

The Heights of Lunar Mountains

Student Manual

A Manual to Accompany Software for
the Introductory Astronomy Lab Exercise
Document : Version 1

Department of Physics
Gettysburg College
Gettysburg, PA 17325

Telephone: (717) 337-6028
email: clea@gettysburg.edu



Contemporary Laboratory
Experiences in Astronomy

Contents

Purpose	3
Equipment	3
Introduction	3
General Procedures	3
Detailed Procedures	3
Conclusions and Summary	7
Endnotes	8

Purpose

Using CCD images of the moon and the IMDISP image processing program¹ for the PC, you will study two regions of the lunar surface. Image processing will enhance the detail of the image, and you will use the software's features to measure shadow lengths. After studying something of the geometry of the Earth-Moon-Sun configuration, you will calculate the height of these features above the lunar surface.

Equipment

Scientific pocket calculator, IBM PC or compatible personal computer with VGA graphics, IMDISP Version 7.8 (or later) image processing software, Interactive Computer Ephemeris (ICE) computer software OR selected pages of Astronomical Almanac for 1992, and lunar maps showing lunar latitude and longitude².

Share the use of the computer and programs with your partner to collect and process data. All calculations, as well as your narratives, must be your own original work.

Introduction

CCD imaging of celestial objects has supplanted the use of photographic techniques in a variety of astronomical applications. The images captured by the electronic eye of the Charge Coupled Device (CCD) camera are adroitly handled by computers, and can be collected, manipulated and viewed in a matter of minutes instead of the many hours typical of emulsion based photography. CCD cameras are particularly good at imaging faint objects, but can be used with equal effectiveness for brighter objects such as the moon and planets. In this exercise we will study some CCD images of the moon. In fact, you may have had the opportunity to take CCD images of the moon yourself at the observatory. If so, ask your lab instructor if your images can be used as part of this laboratory exercise.

General Procedures

The amount and degree of image processing you apply to your images is a matter of personal preference. You should enhance your images using the IMDISP commands until you are confident that the details you are interested in are sufficiently prominent to accurately measure. Too much (or the wrong kind of) image processing can ruin your image. If this happens to you, simply reload the picture as described below and start over, avoiding previous mistakes.

The exercise will proceed as follows, with each procedure explained further in the section titled **Detailed Procedures**. Use this list as a reminder for the various steps:

1. Run the IMDISP program and load a CCD image for analysis. The command HELP will assist you in selecting appropriate tools.
2. Enhance and/or process the original image in order to bring out the details. Measure shadow length.
3. Run the ICE program to determine the angles of the Sun and the Earth with respect to the moon.
4. Measure the position of the object on a map of the moon, and determine its lunar longitude.
5. Calculate the height of the feature.

Detailed Procedures

1. Run the IMDISP image processing program. The instructor will provide details of how to locate and run this program. You will use two images in this lab exercise³.

Within each image, specific objects have been selected for study. All are mountains: PITON28.FTS taken October 6, 1992 at 0015 UTC, GASSENDI.FTS taken May 13, 1992 at 0355 UTC, and PICO.FTS taken November 3, 1993 at 2330 UTC.

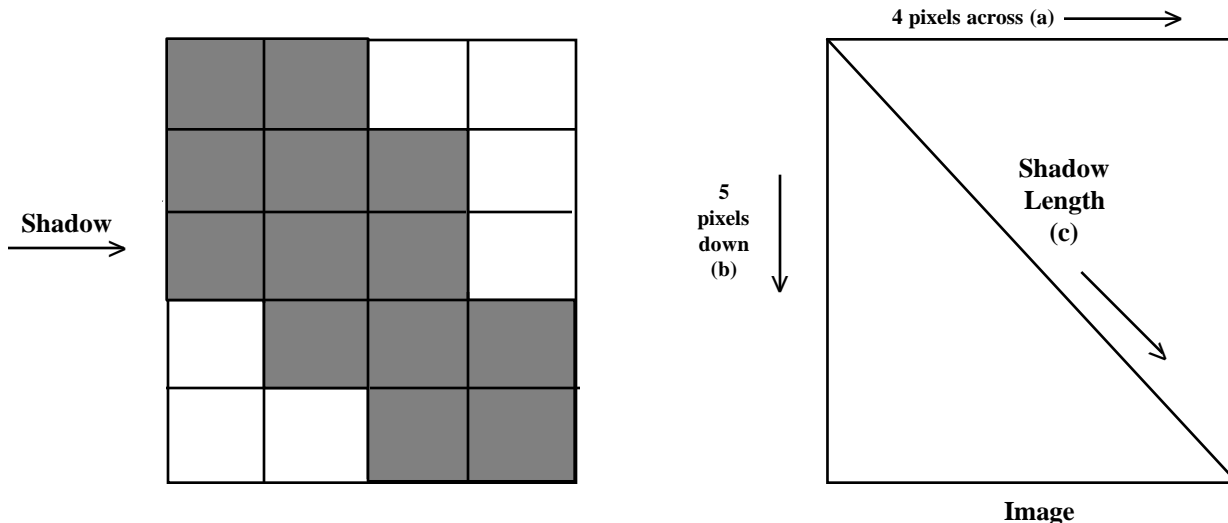
Use the **FILE** command, and from the list select the number representing the PITON28.FTS image, and press ENTER to load it. MONS PITON is a mountain in Mare Imbrium, and you will determine its height by measuring the length of the shadow it casts.

Use the **DISPLAY AUTO** command to display the image. The image should appear in the upper left of your screen.

- Enhancing the image. PITON (and PICO) is very small. Use the finder chart, Figure 1a (or 1b) to identify it on the image. Use the **CURSOR** command to place a small cross on the image. Use the mouse to position the cross over PITON and click the left mouse button. Now, zoom in on the feature with the command: **DISPLAY ZOOM 5 CENTER**.

An enlarged image of the PITON should appear centered on the screen. Check Figure 1a (or 1b) carefully to make sure you have properly identified the object. Piton casts a shadow to the lower-right because sunlight is shining from the upper-left⁴. Identify it's shadow. Then use the command: **DISPLAY ZOOM 15 CENTER**.

To make the image bigger still. Notice at this magnification, individual pixels (picture elements) are obvious and the image takes on a grainy look. Determine the length of the shadow, in pixels, by counting them. Since the shadow falls at an angle, it will be necessary to use the Pythagorean theorem to determine the actual length. See Figure 2. Then enter the result of your shadow length calculation on the worksheet.



Example

$$a^2 + b^2 = c^2$$

$$5^2 + 4^2 = c^2$$

$$25 + 16 = c^2$$

$$41 = c^2$$

$$c = 6.4 \text{ pixels} = \text{shadow length}$$

Figure 2
Calculating Shadow Length

- Run the **ICE (Interactive Computer Ephemeris)**. ICE is a computerized version of the Astronomical Almanac, which can be used if you do not have access to ICE. From the initial menu screen of ICE, **press F1** to set the time and date. Enter the date and time the CCD image was taken in *UTC* time. For example, PITON28.FTS was taken on October 6, 1992 at 0015 UTC, so enter 19921006.0015. Finally, **press F7** to accept the values.

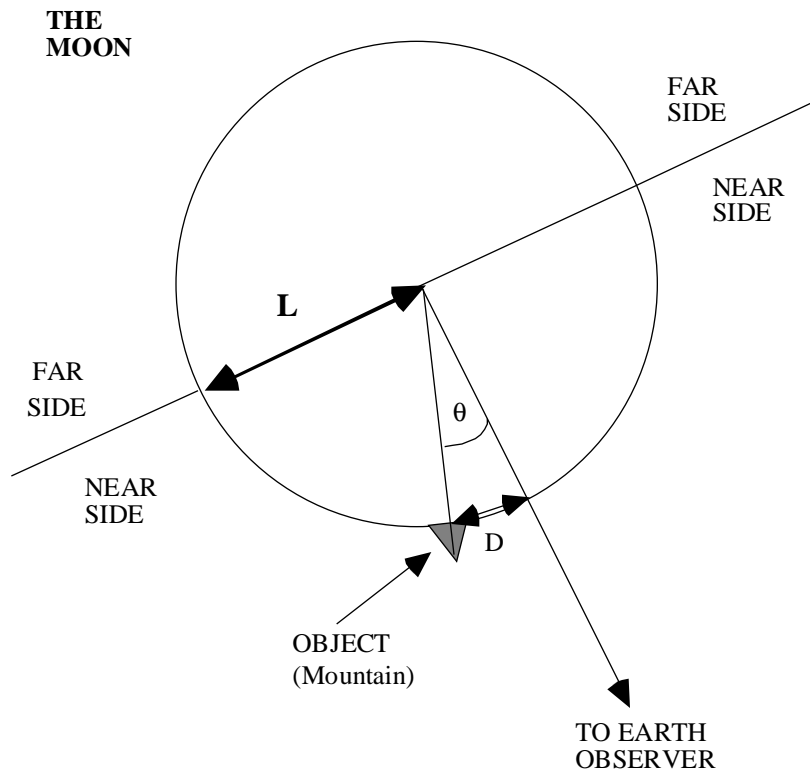
Now press **F4 for PHYSICAL EPHEMERIS**. Then **enter MOON** as the object name and **select ILLUM**. When you press **ENTER**, the computer will calculate the position of the moon in the sky at the time the CCD image was taken.

On the worksheet, **record the ANGLE**. The ANGLE is the angle formed by the EARTH-MOON-SUN. **Press ENTER** to return to the ICE menu, and finally **F10 to quit ICE**.

- Measure the position of the object on the moon map. See Figure 3. Find the object on the map, and measure the perpendicular distance, in millimeters, from the object to the centerline of the moon (distance D). Measure the radius of the moon in millimeters (distance L). Enter D and L on the worksheet.

Measure, to the nearest degree, the number of degrees longitude (**B**) the object sits east or west of the moon's centerline (use Figure 1a or 1b). Enter the longitude on the worksheet.

- Complete the calculations on the worksheet to determine the actual height of the object.



$$\theta = \arcsin \frac{D}{L}$$

Figure 3
Measuring D, L, and determining θ

- GASSENDI is a walled plane with mountains in the center, located in Mare Humorum. Use procedures 1 through 5 to calculate the heights (in km) of the central peaks in GASSENDI. Use image GASSENDI.FTS.

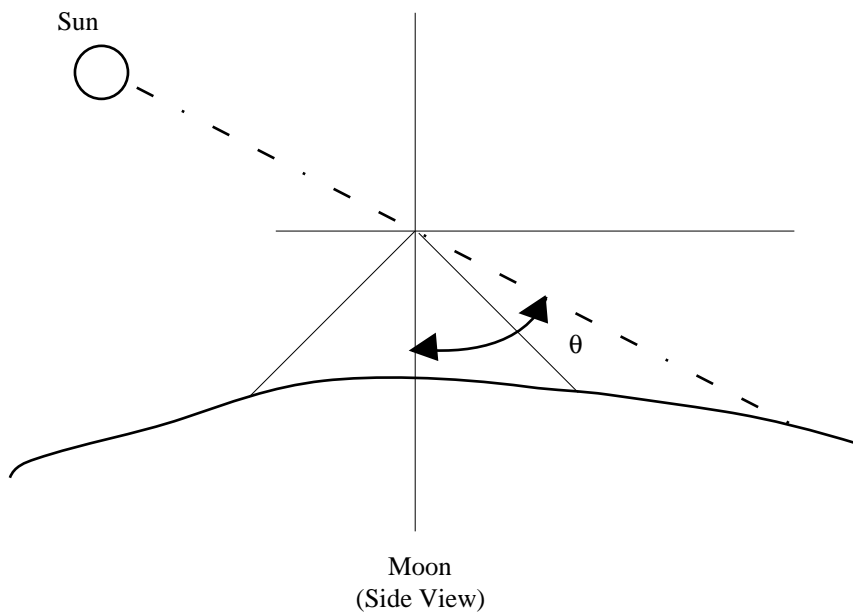
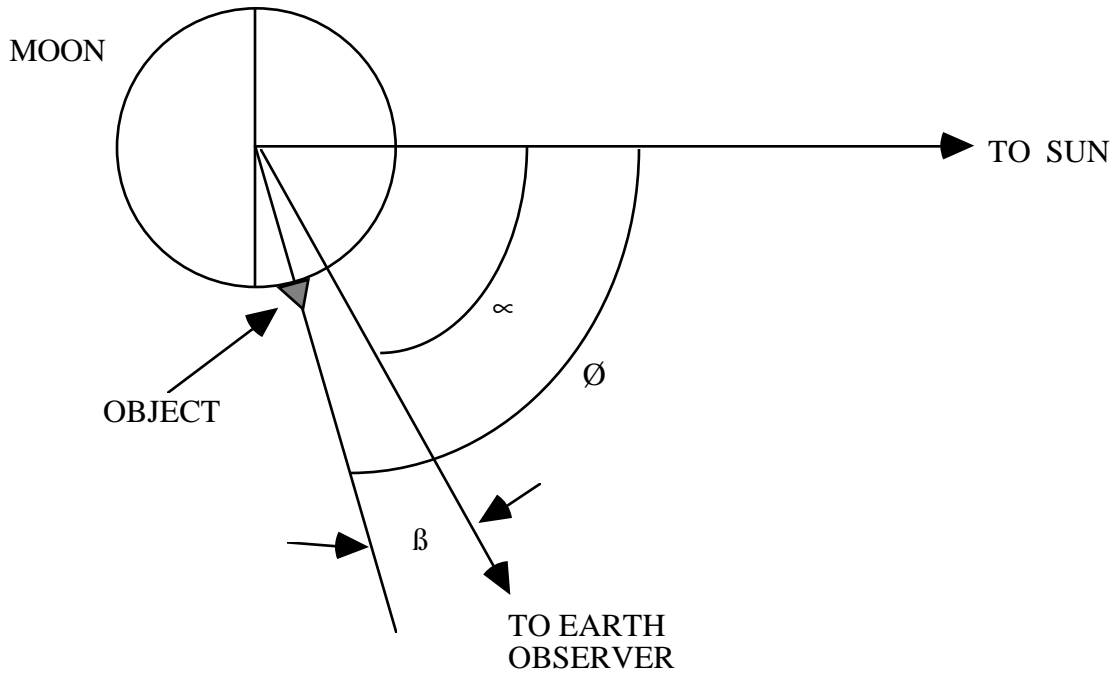


Figure 4
 where α = Earth - Moon - Sun Angle
 β = Longitude of Object
 θ = Illumination Angle

Conclusions and Summary

According to Rukl's Atlas of the Moon, the height of Mons Piton is 2.25 km. Wilkins and Moore state that the highest peak in the middle of Gassendi is 1.22 km. What percentage above or below these values did you calculate? In a brief narrative, compare your results with the known values, list possible sources of errors that may have caused any observed discrepancies, and discuss methods of controlling them.

Endnotes

- ¹ IMDISP is available from the Jet Propulsion Laboratory, Pasadena, CA at no charge, or from anonymous ftp at [ames.arc.nasa.gov](ftp://ames.arc.nasa.gov).
- ² Useful maps can be found in *Sky and Telescope* Reprint [Guide to the Heavens](#) or from *Atlas of the Moon* by Antonin Rukl.
- ³ These images were taken at the Gettysburg College Observatory. PITON28.FTS was taken with an SBIG ST-6 CCD camera and a 0.01 second exposure. GASSENDI.FTS and PICO.FTS were captured using a SpectraSource LYNXX CCD camera using a 0.05 second exposure.
- ⁴ Shadow lengths of features on the moon vary with the phase of the moon. Piton is best and most conveniently observed a day after first quarter. Gassendi's best shadows are visible during waxing gibbous phase.

<i>WORKSHEET</i>	PITON	GASSENDI	PICO
Time and date of Observation (UTC)			
(s) Shadow length (in pixels)			
(α) EARTH-MOON-SUN angle (in degrees)			
Distance (D) from object to centerline (in millimeters)			
Distance (L) Moon's radius (in millimeters)			
(β) Object's longitude from moon map figure 1a or 1b (in degrees W+, E-)			

(Refer to Figures 3 and 4)

1. Calculate the observed angular distance q from the object to the center of the moon viewed from Earth (in degrees):

$$\theta = \arcsin \frac{D}{L}$$

PITON _____ GASSENDI _____ PICO _____

2. Calculate the object's solar illumination angle, f (in degrees):

$$\phi = \alpha + \beta$$

PITON _____ GASSENDI _____ PICO _____

3. Calculate height in pixels, then convert to kilometers:

$$h_{\text{pixels}} = \frac{s}{\tan \phi \cos \theta}$$

PITON _____ GASSENDI _____ PICO _____

4. Multiply the height in pixels by the number of km in one pixel to convert pixels to actual height. The scaling factor (sf) for the PITON image is 3.2 km/pixel and 2.1 km/pixel for GASSENDI and PICO:

$$h_{\text{km}} = h_{\text{pixels}} sf$$

PITON _____ GASSENDI _____ PICO _____

Student Manual

<i>Answer Key</i>	PITON	GASSENDI	PICO
Time and date of Observation (UTC)	10/6/92	5/13/92	11/3/92
(s) Shadow length (in pixels)	1.4	5.0	8.5
(α) EARTH-MOON-SUN angle (in degrees)	63.4	44.2	72.6
Distance (D) from object to centerline (in millimeters)	3.0	59.0	10.2
Distance (L) Moon's radius (in millimeters)	97.5	97.5	97.5
(β) Object's longitude from moon map figure 1a or 1b (in degrees W+, E-)	1°W	40°W	9°W

(Refer to Figures 3 and 4)

1. Calculate the observed angular distance θ from the object to the center of the moon viewed from Earth (in degrees):

$$\theta = \arcsin \frac{D}{L}$$

PITON ____1.8____ GASSENDI ____37.5____ PICO ____6.0____

2. Calculate the object's solar illumination angle, ϕ (in degrees):

$$\phi = \alpha + \beta$$

PITON ____64.4____ GASSENDI ____84.2____ PICO ____81.2____

3. Calculate height in pixels, then convert to kilometers:

$$h_{\text{pixels}} = \frac{s}{\tan \phi \cos \theta}$$

PITON ____0.67____ GASSENDI ____0.64____ PICO ____1.26____

4. Multiply the height in pixels by the number of km in one pixel to convert pixels to actual height. The scaling factor (sf) for the PITON image is 3.2 km/pixel and 2.1 km/pixel for GASSENDI and PICO:

$$h_{\text{km}} = h_{\text{pixels}} sf$$

PITON ____2.1 km____ GASSENDI ____1.34 km____ PICO ____2.65 km____