Project 1

Spectral Analysis of Optical Data

Due date: February 13th

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Office Hours: Scheduled on Request with min 18 hrs notice

Submission Format: All code, and accompanying text submitted in *.pdf, .py, .ipynb.* All questions should be answered and code should be well commented along with a brief qualitative description of any outcome. Figures should have proper axis labels and all files should clearly indicate which problems they are associated with as a comment on the top of the file and in the file name.

In this assignment we will be performing a basic spectral analysis and hoping to identify some properties of the chemical composition of an astronomical source. We will be using real archival data from the Observatoire du Mont-Mégantic in Quebec obtained with the *spectro* instrument.

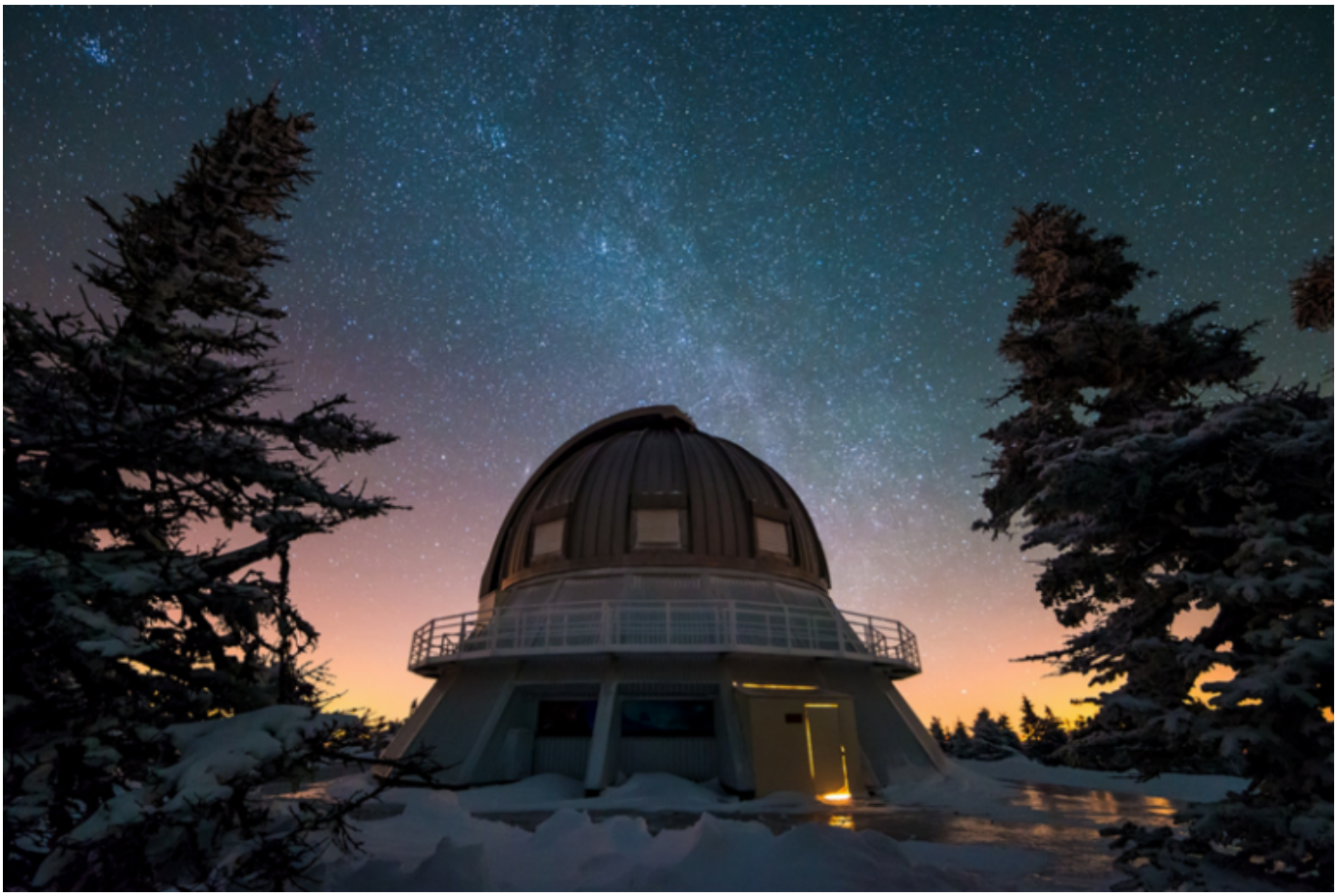

Figure 1: Photograph of OMM (Credit: R. Boucher)

For this assignment you are expected to write the bulk of your code in *python*. You should feel free to use *low-level* packages to perform routines, but not *high-level* software. *High-level* software in this case would be something like *rspec* or *pyraf,* software that is written specifically to tackle the problem of analysing spectra and does not require the user to have a high level of understanding of the underlying steps. *Low-level* packages include things like *numpy, scipy,* and *astropy* these simplify basic operations but do not substitute an understanding of the problem. If you solve the entire question with a single function, you may be using too *high level* a package. If you are worried about a certain routine or package you can always send an email to confirm.

If you have no familiarity working with FITS you should start here: https://docs.astropy.org/en/latest/io/fits/index.html.The only coding ability you will need is basic operations on arrays, the ability to open and extract information from the FITs file format, the ability to fit a function, and the basic numerical operations (like determining maximum of a set of values).

Exploration

1. Import the .fits file into *python* using *astropy* and produce a visualisation. Redo this with the calibration lamp, and the dark frame. Discuss the main features you identify in the data and potential systematics. Ensure that your visualisations are scaled appropriately to highlight the important feature of the dataset.
2. Read out the header information of the file and identify the source that is being studied.
3. Describe what is thermal noise in a CCD and what sort of signature is expected?
4. Convert the 2D image to a 1D spectrum by summing along the vertical axis across a region where a large stripe crosses horizontally. Identify a region where the thermal noise begins to dominate. Record the pixel values of the region for later. You shouldn't need the complete region, in fact a vertical width of 10-20 pixel should be sufficient and reduce issues due to rotation.

Noise removal

1. Create a "master" bias frame by taking the median of all of the bias frames included. A *bias* frame is a minimum duration exposure taken without significant light entering the detector. Plot the resulting frame and describe it qualitatively. What does a *bias* frame try to correct for? Subtract the bias frame from the *dark, flats, arc,* and *data.*
2. Create a "master" dark frame by taking the median of all of the *dark* frames that match the exposure of your data. If none match your data then choose the closest to remove as much as possible. A *dark* frame is an observation of the same duration as your object but with no light entering the CCD. Plot the resulting frame and describe it qualitatively. What does a *dark* frame correct for? Subtract the dark frame from the *data.*
3. Create a "master" flat frame by taking the median of the *flat* frames that don't have significant saturation. A *flat* is an observation of a uniformly illuminated plane by the telescope. Plot the resulting frame and describe it qualitatively. What does a *flat* frame correct for? **Identify one feature in the frame and provide a potential physical explanation (it doesn't need to be right just plausible).** Divide the data by the flat field.

4. Compare the systematic identified in stage one to the present data. Which remain, and which were partially removed?

Wavelength Calibration

You may need https://docs.astropy.org/en/stable/api/astropy.wcs.WCS.html to read the comparison image.

1. Take your cleaned *arc* file and take the region from the first stage to convert the image from 2D to 1D. Plot the result and describe the image qualitatively.
2. Identify a minimum of five spectral lines from the CuAr lamp and the following "cuar.fits" reference. Write a function that returns the maximum of a peak in a given range and use this to obtain pixel values for at least 5 wavelength values in your data and the reference. Try to choose values that span a wide range to improve your later results. You should avoid the brightest lines, but they may help identify neighbouring lines. Why should you do this?
3. Fit and plot the resulting fit (with errors derived from the covariance of the fit) of the pixel to wavelength conversion. Choose a polynomial (power and formulation [i.e. legendre, chebyshev]) and describe why you made that choice.

Investigation + Putting it all together

1. Take your cleaned data array, and convert it into a 1D spectrum. Obtain the wavelength values for every pixel value and plot intensity vs. wavelength.
2. Identify the three brightest emission lines in the resulting spectrum and identify the major chemical elements those lines are associated with.

Discussion

1. This was quite a simple routine, what could we have potentially done to further improve the quality of these results?

You now have a science ready spectrum! If you enjoyed this analysis, then proposals to OMM are open here: https://omm-astro.ca/pourlesobs/demandes-de-temps/. The deadline for next round of proposals will be in April. Although *spectro* is not available, the CCD processing will remain the same if you use PESTO or CPAPIR.