PHY517 / AST443: Observational Techniques

Tutorial 4: Astronomy Software

Wiki pages: *Computing Resources, bash, dfits and fitsort, Astrometry.net, ds9*

1. Ssh into uhura or vulcan, with window forwarding.

2. In the directory
   `/astrolab/anja/tutorial4`
   you will find:

   - 3 "science" images of the field around the star HD189733, `science_1.fits, science_2.fits, science_3.fits` - one for each group member
   - several flat-fields, named `flats.*.FIT` - these are "auto-dark-corrected", i.e. at the time of acquisition, the camera software took and subtracted a dark frame of the same exposure time
   - several dark frames, named `darks.*.DARK.FIT`

   Copy "your" science image to your data directory (`/astrolab/Spring_21/`*username*), as well as all the darks and flats.

3. View the header of your science image. What is the exposure time? Use dfits and fitsort (see wiki page) to output the exposure times of all of the dark frames. Which dark frames need to be used for the calibration of the science data? **Homework:** Submit the answers to these questions.

4. Make a median image of the dark frames (i.e. the masterdark) that are appropriate for you science image. Subtract the masterdark from the science image. You can do this in `python` OR `pyraf`:

Optional / Bonus: pyraf

Wiki page: *pyraf*

pyraf is an adaption of the IRAF astronomy package, which used to be standard for working with astronomical images. It is still used today, although its strength compared to `python` is mainly in spectroscopy. As such, you do not need to learn it, and you are welcome to complete these tasks in python instead.

(a) Follow the pyraf wiki page to set up your pyraf/iraf environment.

(b) Use the `imcombine` command to make a median image of the dark frames (i.e. the masterdark) needed to calibrate the science image (see above). Subtract the masterdark from the science image.

(c) **Bonus:** Submit the pyraf (and bash) commands that you used to combine the images, and to subtract the masterdark.

5. Make an average image of the flatfields, i.e. your masterflat. Divide your science image by it. You can do this in `python` OR `ftools`:

Optional / Bonus: ftools

Wiki page: *Image arithmetic*

Sometimes you just want to quickly manipulate an image with a simple command line arguments. *ftools* is one option to do this. It is part of the HEASARC package, which is widely used in X-ray astronomy.

(a) For each of the flat-fields, determine the mean. Hint: the quickest way to do so is to run a bash loop over all files, run `ftstat` on each file, and search for lines containing "mean":
```
for file in $(ls flats.????????.FIT); do ftstat $file | grep mean ; done
```

(b) Verify that the flat fields have similar count-levels, ideally at $\sim 30\%$ of the saturation threshold. Use `ftpixcalc` (see the ftools wiki page) to take the average of these frames - this is your masterflat.

(c) Submit a screenshot of your masterflat (make sure the ds9 colorbar is visible, and is set to zscale), along with the commands that you used to make it.

6. Open your science image in ds9. Adjust the scale so that you can see the content of the image (check the ds9 wiki page for help on this). Note that the image does not contain World Coordinate System (WCS) information, i.e. we do not know the right ascension and declination of the objects in the image.

7. Determine the astrometric solution of your science image, i.e. its position on the sky, using astrometry.net - see the wiki page for instructions. To significantly speed up this process, look up the coordinates of HD189733 and pass them as a starting guess. Check the output of the program - which file will you want to use in the subsequent analysis? Open it in ds9 to see that for every pixel, the position in right ascension (α) and declination (δ) is also reported.[1]

[1] astrometry.net seems to have a bug that causes a bit shift in the count values of the output image. To fix this, add 32768 to the output image, e.g. by using pyraf or ftools.