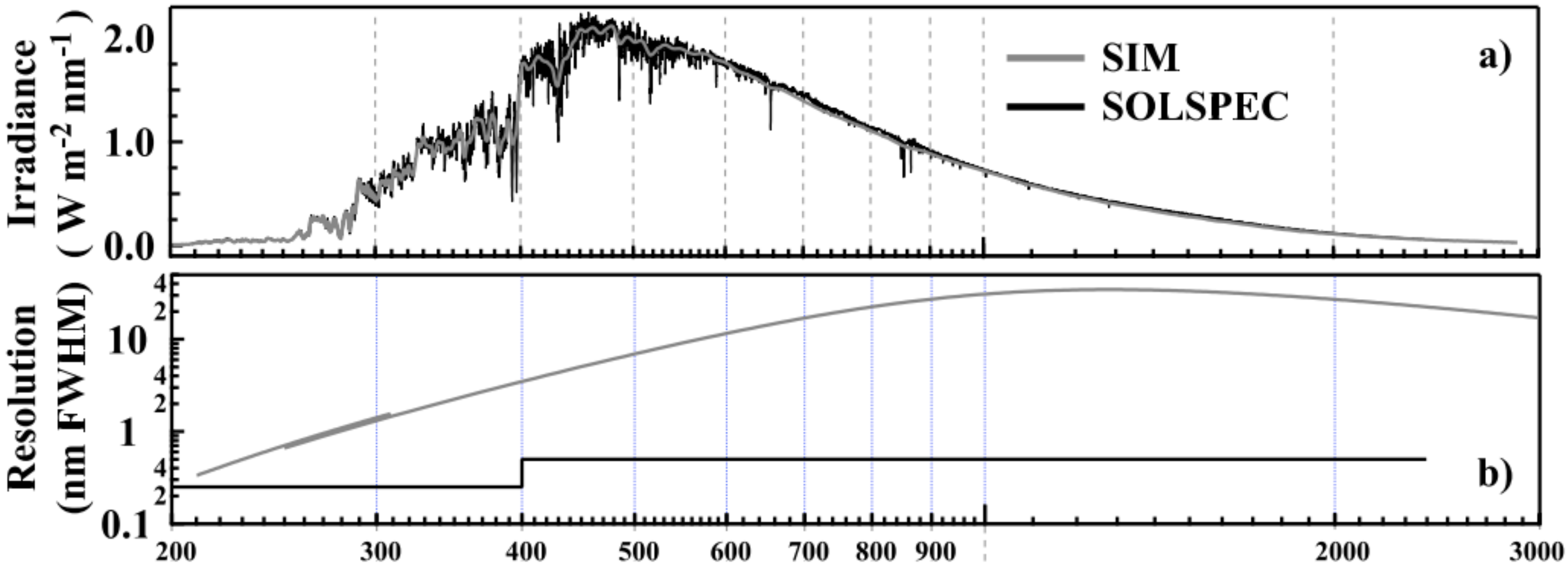
The quest for understanding solar brightness variation. How can SOLSPEC contribute?

LATMOS

Absolute level

Spectral Variability

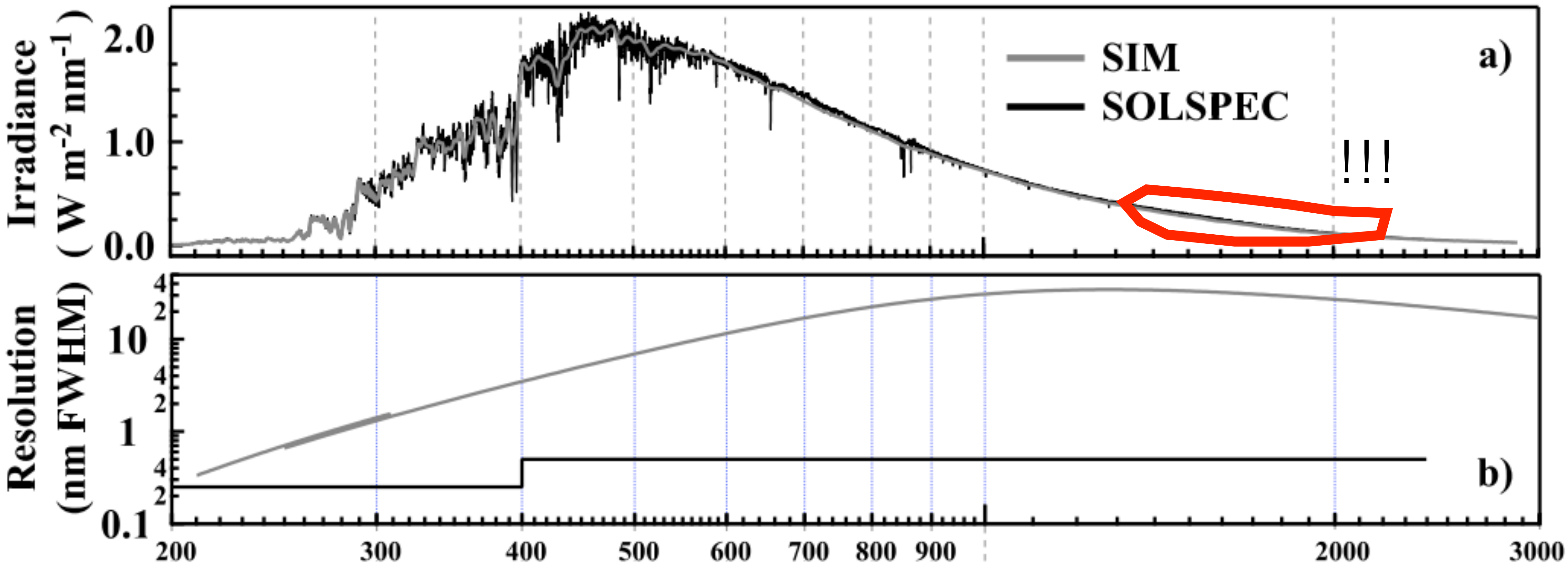
IR mystery



ATLAS3
Gerard Thuillier

WHI
Tom Woods

IR mystery



ATLAS3
Gerard Thuillier

WHI
Tom Woods

Solar Phys
DOI 10.1007/s11207-013-0461-y

The Solar Irradiance Spectrum at Solar Activity Minimum Between Solar Cycles 23 and 24

G. Thuillier · D. Bolsée · G. Schmidtke · T. Foujols · B. Nikutowski · A.I. Shapiro · R. Brunner · M. Weber · C. Erhardt · M. Hersé · D. Gillotay · W. Peetermans · W. Decuyper · N. Pereira · M. Haberreiter · H. Mandel · W. Schmutz

Received: 16 May 2013 / Accepted: 6 December 2013

Abstract On 7 February 2008, the SOLAR payload was placed onboard the *International Space Station*. It is composed of three instruments, two spectrometers and a radiometer. The two spectrometers allow us to cover the 16 – 2900 nm spectral range. In this article, we first briefly present the instrumentation, its calibration and its performance in orbit. Second, the

Solar Phys
DOI 10.1007/s11207-013-0461-y

Accurate Determination of the TOA Solar Spectral NIR Irradiance Using a Primary Standard Source and the Bouguer–Langley Technique

D. Bolsée · N. Pereira · W. Decuyper · D. Gillotay · H. Yu · P. Sperfeld · S. Pape · E. Cuevas · A. Redondas · Y. Hernandéz · M. Weber

Received: 30 April 2013 / Accepted: 2 January 2014

Abstract We describe an instrument dedicated to measuring the top of atmosphere (TOA) solar spectral irradiance (SSI) in the near-infrared (NIR) between 600 nm and 2300 nm at a resolution of 10 nm. Ground-based measurements are performed through atmospheric NIR

Solar Phys (2015) 290:1581–1600
DOI 10.1007/s11207-015-0704-1

The Infrared Solar Spectrum Measured by the SOLSPEC Spectrometer Onboard the International Space Station

G. Thuillier[1] · J.W. Harder[2] · A. Shapiro[3] · T.N. Woods[2] · J.-M. Perrin[4] · M. Snow[2] · T. Sukhodolov[3] · W. Schmutz[3]

Received: 19 June 2014 / Accepted: 18 May 2015 / Published online: 17 June 2015

Abstract A solar spectrum extending from the extreme ultraviolet to the near-infrared is an important input for solar physics, climate research, and atmospheric physics. Ultraviolet measurements have been conducted since the beginning of the space age, but measurements throughout the contiguous visible and infrared (IR) regions are much more sparse. Ageing

Solar Phys (2015) 290:1601–1605
DOI 10.1007/s11207-015-0707-y

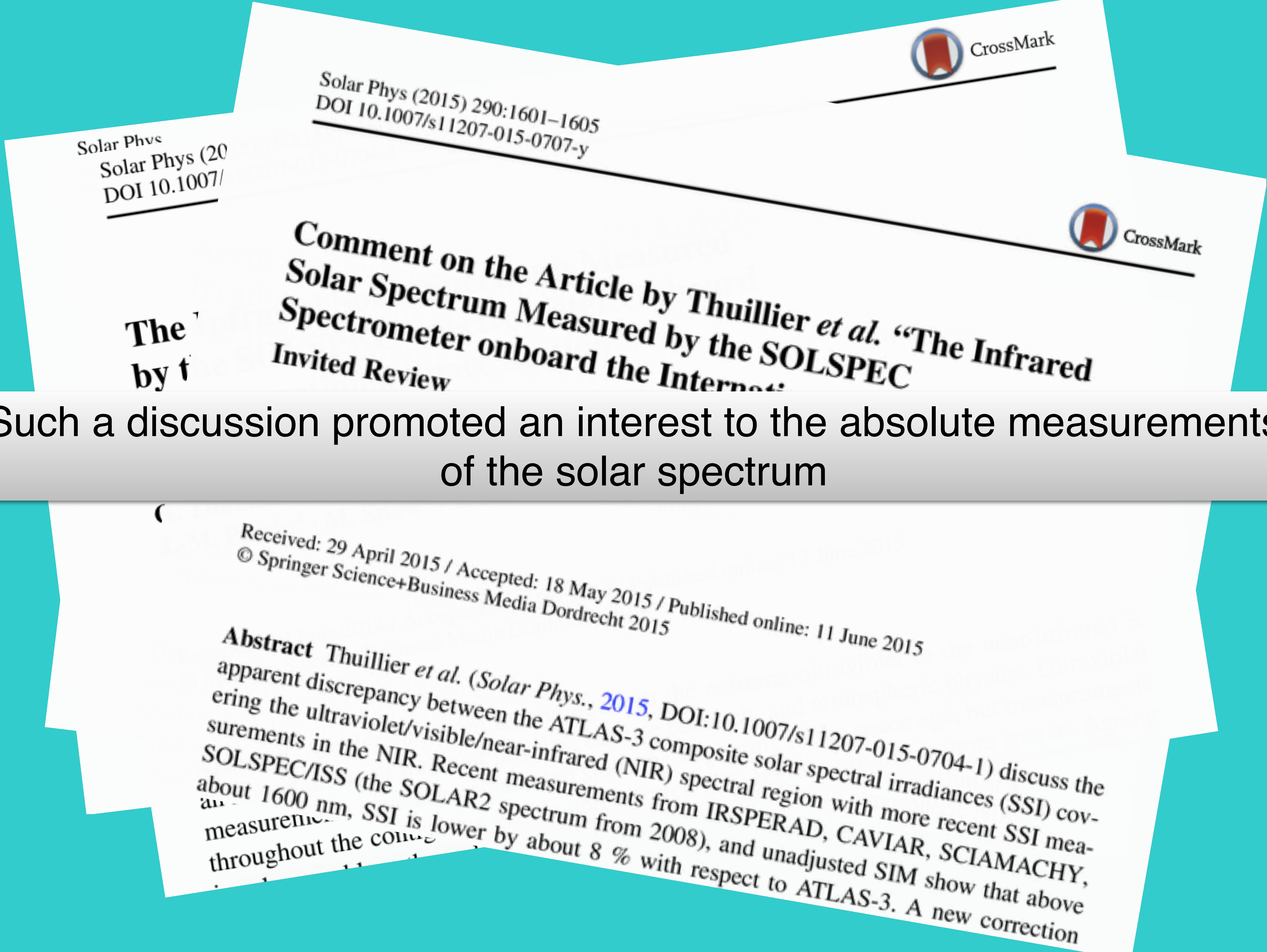
CrossMark

Comment on the Article by Thuillier *et al.* "The Infrared Solar Spectrum Measured by the SOLSPEC Spectrometer onboard the International Space Station"

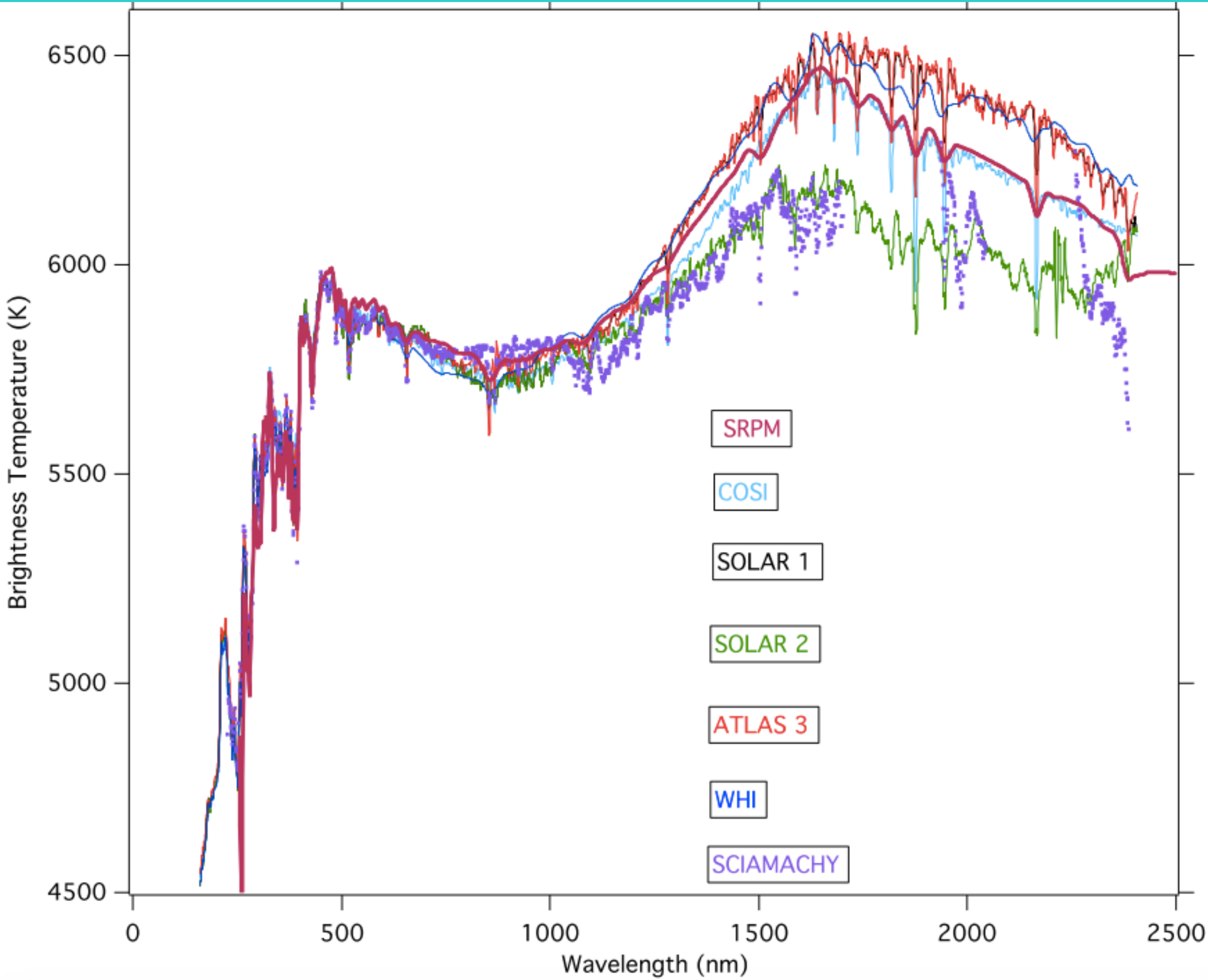
M. Weber[1]

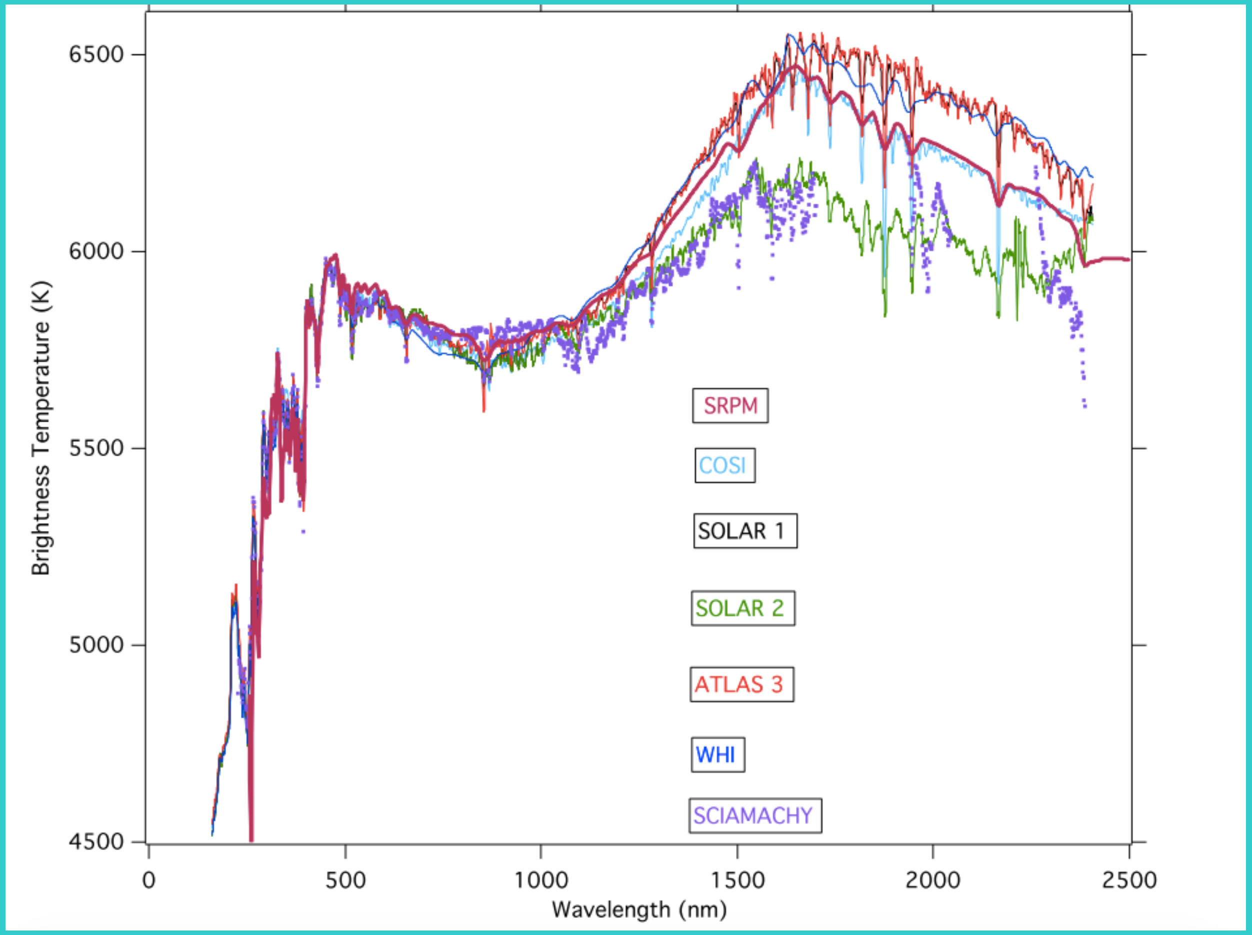
Received: 29 April 2015 / Accepted: 18 May 2015 / Published online: 11 June 2015

Abstract Thuillier *et al.* (*Solar Phys.*, 2015, DOI:10.1007/s11207-015-0704-1) discuss the apparent discrepancy between the ATLAS-3 composite solar spectral irradiances (SSI) covering the ultraviolet/visible/near-infrared (NIR) spectral region with more recent SSI measurements in the NIR. Recent measurements from IRSPERAD, CAVIAR, SCIAMACHY, SOLSPEC/ISS (the SOLAR2 spectrum from 2008), and unadjusted SIM show that above about 1600 nm, SSI is lower by about 8 % with respect to ATLAS-3. A new correction

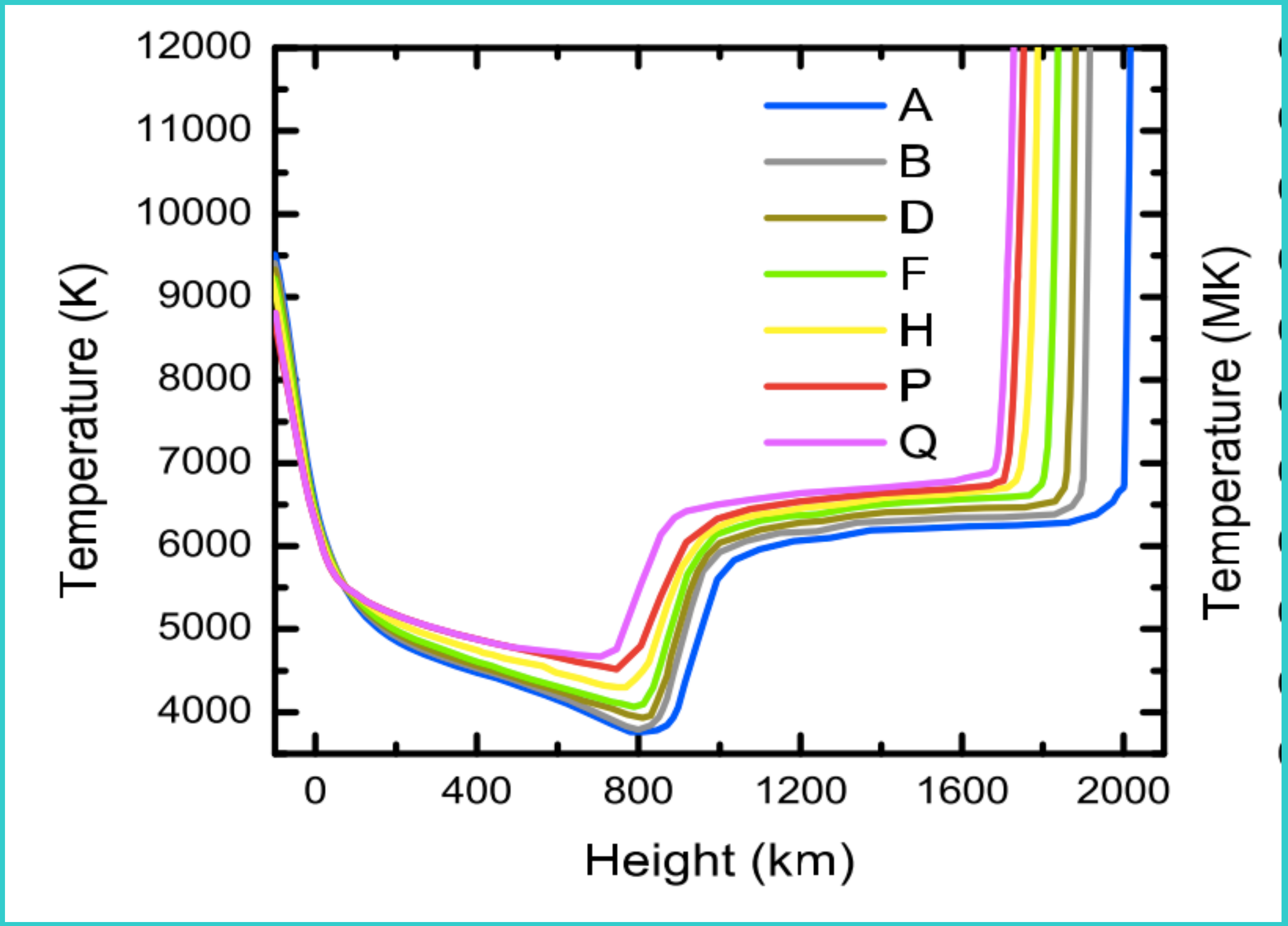


Such a discussion promoted an interest to the absolute measurements of the solar spectrum


Brightness Temperature (K)
6500
6000
5500
5000
4500
0
500
1000
1500
2000
2500
Wavelength (nm)
SRPM
COSI
SOLAR 1
SOLAR 2
ATLAS 3
WHI
SCIAMACHY

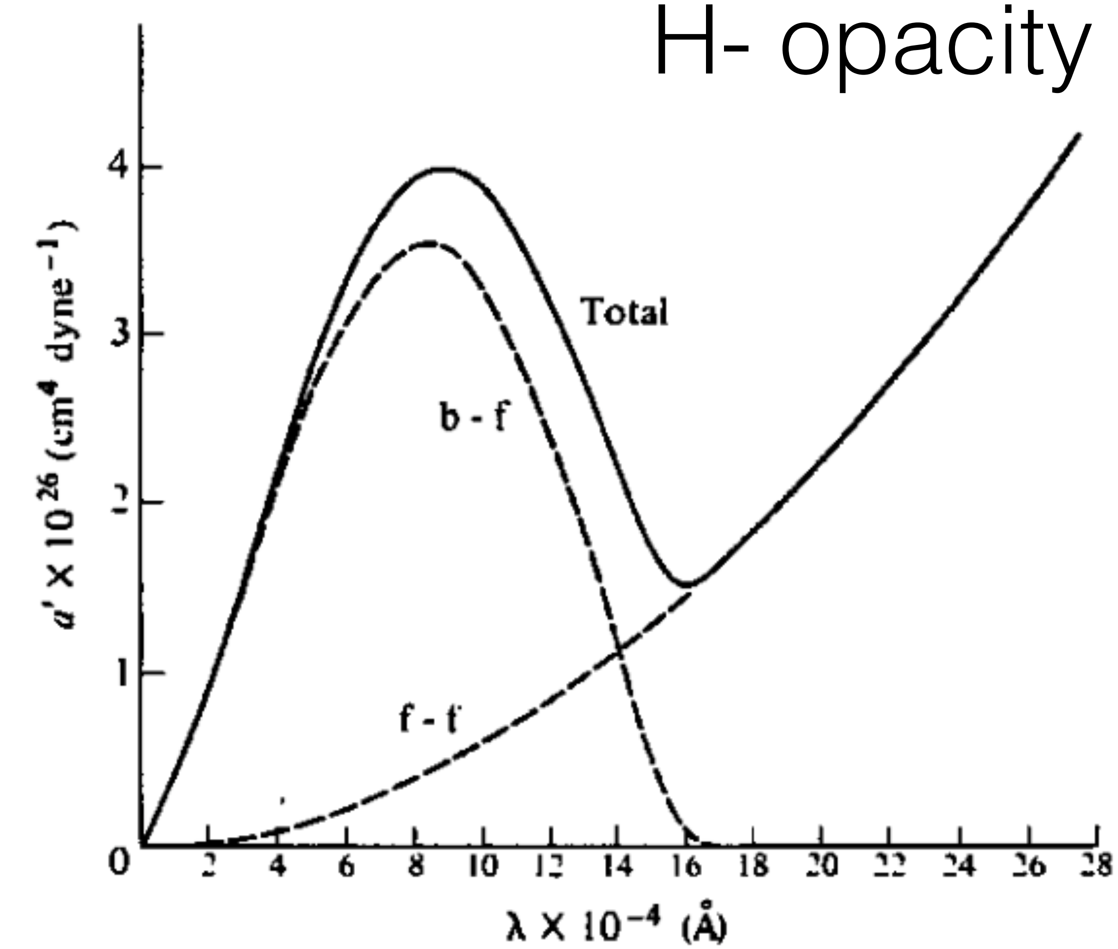


Brightness Temperature (K)
Wavelength (nm)
SRPM
COSI
SOLAR 1
SOLAR 2
ATLAS 3
WHI
SCIAMACHY



Temperature (K)
Temperature (MK)
Height (km)
A
B
D
F
H
P
Q

H- opacity



Total
b - f
f - f
$a' \times 10^{26}$ (cm^4 dyne^{-1})
$\lambda \times 10^{-4}$ (Å)

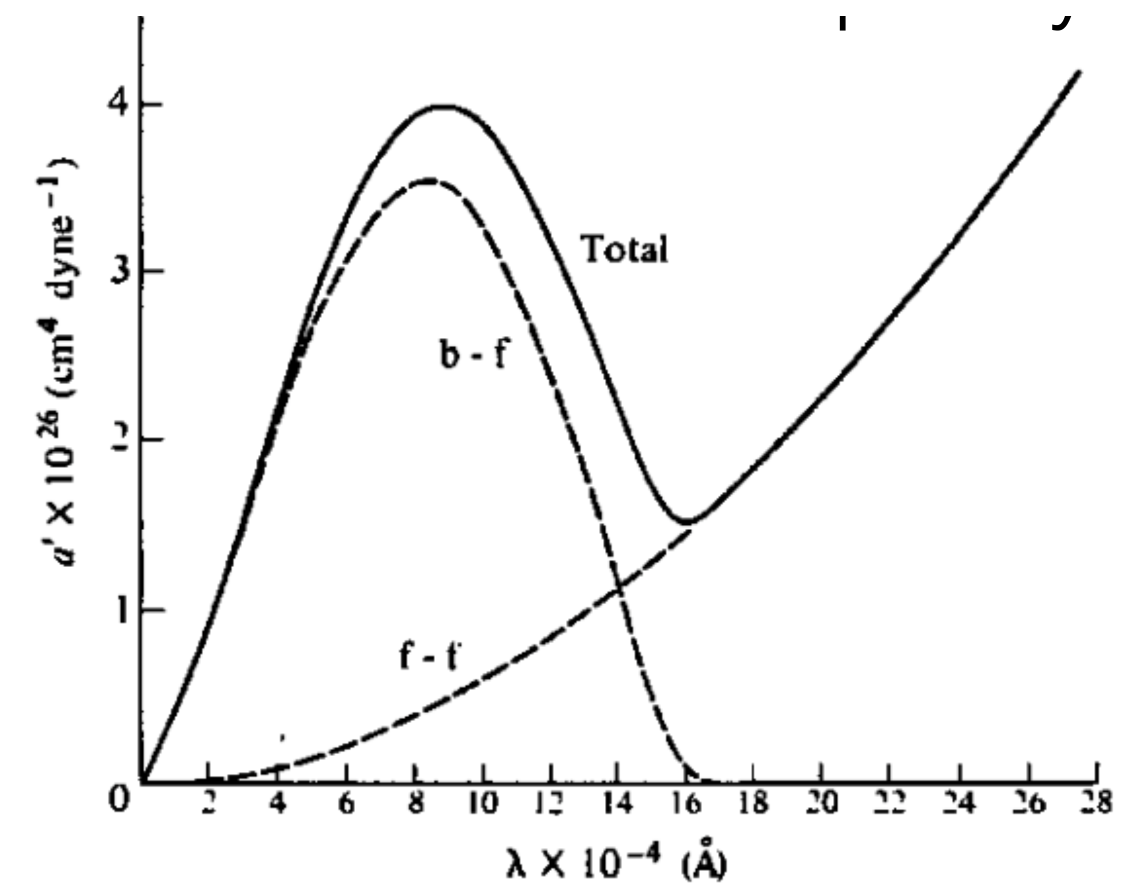
HOW DEEP CAN ONE SEE INTO THE SUN?

THOMAS R. AYRES

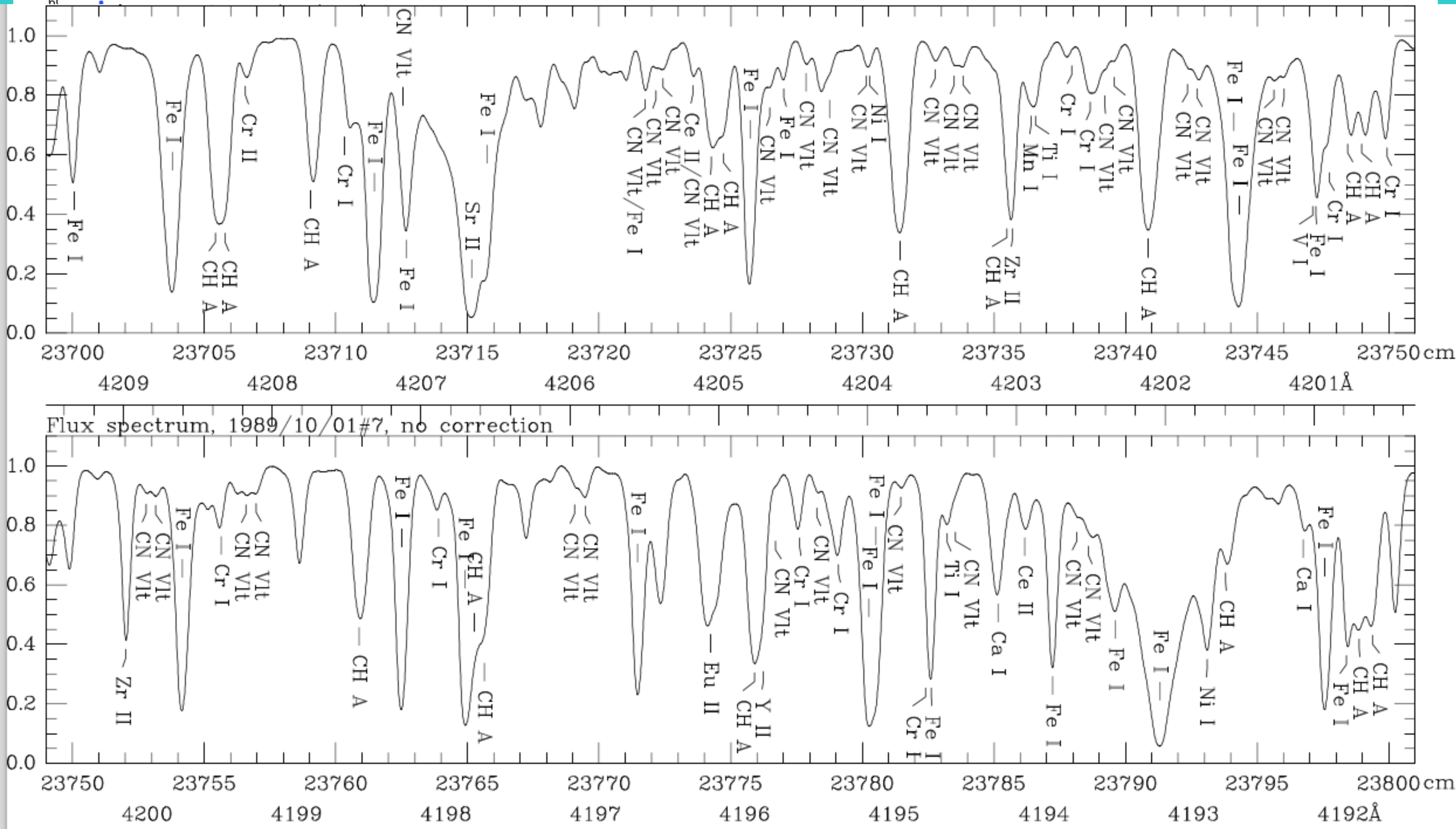
Center for Astrophysics and Space Astronomy, University of Colorado, Boulder, CO 80309–0391, U.S.A.

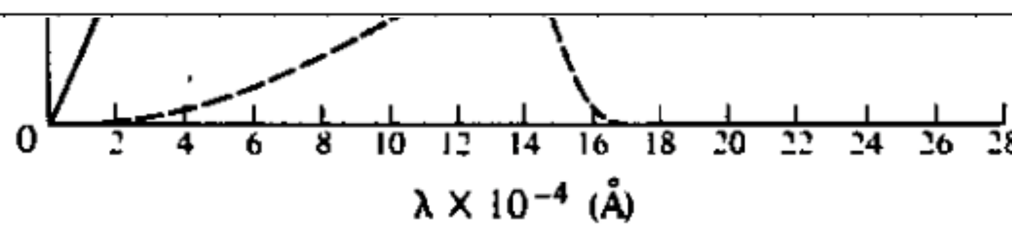
(Received 10 February, 1989; in revised form 30 May, 1989)

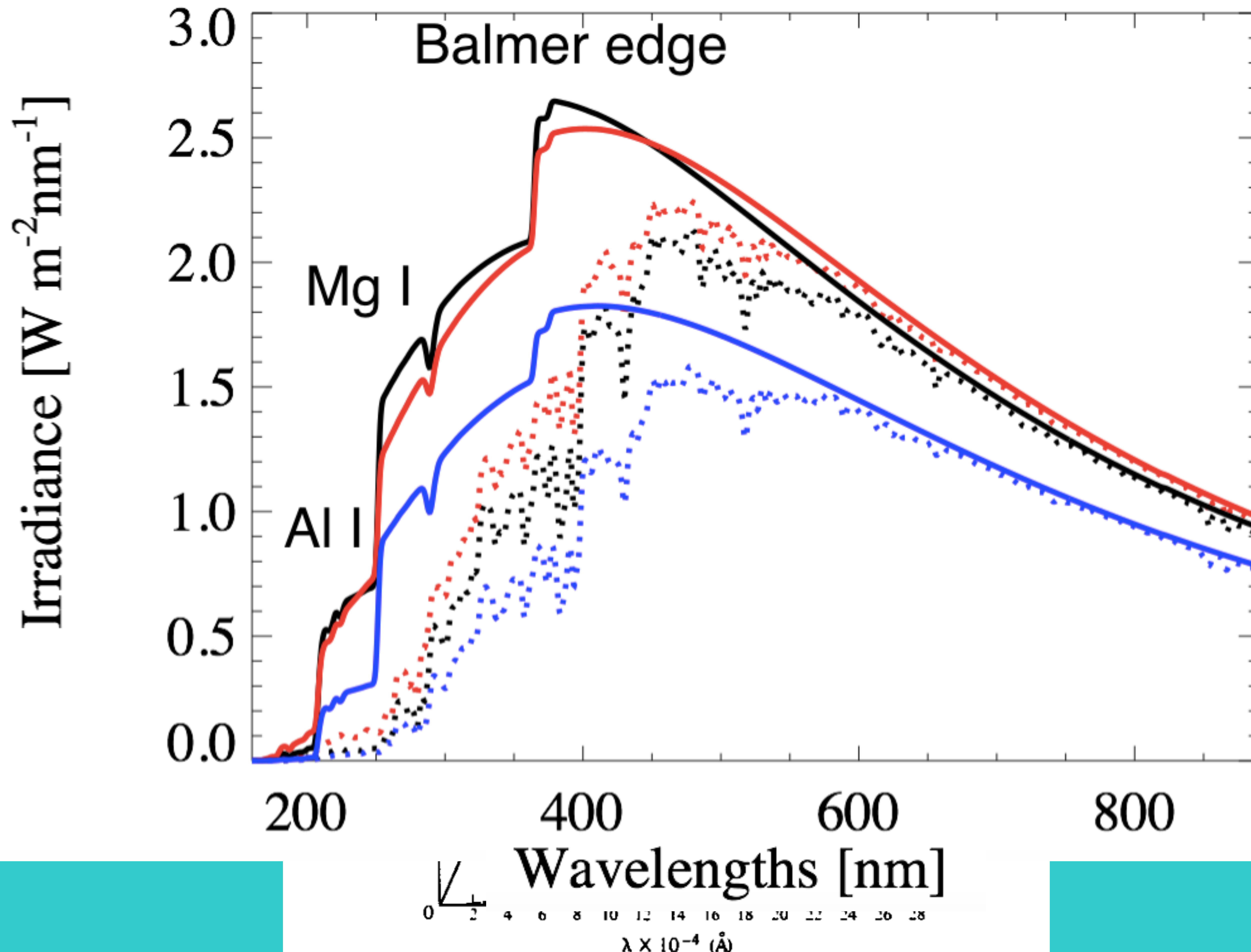
Abstract. Conventional wisdom dictates that the 1.642 μm H^- 'opacity minimum' is the best window to the depths of the solar photosphere. However, the violet continuum near 0.4 μm exhibits a larger intensity response to small thermal perturbations at depth, and thus might offer an even better view of the subsurface roots of granulation cells and magnetic flux tubes.

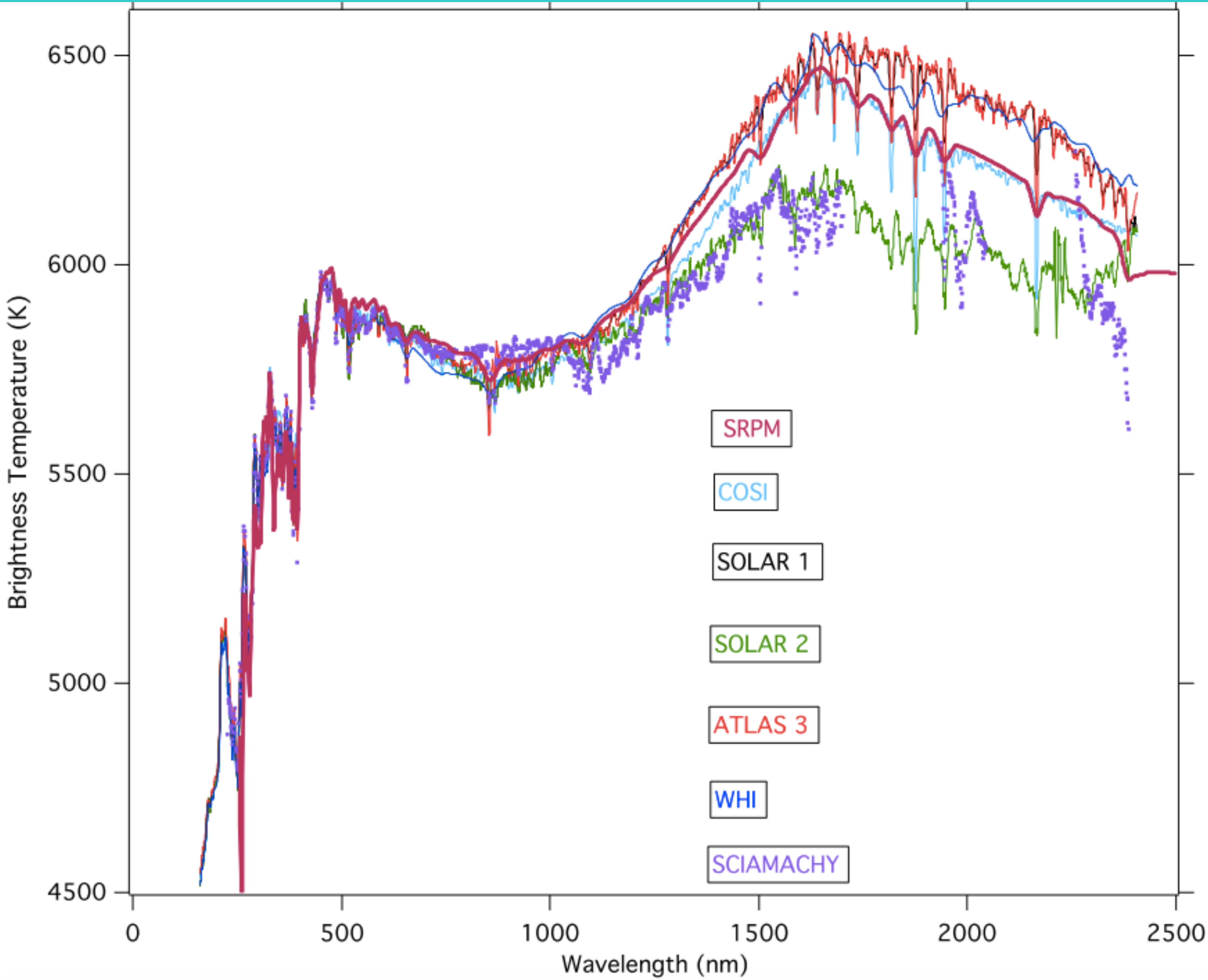


HOW DEEP CAN ONE SEE INTO THE SUN?

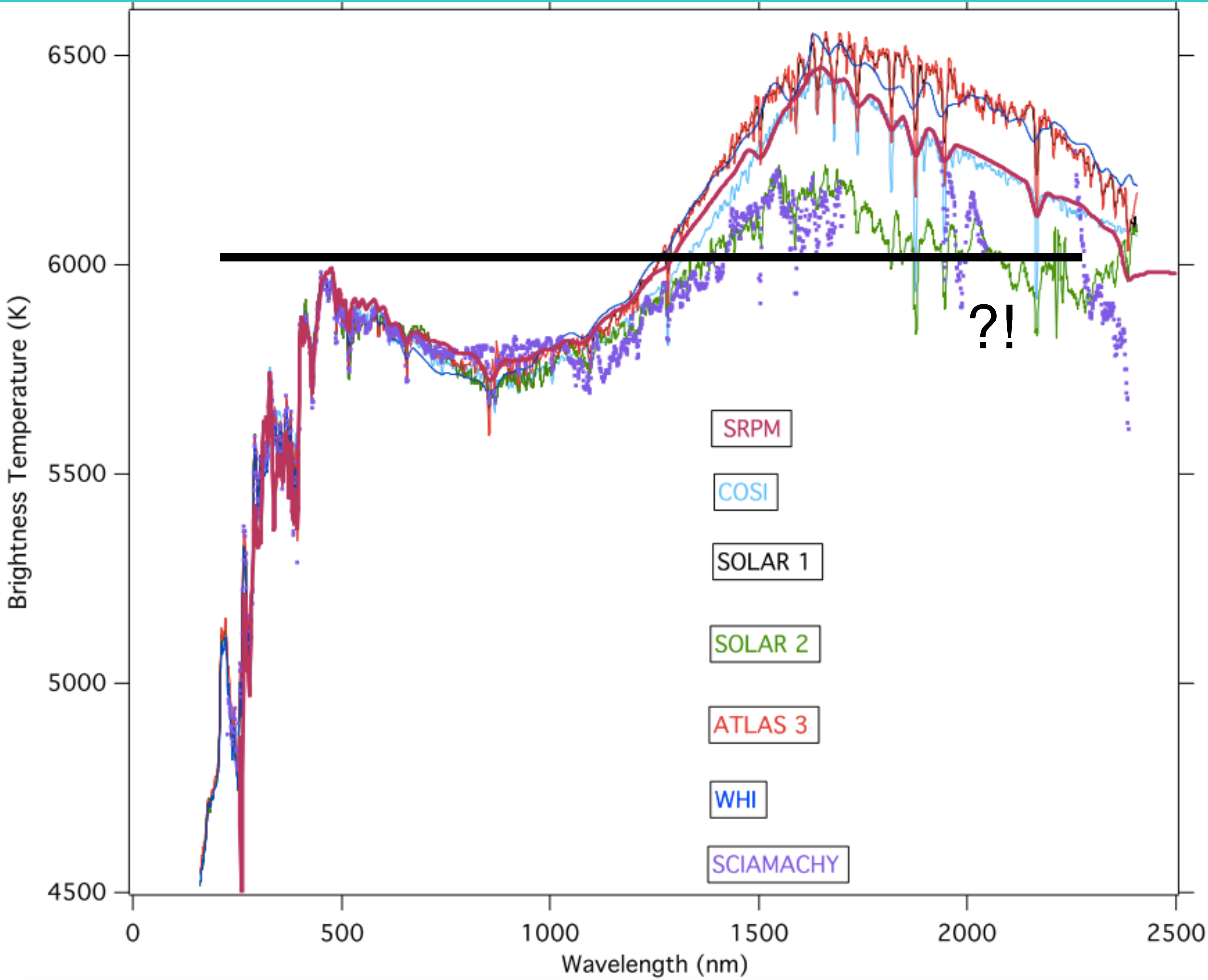





Balmer edge
Mg I
Al I
Irradiance [W m^-2 nm^-1]
Wavelengths [nm]
0.0
0.5
1.0
1.5
2.0
2.5
3.0
200
400
600
800
λ X 10^-4 (Å)



6500
6000
5500
5000
4500
Brightness Temperature (K)
0
500
1000
1500
2000
2500
Wavelength (nm)
SRPM
COSI
SOLAR 1
SOLAR 2
ATLAS 3
WHI
SCIAMACHY

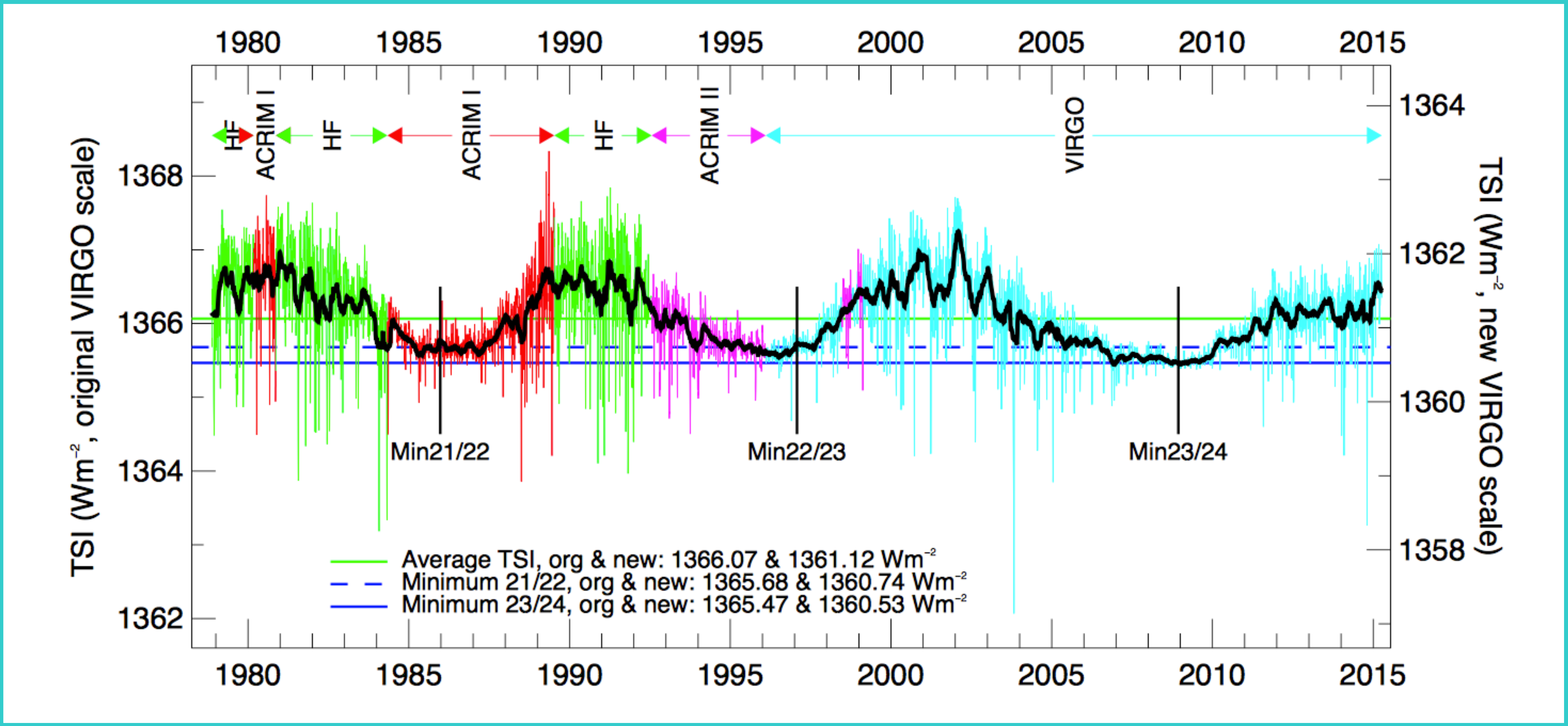


Brightness Temperature (K)
6500
6000
5500
5000
4500
0
500
1000
1500
2000
2500
Wavelength (nm)
?!
SRPM
COSI
SOLAR 1
SOLAR 2
ATLAS 3
WHI
SCIAMACHY

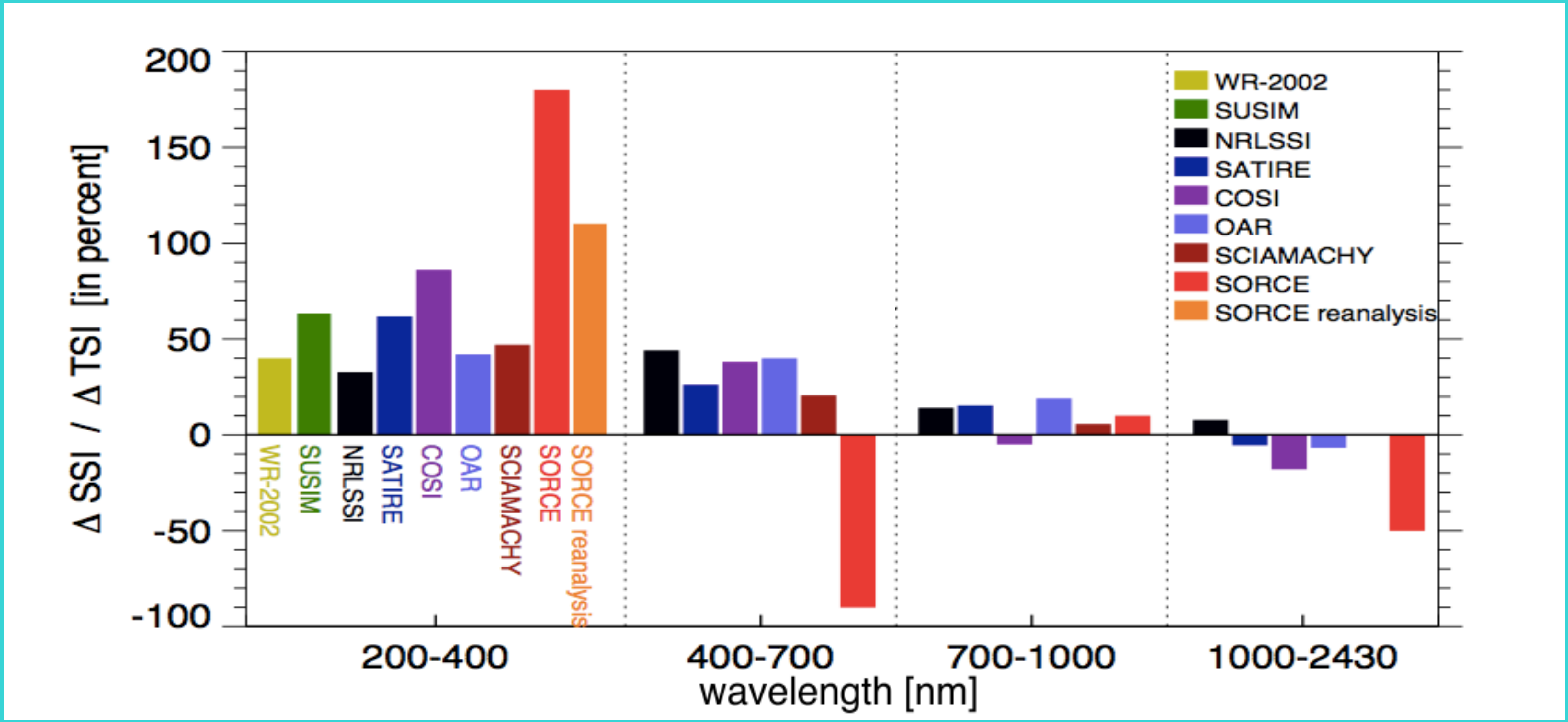
Spectral Variability

Total Solar Irradiance

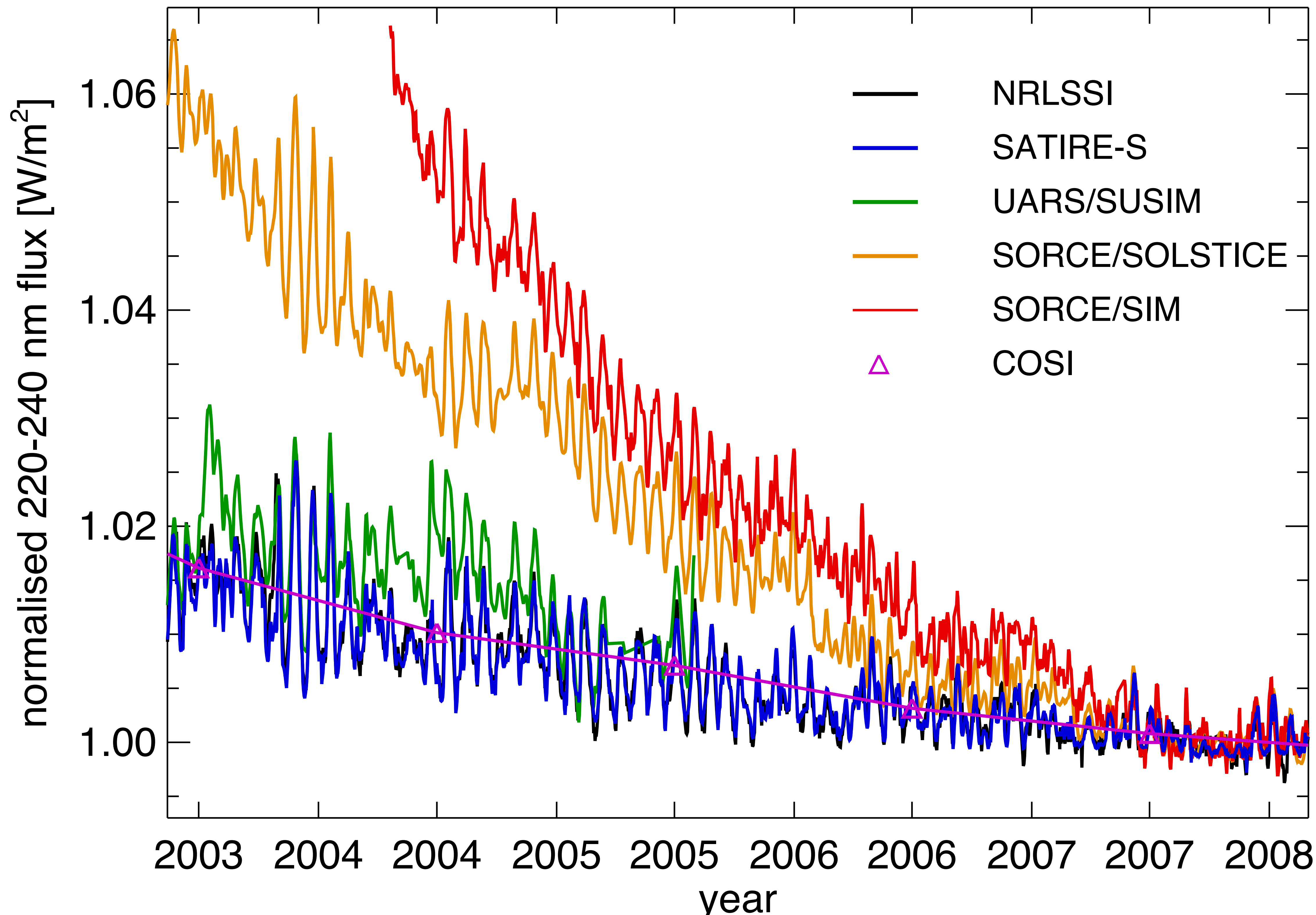
spectrally integrated solar radiative flux at one AU from the Sun



Relative contribution of the UV, visible, near-IR, and IR ranges to the TSI change over the solar cycle

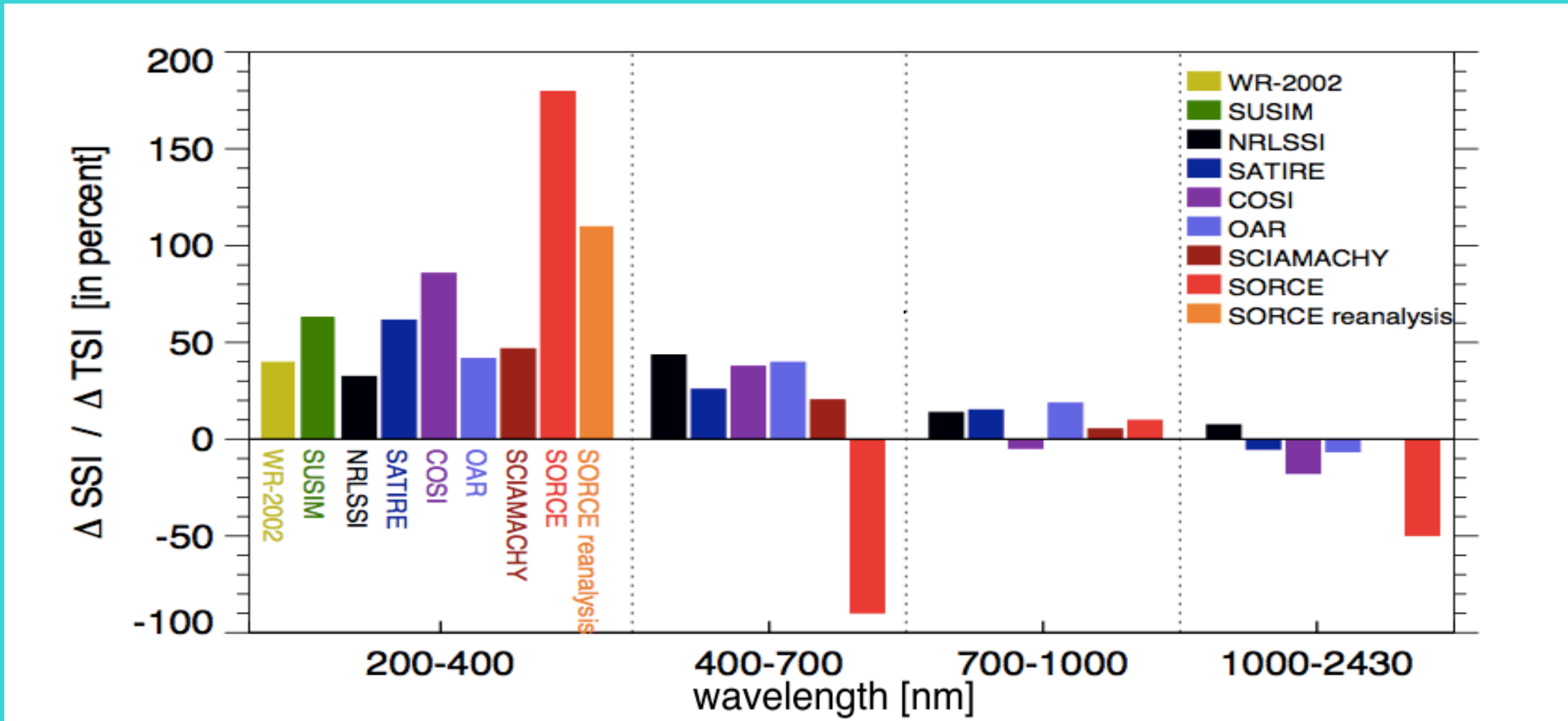


from Ermolli et al. (2013)



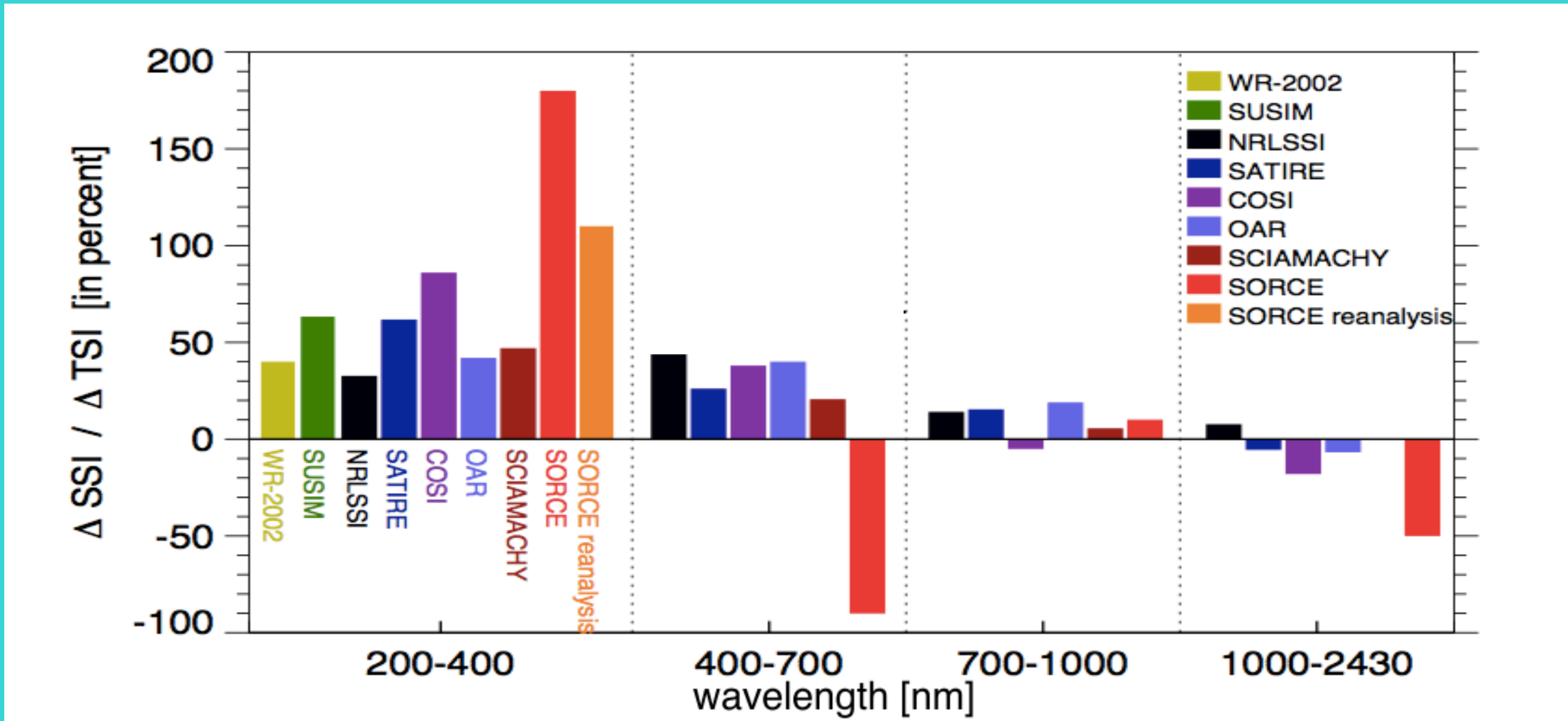
from Ermolli et al. (2013)

Relative contribution of the UV, visible, near-IR, and IR ranges to the TSI change over the solar cycle



from Ermolli et al. (2013)

Relative contribution of the UV, visible, near-IR, and IR ranges to the TSI change over the solar cycle

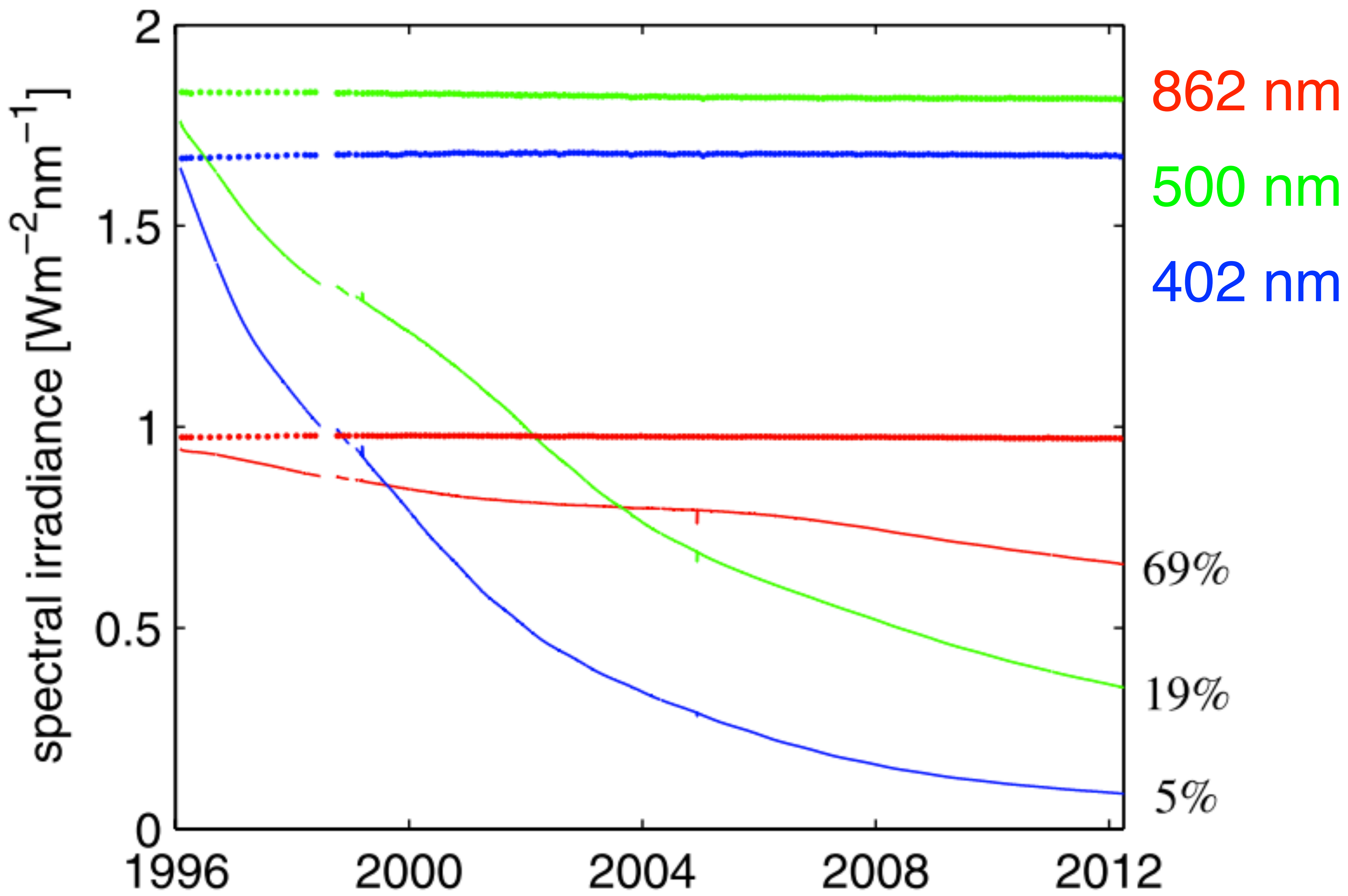


from Ermolli et al. (2013)

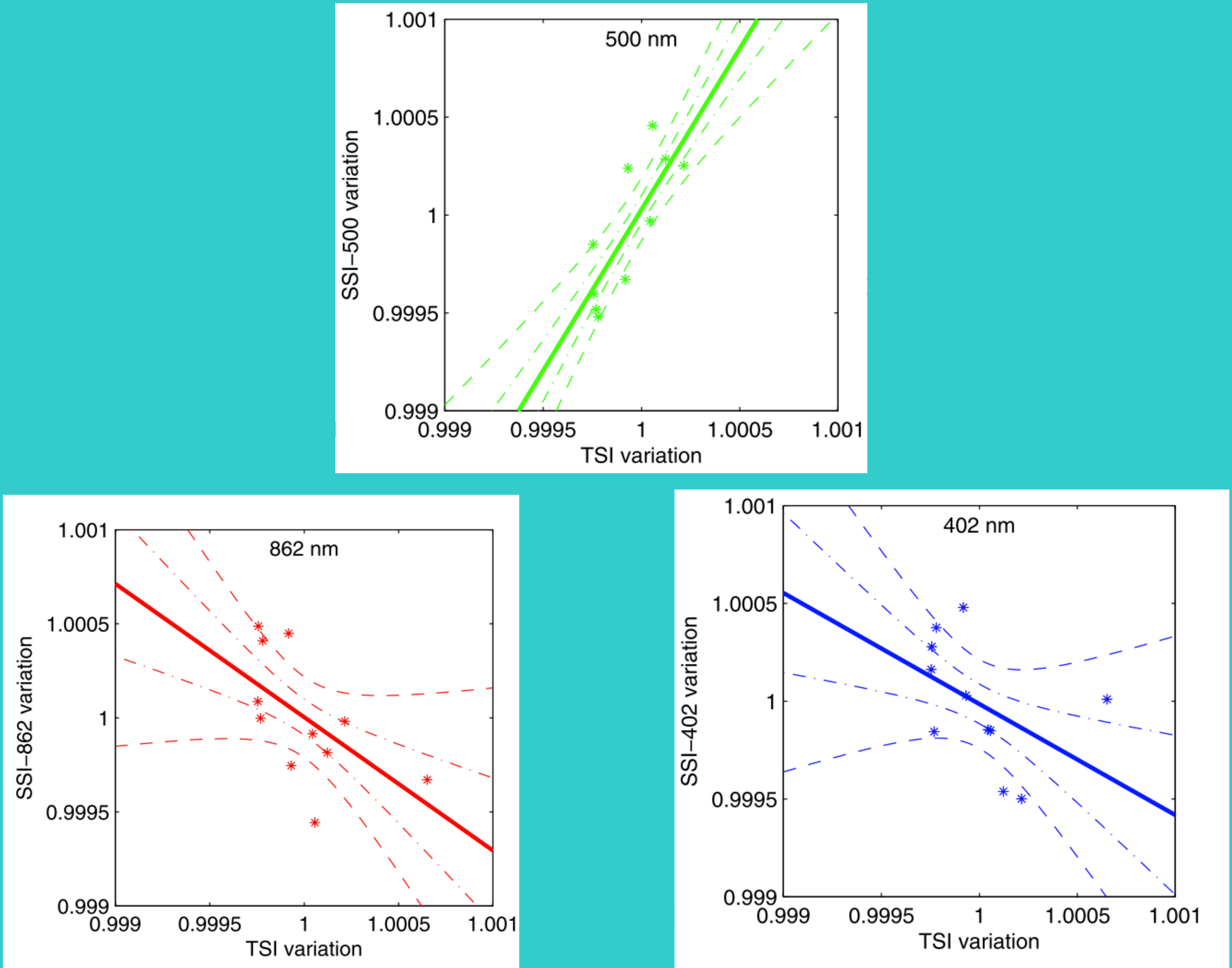
Sun Photometer SOHO/VIRGO
402 nm, 500 nm, 862 nm; 1996 -…

SOLSPEC/ISS
170-2900 nm; 2008 - …

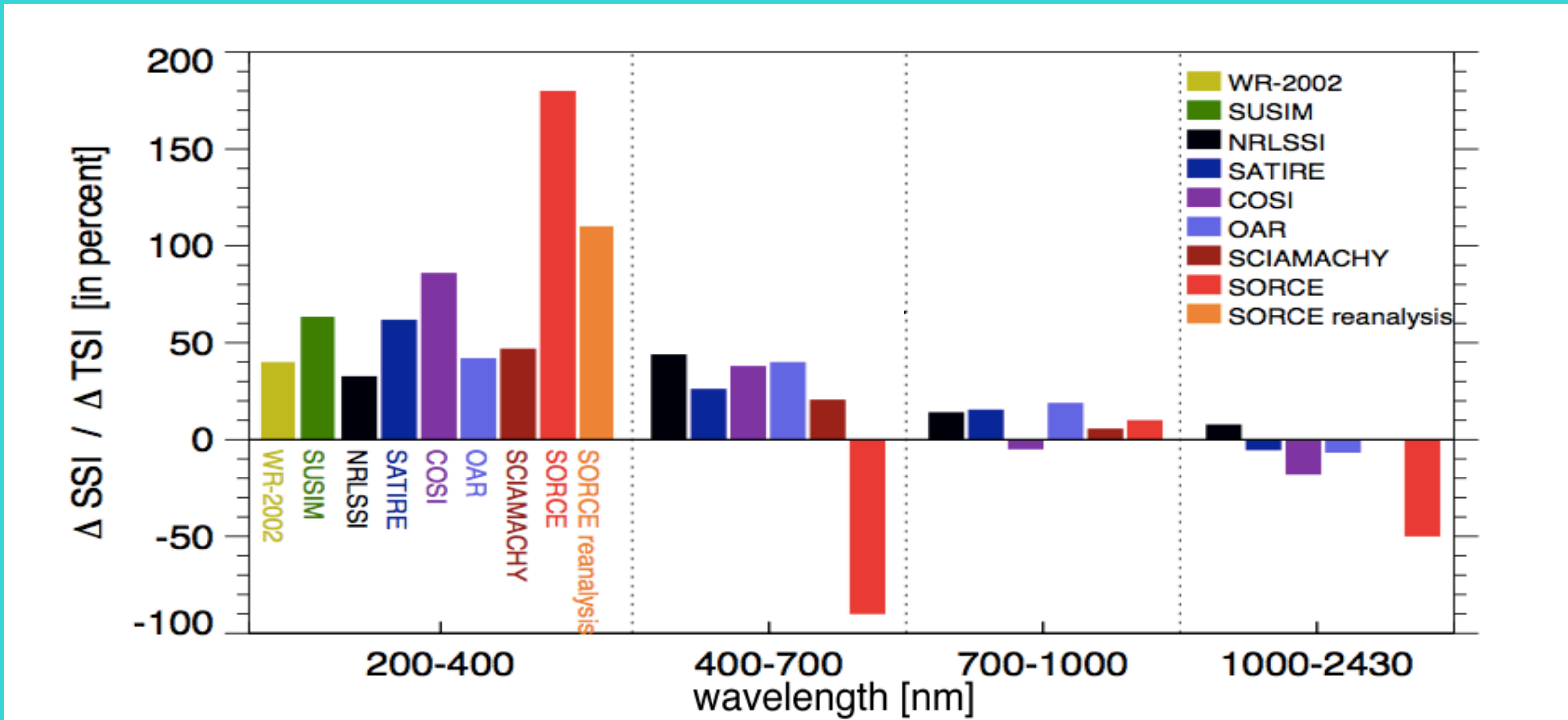
SPM/VIRGO



spectral irradiance [Wm^{-2}nm^{-1}]
2
1.5
1
0.5
0
1996
2000
2004
2008
2012
862 nm
500 nm
402 nm
69%
19%
5%


500 nm
SSI−500 variation
TSI variation
1.001
1.0005
1
0.9995
0.999
862 nm
SSI−862 variation
402 nm
SSI−402 variation

Relative contribution of the UV, visible, near-IR, and IR ranges to the TSI change over the solar cycle

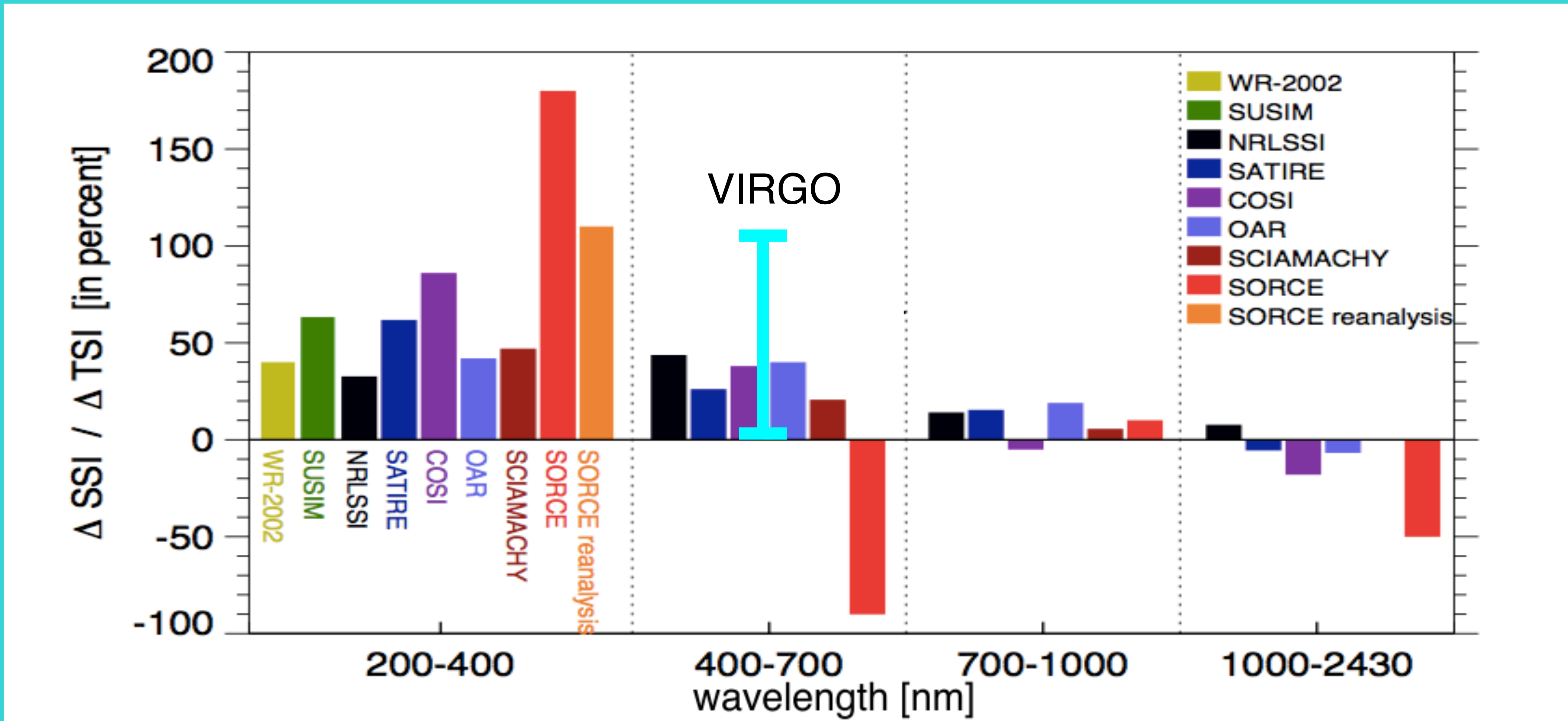


from Ermolli et al. (2013)

Sun Photometer SOHO/VIRGO
402 nm, 500 nm, 862 nm; 1996 -…

SOLSPEC/ISS
170-2900 nm; 2008 - …

Relative contribution of the UV, visible, near-IR, and IR ranges to the TSI change over the solar cycle



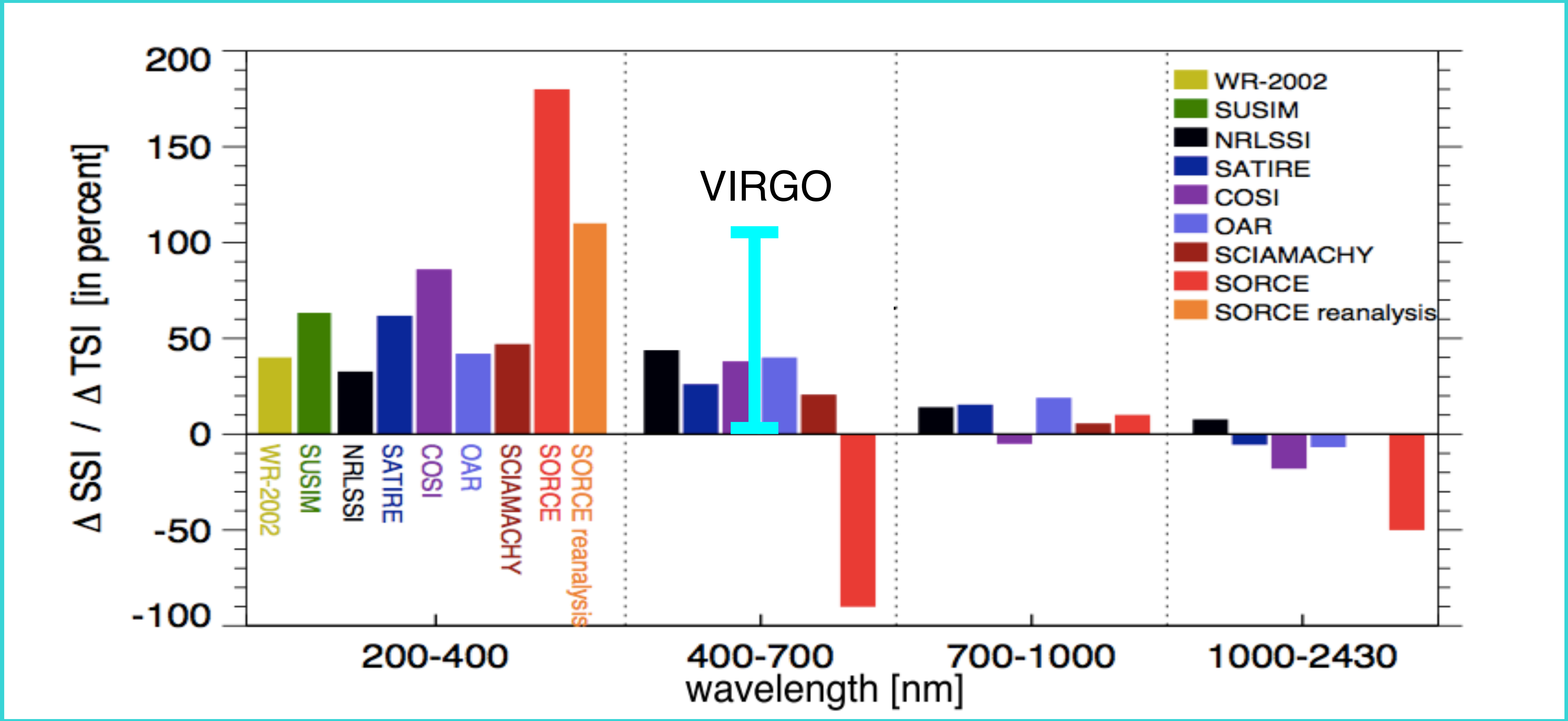
from Ermolli et al. (2013)

Sun Photometer SOHO/VIRGO
402 nm, 500 nm, 862 nm; 1996 -…

Wehrli et al. (2013)

SOLSPEC/ISS
170-2900 nm; 2008 - …

Relative contribution of the UV, visible, near-IR, and IR ranges to the TSI change over the solar cycle



from Ermolli et al. (2013)

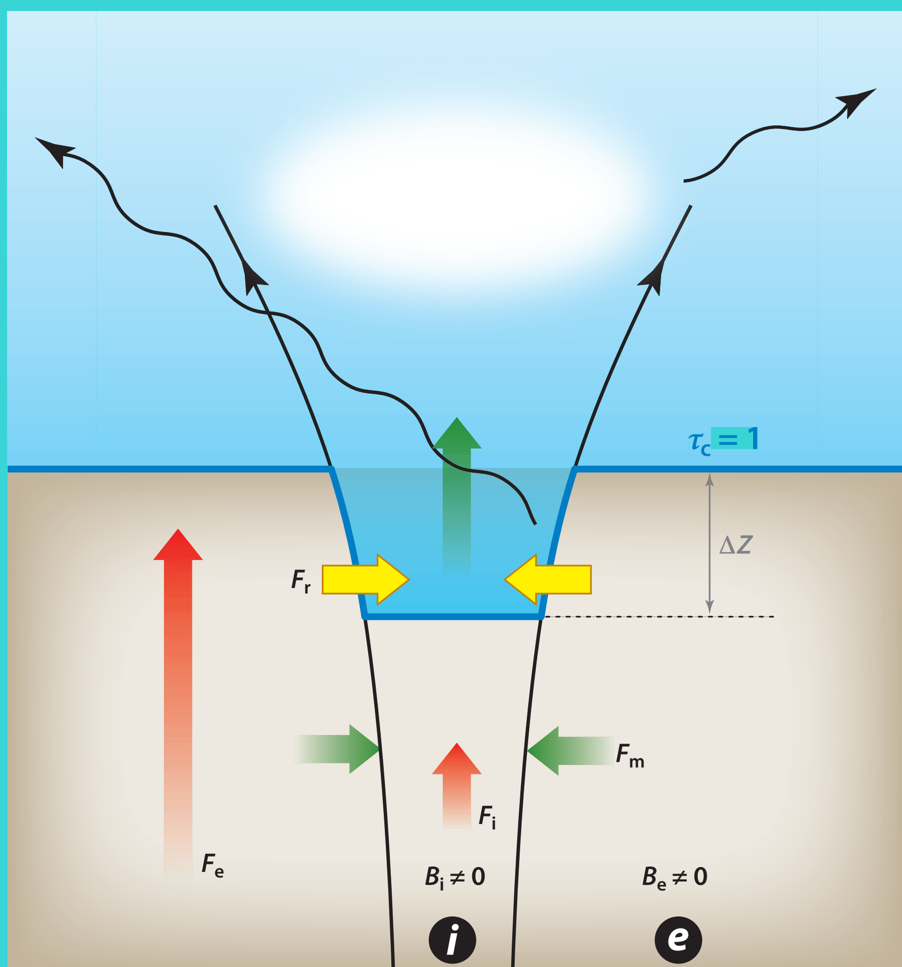
Sun Photometer SOHO/VIRGO
402 nm, 500 nm, 862 nm; 1996 -…

SOLSPEC/ISS
170-2900 nm; 2008 - …

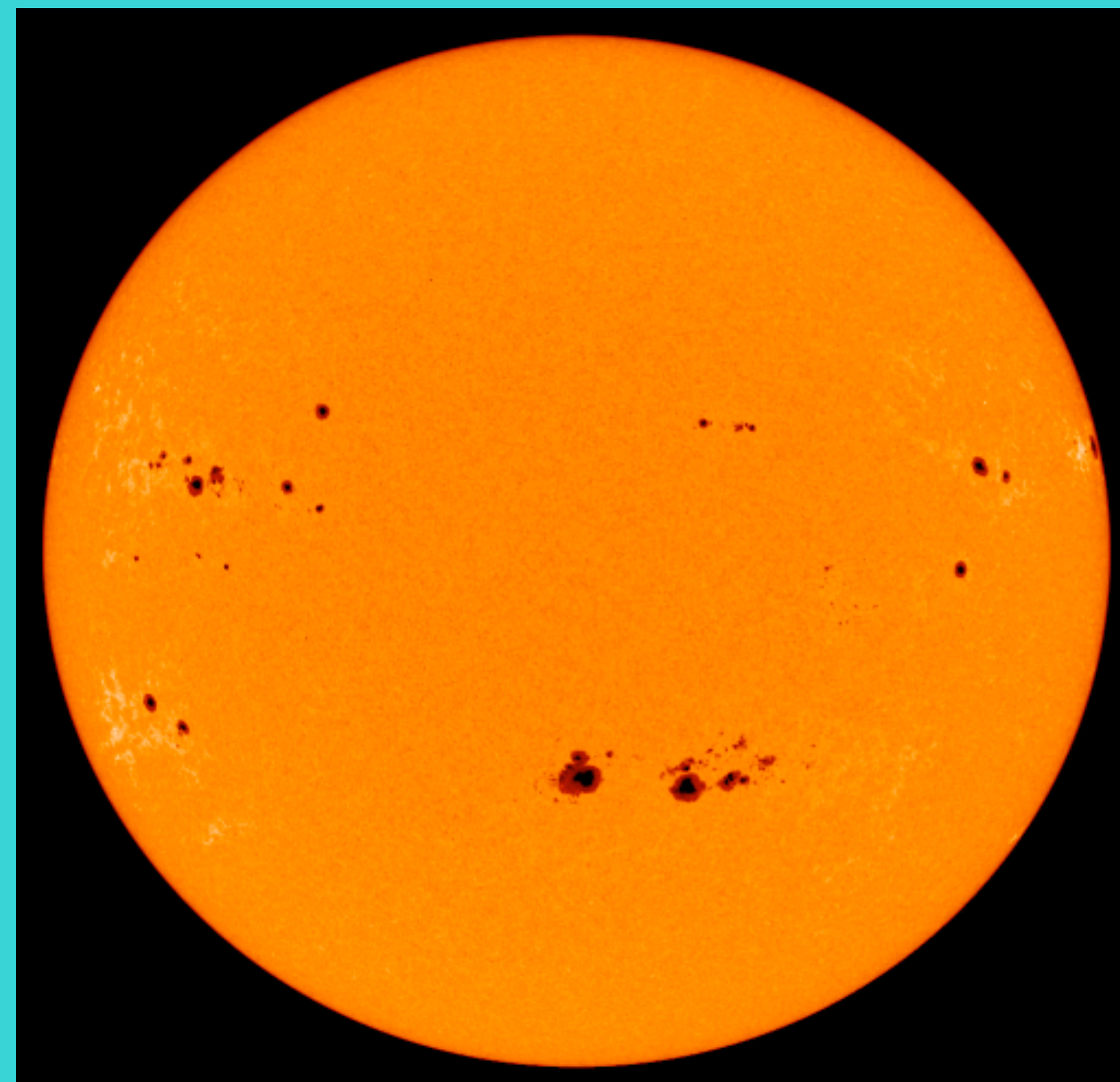
Wehrli et al. (2013)

Models

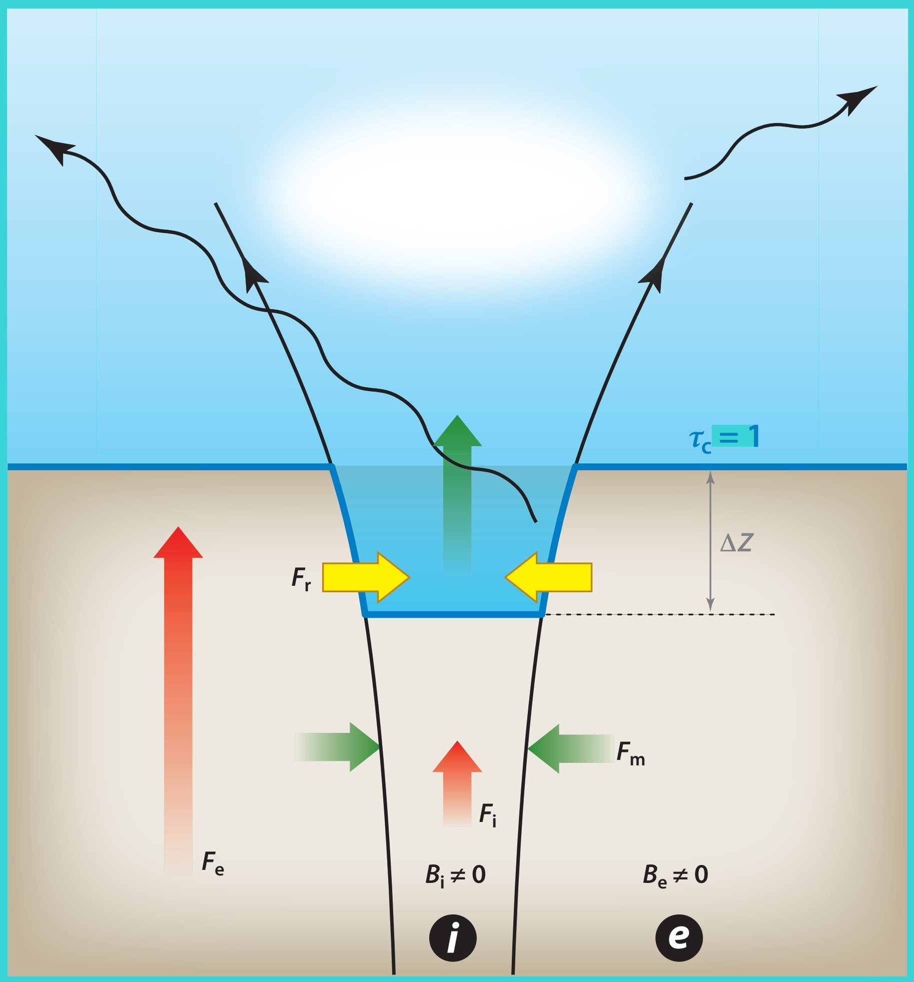
Origin of solar brightness variability



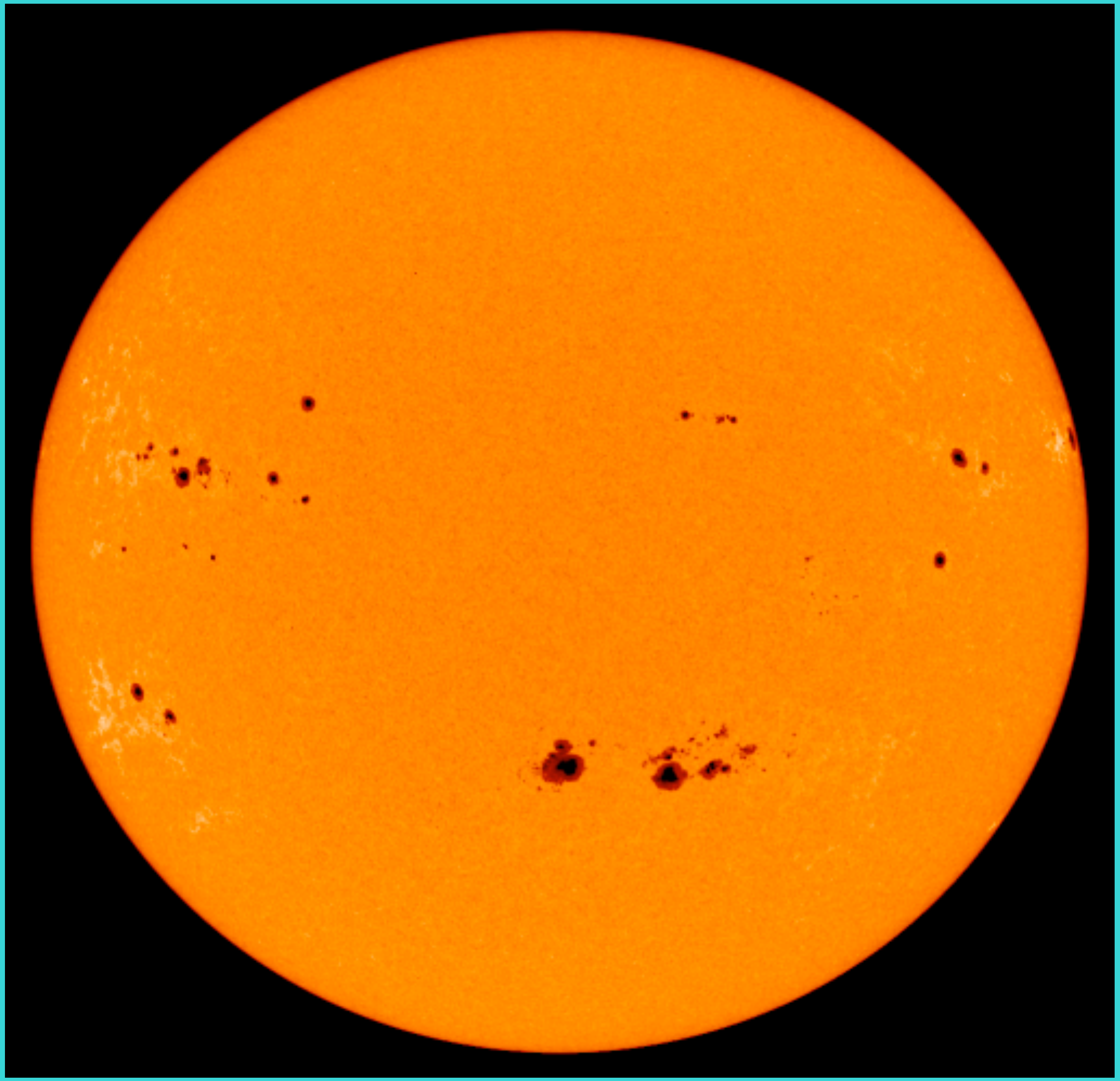
from Solanki et al. 2013



Origin of solar brightness variability



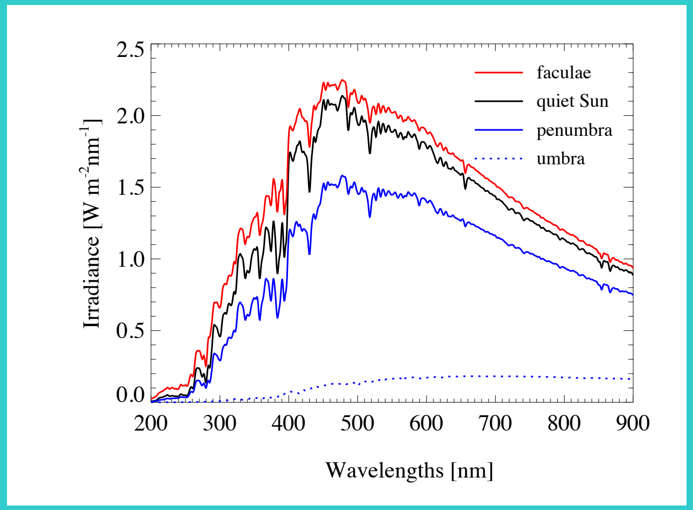
from Solanki et al. 2013



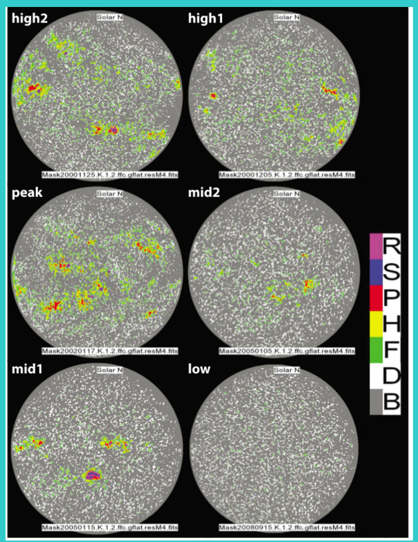
Sunspot (umbra + penumbra) Faculae Network Quiet Sun

Physics-based models

spectra of the individual components

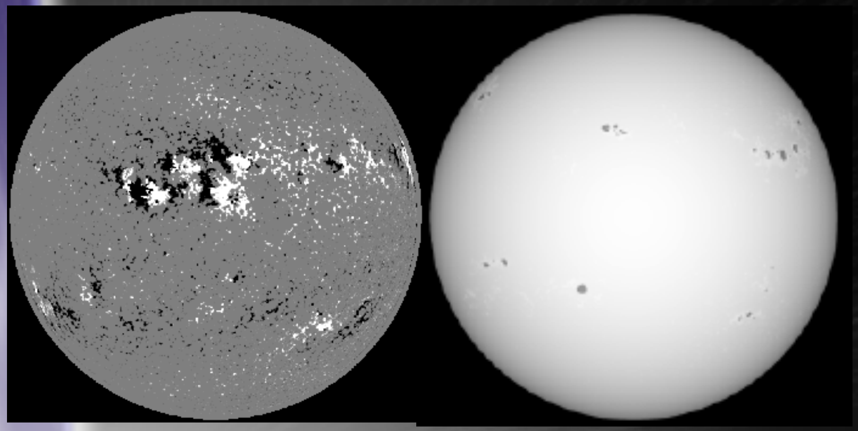


surface coverages



marriage procedure

SATIRE
(Spectral And Total Irradiance REconstructions)



Unruh et al. 1999, 2008
Fligge et al. 2000
Krivova et al. 2003, 2006, 2009a,b, 2011a,b
Wenzler et al. 2004, 2005, 2006, 2009
Solanki & Krivova 2006; Krivova & Solanki 2008; Ball et al. 2014, Yeo et al. 2014

Magnetograms and continuum images → Distribution of features on the solar surface

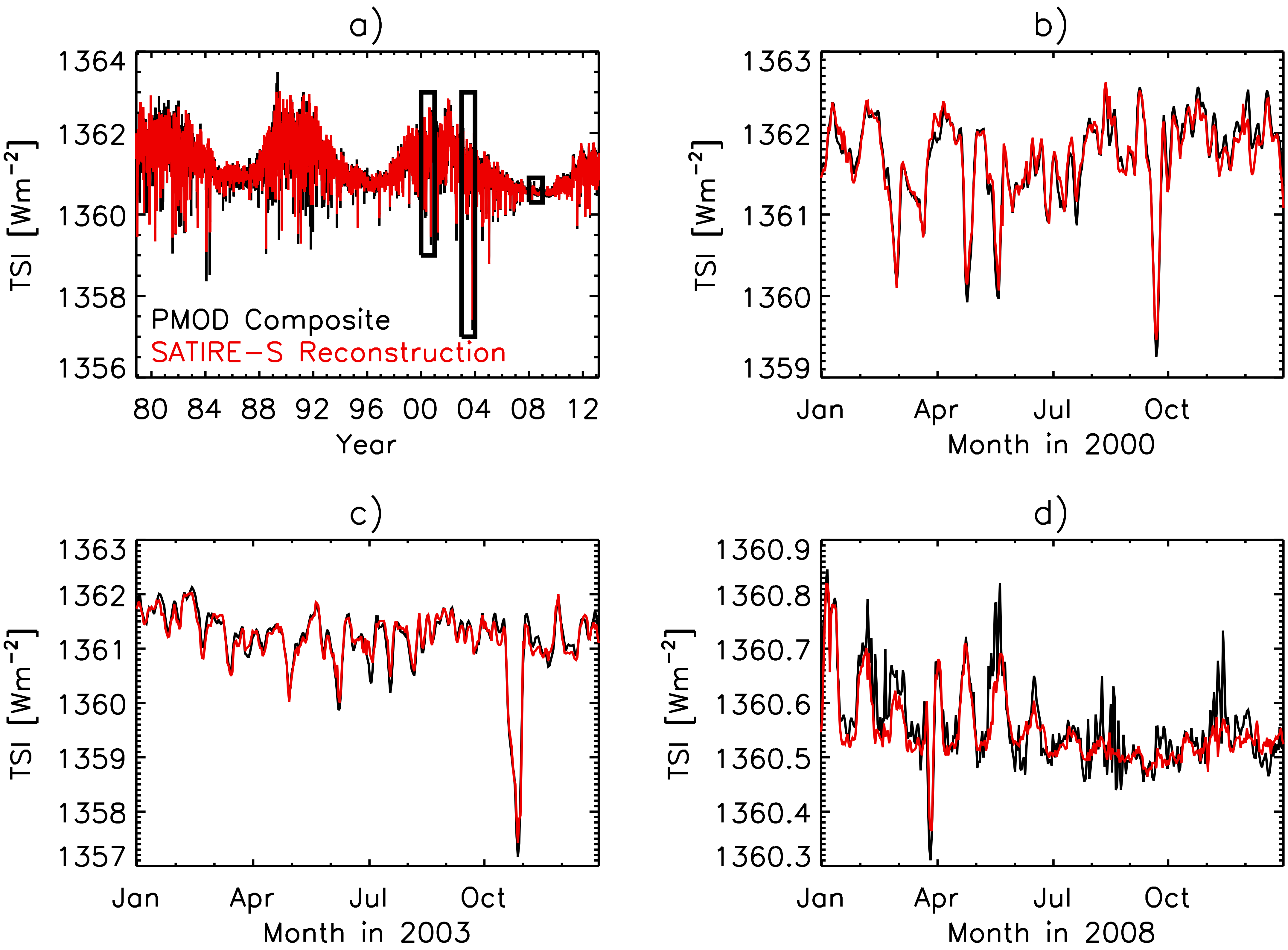
+

Semi-empirical model atmospheres → Brightness of features

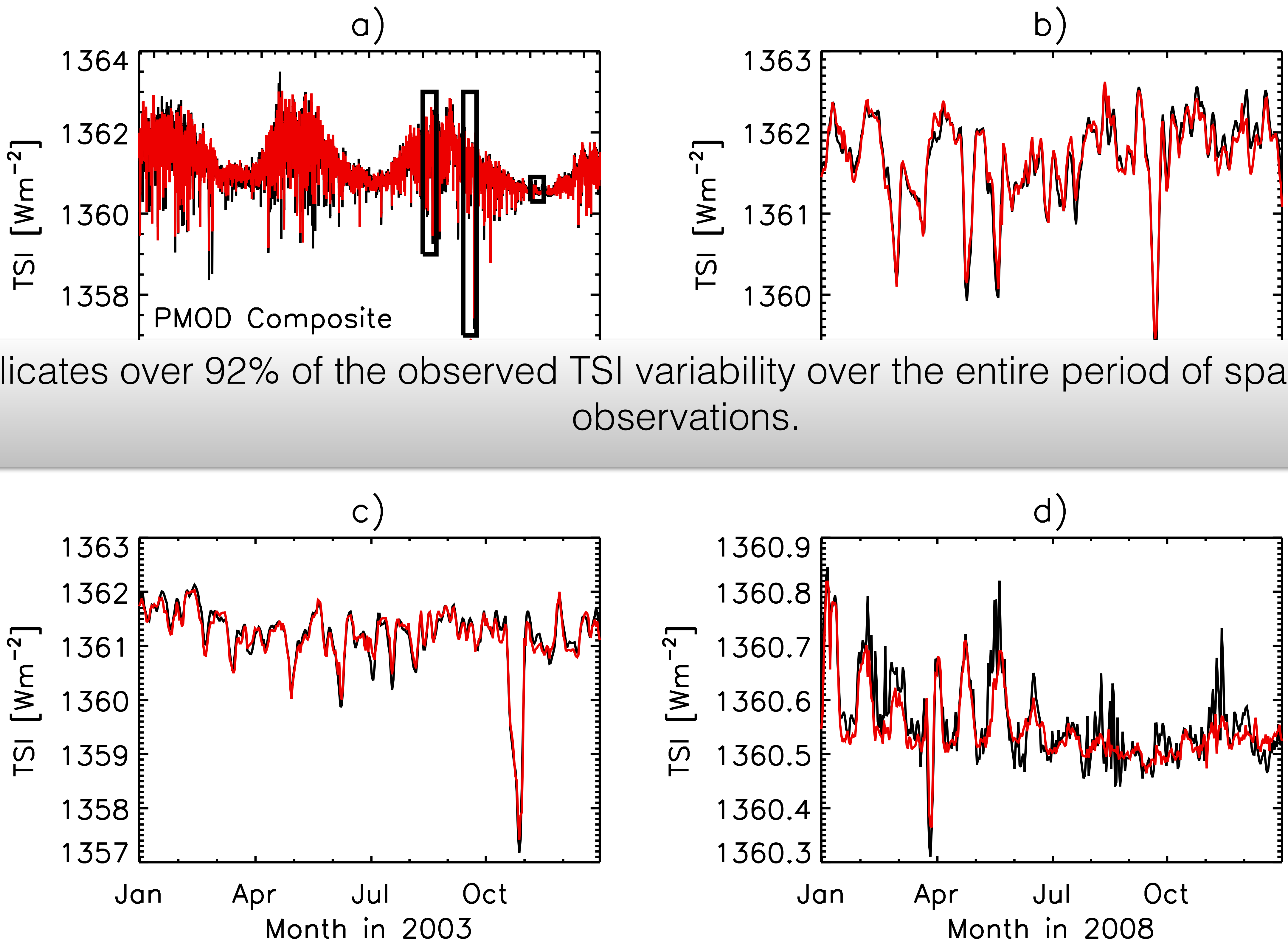
↓

IRRADIANCE

SATIRE-S vs PMOD composite



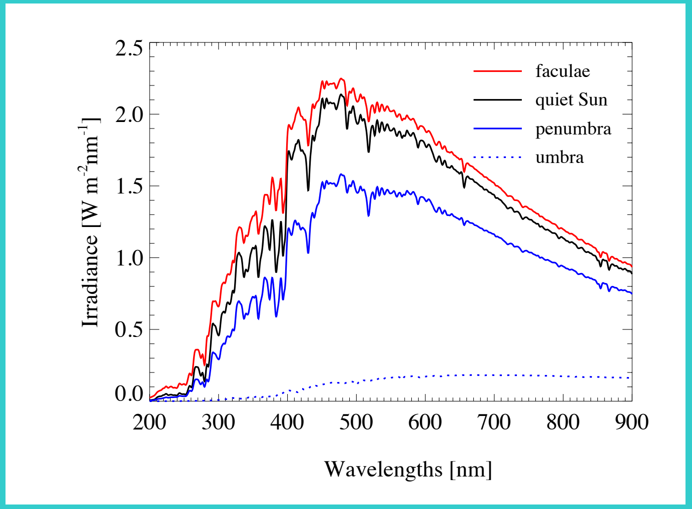
SATIRE-S vs PMOD composite



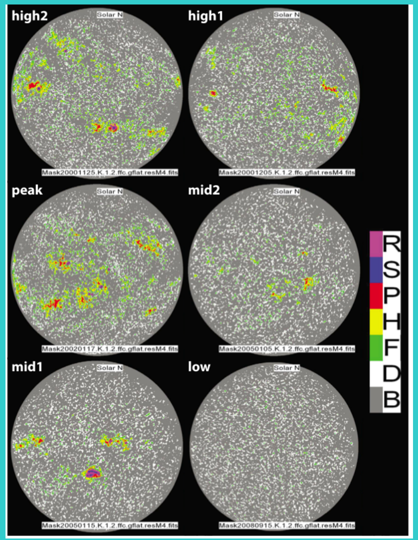
replicates over 92% of the observed TSI variability over the entire period of spaceborne observations.

Physics-based models

spectra of the individual components



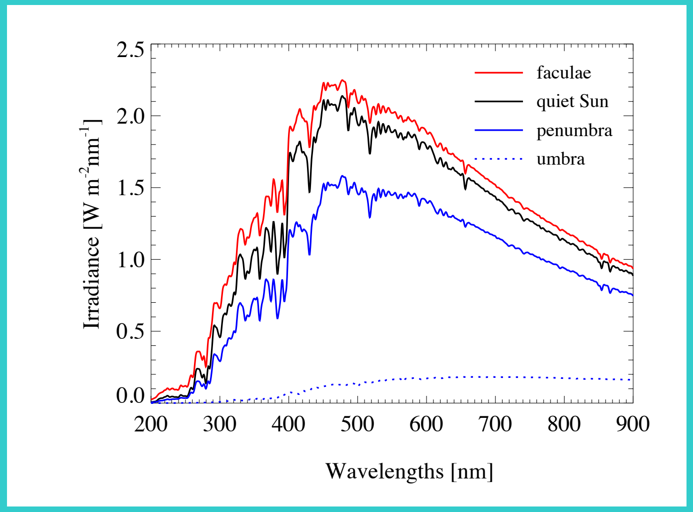
surface coverages



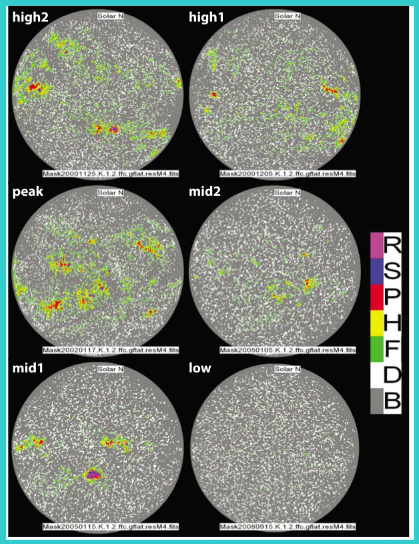
marriage procedure

Physics-based models

spectra of the individual components

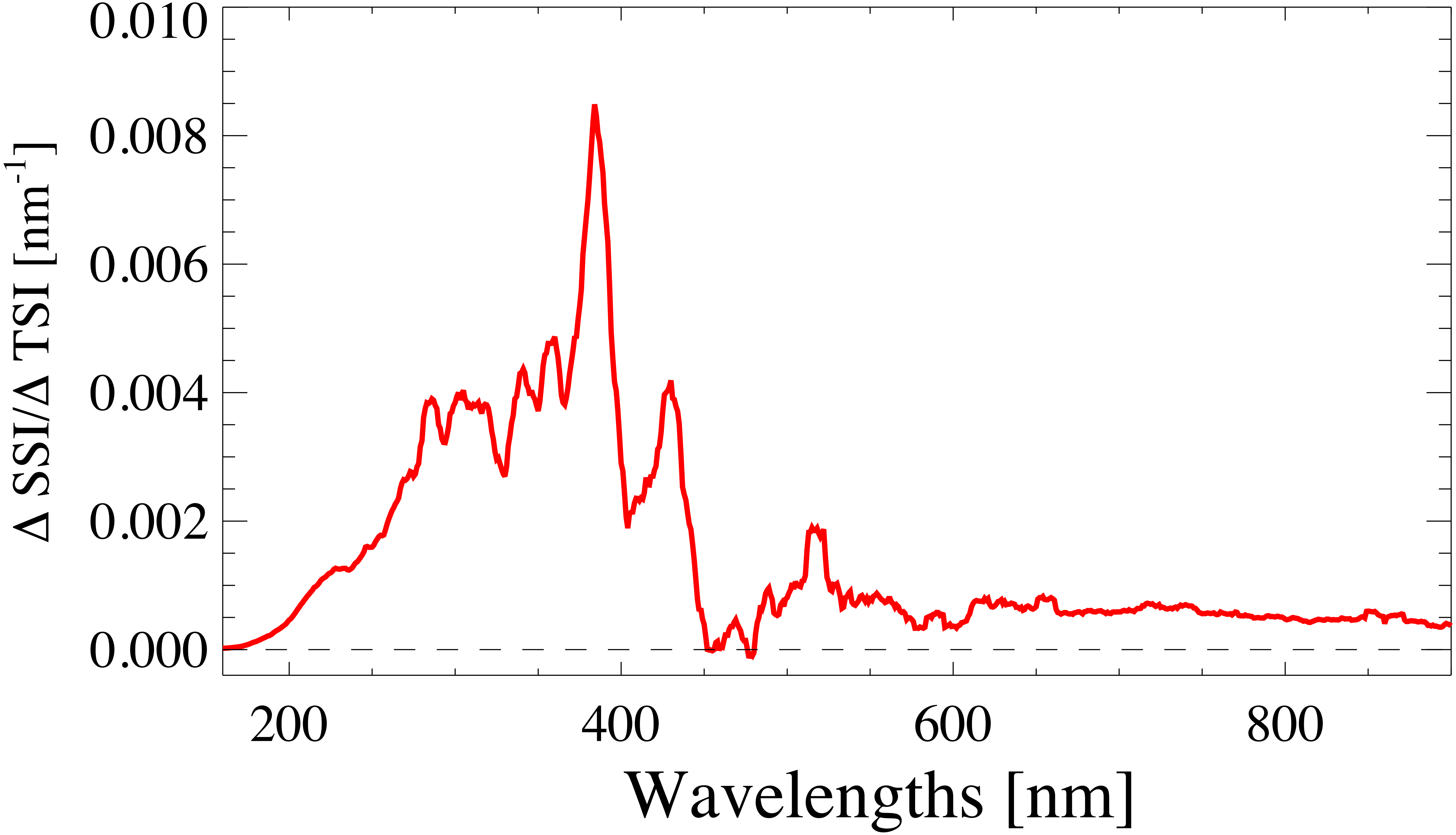


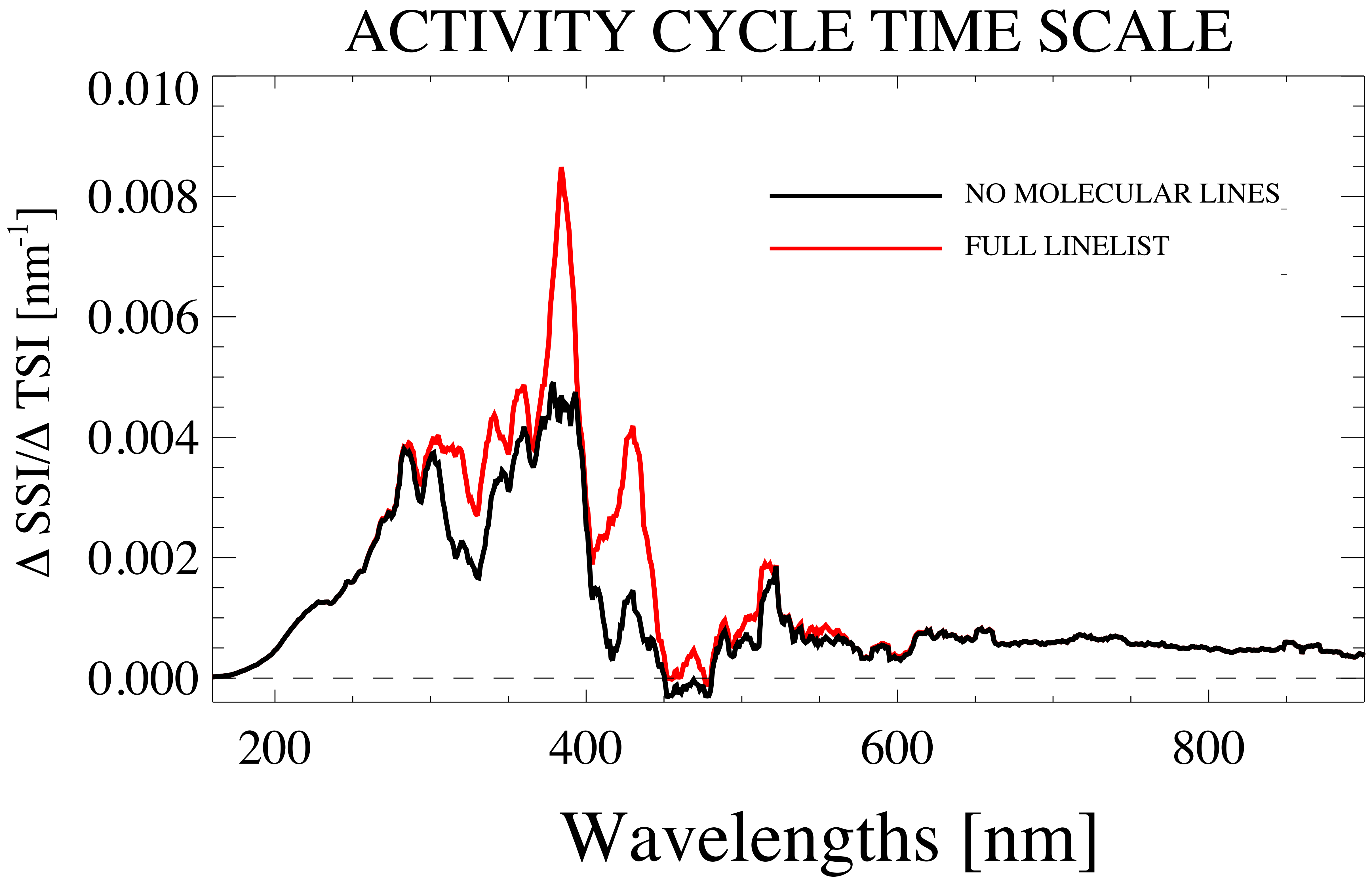
surface coverages



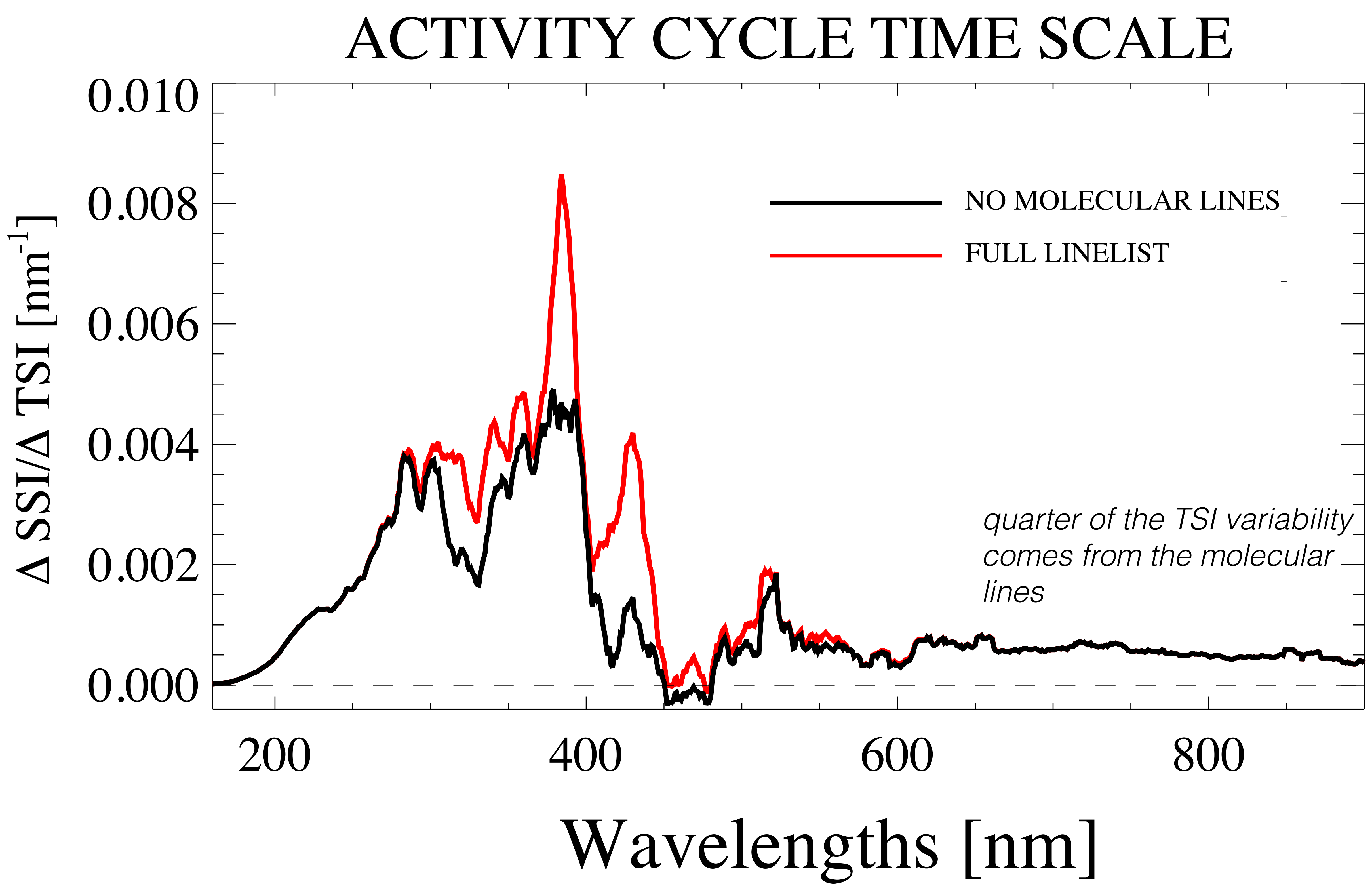
marriage procedure

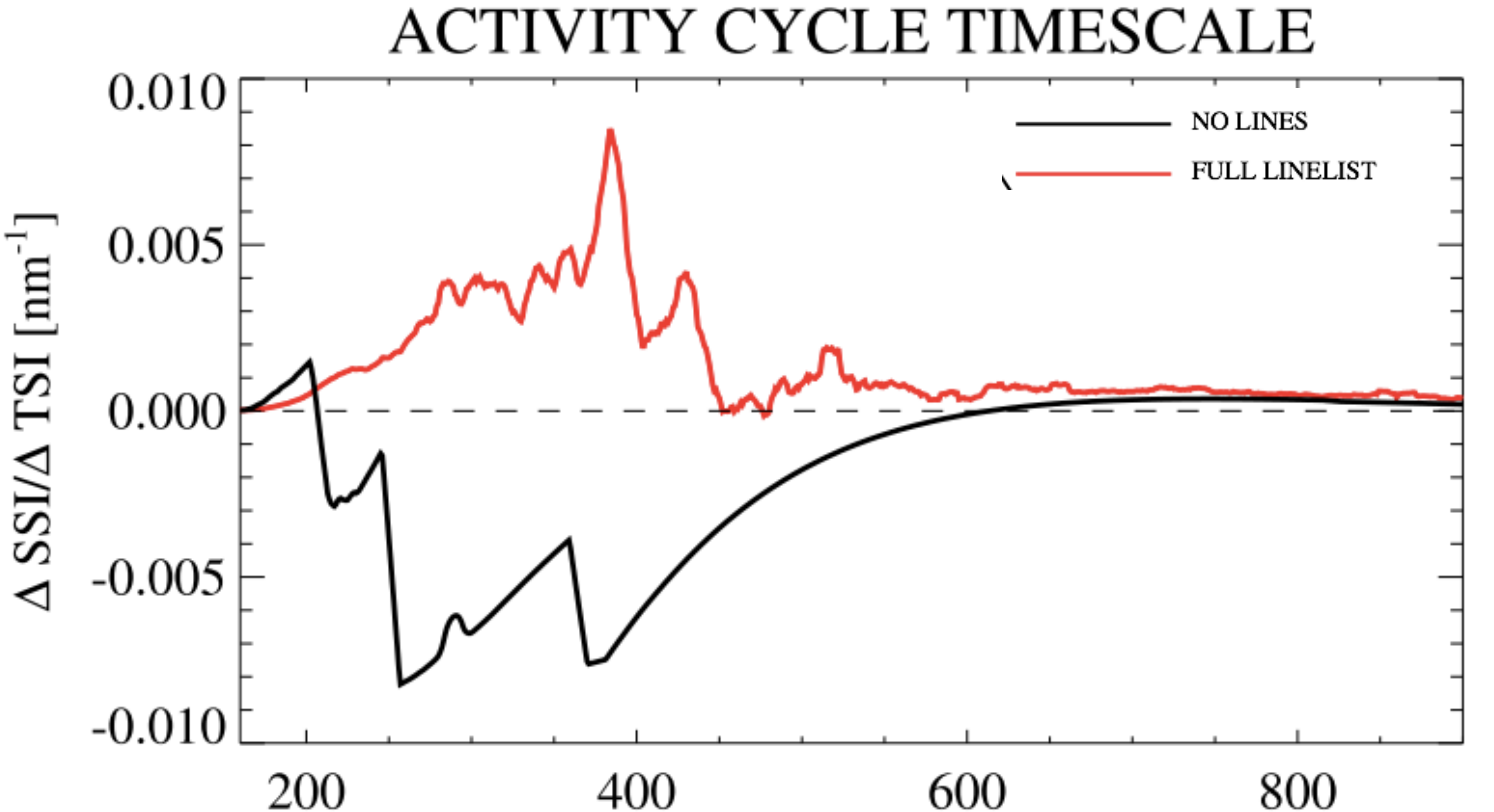
ACTIVITY CYCLE TIME SCALE



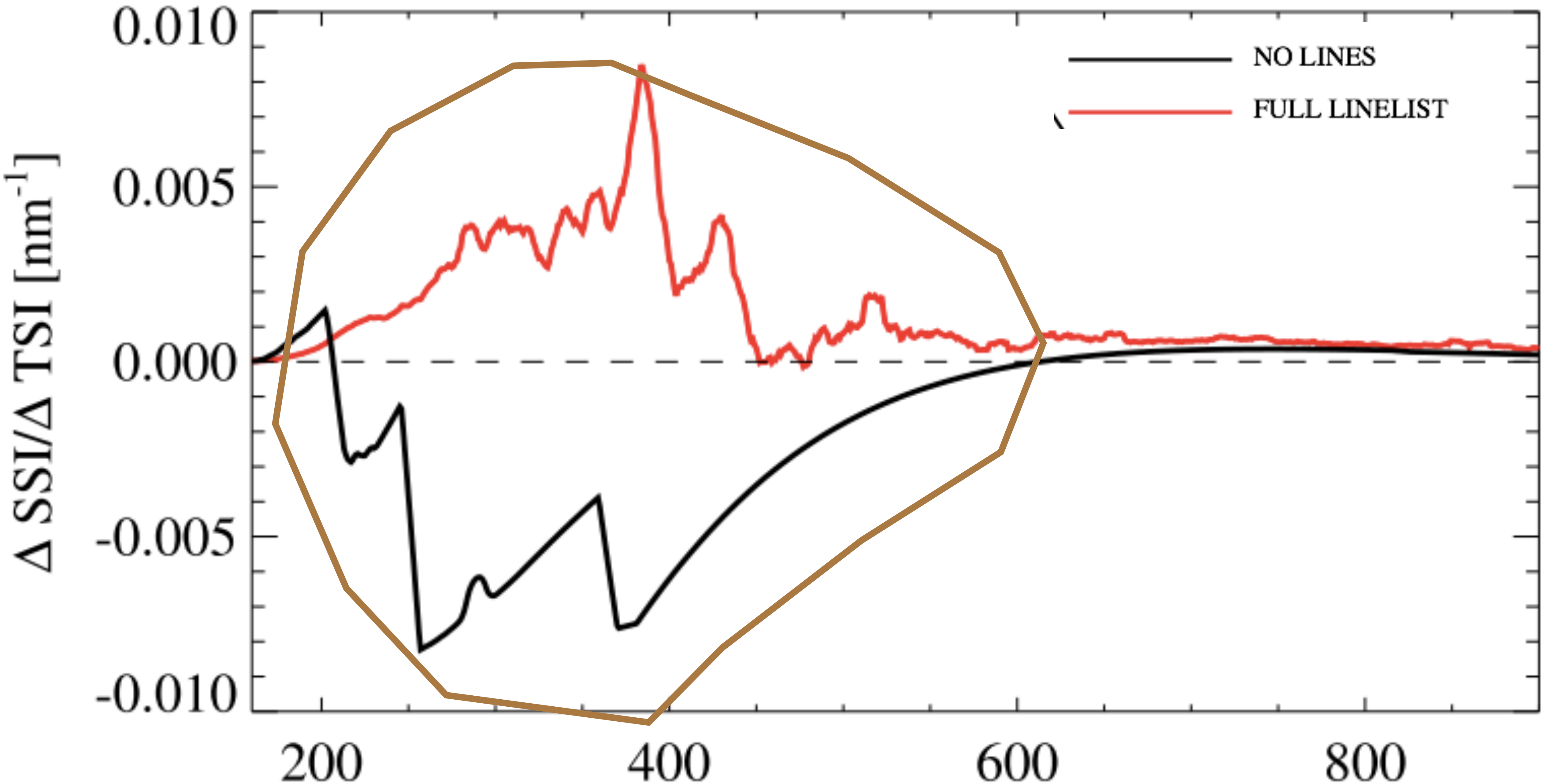


ACTIVITY CYCLE TIME SCALE
0.010
0.008
0.006
0.004
0.002
0.000
Δ SSI/Δ TSI [nm^-1]
NO MOLECULAR LINES
FULL LINELIST
200
400
600
800
Wavelengths [nm]

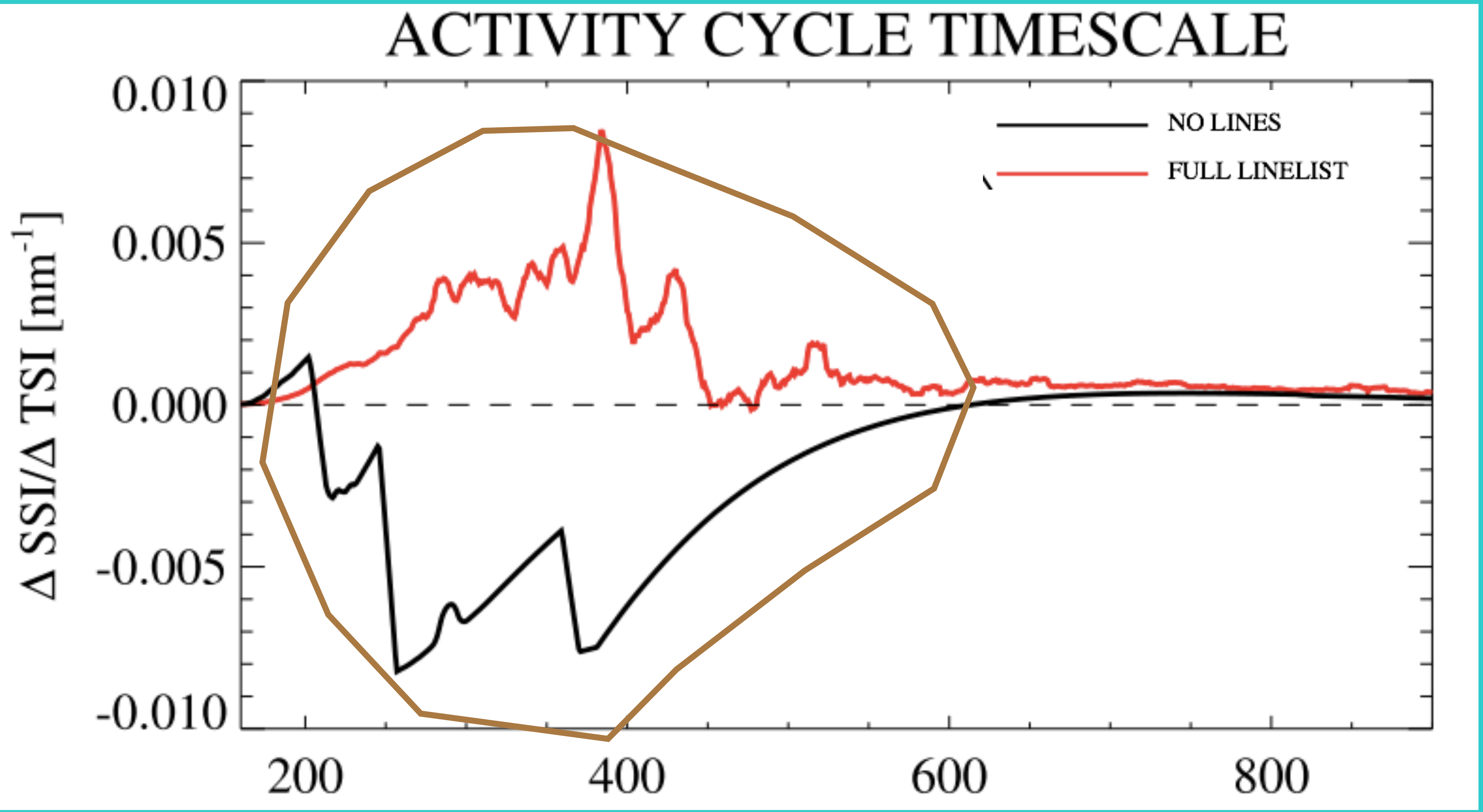

ACTIVITY CYCLE TIME SCALE
0.010
0.008
0.006
0.004
0.002
0.000
Δ SSI/Δ TSI [nm^-1]
NO MOLECULAR LINES
FULL LINELIST
quarter of the TSI variability comes from the molecular lines
200
400
600
800
Wavelengths [nm]


ACTIVITY CYCLE TIMESCALE
0.010
0.005
0.000
-0.005
-0.010
Δ SSI/Δ TSI [nm-1]
200
400
600
800
NO LINES
FULL LINELIST

ACTIVITY CYCLE TIMESCALE

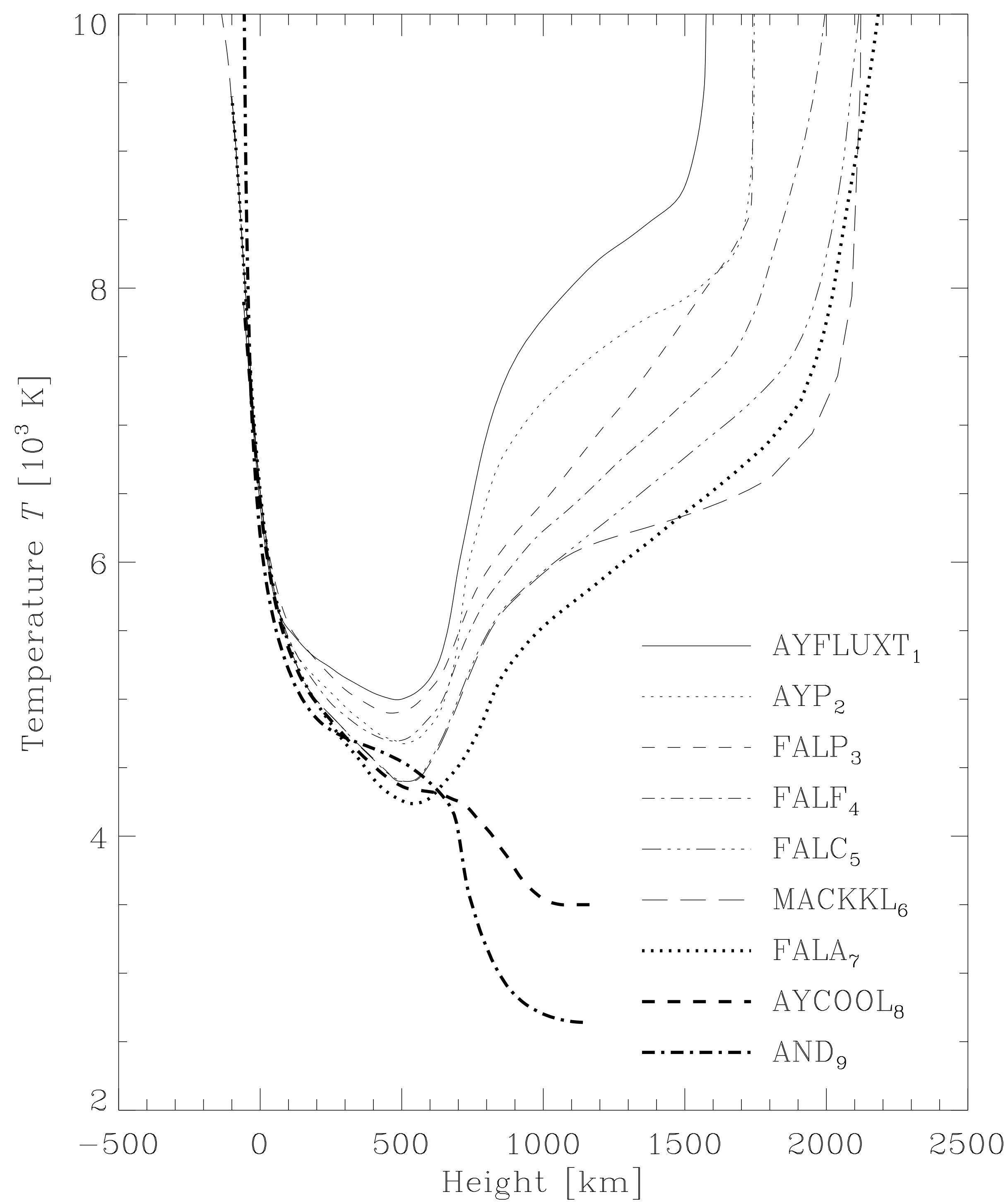


The increase of the TSI at maximum of the activity cycle compared with minimum is directly attributed to the variability in spectral lines



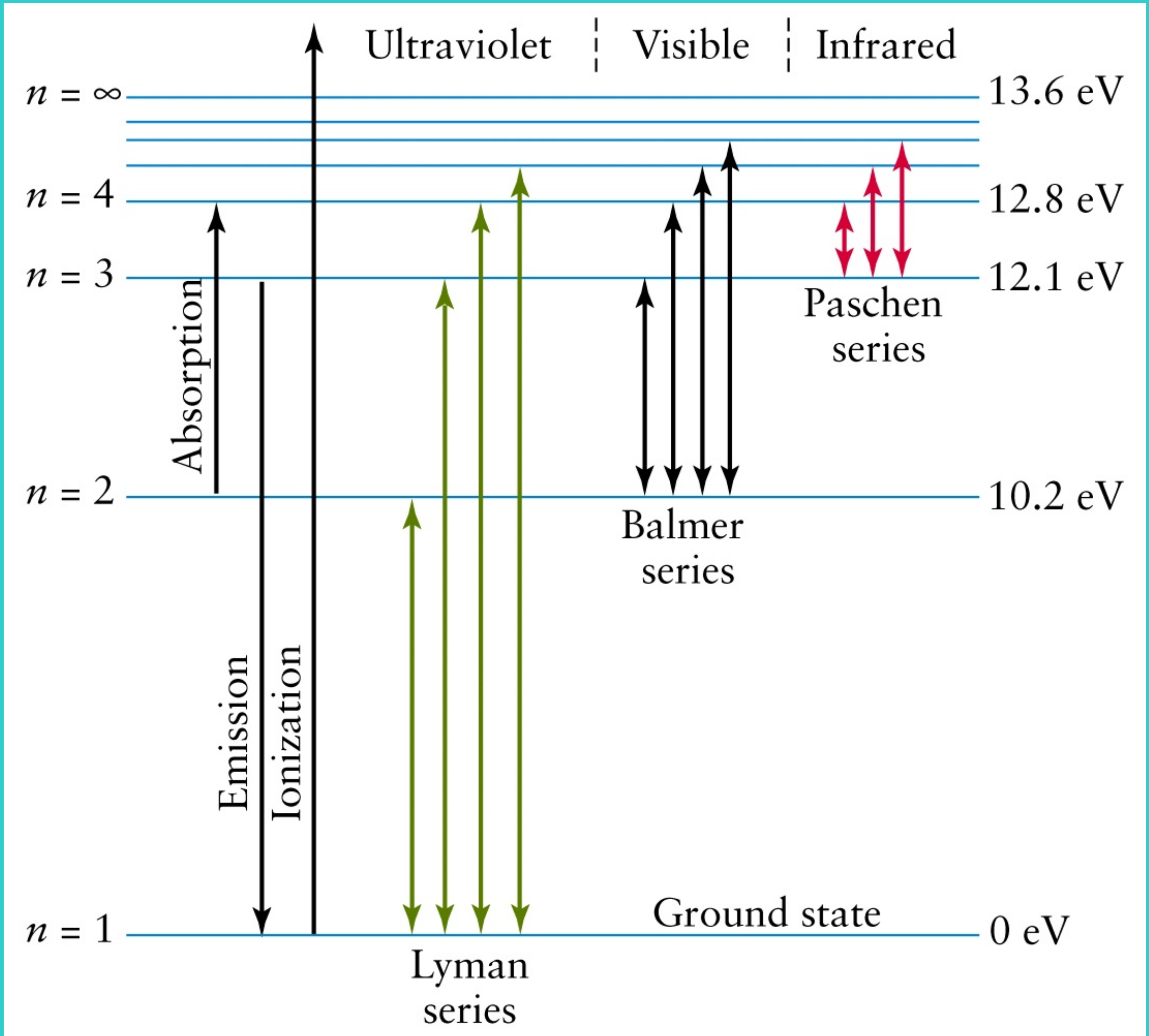
Calculations of the spectra

temperature and density structure of the atmosphere

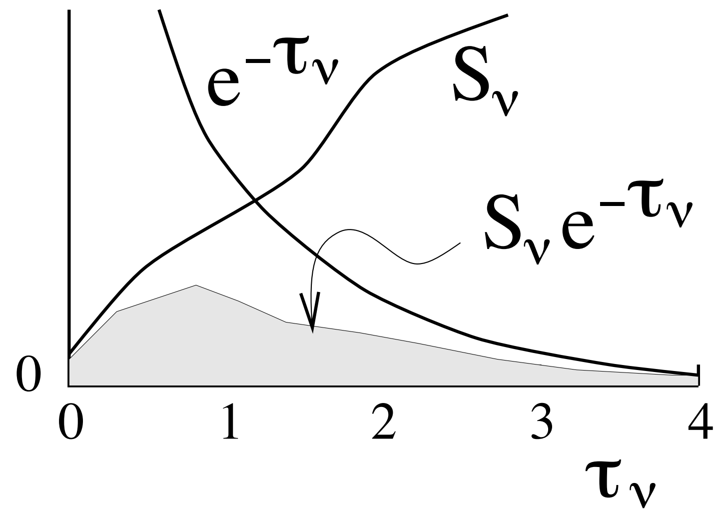


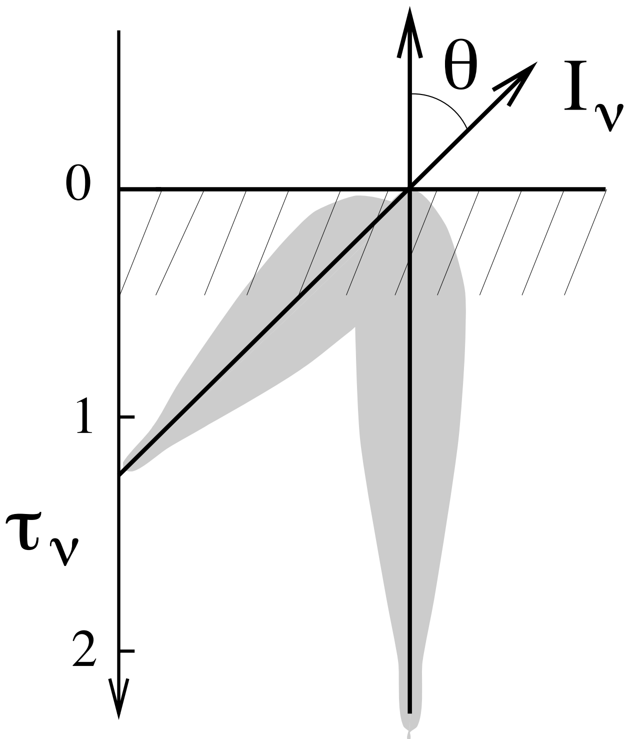
from Fluri et al. 1999

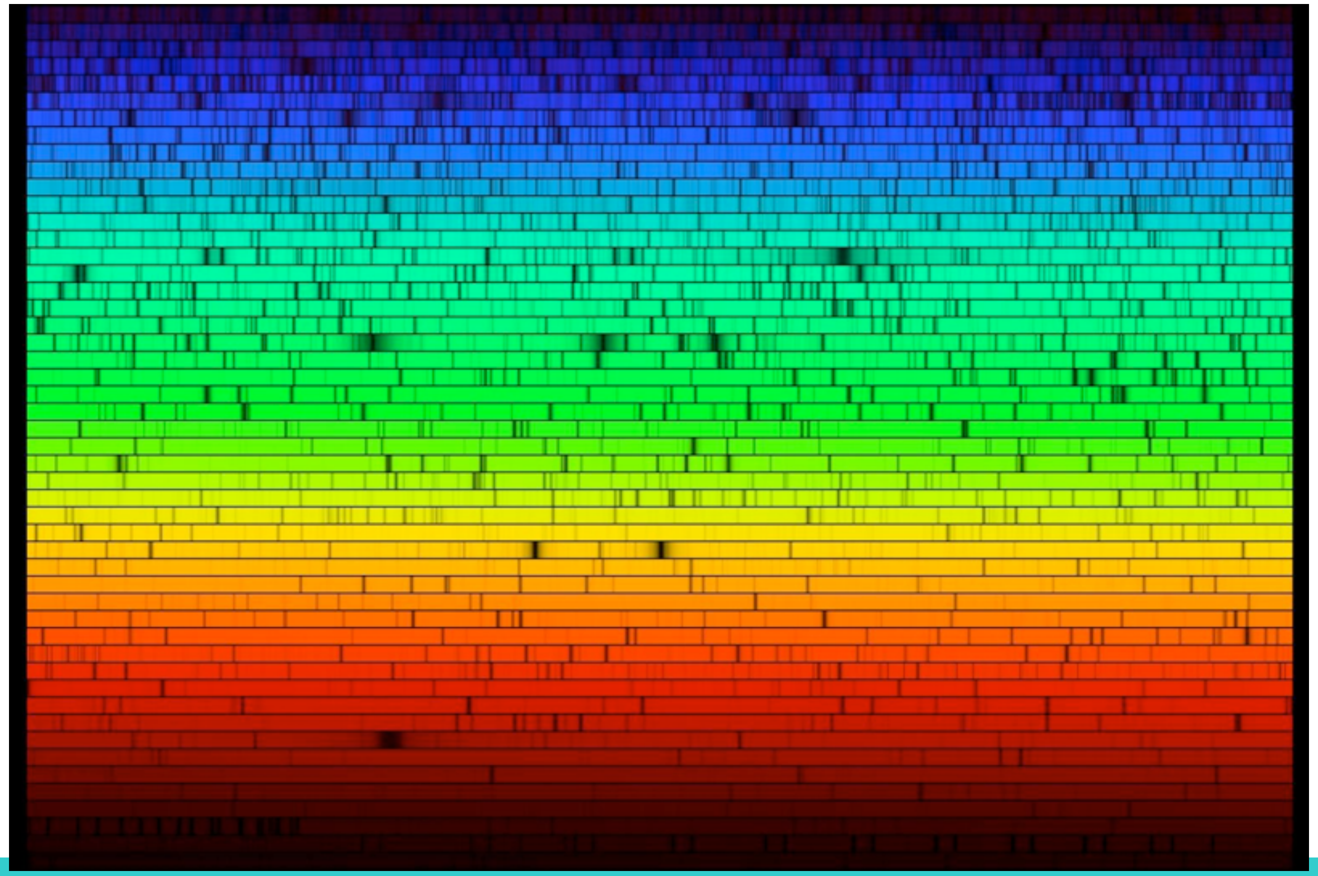
Populations + chemical equilibrium

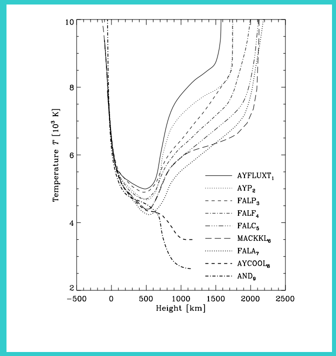


Radiative transfer

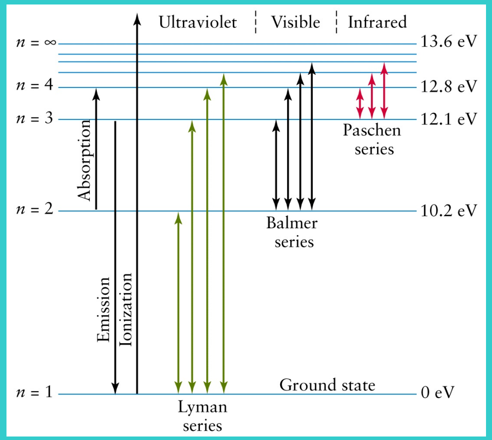




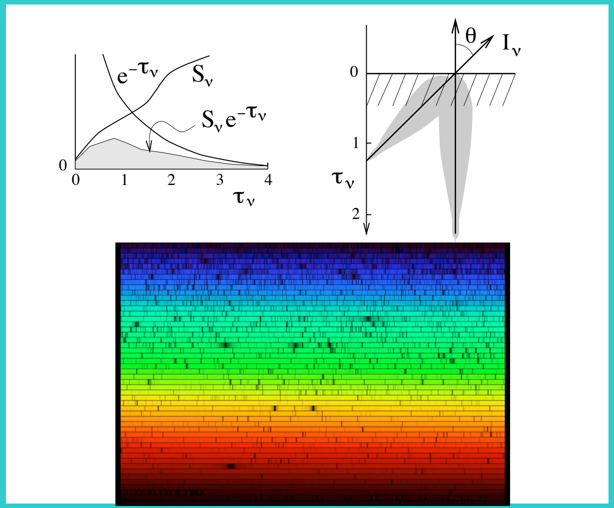




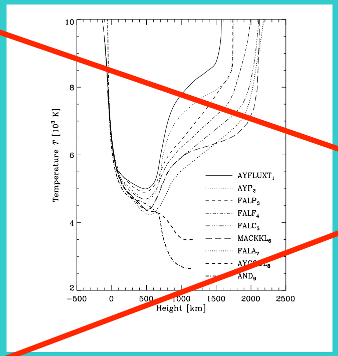
3D MHD



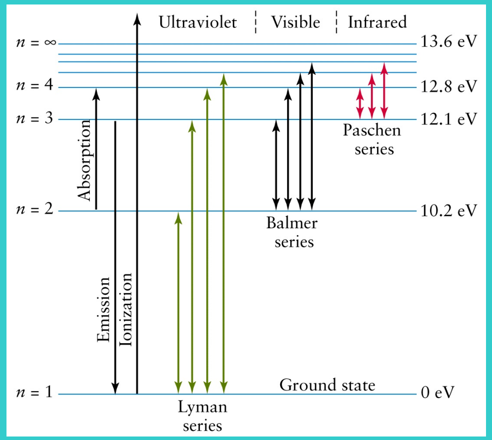
statistical equilibrium



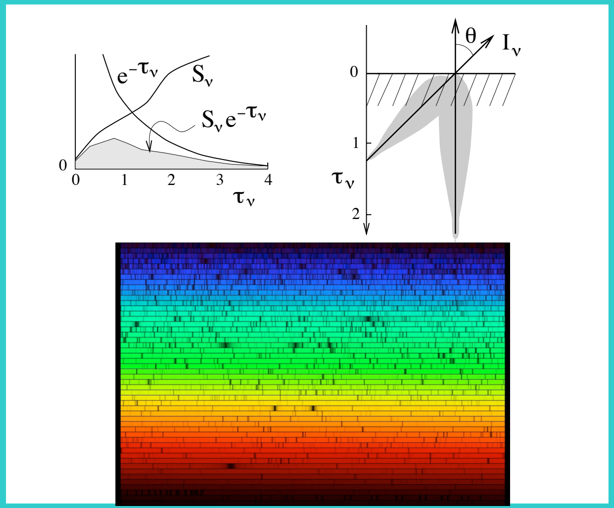
spectrum synthesis



3D MHD

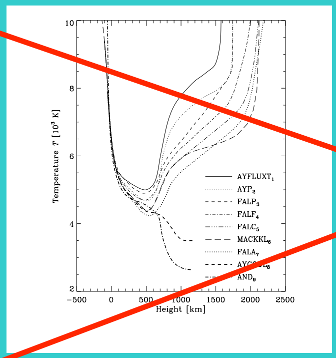


statistical equilibrium

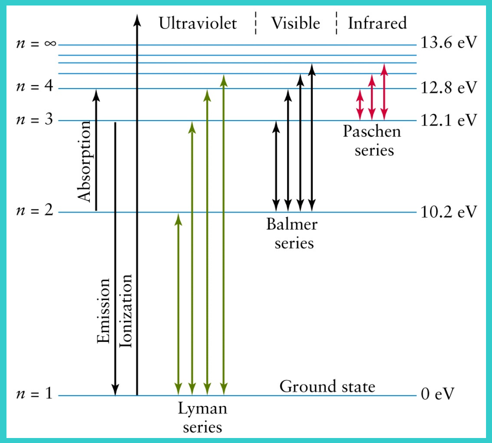


spectrum synthesis

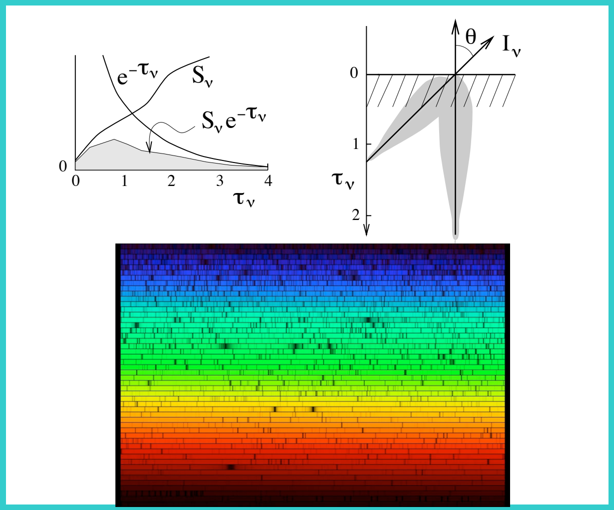
semi-empirical 1D models



3D MHD

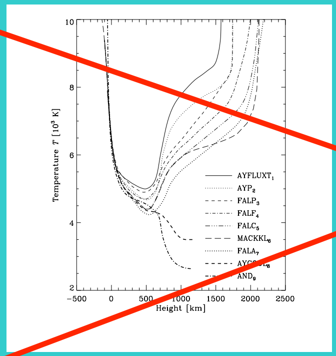


statistical equilibrium



spectrum synthesis

semi-empirical 1D models



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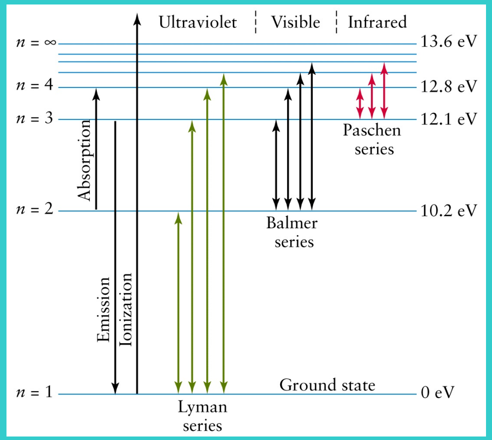
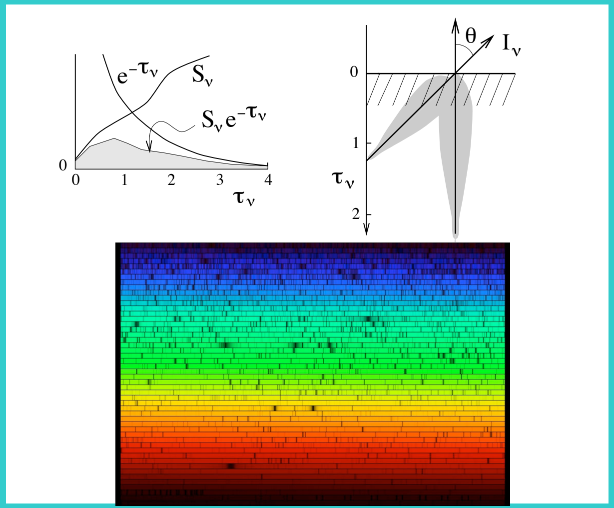
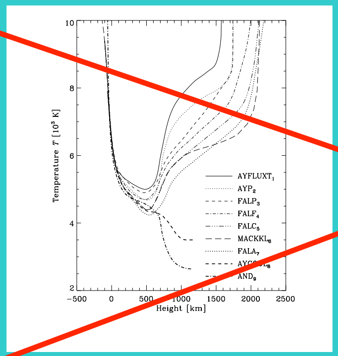


statistical equilibrium

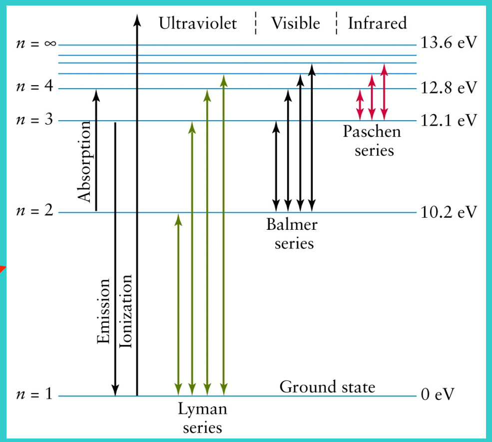


spectrum synthesis

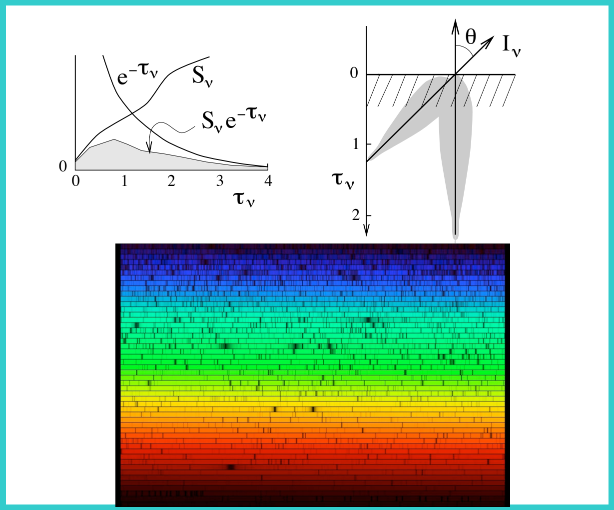
semi-empirical 1D models



3D MHD

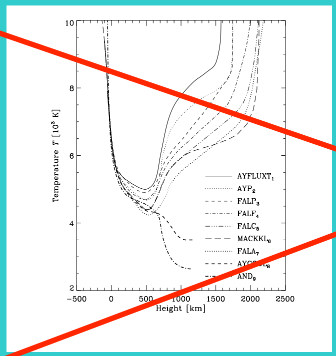


statistical equilibrium

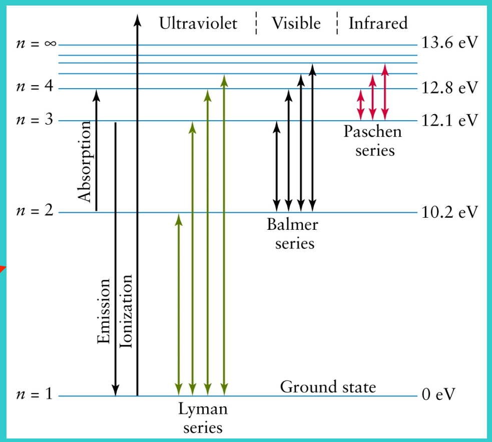


spectrum synthesis

semi-empirical 1D models

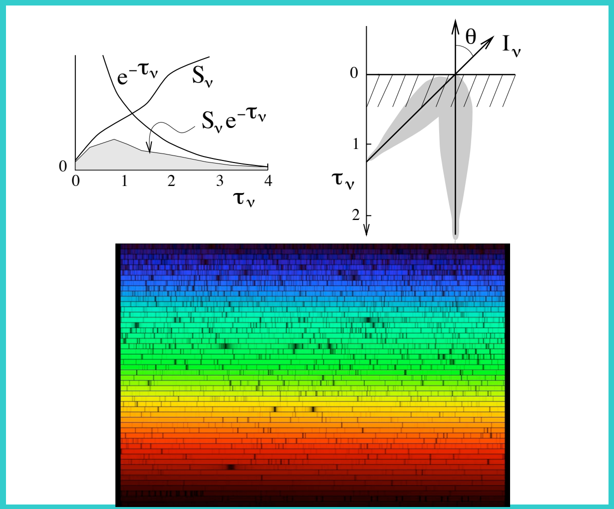


3D MHD



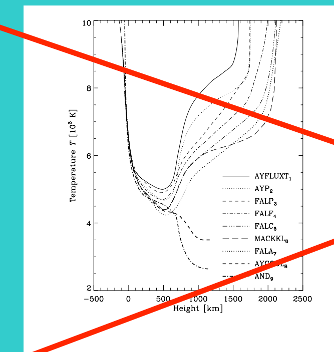
statistical equilibrium

Lambda iterations



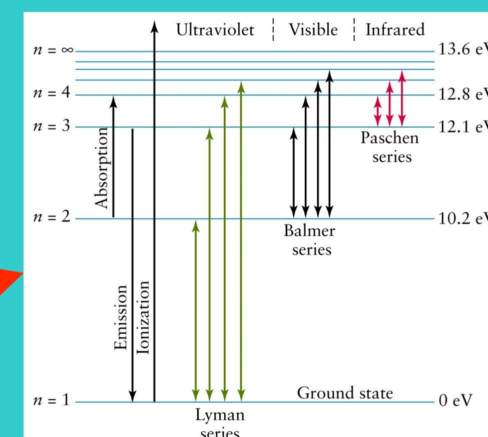
spectrum synthesis

semi-empirical 1D models



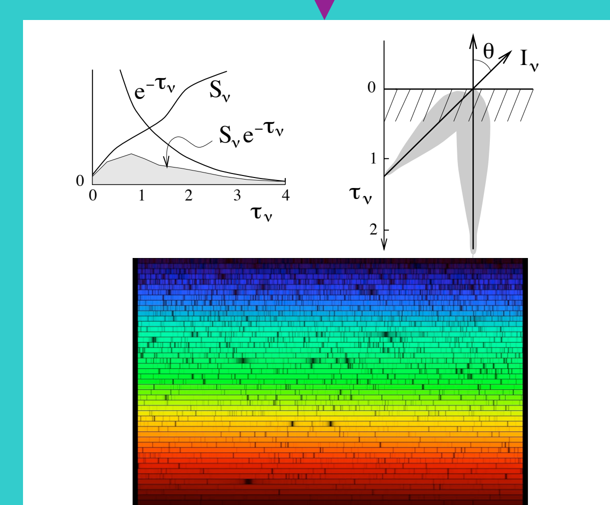
3D MHD

statistical equilibrium

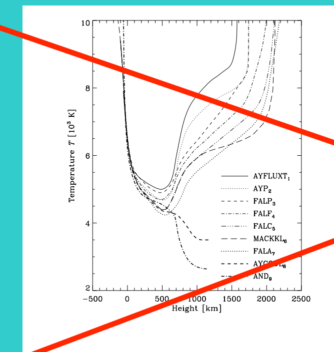


Lambda iterations

spectrum synthesis

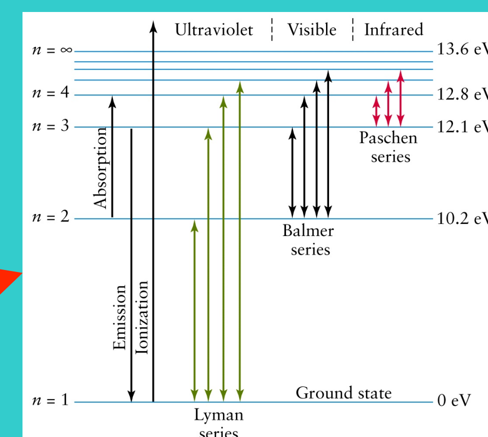


semi-empirical 1D models



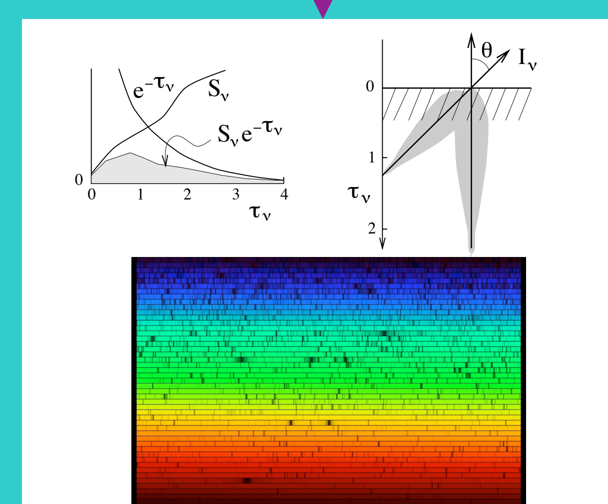
3D MHD

statistical equilibrium

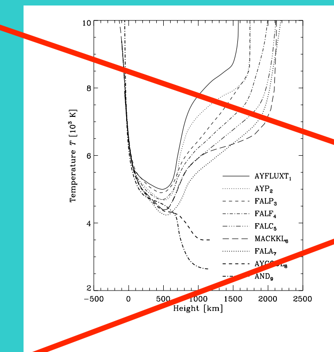


Accelerated Lambda iterations

spectrum synthesis

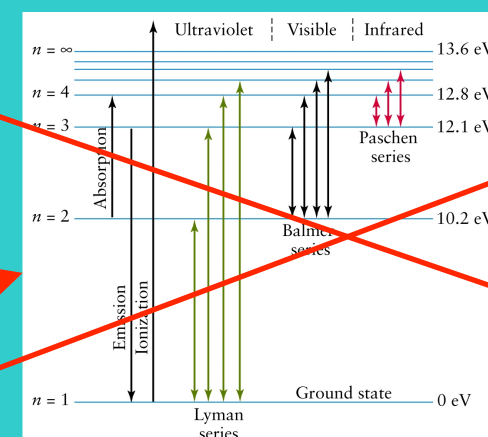


semi-empirical 1D models



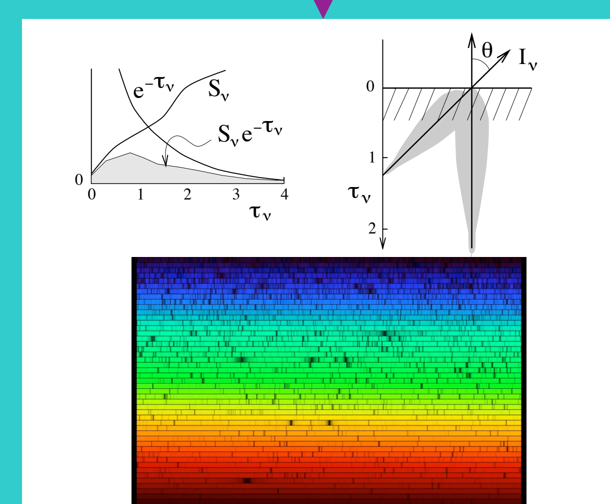
3D MHD

ATLAS9 (SATIRE)
LTE

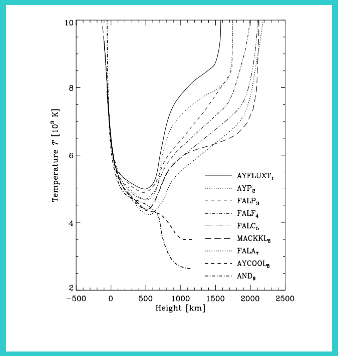


statistical
equilibrium

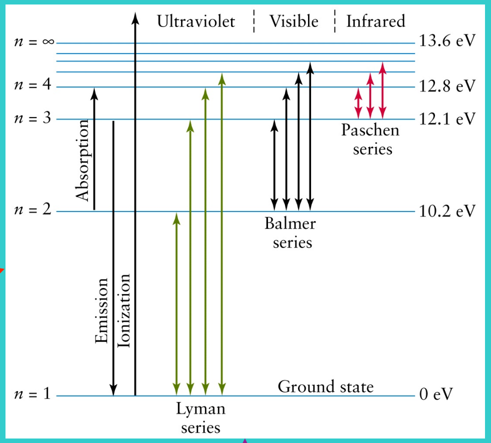
Accelerated Lambda
iterations



spectrum
synthesis

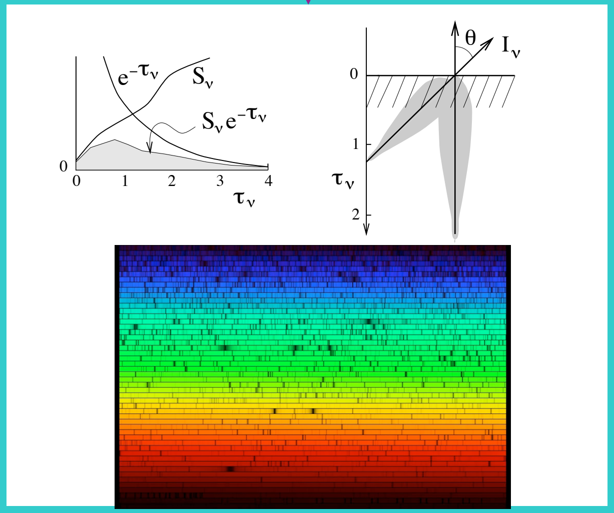


3D MHD simulations

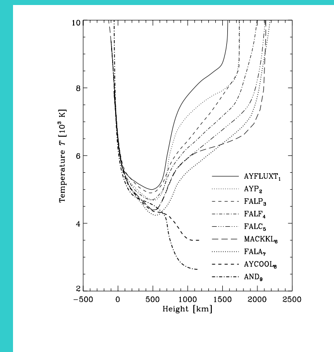


statistical equilibrium

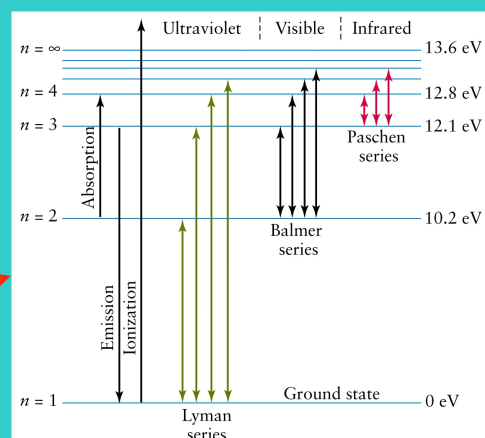
NLTE radiative transfer code



spectrum synthesis

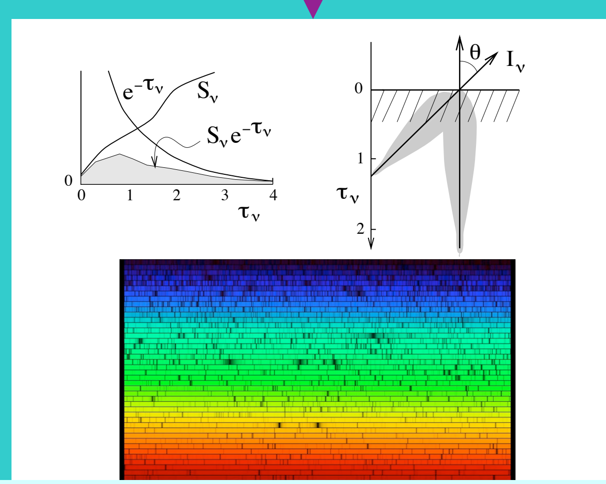


3D MHD simulations



statistical equilibrium

NLTE radiative transfer code



spectrum synthesis

THANK YOU!