Uncovering the Ionizing Radiation Fields in Galaxies Using Detailed Photoionization Modeling

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Introduction

The COS Legacy Archive Spectroscopic SurveY (CLASSY; PI: Berg) marks the construction of the first high quality, high resolution far-UV spectral database of 45 nearby star-forming galaxies. The CLASSY sample of nearby galaxies spans a broad range of properties that pose a challenge to our understanding of how very high ionization emission lines are produced.

Research Goal

Our goal is to use the photoionization modeling code CLOUDY (Ferland et al. 2013) to model each of the 45 CLASSY galaxies individually using Binary Population and Spectral Synthesis (BPASS; Eldridge & Stanway 2016) and the measured nebular conditions (Berg et al. 2021) to constrain the intrinsic ionizing continuum and reproduce the observed emission-line spectra.

The results will be stored as a database of the best CLOUDY models for the CLASSY sample and will be used to inform the stellar contribution to the nebular emission lines (important for the nebular diagnostics). Further, differences between the observed spectra and those produced via the stellar population through CLOUDY reveal cases of missing ionizing flux.

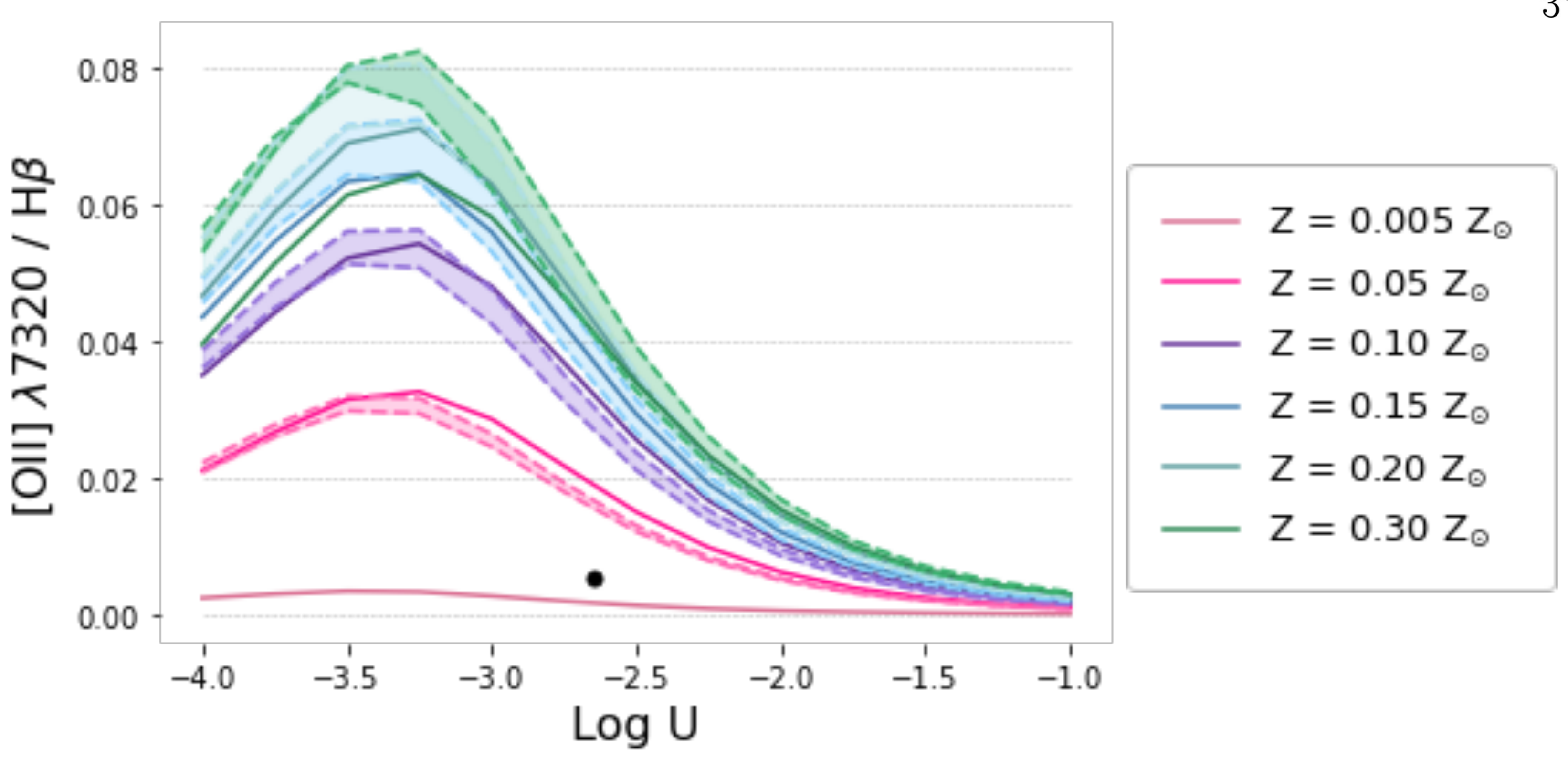
Methods

There are 3 steps we took: (1) Compiled the CLASSY data and created the grids of cloudy files, (2) ran the photoionization models and extracted the resulting parameters, and (3) following the method of Berg et al. (2018), analyzed a test galaxy: J104457.

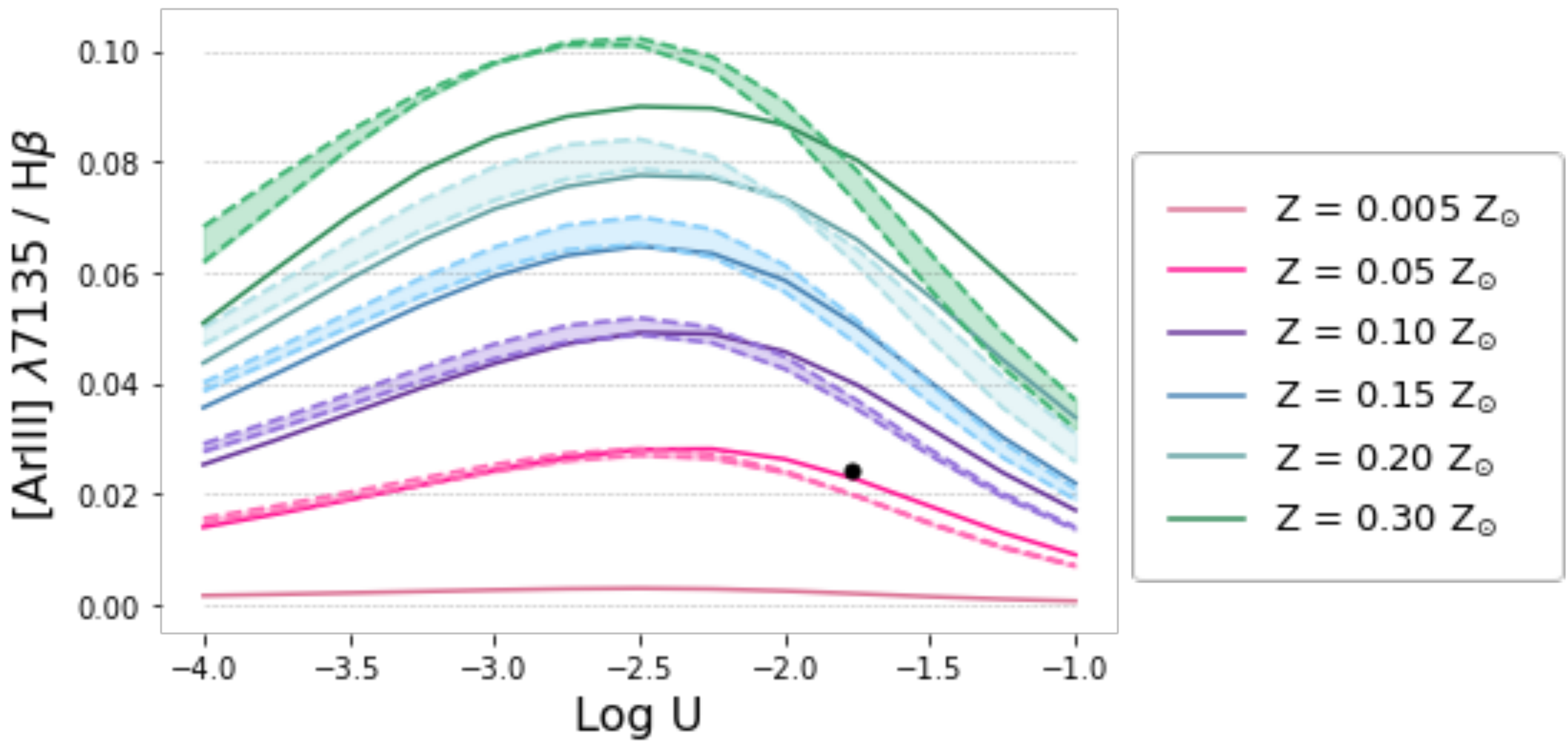
For the first step, we transformed the input parameters into a Pandas DataFrame. We then constrained the parameters using the 3σ error bar to create a grid of galaxy variations (Fig 2.). The galaxies variations were stored as a dictionary of data frames, essentially expanding our data from R^2 to R^3. We programmed a function to scan this dictionary and write the input files. A bash script was used to model the galaxy variations for J1044+0353.

Emission Line Ratios Over Hβ

[O II] Line Ratio Over Varying Metallicity and Age



[Ar III] Line Ratio Over Varying Metallicity and Age



[O III] Line Ratio Over Varying Metallicity and Age

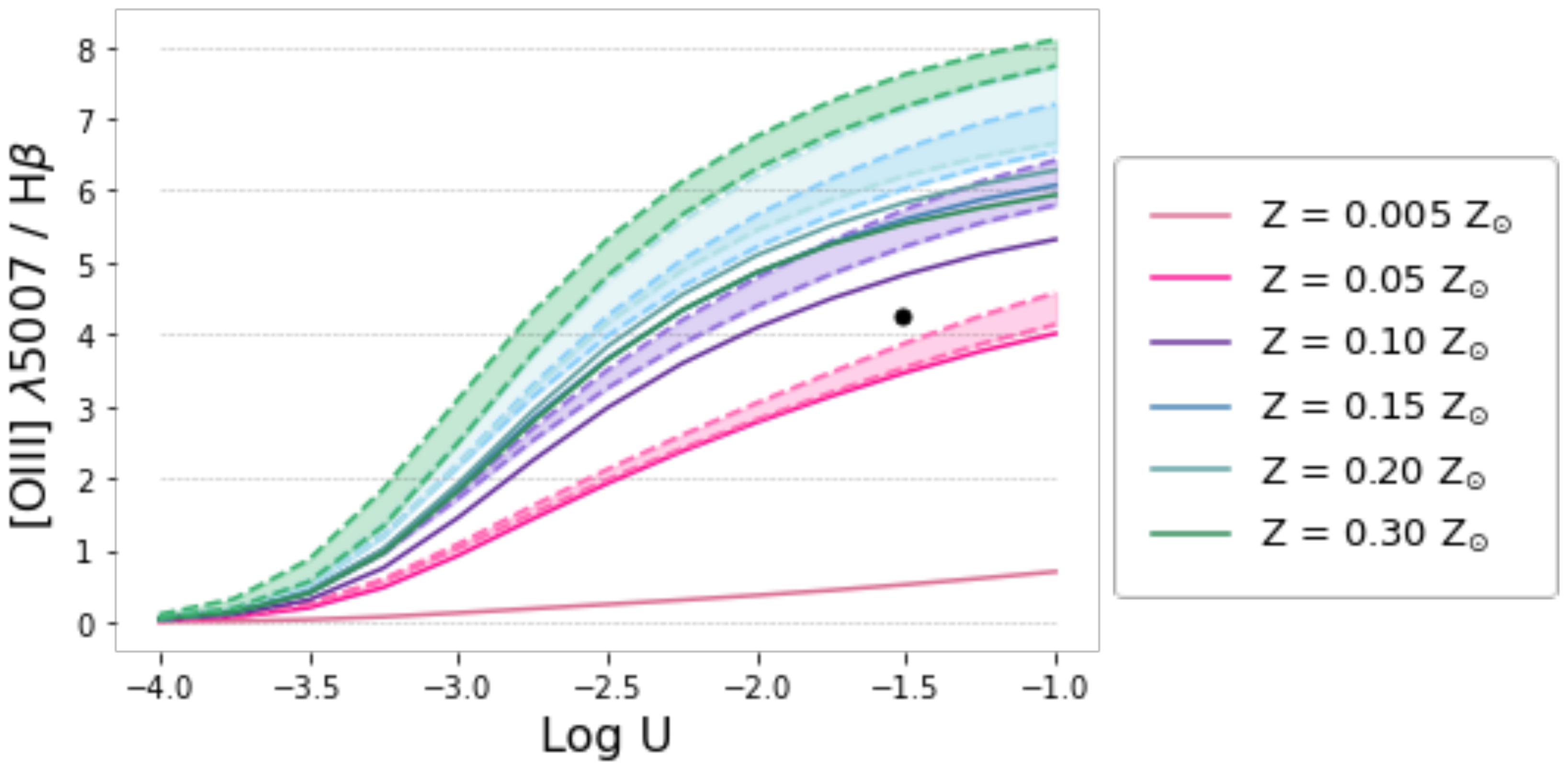


Fig 3. Emission line ratios from our CLOUDY photoionization models, where stellar bursts with ages of $10^{6.7}$ years are solid lines, and the shaded area extends to lower and upper bounds at 10^6 and 10^7 years, respectively. The observed emission line ratios of J104457 are plotted at their corresponding ionization parameters (log U). Note that the metallicity is scaled to the value of solar metallicity.

Galaxy J1044+0353

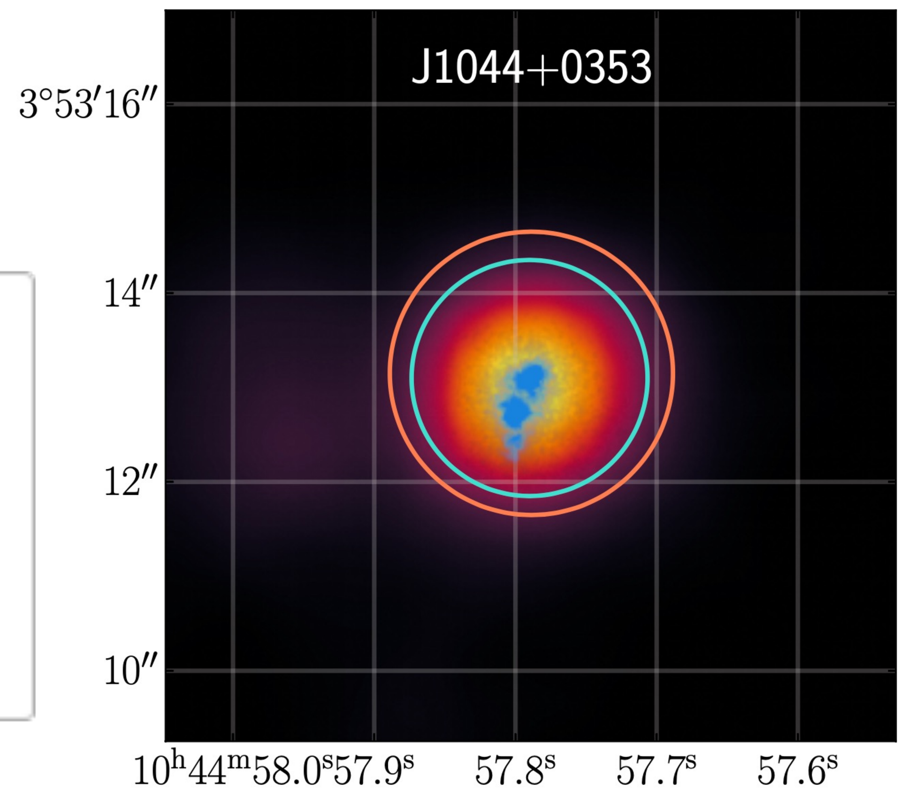


Fig 1. An HST UV image (blue light) overlaid on a SDSS optical image (red light) of the galaxy J1044+0353. Properly constraining the parameters of this galaxy allowed us to use photoionization modeling to reproduce the observed spectrum (Fig 2.). In order to set these constraints, we varied the parameter space by a set amount and stepped through this space in such a way that each step in any dimension is a potential galaxy. Thus, we were able to vary the parameter space in 4 dimensions for 7 steps in each dimension, then we had 7^4 or 2,401 varied galaxies for a single original input galaxy. Using TACC, we modeled every variation of J1044+0353 in CLOUDY to produce a grid of probable spectra that potentially corresponded with J1044+0353's observed spectrum.

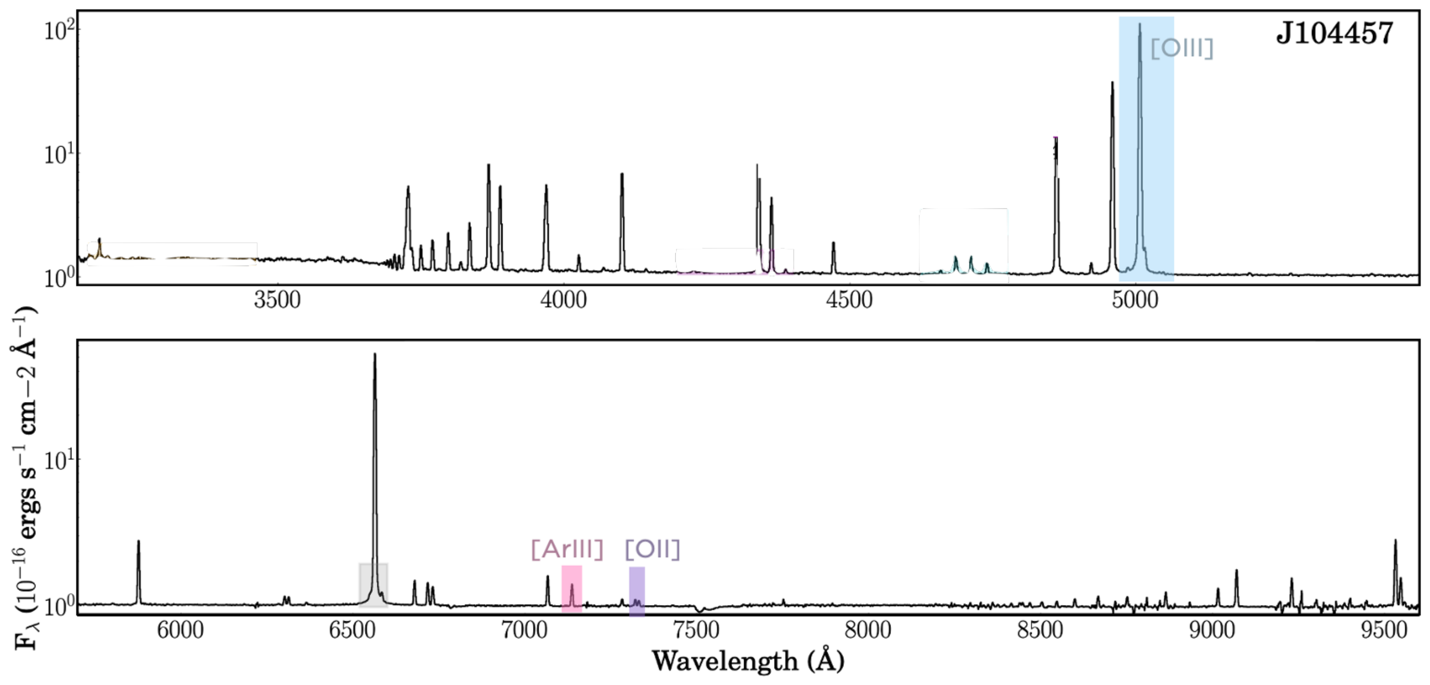


Fig 2. MODS/LBT optical spectrum of J1044+0353.

Results

The current results of the project show that we can effectively write input data using the necessary constraints to model over 2000 variations of J1044+0353, and we were able to match the observed emission line ratios from several ionization stages to the photoionization models, as shown in Figure 3. However, not shown here, emission from very high ionization ions such as [He II] cannot be reproduced from the simple stellar population models explored here.

The next step will be to add an additional contribution to the ionizing continuum to account for this difference.

Acknowledgements & References

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