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Prospects of WSO–UV mission for studies of exoplanetary atmospheres

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Abstract. Ultraviolet (UV) astronomy is a very demanded branch of astrophysics. Many short-term UV experiments in space as well as long-term observatories in last decades have brought fundamental data for the understanding of the physics of the Universe. In this article, we briefly describe the current status of the UV domain role to be played by the World Space Observatory – Ultraviolet (WSO–UV). The WSO–UV was described in previous publications in great detail, therefore only basic information and current state of the project are briefly presented in this paper. A brief overview of major science topics that have been included in the Core Program of the WSO–UV is presented; exoplanetary studies form a considerable part of the Core Program. WSO–UV observations will allow the direct determinations of atomic oxygen content and of the presence of ozone, which will provide breakthrough data for exploring the possibility of life on exoplanets.

Key words. exoplanets – space telescopes – ultraviolet observations – habitable zone – astrobiology

1. Introduction

For almost half a century, astronomers have enjoyed continuous access to the 115–300 nm far- and near-ultraviolet (FUV and NUV) spectral ranges, where the resonance transitions of the most abundant atoms and ions reside. This UV range is not accessible from ground-based facilities.

In recent years, new ideas and concepts of UV observatories and instruments were proposed in various countries, but unfortunately no large UV observatories are planned by major space agencies for launch in the coming 10–15 years. As far as longer term prospects are concerned, a number of very ambitious projects of large aperture (4–16 m) space UV-optical telescopes are proposed. Most intensively discussed are: the European Ultraviolet & Visible Observatory (EUVO), the Telescope for Habitable Exoplanets and Intergalactic/Galactic Astronomy (THEIA), and the Advanced Technology Large-Aperture Space Telescope (ATLAST). In the next section, we present the World Space Observatory–Ultraviolet (WSO–UV) project, which is well developed (C-phase of implementation) and to our knowledge is the only 2-m class UV telescope that will guarantee access to the UV domain, with capabilities similar to the Hubble Space Telescope (HST), during the next decade.

2. WSO–UV mission

The WSO–UV is a multi-purpose international space mission born as a response to the growing demand for UV facilities by the astronomical community. The project is led by the Russian Federal Space Agency (Roscosmos). WSO-UV has been described in previous publications in great detail (see, e.g., Boyarchuk et al. 2014; Shustov et al. 2018). Here we only provide the basic information and current state of the project.

The WSO–UV consists of a 1.7 m aperture Ritchey-Chrétien telescope with a focal length of 17 m. The telescope provides an accessible field of view of 30 arcmin on the telescope focal surface. The telescope is equipped with instrumentation designed to carry out high resolution spectroscopy, long-slit low resolution spectroscopy and direct imaging. The WSO–UV Ground Segment (GS) is under development by Spain and Russia and both countries will coordinate the Mission and Scientific operations and will provide the satellite tracking stations for the project. The nominal lifetime is 5 years, with a planned extension to 10 years.

The telescope T-170M passed dynamic and thermal tests. The optics of the telescope is being manufactured. Both optical quality and quality of coatings (Al+MgF2) meet technical requirements. Major science instruments are: the WSO–UV Spectrographs (WUVS) and the Field Camera Unit (FCU).

WUVS consists of three channels (Panchuk et al. 2014):

- The FUV high resolution spectrograph (VUVES) that will permit to carry out echellé spectroscopy with $R \sim 50\,000$ in the 115–176 nm wavelength range.
- The NUV high resolution spectrograph (UVES) to carry out echellé spectroscopy with $R \sim 50\,000$ in the 174–310 nm range.
- The Long Slit Spectrograph (LSS) that will provide low resolution ($R \sim 1000$), long slit spectroscopy in the 115–305 nm range. The spatial resolution will be better than 0.5 arcsec (0.1 arcsec as the best value).

The spectral resolution provided by VUVES and UVES channels is similar to that offered by the Space Telescope Imaging Spectrograph (STIS, onboard HST) at medium resolution with its echellé gratings, but higher than the maximum resolution provided by Cosmic Origin Spectrograph (COS, also onboard HST) (R ~20 000).

The imaging tasks of the WSO–UV are assigned to the FCU, that permits to carry out imaging and slitless spectroscopy in the 115–320 nm spectral range (Sachkov 2016). The instrument is to be equipped with CCD and MCP detectors. Its capabilities are expected to be similar to those of the Advanced Camera for Survey (ACS, HST). The FCU is under responsibility of Russia and Spain. Currently, there is a discussion about support of this instrument by Mexico.

The brief outline of the current state of the project may be briefly summarized in a few sentences: funding in Russia is guaranteed; there is no critical technical problems in the implementation of the project; international cooperation is established; some organizational problems (induced by known sanctions against Russia) moved the launch date to 2025.

3. WSO–UV key science topics

It is important to focus the science program of the WSO–UV space observatory on the most challenging problems to be treated efficiently with such an instrument. The Program includes:

- The determination of the diffuse baryonic content in the Universe and its chemical evolution. The main topics will be the investigation of baryonic content in warm and hot Inter Galactic Matter and of damped Lyman-α systems.
- The study of the formation and evolution of the Milky Way.
- The physics of accretion and outflows: stars, black holes, and all those objects dominated by accretion mechanisms. The efficiency and time scales of the phenomena will be studied, together with the role of the radiation pressure and the disk instabilities.

- The investigation of the extrasolar planetary atmospheres and astrochemistry in presence of strong UV radiation fields, including astrobiology.

3.1. Extrasolar planetary atmospheres

The instrumentation of the WSO–UV project is very important and helpful for exoplanet studies and the characterization of the exoplanet-stellar environment (Panchuk et al. 2015, 2017). However, there are several difficulties that are at the origin of the major uncertainties on any estimations of exoplanetary atmosphere properties (Fossati et al. 2014):

- the relative faintness of the UV stellar emissions;
- the variability of the sources;
- signal contamination by both the sky background signal (at some spectral lines) and the instrument response.

While the first difficulty can be resolved by focusing on a few close-by and UV-bright stars, the signal variability from both the source and the instrument is a real problem that should be addressed to build a reliable diagnostic to extract an accurate description of the upper atmosphere and of the interaction region between the exoplanet and the impinging wind from its host star.

It should also be mentioned that WSO–UV can be used not only for standard exoplanet observations and characterizations but also for observations of biomarkers. Biomarkers like ozone have very strong transitions in the ultraviolet. These are electronic molecular transitions, hence several orders of magnitude stronger than the vibrational or rotational transitions observed in the infrared or radio range. The spectral resolving power required to detect biomarkers in the atmosphere of exoplanets is not a crucial issue. A resolution of $R \sim 10000$ is adequate for these investigations, and even $R \leq 1000$ could be enough to detect the broad band signatures of many molecules. The presence of biomarkers and other constituents in the atmospheres can be searched by WSO-UV high resolution spectrographs for about 100 exoplanets orbiting K-, G- and F-type main sequence stars.

4. Concluding remarks

Currently, the HST is the main instrument for UV research in all areas of astronomy, including exoplanets and their atmospheres. However, the HST capabilities are not limitless, and the prospects for UV astronomy in 2025–2035 are associated with the WSO–UV mission. During this period, WSO–UV will be the only 2 m class orbital telescope operating in the UV region. Core Program of the WSO-UV remains very relevant.

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