full-Sun mosaics: the sources of novel reference Mg II h & k profiles for radiative-transfer modeling

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Abstract

Data used
- the IRIS catalog of full-Sun near-UV mosaics obtained in the years 2013 – 2020.

Results
- high-precision reference Mg II h & k profiles that represent the quiet Sun during a minimum of the solar activity,
- a novel model of evolution of their spectral shapes over the solar cycle.

Applicability of results
- definition of incident radiation in the Mg II h & k lines for radiative-transfer modeling of prominences, flare loops, CMEs, surges, and spicules.

Data and code availability
- the machine readable tables of reference Mg II h & k profiles with uncertainties and their center-to-limb and cyclic variation are provided online through the NASA's ADS,
- the IDL routines, representing the model of temporal evolution of full-disk Mg II h & k profiles over the solar cycle, are publicly available at:
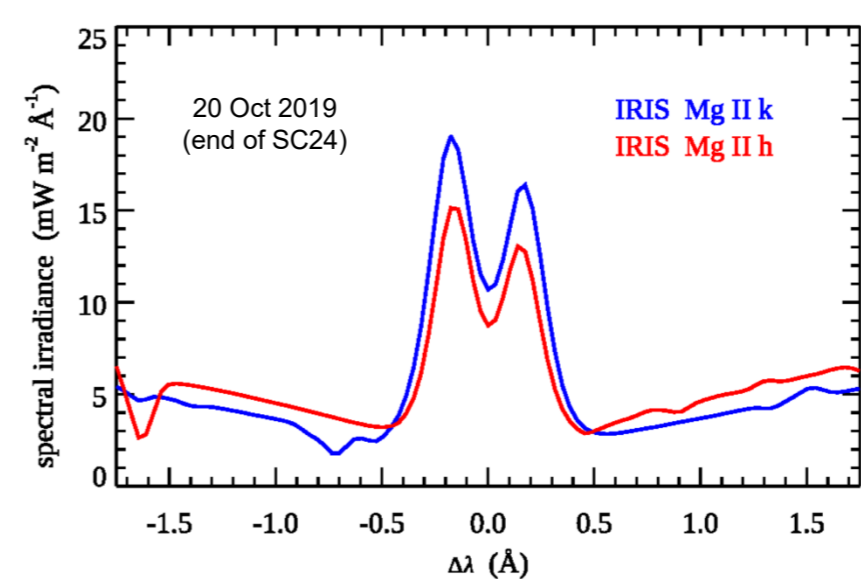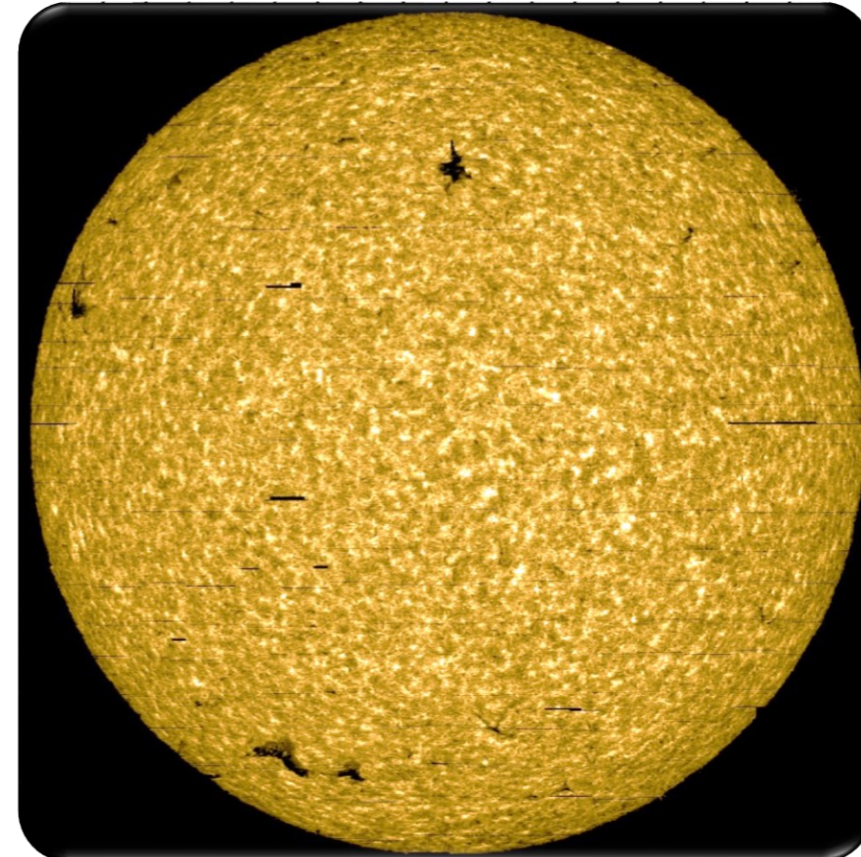
https://github.com/jkidl/IRIS

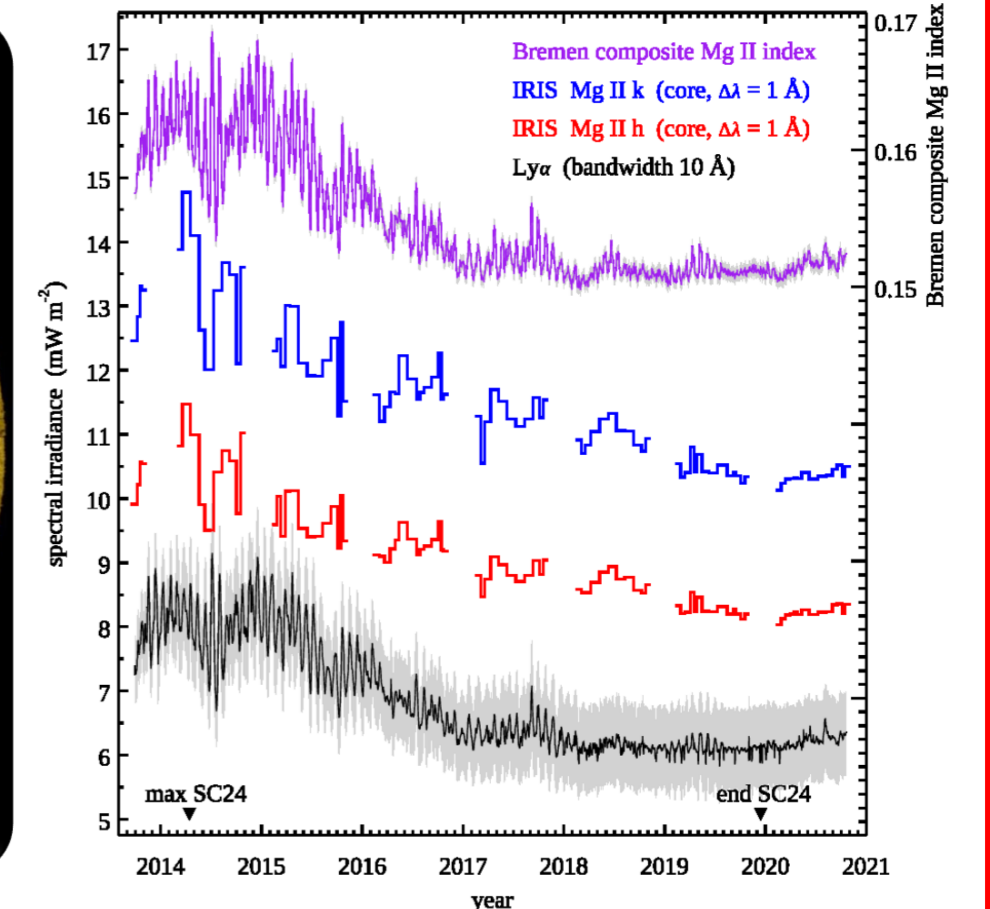## Mg II h & k cyclic variability - IRIS's view of solar cycle 24

Mg II k mosaic in k_3 - 17 Mar 2014
max of solar cycle 24 - Apr 2014
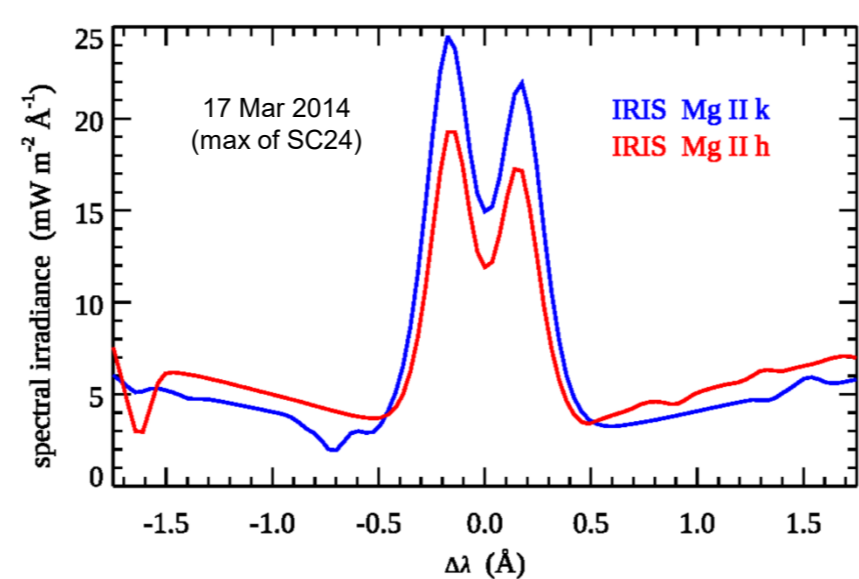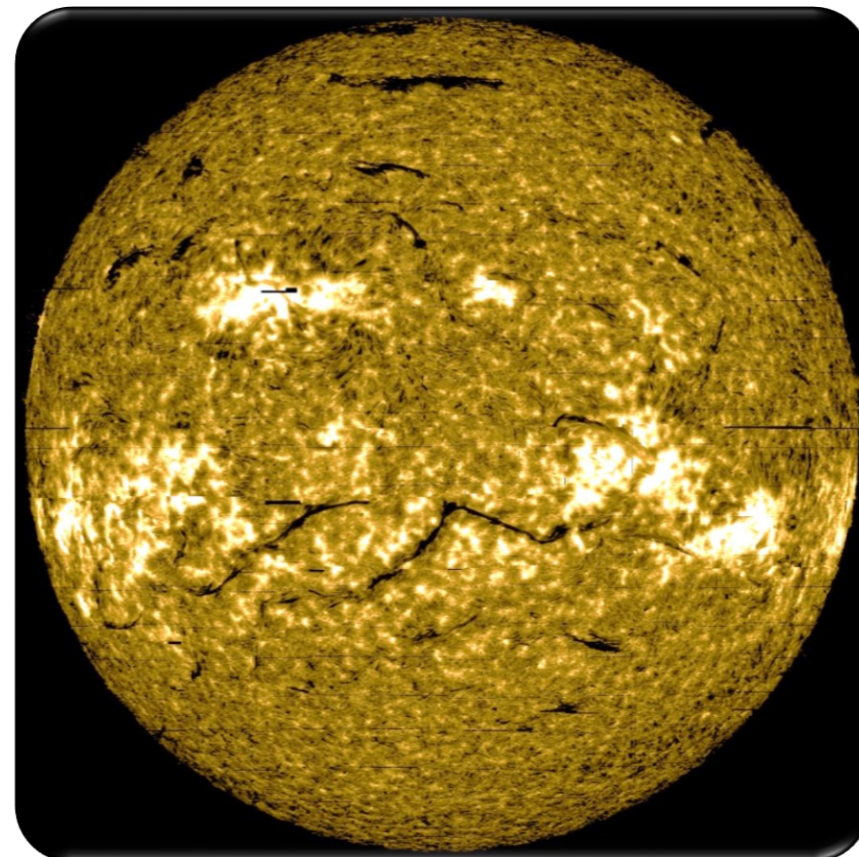
Mg II k mosaic in k_3 - 20 Oct 2019
end of solar cycle 24 - Dec 2019

Comparison with solar UV indices

Disk-averaged Mg II h & k profiles change substantially over solar cycle (compare bottom panels). The wavelength integrated spectral irradiances $SI(\Delta\lambda = 1$ Å$)$ correlate with the Bremen composite Mg II index with cc = 0.94 and the composite Lyman-α index with cc = 0.92 (right panel). The high correlations verify the long-term stability of IRIS radiometric calibration and qualify the IRIS NUV full-Sun mosaics for solar cycle studies and definition of reference profiles.

## Verification of IRIS radiometric calibration
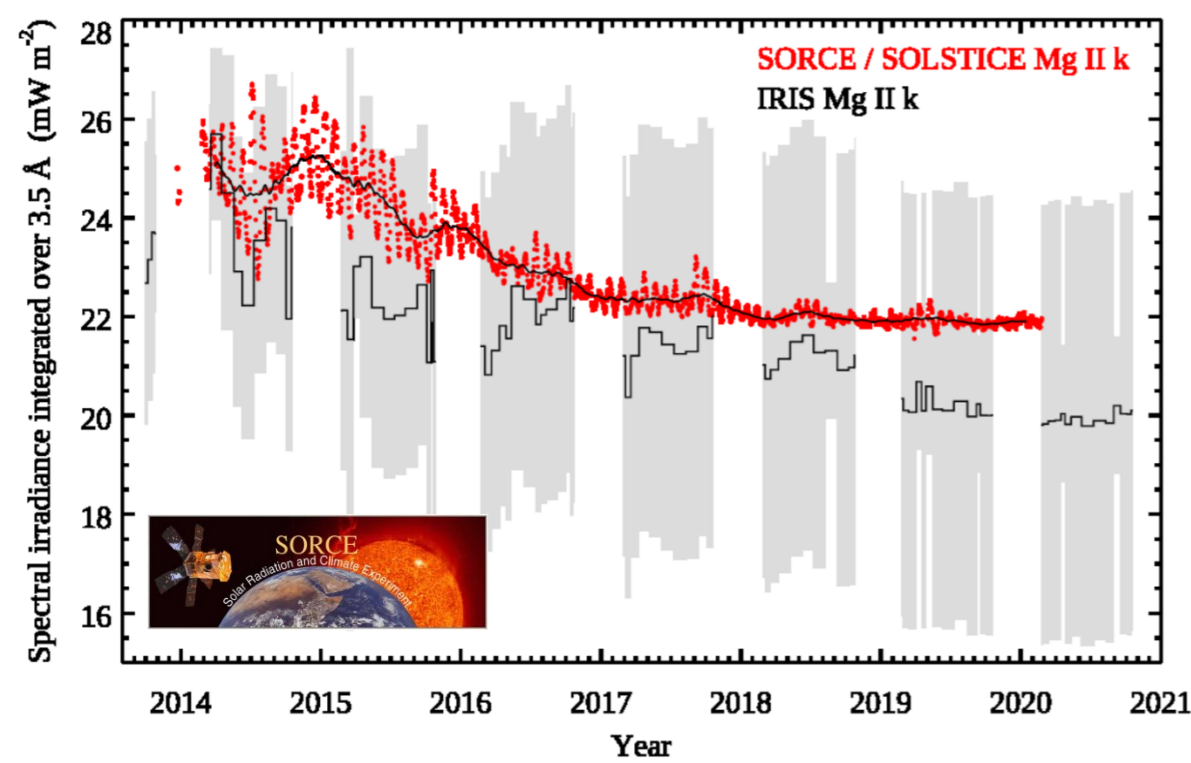
The wavelength integrated spectral irradiance $SI(\Delta\lambda = 3.5$ Å$)$ of disk-average IRIS Mg II k profile was computed and compared with equivalent quantity provided by the radiometer SOLSTICE aboard the SORCE spacecraft. The comparison yields cc = 0.85 and shows IRIS calibration offset of about 2 mW m^{-2} (the relative difference of 10%).

Mg II h & k Center-to-Limb Variation

Zone	⟨μ⟩
a	0.97
b	0.92
c	0.87
d	0.81
e	0.74
f	0.67
g	0.59
h	0.50
i	0.39
j	0.21
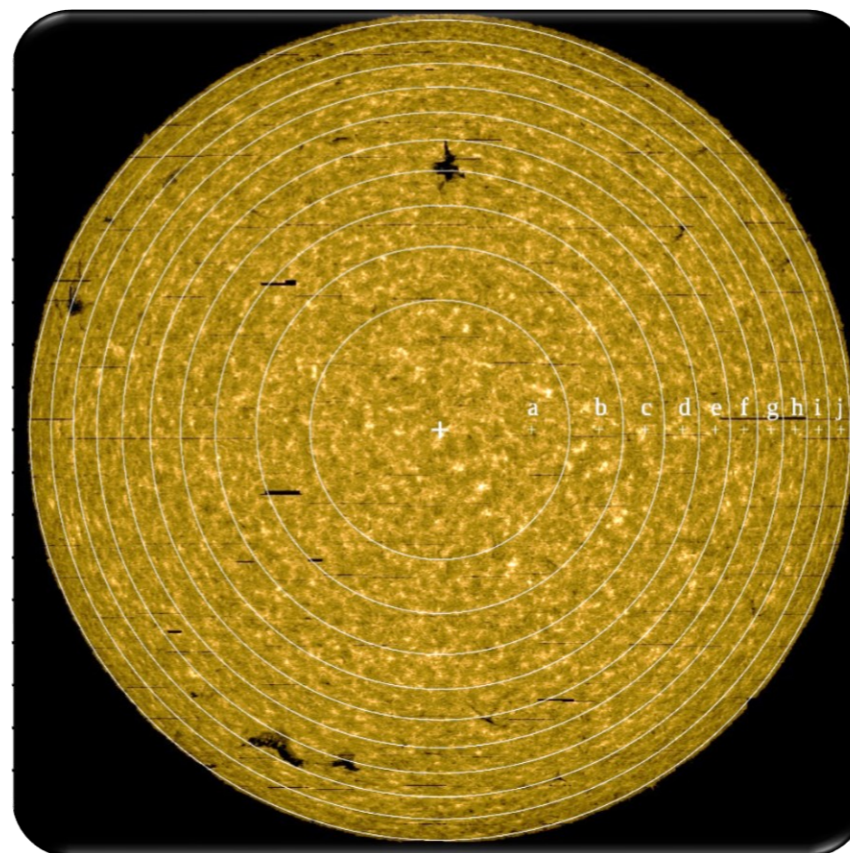
Mg II h & k profiles were averaged over 10 concentric zones a – j of equal area. The profiles show significant center-to-limb variation in contrast with Lyman-α (no Lyman-α center-to-limb variation). The wavelength integrated intensities E show **limb darkening**. The limb profiles are broader than the disk center profiles. As a consequence, **limb brightening** can be observed over a narrow wavelength range in line wings.
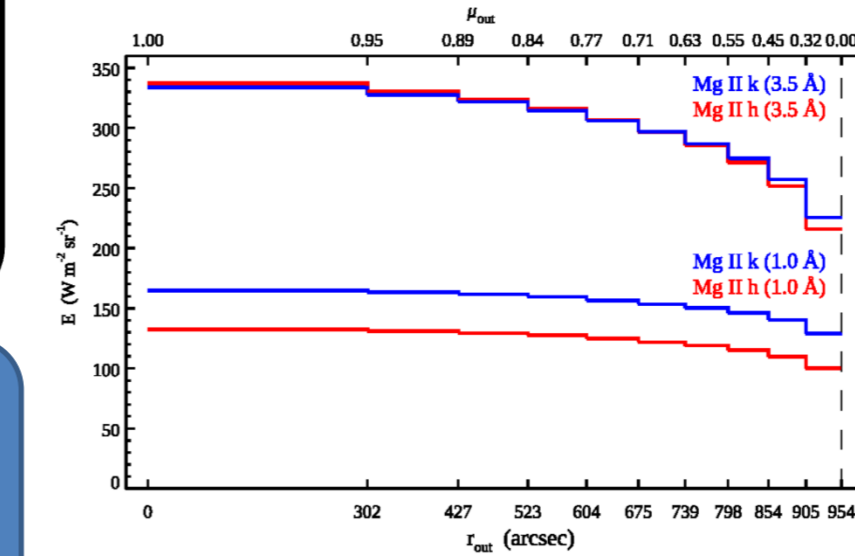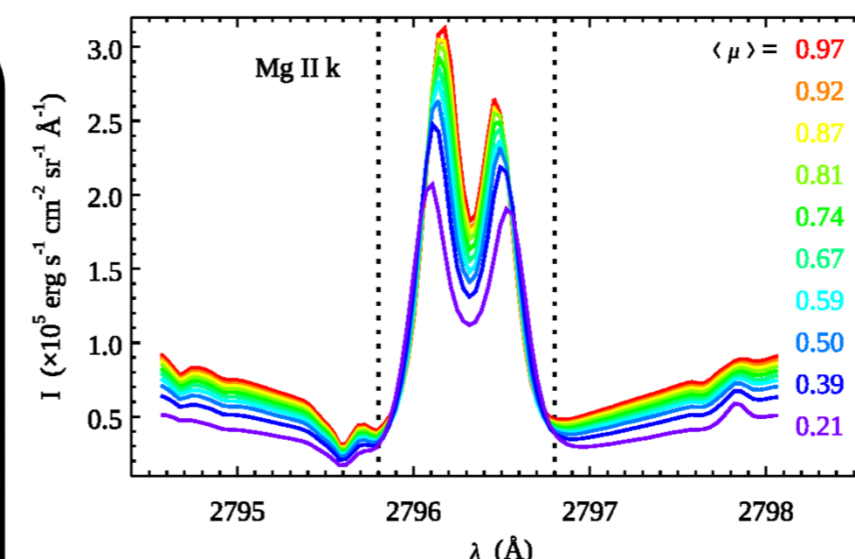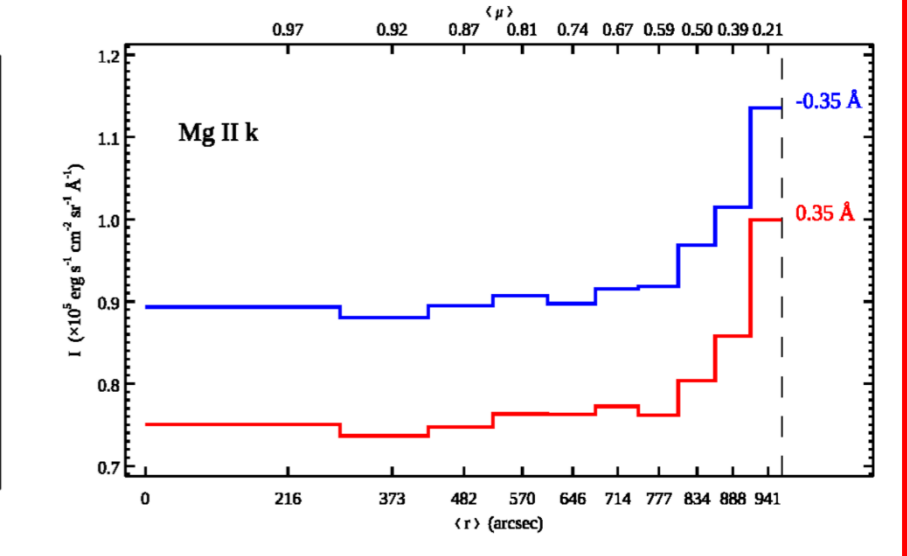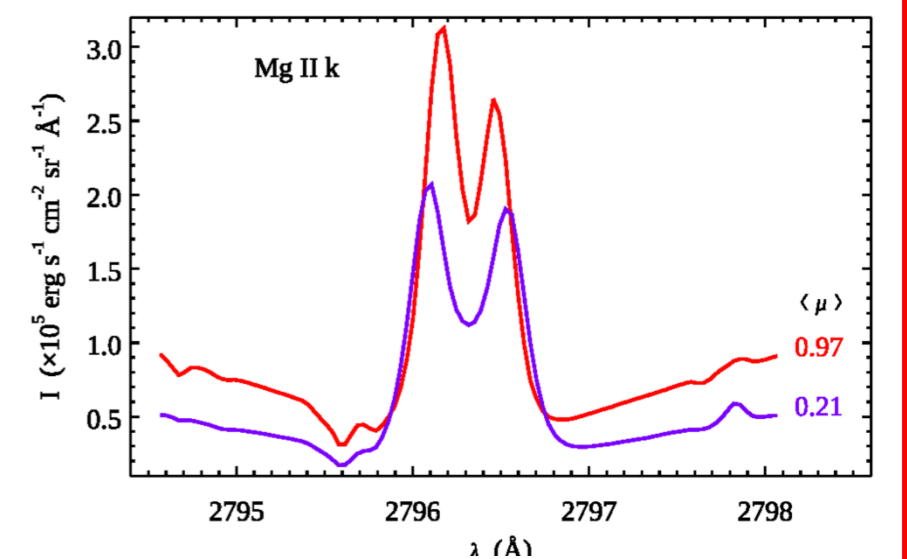
Data-driven Model of Temporal Evolution of Solar Mg II h & k Profiles over the Solar Cycle
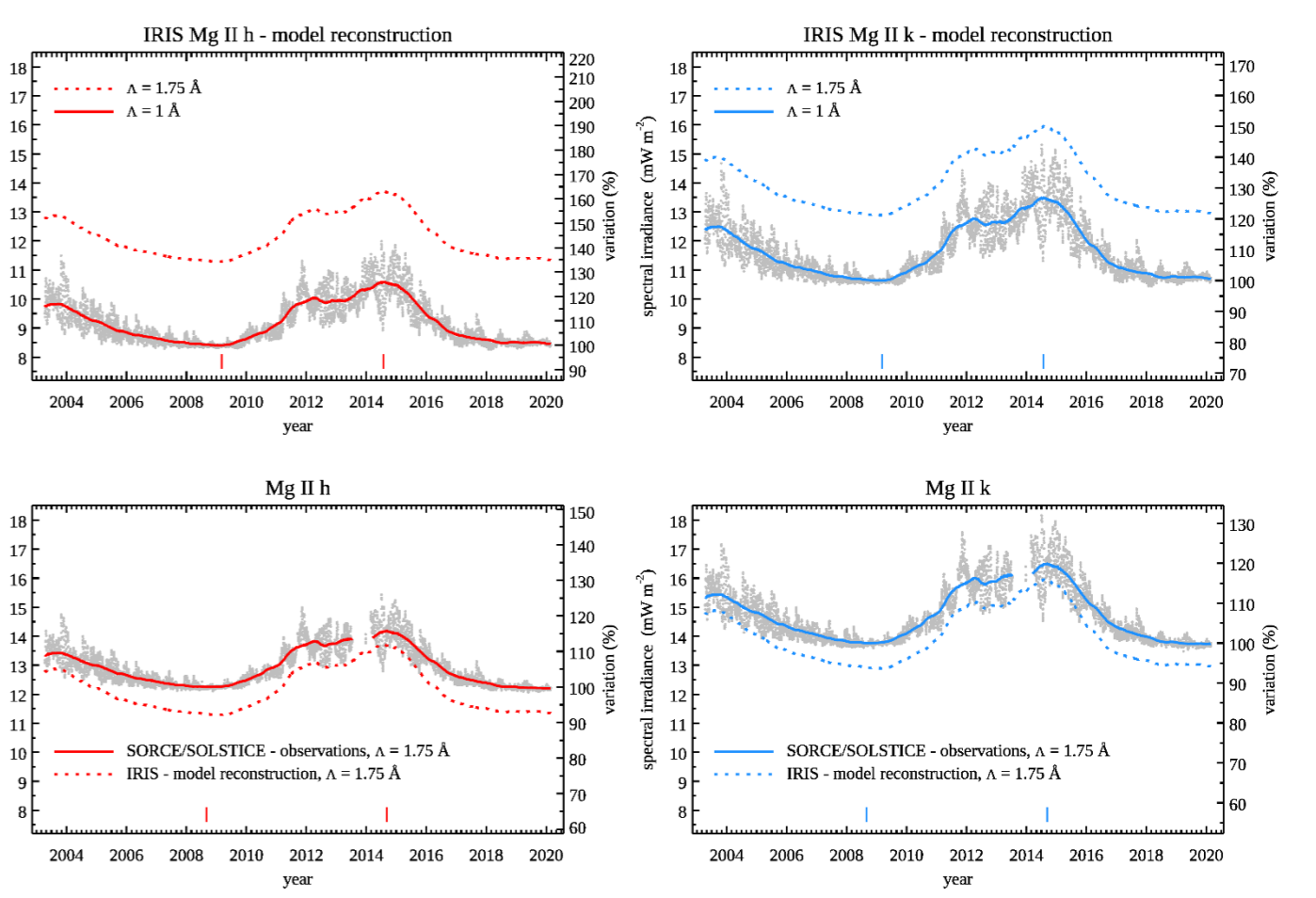
Model construction

- employment of 76 selected IRIS near-UV full-Sun mosaics covering almost the full solar cycle 24,
- finding nine parameters $\{A_i, \Delta\lambda_i, \sigma_i, a, b, c\}$ of additive double-Gaussian model of the disk-averaged profiles,
- finding a liner model of temporal evolution of the double-Gaussian parameters which is pameterized by the Bremen composite Mg II index as a proxy of time.

Additive double-Gaussian model

$$I_{\mathrm{mod}}(\Delta\lambda) = \sum_{i=1}^{2} A_i \exp\left\{-\left(\frac{\Delta\lambda - \Delta\lambda_i}{2\sigma_i}\right)^2\right\} + a + b|\Delta\lambda - c|$$
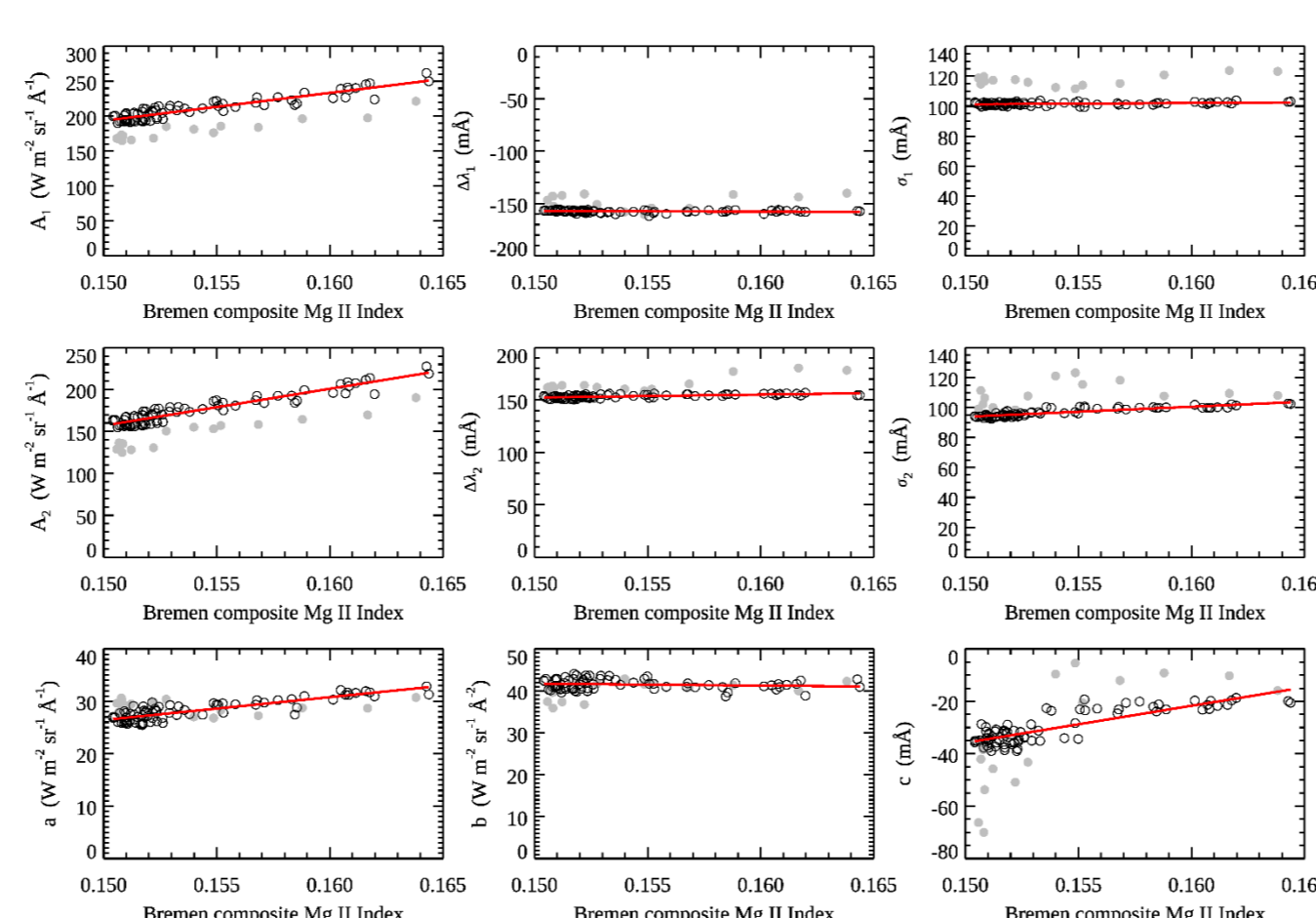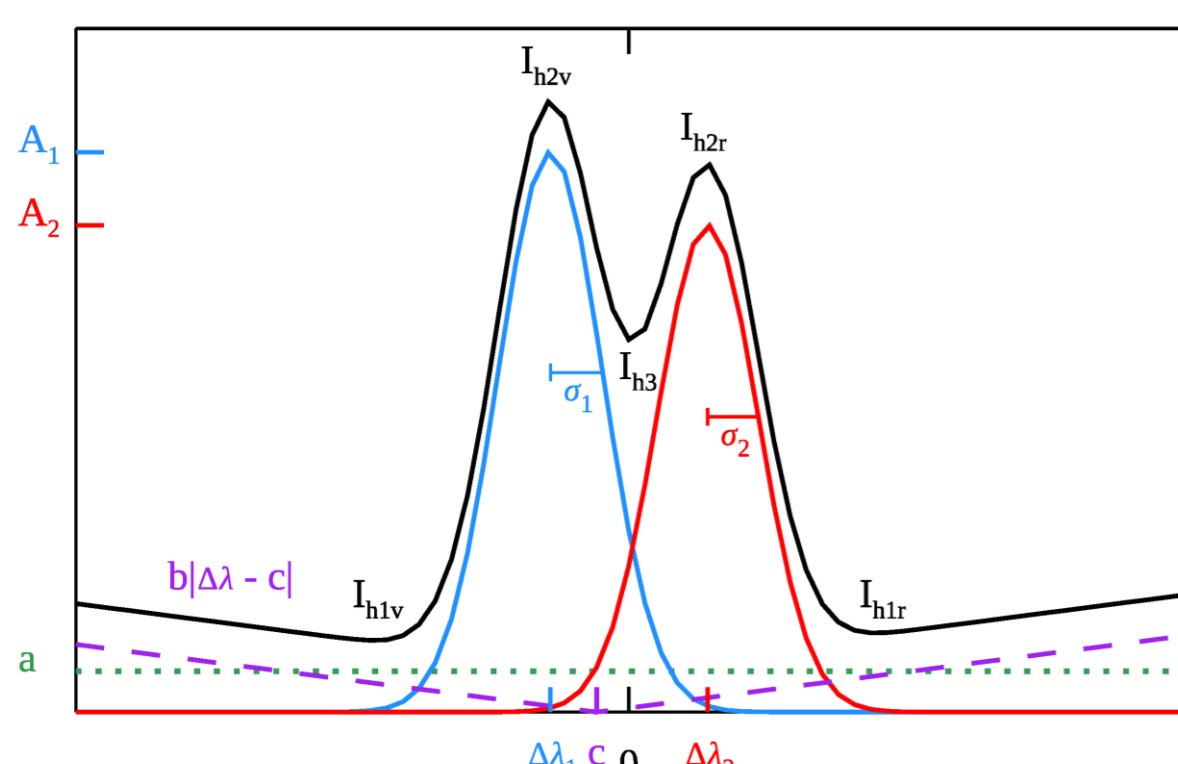
Correlations between the Bremen Mg II index and the parameters $\{A_i, \Delta\lambda_i, \sigma_i, a, b, c\}$ of the double-Gaussian model obtained by fitting disk-averaged Mg II h profiles. The solid lines are linear fits representing the model of evolution of Mg II h profiles in solar cycle 24.

IRIS spectral irradiances reconstructed by the model (gray dots in top panels) and computed by the SORCE/SOLSTICE observations (gray dots in bottom panels) taking integration intervals Δ of 1 Å and 1.75 Å. The red and blue lines represent boxcar-averaged values smoothed over 399 days. The different line styles distinguish between the intervals of 1 Å (solid in top panels) and 1.75 Å (dotted in top and bottom panels) for the IRIS model reconstructions and of 1.75 Å (solid in bottom panels) for the SORCE/SOLSTICE observations (solid in bottom panels). The relative variations with respect to the minima are shown at the right y-axes.

References

"Quiet-Sun Mg II h and k Line Profiles Derived from IRIS Full-Sun Mosaics. I. Reference Profiles and Center-to-limb Variation"
Stanislav Gunár, Július Koza, Pavol Schwartz, Petr Heinzel, and Wenjuan Liu, **ApJS 255, 16 (2021)**

"Data-driven Model of Temporal Evolution of Solar Mg II h and k Profiles over the Solar Cycle"
Július Koza, Stanislav Gunár, Pavol Schwartz, Petr Heinzel, and Wenjuan Liu, **ApJS 261, 17 (2022)**