Using OSLO

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1 What is OSLO?

OSLO, an acronym for *Optics Software for Layout and Optimization*, is a thoroughly developed program that evaluates the performance of optical systems such as astronomical telescopes and associated instrumentation. The educational version you will use is restricted to 10 refracting or reflecting surfaces, but is otherwise complete. The surfaces can be flat, spherical, or more complex curves such as parabolic, hyperbolic, and elliptical surfaces of revolution. You will use OSLO to examine the performance of a classical parabolic mirror reflecting telescope, the Hubble Space Telescope.

2 How do I get started?

You will need a directory with your own copies of files that you can modify. This directory will be created for you in your current working directory the first time that you run the "edu" version of OSLO on our system. Simply use the commands

1. `cd`
2. `oslo`

The `cd` insures that you are running at the top level of your home directory. The command `oslo` will create the necessary files in a new directory `oslo/private`. The next time you run `oslo` it will detect this directory and not rewrite the files.

3 The parabolic mirror

Once the `oslo` command is issued several windows will appear on your computer screen if things are working well. One of them is a window with helpful tips. Click "Close" to make it go away, or use "Next Tip" to look through several hints.

Open an existing lens by selecting the push button in the Startup Option window, and "OK". Then select "Private", and "parabola.len". Click "OK". New graphics windows will appear, including one with a small diagram of the telescope optics. Click on the "GW1" window icon that seems to show two lenses. This button will create a ray trace window. You can expand the window by grabbing a lower corner with the mouse.

The "Surface Data" spreadsheet has three entries:

1. OBJ is the object. It's at infinity, or nearly so, 10^{20} mm to the left of an arbitrary reference point (plus is to the left, minus to the right).

2. AST is an aspherical reflecting surface, in this case a paraboloid. If you right click on the "A" you'll see that "Conic/Toric" is selected. You can change the conic constant from -1 (a parabola) to a positive number (a oblate spheroid), 0, a sphere, a number from 0 to -1 (an ellipsoid), or a number less than -1 (a hyperboloid). For now, leave it parabolic. The surface has a *radius* of of 500 mm, that is, a diameter of 1 meter. Its radius of *curvature* is -8000 mm, negative here because the surface is to the right (negative direction) from the center of curvature. A radius of curvature of -8000 mm causes the focal length of the mirror to be -4000 mm (again, negative because of the sign convention on directions). The f-ratio is the focal length divided by diameter, or 4 in this case. It is also given by $(1/2 \times \text{NA})$ where "NA" is the numerical aperture. The "Thickness" entry controls where the surface is with respect to the last entry in the table. When there are multiple surfaces this entry is the distance from the previous surface to the new surface measured on the axis. Try changing it a small amount, and watch the "Autodraw" window to see what part of the system is visible.

3. IMS is the image surface. The "Thickness" is the distance to the place that the image is observed. In this example, the mirror surface is located at -5000 mm and the focal surface is set at +1000. The image is 4000 mm from the surface. You can "Autofocus" the image by right

clicking on the box next to the Thickness for this surface and selecting the entry for Paraxial rays.

The "Surface Data" spreadsheet also has a "Setup" option. Under `Setup` you can alter the "Entrance beam radius" to define the effective diameter of the telescope. This will change the pattern of the Spot Diagram Analysis that you will use to evaluate optical performance. In this example it is set to 500 mm, the same as the aperture radius in the Surface Data spreadsheet. If you make it smaller, the Airy disk due to diffraction will get larger.

4 Evaluating optical performance

For any lens or mirror system you can observe the image in the focal plane, either by inspecting tables of data or by looking at the graphs. Experiment with the parabola to see what you can find out. For example, select `Evaluate` then `Spot Diagram` and `Report graphic ...`. This brings up a small menu. Accept the defaults, except select "Show Airy Disk". You will see the image in the focal plane, on and off axis, and the image inside and outside the best focus.

Make a slight change to the IMS Thickness to move the image plane and then right-click on the Spot Diagram graphic, select Update, and you will see the new image. To find the best focus, use the Autofocus option above and move the plane back. You can always restart the process with a `File->Exit` selection.

You can evaluate the relative size of the coma and defocusing on the graphical screen. You can also see a numerical value for the diffraction limit with `Evaluate` then `Spot Diagram` and `Spot size analysis ...`

5 Questions

1. For a parabolic mirror 1 meter in diameter with a focal length of 4 meters, what is the diameter of the "Airy" disk, the diffraction disk inside the first minimum of the diffraction pattern? Give your answer in seconds of arc on the sky, and in microns (10^{-6} meter) in the focal plane. You should do this calculation using an expression for the diffraction pattern of a circular aperature, and then verify it with OSLO.

2. How far off the optical axis can a star be, and still have coma less than the size of the Airy disk? This is the diffraction-limited field of view.

3. How large is the coma 15 minutes of arc, 1/4 degree, off axis?

4. Change this mirror to a spherical mirror. What is the size of the best image on axis, again in seconds of arc and in microns? What can you conclude about the choice of the shape of a mirror surface on the performance of a telescope?

5. Start OSLO again, but this time with the Hubble Telescope model.

6. What is the primary mirror diameter, and what are the shapes of the primary and the secondary mirrors here?

7. Answer questions 1-3 above, but now for this system.

8. Assuming that the telescope is perfectly made and that it is used to observe a nearby red giant star 2 astronomical units in diameter, how close would that star have to be for it to appear larger than the Airy disk?

9. Are there any red giants that close? (Use the web or resources of your own choice to find the distances to the nearest stars.)