The Rotational Period of the Sun Using the Doppler Shift of the Hydrogen alpha Spectral Line

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Abstract

The fact that the sun rotates is obvious by observing the daily motion of sunspots. The overall sunspot movement to the west is a result of this solar rotation. However, solar rotation can also be determined by observing the solar spectrum at the solar limbs. The absorption lines in the spectrum will display a Doppler shift since the east limb is coming toward the observer and the west limb is moving away. The velocity of the limb, relative to the observer, can be determined from these spectral line shifts. Knowing the solar radius, the rotational period can be calculated.

1. Introduction

The observation of sunspots demonstrates solar rotation. The overall sunspot movement to the west is a result of this solar rotation. Galileo calculated the suns rotational period in 1610 using these observations.

The utilization of high resolution spectroscopic analysis employing small aperture telescopes (0.35m) can also be used to measure the sun's rotational period.

The rotational velocity can be calculated by using the observed Doppler Effect. Observations of the Hydrogen α absorption line at the limb shows a small spectral shift to shorter wavelengths as the east limb is coming toward the observer and to longer wavelengths as the west limb is moving away. Comparing these wavelength differentials from the laboratory standard of the Hα line, the rotational velocity can be calculated. Knowing the solar radius and the rotational velocity, the rotational period can be calculated.

2. Observations, Measurements and Calculations

Hydrogen absorption spectral lines are quite obvious in both low and high resolution images of the solar spectra and can be measured quite easily using available computer software programs (Figure 1).

High resolution spectra of the sun's Hα absorption line were obtained using the Merritt Observatory 0.35m Schmidt casagrain telescope and the *Merritt Spectrograph.* Spectra were taken on the eastern and western limb of the sun (Figure 2).

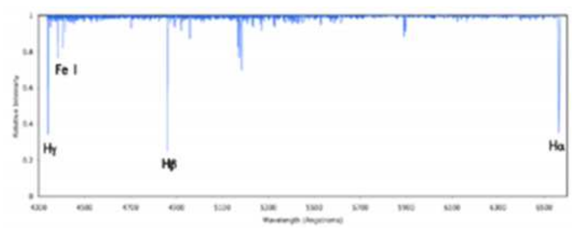

Figure 1. Low resolution solar spectra showing hydrogen alpha absorption lines (*McMath-Pierce Solar Observatory*).

Figure 2. High resolution Hα absorption line.

The spectra were profiled for analysis using *RSpec Real Time Spectroscopy* software (Figure 3). The Hα absorption line wavelength was determined after the spectra was calibrated using a neon standard (Figure 4).

Figure 3. Profiled spectra.

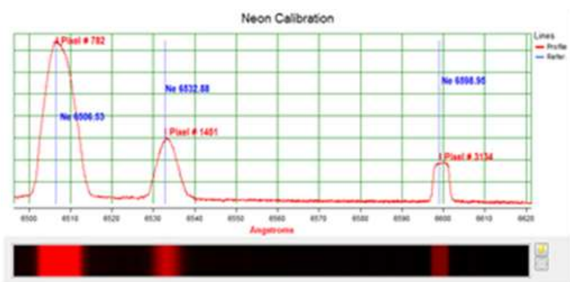

Figure 4. Neon calibration spectra.

From the profiled spectra above, Hα wavelength values were obtained:

Hα eastern limb = 6562.757 ± 0.005 Å
Hα western limb = 6562.837 ± 0.005 Å
Hα lab standard = 6562.797 ± 0.001 Å

Calculating the rotational velocity using:

$$C = 2.99792458 \times 10^{8}\ ms^{-1}$$

and

$$V_{rot} = \frac{\lambda - \lambda_o}{\lambda_o} C = 1999.9\ ms^{-1}$$

Calculating the rotational velocity error using:

$$V_{rot}\ \text{published} = 7.189 \times 10^{6}\ ms^{-1}$$

then

$$\text{Error, } V_{rot} = 2.99\ ms^{-1}$$

Calculating the rotational period using:

$$R_s = 6.955 \times 10^{8}\ m$$

and

$$T_{rot} = \frac{2\pi R_s}{V_{rot}} = 25.3 \text{ days}$$

Calculating the rotational period error using:

$$T_{rot}\ \text{published} = 25.05 \text{ days}$$

then

$$\text{Error, } T_{rot} = 0.25 \text{ days}$$

3. Results

The values calculated apply to the equatorial region of the Sun; the rotational angular velocity varies across the surface of the Sun from the equator to the poles. This is referred to as differential rotation.

At the equator the solar rotation period is 25.05 days. This is the sidereal rotation period (Figure 5), and should not be confused with the synodic rotation period of 26.91 days; which is the time for a fixed feature on the Sun to rotate to the same apparent position as viewed from Earth. The synodic period is longer because the Sun must rotate for a sidereal period plus an extra amount due to the orbital motion of the Earth around the Sun.

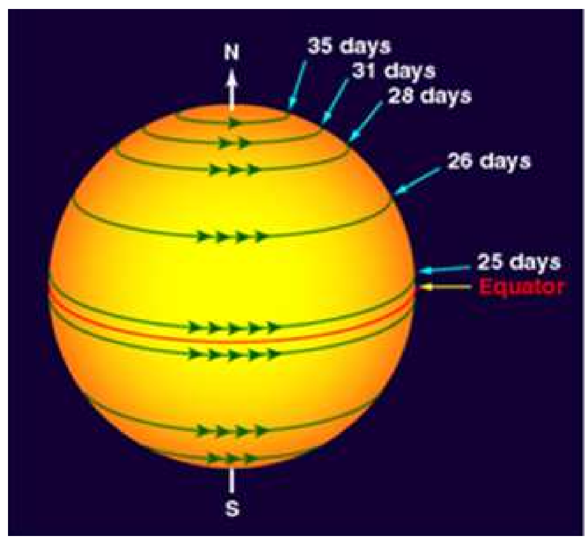

Figure 5. Differential solar sidereal rotation.

4. Conclusion

Significant assumptions have been made when measuring the solar spectral lines. Physical effects such as temperature, pressure, elemental abundance, density and surface gravity have been ignored. These properties affect the width and the height as well as the shape and position of the spectral lines.

Considering that these assumptions and constraints would drastically complicate this exercise, they have been excluded. This technique yields a satisfactory value for the rotational period of the sun considering that the Doppler shifts obtained were at the limits of the resolution of the Merritt Spectrograph. This technique and apparatus can be used as in a simple laboratory exercise for physics and astronomy classes demonstrating the methods and techniques utilized by astronomers.

5. Acknowledgements

I would like to thank Michael Burin, *CSUSM Physics Department, for his insight and willingness to utilize this exercise in his astronomy laboratory class.*

6. References

Gill, R. M. (2011). "Construction of an Inexpensive High Resolution Littrow Spectrograph for Be Star H Alpha Analysis." *in Proceedings of the 30th Annual Symposium on Telescope Science (Warner et al., eds.)*. Society for Astronomical Sciences, Rancho Cucamonga, CA.

RSpec. Real time spectroscopy. *http://www.rspec-astro.com/*