images.
  – RUPhAst fits a gaussian to the profile of the star to determine the FWHM.
  – Smallest FWHM is the best focus.
    • But should also visually assess the quality of the fit to the profile.
    • Subsequent slides show a good and a bad focus that had similar derived FWHM’s.
SBIG STL1100m CCD Camera

• Contains two CCDs
  • 4008 x 2672 pixels main imager
  • 680 x 500 pixels guide imager
Same field in *The Sky*. Rotation tool (in Orientation menu)
Guide CCD field of view; When the telescope is pointing west of the meridian, the position angle of the guide CCD is 270°.
When the telescope is pointing east of the meridian, the position angle of the guide CCD is 90°.
A 10th magnitude star that would be a good guide star.
Offsetting the telescope east and south puts the guide star in the guider.
Guider Setup

Usually have the main imager selected in *Take Image* tab.
However, can select Autoguider to choose binning (1×1) and reduction (autodark subtract).
Set up guiding with the Autoguide tab. Note can guide using either the guide CCD or the main CCD.

Choose exposure for guiding.

Take an image with the selected guider.

Start guiding

Calibrate guider (this sometimes helps if the guiding is poor)
• Select the Autoguide tab and take a test exposure of a few seconds.
• Click in the displayed image to select a guide star. White box flashes and coordinates appear in the tab.
• Start guiding with Autoguide button (will hear clicks of corrections being made).

Figure 2: An autoguide image taken for reference. Note that there is one star significantly brighter than the others; this is a good choice for a guide star.
Over-correcting by the guider can cause the telescope to oscillate back and forth. These images can still be useful if use a big aperture.
Guider Problems

Really bad guiding. Waiting a few correction cycles for the guiding to settle down before starting an exposure can help. If the problem persists, try doing a guider calibration.
Rain (Photons) → Buckets (Pixels) → Vertical Conveyor Belts (CCD Columns) → Measuring Cylinder (Output Amplifier) → Horizontal Conveyor Belt (Serial Register)
Exposure finished, buckets now contain samples of rain.
Conveyor belt starts turning and transfers buckets. Rain collected on the vertical conveyor is tipped into buckets on the horizontal conveyor.
Vertical conveyor stops. Horizontal conveyor starts up and tips each bucket in turn into the measuring cylinder.
After each bucket has been measured, the measuring cylinder is emptied, ready for the next bucket load.
A new set of empty buckets is set up on the horizontal conveyor and the process is repeated.
Eventually all the buckets have been measured, the CCD has been read out.
Asteroid Eunomia
Asteroid Eunomia
Asteroid Eunomia
Asteroid Eunomia
CCD Calibration

• Bias Level: the response of the electronics when no signal is present.
  – Determined with a *bias image*: no light, exposure time \(=0\); subtracted from the science image.
  – Can vary with position, which is reason for subtracting an image.

• Dark Current: rate of thermal emission
  – Determined by a *dark image*: no light, exposure time \(\neq 0\); subtracted from science image.
  – Also can vary with position. Hot pixels have high dark current.
Bias image from our camera (dark images are similar).

Note the top-to-bottom gradient. Is actually dark current.
Zoomed bias frame from our camera.

Note the “hot” pixels with high dark current. One in the image is so “hot” that it is producing a hot column.
CCD Calibration

• Because of the strange features of the bias images in our camera, we usually just take one or more dark images with an exposure time equal to the science image.
  – Subtract the dark from the science image to remove both the bias level and the dark signal.
  – The CCDSOFT system has a mode that automatically takes a dark image after the science image and subtracts it.
CCD Calibration

• Sensitivity variation: pixel-to-pixel variation in the quantum efficiency.
  – Correct for this by taking a uniformly-illuminated “flat-field” image (the inside of dome or the twilight sky). Divide the science images by a normalized flat-field image.
  – Our camera also does not completely illuminate the corners of the CCD (vignetting). This is also corrected with the flat.
The “doughnuts” are the out-of-focus shadows of dust on the filter or CCD window. The corners are darker because of incomplete illumination (vignetting).
Contours of a flat-field image divided by maximum.

So only in the right-hand corners is the illumination less than 90% of maximum.
Horizontal and vertical cuts through a normalized flat.

Note that pixel-to-pixel sensitivity variations are less than 1.5%.