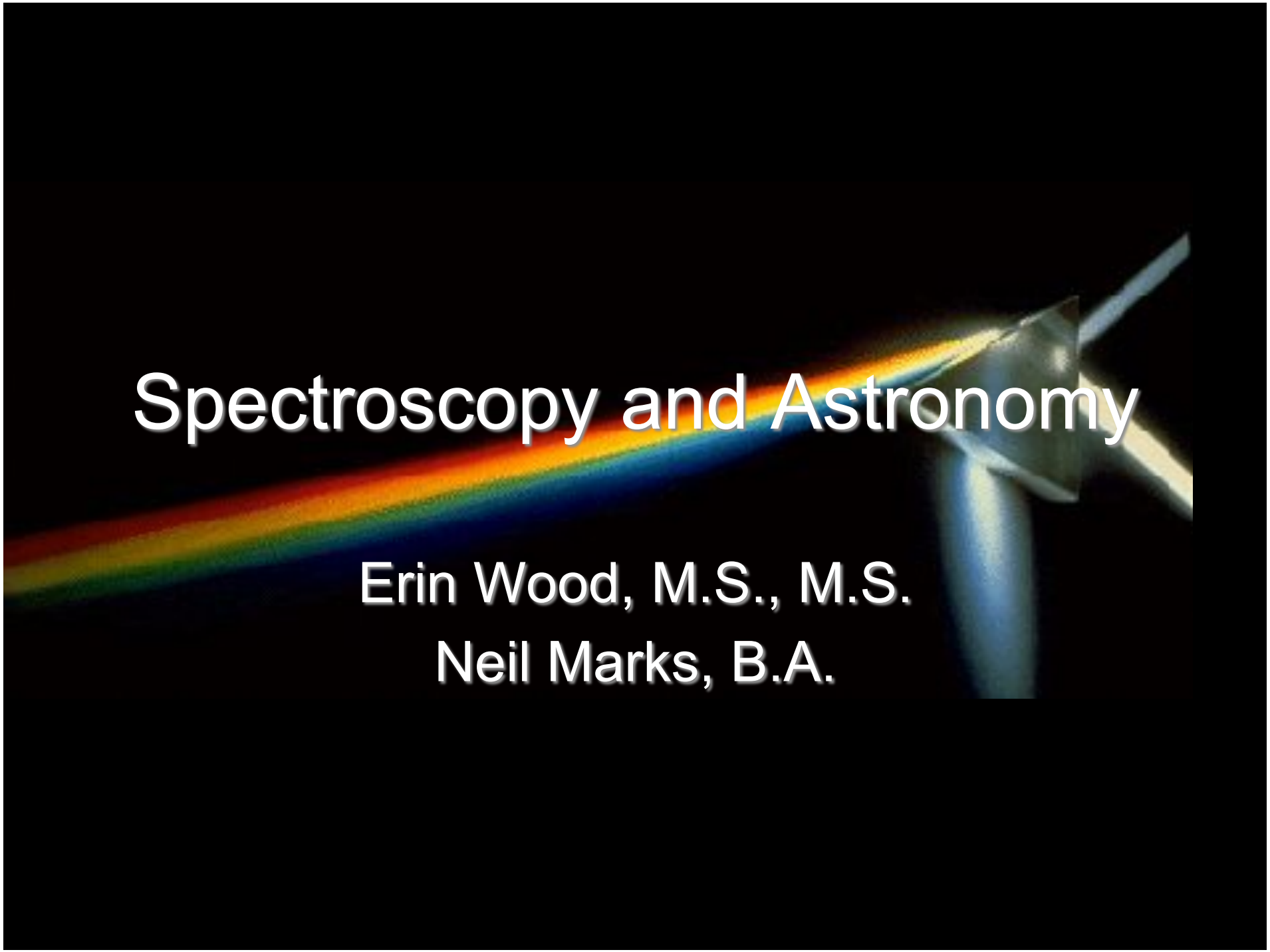
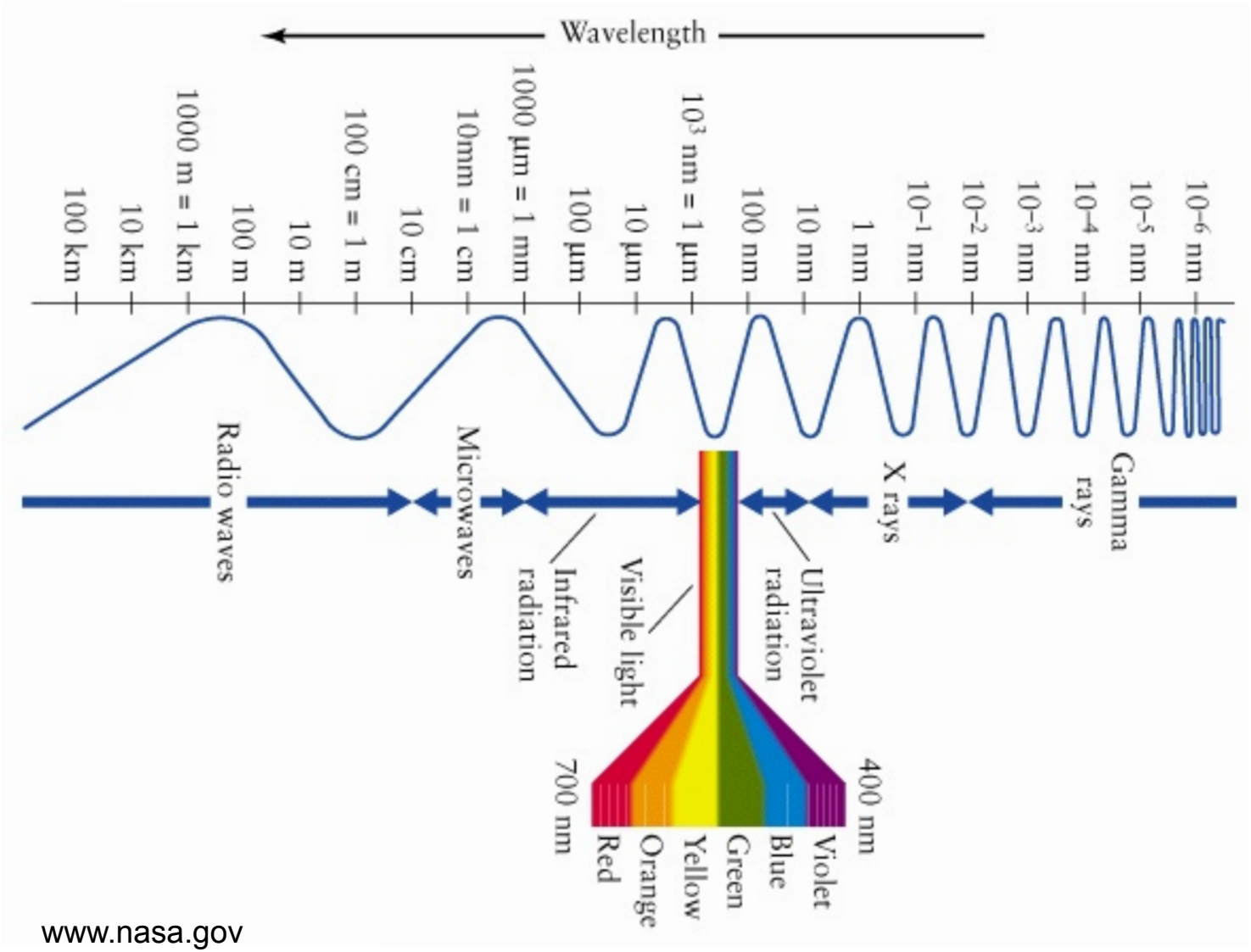

Spectroscopy and Astronomy
Erin Wood, M.S., M.S.
Neil Marks, B.A.

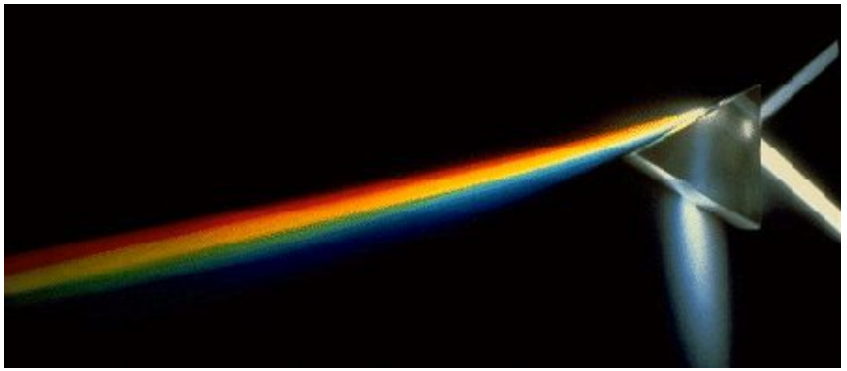
“Light” or the Electromagnetic spectrum



www.nasa.gov

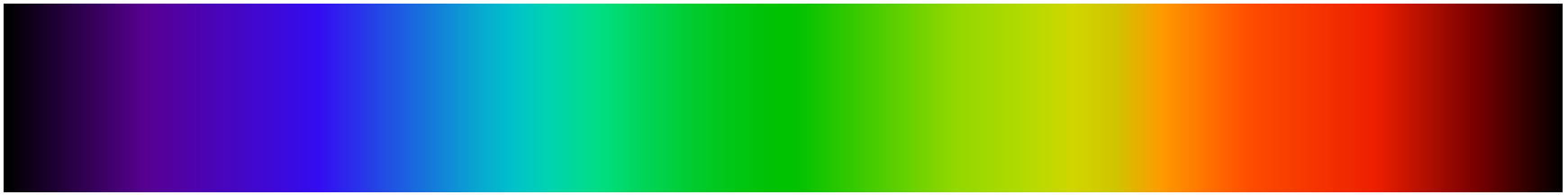
Diffraction and Light

- When passed through a prism or grating, light is separated into its component wavelengths
- This looks like a rainbow in visible light
- There are wavelengths we can’t see with our eyes
- White light contains all visible colors



Nasa.gov

The Visible Spectrum



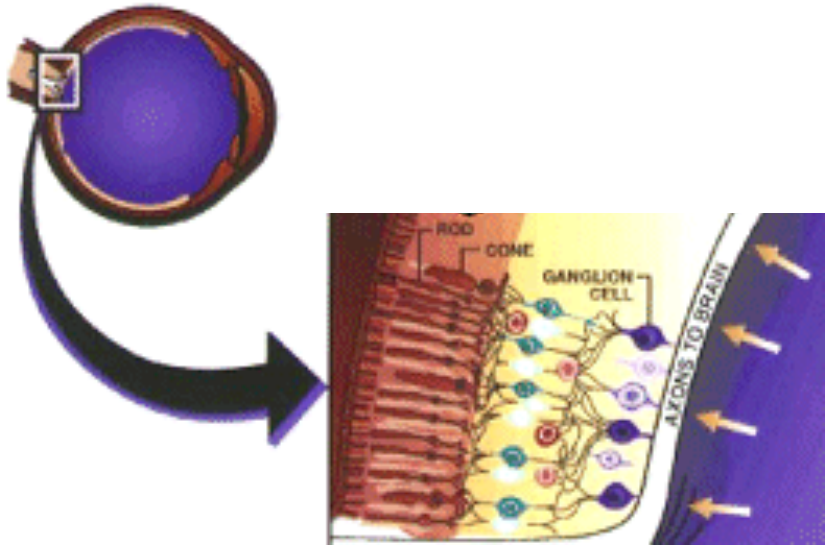
http://en.wikipedia.org/wiki/Visible_spectrum

red	620-750 nm
orange	590-620 nm
yellow	570-590 nm
green	495-570 nm
blue	450-495 nm
indigo	420-450 nm
violet	380-420 nm

What do our eyes have to do with it?

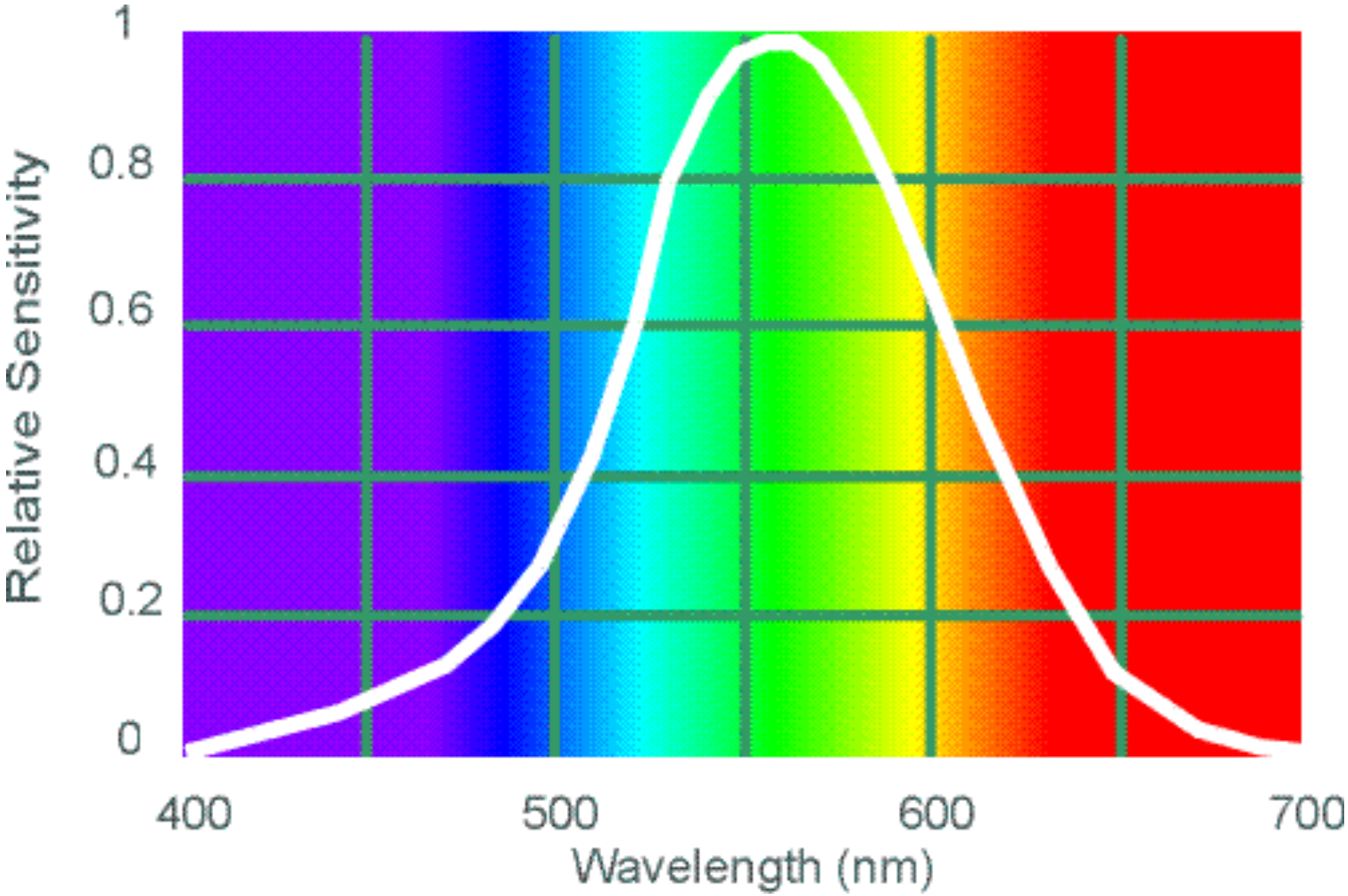
The retina

- Rods detect light and dark
- A cones detects either Red, Blue, or green
- Cones concentrated at the center
- Rods at outside of eye



www.nasa.gov

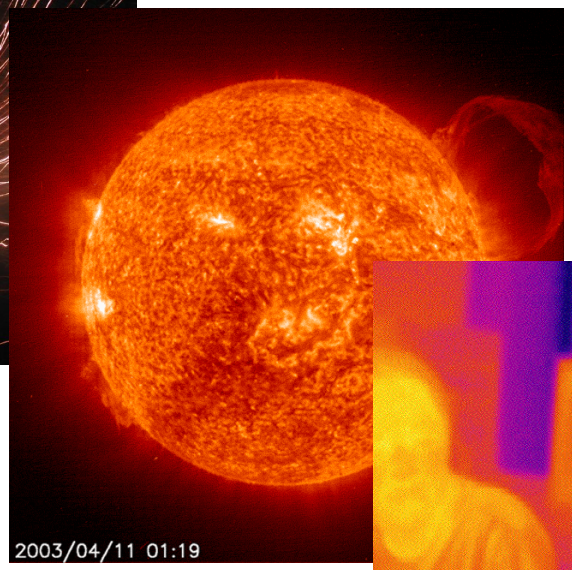
Cone sensitivity

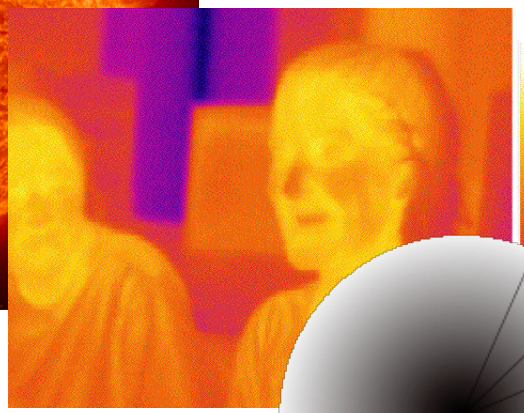


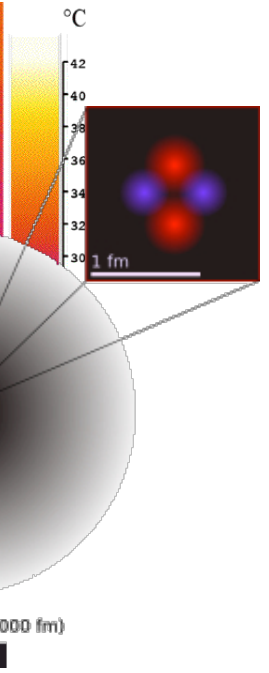
Numb3rs Blog: http://nuweb2.neu.edu/math/cp/blog/?showall=yes

Emission

What causes emission?







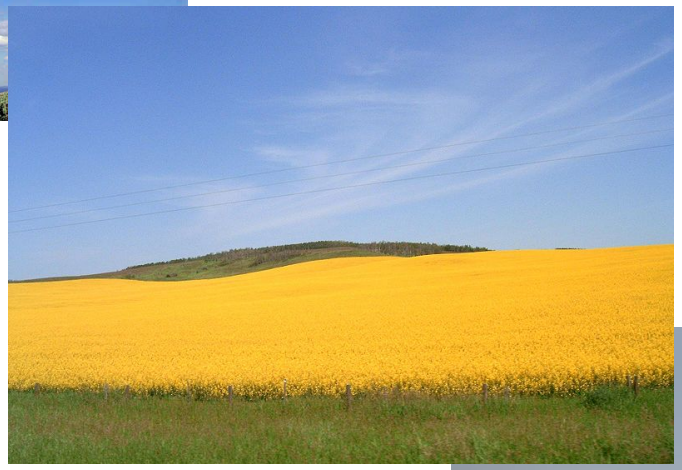
http://www.energystar.gov/

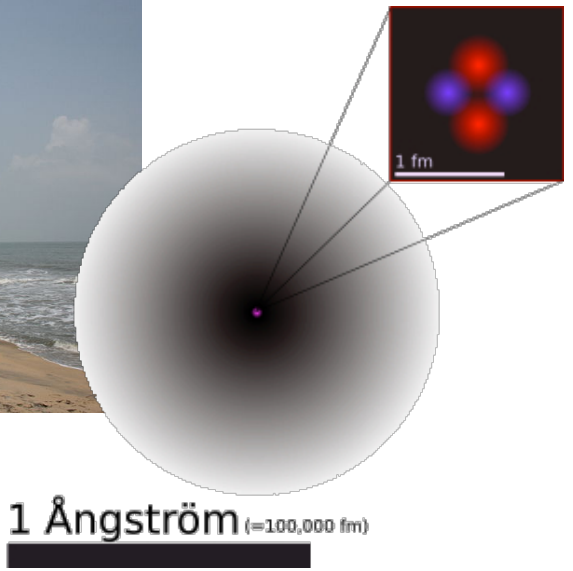
http://commons.wikimedia.org

http://en.wikipedia.org/wiki/Infrared

http://sohowww.nascom.nasa.gov/

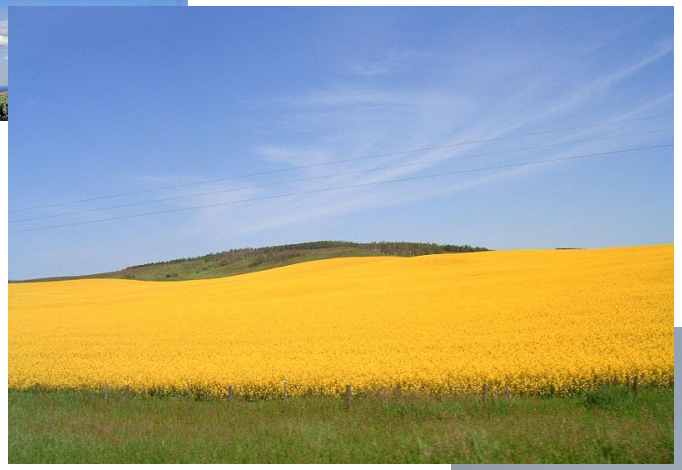
Absorption

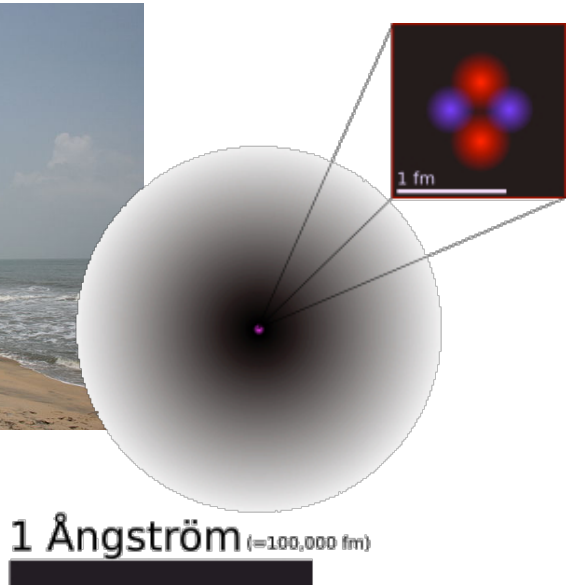




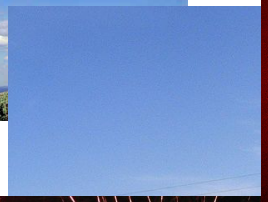
http://commons.wikimedia.org

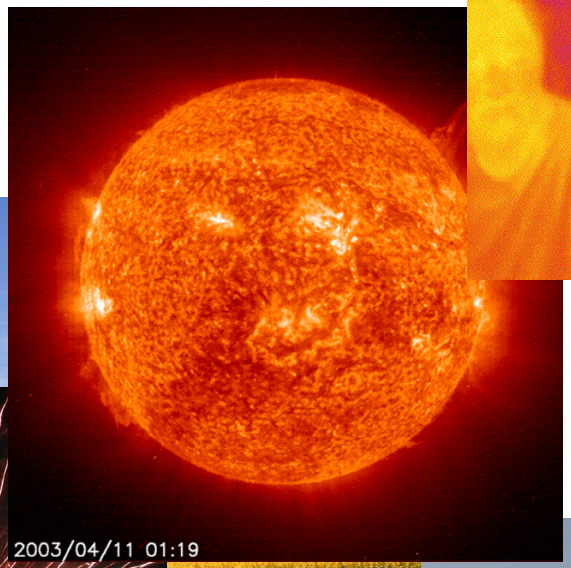
Absorption AND Emission

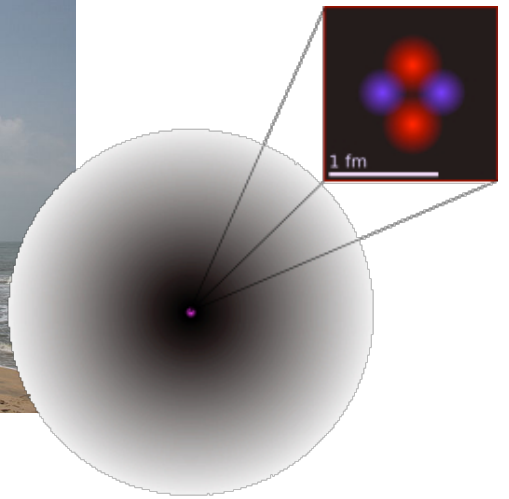




Absorption AND Emission





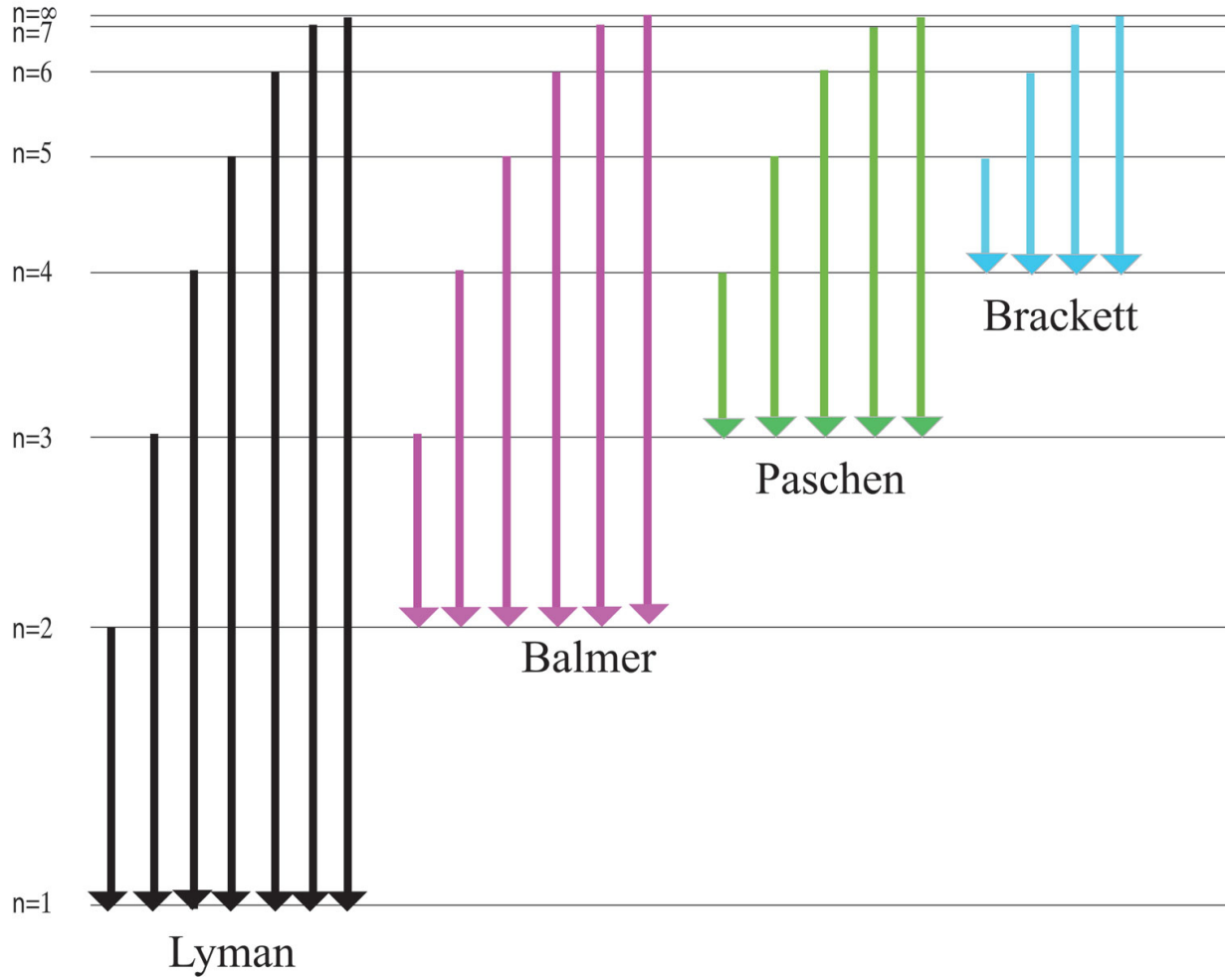


1 Ångström (=100,000 fm)

How is light created?

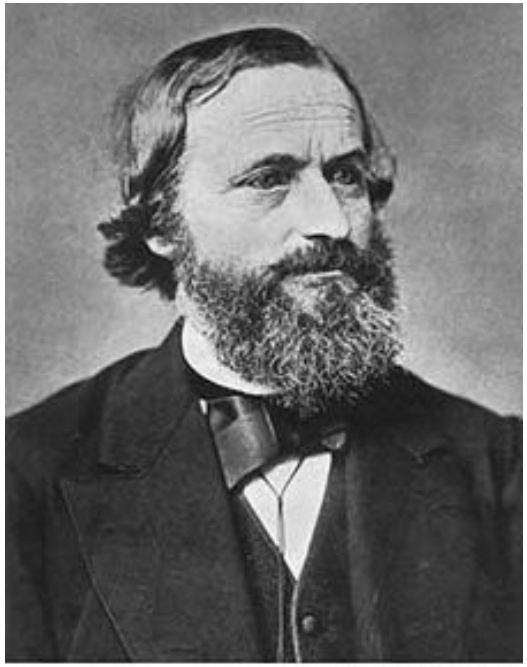
- Think of an atom as a bookshelf
- Think of the books as electrons
- Each atom has a distinct bookshelf not like any other atom!

Bookshelf for Hydrogen



Kirchoff's Laws 1859

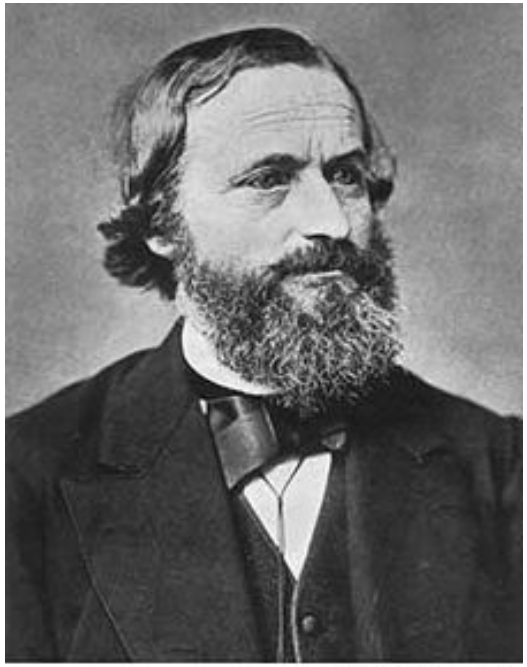
- Law 1- A hot, opaque body produces a continuous spectrum
- Law 2- A hot, transparent gas produces an emission line spectrum
- Law 3- A cool, transparent gas produces and absoption line spectrum



Library of Congress

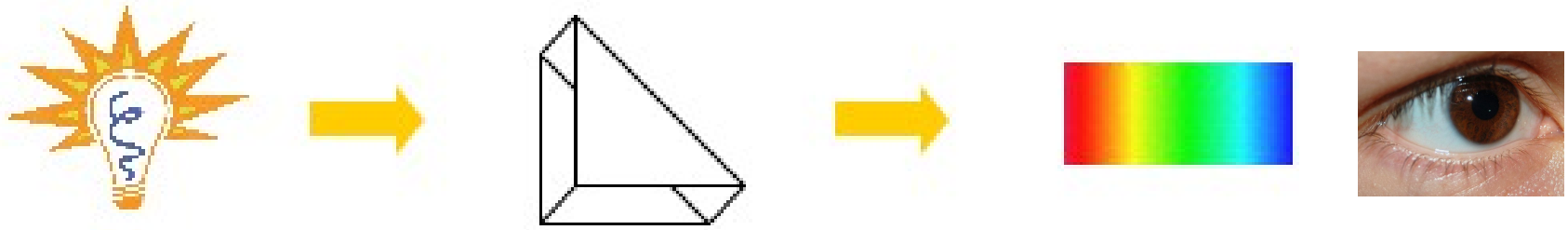
Kirchoff's Laws 1859

- Law 1- A hot, opaque body produc ous spectru
- Law 2- A hot, tra nt gas produces a ission line spectrum
- Law 3- A co nsparent gas produce absoption line spectrum



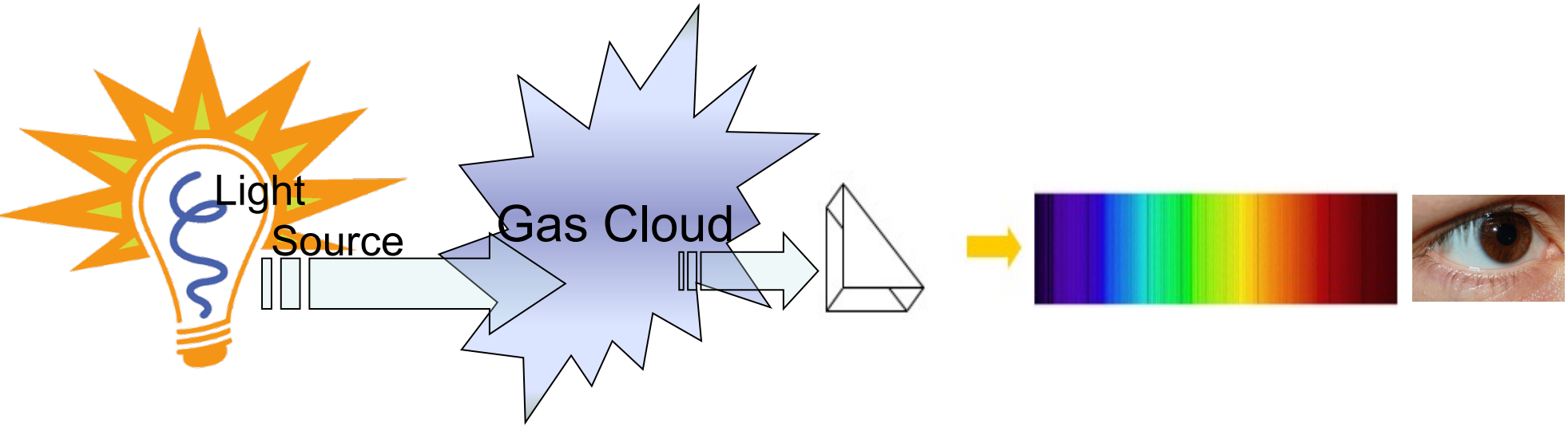
Library of Congress

LAW 1



Continuous Spectrum

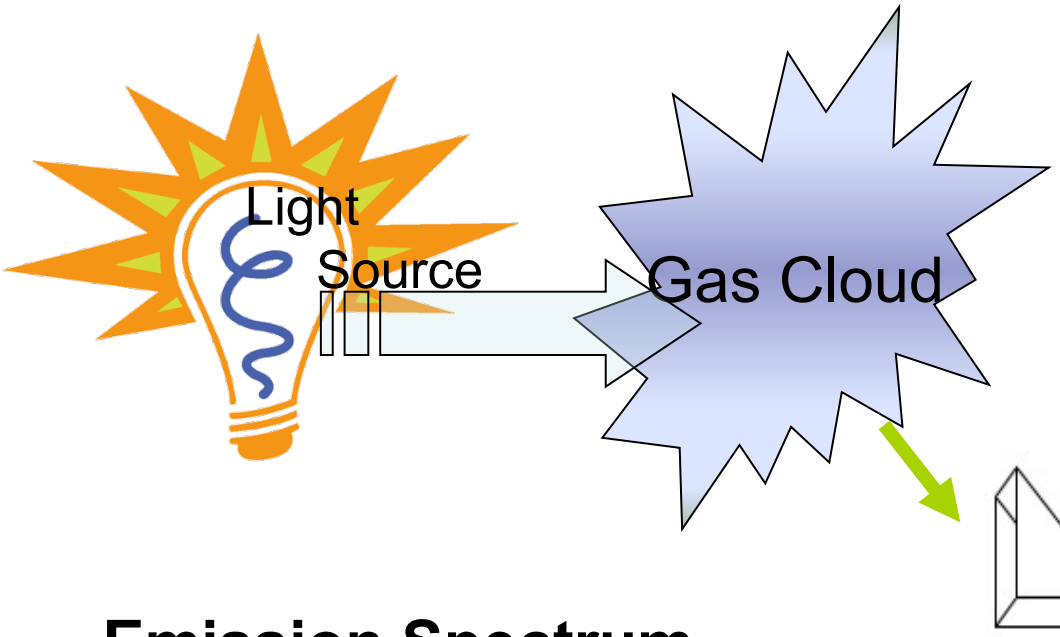
LAW 2



Absorption Spectrum

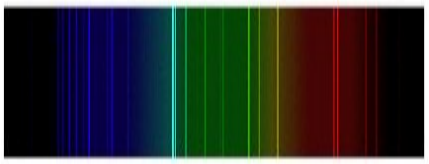
Gas that appears COOLER than the background produces an absorption spectrum

LAW 3

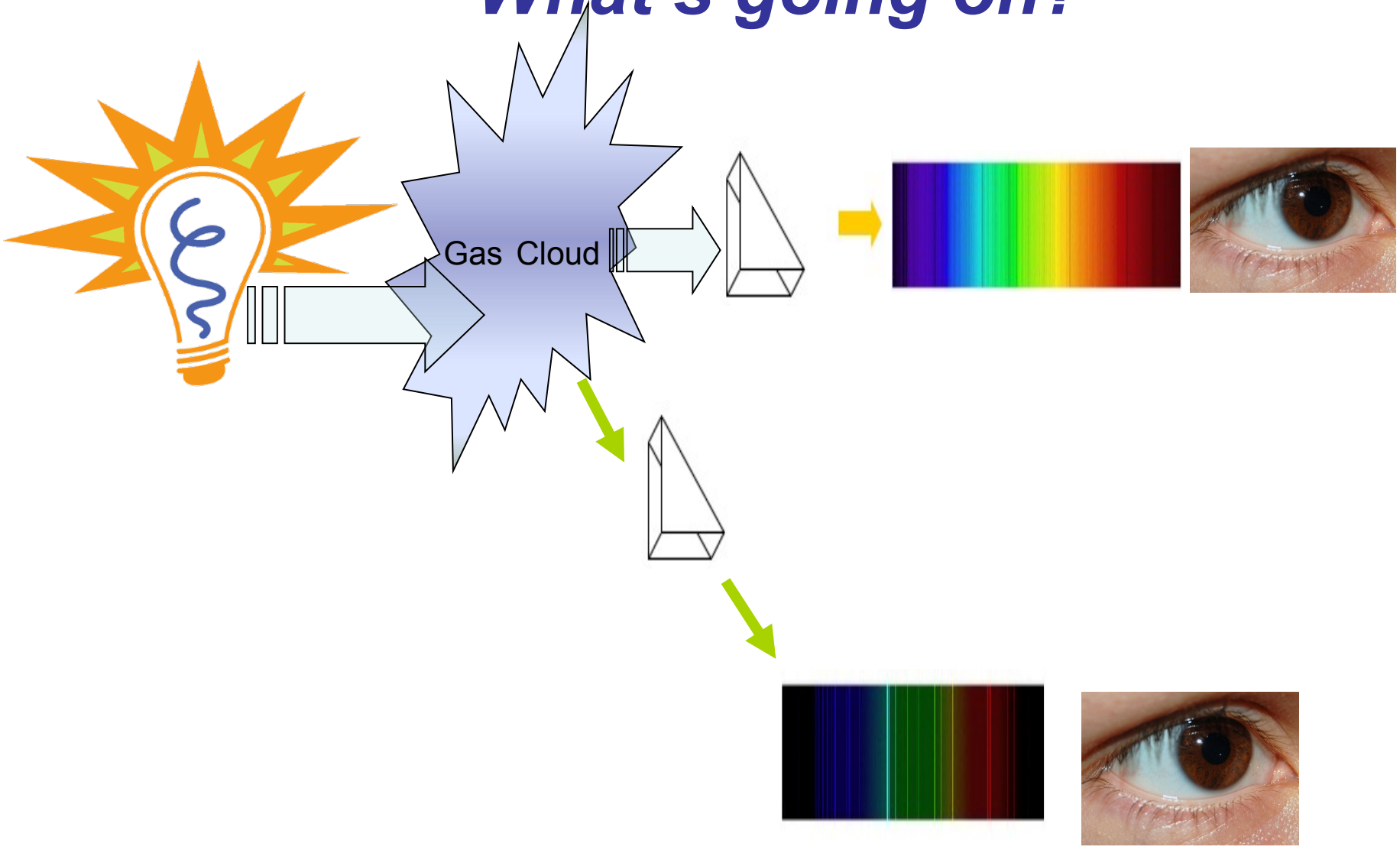


Emission Spectrum

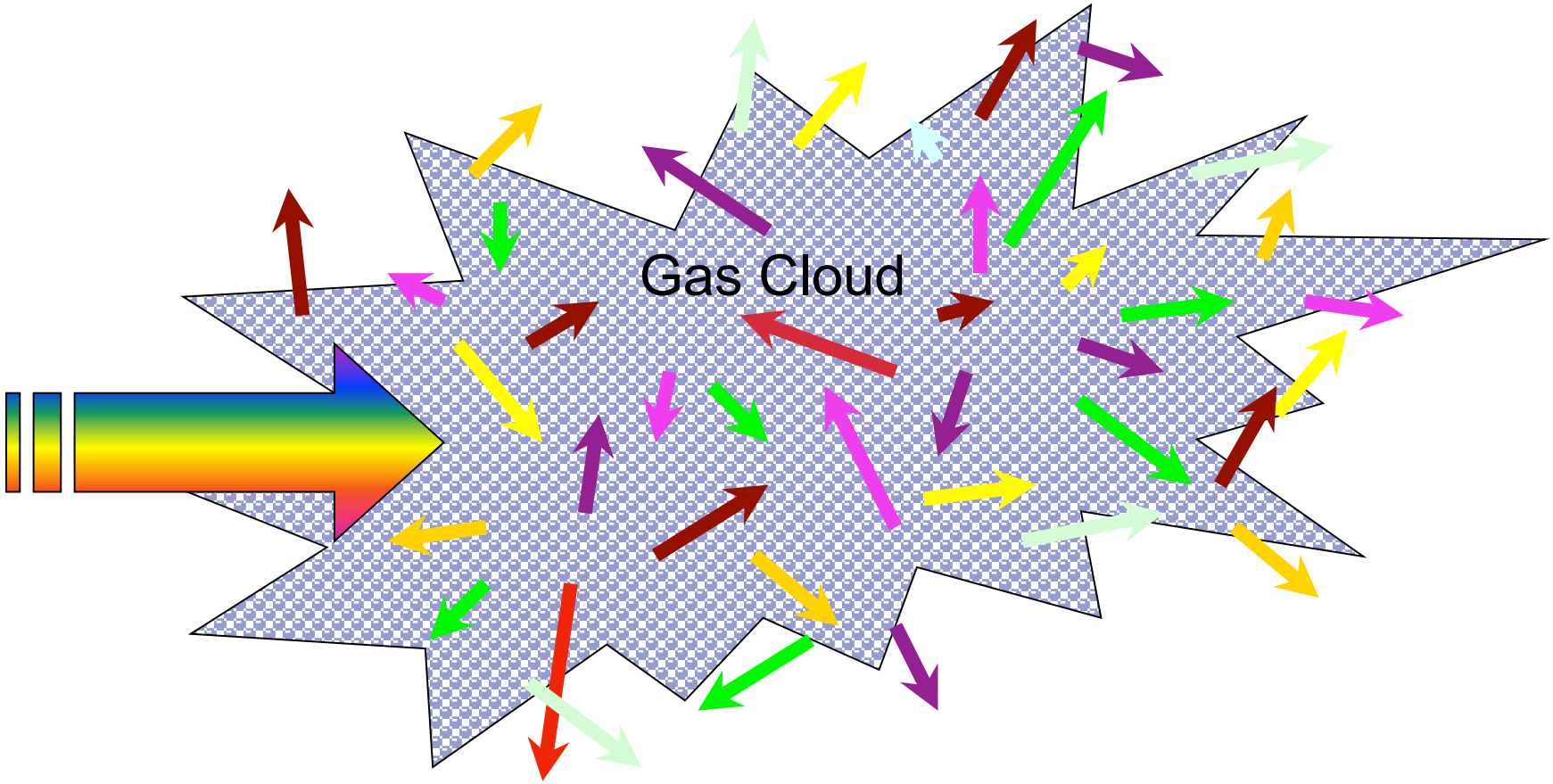
Gas that appears HOTTER than the background produces an emission spectrum



What's going on?



What's going on?



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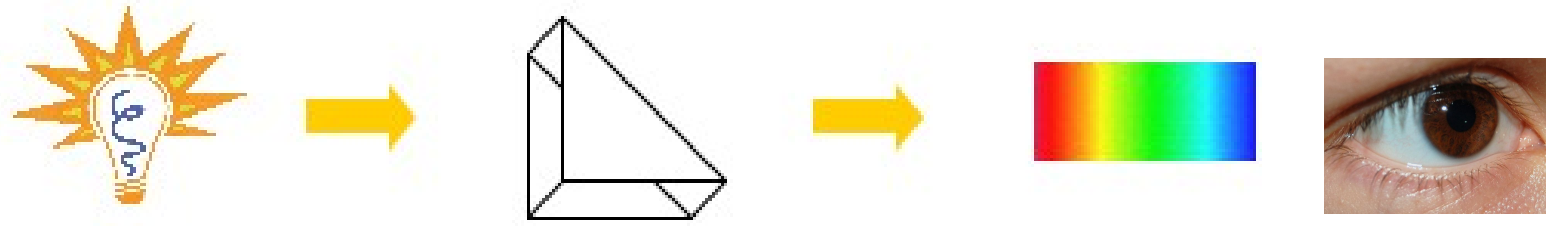

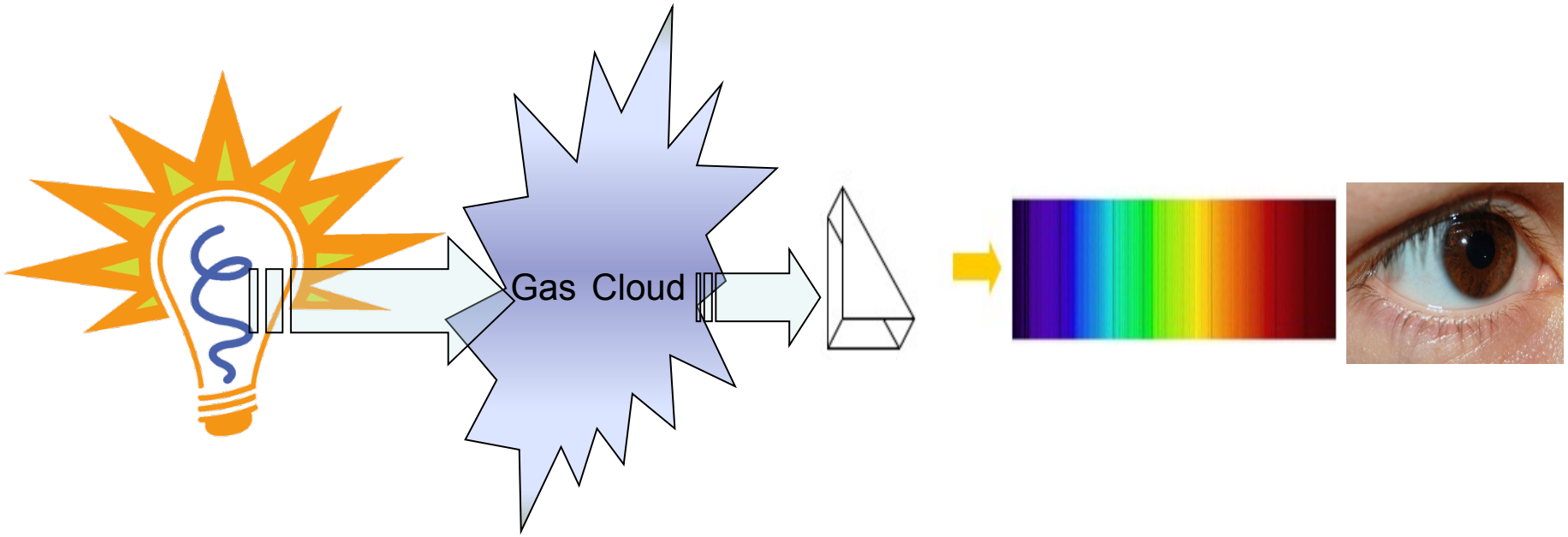

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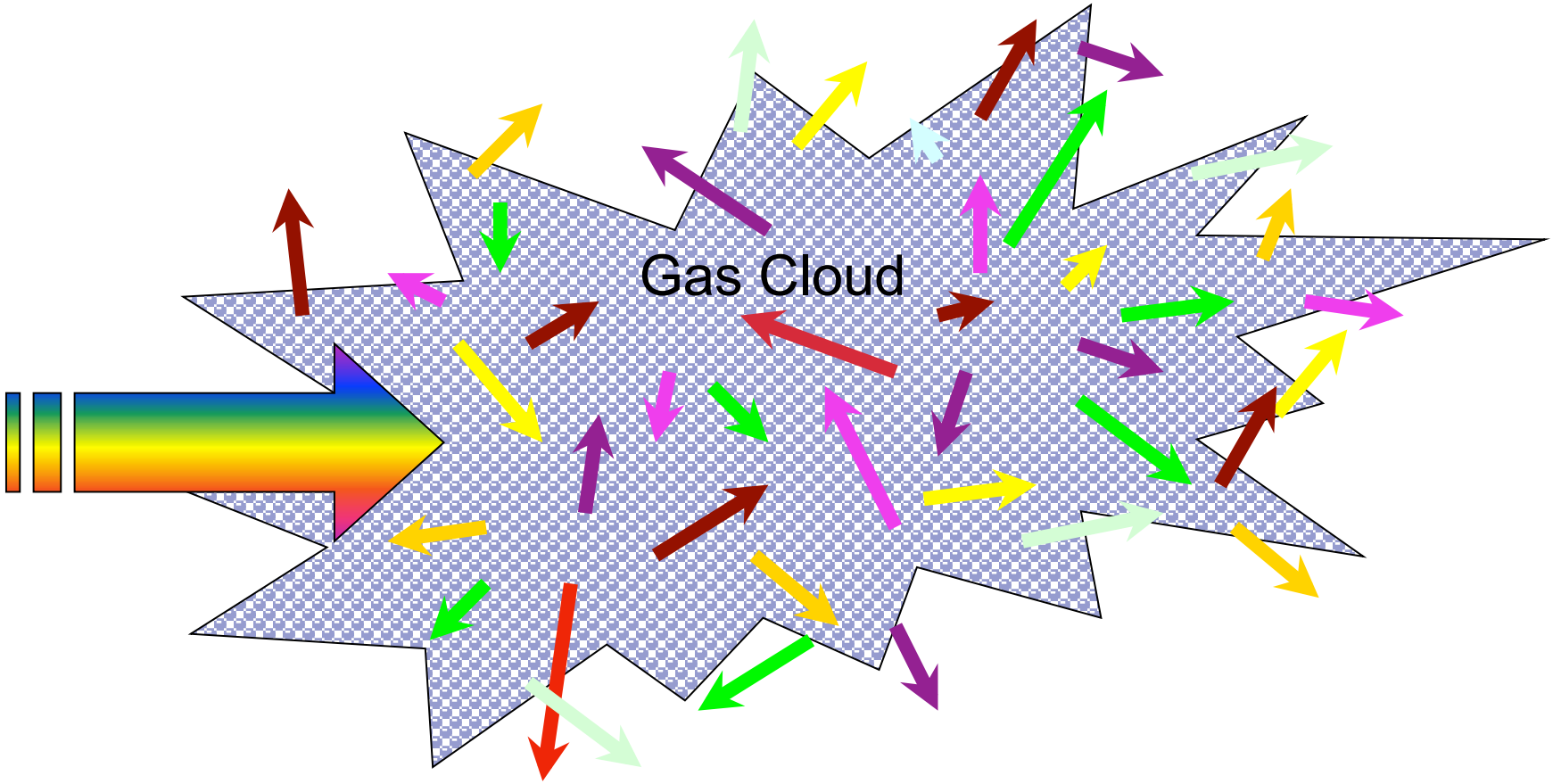

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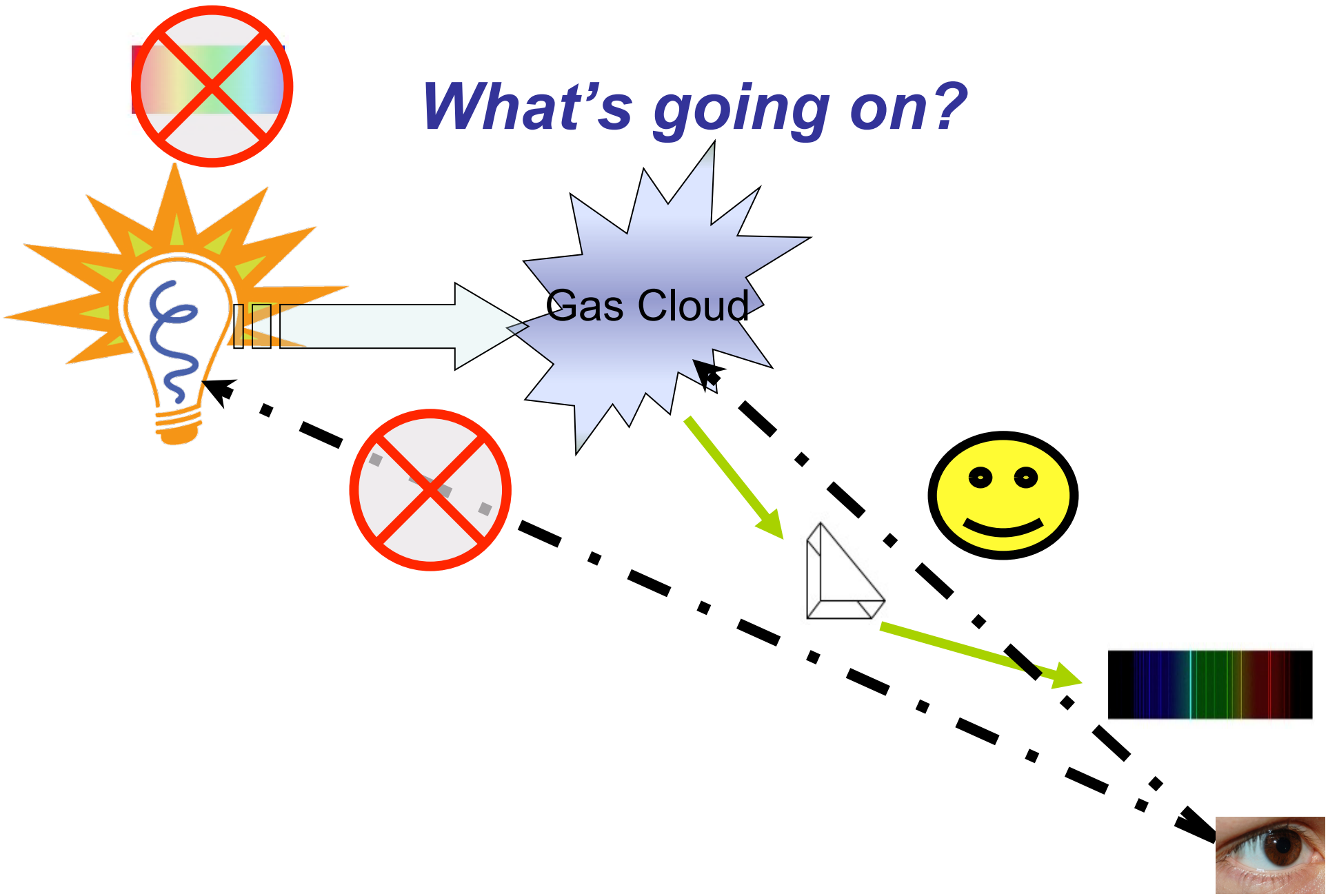
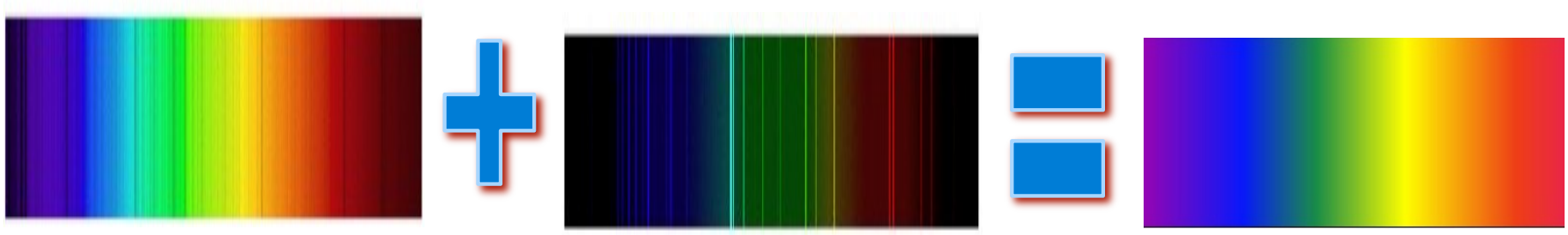
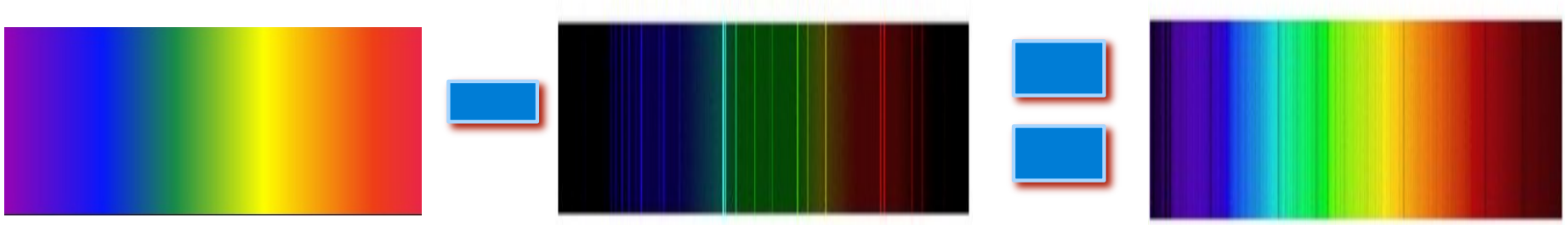


What's going on?



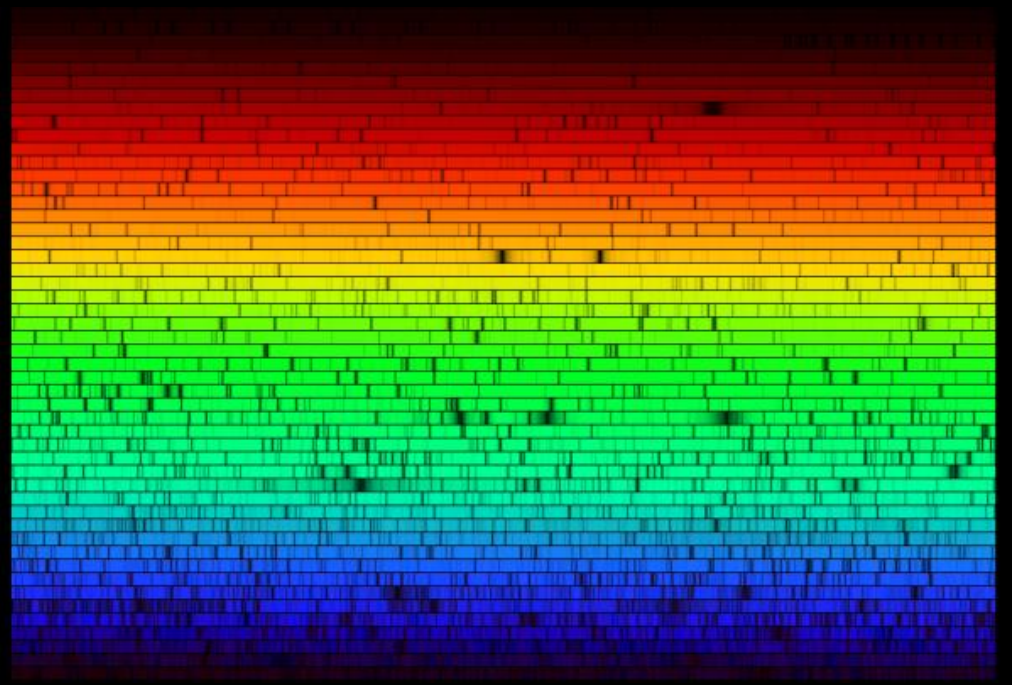
It follows that….



Etc.

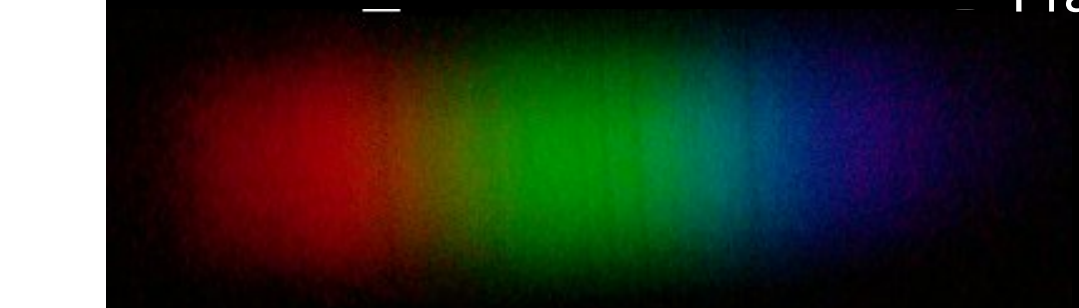
This guy named Fraunhofer

- Early 1800s
- Not the first (just the bestedest-er)
- Remember Kirchoff's Laws--1859
- "Discovered" numerous lines in the solar spectrum using his invention, the "Spectrometer"

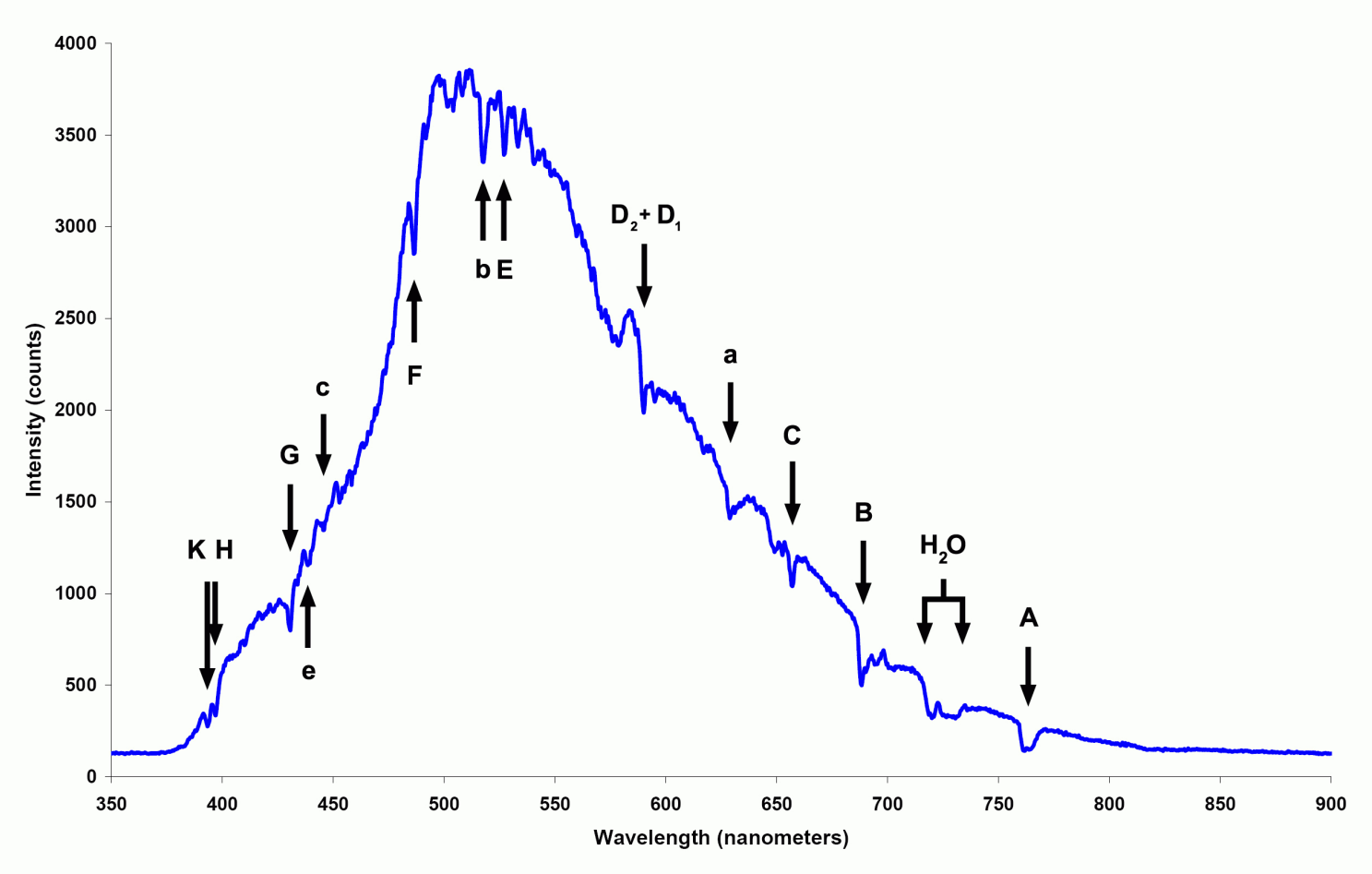


Fraunhofer lines- Solar Spectrum

http://apod.gsfc.nasa.gov/apod/ap030629.html



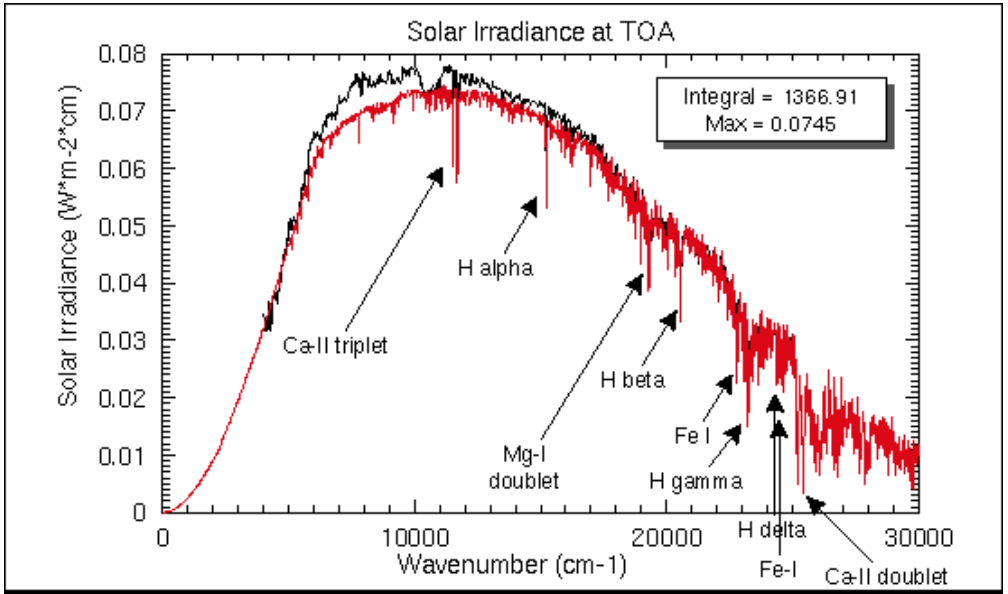
Spectrum recorded as a plot of wavelength vs. intensity of the signal



http://en.wikipedia.org/wiki/File:Spectrum_of_blue_sky.png

What can this tell us?

- About light we can and cannot see
- What's in an atmosphere
- What's on the ground (absorbed then emitted light)
- About the solar atmosphere
- About comet tails
- About our galaxy
- About other planetary systems
- About other galaxies



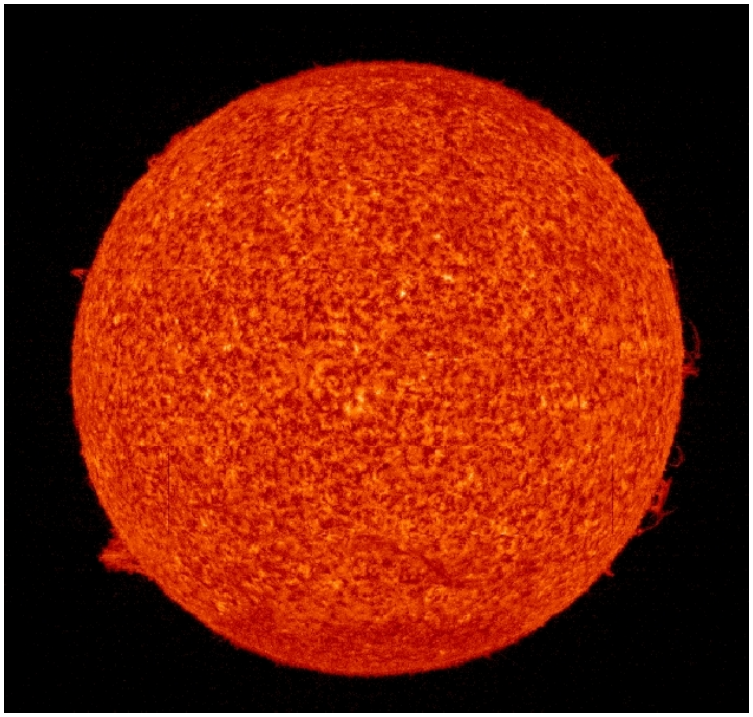
Ca-II triplet:	11545, 11707, 11767
H alpha:	15237
Mg-I doublet:	19292, 19332
H beta:	20571
Fe-I:	22812
H gamma:	23039
H delta:	24380
Fe-I:	24723
Ca-II doublet:	25202, 25426

Balmer Series, n = 2,3,4,5...
27427*(1 -- 4/n^2)
= 27430 * (5/9, 3/4, 21/25, 8/9)
= 15237,20570,23039,24380

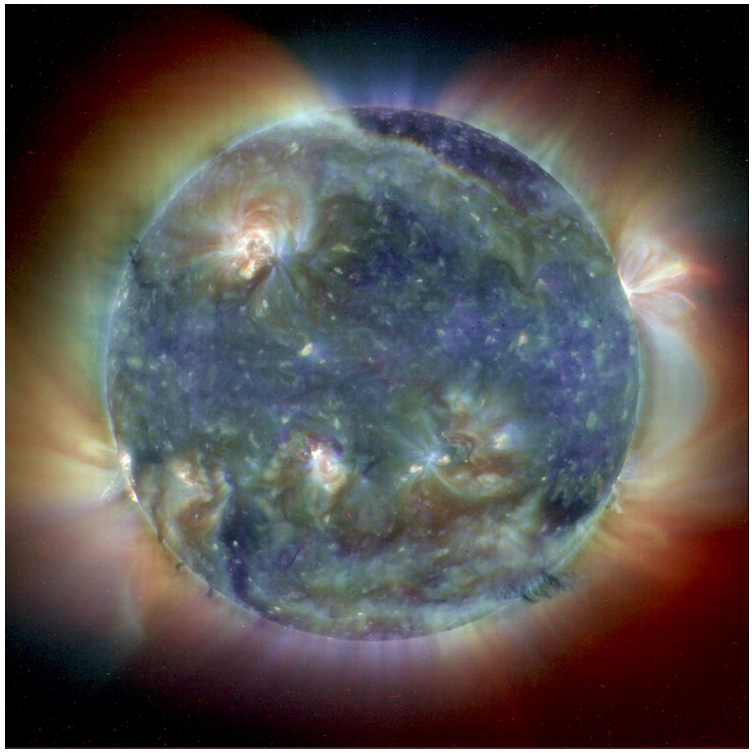
Nasa.gov

Imaging vs. Spectroscopy

- Filters
- Sensitive optics



Sun imaged in He I (5843 nm)

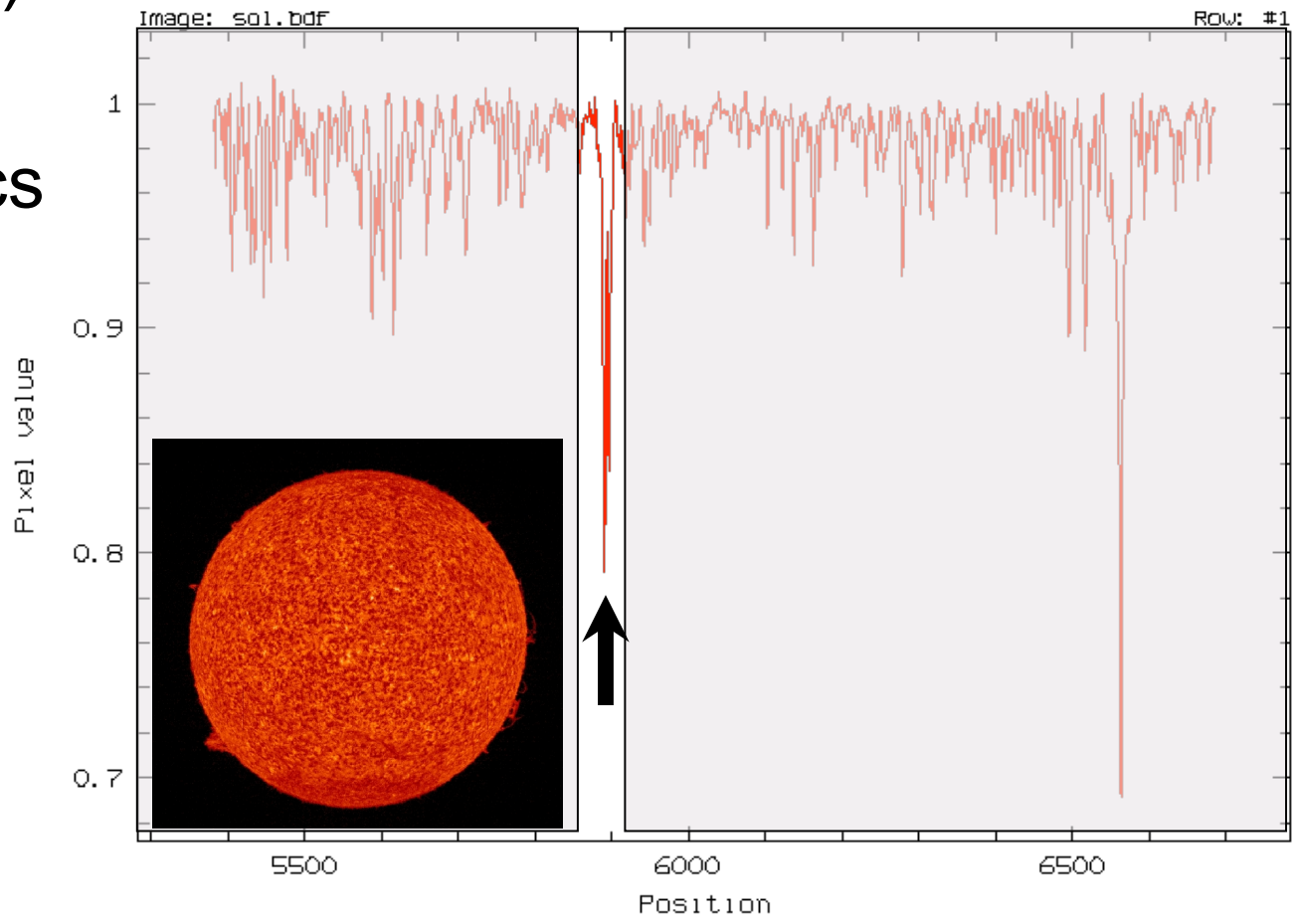


composite image combines EIT images from three wavelengths (171Å, 195Å and 284Å)

http://sohowww.nascom.nasa.gov/

Imaging vs. Spectroscopy

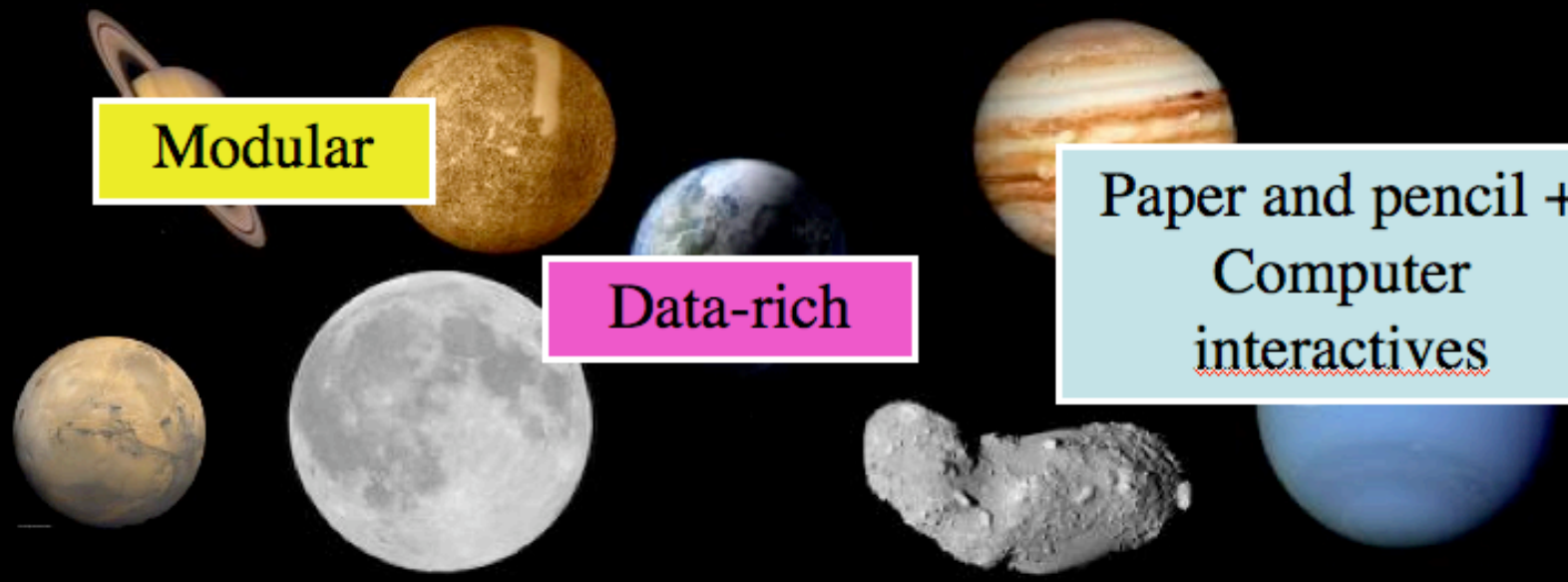
- Sun imaged in He I (5843 nm)
- Filters
- Sensitive optics



http://sohowww.nascom.nasa.gov/

Structure of SPECTRA

SOLAR SYSTEM DATA STORIES



Modular

Data-rich

Paper and pencil + Computer interactives

Graphing the Rainbow

Building a Spectrograph

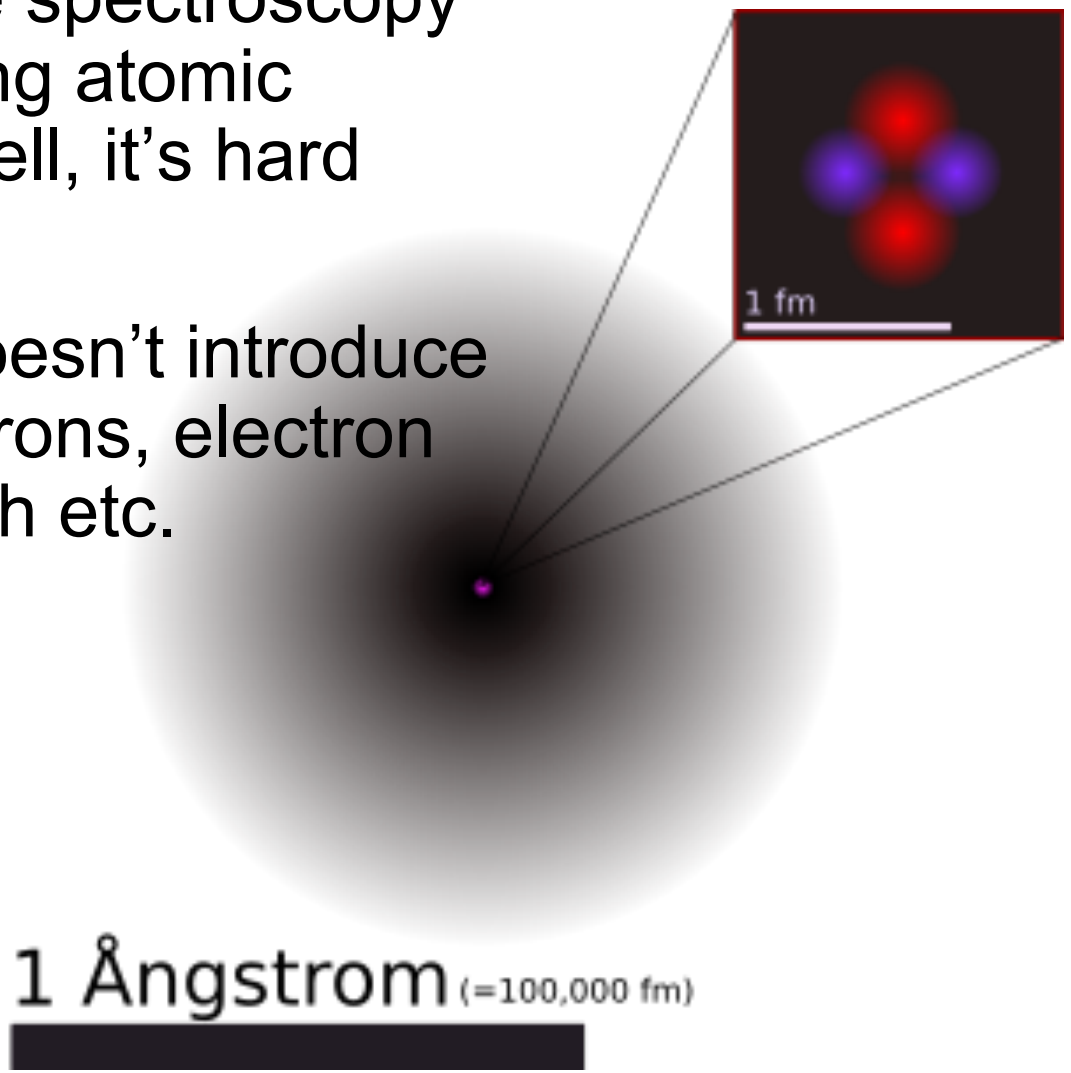
Patterns in Nature

FOUNDATION

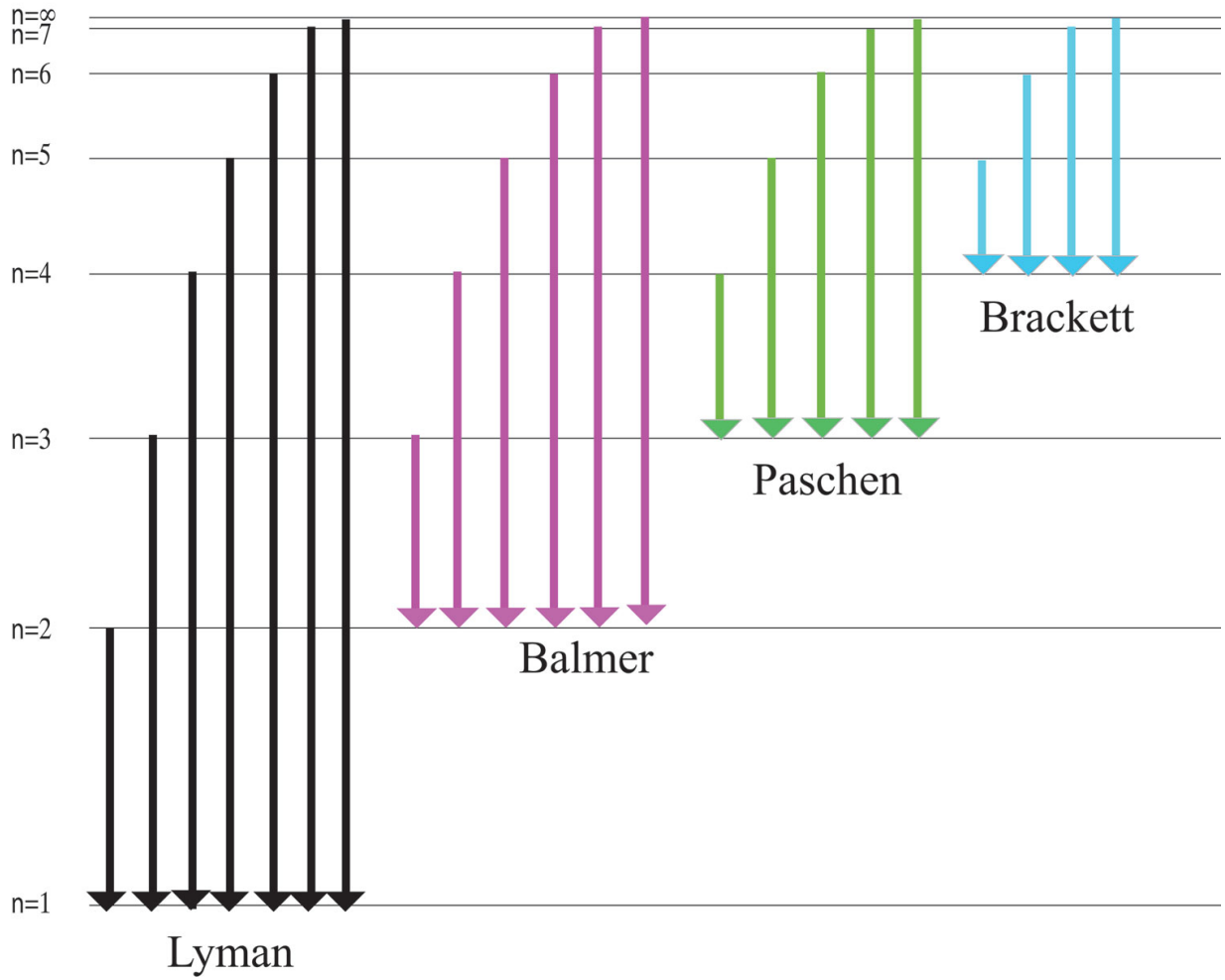
How do we address this in Middle and Early High School?

- Traditionally, because spectroscopy relies on understanding atomic transition states…. Well, it's hard

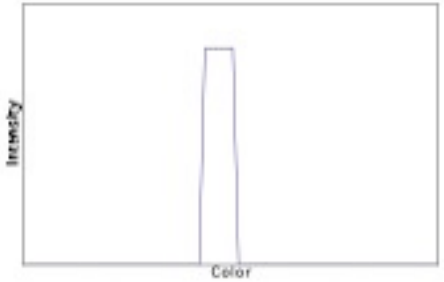
- Project SPECTRA! doesn't introduce atoms, photons, electrons, electron transitions, wavelength etc.

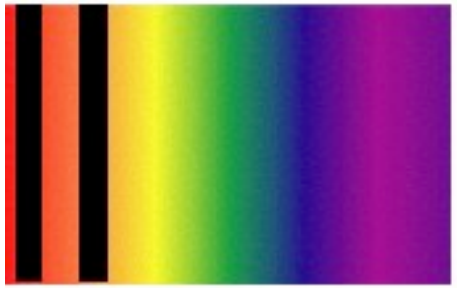


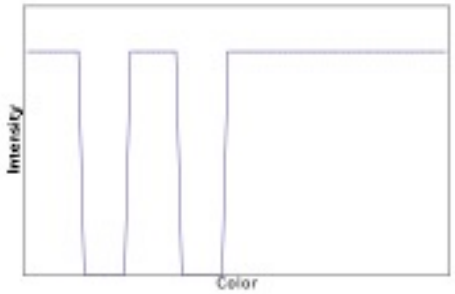
YIKES!



Much Better!





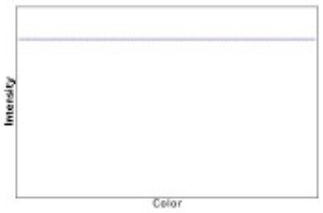


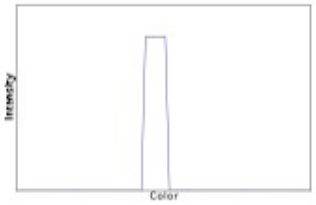
Patterns and Fingerprints

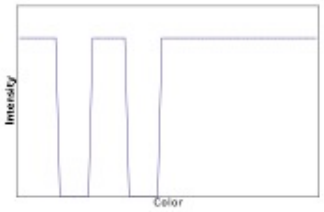
- Students find patterns in classmate's fingerprints
- Students match "known" fingerprints to "unknown"
- Students determine pattern trends in series
- Relate patterns to nature

Graphing the Rainbow

- Bridge lesson
- Activity short (15 min)
- Introduction to light patterns
- Students match light patterns to their corresponding line spectrum







Using Spectral Data to Explore Saturn and Titan

Students view real spectra from the Cassini UVIS instrument to compare Saturn's and Titan's spectra with standard spectra of four different elements and identify which elements are present in Saturn's rings and Titan's atmosphere

Students consider:

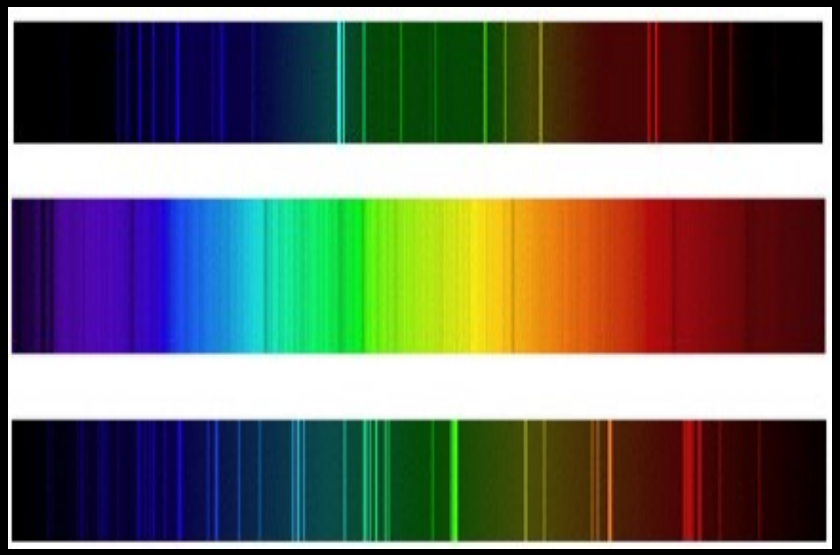
- Why hydrogen is so abundant
- Why nitrogen exists in Titan's atmosphere but not Saturn's rings
- Differences between Titan's atmosphere and Earth's with a focus on planetary habitability

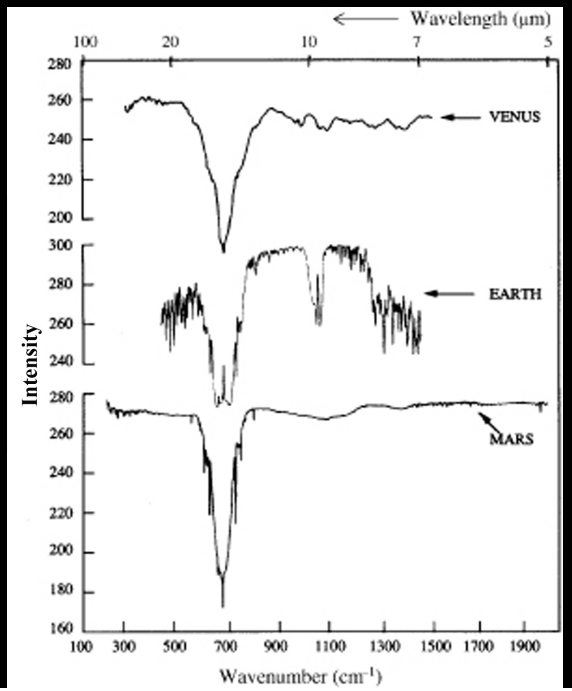
Goldilocks and the Three Planets

Students use historic data on the atmospheres of Venus, Earth and Mars to compare and contrast levels of CO_2.

Students consider:

- How greenhouse gases contribute to planetary temperature
- How atmosphere and distance from the Sun effect planetary temperature and habitability





The Engineering Connection: Building a Fancy Spectrograph

- Promotes engineering and engineering concepts
- Creates enthusiasm about space, planetary science, the Sun and stars, and atmospheres
- Students build (and use) their own inexpensive spectrograph

Designing an Open Spectrograph
and counterpart:
Designing a Spectroscopy Mission

- Students measure angles
- Establish the geometry of the spectrograph
- Students design a mission
- Let students be creative!
- Use missions in the news as an impetus