# AST 301, Lecture 1

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Cosmic Catastrophes (AKA Collisions)

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# Course Components

- Office: ESS 449; Hours: MWF 2 – 3
- URL: `www.astro.sunysb.edu/lattimer/AST301`
- Texts: "Cosmic Catastrophes" (Wheeler); "Disturbing the Solar System" (Rubin); "Extreme Explosions: Supernovae, Hypernovae, Magnetars, and Other Unsual Cosmic Blasts" (Stevenson)
- Supplemental non-required texts (not ordered from bookstore): "Disturbing the Solar System" by Rubin, "The Life and Death of Planet Earth" by Ward and Brownlee, and "Rare Earth" by Ward and Brownlee, "Countdown to Apocalypse" by Halpern. May be useful for term papers.
- Exams: No exams.
- Homeworks: about 10, count 40% of total, 1 per week (except first week), submitted as pdf file to Blackboard. Late penalties apply.

# Course Components, cont.

- Term Reports: Three term reports, counting 60% total. Due dates are 23 February, 23 March , and 20 April. Must be submitted as a pdf file to Blackboard. Late penalties apply. Suggested topics are on course website, and alternate topics that are highly relevant to the course are OK. If you questions, check with me.
- Class Presentation: We want to discuss reports in class, so you will be expected to give a 15-20 minute presentation about your report. I will assign presentation dates when you submit the report; they will be during the first 3 classes following the due date. You may give a blackboard demonstration, or you can use a computer. If you want to use an Apple, bring your machine and a video adaptor.
- Be forewarned about the consequences of plagiarism.

# Course Outline

- Basic Introduction to Astronomy and Measurements
- Properties of Light, Gravity and Kepler's Laws
- Stars: Their birth, evolution and deaths
- Birth and Evolution of the Solar System
- Comets, Asteroids and Meteorites
- Lunar and Other Craters – Impact/Migration Threats
- Catastrophes and Risk
- Evolution of the Earth
- Ice Ages and Global Warming
- Stellar Eruptions (Solar Flares)
- Binary Stars, White Dwarfs and Novae
- Supernovae, both Thermonuclear and Core-Collapse
- Neutron Stars and X-ray Bursts
- Gamma Ray Bursts and Merging Compact Objects
- Collisions and Close Encounters of Stars and Galaxies

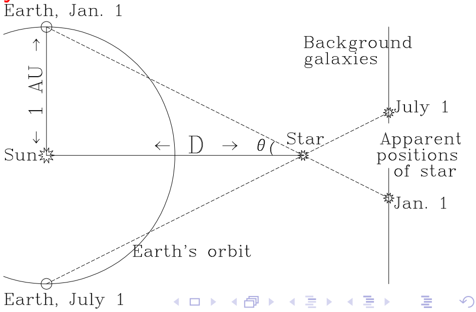
# Distances in Astronomy

- Radius of Earth ($\oplus$): $R_\oplus = 6.4 \cdot 10^8$ cm = 3977 miles
- Radius of Sun ($\odot$): $R_\odot = 7 \cdot 10^{10}$ cm = 435,000 miles
- Earth–Sun distance: 1 Astronomical Unit (1 AU) $= 1.5 \cdot 10^{13}$ cm =93,000,000 miles
- light-year $= 9.5 \cdot 10^{17}$ cm (1 year $= 3.16 \cdot 10^7$ s and $c = 3 \cdot 10^{10}$ cm/s) 1 lt.-yr. $= 3.16 \times 3 \times 10^{7+10}$ cm

parsec (pc) = AU/tan(1″) $= 3.1 \cdot 10^{18}$ cm (3.26 lt.-yr.)
$D(\mathrm{pc}) = 1/\theta('')$ since

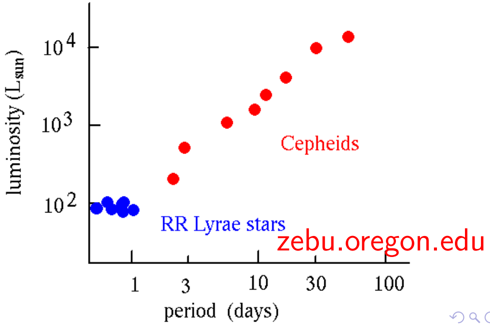
$\tan\theta \simeq \theta$ for very small angles.
1 kpc $= 10^3$ pc

1 Mpc $= 10^6$ pc



# Cosmic Distance Ladder

- Parallax Establish a database of stellar distances to thousands of nearby stars.
- Inverse Square Law of Brightness Stars established to be similar (color, spectra, etc.) have similar luminosities. Their relative brightnesses then yield their relative distances.
- Statistical, Secular and Moving Cluster Parallexes
- Cepheid and RR Lyrae Variable Stars as Standard Candles Henrietta Leavitt discovered in 1912 the period-luminosity relation among Cepheid variables. They are now used as *standard candles*.



- Velocity Measurements With Redshifts
  Planetary nebulae, novae, supernovae,
  orbiting stars.
- Tully-Fisher Relation Relation between the observed velocity width (amplitude of rotation curve) and luminosity of spiral galaxies.
- Type I Supernovae Exploding white dwarfs of similar masses yield similar luminosities and therefore are good standard candles.
- Redshifts of Galaxies, Quasars and Gamma-Ray Bursters
- Gravitational Waves Redshift measurements from merging binaries of black holes and neutron stars.

## The Universe Reduced by a Billion

| Object | Size | Distance from Earth |
|---|---|---|
| Earth | 1.3 cm (grape) | — |
| Moon | .35 cm (corn kernal) | 1 foot |
| Sun | 1.4 m (child's height) | 150 m (1 city block) |
| Jupiter | 15 cm (grapefruit) | 5 city blocks |
| Saturn | 12 cm (orange) | 10 city blocks |
| Uranus | 5.2 cm (apricot) | 20 city blocks |
| Neptune | 5 cm (plum) | 30 city blocks |
| Pluto | 0.23 cm (rice grain) | 40 city blocks |
| $\alpha$ Centauri | 1.6 m (small adult) | Earth's circumference |
| Center of Galaxy | — | 1.7 AU |
| Andromeda Galaxy | Sun – Pluto distance | 400 AU |
| Human | atom | — |

# Energy and Luminosity (Power)

- Power and Luminosity are equivalent
- Power is Energy/Time, or Energy = Power × Time
- Luminosity of the Sun: $L_\odot = 4 \cdot 10^{33}$ erg/s $= 4 \cdot 10^{23}$ kw $= 3 \cdot 10^{23}$ hp
- 1 watt $= 10^7$ erg/s;1 kilowatt $= 10^3$ watt
- 1 kilowatt-hour = 1 kwh $= 3.6 \cdot 10^{13}$ erg
- 1 horsepower = 1 hp = 0.75 kw
- 1 BTU $= 1.055 \cdot 10^{10}$ erg = 1.055 kw-second
- 1 megaton TNT $= 3 \cdot 10^8$ kwh

# Economics of Solar Power

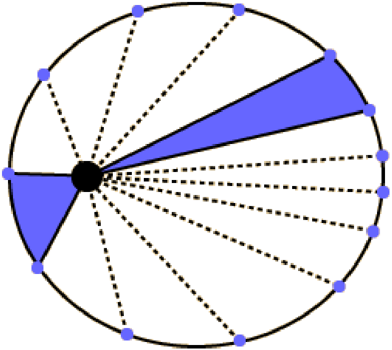
- On Long Island, 1 kwh costs \$0.17
- The world's annual energy use is about $10^{28}$ ergs $\Rightarrow \$4.7 \cdot 10^{13} = \$47$T
- The world's power use thus averages $3.2 \cdot 10^{20}$ erg/s $= 32$ billion kw
- The Solar Constant is solar energy received per unit area per second at the Earth: $\frac{L_\odot}{4\pi(1 \ \mathrm{AU})^2} = 1.3 \cdot 10^6 \frac{\mathrm{erg}}{\mathrm{cm}^2 \ \mathrm{s}} = 0.13 \frac{\mathrm{watt}}{\mathrm{cm}^2}$
- A collector of $2.4 \cdot 10^{14}$ cm$^2$ $= 9300$ mi$^2$ area operating at 100% efficiency is needed to continuously supply the world.

# Mass

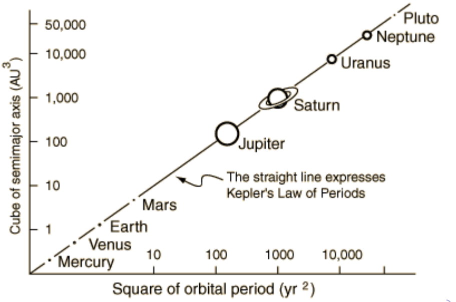
- Mass of the Sun: $\mathrm{M}_\odot = 2 \cdot 10^{33}$ g
- Mass of the Earth: $\mathrm{M}_\oplus = 6 \cdot 10^{27}$ g $= 1.3 \cdot 10^{25}$ lb. $= 6.6 \cdot 10^{21}$ tons $= 3 \cdot 10^{-6}\ \mathrm{M}_\odot$
- $\mathrm{M}_{Jupiter} = 1.9 \cdot 10^{30}$ g $= 318\ \mathrm{M}_\oplus = 0.95 \cdot 10^{-3}\ \mathrm{M}_\odot$

- Mass–energy equivalence stated in Einstein's Law: $E = Mc^2$
- Energy equivalent of the Sun: $\mathrm{E}_\odot = \mathrm{M}_\odot c^2 = 2 \cdot 10^{54}$ erg
- Implied lifetime of the Sun: $\tau_\odot \simeq \mathrm{E}_\odot/\mathrm{L}_\odot = 5 \cdot 10^{20}$ s $= 1.7 \cdot 10^{13}$ yr $=$ 17,000 Gyr (1 Gyr $= 10^9$ yr)
- Nuclear energy reactions in the Sun are only .007 (0.7%) efficient, and only the innermost 10% of the Sun will ever be "burned": $\tau_\odot = 17,000 \times .007 \times .1$ billion yrs $=$ 12 billion yrs

# Kepler's Laws



1. Law of Orbits: planets move in elliptical orbits with Sun at one focus.
2. Law of Areas: a line connecting a planet with the Sun sweeps out equal areas in equal times.
3. Law of Periods: The square of a planet's orbital period (year) is proportional to the cube of its semimajor axis (distance from Sun).



# Mass Measurements

- Kepler's 1-2-3 Law

$$G(M_1 + M_2)P^2 = 4\pi^2(R_1 + R_2)^3$$

Measure orbital period $P$. Measure stellar velocity $V_1 \sin i$ from maximum Doppler shift of spectral lines. The circumference of $M_1$'s orbit is $2\pi R_1 = PV_1$. Total mass is

$$M_1 + M_2 = PV_1^3(1 + M_1/M_2)^3/(2\pi G).$$

If $M_2 >> M_1$ then

$$M_2 = PV_1^3/(2\pi G).$$

Caveat: inclination angle $i$ must be known to find masses. If $V_2$ is also measured, then $M_1/M_2$ is found.

- Gravitational Lensing
- Position in Hertzsprung-Russell Diagram
- Estimates Based on Luminosity Applied to molecular clouds, galaxies, neutron stars and black holes.