Solar Rotations Lab

Introduction:

In this Lab, participants will utilise an Unistellar eVscope 2 to observe the sun over the course of a few weeks. Participants are expected to calculate the differential rotation rates of the sun by latitude using photos taken of the sun with a Longitude-latitude tool. In the process, participants are expected to identify and comment on errors, utilise Python to analyse data and use it to assist with coming up with models that can better fit your data. (!) means possible change due to updates

Objectives:

- Operate a digital telescope
- Utilise image processing software
- Utilise Python data analysis
- Justifying theory

Required Materials / Software

Mobile device with Unistellar App

Python IDE with appropriate modules and packages

Section	Marks
Section 1	/6
Section 2	/21
Section 3	/22
Total	/45

Section 1: Observation of sun [5+1 Bonus Marks]

In this section, participants are expected to familiarise themselves with how to operate the telescope in question, the telescope is an expensive piece of delicate equipment and should be handled with the utmost care. Please go through all steps and content before operating, there will be questions on operational knowledge that are graded for marks.

As of writing the Unistellar app does not have the sun in its catalogue, should the situation change this lab should be updated accordingly.

Note: there are activities that can only be done on specific dates, plan your observation early in case of inclement weather.

WARNING: Do not expose the telescope to sunlight without a solar filter

Procedures:

1. Go to https://www.youtube.com/watch?v=jiAstdnIHk8 to familiarise yourself with how to use the telescope and answer the following questions. Ensure you have downloaded the Unistellar App. Explain briefly why we are not using enhanced vision [1 mark]

2. Identify clear days with good visibility over 2 weeks. It would be beneficial to have photos of the sun taken at the same time but this is not necessary.

3. During observation, set up the tripod first, bring the telescope body into a shaded area remove the cap and put the solar filter over the telescope. Look up and explain why you should not point a telescope at the sun without protection [1 bonus mark]

4. Install the main body on the tripod and take note of which side the pivot is located on relative to the sun. Explain why you need to take note of the orientation of the telescope [1 mark](!)

5. Open up the app and using manual mode locate the sun manually(!). Think about how shadows form and explain a quick way to locate the sun using the shadow of the telescope. [1 mark]

6. Once you locate the sun you can save the image directly to your uninstaller app

7. Over the 2 weeks make sure you have at least 10 distinct sunspots recorded at visually varying latitudes. Make sure there is a timestamp for each image

8. Attach 4 images of the sun of your choice for marks [2 marks]

Section 2: Image Processing, Data Recording [20 +1 Marks]

In this section, you will use a tool to determine the longitude and latitude of each sunspot. You will need to make a table and record the data you collected. Following which you will import the data to the python notebook file provided. You can find the tool at https://github.com/ruyixu00/Long-Lat-Finder

Procedures:

Part 1: Data Collection [10+1 bonus]

1. Take the images and upload them to the Long-Lat tool
2. From the site, using rows for sunspot longitude and columns for date and time, record the latitude of the sunspot over time and calculate the rotation rate. Stop recording the longitude once the spot is past 60˚. Explain why we should stop collecting longitude data once the sunspots are past 60˚ [1 mark]
3. To determine the error in latitude and longitude move your cursor slightly and click around the sunspot. Find the 2 values that are greater than and lesser than the value you obtained, your error will be half of the difference between the 2 values. There are other errors present in this step, identify at least one other error and assign a reasonable error value to it with an explanation [2 marks + 1 bonus for 1 more error provided with explanation] (Examples include the size of the sunspot leading to inconsistent clicking location and errors in setting circle)
4. Error in time uses half of the smallest digit recorded in the time stamp.
5. Using Appendix A calculate the error in Avg Latitude and Rotation Rate and input them in the table.
6. Save the table as a .csv file. Submit the file for grading [2 marks]

Part 2: Data import to Python (Refer to instructions in the .ipynb file provided) [10 marks]

Section 3: Analysis [20 + 2 marks]

In this section, you will first compare your data with what is currently accepted using the data you collected plotted as a line and scatter graph respectively. Following this you will recommend a model and justify why your model fits your data better.

Python Analysis [10 marks]

Questions [10marks +2 bonus]:

1. Looking at your fitted curve and the accepted rotation rate curve does your data support the accepted rotation curve? Comment on the shape, position, and coefficients of your curve compared to the accepted rotation curve [3 marks]
2. Based on the shape of your data points suggest a function that can better fit your data. You may suggest a new form such as linear, exponential, quadratic etc. or modify the accepted rotation rate equation [2 mark]
3. Does your curve fit your data better? Comment on the viability of your model considering shape, slope, intercepts, closeness to data points and etc. [5 marks]
4. Bonus: Repeat steps 2 and 3 with another type of function, and compare this model with your previous one and the accepted rotation rate equation. [2 Bonus marks]

Appendix: Propagation of Error:

For a variable z derived from independent measurements, $x_1, x_2, \cdots, x_n$ the general rule for error s_z is:

$$s_z = \pm\sqrt{\left(\frac{\delta f}{\delta x_1}\right)^2 s_{x_1}^2 + \left(\frac{\delta f}{\delta x_2}\right)^2 s_{x_2}^2 + \cdots + \left(\frac{\delta f}{\delta x_n}\right)^2 s_{x_n}^2}$$

For special cases such as:

1. Sum/difference $z = x + y$

$$s_z = \sqrt{s_x^2 + s_y^2}$$

2. Product and quotient $z = x \cdot y$ or $z = \frac{x}{y}$

$$s_z = z \cdot \sqrt{\left(\frac{s_x}{x}\right)^2 + \left(\frac{s_y}{y}\right)^2}$$

3. Multiplying by constants $z = a \cdot x$

$$s_z = a \cdot s_x$$

4. Linear sum/subtraction $z = x + y$

$$s_z = \sqrt{s_x^2 + s_y^2}$$

5. Exponent of measurement $z = x^a$

$$s_z = a \cdot x^{a-1} \circ s_x$$

6. Logarithms $z = ln(x)$

$$s_z = a \cdot \frac{s_x}{x}$$

7. Exponent by measurement $z = a^x$

$$s_z = s_z \cdot s_x$$