Zeeman Effect in Ap Stars

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Why Ap Stars?

Ap stars, A-peculiar stars, are a type of main-sequence star with chemically-peculiar concentrations of elements such as Si, Cr, or Sr. They have strong absorption lines of certain ionized metals. Some Ap stars exhibit strong magnetic field strengths that can be diagnosed through the observation of circular polarization in spectral lines. These observations help astronomers determine the geometry of magnetic and chemical surface structures, and aid our understanding of the physical mechanisms governing the evolution of the magnetic field. We observed three Ap stars: HD 215441, HD 65339, and HD 47103.

$$B = \frac{\Delta\lambda}{k(g_{eff})(\lambda_0)^2}$$

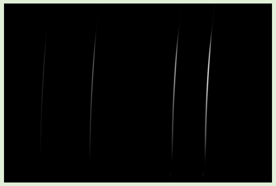
Figure 1. The Zeeman Effect equation uses the observed wavelength separation in spectral lines to determine the strength of the magnetic field required to create the observed separation. The local and global magnetic fields in some stars are strong enough to create spectral-line splitting.

The Zeeman Effect

The Zeeman effect is the splitting of the observed spectral lines created during an electronic transition in an atom while in the presence of a strong magnetic field. It occurs due to the distortion of the electron orbitals in the presence of the field. This phenomenon is also observed in some stars with strong magnetic fields. Ap stars are one kind of star that may have fields strong enough to generate the splitting of atomic spectral lines. Usually, the splitting is observed in the spectral lines of atoms that have relatively high g_{eff} values.[2] Si II and Fe II are such atoms.

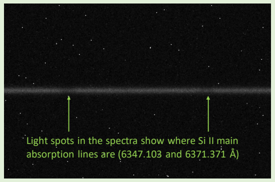
Methods

Calibration



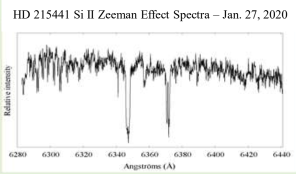
We observed at Mayhill, NM – latitude 32.9° N, longitude 105.5° W – from Jan. 30 to Feb. 2. Our final results also utilized data obtained earlier at the same site. Calibration images, like the one shown above, use Neon lines of known wavelengths to calibrate our spectra.

Getting Spectra



Each star was observed by taking six 600-sec. exposures of the star's center. A processed spectrum of HD 215441 is shown above. The spectra are processed using bias, dark, and flat images to correct for instrument imperfections.

Data Analysis



The final spectral tracing is found using ISIS (Integrated Spectrographic Innovative Software).[1] The spectral tracing for HD 215441 is shown above. This tracing shows the split Si II lines at wavelength 6371.371 Å.

Spectra and Magnetic Field Calculations

Star	Observed Magnetic Field (KiloGauss)	Standard Deviation	Average Literature Value[3]	Percent difference from literature
HD215441	32.19 kG	3.98 kG	33.59 kG	4.2
HD65339	13.00-15.29 kG	--	8.50-16.50 kG	--
HD47103	16.22 kG	3.60 kG	17.32 kG	6.3

Table 1. Using the Zeeman Effect formula, we calculated the magnetic field strength values, in kilo-gauss. The values were similar to established literature values for the strengths.[3] The Spectral line doublet for Si II was used to determine B for HD 215441 and HD 47103. The magnetic field for HD 65339 was not strong enough to use the Si II doublet. Instead the Fe II triplet at 6369.462 Å was used (See **Figure 3**.).

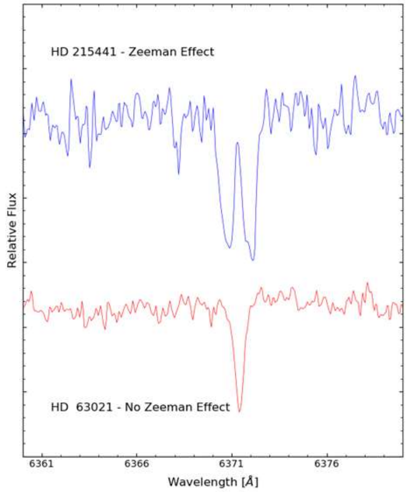


Figure 2. HD 215441, a strong magnetic Ap star, displays a spectral doublet around the Si II base wavelength of 6371.371 Å. The split is easily observed. HD 63021 is a non-magnetic Ae star, that exhibits the typical Si II spectral line.

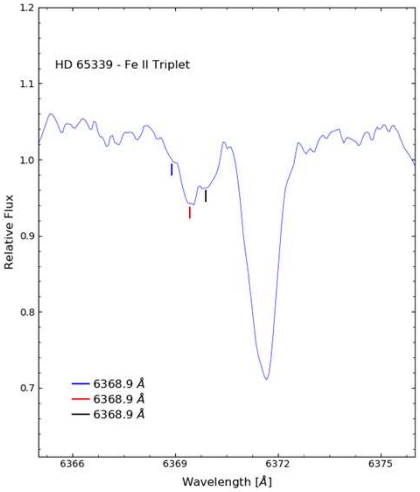


Figure 3. HD 65339 does not have a magnetic field strong enough for the Si II line to be observed with our spectral resolution. Instead, the Fe II (6369.41 Å) triplet was used. The three peaks of the triplet are identified in the image.

What Next?

Further research into the Zeeman Effect:

- Continue observations to evaluate the variable nature of the stellar magnetic field strengths
- Collect additional spectra to share with international databases
- Use spectral observations to evaluate orbital motion parameters for magnetic and non-magnetic stars

Further research into spectra-splitting phenomena:

- Binary stars have separating spectra due to the observation of two stars

Figure 4. Mayhill Observatory: Carbon Fiber Tube 14-in. Celestron SCT fitted with a LHIRES III high-resolution spectrometer for collecting spectra. It uses a high-quality Paramount mount for stable star tracking.

References

1. Buil C. ISIS (Integrated Spectrographic Innovative Software). 1999-2019 [accessed 2020].
2. Chojnowski, D. (2020, April 3). "G_eff Values for Ap Stars". Personal Communication with Dr. James Dull.
3. Mathys G. Ap stars with resolved magnetically split lines: Magnetic field determinations from StokesIandVspectra. Astronomy & Astrophysics. 2017;601. doi:10.1051/0004-6361/201628429

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