Data Reduction Script for the GHOst Ultrafaint Legacy Survey

By Triana Cornejo Gonzalez, Supervised by Professor Kim Venn , Department of Physics and Astronomy
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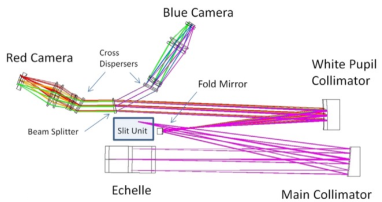
Gemini High-resolution Optical SpecTrograph

Mounted on the Gemini South telescope in Chile, GHOST is designed to capture high resolution spectra in the 383-1000 nm range[1] with optimal performance between 363 and 950 nm [2]. The spectrograph splits the light from a star into its constituent wavelengths which allows astronomers to study the chemical composition of the star's atmosphere.



Optical layout of the GHOST bench spectrograph [2]

Ultra Faints

Are dwarf galaxies residing in the galactic halo whith luminosities L < 10^5 times the solar luminosity L_{sol} (the Milky way has a luminosity of 1.5×10^{10} L_{sol}). The stars in these systems are old (>10 Gyrs) , metal poor [Fe/H] <-2.0 and spatially sparce [3] which is why they are thought to be surviving first galaxies.

GHOst Ultra-faint Legacy Survey

The GHOULS survey seeks to use the GHOST spectrograph in Gemini South to create a complete and homogeneous data set of stellar chemical abundances in the Ultra Faints visible from the southern Hemisphere. This will allow to probe the earliest periods of star formation in the universe. The GHOULS dataset will provide the launching point for detailed chemical abundances through the identification of stars with particularly unique abundance characteristics [4].

DRAGONS Pipeline

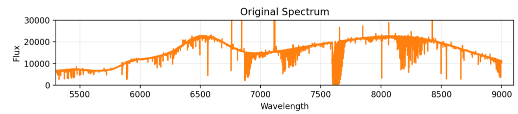
DRAGONS is a Gemini data reduction software that can be used with the file outputs from GHOST to apply the calibration frames (Bias, Flats Arcs) substract Bad pixel Masks, subtract sky frames, and apply barycentric corrections to the images. DRAGONS is a Python meta-package, which, for this project, was run on a terminal using a command line. The output files were in the commonly used FITS format and consisted of two 1D spectra of the target, one over the range 383- 530 nm (Blue Arm) and the other over the range 530 -1000 nm (Red Arm) [1][5].

FIXER 1

FIXER_1 is a Python notebook written to complete the last spectrum reduction steps before performing chemical analysis, and the focus of this research project.

Combining Exposures

For each wavelength, the fluxes on each of the exposures are median combined while the errors are combined with Poisson statistics.

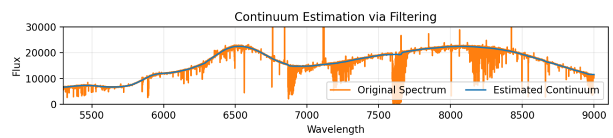


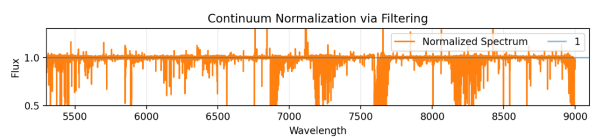
Normalization

This routine requires user input and has two options for estimating a continuum. The spectrum is divided by the estimated continuum from the chosen method.

Method A: Auto-Continuum Normalize
This method uses the ASAP module *spectra* to estimate a continuum via a 'smooth kernel' for which the size (in wavelength) is user specified. This method works best for the **red arm** and the long section of the **blue arm**.

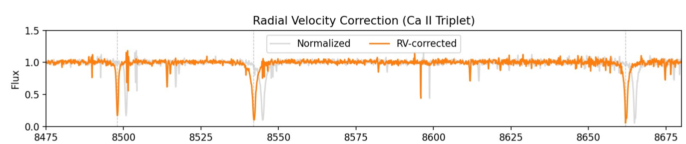
Method B: User specified continuum Curve
This method uses the another function in the ASAP spectra module which allows the user to manually select the continuum. This method works best for the short section if the **blue arm**.





Radial Velocity Correction

The radial velocities of the spectrum are calculated by cross-correlating with a metal poor star template. The radial-velocity functions are imported from APOGEE module.
Apart from calculating the radial velocity from the blue and red arms, the notebook also computes the radial velocities using specifically the calcium triplet and the H-alpha lines, for the user's reference (these are not used in the correction). The found radial velocities are saved to a text file and the arms are corrected.



Radial Velocity corrected spectrum of star in Bootes_1 showcasing the Ca II tripplet lines (RV = 106.34 km/s)

Further Notebooks and Impact

The FIXER_1 **red** and **blue arm** outputs are stitched together using IRAF. The Full spectrum is later fed to the PY_LOOPER noteboooks (Written by by Masters student Dasha Zaremba) which performs the chemical abundance analysis.

These notebooks are currently being used by members of the Uvic Near Field Cosmology research group in the GHOST data reduction routine.

"One Half of a Whole" [6]

Modules

ASAP spectra: Finds the first estimate of the continuum by applying a median filter with width = smooth_kernel to the spectrum and the second by applying a k-sigma clipping routine or it estimates the continuum function via user input i.e. allows user to draw a continuum by placing points on the given figure. (Written by UVic Undergrad J. Glover)

APOGEE dopler.rv: measures the cross-correlation shift between a template and an observed spectrum on the same logarithmic wavelength scale. (Written by David Nidever)

Acknowledgments

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References

[1] *GHOST*. Gemini Observatory. (2025, February 28). https://www.gemini.edu/instrumentation/ghost

[2] McConnachie, A., Hayes, C., & Pazder, J. (2024, March 7). The Science Performance of the Gemini High Resolution Optical Spectrograph. Astronomical Society of the Pacific.

[3] McConnachie, A., & Venn, K. (2023). 2024A Gemini Proposal.

[4] Smith, V., McConnachie, A., Margheim, S., & Venn, K. (2019). Mapping Chemical Evolution and the Sources of Neutron- Capture Nucleosynthesis in Ultra Faint Dwarf (UFD) Galaxies with GHOST and GHOULS.

[5] *Dragons documentation*. DRAGONS Documentation - DRAGONS 3.2.3 documentation. (n.d.). https://dragons.readthedocs.io/en/v3.2.3/

[6] International Gemini Observatory. (n.d.). *One Half of a Whole*. Gemini. Retrieved from https://www.gemini.edu/gallery/images/iotw2032a.