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The World Space Observatory (WSO-UV): Current Status

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Abstract This paper reports on the current status of the World Space Observatory WSO-UV, a space mission for UV astronomy, planned for launch at the beginning of next decade. It is based on a 1.7 m telescope, with focal plane instruments including high resolution spectrographs, long slit low resolution spectrographs and imaging cameras.

Key words: space vehicles: instruments — telescopes — instrumentation: spectrographs — instrumentation: high angular resolution — ultraviolet: general

1 INTRODUCTION

UV spectroscopic and imaging capabilities are fundamental for astrophysics since thermal phenomena at temperatures $T > 10000\,K$, with flux emission mostly in the UV, occur in a wide range of astrophysical events. Also, the electronic transitions of the most abundant molecules in the Universe (H_2, CO, OH, CS, CO_2^+, CO_2) are in the UV range. This results in UV providing the most sensitive tools to trace the distribution of (baryonic) matter in the Universe, other than to diagnose the chemical composition, physical properties and kinematics of astronomical objects of all types.

In recent years, there have been three major instruments working in the UV: *Hubble Space telescope* (HST), *Far Ultraviolet Spectroscopic Explorer* (FUSE) and *Galaxy Evolution Explorer* (GALEX). The first two are observatory–like missions, whereas GALEX is dedicated to an all–sky survey and is currently providing wide field and low resolution spectra of a large number of astronomical objects which will require detailed UV follow-ups. However, after the failure of the HST STIS spectrograph in 2004, no facilities to get medium to high resolution spectra in the classical UV domain (1000–3000 Å) have been available to the community.

Access to UV is becoming problematic. Even with the planned upgrade of HST with the *Cosmic Origin Spectrograph* (COS), during the service mission SM4, HST is planned to work till 2013, thus posing the problem of developing new facilities for UV astrophysics in the post-HST era, before the advent of future large (8m class) UV telescopes, currently under discussion but not yet included in the plans of any space agency (and then to be scheduled unlikely before 2020–2025).

The World Space Observatory Ultraviolet – WSO-UV – is a multi-national project grown out of the needs of the astronomical community to have future access to the ultraviolet range. Planned to operate for 5(+5) years starting from 2011, it will fill in the gap between HST and the future large UV telescopes, complementing the wavelength coverage of the IR *James Webb Space Telescope* (JWST), which will be operative in the same period.

2 MISSION OVERVIEW

The World Space Observatory-UV is an international collaboration led by Russia to build a space telescope optimized in the UV range and devoted to investigate numerous astrophysical phenomena from planetary science to cosmology (Barstow et al. 2003; Pagano et al. 2007). The satellite will be based on the

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Table 1 Main Characteristics of WSO-UV

Spacecraft	
Spacecraft mass with propellant	2900 kg
Payload mass	1600 kg
Instrumentation Compartment power consumption	750 W
Data transmission rate (S-band)	2 Mb s^{-1}
Service telemetry data transmission rate	32 kb s^{-1}
Platform star tracker pointing accuracy	30 arcsec
Stabilization and pointing accuracy	0.03 arcsec
Spacecraft angular rate in stabilization mode	2x10–5 degree s^{-1}
Spacecraft slew rate	0.1 degree s^{-1}
Maximum duration of scientific observation in continuous mode	30 hr
Telescope	
Optical System	Ritchey-Chrétien
Telescope entrance pupil diameter	1.7 m
Effective focal length	17 m
Parameter Value F/ratio	10
FoV diameter	30 arcmin (148, 48 mm)
Scale	12,13 arcsec mm^{-1}
Wavelength range	100–310 nm (with extension to the visible)
Primary wavelength	200 nm

"Navigator" platform, a service module used also for other Russian projects (e.g. Elektro and RadioAstron). Table 1 summarizes WSO-UV spacecraft characteristics. Telescope, launcher (Zenith 2SB) and platform (Navigator) will be developed in Russia, whereas focal plane instruments will be provided by Germany, China and Italy, with contributions from UK, and Spain. Ground Segment is under design mainly in Spain and Russia, with possible contributions from other countries. The spacecraft will be put in a geosynchronous orbit at a height of 35800 km and an inclination of 51.4 degrees.

3 TELESCOPE

The WSO-UV telescope T–170M is a new version of the T–170 telescope designed by Lavochkin Association (Russia) for the Spectrum-UV mission. It is a Ritchey-Chrétien with a 1.7 m hyperbolic primary mirror, focal ratio F/10 (platescale 12.13 arcsec mm^{-1}) and a corrected field of view of 0.5 degrees. The optical quality of the two mirrors is $\lambda/30$ rms at 633 nm. The primary wavelength range is 100–350 nm with extension into the visible range, but the optics are optimized at 200 nm.

The telescope general view is given in Figure 1: the main structural elements are the Primary Mirror Unit (PMU), the Secondary Mirror Unit (SMU) and the Instrumental Compartment (IC). There are three attachment points of the telescope to the spacecraft service module in the bottom frames part. The Optical Bench (OB), carrying the scientific instruments and the Fine Guidance Sensors, is mounted on the PMU frame. The SMU is attached to the telescope with a spider.

4 FOCAL PLANE INSTRUMENTS

WSO-UV will have spectroscopic and imaging capabilities. The telescope will host two spectrographs and one imager. There will be a high resolution echelle spectrograph (*High Resolution Double Echelle Spectrograph* – HIRDES), and a *Long Slit* (low resolution) *Spectrograph* (LSS). The imager, Field Camera Unit (FCU), will allow diffraction limited, deep UV and optical images. Figure 2 shows the location of the instruments in the Instrumental Compartment.

4.1 HIRDES

HIRDES (Kappelmann et al. 2006, see Figure 3) design is based on the heritage of the ORFEUS (*Orbiting and Retrievable Far and Extreme Ultraviolet Spectrometer*) missions (Barnstedt et al. 1999). It comprises two echelle instruments, UVES (178–320 nm) and VUVES (103–180 nm), with high spectral resolution (R$\sim$50000). The detectors of the two channels are photon counting devices based on Microchannel Plates, readout by means of a Wedge & Strip Anode based on the ORFEUS detector design.

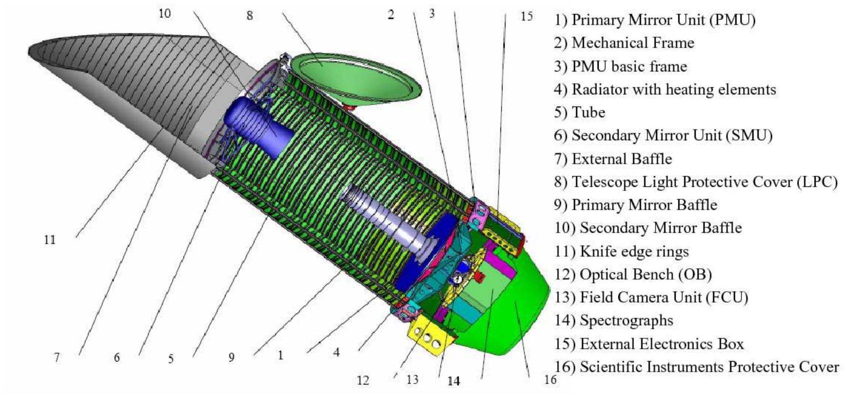

Fig. 1 General view of the T–170M telescope.

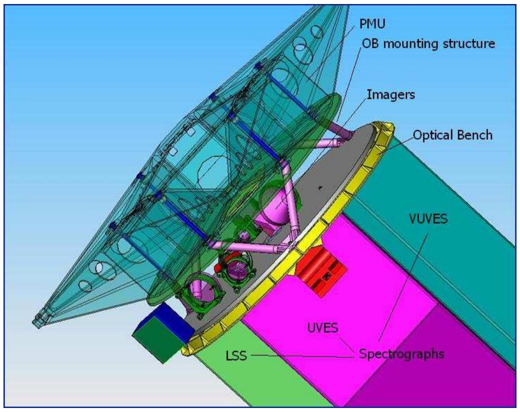

Fig. 2 Instrumental Compartment, showing the location of the focal plane instruments.

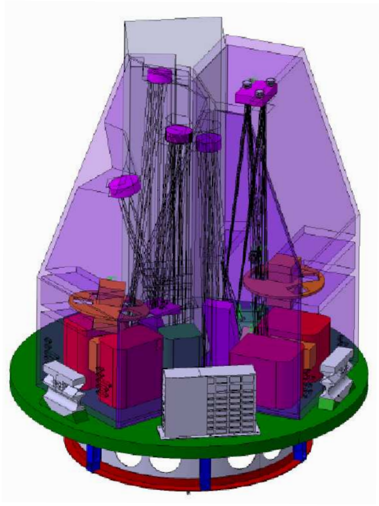

Fig. 3 Schematic overview of HIRDES (Kappelmann et al. 2006).

Each of the channels has its own entrance slit lying in the focal surface of the T-170M telescope, on a circle with diameter 100 mm which also host the LSS slit. The pointing will be monitored by two (visible) sensors (one for UVES and one for VUVES) of the Internal Fine Guidance System (IFGS), which is part of HIRDES and will allow compensating the jitter of the spectral images due to slight variations in the telescope pointing.

An industrial phase A study for all the spectrographs (including a long slit low resolution one, initially designed to be accomodated in a single box), has been completed in 2001 by Jena-Optronik (funded by the German Space Agency DLR). A Phase B1 study for VUVES and UVES has been completed in May 2006 by Germany, with Russia collaboration and with industrial support by Kaiser–Threde (while a modified version of LSS, now considered as a separate instrument, is now under study in China).

With the present design, the limiting UV monochromatic magnitudes (SNR=10 in 10 h) are 18 and 16 for UVES and VUVES, respectively. An Exposure Time calculator is available on the web (*http://astro.uni-tuebingen.de/groups/wso_uv/exptime_calc.shtml*).

The spectral resolution provided by HIRDES is similar to that provided by HST/STIS, but higher than that which will be provided by HST/COS. As far as sensitivity is concerned, WSO-UV/HIRDES is comparable to HST/COS and definitely better than HST/STIS.

4.2 LSS

The Long Slit Spectrograph will provide low resolution (R$\sim$1500–2500) spectra in the range 102–320 nm (possibly divided in two sub–channels: 102–161 nm and 160–320 nm), using a $1'' \times 75''$ slit, with spatial resolution 0.5–1 arcsec. LSS study, ongoing in China, is currently in phase A, with a Phase B expected to be completed by January 2008.

4.3 FCU

The Field Camera Unit (FCU) will include three channels (Scuderi et al. 2007):

FUV channel It covers the far UV providing medium resolution images. To satisfy the high sensitivity requirement below 200 nm, this channel is optimized in the range 115–190 nm, with 0.2 arcsec pixel^{-1} scale. Since it uses the focal ratio of the telescope, this design minimizes the numbers of optical elements (only a pick-up mirror is required, to deviate the optical beam towards the detector), maximizing the throughput. The FUV channel will be equipped with a 2k$\times$2k pixels, photon counting, MCP detector (with CsI photocathode) and will have a FoV=6.0×6.0 arcmin^2. This channel shall be equipped with a filter wheel hosting broad and narrow band filters, neutral filters, and a R$\sim$100 light disperser, allowing also low resolution slitless spectroscopy.

NUV channel It operates in the range 150–280 nm, providing “close to diffraction limit” images at 200 nm, with a 0.03 arcsec pixel^{-1} scale. The NUV channel will be equipped by a 2k$\times$2k pixels MCP detector (with CsTe photocathode) and will have a FoV=1.0×1.0 arcmin^2. This channel shall be equipped with two filter wheels hosting broad and narrow band filters, neutral filters, polarizers and a R$\sim$100 grism, providing slitless spectroscopic and polarimetric capabilities.

UVO channel Near ultraviolet-visual diffraction limit imager, operating in the interval 200–1000 nm, with a 0.07 arcsec pixel^{-1} scale, equipped with a 4k$\times$4k pixels CCD, providing a field of view of 4.6×4.6 arcmin^2. This channel shall be equipped with a set of broad band and narrow band filters, a ramp filter, polarizers and a R$\sim$250 grism.

FUV and NUV channels, using photon counting detectors, will allow also high time resolution observations, down to few ms time scale. Figure 5a shows a preliminary estimate of the system throughput of the three FCU channels compared to the cameras which have flown or will flew on board of HST (WFPC2, ACS/WFC, ACS/HRC and WFC3/UVIS, Bond et al. 2006). As it can be seen, the performance of the FCU cameras compares well with the HST instrument ones. Another useful quantity when comparing different instruments is the discovery efficiency, plotted in Figure 5b, defined as the product of the system throughput and the area of the Field of View (FOV) as projected on the sky. Due to its large FOV, UVO has a discovery efficiency equal or greater than ACS/WFC. In the case of the FUV, the performance are even better when compared to HST because no camera working in this range has a large FOV.

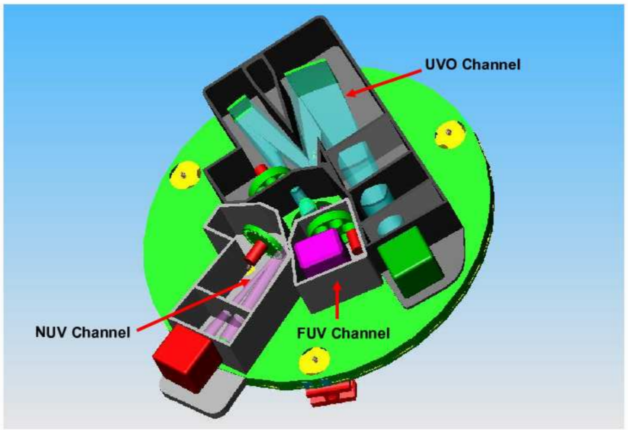

Fig. 4 Layout of the Field Camera Unit.

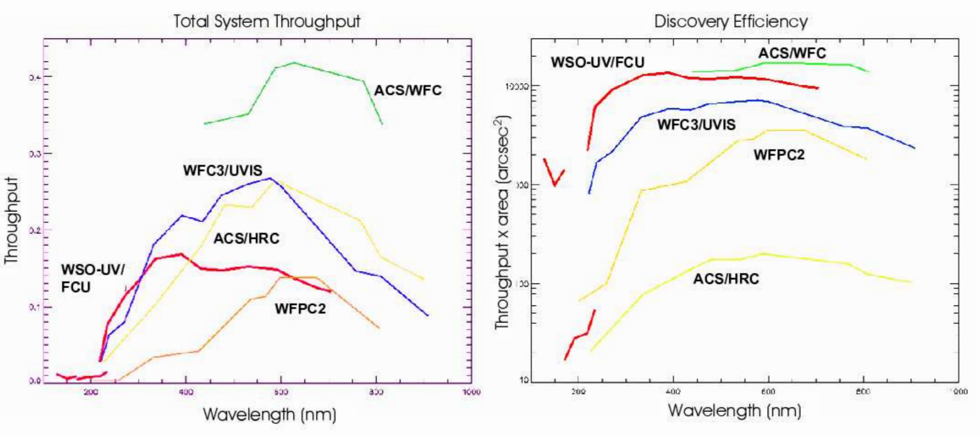

Fig. 5 System throughput (a) and discovery efficiency (b) of the FCU cameras as function of the wavelength, compared with HST imagers.

The Italian Space Agency founded a Phase A/B1 for the FCU. Phase A has been completed in July 2007. Phase B1 will last four months.

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DISCUSSION

JOERN WILMS: What is the time resolution of the UV detectors?

MICHELA USLENGHI: Time resolution will be ~ 10 ms

JIM BEALL: The geosynchronous orbit presents some challenges with respect to satellite electronics. Can you comment on this? How did you pick the orbit?

MICHELA USLENGHI: We are aware of the problem and industry is now working on the electronics design on that base. The first choice for the orbit was an L2 one, the baseline (recently) changed to the geosynchronous one due to cost issues.