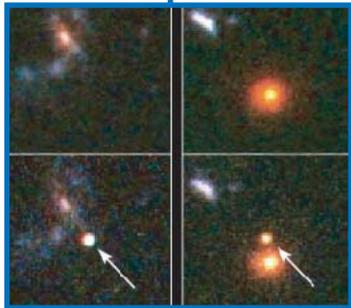


HUBBLE SPACE TELESCOPE'S TOP TEN GREATEST ACHIEVEMENTS



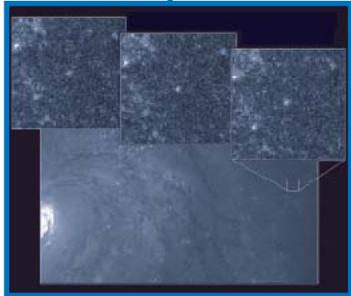
WHEN GALILEO used his homemade telescope 400 years ago to view mountains on the Moon, satellites circling Jupiter, and a myriad of stars in our Milky Way Galaxy, he launched a revolution that changed our view of an Earth-centered universe. The launch of NASA's Hubble Space Telescope aboard the space shuttle Discovery 15 years ago initiated another revolution in astronomy. For the first time, a large telescope that sees in visible light began orbiting above Earth's distorting atmosphere, which blurs starlight and makes images appear fuzzy. Astronomers anticipated great discoveries from Hubble. The telescope has delivered as promised and continues serving up new discoveries. Astronomers and astrophysicists using Hubble data have published more than 4,000 scientific papers, on topics from the solar system to the very distant universe. The following list highlights some of Hubble's greatest achievements.



Distant supernovas. NASA and A. Riess (STScI).
STScI-2004-12

1 The Universe Is Caught Speeding

Hubble played a key role in discovering that a mysterious form of energy called dark energy is acting like a cosmic gas pedal, accelerating the universe's expansion rate. Dark energy shoves galaxies away from each other at ever-increasing speeds and works in opposition to gravity. Hubble observations of distant exploding stars called supernovas placed the most significant constraints to date on the nature of dark energy, revealing that it does appear to be a constant presence as first anticipated early last century by scientist Albert Einstein. Astronomers understand almost nothing about dark energy, even though it appears to comprise about 70 percent of the universe.



Cepheid variable in Galaxy M100.

NASA, STScI, and an international team of astronomers.
STScI-1994-49

2 Tell Us Your Age

Some people hate to reveal their age, and the universe, it seems, is no different. Before Hubble was launched, astronomers had been trying for several years to pin down the universe's age. They came up with a wide age range, 10 to 20 billion years. One of Hubble's key duties was to help astronomers determine a precise age for the universe. The telescope helped astronomers accomplish that goal, narrowing the universe's age to 13 to 14 billion years old, an accuracy of about 10 percent. Astronomers made observations of Cepheid variable stars — pulsating stars used to measure vast distances — in the Virgo and other clusters to establish the expansion rate and the universe's age.



Detail of the Hubble Ultra Deep Field.

NASA, ESA, S. Beckwith (STScI), and the HUDF Team.
STScI-2004-07

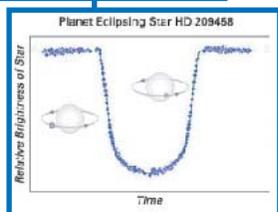
3 Postcards from the Edge of Space

Hubble provided astronomers with a “scrapbook” full of snapshots of the early universe. The scrapbook photographs revealed “toddler” galaxies that existed billions of years ago when the universe was young. The telescope snapped the pictures of the “deep” universe in a series of unique observations: the Hubble Deep Fields, the Great Observatories Origins Deep Survey, and the Hubble Ultra Deep Field. The observations provided the deepest views of the cosmos in visible, ultraviolet, and near-infrared light. In the most recent foray into the farthest regions of the universe, Hubble uncovered 10,000 galaxies, some of which existed 400 to 800 million years after the Big Bang. Unlike our Milky Way Galaxy, the galaxies spied in the Hubble observations take many other shapes. Some are shaped like toothpicks, others like links on a bracelet. Through these observations, astronomers can follow the evolution of the star-formation rate and witness how galaxies form. By studying galaxies at different eras, astronomers can see how galaxies change over time.



4 Worlds Beyond Our Sun

Astronomers using ground-based telescopes to hunt for planets outside our solar system, dubbed extrasolar planets, have nabbed more than 100 alien worlds. But they needed the keen “eye” of Hubble to make the first direct measurement of the chemical makeup of an extrasolar planet's atmosphere. The telescope detected the elements sodium, hydrogen, carbon, and oxygen in the atmosphere of a Jupiter-sized planet. The unique observation demonstrates that Hubble and other telescopes can sample the chemical makeup of the atmospheres of alien worlds. Astronomers could use the same technique someday to determine whether life exists on extrasolar planets. Besides testing the atmosphere of an extrasolar planet, Hubble also made precise measurements of the masses of two distant worlds. Astronomers believe that one of those worlds is the oldest known planet. The planet, whose estimated age is 13 billion years, is more than twice as old as 4.5-billion-year-old Earth.



Artist's concept of an extrasolar planet

orbiting star HD 209458 [top].

NASA, ESA, and G. Bacon (STScI).

STScI-2001-38

Light curve of planet eclipsing the star [bottom].

NASA, T. Brown (NCAR) and R. Gilliland (STScI).

STScI-2000-33d

5 Monster Black Holes Are Everywhere

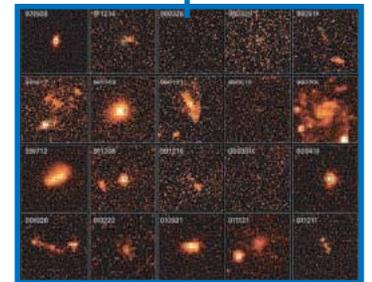
The hubs of most galaxies have a mammoth resident that loves to gobble up anything that wanders near it. This sleeping monster, Hubble observations confirmed, is a black hole with a mass millions to billions times that of our Sun. Not only are black holes everywhere, but they also have an intimate relationship with their host galaxies. Hubble observations revealed that a tight relationship exists between the masses of the central black holes and those of the galactic bulges of old stars, gas, and dust that surround them. Monstrous galaxies, for example, have titanic black holes. This close relationship may be evidence that black holes grew with their galaxies, feasting on a measured diet of gas and stars swirling around the hearts of those galaxies.



Visible-light image of giant elliptical galaxy M87.
NASA and John Biretta (STScI/JHU).
STScI-1999-43

6 The Biggest “Bangs” Since the Big Bang

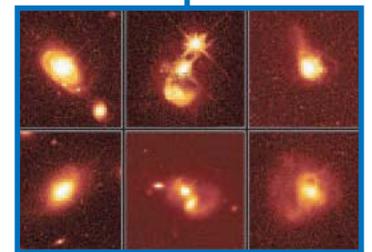
Imagine a powerful burst of light and other radiation that can burn away the ozone in Earth’s atmosphere. Luckily, bursts of light that strong occur so far away they will not scorch our planet. These bursts of light are called gamma-ray bursts. They may represent the most powerful explosions in the universe since the Big Bang, the explosive birth of our universe. Hubble images showed that these brief flashes of radiation come from far-flung galaxies that are forming stars at enormously high rates. By pinpointing the host galaxies, Hubble also identified the sources of the “bursts”: the collapse of massive stars.



Fading optical afterglow of gamma-ray bursts.
NASA and A. Fruchter (STScI).
STScI-1999-09

7 Quasars, the Light Fantastic

Quasars have been so elusive and mysterious that the hunt to define them would have taxed even the superior analytical skills of detective Sherlock Holmes. Since their discovery in 1963, astronomers have been trying to crack the mystery of how these compact dynamos of light and other radiation, which lie at the outer reaches of the universe, produce so much energy. Quasars are no larger than our solar system but outshine galaxies of hundreds of billions of stars. These light beacons have left trails of evidence and plenty of clues, but scientists have only just begun to understand their behavior. Astronomers using Hubble tracked down the “homes” of quasars, proving that these dynamos reside in the centers of galaxies.



Quasar host galaxies.
John Bahcall (Institute for Advanced Study, Princeton),
Mike Disney (University of Wales), and NASA.
STScI-PRC 1996-35a

8 Planet Construction Zones

Peering into the gaseous clouds in the Milky Way Galaxy where stars are born, Hubble discovered that many young stars are surrounded by flattened disks of gas and dust. These disks, now known as “proplyds” (short for protoplanetary disks), are the likely birthplaces of new planetary systems. Hubble provided visual proof that pancake-shaped dust disks around young stars are common, suggesting that the building blocks for planet formation are in place.



Orion Nebula Mosaic.
NASA, C.R. O'Dell and S.K. Wong (Rice University).
STScI-1995-45
Inset: Detail of Orion showing proplyds.
NASA and C.R. O'Dell (Rice University).
STScI-1994-24



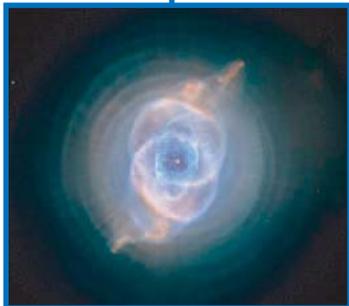
Effects of Comet Shoemaker-Levy 9's impact with Jupiter.

NASA and the Hubble Space Telescope Comet Team.
STScI-1994-34

9

A Shattered Comet Rocks Jupiter

Imagine setting off every atomic bomb on Earth all at once. Now imagine repeating such an apocalyptic explosion two dozen times in a week! Unleashing such energy would destroy Earth's surface, but the giant planet Jupiter hardly flinched when it underwent such a catastrophe in 1994. Hubble provided a ringside seat to a once-in-a-millennium event when nearly two dozen chunks of a comet smashed into Jupiter. Hubble provided dramatic images of massive explosions that sent towering mushroom-shaped fireballs of hot gas into the Jovian sky. The doomed comet, called Shoemaker-Levy 9, had been pulled apart two years earlier by Jupiter's gravity. Each impact left temporary black sooty scars in Jupiter's planetary clouds.



The Cat's Eye Nebula [top].

NASA, ESA, HEIC, and
The Hubble Heritage Team (STScI/AURA).
STScI-2004-27

Supernova1987A [bottom].

NASA, P. Challis, R. Kirshner (Harvard-Smithsonian
Center for Astrophysics), and B. Sugerman (STScI).
STScI-2004-09

10

Going Out in a Blaze of Glory

A Sun-like star's death is as colorful as maple leaves in autumn. Sun-like stars die gracefully by ejecting their outer gaseous layers into space. Eventually, the outer layers begin to glow in vibrant colors of red, blue, and green. The colorful glowing shroud is called a planetary nebula. Hubble revealed unprecedented details of this process. Ground-based images suggested that many of these objects had simple shapes, but Hubble showed that their shapes are more complex. Hubble's keen "eye" disclosed that planetary nebulas are like snowflakes: no two are alike. Turning its vision to the tattered remains of a massive star that exploded as a supernova in 1987, Hubble found three mysterious rings of material encircling the doomed star. During the years since the eruption, Hubble spied brightened spots on the middle ring caused by material ejected from the explosion slamming into it.

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