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SINGIN' THE BLACK AND BLUES

Unless you are a troglodyte and never leave your cave, you most likely see the sky every day and maybe even some nights. Like most curious little kids, you probably asked some adult a long time ago, "Why is the sky blue?" Or if you saw a beautiful sunset or sunrise, you might have asked, "Why is the sky red?" Come to think of it, why is the sky black at night, even though we can see thousands of other suns?

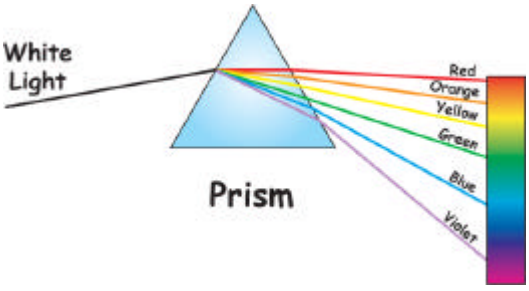
It's so obvious that the sky is blue in the daytime and black at night, you might think the reasons would be just as obvious. They aren't! It took the smartest humans thousands of years of observation, thought, discussion, conjecture, and analysis to finally come up with answers that make scientific sense.

Do you have some ideas? Why not stop right here for a few minutes and see what everybody thinks or has heard about "Why is the sky blue in the daytime?" and "Why is the sky dark at night?"

NOW . . . OF ALL THE COLORS OF THE RAINBOW, WHY BLUE?

Couldn't the sky just as easily be green? Or yellow? When we see a rainbow, we do see green and yellow in the sky, as well as blue, violet, orange, yellow, red, and everything in between.

The white light coming from the Sun is really made up of all the colors of the rainbow. We see actual rainbows as by-products of rain. Raindrops act as tiny prisms when lit by the Sun, bending light and separating it into its different colors.



But why are there different colors? The light you see is just one tiny bit of all the kinds of light energy beaming around the Universe—and around you! Like energy passing through the ocean, light energy travels in waves, too.

What makes different kinds of light different are the lengths of their waves. Visible light includes the wavelengths our eyes can see. The longest wavelengths we can see look red to us. The shortest wavelengths we can see look blue or violet.

THE TOP-DOWN BLACK & BLUES

(to the tune of "Ob la di, ob la da" by the Beatles: John Lennon and Paul McCartney)

Ridin' with the top down in my Granny's car
The bluest light above and all around.
I asked her what's the story with this sky of ours,
And then she hit me with these phrases so profound:

(chorus)
Ob la di, ob la da
Light waves on, la
La la how the light waves on.
Ob la di, ob la da
Light waves on, la
La la how the light waves on.

Sun sends out all colors in a dazzling glow,
Blended all together they make white.
And when this light meets air the blue plays "do si do,"
While all the rest just zip right through most impolite.

(Repeat chorus)

Like splattered paint, blue waves wash
All through the sky.
Like zippy lightsome twinkletoes,
They really are quite spry.

So then I asked old Granny why the night is black,
'Cause even tho' the Sun's no more on high
It seemed to me with all those stars there'd be no lack
Of starlight blazing through and lighting up the sky.

(Repeat chorus)

Like blackest ink, darkness fills
The nighttime sky.
Like sparkling diamond sapphire lights
The star lights touch my eyes.

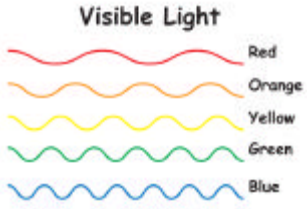
She told a tale, a large explosion, long ago
The universe expanding endlessly.
The light from fleeing galaxies just peters out
Red-shifting well beyond the lengths that we can see.

(Repeat chorus)

Granny knows the scoop 'cause she's a scientist
Who looks through telescopes and studies hard.
I'd like to grow up like her and be just as cool
And drive a top down, blue-sky, black-as-night hot car.

(Repeat chorus)

And if you want some fun,
Take Granny for a drive.

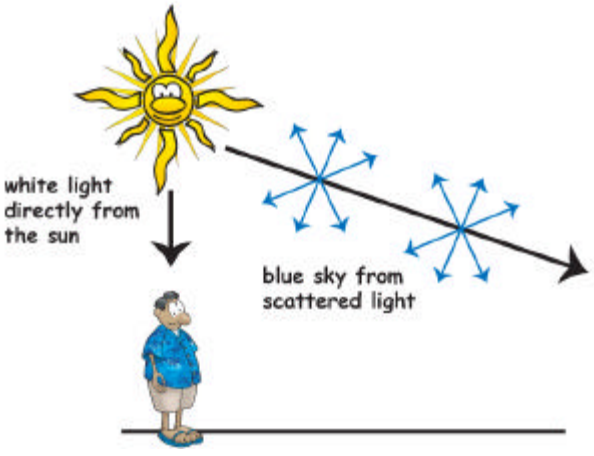


Keep in mind, the wavelengths in this picture are not to scale. A red light wave is about 750 nanometers, while a blue or violet wave is about 400 nanometers. A nanometer is one-billionth of a meter. A human hair is about 50,000 nanometers thick! So these visible light wavelengths are very, very tiny.

Another important thing to know about light is that it travels in a straight line unless something gets in the way to—

- reflect it (like a mirror)
- bend it (like a prism)
- or scatter it (like molecules of the gases in the atmosphere)

As the white light from the Sun enters Earth's atmosphere, much of the red, yellow, and green wavelengths of light (mixed together and still nearly white) pass straight through the atmosphere to our eyes. For much of the blue and violet light, however, it's a horse of a whole different color! These wavelengths are just the right size to get absorbed by the molecules of gas in the atmosphere, then spit out again, but in all directions.

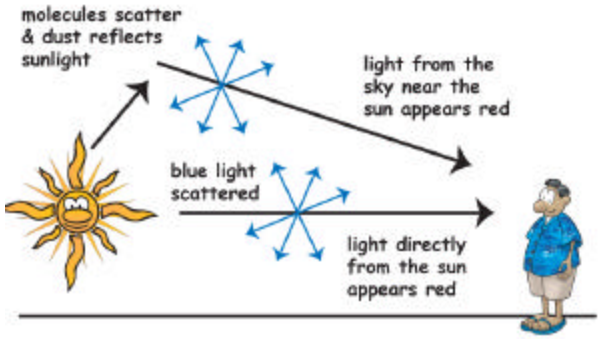


So what happens to all the "non-blue" wavelengths? They are still mixed together, unscattered by the atmosphere, so appear white. The scattered violet and blue light dominates the sky, making it appear blue. Why not violet? Some of the violet light is absorbed by the upper atmosphere. Also, our eyes are not as sensitive to violet as they are to blue.

Closer to the horizon, the sky fades to a lighter blue or white. The sunlight reaching us from the horizon has passed through even more air than the sunlight reaching us from overhead. The molecules of gas have rescattered the blue light in so many directions so many times that less blue light reaches us.

What Makes a Sunset Red?

As the Sun gets lower in the sky, its light is passing through more of the atmosphere to reach you. Even more of the blue and violet light is scattered, allowing the reds and yellows to pass straight through to your eyes without all that competition from the blues.



Also, larger particles of dust, pollution, and water vapor in the atmosphere reflect and scatter more of the reds and yellows, making the whole western sky glow red.

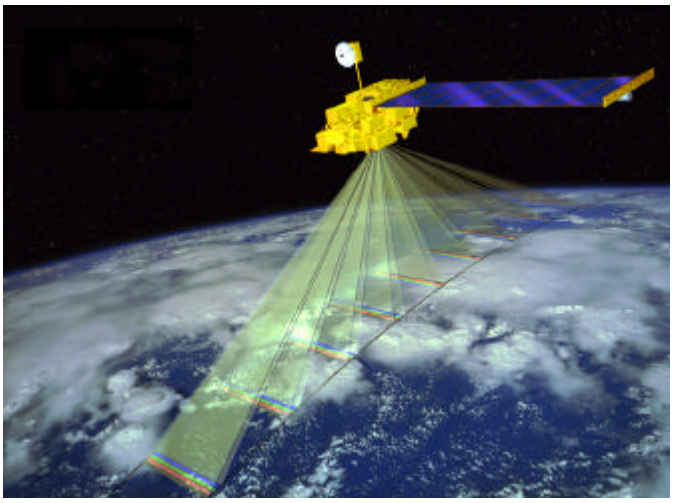
Why Does Scattering Matter?

How much of the Sun's light gets bounced around in Earth's atmosphere and how much gets reflected back into space? How much light gets soaked up by land and water, asphalt freeways and sunburned surfers? How much light do water and clouds reflect back into space? And why do we care?

Sunlight carries the energy that heats Earth and powers all life on Earth. Our climate is affected by how sunlight is scattered by forests, deserts, snow- and ice-covered surfaces, different types of clouds, smoke from forest fires, and other pollutants in the air.

MISR (for Multi-angle Imaging SpectroRadiometer) is one of several instruments onboard NASA's Terra satellite. MISR has nine separate cameras that take pictures of Earth's atmosphere and surface from different angles as the Terra satellite passes over a region during its

orbit. Seeing the same piece of Earth's surface or atmosphere from nine different angles tells scientists a lot more than seeing it from just one angle.



As MISR passes over an area, each camera gets a shot from its own angle.

Find out more about MISR and see images of recent happenings on Earth at www-misr.jpl.nasa.gov .

Now That the Sun Has Set, Why is it So Dark?

What a stupid question!

You might be thinking, of course the sky is dark at night because that is when our side of Earth faces away from the Sun as our planet rotates on its axis every 24 hours. But what about all those other far away suns that appear as stars in the night sky? Our own Milky Way galaxy contains over 200 billion stars, and the entire universe probably contains over 100 billion galaxies. You might suppose that that many stars would light up the night like daytime!

If the universe goes on forever and has an infinite number of stars, no matter where you looked in the sky, you should see a star. So the night sky should be as bright as day!

Until the 20th century, astronomers didn't think it was even possible to count all the stars in the universe. They thought the universe went on forever. In other words, they thought the universe was infinite.

Uh-oh. No Paradoxes Allowed

Besides being very hard to imagine, the trouble with an infinite universe is that no matter where you look in the night sky, you should see a star. Stars should overlap each other in the sky like tree trunks in the middle of a very thick forest. But, if this were the case, the sky would be blazing with light. This problem greatly troubled astronomers and became known as "Olbers' Paradox" after Heinrich Wilhelm Matthuas Olbers (1758 - 1840), the German physician and amateur astronomer who wrote about it in 1823. A paradox is a statement that seems to disagree with itself.

To try to explain the paradox, some 19th century scientists thought that dust clouds between the stars must be absorbing a lot of the starlight so it wouldn't shine through to us. But later scientists realized that the dust itself would absorb so much energy from the starlight that it would glow as hot and bright as the stars themselves!

Ah. Bad Assumptions

Astronomers now realize that the universe is neither infinitely large nor infinitely old.

A finite universe—that is, a universe of limited size—even one with trillions and trillions of stars, just wouldn't have enough stars to light up all of space.

Although the idea of a finite universe explains why Earth's sky is dark at night, other causes work to make it even darker.

Not only is the universe finite in size, it is also finite in age. That is, it had a beginning, just as you and I did. The universe was born about 14 billion years ago in a fantastic explosion called the Big Bang. It began at a single point and has been expanding ever since.

W-a-a-a-a-a-ve Bye-bye

Because the universe is still expanding, the distant stars and galaxies are getting farther away all the time. Although nothing travels faster than light, it still takes time for light to cross any distance. So, when astronomers look at a galaxy a million light years away, they are seeing the galaxy as it looked a million years ago. The light that leaves that galaxy today will have much farther to travel to our eyes than the light that left it a million years ago or even one year ago, because the distance between that galaxy and us constantly increases. That means the amount of light energy reaching us from distant stars dwindles all the time. And the farther away the star, the less bright it will look to us.

In addition, because the stars are constantly moving away from us, the wavelengths of their light get stretched out. Longer wavelengths of light have less energy than shorter wavelengths. Astronomers say the light is "red shifted" because red is the longest wavelength of visible light.

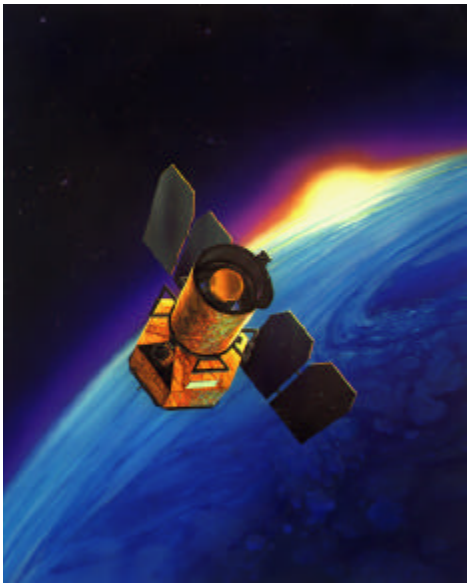
Red-shifting is similar to the Doppler effect you've probably noticed with sound. As you are riding down a road in a car, a truck approaches from the other direction, blowing its horn. As the truck zooms past, the pitch of the horn suddenly sounds lower. When the truck was moving toward you, the sound waves were piling up as the distance between "transmitter" (the horn) and "receiver" (your ears) decreased, so the wavelength was shorter and the sound seemed higher pitched. As the truck moves away, the distance is constantly increasing, so the sound waves gets stretched out and the sound seems lower.

In the case of starlight, as the stars move away, the wavelength increases and therefore the energy reaching Earth is reduced. These two effects reduce the contributions of distant stars to the brightness of the sky below what would be observed if Olbers' assumption that the universe is unchanging were true. Although the expansion of the universe by itself turns out to be insufficient to produce a dark sky, it does contribute to the explanation of how dark the sky is.

The universe, both finite in size and finite in age, is full of wonderful sights.

Taking the Galactic Roll

GALEX (for Galaxy Evolution Explorer) is an Earth-orbiting telescope that is looking back 10 billion years to help scientists understand how galaxies like our Milky Way came to be and how they have changed over cosmic time. During its 29-month mission, GALEX is surveying nearly the entire sky and gathering galactic light that has been journeying toward us for nearly the entire history of the universe.



Visit www.galex.caltech.edu to learn more about GALEX and see some images it has captured.

Bluest Day or Blackest Night: An activity for you

Write a poem or essay (or song!) about the bluest sky you ever saw or the blackest night you ever experienced. How did the sky look? Where were you? What time of year was it? What were you doing? Who were you with? How did it smell? What did you hear? Was it cold or hot or something in between? What did you feel?

Does looking at a blue or a black sky seem any different now that you know why it appears as it does?

This article was written by Diane Fisher, writer and designer of The Space Place website at ***spaceplace.nasa.gov****. Alex Novati drew the illustrations. The article was provided through the courtesy of the Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, under a contract with the National Aeronautics and Space Administration.*