Chapter 2
A User's Guide to the Sky

Guidepost

Astronomy is about us. As we learn about astronomy, we learn about ourselves. We search for an answer to the question "What are we?" The quick answer is that we are thinking creatures living on a planet that circles a star we call the sun. In this chapter, we begin trying to understand that answer. What does it mean to live on a planet?

Chapter 2 and the next help us understand what the universe looks like seen from our spinning planet.

What we see is caused by the cycles of Earth, its moon, and the sun. We will see in the next chapter how Renaissance astronomers analyzing these cycles first realized that we do indeed live on a planet.

Outline

I. Stars and Constellations
- A. Constellations
- B. Star Names
- C. Favorite Stars
- D. Star Brightness
- E. Magnitude and Flux

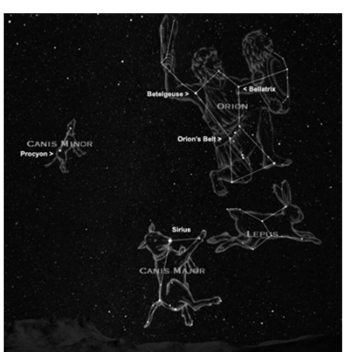
II. The Sky and Celestial Motions
- A. The Celestial Sphere
- B. Precession

Outline (continued)

III. Sun and Planets
- A. Annual Motion of the Sun
- B. Seasons
- C. Motions of the Planets

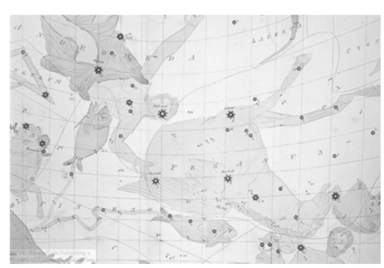
IV. Astronomical Influences on Earth's Climate
- A. Milankovitch Climate Cycles: Hypothesis
- B. Evidence

Constellations



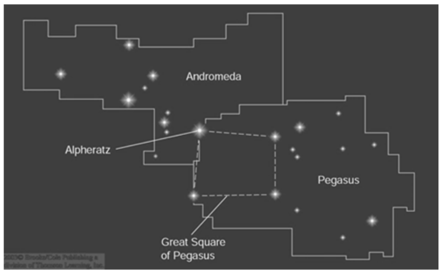
From: http://etravelgreece.blogspot.com/2011/12/greek-mythology-of-constellation-orion.html

Constellations (2)



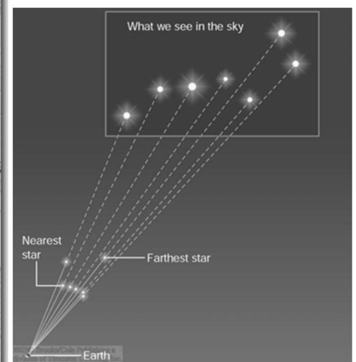
In ancient times, constellations only referred to the brightest stars that appeared to form groups, representing mythological figures.

Constellations (3)



Today, constellations are well-defined regions on the sky, irrespective of the presence or absence of bright stars in those regions.

Constellations (4)



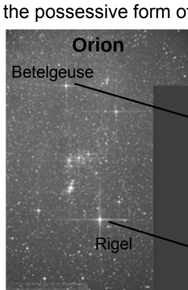
The stars of a constellation only appear to be close to one another

Usually, this is only a *projection effect*.

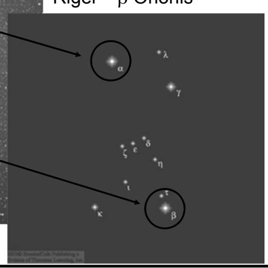
The stars of a constellation may be located at very different distances from us.

Constellations (4)

Stars are named by a Greek letter (α, β, γ) according to their relative brightness* within a given constellation + the possessive form of the name of the constellation:



Betelgeuse = α Orionis
Rigel = β Orionis



*Not always!

The Magnitude Scale

First introduced by Hipparchus (160 - 127 B.C.):

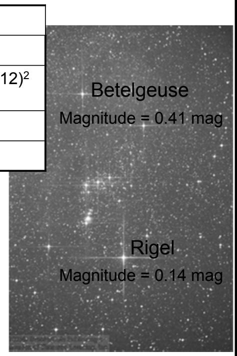
- Brightest stars: ~1st magnitude
- Faintest stars (unaided eye): 6th magnitude

More quantitative:

- 1st mag. stars appear 100 times brighter than 6th mag. stars
- 1 mag. difference gives a factor of 2.512 in apparent brightness (larger magnitude => fainter object!)

The Magnitude Scale (Example)

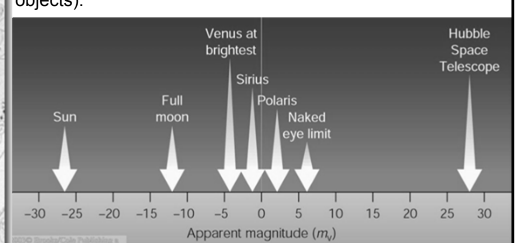
Magn. Diff.	Intensity Ratio
1	2.512
2	2.512*2.512 = $(2.512)^2$ = 6.31
…	…
5	$(2.512)^5$ = 100



For a magnitude difference of 0.41 – 0.14 = 0.27, we find an intensity ratio of $(2.512)^{0.27}$ = 1.28.

The Magnitude Scale (2)

The magnitude scale system can be extended toward negative numbers (very bright) and numbers > 6 (faint objects):



Sirius (brightest star in the sky): m_v = -1.42
Full moon: m_v = -12.5
Sun: m_v = -26.5 (a star also!)

Table 2.1 (p.16)

Magnitude Difference	Corresponding Flux Ratio
0	1
1	2.5
2	6.3
3	16
4	40
5	100
10	10,000
15	1×10^6
20	100×10^6
25	10×10^9

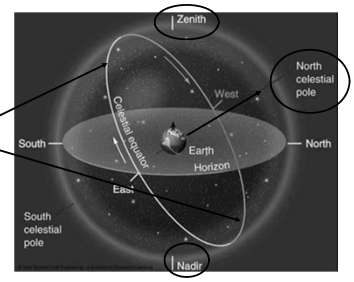
The Celestial Sphere

Zenith = Point on the celestial sphere directly above an observer

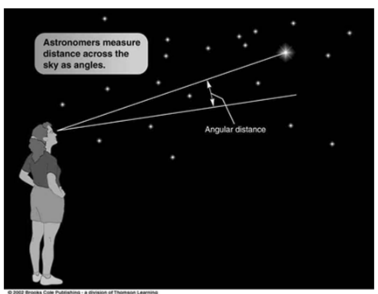
Nadir = Point on the celestial sphere directly below an observer (not visible!)

Celestial equator = projection of Earth's equator onto the c. s.

North celestial pole = projection of Earth's north pole onto the c. s.

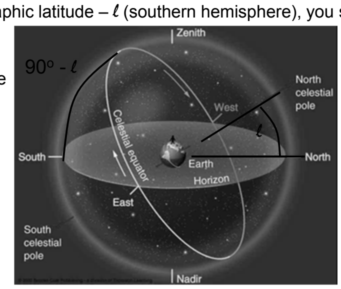


Distances on the Celestial Sphere



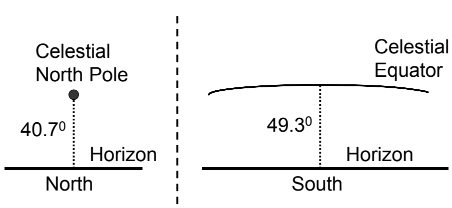
The Celestial Sphere (2)

- From geographic latitude ℓ (northern hemisphere), you see the celestial north pole ℓ degrees above the horizon;
- From geographic latitude $-\ell$ (southern hemisphere), you see the celestial south pole ℓ degrees above the horizon.
- Celestial equator culminates $90° - \ell$ above the horizon



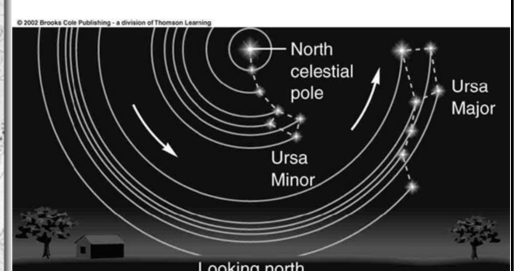
The Celestial Sphere (Example)

New York City: $\ell \approx 40.7°$

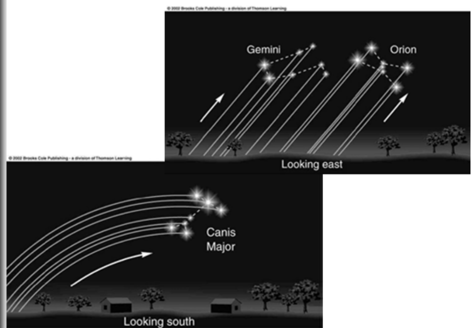


The Celestial South Pole is not visible from the northern hemisphere.

Apparent Motion of the Celestial Sphere

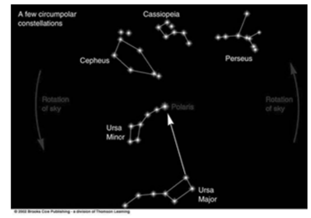


Apparent Motion of the Celestial Sphere (2)

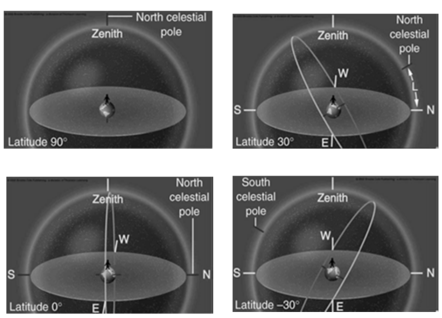


The Circumpolar Circle

- Some stars and constellations are so close to the Celestial North Pole that they never set
- Those are called **circumpolar constellations**

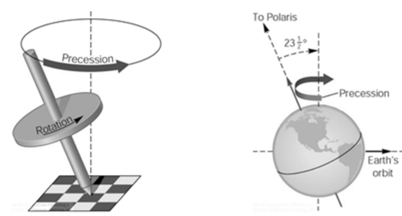


The Celestial Sphere (3)



Precession

At left, gravity is pulling on a slanted top. => Wobbling around the vertical.



The Sun's gravity is doing the same to Earth.

The resulting "wobbling" of Earth's axis of rotation around the vertical with respect to the ecliptic takes about 26,000 years and is called **precession**.

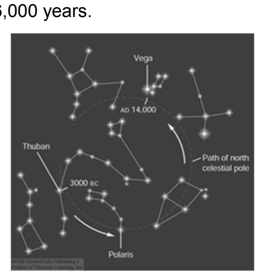
Precession (2)

As a result of precession, the celestial north pole follows a circular pattern on the sky, once every 26,000 years.

It will be closest to Polaris ~ A.D. 2100.

There is nothing peculiar about Polaris at all (neither particularly bright nor nearby etc.)

~ 12,000 years from now, it will be close to Vega in the constellation Lyra.



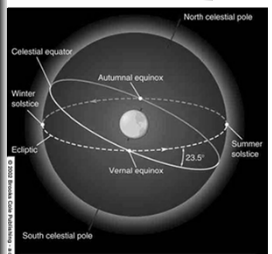
The Annual Motion of the Sun

Due to Earth's revolution around the sun, the sun appears to move through the zodiacal constellations.

The sun's apparent path on the sky is called the **ecliptic**.

OR "The ecliptic is the projection of Earth's orbit onto the celestial sphere."

The Seasons



Event	Date*	Season
Vernal equinox	March 21	Spring begins
Summer solstice	June 22	Summer begins
Autumnal equinox	September 22	Autumn begins
Winter solstice	December 22	Winter begins

* Give or take a day due to leap year and other factors.

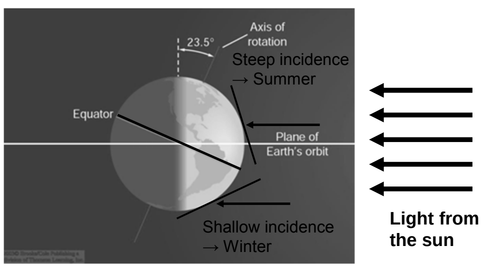
Earth's axis of rotation is inclined against the normal to its orbital plane by 23.5^0, which causes the seasons.

The Seasons (2)

When the sun shines on Earth's surface at a steeper angle (left), it is more efficient in heating the surface.

The Seasons (3)

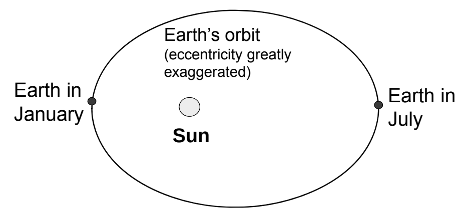
The seasons are only caused by a varying angle of incidence of the sun's rays (not to distance from the Sun).



Light from the sun

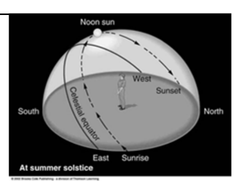
The Seasons (4)

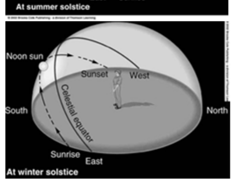
Earth's distance from the sun has only a very minor influence on seasonal temperature variations.



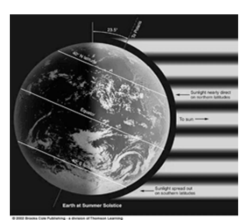
The Seasons (5)

In the summer, the sun culminates higher above the horizon than in the winter

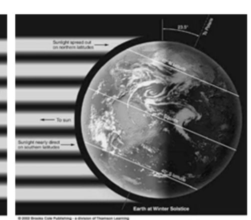




The Seasons (6)

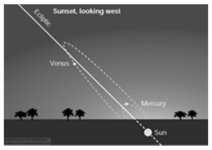


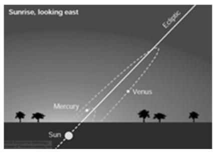
northern summer = southern winter



northern winter = southern summer

The Motion of the Planets





Mercury appears at most ~28° from the sun.

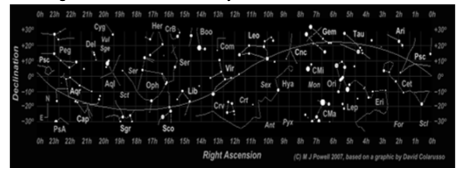
It can occasionally be seen shortly after sunset in the west or before sunrise in the east.

Venus appears at most ~46° from the sun.

It can occasionally be seen for at most a few hours after sunset in the west or before sunrise in the east.

The Motion of the Planets (2)

The Sun, Moon and planets are seen to move along a fairly narrow band (the ecliptic) of the night sky which passes through the twelve commonly-known zodiac constellations



This apparent motion caused ancient peoples to ascribe a mystical significance to motion of these bodies along the ecliptic, thus inventing the pseudoscience of astrology.

From: http://www.nakedeyeplanets.com/movements.htm

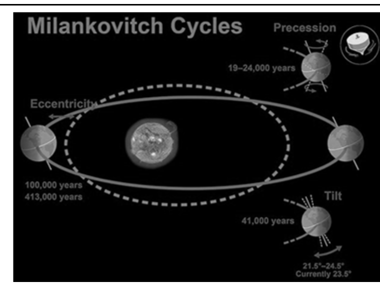
Astronomical Influences on Earth's Climate

Astronomical factors affecting Earth's climate:

- Eccentricity of Earth's orbit around the sun (varies over period of ~ 100,000 years)
- Precession (Period of ~ 26,000 years)
- Inclination of Earth's axis versus orbital plane (41,000 years)

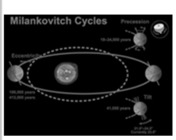
Milankovitch Hypothesis: Changes in all three of these aspects are responsible for long-term global climate changes (ice ages).

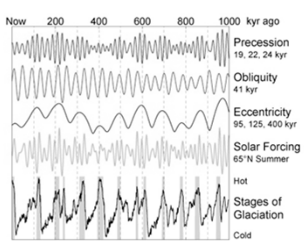
Astronomical Influences on Earth's Climate (2)



From: http://www.eoearth.org/article/Milankovitch_cycles

Astronomical Influences on Earth's Climate (2)





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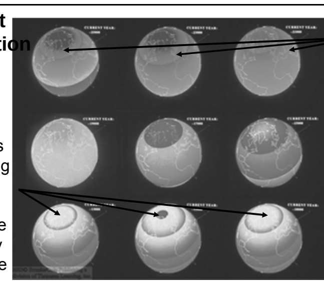
Astronomical Influences on Earth's Climate (3)

Last glaciation

Polar regions receiving less than average energy from the sun



Polar regions receiving more than average energy from the sun

End of last glaciation