Proceedings of the Iowa Academy of Science

Volume 20 | Annual Issue Article 31

1913

An Experimental Investigation of the Relation Between the Aperture of a Telescope and the Quality of the Image Obtained by It

Fred Vorhies

Let us know how access to this document benefits you

Copyright ©1913 Iowa Academy of Science, Inc.
Follow this and additional works at: https://scholarworks.uni.edu/pias

Recommended Citation
Vorhies, Fred (1913) "An Experimental Investigation of the Relation Between the Aperture of a Telescope and the Quality of the Image Obtained by It," *Proceedings of the Iowa Academy of Science, 20(1),* 282-287.
Available at: https://scholarworks.uni.edu/pias/vol20/iss1/31

This Research is brought to you for free and open access by the Iowa Academy of Science at UNI ScholarWorks. It has been accepted for inclusion in Proceedings of the Iowa Academy of Science by an authorized editor of UNI ScholarWorks. For more information, please contact scholarworks@uni.edu.

AN EXPERIMENTAL INVESTIGATION OF THE RELATION BETWEEN THE APERTURE OF A TELESCOPE AND THE QUALITY OF THE IMAGE OBTAINED BY IT.

BY FRED VORHIES.

The subject of telescopic vision was presented to the scientific world a few years ago in a series of articles written by Dr. G. J. Stoney.[1] At that time Dr. Stoney discussed the proposition as applied to the vision of distant planets and drew the conclusion that astronomers were not able to detect certain details upon the planet Mars. Since the appearance of this series of articles a considerable discussion has taken place but no definite conclusions have been drawn.

With these things in mind I set up in one of the physics research laboratories of the State University, apparatus designed especially for the purpose of investigating the effects that we get when viewing an illuminated surface through telescopes of different apertures. It is understood that the focal length of the lens is not important if the magnification is sufficient.

For the purpose of clearness and simplicity, I made the following assumption which I later proved, experimentally, to be correct. In looking at the planet Mars, or any illuminated surface the same effects are obtained, whether we illuminate the surface from in front with diffused light or whether we remove the object and place in its stead a transparent object with the same details painted upon it and illuminate this new object from behind.

Taking it for granted that the above assumption is correct, let us imagine that the planet Mars is removed and in its place a transparent object is located. In order to simplify matters still more let us illuminate this transparent object from behind with a point source of light, instead of with an infinite number of point sources, as we have in diffused light. If we then imagine a large lens placed in front of this transparent object we shall be ready to consider the different effects that appear. The lens is introduced for the purpose of analysis and has no effect on the image. This lens will focus the image at some definite point. If we should imagine this light after it has been focussed we would find that it consists of a central bright spot surrounded by a

[1]Philosophical Magazine vol. 16, 1908.

series of diffraction rings. Allowing this diffraction pattern to fail within a telescope we find that it gives us an image of the illuminated object. Airy investigated this diffraction pattern and gave us a formula for measuring the diameter of these rings.[2] Since most of the light is contained in the central bright spot and the first five diffraction rings, we shall make use of this particular number in our discussion.

In order better to understand the last paragraph let us refer to Fig. 1. Light from the monochromatic illuminator M, is focussed by lens L_1 upon the pin hole S. The lens L_2 focusses this pin hole upon the aperture A, and provides the light for an image of object O in the camera or telescope C. If we wish to use diffused light from the back, S is replaced by a carbon lamp which has a ground glass in front of it. If we wish to illuminate O from in front, the lamp can be moved to the position R, which is in front and a little to one side of O. In the last case as a matter of convenience, it is well to remove the lens L_2.

Now Airy's formula for the radius of the fifth diffraction ring is Sin $y=2.621 \Delta/r$ where y is the angle of diffraction, Δ the wave length of the light used, and r the radius of the lens casting the image of the point. Since the radius of Mars is about 2,100 miles, we have Sin $y=2.621 \times .000055/2100$ where .000055 cm. is the average wave length of light in the visible spectrum. Let X equal the radius of the fifth minimum diffraction ring and we have Sin $y=X/35,050,000$ where 35,050,000 miles is the closest distance Mars gets to the earth. From these two expressions for Sin y we get the value of X which is 2.406 cm., the radius of the fifth dark ring, or 2X equal 4.812 cm. the diameter of the fifth dark ring for Mars.

If we use a 24 in. telescope, we find that the telescope diameter is 12.66 times as great as the diameter of the diffraction pattern, out to and including the fifth dark ring from Mars.

Taking as the object which represents Mars, a hole 1.05 mm. in diameter, I illuminated it from behind with a point source of light and brought this light to a focus with the lens L_2 as shown in Fig. 1. Focussing a lens on the point where this light was focussed I was able to study the diffraction pattern, and by means of a scale on the lens, I measured the diameter of the fifth ring. This observed value was 6 mm., a value a trifle smaller than that computed for these conditions.

If the telescope aperture is 4 mm. in diameter, the diameter of the fifth diffraction ring admitted should be 4/12.66 which equals .3159 mm. Reasoning from this, .3159 : 6 : : 1.05 : X and X equals 1.994 cm. which

[2] Wood's Physical Optics, p. 237.

is the diameter of the object which is to represent Mars. This value was so near to an even number that I made the object which I used 2 cm. in diameter. We are told that Astronomers are able to detect certain so called "canals" upon Mars which vary from twenty to sixty or seventy miles in width. To represent these I used wires of suitable dimensions and placed them in such shapes that they formed patterns which could be studied in the different photographs which I later took.[3]

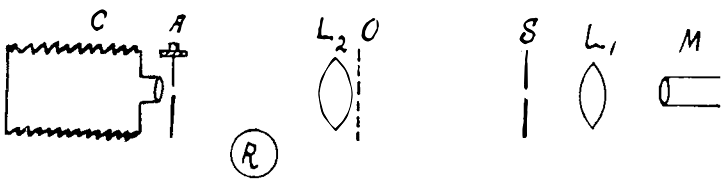

Fig. 1.

The apparatus in its final form is shown in diagram in Fig. 1 and in the photograph, Fig. 2. To the right and not shown in the picture is a large box containing an arc light. Light from this is passed through a lens in the front of the box and is focussed after reflection by a mirror onto the slit of the monochromatic illuminator which appears to the right. From the illuminator green light of .000055 cm. wave length passes through a lens and is focussed upon a pin hole. This in turn acts as a final light source and illuminates the object which is mounted upon the optical bench. Directly in front of this object and on the same support is a large acromatic lens which focusses the light from the point source upon the camera aperture to the left of the figure. The camera in this case taking the place of a telescope. The aperture of the camera is separate from the camera itself and is mounted upon a support which has a micrometer screw attached. This permits a motion of the aperture and thus enables me to admit any portion of the diffraction pattern that I wish.

To get the effects of a smaller sized telescope, all that is necessary, is to remove the 4 mm. aperture which is made in a plate of tin, and replace it with a smaller opening. In my work a 4 mm. aperture represents a 24 in. telescope; 3 mm., 18 in.; 2 mm., 12 in.; 1 mm. 6 in.; and .4 mm., 2.5 in.

Fig. 3 is a series of photographs which show not only the different effects that we would get in looking at an object optically similar to Mars with telescopes of different sizes but also gives an analysis of the image. Nos. 1-9 form a series taken with a 24 in. telescope. No. 1 was

[3]Because of a slight error in my calculations the apertures used are about seven per cent too small.

taken with the diffraction pattern directly in the center of the camera. The rest were taken by moving the aperture of the camera 1/2 mm. to one side each time. This means that the central bright spot was not in the camera when Nos. 5-9 were taken. You will notice that the lines have changed from black to white and that some of the original single ones now appear double. This is simply a diffraction effect that we would expect to get under these conditions. No. 1 was taken under the best possible conditions and is a better image than can be obtained in actual observations of Mars or of my substitute for Mars. I have chosen to call this an optimum image. Now if we had used diffused light instead of light from a point source we would have obtained the sum total of an infinite number of images like the ones shown in this series. To investigate this point I made a composite picture of the first nine by making all of these exposures in one place instead of moving the plate as I had done before. From this exposure I obtained No. 10, which you see is not as good as No. 1. Realizing, however, that I had over emphasized the poorer images in this series by longer exposures, I made No. 11 which is also a composite picture of Nos. 1-9. In this case I exposed the plate one minute for each one of the nine different exposures. This picture is equivalent to one obtained with diffused light and is almost as good as No. 1. From this I drew the conclusion that under normal conditions one should be able to see such details as those of the dimensions I had chosen, upon the planet with a 24 in. telescope.

Nos. 12-20 form another series taken under the same conditions as the first series, except that the equivalent of a 12 in. telescope was used. While in the second series the optimum is very good we see that the images rapidly fall off in distinctness and that where above we have five good images and four poor ones, we now have two good ones and seven poor ones. The total composite, No. 21, is very poor while No. 22, the normal composite, is fairly good. It is quite evident, however, that No. 22 is not as good as No. 11.

Nos. 23-27 form a series of optima made with telescopes of 24 in., 18 in., 12 in., 6 in., and 2.5 in. respectively. While these images are better than can be obtained in actual practice they do show an interesting point. It is quite evident that the larger telescopes are the more efficient.

Nos. 28-32 and 33-36 were taken with the above telescopes with diffused light from the back, and reflected light from the front, respectively. These images give us an idea of what we should expect in actual observation work and they correspond to telescope apertures given for the images immediately above them, from Nos. 23-27. The main point

Vorhies: An Experimental Investigation of the Relation Between the Apertur

brought out by these is the fact that there is no difference between those taken with the diffused light from behind and those illuminated from the front. This is an important point for it proves the assumption which I made early in the paper.

As I have already explained, this diffused light from the back was obtained by placing an incandescent light covered with ground glass, in the place of my point source. To get the illumination in front, I moved this light in front and a little to one side of the object, removed the lens, and placed just back of the object a piece of white card board which acted as a background. The removal of the lens did not change the optical conditions in any way.

You will notice that what would have been No. 37, which would have been taken with reflected light with the 2.5 in. telescope is missing. I made several attempts to get this picture but could get no effects. I made one exposure of eighteen hours but got no fogging of the plate.

After making one hundred forty different exposures and studying them carefully I have come to the conclusion that astronomers can see, without question, certain details upon the planet Mars. While I do not have absolute evidence, yet I also believe that there is very little advantage in using a telescope larger than twenty-four inches for obtaining details of objects as large as 20 miles across.

For fear that I may be misunderstood I want to say that I have not taken into account the different atmospheric conditions with which the astronomer has to contend. I wish to state also that this investigation does not apply alone to the planet Mars but may be applied to the study of any illuminated surface.

My work is by no means completed. I expect to continue by investigating smaller details upon my object and by varying the atmospheric conditions and noting the effects produced.

In closing I wish to express my thanks to Dr. L. P. Sieg for the valuable advice he gave me during the course of my work and for the assistance he rendered on many occasions.

Published by UNI ScholarWorks, 1913

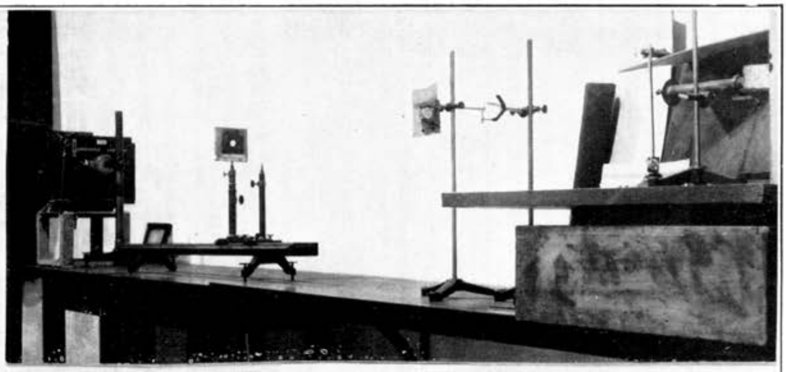

Fig. 2.

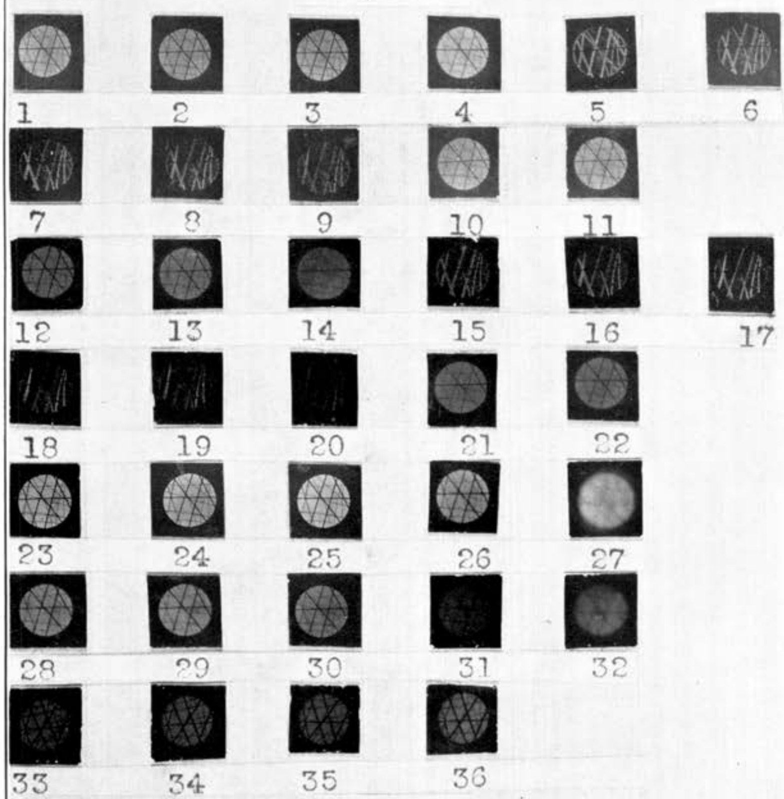
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36

Fig. 3.