

## Stars, Galaxies & Universe Announcements

- Science library (120 Iowa Ave (across from Joe's Place) has copies of the textbook on reserve

- Labs start this week – print out lab document before class (see link on the course website) or the email I sent to lab students!

- Second **reading quiz**: Wednesday (9/8) – multiple choice questions (10 questions; 10 pts).

- Second **homework** in ICON should be completed between 9/1 (Thurs) and 9/8 (Wed); multiple choice questions

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## Stars, Galaxies & Universe Lecture #3

- Reading Quiz questions
- Phases of the Moon & Eclipses
- How Basic Physics Fits in to Astronomy
  - Newton's laws of motion and gravity
  - Planetary motion
  - Orbits/Tides

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### Astronomy Misconception

**Phases of the Moon are caused by the shadow of the Earth on the Moon**

Phases of the Moon are caused by our changing view of the illuminated side of the Moon

- $\frac{1}{2}$  Moon is always illuminated by the Sun
- Moon is orbiting the Earth with a period of ~1 month (27  $\frac{1}{3}$  days)

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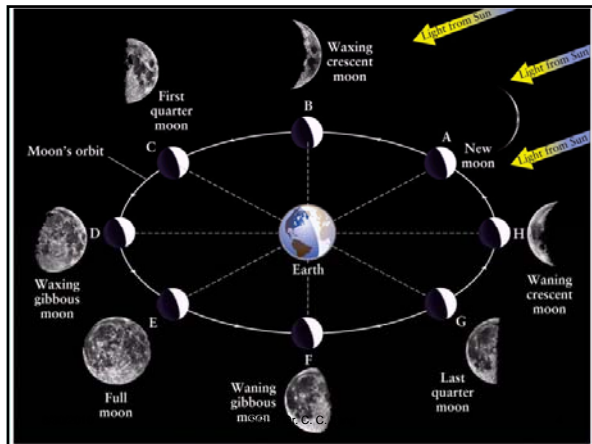
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### Phases of the Moon

- cycle repeats every  $\sim 29 \frac{1}{2}$  days – “month” (compare to orbital period)

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### You can tell the moon phase by

- looking at its face
- observing what time it rises/sets

**Full Moon**  
Rises ~ sunset  
Sets ~ sunrise  
Highest ~ 12 am

**New Moon**  
Rises ~ sunrise  
Sets ~ sunset  
highest ~ noon

**First Quarter Moon**  
Rises ~ noon  
Sets ~ midnight  
Highest ~ 6 pm

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## Moon phases viewed during day



First quarter moon: rises at noon, sets at midnight



Third quarter: rises at midnight, sets at noon



Waning Crescent: rises at 3 am; set at 3 pm

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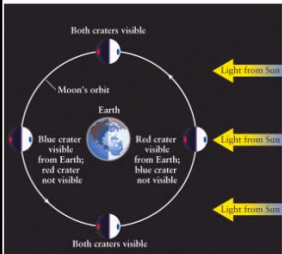
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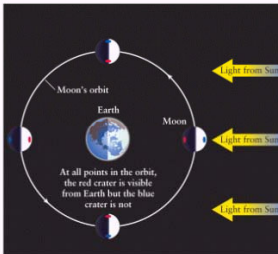
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## Synchronous Rotation

moon takes exactly the same amount of time to orbit Earth as it does to rotate on its own axis



a If the Moon did not rotate, we could see all sides of the Moon



b In fact the Moon does rotate and we see only one face of the Moon

→ no “dark side” of the Moon  
 each location experiences 14 days of daylight and 14 days night.<sup>8</sup>

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## ECLIPSES



- one of the most striking astronomy events
- happen when one object blocks another
  - Moon, Sun, Earth
- two types:
  1. LUNAR eclipse (common)
  2. SOLAR eclipse (rare!)



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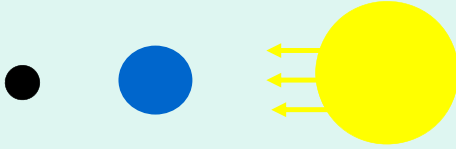
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## LUNAR ECLIPSE

Moon passes through Earth's shadow  
(or Earth is between Sun and Moon)



normally, moon would appear *FULL*

during a lunar eclipse, moon appears dim  
(red in color)

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Time-lapse picture of a total lunar eclipse



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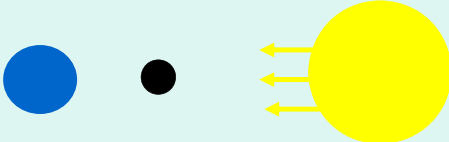
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## SOLAR ECLIPSE

Earth passes through Moon's shadow  
From Earth, appears that Moon covers Sun



normally, moon would appear *NEW*

during a solar eclipse, part or all of the Sun  
is blocked out

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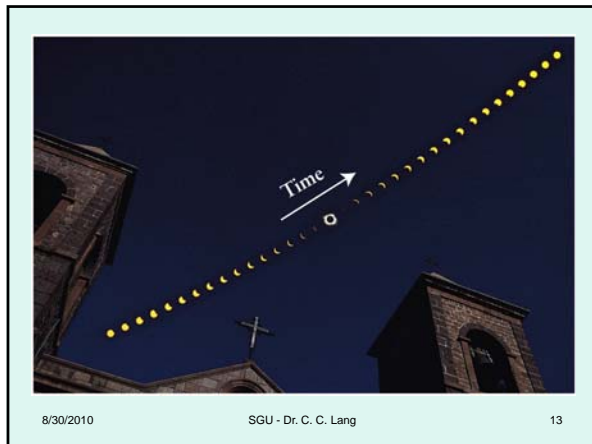
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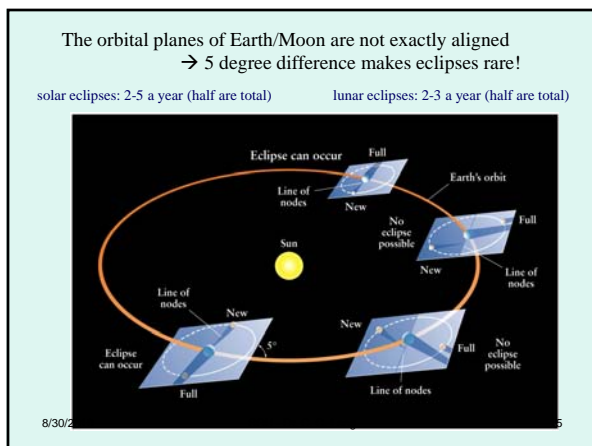
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Lunar eclipses occur fairly  
Often and are more widespread

Next lunar eclipses visible for  
North Americans:

6 August 2009: Partial  
26 June 2010: Partial  
21 Dec 2010: Total  
10 Dec 2011: Total  
4 June 2012: Partial  
28 Nov 2012: Penumbral



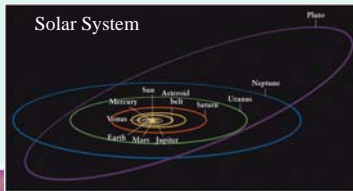
- <http://www.youtube.com/watch?v=IVkkCVh5t0E>

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## Solar System



- Example -- use the orbital period to find the distance of object: an object discovered with an orbital period of 4.6 years -- what Distance and type of object?

Planet	Sidereal period $P$ (years)	Semimajor axis $a$ (AU)	$P^2$	$a^3$
Mercury	0.24	0.39	0.06	0.06
Venus	0.61	0.72	0.37	0.37
Earth	1.00	1.00	1.00	1.00
Mars	1.88	1.52	3.53	3.51
Jupiter	11.86	5.20	140.7	140.6
Saturn	29.46	9.54	867.9	868.3
Uranus	84.01	19.19	7,058	7,067
Neptune	164.79	30.06	27,160	27,160
Pluto	248.54	39.53	61,770	61,770

Kepler's Laws suggest that a force from the Sun causes the motion

## Sir Isaac Newton (1642–1727)

- British (born in Lincolnshire, England)
- 1666 - moment of inspiration when he observed an apple falling to the ground: *the force making the apple fall down was the same force keeping the Moon in orbit around Earth*
- this changed the idea that Earth and the Heavens are separate (Aristotle's belief was they were separate)

Highlights of Newton's Work:

- quantified the laws of motion and gravity
- conducted important experiments on the nature of light
- built the first reflecting telescopes (early telescopes were refracting)
- invented the mathematics of Calculus

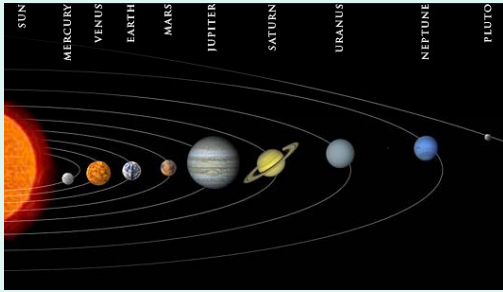


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Newton's Laws explain that *something* must be acting on the planets to keep them in orbit



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### Newton's Universal Law of Gravitation

$$F_{grav} = \frac{GMm}{r^2}$$



**M** is the mass of the Sun

**m** is the mass of a planet (i.e., Earth)

**r** is the distance between them

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**Example:** What if you discovered a planet with the same mass as Earth but THREE times as far from the Sun—how would its gravitational pull by the Sun compare to Earth's?

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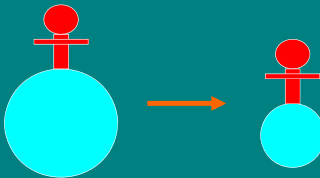
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**Example:** How would your weight (i.e., the force of gravity) compare a planet which has the **same mass** as the Earth but is **half** the size?



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### Is there gravity beyond the Earth's surface?



"weightless": NOT beyond influence of gravity

- treat astronaut as any other orbiting body around Earth
- Earth's pull and astronaut's motion keeps astronaut in orbit
- feels 'weightless' because she is in a constant state of "free fall" but actually the force of gravity is exactly balanced by her motion

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Earth-orbiting satellite (low)

### Altitudes of Different Earth Orbits

- satellites (communication, science) – more than 8,500 objects
- observatories (Hubble ST, Spitzer ST, Chandra X-ray Observatory, etc.)
  - Low Earth Orbit: between 160 - 2000 km
- Geostationary Orbit: period=sidereal period; from Earth, appear fixed
  - Highly Elliptical Orbits (HEO): 24 hour period; Sirius radio
  - low altitude perigee and high altitude apogee

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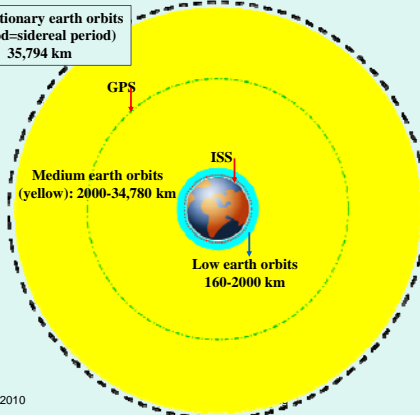
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Geostationary earth orbits  
(period=sidereal period)  
35,794 km



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Earth-orbiting satellite (low)

### Atmospheric Drag

- Friction can cause objects to lose orbital energy
- Low-earth orbiting satellite (alt = few 100 km)
- drag from atmosphere causes energy to be lost to thermal energy in atmosphere (can burn up if/when fall!)

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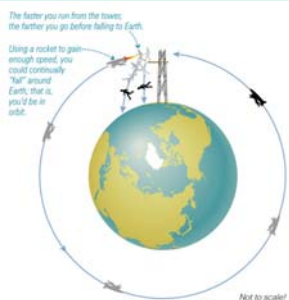
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### Why don't objects above the Earth's surface just FALL onto the Earth?



if things are moving with any **horizontal motion**, they can oppose the downward **PULL** of gravity

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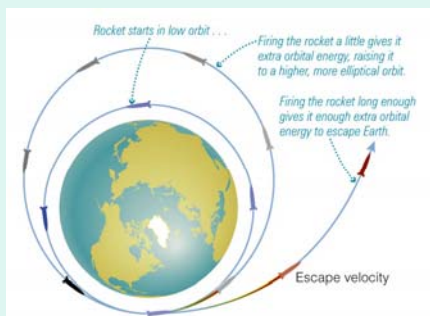
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### Escape velocity: increasing the orbital energy enough to escape!



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Some parts of the North Atlantic coasts experience  
HUGE changes in tides 4x daily!



- Most places on Earth with oceans experience two high tides  
and two low tides a day, spaced about 6 hours apart

How does gravity cause tides on Earth?

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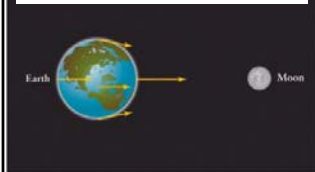
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What is the misconception about  
the cause of the tides?



• Tides are NOT caused by  
the Moon pulling the Earth's  
oceans toward it in 1-direction  
- then only one tidal "bulge"  
- then only one high tide a day

• Actually, tides are the result  
of the difference in the gravity  
force from the Moon acting  
on different parts of the Earth

-tides are caused by "stretching  
forces" which create TWO  
tidal bulges (one on each side  
of the Earth)  
-high tides are when Earth rotates  
through each tidal bulge

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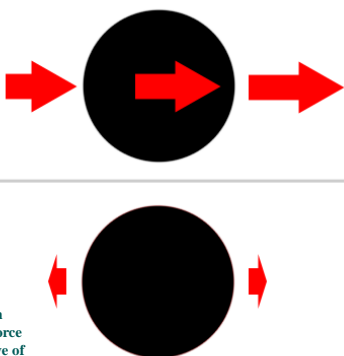
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Gravitational  
force acting on  
earth from body  
to the right

Difference in  
gravitational force  
from perspective of  
Earth




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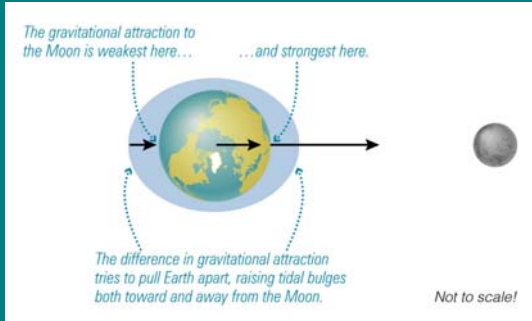
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### Tides on Earth: Tidal Forces from the Moon

- Both land and water are affected, but changes in water obvious
- Two "high" tides a day as Earth rotates through these bulges




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### Spring Tides:

Sun, Moon in same alignment magnify effect



### Neap Tides

### Neap Tides:

Sun, Moon in opposite alignment diminish effect



Sun also plays a role, but surprisingly, the Moon has a more important role because the difference in gravitational force from one side to the other of the Earth is more than the difference of the Sun's pull!

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