Physikalisch-Meteorologisches Observatorium Davos
World Radiation Center

pmod wrc

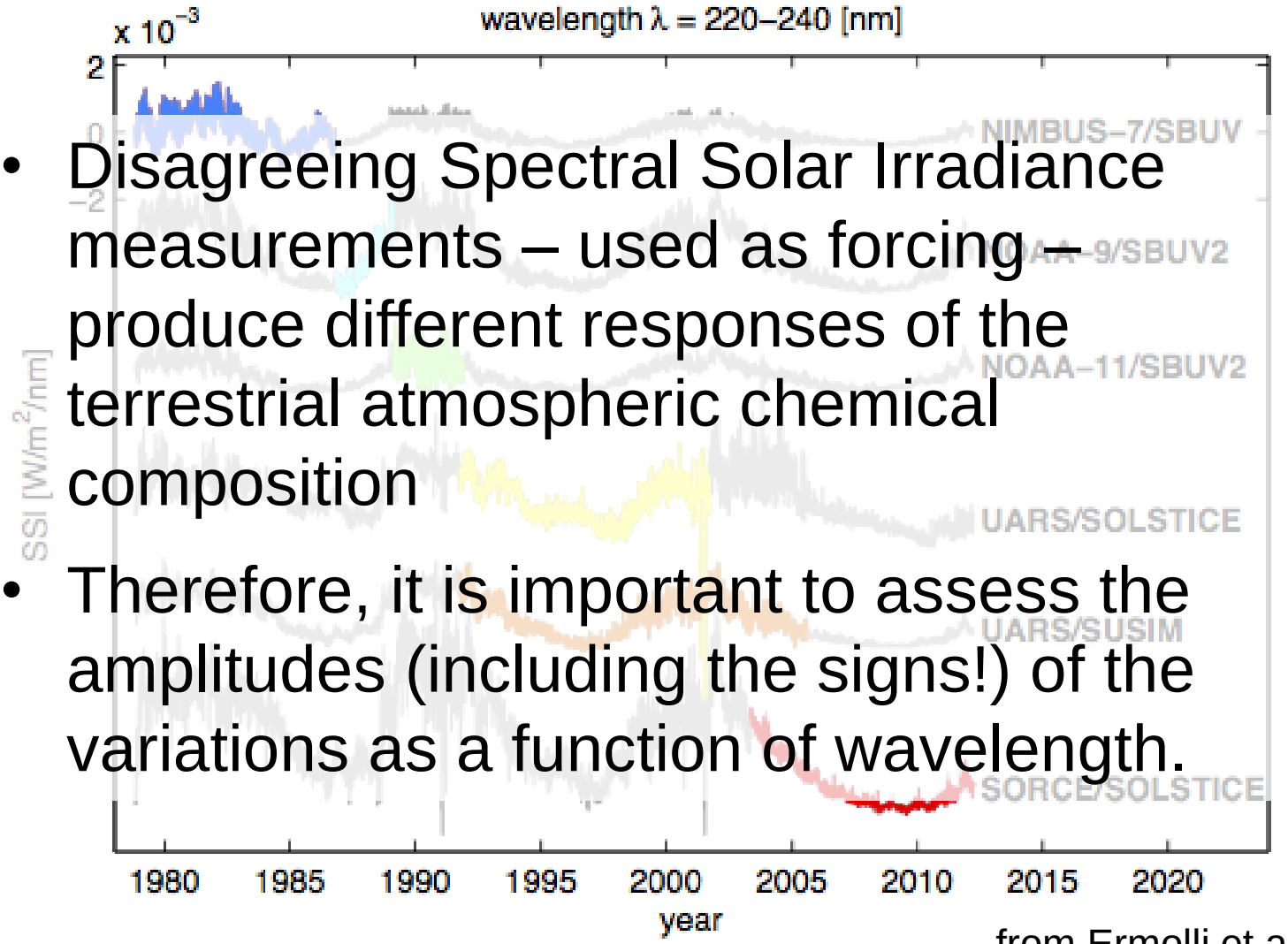
Variations of Near-UV and Visual Solar Spectral Irradiance as Measured by VIRGO/SoHO and PREMOS/Picard

Werner Schmutz, Alexander Shapiro, and Christoph Wehrli

Talk based on Wehrli et al. 2013, A&A 556, L3:
”Correlation of spectral solar irradiance with solar activity as measured by VIRGO”

SORCE Science Meeting Cocoa Beach, Florida
January 28-31, 2014

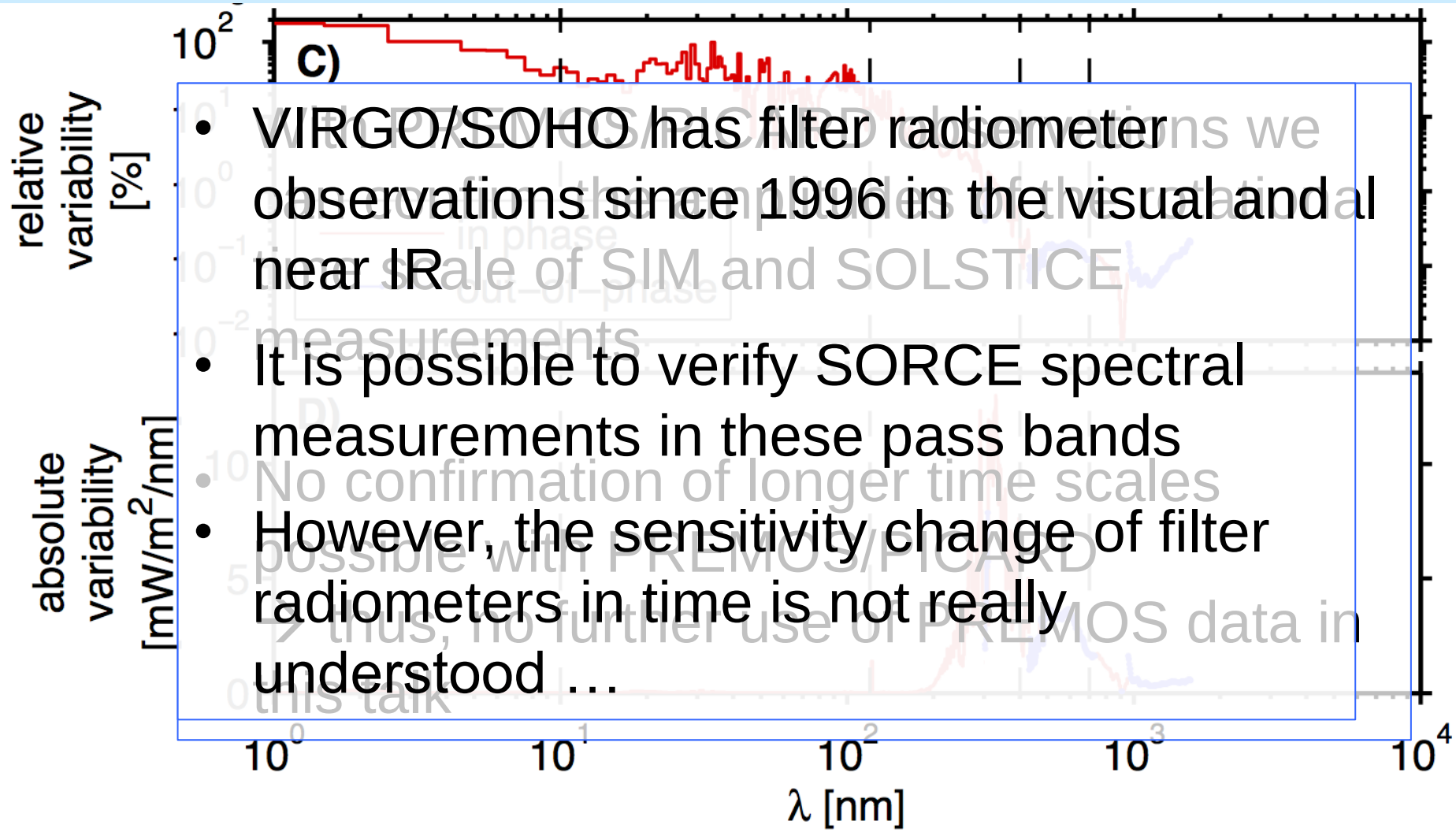
Introduction I



- Disagreeing Spectral Solar Irradiance measurements – used as forcing – produce different responses of the terrestrial atmospheric chemical composition
- Therefore, it is important to assess the amplitudes (including the signs!) of the variations as a function of wavelength.

from Ermolli et al. 2013

Introduction II



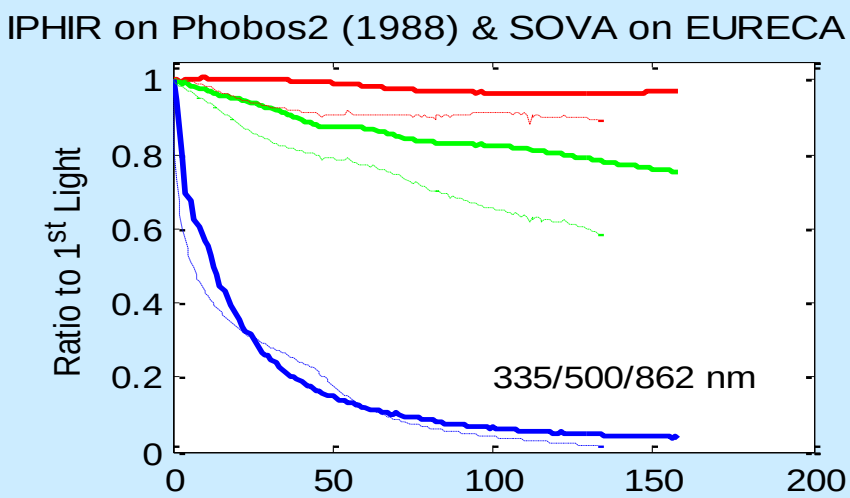
- VIRGO/SOHO has filter radiometer observations since 1996 in the visual and near IR
- It is possible to verify SORCE spectral measurements in these pass bands
- However, the sensitivity change of filter radiometers in time is not really understood …

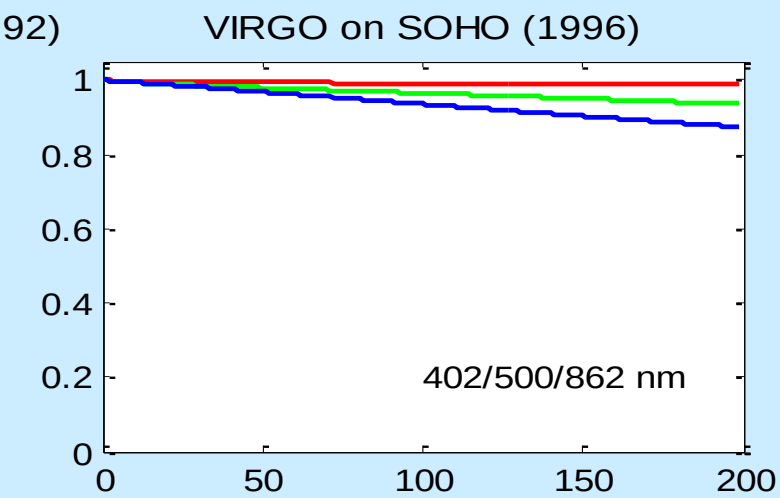
from Ermolli et al. 2013

Overview

- Some words of caution about filter radiometers;
- VIRGO/SoHO SPM data and “as-little-as-possible” degradation correction;
- Results for rotational time scales;
- Results for variation on an activity-cycle time scale

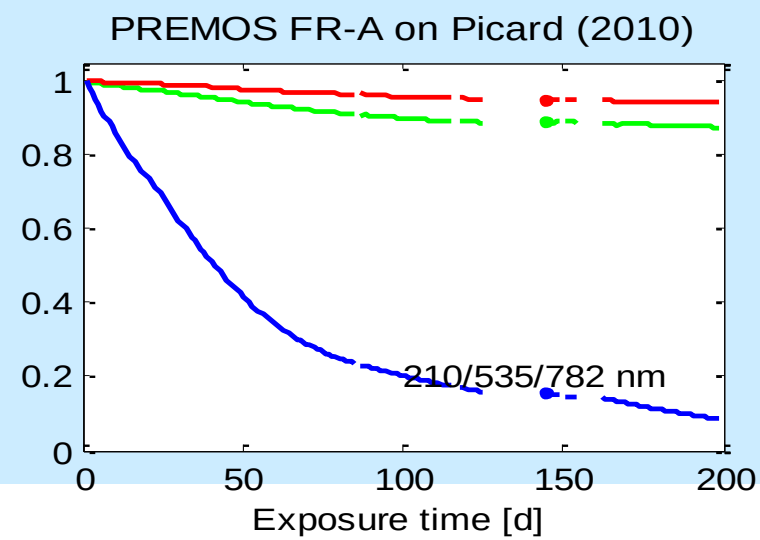
Degradation rates on 4 S/C 1st 200 *exposure* days



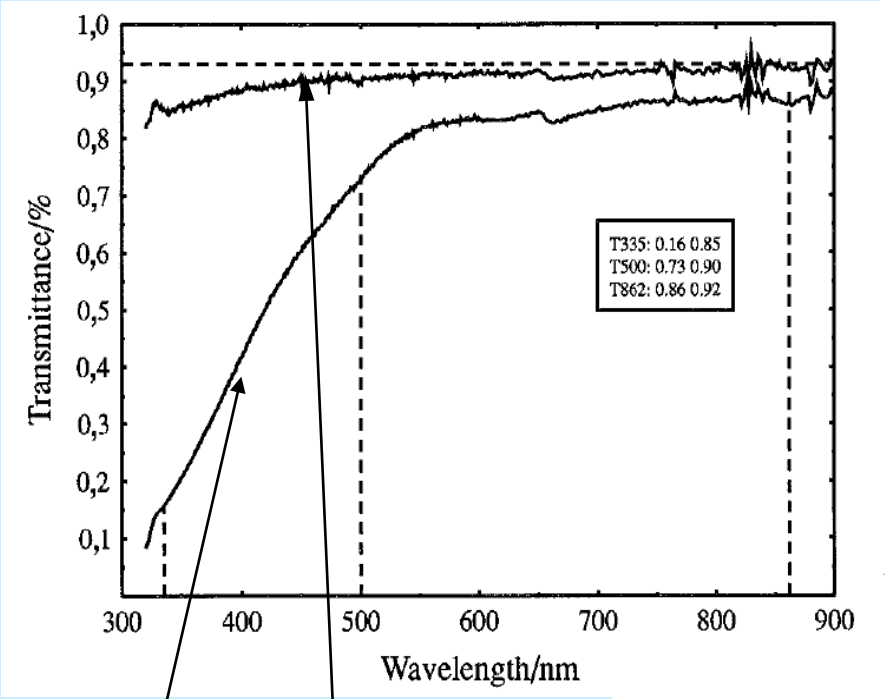


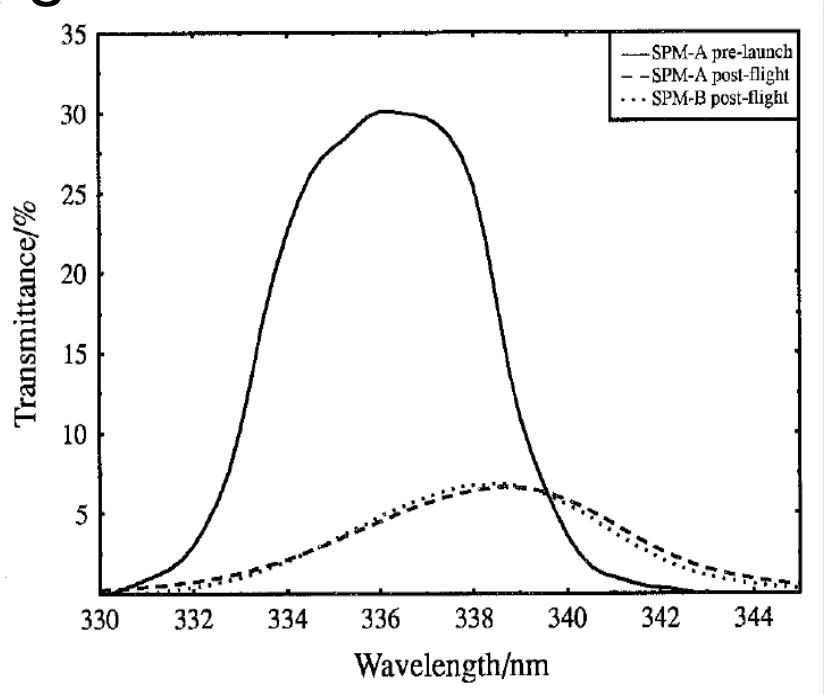
PREMOS 535, 782 differs not much from VIRGO 500, 862, whereas 210 resembles IPHIR 335.

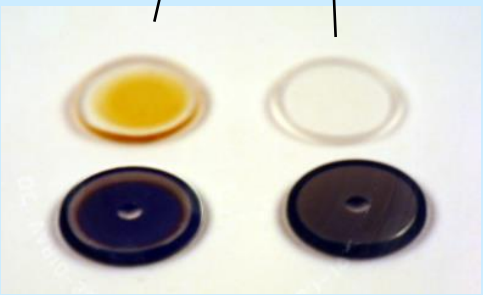
- Picard cleanliness comes close to SOHO



SOVA2/EURECA (1992)
Instruments returned after flight





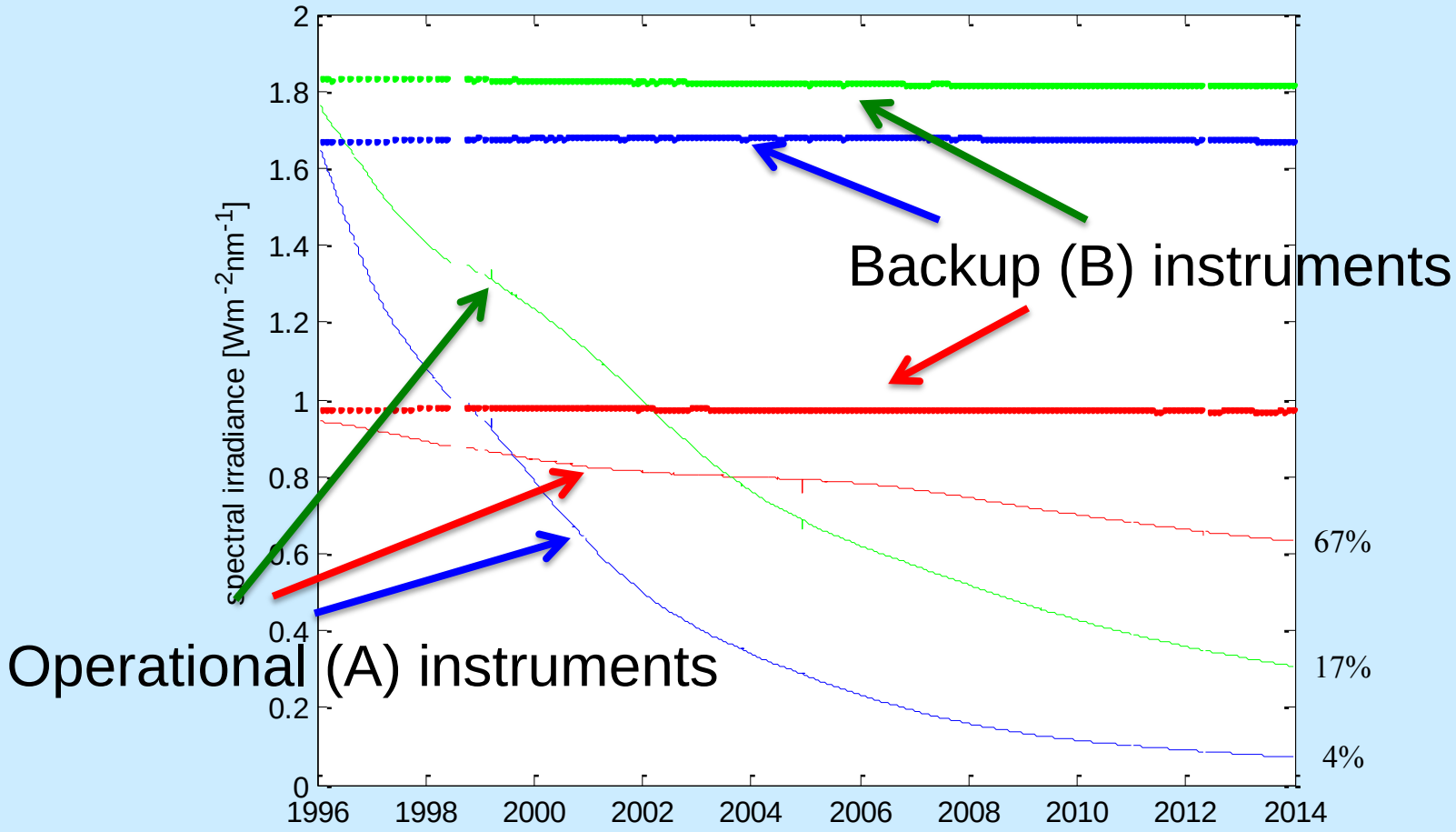


Wehrli et al., 1995, Metrologia

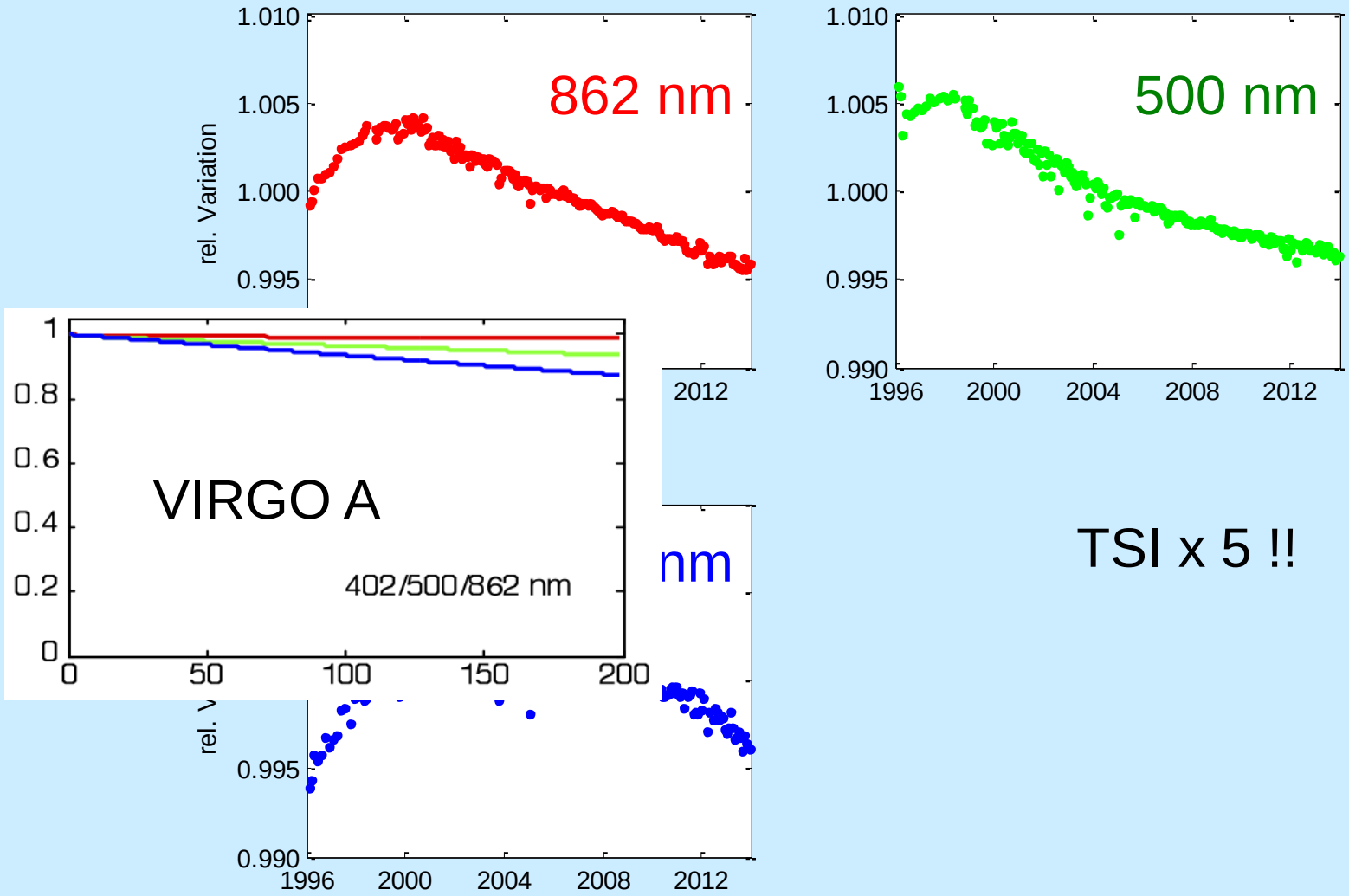
Right: 335nm filter band pass <u>degraded the same way</u> for both operational SPM-A and backup SPM-B;

Left: Rapid solarization of UG1 blocking glass!

Sensitivity changes of VIRGO filter radiometers

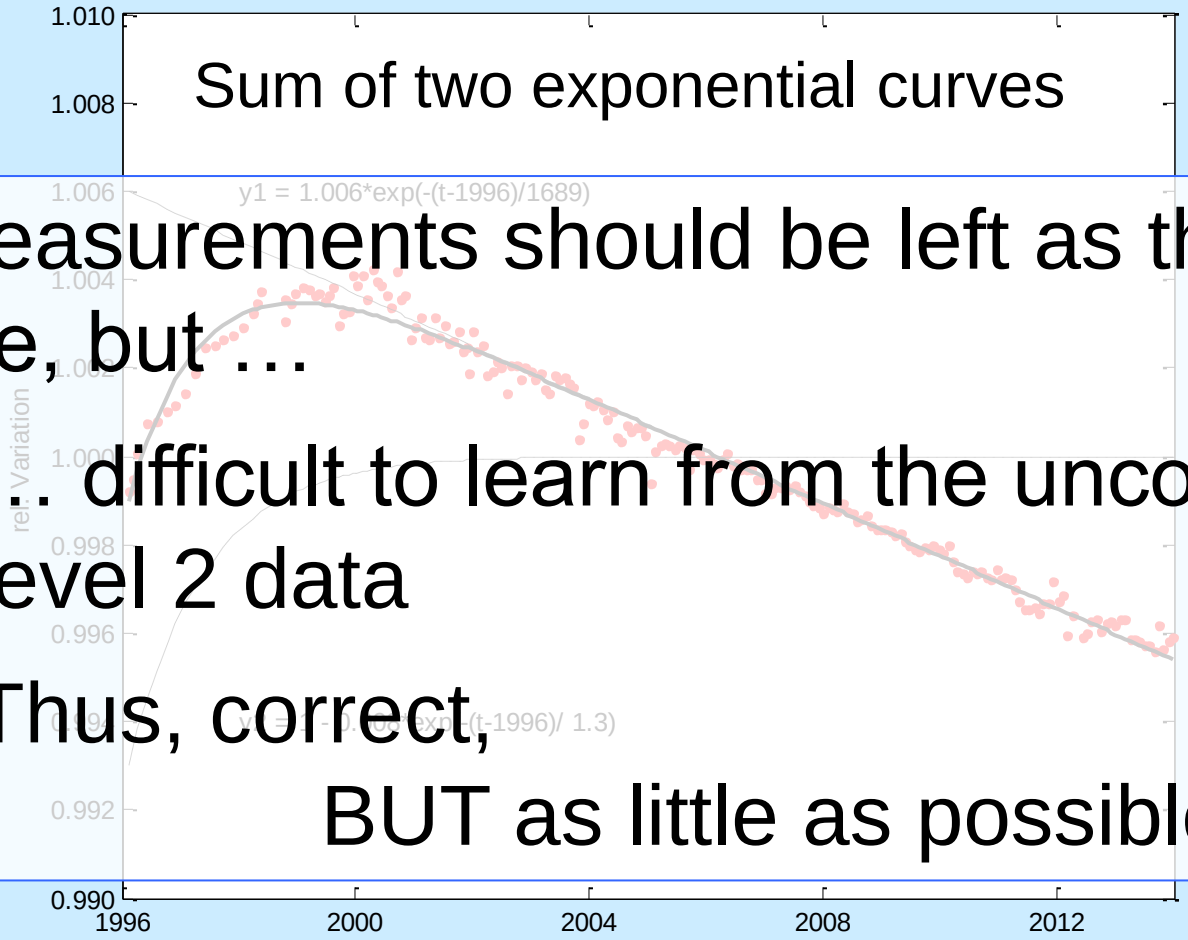


Sensitivity changes of VIRGO backup filter radiometers



TSI x 5 !!

Simple fit to sensitivity change



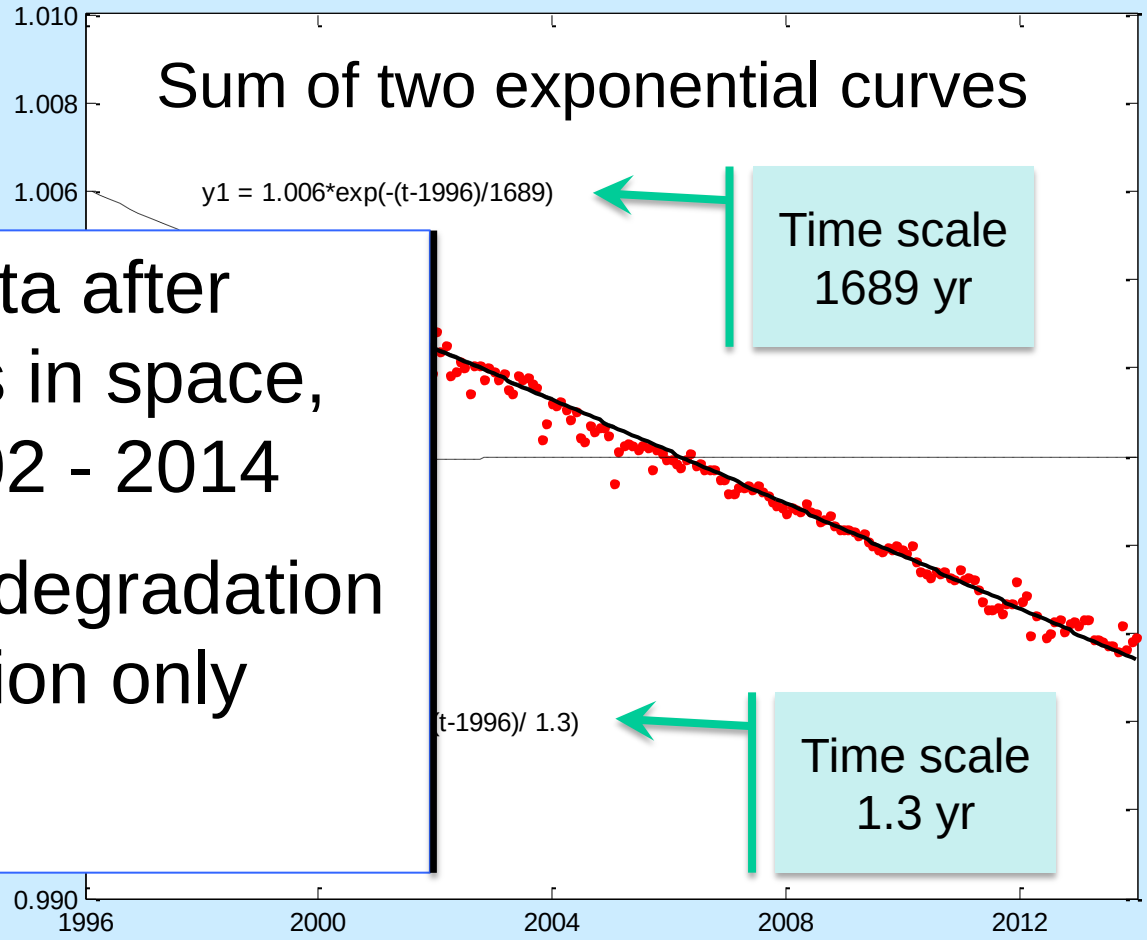
- Measurements should be left as they are, but …

→ … difficult to learn from the uncorrected level 2 data

→ Thus, correct,

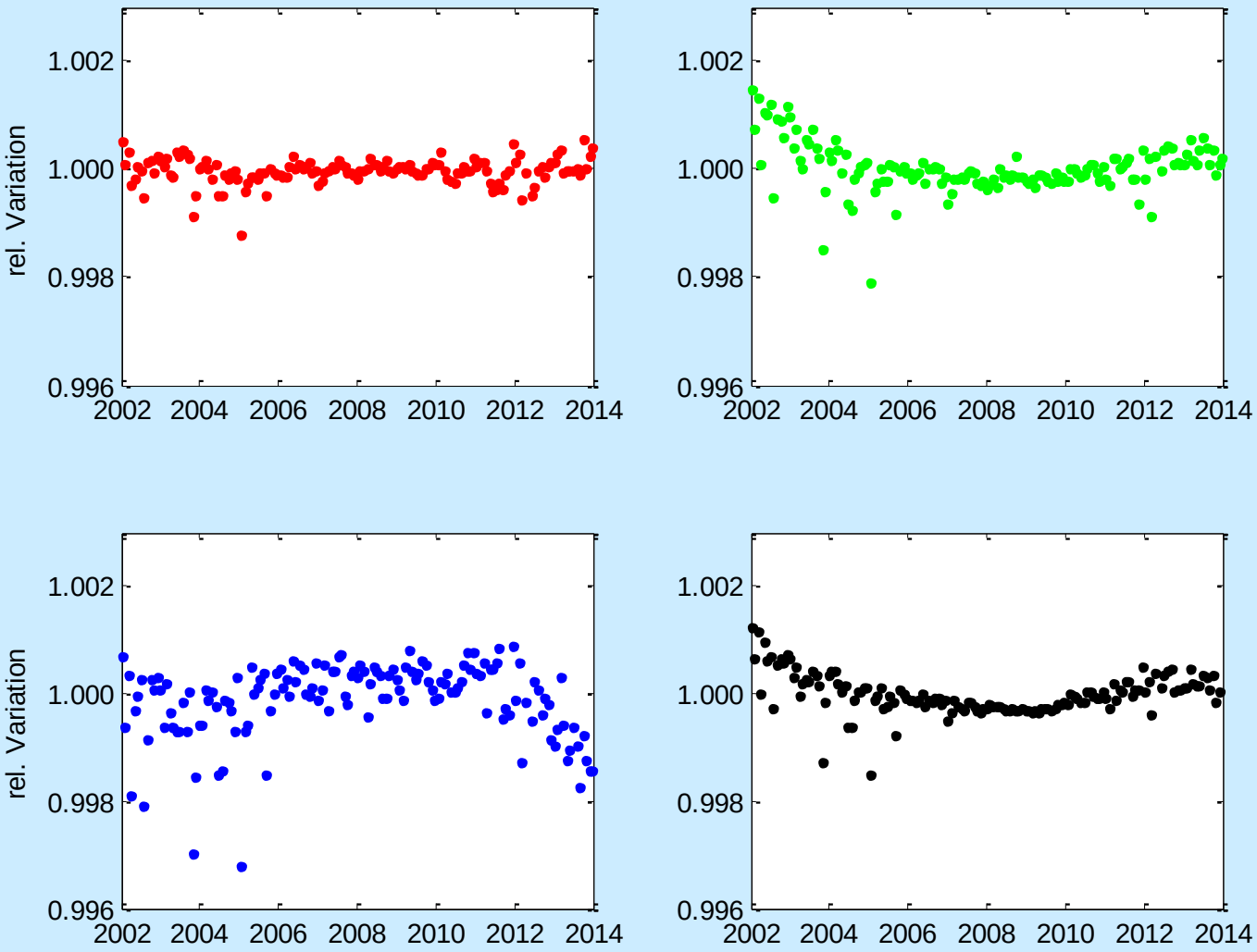
BUT as little as possible !

Simple fit to sensitivity change



- Use data after 6 years in space, i.e. 2002 - 2014
- Linear degradation correction only

Linearly detrended SPM-B measurements



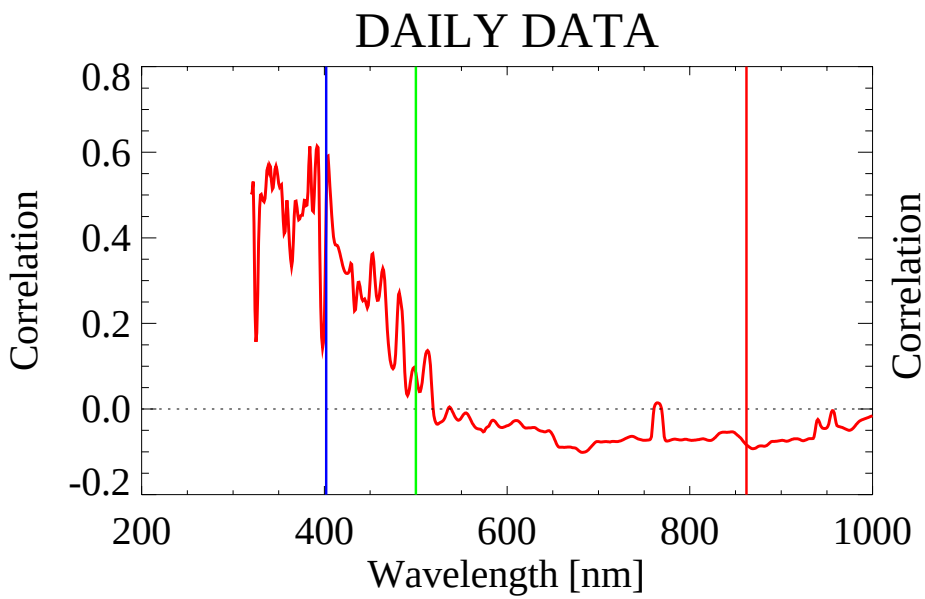
Correlation of SPM-B measurements with TSI

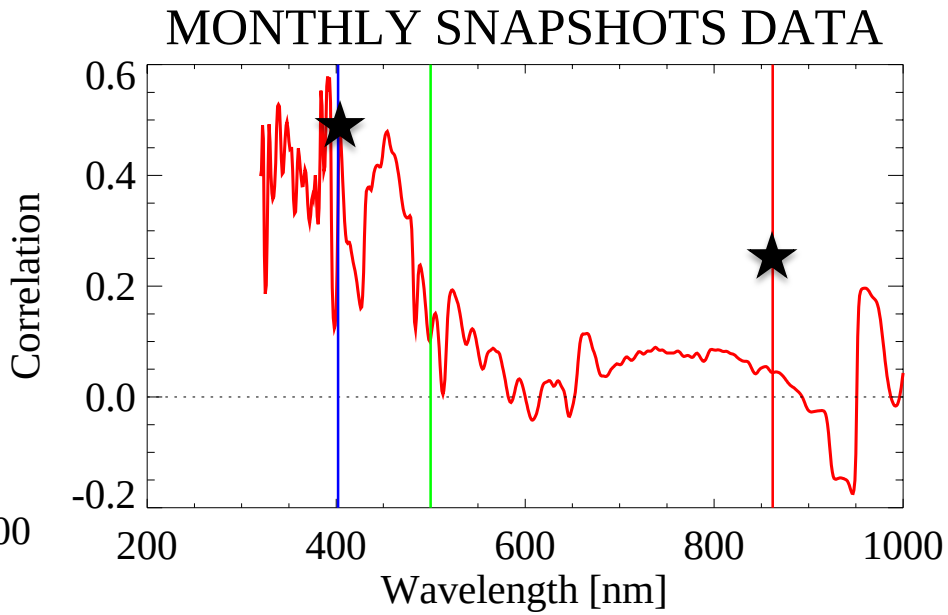
Table 1. Correlation coefficients between relative variations in TSI and averages (Cols. 5–7) are listed with 95% uncertainties in brackets.

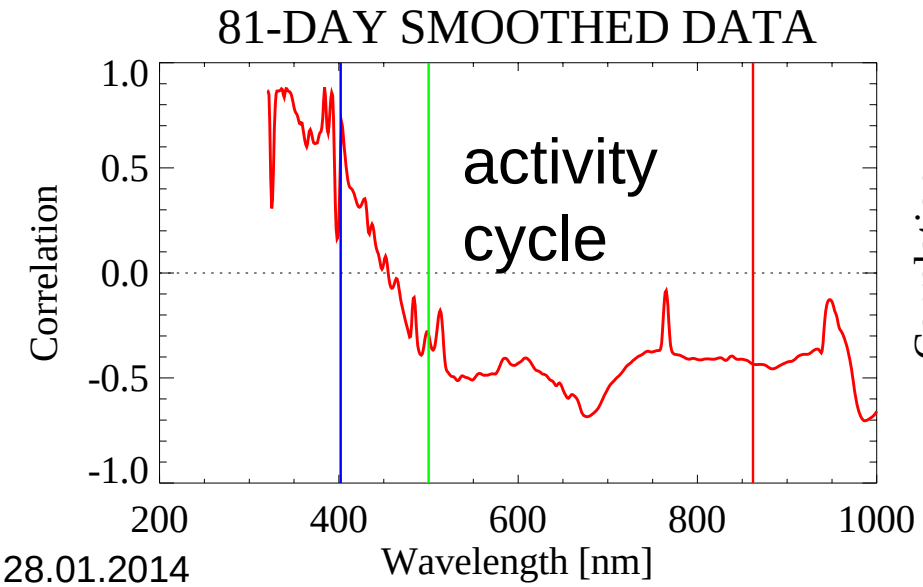
	Monthly snapshots		
	SSI-862	SSI-500	SSI-402
TSI	0.25[0.08, 0.41]	0.87[0.83, 0.91]	0.48[0.33, 0.60]
SSI-862	1.0	0.45[0.30, 0.58]	0.55[0.42, 0.66]
SSI-500		1.0	0.68[0.58, 0.77]
SSI-402			1.0

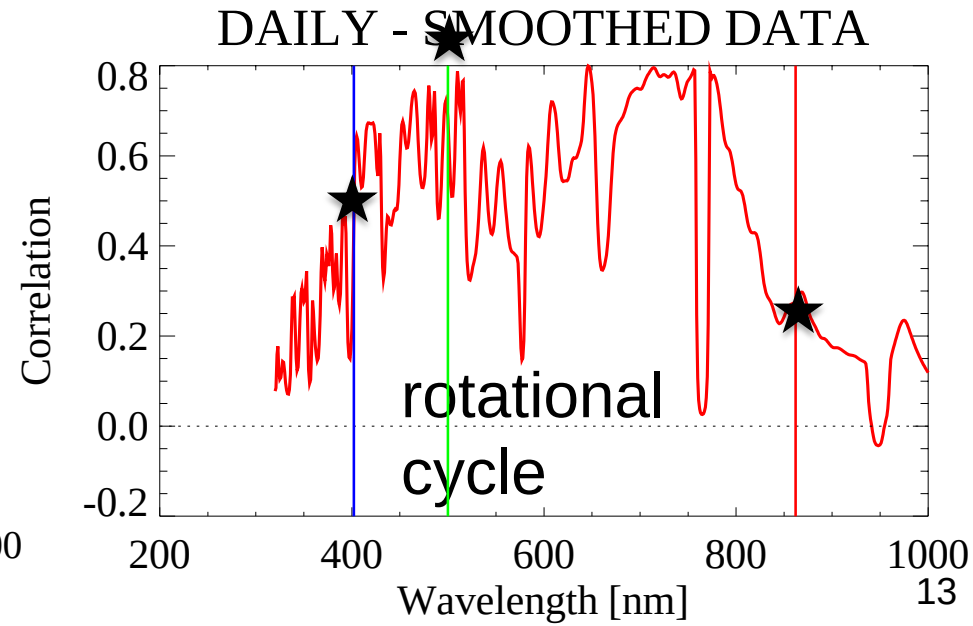
Notes. The number of monthly values are 124

Correlation between TSI and SSI (SIM)
Data 21/04/2004 - 22/08/2011



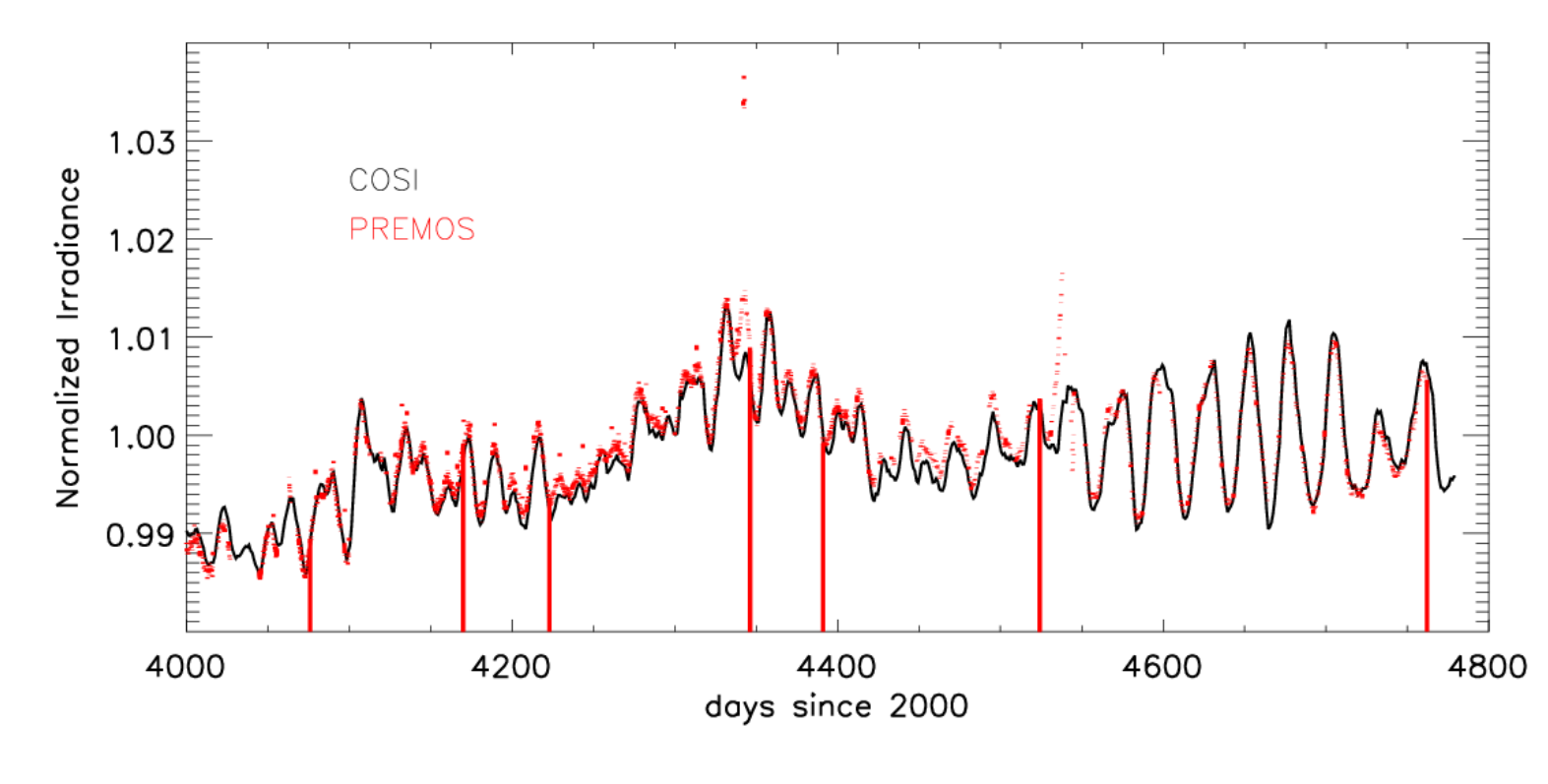






Solar rotational time scale

Irradiance at 215 nm

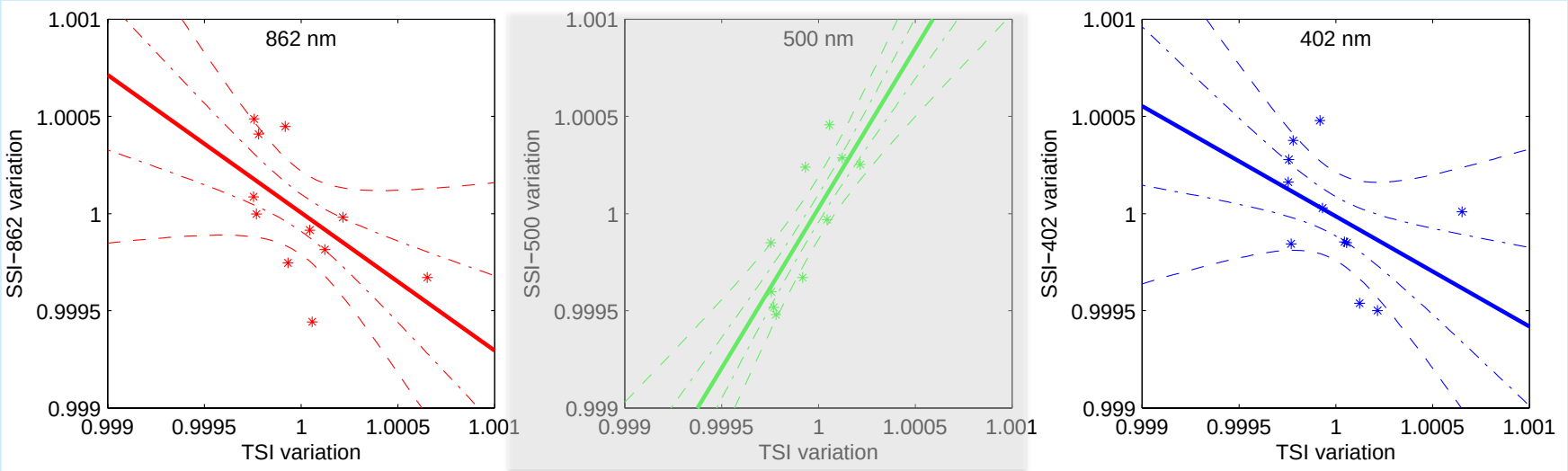


Correlation of SPM-B measurements with TSI

Table 1. Correlation coefficients between relative variations in TSI and averages (Cols. 5–7) are listed with 95% uncertainties in brackets.

	Annual averages	
SSI-862	SSI-500	SSI-402
−0.58[−0.88, 0.03]	0.91[0.68, 0.98]	−0.43[−0.82, 0.23]
1.0	−0.79[−0.94, −0.36]	0.65[0.09, 0.90]
	1.0	−0.47[−0.82, 0.24]
		1.0

Notes. The number of annual values a 11.



from Wehrli et al. 2013

Channel	Slope	2-σ uncertainty	1-σ uncertainty	R^2
SSI-862	−0.71	[−1.55, 0.13]	[−1.08, −0.34]	0.22
SSI-500	1.65	[1.02, 2.27]	[1.37, 1.92]	0.79
SSI-402	−0.57	[−1.45, 0.32]	[−0.96, −0.17]	0.01

CAUTION:
slope values might be affected by the subtraction of the linear trend

„Max-Min“ Irradiance Variation

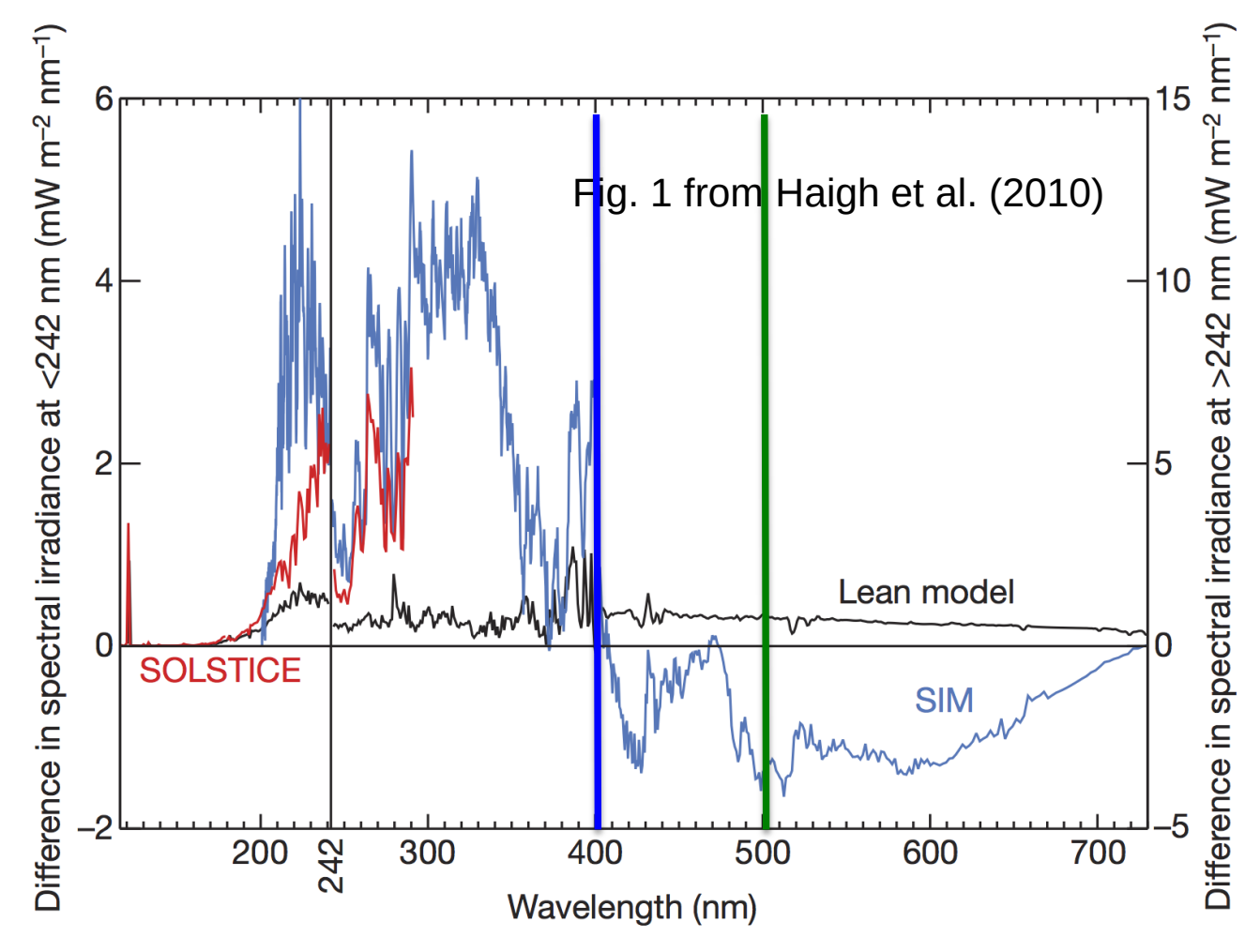


Figure 1 | Difference in solar spectrum between April 2004 and November 2007. The difference (2004–2007) in solar spectral irradiance (W m^{-2} nm^{-1})

Wavelength band variations

Example: variability does not depend on the wavelength

$$\frac{\Delta F}{\Delta TSI} = slope \cdot \frac{F}{TSI}$$

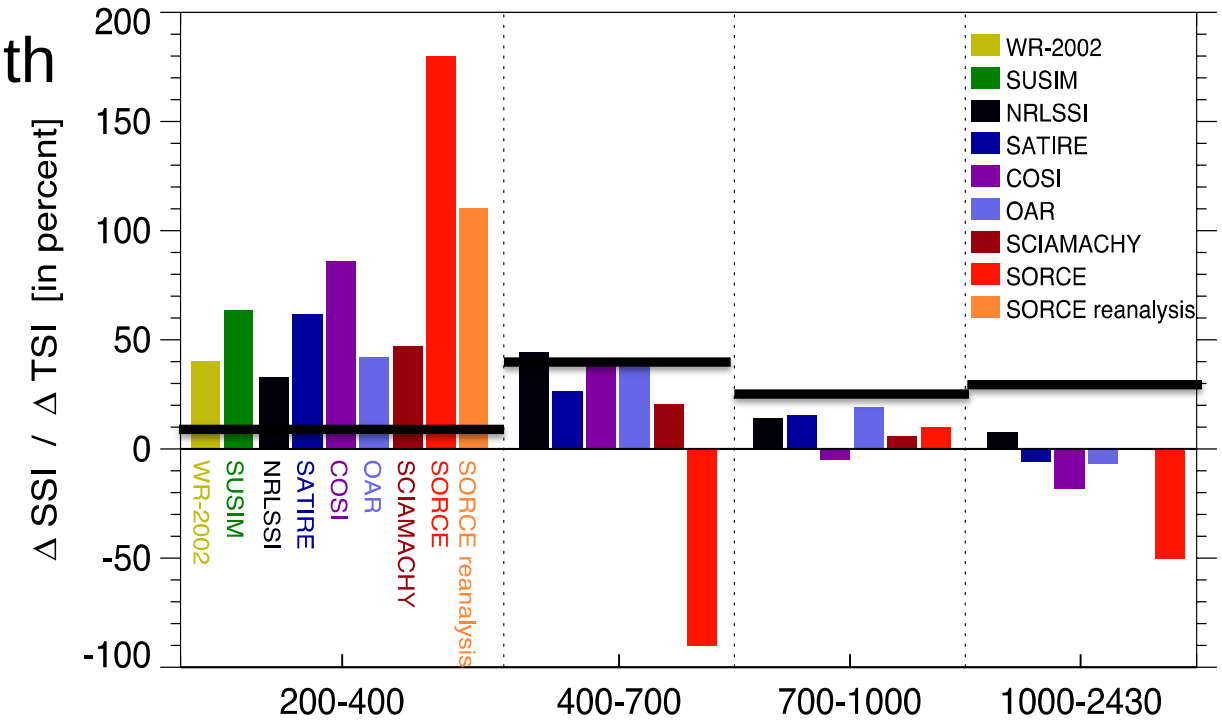
8% of TSI

39% of TSI

23% of TSI

27% of TSI

<4% of TSI



neglected

from Ermolli et al. (2013)

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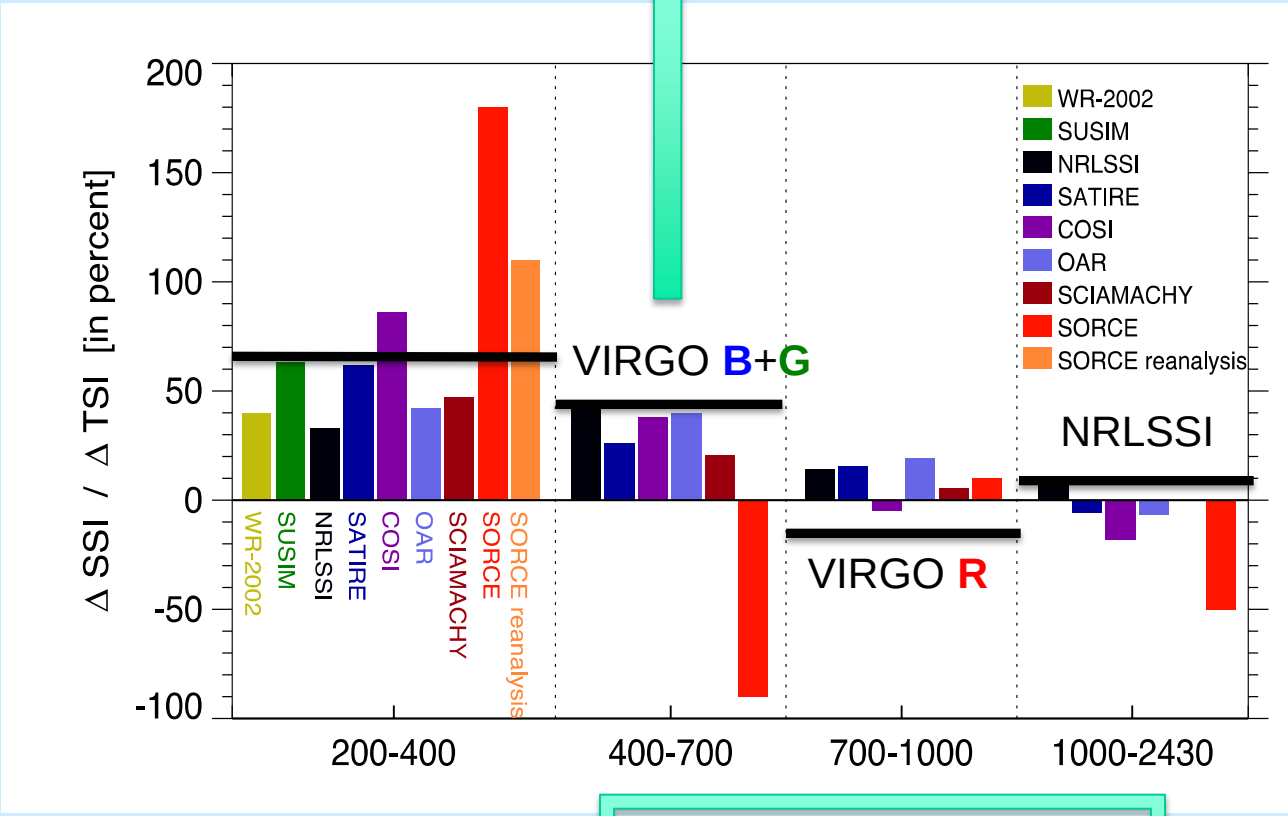
400-450 nm: VIRGO **B**
450-700 nm: VIRGO **G**



67% | 42% | -16% | 7%

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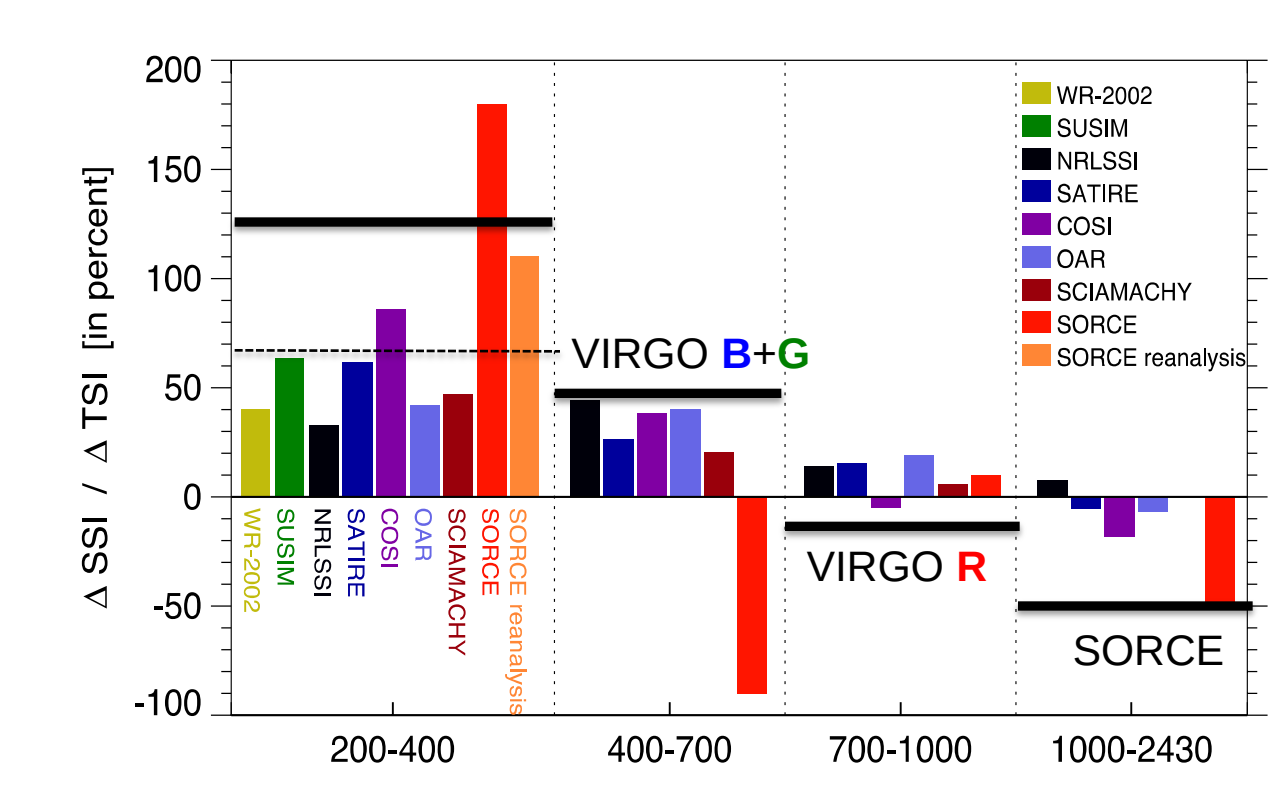

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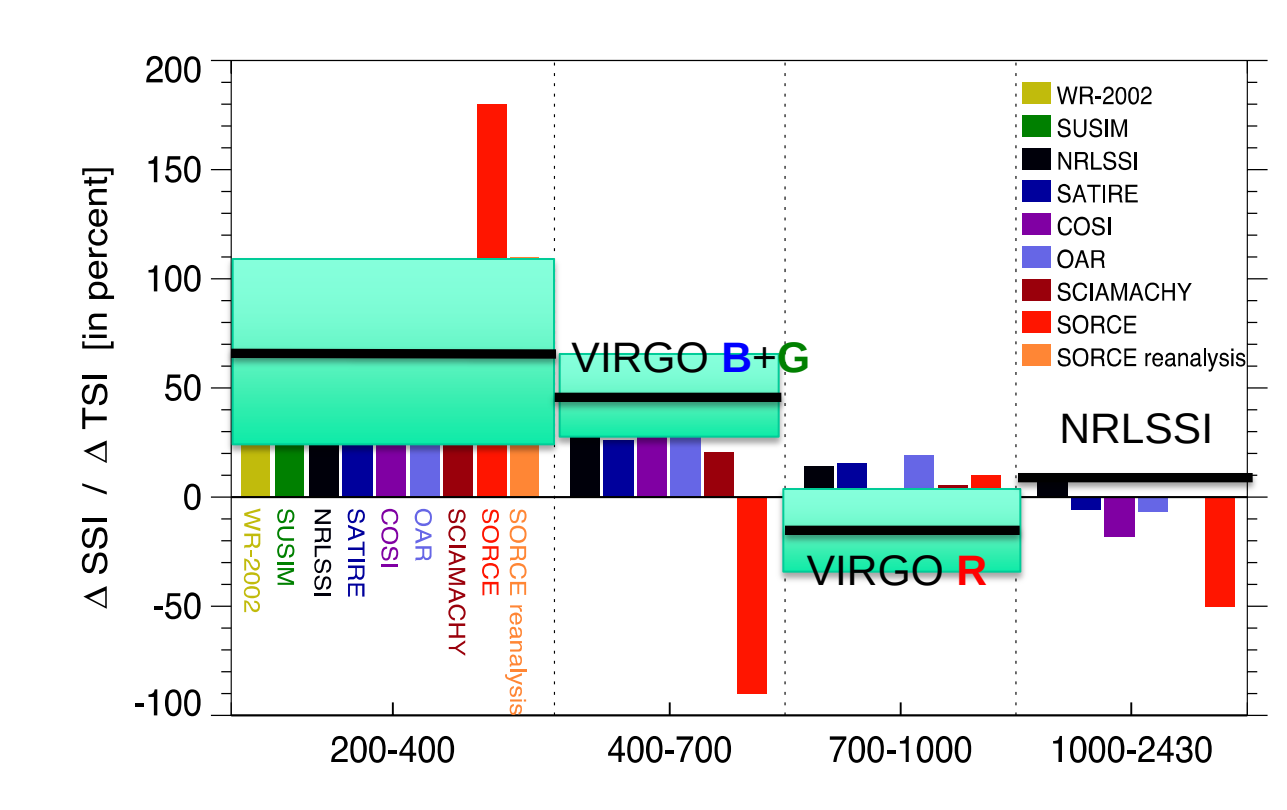

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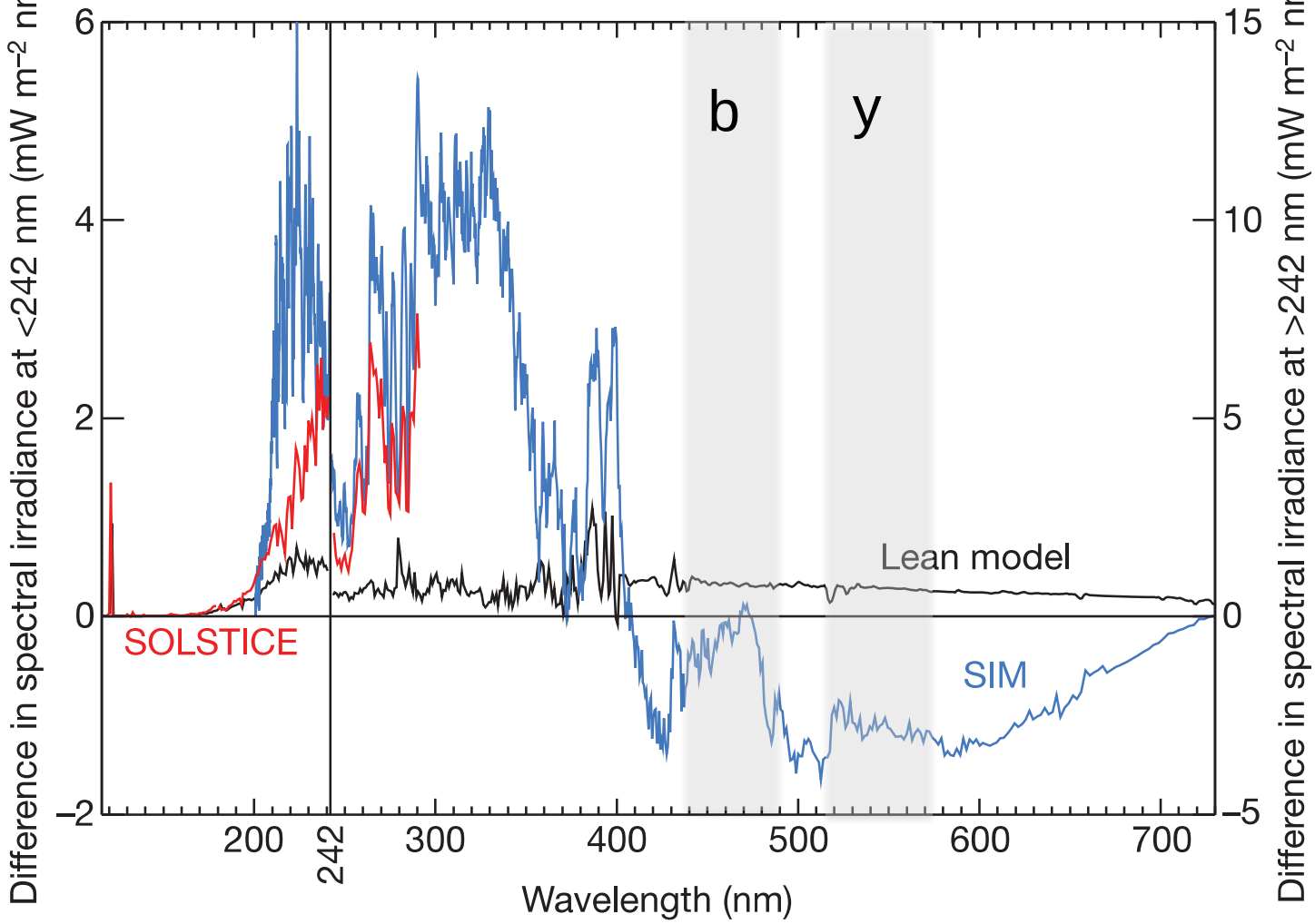
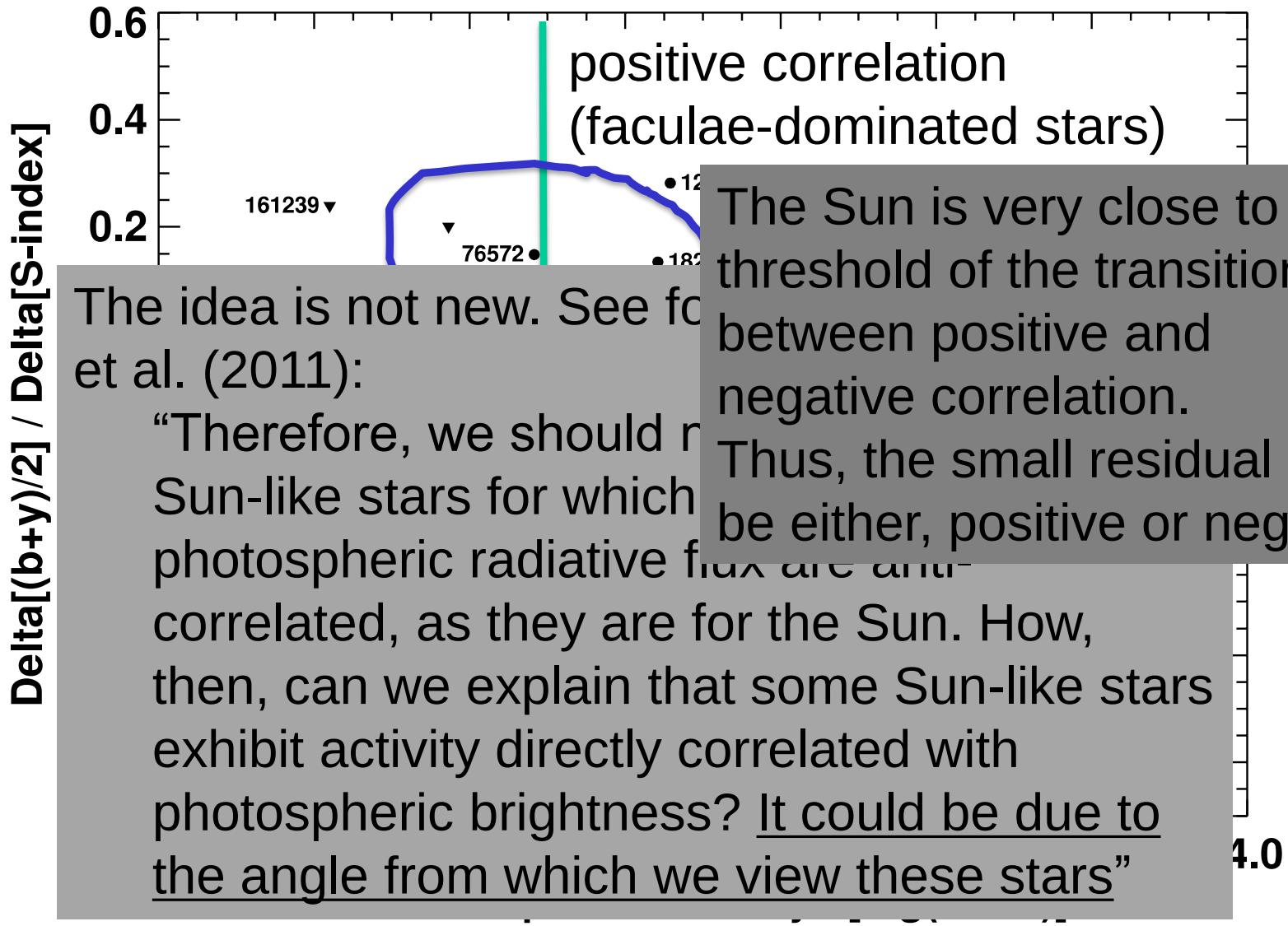
- VIRGO/SOHO and SIM/SORCE measurements are in contradiction to each other in the visible part of the solar spectrum
- But, taken into account the uncertainties of the VIRGO-TSI correlations, this does not imply that the large UV-amplitudes of the SORCE measurements are wrong

Stellar observations

Most of stellar data are in Strömgern (b+y)/2



Stellar brightness variations versus activity



The Sun is very close to the threshold of the transition between positive and negative correlation.
Thus, the small residual could be either, positive or negative.

The idea is not new. See fo
et al. (2011):

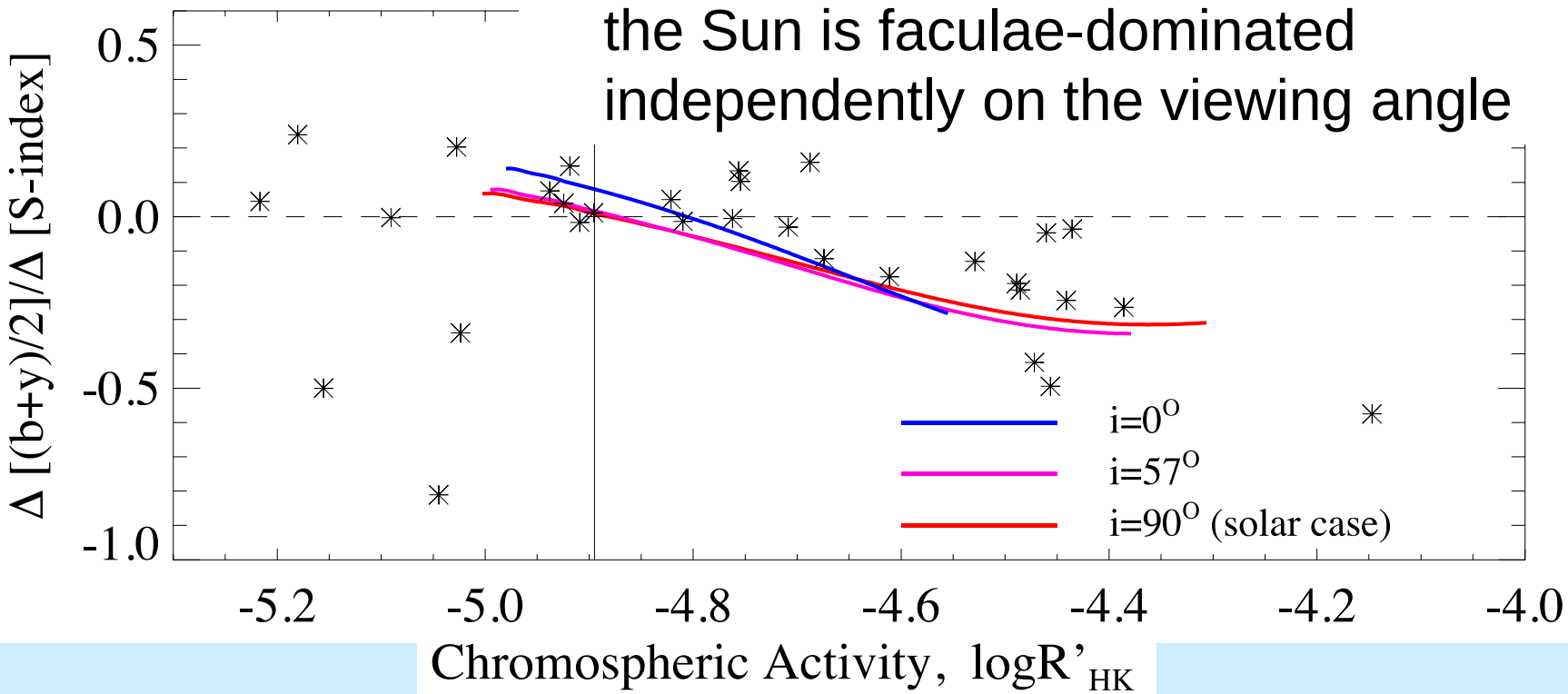
"Therefore, we should r
Sun-like stars for which
photospheric radiative flux are anti-
correlated, as they are for the Sun. How, then, can we explain that some Sun-like stars exhibit activity directly correlated with photospheric brightness? <u>It could be due to the angle from which we view these stars</u>"

Fig. from Lockwood et al. (2007)

Activity models for stars

Result:

the Sun is faculae-dominated independently on the viewing angle



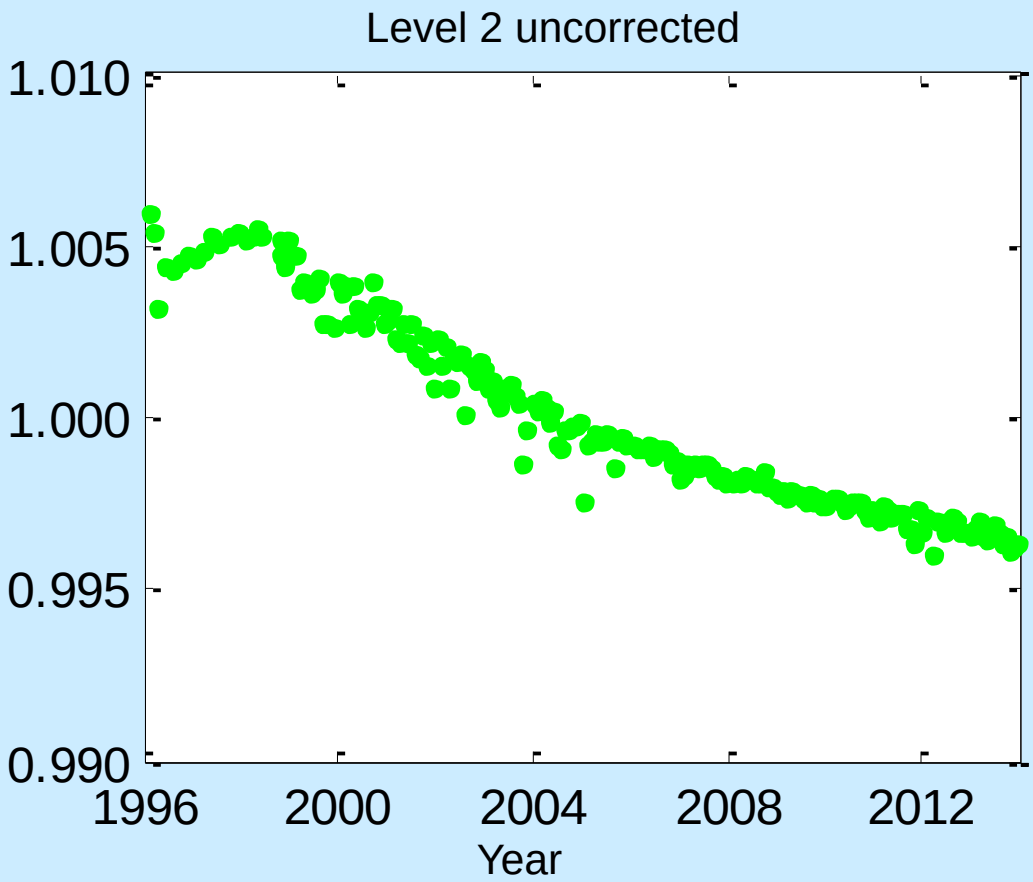
Shapiro et al. (2014) submitted:

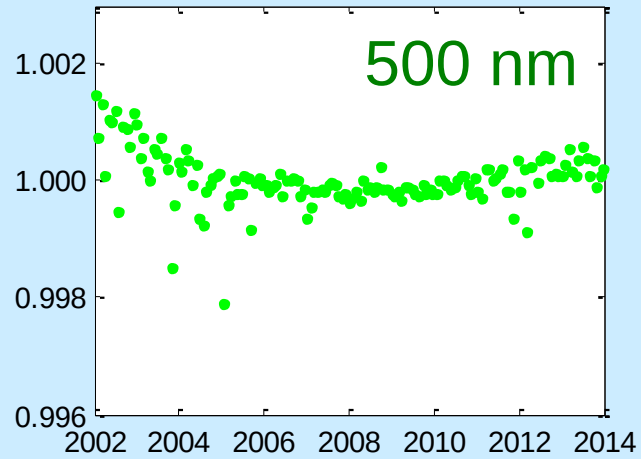
SATIRE model extrapolated to stars with different levels of magnetic activity

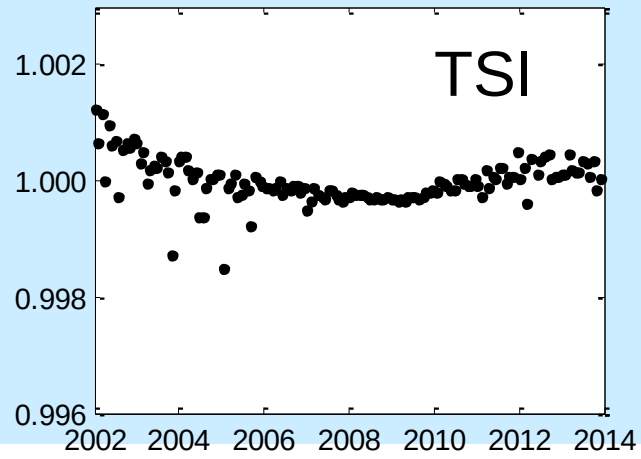
Conclusions

- The “simple” question if the Spectral Solar Irradiance is positively ☺ or negatively ☐ correlated with Total Solar Irradiance is answered by VIRG/SOHO as:
  - 500 nm is clearly positive *!*

Green 500 nm


Level 2 uncorrected
1.010
1.005
1.000
0.995
0.990
1996
2000
2004
2008
2012
Year


500 nm
1.002
1.000
0.998
0.996
2002
2004
2006
2008
2010
2012
2014


TSI
1.002
1.000
0.998
0.996
2002
2004
2006
2008
2010
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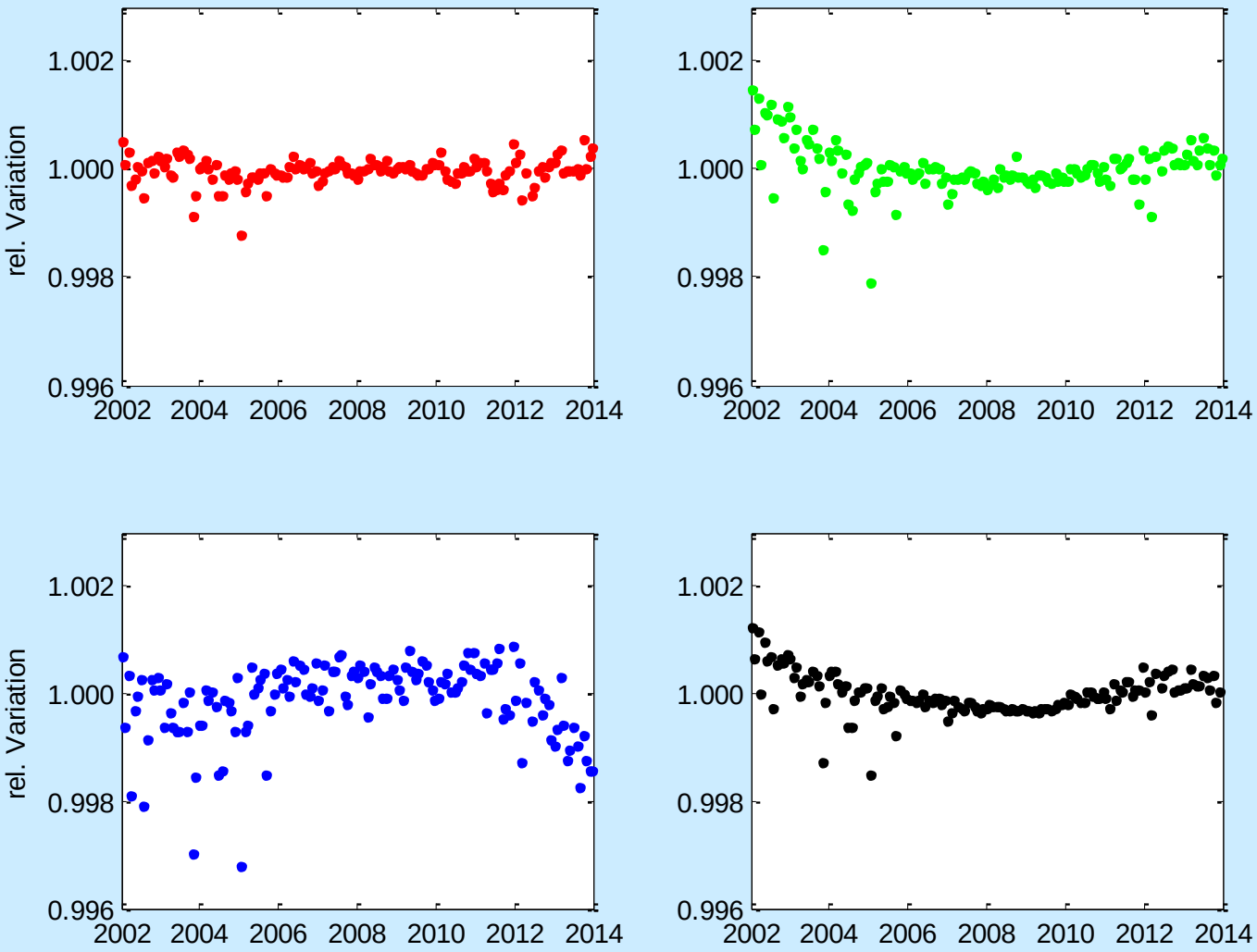
2014

Conclusions

- The “simple” question if the Spectral Solar Irradiance is positively ☺ or negatively ☐ correlated with Total Solar Irradiance is answered by VIRG/SOHO as:
  - 500 nm is clearly positive;
  - 862 nm is straight, i.e. a very small amplitude (SIM/SORCE “ok”);
  - 400 nm is difficult, possibly negative but maybe, also an additional instrumental effect.

Linearly detrended SPM-B measurements



Conclusions

- VIRG/SOHO:
  - 500 nm is clearly positive;
  - 862 nm is straight, i.e. very small amplitude;
  - 400 nm is difficult, possibly negative but maybe also an additional instrumental effect.
- Thus, published SIM/SORCE long-term trends are NOT confirmed by VIRGO/SOHO and most likely <u>incorrect</u> – in the <u>visible</u>
- But:

Large UV amplitudes are not excluded !

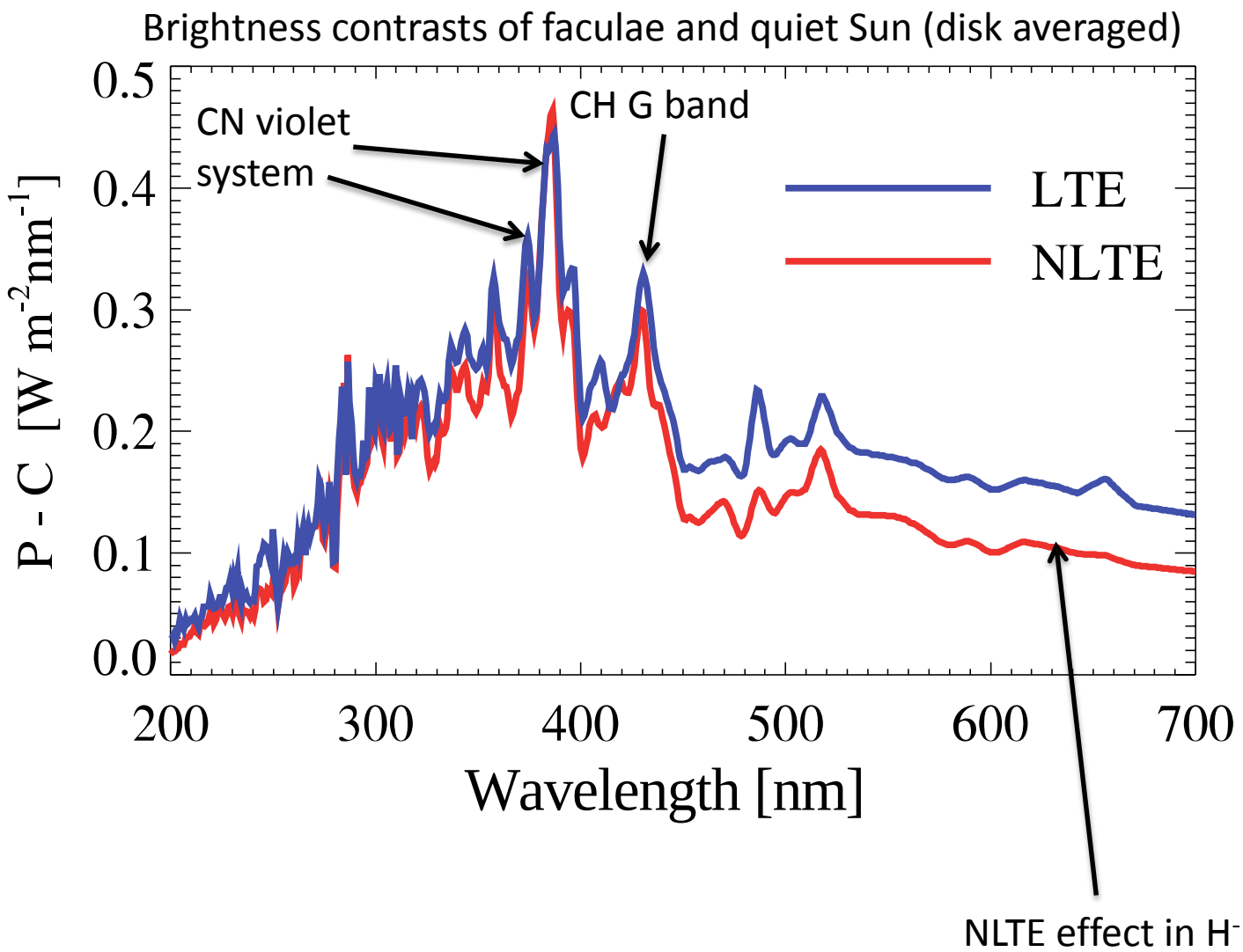
Thank you

for your attention

PICARD

SOHO

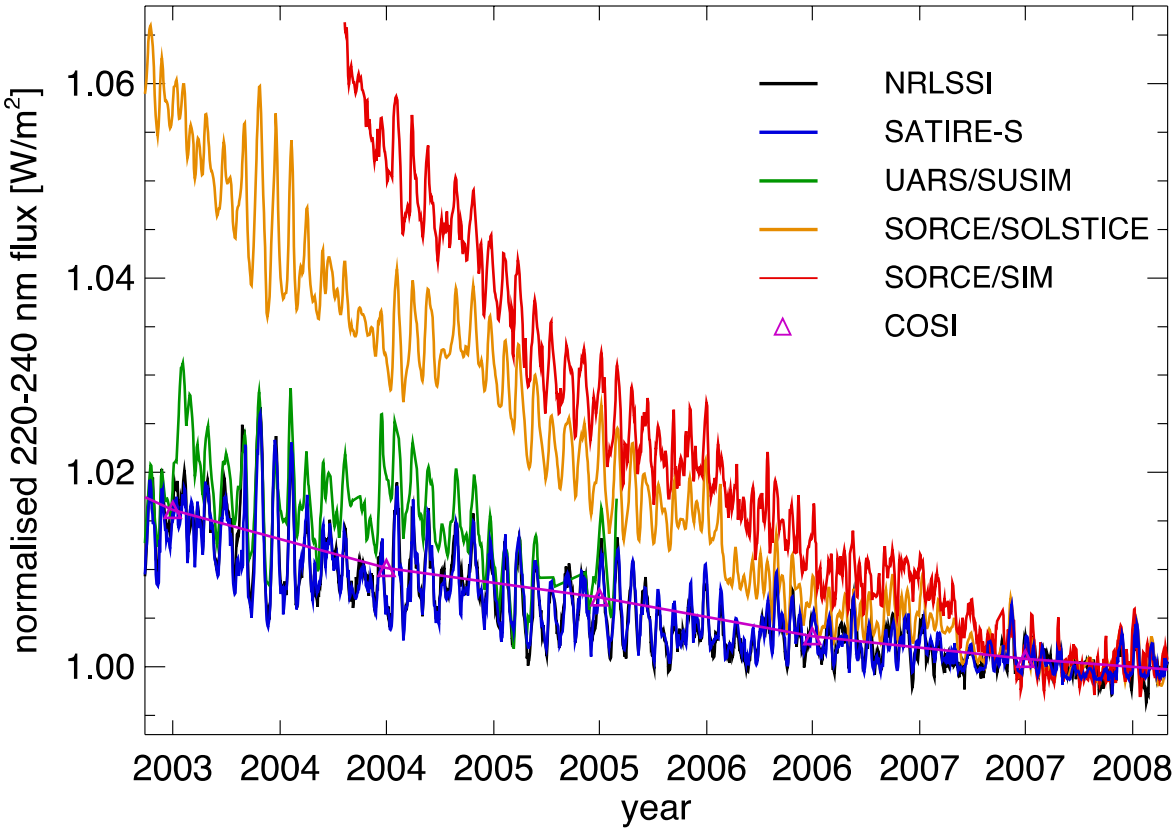
What determines the spectral profile of the solar irradiance variability?



SORCE data vs. Models

Rotational variability

Activity trends

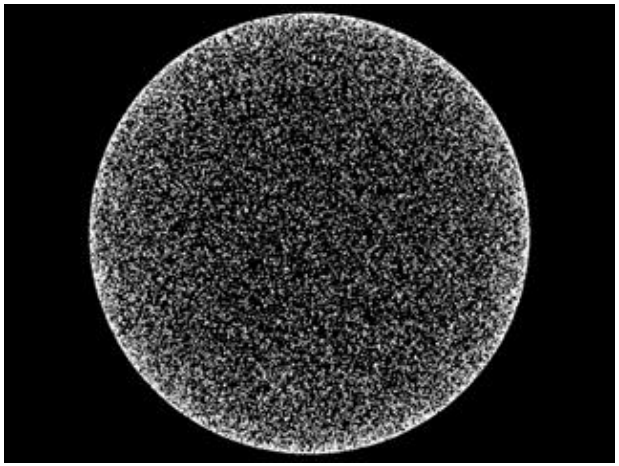


from Ermolli et al. (2013)

also Ball et al. (2011), Lean & Deland (2012), Unruh et al. (2012)

Can the modelers change the 11-year variability without spoiling the rotational one?

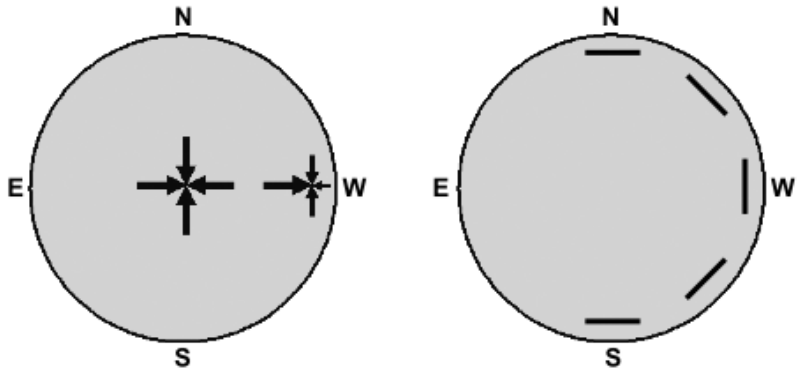
In principle, YES



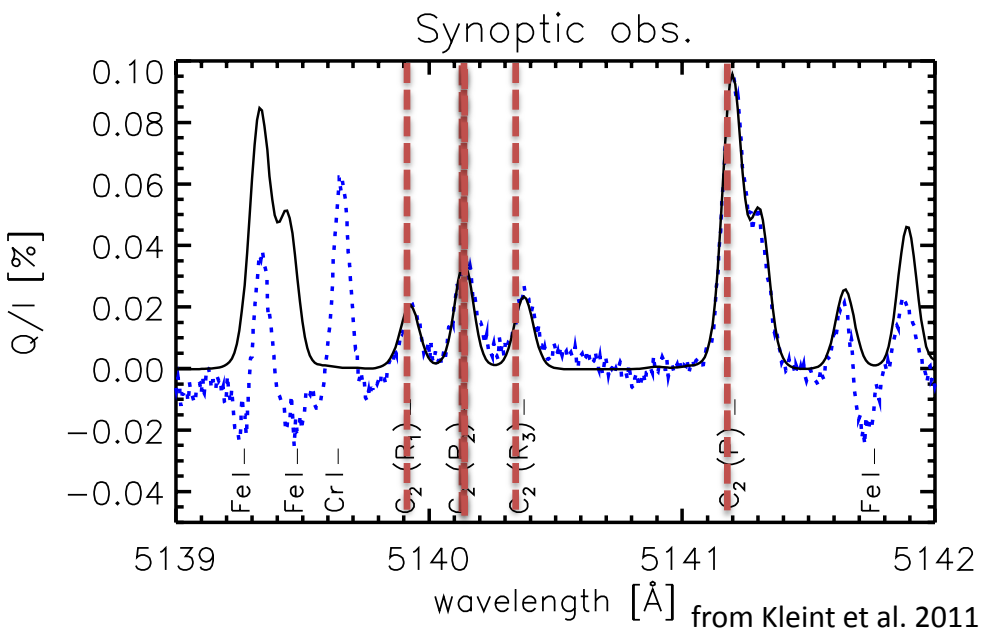
noise to the rotational variability

possible contribution to the activity trends

Does the level of the quiet Sun activity change with time?



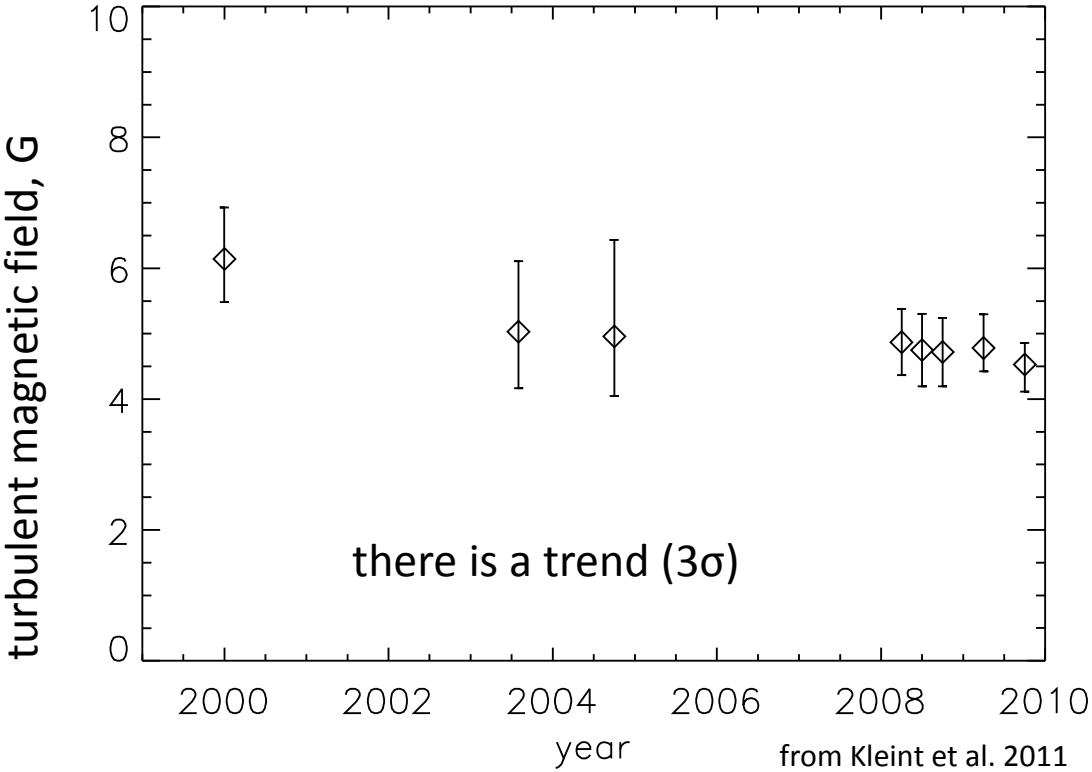
Hanle effect diagnostics allows one to go beyond the spatial resolution of the available magnetogramms



from Kleint et al. 2011

differential effect (very robust)

line ratios depend on the magnetic field



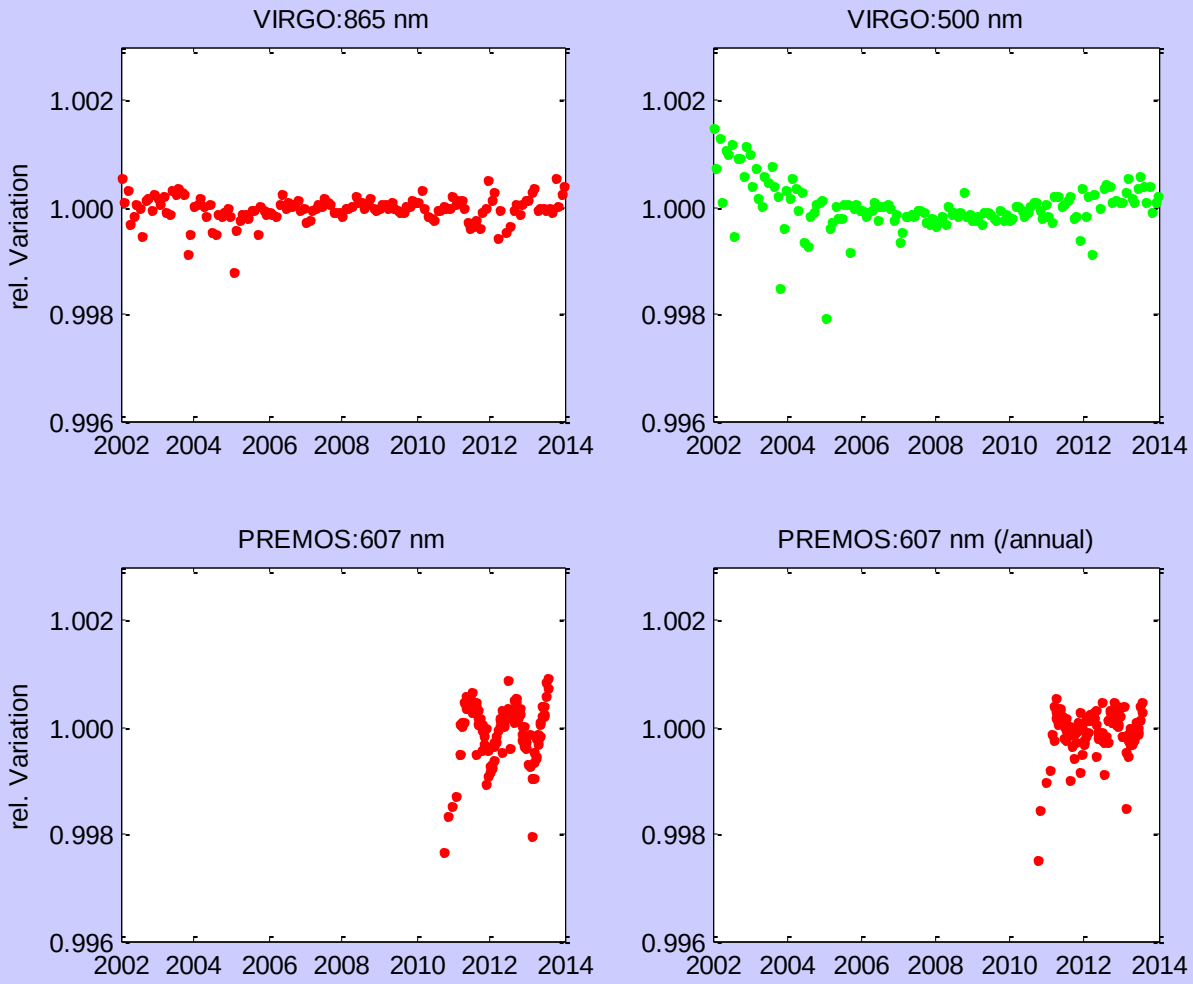
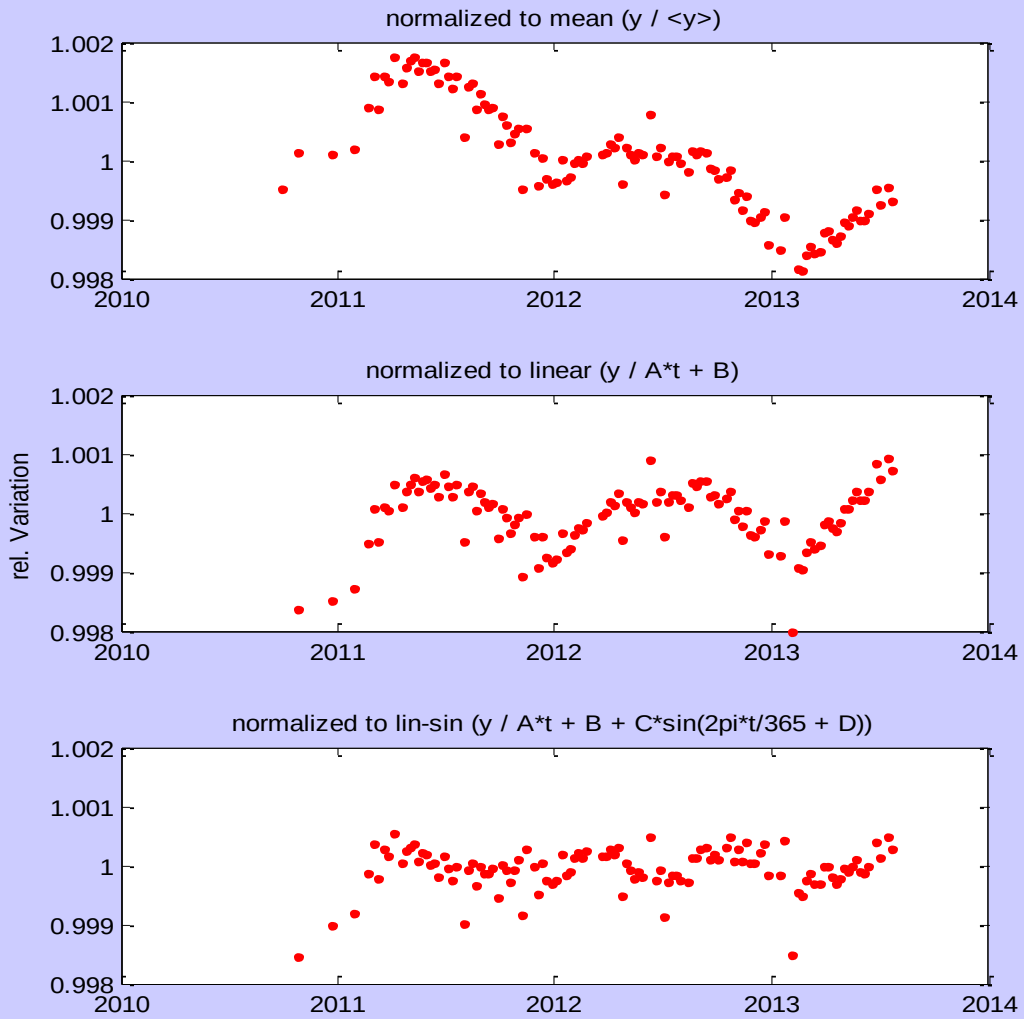
from Kleint et al. 2011

BUT no clear trend in 2011-2013 data (Rameli et al. 2014)

REMARK: The exact value of the magnetic field depends on the number of strong assumptions since a tricky NLTE radiative transfer calculations are involved. Nevertheless, the conclusion about the trend is robust.

presently there is NO evidence for a link between the irradiance and turbulent magnetic field

VIRGO and PREMOS



PREMOS 607 nm