CHAPTER 4: SPACE AND TIME

REFERENCE: The Blue Planet

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This photograph by the Hubble Space Telescope shows Spiral Galaxy NGC 3949, a galaxy that is quite similar to the Milky Way in both shape and structure, located in the constellation Ursa Major about 50 million light-years from Earth. Because our solar system is embedded in the Milky Way galaxy, it is impossible to get the right perspective to photograph the large-scale features of our own galaxy.
THE SOLAR SYSTEM
HELIOCENTRIC SYSTEM

<table>
<thead>
<tr>
<th></th>
<th>Mercury</th>
<th>Venus</th>
<th>Earth</th>
<th>Mars</th>
<th>Jupiter</th>
<th>Saturn</th>
<th>Uranus</th>
<th>Neptune</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter (km)</td>
<td>4880</td>
<td>12,104</td>
<td>12,756</td>
<td>6787</td>
<td>142,800</td>
<td>120,000</td>
<td>51,800</td>
<td>49,500</td>
</tr>
<tr>
<td>Mass (Earth=1)</td>
<td>0.055</td>
<td>0.815</td>
<td>1</td>
<td>0.108</td>
<td>317.8</td>
<td>95.2</td>
<td>14.4</td>
<td>17.2</td>
</tr>
<tr>
<td>Density, g/cm³ (water=1)</td>
<td>5.44</td>
<td>5.2</td>
<td>5.52</td>
<td>3.93</td>
<td>1.3</td>
<td>0.69</td>
<td>1.28</td>
<td>1.64</td>
</tr>
<tr>
<td>Number of moons</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>16</td>
<td>18</td>
<td>15</td>
<td>8</td>
</tr>
<tr>
<td>Length of day (in Earth hours)</td>
<td>1416</td>
<td>5832</td>
<td>24</td>
<td>24.6</td>
<td>9.8</td>
<td>10.2</td>
<td>17.2</td>
<td>16.1</td>
</tr>
<tr>
<td>Period of one revolution around Sun (in Earth years)</td>
<td>0.24</td>
<td>0.62</td>
<td>1.00</td>
<td>1.88</td>
<td>11.86</td>
<td>29.5</td>
<td>84.0</td>
<td>164.9</td>
</tr>
<tr>
<td>Average distance from Sun (millions of kilometers)</td>
<td>58</td>
<td>108</td>
<td>150</td>
<td>228</td>
<td>778</td>
<td>1427</td>
<td>58</td>
<td>4497</td>
</tr>
<tr>
<td>Average distance from sun (astronomical units)</td>
<td>0.39</td>
<td>0.72</td>
<td>1.00</td>
<td>1.52</td>
<td>5.20</td>
<td>9.54</td>
<td>0.39</td>
<td>30.06</td>
</tr>
</tbody>
</table>
According to the Big Bang model, the universe expanded from an extremely dense and hot state and continues to expand today. A common and useful analogy explains that space itself is expanding, carrying galaxies with it.

Based on measurements of the expansion, measurements of temperature fluctuations in the cosmic microwave background, and measurements of the correlation function of galaxies the universe has a calculated age of:

**13.73 ± 0.12 billion years.**

HOW MANY “SUNS” IN THE UNIVERSE?

100 BILLION GALAXIES

ANSWER: HUNDRED BILLION BILLION (10^{20}) OF SUNS
1. The Sun is a star approximately 5 billion years old.

2. But, the universe is at least twice and possibly three times as old as the Sun.

3. The origin of the Sun was probably similar to the origin of billions of other stars.

4. Scientists hypothesize that the solar system formed from a huge, rotating cloud of cosmic gas (Nebular Hypothesis).
A. The gathering of matter in space created a cloud of dust and gas, which began to rotate.
B. As the cloud of gas and dust became smaller and denser, it flattened, and its center eventually collapsed inward to become the Sun.
C. The planets were formed by condensation from the gas cloud and accretion of the condensed particles.
D. Today all the planets orbit the Sun in the same direction.
NEBULAR HYPOTHESIS

Watch the YouTube video called “Birth of the Solar System”
KEY FACTORS IN PLANETARY EVOLUTION

1. Melting

Moving bodies collided and the energy of their motion was converted to heat energy. This energy partially melted the terrestrial planets and separated their elements.
After partial melting, the planets remained hot inside because of the radioactive elements. This internal heat is released by different mechanisms, like volcanism.
The mass determined the orbital characteristics of planets as well as its ability to retain an atmosphere. Ex. Mercury (left) in comparison with Earth (right) is too small to retain an atmosphere.
KEY FACTORS IN PLANETARY EVOLUTION

4. Distance from the Sun

The Sun-planet distance determines whether or not liquid water (i.e. oceans) can exist.
5. Development of a biosphere

This factor controls the biogeochemical cycles that determine the composition of the atmosphere, affecting other components.
The issue of a clear definition for "planet" came to a head in 2005 with the discovery of the trans-Neptunian object Eris, a body larger than the smallest then-accepted planet, Pluto.

In its 2006 response, the International Astronomical Union (IAU), recognized by astronomers as the world body responsible for resolving issues of nomenclature, released its decision on the matter.

This definition, which applies only to the Solar System, states that a planet is:

1. a body that orbits the Sun,
2. is large enough for its own gravity to make it round,
3. and has "cleared its neighborhood" of smaller objects.

Under this new definition, several trans-Neptunian objects, does not qualify as a planet.
Pluto was considered a planet since its discovery in 1930. Under the new guidelines, it's now considered a "dwarf planet," leaving only eight planets in our solar system.

Pluto, which is smaller than Earth's moon, doesn't fit the new criteria for a planet:
“a celestial body that is in orbit around the sun, has sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a … nearly round shape, and has cleared the neighborhood around its orbit.”

Pluto doesn't qualify because its orbit is inclined relative to the rest of the solar system and crosses over the orbit of Neptune.
At the time Earth formed 4.5 billion years ago, other smaller planetary bodies were also growing. One of these hit Earth late in Earth's growth process, blowing out rocky debris. A fraction of that debris went into orbit around the Earth and aggregated into the moon.
Some 4.5 billion years ago, the still-forming Earth runs into another growing planet, which scientists have dubbed Theia. Theia is destroyed, and its remnants—along with a good chunk of Earth's mantle—are blasted into orbit around Earth. The off-center impact knocks Earth's axis of rotation askew. The debris spreads itself into a ring and begins to clump together. The largest clump starts to attract other fragments and is well on its way toward becoming the Moon.

Watch the YouTube video called “How the Moon was Born!”
THE SPACE EXPLORATION
On October 24, 1946, not long after the end of World War II, a group of soldiers and scientists in the New Mexico desert saw something new and wonderful—the first pictures of Earth as seen from space and taken by a rocket-borne cameras.
History changed on October 4, 1957, when the Soviet Union successfully launched Sputnik I. The world's first artificial satellite was about the size of a beach ball (58 cm. or 22.8 inches in diameter), weighed only 83.6 kg. or 183.9 pounds, and took about 98 minutes to orbit the Earth on its elliptical path. That launch ushered in new political, military, technological, and scientific developments. While the Sputnik launch was a single event, it marked the start of the space age and the U.S.-U.S.S.R space race.
THE APOLO PROGRAM
1963-1972
APOLO 8: EARTH ABOVE HORIZON
APOLLO 11: LUNAR LANDING
• Skylab was the first US space station.
• It was launched into a 435 km (270 miles) altitude orbit on May 14, 1973 as part of the Apollo program.
• Skylab program objectives were twofold:
  • To prove that humans could live and work in space for extended periods.
  • To expand our knowledge of solar astronomy well beyond Earth-based observations.
• Successful in all respects despite early mechanical difficulties, three three-man crews occupied the Skylab workshop for a total of 171 days, 13 hours.
• It was the site of nearly 300 scientific and technical experiments: medical experiments on humans' adaptability to zero gravity, solar observations, and detailed Earth resources experiments.
• The empty Skylab spacecraft returned to Earth July 11, 1979 scattering debris over the Indian Ocean and the sparsely settled region of Western Australia.
# SPACE SHUTTLE MAJOR EVENTS

<table>
<thead>
<tr>
<th>Date</th>
<th>Orbiter</th>
<th>Major event / remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>September 17, 1976</td>
<td>Enterprise</td>
<td>Prototype Space Shuttle <em>Enterprise</em> was rolled out of its assembly facility in Southern California and displayed before a crowd several thousand strong.(^{[71]})</td>
</tr>
<tr>
<td>February 18, 1977</td>
<td>Enterprise</td>
<td>First flight; Attached to <em>Shuttle Carrier Aircraft</em> throughout flight.</td>
</tr>
<tr>
<td>August 12, 1977</td>
<td>Enterprise</td>
<td>First free flight; Tailcone on; lakebed landing.</td>
</tr>
<tr>
<td>October 26, 1977</td>
<td>Enterprise</td>
<td>Final <em>Enterprise</em> free flight; First landing on Edwards AFB concrete runway.</td>
</tr>
<tr>
<td>April 12, 1981</td>
<td>Columbia</td>
<td>First <em>Columbia</em> flight, first orbital test flight; STS-1</td>
</tr>
<tr>
<td>November 11, 1982</td>
<td>Columbia</td>
<td>First operational flight of the Space Shuttle, first mission to carry four astronauts; STS-5</td>
</tr>
<tr>
<td>April 4, 1983</td>
<td>Challenger</td>
<td>First <em>Challenger</em> flight; STS-6</td>
</tr>
<tr>
<td>August 30, 1984</td>
<td>Discovery</td>
<td>First <em>Discovery</em> flight; STS-41-D</td>
</tr>
<tr>
<td>October 3, 1985</td>
<td>Atlantis</td>
<td>First <em>Atlantis</em> flight; STS-51-J</td>
</tr>
<tr>
<td>October 30, 1985</td>
<td>Challenger</td>
<td>First crew of eight astronauts; STS-61-A</td>
</tr>
<tr>
<td>January 28, 1986</td>
<td>Challenger</td>
<td>Disaster starting 73 seconds after launch; STS-51-L; all seven crew members died.</td>
</tr>
<tr>
<td>September 29, 1988</td>
<td>Discovery</td>
<td>First post-<em>Challenger</em> mission; STS-26</td>
</tr>
<tr>
<td>May 4, 1989</td>
<td>Atlantis</td>
<td>The first Space Shuttle mission to launch a space probe, <em>Magellan</em>; STS-30</td>
</tr>
<tr>
<td>April 24, 1990</td>
<td>Discovery</td>
<td>Launch of the <em>Hubble Space Telescope</em>; STS-31</td>
</tr>
<tr>
<td>May 7, 1992</td>
<td>Endeavour</td>
<td>First <em>Endeavour</em> flight; STS-49</td>
</tr>
<tr>
<td>November 19, 1996</td>
<td>Columbia</td>
<td>Longest Shuttle mission at 17 days, 15 hours; STS-80</td>
</tr>
<tr>
<td>December 4, 1998</td>
<td>Endeavour</td>
<td>First ISS mission; STS-88</td>
</tr>
<tr>
<td>February 1, 2003</td>
<td>Columbia</td>
<td>Disintegrated during re-entry; STS-107; all seven crew members died.</td>
</tr>
<tr>
<td>July 25, 2005</td>
<td>Discovery</td>
<td>First post-<em>Columbia</em> mission; STS-114</td>
</tr>
<tr>
<td>February 24, 2011</td>
<td>Discovery</td>
<td>Last <em>Discovery</em> flight; STS-133</td>
</tr>
<tr>
<td>May 16, 2011</td>
<td>Endeavour</td>
<td>Last <em>Endeavour</em> mission; STS-134(^{[72]})[(^{[73]})]</td>
</tr>
<tr>
<td>July 8, 2011</td>
<td>Atlantis</td>
<td>Last <em>Atlantis</em> flight and last Space Shuttle flight; STS-135</td>
</tr>
</tbody>
</table>

**6 Shuttles**

**35 Years**
MAGELLAN DEPLOYMENT
GALILEO DEPLOYMENT
HUBBLE TELESCOPE REFURNISH
• Research facility assembled in outer space.
• The on-orbit construction of which began in 1998.
• The space station is in a Low Earth Orbit (~350 km) and can be seen from Earth with the naked eye.
• Travels at an average speed of 27,700 kilometres (17,210 mi) per hour, completing 15.7 orbits per day.
• Joint project among the space agencies of the United States (NASA), Russia (RKA), Japan (JAXA), Canada (CSA) and ten European countries (ESA).
• The station was completed in 2011.
• The ISS is funded until 2020, and may operate until 2028.
Puerto Rico visto por el astronauta Joseph Acabá el 1 de septiembre del 2012 desde la cúpula de cristales de la Estación Espacial Internacional.
Así luce Puerto Rico visto desde la Estación Espacial Internacional. Foto NASA
BACK TO THE MOON
ORION: Next Generation of Spacecrafts

Orion is a spacecraft design currently under development by the United States space agency NASA. Each Orion spacecraft will carry a crew of four to six astronauts, and will be launched by the Ares I, a launch vehicle also currently under development. Both Orion and Ares I are elements of NASA's Project Constellation, which plans to send human explorers back to the Moon by 2020, and then onward to Mars and other destinations in the solar system.
This mosaic of Mercury was taken by the Mariner 10 spacecraft during its approach on 29 March 1974. The mosaic consists of 18 images taken at 42 s intervals during a 13 minute period when the spacecraft was 200,000 km (about 6 hours prior to closest approach) from the planet.
Ultraviolet image of Venus' clouds as seen by the Pioneer Venus Orbiter (Feb. 5, 1979).
Magellan synthetic aperture radar mosaics from the first cycle of Magellan mapping are mapped onto a computer-simulated globe to create this image.
PATHFINDER MISSION

Launched: December 4, 1996
Landed: July 4, 1997
NASA’s Mars Exploration Rover Mission (MER) is an ongoing robotic space mission involving two rovers, Spirit and Opportunity, exploring the planet Mars. It began in 2003 with the sending of the two rovers—MER-A Spirit and MER-B Opportunity—to explore the Martian surface and geology.

**Launch:** July 2003  
**Arrival:** January 2004  
**Science instruments:**  
- Panoramic Camera,  
- Miniature Thermal Emission Spectrometer, Mössbauer Spectrometer, Alpha Particle X-ray Spectrometer,  
- Microscopic Imager
Opportunity landed in a crater, and hits scientific jackpot with views of first rock outcrop ever seen on Mars.
Curiosity Mission

- It landed on August 6, 2012.
- The objectives include determining the habitability of Mars, studying its climate and exogeology, and collecting data for future human missions.
- It is about twice as long and five times as massive as the Spirit and Opportunity Mars exploration rovers, and carries over ten times the mass of scientific instruments.
This is a portion of the first color 360-degree panorama from NASA's Curiosity rover in Mars, released by NASA August 9, 2012.
In this image from NASA's Curiosity rover, a rock outcrop called Link pops out from a Martian surface that is elsewhere blanketed by reddish-brown dust. The fractured Link outcrop has blocks of exposed, clean surfaces. Rounded gravel fragments, or clasts, up to a couple inches (few centimeters) in size are in a matrix of white material. Many gravel-sized rocks have eroded out of the outcrop onto the surface, particularly in the left portion of the frame. The outcrop characteristics are consistent with a sedimentary conglomerate, or a rock that was formed by the deposition of water and is composed of many smaller rounded rocks cemented together. Water transport is the only process capable of producing the rounded shape of clasts of this size.
NASA's Curiosity rover found evidence for an ancient, flowing stream on Mars at a few sites, including the rock outcrop pictured here, which the science team has named "Hottah" after Hottah Lake in Canada’s Northwest Territories. It may look like a broken sidewalk, but this geological feature on Mars is actually exposed bedrock made up of smaller fragments cemented together, or what geologists call a sedimentary conglomerate. Scientists theorize that the bedrock was disrupted in the past, giving it the titled angle, most likely via impacts from meteorites. Ref. http://www.nasa.gov/mission_pages/msl/multimedia/pia16156.html
MARS VIEW AS DETECTED BY CURIOSITY
MARS RECONNAISSANCE ORBITER (MRO)

August 12, 2005: It lifted off at 7:43 AM EDT from Launch Complex 41 at Cape Canaveral Air Force Station, Florida.

March 10, 2006: Successfully enters orbit around Mars.

March 26, 2006: First image from orbit.
• Science Instruments: During its two-year primary science mission, the Mars Reconnaissance Orbiter will conduct eight different science investigations at Mars. The investigations are functionally divided into three purposes: global mapping, regional surveying, and high-resolution targeting of specific spots on the surface.

• Cameras: HiRISE (High Resolution Imaging Science Experiment) This visible camera can reveal small-scale objects in the debris blankets of mysterious gullies and details of geologic structure of canyons, craters, and layered deposits. CTX (Context Camera) This camera will provide wide area views to help provide a context for high-resolution analysis of key spots on Mars provided by HiRISE and CRISM. MARCI (Mars Color Imager) This weather camera will monitor clouds and dust storms.

• Spectrometer: CRISM (Compact Reconnaissance Imaging Spectrometer for Mars) This instrument splits visible and near-infrared light of its images into hundreds of "colors" that identify minerals, especially those likely formed in the presence of water, in surface areas on Mars not much bigger than a football field.

• Radiometer: MCS (Mars Climate Sounder) This atmospheric profiler will detect vertical variations of temperature, dust, and water vapor concentrations in the Martian atmosphere.

• Radar: SHARAD (Shallow Radar) This sounding radar will probe beneath the Martian surface to see if water ice is present at depths greater than one meter.
FROM ROBOT GEOLOGISTS TO HUMAN GEOLOGISTS ON MARS
JUPITER
This true color mosaic of Jupiter was constructed from images taken by the narrow angle camera onboard NASA's Cassini spacecraft on December 29, 2000, during its closest approach to the giant planet at a distance of approximately 10 million kilometers (6.2 million miles).
This captivating natural color view was created from images collected shortly after Cassini began its extended Equinox Mission in July 2008. This mosaic combines 30 images—10 each of red, green and blue light—taken over the course of approximately two hours as Cassini panned its wide-angle camera across the entire planet and ring system on July 23, 2008, from a southerly elevation of 6 degrees.
ERIS
Watch the YouTube video called “NASA | We Did All That in 50 Years!”