Sun light, blackbodies & spectra

Week 5

Remember:



• Sun is 99.9% of the mass of Solar System

Sun's composition is mostly H, with lots of He and a little bit of other elements

TABLE 8-1The Most Abundant Elements in the Sun

| Element | Percentage by Number of Atoms | Percentage by Mass | | | |
|--------------------------------------|----------------------------------|-----------------------|--|--|--|
| Hydrogen | 91.0 | 70.6 | | | |
| Helium | 8.9 | 27.5 | | | |
| Carbon | 0.03 | 0.3 | | | |
| Nitrogen | 0.01 | 0.1 | | | |
| Oxygen | 0.05 | 0.6 | | | |
| Neon | 0.01 | 0.2 | | | |
| Magnesium | 0.003 | 0.07 | | | |
| Silicon | 0.003 | 0.07 | | | |
| Sulfur | 0.002 | 0.04 | | | |
| Iron | 0.003 | 0.1 | | | |
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Sun's surface Temperature is 5500 °C



• How do we know the properties of the Sun?

Mass? Temperature of the Sun? Composition of the Sun?

How do we know the mass of the Sun?

- A. We measure the pull of gravity on the Earth and Moon.
- B. We observe the orbital periods and distances of planets.
- C. We track the rise and fall of tides in Earth's oceans.
- D. We estimate mass based on what the Sun is made of.

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Recall, combining Kepler and Newton:

$$P^{2} = \left(\frac{4\pi^{2}}{GM}\right)a^{3} \quad \longrightarrow \quad M = \left(\frac{4\pi^{2}}{G}\right)\frac{a^{3}}{P^{2}}$$

What is Mass?

• Physical body that accelerates when a force is applied to it

- Material
- Generally, material is made of *elements*

| period 1 | group 1 1.00794 Las 1 Hydrogen | 2 | The Periodic Table of the Elements | | | | | | | | | | | | | 18 4.002602 2 Helum | | |
|---|--|---------------------------------------|--|-----------------------------------|-------------------------------------|---|-----------------------------|--|---------------------------------|--|---|---|------------------------|--|--|--|------------------------------------|--------------------------------|
| 2 | 6.941 am 3 Lithium | 9.012182 Beeylitum | or most stable mass number 1st ionization energy in k1mpt chemical symbol | | | Fe +5 +1 | | alkaline metals other metals transition metals | | nonmetals halogens noble gases | | Boron Branar | Carbon | 14.0067 Sins Sin 7 Navogen Interfer | 15.9994 8 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 | 18.998403 9 Jenus kar Fluorine Let 20120 ¹ | 20.1797 10 Meon Neon Meon | |
| 3 | Na Sodium | Magnéslum Pecter | name | | | Iron -1 Oxidation states [Ar] 3d ⁶ 4s ² -2 most common are bold 5 6 7 8 | | actinoids 9 10 | | adioactive elements have masses in parentheses | | Aluminium | Silicon | Phosphorus per la ray | Suttur focur at | Chlorine | Argon Prefer set | |
| 4 | Potassium | Calcium | 44.95591 21 Scandium Scandium | 47.867 mar Lba 22 Titanium | Vanadium | Chromium | Manganese | 55.845 Econ (c) af ar | 58.93319 27 CODAT (00 DAT | 58.6934 28 Nickel | 63.546 Copper Copper (copper (copper) | ^{65,38} 30 Zn Znc No.147 40 | Gallium | Germanium | Arsenic | Selenium | Bromine | Krypton |
| 5 | Rubidium | 87.62 583 88 38 Strontum | 88.90585 39 | 91.224 40 Zirconium | 92,90638 41 NL LIN 41 Niobium | 95.96 42 Molybdenum | (98) 43 TC Technetium | Ruthenium | Rhodium | 106.42 46 Pd Palladium | 107.8682 47 | Cadmium | Indium | 118.710 50 Sn Tin | 121.760 51 Sb Antimorry | Tellarlum | 126.9044 53 | Xenon |
| 6 | 132 9054 55 2017 0.79 Caesium Caesium | 137.327 56 Baa Baanum Baanum | Lutetum | 178.49 72 Hf Hathium | 180.9478 73 7810 150 Tantalum | 183.84 74 W Tungsten | Rhenium | 190.23 Total 2 and 76 OS Osmium | 192.217 77 | 195.084 78 Platnum | 196.9665 79 Au Gold | 200.59 801.1 200 80 Hg Mercory | 204.3833 81 | Pb | 208.9804 83 Bi Bismuth | Polonium | (210) 85 At Astatine | Radon |
| 7 | (223) and 87 Francium | Radium | (262) 103 Lawrencium | (261) 104 Ref Rutherfordium | (262) 105 Db Dubnium | (266) 106 Sg Seatorgium | (264) 107 Bh Bohrium | (277) 108 Hassium | (268) 109 Mt Meitherium | (271) 110 DS Darmstadium | (272) 111 Rg Roentgenium | (285) 112 Con Copernicium | (284) 113 Ununatium | ⁽²⁸⁹⁾ 114 Ferovium | (288) 115 Uup Ununpentium | (292) 116 | 117 Uus Ununseptum | (294) 118 Uuo Ununoctium |
| Image: section configuration blocks Image: section configuration blocks Image: section configuration blocks Image: section configuration blocks Image: section configuration blocks Image: section configuration blocks Image: section configuration blocks Image: section configuration blocks Image: section configuration blocks Image: section configuration blocks Image: section configuration blocks Image: section configuration blocks Image: section configuration blocks I | | | | | | | | | | | | | | | | | | |

Elements, atoms & compounds



Atoms

- Nucleus
 - Protons (+ charge) [p⁺]
 - Neutrons (no charge) [n⁰]
- Orbitals
 - Electrons (- charge) [e⁻]
- Type of element = # of p⁺
- Atomic mass = $p^+ + n^0$
- Electrons
 - important for bonding
 - interact with electromagnetic radiation





Atoms and EM radiation

• Electrons move and atoms vibrate, which releases energy

Blackbody radiation ('continuous spectra')

- Electrons in specific/discrete orbitals that have specific energy associated with them
 - Electrons move between orbitals
 - Specific orbitals depend on the number of protons (i.e., the element of the atom)



What is a Blackbody?

Definition:

Sometimes astronomers use the term ``blackbody'' spectrum for a thermal spectrum. A ``blackbody'' is an object that absorbs all the *light falling on it, reflecting none of* it, hence, it appears black. When the ``blackbody" object is heated, it emits light very efficiently without any gaps or breaks in the **brightness**. Though no object is a perfect ``blackbody'', most stars, planets, moons and asteroids are near enough to being ``blackbodies'', that they will produce spectra very similar to a perfect thermal spectrum.

10 ultraviolet visible infrared 8 I (arb. units) 6 T = λ_{max} 6000 K Intensity 5000 K λ_{max} 4000 K 2 3000 K 1.0 2.00 3.0 Wavelength λ (µm)

Blackbody curves

Blackbody curves

Flux (or intensity, radiance)

Amount of radiation ≈ number of photons



Wavelength (in units of m, μ m, or nm)



http://astro.unl.edu/classaction/animations/light/bbexplorer.html

Thermal emission produces continuous spectra.



Note that temperatures are given in Kelvin

Degrees Fahrenheit (°F) \rightarrow Degrees Celsius (°C)

$$^{\circ}C = (^{\circ}F - 32) * \frac{5}{9}$$

Degrees Celsius (°C) \rightarrow Kelvin

 $K = {}^{\circ}C + 273.15$



0 K = "absolute zero" (atoms stop vibrating)

Wien's Law



For more info <u>http://hyperphysics.phy-astr.gsu.edu/hbase/wien.html</u>

The peak of the blackbody curve can tell you the surface temperature of the star using Wien's law but it can also tell you what color the star will appear.

Will the star that has a surface temperature of 6000K appear...

- A. Red
- B. Blue
- C. White

Wien's Law



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Actual spectral measurements of the Sun and Earth's Sky

Blackbody curves, but more complex



Spectrum of Solar Radiation (Earth)



The mean solar spectrum also contains absorption lines that <u>precisely</u> match the colors+wavelengths of **Hydrogen lines**.



Atomic structure: electrons orbit atomic nuclei in specific orbits/energy levels.

- Each orbit has a particular energy associated with it.
- To move from one orbit to another, an electron must absorb or emit energy.



Atomic emission: electrons can move to a higher energy level by absorbing a photon, or can move to a lower energy level by emitting a photon.



Atomic spectra: changes between different electron energy levels are associated with particular types of light.



Atomic spectra: each element has a unique pattern of energy levels, and thus produces a unique spectral pattern when atoms emit light.

Spectroscopy: The study of absorption and emission spectra. These spectra can tell you what elements are in the atmosphere of Stars like our Sun or can tell you what elements are in a gas being heated up.



The presence of Hydrogen absorption lines in the Solar spectrum proves that the Sun has a cooler 'atmosphere' containing Hydrogen.



Wavelength (nm)

Aug. 18, 1868: Helium Discovered During Total Solar Eclipse

http://www.wired.com/2009/08/dayintech 0818/



Activity 8: Light and Spectra

Pre-8.1: If you used a spectrometer to view a 500-W incandescent light bulb at full power, what colors would dominate the spectrum?

- a. only the blue-green part of the spectrum
- b. primarily the orange-red part of the spectrum
- c. the full continuous rainbow of colors
- d. bright lines at specific wavelengths

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Pre-8.2: If you used a spectrometer to view a 500-W incandescent light bulb dimmed to its lowest power, what color(s) would dominate the spectrum?

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- a. only the blue-green part of the spectrum
- **b.** primarily the orange-red part of the spectrum
- c. the full continuous rainbow of colors
- d. bright lines at specific wavelengths

Pre-8.3: If you used a spectrometer to view a 500-W incandescent light bulb at its brightest and then at its lowest power, what would happen to the overall intensity of the light?

- a. The overall intensity will not change very much.
- b. The overall intensity will be less because less power is being produced.
- c. The overall intensity will be more because more power is being produced.
- d. The overall intensity will depend on what kind of incandescent light bulb is being used.

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Unknown Elements

C = ?

Post-8.1: If we assume the incandescent light bulb is a good representation of how stars "work," we would conclude that

- a. the hotter the star is, the more luminous it is, and the brighter the colors will be overall.
- b. the cooler the star, the less luminous it is; the brighter part of the spectrum will be toward longer wavelengths.
- c. the luminosity of a star, its temperature, and the overall color pattern are all related.
- d. All of these answers are correct.

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Post-8.3: True or False: Because the heaviest elements in the periodic chart—tungsten, gold, mercury, lead—have so many electrons their emission spectra are identical.

a. trueb. false

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This concludes Activity 8: Light and Spectra

