Examining images with ds9

Things you type in a terminal window are shown in **`bold Courier font`**.
ds9 drop-down instructions are shown in *italic font* with "⇒" to indicate submenuing

Step 1: Set up (For classroom linux machines)

- Open a terminal window by right clicking "Applications" at the upper left of the screen, then "Favorites", then "Terminal".
- In this terminal window, type the following to move into the CCDIntro directory and start xgterm and ds9:
  - **`cd Desktop/CCDIntro <return>`** *(note: this is case sensitive)*
  - **`xgterm & <return>`**
  - **`ds9 & <return>`**

Note: After starting ds9, you can start an ipython session by typing **`ipython`** in that terminal window. That's helpful to have going if you want to calculate something on the fly.

Step 2: Examining an individual zero image

- Open the image
  - *File ⇒ Open ⇒ pzero0419025.fits*

- Examine the image
  - Mouse wheel zooms in and out
  - Center click (mouse wheel) re-centers on mouse position, or left click and drag the box in panner frame
  - Right click/hold/drag changes the brightness and contrast

- Doing simple stats in a region
  - Left click and drag to create a region
  - Double-left-click inside the region to get a region menu
  - In that menu, do *Analysis ⇒ Statistics*
    (be careful when reading the stats info, the headers and numbers don't line up right.)
  - Note that dragging the region around *(left click/hold/drag)* will update the statistics on the fly.

Helpful Tip: if you accidently generate unwanted regions (green circles), single-left-click them to activate them, then hit delete key to delete them.

- **Estimate the noise in the image** (look at the standard deviation, stddev)
    - **In counts (ADU)**
    - **In electrons** (note: CCD gain is 2.5 electrons/ADU)
    - **If we average 25 individual zeros together, what noise level do we expect for the output image** (in electrons)?

Step 3: Compare to a nightly master zero

- Initialize a new ds9 frame, load the master zero into the new frame, and lock the two frames together:
    - *Frame ⇒ New Frame*
    - *File ⇒ Open ⇒ Zero041909.fits*
    - *Frame ⇒ Lock ⇒ Frame ⇒ Image*
- Now you can hit the tab key to toggle back and forth between the images and compare them. If you pan/zoom one, the other will be adjusted accordingly. Try it!
- **How does the noise level (stddev) in this image compare to the noise level in a single zero, measured above**?
- **How much does the average level change across the image?** (drag the region around and look at mean or median in the stats box)

Now delete your zero frames from ds9: *Frame ⇒ Delete Frame*

Step 4: Examine a flat field image:

- *Frame ⇒ New Frame*
- *File ⇒ Open ⇒ SkyFlat2009B.fits*
- **What is the difference in intensity between the upper and lower half of the image**?
- Zoom and pan around to find various artifacts: bad columns, spots on CCD, dust spot. **What is the sensitivity difference between these regions and the surrounding parts of the detector?**
- Note the edge vignetting.

Step 5: Examine a raw object frame

- *File ⇒ Open ⇒ pobj0419029.fits*
- Zoom around and look. What do you see? **Find the flat fielding artifacts**.
- **What is overall sky level (in ADU)? What is the noise level in the sky?**
- Note WCS info (RA, dec coordinates) in the information panel
- Open a new frame and load the reduced image:
    - *Frame ⇒ New Frame*
    - *File ⇒ Open ⇒ reduced.fits*
- Lock the two frames together in position and display:
    - *Frame ⇒ Lock ⇒ Frame ⇒ WCS*
    - *Frame ⇒ Lock ⇒ Scale*
    - *Frame ⇒ Lock ⇒ Colorbar*
- Manually set the intensity scaling and colormapping:
    - *Scale ⇒ Scale Parameters*
        - set Low=550, High=5000, hit Apply, then hit Close
    - *Scale ⇒ Log*
- Compare raw and reduced frames by tabbing back and forth between the images. Look at the places where the flat field correction has "fixed" things! Also look where it hasn't.
- Look at header info: *File ⇒ Header*
    - OBJECT: target name
    - DATE-OBS: date/time of exposure
    - EXPTIME: exposure time
    - WCS information, in particular pixel scale (CD1_1, CD1_2, etc) in degrees per pixel.
    - Other information varies by dataset

Step 6: Make a radial profile of a star (using IRAF)

- In the xgterm window, start IRAF and imexam by typing
  - **`cl <return>`** *(note: no "&" this time!)*
  - **`imexam <return>`** *(again, no "&")*
- A flashing cursor will pop up in the ds9 window. Zoom in on a star and hit the "r" key to generate a radial profile. Drag the lower right corner of the plot window to make it bigger, then go back to the image, find the star, and hit "r" again.
- The screen shows the radial profile of the star as measured (+ symbols) and fitted Gaussian profile (dashed line). At the bottom of the screen you will see a line of numbers. They show the following:
  - #1: aperture radius (in pixels) where star counts are summed.
  - #2: instrumental magnitude: = $-2.5\log(counts) + 25$
  - #3: total counts in the star
  - #4: sky estimate (in counts)
  - #5: peak counts in star pixels *(should be < 60,000 for an unsaturated star!)*
  - #6: ellipticity of star (0=round)
  - Last three numbers: different estimates of the full width at half max (FWHM) of the star profile, in pixels.

- **Look at different stars, look at their FWHM values. If the pixel scale of the image is 1.5 arcsec per pixel, what is the FWHM in arcsec?**
- **Look at the profile of a small galaxy, and see how much broader it is (and how bad the gaussian fit is) compared to a star.**
- Make sure your flashing imexam cursor is in the ds9 window and then hit 'q' to quit imexam.

Step 7: (Homework!) On Your Laptop:

- Download and install ds9, following Bill Janesh's instructions
- Download the reduced image at http://burro.case.edu/Academics/Astr306/CCDIntro/reduced.fits
- Start ds9. (How you do this depends on your OS and how ds9 got installed.)
- Open the image (from wherever you put it when you downloaded it).
- Play around!
- All the other files are available at http://burro.case.edu/Academics/Astr306/CCDIntro/