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P4_4 Observing Curiosity

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Abstract

In 2012, the Curiosity rover landed on the surface of Mars. In this paper, we consider the angular size of Curiosity from the Earth at the shortest Earth-Mars separation distance. We then equate this angular size to the Rayleigh criterion to determine the diameter of a telescope's aperture in order to resolve Curiosity for varying wavelengths of electromagnetic radiation.

Introduction

On August 5 2012, the Curiosity rover landed on the surface of Mars [1]. In this paper, we will be determining the diameter of a telescope's aperture needed to resolve Curiosity from the surface of the Earth for varying wavelengths of electromagnetic radiation, when the separation between the Earth and Mars is at a minimum.

Assumptions

There will be some major unphysical assumptions made in this paper which need to be addressed. Firstly, we will be neglecting the atmosphere of the Earth, as this will cause image distortion and will produce complications with the calculations involved.

In addition to this, we will assume the Curiosity rover and our telescope are perfectly alligned. In reality, as both the Earth and Mars rotate, there is a small chance that Curiosity will be facing away from the Earth at the shortest separation position.

Finally, we will assume the Curiosity rover is 100% reflective across all wavelengths of electromagnetic radiation. We recognise this is not true, as some absorption at particular wavelengths will occur and very short wavelength radiation (i.e. gamma rays) will pass right through Curiosity.

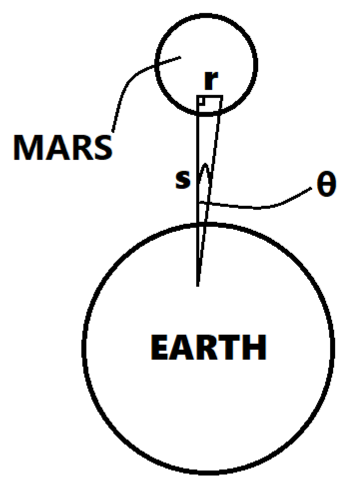

Figure 1: A diagram we created demonstrating the setup of the problem, where there is a right-angled triangle with base length r and height s. This diagram is not to scale.

Theory

As shown in Figure (1), the angular size θ of Curiosity can be determined by doing:

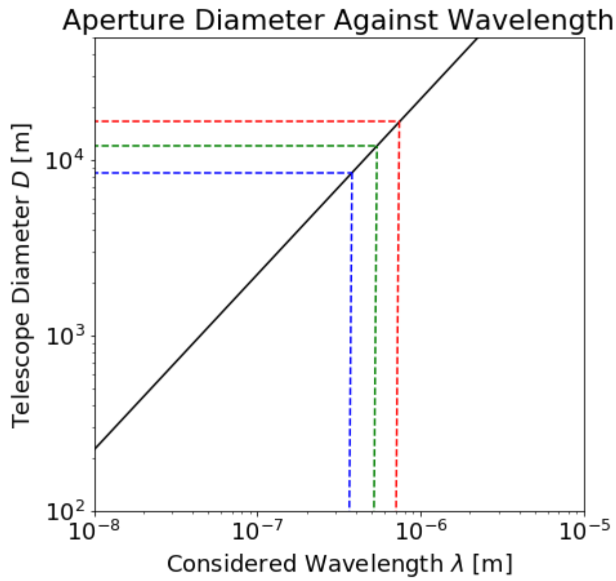

Figure 2: A plot we produced showing the diameter of a telescope's aperture versus the considered wavelength of electromagnetic radiation, highlighting the region of visible light. The axes of the plot have been scaled logarithmically.

$$\tan(\theta) = \frac{r}{s}, \quad (1)$$

where r is the length of Curiosity and s is the Earth-Mars separation distance. As the angular size θ will be small, we will make use of the small angle approximation:

$$\tan(\theta) \approx \theta \approx \frac{r}{s}. \quad (2)$$

We will be equating this angular size to the Rayleigh criterion for a circular shaped aperture, which is defined as:

$$\theta = \frac{1.22\lambda}{D}, \quad (3)$$

where λ is the wavelength of the considered electromagnetic radiation and D is the diameter of the telescope's aperture. By substituting θ from Equation (2) into Equation (3) and rearranging for D, we end up with:

$$D = \frac{1.22\lambda s}{r}. \quad (4)$$

Results

The smallest separation between the Earth and Mars is 54.6 million km [2], so $s = 5.46 \times 10^{10}$ m. The length of Curiosity is about 3 m [3]. We have produced Figure (2) from Equation (4) for a wide range of wavelengths, highlighting the linear dependence of the wavelength on the diameter needed in order to resolve Curiosity.

For multiple telescopes working in unison (interferometry), a baseline is established due to the contribution of multiple telescope separations [4]. For instance, if we consider a fictitious interferometer with a baseline size of 10000 km (same order as the diameter of the Earth), then the wavelength needed will be 450 nm corresponding to visible blue light.

Conclusion

To conclude, we have derived Equation (4), which is the diameter of an aperture needed to resolve Curiosity from Earth for a specific wavelength of electromagnetic radiation. In addition to this, we have produced Figure (2), which demonstrates the aperture's diameter requirement for specific wavelengths. We believe that a singular telescope will not be sufficient to resolve Curiosity, as the diameter of the aperture required will be far too great to construct.

However, interferometry techniques could be able to observe Curiosity, though at least two telescopes would have to span the diameter of the Earth and work in unison for this to be achieved.

References

[1] `https://mars.nasa.gov/msl/timeline/summary/` [Accessed 22 October 2019]

[2] `https://www.space.com/14729-spacekids-distance-earth-mars.html` [Accessed 22 October 2019]

[3] `https://mars.nasa.gov/msl/spacecraft/rover/summary/` [Accessed 23 October 2019]

[4] `https://www.eso.org/public/teles-instr/technology/interferometry/` [Accessed 04 December 2019]