Note to those reading through this PDF.

This is the result of a lot of hard work. Please read through it and get what you can from it. But, if you want to do your own program on the same topic, please do the homework yourself. You learn it a whole lot better that way, and make it your own. Moreover, it takes a while to go through all the sources on the internet and elsewhere to put something like this together. I try to let people know the source of pictures I took off the internet, but failed more often that I succeeded. So, I have no place to complain about attribution and intellectual property. This is based on a stand-up guest speaker program I offer to my club, to other astro clubs, and such. It is offered only for instruction, and I do not accept compensation for doing such programs for fellow hobbyists (and, really, nobody else would really care to see these programs). So, take it in that spirit. Learn from it, but do not pass it off as your own. And, remember, I am a retired English teacher, not a science teacher, a professor, a scientist, or …….I just read Wikipedia a lot. So, don't use any of this information on your quiz in class next week.

Those who “see the world through rose colored glasses” tend to see things rosy and pleasant. Go through life expecting the best and you will see the best.

Grouchy old pessimists say these optimists are fools. But that is a discussion for the some cloudy windy night.

I am just using the old expression “He sees the world Through Rose Colored Glasses,“ to launch us on a little discovery that what you see when you look to the heavens depends on what you are looking through.

In particular, our perception can be changed through filters—changing our glasses to rose and other colors. Then, using the concepts that we learned from that, we will talk about telescopes.

So what we are going to be talking about is a little bit of the science behind filters and different telescopes.

This all started a few months ago when a few of us were just starting out in narrowband imaging. One of our Riverside Astronomical Society members sent me a very nice picture of the Orion nebula.

I think we all know the Orion Nebula. Here is Alson' Wongs picture of it. I want you to note the nebulosity, the glowing colors. See how all the glowing red up here is different from that over here and down there. See all the colors and even the tannish-brown around the trapezium. Notice the gradations of brightness. I want you to notice in particular, the "Running Man Nebula." See the pretty blue…..But it also has red in it, even in the parts overwhelmed by the blue you can see the red that makes it purply.

Well, if you were in fact looking through the telescope, you would not see that color, because our eyes aren't as sensitive to colors as cameras, so here is that same picture with the color removed.

CLICK

And here is the narrowband image that was sent to me from another RAS member, Ichiki Masami, whom we all know as Sam. As one of our first narrowband images, it was impressive. Of course it is taken with a monochrome camera, so it could only show black and white. It shows us the intensity or luminosity only, not the color. More importantly for our discussion, it uses narrowband, and shows the luminosity of only one color of light--that color is a very distinct red from the hydrogen alpha glow.

And what disappointed Sam was that his Running Man had run away and was nowhere to be found!

Let’s see why. Here is Sam’s picture.

And here in one of my own from long ago.

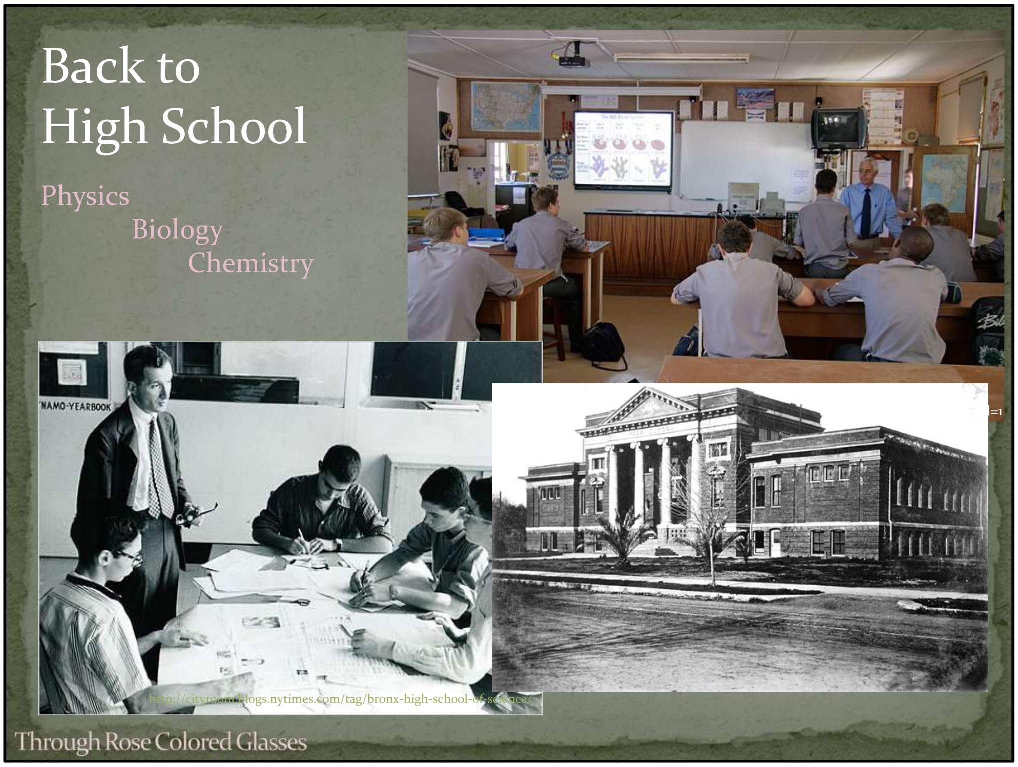
Click
I am going to take the color out of mine and balance it a bit to make it comparable to Sam’s. But notice that I am just taking the color out, the luminance—the relative brightnesses are staying the same. This brighter blue is still a brighter gray. The brighter reddish parts are staying brighter gray. Everything has the same brightness it used to have. It is just that you no longer know what colors that brightness had.

Sam was complaining that his picture did not show the "Running Man Nebula" very well.

It did not take Sam long to realize that some of the Running Man area was there--the red part. But the blue part was not, and the contrast of the blue against the red is what makes the Running Man the Running Man!

Alson's picture and mine, which use all of the visible spectrum, show us gases and dust in all colors and we can still see the luminosities of those grays even when we take the color values out, but Sam's showing only the brightness of a very specific red, pretty much misses out on anything that does not have red. Without the contrasting blue, his running man is hidden.

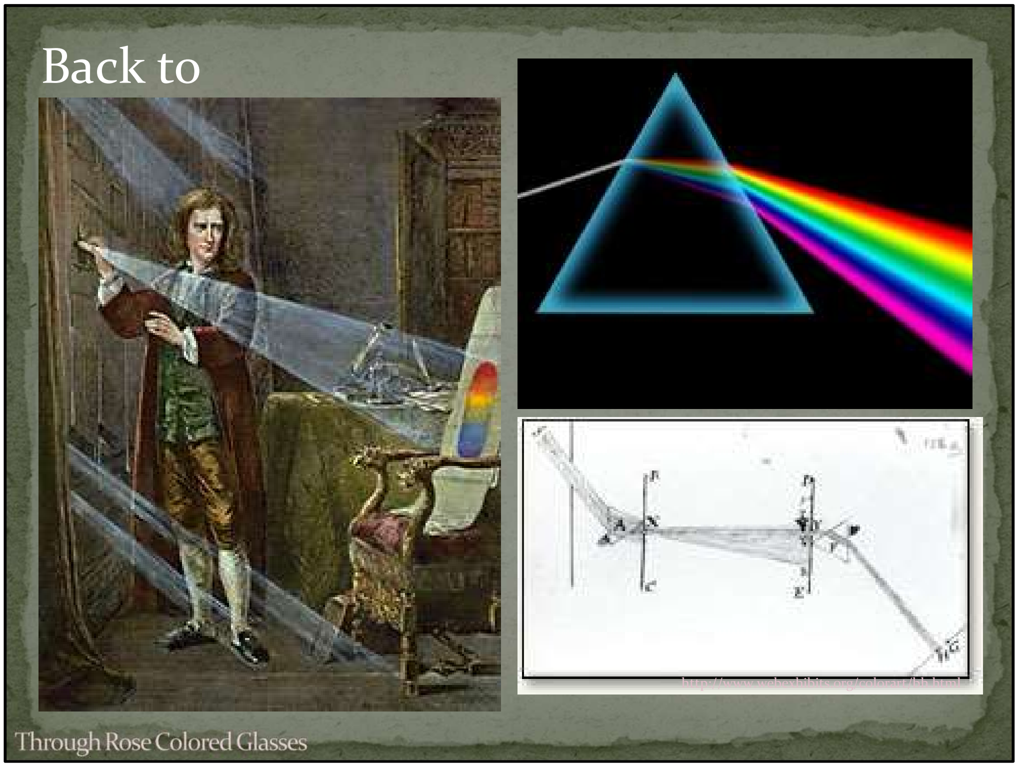
What is happening and how can we use this phenomena?



Before we go there, though, we need to go back to High School

We are going to stop by Physics class, then the Bio Lab, and the Chemistry Class.

So get your memory caps back on to those good old days.



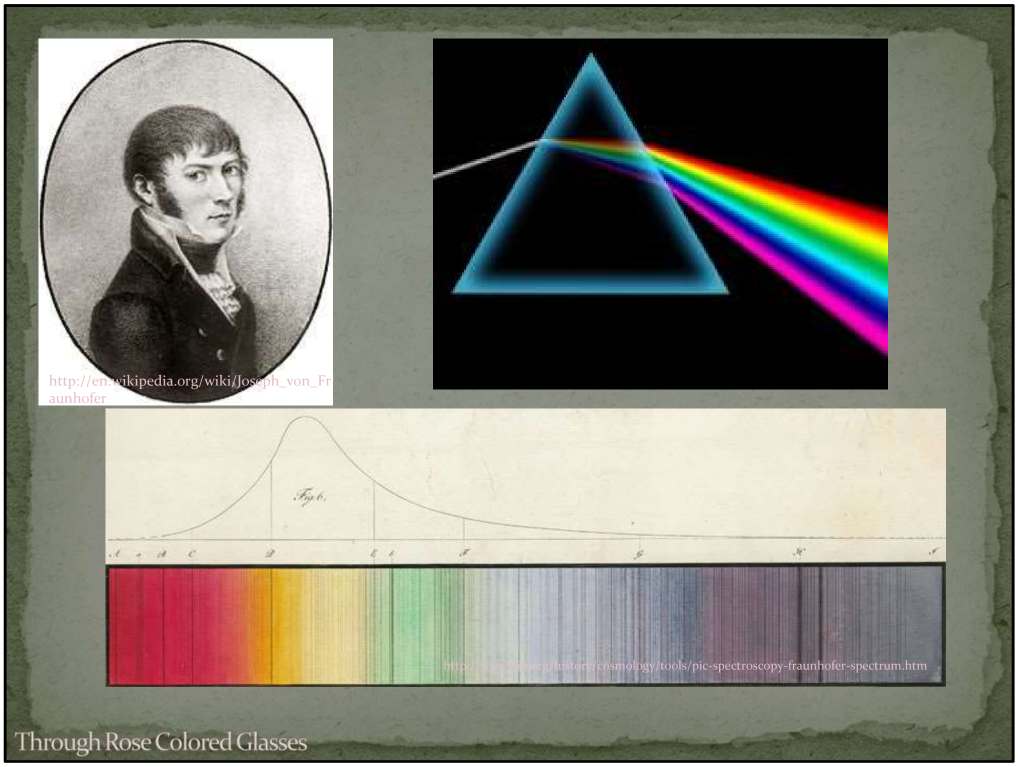
Our modern understanding of light and color begins with Isaac Newton (1642-1726) and a series of experiments that he publishes in 1672. It was common knowledge that a prism of glass, when exposed to white light from the sun, would generate a wide spectrum of colors—all the colors of the rainbow.

At the time, people thought that color was a mixture of light and darkness, and that prisms *colored* light. Newton realizes this theory was false.

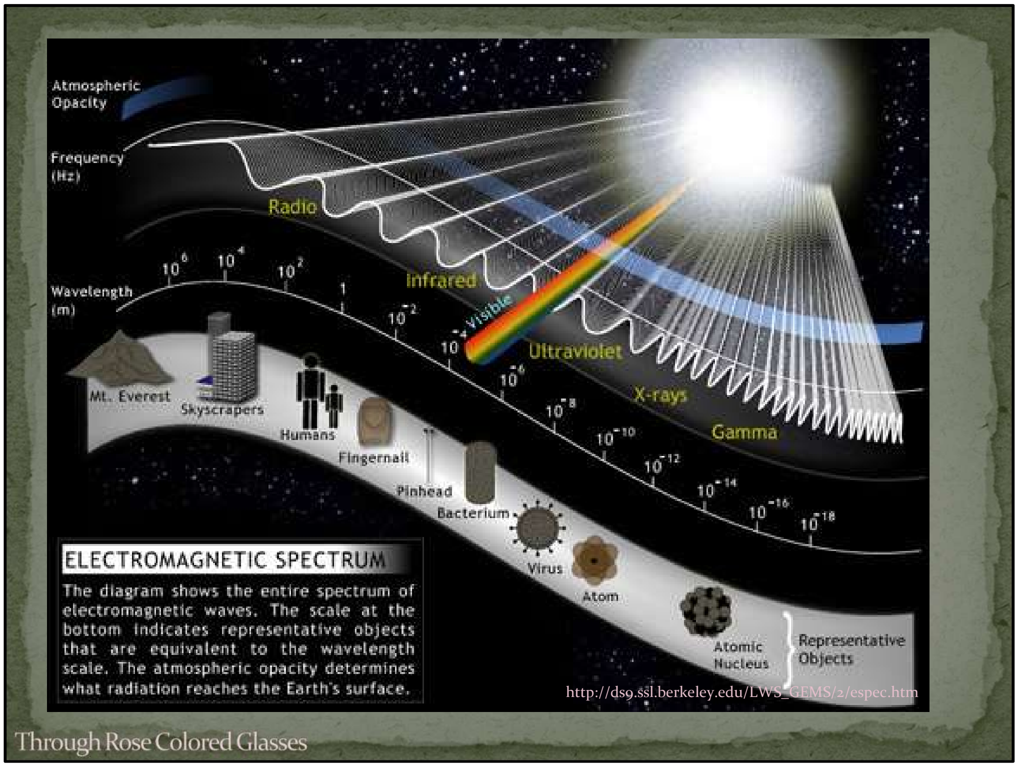
Newton is the first to understand the rainbow — he refracts white light with a prism, resolving it into its component colors: red, orange, yellow, green, blue and violet.

Newton set up a prism near his window, and projected a beautiful spectrum 22 feet onto the far wall. Further, to prove that the prism was not coloring the light, he refracted the light back together.
Artists were fascinated by Newton's clear demonstration that light alone was responsible for color.

And while that was important in general, for our discussion, what is important to us is that what we perceive as "light" is not really a single unified thing, but a range of things.



And, of course, things are never as simple as when they are first discovered. Two centuries ago, Joseph Von Fraunhofer had realized that the spectrum of the sun was a lot more complicated than the simple illustration Newton showed us. His spectrum showed lines. What was the cause of these weird gaps? We'll come back to that later.



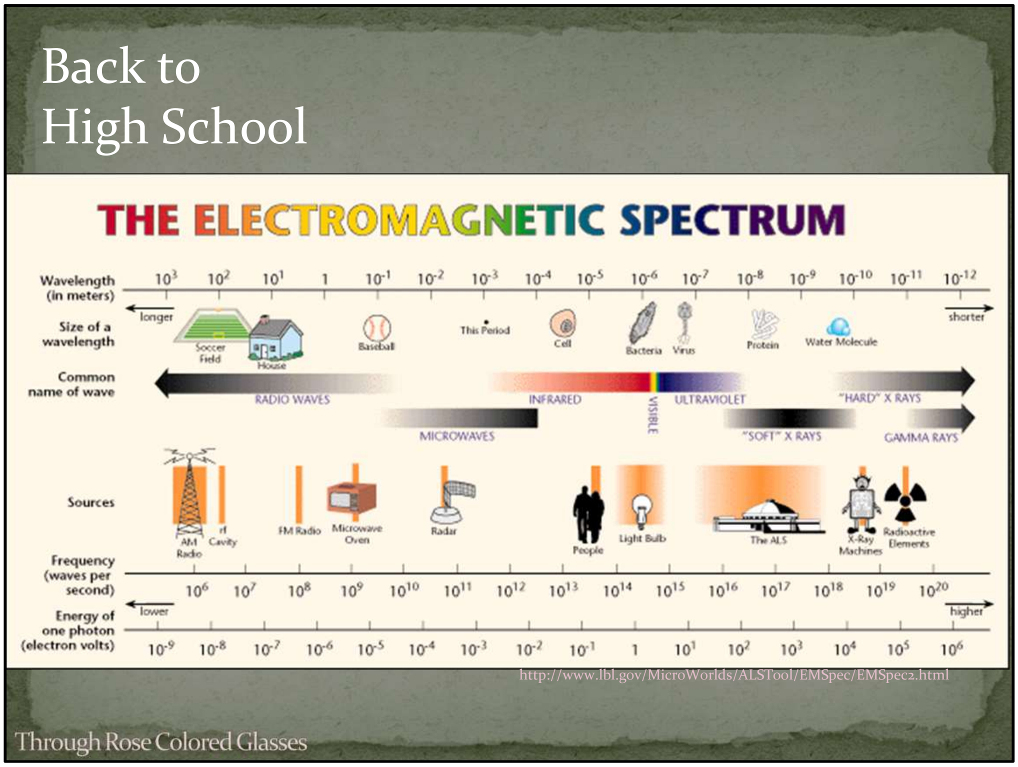
Suffice it to say for now, though, that through the years, other observers and theorists came to realize that “light” is only the visible spectrum. And there is a lot of light we can’t see. Visible is just a small slice of the overall spectrum that runs from gamma rays through x-rays, Ultraviolet, the visible (that we traditionally called “light), infrared, and radio waves.

It is all the same phenomena---but manifests itself in different ways depending on the energy of the wave.

Here is a summary of those observations. Notice that what we call the electromagnetic wave depends on how big the wave is that carries that energy through space.

If the wavelength is about the size of an atomic nucleus, (about 10 to the minus 14 to 16 meters) we call it gamma rays, and if it is about the size of a good size building, (a hundred meters or so) It is called “radio waves.”

If it is right about here (which is a few hundred nanometers—the size of a typical bacterium), it is called visible light, and a human can see it using his or her own eyes. A typical human eye will respond to wavelengths from about [390 to 750 nm](). A nanometer is one billionth of a meter.

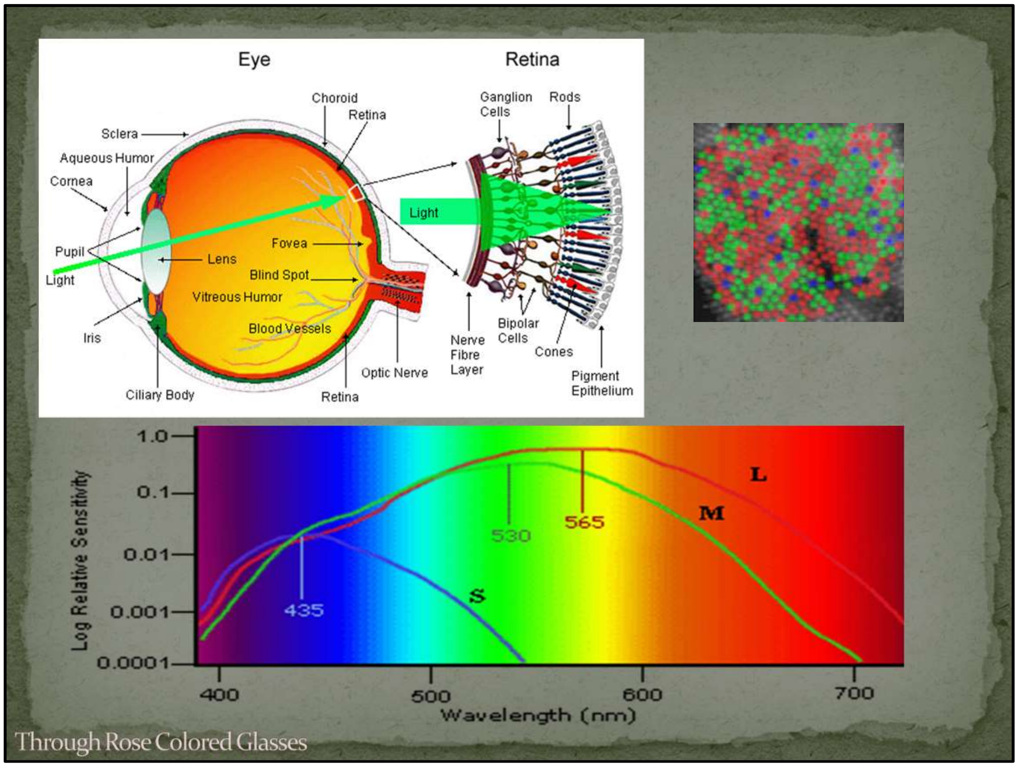


Knowing that there are lots of kinds of “light” we have developed many kinds of sensors and many devices to use the different kinds of light.

Okay, this is all good to know, and we will return to it later when we get to Chemistry class…..but, really, our discussion must return to this little band right in here. We must consider for our rose colored glasses only this little stretch right here—the visible band, because that is what we use with our visual and photographic telescopes.

And we use it with our telescopes largely because our eyes are equipped to sense only the stuff that comes to us in this narrow range.

To understand why, we must go to High School Biology class.



There, we learned that the eye has a retina with two kinds of sensors, rods and cones. The Cones see Color, but the rods don’t.

Cones come in three colors.

Looking at the spectrum, we have to recall that I said earlier that the human vision system sees electromagnetic waves that come at us only if they are from about 390 to 750 nanometers in wavelength.

To get more specific, those Cones are also specialists.

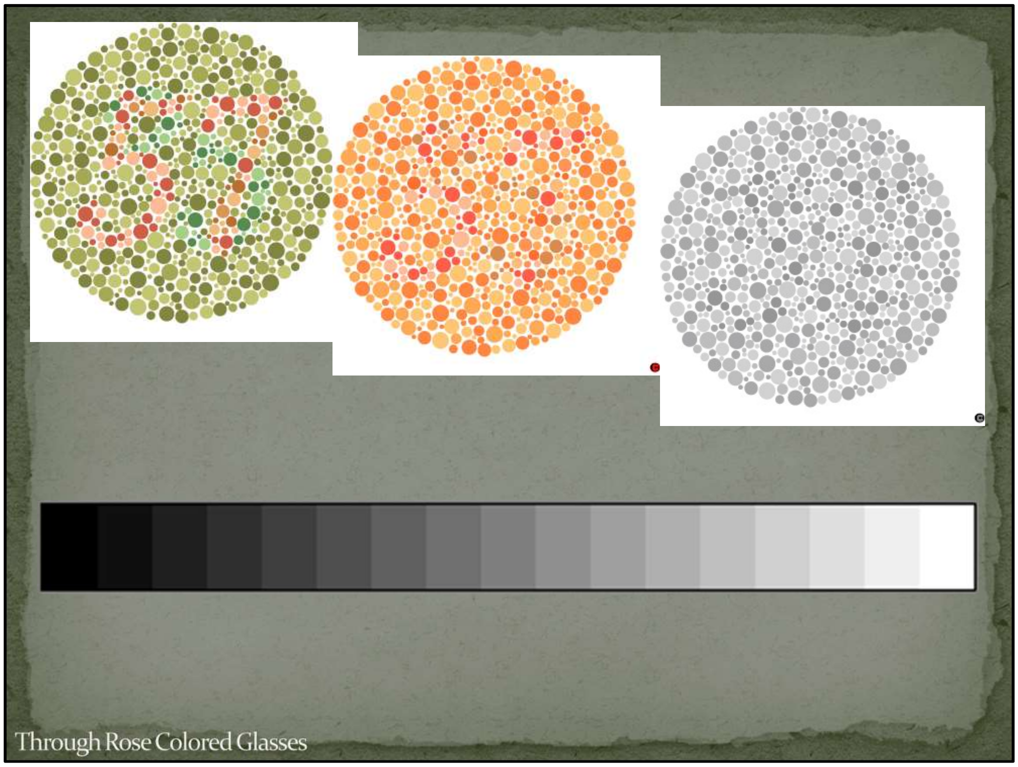
Some see blue. They are not very sensitive at 390 nm, reach a peak at about 435, and then fall off.

The Green are also not very sensitive down low, but peak at about 530 nm, smack in the middle of the green light.

And what we call “Red” cones are actually most sensitive in the yellow, but stay sensitive will into the reds.

So, yes, we do not actually have red, Green, Blue sensors at the bottom of our foreheads, but Yellow, Green, Blue. But the analogy to computer RGB color works well for our purposes.)

And as we saw from Newton in Physics class, that mixing all those colors gives us all the colors in between. In fact, if we mix all the colors in the right proportions, we get what we call “White.” If we see relatively more red than blue or green, we will see a reddish cast to everything.



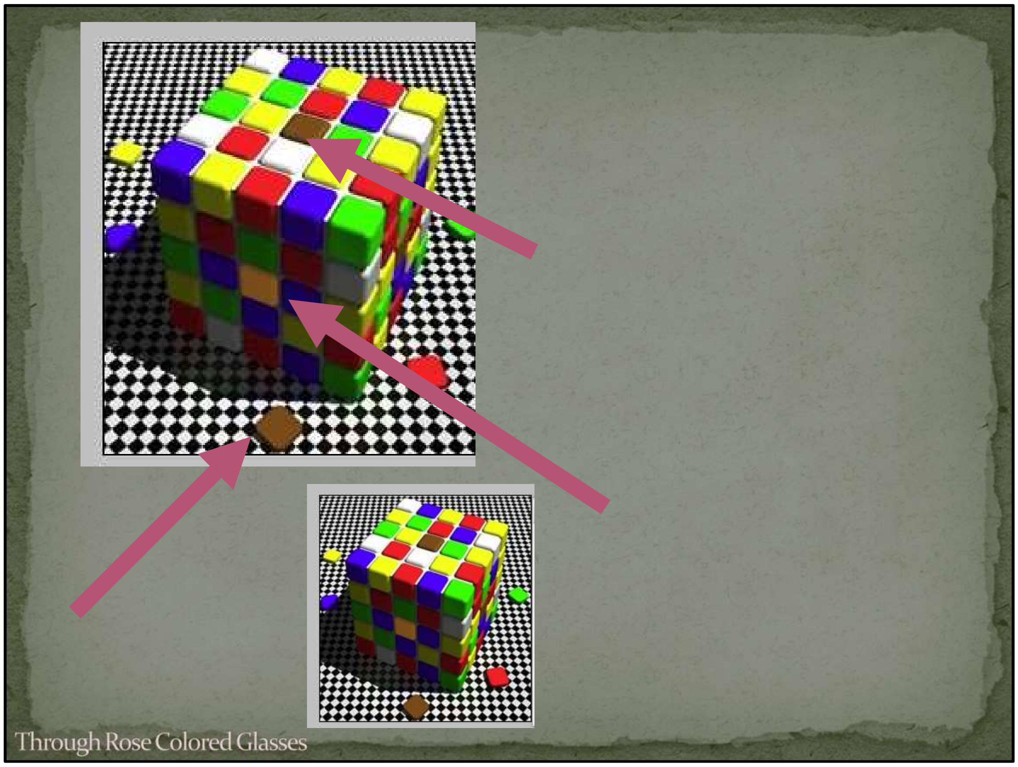
But what if were were to knock out one of those sets of cones.

We know that some people are color blind. That means some of their Cone receptors are not working well. This is a standard chart for eye tests. If you can see the 57 on the screen here, you are not color blind. At least not this kind of color blind.

But, Alas, if your blues and greens were not working, that 57 would pretty much disappear and you would see this (The same picture with the blues and greens removed). Actually, you would probably sense something like this gray version.

And, Remember, Astronomers, none of our cones, the color receptors, work very well in dim light. Therefore, the other sensors, rods, take over. They are monochrome, and pretty much see this. So, at night we have no hope of seeing the 57 at all. Luckily, there are 18 times as many rods as there are cones, so what we can see we can see better. But rods see don't see color, but contrast, the difference between black, white, and all the grays in between.

This is an important distinction. The eye/brain is not particularly good at seeing things all by themselves. In the absence of other clues, we cannot tell how bright something is. We can only tell how bright something is in relation to other things around it.

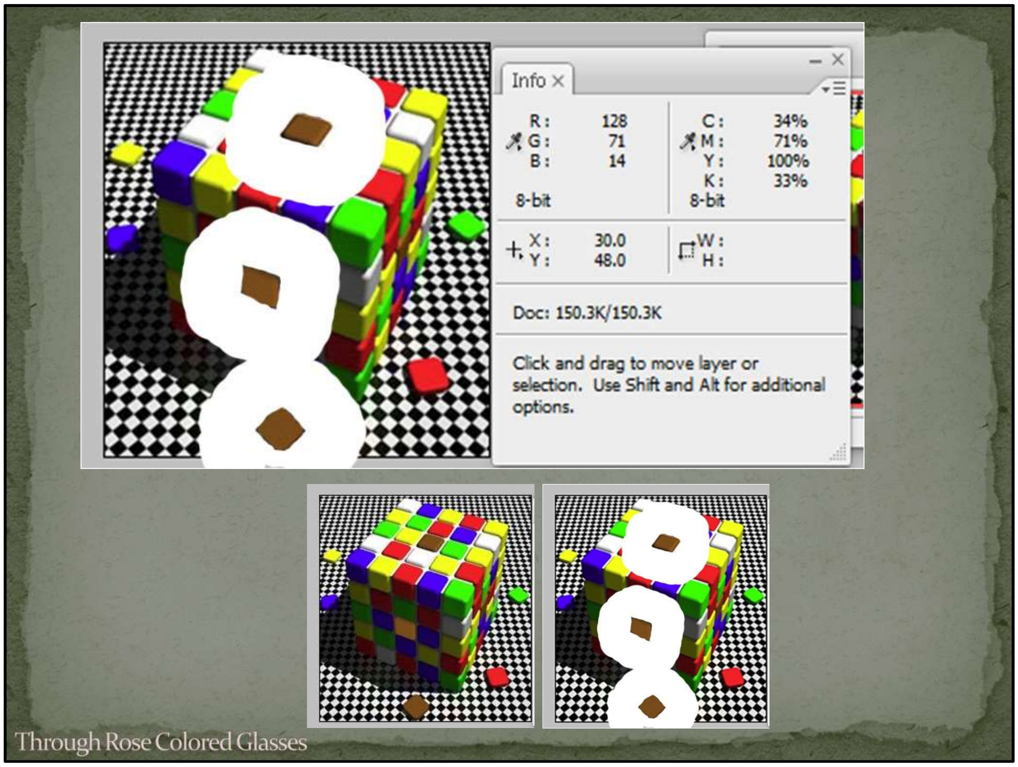


And remember when I said earlier that if we mixed red, green, and blue in equal proportions we would get white—well I lied. Our brain has as much to do with telling us what color we are seeing as the actual light coming from the object. This is because of this sensing contrast and such as much as the absolute values of the light.

What I said about intensity in brightness holds for color.

Our eye/brain system does not see absolute values for intensity and color, but relative contrasts, and then tells us what we are sensing depending on a lot of factors.

Check this out. What color is this square here? And this one here? This one?



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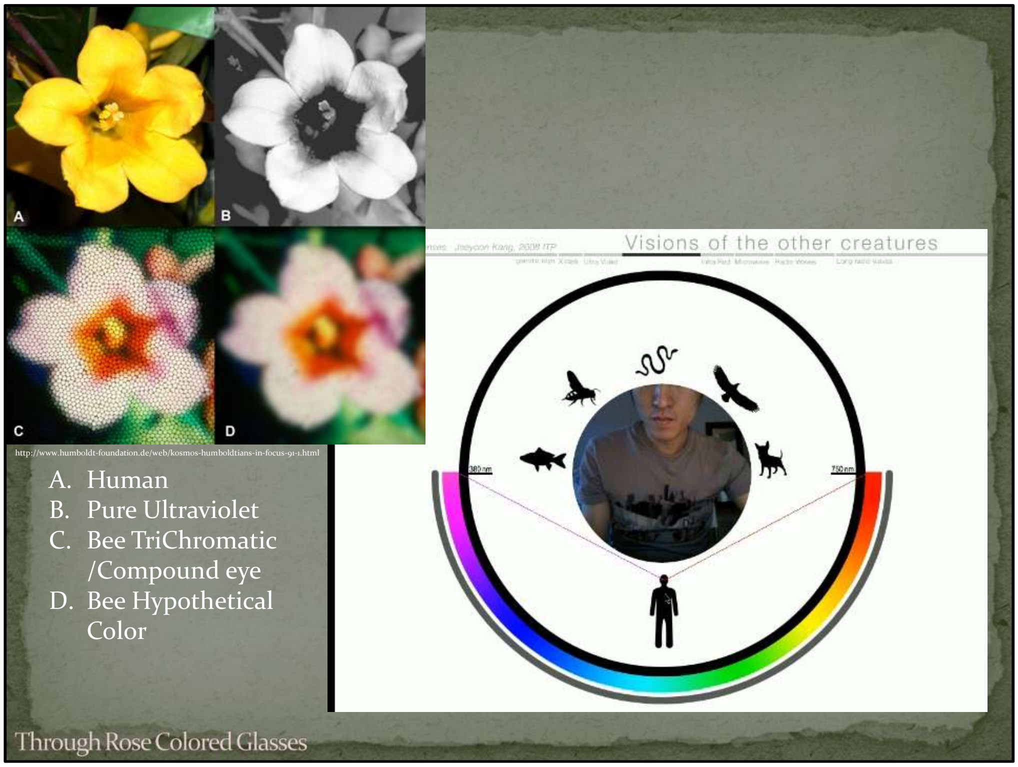
Actually, they are exactly the same color. This one looks orange, and this one brown because of the field in which they are set. You can look it up in Photoshop! The eyedropper tool will give you the exact same color valued on this square and this!!! 128 units of red, 71 of Green, and 14 of Blue. If I hide the field around the dots, and show you the background as white, you can see that all three dots are the same color.



And while we are in biology class, I should mention that I am speaking of human vision here.

If we were a bee, we could see ultraviolet. (Which humans cannot.)

This, and a compound eye, would mean we see something like this in color. Or, smoothed out, something like this.

CLICK

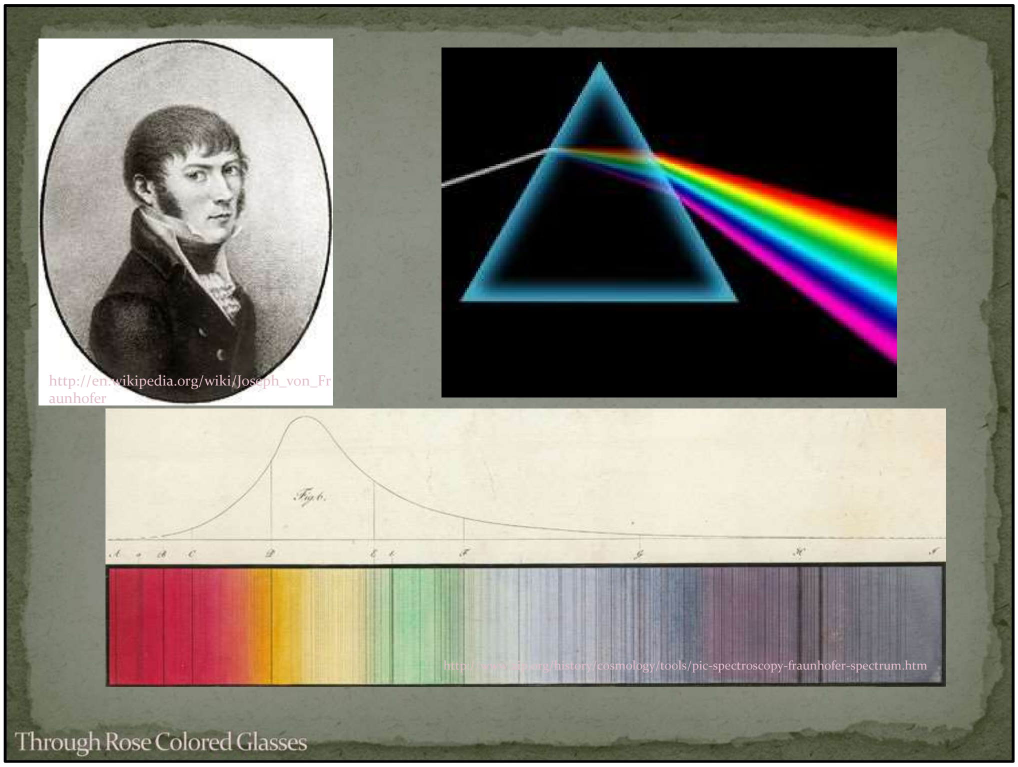
If we were a fish, we could see more ultraviolet, and a bee, a whole lot more ultraviolet, with less infrared. Snakes would be seeing all infrared, and just looking for the contrast between warm spaces (which show in infrared, and cool, which do not). Birds see a wider spectrum extending to the ultraviolet, and apparently brighter, and dogs, which see a narrower range than humans, are famously kinda color blind.

NOTE TO THOSE WATCHING IN PDF, AND NOT IN REAL LIFE: THIS MOVIE (THE LOWER RIGHT CORNER) IS PRETTY COOL> TO SEE IT, GO TO https://vimeo.com/8979121

So, from biology class we have learned:
We cannot see many colors in astronomy because the light is too dim.
Our eye/brain system is better at seeing contrast rather than absolute values of the light.

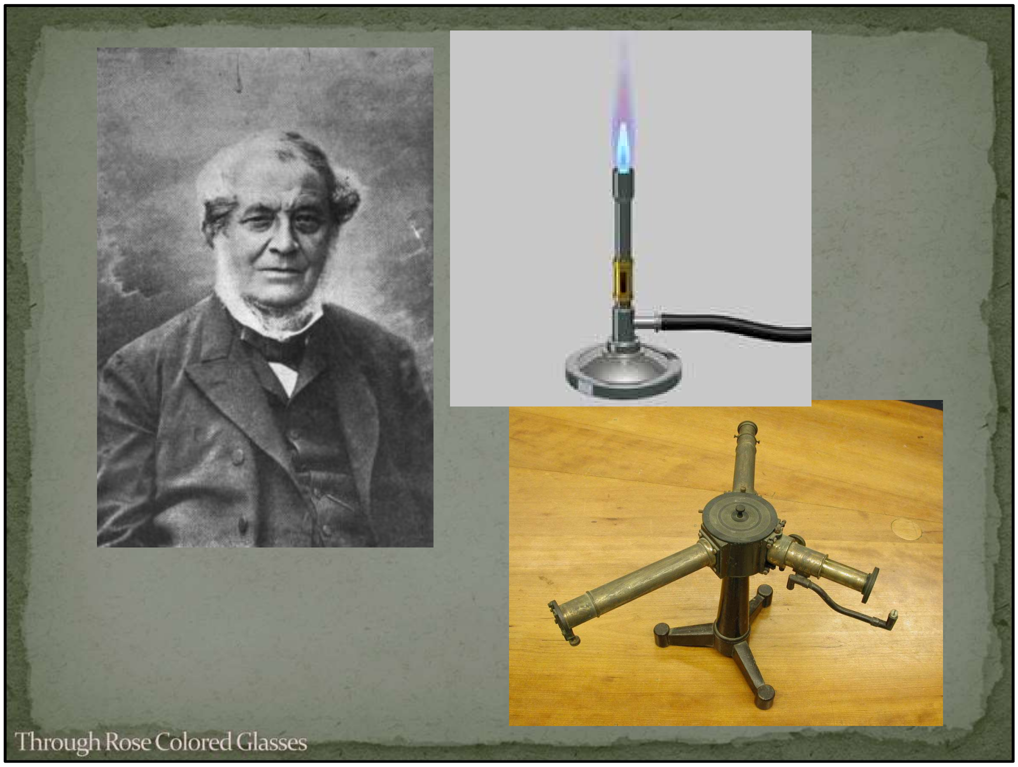
Are we ready to start talking types of telescopes and filters----

Almost—we have to stop off in the Chem lab for a minute or two before going further.



Flashback---remember Fraunhofer and those mysterious lines that disrupted the smooth spectrum Newton had found?

What caused them?



Let's ask this hale, very well liked fellow, Robert Bunsen.

In the mid 1800's Robert Bunsen had been asked to help design a new science lab at he University of Heidelberg. He and his colleague, Peter Desaga came up with something that we all know as the "Bunsen Burner." The Bunsen/Desaga design succeeded in generating a hot, sootless, non-luminous flame by mixing gas with air in a controlled fashion before combustion.

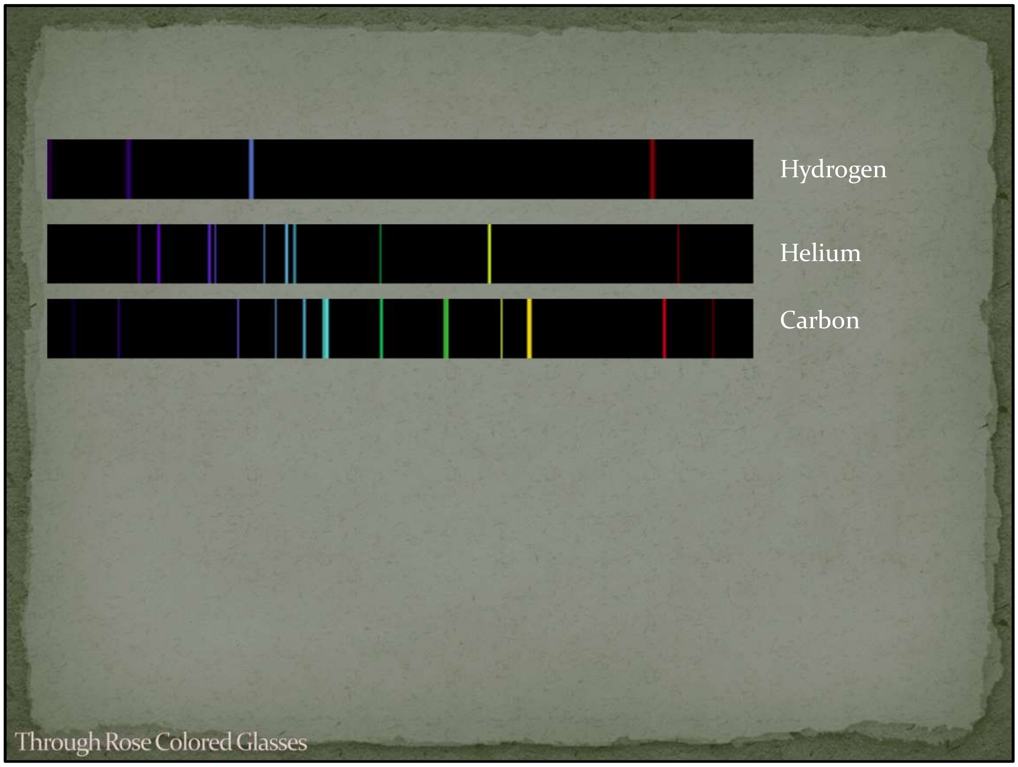
In other words, you had heat without light. Or at least much light. Which means whatever light you were getting was from the object being heated, not from the heater.

There had been earlier studies of the characteristic colors of heated elements, but nothing systematic. In the summer of 1859, Bunsen began a systematic study. By October he and a colleague, Gustav Kirchhoff, had invented an appropriate instrument, a prototype spectroscope. Using it, they were able to identify the characteristic spectra of sodium, lithium, and potassium in their labs. After numerous laborious purifications, Bunsen and Kirchoff proved that highly pure samples gave unique spectra. In other words—different spectra could be matched to specific elements. In short, hydrogen glowed in one color, and oxygen in another.

When Bunsen noticed some spectral lines that he could not otherwise identify, he realized that he was discovering new elements, including rhodium and cesium.

In 1859 Bunsen reported to a colleague that Kirchhoff had made "a totally unexpected discovery." He had identified the cause of the dark lines seen in the solar spectra by Fraunhofer and others. When certain chemicals were heated in Bunsen's burner, characteristic bright lines appeared. In some cases these were at exactly the same points in the spectrum as Fraunhofer's dark lines. The bright lines were light coming from a hot gas, whereas the dark lines showed absorption of light in the cooler gas above the Sun's surface.

The two scientists found that every chemical element produces a unique spectrum. This provides a sort of "fingerprint" which can confirm the presence of that chemical. Kirchhoff and Bunsen recognized that this could be a powerful tool for "the determination of the chemical composition of the Sun and the fixed stars." Throughout the 1860s, Kirchoff managed to identify some 16 different chemical elements among the hundreds of lines he recorded in the sun's spectrum. From those data, Kirchoff speculated on the sun's chemical composition as well as its structure.



One could sit in ones lab and look at the spectrum of the light being emitted from heated, glowing objects, and see what elements were in the object, and deduce the temperature of the object.

But one could also look at the light from a very distant celestial object and see these same lines.

Here are the lines one would see with Hydrogen, Helium, and Carbon. These are the pretty much the same lines one sees whether looking at heated gas in a beaker in the lab or when looking at a distant star.

So let's regroup.

We know that when working in color, the eye uses three sensors, a red, blue, and green, to see color and contrast.

This may do us some good when we are looking at something bright enough to have color, like a planet. But it does not do us much good when dealing with dim fuzzy gray objects.

We know that the eye-brain system sees contrast, not absolute values for light.

We know that different elements glow in different colors.

Even though we may not be able to see in colors, we need something that allows us to manipulate the intensity of different colors so we can see the contrast between the various elements.

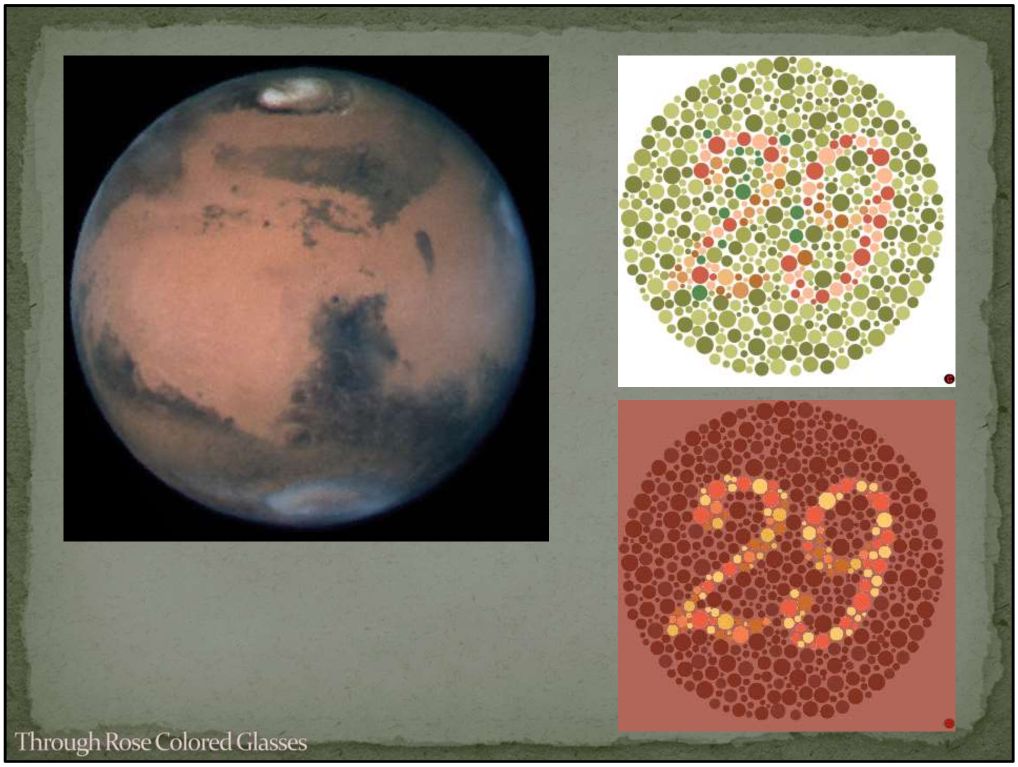
That is when we need Rose Colored Glasses.

Now, all we have covered so far has been pretty much theory and the science behind how filters work. From here on, we are going to be looking at some filters and see how they work in particular. Then we will take a look at different types of telescopes to see how our choice of instrument determines what we see.

Lets start with simple filters on optical telescopes.

Planetary Filters are colored glass that absorb most light and let one major color pass through. Deep Space are much more sophisticated pieces of glass with special reflective coatings that bounce light around in such a way that only very specific, narrow bands of light get in.

Let's see how that works.



Let's take an example of a bright object, the planet Mars. Mars is predominantly red because of the rust on its surface. But it has some blue areas.
Would it be possible to look from earth to enhance this red light while blocking and darkening the blue?

Let us look at another of the color blind test charts.

Notice this area. It is made up of reddish dots and greenish dots. See the background, which is made up of equal red, green, and blue—An equal mix of R, G, B means white.

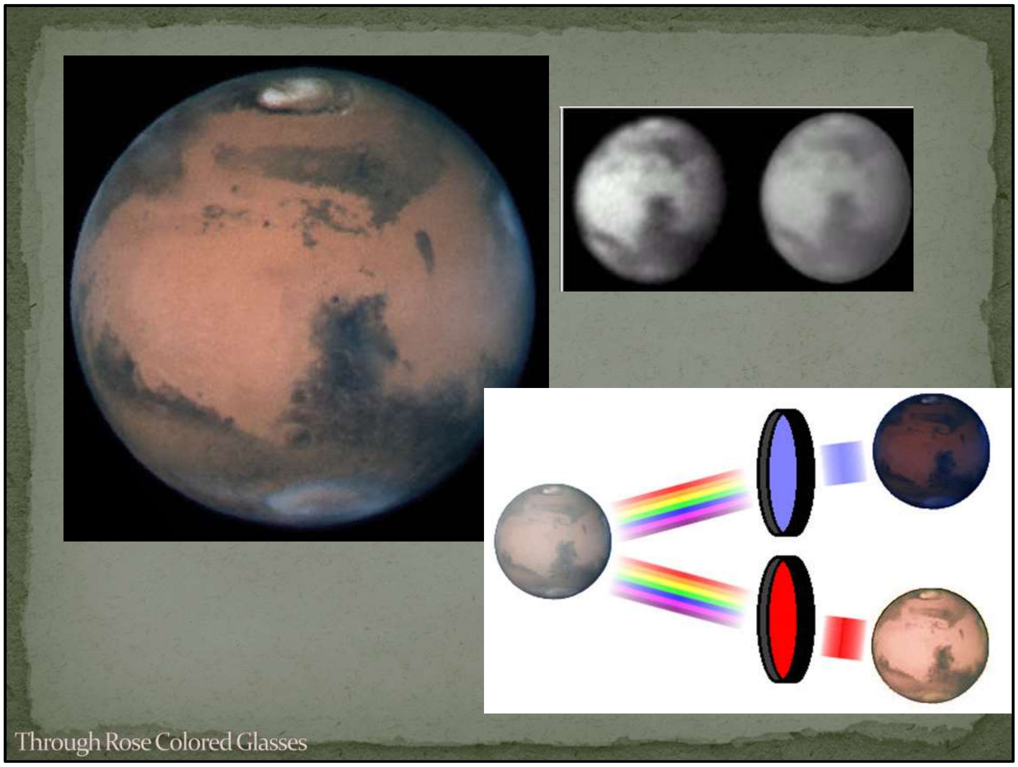
What if I were to put a filter in that would allow red things to show through while cutting of the green things and blue things?

CLICK

See the 29 up here

CLICK

Now see it? Well, up pops the 29. It was always there, but since the green and blue stuff got dimmer, the contrast really popped the number 29 out to us.

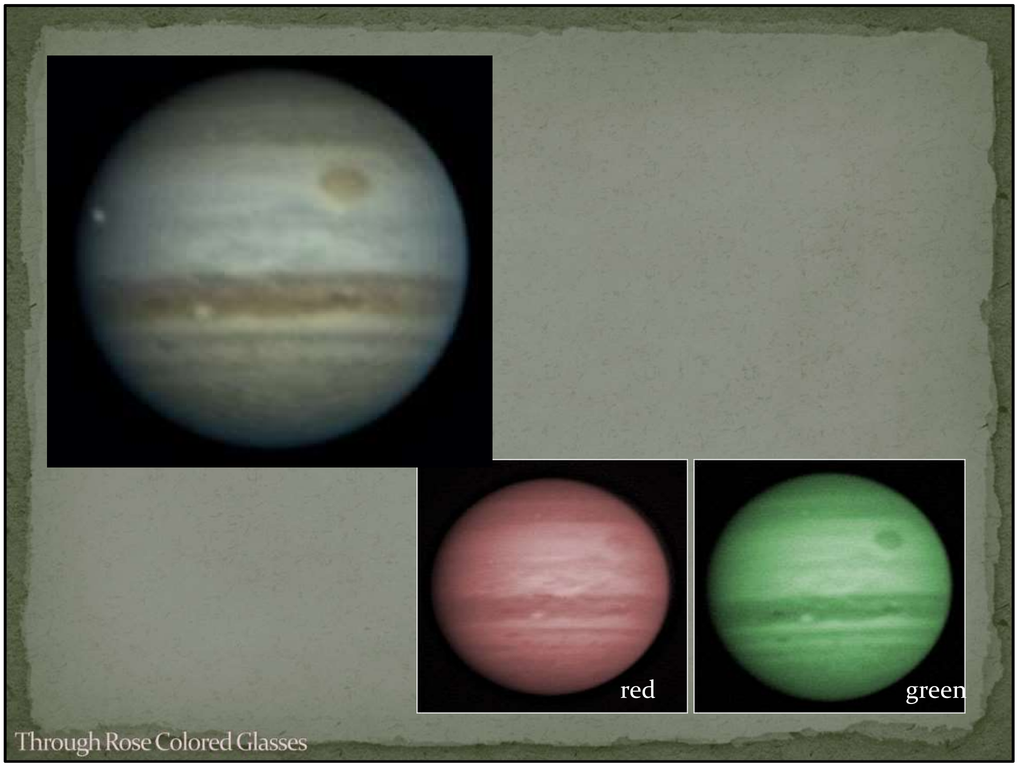


The same thing can be done by putting a deep Rose colored (ok, red) filter on Mars.

There are red areas. We expect them to stay red and fairly bright with a red filter. But since the red filter is not letting in any of the blue, we would expect that to dim. Dimmer blues with just as bright reds means greater contrast, and thus visibility.

Similarly, the blue filter would keep the blue things the same dark blue, but severely cut off the reddish light, leaving them even darker, with less contrast between the blue and red, the main detail seems to disappear.

But either filter helps with the contrast in the white region at the polar caps!

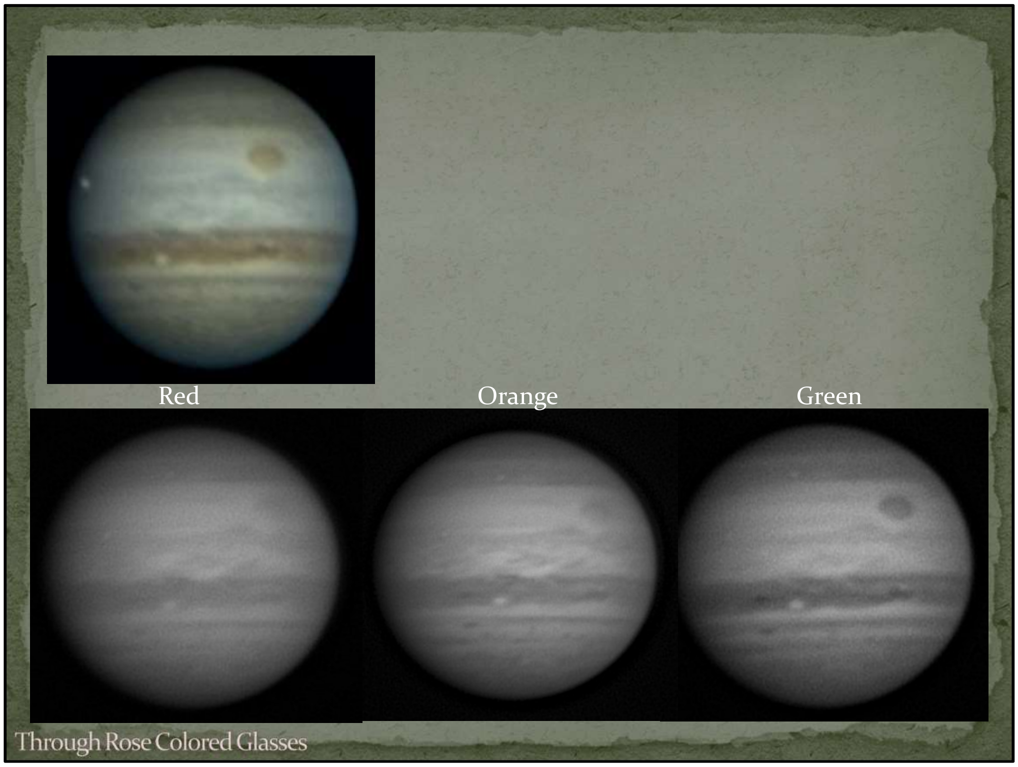


Another example, Jupiter. As a tricolor image, you can see various details, but if you want to emphasize one thing or another, you might be wise to use a colored filter.

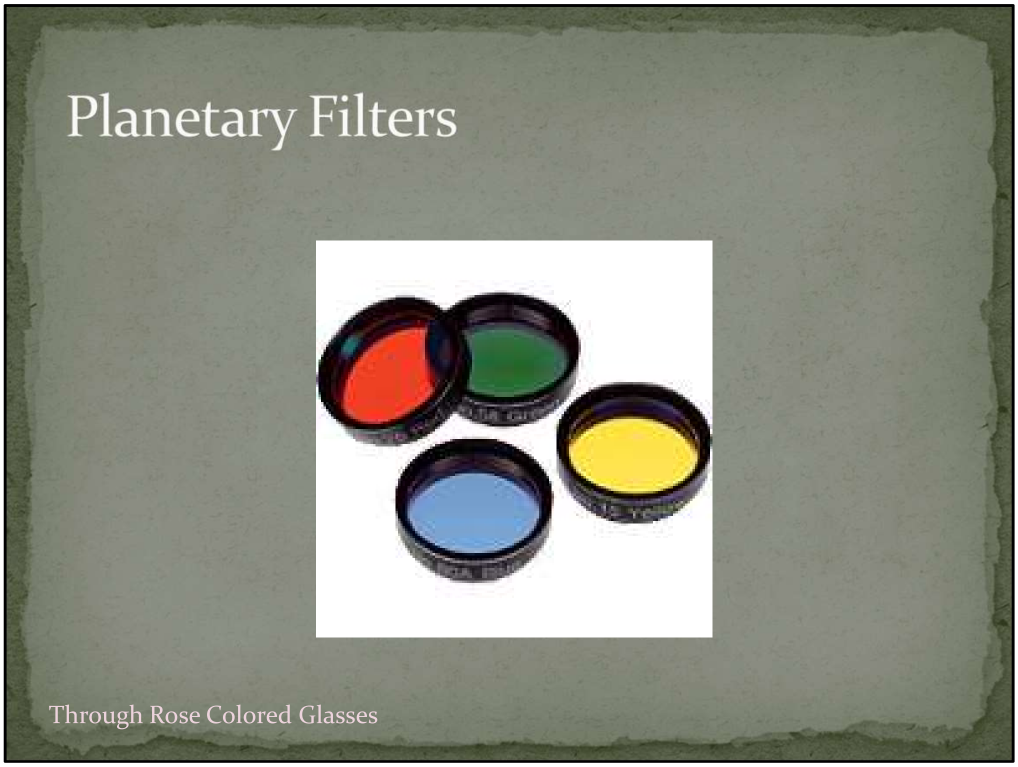
Notice that there is a Great Red spot here in the middle of a whitish field. The whitish field has a mix of red, green, and blue. And the red spot is mostly red. So, we have something that is red in a field of red, green, and blue.

Let only the red in, you are letting in the red of the red green blue area in with the red of the red spot, and the Red Spot does not stand out much.

But let in only the green, the green continues to show in the area that is red-blue-green (In other words, this wide white band continues to shine brightly through), but there was no green in the red spot, So, this area (the red of the great red spot) stays dark. And the red spot is separated from the whitish area.



In the previous slide, I manufactured the pictures with photoshop showing you what you might see with a red or green filter. Here is the actual monochrome photographic effects of the same thing. If you are relying strictly on the brightness of the objects, you can see how much more clearly the red spot and other features show up in a green filtered image of Jupiter.



The little buggers that do this are called planetary filters.

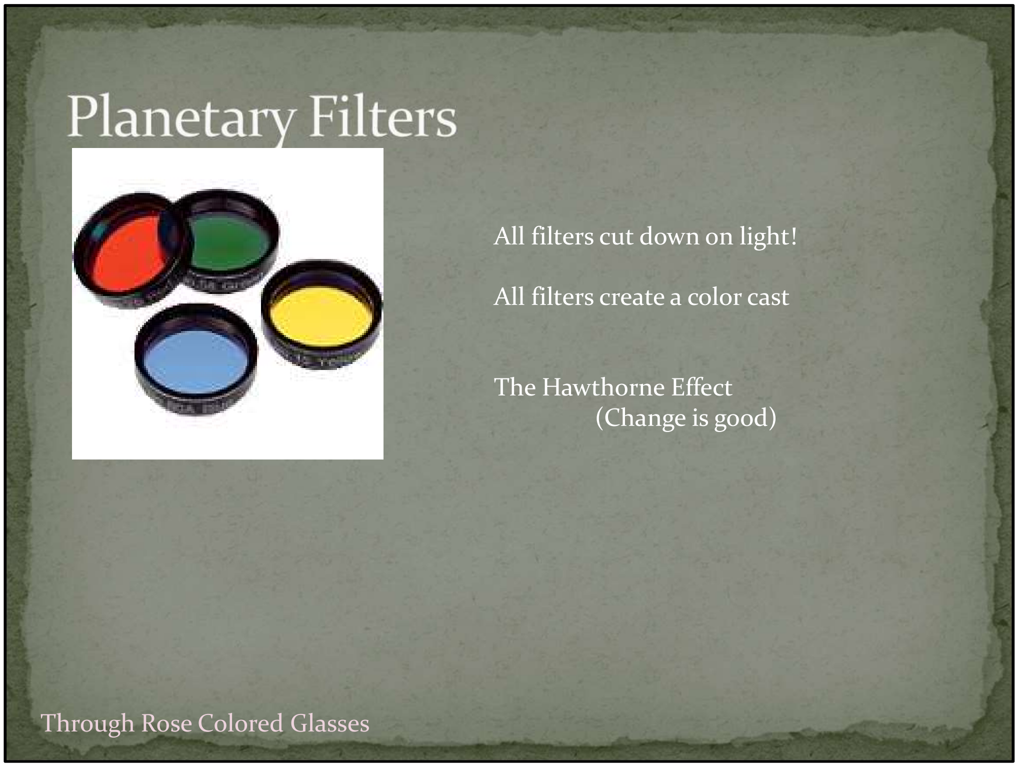
They come in many colors, but a basic set of four will do you for a long time.
This set, from Orion, costs $49.95, and includes Includes #15 Deep Yellow, #25 Red, #58 Green and #80A Medium Blue. Those numbers, incidentally are left over from black and white film days when all filters had a standard number to insure that folks could get repeatable results in their imaging.

They generally screw into the end of a 1.25 inch eyepiece.

Another kind of simple glass filter is “colored” a neutral gray.

The point is not to let in some colors while blocking others, but instead to cut down the light evenly across the spectrum. These neutral density filters are quite nice in lunar observing. They cut down on the glare and make the observing much more comfortable. I generally have one on my scope at lunar observing time. They cost $15 or so, and you should have one if you observe the moon.

I did not use one the night I caught the ISS going across the face of the moon-----but it is such a cool picture and I wanted to show it off.



The filters I have talked about so far can be bought for as little as $5.00 at RTMC. And rarely do they cost much more than $15 or $20 apiece.

There are some things to remember here……

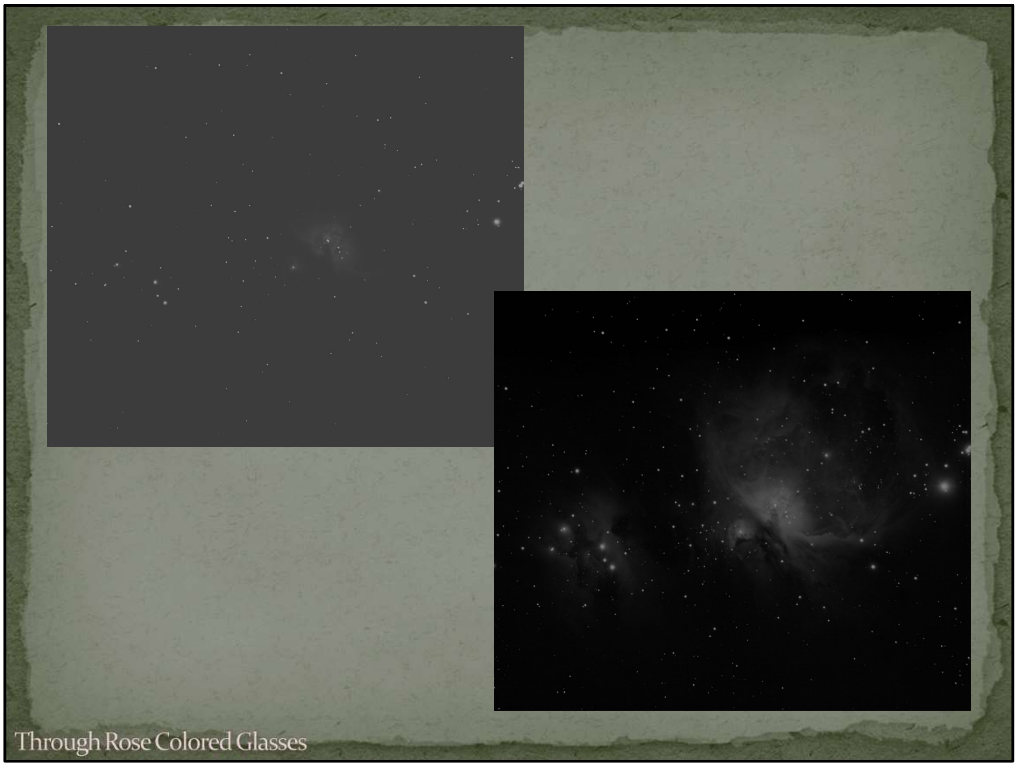
All filters cut down on some light. Things will be dimmer, even in the color you are letting through. TO compensate for this, your eye just adjusts. But you may wish to adjust also by getting more aperture.

All filters create a color cast. You are dealing with bright objects in the planets. If you use a green filter, everything will appear green. So, you lose the natural color. You exchange it for better contrast in what becomes essentially a monochrome image with a color cast.

And finally, Much of the effect of the filters is real, as we discussed earlier. They do increase the contrast and thus visibility of objects. But some of it is the “Hawthorne” effect. Remember the Hawthorne effect in early studies of industrial efficiency…..They wanted to study the effect of lighting on the workplace, so they increased the lighting, and production sped up. So they did it again, and it sped up again. At some point, they said they wanted to check the effect of decreasing the lighting, and production sped up again……Point was, eventually, that it was the fact that they were doing an experiment that sped up production—not the change in lighting itself.

Like many audiophiles who believe you should change your speakers now and then just so you hear differences (which are often interpreted as “Improvement”) changing the filter itself makes you think you are seeing more.

23 minutes to here.



But, This filter stuff gets even better than that!!!

All that we just learned about manipulating light—letting some in while blocking others, can be applied to deep space objects.

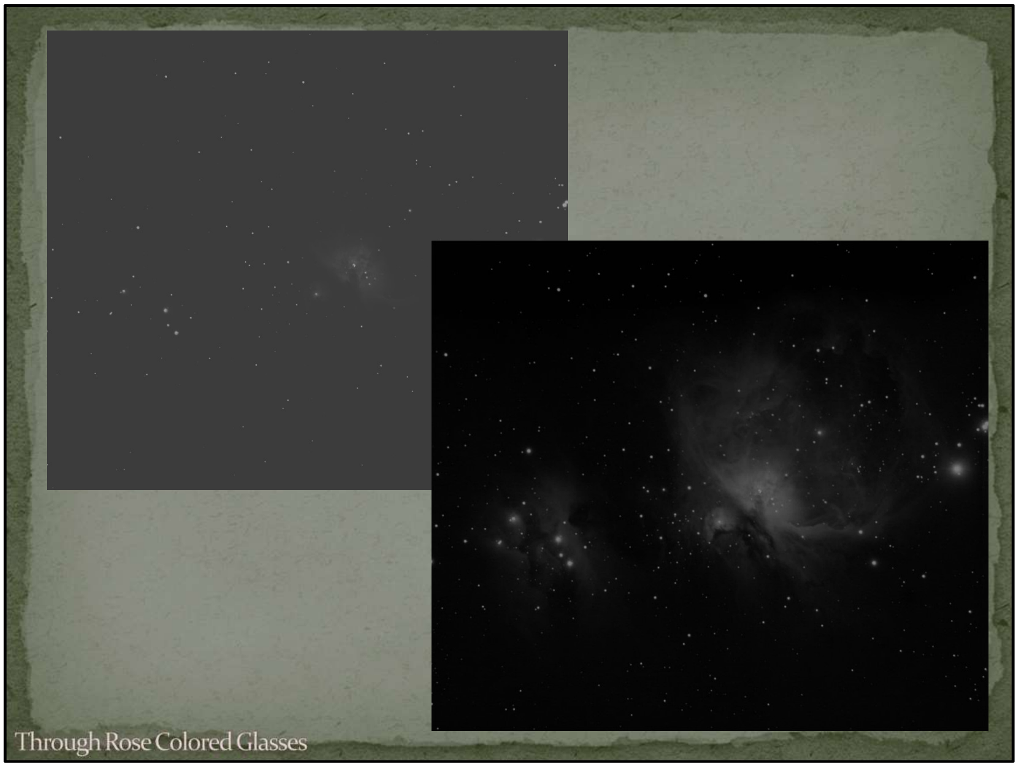
Let’s say you wanted to see something from the city.

On a good night, this would be the Orion Nebula. There is some glow in the right places, but it is nothing like the cool things we saw a bit earlier. Notice also that the sky itself is not black. It is a hazy, low contrast gray.

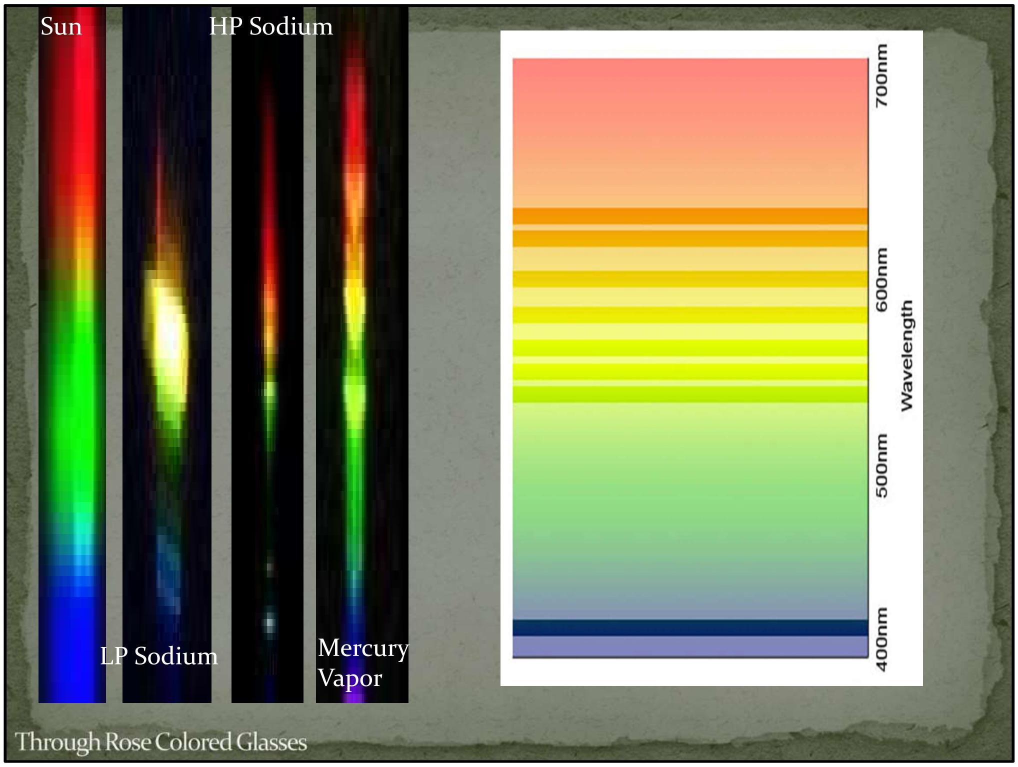
This is because of light pollution as it bounces off dust, aerosols, and other things in the atmosphere.

CLICK

Without that light and air pollution, it would look kinda like this…..



The key to making this look like this without heading out to GMARS or another dark site is to figure out what colors you want to let in and which to keep out.



And to start that, you need to figure out what is causing the problem!

Now we have known since high school after studying Newton's work that if we split sunlight—what we call white light—into its parts, we get a continuous spectrum from red, to green, and blue…..

Click

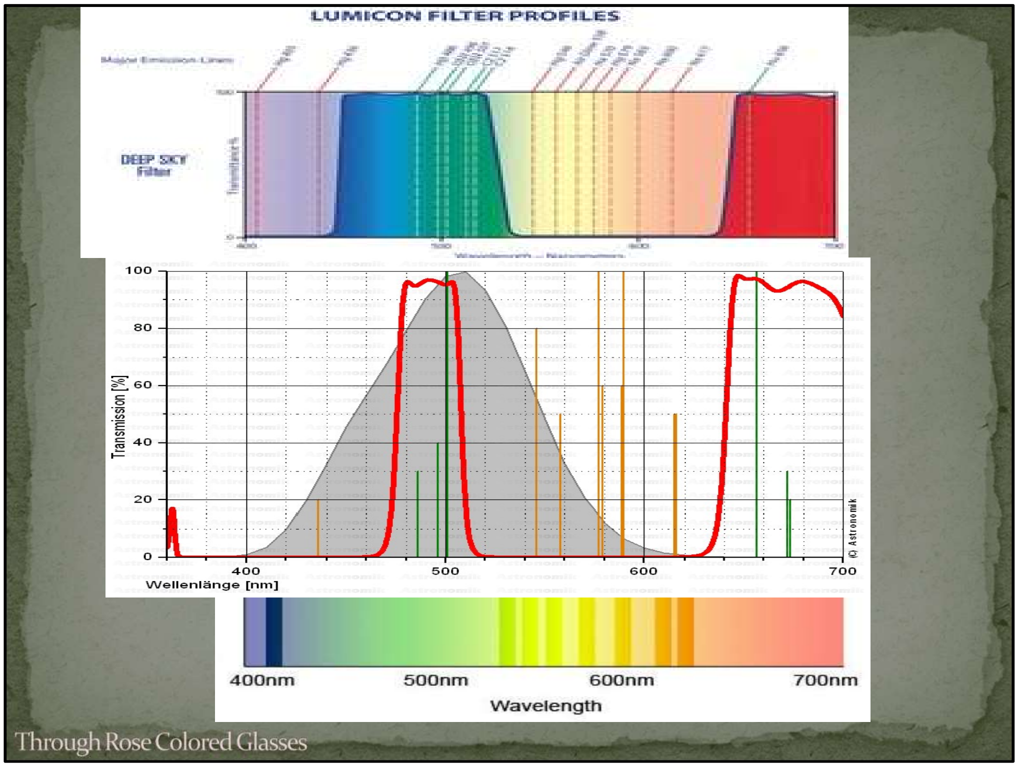
But, remembering the work of Bunsen, Kirchoff, and others, we know that light is not continuous, but every element has a characteristic color.

Look at the other common sources of night time light in the world: Low Pressure sodium, High Pressure Sodium and Mercury Vapor……Notice that instead of a continuum, we get discontinuous bright and dark spots.

A nice little illustration from the Starizona website that shows us the whole spectrum, with the most common region for light pollution highlighted.

See how all three sources of light pollution glow in blue. So there is a bright blue line here to mark that. And all are pretty strong in the yellow-green, so there are a number of lines showing in yellow-green. But right here in the blue moving to green there seems to be not much coming from light polluters (except Mercury vapor)—so there is no real strong line in the blue-green.

What we want to do is somehow block certain colors of light out, while allowing others in.



Lets slow down and take a notice of what these charts are telling us.

These charts may not be as clear as I would like because they came from different places and they had to be stretched and squashed to make their scales the same.

Let's start at the bottom----this, from the last slide, tells us where the common light pollution sources are.

Then at the top, are lines showing us where the different elements glow.

This chart in the middle, from Astronomik for their low cost Ultra High Contrast Filter, one that would be a general purpose filter for use in light polluted areas on deep sky subjects.

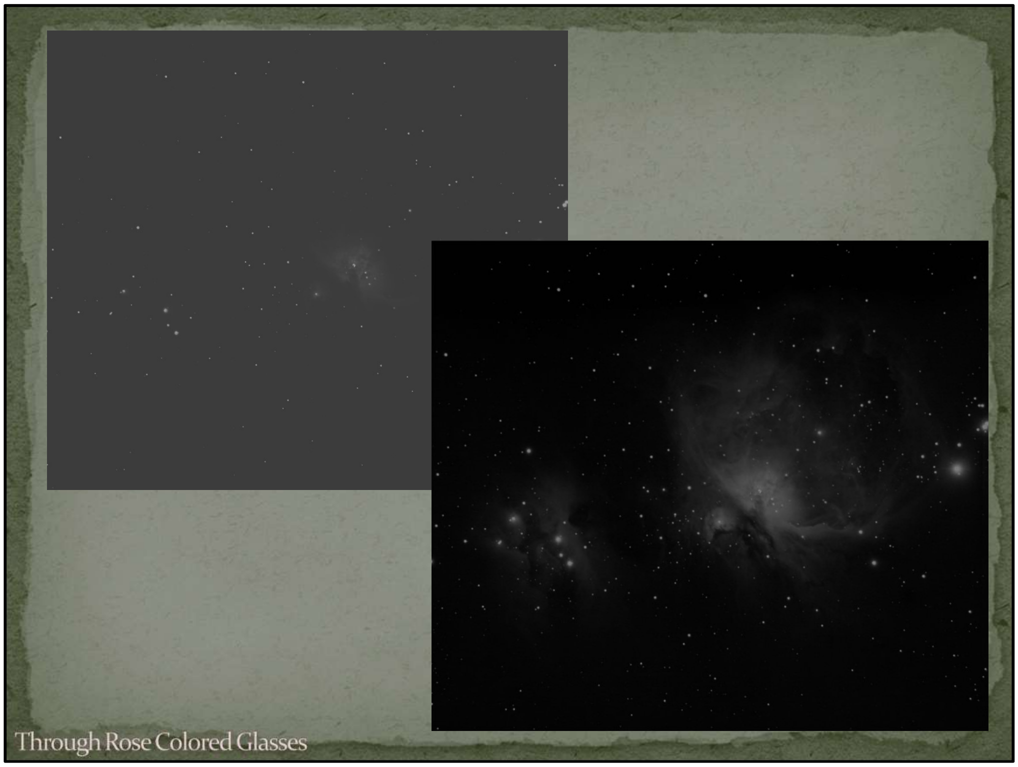
The **horizontal axis** is the **Wavelength in Nanometers** (nm). 400nm is deep blue, at 520nm the human eye senses green and at 600nm orangy red. At 656nm is the famous "H-Alpha" emission line of hydrogen.

The **transmission in %** is plotted on the **vertical axis**.
The **red** line shows the **transmission of the filter**.

In other words, at 500 nanometers—a green color– the filter lets in about 95 or so per cent of the light. But at 540 or so, it lets in zero per cent.

Visual filters: The **grey** line in the background shows the relative sensitivity of the human eye at night. The maximum is at ~510nm and drops to longer and shorter wavelengths. You can easily see, that you can´t see anything of the H-alpha line at night (even if you can during daylight!) The sensitivity at 656nm is 0% at night! However, a camera can see will into the 700 range.

Your filter should match what you want to see, with a high transmission of the available light of that color, and cut out the things you do not want to see, with no transmission of that.!



So, by cutting some light out, while allowing other light in, at specific frequencies, you can turn this into this.

Oh, yes, not all deep space objects are created equal……..Here is a photo of M20 and M8 by Riverside Astronomical Society Imager Mark Melnyk taken from Goat Mountain in early May.

Think back to the earlier example of the Running Man and Orion Nebula. You can see the same things here….. The colors are different. Blues, reds mostly, but there are others in there, also. It is important to know that different colors come from different conditions in the glowing object.

Different elements (hydrogen, Oxygen, sodium) glow at different wavelengths characteristic of the element itself. That is, hydrogen is a different color (red) from oxygen (blue).

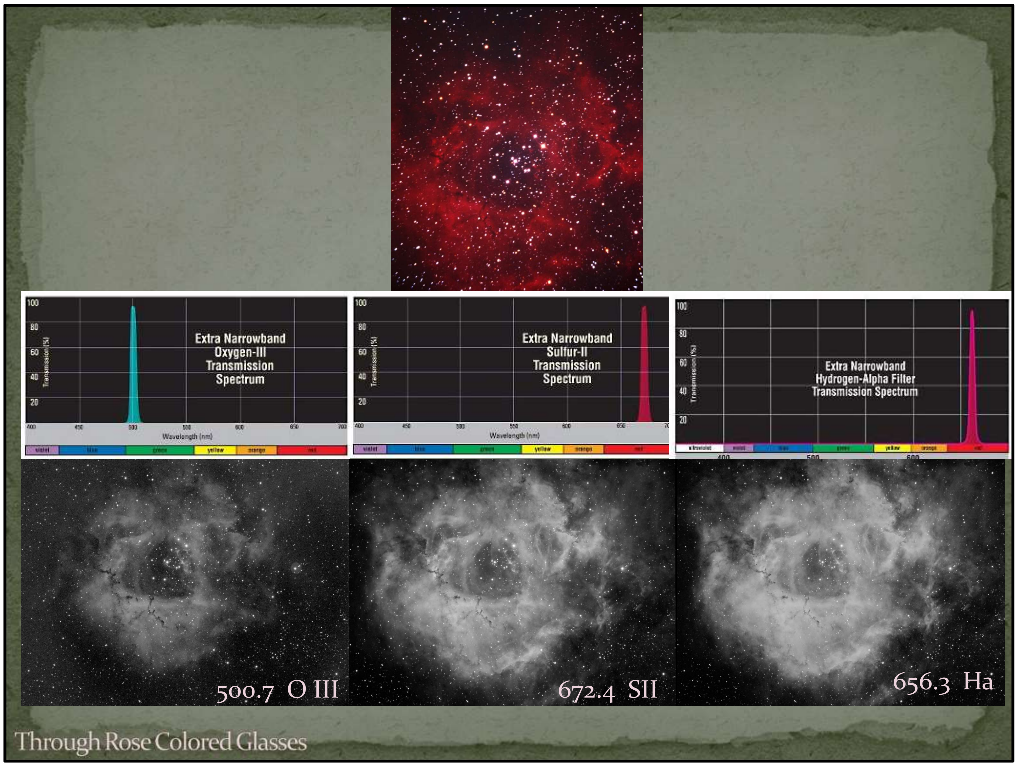
Any given element can glow at several different wavelengths depending on its temperature.

Different gasses and dusts glow at different colors depending on whether they are simply reflecting light from nearby stars, or are in fact heated so hot that they are beginning to flouresce or glow on their own.

The different colors you see in this photo are the result of the different conditions under which the gasses and dust are glowing! You have to match your filter transmission to the gas and its temperature and other conditions.

It hard to believe sometimes that changing the filter alone can change what we see. But looking at the Rosette may help illustrate the point.

Here is the Rosette taking in a broad spectrum one shot color picture with a DSLR. Note that it is dominated by the red.



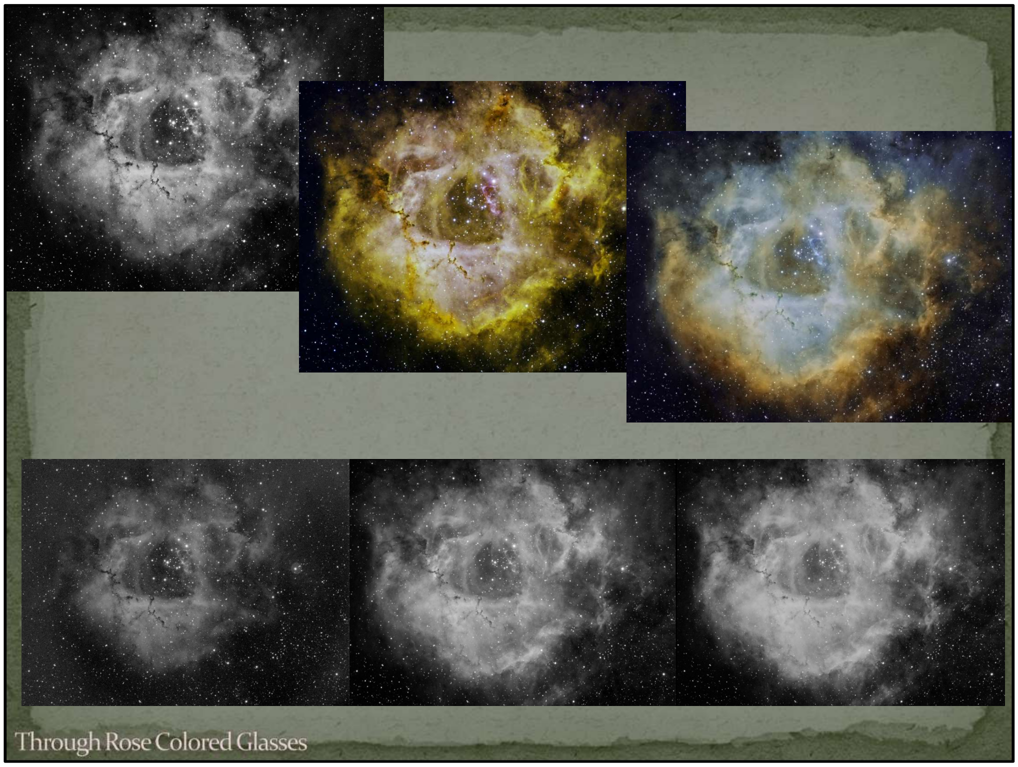
Here is the same object taken monochrome with three different extremely narrow band filters. By Narrow Band, I mean that only a small portion of the spectrum is allowed to pass….in this case just one color of blue, and in these just two different specific colors of red.

In the first, only the Oxygen heated to its third excitation state shows. It is at 500.7 nanometers. There is not much of it. It is in a blue light—and you will recall that the Rosette is basically a red object. See how much structure shows in this blue light, with the tendrils here and here fairly bright. Notice that there is a general glow around the area.

The other two pictures are taken in reds. Sulfur II glows at 672.4 and Hydrogen alpha glows at 656.3. There is not as much Sulfur as there is Hydrogen, and so the Sulfur is a little darker, and a little more sharply defined. The Hydrogen, on the other hand, is a bit more diffuse and brighter.

Contrast these reddish pictures with the bluish. Notice the details that show in red that are not present in blue.

If light were all the same, these three pictures would be identical. But in fact, I have used filters to emphasize that different parts of the nebula are in fact glowing in different colors, and therefore show different details.



Now, this presentation is about visual use of filters, not about narrowband imaging. But I would like to take just a moment to show you some of the magic of narrowband imaging. In the first place, these images were all taken from Moreno Valley, which suffers from light pollution, being a suburb of the LA megalopolis. These were from my backyard.

Secondly, I have here a picture taken in blue light and two reds. But to make a full color picture, I have to have red, green , and blue. Which of the two reds should play the roll of the green? Well, I have my choice. And what I choose makes a difference in my final result.

Here is what I get if I make the Sulfur green, and here is what happens if the Hydrogen Alpha is green. They are both pretty interesting, and they show different detail. But again, these are photographic. What you would get visually is more like a dimmer version of this blue…….O3.

37 minutes to here.

Okay, so I can change colors around. Who gives a rat's behind? I mean, what good does it do us in exploring the universe?

Well, I am not just changing colors around. I'm actually making things visible that were invisible. Filters make it so you can see things you would not otherwise see.

Check out this picture of the sun that I took from my back yard yesterday. Notice the sunspots. Even the smallest is larger than the earth. They are cool spots on the sun, about 4500 degrees instead of the usual 5000 degrees. So, they do not put out as much light. This picture was taken in "White Light." That means I let in all the light of every wavelength. When you do that, you get a whitish looking sun with dark and bright orangepeel effect. And you get the dark of the sunspots. I colored my "white" sun because I want to compare it to another picture I took. This is Pretty interesting.

But, what if, instead of letting in all the light, I let in only the light from hydrogen that has been heated to a certain point that it gives off one electron. This hydrogen glows in a specific color, right at 656.3 angstroms.

Click

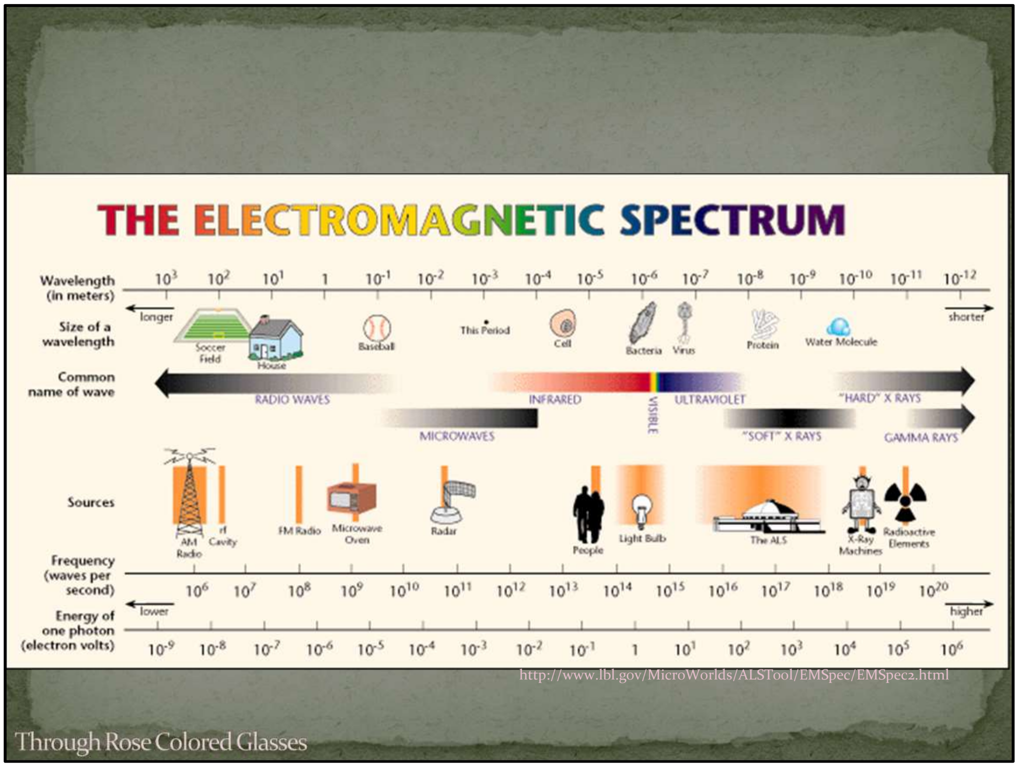
Pop—look what happens. You can see the orange peel much better, and you can see there are other features that just did not show up in the white light. These smooth whitish areas, these gray streaks? You do not see the sunspots as well, but there is a lot of interest here, too.

But the Hydrogen alpha light is drowned out in white light, so you cannot see these features. And one thing that you really want to see on the sun is the prominences:

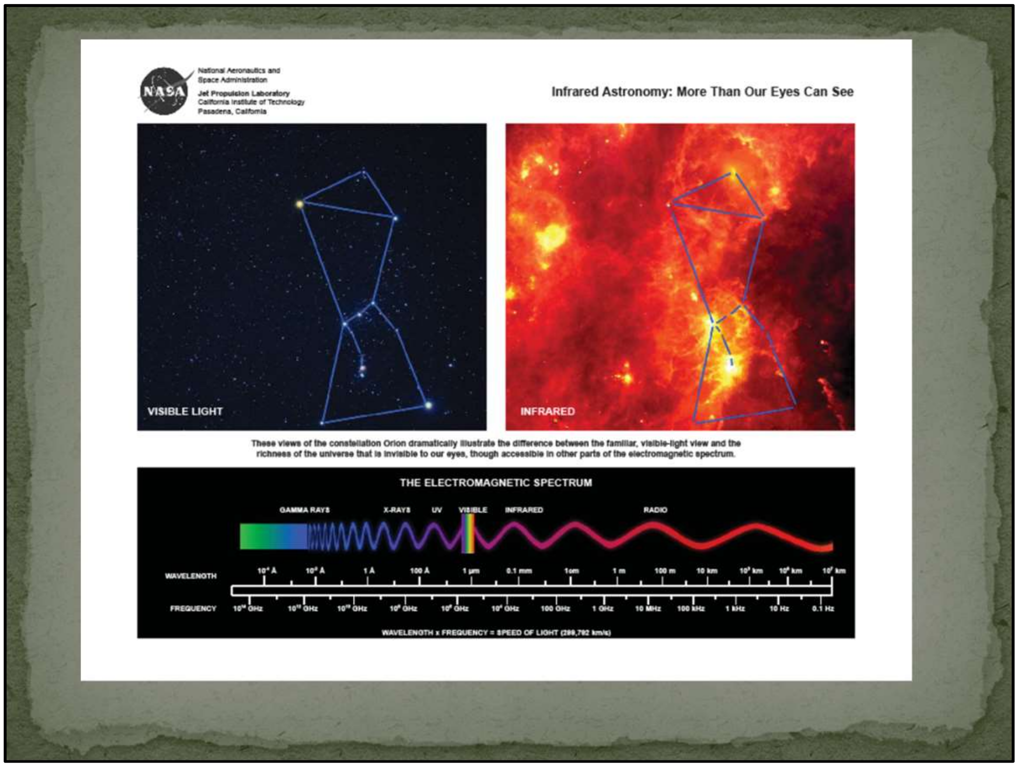
Click

And here they are, visible only when you take out most of the light, and let in only a narrow sliver of a certain red.

That is why filtering is important.



Now, so far, we have been playing only with light for our own eyeballs. Just this teensy part of the spectrum. What if, like the bee, we wanted to see things in the ultraviolet? Or like a snake, we wanted to see things in the infrared only. We would need a different type of telescope. And there are a number of types of telescopes, depending on what we are after.

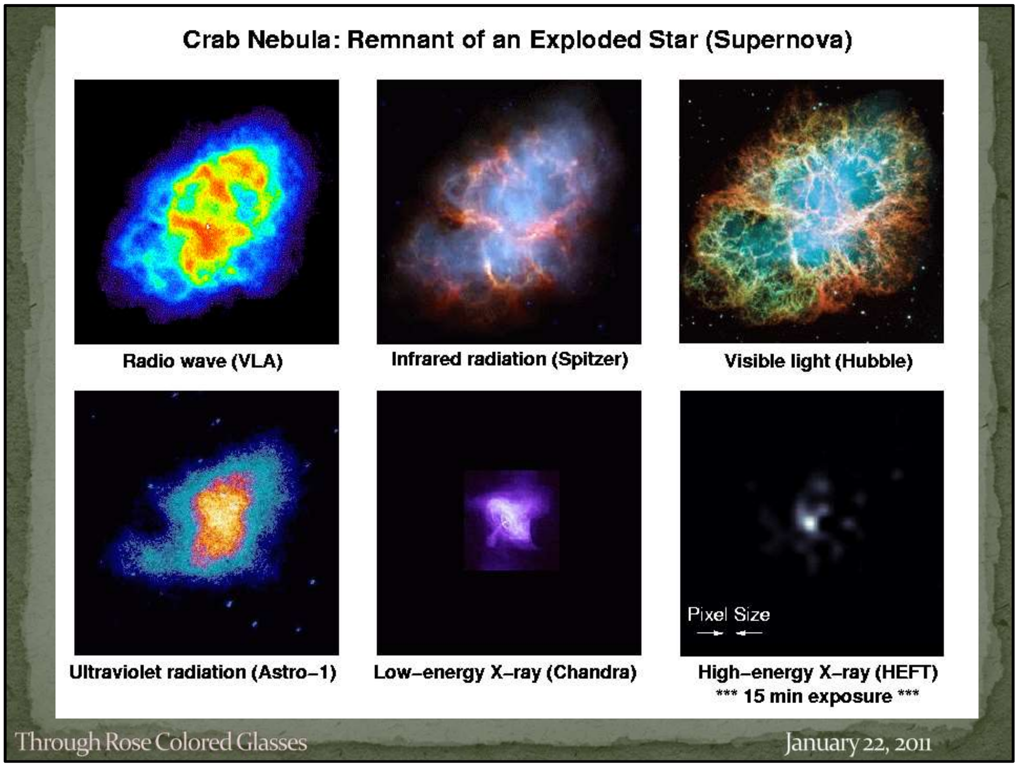


Look at this……

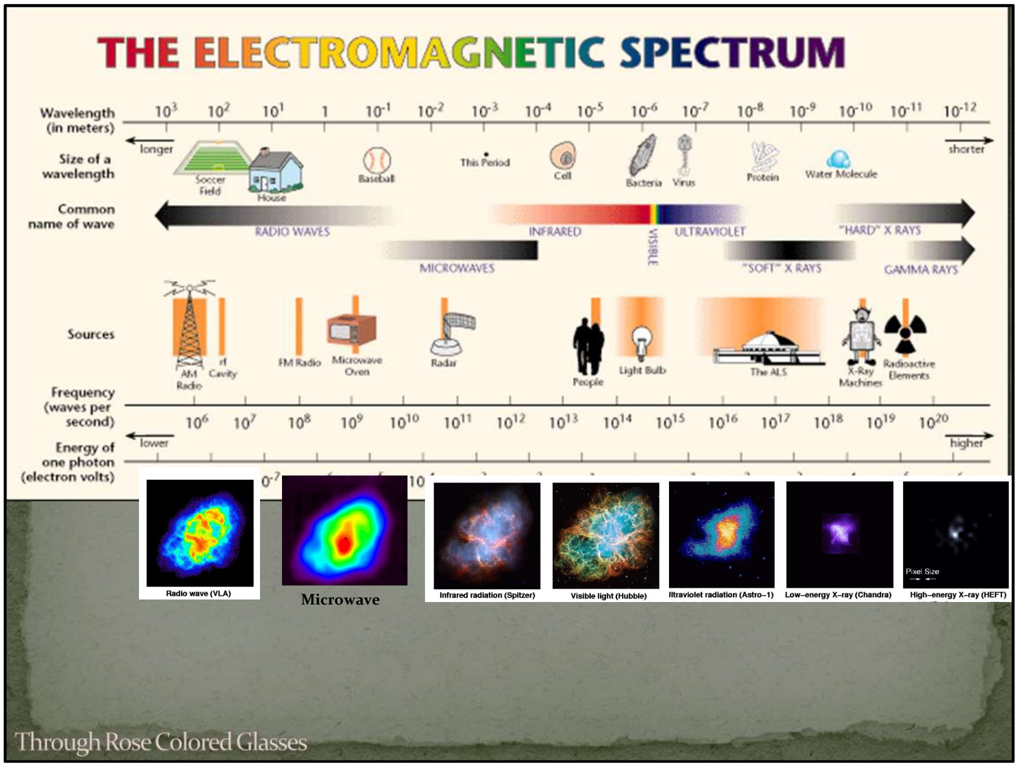
This is Orion, the Hunter as he might appear under a dark sky.

This is Orion, the Hunter as he might appear to us if we had infrared vision like the snake's only better.

With Infrared, we can see all the hot dust floating around in the area.

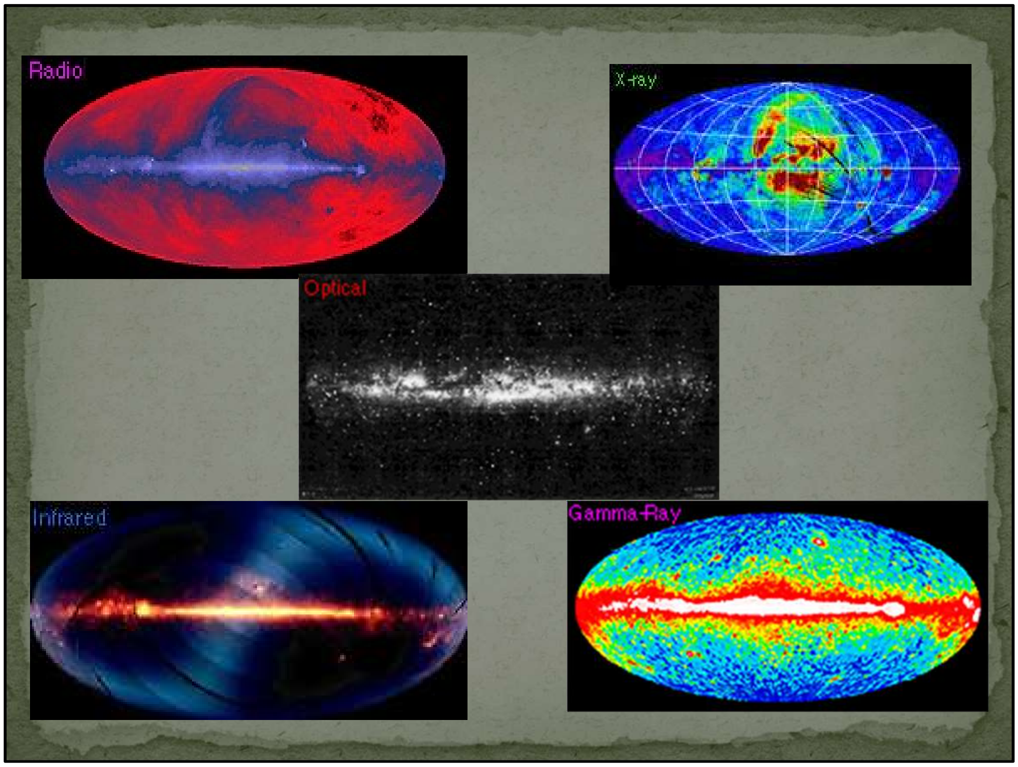


Look at this set of pictures of the Crab Nebula, taken with a variety of sensors. All represent the same target. All are at the same scale. But all are dramatically different. Only one is in the visible light—this one here from the Hubble. The others range from radio wave to high energy X-ray. Notice that some structures show in several of the photos. See this horizontal stretch across here. It shows again here and here. But, it is not here, here, or here. See how this low energy X Ray picture gets some tight circular spirals that are not present in the other images.

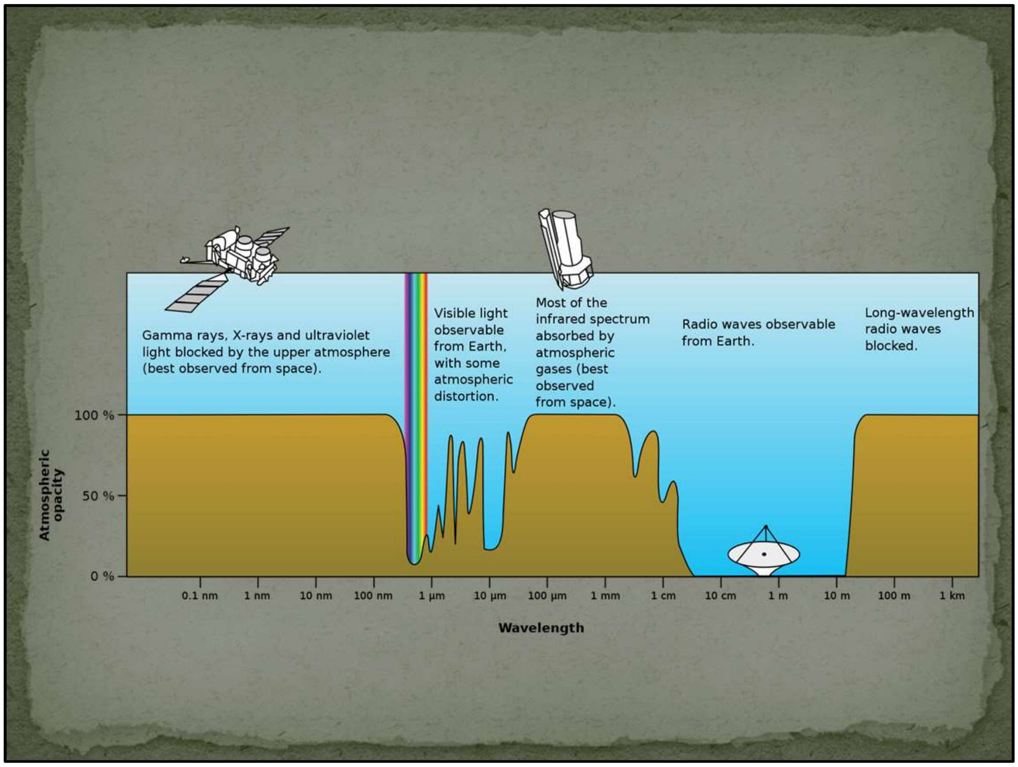


These different versions of the same object result from looking at different parts of the spectrum. And here I have them spread out according to their positions on that spectrum.

Note that this microwave representation was not in the same set as the other pictures. Also note, that all these, except for the Hubble shot in Visible Light, all are shown in false color, with certain frequencies of the electromagnetic spectrum being represented by frequencies in the visible spectrum.



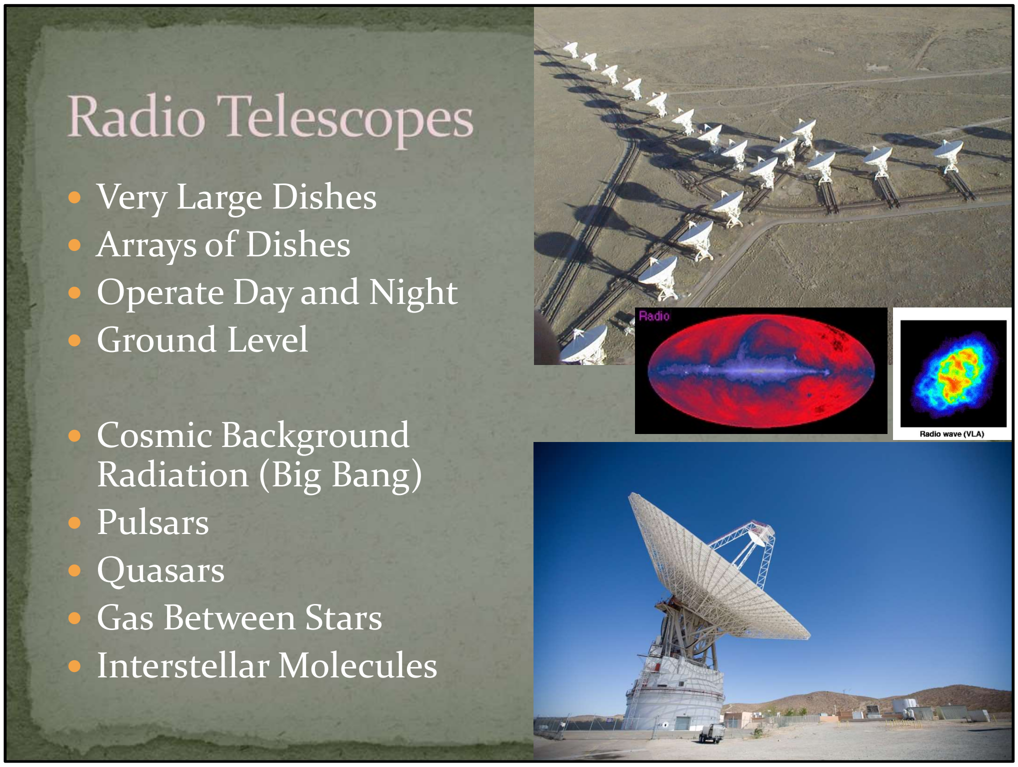
If you take a picture of the whole sky in visible light, you see stars. In other parts of the spectrum, however, you see hot gasses, dust, heat sources that are not putting out visible light, and energy leftover from the big bang.



Another factor to consider is that our atmosphere shields us from many types of electromagnetic energy. Let us look at this chart. Note that it is backward from the other illustrations of spectra we have seen. They each had low energy radio on the left, with his energy gamma rays to the right.

But here you can see that the longest wavelengths get blocked. Shorter radio frequencies make it through, so radio telescopes can be at the surface. Much of the rest of the spectrum is blocked until we get down towards Visible, and then below visible, everything is blocked, So. We need to go into space if we want to see them.

Of course, the earth's atmosphere also shakes and shimmies, the same phenomenom that makes a distant mirage wiggle. So even visible light, which does get thorugh, is better seen from space.

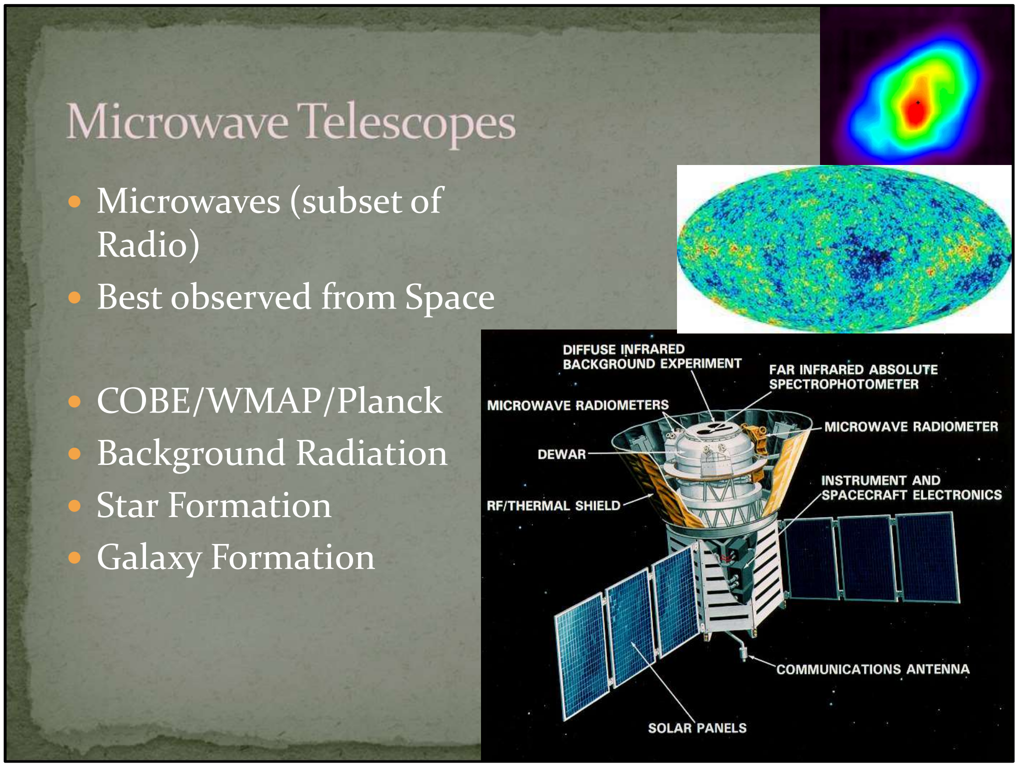


Radio waves are very long compared to waves from the rest of the spectrum. They are the size of houses and skyscrapers.

So, radio telescopes are large, This one, at Goldstone about sixty miles north of here, is 70 meters across. This one, the Very Large Array in New Mexico, is composed of 27 large dishes—each 25 meters across—And they are on railroad tracks so they can be separated and operate as one large instrument 36 km across. Radio telescopes use a large metal dish to help detect radio waves and bounce them to the receiver.

Radio Waves can penetrate the atmosphere day and night.

The study of the radio universe brought us the first detection of the radiation left over from the Big Bang. Radio waves also bring us information about supernovae, quasars, pulsars, regions of gas between the stars, and interstellar molecules.



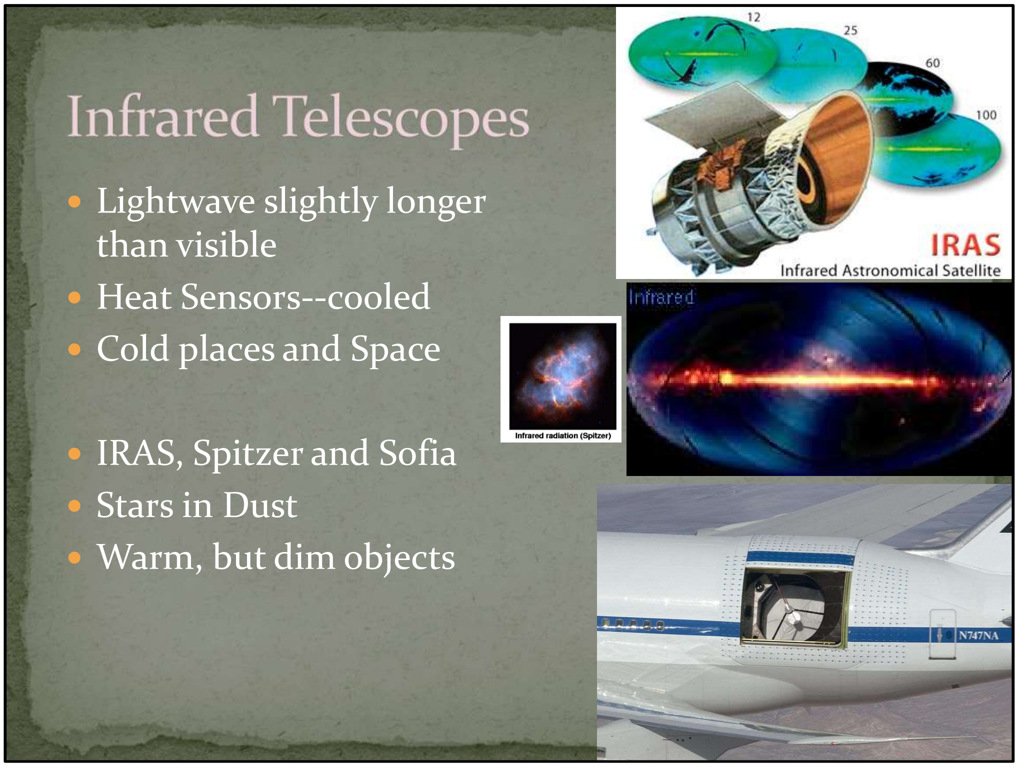
Microwave telescopes, use a subset of radio waves called the sub millimeter range.

This part of the electromagnetic spectrum is absorbed by the various molecules, including water vapor, in our atmosphere, so it is best observed from space.

The devices to observe it are therefore necessarily complex, involving heat sensors, and cooling systems to mask all other heat. And, of course all the things necessary to keep these things operating in orbit.

These spacecraft, with the names of Cosmic Background Explorer, the Wilkinson Microwave Anistrophy Probe, and the newest ESA's Planck, are all trying to define the shape of the Background Radiation. This is the stuff left over from the Big Bang. You can see it on a television if you disconnect the antenna. (Or used to be able to when televisions were not digital.) That white noise is partially left over from the big bang.

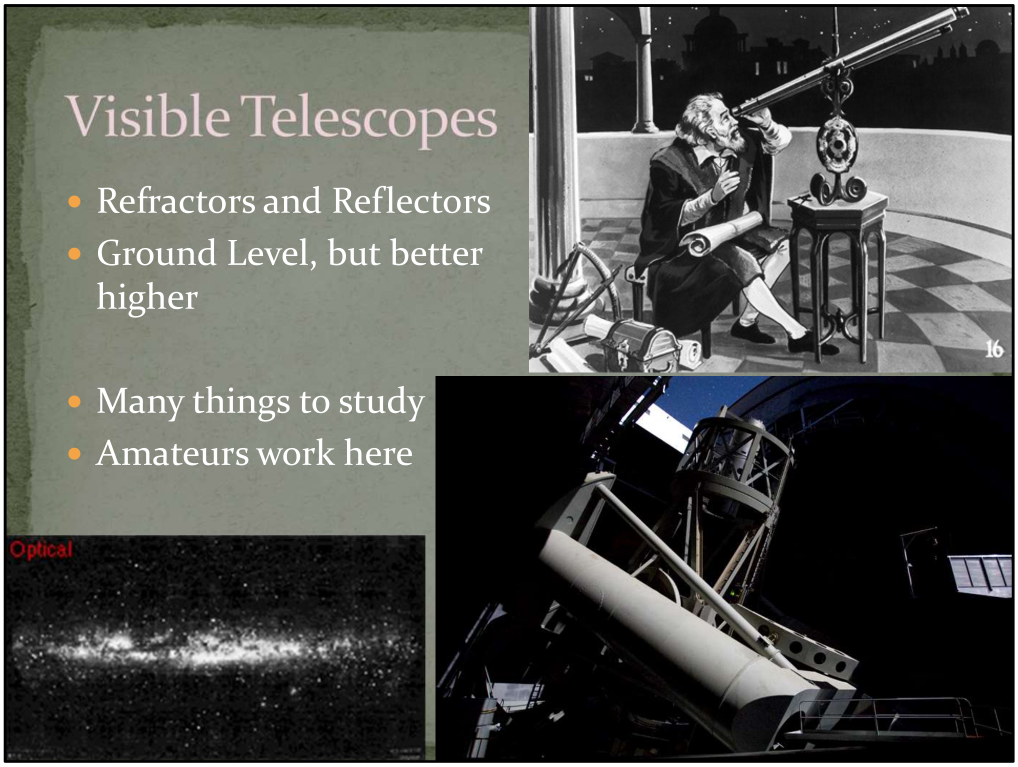
And you can see it on a big radio telescope. But, with the resolution you get on those instruments you cannot tell detail. And the detail is where you start finding out how stars are born, and how early galaxies were formed.



Only a few narrow bands of infrared light can be observed by ground-based observatories. To view the rest of the infrared universe we need to use space based observatories or high-flying aircraft. Infrared is primarily heat radiation and special detectors cooled to extremely low temperatures are needed for most infrared observations.

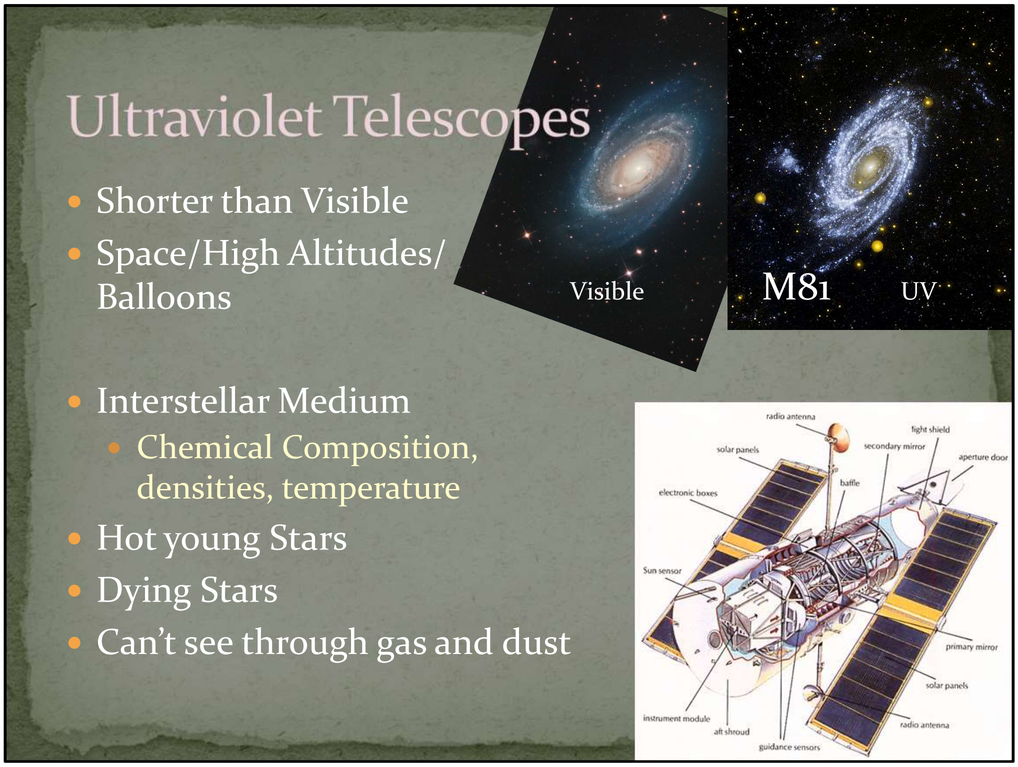
Since infrared can penetrate thick regions of dust in space, infrared observations are used to peer into star-forming regions and into the central areas of our galaxy. This gives us some insight as to what the center and far side of our Milky Way looks like. They can also look for very dim objects that give off some kind of heat, like brown dwarfs and asteroids, cool stars and cold interstellar clouds. The mission of the Spitzer Infrared telescope is typical:

physical studies of the planetary system
detailed study of cold circumstellar dust clouds
a search for the enigmatic brown dwarfs
Star formation at lower temperatures and luminosities
identification and study of powerful infrared galaxies
infrared measurements of all presently catalogued quasars



The telescopes we are most familiar with depend on bending visible light. As such, they are subject to the vagaries of our atmosphere. Clouds and water vapor affect what we can see. Also, we are highly subject to the varying seeing caused by disturbances in out atmosphere. This causes stars to twinkle. Really romantic, but annoying to anybody with a telescope looking for a steady view. This unsteady atmosphere, called seeing, is the same stuff you see on a warm day, with the heat rising off the road causing distant objects to shimmer like a mirage. That is why we put telescopes high on a hill, or out in space like the Hubble.

Nearly all our astronomical observations until the last hundred years were done in visible light. Visible light observations have given us the most detailed views of our solar system, and have brought us fantastic images of nebulae and galaxies.



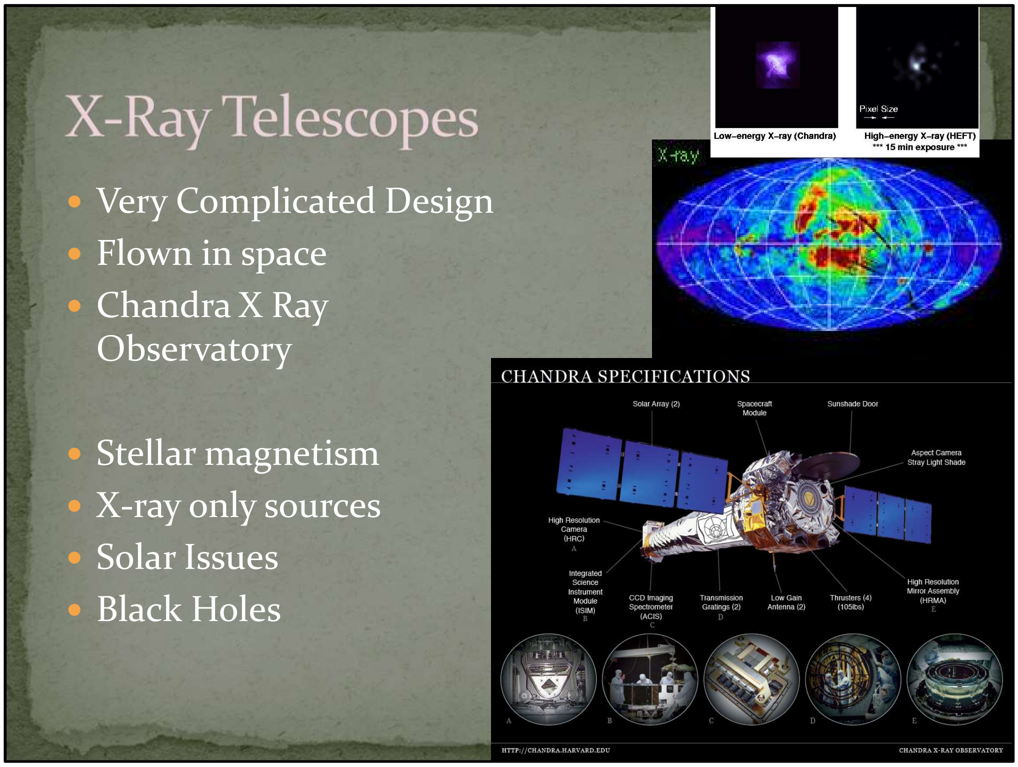
Ultraviolet astronomy is generally used to refer to observations of electromagnetic radiation at ultraviolet wavelengths a little shorter than visible light.

Light at these wavelengths is absorbed by the Earth's atmosphere, so observations at these wavelengths must be performed from the upper atmosphere or from space.[1]

Ultraviolet line spectrum measurements are used to discern the chemical composition, densities, and temperatures of the interstellar medium, and the temperature and composition of hot young stars. UV observations can also provide essential information about the evolution of galaxies.

Most stars are actually relatively cool objects emitting much of their electromagnetic radiation in the visible part of the spectrum. Ultraviolet radiation is the signature of hotter objects, typically in the early and late stages of their evolution. If we could see the sky in ultraviolet light, most stars would fade in prominence. We would see some very young massive stars and some very old stars and galaxies, growing hotter and producing higher-energy radiation near their birth or death.

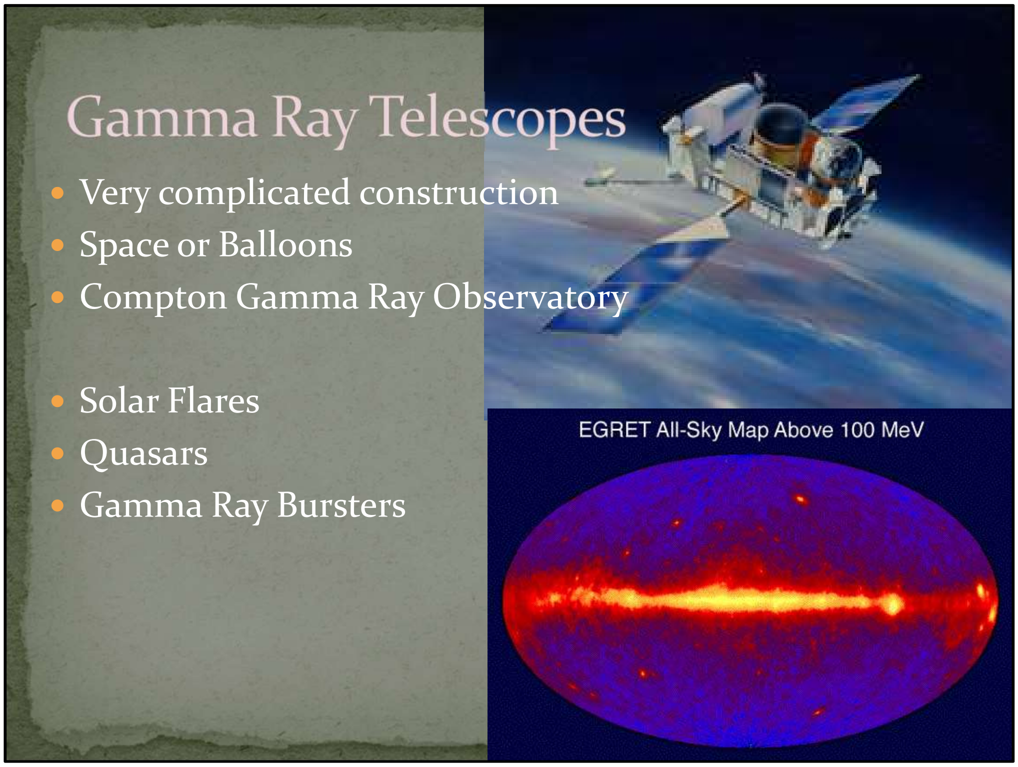
Clouds of gas and dust would block our vision in many directions along the Milky Way.



X-rays are very energetic. They will pass through most objects, thus making them very useful for seeing what a broken bone inside a body looks like. In astronomy, though, this makes it very difficult to detect. Therefore, the special satellites look very different from optical telescopes, with mirrors reflecting at very slight angles.

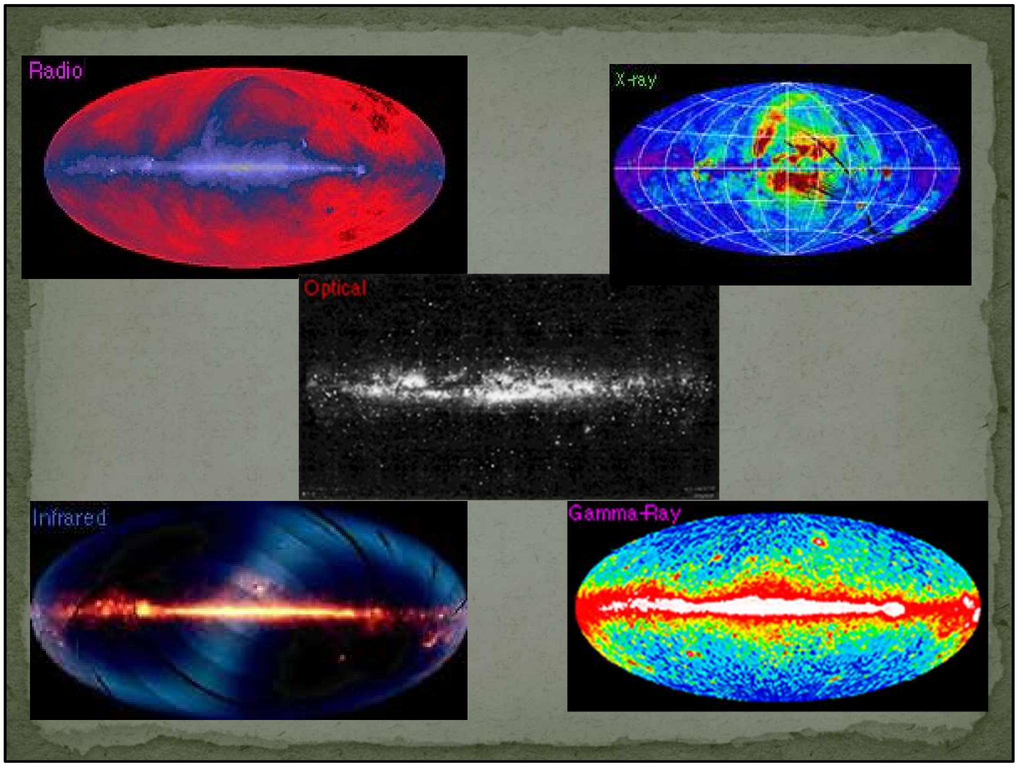
Again, these things work best above our atmosphere, and so are usually satellites, although rockets and balloons are sometimes used.

The major questions of X-Ray Astronomy is the study of stellar magnetic fields, mapping sources which do not glow other parts of the spectrum, but can be seen only in x rays, solar astronomy like the question of why the sun is so much hotter a few thousand miles above its surface than it is at the surface itself, and phenomenom associarted with black holes like that at the center of our galaxy.



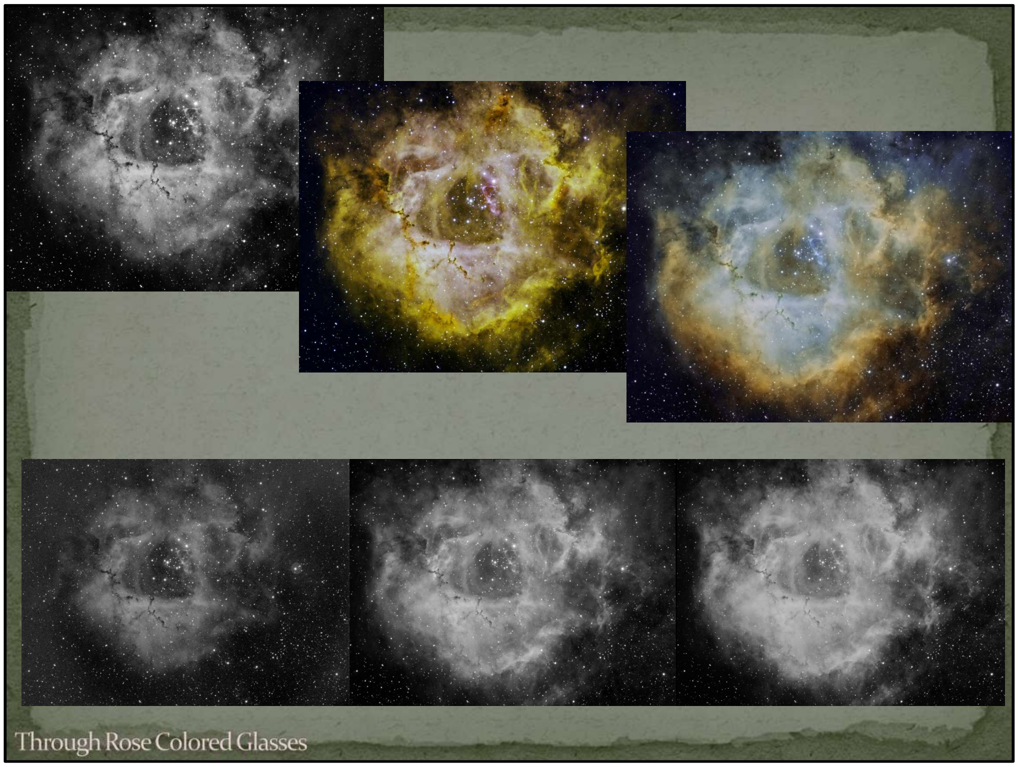
Gamma Rays are the shortest and most energetic part of the electromagnetic spectrum. Gamma Rays are produced by high energy impacts and great heat. Because the light is so energetic, it can actually pass right through many substances used as detectors in other telescopes. So, the construction of these telescopes is very complex. Specially made, angled mirrors must be used to help collect this type of light. They must be in space or high in balloons because our atmosphere absorbs most gamma rays.

The Comptom Gamma Ray Observatory has been very instrumental in studying Solar Flares, Quasars, and a phenomenom discovered in the early cold war by satellites sent up to detect Nuclear tests. They found them, alll right, but they were not coming from the earth. They were having blasts come from all around the universe. They last only a few seconds, and have more energy than is normally put out by whole galaxies. They are just now figuring out that they might be some kind of hyper nova.



Well folks, that about does it. In 45 minutes, one can only talk so much about the different ways to see the world.

I hope after this afternoon you realize that what you see is largely dependent on what you use to look, and that you can increase your vision by looking at things in different ways.



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