Notes
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Topic: Video Tutorial Part 3

Create combined science image without cosmic rays.

N	Points, Ideas, Thoughts	Research Notes
1	What are we doing today? • **Main point: Combine three science images into one, to get rid of cosmic ray hits.** • "frills" points: ☑ ~~Continue to use the Terminal environment~~ ☑ ~~Writing light scripts~~ ☑ ~~Introduction to IRAF environment~~ ☑ ~~Note on the clunky environment parts (non intuitive to modern computer users), quickly can be learned~~ Note: ☑ ~~There are many solutions to a problem.~~ ☑ ~~For example, to use python or iraf~~ ☑ ~~For example, checking the header - QFitsView (Search convenient), astropy tools, iraf tools, etc.~~ ☑ ~~Remember. Python - starts counting from 0, FITS counts starting from 1! Also, FITS vs Python have rows/columns- make sure they are the same~~	• We are working on "Quasar 103" (qso103) •
2	2D image pixel grid pixel | pixel | … | pixel | … | … | … | ☑ ~~Each pixel has a location described by two coordinates (row and column)~~ ☑ ~~Each pixel in an image has a value associated with it (how bright it is - flux indicator)~~ ☑ ~~Question. What are the dimensions of ALFOSC image? i.e., how many pixels on each axis? -check the HEADER~~ ☑ ~~**2148x2102** (in white, highlight to see :D)~~	
3	Review of the past steps. **The aim of this project is to reduce and analyze spectroscopy data from the NOT telescope.** It is an open science tutorial where I hope to demystify science project work to the general public (Tutorial 1).	

	What did we do last time? • We downloaded the data from the NOT archive. (Tutorial 1) • We focused on the observations from one night and sifted through the files of that night. (Tutorial 2)	
4	What am I trying to do now? Thank you God. Prayer for wisdom, encouragement, blessing, good fruit. In the name of Jesus. Amen. ☑ ~~Review the "Summary" of the procedure log.~~ ☑ ~~Highlight which step we are working on today~~ ☑ ~~Getting flavor of working in IRAF~~ ☑ ~~! check after each step to make sure that the reduction steps are working as expected,~~ ☑ ~~open before and after in DS9 to compare~~ ☑ ~~Write a summary of what we did after each step, if needed~~ ☑ ~~Record each decision~~ Information on procedures and working flow It is good to learn from other people. • Example of my mentor at NASA who explained ins and outs well, while one of my PhD supervisors was extremely hands off -> where to get information? ☑ ~~Websites, other people, peers, online tutorials, documentation, manuals, textbooks, technical guidebooks, other papers/publications~~ ■ **If you see a paper that has similar methodology, email the corresponding author with your question.** • Also, learning about other people's work process might give you ideas to improve your work flow. ☑ ~~Example, in a coding meetup, I learned in Helsinki from a Chemistry professor an organizational tip for functions -> put all functions into a single file and call the function from there. Many functions repeat, especially within the same project's coding.~~ ☑ ~~From my husband, Jamesstone.com, I learned the concept of iterations,I name my files i01, i02, i03, etc….~~	☑ ~~Describe the science exposures~~ For Quasar 103, 4 exposures were obtained, but only 3 had 1800s exposure time. The last exposure was very short and will not be used at this point.
5	What were the changes that I made off-line? ☑ ~~I just studied and wrote out the tutorial steps to do, but we are going to do them together.~~ ☑ ~~I reformatted and clarified some of the Procedure log for ALFOSC spectroscopy.~~ ☑ ~~Created a directory for code~~	
6	Check that I am using homogeneous data ☑ ~~Same grism~~ ☑ ~~Same size of data~~ ☑ ~~One night~~ ☑ ~~Same slit (some quasars have >1 observations, with different position angle, PA)~~ ☑ ~~Same readout time~~	**Working directory** /Volumes/Gyumri_HD/Documents/1_Research/5_Dusty_quasars/4_data_working/qso_103 • # record from the HEADER • **RDNOISE = 4.3 e-** • **GAIN = 0.16 e-/ADU**

- [x] ~~ANSWER the Question: Why are there two standard star exposures? What happened? Go through my night records of that observing night. -> Different slit width!~~
- [x] ~~# record from the HEADER~~
  - [x] ~~RDNOISE = 4.3 e-~~
  - [x] ~~GAIN = 0.16 e-/ADU~~
  - [x] ~~BIASSEC = [3:52, 1:2102]~~

Create a copy of the files but only with the needed extension

- [x] ~~IRAF setup/launching -> follow the steps in the Procedure log~~
- [x] ~~FITS files and their extensions.~~

FITS files can have multiple extensions. Like a drawer with several compartments.
In this case, there are two extensions. Which one do we need? **We need the one labeled with index [1].**

- [x] ~~In Terminal, create a list of files~~

TERMINAL$ ls *.fits > 1_listofnightfiles.list

- [x] ~~In Sublime, modify the list to create the IRAF commands~~

edit the "**1_listofnightfiles.list**" file in Sublime
#change each line "ALGi150061.fits" to "imcopy ALGi150061[1] ALGi150061.ex1"
#new file name for the modified list is "2_tomake_list_with_1st_extensions_only.cl"

- [x] ~~In IRAF~~

#execute the "2_tomake_list_with_1st_extensions_only.cl" in iraf to keep the image from only the single needed extension of the FITS file.

cl> cat 2_tomake_list_with_1st_extensions_only.cl | cl

- [x] ~~Check the results -> how many extensions are there in one random case?~~
- [x] ~~Update research notes~~

Step. COMBINE individual science frames into one

- [x] ~~We will get rid of the cosmic rays~~
- [x] ~~in IRAF,~~

ccdred> imcombine ALGi150061.ex1,ALGi150062.ex1,ALGi150063.ex1 qso103 combine=median reject=crreject rdnoise=4.3 gain=0.16

Jan 3 20:58: IMCOMBINE
combine = median, scale = none, zero = none, weight = none
reject = crreject, mclip = yes, nkeep = 1
rdnoise = 4.3, gain = 0.16, snoise = 0., hsigma = 3.
blank = 0.
Images
ALGi150061.ex1
ALGi150062.ex1
ALGi150063.ex1

- **BIASSEC = [3:52, 1:2102]**
-

	Output image = qso103, ncombine = 3 # **the output image qso103.fits** is the combined image - [x] ~~Check the results-> inspect the output image. Is it free of cosmic ray hits? Compare to an individual exposure frame.~~ - [x] ~~Question. Where do cosmic rays come from?~~	
7	Update the paper - [x] ~~Make a note about the reduction, that it is with IRAF~~	

8	Evaluation and Close-up steps
	- [x] ~~Update the Procedures log~~
	  - [x] ~~Highlight in green what I have done~~
	  - [x] ~~in orange what needs to be done~~
	  - [x] ~~make in bigger fontsize the NEXT STEP~~
	- [x] ~~Research Notes~~
	- [x] ~~Acknowledgements~~
	- [x] ~~What is the next step? TODO NEXT.~~
	- [x] ~~How do we feel?Good, accomplished.~~
	- [x] ~~Cleanup~~
	  - [x] ~~close windows~~
	  - [x] ~~save~~	

9	TODOs for the tutorial
	- [x] ~~Add tools / skills used and links to resources:~~
	  - [x] ~~iraf~~
	  - [x] ~~I already have IRAF, but you might need to install it. Need to post the IRAF documentation. Semi-obsolete tool.~~
	  - [x] ~~# the Trim Section values are taken from the following website, http://www.not.iac.es/instruments/alfosc/calibration/flat.html~~
	  - [x] ~~QFitsView~~
	  - [x] ~~DS9~~
	  - [x] ~~python, astropy~~
	  - [x] ~~FITS header, FITS files, FITS extensions~~
	  - [ ] image files (pixel grid and brightness values)
	  - [x] ~~maybe some online tutorials~~
	  - [x] ~~Instrument web pages (ALFOSC), https://www.not.iac.es/instruments/alfosc/~~
	  - [x] ~~Readout times are explained for ALFOSC here, http://www.not.iac.es/instruments/alfosc/readout.html~~
	  - [x] ~~TODO: post resources for FITS header / astropy, FITS files~~
	  - [x] ~~TODO: post either resources for bash scripts or make my own tutorial on that~~
	  - [x] ~~IRAF documentation -- post~~	

	☐ maybe use some snapshots into the Text part of the tutorial? ☐ Create a section on my website, of “HOW To” procedures 😀	
10	Inspirational and encouraging quotes # You can do it! # A long journey starts with a single step.	