

**ASTR 1040:**  
**Stars & Galaxies**



SDO: Eruption on solar surface

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Lecture 2 Thur 18 Jan 2018  
[zeus.colorado.edu/astr1040-toomre](http://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](http://course website zeus.colorado.edu/astr1040-toomre)
- D2L course site also up and running

**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 Jan 23, 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 "ASTR1040TOOMRE2018A" -- 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

**FUNDAMENTAL ASSUMPTION #2**

**UNIVERSALITY OF 'LAWS'**

**ATOMS BEHAVE THE SAME EVERYWHERE**

(we hope, and keep testing !)

**GRAVITY ACTS EVERYWHERE**

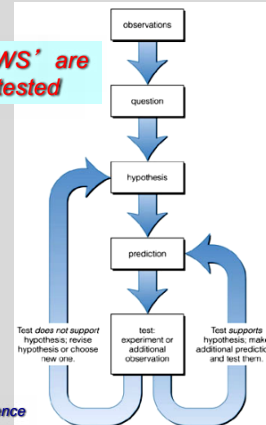
UNIVERSALITY OF LAWS OF NATURE

SAME GENERAL LAWS APPLY EVERYWHERE IN UNIVERSE

Examples:

- PROTONS AND ELECTRONS ON EARTH BEHAVE SAME AS THOSE ON SUN
- ATOMS OF DIFFERENT ELEMENTS BEHAVE THE SAME EVERYWHERE
- MOON ORBITS EARTH ORBIT SAME RULES OR " = " STAR ORBITS 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 elliptical orbits – beginning of a new math and science (Chap 4)

**3.3 Copernicus - Tycho - Galileo - Kepler**

Timeline of key events:

- 1473-1543: Nicolas Copernicus
- 1543: De Revolutionibus by Copernicus
- 1545-1601: Tycho Brahe
- 1564-1642: Galileo Galilei
- 1564-1616: William Shakespeare
- 1571-1630: Johannes Kepler
- 1588: Defeat of Spanish Armada
- 1606: Discovery of Australia by William Janszoon
- 1607: Jamestown established
- 1608: Telescope invented by Johann Lippershey
- 1611: King James Version of The Holy Bible
- 1618-1648: Thirty Years War
- 1620: Pilgrims landed at Plymouth
- 1626: Dutch bought Manhattan for \$24.00
- 1632-1645: Taj Mahal built
- 1636: Harvard College founded
- 1642-1727: Isaac Newton
- 1643-1715: Reign of Louis XIV

Portraits of Copernicus, Tycho Brahe, and Galileo.

**Kepler and planetary orbits**

$p^2 = a^3$

*p*: planet's orbital period in years      *a*: average distance from Sun in a.u.

1571-1630

**Isaac Newton and Gravitation**

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

1687

(1642-1727)

Newton explains Kepler's orbits:

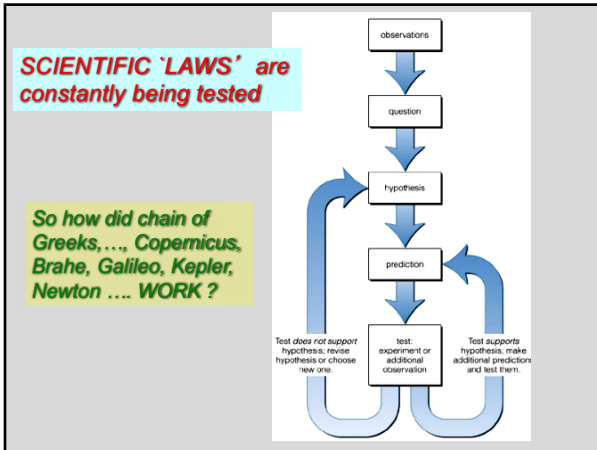
$p^2 = a^3 4\pi^2 / G(M_1 + M_2)$

**Newton's Gravitational Force admits these orbits**

**Elliptical is the general "bound orbit"**

a Orbits allowed by the law of gravity.

b Ellipses (which include circles), parabolas, and hyperbolas are conic sections, made by slicing a cone at different angles.



**Moral on scientific method: orbits**

**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 AB  
 - Hold down power until blue light blinks... then press A, then B

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**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  $\lambda$   
 FREQUENCY  $f$  (also  $\nu$ )  
 AMPLITUDE  $A$   
 SPEED  $C$

WAVELENGTH  $\times$  FREQUENCY = SPEED  
 $\lambda \times f = C$

**OTHER USEFUL PROPERTIES:**

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

**E-M (LIGHT) AS WAVES**

**ELECTROMAGNETIC RADIATION AS A WAVE**

$\lambda \times f = C$   
 WAVELENGTH  $\times$  FREQUENCY = SPEED OF "LIGHT"  
 $\lambda = c/f$  ,  $f = c/\lambda$

PROPAGATION SPEED OF ALL EM WAVES IS THE SAME!  
**C IS A CONSTANT**  $\approx 300,000$  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**

PHOTON ENERGY = PLANCK'S CONSTANT  $\times$  FREQUENCY  
 $E = hf$

HIGHER FREQUENCIES OR SHORTER WAVELENGTHS  $\Rightarrow$  MORE ENERGY  
 (UV, X-RAYS MORE DANGEROUS!)

**Electromagnetic Spectrum**

400 nm to 700 nm visible light

gamma rays X rays ultraviolet 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