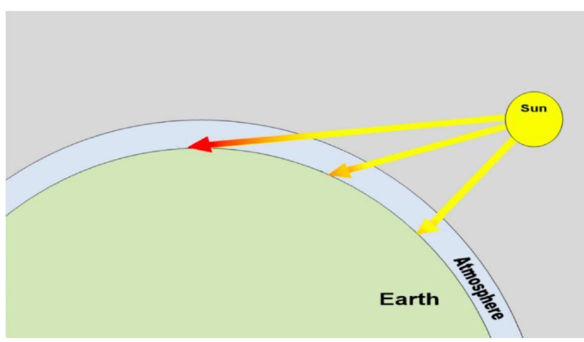
Reading: How do we use spectra to determine what exoplanets are made of?

<table>
<tr><th colspan="2">Obtaining Information from Scientific Texts</th></tr>
<tr><td>Before</td><td>1. With your group: Identify the question(s) you are trying to answer. Record them in your notebook.</td></tr>
<tr><td rowspan="2">During</td><td>2. Read once individually for understanding to see what the reading is about.
Read for the gist - skim the title, headings, and images.
What is the central idea or claim?
Select methods for marking up the text. For example...
Keep track of questions you have in the margins.
Circle key words.
Put question marks by words you want to learn more about.
Underline main ideas.
Examine any images, graphs, or tables. Write one sentence about the central point of each image, graph, or table.</td></tr>
<tr><td>3. Read a second time out loud with your group to identify the key ideas.</td></tr>
<tr><td>After</td><td>4. Summarize the key ideas in your notebook.</td></tr>
</table>

What happens to starlight when it passes through the atmosphere of a planet?

Think back to a sunset on Earth. The Sun's light sometimes looks reddish! This is because when the Sun is low on the horizon, the sunlight passes through more of the Earth's atmosphere than when it is high in the sky in the middle of the day. The Earth's atmosphere lets more red light through than blue light. The blue light bounces off particles in the atmosphere and goes in all directions, a process called scattering. This scattering is what makes the sky look blue during the day. But as the Sun gets lower on the horizon, more and more blue light is scattered as that light now passes through a larger amount of the atmosphere and the light that makes it through to our eyes (or a detector) has much more red light in its spectrum. This is why we see a reddish sunset.



This phenomenon is not unique to Earth's atmosphere. Different substances interact differently with different colors of light. For example, a photography filter, like the one in the image below, contains a substance in it that absorbs or reflects the blue, red, violet, and green colors of light in the spectrum and lets through yellow light, so that the image we see appears yellow.

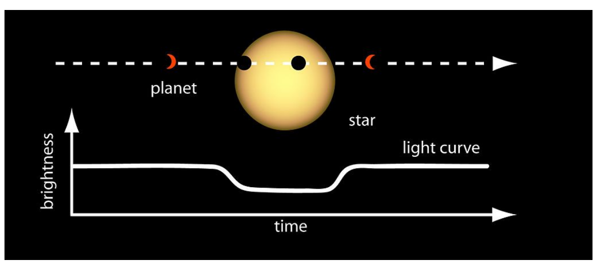
Why do different colors interact differently with matter?

Light is a wave. Just like sound waves, light waves transfer energy through space. Waves can be described by the distance between each high point, or crest. Scientists call this the wavelength. The wavelength changes the properties of the wave. For example, a sound wave with a long wavelength will sound low, like a bass drum. But a sound wave with a short wavelength will be high-pitched, like a flute. A light wave with a long wavelength will be more reddish/orange, while a light wave with a short wavelength will be more bluish/purple.

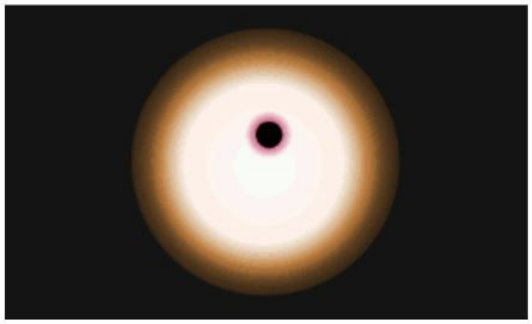
Color		Wavelength (nm)
red		630–750
orange		590–630
yellow		570–590
green		490–570
blue		450–490
indigo		420–450
violet		380–420

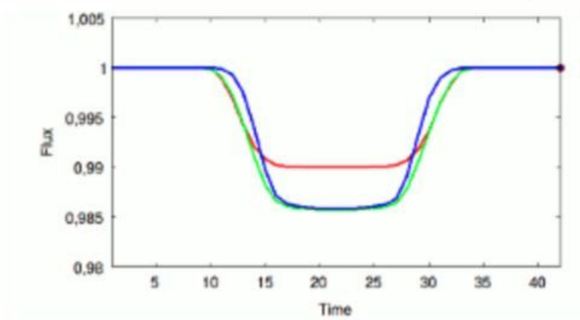
Different materials absorb, reflect, and transmit light differently. The type of substance can therefore affect which colors of light end up being transmitted through it. For example, water absorbs more red light than blue light. This is why when SCUBA divers are underwater everything looks more bluish to them. The further down divers goe, the more red light is absorbed, which results in the light reaching them becoming more and more bluish.

How does color help scientists figure out what exoplanets are made of?
Astronomers can use this same principle to study the light passing through the atmosphere of an exoplanet. Recall that when an exoplanet passes in front of a star from our perspective, we call this a transit. There is a dip in the amount of light scientists measure from Earth when the planet passes in front of the star.



Astronomers can separate the starlight into different colors and measure how much of each color of light is blocked by the planet. Sometimes, astronomers see that more of one color is being blocked than another color. Just like Earth's atmosphere absorbs blue light and transmits red light, exoplanets absorb some colors, and transmit others. The missing colors are like a fingerprint that helps scientists identify what kind of matter the light has passed through.





The data above represent a simulation of a light curve taken when a planet transits a star. The data show three different light curves. One is a measure of the change in the amount of blue light over time, one is a measure of the change in the amount of green light over time, and one is a measure of the change in the amount of red light over time. What do you notice about these data?

You may have noticed that the dip in the red light is not as deep as the other colors. That information tells scientists that more red light is passing through the atmosphere of the exoplanet, while more green and blue light is being absorbed.

Astronomers get more information about what wavelengths of light are being absorbed and transmitted by taking the spectra of the star. The image below shows 13 spectra, the light from 13 different stars, broken into all the colors. Each row is a different star. You may have noticed that these spectra are missing some colors. This may be because of the composition of the star itself. But this may also be because an exoplanet in front of the star has an atmosphere that absorbs or scatters that light before it can reach Earth.

Scientists can use spectra to identify exactly which wavelengths of light are present in the starlight, and which are missing. By identifying which colors are missing from starlight that has passed through the atmosphere of an exoplanet, scientists can make predictions about what the exoplanet's atmosphere is made of.