# An empirical model of the variation of the solar Lyman-α spectral irradiance

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## Abstract

We propose a simple model that computes the spectral profile of the solar irradiance in the hydrogen Lyman alpha line, H Ly-α (121.567nm), from 1947 to present. Such a model is relevant for the study of many astronomical environments, from planetary atmospheres to interplanetary medium. This empirical model is based on the SOHO/SUMER observations of the Ly-α irradiance over solar cycle 23 and the Ly-α disk-integrated irradiance composite. The model reproduces the temporal variability of the spectral profile and matches the independent SORCE/SOSLTICE spectral observations from 2003 to 2007 with an accuracy better than 10%.

## The SOHO/SUMER Lyman alpha irradiance time series and profiles

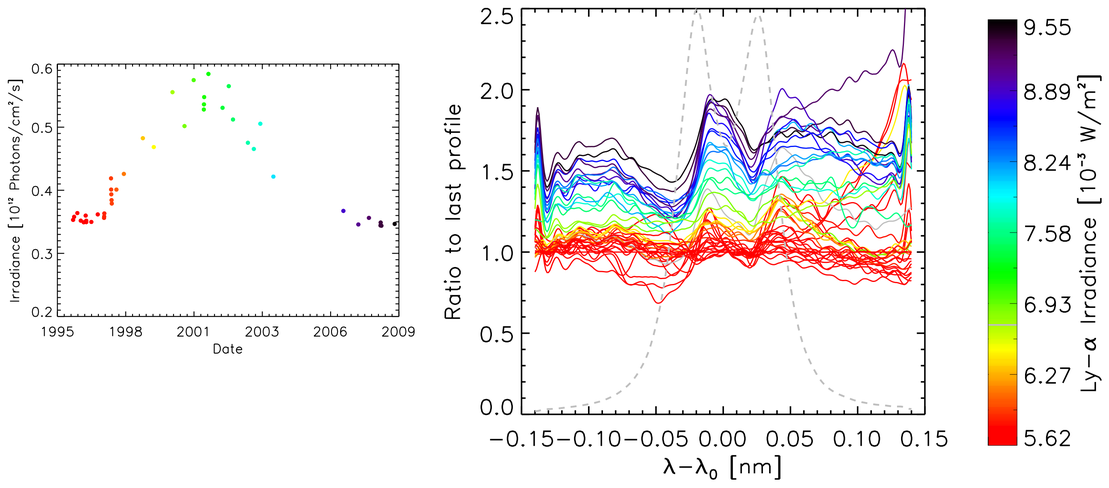



**Fig. 1:** Left: SOHO/SUMER Ly-α integrated irradiance vs time. Colors correspond to Ly-α irradiance and is used in other figures. Right: ratio of the 43 profiles to the last one (April 2009). The Ly-α spectral profile is shown for reference in arbitrary units in grey dashed line. The central wavelength is 121.567nm.

➡ **Correlation with proxies**

- Strongest correlation with Ly-α composite and faculae proxies.
- Spectrally dependent and non-symmetric.
- The excluded profiles indeed appear unphysical.

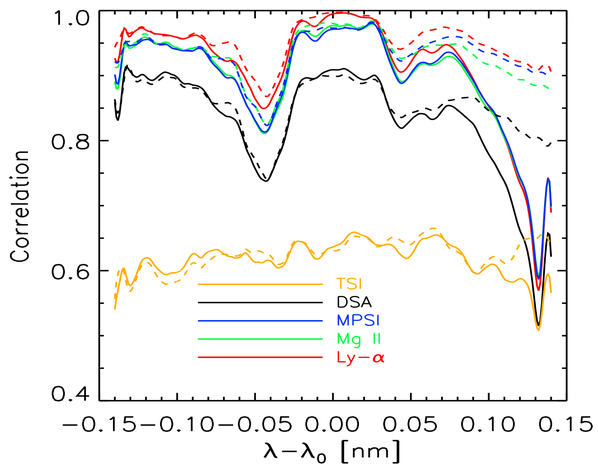



**Fig. 2:** Correlation with proxies. Dashed lines show the correlation computed without the profiles having a clear strong red wing.

## To fit or not to fit ?

**Should the profile be fitted before temporal modeling ?**

- We tried several analytical functions to fit the observed profiles
  - linear+two Lorentzian+Gaussian
  - linear+Voigt+Gaussian
  - linear+Kappa+Gaussian
- None of these combinations is able to reproduce the profiles with sufficient accuracy

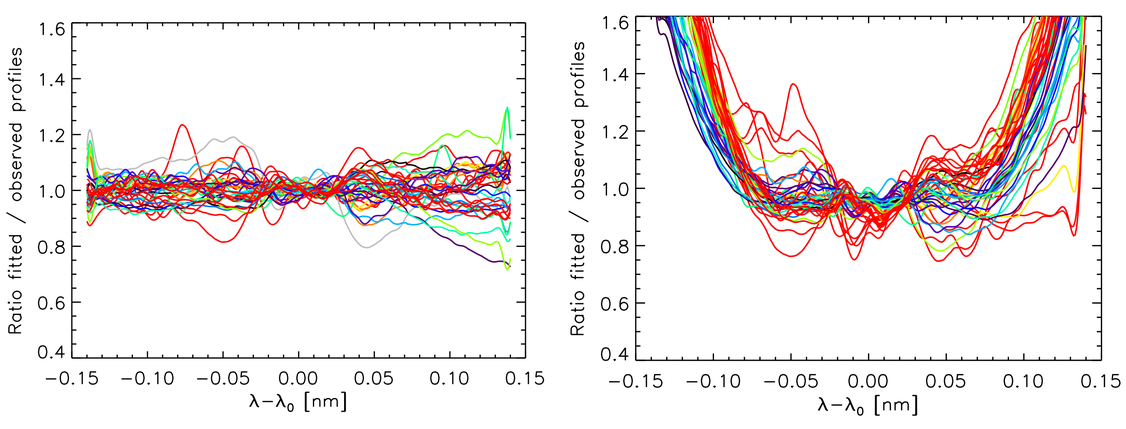



**Fig. 3:** Residuals modeled/observed profiles for 1) **Left, this work**: the temporal variability is directly deduced from the observed profiles 2) **Right, Kowalska—Leszczynska+ (2018)**: Each profile is first fitted with a linear+Kappa+Gaussian function before deducing the temporal variability of the model parameters.

## Reference:

Kretzschmar, M., Snow, M., & Curdt, W. (2018). An empirical model of the variation of the solar Lyman-α spectral irradiance. Geophysical Research Letters, 45. https://doi.org/10.1002/2017GL076318.

## Best performing model

In this case, the best performing model is also the simplest !!

$$Ly\alpha(\lambda, t) = a_0(\lambda) + a_1(\lambda) \times P_{Ly\alpha}(t)$$

Adding another proxy (e.g., DSA) does not improve the model.

## Results & Comparisons

The output of the model, i.e. time series of the solar Ly-α spectral irradiance from 1947 to present, agrees with the SORCE/SOLSTICE observations with an uncertainty better than 10%.

The daily Ly-α profile will be available on the LASP Interactive Solar Irradiance Datacenter (http://lasp.colorado.edu/lisird) and on the SOLID (SOLar Irradiance Data Exploitation) database (https://projects.pmodwrc.ch/solid).

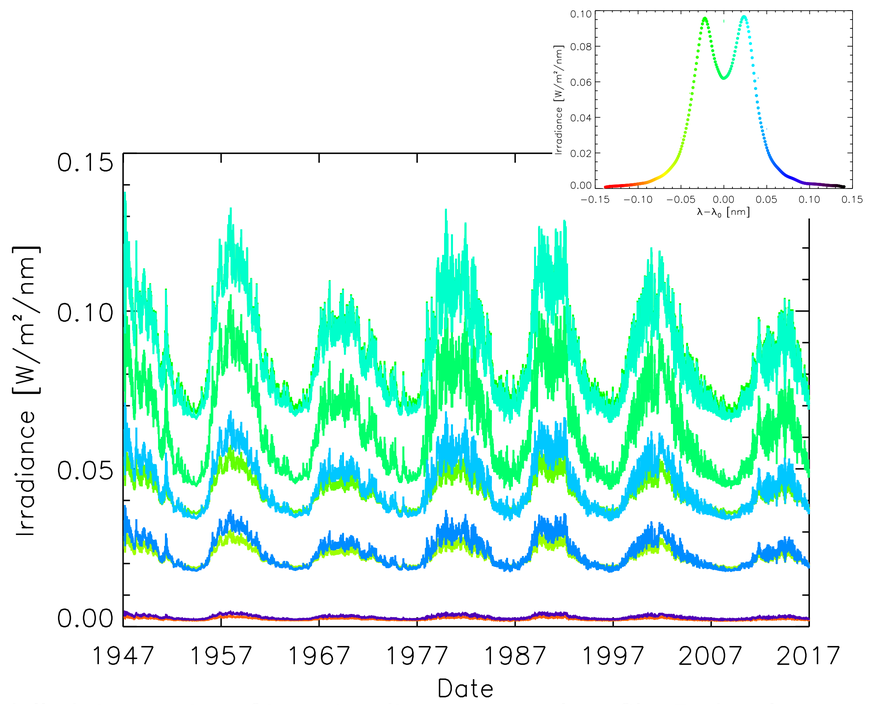
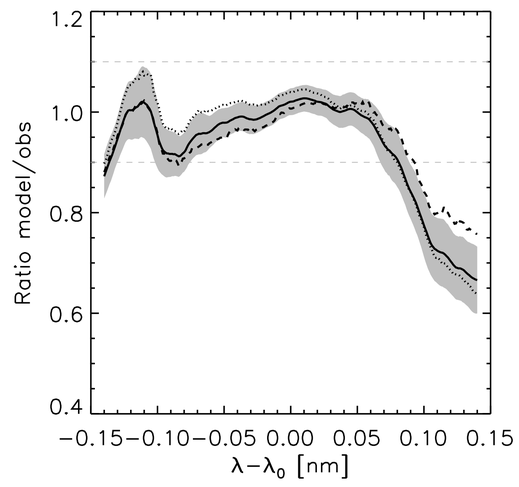



**Fig. 4:** Modelled time series of Ly-α irradiance spectral profile. Each color corresponds to a wavelength, as indicated in the upper right figure.

**Fig. 5:** Ratio of the modelled profiles to the SORCE/SOLSTICE observations. The plain line shows the average ratio over all SOLSTICE profiles, and the shaded area corresponds to 1σ-variation of the ratio value. The dotted line shows the average ratio for low solar activity, and the dashed line for high solar activity.



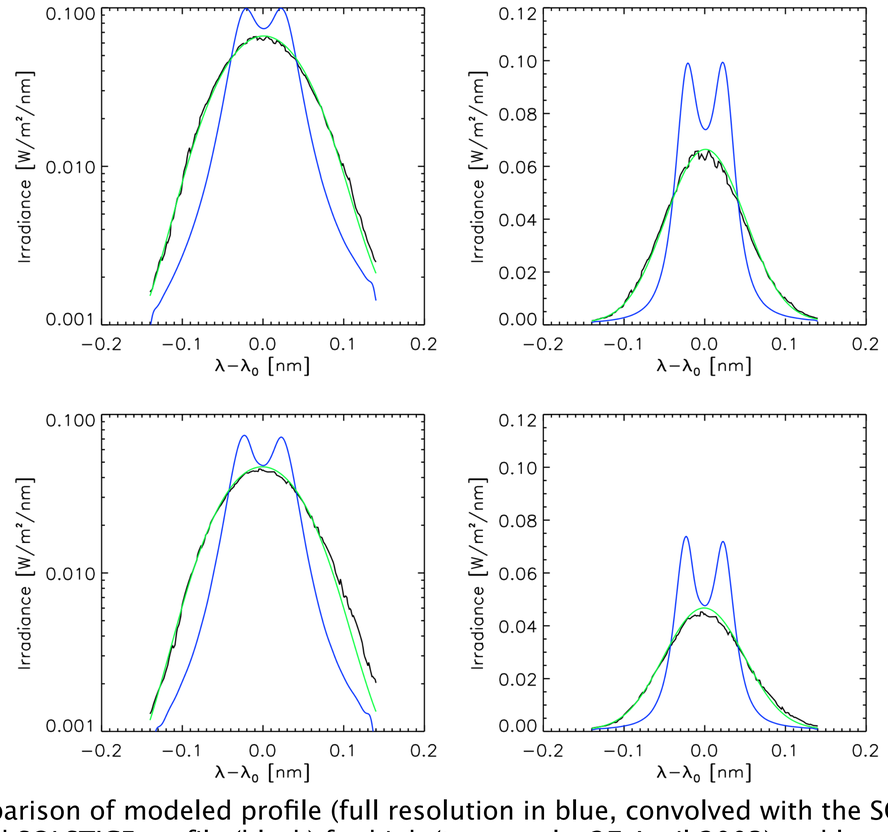




**Fig. 6:** Comparison of modeled profile (full resolution in blue, convolved with the SOLTICE PSF in green) and SOLSTICE profile (black) for high (top panels, 27 April 2003) and low (bottom panels, 8 July 2007) solar activity.
In this case, the best performing model is also the simplest !!