Spectra, Blackbody Radiation and Astrophyics

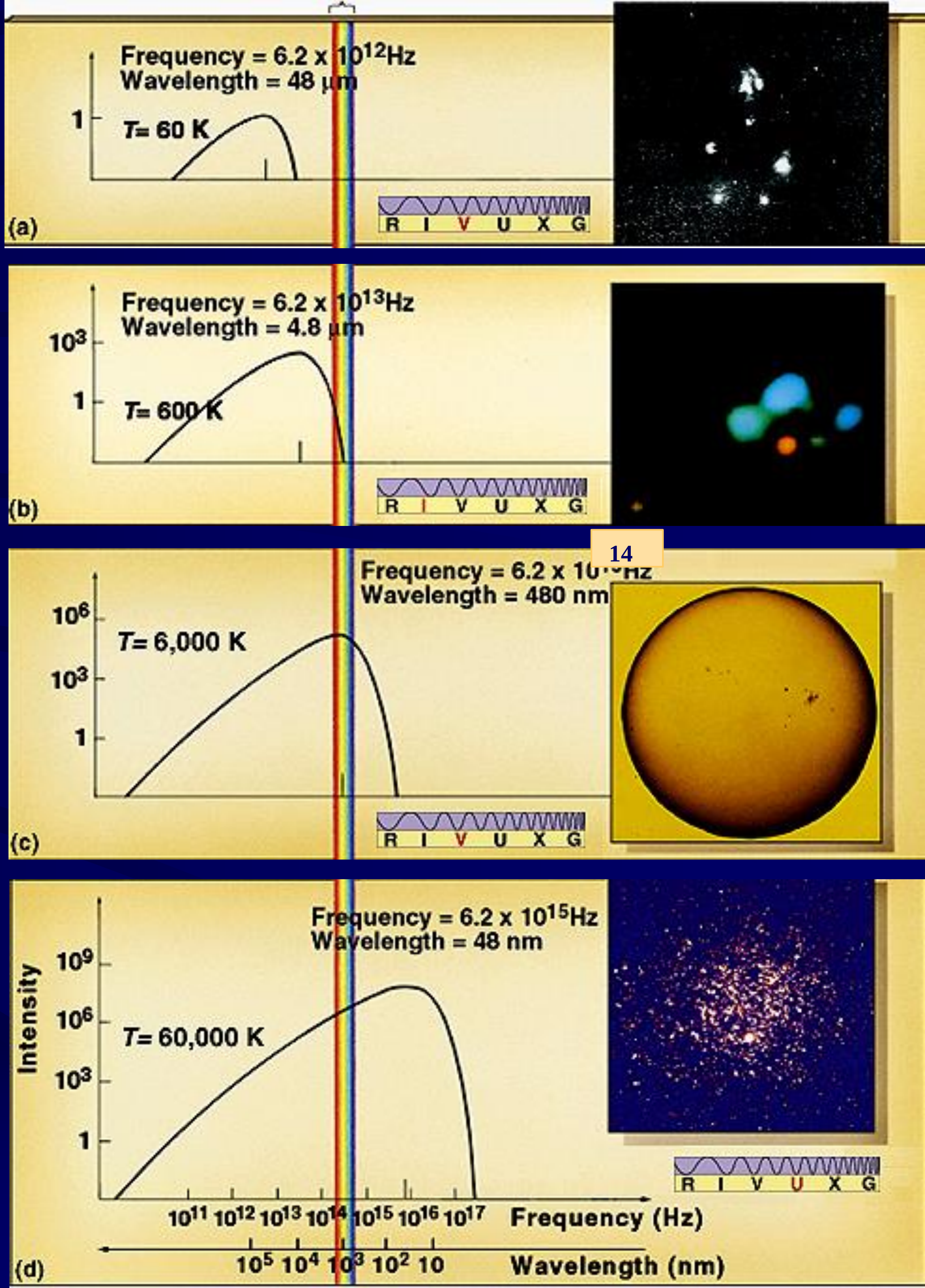
Cool, invisible galactic gas (60 K, f_{peak} in low radio frequencies)

Dim, young star (600K, f_{peak} in infrared)

The Sun's surface (6000K, f_{peak} in visible)

Hot stars in Omega Centauri (60,000K, f_{peak} in ultraviolet)

The higher the temperature of an object, the higher its I_{peak} and f_{peak}



Wien's Law

- The peak of the intensity curve will move with temperature, this is Wien's law:

Temperature * wavelength = constant

= 0.0029 K*m

So: the higher the temperature T, the smaller the wavelength, i.e. the higher the energy of the electromagnetic wave

Example

- Peak wavelength of the Sun is 500nm, so

  $T = (0.0029\ K*m)/(5 \times 10^{-7}\ m) = 5800\ K$

- Instructor temperature: roughly 100 °F = 37°C = 310 K, so

  wavelength = (0.0029K*m)/310 K

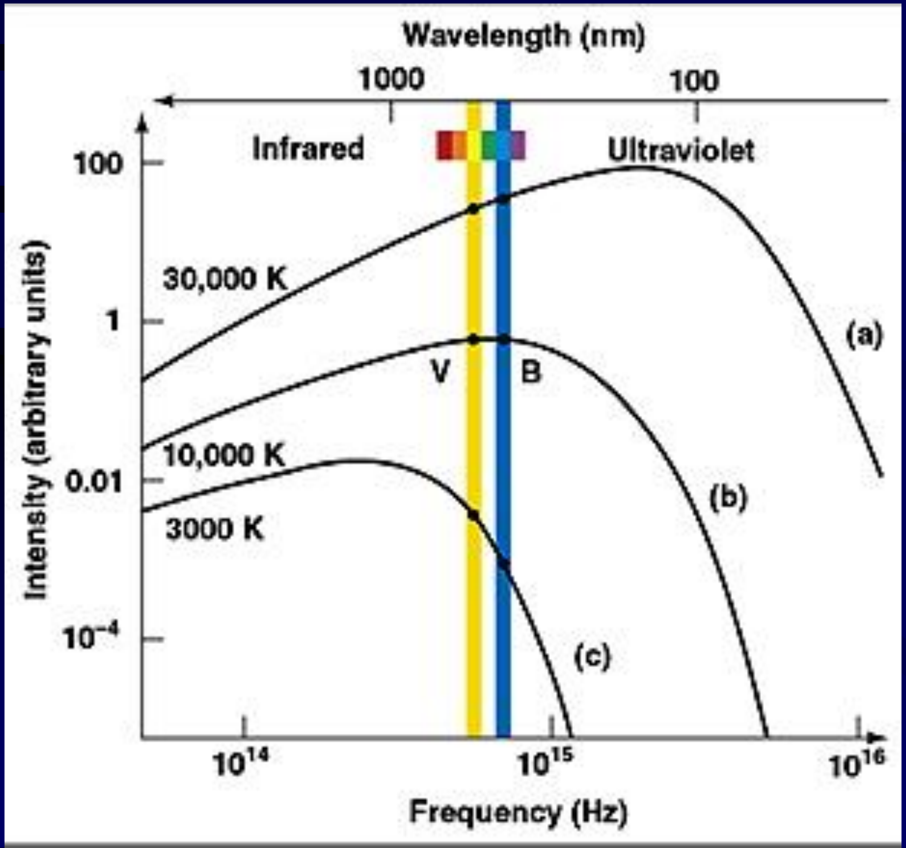
  $= 9.35 * 10^{-6}$ m

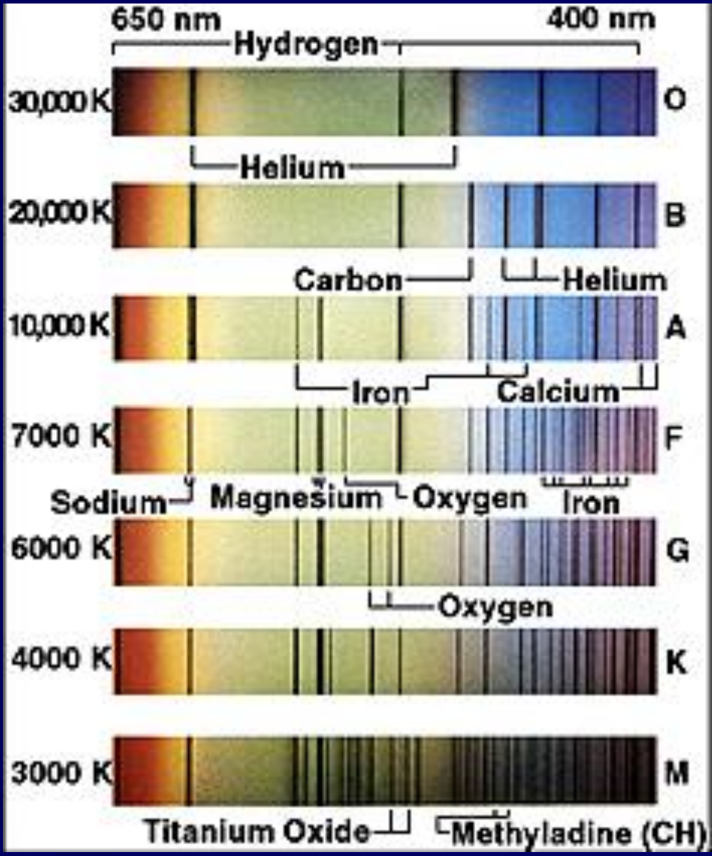
  = 9350 nm → infrared radiation

  ≈ 10 μm = 0.01 mm

Measuring Temperatures

- Find maximal intensity
  → Temperature (Wien's law)





Identify spectral lines of ionized elements
→ Temperature

Astronomy + Physics = Astrophysics

- Apply physics results to astronomy!
- Thermodynamics describes systems with exceedingly many particles
  - Pressure, volume, temperature of gases and other substances are related
- Apply to stars – model them as gigantic hot gas balls

Astrophysics

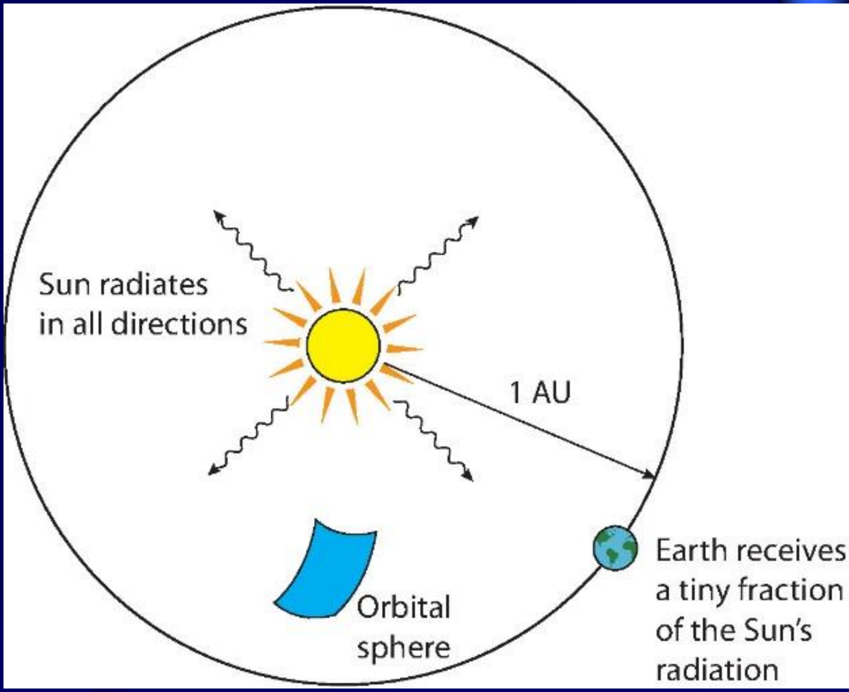
- Spectroscopy – starlight tells us about temperature, velocity, chemical composition of stars (and other objects)
- Masses of stars from double stars
- First stellar Models
- Astrophotography
- Variable Stars
- Classification of stars

Thermodynamics

- First Law (1847): Energy is conserved!
- Second Law: Entropy increases, heat flows spontaneously only from hot to cold objects
- Consequence: the universe will run out of things to do
- ➔ Heat death of the universe (in the far distant future)

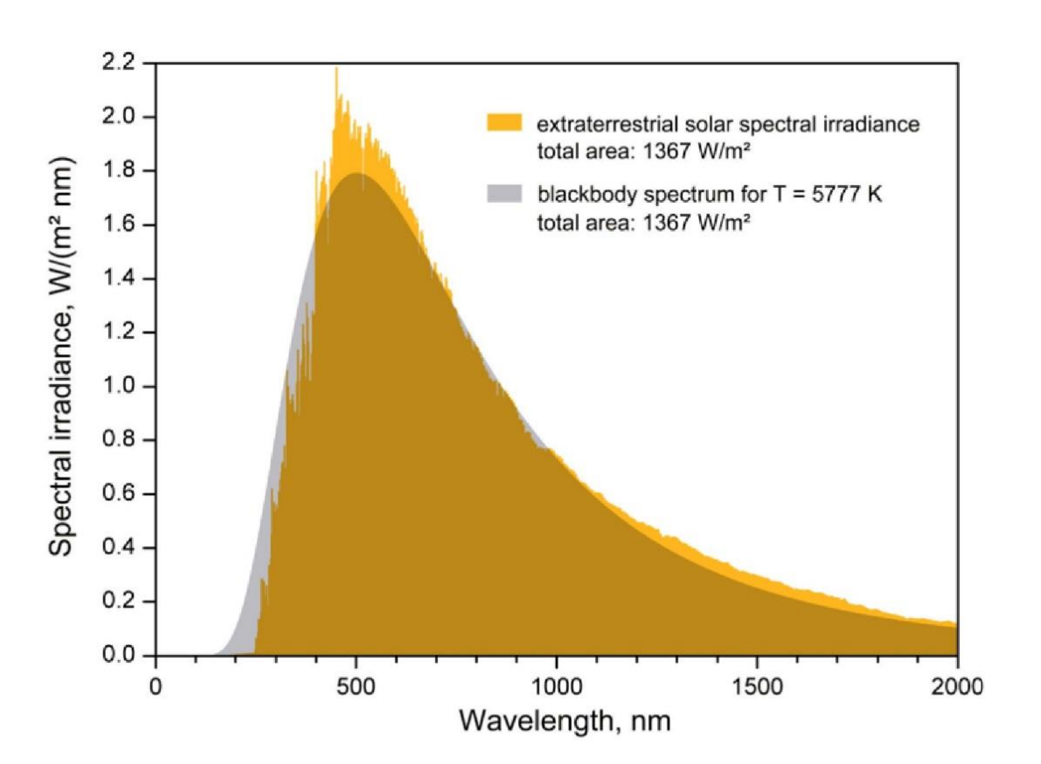
The Sun as a Blackbody

- Solar constant: the amount of energy we receive on earth per second per area
- In 1837: 1400 W/m^2
- Scale up to area of sphere with radius 1AU
- Total power radiated by the sun:
- $P_{sun} = 3.8 \times 10^{26}$ W

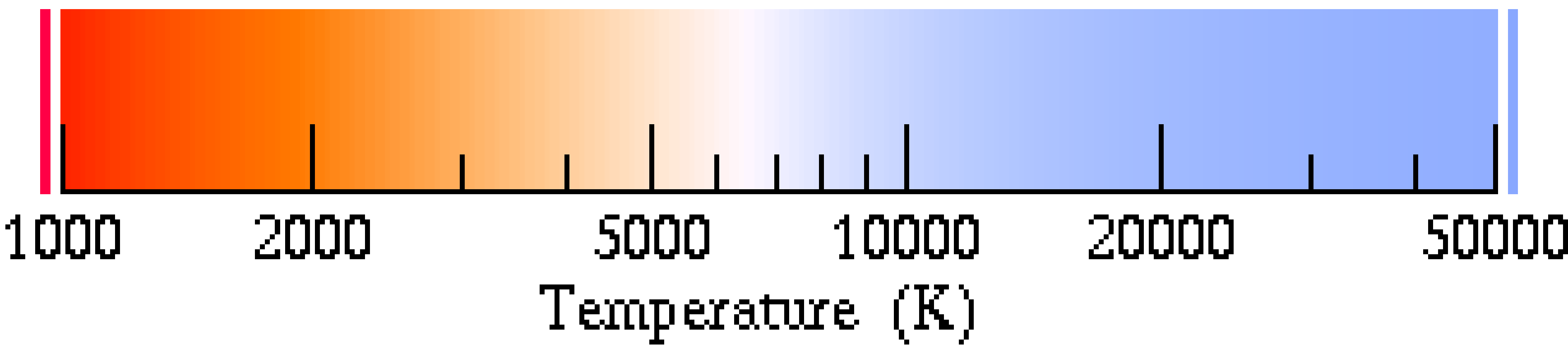


The Sun's Blackbody spectrum

- Peaks at 500nm (green)
- is more complicated than a perfect blackbody
- Still, a good approximation
- Used by J. Stefan in 1869 to calculate the temperature of the Sun for the first time!



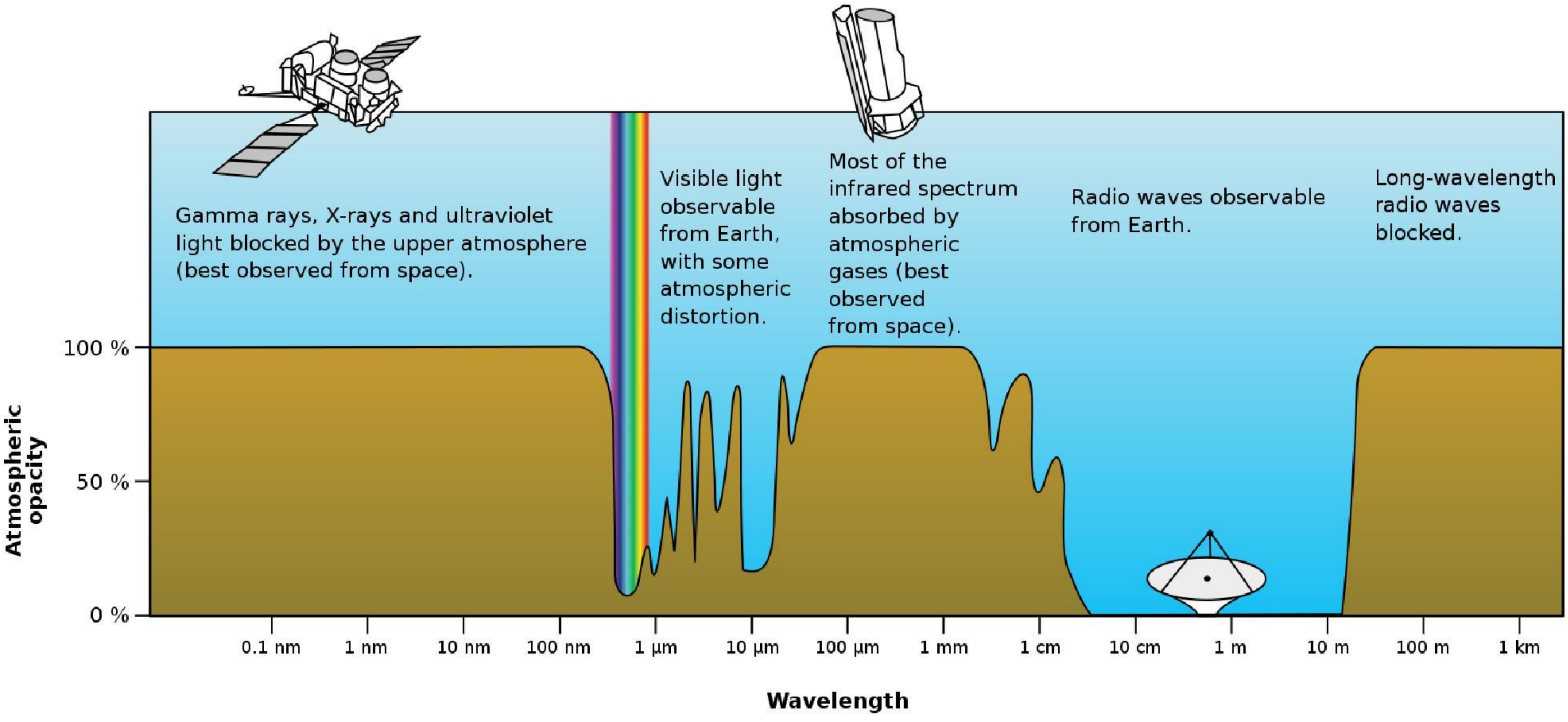
Why isn't the Sun green? Color of a radiating blackbody as a function of temperature



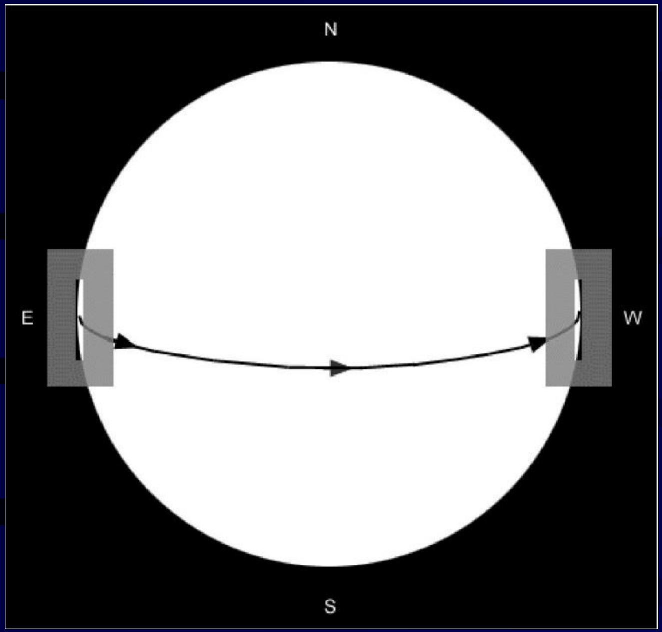
- Think of heating an iron bar in the fire: red glowing to white to bluish glowing
- Apparent color is a mixture of many colors – green is not a possibility!

Which EM waves can we see from the Earth's surface?

- Visible light, radio waves, some IR light

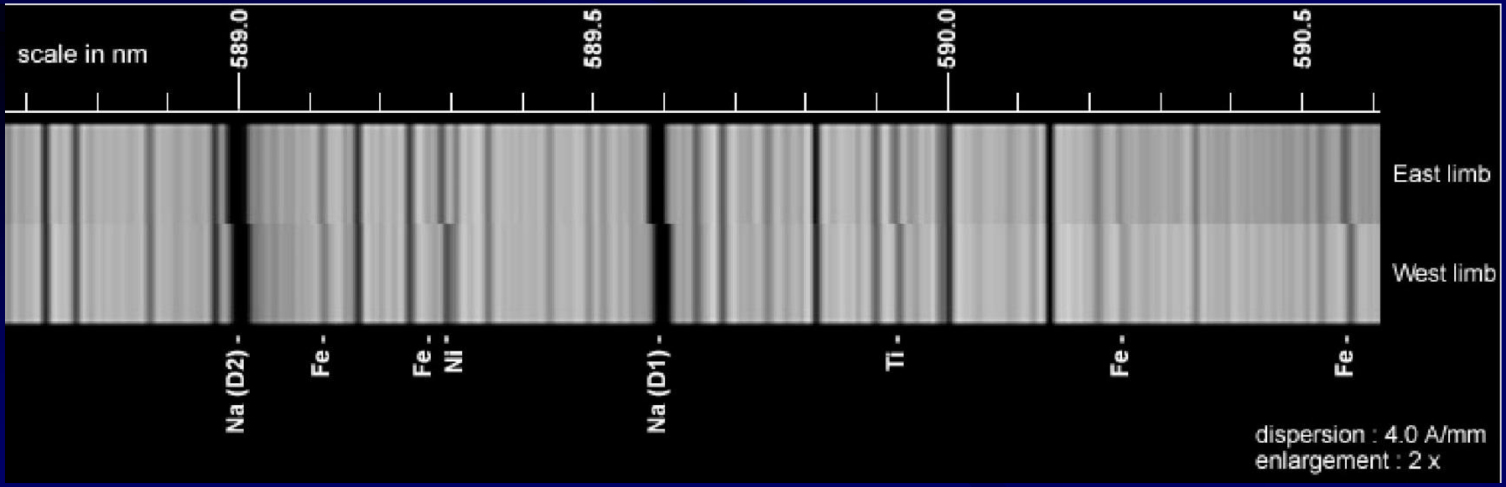


Doppler Shift applied to Sun's Rotation



Vogel (1871): Sun rotates, so its eastern limb is coming towards us ➔ blue-shifted spectral lines

➔ Accurate measurement of sun's rotation period



Conclusions II

- Understanding planetary motion allowed for a different view and method of description of the cosmos
  - Orbits of planets instead of concentric, impenetrable spheres
  - Stars are very far away
  - Parallactic measurements are possible
  - Formulation of description of the universe in mathematical language
- Advances in technology (telescopes, spectral lines, Doppler shift) allow for observation of much finer details of patterns in Nature