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P2_6 "Legolas! What do your elf eyes see?"

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Abstract

In "The Lord of the Rings: The Two Towers", Legolas claims that the yellow haired riders he described are a little more than five leagues away. We have found that for him to be able to see a yellow wavelength at a distance of five leagues, Legolas would have to be at a height of 44.1 m, and his pupil dilation to be 8.47 mm.

Introduction

In the second chapter of "The Lord of the Rings: The Two Towers", Aragorn spots riders, which then Legolas begins to describe: "there are one hundred and five. Yellow is their hair, and bright are their spears. Their leader is very tall" and then proceeds to say that they are more than five leagues distant [1]. In the book it is said that the elves have a keen eyesight by Gandalf: "You have the keen eyes of your fair kindred, Legolas," he said; "and they can tell a sparrow from a finch a league off." [2]

In this paper we investigate how high up Legolas would have to be in order to see a distance of five leagues (24155 m) and by how much his pupils would have to dilate. We model the elvish eyes to be a circular aperture and that Legolas is the same height as the actor who portrayed him (Orlando Bloom).

Method

The Rayleigh's criterion for resolution is the minimum distance between two point sources that can be resolved into distinct objects, it is a diffraction limited imaging process when the first diffraction minimum of the image of one source coincides with the maximum of another [3]. A circular aperture produces an Airy disc, which is a disc surrounded by other fainter discs. In human eyes this would appear as smearing of the image at greater distances.

The average human pupil size is 2 to 4 mm in bright light [4]. This means that using Rayleigh's criterion, we can calculate the resolution of the human eye at the distance of 5 leagues and using the wavelength of yellow light (590 to 560 nm) [5],

$$\sin\theta_R = \frac{1.22\lambda}{d}. \tag{1}$$

First, using Eq. (1) we calculated the resolution (θ_R) of the average human eye, using the average value of 3 mm (d) of the pupil and an average of 575 nm (λ) for the wavelength of yellow light. We obtained the value of 0.013°.

Using this resolution (converted to radians) and multiplying it by the distance of 24155 m (5 leagues) we found that we wouldn't be able to resolve objects smaller than 5.5 m. This proves that in order for Legolas to be able to resolve the hair colour at that distance, he would have to have larger pupils than normal humans.

Using the distance of five leagues and assum-

ing the separation between the riders that Legolas sees to be 2.0 m, we can use the small angle approximation, which states that for small θ

$$sin\theta \approx tan\theta \approx \theta, \tag{2}$$

to allow us to equate this to Rayleigh's criterion. This gives

$$\frac{2}{24155} = \frac{1.22\lambda}{d}, \tag{3}$$

which can be rearranged to find the diameter of Legolas' pupil. We found this to be 8.5 mm, which is over 2 times greater than the average human pupil in bright light.

However, due to the curvature of the Earth and Legolas being 1.8 m tall [6], he would only be able to see to a distance of 4.7 km [7]. Therefore, he would have to be a at a certain height above the ground.

For an observer at a height h (in m), we can use

$$D = 3.57\sqrt{h}, \tag{4}$$

where D is the distance (in km) [7], to calculate at what height Legolas would have to be (ignoring the effect of atmospheric refraction).

Rearranging Eq. (4) for h, we calculated that Legolas would have to see the riders from 45.8 m. Therefore accounting for his height and assuming his eye level is approximately at 1.7 m, he would have to be at an elevation of approximately 44.1 m.

Conclusion

In this investigation, we calculated the resolution of the human eye and calculated whether an average human would be able to distinguish between riders at the distance of 5 leagues which ended up not being possible. After this we calculated the size of Legolas' pupil to be 8.5 mm, which is over twice as large as a normal human's.

Furthermore, we calculated how high up Legolas would have to be, to see to a distance of 5 leagues. We found this to be approximately 44.1 m.

A pupil size of 8.5 mm isn't that far fetched, since the human pupil can dilate up to 8 mm in the dark [4], however this would look rather weird in bright light.

References

[1] J. R. R. Tolkien, *The Two Towers*, p. 7

[2] J. R. R. Tolkien, *The Two Towers*, p. 43

[3] `http://astronomy.swin.edu.au/cosmos/R/Rayleigh+Criterion` [Accessed 28 October 2018]

[4] `https://www.ncbi.nlm.nih.gov/books/NBK381/` [Accessed 28 October 2018]

[5] `https://en.wikipedia.org/wiki/Color` [Accessed 28 October 2018]

[6] `https://healthyceleb.com/orlando-bloom-height-weight-body-statistics/18009` [Accessed 28 October 2018]

[7] `https://en.wikipedia.org/wiki/Horizon` [Accessed 28 October 2018]