NASA Facts

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Hubble Space Telescope Yields Unprecedented Scientific Accomplishments In the First Decade of Observations

Hubble orbits the Earth at an altitude of approximately 370 miles. It takes 97 minutes for the telescope to complete one orbit around the Earth. Hubble is in a 28.5 degree inclination and passes into the shadow of the Earth for 28 to 36 minutes in each orbit. Hubble is high enough above the Earth's atmosphere to conduct science operations without encountering the negative effects of the atmosphere.

The Hubble Space Telescope (HST) provides a detailed view of the unimagined complexity and diversity of the universe, as well as its startling beauty. It has yielded numerous surprises and raised new questions. The unique power of the HST derives from its combination of extremely sharp images covering relatively wide fields of view in the sky with the ability to record very faint and very bright objects together in one image, the freedom from atmospheric distortions, and the sensitivity to different types of light from ultraviolet to near-infrared.

However, the HST does not work in isolation. It is the flagship of a growing fleet of modern astronomical telescopes. Most of the HST’s accomplishments build upon the work of ground-based astronomers over many decades, or even centuries. Perhaps the HST’s greatest achievement is the facility with which it has converted so many prior hypotheses, for which supporting empirical data were scant, ambiguous and painfully difficult to obtain, into clearly and decisively demonstrated truth.

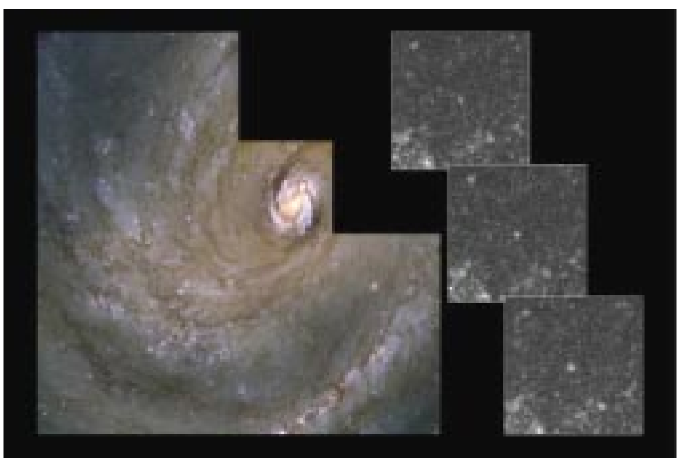
With each new instrument inserted by the astronauts on servicing missions, the HST grows in capability by factors of 10. It can reasonably be anticipated that the HST’s second decade will be its best decade.

Imaging the Distant Universe

Looking into the distant universe also means seeing into the past because of the limited speed of light — light from remote objects takes longer to reach the Earth than light from nearby ones. The HST provided the first deep, clear view of the distant universe. This view shows that remote galaxies, believed to be the building blocks of present-day galaxies, are very different from our galaxy and others nearby.

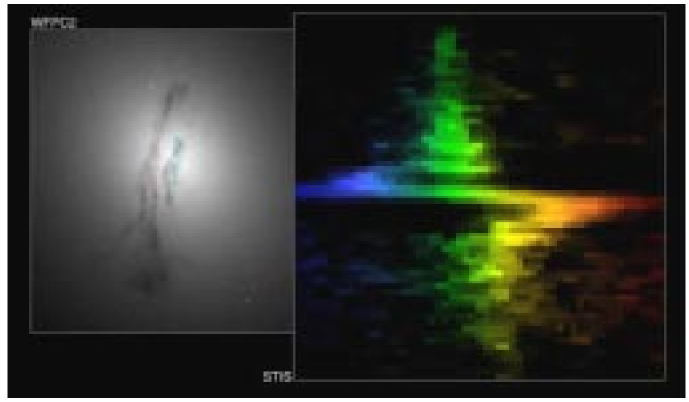
Precise Calibration of the Distance Scale

The universe is so vast that it is difficult to measure exactly how big it really is. To measure cosmic distances, astronomers need a type of star that serves as a "standard candle," a star whose true brightness is known, so our distance from it can be calculated by how bright it appears in the sky. The HST was the first telescope capable of resolving the "standard candle" Cepheid variable stars and using them to obtain very accurate distances to a large number of moderately distant galaxies. These distances were used in turn to recalibrate a number of other standard distance indicators which were applied in extending distance measurements to galaxies much further away.



Showcased above is a rare class of pulsating stars called Cepheid Variables. Cepheids are used to determine the distances of galaxies from Earth which ultimately helps astronomers determine the age and size of the universe.

The result is a much more accurate measure of the rate at which the universe is expanding (the Hubble Constant) and a determination that the universe is younger than many astronomers had believed it to be; 12-14 billion years have elapsed since the Big Bang.



The zigzag on the right is the signature of a supermassive black hole in the center of galaxy M84. The image on the left shows the galaxy's core in visible light.

Measuring the Cosmological Constant

The observation that distant galaxies are receding from ours leads astronomers to believe that the universe began in a primordial explosion called the Big Bang and has been expanding ever since.

Although uncertain if the expansion of the universe would eventually cease, astronomers believed it would gradually slow over time, because the gravitational attraction of all the matter in the universe would act as a cosmic brake. In partnership with ground-based telescopes, HST observed the brightnesses of many exploding stars (supernovae) in distant galaxies in order to measure their distances. The HST's major contribution was the accurate measurement of the brightnesses of the most distant supernovae in this sample.

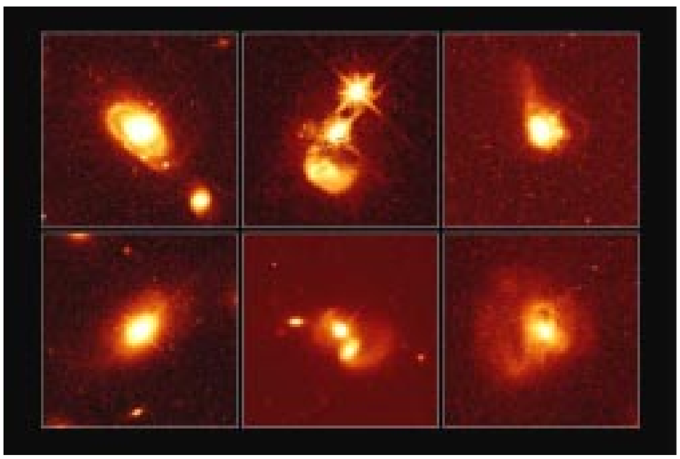
The result was remarkable, providing the first tentative clue that the expansion of the universe is accelerating – driven by an unknown repulsive "force" strong enough to overcome gravity. Einstein anticipated this possibility by adding a "cosmological constant" to his equations of general relativity.

Detection and Measurement of Supermassive Black Holes

A black hole is an object with gravity so strong that near it, nothing, not even light, can escape. Black holes come in different sizes, and

HST provided evidence for supermassive black holes that are millions to billions of times as massive as the Sun.

The HST was the first optical telescope capable of probing sufficiently close to the center of a galaxy to measure the velocity of stars and gas in orbit around an unseen central mass concentration suspected of being a supermassive black hole. HST also was first to measure accurately by direct imaging the size of the central cusp of starlight. These observations provided the first convincing proof for the existence of a central black hole several billion times the mass of the Sun.



These Hubble images show where quasars can be found in the galaxy.

The Nature of Quasars

Quasars (quasi-stellar radio sources) are the most distant and energetic objects known. Before HST, astronomers using ground-based telescopes had suggested a possible relationship between the quasars and another puzzling phenomenon – the highly active and energetic central region (nuclei) of certain galaxies at more moderate distances, the Active Galactic Nuclei (AGN). The detection of a very faint “fuzz” around some quasars seen with ground-based telescopes supported the hypothesis that they might be very distant AGN’s in the early universe, undergoing especially intense outbursts of activity. The HST has completely verified this idea. The telescope’s resolution and ability to view very faint and very bright objects in one image clearly reveals a variety of underlying host galaxies of quasars.

The Origin of Gamma Ray Bursts

Gamma ray bursts are now known to be the most powerful explosions in the universe, equal in fury to a hundred exploding stars, but for decades scientists did not even know where in the cosmos they came from, and speculation about their cause continues to this day.

The joint Italian-Dutch satellite Beppo-Sax was designed to spot gamma ray bursts very quickly and to locate their positions accurately. This permitted other telescopes, sensitive to the different kinds of light emitted by the gamma-ray burst fireball as it expands and cools, to be trained on the fireballs while they were still bright.

Using this information, astronomers trained the HST on the visible-light counterparts of multiple gamma ray bursts. The HST’s resolution and sensitivity gave it the unique ability to show that the sources of the gamma ray bursts were embedded in faint, remote galaxies at random distances from their galactic centers. By following the brightness changes in the sources to very faint levels, the HST provided important constraints on theories of the stellar “catastrophes” that produce these extraordinarily intense and rapid outbursts of energy.

The Birth of Stars

The HST’s resolution and sensitivity to both visible and infrared light have given it unprecedented, clear views of the rich, diverse, and complex processes that lead to star formation. For the first time, astronomers have directly observed the infalling gas and dust, disks and jets associated with the birth of stars like our own Sun.

The Formation of Planetary Systems

HST observations of gas and dust disks surrounding young stars has opened a new area of observational astronomy – the empirical study of the structure and evolution of proto-planetary systems. For centuries it has been believed that such a disk must have been the precursor to our own solar system, providing the raw material from which the planets were constructed. HST has shown that these disks are common and

In this Hubble image, two galaxies have collided and triggered a firestorm of star-birth activity.

they contain enough material to form entire planetary systems equivalent to our solar system. HST has revealed, for the first time, the internal structures of protoplanetary disks and of the debris left behind by prior planet formation.

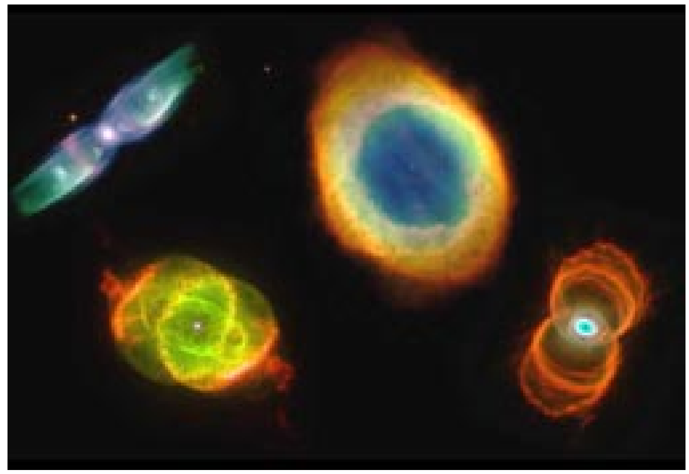
The Death of Stars

Dying stars shed material into interstellar space, sometimes gently and episodically, sometimes in explosive catastrophes. In either case the ejected material is enriched in chemical elements produced in the interior nuclear furnaces of these stars and thus “seeds” the interstellar gas and dust with the basic building blocks from which new stars, planets and life may originate.

The HST has provided exquisite images of dying stars. These are the basis for a remarkably detailed understanding of the events preceding the deaths of stars, how material is shed from dying stars, how that material interacts with the environment around the star, and how the process is influenced by each star’s individual circumstances.

Our Dynamic Solar System

HST has provided astronomers with a virtual planetary probe capable of instantly “visiting” any planet in the solar system without leaving Earth’s orbit. Its spectacular pictures include the first resolved images of Pluto and its satellite Charon, enabling measurement of their masses and crude mapping of their surfaces, massive storms on Uranus and Neptune, northern and southern lights on Jupiter, Saturn and Ganymede, the constantly changing rings of Saturn, and the explosive impact of comet fragments into Jupiter.



At one time, the end of a Sun-like star was thought to be simple. The star cast off a shell of gas and then settled into a long retirement as a burned-out white dwarf. This collection of images reveals a far more complicated situation as evidenced by the elegant and intricate shapes and patterns of these dying stars.

Related Web Sites

More Information about HST:
http://www.gsfc.nasa.gov/gsfc/spacesci/hst10/hst_main.htm

http://hubble.stsci.edu/go/tenth

http://oposite.stsci.edu/pubinfo/

HST’s Greatest Hits Picture Gallery 1990-1998:
http://oposite.stsci.edu/pubinfo/pr/1998/18/greatest-hits-gallery.html

More HST Pictures:
http://oposite.stsci.edu/pubinfo/pictures.html

HST Movies and Animations:
http://oposite.stsci.edu/pubinfo/Anim.html