Astronomy Satellites

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Why Space Astronomy?

- SHARPER PICTURES (Spatial Resolution)

  The Earth's atmosphere messes up the light coming in (stars twinkle, etc).

- TECHNICOLOR (X-ray, infrared, etc)

  The atmosphere also absorbs light of different wavelengths (colors) outside the visible range. X-ray astronomy is impossible from the Earth's surface.

What are the differences between satellite instruments?

- Focussing optics or bare detectors
- Wavelength or energy range - IR, UV, etc. Different technology used for different wavebands.
- Spatial Resolution (how sharp a picture?)
- Spatial Field of View (how large a piece of sky?)
- Spectral Resolution (can it tell photons of different energies apart?)
- Spectral Field of View (bandwidth)
- Sensitivity
- Pointing Accuracy
- Lifetime
- Orbit (hence operating efficiency, background, etc.)
- Scan or Point

What are the differences between satellites?

- Spinning or 3-axis pointing (older satellites spun around a fixed axis, precession let them eventually see different parts of the sky)
- Fixed or movable solar arrays (fixed arrays mean the spacecraft has to point near the plane perpendicular to the solar-satellite vector)

- Low or high orbit (low orbit has higher radiation, atmospheric drag, and more Earth occultation; high orbit has slower precession and no refurbishment opportunity)
- Propulsion to raise orbit?
- Other consumables (proportional counter gas, attitude control gas, liquid helium coolant)

What are the differences in operation?

- PI mission vs. GO mission

  PI = Principal Investigator. One of the people responsible for building the satellite. Nowadays often referred to as IPIs (Instrument PIs).

  GO = Guest Observer. Someone who just want to use the satellite. (Confusingly. the GO is the PI on his or her own grant, which is different from being a PI on the mission).

  A 'PI mission' is one in which the PIs get all the observing time. A 'GO mission' is one in which the GOs get most of the time. The PIs are guaranteed some fraction of the time (and are GTOs, Guaranteed Time Observers) as a reward for the decades of work invested in building it.

  The first GO missions were IUE and Einstein. Nowadays all big missions are GO missions (ASCA, AXAF, HST) but some smaller ones (COBE, Alexis) are PI missions.

- Sky Survey vs. Observatory

  Some missions scan the whole sky, cataloging every source they can see. Other missions are pointed at specific targets which are already known to be there (because they were discovered in a sky survey).

Who launches astronomy satellites?

There are three main players:

- NASA, the US National Aeronautics and Space Administration
- ESA, the European Space Agency,
- ISAS, the Japanese Institute of Space and Astronautical Sciences.

  There are a number of other agencies which occasionally launch astronomy satellites:

- The US Air Force and the US Navy
- IKI (The Institute for Space Exploration of the Russian Academy of Sciences)
- The Indian Space Research Organization
- Individual European nations (Italy; Germany; Denmark; formerly, England and France)
- Argentina and Israel also have plans.

Solar physics in space

I won't cover this topic, nor will I touch on planetary astronomy.

The key astronomy satellites to know

HEAO-1	1977-79	Hard X-ray sky survey
IUE	1978-*	Ultraviolet spectroscopy
Einstein	1978-81	Soft X-ray observatory
IRAS	1983	Infrared sky survey
HST	1990-*	Ultraviolet observatory
ROSAT	1990-*	Soft X-ray sky survey and observatory
CGRO	1991-*	Gamma ray observatory
Asuka (ASCA)	1993-*	Hard X-ray observatory
ISO	1995?	Infrared observatory
AXAF	1998?	X-ray observatory

Satellite	Data Center	Software package
IRAS	IPAC	IRSKY
IUE	GSFC	IDL/RDAF
Einstein	SAO	IRAF/PROS
Rosat	GSFC	IRAF/PROS
HST	STScI	IRAF/STSDAS

Radio astronomy from space

Very low frequency radio waves are only detectable from space. Radio Astronomy Explorer 1 (1968) discovered that even in orbit there's a lot of terrestrial interference. Radio Astronomy Explorer 2 (1973) hid behind the moon.

High frequency (C-band) radio waves can be detected from the ground, but you need a large telescope, or a pair of telescopes a long way apart. Space offers the possibility of putting a pair of telescopes a VERY long way apart. Early experiments were KRT-10 (Soviet Union, 1979) and TDRS-1 (NASA/JPL, 1991). Lots of future plans but no hardware built yet.

Millimetre wave astronomy

The only significant flight to date is COBE (NASA, 1989-92), a specialized mission which did a sky survey with very high sensitivity and accuracy, but very low spatial resolution (7 degrees). It studied the microwave background radiation. An earlier Soviet mission (Prognoz-9/Relikt) returned some limited results.

Infrared astronomy

A lot of progress was made with suborbital rocket flights (USAF, 1966-76). A classified survey was made in 1971 by P70-1 (USAF). The first real IR mission was IRAS (NASA, UK, Holland, 1983), which did a sky survey from 12 to 100 microns with low spectral resolution and a spatial resolution of about 5 arcminutes. Next comes ISO (ESA, 1995) which will be a pointed observatory with very high spectral resolution (and improved spatial resolution at the shorter (2-20 micron) wavelengths). ISO will last only 18 months before its helium runs out. NASA has long planned the SIRTF observatory (NASA, 2000+?) which would have spatial resolution of a few arcseconds. ESA is studying a proposal called EDISON which would be a longer lasting observatory.

Optical and Ultraviolet astronomy

The 5E-5 satellite (US Navy, 1964) and Kosmos-51 (USSR, 1964) made early measurements of the UV background. OAO 2 (NASA, 1968-73) was the first successful space astronomy satellite with a 40cm telescope. It took ultraviolet spectra of bright stars and comets. OAO 3, renamed Copernicus (NASA, 1972-1980) studied the ultraviolet spectrum of the interstellar medium with a 1m telescope. ANS (Netherlands, 1974-77) and TD-1A (Europe, 1972) made ultraviolet star catalogs.

The breakthrough mission was IUE (NASA, UK, and ESA, 1978 - still going), a small 45cm telescope with a pair of spectrographs placed in geostationary orbit. It had the sensitivity to take spectra of faint objects, and has been used to study every kind of astronomical object. A similar Soviet observatory, Astron (IKI, 1983) with an 80cm telescope did not publish many results.

Hipparcos (1989-92) was a specialized mission which made an accurate star catalog.

The Hubble Space Telescope (HST) (NASA and ESA, 1990 to present) is a 2.4 metre telescope with four instruments: WF/PC2, the Wide Field and Planetary Camera II, for pictures in the optical; FOC/COSTAR, the Faint Object Camera for pictures in the ultraviolet; GHRS/COSTAR, the Goddard High Resolution Spectrograph for very high resolution UV spectra of relatively bright objects; and FOS/COSTAR, the Faint Object Spectrograph for lower resolution UV spectra of fainter objects.

The STIS (Space Telescope Imaging Spectrograph) is due to be added to HST at the end of the decade.

Extreme Ultraviolet

Apollo-Soyuz (NASA, 1975) carried an EUV experiment which detected the white dwarf star HZ43. ASTRO-1 (NASA, 1990) spent a week in space studying the UV and extreme UV.

The WFC (Wide Field Camera, UK 1990-91) telescope on ROSAT made the first EUV sky survey. This was followed up by the EUVE (Extreme Ultraviolet Explorer, NASA 1992- present) which also has a spectrograph.

Hard X-ray

The first X-ray star was discovered by a rocket flight (USAF, 1962). The same astronomers who developed the rocket later built Small Astronomical Satellite 1, SAS 1 which was called Uhuru after launch (NASA, 1970-72). This did a sky survey with a spatial resolution of several degrees (3U and 4U catalogs). This group became the CfA High Energy Division. The MIT group did another survey on Orbiting Solar Observatory 7 (NASA, 1971-73) generating the 1M and MX catalogs. A third survey was done by Ariel 5 (UK, 1974), the 3A catalog. More sensitive surveys were then done, led by the NRL and Goddard groups, with HEAO-1 (NASA, 1977-79). There were a number of other smaller missions (ANS, SAS 3, etc). The European EXOSAT satellite (1983-1986) was a pointed mission which studied the spectra of sources in more detail.

In the 1980s the Japanese took over with more pointed missions: Tenma/ASTRO-B (ISAS, 1983) and Ginga/ASTRO-C (ISAS, 1987-1991). Ginga had higher spectral resolution than previous flights. These missions still had lousy spatial resolution.

In 1990 the BBXRT (NASA) flew for a week on the Shuttle; it had a foil mirror telescope and much higher spectral resolution. Finally, Asuka (ASCA, ASTRO-D) (ISAS, 1993-present) used foil telescopes and a CCD detector to combine fair imaging (few arcmin) quality and very high spectral resolution in a GO observatory. Granat (IKI/France, 1989-present) studies very hard x-rays.

AXAF (NASA, 1998) will have much higher (1 arcsec) spatial resolution and even better spectral resolution. XTE (NASA, 1996) will be specialized for the study of rapidly time variable x-ray sources. Other planned missions include Spektr-RG (IKI, 1996?) and XMM (ESA, 2000?) which will both be imaging x-ray telescopes.

Soft X-ray

There were a few soft x-ray detectors on earlier satellites (ANS, Netherlands 1974) but the breakthrough mission was Einstein (NASA, 1978-81). It had the first imaging x-ray telescope (not counting solar ones) and made 10000 pointings at celestial targets. Its spatial resolution was 3 arcmin in the Imaging Proportional Counter (IPC) which also had weak energy resolution; the High Resolution Imager (HRI) could take pictures with a resolution of a few arcseconds, but the sensitivity wasn't that great. Exosat (ESA, 1983-86) also carried a soft x-ray telescope. ROSAT (Germany/NASA, 1990- present) is similar to Einstein but significantly improved in both spatial and spectral resolution. It carries two similar instruments, but the "IPC" on ROSAT is called PSPC.

AXAF (NASA, 1998) will combine better spatial resolution than the ROSAT HRI with better spectral resolution than the Asuka SIS and will blow all previous x-ray satellites out of orbit (metaphorically speaking). It will carry two main instruments, ACIS (a CCD, successor to the ASCA SIS) and HRC (successor to the ROSAT HRI). There will also be grating spectrometers for very high spectral resolution. The AXAF telescope will give subarcsecond spatial resolution.

Gamma Ray

Vela 5A (USAF, 1969) was looking for nuclear explosions in Russia and China. It found them in the sky instead. The bright gamma ray burst sources were studied by a number of spacecraft, notably the Russian Venera Venus probes and NASA's ISEE 3 satellite.

Steady gamma ray sources were first studied by SAS 2 (NASA, 1972) and above all by COS-B (ESA, 1975-1980). The 2CG catalog from COS-B had 25 sources.

The breakthrough mission in gamma ray astronomy is the Compton Observatory (NASA, 1991-present). It carries 4 experiments - BATSE, for the gamma ray bursts; OSSE and Comptel for medium energy gamma rays, and EGRET for high energy gamma rays.

ESA is studying a follow on mission called INTEGRAL.