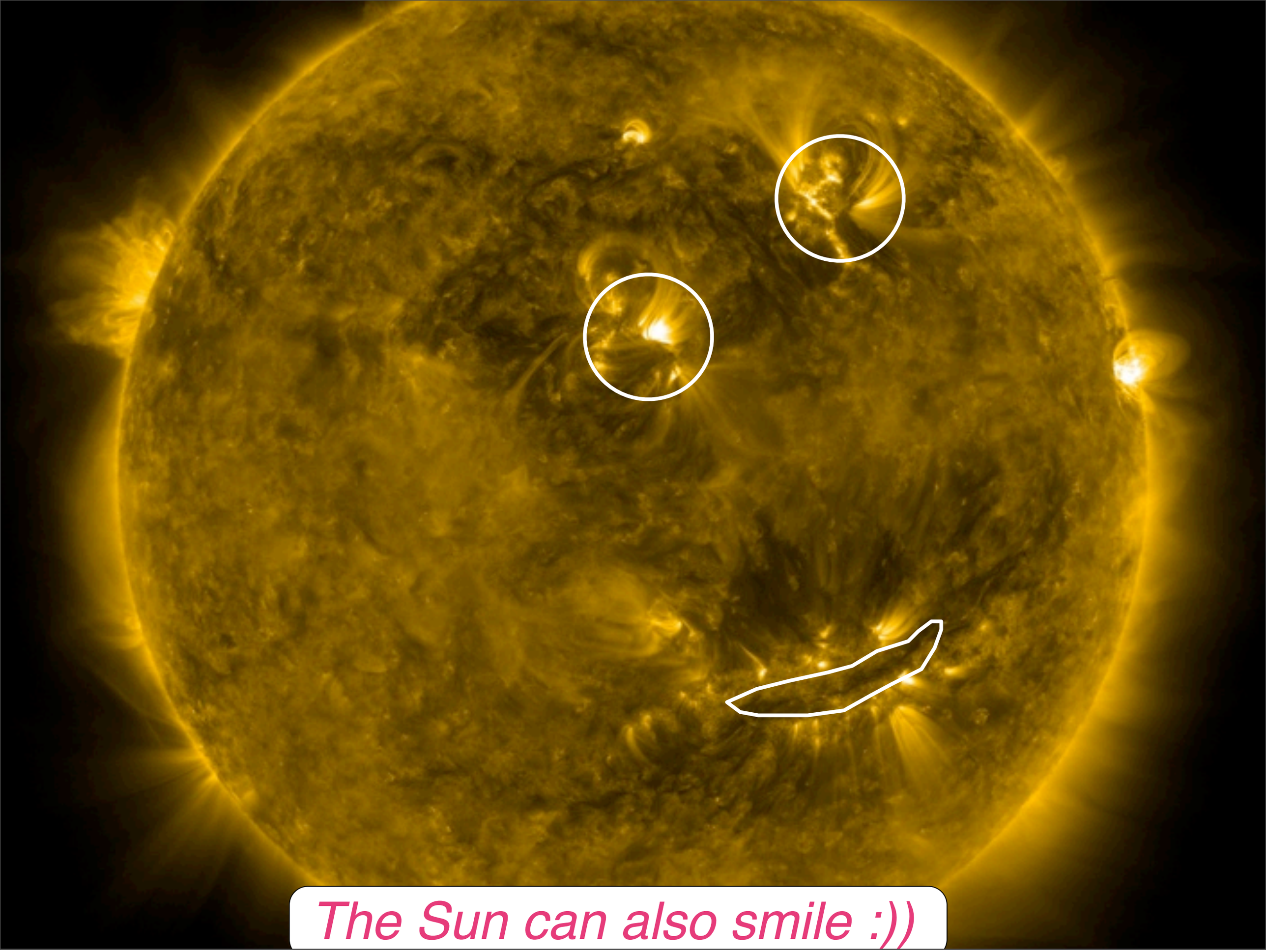
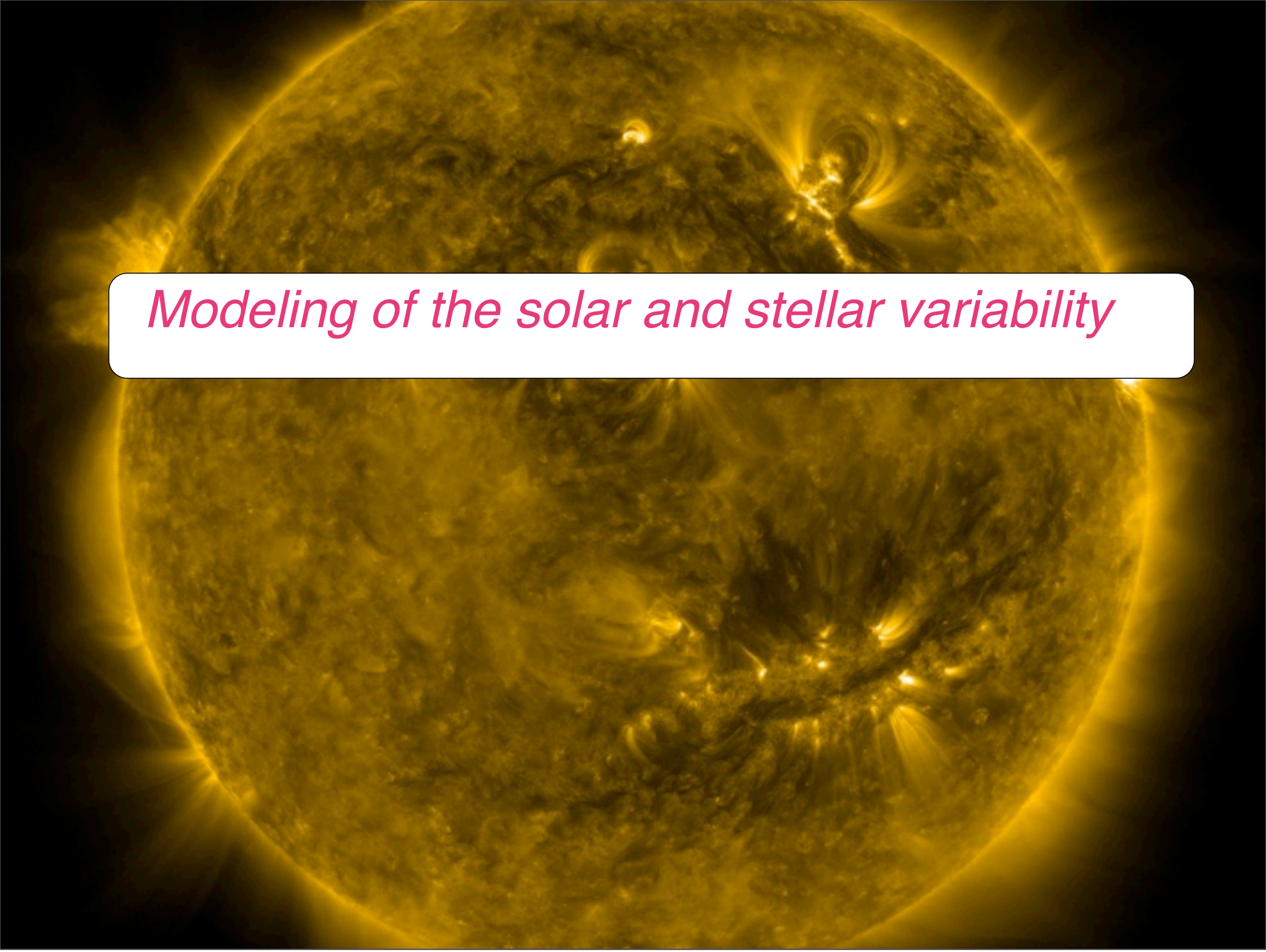
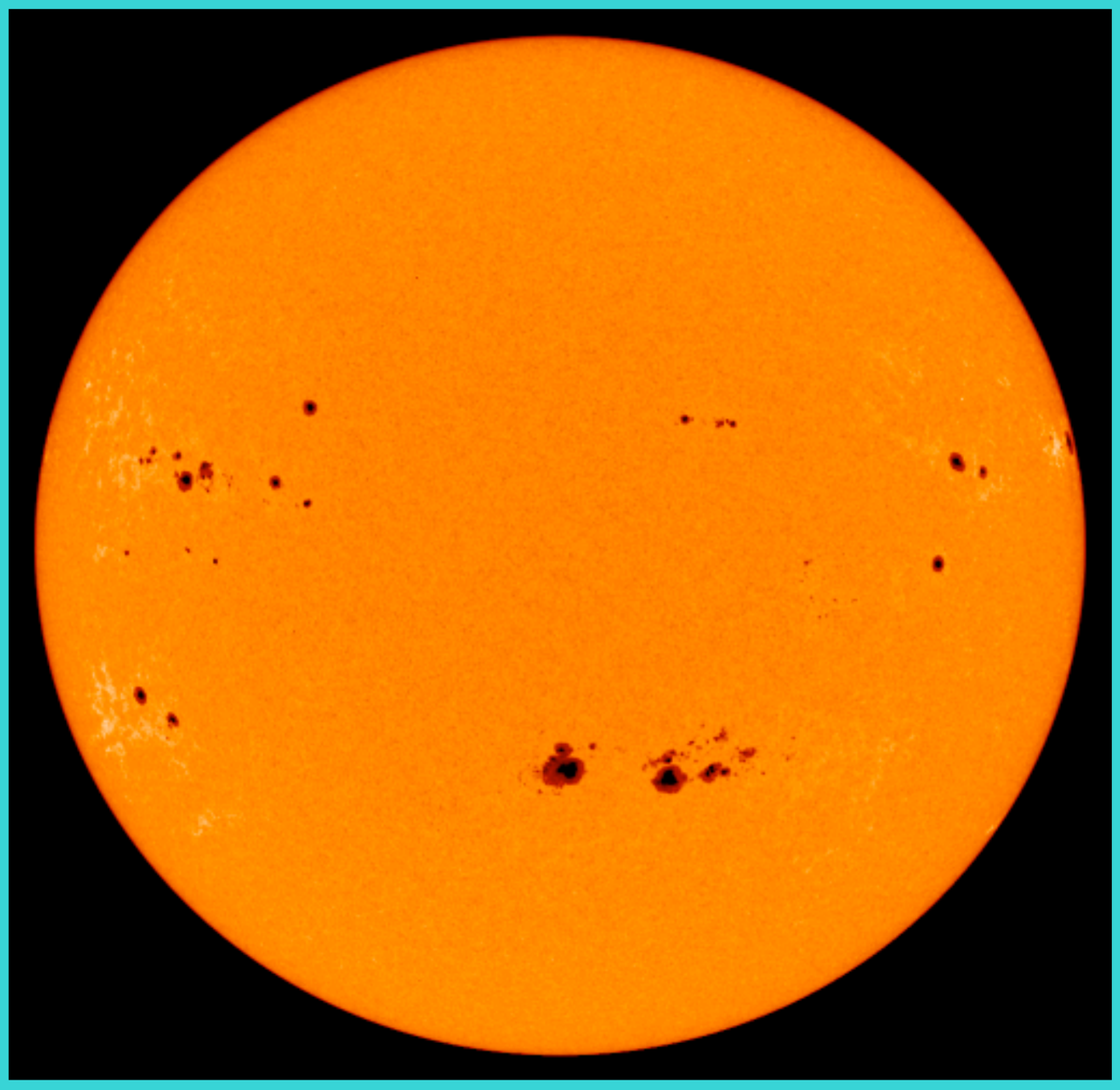

The Sun can also smile :))



Modeling of the solar and stellar variability

Main assumption. Variations in the solar irradiance are directly related to the evolution of surface magnetic flux



Sunspot Model S

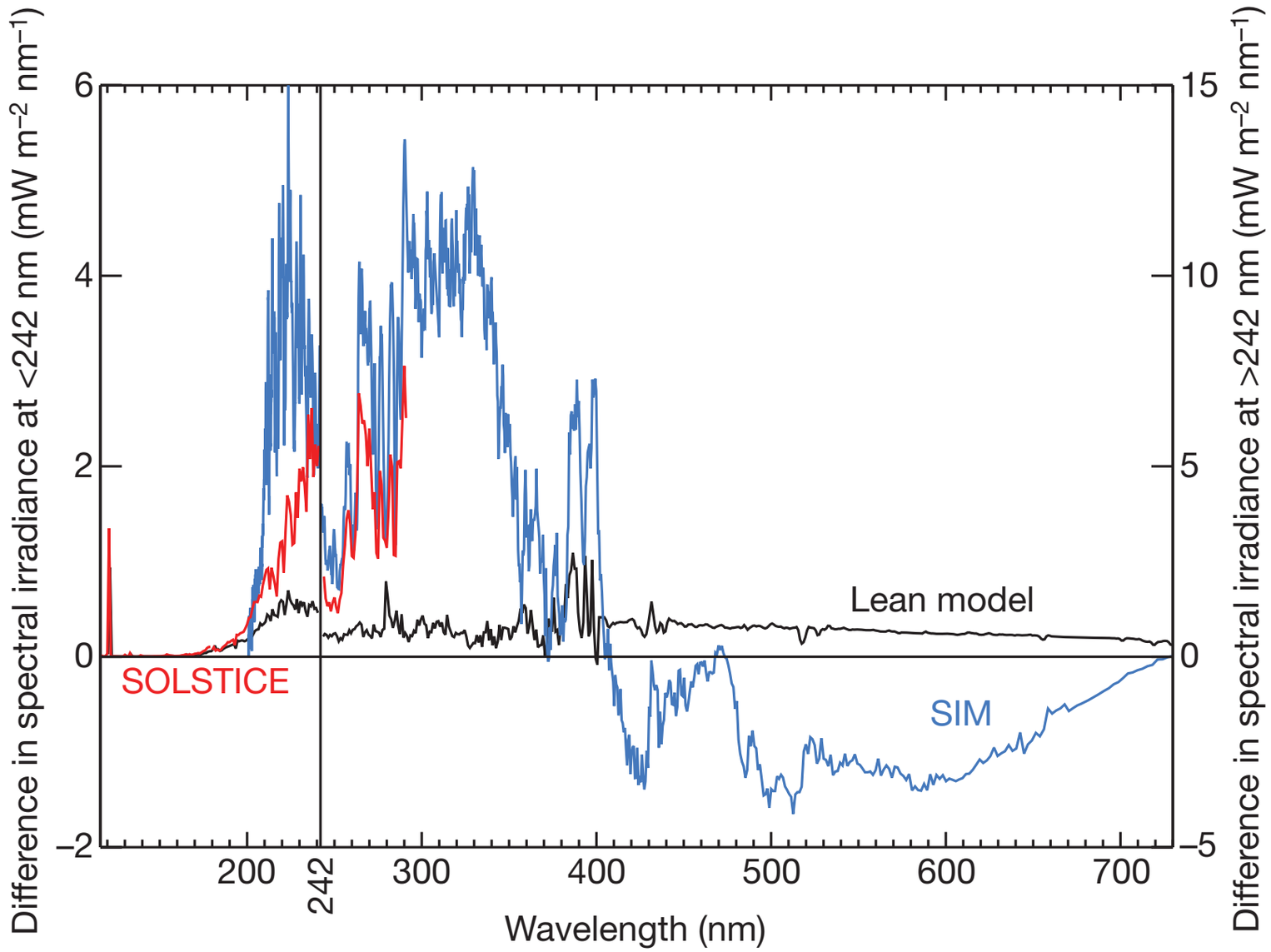
Plage Model P

Bright network Model F

Quiet Sun Model C

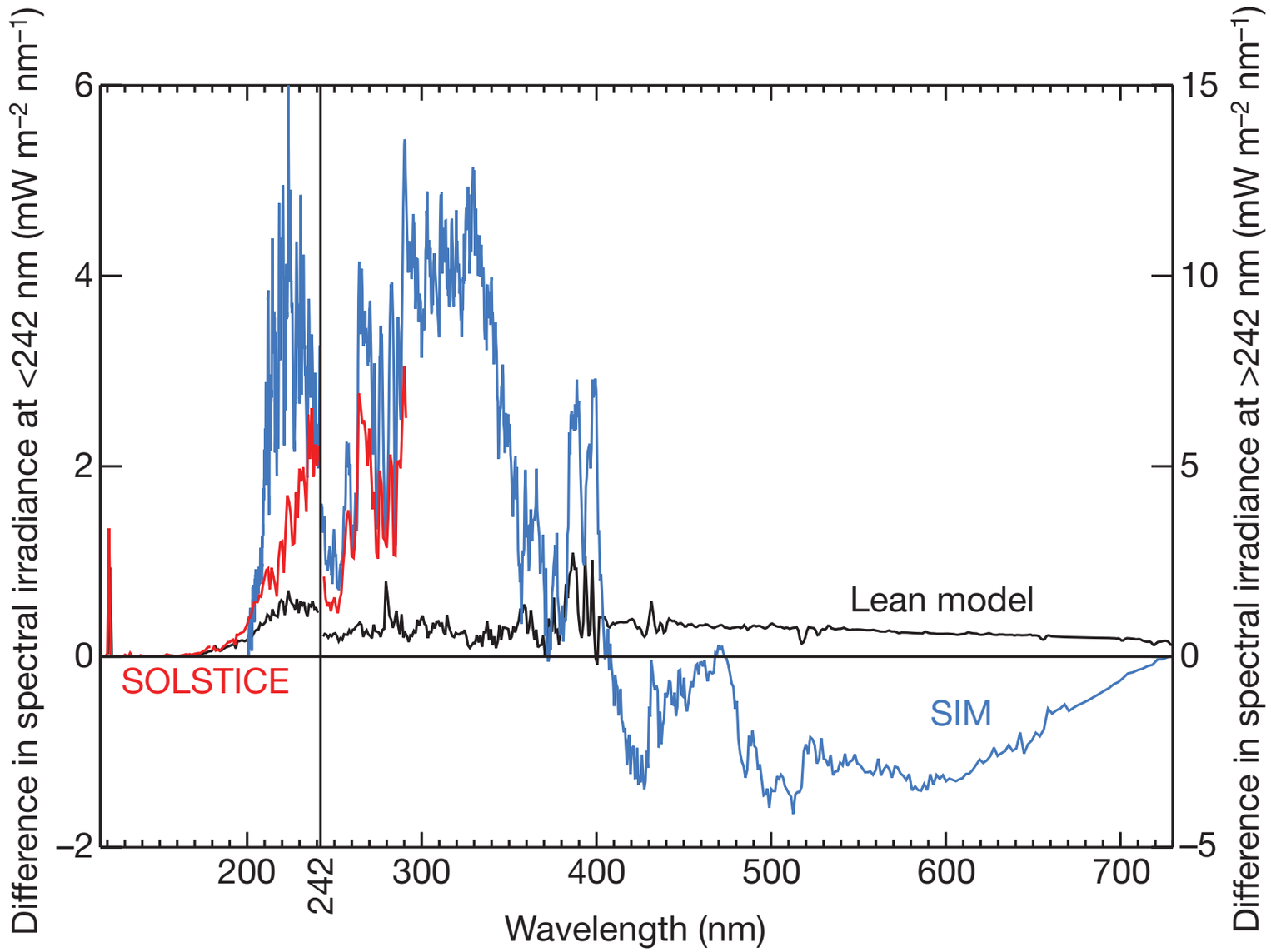
$$I(\lambda,t) = \sum_k (\alpha_{\rm QS}(\mu_k,t) I_{\rm QS}(\lambda,\mu_k) + \alpha_{\rm S}(\mu_k,t) I_{\rm S}(\lambda,\mu_k) +$$
$$+ \alpha_{\rm AN}(\mu_k,t) I_{\rm AN}(\lambda,\mu_k) + \alpha_{\rm P}(\mu_k,t) I_{\rm P}(\lambda,\mu_k)) ,$$

Spectral profile of variability



$$I(\lambda,t) = \sum_k \left(\alpha_{\mathrm{QS}}(\mu_k,t) I_{\mathrm{QS}}(\lambda,\mu_k) + \alpha_{\mathrm{S}}(\mu_k,t) I_{\mathrm{S}}(\lambda,\mu_k) + \right.$$
$$\left. + \alpha_{\mathrm{AN}}(\mu_k,t) I_{\mathrm{AN}}(\lambda,\mu_k) + \alpha_{\mathrm{P}}(\mu_k,t) I_{\mathrm{P}}(\lambda,\mu_k)\right),$$

Spectral profile of variability



$$I(\lambda,t) = \sum_k (\alpha_{\mathrm{QS}}(\mu_k,t) I_{\mathrm{QS}}(\lambda,\mu_k) + \alpha_{\mathrm{S}}(\mu_k,t) I_{\mathrm{S}}(\lambda,\mu_k) +$$
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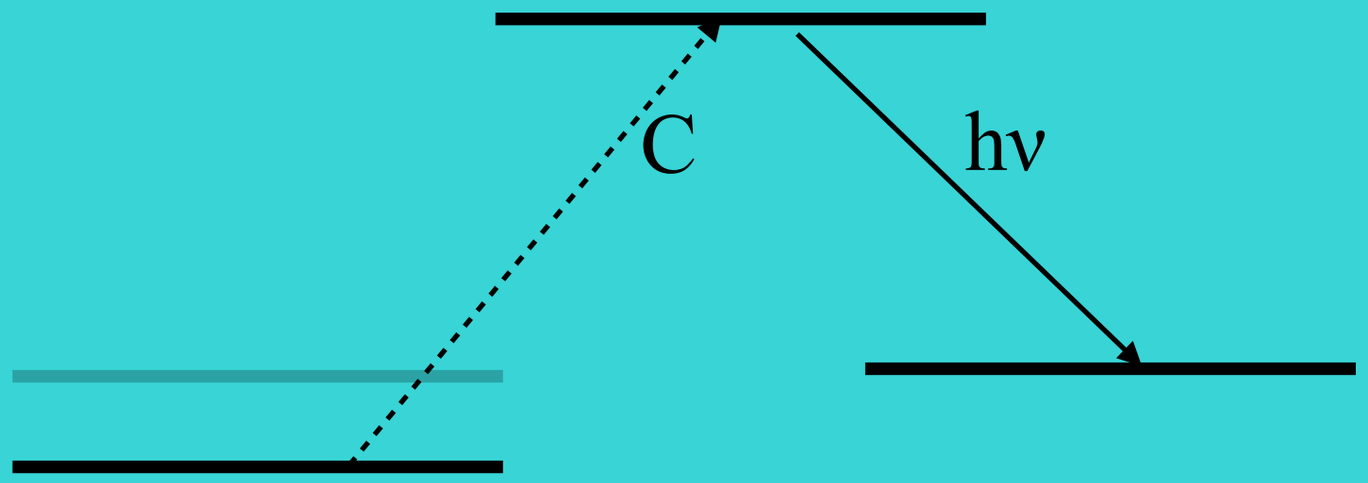
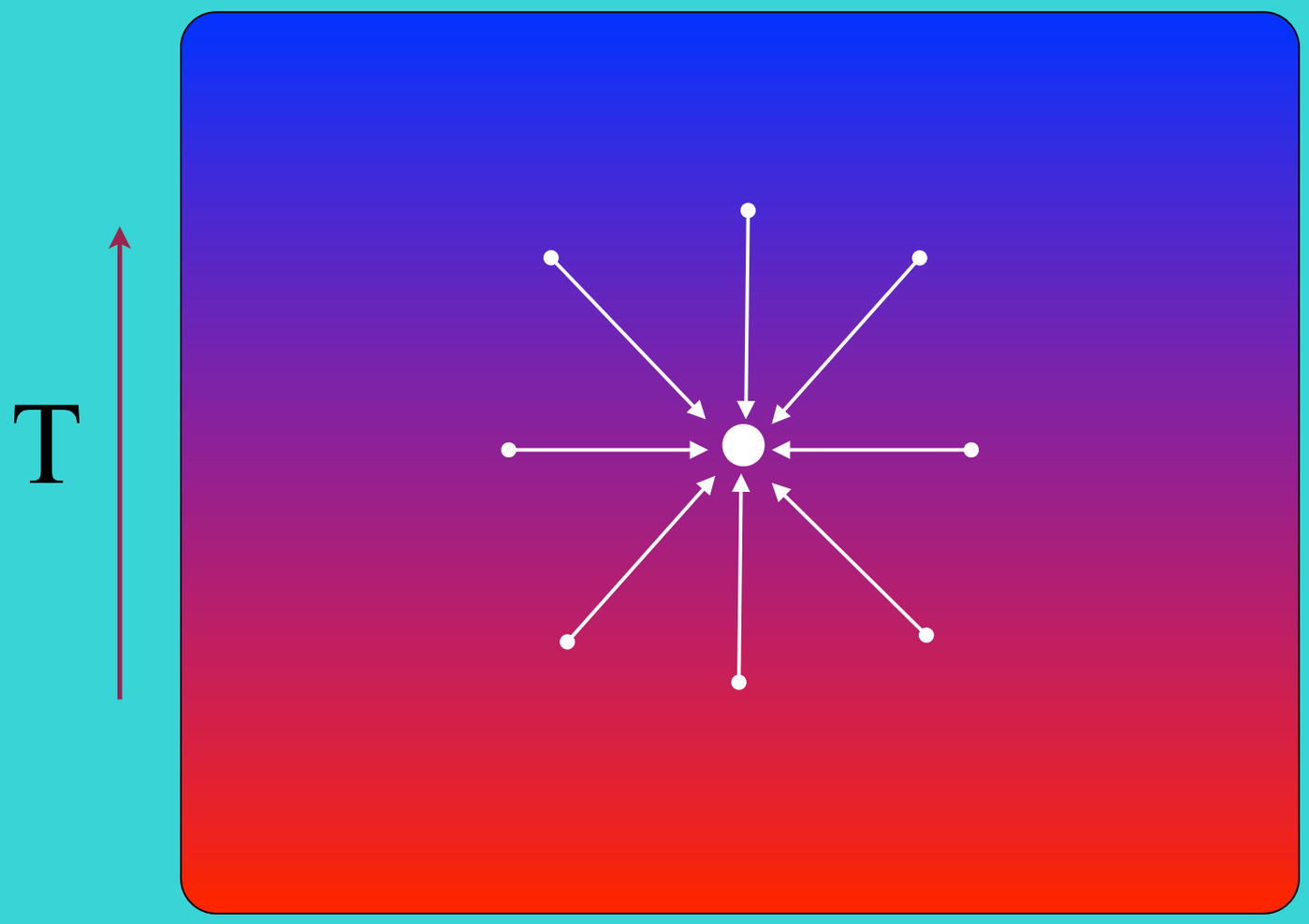
Calculations of the solar spectrum

Millions of atomic and molecular transitions

Non-local thermodynamic equilibrium

Non Local Thermodynamic Equilibrium (NLTE)



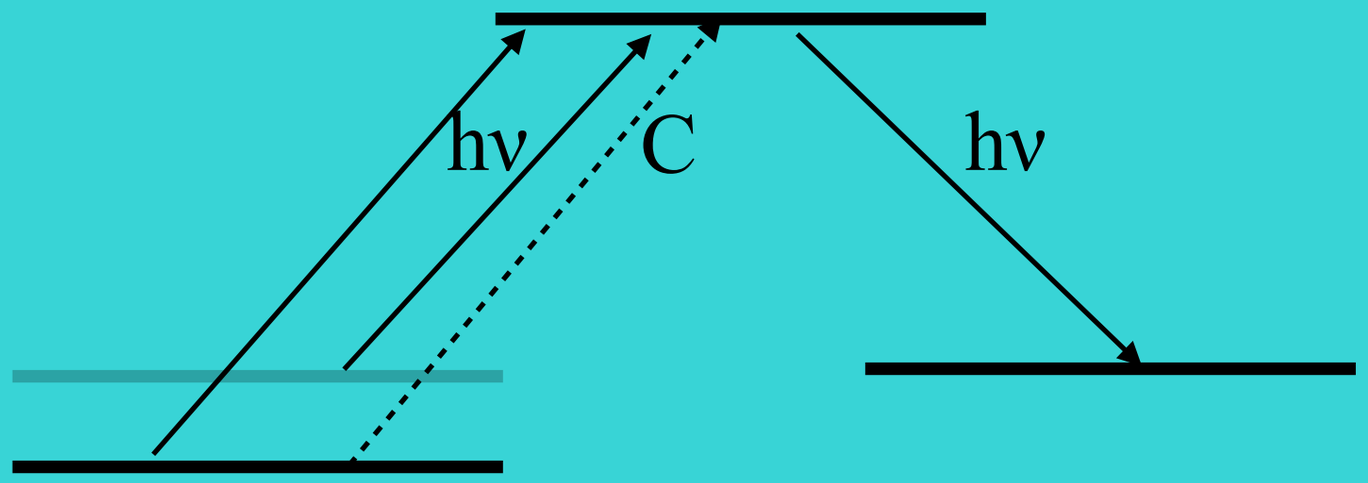


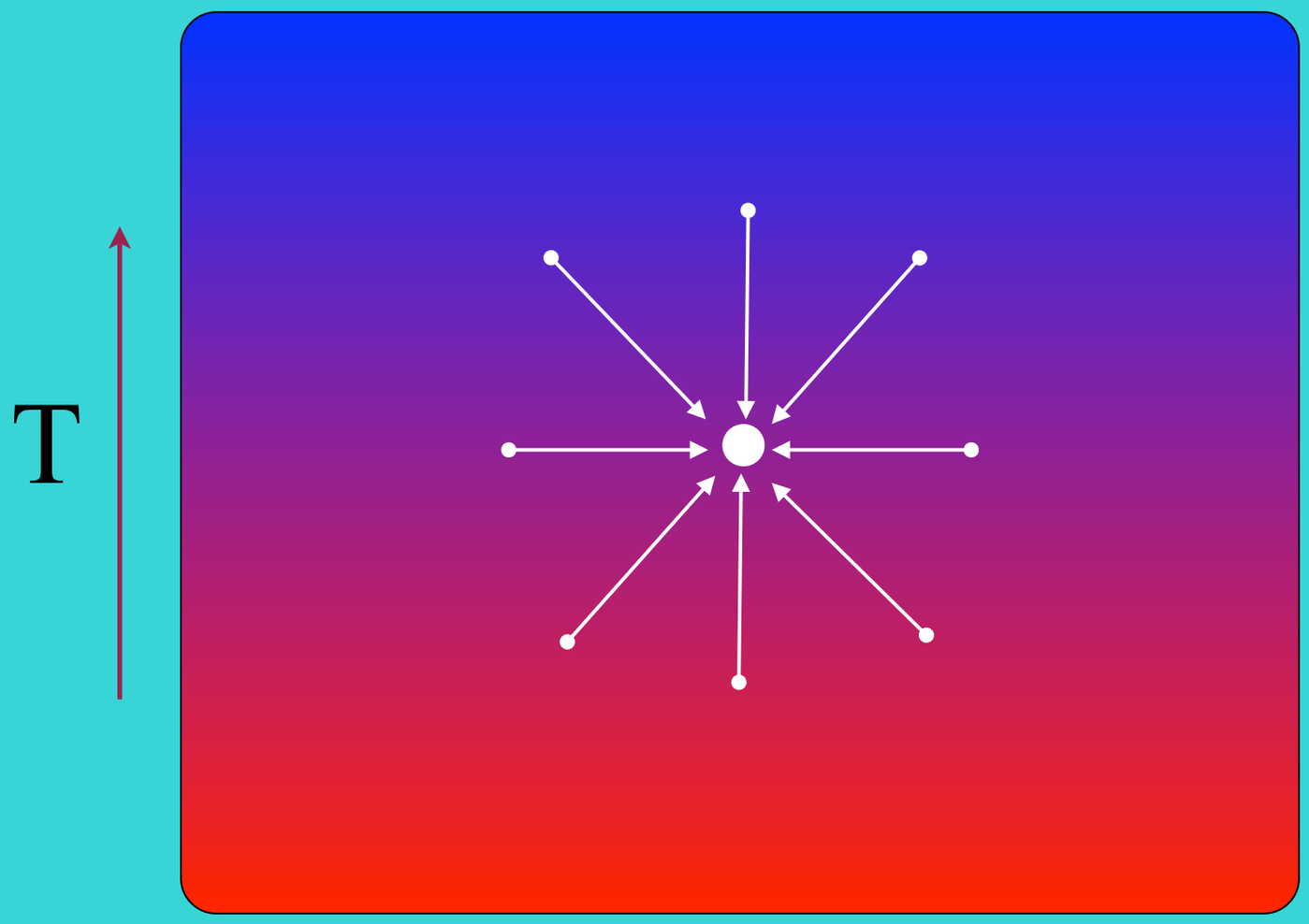
Maxwell-Boltzmann distribution

Saha ionization equation

Source function obeys the Planck's law

Non Local Thermodynamic Equilibrium (NLTE)





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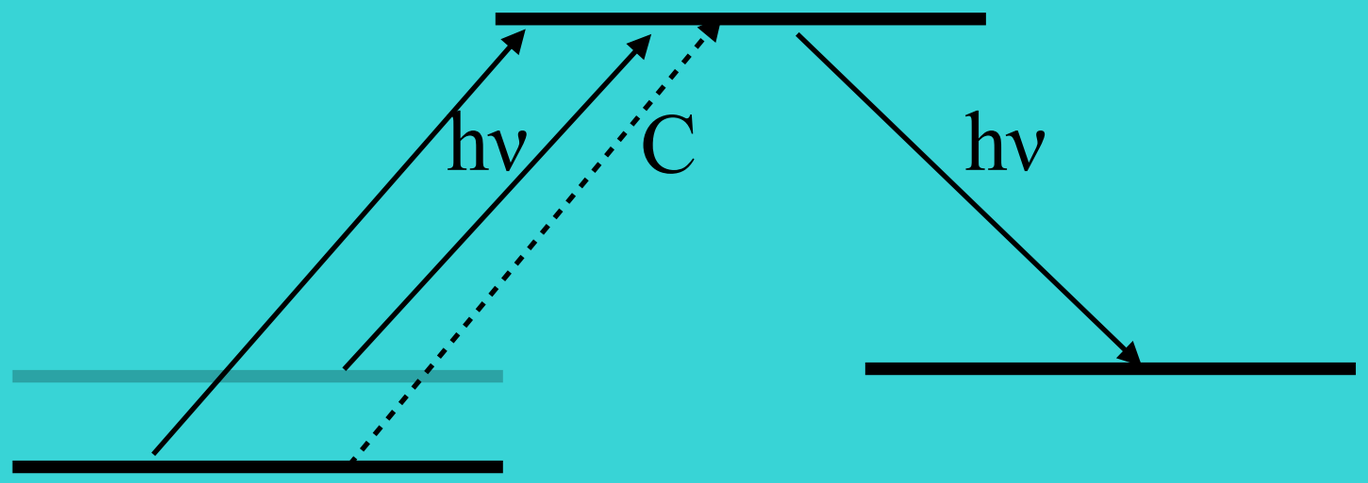
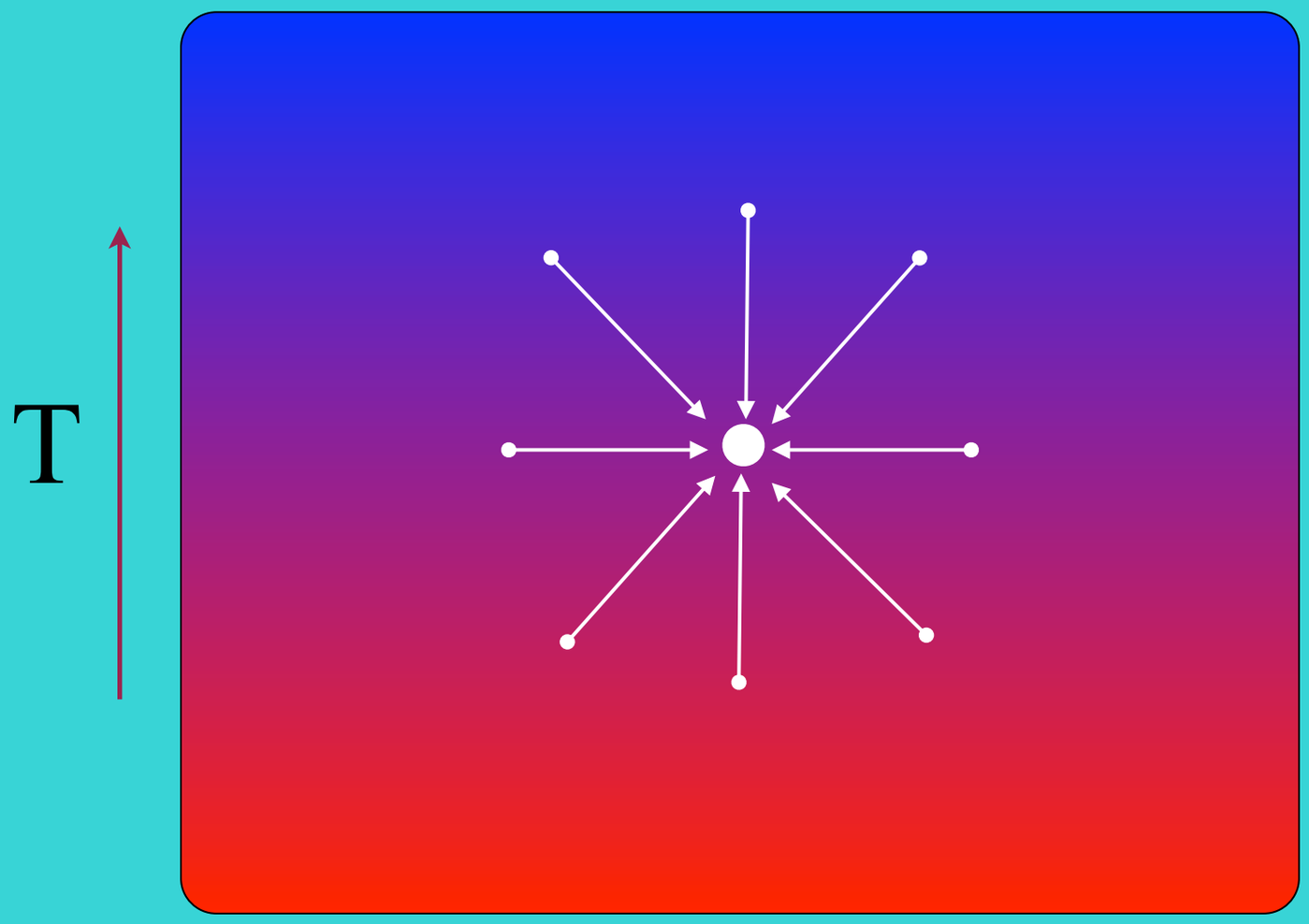


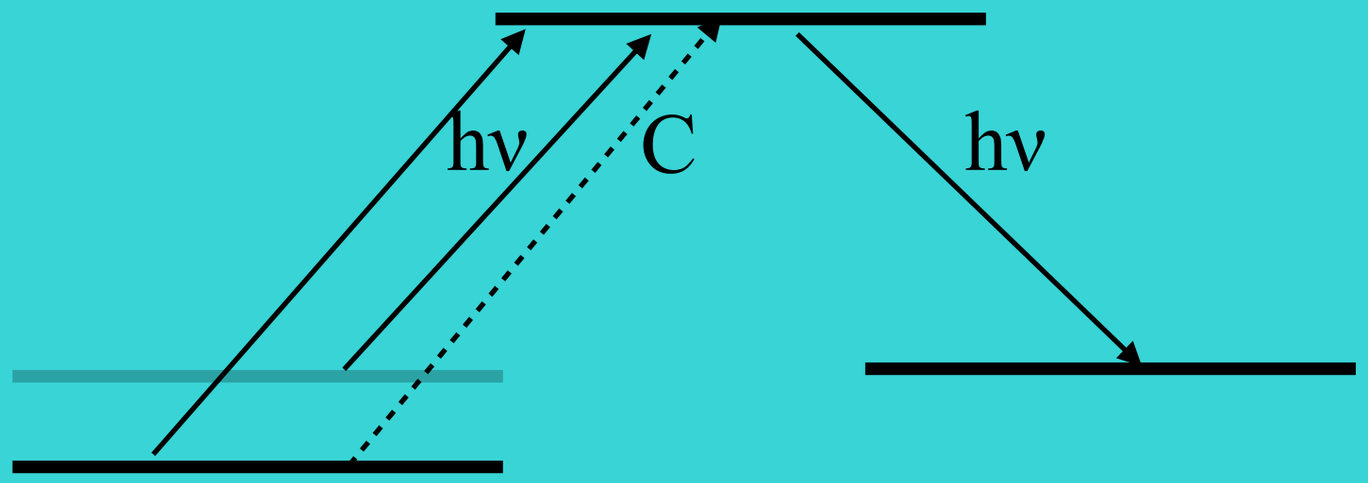


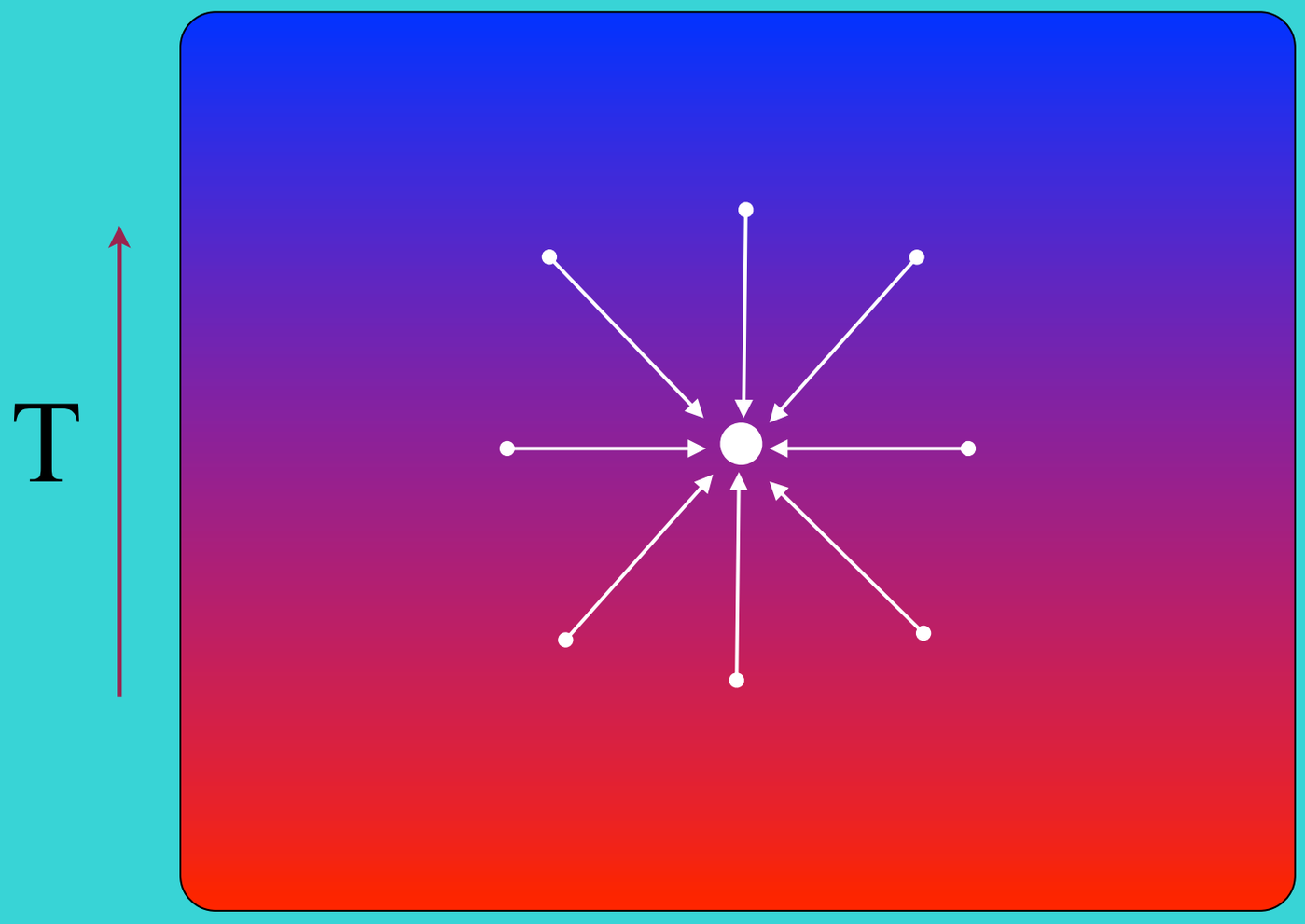
~~Maxwell-Boltzmann~~ distribution

~~Saha ionization equation~~

~~Source function obeys the Planck's law~~

Non Local Thermodynamic Equilibrium (NLTE)





Maxwell-~~Boltzmann~~
distribution

Statistical
Equilibrium
Equations

The COSI code

COde for Solar Irradiance

NLTE Model Atmosphere Code

$\sim 10^2$ levels

Spectrum Synthesis Program

$\sim 10^7$ lines

The COSI code

COde for Solar Irradiance

Populations of the NLTE Levels

NLTE Model Atmosphere Code

$\sim 10^2$ levels

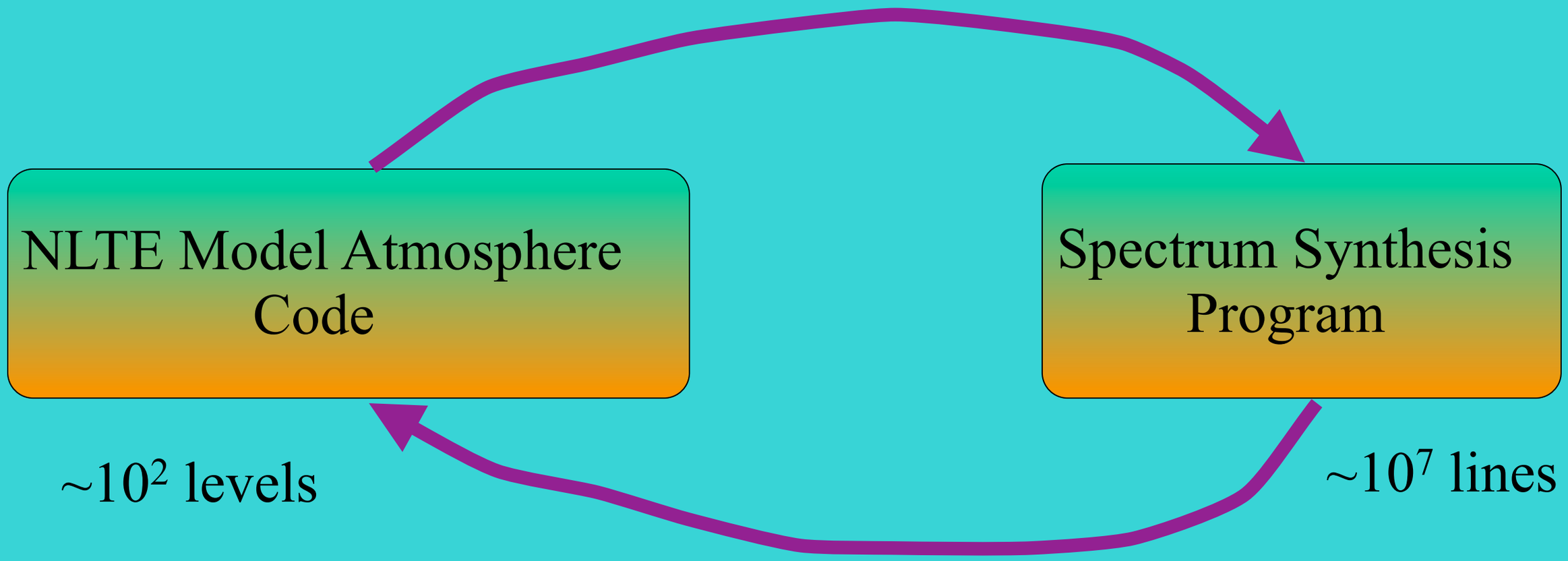
Spectrum Synthesis Program

$\sim 10^7$ lines

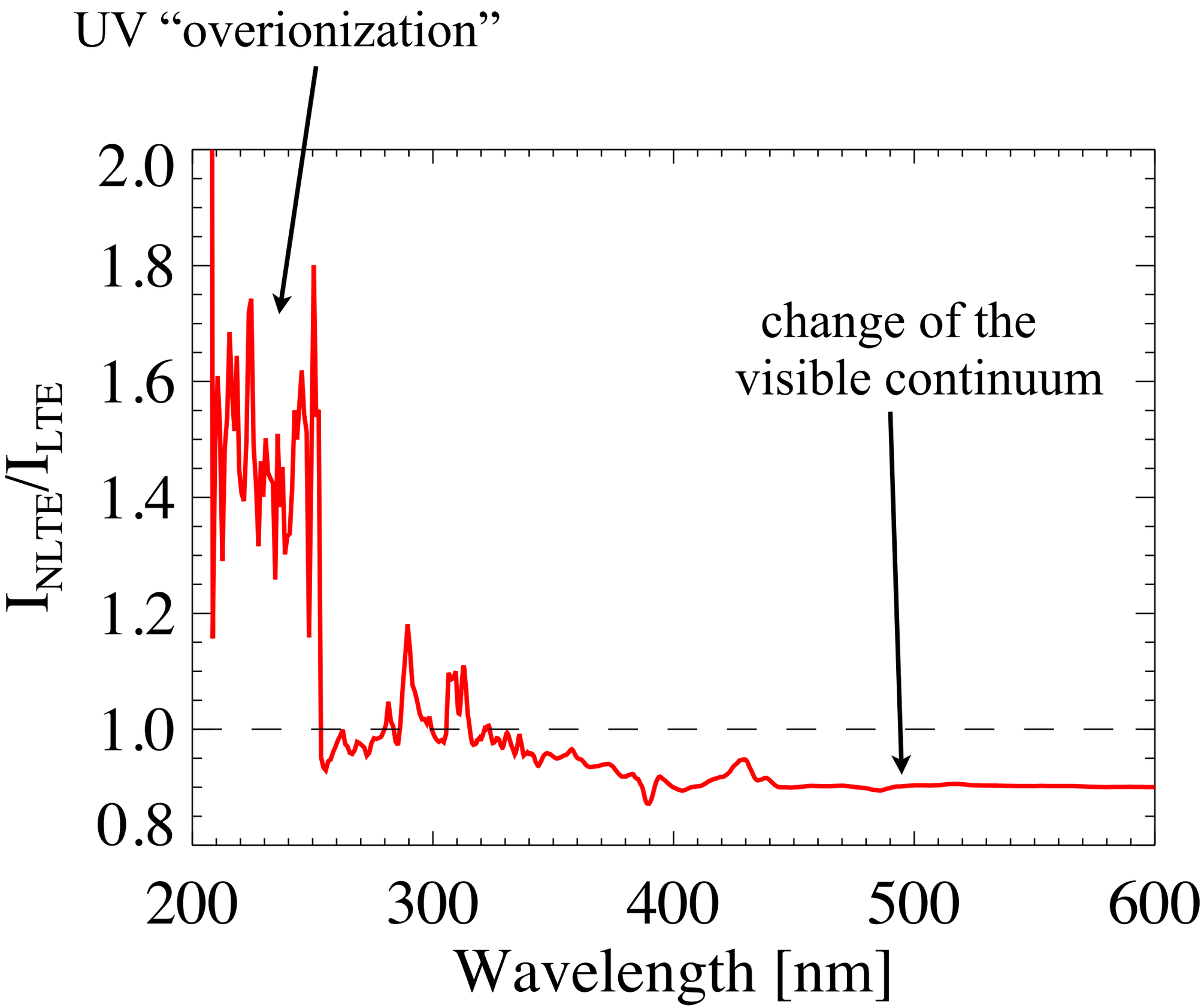
The COSI code

COde for Solar Irradiance

Populations of the NLTE Levels



NLTE effects



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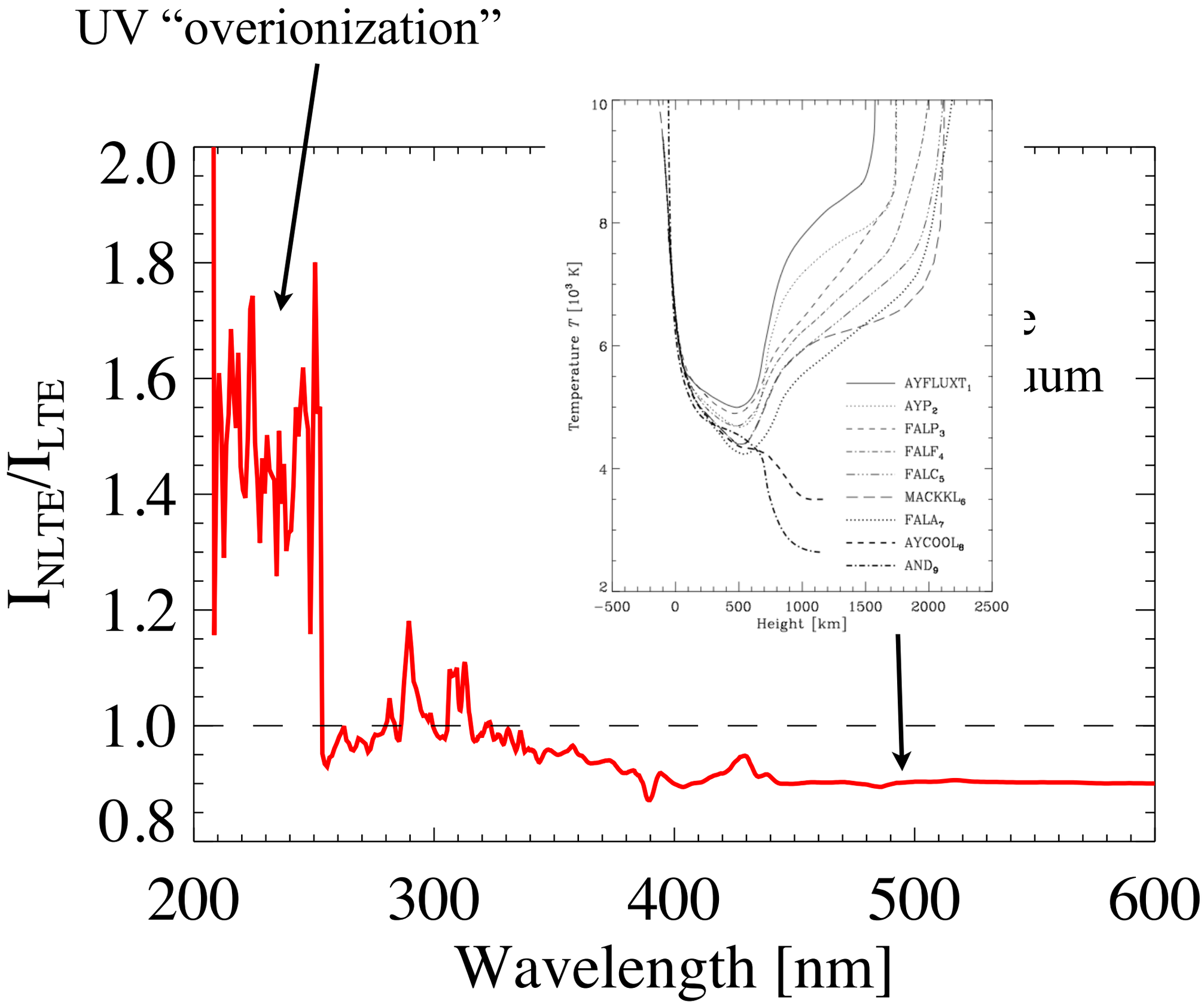

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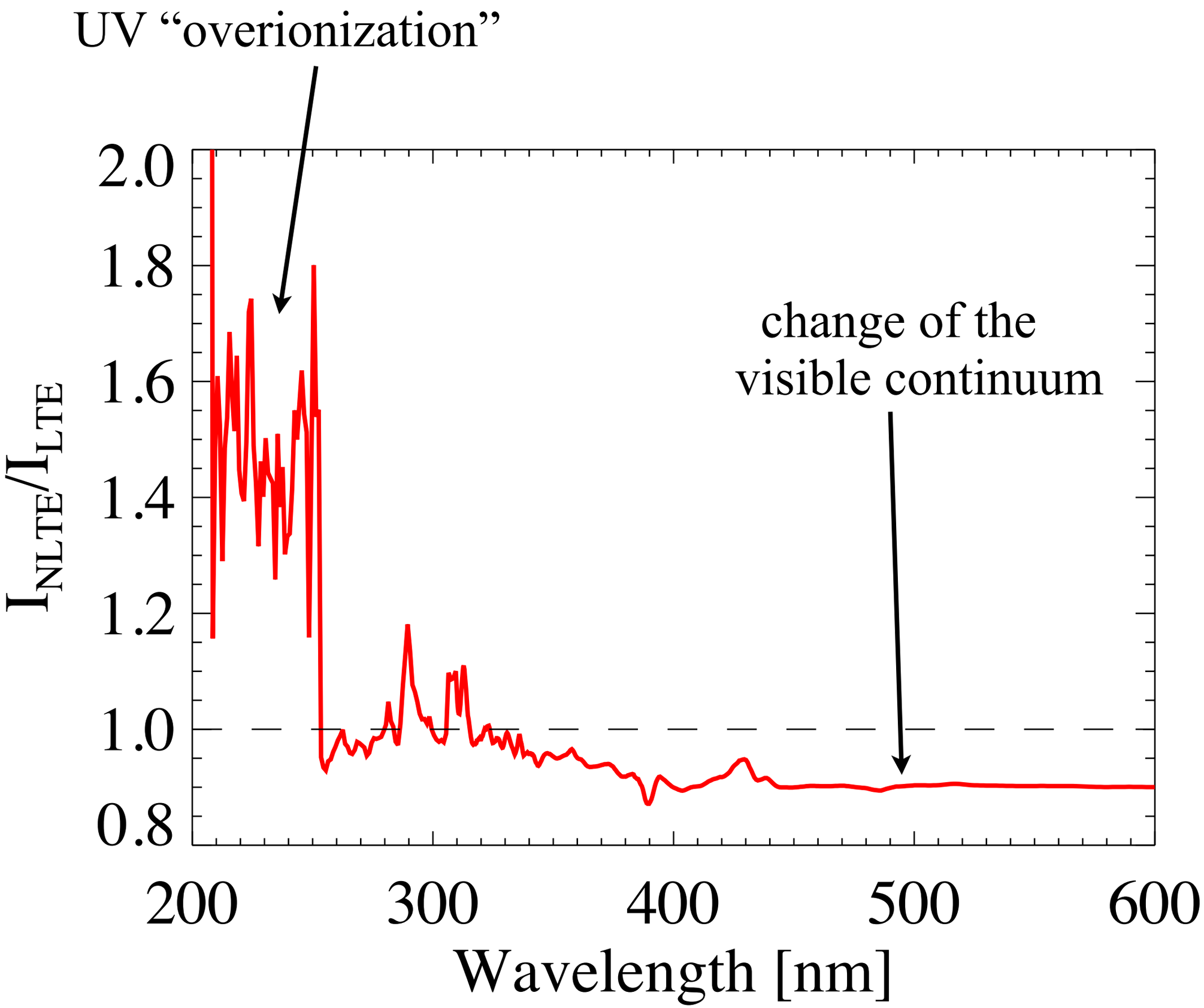
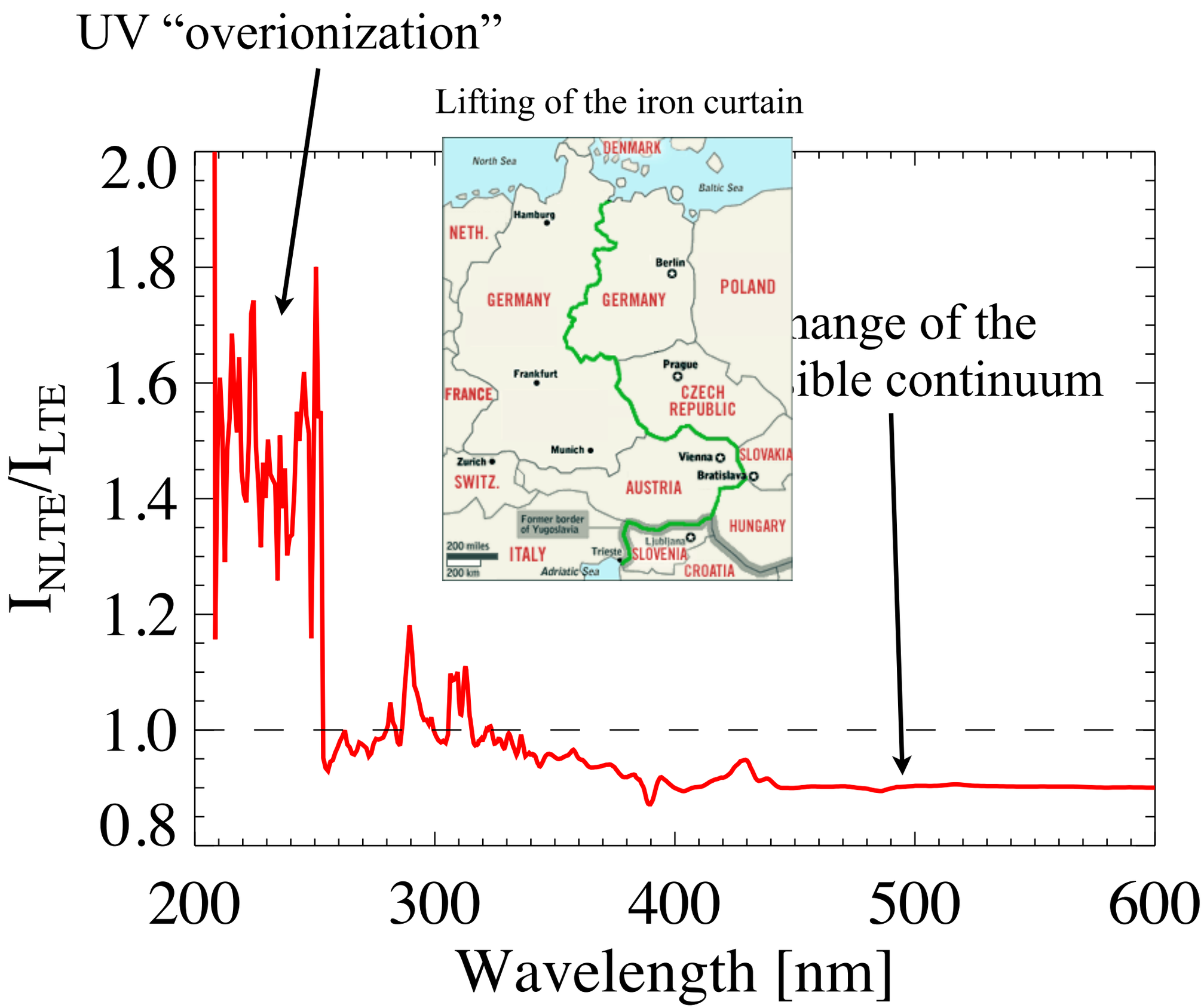
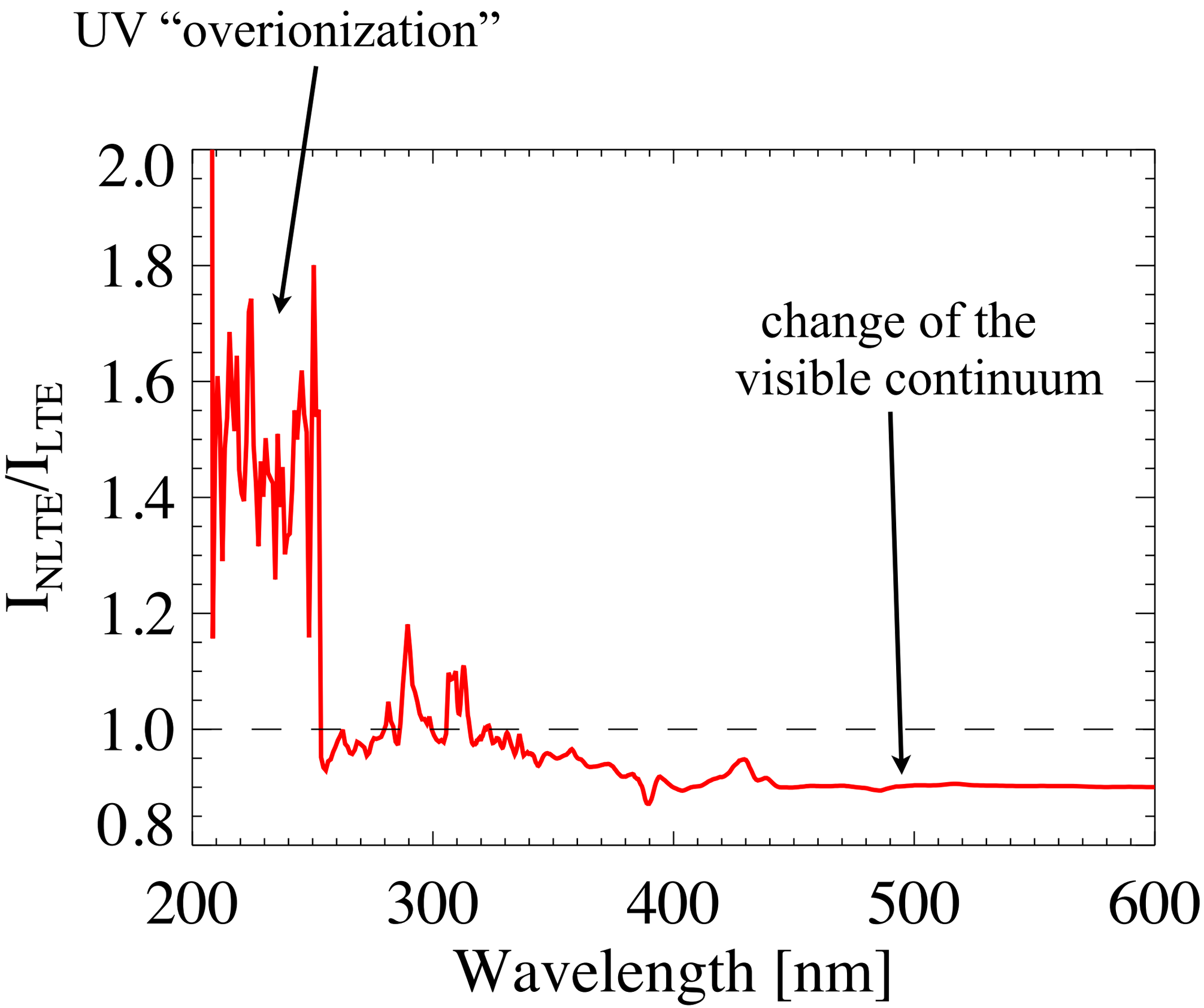


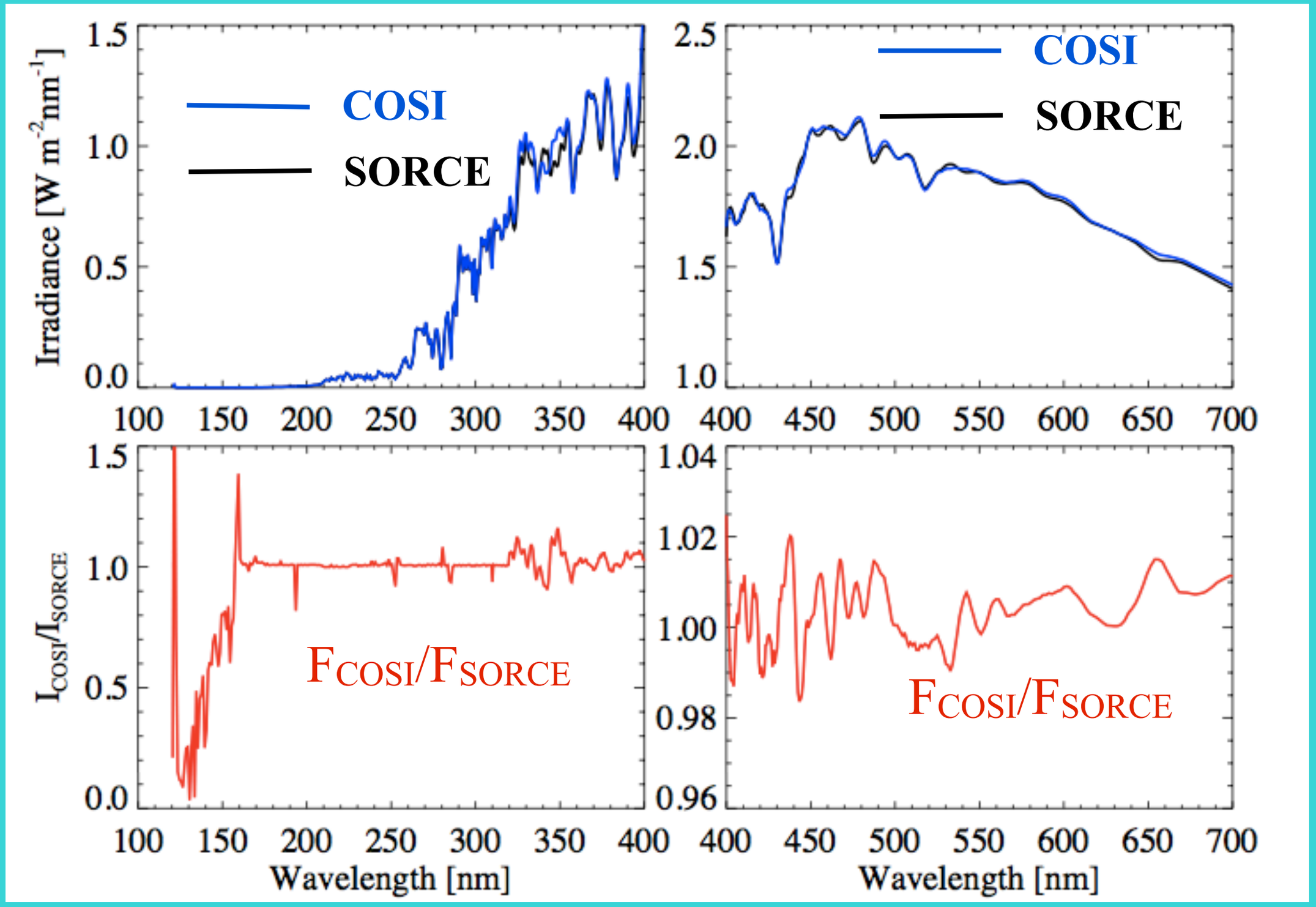
NLTE effects



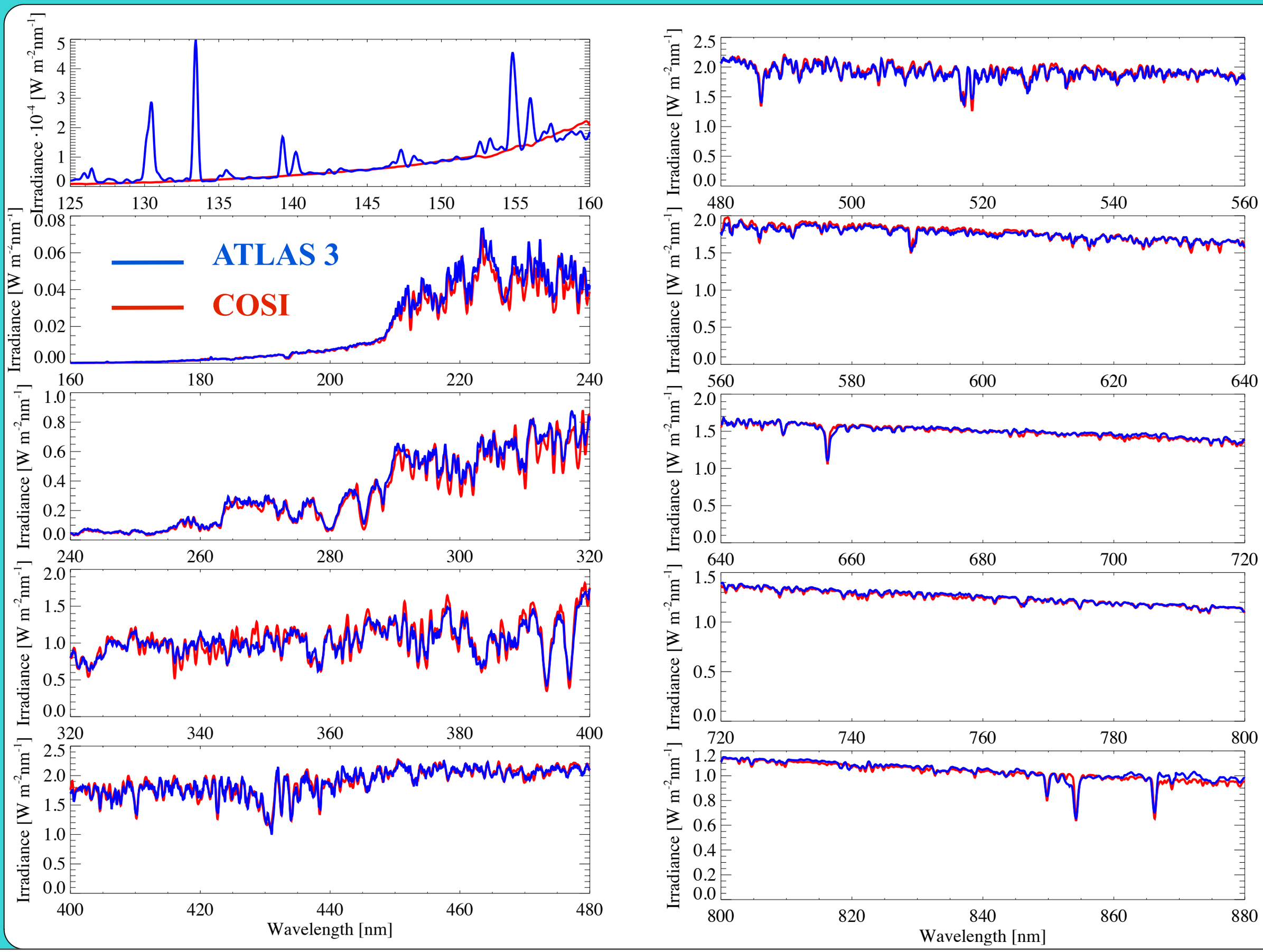
NLTE effects



Comparison with SORCE



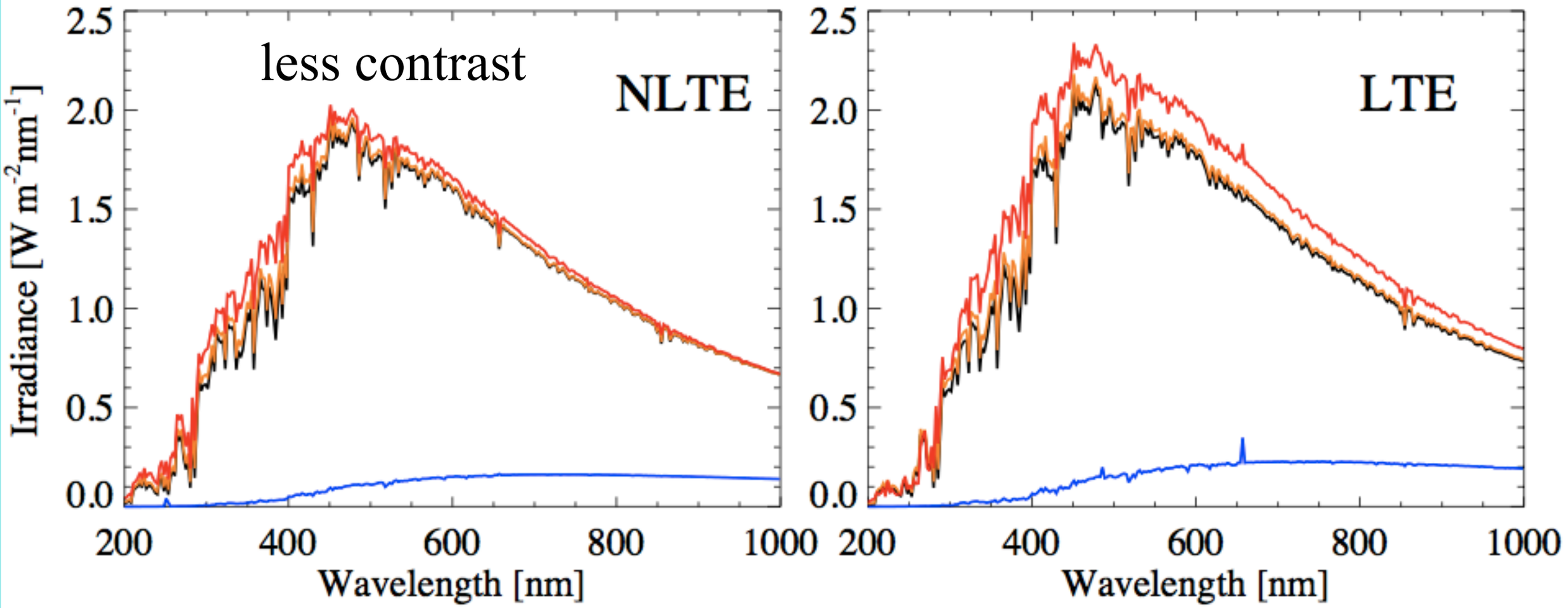
Comparison with ATLAS 3



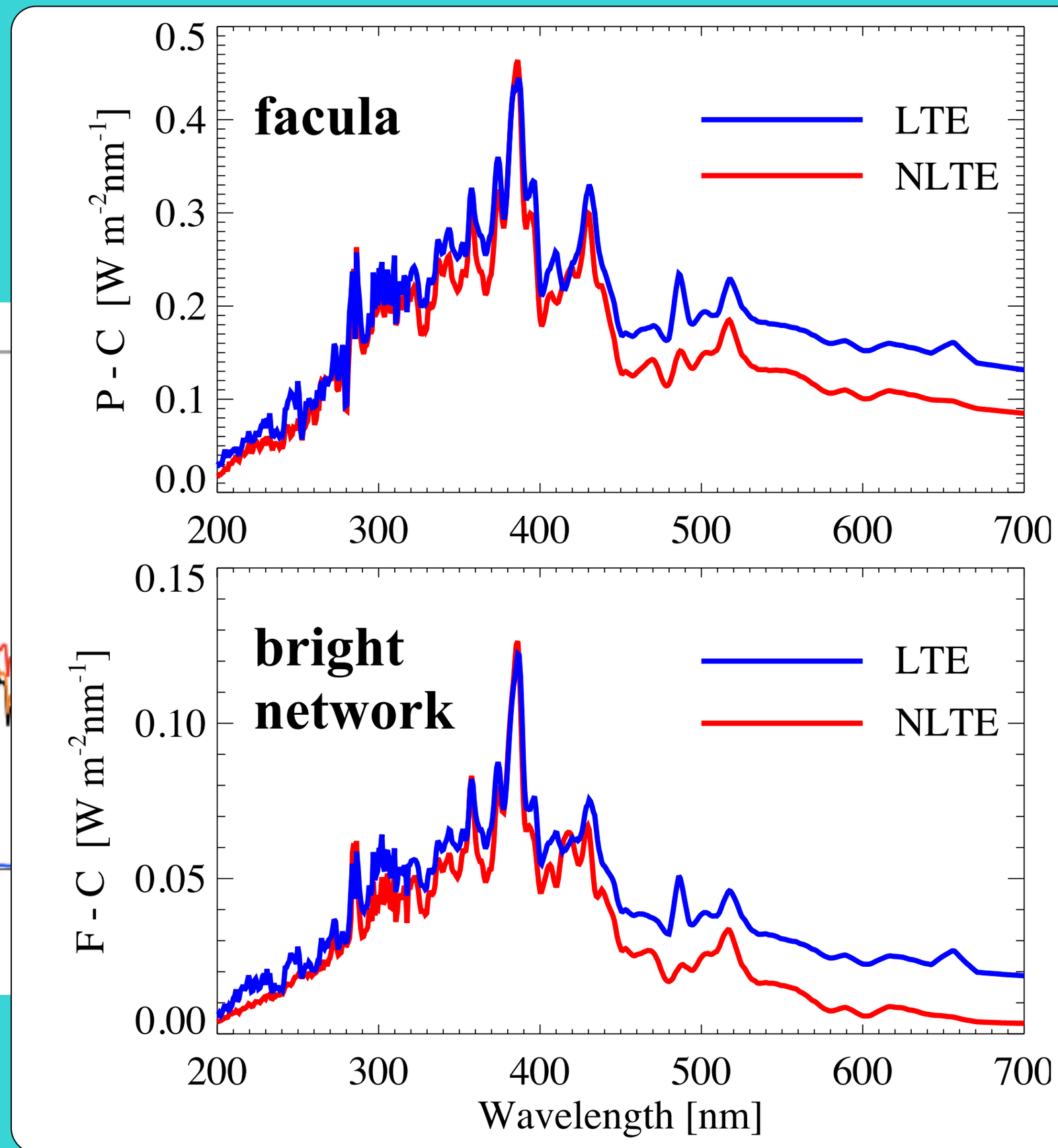
Irradiance from active components

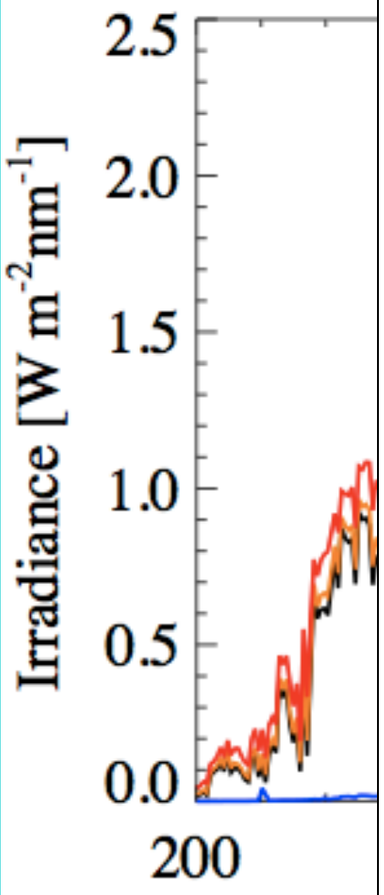
Plage **Quiet Sun**

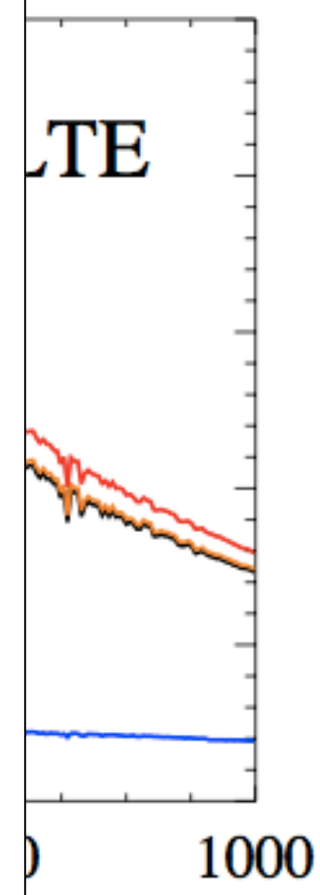
Bright network **Sunspot**



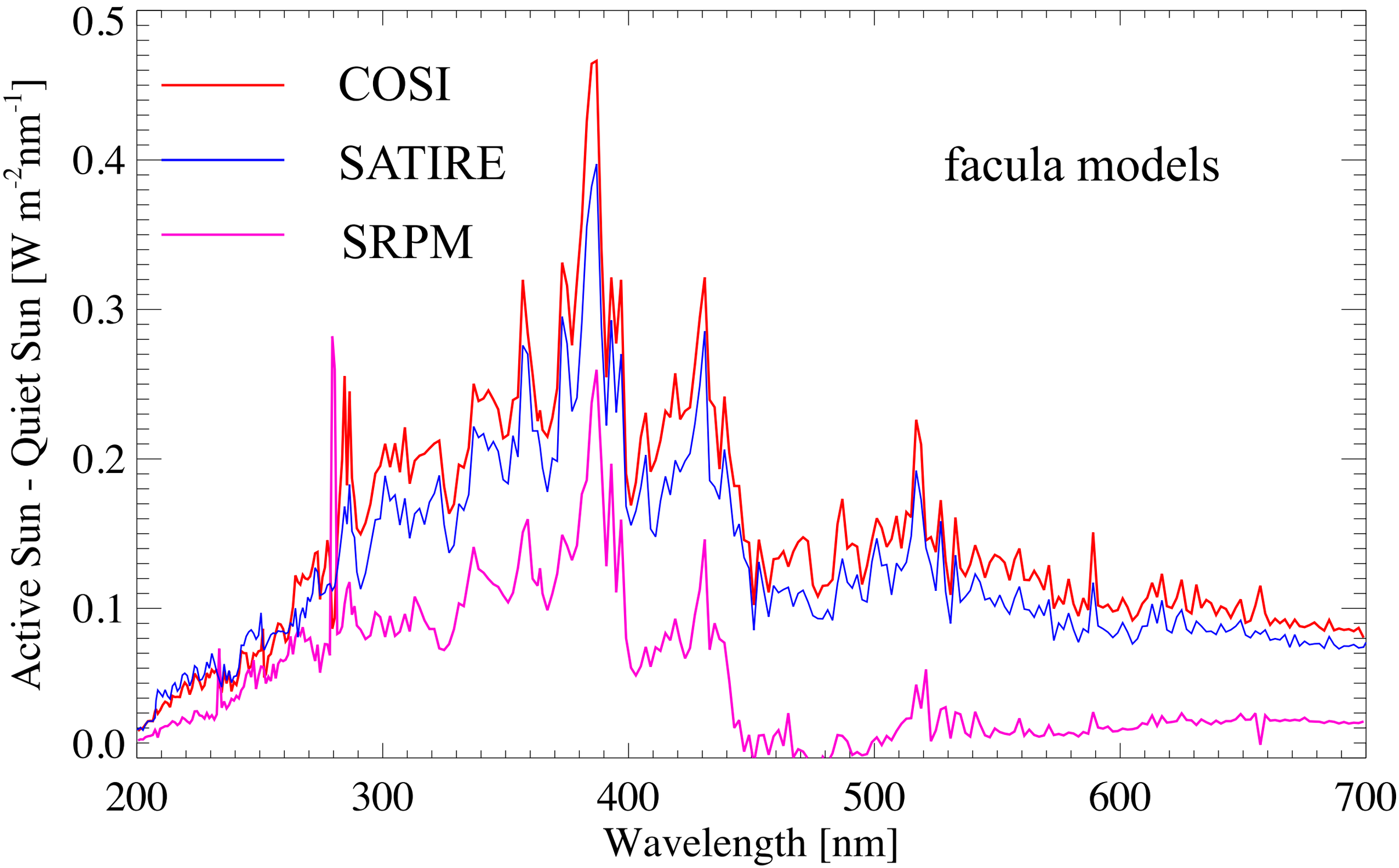
Irradiance from active components





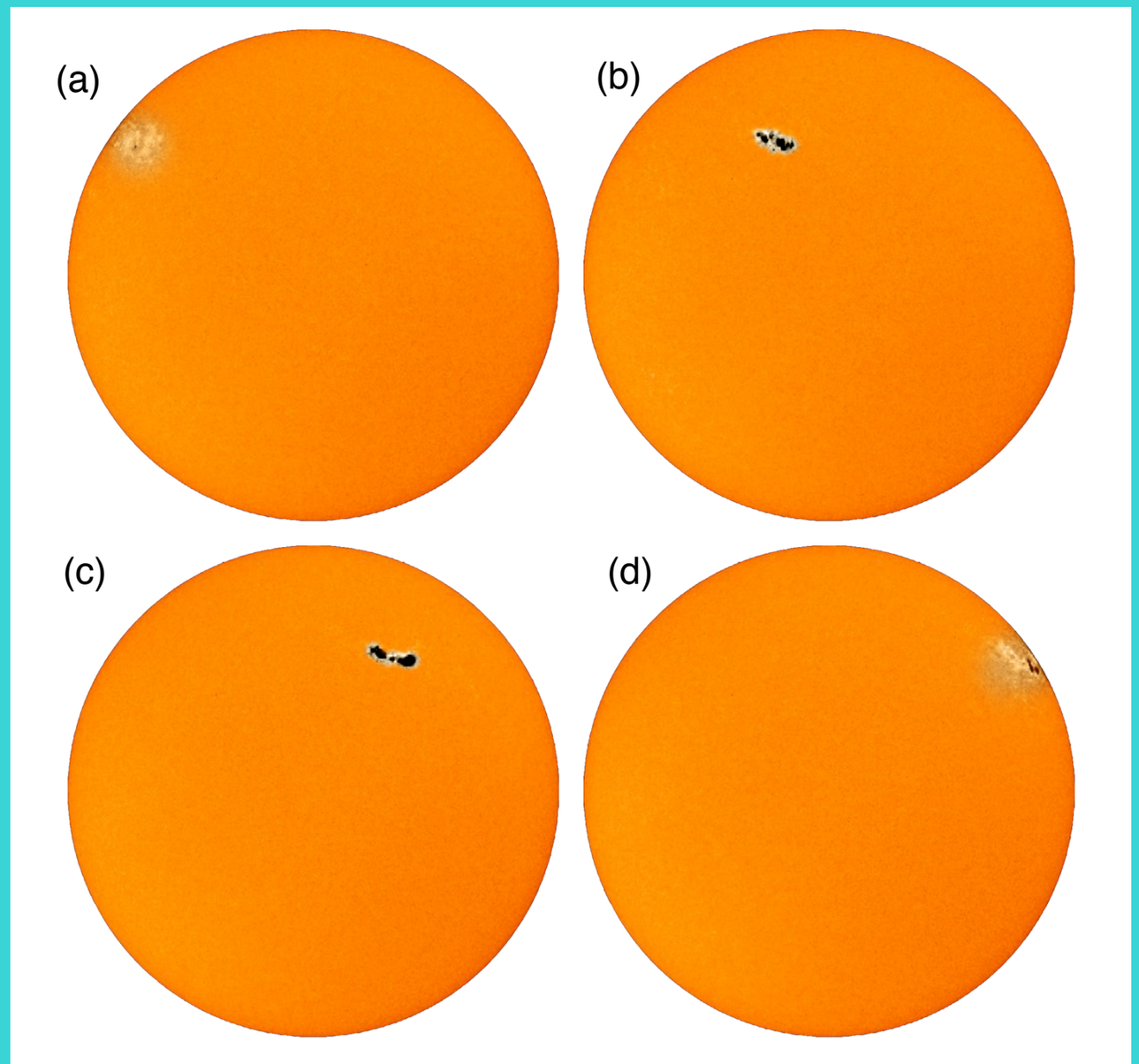


Irradiance from active components



Center-to-limb variations of the solar brightness

Important for the modeling of the solar variability



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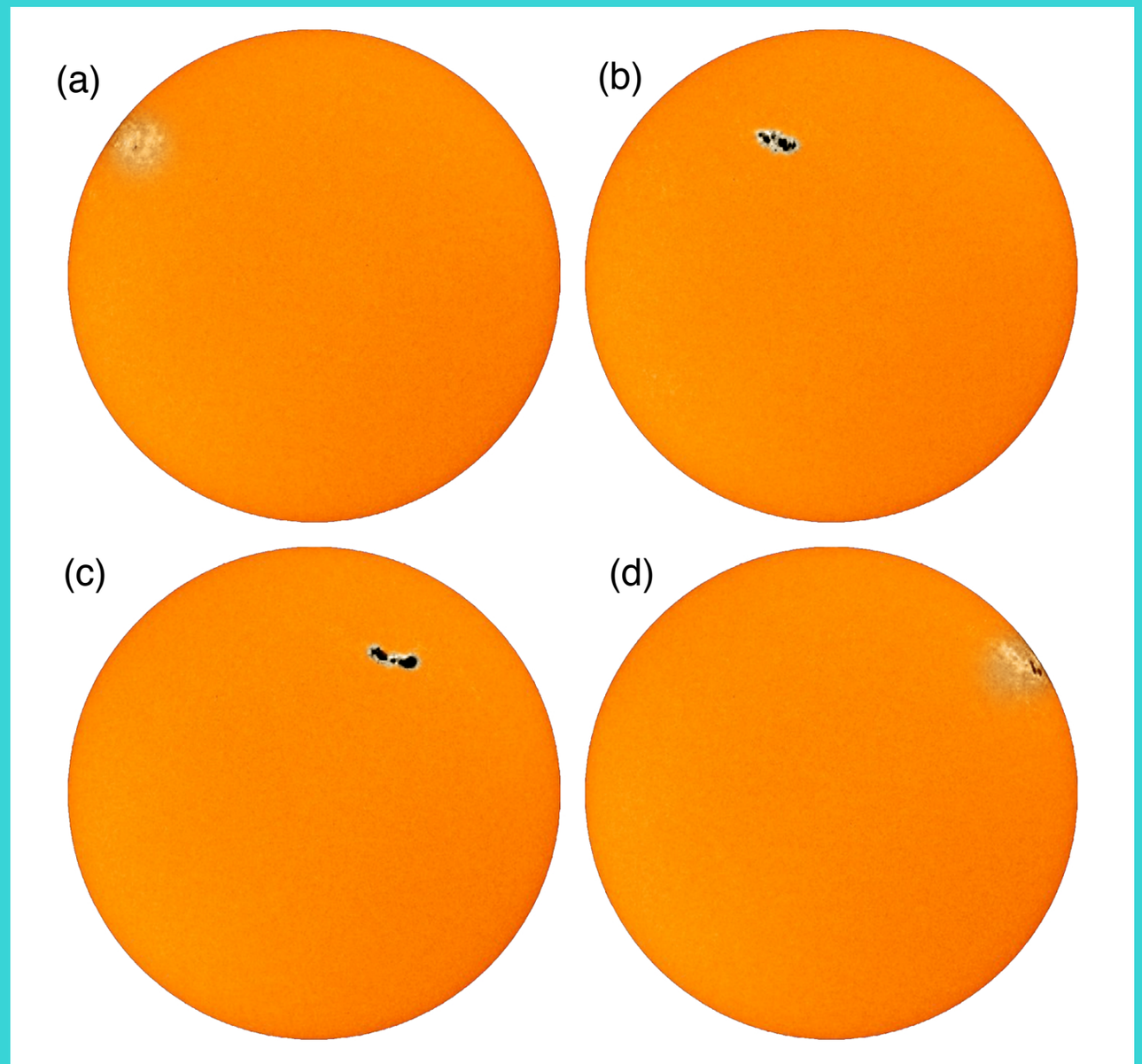
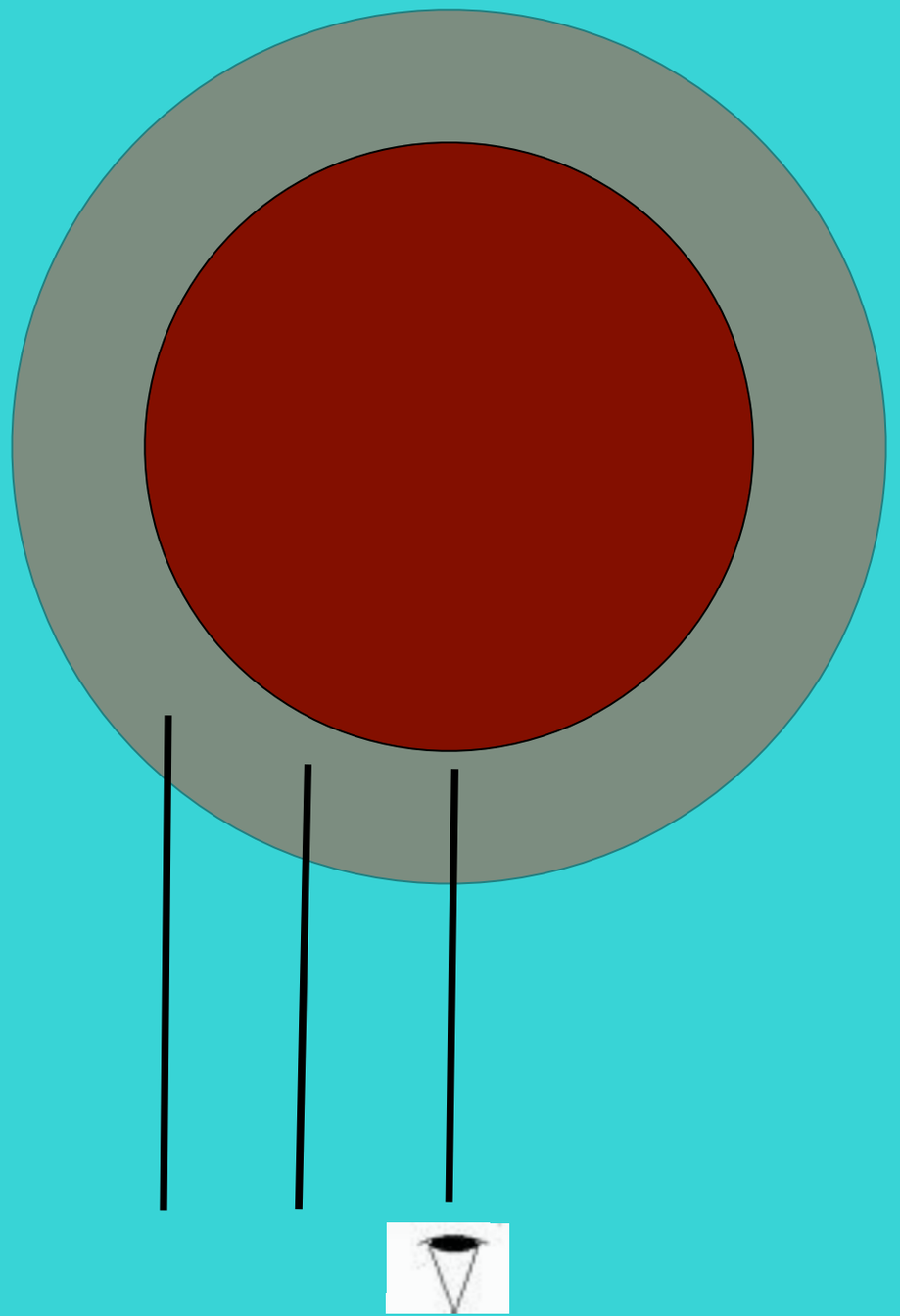
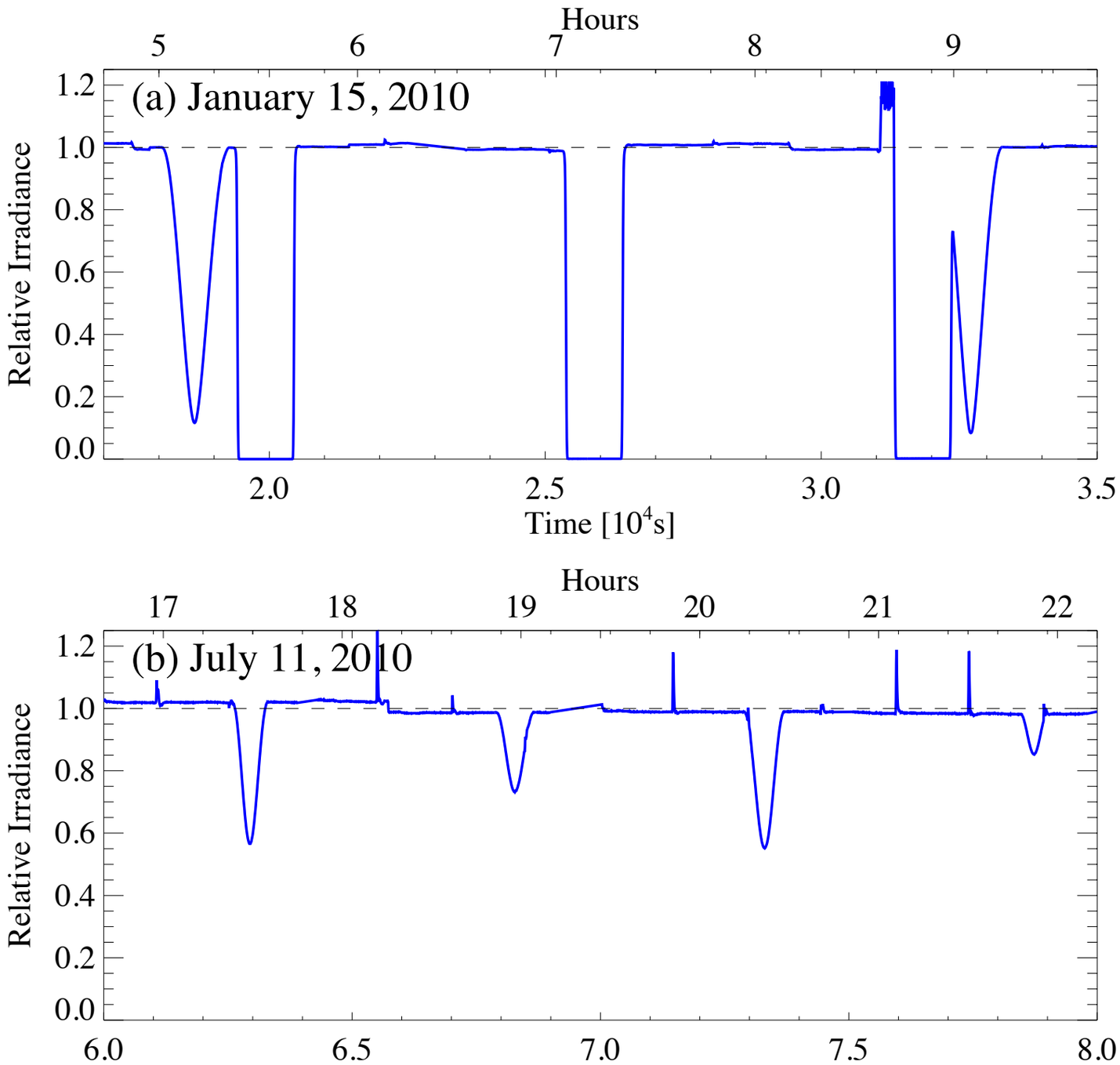


Constrain semi-empirical models of the solar atmosphere



Eclipses and Occultations observed by LYRA/PROBA2

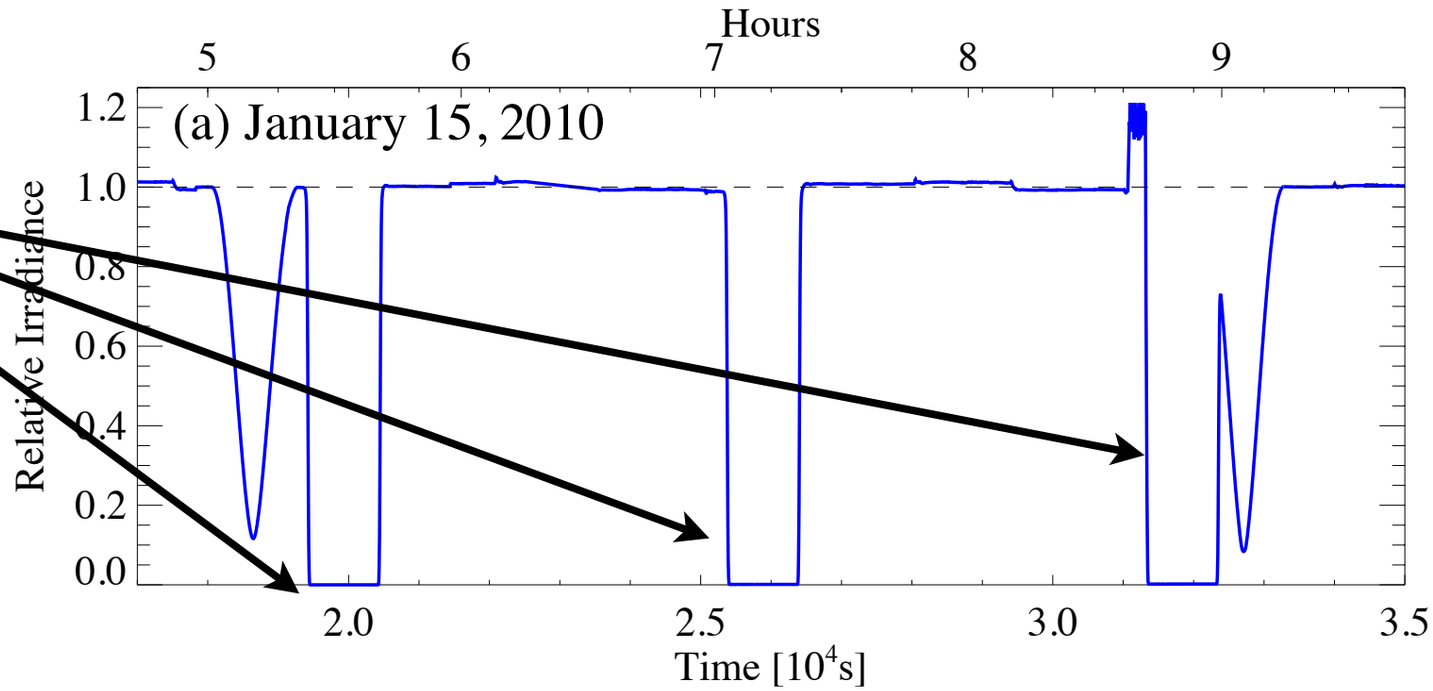


January 15, 2010

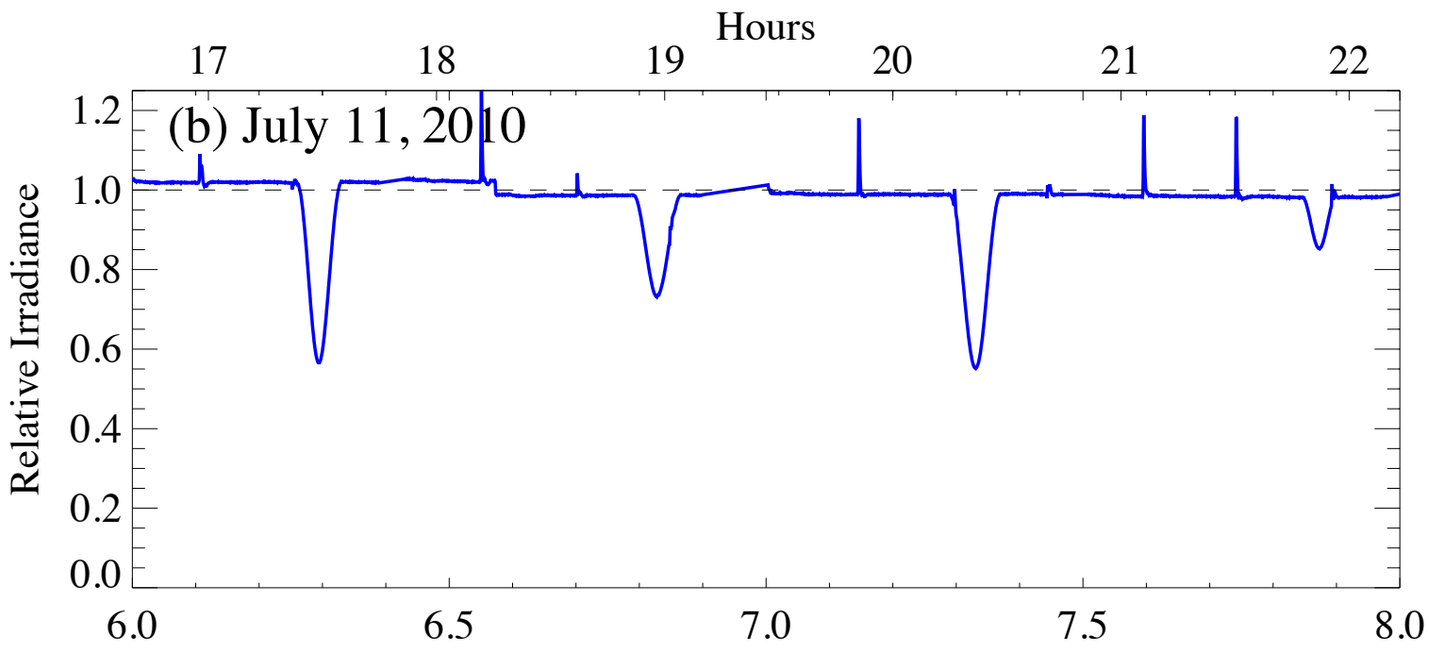
July 11, 2010

Eclipses and Occultations observed by LYRA/PROBA2

occultations

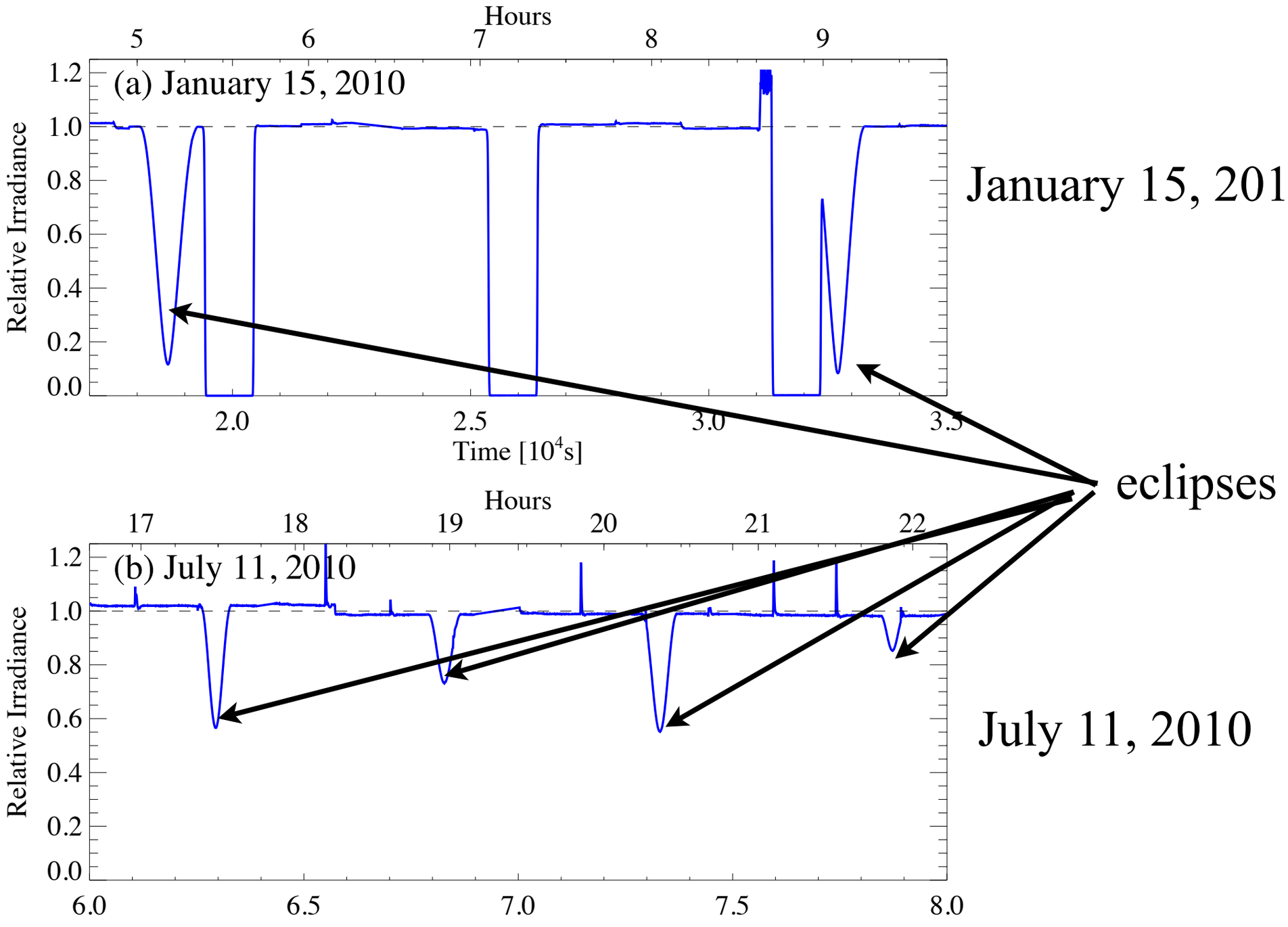


January 15, 2010

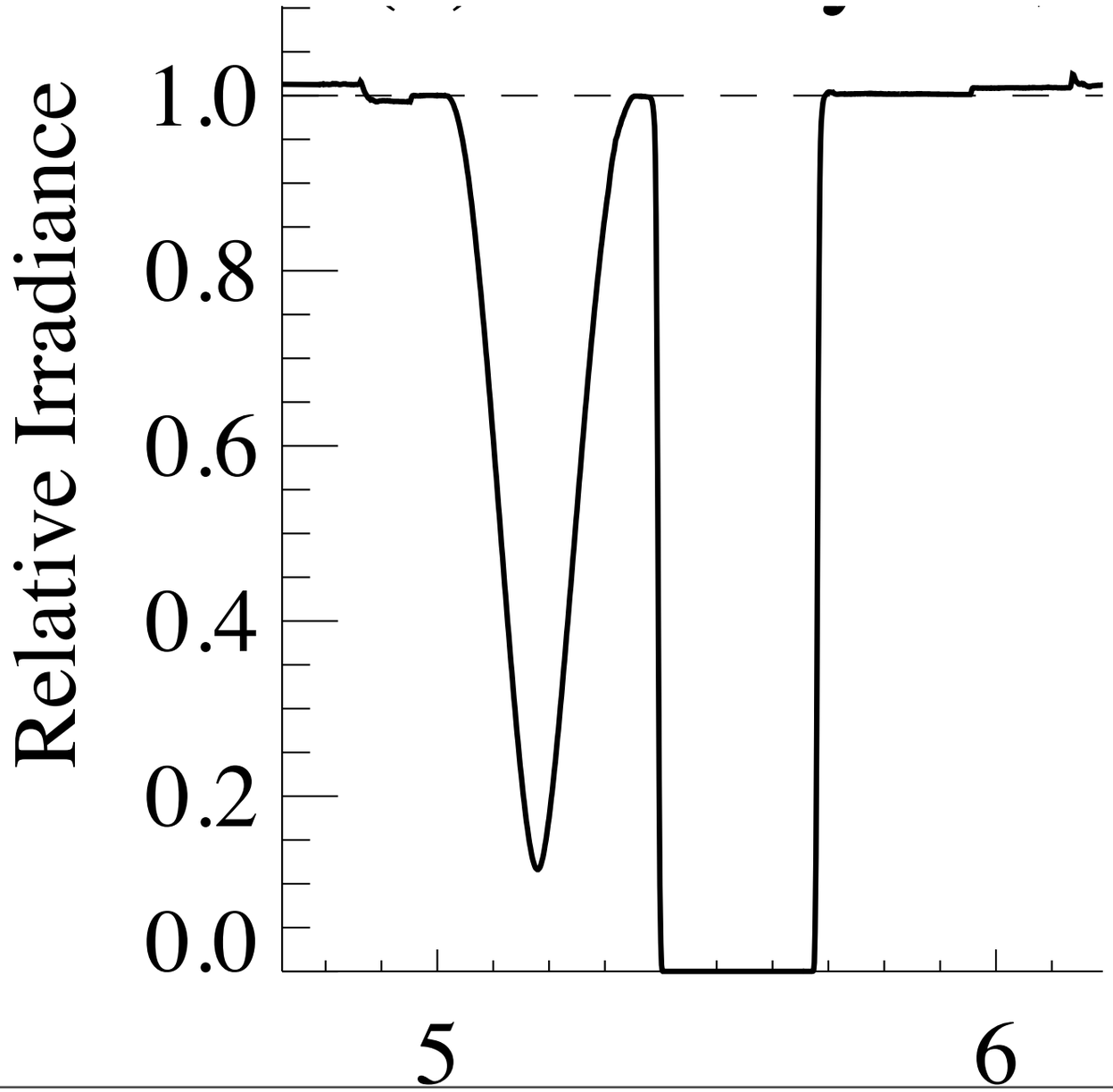


July 11, 2010

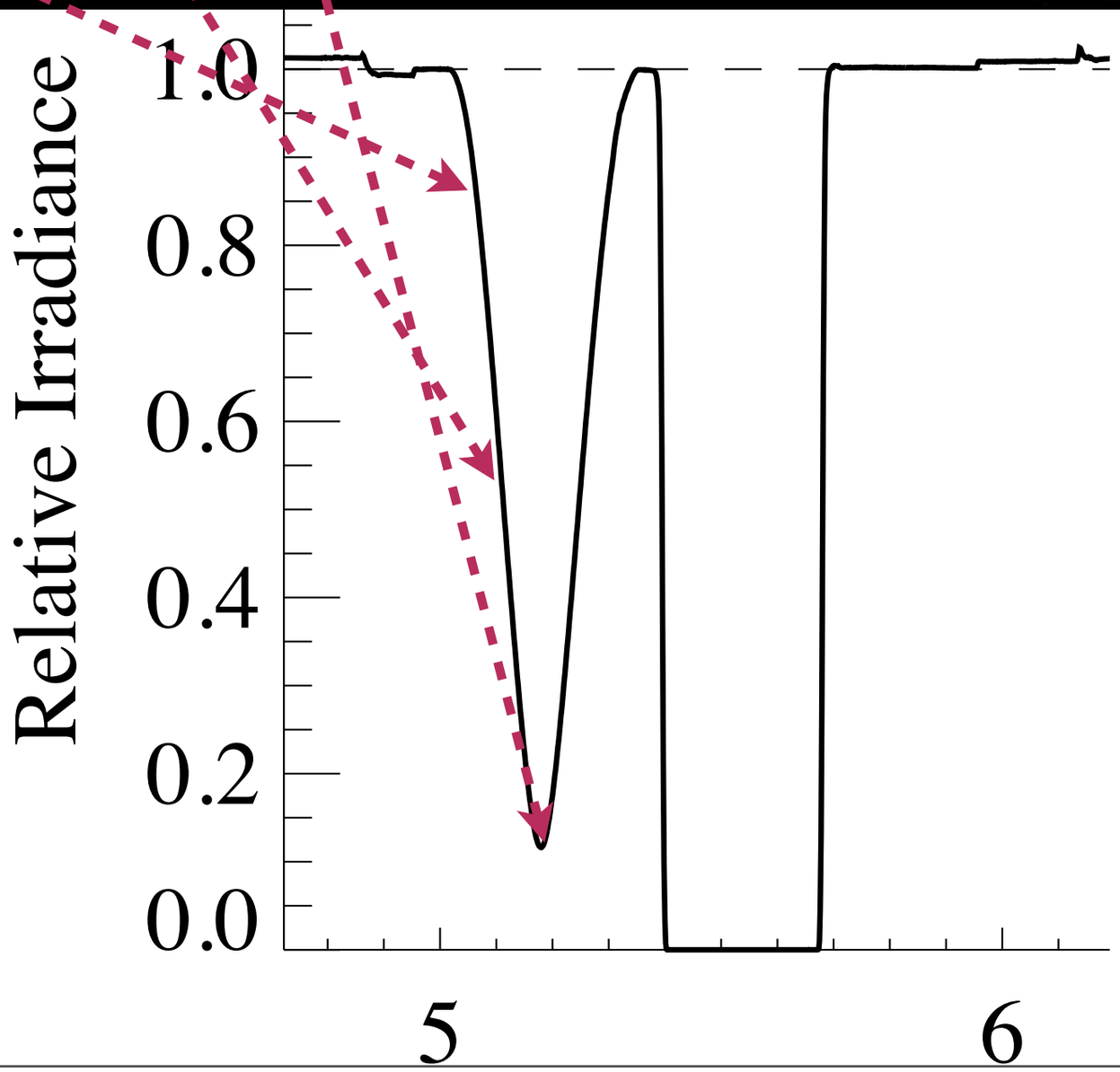
Eclipses and Occultations observed by LYRA/PROBA2



Center-to-limb variations of the solar brightness



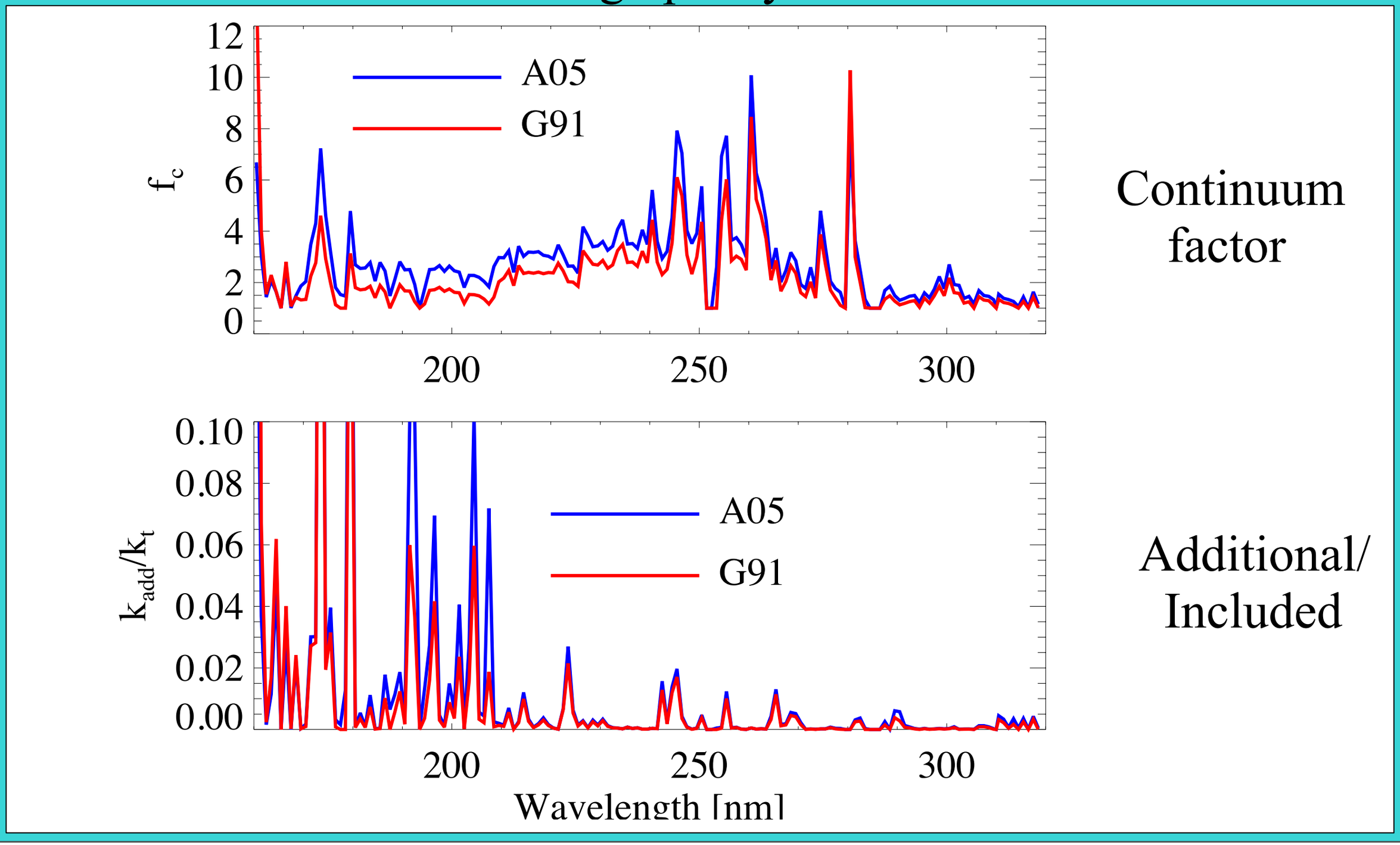
Center-to-limb variations of the solar brightness



“Dark opacity”

99% of molecular and atomic lines are predicted only theoretically

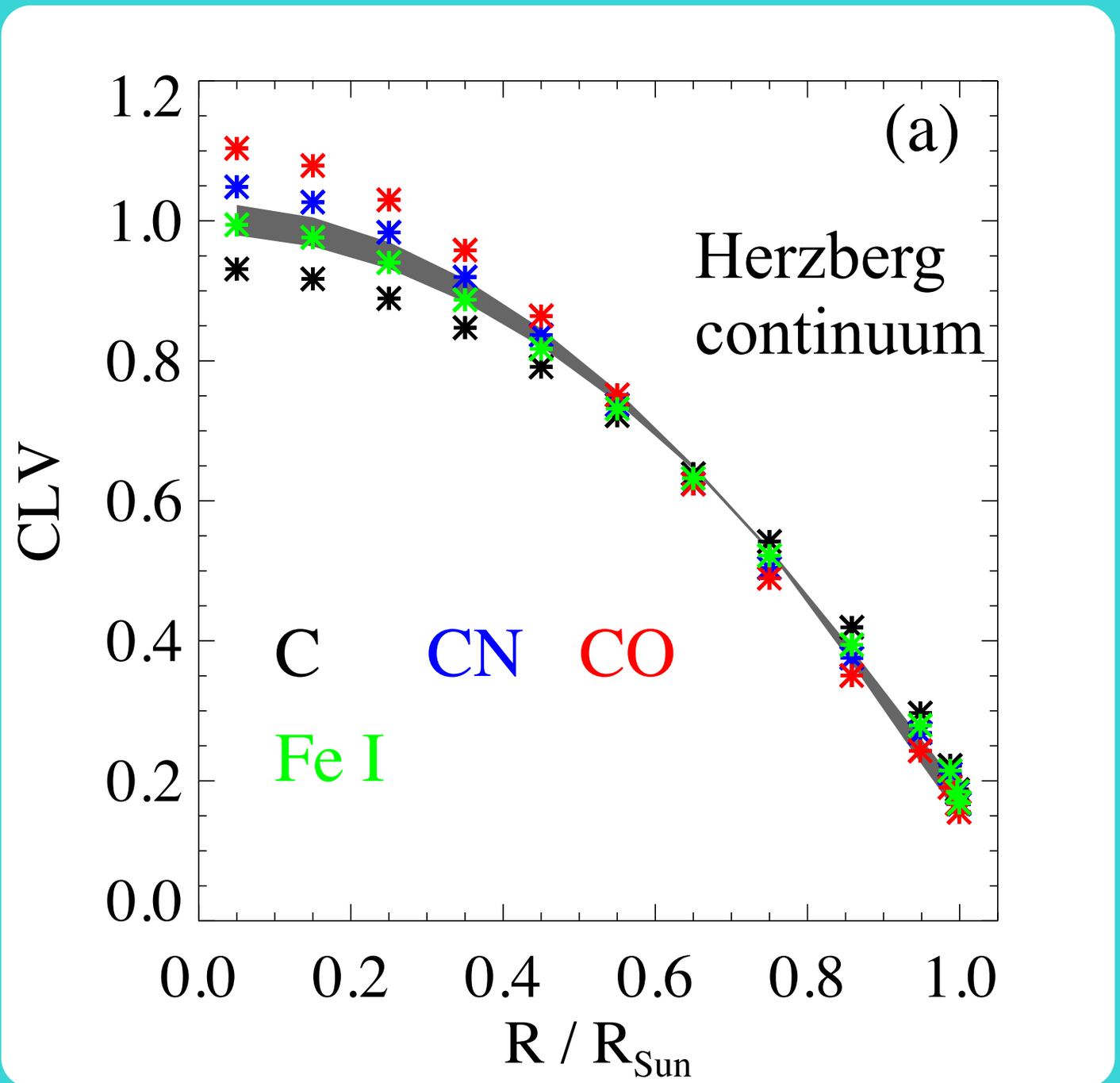
Missing opacity



Continuum factor

Additional/ Included

Center-to-limb variations of the solar brightness



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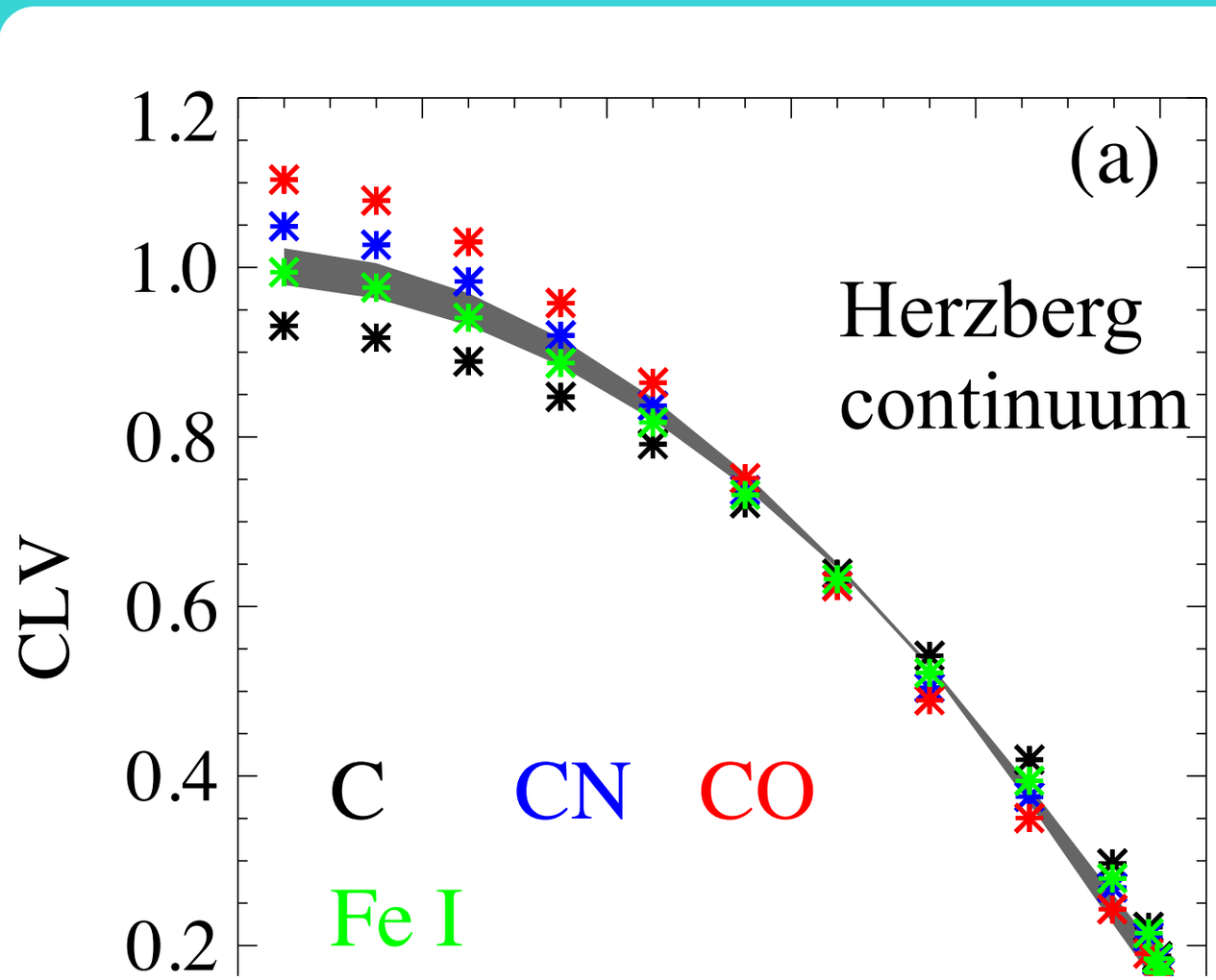

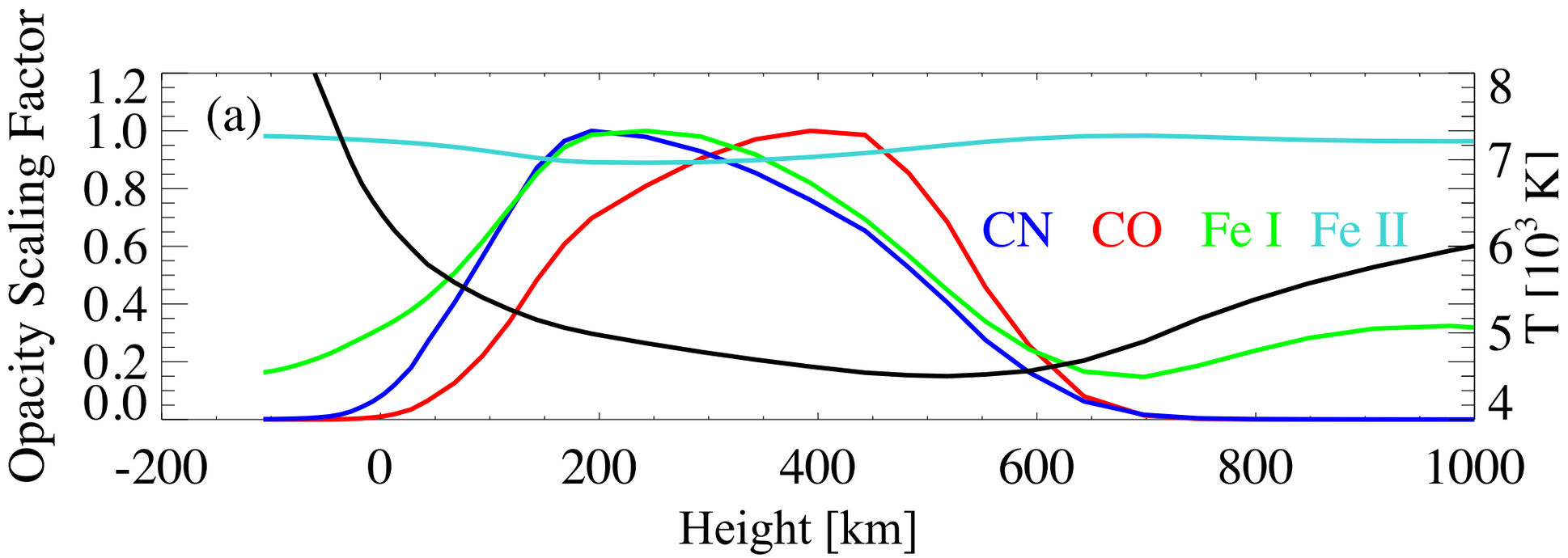

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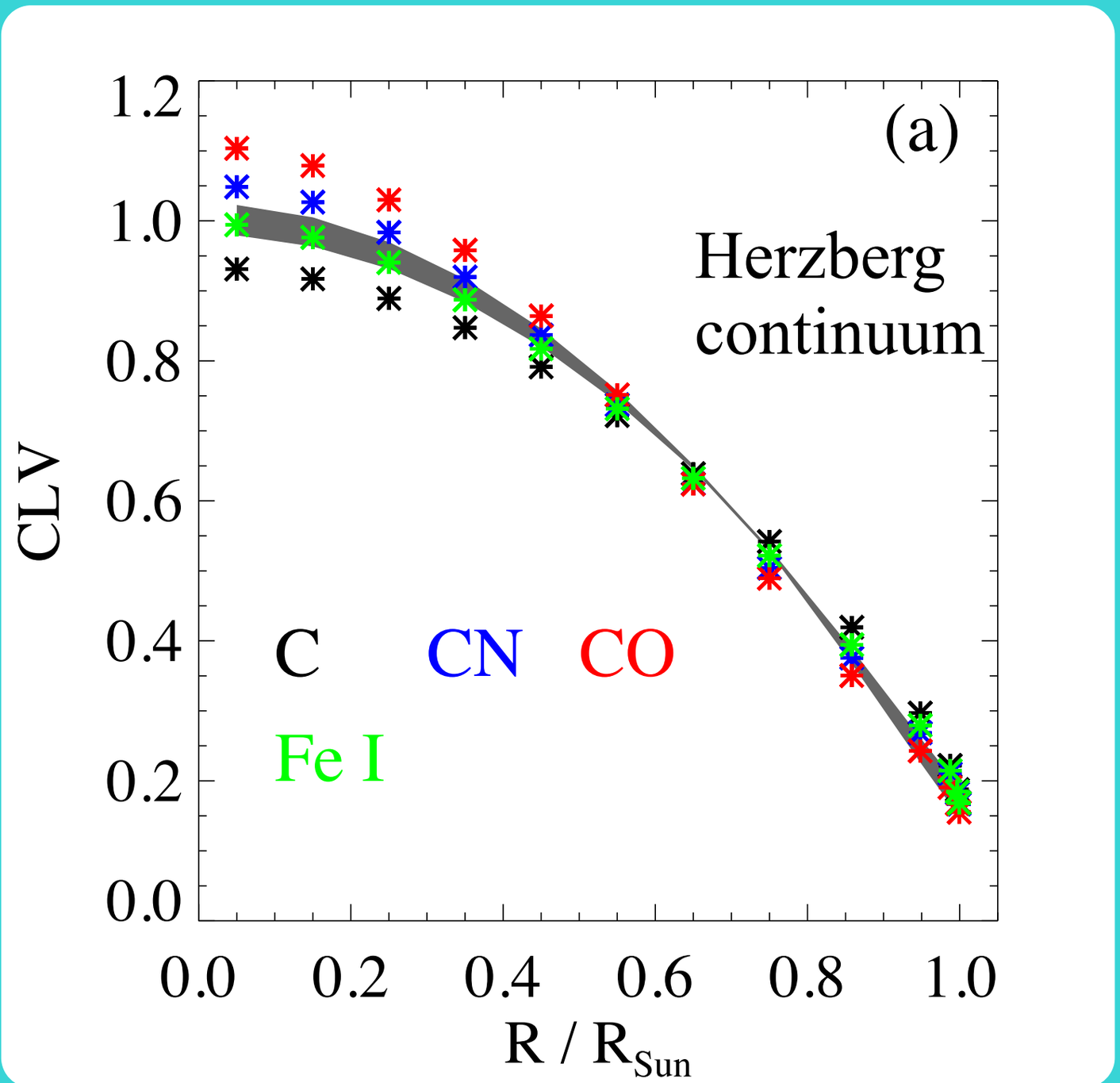
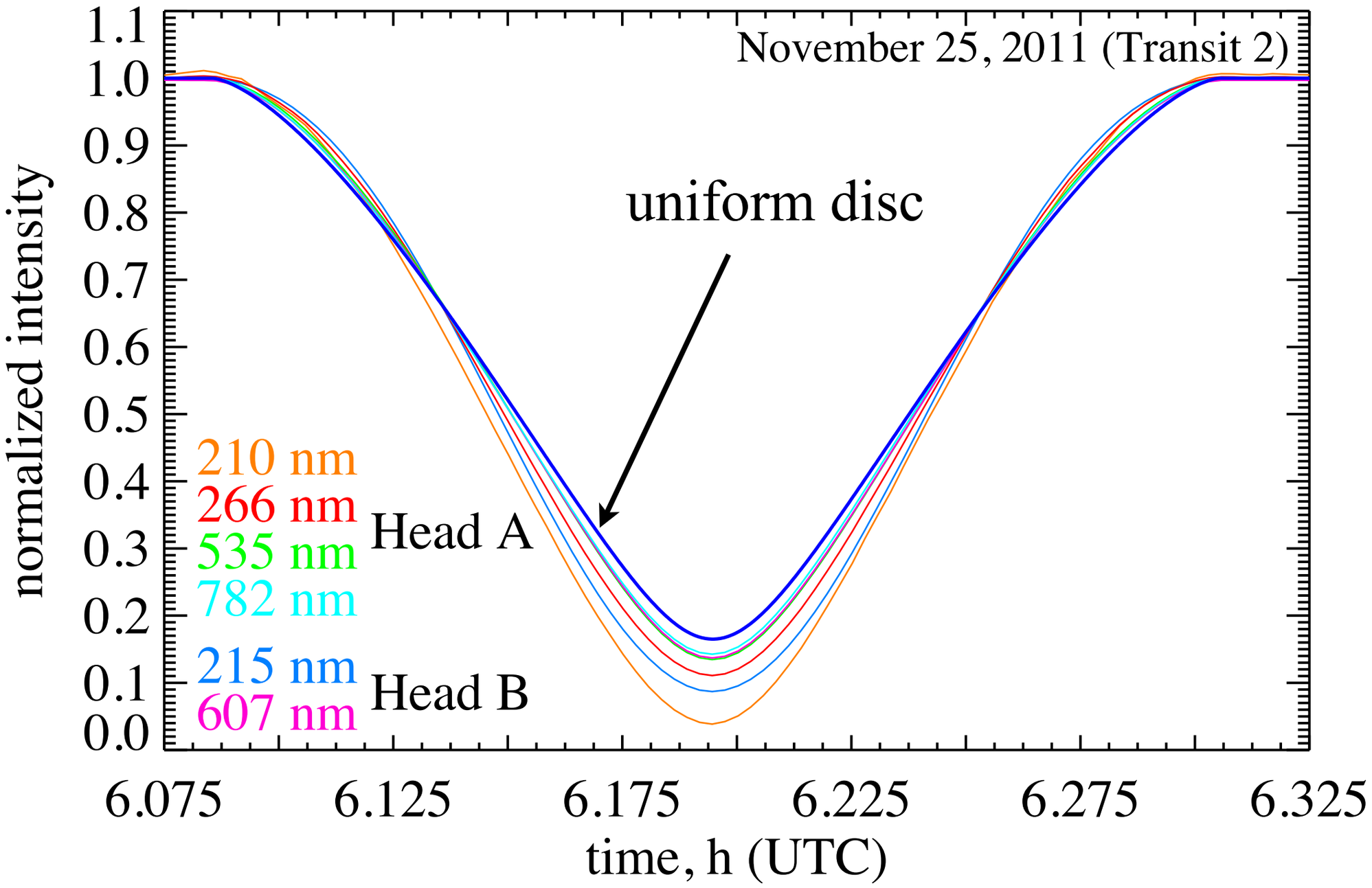
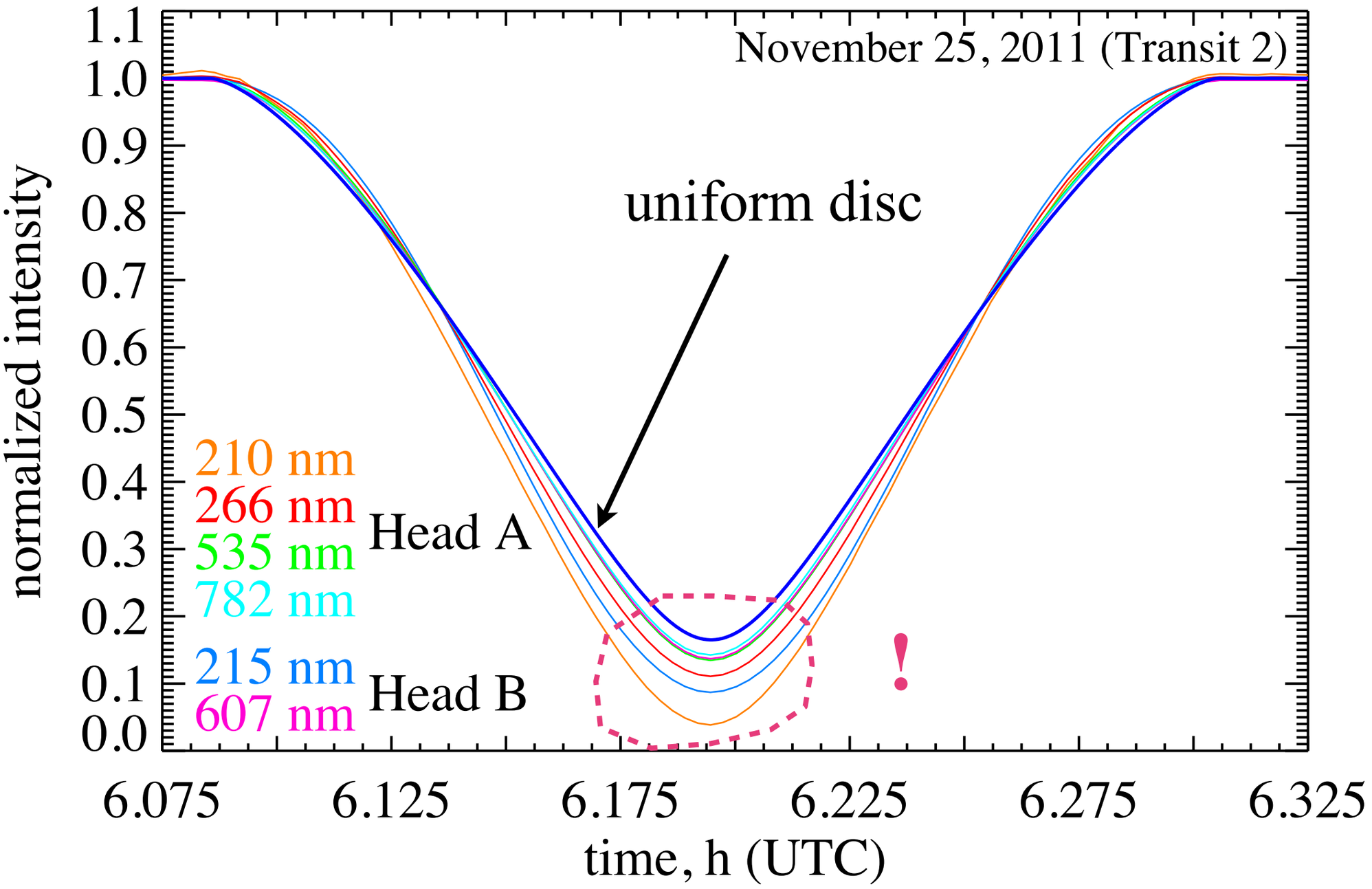


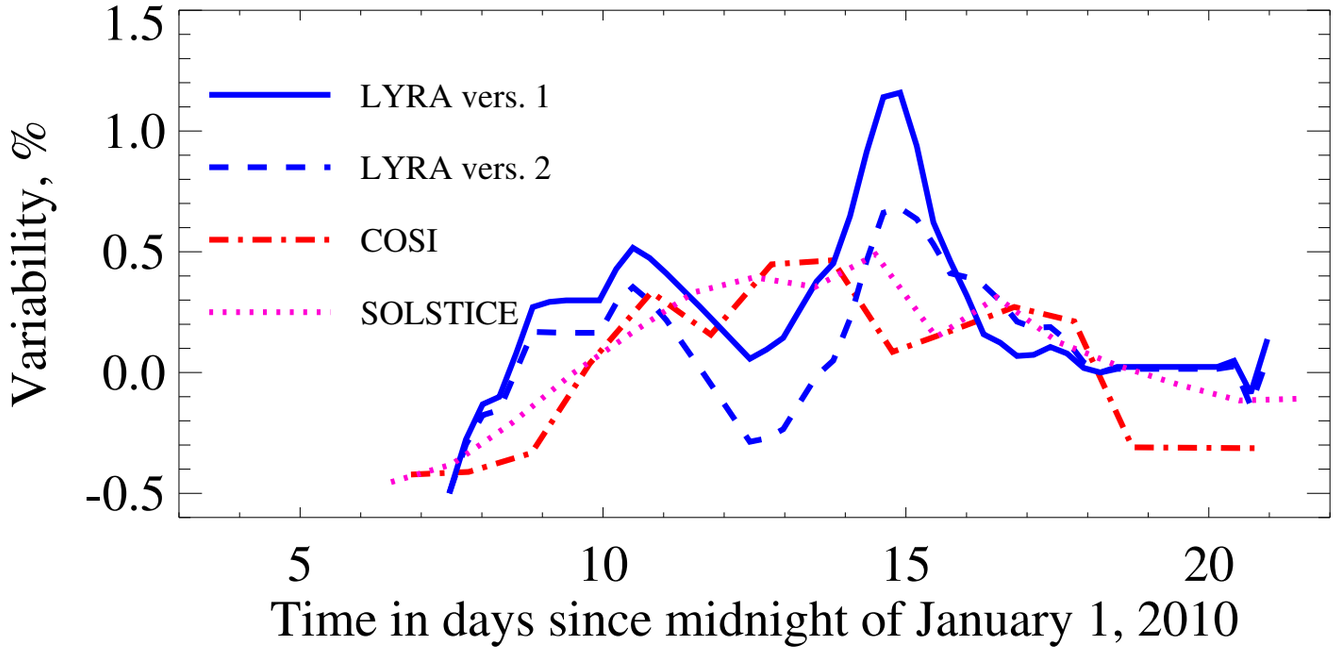
Eclipses observed by PREMOS/PICARD



Eclipses observed by PREMOS/PICARD

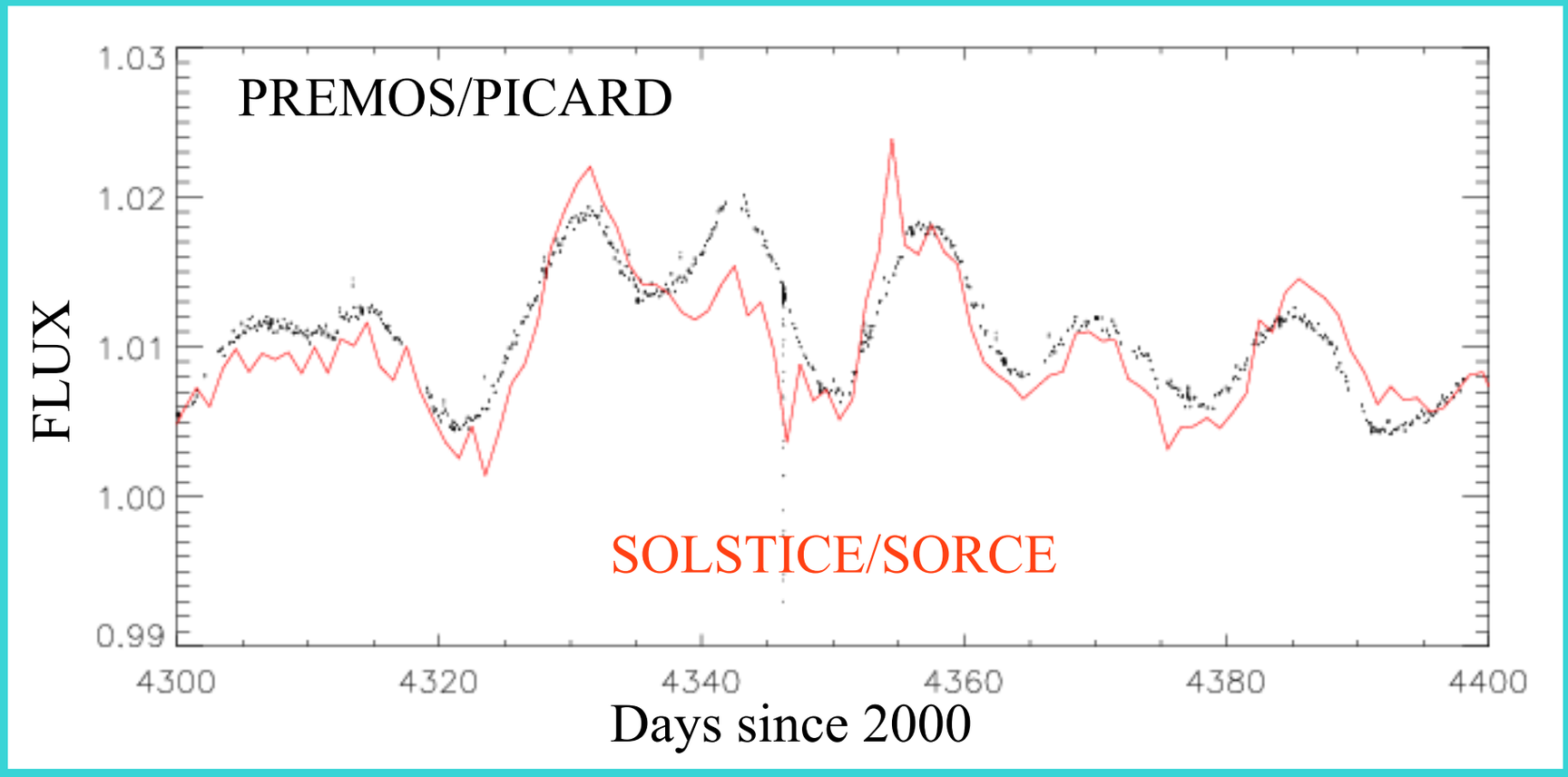


Modeling of the solar rotational cycle



comparison with LYRA/PROBA2

COSI + PSPT filling factors



comparison with PREMOS/PICARD

COSI + HMI filling factors

The Sun among its stellar cohort

The Sun

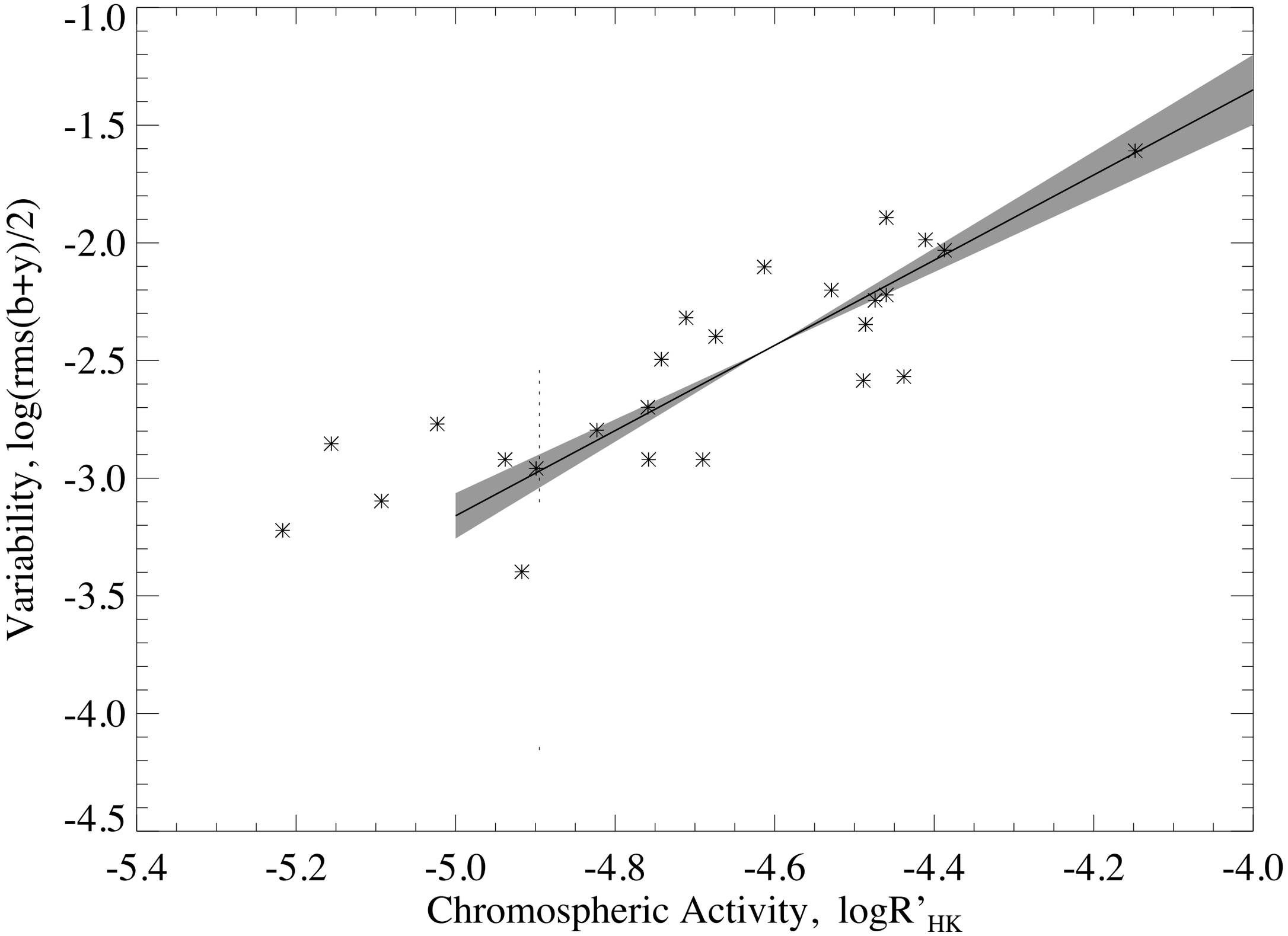
30 years of observations

The Sun among its stellar cohort

The Sun 30 years of observations

25 Sun-like stars × 20 years of observations = 500 years

The Sun among its stellar cohort



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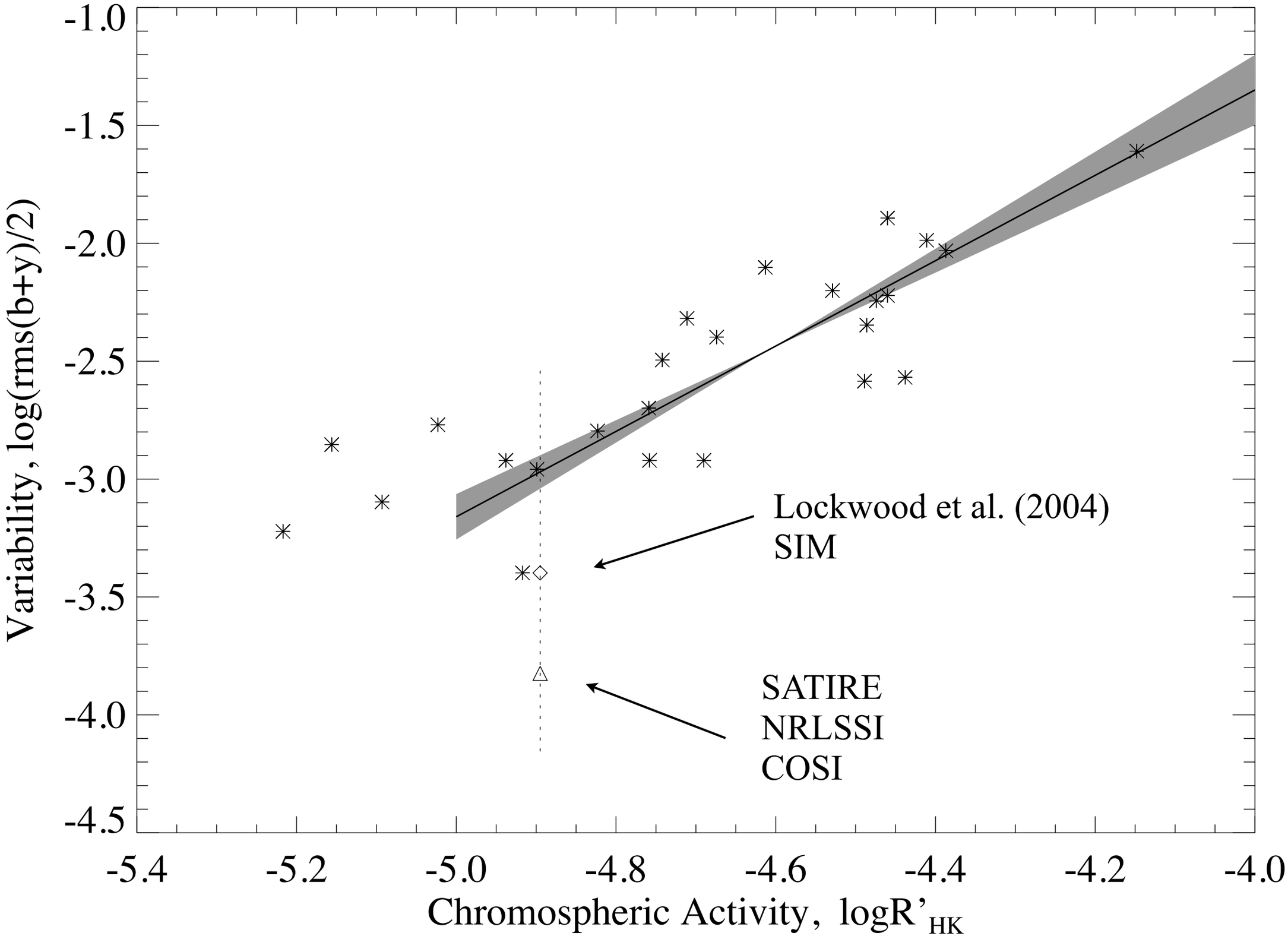


Different scenarios for the solar trajectory

two free parameters

amplitude of the 11-year cycle

amplitude of the long-term trend

Different scenarios for the solar trajectory

two free parameters

amplitude of the 11-year cycle

amplitude of the long-term trend

chromospheric activity

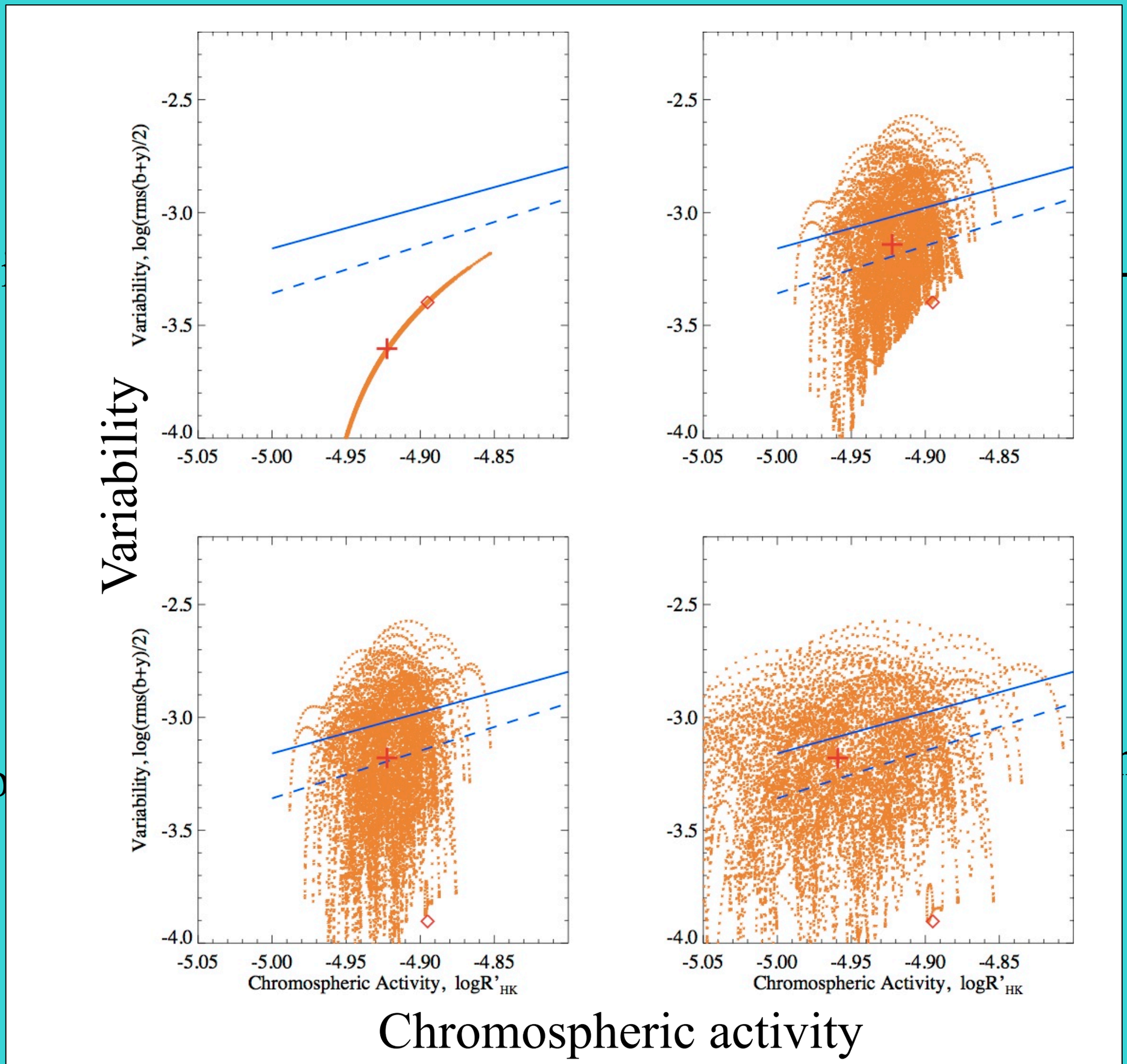
no long-term trend

strongest possible long-term trend (Saar, 2006)

Different scenarios for the solar trajectory

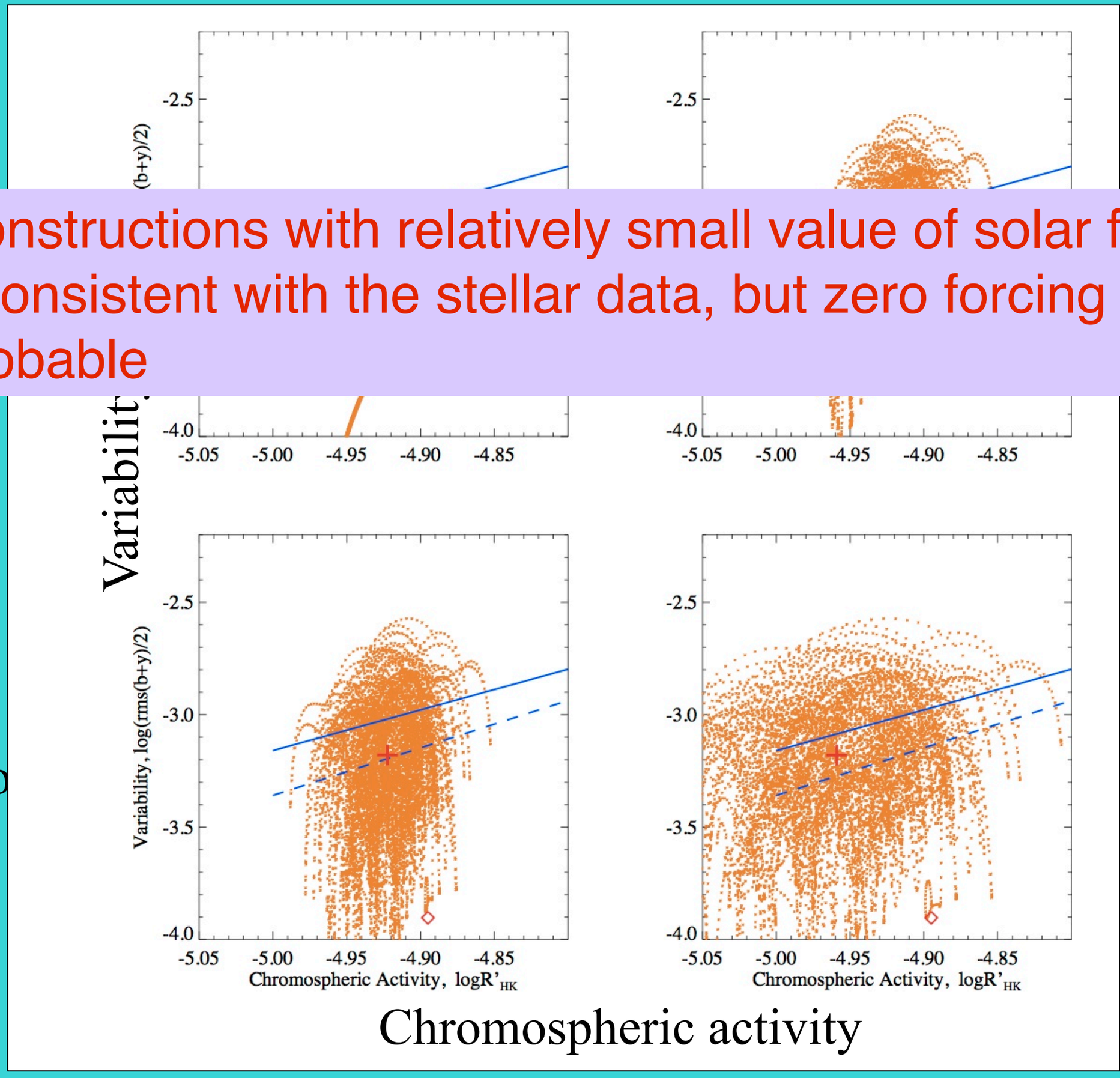
ampli -term trend

no ng-term

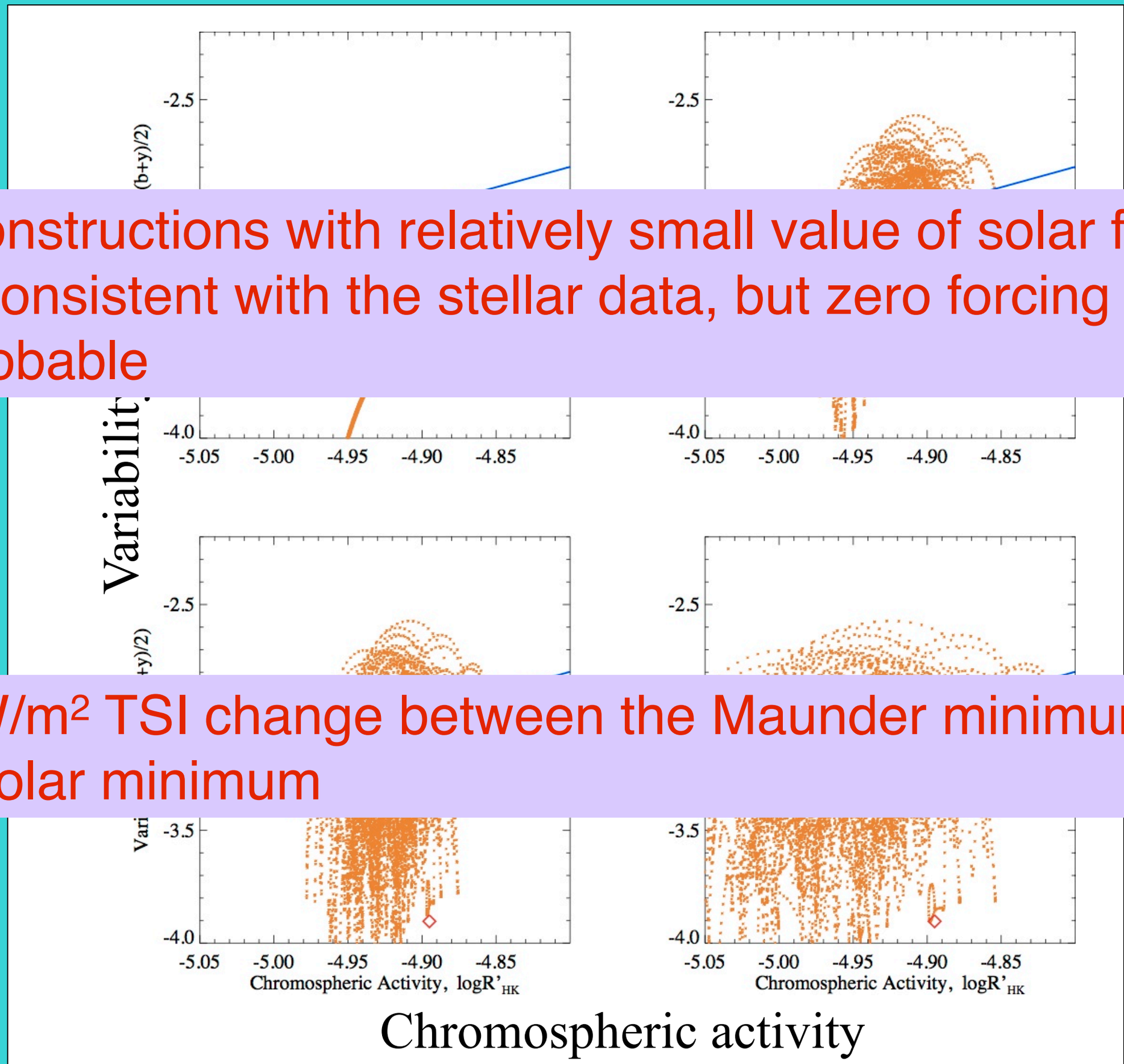


Different scenarios for the solar trajectory

Reconstructions with relatively small value of solar forcing are consistent with the stellar data, but zero forcing is very improbable



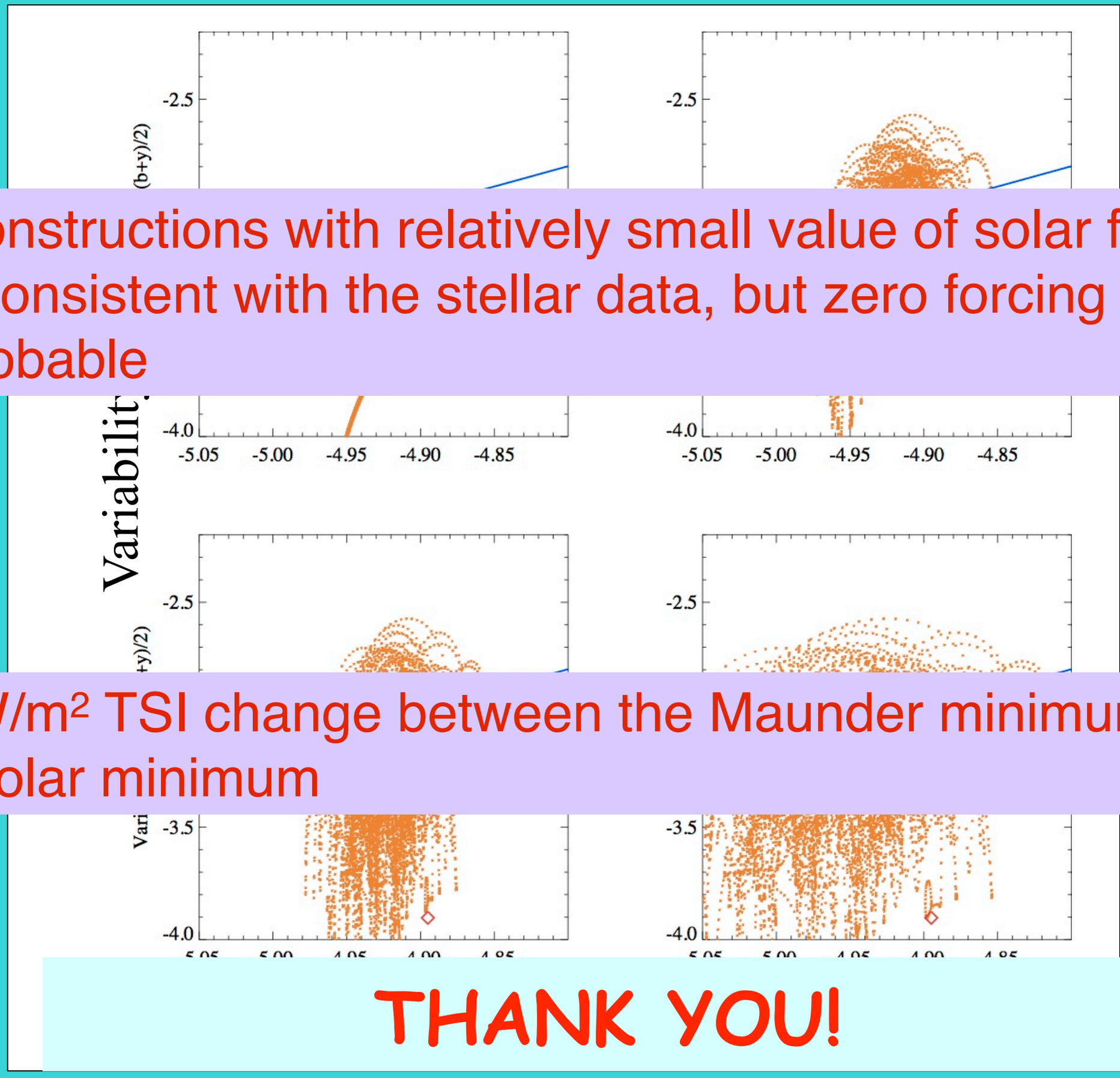
Different scenarios for the solar trajectory



Reconstructions with relatively small value of solar forcing are consistent with the stellar data, but zero forcing is very improbable

1.9 W/m² TSI change between the Maunder minimum and last solar minimum

Different scenarios for the solar trajectory



Reconstructions with relatively small value of solar forcing are consistent with the stellar data, but zero forcing is very improbable

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THANK YOU!