ASTR469: Final Project, Astro Photography

Due 3 May by 5pm over email, in my box, or under my office door.

I will not give extensions on this deadline. Please plan your time wisely!

Including today, we will have four in-class sessions to work on this assignment. You and your observing partner(s) will take observations yourselves (assuming we can get the observatory computer working!).

Concepts practiced: Coordinates; Time and Planning observations; Optical CCD photography; Unix; Python; LaTeX.

Description:

Finally you are nearly a real astronomer! You will be making your own real astronomical images, using the CCD on the rooftop telescope. You may work in groups to plan observations. You may only use the telescope in pairs or threes; as such, you should collect the images with a partner or two (and work together on calibration, if desired) but do the remainder of this project alone. **SAGE ADVICE: Plan to do your observations very soon, not close to when the project is due! We cannot plan the weather, and there may be some cloudy nights in the future. You can develop your calibration code regardless of whether you have data.** You have at your disposal: a whole sky full of objects, a CCD that can take exposures of a variety of integration times, and the ability to observe objects many times throughout a night or over the course of a few days. Have fun with it!

Project tasks:

In this project you will have to do the following things. The rough grade breakdown for each part is below.

1. **Pick an object** (some suggestions below). Note that you should be sure your object rises to at least an altitude of at least 40° so that you can see it from the rooftop observatory.
2. **Determine when your object is observable (tip: calculate by hand, or write a script to calculate, or use online tools to help you here).**
3. **Observe your object.** You will need to take several calibrator images in addition to your actual target observation, as described on page 3 of this document. Rooftop telescope safety and operation procedures will be handed out in class and posted here.
4. **Calibrate your images** (see procedure below).
5. **Do some science!**
6. **Write up your project.** I'd like to give you precise guidance on what's expected from this final write-up. Please include the following components/calculations, which make up the final grade as noted. Excluding figures and tables, 4–6 pages of text would probably be appropriate for this project.
    (a) (up to 10% off if not included) An abstract that states the problem and the hypothesis

(b) (10%) An introduction that describes your target and some relevant information about it.

(c) (10%) The goal of your observation (the hypothesis; can be included in the introduction).

(d) (25%) An "observations" section that includes:

- The instrument you used (what telescope design, size of primary mirror, what data collection device).
- The local time/date of your observations, the LST of your observations, and the hour angle of the source when you observed it.
- A representative value for the telescope's altitude, azimuth, and the airmass at the time of your observations. Include relevant equations.
- On the day that you took the observation, about what LST range would have been the best time to observe your object and why? (If your observation was at a different time, why did you decide to observe at the time you did?)
- A section describing your "data reduction" (calibration). Include relevant details about the length of your observations.
- (15%) A brief discussion of calibration steps you took, and a presentation of the final image. This can be in the "Data" section but I wanted to highlight its importance. Discuss any residual issues you see in the image.

(e) (15%) A scientific discussion and/or a measurement of what you observed, including references (to non-wikipedia sources). Relate your discussion here specifically to what you observed.

(f) (10%) Summary/conclusions.

(g) (10%) Not a separate section, but be sure to present all figures with labelled axes and detailed captions noting what is shown in the image. Mention each figure individually in the text, and put them in the relevant sections (e.g., no "Figures" section.).

(h) (5%) Grammar and general usage of formal (non-colloquial) English, and generally good narrative flow throughout the document.

Below is relevant info on targets and processing.

TARGETS:

Here are objects that may be interesting, and may be observable this time of year. For other targets, note that depending on exposure time and staacking you might be able to see objects brighter than magnitudes of a few (∼3), I believe:

Name	**Type**	**RA**	**Dec.**
M42 (Orion Nebula)	HII region	05h 35m 17.3s	–05° 23′ 28″
M13	Globular Cluster	16h 41m 41.24s	+36° 27′ 35.″
The Pleides (M45)	Open Cluster	03h 47m 24s	+24° 7′ 0″
The Hyades	Open Cluster	04h 27m	+15° 52′
Andromeda (M31)	Galaxy	00h 42m 44s	+41° 16′ 9″
Dumbbell Nebula (M27)	Planetary Nebula	19h 59m 36s	+22° 43′ 16″
Jupiter & its moons	Solar system body	Varies	Varies
	Currently	01h 29m 03s	+08° 11' 08"

CALIBRATIONS:

To create good astronomical images, we need to do a few calibration operations. These operations are meant to remove instrumental effects.

There are three calibration images you need to take for one night's work:

1. A "bias" frame. This is as short an exposure as possible (0.12s with current CCD/software), made so that no light reaches the camera's sensor (the lens cap is on the telescope). Since the exposure time is close to zero, the bias is a direct measurement of the read noise. Bias frames must be subtracted off all other frames (including other calibration frames), since they will all have the same read noise.

2. A "flat field" or "flat". A flat is a uniformly illuminated image of blank sky during daytime (always done at twilight or dawn) or the inside of the telescope dome (can of course be done at night). The goal is to see the camera and telescope response across the field. Some parts of the image will be lighter, and some will be darker due to imperfections in the optics and camera. A real image of the sky will also have the same light and dark areas, so this can calibrate for the CCD response.

   A good exposure time is one that allows you to see such variations, but does not saturate the detector.

3. A "dark frame" or "dark." A dark is an image of the same length (in time) as the astronomical observations, but again with the telescope capped. The goal is to determine the response of the optical system, with the same conditions as the observations (minus the actual data). A typical dark will show some bright pixels, but these are not real in the sense that the signal is not from space, but due to the electronics.

   Since you may not know the exposure time for your science target a priori, it is wise to take the dark frame after you are happy with the science observation.

Finally, of course, you should take a "light frame," which is of your actual science target.

Once these images are taken, we calibrate the light frame by combining the observations:
`calibrated_image = ((light - bias) - (dark - bias)) / (flat - bias)`

In python, you will just subtract the arrays from one another. Your input images will either be .txt files or .fits files. Note: Python sometimes prefers "lists" to arrays. To convert to an array, use `arr = np.asarray(list)`. Notice how the bias (the read noise) must be subtracted from all frames. The dark is a linear offset. This subtraction of the dark gives an image corrected for artifacts introduced by the camera. The image is divided by the flat, and this corrects for differential exposures across the field.

To create even more sensitive images, you can average together a series of calibrated images (this is referred to as "stacking"). This involves registering the images so they are all pointing at the same location. This can be a complicated step, but averaging multiple frames can result in significantly better results.