PHB905: Astronomy Techniques Portfolio

Show evidence of being able to use a range of practical astronomy techniques.

# Student Details

Student ID: F011489

# Introduction

Over the course of this module you will have the opportunity to try out a range of different astronomical techniques. These will include the use of the Lboro Observatory and data from remote sources. This portfolio proforma will allow you to evidence your ability to perform these techniques.

The portfolio is broken into six sections; astronomical imaging, spectroscopy, photometry, planning, radio astronomy and solar observing. Drawing from your work in the computer labs, observatory sessions and any additional analysis at home you will need to provide examples of having performed these different techniques.

You are limited by the size of the box on the proforma and your font size should be no smaller than 8pt. Do not resize the box and any information that spills onto the next page WILL NOT be marked. So, consider carefully what information, images and graphs you may need to include.

The portfolio will be assessed using the marking rubric provided on Learn. Each section of the portfolio has its own row on the rubric and all are equally weighted.

The completed portfolio should be submitted to Learn by … If your submission is even after the deadline, it will be considered late. The module team do not have the authority to grant extensions or accept late work. You should contact [sci-progadmin@lboro.ac.uk](mailto:sci-progadmin@lboro.ac.uk) *before* the deadline if you need to request an extension (typically no more than 48 hours) or submit a mitigating circumstances claim.

You should submit a single document as either a Word doc or a PDF (Learn will only accept these file types). Do not submit images, figures etc. as separate files (Learn will only accept one file).

Only include your student ID on this proforma. It will be marked anonymously and should not include your name anywhere.

|  |
| --- |
| Present an example of your astronomical imaging. Include examples of raw images, stacked images and processed images (including those taken with the Lboro Observatory) with a brief description of what steps you performed to process the image and details on what objects are present in the image.   Stacking the frames using DeepSkyStacker. There are multiple photos along with biases, darks and flats in seperate folders which it utilises to process the image. Use the recommended the settings after selecting the biases, darks and flats. Deepskystacker stacks the photos and saves it into the file.  Open the stacked photo into photoshop -   1. Cropping Errors out of the edge of the image 2. Adjusting the levels of the image - Move left slider towards centre of histogram and right slider to meet the uppermost date. Background becomes darker and the stars become brighter. 3. Convert to 16 bit such that the curves can be adjusted 4. Perform a curves adjustment - Start with auto curves adjustment, and then adjust based on how the image can be improved. The objective was to make an “S” shape such that it darkens the lower input values and brightens the higher input values. 5. Remove the sky gradient - Duplicate the image, and remove all the bright points of the image using the heal brush that automatically fills in the background. The Bright stars can be removed by selecting the color range and edit the content aware fill. After this, the remaining stars can be removed by filtering out the noise in the dust and scratches settings. We are left with the gradient of the image. 6. Subtract the gradient from the original image 7. Set Black and white points - Levels window. Black point eye dropper, empty patch of sky. White Point dropper and click on the bright stars in the image. 8. Do another levels and curves adjustment. 9. Finishing touches |
|  |

|  |
| --- |
| Present an example of your astronomical spectroscopy. Include example spectra (taken from the Lboro observatory or the SDSS) and identify any key wavelengths. Also include a brief description of what steps you performed to obtain and analyse the spectra and details on what object the spectra are from. Spectral lines in stars can be used to identify atoms or molecules that are dominantly present in it. This can give us any idea of the chemical composition of the star we are studying and help create a picture of the area surrounding it. Spectroscopy can be performed in Python using AstroPy, the common core package for Astronomy in Python. The steps to do so are outlined below.  First, we obtained the mastar fits file by downloading from the target source. Following this, we used astropy to import the data into Python so we could use it to get the stars in the specific temperature range we wanted and use the corresponding manga\_id to obtain their spectra from the mastar\_goodfits file. This was done via the command *np.logical\_and(data[1].data[‘INPUT\_TEFF’] > temp\_min, data[1].data[‘INPUT TEFF’] < temp\_max).* This let us obtain all the stars which were in a specific temperature range. Once we had the manga\_id of a specific star, we could then use that to obtain the same star’s spectrum from mastar\_goodfits file. The code that was used is shown below.  To locate the absorption and emission lines, the specific wavelengths corresponding to certain elements were used from [1], and were labelled using matplotlib in the spectrum plot. Specific type of stars also tended to have higher or lower wavelengths that led to certain type of elements, whose data was also extracted from [1].      The differences in the spectrum of stars are quite evident at different temperatures. On the top from left to right, is a K star, a F star and an A star. From looking at the plots, it is clear to see that for one, as the temperature of the star increased, the flux peaked at a much shorter wavelength, which meant that there was a change in the constituent components as well, since the flux intensity reduced at the higher bands where for instance Calcium’s spectral line would be observed. This can help us draw conclusions of the properties of a star solely based on its temperature category when looking at data from many stars and their spectrums. Analysis like this has enabled us to create spectral classes that have certain properties of color, mass, radius, etc. that can be predetermined purely by knowing the star’s temperature. The code for performing the operations labelled above is shown on the left.  [1] Sloan Digital Sky Server- https://skyserver.sdss.org/dr1/en/proj/advanced/spectraltypes/lines.asp |
|  |

|  |
| --- |
| Present an example of your astronomical photometry. Include an example of a lightcurve and identify any key features. Also include a brief description of what steps you performed to obtain and analyse the lightcurve, details on what object the lightcurve is from and values for orbital period, radius etc. I started by importing Lightcurve into the environment and downloading the target file for Kepler 8 using *lk.search\_targetpixelfile(“KIC 6922244”, author =”Kepler”, cadence=”long”, quarter=4).download()* which downloads a pixel file that is an aggregation of the brightness changes over multiple days. I then plotted the pixel plot which is shown in figure 1. It gives us a good idea of the star’s position and brightness. There are two ways that the lightcurve can be obtained. One of the options were to convert the pixel file into a lightcurve, and the other one was to download the lightcurve by itself using a similar command as before. Once I had the lightcurve, I removed the defects and the errors from the lightcurve after plotting it in figure 2. There were two types of flux postprocessing that could be done, which are showed in figure 2. Since PDSCAP flux was more oriented towards photometry and removing noise to determine the lightcurve of stars, I decided to use that one. Once I had plotted it, the next step I took was to fold the lightcurve over itself, with the period that is closest to the eclipsing planet. This process was a bit of trial and error, but after some experimentation and research, folding it with a period of 3.523 resulted in figure 3, and the command used was *klc.remove\_nans.flatten(window\_length=401).fold(period=3.523).bin(time\_bin\_size=0.01).plot(title=title).* After having plotted that, it became clear that the true period was close to that value, and using the folded lightcurve, I could obtain the exact drop in flux due to the planet. I could then use this in the formula , where Rstar was the radius of Kepler 8. Using this we found a value of 9.21 x m, where the uncertainties were calculated by adding the uncertainty in literature values to the uncertainty propagated through the equation on reading the values from the folded lightcurve. The Literature value of the same from (1) is , which shows that the calculated value is within 90 % of the literature value, showing that even on following such a simple method like this, we can come quite close to the answer. For calculating the value of the period of the orbiting body, I converted the lightcurve into a periodogram which converts the lightcurve into a power spectrum, from which we can see the period that it has as the lowest flux or the highest power. This is the same as the period of the orbiting body. The command used for the same was *lc.to\_periodogram(method = ‘bls’, minimum\_period=2.0)*  and then *print(pg.period\_at\_max\_power)*. The full width half maximum of the period was calculated by reading off from the graph, and the uncertainty was taken to be half of its value. The final calculated value was thus which compared to the literature value of days is very close.  **Figure2:** Lightcurve for Kepler 8 using two different flux distributions  **Figure1**: Pixel Plot of Kepler 8  A picture containing chart  Description automatically generatedChart  Description automatically generatedA picture containing diagram  Description automatically generatedChart  Description automatically generated  **Figure4**: Folded lightcurve for Kepler 8. The drop in flux is due to eclipsing planet Kepler 8b  **Figure 3**: Lightcurve for Kepler 8   1. - Borucki, W.J., Koch, D., Basri, G., Batalha, N., Brown, T., Caldwell, D., Caldwell, J., Christensen-Dalsgaard, J., Cochran, W.D., DeVore, E. and Dunham, E.W., 2010. Kepler planet-detection mission: introduction and first results. *Science*, *327*(5968), pp.977-980. |
|  |

|  |
| --- |
| Present evidence of your ability to plan an observing session for the week of your scheduled observatory session. You should include details of the time, date and location of the observations, the objects to be observed and examples of using software to simulate the observing conditions. Observing Location – Loughborough University Observatory - 1.24 52.76 69 +1  Time and Date – 25/10/21 – 19:00 – 21:00  Equipment – 16 inch Meade LX200 R, 80 mm Starlight – Camera – Canon EOS 400 D  Light Pollution – Location is a Class 6 on the Bortle Scale, so there is relatively high light pollution. Simulation in Stellarium shows how the light pollution affects the night sky. The Moon is also near its maximum, and thus will affect the conditions. However, during the observing conditions, the Moon is at its minimum and approaching its maximum (check body number 4 in the Star Alt map provided). There is slight cloud cover as predicted through [ClearOutside](https://clearoutside.com/forecast/50.7/-3.52), however, the conditions should be good enough to picture the Targets listed below.  Calibration Frames – We plan to take 20 frames of both Bias and Dark which are used to estimate the noise and are taken with the lens cap on. The Bias is the zero second exposure and the Darks are the exposure settings that we would use to picture our targets. However, with the limited observation time period, we might have to change our strategy based on how the session goes.  Strategy – The Targets will be photographed in the order that they are presented in the table. However, we may omit pictures of M33 and NGC 7293 if Andromeda turns out well. We may also not attempt to take pictures of the Moon if all goes to plan. We plan to start with a 2 minute Exposure and keep increasing it by 30 seconds until we feel the photos are good enough or we start obtaining trails. Since we have a guided mount for our camera, we can use a lower ISO of 200 – 400 to photograph our targets. However, these plans our subject to change based on the session and the advice of our professor.    The Targets chosen were carefully considered based on keeping an altitude greater than 45 degrees in the night sky, as the higher the position of the object, the easier it is to observe. The Airmass was computed using the [sec approximation](https://www.ftexploring.com/solar-energy/air-mass-and-insolation2.htm#:~:text=Air%20mass%20%3D%201%2Fcos(,air%20mass%20and%20sun%20angle.&text=air%20mass%20intro.,directly%20overhead%20the%20sun%20is.) and using the StarAlt Values. A range of bodies were chosen for observing. The Magnitude of these bodies were also less than 16, which was the maximum for the observing equipment. Simulation Pictures below. |

|  |
| --- |
| Present evidence of radio telescope measurements and analysis. This can be measurements of the solar output, pulsars or galactic rotation. Include a brief description of how the data was obtained and analysed and calculated values such as solar cycle, pulsar distance or galactic mass. Chart, histogram  Description automatically generatedChart, histogram  Description automatically generated  The data shows the average of the flux for the years from 1951 – 2020. It was obtained from the Nobeyama Radio Observatory(<https://spaceweather.cls.fr/services/radioflux/>). This data was put into an Excel spreadsheet.  The data was read using Pandas and imported it into a dataframe. A numpy array was initialized for storing the values for the flux of each year. A function to store the values of the yearly average into the arrays was called. The function iterated over the flux values and added the values that had the same year and took their average by dividing by the number of these values. After these steps, the average value for the flux of the year was stored in the array. This function was then called for the different flux parameters and plotted.  Through the Flux Spectrum, it was evident that there was oscillatory behaviour in the yearly averages for the solar flux, which pointed to a steady number for the Solar Cycle. As such, the Fourier transform of the yearly average data proved a useful method for obtaining the length of the Solar Cycle. Any one of the wavelengths could be chosen as each of them corresponded to the same cycle. The Fourier transform was used using Scipy’s implementation of the Discrete Fourier transform - Real Fast Fourier transform was used to perform the Fourier transform on the data. The code to do so can be accessed at [1]. The results are shown in Figure 2. To avoid the noise centred at 0 Hz, the mean of the signal was subtracted from the signal in order to normalise it. The maximum value of the Fourier-transformed data was obtained from the array and used to extract the characteristic frequency. By inverting the characteristic frequency,the length of the solar cycle was evaluated. The number calculated through this method for the Solar Cycle was 10 ± 0.014 years for the f10.7 band. The Uncertainty was calculated using the Standard Error - since no error was found in the data for individual measurements. Similar results were verified in [2], where they used the continuous wavelet transform to verify how the Solar Cycle has varied over the years. The same method followed in [3] obtains a number of 9.81 years for the Solar Cycle using the Plain Fourier Transform. However, a more accepted figure of the Solar Cycle seems to be 11 years, as shown in [4].    Code for taking the Yearly Average (left) and calculating the length of the Solar Cycle (right) |

|  |
| --- |
| Present evidence of solar observing. You should include images of the sun taken using the Lboro Observatory and examples from the Solar Dynamics Observatory. Identify the features present, compare and contrast different bandwidths and measure the solar rotation. Include a brief description of how the images were obtained and analysed. |