Astro 210

Lecture 10

Sept 15, 2010

Announcements

- HW3 due in class next time
- HW2 Q4 (10 bonus points) available till Oct 1

- Bigshot astronomer speaks today!
  Iben Distinguished Lecturer: Tony Tyson
  lead scientist on top new telescope for 2010-2020 decade!
  "Exploring the Dark Side of the Universe"
  7pm Wed Sept 15, Foellinger; more info on course page
- **5 bonus homework points**
  for attending and posting a brief summary on Compass

Last time: Gravity and energy

- bound vs unbound orbits
  Q: which is which? what is condition for bound vs unbound?
- escape speed $v_{\text{esc}} = \sqrt{2GM/r}$
  Q: why is this important?
- tests of Newton's gravity: Neptune discovered as "dark matter" perturbing orbit of Uranus

Stepping back:

now have explained in detail *how* and *why* the heliospheric solar system works as it does

3-Minute Essay

What is the main lesson, for the practice of science, of the geocentric vs heliocentric shift?

Note:
not asked *content* of science (don't say lesson=heliocentric) but rather the *practice*–what does it tell us here and now about how to do science?

- Write your name and NetID!
- more than one right answer/viewpoint
- credit for thoughtful effort
- good 3-Min Essay record can "boost" borderline final grade

Geocentric vs Helocentric: Lessons

For me, a big lesson is **Humility!**
naive to think: "Greeks dumb, we're smart"
rather a sobering reminder: sometimes, same observations can be explained in radically different ways

also: can have bias not even aware of
shapes how view world, seems reasonable to everyone
humbling! examples in QM, relativity

what's more...probably going on still today!
remember: all astronomy, all science ultimately tentative
In this course: my guess: $\sim 80\%$ stand test of time
but don't know which 20% is wrong...so have to learn it all!

that said, not everything up for grabs or matter of taste...
confidance/uncertainty varies tremendously
Wagers

Changing Gears

Ready to begin scientific exploration of the cosmos

`www: Big Picture`

Need to assemble & understand available tools

What can we **directly** measure, from Earth,
about planets/stars/galaxies?
With partner: write list

Astrophysicist's Wishlist

Note that much of what we would *like* to know about celestial objects, such as

- properties: distance, size, mass, temperature, speed, spin rate, composition, ...
- physics: orbits, origin, evolution, ...

are **not** directly observable

i.e., these data aren't output of a telescope

what is?

Observer's Toolbox

hard-nosed list of direct observables which **do** come out of a scope:

- position on sky
- color/spectrum
- brightness
- polarization
- time changes in any/all of these above

lesson: can only measure light! can look but not touch!
⇒ need to understand light
and its interactions with matter
to decode maximum available cosmic information

amazingly lucky circumstance: can get there from here!

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You can't always get what you want
No you can't always get what you want
You can't always get what you want
But if you try sometimes
You might find
You get what you need
  -- Astrophysicist Mick Jagger
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Electromagnetic Radiation: Wave-Particle Duality

Heads-up: in physics/astrophysics "radiation" $\equiv$ EM radiation
i.e., transport of EM energy across space by particles or waves
$\neq$ radioactivity = "ionizing radiation"
Q: examples of radiation in ASTR210 sense?

Wave Properties

Maxwell's eqs: electric & magnetic fields* can support waves
$\rightarrow$ light is **electromagnetic radiation**

simplest wave: sinusoidal; more complex patterns
can be decomposed into sums of sinusoids (Fourier)
Q: basic anatomy of any propagating sinusoidal wave?
Q: corresponding properties of light waves?
i.e., how interpreted by your personal photodetectors?

∞

* no relation to instructor

Electromagnetic Waves

- EM wave speed: $c = 3.0 \times 10^8$ m/s
- spatial oscillation period: wavelength λ
- time oscillation period: P [sec/cycle]
  related to frequency: $f = \nu = 1/P$ [cycles/sec]
- wave travels: in time $\Delta t = P = 1/f$, pattern moves distance $\Delta x = \lambda$, and since speed is
  $c = \Delta x / \Delta t \rightarrow \boxed{c = \lambda f}$

note: EM radiation can have any wavelength
from subatomic through to macroscopic!

radio	infrared	visible	ultraviolet	X-ray	γ-ray
$< 10^{11}$ Hz	$\sim 10^{13}$	$\sim 5 \times 10^{14}$	$\sim 10^{16}$	$\sim 10^{18}$	$\sim 10^{20}$
$> 10^{-3}$ m	$\sim 10^{-5}$	$\sim 5 \times 10^{-7}$ m	$\sim 10^{-9}$	$\sim 10^{-11}$	$\sim 10^{-12}$

Example: what is freq. of green light at 500 nm?

$$f = \frac{c}{\lambda} = \frac{3 \times 10^8 \text{ m/s}}{5 \times 10^{-7} \text{ m}} = 6 \times 10^{14} \text{ Hz} \tag{1}$$

Radiation Particle Properties: Photons

leap forward: 20th century revolution of quantum mechanics
Max Planck (1858–1947):
light comes in "chunks" or "packets" of energy
$\rightarrow$ **quantized** $\Rightarrow$ photon (symbol γ)

A photon's energy set by color: $E_\gamma = hf = hc/\lambda$
where Planck's constant $h = 6.63 \times 10^{-34}$ J s
often also use $\hbar = h/2\pi$

Ex: what is energy of 1 photon of green light?

$$E_\gamma = \frac{hc}{\lambda} \quad (2)$$

$$= \frac{6.6 \times 10^{-34} \text{ Js } 3.0 \times 10^{8} \text{ m/s}}{5.0 \times 10^{-7} \text{ m}} = 4.0 \times 10^{-19} \text{ J} \quad (3)$$

$$= 2.5 \text{ eV} \quad (4)$$

very small!

new energy unit: electron Volt

1 eV $= 1.602 \times 10^{-19}$ Joule

energy gained by 1 e^- going thru

potential difference of 1 Volt

iClicker Poll: Laser Pointer

Demo: laser pointer – emits photons all with one *same* wavelength

if I double the power output of green laser pointer beam:
e.g., crank from 1 mWatt $\rightarrow$ 2 mWatt

What changes, what stays the same?

A more photons emitted, but each photon has same energy

B same number of photons emitted, but photon each has more energy

C more photons emitted *and* each photon has more energy

- each photon's E depends on f only
- **total** energy in light beam depends on # photons

crank emitted power $\rightarrow$ add more photons
so total energy output (power) $\propto$ # photons emitted per sec