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Stellar imaging coronagraph an additional instrument for exoplanet exploration onboard the WSO-UV 1.7 meter orbital telescope

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Abstract

The WSO-UV (World Space Observatory for Ultraviolet) is the orbital optical telescope with a 1.7 m diameter of primary mirror under construction. The WSO-UV is aimed for a 110-310 nm UV spectral range observations and it will have onboard science instruments: the spectrographs in UV and the imaging field cameras with filter wheels. Currently the WSO-UV project has the development up to a “C” phase and the telescope launch is optimistically scheduled to 2022. Recently, a new science instrument dedicated for exoplanets exploration has been proposed to the WSO-UV named *SCEDI* – Stellar Coronagraph for Exoplanet Direct Imaging.

1. Introduction

The WSO-UV mission. The WSO-UV consists of a 1.7 meter telescope equipped with instrumentation set to carry out the spectroscopy and the direct sky imaging. The WSO-UV telescope is mainly designed for spectroscopy and for imaging in the UV band of 110–310 nm, it allows to work in the visible wavelength range with a good quality diffraction-limited imaging [1, 2]. The telescope passed vibration tests successfully. The WSO-UV will use the Russian NAVIGATOR platform from the Lavochkin Science & Technology Association. The NAVIGATOR platform has a payload mass of 1600 kg. With the fine guidance system through the telescope, the pointing stabilization is accurate to 0.1 arcsec within three sigma accuracy. The WSO-UV is targeting to geosynchronous orbit which has an inclination of 51.6^{o}. Earth occultation periods will be short enough so the WSO-UV orbital period will allow the long term monitoring and the rapid access to targets of opportunity.

The coronagraph *SCEDI* is aimed to detect the filtered from the starlight the reflected light, coming from the exoplanets orbiting nearby the parent stars and from the star vicinity including circumstellar discs, dust and clumps. It is dedicated to enable an achromatic, optimized to 420-700 wavelength range, high-contrast stellocentric coronagraphic image of a circumstellar vicinity.

2. WSO-UV coronagraph science goal

The direct observation of exoplanets in *sufficient* elongations apparently from their host stars is possible by the coronagraphic imaging, which has the unique potential to study the non-transiting planets optically and therefore directly. The coronagraph onboard a space telescope of two-meter-class enables observations above the turbulent Earth atmosphere. Space-based telescope realizes a diffraction-limited resolution and therefore principally it can study non-transiting exoplanets even the telluric Earth-like planets in a habitable zone. Several stellar coronagraphs capabilities to study the exoplanets are shown in Figure 1, where several modern facilities are compared. Initial *optimistic* science goal for a stellar coronagraph onboard a space telescope is to directly image exoplanets and circumstellar discs by the search of nearby to Solar system 20-30 stars, which can be observed at multiple epochs. Planets and discs can be observed down to 7-9-th order peak-to-peak (star-to-planet) coronagraphic contrast, which enables detecting and characterizing exoplanets down to super - Earth sizes. Under the *pessimistic* scenario, the goal is to photometrically characterize 10 giant planets detected to-date by a radial velocity technique.

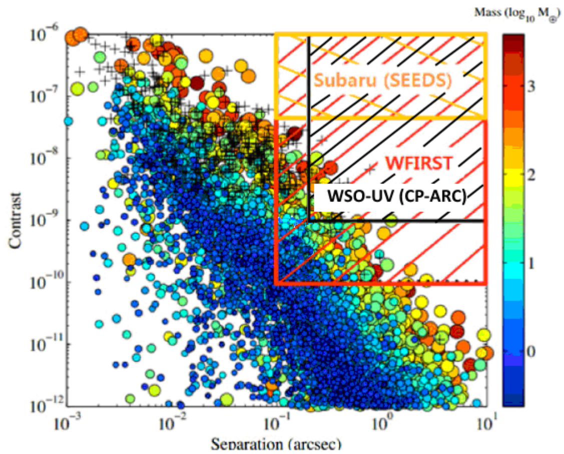


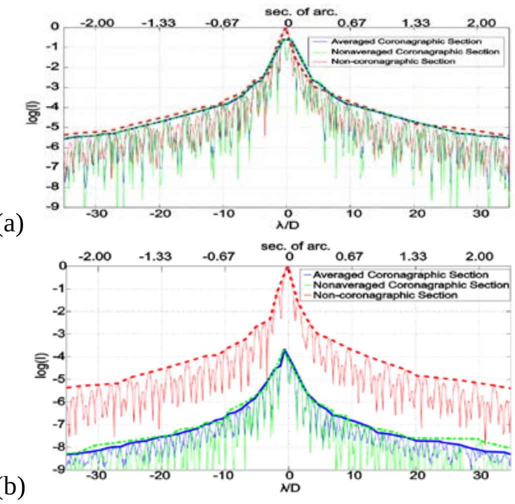
Figure 1: Ground-based telescope Subaru (8.2 meter primary mirror) using the *HICIAO* coronagraphic instrument, is framed in orange rectangle, the WFIRST-AFTA will implement the *CGI* instrument, is framed in red rectangle. WSO-UV telescope using the *SCEDI* instrument is framed in black rectangle.

3. WSO-UV coronagraph without an adaptive optics

Due to simplification requirement, the *SCEDI* coronagraph onboard the *WSO-UV* orbital telescope shall not use any adaptive optics (AO). Both the mid- and the high spatial frequencies of the telescope optics have the surface errors and the diffraction on aperture edges, to be optimized in UV band, therefore all these factors become reduced in the visible light band in the *WSO-U*V telescope.

A CP-ARC – common-path achromatic rotational shear coronagraph [3, 4] introduces a centrostellar occultation under a variable angle of rotational shear. Rotational shear interferometer (RSI) superposes a telescope pupil and its rotated copy with an achromatic antiphase providing the destructive interference. If the angle of rotational shear is fixed between 5...10 deg., then a nulling interferometer demonstrates a reduced sensitivity to the low-order aberrations from the telescope optics. They are nominally: the low spatial frequencies aberrations below a λ/5 @ λ=633 nm and the micro-roughness in a mid frequency below 1 nm rms.

Simulated results shown in Figure 2 demonstrate the almost disabled coronagraphic mode by means of a *classic* interfero-coronagraph with a 180° rotational shear. With a 5° we see the coronagraphic mode enabled with the *raw* contrast exceeded a 10^7 peak-to-peak at 5..10 λ/D stellocentric distance.



(a) (b)

Figure 2: Coronagraphic (raw) contrast achievable by an interfero-coronagraph with the rotational shear at 180º (a) and 5º (b), for the WSO-UV telescope, considering aberrations: dash-marked (red) graph represents a non-coronagraphic (PSF), down solid (green) graph corresponds to coronagraphic PSF.

Acknowledgements

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