Lights

Astronomy is based on observing lights from celestial bodies.

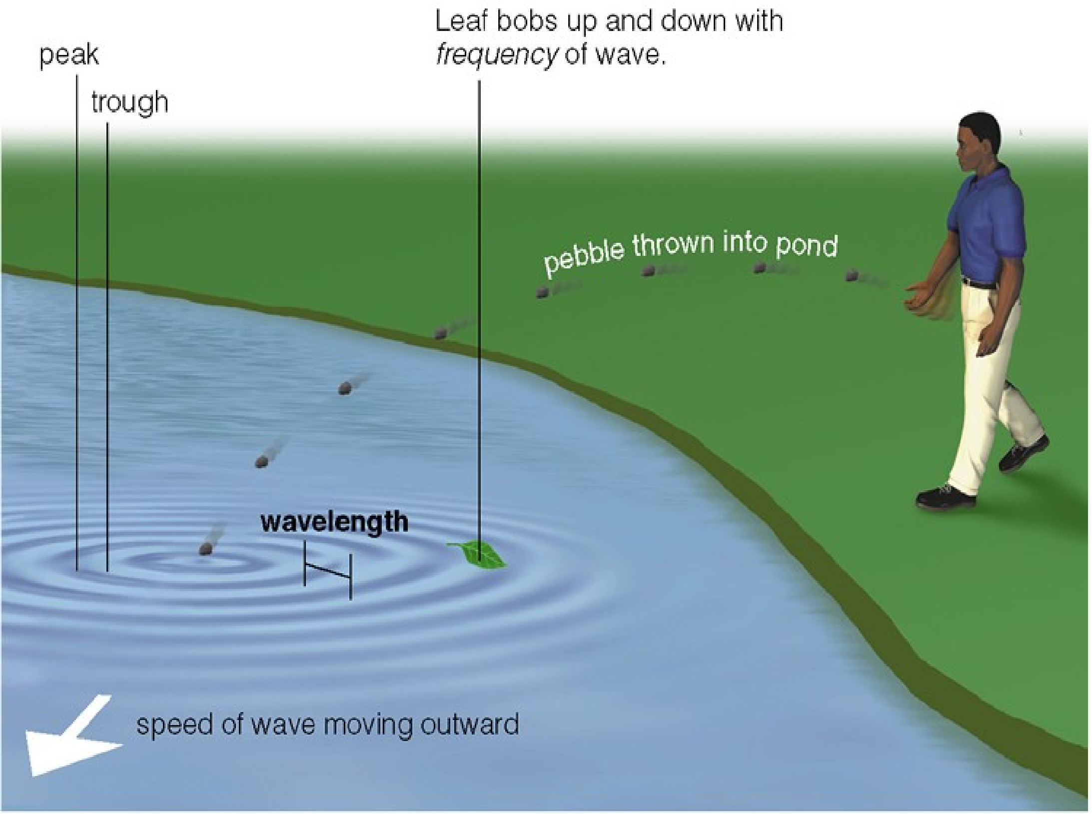
And God said, "Let there be light"; and there was light.
And God saw that the light was good; (Bible: Genesis I)

Cat's Eye planetary Nebula

Photons: "*bullets*" that hit our retina ---- "*bullets*" with color

A photon is both a particle and a wave *(wave-particle duality)*
so it has a **wavelength** associated with it.

So is an electron, a proton....
a human, a galaxy...



shorter wavelength
||
higher energy

a radio photon (~ metre)
~ 10^{-6} electron volts

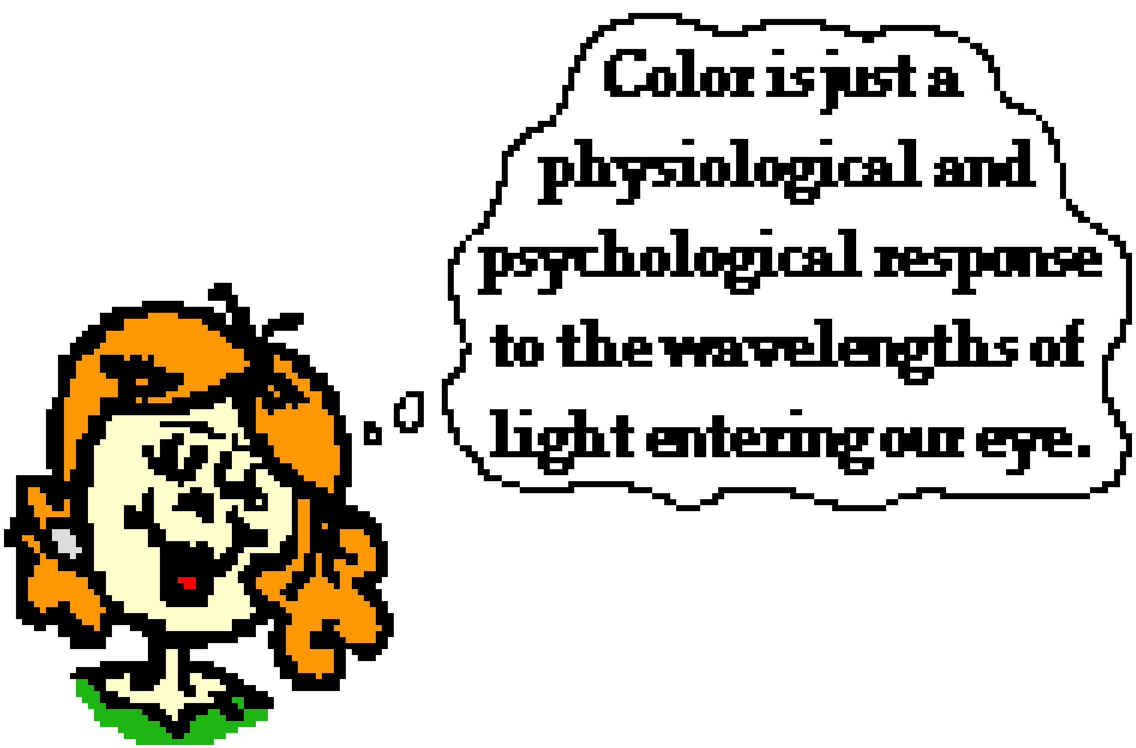
visible photon (~ 5×10^{-7} m)
~ 2 electron volts

X-ray photon (~ 10^{-9} m)
~ 1000 electron volts
able to wreak havoc..

Color of a Photon?

--- Color is in the eyes of the beholder.

photons are only tagged with wavelengths
human eye converts this information to 'color'



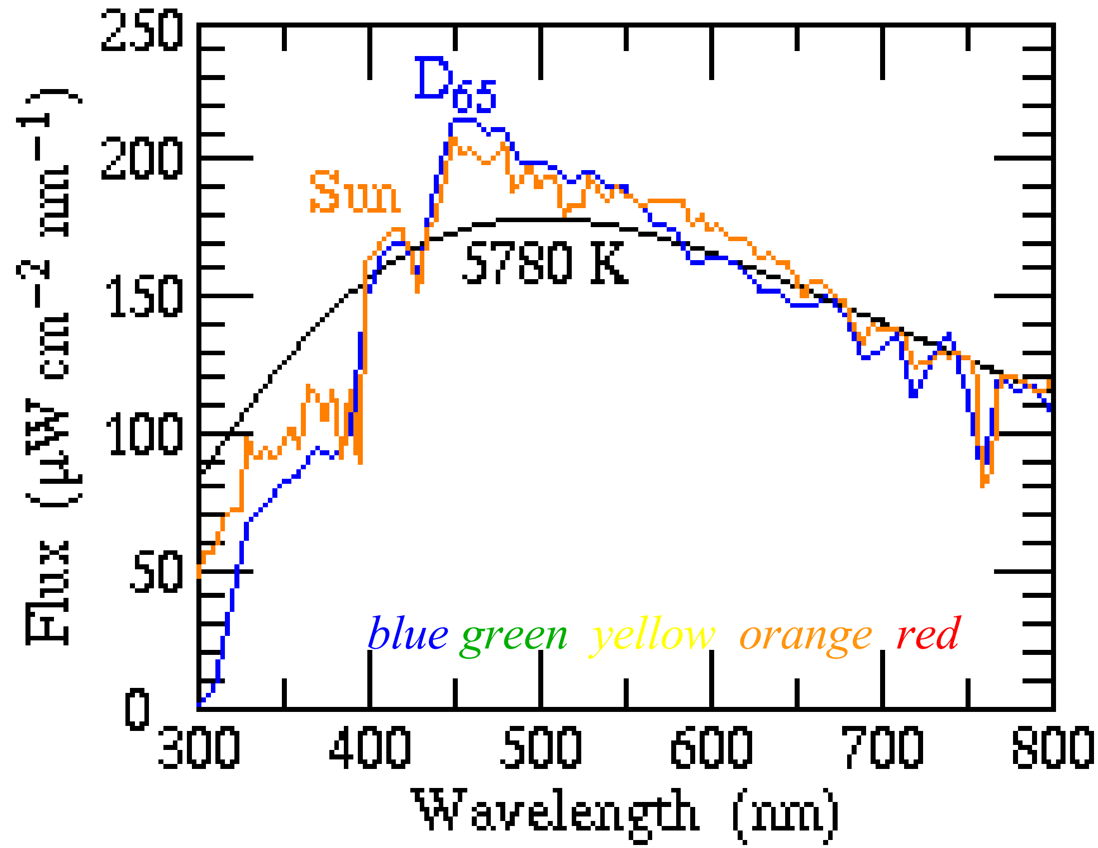
longer wavelength photon
look redder

shorter: look bluer

Visible light

What is color WHITE?

Defined to the composite color of the Sun



The Sun's chromaticity (seen from space, CIE x y: 0.326 0.338

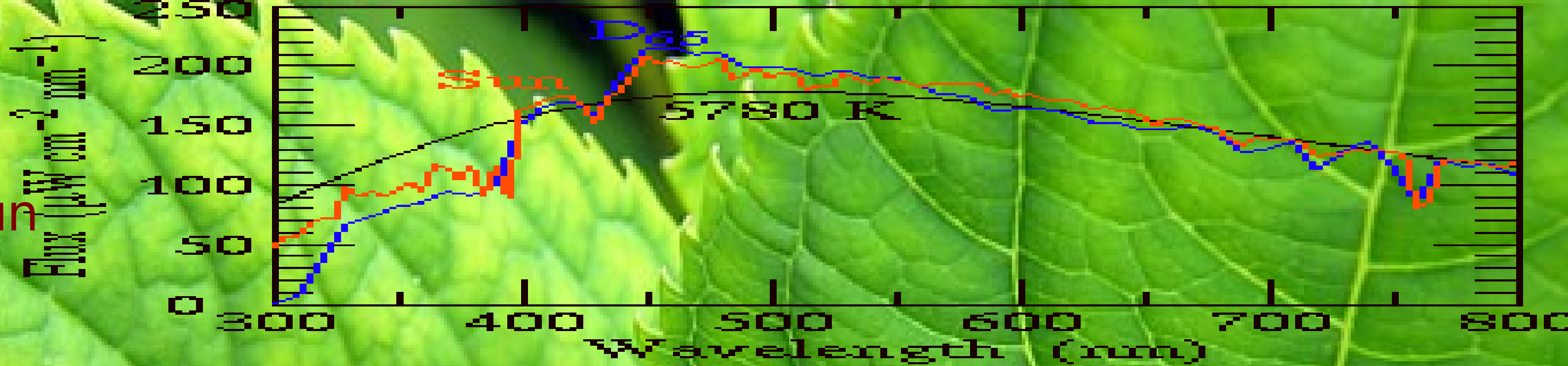
So, a pixel color of #fff3ea

Here is a comparison with various whitepoints:

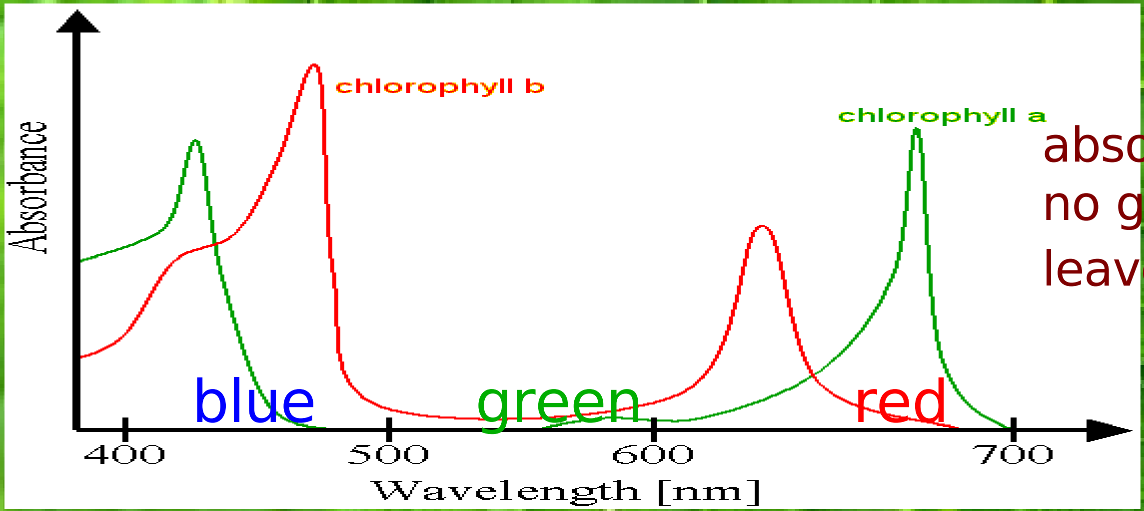
	x	y	sRGB pixel color
Sun above atmosphere	0.3259	0.3379	#fff3ea
Illuminant B *("direct sunlight")*	0.3840	0.3516	#ffbfaa

+blue sky=white light

Sun

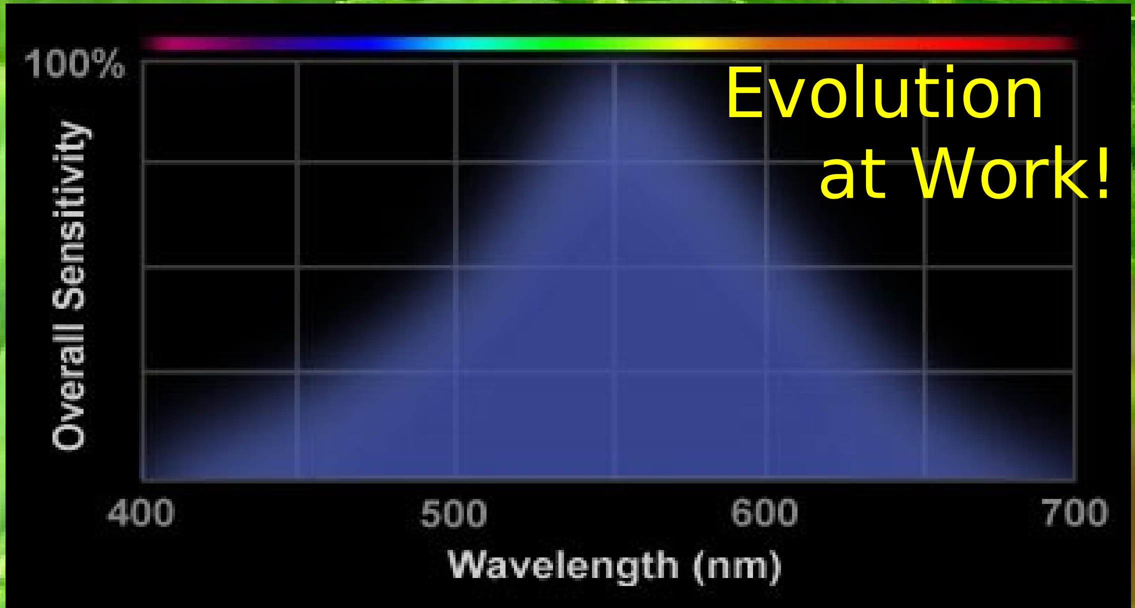


Chlorophyll absorptivity



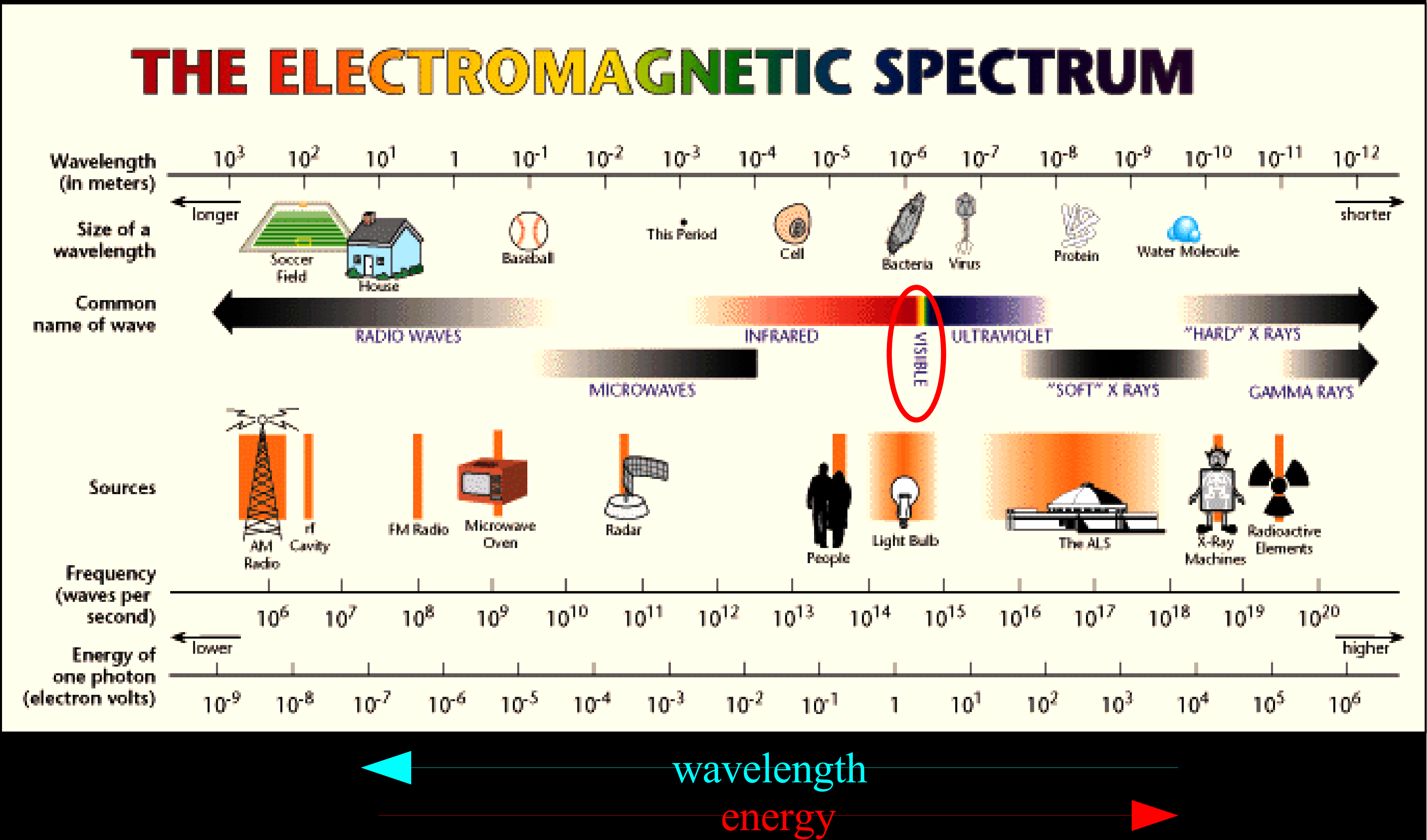
absorb blue & red, no green. So leaves appear ...

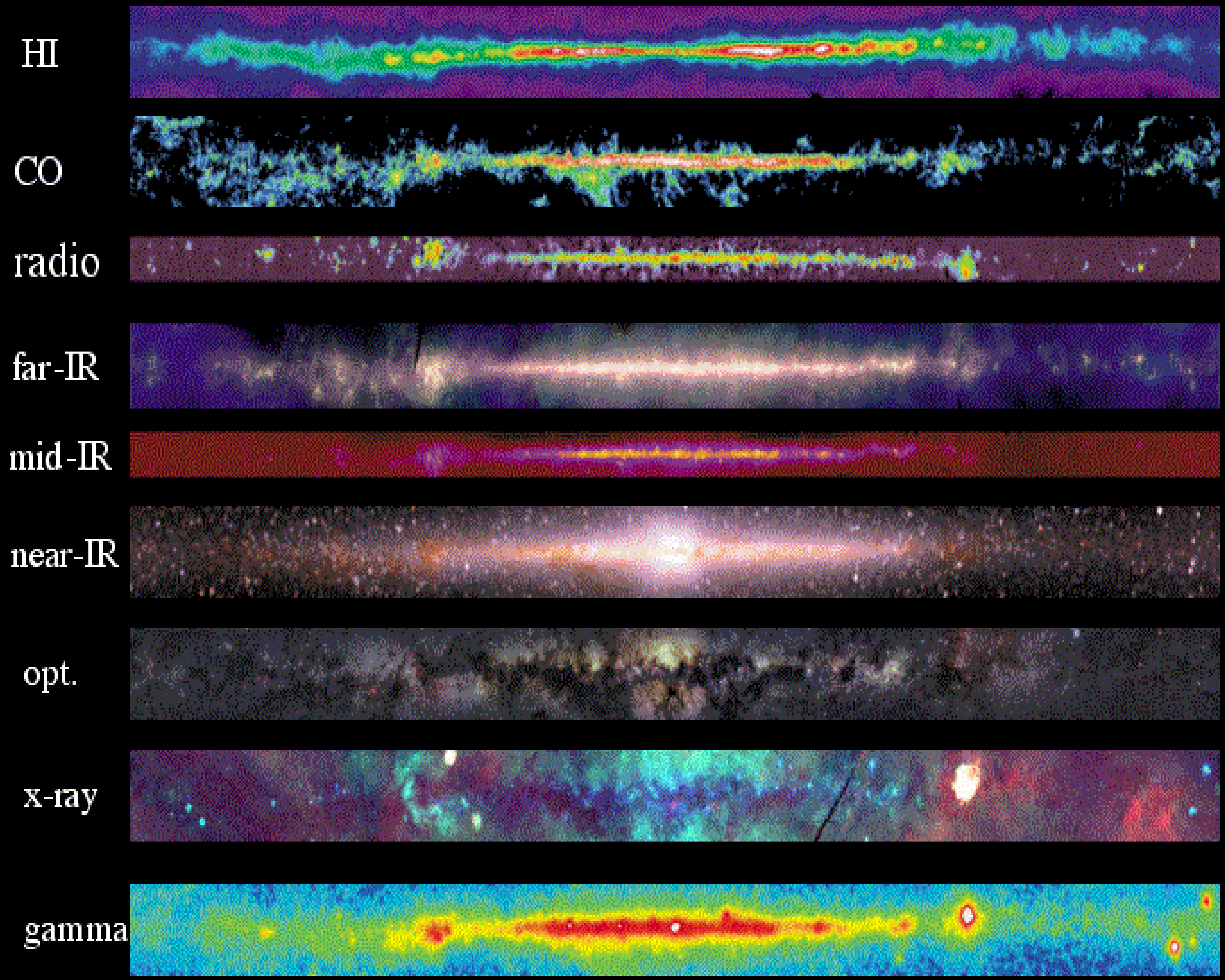
Human Eye overall sensitivity



most sensitive to all shades of green

The electro-magnetic radiation spectrum





Milky Way galaxy --- astronomical objects radiate at all wavelengths

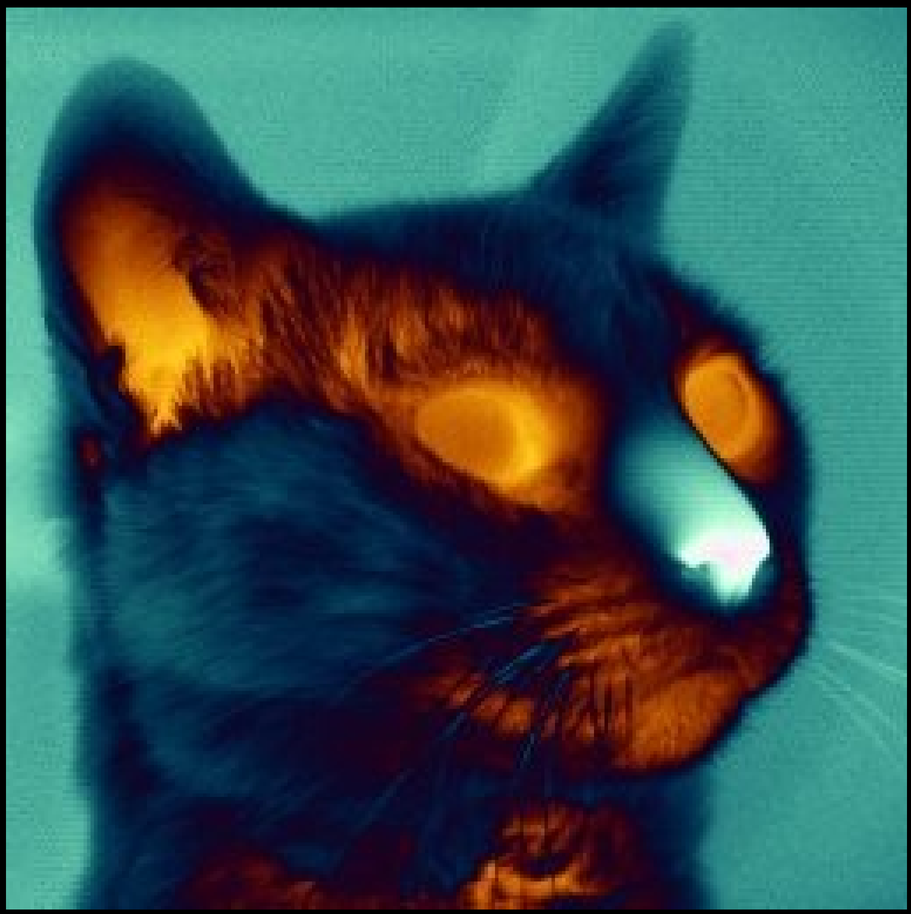
What makes the color of an object?

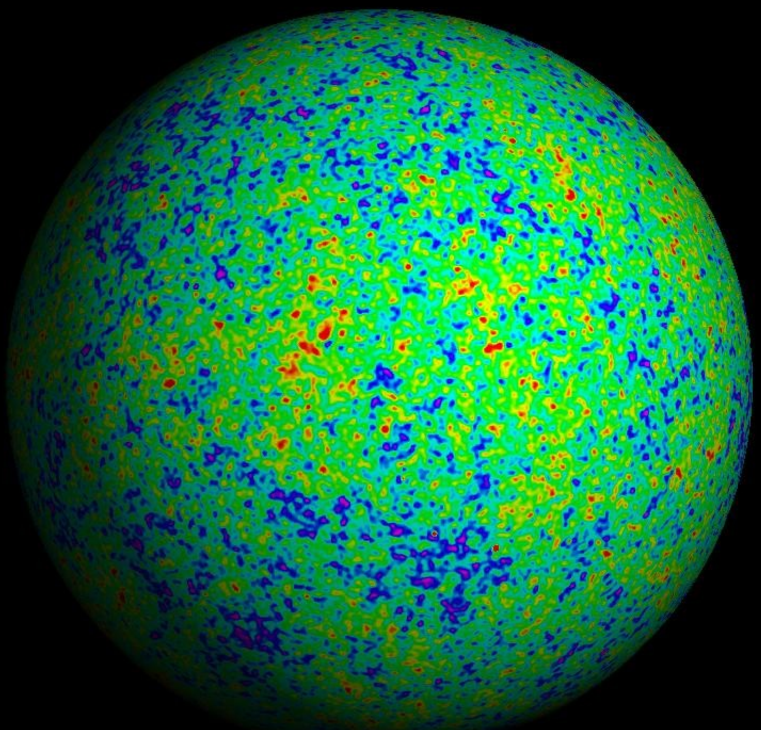
Most objects around us are seen by their reflected light --- Relies on external illumination.

All objects also emit light.

Candle ~ 3000K, visible

Cat ~ 300K, infrared





Cosmos: 3 Kelvin background, radio

So each object around us has really two colors.

1) it reflects light shine on it. Its material property (wood, steel, paper...) determines this color.

2) it also radiates photons because it is not 0 Kelvin. Its temperature determines the color of this radiation.

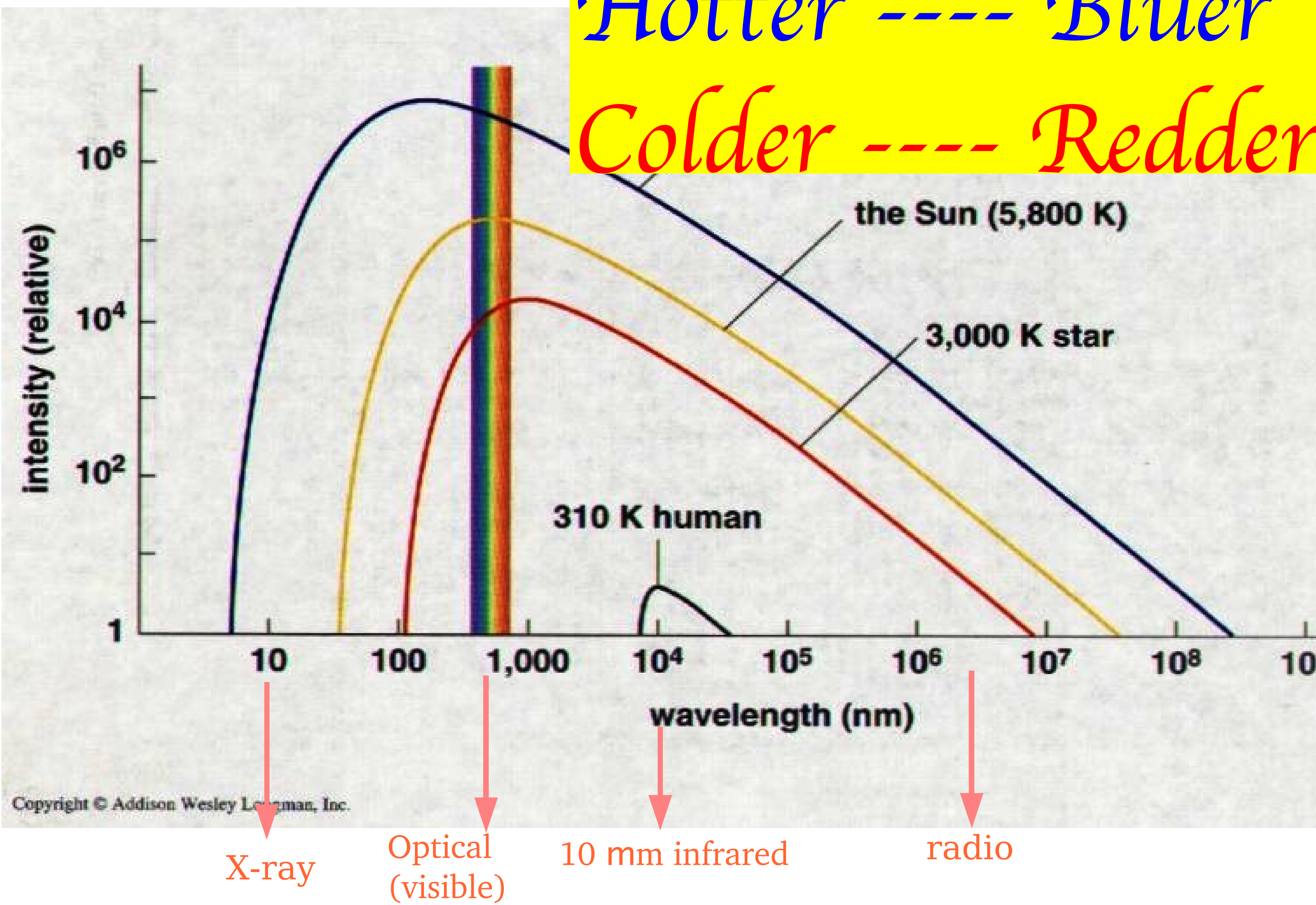
Astronomical objects are mostly seen by their radiation. Namely, you see them because they are hot. Their color therefore depends on their temperature (only).

We call them 'blackbody' because they are as if they don't reflect lights.

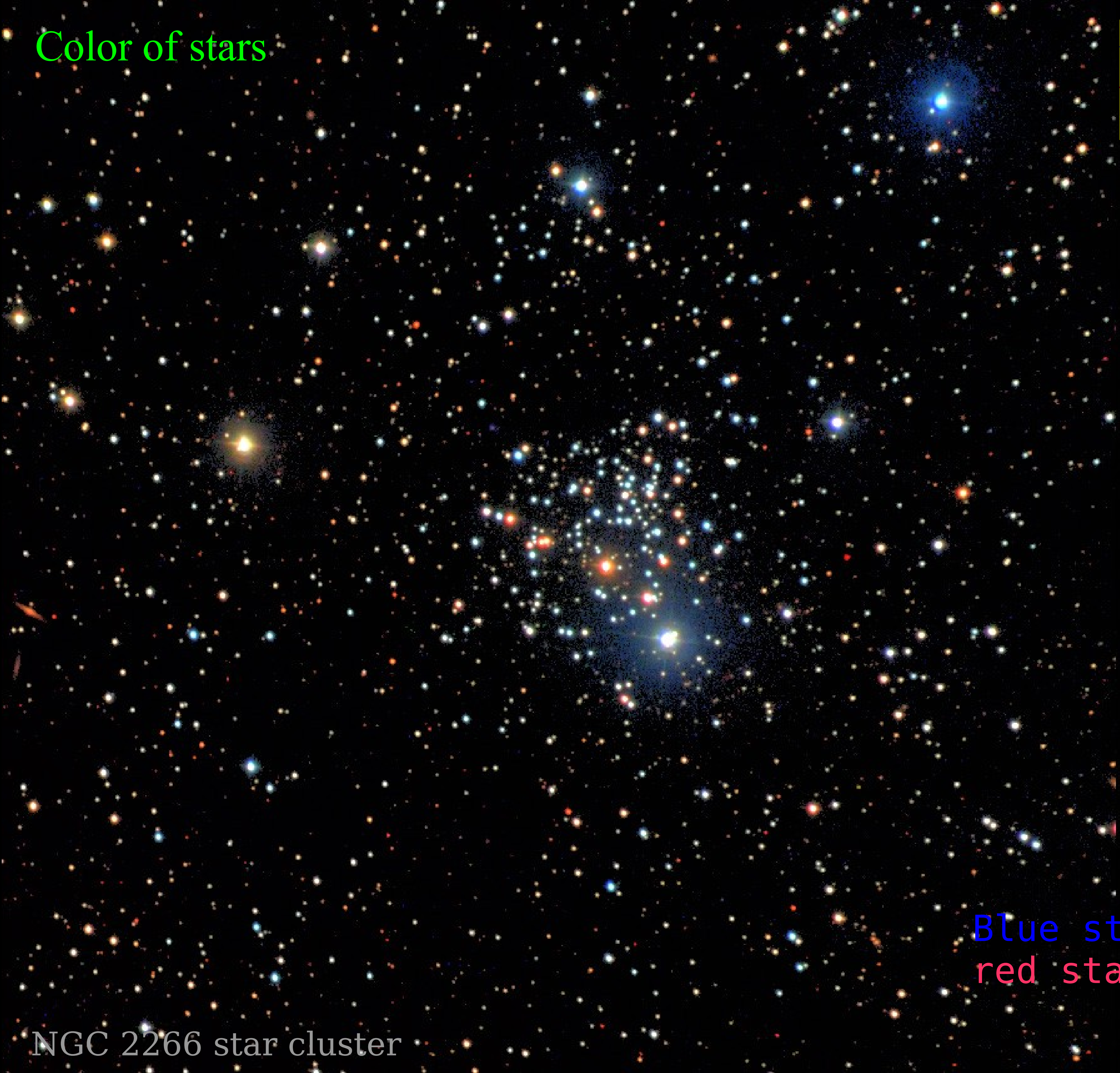
Universal Radiation of a **blackbody** (only depends on T):

Hotter ---- Bluer

Colder ---- Redder



Color of stars

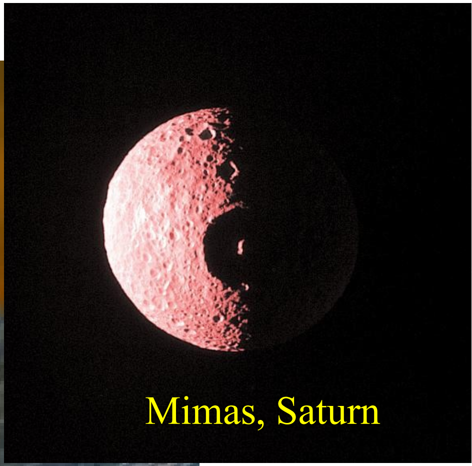


tter ---- Bluer
der ---- Redder

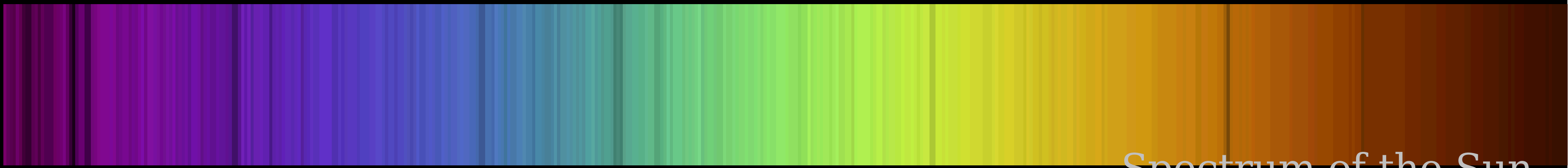
Blue stars: ~ 20,000K
red stars: ~ 2,000 K

NGC 2266 star cluster

“true color” of an object (seen in emitted light)

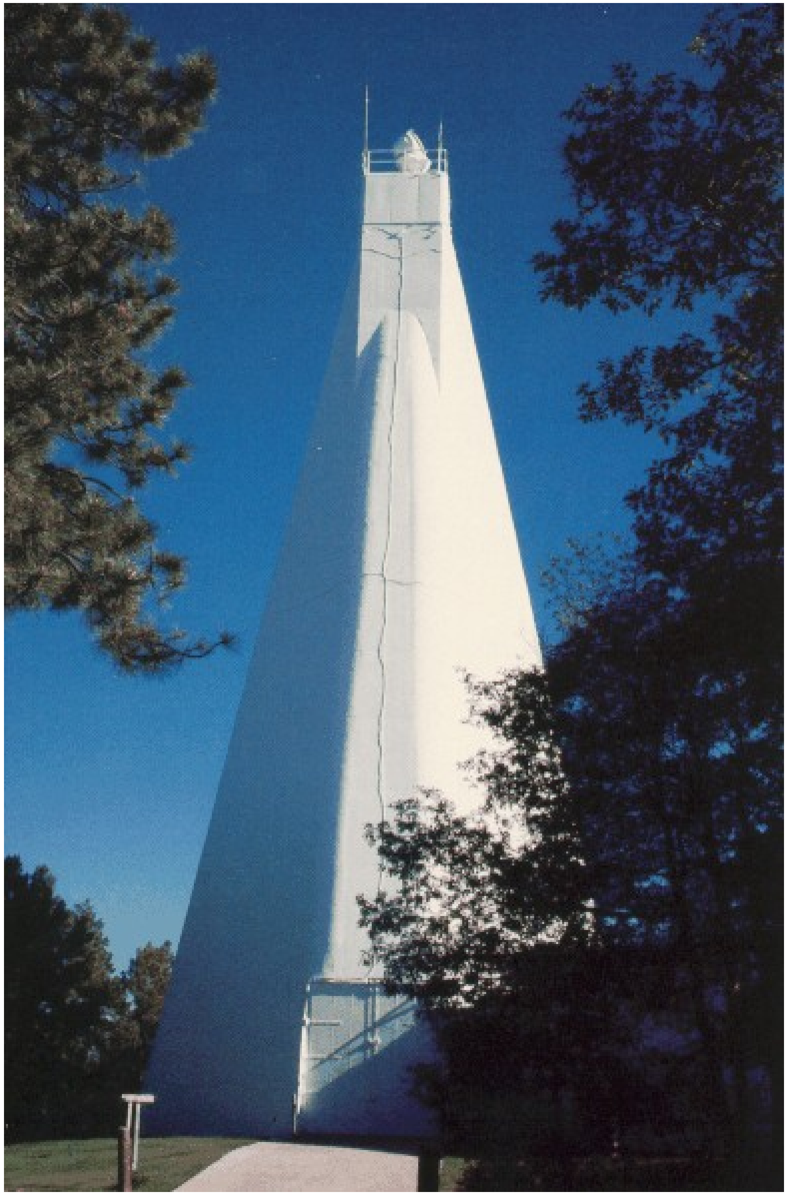


Spectrum



Spectrum of the Sun

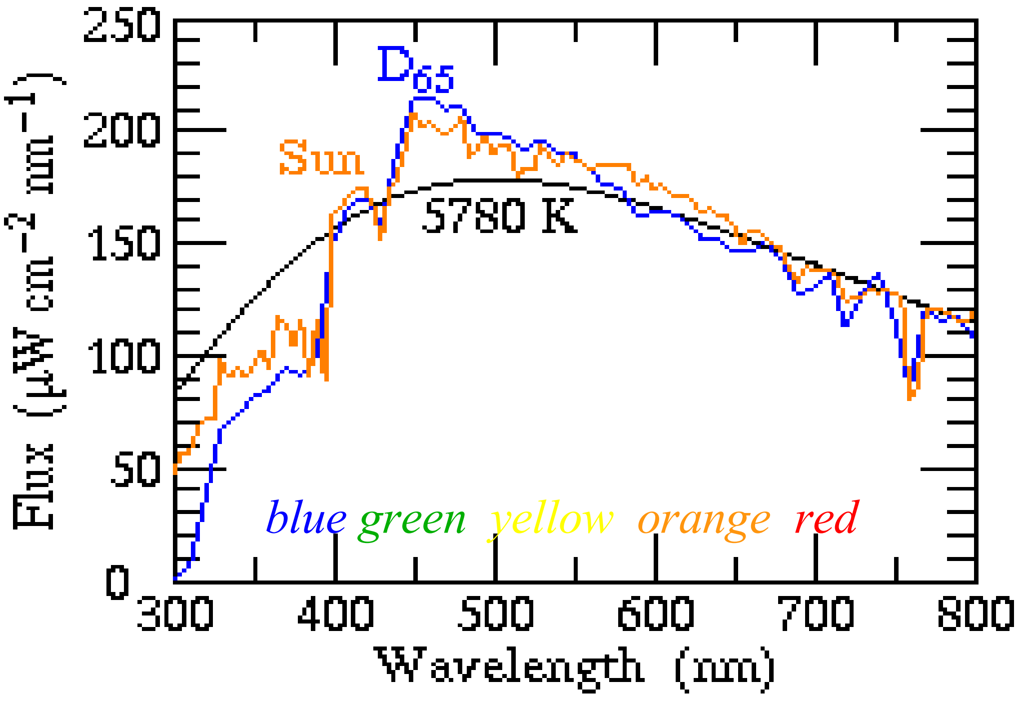
Spectrum: dispersed light according to wavelength

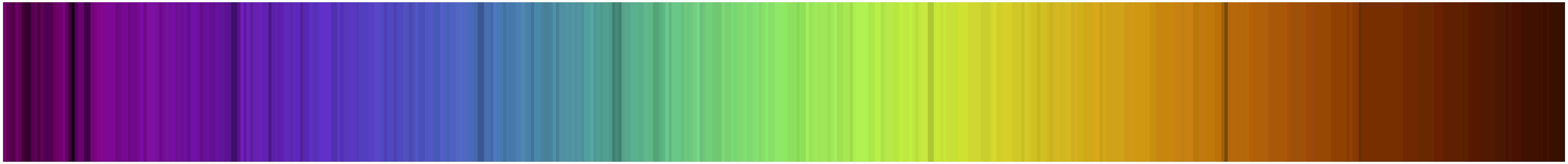


NSO Solar telescope

A spectrum of the Sun:

(intensity at diff. wavelengths)

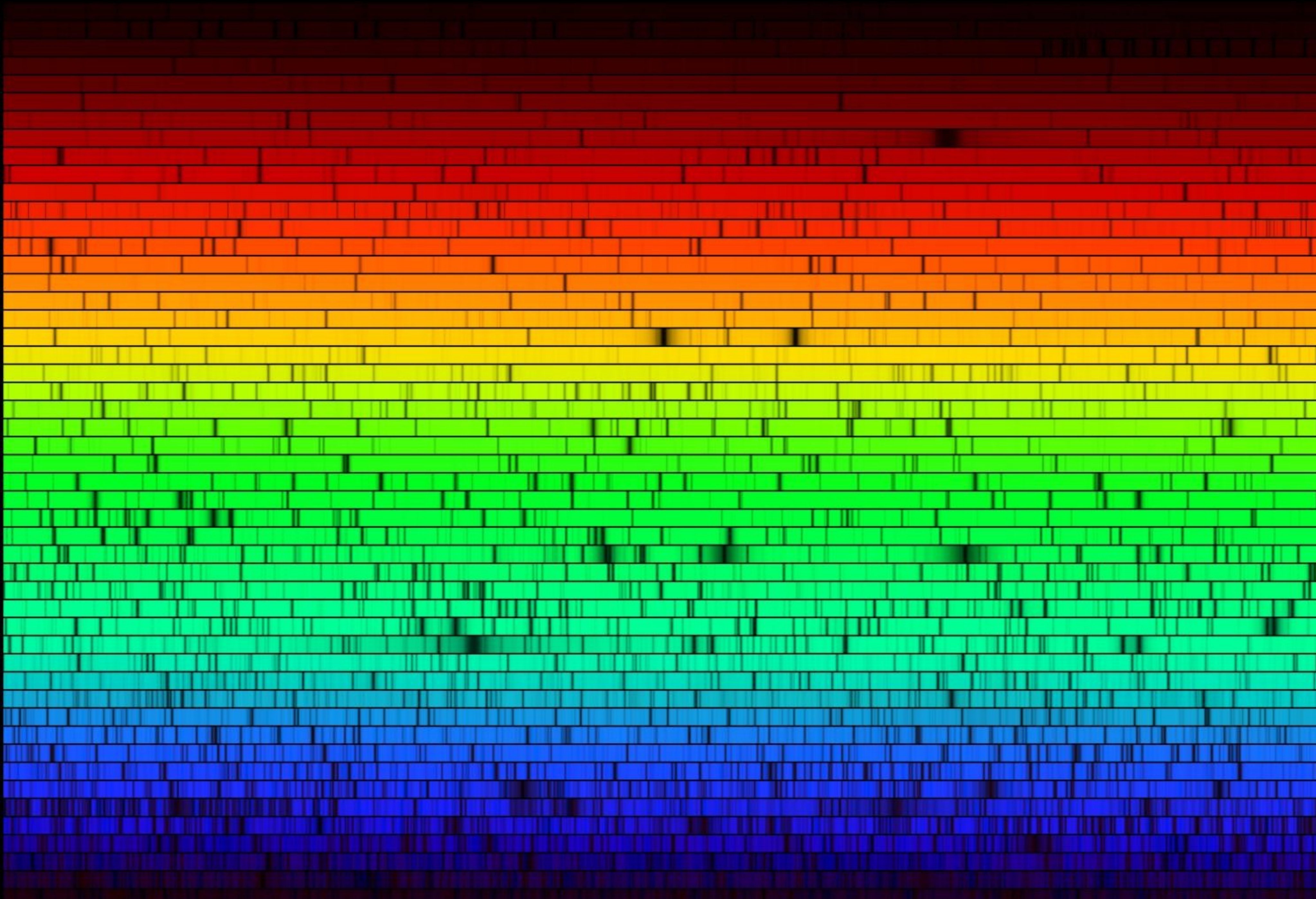


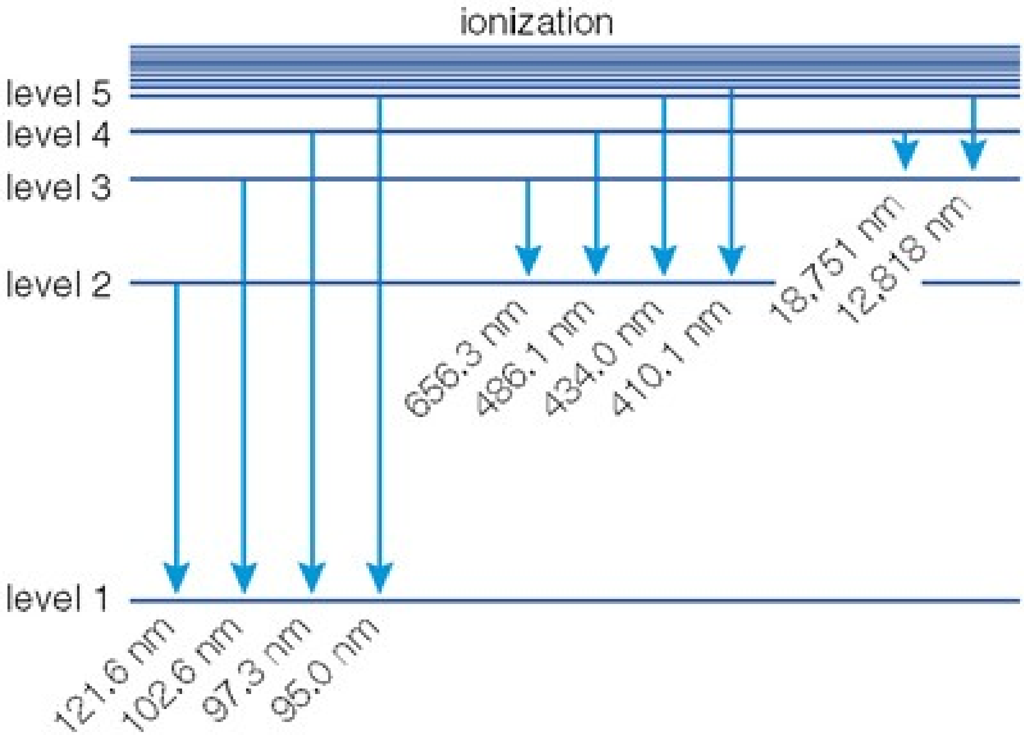


Mid-resolution solar spectrum

dark lines: deficit of flux

and a really high resolution solar spectrum…





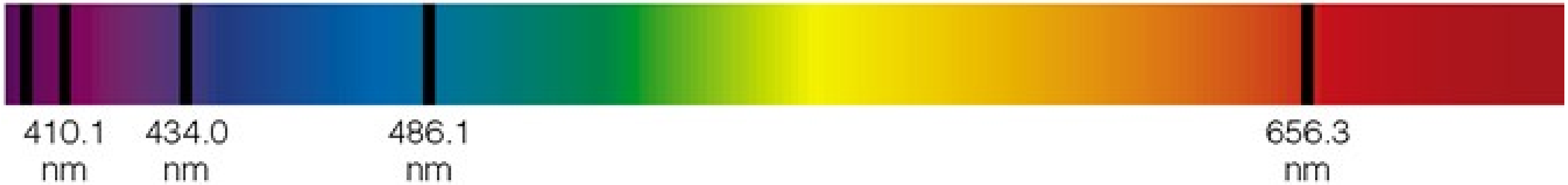
Wavelengths of the spectral features correspond to energy differences between different states.The states depend on what atom it is.

Low --> High, absorb a photon

High --> Low, releases a photon

Hydrogen spectra

emission lines



absorption lines

Spectrum of a star:

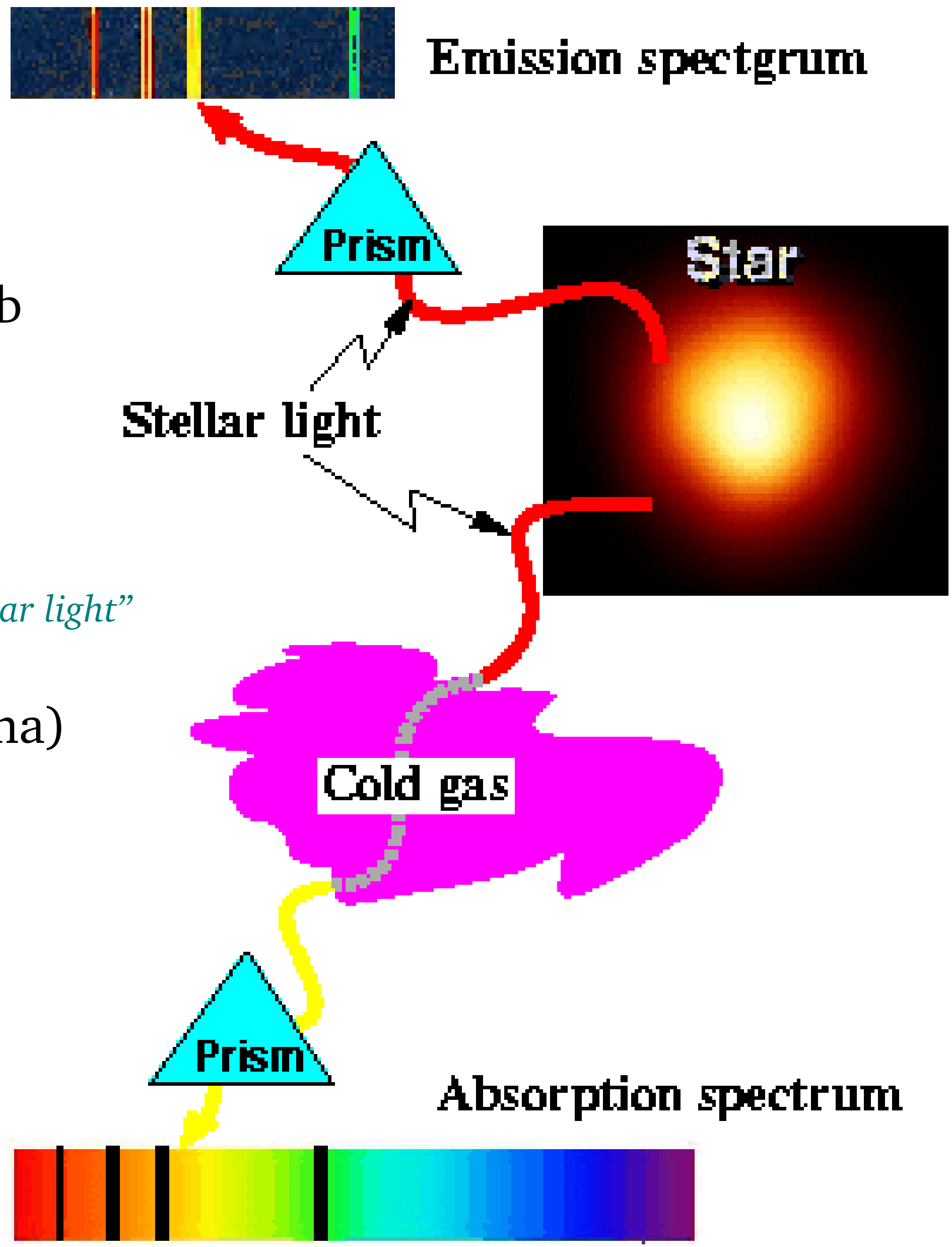
1) smooth blackbody radiation
from the hot interior,

2) cooler gas near the surface absorb
at particular frequencies

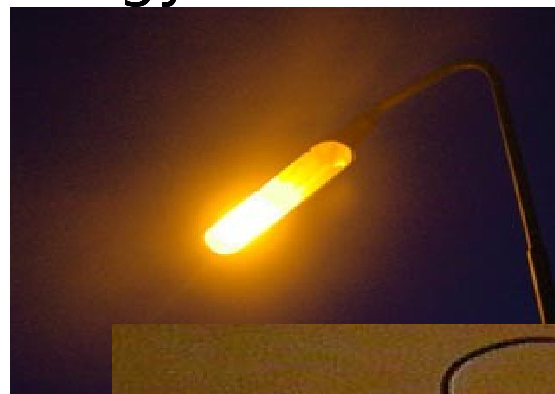
--- forming absorption lines
(absorption spectrum)
"silouette of a person in front of bright car light"

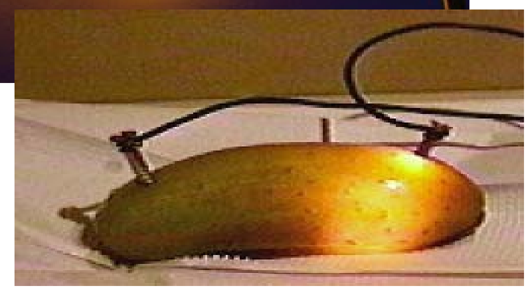
3) hotter gas near the surface (corona)
emits in certain frequencies

--- emission spectrum

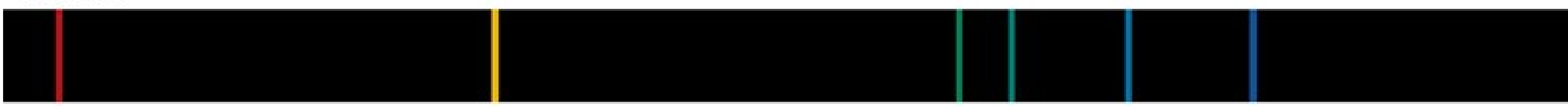


Emission Spectrum : neon lights,
street lamps,
energy-efficient fluorescent bulbs...

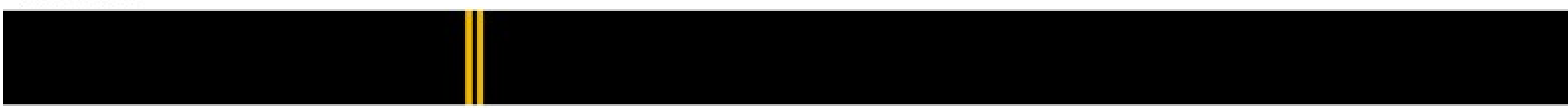




helium



sodium

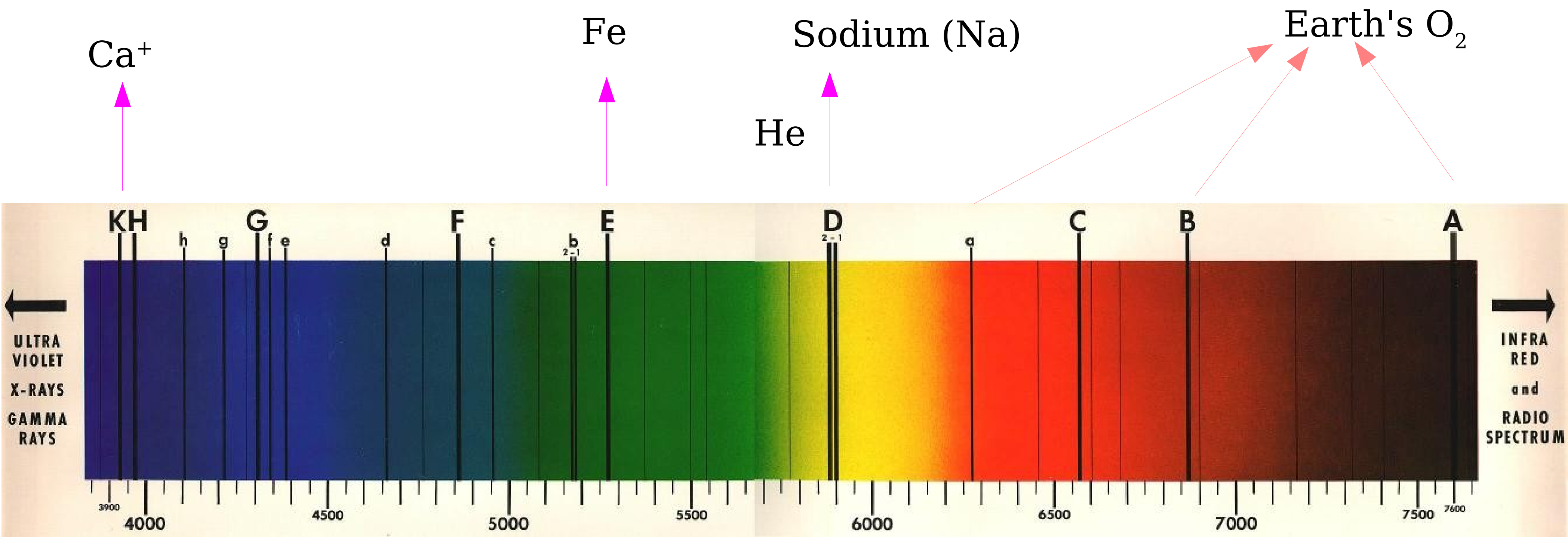


neon

Optical Spectrum of the Solar lights ---- Fraunhofer lines

from www.harmsy.freeuk.com/fraunhofer.html

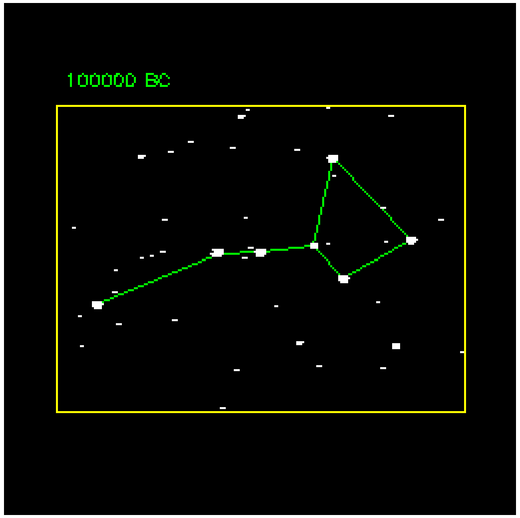
absorption features: flux deficit in the radiation spectrum



Chemical composition of the celestial objects is revealed.

I. One example of motion in astronomy

projected positions on the celestial orb changes



II. but stars/galaxies also move toward or away from us.
The projected position doesn't change.

So how do we know that they are moving?

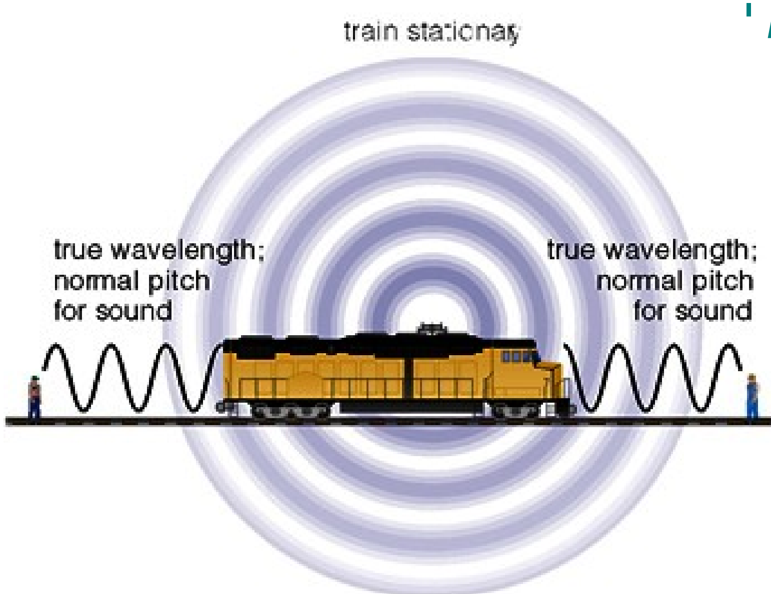
Doppler Shifts:

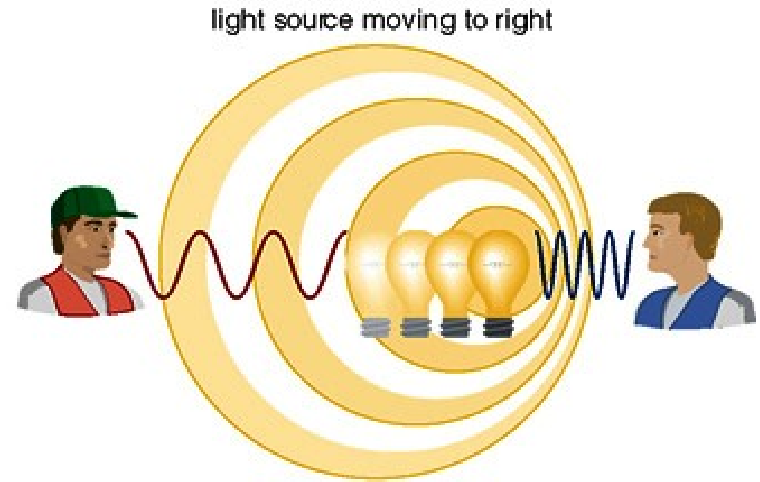
light emitter moving,

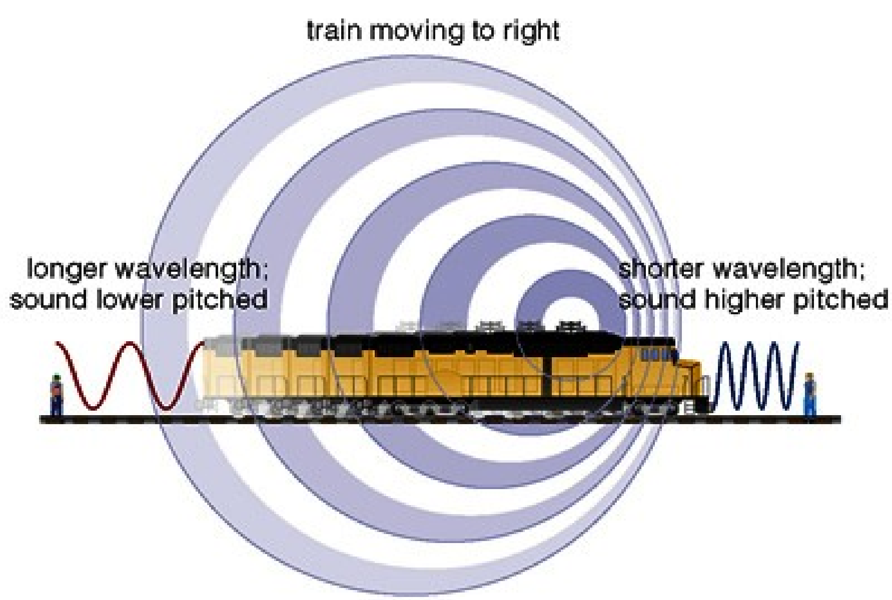
if toward observer (us), the light looks bluer

if away from observer, the light looks redder

'redshift' of galaxies...

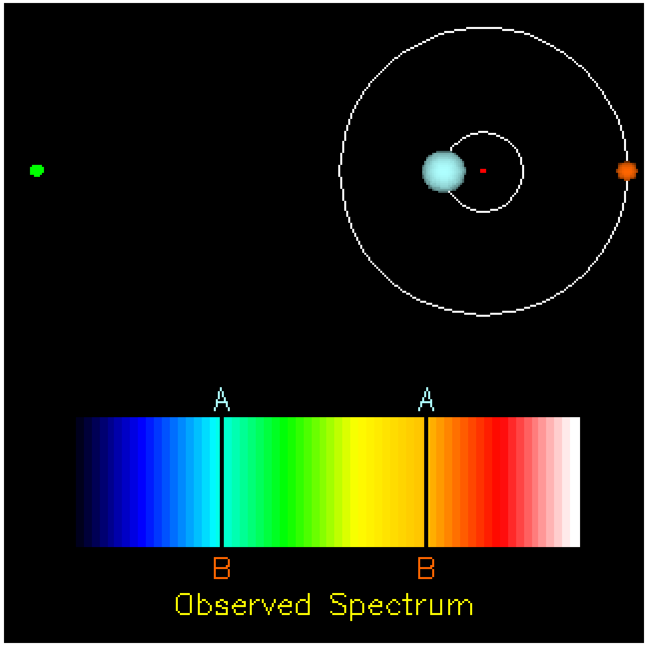






Use Doppler Effect to study movement of the binary star

you



Finding out velocities for any moving objects

1) Expansion of the universe

2) detecting planets around other stars

3) finding blackholes

4) measuring stellar masses in binaries

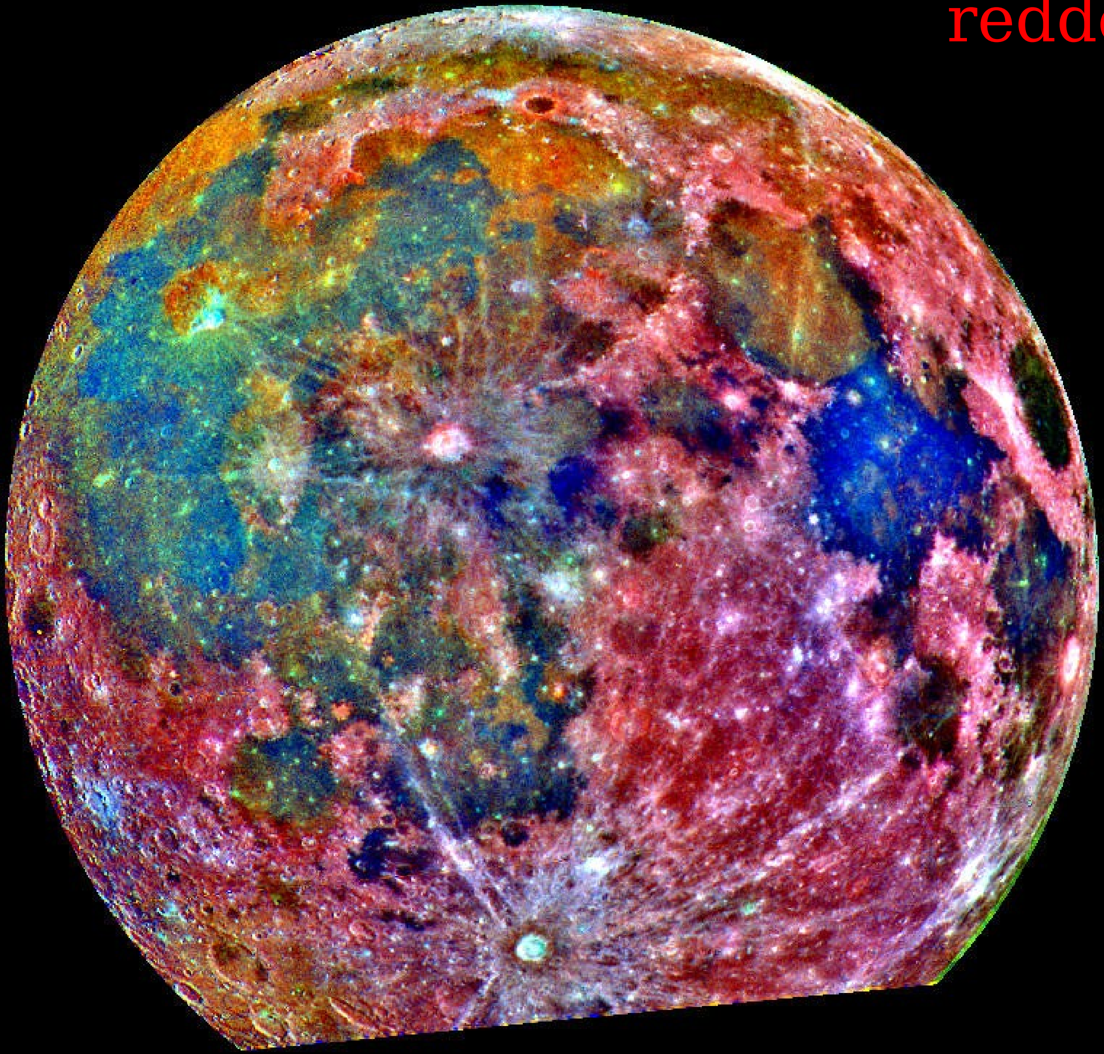
5) rotation of the galaxy

... getting out of the way for the fire-engine

Color representation in astronomical images

blue: shorter wavelength

redder: longer wavelength



"false-color image"


Proto-star HH34

Sombrero Galaxy