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ANDES, the high resolution spectrograph for the ELT: the exposure time calculator

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ABSTRACT

We present the Exposure Time Calculator (ETC) in development for ANDES, the high-resolution optical-infrared spectrograph for the Extremely Large Telescope. The ETC is a tool to predict the performances of the instrument for different parameters and environmental conditions. For these reasons, it is extremely useful in several stages of the project, from the design of the instrument to the preparation of the observations.

Keywords: ANDES; Extremely Large Telescope; astronomical simulations; astronomy software

1. INTRODUCTION

In recent years, thanks to the complexity of the last-generation instruments, it has been more evident that the Exposure Time Calculator (ETC) assumes an important role as an indispensable instrument for the comprehensive estimation and prediction of the operational efficacy of an advanced optical-infrared spectrograph. This sophisticated tool is absolutely relevant during the first stages of a project, from the conception to the design. Moreover, its relevance extends beyond this, playing a crucial role in guiding the astronomical community towards higher precision observations. In this work, we aim to provide a detailed description of the functionalities inherent within the context of the ETC, specifically custom-made for ArmazoNes high Dispersion Echelle Spectrograph (ANDES), the high-resolution optical-infrared spectrograph for the Extremely Large Telescope (ELT)/ESO. ANDES will work at a resolution of R $\sim$ 100,000 from 0.4 to 1.8 microns, with a possible extension in the blue (down to 0.35 microns) and in the red (up to 2.4 microns). The instrument consists of

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different spectrometers sharing the same Front End and fiber-fed to the telescope ([1], [2]). The Preliminary Design Review (PDR) is foreseen for mid-2025. It will work in seeing-limited and in IFU+SCAO modes in the red. The ETC produces a meticulous evaluation of ANDES's performance potential by encompassing a broad spectrum of wavelength bands.

2. DESCRIPTION OF THE ETC

The ETC is a powerful tool at any stage of the project. In fact, on one side it helps the architects in designing the instrument, on the other it helps the scientific community to define the science cases. In this paper, we present the ETC for the seeing-limited mode. Several parameters have been taken into accounts and a large number of input parameters can be modified, from the dimension of the telescope, to the pixel size, to the detectors, as well the resolving power and many others, in order to study the capability of the instrument. The current ETC is based on [3] and [4], where detailed description of the ETC for the preliminary designs of the instrument are presented. In [4] we described the ETC based on the instrument concept presented during the ESO Phase-A study (successfully passed in 2018). In particular, the ETC we are developing can derive the signal to noise ratio (S/N) for a given exposure time. In respect [4], we are now improving *(i)* the instrument efficiency and *(ii)* the atmospheric transmission.

In fact, with the approaching of the PDR, the design is more consolidated and we are now taking into account an accurate estimation of the instrument efficiency considering the efficiencies of different parts: front end, fiber link, spectrographs (including optics and detectors) instead of a general value. The overall efficiency, however, is consistent with the previous estimation of 10%, but it is not constant in the entire spectral range.

Moreover, in [4] the atmospheric transmission, especially the telluric absorption lines in the near-infrared, were not appropriately taken into account. We implemented the use of TAPAS ([5]) in our code, together with a more realistic treatment of the airmass dependence. Fig. 1 shows the S/N achievable for a given target in a given exposure time with the four spectrometers. The atmospheric contribution can partially explain the non-linear behavior found.

The ETC presented in [4] worked wavelength by wavelength, adopting as input the magnitude in AB system for a compact object or the surface brightness/arcsec^2 for extended sources. We are now developing an ETC that allows an immediate investigation of the entire spectral range. For doing this, we are including more options as input parameters.

3. PRELIMINARY RESULTS

As first test, in case of compact sources we are implementing in the ETC the possibility to select the flux of the star using the Pickles library ([6]) that includes spectra of different types covering the entire wavelength range of ANDES. This is the same spectral library used by ESO for the VLT instrumentation. Once the flux is converted in AB mag by the code, the same procedures described in [4] are used to estimate the S/N achievable. In order to investigate the capabilities of ANDES and the contribution of any input parameter, we performed different simulations, changing one parameter per time. Here we present the preliminary results of these investigations. In particular, Fig. 2 shows the comparison between stars of different spectral type. Fig. 3 shows the case of three stars of the same spectral type but different brightness. Fig. 4 shows the case of the same star but observed for different time. Fig. 5 shows the impact of the airmass on an observation of a star.

4. SUMMARY AND FUTURE DEVELOPMENTS

We develop the exposure time calculator for ANDES, the high resolution spectrograph for the ELT. ANDES will work in seeing-limited mode for the entire spectral range and in IFU+SCAO mode in the infrared. The ETC allows to investigate the capabilities of the instrument and it is a powerful tool to design the instrument. In the current study we present the ETC for the seeing-limited mode, but in the next future we will develop a specific ETC for the AO mode. Thanks to the more consolidate design of the instrument, we included in the ETC a more accurate estimation of the instrument efficiency. Moreover, a more reliable atmospheric contribution has been considered, especially concerning the telluric absorption lines in the near-infrared. While the ETC

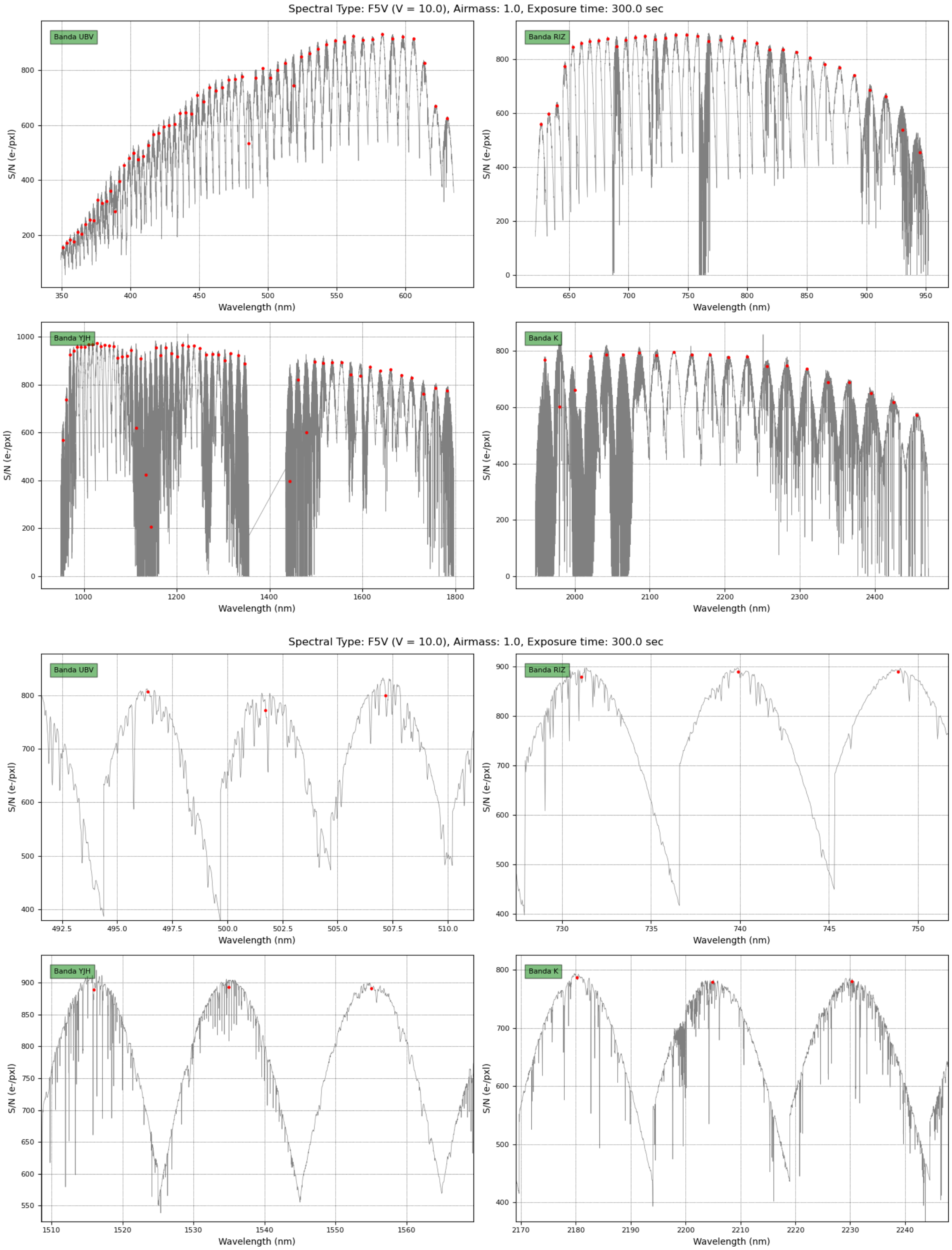

Figure 1. Example of the S/N expected for a F5V star of V=10 mag (Vega system) with airmass=1 and exposure time=300sec. The upper and middle-upper panels show the results for the entire wavelength range, while middle-bottom and bottom panels show a zoom in different regions of the spectra. The red dots are obtained by averaging 20 points around the peak of the Blaze function for each order. The contribution of the atmospheric transmission is evident.

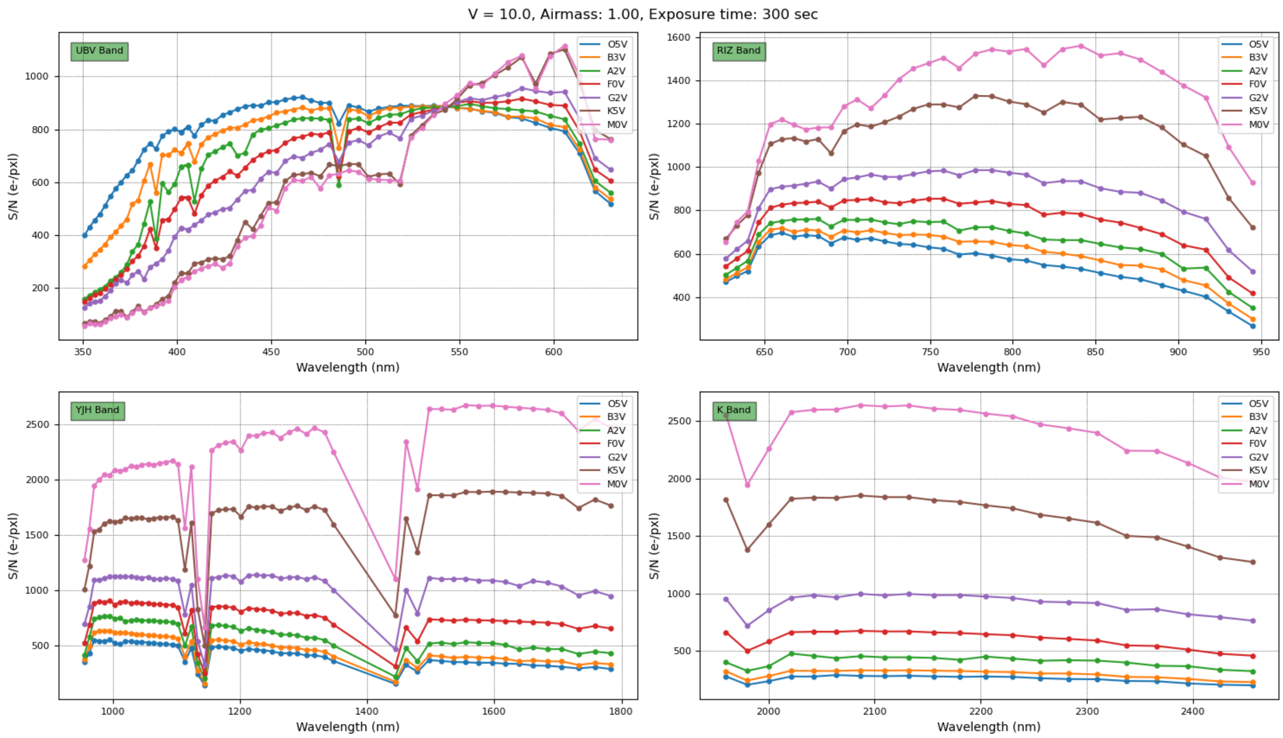

Figure 2. 3: Examples of S/N achieved for a star with V=10 mag, airmass=1.0, and Texp=300 sec, for different spectral types (O5V, B3V, A2V, F0V, G2V, K5V, and M0V).

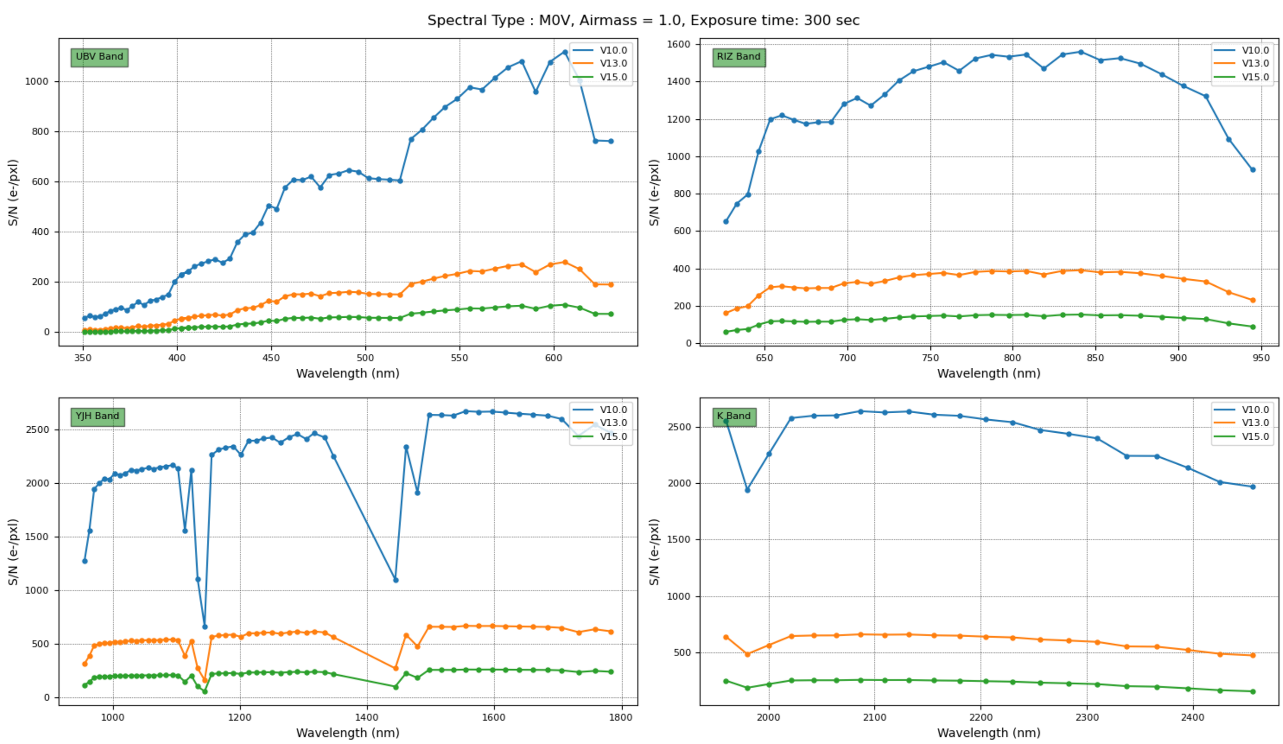

Figure 3. Examples of S/N achieved for a star with spectral type M0V, airmass=1.0, and Texp=300 sec, for different brightness levels (V=10, 13, and 15 mag).

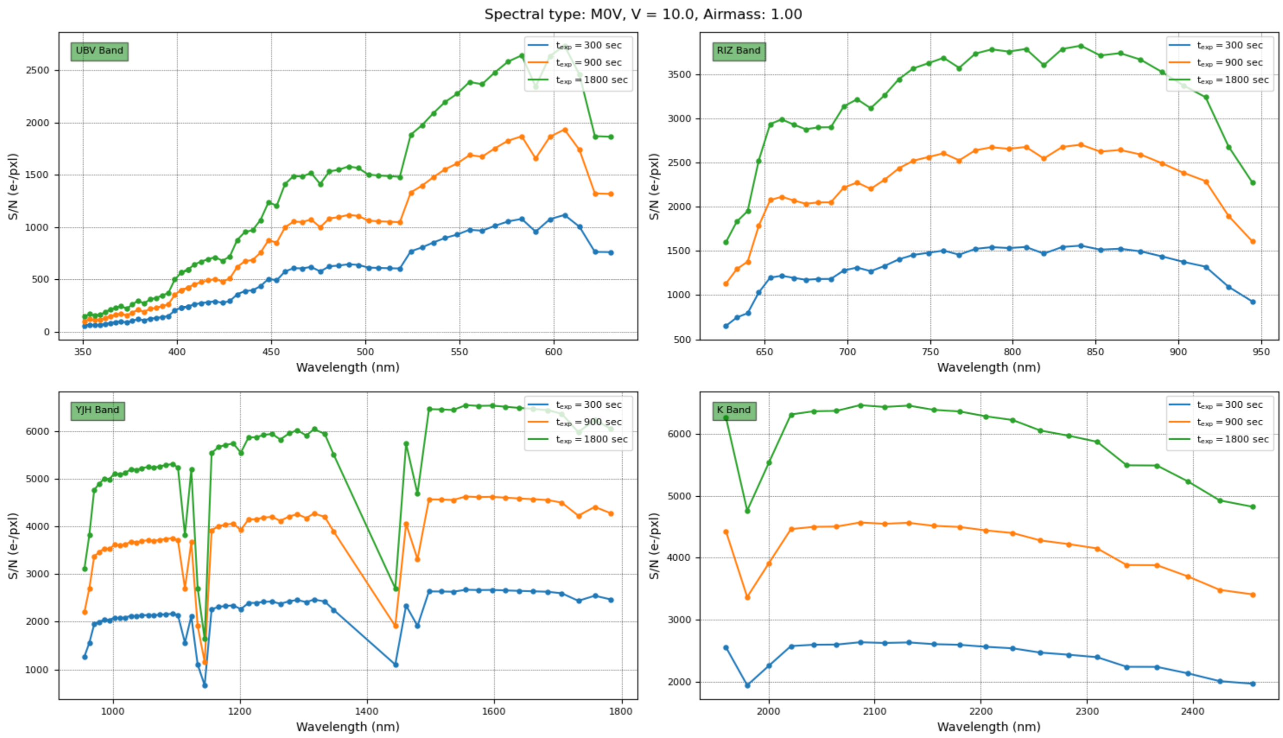

Figure 4. Examples of S/N achieved for a star with spectral type M0V (V=10 mag) and airmass=1.0, and different exposure times (Texp=300, 900, and 1800 sec).

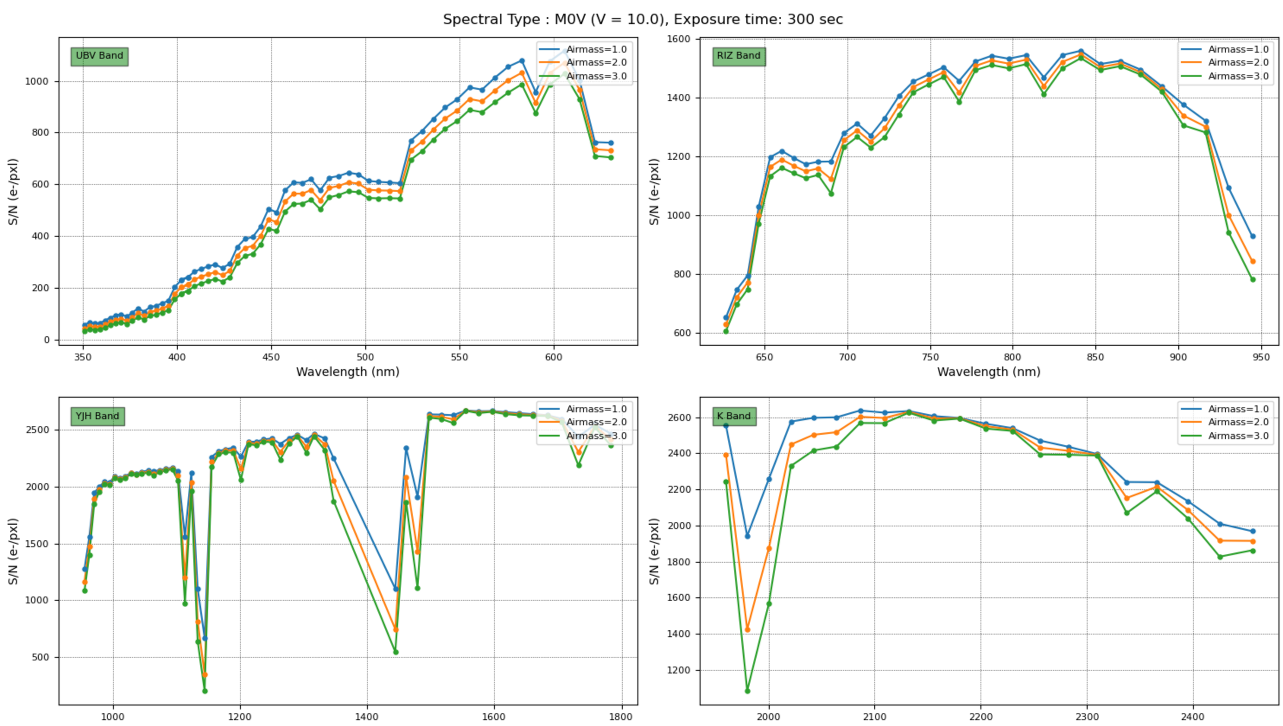

Figure 5. Examples of S/N achieved for a star with spectral type M0V (V = 10 mag) and Texp = 300 sec, for different airmass values (1.0, 2.0, and 3.0).

developed in the previous phase of the project worked wavelength by wavelength considering magnitudes and surface brightness in AB system, here we implement the spectrum of the target as input parameter. In particular, as a first test, we consider stars of different spectral types, using the Pickles library. We are now investigating the possibility to implement other parameters as input, like power law or different templates in order to cover the entire wide range of science case presented for ANDES ([7], [8], [9], [10]).

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