Lecture 2
Motions in the Sky
January 2b, 2014
Yearly Motions

- The Earth travels around the Sun once every year.
- The Earth is tilted by 23.5 degrees with respect to the orbital plane.
What is a Day?

- **Solar Day** = amount of time for Earth to rotate once on its axis with respect to the Sun.
- **Sidereal day** = amount of time for Earth to rotate once with respect to the stars.
  - Shorter than solar day by 4 minutes.
- Since solar and sidereal days are **NOT** the same, a star will typically rise ~4 minutes earlier each day.
The star Sirius in the constellation Canis Major crosses our meridian at 10:30 pm on January 23. When will it cross the meridian one month (30 days) later?

A. 8:30 pm
B. 10:14 pm
C. 10:26 pm
D. 10:30 pm
E. 12:30 am
The star Sirius in the constellation Canis Major crosses our meridian at 10:30 pm on January 23. When will it cross the meridian one month (30 days) later?

A. 8:30 pm  Stars rise 4 minutes earlier each day, so Sirius will rise 120 minutes earlier after one month has passed.
B. 10:14 pm
C. 10:26 pm
D. 10:30 pm
E. 12:30 am
• The Sun lines up with different constellations during the year.

Presently

These stars are overhead during the day. Sun is too bright to see them.

These stars are visible at night.

6 months later

These stars are visible at night.

These stars are overhead during the day. Sun is too bright to see them.
Ecliptic

- Path of the sun through the celestial sphere.
- Not aligned with Celestial Equator due to tilt of the Earth
Zodiac

• The 13 constellations through which the sun passes during the course of a year.
## The Real Signs of the Zodiac

<table>
<thead>
<tr>
<th>Constellation</th>
<th>Traditional</th>
<th>Actual (2000)</th>
<th>Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capricornus</td>
<td>Dec. 22-Jan. 21</td>
<td>Jan. 21-Feb. 16</td>
<td>26</td>
</tr>
<tr>
<td>Aquarius</td>
<td>Jan. 22-Feb. 21</td>
<td>Feb. 16-Mar. 11</td>
<td>24</td>
</tr>
<tr>
<td>Pisces</td>
<td>Feb. 22-Mar. 21</td>
<td>Mar. 11-Apr. 18</td>
<td>38</td>
</tr>
<tr>
<td>Aries</td>
<td>Mar. 22-Apr. 21</td>
<td>Apr. 18-May 13</td>
<td>25</td>
</tr>
<tr>
<td>Taurus</td>
<td>Apr. 22-May 21</td>
<td>May 13-June 22</td>
<td>40</td>
</tr>
<tr>
<td>Gemini</td>
<td>May 22-June 21</td>
<td>June 22-July 21</td>
<td>29</td>
</tr>
<tr>
<td>Cancer</td>
<td>June 22-July 21</td>
<td>July 21-Aug. 10</td>
<td>20</td>
</tr>
<tr>
<td>Leo</td>
<td>July 22-Aug. 21</td>
<td>Aug. 10-Sept. 16</td>
<td>37</td>
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<tr>
<td>Virgo</td>
<td>Aug. 22-Sept. 21</td>
<td>Sept. 16-Oct. 31</td>
<td>45</td>
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<tr>
<td>Libra</td>
<td>Sept. 22-Oct. 21</td>
<td>Oct. 31-Nov. 23</td>
<td>23</td>
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<tr>
<td>Scorpius</td>
<td>Oct. 22-Nov. 21</td>
<td>Nov. 23-Nov. 29</td>
<td>6</td>
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<tr>
<td>Ophiuchus</td>
<td>Nov. 29-Dec. 18</td>
<td>Nov. 29-Dec. 18</td>
<td>19</td>
</tr>
<tr>
<td>Sagittarius</td>
<td>Nov. 22-Dec. 21</td>
<td>Dec. 18-Jan. 21</td>
<td>34</td>
</tr>
</tbody>
</table>
Planetary Motion

The planets all move in the same plane about the Sun so they all appear to move along the ecliptic.
Parallax

• If you look at an object from two different places (but at same distance) it will appear to move with respect to the background.

• Change in position = parallax angle
Parallax

- The greater the distance, the smaller the parallax angle.
- The greater the baseline (distance from A to B), the greater the parallax angle.

\[
\text{parallax angle (°)} = 57.3 \times \frac{\text{baseline (km)}}{\text{distance (km)}}
\]

or

\[
\text{distance (km)} = 57.3 \times \frac{\text{baseline (km)}}{\text{parallax angle (°)}}
\]
• Review angular measures

• Parallax in-class activity

\[ r = \frac{D}{\theta} \frac{180^\circ}{\pi} = 57.3 \frac{D}{\theta} \]
Solstices and Equinoxes

• Solstice
  – position in Earth’s orbit at which the Sun is furthest from the Celestial Equator.
  – Longest and shortest days of the year.

• Equinox
  – position in Earth’s orbit at which the Sun crosses the Celestial Equator.
  – Day and Night are the same length.
The Ecliptic (Path of the Sun)

**Autumnal Equinox:**
Sun crosses Celestial Equator. (September 21)

**Winter Solstice:**
Sun at lowest point in sky for N. Hemisphere. (December 21)

**Summer Solstice:**
Sun reaches highest point in sky for N. Hemisphere. (June 21)

**Vernal Equinox:**
Sun crosses Celestial Equator. (March 21)
Suppose your latitude is 45°N. What is the Sun’s elevation above the southern horizon at noon on the summer solstice?

A. 45.0°
B. 23.5°
C. 68.5°
D. 105°
Suppose your latitude is 45°N. What is the Sun’s elevation above the southern horizon at noon on the summer solstice?

A. 45.0°  
B. 23.5°  
C. 68.5°  
D. 105°

The celestial equator is tilted at an angle equal to your latitude from the zenith. In this case, the celestial equator is 45° from your zenith and therefore 45° above the southern horizon. The Sun is 23.5° above the celestial equator on the summer solstice. Therefore the Sun is 23.5° + 45° = 68.5° above the southern horizon.
Celestial Coordinates

- **Declination** (DEC): Degree north (+) or south (−) of the Celestial Equator. Similar to latitude.
• **Right Ascension** (RA): Position east or west of the position of the Sun at the Vernal Equinox. Similar to longitude.

  – Sky split into 24 hours such that 1 hour = 15°

As the Earth rotates, the sky appears to move through 1 hour of RA each hour.
What is the right ascension of a star that is on the meridian at midnight on the summer solstice?

A. 0 h 0 min
B. 6 h 0 min
C. 12 h 0 min
D. 18 h 0 min
What is the right ascension of a star that is on the meridian at midnight on the summer solstice?

A. 0 h 0 min  
B. 6 h 0 min  
C. 12 h 0 min  
D. 18 h 0 min

At the summer solstice, the R.A. of the Sun is 6 h 0 min. A star at midnight is exactly 12 h from the Sun, so its R.A. is 18 h 0 min.
The Seasons

- The Seasons are due to the tilt of the Earth with respect to the orbital plane.
  - Not distance from the Sun.
Why are the seasons warm and cold?

- During the Summer the sun is higher in the sky so the light is more direct.

Full beam falls on A.

Sunlight

Only part of the beam falls on A.

Less heat is received because the surface is “tilted.”
Why are the seasons warm and cold?

- Sun is above the horizon longer in the summer.
- This interactive exercise shows the Sun’s path through the sky from two perspectives.
- This animation depicts the Sun’s eastward journey along the ecliptic, and shows it is highest in the sky during the summer. Try slowing the speed control way down at first.
Earth in June (Summer Solstice)

- Sun’s rays
- Arctic circle
- Tropic of Cancer
- Equator
- Tropic of Capricorn
- Antarctic circle
Earth in December (Winter Solstice)
Precession

- Discovered by Hipparchus (~150 BC)
- Position of North Celestial Pole changes on Celestial Sphere over time.

- Earth’s spin axis points to different locations on the celestial sphere over time.
What causes precession?

• The Earth experiences a slow wobble due to the gravitational tugs of the Moon and Sun.
Precession Observations

- One full precession period = 26,000 years.
  - The yellow circle is the path of the north celestial pole through the constellations.
  - Thuban = 3000 BC
  - Polaris = Present
  - Vega = 14,000 AD