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ASTRONOMY

Chapter 2 OBSERVING THE SKY: THE BIRTH OF ASTRONOMY
PowerPoint Image Slideshow

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2.1 THE SKY ABOVE

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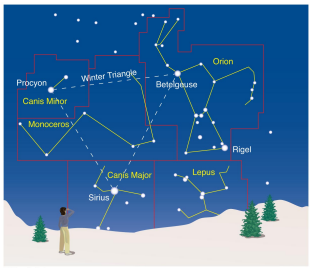
- **Night Sky(Fig2.1).** In this panoramic photograph of the night sky from the Atacama Desert in Chile, we can see the central portion of the Milky Way Galaxy arcing upward in the center of the frame. On the left, the Large Magellanic Cloud and the Small Magellanic Cloud (smaller galaxies that orbit the Milky Way Galaxy) are easily visible from the Southern Hemisphere. (credit: modification of work by ESO/Y. Beletsky)

Constellations

- A constellation is a *region* of the sky.
  - Eighty-eight constellations fill the entire sky.
- An asterism is an easily recognizable group of stars.
  - The big dipper is an asterism



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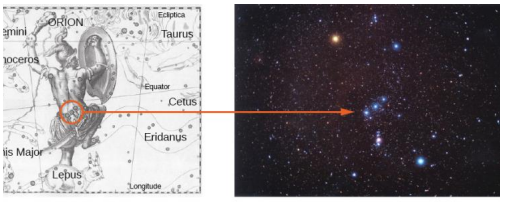
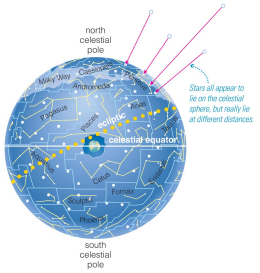


- **Orion (Fig 2.8).**
  - (a) The winter constellation of Orion, the hunter, is surrounded by neighboring constellations, as illustrated in the seventeenth-century atlas by Hevelius.
  - (b) A photograph shows the Orion region in the sky. Note the three blue stars that make up the belt of the hunter. The bright red star above the belt denotes his armpit and is called Betelgeuse (pronounced "Beetel-juice"). The bright blue star below the belt is his foot and is called Rigel. (credit a: modification of work by Johannes Hevelius; b: modification of work by Matthew Spinelli)

The Celestial Sphere

- Stars at different distances all appear to lie on the celestial sphere.
- The 88 official constellations cover the entire celestial sphere.



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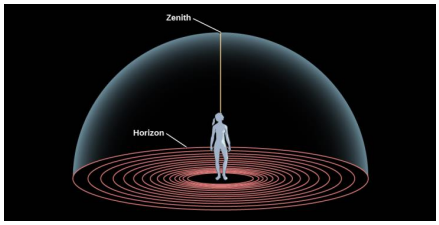
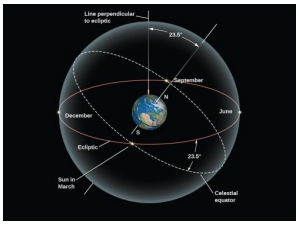
The Local Sky

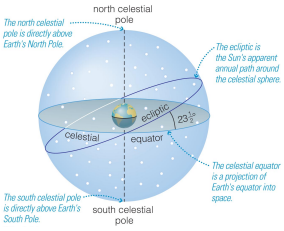
- **Zenith:** the point directly overhead
- **Horizon:** all points 90° away from zenith



Celestial tilt 23.5°



The Celestial Tilt (Fig 2.7) . The celestial equator is tilted by 23.5° to the ecliptic. As a result, North Americans and Europeans see the Sun north of the celestial equator and high in our sky in June, and south of the celestial equator and low in the sky in December.



- **North celestial pole** is directly above Earth's North Pole.
- **South celestial pole** is directly above Earth's South Pole.
- **Celestial equator** is a projection of Earth's equator onto sky.
- The **ecliptic** is the Sun's apparent path through the celestial sphere.

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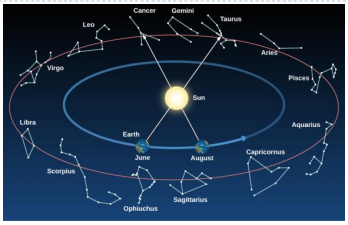
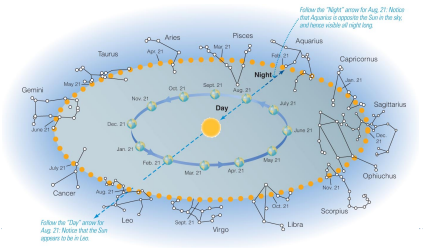
The Zodiac



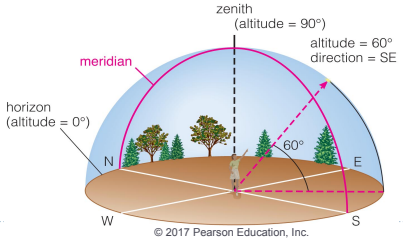
Constellations on the Ecliptic (Fig 2.6). As Earth revolves around the Sun, we sit on "platform Earth" and see the Sun moving around the sky. The circle in the sky that the Sun appears to make around us in the course of a year is called the *ecliptic*. This circle (like all circles in the sky) goes through a set of constellations. The ancients thought these constellations, which the Sun (and the Moon and planets) visited, must be special and incorporated them into their system of astrology. Note that at any given time of the year, some of the constellations crossed by the ecliptic are visible in the night sky; others are in the day sky and are thus hidden by the brilliance of the Sun.

- As the Earth orbits the Sun, the Sun appears to move eastward along the ecliptic.
- The constellations along the ecliptic make up the **zodiac**
  - The 13th constellation is Ophiuchus



How to locate an object

- **altitude** is position above horizon
- **direction** (azimuth) degrees clockwise from due N along horizon



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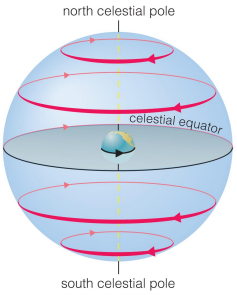
Why do stars rise and set?

- Earth rotates from west to east, so stars appear to circle from east to west.



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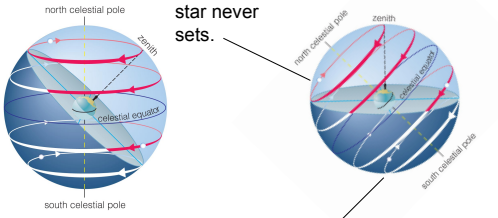
Circumpolar



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- Stars near the celestial pole are **circumpolar** and never set.

Here in Long Beach we cannot see stars near the south celestial pole.

Wandering stars

- The word "planet," in fact, means "wanderer" in ancient Greek.
- The planets that are easily visible to the unaided eye
  - Mercury, Venus, Mars, Jupiter, Saturn.
- With the Sun and Moon the planets, make up all seven moving objects in the sky.
  - Hence, 7 days in a week

2.2 ANCIENT ASTRONOMY

- Astronomy is the oldest of the sciences.

Why study it?

- Inherent curiosity
- Keeping track of time and seasons
  - for practical purposes, including agriculture
  - for religious and ceremonial purposes
- In aiding navigation

- Mayans developed a sophisticated calendar by calculated synodic periods of the moon, Venus and Mars.

Palenque (600 AD) modern day Chiapas Mexico, Mayan structures aligned with solstices

France: Cave paintings from 18,000 B.C. may suggest knowledge of lunar phases (29 dots).

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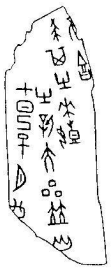

"On the Jisi day, the 7th day of the month, a big new star appeared in the company of the Ho star."

"On the Xinwei day the new star dwindled."

Bone or tortoiseshell inscription from the 14th century B.C.

China: Earliest known records of supernova explosions (1400 B.C.)

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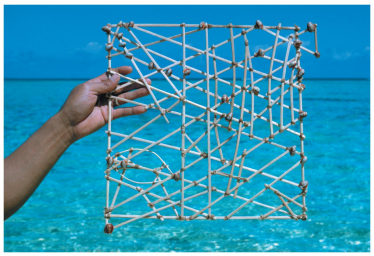

South Pacific: Polynesians were very skilled in the art of celestial navigation.

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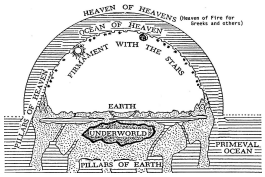
Ancient views of the universe

- The Earth is a great island carried on a turtles back

- A three tier world of heaven, earth and underworld floating on the cosmic ocean



Early Greek and Roman Cosmology

- Geographical location
- Rational ideas
- Conquest of Alexander the Great

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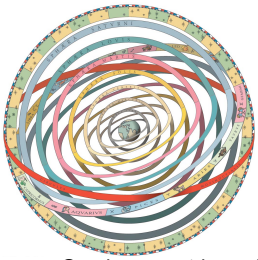
Models of Nature



- Greeks were the first people known to make ***models*** of nature.
- A ***Model*** is a conceptual representation created to explain and predict observed phenomena

Greek geocentric model (400 B.C.)

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Aristotle (c. 384–322 BC)

- New the Earth was round
- Sun was further than the moon from Earth

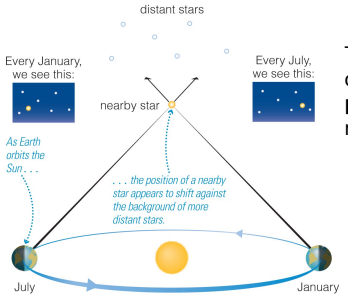
- **Earth's Round Shadow (Fig 2.9).** A lunar eclipse occurs when the Moon moves into and out of Earth's shadow. Note the curved shape of the shadow—evidence for a spherical Earth that has been recognized since antiquity.

Greeks geocentric model

Aristarchus (c. 310–230 BC), did suggested that Earth was moving around the Sun however, most of the ancient Greek scholars rejected this idea.

- Heavens must be "perfect"—objects move on perfect spheres or in perfect circles.
- Earth at the center of the universe

Why did the ancient Greeks reject the real explanation for planetary motion?



Their inability to observe **stellar parallax** was a major factor.

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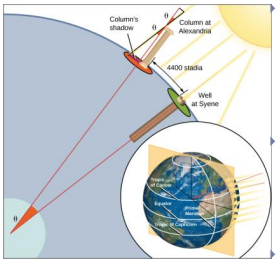
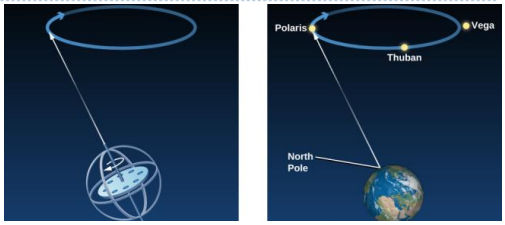
Eratosthenes (c. 276–194 BC)



- Eratosthenes measured the size of Earth by observing the angle at which the Sun's rays hit our planet's surface.
- A ray at Syene comes straight down whereas a ray at Alexandria makes an angle of 7° with the vertical.
- Calculated circumference 40,100km vs 42,000km

Hipparchus (c. 150 BC)



- He discovered the position in the sky had altered over the last 150 years.
- Earth's precession cycle takes 26,000 years.
- Today the north celestial pole is near the star Polaris, but about 5000 years ago it was close to a star called Thuban, and in 14,000 years it will be closest to the star Vega.

Ptolemy (c. 100-170 AD)

The most sophisticated geocentric **Ptolemaic model:**

- Sufficiently accurate to remain in use for 1500 years
- Arabic translation of Ptolemy's work named *Almagest* ("the greatest compilation")

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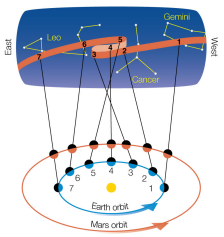
Retrograde Motion

- The temporary apparent backward motion of a planet
  - A geocentric model makes it extremely difficult to explain retrograde motion of planets
  - Over a period of 10 weeks, Mars appears to stop, back up, then go forward again.



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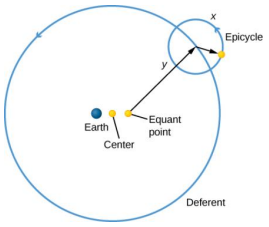

Ptolemy's Complicated Cosmological System (fig 2.14). Each planet orbits around a small circle called an *epicycle*. Each epicycle orbits on a larger circle called the *deferent*. This system is not centered exactly on Earth but on an offset point called the *equant*. The Greeks needed all this complexity to explain the actual motions in the sky because they believed that Earth was stationary and that all sky motions had to be circular.

2.4 THE BIRTH OF MODERN ASTRONOMY

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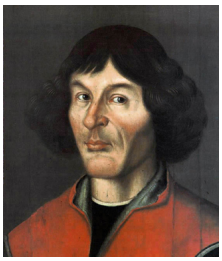
- Copernicus and the Copernicus revolution

Nicolaus Copernicus (1473–1543) Fig 2.16. Copernicus was a cleric and scientist who played a leading role in the emergence of modern science. Although he could not prove that Earth revolves about the Sun, he presented such compelling arguments for this idea that he turned the tide of cosmological thought and laid the foundations upon which Galileo and Kepler so effectively built in the following century.



Heliocentric model

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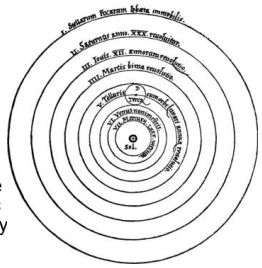
- Copernicus proposed the Sun-centered model (published 1543).
- He used the model to determine the layout of the solar system (planetary distances in AU).
- But The model was no more accurate than the Ptolemaic model in predicting planetary positions, because it still used perfect circles.



Tycho Brahe (1546–1601)

- Brahe compiled the most accurate (1 arcminute) naked eye measurements ever made of planetary positions.
- He still could not detect stellar parallax, and thus still thought Earth must be at the center of the solar system (but recognized that other planets go around the Sun).
- He hired Kepler, who used Tycho's observations to discover the truth about planetary motion.

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Johannes Kepler (1571–1630)

- Kepler first tried to match Tycho's observations with circular orbits.
- But an 8-arcminute discrepancy led him eventually to ellipses.

"If I had believed that we could ignore these eight minutes [of arc], I would have patched up my hypothesis accordingly. But, since it was not permissible to ignore, those eight minutes pointed the road to a complete reformation in astronomy."

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Galileo and the Beginning of Modern Science

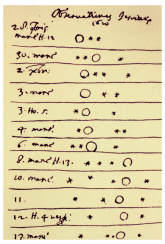
- **Galileo Galilei (1564–1642) Fig 2.19.** Galileo advocated that we perform experiments or make observations to ask nature its ways. When Galileo turned the telescope to the sky, he found things were not the way philosophers had supposed.

Galileo's Astronomical Observations

- Galileo did not drop objects from the Leaning Tower of Pisa but, he did study the way objects accelerate.
- Video: Moon gravity 1min

- **Telescope Used by Galileo (Fig 2.20).** The telescope has a wooden tube covered with paper and a lens 26 millimeters across.

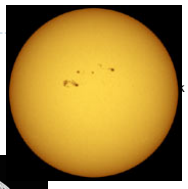
Galileo observed ...



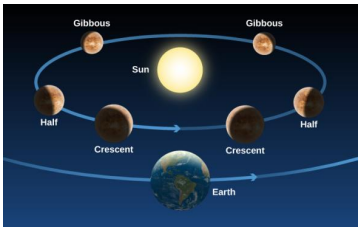
- four moons orbiting Jupiter.

- Sunspots

WARNING: never look directly at the Sun



- mountains and valleys on the Moon.



- **Phases of Venus (Fig 2.18).** As Venus moves around the Sun, we see changing illumination of its surface, just as we see the face of the Moon illuminated differently in the course of a month.

How did Galileo solidify the Copernican revolution?

- Galileo overcame three major objections to the Copernican view from ancient astronomers.

1. Earth could not be moving because objects in air would be left behind.
2. Noncircular orbits are not "perfect" as heavens should be.
3. If Earth were really orbiting Sun, we'd detect stellar parallax.

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Overcoming the first objection (nature of motion):

Galileo's experiments showed that objects in air would stay with a moving Earth.

- Aristotle thought that all objects naturally come to rest.
- Galileo showed that objects will stay in motion unless a force acts to slow them down (Newton's first law of motion).

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Overcoming the second objection (heavenly perfection):

- Using his telescope, Galileo saw:
  - Sunspots on the Sun ("imperfections")
  - Mountains and valleys on the Moon (proving it is not a perfect sphere)
  - 4 moons orbiting Jupiter (proving not all objects orbit earth)
  - Observed phases of Venus (proving it orbits the Sun not Earth)

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Overcoming the third objection (parallax):

- Tycho *thought* he had measured stellar distances, so lack of parallax seemed to rule out an orbiting Earth.
- Galileo showed stars must be much farther than Tycho thought—in part by using his telescope to see that the Milky Way has countless individual stars.
- If stars were much farther away, then lack of detectable parallax was no longer so troubling.

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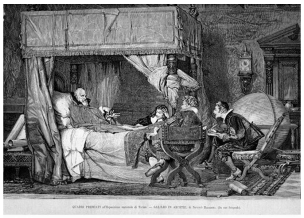
- In 1633 the Catholic Church ordered Galileo to recant his claim that Earth orbits the Sun.
- His book on the subject was removed from the Church's index of banned books in 1824.
- Galileo was formally vindicated by the Church in 1992.



Links

- VIDEO: Copernicus (3 min)
- VIDEO: Galileo (3 min)

Reading

- 2.1
- 2.2
- 2.4