Journal of Physics Special Topics

An undergraduate physics journal

A6_5 Man's Small Footprints

W. Schulz, P. Doyle, J. Heaps, E. Minnis

Department of Physics and Astronomy, University of Leicester, Leicester, LE1 7RH

December 17, 2017

Abstract

We analyse the feasibility of imaging the footprints left on the surface of the moon by Neil Armstrong in the 1969 moon landing. We find that a telescope roughly 1.5 km across would be needed to resolve the bootprints from earth, and a telescope of 13.7 km diameter would be needed to resolve the details of the bootprints. We then evaluate the distance at which a probe would need to orbit the moon to image the bootprints. We find a probe would need to orbit at 117 km to resolve the bootprints and 12.7 km to resolve the bootprints in detail.

Introduction

The Apollo 11 mission in 1969, which successfully landed astronauts on the moon, was one of the most historic events of the 20th century. Footage of Neil Armstrong's "One small step for man" speech has been viewed by millions since, and the footprints he left behind on the lunar surface to mark man's scientific and engineering prowess are still there today. Because the moon has no atmosphere, and thus no wind or weather, nothing has disturbed them. Assuming image distortion due to the atmosphere is minimal, we estimate the diameter of the telescope necessary to image those footprints and take detailed photographs of them from Earth. We then estimate the distance at which a telescope 0.5 m across would need to be to do the same from a lunar orbiter.

Observing From Earth

We set the distance between the observer and the the moon to be the minimum possible, to make the observation easier. At perigee (the point at which the Moon is closest to Earth), the Moon and the Earth are 356000 km apart [1]. Subtracting the radii of the Earth and Moon, the observer and the bootprints would be 348000 km apart. Given that Neil Armstrong was a shoe size $9\frac{1}{2}$[3], with about an inch of insulation, we defined the length and width of the bootprints to be 33 cm (13 inches) and 15.2 cm (6 inches) respectively. As shown in Figure 1 the bootprints have 10 ridges, so we defined the ridges as being 1.65 cm across. Assuming the width of the boot-

Figure 1: Photograph of Neil Armstrong's bootprints taken by the Apollo 11 crew [2]

prints would be the limiting factor in resolving them, and the width of the ridges would be the limiting factor in resolving detailed images, we calculated the angular resolution needed to image the bootprints using the small angle equation Eq.(1).

$$\theta = \frac{D \times 206265}{d} \qquad (1)$$

In Eq.(1)[4] θ is angular width in arcseconds, D is the width of the object in meters, and d is the distance between the observer and the object in meters. 206265 is a dimensionless conversion factor. We calculated the angular width of the bootprints to be 9.0×10^{-5} arcseconds and the angular width of the details of the bootprints to be 9.8×10^{-6} arcseconds.

$$R = \frac{134}{T} \qquad (2)$$

In Eq(2)[5] R is the resolution limit of a telescope in arcseconds, and T is the diameter of the telescope in millimetres. Letting $R = \theta$ to find the minimum diameter required to resolve the bootprints and their details, we calculated that a telescope of diameter 1.5 km would be needed to resolve the bootprints from Earth, while a telescope of 13.7 km would be needed resolve details. These sizes are far greater greater than what is feasible, making imaging the bootprints from Earth impossible.

Observing From Orbiter

To find the distance at which a lunar orbiter could image the bootprints, we assumed the probe would carry a telescope with a diameter of 0.5 m; quite large for an orbiter. Using Eq.(2), we calculated that the telescope would have a resolution limit R of 0.268 arcseconds. Again we set $\theta = R$ to find the maximum distance at which the telescope could resolve the bootprints and their details. We used Eq.(1) to find the maximum distance at which the lunar orbiter could resolve the bootprints would be 117 km above the lunar surface, while to capture detailed images of the bootprints the orbiter would need to drop to 12.7 km. While 117 km is a perfectly reasonable distance for a probe to orbit the moon, below about 100 km altitude above the moon the probe would be in Low Lunar Orbit (LLO). To image the bootprints in detail would subject the probe to intense perturbations in its orbit around the moon, making this a risky prospect if recovering the probe is to be assured [6].

Conclusion

Due to the small nature of Neil Armstrong's bootprints in comparison to the distance between the Earth and the Moon, or even the Moon and a probe orbiting it, resolving them is a challenging prospect. Building a telescope large enough to do so on Earth would be impossible, and while sending a probe capable of resolving the bootprints is possible, acquiring detailed images risks the orbiter. While we assumed a reasonable value for the dimensions of the bootprints, there is a degree of error associated with our results, but not great enough to render them invalid. Even a 10% change in any of the calculated distances would not make resolving the bootprints feasible from Earth.

References

[1] https://nssdc.gsfc.nasa.gov/planetary/factsheet/moonfact.html [Last Accessed 16 Nov 2017]

[2] https://www.nasa.gov/mission_pages/apollo/40th/images/apollo_image_11a.html [Last Accessed 2 Nov 2017]

[3] http://ngm.nationalgeographic.com/ngm/0609/feature2/online_extra04.html [Last Accessed 14 Dec 2017]

[4] http://astronomyonline.org/Science/SmallAngleFormula.asp [Last Accessed 14 Dec 2017]

[5] https://spacemath.gsfc.nasa.gov/weekly/10Page35.pdf [Last Accessed 2 Nov 2017]

[6] https://science.nasa.gov/science-news/science-at-nasa/2006/06nov_loworbit/ [Last Accessed 16 Nov 2017]