INES

IUE Newly Extracted Spectra

The IUE Project

The International Ultraviolet Explorer satellite (IUE) was a joint project between **NASA**, **ESA** and **PPARC** (formerly SERC). IUE has been the most productive astronomical telescope ever: its 18.7 years of operations returned 104470 high- and low-resolution images of 9600 astronomical sources from all classes of celestial objects in the 1150-3350 Å UV band.

IUE was a trilateral project, in which NASA provided the spacecraft, telescope, spectrographs and one ground observatory, ESA the solar panels and the second observatory, and the UK the four spectrograph detectors. In addition to controlling the satellite, the ground sites acted as typical astronomical observatories, except that the telescope hovered far out in space. ESA's 'IUE Observatory' was established in 1977 at the Villafranca Satellite Tracking Station (**VILSPA**), Villanueva de la Canada, Madrid, Spain. The NASA IUE Observatory was located in Goddard Space Flight Centre (**GSFC**) in Greenbelt (Md.). The satellite was launched into geosynchronous orbit on January 26 1978 from Kennedy Space Centre.

During IUE's life, more than 1000 European observing programmes were conducted from Villafranca, returning more than 30000 spectra from about 9000 targets, extending from Comets to far away quasars at the early days of the Universe and covering a brightness range of 10 orders of magnitude (extending from M_V=-4 to M_V=21).

IUE was the first scientific satellite that allowed 'visiting' astronomers to make real time observations of UV spectra: the impressive response time of less than one hour provided an unparalleled flexibility in scheduling targets of opportunity. This has given rise to the concept of Multi-wavelength Astrophysics, where observations with instruments on the ground and in space are co-ordinated to obtain simultaneous measurements over a wide range of the electromagnetic spectrum. The flexibility of IUE demonstrated for the first time the power of such diagnostic tools in astrophysics. IUE provided astronomers with a unique tool and requests for observing time remained two-three times greater than could be satisfied, even at the end of orbital operations.

During its lifetime IUE greatly surpassed the expectations of the original science goals set to justify the mission:

- To obtain high-resolution spectra of stars of all spectral types to determine their physical characteristics;
- To study gas streams in and around binary star system;
- To observe faint stars, galaxies and quasars at low resolution, interpreting these spectra by reference to high-resolution spectra.
- To observe the spectra of planets and comets.
- To make repeated observations of objects with variable spectra.
- To study the modification of starlight caused by interstellar dust and gas.

IUE's only serious problems stemmed from the failures of five (1979, 1982, 1982, 1985, 1991, 1996) of the six gyros in its attitude control system. When the fourth failed in 1985, IUE continued operations thanks to an innovative reworking of its attitude control system by using the fine Sun sensor as a substitute. Even with another lost in the last year, IUE could still be stabilized in 3-axes, with only one single gyroscope, by adding star tracker measurements.

Until October 1995, IUE was in continuous operation, controlled 16 h daily from GSFC and 8 h from VILSPA. After that, ESA took on a major role to alleviate financial problems of the partners. The operational schemes were completely redesigned and an innovative control system was implemented. With these innovations it became feasible to do science operations fully controlled from VILSPA. For practical reasons, only 16 hours were used for scientific operations, with 8 hours -in the low quality part of the orbit- were used for spacecraft housekeeping. IUE remained operational until its hydrazine was deliberately vented, its batteries drained and its transmitter turned off on 30 September 1996.

The IUE Scientific Instruments

TELESCOPE : 45 cm, f/15 Ritchey-Chretien Cassegrain

SPECTROGRAPHS : Echelle (1150 Å to 1980 Å and 1800 Å to 3350 Å)

APERTURES : 3"; and 10" by 20"; image quality 2"

RESOLUTION :

High dispersion:

- 1.8 10^4 corresponding to 0.08 Å at 1400 Å (17 km sec^{-1})
- 1.3 10^4 corresponding to 0.17 Å at 2600 Å (20 km sec^{-1})

Low dispersion:

- 270 at 1500 Å
- 400 at 2700 Å

CAMERAS:

SWP (1150-1980 Å) : sensitivity: 2 10^{-15} erg sec^{-1} cm^{-2} $Å^{-1}$

LWP (1850-3350 Å) : sensitivity: 1 10^{-15} erg sec^{-1} cm^{-2} $Å^{-1}$

LWR (1850-3350 Å) : sensitivity: 2 10^{-15} erg sec^{-1} cm^{-2} $Å^{-1}$

SWR : Never operational

FES #1 : Fine-Error-Sensor #1 not used in operations.

FES #2 : Fine-Error-Sensor #2 was always been used for fine guidance throughout the mission. It has also been important as a photometer to measure the optical brightness of the sources observed. In 1991 scattered light entering the Telescope required a revision of guidance procedures and affected its photometric performance.

The IUE Archive (/ines/)

With more than 250 Ph.D dissertations world-wide using data from the IUE Project, the project has played an important role in the formation of a complete generation of Astronomers. From launch to 1998 3585 publications have been published in the refereed scientific literature using IUE results, and currently the IUE Archive is still regularly used and many publications will continue to use the Archival data from IUE.

The 104000 images obtained with IUE were transformed into 111000 spectral files now collected and world-wide accessible through National Hosts with ESA's **INES** system, which is operated for the astronomical community by the **LAEFF**. The IUE Data Archive remains the most heavily used astronomical archive in existence: with 500000 data delivered in archive form and more than 100000 spectra taken, each IUE spectrum has already been used six times.

The IUE Spacecraft

Dimensions: 142 × 422 cm

Launch vehicle/site: Delta 2914, from Cape Canaveral, Florida

Launch mass: 671 kg (122 kg science, 237 kg apogee boost motor)

Orbit: Geo-synchronous over Atlantic: initially 32 050×52 254 km, 28.6º, 23.927 h; at mission end 36 360×48 003 km ,35.9º

Satellite configuration: 1.45 m-diameter hexagonal-prism bus with telescope assembly along main axis, and fixed solar wings extending from opposing faces. Most of the high-power electronics were mounted in the main equipment bay at the base, near the passive thermal louvers, while the experiment electronics and attitude control elements were on the upper equipment platform.

Attitude/orbit control: 3-axis control with 6 Gyroscopes. Spacecraft coarse pointing with three reaction wheels (one spare has never been used in orbit), precision pointing (<1 arcsec. stabilization over 24 hrs.) with Fine Error Sensors (2-axis star trackers using the telescope optics. 0.27 arcsec resolution in 16 arcmin FOV), fine/coarse Sun sensors, and 8×9 N + 4×22 N hydrazine thrusters (27.3 kg hydrazine in 6 tanks) for momentum dumping and orbit adjust.

Power system: 424 W BOL/28 Vdc provided by two fixed 3-panel arrays (210 W required) carrying 4980 2×2 cm Si cells; degraded after 18 yrs. in orbit to 40%; supported by 2×6 Ah nickel cadmium batteries (17 cells each).

Communications/data: 1.25-40 kbit/s 2.25 GHz 6 W S-band (circular polarization) downlink; fixed and reprogrammable formats. 139 MHz VHF for telecommand.

Operations Summary Report: **IUE Spacecraft Operations Final report**. ESA SP-1215, 1997

IUE Highlights

Spacecraft and Operations:

- the first 3 axis stabilized spacecraft with only two functional Gyroscopes
- the first 3 axis stabilized spacecraft with only one functional Gyroscope
- the first telescope in Space used for simultaneous multi-wavelength studies
- the first Space Observatory operated in the manner of ground based observatories with a direct interaction for the visiting scientists

Science:

- the first detection of the existence of an Aurora in Jupiter
- the first detection of sulphur in a Comet
- the first quantitative determination of H_2O (water) loss in a Comet (some 10 tons per second)
- the first evidence for strong magnetic fields in chemically peculiar stars
- the first orbital radial velocity curve for a WR star allowing its mass determination
- the first detection of hot dwarf companions to Cepheid variables
- the first observational evidence for semi-periodic mass loss in high mass stars
- the first discovery of high velocity winds in stars other than the Sun
- the first identification of the progenitor of any supernova in history (Supernova 1987A)
- the discovery of starspots on late type stars through the Doppler mapping techniques
- the discovery of large scale motions in the transition regions of low gravity stars
- the discovery of high temperature effect in stars in the early stages of formation
- the discovery of high velocity winds in cataclysmic variables
- the discovery of the effect of chemical abundance on the mass loss rate of stars
- the first determination of a temperature and density gradient in a stellar corona outside the Sun
- the first detection of gas streams within and outflowing from close binary stars.
- the determination that no nova ejects material with Solar abundance.
- the discovery of the "O-Ne-Mg" novae, where the excess of these elements can be directly traced to the chemical composition of the most massive white dwarfs
- the discovery of a ring around SN 1987A, a leftover from previous evolutionary stages
- the first direct detection of galactic halos
- the first observations of extragalactic symbiotic stars
- the first uninterrupted light curves of stars for more than 24 hours continuously
- the first detection of photons at wavelengths less than 50 nm from any astronomical source apart from the Sun
- the first direct determination of the size of the active regions in the nuclei of Seyfert galaxies (mini-quasars)
- the first detection of a transparent sightline to a quasar at high redshift allowing the first abundance determination of the intergalactic medium in the early Universe
- the first astronomical and satellite facility ever, to deliver fully reduced data within 48 hours to the worldwide community of scientists
- the creation of the first the first worldwide astronomical reduced-data archive delivering 44,000 spectra per year (5 spectra per hour) to astronomers in 31 countries

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