S4_2 Ant-Man: Resolving stars in the Hercules Constellation

M. J. Duggan, J. T. Best, S. M. B. Croxford

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

October 18, 2017

Abstract

In the penultimate fight scene in 2016's "Captain America: Civil War", Ant-Man stuns the other superheroes by becoming Giant-Man. The diameter of his eye has now drastically increased, allowing more light to enter. We determined his optical resolution using the Rayleigh Criterion to be $1.68''$ (arc-seconds), resulting in him being capable of resolving the Zeta Hercules multiple star system in the constellation of Hercules, at a distance of 10.72 pc.

Introduction

In the 2015 superhero hit "Ant-Man", Scott Lang (who is the tiny hero) demonstrated that when wearing the Ant-Man suit he can shrink down to the size of an ant. Later, in the 2016's "Captain America: Civil War" Ant-Man reveals that his suit also enables him to become 'Giant Man', whereby his dimensions are uniformly increased. In this paper we will investigate how the change from Ant-Man to Giant-Man will enable him to resolve astronomical objects.

Theory

In order to determine whether Giant-Man can resolve astronomical objects, surpassing the ability of the eye of the average human, we need to compare his height to that of the average human. The average height of an American male is 1.763 m [1]. An estimation of Giant-Man's height was made by comparing him to an Airbus A340 commercial plane which can be seen during the fight scene in "Captain America: Civil War". The plane model has an average height of 17 m [2], and Giant-Man was estimated to be twice the

height of the plane, resulting in a height of 34 m. Thus Giant-Man is 19.3 times taller than the average American man.

The pupil of the human eye receives light in a similar fashion to the lens of a telescope. The greater the diameter of the pupil, the more light can be received, and the greater the resolving power. The average Caucasian pupil diameter is 4.30 mm [3], therefore Giant-man's pupil is 19.3 times greater at 8.3 cm.
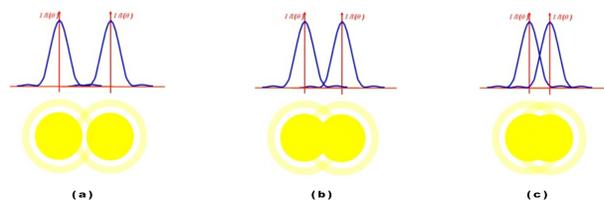
Figure 1: Illustrates the optical resolution limit of two different stars. (a) Since the Airy disk do not overlay, the stars are resolvable. (b) Even thought the Airy disks overlap, the stars are just resolvable because their separation is greater than the Airy disk radius. (c) Airy disks have a critical overlap, resulting in the stars not being resolvable.[4].

The Rayleigh Criterion specifies the minimum separation of two point sources at which they can still be resolved, as the coincidence of the first diffraction maximum of one source with the first minimum of the second [5]. This criterion applies only to circular aperture lenses, thus is ideal for determining the resolution of the human eye. The circular aperture creates an Airy disk (also known as an Airy pattern), which describes the rings of bright and dark fringes; these can be seen in Figure 1. The equation for the optical resolution [6] for a small angle (limiting angle), θ of a given wavelength λ for a circular aperture with diameter D is given by

$$\theta_{\min} \approx \frac{1.22\lambda}{D} \qquad (1)$$

Figure 1.b illustrates $\theta_{\min}$ to be just resolvable.

Results

Using the optimal wavelength for the average human eye (555 nm) [7] and equation (1), the optical resolution for Giant-Man and the average human is $1.68''$ (arc-seconds) and $32.4''$, respectively. This new power will enable him to resolve a binary star system at a distance of 10.72 pc in the constellation Hercules, which is readily visible to the naked eye. Here, a parsec is defined as the distance at which one Astronomical Unit subtends an angle of one arcsecond.

Discussion

Since he is effectively a ground-based telescope, there are several limiting factors which he would share with conventional ground-based telescopes such as light pollution and atmospheric turbulence. These would decrease the sharpness of the images. Both of these factors can be minimised by observing at high altitudes and away from built up areas, such as the Very Large Telescope in Chile. Giant-Man's optical resolution will be less than the value given in the paper based on these limitations. The atmosphere also absorbs significant proportions of the electromagnetic spectrum. Fortunately for Giant-Man, this factor will not hinder him since he can only observe in the visible part of the EM spectrum. Figure 2 demonstrates what Giant-Man would be able to see.
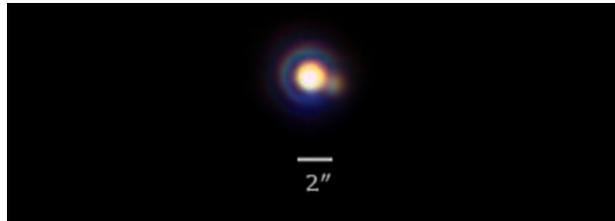
Figure 2: Image of binary star system Zeta Hercules [8].

Pupils dilate at low light intensity (for instance at night), thereby trying to maximise light intake; this paper could be improved by completing the optical resolution for a dilated pupil. The limiting angle, $\theta_{\min}$, would reduce leading to a greater resolution power.

References

[1] https://goo.gl/QYGF71 [Accessed 12 October 2017]

[2] https://goo.gl/wuGyKS [Accessed 12 October 2017]

[3] Y. Li, and D. Huang, "Pupil size and iris thickness difference between asians and caucasians measured by optical coherence tomography", Investigative Ophthalmology and Visual Science, 2009.

[4] https://goo.gl/PagYkb [Accessed 12 October 2017]

[5] https://goo.gl/Mokexn [Accessed 12 October 2017]

[6] N. Bannister, "Inference and diffraction, course 112, unit 4".

[7] https://goo.gl/22FsNo [Accessed 12 October 2017]

[8] https://goo.gl/aJVYEM [Accessed 12 October 2017]