Chapter S1
Celestial Timekeeping and Navigation

Agenda

- Announce:
  - Test 1 on Thursday
  - Read Ch. 4 (and quiz) for following Tuesday
- Science
- Chapter S1.2 and S1.3
- Planning Observations
- Exercise: The Celestial Sphere

Science

- Method of answering questions:
  - Hypothesize/predict/explain
  - Take data/observe/measure
  - If data matches, more credence (no proof)
  - If data contradicts, reject! (possibly alter hypothesize)
- (Unfounded) Criticisms of science:
  - Doesn't answer all the questions…so?
  - Science makes mistakes…well scientists do, but science tends to correct them
  - Science removes the beauty of nature…see next slide

I have a friend who's an artist and he's some times taken a view which I don't agree with very well. He'll hold up a flower and say, "look how beautiful it is," and I'll agree, I think. And he says, "you see, I as an artist can see how beautiful this is, but you as a scientist, oh, take this all apart and it becomes a dull thing." And I think he's kind of nutty.

First of all, the beauty that he sees is available to other people and to me, too, I believe, although I might not be quite as refined aesthetically as he is. But I can appreciate the beauty of a flower.

At the same time, I see much more about the flower that he sees. I could imagine the cells in there, the complicated actions inside which also have a beauty. I mean, it's not just beauty at this dimension of one centimeter: there is also beauty at a smaller dimension, the inner structure…also the processes.

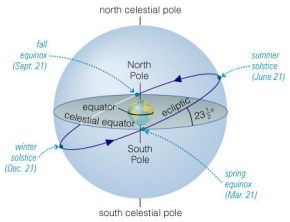
The fact that the colors in the flower are evolved in order to attract insects to pollinate it is interesting – it means that insects can see the color.

It adds a question – does this aesthetic sense also exist in the lower forms that are…why is it aesthetic, all kinds of interesting questions which a science knowledge only adds to the excitement and mystery and the awe of a flower.

It only adds. I don't understand how it subtracts.

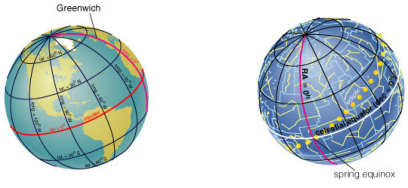
Quote by Richard Feynman:
(As quoted from the "Best Mind Since Einstein" NOVA Video)

How do we locate objects on the celestial sphere?



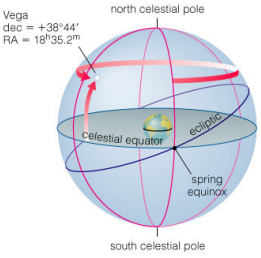
- Each point in the sky corresponds to a particular location on the celestial sphere
- Equinoxes and solstices occur when Sun is at particular points on celestial sphere

Celestial Coordinates



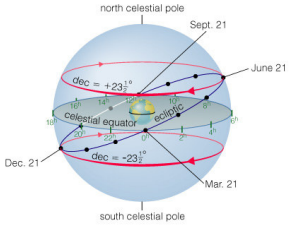
- **Right ascension:** Like longitude on celestial sphere (measured in hours with respect to spring equinox).
- **Declination:** Like latitude on celestial sphere (measured in degrees above celestial equator)

Celestial Coordinates of Vega



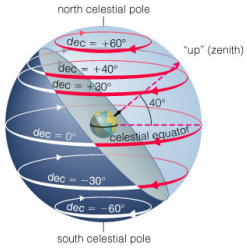
- **Right ascension:** Vega's RA of $18^h35.2^m$ (out of 24^h) places most of the way around celestial sphere from spring equinox.
- **Declination:** Vega's dec of +38°44' puts it almost 39° north of celestial equator (negative dec would be south of equator)

Celestial Coordinates of Sun



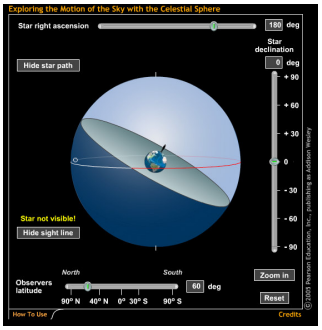
- The Sun's RA and dec change along the ecliptic during the course of a year
- Sun's declination is negative in fall and winter and positive in spring and summer

How do stars move through the local sky?

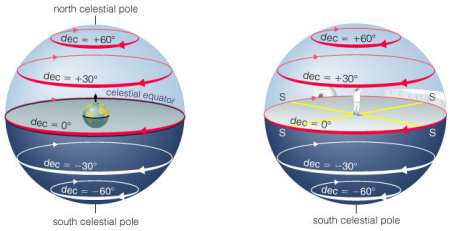


- A star's path depends on your latitude and the star's declination

Star Paths in the Local Sky

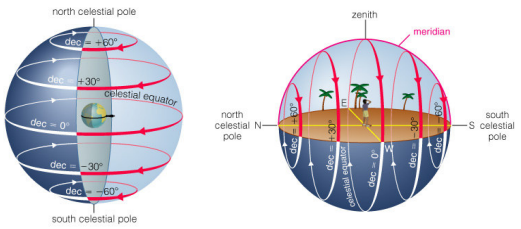


Star Paths at North Pole



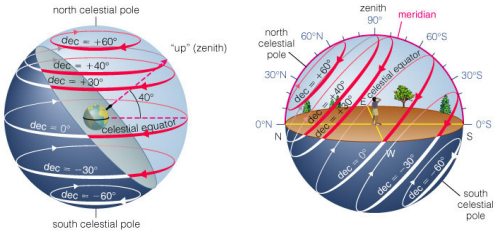
- At the North Pole stars remain at same altitude as Earth rotates
- Star's altitude above horizon equals its declination

Star Paths at Equator



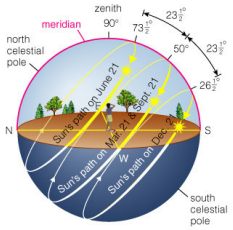
- At the Equator, all stars remain above horizon for exactly 12 hours each day
- Celestial equator passes overhead

Star Paths in Northern Hemisphere



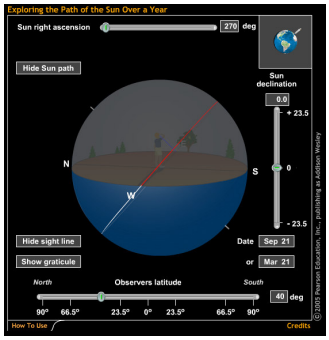
- In north, stars with dec > 90° - (your latitude) are circumpolar
- Celestial equator is in south part of sky

How does the Sun move through the local sky?

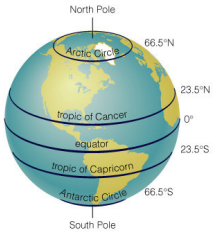


- Sun's path is like that of a star, except that its declination changes over the course of a year

Sun's Path in the Local Sky

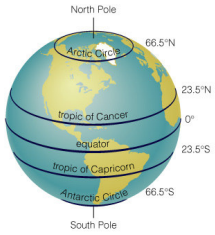


Special Latitudes



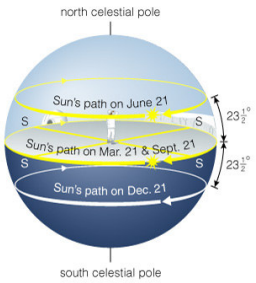
- **Arctic Circle (66.5°N):** Sun never sets on summer solstice
- **Tropic of Cancer (23.5°N):** Sun directly overhead at noon on summer solstice

Special Latitudes



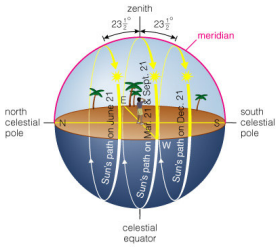
- **Antarctic Circle (66.5°S):** Sun never sets on winter solstice
- **Tropic of Capricorn (23.5°S):** Sun directly overhead at noon on winter solstice

Sun's Path at North Pole



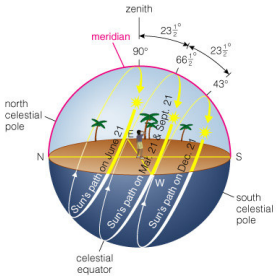
- Sun remains above horizon from spring equinox to fall equinox
- Altitude barely changes during a day

Sun's Path at Equator



- Sun rises straight up and sets straight down
- North of celestial equator during spring and summer
- South of celestial equator during winter and fall

Sun's Path at Tropic of Cancer



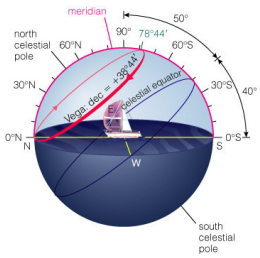
- Sun passes through zenith at noon on summer solstice

S1.3 Principles for Celestial Navigation

Our goals for learning:

- How can you determine your latitude?
- How can you determine your longitude?

How can you determine your latitude?



- Latitude equals altitude of celestial pole
- Altitude and declination of star crossing meridian also gives latitude.

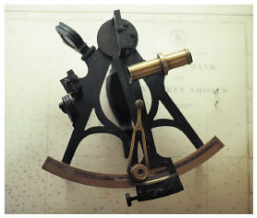
How can you determine your longitude?

- In order to determine your longitude from the sky, you need to know time of day because of Earth's rotation
- You also need to know day of year because of Earth's orbit
- Accurate measurement of longitude requires an accurate clock.

Instruments for Navigation

- An astrolabe can be used to measure star positions and to determine the time of day from them

Instruments for Navigation



- A cross-staff or sextant can be used to make accurate measurements of angles in the sky

GPS Navigation

- The Global Positioning System (GPS) uses a set of satellites in Earth orbit as artificial stars
- GPS devices use radio signals to determine your position relative to those satellites

Aspects of Observing

Observations

- Observation next week
- Attend either Tuesday or Thursday 7:15pm Great Lawn
- Weather Permitting
- Dress Warm!
- What should we see?

What's out there to see?

- Open clusters—young group of stars clumped together, view resembles that of twinkling jewels
- Galaxies—view resembles a little cloud of light
- Globular clusters—group of hundreds of thousands of stars within our own galaxy
- Diffuse nebulae—clouds of gas and dust from which young stars form (e.g. Orion Nebula)
- Planetary nebulae—hollow shells of gas thrown out by old stars (e.g. Ring, Dumbbell)
- Planets—often bright and easy

The Planets

- Bright and small—use high power eyepiece
- Follow the ecliptic
- Rise high in the winter (opposite Sun's daytime path)
- Don't twinkle
  - Uranus/Neptune—faint and small, greenish disks
  - Mars—bright red, polar ice caps may be visible

Tips

- Ideal sky conditions:
  - Low humidity, cloudless
  - Stable air (no large temperature gradients
  - Little light pollution
- Setup telescope(s) 15 minutes before observing to equalize temperature—avoid convection currents in air inside
- Get your eyes dark adapted—don't look at bright lights, use red covered flashlights

Winter Guideposts

- Big Dipper's forward bowl edge points up to Polaris
- 5 bright stars in "W" shape are Cassiopeia

Stuff We may see

- Mars
- Andromeda (M31)—a galaxy
- The Pleiades (M45)—an open cluster
- Open Clusters of Cassiopeia
- Uranus and Neptune
- Which constellations?