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Performing simulations for the WSO-UV spectrographs

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Abstract

The World Space Observatory - Ultraviolet (WSO-UV) is a space telescope, equipped with a high resolution spectrograph (WUVS - WSO UltraViolet Spectrograph) that provides high resolution spectroscopy ($R \sim 55,000$) in two channels VUVES and UVES. VUVES is a far UV echelle spectrograph designed to observe point sources in the range 1020-1800 Å. UVES is the near UV echelle spectrograph, working in the range 1740-3100 Å. These instruments can be evaluated, in terms of performance, from an appropriate overall instrument model through simulations of the expected observations. Since it is not feasible to build and test a prototype of a space-based instrument, numerical simulations performed by an end-to-end simulator are used to model the noise level expected to be present in the observations. The performance of the instrument can be evaluated in terms of noise source response, data quality, and fine-tuning of the instrument design for different types of configurations and observing strategies.

1 Introduction

The WUVS Simulator has been implemented as a further development of the ASTROID Simulator [2], and its posterior version applied to the PLATO M3 European Space Agency (ESA) mission. The PLATO Simulator [3] software tool was adapted to the WUVS instrument specific characteristics. This new version of the simulator, named WUVS Simulator, has been designed to generate synthetic time series of CCD images by including models of the CCD and its electronics, the telescope optics, the jitter movements of the spacecraft and all important natural noise sources of an echelle spectrograph. We provide a detailed description of several noise sources and discuss their properties, in connection with the optical design, the quantum efficiency of the detectors, etc. The expected overall noise budget of the output spectra is evaluated as a function of different sets of input parameters describing the instrument properties.

2 Noise model

Each simulation generates time-series of CCD images in the widely extended Flexible Image Transport System (FITS) format in order to provide to the user with an easy-to-handle set of products. Each of these images is modeled based on a number of input parameters that characterize the observing circumstances, the platform, telescope, CCD and all related noise sources. This model is sketched in the following order:

- Observed source spectrum.
- Imaging FoV:
  - The CCD sub-pixel matrix;
  - High-energy particle hits;
- CCD Sensitivity variations: PRNU;
- Noise effects:
  - Sky background;
  - Photon noise;
  - Electronic noise sources.

3 Simulations for WUVS

We have implemented a number of modification to the WUVS Simulator in order to apply it to the WSO-UV space observatory, but the most relevant to other possible instruments is taking a FITS file image as input. This modification allows to apply the noise model in a more flexible manner. The main properties of the noise effects applied in the simulations (see Table 1) have been taken from [4].

The input FITS image used in the simulations that we performed for this work consists in an echelle image of a flat illuminated source. This flat image was modified to include the real spectrum from an observational source, DG Tau, as observed with the STIS spectrograph on board the Hubble Space Telescope [1]. The reason to use the STIS instrument is that its E140M grating provides echelle spectra at a resolving power of $R \sim 45.800$ from 1144Å to 1710Å, similar to that of VUVES at WSO-UV.

We took certain spectral lines of the STIS calibrated spectrum of the DG Tau source with different grades of intensity in order to evaluate how will these lines be affected by noise in a VUVES observation. These lines of interest are Lyman-alpha(1215Å), OI(1306Å), CII(1335Å) and CI(1670Å). The STIS spectrum was normalized in flux and corrected in

Table 1: Values of the input parameters applied to the WUVS simulations..

Input Parameter	*Value*
CCD Size	$4096 \times 3112\,px$
Collecting area	$113.09\ cm^2$
Sub-Field size	$4096 \times 3112\,px$
Digital saturation	$16384\ ADU$
Pixel resolution	$1/4$
Full well pixel capacity	$1243000\ e^-$
Gain	$6\ e^-/ADU$
Electronic offset	$100\ ADU$
Readout noise	$3\ e^-$
Exposure time	$22\ s$
Flatfield pixel-to-pixel noise	1.6 %
Pixel scale	$0.101\ arcsec/px$
Pixel size	$12\ \mu m$

terms of spectral resolution per pixel according to the VUVES resolution (0.0066Å/px). The spectral orders of interest from STIS were superimposed on the corresponding pixel positions of the echelle image. The resulting image was taken as input to the VUVES simulations.

The above described image was taken as input to the simulations, together with the input parameters characterizing the VUVES instrument (some of these parameters are included on Table 1). The analysis of the resulting time-series images provides with the expected flux of the lines of interest as they will be affected by the noise in the observation.

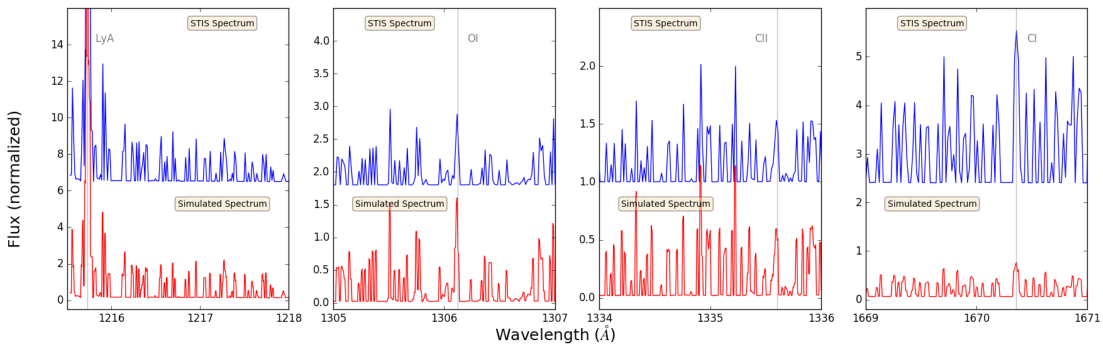

Figure 1: Normalized flux as a function of wavelength for four spectral lines (Lyman-alpha, CI, CII and OI) of DG Tau as obtained from STIS (in blue color) and from the simulated image (in red color). The STIS spectra have been shifted upwards for comparison purposes.

Figure 1 shows the selected STIS spectral orders (blue colored-upper panels), together with the spectra of the simulated image as they will be observed with VUVES (red colored-lower panels) for comparison. In this analysis, the flux for each spectral order has been measured in number of counts and normalized in order to compare performance to that of provided by STIS instrument, but no further flux calibration has been applied, therefore there is room for VUVES to provide an even better performance.

4 Conclusions and future prospects

The WSO-UV observatory will carry high precision instrumentation whose expected performance must be evaluated carefully from an appropriate overall instrument model. The performance of the instrumentation on-board can be evaluated in terms of noise source response, data quality, and fine-tuning of the instrument design for different types of configurations and observing strategies.

It is important for the success of the mission to perform a complete evaluation of the expected instrumental behavior of the observation campaigns to be overcome during its lifetime. And that is the aim of this work by providing with the tool that can validate those observations.

References

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