LUCI: Natively Incorporating Machine Learning into Spectral Analysis

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Introduction

HII Regions

- HII regions are formed from gaseous clumps ionized by young, hot OB stars
- Characterized by strong recombination or collisional emission lines
- Tracers of different feedback mechanisms

SITELLE/SIGNALS

- Imaging Fourier Transform Spectrograph at Canada-France-Hawai'i Telescope
- 11'x11' Field-of-View
- Spectral Resolution up to 10,000
- Star formation, Ionized Gas, and Nebular Abundances Legacy Survey

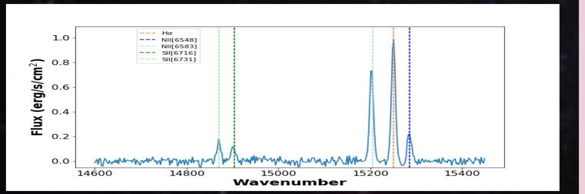
The Issue

Standard fitting procedures require a priori estimates of kinematic parameters that are often unknown initially. Our solution is to use machine learning to estimate these variables

Training

SITELLE Filter SN3 (657-685 nm), SN2 (48-520 nm), & SN1 (367-385 nm)
Sincgauss function with added noise

- [NII[λ6548
- [NII[λ6583
- [SII[λ6716
- [SII[λ6731
- Hα6563
- Hβ4681
- [OII]3726/3729
- [OIII]4959
- [OIII]5007



Example SN3 spectrum

Machine Learning Approach to Integral Field Unit Spectroscopy Observations: I. HII Region Kinematics

We present a method that uses Convolution Neural Networks (CNN) for estimating emission line parameters in optical spectra obtained with SITELLE as part of the SIGNALS large program. Our algorithm is trained and tested on synthetic data representing typical emission spectra. Once trained, the algorithm was tested on real SITELLE observations in the SIGNALS program of one of the South West fields of M33. The CNN recovers the dynamical parameters with an accuracy better than 5 km s-1 in regions with a signal-to-noise ratio greater than 15 over the H{\alpha}line. More importantly, our CNN method reduces calculation time by over an order of magnitude on the spectral cube with native spatial resolution when compared with standard fitting procedures.

A Machine Learning Approach to Integral Field Unit Spectroscopy Observations: II. HII Region LineRatios

In this paper we develop an artificial neural network to estimate the line ratios of strong emission-lines present in the SN1, SN2, and SN3 filters of SITELLE. Residual analysis of the network on the test set reveals the network's ability to apply tight constraints to the line ratios. We verified the network's efficacy by constructing an activation map, checking the [N ii] doublet fixed ratio, and applying a standard k-fold cross-correlation. Additionally, we apply the network to SITELLE observation of M33; the residuals between the algorithm's estimates and values calculated using standard fitting methods show general agreement. Moreover, the neural network reduces the computational costs by two orders of magnitude. The neural network can also excel at predictions in the low signal-to-noise regime.

A Machine Learning Approach to Integral Field Unit Spectroscopy Observations: III. Disentangling Multiple Components in Hii regions

In this third installment, we develop a framework using a convolutional neural network trained on synthetic spectra to determine the number of line-of-sight components present in the SN3 filter (656--683nm) spectral range of SITELLE. We compare this methodology to standard practice using Bayesian Inference. Our results demonstrate that a neural network approach returns more accurate results and uses less computational resources over a range of spectral resolutions. Furthermore, we apply the network to SITELLE observations of the merging galaxy system NGC2207/IC2163. We find that the closest interacting sector and the central regions of the galaxies are best characterized by two line-of-sight components while the outskirts and spiral arms are well-constrained by a single component. Determining the number of resolvable components is crucial in disentangling different galactic components in merging systems and properly extracting their respective kinematics.

LUCI: A Python package for SITELLE spectral analysis

LUCI is a simple-to-use python module intended to facilitate the rapid analysis of IFU spectra. LUCI does this by integrating well-developed pre-existing python tools such as astropy and scipy with new machine learning tools for spectral analysis. Furthermore, LUCI provides several easy-to-use tools to access and fit SITELLE data cubes. Luci includes a full Bayesian approach to calculating posteriors on key parameters such as flux, velocity, and velocity dispersion.

Papers using LUCI

Beyond the BPT Diagram: A Machine Learning Approach to Galactic Emission-Line Region Classification (Rhea; submitted)
SITELLE/CFHT Observations of the filamentary nebula surrounding M87 (Guité; in prep)
"Revealing the Nature and Kinematics of the Filamentary Nebula of NGC 1275 with High-Resolution Observations (Vigneron; in prep)

Conclusions:

★ Machine Learning is a viable method for emission line analysis
★ Training set must be developed with care
★ Errors are similar to those achieved with traditional methods
★ Considerably less computationally expensive than traditional methods

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https://crhea93.github.io
https://crhea93.github.io/LUCI/index.html
https://github.com/sitelle-signals/Pamplemousse