Introductory Astronomy

Week 2: Newton's Universe

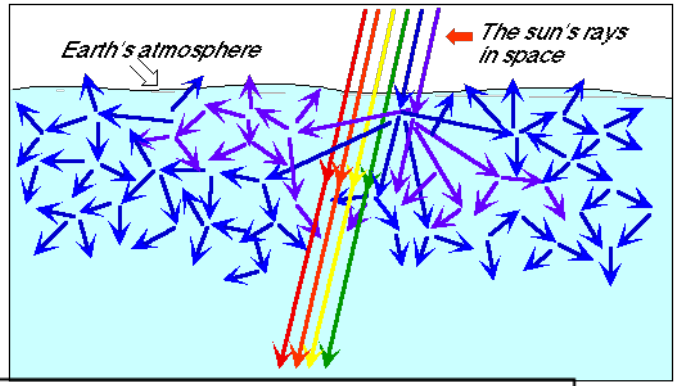
Clip 7: Matter, Radiation, Quantum Physics

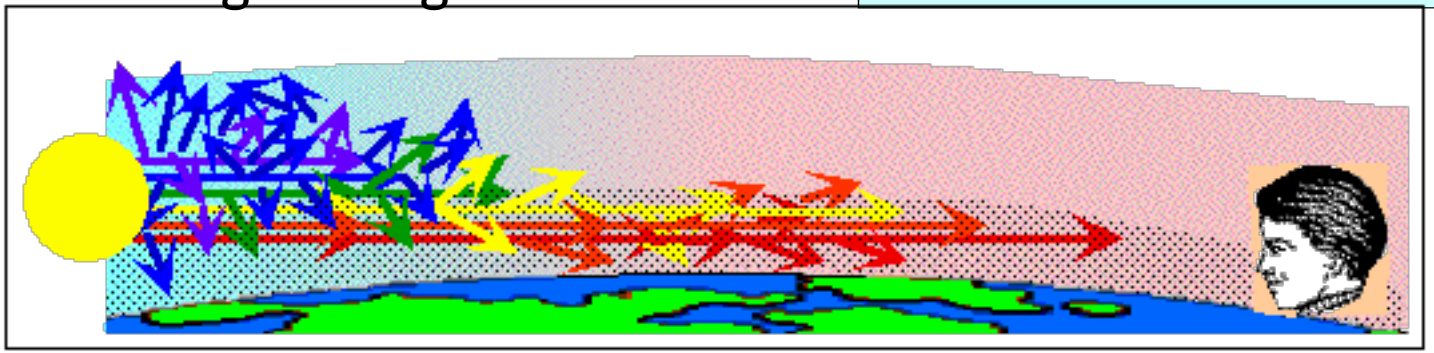
When Light Meets Matter

- Dense objects absorb light energy or reflect it.
- How much absorbed can depend on wavelength – dyes. Can learn composition from reflected spectrum
- Light scatters off tenuous matter (Rayleigh 1871)
- Scattering decreases with wavelength: blue scatters more than red

Scattering on Earth

- Atmosphere scatters blue light making sky glow blue and Sun appear yellow
- When we get more scattering – when Sun low in sky – lose green to scattering leaving Sun red





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Scattering and Refraction

Moon halo

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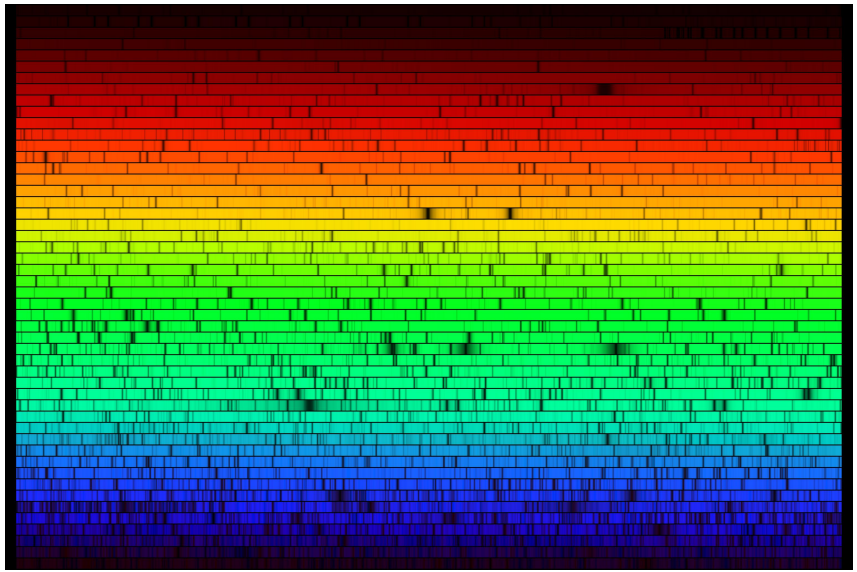
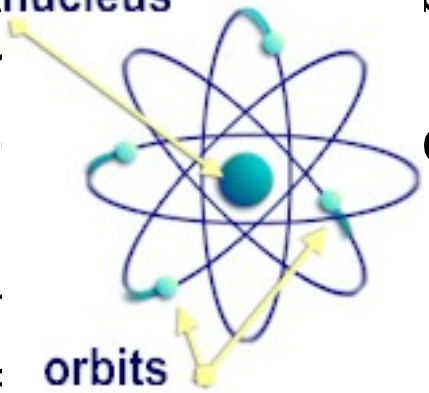
Line Spectra

- Fraunhofer 1814: Sun's spectrum has gaps
- Kirchoff-Bunsen 1859: Tenuous gas emits line spectrum
- Atoms and molecules emit/ absorb at characteristic wavelengths when heated or ionized
- Line spectrum yields chemical composition
- At higher pressure and density lines broadened



Inside the Atom

- Rutherford 1909: Structure of the Atom is Keplerian
- Heavy nucleus of positive charge Z of size $10^{-15}\,\mathrm{m}$
- Orbited by Z light electrons of negative charge in orbits of size $10^{-10}\,\mathrm{m}$



- A by tr or d electrons.
- C science o r
- Elements immutable because nucleus not affected

Problems?

- Electrons in an atom are accelerating so should radiate losing energy. How are atoms stable?
- Why are line spectra discrete?
- Light observed to have particle behavior (Planck 1900, Einstein 1905) $E = hf \;\; h = 6.626 \times 10^{-34}\,\mathrm{J \cdot s}$
- Electrons exhibit interference (Davisson-Germer 1927)

Quantum Mechanics

- All resolved by a revolution in our understanding of Nature
- Particles described by a wave function whose value at any position predicts probability of finding particle there
- Wavelength related to momentum $\lambda = h/p$
- My wavelength is negligible

- Solving wave equation for electrons in atom find discrete energy levels $E_n = -K/n^2$
- Dominant interaction with radiation is emission/ absorption of a single photon and transition between levels

$$hf = E_n - E_m = K(1/m^2 - 1/n^2)$$

- Pauli (1925) exclusion principle: At most two electrons can occupy a given state. Explains periodic table and much else

Lots of Physics!

- We have come a long way since Newton
- Understand many phenomena on Earth and off. Atoms are the same everywhere!
- Time to look back up and see what all this knowledge – and the technology it led to – has taught us.

Credits

- Solar Spectrum: N.A.Sharp, NOAO/NSO/Kitt Peak FTS/AURA/NSF http://www.noao.edu/image_gallery/html/im0600.html
- Astronomy Animations: University of Nebraska-Lincoln Astronomy Education Group http://astro.unl.edu/
- Rayleigh Scattering: NOAA http://www.esrl.noaa.gov/gmd/grad/about/redsky/index.html
- Rainbow: Nicholas A. Tonelli http://www.flickr.com/photos/nicholas_t/281820290/
- Glory: Deanna Hutchison, http://blog.nwparagliding.com/2009_05_01_archive.html
- Rutherford Atom, David Darling http://www.daviddarling.info/encyclopedia/R/Rutherfords_experiment_and_atomic_model.html
- Hydrogen Atom: PhET Interactive Simulations, University of Colorado http://phet.colorado.edu
- Moonrise: NASA http://www.nasa.gov/mission_pages/apollo/40th/images/apollo_book_images.html#