Lecture Seven

The Space-Age Solar System

Scope: At the dawn of space exploration, astronomers had a well-defined overview of the solar system. The Sun has a collection of planets, moons, asteroids, and comets orbiting around it. These are spread across a scale so vast that it can be only partially breached by telescopes and photographic plates. New dimensions were revealed when astronomers developed telescopes in other wavelengths, such as radio waves and infrared light. The advent of computers and digital technology created new and faster ways to observe, analyze, and simulate the heavens. The most amazing details are those returned by an armada of satellite missions sent to fly by, orbit, and land on these diverse worlds. In just a few decades, the richness of our knowledge expanded exponentially. The golden age of solar system exploration had arrived.

Outline

I. The space age transformed our view of the solar system.

- **A.** The space age began on October 4, 1957, when the first satellite, Sputnik 1, was launched into orbit for 22 days.
- **B.** NASA was founded one year later.
- **C.** The ability to explore the solar system led to a knowledge explosion.
- **D.** At the start of the space age, our model of the solar system was well established.
  1. The contents included the Sun, planets, their moons, asteroids, and comets.
  2. The orbits are a mixture of almost circular to highly elliptical shapes confined mainly to the plane of the ecliptic.
  3. Planets complete their orbits in timescales from months to centuries.

II. The scale of the solar system is vast, almost too vast to be comprehensible.

- **A.** It helps to consider a scale model of the solar system in which the Sun is the size of a basketball: 9 inches (23 cm) in diameter.
- **B.** The sizes of the planets are much smaller than most expect.
  1. Jupiter is a little less than 1 inch in diameter (2.4 cm), and Saturn about 3/4 of an inch (2 cm).
  2. Uranus and Neptune are both about 1/3 of an inch (0.8 cm).
  3. Earth is less than 1/10 of an inch—only 2 millimeters in size.
  4. Venus is also 2 millimeters, with Mars just over 1 millimeter in diameter.
  5. The rest are submillimeter size, including Mercury (0.8 mm) and Pluto (0.4 mm).
  6. From this model it is easy to see that the Sun contains 99.86% of all the mass in the solar system.
- **C.** The orbital distances in this scale model strain the imagination.
  1. Putting our basketball Sun on the goal line of a football field, Mercury (0.8 mm) is at the 21-yard line, Venus (2 mm) is at the 39-yard line, Earth is past midfield on the opponent's 46-yard line, and Mars is on the opponent's 20-yard line.
  2. Our 1-inch Jupiter is more than 2.5 football fields (260 m) away, and 0.75-inch Saturn is about 5 football fields (470 m) distant.
  3. Uranus is a bit less than 1 kilometer out (0.94 km), and Neptune a bit less than 1 mile (1.5 km).
  4. Pluto, less than 1/2 a millimeter in diameter, is 2 kilometers from the basketball-sized Sun.
  5. Examining a scale model emphasizes that the solar system is mostly empty space.

III. The space age brought about a revolution in our observation of and understanding of the solar system.

- **A.** Advances in technology enabled astronomers to build telescopes in other wavelengths of light.
  1. Visible light is but a small part of the electromagnetic spectrum.
  2. Infrared and ultraviolet observations of the planets reveal details unseen in visible light.
  3. The Sun takes on an entirely new visage in the high energy radiation of ultraviolet light and X-rays.
  4. Studying all wavelengths of light gives astronomers a more complete picture of the physical processes taking place.

B. The digital technology of computers revolutionized astronomical research.
   1. Conventional photographs do not have a simple relationship between the amount of light received and the brightness of the image.
   2. Digital images provide a quantified numerical measure of the light received.
   3. Computer processing of digital images can bring out details that are impossible to extract from a photograph.
   4. Computer analysis of data and physics simulations opened up new fields of research.

C. Computer-controlled telescopes can be larger, more accurate, and easier to operate.
   1. Professional telescopes are now run by observatory staff, not astronomers, and can sometimes be accessed over the Internet.
   2. Computers enable multiple mirror telescopes by adjusting the mirror segments many times per second.
   3. Computers allow arrays of smaller telescopes to combine their observations and function like one larger telescope.

D. Telescopes in orbit bypass the limitations of Earth's atmosphere.
   1. Earth's atmosphere blocks most wavelengths and can distort the light that does pass through.
   2. Satellite telescopes both improve observations and enable observations not possible from the ground.
   3. NASA's "Great Observatories" are Hubble in visible light, Compton in gamma rays, Spitzer in infrared, and Chandra in X-rays.
   4. A fleet of more specialized missions has covered the wavelengths from radio waves to gamma rays.

E. Manned and satellite missions across the solar system uncover details that enrich and transform our scientific views.
   1. The Apollo missions to the Moon made space a visceral reality.
   2. The Voyager missions made a grand tour of the outer planets.
   3. A fleet of Mars missions has orbited, landed on, and explored the red planet.
   4. The numerous satellite missions have transformed those tiny spots of light, so very far away, into known worlds and familiar sights within our neighborhood in space.

IV. The decades of the space age have brought us new ways to observe, analyze, and explore the solar system.
   A. Historians generally cite the Copernican revolution as the biggest change in perspective on the solar system.
   B. I disagree: I feel that the space-age transformation from observers to explorers has changed our perspective more than anything else in history.

Suggested Readings:

Bennett, Donahue, Schneider, and Voit, *The Cosmic Perspective*, chaps. 6–7.

Benson, *Beyond: Visions of Interplanetary Probes*.

Hey, *Solar System*.

McFadden, Weissman, and Johnson, *Encyclopedia of the Solar System*, chaps. 35–42, 46.

Moore and Arnold, *Space: The First 50 Years*.

Wilson, *Astronomy through the Ages*, chap. 9.

Questions to Consider:

1. The nearest star is about 250,000 times farther from the Sun than Earth is. Given the Sun as a basketball-scale model, how far away is that second basketball?
2. Different wavelengths of light show different objects and features of objects on the sky. How would you cross-correlate positions in images that show little similarity?
3. How should we spend our limited science satellite budget: on a few expensive general-purpose space telescopes or on a larger number of cheaper special-purpose missions?