THE OPTICAL TELESCOPE

OBJECTIVE

This exercise introduces the student to the telescope and how to operate it before using it to observe astronomical objects.

EQUIPMENT

The student will need a telescope and two different eyepieces in order to complete this exercise.

INTRODUCTION

The telescope can be defined as a 'light bucket' with the function of gathering as many photons as possible from a given region of the sky and directing them to a focal point. Today, we have many kinds of telescopes so that we can view the sky in many different wavelengths of the electro-magnetic spectrum. But the first telescopes, and the most common, are the optical telescopes, which collect light in the visible region.

The discovery of the telescope was first announced by Hans Lippershey, a Dutch optician, in 1608 when he filed for a patent. Galileo then became the first to use one to perform astronomical observations in late 1609, or early 1610. One of the first things he discovered was that the Moon was not perfect, there were mountains and craters on its surface. He also found that there were spots on the face of the Sun, Venus went through phases like the Moon, and discovered the first four moons of Jupiter - today known as the Galilean moons. All of these were very dramatic contradictions with Aristotle's geocentric, perfect universe and strongly supported the heliocentric universe of Copernicus. Thus, the age of the telescope began, and immediately began changing our understanding of the universe.

These early telescopes used a lens that would bend the rays of light to a focal point. Telescopes of this kind are called refracting telescopes. Though they provided a tremendous advance over the bare eye, they also had problems, among them was the problem of making lenses with great accuracy. Also, there was the problem of color fringes along the edges of objects, known as chromatic aberration. This was due to the fact that glass bends light, but it bends different colors different angles, thus making a small rainbow (chroma means color). A solution to this problem was found in 1757 by using two lenses. The second lens is made of a slightly different kind of glass and would then cancel out the chromatic aberration of the first. But now, the light is passing through two lenses and is being absorbed by both. Since glass absorbs certain wavelengths, this makes these telescopes much less useful at those wavelengths.

Later, as telescopes became bigger, making larger and larger lenses became a problem, as well as very expensive. Supporting these large lenses is also difficult. They have to be supported at the edges so as not to block the light and this causes them to sag slightly in the middle, resulting in a slight unfocusing of the image. In addition, refractors are of necessity very long, which makes them susceptible to wind and vibrations. The world's largest refractor is at the Yerkes Observatory in Williams Bay, Wisconsin. It was constructed in 1897, has a lens 1.02 meters in diameter and is 19.5 meters long.

In the 1600's, Sir Isaac Newton, convinced there was no solution to the problem of chromatic aberration, developed a telescope that used mirrors, not lenses, to focus a large amount of light on a small eyepiece. A telescope that uses a mirror instead of a lens is called a reflecting telescope. The lenses are located within the eyepiece and are kept small. The mirror can be supported everywhere along the backside of it, so they are much more stable and can be considerably larger.

While easier to make than lenses, the mirrors are still very difficult to make. It use to take as much as 5-6 years to make a mirror for a giant telescope, and there was an effective limit on how big you could make it. Just to let the molten material cool can take years to prevent flaws from forming. Then it takes years to grind them. The final product will then be very heavy and requires a custom made mount. Eventually, the mirror becomes so large that its nearly impossible to make them flawless, and the finished product would weigh so much that it would be extremely difficult to keep it steady. This is the way it was for about 40 years. However, new technologies are now allowing a new generation of larger telescopes. Now, they can make mirrors and lenses in 2-3 years, and they can make them as big as you want. New technologies in mounts, instruments, and even in the environmental domes themselves have led to a sudden explosion in giant telescopes.

Previously, the largest effective telescopes were the 5-meter Hale telescope at Mt. Palomar, and a 6-meter telescope made by the Soviet Union. Now, due to these new technologies, more than a dozen telescopes larger than Hale will be operational by the end of the decade. The largest reflectors in the world are the 11-m Hobby-Eberly Telescope at the McDonald Observatory in Texas (which is used for spectroscopy only) and the two 10-m Keck telescopes at Mauna Kea, Hawaii. The Hubble Space Telescope is a reflecting telescope with a 2.4-m mirror.

In a reflecting telescope, any ray of light that enters the telescope parallel to the telescope's axis is reflected by the mirror to a point called the prime focus. The distance from the mirror to this point is known as the focal length. Any instrument - the eye, a camera or an electronic device - at this location can view the image. However, light rays are not absolutely parallel, and this results in an elongation of images the further we get from the prime focus. This elongation is called coma, and is the main limiting factor of a reflecting telescope. Refractors also have better overall clarity than reflectors. However, reflectors are still the telescope of choice among amateurs and professionals.

One purpose of the large aperture of a telescope is to collect light and bring it to a point, concentrate it, so to speak. This way, it is possible to see very faint objects. Another purpose is to provide greater resolution. Resolution is the ability to distinguish between objects. The greater the resolution, the greater the ability to distinguish objects, or features. And the greater the aperture on the telescope, the greater the resolution. Resolution is a function of how many wavelengths can be fit across the aperture. On a refracting telescope, aperture is measured by the lens size. On a reflecting telescope, aperture is measured by the mirror size. In the visual spectrum, wavelengths are very small, thus we can achieve very great resolution.

But there is another limiting factor - the atmosphere and what is in it. These atmospheric effects include the weather (you can't see through clouds), moisture (water absorbs certain wavelengths), dust and dirt (natural or manmade), and the air itself, which causes 'twinkling'. The atmosphere is the major limiting factor for most telescopes, and keeps us from reaching the theoretical limit on ground based telescopes. Due to atmospheric effects, the 10-m Keck I telescope would have the same resolving power of a 10-inch telescope if it were located at sea-level. For this reason, we place telescopes at locations that limit atmospheric effects, usually on mountain tops above the weather, above the moisture, above the dirt and dust, and above as much of the atmosphere as possible. The observatories on Mauna Kea, Hawaii are at over 4200 meters and above 40% of the atmosphere. These mountain tops need to be remote because another factor limiting telescopes is light pollution, light escaping skyward from manmade sources.

BIBLIOGRAPHY

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QUESTIONS

1. What is the principle difference between a reflector and an refractor?

2. A increasingly important observatory site is Antarctica. List four reasons why a location on top of an ice sheet would make a good observatory site.

3. The Hubble Space Telescope cost over $2 billion. Why would we want to spend this much money to put a 2.4-meter telescope in orbit when we have 10-meter telescopes on the Earth's surface that cost much less (The Keck telescopes cost about $70 million)?

4. Besides cost, what are two advantages to a telescope on the ground compared to a telescope in orbit?

5. If reflecting telescopes are so much better than refractors, why are refracting telescopes still made and used?

6. Why would we be interested in placing telescopes at lower altitudes at a site in the southern hemisphere, when we can put them at higher altitudes in the northern hemisphere?

7. The mirrors in the giant reflectors have to be periodically removed, polished clean, and re-aluminized (a thin layer of aluminum is applied to the glass to make the mirror). Which month of the year is this operation usually done? Why?

EXERCISE

1. Find the focal length of the telescope you are using.

2. Find the aperture of the telescope you are using.

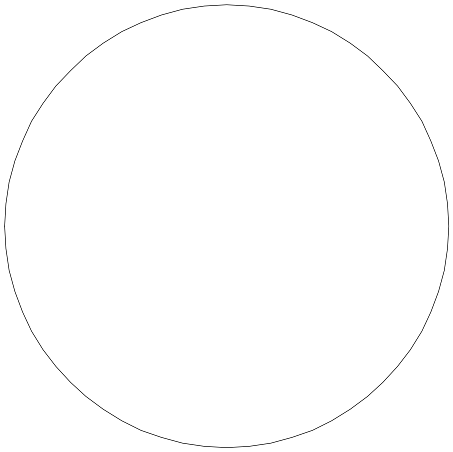
3. What is the size of eyepiece #1 that you are using?

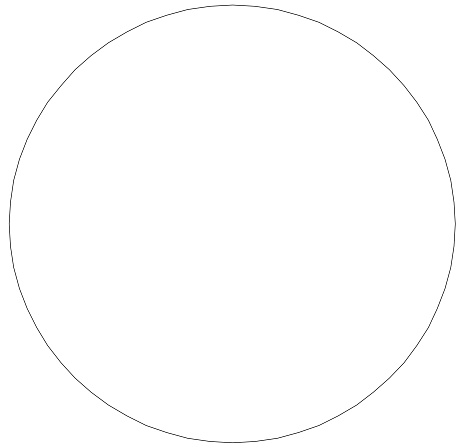
4. What is the size of eyepiece #2 that you are using?

5. Calculate the magnification, M, for eyepiece #1.
Use the equation M = focal length of telescope/focal length of the eyepiece.

6. Calculate the magnification for eyepiece #2.

7. Aim the telescope at something familiar, such as a STOP sign or a tree in the distance.
Sketch what you see through the spotting scope.





8. In the diagram below, sketch what you see through eyepiece #1.

9. In the second diagram, sketch what you see through eyepiece #2.

10. Which eyepiece gives a wider field of view?

11. Calculate the telescope's light gathering power, P. Use the equation P = ðr^2, where r is the radius of the telescope in centimeters.

12. Calculate the telescope's resolving power, R. Use the equation R = 5.7/r.

13. Does the telescope's light gather power change with eyepieces? Why or why not?

14. Calculate the rotation rate of the Earth by timing a star's drift across the field of view of the telescope.

Star name:

Star's declination ä:

Drift time in seconds:

Drift time in hours:

Telescope aperture á:

r = á/drift time in hours =

Rotation rate of the Earth = R = r/cos ä =

% Error = (15-5)/15 x 100 =