Please register for MasteringAstronomy …

Homework #0 due on **Friday** (tomorrow)
[for practice, not credit]

Homework #1 due next **Tuesday**
[for credit!]

Read: Chap 1 & 3
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Orchard Hill Observatory Open House

- The Observatory will open for the semester on Thursday, September 6th at 9:00pm!
- Observatory open nights are every (clear) Thursday from 8:30 - 10:30 PM.
- http://www.astro.umass.edu/~orchardhill
Announcements

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- Questions??

Read: Chap 1 & 3
Today’s topics:

- Scales: a quick review
- Motions
- Origin of elements
- Scientific discovery

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09/06/12 – slide 3
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Topics from last class: astronomical scales

- Length scales
- Time scales
- Dealing with large numbers at any scale!
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Questions?
Thought question #1

Suppose you tried to count the more than 100 billion stars in our galaxy, at a rate of one per second . . .

How long would it take you?

A. a few weeks
B. a few months
C. a few years
D. a few thousand years
Suppose you tried to count the more than 100 billion stars in our galaxy, at a rate of one per second . . .

How long would it take you?

A. a few weeks  
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Thought question #2

Why can’t we see a galaxy 15 billion light-years away? (Assume the Universe is 14 billion years old.)

A. Because no galaxies exist at such a great distance.
B. Galaxies may exist at that distance, but their light would be too faint for our telescopes to see.
C. Because looking 15 billion light-years away means looking to a time before the Universe existed.
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How big is the Universe?

- The Milky Way is one of about 100 billion galaxies.
- \(10^{11} \text{ stars/galaxy} \times 10^{11} \text{ galaxies} = 10^{22} \text{ stars}\)
How big is the Universe?

- The Milky Way is one of about 100 billion galaxies.
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As many stars as grains of (dry) sand on all Earths beaches…

Read: Chap 1 & 3

09/06/12 – slide 6
What have we learned?

- **How big is Earth compared to our solar system?**
  - The distances between planets are huge compared to their sizes. Scale model: if the Earth is the size of a ball point, the Sun is 15 meters away.

- **How far away are the stars?**
  - On the same scale, the stars are thousands of kilometers away.

- **How big is the Milky Way Galaxy?**
  - It would take more than 3000 years to count the stars in the Milky Way Galaxy at a rate of one per second, and they are spread across 100,000 light-years.

Read: Chap 1 & 3

Powers of 10
What have we learned?

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What have we learned?

- **Grains of sand**

- **Local motions**

- **Galactic motions**

- **Dark Matter**

- **Expanding Universe**

- **Motions summary**

- **Time scales redux**

- **Origin of the elements**

- **What’s next?**

---

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How do our lifetimes compare to the age of the Universe?

The cosmic calendar: a scale on which we compress the history of the Universe into 1 year.
What have we learned?

How big is the Universe?

- The observable Universe is 14 billion light-years in radius and contains over 100 billion galaxies with a total number of stars comparable to the number of grains of sand on all of Earth’s beaches.

How do our lifetimes compare to the age of the Universe?

- On a cosmic calendar that compresses the history of the Universe into 1 year, human civilization is just a few seconds old, and a human lifetime is a fraction of a second.

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Local motions

Earth rotates: speed = 0.5 km/s = 1,700 km/hour = 1,000 miles/hour

It may seem that the Earth is standing still but . . .
Earth rotates: speed = 0.5 km/s = 1,700 km/hour = 1,000 miles/hour

Earth orbital speed (solar system) = 30 km/s = 170,000 km/hour = 67,000 miles/hour
Local motions

- Earth rotates: speed = 0.5 km/s = 1,700 km/hour = 1,000 miles/hour

- Earth orbital speed (solar system) = 30 km/s = 170,000 km/hour = 67,000 miles/hour

- Sun’s orbital speed (Galaxy) = 200 km/s = 450,000 miles/hour
Motions in the galaxy

Stars in the local solar neighborhood move randomly relative to one another...

...while the galaxy's rotation carries them around the galactic center at even higher speed.

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Read: Chap 1 & 3

09/06/12 – slide 11
Most of the galaxy’s light comes from stars and gas in the galactic disk and central bulge.

... but measurements suggest that most of the mass lies unseen in the spherical halo that surrounds the entire disk.
Discovery by Edwin Hubble in 1929

- All galaxies outside of our Local Group are moving away from us
- The more distant the galaxy, the faster it is moving
- Assume: nothing special about our location in the Universe
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Conclusion: We live in an expanding Universe!
Expanding Universe

Distances and Speeds as Seen from the Local Raisin

<table>
<thead>
<tr>
<th>Raisin Number</th>
<th>Distance Before Baking</th>
<th>Distance After Baking (1 hour later)</th>
<th>Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1 cm</td>
<td>3 cm</td>
<td>2 cm/hr</td>
</tr>
<tr>
<td>2</td>
<td>2 cm</td>
<td>6 cm</td>
<td>4 cm/hr</td>
</tr>
<tr>
<td>3</td>
<td>3 cm</td>
<td>9 cm</td>
<td>6 cm/hr</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>
Earth rotates around its axis once each day, carrying people in most parts of the world around the axis at more than 1,000 km/hr.

Earth orbits the Sun once each year, moving at more than 100,000 km/hr.

The Solar System moves relative to nearby stars, typically at a speed of 70,000 km/hr.

The Milky Way Galaxy rotates, carrying our Sun around its center once every 230 million years, at a speed of about 800,000 km/hr.

Our galaxy moves relative to others in the Local Group; we are traveling toward the Andromeda Galaxy at about 300,000 km/hr.

The universe expands. The more distant an object, the faster it moves away from us; the most distant galaxies are receding from us at speeds close to the speed of light.
What have we learned?

- How is Earth moving in our solar system?
  - It rotates on its axis once a day and orbit the Sun at a distance of 1 A.U. = 150 million km = $1.5 \times 10^8$ km
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\text{Speed} = \frac{2\pi \times 1.5 \times 10^8 \text{ km}}{365 \text{ day}}
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$$= 3.0 \times 10^1 \text{ km/sec}$$
What have we learned?

How is Earth moving in our solar system?

- It rotates on its axis once a day and orbit the Sun at a distance of 
  1 A.U. = 150 million km = $1.5 \times 10^8$ km
- Speed = 30 km/sec

How is our solar system moving in the Milky Way galaxy?

- Stars in the Local Neighborhood move randomly relative to one another and orbit the center of the Milky Way in about 230 million years
What have we learned?

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- How is our solar system moving in the Milky Way galaxy?
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- How do galaxies move within the Universe?
  - All galaxies beyond the Local Group are moving away from us with expansion of the Universe: the more distant they are, the faster they’re moving
Are we ever sitting still?

- Earth rotates on axis: > 1000 km/hr
- Earth orbits Sun: > 100,000 km/hr
- Solar system moves among stars: ~ 70,000 km/hr
- Milky Way rotates: ~ 800,000 km/hr
- Milky Way moves in Local Group
- Universe expands

Read: Chap 1 & 3
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Milky Way moves in Local Group
Universe expands

No!

Read: Chap 1 & 3
Time for Earth to make one rotation: 1 day
Time scales for motion: a brief interlude

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\[
= 2.4 \times 10^8 \text{ year} = 240 \times 10^6 \text{ year}
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- Time for Milky Way to collide with Andromeda Galaxy: 10 billion years
- Time for light to get to us from the most distant galaxy: 14 billion years
Gas (mostly hydrogen) settles in the disk of galaxies
This gas fragments into dense knots, forms stars
The stars fuse hydrogen into helium and heavier elements, generating energy
The star explodes!

Galaxy: a huge “island” of stars moving around a common center and held together by gravity.
Gas (mostly hydrogen) settles in the disk of galaxies

This gas fragments into dense knots, forms stars

The stars fuse hydrogen into helium and heavier elements, generating energy

The star explodes!

Nebula: an interstellar cloud of dust and/or gas
Gas (mostly hydrogen) settles in the disk of galaxies

This gas fragments into dense knots, forms stars

The stars fuse hydrogen into helium and heavier elements, generating energy

The star explodes!

Star: generates heat and light through nuclear fusion
Origin of the elements

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Supernova: fusion fuel exhausted, the star explodes
Origin of the elements

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How has the study of astronomy affected human history?

- Copernican Revolution showed that Earth was not the center of the Universe (Chapter 3)
- Study of planetary motion led to Newton's Laws of motion and gravity (Chapter 4)
- Newton's laws laid the foundation of the industrial revolution
- Modern discoveries are continuing to expand our cosmic perspective
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