The calibration of SOHO CDS

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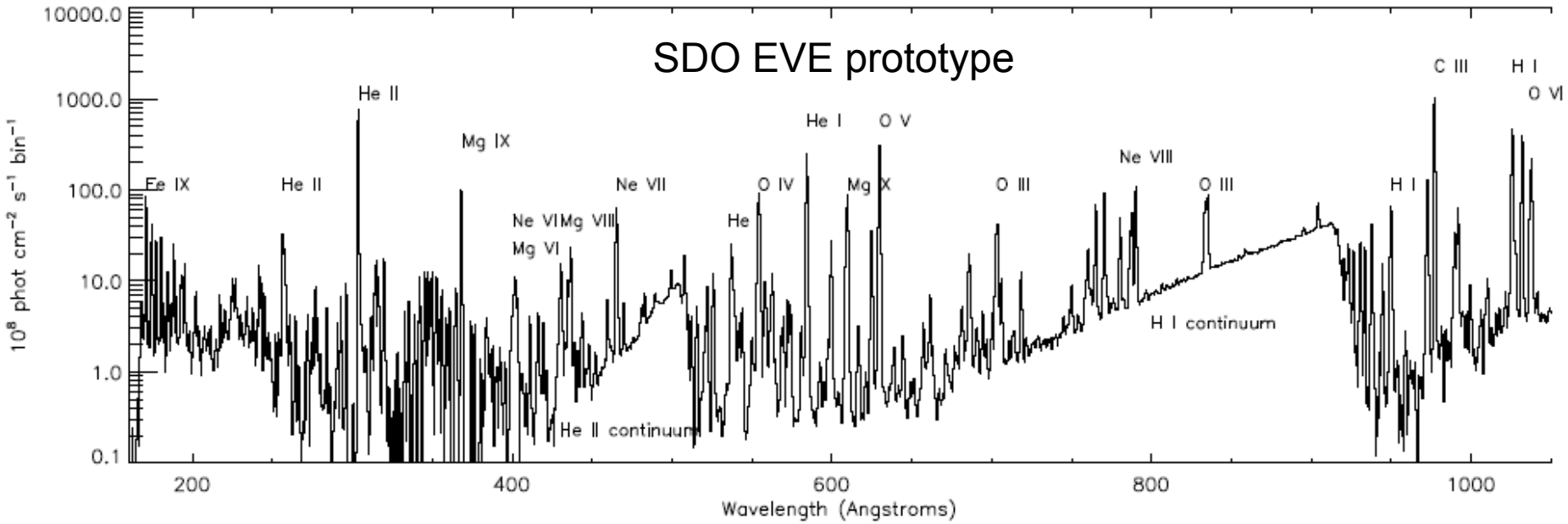
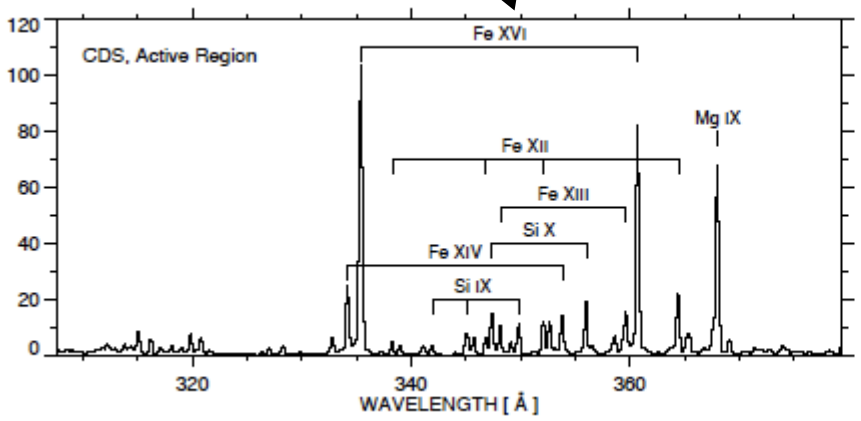
Results from a series of papers:

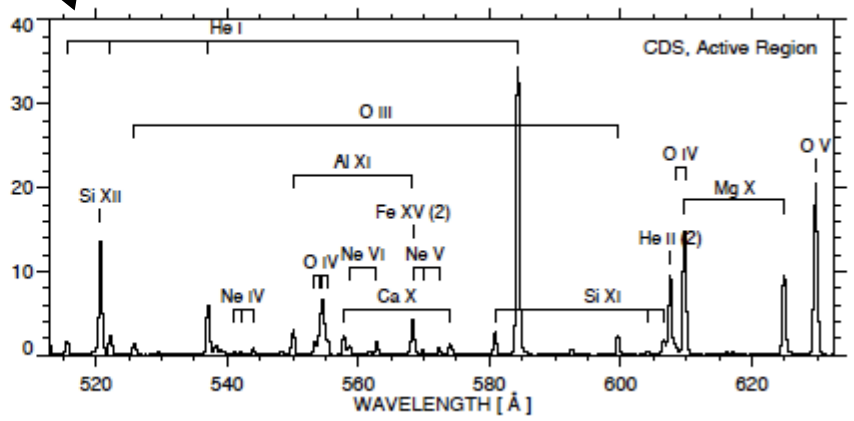
Del Zanna et al. (2001), A&A, 379, 708-734
Del Zanna et al. (2005) Mem. Sait., 76, 953
Del Zanna & Andretta (2006), ESA-SP 617
Del Zanna & Andretta (2010), proc. IAU symp., no. 264, 78.
Del Zanna et al. 2010, A&A, 518, A49
Del Zanna & Andretta,2011, A&A, 528, A139

SDO EVE and SOHO CDS NIS

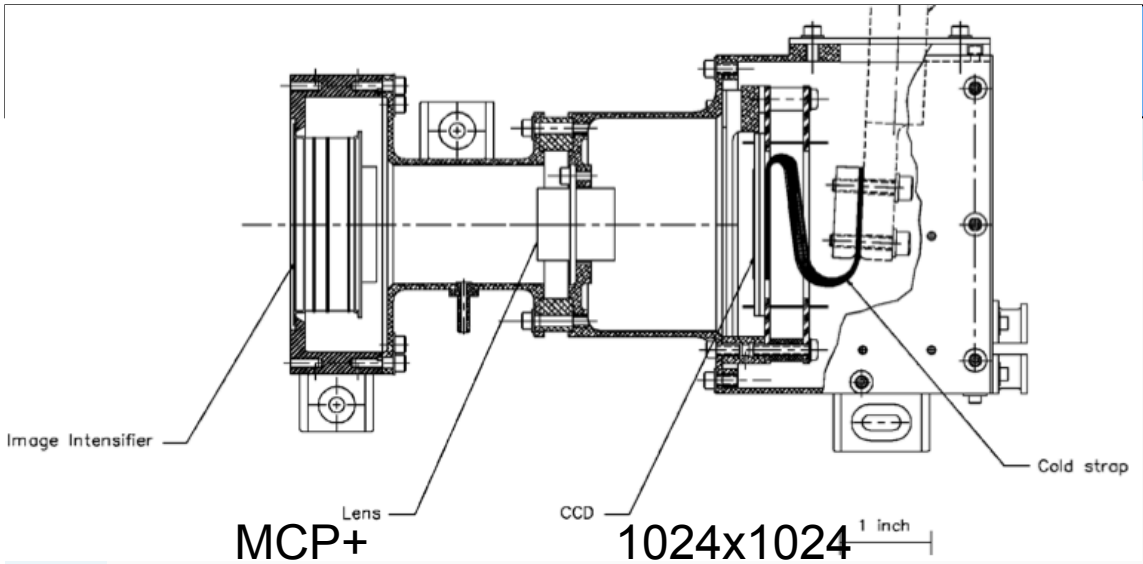


SOHO CDS NIS – launched 1995 – operational in 2012





SOHO CDS



MCP+ phosphorus plate

1024x1024 CCD (visible)

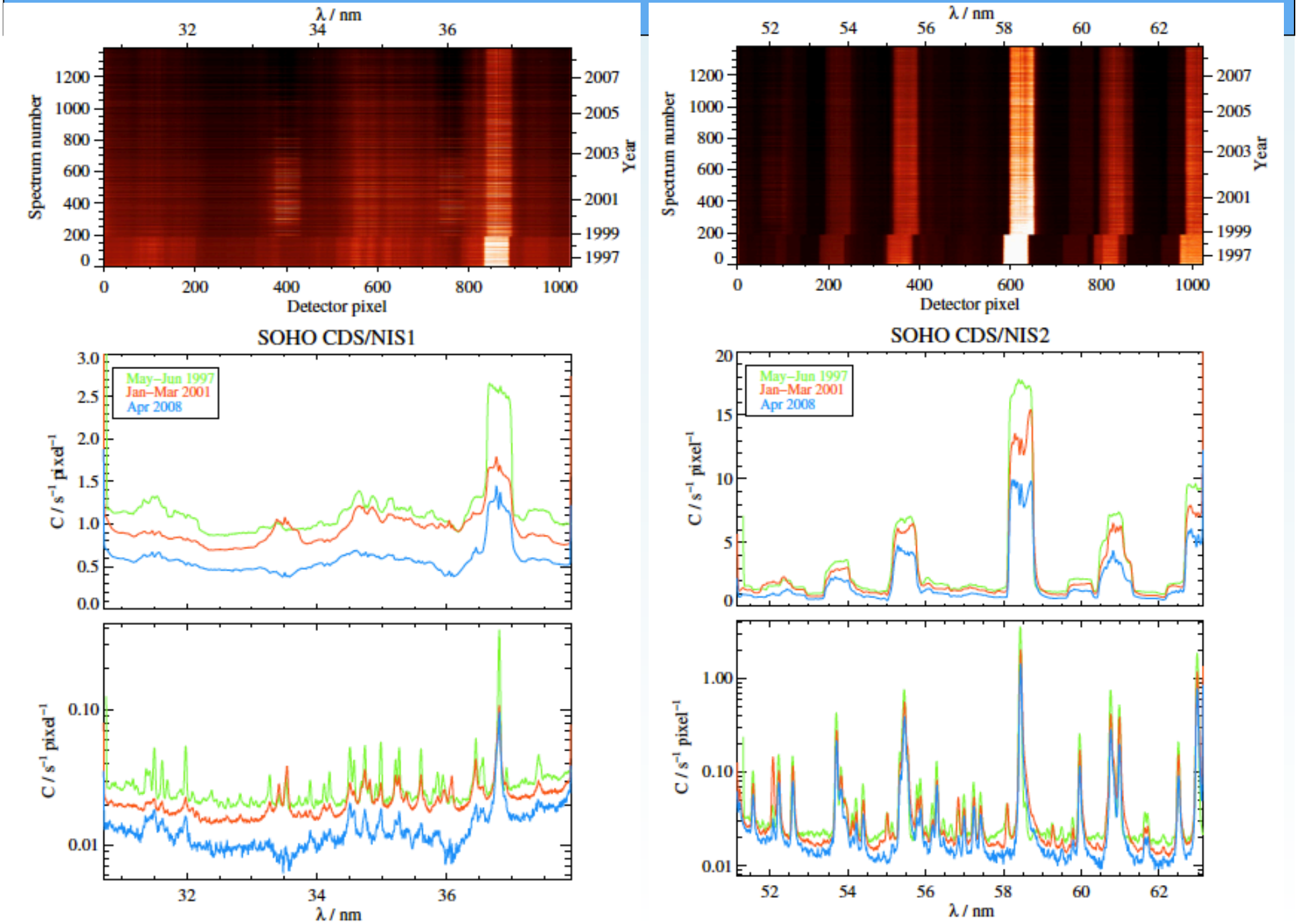
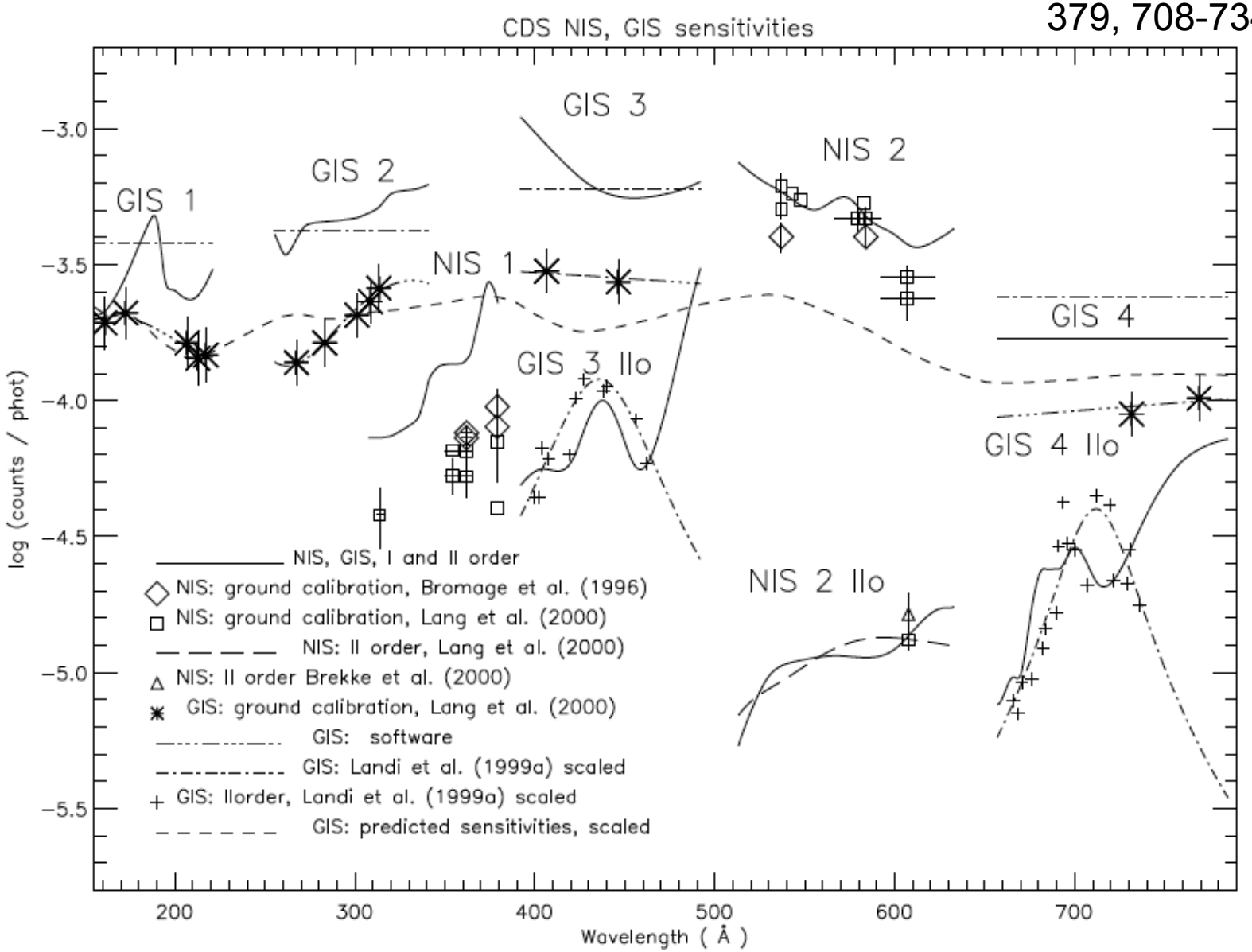


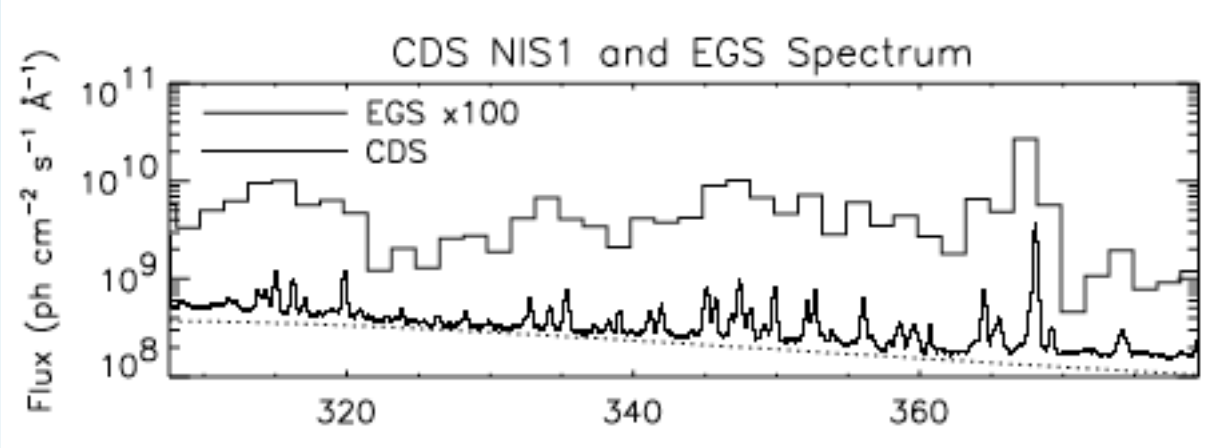
Fig. 2. As Fig. 1, but for the NIS 1 channel.

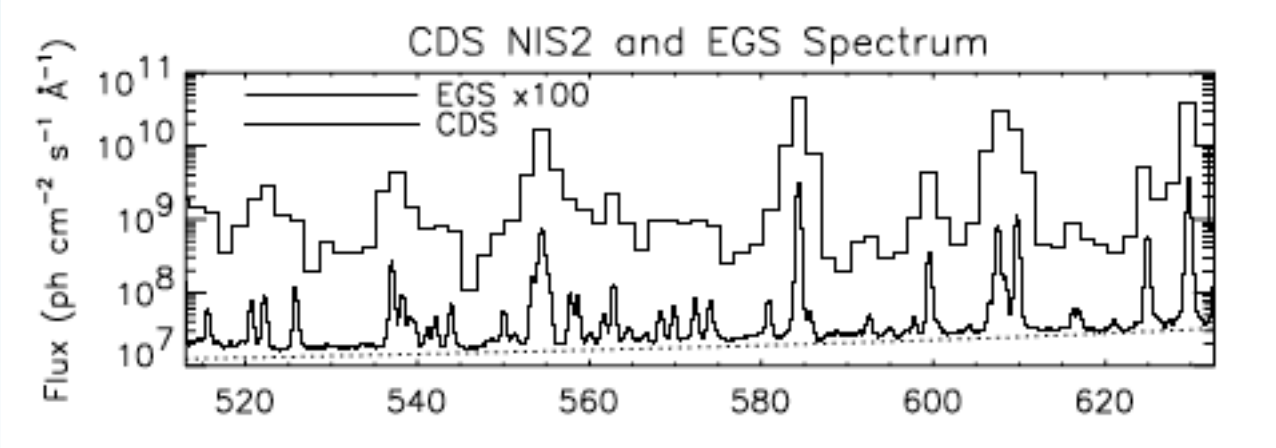
Ground CDS calibration incorrect

Only in-flight calibration of all channels

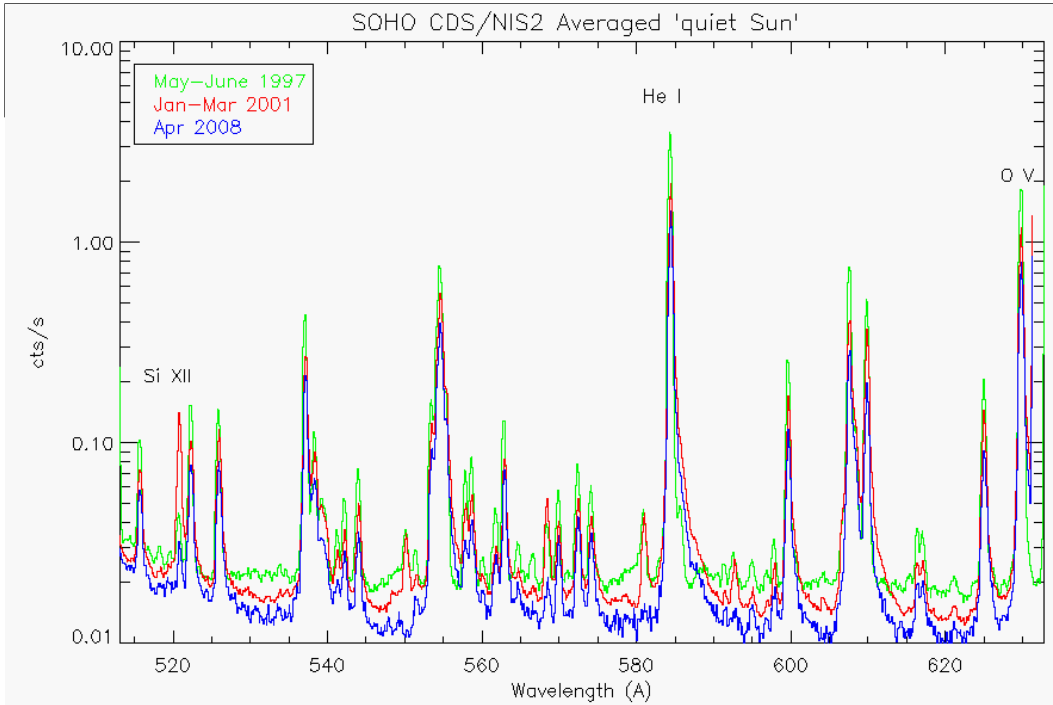
Del Zanna et al. (2001), A&A, 379, 708-734

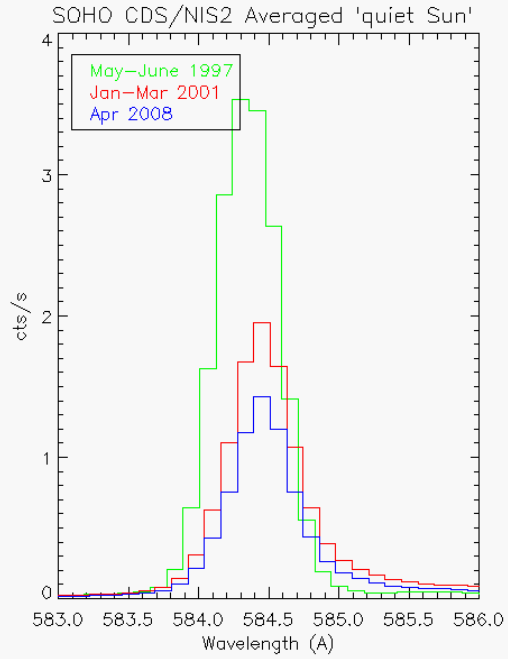


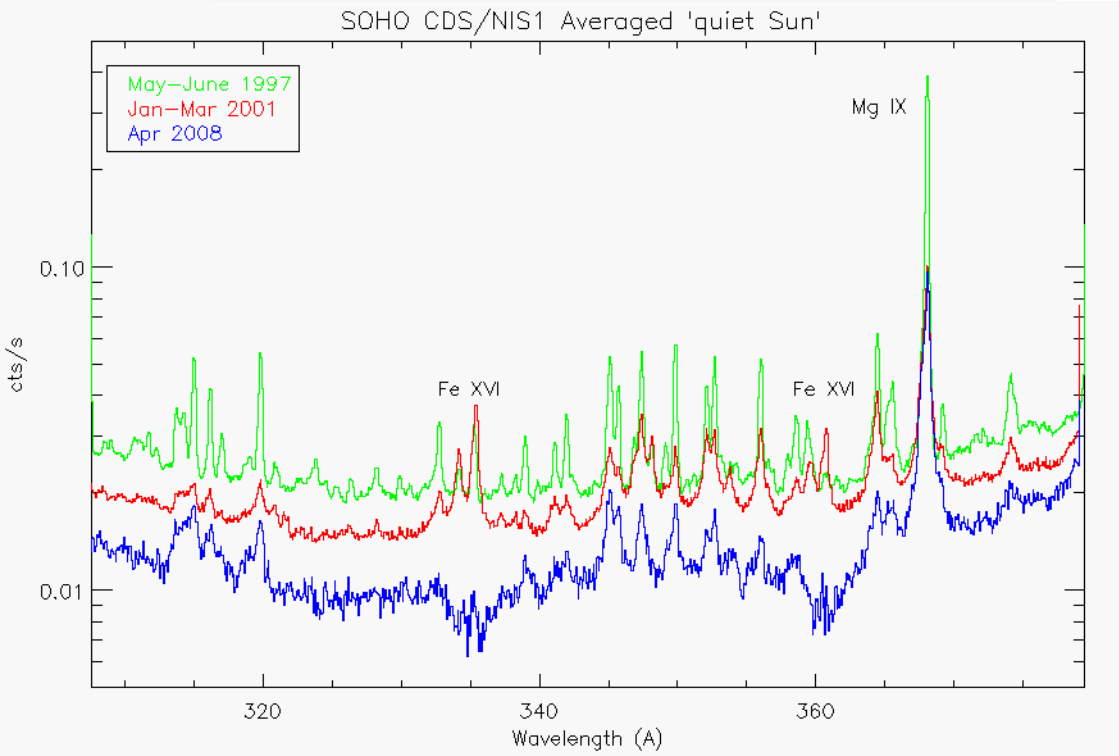


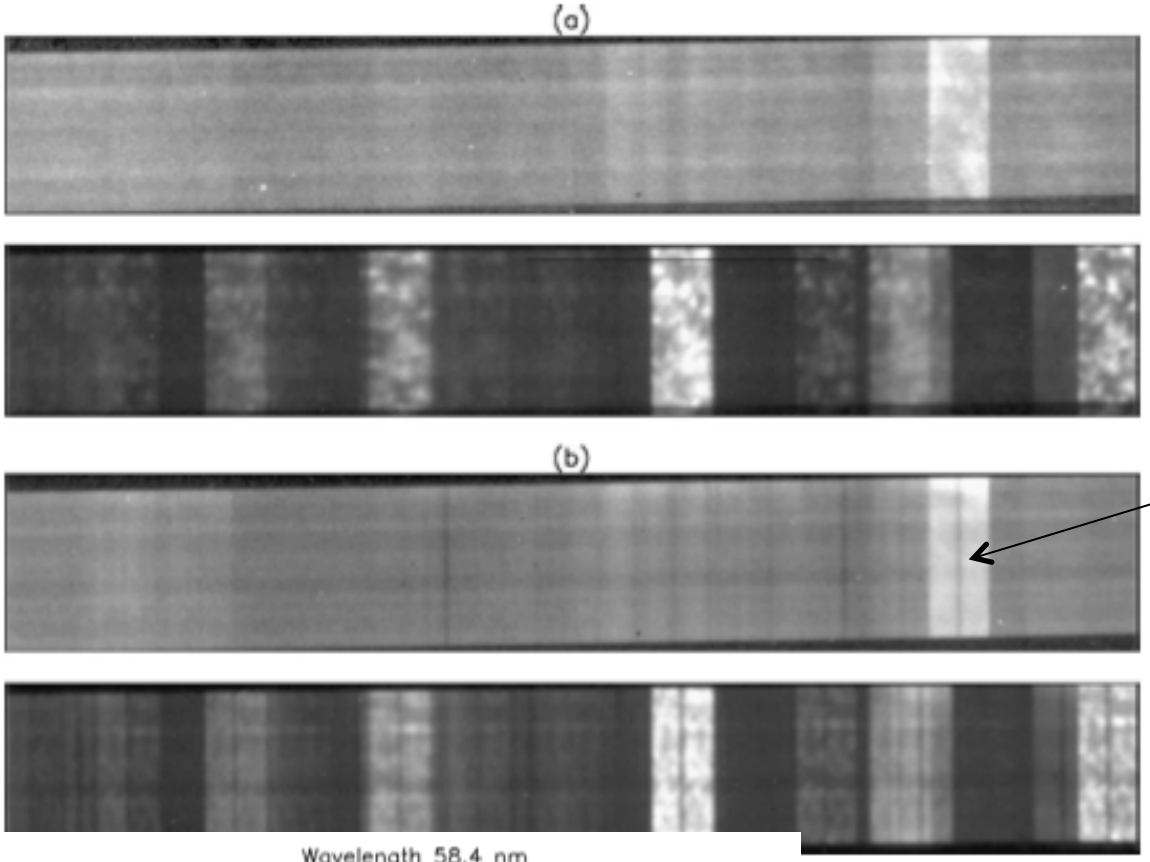


May 1997 rocket EGS (Brekke et al. 2000)


SOHO CDS/NIS2 Averaged 'quiet Sun'
May–June 1997
Jan–Mar 2001
Apr 2008
He I
O V
Si XII
cts/s
Wavelength (A)


SOHO CDS/NIS2 Averaged 'quiet Sun'
May–June 1997
Jan–Mar 2001
Apr 2008
cts/s
Wavelength (A)

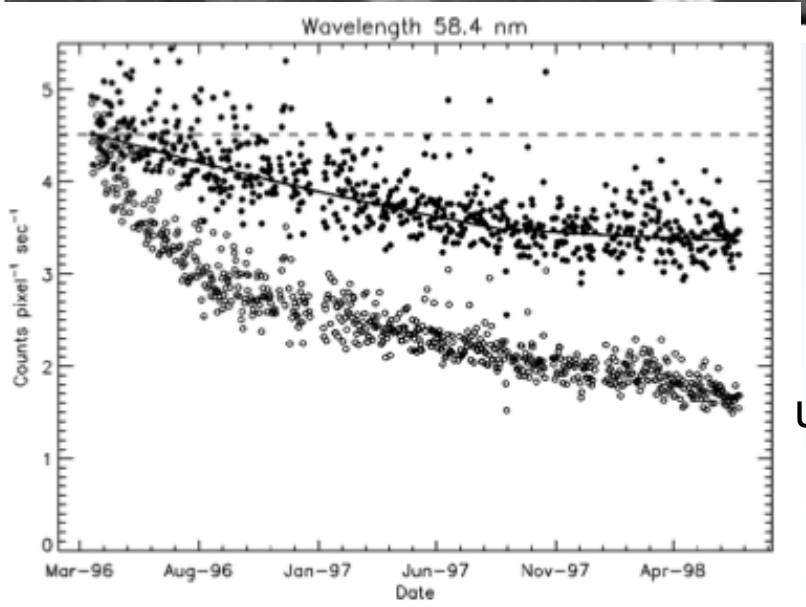

SOHO CDS/NIS1 Averaged 'quiet Sun'
May–June 1997
Jan–Mar 2001
Apr 2008
Mg IX
Fe XVI
Fe XVI
cts/s
Wavelength (A)



1996

Burn-in

1998

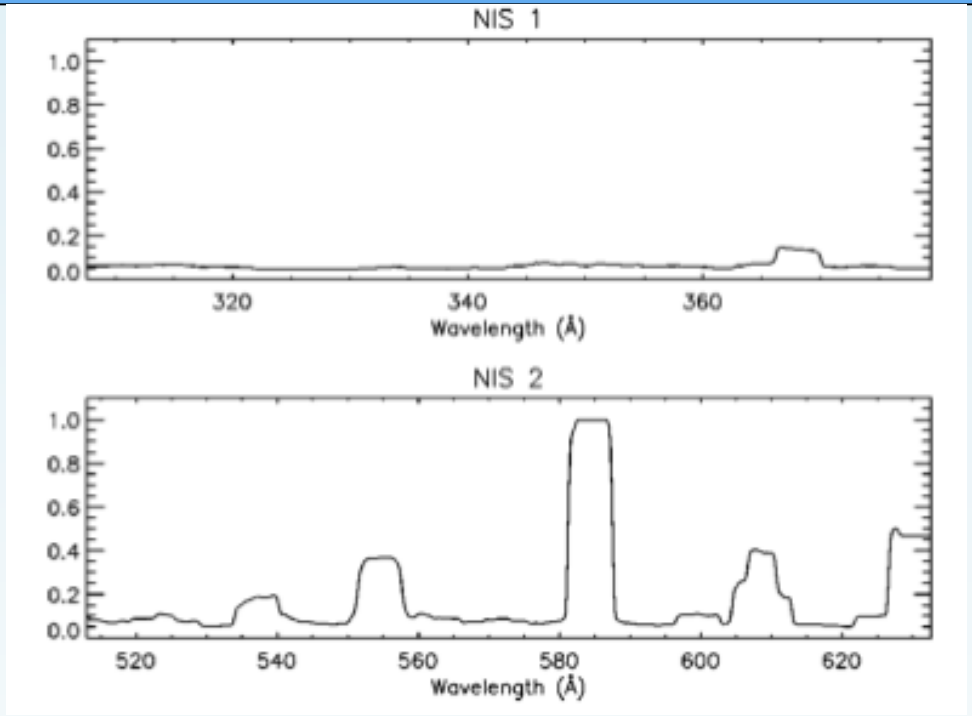


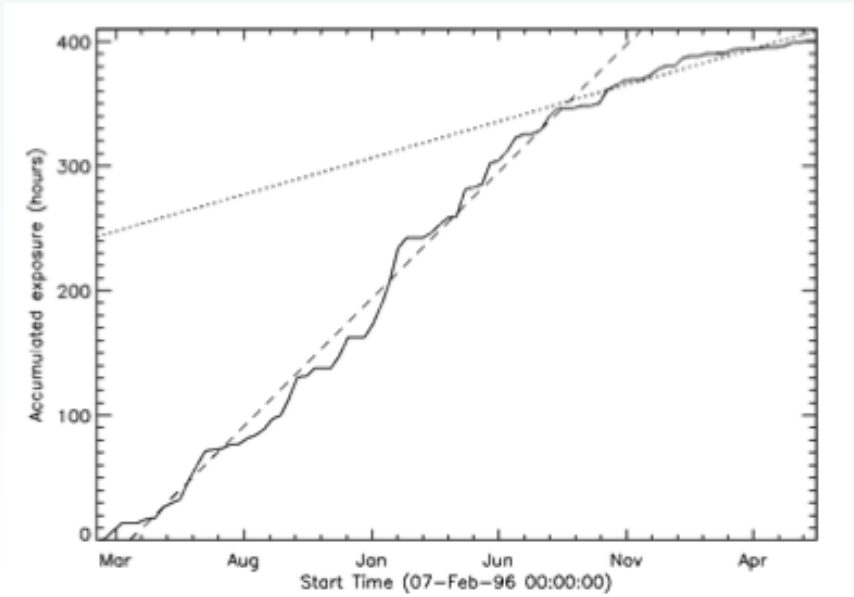
corrected

uncorrected

The correction to the use of the narrow slit is fairly straightforward and obtained from 90” slit data (Thompson 2000).

Calibration of the long-term gain depression (LTGD) in NIS

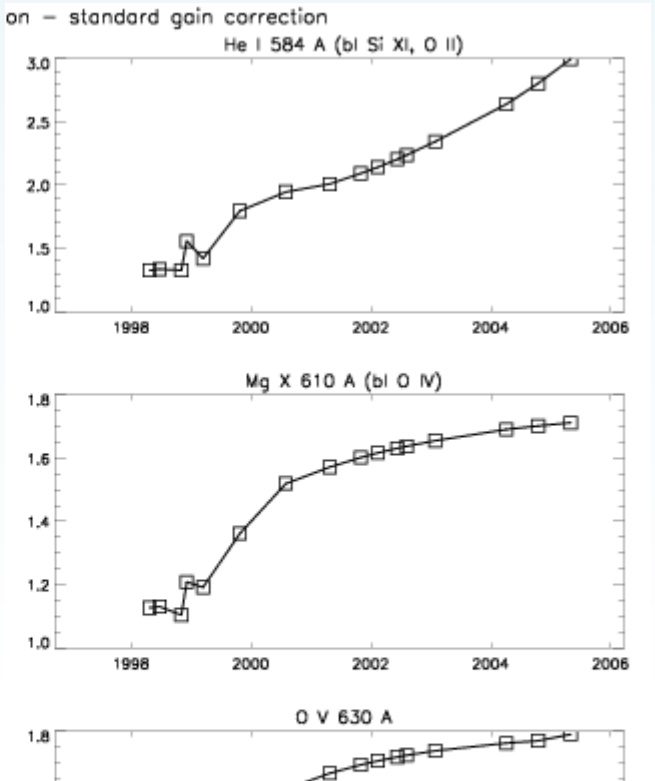




'standard correction'
(Thompson 2000):

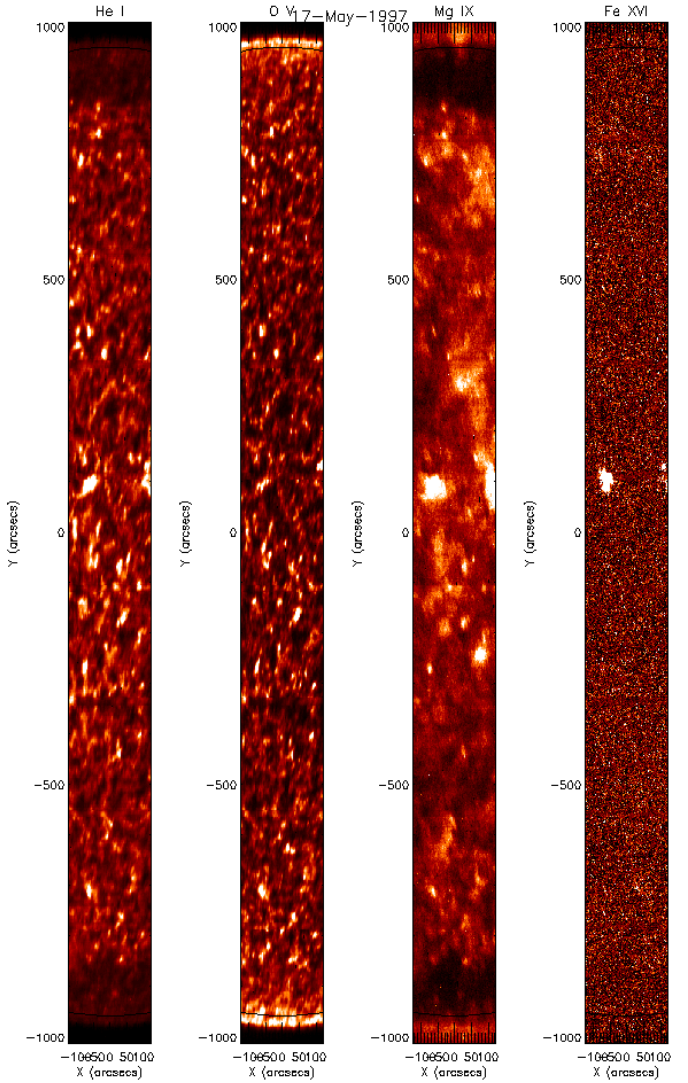
1) Due to the use of the 90"slit
2) Assume a standard QS spectrum
3) Estimate from the total exposure

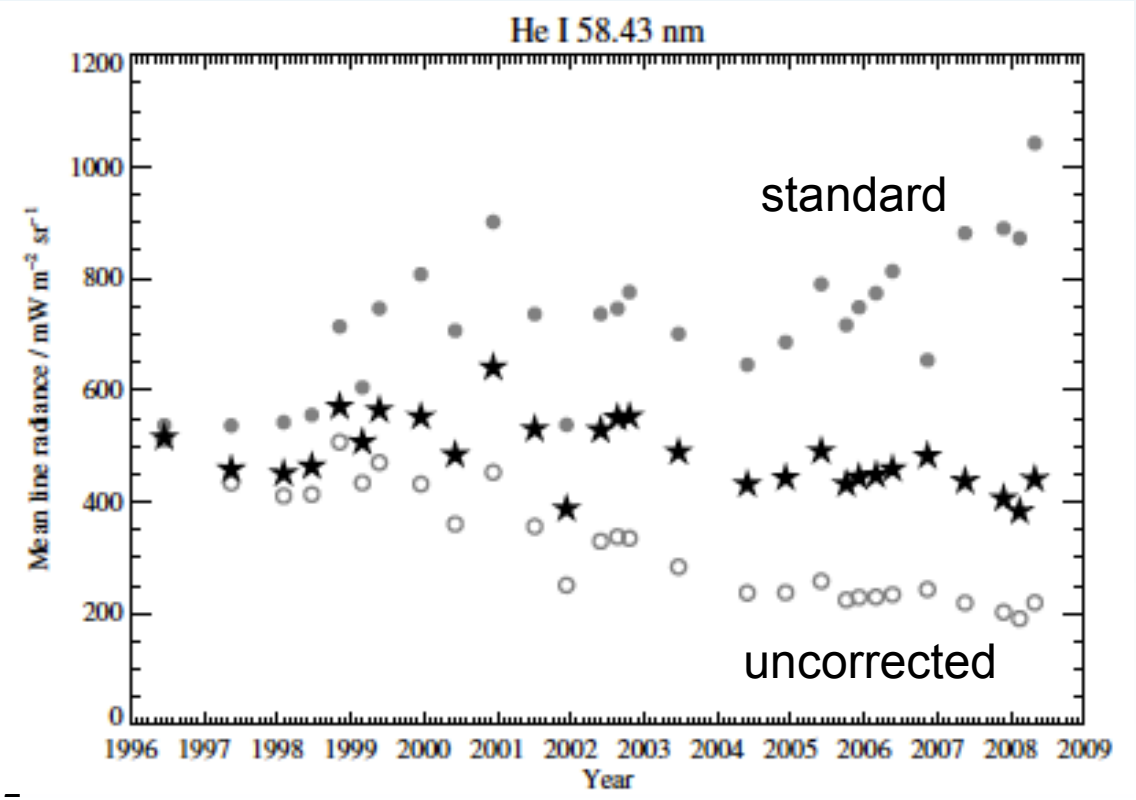
Turned out to be incorrect (factor 2-3)



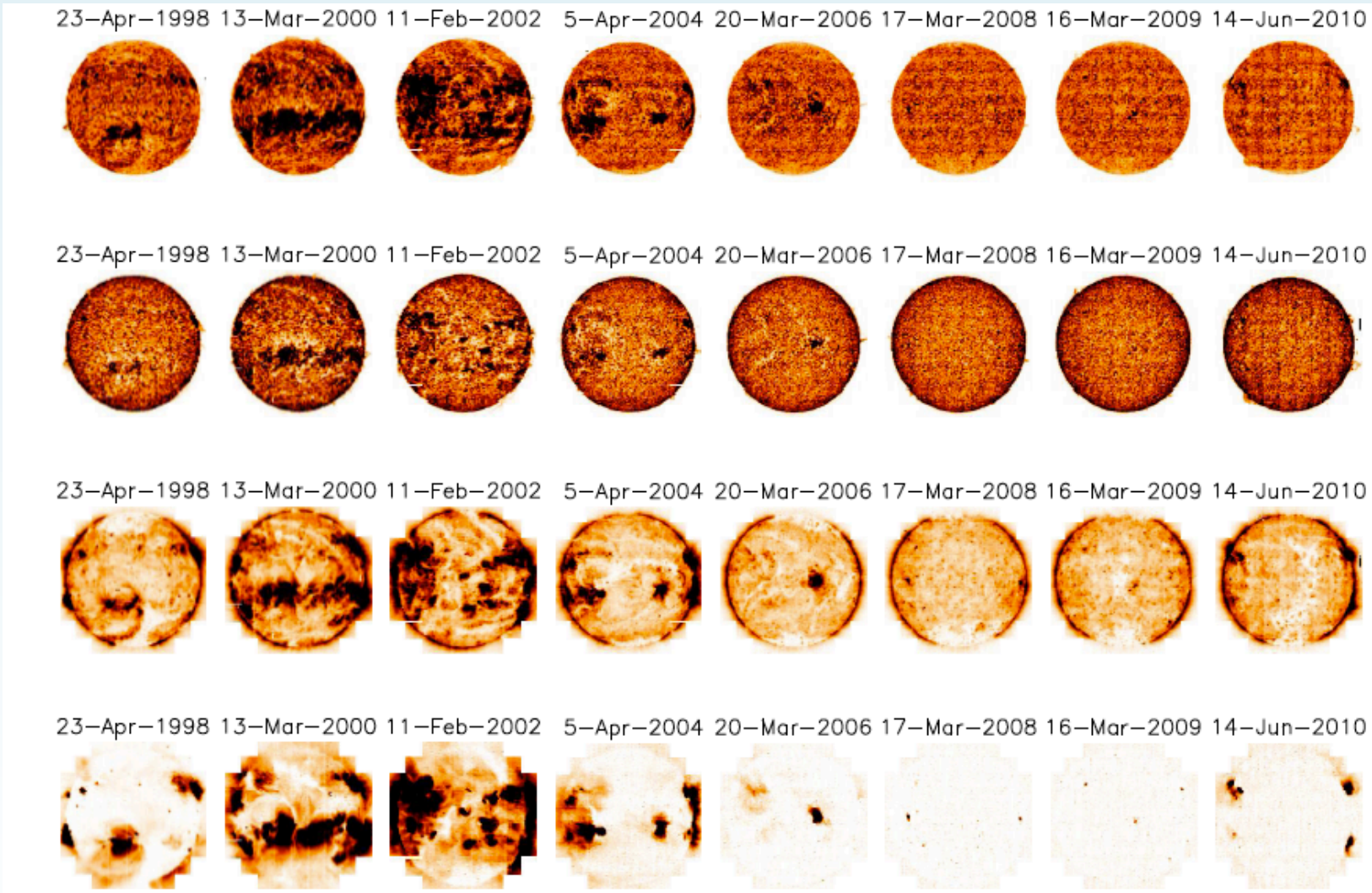
Synoptic

We have analysed a sample of the 13 years of NIS synoptic observations to study the radiance distributions. He I radiances over-estimated by a factor of 3 by 2010





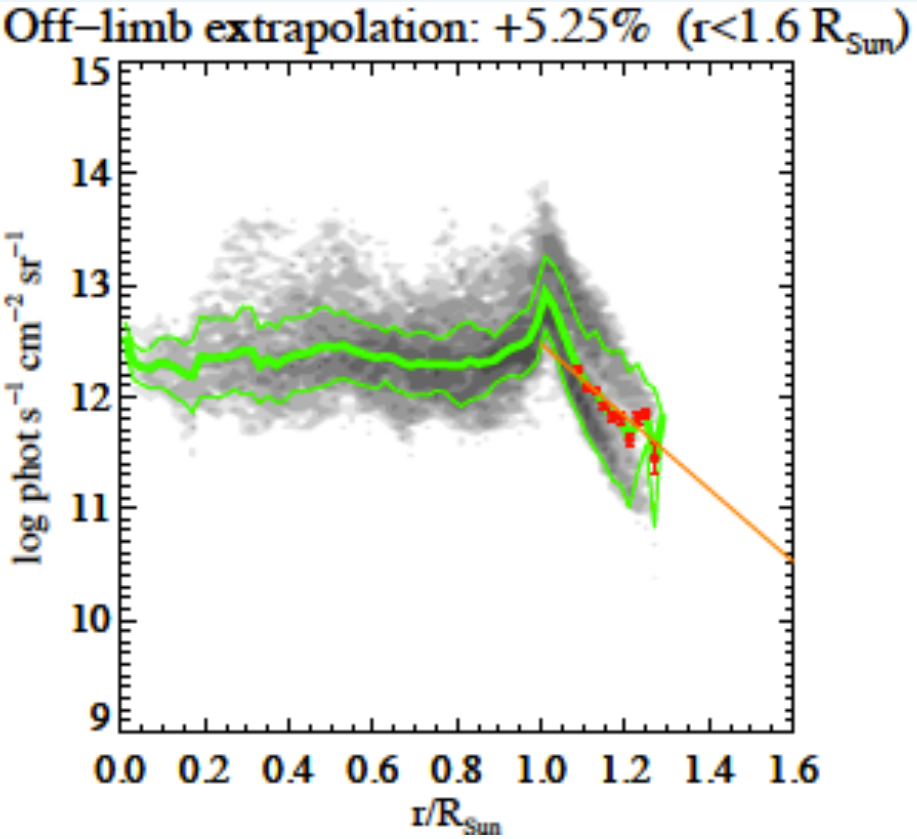
SOHO CDS NIS USUN: first EUV radiances along a cycle

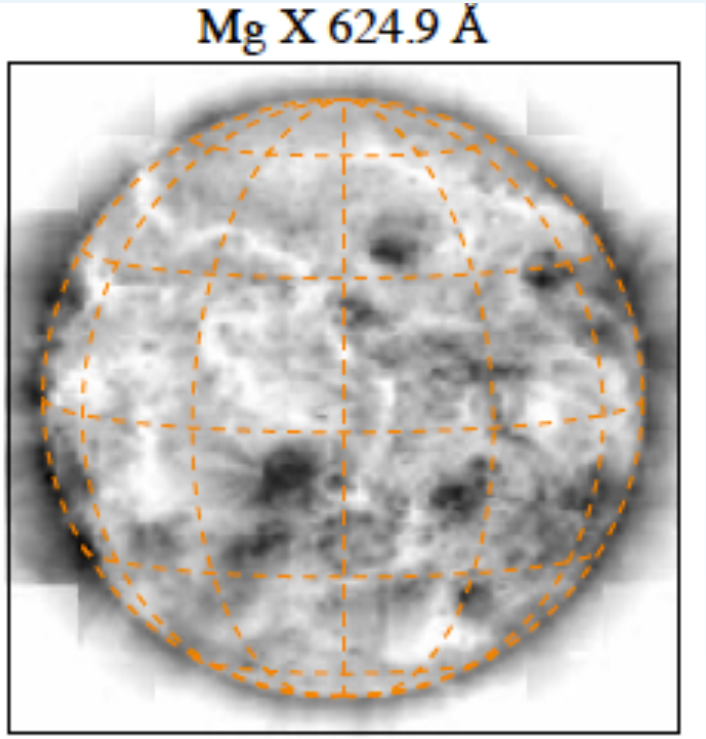


Obtaining irradiances from radiances

First, we interpolate the radiances (CDS subsamples the Sun by a factor of 4—6)

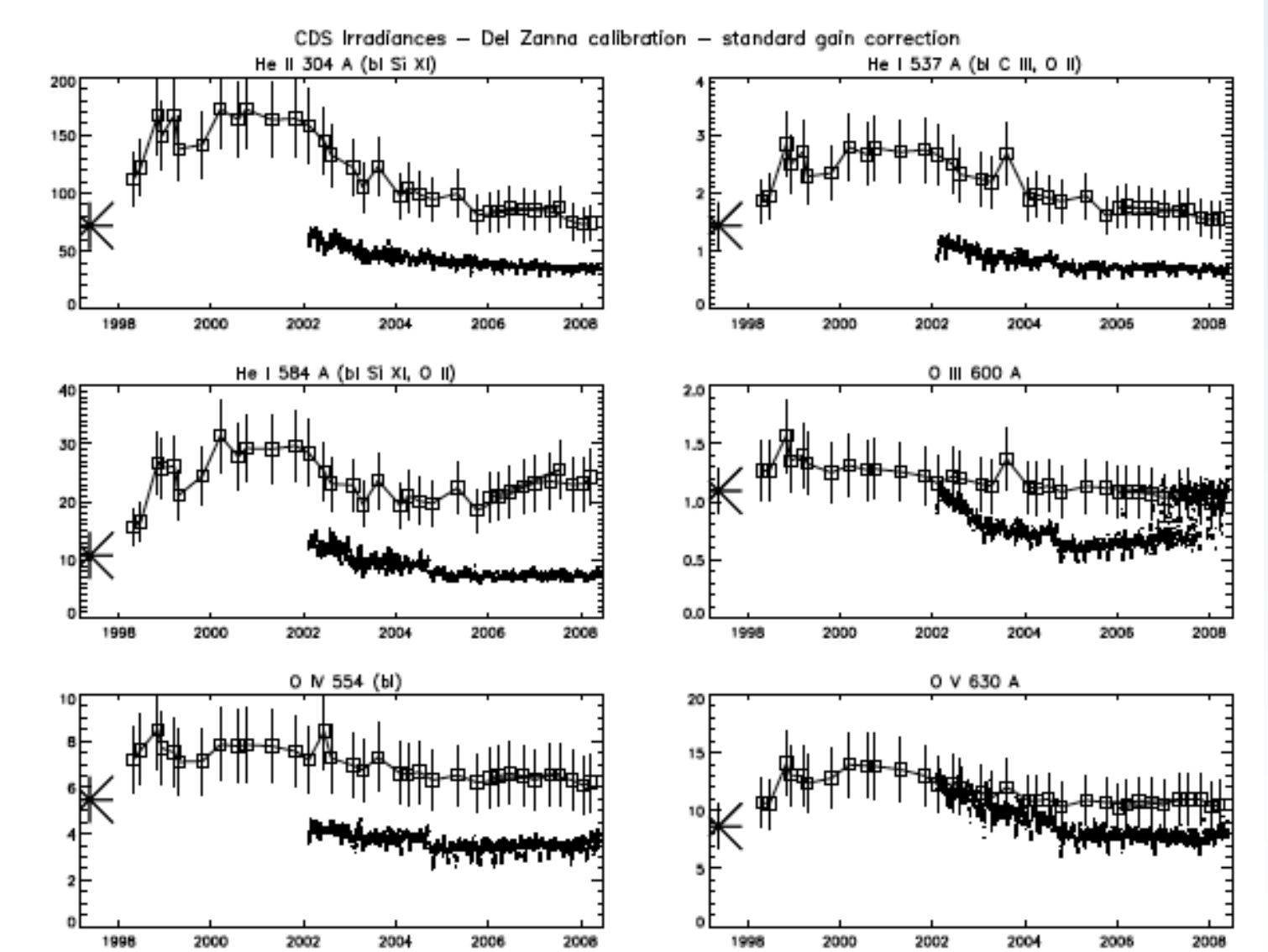
The radiances of the observed Sun are totalled, and an estimated contribution from the not observed off-limb corona is added. Typically, for coronal lines, this addition is just a few percent.





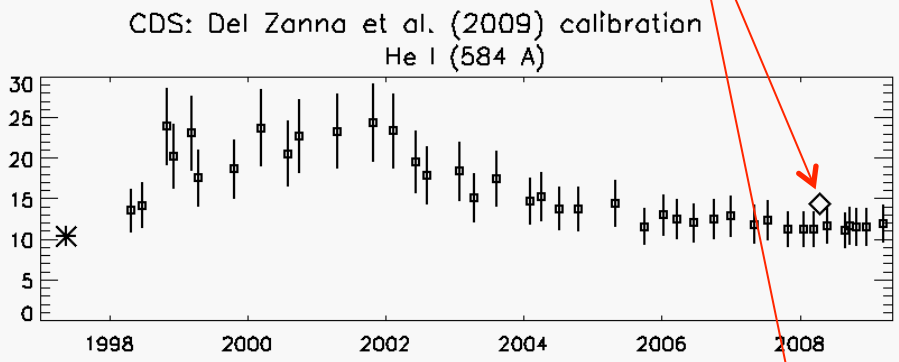
CDS vs. TIMED/SEE EGS - Aug 2008

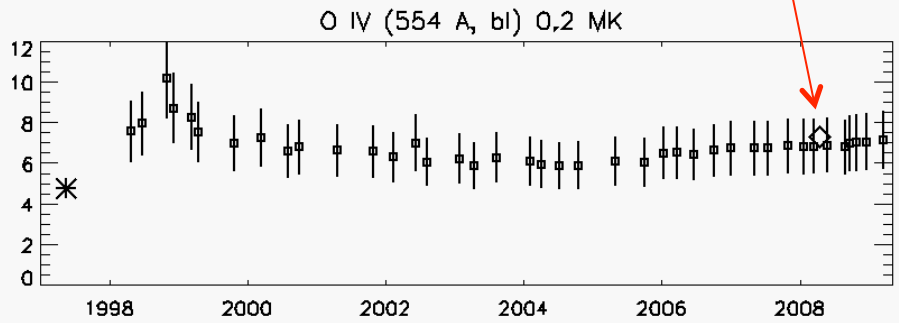
It took 5 years of comparisons (+1 for the referee), starting in 2005…

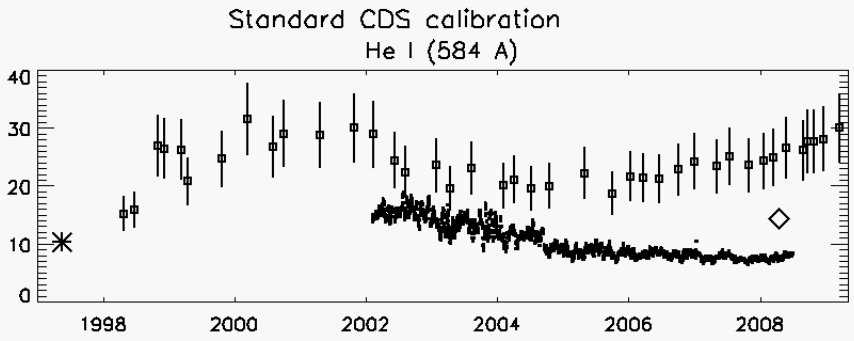


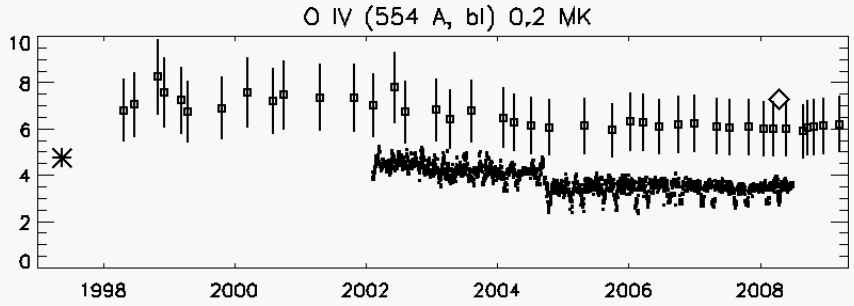
SOHO NIS irradiances vs. EVE prototype

SDO/EVE



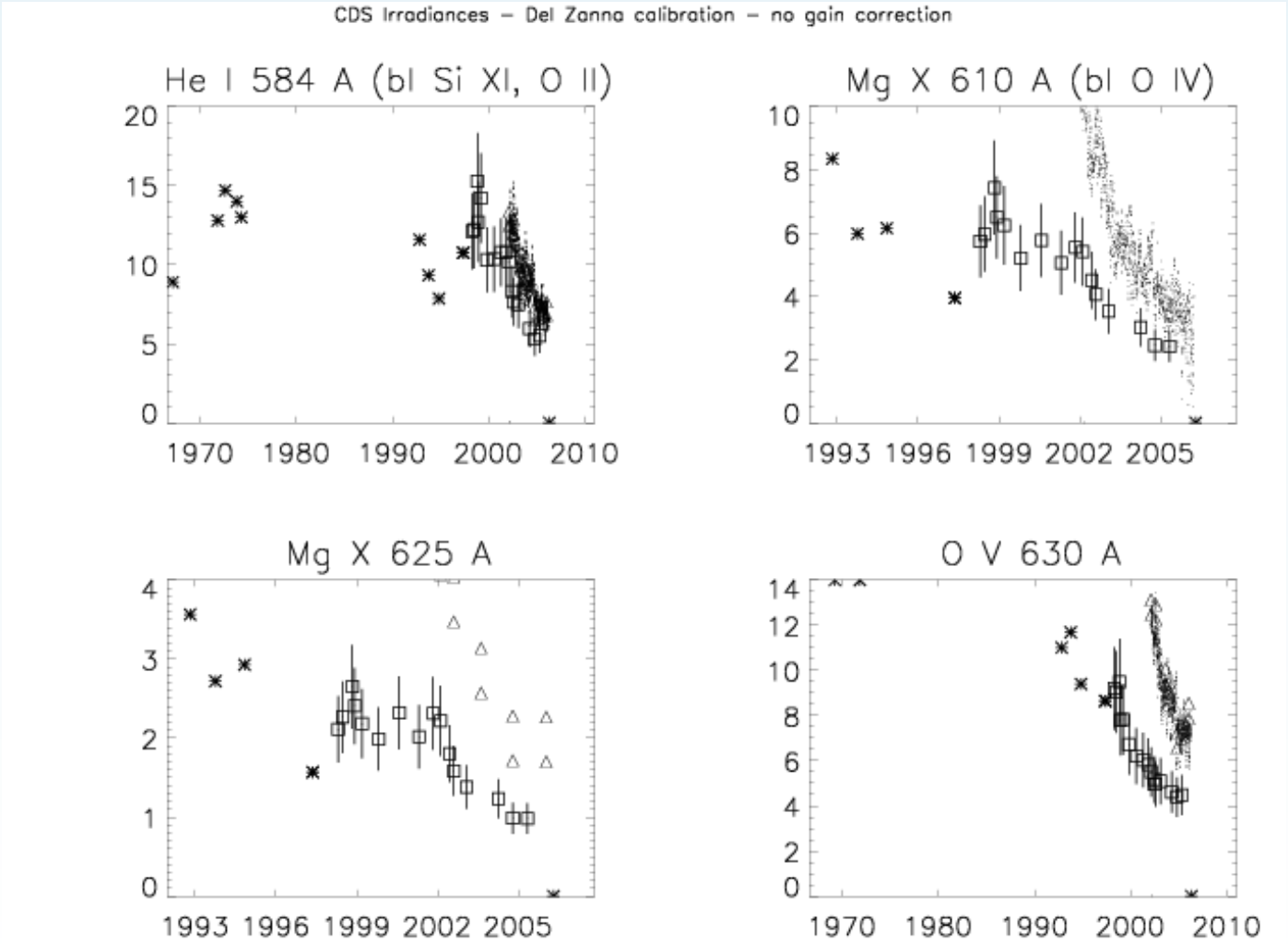






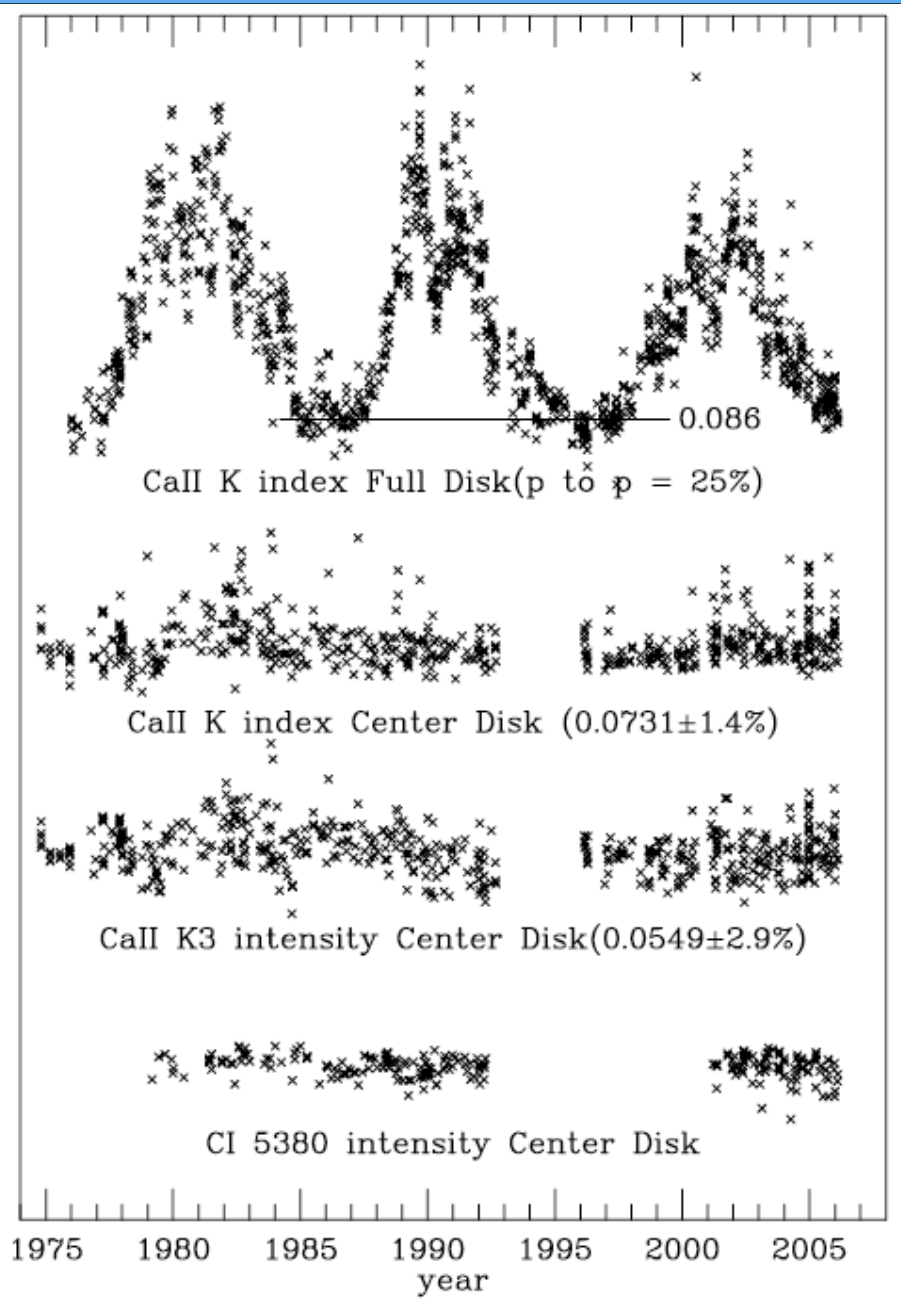
We have compared the TIMED/EGS measurements (dots), that have been absolutely calibrated between Feb 2002 and Oct 200, taking into account the lower EGS resolution.

We compared the NIS EUV irradiances to earlier measurements (e.g. Hall 1970, Chapman & Neupert 1974, Heroux et al. 1974, Woods et al. 1998), but did not help.



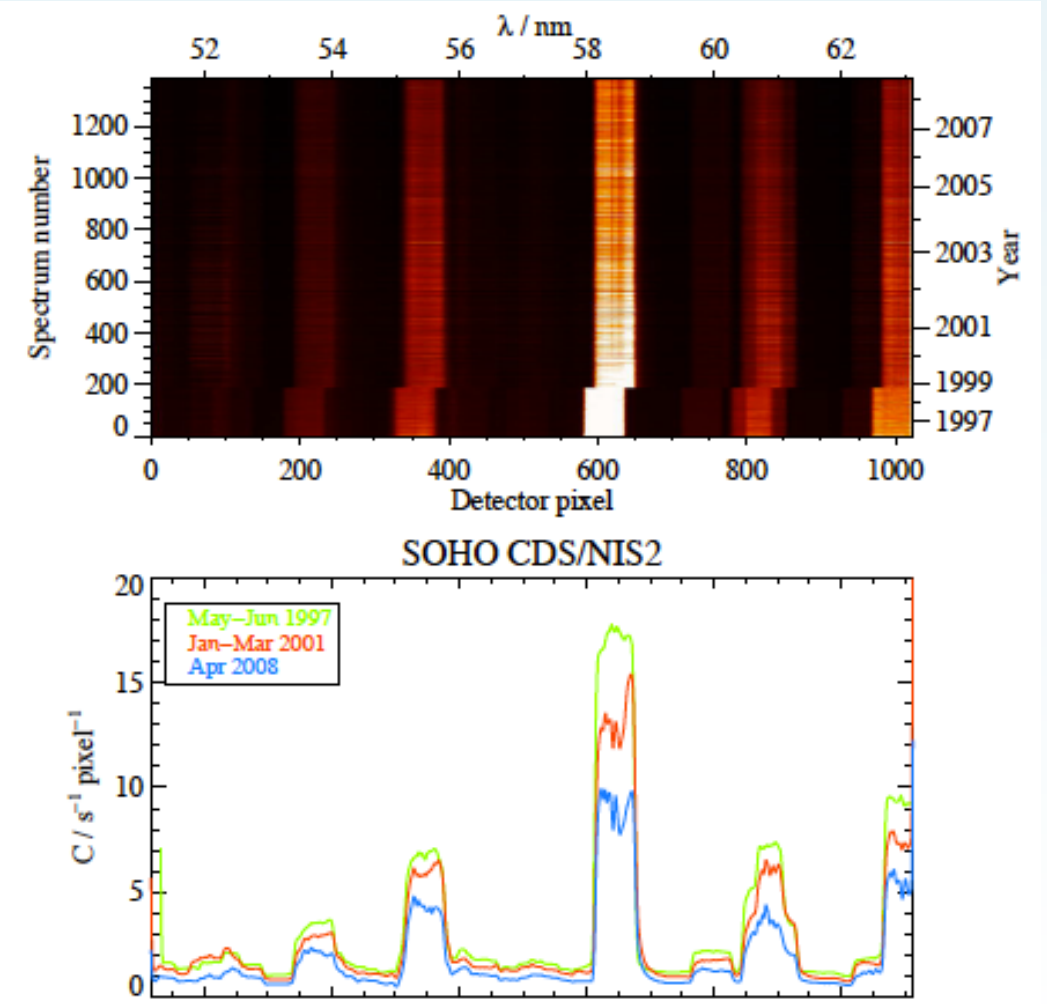
Using the quiet Sun as a standard candle!

There are no obvious long-term variations of the 'quiet Sun' at chromospheric levels (Livingston et al. 2007)

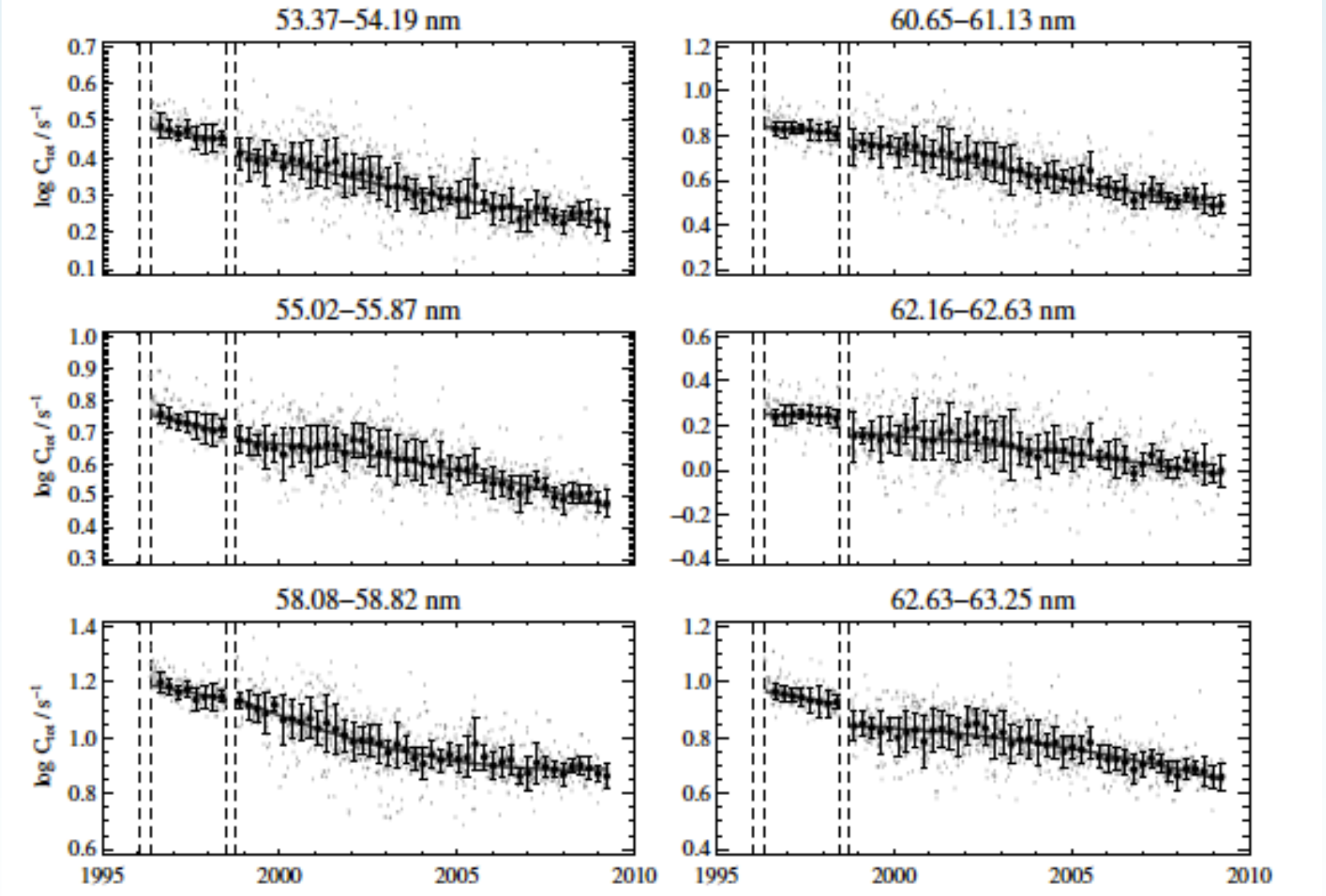


A new method

The new corrections have been found studying the behaviour of quiet Sun regions as observed routinely with the wide 90” slit (NIMCP monitoring) during 1996—2010 and assuming radiances do not change.

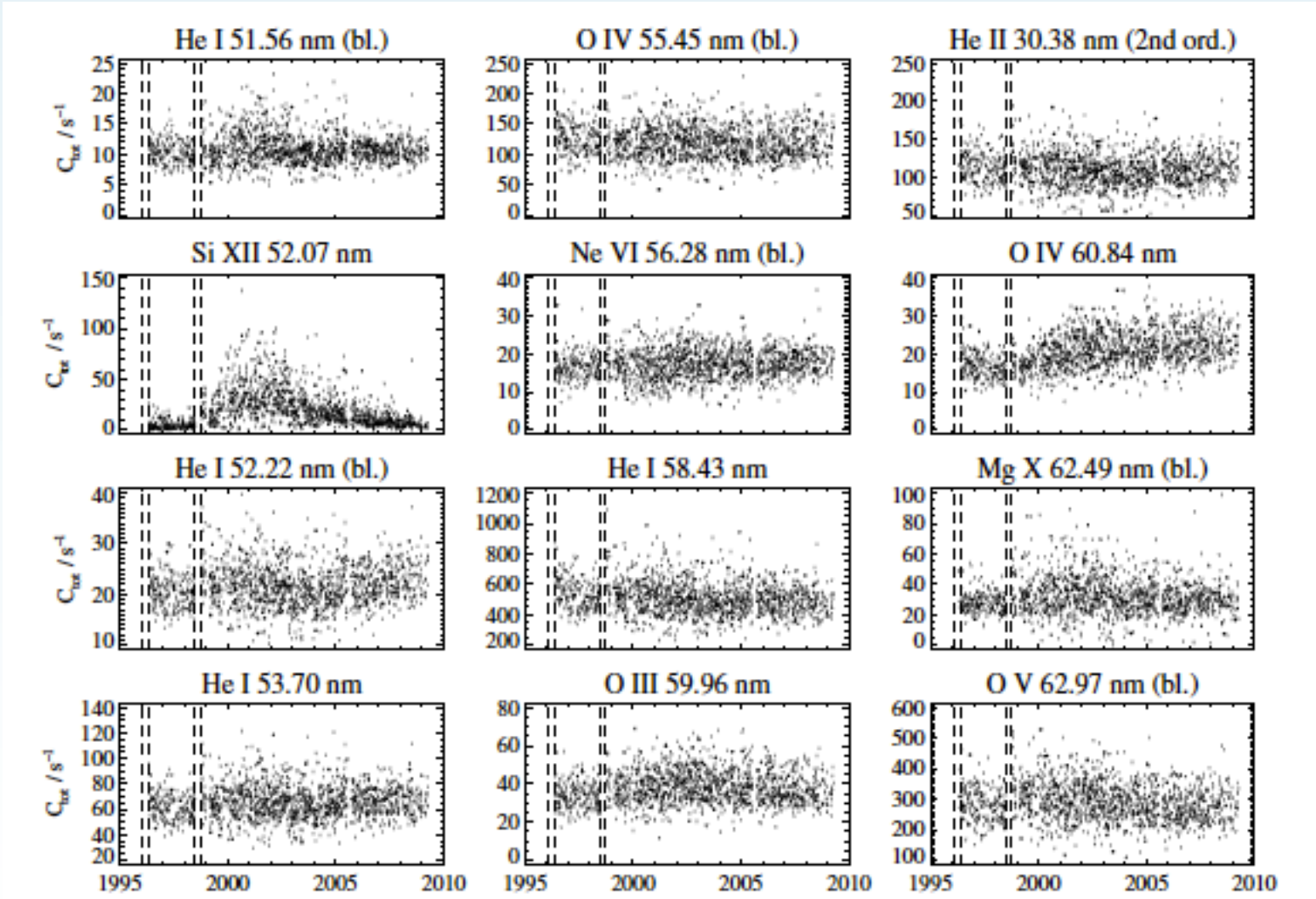


Count rates in QS with 90” slit



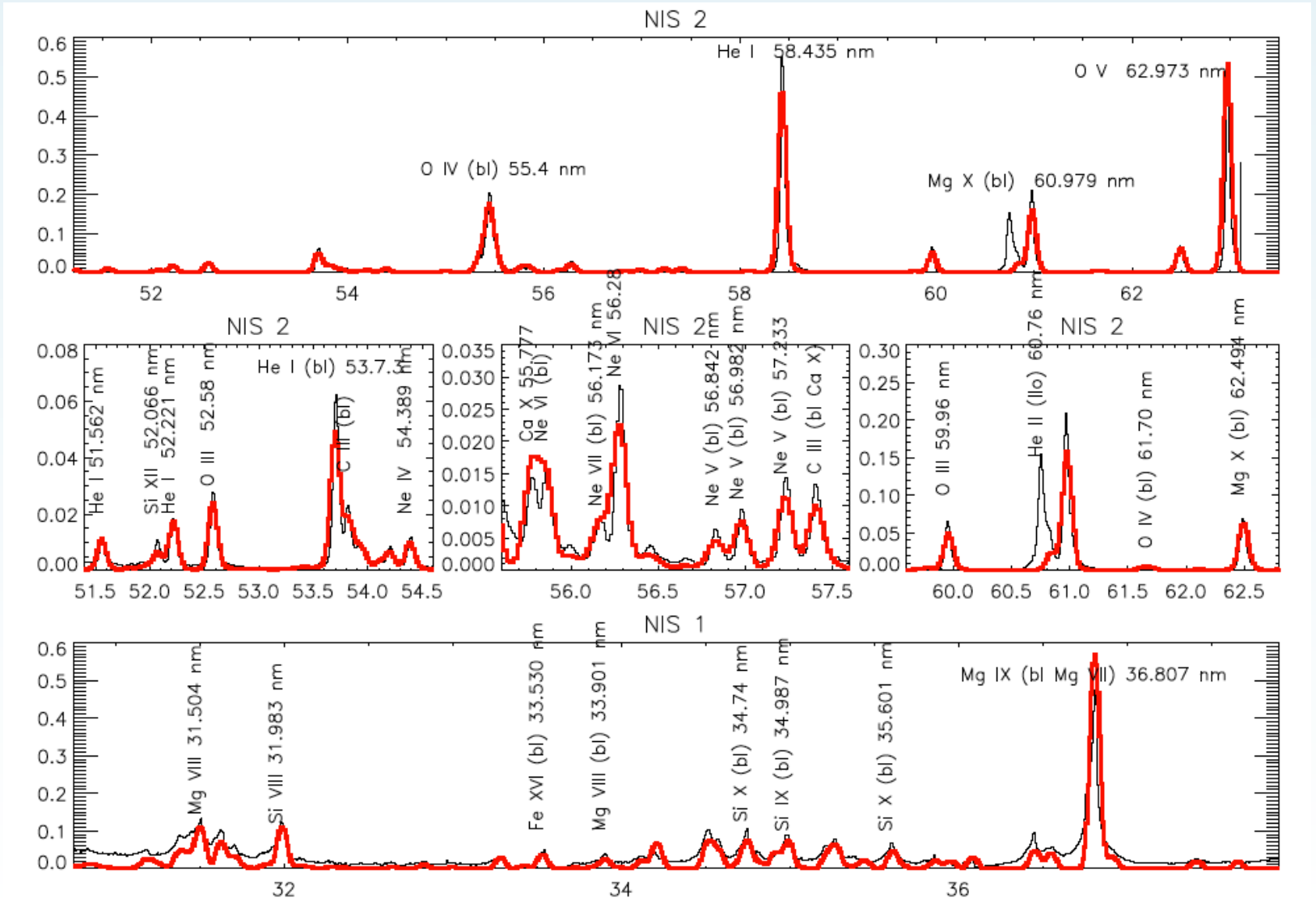
Count rates in QS with 2” slit

After the new LTGD correction

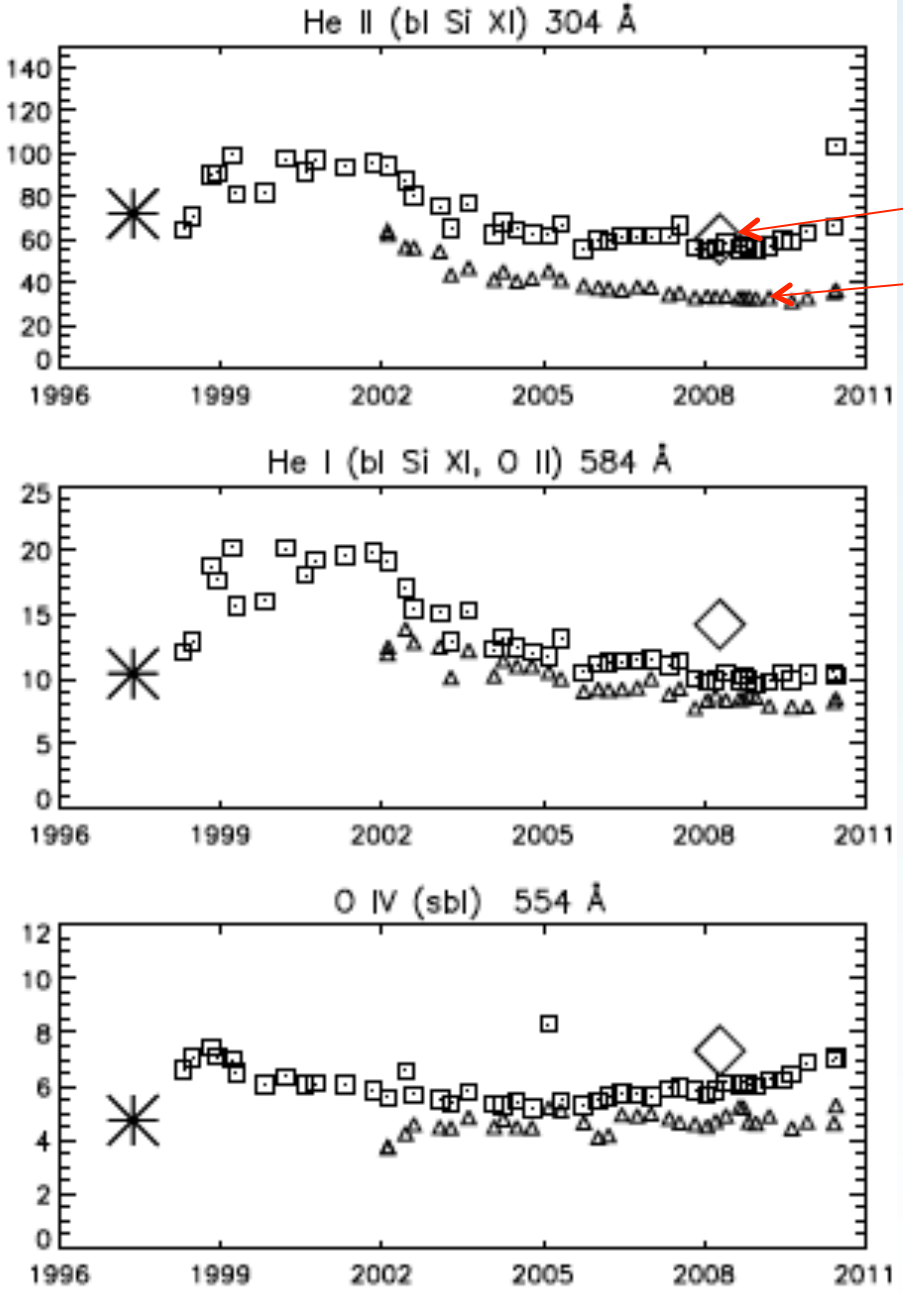


NIS vs. SDO PEVE

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



SOHO NIS irradiances vs. EVE and TIMED/EGS



Boxes:CDS NIS

SDO/EVE prototype

TIMED/EGS

Overall good agreement !

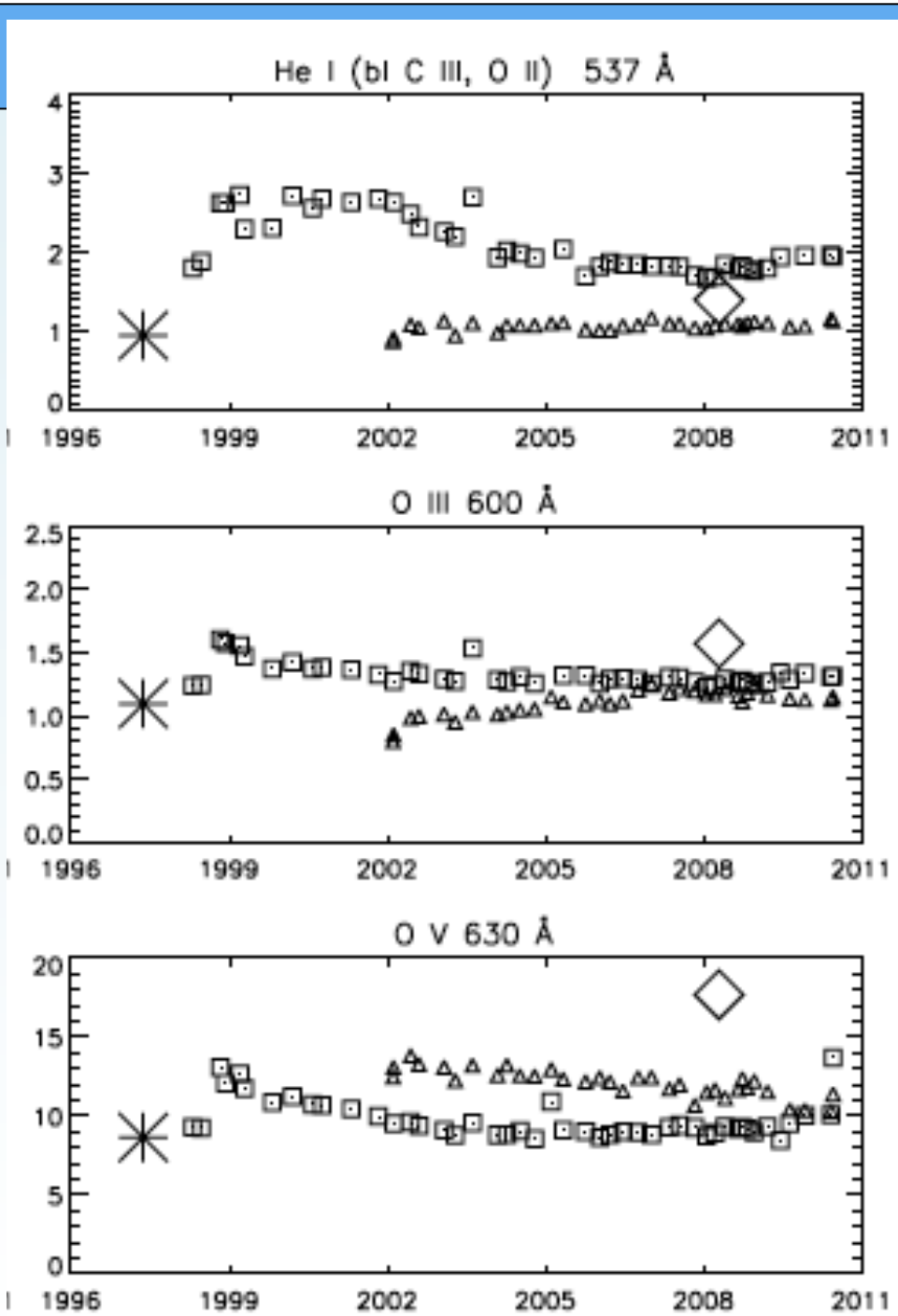
`Chromospheric' helium lines

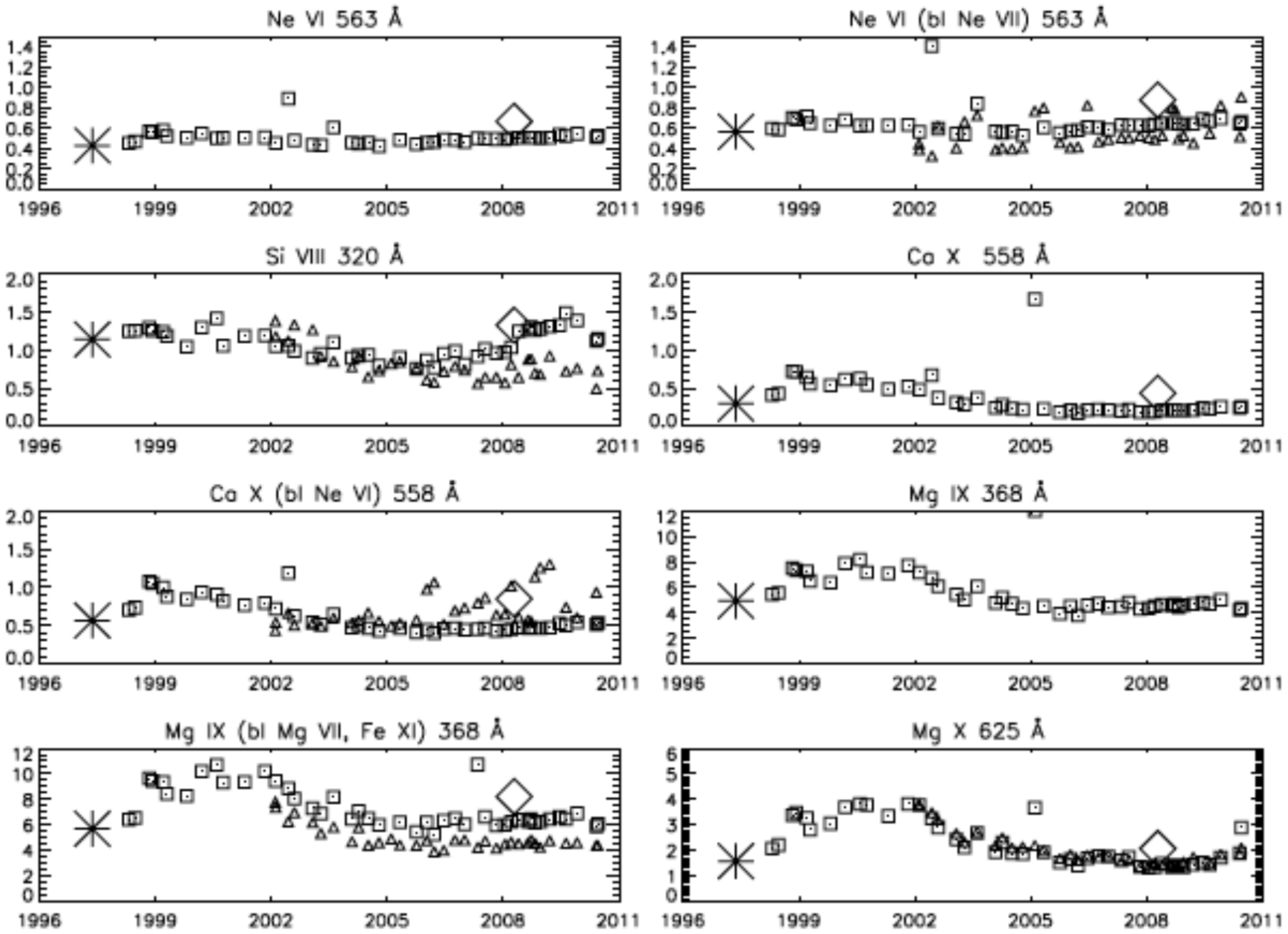
Note: the NIS He II irradiance is obtained with a new suggested responsivity (Del Zanna & Andretta 2011)

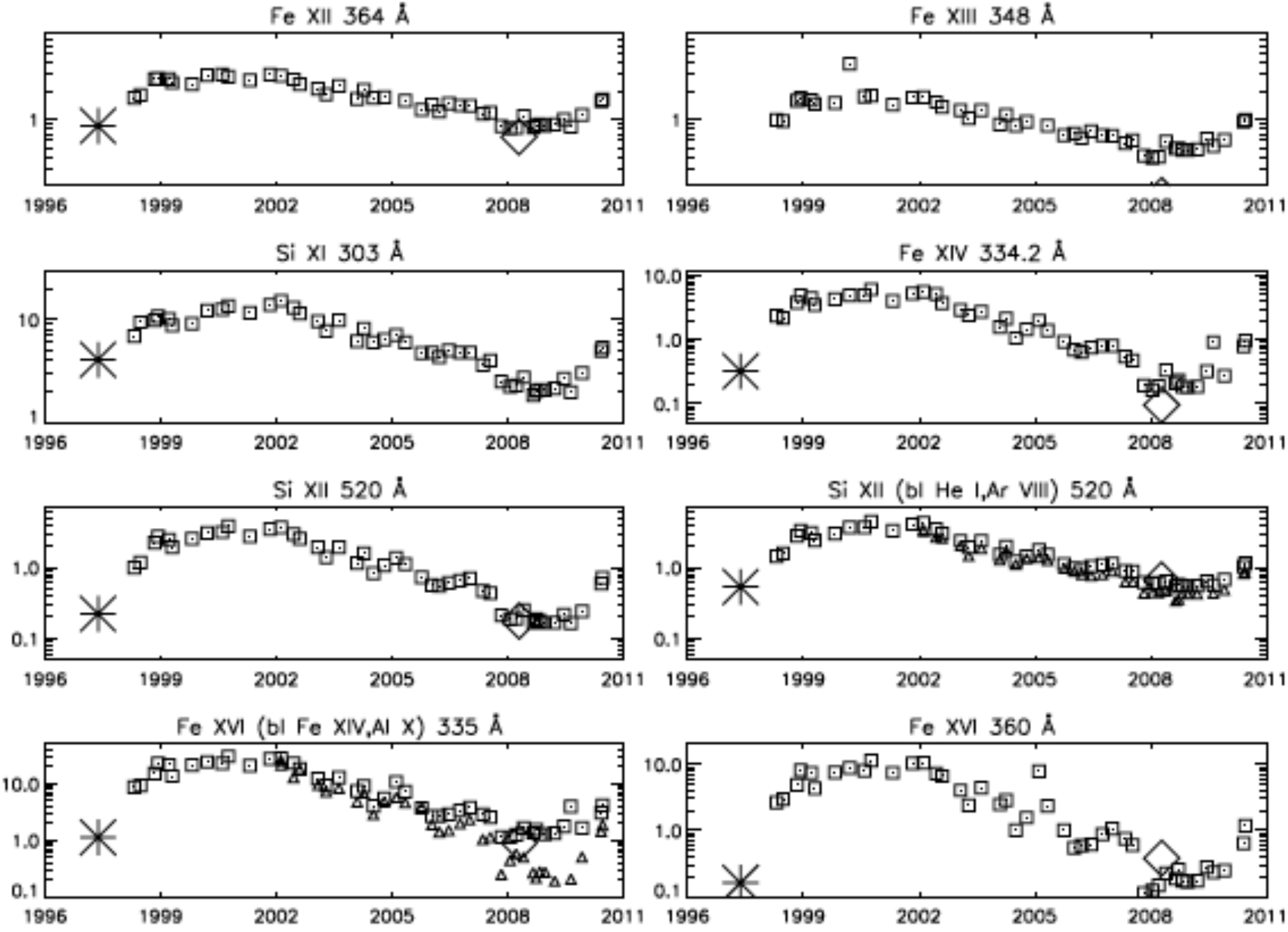
`TR' line

- TR lines have small cycle variability -> are good for the calibration.

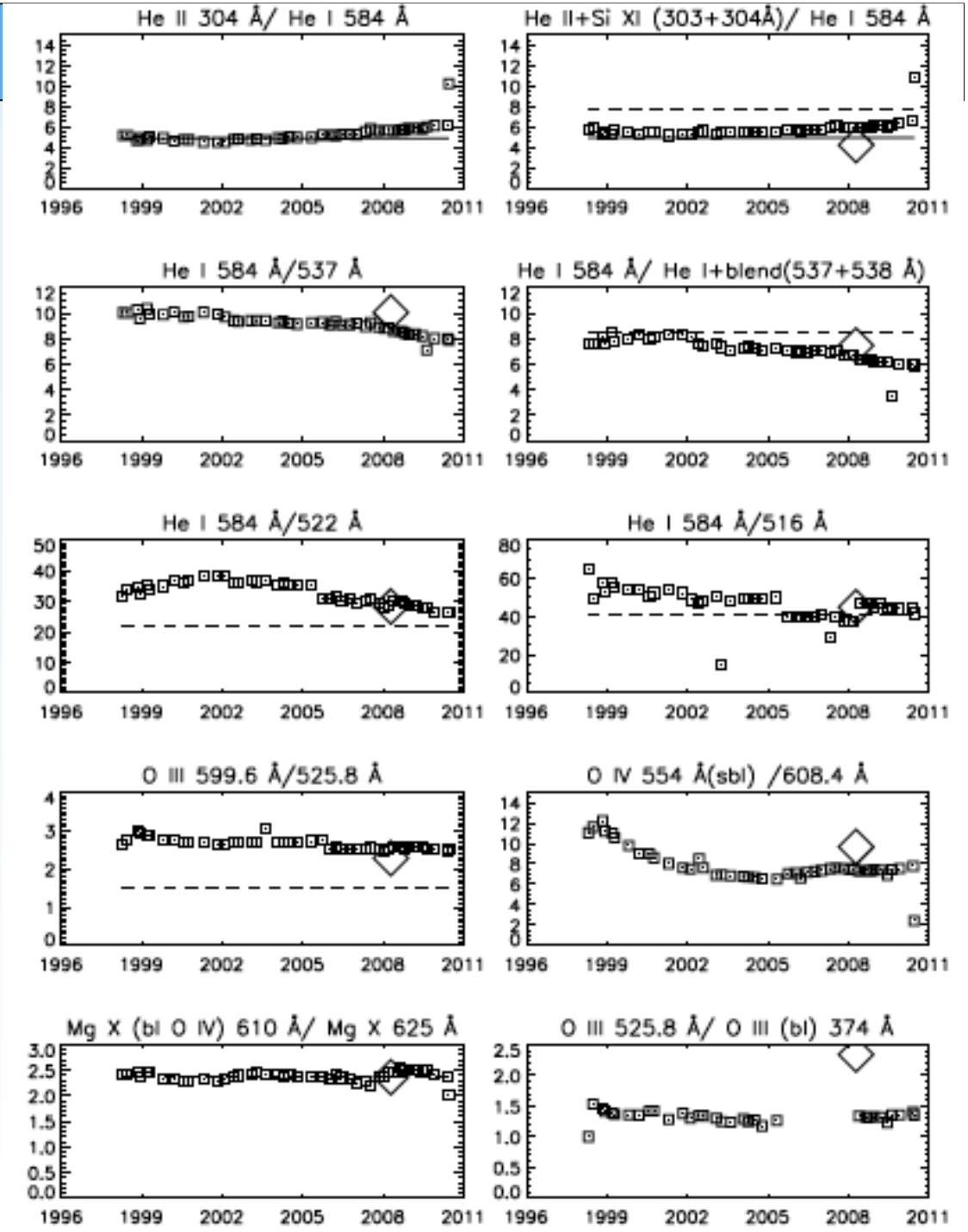
(indeed they were used to calibrate GIS Kuin & Del Zanna (2007) Sol. Phys., 242, 187




Ne VI 563 Å
Ne VI (bl Ne VII) 563 Å
Si VIII 320 Å
Ca X 558 Å
Ca X (bl Ne VI) 558 Å
Mg IX 368 Å
Mg IX (bl Mg VII, Fe XI) 368 Å
Mg X 625 Å
1996
1999
2002
2005
2008
2011


Fe XII 364 Å
Fe XIII 348 Å
Si XI 303 Å
Fe XIV 334.2 Å
Si XII 520 Å
Si XII (bl He I,Ar VIII) 520 Å
Fe XVI (bl Fe XIV,Al X) 335 Å
Fe XVI 360 Å
1996
1999
2002
2005
2008
2011

- Cross-check with line ratios



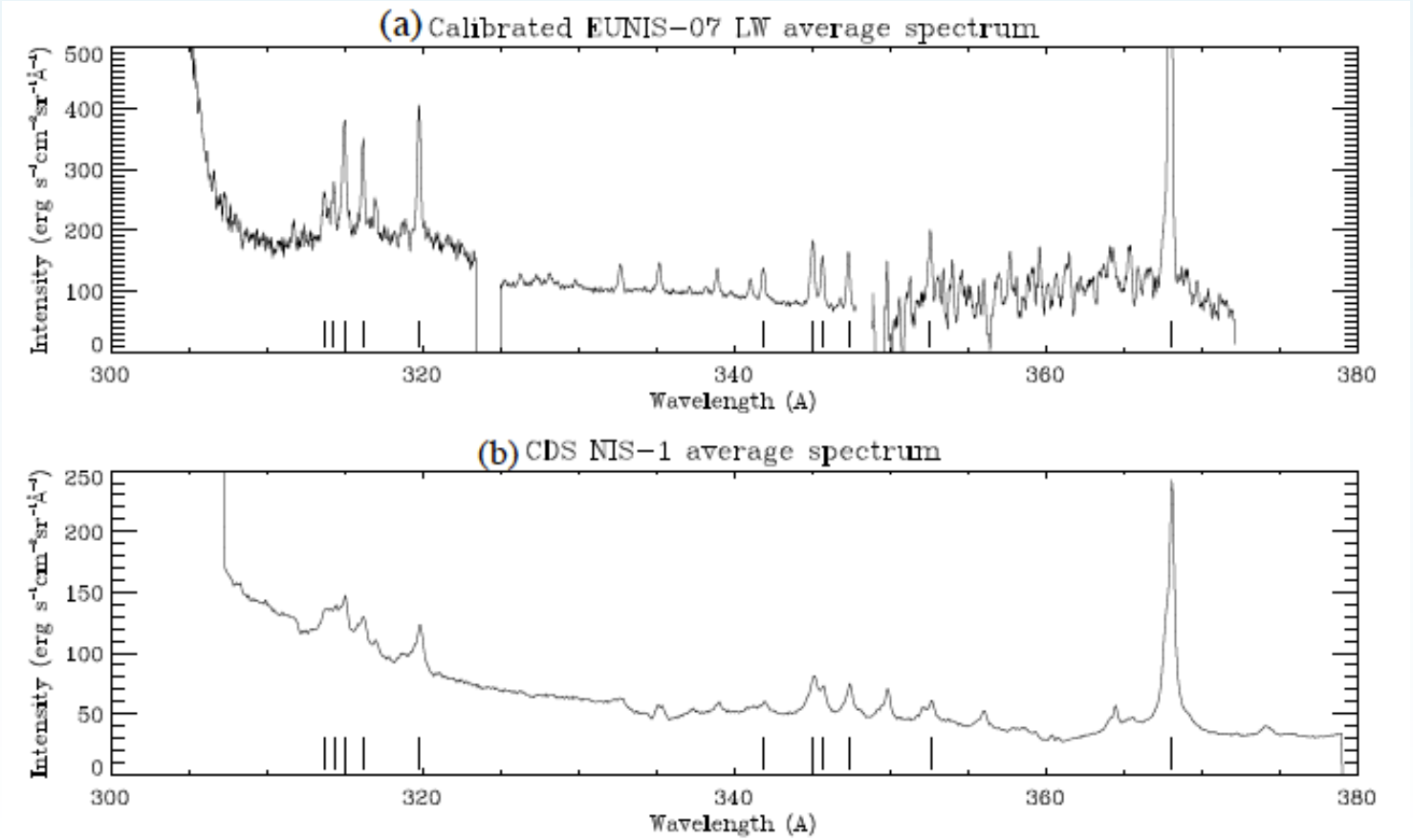
EUNIS vs. CDS NIS 1

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.

Very good agreement (10%) between the radiances of the strongest line (Mg IX 368) is found when the Del Zanna sensitivities and long-term corrections are applied.

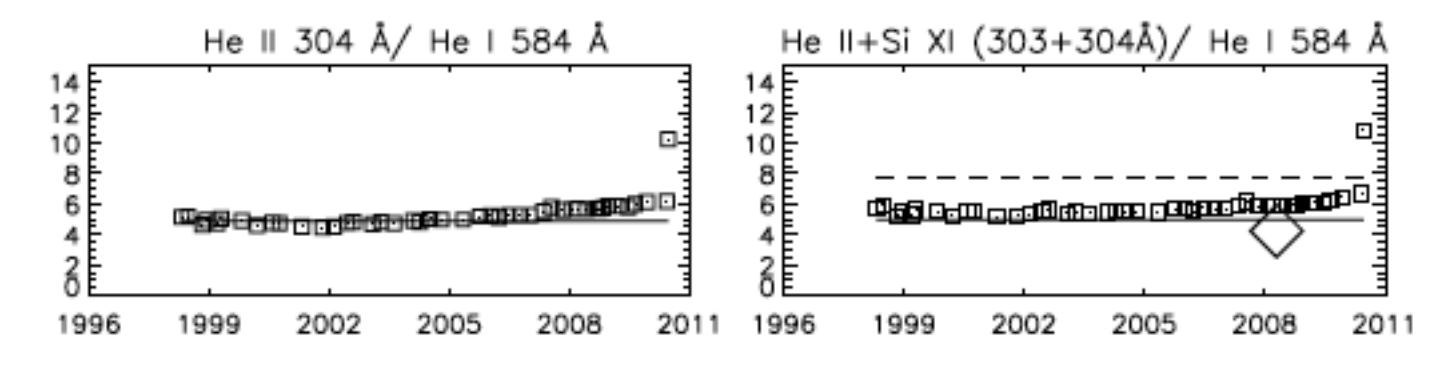
Wang et al. (2011), ApJ, 197, 32



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. The 304 is observed in second order by CDS/NIS.

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.

The problems with the He II 304 (2)

Comparisons between our CDS NIS measurements and EUNIS measurements led to the discovery of two significant software errors, one in the EUNIS and one in the CDS software (for the second order lines). Not all the CDS published measurements were affected though. Certainly not those of Del Zanna et al.

The EUNIS 2007 flight observed the He II 304 in first order on the quiet Sun.

Excellent agreement, within a relative 6%, between the EUNIS 2007 and CDS radiances is found, when the Del Zanna et al. (2010) NIS long-term corrections and the Del Zanna & Andretta (2011) sensitivity are adopted. This is shown in Wang et al. (2011).

So for the first time we now have good agreement between EUNIS, CDS, and SDO/EVE. Is this the end of the story ?

Summary and further work

Synoptic observations have been the key to measure the in-flight degradation.

Rocket flights calibrated on the ground are necessary.

The NIS sensitivity has dropped by only a factor of about two in 13 years. Very little degradation was seen in GIS. Very good indeed. Lesson: CLEANLINESS !

The calibration method will be extended to cover the entire lifetime of the CDS instrument (SOLID FP7 network).

Further comparisons if ISSI workshop approved.