

# EVE - a personal selection of highlights

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Long-term irradiances  
Instrument calibrations  
Flare diagnostics  
Benchmarking atomic data  
Photospheric abundances of the corona



# Atomic data for astrophysics

## SCATTERING CALCULATIONS:

**UK APAP Network** <http://www.apap-network.org/>  
funded by STFC has become the main ion  
atomic data provider for fusion and astrophysics  
(cf. Badnell, Del Zanna+2017),

## STRUCTURE CALCULATIONS:

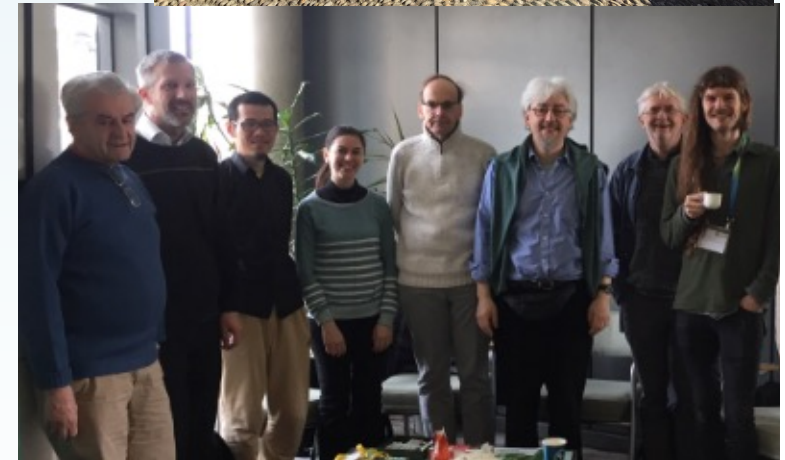
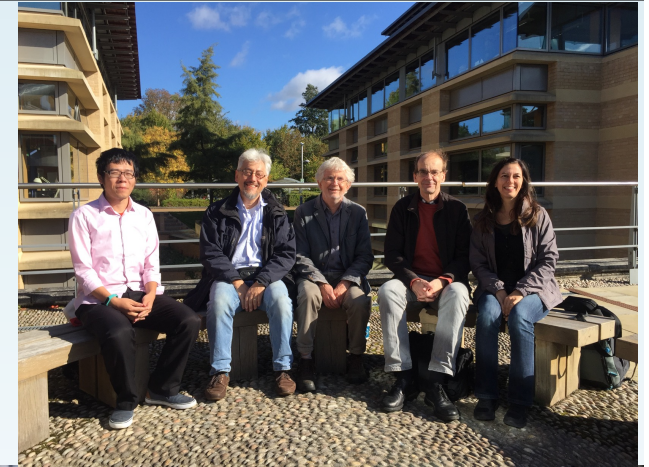
**COMPAS group (GRASP2K)**  
cf. Jonsson+(2017)

## BENCHMARK:

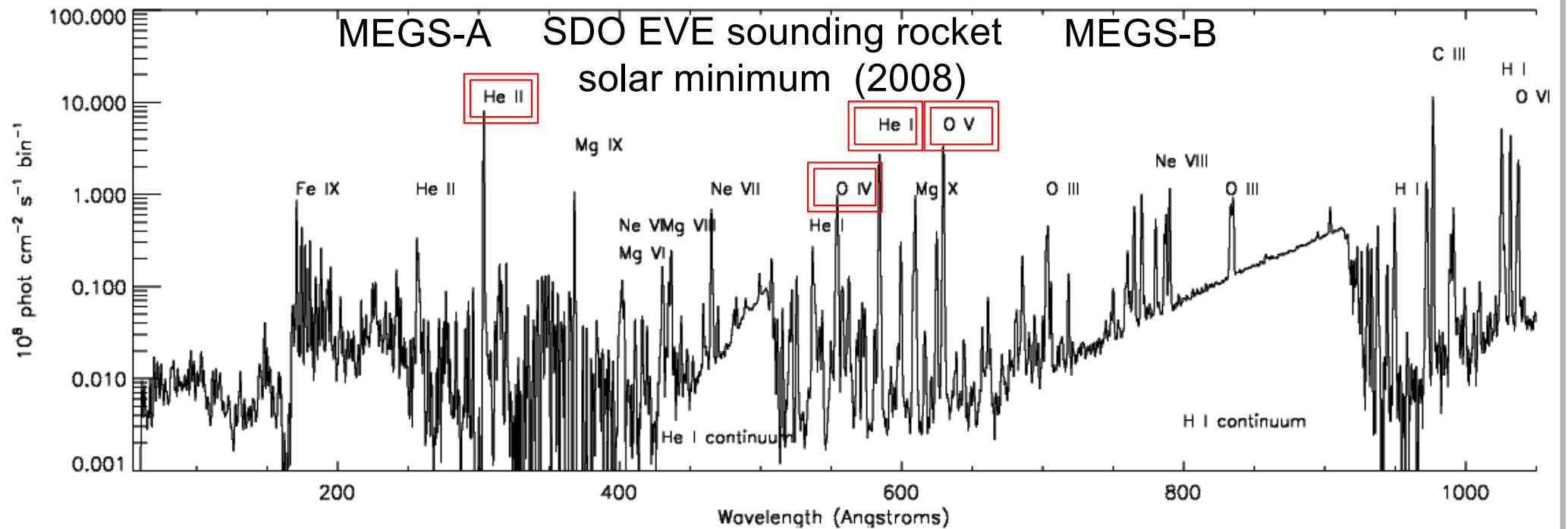
line identifications and benchmark (novel)

## DISTRIBUTION:

**CHIANTI** ([www.chiantidatabase.org](http://www.chiantidatabase.org)), with over 3000  
citations, main database for ions.



# SDO EVE



P. Storey (UCL, UK):

*you could spend a lifetime to understand this single spectrum*

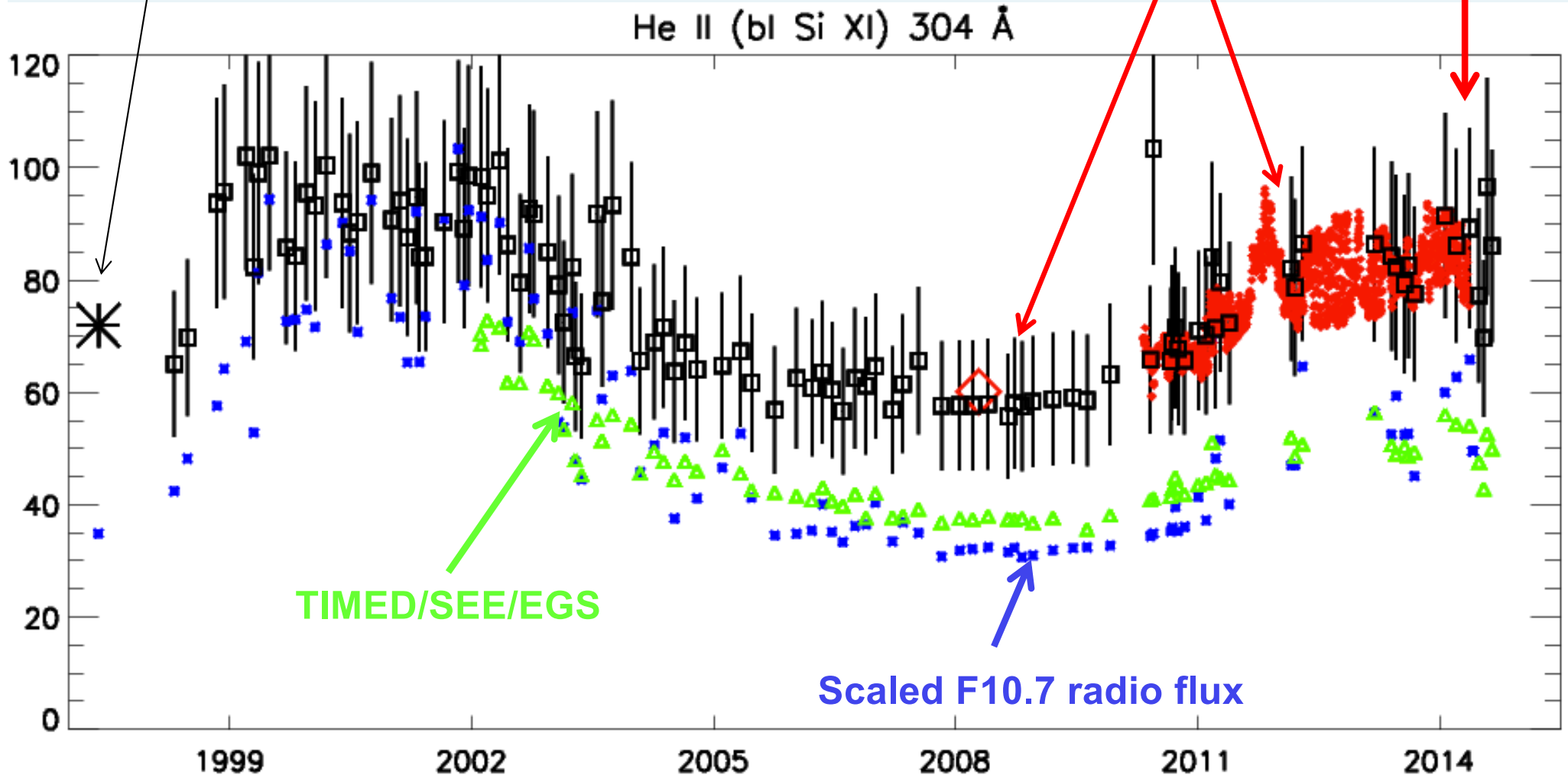
# Irradiances in the strongest EUV line

LASP NIS  
calibration  
rocket flight

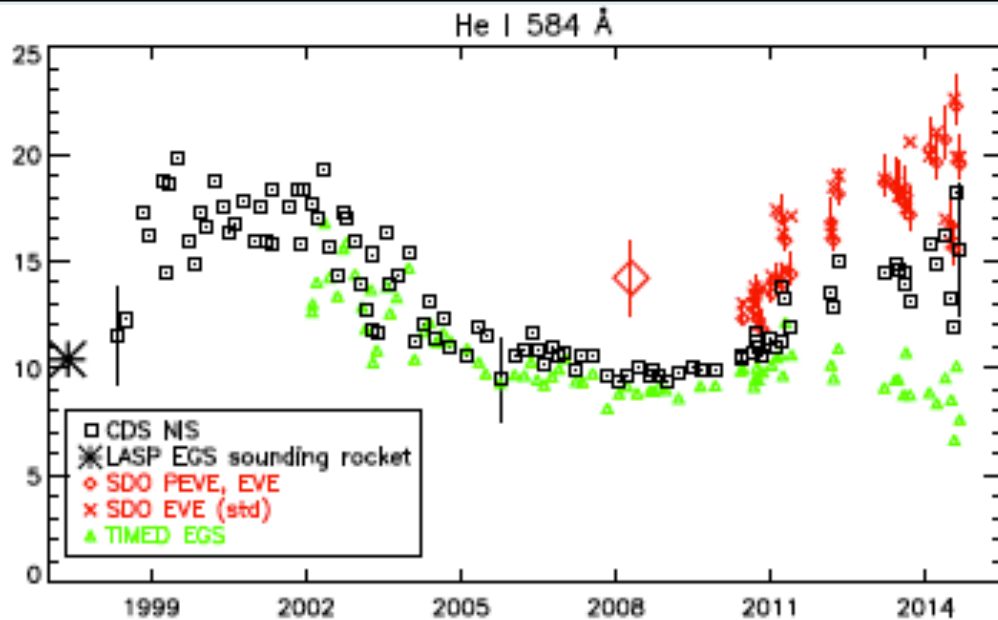
CDS and EVE in agreement!  
Discrepancies  $\sim 2$  in all previous  
measurements.

SDO/EVE

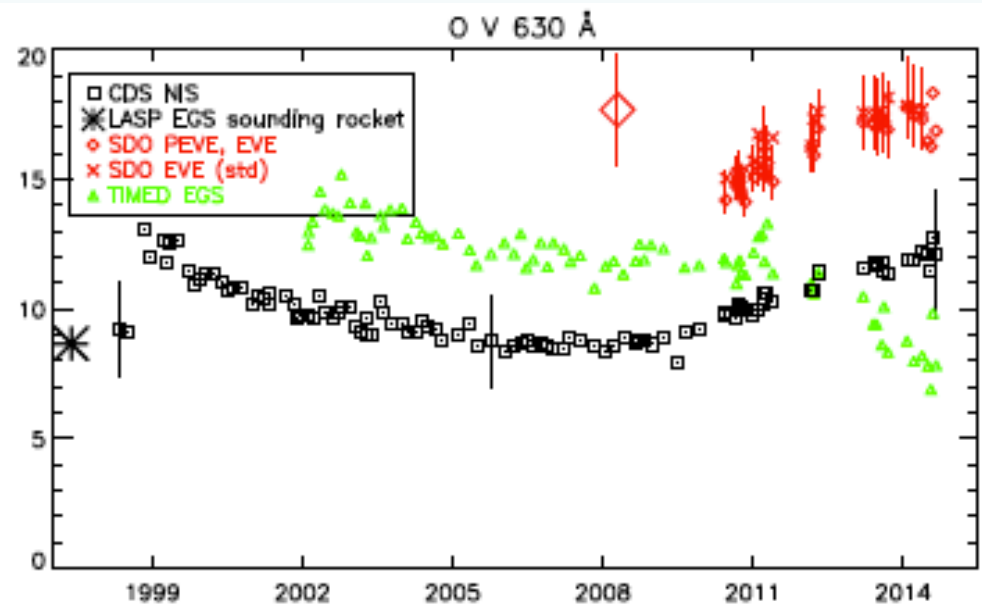
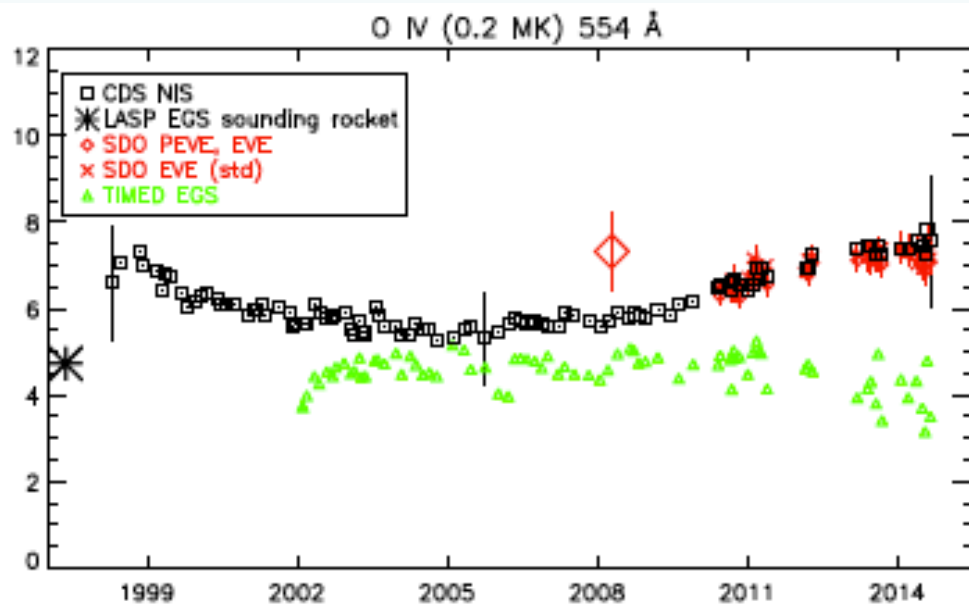
Last data  
May 2014



# Del Zanna & Andretta (2015)

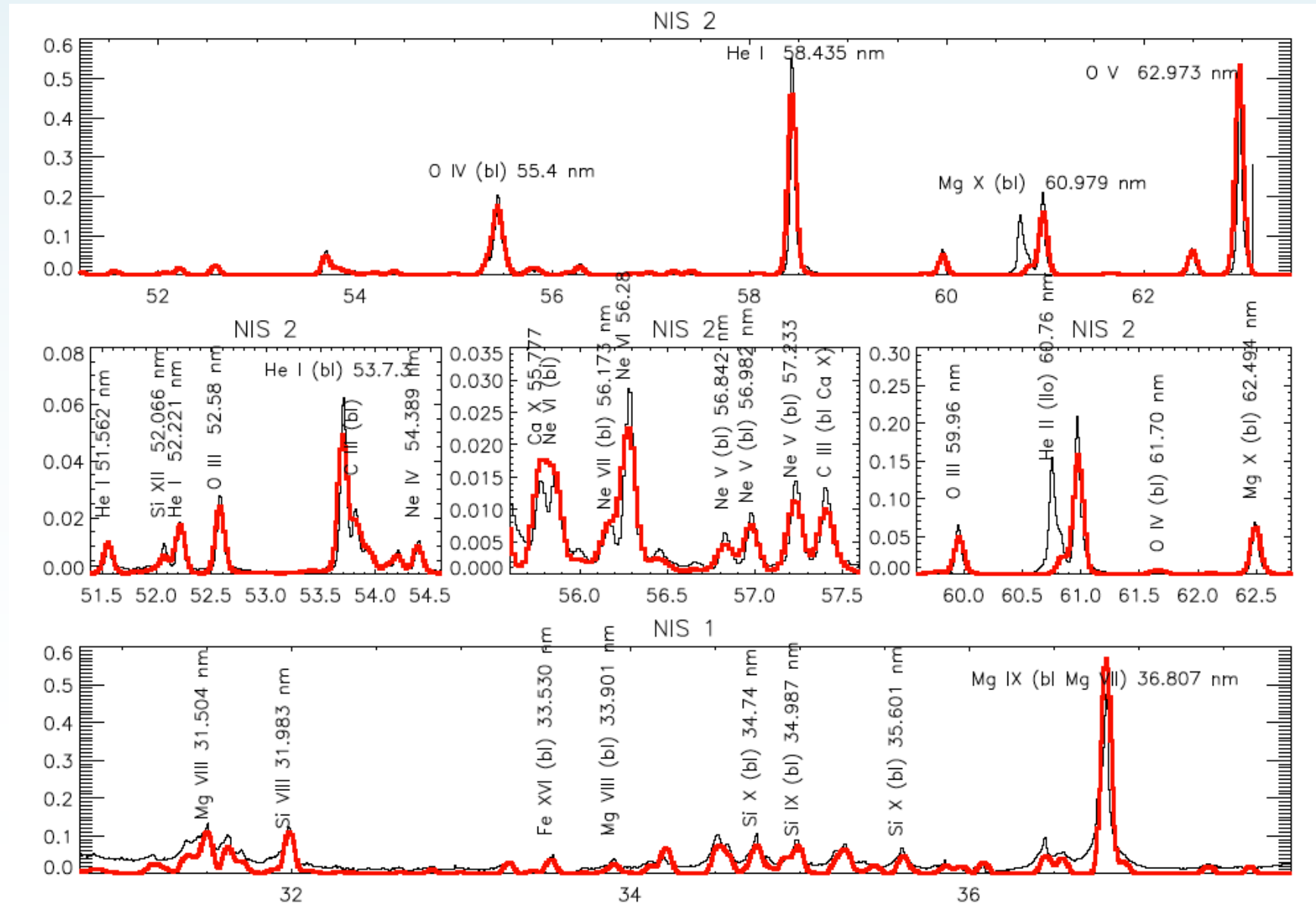


Important results on EUV irradiance from EVE, although some problems in the calibration have been present.



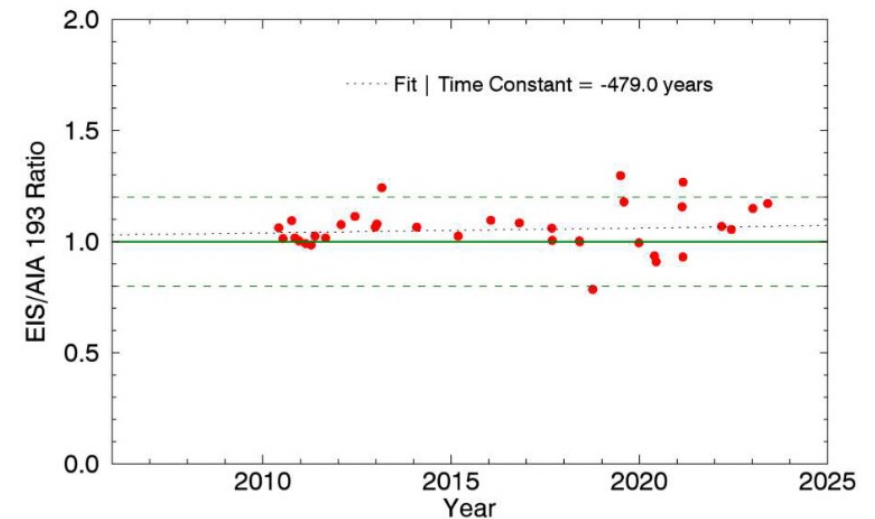
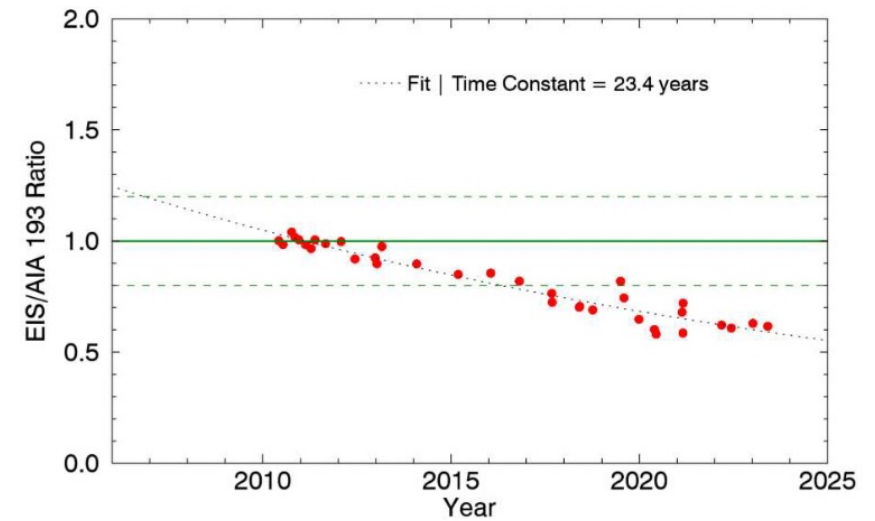
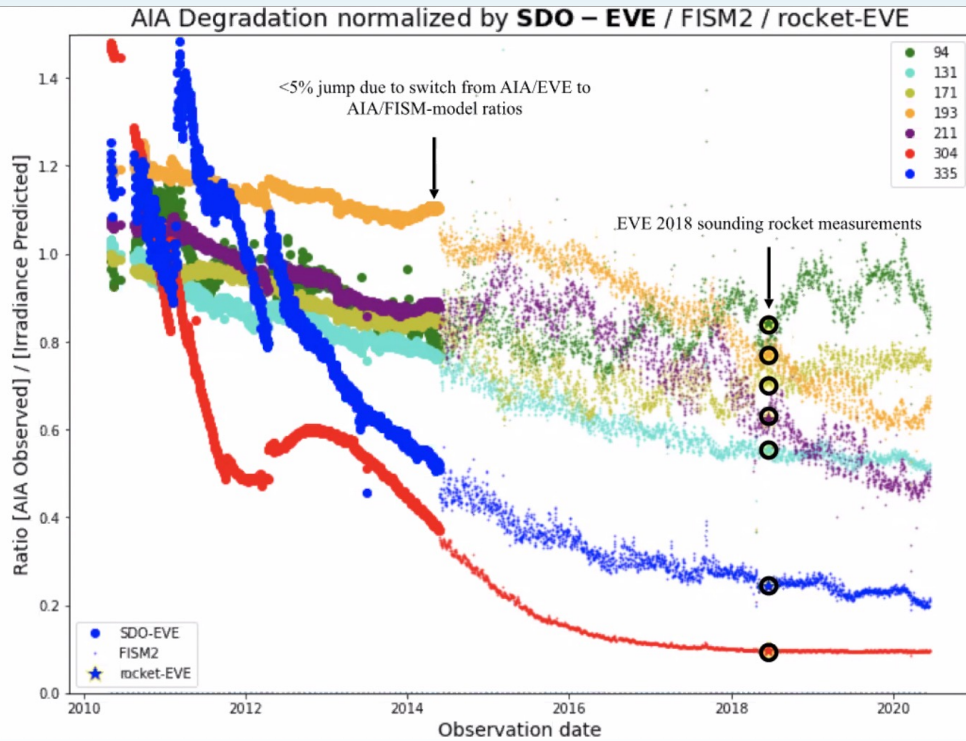
# Validation of CDS calibration using PEVE (2008)

Black: CDS - Red: SDO/EVE 2008 prototype (Del Zanna et al. 2010)





# Calibration of AIA and Hinode EIS

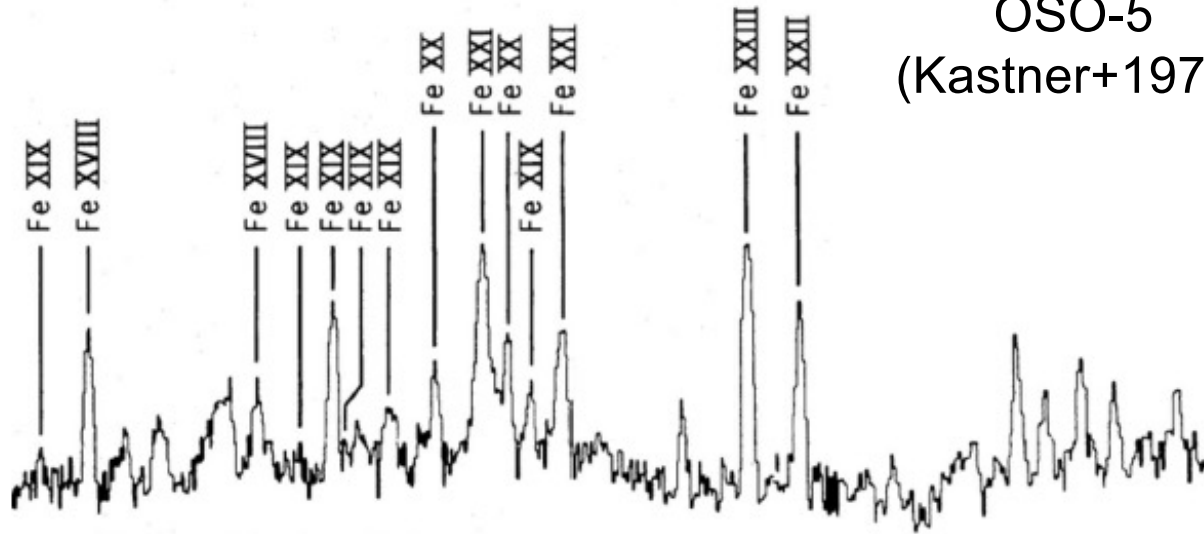


? Chamberlin+2020

We have carried out the absolute calibration of Hinode EIS from 2010 relative to AIA 193 / EVE (Del Zanna, Warren, Weberg 2023)

# “Soft” X-rays

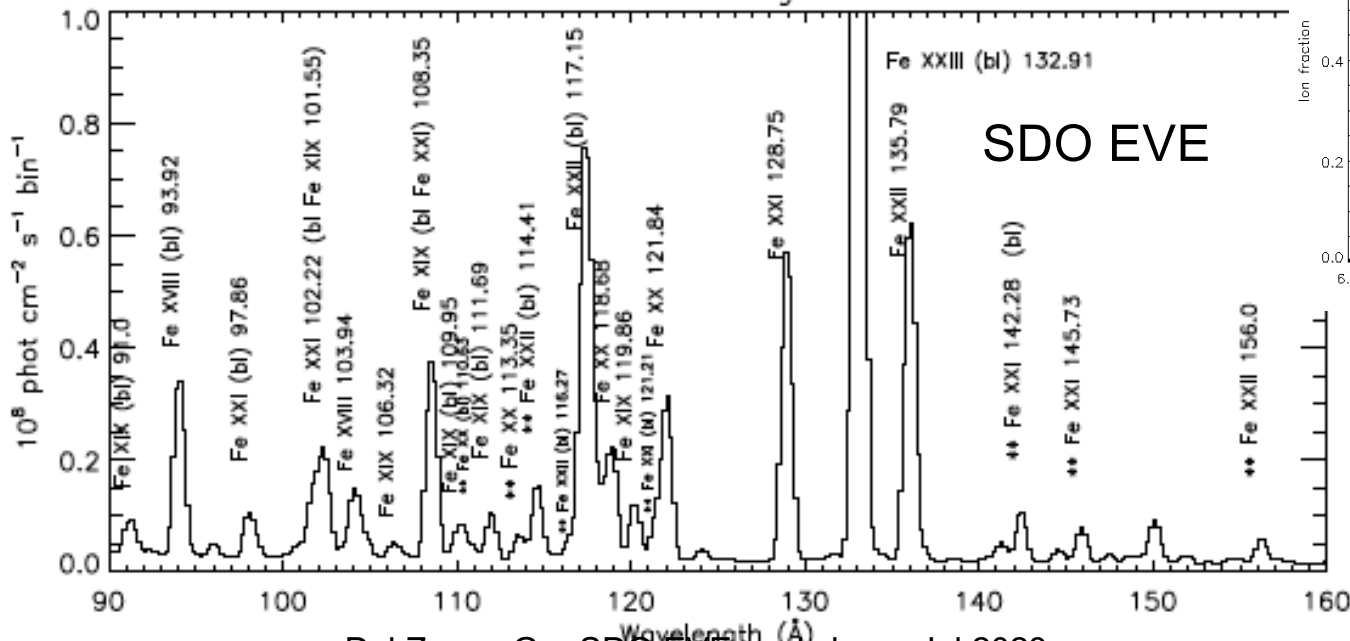
OSO-5  
(Kastner+1974)



FLARE SPECTRUM

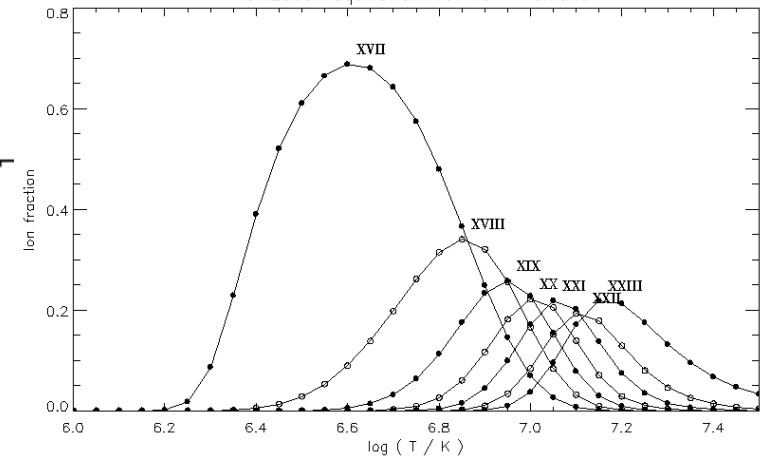
First spectra since OSO-5

EVE flare - 9 August 2011



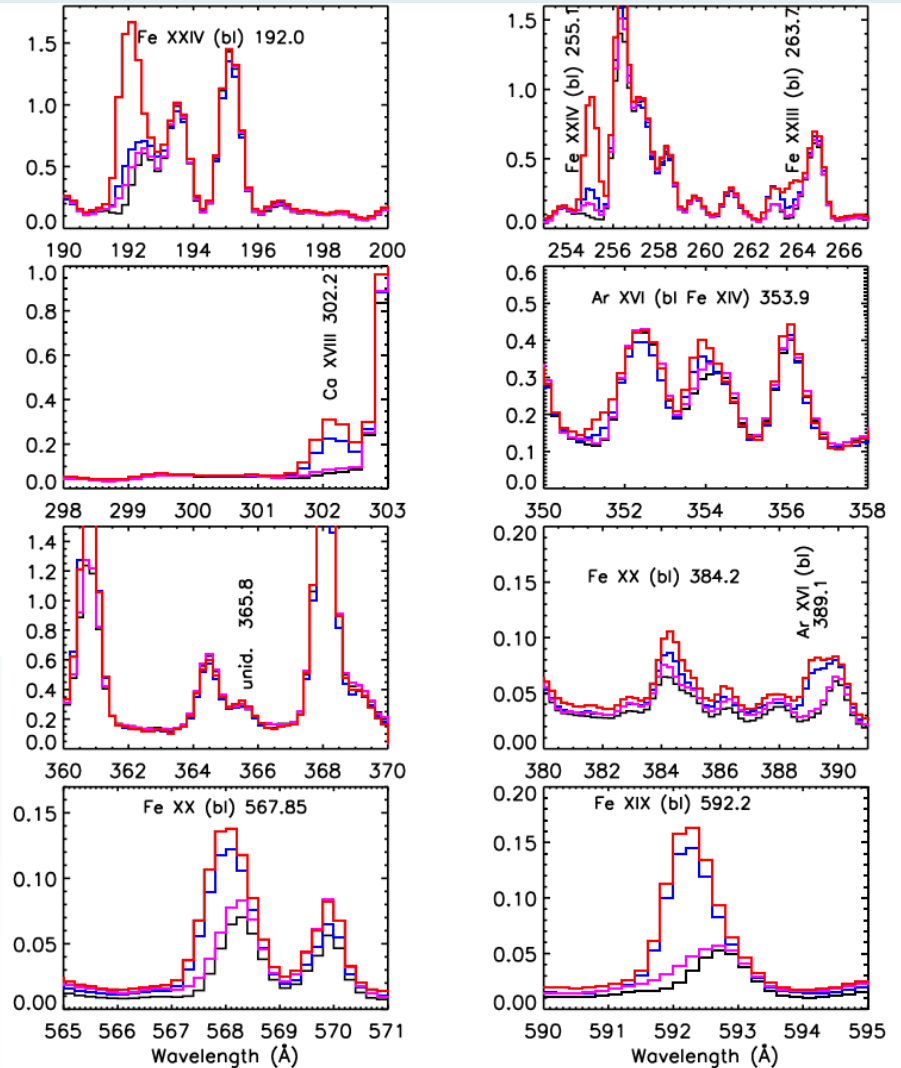
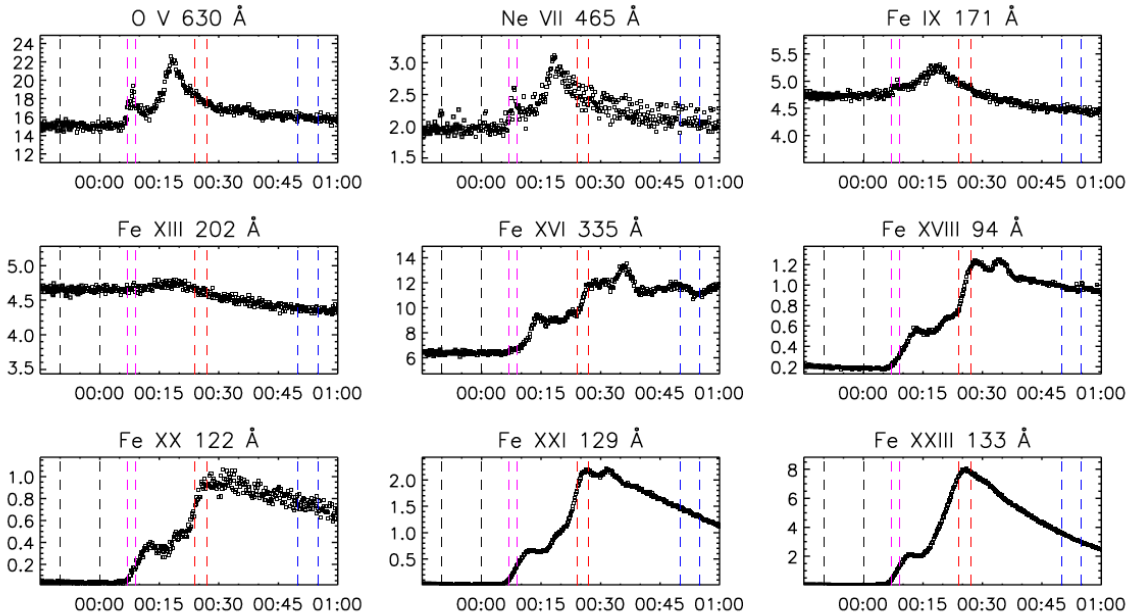
SDO EVE

Ionization equilibrium for Fe - chianti





# X-class flares (Del Zanna & Woods 2013)



EVE is excellent to measure ionization temperatures.

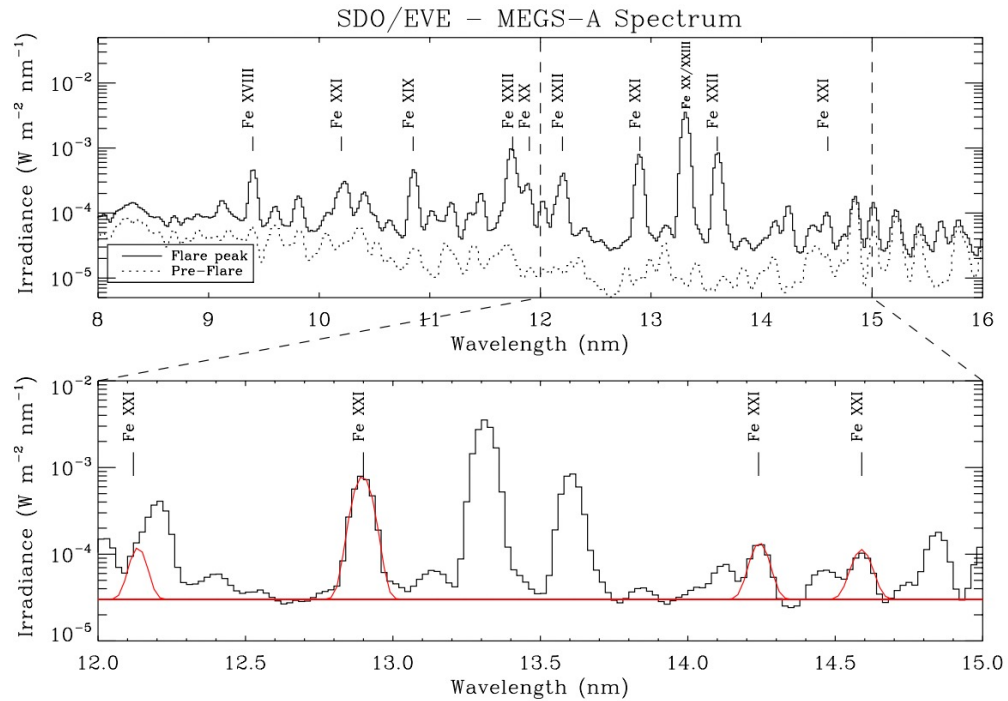
During flares, Ar/(Ca, Fe) abundance photospheric, in agreement with previous results.

See also Warren (2014) on Fe abundance

# Flare densities

THE ASTROPHYSICAL JOURNAL LETTERS, 755:L16 (6pp), 2012 August 10

MILLIGAN ET AL.

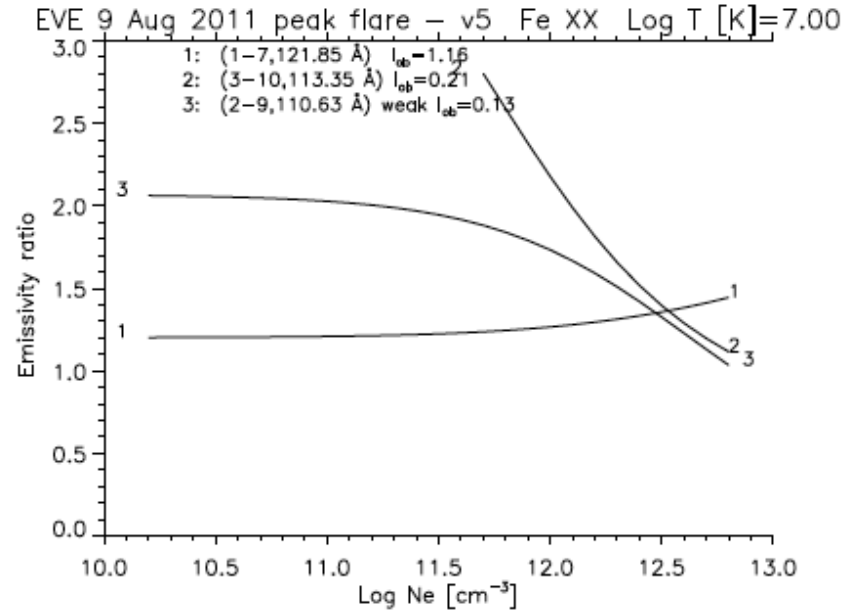
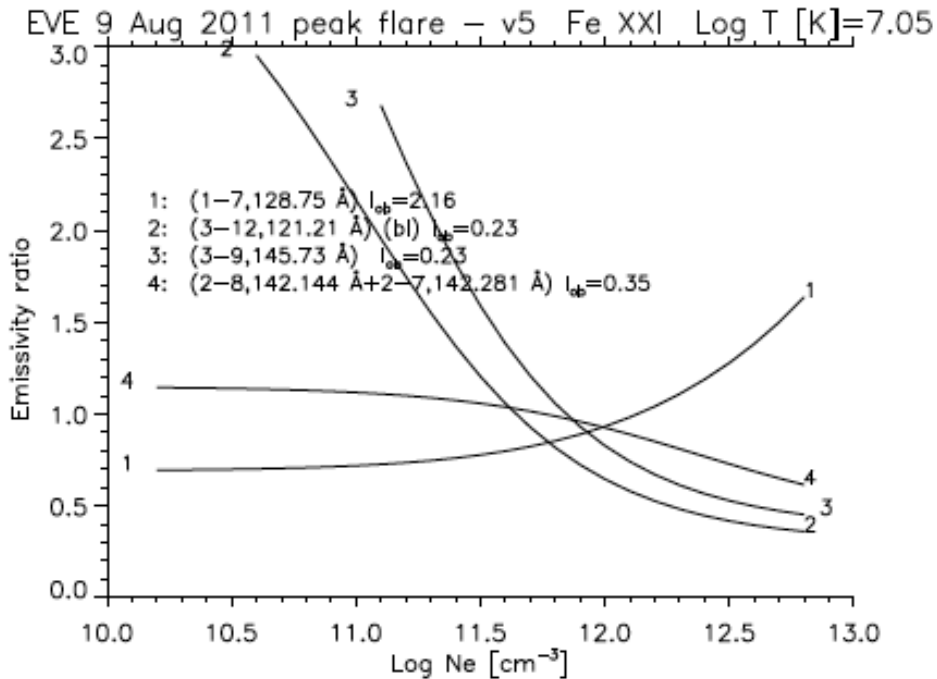


measurements of densities!  
(Mason+1986, Milligan+2012,  
Del Zanna & Woods  
2013, Keenan+2017)

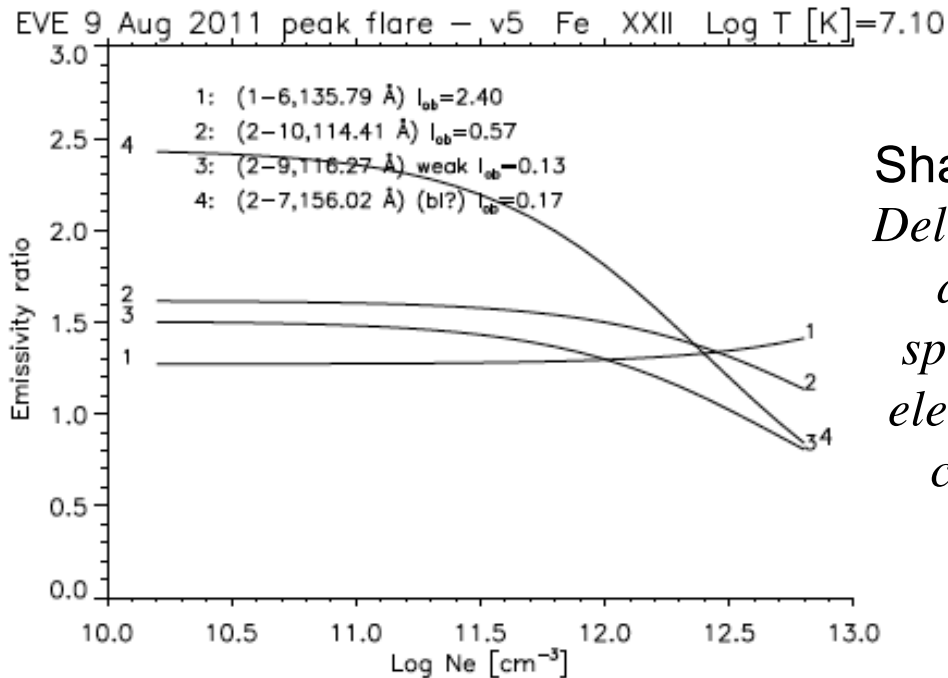
Milligan+2012 measured densities from Fe XXI lines.  
General problem: background spectrum?

We (PI: A.Gall, CfA) are preparing a proposal to  
investigate the SXR with EBIT. SXR unexplored!

# Diagnostics of Ne



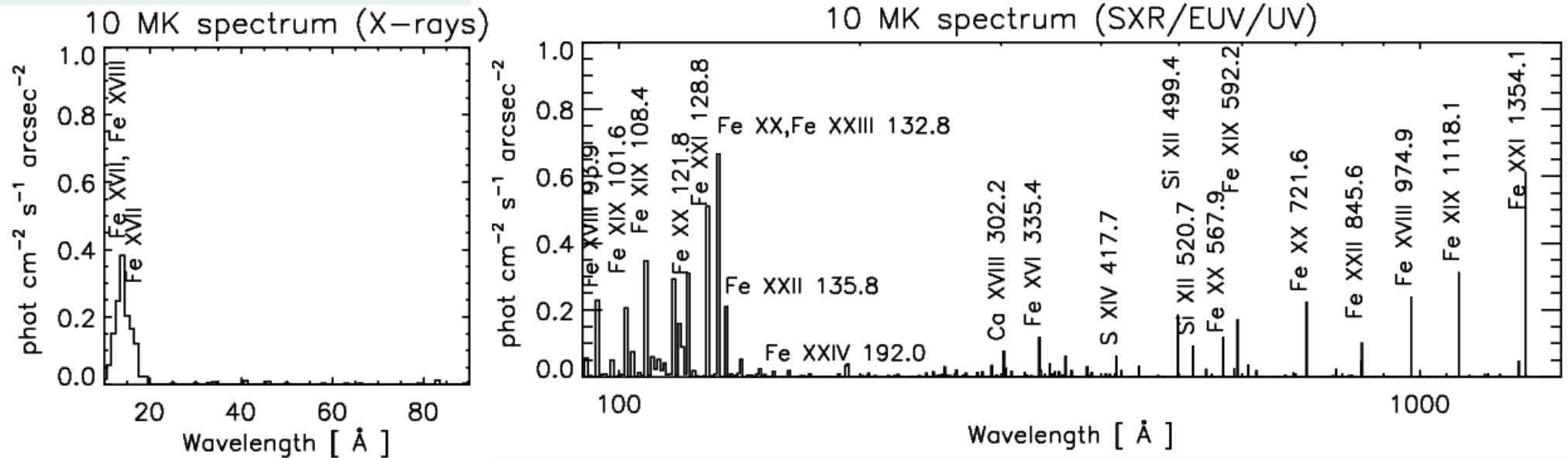
Del Zanna & Woods (2013)  
 analysed all possible diagnostics



Shameful citation by Keenan, Milligan et al. (2017)  
*Del Zanna & Woods (2013) have previously undertaken an analysis of Fe XVIII–Fe XXIV features in EVE spectra [...] However, these authors did not consider electron density diagnostics in detail, in particular the consistency of densities derived from different line ratios.*

# The unexplored “Soft” X-rays (SXR: 90-150 Å)

Much interest for future missions

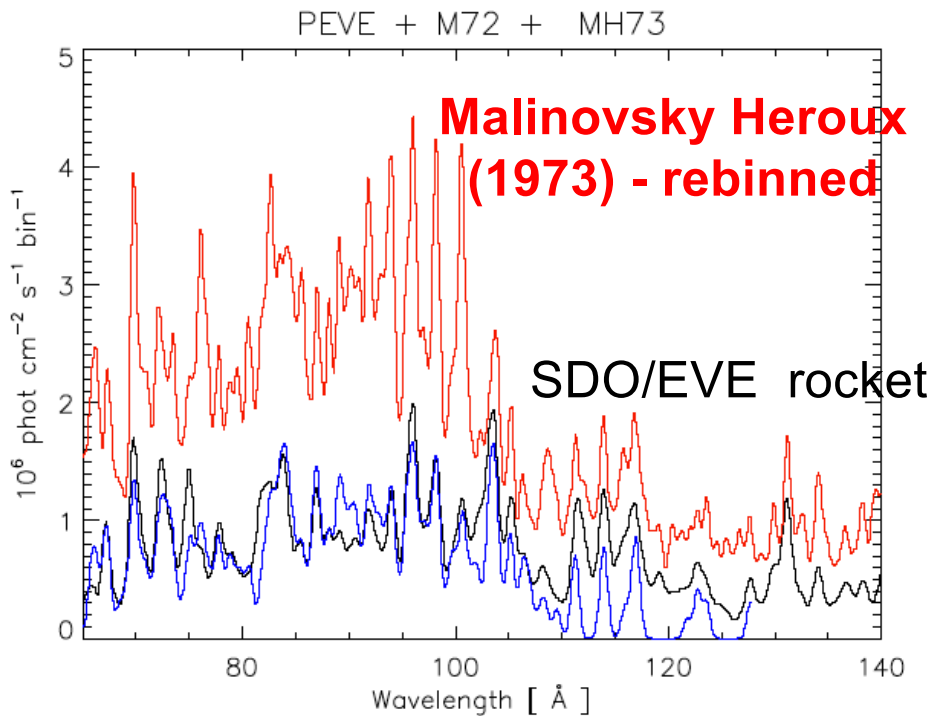


Review on SXR and proposal for an instrument with novel multilayers:  
[Del Zanna+, Frontiers in Astronomy and Space Sciences, 2021](#)

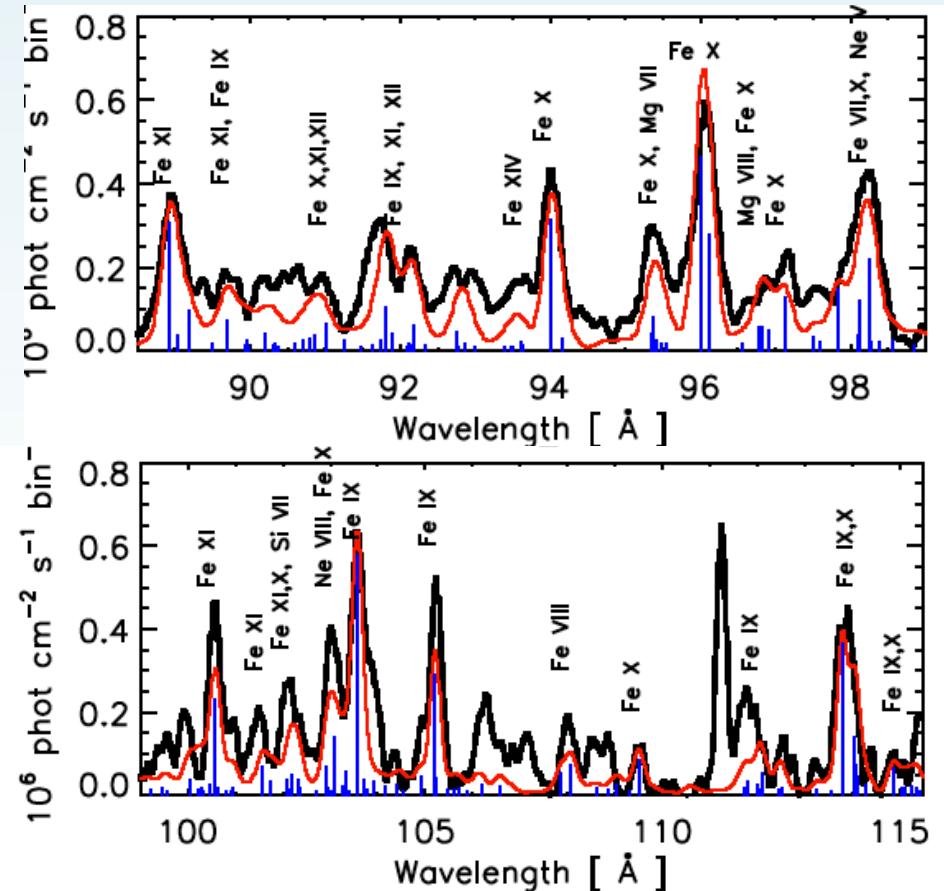
# EVE for calibrating/benchmarking the SXR

I used EVE to calibrate the SXR and benchmark new atomic data (almost no data for coronal iron ions were available).

The Malinovsky & Heroux (1973) irradiances are clearly overestimated.



Manson (1972) - rebinned



Black: calibrated spectrum from Manson (1972). Red: theoretical spectrum obtained with the new atomic data (Del Zanna+) and identifications (Del Zanna 2012).

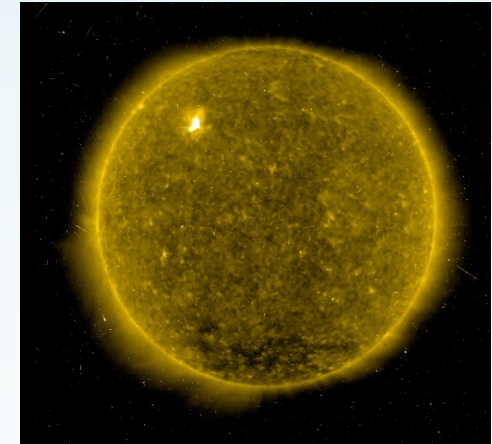
# Modelling solar minimum EUV irradiances

Replaced the PEVE irradiances of some lines with EVE data from 2010 May 16.

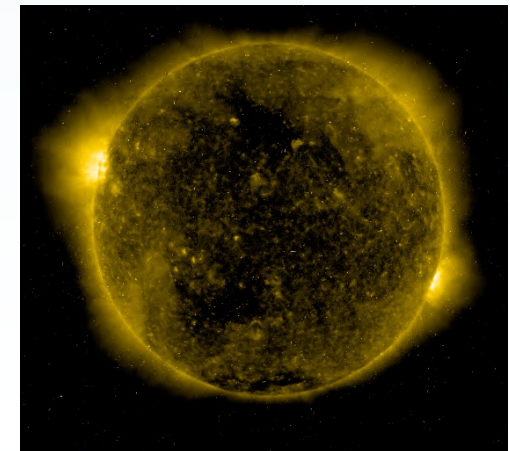
First ever benchmark across the entire EUV of the atomic data. I produced most of the new data for CHIANTI v.8 (Del Zanna+ 2015) and v.10 (Del Zanna+2019).

Gratifying results after a lot of effort: database is complete and accurate for most strong lines.

2008 Apr 14 minimum F10.7 =69

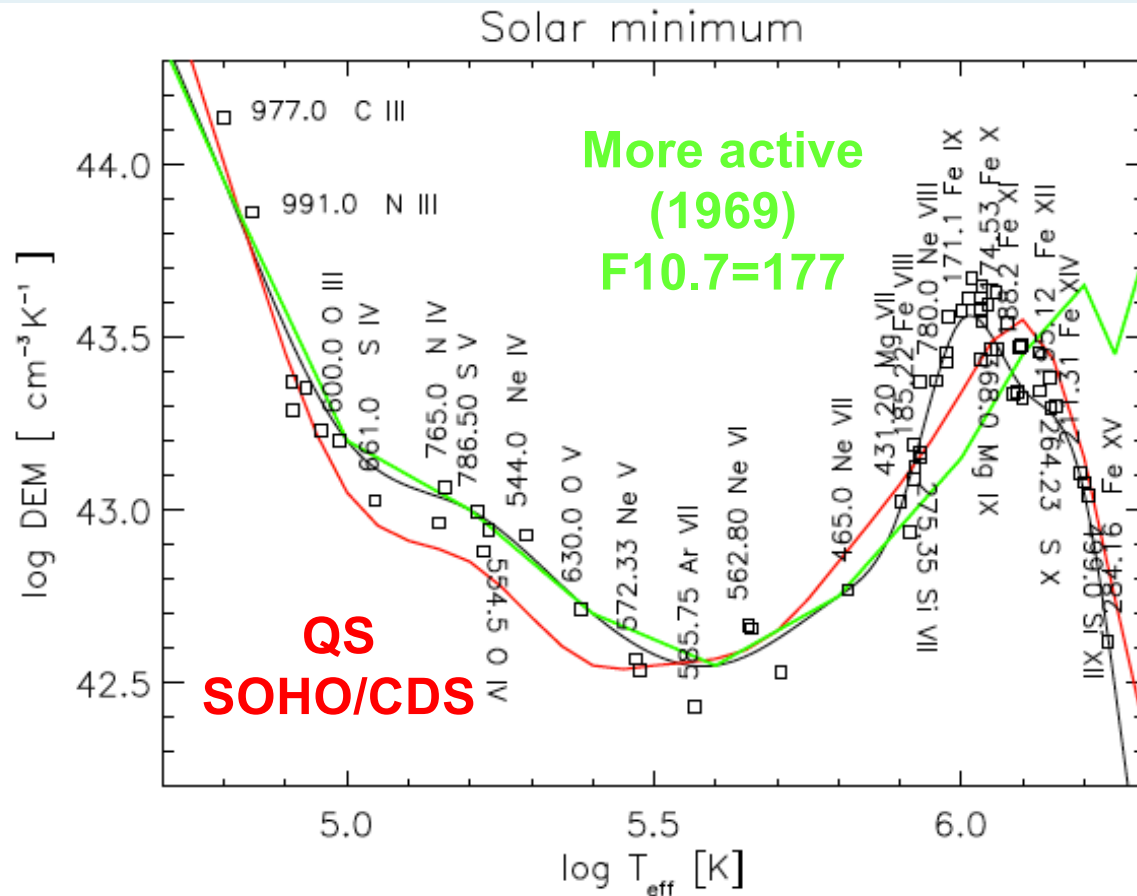


2010 May 16 minimum F10.7=70



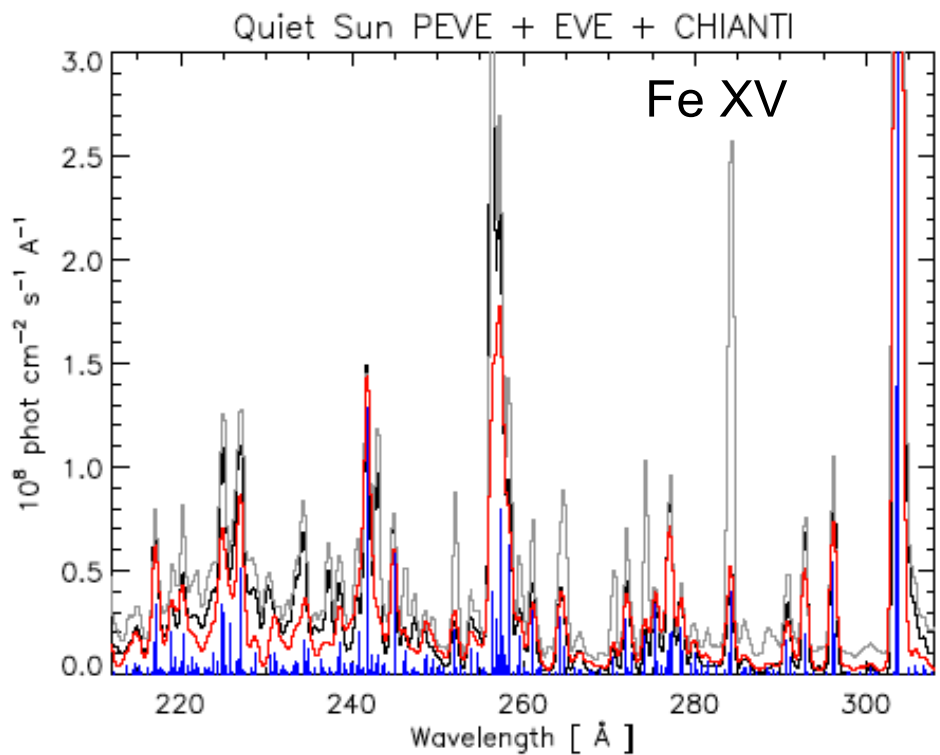
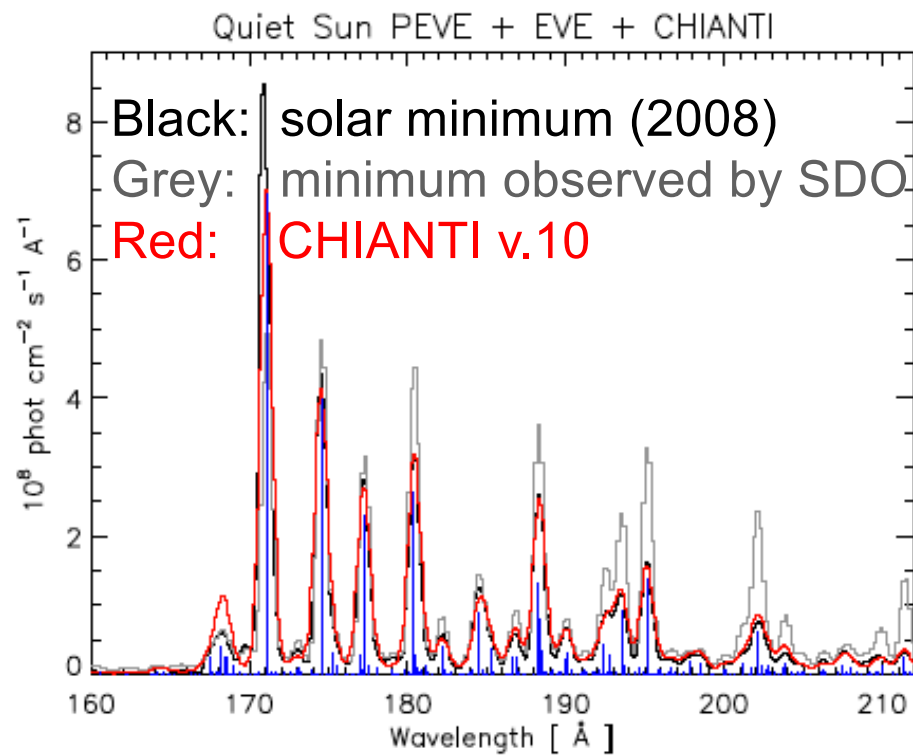
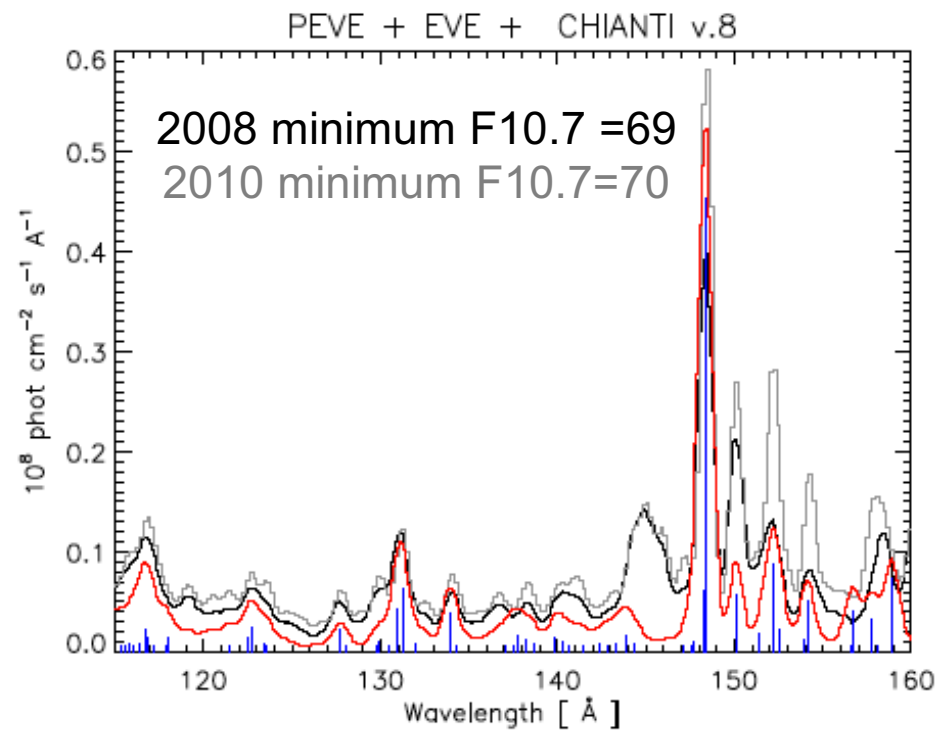
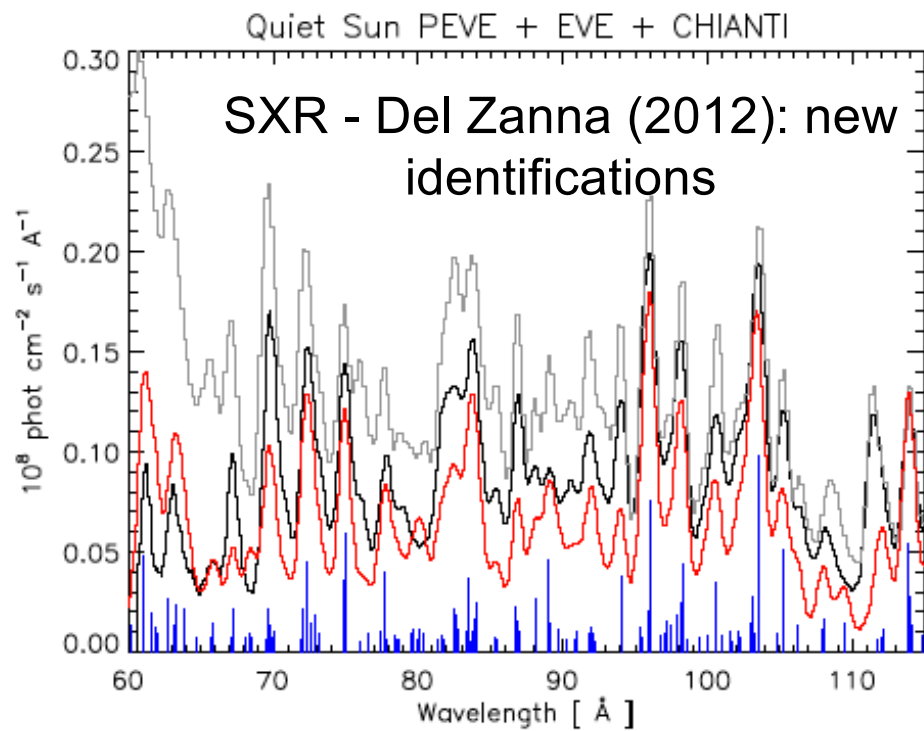


# PEVE quiet Sun (Del Zanna 2019)



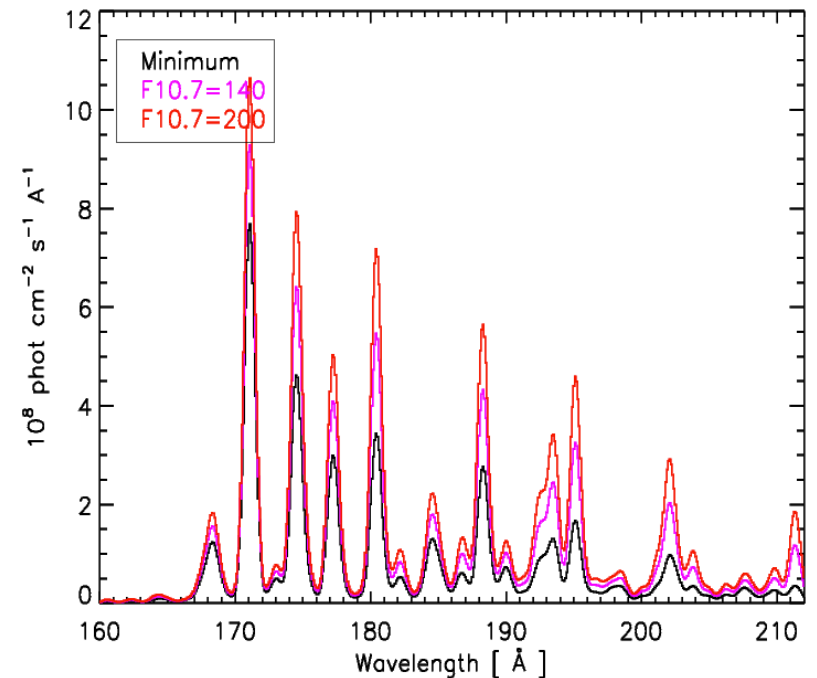
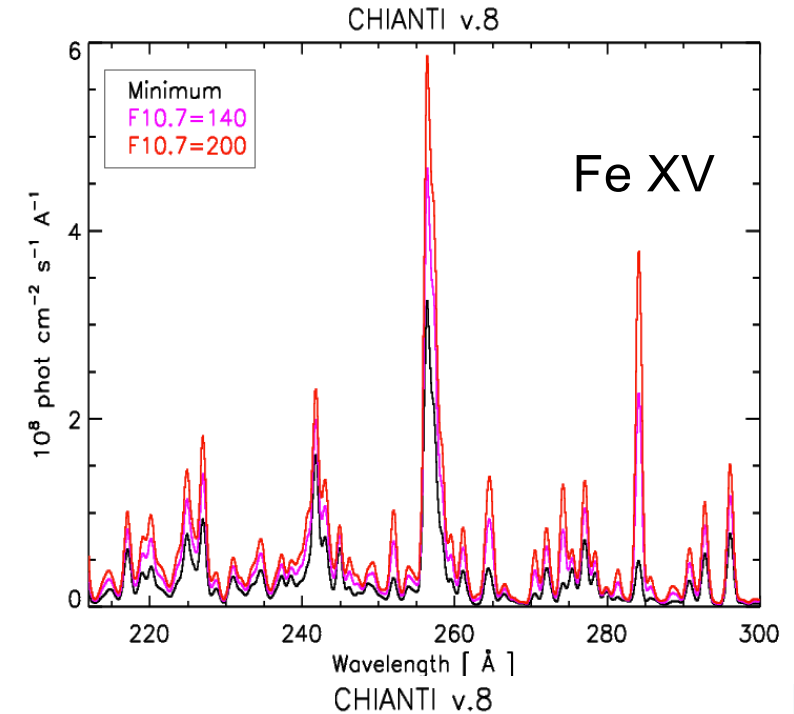
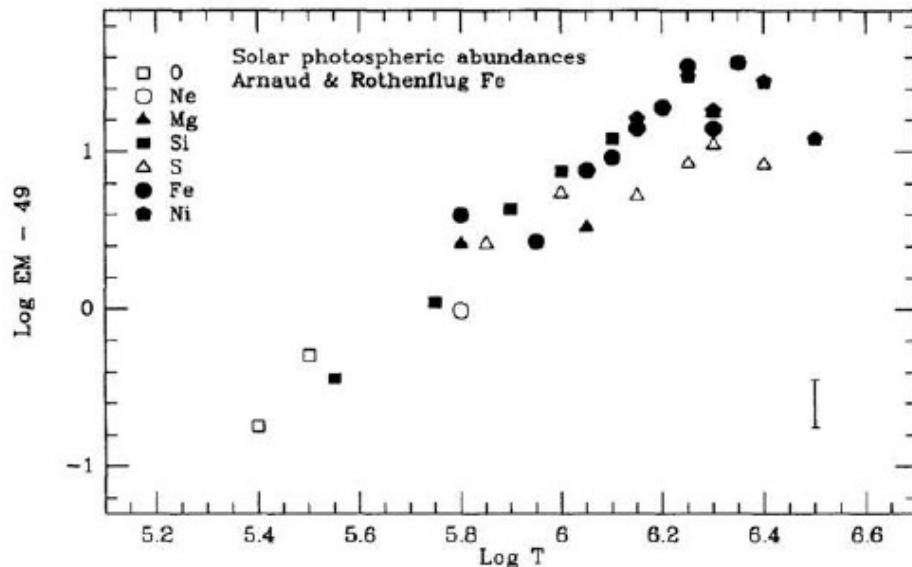
Asplund+(2009) photospheric abundances !

In agreement with results from many missions (CDS, SUMER, EIS, AIR-Spec, AIA), although most of the community still refers incorrect results published on elemental abundances.



# Why the Laming results then ?

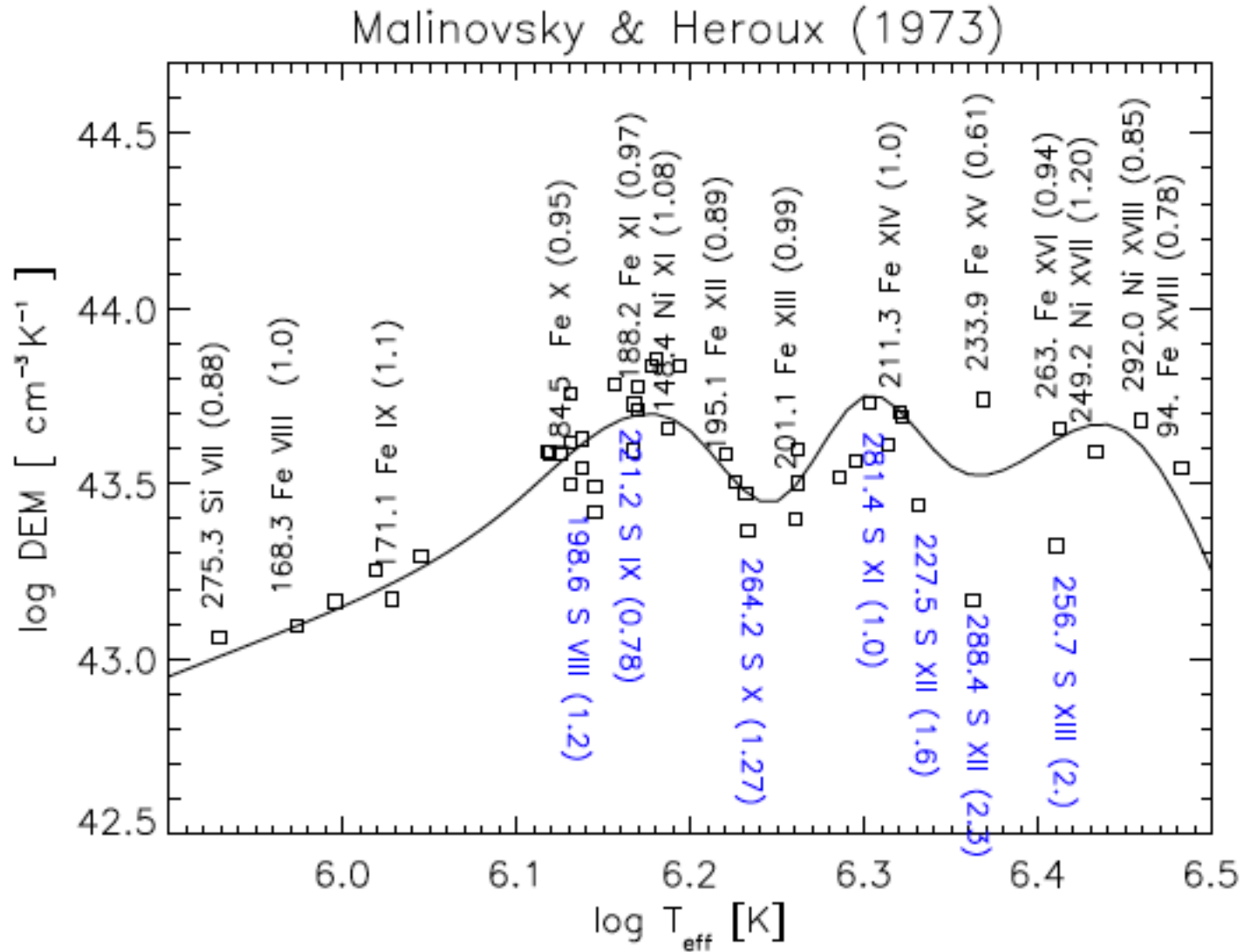
Laming+(1995):  
no FIP bias at  $T < 1\text{MK}$   
FIP bias=4 at  $T > 1\text{MK}$



But.. during the 1969 rocket flight  
the Sun was active.

**Strong AR contribution! EVE  
showed that the hot lines vary**

# More active Sun in 1969 (F10.7=177)



~ photospheric abundances until 1 MK, FIP bias about 2 at higher  $T_e$ , in agreement with GDZ previous results (cf. Living Review)

# Conclusions

SDO/EVE has shown the power of spectroscopy, even at low resolution.

The LASP team did an exemplar job to calibrate the data and make them available to the community.

There is still scope for a lot more studies.