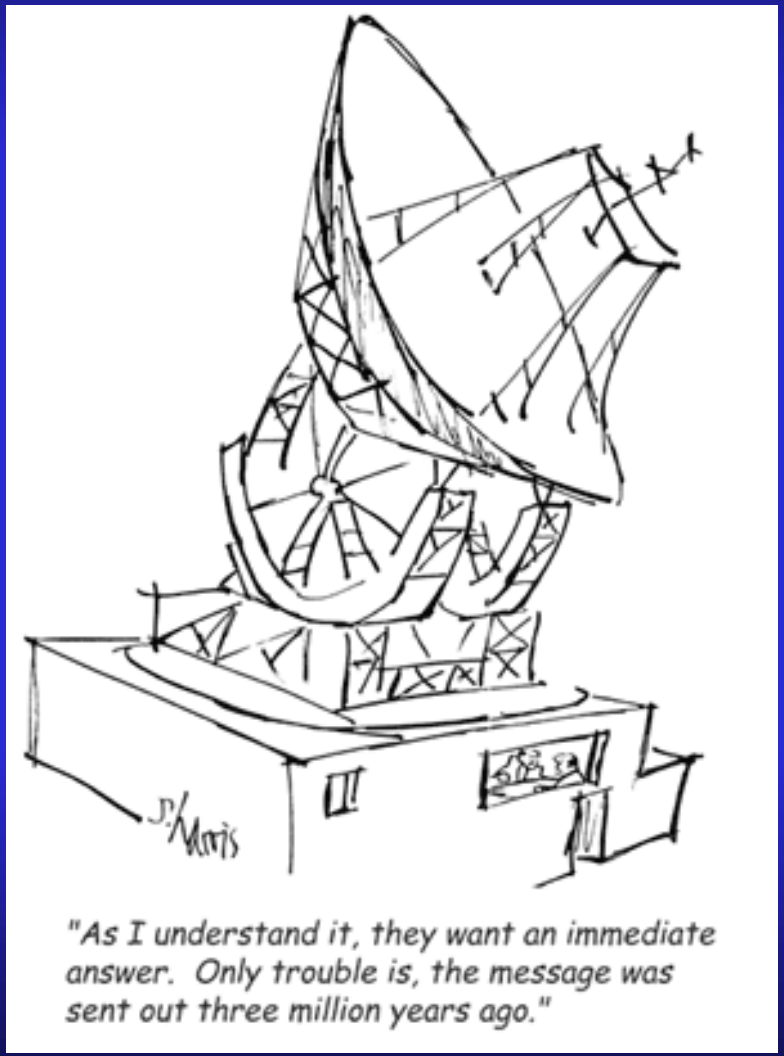
# Light



"As I understand it, they want an immediate answer. Only trouble is, the message was sent out three million years ago."

# What is Light?

The third form of energy

The thing that our eyes detect

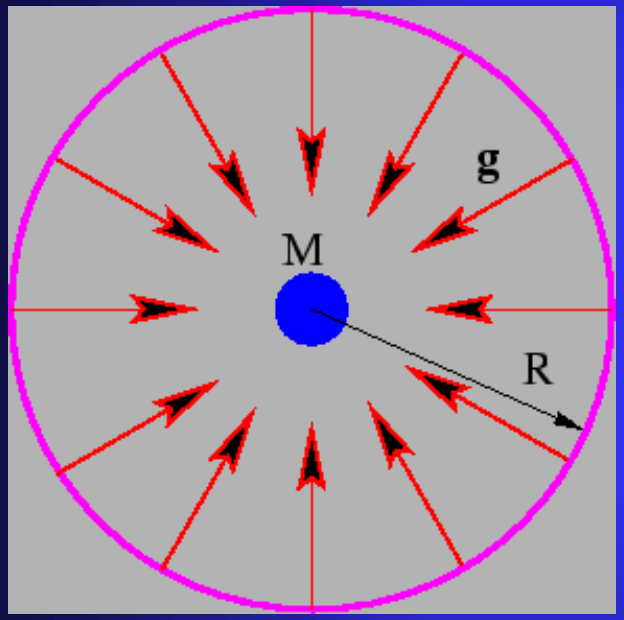
How radio works

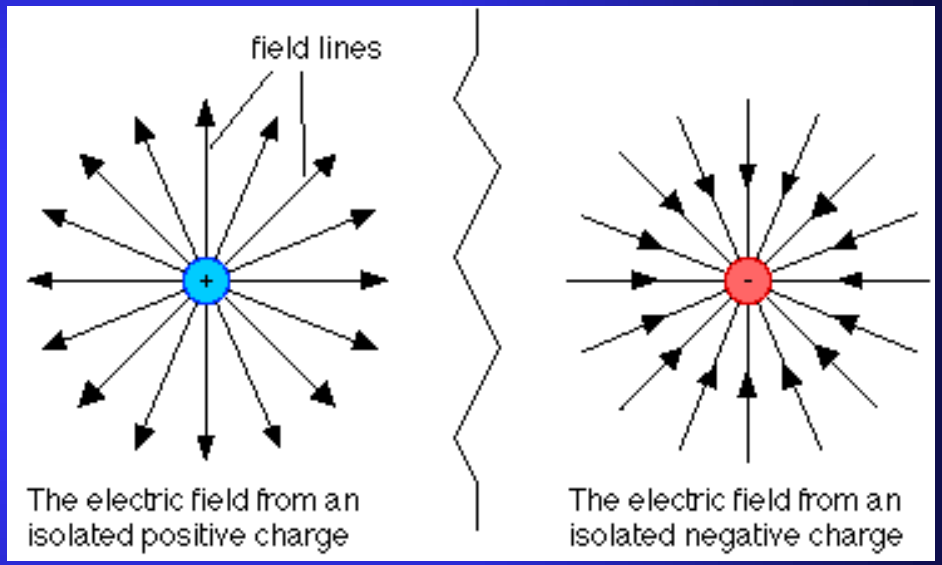
The only thing astronomers study

Electromagnetic radiation

# Electric Fields

Force Fields! Just like on Star Trek!
Sort of…

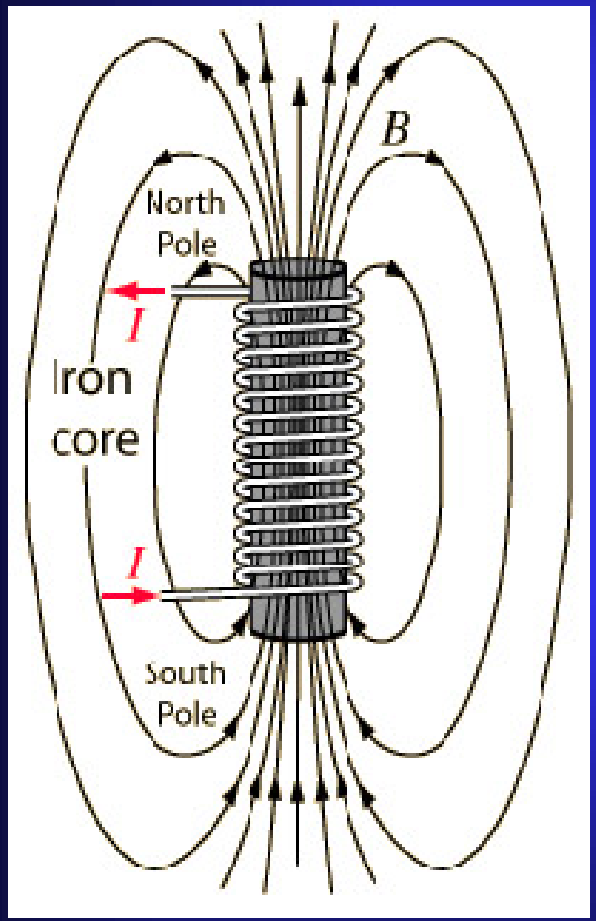


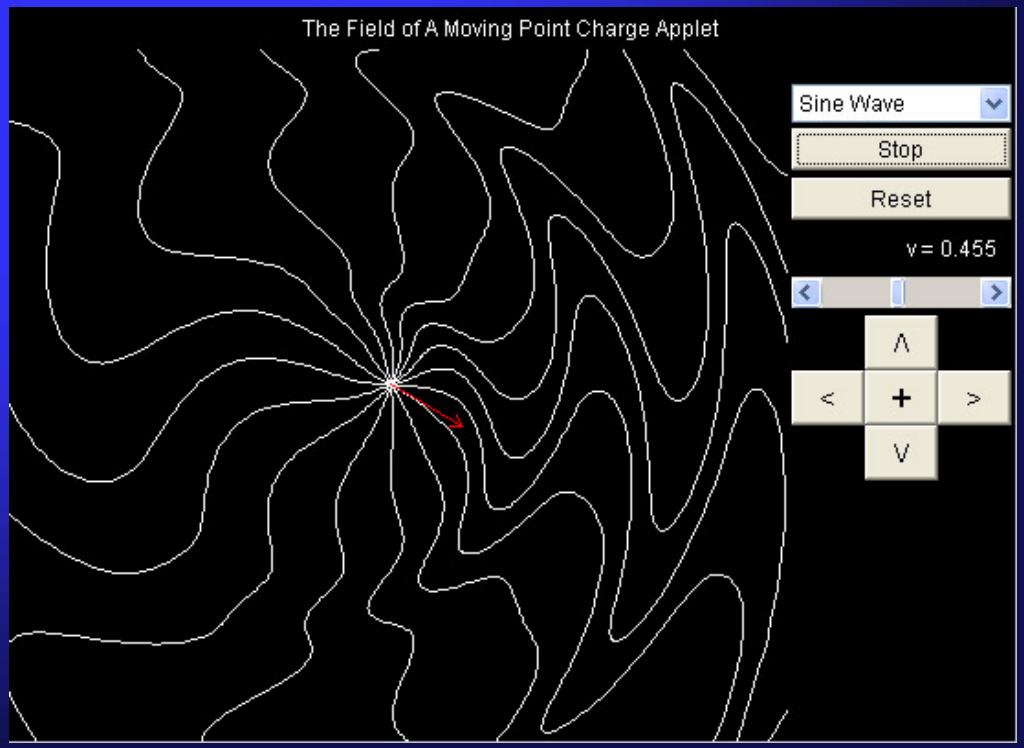

$$F = G\frac{M_1 M_2}{r^2}$$

$$F = k\frac{q_1 q_2}{r^2}$$

# Magnetic Fields




## Changing E fields create B fields



# ABCD

A charged particle moving uniformly in a straight line creates

A. EM radiation

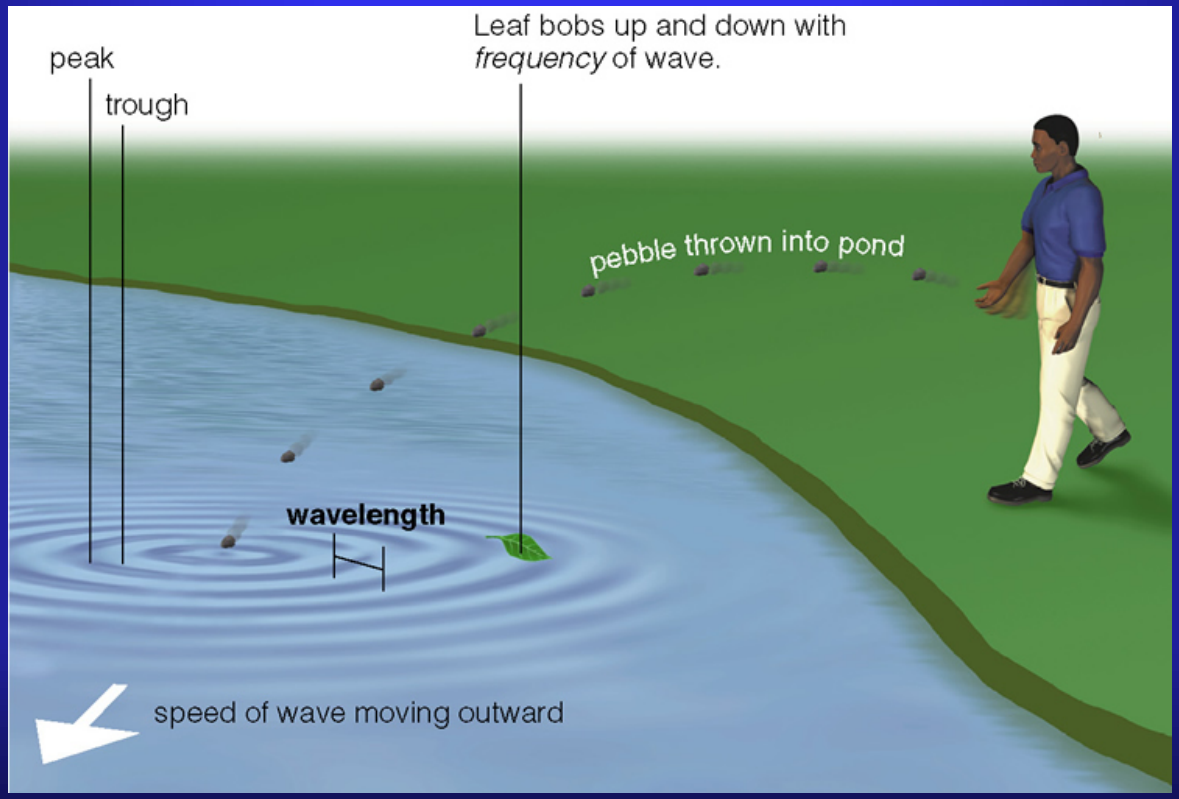
B. EM fields, no radiation

C. Only electric fields

D. EM radiation, but no E or M fields

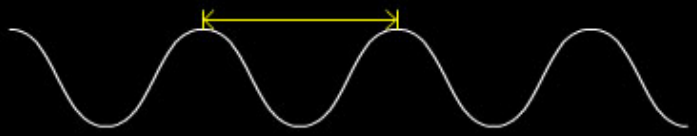
# Waves

## Waves carry energy



# Waves

***Wavelength:*** the distance between adjacent crests (or troughs)



***Amplitude:*** half the difference in height between a crest and a trough

***Frequency:*** the number of crests that pass through a point (such as the leaf) each second. It is measured in units of hertz (Hz), which are cycles per second

Blink rate = frequency

***Speed:*** how fast the pattern of crests and troughs moves forward

*Definitions* Comparison

# ABCD

Longer wavelength means:

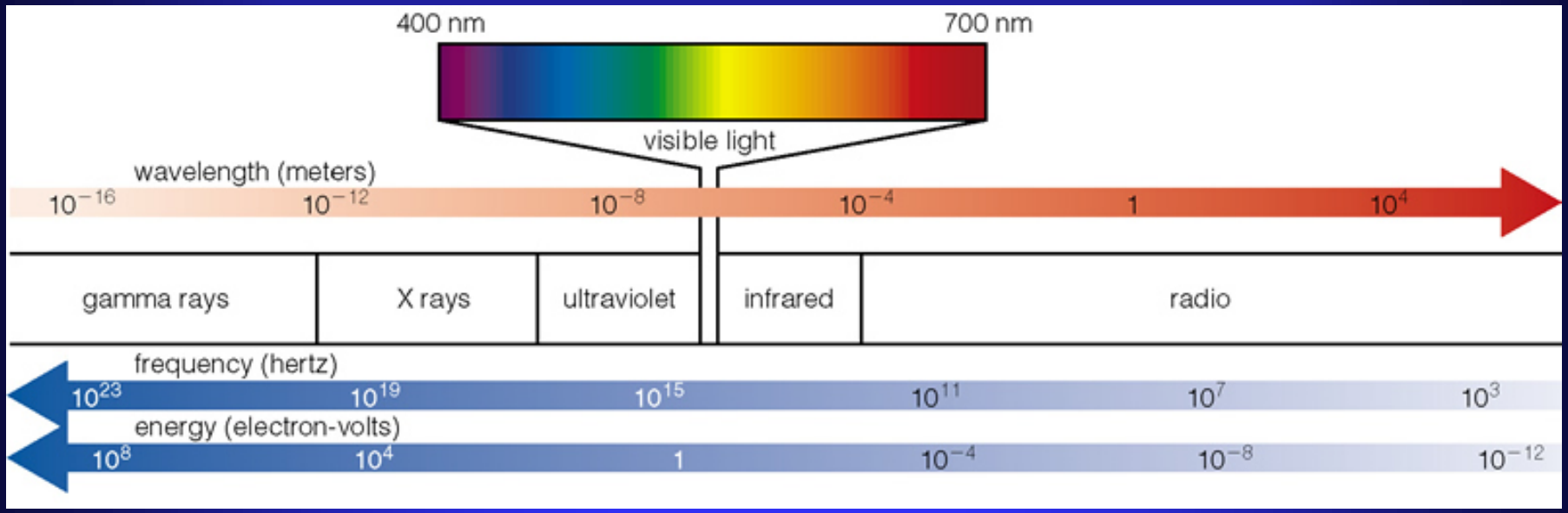
A. lower frequency and lower energy

B. higher frequency and lower energy

C. lower frequency and higher energy

D. Higher frequency and higher energy

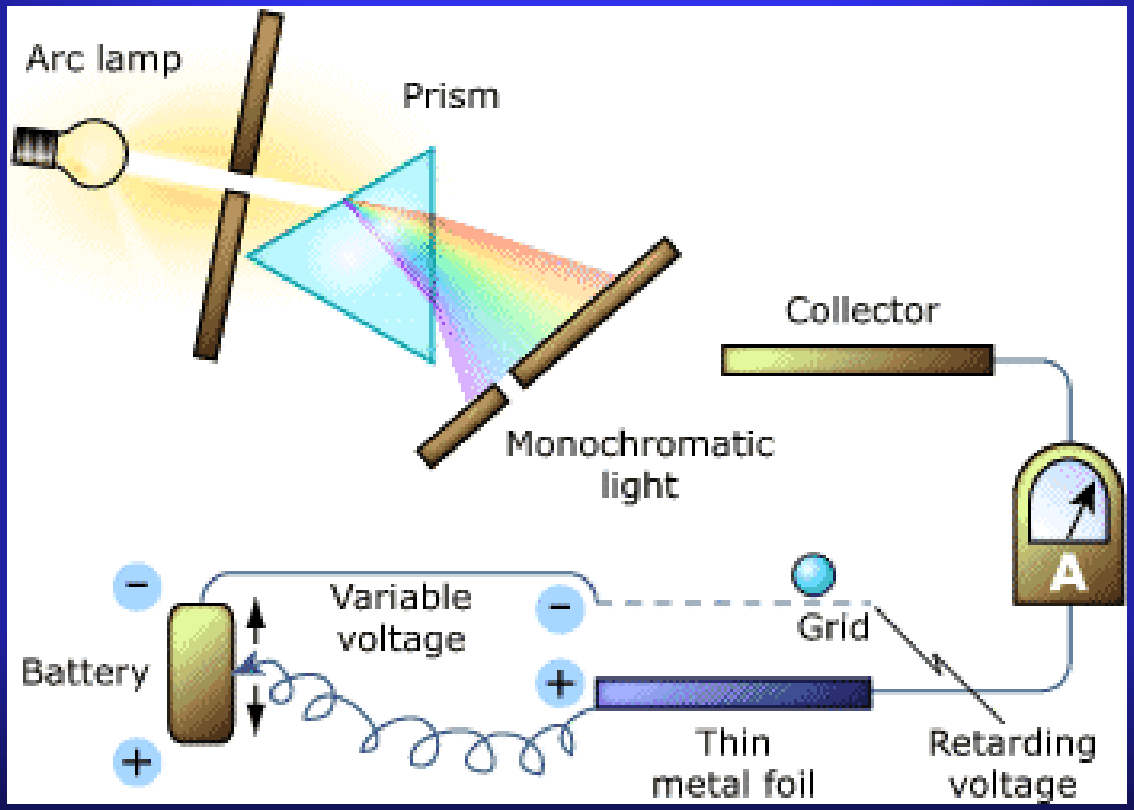
# The Spectrum




The *visible* part of the spectrum is rather small

# Particles of Light

## The photoelectric effect



# Interactions

## Emission

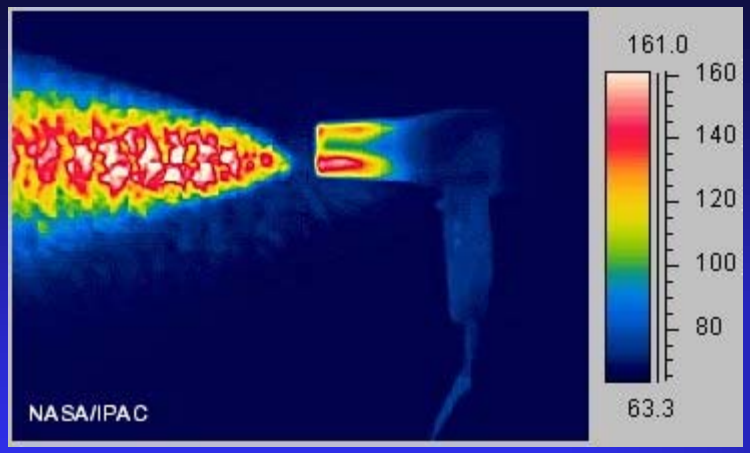
## Reflection

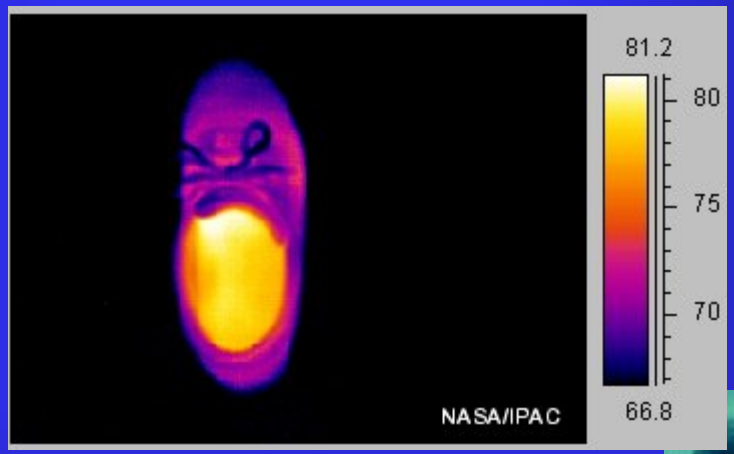
## Absorption

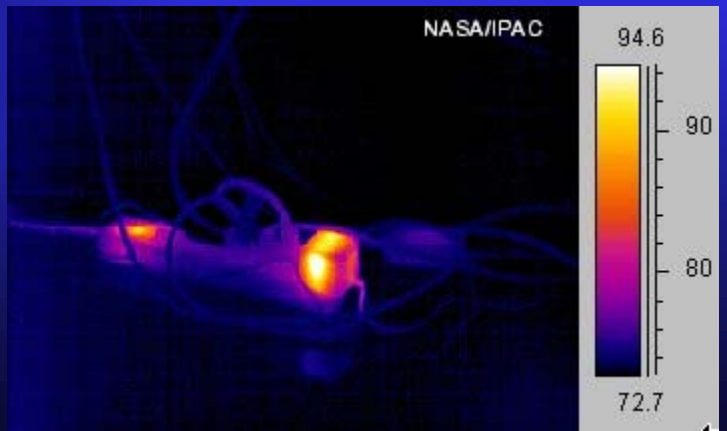
# Thermal Emission

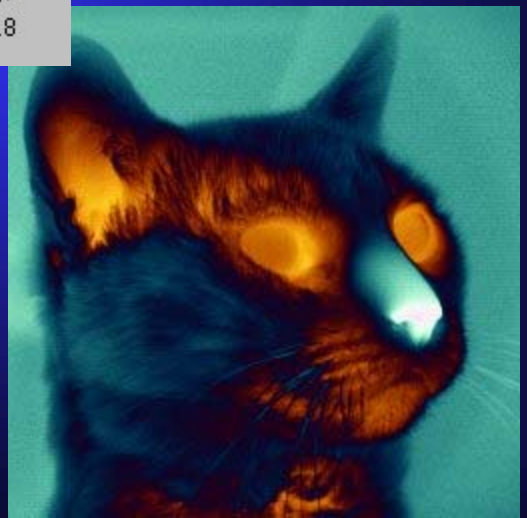
Everything with a temperature emits light

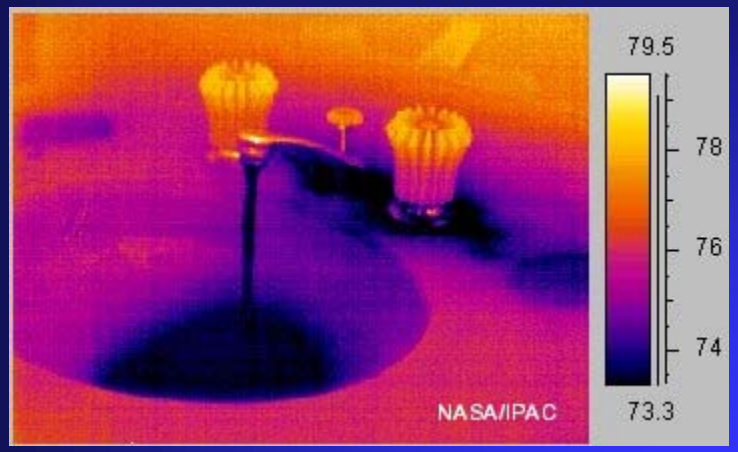
Power per unit Area (Flux) and color depend only on the temperature

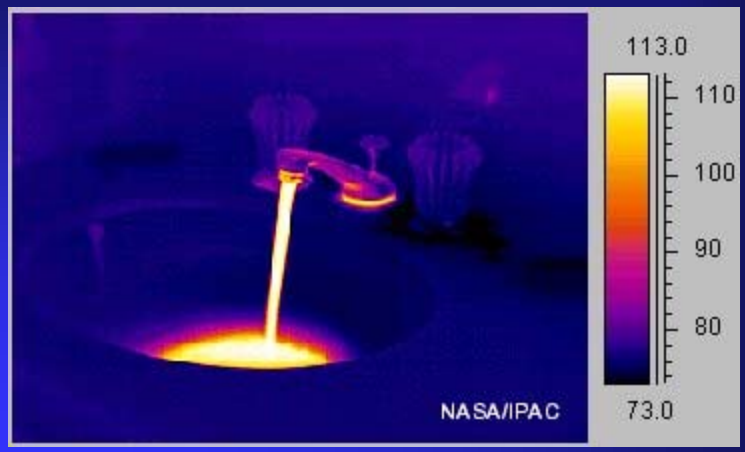

161.0
160
140
120
100
80
63.3
NASA/IPAC


81.2
80
75
70
66.8
NASA/IPAC


NASA/IPAC
94.6
90
80
72.7




79.5
78
76
74
73.3
NASA/IPAC


113.0
110
100
90
80
73.0
NASA/IPAC

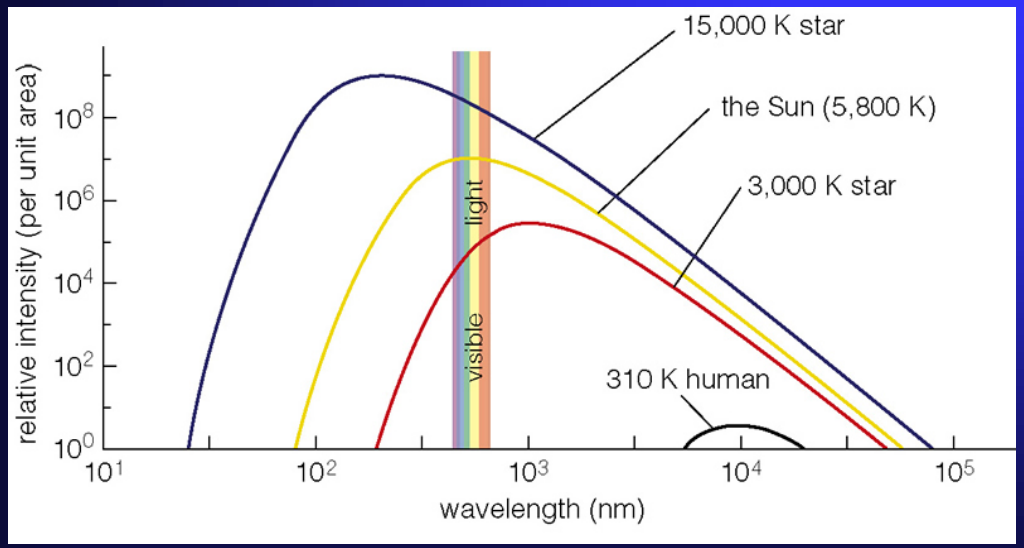

SIRTF

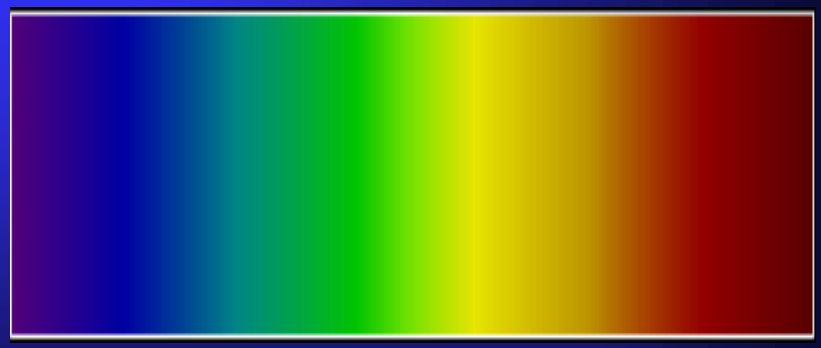

NASA/IPAC
93.4
90
85
80
75
73.6

# Blackbody

$$\lambda_{max} T = 2.9 \times 10^{6}\ nm \cdot K$$

$$F = \sigma T^{4}$$

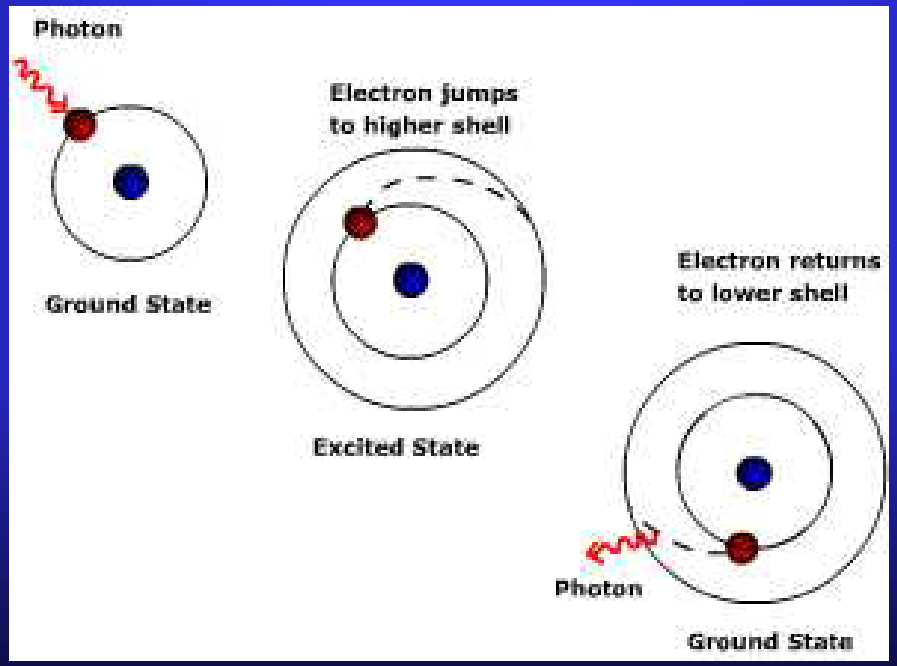


# Atomic Structure

## Classical View

Electrons are in *orbits* about the nucleus



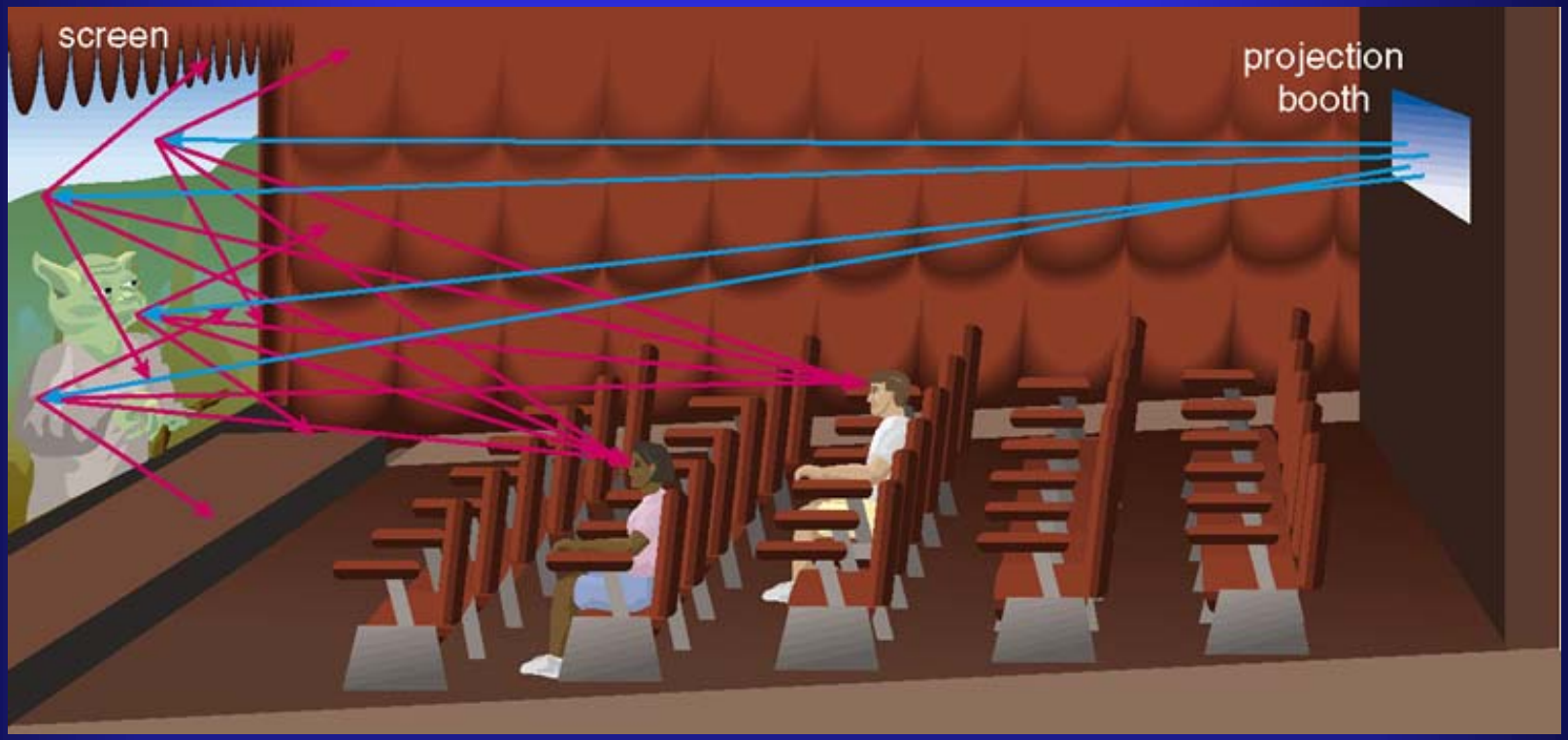
# Emission Lines

Every substance has its own spectral fingerprint


Red
Low Energy

Blue
High Energy

# Reflection and Scattering

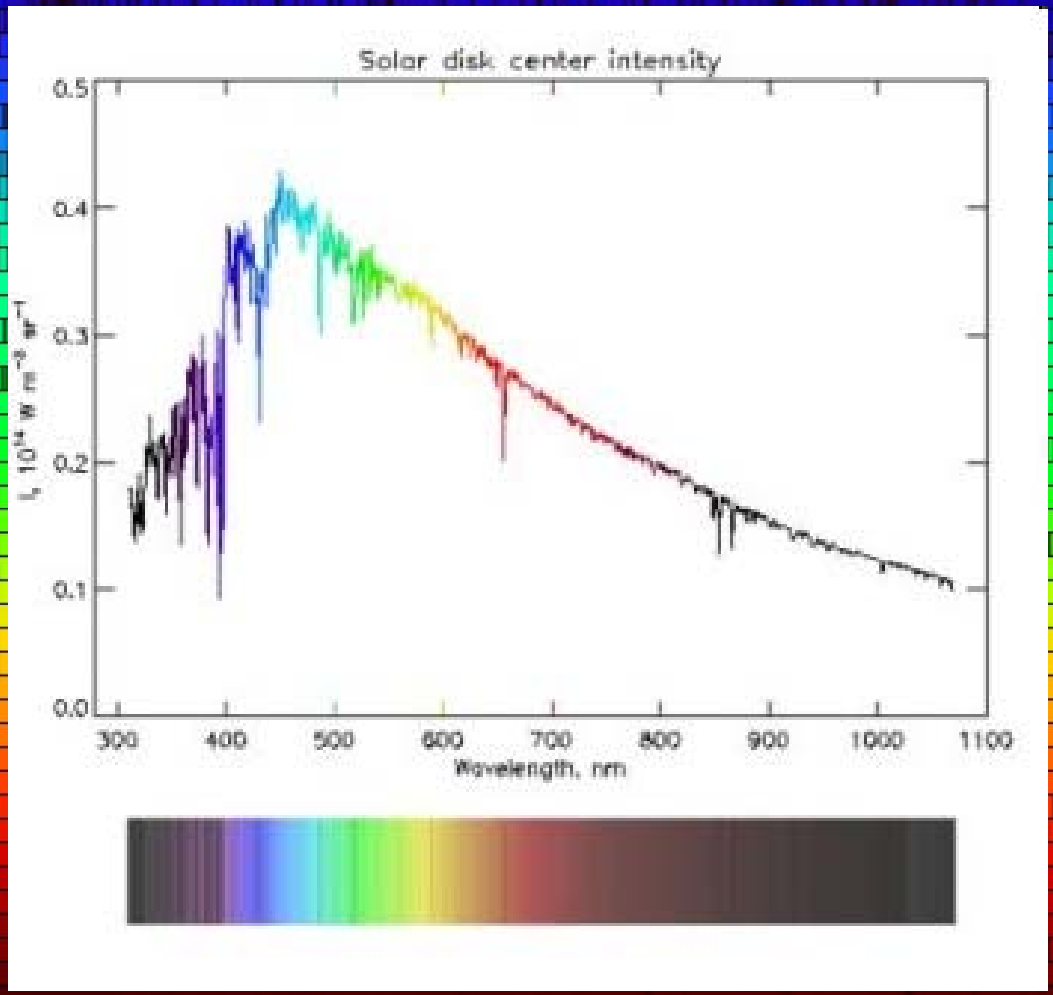


# Absorption

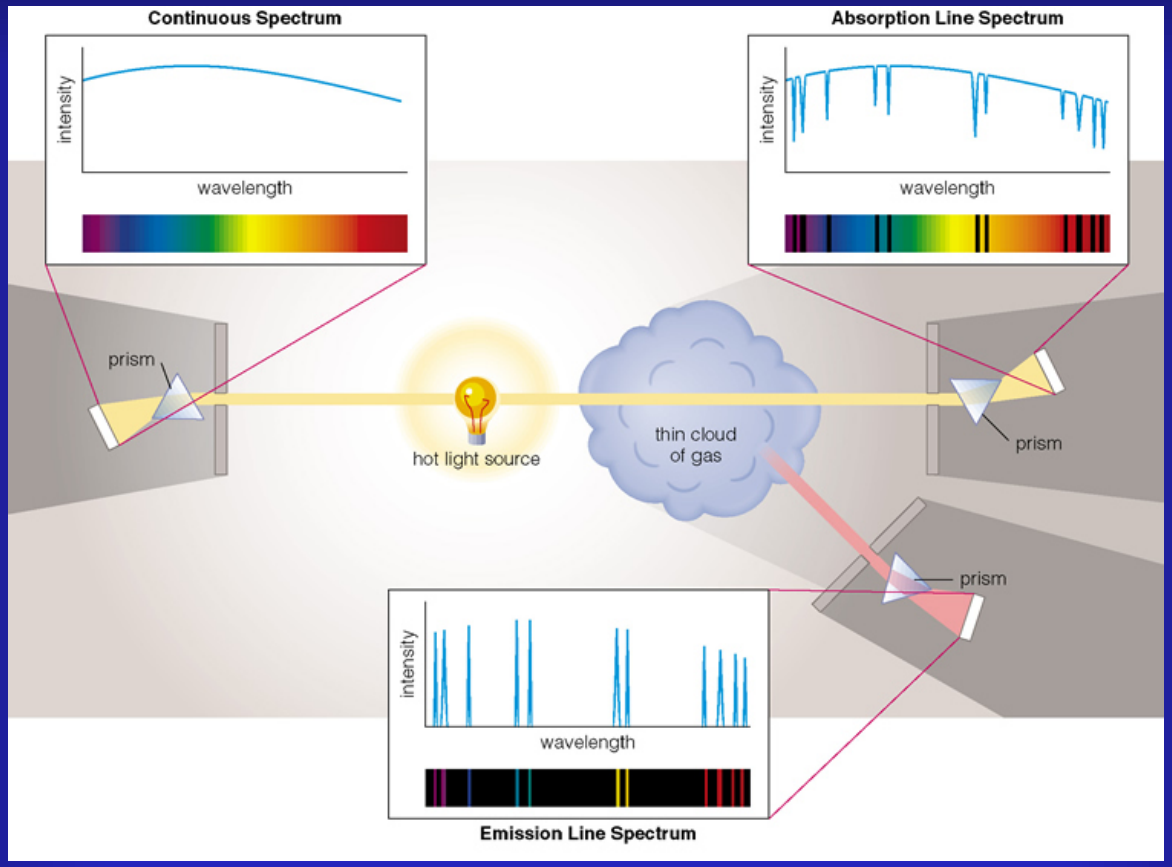
A perfect absorber is a black body

Absorbs all but red

# Absorption


Solar disk center intensity
0.5
0.4
0.3
0.2
0.1
0.0
300
400
500
600
700
800
900
1000
1100
Wavelength, nm

# Absorption




Atoms and molecules can absorb photons

# ABCD

In the Sun, the 4 to 2 hydrogen transition produces photons with $\lambda$=486.1 . If the Sun were twice the temperature, $\lambda$ would be:

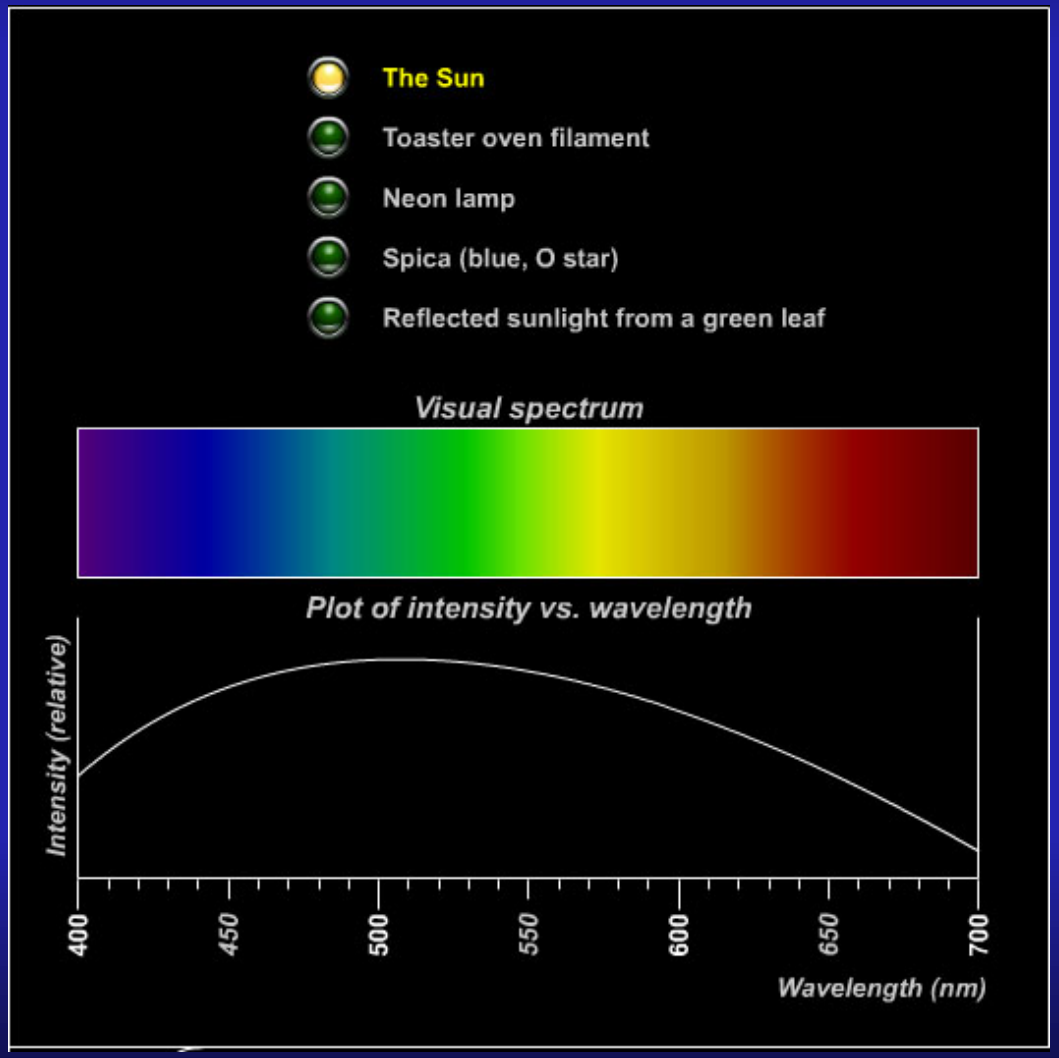
A. half as big

B. 4 times as big

C. the same

D. twice as big

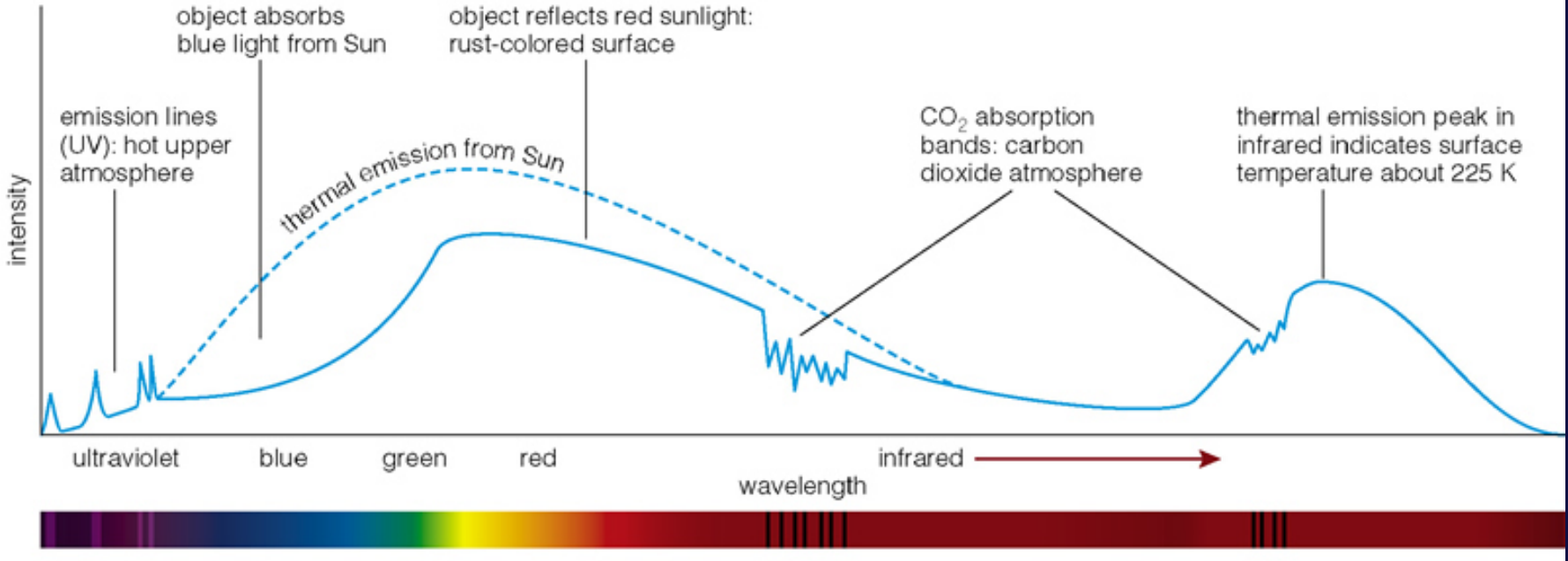
# QUIZ!


The Sun
Toaster oven filament
Neon lamp
Spica (blue, O star)
Reflected sunlight from a green leaf
Visual spectrum
Plot of intensity vs. wavelength
Intensity (relative)
400
450
500
550
600
650
700
Wavelength (nm)

# Why is the Sky Blue?

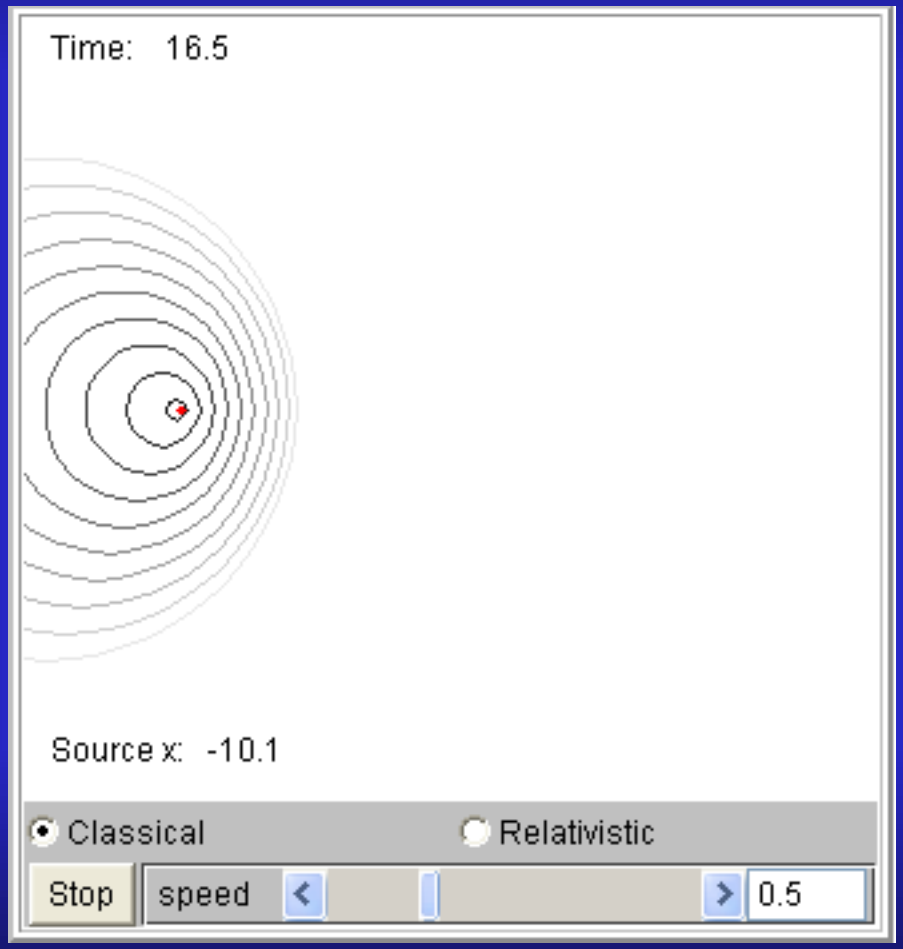

For the same reason that sunsets are red.

# Putting it All Together



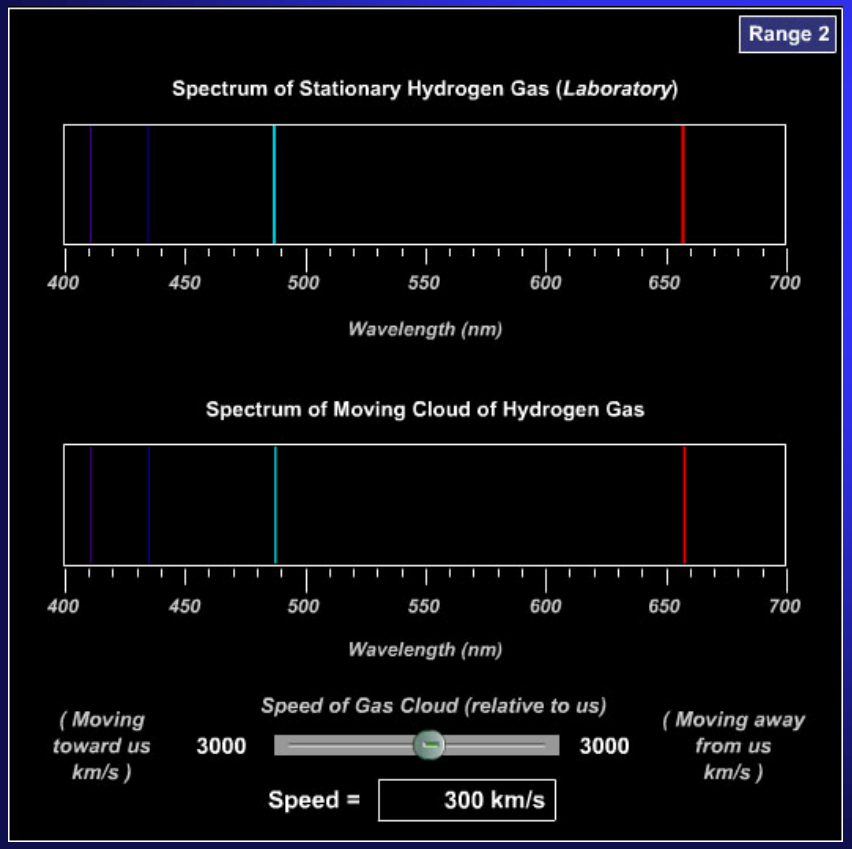

# Spectroscopy!

# Doppler shift



# Measuring Velocity

If we know the REST wavelength of an emission line...




$$\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$$