

Solar Activity and Responses Observed in Balmer Lines

S. Marchenko^{1,2}, S. Criscuoli³, M. DeLand^{1,2}, D. P. Choudhary⁴, G. Kopp⁵

¹ Science Systems and Applications, Inc. (SSAI), Lanham, MD, USA

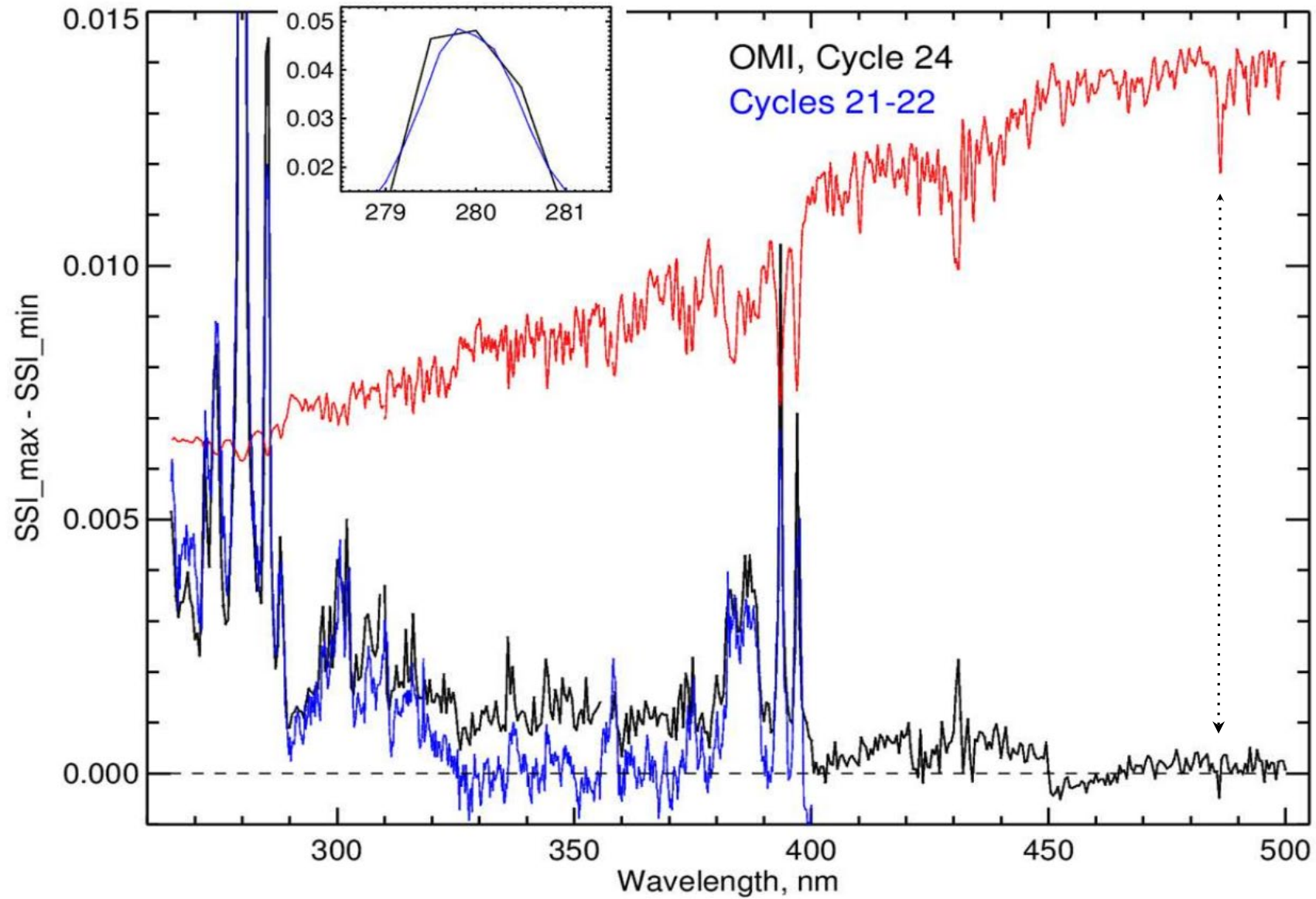
² NASA Goddard Space Flight Center (GSFC), Greenbelt, MD, USA

³ National Solar Observatory, Boulder, CO, USA

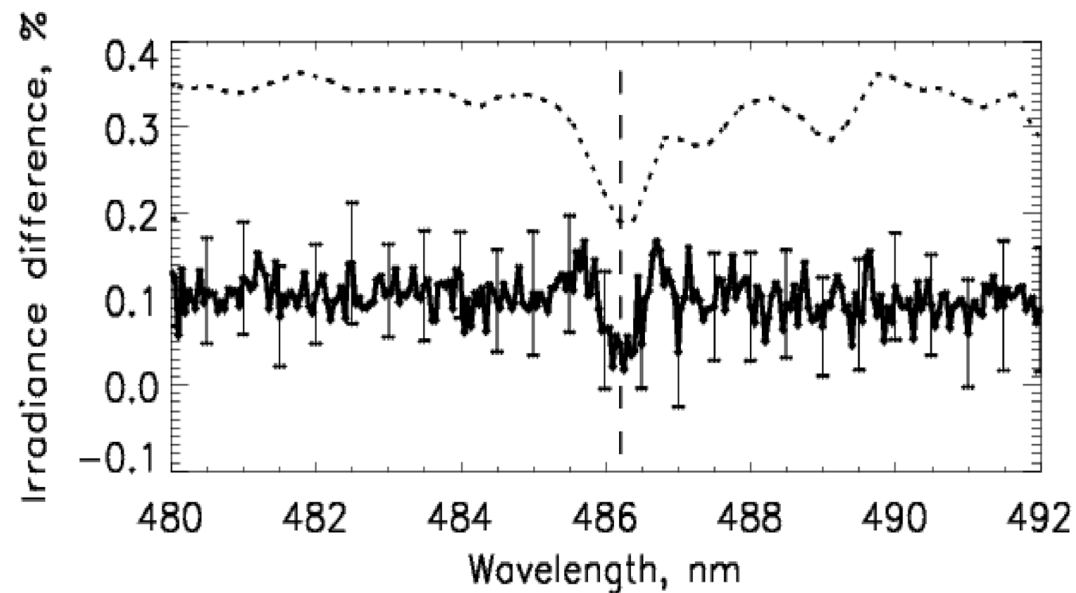
⁴ San Fernando Observatory, California State University – Northridge, CA, USA

⁵ University of Colorado / LASP, Boulder, CO, USA

SSI variability: Solar cycle @ ~ 1 nm spectral resolution

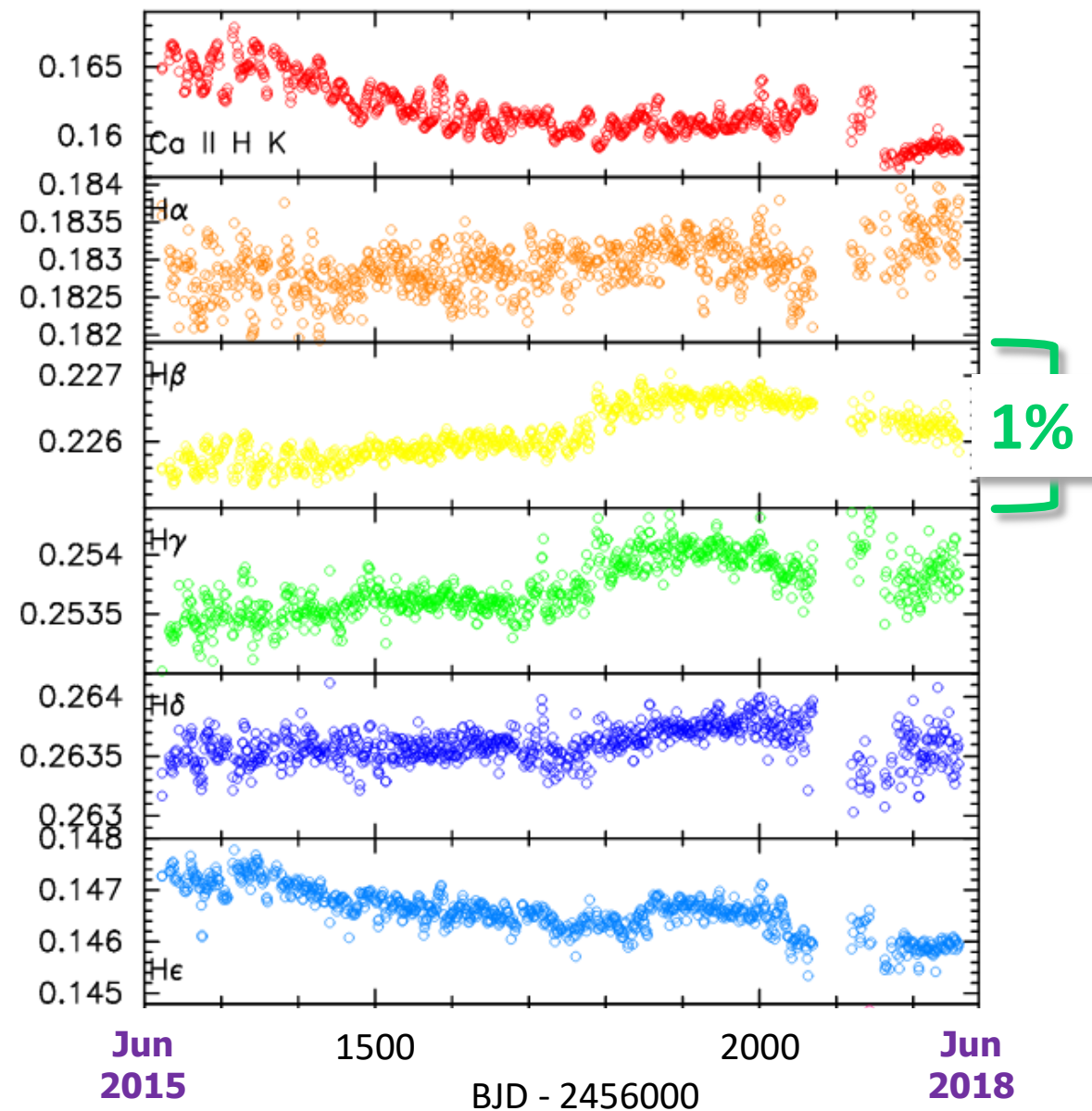


Solar cycle 24: max SSI - min SSI



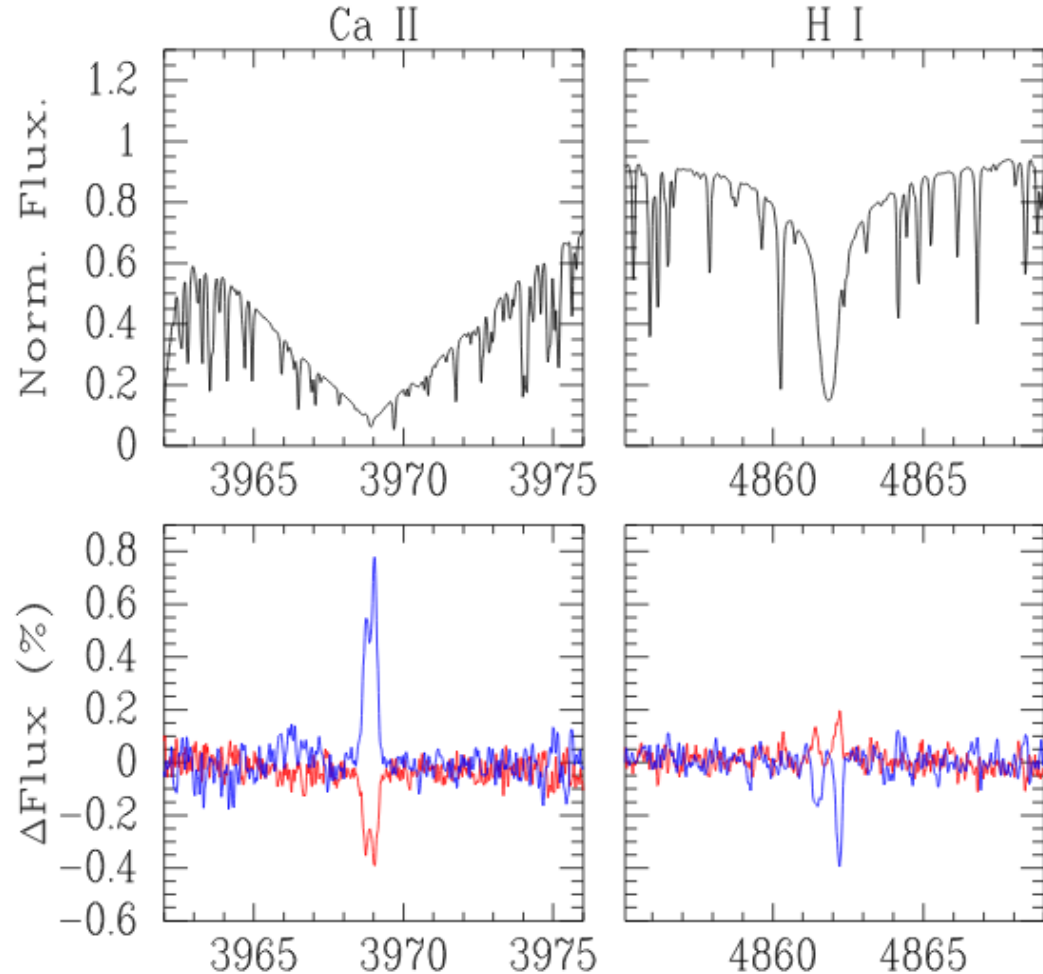
Marchenko & DeLand, 2014

Solar cycle 24: line-activity indices



Adapted from: Maldonado et al., *A&A* 627, A118 (2019)

Variability in Other Stars



Solar analog **HD 38858**: G2V, $P \sim 10.8$ y 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

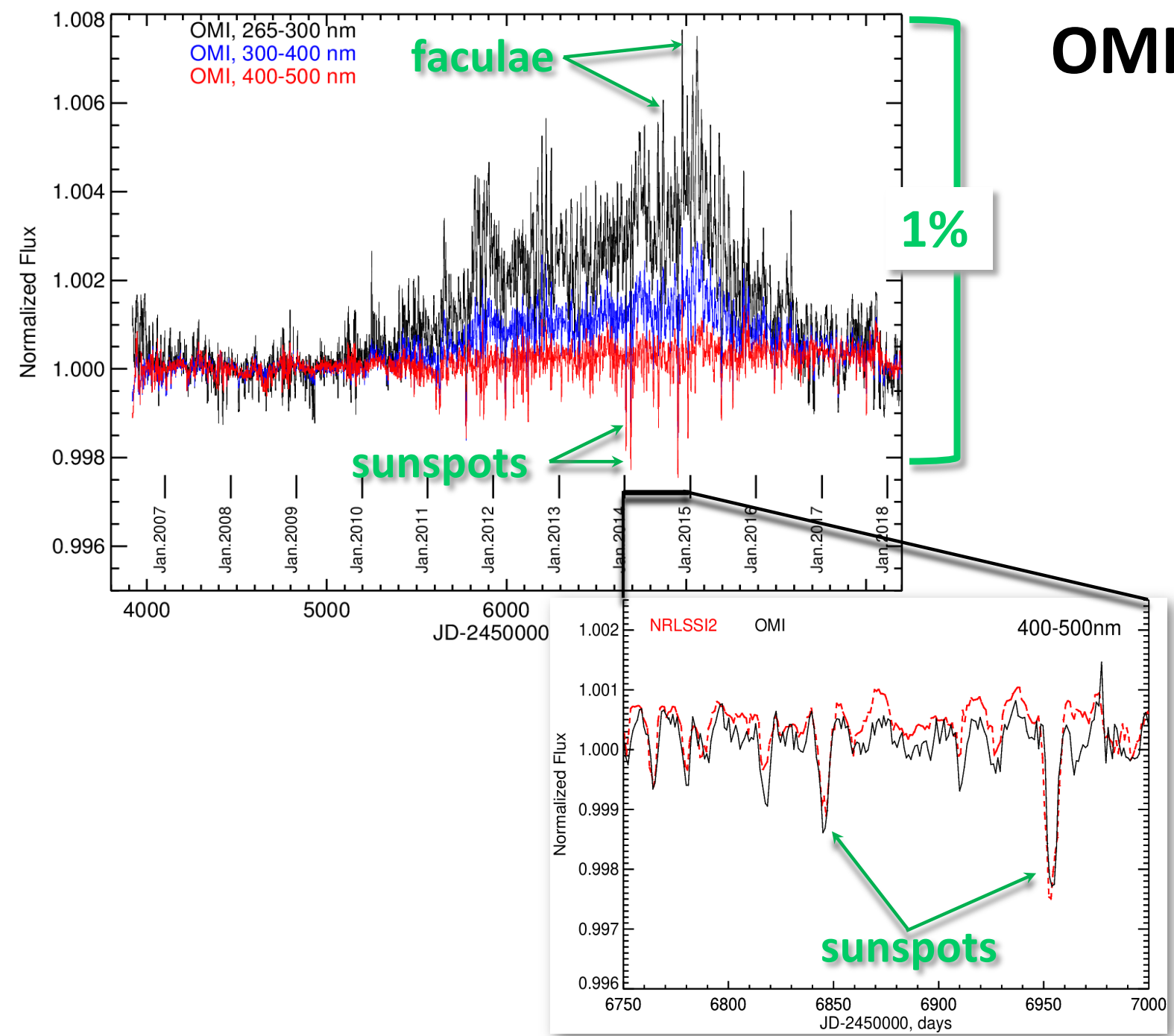
Overall, the chromospheric activity (H&K CaII) level correlates with H α line-core flux in **only 23%** (20% positive, 3% negative) of FGK stars (a sample of 271 stars: Gomes da Silva et al. 2014).

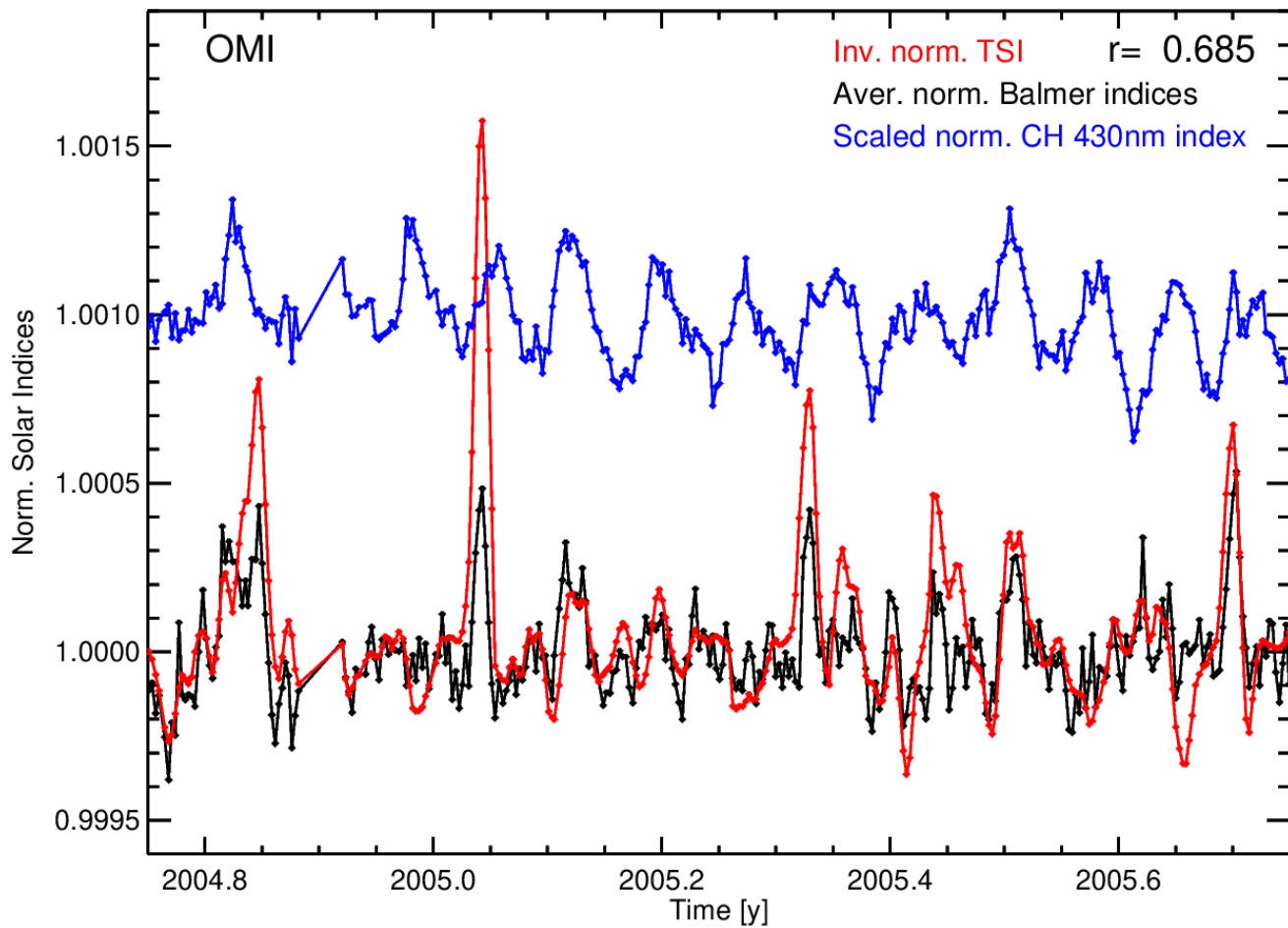
SSI Instrument Comparison

	OMI	TROPOMI
Timeline	July 2004 - present	October 2017 - present
Spectral coverage	264-504 nm	270-2385 nm (270-495 nm contiguous)
Spectral resolution	0.41-0.63 nm	0.25-0.54 nm
Optical layout	Push-broom; 30-60 FOVs; spectral smile	Push-broom; 450 FOVs; spectral smile
Solar measurements	~daily	~daily
Traceable absolute calibration	None	None



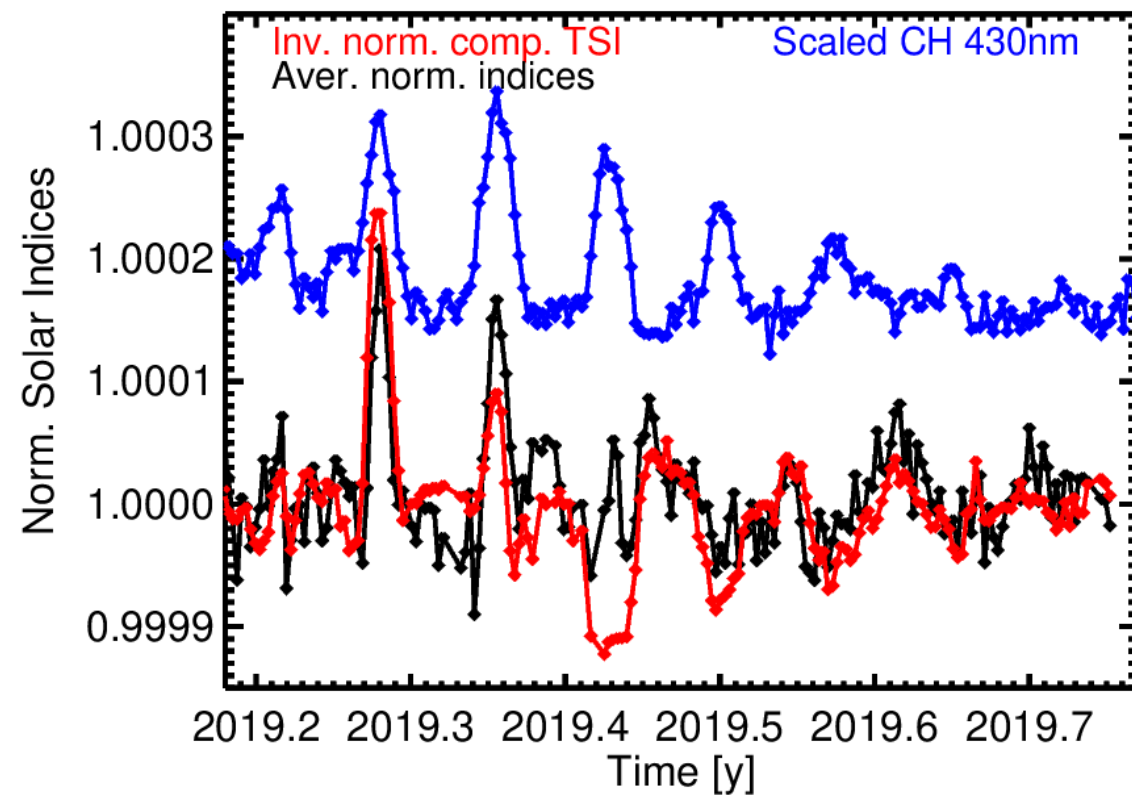
OMI: Solar cycle 24

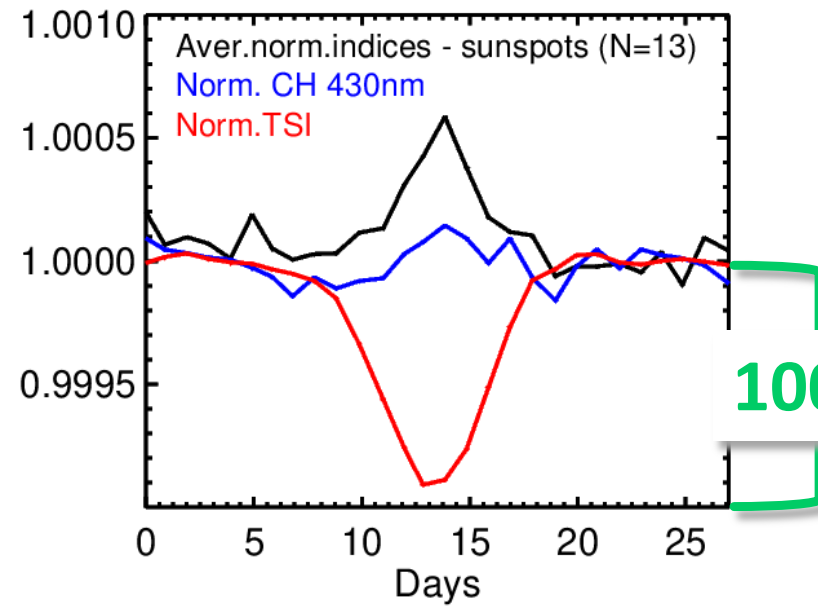
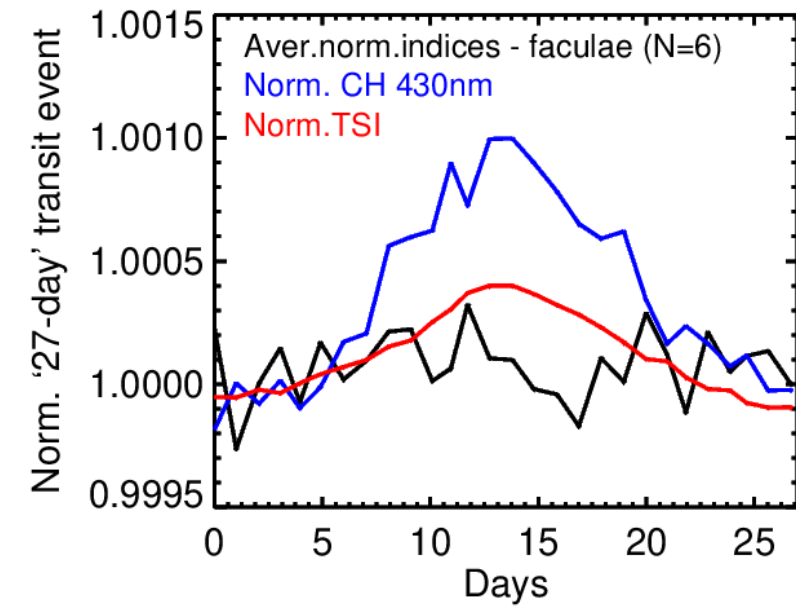




Cycle 23: OMI

Cycle 24/25 minimum: TROPOMI



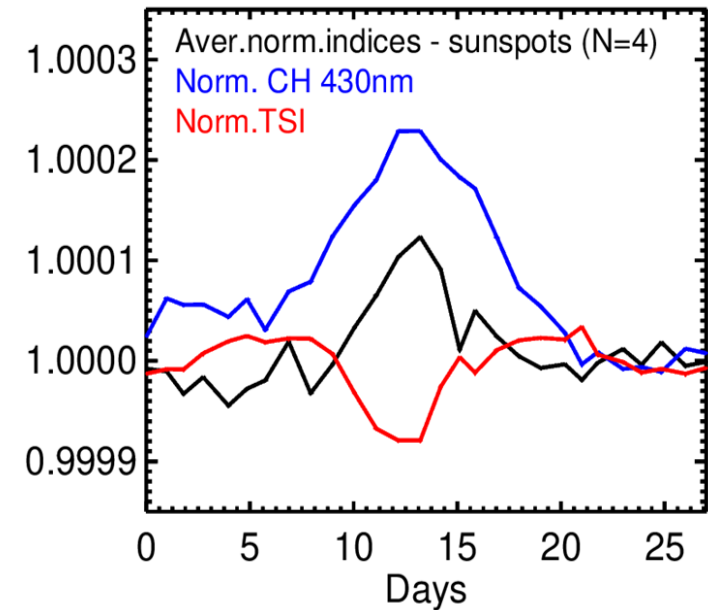
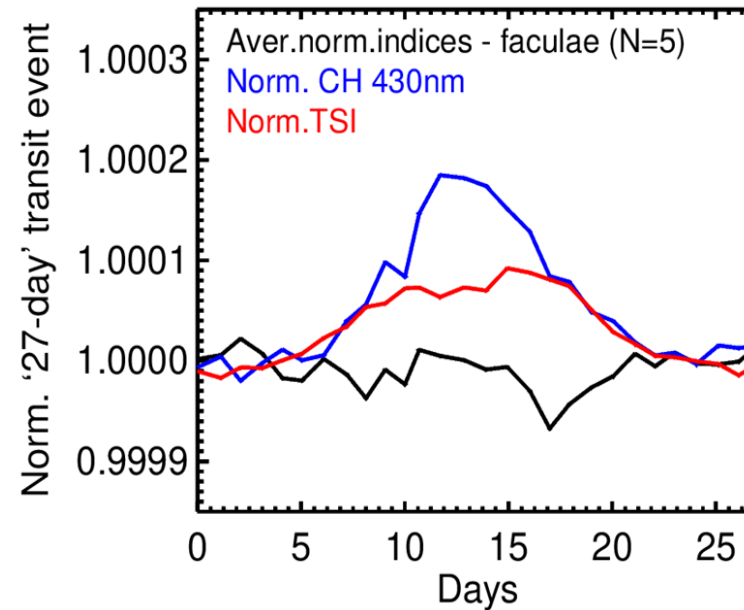


1000 ppm

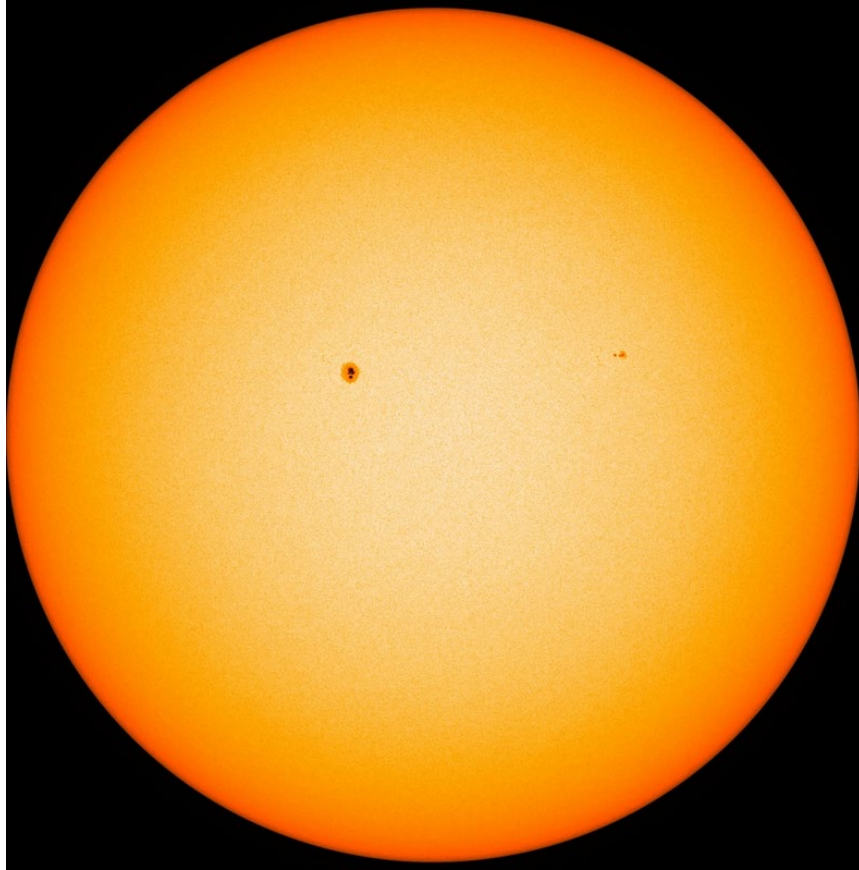
OMI: '13-day transits'

TROPOMI: '13-day transits'

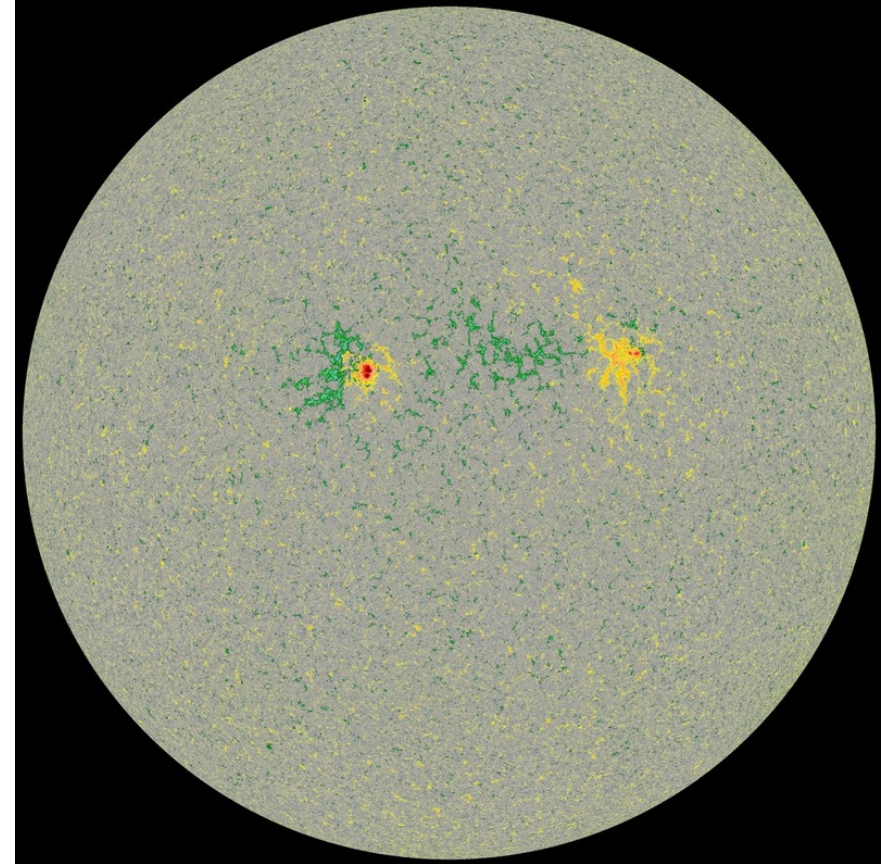
200 ppm



The SDO/HMI images from May 12, 2019



The Fe I 6173.3 Å continuum intensity



The Fe I 6173.3 Å colored magnetogram

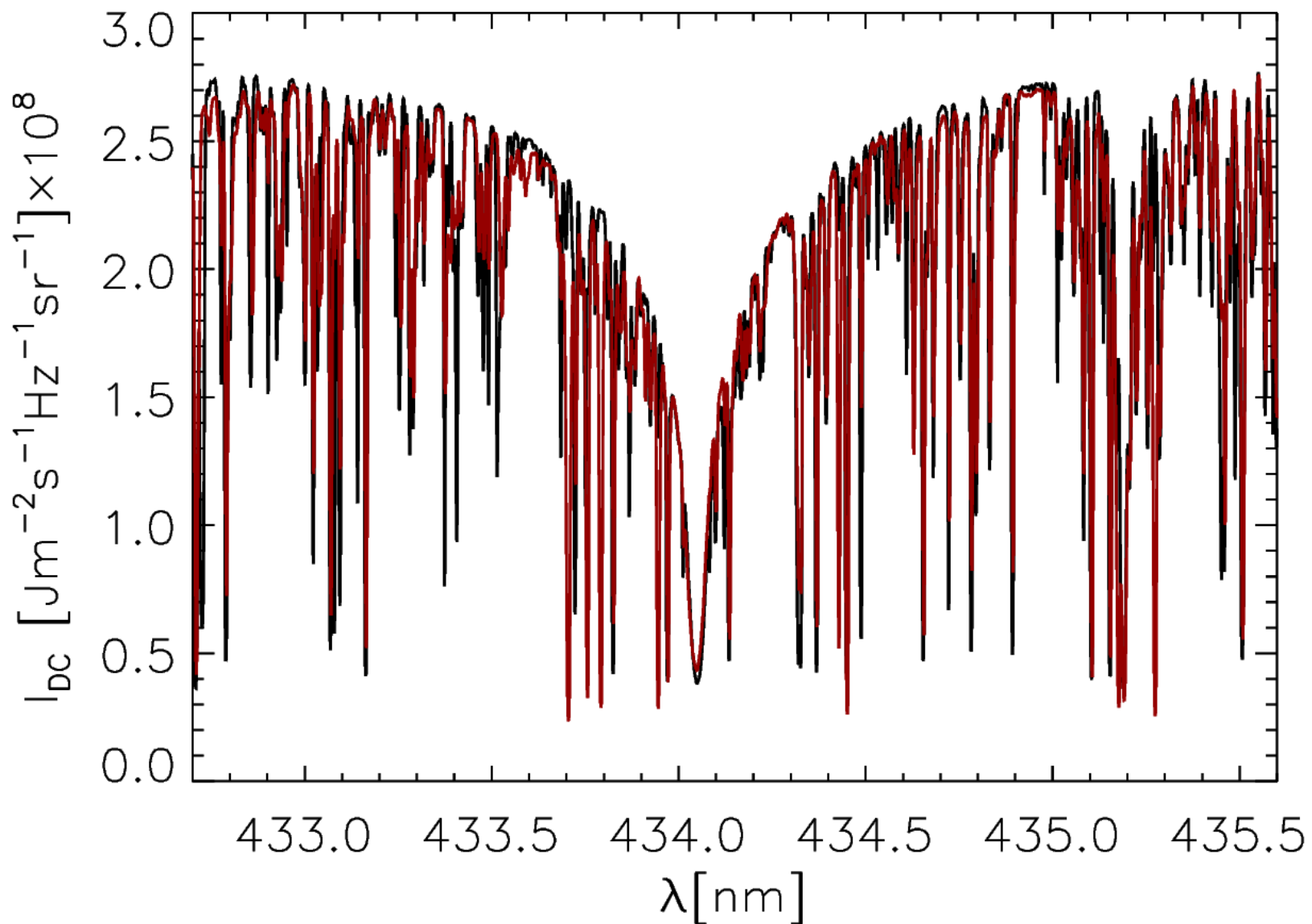
Modelling Overview

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.

Modelling – Sanity Check

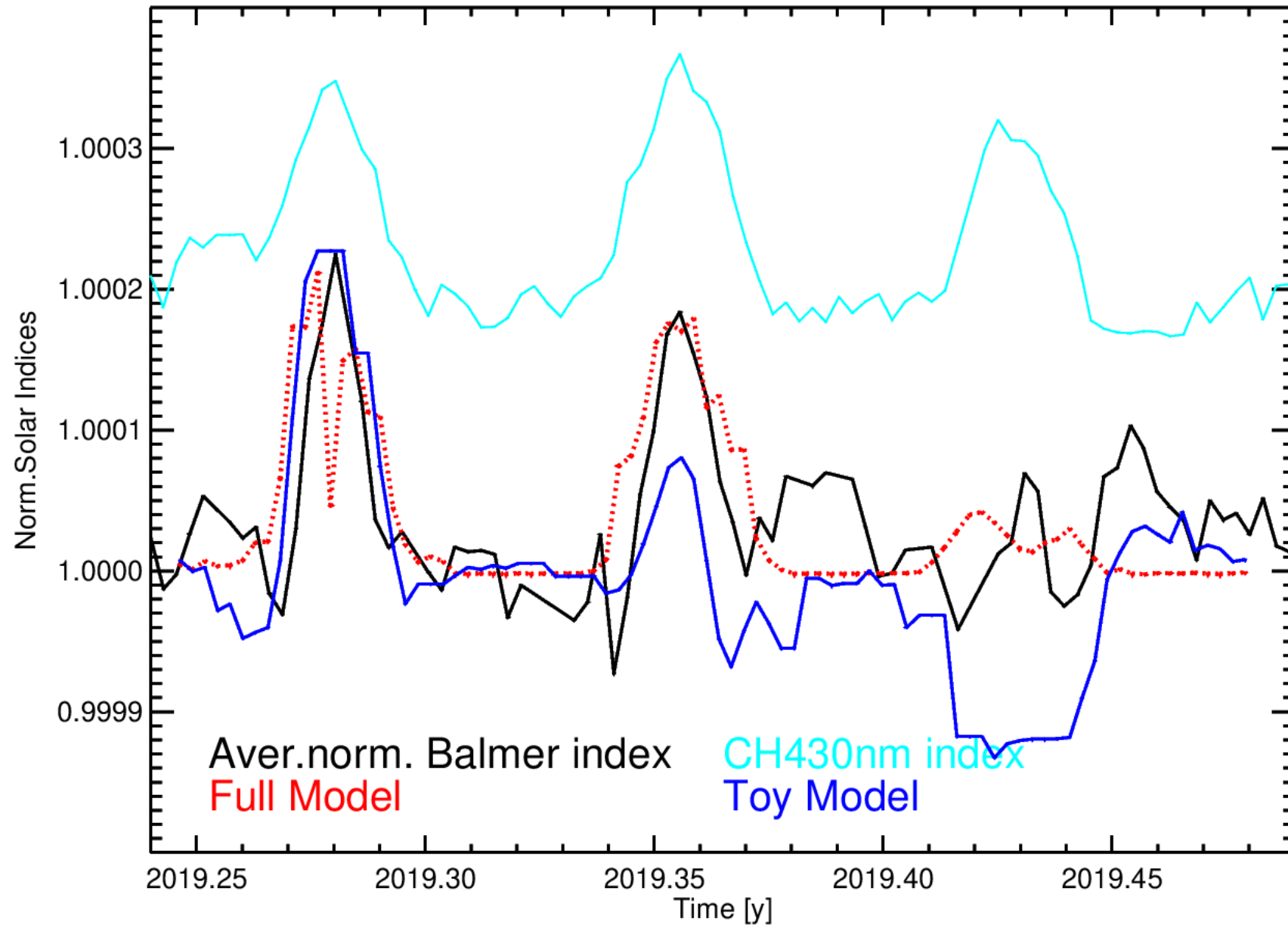


**Observed: disk-center
(Brault & Neckel, 1987)**

Model: disk-center

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

Modelling – Initial Results



Conclusions



H β , H γ , H δ line-activity indices closely ($r = - (0.7-0.8)$) and consistently (solar cycles 23, 24) follow **TSI changes** on the rotational (\sim months) timescales.



rotational modulation in H α ?



solar-cycle timescales ... ? (H α \sim follows Call – Livingston et al. 2010)