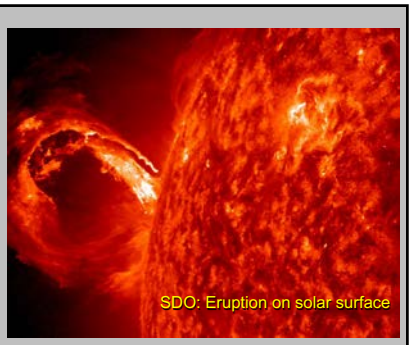
ASTR 1040: Stars & Galaxies



Prof. Juri Toomre TAs: Ryan Horton, Loren Matilsky

Lecture 2 Thur 30 Aug 2018

zeus.colorado.edu/astr1040-toomre

Reading for today's and Tues class:

How to Succeed in this course, p. xxiv+

- Chapter 1, all *(Our Place in Universe)*
- Review *Basic Astronomical* terms, p. 6
- Chap 3, sec 3.3, 3.4 *(Kepler, Nature of Science)*
- Chap 4, read all *(Making Sense of Universe)*

- Begin reading Chap 5, carefully *(Light and Matter)*

- You can get a copy of all our slides after class from course website zeus.colorado.edu/astr1040-toomre
- D2L course site also up and running

REMINDER

Mastering Astronomy (MA) + homeworks

- Online MA Assignment (HW # 0) available NOW
  Walks you through how to submit all the assignments and MA resources available, and some review of concepts (good practice, extra credit)
  Complete by Tues, 4 Sept 6pm
- Homework # 1 on "Light & Spectroscopy" now available for pickup, *involves both MA portion and written portion, to be turned in by Thur Jan 25 class*

- Get your MA account set up asap, linking to "ASTR1040TOOMRE2018B" -- your MA account from 1030 should carry over -- see our syllabus or go to our D2L site if need further instructions or help

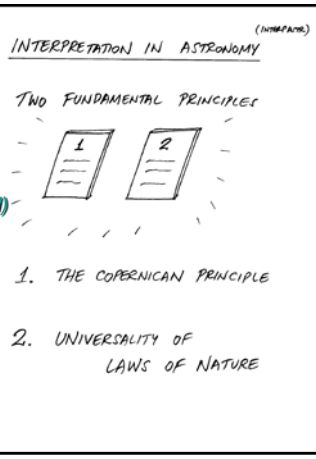
Topics for Today and Tues

- Nature of astronomy as a science
- Scientific method: we observe, hypothesize, test its predictions, maybe fix it and try again
- Mystery of planetary orbits: gravity makes you move on ellipses (..Kepler, Newton)
- Light as waves (and as particles)
- Special colors of light associated with each element

- First *Observatory Night* on Tues 4 Sept, by signup (8:30pm, 9:00pm, 9:30pm)

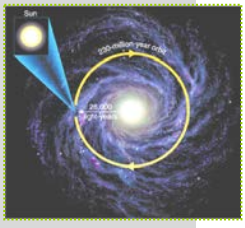
FUNDAMENTAL ASSUMPTIONS

(always being tested)



COPERNICAN PRINCIPLE

Copernicus (1473-1543)



THE COPERNICAN PRINCIPLE

Original Form:
EARTH NOT AT CENTER OF SOLAR SYSTEM

More General:
NOTHING SPECIAL ABOUT LOCATION OF ...
...EARTH IN SOLAR SYSTEM (16th - 17th C)
... SOLAR SYSTEM IN MILKY WAY GALAXY (SHAPLEY 1915 - 1919)
... M.W. GALAXY IN UNIVERSE (HUBBLE 1923)

Practical Implications for Astronomy:
ANYTHING OBSERVED ONCE PROBABLY OCCURS ELSEWHERE IN UNIVERSE

Thus, expect to find ...
... OTHER SUNS (STARS)
... OTHER MILKY WAYS (GALAXIES)
... OTHER PLANETARY SYSTEMS (?)
... OTHER LIFE FORMS (?)

FUNDAMENTAL ASSUMPTION #2

UNIVERSALITY OF 'LAWS'

ATOMS BEHAVE THE SAME EVERYWHERE

(we hope, and keep testing !)

GRAVITY ACTS EVERYWHERE

UNIVERSALITY OF LAWS OF NATURE

SAME GENERAL LAWS APPLY EVERYWHERE IN UNIVERSE

Examples:

- PROTONS AND ELECTRONS ON EARTH SAME AS THOSE ON SUN
- ATOMS OF DIFFERENT ELEMENTS THE SAME EVERYWHERE
- MOON ORBITING EARTH OBEYS SAME RULES OR " = " STAR ORBITING ANOTHER STAR
- GRAVITY HOLDS TOGETHER .... STAR ... GALAXY ... CLUSTER OF GALAXIES ... ACCORDING TO ONE LAW

SCIENTIFIC 'LAWS' are constantly being tested

Sec 3.4: Nature of Science

FOUR FUNDAMENTAL FORCES

At work everywhere, "Universal" – we assume and test

FOUR TYPES OF FORCES IN NATURE

1. GRAVITY
   WEAKEST, BUT DOMINATES UNIVERSE
2. ELECTROMAGNETIC (EM)
3. STRONG NUCLEAR
   100 x EM, BUT ONLY IN NUCLEUS OF ATOM
4. WEAK NUCLEAR
   1/1000 x EM, ONLY IN ATOMIC NUCLEUS

Great puzzle: Earth or Sun Centric?

- Perfect harmony of Sun and planets moving on circles around the Earth had problems: thus epicycles ….
- *Copernicus* (1543) argued that Sun is instead the center around which the planets move
- Good data from *Tycho* allowed *Kepler* (1609, 1619) to devise three "laws" with motion on ellipses (Chap 3)
- *Newton* showed (~1687) that force of gravity could yield elliptic orbits – beginning of a new math and science (Chap 4)

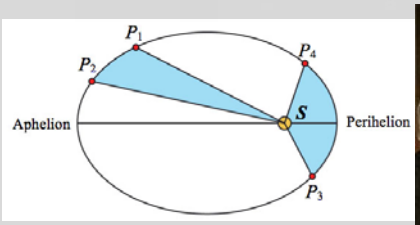
3.3 Copernicus - Tycho - Galileo – Kepler


Copernicus


Galileo


Tycho Brahe

Kepler and planetary orbits




1571-1630

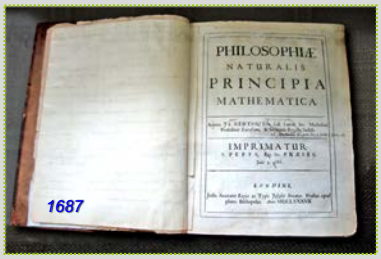
$p^2 = a^3$

p: planet's orbital period in years

a: average distance from Sun in a.u.

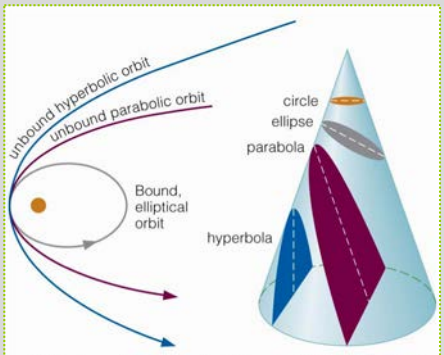
Isaac Newton and Gravitation

$$F_g = G(M_1 M_2)/d^2$$



Newton explains Kepler's orbits:

$$p^2 = a^3 4\pi^2 / G(M_1 + M_2)$$

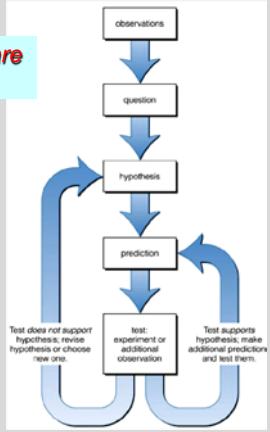


Newton's Gravitational Force admits these orbits

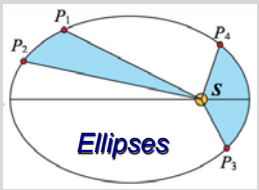
Elliptical is the general "bound orbit"

SCIENTIFIC `LAWS' are constantly being tested

So how did chain of Greeks,…, Copernicus, Brahe, Galileo, Kepler, Newton …. WORK ?



Moral on scientific method: orbits



1619

1687

Force of gravity

$$F_g = G(M_1 M_2)/d^2$$

Property of elliptic orbits

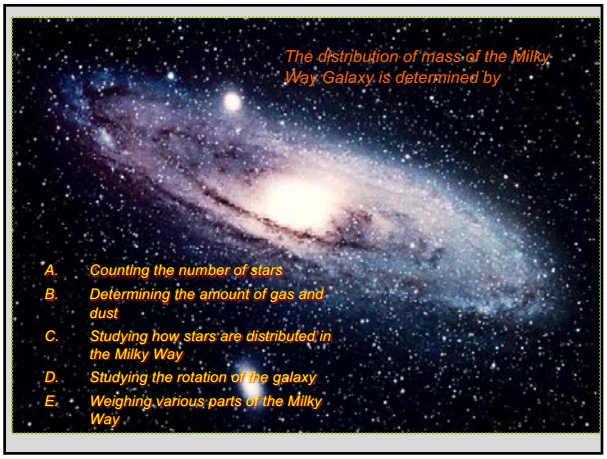
$$p^2 = a^3 4\pi^2 / G(M_1 + M_2)$$

Reading Clicker Question (real credit starts next week)

The distribution of mass of the Milky Way Galaxy is determined by

A. Counting the number of stars
B. Determining the amount of gas and dust
C. Studying how stars are distributed in the Milky Way
D. Studying the rotation of the galaxy
E. Weighing various parts of the Milky Way

- You must change your clicker channel to DA
  -Hold down power until blue light blinks…then press D, then A



Light: The Cosmic Messenger

ELECTRO-MAGNETIC RADIATION

(used for most deductions)

PHOTONS (quanta – particles of light)

ELECTROMAGNETIC RADIATION (EMRAD)

γ-RAYS, X-RAYS, UV, VISIBLE, IR, MICROWAVE, RADIO

← "LIGHT" →

ACT BOTH LIKE

WAVES AND PARTICLES (PHOTONS)

PHOTONS

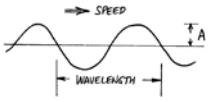
SMALLEST PACKETS ("QUANTA") OF LIGHT ENERGY

QUANTUM NATURE OF LIGHT MOST EVIDENT WHEN LIGHT INTERACTS WITH ATOMS

⇒ SPECTRAL LINES

PROPERTIES OF WAVES

WAVES



PROPERTIES:

WAVELENGTH	λ	
FREQUENCY	f	(ALSO ν)
AMPLITUDE	A	
SPEED	C	

WAVELENGTH × FREQUENCY = SPEED

$\lambda \times f = c$

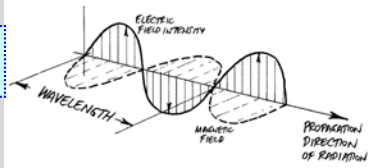
OTHER USEFUL PROPERTIES:

DIFFRACTION	(GRATING)
REFLECTION	(MIRROR)
REFRACTION	(PRISM, LENS)
DOPPLER SHIFT	

E-M (LIGHT) AS WAVES

Speed of light SAME for all wavelengths

ELECTROMAGNETIC RADIATION AS A WAVE



$\lambda \times f = c$

WAVELENGTH × FREQUENCY = SPEED OF "LIGHT"

$\lambda = c/f$, $f = c/\lambda$

PROPAGATION SPEED OF ALL EM WAVES IS THE SAME !

C IS A CONSTANT ≈ 300,000 Km/sec

$= 3 \times 10^{10}$ cm/sec

Discuss SI units and "how to get comfortable with the speed of light"

meters, kilograms, seconds

c = 300,000 km/sec

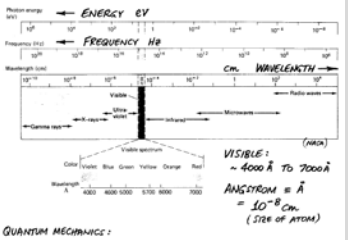
30 cm in 1 nanosecond (10^{-9} sec)

E-M SPECTRUM

Quantum Mechanics

(energy of photons varies)

ELECTROMAGNETIC SPECTRUM



VISIBLE: ~ 4000 Å TO 7000 Å

ANGSTROM = Å = 10^{-8} Cm. (SIZE OF ATOM)

QUANTUM MECHANICS:

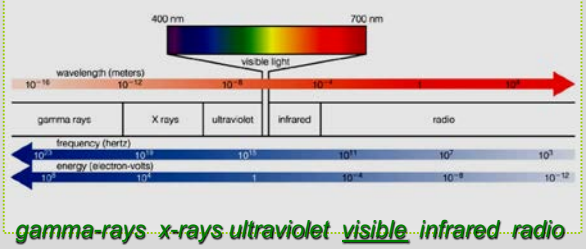
PHOTON ENERGY = PLANCK'S CONSTANT × FREQUENCY

$E = h \times f$

HIGHER FREQUENCIES OR SHORTER WAVELENGTHS ⇒ MORE ENERGY

(UV, X-RAYS MORE DANGEROUS!)

Electromagnetic Spectrum



gamma-rays x-rays ultraviolet visible infrared radio

$$c = \lambda \cdot f$$

DEMO of Bright Line EMISSION from different hot gases

Hydrogen (bottom), Helium, Incandescent White, Fluoresc White, Neon, Argon (top)

You should each have a small plastic diffraction grating