THE SPECTRUM-UV PROJECT

THE SPECTRUM-UV TEAM

Abstract. The Ultra-Violet Space Telescope "SPECTRUM-UV" consists of a 170-cm diffraction limited telescope for spectroscopy and imaging at $\lambda \geq 912$ Å and a co-aligned assembly of two 50-cm telescopes for imaging and spectroscopy in the 400 to 1200 Å range and of four 20-cm, multilayer coated telescopes for narrow band imaging in the 100 to 400 Å range. The Observatory is an international facility to be launched in a highly eccentric orbit in the mid-1990s.

1. Project Outline

The SPECTRUM-UV mission, recently approved by the Academy of Sciences of the U.S.S.R., is an international orbiting observatory aimed for spectroscopy and imaging in the UV, EUV and XUV domains. It will be launched in the mid-1990s in a highly eccentric orbit with period 4 to 7 days, as to allow long (up to 24 hours), uninterrupted exposures.

The instrument complement will consist of:

- a 170-cm telescope (T-170) for both high and low dispersion spectroscopy and for wide field, broad band imaging in the 1150 to 3500 Å range. Medium dispersion spectroscopy will be extended to the 912 to 1150 Å region where, in spite of the low normal-incidence reflectivity, an accurate control of the thickness of the overcoating layers and the large collecting surface can provide a sizable effective area.
- two iridium (or SiC) coated 50-cm telescopes for, respectively, imaging and low resolution ($\Re \approx 20$) spectroscopy in the 400 to 1200 Å range.
- four multilayer coated 20-cm telescopes (T-20) for narrow band imaging in the 100 to 400 Å interval.

A $\simeq 2.5$ arcsec stability of the spacecraft will be provided on three axis. For the main T-170 telescope, a $\simeq 0.1$ arcsec pointing and tracking performance will be obtained by tilting the secondary mirror around the neutral point. A Fine Guidance System (FGS) will control the actuators of the secondary mirror.

A *real time observatory* concept is adopted as a baseline. A backup automated operating mode is also provided in case of unavailability of the link through the Deep Space Network. The ground segment will be kept as close as possible to that of other missions like the NASA/ESA/SRC International Ultraviolet Explorer and the INTERCOSMOS Astron: a Mission Operation Center will bear the overall responsibility of all spacecraft related tasks, while a Science Operation Center, under direct control of the USSR Academy of Sciences, will be responsible for the scientific exploitation of the mission, and, in particular, of the operational mode, scientific data flow, pointing and tracking.

Y. Kondo (ed.), Observatories in Earth Orbit and Beyond, 185–190.

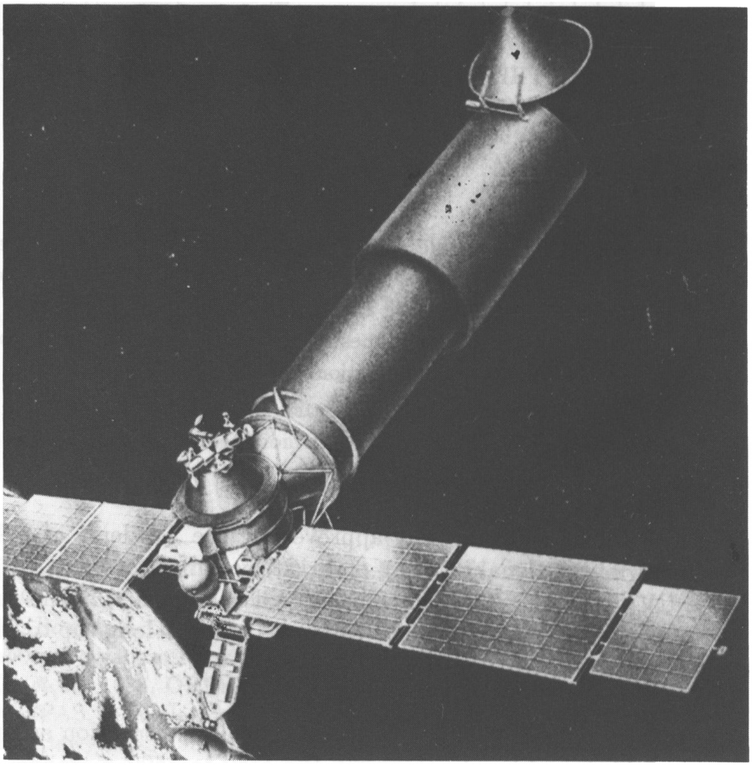


Fig. 1. SPECTRUM-UV concept.

A feasibility study of the Project is being carried out by an international Team which includes scientists from Bulgaria, Canada, Czechoslovakia, East Germany, Italy and the USSR.

2. The T-170 telescope

The T-170 telescope is in the Ritchey-Chrétien configuration with a primary mirror diameter of 170 cm and an equivalent focal length of 17.0 m. The main parameters are given in Table I.

The primary mirror consists of a thin (10 cm) meniscus of equal thickness, with a 58 cm central hole. The hyperbolic secondary is at 3.5 m from the primary apex and can be rotated on two axis around the neutral point as to achieve the fine pointing and tracking required, while keeping to a minimum the aberrations due to decentering. Both optical elements will be polished with the ion etching technique, now being implemented at the Crimea Observatory for mirrors up to 3 m diameter.

The on axis overall image quality will be kept close to the diffraction limit over the whole wavelength range with at least 70% of the energy encircled within 1 arcsec over the whole (40 arcmin) f.o.v.

A dual echelle spectrograph ("A" and "B" of Figs. 3 and 5), similar to that

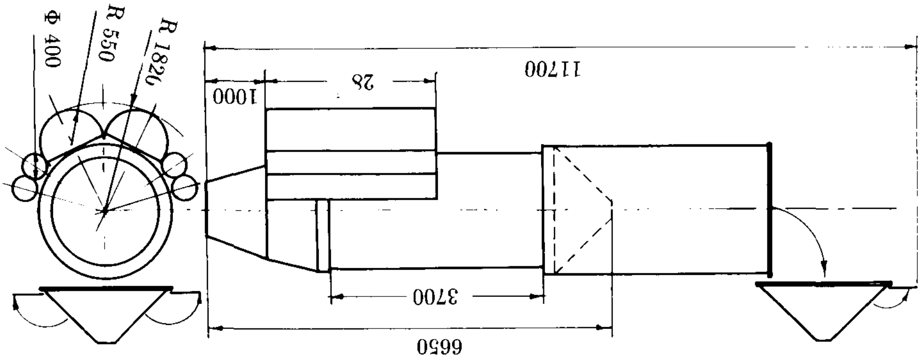


Fig. 2. Telescope assembly layout.

TABLE I
T-170 Telescope Parameters

Primary Mirror	
Diameter	1.7 m
Focal ratio	f/2.8
Curvature	$0.10589 \cdot 10^{-3}$ mm^{-1}
Asphericity	1.0539
Secondary Mirror	
Diameter	0.5 m
Curvature	$-0.29545 \cdot 10^{-3}$ mm^{-1}
Asphericity	3.6829
Overall Parameters	
Equivalent focal length	17 m
Plate scale	12.13 *arcsec*$\cdot$ mm^{-1}
Field of view (2β)	40 arcmin
PSF on axis	diffraction limited
PSF 20 *arcmin* off-axis	1.0 arcsec (70%EE)
Mirrors separation	3500 mm
Focal extraction	900 mm
F.P. Curvature	1270 mm

aboard of IUE, is being designed to achieve high resolving power ($\Re \simeq 4 \times 10^4$) for the 120–190 nm and 190–350 nm intervals.

A low resolution ($\Re \simeq 10^3$) mode can be obtained by inserting a flat mirror in front of the echelle. A second spectrograph ("C" and "D" of Figs. 3 and 56), with turnable gratings in the Rowland mounting, will provide a resolving power $\Re \simeq 10^4$ in the Lyman region and $\Re \simeq 3 \times 10^3$ over the 120–320 nm interval. In both spectrographs the entrance slits open into the flat mirrors of the FGS, to minimize acquisition and tracking problems.

A nebular spectrograph ("E" of Figs. 3 and 5), with a 200×2 arcsec^2 slit, provides $\Re \simeq 10^2$ in the 400 to 900 nm range.

A direct imaging camera with broad band filters in the region 120–300 nm and f.o.v. $\sim$ 6 arcmin will be mounted on-axis. A $\sim$ 16 arcmin f.o.v., off-axis focal reducer in the 190–350 nm range will feed a low resolution imaging camera.

To ensure the full exploitation of the the instrument complement and of the expected mission profile, state-of-the-art detectors will be adopted. Large format CCD with enhanced UV response and with pixel size adequate for optimal sampling of the expected PSF are now becoming available. The low read-out noise (2 to 3 electrons rms) and the high quantum efficiency achievable make them eligible for the imaging cameras. Thermal control to maintain the detector system at the operating temperature ($\sim$ -100 °C) will consist in a thermoelectric cooler connected to large size radiator plates having direct view to space. The detectors in the main spectrographs will all be two-dimensional photon-counting devices, based on microchannel plate (MCP) technology with a serial read out system (e.g. wedge and strip anodes). Detector quantum efficiency as high as 40% can be obtained in the UV and FUV region with KBr and CsI photocathodes.

3. The T-50 and T-20 Telescopes

The following ancillary telescopes will be mounted co-aligned with the T-170 telescope (see Figs. 2 and 4):

– two off-axis paraboloids (T-50), each consisting of a half 80-cm mirror (collecting surface equivalent to a 50 cm diameter mirror) with iridium (or SiC) coating to enhance reflectivity in the $400 \div 1200$ Å range. The "T-50 I" telescope will be equipped with a direct imaging camera to achieve a few arcsec angular resolution over the whole 4 arcmin f.o.v.. The "T-50 S" telescope will be equipped with a very low resolution ($\Re \simeq 20$) grating objective.

– four 20-cm off-axis, f/12.5 paraboloids (T-20) with multilayer coatings to cover four narrow bands $\Delta\lambda/\lambda = 0.05$ in the $100 \div 400$ Å region.

Windowless MCP detectors, in the photon counting mode will be used in the focal plane of these telescopes.

4. The Spacecraft

The design of the spacecraft for the SPECTRUM-UV mission is under the joint responsibility of the Babakin Research Center and the Lavochkin Science and Industry Corporation. It is a common design platform to be used also for the RADIO-

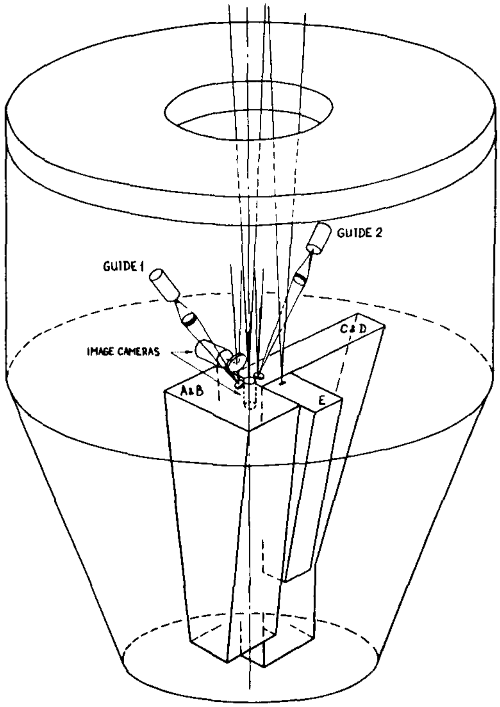
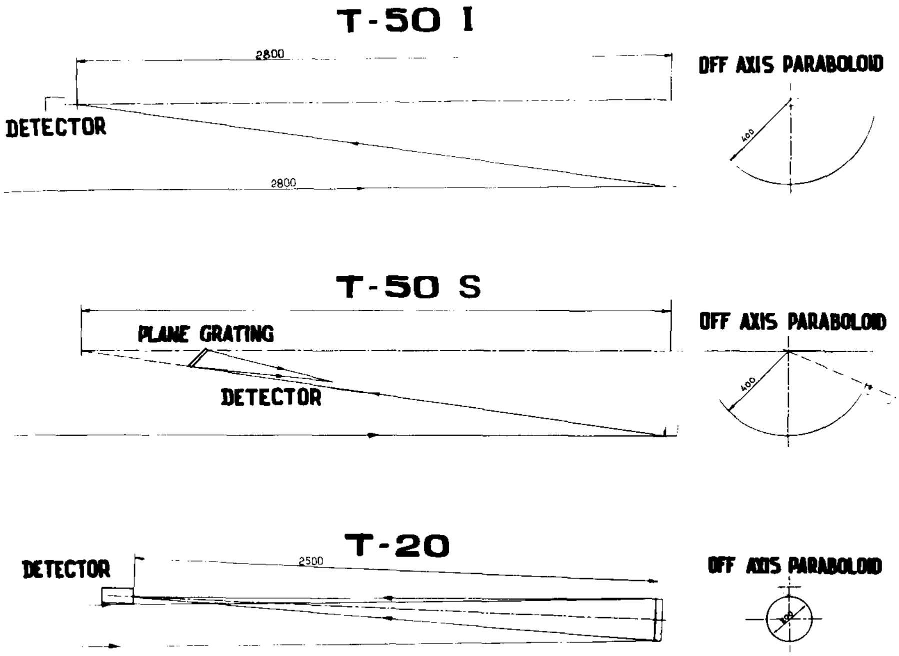


Fig. 3. T-170 telescope: focal instruments accommodation study.


T-50 I

T-50 S

T-20

Fig. 4. Optical scheme of the T-50 and T-20 telescopes.

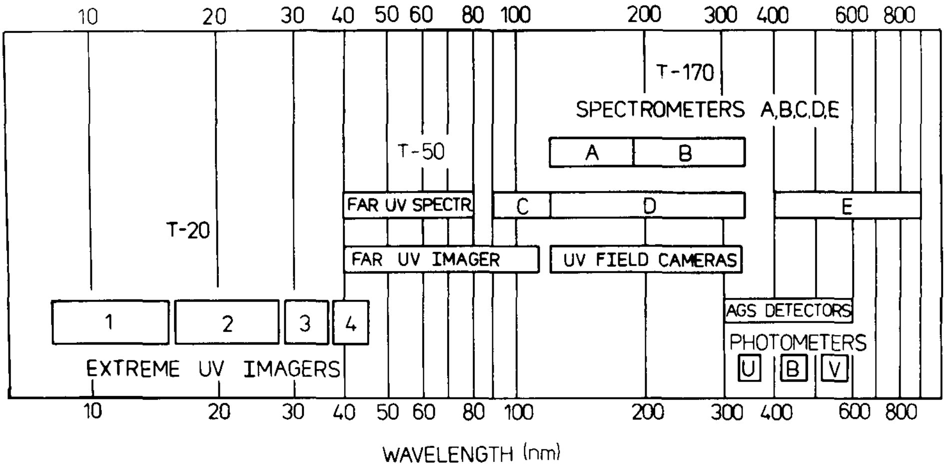


Fig. 5. Overview of the wavelength coverage of the instrument complement.

ASTRON Project (a 10-m radio telescope) and the SPECTRUM-X mission (a high energy orbiting observatory).

The platform will host scientific payloads up to 2.5 tons, providing an operational life in excess of 3 years. The telemetry bit rate is of 64 kbit sec^{-1} up to a distance of the satellite of 5×10^5 km. The satellite will be equipped with an on-board timing system of synchrofrequency generation from 1 Hz to 1 mHz.

The basic attitude determination system of the spacecraft consists of high precision gyros. In order to derive absolute pointing direction and to correct for drifts, the spacecraft relies on sun and star sensors. The actuators are reaction wheels periodically unloaded by gas jets. The spacecraft will be 3-axis stabilized in an inertial coordinate system. Its stability under the control of the gyros will be 1 to 3 arcsec on 1 minute time scale and 30 to 40 arcsec on a time scale of 24 hours, due to temperature instabilities.

For fine pointing and stabilization, the signal from the star under investigation or from a nearby offset star will be used. This signal will be obtained from the main optical system of the telescope. Stars brighter than $m_V = 14$ can be used as guiding star. Two guiding stars are needed to ensure stability during long exposures (up to 24 hours). The change of instrument configuration or mode of operation can be performed automatically without any command from the ground, except the change of the entrance diaphragm or the spectrometer slit, which should be made under control by the ground during the communication section. Such a session to change either the target object or an entrance slit of an instrument can take about 0.5 hours, whereas the data dump session and software uplink can take 2–3 hours.

The spacecraft will be launched by a PROTON booster on a high apogee orbit with initial inclination of 51°. Both solar and chemical batteries will supply 1 kW for the scientific payload for any attitude of the spacecraft.