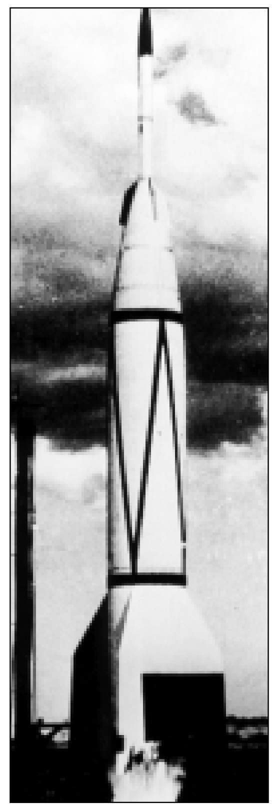
A BRIEF HISTORY OF THE UNITED STATES ASTRONOMY SPACECRAFT AND CREWED SPACE FLIGHTS

The early successes of Sputnik and the Explorer series spurred the United States to develop long-range programs for exploring space. Once the United States became comfortable with the technical demands of spacecraft launches, NASA quickly began scientific studies in space using both crewed and non-crewed spacecraft launches.

Teams of scientists began their studies in space close to home by exploring the Moon and the solar system. Encouraged by those successes, they have looked farther out to nearly the beginning of the universe.

Observing the heavens from a vantage point above Earth is not a new idea. The idea of placing telescopes in orbit came quite early—at least by 1923 when Hermann Oberth described the idea. Even before his time, there were a few attempts at space astronomy. In 1874, Jules Janseen launched a balloon from Paris with two aeronauts aboard to study the effects of the atmosphere on sunlight. Astronomers continue to use balloons from launch sites in the Antarctic; Palestine, Texas; and Alice Springs, Australia. After launch, scientists chase the balloon in a plane as the balloon follows the prevailing winds, traveling thousands of kilometers before sinking back to Earth. A typical balloon launch yields many hours of astronomical observations.

Rocket research in the second half of the 20th century developed the technology for launching satellites. Between 1946 and 1951, the U.S. launched 69 V-2 rockets. The V-2 rockets were captured from the Germans after World War II and used for high altitude research. Several of those flights studied ultra-

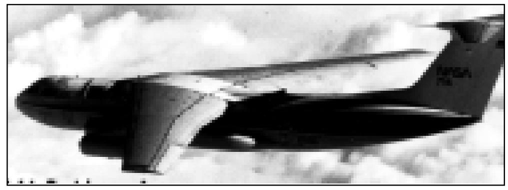


U.S. V-2 rocket launch

violet and x-ray emissions from the Sun. Today, sounding rockets are used primarily by universities. They are inexpensive and quick, but provide only a few minutes of observations.

To conduct its current research, NASA uses big rockets like Atlas, Delta, Titan, and the Space Shuttle as well as small rockets launched from a B-52 aircraft to lift satellites into orbit. Except for the largest rockets, which are launched in Florida and California, rocket research and launches occur at many places around the United States. NASA also uses the Kuiper Airborne Observatory (KAO) that carries a 0.9-meter telescope inside a C-141 aircraft. It flies above the densest part of the atmosphere and observes in the far-infrared and submillimeter wavelengths. KAO flies approximately 80 times a year. KAO can reach an altitude of 13,700 meters with a normal flight time of 7.5 hours.

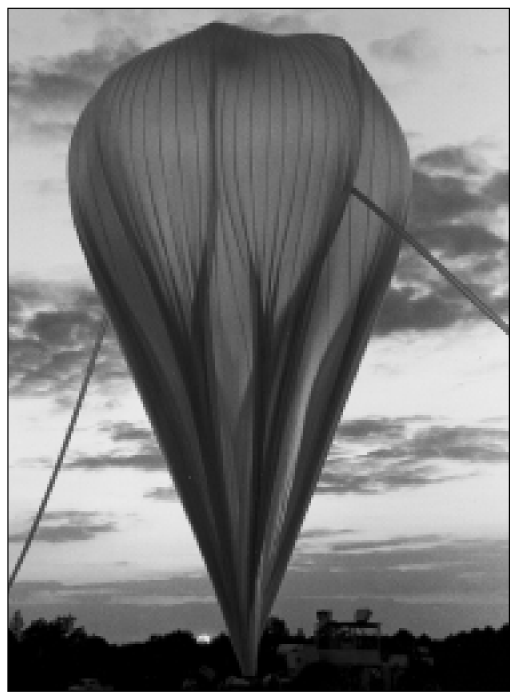
In the near future, NASA will begin flying the Stratospheric Observatory for Infrared Astronomy (SOFIA). SOFIA is a 747 aircraft modified to accommodate a 2.5 meter reflecting telescope, which is slightly larger than the Hubble Space Telescope (HST) at 2.4 meters. Like KAO, SOFIA will conduct infrared astronomy and fly at an altitude of 13,000 meters for 8 hours.



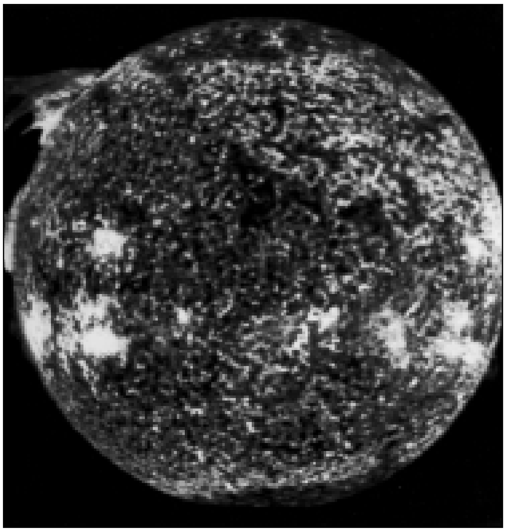
NASA's Kuiper Airborne Observatory

Over the years, NASA space probes have sent back detailed images of the planets Mercury, Venus, Mars, Jupiter, Saturn, Uranus, and Neptune. Mariner 2 was the first spacecraft to explore another planet when it flew past Venus in 1962. The missions to the planets have redefined the picture of our solar system. Scientists have an incredible set of data from almost every planet in the solar system.

Black Brandt sounding rocket ready for launch to study Supernova 1987A



Final inflation of an instrument-carrying helium balloon before launch from Palestine, TX



Skylab 4 picture of the Sun in ionized helium light

We learned that Venus is hotter than Mercury. Data from satellites in orbit around Venus have told us about the atmosphere and terrain of the planet. By monitoring Venus' atmosphere, scientists can study the effects of a runaway greenhouse effect. Several Russian spacecraft have explored the surface of Venus as well as the Moon and Mars.

Although spacecraft have mapped the surface of Mars, the Mars Viking mission gently deposited two landers on the surface that sent back data. They still sit on the surface there. The two interplanetary travelers, Voyager 1 and 2 (launched in September and August 1977, respectively) visited Jupiter, Saturn, Uranus, and Neptune and are now leaving the solar system on their way into interstellar space. They sent back new data on these gas giant planets. Their discoveries included volcanoes on Io (a satellite of Jupiter), storms on Neptune, and ring shepherd satellites around Saturn. The two Voyager missions represent an incredible success story. They provided unique glimpses of the planets and redefined the history of our solar system.

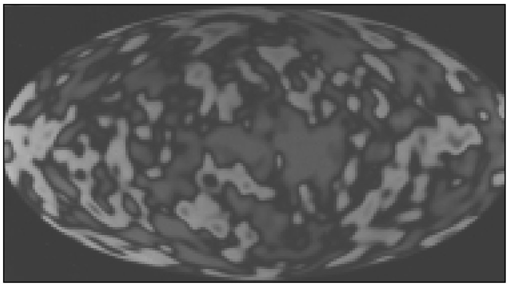
Beginning in 1962, NASA launched a series of nine orbiting observatories to observe the Sun. Astrophysicists began to understand the interior of our nearest star. In the 1970's, Skylab astronauts brought back from orbit a wealth of data on the Sun, using x-rays to study its activity.

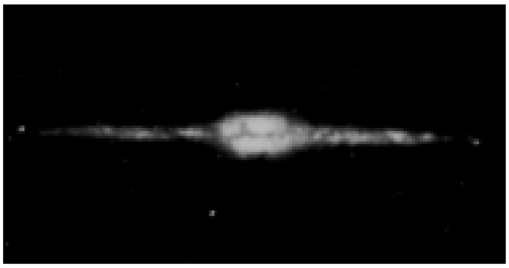
In 1978, one of the most successful astronomical satellite missions, the International Ultraviolet Explorer (IUE), was launched. This satellite has an ultraviolet telescope that has been used to study the universe in the ultraviolet portion of the electromagnetic spectrum. Many scientists continue to use IUE simultaneously with other satellites and Earth telescopes to gather multi-wavelength data on astronomical objects.

Other NASA satellites have carried x-ray detectors into space. One of the first (1970)—called Uhuru (Swahili for freedom)—mapped the entire sky in x-ray wavelengths. Later (1978), the second High Energy Astrophysics Observatory (HEAO-2), called Einstein, imaged many objects in x-ray light. Today a satellite called ROSAT (a name honoring the physicist who discovered x-rays, Dr. Wilhelm Roentgen) continues the study of individual sources of x-rays in the sky. All of these satellites added new objects to the astronomical zoo and helped scientists understand the processes that make x-rays in space. The sheer number of high-energy objects discovered by these satellites surprised and excited the scientific community.

The Infrared Astronomical Satellite (IRAS) was launched in 1983. It mapped the sky in infrared wavelengths. IRAS scientists have discovered thousands of infrared sources never seen before. The infrared part of the spectrum tells about molecules in space and gas and dust clouds where new stars are hidden until they are bright enough to outshine their birth cloud.

The Space Shuttle is used to introduce instruments into low Earth orbit. Satellites like the HST orbit about 600 kilometers above Earth's surface. This is a low Earth orbit and accessible to the Shuttle. To put satellites into high Earth orbit, an upper stage must be carried in the





Top: Thermal background radiation measured by the COBE spacecraft

Bottom: Image of the Milky Way taken by the COBE spacecraft

The *Hubble Space Telescope* attached to the Space Shuttle *Endeavour* during the 1993 service mission

Shuttle's payload bay or the satellite is lofted with one of several different kinds of non-crewed launch vehicles. For example, the Geostationary Operational Environmental Satellite (GOES) orbits about 40,000 kilometers above Earth's surface. A Delta rocket was used to put GOES into high orbit. The choice of altitude—high Earth orbit or low Earth orbit—depends on the data to be measured.

Recent and Multi-Mission Programs

Magellan

In May 1989, the Magellan spacecraft was released from the Space Shuttle and sent on its way to orbit Venus. The atmosphere of Venus is unfriendly to humans with its thick sulfuric acid clouds, high pressures, and high temperatures. Magellan used radar to penetrate Venus's dense atmosphere and map the planet's surface.

Galileo

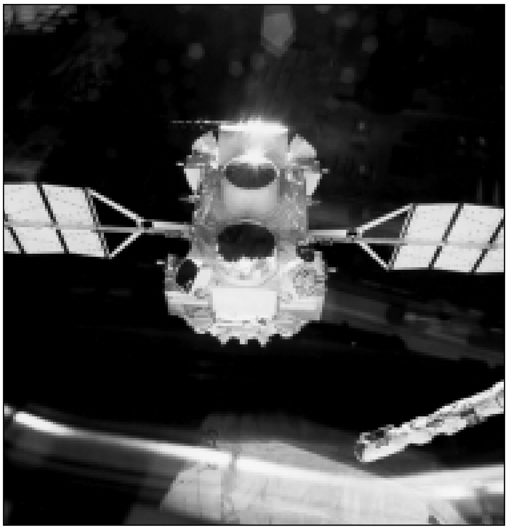
In October of that same year, another Shuttle mission launched Galileo on its way to visit the planet Jupiter. On its way out to Jupiter, Galileo (named after Galileo Galilei, an Italian astronomer of the 17th century) took pictures of several asteroids. The Galileo spacecraft was designed to study Jupiter's atmosphere, satellites, and surrounding magnetosphere. The spacecraft is currently orbiting Jupiter and performing an extended study of the planet's moons.

Cosmic Background Explorer (COBE)

Just a month later, in November 1989, the Cosmic Background Explorer (COBE) was launched from a Delta rocket. This satellite surveyed the entire sky in microwave wavelengths and provided the first precise measurement of variations in the background radiation of the universe. The distribution of this radiation does not follow the predictions of the Big Bang Theory.

The Hubble Space Telescope (HST)

In April 1990, the crew of the Space Shuttle Discovery launched the HST. This telescope combines ultraviolet and optical imaging with spectroscopy to provide high quality data of a variety of astronomical objects. Although the primary mirror aboard the satellite was later discovered to be slightly flawed, astronomers were able to partially compensate for the slightly out-of-focus images through computer processing. In December 1993, the Hubble servicing mission



Deployment of the *Compton Gamma Ray Observatory* from the Space Shuttle *Atlantis* in 1991

permitted astronauts to add compensating devices to the flawed mirror, to readjust its focus, and to replace or repair other instruments and solar arrays. The servicing mission has led to images of unprecedented light sensitivity and clarity.

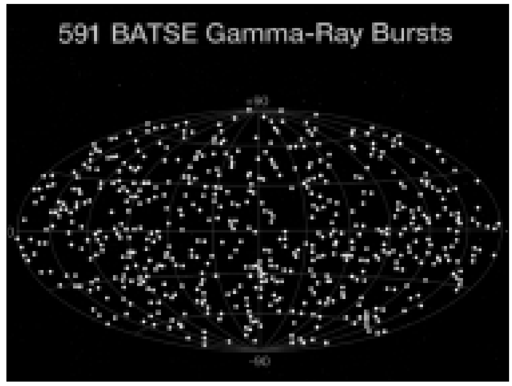
Astro-1 and the Broad-Band X-ray Telescope (BBXRT)

In December 1990, the crew of the Space Shuttle Columbia conducted two experiments during its flight. The Astro-1 instrument platform and the Broad-Band X-ray Telescope (BBXRT) both study the x-ray and ultraviolet emissions of astronomical objects.

Compton Gamma Ray Observatory (CGRO)

A few months later, in April 1991, the Compton Gamma Ray Observatory (CGRO) was launched from the Space Shuttle. CGRO is the second of NASA's Great Observatories. During its lifetime, CGRO made some of the most important discoveries in the field of gamma-ray astronomy:

- Gamma ray bursts (short-lived, but extremely powerful explosions) are evenly distributed across the sky, and thus outside the Milky Way galaxy;



Gamma ray bursts detected by the *Compton Gamma Ray Observatory*

- Gamma ray loud blazars (quasars with particle jets aimed at us) to be a new class of objects; and

- The galactic center glows in antimatter radiation.

CGRO was safely and flawlessly de-orbited over the Pacific Ocean on June 4, 2000.

Extreme Ultraviolet Explorer (EUVE)

In May 1992, a Delta rocket boosted the Extreme Ultraviolet Explorer (EUVE) into orbit. This satellite, which concluded its mission in December 2000, studied the far ultraviolet part of the spectrum. One unexpected result from this mission was the distances at which ultraviolet sources were seen. The scientists expected to see ultraviolet radiation only from within 50 light years of the Sun. EUVE detected extreme ultraviolet emissions from distant galaxies in its first year of operation.

Cassini-Huygens

Launched in October 1997, the Cassini-Huygens mission will do a detailed study of Saturn, its rings, its magnetosphere, its icy satellites, and its moon Titan. The Cassini Orbiter's mission consists of delivering the Huygens probe (provided by the European Space Agency) to Titan to study its clouds, atmosphere, and surface, and then remaining in orbit around Saturn for detailed studies of the planet and its rings and satellites. Cassini will arrive at Saturn on July 1, 2004.

Chandra X-ray Observatory

Launched in July of 1999, Chandra is the third of NASA's Great Observatories, after the HST and CGRO. It is performing an exploration of the hot turbulent regions in space and has 8-times greater resolution than previous x-ray telescopes enabling it to detect sources more than 20-times fainter than previous observations. Chandra's improved sensitivity will make possible more detailed studies of black holes, supernovas, and dark matter and increase our understanding of the origin, evolution, and destiny of the universe.

The Discovery Program

Discovery represents the implementation of "Faster, Better, Cheaper" planetary missions. The philosophy of Discovery is to solicit proposals for an entire mission, put together by consortia comprised of industry, small businesses, and universities. The goal is to launch many, smaller missions that do focused science with fast turnaround times and for which the entire mission cost (design, development, launch vehicle, instruments, spacecraft, launch, mission operations, and data analysis) is minimal. Discovery missions selected to date include:

- Near Earth Asteroid Rendezvous (NEAR)
- Mars Pathfinder
- Lunar Prospector
- Stardust
- Genesis
- Comet Nucleus Tour (CONTOUR)
- ASPERA-3
- Deep Impact
- Mercury Surface Space Environment Geochemistry and Ranging mission (MESSENGER)

The Explorer Program

The Explorer Program began with the launch of Explorer 1 in 1958, and became a sustained program beginning in 1961. Over 70 "Explorer" missions have been launched successfully, pioneering space research on micrometeoroids, the Earth's magnetosphere, x-ray astrophysics, the cosmic microwave background and many other fields of space science investigation. In addition, the Explorer program has a long history of providing scientific instruments as part of other nations' missions. Current Explorer missions include:

- Submillimeter Wave Astronomy Satellite (SWAS)
- Advanced Composition Explorer (ACE)
- Transition Region and Coronal Explorer (TRACE)
- Fast Auroral Snapshot Explorer (FAST)
- Solar Anomalous and Magnetospheric Particle Explorer (SAMPEX)
- Far Ultraviolet Spectroscopic Explorer (FUSE)
- Imager for Magnetopause-to-Aurora Global Exploration (IMAGE)
- High Energy Transient Explorer-2 (HETE-2)
- High Energy Solar Spectroscopic Imager (HESSI)
- Microwave Anisotropy Probe (MAP)
- Cooperative Astrophysics and Technology Satellite (CATSAT)
- Galaxy Evolution Explorer (GALEX)
- Cosmic Hot Interstellar Plasma Spectrometer (CHIPS)
- Inner Magnetosphere Explorer (IMEX)
- Two Wide-Angle Imaging Neutral-Atom Spectrometer (TWINS)
- Swift
- Full-Sky Astrometric Mapping Explorer (FAME)
- Coupled Ion-Neutral Dynamics Investigations (CINDI)

The Mars Surveyor Program

The Mars Surveyor program reflects a long-term commitment to the exploration of the Red Planet. NASA intends to launch one or two spacecraft to Mars whenever Mars' orbit allows, approximately every 26 months. The first spacecraft in this series was the Mars Global Surveyor in 1996. The Mars '98 Orbiter and Lander were launched in December 1998 and January 1999 but were lost during their journey to Mars. The 2001 Mars Odyssey orbiter is scheduled to arrive at Mars in late 2001 and is expected to produce exceptional science mapping the mineralogy of the Martian surface. Currently under development are twin scientific exploration rovers scheduled for launch in 2003. Each of the rovers will

Astronomy Space Missions
(partial list)

Year	Mission	Target
1957	Stratoscope I	Sun
1961	Explorer 11	gamma rays
1962	Arobee	X-ray sources
1962	Mariner 2	Venus
1963	Mars 1	Mars
1965	Mariner 4	Mars
1967	OSO-3	gamma rays
1968	RAE-1	radio
1968	OAO-2	UV sky
1969	Vela 5A	gamma rays
1969	Apollo 11	Moon
1970	SAS-1	X-ray sky
1971	Explorer 43	solar wind/ radio
1971	Mariner 9	Mars
1972	Pioneer 10	deep space
1972	Copernicus	UV sky
1973	Pioneer 11	deep space
1973	Skylab	Sun
1973	Explorer 49	radio sources
1974	Mariner 10	Mercury
1975	SAS-3	X-ray sources
1975	Viking 1 & 2	Mars
1976	Viking 1 & 2	Mars
1977	Voyager 2	outer planets
1977	Voyager 1	outer planets
1978	IUE	UV sky
1978	Pioneer Venus-A	radar studies
1978	HEAO-2	X-ray sky

Year	Mission	Target
1983	IRAS	infrared sky
1985	Spacelab-2	infrared sky
1989	Magellan	Venus
1989	Galileo	Jupiter/asteroids/ Earth/Venus
1989	COBE	microwave sky
1990	HST	UV sky
1990	ROSAT	X-ray sky
1990	Ulysses	Sun
1990	ASTRO-1	X-ray and UV sky
1990	ROSAT	X-ray sky
1991	Yohko	Sun in X-rays
1992	Extreme UV Explorer	X-ray sky
1994	Wind	Solar wind
1994	Clemintine	Moon
1995	Infrared Telescope in Space	IR sky
1995	Infrared Space Observatory	IR sky
1995	Rossi X-ray Timing Explorer	X-ray sky
1995	Solar Heliospheric Observatory	Sun
1995	ASTRO-2	UV sky
1996	Mars Global Surveyor	Mars
1996	Near Earth Asteroid Rendezvous	Asteroid
1996	Mars Pathfinder	Mars
1997	Cassini	Saturn
1998	Lunar Prospector	Moon
1999	Stardust	Comet
1999	Mars Climate Orbiter	Mars
1999	Mars Polar Orbiter	Mars
1999	Chandra X-ray Observatory	X-ray sky

be delivered to the surface protected by inflated airbags similar to the successful Mars Pathfinder. Each rover will be equipped with an integrated suite of instruments (cameras, spectrometers, microscopes, and abrasion tool) that will allow it to behave as a robotic field geologist. They will have an exploration range of up to 1 kilometer during their 90 days of operational life on the surface of Mars. In 2005, NASA plans to launch a powerful scientific orbiter. This mission, the Mars Reconnaissance Orbiter, will focus on analyzing the surface at new spatial scales and in new spectral regions in an effort to follow the potential evidence of water from the Mars Global Surveyor images and to bridge the gap between surface observations and measurements from orbit. The next step in the Mars exploration program strategy will be to send a long-range, long-duration mobile science laboratory to Mars (at least by 2009, and as early as 2007). This “smart lander” will be a major leap in surface measurements and pave the way for a future sample return mission.

New Millennium Program

NASA has an ambitious plan for space exploration in the next century. It envisions a scenario in which spacecraft will have revolutionary new capabilities compared to those of today. Spacecraft are envisioned as flying in formation, or in fleets, or having artificial intelligence to provide the kind of capability that can answer the more detailed level of questions that scientists have about the universe. Missions include:

- Deep Space 1
- Deep Space 2
- Starlight
- Earth Observing 1
- Earth Observing 3
- Space Technology 5
- Space Technology 6

The goal of the New Millennium Program (NMP) is to identify and test advanced technologies that will provide spacecraft with the capabilities they need in order to achieve NASA’s vision.

Technologies such as solar electric propulsion and artificial intelligence promise a great leap forward in terms of future spacecraft capability, but they also present a risk to missions that use them for the first time. Through a series of deep space and Earth orbiting flights, NMP will demonstrate these promising but risky technologies in space to prove that they work. Once validated, the technologies pose less of a risk to missions that would like to use them to achieve their scientific objectives.

International Solar Terrestrial Physics (ISTP) Program

Collaborative efforts by NASA, the European Space Agency (ESA), and the Institute of Space and Astronautical Science (ISAS) of Japan led to the International Solar-Terrestrial Physics program, consisting of a set of missions being carried out during the 1990's and into the next century. This program combines resources and scientific communities on an international scale using a complement of several missions, along with complementary ground facilities and theoretical efforts, to obtain coordinated, simultaneous investigations of the Sun-Earth space environment over an extended period of time. Missions include:

- Wind
- Polar
- Geotail
- The Solar and Heliospheric Observatory (SOHO)
- Ulysses
- Advanced Composition Explorer (ACE)
- IMP-8
- EQUATOR-8

Living With A Star (LWS)

Living With A Star (LWS) is a NASA initiative that will develop the scientific understanding necessary to effectively address those aspects of the coupled Sun-Earth system that directly affect life and society on Earth. LWS missions include:

- Solar Dynamics Observatory (SDO)
- Sentinels
- Radiation Belt Mappers (RBM)
- Ionospheric Mappers (IM)

Scientific Balloon Program

Balloons offer a low-cost, quick response method for doing scientific investigations. Balloons are mobile, meaning they can be launched where the scientist needs to conduct the experiment, and can be readied for flight in as little as six months. Balloon payloads provide us with information on the atmosphere, the universe, the Sun, and the near-Earth and space environment. NASA launches about 30 scientific balloons each year.

Sounding Rocket Program

Experiments launched on sounding rockets provide a variety of information, including chemical makeup and physical processes taking place in the atmosphere; the natural radiation surrounding the Earth; and data on the Sun, stars, and galaxies. Sounding rockets provide the only means of making in-situ measurements at altitudes between the maximum altitudes for balloons (about 30 miles or 48 kilometers) and the minimum altitude for satellites (100 miles or 161 kilometers).

Using space-borne instruments, scientists now map the universe in many wavelengths. Satellites and telescopes provide data in radio, microwave, infrared, visible, ultraviolet, x-ray, and gamma ray. By comparing data from an object in the sky, in all wavelengths, astronomers are learning more about the history of our universe. Visit *http://spacescience.nasa.gov,* for more information about NASA Space Science missions and programs.