Analysis of the Gaia RVS Region in ESPaDOnS Spectra of Asteroseismic Calibration Stars

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Introduction

Spectroscopy is the distribution of light intensity versus wavelength. In particular, absorption spectra are what an observer sees when looking through the stellar atmosphere, and the absorption lines occur when incoming photons are absorbed. These lines differ in shape depending on a variety of reasons, but they all have a natural line width due to Heisenberg's time-energy uncertainty principle. Line broadening is influenced by Doppler broadening, pressure broadening, and rotational broadening. In general, faster moving molecules, frequent collisions, and a rapidly rotating star produce broadened absorption lines.

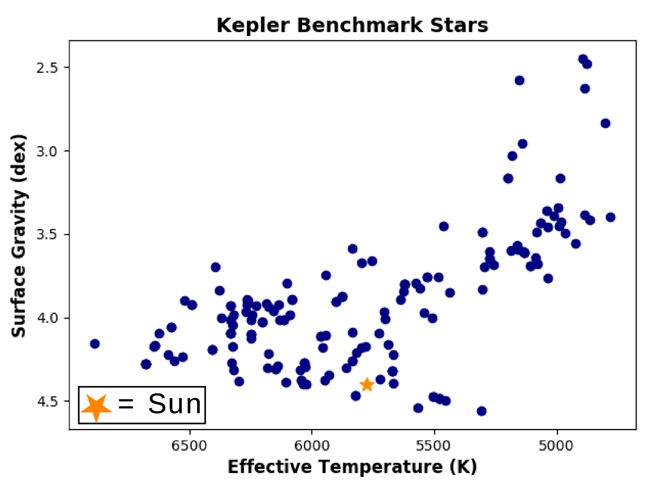
With spectra, important stellar parameters can be derived, such as effective temperature, surface gravity, composition, etc. For this reason, spectra is used to classify stars. For this project, surface gravity is an important stellar parameter to derive because with the following equation

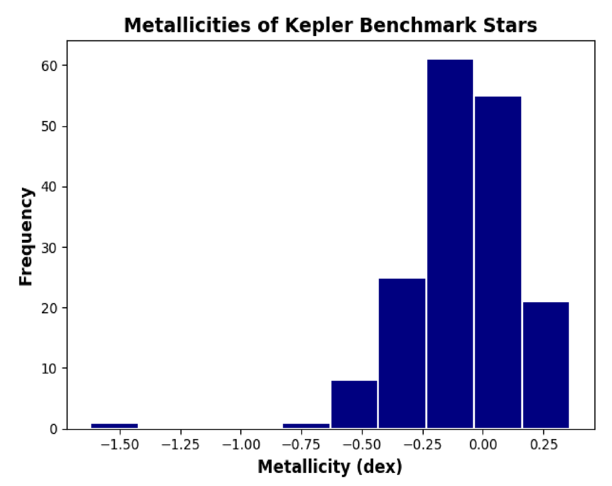
$$g = \frac{GM_S}{R_S^2} \; ,$$

a star's radius can be determined. This is important in the characterization of host stars of exoplanets. If used in tandem with the transit depth equation of an exoplanet orbiting a star, we can then obtain the planet's radius, as well. This project is in preparation for a future Gaia data release. By discovering a true indicator of surface gravity, this technique can be applied to the Gaia radial velocity spectra (R ~ 11000) being released for millions of stars.

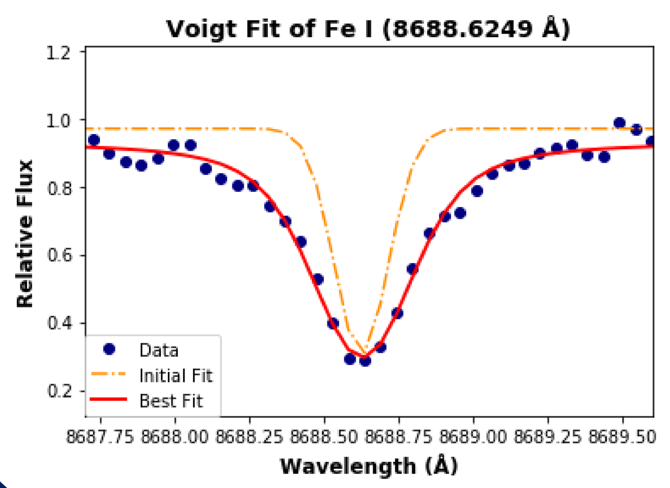
Methodology and Data

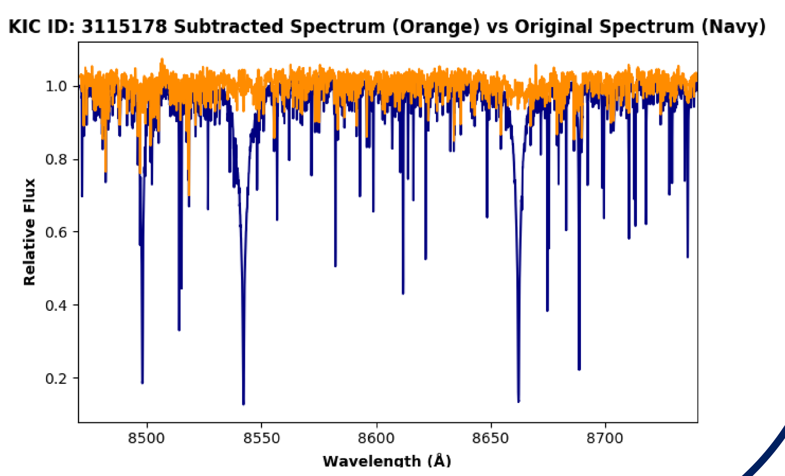
172 Kepler Input Catalogue stars, whose surface gravities are well-known from asteroseimology, σ = ±0.01-0.03 (Chaplin et al. 2014), were used. The spectra were obtained in 2017 from ESPaDOnS on the CFHT, and radial velocity shifts were applied to correct for any Doppler shifts.





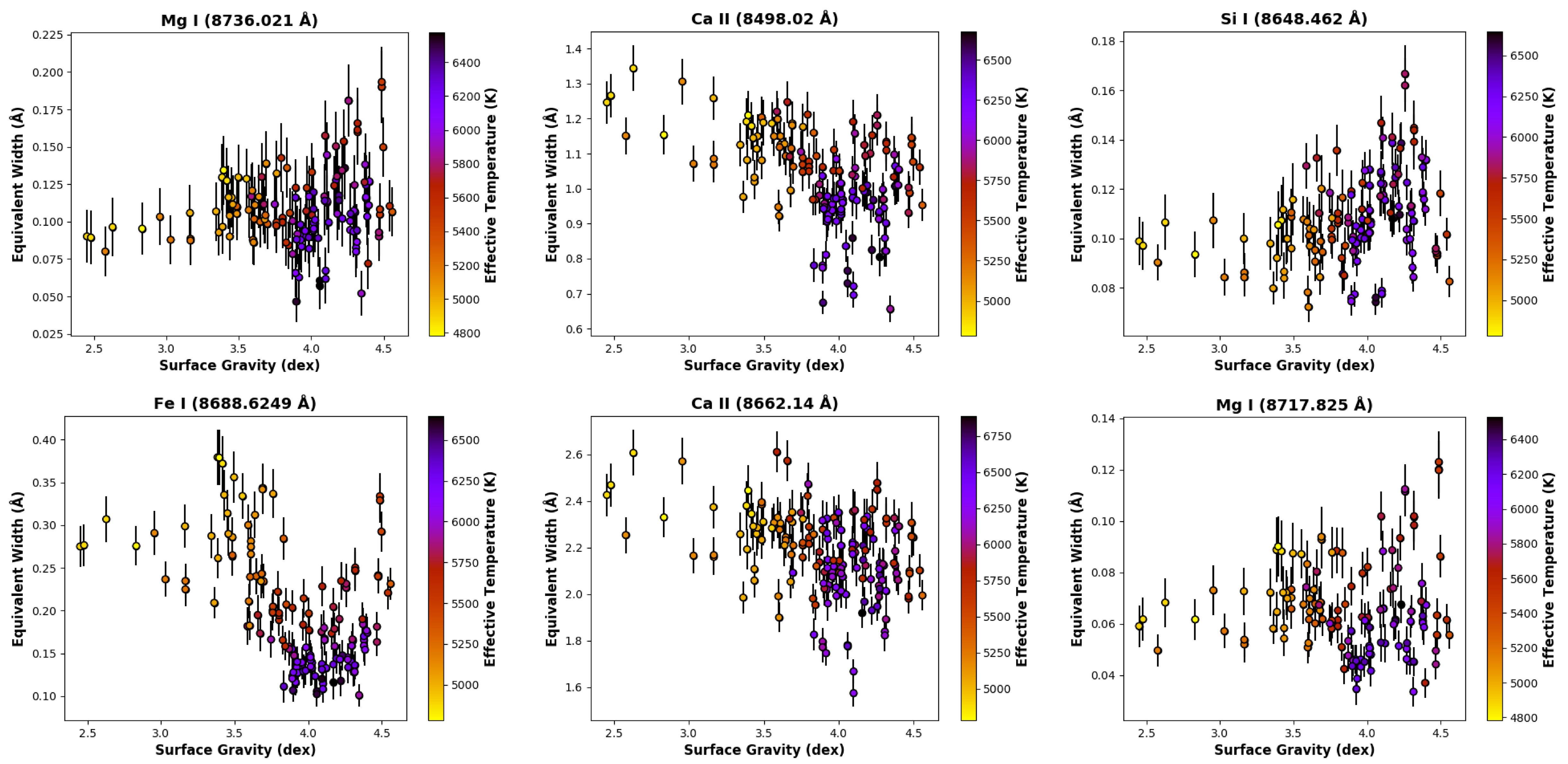
To evaluate the sensitivity of the spectral lines in the infrared Ca II triplet region (8470-8740 Å) to surface gravity, equivalent widths were obtained. The equivalent widths were extracted from a curve fitting process done in Python that uses a non-linear least squares method. The fits were then subtracted from the original spectrum. Fits that did not fit the center right or if the spectral lines were too broad were considered outliers.





Results

These spectral lines indicate the strongest correlation between equivalent width and surface gravity from this spectral region. A colorbar in terms of effective temperature was added since effective temperature correlates with equivalent width, as well. The goal is to find a spectral line that is mostly dependent on surface gravity.



Conclusion

The Mg I (8736.021 Å), Ca II (8498.02 Å), Ca II (8662.14 Å), and Mg I (8717.825 Å) lines appear to be the best indicators of a linear correlation between equivalent width and surface gravity so far; however, more work needs to be done to explore the effects of effective temperature. In particular, the Ca II (8498.02 Å) and Ca II (8662.14 Å) lines appear to be more temperature sensitive. It is interesting to note that the Mg I (8736.021 Å), Si I (8648.462 Å), and Mg I (8717.825 Å) plots show equivalent width increasing as a function of surface gravity. On the other hand, the Ca II (8498.02 Å) and Ca II (8662.14 Å) plots show equivalent width decreasing as a function of surface gravity. Additionally, the Fe I (8688.6249 Å) plot shows some gravity and temperature sensitivity. However, the sensitivity is much more complex than just a linear relationship. Future work needs to be done into performing regressions of the equivalent widths, performing the same process with more stars, and degrading the spectra. The spectra needs to be degraded prior to applying it to the Gaia spectra because the original spectra have a resolution of 81,000.

Acknowledgements

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Reference

Chaplin, W. J., et al. 2014, ApJS