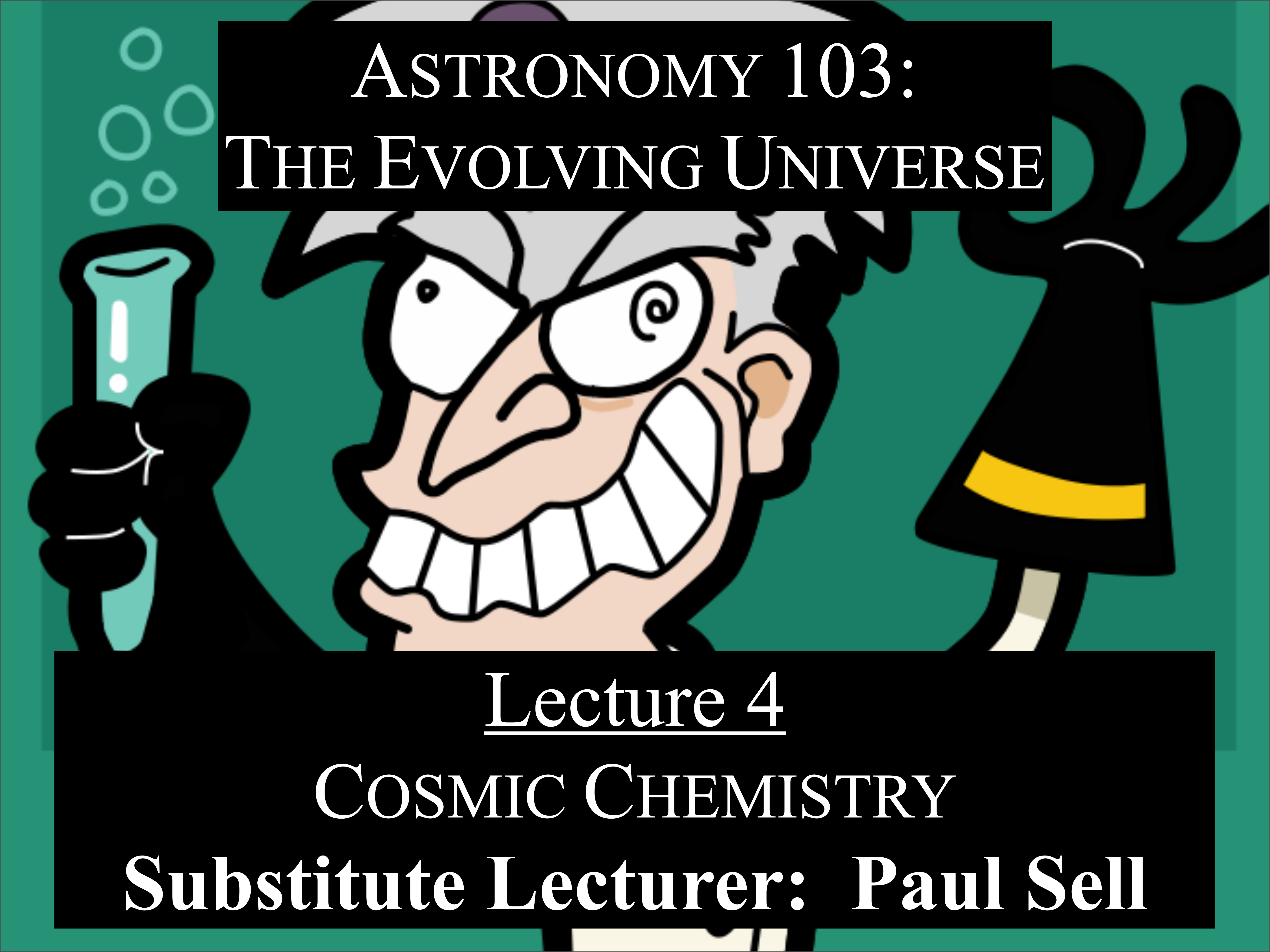


Astronomy 103: The Evolving Universe

Lecture 4

Cosmic Chemistry

Substitute Lecturer: Paul Sell

Two Blackbody Trends

1. Wein's (Veen's) Law

$\lambda_p \propto 1 / T$

or

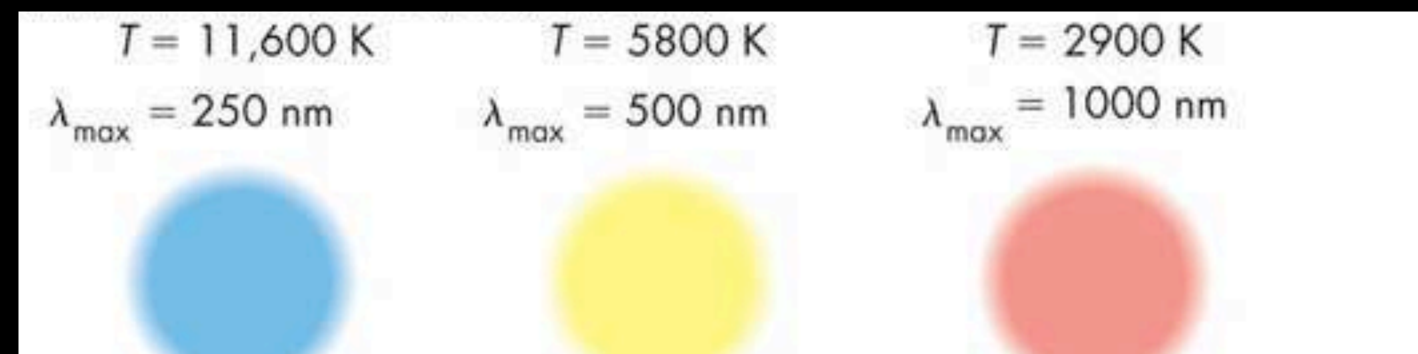
$\lambda_p = 2900 / T$

(λ_p is the "peak wavelength" in micrometers or microns and T is the temperature in Kelvin)

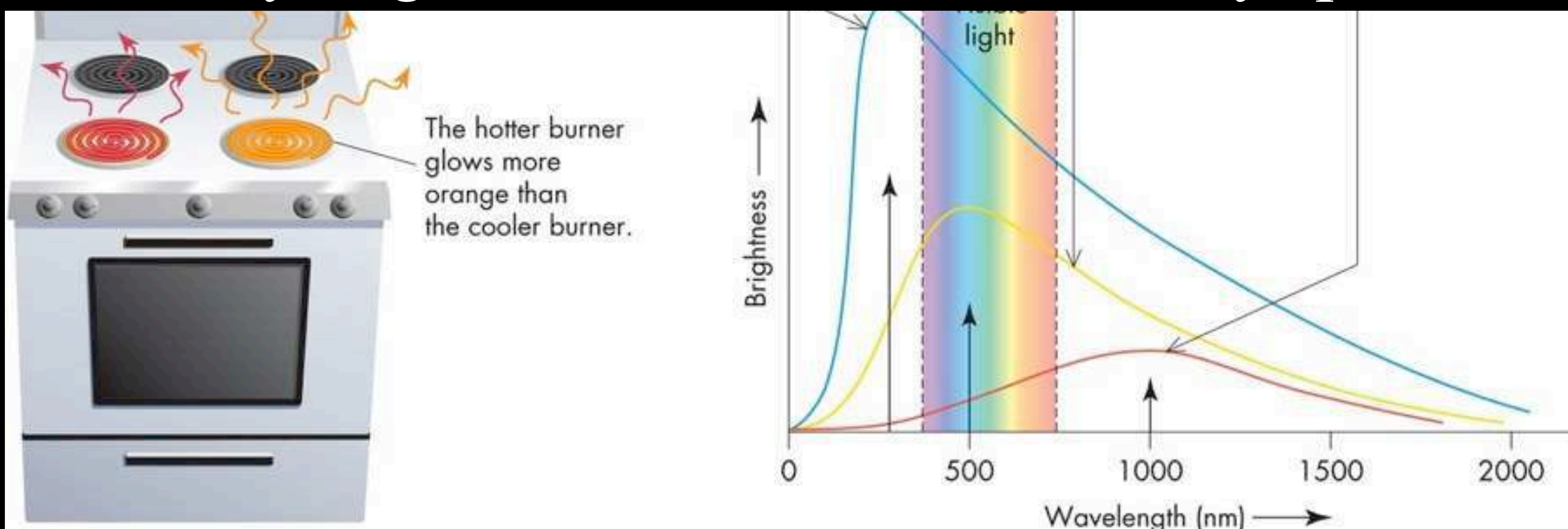
2. Stephan-Boltzman Law

$F_{tot} \propto T^4$ or $F_{tot} = \sigma T^4$

F_{tot} is the "total flux" or the amount of photons emitted per unit area from the surface of the object



How do you get a continuous or blackbody spectrum?



Multiple Choice Question

Q3.1 The sun's surface temperature is around 6000 degrees Kelvin. If it were to suddenly become hotter, where would most of it's radiation be emitted?

a) in the optical, ultraviolet, x-ray or gamma ray region, depending on the temperature change

b) in the optical

c) in the optical, infrared, microwave or radio region, depending on the temperature change

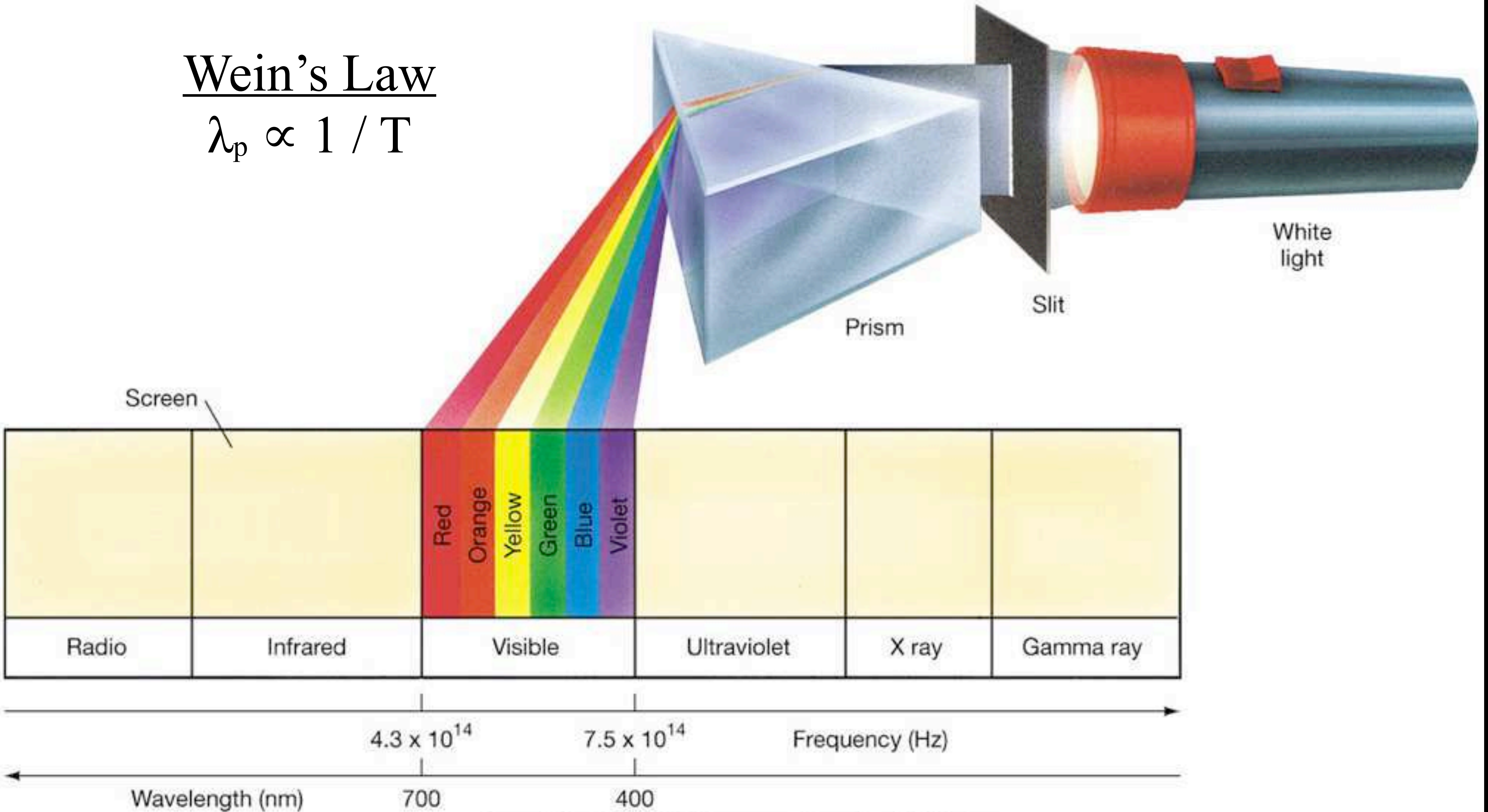
d) uniformly at all wavelengths

e) in the infrared where it is hottest

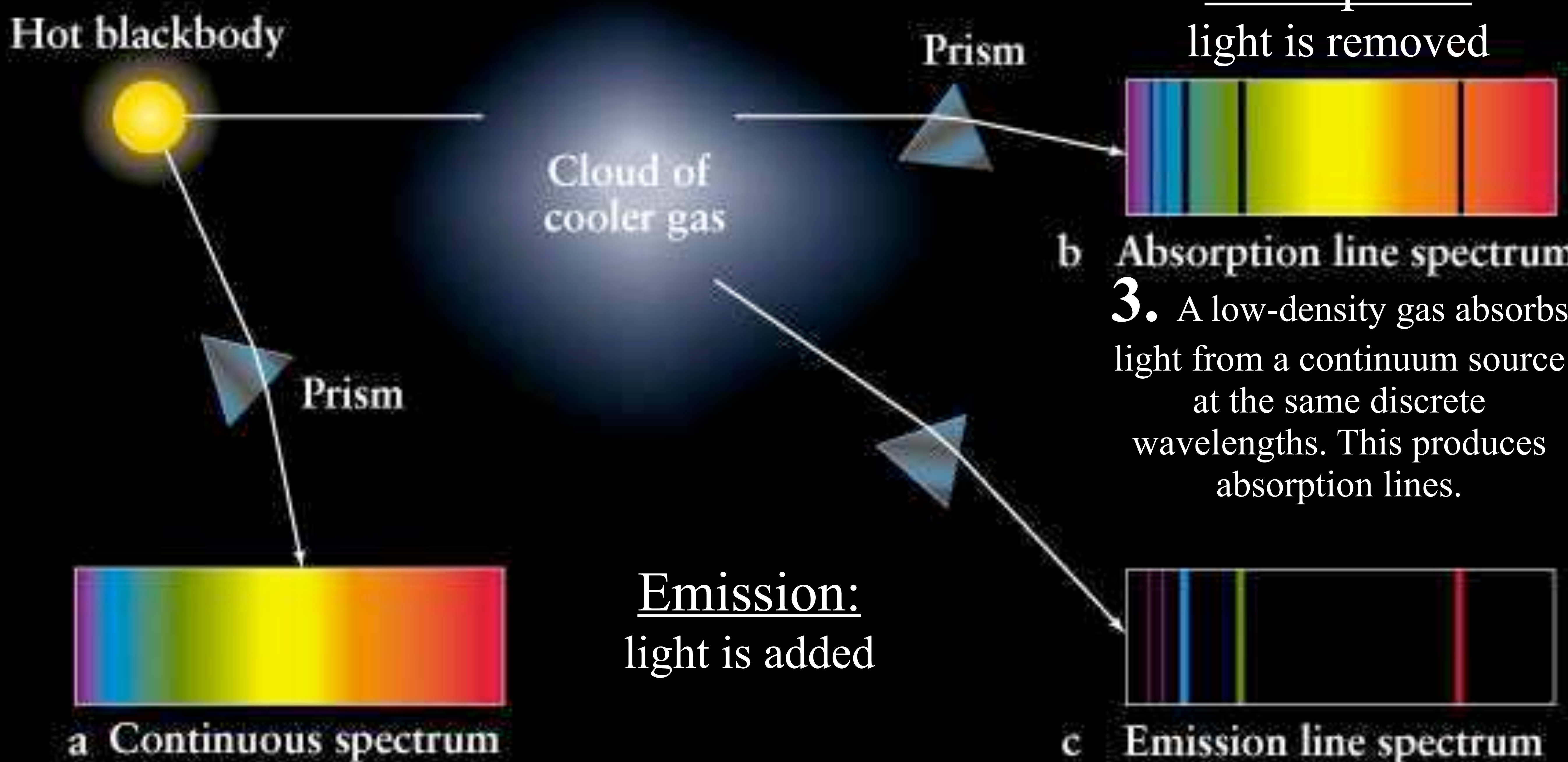
Multiple Choice Question

Wein's Law

$\lambda_p \propto 1 / T$



Kirchoff’s Laws



Absorption:
light is removed

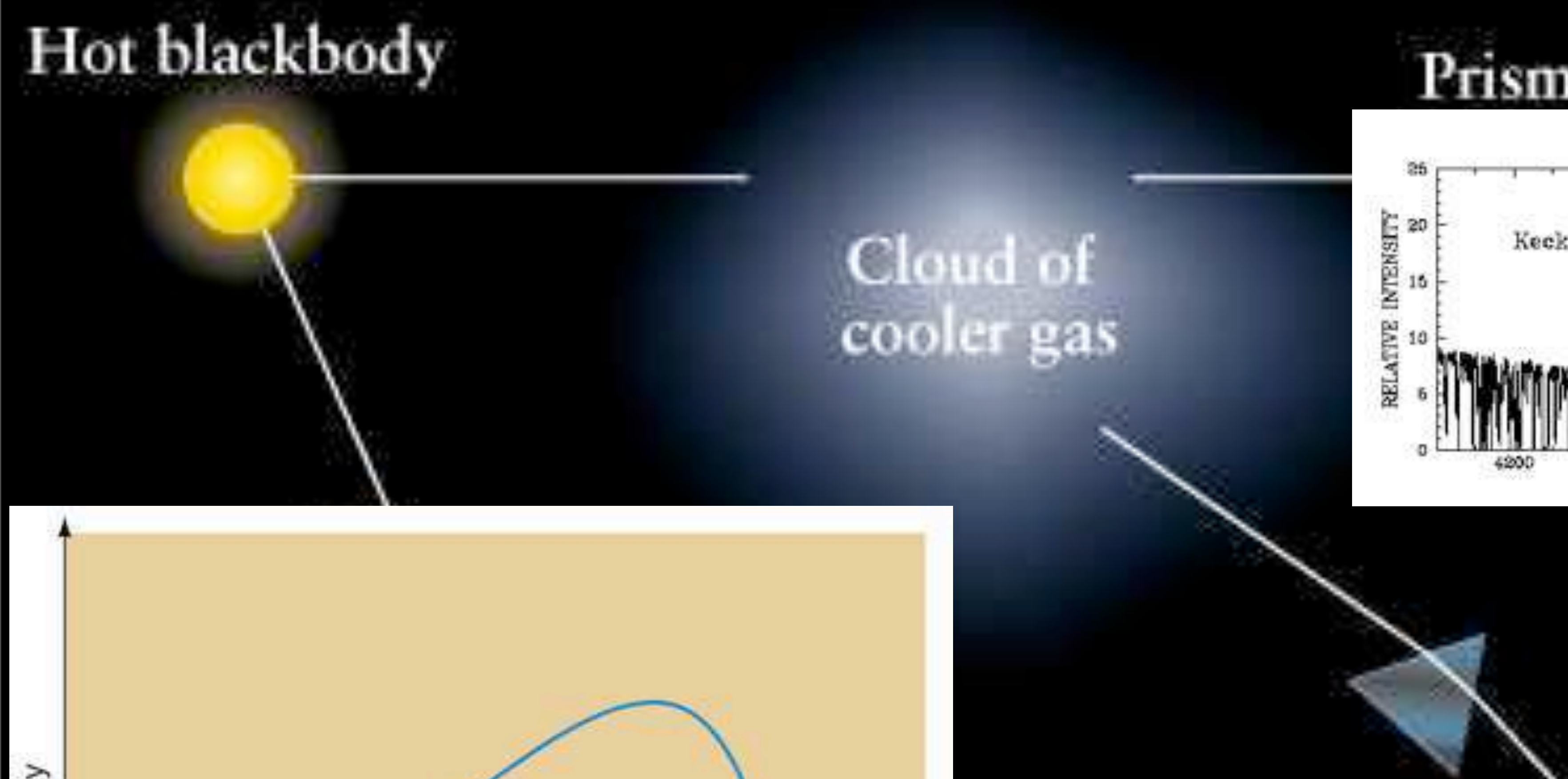
3. A low-density gas absorbs light from a continuum source at the same discrete wavelengths. This produces absorption lines.

Emission:
light is added

1. A luminous solid or liquid (or dense gas) emits light at all wavelengths. This produces a continuous spectrum of radiation.

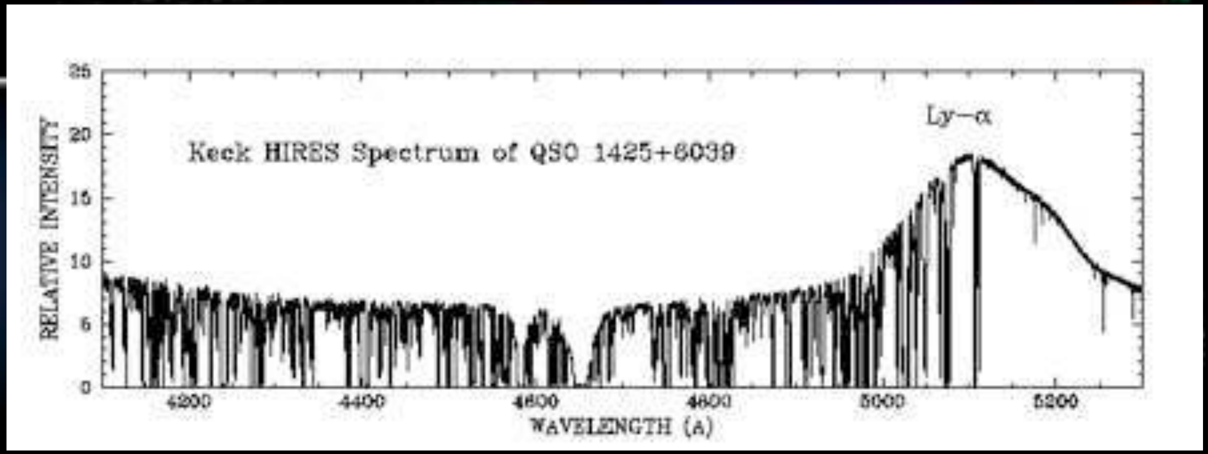
2. A low-density gas emits light at discrete wavelengths (or frequencies) that are called emission lines.

Kirchoff's Laws

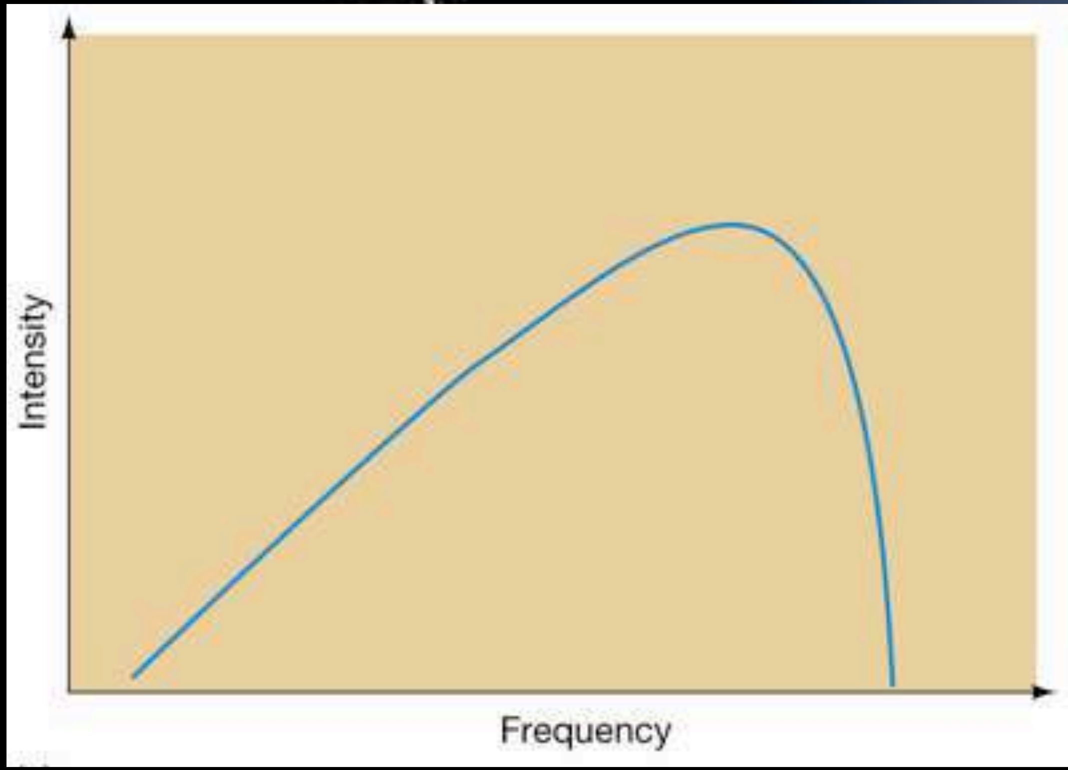


Absorption:

light is removed

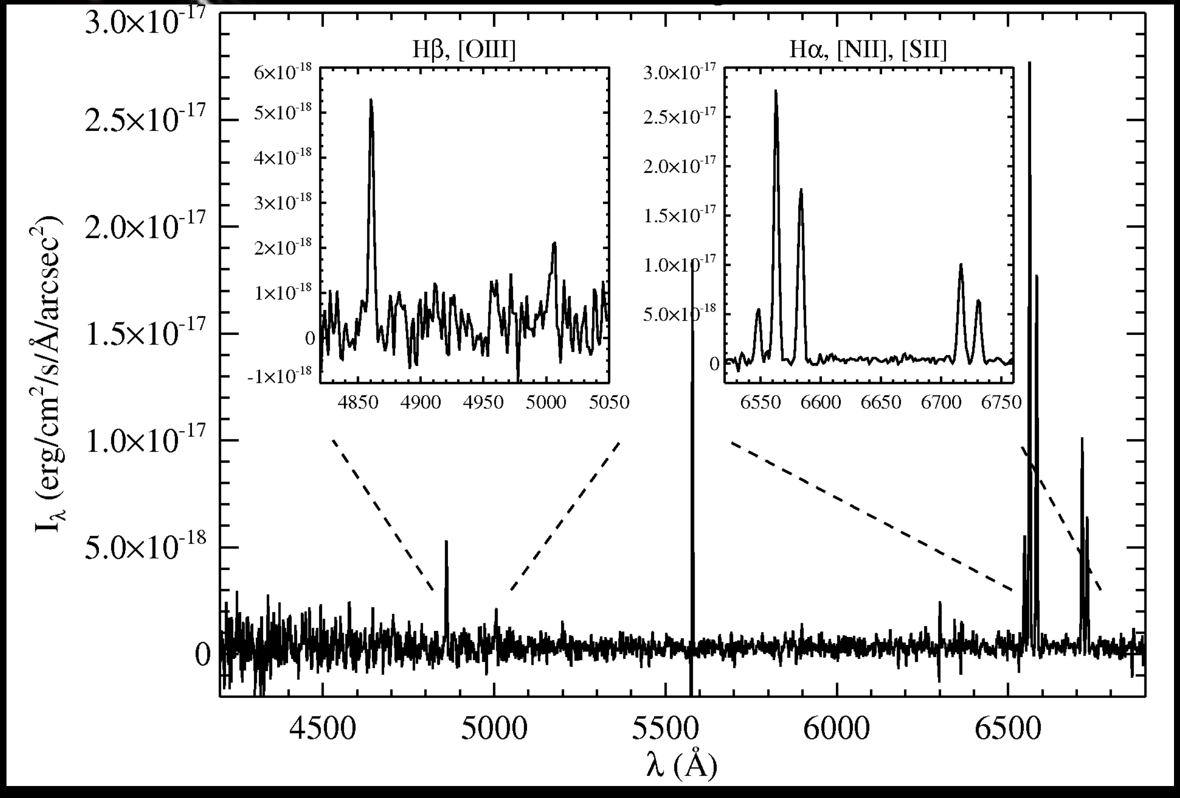


light from a continuum source at the same discrete wavelengths. This produces absorption lines.



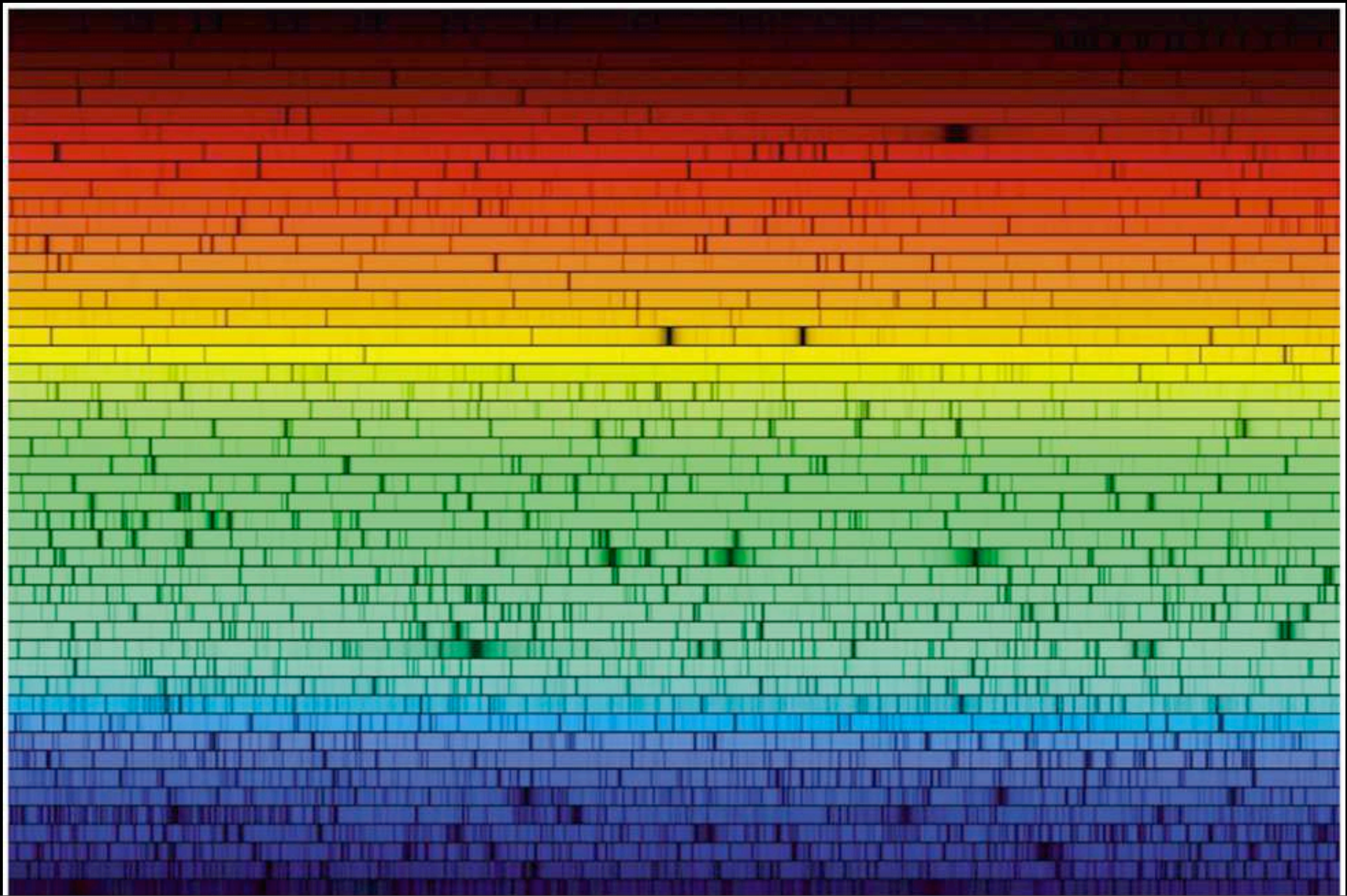
Emission:

light is added

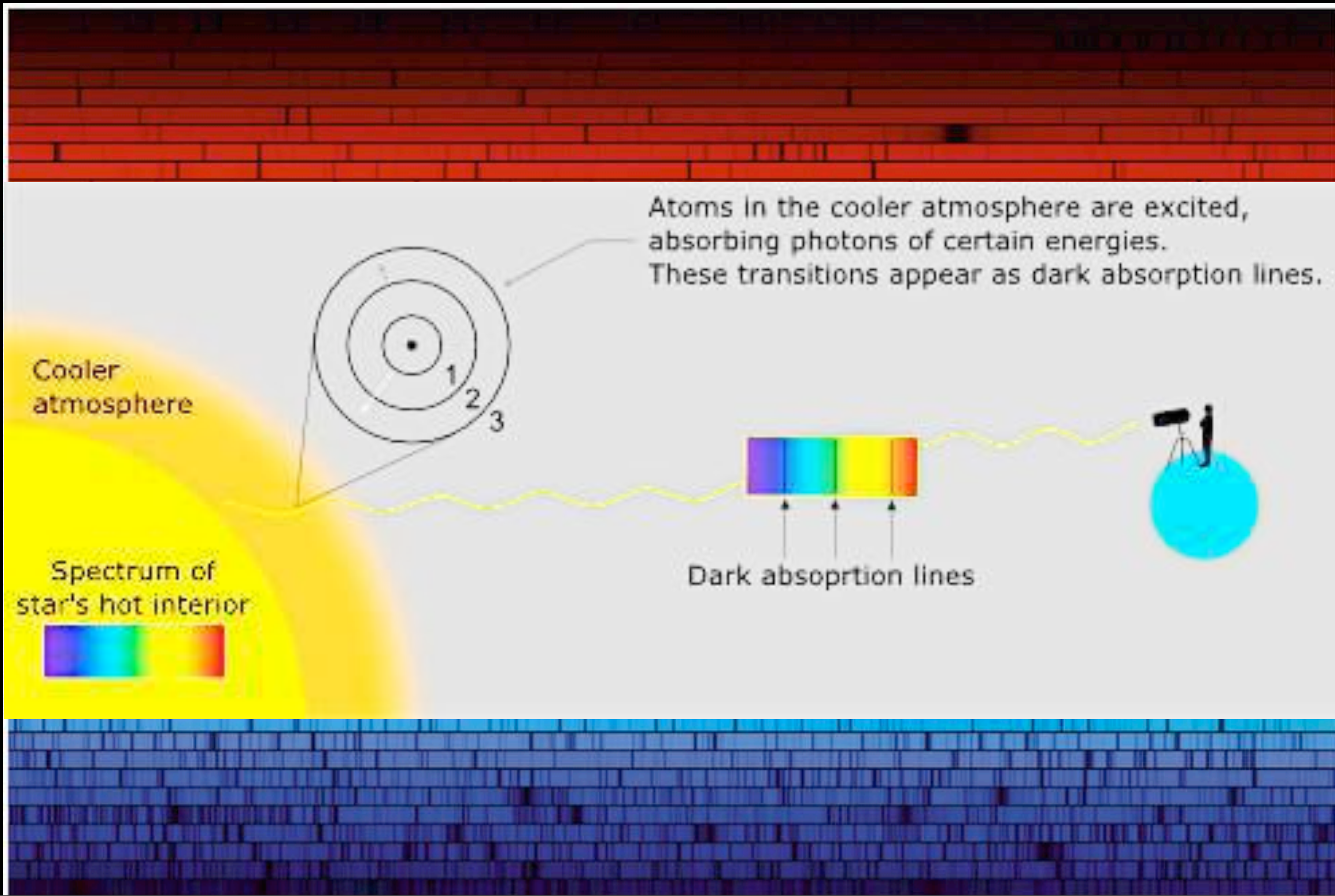


1. A luminous solid or liquid (or dense gas) emits light at all wavelengths. This produces a continuous spectrum of radiation.

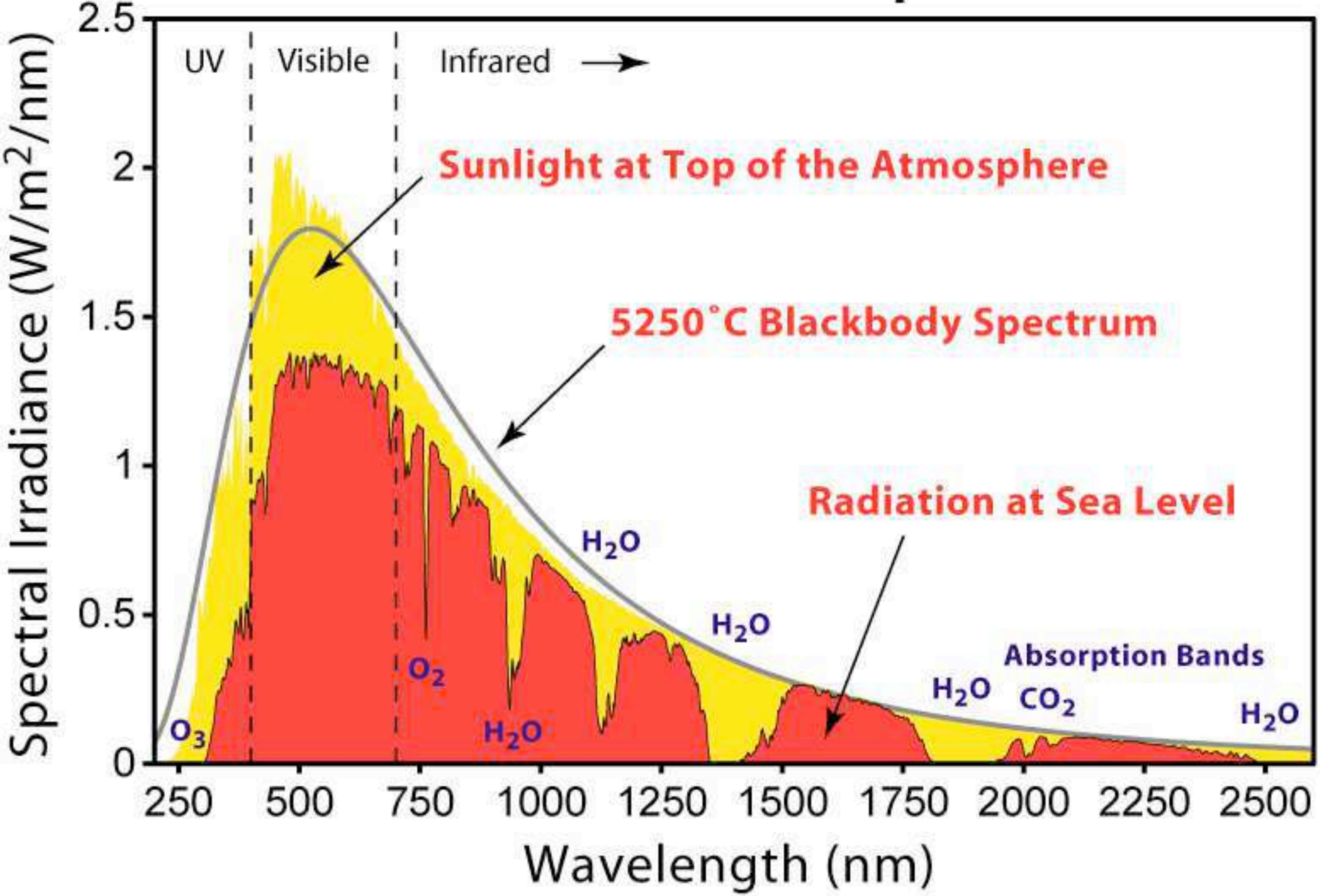
No Star is a Perfect Blackbody
Example: Fraunhofer Lines in the Solar Spectrum



No Star is a Perfect Blackbody
Example: Fraunhofer Lines in the Solar Spectrum



Solar Radiation Spectrum



Multiple Choice Question

Imagine you are sitting in a giant cloud of tenuous gas in outer space. The gas is so tenuous, you can see stars through it, but you can tell that they are a little bit dimmer than they would be if you weren't in the cloud. Suppose the stars are perfect blackbody emitters. If you took a spectrum of any of these stars from inside the cloud, what would you see?

a) a blackbody or Planck spectrum

b) emission lines only

c) absorption lines only

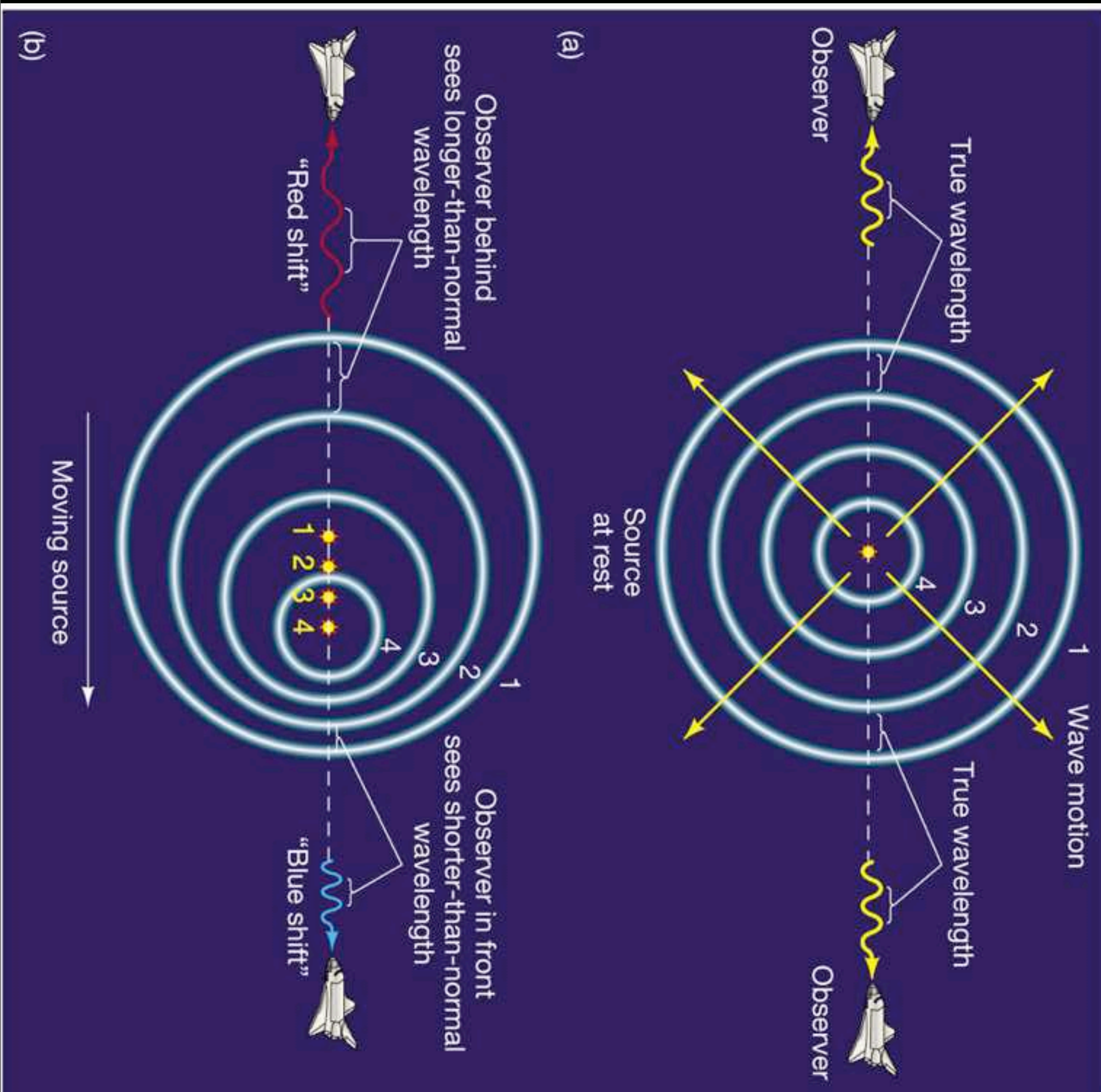
d) a blackbody spectrum with absorption lines superimposed

e) a blackbody spectrum with emission lines superimposed

Doppler Shift

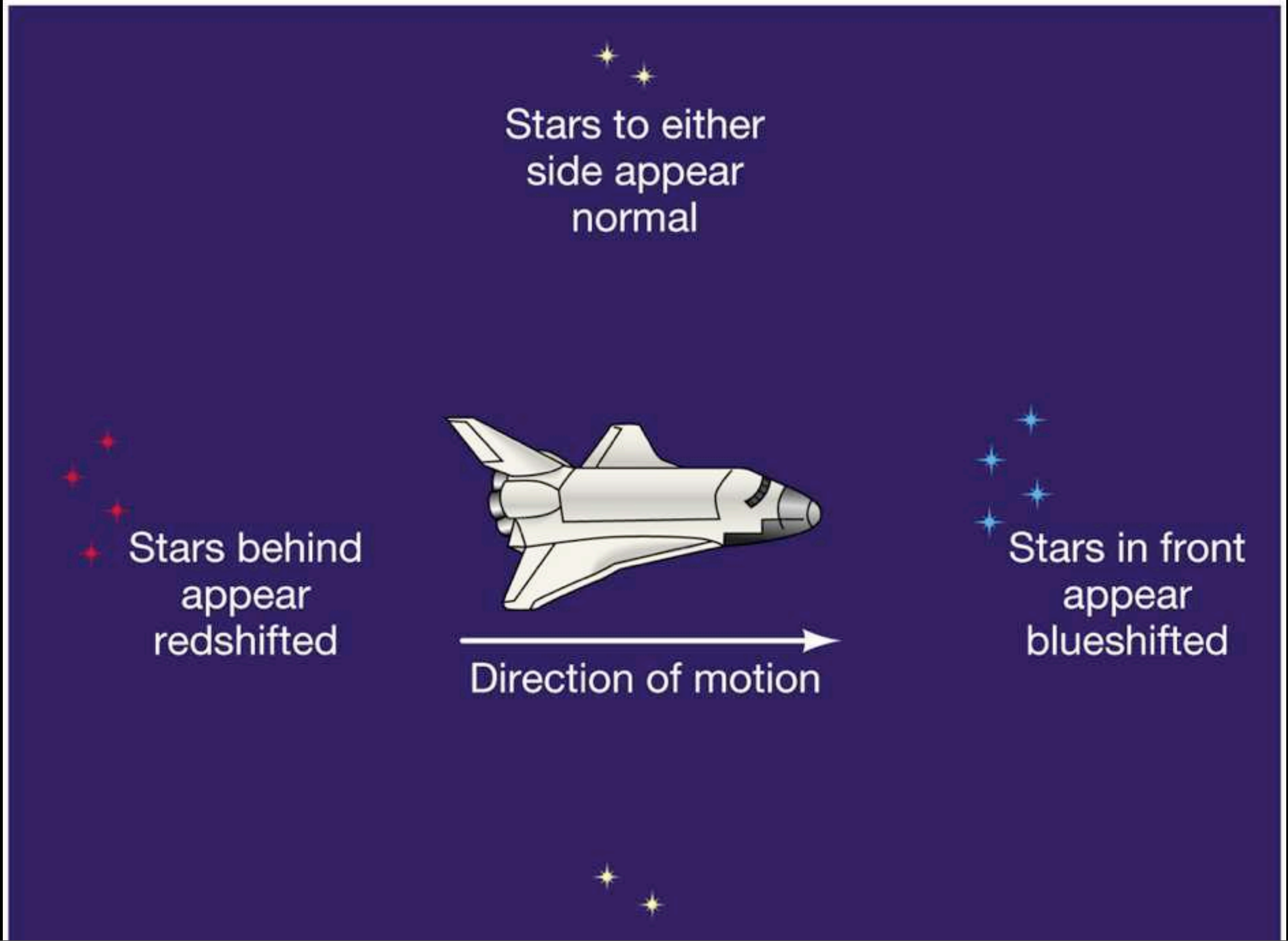
Example: The Pitch of a Train's Horn

Doppler

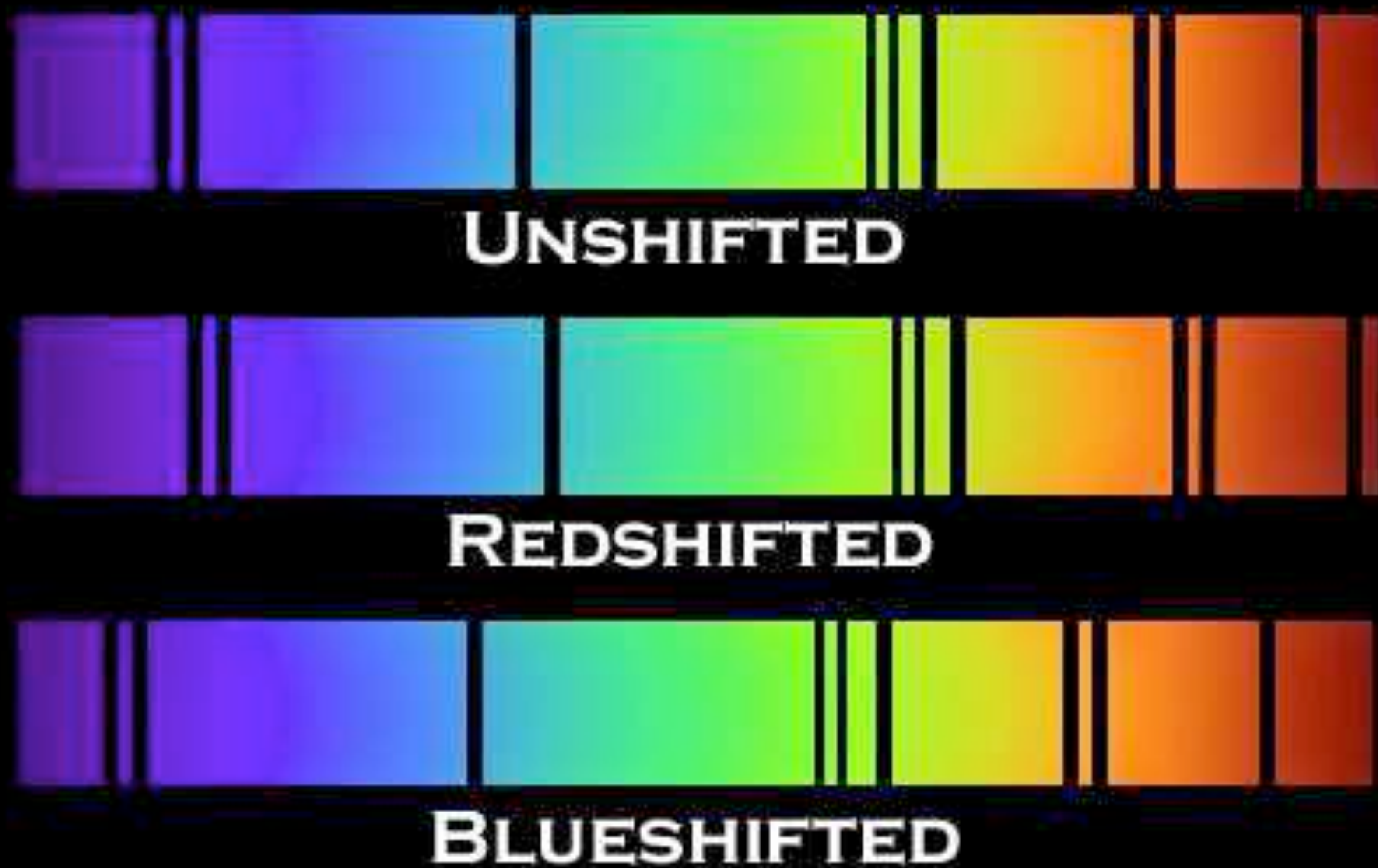


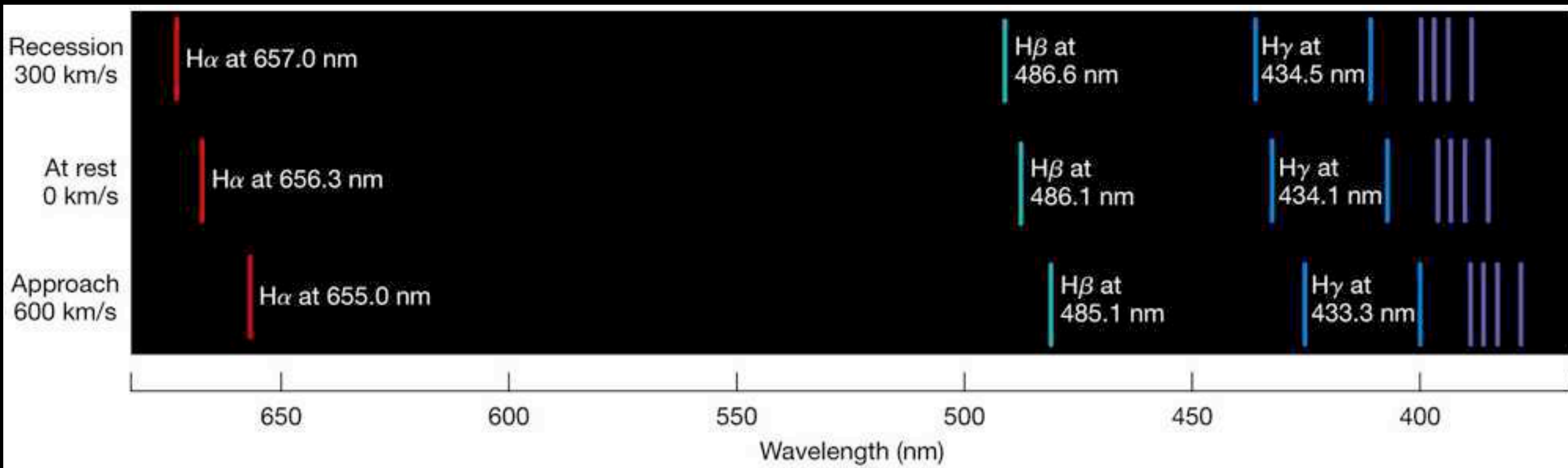
Shift

Doppler Shift (relative motion)

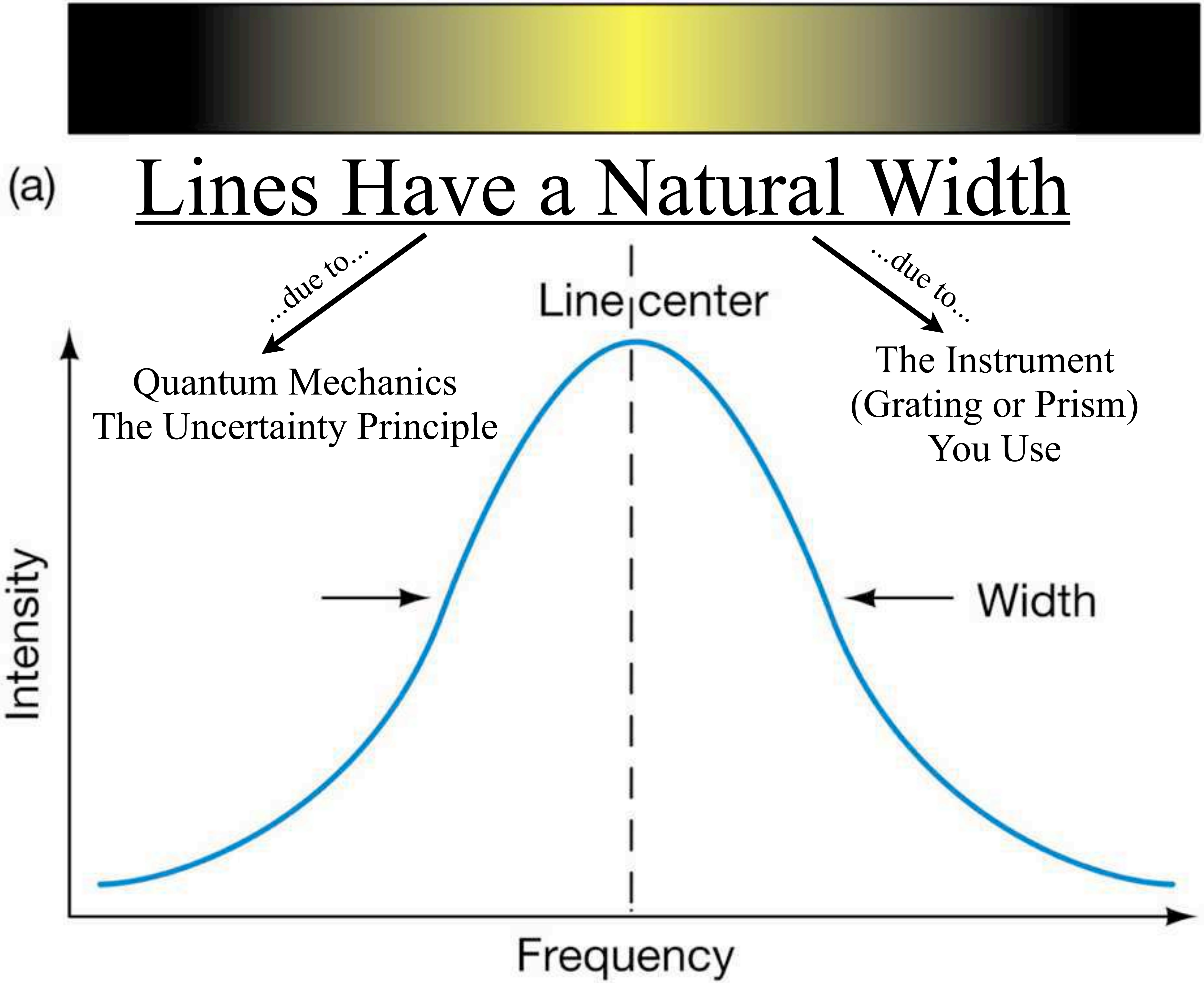


Doppler Shift of Spectral Lines





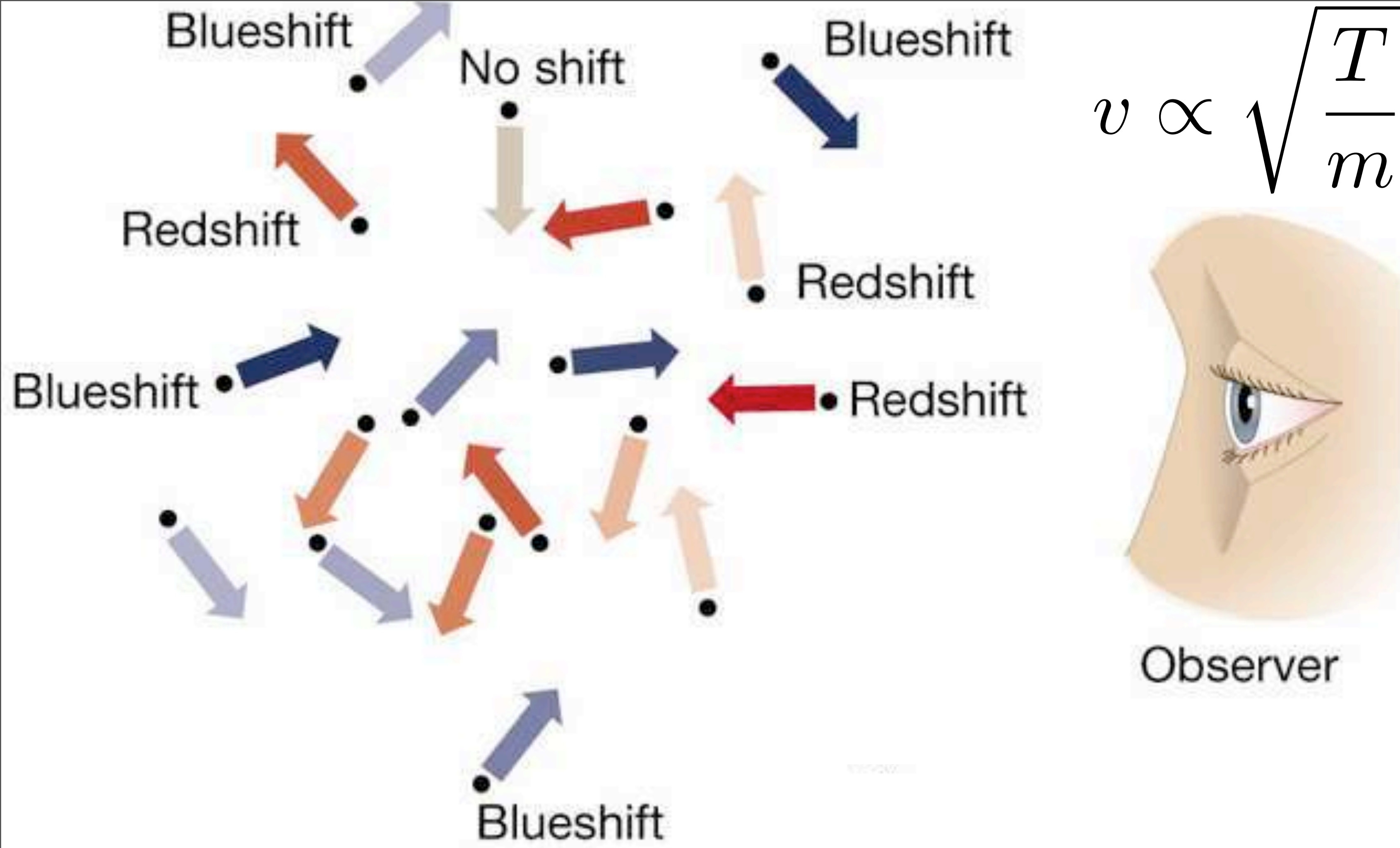
Lines Have a Natural Width



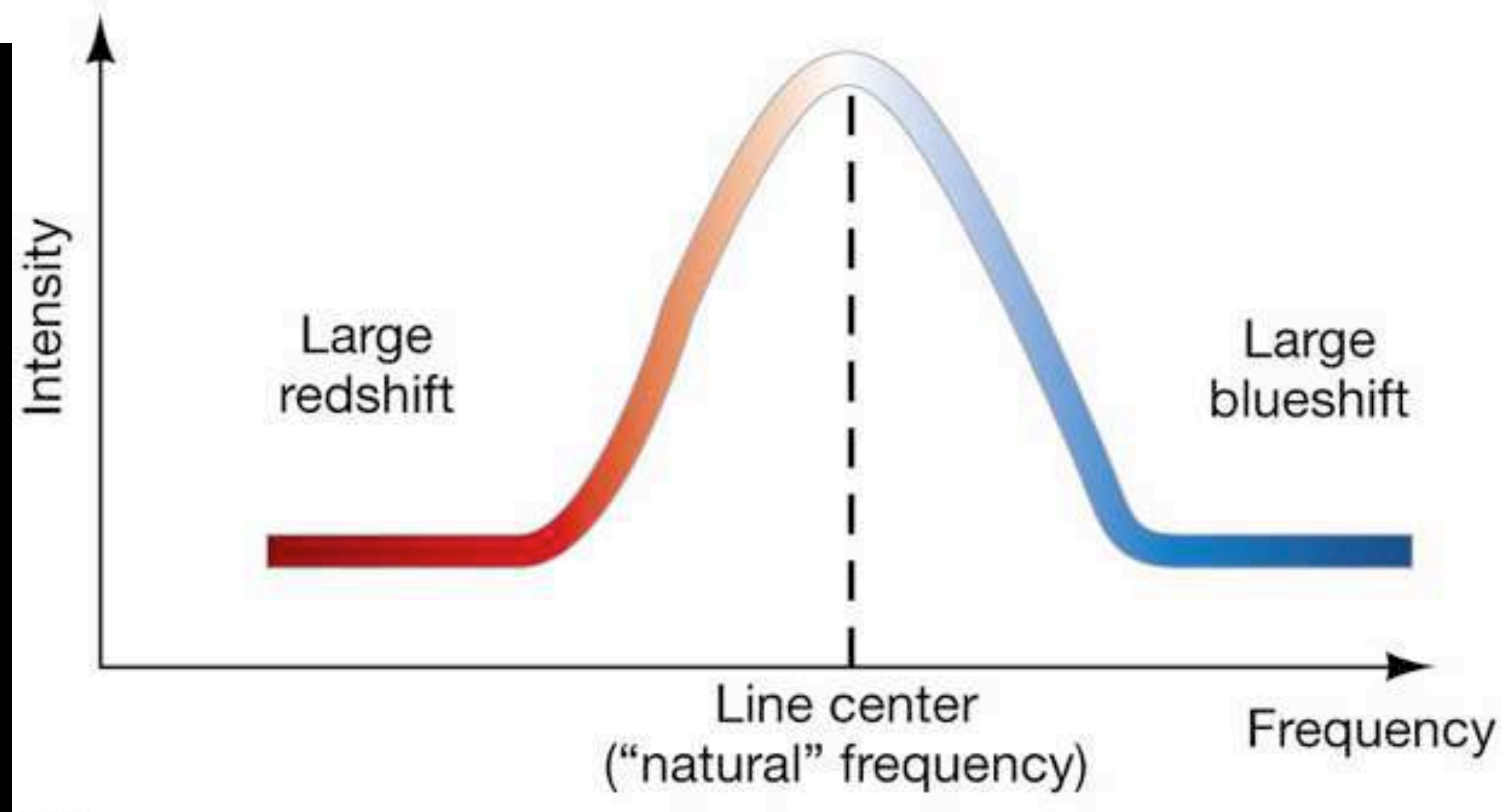
Doppler Broadening

$$v \propto \sqrt{\frac{T}{m}}$$

This why there is essentially no free hydrogen and helium in our atmosphere



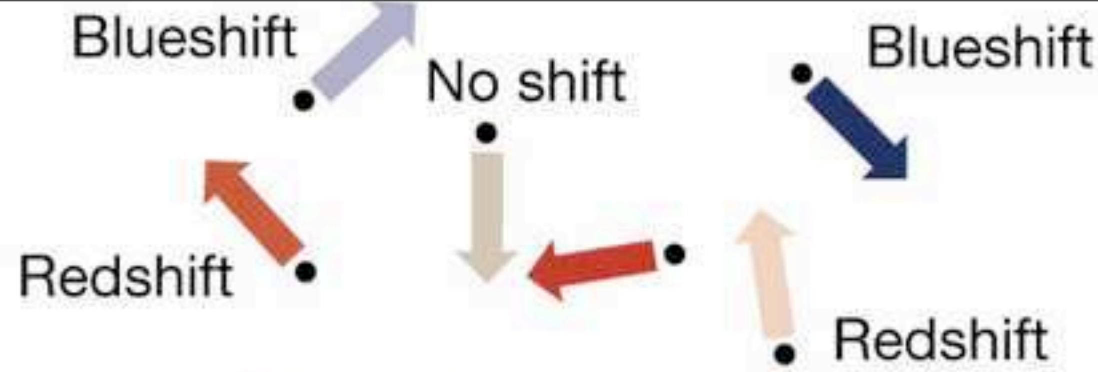
(a)

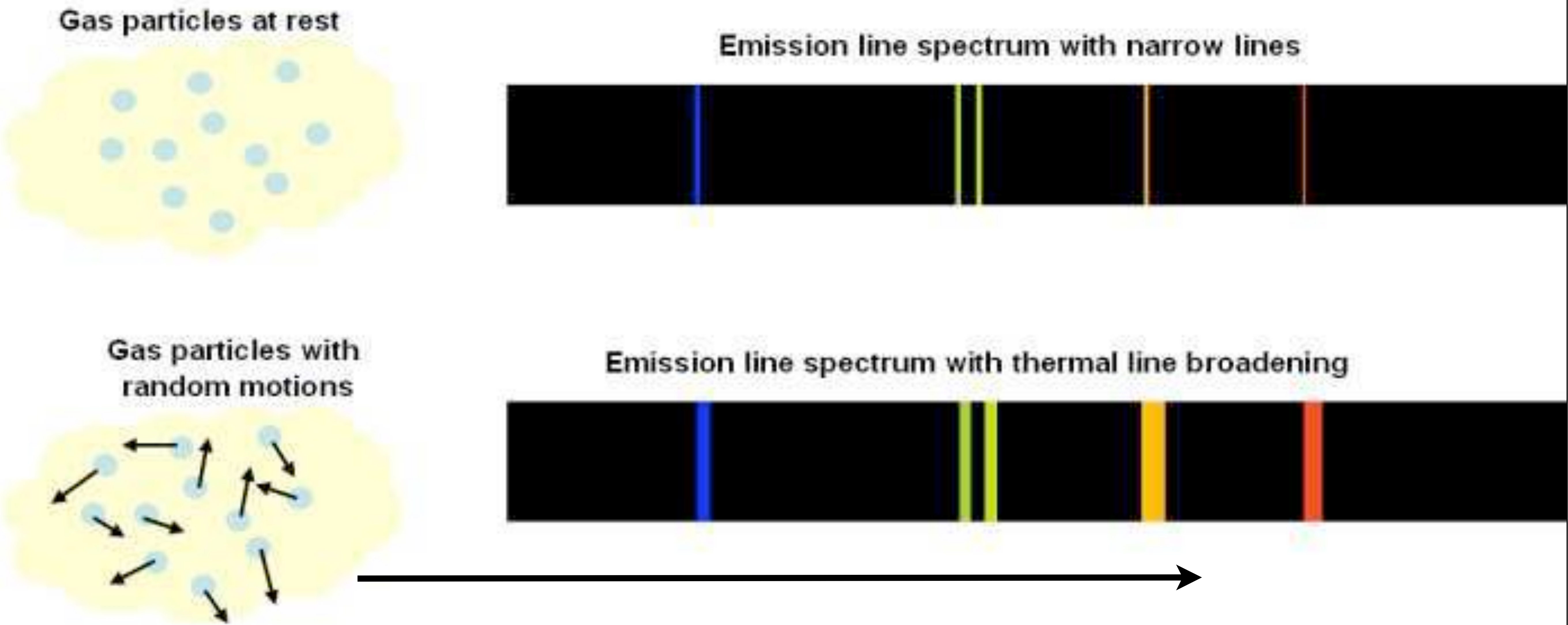


(b)

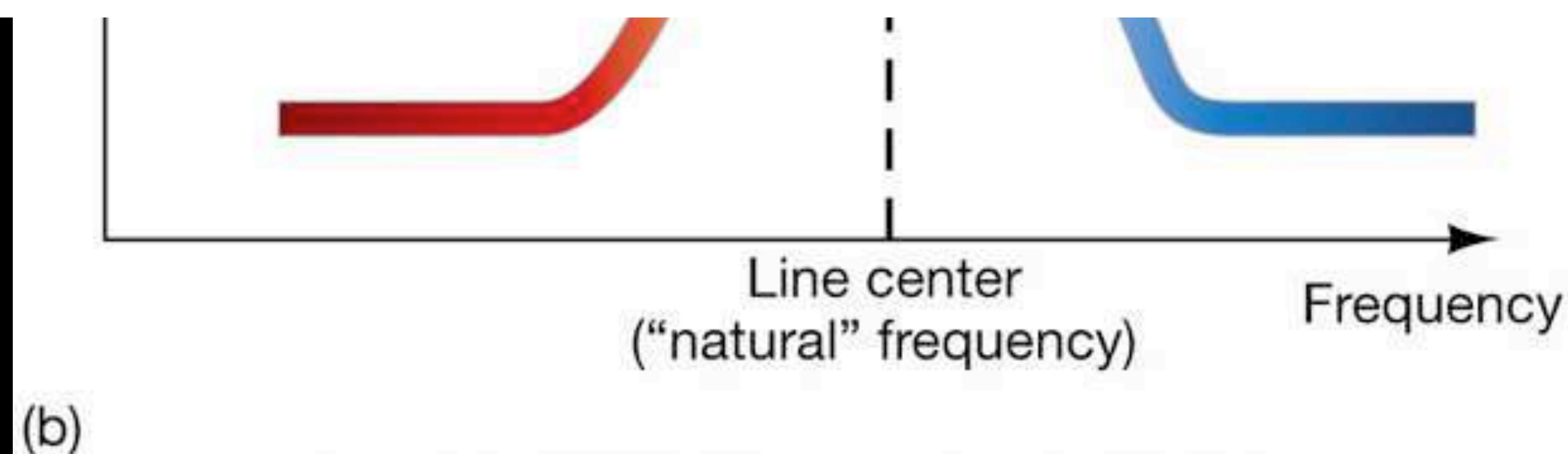
Doppler Broadening

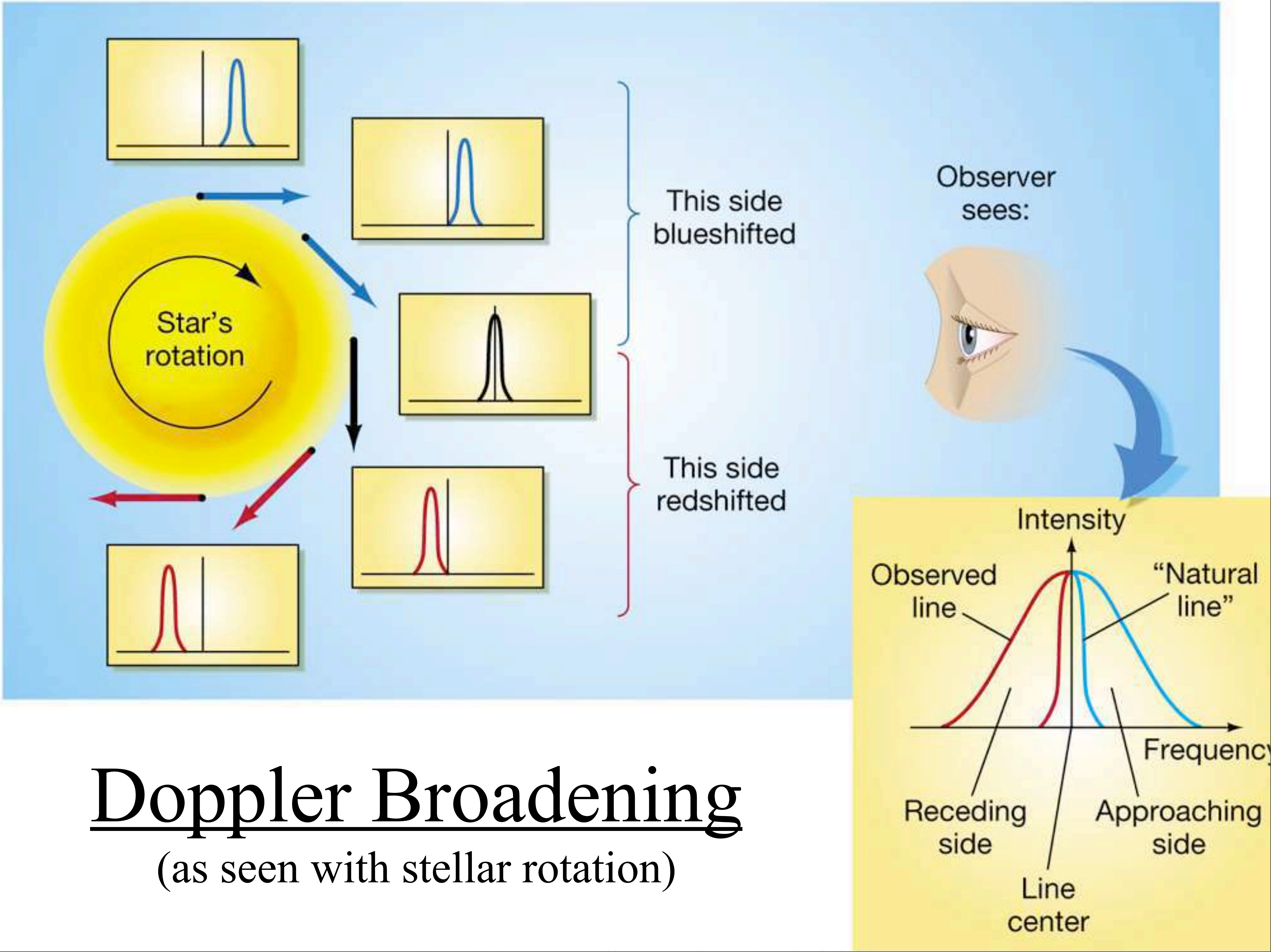
$$v \propto \sqrt{\frac{T}{m}}$$





Doppler Broadening + Doppler Shifting is Allowed



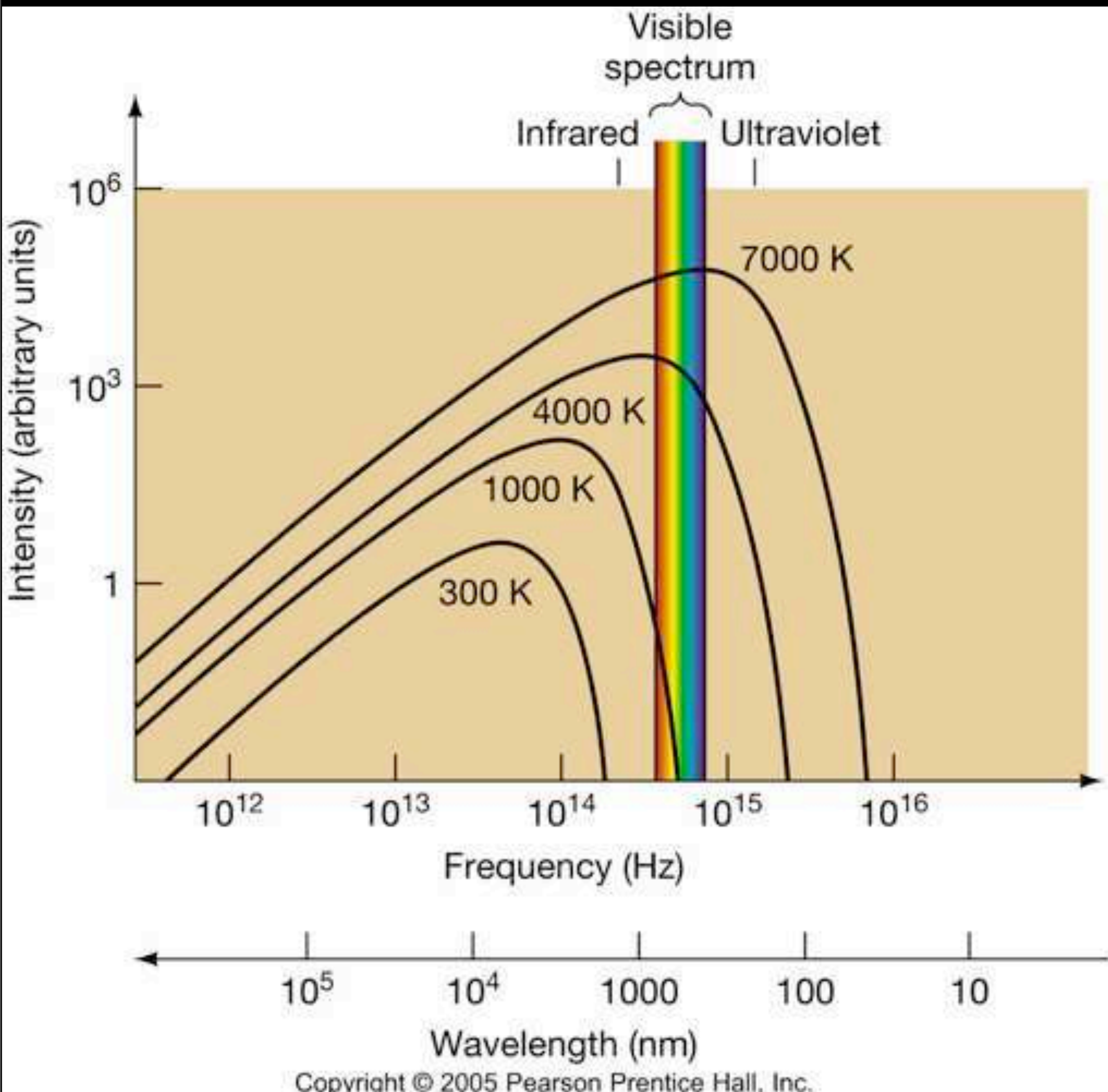


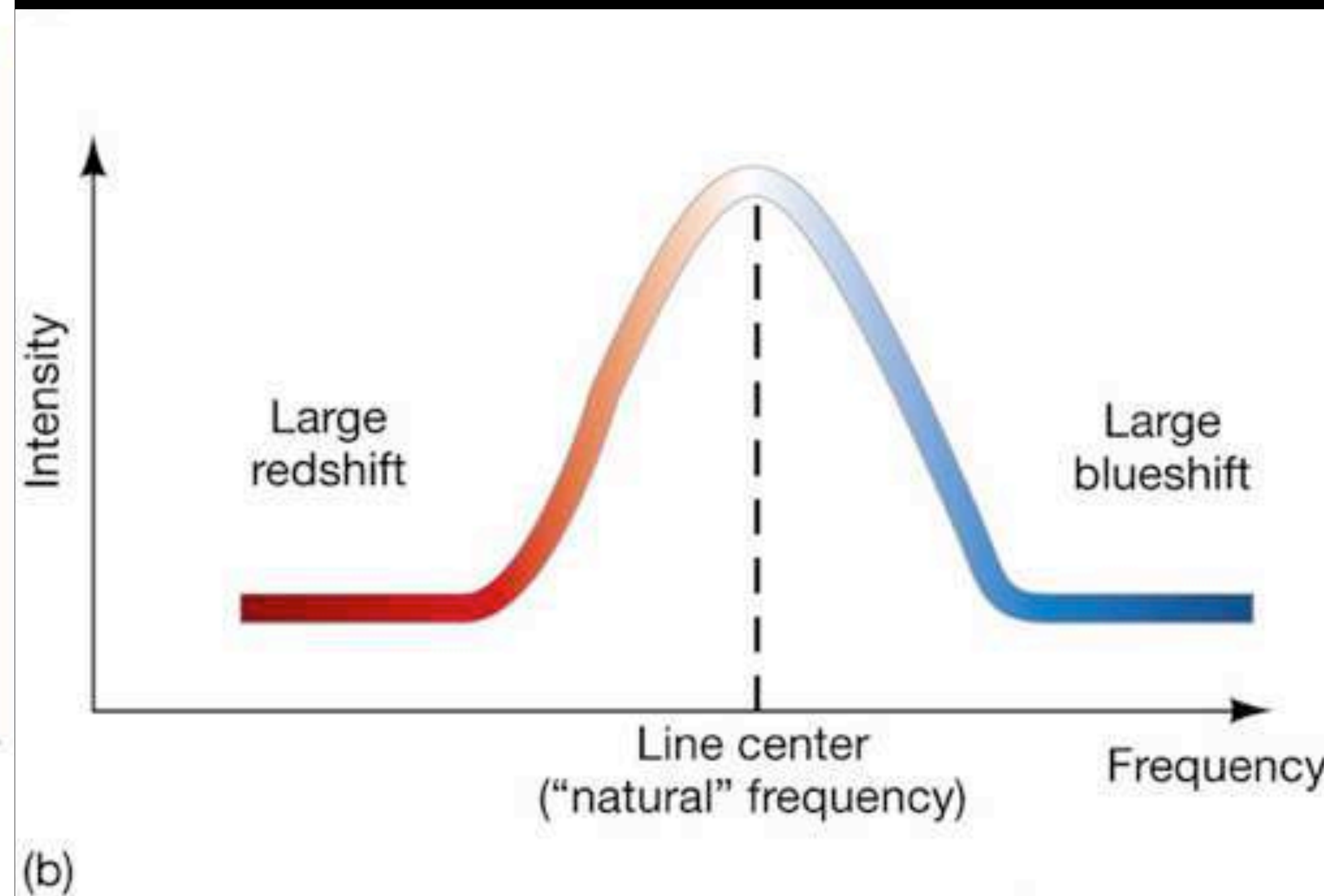
Doppler Broadening

(as seen with stellar rotation)

Why Are Spectra Important?

Temperature



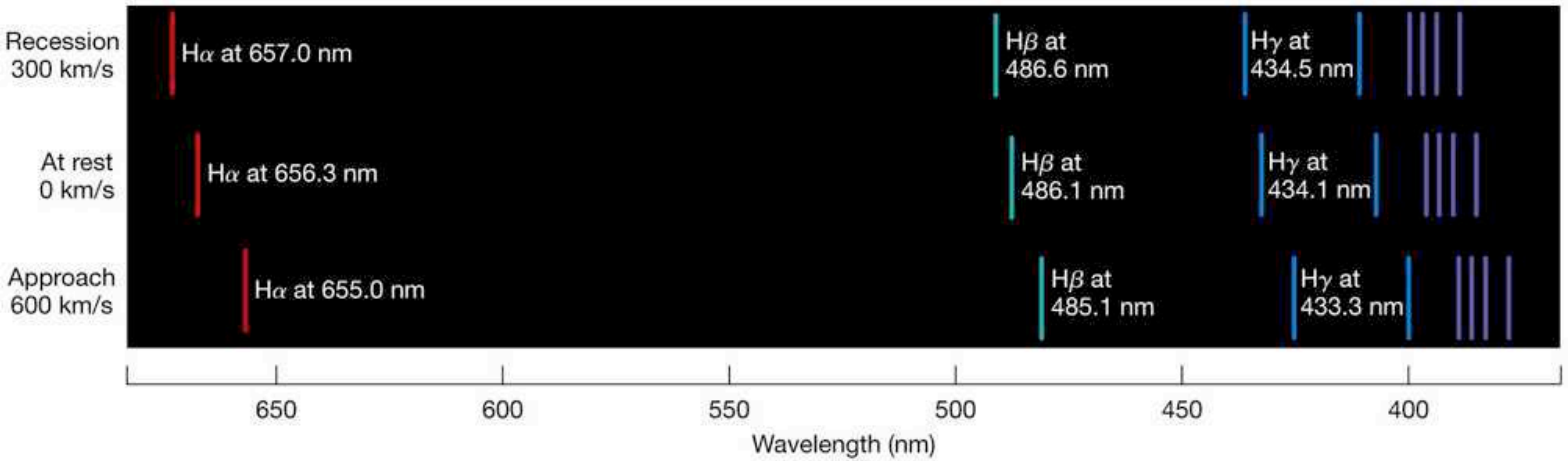


Continuous Spectrum: Peak and Flux of Blackbody

Discrete Line: Width (Doppler Broadening)

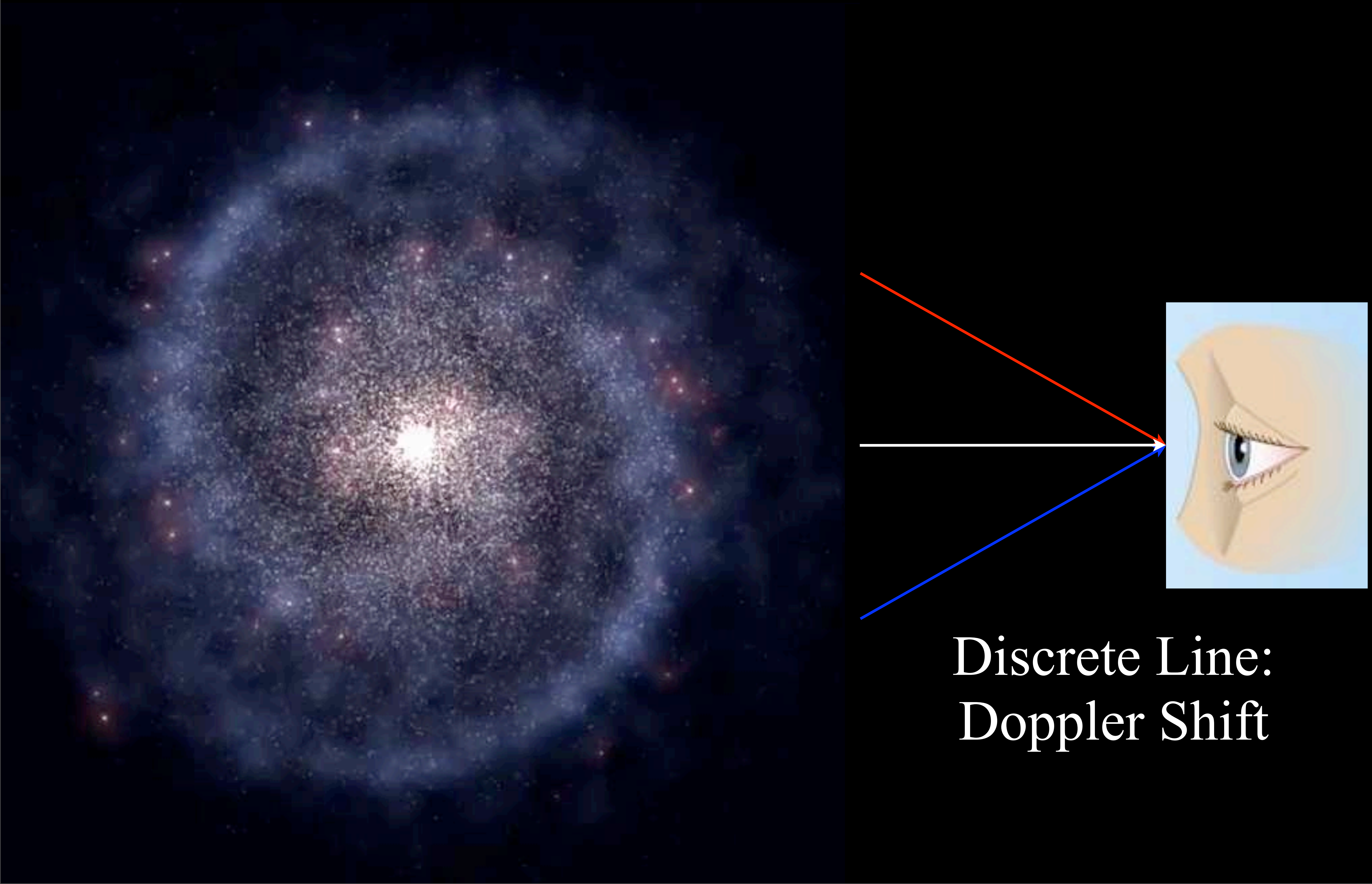
Why Are Spectra Important?

Velocity/Geometry



Why Are Spectra Important?

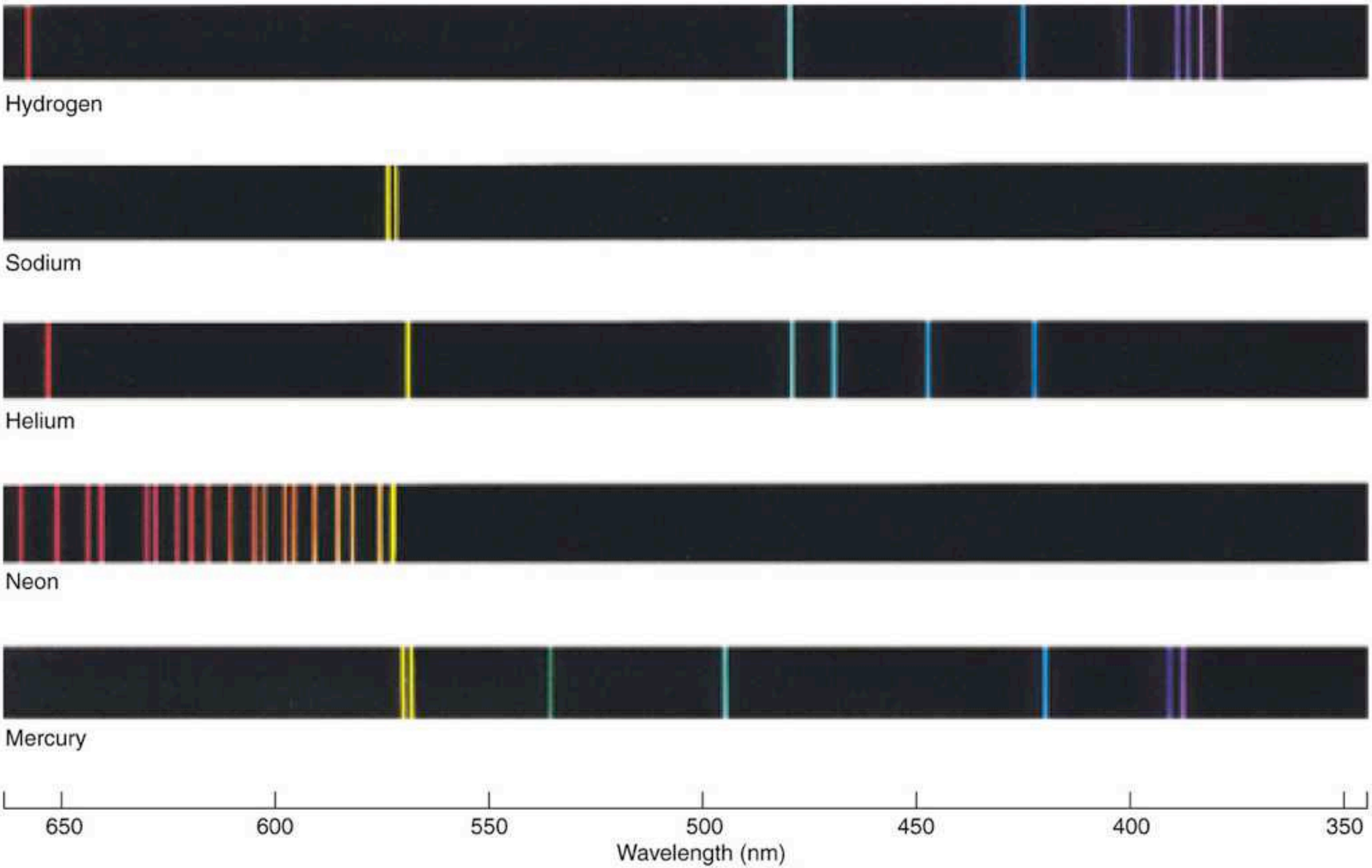
Velocity/Geometry



Discrete Line:
Doppler Shift

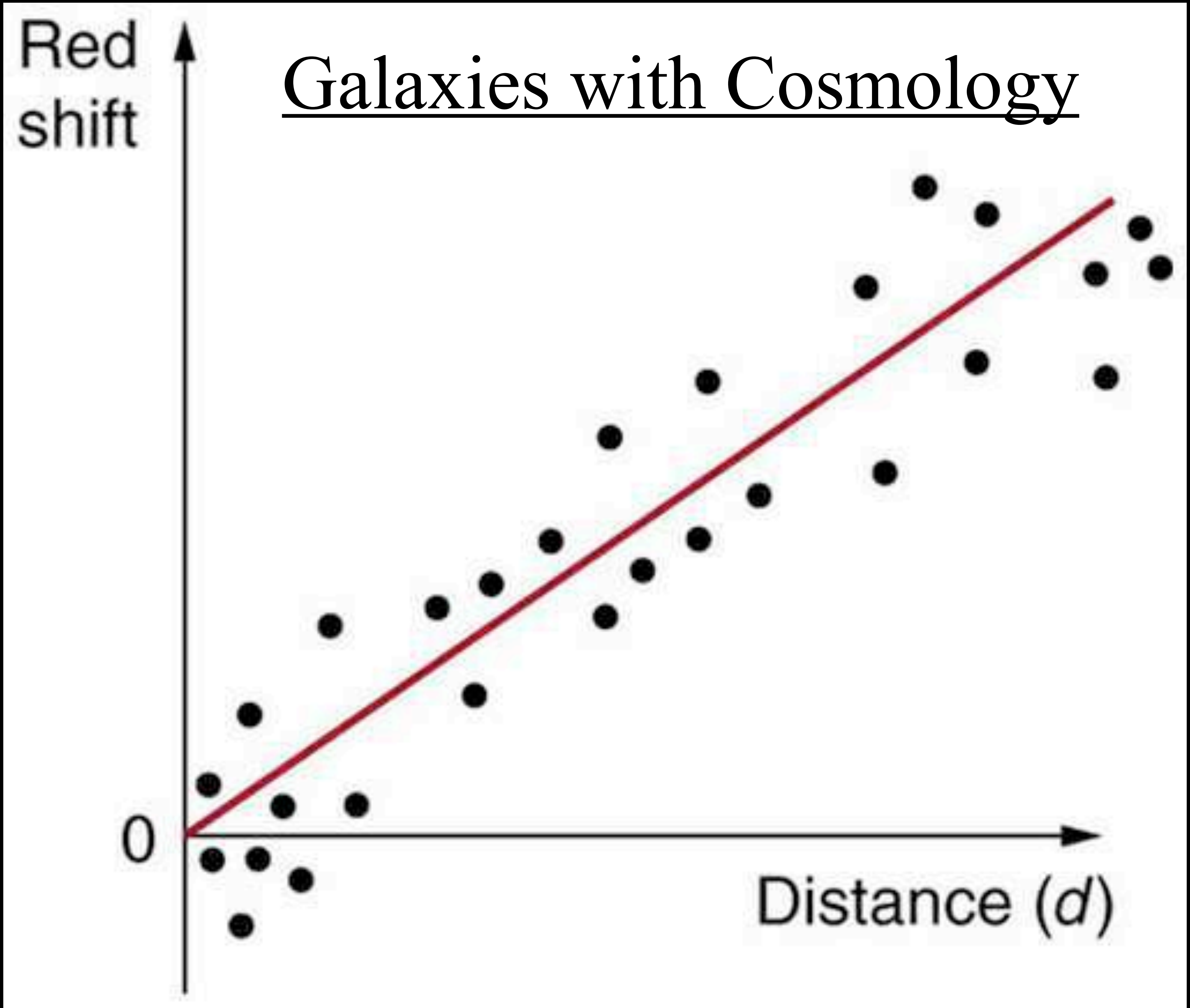
Why Are Spectra Important?

Composition (the element's fingerprint)



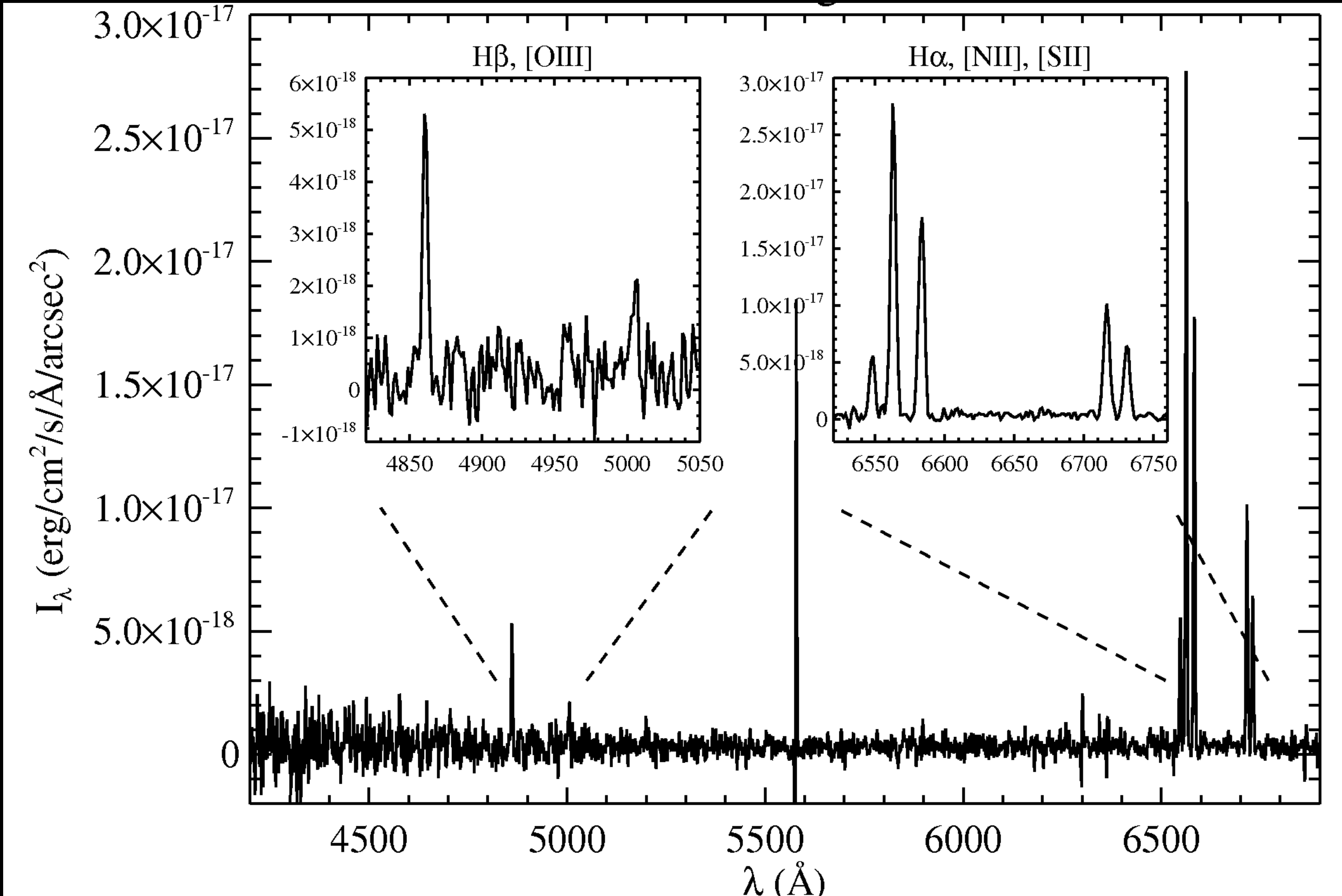
Why Are Spectra Important?

Distance



Why Are Spectra Important?

Temperature and Density

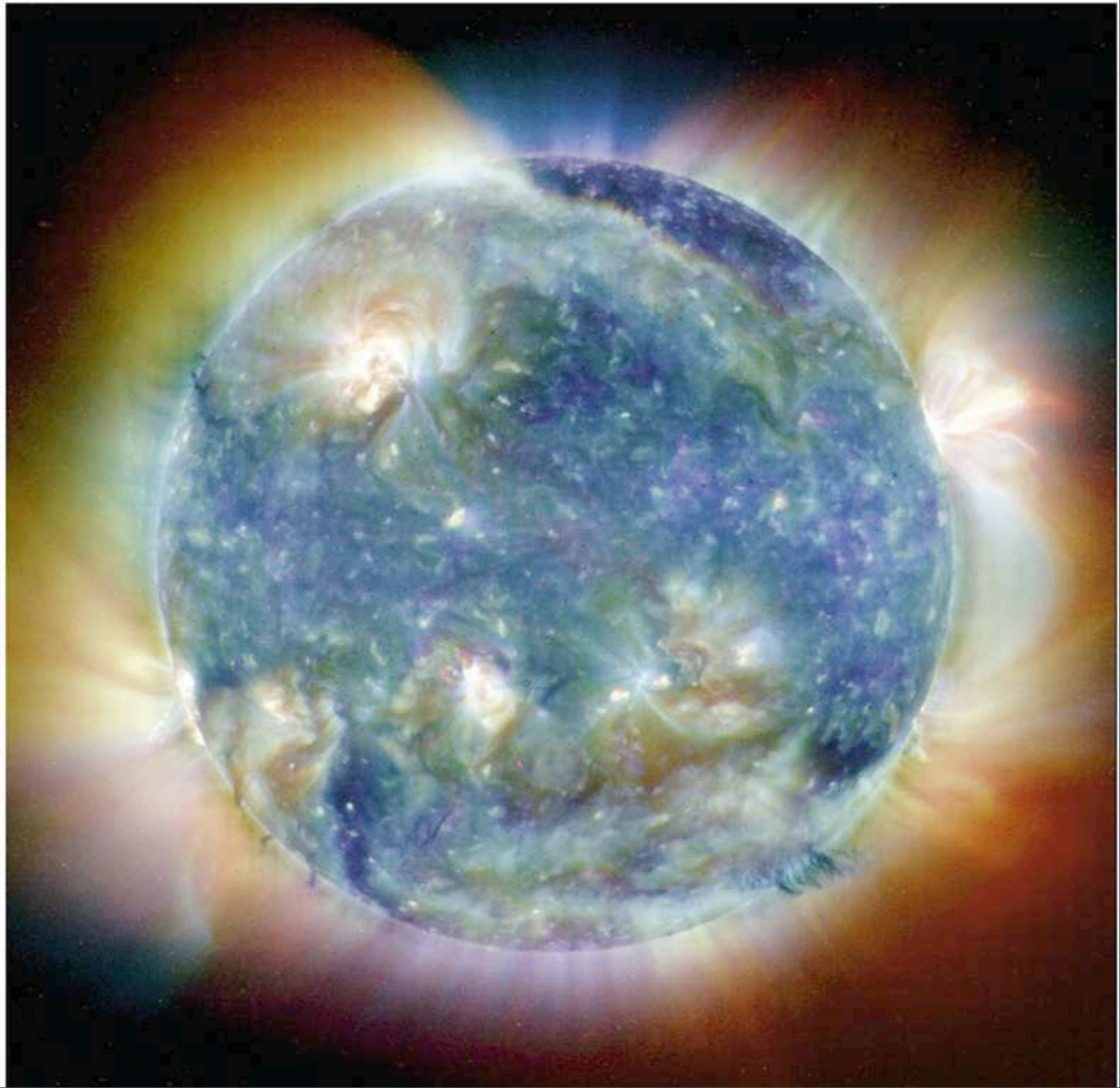


Why Are Observing at Different Wavelengths Important?

The Sun (optical)

Why Are Observing at Different Wavelengths Important?

The Sun (UV/X-ray)



Multiple Choice Question

You go through a red light and are stopped by a police officer. To get out of being given a ticket you argue: ``As I approached the light, officer, it appeared to be green!" It works. Whom of the following should you thank:

a) Kirchhoff (types of spectra)

b) Wien (blackbody tail and peak shift)

c) Stefan (flux)

d) Doppler (shift and broadening)

e) Planck (blackbody, quantum theory)

Doppler Formula

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

Relativistic Doppler Formula

$$\frac{\lambda}{\lambda_0} = \sqrt{\frac{1+v/c}{1-v/c}}$$

NB: Don't try this! It implies you were traveling at 0.3c -- 30% of the speed of light. You will get a very large speeding ticket. Get new brakes.