Astro 210
Lecture 14
Sept 27, 2010

Announcements
- HW4 available, due Friday
- HW2 Q4 (10 bonus points) available till Friday
- Planetarium shows continue this week
  download & bring question sheet; due Friday

Hour Exam 1: being graded

Before exam: telescopes
- light gathering ("photon bucket")
- angular resolution *Q: meaning?*
- refractors vs reflectors *Q: meaning? your eye is which?*

The Division of Labor in Astronomy/Astrophysics

Working astronomers/astrophysicists generally spend their time in *one* of these roles

- **observer**: collect, analyze, and interpret telescope data
- **theorist/simulator**: use physics to make models/predictions
- **instrumentalist**: design/build new scopes/detectors

A few very talented people do more than one of these well

Beware! each comes with its own biases and "culture"!

iClicker Poll: Instructor Culture of Origin

Vote your conscience!

Which of these is your instructor?

A observer

B theorist

C instrumentalist

Telescopes: Detectors

Once light collected, focussed, need to detect

- **naked eye** – just look!

Q: Problems? other means of detection?

naked eye as photodetector

benefits:

- readily available, and cheap!

problems:

- only $\sim$ 1% of photons detected!
- can't store image
- only sensitive to small portion of EM spectrum (visible λs)

photographic film

better!

- can collect light $\rightarrow$ see much dimmer objects
- stores image

but: efficiency still small

only $\sim$ few% of incoming γs registered on film

- **Charged-Coupled Device (CCD)**

like camcorder, digital camera!

photons $\rightarrow$ silicon wafer $\rightarrow$ e knocked out (photoelectric effect)

- moving charges = current

$\Rightarrow$ CCD converts light $\rightarrow$ electrical signal

to make image: create *grid/array* of picture elements ("pixels")

great!

⋆ digital data $\rightarrow$ good for computers

⋆ efficiency $\rightarrow$ 80% of incident photons detected

downside: expen$ive, hard to make large CCD's

⋆ essentially all modern telescopes – HST, Keck – use CCD's

℘ Note: distinguished speaker Tony Tyson was early pioneer of CCD use for astronomy

Field of View

key telescope property: *field of view*

$\rightarrow$ angular area Ω_{fov} of celestial sphere visible in each pointing

- naked eye: see almost a full hemisphere
  $\Omega_{\mathrm{fov}} \approx 2\pi$ steradian $= 2\pi$ rad^2
- typical modern telescopes, e.g., Hubble, Keck:
  $\Omega_{\mathrm{fov}} \approx 1$ arcmin $\times$ 1 arcmin $= 1$ arcmin^2

---

iClicker Poll: Rank these from *largest* to *smallest* field of view

A paper towel tube, drinking straw, Hubble telescope

B paper towel tube, Hubble telescope, drinking straw,

C Hubble telescope, paper towel tube, drinking straw

Field of View and LSST

typical modern telescopes: $\Omega_{\rm scope} \approx 1\ \text{arcmin}^2$
drinking straw: $\Omega_{\rm straw} \approx 1\ \deg^2 = 3600\ \text{arcmin}^2 \approx 3600\ \Omega_{\rm scope}$!
$\Rightarrow$ modern telescopes (so far!) have *tiny* fields of view!

Large Synoptic Survey Telescope `www: LSST`

- site: Cerro Pachón ridge, Andes mountains, Chile
- primary mirror diameter $D = 8.4$ m: large but not unusual
- field of view $\Omega_{\rm fov} = 10\ \deg^2$ **enormous!**
  requires 3.2 Gigapixel camera!
  first telescope to have such a large field of view
- Illinois is LSST member; Astronomy, Physics, NCSA involved

∞

Q: why is such a large field of view useful? what does this allow?

Coming Soon–Cosmic Movie & Wallpaper

thanks to large field of view
LSST can **scan entire night sky** in a few days!
and then **repeat** this scan for ≈ 10 years

result: ≈ 1000 deep digital images of *every point* on the southern celestial sphere, spanning 10 years!

Strategy: *compare* images of *same* region

- some things won't show any change *Q: like?*
  add exposures to get *very* deep images
  "The Sky: The Wallpaper"
- other things *will* show change! *Q: like?*
  subtract exposures to find & monitor changes
  → reveal celestial variability over timescales ∼hours to years
  "The Sky: The Movie"
  ⇒ this has never been done on such a huge scale!

Invisible Astronomy

before 20th century: astronomy = optical astronomy
visible waveband only known form of light

Now: want to take advantage of full EM spectrum
$\rightarrow$ radio, IR, UV, X-ray, γ-ray

radio: large antennas
since λ very large
$\rightarrow$ need huge collecting area for angular res.
$\rightarrow$ arrays of antennae
`www: VLA, Arecibo`

X-ray: don't penetrate atmosphere
$\rightarrow$ must go to space
to focus: scatter at glancing angle
detectors: measure energy deposited

`www: Chandra, XMM`

Also: the cosmos contains more than photons!
particles from space already detected
$\star$ neutrinos
$\star$ cosmic rays (relativistic nuclei and electrons)
confidently expected but only indirect evidence so far:
$\triangleright$ gravitational radiation ("gravity waves")

The Solar System

The Solar System

`www: Place in the Big Picture`

Why study the Solar System?

▷ it's home!

▷ use present to learn about past

$\rightarrow$ clues for origins of Earth & Sun

▷ help understand origin of exoplanets: compare/contrast

Sociology: traditionally, astronomy divided into study of solar system vs extrasolar objects
boundary is artificial, and somewhat loosening now...

Basic Organization `www: SS lineup`

Terrestrial (Earth-like) planets: smaller, rocky
Mercury, Venus, Earth/Moon, Mars

Asteroid Belt: rocky debris

Jovian (Jupiter-like) planets: large, gaseous
Jupiter, Saturn, Uranus, Neptune

Kuiper Belt & Oort Cloud: Icy debris

Pluto: in summer 2006, demoted to "dwarf planet"
→ will discuss what's behind this

Orbital dynamics show clear patterns

all planets & asteroids:

- move in same direction
- close to ecliptic plane
  ...except Pluto
- note also that most orbits almost circular
  biggest exception is Pluto

But could it have been otherwise?

Q: What rules does Newton impose on bound orbits?

And note the near-circularity of orbits:

consider a planet at distance $\vec{r}$

and release it with velocity $\vec{v}$

Q: how does orbit depend on $\vec{v}$ magnitude, direction?

Q: how to adjust $\vec{v}$ to get a circular orbit?