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SPECTROSCOPYPIPELINE: multi-instrument python-based pipeline for long-slit asteroid visible spectroscopy reduction

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Abstract

SPECTROSCOPYPIPELINE (SP) is a pipeline dedicated to the reduction of long-slit visible spectroscopic data. The pipeline can perform reduction of any spectroscopic data, but has been primarily developed and optimized for complete reduction of asteroid spectroscopic observation. It is a python-based open source pipeline intended to be easily portable to any long-slit spectrometer. It currently supports both Gemini North and South GMOS instruments, Lowell Observatory's 4.3m Discovery Channel Telescope DeVeny spectrograph and the SOAR 4.1m Goodman spectrograph.

1. Introduction

Reflectance spectroscopy is the primary tool to obtain information about the surface composition of an asteroid. The measured Sun light scattered by the surface of an asteroid contains a combination of signatures including the solar spectrum, atmospheric telluric features, and the intrinsic reflectance of the asteroid. After the removal of the spectrum of the Sun and telluric absorption bands by dividing the asteroid spectrum by that of a solar analog star, one can obtain the reflected spectrum of the asteroid. This reflected spectrum contains information about the composition of the surface of the target that can be constrained by analyzing the spectral slope and/or absorption bands at specific wavelengths.

Asteroid have been classified into several categories by the development of taxonomic systems [3]. Taxonomic classification of large samples belonging to different regions of the Solar System can provide information about formation and evolution processes.

Currently, no instrument-agnostic open source spectroscopic reduction tools using a state of the art programming language exist. Our goal is to try to solve this issue by developing a solution that takes advantage of the similarities of the reduction steps of all single-order long slit spectrographs. Instrument specific reduction procedures can be implemented using configuration files or separate additional sub-routines. In order to try to fulfill that goal, we present here a reduction pipeline optimized for visible long-slit spectral reduction written in the PYTHON programming language. It will be subject to a public release and will be open source. It has been successfully used for the reduction of 210 asteroid spectra presented in [4] in the framework of the MANOS program [5].

2. Methods and implementation

SP consist of a series of stand-alone scripts which can be run independently from each other. It allows the user to construct and correct for bias and flat fields. Nodding techniques in either spatial or wavelength space is supported by either subtracting images from each other or co-adding final wavelength calibrated spectra. Cosmic ray correction can be performed using the *astroscrappy* package[1] based on Pieter van Dokkum's L.A.Cosmic algorithm [6]. Background and telluric lines removal can be performed by fitting the brightness of the sky-background around the spectra with sigma clipping removal of the signal from the spectrum or spurious pixels. Wavelength calibration is performed by an automatic detection of the arc line from a calibration lamp. The relative distance between each detected line is computed and compared with templates constructed for the specific calibration lamp. The asteroid spectrum can be corrected from the Solar spectrum by dividing it by the spectrum of a solar analogue star. Both spectra are shifted relative to each other to optimize the correction of telluric absorption lines. The final step consists of assessing the taxonomic classification of the final asteroid spectrum by comparing it with taxonomy templates using a chi-square minimization technique.

[1] 10.5281/zenodo.1482018

3. Supported instruments

The pipeline currently supports both Gemini GMOS North and South instruments, the DeVeny spectrograph from the Lowell Observatory's DCT and the Goodman spectrograph from the SOAR 4.1m telescope. However, the pipeline has been developed to allow easy portability to any other spectrograph.

3.1 GMOS @ Gemini North and South

SP supports both original EEV CCDs and recently upgraded Hamamatsu e2v deep depletion detectors from both GMOS North and South. The supported gratings are the R150 providing a resolution of 0.174 nm per pixel and allowing observation from 0.36 to 0.94 μm and the R400 providing a resolution of 0.067 nm per pixel with a coverage from 0.5 to 0.9 μm. However, the GMOS focal plane is populated with 3 individual CCDs which produces chip gaps that prevent covering the entire wavelength range with a single exposure. The pipeline allows for dispersion offsets (controlled by dithering the grating angle) that are employed to mitigate through multiple exposures the effects of the chip gaps. Fig. 1 shows an example obtained with SP compared with other spectra for the same object obtained at different facilities and instruments.

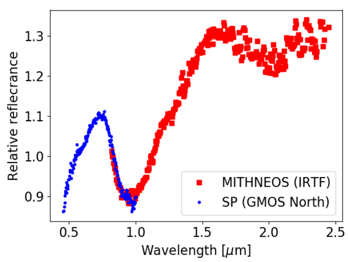

Figure 1: Comparison between the results from Gemini-GMOS (blue dots) and IRTF-Spex (red squares) [1] in for 2013 BO76

3.2 DeVeny @ DCT

The DeVeny spectrograph is mounted on one of the side ports of the instrument cube on Lowell Observatory's 4.3m Discovery Channel Telescope. The pipeline supports the 150 lines per mm grating providing a resolution of $4.3 * 10^{-4}$ nm per pixel and a free spectral range of 0.88 μm from 0.32 to 1.2 μm. Fig. 2 shows an example of reduction obtained with SP compared with other spectra for the same object obtained at different facilities and instruments.

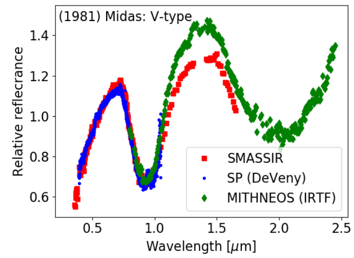

Figure 2: Comparison between spectra from DCT-DeVeny (blue dots), SMASSIR (red squares) [2], and IRTF-Spex (green diamonds) [1] for (1981) Midas.

3.3 Goodman @ SOAR

The Goodman spectrograph is mounted on the 4.1m SOAR telescope. The pipeline is currently supporting the 400 lines per mm grading providing a dispersion of 10^{-4} nm per pixel covering from 0.5 to 0.9 μm.

Acknowledgements

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