2. General spacecraft description.

The IUE spacecraft is shown in mission orbit configuration and in an exploded view in figures 2-1 and 2-2 respectively.

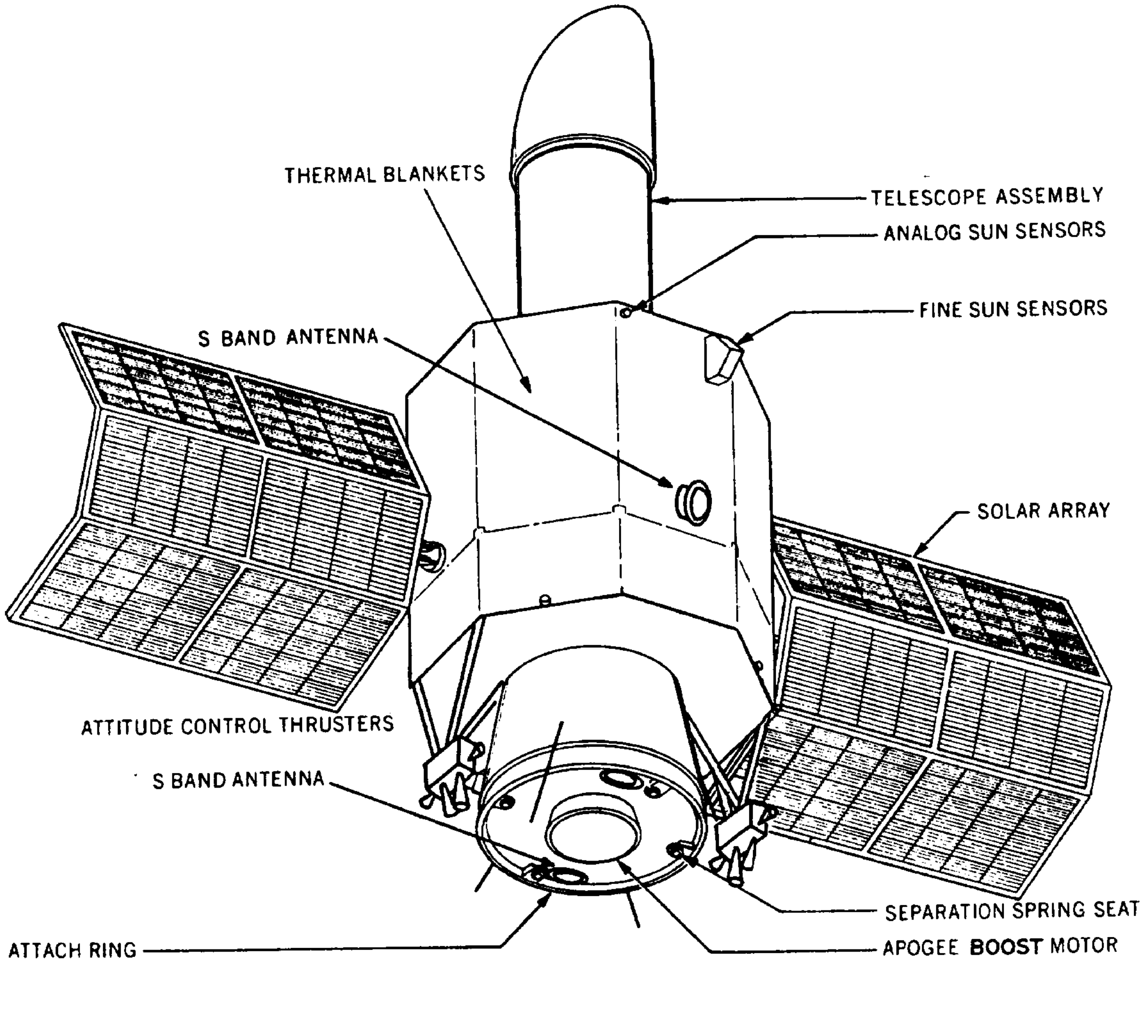

Figure 2-1. IUE Spacecraft in Mission Orbit Configuration.

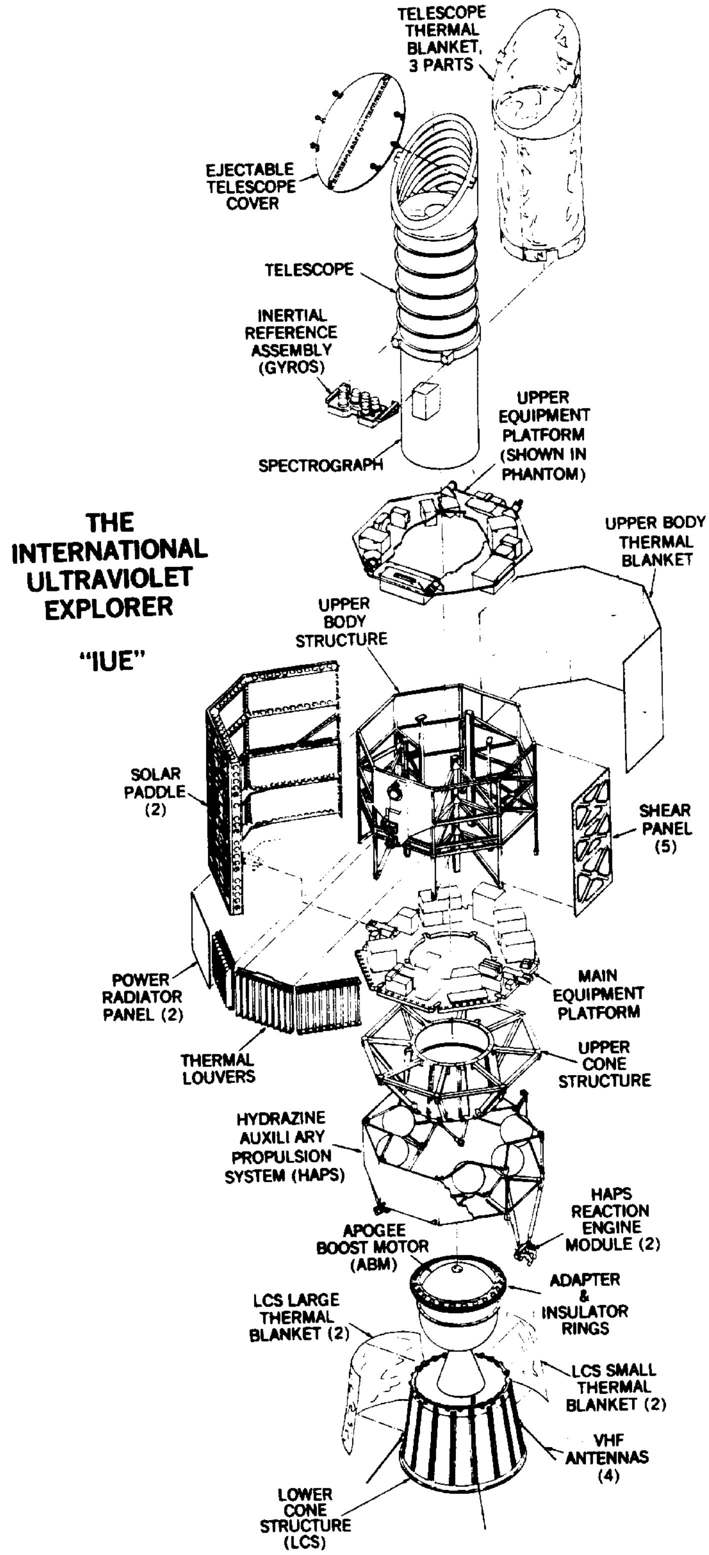

Figure 2-2. IUE Exploded View.

The spacecraft's main body is octagonal in shape; and its fixed solar arrays extend outward from two opposite sides. In mission orbit, the attitude control system maintains the spacecraft orientation such that the front of the solar arrays always face toward the Sun and thermal louvers face away from the Sun. Thermal louvers, thermal blankets, heat pipes mounted to the underside of the main equipment platform, and heaters within the spacecraft main body and scientific instrument provided thermal control and maintained temperatures within acceptable ranges.

The apogee boost motor used to insert the spacecraft from transfer orbit into synchronous orbit and the hydrazine auxiliary propulsion system are both located in the lower cone assembly. The hydrazine auxiliary propulsion system was required for nutation control, precession, and despin during the transfer orbit operations and was used for Sun acquisition, reaction wheel momentum unloading, station acquisition, and east-west station keeping during the mission orbit. The hydrazine system consists of tanks, plumbing, thruster assemblies, valves, heaters, and supporting structure. The composite of this hardware forms an integrated, self contained unit.

The majority of the higher power electronics equipment is located on the main equipment platform within the main spacecraft body and adjacent to the louvers, while the experiment electronics, the attitude control reaction wheels, gyro electronics, and Sun sensor electronics are located on the spacecraft upper equipment platform.

The Scientific Instrument, consisting of the telescope and spectrograph, is mounted to the spacecraft structure by means of a strong ring. The strong ring rests on three columns which carry the load to the lower spacecraft structure and these columns are supported laterally by truss members of the main body structure.

An inertial reference assembly is mounted directly to the strong ring to simplify alignment and to minimize relative motion between the inertial reference sensor and the scientific instrument. This arrangement permitted alignment of the scientific instrument and the inertial reference assembly as an integral unit and it assures maximum precision with regard to pointing the telescope.

The inertial reference assembly was the primary rate and position sensor for the attitude control subsystem and it provided the spacecraft with position stability on the order of a fraction of an arc-second. Fine error sensors and fine Sun sensors afford the inertial reference a drift trim and highly accurate position reference capability. The fine error sensors are in fact two axis star trackers that are mounted within the spectrograph along with the vidicon cameras that were used to store the spectral images. The importance of the fine Sun sensor and the fine error sensor increased along the mission. The Two-Gyro/FSS system used the fine Sun sensor in combination with the two remaining gyros to provide three axis control. In a similar way, the One-Gyro system provided a course spacecraft stabilization using the fine Sun sensor and the last gyro, and, a fine control, adding the fine error sensor measurements.

The spacecraft characteristics are summarized in the next table.

Characteristics	Description
Spacecraft Weight	312 Kg
Scientific Instrument Weight	122 Kg
Apogee Motor Weight	237 Kg
Launch Vehicle Adapter Weight	29 Kg
Total Launch Weight	700 Kg
Launch Vehicle	Delta 2914
Life	3 - 5 years
Orbit (Mission)	Elliptical Geosynchronous (28.6° inclination)
Power Required (Spacecraft & Experimentation)	210 watts average
Array Capability (Beginning of Life)	424 watts at beta equal to 67.5° 238 watts at beta equal to 0° and 135°
Batteries (2)	6 ampere-hour NiCad (17 cells each)
Telemetry Bit Rate	1.25 Kbits/sec to 40 Kbits/sec with fixed and reprogrammable formats
Command	PCM/FSK/AM, 800 bits/sec
Stabilization and Control	Spinning during transfer orbit, 3 axis stabilized with better than 1 arc-second control for mission orbit.

Spacecraft subsystems.

The major subsystems that are required to support the operation of the scientific instrument as well as the spacecraft itself include the power, communications, command and data handling, and stabilization and control subsystem.

The figure 2-3 is an overall system block diagram. Duplication is used extensively to ensure long term reliability.

In the discussion that follows, each of the major spacecraft subsystems is described. More details about each subsystem are given in section 5, where the technical characteristics are explained, as well as the evolution of the mission and the anomalies experienced.

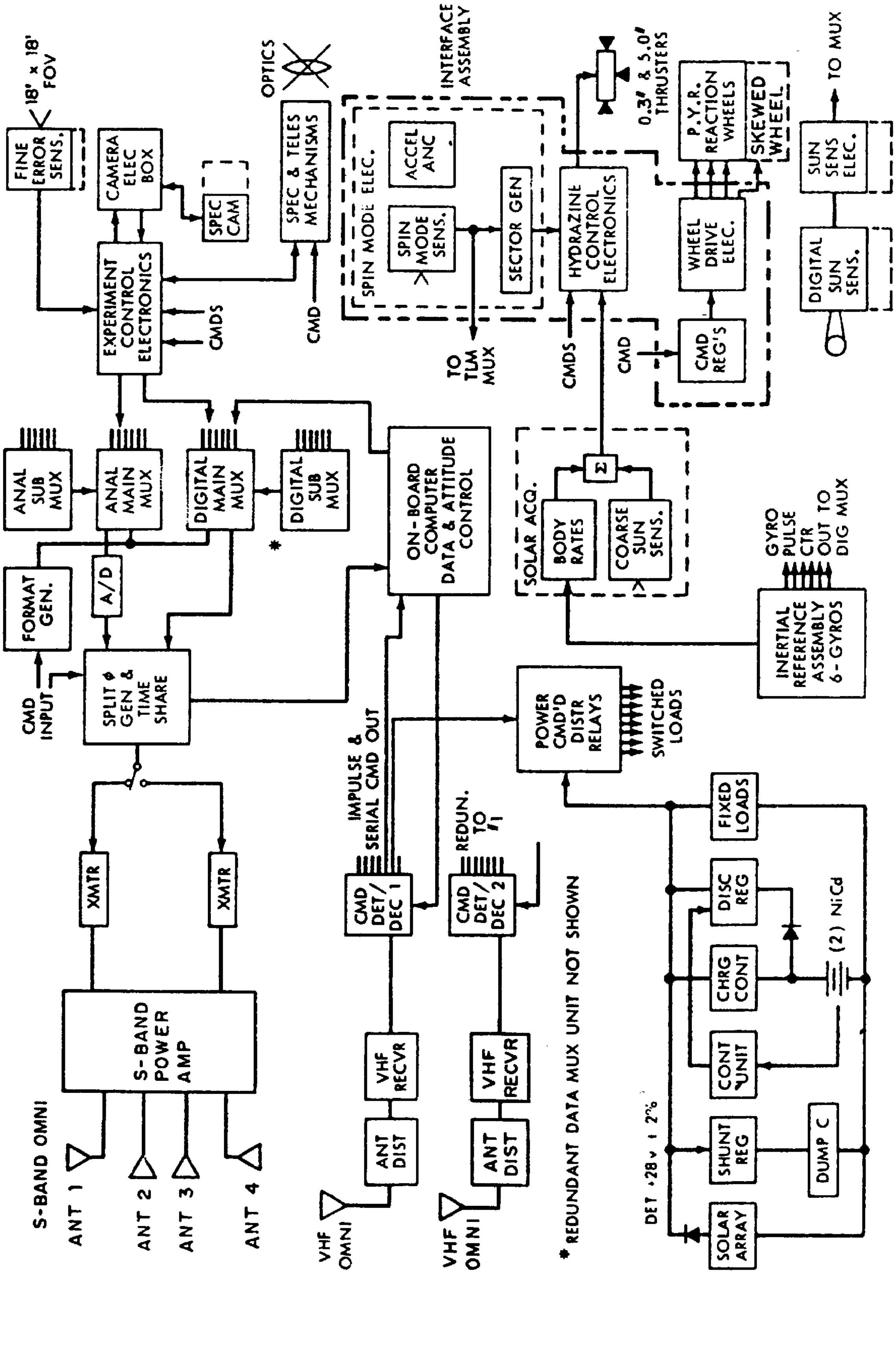

Figure 2-3. IUE System Block Diagram.

Power was provided by two solar arrays and a highly efficient distribution and regulating system. During eclipse, and other periods when demand exceeds solar array output, power was provided through a boost regulator from two 6 ampere-hour nickel-cadmium batteries.

The communications subsystem consists of VHF transponders, S-band transmitters, RF amplifiers and antennas. The characteristics of the VHF and the S-band systems are summarized in the next table.

	VHF	S-band
Transmitter frequency	138.860 MHZ	2249.80 MHZ
Power output	6 Watts.	6 Watts.
Modulation	PCM/FSK/AM	PM
Telemetry rate	800 bits/sec	1.25 Kbits/sec to 40 Kbits/sec with fixed and reprogrammable formats
Antenna polarization	Turnstile	Circular
Antenna pattern	Omnidirectional	60° conical
Receiver frequency	148.980 MHZ	-
Receiver sensitivity	-106 dBm	-

The S-band system was used only for transmission of telemetry data. The two transmitters can be connected to any of four power amplifier antenna combinations, but only one transmitter and one power amplifier may be selected at any one time and this will depend on which antenna has the most favourable view of the Earth. The VHF system consists of duplicate transponders and a four-element turnstile antenna and was used for the reception of ground generated commands, the turn-around transmission of range and range-rate signals for tracking the spacecraft, and also to provide a backup telemetry down-link.

Commands initiated by the onboard computer or received directly from the ground are all processed by the two command decoders.

The data handling system is composed of the data multiplexer and the onboard computer. The data multiplexer serves as the spacecraft telemetry encoder and as the input data interface between the onboard computer and the rest of the spacecraft. 8-bit words are transferred to a serial data stream which is alternately made available to the ground and to the onboard computer using time sharing techniques. The telemetry bit rate was selectable by ground command from 1.25 to 40 Kbits/sec.

The onboard computer performed all attitude control computations and issued all reaction wheel torquing commands. It performed self-checks, monitored spacecraft performance safety functions, controlled camera exposure times and stored commands.

The stabilization and control system was used in orbital maneuvers which include station keeping, pointing, and maneuvering of the spacecraft. It has three different reference systems:

- Six gas-bearing, pulse rebalanced, inertial-grade gyroscopes providing 0.01 arcseconds integrated rate resolution over 600 arcseconds per second.

- Star trackers (the FESs) in the scientific instrument which use the telescope optics to provide an angular resolution of 0.27 arcseconds throughout a 16 arcminutes field-of -view. Comet Hyakutake as seen by IUE's FES is displayed in figure 2-4.

- A two axis digital Sun sensor (FSS) which provides angular resolution to 15 arcseconds over a field-of-view of 64° x 124°.

When a bright star is within 9 arcminutes of the target source, the guidance system used the FES for position information and the gyro system for rate damping. When a guide star was not available, precision-hold depended solely on a well-trimmed gyro reference with low frequency updates from the target or other source. The One-Gyro system always needed the FES to provide fine control.

The control system used a set of momentum exchange reaction wheels for attitude control and relied on the hydrazine thrusters for momentum dumping.

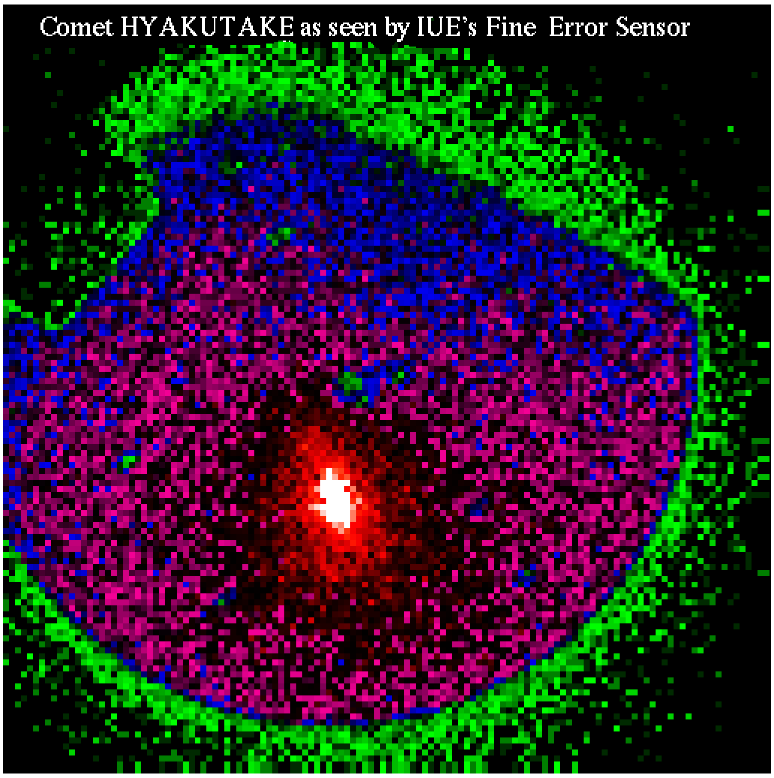

Figure 2-4. Hyakutake FES image (March 26, 1996).

The active thermal control system used louvres, insulation, heat pipes and heaters. Multi-nodal analysis of a thermal model and solar simulation tests were used to prove the design. The spacecraft may be divided into five sections, each with unique thermal requirements: the hydrazine bay, the main spacecraft compartment, the telescope, the spectrograph and the solar arrays.

Ground observatory control systems.

Unlike previous unmanned astronomy spacecraft, IUE was operated in real-time by guest observers who generally lacked detailed knowledge of the complex spacecraft and ground systems. Ground operating procedures were, therefore, designed to allow the observer's research programme to be accomplished by selection from a library of modular preprogrammed operating sequences.

IUE ground control was based on a large real-time computer software system to process telemetry and commands. Relatively complex spacecraft operations were accomplished by calling a series of operating procedures, each designed to accomplish a particular function, such as reading an image from a camera. Procedure execution was controlled by trained spacecraft controllers. A computerized image processing system was then run offline to correct the astronomical images and produce a spectrum in absolute units as a function of wavelength. The processing sequence consisted of geometric and photometric correction, wavelength identification, data extraction and system efficiency correction and used calibration tables derived from period analysis of calibration images.

The next figures shows the last IUE images taken on September 27, 1996, and their extracted spectrum.

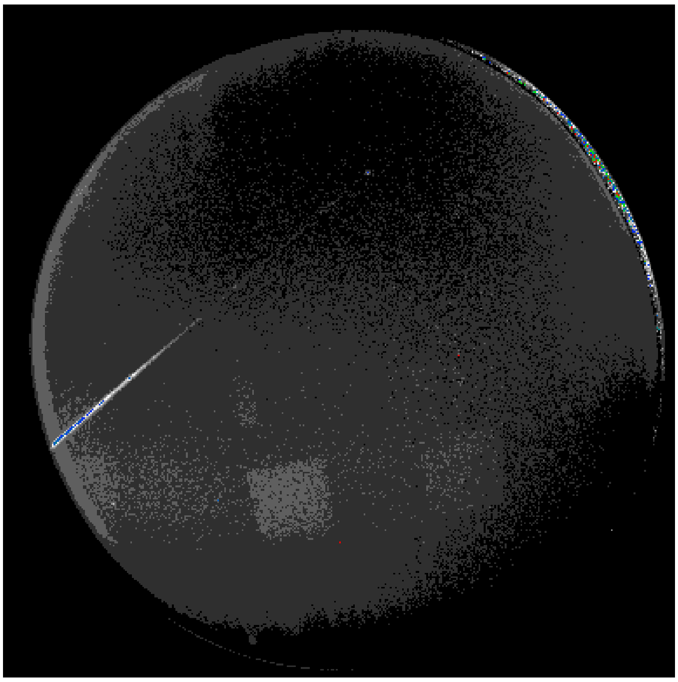

Figure 2-5. SWP 58388 raw image.

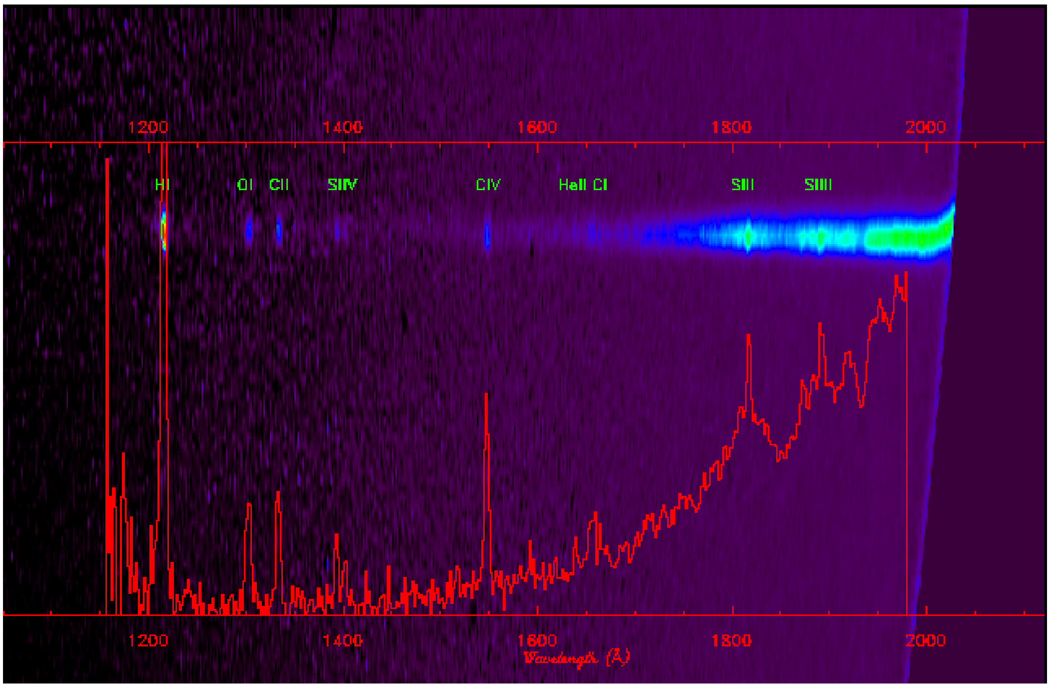

Figure 2-6. SWP 58388 extracted spectrum.

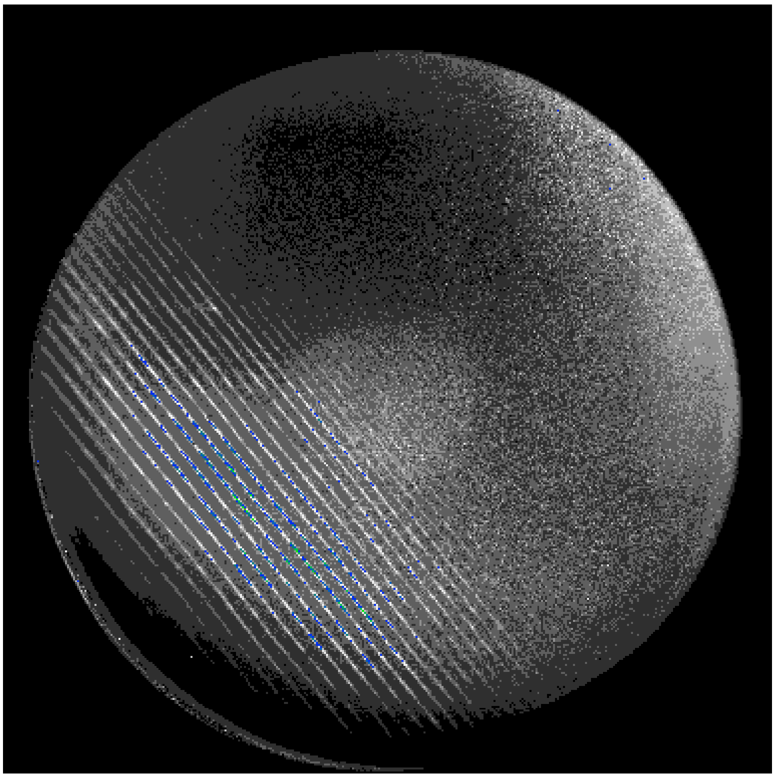

Figure 2-7. LWP 32696 raw image.

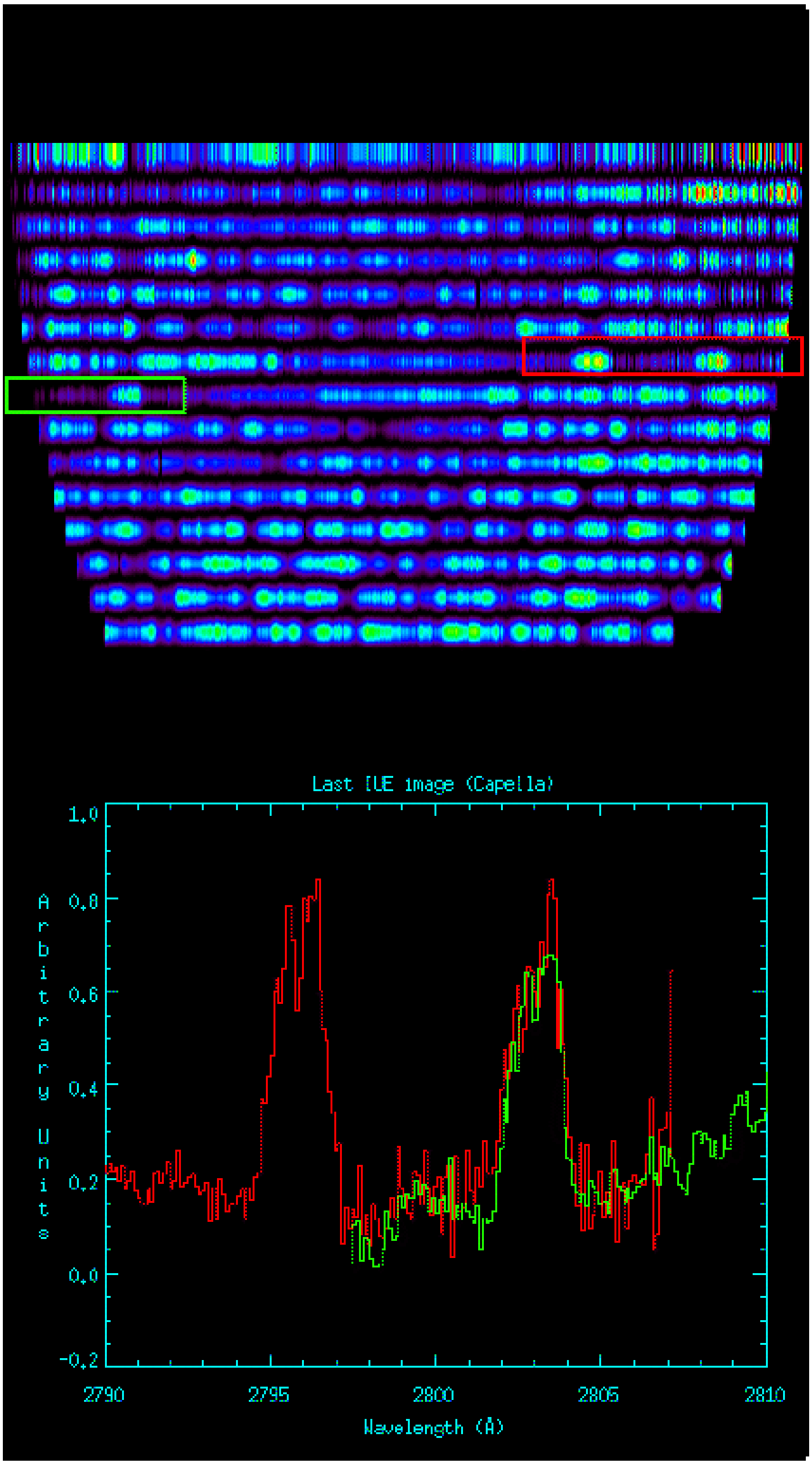

Figure 2-8. LWP 32696 extracted spectrum.