Astro 210

Lecture 11

Sept 17, 2010

Announcements

- HW3 due now
- HW2 Q4 (10 bonus points) available till Oct 1
- good news: no HW for next Friday
- bad news: Hour Exam 1 next Friday

`www: info online`

Last time:

light = electromagnetic radiation

- color: wavelength λ, freq f
- speed $\lambda f = c =$ constant
- particle properties: photons γ: $E_\gamma = hf = hc/\lambda$

Spectroscopy

key property of light:

Flux: energy flow per unit area per unit time

diagram: light flow, area A, $dE = FAdt$, $F = 1/A\ dE/dt$

intuitively: "apparent brightness"

spectrum: flux distribution vs λ

Demo: use gratings

Q: what does white light spectrum look like?

Q: what does laser pointer spectrum look like?

Q: what's the spectrum of a neon light?

iClicker Poll: Space Heater Spectrum

What's the spectrum of a hot, glowing metal (mostly iron)?

A a single color (wavelength)

B a set of several sharply defined colors (wavelengths/ "lines")

C a continuous band of color from red to orange

D a continuous band of color from red to green

E a continuous band of color from red to violet

can classify three basic kinds of spectra: **Kirchoff's Rules**

diagram: hot solid, cooler gas, lines of sight

1. A hot and opaque solid, liquid or dense gas emits
a continuous spectrum (A)
diagram: continuous spectrum: F *vs* λ

2. A hot low-density (transparent) gas produces emission line spectrum
note: pattern of lines specific to element
diagram: emission line spectrum: F *vs* λ

3. Continuous radiation viewed though cooler gas produces an absorption line spectrum

label C on diagram

diagram: absorptions line spectrum

note: the lines absorbed have same color/wavelength as the lines in emission line spectrum: F vs λ

these effects are godsends for astrophysics!

Q: why?

Observer's Scorecard

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You can see an awful lot, just by looking.
  -- Asrophysicist Yogi Berra
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can use emission/absorption lines to inventory kinds of elements in an astronomical source

light spectrum gives atom "fingerprint" or "barcode"

spectrum $\rightarrow$ composition

Example: The Sun

Sun, stars hotter, denser in center cooler, less dense at surface

so: sunlight/starlight shows *Q: what kind of spectrum?*

`www: Sun spectrum`

amount absorbed in each line $\rightarrow$ amount of atoms

$\rightarrow$ **composition** of Sun; works for other stars too!

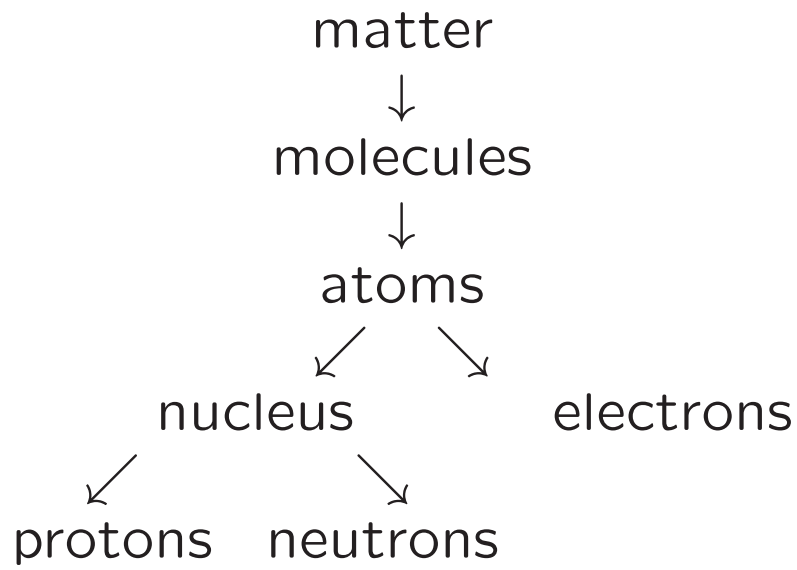
Note: as yet, don't know where lines comes from

who assigns cosmic barcodes?

for this, need to understand how light interacts with matter

Matter

Recall:



atoms come in **elements**

92 natural, 23+ artificial

`www: periodic table`

determined by nuclear charge $Z = \#$ protons

e.g., hydrogen H: $Z = 1$

uranium U: $Z = 92$

same element (same # p) can have different # neutrons
$\rightarrow$ "isotopes"
examples: most H is ^{1}H $= 1p$, $0n$
but $\sim 10^{-4}$ of H is deuterium ^{2}H $= 1p$, $1n$

most U is ^{238}U $= 92p$, $146n$

atom net charge fixed by # electrons
e = # p $\rightarrow$ neutral
e = # $p - 1$ $\rightarrow$ singly ionized

Note: all p, n, e are absolutely identical
this turns out to be crucial for the understanding of matter
in a quantum mechanical way

Atoms & Spectra

how are spectral lines ("barcode") related to atom structure?

Balmer hydrogen gas $\rightarrow$ emission line spect. (visible λ)
found empirical pattern to lines

$$\lambda = 3.65 \times 10^{-7} \, \frac{n^2}{n^2 - 4} \, \text{m} \quad n \text{ integer } \geq 3 \qquad (1)$$

(1) only these lines seen and no others
(2) simple mathematical structure cries out for explanation!

try it! for $n = 3$:
$\lambda_{n=3} = 3.65 \times 10^{-7} \frac{9}{9-4} \text{m} = 656\text{nm}$
Q: what color is this? `www: EM spectrum`
Demo: H discharge tube
`www: Sun spectrum;` Hα $\rightarrow$ the Sun contains hydrogen!