The Search for Other Earths

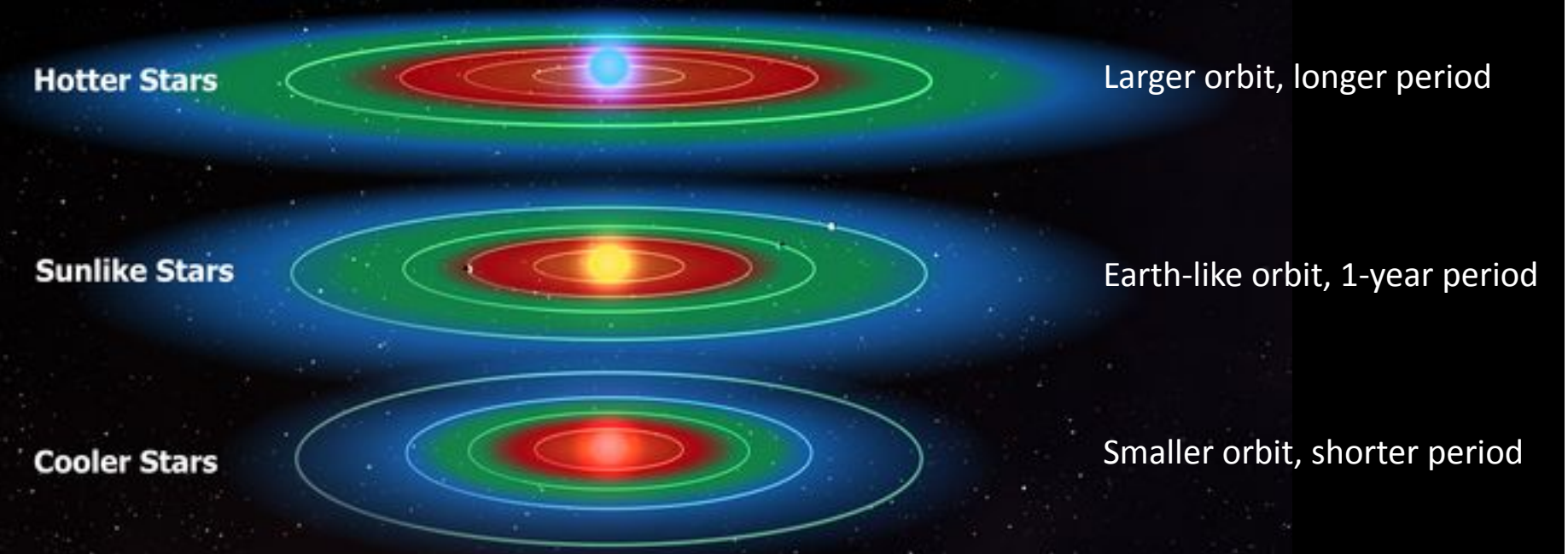
Class 2: Stars

Steve Bryson

Questions?

What We're Looking For

- An Earth-size, rocky planet in the Habitable Zone
  - Not too hot, not too cold for liquid water



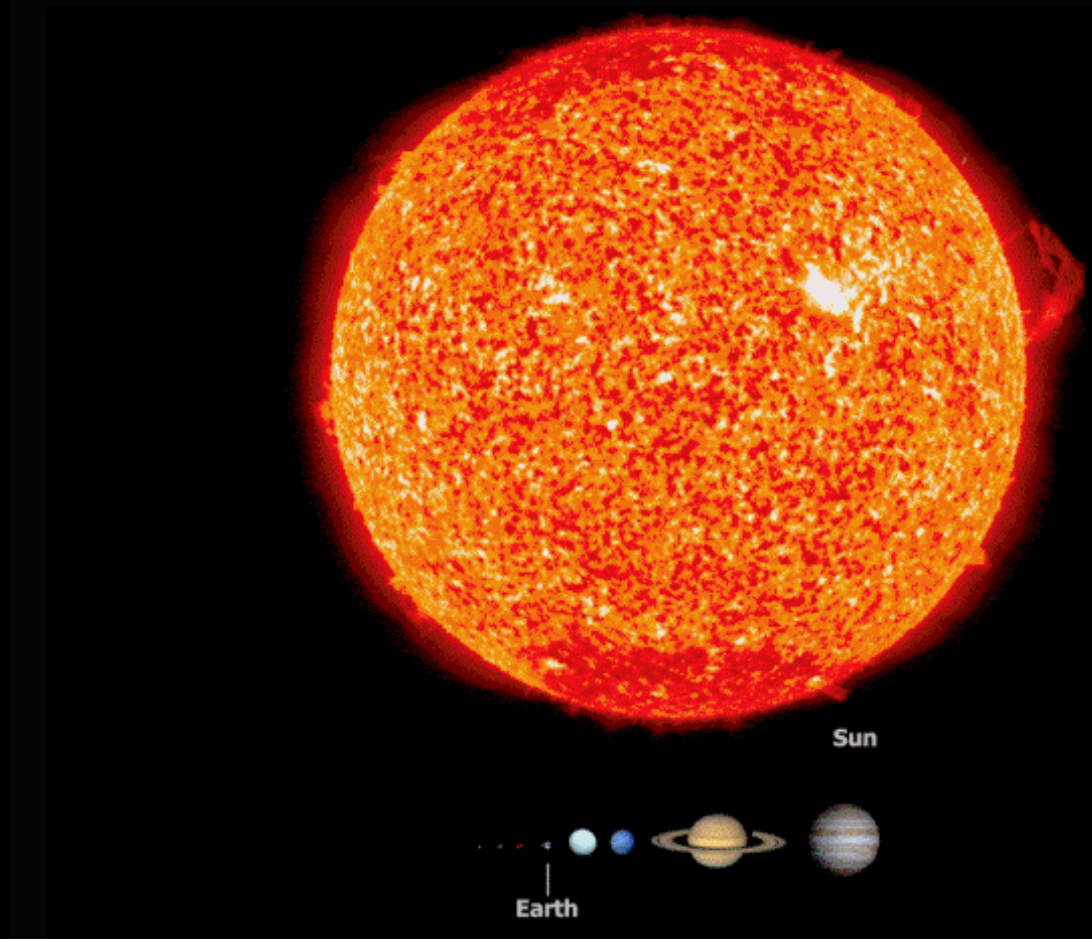
What Do We Need to Know About Stars?

What Do We Need to Know About Stars?

- How hot they are
- How bright they are
- How far away they are
- How big they are
- We'll learn all this from starlight

Stars are Big!

- The Sun is about 100 times the size of Earth



Stars are Really Far Away

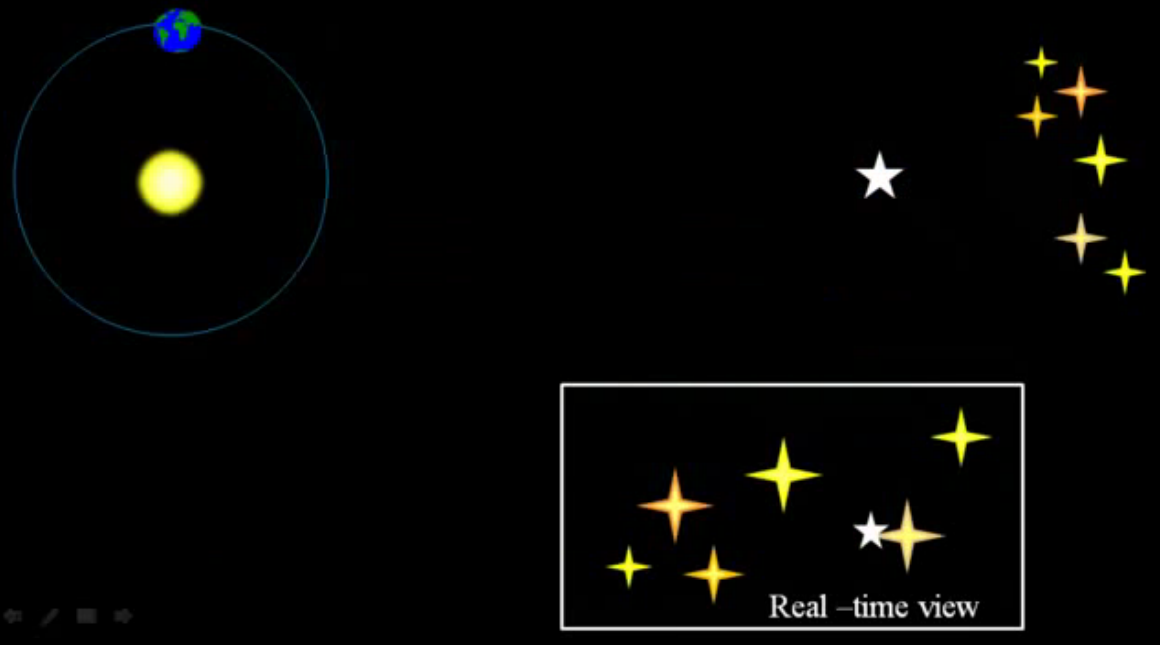
- If the Earth were the size of a basketball…
  - The Moon would be 75 feet away
  - The Sun would be about 250 feet across
  - The Sun would be 5.5 miles away
  - The nearest star would be 1.4 million miles away
    - 10,000 times the distance to the moon
  - A typical star in the sky would be a billion miles away
    - About as far as the orbit of Uranus

Distances to Stars

- We measure distances to nearby stars by watching how their positions change relative to background stars as the Earth orbits the Sun

Distances to Stars

- We measure distances to nearby stars by watching how their positions change relative to background stars as the Earth orbits the Sun



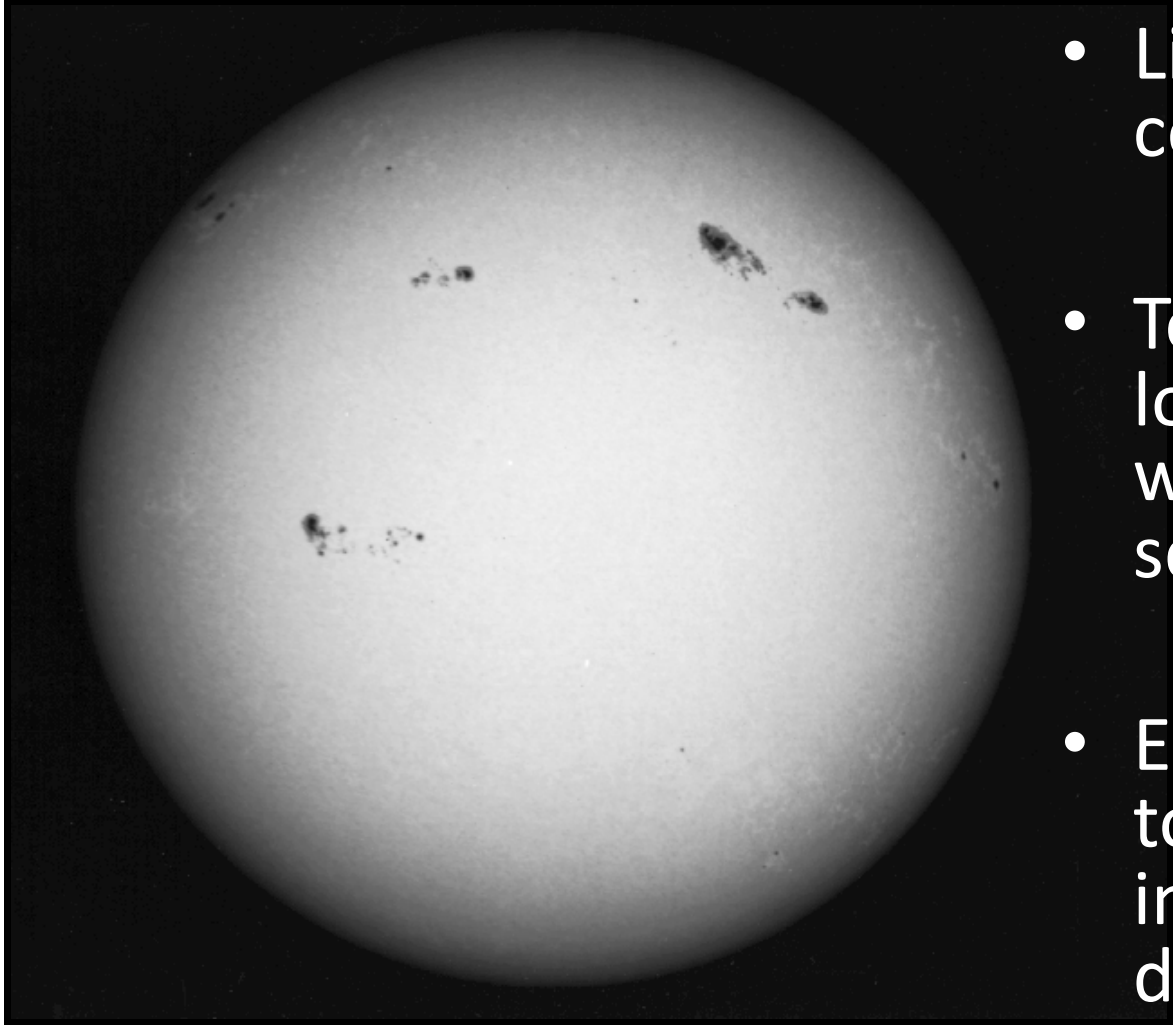
Back to the iPad

But What Are Stars?

"...balls of gas burning billions of miles away"

- Pumbaa, *the Lion King*

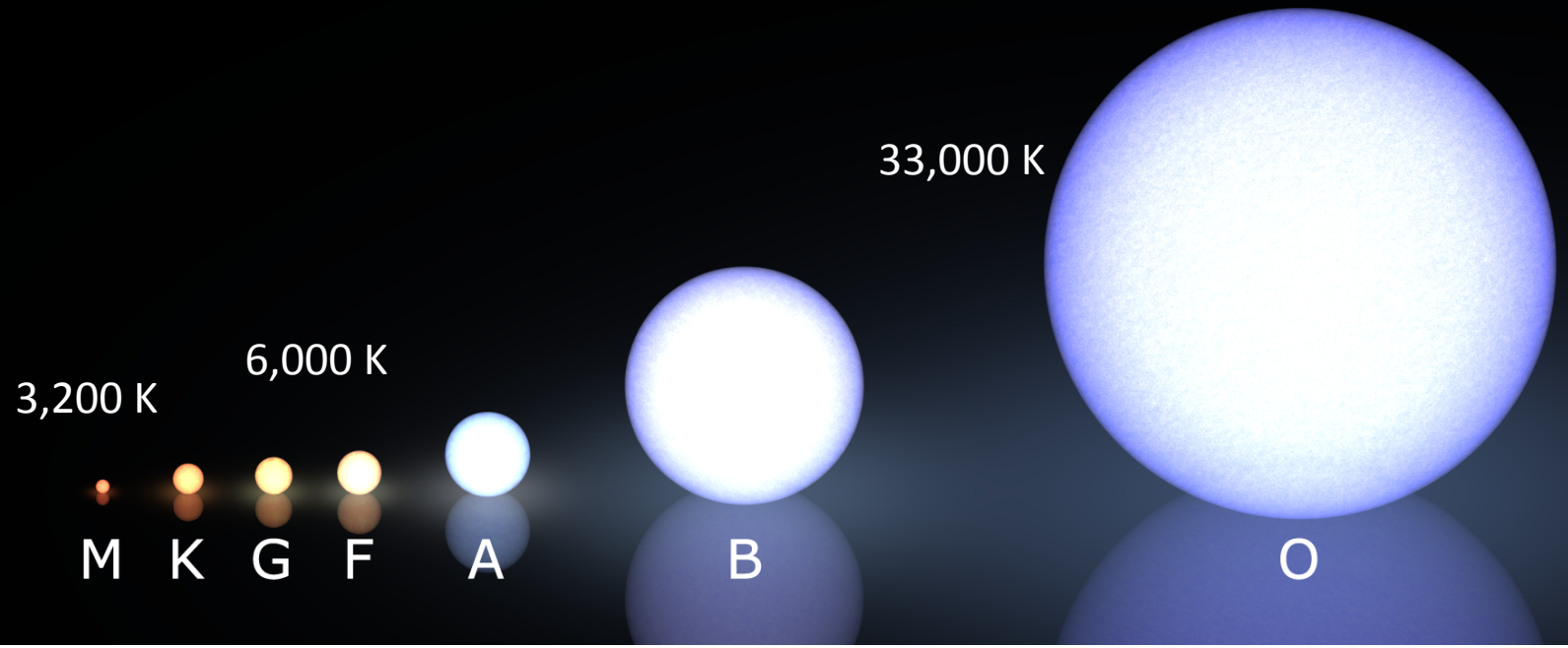
Big Ball of Gas Glowing from the Inside



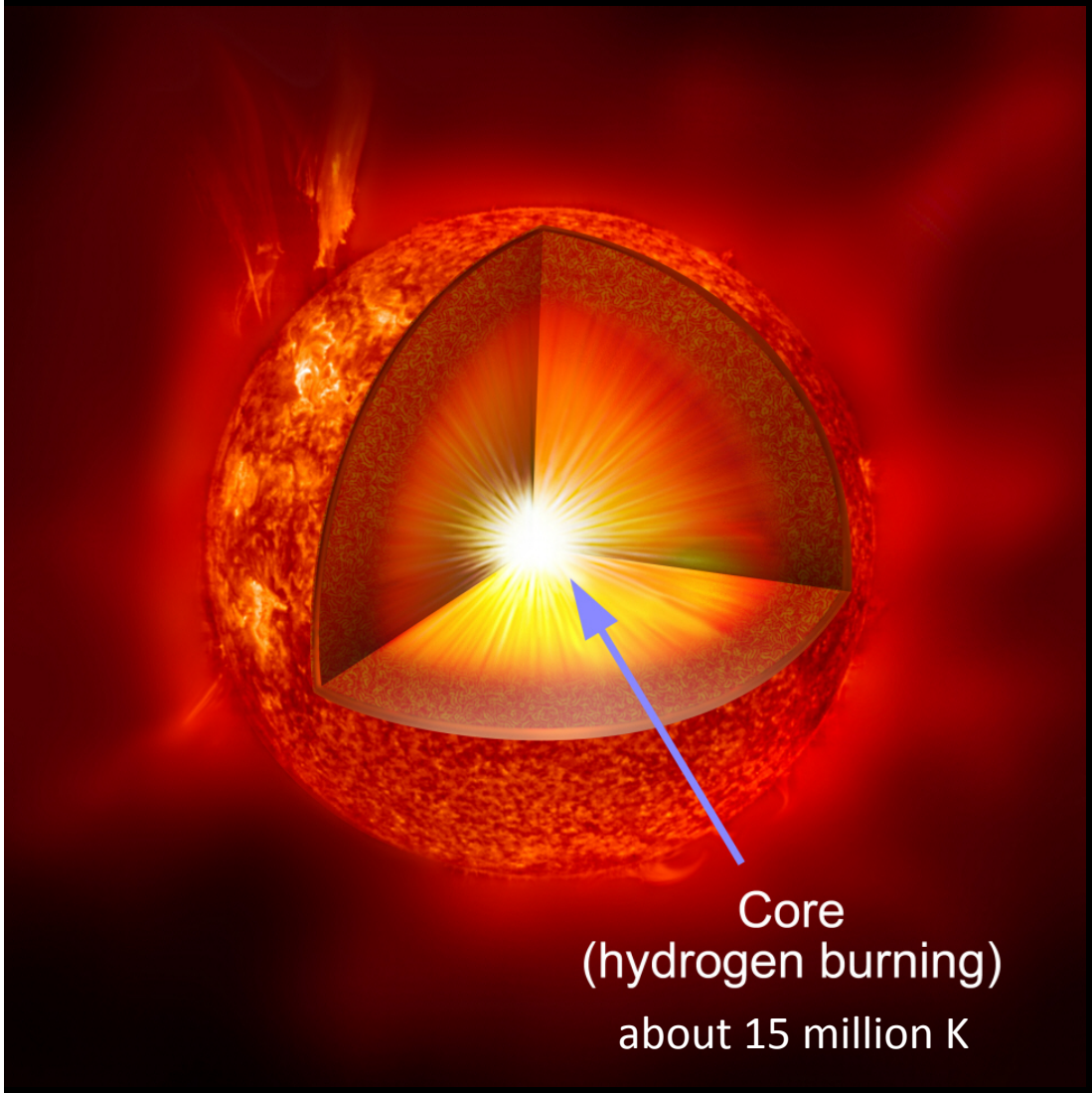
- Light is created in the center
- Towards the edge it looks darker because we're seeing light scattered by the gas
- Exactly how it darkens toward the edge is important for planet detection

Temperature Determines Color

- All materials glow with the same color at the same temperature
  - Orange coals are about 1,000 K = 1,340° Fahrenheit
- The temperature of the surface of the star determines the color
  - The Sun is about 5,800 K = 9,941° Fahrenheit

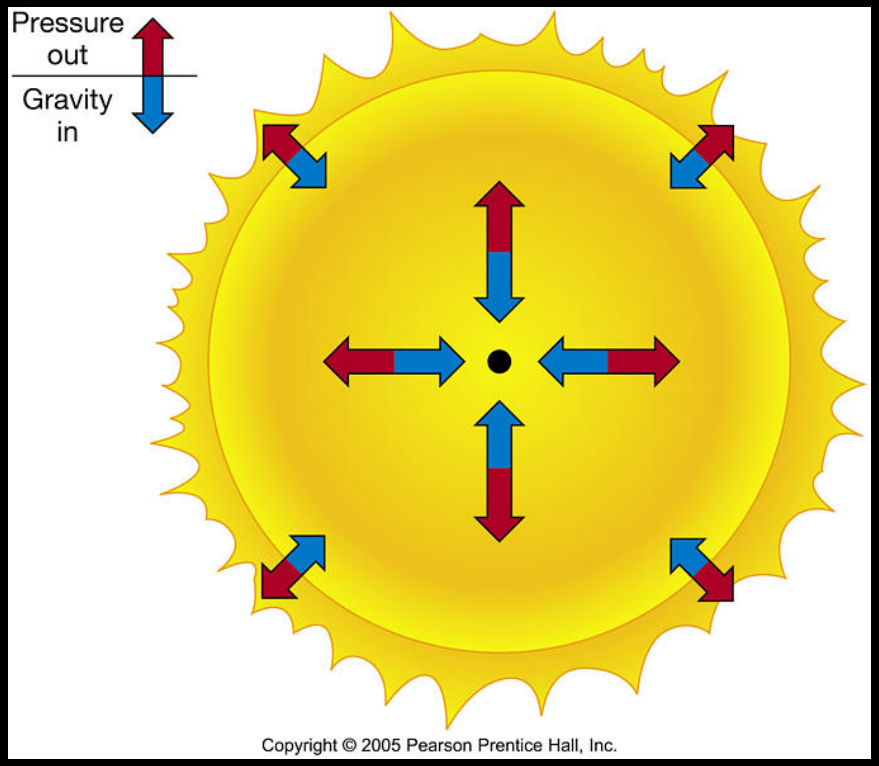


Most Stars Shine by Burning Hydrogen



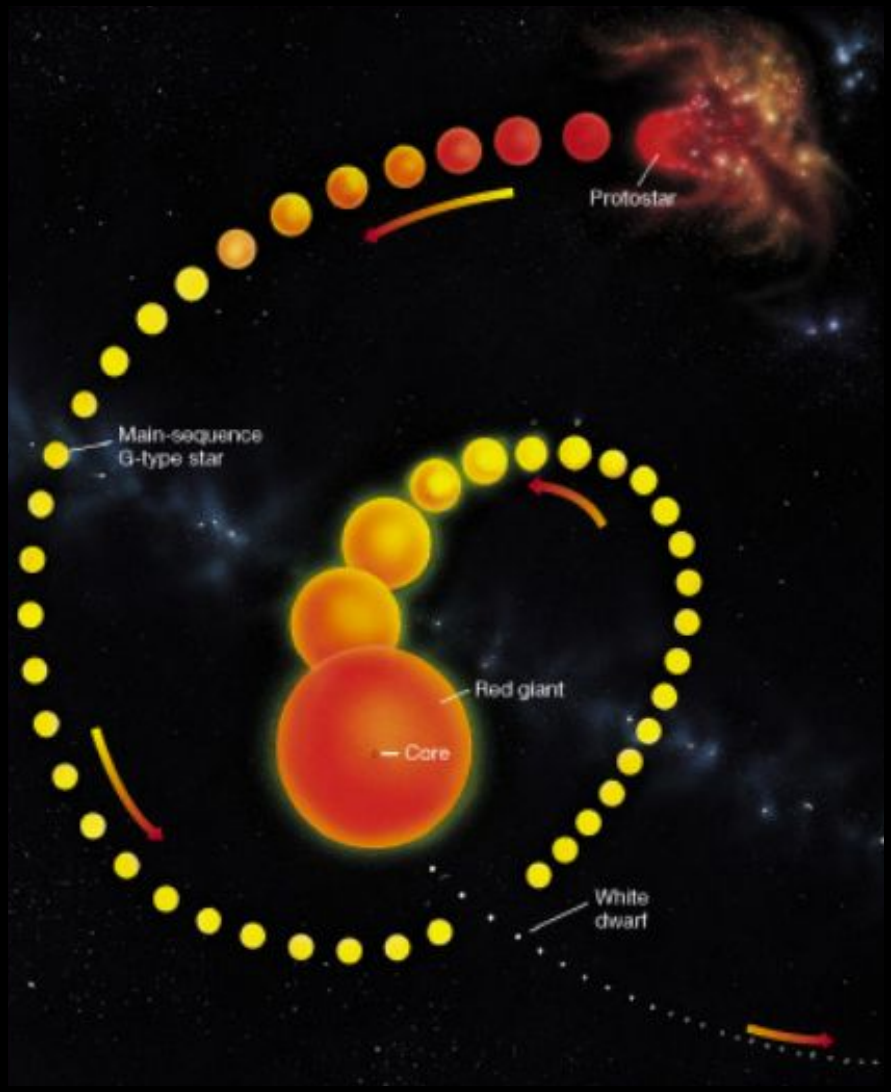
- Hydrogen fusion in the center
- Caused by the very high pressure and temperature from gravity
- Older stars burn heavier elements

The Stellar Thermostat



- If the star expands,
  - The center cools
  - So less force from the center
  - So gravity makes it contract
  - Which heats the center
  - Which makes the star expand…
- A stable star is in perfect balance

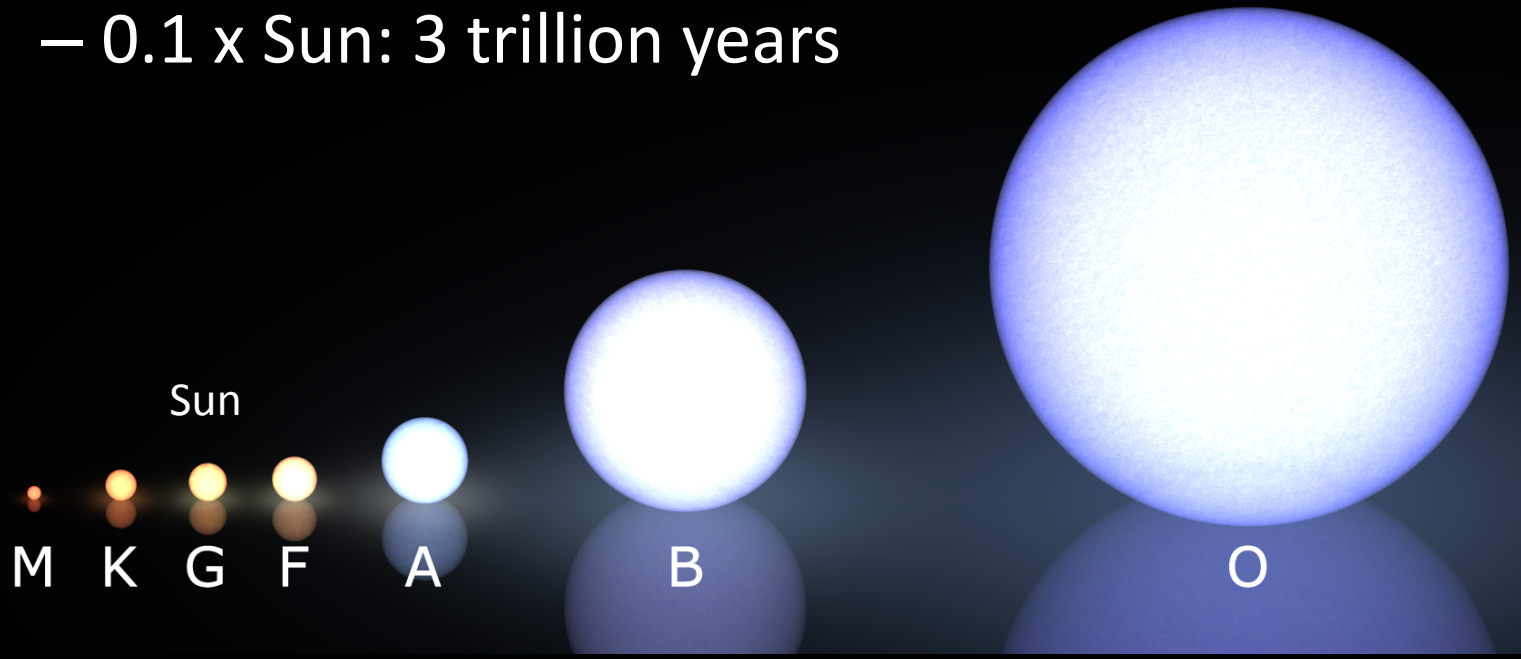
Life Cycle of Stars



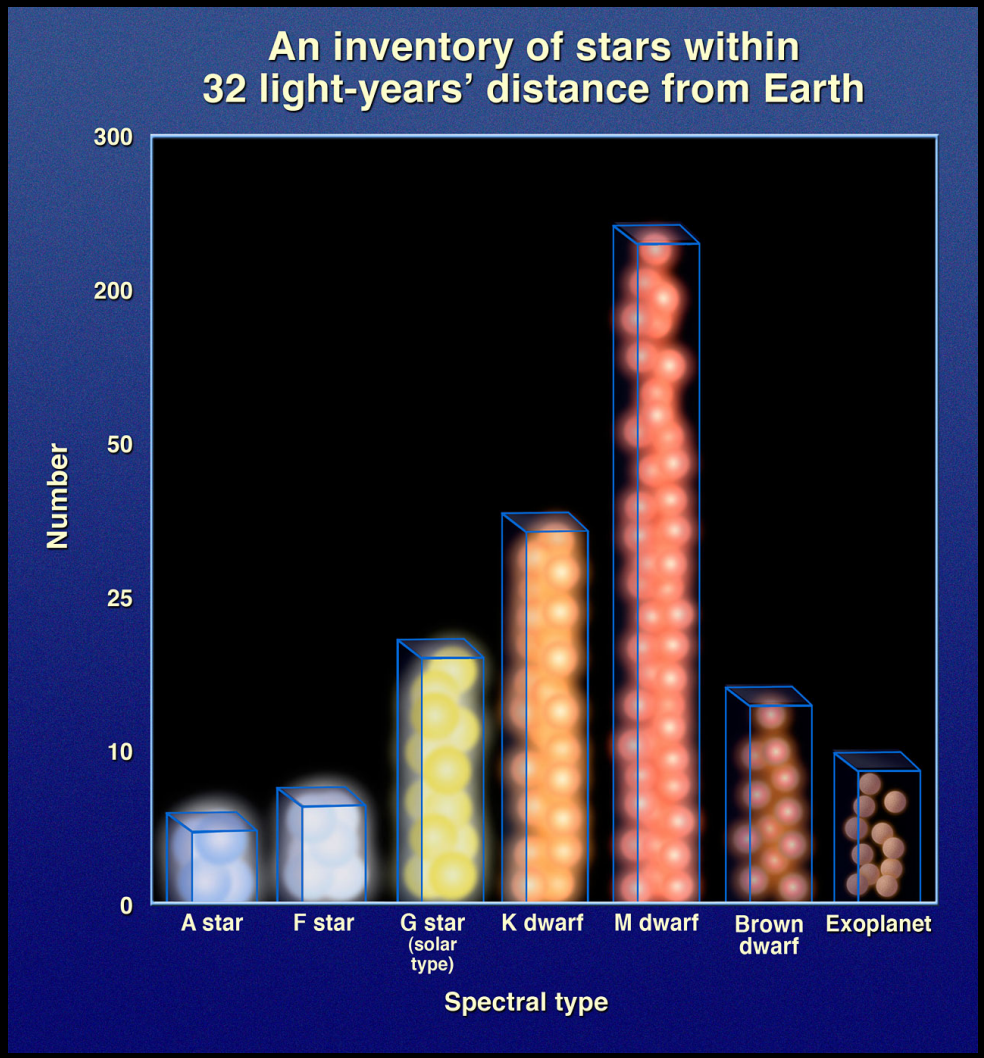
- Most of the time in the "Main Sequence"
  - The time of Hydrogen burning
- Total lifetime depends on mass
  - The heavier the star the shorter the life

Size, Color and Lifetime Depend on Mass

- Heavier stars burn faster and hotter
  - 10 x Sun: 32 million years
  - Sun: 10 billion years
  - 0.1 x Sun: 3 trillion years



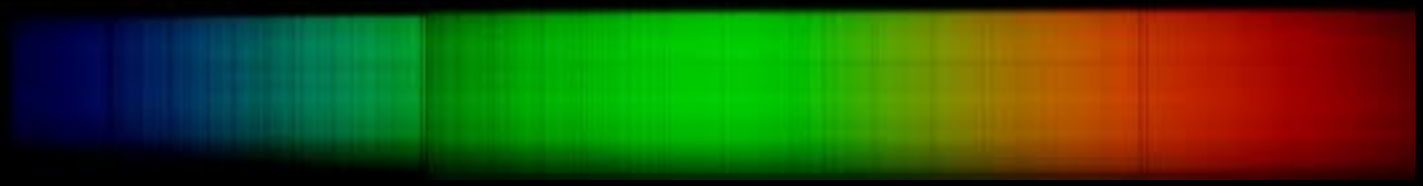
Distribution of Star Sizes



- There are many more small, cool stars

More From Starlight

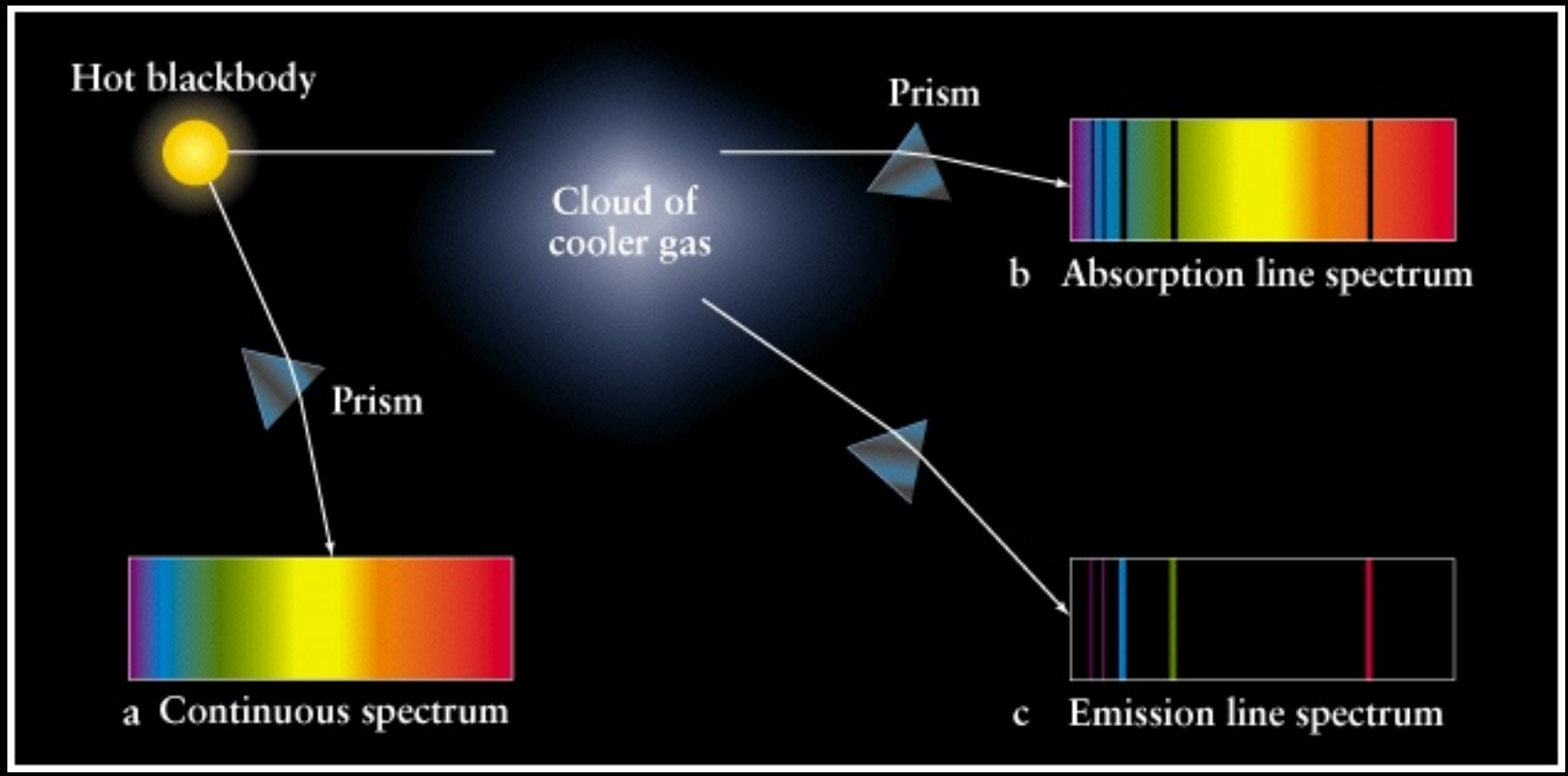
- We can break starlight into its colors by using a prism (or diffraction grating)
- The resulting rainbow is called a spectrum
- Many rainbows are called spectra
- We can learn many things from spectra



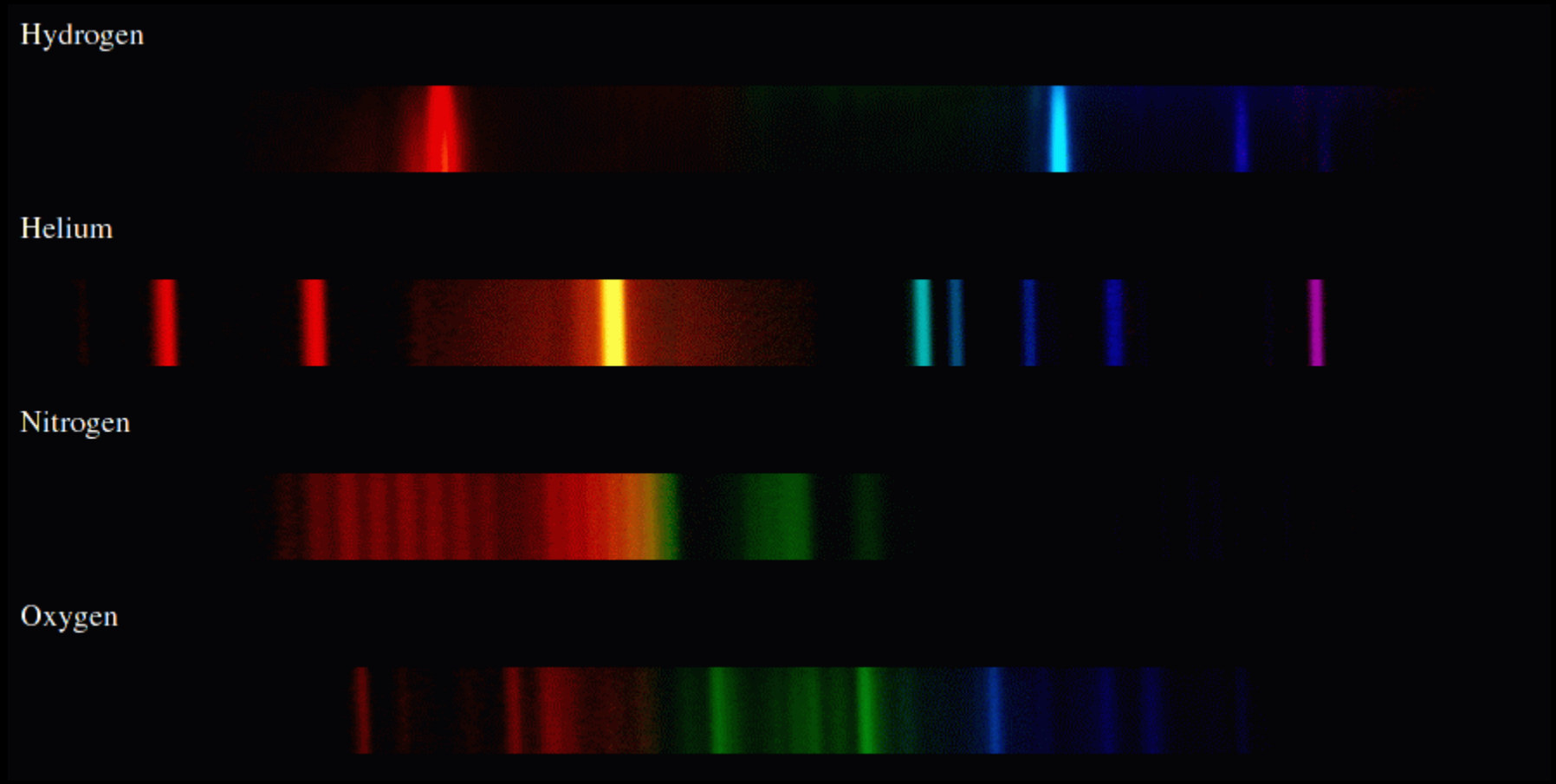
Try Your Spectrum

Spectra

- Gas absorbs light of very specific colors
- Then re-emits the same colors

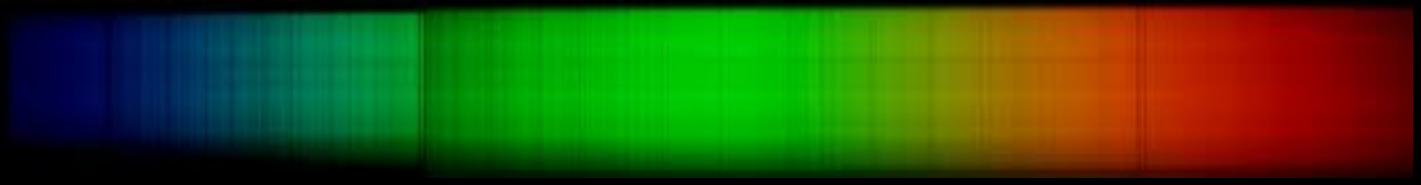


Example Gases and their colors

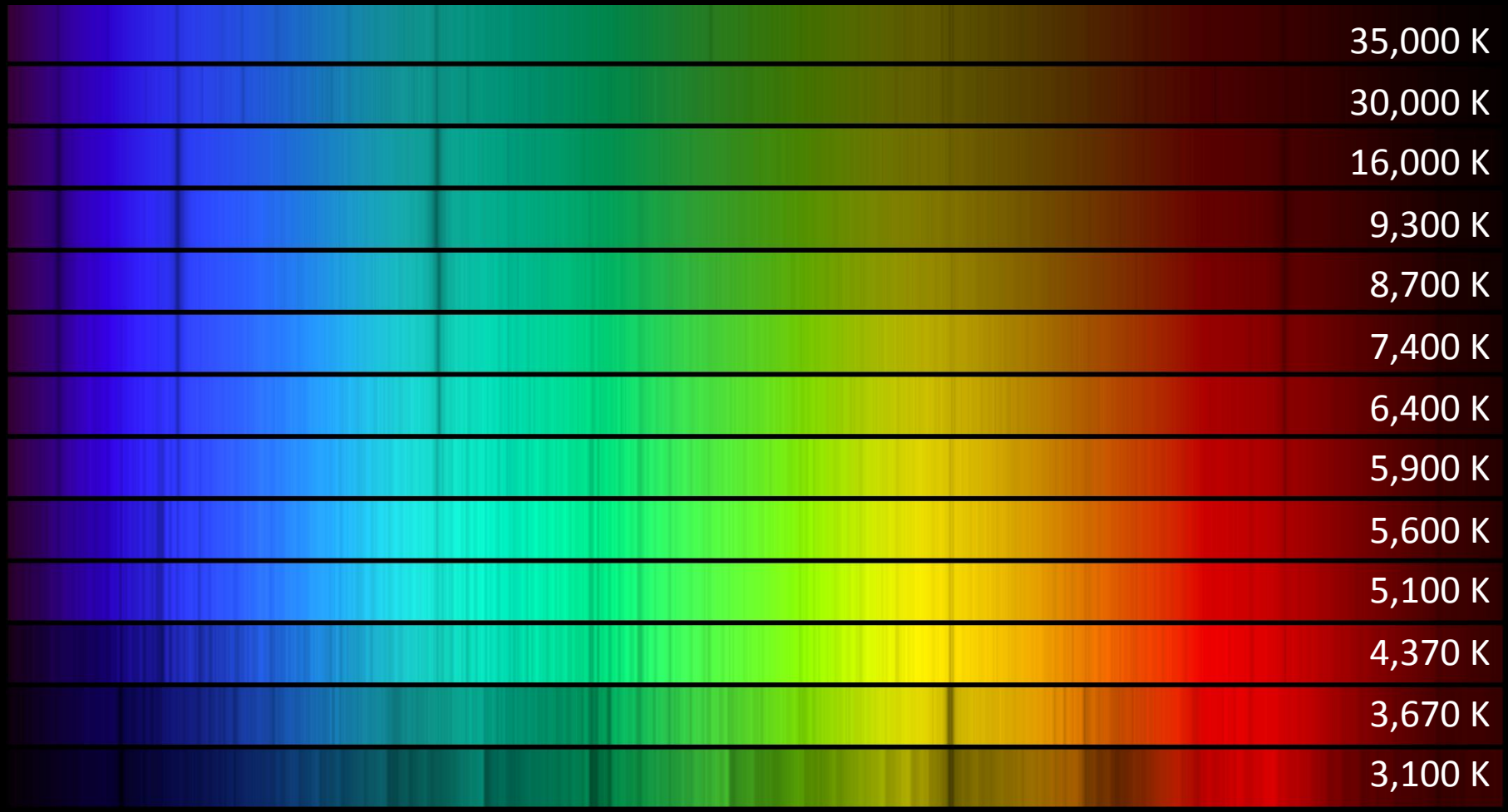


Measuring the Composition of Stars

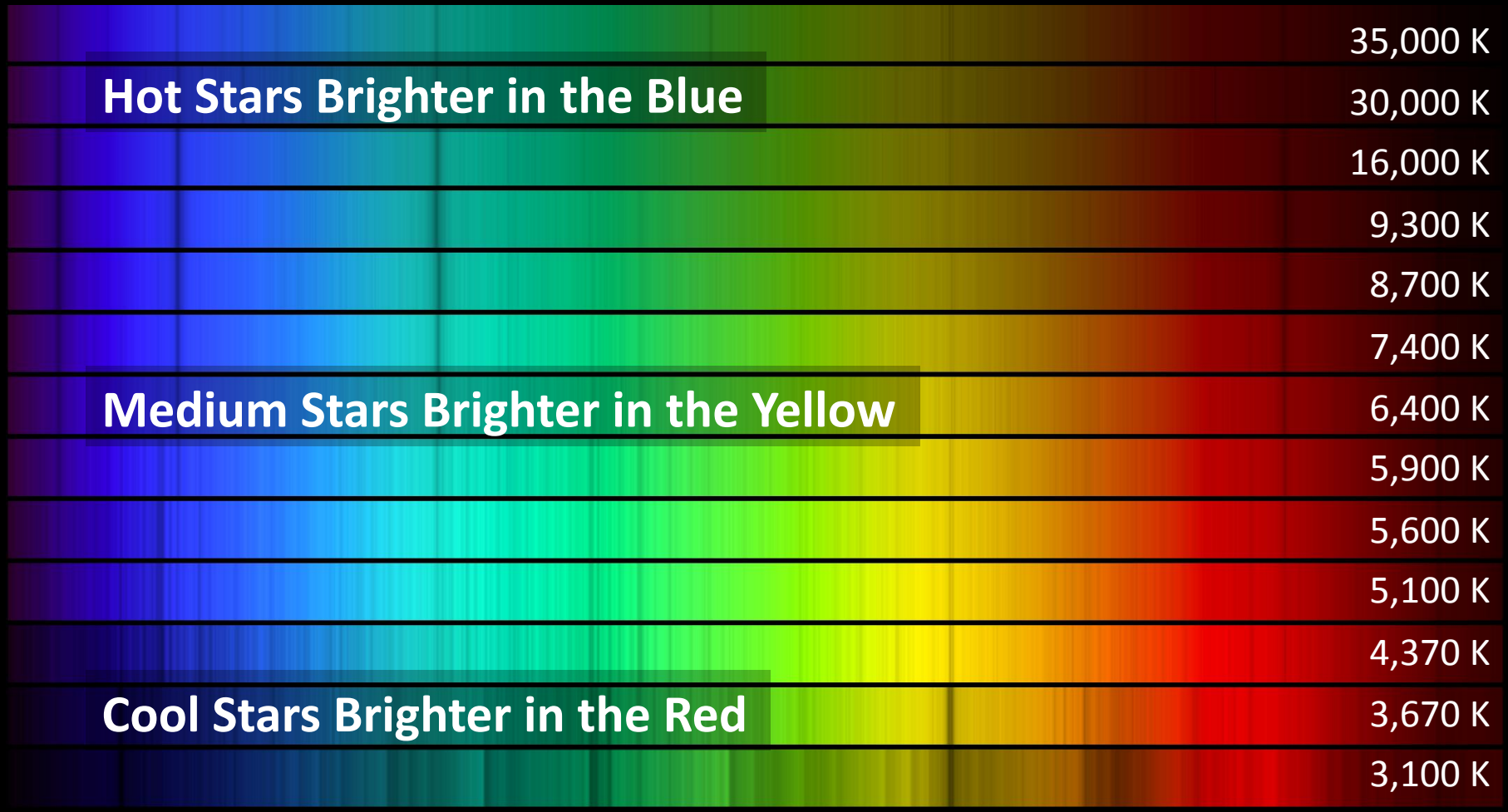
- The light from the center of the star goes through the star's atmosphere
  - Gases in the star's atmosphere absorb the light, creating lines in the spectrum
- The star's absorption lines are at the same colors as those we see in spectra on Earth
  - So they must be due to the same gases!
  - So we can say what Stars are made of!!



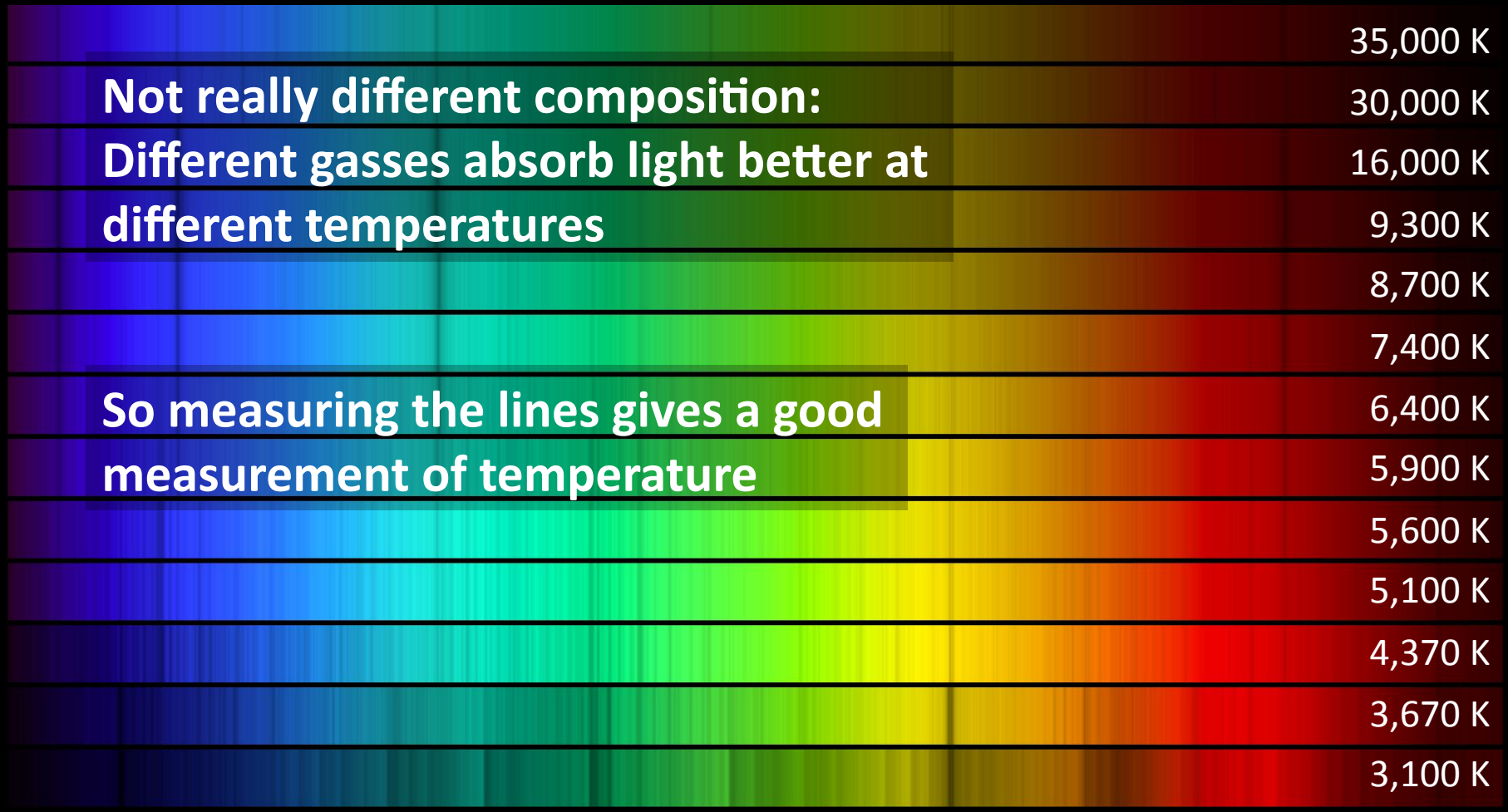
Star Spectra of Different Temperatures



Color Depends on Temperature



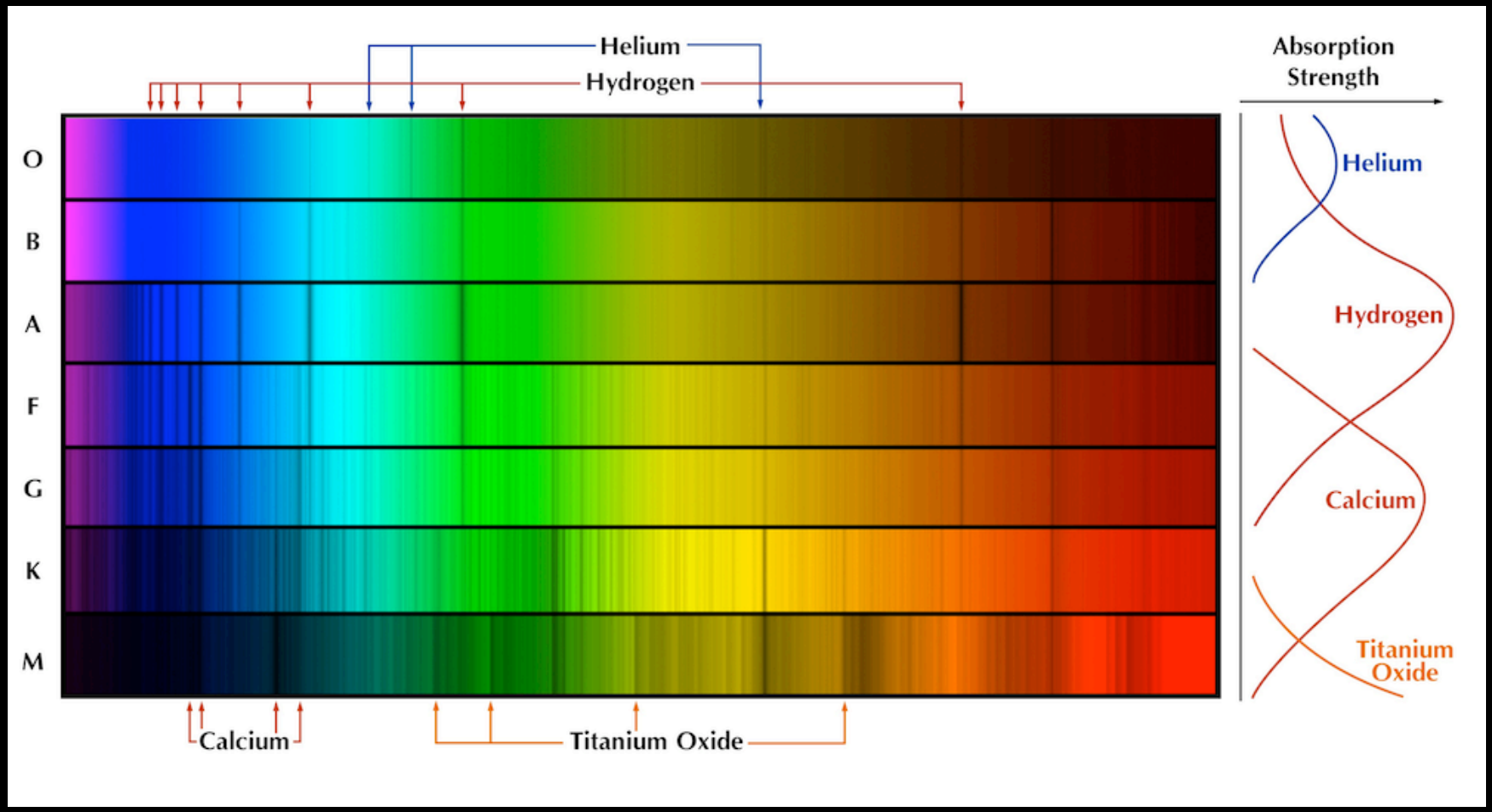
Lines Depend on Temperature



Not really different composition:
Different gasses absorb light better at different temperatures

So measuring the lines gives a good measurement of temperature

Example Gasses and how their Absorption Depends on Temperature

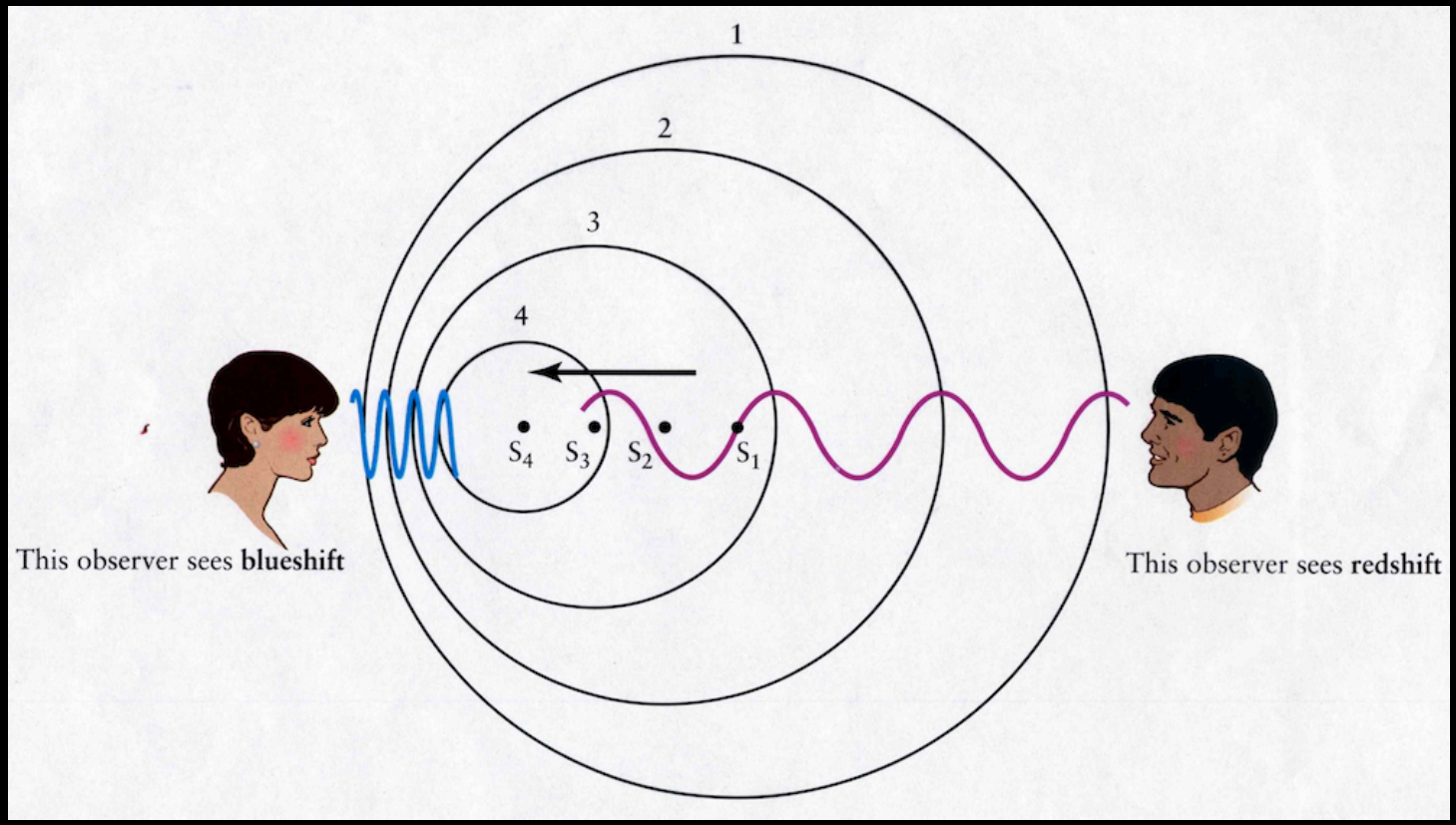


Doppler Effect

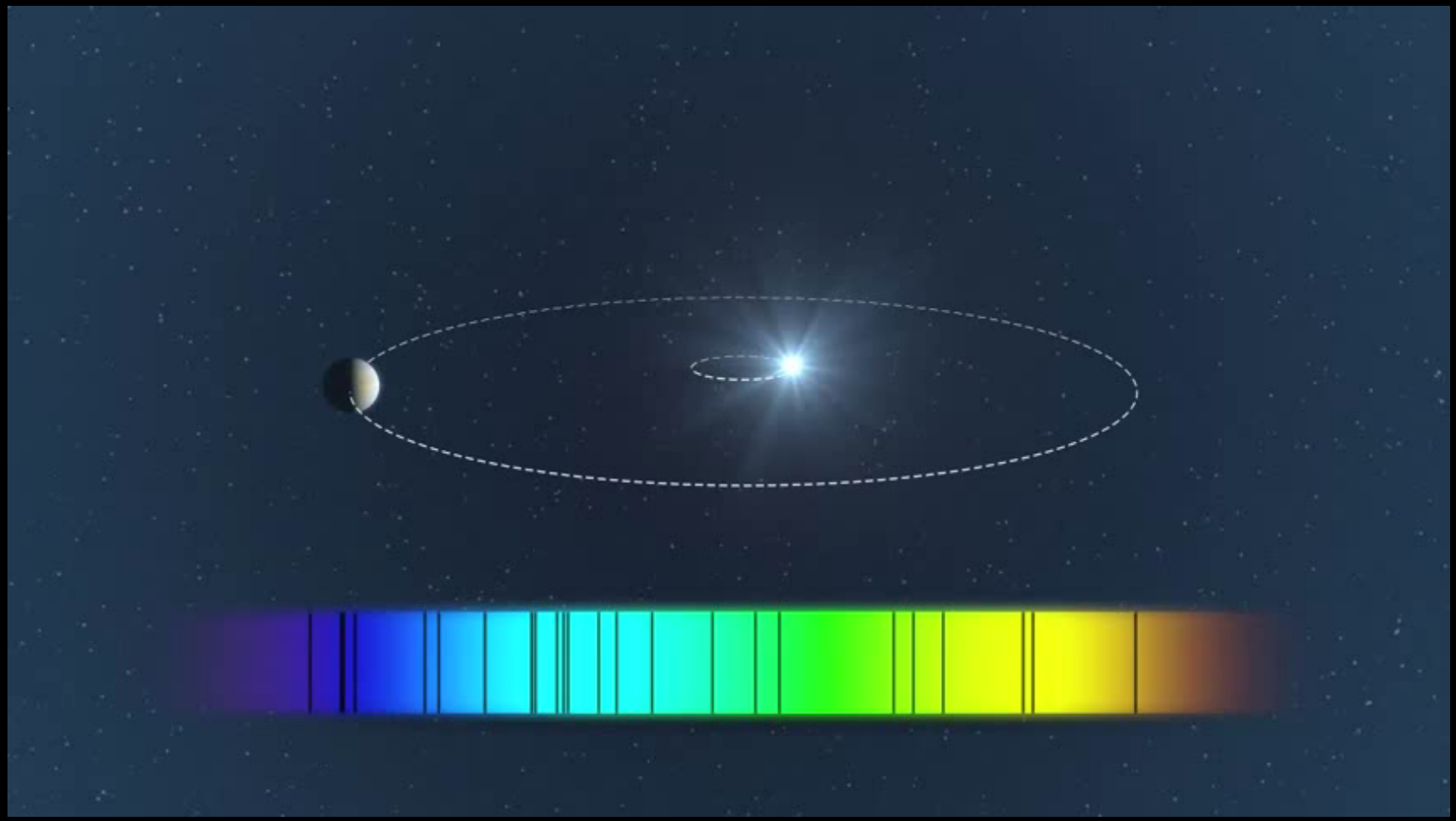
- Light is made of waves
  - in the electromagnetic field
  - Just like for sound waves, if the source is moving towards you it sounds like a higher frequency
    - Sound: higher pitch
    - Light: more blue
  - Moving away: lower frequency
    - Sound: lower pitch
    - Light: more red

Doppler Effect

- Something moving away looks redder
- Something moving closer looks bluer



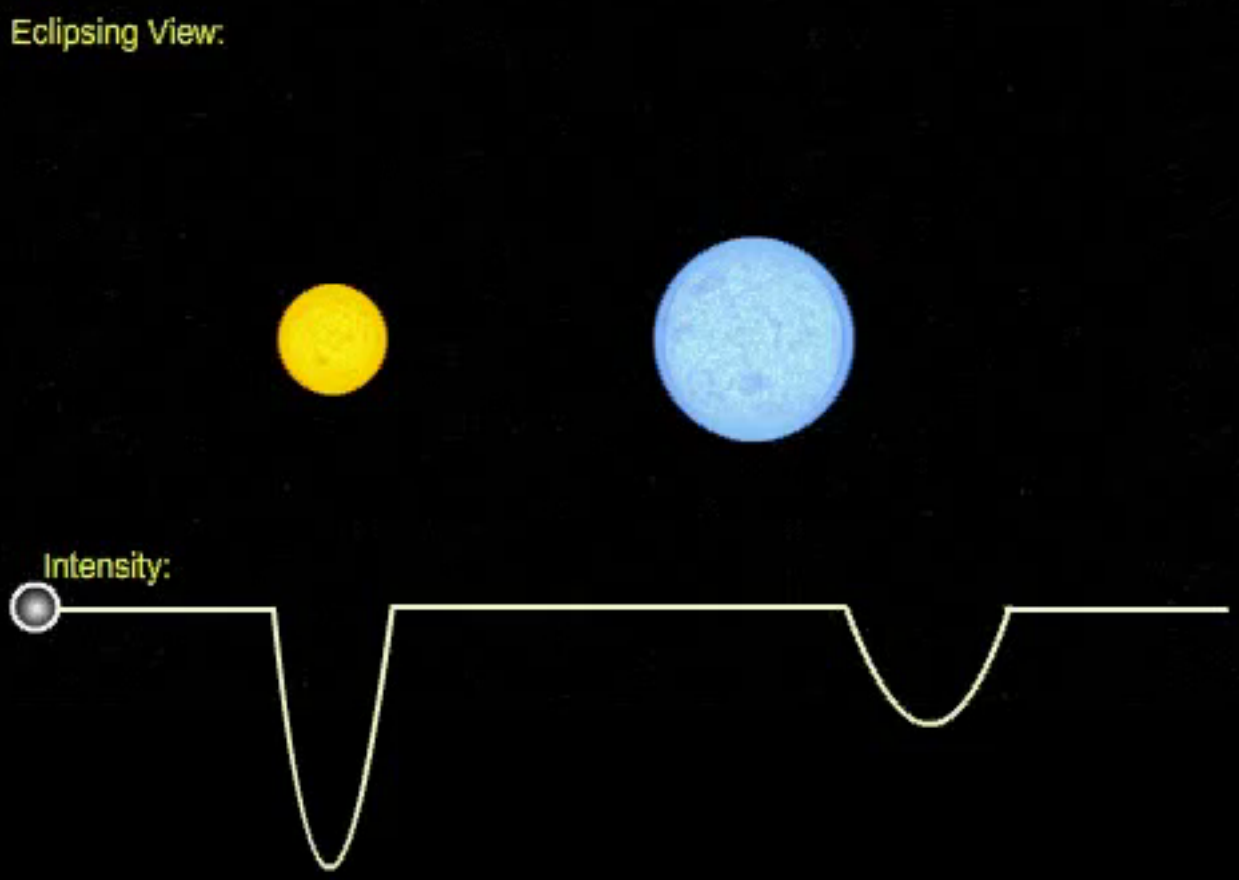
Doppler Effect for Things Orbiting Stars



Multiple Star Systems

- Half the “stars” in the sky are actually more than one star orbiting each other
- From the Doppler effect in the spectra we can measure the stars’ orbits
- From the orbit we can measure the stars’ masses

Eclipsing Binaries



- If we're in the right place the stars will sometimes block each other
- So the pair gets dimmer
- Tells us relative size

Important Facts About Stars for Planet Detection

- They are big balls of gas that shine from the inside
  - Light absorbed by their atmosphere
    - Creates spectral lines
      - Measure composition and motion
- They are very far away
- They live a long time
  - Size, temperature and color determined by mass
- The spectral lines can tell us how the star moves
- Sometimes stars orbit each other
  - Eclipsing Binaries
  - Lets us measure mass