JWST TRAINING EXERCISES

Research and Instrument Analysis Branch

Versions:
4.0: 2014, Lajoie, Anderson, Bright
3.0: 2011, Rachel Anderson
2.0: 2009, Elizabeth Barker, Misty Cracraft, Sherie Holfeltz, Diane Karakla
1.0: 2009, Scott Friedman, Mike Regan, Massimo Robberto

This set of exercises is broken up into three sections. There are several 'thought exercises' scattered in among the questions. These are questions that are worth consideration, but do not need to be answered. If you find you are spending too much time on them, feel free to simply move on.

All pixel coordinates given below refer to IDL/Python coordinates, which are 0 indexed. To get the equivalent DS9 coordinates, which are 1 indexed, just add 1.

All data can be found in this directory: /grp/jwst/wit/miri/randers/JWST_Training/data/

1. FITTING A SLOPE TO A FITS IMAGE AND COSMIC RAY (CR) DETECTION

Problem 1.1

Write a program *makediffcube* that reads in a fits data cube with multiple frames (contains data in x, y, and z dimensions) and writes out the first-differences data cube. The output cube frame[i] will be input cube frame[i+1] – frame[i].

Use *makediffcube* on the file **hw1.fits** and find the largest CR in the cube. What are its coordinates and in what frame did it occur?

Problem 1.2

Use the IDL routine LINFIT or the Python routine numpy.polyfit to find the slopes and intercepts for each pixel in the cube **hw1.fits**. Write out the slope and intercepts to a fits data cube. What are the average and median slopes of the reference pixels? What are they for the active science pixels?

Find the population of unusual pixels in the corner regions of the array. What is strange about their slopes and intercepts? What is strange about the pixels adjacent to these pixels?

Extra credit: Could we use either set of pixels for science?

Problem 1.3

What is the slope of the pixel at location (999, 1235) in units of DN/sec? Assume each group is an average of four frames and the frame time is 10.6 seconds. Why is the slope high? What do it's adjacent pixel slopes look like? Is the y-intercept unusual?

Blink the slope image with the y-intercept image. Can you find the CRs by looking at just the slope image? Can you find the CRs by looking at just the y-intercept image? Find 5 CRs and find the average number of pixels affected by the CR. What are their locations and frame numbers?

Problem 1.4

Calculate the slopes and intercepts for all the pixels in the file **miri_small.fits**. What is the median slope in the region [30:100,1040:1080]? What is the median slope in the region [700:799,800:899]?

2. SAMPLING UP THE RAMP AND READ MODES

Problem 2.1: Single Sample

Given that **darkbias.fits** is a bias image for the detector and **read99.fits** is a cube with 25 single sample frames after a reset, subtract the bias from each frame in **read99.fits**. Note that the readXX.fits files provided here contain 25 frames taken at time XX, and you should find the median standard deviation from these 25 samples.

Calculate the slope (DN/sec) for each pixel and find their standard deviation to make a standard deviation image. Also find the median over the standard deviation image plane. This is the *median standard deviation* of the bias-subtracted image.

Problem 2.2: Correlated Double Sample

Use **read0.fits** and **read99.fits**, both cubes of 25 frames, to form a cube of 25 Correlated Double Sampled (CDS) images. Find the slope and the median standard deviation of the CDS images.

Extra credit: How can you use the reference pixels to correct for 1/f drift during the CDS exposure?

Problem 2.3: Fowler-2

Use **read0.fits**, **read1.fits**, **read98.fits**, and **read99.fits** to form 25 Fowler-2 images and calculate the median standard deviation of the slopes.

Problem 2.4: Up-the-Ramp

Each file named **dark_37K_100_min_2_XX.fits** is of a single integration, 100 frames up-the-ramp exposure. Find the slope for each pixel in each exposure and save it to a slope image. From these slope images, calculate the median standard deviation.

Problem 2.5

Plot the all the results of Problems 2.1–2.4 with the y-axis showing the standard deviation and the x-axis the various methods of determining the standard deviation. Note that the time to read one frame is stored in the fits header variable FRMTIME. Use this to convert everything to the same units (DN/sec).

3. REFERENCE OUTPUT AND REFERENCE PIXEL CORRECTIONS

All questions pertain to the file **MIRI_VM1_0584.fits**.

We will be computing some statistics on the image. Because this detector has regions that are somewhat noisy, all statistics will be done in this 100x100 clean subarray region:

X coordinates from 200 to 299
Y coordinates from 700 to 799

In the problems below, do all the reference output and reference pixel manipulations on the entire array, and then compute the requested statistics on the sub-array region only.

The gain of this detector system is 6 electrons/DU. However, it will lead to less confusion if we calculate everything in DU rather than in electrons.

Problem 3.1

Subtract the appropriate reference output from each image pixel. Recall that 4 consecutive image pixels correspond to the same reference output. Note also that the reference pixels on the left and right sides of the arrays have reference outputs.

You now have a reference output corrected image.

For each pixel in the subarray region, ignore the first 20 frames (to avoid the reset transient) and ignore the last frame (to avoid the final frame effect). For the remaining 279 reads up the ramp, perform a linear least squares fit to find the slope. What are the median value and standard deviation of these 10,000 slope values?

Hint: use the POLY_FIT routine in IDL, or the numpy.lstsq function in Python.

Problem 3.2

Now we will make a correction using the reference pixels. Treat each row, each amplifier, and each frame separately. Start with the reference output corrected image from Prob. 3.1.

In each row, the reference pixels for amplifier 1 are pixels 0 and 1028; the reference pixels for amplifier 2 are pixels 1 and 1029, etc. Consider amp 1: fit a straight line to the left and right reference pixel values. For each amp 1 image pixel in the row (that is, pixels 4, 8, 12,...) subtract the value of the reference pixel fitted line corresponding to that image pixel location from the image pixel. Do the same for amps 2, 3, and 4, and repeat for all 1024 rows.

Once again, drop the first 20 frames and the last frame in each ramp for pixels in the subarray region. Fit a straight line to the remaining ramp values. What are the median and standard deviation of the slopes?

One of the disadvantages of this method of treating reference pixels is that by fitting a line to a single reference pixel on the left and a single reference pixel on the right, we imprint the noise of these single reads on every pixel in the row. We will attempt to address this in Problem 3.3.

Problem 3.3

The reference pixels are not well behaved in this data set. Using the reference output corrected image, plot out the 8 reference pixel columns in the 21^{st} frame (to avoid the reset transient). It's crowded, so zoom in on our sub-array rows (700 to 799). Notice the strong even-odd row effect? To remove this and attempt to reduce the noise associated with subtracting reference pixels, try the following:

Again, treat each frame separately. We could treat each amp separately, but for simplicity in this exercise we will not.

Find the median of all the reference pixels in the even rows, regardless of which amp they correspond to. Also find the median of all the reference pixels in the odd rows. Now subtract the even median from all even row pixels, and subtract the odd median from all the odd row pixels.

In the 21^{st} frame (that is, the first after discarding 20 frames of reset transients), what are the values of the even row and odd row median reference pixels?

Once again, in the subarray region, drop the first 20 frames and the last frame in each ramp. Fit a straight line to the remaining ramp values. What are the median and standard deviation of the slopes?

Problem 3.4

Plot the all the results of Problems 3.1–3.3 with the y-axis showing the standard deviation (in DN/s) and the x-axis the various methods of reference output/pixel correction. In the plot, also include the standard deviation of the slopes when no correction is used. How do the methods compare?

4. PERSISTENCE

Install the MIRI DHAS from here (ask for password): http://tiamat.as.arizona.edu/dhas/

All questions pertain to the file **MIRI_FM1_12034_2.fits**.

Problem 4.1

Look at the header of the file. How many integrations are there? How many frames are there per integration? Plot the median frames up the ramp for the exposure. What is going on here? You might have to zoom in on different sections of the exposure to see.

Problem 4.2

For the last 25 integrations only, calculate the median slope for each integration. Since we do not have enough frames to ignore the reset anomaly, use the MIRI DHAS for this step using miri_sloper with options set for cosmic ray detection, reference pixel correction, and last frame rejection. Plot the median slope vs. time since illumination. What trend do you notice?

Problem 4.3

File **MIRI_FM1_13520.fits** is a dark exposure that was taken after several hours of darks. Follow the same procedure to calculate a median slope for each integration and add it to your plot from Problem 4.2 to compare to the data from **MIRI_FM1_12034_2.fits**.

RECOMMENDED READING:

- JWST Primer (http://www.stsci.edu/jwst/doc-archive/handbooks)
- Infrared Detector Arrays for Astronomy, Rieke, G.H., 2007, Annual Review of Astronomy and Astrophysics, Vo. 45
- Handbook of IR Astronomy, Glass, I.S., 1999, Cambridge University Press
- Optimum Integration Times for Different Read Modes, Regan, M., Stockman, P., 2001,

JWST-STScI-000323 [SOCCER document]

- Characterization of Persistence on the MIRI Imager: I. Progress Report, Lajoie, C.-P., 2014, JWST-STScI-003622 [SOCCER document]