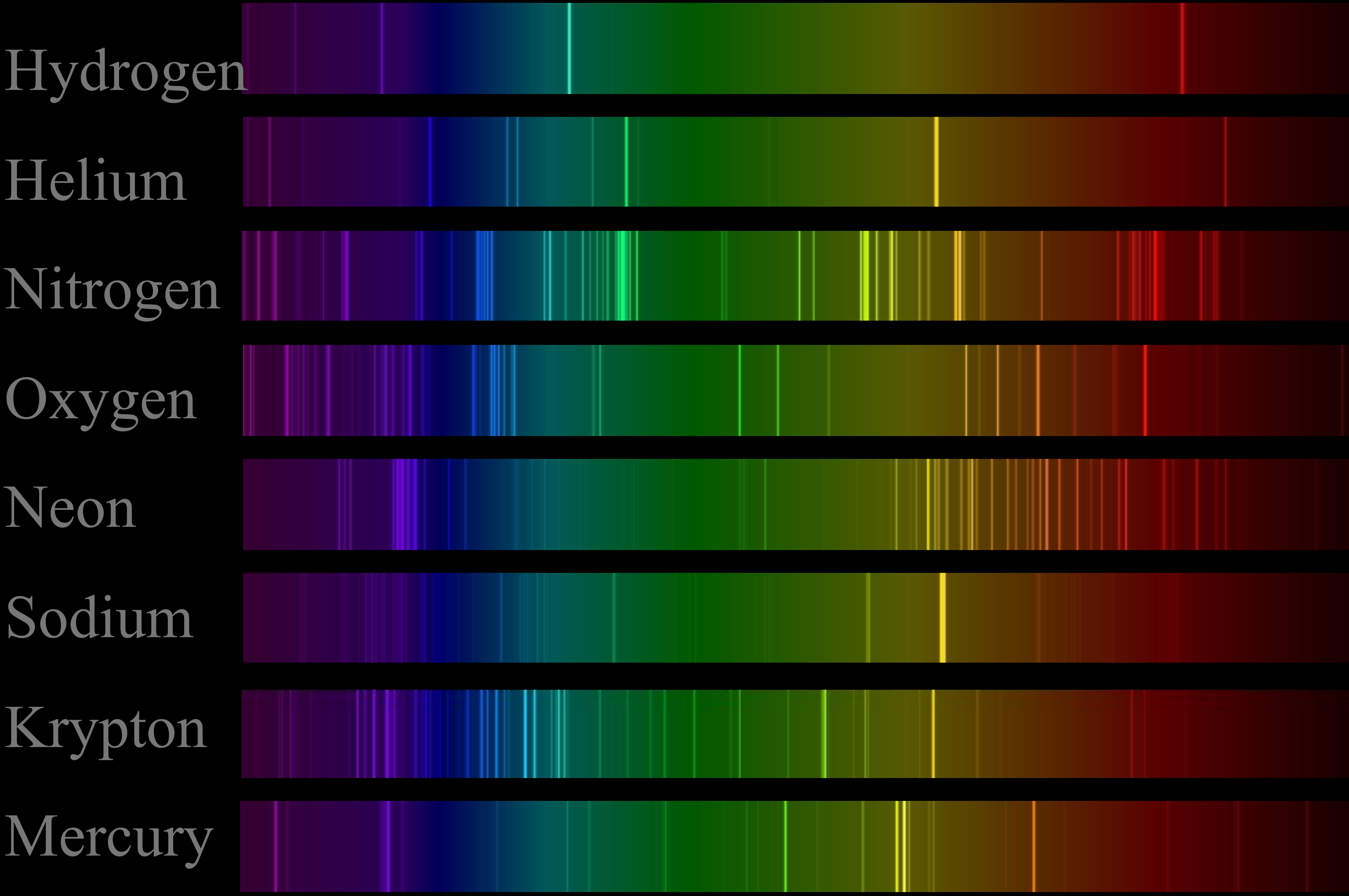
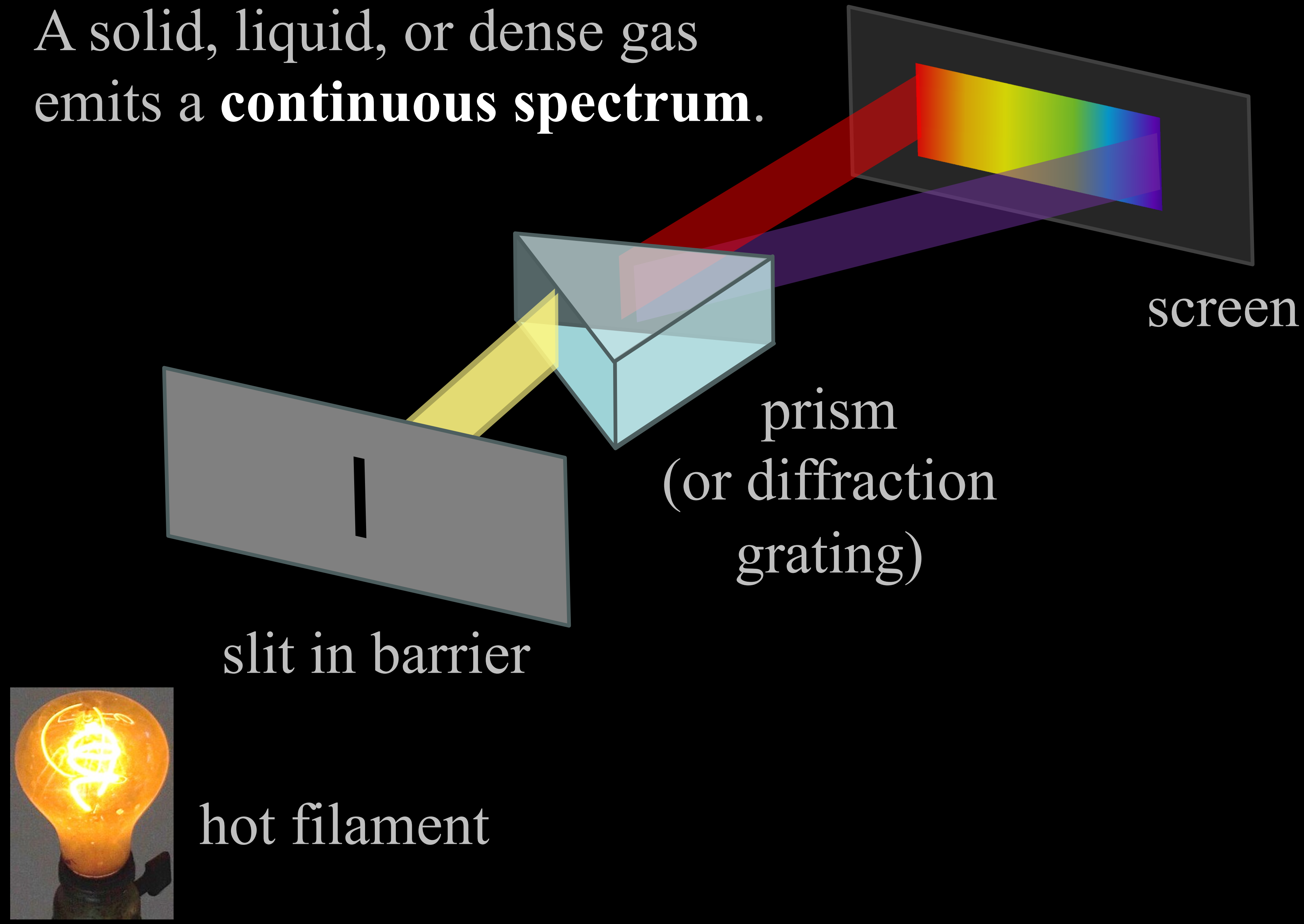
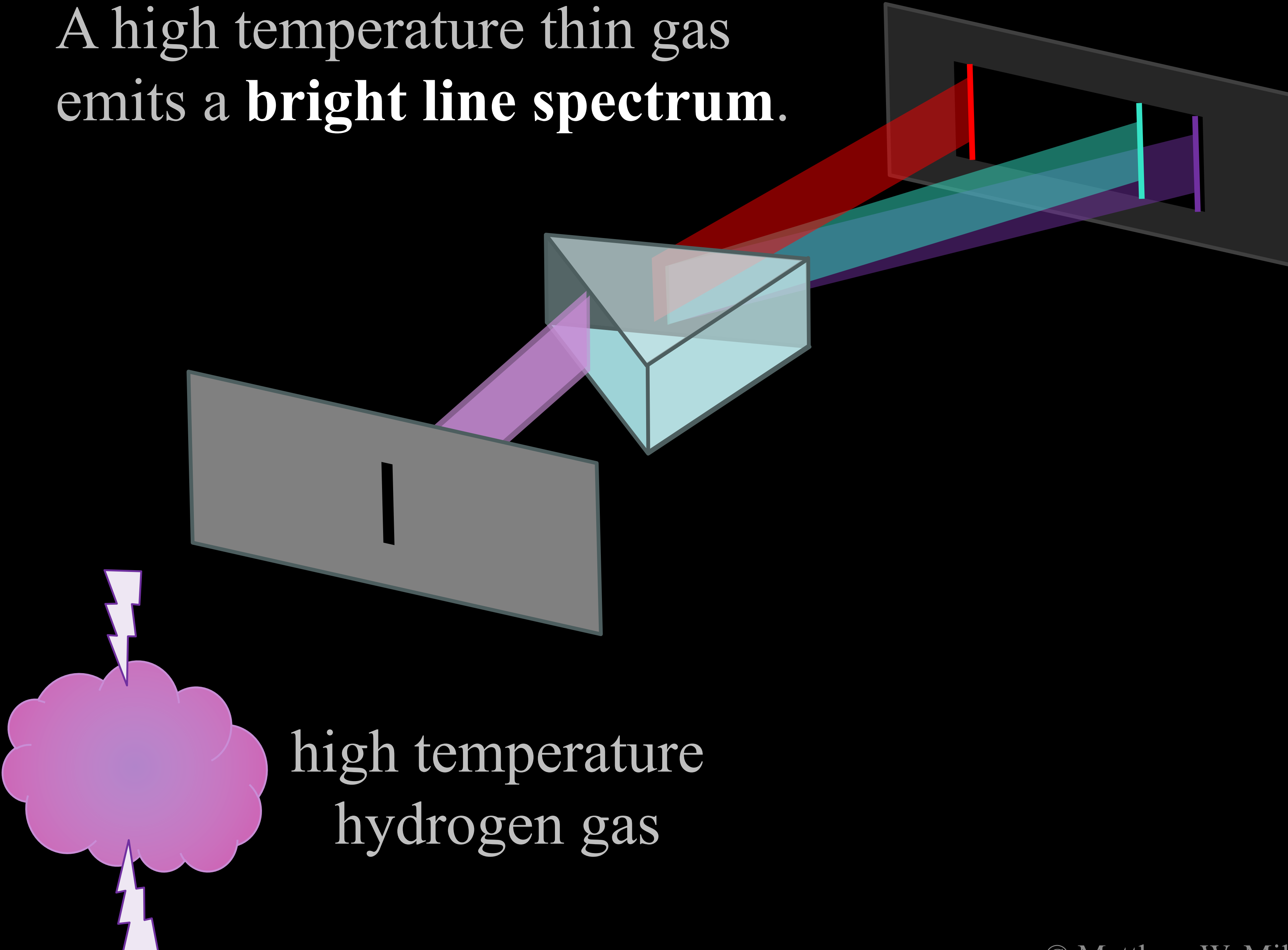

Hydrogen
Helium
Nitrogen
Oxygen
Neon
Sodium
Krypton
Mercury

# Kirchoff's Laws

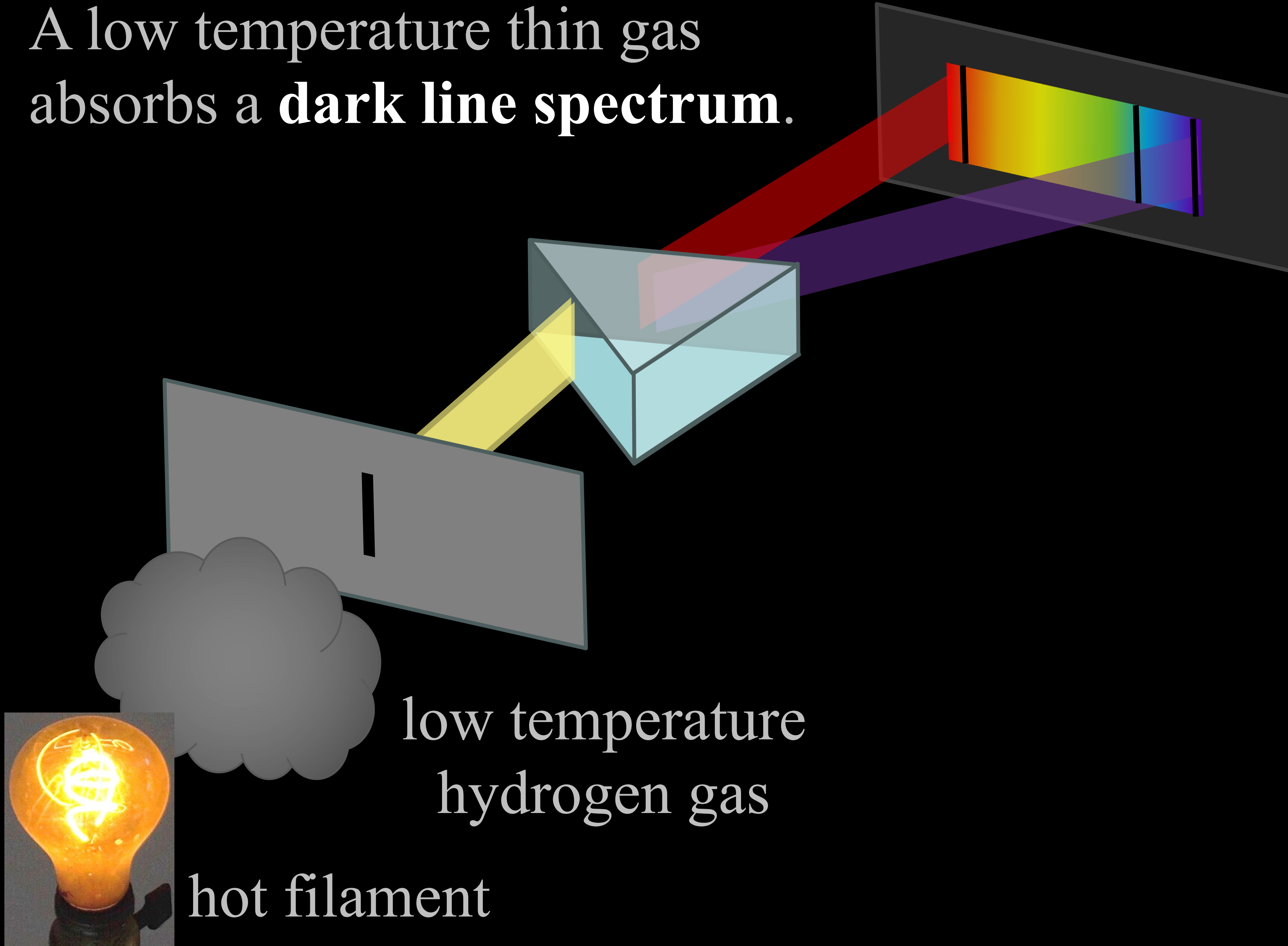
- A solid, liquid, or sufficiently dense gas emits light (EMR) of all frequencies and wavelengths – a continuous spectrum. (blackbody radiation)
- At "high" temperatures a thin, low density gas emits unique and discrete frequencies and wavelengths – a bright line spectrum.
- At "low" temperatures a thin, low density gas absorbs unique and discrete frequencies and wavelengths – a dark line spectrum.
- For a given gas the bright lines and dark lines occur at exactly the same frequencies and wavelengths.


A solid, liquid, or dense gas
emits a **continuous spectrum**.
screen
prism
(or diffraction
grating)
slit in barrier
hot filament
© Matthew W. Milligan

A high temperature thin gas emits a **bright line spectrum**.



A low temperature thin gas absorbs a **dark line spectrum**.



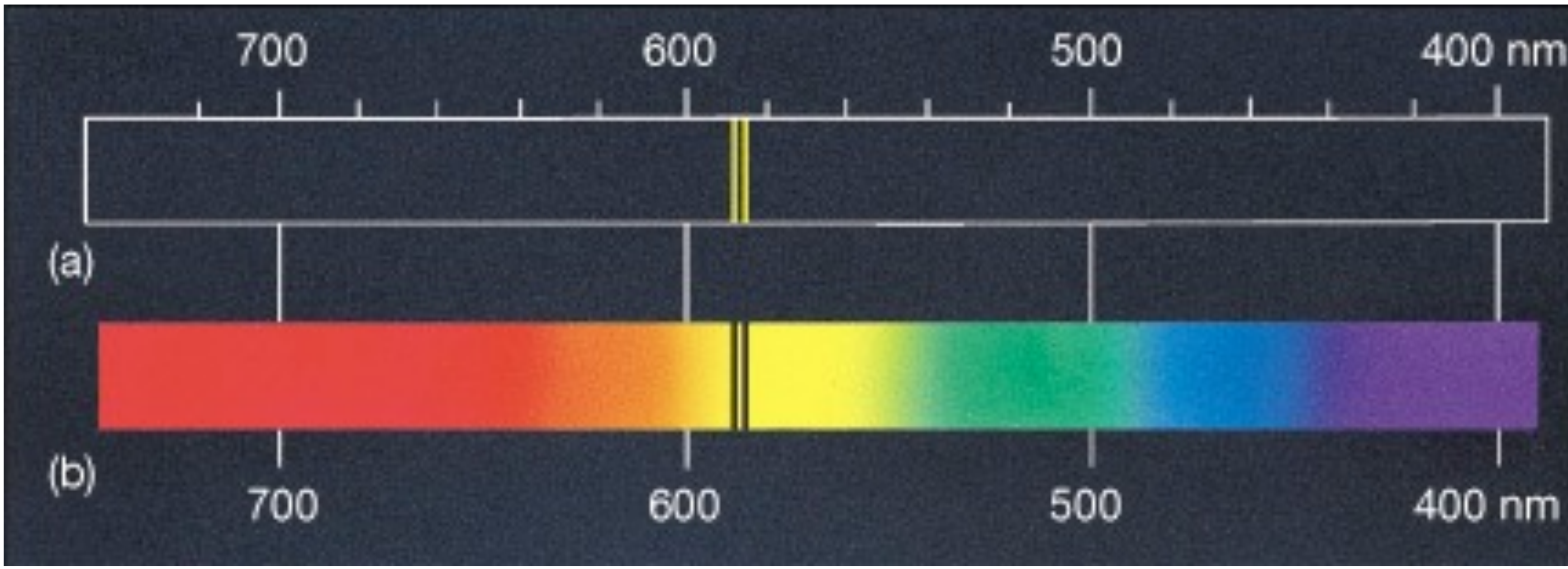
Hydrogen Emission Spectrum

Hydrogen Absorption Spectrum

Helium Emission Spectrum

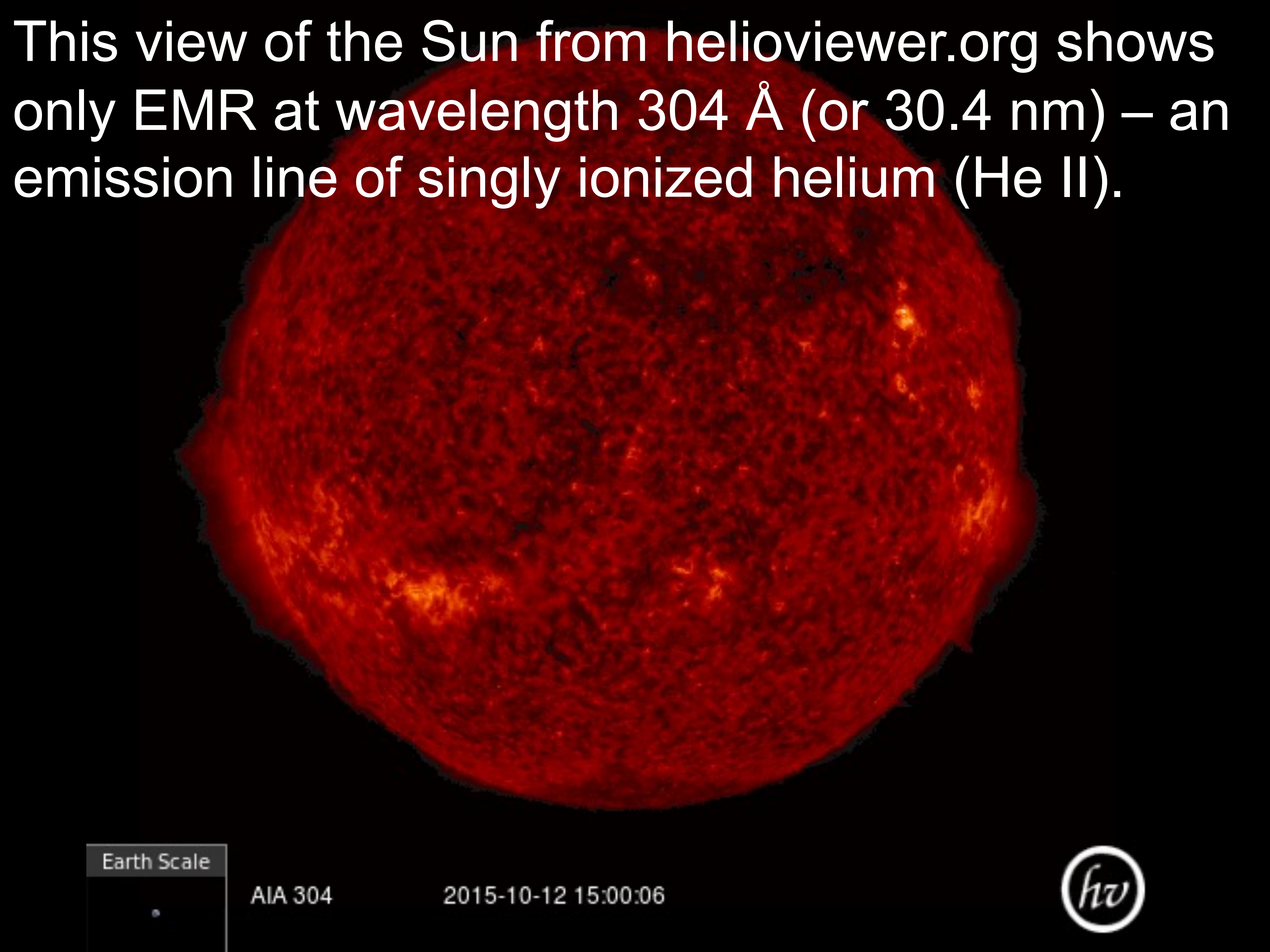
Helium Absorption Spectrum

# Sodium Emission Spectrum




# Sodium Absorption Spectrum

This view of the Sun from helioviewer.org shows only EMR at wavelength 304 Å (or 30.4 nm) – an emission line of singly ionized helium (He II).



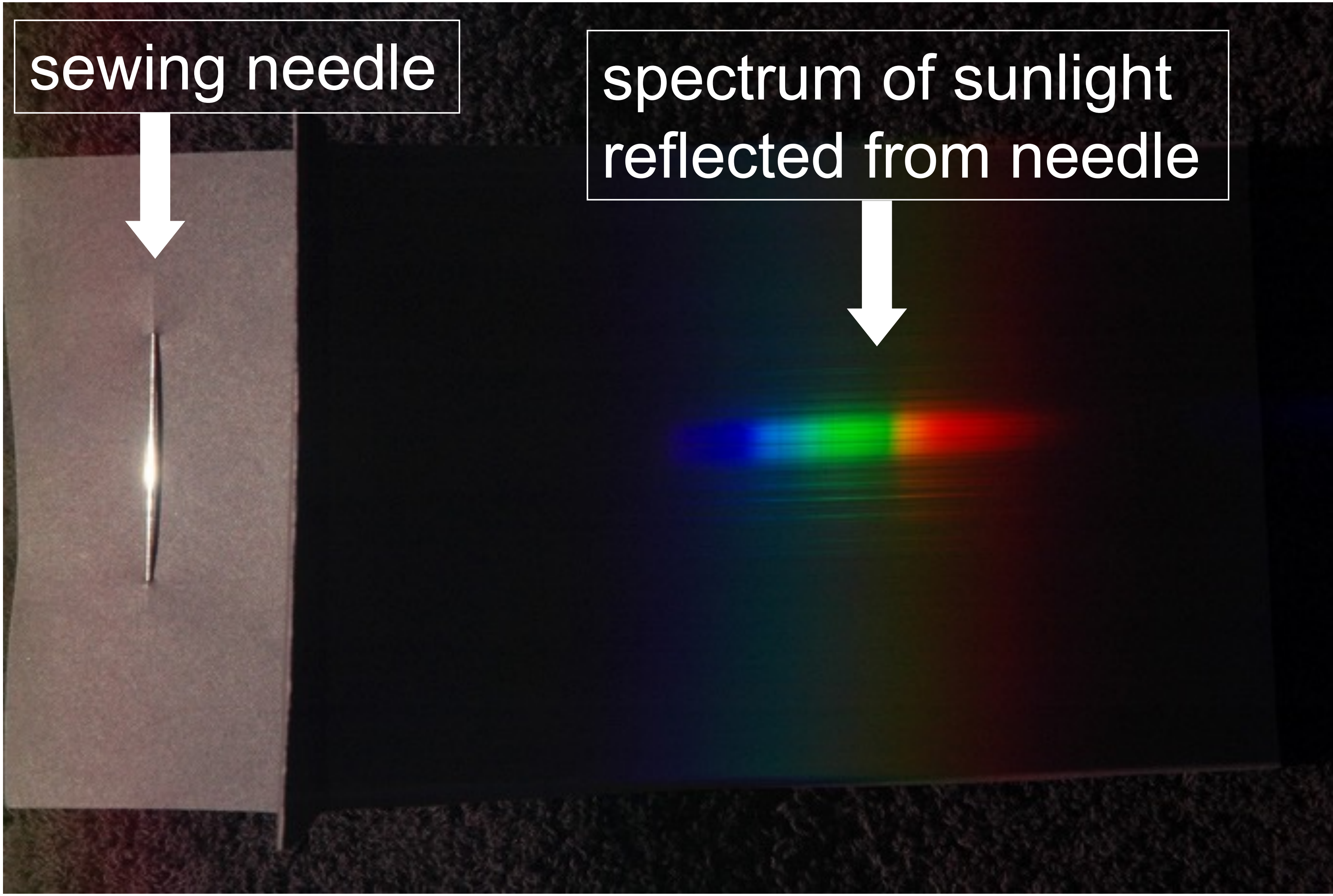



Image credit:  RSpec-Astro.com

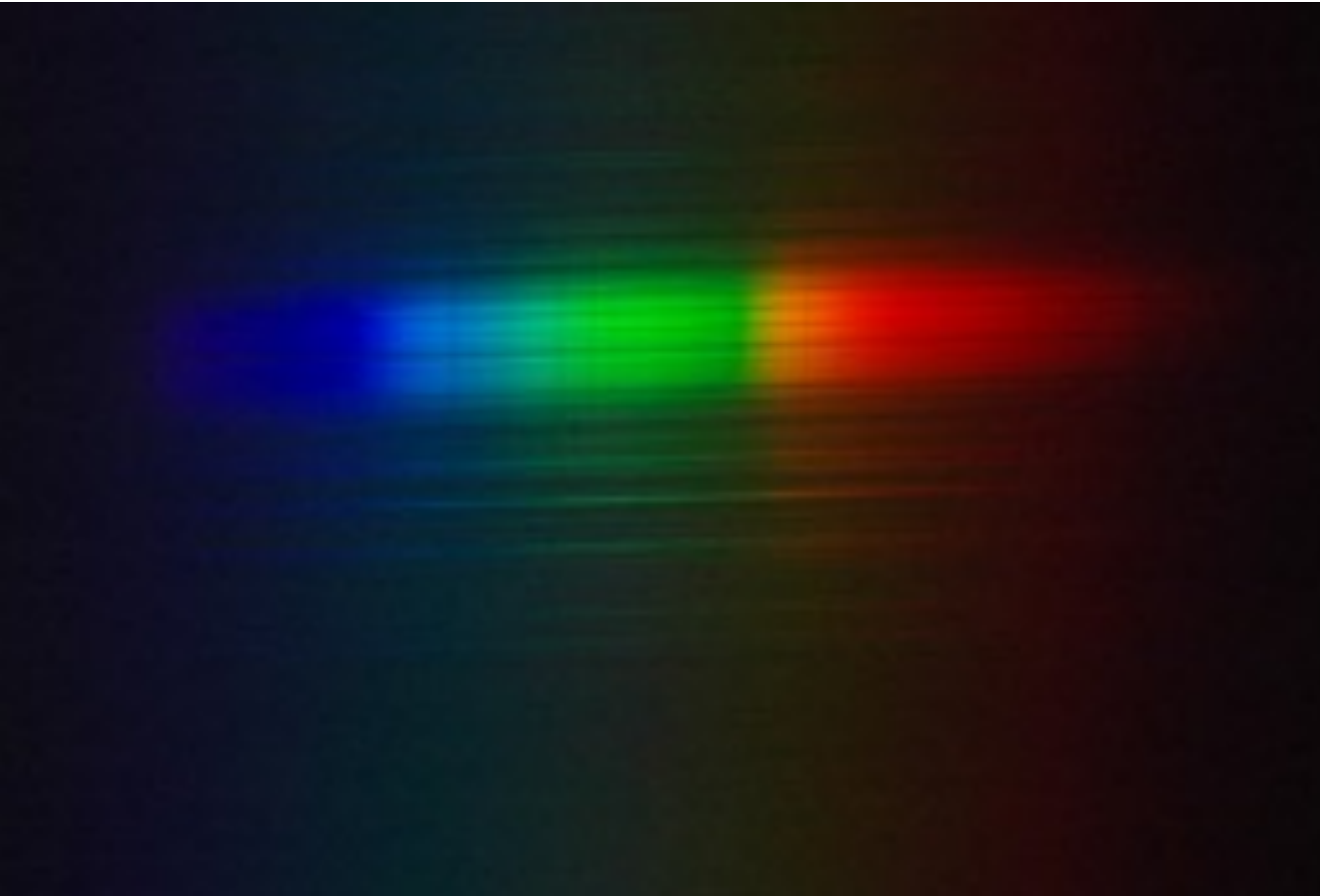
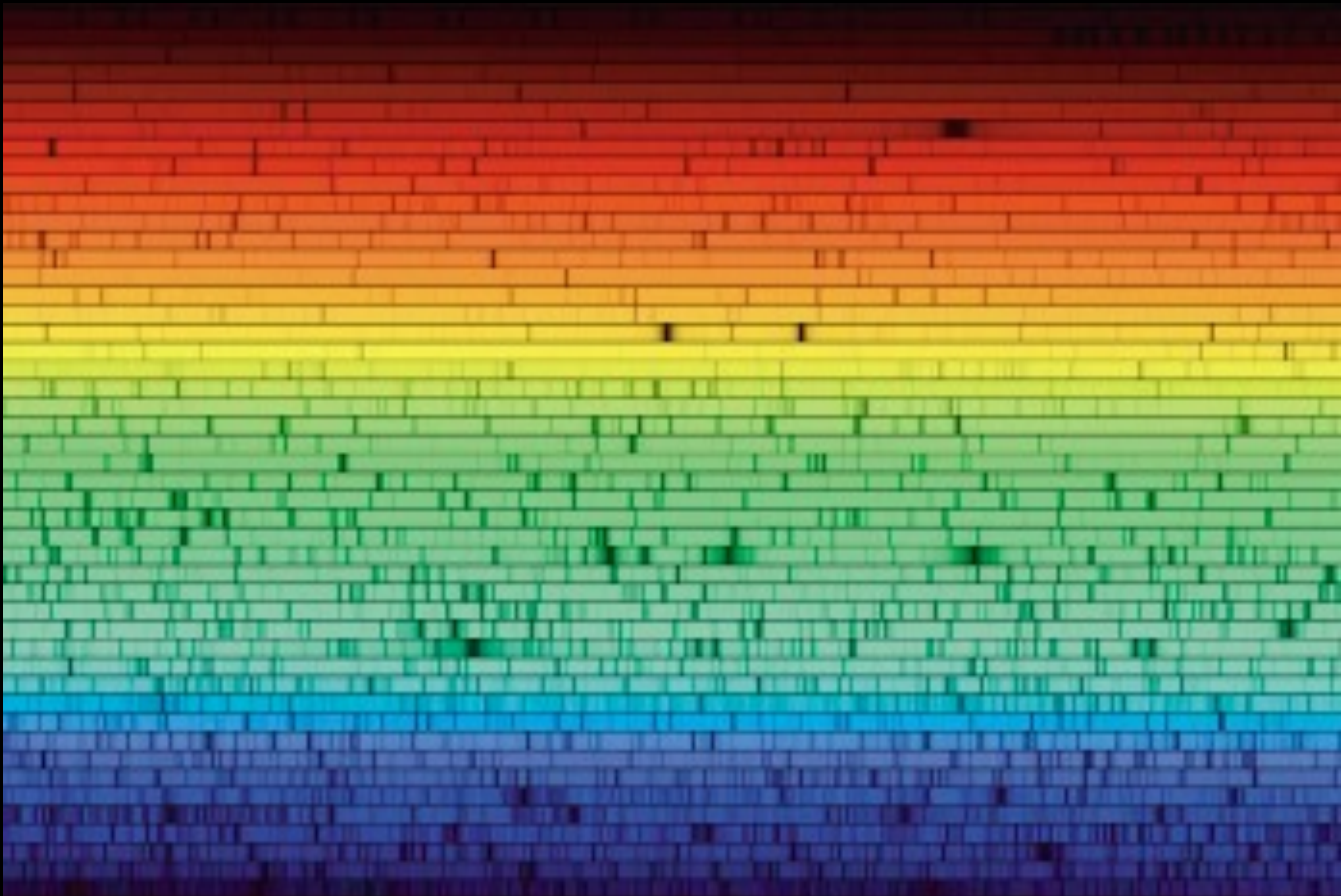


Image credit:  RSpec-Astro.com



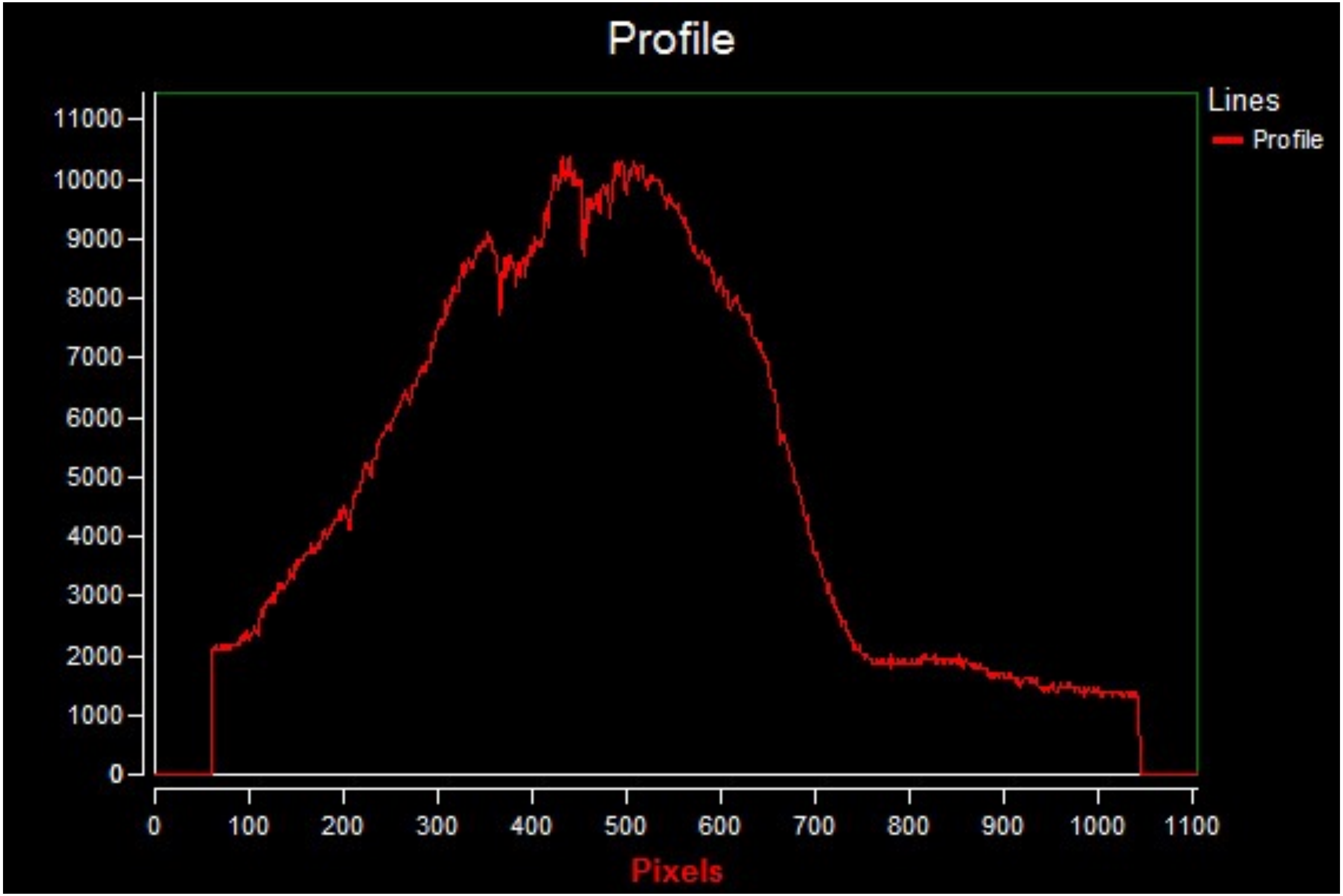



Image credit:  RSpec-Astro.com

Both of these spectra are for Hydrogen.

Why the difference?

Molecular Hydrogen

Atomic Hydrogen

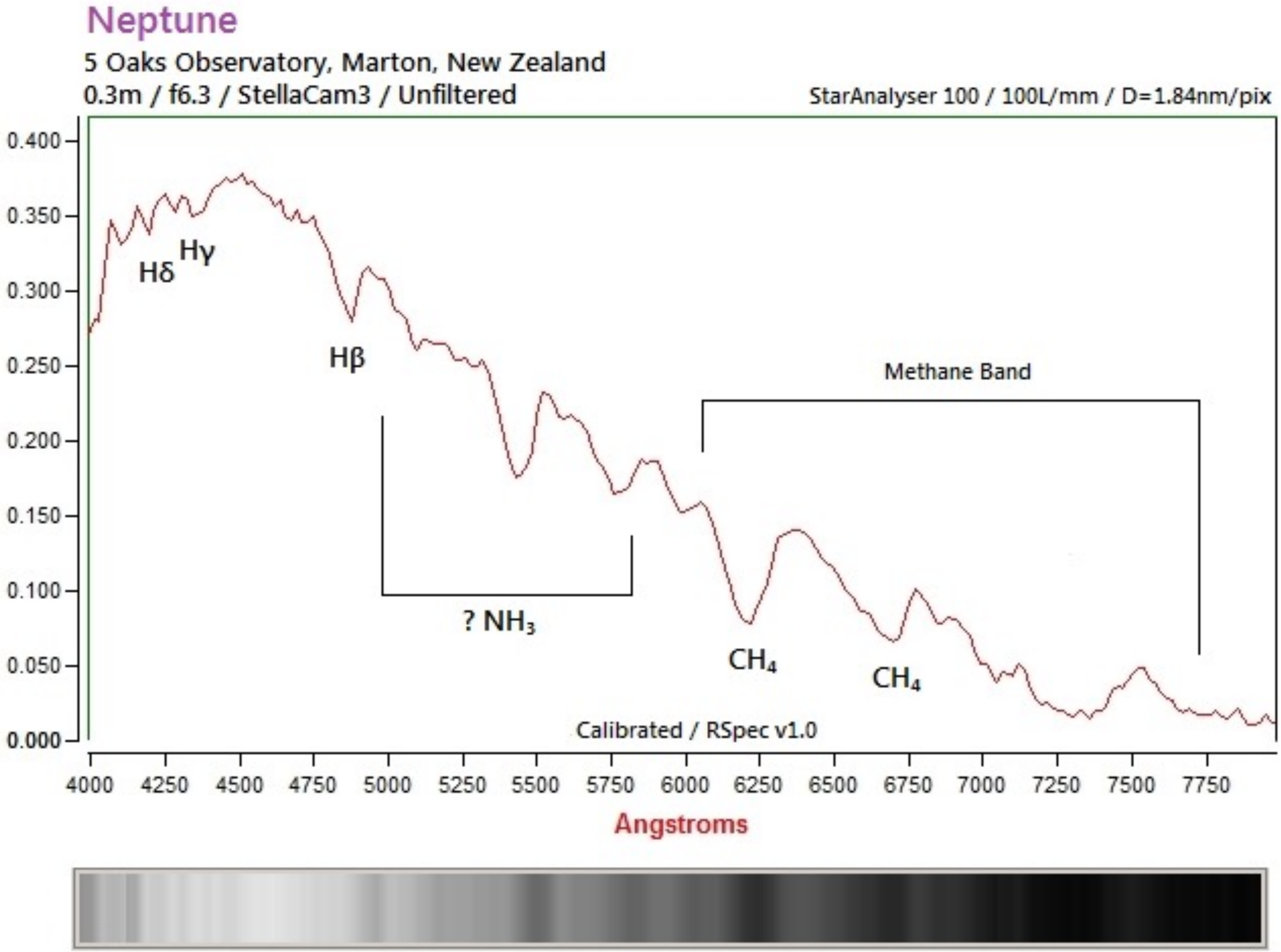
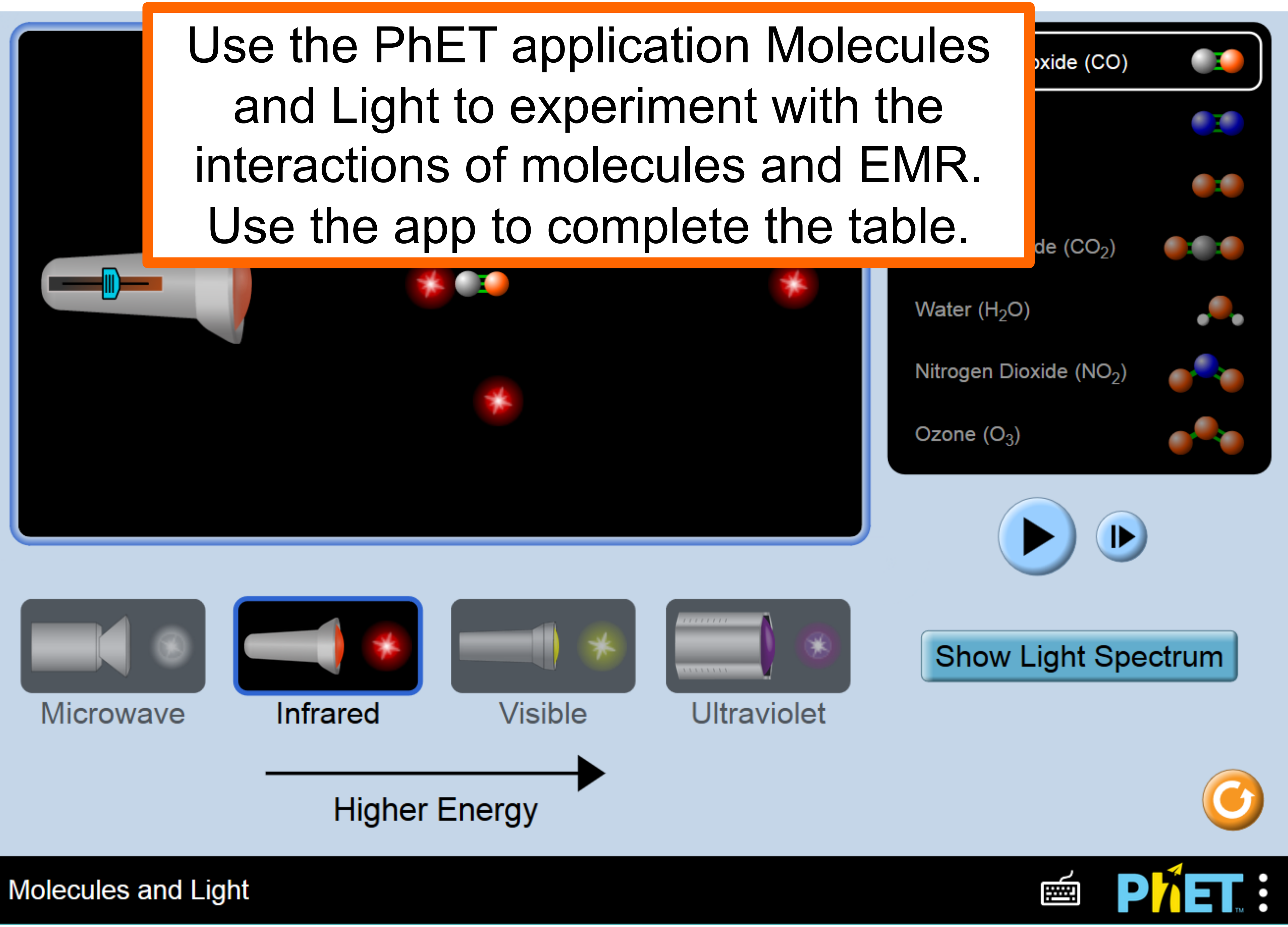



Image credit: RSpec-Astro.com

Use the PhET application Molecules and Light to experiment with the interactions of molecules and EMR. Use the app to complete the table.



| | Interacts with: (MW, IR, V, UV) | Effect on molecule: (type of reaction) |
|---|---|---|
| $CO$ | | |
| $N_2$ | | |
| $O_2$ | | |
| $CO_2$ | | |
| $CH_4$ | | |
| $H_2O$ | | |
| $NO_2$ | | |
| $O_3$ | | |

Why are some photons absorbed but others are not?

How does a photon *emitted* by a molecule compare to the photon that excited it in the first place?

How are molecules that rotate different than the others?

| | Interacts with: (MW, IR, V, UV) | Effect on molecule: (type of reaction) |
|---|---|---|
| $CO$ | MW, IR | rotation, vibration |
| $N_2$ | – | – |
| $O_2$ | – | – |
| $CO_2$ | IR | vibration |
| $CH_4$ | IR | vibration |
| $H_2O$ | MW, IR | rotation, vibration |
| $NO_2$ | MW, IR, V, UV | rotation, vibration, excitation, dissoc |
| $O_3$ | MW, IR, UV | rotation, vibration, dissociation |

Why are some photons absorbed but others are not?

How does a photon *emitted* by a molecule compare to the photon that excited it in the first place?

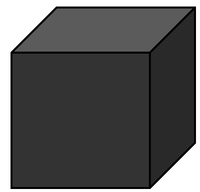
How are molecules that rotate different than the others?

# What’s up with this dog?

# Blackbody Radiation

- Any object will naturally emit some amount (and type) of electromagnetic radiation!
- This radiation is a result of the inherent temperature of the object. This radiation represents energy lost by the atoms that make up the substance.
- It is called *black*body radiation to distinguish it from radiation that may be reflected by the object. (The object doesn't have to be black!)

# Blackbody Radiation

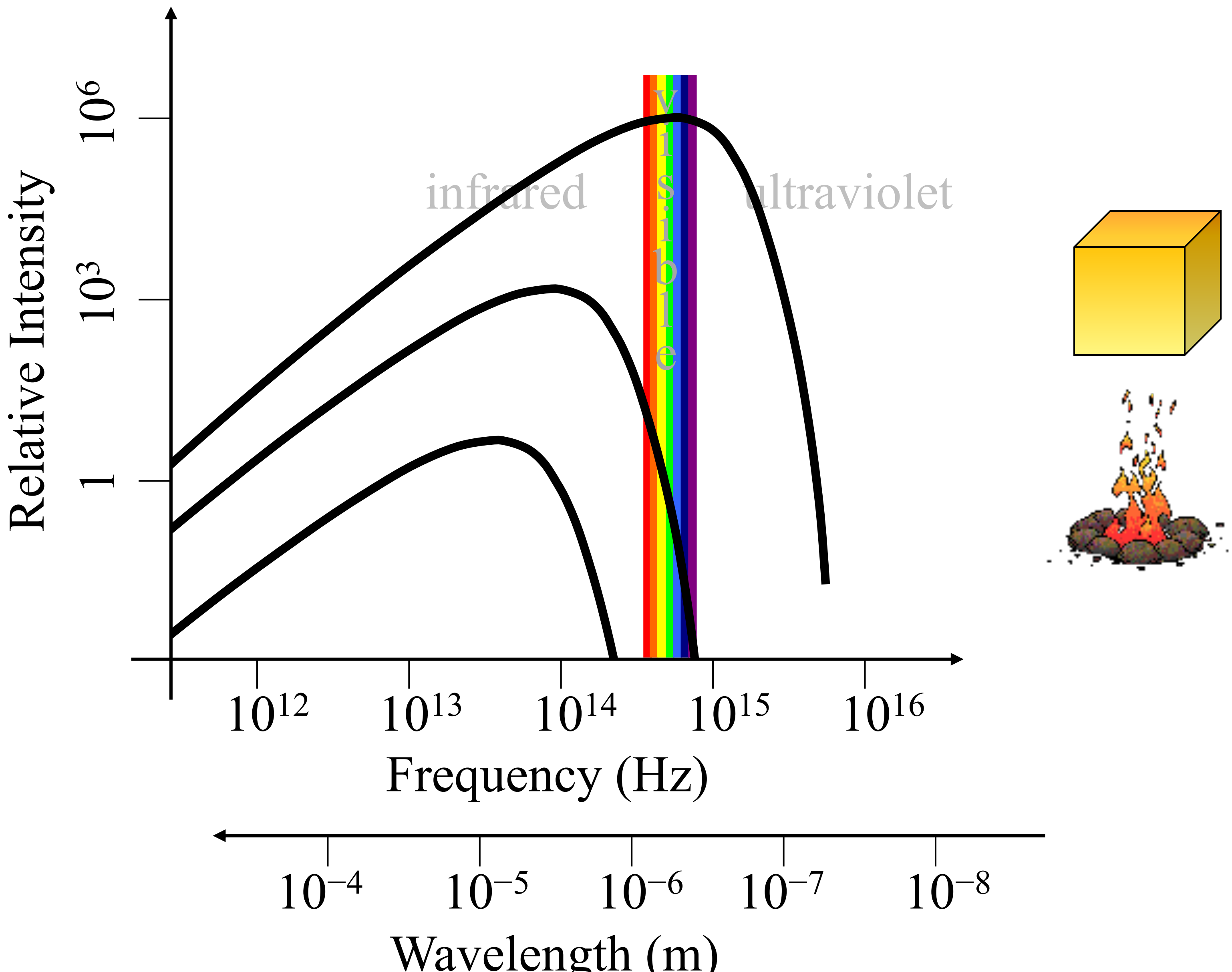


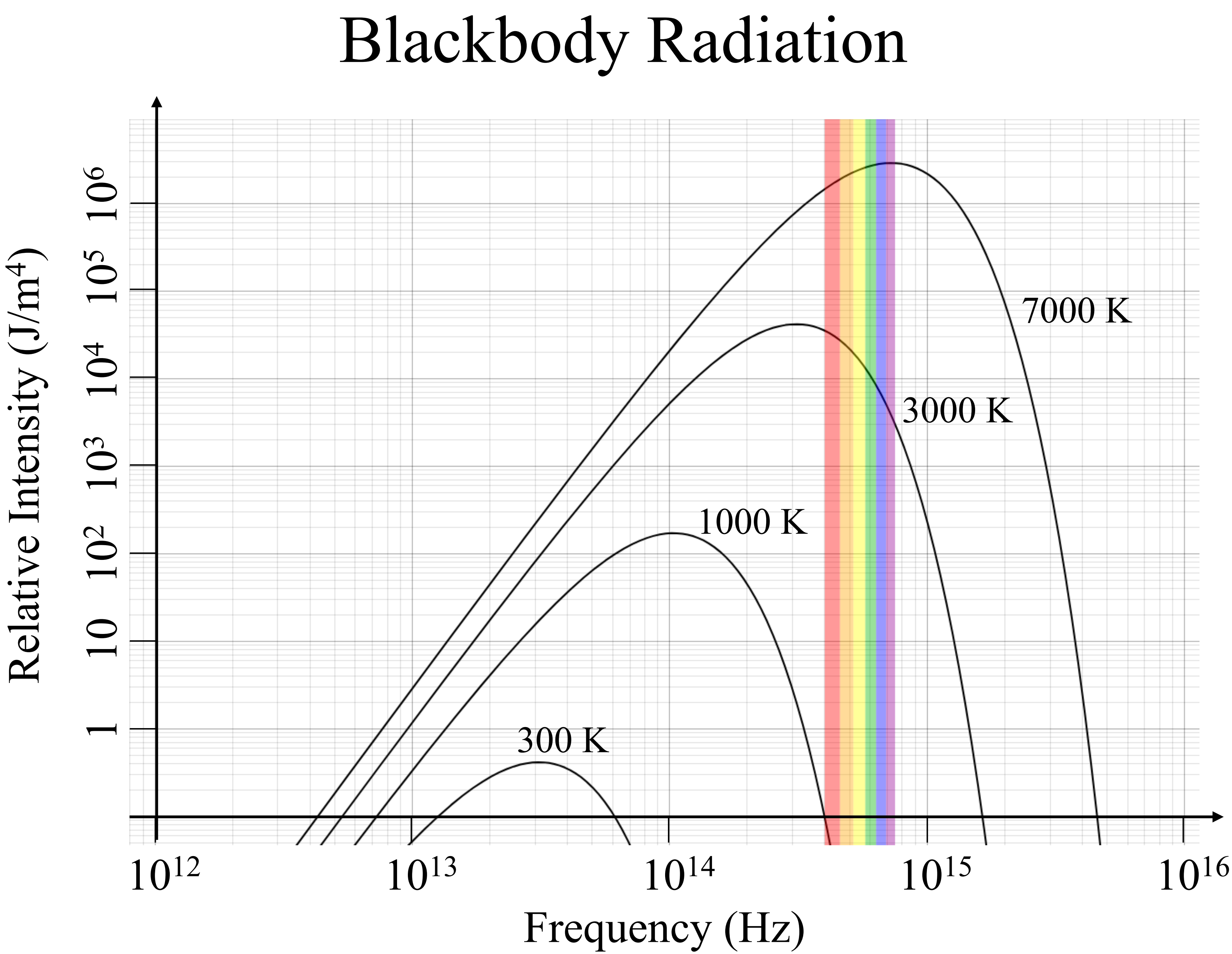
Oh, look!  A "black body"!

(*i.e.* an object that happens to be black…)

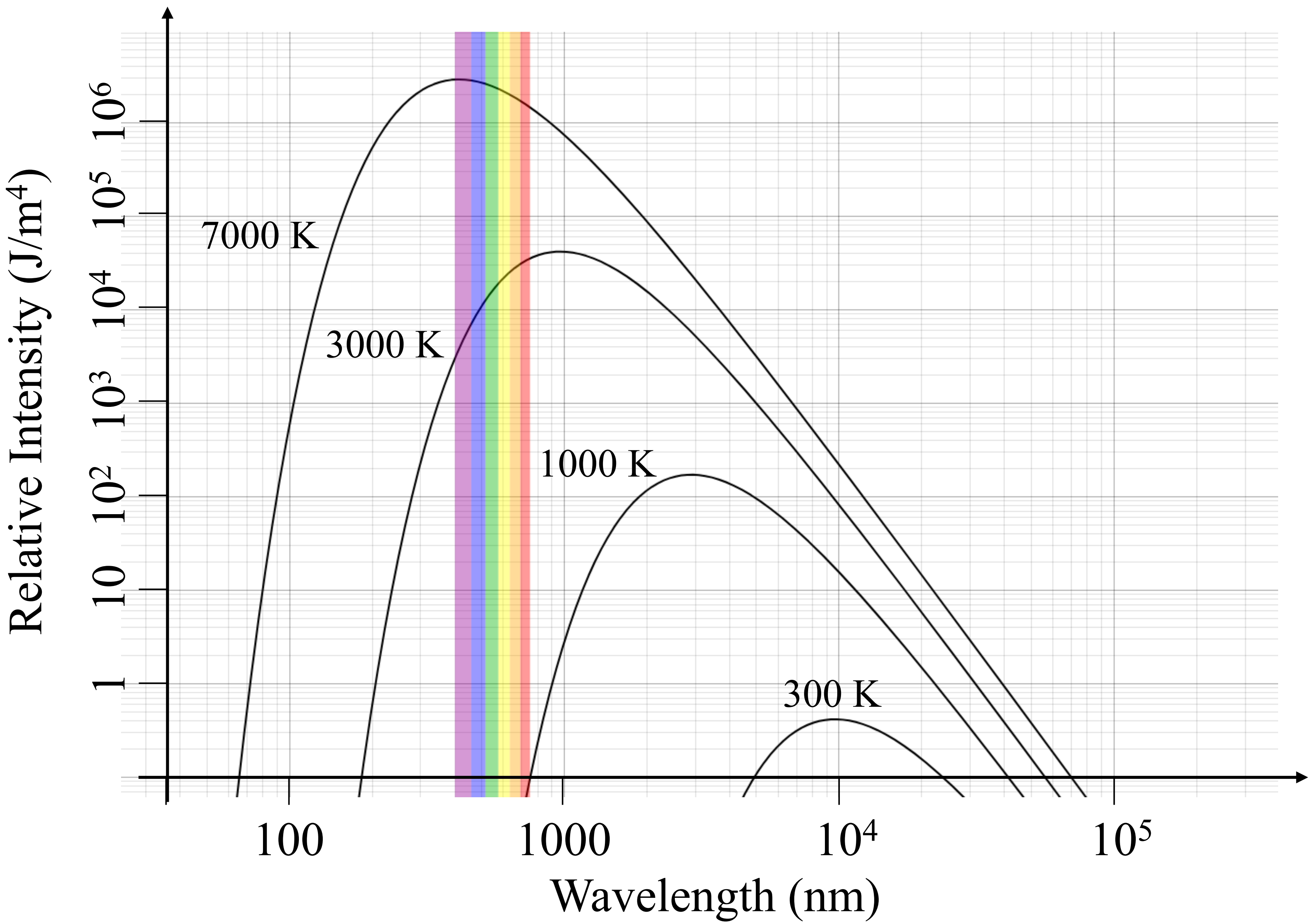
Let's put it in the fire!

# Blackbody Radiation




Blackbody Radiation
Relative Intensity (J/m⁴)
10⁶
10⁵
10⁴
10³
10²
10
1
7000 K
3000 K
1000 K
300 K
10¹²
10¹³
10¹⁴
10¹⁵
10¹⁶
Frequency (Hz)

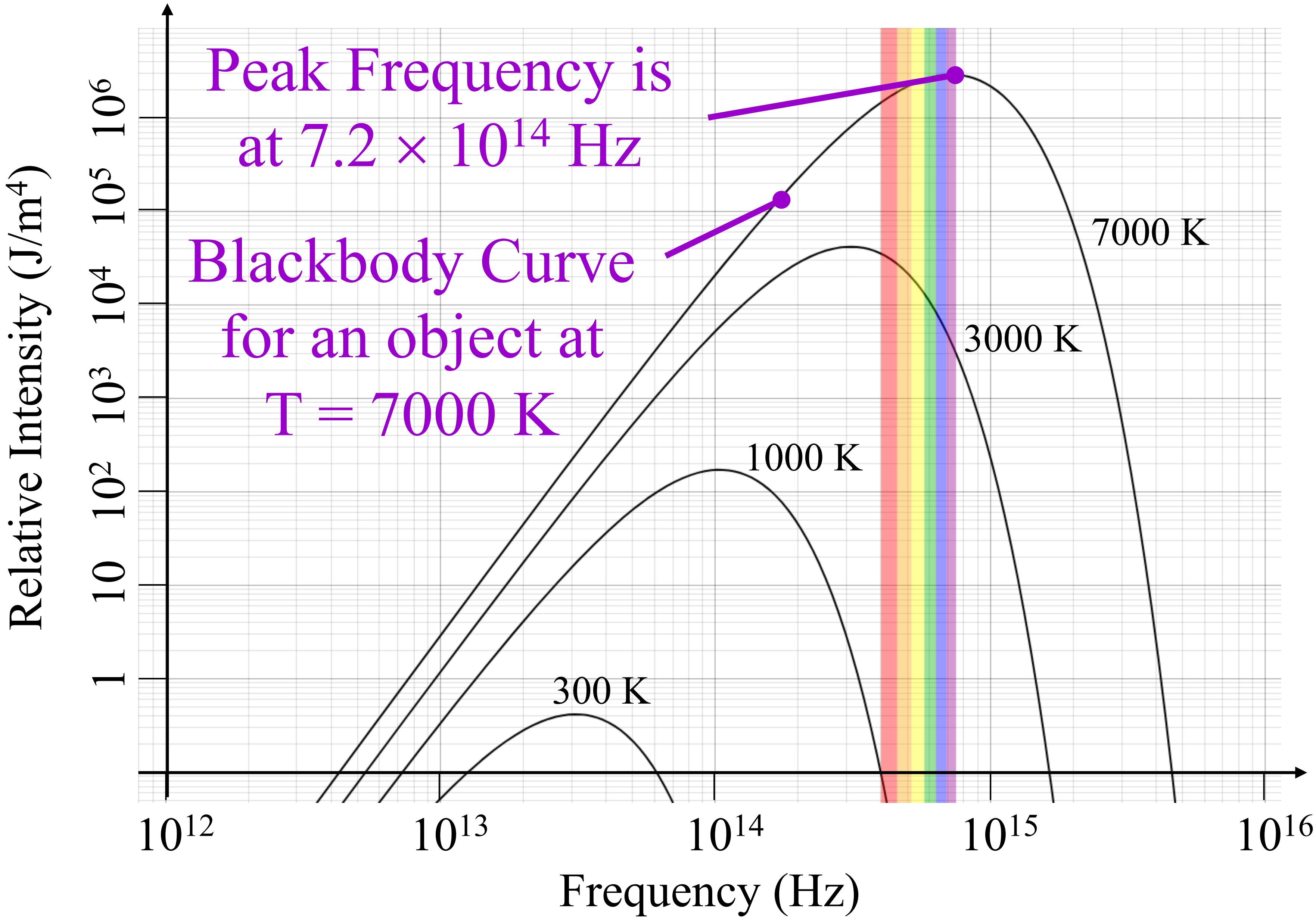
# Blackbody Radiation



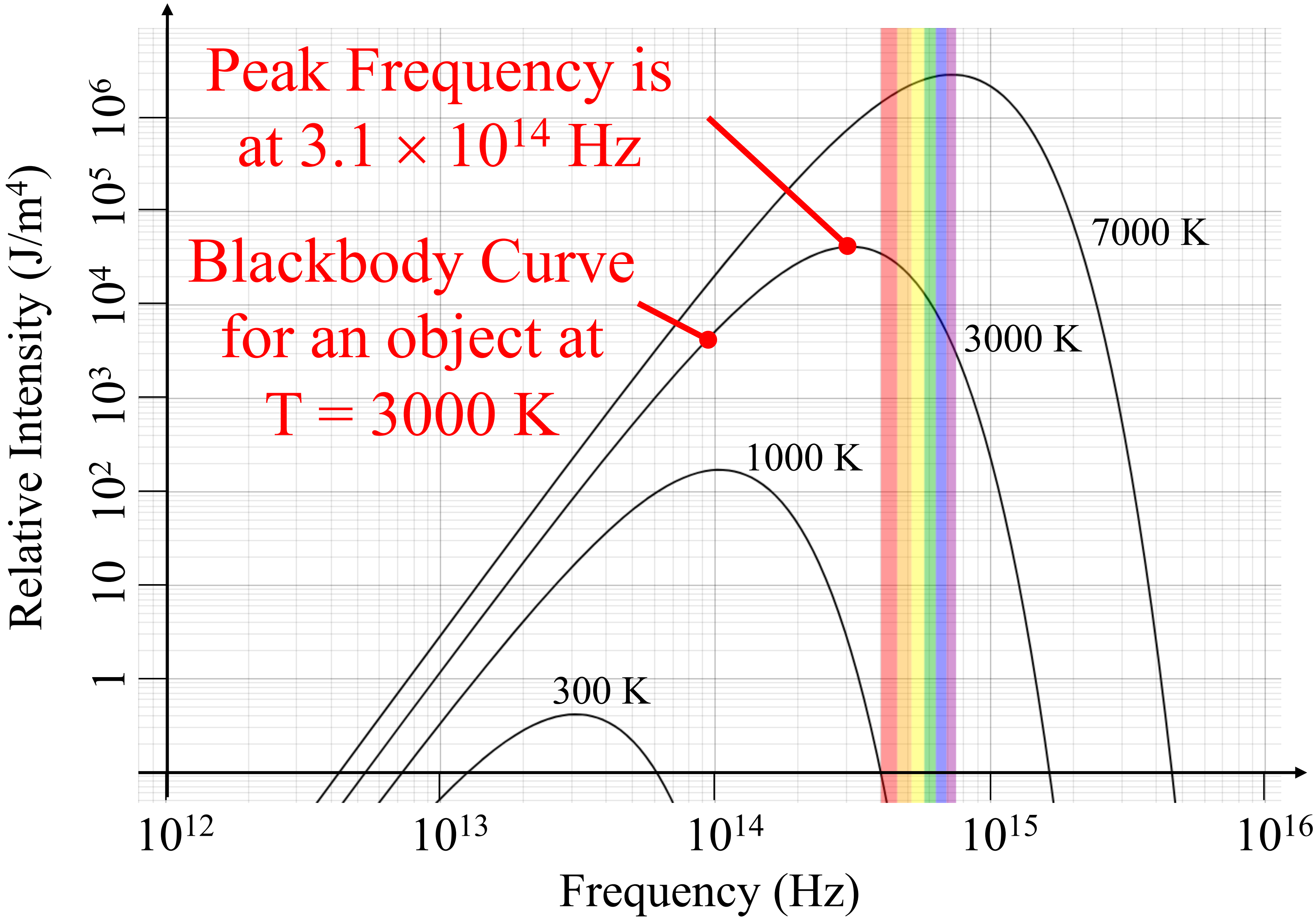
The hotter the object, the greater the *amount* of radiation and the greater the *frequency* of the radiation that it emits.

The blackbody curve reveals the frequency or wavelength at which the object emits the *most* radiation. This is called the peak frequency or peak wavelength.

# Blackbody Radiation



# Blackbody Radiation



# Wein’s Law

Wein’s displacement law relates the peak *wavelength* of the radiation to the temperature of the object.

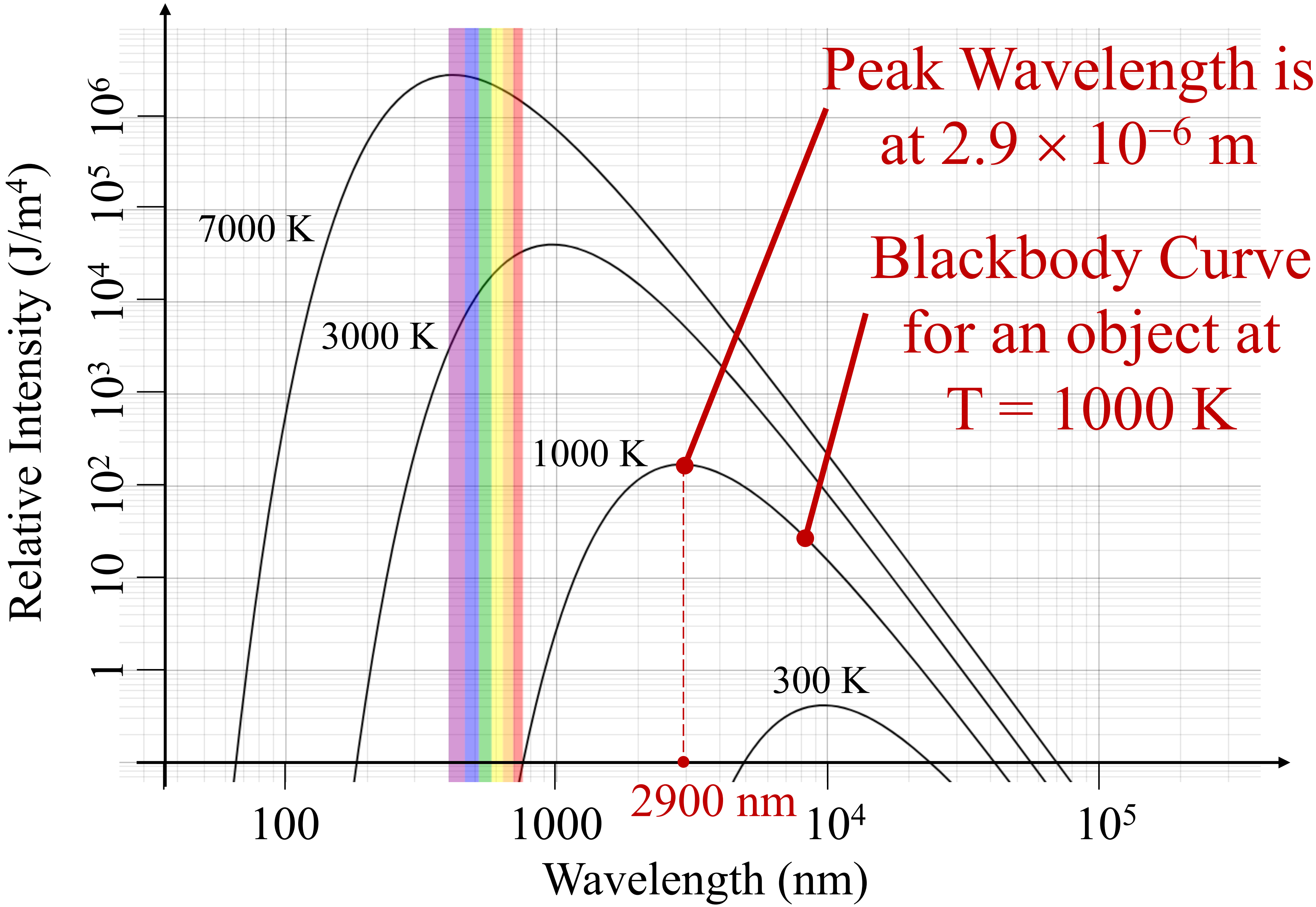
$$\boxed{\lambda_{peak} = \frac{b}{T}}$$

where: $b = 2.898 \times 10^{-3}\ \mathrm{m{\cdot}K}$

$\lambda =$ wavelength

$T =$ temperature

# Blackbody Radiation



# Stefan-Boltzmann Law

The total power output of a blackbody radiator is proportional to the product of temperature to the fourth power and surface area:

$$\boxed{P = A\sigma T^4}$$

where: $\sigma = 5.670 \times 10^{-8}\ \mathrm{W/m^2{\cdot}K^4}$
$A$ = surface area
$T$ = temperature