WHAT CAN WE LEARN FROM SORCE ABOUT THE CONTRIBUTION OF DIFFERENT MAGNETIC STRUCTURES TO THE SOLAR SPECTRAL IRRADIANCE (SSI)?

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SORCE
Solar Radiation and Climate Experiment

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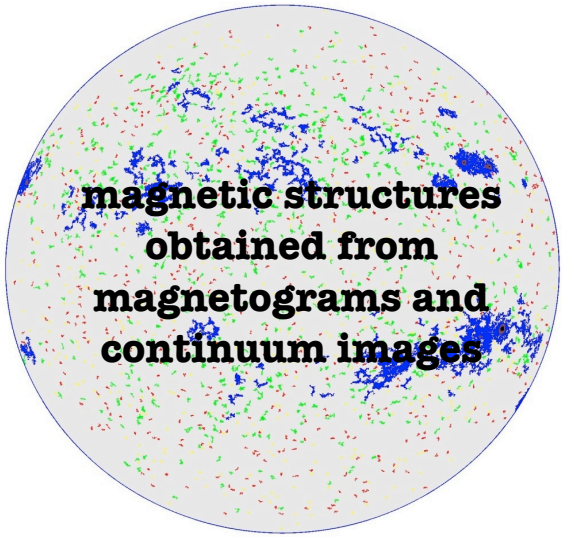

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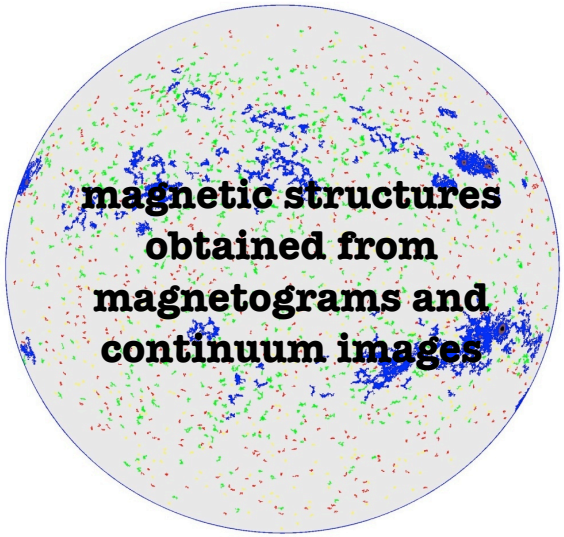

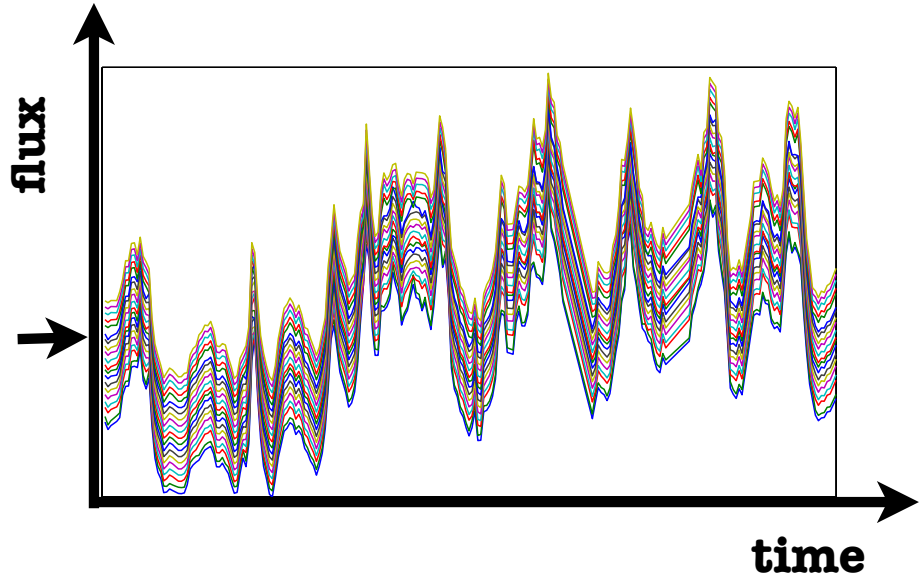

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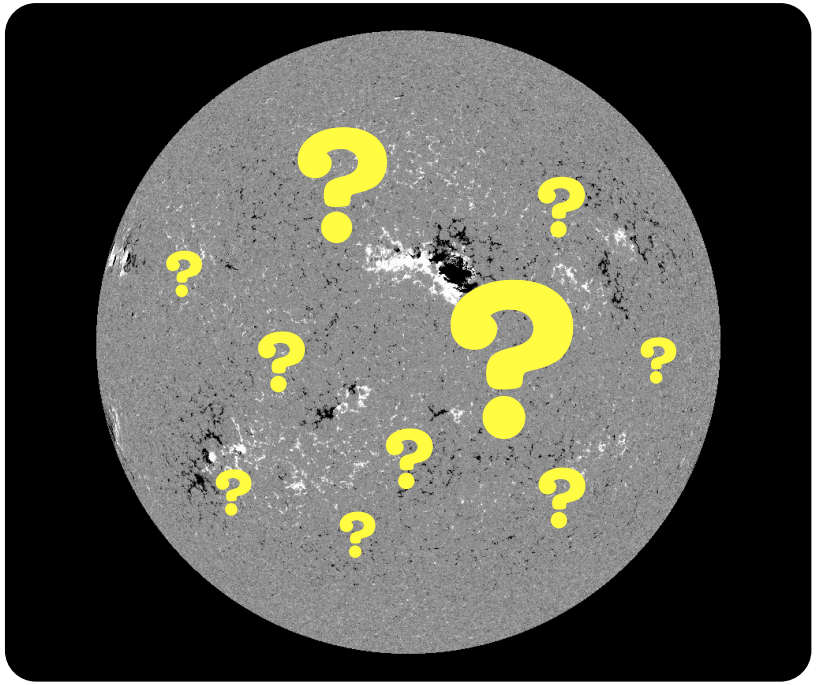

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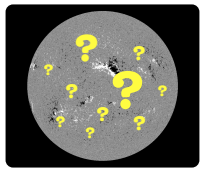

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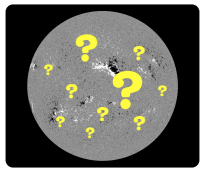

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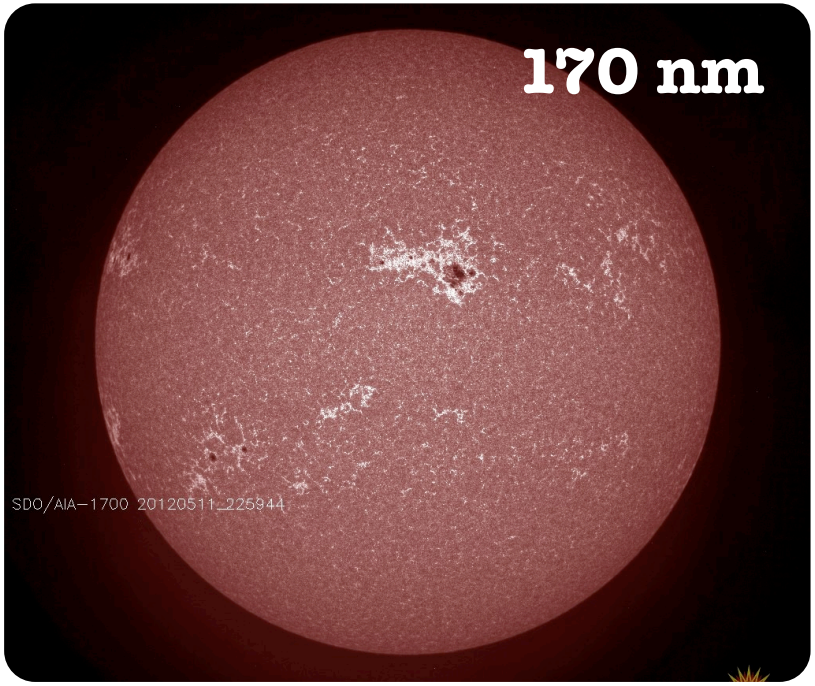

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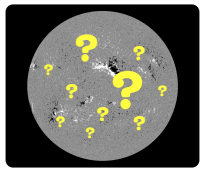

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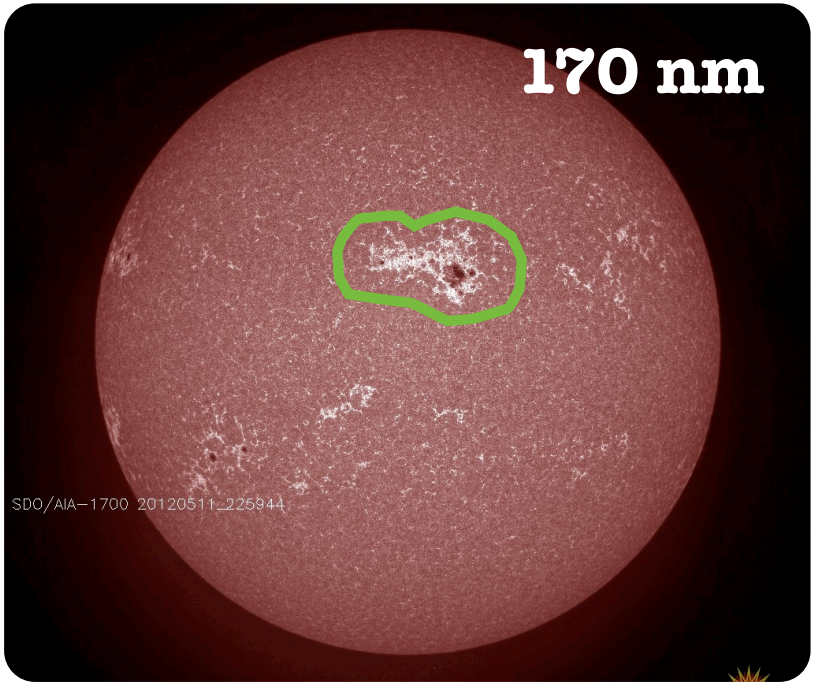

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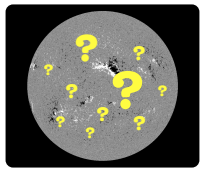

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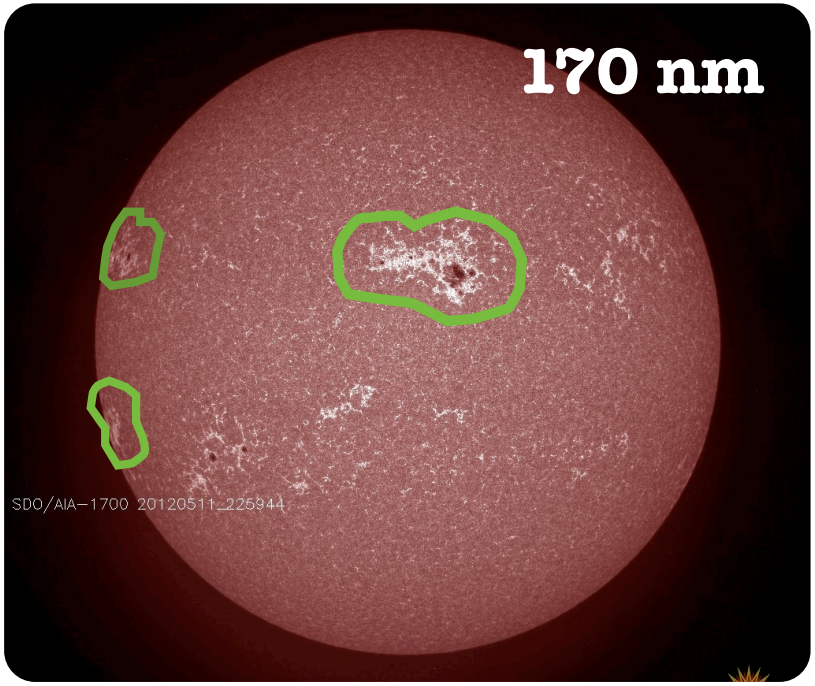

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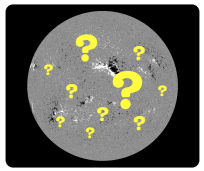

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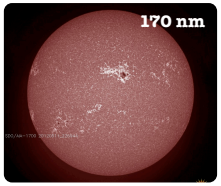

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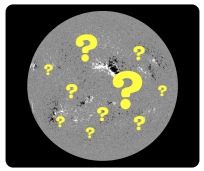

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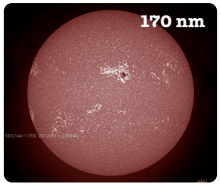

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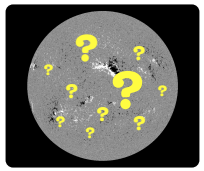

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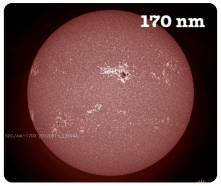

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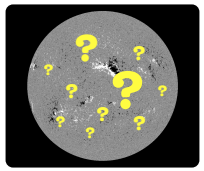

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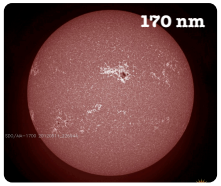

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To answer these questions consider an empirical ("less biased") approach. No assumptions on atmospherical models.

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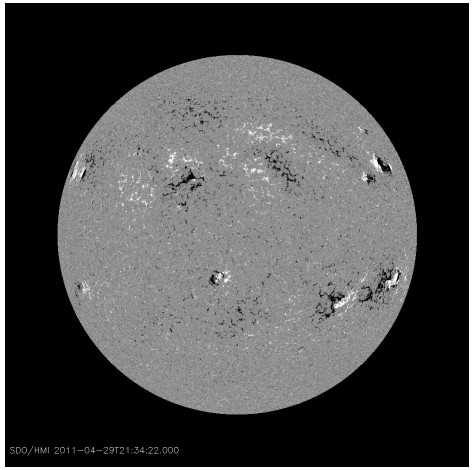

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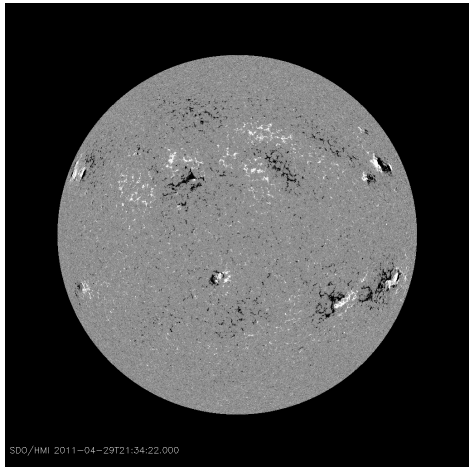

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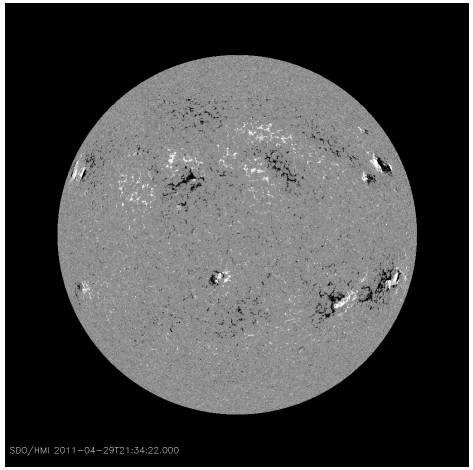

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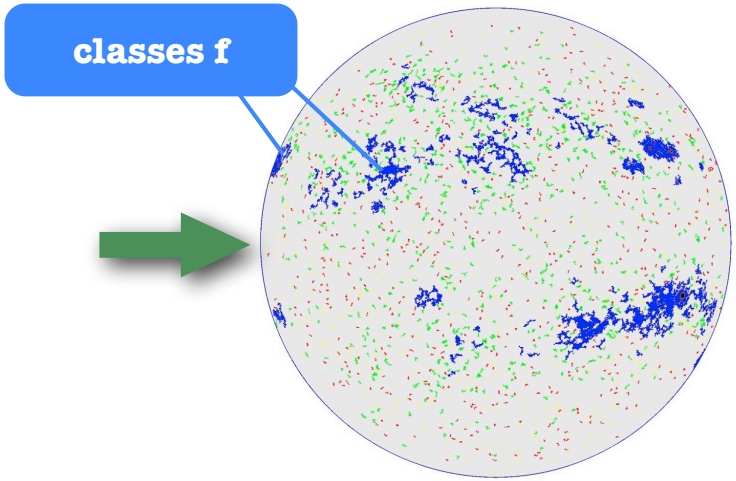

segmentation map

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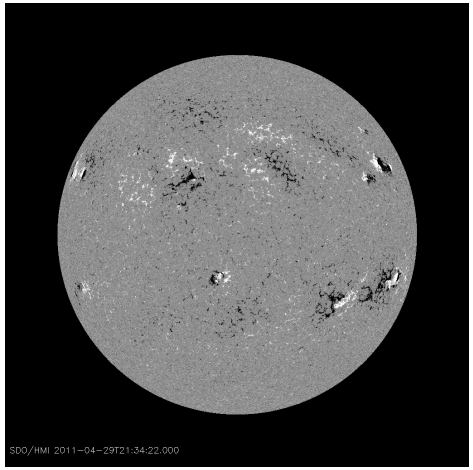

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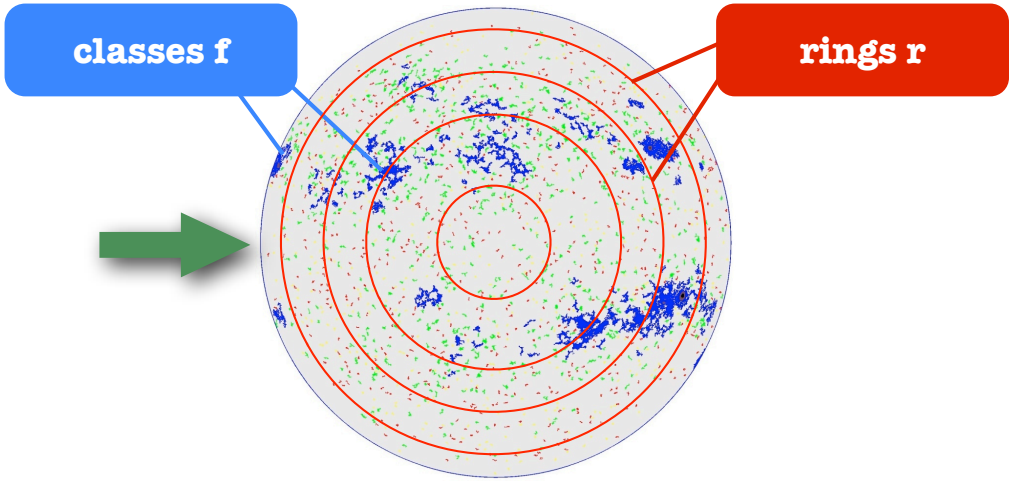

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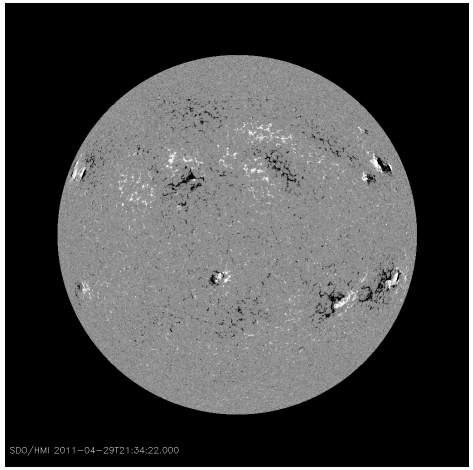

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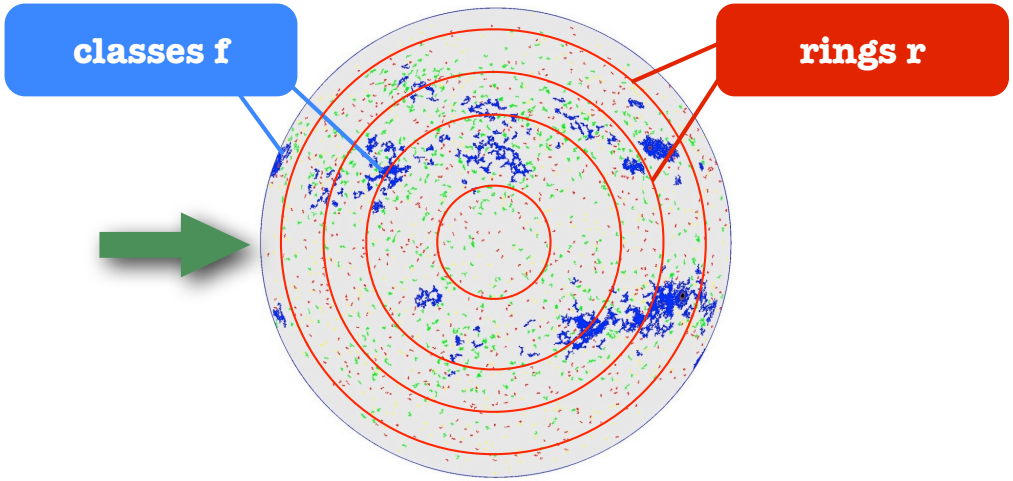

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Linear SATIRE-like model:

$$I(\lambda, t) = \sum_r \sum_f S(\lambda, f, r) \cdot F(f, r, t) + S_0(\lambda) + \xi(\lambda, t)$$

$S(\lambda, f, r)$ - characteristic spectrum of class f in ring r

$F(f, r, t)$ - filling factor of class f in ring r (fraction of solar disk covered by magnetic structures of this class)

MODEL BUILDING

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$$S = I\, F^{-1}$$

S - model atmosphere
I - spectral irradiance observations
F -filling factors

DATA

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- Model is calibrated with SSI observations (daily averages).

Instrument	Wavelength, nm	Spectral band
SDO/EVE	6.5-9.5	XUV
SDO/EVE	10.5-35.5	EUV
TIMED/SEE	36-115	EUV
SORCE/SOLSTICE	121	LyA
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SDO/HMI and SDO/AIA respectively (4096x4096 compressed to 2048x2048 pxls)

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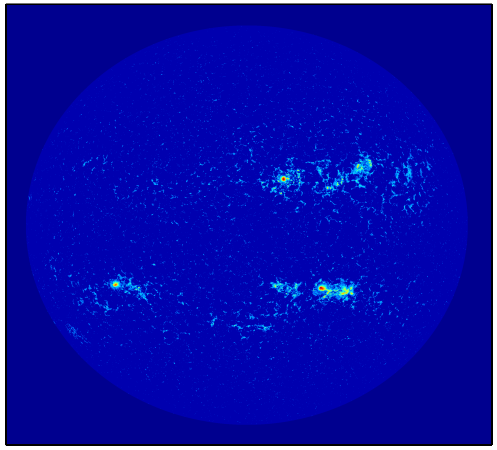
Time interval: 24/04/2010 - 01/07/2013 (about 3 years of data)

SEGMENTATION OF MAGNETOGRAMS BY AREA VS INTENSITY



Segmentation by magnetic field intensity is common approach.

Disadvantages:

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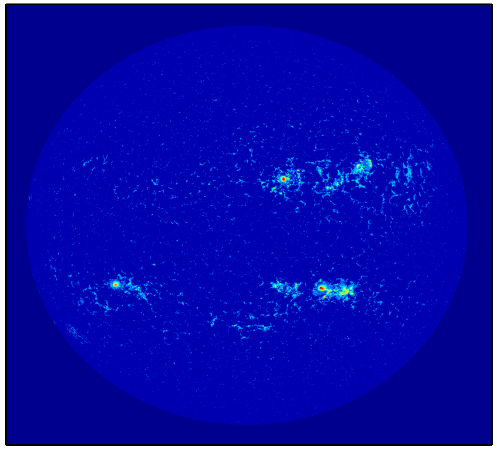

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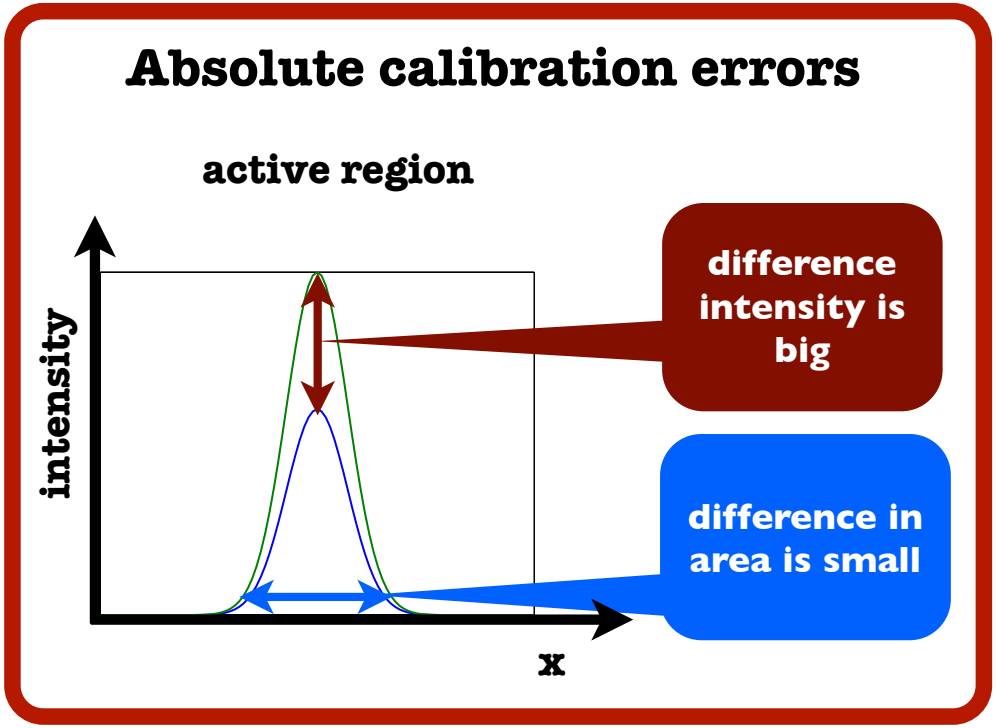

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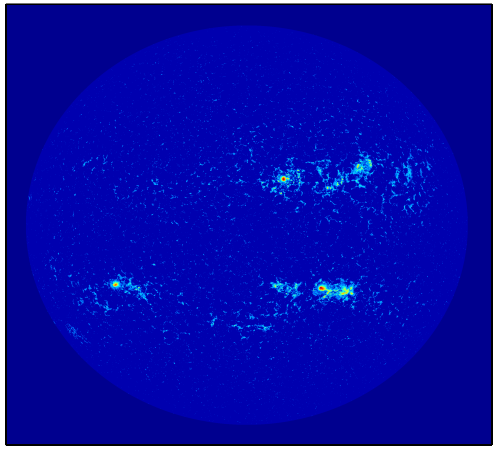

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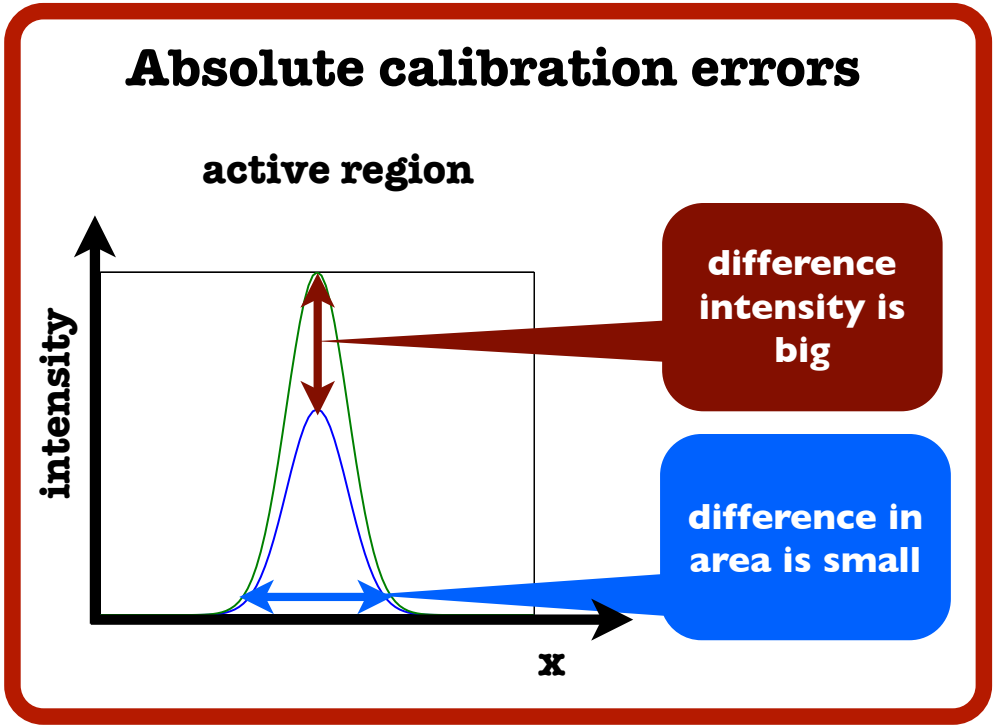

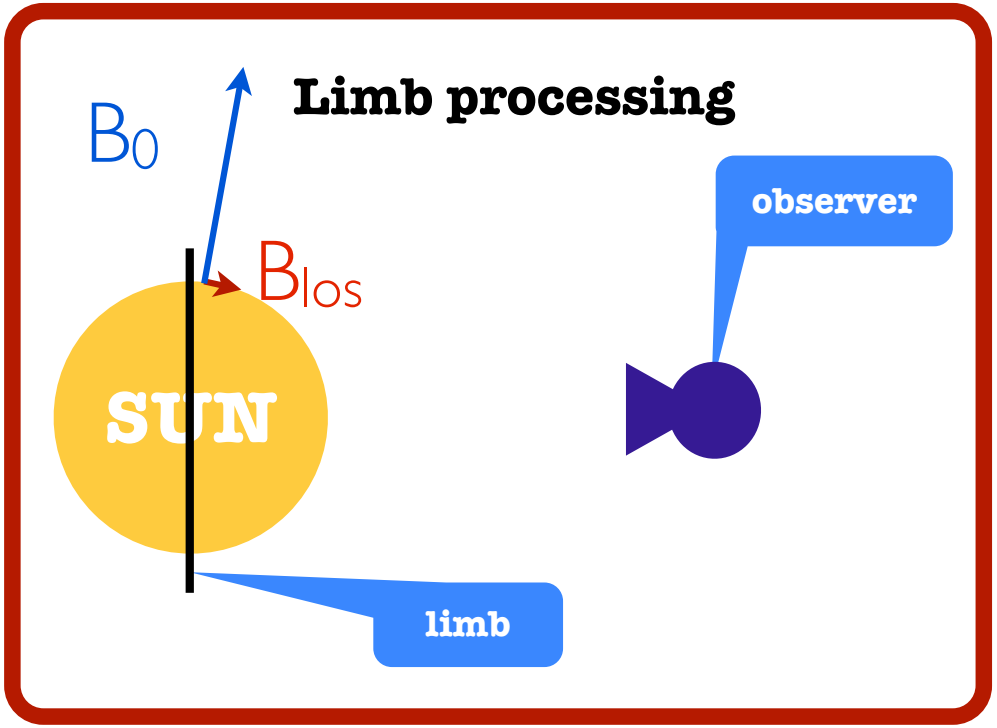

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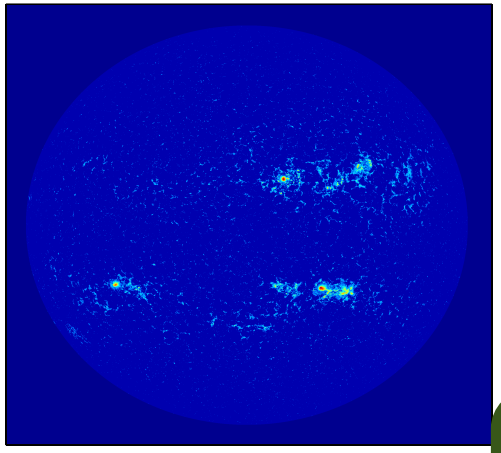

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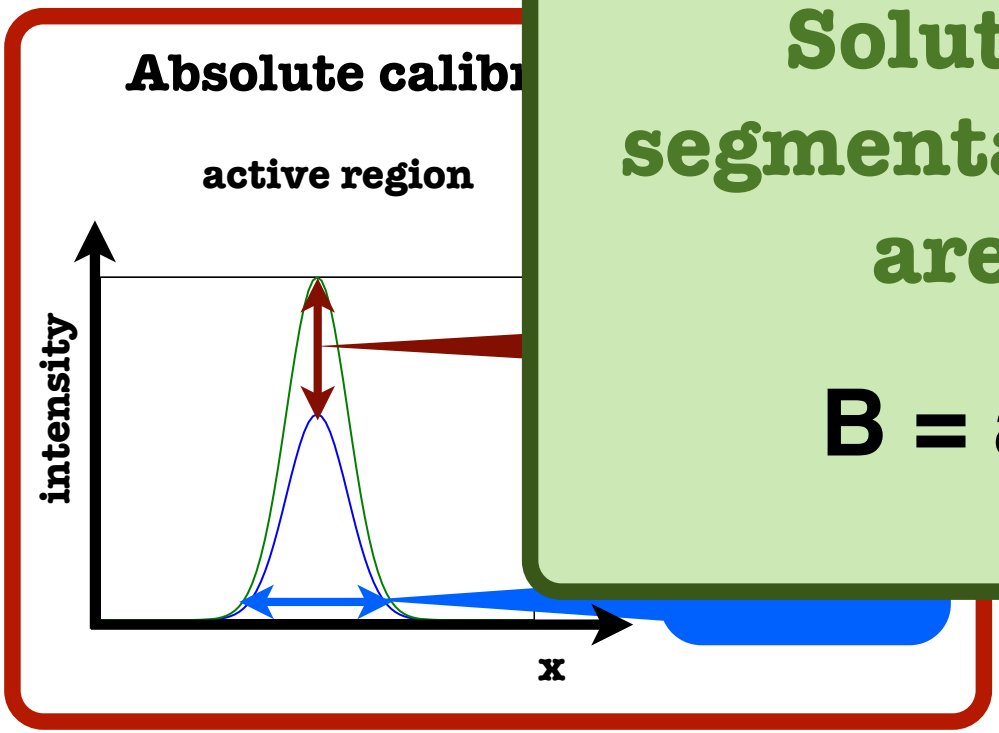
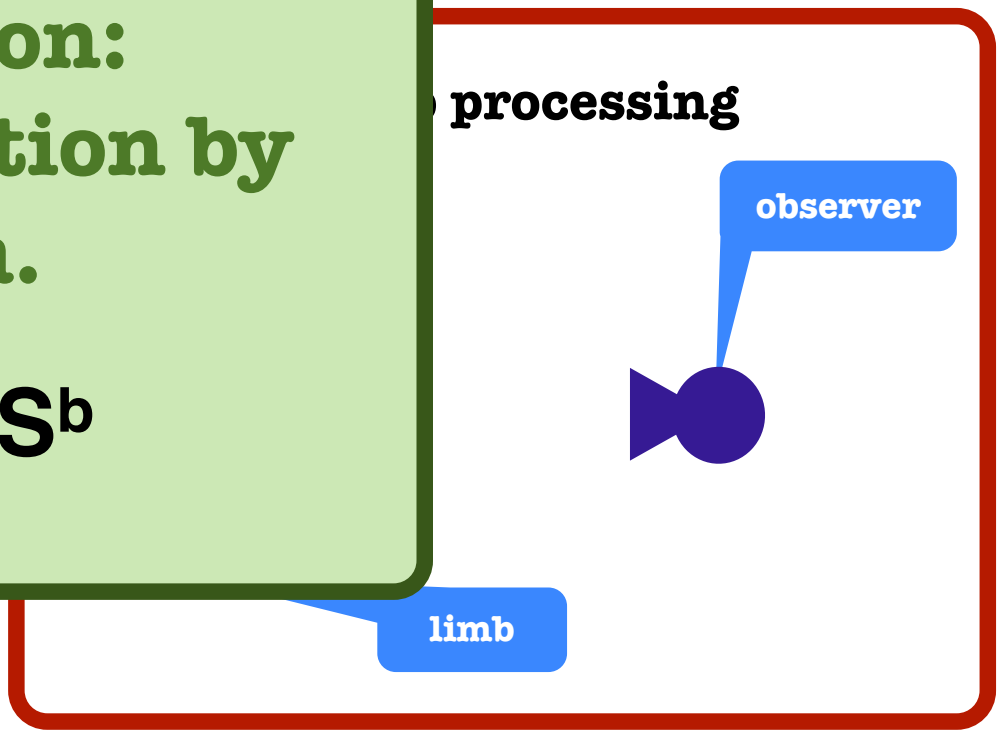
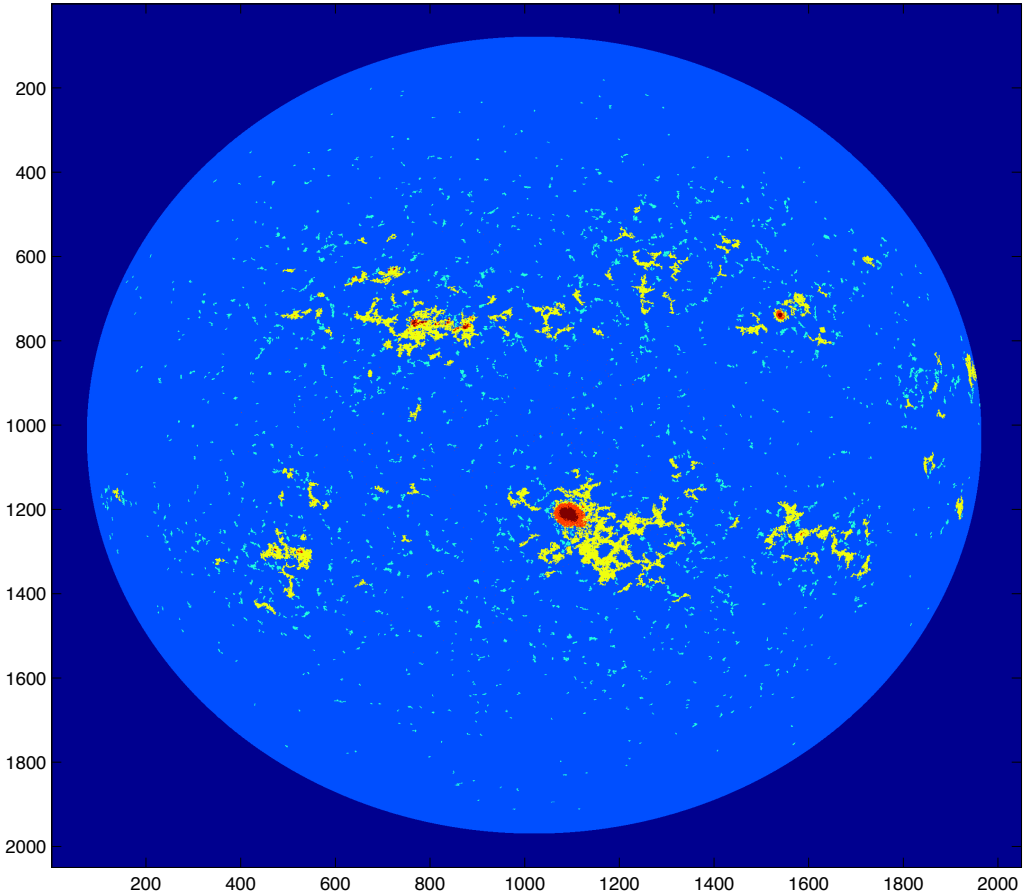


Solution: segmentation by area.

$$B = aS^b$$



MAGNETIC STRUCTURES



small structures ≈ active network

big structures ≈ faculae

umbra

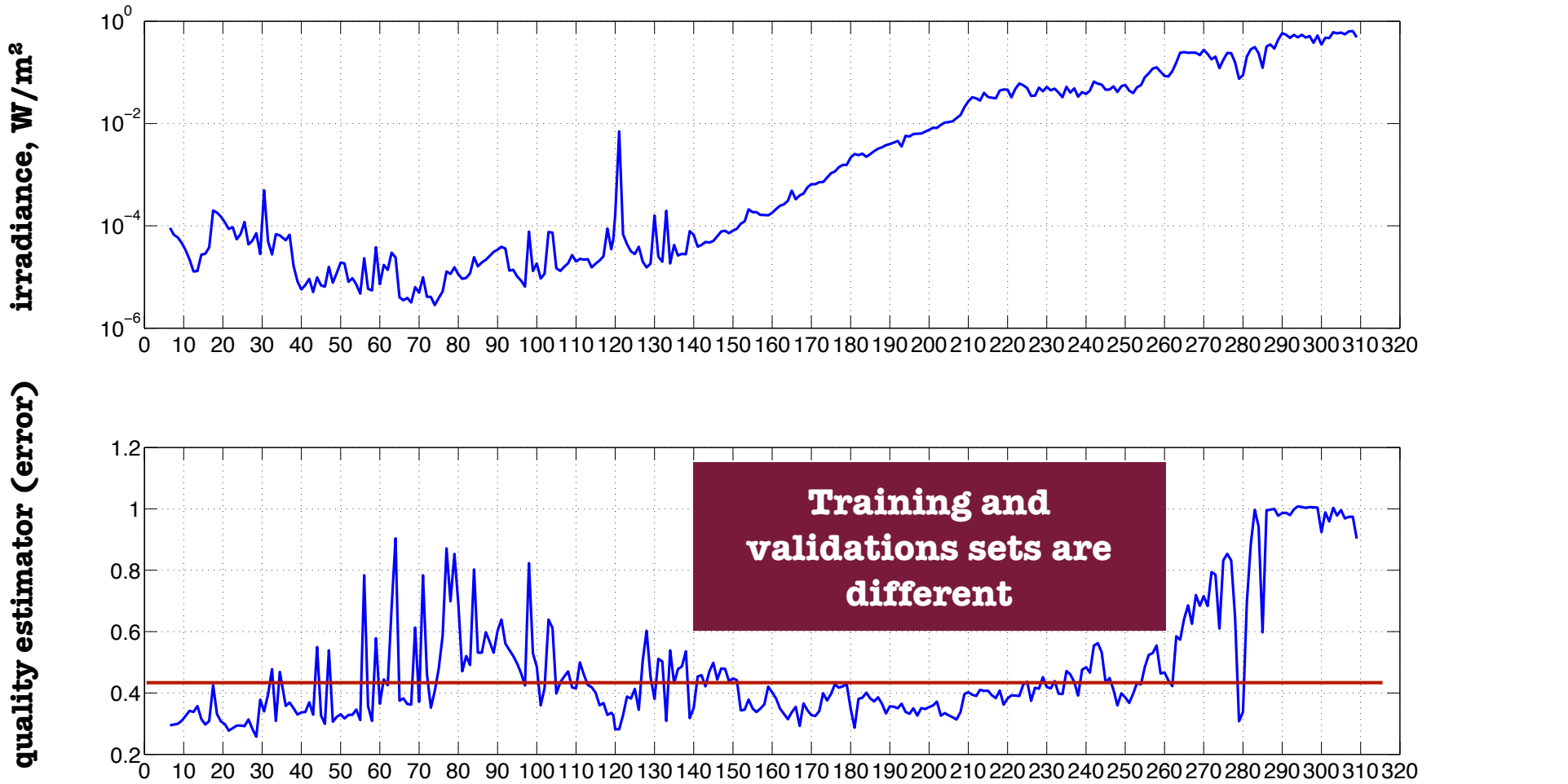
penumbra

quiet sun

MODEL QUALITY

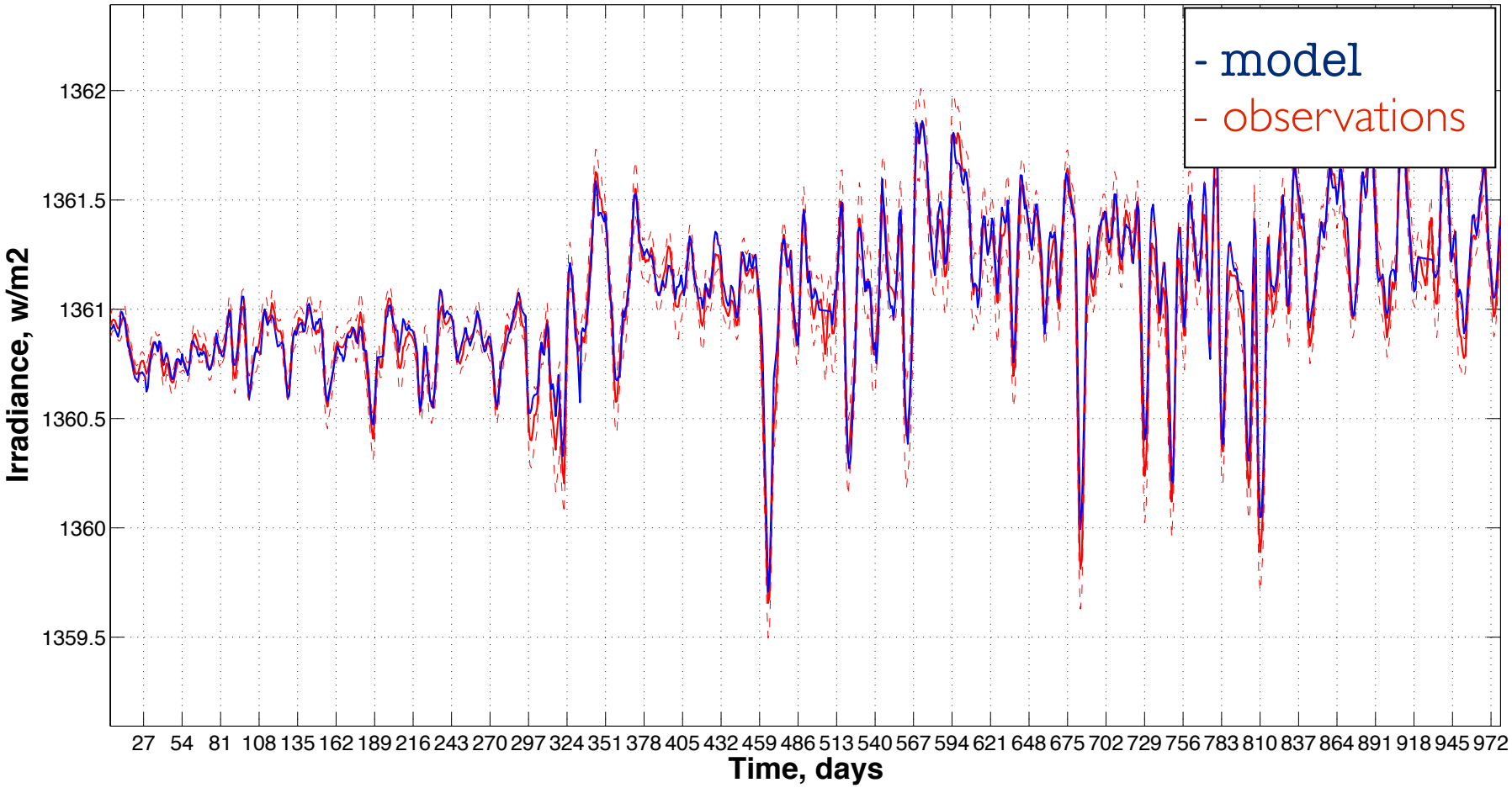
Model quality estimator:

$$E(f,r) = \frac{1}{N}\sum_n \frac{(\overline{y}(f,r) - y)^2}{\sigma_y^2}$$



RECONSTRUCTION EXAMPLES

TSI



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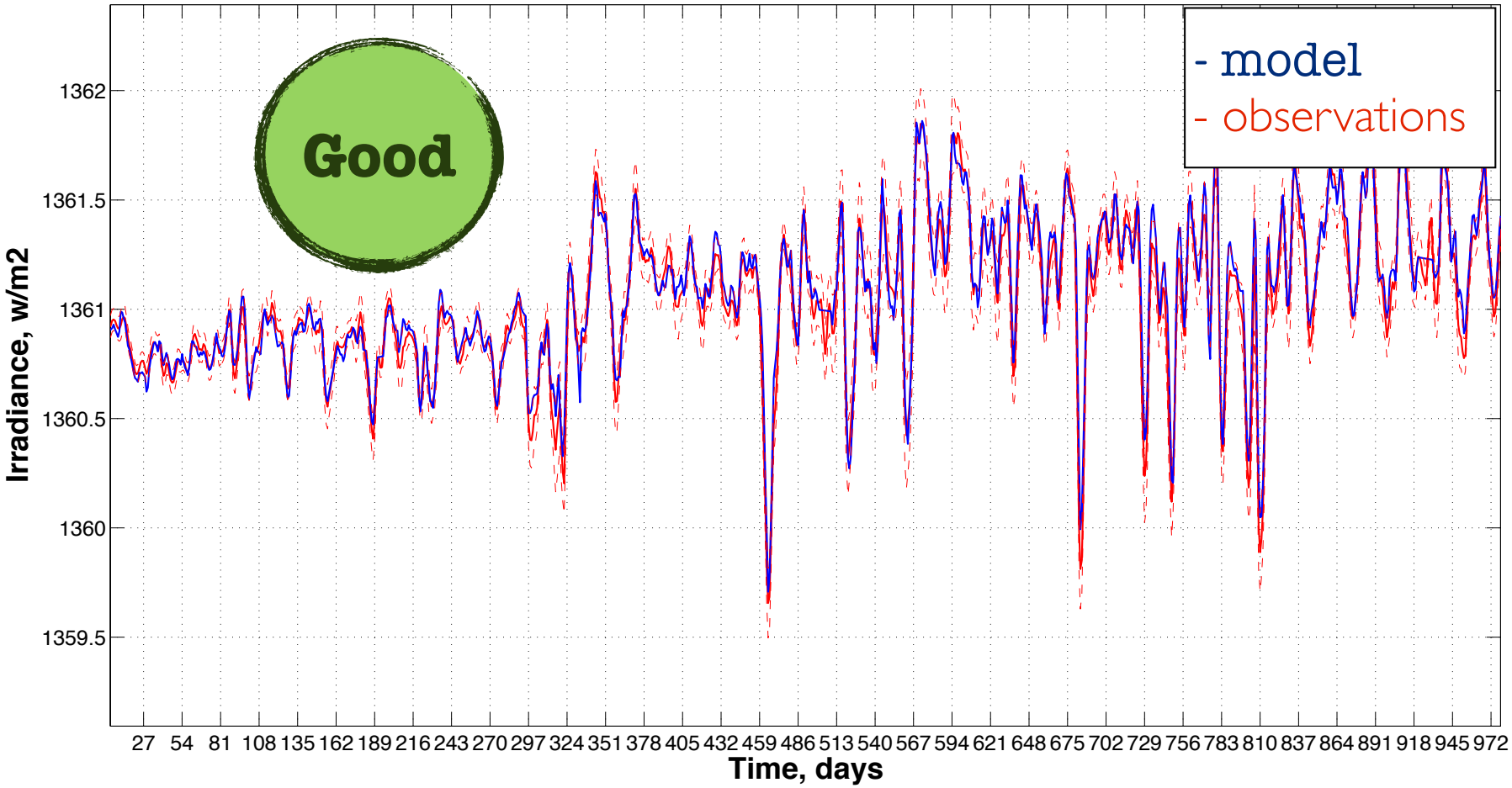

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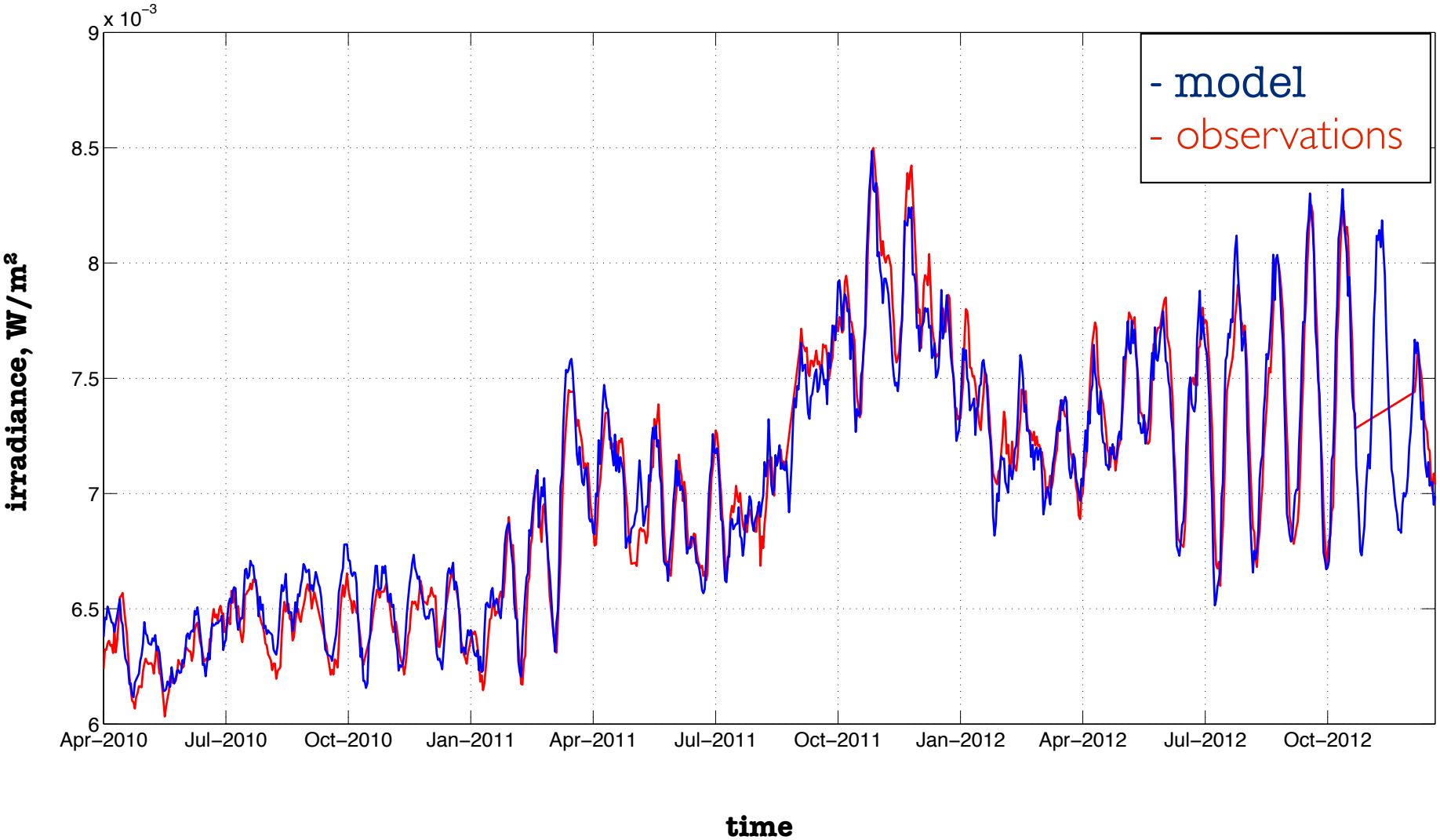
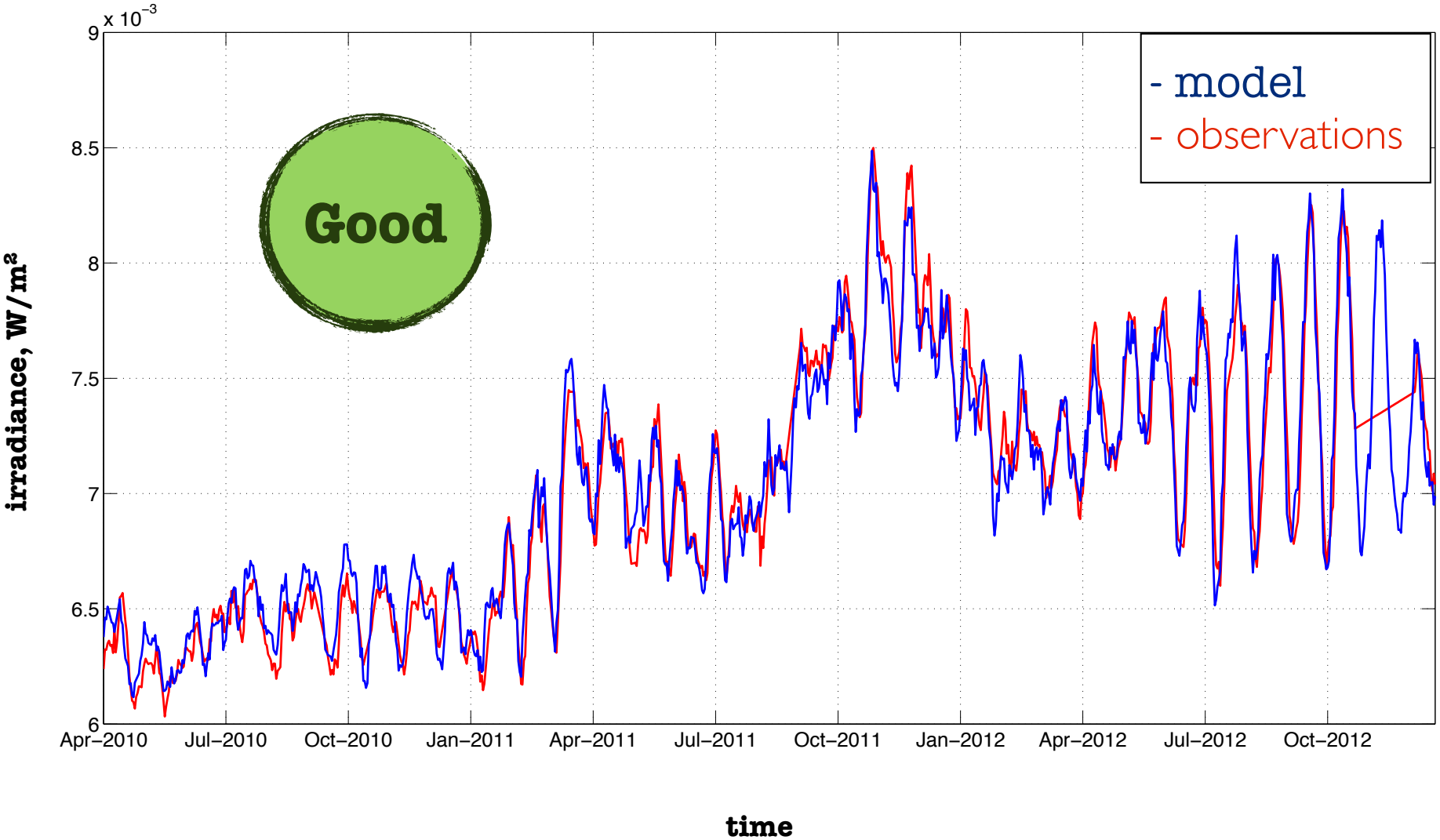


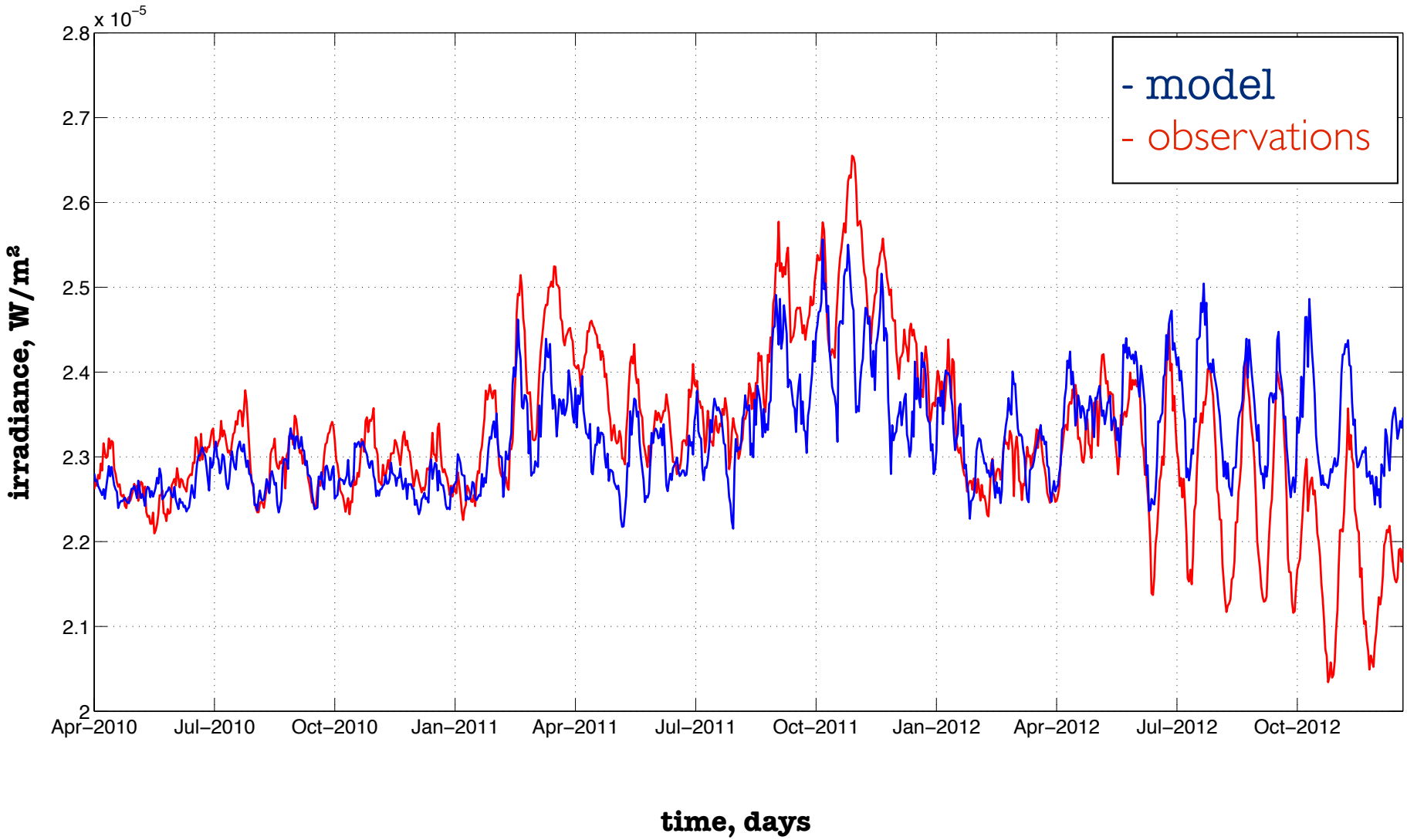
RECONSTRUCTION EXAMPLES

Ly Alpha, 121 nm (SORCE)



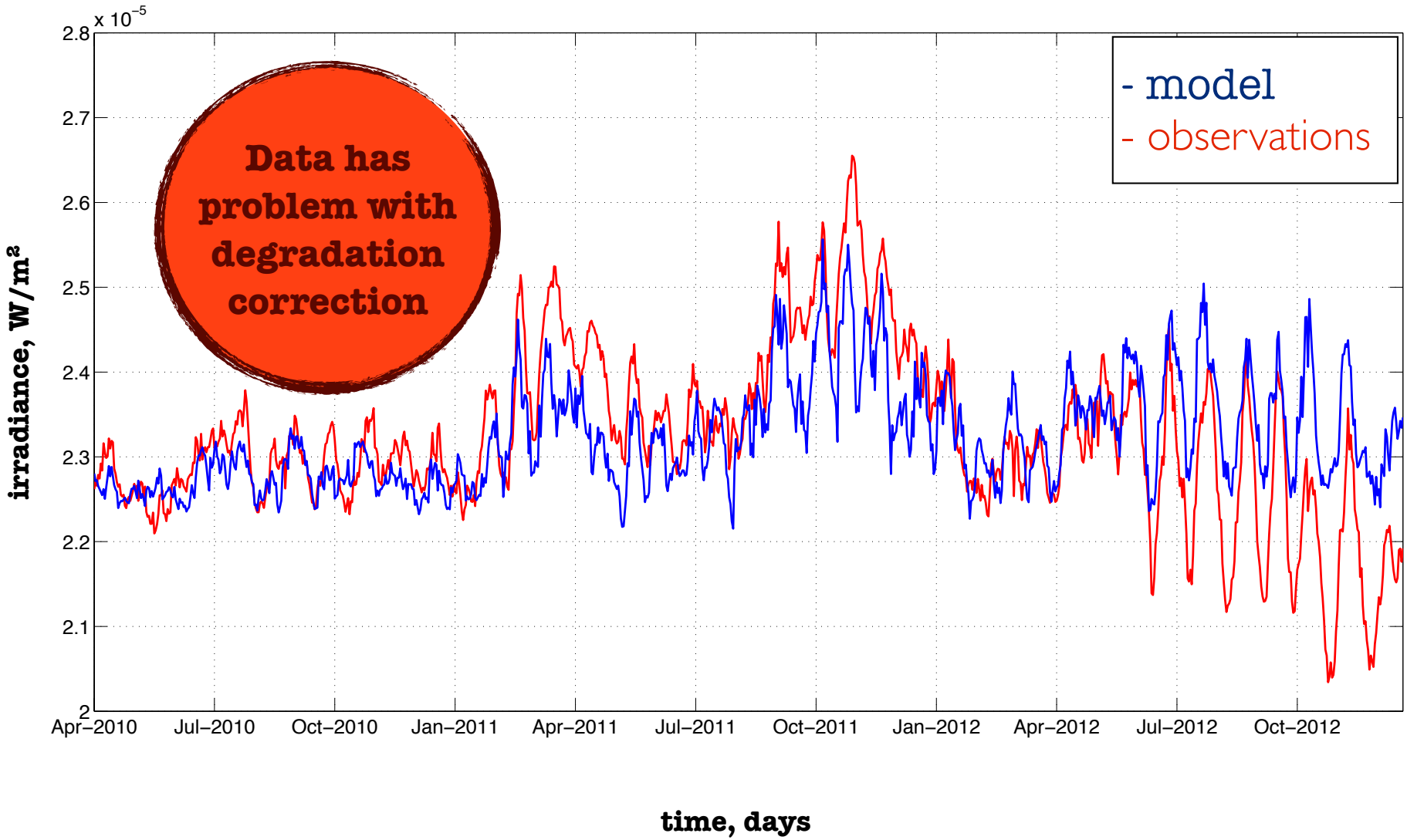
RECONSTRUCTION EXAMPLES

56 nm (TIMED)



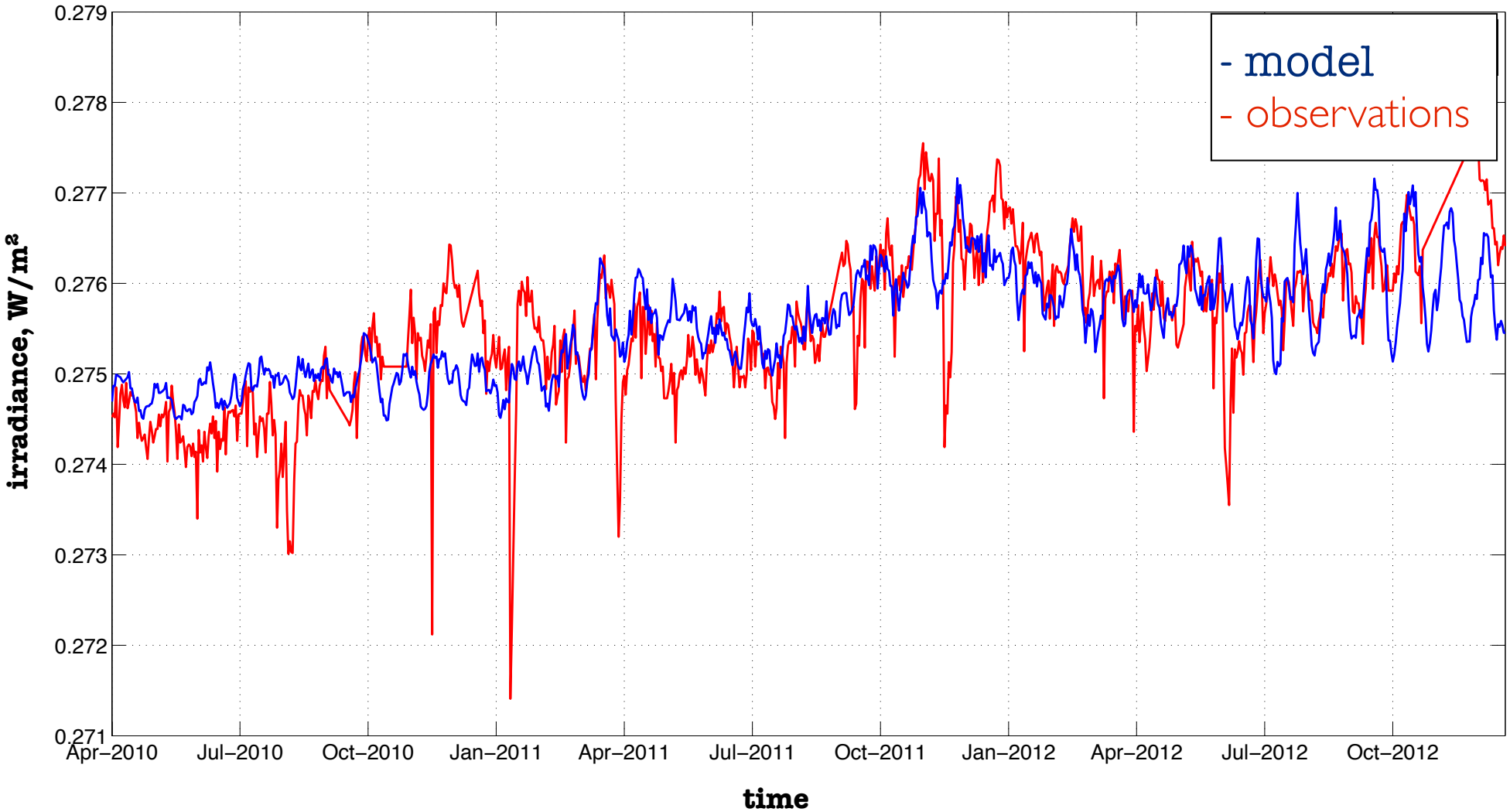
RECONSTRUCTION EXAMPLES

56 nm (TIMED)



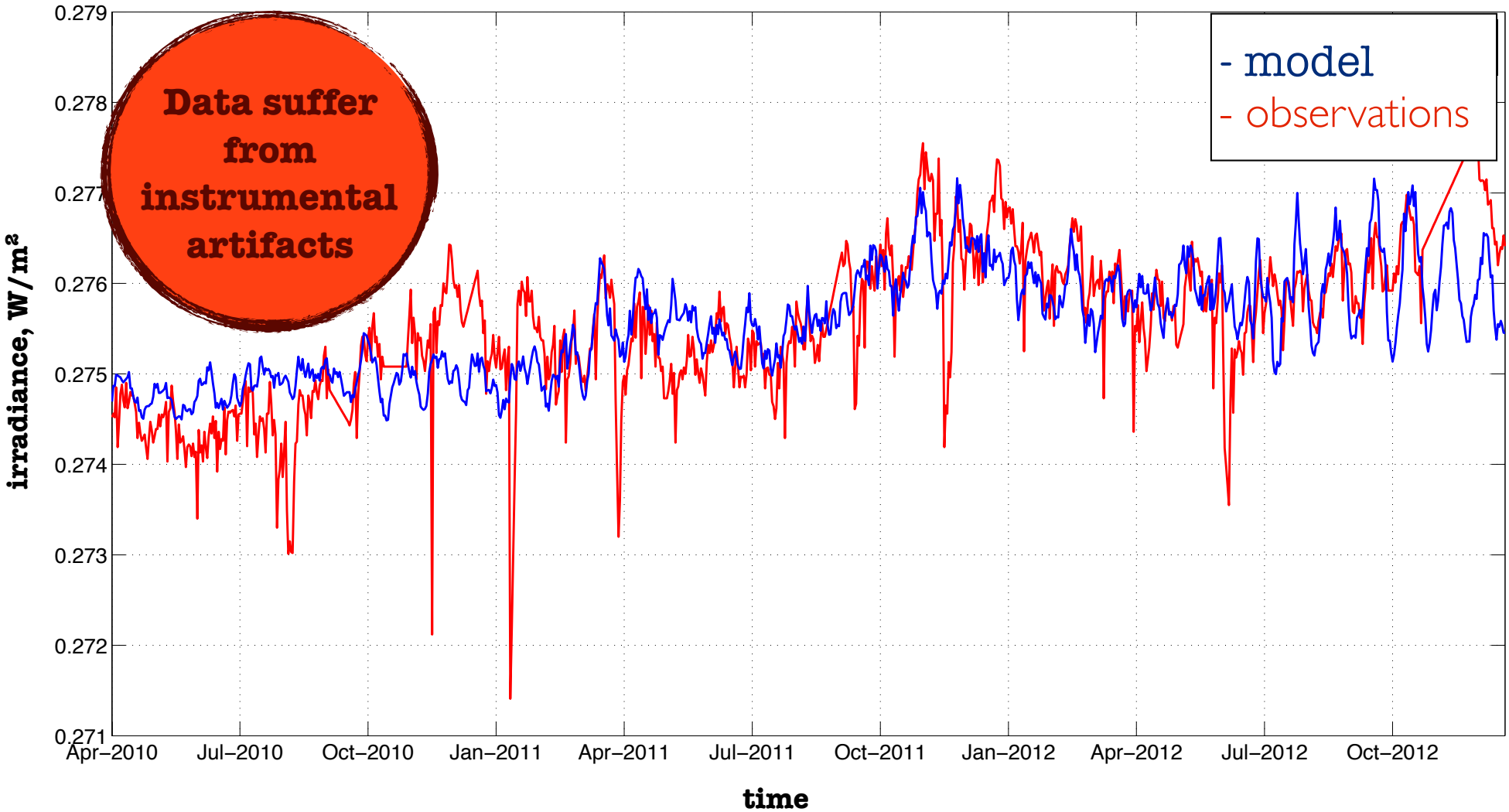
RECONSTRUCTION EXAMPLES

270 nm (SORCE)



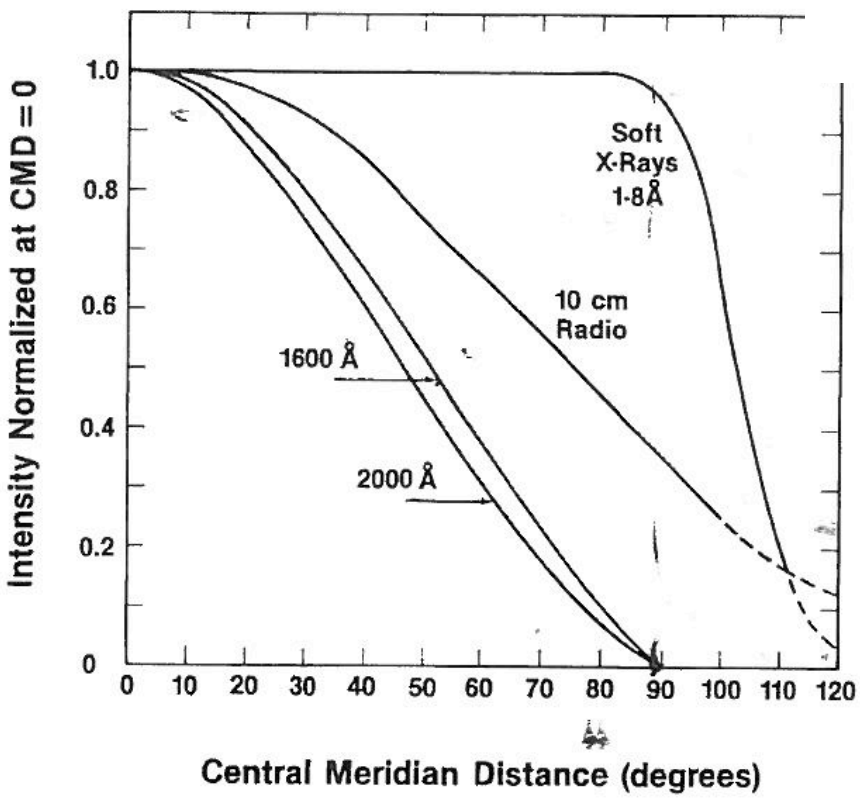
RECONSTRUCTION EXAMPLES

270 nm (SORCE)



THE CENTER-TO-LIMB VARIATION

Theoretical center-to-limb curves



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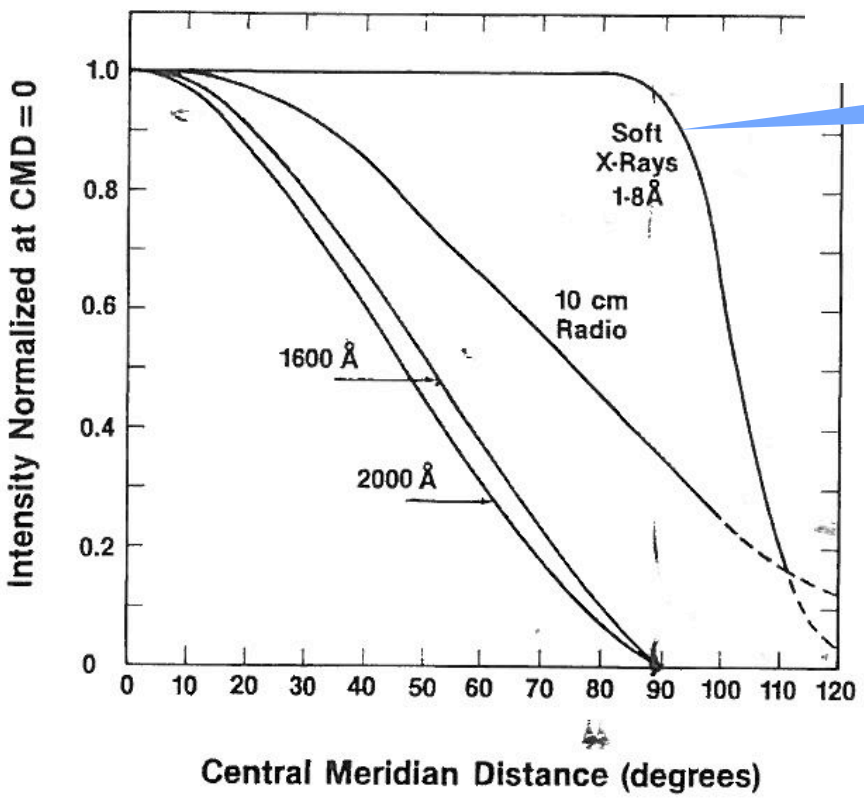
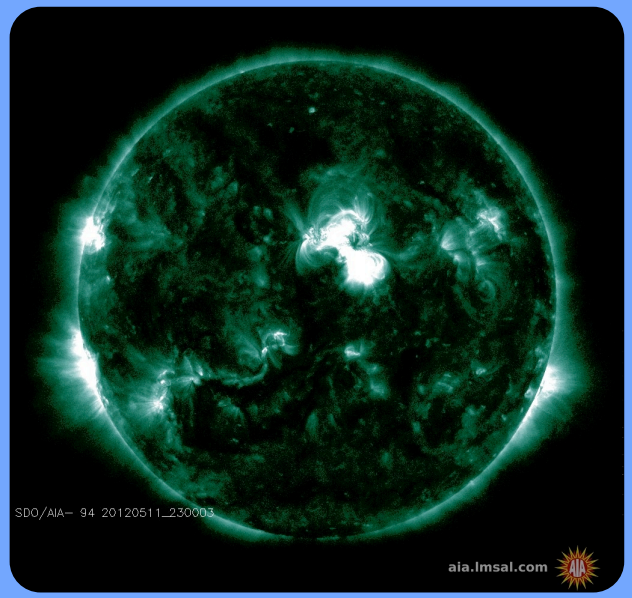


optically **thin** emissions



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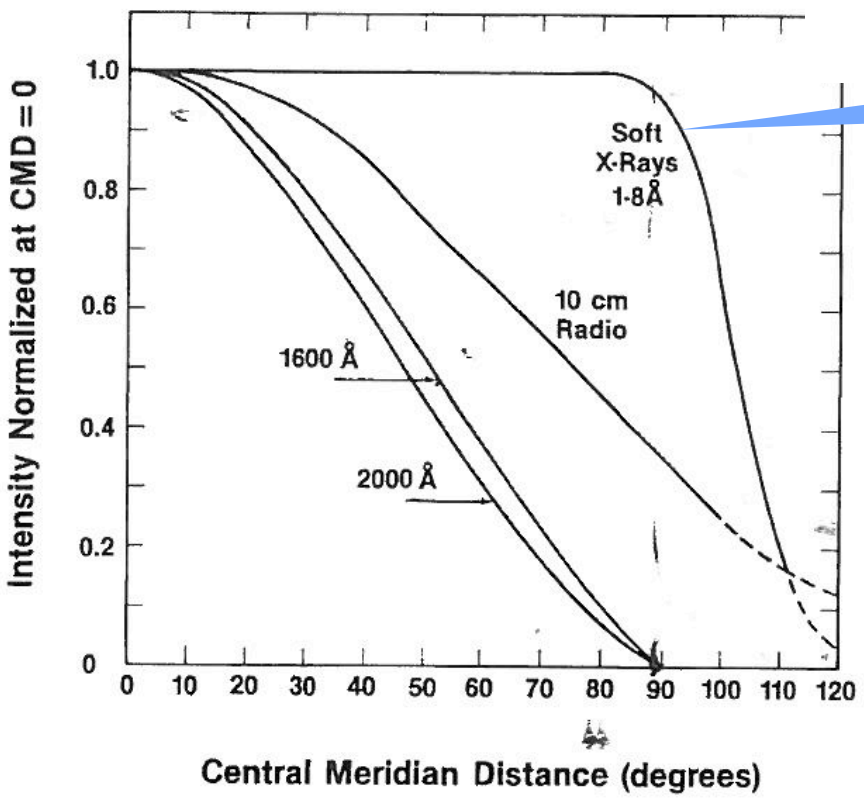

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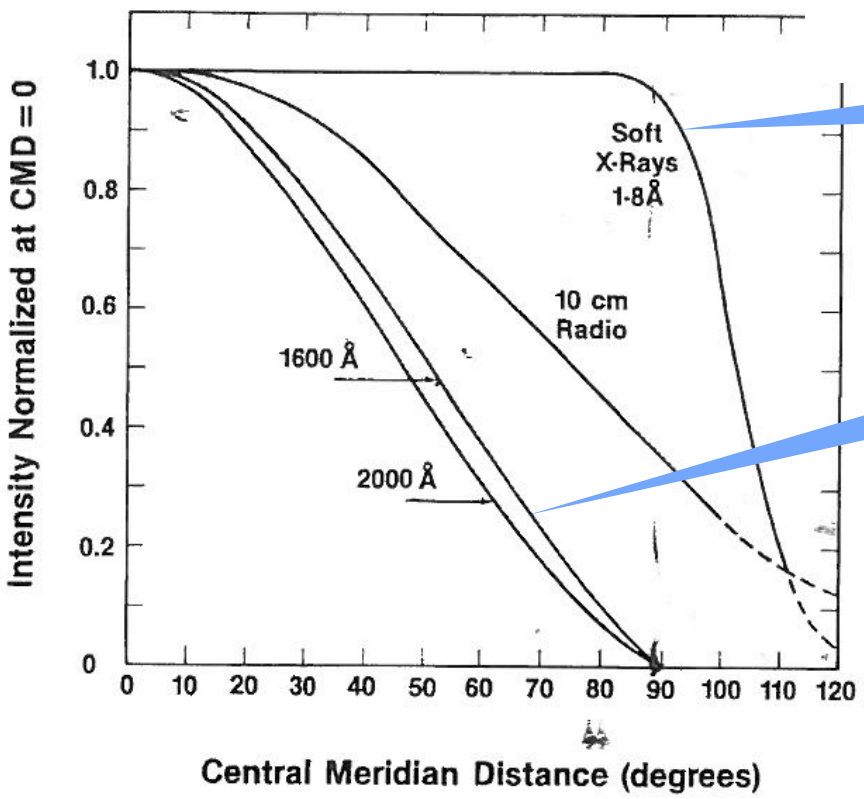
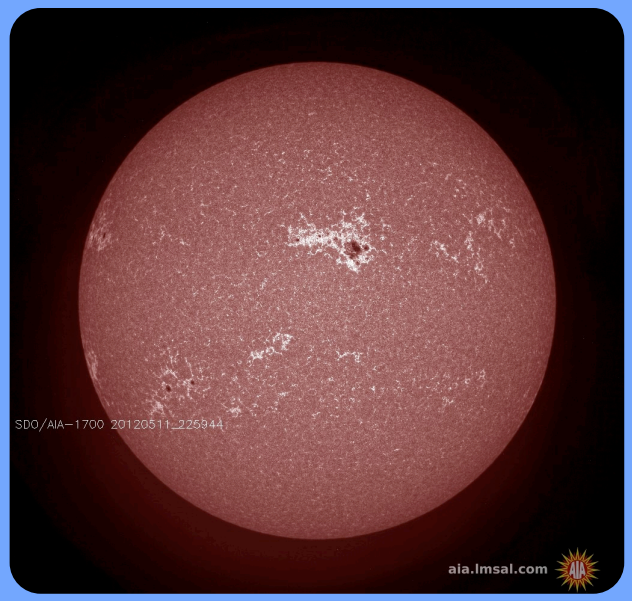


optically **thin** emissions

optically **thick** emissions



THE CENTER-TO-LIMB VARIATION

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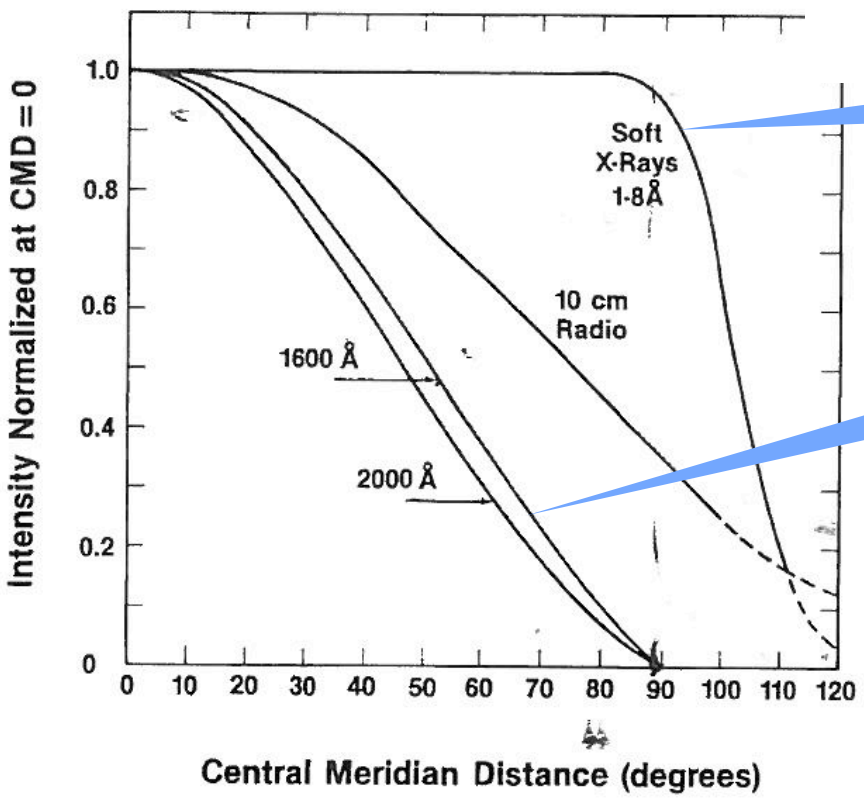

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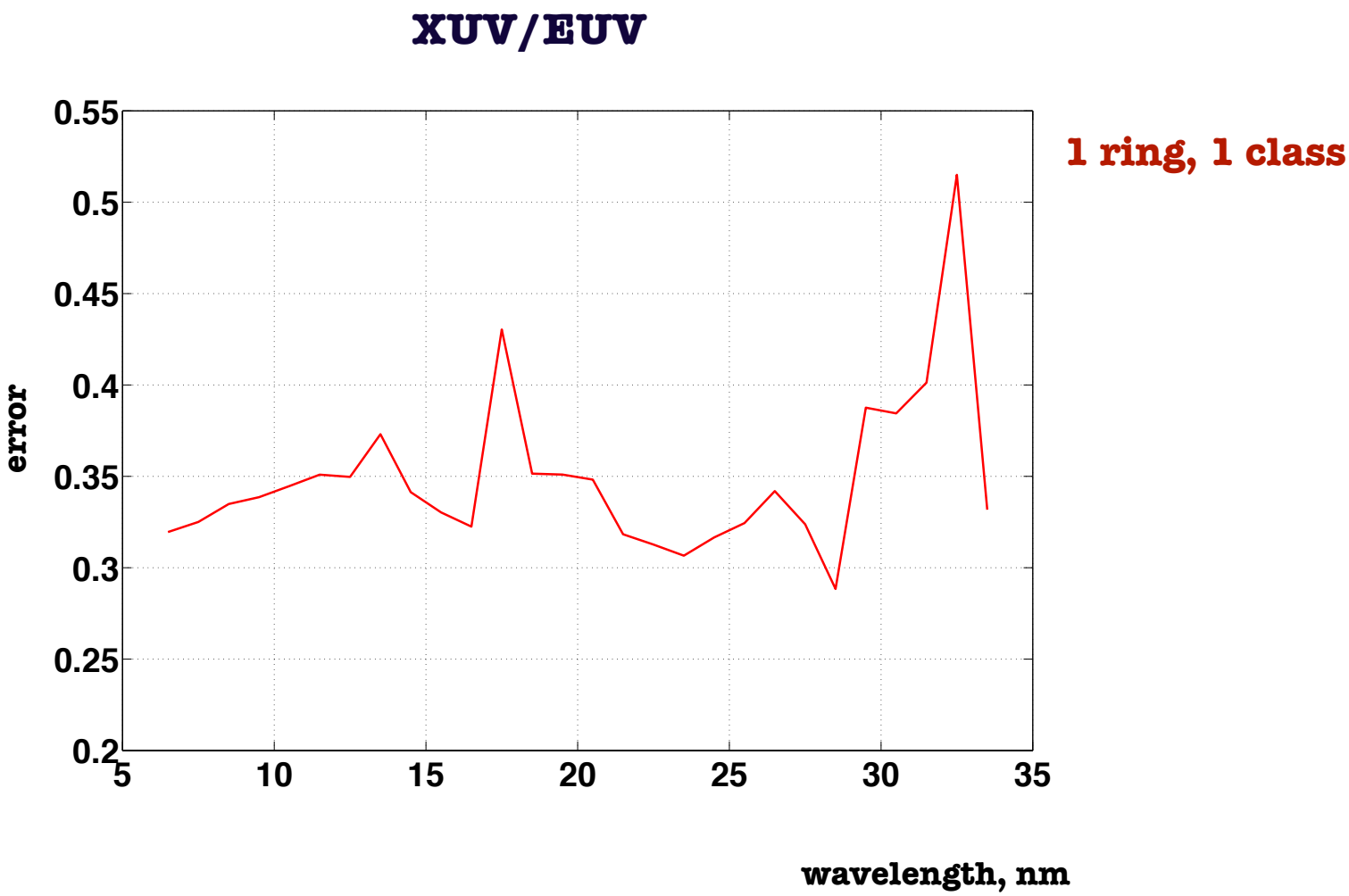
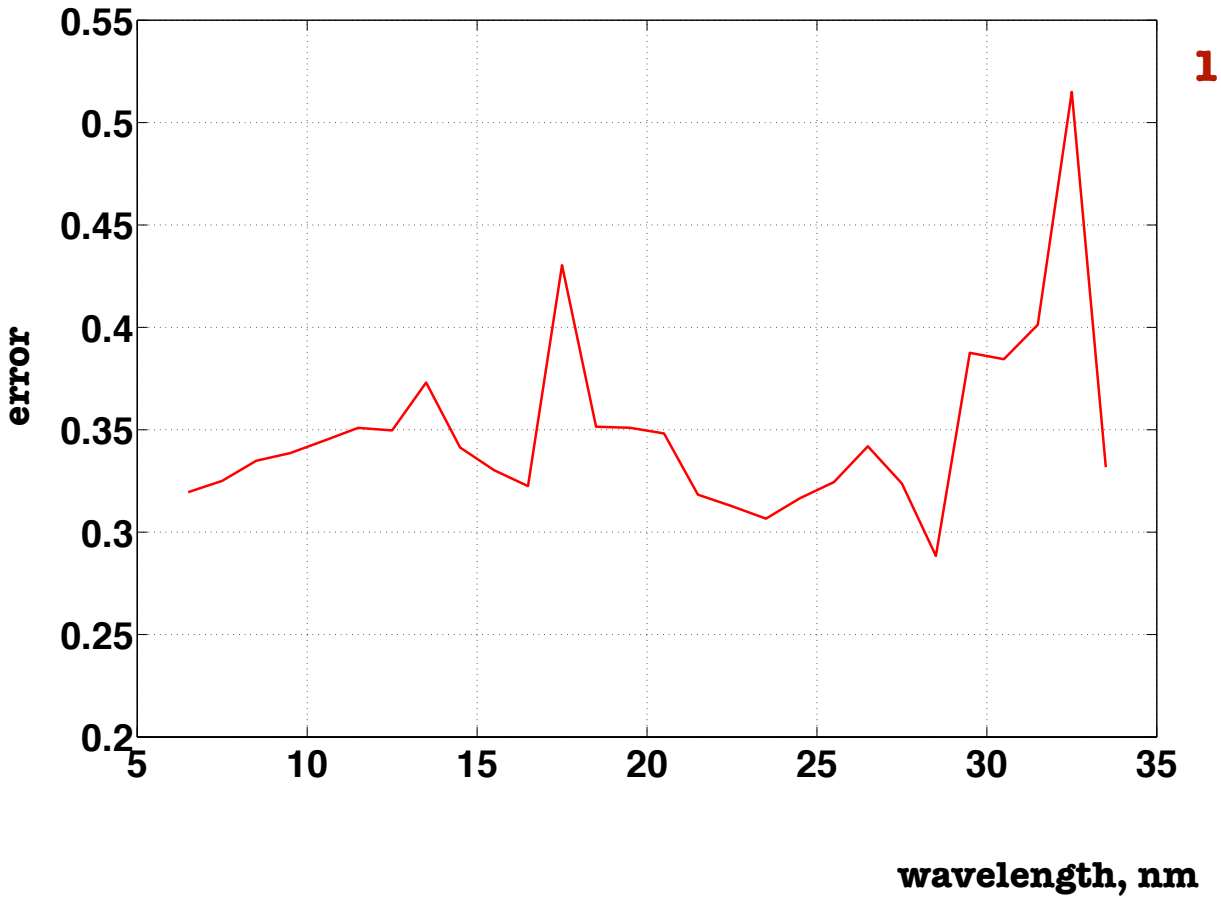


THE CENTER-TO-LIMB VARIATION

Rings in model = CTL effect

XUV/EUV



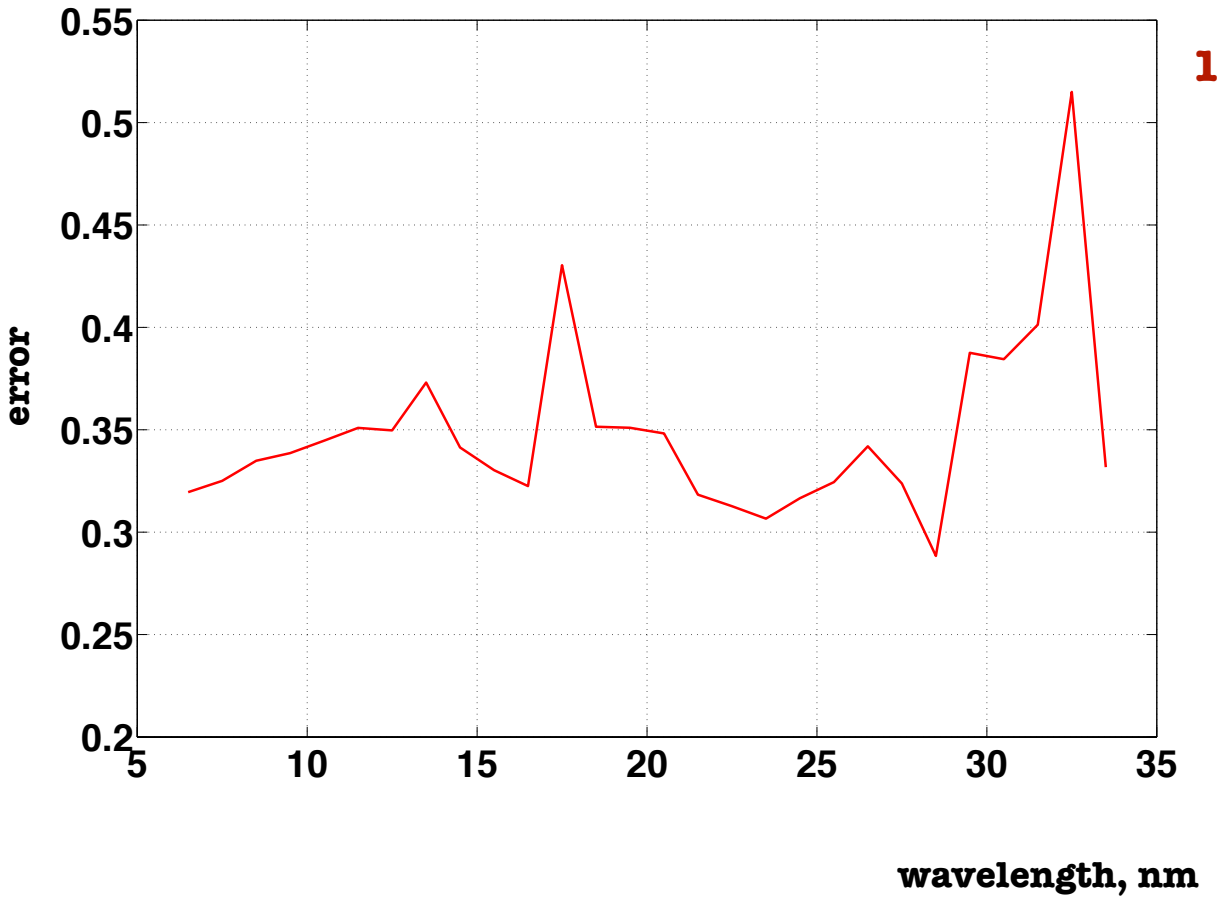
1 ring, 1 class

THE CENTER-TO-LIMB VARIATION

Rings in model = CTL effect

Classes in model = atmosphere models

XUV/EUV



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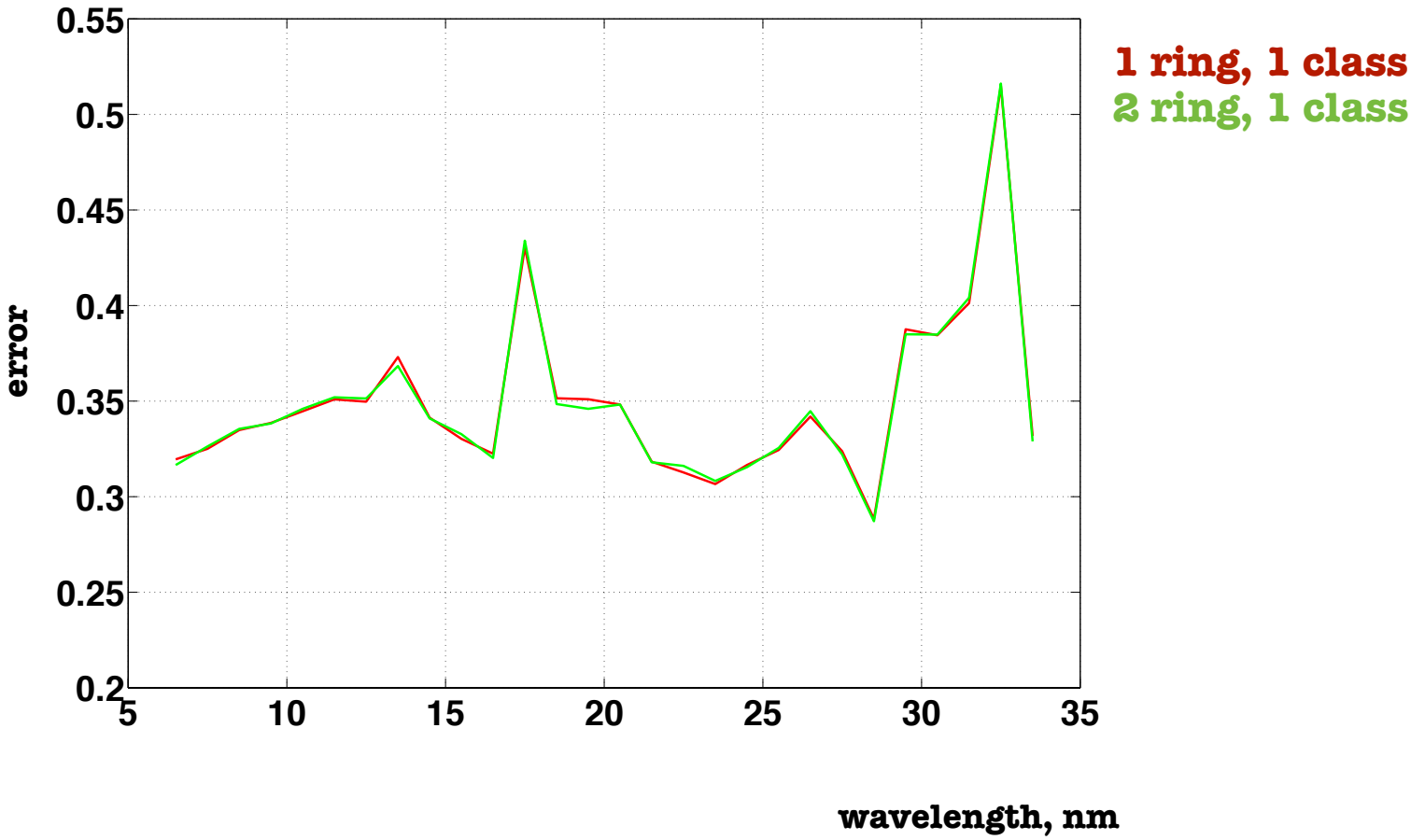

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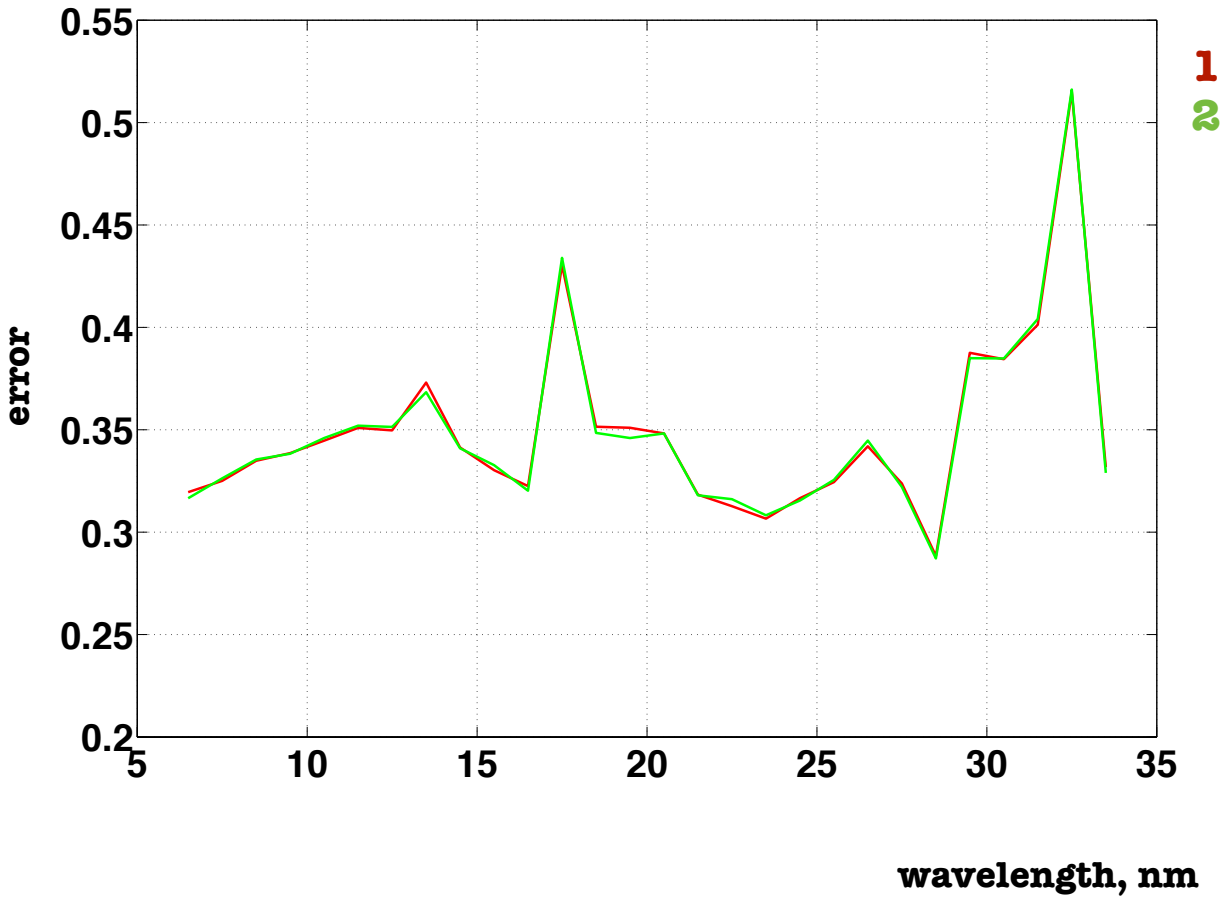


1 ring, 1 class
2 ring, 1 class

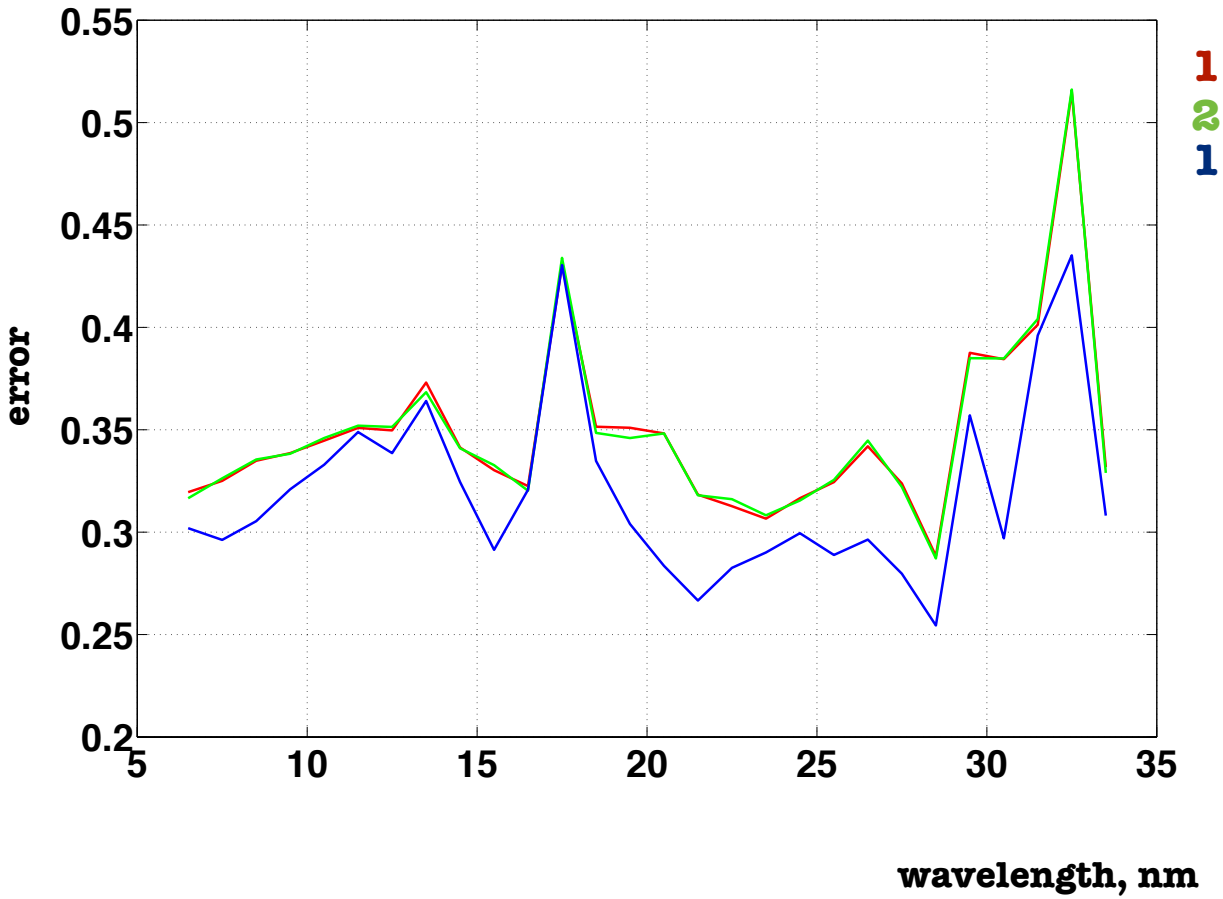
Empirical refinement: major part of XUV/EUV emission is optically thin (as expected).

THE CENTER-TO-LIMB VARIATION

Rings in model = CTL effect

Classes in model = atmosphere models

XUV/EUV



1 ring, 1 class
2 ring, 1 class
1 ring, 2 class

Empirical refinement: major part of XUV/EUV emission is optically thin (as expected).

THE CENTER-TO-LIMB VARIATION

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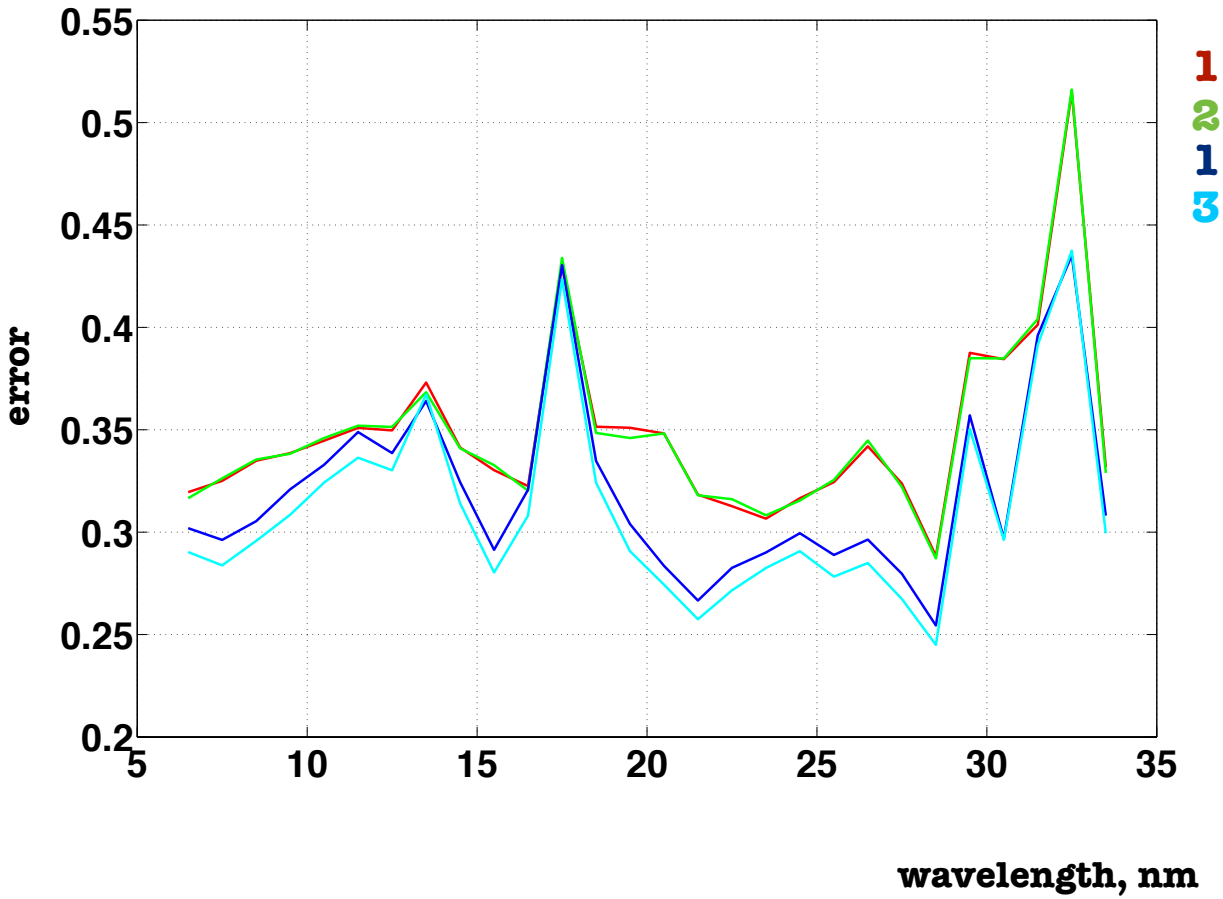
Classes in model = atmosphere models

XUV/EUV



1 ring, 1 class
2 ring, 1 class
1 ring, 2 class
3 ring, 2 class

Empirical refinement: major part of XUV/EUV emission is optically thin (as expected).

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Rings in model = CTL effect

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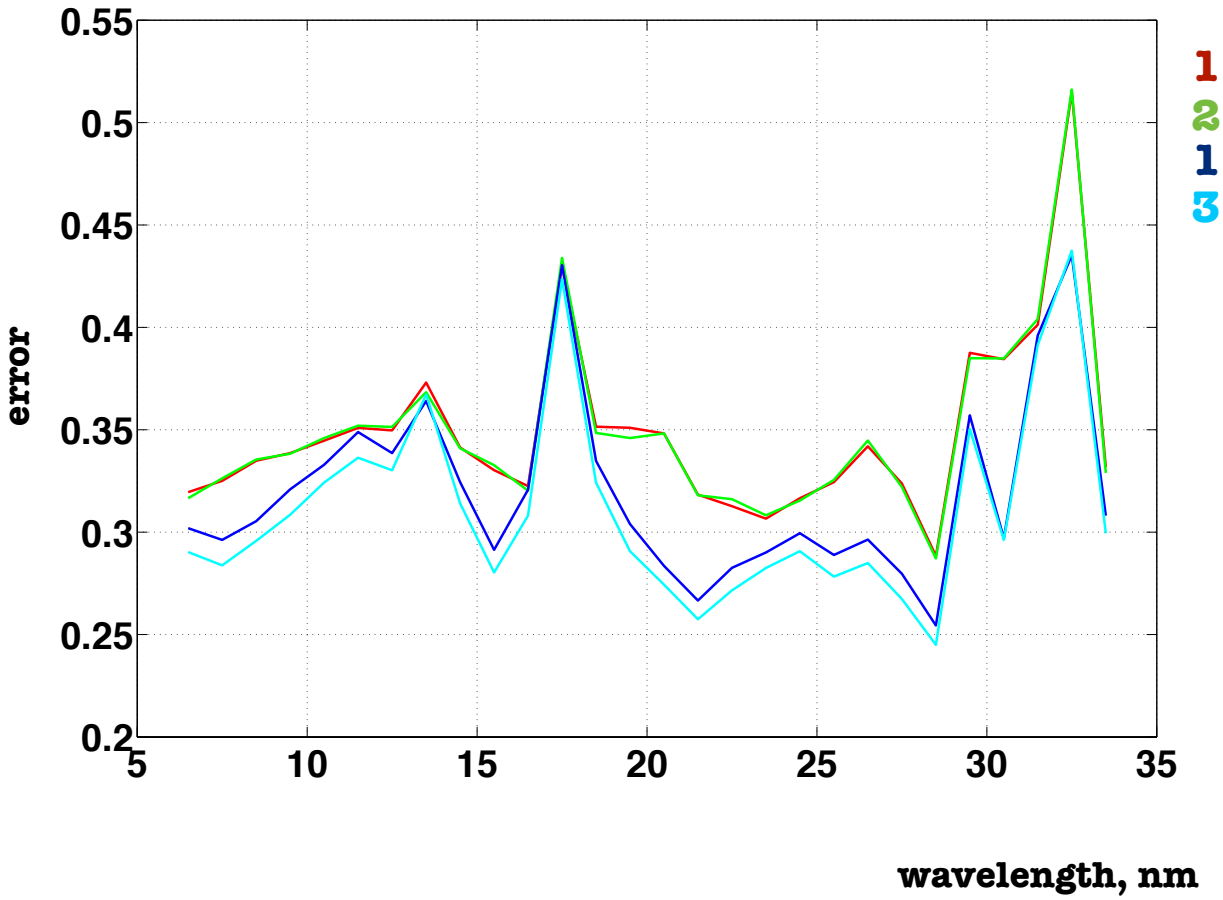
XUV/EUV



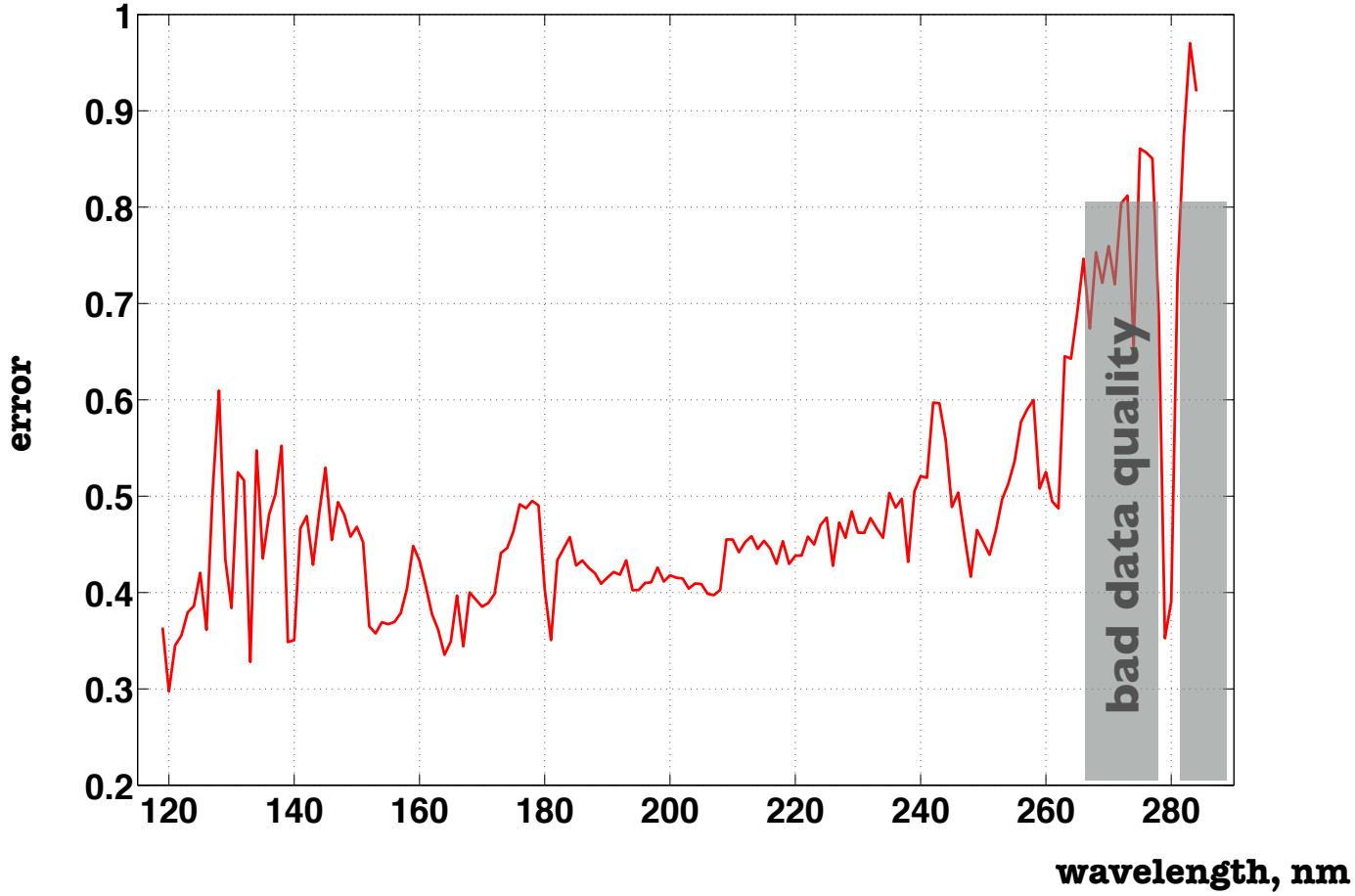
1 ring, 1 class
2 ring, 1 class
1 ring, 2 class
3 ring, 2 class

Empirical refinement: major part of XUV/EUV emission is optically thin (as expected).

Empirical refinement: 2 classes are needed to reconstruct XUV/EUV.

THE CENTER-TO-LIMB VARIATION

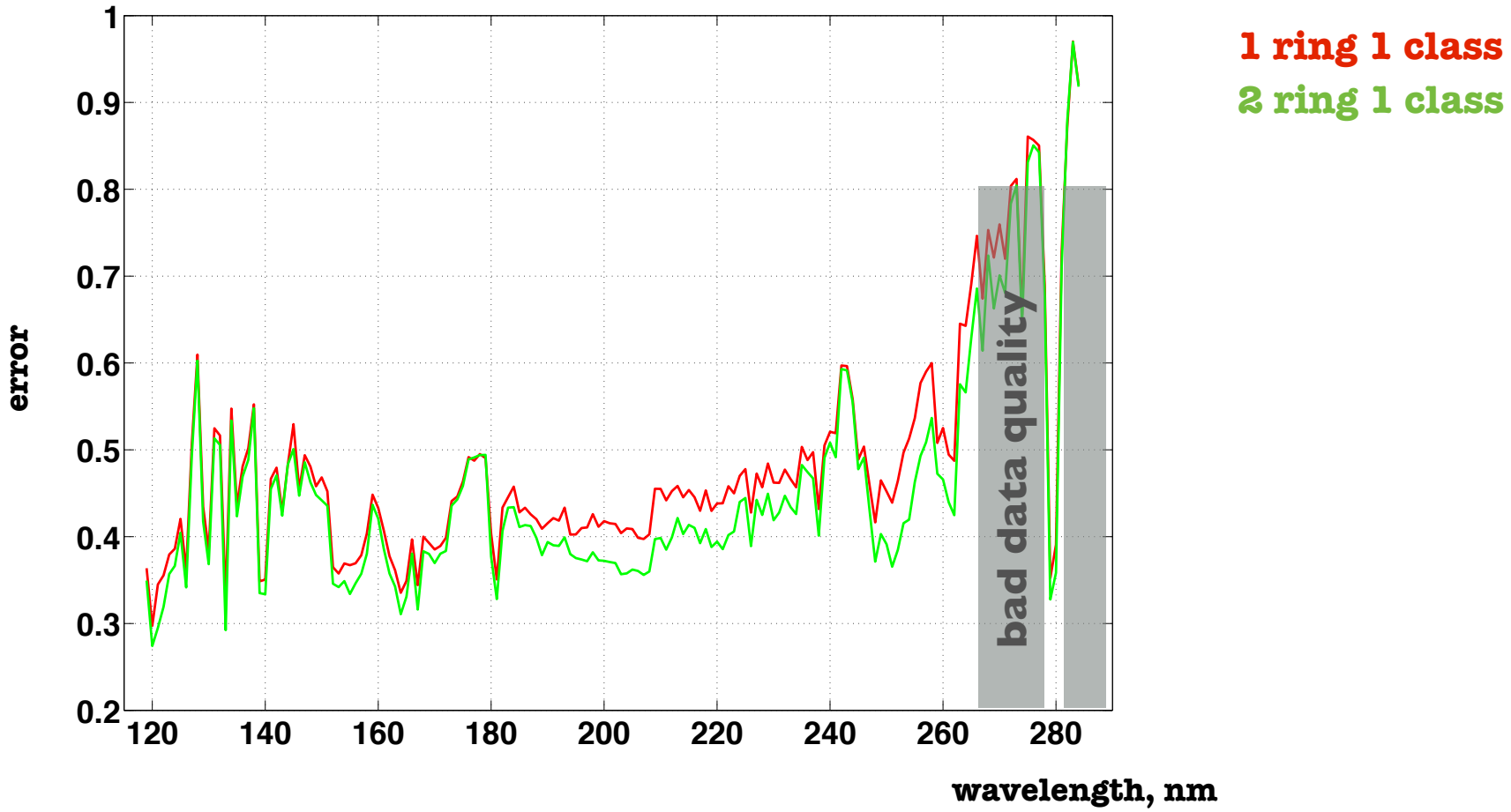
FUV/MUV



1 ring 1 class

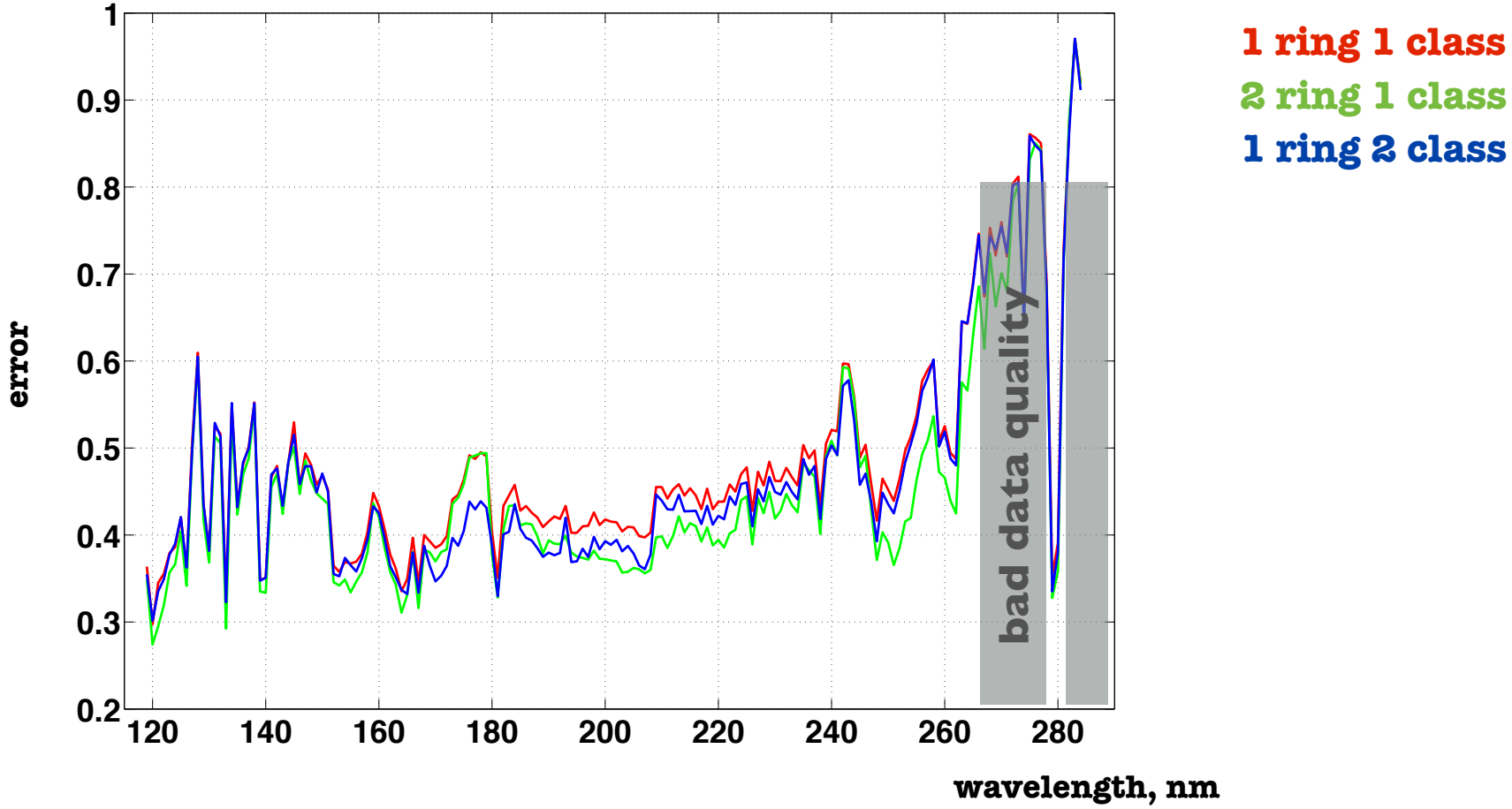
THE CENTER-TO-LIMB VARIATION

FUV/MUV



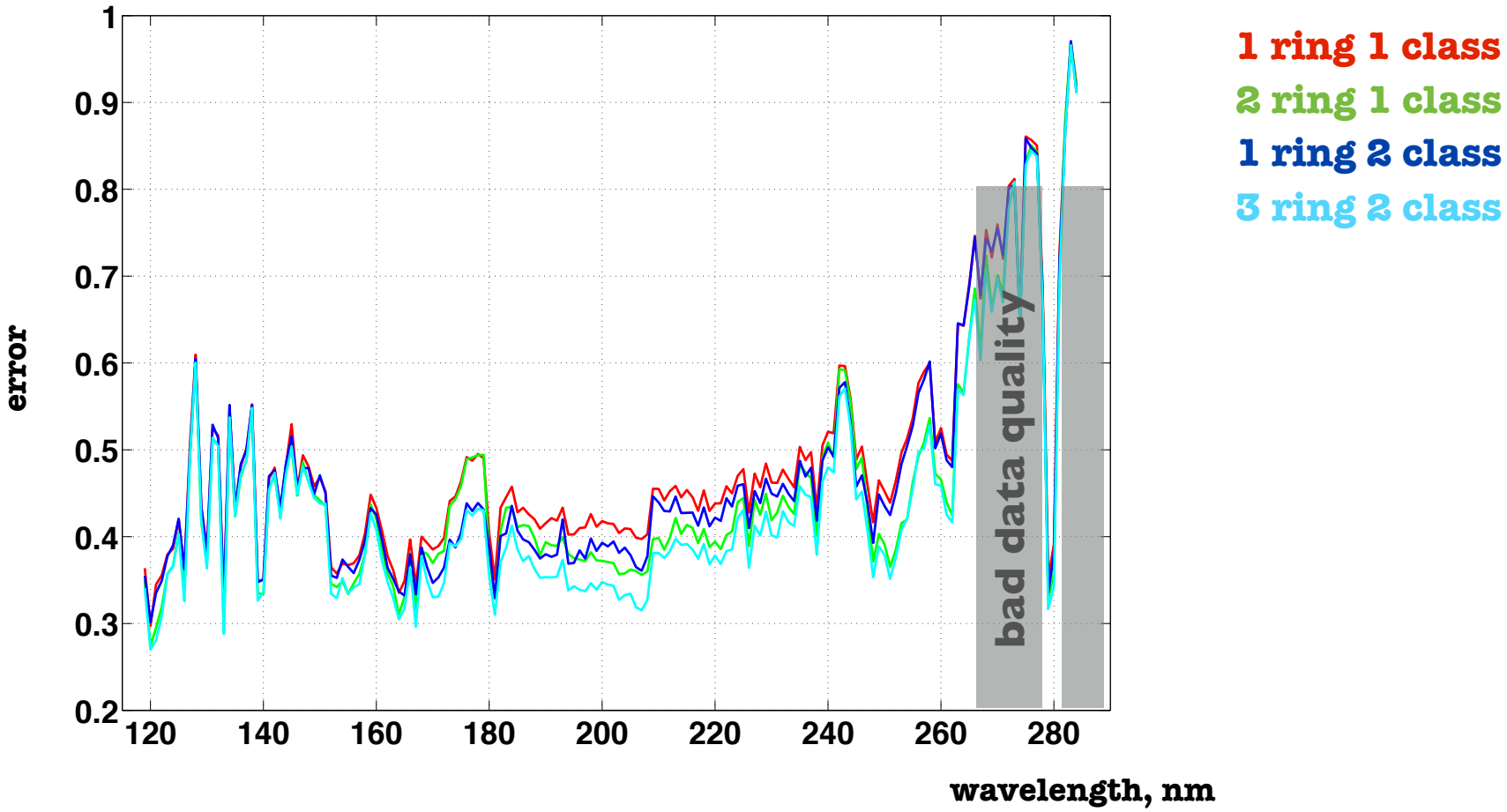
THE CENTER-TO-LIMB VARIATION

FUV/MUV



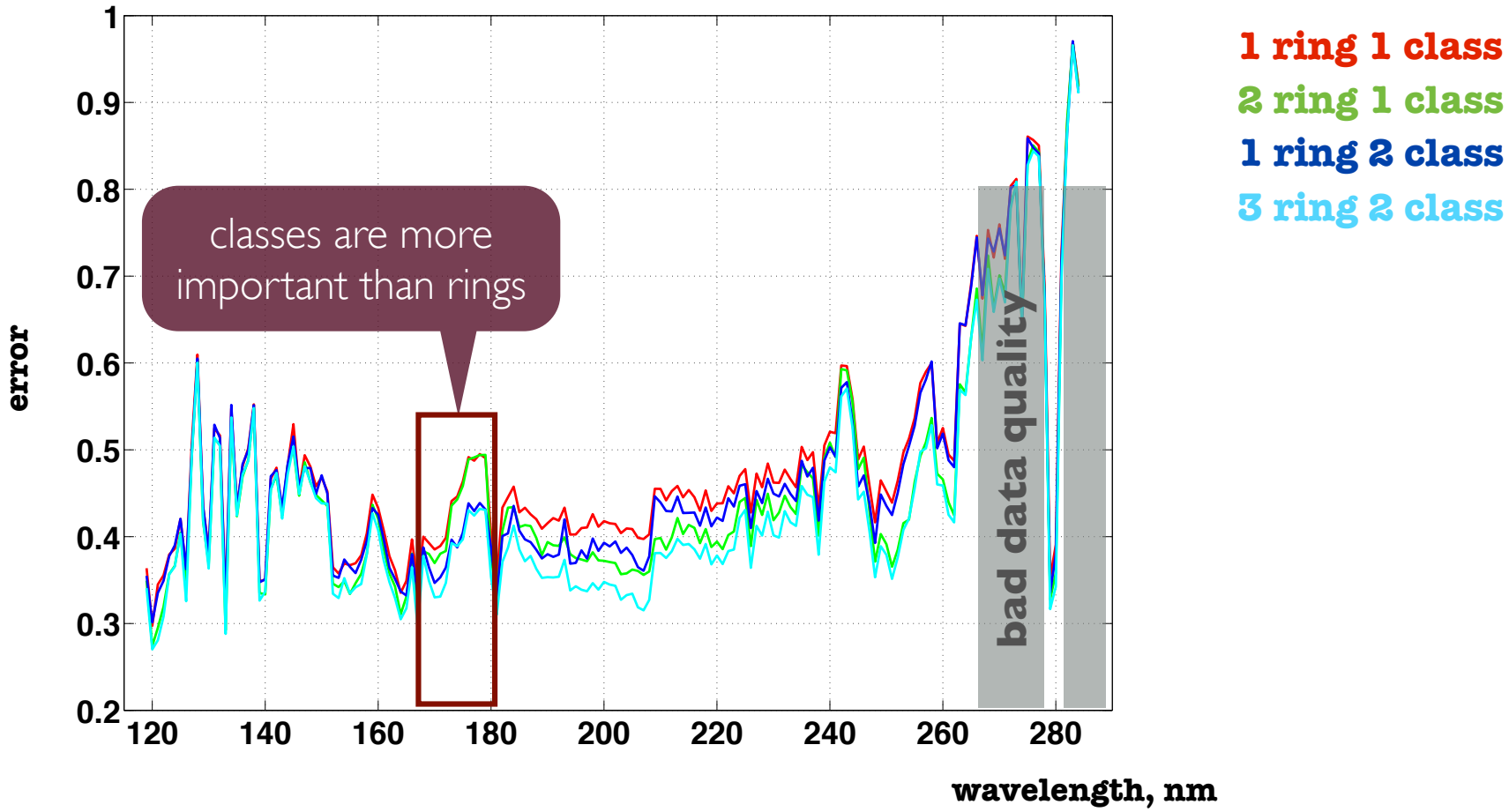
THE CENTER-TO-LIMB VARIATION

FUV/MUV



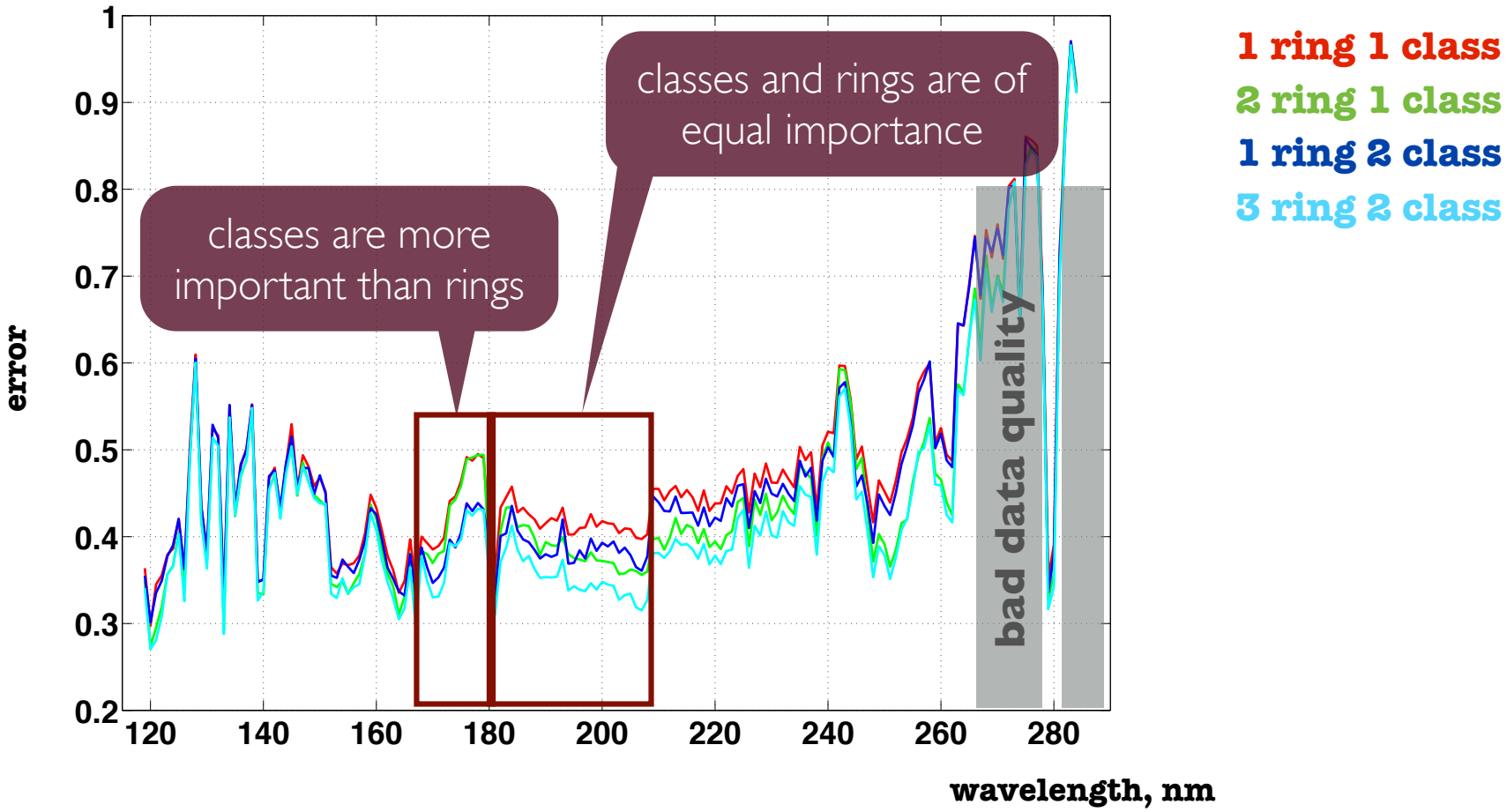
THE CENTER-TO-LIMB VARIATION

FUV/MUV



THE CENTER-TO-LIMB VARIATION

FUV/MUV



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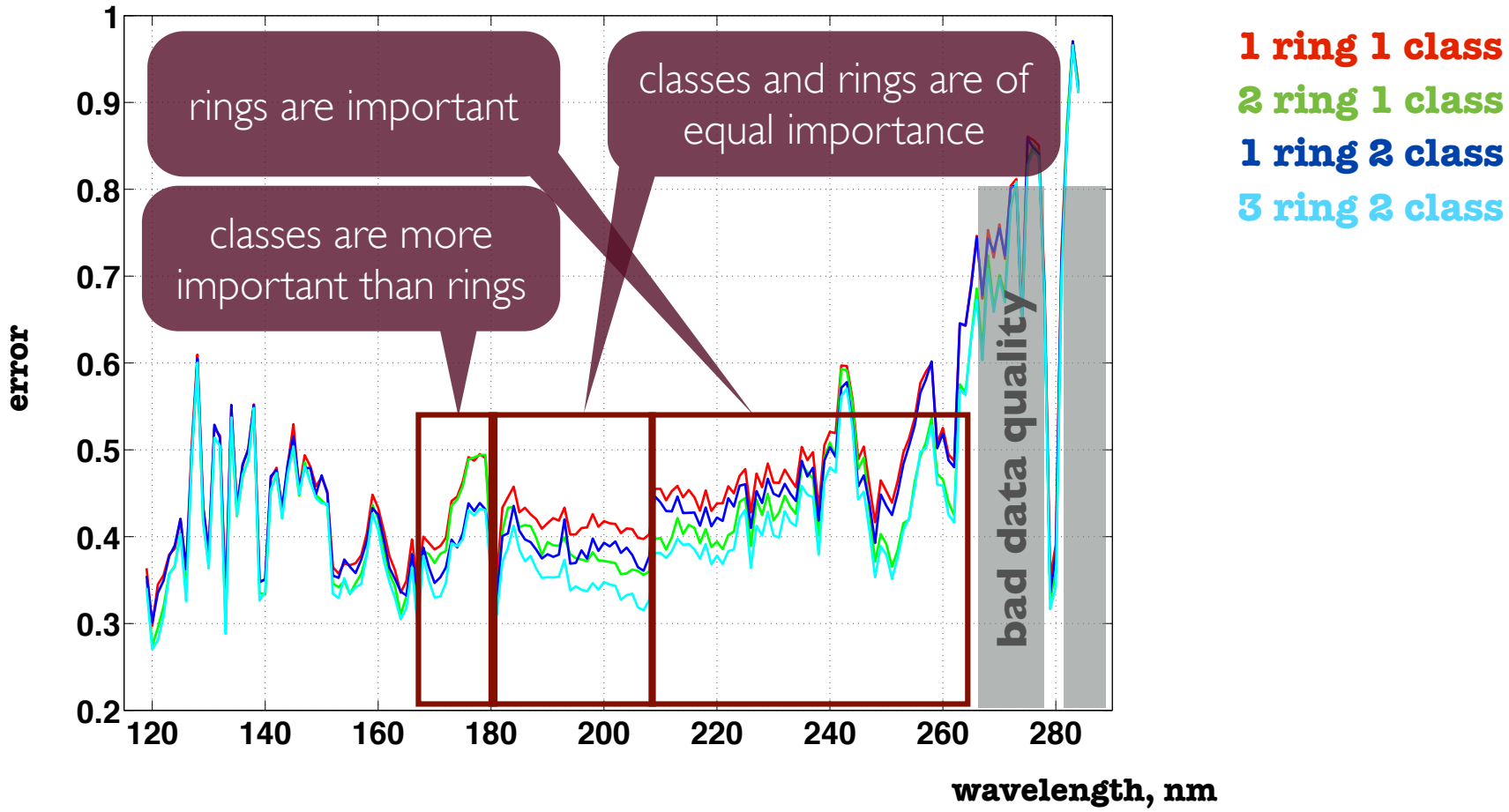
FUV/MUV



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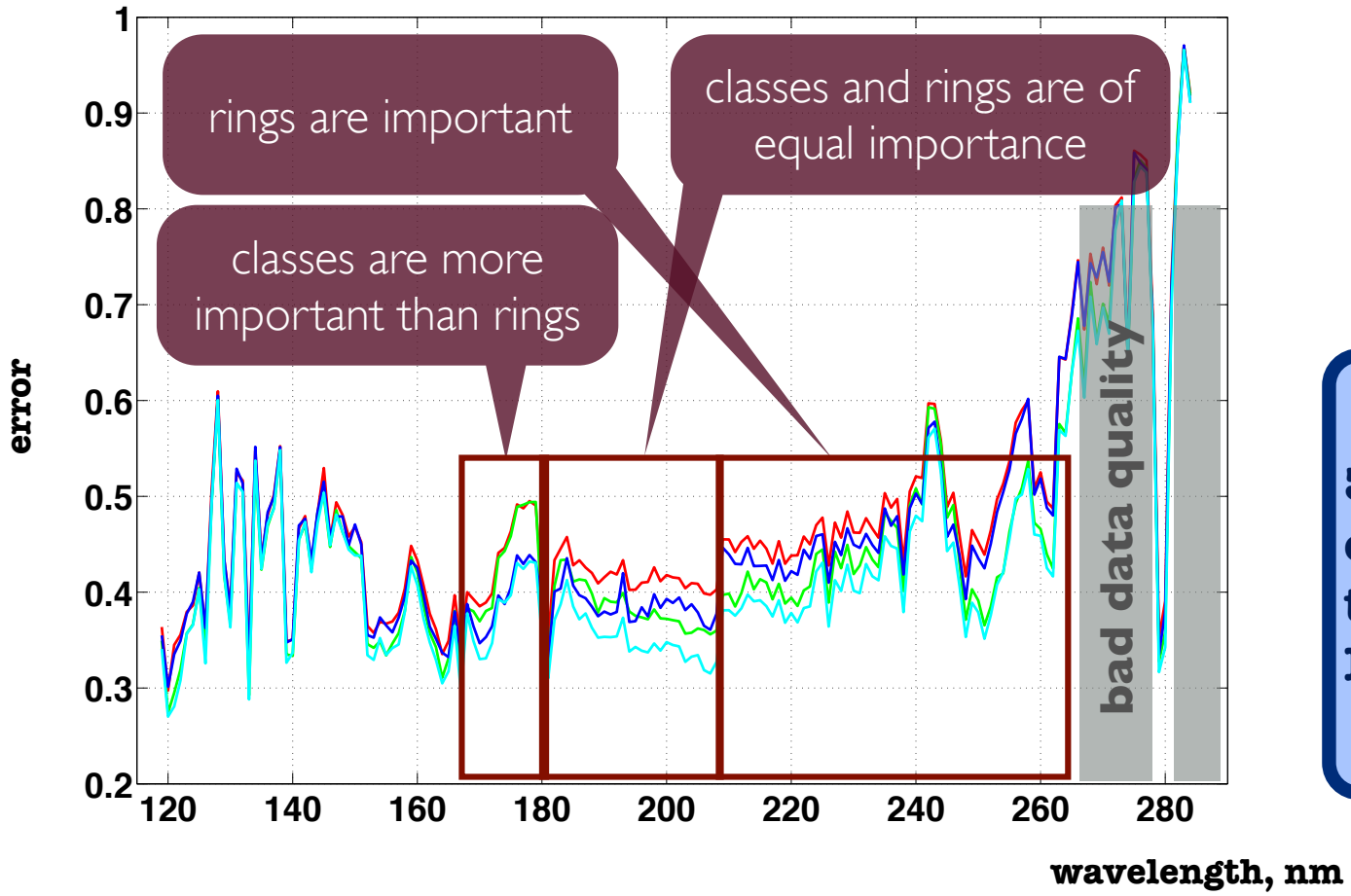
FUV/MUV

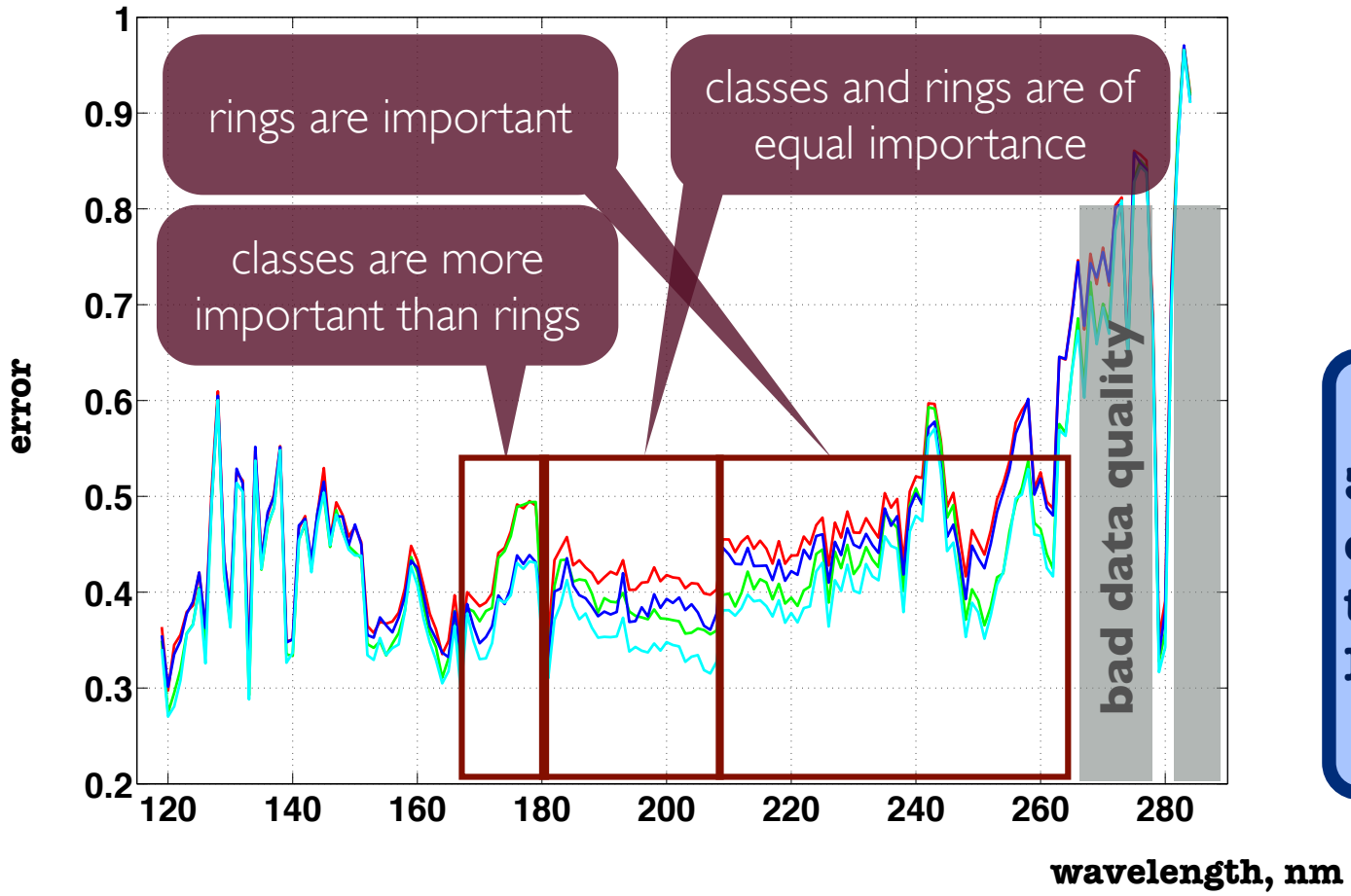


1 ring 1 class
2 ring 1 class
1 ring 2 class
3 ring 2 class

3 rings and 2 classes are needed to reconstruct FUV/MUV range.

THE CENTER-TO-LIMB VARIATION

FUV/MUV

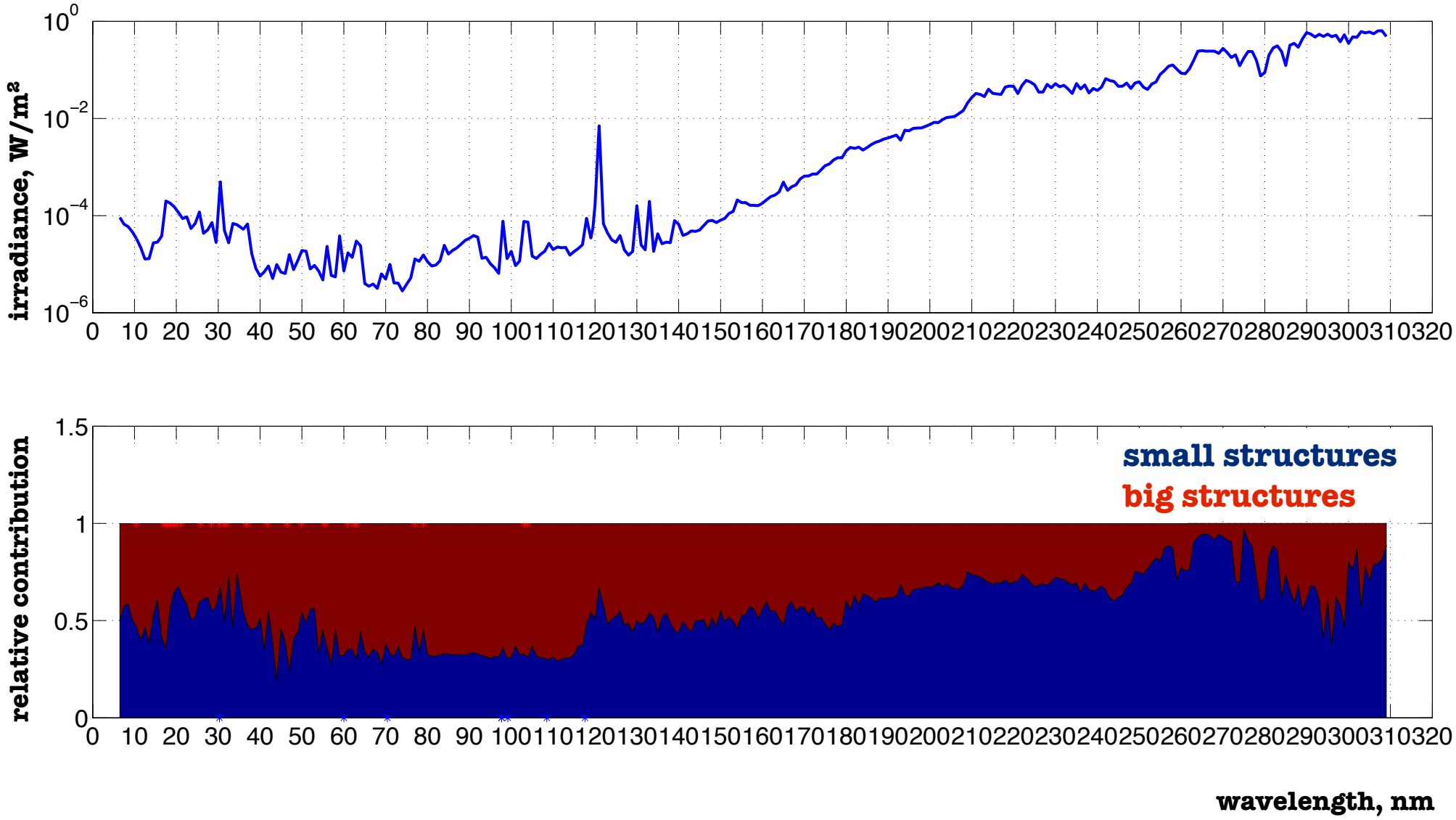


1 ring 1 class
2 ring 1 class
1 ring 2 class
3 ring 2 class

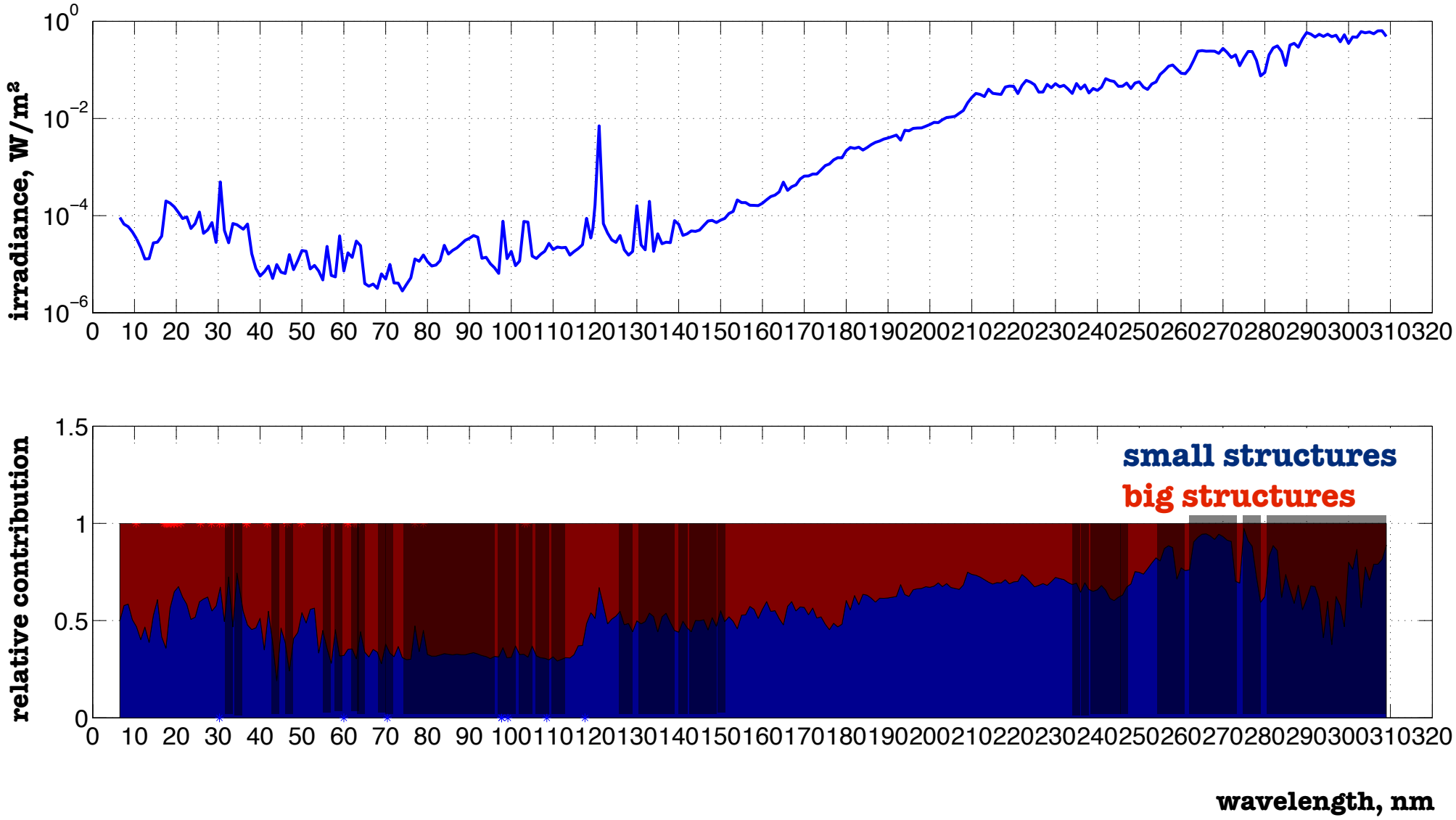
3 rings and 2 classes are needed to reconstruct FUV/MUV range.

Most part of FUV/MUV emission is optically thick. Especially in range: 170-265 nm.

CONTRIBUTION OF DIFFERENT CLASSES TO SSI VARIABILITY



CONTRIBUTION OF DIFFERENT CLASSES TO SSI VARIABILITY



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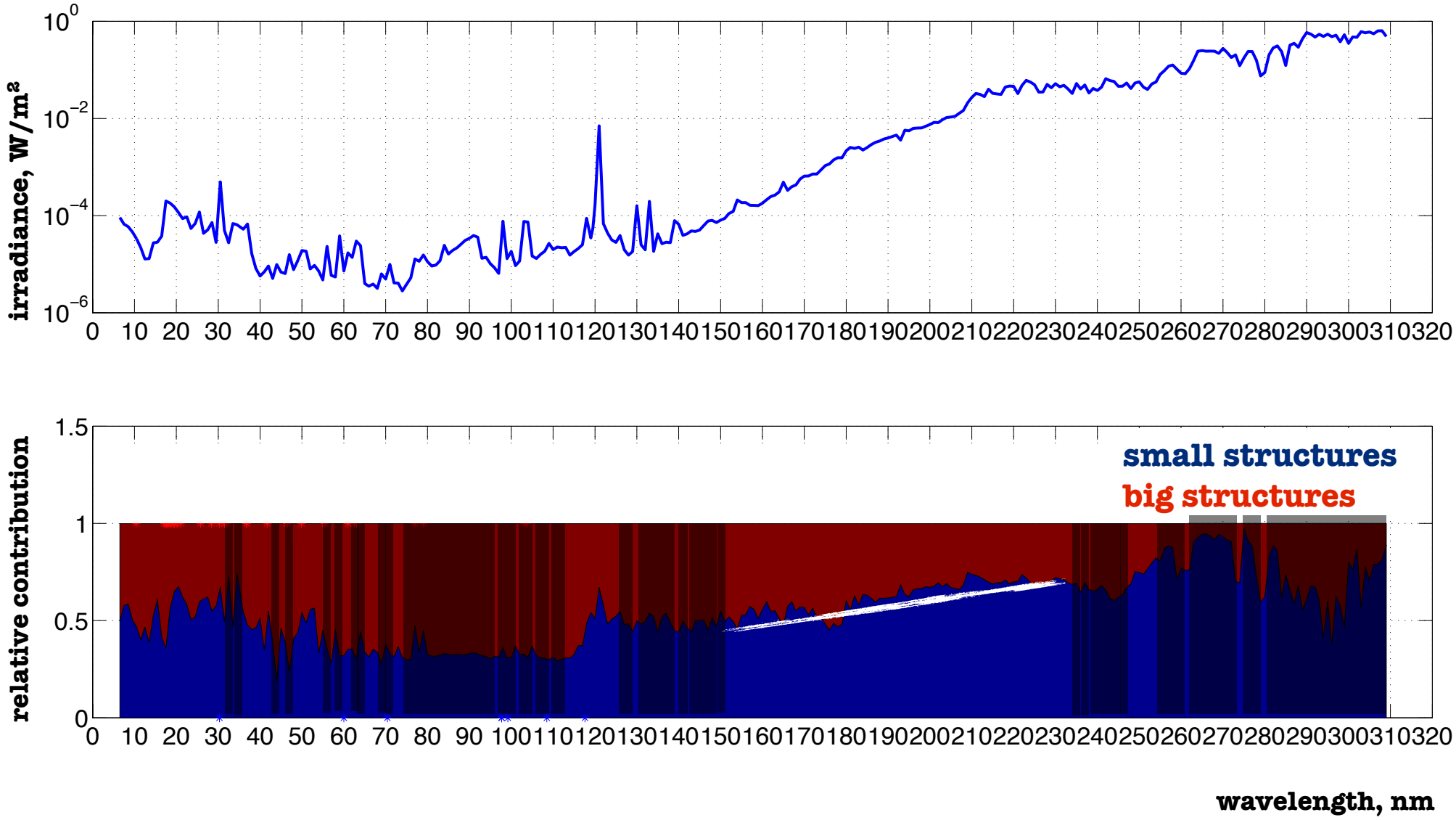

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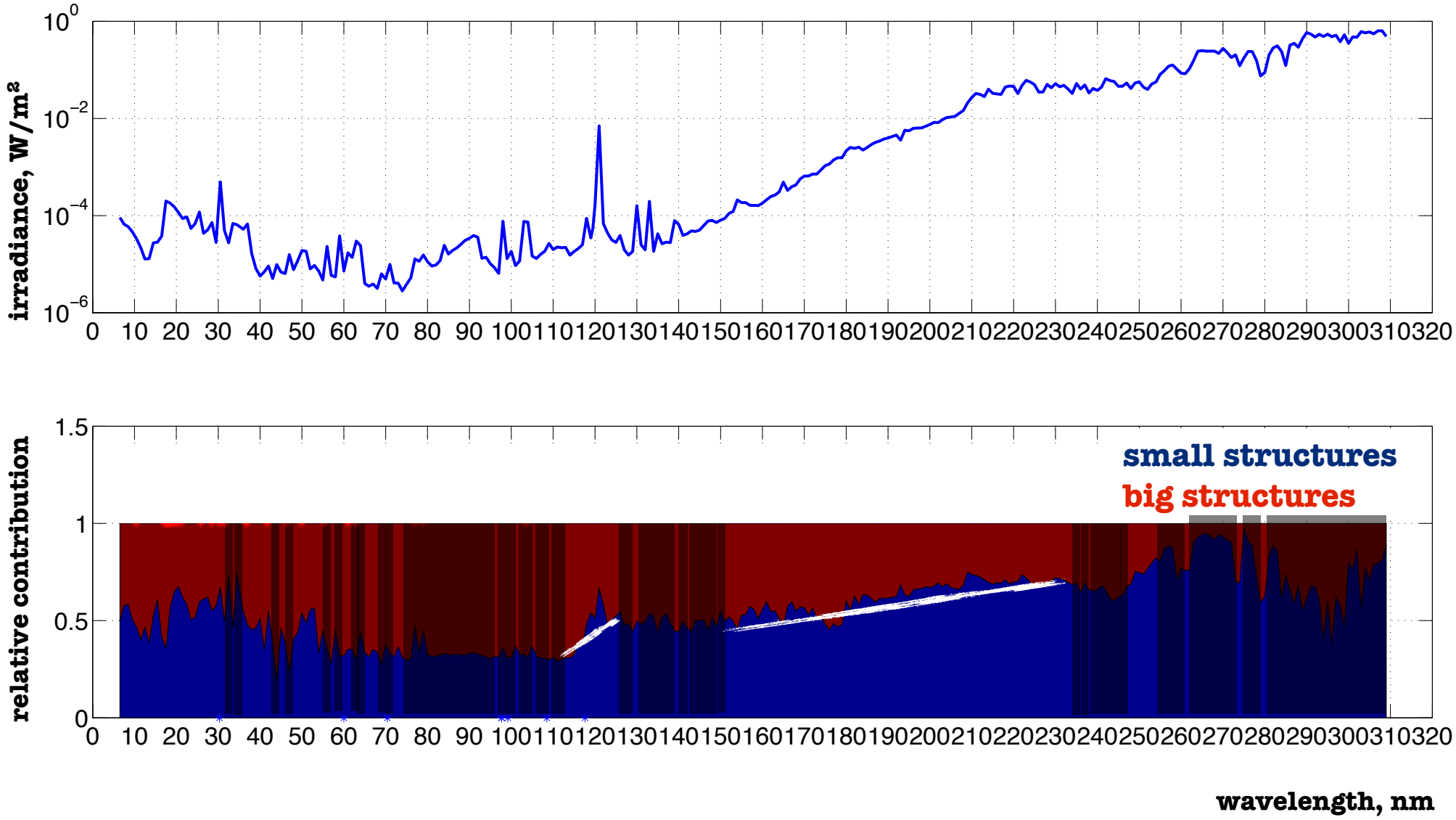

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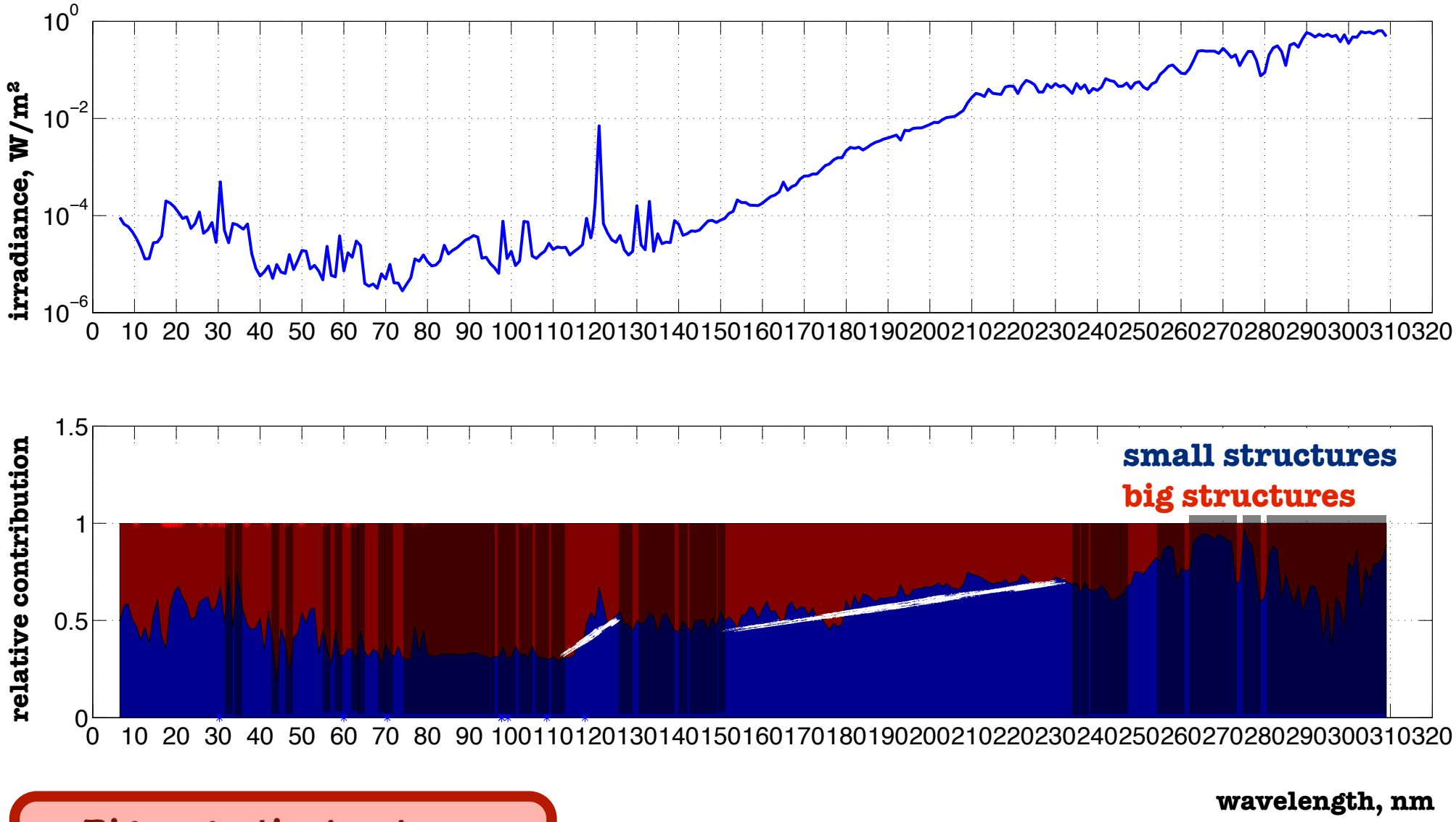
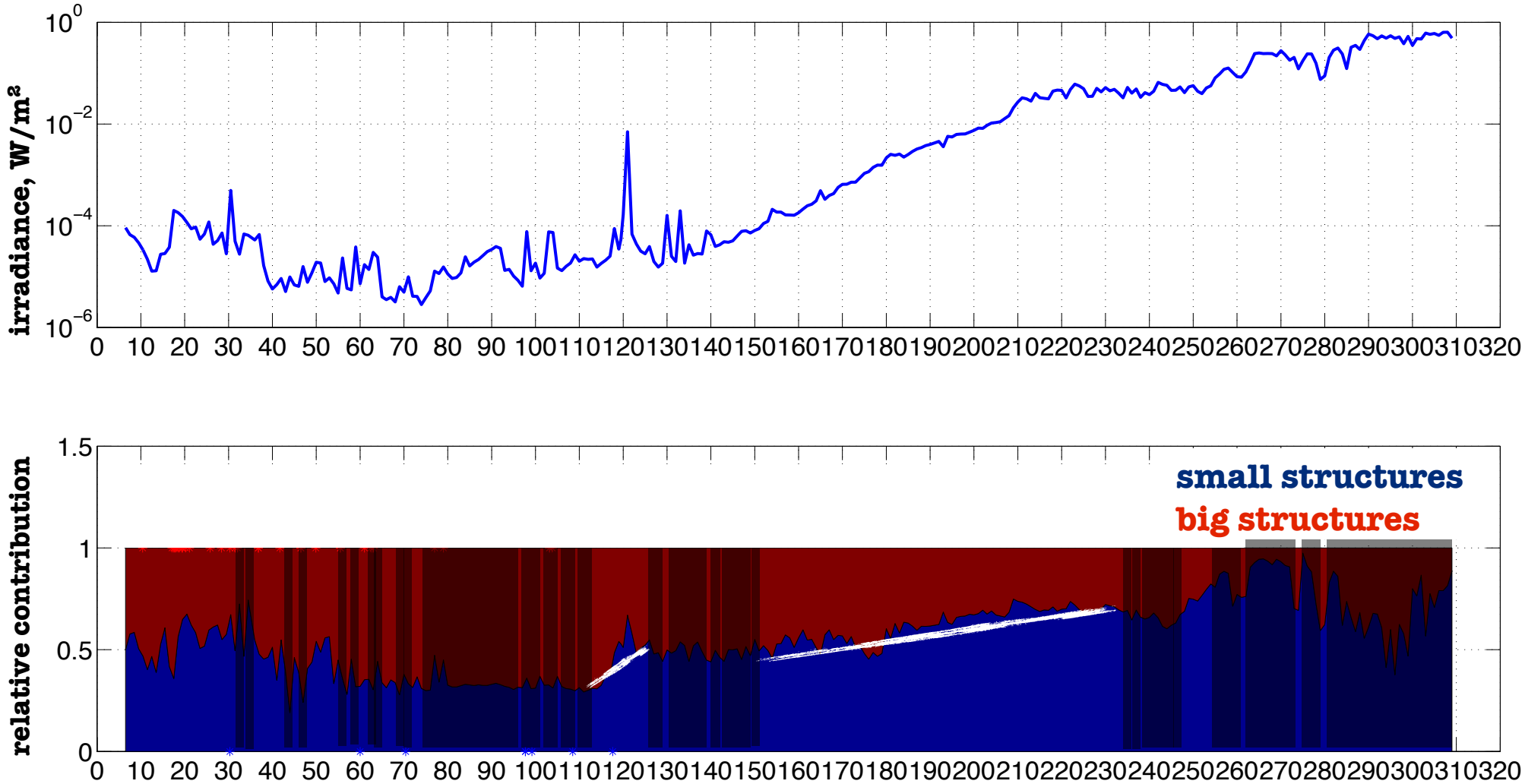


Big magnetic structures contribute more to short-wavelength emissions

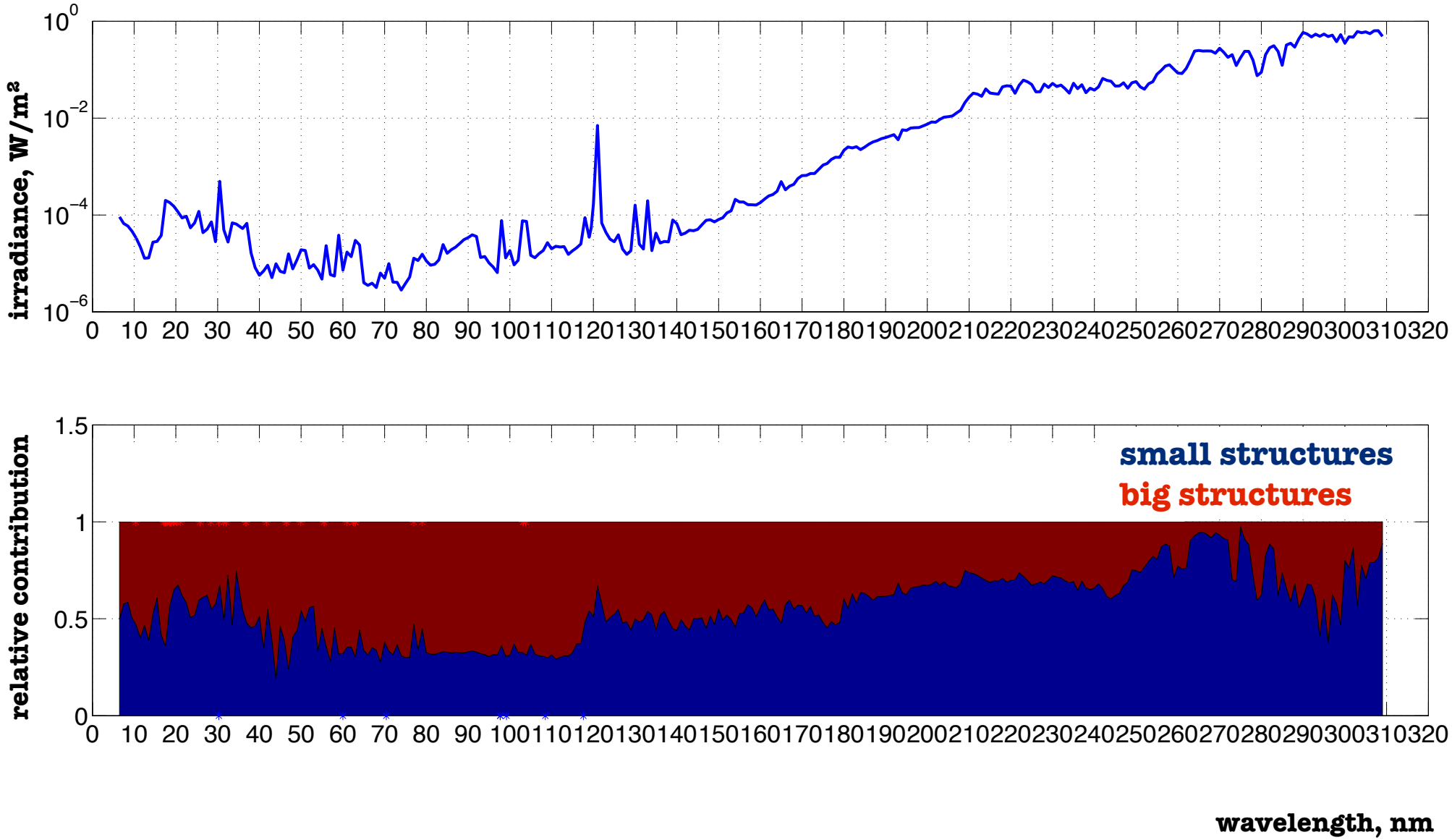
CONTRIBUTION OF DIFFERENT CLASSES TO SSI VARIABILITY



Big magnetic structures contribute more to short-wavelength emissions

Small magnetic structures contribute more to long-wavelength emissions

CONTRIBUTION OF DIFFERENT CLASSES TO SSI VARIABILITY



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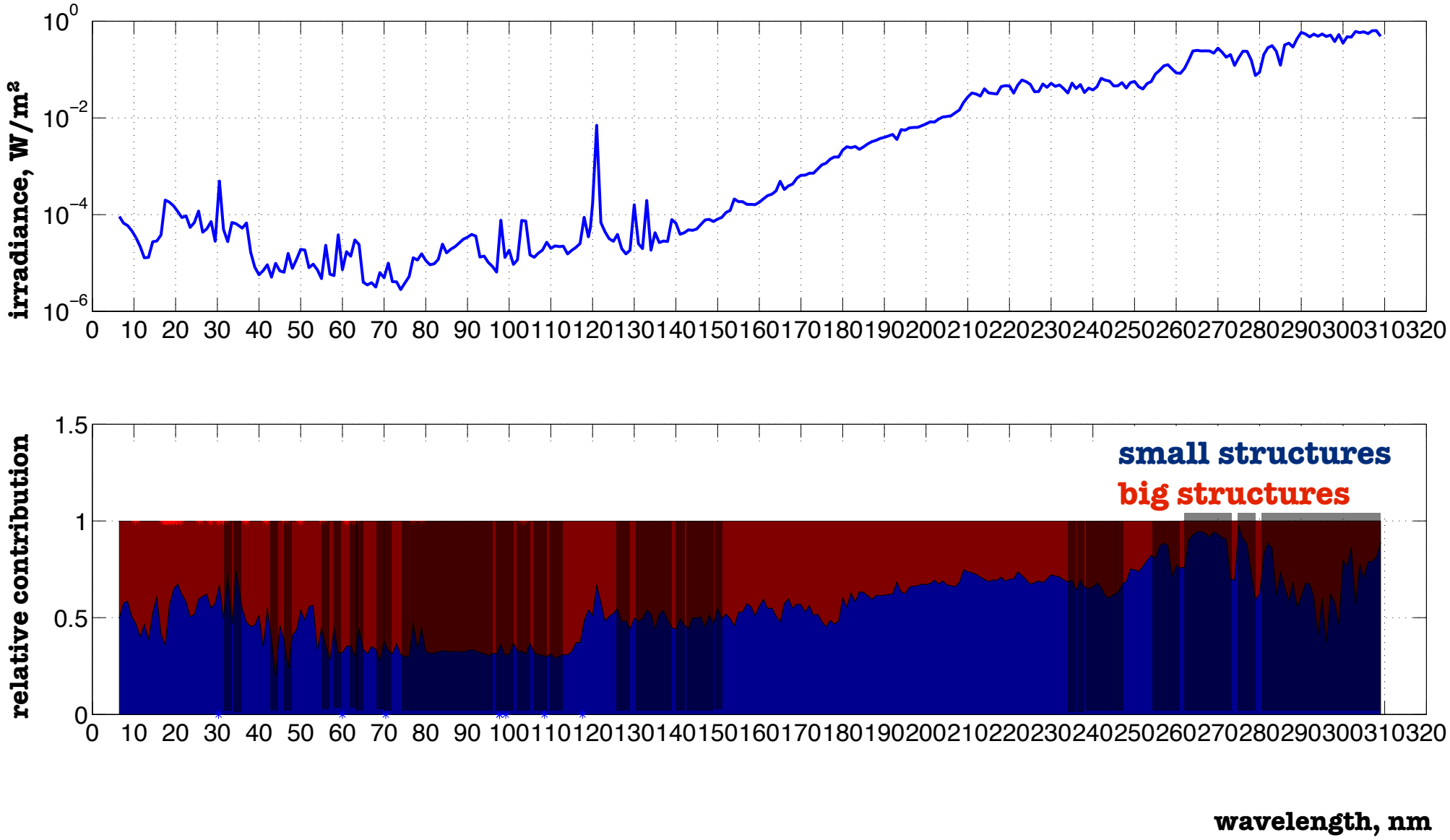

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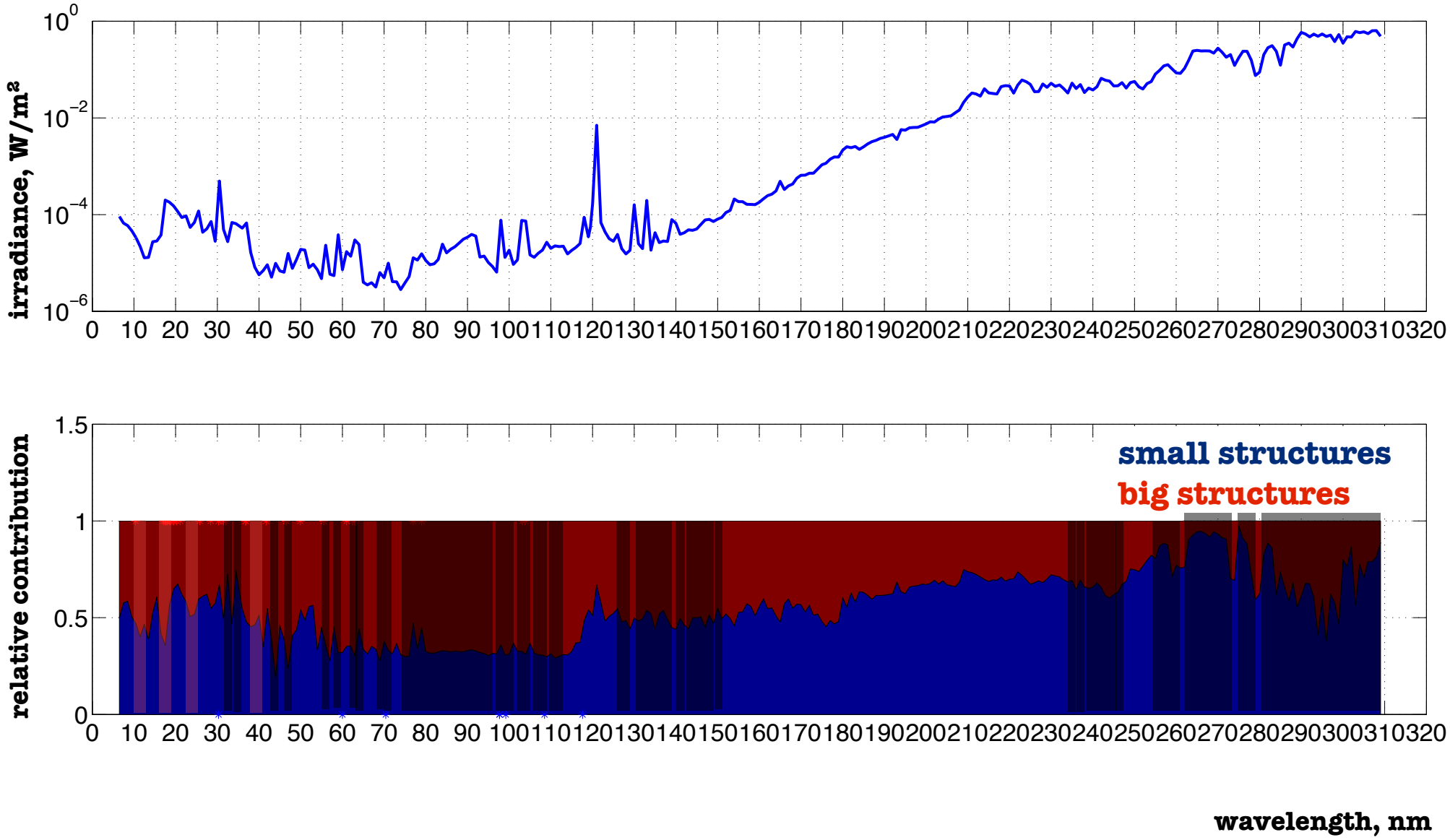

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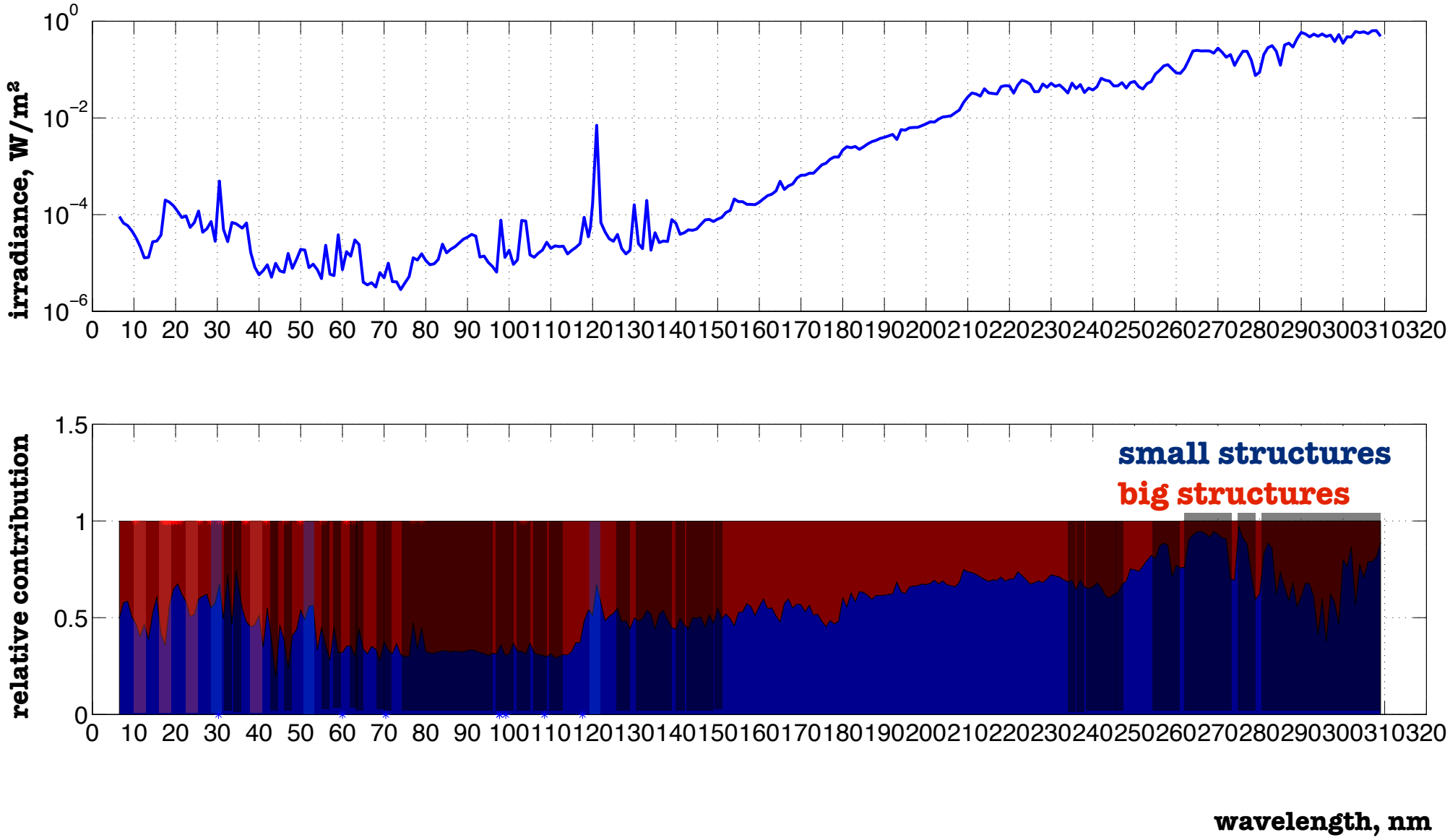

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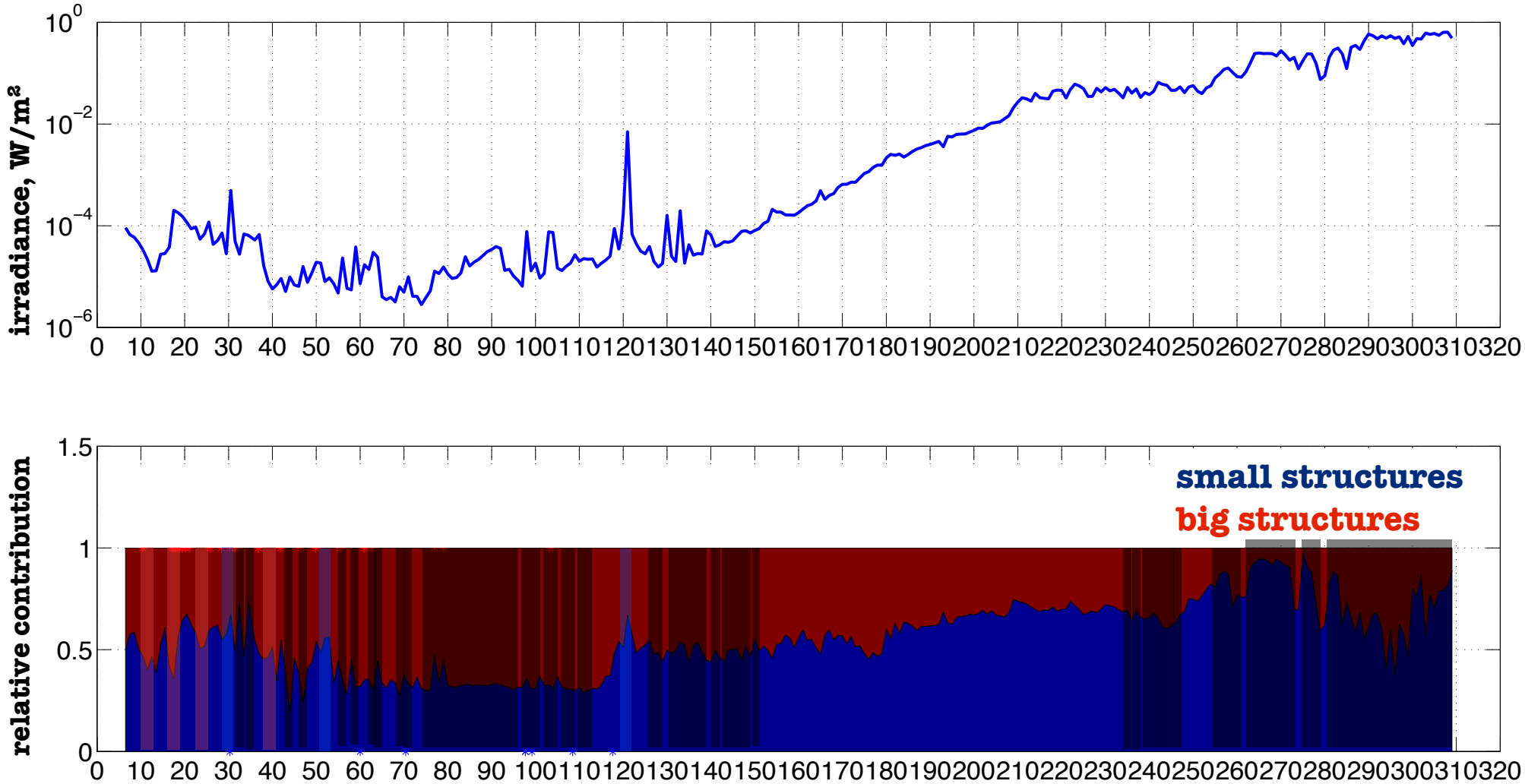
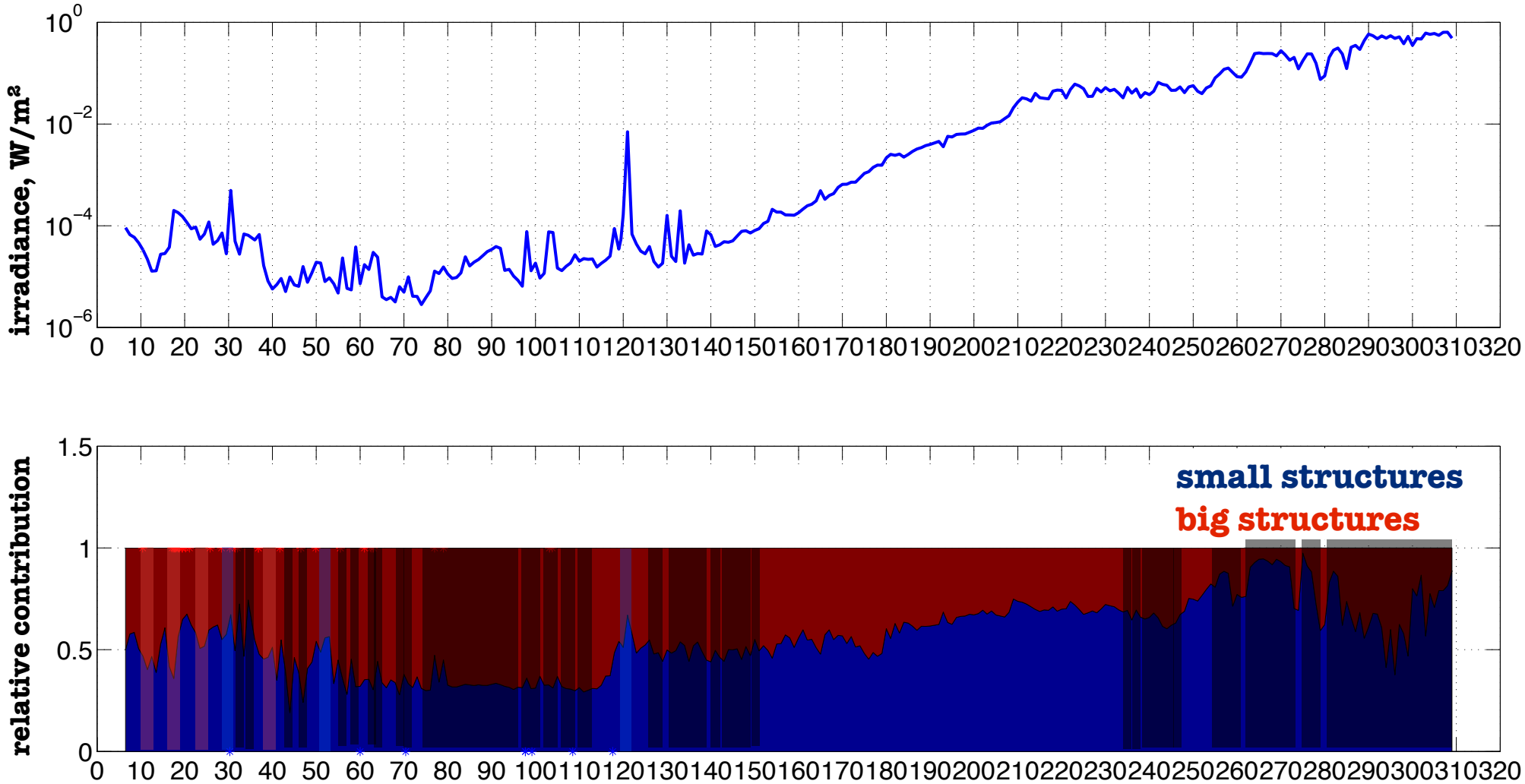


Big magnetic structures contribute more to hot lines (T > 5K °C)

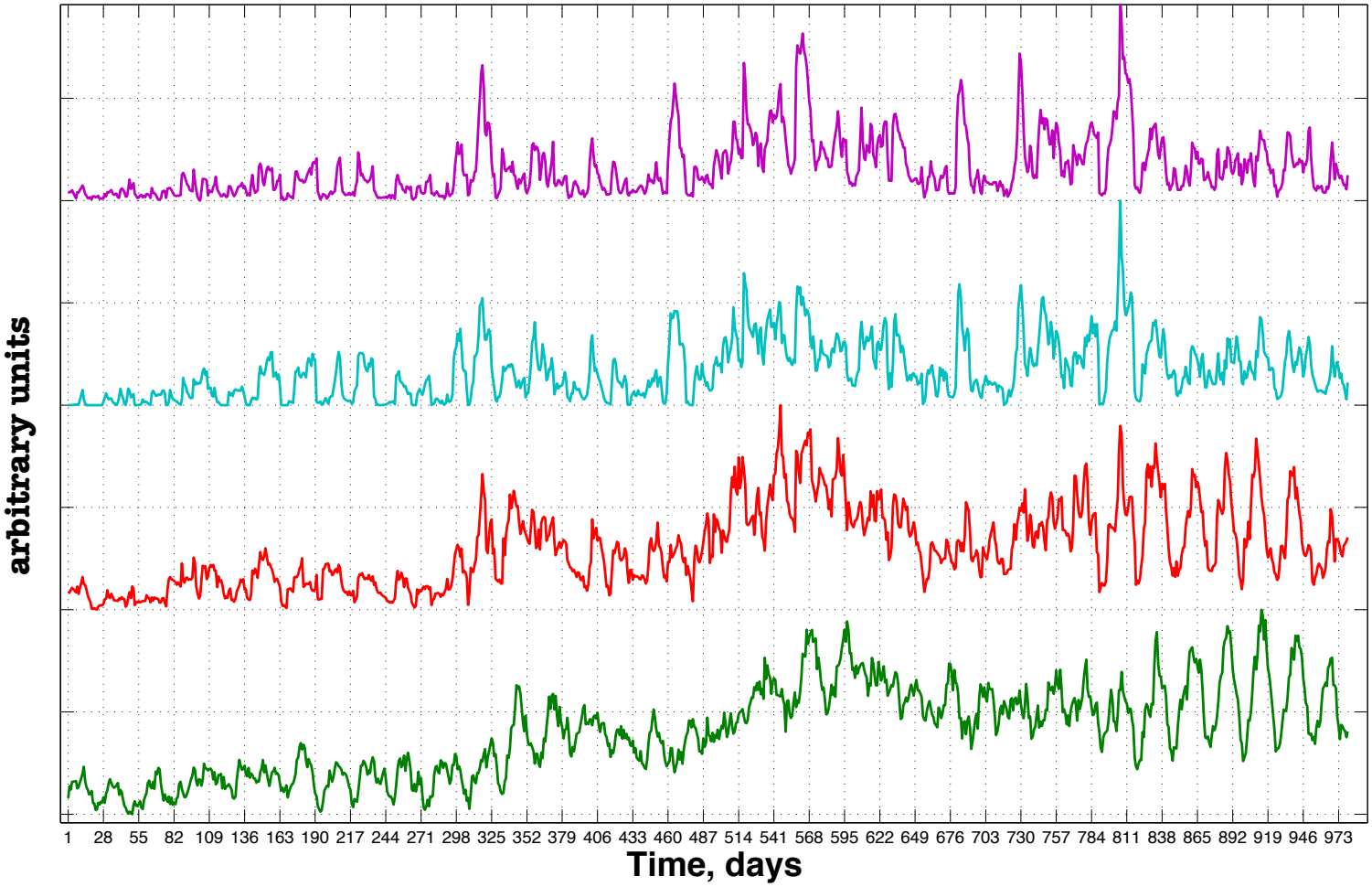
CONTRIBUTION OF DIFFERENT CLASSES TO SSI VARIABILITY



Big magnetic structures contribute more to hot lines (T > 5K °C)

Small magnetic structures contribute more to cold lines (T < 5K °C)

FILLING FACTORS



-penumbra

- umbra

- large structures ≈ faculae

- small structures ≈ active network

LOWER THRESHOLD FOR AREA

What spatial resolution for solar images is needed?

Gradually increase the lower limit for area of active regions that are taken into the model and see how the reconstruction quality changes.

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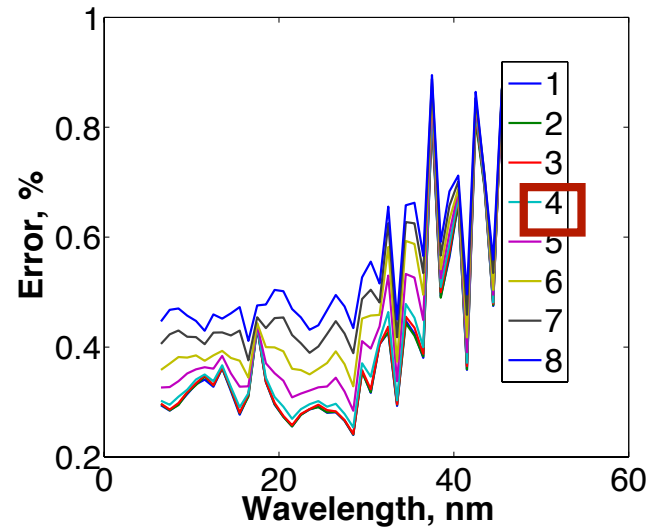
XUV/EUV



size[pixels] = 2 pow (bin number - 1)

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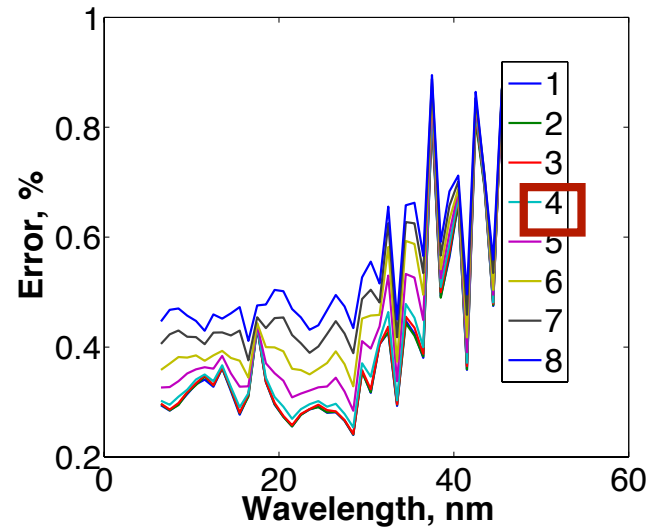

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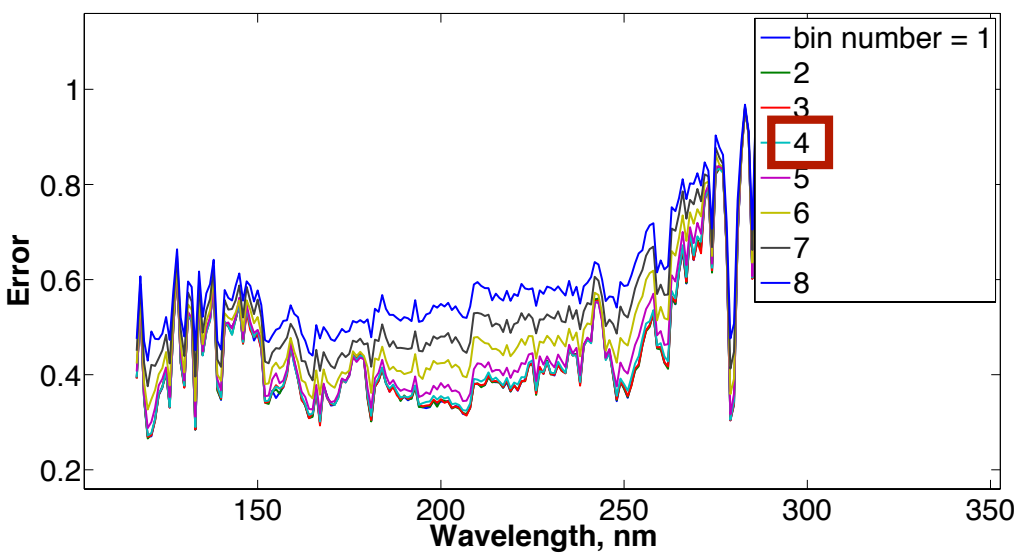
FUV/MUV



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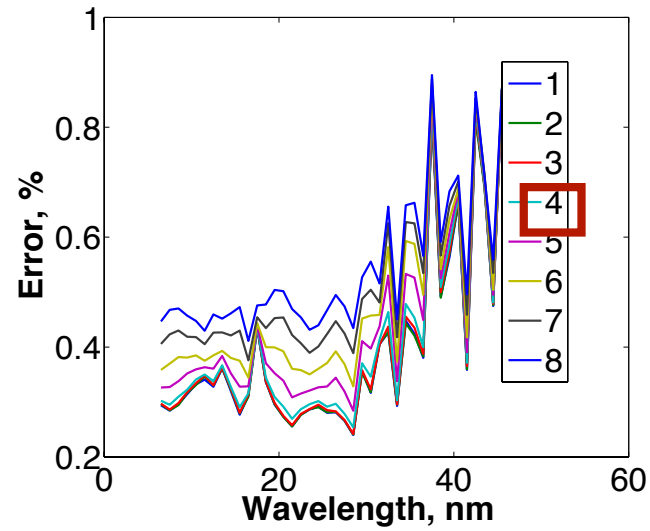

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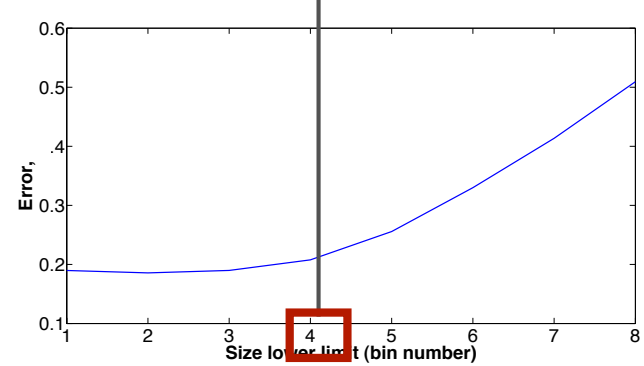
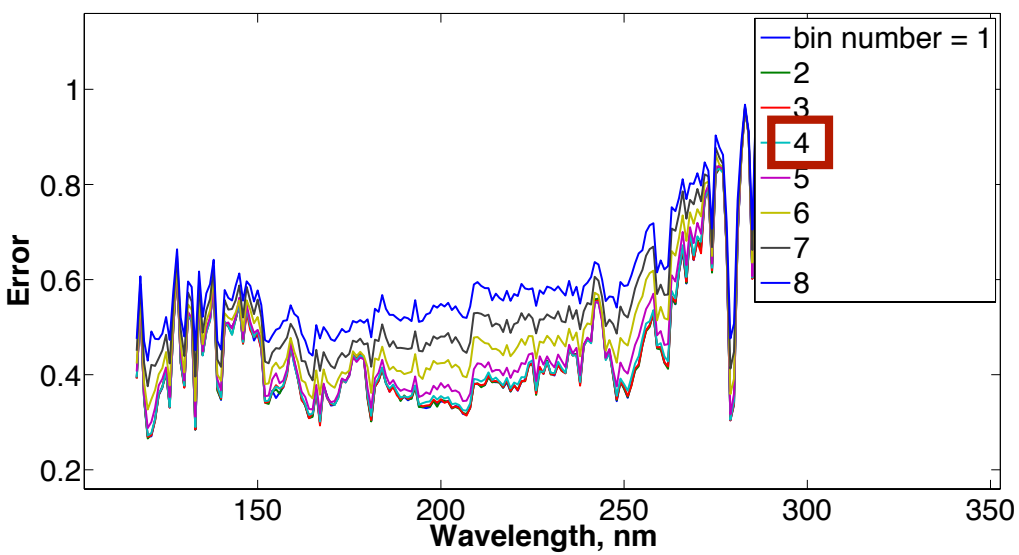
TSI



FUV/MUV



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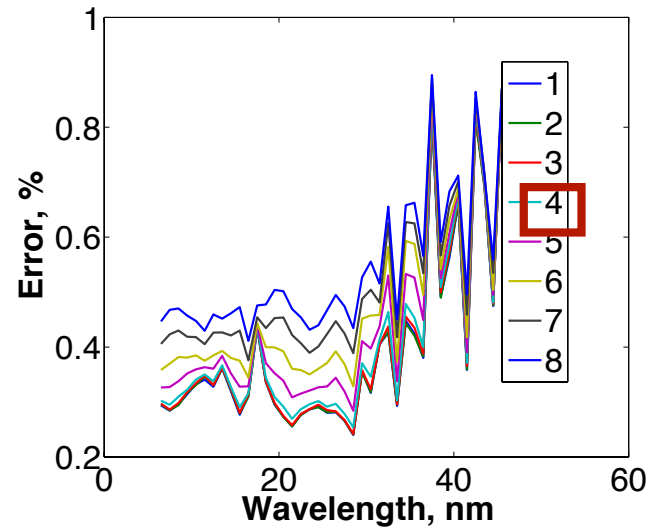

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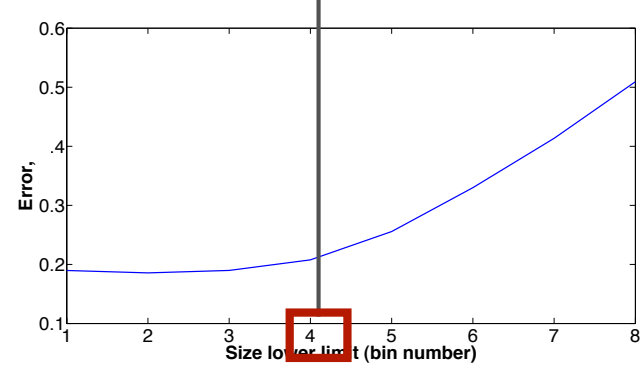
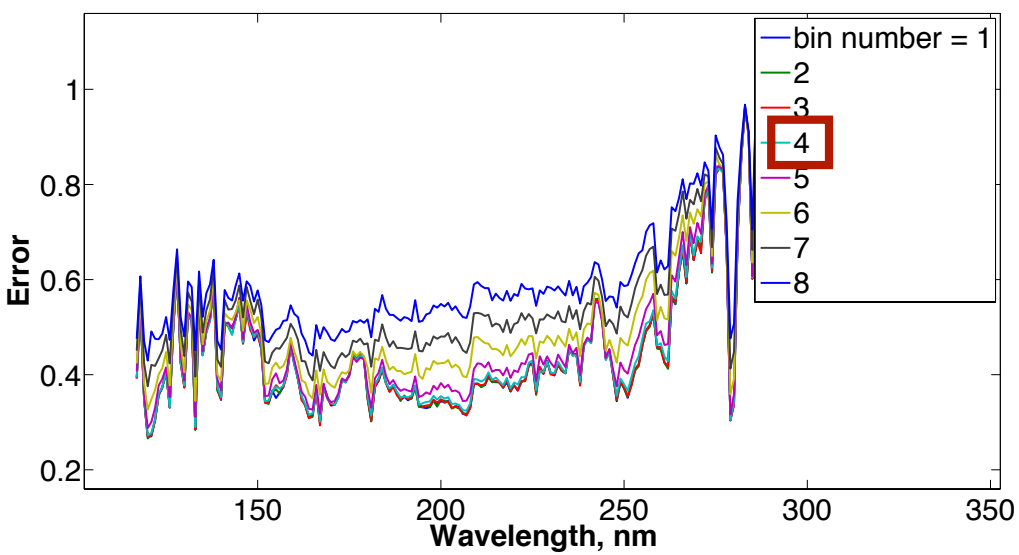


FUV/MUV



Magnetic structures with are less than 2^3 pixels (8''x 8'') do not bring new information to the model.

CONCLUSIONS

- We find 4 principal classes of magnetic structures (big magnetic structures ≈ faculae, small magnetic structures ≈ active network, umbra and penumbra) that allow to reconstruct the SSI variability in the optimal way.

- Big magnetic structures have size grater that 128'' x 128''.

- Small magnetic structures have size from 8'' x 8'' to 128'' x 128 ''.

- Small magnetic structures contribute more to cold emissions from chromosphere and photosphere.

- Big magnetic structures contribute more to hot lines .

- Center -to-limb variation effect plays significant role for MUV/FUV emissions in range from 170 to 265 nm.

Thank you!