Coordinates and Motions
ASTR 2110
Sarazin
** Astronomy **

- What is the Universe made of?
- How does the Universe work?
- How has the Universe changed?
  Where is it going?
- Where do we (humans) fit in?
Why study astronomy?

• Cultural value
• Influence on Man’s view of himself
• Practical applications (eventually)
• Hot subject now
Science

Not a collection of facts, but a method of arriving at truth

• Always adopt the simplest theory which explains the data

• Theories must make predictions

• Theories and predictions must be quantitative
Astronomy vs. Physics

Physics:
- Experimental
- Fundamental

Astronomy
- Observational
- Morphological

Most important idea in astronomy is that physics works

Same laws of physics apply to quasars across universe, black holes, etc.
Astronomical objects are so far away, we have no ability to judge depth.

Stars which appear close on the sky can be very far apart.
The Celestial Sphere
Measuring Angles

Degree $^\circ$ : $360^\circ$ = full circle, $90^\circ$ = right angle

Arcminute $'$ : $1^\circ$ (degree) = $60'$ (minutes)
also called minutes

Arcsecond $''$ : $1'$ (minute) = $60''$ (seconds)
also called seconds
Angles in the Sky
Horizon and Zenith

At any given place on Earth and time, we can only see ½ of the sky

Horizon = plane parallel to Earth’s surface
Altitude and Azimuth

- **meridian**: The vertical line passing through the zenith and the horizon.
- **horizon**: The apparent line where the sky meets the Earth's surface.
- **zenith**: The point directly above the observer.
- **60°**: The angle between the horizon and the position of an object in the sky.
Horizon and Zenith

At any given place on Earth and time, we can only see ½ of the sky

Horizon = plane parallel to Earth’s surface
Latitude and Longitude on Earth

- Washington, D.C.
- Prime Meridian of longitude
- Longitude
- Equator
- Latitude
The Celestial Sphere
<table>
<thead>
<tr>
<th>Geographical</th>
<th>Astronomical</th>
</tr>
</thead>
<tbody>
<tr>
<td>North pole</td>
<td>North celestial pole</td>
</tr>
<tr>
<td>Equator</td>
<td>Celestial equator</td>
</tr>
<tr>
<td>Latitude</td>
<td>Declination (Dec, $\delta$)</td>
</tr>
<tr>
<td>Longitude</td>
<td>Right Ascension (RA, $\alpha$)</td>
</tr>
</tbody>
</table>

24$^h$ = 360°  
1$^h$ = 15°  
1$^m$ = 15´  
1$^s$ = 15´´
Coordinates and Motions
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Daily (Diurnal) Rotation

Earth rotates each day

- Polaris
- North Star
- North Pole
- Equator
- South Pole
Precession

The Earth not only spins like a top, but it wobbles.
- The period of the wobble is 25,725 years.
- This wobble causes the North and South celestial poles to move through the sky.
- Precession is due to gravity of Sun and Moon.
- Discovered in 129 B.C by Hipparchus.
Precession of the Earth's Axis

Thuban (pole star in 3000 BC)

Polaris (pole star today)

Vega (pole star in 14,000 AD)
Precession: Gravity not parallel to rotation axis
Precession: Gravity not parallel to rotation axis
Precession of the Earth's Axis

Thuban (pole star in 3000 BC)

Polaris (pole star today)

Vega (pole star in 14,000 AD)
Precession and the Pole Star
Precession: A Problem for Astrology

European system of astrology set up roughly 2500 years ago, before precession was known.

– Never corrected for precession
– Personal traits supposed to reflect constellation in which Sun was located when you were born
– But, constellations (signs) are wrong today
Precession: A Problem for Astrology

Example: I was born on August 11, my sign is Leo

– I am suppose to have “lion-like” properties
  (Actually, I sort of like that image!)
– But, Sun was in Cancer when I was born
Precession:
A Problem for Astrology

Example: I was born on August 11, my sign is Leo
  – I am suppose to have “lion-like” properties
  – But, Sun was in Cancer when I was born
  – Should I be “crab-like” instead?
  – (You can decide whether I am crabby or not!)
Daily (Diurnal) Rotation

Earth rotates each day

Polaris
North Star

North Pole

Equator

South Pole
Rotation Changes Plane of Horizon

Stars, Sun, Moon, planets rise (in east) and set (in west) each day
Stars Rise and Set
Which stars can you see?
Which stars can you see?

B: stars rise and set, can be seen at some time
Stars Rise and Set
Which stars can you see?

A: circumpolar region = stars always up
Circumpolar stars
Which stars can you see?

C: always below horizon, never can be seen
The Southern Sky

Charlottesville: latitude = 35°, can’t see stars below -55°

- Southern Cross
- Coal Sack
- Large Magellanic Cloud
- Small Magellanic Cloud
Annual Revolution or Orbital Motion of Earth
Time

• Solar Time
  – “Day” = time for Sun to return to same position
  – Day should start at noon, but more convenient at midnight
Earth’s Rotation and Solar Time
Time

• Solar Time
  – “Day” = time for Sun to return to same position

• Sidereal Time (ST)
  – “Day” = time for stars to return to same position
  – Actual rotation period of Earth
  – ST = 0\(^h\) when Vernal Equinox is overhead
Solar day is longer than one Earth rotation period

Because the Earth is moving in its orbit, solar day is about 4 minutes longer than sidereal day. 4 minutes per day = one extra sidereal day per year.
HA = ST - RA
Orbit of Earth

North

Sun

Earth

Period of orbit = year
Relation of ST and Solar Time

Ignore complications: Earth’s orbit not circular, time zones, daylight savings, . . .
One extra sidereal day / year
1 day / year = (24 h / day) x (60 m / h) / (365.2425 days)
≈ 4 minutes / day
At Vernal Equinox, Solar Time = 12h, ST = 0h
Agree on Autumnal Equinox
ST ≈ Solar Time + (4 min/day) x (# of days after Sept. 21)
Relation of ST and Solar Time

Ignore complications: Earth’s orbit not circular, time zones, daylight savings, . . .

One extra sidereal day / year

\[
1 \text{ day / year} = \left( \frac{24 \text{ h}}{\text{day}} \right) \times \left( \frac{60 \text{ m}}{\text{h}} \right) / (365.2425 \text{ days}) \\
\approx 4 \text{ minutes / day}
\]

At Vernal Equinox, Solar Time = \(12^\text{h}\), ST = \(0^\text{h}\)

Agree on Autumnal Equinox

\[
\text{ST} \approx \text{Solar Time} + (4 \text{ min/day}) \times (\# \text{ of days after Sept. 21})
\]

When can you observe stars or other objects at night?
Example

Deneb: When is it overhead at midnight?

\[
\begin{align*}
\text{R.A.} &= 20^\text{h} 41^\text{m} \\
\text{Overhead} \Rightarrow \text{H.A.} &= 0^\text{h} \\
\text{H.A.} &= \text{S.T.} - \text{R.A.} \\
0^\text{h} &= \text{S.T.} - 20^\text{h} 41^\text{m} \Rightarrow \text{S.T.} = 20^\text{h} 41^\text{m} \\
\text{Midnight} \Rightarrow \text{Solar Time} &= 0^\text{h} \\
\text{S.T.} &\approx \text{Solar Time} + \left( \frac{4 \text{ min}}{\text{day}} \right) D \\
D &= \# \text{ of days after Sept. 21} \\
D &\approx \frac{20^\text{h} 41^\text{m}}{4\text{min/day}} = \frac{1241\text{min}}{4\text{min/day}} = 310 \text{ d} = (365 - 55)\text{d} \\
&\approx \text{August 1}
\end{align*}
\]
Calendars

Complicated by fact that year is not even number of days

Gregorian Calendar:
  Uses leap years to account for this

What is time between two events?
  Complicated by unequal months, leap years, time zones, daylight savings, . . .

Julian Date:
  Gives time as number of days or fraction since noon (UT) on January 1, 4713 BC

Current Julian date ≈ 2456899