
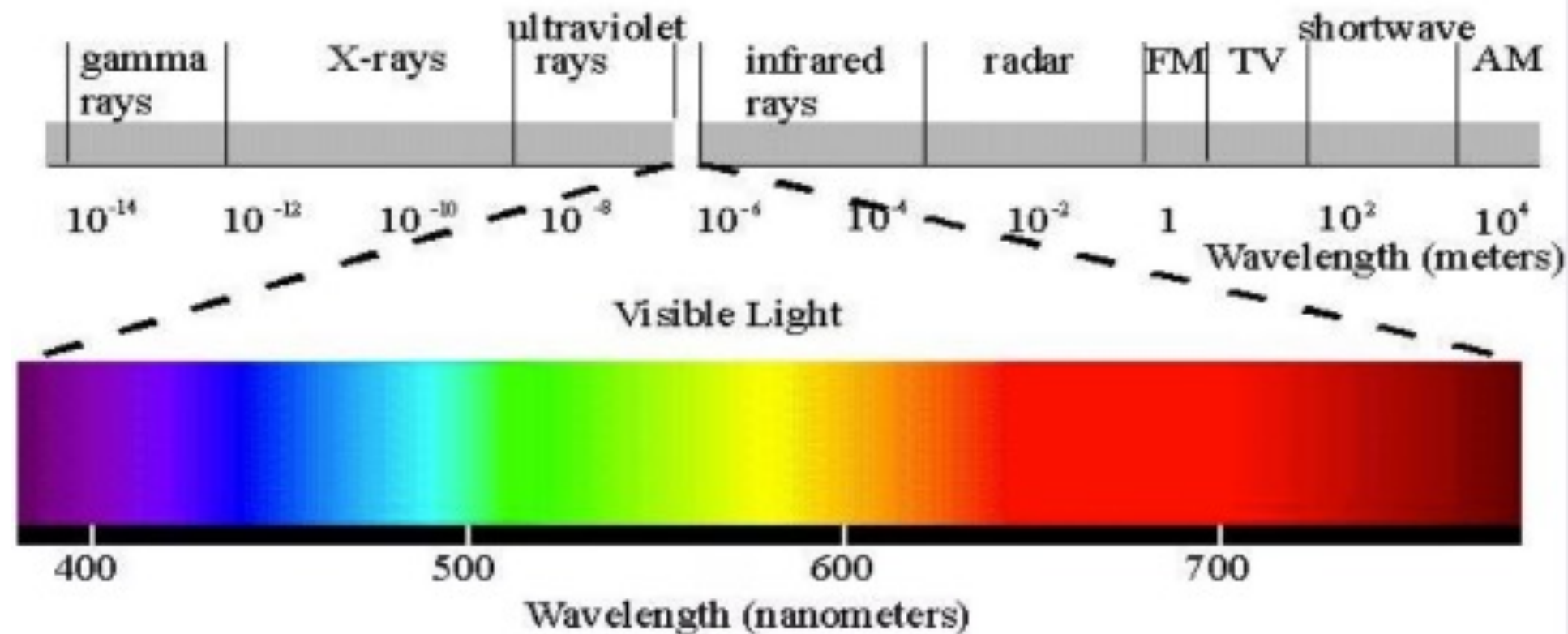


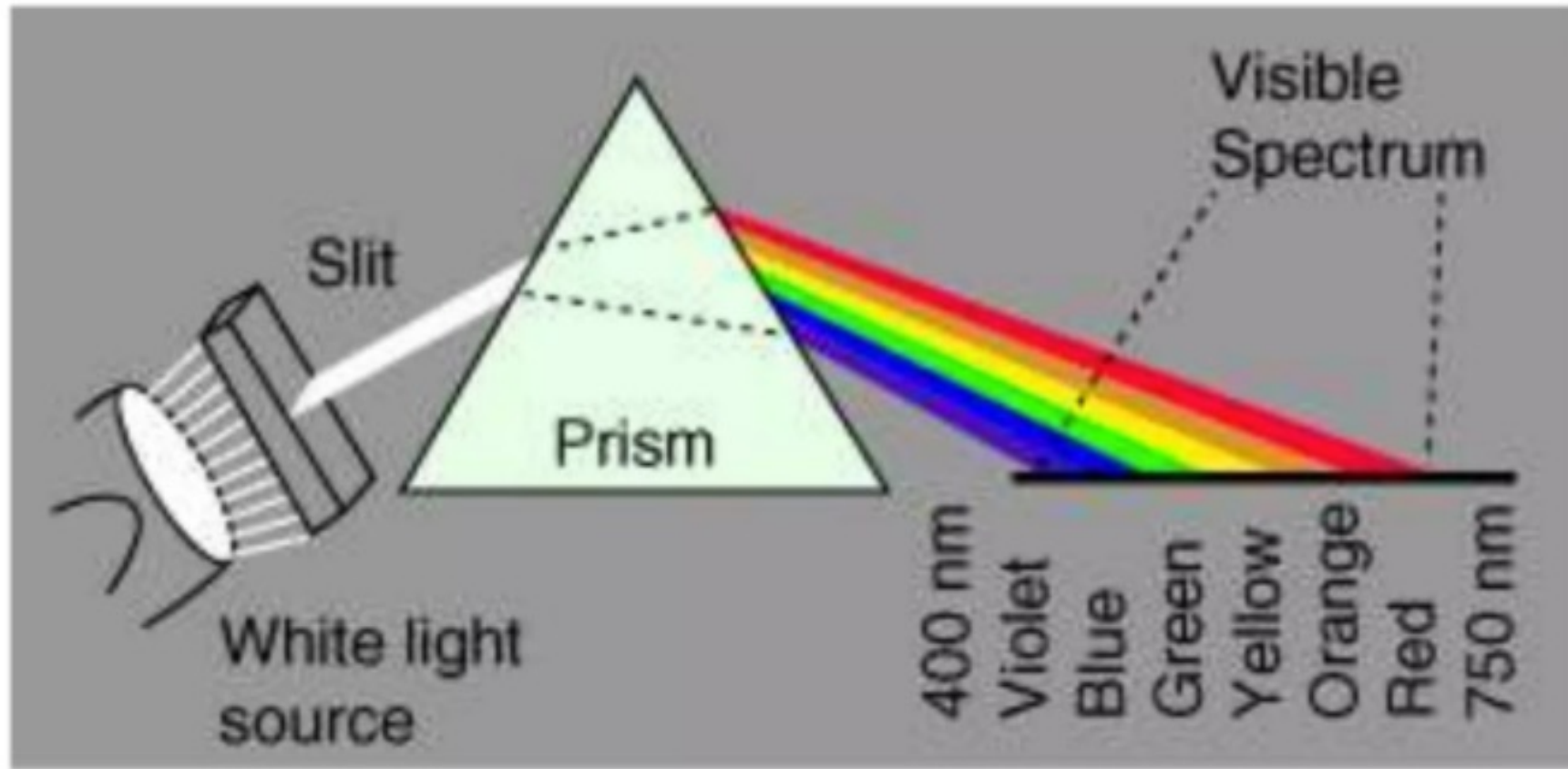
How do we really know what's out there?



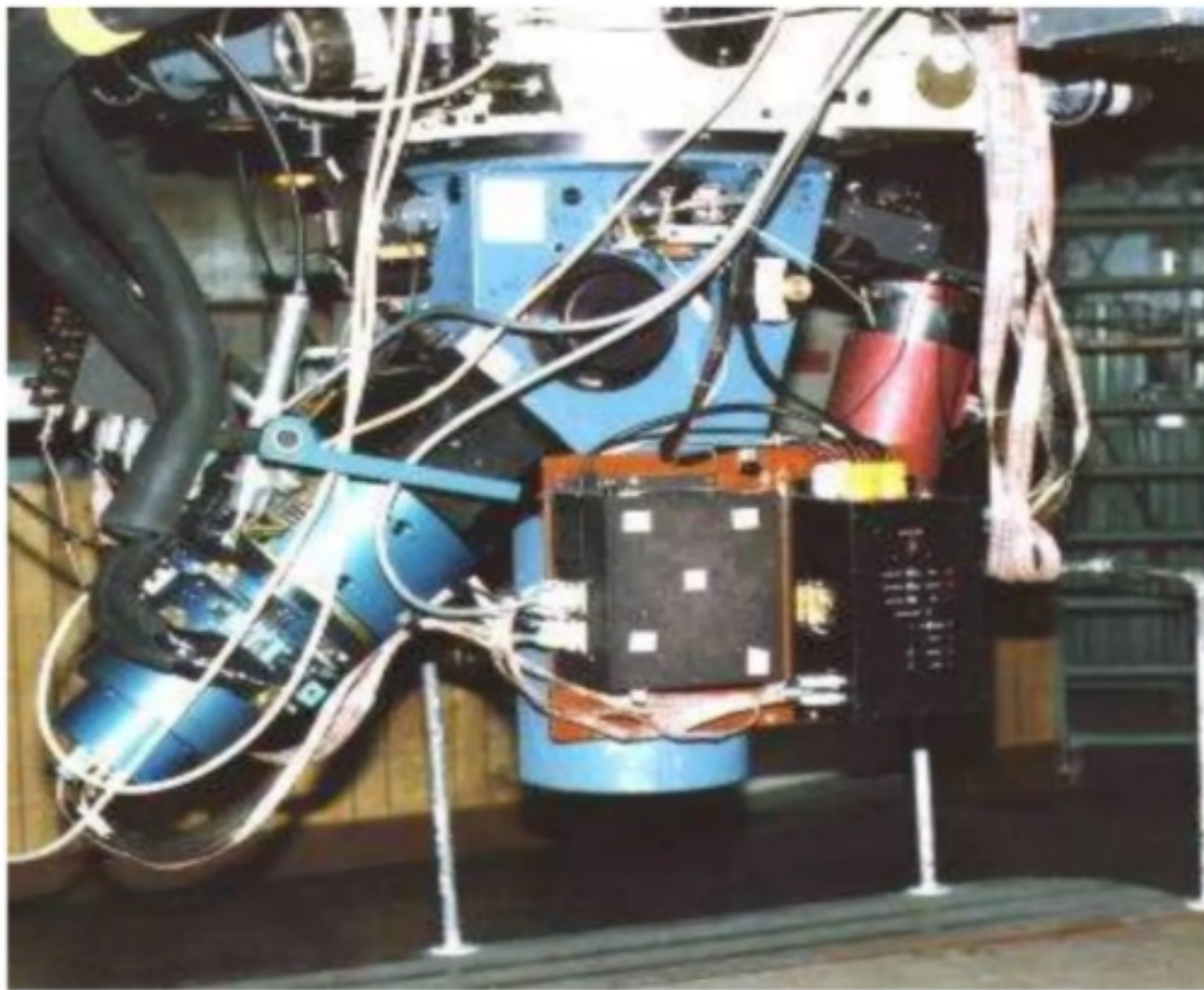
Space is a pretty big place and, after all, we've never been farther from earth than our moon. How do we know what the stars are made of?

This is the *electromagnetic spectrum*. It consists of waves which vary in length from very long (radio waves) to incredibly short (gamma rays). A special part of the spectrum consists of waves that we can see. This is called the *visible spectrum*. We see different wavelengths as different colors ranging from *red (long wavelengths)* to *blue/violet (short wavelengths)*.





White light consists of all visible wavelengths together. When white light passes through a prism, a triangular piece of glass or plastic, the different wavelengths are separated and can be seen individually.



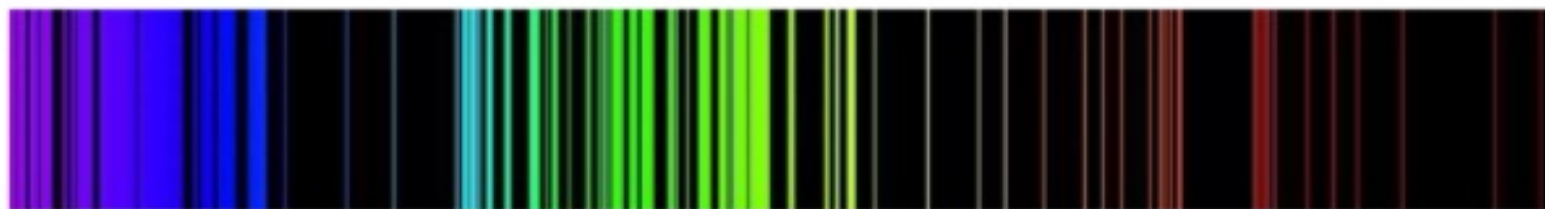
This instrument is a *spectroscope*. This one is attached to a telescope to separate the light from stars into a spectrum of different wavelengths. Scientists can then look for specific patterns of wavelengths.



When any element is heated hot enough it begins to emit light. The pattern of wavelengths emitted by an element are like a fingerprint. Each element emits its own unique pattern.

Above you can see the pattern of wavelengths emitted by the element *hydrogen*. Whenever this pattern is seen in the light coming from a star it means that hydrogen is present on that star.

This is called the *emission spectrum* of hydrogen.

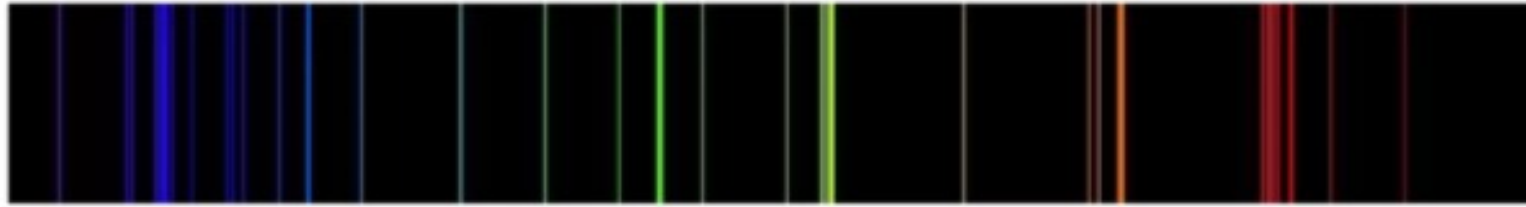


This is the pattern of wavelengths emitted by *iron*. When iron is heated until it vaporizes, as in a star, it emits this unique pattern of wavelengths. This is the *emission spectrum* of iron.

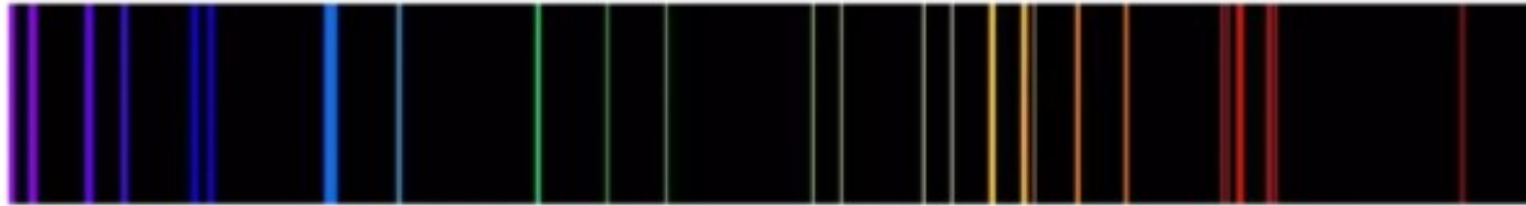
Below is the *emission spectrum* of **nitrogen**. If scientists see this pattern in the light from a star they know that nitrogen is present.



So by using a spectroscope scientists can analyze all the wavelengths that are emitted by a star and can tell exactly what the star is made of even though it may be thousands of light years away.



calcium



uranium



oxygen

What else can the light from distant stars and galaxies tell us?

When an object such as a star or galaxy is moving *towards* us the wavelengths of the light it emits are shifted towards the *blue* end of the spectrum (*frequency is shifted higher*). This is called *blue shift*.

If the object is moving away its light is shifted towards the *red* end of the spectrum (frequency is shifted lower) . This is called *red shift*. This phenomenon, the shifting of wavelengths due to the relative motion of objects, is called the *Doppler Effect*.

- Shifting of wavelengths can occur with both sound and light
- Doppler effect is easier to observe with sound
 - With sound you will hear a change in pitch
 - Imagine an ambulance approaching a person standing on a sidewalk:
 - As the ambulance moves closer the pitch becomes higher
 - As the ambulance moves away the pitch becomes lower

The Doppler Effect is used.....

- > to tell us the speed of a fastball.
- > to help police to catch people traveling over the speed limit.
- > permit meteorologists to identify and track storms such as tornados.
- > analyze the flow of blood through arteries.

To sum up..... If frequency is shifted lower (red shift) it means the object is moving *away*,
If frequency is shifted higher (blue shift) it means something is moving *closer*,
and the *amount* of shift indicates the *speed* that object is traveling.

How is the Doppler effect used in astronomy?



This is the pattern of wavelengths emitted by the element helium.



This is the pattern of wavelengths of helium that is found in the light from distant stars and galaxies. We know it's helium because the pattern is the same but notice that all the wavelengths are shifted towards the **red** end of the spectrum.

What does this mean?

First, it means that there is helium on that star and.....

second, it means that the star is moving away from us. ***Red shift!***

Remember, the greater the amount of shift,
the faster the star is moving!



Helium



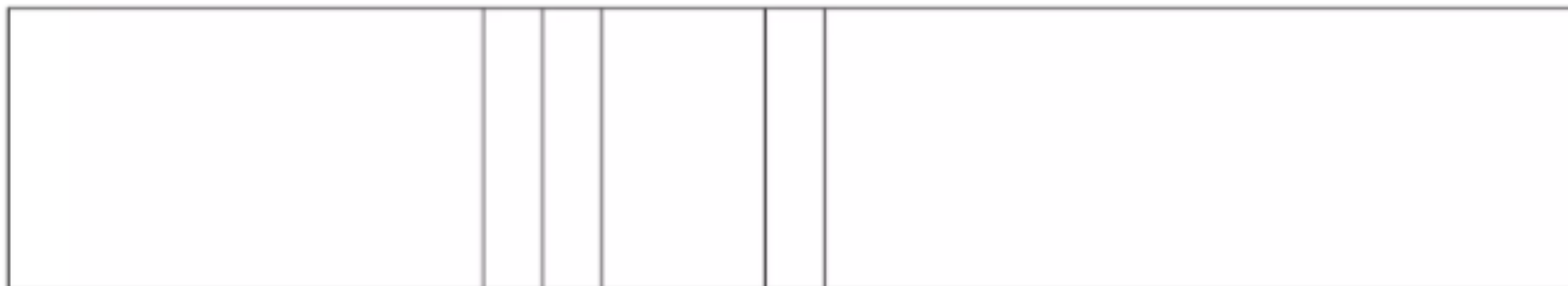
Helium slightly red shifted. Moving away.



*Helium more **red shifted**. Moving away even **faster!***

Blue

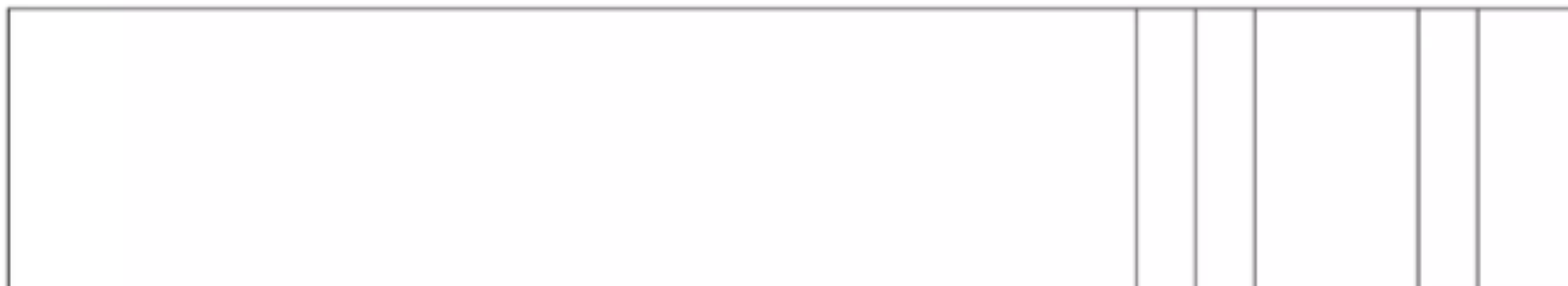
Red



— object is moving —

Blue

Red



Blue

Red



– object is moving

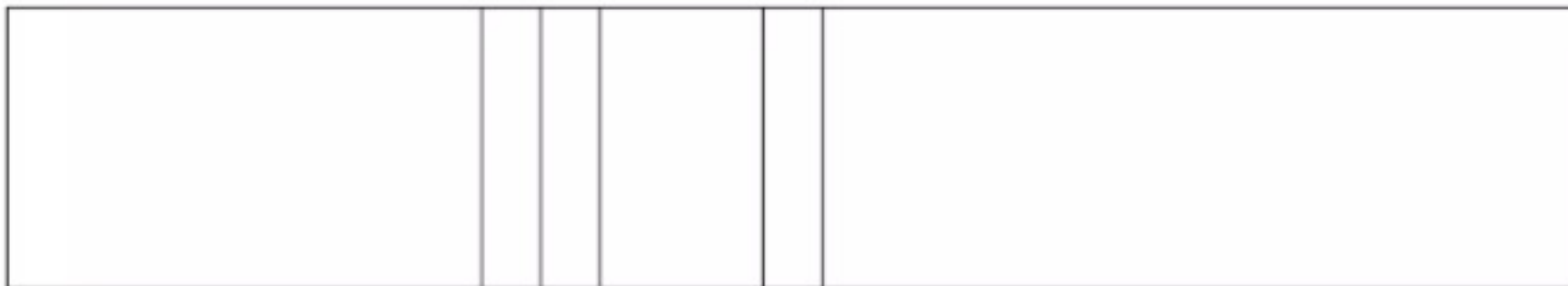
Blue

Red



Blue

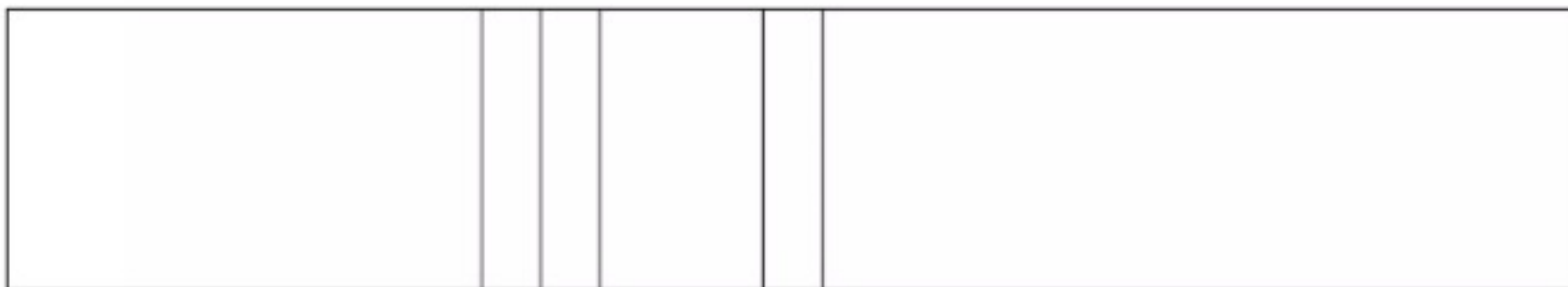
Red



_____ – object is moving same _____

Blue

Red



ALL of the light from stars and galaxies that reaches the earth is _____ What does that mean?

It means that everything is moving away from us!

How can everything be moving away from us?

The only explanation for that is

THE UNIVERSE IS _____

And if the universe is expanding then long ago it must have been much smaller. The expansion began about 12 billion years ago with the.....

BIG BANG!



*To understand the Big Bang
just imagine that the galaxies
are located on the surface of
an inflating balloon.
As the balloon expands, every
point on its surface is moving
away from every other point.*

So what can we learn from the light from stars?

We can find out what stars are made of by examining the spectra.

We can tell that they are moving away from us and that.....

The universe is expanding.

We can calculate the speed of that expansion and.....

And we can infer the age of the universe (12 billion years).

All this just from starlight!