Comparison of the modelled EUV with observations

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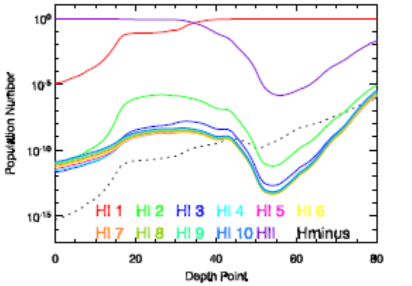
FP7 Project SOLID (projects.pmodwrc.ch/soli

EUV reconstruction - Semi-empirical modeling

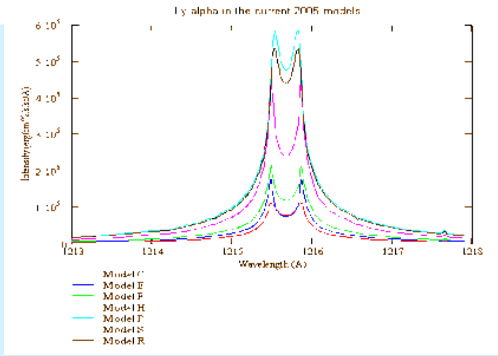


n_{level}, n_{el}, n_{ion}, …

(x,y,z,t)

Population numbers, Radiation field

Synthetic Spectrum



$I(\lambda,\mu,\varphi,t)$

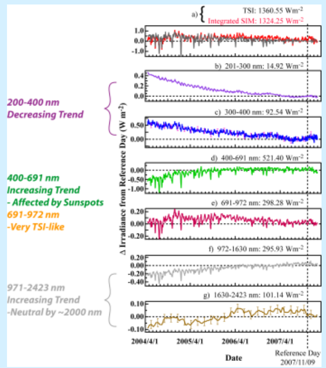
Iterative process

Atomic physics, collisional and radiative rates, abundances

El	A	W	ab_{Kur}	ab_{Hub}	ab_{Font}	$\frac{ab_{Font}}{ab_{Kur}}$
H	1	1.008	0.911 E 0	0.911 E 0	0.911 E 0	1.000
He	2	4.003	8.900 E -2	0.911 E -1	0.911 E -1	1.023
Li	3	6.941	1.318 E -11	3.552 E -12	1.022 E -11	0.775
Be	4	9.012	1.288 E -11	1.002 E -11	2.185 E -11	1.696
B	5	10.810	3.631 E -10	5.648 E -10	4.566 E -10	1.257
C	6	12.011	3.311 E -4	3.352 E -4	2.236 E -4	0.675
N	7	14.007	1.023 E -4	1.038 E -4	5.490 E -5	0.536
O	8	16.000	7.762 E -4	6.103 E -4	4.164 E -4	0.536
F	9	18.918	3.311 E -8	3.306 E -8	3.308 E -8	0.999
Ne	10	20.179	1.122 E -4	2.541 E -5	6.302 E -5	0.562
Na	11	22.990	1.950 E -6	1.567 E -6	1.347 E -6	0.691
Mg	12	24.305	3.467 E -5	3.125 E -5	3.086 E -5	0.890
Al	13	26.982	2.691 E -6	2.268 E -6	2.135 E -6	0.793
Si	14	28.086	3.236 E -5	3.198 E -5	2.948 E -5	0.911
P	15	30.974	2.570 E -7	2.432 E -7	2.087 E -7	0.812
S	16	32.060	1.479 E -5	1.467 E -5	6.302 E -6	0.426
Cl	17	35.453	2.884 E -7	4.026 E -7	2.880 E -7	0.999
Ar	18	39.948	3.311 E -6	4.026 E -6	1.379 E -6	0.416
K	19	39.098	1.513 E -7	1.011 E -7	1.095 E -7	0.724
Ca	20	40.080	2.089 E -6	1.931 E -6	1.860 E -6	0.890
Sc	21	44.956	1.148 E -9	1.057 E -9	1.022 E -9	0.890
Ti	22	47.900	8.912 E -8	4.955 E -8	7.236 E -8	0.812
V	23	50.941	9.120 E -9	1.139 E -8	9.110 E -9	0.999
Cr	24	51.996	4.266 E -7	4.518 E -7	3.976 E -7	0.932
Mn	25	54.938	2.239 E -7	1.430 E -7	2.236 E -7	0.999
Fe	26	55.847	4.266 E -5	2.268 E -5	2.567 E -5	0.602
Co	27	58.933	7.586 E -8	2.851 E -8	7.577 E -8	0.999
Ni	28	58.700	1.622 E -6	1.721 E -6	1.546 E -6	0.953
Cu	29	63.546	1.479 E -8	2.541 E -8	1.477 E -8	0.999
Zn	30	65.380	3.630 E -8	2.368 E -8	3.627 E -8	0.999

Observed Spectrum

$I(\lambda,\mu,\varphi,t)$



Update of Physical Models
T(z), ne(z), nh(z)

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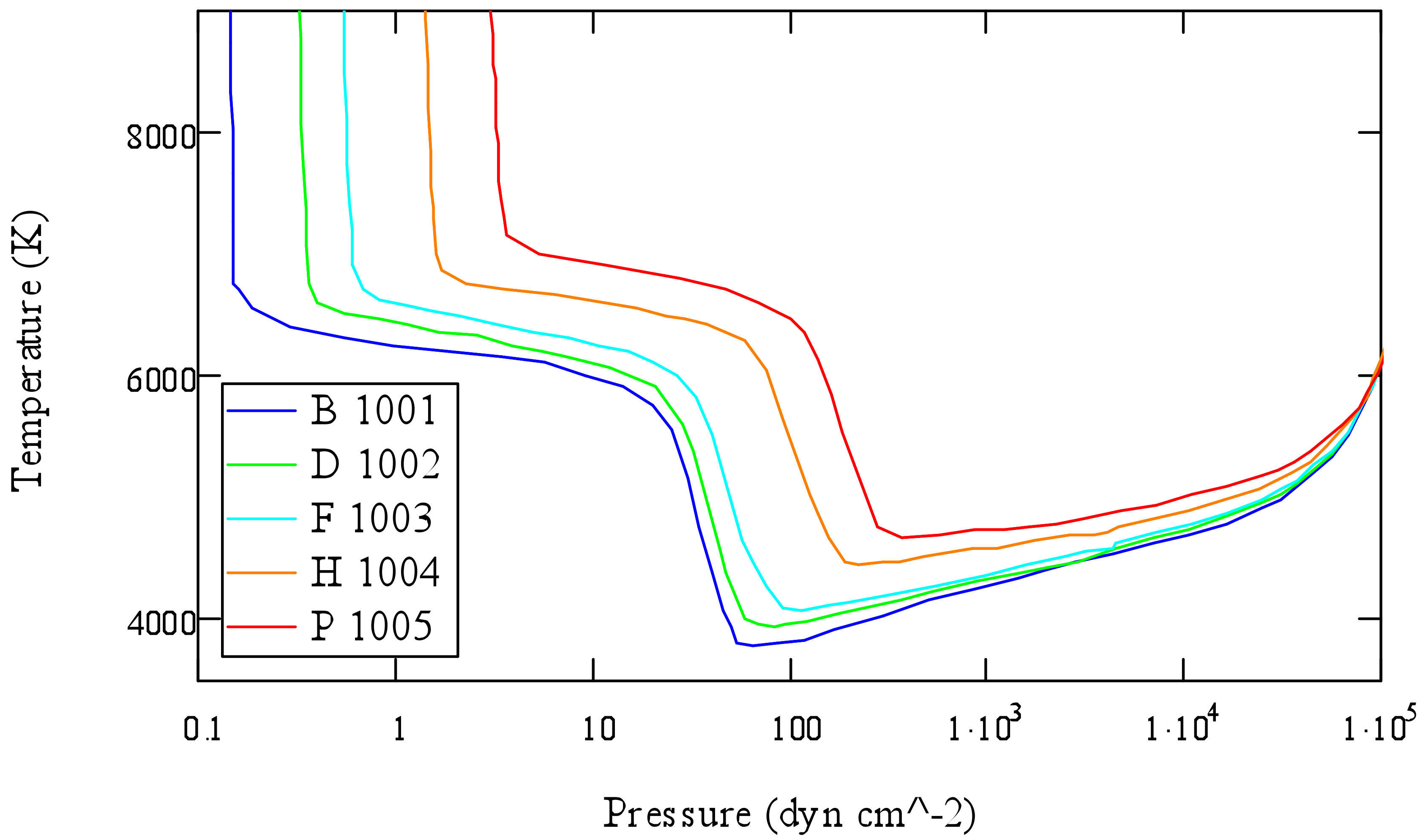
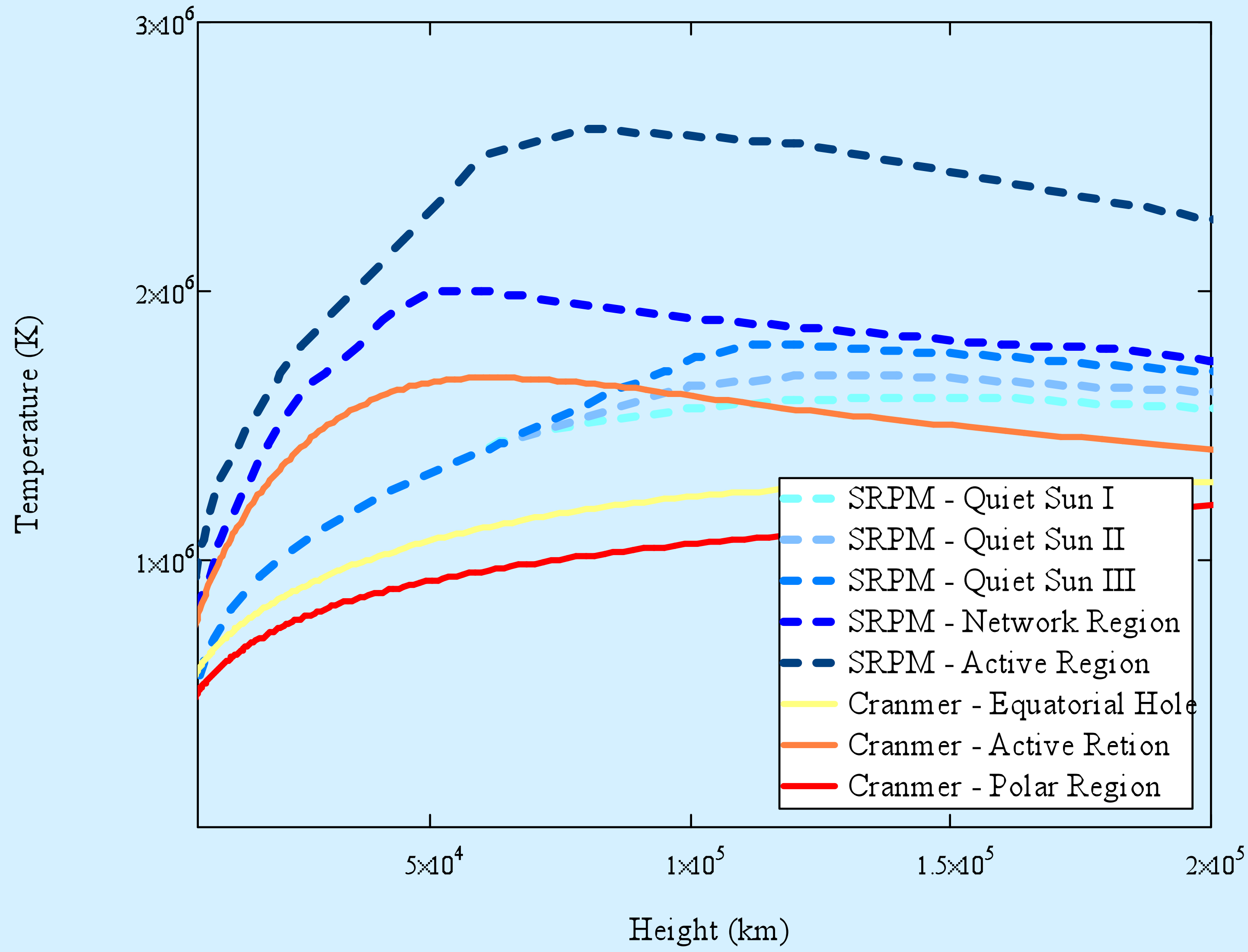
Solar **Mod**eling (SolMod)

- **Multi level atoms**
  - 373 ions, from H to Ni with ioncharge 25
  - ~14’000 atomic levels
  - ~170’000 spectral lines
  - Statistical equation is solved to get the level populations
- **Chromosphere and transition region**
  - for ioncharge ≤ 2:
  - full NLTE (Fontenla et al., 2006; 2007; 2009)
  - plus optically thin transition region lines
  - **Spherical symmetry**
- **Corona**
  - ioncharge >2
  - optically thin, i.e. collisions and spontaneous emission
  - Line of sight integration accounts for opacity
  - **Spherical symmetry**

1D Atmosphere Structures
Photosphere and Chromosphere

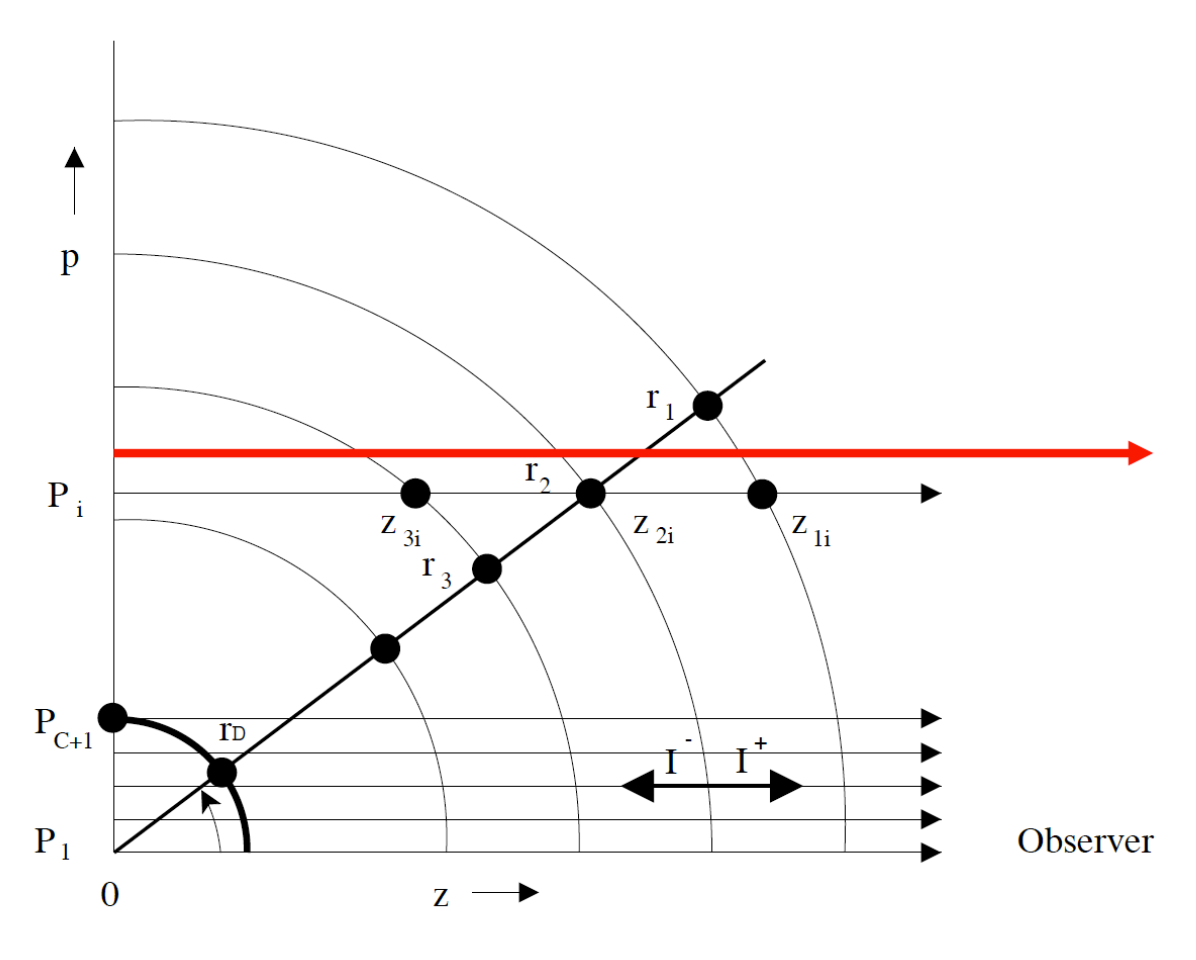


1D Atmosphere Structures - Corona



- SRPM Models are based on Doschek (1997), ApJ, 476, 903, Singh et al., 1982, J. Astrophys. 3, 249
- Cranmer et al, 2007, ApJS 171, 520

Spherical Symmetry



Allows the calculation of intensities at and beyond the limb

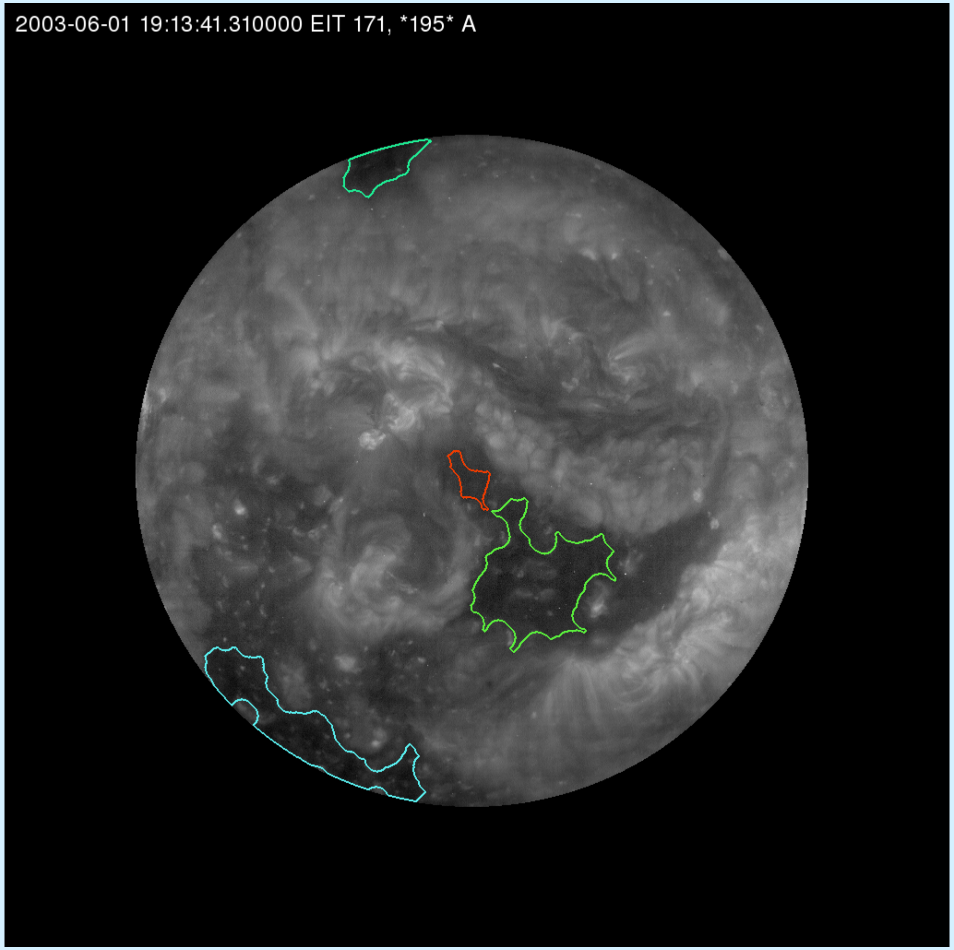
Up to a factor of 2!

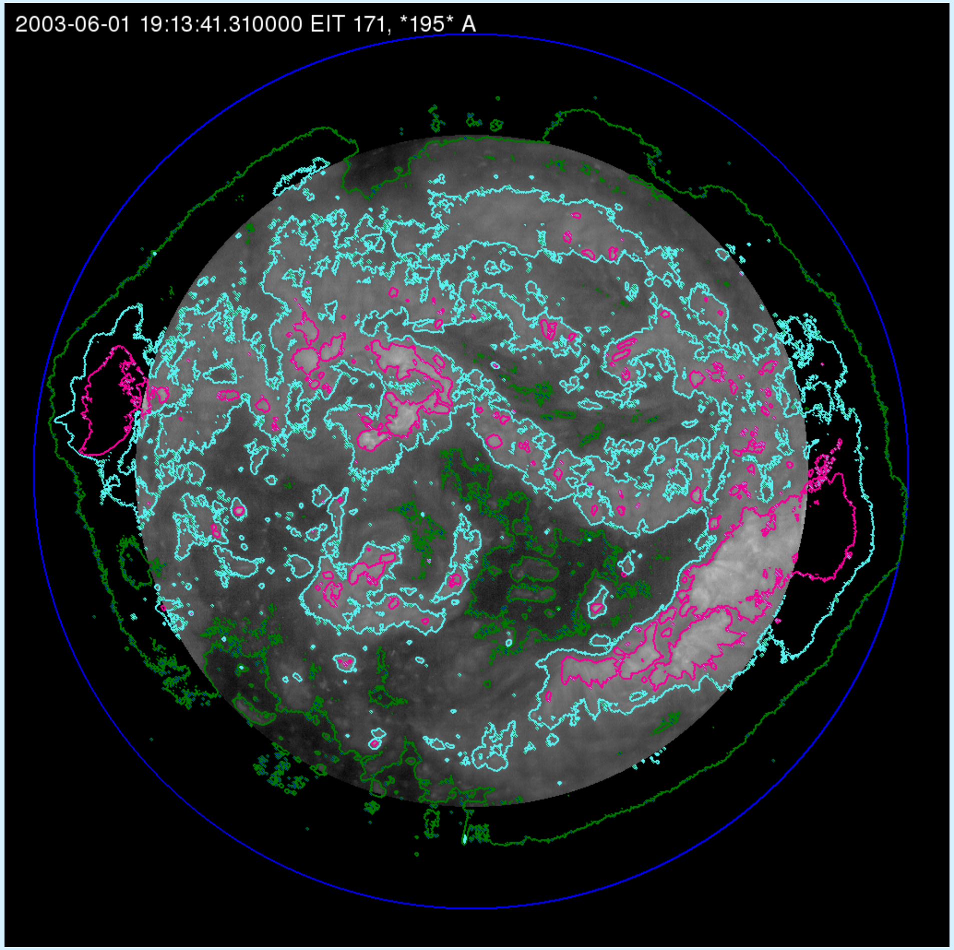
Account for corona over Up to 1.4 Solar Radii

(e.g. Haberreiter et al. 2008)

2. Corona - Segmentation of EIT images – work in progress

June 1, 2003





Coronal Hole Mask

Active Region Mask

SPoCA Image Decomposition: Cis Verbeeck, ROB

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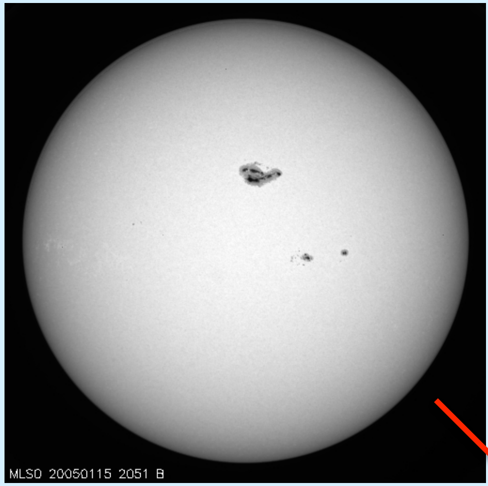
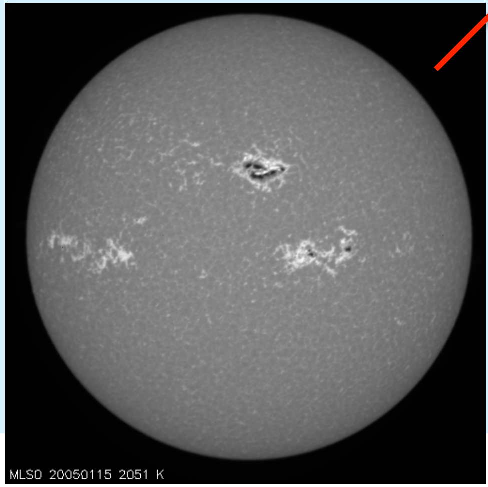
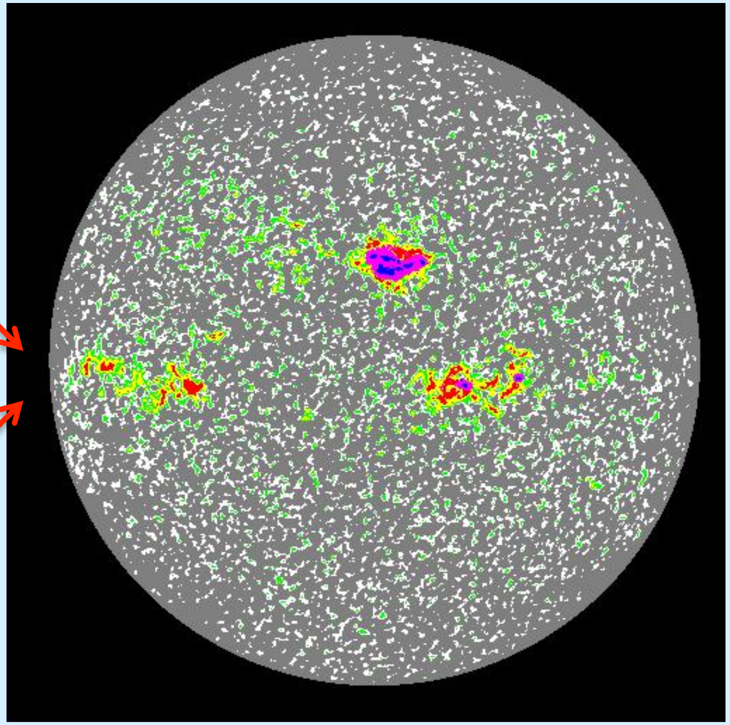
1. Variations of the Photosphere/Chromosphere are based on Segmentations Masks from PSPT

Continuum, 607 nm







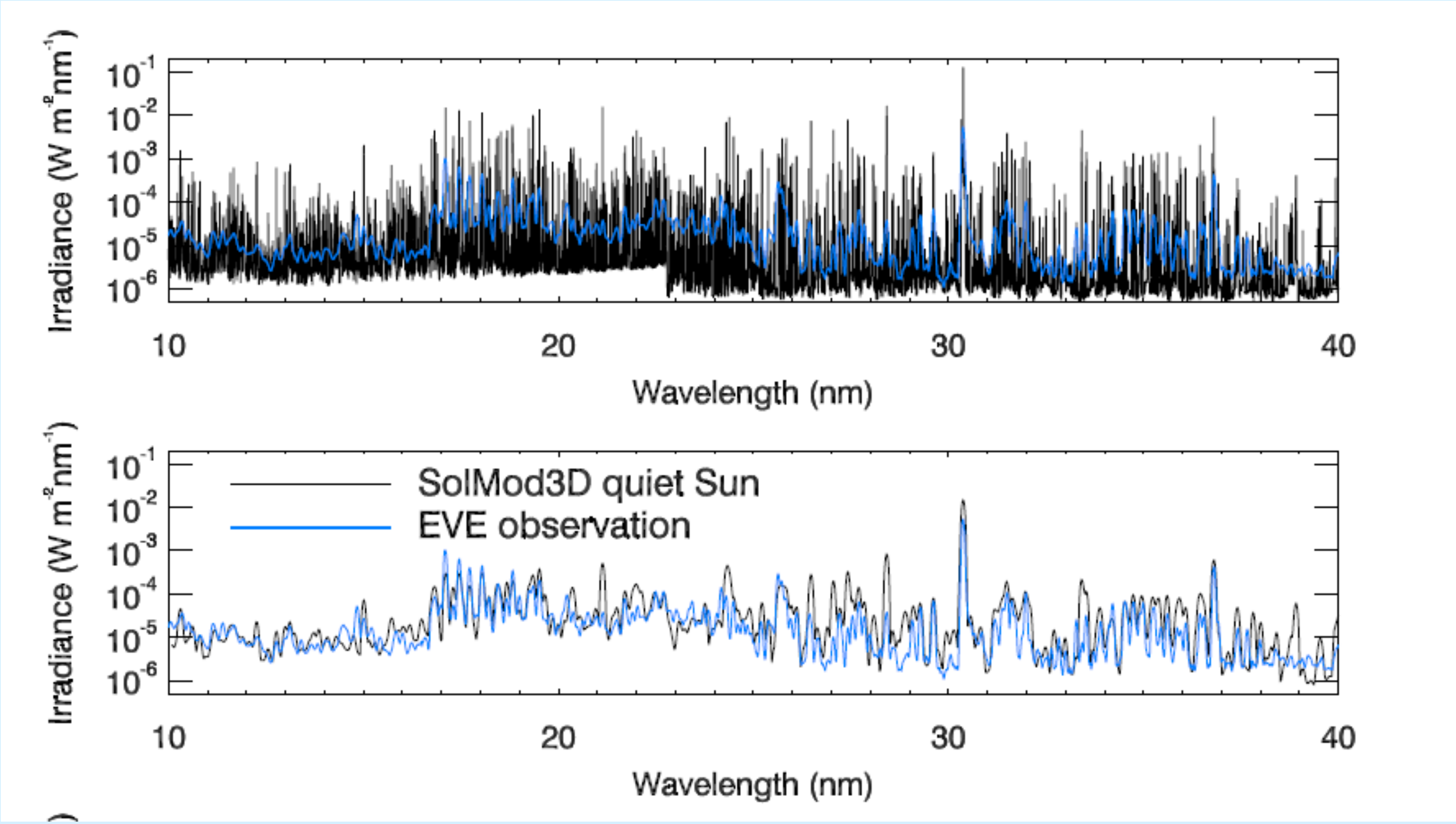
Disk mask on 2005/9/12 obtained from PSPT data, Mauna Loa, Hawaii

http://lasp.colorado.edu/pspt_access/

(R) Sunspot Penumbra
(S) Sunspot Umbra
(P) Faculae
(H) Plage
(F) Active network
(D) Quiet network (white)
(B) Intergranular Cells

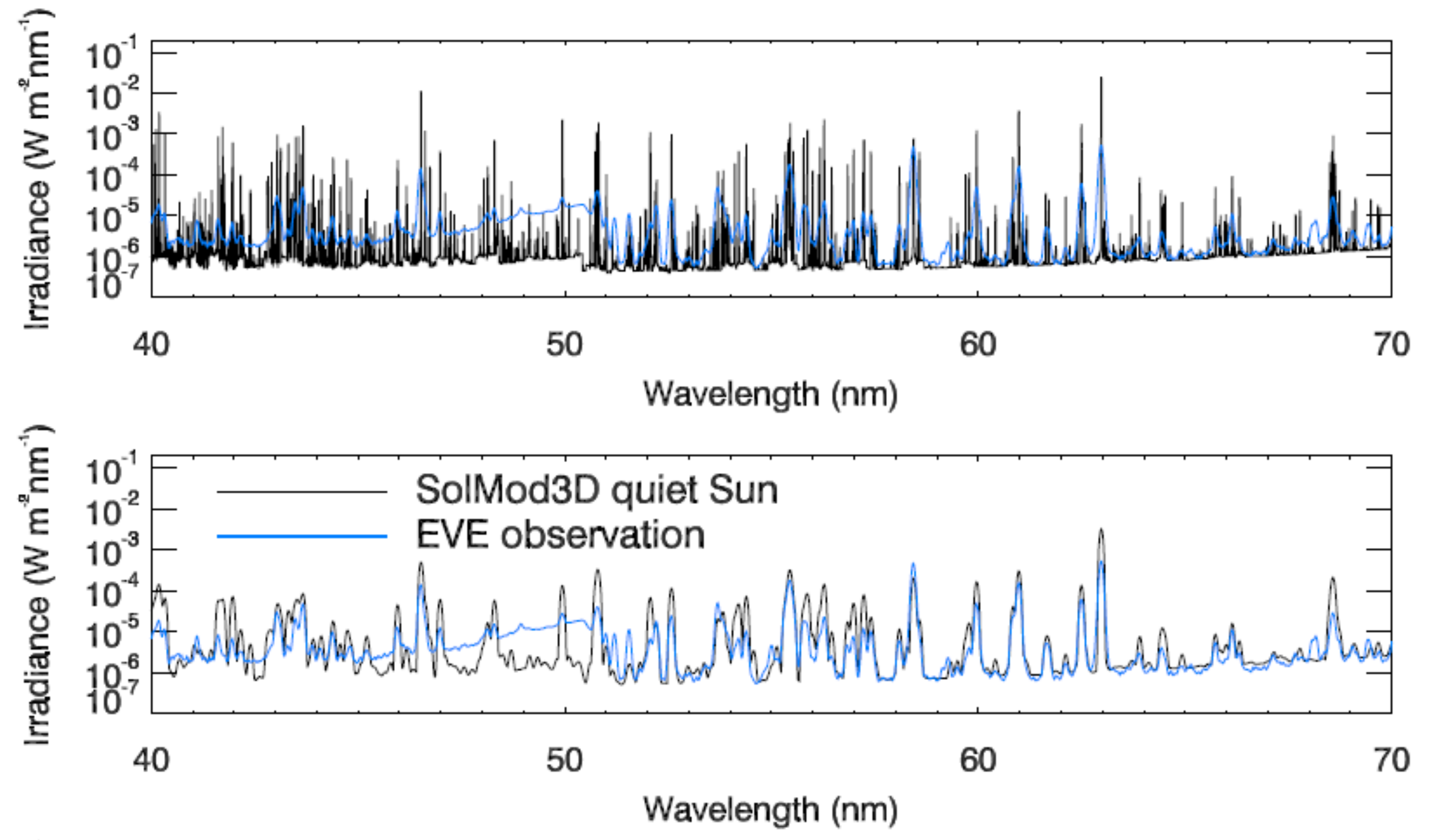
Determined by the contrast as a function of the position on the disk
-Only possible with respect to a
-normalized quiet Sun intensity

Comparison of SolMod to SDO/EVE



Haberreiter, 2011, Solar Physics, 274, 473

Comparison of SolMod to SDO/EVE



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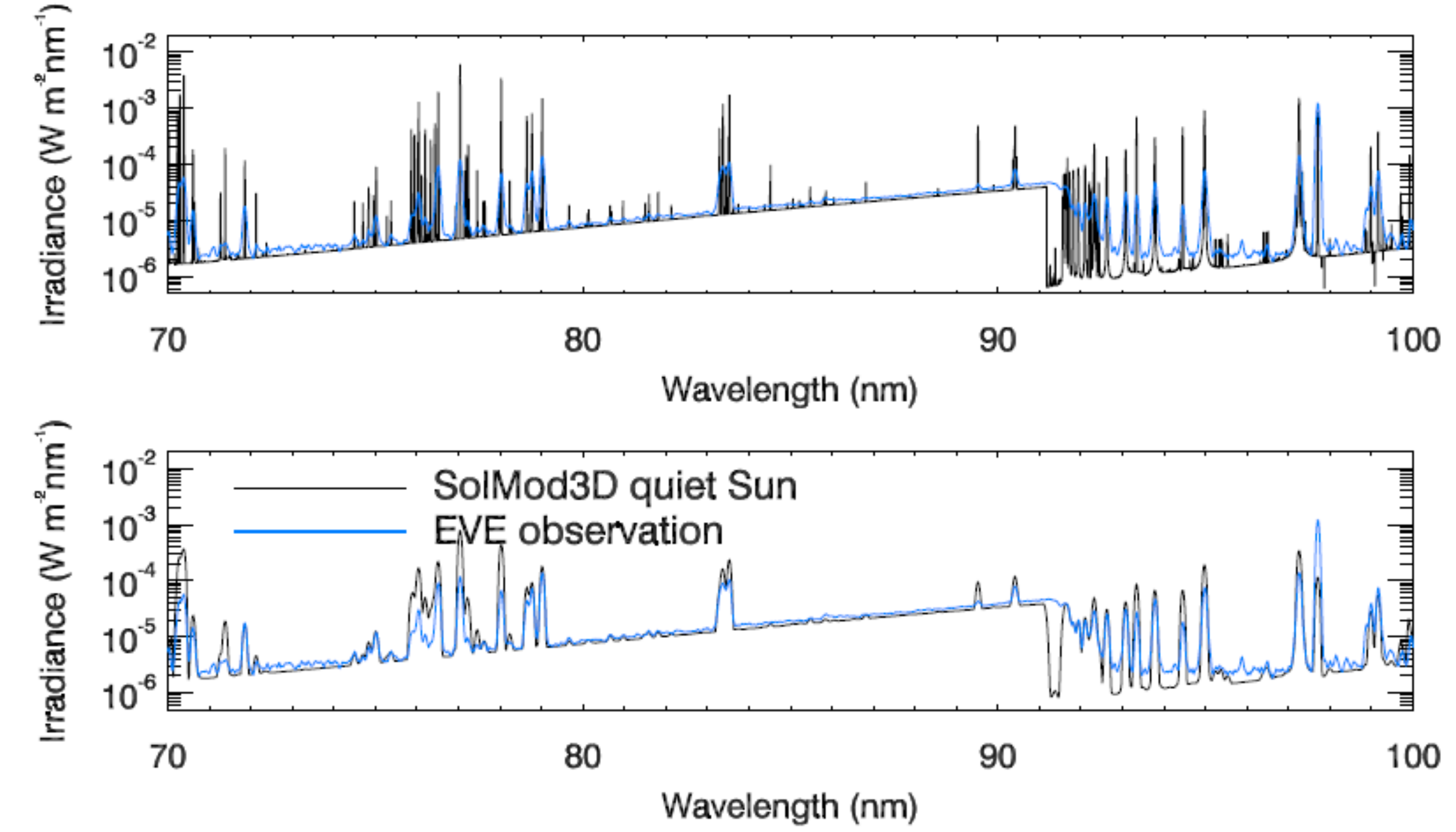
Comparison of SolMod to SDO/EVE



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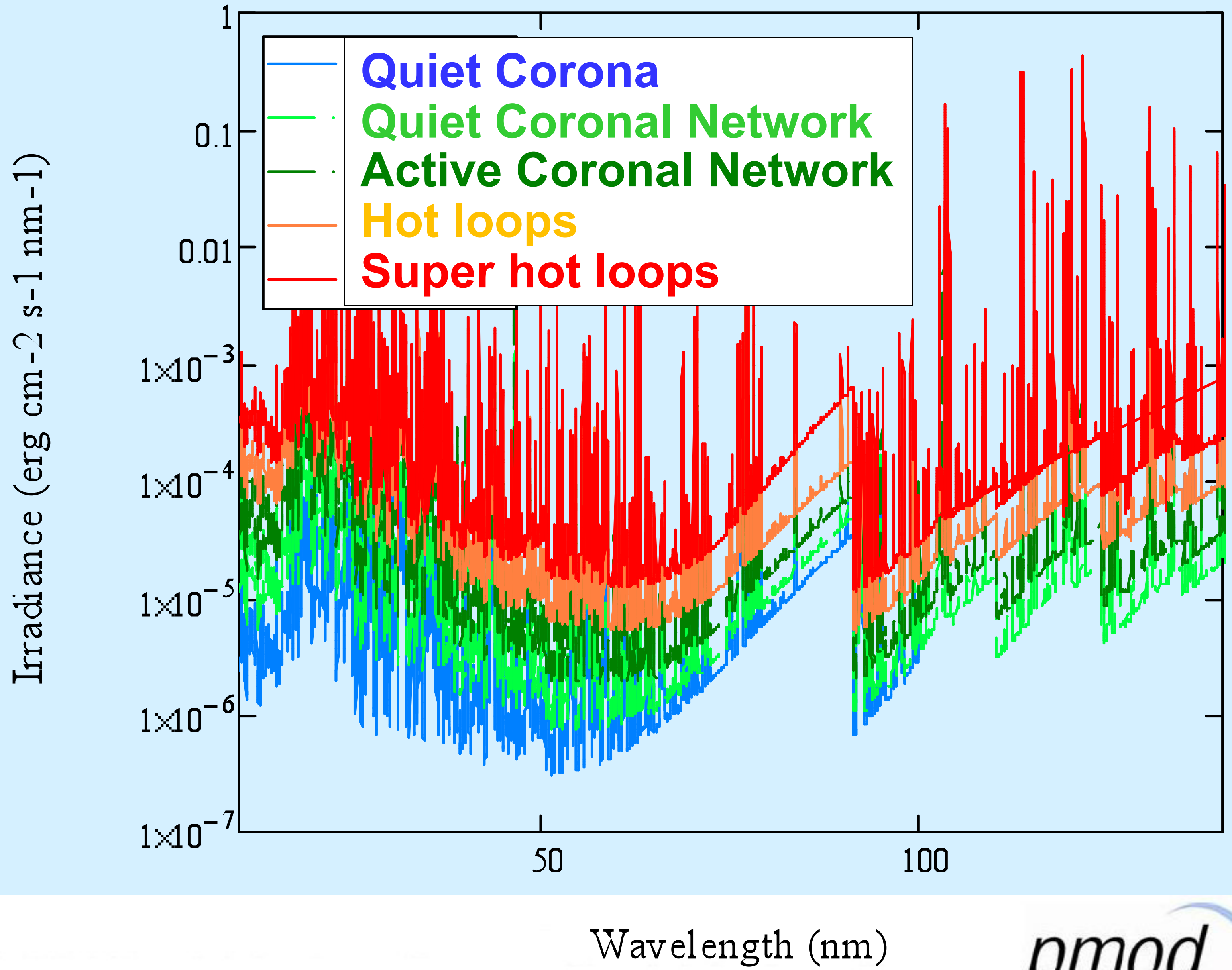
Synthetic SolMod EUV Spectra



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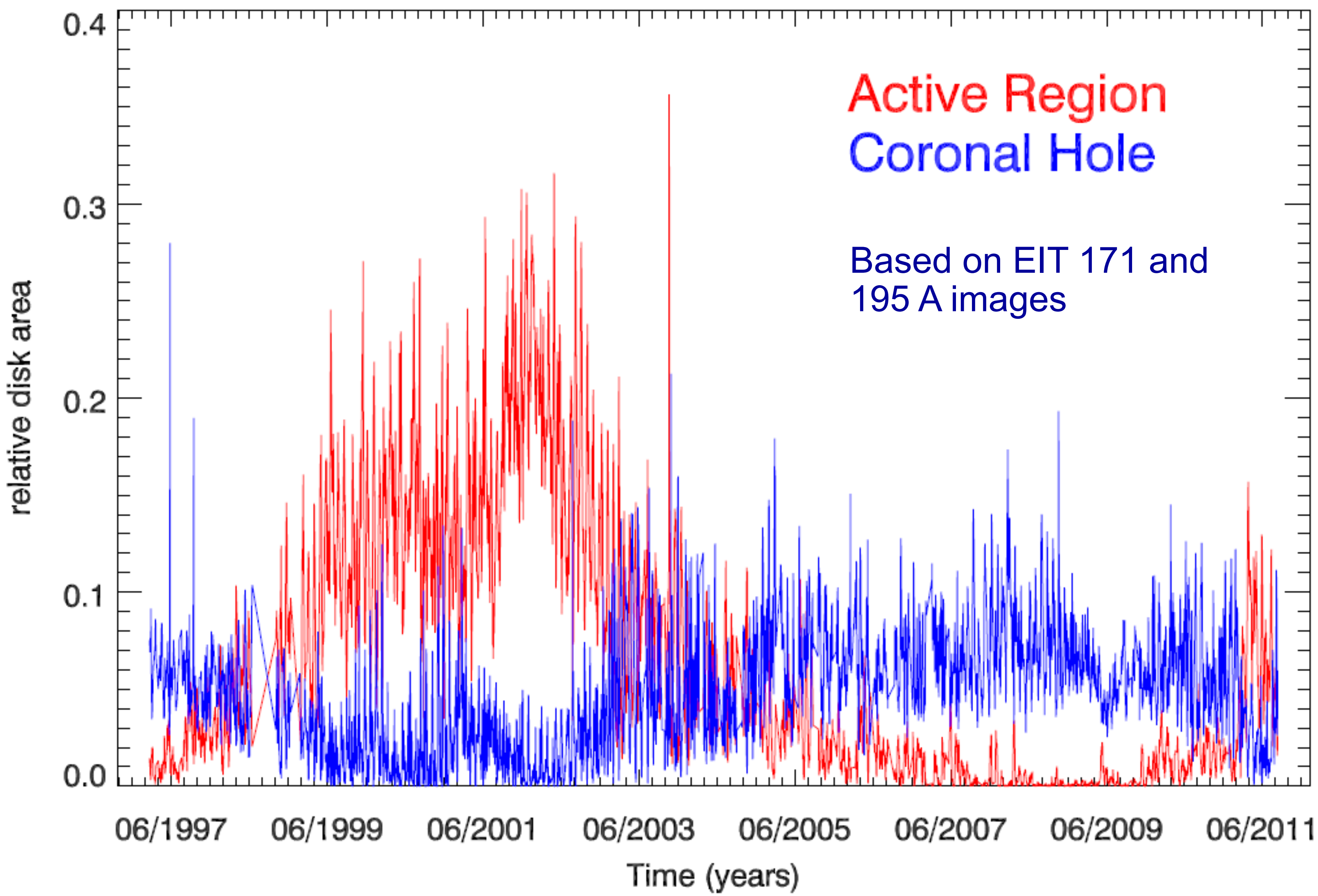
Scheme for Spectral Irradiance Reconstruction

1. Intensity spectra are calculated for different positions on the solar disk

2. Spectra are weighted based on the relative area coverage of different solar features for different posititions on the solar disk

3. Result: Spectral variability for various time-scales over a broad wavelength range

EIT analysis 1997 - 2011



Verbeeck et al, 2013, submitted to A&A

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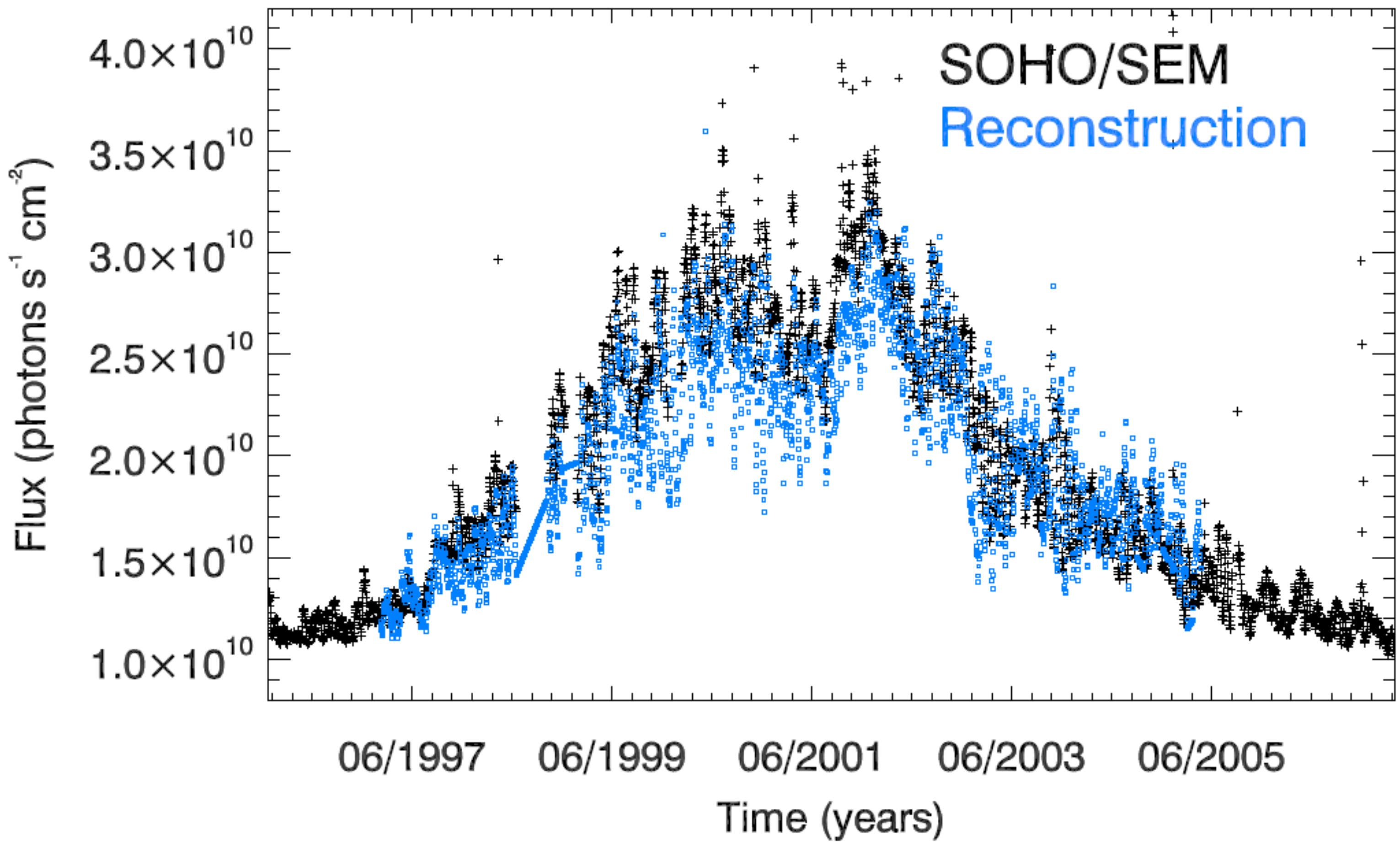
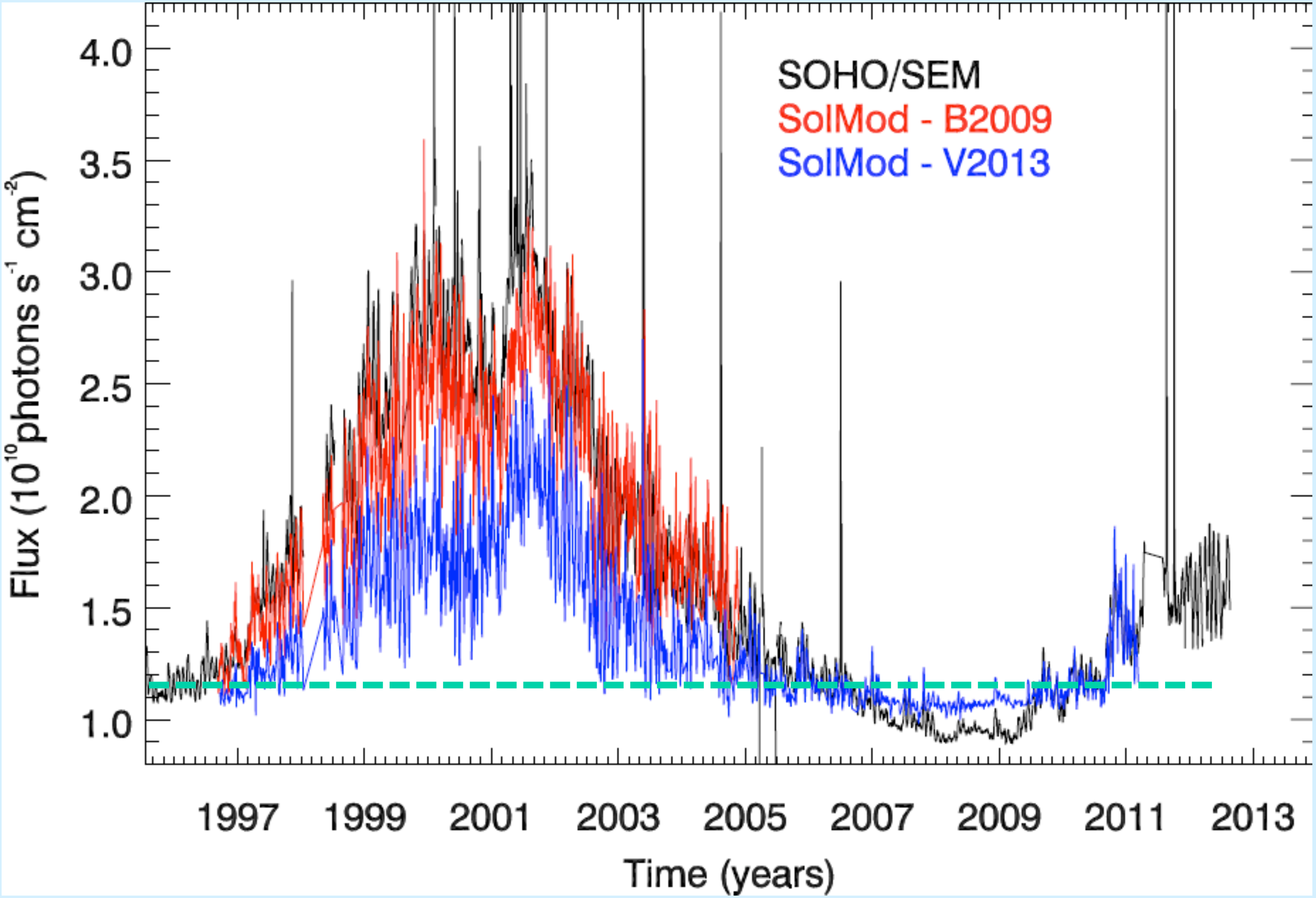
Reconstruction of the EUV for solar cycle 23



Haberreiter, 2012, IAU Symposium 286

EUV Reconstruction vs SEM Data



B2009: input to SolMod: Barra et al., 2009
V2013: input to SolMod: Verbeeck et al., 2013

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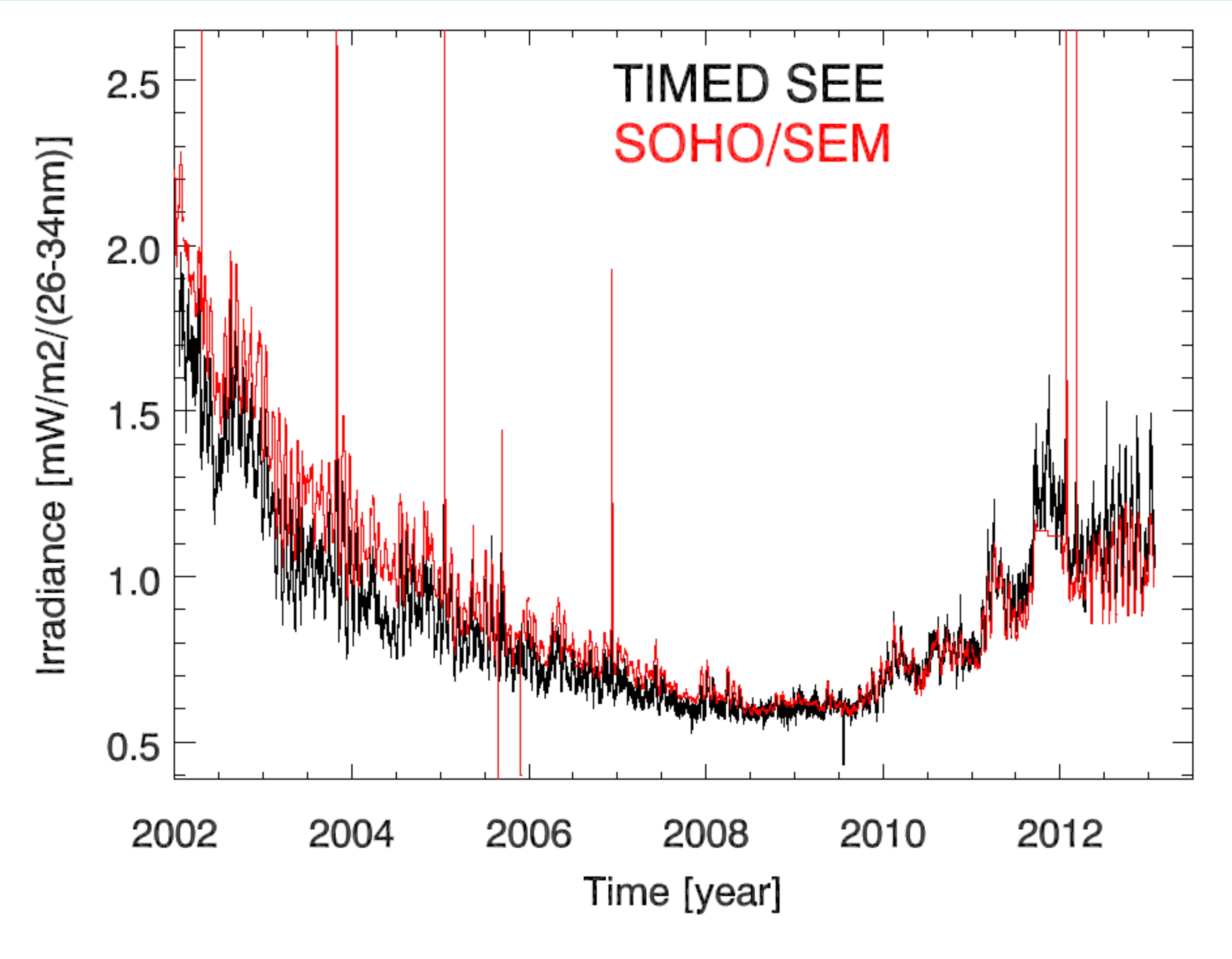
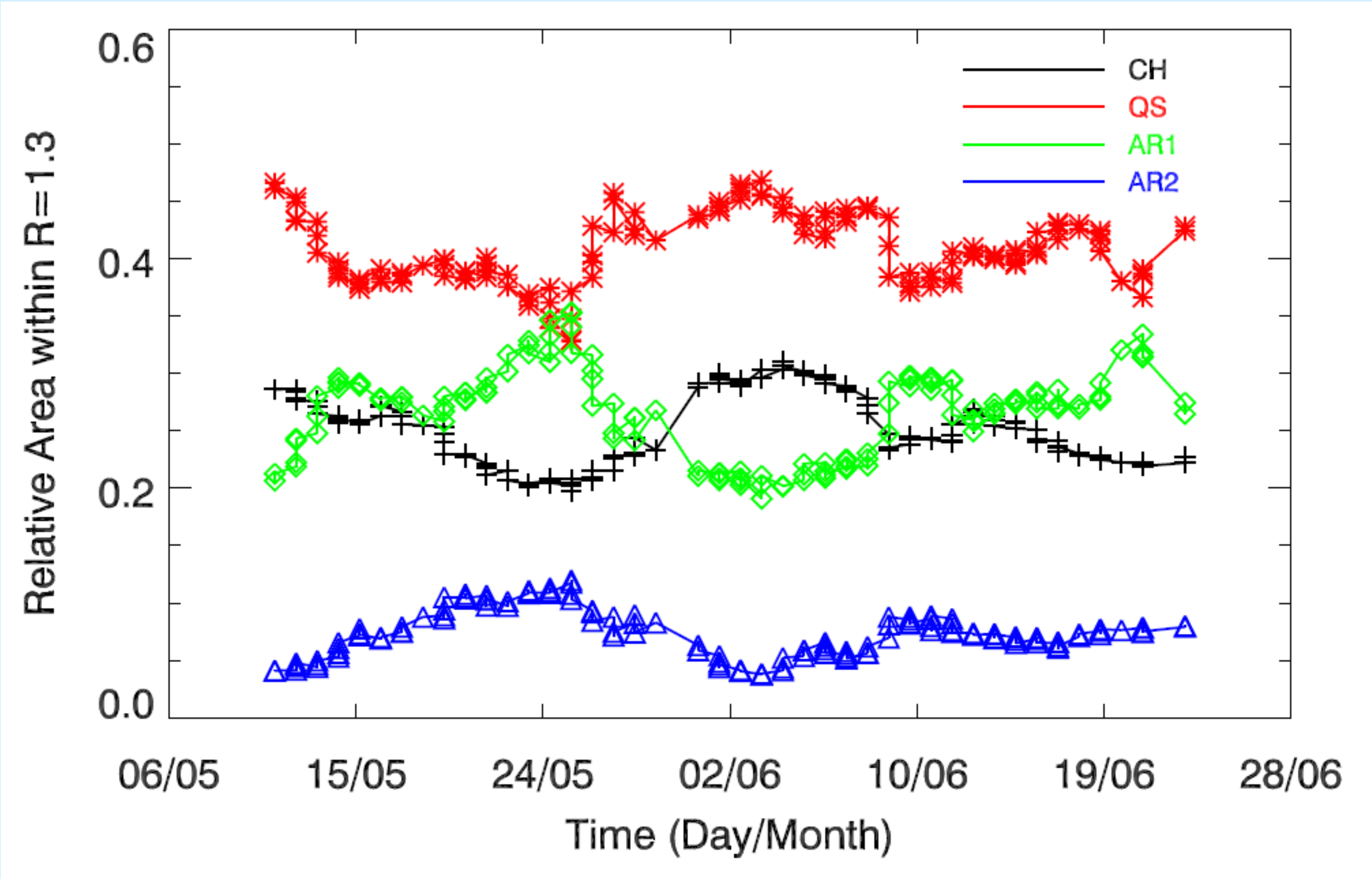
TIMED/SEE vs SOHO/SEM Data



The uncertainty in the measurements will be solved within this workshop and is also the aim of the FP7 project SOLID.

Test case for EUV reconstruction



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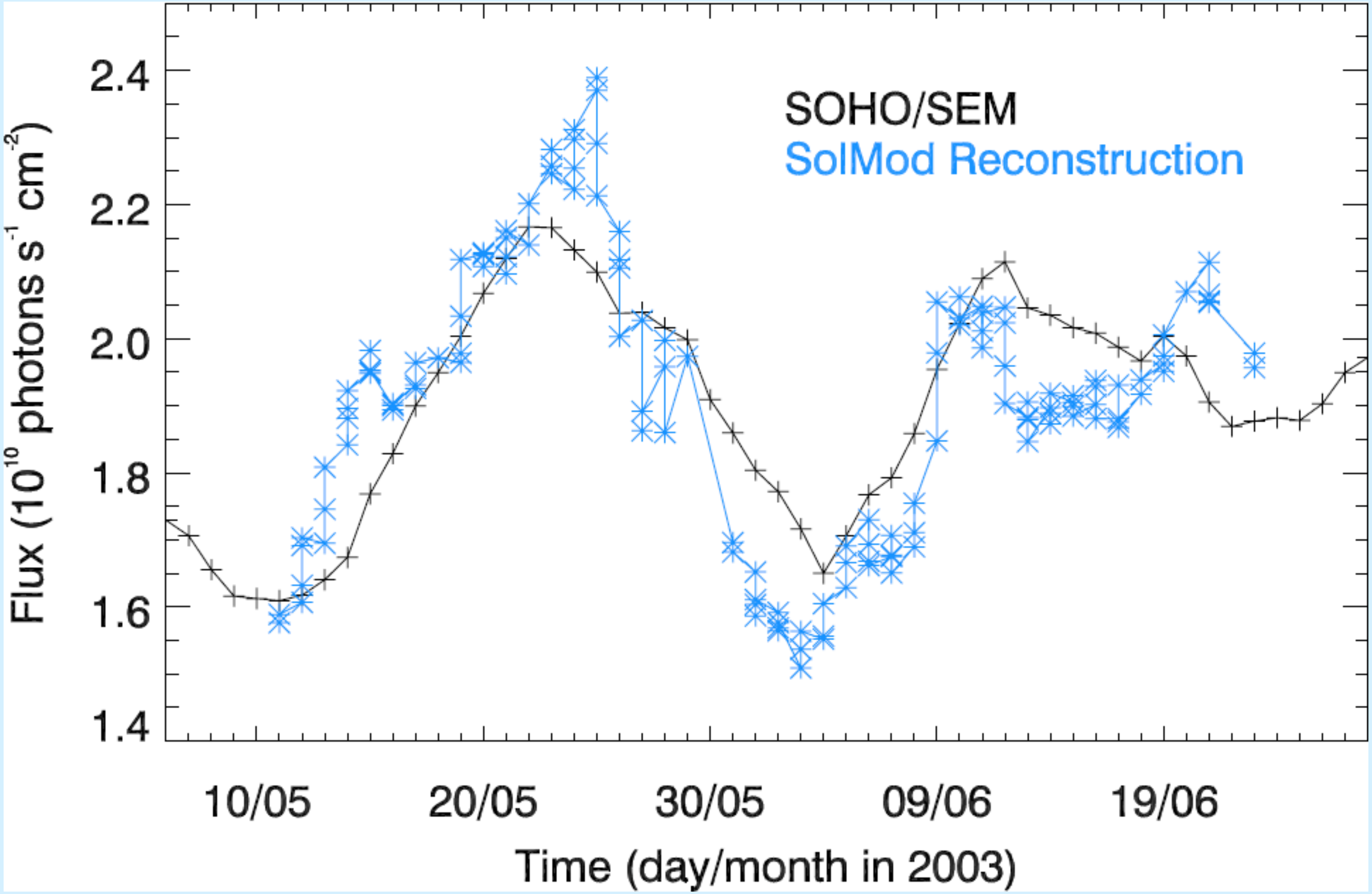
EUV reconstruction for test period



The reconstruction is scaled by a factor of 1.2
(this is within the uncertainty of the measurement)

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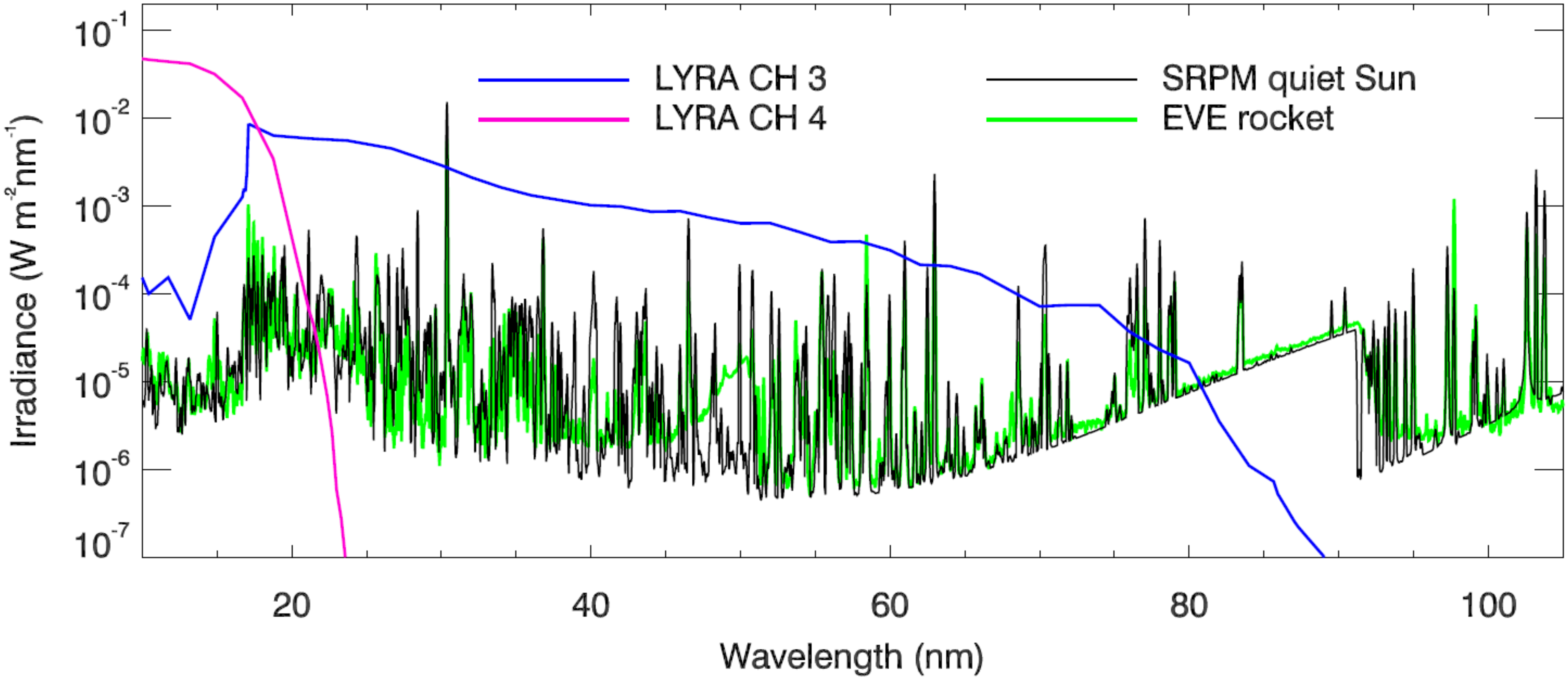
Reconstruction also covers LYRA passbands



LYRA CH 3: 17-80 nm
LYRA CH 4: 6-20 nm

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Conclusion

- The agreement of the reconstruction with SOHO/SEM is within the uncertainty of the observation

- Reconstruction will be updated with a 6-component model

- There are strong synergies between the FP7 SOLID project and the EUV calibration workshop