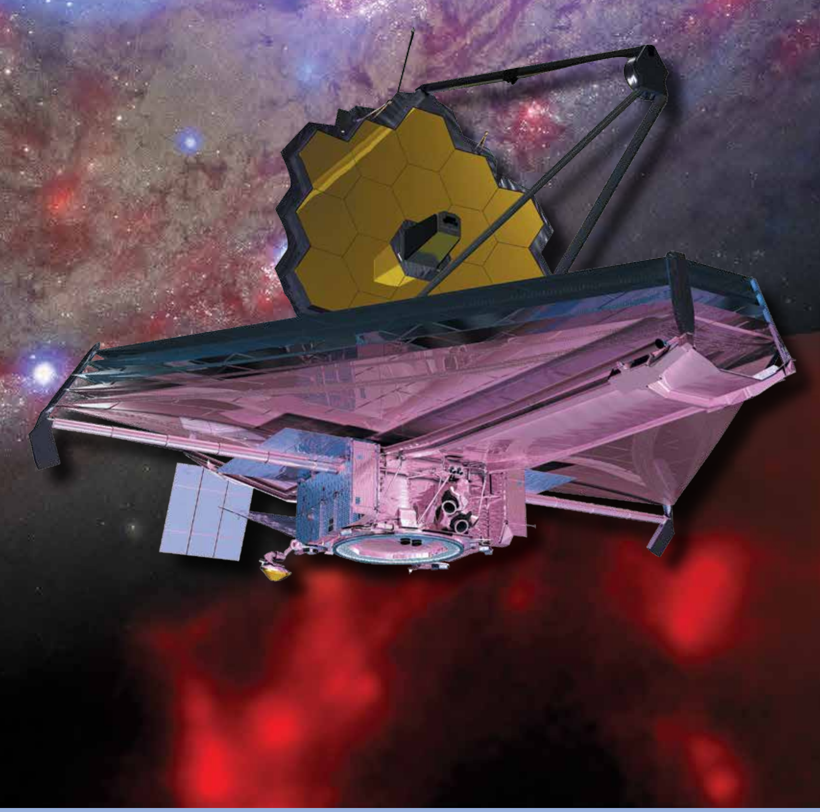
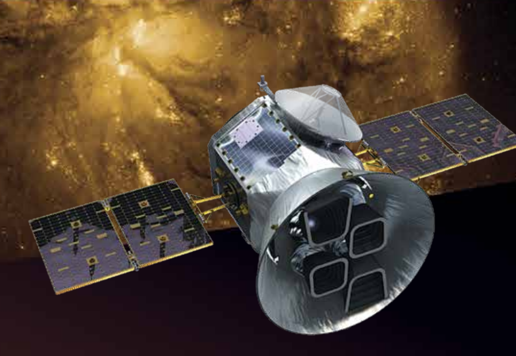
NASA Science

National Aeronautics and Space Administration

ASTROPHYSICS

Discover how the universe works, explore how it began and evolved, and search for life on planets around other stars.





- Probe the origin and destiny of our universe, including the nature of black holes, dark energy, dark matter, and gravity.
- Explore the origin and evolution of the galaxies, stars, and planets that make up our universe.
- Discover and study planets around other stars, and explore whether they could harbor life.

Programs

Cosmic Origins Program

The Cosmic Origins Program (COR) seeks to understand how the universe has evolved since the Big Bang, and how its constituents were produced—the familiar night sky we see today, the planet we live on, and all the chemical elements that sustain life. To explore these topics, NASA's Cosmic Origins space telescopes explore the origin and evolution of the galaxies, stars, and planets that make up our universe.

Physics of the Cosmos Program

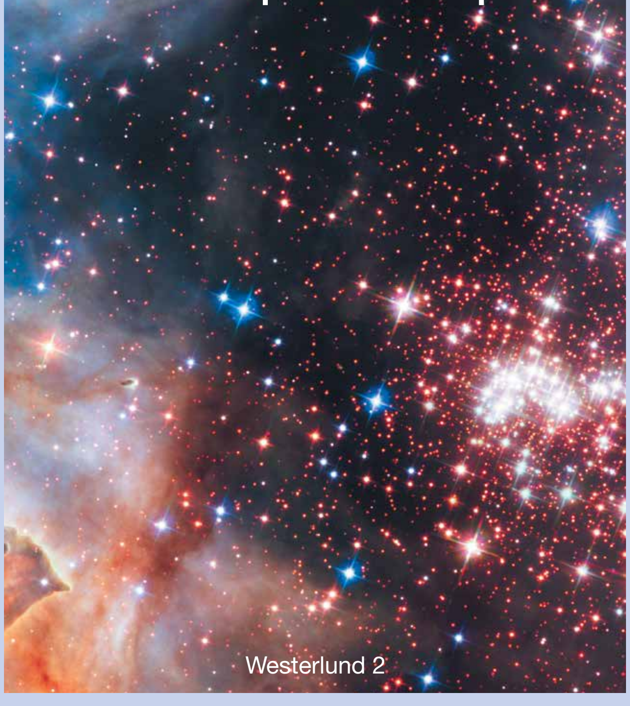
The Physics of the Cosmos Program (PCOS) addresses the most extreme physical conditions of the universe and the study of the building blocks of the universe at the most basic level: the space, time, matter, and energy that constitute it. The scope of the Physics of the Cosmos Program includes understanding the birth and evolution of the universe (dark energy and cosmic microwave background), the conditions of matter in strong gravitational fields and the hot universe (X-rays and Gamma-rays), and the detection and characterization of gravitational waves from space.

Exoplanet Exploration Program

The Exoplanet Exploration Program (ExEP) seeks to discover and study planets orbiting around other stars. Since the seminal moment in 1992 when an exoplanet was discovered orbiting a pulsar, there has been explosive growth in the number of exoplanets identified. The Exoplanet Exploration Program aims at discovering planets around other stars, characterizing their properties, and identifying candidates that could harbor life.

Hubble

Hubble Space Telescope



Westerlund 2

Hubble Mission Overview

Hubble

The **Hubble Space Telescope** was launched in 1990 aboard the space shuttle Discovery. Hubble is a collaboration between NASA and the European Space Agency. Among its many accomplishments, Hubble has helped reveal the first exoplanets, played a key role in the discovery of dark energy, shown scientists galaxies in all stages of evolution, and found protoplanetary disks likely to function as birthing grounds for new planets.

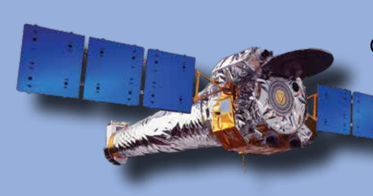
The only one of NASA's four "Great Observatories" (Hubble, Compton Gamma-Ray Observatory, Chandra X-Ray Observatory, and Spitzer Space Telescope) that was designed to be serviceable by space shuttle astronauts, Hubble has seen its capabilities grow immensely during its more than 25 years of operations.

Science Instruments

Space Telescope Imaging Spectrograph (STIS)	• spectroscopy from the ultraviolet (UV) to the near-infrared (IR) • imaging in the UV and optical range
Advanced Camera for Surveys (ACS)	• deep, wide-field survey capability from the visible to near-IR • imaging from the near-UV to the near-IR • solar blind, far-UV imaging
Fine Guidance Sensors (FGS)	precision astrometry and milliarcsecond resolution over a wide range of magnitudes
Cosmic Origins Spectrograph (COS)	high-sensitivity, moderate- and low-resolution spectroscopy in the wavelength range (90–320 nm)
Wide Field Camera 3 (WFC3)	wide-field imaging with continuous spectral coverage from UV into the IR

Chandra

Chandra Mission Overview



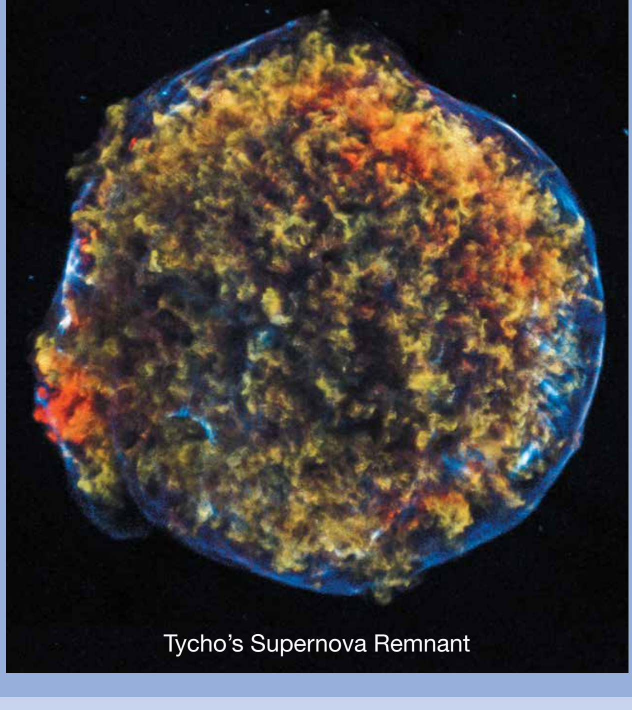
Chandra

The **Chandra X-Ray Observatory** is designed to observe X-rays from high-energy regions of the universe, such as the remnants of exploded stars.

Chandra combines its mirrors with four science instruments to capture and probe the X-rays from astronomical sources. The incoming X-rays are focused by the mirrors to a tiny spot (about half as wide as a human hair) on the focal plane, at a little over 9 meters (~30 feet) away.

The science instruments have complementary capabilities to record and analyze X-ray images of celestial objects and probe their physical conditions with unprecedented accuracy.

Chandra X-ray Observatory



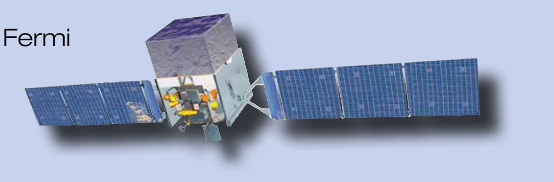
Tycho's Supernova Remnant

Science Instruments

High Resolution Camera (HRC)	• images hot matter in remnants of exploded stars and in distant galaxies and clusters of galaxies, and identifies very faint sources • can make images revealing detail as small as 0.5 arcsecs	
Advanced CCD Imaging Spectrometer (ACIS)	• measures temperature variations across X-ray sources such as vast clouds of hot gas in intergalactic space, or chemical variations across clouds left by supernova explosions • makes X-ray images and simultaneously measures the energy of each incoming X-ray	
High Energy Transmission Grating Spectrometer (HETGS)	high-resolution X-ray spectroscopy enabling measurement of temperature and ionization state, and chemical analysis of deep-space objects	spectroscopy from (0.4–10 keV)
Low Energy Transmission Grating Spectrometer (LETGS)		spectroscopy from (0.08–2 keV)

Fermi

Fermi Mission Overview



Fermi

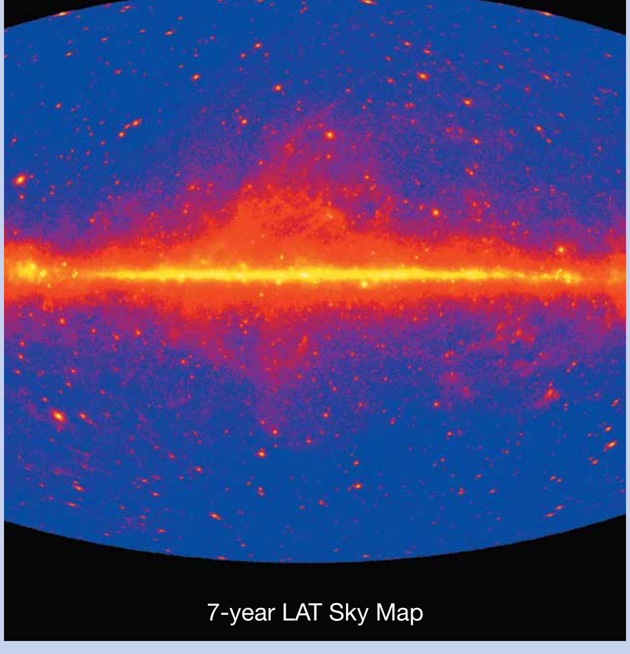
The **Fermi Gamma-ray Space Telescope** focuses on studying the most energetic objects and phenomena in the universe. It is an international and multi-agency space mission that studies the cosmos using two different instruments operating at energies thousands to hundreds of billions of times greater than those we can see with our eyes.

Fermi is able to observe gamma-ray sources near the edge of the visible universe. Gamma rays detected by Fermi originate near the otherwise-obscured central regions of exotic objects like supermassive black holes, pulsars, and gamma-ray bursts. Fermi aids in the study of mechanisms of particle acceleration in extreme astrophysical environments. Among topics of cosmological interest is the information obtained about dark matter and the periods of star and galaxy formation in the early universe.

Science Instruments

Large Area Telescope (LAT)	• observes high-energy gamma rays from (20 MeV–300 GeV) • covers 20% of the sky at once, observing the whole sky every 3 hours • has four main subsystems: - tracker - calorimeter - anticoincidence detector - data acquisition system
Gamma-ray Burst Monitor (GBM)	• makes observations of transient sources • detects X-rays and low-energy gamma rays (8 keV–40 MeV) • has three main components: - low-energy sodium iodide detectors - high-energy bismuth germanate detectors - data processing unit

Fermi Gamma-ray Space Telescope



7-year LAT Sky Map

SOFIA

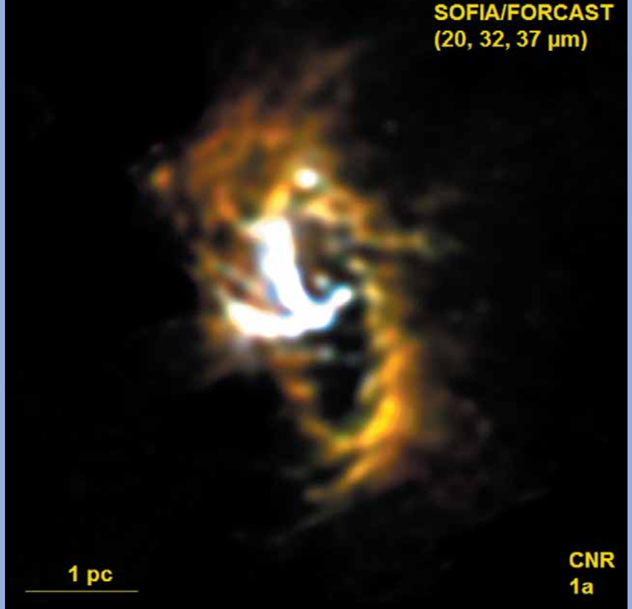
SOFIA Mission Overview

SOFIA

Stratospheric Observatory for Infrared Astronomy (SOFIA) is an airborne observatory. It is a joint program between NASA and the German Aerospace Center (DLR). The observatory is a heavily modified Boeing 747SP aircraft carrying a reflecting telescope with an effective diameter of 2.5 meters (8 feet). Flying at altitudes between 12 and 14 km (39,000 and 46,000 feet)—above 99.8% of the water vapor in Earth's lower atmosphere that blocks most IR radiation from celestial sources—SOFIA conducts astronomical research not possible with ground-based telescopes. The aircraft and associated systems are provided by NASA; the telescope is provided by DLR.

SOFIA conducts IR and optical observations of star and planet formation, the interstellar medium, the galactic center, and planets and near-Earth objects.

Stratospheric Observatory for Infrared Astronomy

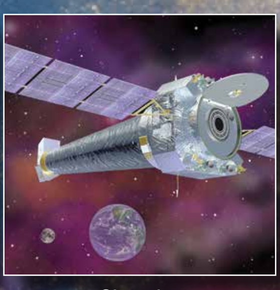


Galactic Center

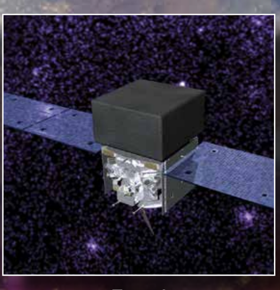
Science Instruments (First and Second Generation)

Echelon-Cross-Eschell Spectrograph (EXES)	US-Developed Mid-IR High-Resolution Echelon Spectrometer (5–28 μm)
Far-Infrared Field Imaging Line Spectrometer (FIFI-LS)	German-Developed Dual Channel Integral Field Grating Spectrometer (42–110 μm; 100–210 μm)
First Light Infrared Test Experimental Camera (FLITECam) (Can be used in combination with HIPO)	US-Developed Near Infrared Imaging and Grism Spectroscopy, (1–5.5 μm)
Faint Object InfraRed Camera for SOFIA (FORCAST)	US-Developed Simultaneous Dual Channel Imaging and Grism Spectroscopy (5–25 μm and 25–40 μm)
German Receiver for Astronomy at Terahertz Frequencies (GREAT)	German-Developed High Resolution Heterodyne Spectrometer (1.6–1.9 THz; 2.4–2.7 THz; 4.7 THz)
High-resolution Airborne Wideband Camera (HAWC+)	US-Developed High-Angular Resolution Wide-Band Camera and Polarimeter with 5 Channels (53, 63, 89, 154, 214 μm)
High-Speed Imaging Photometer for Occultations (HIPO)	US-Developed Visible Light High-Speed Camera (0.3–1.1 μm)
Updated German Receiver for Astronomy at Terahertz Frequencies (upGREAT)	German-Developed Far-IR Heterodyne 7-pixel Array Spectrometer (1.9 THz, 4.7 THz)

Hubble



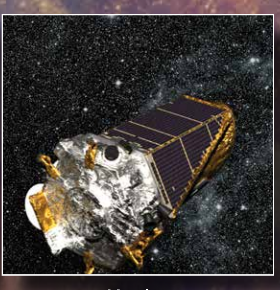
Chandra



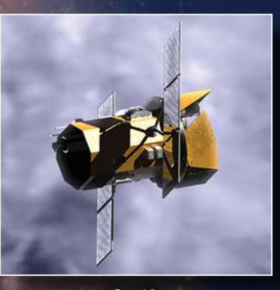
Fermi

SOFIA

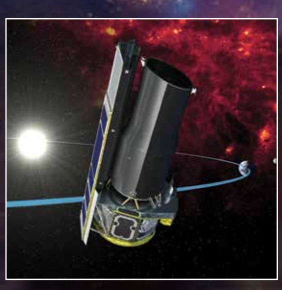
Webb



Kepler



Swift

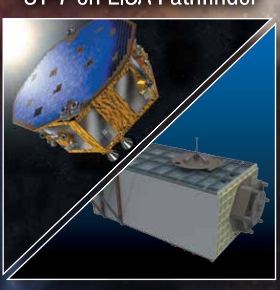


Spitzer

NuSTAR

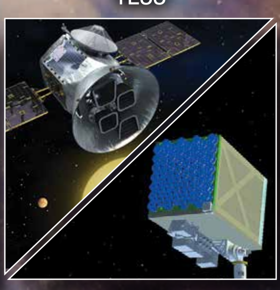
ASTRO-H

ST-7 on LISA Pathfinder



CREAM

TESS



NICER

For more information, visit:
science.nasa.gov/astrophysics/missions

NP-2015-9-341-GSFC

Webb

Test Fitting of the Flight Backplane

Webb Mission Overview

James Webb Space Telescope

The **James Webb Space Telescope** is a large infrared telescope with a 6.5 meter (~21 foot) primary mirror. The observatory is planning for launch in October of 2018. Webb will be the premier space observatory of the next decade, serving thousands of astronomers worldwide. This tennis court-sized observatory orbiting far beyond Earth's moon will detect infrared radiation and be capable of seeing at those wavelengths as well as Hubble sees in visible light. It will study every phase in the history of our universe, ranging from the first luminous glows after the Big Bang, to the formation of solar systems capable of supporting life on planets like Earth, to the evolution of our own Solar System. Webb is an international collaboration between NASA, the European Space Agency, and the Canadian Space Agency.

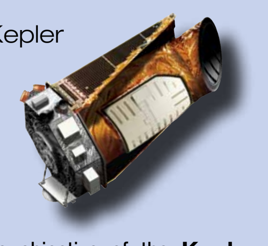
Science Instruments

- Near-Infrared Camera (NIRCam) — NIRCam observes in near-infrared wavelengths (0.6–5 micrometers). It is capable of wide field imaging and it is also the instrument that Webb uses for measuring and correcting the segmented primary mirror.
- Near-Infrared Spectrometer (NIRSpec) — NIRSpec is called a *multi-object near-infrared spectrometer*. A spectrometer is a device that breaks light up into its colors. NIRSpec observes near-infrared wavelengths (0.6–5 micrometers) and will be capable of observing more than 100 objects simultaneously.
- Mid-Infrared Instrument (MIRI) — MIRI observes mid-infrared wavelengths (5–28 micrometers), using both its imaging mode as well as a spectroscopy capability.
- Fine Guidance Sensor/Near-Infrared Imager and Slitless Spectrograph (FGS and NIRISS) — FGS is Webb's guide camera, which helps point the telescope. Like NIRSpec, NIRISS sees spectra, with a focus on extremely bright objects and the detection of faint objects near bright stars. FGS and NIRISS have different purposes but are packaged together into one unit. Both FGS and NIRISS observe near-infrared wavelengths (0.6–5 micrometers).

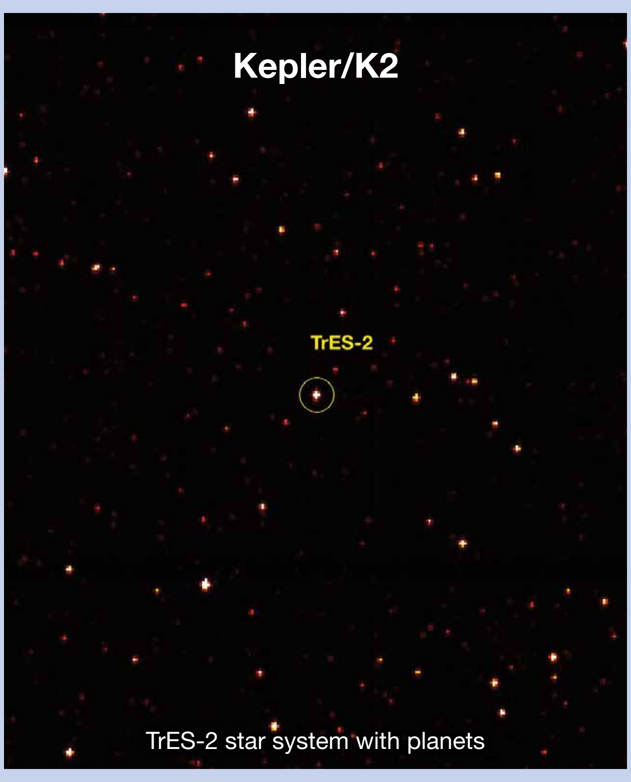
Kepler/K2

Kepler/K2 Mission Overview

Kepler



The principle scientific objective of the **Kepler** mission was to discover Earth-like planets orbiting other stars. The mission ended in August 2013 and repurposed as K2 to detect habitable planets around smaller, dimmer red dwarf stars. This observatory surveys a large sample of stars to: determine the abundance of terrestrial and larger planets in or near the habitable zone of a wide variety of stars; determine the distribution of sizes and shapes of the orbits of these planets; estimate how many planets there are in multiple-star systems; determine the variety of orbit sizes and planet reflectivity's, sizes, masses, and densities of short-period giant planets; identify additional members of each discovered planetary system using other techniques; and determine the properties of those stars that harbor planetary systems.



TrES-2 star system with planets

Science Instrument

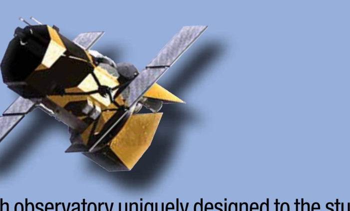
The Kepler instrument is a specially designed Schmidt telescope called a photometer with a 0.95-meter (37-inch) aperture. It has a very large field-of-view for an astronomical telescope, with an area of 105 square degrees, comparable to the area of your hand held at arm's length. The fields-of-view of most telescopes are less than one square degree. The photometer must be space-based to obtain the photometric precision needed to reliably see an Earth-like transit and to avoid the interruptions caused by the day-night cycles, seasonal cycles, and atmospheric absorption associated with ground-based observing.

During its prime mission, Kepler needed the large field-of-view to observe more than 150,000 stars located in the same star field. For more than four years it continuously and simultaneously monitored the brightnesses of these stars.

Swift

Swift Mission Overview

Swift



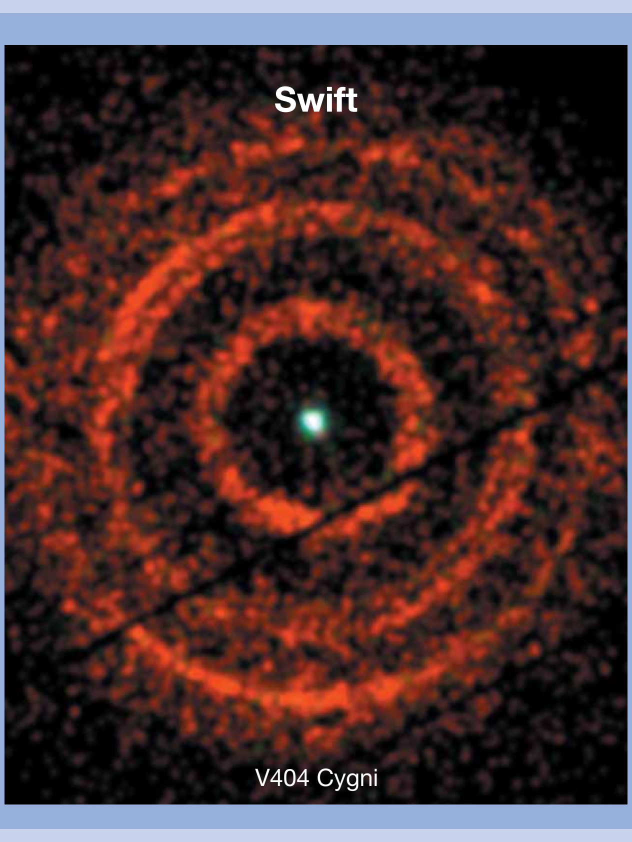
Swift is a multi-wavelength observatory uniquely designed to the study of gamma-ray burst science. Swift is a partnership with Italy and the United Kingdom. Its three instruments work together to observe gamma-ray bursts and afterglows in the gamma-ray, X-ray, UV, and optical wavebands.

The main mission objectives for Swift are to: determine the origin of gamma-ray bursts; classify gamma-ray bursts and search for new types; determine how the bursts evolve and interact with the surroundings; use gamma-ray bursts to study the early universe; and perform the first sensitive hard X-ray survey of the sky.

The diverse Swift instrumentation has amassed a treasure trove of data and scientific insight from the transient universe. Swift is NASA's workhorse for detecting and characterizing the explosive environments around compact objects, while also observing hot young stars that trace massive regions of star-formation. As such, Swift is a remarkable observer of both stellar birth and death.

Science Instruments

Burst Alert Telescope (BAT)	• detects about 100 gamma-ray bursts per year • computes burst positions onboard the satellite with arcminute positional accuracy • spectroscopy from (15–150 keV)
X-ray Telescope (XRT)	• takes images and obtains spectra of gamma-ray burst afterglows during pointed follow-up observations • spectroscopy from (0.3–10 keV)
UV/Optical Telescope (UVOT)	• takes images and obtains spectra of gamma-ray burst afterglows during pointed follow-up observations • spectra taken for the brightest UV/optical afterglows from (170–600 nm)



V404 Cygni

Spitzer

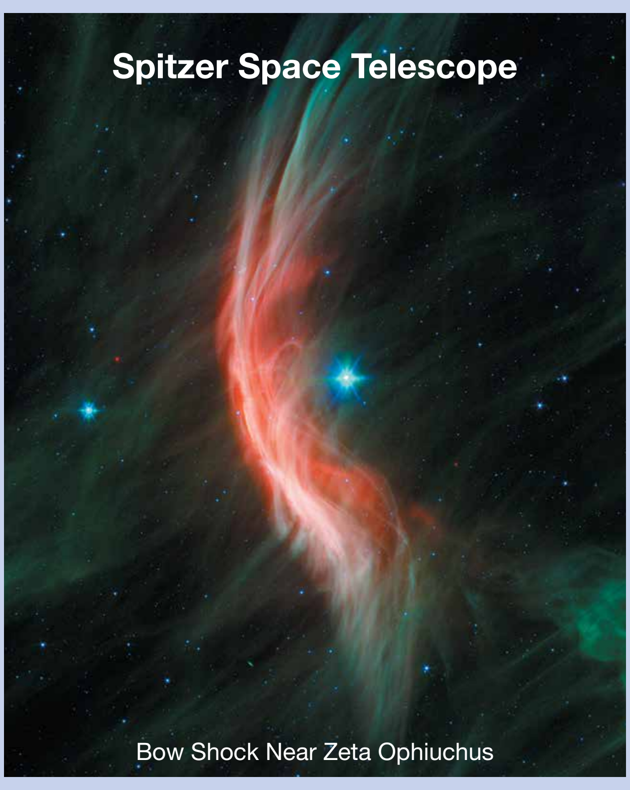
Spitzer Mission Overview

Spitzer

The **Spitzer Space Telescope**'s highly sensitive IR instruments allow scientists to peer into cosmic regions that are hidden from optical telescopes, including dusty stellar nurseries, the centers of galaxies, and newly forming planetary systems.

Spitzer's IR sensors also allow astronomers see cooler objects in space, like failed stars (brown dwarfs), extrasolar planets, giant molecular clouds, and organic molecules that may hold the secret to life on other planets.

The cryogenic mission ended in May 2009. The instruments have warmed up to around -242 ºC (-404 ºF), allowing only two Infrared Array Camera (IRAC) channels to work, studying a range of objects including asteroids and comets in our solar system, dusty stars, planet-forming disks, exoplanets, and distant galaxies.



Bow Shock Near Zeta Ophiuchus

Science Instruments

The Infrared Array Camera (IRAC)	general-purpose camera detecting light at near- and mid-IR wavelengths at 3.6 μm, 4.5 μm, 5.8 μm*, and 8.0 μm* * 5.8 μm and 8.0 μm channels not operational
The Infrared Spectrograph (IRS) * no longer operational	• high- and low-resolution spectroscopy at mid- IR wavelengths from 5 to 40 μm • four different modules: - a low-resolution, short-wavelength module: (5.3–14 μm) - a low-resolution, long-wavelength module: (14–40 μm) - a high-resolution, short-wavelength module: (10–19.5 μm) in high detail - a high-resolution, long-wavelength module: (19–37 μm)
Multiband Imaging Photometer (MIPS) * no longer operational	• far-IR detection at wavelengths of 24 μm, 70 μm, and 160 μm • fields of view: - 5 x 5 arcminutes at 24 μm - 2.5 x 5 arcmins (operational) at 70 μm - 0.5 x 5 arcmins at 160 μm • simple spectra from 50 to 100 μm with 70 μm detector

NuSTAR

NuSTAR Mission Overview

NuSTAR

The **Nuclear Spectroscopic Telescope Array** (NuSTAR) is an Explorer mission that allows astronomers to study the universe in high energy X-rays. Launched in June of 2012, NuSTAR is the first focusing hard X-ray telescope to orbit Earth.

NuSTAR's primary science objectives include: Conducting a census for black holes on all scales using wide-field surveys of extragalactic fields and the Galactic center. Mapping radioactive material in young supernova remnants. Studying the birth of the elements and to understand how stars explode. Observing relativistic jets found in the most extreme active galaxies and to understand what powers giant cosmic accelerators.

Science Instruments

The NuSTAR instrument consists of two co-aligned grazing incidence telescopes with specially coated optics and newly developed detectors that extend sensitivity to higher energies as compared to previous missions such as Chandra and ESA's XMM-Newton. After launching into orbit, the NuSTAR telescope was extended to achieve a 10-meter (~33-foot) focal length. The observatory provides a combination of sensitivity, spatial, and spectral resolution factors of 10 to 100 improved over previous missions that have operated at these X-ray energies.

Pulsar PSR J1640-4631

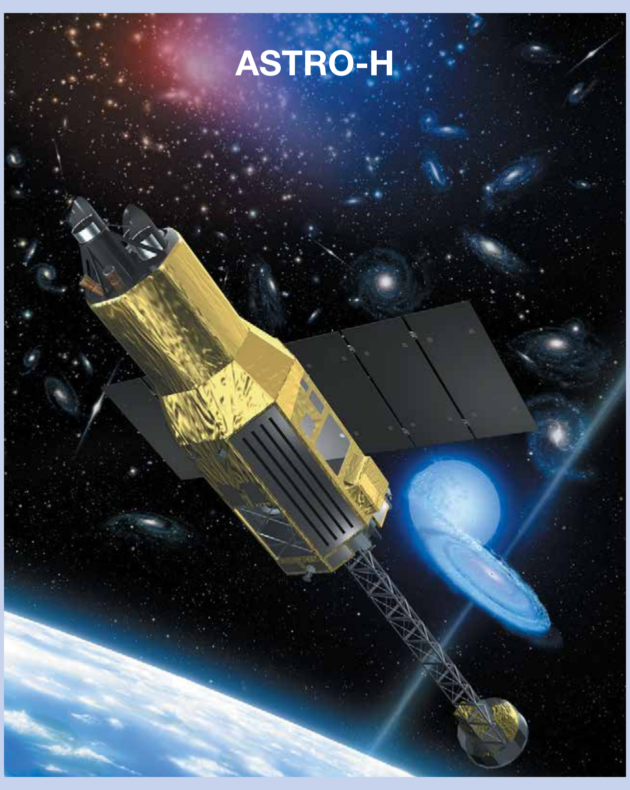
ASTRO-H

ASTRO-H Mission Overview

ASTRO-H

ASTRO-H is an international X-ray observatory, which is the 6th in the series of the X-ray observatories from Japan. It is being developed by the Japan Aerospace Exploration Agency (JAXA) for studying extremely energetic processes in the universe. The mission will explore the extreme environment in the vicinity of black holes, and investigate how galaxies and clusters of galaxies form and evolve. The mission will also provide key new constraints on the nature of dark matter and dark energy on the largest scales in the universe. ASTRO-H will be launched into low-Earth orbit from the Tanegashima Space Center, Japan, by a JAXA H-IIA rocket. The mission duration is three years.

Planned for launch in early 2016.



Credit: Akihiro Ikeshita / JAXA

Science Instruments

Achieving the mission objectives requires the Soft X-ray Spectrometer (SXS), which combines a lightweight Soft X-ray Telescope paired with an X-ray Calorimeter Spectrometer, providing non-dispersive 7 eV resolution in the 0.3–10 keV bandpass. NASA and the JAXA have teamed up to develop the SXS instrument. The NASA contribution includes key instrumentation to the SXS; a state-of-the-art X-ray Calorimeter focal plane detector array, including the Adiabatic Demagnetization Refrigerator (ADR), read-out and control electronics and the mirror assembly for the SXS.

Three additional scientific instruments extend the bandpass to produce an observatory with extraordinary new capabilities. The Hard X-ray Imager (HXI) performs sensitive imaging spectroscopy in the 5–80 keV band; the non-imaging Soft Gamma-ray Detector (SGD) extends ASTRO-H's energy band to 300 keV; and the Soft X-ray Imager (SXI), for which the U.S. contributed the soft X-ray mirror assembly, expands the field of view with a new generation CCD camera in the energy range of 0.5–12 keV.

ST-7

Mission Overview

LISA Pathfinder

ST-7 Disturbance Reduction System (DRS) will control the position of ESA's LISA Pathfinder spacecraft with nanometer precision, enabling space based gravitational wave detectors, high resolution telescopes, planetary gravity measurements, and ultra-stable platform applications.

Planned for launch in late 2015.

Science Instruments

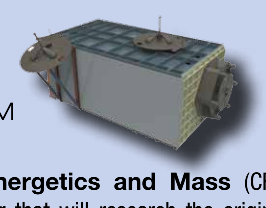
DRS is needed to measure the effects of gravity 10,000 times better than before.

- Eight microthrusters accelerate drops of liquid in an electric field to exert up to 30 micronewtons thrust.
- An attitude control system that uses measurements of the position of a free-flying test mass in the ESA payload and applies forces to the spacecraft to resist external disturbances.

LISA Pathfinder Satellite

Credit: ESA – D. Ducros, 2010

CREAM



CREAM

Cosmic Ray Energetics and Mass (CREAM) is a cosmic ray particle detector that will research the origin, acceleration, and propagation of cosmic ray particles. CREAM is planned as an externally attached payload on ISS JEM Exposed Facility.

Planned for launch in 2016.

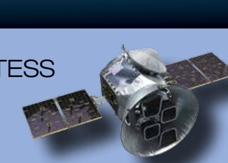
CREAM will measure cosmic ray particles in the 10^{12} to 10^{15} eV energy range. CREAM will include:

- Tungsten/scintillating-fiber calorimeter
- Silicon Charge Detector
- Top and bottom Counting Detectors
- Boronated Scintillator Detector

TESS

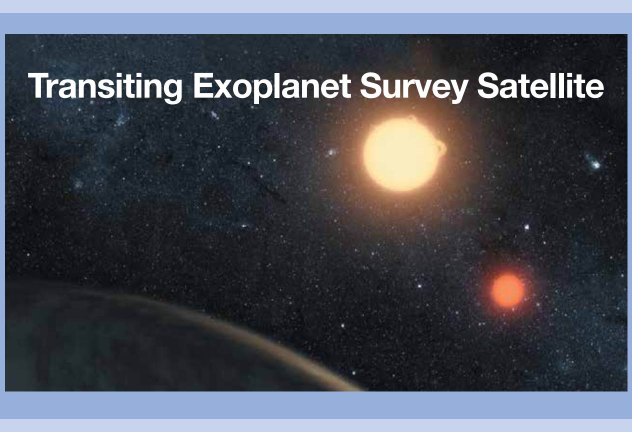
Mission Overview

TESS



Transiting Exoplanet Survey Satellite (TESS) will search for transiting planets around nearby bright stars in the sky with an emphasis on discovering Earth-sized and Super-Earth-sized planets in the solar neighborhood.

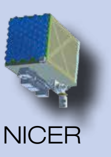
Launching no later than 2018.



Science Instruments

TESS science operations will be accomplished with 4 CCD cameras with wide fields of view (24° by 24°) operating in the visible-IR spectrum 0.6–1.0 μm.

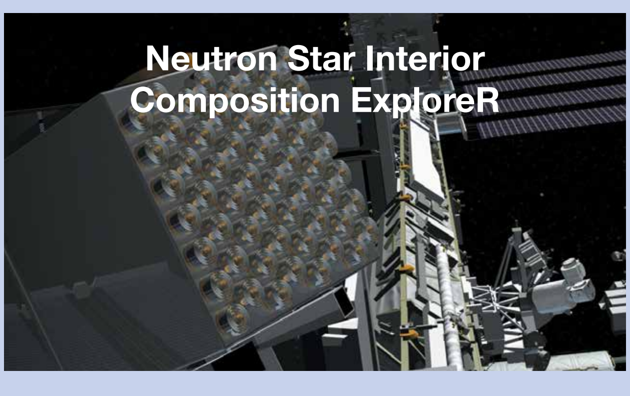
NICER



NICER

The **Neutron Star Interior Composition ExploreR** (NICER) is an X-ray astrophysics Mission of Opportunity that will reveal the inner workings of neutron stars. NICER will achieve this objective by deploying a high-heritage instrument as an attached payload on a zenith-side ExPRESS Logistics Carrier (ELC) aboard the International Space Station. Using data collected from the NICER mission, a technology demonstration initiative, the Station Explorer for X-ray Timing and Navigation (SEXTANT) provides high bandwidth communications and advanced navigation capabilities that will enable future deep space exploration.

Launching no later than 2017.



NICER will carry the X-ray Timing Instrument (XTI), operating in the energy range 0.2-12 keV. The heart of the XTI is an aligned collection of 56 X-ray concentrator (XRC) optic/silicon drift detector (SDD) pairs. Each XRC collects photons from a large area over a 20 $arcmin^2$ patch of sky, and focuses them onto a small SDD. The SDDs detect individual X-ray photons, recording their energies and times of arrival to high precision. Together, this assemblage of mature technologies provides a photon counting capability with large effective area (more than 2000 cm^2), high time resolution (better than 300 nsec), moderate (<3%) energy resolution, and low background.