SOHO SEM vs. CDS/NIS

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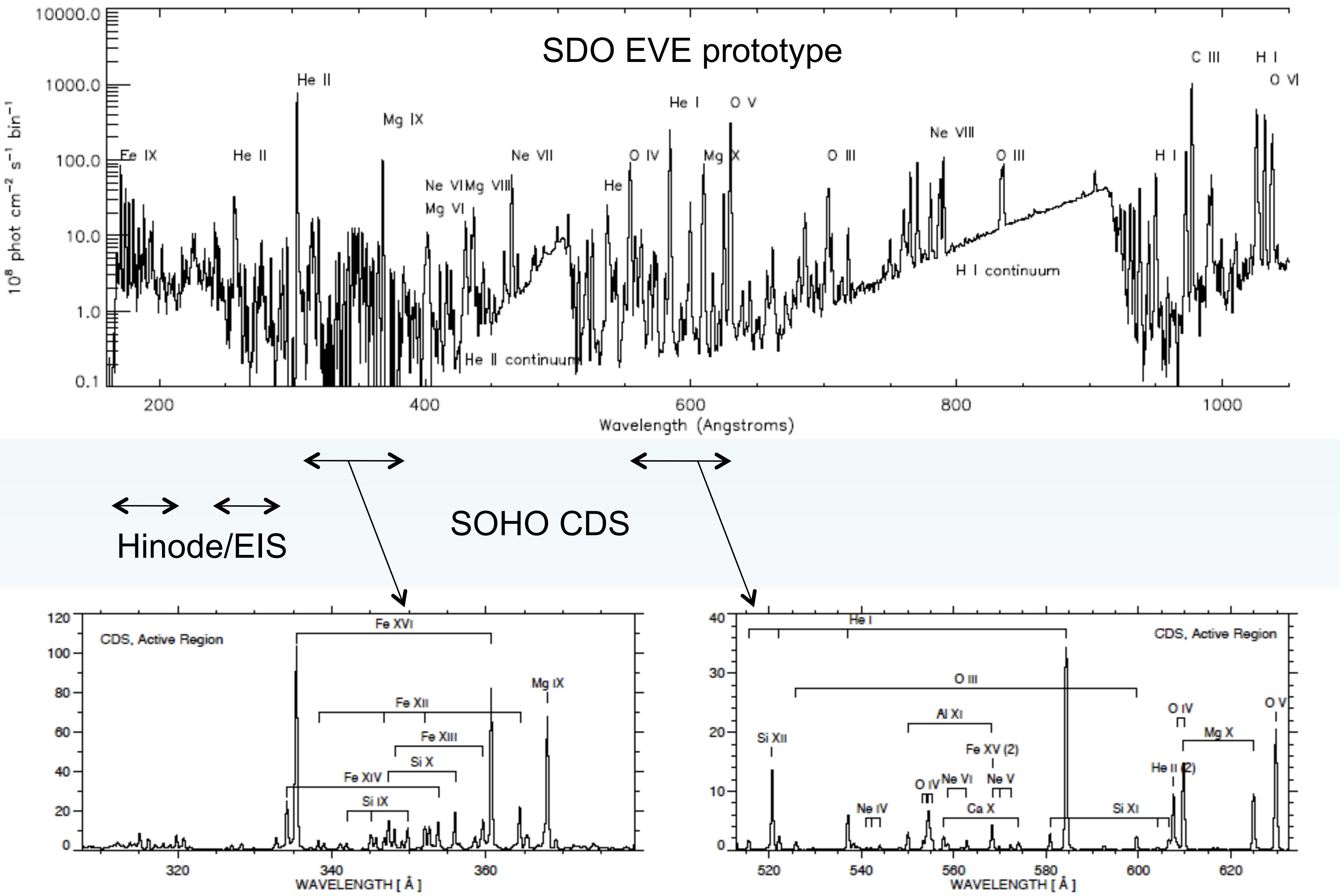
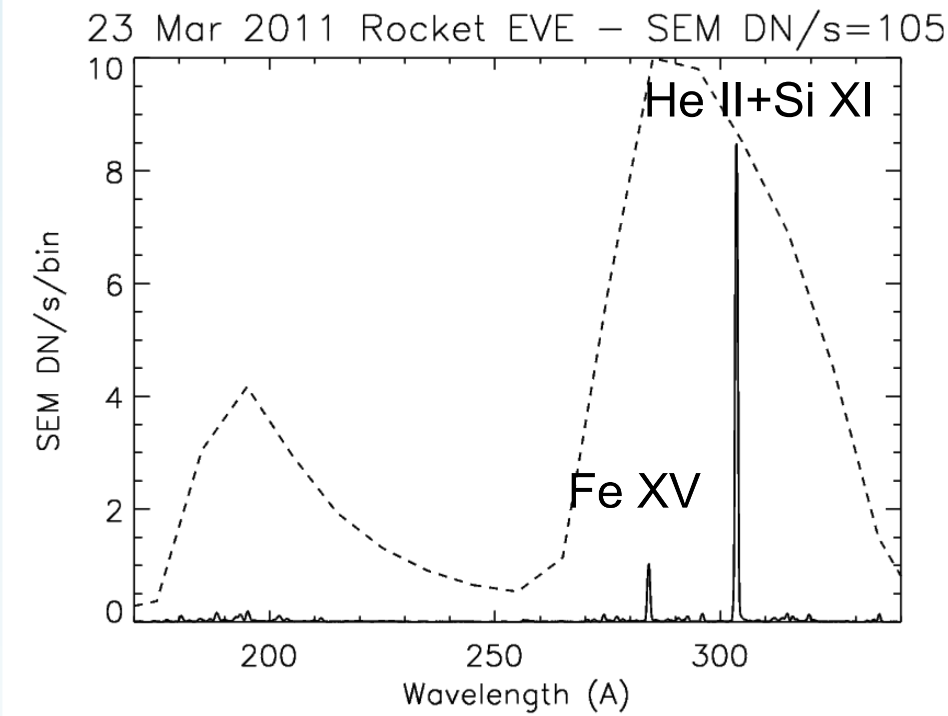
The EUV



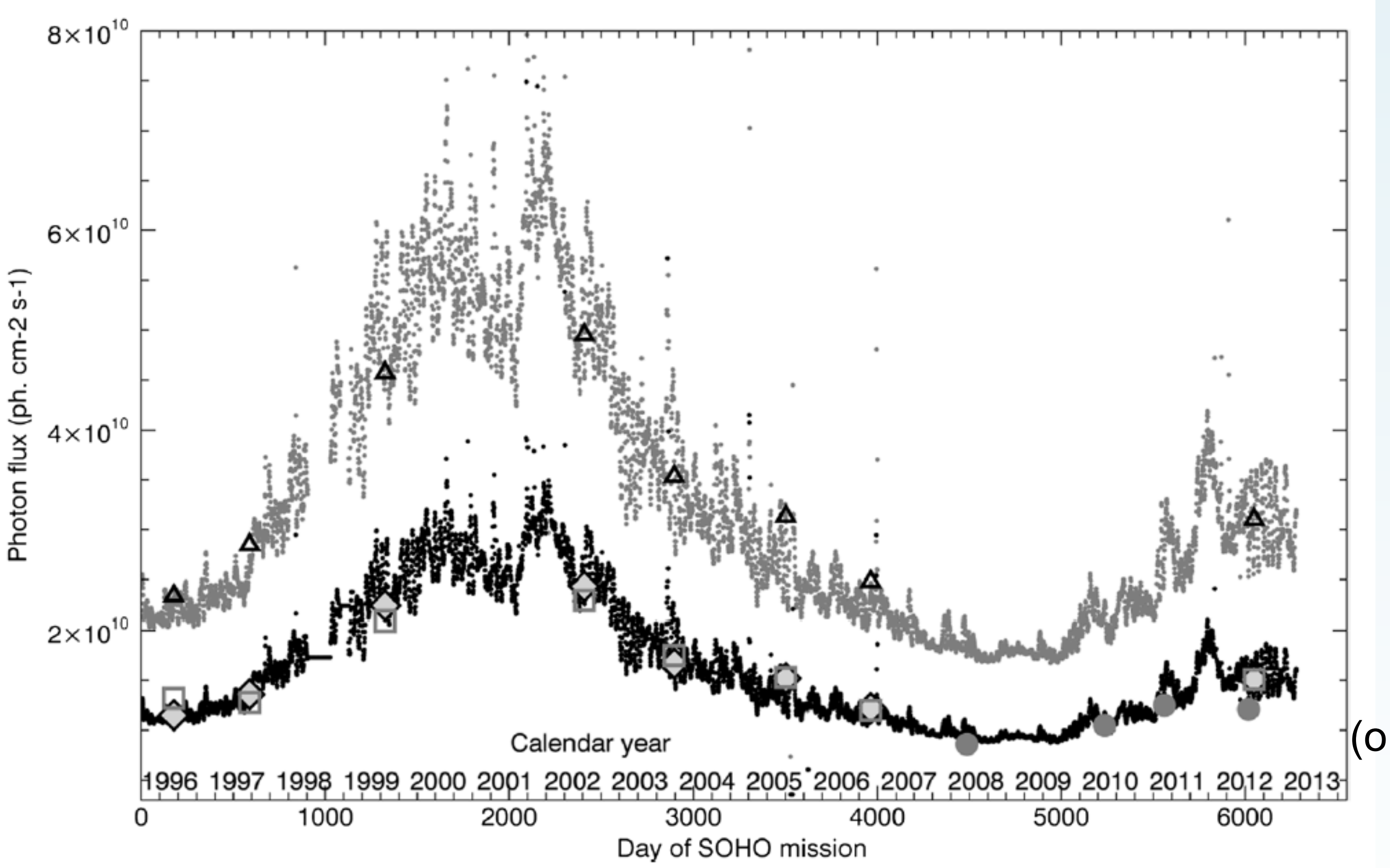
SDO EVE prototype
10^8 phot cm^{-2} s^{-1} bin^{-1}
Wavelength (Angstroms)
Fe IX
He II
He II
Mg IX
Ne VI
Mg VIII
Mg VI
Ne VII
He II continuum
He
O IV
He I
O V
Mg X
O III
Ne VIII
O III
H I continuum
H I
C III
H I
O VI
SOHO CDS
Hinode/EIS
CDS, Active Region
Fe XVI
Fe XII
Fe XIII
Si X
Fe XIV
Si IX
Mg IX
WAVELENGTH [Å]
CDS, Active Region
He I
O III
Al XI
Si XII
Fe XV (2)
O IV
Ne VI
Ne V
Ne IV
Ca X
Si XI
He II (2)
O IV
Mg X
O V
WAVELENGTH [Å]

SOHO SEM 1 band

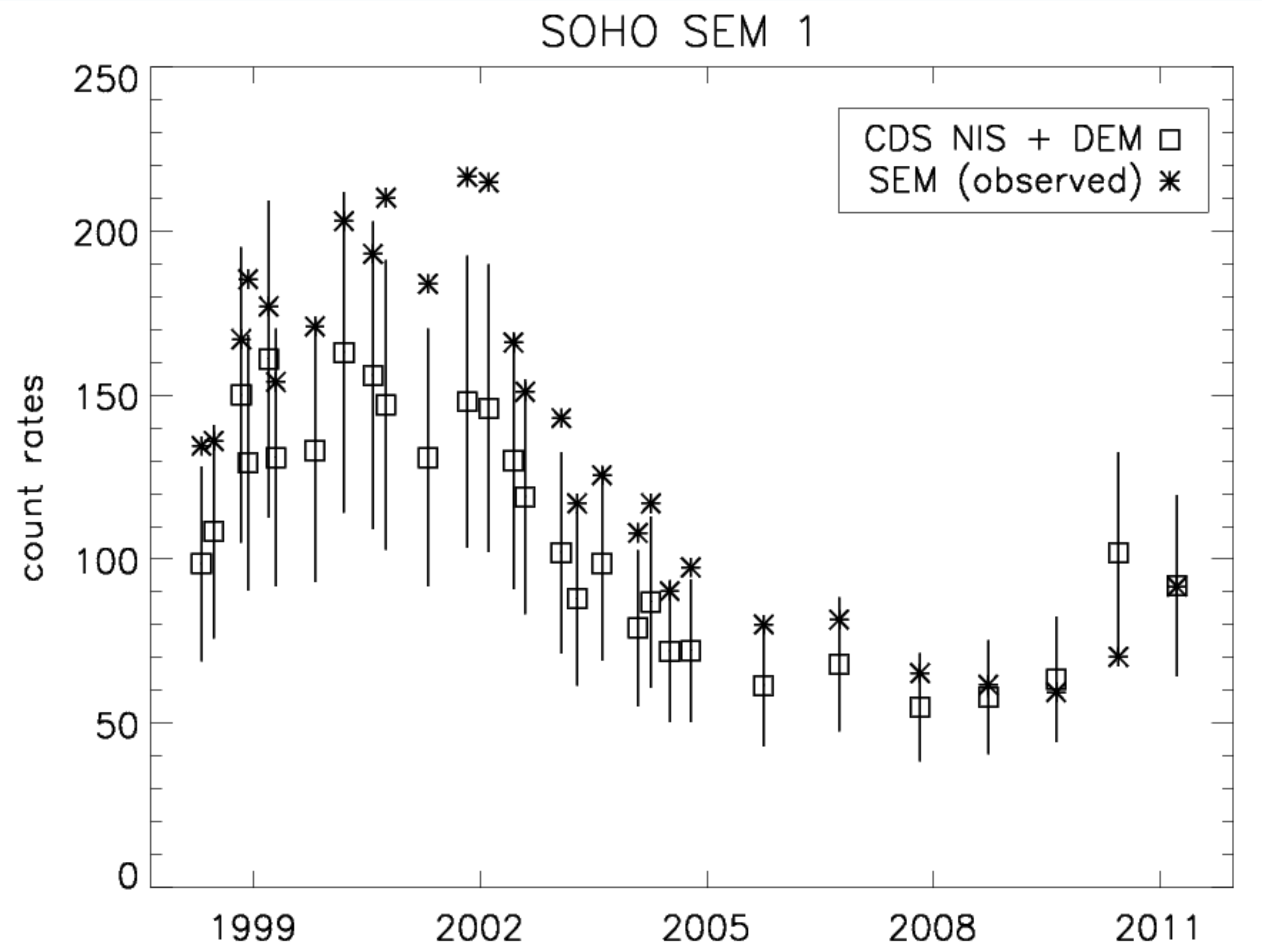


- The He II 304 and Si XI 303 are observed by NIS in second order.

Need reference spectra to convert DN/s into calibrated units !

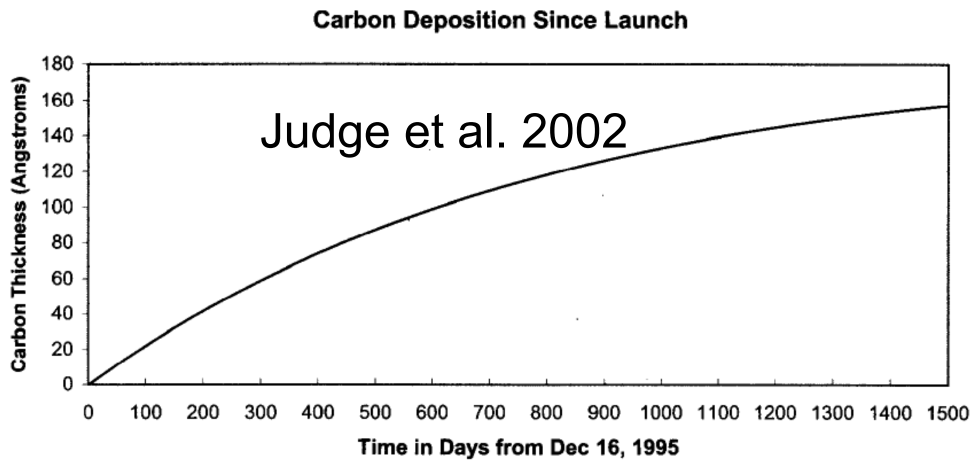


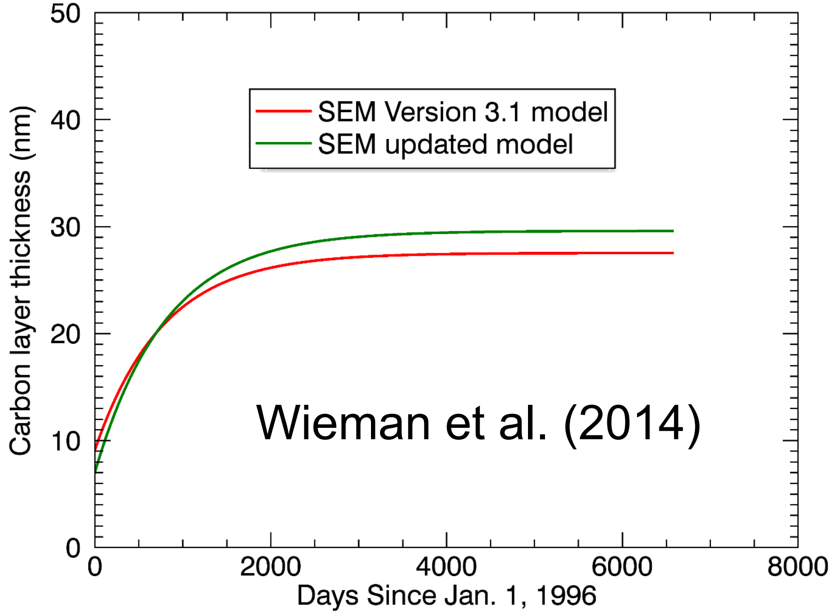
SEM 1
Ver. 3.1
(old calibration)

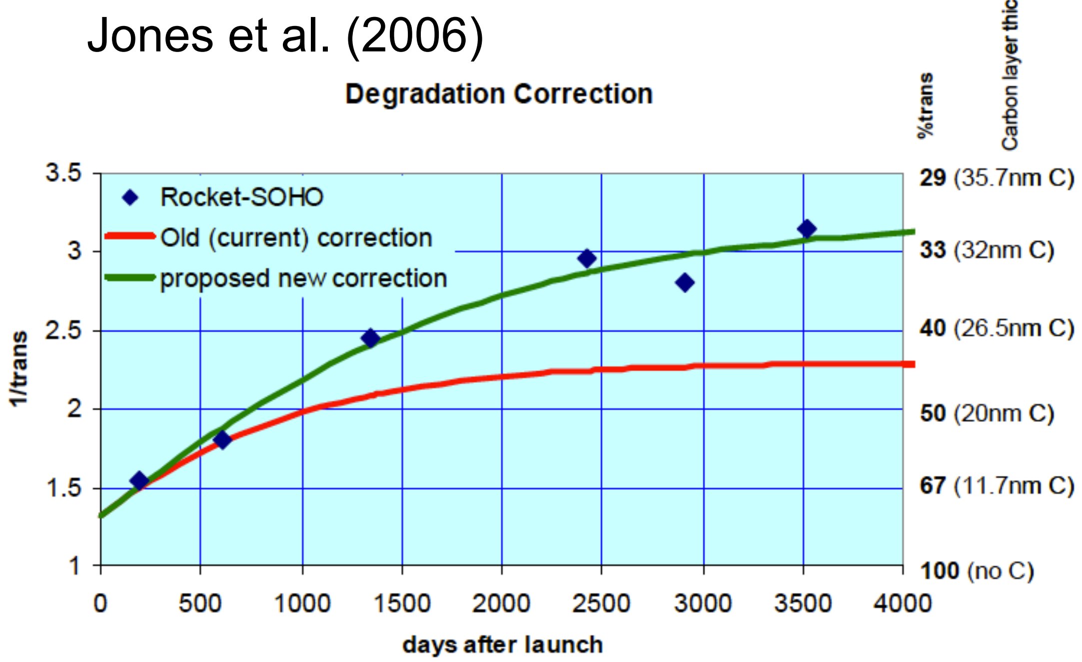


SOHO SEM 1
CDS NIS + DEM
SEM (observed)
count rates
0
50
100
150
200
250
1999
2002
2005
2008
2011

SOHO SEM degradation

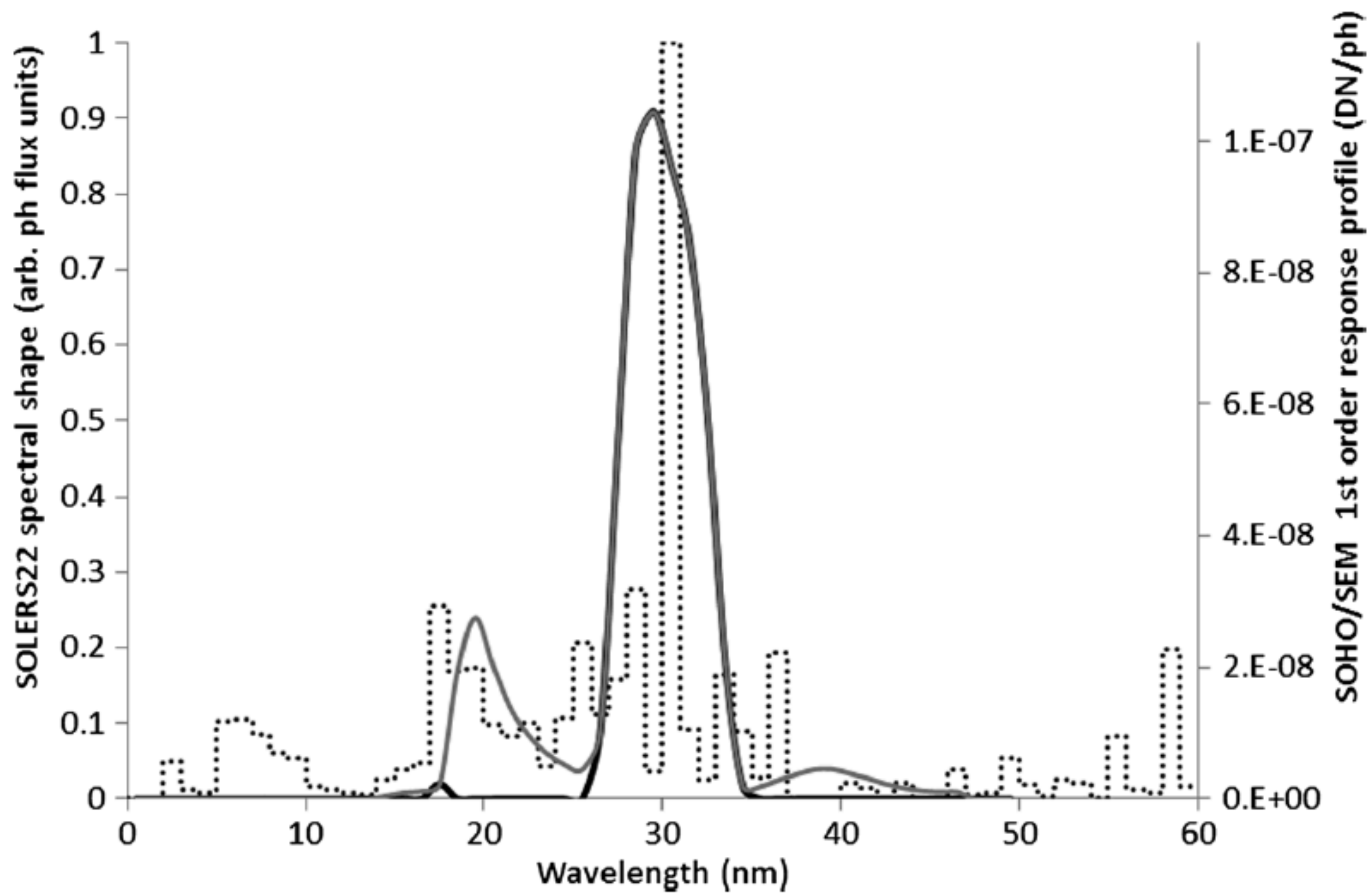


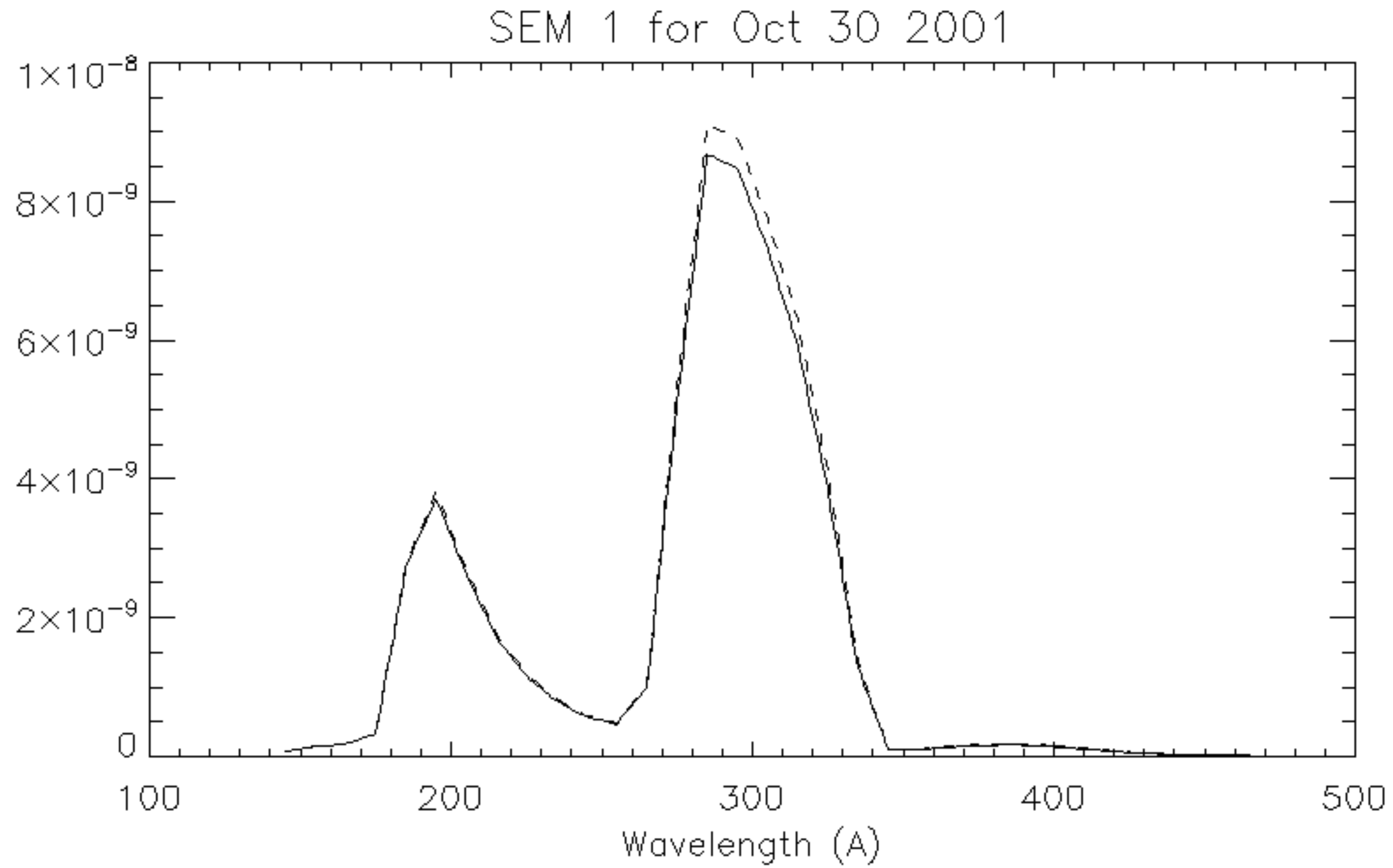


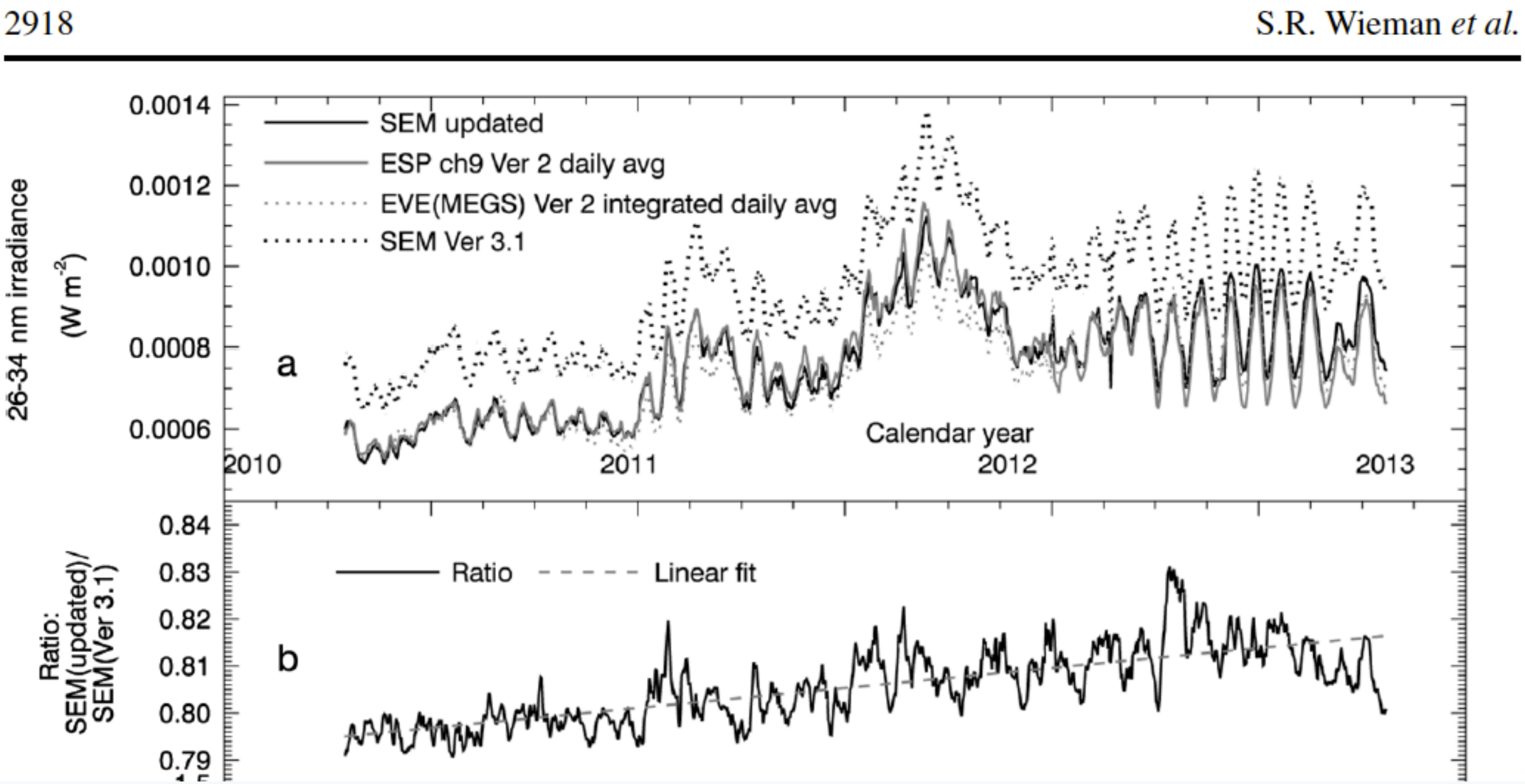


SEM 1 effective area – v 3.1 vs. current

Significant off-band responsivity (grey) found during 2007 calibration rocket, which included housing. The peaks are thought to be due to grazing incidence reflections off the housing walls.   Wieman et al. (2014)




SEM 1 for Oct 30 2001
1×10⁻⁸
8×10⁻⁹
6×10⁻⁹
4×10⁻⁹
2×10⁻⁹
0
100
200
300
400
500
Wavelength (A)



Taking into account the off-band contributions and using the observed SDO EVE MEGS spectra instead of the reference spectra lowers by 20% or more the SEM 1 irradiances during 2010-2013

SOLID - EUV irradiances

SOLID EU FP7 network: Solar Spectral Irradiance collection and modelling

1. Extend the SOHO CDS calibration to cover the entire lifetime of the CDS instrument.
2. Extend the database of CDS irradiances from the radiances
3. Compare CDS irradiances with calibration rocket flights for SDO/EVE, SDO/EVE, TIMED/SEE EGS
4. Provide reference EUV spectral irradiances that can be used to calibrate the SOHO/SEM 26-34 nm broad-band data during solar max.
5. Task 4.2: improvement of the CHIANTI atomic data for irradiance modelling (SolMoD3D).

CHIANTI v.8

1. **Li-like:** Liang & Badnell (2011).
2. **B-like:** Liang Badnell & Zhao (2012): C II (*IRIS*), N III,O IV (*IRIS*)
3. **F-like:** Witthoeft, Whiteford, Badnell (2007): Ne II, Na III, Mg IV, Al V new additions.
4. **Ne-like:** Liang & Badnell (2010): Na II, Mg III, Al IV, P VI, K X, Cr XV Mn XVI, Co XVIII new additions. Si V, S VII, Ar IX, Ca XI, Ni XIX updated.
5. **Na-like:** (Liang, Whiteford & Badnell 2009a; Liang, Whiteford & Badnell (2009b). Mg II, (**IRIS**), Al III, Si IV, P V, S VI, Ar VIII, K IX, Ca X, Cr XIV, Mn XV, Fe XVI, Co XVII, Ni XVIII
6. **Fe III (Badnell & Ballance 2014), Fe VI (Ballance & Griffin 2008), Fe X (Del Zanna et al. 2012), Fe XI (Del Zanna & Storey 2011), Fe XII (Del Zanna et al. 2012), Fe XIII (Del Zanna & Storey 2012), Fe XIX (Butler & Badnell 2008).**
7. New atomic data for low charge states and neutrals, to improve atomic data for solar irradiance modelling (SOLID EU FP7 Network): **S I (Tayal 2004), S II (Tayal & Zatsarinny 2010), S III (Hudson+2012), N I (Tayal 2006), C I (Wang+2013)**

SOHO CDS calibration and EUV irradiances

- SOHO CDS calibration (1996-2010)
- Del Zanna et al. (2001), A&A, 379, 708-734
- Del Zanna et al. (2005) Mem. Sait., 76, 953
- Del Zanna & Andretta (2006), ESA-SP 617
- Del Zanna & Andretta (2010), proc. IAU symp., no. 264, 78.
- Del Zanna et al. 2010, A&A, 518, A49

  The long-term correction was adopted by the CDS team.

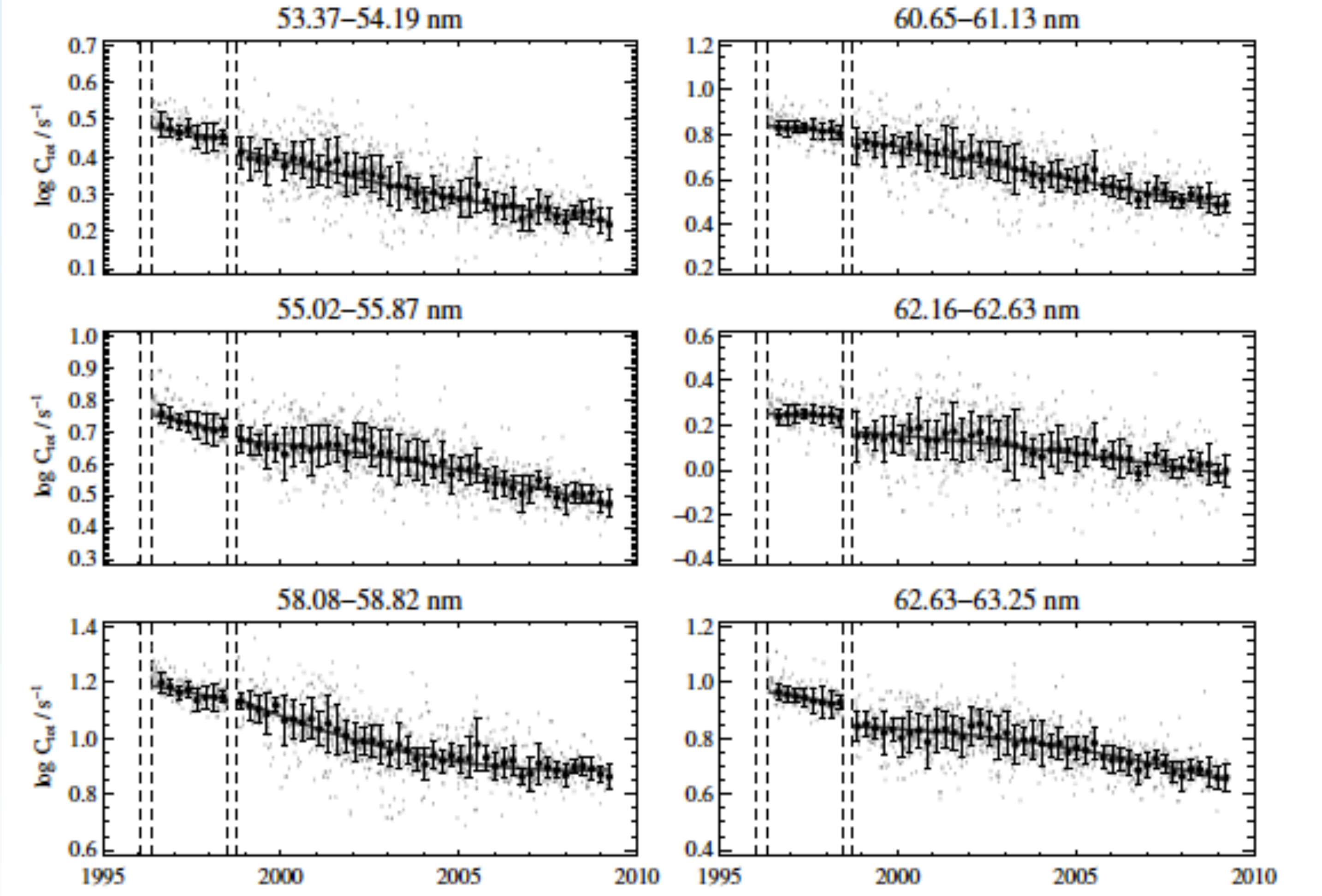
- First EUV irradiances along a solar cycle:

  Del Zanna & Andretta,2011, A&A, 528, A139

- First analysis of EUV radiances along a solar cycle:

  Andretta & Del Zanna, 2014, A&A, 563, A26

Count rates in QS with 90" slit



Overall degradation similar at all wavelengths.
New correction: **assume that radiances in TR lines are constant.**

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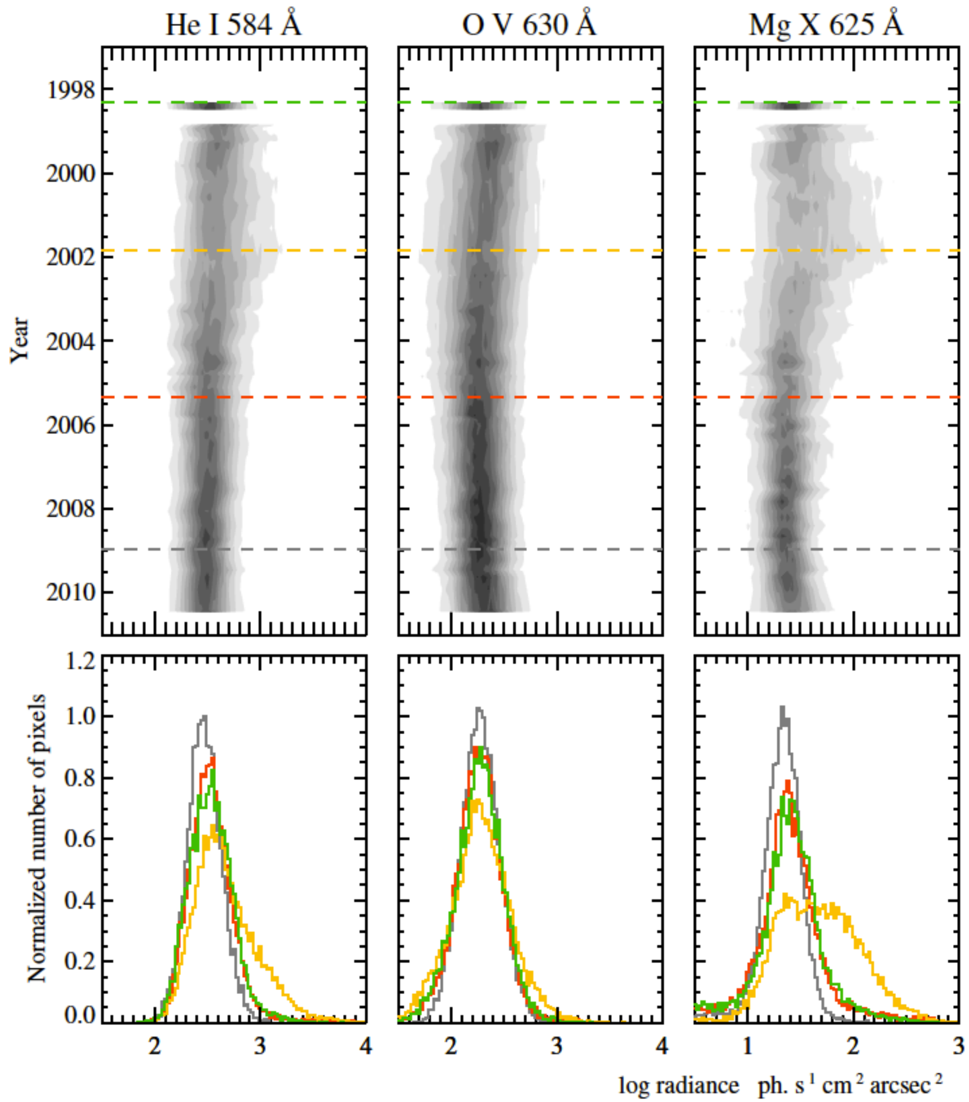
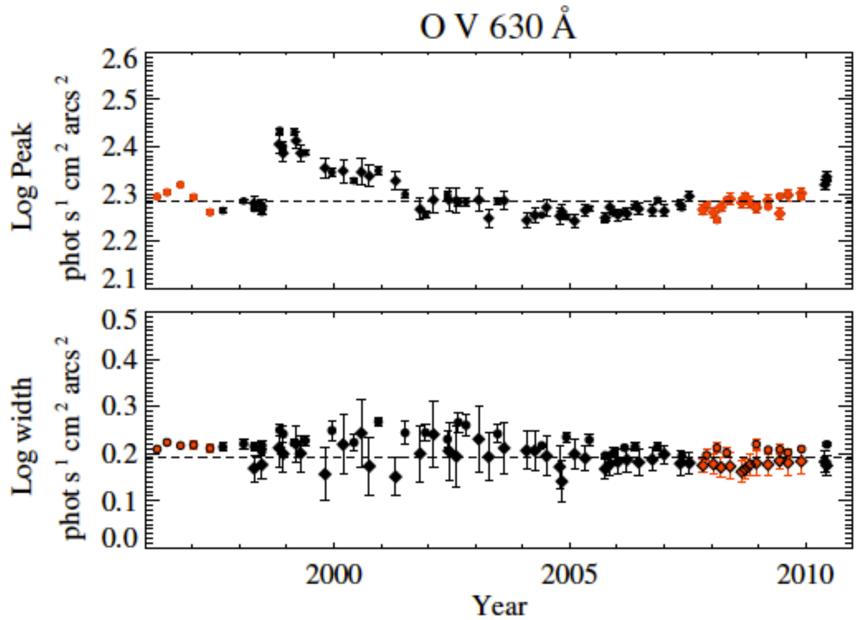
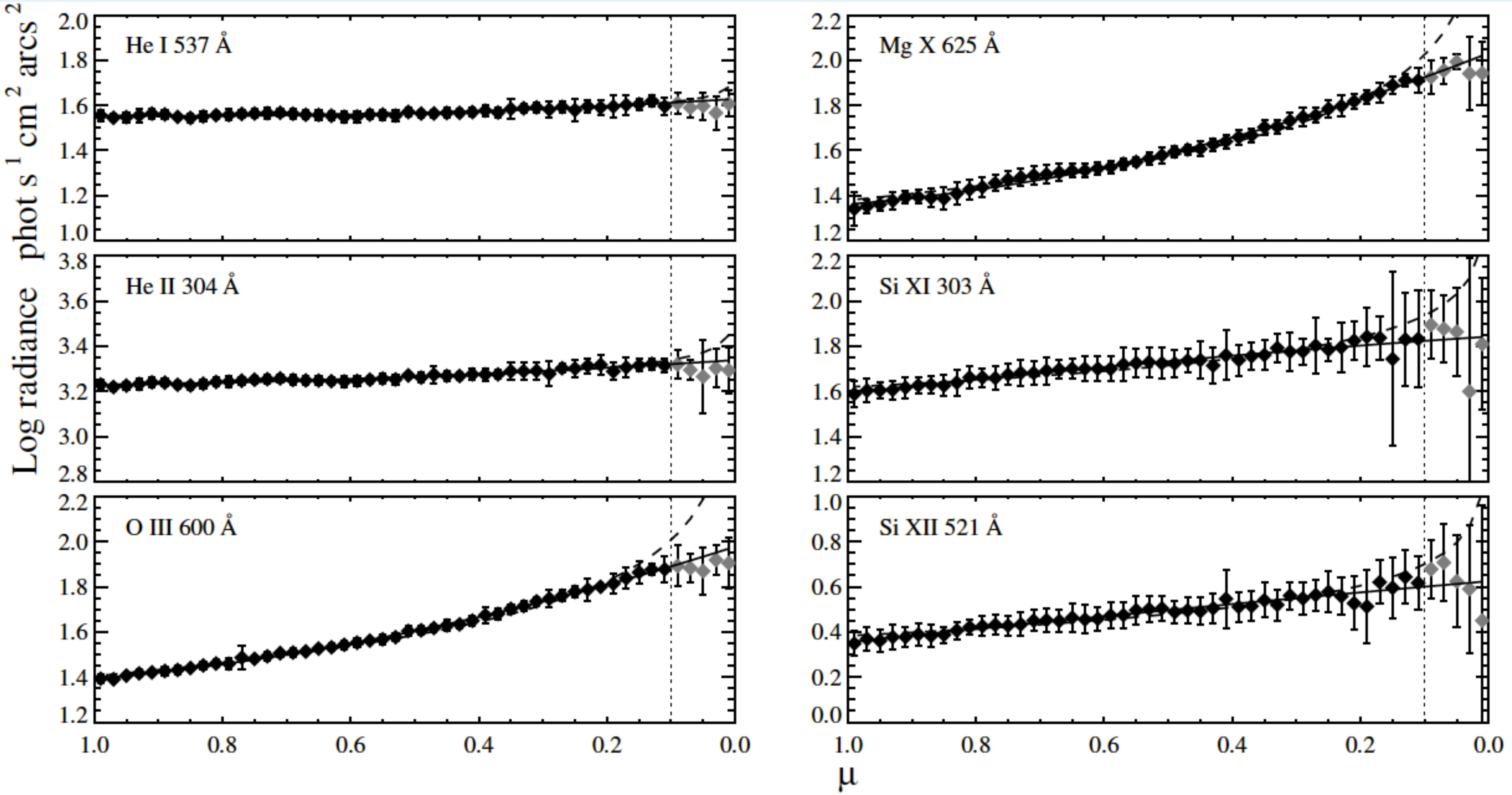




The QS radiances and widths are constant

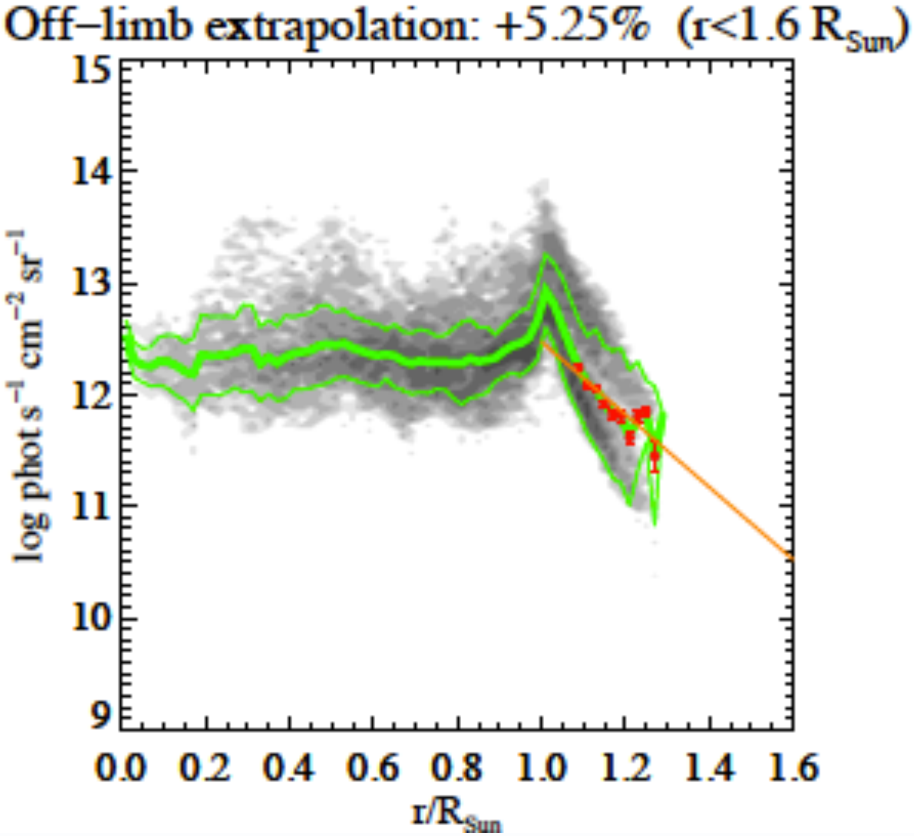
QS limb-brightening (Andretta-Del Zanna 2014)

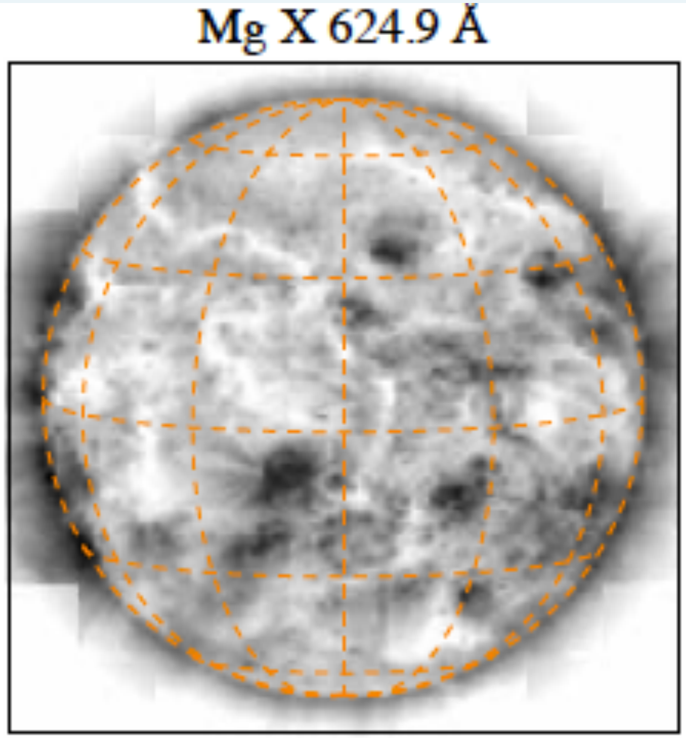
QS limb-brightening curves are the same for the two solar minima (1996, 2008)



Obtaining irradiances from radiances

1) Interpolate the radiances (CDS subsamples the Sun by a factor of 4-6)
2) Add the off-limb contribution. Typically, for coronal lines, a few percent,so uncertainty is negligible here.





CDS vs. PEVE (2008)

These spectral irradiances do not contain a correction for the missing off-limb contribution. Black: CDS - Red: SDO/EVE 2008 prototype (Del Zanna et al. 2010)

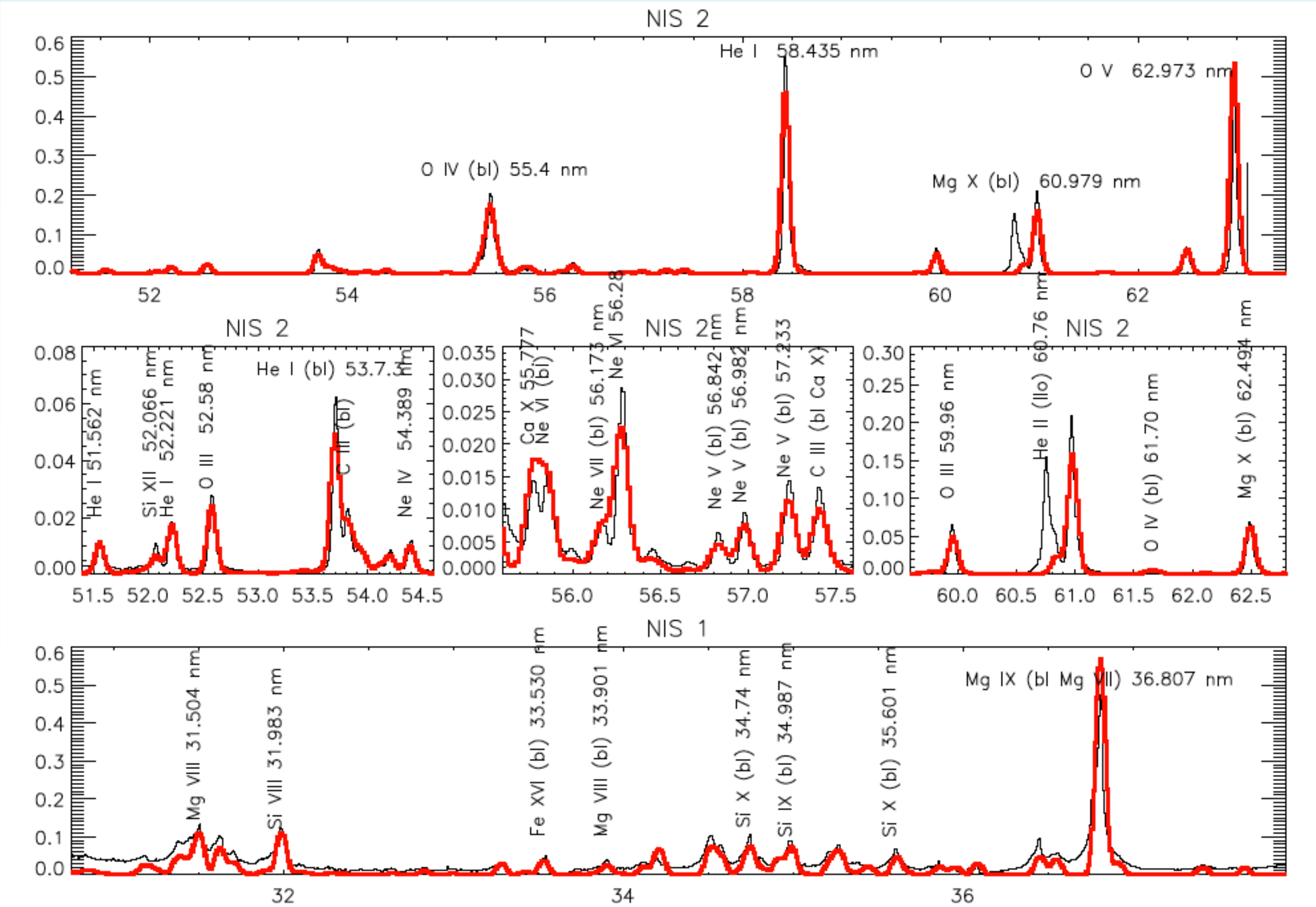


Table 1. Irradiances in μW m^{-2}.

Spectral lines	λ (nm)	PEVE	P
He II (bl Si XI)	30.400	309	663
Si VIII	31.983	8.2	11.7
Fe XVI (bl Mg VIII)	33.530	2.7	2.0
Mg VIII (bl)	33.901	1.9	1.8
Si X (bl)	34.750	5.6	6.3
Si IX (bl)	34.987	5.1	5.6
Si X (bl)	35.601	3.3	4.0
Mg IX (bl Mg VII)	36.800	42.	39.4
He I	51.562	1.2	1.0
Si XII	52.066	0.67	0.82
He I (bl)	52.221	1.9	1.5
O III	52.600	2.6	2.2
He I (bl)	53.703	5.2	4.9
Ne IV	54.207	0.66	0.51
Ne IV (sbl)	54.400	1.1	0.84
O IV (sbl)	55.450	26.4	25.4
Ne VI (2) (bl)	56.280	2.3	2.1
Ne V (2)	56.982	0.80	0.62
Ne V (3)	57.233	1.2	1.1
C III (bl Ca X)	57.420	1.1	1.0
He I	58.400	48.	36.
Ar VII	58.575	0.89	0.60
O III	60.000	5.2	4.8
Mg X (bl O IV)	61.000	16.	14.3
Mg X (bl)	62.500	6.6	5.8
O V	63.000	56.	35.

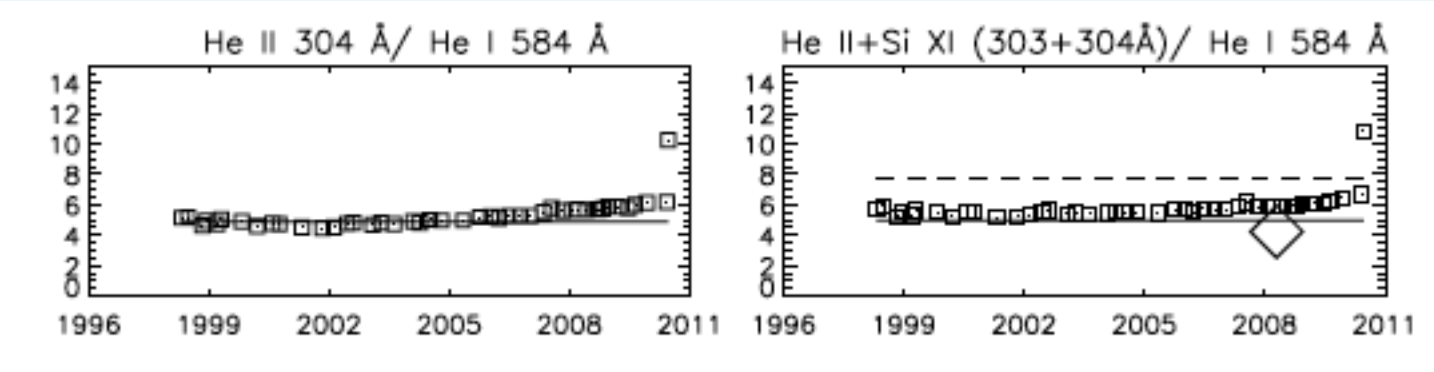
Relative agreement between NIS and PEVE is good, within 20% for most lines (Del Zanna 2010).

Problem with the He II 304

The problems with the He II 304 (1)

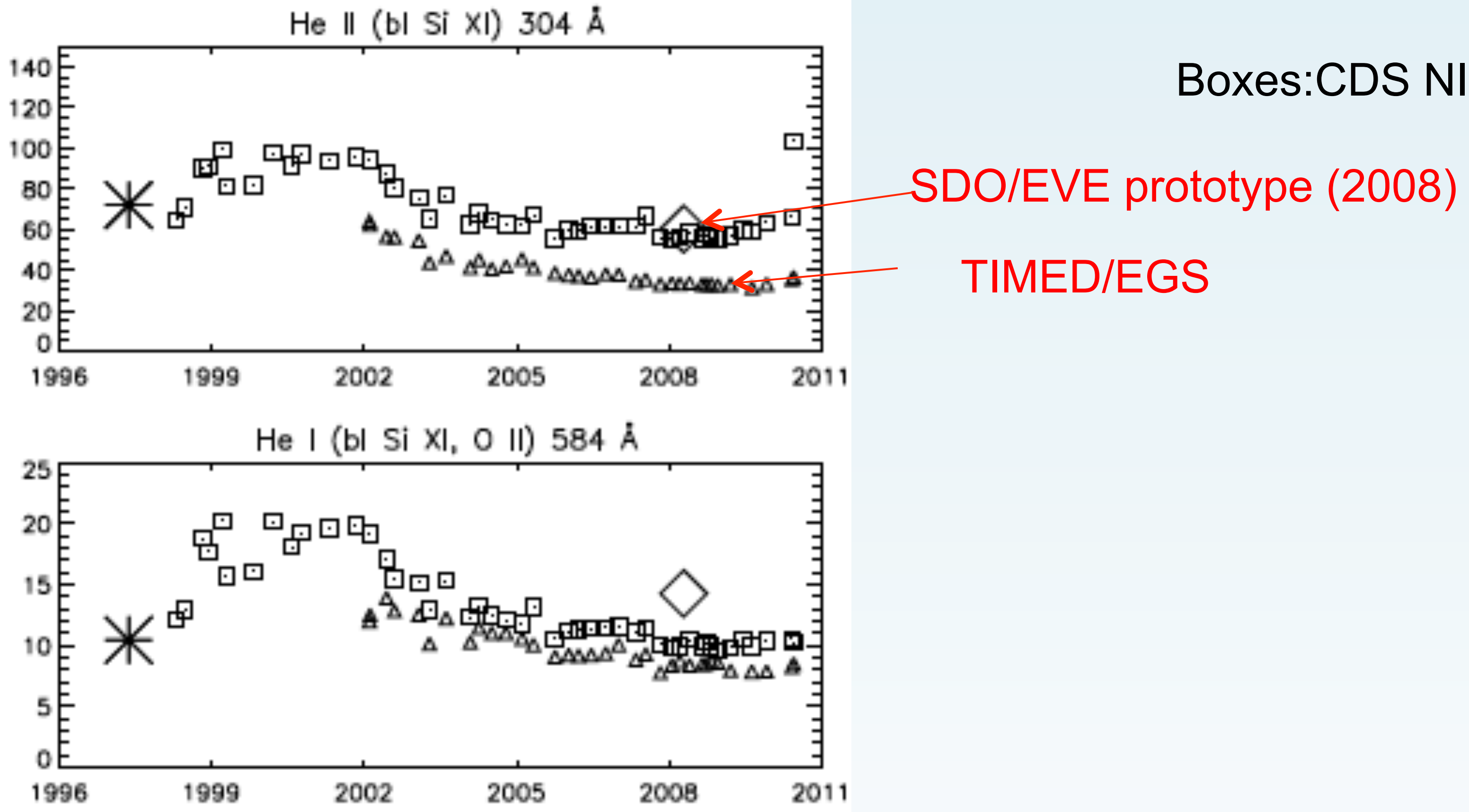
Historically, there have been large discrepancies between measurements obtained by various instruments.
The early CDS/TIMED-EGS and SDO/EVE 2008 flight comparisons (Del Zanna et al. 2010) were not good.

Del Zanna & Andretta (2011) assumed that the NIS responsivity at 584 A (based on a 1997 LASP EGS flight) was correct, and adopted a responsivity for the He II 304 that would produce a 304/584 ratio as measured by Heroux et al. (1974).
This ratio is known to be very stable:



The resulting He II irradiances are in good agreement with those measured by the SDO/EVE 2008 prototype.
Del Zanna & Andretta (2011) suggested that previous Skylab ATM, TIMED/SEE, SERTS and EUNIS measurements were incorrect.

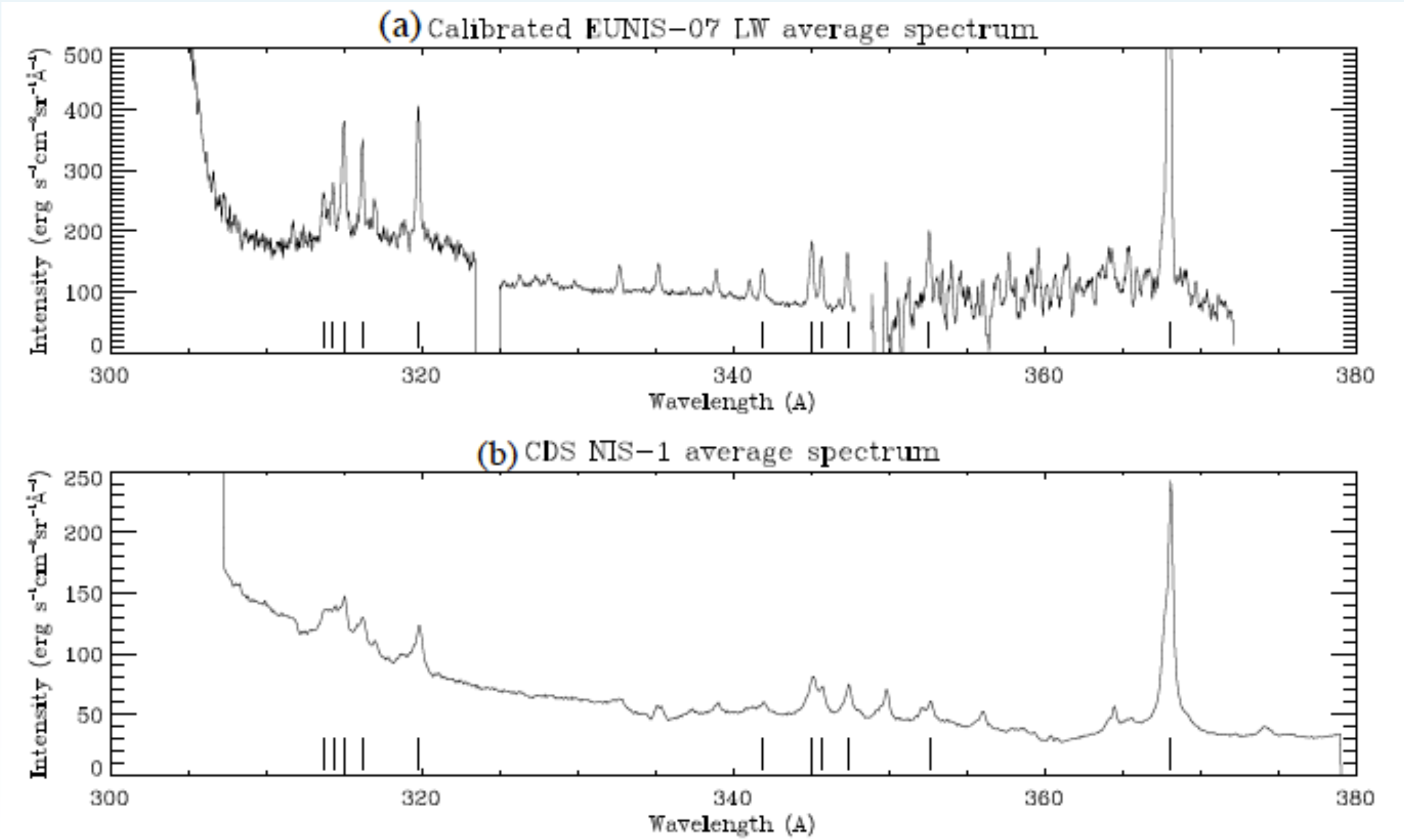
SOHO NIS irradiances vs. EVE and TIMED/EGS



EUNIS 2007 vs. CDS NIS 1

EUNIS was flown in 2007 and calibrated on the ground in may 2008 at RAL using the same secondary standard used for CDS, which was calibrated against the syncrotron BESSY-II.

Near-simultaneous CDS NIS observations of the quiet Sun were obtained.



EUNIS 2007 vs. NIS 1 (Wang+2011)

Quiet Region Line Intensities (erg s^{-1} cm^{-2} sr^{-1}) for EUNIS-07 LW and CDS[a]

Wavelength (Å)	Ion	I_{E07}	I^{SN}_{CDS}	I^{GZ}_{CDS}	I^{S}_{CDS}	I_{E07}/I^{SN}_{CDS}	I_{E07}/I^{GZ}_{CDS}	I_{E07}/I^{S}_{CDS}
303.78	He II	4759	5244	4484	4290	0.91 ± 0.13	1.06 ± 0.15	1.11 ± 0.16
313.76	Mg VIII	25.2	31.7	25.9	14.1	0.79 ± 0.11	0.97 ± 0.14	1.79 ± 0.25
314.31	Si VIII	25.1	36.1	30.0	24.1	0.70 ± 0.10	0.84 ± 0.12	1.04 ± 0.15
315.01	Mg VIII	62.3	37.6	31.7	22.0	1.66 ± 0.23	1.97 ± 0.28	2.83 ± 0.40
316.20	Si VIII	39.2	44.7	38.7	26.6	0.88 ± 0.12	1.01 ± 0.14	1.47 ± 0.21
319.81	Si VIII	60.5	48.6	45.5	26.4	1.24 ± 0.18	1.33 ± 0.19	2.29 ± 0.32
341.91	Si IX	15.0	17.0	15.4	13.9	0.88 ± 0.12	0.97 ± 0.14	1.08 ± 0.15
345.04	Si IX	34.0	66.8	60.9	46.5	0.51 ± 0.07	0.56 ± 0.08	0.73 ± 0.10
345.67	Fe X	20.6	14.7	13.4	15.7	1.40 ± 0.20	1.54 ± 0.22	1.31 ± 0.19
347.34	Si X	24.0	27.6	25.6	22.2	0.87 ± 0.12	0.94 ± 0.13	1.08 ± 0.15
352.58	Fe XI	30.3	19.9	20.0	20.4	1.52 ± 0.22	1.51 ± 0.21	1.49 ± 0.21
368.11	Mg IX[b]	285.8	262.4	252.4	172.1	1.09 ± 0.15	1.13 ± 0.16	1.66 ± 0.23

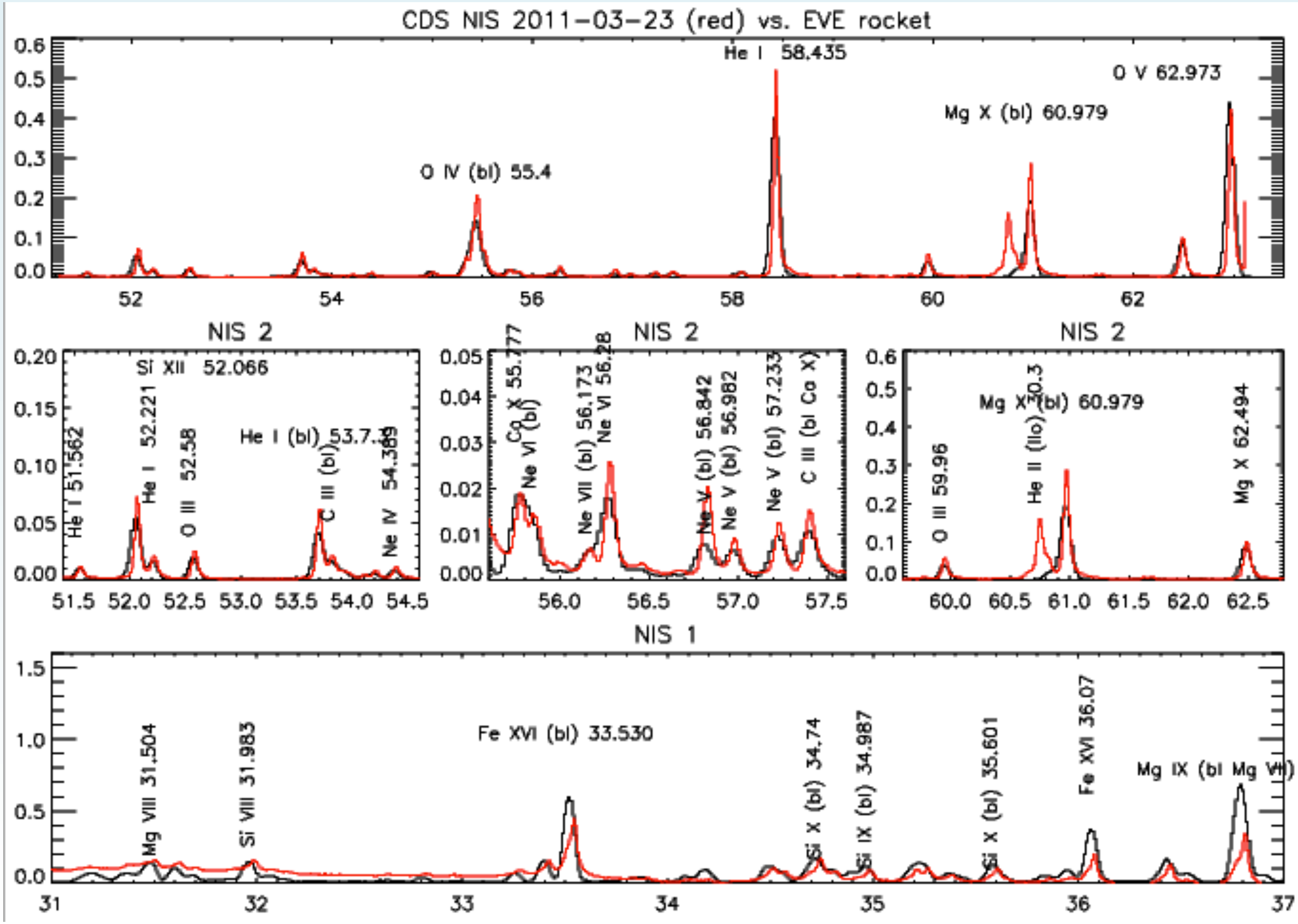
Notes.

[a] Column 1 is the wavelengths which are measured from the EUNIS-07 LW spectrum. Column 2 is the ion name. Column 3 (I_{E07}) is the EUNIS-07 line intensity. Column 4 (I^{SN}_{CDS}) is the CDS line intensity with the standard calibration and the new long-term correction. Column 5 (I^{GZ}_{CDS}) is the CDS line intensity with the Del Zanna et al. (2001) calibration and the new long-term correction. Column 6 (I^{S}_{CDS}) is the CDS line intensity with the standard calibration and standard long-term correction. Columns 7–9 are the EUNIS-to-CDS line intensity ratios.

[b] The listed line intensity for Mg IX 368.1 Å includes the emission from the blended line, Mg VII 367.7 Å.

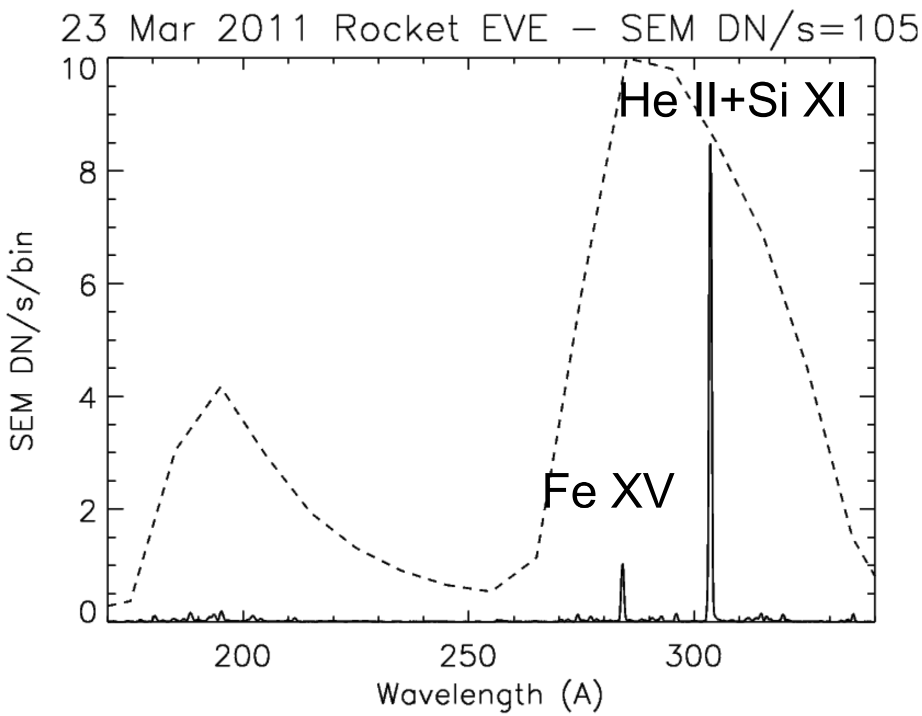
Very good agreement (within 6%) between the radiances of the He II 304 A line is found when the Del Zanna sensitivities and long-term corrections are applied. (Wang et al. 2011, ApJ, 197, 32)

CDS vs. EVE rocket March 2011

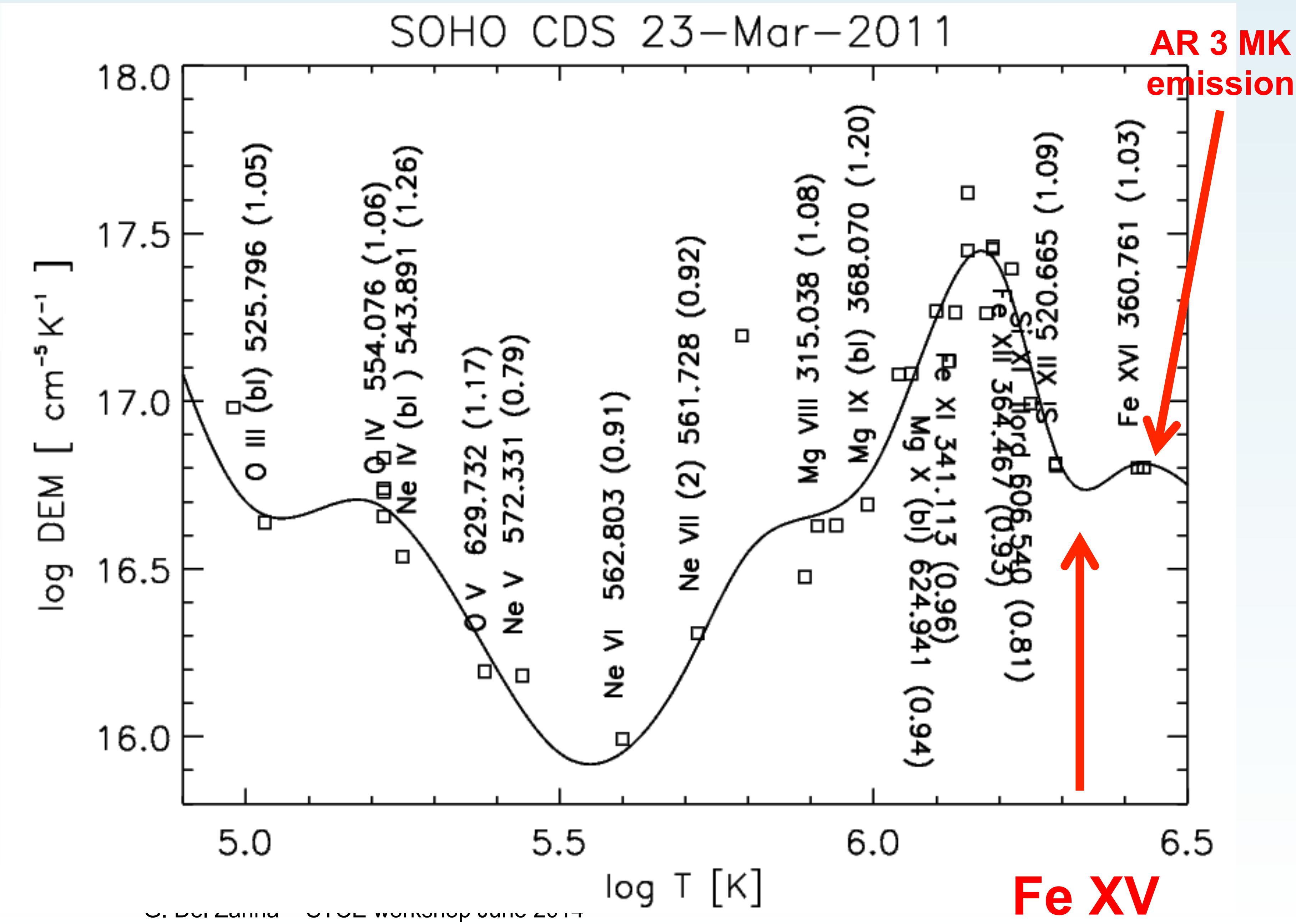


SOHO SEM 1 band

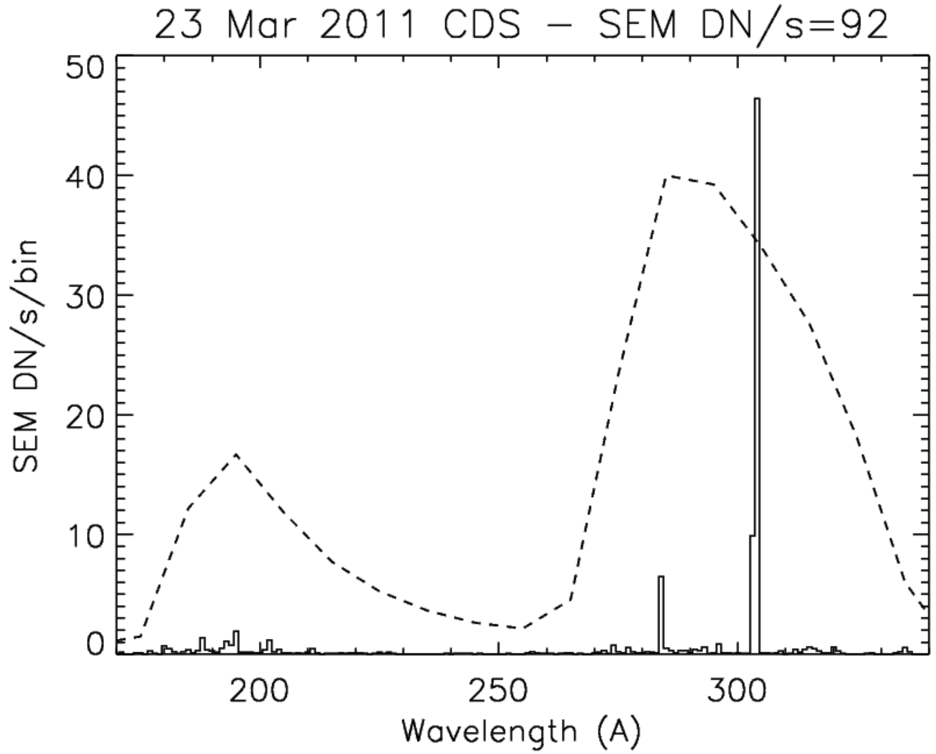
- The He II 304 and Si XI 303 are observed by NIS. The other lines are estimated from DEM

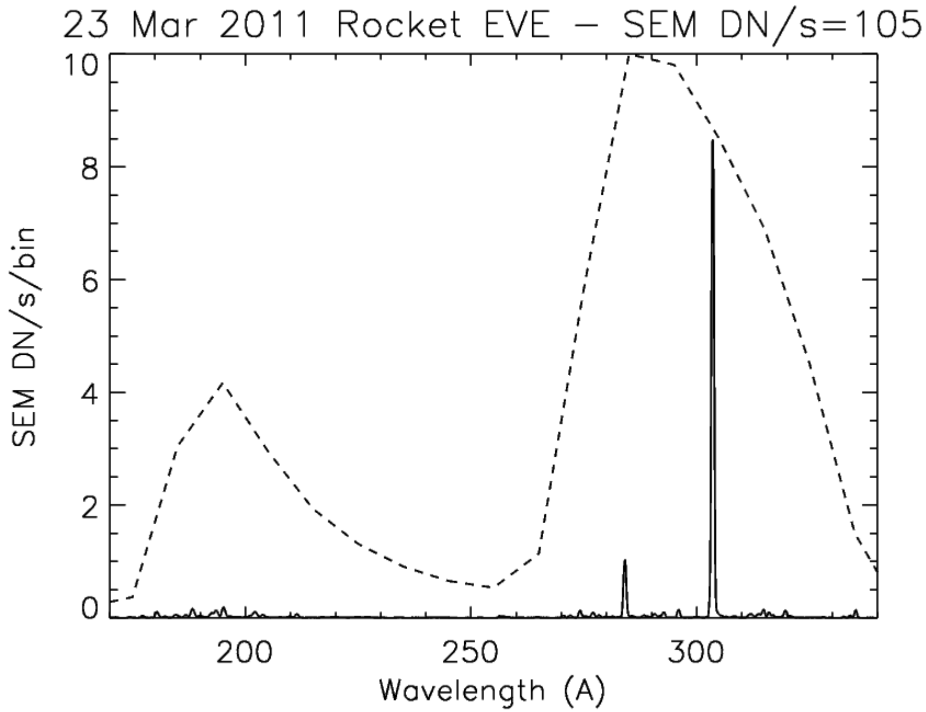


- CHIANTI v.7.1 ionization equilibrium
- CHIANTI v.8 (test version)
- Photospheric abundances
- Constant density 3x 10^8 (cm^{-3})


SOHO CDS 23-Mar-2011
log DEM [cm^-5 K^-1]
log T [K]
18.0
17.5
17.0
16.5
16.0
5.0
5.5
6.0
6.5
O III (bl) 525.796 (1.05)
O IV 554.076 (1.06)
Ne IV (bl) 543.891 (1.26)
O V 629.732 (1.17)
Ne V 572.331 (0.79)
Ne VI 562.803 (0.91)
Ne VII (2) 561.728 (0.92)
Mg VIII 315.038 (1.08)
Mg IX (bl) 368.070 (1.20)
Mg X (bl) 624.941 (0.94)
Fe XI 341.113 (0.96)
Fe XII 364.467 (0.93)
Si XI 606.540 (0.81)
Si XII 520.665 (1.09)
Fe XVI 360.761 (1.03)
AR 3 MK emission
Fe XV

SOHO CDS vs. SEM

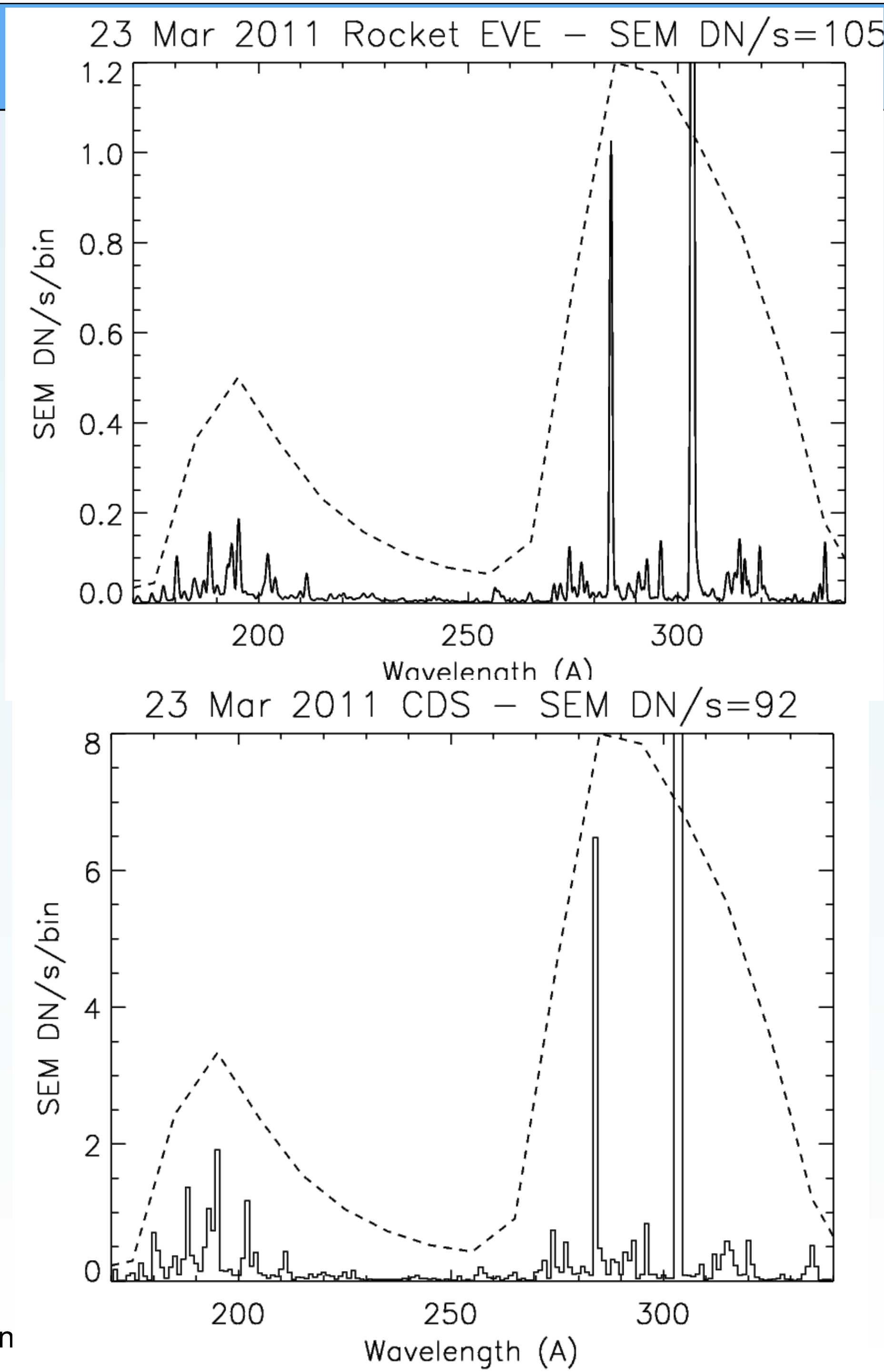




The SEM 1 effective areas include a correction for the degradation of the SEM, provided by Seth Wieman

Exact CDS/SEM agreement.

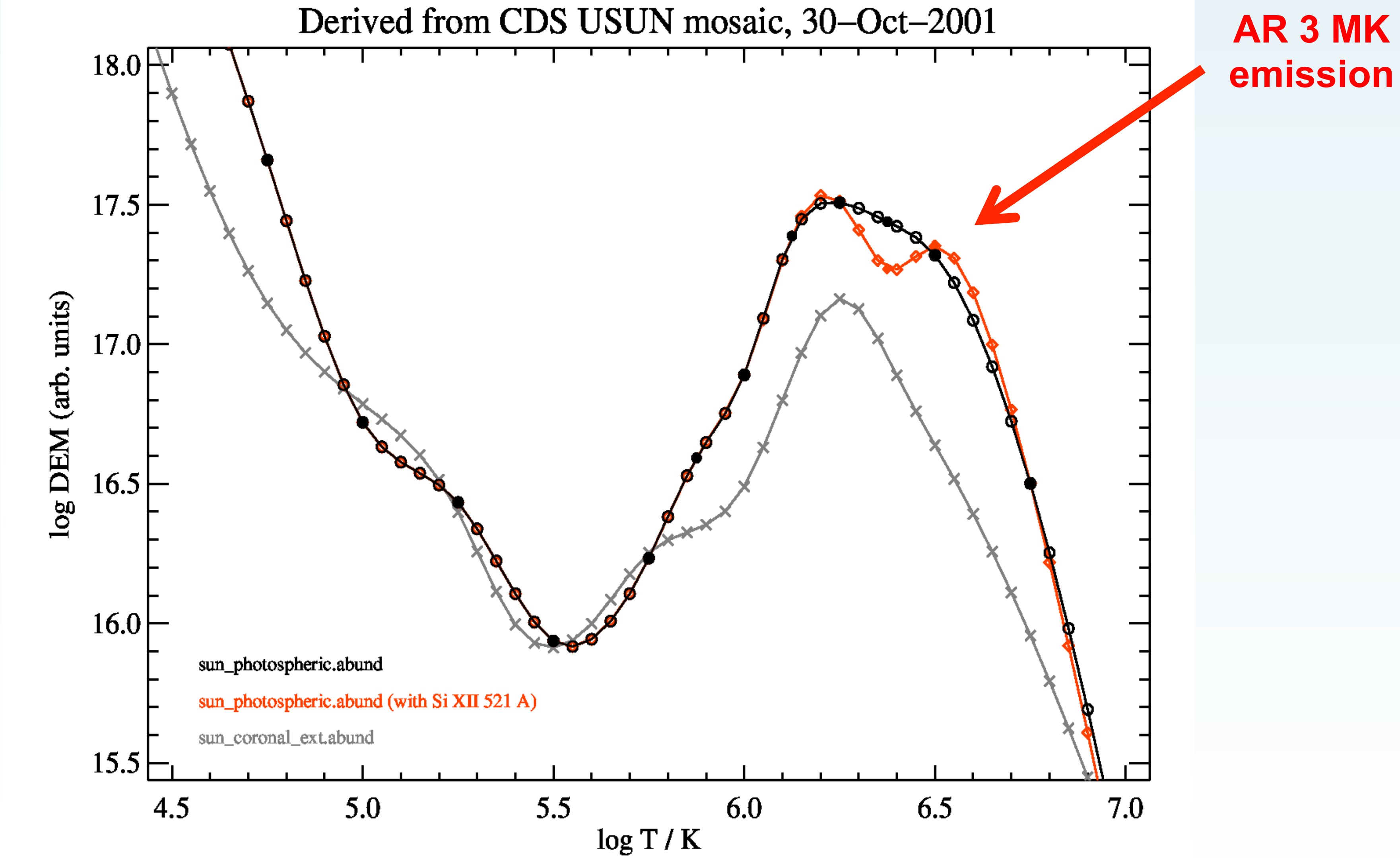
Observed SEM=92 DN/s!



23 Mar 2011 Rocket EVE – SEM DN/s=105
SEM DN/s/bin
1.2
1.0
0.8
0.6
0.4
0.2
0.0
200
250
300
Wavelength (A)
23 Mar 2011 CDS – SEM DN/s=92
SEM DN/s/bin
8
6
4
2
0
200
250
300
Wavelength (A)

G. Del Zann

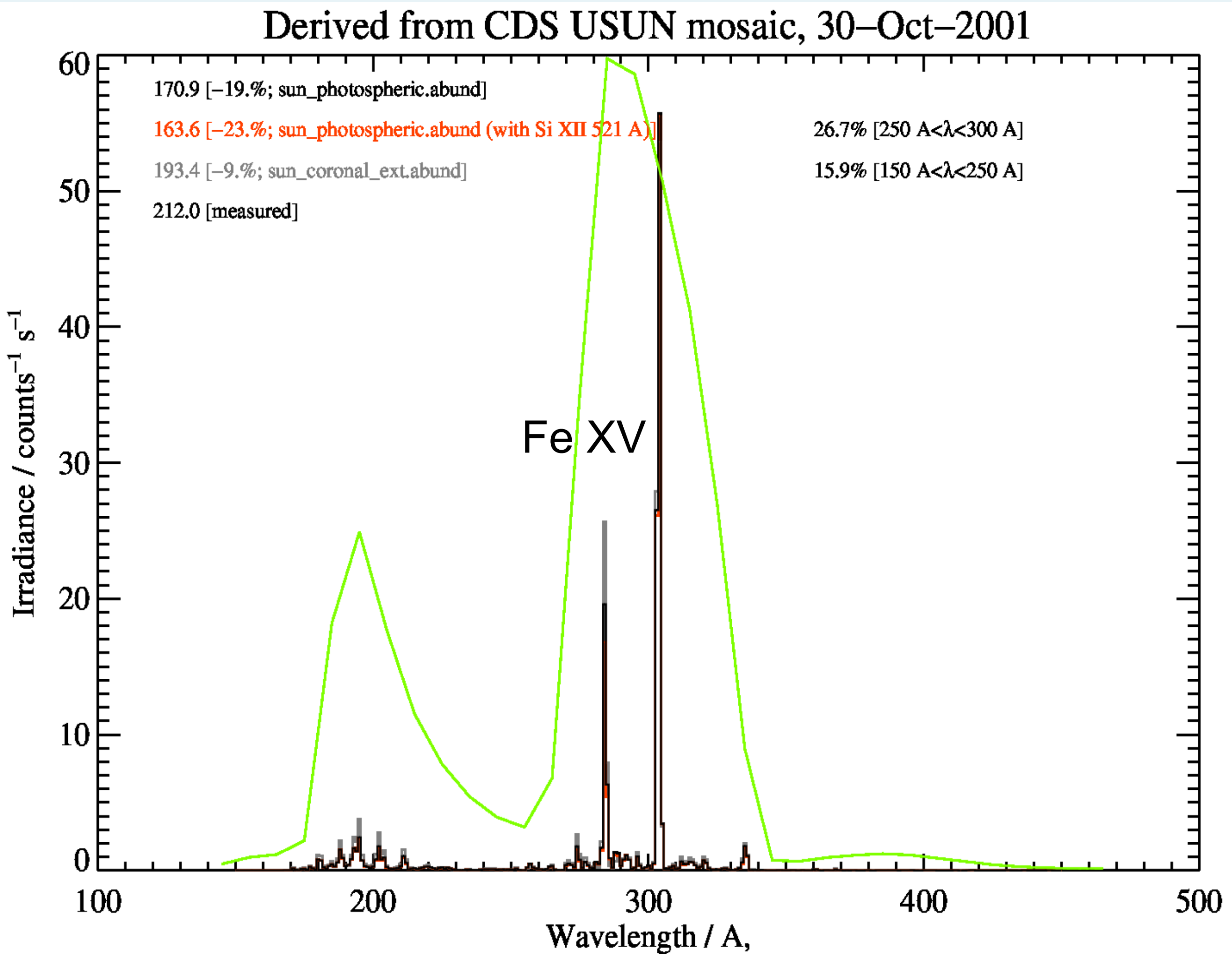
During solar max



Solar Max

The contribution of the He II to the band is typically less than 40%

The contribution of the Fe XV 284 A and Si XI is significant (30% or more) during solar maximum



The problem of varying abundances

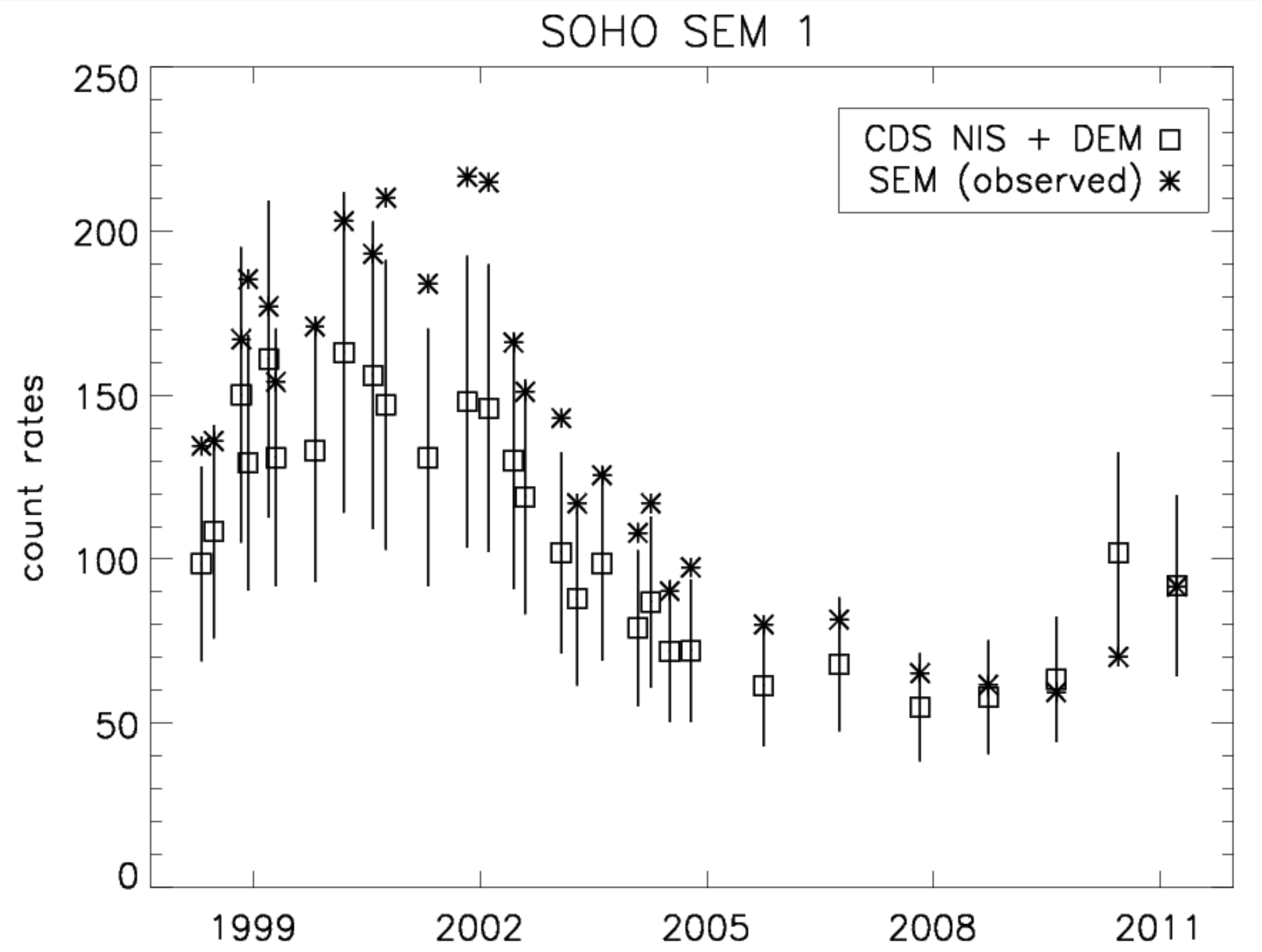
- The QS corona has nearly photospheric abundances.
- Which photospheric ? Asplund+2009 !
- Conflicting results form in-situ SW measurements, but EUV spectroscopy is quite consistent (e.g. PEVE analysis, Del Zanna in prep.).

- AR cores are nearly isothermal (3 MK – log T=6.5) and have enhanced emission from low-FIP elements (Fe, Mg, Si) by ~3 (Del Zanna 2013).

Table 1. Abundance measurements relative to iron (Del Zanna 2013; Del Zanna & Mason 2014)

El.	FIP (eV)	AR core	"Photospheric"	Ratio	
Fe/Ne	7.9/21.5	1.2	0.34 (G), 0.37 (QS), 0.8 (SW)	3.5 (G), 3.2 (QS), 1.5 (SW)	X-ray
Fe/Ar	7.9/15.8	50	7.4 (G) - 33 (SW)	6.8 (G), 1.5 (SW)	EUV
Fe/O	7.9/13.6	0.2	0.065 (A)	3.1	X-ray
Fe/S	7.9/10.4	6.8	2.4 (A)	2.8	EUV
Fe/Si	7.9/8.1	1.0	1.0 (A)	1.0	EUV
Fe/Ni	7.9/7.6	29.5	19.1 (A)	1.5	EUV
Fe/Ca	7.9/6.1	13.5	14.5 (A)	0.93	EUV

Notes. QS: quiet - Sun EUV measurements of neon (Del Zanna, in prep.). SW: fast solar wind observations from Gloecker and Geiss (2007). G: Galactic, for neon, Morel and Butler (2008) from Ne I and Ne II lines in nearby, early B-type stars argon: Lanz et al. (2008), from B main-sequence stars in the Orion association ; A: (Asplund+2009)


SOHO SEM 1
CDS NIS + DEM
SEM (observed)
count rates
250
200
150
100
50
0
1999
2002
2005
2008
2011

Summary-Conclusions

The NIS and SEM were calibrated independently.

The NIS calibration of the He II line was done 'ad-hoc',

but good agreement is found with rocket flights and EVE.

We obtain good agreement during low-activity conditions,
but not during solar max.

Main effect: need to revise the SEM calibration !
Minor effects (10%): Coronal lines under-estimated?

Need to improve simultaneity of observations,

and investigate the effect of 'coronal abundances'.

The structure of the lower atmosphere- TR has not

changed since 1998, nor its abundances.