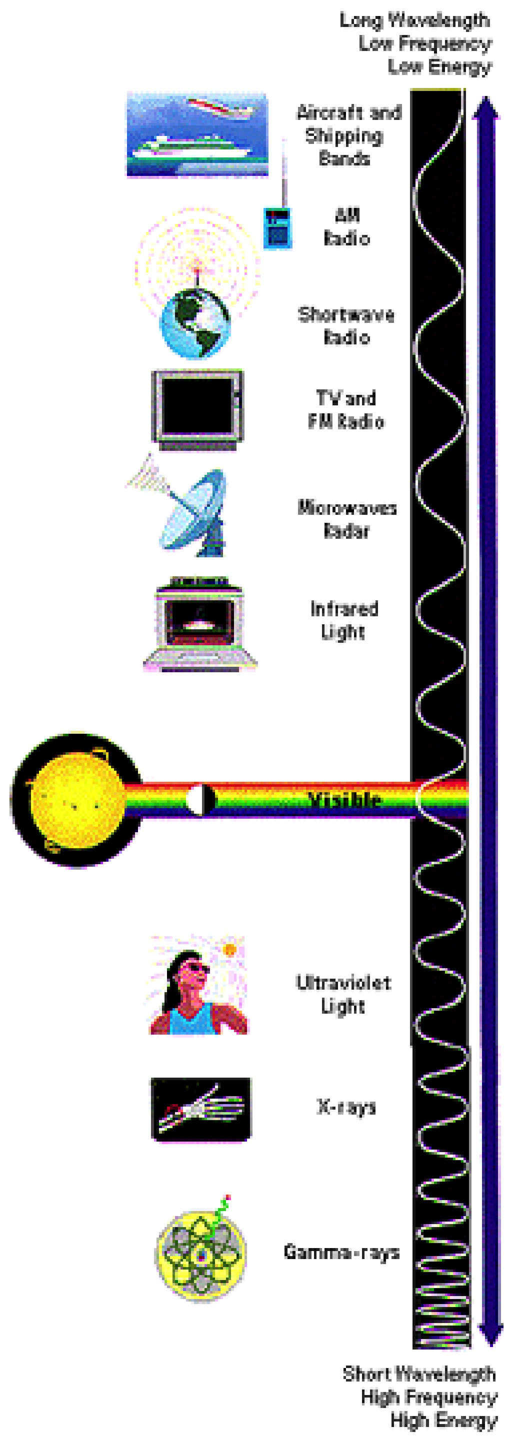
The Colors of Light

What colors are in light?
Humans have eyes that are sensitive to light in the "visible" portion of the spectrum (red, orange, yellow, green, blue, violet, or "Roy G. Bv".) The visible portion is only a very small part of the electromagnetic spectrum. The lowest energy waves have low frequencies, in the radio portion of the spectrum. The next more energetic waves are infrared. Then the visible part of the spectrum occurs at mid-energies. At energies greater than visible, we have ultraviolet, X-ray and Gamma-ray. Scientists use the light from all parts of the electromagnetic spectrum to study objects in space. The wavelength of the light λ in meters is related to its frequency f by $\lambda = c/f$ where c is the speed of light, 300,000 kilometers per second, and the frequency is measured in cycles per second (Hertz). So, a VHF radio signal with a wavelength of 2 meters has a frequency of 150 MHz (MegaHertz).



Splitting the spectrum:
Light can be split into its component frequencies by using a prism or a diffraction grating (a slide or a pair of special glasses with fine lines on them.) The glasses split the light into its component colors.

Where does light come from?
Light is emitted one of two ways:

Blackbody emission: A broad continuous spectrum from a dense or solid source, like an incandescent light bulb or hot piece of glowing iron. The brightness peaks at a certain wavelength, given by the temperature of the source. For a source with temperature of T (Kelvins), the spectrum will peak at 0.3 cm / T. For the Sun, whose surface temperature is 6000 K, the wavelength will peak at $0.3 / 6000 = 3 \times 10^{-3}$ m / $5 \times 10^{-3} = 5 \times 10^{-7}$ m = 500 nm (nanometers) = 5000 Å (Angstroms). The sun is therefore yellow, but has light from all parts of the visible spectrum. A hotter star (like Sirius) will look blue; a cooler star (like Betelgeuse) will look red.

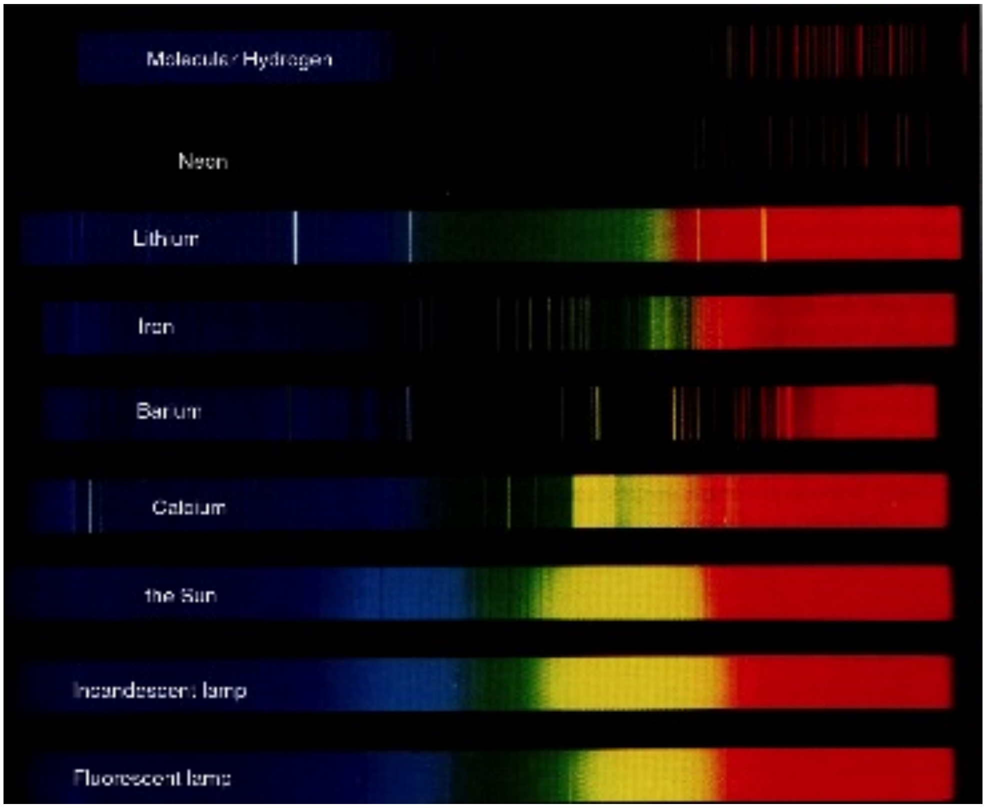
Line emission: A thin gas will emit light only in specific wavelengths of light. A (low-pressure) sodium lamp glows with two narrow lines of yellow. A mercury vapor lamp has blue and purple. The color "fingerprint" which is seen uniquely specifies the gas that is glowing, even at a far distance!

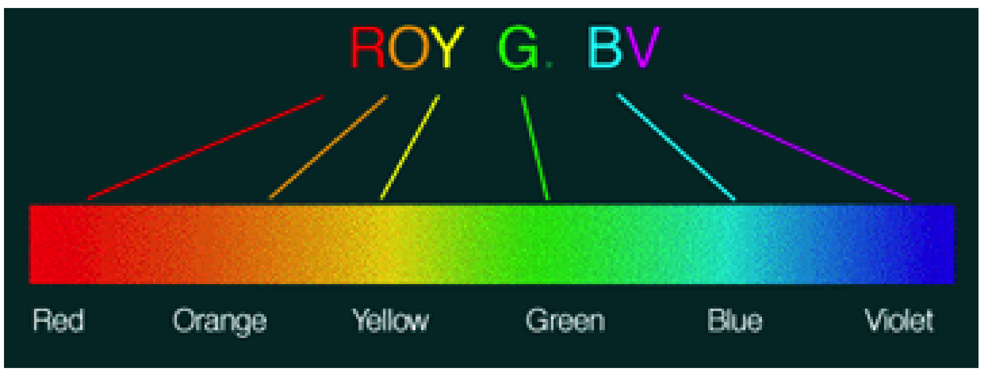
If the lines are shifted in frequency a little to the red or to the blue, we know that the source is moving away from us (red) or towards us (blue). That is the *Doppler effect*.

If light from a continuous source goes through a thin gas, the gas absorb their favorite colors and reradiate them in all directions. So if you look *through* a thin gas at the source, you see dark lines, called *absorption lines*; if you look at an illuminated thin gas from another direction you see them as bright *emission lines*.

Experiment: Take the diffraction grating (which works like a prism) and observe at least 4 different sources. Sketch the spectra of: an incandescent light, a sodium vapor or mercury vapor light; neon signs (at least two different colors of neon). Look at a stoplight: is the green a pure green? Is the red a pure red? If the source (e.g. the neon sign) has line segments, orient the grating so that the lines in the source are perpendicular to the spread of the spectrum (as in the figure above).

Use colored pencils to sketch the spectra of at least four sources: a red stoplight (is it pure red?) a green stoplight (is it pure green?), sodium vapor lights and Mercury vapor lights (orange and blue parking lot lights).





Sketch spectra below:	type of source