A View of the Invisible Universe

Astro-1

Astro-1 is an observatory consisting of four telescopes. Three of the telescopes, equipped with instruments sensitive to ultraviolet (uv) light, are mounted on a single pointing system. A fourth telescope with an X-ray sensitive instrument has its own pointer. The telescopes are capable of independent or simultaneous observations of selected targets. Each gathers light for a different astronomical instrument designed to measure light at uv or X-ray wavelengths. These are invisible to the human eye and cannot be measured on the Earth's surface due to absorption by the Earth's atmosphere. To observe the invisible universe, we must climb above the Earth's atmosphere to study the stars from space. The Astro-1 Observatory works much like a mountaintop observatory with astronomer/astronauts on board the Space Shuttle operating the uv telescopes and astronomers on the ground operating the X-ray telescope. Observation data are recorded on photographic film or transmitted to the ground for scientists to analyze.

Hopkins Ultraviolet Telescope—HUT

■ The Vela supernova remnant is the remains of a star that exploded about 30,000 years ago, forming an expanding shell of hot dust and gas.

■ HUT will obtain far-ultraviolet spectroscopic data from white dwarfs, emission nebulae, active galaxies, and quasars.

Hale Observatories photograph

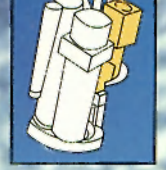
Ultraviolet Imaging Telescope—UIT

■ The Galaxy M83 shines brightly in the ultraviolet portion of the spectrum because its spiral arms contain many young stars.

■ UIT will record photographic images in ultraviolet light of galaxies, star clusters, and nebulae.

Goddard Space Flight Center photograph

Wisconsin Ultraviolet Photo-Polarimeter Experiment—WUPPE



■ Interstellar dust in the Pleiades star cluster can be seen in the reflected light of nearby stars.

■ WUPPE will study polarized ultraviolet light from magnetic white dwarfs, binary stars, reflection nebulae, and active galaxies.

Hale Observatories photograph

Broad Band X-Ray Telescope—BBXRT

■ Centaurus A is an active galaxy and X-ray source. The central portion of this galaxy is obscured by a disk of dust and gas where young stars reside and new stars are forming.

■ BBXRT will obtain high-resolution X-ray spectra from stellar coronae, X-ray binary stars, active galactic nuclei, and galaxy clusters.

National Optical Astronomy Observatories photograph

NASA
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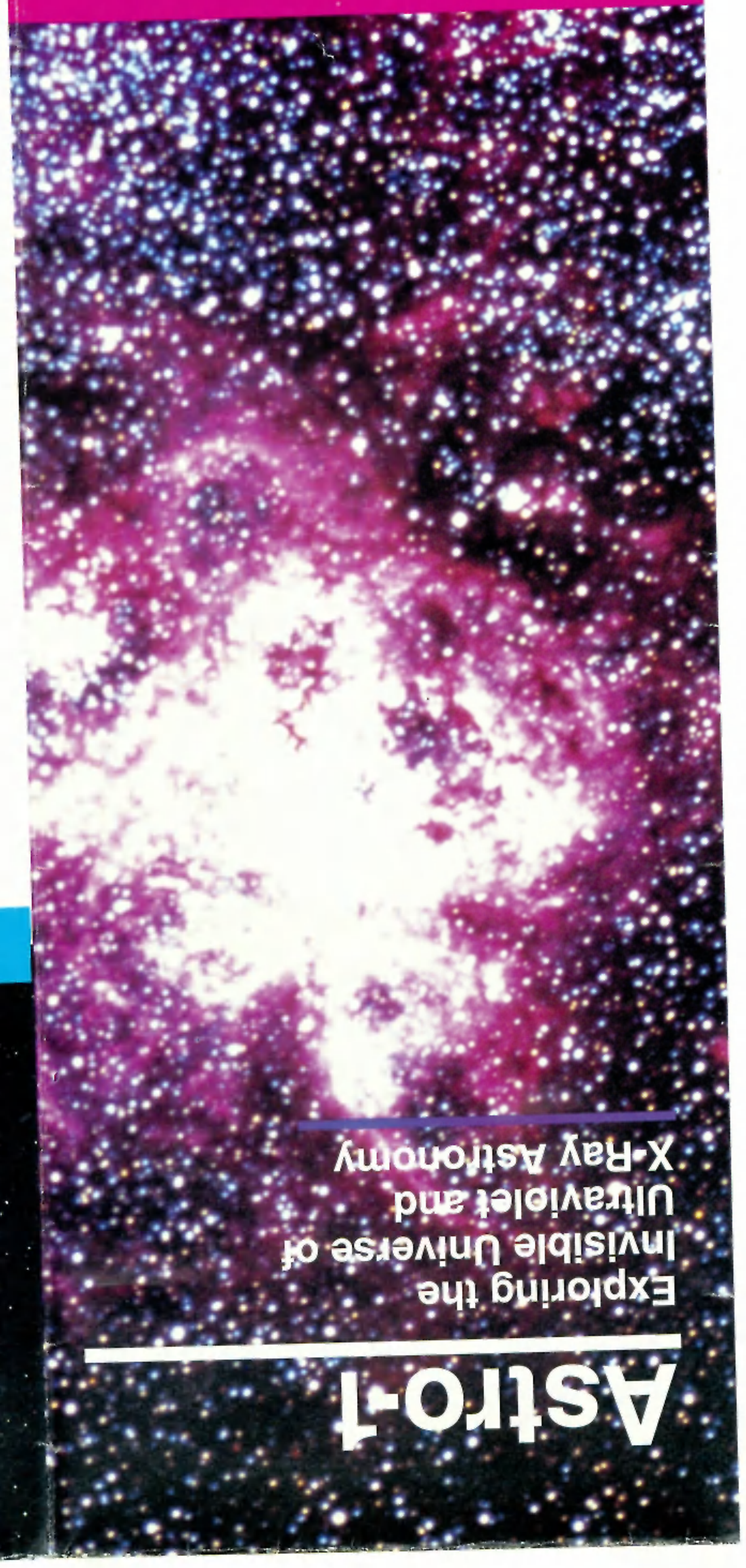
Astro-1

Exploring the Invisible Universe of Ultraviolet and X-Ray Astronomy



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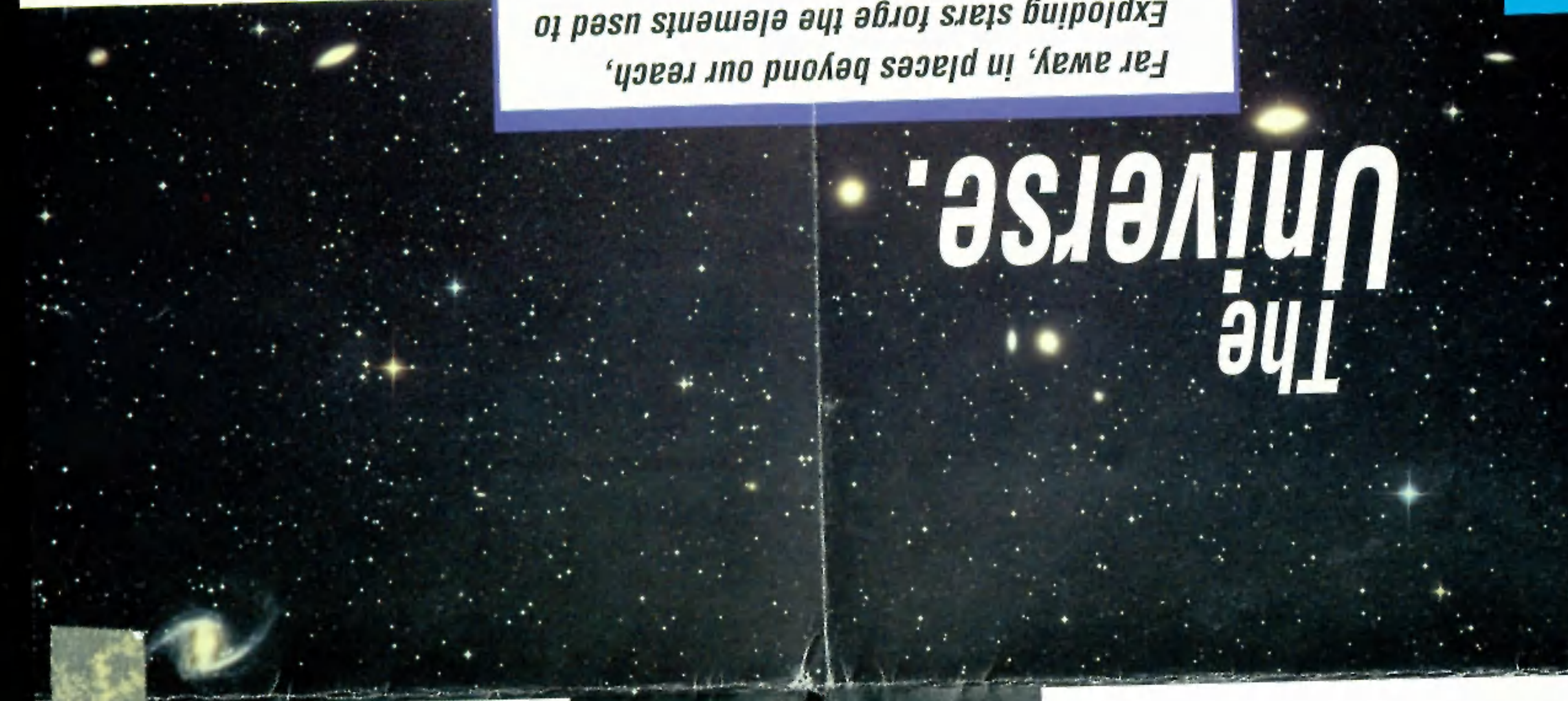


The Universe.

> *Far away, in places beyond our reach,*
> *Exploding stars forge the elements used to make new stars, planets, and even life,*
> *Stars are locked in intricate dances of mutual attraction,*
> *Tiny stars exist where a sugar cube of matter weighs as much as a billion tons,*
> *Active galaxies eject matter from their centers at incredible speeds,*
> *Mysterious objects shine with the brilliance of 10 trillion suns,*
> *Holes in the fabric of space consume matter and even light.*

We ponder these exotic locales and say, "impossible." Yet, such places do exist, and astronomers are showing them to us. The science of astronomy – the study of the heavens – is expanding our ideas about the Universe.

As part of our exploration of the Universe, the National Aeronautics and Space Administration (NASA) is launching an observatory called Astro-1. It will be carried on the Space Shuttle for a mission lasting 10 days. Astro-1 has four telescopes that will examine many bizarre cosmic objects as well as more commonplace stars like our Sun and galaxies like our Milky Way. Crew members who are astronomers will operate the telescopes in much the same way that they use huge telescopes on the ground. Astro-1 is scheduled to fly in 1990, with more flights planned during the next decade.

A Messenger Called Light

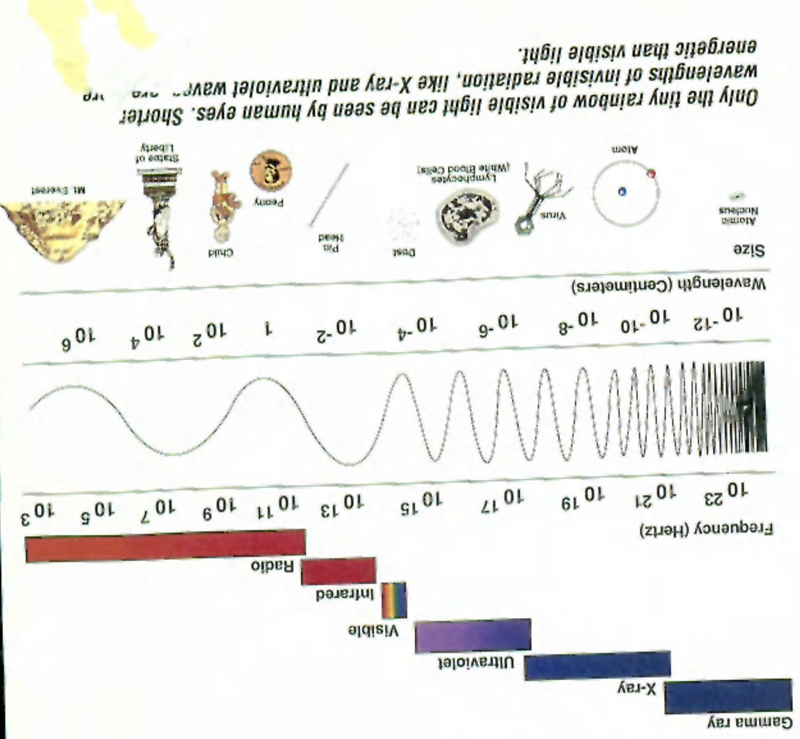
Why do astronomers study light from cosmic sources? Observatories like Astro-1 gather light from great distances to show us fascinating objects that reside in the far reaches of the Universe. It would be nice if we could visit stars and other celestial bodies to get a first-hand look, the way geologists examine rock formations on Earth. Unfortunately, all stars, except our Sun, are too far away to study in detail. Even if we could travel as fast as a speeding bullet, it would take a million years to reach even the nearest star beyond our solar system.

Although traveling to the stars is not yet possible, astronomers can study stars by their light emissions. For thousands of years, people used their sight to chart and catalogue the 6,000 or so stars visible to the naked eye. With the invention of the telescope, astronomers extended their vision over awesome distances. They learned that stars are as common as grains of sand and collections of hundreds of billions of stars, called galaxies, are as numerous as blades of grass.

We can learn even more about stars and galaxies by breaking their visible light into a rainbow of colors: violet, indigo, blue, green, yellow, orange, and red. What do these colors mean? If you look at a fire or candle flame, the hottest part is blue and the coolest part is red. Stars are the same way. Red stars are cooler than blue ones.

To take a star's temperature, instruments called spectrometers separate starlight into colors. Telescopes also see lines of color called spectra which are emitted when elements such as hydrogen and iron are heated. The patterns of these chemical signatures help us determine the makeup of stars.

ABOVE: Fornax cluster of galaxies (Royal Observatory)
COVER: Astro-1 will look at some of the most interesting objects in the Universe, such as Supernova 1987A, the first explosion of a star witnessed by the naked eye since the invention of the telescope. (European Southern Observatory Photograph)



Only the tiny rainbow of visible light can be seen by human eyes. Shorter wavelengths of invisible radiation, like X-ray and ultraviolet waves, are more energetic than visible light.

Beyond the Visible Rainbow

For thousands of years, visible light was our only source of information about the Universe. Now we know that stars and other objects radiate energy that we cannot see. The rainbow of visible light is only a tiny part of the radiation that makes up the entire electromagnetic spectrum which includes gamma ray, X-ray, ultraviolet, visible, infrared, and radio emissions.

Each type of radiation has its own amazing story to tell. Looking at the Universe in visible light is like only being able to read a few pages of a book. We do not get the whole story. To understand the Universe, we must analyze all parts of the electromagnetic spectrum.

All radiation is similar in nature: waves of energy rippling from a source. Traveling at the speed of light in packets of energy called photons, radiation vibrates in waves that span the electromagnetic spectrum. The size of the waves, the distance from crest to crest, is the wavelength. Radiation with longer wavelengths, like radio waves, is less energetic; shorter wavelengths, like X-rays, have more energy. Some of the most dynamic events in the Universe, such as exploding stars, produce most of their energy at shorter wavelengths. We can learn more about them by studying this high-energy radiation.

The Astro-1 Observatory is designed to help us analyze two of the most energetic parts of the spectrum: ultraviolet and X-ray waves. To most of us, ultraviolet rays are the ones that tan or burn our skin. To astronomers, ultraviolet radiation tells about hot, young stars that have just been born or hot, old stars near their deaths. Ultraviolet radiation carries the imprints of clouds of dust and gas: nebulae that are stellar nurseries and supernova remnants, debris left thousands of years after a star explodes.

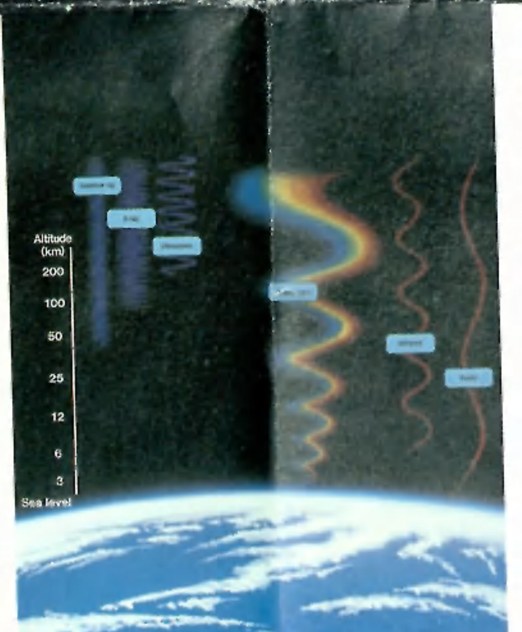
Even though we cannot see X-rays, we know that they can penetrate our skin and reveal the structure of our bones. To astronomers, X-rays come from gases superheated to temperatures over a million degrees. X-rays are produced by stellar blasts; heated matter lured into the inescapable gravity of a rapidly spinning star or black hole; and jets of gas spewing from galaxies and exotic objects.

Above the Atmospheric Veil

While astronomical objects emit a wide gamut of radiation, telescopes on Earth can only detect a small portion of it. Most radiation is blocked by the atmosphere. To detect ultraviolet and X-ray wavelengths, we must send electronic eyes to space on rockets, satellites, and other vehicles.

To see invisible radiation, other technical challenges also had to be met. Scientists and engineers had to design instruments to turn the invisible into images, spectra, and other data that they could see and comprehend.

The Astro-1 mission takes advantage of both these advances in modern astronomy. The Space Shuttle will carry Astro-1 into an orbit 354 kilometers (220 statute miles) above Earth so that the observatory can detect ultraviolet emissions and X-rays from the cosmos. Teams of scientists and engineers from NASA centers, universities, and private industry have used the latest technology to create an observatory with advanced mirrors and complex detectors – a complement of instruments capable of scrutinizing the invisible Universe.



Most radiation cannot penetrate Earth's atmosphere.

1. Hopkins Ultraviolet Telescope
2. Ultraviolet Imaging Telescope
3. Wisconsin Ultraviolet Photo-Polarimeter Experiment

Broad Band X-Ray Telescope

New Eyes on the Universe

The Astro-1 Observatory will turn four new eyes on the Universe: the Hopkins Ultraviolet Telescope, the Ultraviolet Imaging Telescope, the Wisconsin Ultraviolet Photo-Polarimeter Experiment, and the Broad Band X-Ray Telescope. By using more than one instrument, Astro-1 will gather different types of information at the same time on the same objects. It is the first observatory that can simultaneously take ultraviolet pictures of objects, study their ultraviolet and X-ray spectra, and determine their brightness and structure.

The Hopkins Ultraviolet Telescope, developed by The Johns Hopkins University in Baltimore, Maryland, will examine the most energetic ultraviolet wavelengths. Some of these wavelengths have never been studied in detail because, until recently, no instruments were capable of recording them. Many important elements, such as hydrogen, helium, and carbon, have unique emissions that appear in this range and no other. Astronomers can decipher these spectral fingerprints to determine what objects are made of, their temperature, and the physical processes producing radiation.

The Ultraviolet Imaging Telescope, developed by NASA's Goddard Space Flight Center in Greenbelt, Maryland, will take the best set of ultraviolet photographs ever made of the cosmos. A 30-minute exposure will reveal a blue star about 100 million times fainter than the faintest star visible to the naked eye on a dark, clear night. The telescope can see a wide area of the sky, capturing an entire galaxy that is nearby or clusters of distant galaxies on a single exposure. It will use different filters to separate specific ultraviolet wavelengths. This helps astronomers determine the brightness, location, temperature, and structure of sources.

The Wisconsin Ultraviolet Photo-Polarimeter Experiment, developed by the University of Wisconsin in Madison, Wisconsin, will give us clues about the shape and size of objects by studying the way their light is polarized. Usually waves of light move randomly, but polarized light waves vibrate in the same direction. Light that is scattered, like sunlight reflecting off water, is often polarized. Astro-1 astronomers expect to learn about ultraviolet light that is scattered by dust strewn among stars and galaxies. They can also learn about the geometry of stars by studying how starlight is polarized. In addition, the telescope will measure the brightness of sources and study their chemical makeup.

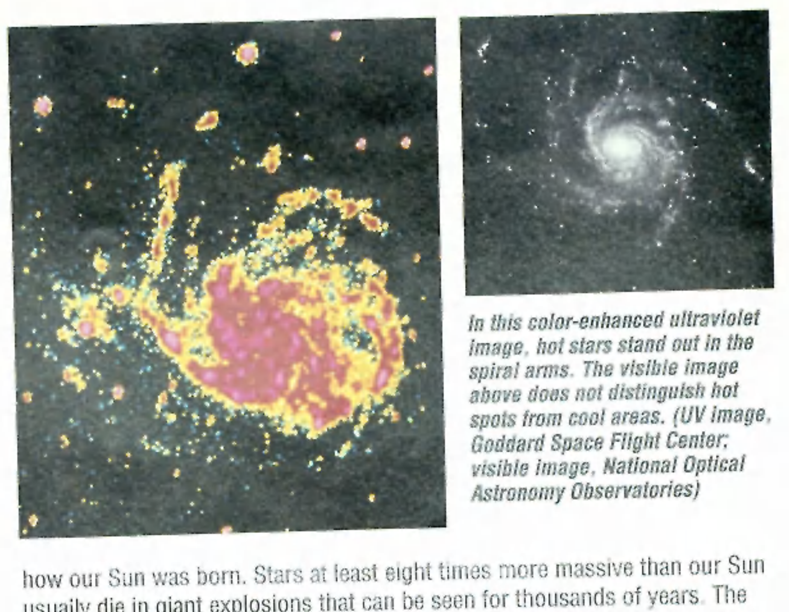
The Broad Band X-Ray Telescope, developed by NASA's Goddard Space Flight Center, will record high-energy spectra of many X-ray sources discovered by earlier satellites. The telescope will give us information on the chemistry, temperature, and structure of some of the most unusual and interesting objects in the Universe. It can see fainter and more energetic objects than any yet studied. It will look for signs of heavy elements such as iron, oxygen, silicon, and calcium. These elements are usually formed in exploding stars and during mysterious events occurring at the core of galaxies and other exotic objects.

Cosmic Questions

The Astro-1 Observatory will help us answer questions about the way the Universe works.

How do stars live and die?

Astro-1 will chronicle the lives of stars. Just as anthropologists study all ages and types of people to learn about ancient civilizations, astronomers need to study all kinds of stars. They can examine old stars to learn the fate of our Sun and younger ones to learn how our Sun was born. Stars at least eight times more massive than our Sun usually die in giant explosions that can be seen for thousands of years. The resulting stellar corpses sometimes become bizarre objects such as neutron stars – so dense that a teaspoon of their material weighs a billion tons – and black holes with gravity so powerful that neither matter nor even light can escape. These objects are the sites of high-energy processes that release X-ray and ultraviolet waves which Astro-1 will record.



In this color-enhanced ultraviolet image, hot stars stand out in the spiral arms. The visible image above does not distinguish hot spots from cool areas. (UV image, Goddard Space Flight Center; visible image, National Optical Astronomy Observatories)

How do stars interact?

Most stars are found in pairs or groups. Stellar marriages can be very interesting. Many combinations are possible. For example, a red giant may be paired with a small dense object such as a black hole or neutron star. In this case, astronomers believe, the intense gravity of the small object captures material from the red giant. As the gas from the giant is drawn in, it is heated to extreme temperatures and produces X-rays and ultraviolet light. By studying these emissions, Astro-1 can record how stars interact and may discover unique objects such as black holes or neutron stars. Some stars are part of large globular clusters with millions of members. These clusters are ideal for examining how different stars that formed from the same material at the same time have evolved.

How have galaxies changed with time?

Galaxies come in different shapes and sizes: pinwheels like our Milky Way, egg (elliptical) shapes, and irregular shapes with no preferred form. Astro-1 will survey different types of galaxies and study their evolution. Since light travels at a fixed speed, as astronomers look farther away, they will be looking back in time. Nearby galaxies will appear as they were millions of years ago, while the most distant ones will look as they did billions of years ago. By comparing young and old galaxies, astronomers can trace the history of the Universe.

Where are the hottest, most active parts of galaxies?

X-ray and ultraviolet emissions will reveal the hottest, most active regions of galaxies. The hottest place in most galaxies appears to be the center. Astro-1 will help astronomers find out why. Are these central regions powered by black holes or huge populations of exploding stars? Active galaxies have particularly violent nuclei, spewing energy from their centers at incredible speeds. Astro-1 will help determine the source of these ejections.

What are quasars?

Astro-1 will detect quasars: very distant, compact objects that radiate more energy than 100 normal galaxies. Some astronomers think that quasars are the centers of ancient active galaxies. X-ray and ultraviolet radiation from the central cores of these powerful objects may help explain what they really are.

Astro-1 Observatory

The Astro-1 Observatory is more than just a group of telescopes launched into space. It includes the crew, investigators, and ground support personnel. Teams of investigators have spent many years developing the telescopes and planning observations. Once the instruments are built, they are delivered to the Kennedy Space Center in Florida, where they are assembled to form an observatory, tested, placed in the Shuttle payload bay, and launched into space. Once the Shuttle reaches orbit, the payload bay doors will be opened and the instruments turned on. A seven-member crew will work around the clock in 12-hour shifts to accomplish the Astro-1 science goals.

The flight crew – a commander, a pilot, and a mission specialist – are responsible for pointing the Astro-1 Observatory toward an object. They will maneuver the Space Shuttle in the general direction of the object to be observed. Two other mission specialists (NASA astronauts who are trained astronomers) and two payload specialists (astronomers who helped develop the instruments) operate the three ultraviolet telescopes and their pointing system. They will aim the pointing system toward the target and prepare each telescope to gather data by selecting filters, spectrograph settings, and exposures and making sure targets are in each instrument's view. The X-ray telescope, which has its own pointing system, will be operated from the ground by Goddard Space Flight Center personnel. They will send commands to the telescope via computer. When the astronauts position the Shuttle in the direction of a target, engineers and scientists at Goddard will point the X-ray telescope toward an object and begin collecting data. All the telescopes will observe targets from about 10 minutes to a little more than an hour.

The Astro-1 mission could not fly without help from people on the ground. Teams of scientists and engineers will support the mission from the Payload Operations Control Centers at Marshall Space Flight Center in Huntsville, Alabama, and at Goddard Space Flight Center in Greenbelt, Maryland.

Marshall Space Flight Center Payload Operations Control Center

The Marshall Space Flight Center is responsible for the Astro-1 mission. They have spent years planning to ensure mission success. During the mission, they will talk with the crew and Goddard personnel to help with observations, replan observations if necessary, and monitor the health of the telescopes, the pointing systems, the computers, and other subsystems. The scientists who developed the Astro-1 telescopes are part of this team and will participate in making science decisions and analyzing data from the instruments. The Marshall mission team will work closely with the Johnson Space Center which is responsible for Shuttle operations.

After 10 days in space, Columbia is scheduled to land at Edwards Air Force Base in California. Scientists will analyze data and begin formulating questions to be answered during the next Astro mission. The primary purpose of the Astro-1 Observatory is to explore the invisible Universe. We will soon discover what surprises await us there.

Astro-1 Crew

Commander	Vance D. Brand
Pilot	Guy S. Gardner
Mission Specialists	Jeffrey A. Hoffman
	John M. (Mike) Lounge
	Robert A. R. Parker
Payload Specialists	Samuel T. Durrance
	Ronald A. [illegible]
Alternate Payload Specialist	Kenneth H. [illegible]