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SALT-RSS Multi-Object Spectroscopic Data Reduction to Reveal Physical Properties of [O II]-Emitting Galaxies from HETDEX & ODIN

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ABSTRACT

Line flux ratios from [O II] doublets can probe electron densities in the interstellar medium (ISM) of galaxies. We employ the Southern African Large Telescope's (SALT) Robert Stobie Spectrograph (RSS), which provides sufficient resolution (R ∼ 3000) to split the [O II] doublets, to target galaxies from HETDEX and ODIN with emission line fluxes of at least 2×10^{-16} erg cm^{-2} s^{-1}. Reduction is carried out using RSSMOSPipeline (Hilton et al. 2018) to reduce SALT-RSS data through wavelength calibration. Despite SALT-RSS being known for its difficulty to flux calibrate, we present spectra that have been flux calibrated using alignment stars with SDSS spectra as standards. We combine multiple spectroscopic settings to obtain full 2D spectra across a wavelength range of 3500Å-9500Å. A 1D spectrum can then be extracted to calculate flux ratios and line widths, revealing important physical properties of these bright [O II]-emitters.

Keywords: Spectroscopy (1558) — Galaxy spectroscopy(2171) —Emission line galaxies(459) — Astronomy data reduction(1861)

1. INTRODUCTION

Nebular emission lines allow researchers to probe the characteristics of emission-line galaxies such as electron densities, ionization parameters, dust reddening, velocity dispersion, metallicities, and star formation rates. Before these measurements can be made, proper reduction must be carried out so we can measure fluxes and observed wavelengths of emission lines found from our targets of interest. We investigate [O II]-emitters at redshift $z < 0.4$ using the Southern African Large Telescope's (SALT) Robert Stobie Spectrograph (RSS). Previously, our program only performed reduction up to wavelength calibration, as absolute flux calibration is often thought to be impossible on SALT-RSS. This paper describes a novel approach to flux calibrating an instrument such as SALT-RSS, followed by an additional routine that seeks to combine multiple spectroscopic settings on a single non-linear wavelength axis.

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[O II]-emitters are particularly important since their flux ratios are useful in determining electron densities. Hα and [N II] can also be present in these [O II]-emitters, which can help us measure metallicity using the [N II] λ6583/Hα line ratio as described in Pettini & Pagel (2004). This can be done prior to flux calibration since [N II] and Hα are close in wavelength, but better indicators like the [N II] λ6584/[O II] λ3727 (Kewley & Dopita 2002) line ratio require flux calibration, since the sensitivity function (described in Section 4) and dust attenuation vary with wavelength.

2. SALT-RSS INSTRUMENTATION

An instrument like SALT-RSS is necessary for our program because it can resolve the [O II] doublet with its high resolution settings (up to R ∼ 3000), with the Multi-Object Spectroscopy (MOS) mode enabling us to simultaneously target more than 10 galaxies and 4-5 alignment stars.

2.1. *Data Collection*

Our goal is to include as many [O II]-emitters as possible with fluxes of at least 2×10^{-16} erg cm^{-2} s^{-1} but with a priority on those with fluxes greater than 6×10^{-16} erg cm^{-2} s^{-1}. The lower limit should be sufficient in capturing low emission line fluxes while our priority targets maintain high S/N across multiple lines. We include alignment stars with Sloan Digital Sky Survey spectra (SDSS, Alam et al. 2015) to use as standards for flux calibration as described in Section 4. We take observations using multiple spectroscopic settings to obtain full 2D spectra of galaxies from a wavelength range of 3500Å to 9500Å. The spectral resolution and coverage are achieved using three gratings in RSS: PG3000 in the blue, PG2300 in the green, and PG0900 in the red, using two camera angles from each grating to fill in chip gaps and increase overall wavelength coverage.

The Hobby-Eberly Telescope Dark Energy Experiment (HETDEX, Ramsey et al. 1998; Hill et al. 2021) is a blind spectroscopic survey of the universe that covers a wavelength range of 3500 to 5500Å. The One-hundred-deg^2 DECam Imaging in Narrowbands (ODIN, Lee et al. 2024) is a NOIRLab survey that selects emission-line galaxies using narrowband filters that are expected to be similar to HETDEX [O II]-emitters. Datasets from both ODIN and HETDEX have been obtained and are ready for data reduction and analysis (Firestone et al. 2023).

3. BASIC DATA REDUCTION

We employ the RSSMOSPipeline (Hilton et al. 2018), which was created with the intention of performing reduction up to wavelength calibration specifically on SALT-RSS data. We cross-check the accuracy of the calibration by comparing observed wavelengths ofour HETDEX targets to the wavelengths that HETDEX reports. We can then identify emission lines through visual inspection, and do some preliminary measurements of electron density and velocity dispersion.

4. FLUX CALIBRATION & WAVELENGTH REPROJECTION

Flux calibration on SALT-RSS has often been considered an impossible task to due to variability in primary mirror illumination (Romero Colmenero et al. 2023). However, we develop a novel approach that addresses this limitation. When choosing alignment stars, our program selects at least 2 stars that also have SDSS spectra to use as standards. We develop a routine to take in the spectra of any number of SDSS stars in a given mask, however we recommend adding as many SDSS stars as needed to have the necessary wavelength coverage. The RSS spectra of stars previously observed by SDSS are divided by the corresponding stars' SDSS spectra to produce a sensitivity function.The newly created sensitivity function is subjected to polynomial regression before applying to the science images, removing chip gaps and systematics.

The final step before 1D spectral extraction involves reprojecting all the data onto a single non-linear wavelength axis covering the full 3500Å to 9500Å range. We use an exponential fit that maintains resolution in the green and blue gratings while intentionally oversampling in the red grating. This is done because the intrinsic resolution of the red grating is much lower, and we expect the [O II] doublets to be present in the green and blue gratings. Once reprojected, the data is written as a new 2D spectroscopic image in a fits file.

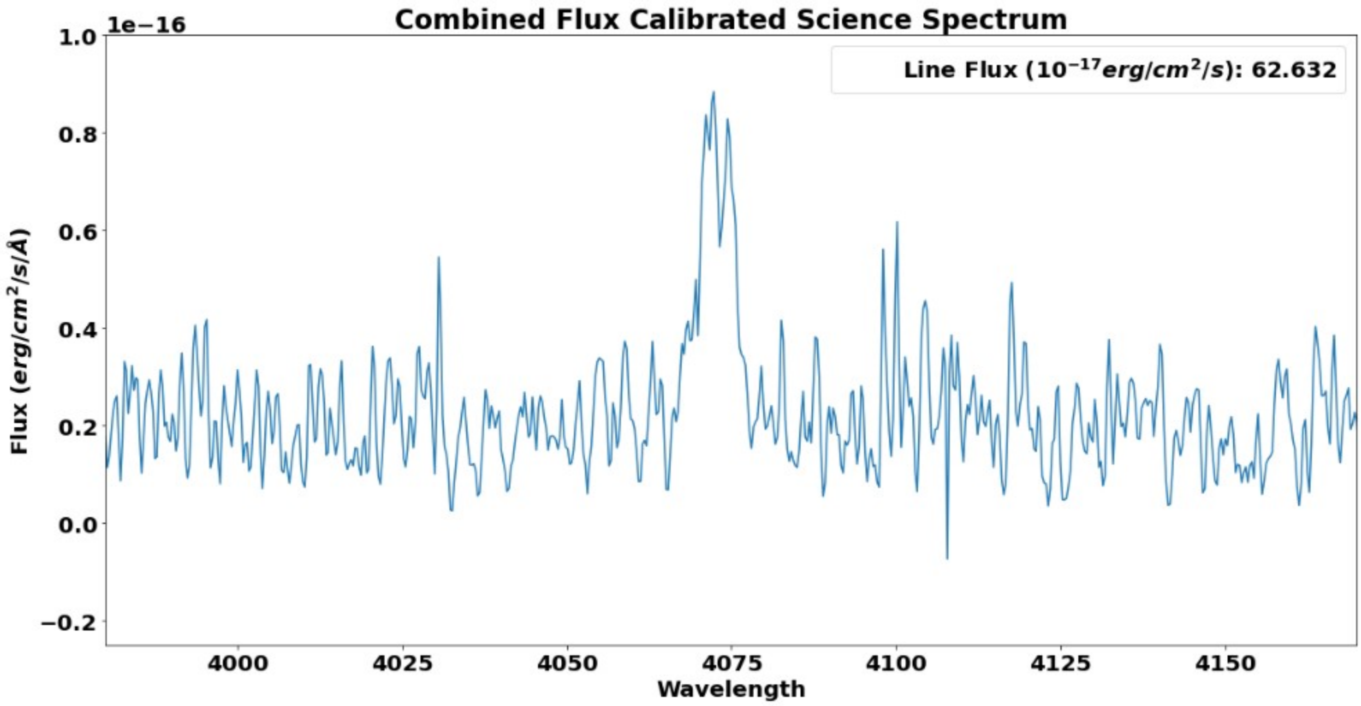

Figure 1. This is J100048.38+021454.2 (Gebhardt et al. 2021), an [O II]-emitter from HETDEX, with an [O II] line flux of 6.26×10^{-16} erg cm^{-2} s^{-1} visible at 4073Å. The value was derived post reduction and reprojection.

5. DISCUSSION

The results yield a roughly 25% accuracy in [O II] line fluxes when compared to HETDEX for two targets measured, including the target in Figure 1. We seek to maintain and improve this accuracy with upcoming developments to the pipeline after several more masks are reduced. One of these developments includes putting the SDSS alignment stars in slits the same size as our science slits instead of boxes. This should further improve the accuracy of our flux calibration routine by better representing slit losses and by minimizing the chances of star saturation. Currently, a 1D extraction routine is being adapted from RSSMOSPipeline's 1D extraction module, which needs to be restructured to work with flux calibrated and reprojected data (accounting for spatially varying emission lines across the entire wavelength coverage). There are currently several masks that can be reduced, and we plan more observations to be carried out in upcoming semesters.

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