
Be A
Stargazer
A Guide To Astronomy

PREFACE

All sciences are making an advance, but Astronomy is moving at high speed. Since the principles of this science were settled by Copernicus, four hundred years ago, it has never had to beat a retreat. It is rewritten not to correct material errors, but to incorporate new discoveries.

At one time, Astronomy studied mostly tides, seasons, and telescopic aspects of the planets; now these are only primary matters. Once it considered stars as mere fixed points of light; now it studies them as suns, determines their age, size, color, movements, chemical constitution, and the revolution of their planets. Once it considered space as empty; now it knows that every cubic inch of it quivers with greater intensity of force than that which is visible in Niagara. Every inch of surface that can be conceived of between suns is more wave-tossed than the ocean in a storm.

The invention of the telescope constituted one era in Astronomy; its perfection in our day, another; and the discoveries of the spectroscope a third—no less important than either of the others. New discoveries are made every day with the advancement of telescopes. The Hubble space telescope has let man see further into the universe then ever before. Astronomy and space science is an ever changing study, and possibly the most exciting of the sciences. It is for one reason that this book was written, to hopefully interest more people in the exciting study of the universe around us.

CONTENTS

Why Study Light?

For most of history, humans have used visible light to explore the skies. With basic tools and the human eye, we developed sophisticated methods of time keeping and calendars. Telescopes were invented in the 17th century. Astronomers then mapped the sky in greater detail––still with visible light. They learned about the temperature, constituents, distribution, and the motions of stars.

There are two main techniques for analyzing starlight. One is called spectroscopy and the other photometry. Spectroscopy spreads out the different wavelengths of light into a spectrum for study. Photometry measures the quantity of light in specific wavelengths or by combining all wavelengths. Astronomers use many filters in their work. Filters help astronomers analyze particular components of the spectrum. For example, a red filter blocks out all visible light wavelengths except those that fall around 600 nanometers (it lets through red light).

Introduction to Light

Light is a form of radiant energy or energy that travels in waves. Since Greek times, scientists have debated the nature of light. Physicists now recognize that light sometimes behaves like waves and, at other times, like particles. When moving from place to place, light acts like a system of waves. In empty space, light has a fixed speed and the wavelength can be measured. In the past 300 years, scientists have improved the way they measure the speed of light, and they have determined that it travels at nearly 299,792 kilometers, or 186,281 miles, per second.

When we talk about light, we usually mean any radiation that we can see. These wavelengths range from about 16/1,000,000 of an inch to 32/1,000,000 of an inch. There are other kinds of radiation such as ultraviolet light and infrared light, but their wavelengths are shorter or longer than the visible light wavelengths. When light hits some form of matter, it behaves in different ways. When it strikes an opaque object, it makes a shadow, but light does bend around obstacles. The bending of light around edges or around small slits is called diffraction and makes patterns of bands or fringes.

All light can be traced to certain energy sources, like the Sun, an electric bulb, or a match, but most of what hits the eye is reflected light. When light strikes some materials, it is bounced off or reflected. If the material is not opaque, the light goes through it at a slower speed, and it is bent or refracted. Some light is absorbed into the material and changed into other forms of energy, usually heat energy. The light waves make the electrons in the materials vibrate and this kinetic energy or movement energy makes heat. Friction of the moving electrons makes heat.

Experiments With Light

A light set in a room is seen from every place; hence light streams in every possible direction. If put in the centre of a hollow sphere, every point of the surface will be equally illumined. If put in a sphere of twice the diameter, the same light will fall on all the larger surface. The surfaces of spheres are as the squares of their diameters; hence, in the larger sphere the surface is illumined only one-quarter as much as the smaller. The same is true of large and small rooms. In Fig. 7 it is apparent that the light that falls on the first square is spread, at twice the distance, over the second square, which is four times as large, and at three times the distance over nine times the surface. The varying amount of light received by each planet is also shown in fractions above each world, the amount received by the earth being 1.

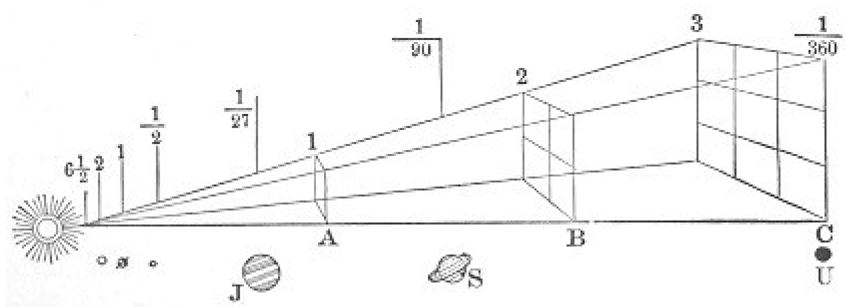


Fig. 7.

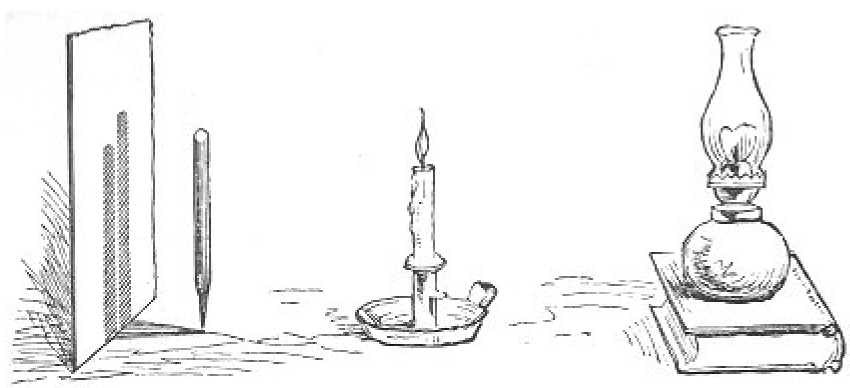


Fig. 8.—Measuring Intensities of Light.

The intensity of light is easily measured. Let two lights of different brightness, as in Fig. 8, cast shadows on the same screen. Arrange them as to distance so that both shadows shall be equally dark. Let them fall side by side, and study them carefully. Measure the respective distances. Suppose one is twenty inches, the other forty. Light varies as the square of the distance: the square of 20 is 400, of 40 is 1600. Divide 1600 by 400, and the result is that one light is four times as bright as the other.

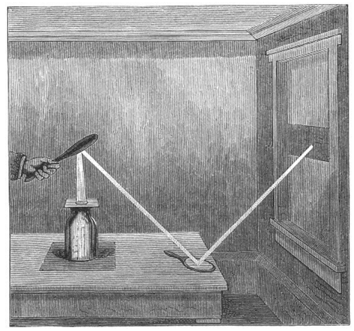


Fig. 9.—Reflection and Diffusion of Light.

Light can be handled, directed, and bent, as well as iron bars. Darken a room and admit a beam of sunlight through a shutter, or a ray of lamp-light through the key-hole. If there is dust in the room it will be observed that light goes in straight lines. Because of this men are able to arrange houses and trees in rows, the hunter aims his rifle correctly, and the astronomer projects straight lines to infinity. Take a hand-mirror, or better, a piece of glass coated on one side with black varnish, and you can send your ray anywhere. By using two mirrors, or having an assistant and using several, you can cause a ray of light to turn as many corners as you please.

Set a small light near one edge of a mirror; then, by putting the eye near the opposite edge, you see almost as many flames as you please from the multiplied reflections. How can this be accounted for?

Into your beam of sunlight, admitted through a half-inch hole, put the mirror at an oblique angle; you can arrange it so as to throw half a dozen bright spots on the opposite wall.

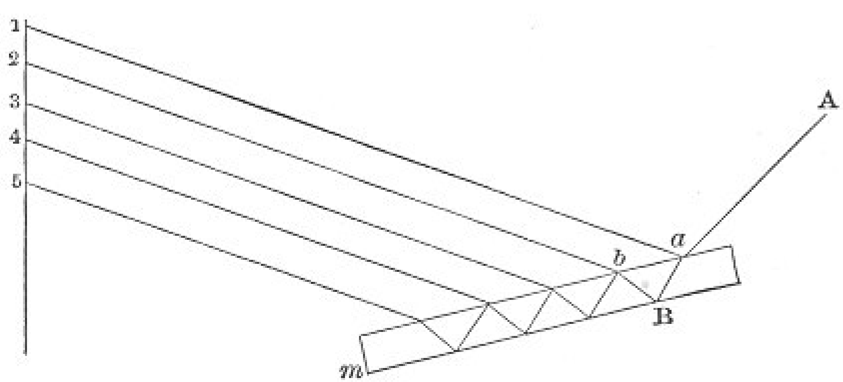


Fig. 10.—Manifold Reflections.

In Fig. 10 the sunbeam enters at A, and, striking the mirror m at a, is partly reflected to 1 on the wall, and partly enters the glass, passes through to the silvered back at B, and is totally reflected to b, where it again divides, some of it going to the wall at 2, and the rest, continuing to make the same reflections and divisions, causes spots 3, 4, 5, etc. The brightest spot is at No.2, because the silvered glass at B is the best reflector and has the most light.

Take a small piece of mirror, say an inch in surface, and putting under it three little pellets of wax, putty, or clay, set it on the wrist, with one of the pellets on the pulse. Hold the mirror steadily in the beam of light, and the frequency and prominence of each pulse-beat will be indicated by the tossing spot of light on the wall. If the operator becomes excited the fact will be evident to all observers.

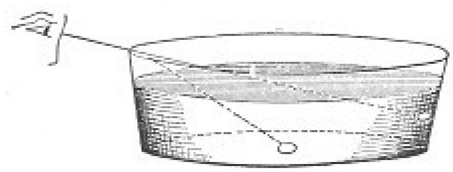


Fig. 11.

Place a coin in a basin (Fig. 11), and set it so that the rim will conceal the coin from the eye. Pour in water, and the coin will appear Page 40 to rise into sight. When light passes from a medium of one density to a medium of another, its direction is changed. Thus a stick in water seems bent. Ships below the horizon are sometimes seen above, because of the different density of the layers of air.

Thus light coming from the interstellar spaces, and entering our atmosphere, is bent down more and more by its increasing density. The effect is greatest when the sun or star is near the horizon, none at all in the zenith. This brings the object into view before it is risen. Allowance for this displacement is made in all delicate astronomical observations.

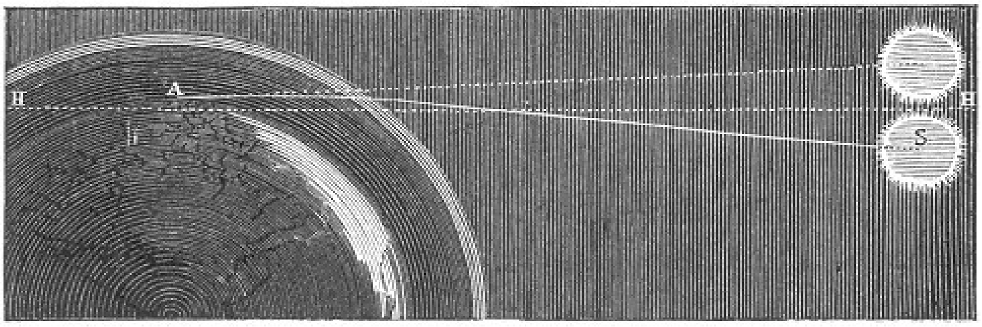


Fig. 12.—Atmospherical Refraction.

Notice on the floor the shadow of the window-frames. The glass of almost every window is so bent as to turn the sunlight aside enough to obliterate some of the shadows or increase their thickness.

DECOMPOSITION OF LIGHT

Admit the sunbeam through a slit one inch long and one-twentieth of an inch wide. Pass it through a prism. Either purchase one or make it of three plain pieces of glass one and a half inch wide by six inches long, fastened together in triangular shape—fasten the edges with hot wax and fill it with water; then on a screen or wall you will have the colors of the rainbow, not merely seven but seventy, if your eyes are sharp enough.

Take a bit of red paper that matches the red color of the spectrum. Move it along the line of colors toward the violet. In the orange it is dark, in the yellow darker, in the green and all beyond, black. That is because there are no more red rays to be reflected by it. So a green object is true to its color only in the green rays, and black elsewhere. All these colors may be recombined by a second prism into white light

Introduction to Color

Color is a part of the electromagnetic spectrum and has always existed, but the first explanation of color was provided by Sir Isaac Newton in 1666. Newton passed a narrow beam of sunlight through a prism located in a dark room. Of course all the visible spectrum (red, orange, yellow, green, blue, indigo, and violet) was displayed on the white screen. People already knew that light passed through a prism would show a rainbow or visible spectrum, but Newton's experiments showed that different colors are bent through different angles. Newton also thought all colors can be found in white light, so he passed the light through a second prism. All the visible colors changed back to white light. Light is the only source of color.

The color of an object is seen because the object merely reflects, absorbs, and transmits one or more colors that make up light. The endless variety of color is caused by the interrelationship of three elements: Light, the source of color; the material and its response to color; and the eye, the perceiver of color. Colors made by combining blue, yellow, and red light are called additive; and they are formed by adding varying degrees of intensity and amounts of these three colors. These primary colors of light are called cyan (blue-green), yellow, and magenta (blue-red).

Pigment color found in paint, dyes, or ink is formed by pigment molecules present in flowers, trees, and animals. The color is made by absorbing, or subtracting, certain parts of the spectrum and reflecting or transmitting the parts that remain. Each pigment molecule seems to have its own distinct characteristic way of reflecting, absorbing, or transmitting certain wavelengths. Natural and manmade colors all follow the same natural laws.

Building A Simple Spectroscope

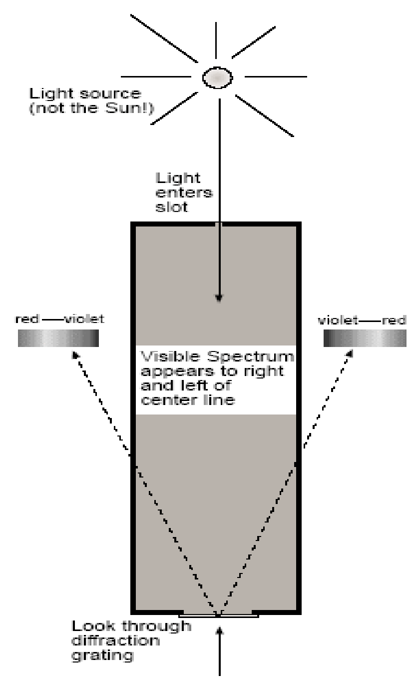
A basic hand-held spectroscope can be made from a diffraction grating and a paper tube.

Objective:

To construct a simple spectroscope with a diffraction grating and use it to analyze the colors emitted by various light sources.

Materials:

Diffraction grating, 2-cm square
Paper tube (tube from toilet paper roll)
Poster board square (5 by 10-cm)
Masking tape
Scissors
Razor blade knife
2 single-edge razor blades
Pencil



Procedure:

1. Using the pencil, trace around the end of the paper tube on the poster board. Make two circles and cut them out. The circles should be just larger than the tube's opening.

2.Cut a 2-centimeter square hole in the center of one circle. Tape the diffraction grating square over the hole.

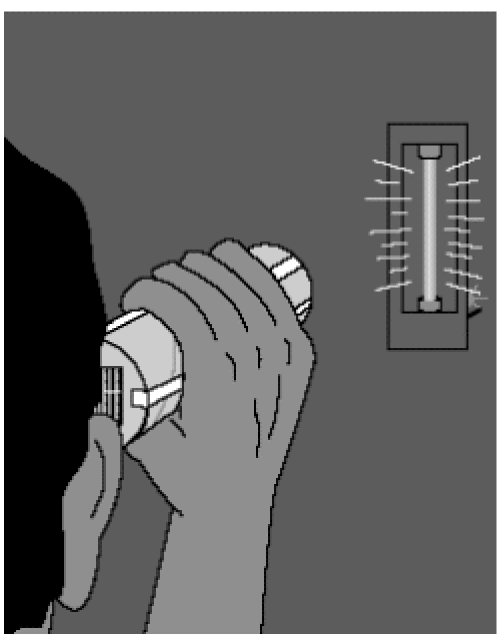
3. Tape the circle with the grating inward to one end of the tube.

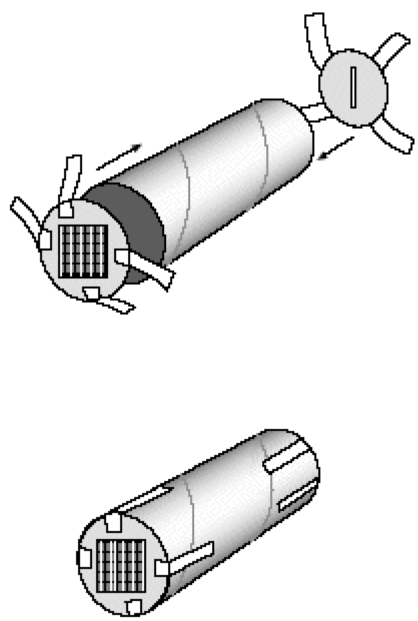
4. Make a slot cutter tool by taping two single- edge razor blades together with a piece of poster board between. Use the tool to make parallel cuts about 2 centimeters long across the middle of the second circle. Use the razor blade knife to cut across the ends of the cuts to form a narrow slot across the middle of the circle.

5. Place the circle with the slot against the other end of the tube. While holding it in place, observe a light source such as a fluorescent tube. Be sure to look through the grating end of the spectroscope. The spectrum will appear off to the side from the slot. Rotate the circle with the slot until the spectrum is as wide as possible. Tape the circle to the end of the tube in this position. The spectroscope is complete.

6. Examine various light sources with the spectroscope.
If possible, examine nighttime street lighting. Use particular caution when examining sunlight. Do not look directly into the Sun.

Background:





Simple spectroscopes, like the one described here, are easy to make and offer users a quick look at the color components of visible light.

Different light sources (incandescent, fluorescent, etc.) may look the same to the naked eye but will appear differently in the spectroscope. The colors are arranged in the same order but some may be missing and their intensity will vary. The appearance of the spectrum displayed is distinctive and can tell the observer what the light source is.

A diffraction grating can spread out the spectrum more than a prism can. This ability is called dispersion. Because gratings are smaller and lighter, they are well suited for spacecraft where size and weight are important considerations. Most research telescopes have some kind of grating spectrograph attached. Spectrographs are spectroscopes that provide a record, photographic or digital, of the spectrum observed.

Many school science supply houses sell diffraction grating material in sheets or rolls. When using the spectroscope to observe sunlight, students should look at reflected sunlight such as light bouncing off clouds or light colored concrete. Other light sources include streetlights (mercury, low-pressure sodium, and high-pressure sodium), neon signs, and candle flames.

ASTRONOMICAL INSTRUMENTS

THE TELESCOPE

Some astronomical instruments are of the simplest character, some most delicate and complex. When a man smokes a piece of glass, in order to see an eclipse of the sun, he makes a simple instrument. Ferguson, lying on his back and slipping beads on a string at a certain distance above his eye, measured the relative distances of the stars.

Refracting Telescope

The use of more complex instruments commenced when Galileo applied the telescope to the heavens. He cannot be said to have invented the telescope, but he certainly constructed his own without a pattern, and used it to good purpose. It consists of a lens, O B (Fig. 13), which acts as a multiple prism to bend all the rays to one point at R. Place the eye there, and it receives as much light as if it were as large as the lens O B. The rays, however, are convergent, and the point difficult to find. Hence there is placed at R a concave lens, passing through which the rays emerge in parallel lines, and are received by the eye. Binoculars are made upon precisely this principle today, because they can be made conveniently short.

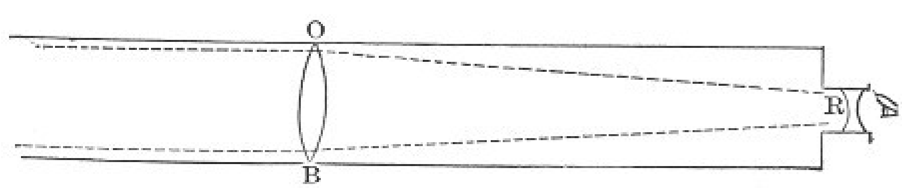


Fig. 13.—Refracting Telescope.

If, instead of a concave lens at R, converting the converging rays into parallel ones, we place a convex or magnifying lens, the minute image is enlarged as much as an object seems diminished when the telescope is reversed. This is the grand principle of the refracting telescope. Difficulties innumerable arise as we attempt to enlarge the instruments. These have been overcome, one after another.

The Reflecting Telescope

This instrument differs radically from the refracting one already described. It receives the light in a concave mirror, M (Fig. 14), which reflects it to the focus F, producing the same result as the lens of the refracting telescope. Here a mirror may be placed obliquely, reflecting the image at right angles to the eye, outside the tube, in which case it is called the Newtonian telescope; or a mirror at R may be placed perpendicularly, and send the rays through an opening in the mirror at M. This form is called the Gregorian telescope. Or the mirror M may be slightly inclined to the coming rays, so as to bring the point F entirely outside the tube, in which case it is called the Herschelian telescope. In either case the image may be magnified, as in the refracting telescope.

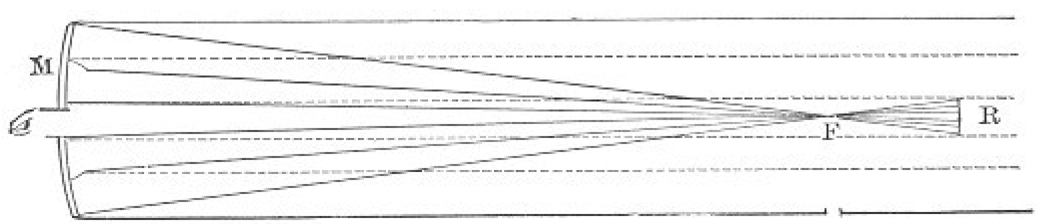


Fig. 14.—Reflecting Telescope.

Reflecting telescopes are made of all sizes, up to the Cyclopean eye of the Subaru telescope which is 327 inches i diameter. The form of instrument to be preferred depends on the use to which it is to be put. The loss of light in passing through glass lenses is about two-tenths. The loss by reflection is often one-half. In view of this peculiarity and many others, it is held that a twenty-six-inch refractor is fully equal to any six-foot reflector.

The mounting of large telescopes demands the highest engineering ability. The whole instrument, with its vast weight , with its accompanying tube and appurtenances, must be pointed as accuratley as a rifle, and held as steadily as the axis of the globe. To give it the required steadiness, the foundation on which it is placed is sunk deep in the earth, far from rail or other roads, and no part of the observatory is allowed to touch this support.

When a star is once found, the earth swiftly rotates the telescope away from it, and it passes out of the field. To avoid this, clock-work is so arranged that the great telescope follows the star by the hour, if required. It will take a star at its eastern rising, and hold it constantly in view while it climbs to the meridian and sinks in the west. The reflector demands still more difficult engineering.

The Spectroscope

A spectrum is a collection of the colors which are dispersed by a prism from any given light. If it is sunlight, it is a solar spectrum; if the source of light is a star, candle, glowing metal, or gas, it is the spectrum of a star, candle, glowing metal, or gas. An instrument to see these spectra is called a spectroscope.

Considering the infinite variety of light, and its easy modification and absorption, we should expect an immense number of spectra. A mere prism disperses the light so imperfectly that different orders of vibrations, perceived as colors, are mingled. No eye can tell where one commences or ends. Such a spectrum is said to be impure. What we want is that each point in the spectrum should be made of rays of the same number of vibrations. As we can let only a small beam of light pass through the prism, in studying celestial objects with a telescope and spectroscope we must, in every instance , contract the aperture of the instrument until we get only a small beam of light.

In order to have the colors thoroughly dispersed, the best instruments pass the beam of light through a series of prisms called a battery, each one spreading farther the colors which the previous ones had spread.

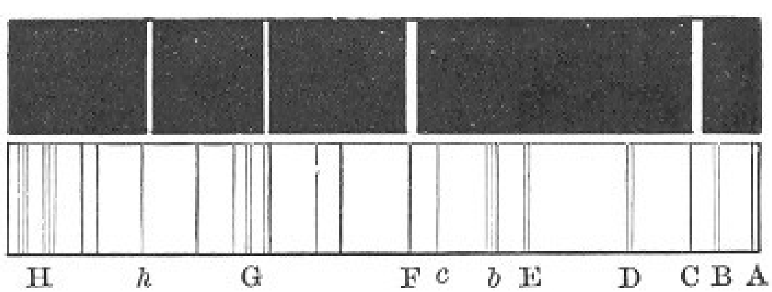


Fig. 18.—Spectra of glowing Hydrogen and the Sun.

In Fig. 18 is seen, in the lower part, a spectrum of the sun, with about a score of its thousands of lines made evident. In the upper part is seen the spectrum of bright lines given by glowing hydrogen gas. These lines are given by no other known gas; they are its autograph. It is readily observed that they precisely correspond with certain dark lines in the solar spectrum. Hence we easily know that a glowing gas gives the same bright lines that it absorbs from the light of another source passing through it—that is, glowing gas gives out the same rays of light that it absorbs when it is not glowing.

The subject becomes clearer by a study of the chromolithic plate. No. 1 represents the solar spectrum, with a few of its lines on an accurately graduated scale. No.3 shows the bright line of glowing sodium, and, corresponding to a dark line in the solar spectrum, shows the presence of salt in that body. No. 2 shows that potassium has some violet rays, but not all; and there being no dark line to correspond in the solar spectrum, we infer its absence from the sun. No.6 shows the numerous lines and bands of barium—several red, orange, yellow, and four are very bright green ones. The lines given by any volatilized substances are always in the same place on the scale.