A.2 Angular Resolution: Seeing Details with the Eye

I. Introduction

We can see through a telescope that the surface of the Moon is covered with numerous impact craters of various sizes. Some craters are hundreds of kilometers across; some are less than one millimeter. But, what is the diameter of the smallest crater that you can see on the Moon with your naked eyes? In this activity you are going to determine the smallest object (or separation) that your eyes can see at a given distance.

II. Reference

• 21st Century Astronomy, Chapter 4, pp. 94, 96; Appendix A5 – A6

III. Materials Used

• fantailed chart
• blank sheet
• meter stick

IV. Activities

One measure of the performance of an optical instrument is its angular resolution. Angular resolution refers to the ability of a telescope to distinguish between two objects located close together in the sky. If someone holds up two pencils 10 cm apart and stands just 2 m away from you, you can tell there are two pencils. As the person moves away from you, the pencils will appear to be closer together to your eye. In other words, their angular separation decreases although their actual separation has not changed. This is the same phenomenon that makes railroad tracks appear to come together in the distance. For telescopes and most other optical instruments, the diameter of the aperture is the factor which determines the angular resolution. The finer (smaller the angle) the resolution, the better the instrument. In this lab, rather than directly measuring the angle, you will measure the spacing between lines in a grating that you can see and compare that to the distance from the grating. In this case, the higher the ratio, the better your eyes’ angular resolution.

① Tape the “fantailed” chart (Fig. A.8) to a wall in a well-lit classroom.

② Stand 10 m from the chart.

③ Your partner will hold a sheet of paper over the chart, hiding all but the bottom tip. Tell your partner to move the paper very slowly up the chart, keeping the paper horizontal. When you start to see the chart lines clearly separated from each other just below the paper, tell your partner to hold the paper in place.

④ Your partner will read the line spacing printed on the chart nearest to the top of the paper.

⑤ Repeat the measurement at 5 m.
Table A.5: The distance-to-size ratio for your eye.

<table>
<thead>
<tr>
<th>distance (m)</th>
<th>line spacing value (mm)</th>
<th>distance-to-size ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Suppose when your classmate stood 10 m (= 10,000 mm) from the chart, she was just able to distinguish the separation of the lines spaced 4.5 mm apart. The distance-to-size ratio for her eyes is 10,000 mm (the distance to the chart) divided by 4.5 mm (the line spacing):

\[
\frac{10,000 \text{ mm}}{4.5 \text{ mm}} = \frac{2,200}{1}.
\]  

This ratio can be written as \(2,200/1\), the distance-to-size ratio for her eyes. This ratio is read as “2,200 to 1” and can also be written as \(2,200:1\). The larger the distance-to-size ratio, the more detail your eyes can see.

⑤ Calculate the distance-to-size ratio for your eyes.

⑥ How do the two ratios compare?

⑦ Find the average of two measurements for your distance-to-size ratio. You will be using this average value for the problems in the Questions section later.

The distance-to-size ratio for your eyes determines how much detail you can see. Using the triangle method, you can estimate the “sharpness” (ability to see detail) of your eyesight. In Fig. A.7, \(O\) is the position of your eyes; \(A\) and \(B\) are two side-by-side lights. The distance of the observer from the lights is \(OA\) (or \(OB\)); the distance (i.e., size) between the lights is \(AB\).

In the previous example, your classmate had the distance-to-size ratio of \(2,200/1\). This ratio means that if she were closer than 2,200 m away from two lights separated by 1 m, she would see two separate lights. If she were farther away than 2,200 m, she would not be able to distinguish the two lights; she would see only one light.

V. Questions

1. What is the farthest distance you could be from two lights, separated by 1.0 cm, and still see them as two lights?
2. What is the farthest distance you could be from two lights, separated by 30 m, and still see them as two lights?

3. Will you be able to distinguish two lights separated by 50 cm if you were standing 500 m from them? Show your work.

4. An automobile has headlights placed 1.2 m apart. If the car were driving toward you at night, how close to you would it have to be for your to tell it was a car and not a motorcycle?

5. The Moon is about 384,000 km from the Earth. What is the diameter of the smallest crater that you could see on the lunar surface?
VI. Credit

To obtain credit for this lab, you need to turn in appropriate tables of data, observations, calculations, graphs, and a conclusion as well as the answers to the above questions. Do not forget to label axes and give a title to each graph. Show your work in calculations. A final answer in itself is not sufficient. Don’t leave out units. In the conclusion part, briefly summarize what you have learned in the lab and possible sources of error in your measurements and how they could have affected the final result. *(No, you cannot just say human errors – explain what errors you might have made specifically.)* You may discuss this with your lab partners, but your conclusion must be in your own words.
Figure A.8: The fantailed chart for measuring the distance-to-size ratio.