Low-Resolution Stellar Spectroscopy at the UNH Observatory: Resolving Absorption Features Across the OBAFGKM Sequence

Joseph Arena, John Gianforte (Faculty Advisor)
Department of Physics and Astronomy, University of New Hampshire, Durham, NH 03824

Introduction

The chemical composition of a star is encoded within their starlight that it emits and can be analyzed using spectroscopy. For my thesis I investigated the limits of the UNH Observatory's capability in distinguishing absorption lines across the spectral sequence using low-resolution visible spectroscopy.

Spectroscopy is the primary tool astronomers use to determine the chemical composition, temperature and radial velocity of astronomical objects such as stars, nebulae, and galaxies. For stars, they are classified into the following sequence by decreasing surface temperature:

O > B > A > F > G > K > M

Each spectral class exhibits characteristic absorption features. For example, A-type star show strong hydrogen Balmer lines, while cooler K and M stars show prominent molecular absorption bands (e.g. TiO)

Methodology

Equipment & Software
- 14" SCT with the Star Analyzer 100 and Canon EOS 2000D DSLR
- Stellarium and TheSkyX Professional Edition for locating target stars
- RSpec to analyze the data

Selecting a Star
- Two stars per spectral class
- Altitude >30° to reduce atmospheric effects
- Isolated and bright star for ease in imaging and negligible spectral contamination of nearby stars

Capturing Image
- Multiple bracketed exposures to avoid oversaturation
- Remote/timed capture used to reduce vibrations on camera

Calibration
- Spectra extracted using RSpec
- Wavelength calibration using known H-beta line of an A-type star

Observed Targets

Object Type	Object Names
O	AE Aur, 9 Cam
B	Regulus, Alkaid
A	Tania Borealis, Merak
F	Wasat, Zavijava
G	Mebsuta, 77 Gem
K	Pollux, 46 Gem
M	69 Gem, Tania Australis

Table 1: These two representative stars for each spectral class were chosen due to their location in the sky during observation and having either a dim or no companion stars.

Taking Data

Star Analyzer 100

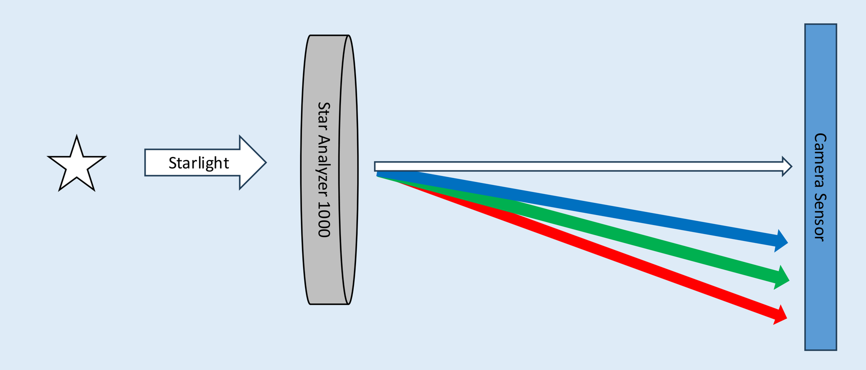

Figure 1a: Starlight passes through the diffraction grating of the star analyzer 100, most of the light is diffracted to one side of the sensor to create a spectra.

Raw Spectrum of Tania Borealis

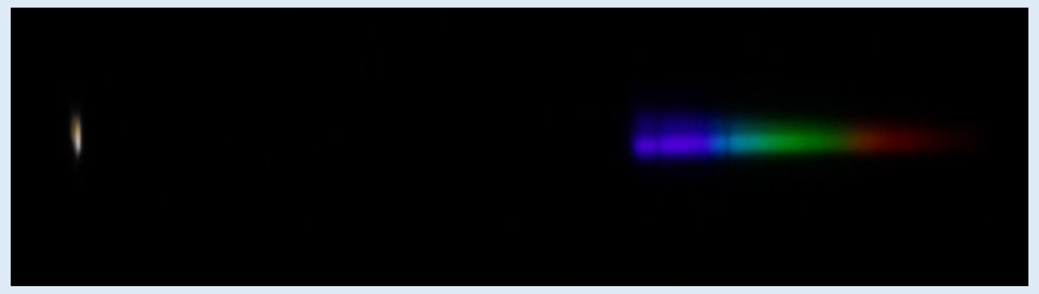

Figure 1b: Extracted spectrum of an A-type star Tania Borealis. The zero-order image is visible to the left and the spectrum dispersed to the right.

Calibration

Reference Star

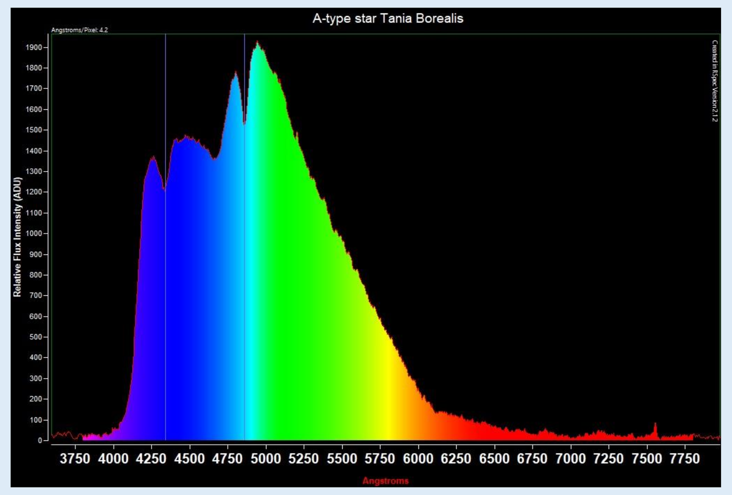

Figure 2a: A-type star Tania Borealis star spectrum with absorption features noted

RGB Profiles

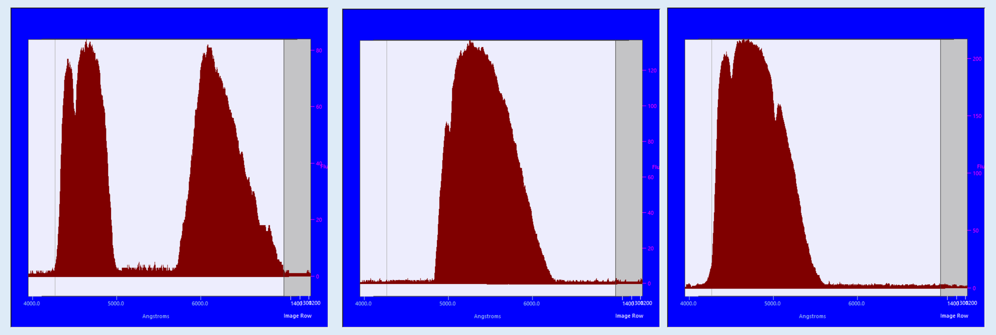

Figure 2b: Left to Right: Pixel map of Tania Borealis on the Red, Green and Blue pixels in the DSLR camera

Spectrum of Stars

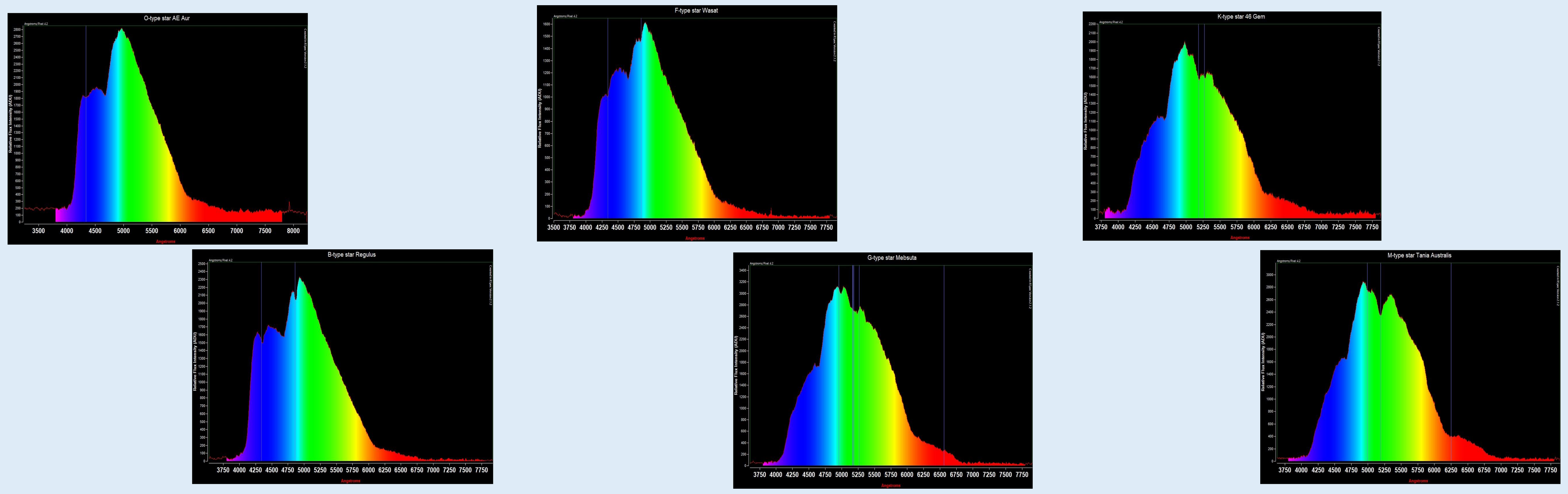

Figure 3: Left to right: O, B, F, G, K, M spectra for each stellar spectral class. As temperature decreases from O to M type stars, the spectra shows a transition from weak hydrogen and helium absorption lines to strong absorption lines in A type stars followed by increasing metal lines and weakening Balmer lines. Additionally, following Wien's law, the overall continuum shifts to longer wavelengths as temperature decreases.

Results

Table 2: By comparing observed absorption patterns with standard low-resolution spectral atlases, these were the features detected.

Object Type	Spectral Features Detected
O	H-gamma, He I (447 nm)
B	H-gamma, H-beta
A	H-gamma, H-beta
F	H-gamma, H-beta
G	Fe I (496 nm), Mg I triplet+Fe I (~517 nm), Fe I (527 nm), H-alpha
K	Mg I triplet+Fe I (~517 nm)
M	TiO 499 nm, TiO 519 nm, TiO 625 nm

An artificial feature between 462-469 nm is present throughout all my data, this is due to an overlap in the DSLR Bayer filter response.

Conclusions

The UNH Observatory can resolve several prominent spectral features at 100 lines/mm grating (R ~ 100).
- O-type stars: detection of Hydrogen gamma and neutral helium
- B-A-F type stars: Hydrogen gamma and beta features observed with A-type stars hosting the most prominent Balmer lines
- G-K type stars: blended neutral metal features of Fe I and Mg I, Hydrogen alpha is faintly detectable
- M type stars: broad molecular absorption bands

However, without calibrating for the instrument response, the camera's Bayer filters overlap prevent the detection of several spectral lines
- Doubly ionized carbon in O and B stars
- Doubly ionized nitrogen and singly ionized helium in O stars
- Individual neutral iron lines in G and K stars

A few things I could have done differently is compare absorption features of a star using a different telescope, compensating for the instrument response and using a wider variety of stars.

Acknowledgements

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References

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