Chapter 00: Exploring the Heavens

Notes and Sketches

0.1: The Obvious View

Our Place in Space

- Astronomy: study of the universe
- Earth does not occupy a central or special place

Constellations In The Sky

- About 3000 stars visible to naked eye from any random location on earth
- Constellation: pattern identified, "picture" formed by group of stars
- No astronomical significance because stars in specific constellation have no relationship to each other
- Cultural significance: important way for non-literate societies to preserve and pass on important information

The Celestial Sphere

- Method for locating objects in the sky
- Ignores the fact that objects are at different distances from the earth
- Project an invisible sphere out from the earth
- NCP: North Celestial Pole = projection of earth's North pole into the sky
- SCP: South Celestial Pole = projection of Earth's South pole into sky
- CE: Celestial Equator = projection of Earth's equator into the sky
- Stars appear fixed with respect to each other, but entire celestial sphere "spins" as Earth turns on its axis

Celestial Coordinates

- To precisely locate an object, two coordinates required
- On Earth: latitude measures degrees of angle from 0° to 90° north or south of equator
- In space: declination measured in degrees from 0° to 90° north (+) or south (–) of celestial equator
- On Earth: longitude measured in degrees around the equator
- Zero chosen arbitrarily: 0° longitude = Royal Observatory, Greenwich, England
- Measure from 0° to 180° East (towards Asia) or 0° to 180° West (towards N America)
- In space: right ascension measured in hours, minutes, seconds around the celestial equator
- Zero chosen arbitrarily: 0h RA = where sun crosses the celestial equator on vernal equinox (HUH?!?!?)
- Measure from 0h to 24 h RA around CE in the same direction as the earth spins

0.2: Earth's Orbital Motion

Day-to-Day Changes

- Solar day: Earth completes one rotation with respect to the sun = 24 hours
- Start timing when sun crosses S meridian (noon), stop timing when sun crosses meridian again tomorrow
- Sidereal day: Earth completes one rotation with respect to distant star = 23h56m
- Start timing when star crosses S meridian, stop timing when same star crosses meridian again tomorrow

Seasonal Changes
- Earth's axis is tilted
- Draw an enormous flat plane through the equator of the sun, and extend it all the way through the solar system
- This plane does not cut the Earth in half at its equator
- Axis tilt = 23.5°

Ecliptic
- Apparent path of the sun across the sky (really the Earth in motion, not the sun)
- Ecliptic is tilted b/c Earth's axis is tilted

Seasons
- Tilt of axis creates changing seasons
- Distance from sun does not create seasonal changes
- Earth is marginally closer to sun in Dec than Jun, but Dec is not the hottest month in the N hemisphere!

Summer Solstice
- Usually 06/21 (may fall ± a calendar day)
- Longest day of the year (N hemisphere) because sun has maximum declination (+23.5°)
- N hemisphere is tipped toward sun, more direct daylight makes the season summer

Winter Solstice
- Usually 12/21 (may fall ± a calendar day)
- Shortest day of the year (N hemisphere) because sun has minimum declination (–23.5°)
- N hemisphere is tipped away from sun, less direct daylight makes season winter

Equinoxes
- Vernal (Spring) Equinox: 03/21 (may fall ± a calendar day)
- Autumnal Equinox: 09/21 (may fall ± a calendar day)
- Equal length day & night because sun crosses CE (dec = 0°)

Long-Term Changes
- Earth's axis wobbles slightly as it spins
- Today, NCP points almost perfectly at Polaris
- Wobble means that Polaris was not always the Pole Star, and will not be forever

0.3: The Motion of the Moon

Lunar Phases
- Understanding the phases helps us really start to get to grips with the layout of the solar system
- New moon: moon located in between Earth and sun (angle is 0°)
- 1st quarter: moon makes a 90° angle (If you are the Earth, stick your right arm straight out and make a fist: your fist is the sun. Stick your left arm straight out to your side, so your arms make a 90° angle. Your left fist is the moon.)
- Full moon: moon is 180° away from sun in sky (If you are the Earth, the sun is directly in front of you, then the moon would be directly behind you.)
- 3rd quarter: moon makes 90° angle (switch hands, and let your left fist be the sun sticking straight out in front. Make a 90° with your right arm, and your right fist is the moon)

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Lunar Month

- Sidereal Month: 27.3 days for the moon to complete one full rotation with respect to distant star
- Synodic Month: 29.5 days for moon to complete one full cycle of phases, or a complete rotation with respect to the sun (as seen from the earth)

Solar Eclipse

- Sun is eclipsed by the moon: moon passes in between Earth and sun
- Can only happen when phase of moon is new
- Does not happen every month because moon's orbit is tiled with respect to ecliptic
- Annular eclipse: moon is farthest from Earth, making it appear slightly smaller (so it does not completely cover solar disk)

Lunar Eclipse

- Shadow of the Earth eclipses the moon: Earth passes in between sun and moon
- Can only happen when moon is full
- More frequent occurrence than solar eclipse
- Partial eclipses not uncommon

0.4: The Measurement of Distance

Triangulation

- Measure distance to objects that are too far or inconvenient to be measured directly
- Requires some geometry and trigonometry
- Observe the same object from two different vantage points, compare
- This works for stationary objects on Earth, but can also be used to locate planets

Parallax

- Apparent shift in the position of an object in the foreground with respect to the background
- Result of changing point of observation, not the motion of the actual object
- For close object, large parallax observed with relatively small baseline shift
- The farther an object, smaller the parallax: increase baseline to increase parallax

0.5: Scientific Theory and Scientific Method

It's Only a Theory...

- A scientific theory has been repeatedly tested, and never found to be false (not once, not even a little bit)
- If something is referred to by scientists as a theory, it is widely accepted as the best framework for explaining something
- A theory must be able to explain what has been observed and predict what should happen as a consequence
- Scientists accept that, if new facts or experiments reveal a flaw, the theory must be modified or discarded

Scientific Method

- Process by which science gets done
- The whole point is, it's never actually done

Sizing Up Planet Earth

- Eratosthenes accurately measured Earth's circumference and diameter in about 200BC
- All you need are two sticks and scratch paper
- More to the point: He apparently took it for granted that the Earth was a sphere...in 200BC

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