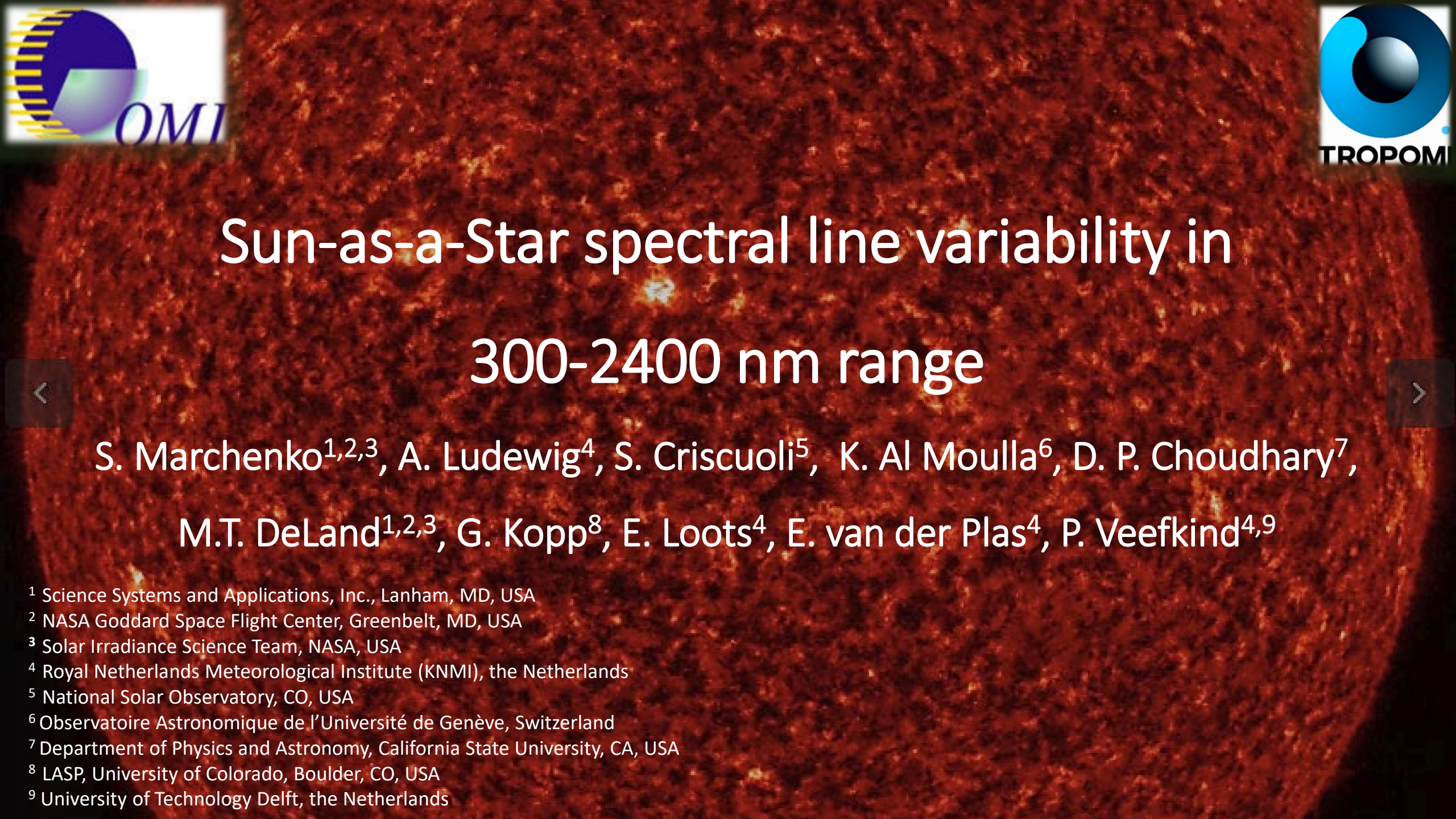

Sun-as-a-Star spectral line variability in 300-2400 nm range

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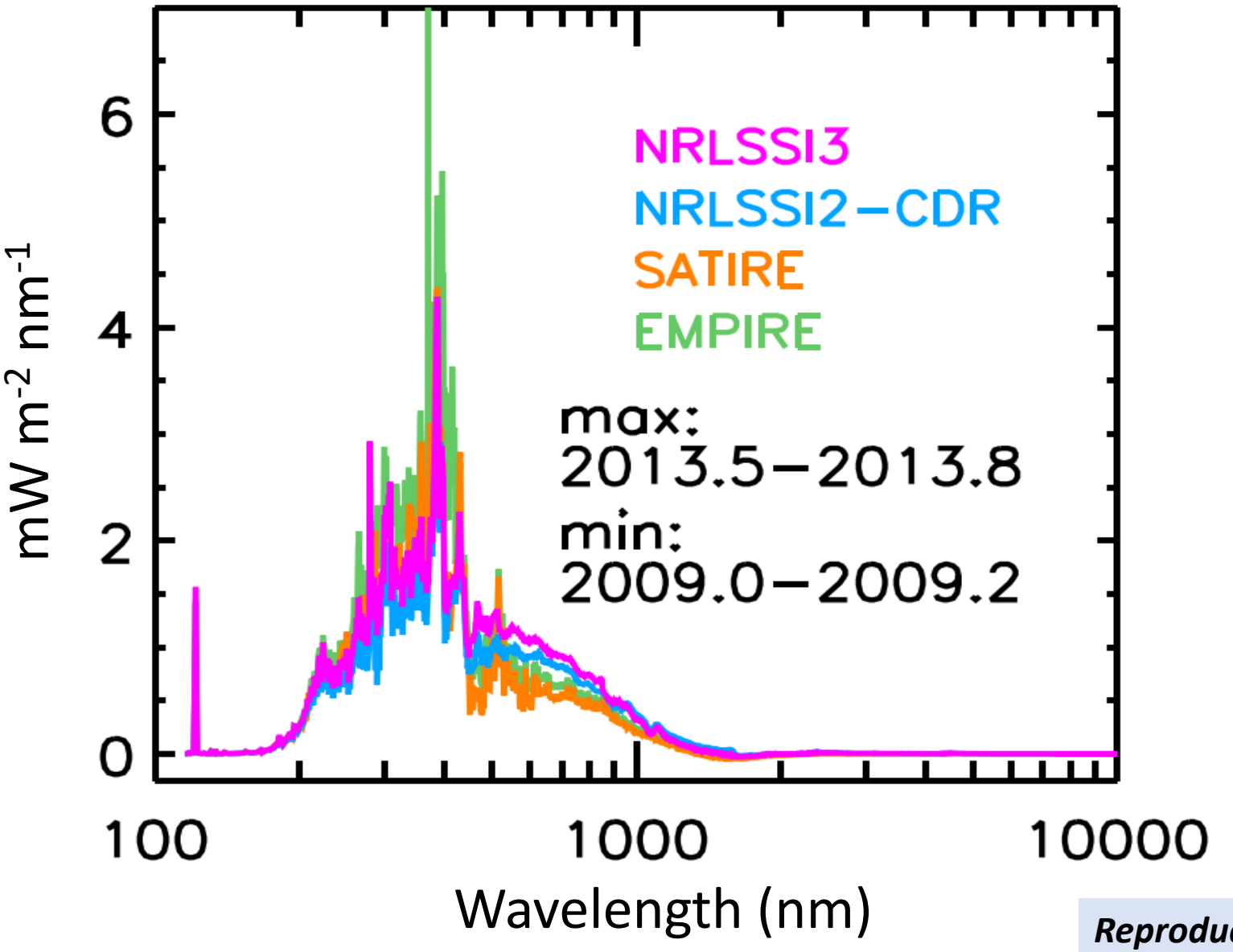
[1] Science Systems and Applications, Inc., Lanham, MD, USA
[2] NASA Goddard Space Flight Center, Greenbelt, MD, USA
[3] Solar Irradiance Science Team, NASA, USA
[4] Royal Netherlands Meteorological Institute (KNMI), the Netherlands
[5] National Solar Observatory, CO, USA
[6] Observatoire Astronomique de l'Université de Genève, Switzerland
[7] Department of Physics and Astronomy, California State University, CA, USA
[8] LASP, University of Colorado, Boulder, CO, USA
[9] University of Technology Delft, the Netherlands

Modeled solar Cycle 24 max-min energy balance: in-phase (almost…) everywhere



TSI variability is governed by two factors (both related to changing magnetic flux):

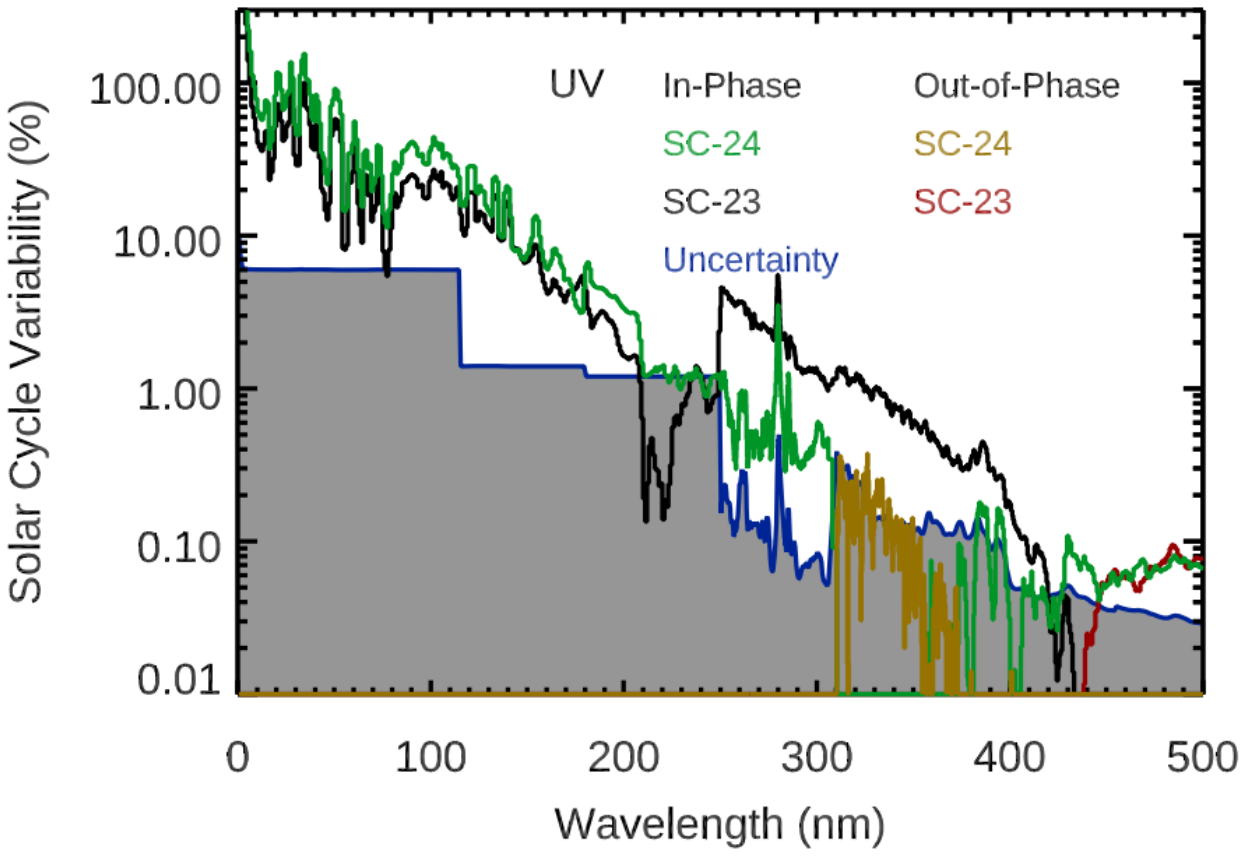
- ‘hot’ (mostly, faculae/plages)

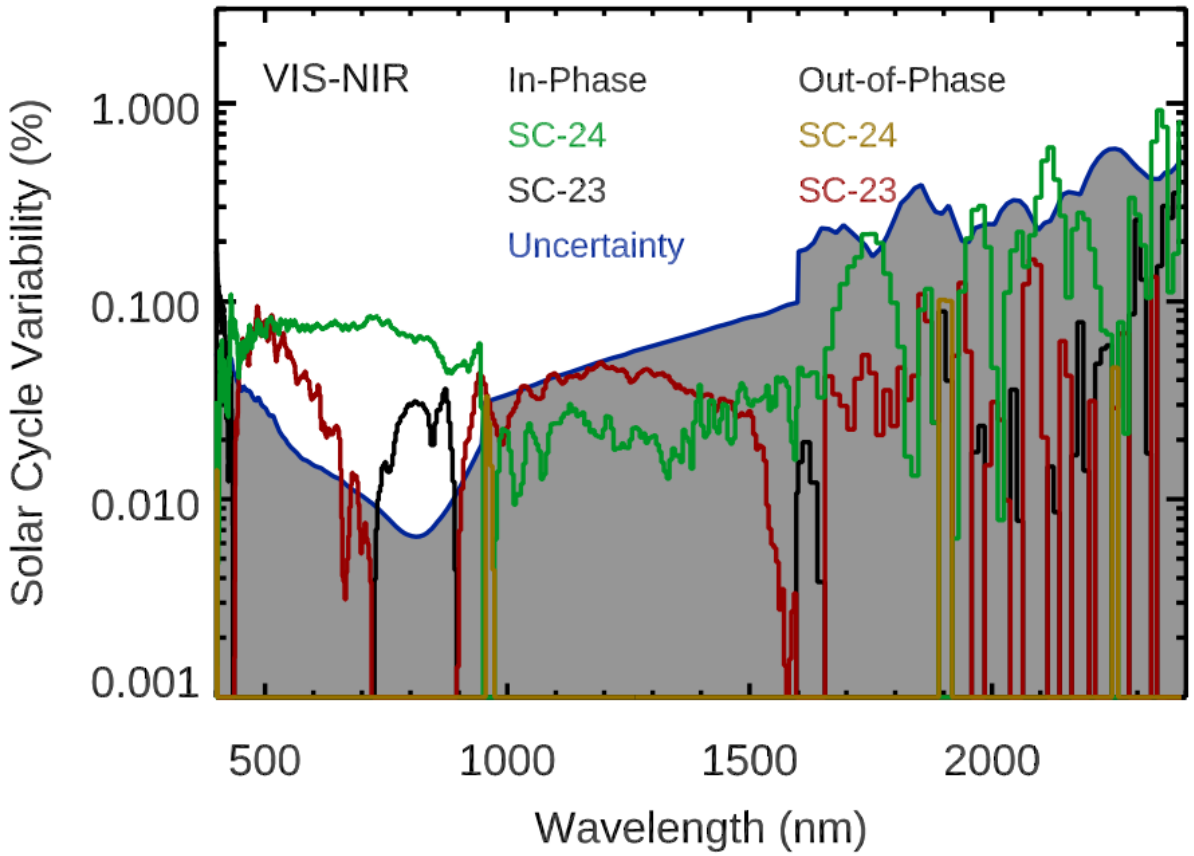
- ‘cold’ (sunspots)

These are not easy to disentangle in the Sun-as-a-star measurements… **a true headache**!

Reproduced from: Lean, J., et al., Earth & Sp.Sci., (2020)

What really happens at λ > 300 nm ?





Woods, T., et al., Sol.Phys. (2022) : SORCE/XPS, SORCE/SOLSTICE SORCE/SIM, TIMED/SEE

OMI & TROPOMI remote-sensing instruments: precise, stable, long-term irradiance measurements

OMI: October 2004 – present
TROPOMI: April 2018 - present

- Primary objective: the Earth, [almost] full-surface coverage in 1-2 days

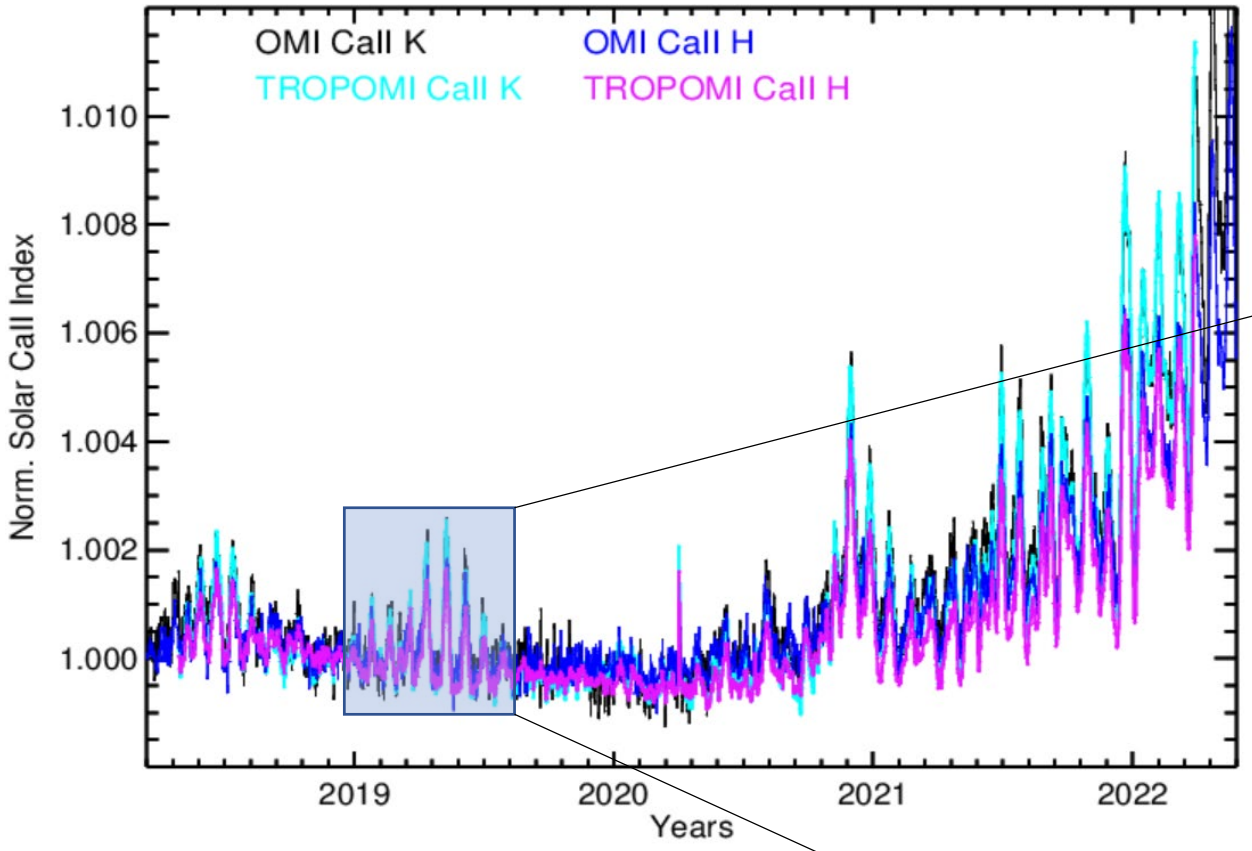
- Spectral coverage:
  262-504 nm (OMI);
  267-499 nm + 661-786 nm + 2300-2389 nm (TROPOMI)

- *Moderate* spectral resolution: 0.2-0.6 nm [this is called 'hyper-spectral' … hmmm…]

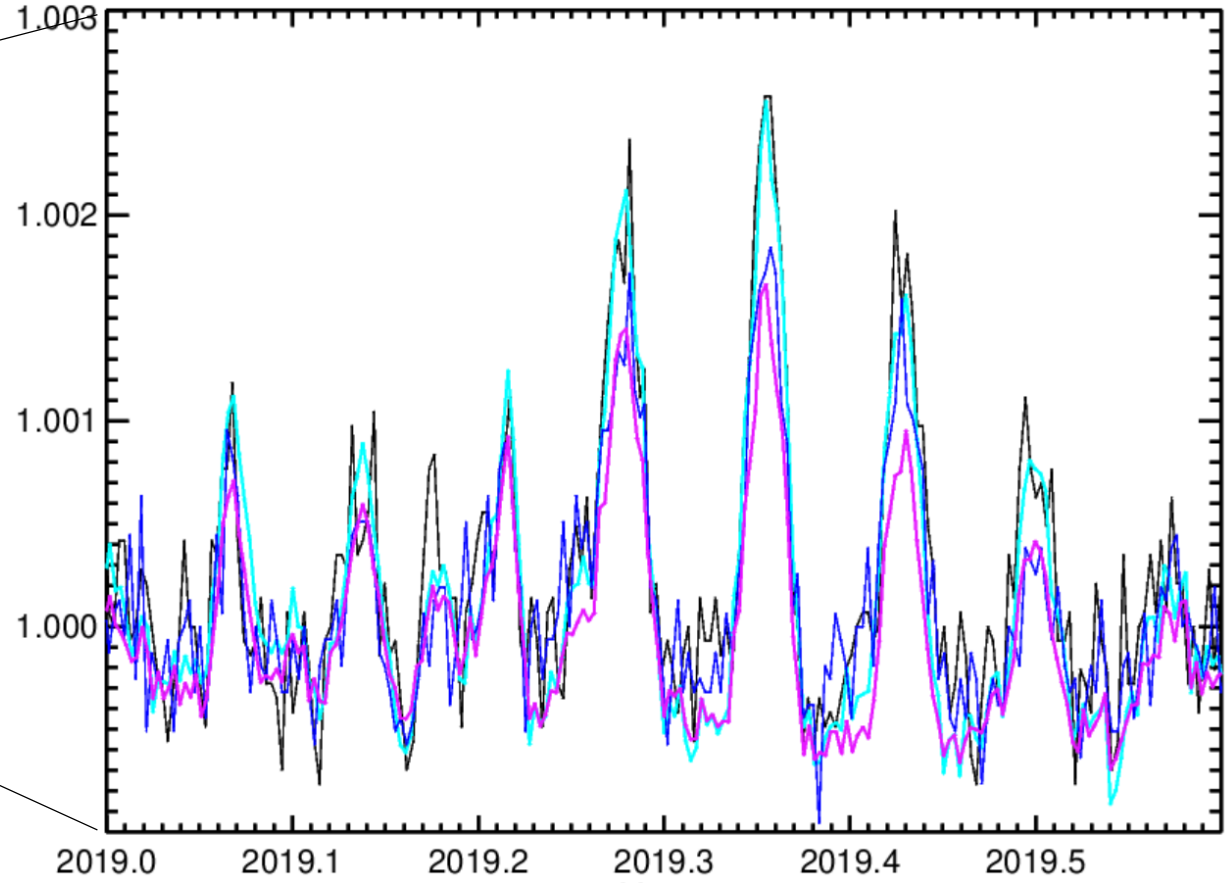
- Calibration: Sun-as-as-star, ~once/day observations, however producing
  up to ~40000 solar spectra/day !

- OMI is proven to be a stable instrument: <0.2 %/yr degradation rate in the visible

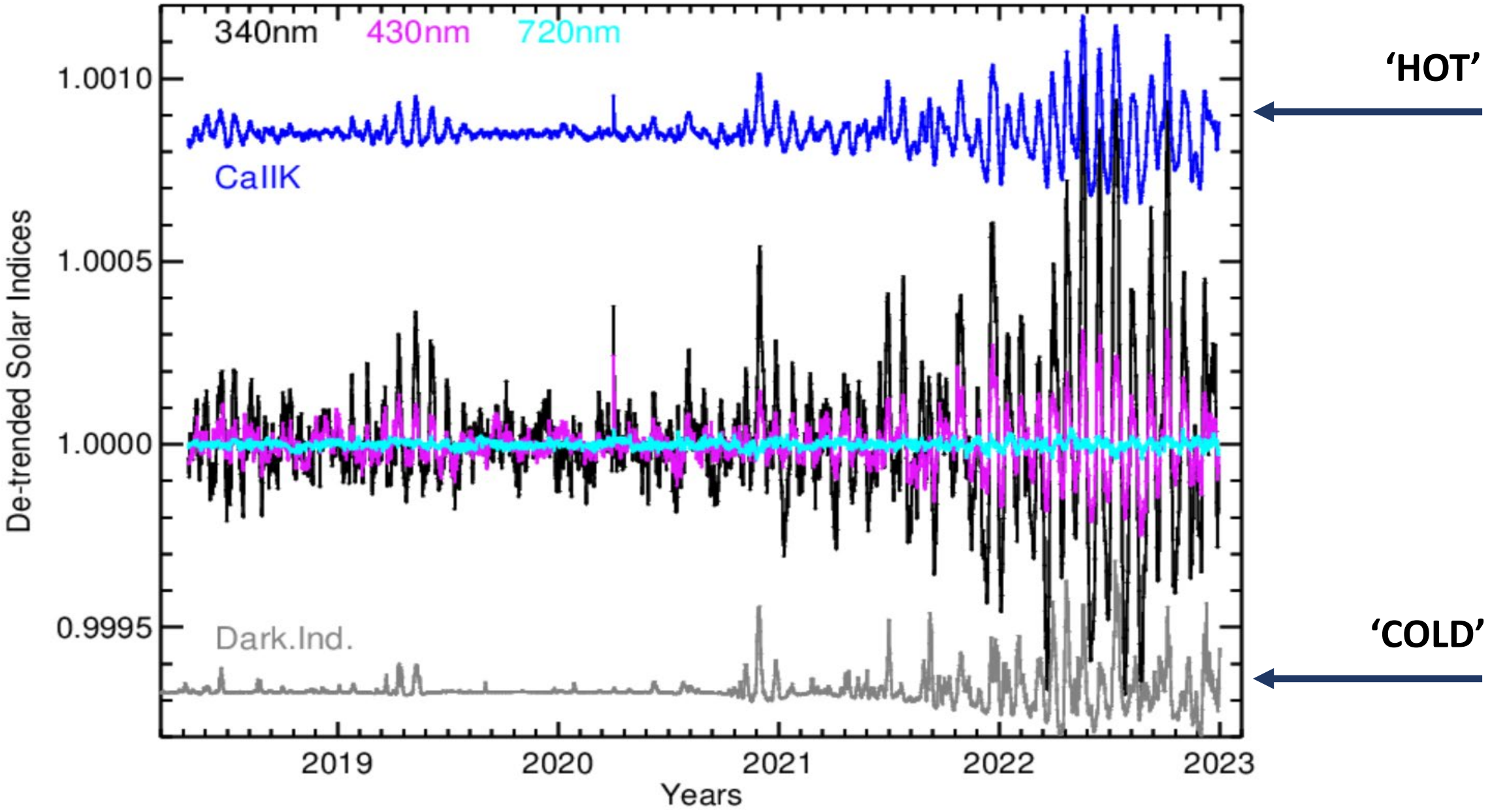
OMI & TROPOMI CaII indices: confidently detecting ~0.05% (TROPOMI), ~0.1% (OMI) variability



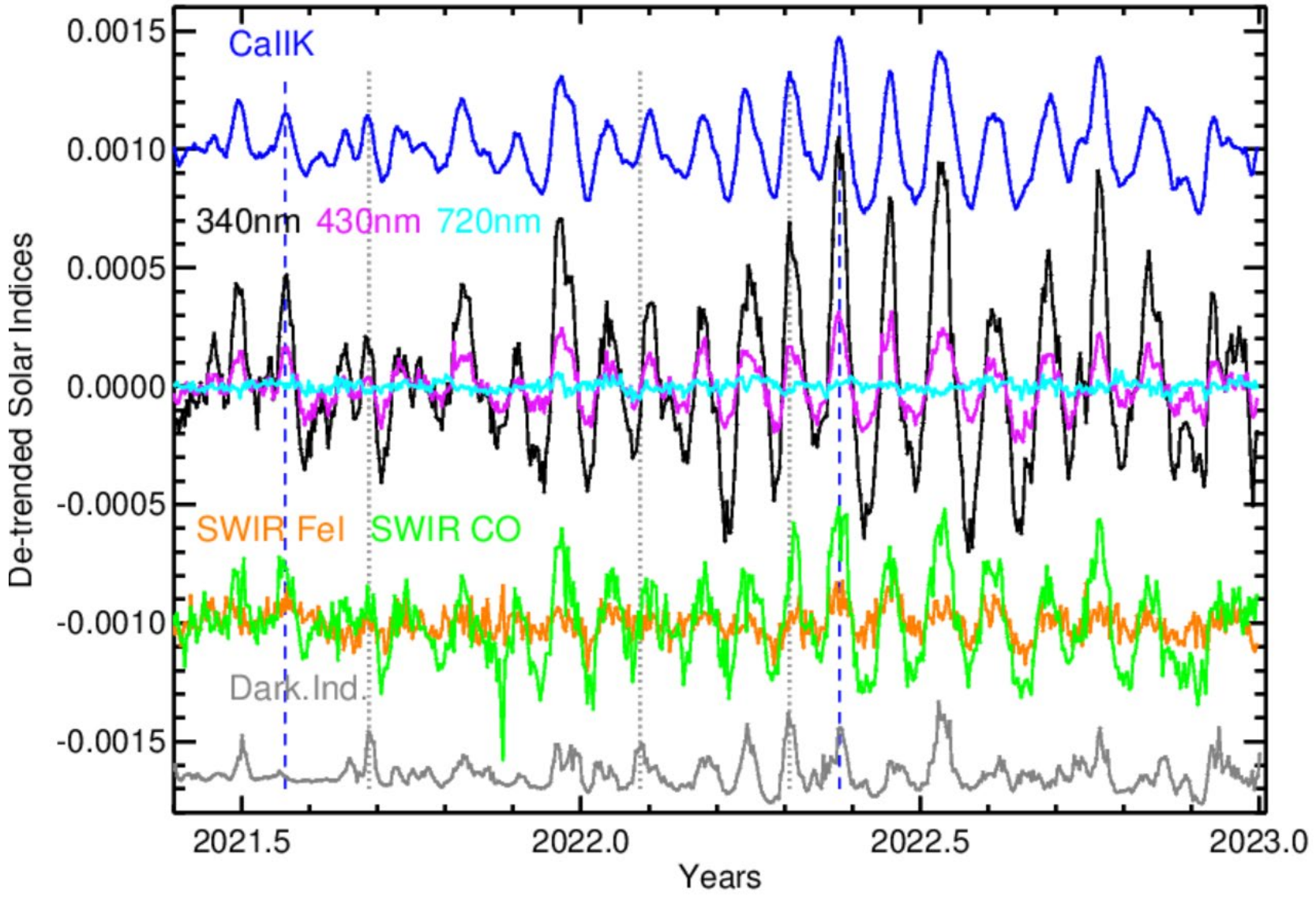
0.03% OMI-TROPOMI agreement



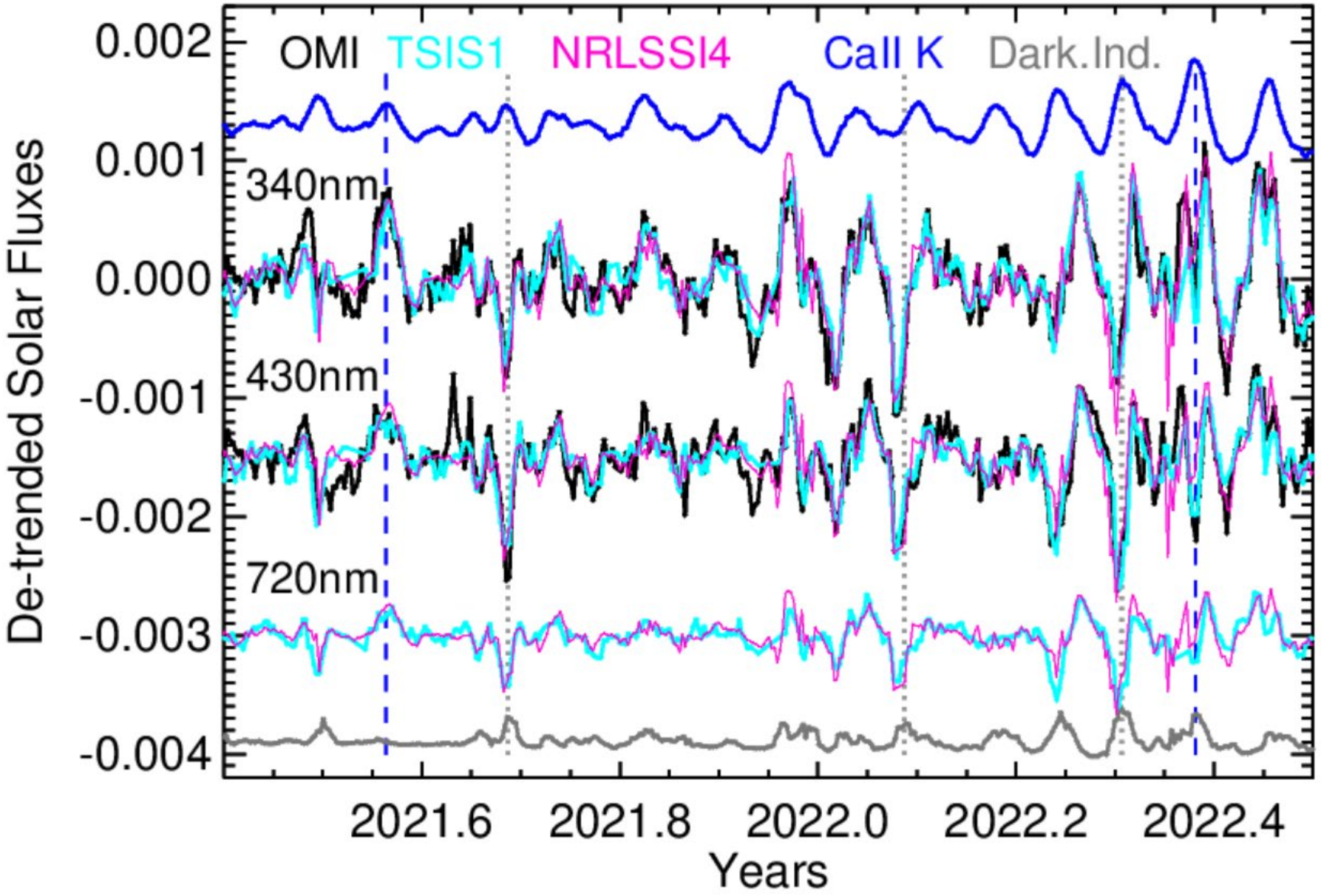
81d de-trended Fe I line indices from TROPOMI



81d de-trended line indices: the 'hot' component rules at λ < 500 nm, … and then again at λ=2350 nm

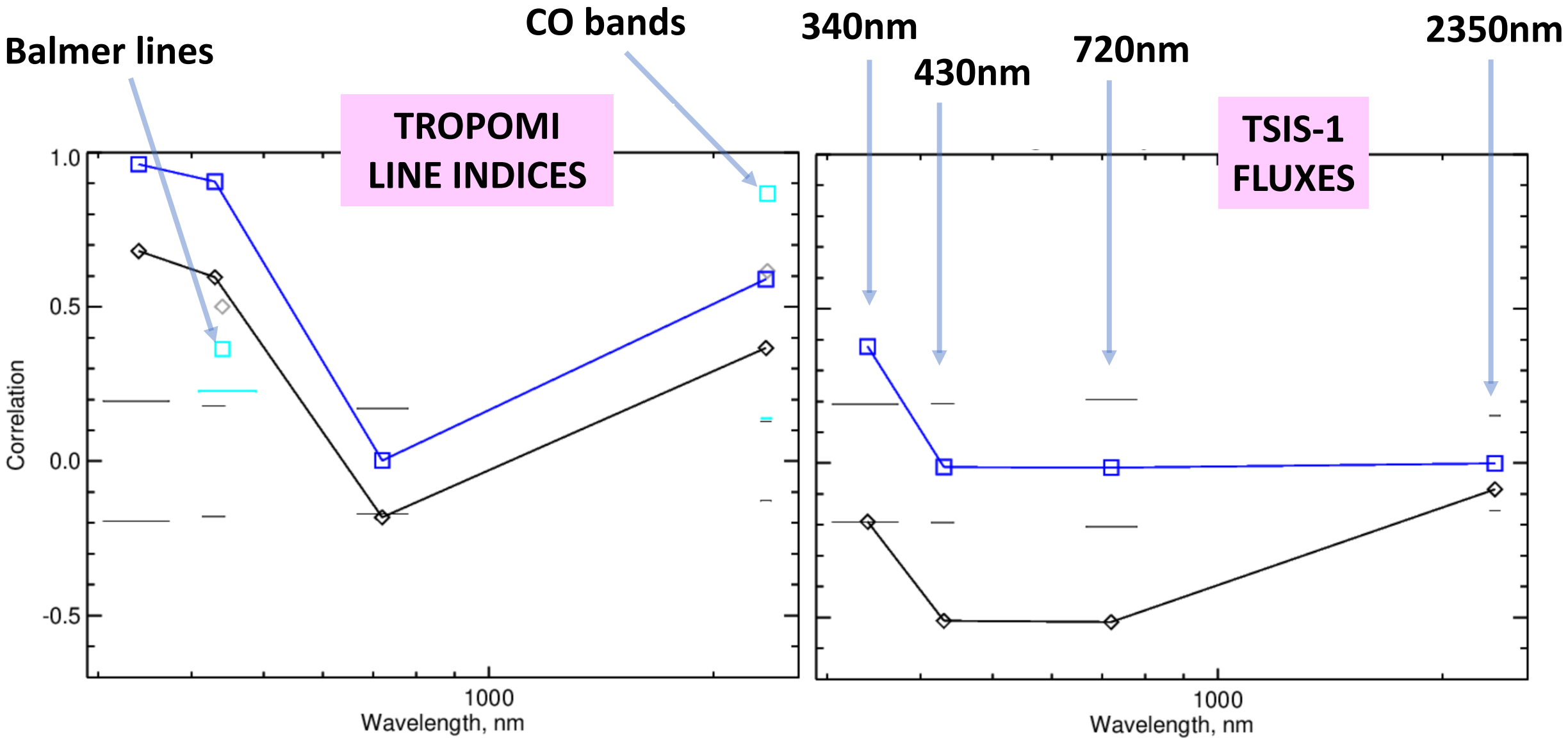


81d de-trended solar fluxes: the **sunspot** dominance



NRLSSI4: J. Lean, priv. comm, 2023

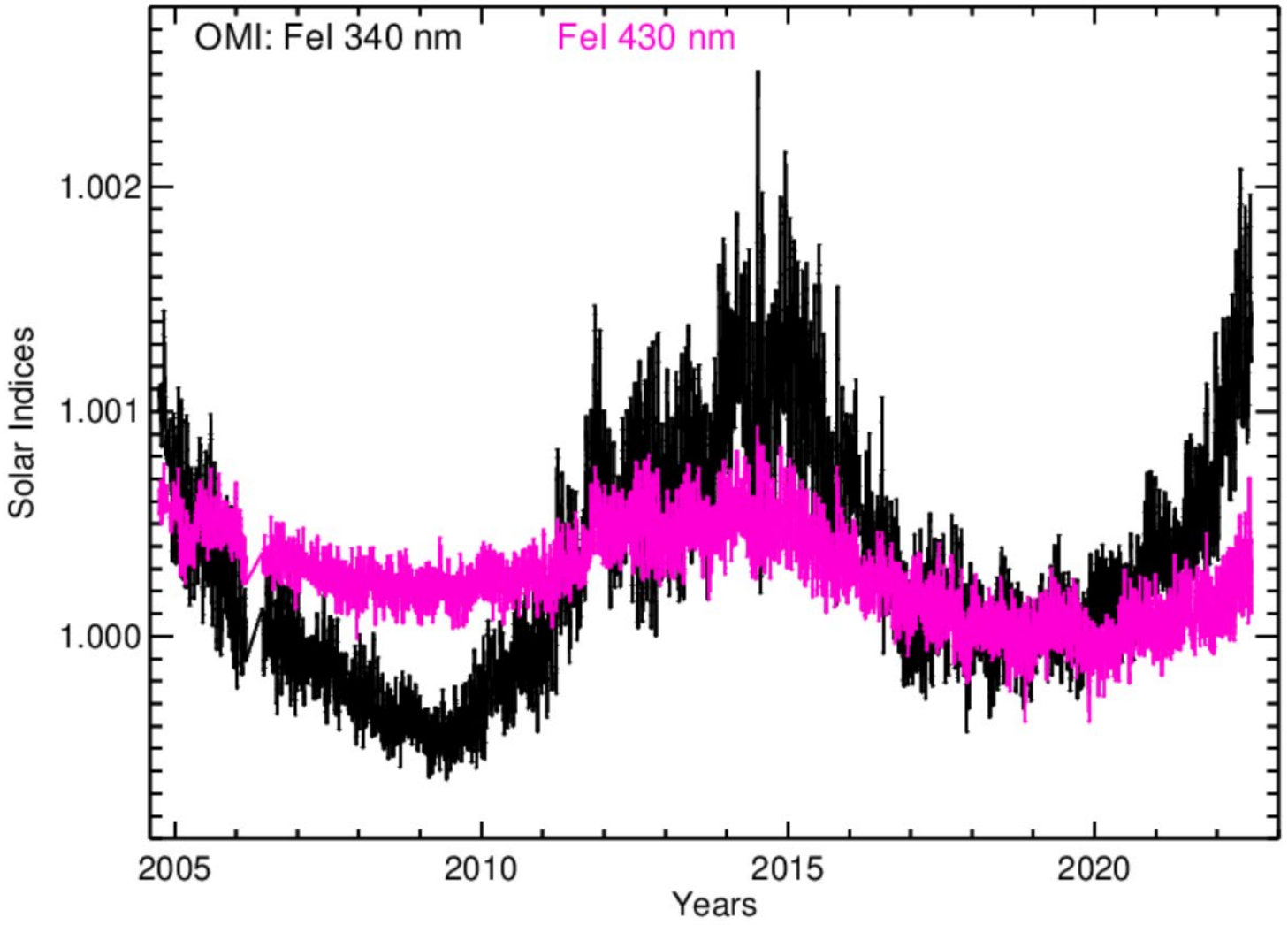
100-250 ppm [sic] data vs. model agreement



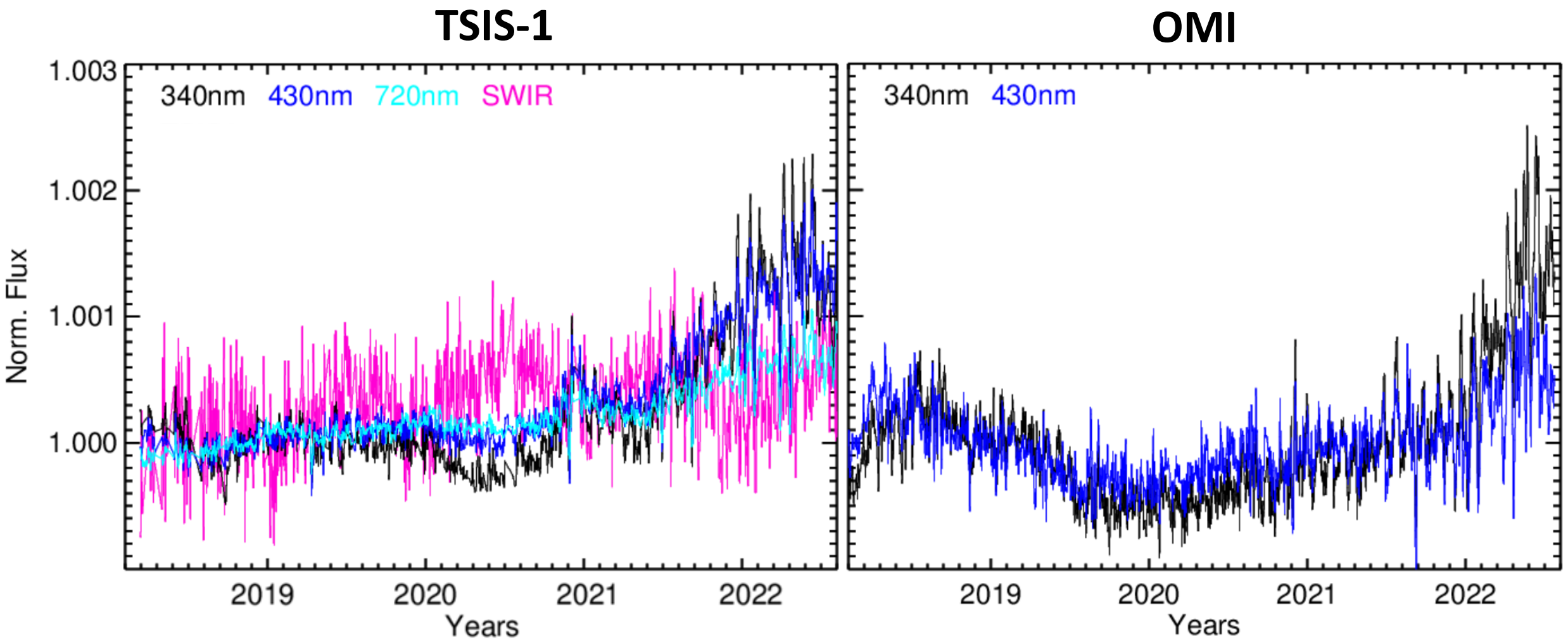
The 81d de-trended data (rotational variability): **faculae** control the line indices, while **sunspots** dominate the averaged fluxes

Fe I line indices: in-phase solar-cycle changes at λ < 500 nm

OMI



Fluxes: in-phase solar-cycle changes at λ < 500 nm



Solar spectral irradiance changes in 300-2400 nm region

On the rotational time-scales:

- with the [in-phase] **facular** component as a prime driver at $\lambda < 500$ nm, the **line index activity** rapidly diminishes towards near-IR, with a surprising SWIR rebound;

- the **solar fluxes** are more sensitive to the [out of phase] **sunspot** variability factor.

On the solar-cycle time-scales:

both the line indices and the [line-dominated!] fluxes change **in-phase at $\lambda < 500$ nm**;

'terra incognita' at $\lambda > 500$ nm: probable instrument-related trends;

considering the line/continuum balance, **700-800 nm range** should be changing out-of-phase: the workings of an elusive 3rd variability factor, beyond the facular and sunspot components? or instrument trends?