Solar Activity and Responses Observed in Balmer Lines

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SSI variability: Solar cycle @ ~1 nm spectral resolution

Marchenko et al., 2019
Solar cycle 24: max SSI - min SSI

Marchenko & DeLand, 2014

Adapted from: Maldonado et al., A&A 627, A118 (2019)
Overall, the chromospheric activity (H&K CaII) level correlates with Hα line-core flux in only 23% (20% positive, 3% negative) of FGK stars (a sample of 271 stars: Gomes da Silva et al. 2014).

Solar analog **HD 38858**: G2V, P~10.8y activity cycle (Flores et al. 2018), similar to the case of another solar analog, **HD 45184** (Flores et al. 2016)

- **Blue**: high-activity – reference
- **Red**: low-activity – reference

**Variability in Other Stars**
### SSI Instrument Comparison

<table>
<thead>
<tr>
<th></th>
<th>OMI</th>
<th>TROPOMI</th>
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<tbody>
<tr>
<td>Timeline</td>
<td>July 2004 - present</td>
<td>October 2017 - present</td>
</tr>
<tr>
<td>Spectral coverage</td>
<td>264-504 nm</td>
<td>270-2385 nm (270-495 nm contiguous)</td>
</tr>
<tr>
<td>Spectral resolution</td>
<td>0.41-0.63 nm</td>
<td>0.25-0.54 nm</td>
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<tr>
<td>Optical layout</td>
<td>Push-broom; 30-60 FOVs; spectral smile</td>
<td>Push-broom; 450 FOVs; spectral smile</td>
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<tr>
<td>Solar measurements</td>
<td>~daily</td>
<td>~daily</td>
</tr>
<tr>
<td>Traceable absolute</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>calibration</td>
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</tbody>
</table>
OMI: Solar cycle 24

Marchenko et al., 2019
Cycle 23: OMI

Cycle 24/25 minimum: TROPOMI
OMI: ‘13-day transits’

TROPOMI: ‘13-day transits’
The SDO/HMI images from May 12, 2019

The Fe I 6173.3 Å continuum intensity

The Fe I 6173.3 Å colored magnetogram

Images provided by: http://jsoc.stanford.edu/HMI/hmiimage.html
Modelling Overview

**Full model:**
- the wavelength- and heliocentric-angle-dependent models (quiet-Sun, active networks, plages, sunspots, etc. — 8 components) are taken from Fontenla et al. (1999, 2006, 2011) and convolved with TROPOMI instrument transfer function;
- the models are weighted using the ‘brightening’ and ‘darkening’ NRLSSI2 factors (Coddington et al. 2016) for y2019, and the full-disk area-coverage stats (areas as in Fontenla & Harder 2005) from the PSPT (Rast et al. 1999) database;
- the weighted composites are averaged using the active-region geometry from SDO/HMI images.

**Toy model:** the quiet-Sun component (as above), with the line-wing intensities modulated by TSI.
Observed: disk-center (Brault & Neckel, 1987)

Model: disk-center

Balmer lines were synthetized under Non-Local Thermodynamic Equilibrium using the RH code (Uitenbroek 2001, Kowalski 2017).
Conclusions

Hβ, Hγ, Hδ line-activity indices closely (r = - (0.7-0.8)) and consistently (solar cycles 23, 24) follow TSI changes on the rotational (~months) timescales.

Rotational modulation in Hα?

Solar-cycle timescales ... ? (Hα ~follows CaII – Livingston et al. 2010)