Lecture 14: Announcements

-- Quiz 3 today

-- Hwk3 and the reading assignment for question 5 are on class website

-- The following students should please see me after class: Carla Rogers
Recent and Upcoming topics in class

--- The Scientific Method

--- History and Science of Astronomy (300 BC to 1915 AD)
- Chinese, Egyptian and Babylonian astronomy
- Geocentric models and Greek Astronomy:
  Thales, Pythagoras, Democritus, Plato Eudoxus, Aristotle, [Aristarchus], Apollonius, Hipparchus, Ptolemy
- Development of Geocentric models during European Renaissance (1473-1670)
  Copernicus, Brahe, Kepler, Galilei
  Kepler’s laws of motion
- Modern Astronomy: Newton, Einstein, Hubble

--- Energy
-- Forms of Energy.
-- Principle of Conservation of Energy
-- Equivalence of Mass and Energy or \( E=mc^2 \)
  Fission, fusion, accretion of matter onto a black hole
-- General Principles of Nuclear Fusion
Recent and Upcoming topics in class

--- Energy
-- Forms of Energy.
-- Principle of Conservation of Energy
-- Equivalence of Mass and Energy or $E=mc^2$
  Fission, fusion, accretion of matter onto a black hole
-- General Principles of Nuclear Fusion
History and Science of Astronomy

- 3000 BC  Chinese astronomy
- 2700-2100 Egyptians & Babylonians

- 625 BC-150 AD Greek scientists and geocentric models (Thales, Pythagoras, Democritus, Plato Eudoxus, Aristotle, [Aristarchus], Apollonius, Hipparchus, Ptolemy)

- 300 BC  Expansion of Greek empire into Middle East (Egypt, Mesopotamia)

- 300 BC-400 AD Library of Alexandria


- 800-1400 Knowledge compiled by Arabs spreads throughout the Byzantine Empire

- 1453 Capital of Byzantine Empire, Constantinople, falls to the Turks. Eastern scholars move to Europe transferring knowledge, leading to European Renaissance

- 1473—1642 Heliocentric models and birth of modern astronomy (Copernicus, Brahe, Kepler, Galilei)
Heliocentric Models and Modern Astronomy
**Heliocentric Models and Modern Astronomy**

Copernicus (1473-1543)  
Polish

- Heliocentric model made of perfectly circular orbits to which a very large no of epicycles had to be added in order to account for observed planetary motions
- ‘De Revolutionibus Orbium Celestium’ = “Concerning the Revolutions of the Heavenly Spheres” published in 1543 on the day he died.
Heliocentric models, like those of Aristarchus (310-230 BC) and Copernicus (1500s) easily explain apparent retrograde motion of Mars.

When the line of sight from Earth to Mars changes from pointing Eastward (or North) to WESTWARD, then see apparent retrograde motion of Mars.

Note: Earth’s orbital period about Sun = 1.0 year
Mars orbital period about Sun = 1.88 years.
Copernicus’s heliocentric model did not predict the position of planets to a better accuracy than the geocentric model of Ptolemy. It had so many epicycles that it was as complex as the geocentric model of Ptolemy.

Was Copernicus and his models ‘overrated’? Or did he really deserve a lot of credit for his contribution to astronomy?
Heliocentric Models and Modern Astronomy

Tycho Brahe (1546-1601)
Danish

Naked-eye observatory of Tycho Brahe funded by King Frederic II
Heliocentric Models and Modern Astronomy

- Stellar parallax = apparent shift of a nearby star against background of distant stars, as seen from Earth, due to the motion of Earth about Sun
- Too small to see in naked-eye observation by Tycho
Heliocentric Models and Modern Astronomy

Johannes Kepler (1571-1630) German. Started as an assistant to Tycho Brahe
Kepler’s laws of heliocentric planetary motions

Ellipse = Oval defined by 2 points called foci as above
Distance from planet to focus varies; aphelion=furthest, perihelion=closest
Semimajor axis = a Semiminor axis = b. For ellipse b/a<1

Circle = Defined by one focus or center
b = a = radius of circle; For circle b/a = 1
Kepler’s laws of heliocentric planetary motions

Law I: Orbit of each planet about the Sun is an ellipse with the Sun at one focus.
- Nothing lies at the other focus.
- Sun lies at one focus.
- semimajor axis
- aphelion
- perihelion

Near perihelion, in 30 days a planet sweeps out an area that is short but wide.

Law II: Line joining Sun and planet sweeps out equal areas in equal areas of time.
- planet moves slower when it is farther from Sun
- Max speed at aphelion
- aphelion
- perihelion
- Near aphelion, in 30 days a planet sweeps out an area that is long but narrow.
Kepler’s laws of heliocentric planetary motions

Law III: Planet moves around Sun such that they obey the relationship

\[(\text{Period } P \text{ in years})^2 = (\text{Semi-major axis } a \text{ in AU})^3\]

planet moves slower when it is farther from Sun

can use observed Period P to infer a, and hence mean orbital speed in km/s
Heliocentric Models and Modern Astronomy

Kepler’s laws of heliocentric planetary motions consistent will all of Tycho Brahe’s data but obtained very strong support only after vindication by accurate + unprecedented observations taken by Galileo Galilei with the recently invented telescope

Galileo Galilei
1564-1642
Galileo observed that planet Venus went through all ‘lunar-type’ phases, including the full phase. This shows that Venus must revolve about the Sun (top figure) rules out the model where both Venus and Sun revolve about the Earth. In such a case we would see only specific phases of Venus …..? which ones? ….
Heliocentric Models and Modern Astronomy

Moon of Jupiter orbit Jupiter and NOT Earth  
not everything revolves around E

Imperfections on the surface of the Moon and sunspots on Sun observed by Galileo

Heavenly bodies are not perfect  
need not move in perfect shapes circles
Newton’s law of gravity: Explain + Generalise Kepler’s laws

- Orbital paths allowed by law of gravity: ellipses, hyperbolas, parabolas

- Ellipses = only orbits that are bound
History and Science of Astronomy: Summary

- 3000 BC  Chinese astronomy
- 2700-2100 Egyptians & Babylonians

- 625 BC-150 AD Greek scientists and geocentric models (Thales, Pythagoras, Democritus, Plato Eudoxus, Aristotle, [Aristarchus], Apollonius, Hipparchus, Ptolemy)

- 300 BC Expansion of Greek empire into Middle East (Egypt, Mesopotoamia)
- 300 BC-400 AD Library of Alexandria

- 800-1400 Knowledge compiled by Arabs spreads throughout the Byzantine Empire
- 1453 Capital of Byzantine Empire falls to the Turks. Eastern scholars move to Europe transferring knowledge ....European Renaissance

- 1473—1642 Heliocentric models and birth of modern astronomy (Copernicus, Brahe, Kepler, Galilei)
- 1642-1747 Newton: Laws of gravity
- 1905-1915 Einstein’s Special and General Theory of Relativity
Picture of the Day

Disorder in Stephan's Quintet
Lecture 15: Announcements

-- Quiz 3 grades online

-- Exam 1 and hwk 2 solution set posted outside lecture hall. Please check solution set first and then come to us

-- Hwk3 and the reading assignment for question 5 are on class website Due on Tue

-- The following students should please see me after class: Carla Rogers
Energy: Forms and Conservation of Energy
## Energy and Work

### Table 4.1 Energy Comparisons

<table>
<thead>
<tr>
<th>Item</th>
<th>Energy (joules)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average daytime solar energy striking Earth, per m² per second</td>
<td>$1.3 \times 10^3$</td>
</tr>
<tr>
<td>Energy released by metabolism of one average candy bar</td>
<td>$1 \times 10^6$</td>
</tr>
<tr>
<td>Energy needed for 1 hour of walking (adult)</td>
<td>$1 \times 10^6$</td>
</tr>
<tr>
<td>Kinetic energy of average car traveling at 60 mi/hr</td>
<td>$1 \times 10^6$</td>
</tr>
<tr>
<td>Daily energy needs of average adult</td>
<td>$1 \times 10^7$</td>
</tr>
<tr>
<td>Energy released by burning 1 liter of oil</td>
<td>$1.2 \times 10^7$</td>
</tr>
<tr>
<td>Energy released by fission of 1 kg of uranium-235</td>
<td>$5.6 \times 10^{13}$</td>
</tr>
<tr>
<td>Energy released by fusion of hydrogen in 1 liter of water</td>
<td>$7 \times 10^{13}$</td>
</tr>
<tr>
<td>Energy released by 1-megaton H-bomb</td>
<td>$5 \times 10^{15}$</td>
</tr>
<tr>
<td>Energy released by major earthquake (magnitude 8.0)</td>
<td>$2.5 \times 10^{16}$</td>
</tr>
<tr>
<td>Annual U.S. energy consumption</td>
<td>$10^{20}$</td>
</tr>
<tr>
<td>Annual energy generation of Sun</td>
<td>$10^{34}$</td>
</tr>
<tr>
<td>Energy released by supernova (explosion of a star)</td>
<td>$10^{44}$–$10^{46}$</td>
</tr>
</tbody>
</table>
Forms of Energy

Kinetic energy
Thermal Energy
Radiative energy (light)
Gravitational potential energy
Sound energy
Thermal Energy of each particle depends on temperature $T$

Total thermal energy of 2 blocks of matter having same volume is larger for block having more particles — higher density
**Equivalence of Mass and Energy; \( E=Mc^2 \)**

- Energy \( E \) stored in Mass \( M = Mc^2 \)  
  (Einstein)

- \( E < 0.007 Mc^2 \) from fission of Ura. or Plu.  
  Hiroshima bomb (1945): fission of 1 g of Uranium. E released equivalent to that of 20 kilo-tons of TNT

- \( E= 0.007 Mc^2 \) from Hydrogen fusion  
  Hydrogen bomb in 1952

- \( E= 0.1 Mc^2 = \) energy released (X rays, etc)  
  as mass M falls onto the accretion disk of a black hole