If your last name begins with The letter A–K, you should be in the Planetarium.
This Week: In-Class Planetarium Show

- **Tue, Oct 5th, Last Names A–K:** Go to planetarium

- **Thu, Oct 7th, Last Names L-Z:** Go to planetarium

- **Jot some notes down for writing up your experience on the Mastering Astronomy final assignment on your out-of-class exercises.**
Announcements

- Exam #2 Buy-back due in class or by email, by Thursday, Oct. 7th, 12pm.

- Exam #2 grades and discussion after fall break.

- HW #4 Due this Sunday, 11:45pm

- No Class Next Tuesday: Enjoy fall break!
Doppler Shift
Doppler Shift

This happens to light too:
Moving away? Frequency goes down. Shifts red.
Last Time

Electromagnetic Spectrum: Full range of Light, only a tiny portion of which we can see.

Spectroscopy divides light into its “colors”.

Blackbody spectrum contains all colors... the sun is very close to a blackbody spectrum.
Light

- We use light to study the universe.

- We can infer temperature, composition, motion, and more, just by studying the spectrum of light from a distant object.

- Even if it’s all the way across the universe!
LAST TIME

Absorption spectrum: some colors missing.

Emission spectrum: only certain colors present.
All atoms have distinct energy levels.

As electrons transition between them, they lead to photons of the specific wavelengths.

A “fingerprint” in the spectrum.
Spectrum Demo

- Get a grating.

- Hold it up and look through it at the lamps, first the normal incandescent, then special lamps that glow in a single element.

- Should see various “Rainbows” going off in several directions.

- Please return at the table up top at the end of class.
What good are telescopes?

- Like giant “light buckets”, they collect more light than our eyes can (larger collecting area).

- They can see more detail than our eyes can (better resolution).

- They can detect other forms of light, like x-rays, infrared, radio (better wavelength coverage).
Bigger is better!

Collects more light
Bigger is better!

- Better angular resolution
- Ability to separate two nearby objects.
Basic Telescope Design

Refracting: lenses

Refracting Telescope

Yerkes 1-m Refractor
Basic Telescope Design

Reflecting: mirrors

Reflecting Telescope

Gemini 8 meter
Twin 10-m Keck Telescopes
Using Telescopes

- Astronomers almost never “look through” a telescope with their eyes.

- Instead instruments are used which are more sensitive, can see other wavelengths of light, and can record their data directly are used.
Radio Telescopes
Why do we put telescopes in space?

We can overcome problems with the Earth’s atmosphere.
1. Light Pollution
1.) **Light Pollution**

**Bright Sky**

**Dark Sky**

Tuesday, October 5, 2010
2) Atmospheric Turbulence

Atmospheric turbulence causes "twinkling" which blurs the image. This limits the angular resolution of all big telescopes to about 0.5 arcseconds.
2) Atmospheric Turbulence

- **Image 1**: From sea level (3 arcseconds)
- **Image 2**: From a mountain (0.5 arcseconds)
- **Image 3**: Hubble Space Telescope (0.1 arcseconds)
3) Atmospheric Absorption

Most radiation is absorbed by the atmosphere (which is a good thing!)
Technology & Astronomy

Adaptive optics: A fast computer figures how the atmosphere is distorting the light and moves a deformable mirror to compensate.
**Technology & Astronomy**

**Adaptive optics:** A fast computer figures how the atmosphere is distorting the light and moves a deformable mirror to compensate.
Interferometry: allows individual telescopes to work together to achieve the angular resolution of a larger telescope.
Very Large Array (New Mexico)
First, something amazing!!!

The first discovered truly earth-like planet, discovered around a star 20 light years away. Announced over the weekend.

Close enough to its dim, red star for liquid water to exist, in a 37 day orbit.
The Sun
The Sun Rules

- Largest in the solar system, by far (108 times Earth’s diameter).
- Almost entirely Hydrogen & Helium (98%)
### Mass in Solar System

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sun</td>
<td>99.8%</td>
</tr>
<tr>
<td>Jupiter</td>
<td>0.1%</td>
</tr>
<tr>
<td>Comets</td>
<td>0.05%</td>
</tr>
<tr>
<td>All Other Planets</td>
<td>0.04%</td>
</tr>
<tr>
<td>Earth</td>
<td>0.0003%</td>
</tr>
</tbody>
</table>
Earth and moon, to scale
The image at right shows a picture of the Sun. The dark spots located on this image are sunspots. How does the size of Earth compare (approximately) to the size of the sunspot that is identified on the image of the Sun?

A) Earth and the sunspot are about the same size.

B) The sunspot is much larger than Earth.

C) The sunspot is much smaller than Earth.
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## Solar System Temperatures

<table>
<thead>
<tr>
<th>Planet</th>
<th>Distance</th>
<th>Temperature (top of atmosphere)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury</td>
<td>0.38 AU</td>
<td>450 K</td>
</tr>
<tr>
<td>Venus</td>
<td>0.72 AU</td>
<td>330 K</td>
</tr>
<tr>
<td>Earth</td>
<td>1.00 AU</td>
<td>280 K</td>
</tr>
<tr>
<td>Mars</td>
<td>1.52 AU</td>
<td>230 K</td>
</tr>
<tr>
<td>Jupiter</td>
<td>5.20 AU</td>
<td>120 K</td>
</tr>
<tr>
<td>Saturn</td>
<td>9.54 AU</td>
<td>90 K</td>
</tr>
<tr>
<td>Uranus</td>
<td>19.22 AU</td>
<td>60 K</td>
</tr>
<tr>
<td>Neptune</td>
<td>30.06 AU</td>
<td>50 K</td>
</tr>
<tr>
<td>Pluto</td>
<td>39.5 AU</td>
<td>40 K</td>
</tr>
</tbody>
</table>

350 F

45 F

-390 F
**Planet Orbits**

- **Orbits aligned in same plane (ecliptic)**
- Explains why planets always in Zodiac
- **Pluto’s orbit tipped most (17 degrees)**
- **All planets orbit counter-clockwise**
- **Planets rotate counter-clockwise**
  - except Venus
- **Rotation axis roughly perpendicular to orbit**
  - except Uranus and Pluto

Tuesday, October 5, 2010
Orbits to scale; planet sizes exaggerated about one million times. Sun not to scale.
Planet Orbits
Types of Planets

- Two basic “flavors” of Planets:
  - Terrestrial (small, rocky, close to the sun)
  - Jovian (large, gas rich, far out from the sun)
Four Terrestrial Planets

APOD/2008-09-30

Tuesday, October 5, 2010
Terrestrial Planets

Terrestrial = Earth-like

- Mercury
- Venus
- Earth (and Moon)
- Mars

Small, low mass

No large moons except for Earth's Moon (Mars has two small ones…)

Close to Sun
**Terrestrial Planets**

- **Rocky Surface**
  - High density (3-5 gm/cm$^3$)  
    (water has density of 1 gm/cm$^3$)

- **Geologic Activity (volcanoes, continental drift)**
  - Present on larger planets (Earth and Venus)
  - Absent on smaller planets (Moon, Mercury, and Mars)

- **Atmosphere**
  - Little hydrogen and helium
  - Mostly carbon dioxide (Venus and Mars) or nitrogen (Earth)
  - Smaller planets have no atmosphere (Mercury, Moon)
Surface of Venus
Asteroids

The Asteroid Belt

About the Size of Toledo
Asteroids

- Small rocky bodies
- High density (3-5 gm/cm³)
- Usually not round
- Primitive composition
  - (oldest bodies in solar system)

Asteroid Belt

- Found mostly between Mars and Jupiter
- Probably a failed planet?
Plots from the Minor Planet Center

http://www.cfa.harvard.edu/iau/lists/InnerPlot.html

Plot prepared by the Minor Planet Center (2008 Feb.12).
THE MIDDLE SOLAR SYSTEM

This animation shows the motion of the middle part of the solar system over a two-year time period. The sun is at the center and the orbits of the planets Mercury, Venus, Earth Mars and Jupiter are shown in light blue (the locations of each planet are shown as large crossed circles). Comets are shown as blue squares (numbered periodic comets are filled squares, other comets are outline squares). Main-belt minor planets are displayed as green circles, near-Earth minor planets are shown as red circles.

The individual frames were generated on an OpenVMS system, using the PGPLOT graphics library. The animation was put together on a RISC OS 4.03 system using !InterGif.
A Different Kind of Planet

- Bigger and move massive
- Lower density, and different composition
- Rings and numerous moons
Jovian (Giant) Planets: Basics

- **Distance:** 5-30 AU
  - Much farther from Sun than terrestrial planets
  - Much colder (50-100 K)

- **Mass:** 10-100 Earth masses
  - Much more massive than terrestrial planets

- **Jupiter & Saturn are similar**
  - Size (about 10 Earth diameters)
  - Composition: mostly hydrogen and helium

- **Uranus & Neptune are similar**
  - Smaller than Jupiter & Saturn
  - Less hydrogen and helium, more methane, ammonia, water. Some metal and rock.
Reminders

- Go to the planetarium on Thursday. No ticket needed.

- Finish reading 6.1–6.2

- Buy-back by Thursday in class.

- No class next Tue: have a nice fall break.