An exposure time calculator for the Maunakea Spectroscopic Explorer

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INTRODUCTION

The Maunakea Spectroscopic Explorer (MSE) will convert the 3.6-m Canada-France-Hawaii Telescope (CFHT) into an 11.25-m primary aperture telescope, to produce multi-object spectroscopy with a suite of spectrographs that are capable of detecting over 4,000 objects per pointing. The MSE-ETC has individual computation modes for SNR, exposure time, and the relation between SNR and AB magnitude, or wavelength. The software is developed with Python 3.7, and Tkinter graphical user interface is implemented to facilitate cross-platform use. In this research, we present the logical structure by the functionality of MSE-ETC, including a software design and a demonstration.

SOFTWARE STRUCTURE

The MSE spectrographs consist of two instrument platforms with low/moderate resolution (LMR) and high resolution (HR). They have a spectral resolution range from R~3,000 to R~40,000 and a full wavelength range from 360 nm to 1800 nm. The MSE-ETC provides four calculation mode:

① S/N Calculation	② Exposure Time Calculation
③ S/N vs. Magnitude	④ S/N vs. Wavelength

Thus, the algorithm (Fig. 1) and the GUI (Fig. 2) of the MSE-ETC are designed based on the simulation mode. Except for fixed variables, the instrument parameters for these modes are imported by selecting the spectral resolution modes from a user.

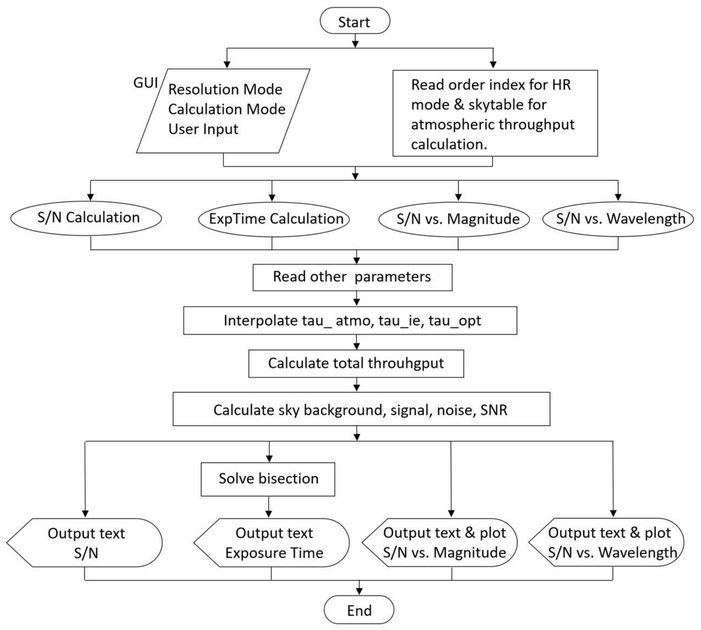


Fig. 1 Software architecture including data flow for MSE-ETC. The functions, parameters, and outputs are determined by a user's selection on the GUI.

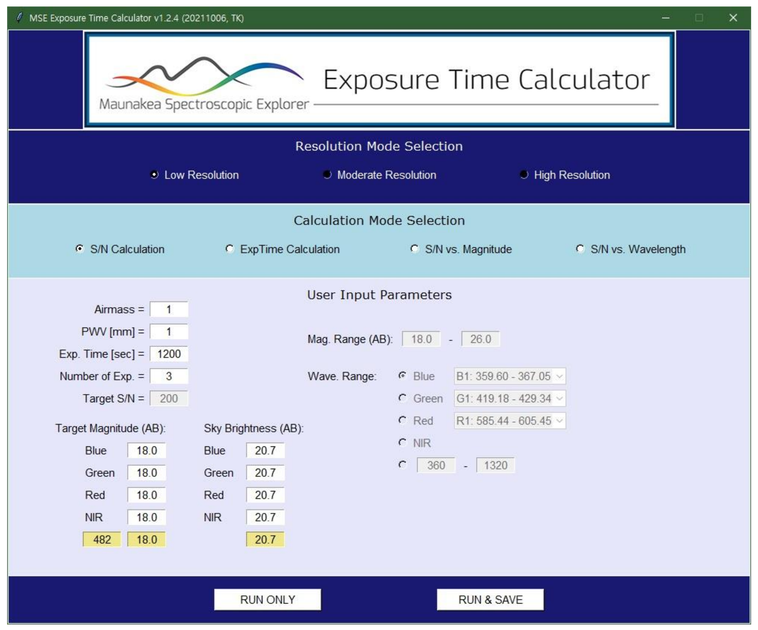


Fig. 2 The GUI of the MSE-ETC. It is designed with an pop-up application, which is written by Tkinter library on Python 3.

SIMULATION METHODS

1 Continuum Signal for Point Source

(Continuum) Signal from point source target

$$S_{cont} = \frac{t_{exp}\, n_{exp}\, A_{tel}\, \tau_{atmo}\, \tau_{opt}\, \tau_{IE}\, f_\nu(m_{AB})}{h\, R}$$ [e /resolution elements]

Signal from the sky background

$$B_{sky} = \frac{t_{exp}\, n_{exp}\, A_{tel}\, \tau_{atmo}\, \tau_{opt}\, \Omega_{fiber}\, b_\nu(m_{AB})}{h\, R}$$ [e /resolution elements]

where, Ω_{fiber} in units of arcsec^2, $b_\nu(m_{AB})$ in units of W m^{-2} Hz^{-1} arcsec^{-2}

Detector dark current: d_{dark} [e /sec /pixel] Detector Read noise: d_{read} [e /pixel]

The total noise

$$N_{cont}^2 = S_{cont} + B_{sky} + n_{res} n_{exp}\left[t_{exp}\, d_{dark} + d_{read}^2\right]$$ [e /resolution elements]

Signal to noise ratio = S_{cont}/N_{cont}

2 Telluric Absorption Spectra

Telluric absorption spectra are gained from the model data of the ESO SkyCalc Sky Model Calculator. The MSE-ETC uses a dataset that is made by convolution to match the spectral resolution (Fig. 3).

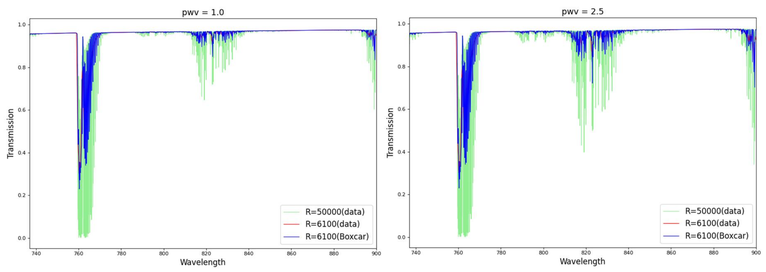


Fig. 3 Convolution sample in the red band (737~900 nm) of MR instrument for PWV 1.0 mm (left), 2.5 mm (right).

3 OH Sky Lines

The wavelengths of the OH emission lines are gained by convolution to R~40000 OH line data (1400nm ~ 1800nm) (Fig. 4).

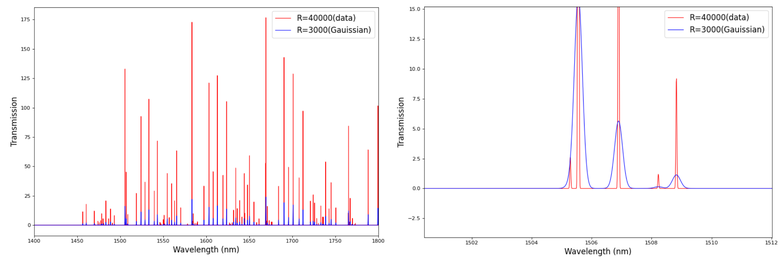


Fig. 4 Convolution sample of OH emission lines. Here the data is regenerated by resolution of R~40000 to R~3000.

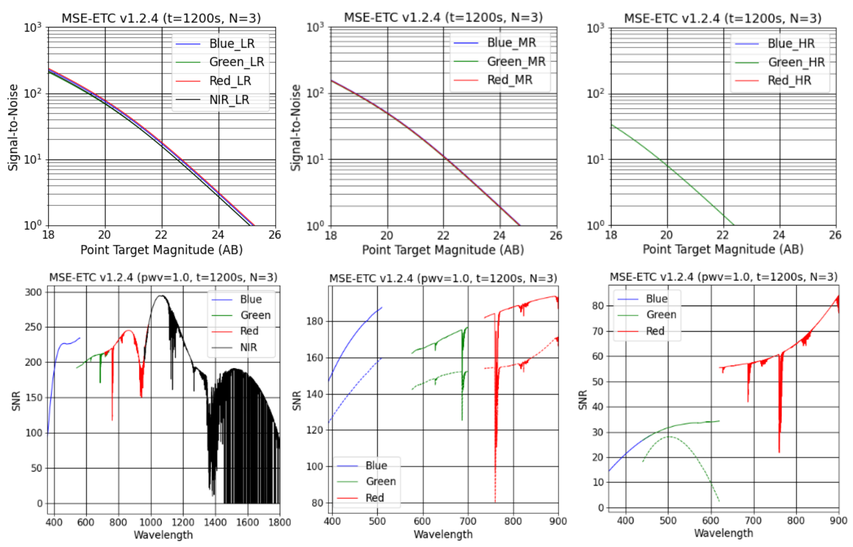
RESULTS

The results of S/N and exposure time calculation are indicated by text in the output terminal. S/N vs. magnitude and S/N vs. wavelength results are displayed by figures and they can be saved with the data array.

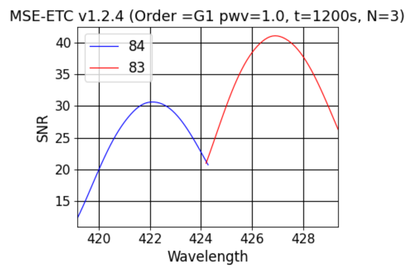
```
The calculation Signal-to-Noise from single magnitude input

Resolution Mode   = Low Resolution
Airmass           = 1.0
PWV [mm]          = 2.5
Exposure Time [s] = 1200
Exposure Number   = 1

Band     Mag.    Sky     S/N
[Blue]   18.00   20.70   130.586203
[Green]  18.00   20.70   118.995047
[Red]    18.00   20.70   135.605177
[NIR]    18.00   20.70   122.438072
[482.0]  18.00   20.70   130.586203      (Band = Blue)
```

```
The calculation exposure time for target S/N

Resolution Mode   = Low Resolution
Airmass           = 1.0
PWV [mm]          = 2.5
Exposure Number   = 1
Target S/N    = 200

Band     Mag.    Sky     ExpTime [s]
[Blue]   18.00   20.70   2784.179688
[Green]  18.00   20.70   3346.679688
[Red]    18.00   20.70   2590.820312
[NIR]    18.00   20.70   3100.585938
[482.0]  18.00   20.70   2784.179688      (Band = Blue)
```

Fig. 5 Results of S/N (left) and exposure time (right) calculation for LR instrument. In the sky parameters, the airmass is fixed to 1.0 and the PWV 2.5 mm.



◀ Fig. 6 The results for S/N vs. magnitude (top) and S/N vs. wavelength (bottom) for LR (left), MR (middle), and HR (right). In the S/N vs. wavelength plots, the dashed line indicates in cased of the MR and HR with grating mode.



◀ Fig. 7 S/N vs. wavelength plot for specific order in HR instrument calculation. The index is set from dropdown menu on the GUI.

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