Solar Cycle-Related Variability of Sun-as-a-Star Spectral Line Profiles

Matt Kalscheur[1,2], Serena Criscuoli[2], Luca Bertello[2], Alexei Pevtsov[2]

[1] University of Wisconsin-Madison, [2] National Solar Observatory

1. Introduction

We use daily observations of the Sun-as-a-star by the high resolution Integrated Sunlight Spectrometer (ISS) to investigate solar cycle-related variations in line profiles of the ISS's CN, C I and Mn I spectral bands. Magnetohydrodynamic simulations show that the magnitude of the CN band-head jump is anti-correlated with magnetic flux density (see Fig. 1). Similarly, absorption line parameters (core intensity, full width at half maximum and equivalent width) of the C I and Mn I bands are expected to vary with thermal and magnetic activity in the solar photosphere. [2]

If confirmed by observation, these line properties can be used to disentangle thermal and magnetic effects in the Sun, and trace activity cycles of other Sun-like stars. An improved understanding of stellar activity cycles could shed light on the Sun's long-term magnetic future, and speak to such topics as the habitability potential of respective star systems.

2. Data Analysis

- Extracted line parameters from ISS observations covering the decline phase of Solar Cycle 23 and rise and fall of Solar Cycle 24 for CN, C I and Mn I bands (see Fig. 4 for sample spectrum of Mn I band). No observations beyond October of 2017 currently exist as the instrument is being moved to a new location
- Magnitude of CN jump measured as the scaled intensity difference between mean of continuum values immediately to the right of the jump and mean of a cubic spline fit to the line features from 388.29 to 388.32 nm immediately to the left of the jump (see Fig. 2)
- Core intensities determined from polynomial fits to the bottom of absorption line profiles of C I and Mn I bands (C I results not shown, but broadly similar to Mn I)
- Full widths at half maximum determined from cubic spline interpolations at proper intensity levels
- Equivalent widths calculated by numerical integration with the following formula: $\int (1 - I_\lambda)\, d\lambda$
- C I and Mn I analyses a continuation of work done by Bertello et al. 2014

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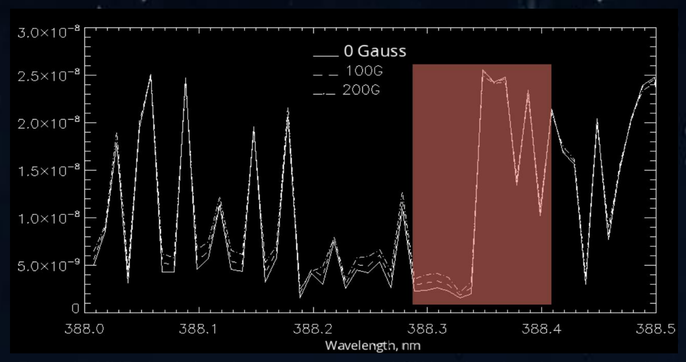

Figure 1 - MHD simulation of spectral response of CN band to changing magnetic flux density. The CN jump refers to the abrupt change in intensity at ~388.34 nm.

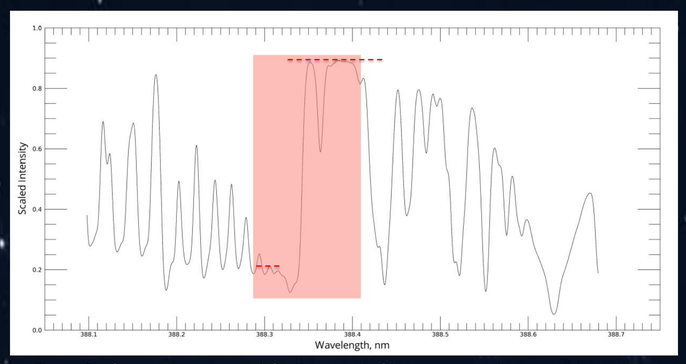

Figure 2 - Sample spectrum of CN band with CN jump area of interest highlighted. Dashed red lines give indication of positions used to measure magnitude of jump.

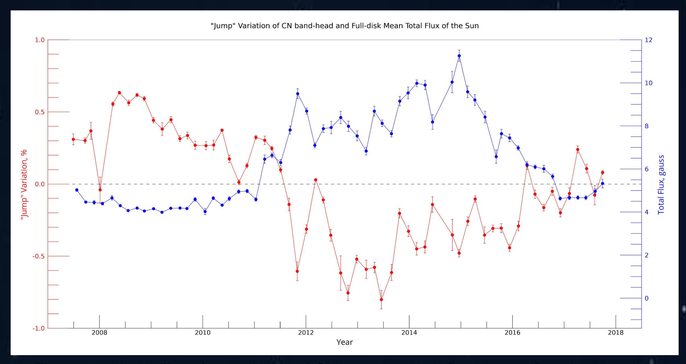

Figure 3 - Variability of magnitude of CN jump and total unsigned flux density with respect to their time series median values. Observations were averaged into 60-day intervals.

3. Results & Conclusions

- Observations show CN jump anti-correlated with magnetic flux density, indicating its potential as a tracer of activity cycles in Sun-like stars
- Core intensity, FWHM and EQW parameters vary with the solar cycle, but correlations not as robust as with CN jump
- Would like to see the ISS up and running again in order to extend the time series
- Would also like to see results compared with measurements from other high resolution spectrometers, such as PEPSI on the Large Binocular Telescope

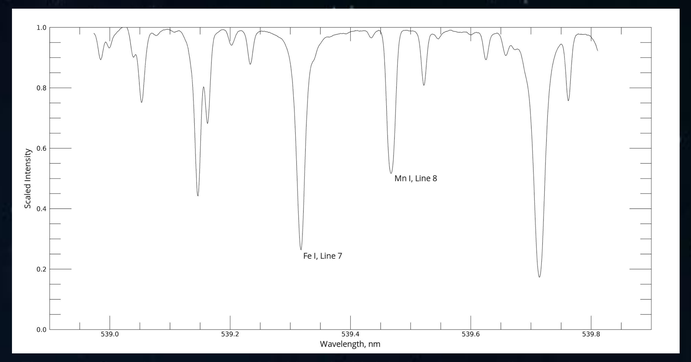

Figure 4 - Sample spectrum of Mn I band with labels corresponding to absorption line parameters plotted in Fig. 5.

Figure 5 - Variability of core intensity, full width at half maximum and equivalent width of Lines 7 and 8 of Mn I band with respect to their time series median values. Observations were averaged into 60-day intervals.

4. References

[1] Uitenbroek & Tritschler (2006), ApJ, 639, 525

[2] Criscuoli et al. (2013), ApJ, 763, 144

[3] Bertello et al. (2014), Cool Stars 18, 693