CXC First Light Press Kit ① ② ③

CHANDRA X-RAY OBSERVATORY

The Chandra X-ray Observatory is the third in NASA's family of Great Observatories that includes the Hubble Space Telescope and the Compton Gamma Ray Observatory. NASA's Marshall Space Flight Center manages the Chandra program. TRW is the prime contractor for the spacecraft. Key subcontractors include Ball Aerospace & Technologies, Inc., Eastman Kodak Company, and Raytheon Optical Systems, Inc. The scientific instruments were built by teams from MIT, Pennsylvania State University, the Smithsonian Astrophysical Observatory, the Laboratory for Space Research in the Netherlands, and the Max Planck Institute in Germany. The Smithsonian's Chandra X-ray Center controls science and flight operations from Cambridge, MA.

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The Chandra X-ray Observatory & First Light

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Fact Sheet

CASSIOPEIA A

Cassiopeia A (Cas A) is the remnant of a massive star that exploded about 300 years ago. The X-ray image shows an expanding shell of hot gas produced by the explosion. This gaseous shell is about 10 light years in diameter, and has a temperature of about 50 million degrees.

The material from the explosion is rushing outward at supersonic speeds in excess of ten million miles per hour. As this matter crashes into gas that surrounds the former star, shock waves analogous to awesome sonic booms heat the gas and heat the ejected matter.

The Cas A Supernova

A supernova occurs when a massive star has used up its nuclear fuel and the pressure drops in the central core of the star. The matter in the core is crushed by gravity to higher and higher densities, and temperatures reach billions of degrees. Under these extreme conditions, nuclear reactions occur violently and catastrophically reversing the collapse. A thermonuclear shock wave races through the now expanding stellar debris, fusing lighter elements into heavier ones and producing a brilliant visual outburst.

About every fifty years in our galaxy, a massive star explodes. The shell of matter thrown off by the supernova creates a bubble of multi-million degree gas called a supernova remnant. Cas A is a prime example. The hot gas will expand and produce X-rays for thousands of years.

The nature of the explosion that produced Cas A has been an enigma. Although radio, optical and x-ray observations of the remnant indicate that it was a powerful event, the visual brightness of the outburst was much less than a normal supernova. Apparently Cas A was produced by the explosion of an unusual massive star that had previously ejected most of its outer layers.

Probing Cas A Mysteries with NASA's Chandra X-ray Observatory

Chandra's spectacularly vivid images of Cas A allow scientists to trace the dynamics of the remnant and its collision with any material ejected by the star before it exploded. Chandra detectors provide scientists with precise x-ray spectra– measurements of the energies of individual x-rays–from the Cas A remnant. These measurements make it possible to identify which heavy elements are present and in what quantities. Chandra's observations should help astronomers to resolve the long-standing mystery as to the nature and origin of Cas A.

A related mystery is whether the explosion that produced Cas A left behind a neutron star, black hole, or nothing at all. This "First Light" Chandra image of Cas A shows a bright object near the center of the remnant! Longer observations with Chandra can determine if this is the long sought for neutron star or black hole.

Importance of Supernovae

The study of remnants of exploded stars, or supernovae, is essential for our understanding of the origin of life on Earth. The cloud of gas and dust that collapsed to form the sun, Earth and other planets was composed mostly of hydrogen and helium, with a small amount of heavier elements such as carbon, nitrogen, oxygen and iron. The only place where these and other heavy elements necessary for life are made, is deep in the interior of a massive star. There they remain until a catastrophic explosion spreads them throughout space.

Supernovae are the creative flashes that renew the galaxy. They seed the interstellar gas with heavy elements, heat it with the energy of their radiation, stir it up with the force of their blast waves and cause new stars to form.

Fact Sheet

PKS 0637-752

PKS 0637-72 is so distant that we see it as it was 6 billion years ago. It is a luminous quasar that radiates with the power of 10 trillion suns from a region smaller than our solar system. The source of this prodigious energy is believed to be a supermassive black hole.

Radio observations of PKS 0637-752 show that it has an extended radio jet that stretches across several hundred thousand light years. Chandra's x-ray image reveals a powerful x-ray jet of similar size that is probably due to a beam of extremely high-energy particles.

Quasars

Quasars are distant, energetic objects. They are compact intense sources of X-rays as well as visible light, and can be brighter than hundreds of galaxies put together.

Through an optical telescope quasars look star-like. It wasn't until the 1950's, when radio astronomy was first developed, that astronomers realized these were extra-galactic objects that were emitting enormous amounts of radio energy. This important discovery caused them to be named quasars, short for "Quasi-stellar radio sources". Since then, many quasars have been discovered that produce little or no radio emission. They are sometimes called quasi-stellar objects or QSO's, but the name quasars is generally used to describe both types of objects.

The power of a quasar depends on the mass of its central black hole and the rate at which it swallows or accretes matter. Almost all galaxies, including our own, are thought to contain a supermassive black hole in their centers. Quasars represent the extreme cases where the rate of accretion is so high that the energy output due to the infalling matter is a thousand times greater than the galaxy itself.

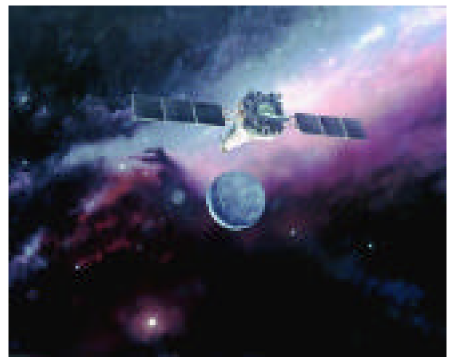
One of the most intriguing features of supermassive black holes is that they do not suck up all the matter that falls within their sphere of influence. Most of the matter falls inexorably toward the black hole, but some explodes away from the black hole in high energy jets that move at near the speed of light. Radio observations have revealed that these jets are a common feature of quasars.

NASA's Chandra X-ray Observatory Reveals Powerful X-ray Jet in PKS 0637-752

The x-ray jet observed for the first time by Chandra in PKS 0637-752, is a dramatic example of a cosmic jet. It has blasted outward from the quasar into intergalactic space for a distance of at least 200,000 light years! The jet's presence means that electromagnetic forces are continually accelerating electrons to extremely high energies over enormous distances. Chandra observations, combined with radio observations, should provide insight into this important cosmic energy conversion process.

Fact Sheet

THE CHANDRA X-RAY OBSERVATORY CENTER



The Chandra X-Ray Observatory, launched on July 23, 1999, has taken its place with the Hubble Space Telescope and Compton Gamma Ray Observatory in NASA's fleet of GreatObservatories. As the world's premier X-ray observatory, Chandra gives astronomers a powerful new tool to investigate the hot regions of the universe where black holes, exploding stars, and colliding galaxies hold sway.

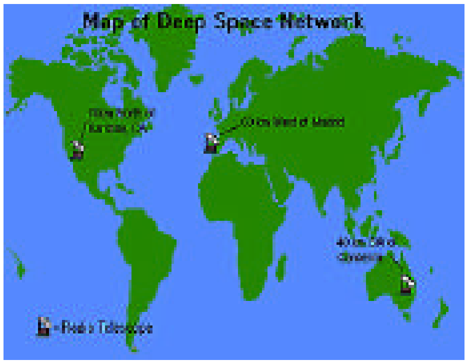
The Chandra X-Ray Observatory Center

The Chandra program, managed by NASA's Marshall Space Flight Center in Huntsville, Alabama, is an example of NASA's initiative to streamline the operations of its space science missions. The Smithsonian Astrophysical Observatory's Chandra X-Ray Center (CXC), under the direction of Dr.Harvey Tananbaum, is located at the Harvard-Smithsonian Center for Astrophysics in Cambridge Massachusetts. The CXC is responsible for planning the science observations based on proposals from the scientific community, processing data received from the observatory, and providing technical and scientific support to the scientists who use Chandra. The Center operates the observatory from its Operations & Control facility located at One Hampshire Street in Cambridge, Massachusetts.

Chandra Operations Control Center

The CXC is a collaboration of personnel from the Smithsonian Astrophysical Observatory, the Massachusetts Institute of Technology (MIT), and the Chandra prime contractor, TRW.

The Operations & Control Center (OCC) is staffed by the CXC, with the Flight Operations Team provided by TRW. The OCC has a glass-walled area outside the main control room where visitors and press can watch the Flight Operations Team and mission specialists as they communicate with the observatory and carry out the space flight operations.



Commands for executing the observation plan are transmitted from the OCC to one of three ground stations (in Spain, Australia, or California) that make up NASA's Deep Space Network (DSN). The DSN relays the commands to the orbiting spacecraft. The spacecraft carries out the commands and points the telescope to the specified targets, and moves the science instruments to their appropriate positions.

During routine operations, science data and monitoring data will be sent from the spacecraft to the OCC, via the DSN, approximately every eight hours. Scientists and engineers will use monitoring data to assess Chandra's condition. If the health or safety of the observatory appears to be in danger, the operating mode and the observation plans will be modified.

Data from Chandra observations are processed at the Chandra Center. Observatory calibration data will be made public as soon as possible. The scientific data belonging to guest observers and guaranteed time observers can be held by them for one year to allow time for analysis and publication of scientific results. The data are then placed in the public archive.

Marshall Space Flight Center Fact Sheet

Exploring The Invisible Universe: The Chandra X-ray Observatory

To the human eye, space appears serene and void. It is neither.

To the "eye" of an X-ray telescope, the universe is totally different – a violent, vibrant, and ever-changing place. Temperatures can reach millions of degrees. Objects are accelerated by gravity to nearly the speed of light and magnetic fields more than a trillion times stronger than the Earth's cause some stars to crack and tremble.

NASA's newest space telescope, called the Chandra X-ray Observatory, will allow scientists from around the world to obtain unprecedented X-ray images of these and other exotic environments to help understand the structure and evolution of the universe. The observatory will not only help to probe these mysteries, but also will serve as a unique tool to study detailed physics in a laboratory that cannot be replicated here on earth – the universe itself. NASA's Chandra X-ray Observatory has every prospect of rewriting textbooks and helping technology advance in the coming decade.

The Chandra X-ray Observatory will provide unique and crucial information on the nature of objects ranging from comets in our solar system to quasars at the edge of the observable universe. The observatory should provide long-sought answers to some major scientific questions, such as:

- What and where is the "Dark Matter" in our universe? The largest and most massive objects in the universe are galaxy clusters - enormous collections of galaxies, some like our own. These galaxies are bound together into a cluster by gravity. Much of their mass is in the form of an incredibly hot, X-ray emitting gas that fills the entire space between the galaxies. Yet, neither the mass of the galaxies, nor the mass of the hot X-ray gas is enough to provide the gravity that we know holds the cluster together. X-ray observations with the Chandra X-ray Observatory will map the location of the dark matter and help us to identify it.

- What is the powerhouse driving the explosive activity in many distant galaxies? The centers of many distant galaxies are incredible sources of energy and radiation – especially X-rays. Scientists theorize that massive black holes are at the center of these active galaxies, gobbling up any material – even a whole star – that passes too close. Detailed studies with the Chandra X-ray Observatory can probe the faintest of these active galaxies, and study not only how their energy output changes with time, but also how these objects produce their intense energy emissions in the first place.

Since X-rays are absorbed by the Earth's atmosphere, space-based observatories are necessary to study these phenomena. To meet this scientific challenge, the Chandra X-ray Observatory, NASA's most powerful X-ray telescope, was launched in July 1999. Complementing two other space observatories now orbiting Earth – the Hubble Space Telescope and the Compton Gamma Ray Observatory – this observatory studies X-rays rather than visible light or gamma rays. By capturing images created by these invisible rays, the observatory will allow scientists to analyze some of the greatest mysteries of the universe.

Named in honor of the late Indian-American Nobel Laureate Subrahmanyan Chandrasekhar, the observatory was formerly known as the Advance X-ray Astrophysics Facility. The Chandra X-ray Observatory was carried into low Earth orbit by the Space Shuttle Columbia. The observatory was deployed from the shuttle's cargo bay at 155 miles above the Earth. Two firings of an attached Inertial Upper Stage rocket and several firings of its own on-board rocket motors after separating from the Inertial Upper Stage placed the observatory into its working orbit.

Unlike the Hubble Space Telescope's circular orbit that is relatively close to the Earth, the Chandra X-ray Observatory was placed in a highly elliptical (oval-shaped) orbit. At its closest approach to Earth, the observatory will be at an altitude of about 6,000 miles. At its farthest, 86,400 miles, it travels almost one-third of the way to the Moon. Due to this elliptical orbit, the observatory circles the Earth every 64 hours, carrying it far outside the belts of radiation that surround our planet. This radiation, while harmless to life on Earth, can overwhelm the observatory's sensitive instruments. The X-ray observatory is outside this radiation long enough to take 55 hours of uninterrupted observations during each orbit. During periods of interference from Earth's radiation belts, scientific observations are not taken.

The Chandra X-ray Observatory has three major elements. They are the spacecraft system, the telescope system and the science instruments.

The Spacecraft System

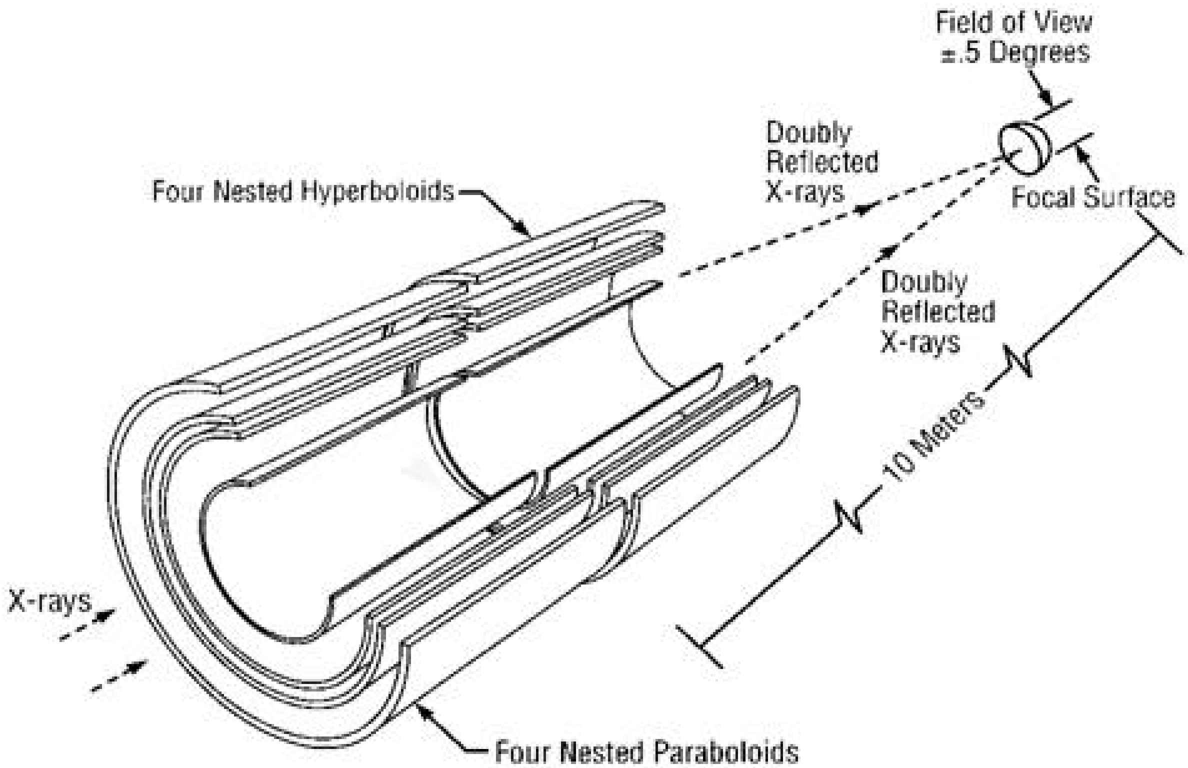
The spacecraft module contains computers, communication antennas and data recorders to transmit and receive information between the observatory and ground stations. The onboard computers and sensors, with ground-based control center assistance, command and control the vehicle and monitor its health during its expected five-year lifetime.

The spacecraft module also provides rocket propulsion to move and aim the entire observatory, an aspect camera that tells the observatory its position relative to the stars, and a Sun sensor that protects it from excessive light. Electrical power is provided by solar arrays that also charge three nickel-hydrogen batteries that provide backup power.

The Telescope System

At the heart of the telescope system is the High-Resolution Mirror Assembly. Since high-energy X-rays would penetrate a normal mirror, special cylindrical mirrors were created. The two sets of four nested mirrors resemble tubes within tubes. Incoming X-rays graze off the highly polished mirror surfaces and are funneled to the instrument section for detection and study.

The mirrors of the X-ray observatory are the largest of their kind and the smoothest ever created. If the surface of the state of Colorado were as relatively smooth, Pike's Peak would be less than one inch tall. The largest of the eight mirrors is almost 4 feet in diameter and 3 feet long. Assembled, the mirror group weighs more than 1 ton.



The High-Resolution Mirror Assembly is contained in the cylindrical "telescope" portion of the observatory. The entire length of the telescope is covered with reflective multi-layer insulation that assists heating elements inside the unit in keeping a constant internal temperature. By maintaining a precise temperature, the mirrors within the telescope are not subjected to expansion and contraction – thus ensuring greater accuracy in observations.

The assembled mirrors were tested at NASA's Marshall Space Flight Center in Huntsville, Ala. Marshall's world-class X-ray Calibration Facility verified the mirrors' exceptional accuracy – comparable to the accuracy required to hit a hole-in-one from Los Angeles to San Diego. This achievement allows the observatory to detect objects separated by one-half arc second. This is comparable to reading the letters of a stop sign 12 miles away.

The Chandra X-ray Observatory represents a scientific leap in ability over previous X-ray observatories like NASA's Einstein, which orbited the Earth from 1978 to 1981. With its combination of large mirror area, accurate alignment and efficient X-ray detectors, the Chandra X-ray Observatory has eight times greater resolution and is 20-to-50 times more sensitive than any previous X-ray telescope.

Science Instruments

Within the instrument section of the observatory, two instruments at the narrow end of the telescope cylinder will collect X-rays and study them in various ways. Each of the instruments can serve as an imager or spectrometer.

A High-Resolution Camera will record X-ray images, giving scientists an unequaled look at violent, high-temperature occurrences like the death of stars or colliding galaxies. The High-Resolution Camera is composed of two clusters of 69 million tiny lead-oxide glass tubes. The tubes are only one-twentieth of an inch long and just one-eighth the thickness of a human hair. When X-rays strike the tubes, particles called electrons are released. As the electrons are accelerated down the tubes by high voltage, they cause an avalanche of about 30 million more electrons. A grid of electrically charged wires at the end of the tube detects this flood of particles and allows the position of the original X-ray to be precisely determined. The High-Resolution Camera also complements the Charge-Coupled Device Imaging Spectrometer, described below.

The Chandra X-ray Observatory's Imaging Spectrometer is also located at the narrow end of the observatory. This detector is capable of recording not only the position, but also the color (energy) of the X-rays. The imaging spectrometer is made up of 10 charge-coupled device arrays. These detectors are similar to those used in home video recorders and digital cameras but are designed to detect X-rays. Commands from the ground allow astronomers to select which of the various detectors to use. The imaging spectrometer can distinguish up to 50 different energies within the range the observatory operates. In order to gain even more energy information, two screen-like instruments, called diffraction gratings, can be inserted into the path of the X-rays between the telescope and the detectors. The gratings change the path of the X-ray depending on its color (energy) and the X-ray cameras record the color and position. One grating concentrates on the higher and medium energies and uses the imaging spectrometer as a detector – the other grating disperses low energies and is used in conjunction with the High Resolution Camera.

By studying these X-ray rainbows, or spectra, and recognizing signatures of known elements, scientists can determine the composition of the X-ray producing objects, and learn how the X-rays are produced.

Observatory Operations

The Smithsonian Astrophysical Observatory controls science and flight operations of the Chandra X-ray Observatory for NASA from Cambridge, Mass. The Smithsonian manages two electronically linked facilities – the Operations Control Center and the Science Center.

The Operations Control Center is responsible for directing the observatory's mission as it orbits Earth. A control center team interacts with the observatory three times a day – receiving science and housekeeping information from its recorders. The control center team also sends new instructions to the observatory as needed, as well as transmit scientific information from the X-ray observatory to the Science Center.

The Science Center is an important resource for scientists who wish to study X-ray emitting celestial objects like quasars and colliding galaxies. The Science Center will provide user support to researchers, including science data processing and a science data archive. The Science Center will work with NASA and the scientific community to allow public access to the scientific results.

NASA and Partners

The Chandra X-ray Observatory program is managed by the Marshall Center for the Office of Space Science, NASA Headquarters, Washington, D.C. TRW Space and Electronics Group of Redondo Beach, Calif., is the prime contractor and has assembled and tested the observatory for NASA. Using glass purchased from Schott Glaswerke, Mainz, Germany, the telescope's mirrors were built by Raytheon Optical Systems Inc., Danbury, Conn. The mirrors were coated by Optical Coating Laboratory, Inc., Santa Rosa, Calif., and assembled by Eastman Kodak Co., Rochester, N.Y.

The Chandra X-ray Observatory Charge-Coupled Device Imaging Spectrometer was developed by Pennsylvania State University, University Park, Pa., and the Massachusetts Institute of Technology (MIT), Cambridge. One diffraction grating was developed by MIT, the other by the Space Research Organization Netherlands, Utrecht, Netherlands, in collaboration with the Max Planck Institute, Garching, Germany. The High Resolution Camera was built by the Smithsonian Astrophysical Observatory. Ball Aerospace & Technologies Corporation of Boulder, Colo., developed the aspect camera and the Science Instrument Module.

Chandra X-ray Observatory Technical Details

Size	45.3 feet long x 64.0 feet wide (solar arrays deployed)
Weight	10,560 pounds
Life	Minimum 5 years
Orbit	6,000 x 86,400 miles, 64-hour period per orbit
Power	Two 3-panel, silicon solar arrays (2,350 watts). Three 40-amp-hour nickel-hydrogen batteries for power in eclipse
Data recording	Solid-state recorder; 1.8 gigabits (16.8 hours) of recording capability
High-Resolution Mirror Assembly	4 sets of nested, grazing incidence paraboloid/hyperboloid mirror pairs, constructed of Zerodur material - Weight of assembly: 2,104 pounds - Focal length: 10 meters (about 33 feet) - Outer diameter: 1.2 meters (about 4 feet)
Charge-coupled Imaging Spectrometer	Ten charge-coupled device arrays provide simultaneous imaging and spectroscopy
High-Resolution Camera	Micro-channel plates detect X-ray photons
Transmission Gratings	One high/medium- and one low-energy, gold grating

Marshall Space Flight Center Fact Sheet

Quick Facts:
The Chandra X-ray Observatory

NASA's newest space telescope, the Chandra X-ray Observatory, will allow scientists from around the world to obtain unprecedented X-ray images and spectra of violent, high-temperature events and objects to help us better understand the structure and evolution of our universe.

It will also serve as a unique tool to study detailed physics in a unique laboratory -- the universe itself – one that cannot be replicated here on Earth.

Managed by NASA's Marshall Space Flight Center in Huntsville, Ala., Chandra is a sophisticated, state-of-the-art instrument that represents a tremendous technological advance in X-ray astronomy.

Did you know?

- The Chandra X-ray Observatory is the world's most powerful X-ray telescope. It has eight-times greater resolution and will be able to detect sources more than 20-times fainter than any previous X-ray telescope.
- The Chandra X-ray Observatory, with its Inertial Upper Stage and support equipment, is the largest and heaviest payload ever launched by the Space Shuttle.
- The Chandra X-ray Observatory's operating orbit takes it 200-times higher than the Hubble Space Telescope. During each orbit of the Earth, Chandra travels one-third of the way to the Moon.
- The Chandra X-ray Observatory's resolving power is – 0.5 arc-seconds -- equal to the ability to read the letters of a stop sign at a distance of 12 miles. Put another way, Chandra's resolving power is equivalent to the ability to read a 1-centimeter newspaper headline at the distance of a half-mile.
- If the State of Colorado were as smooth as the surface of the Chandra X-ray Observatory mirrors, Pike's Peak would be less than an inch tall.
- Another of NASA's incredible time machines, the Chandra X-ray Observatory will be able to study some quasars as they were 10 billion years ago.
- The Chandra X-ray Observatory will observe X-rays from clouds of gas so vast that it takes light more than five-million years to go from one side to the other.
- Although nothing can escape the incredible gravity of a black hole, not even light, the Chandra X-ray Observatory will be able to study particles up to the last millisecond before they are sucked inside.
- It took almost four centuries to advance from Galileo's first telescope to NASA's Hubble Space Telescope — an increase in observing power of about a half-billion times. NASA's Chandra X-ray Observatory is about one-billion times more powerful than the first X-ray telescope, and we have made that leap in slightly more than three decades.

Chandra Mission at a Glance:

Chandra X-ray Observatory Mission Duration

Chandra science mission	Approx. 5 yrs
Orbital Activation & Checkout period	Approx. 2 mos

Orbital Data

Inclination	28.5 degrees
Altitude at apogee	86,487 sm
Altitude at perigee	5,999 sm
Orbital period	64 hrs
Observing time per orbital period	Up to 55 hrs

Dimensions

Length – (Sun shade open)	45.3’
Length – (Sun shade closed	38.7’
Width – (Solar arrays deployed)	64.0’
Width – (Solar arrays stowed)	14.0’

Weights

Dry	10,560 lbs
Propellant	2,153 lbs
Pressurant	10 lbs
Total at launch	12,930 lbs

Integral Propulsion System

Liquid Apogee Engines	4 engines (Only 2 used at a time)
Fuel	Hydrazine
Oxidizer	Nitrogen tetroxide
Thrust per engine	105 lbs

Electrical Power

Solar Arrays	2 arrays 3 panels each
Power generated	2,350 watts
Electrical power storage	3 batteries 40-amp-hour nickel hydrogen

Communications

Antennas	2 low-gain antennas
Communication links	Shuttle Payload Interrogator Deep Space Network
Command link	2 kbs per second
Data downlink	32 kbs to 1024 kbs

On-board Data Capture

Method	Solid-state recorder
Capacity	1.8 gbs 16.8 hrs

High Resolution Mirror Assembly

Configuration	4 sets of nested, grazing incidence paraboloid/hyperboloid mirror pairs
Mirror Weight	2,093 lbs
Focal length	33 ft
Outer diameter	4 ft
Length	33.5 in
Material	Zerodur
Coating	600 angstroms of iridium

Attitude Control & Pointing

Reaction wheels	6
Inertial reference units	2
Aspect camera	1.40 deg x 1.40 deg fov

Science Instruments

Charged Coupled Imaging Spectrometer (ACIS)
High Resolution Camera (HRC)
High Energy Transmission Grating (HETG)
Low Energy Transmission Grating (LETG)

The Inertial Upper Stage

Dimensions

Length	17.0’
Diameter	9.25’

Weights

Stage 1 – Dry	2,566 lbs
Stage 1 – Propellant	19,621 lbs
Stage 1 - Total	22,187 lbs
Stage 2 – Dry	2,379 lbs
Stage 2 – Propellant	6,016 lbs
Stage 2 - Total	8,395 lbs
Total Inertial Upper Stage – At launch	30,582 lbs

Performance

Thrust – Stage 1	46,198 lbs, average
Burn Duration – Stage 1	125 seconds
Thrust – Stage 2	16,350 lbs, average
Burn Duration – Stage 2	117 seconds

Support Equipment

Weights

Airborne Support Equipment	5,365 lbs
Other	1,285 lbs
Total Support Equipment	6,650 lbs

Total Payload

Weight

Total Chandra/IUS/Support equipment at liftoff	50,162 lbs

Length

Total IUS/Chandra	57.0’

Biographies

DR. ROBERT KIRSHNER
ASSOCIATE DIRECTOR, HARVARD-SMITHSONIAN CENTER FOR ASTROPHYSICS

Robert Kirshner is Professor of Astronomy at Harvard University and an Associate Director of the Harvard-Smithsonian Center for Astrophysics. He graduated from Harvard College in 1970 and received a Ph.D. in astronomy at Caltech four years later. After a postdoc at Kitt Peak National Observatory in Tucson, he joined the faculty at the University of Michigan for 9 years before moving to the Harvard Astronomy Department in 1986. He served as Chairman of the department from 1990-1997.

Professor Kirshner is an author of 200 research papers dealing with supernovae, the large-scale distribution of galaxies, and the size and shape of the Universe. His recent work on the acceleration of the Universe was dubbed the "Science Breakthrough of the Year for 1998" by Science Magazine. An article by Kirshner and his collaborators on this topic appears in the January 1999 Scientific American. He was elected to the National Academy of Sciences in 1998.

Kirshner is a frequent public lecturer on science, including the 1997 Princeton University lectures, the 1998 Seyfert Lecture at Vanderbilt University, and a featured talk to the National Science Teachers Association at their national meeting in 1999. He is also the teacher of Science A-35, a core curriculum course for 250 Harvard undergraduates entitled "Matter in the Universe." The vivid (and slightly hazardous) demonstrations in Science A-35 led to Kirshner's being featured in Boston Magazine in their October 1998 article on "Nutty Professors". Kirshner has made a series of video tapes on "Cosmic Questions" for The Teaching Company which are widely available.

Biographies

DR. HARVEY TANANBAUM
DIRECTOR, CHANDRA X-RAY CENTER

Dr. Harvey Tananbaum is director of the Smithsonian Astrophysical Observatory's Chandra X-ray Center (CXC). In this capacity he is responsible for overseeing the operation of the Chandra X-ray Observatory and providing support to the scientific users of the observatory.

Tananbaum graduated from Yale University in 1964. After receiving his Ph.D. in physics from MIT in 1968, he joined American Science & Engineering where he became project scientist for NASA's Uhuru X-ray Satellite. In 1973 he moved to the Harvard-Smithsonian Center for Astrophysics. The launch and operation of the Chandra Observatory will be the culmination of a 23 year journey for Tananbaum, who has been involved with the Chandra project from the beginning. In 1976, he and Riccardo Giacconi submitted a proposal letter to NASA to initiate the study and design of a large x-ray telescope. In 1977, work was begun on the project, which was then known as the Advanced X-ray Astrophysics Facility (AXAF). In 1998, AXAF was renamed the Chandra X-ray Observatory.

Tananbaum has been working in x-ray astronomy since his graduate days at MIT. His thesis research was on a mysterious type of cosmic x-ray source. Later, when he was project scientist for the Uhuru X-ray Satellite, observations by the satellite were instrumental in showing that this source was due to matter falling into a black hole. Tananbaum was the scientific program manager for the Einstein Observatory, the first large imaging x-ray telescope. In 1981 he became Associate Director for High Energy Astrophysics at the Harvard-Smithsonian Center for Astrophysics, a position he held for 12 years. In 1991, he was appointed director of the CXC.

Tananbaum received the NASA Exceptional Scientific Achievement Medal in 1980, and the NASA Public Service Award in 1988. He is a fellow of the American Association for the Advancement of Science, and has served as vice-president of the American Astronomical Society, as well as on numerous NASA advisory committees.

Biographies

DR. EDWARD J. WEILER
ASSOCIATE ADMINSTRATOR FOR SPACE SCIENCE, NASA

In November 1998 Dr. Edward J. Weiler was appointed as NASA's Associate Administrator for Space Science. In this capacity, Weiler is responsible for providing overall executive leadership of NASA's Space Science Enterprise. This enterprise aims to achieve a comprehensive understanding of the origins and evolution of the Solar System and the Universe, including connections between the Sun and the Earth, the beginnings of life and the question of whether life exists elsewhere beyond Earth. It also is charged with communicating this knowledge to the public.

Weiler was appointed as Science Director of the Astronomical Search for Origins and Planetary Systems theme within the Office of Space Science in March 1996. He will continue to serve as the Program Scientist for the Hubble Space Telescope, a position he has held since 1979, until a replacement for that position is selected. Weiler joined NASA in 1978 as a staff scientist.

Prior to that, Weiler was a member of the Princeton University research staff and was based at NASA'S Goddard Space Flight Center, Greenbelt, MD, as the director of science operations of the Orbiting Astronomical Observatory-3 (COPERNICUS). Weiler received his Ph.D. in astrophysics from Northwestern University in January 1976. He has published over 20 papers in the scientific journals. Dr. Weiler has received numerous awards, including the NASA Outstanding Leadership Medal and the 1994 Presidential Rank Award of Meritorious Executive for his work on HST.

Biographies

DR. MARTIN C. WEISSKOPF
PROJECT SCIENTIST, CHANDRA X-RAY OBSERVATORY

Dr. Martin C. Weisskopf is Project Scientist for NASA's Chandra X-ray Observatory and Chief Scientist for X-ray Astronomy at NASA's Marshall Space Flight Center in Huntsville, Ala.

NASA's Chandra X-ray Observatory, the world's most powerful X-ray telescope, will help scientists understand the structure and evolution of the universe.

Weisskopf began his post-graduate career at Columbia University in 1969, where he became an assistant professor and performed many pioneering experiments in X-ray astronomy including helping to write the proposal for what was to become the Einstein Observatory, the forerunner to the Chandra X-ray Observatory. In 1977, Weisskopf left Columbia to become senior X-ray astronomer at Marshall Center and Chandra X-ray Observatory Project Scientist. In this capacity he is responsible for the scientific integrity of the Chandra X-ray Observatory.

Weisskopf has held numerous special appointments during his career. He is a Senior Co-investigator of the European Space Agency's international X-ray imaging experiment, called IBIS, and holds a similar position for an experiment to fly on the SPECTRUM-X mission being developed for X-ray study by the Russian Space Research Institute. He is Principal Investigator of a major experimental research program initiated in 1978 that currently concentrates on the development of X-ray optics.

He has served on numerous committees, including the National Academy of Science's Panel on High-Energy Astrophysics from Space, Astronomy and Astrophysics Survey Committee. He is a member of the American Astronomical Society High-Energy Astrophysics Division; the American Association for the Advancement of Science; the International Astronomical Union; Sigma Xi, a scientific research society; Phi Beta Kappa, the National Honor Society and a Fellow of the American Physical Society Astrophysics Division.

Weisskopf is the recipient of numerous awards, including the NASA Medal for Exceptional Service. He is author or co-author of 171 journal articles, books, monographs and papers in conference proceedings.

In 1964, he received his bachelor's degree with honors in physics from Oberlin College in Cleveland, Ohio, and in 1969 received his doctorate in physics from Brandeis University in Waltham, Mass.