Uncertainties in atomic data
(O VII and Fe XIII ratios)

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O VII

- Connor Balance (QUB) has run 12 new calculations for O VII, for 11 of them varying the atomic structure between the H-like and Li-like.

One of them had the He-like target and is comparable with what we have in CHIANTI.

- I have converted the data into CHIANTI format and calculated the two main ratios using the same IDL routines and auxiliary files.
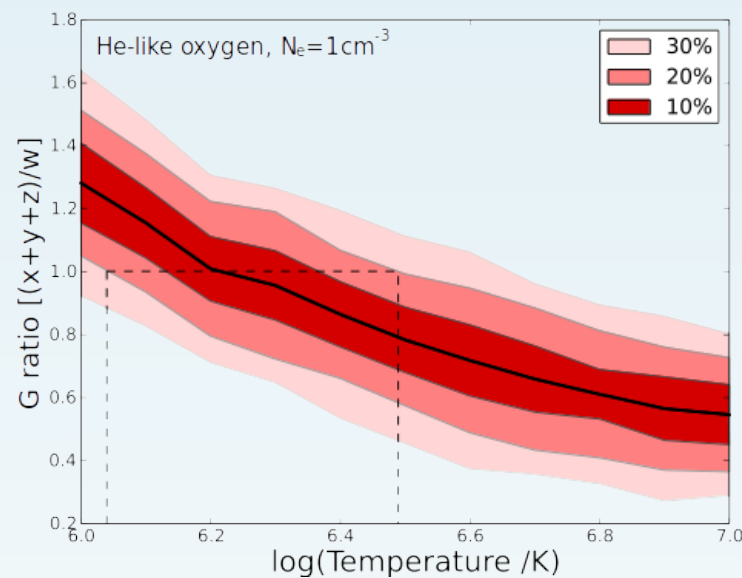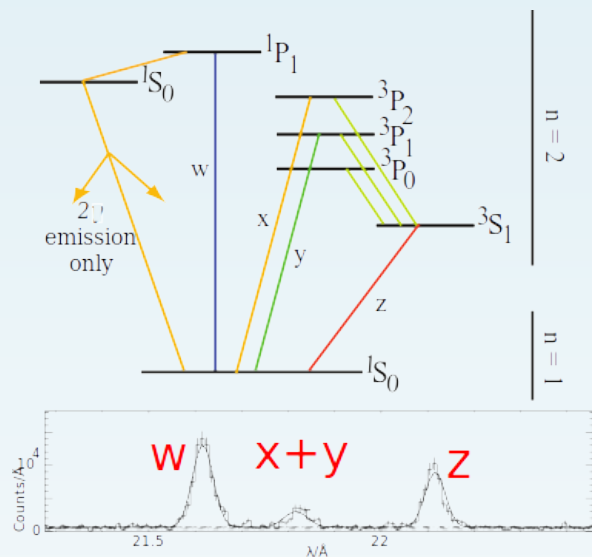
O VII R-ratio (Ne-sensitive)
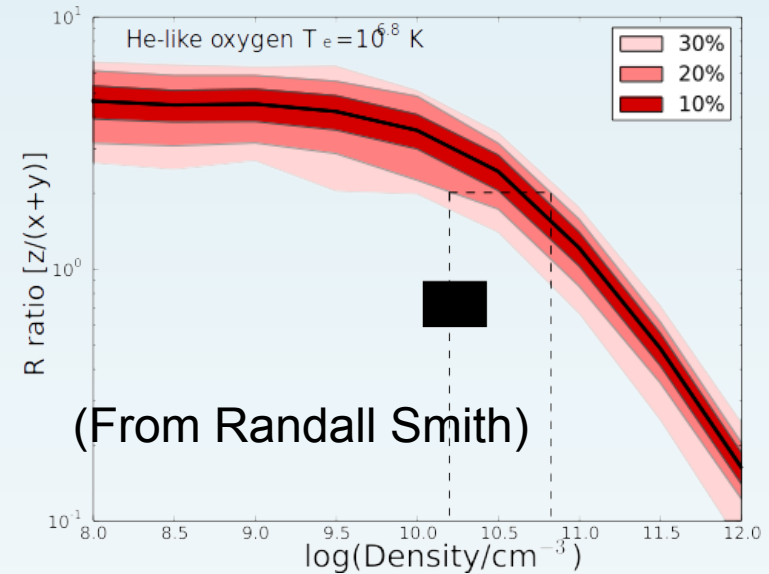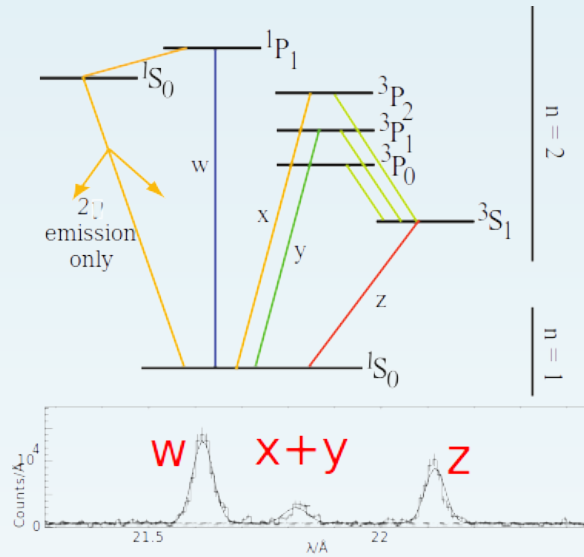
(From Randall Smith)
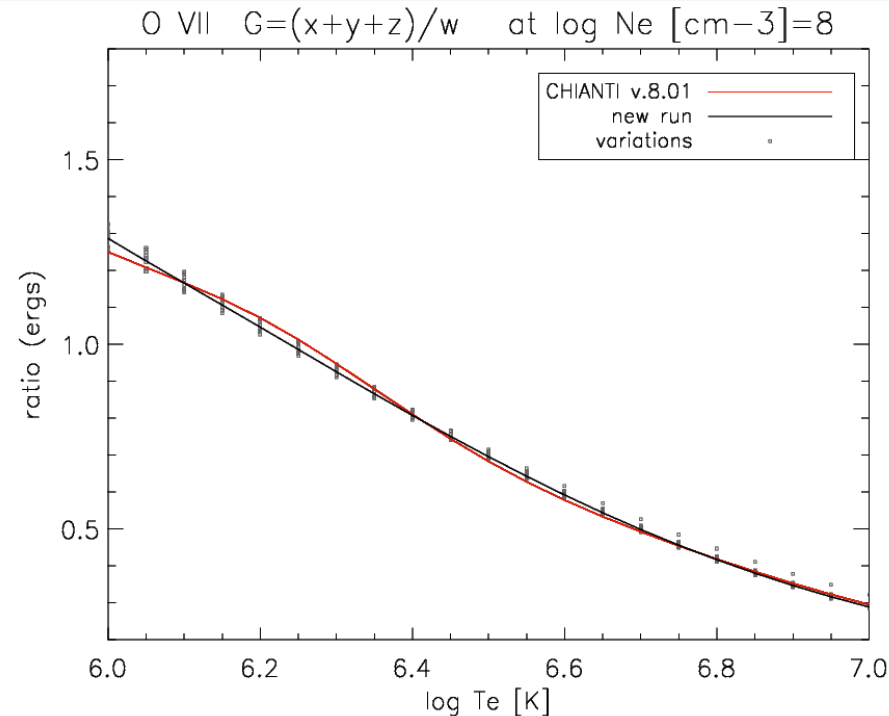
Note: the results of the variations are well centred on the He-like target, but there is a small offset with the CHIANTI data

Peak ion abundance.

Black: He-like target.
Squares: 12 runs
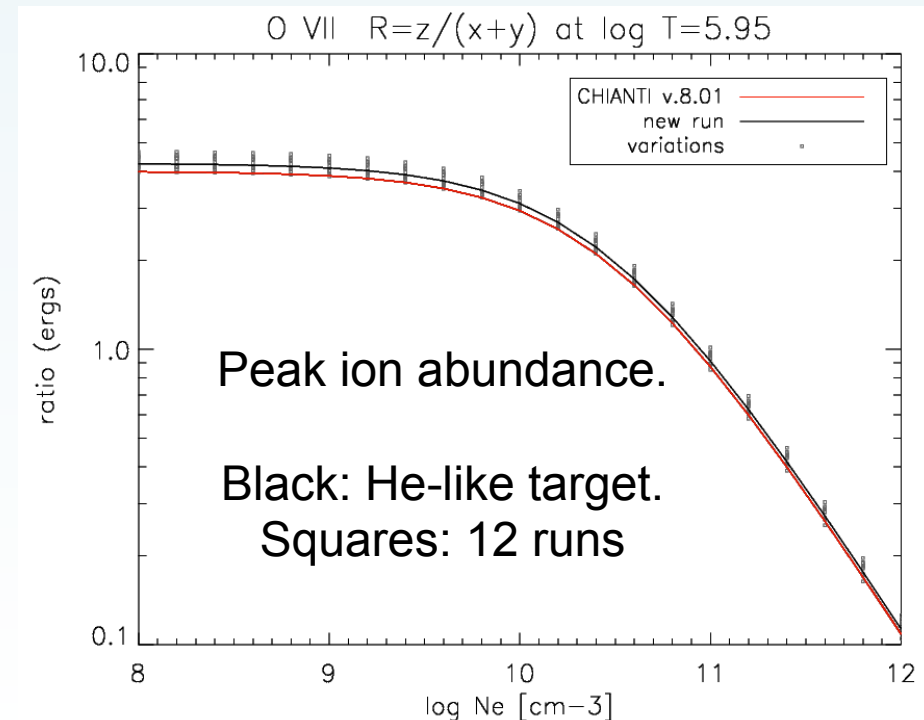
O VII G-ratio (Te-sensitive) at low Ne

(From Randall Smith)

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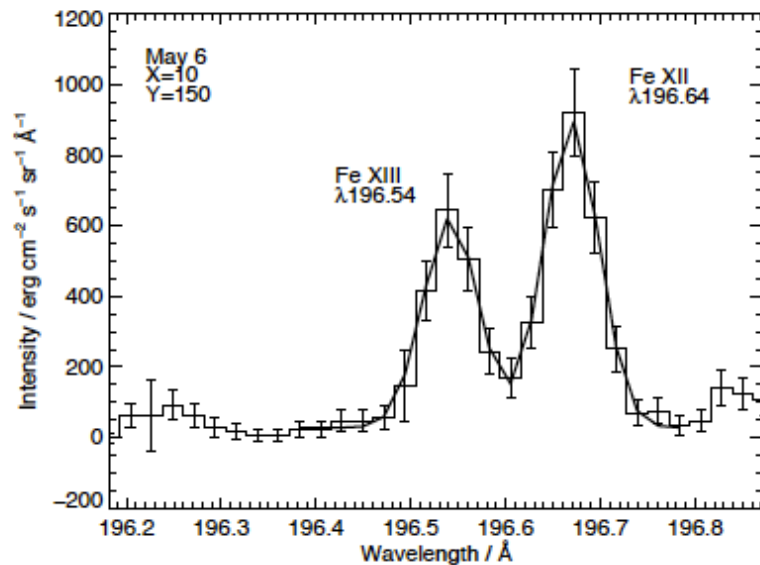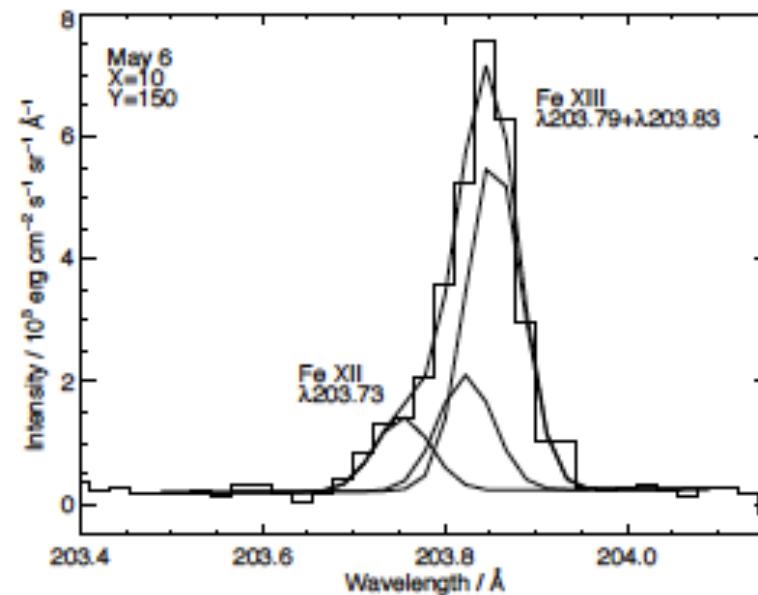
Fe XIII

Fe XIII

Some among the main EUV
Fe XIII lines to measure Ne
as observed with Hinode EIS
(Young et al. 2008)

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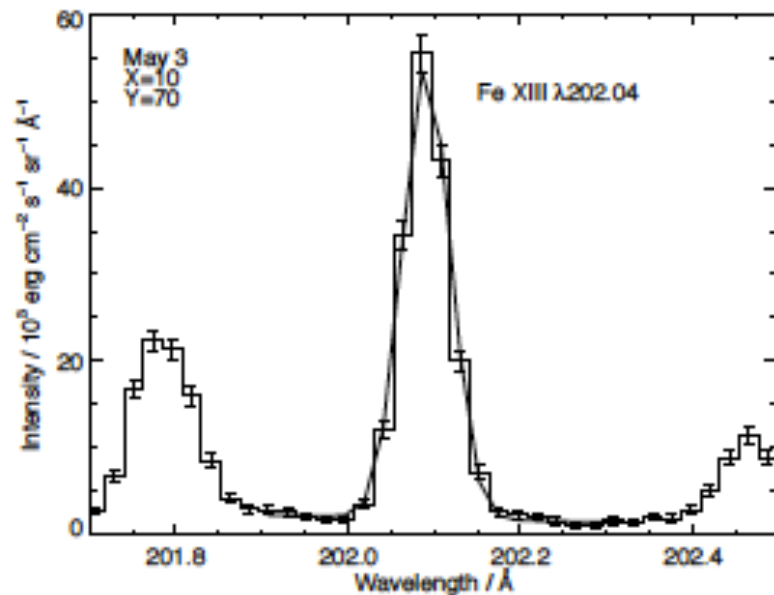
Fe XIII – processes at 10^8 cm^{-3}

(26) 3s^2 3p 3d ^{1}F$_3$

(25) 3s^2 3p 3d ^{3}D$_3$

(24) 3s^2 3p 3d ^{3}D$_2$

(20) 3s^2 3p 3d ^{3}P$_1$

3s^2 3p^2 ^{1}D$_2$

3s^2 3p^2 ^{3}P$_2$

3s^2 3p^2 ^{3}P$_1$

3s^2 3p^2 ^{3}P$_0$

196.6 Å

203.83 Å

203.79 Å

202 Å

Å

24%

10%

10%

43%

19%

34%

11%

78%

47%

97%

64%

75%

90%
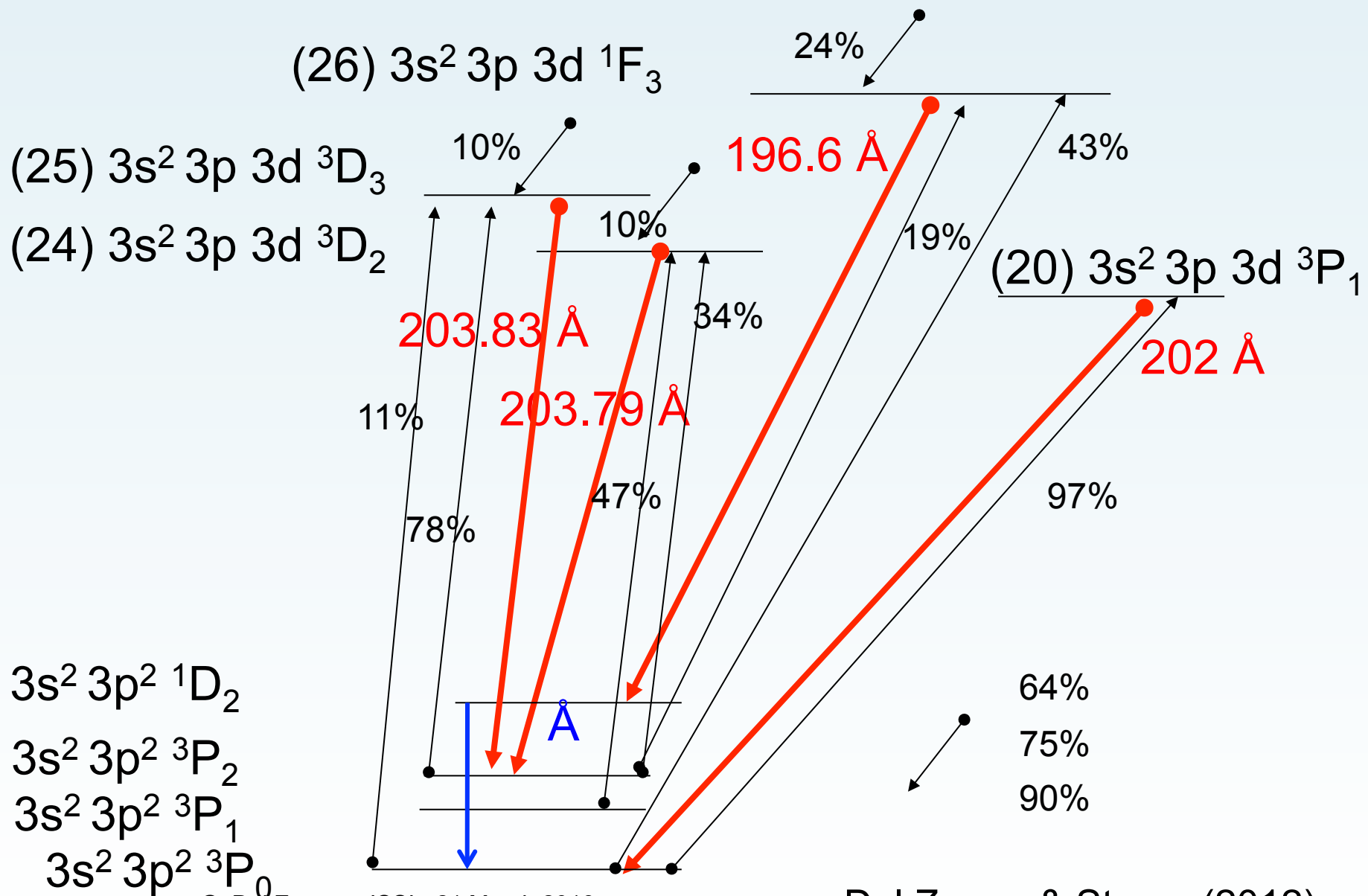
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Del Zanna & Storey (2012)
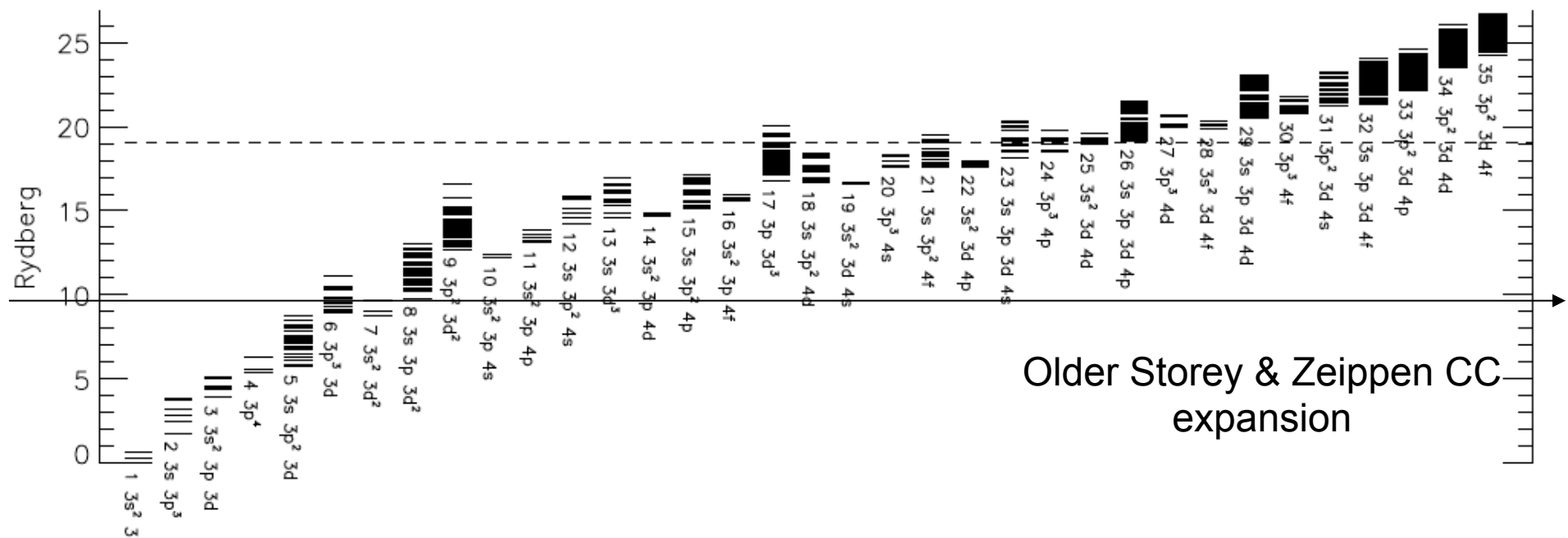
Del Zanna & Storey (2012, A&A): largest scattering calculation to date, included in CHIANTI v.8 (Del Zanna+2015, A&A).

Malinovski & Heroux (1973) – CHIANTI v6

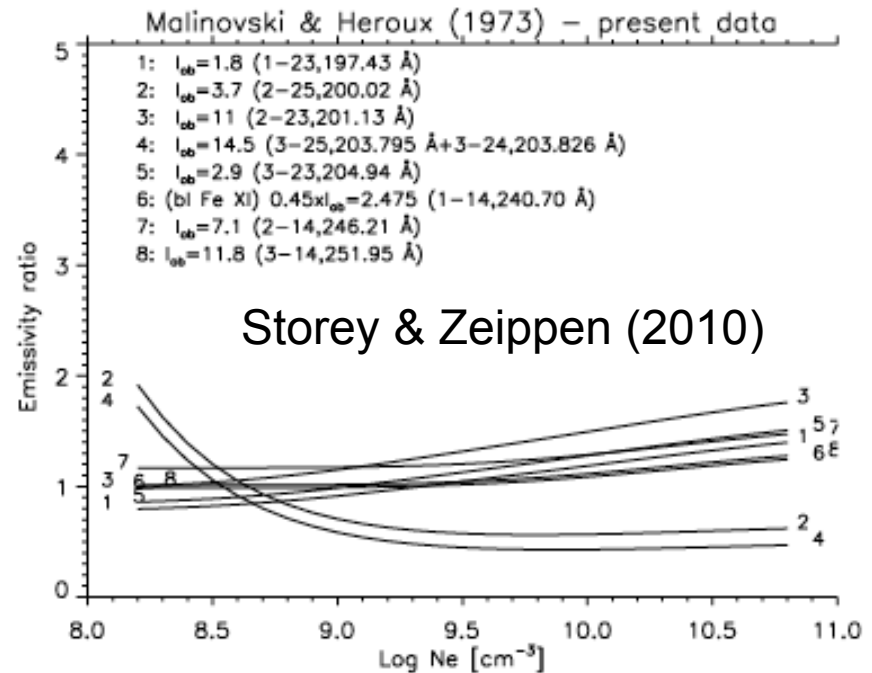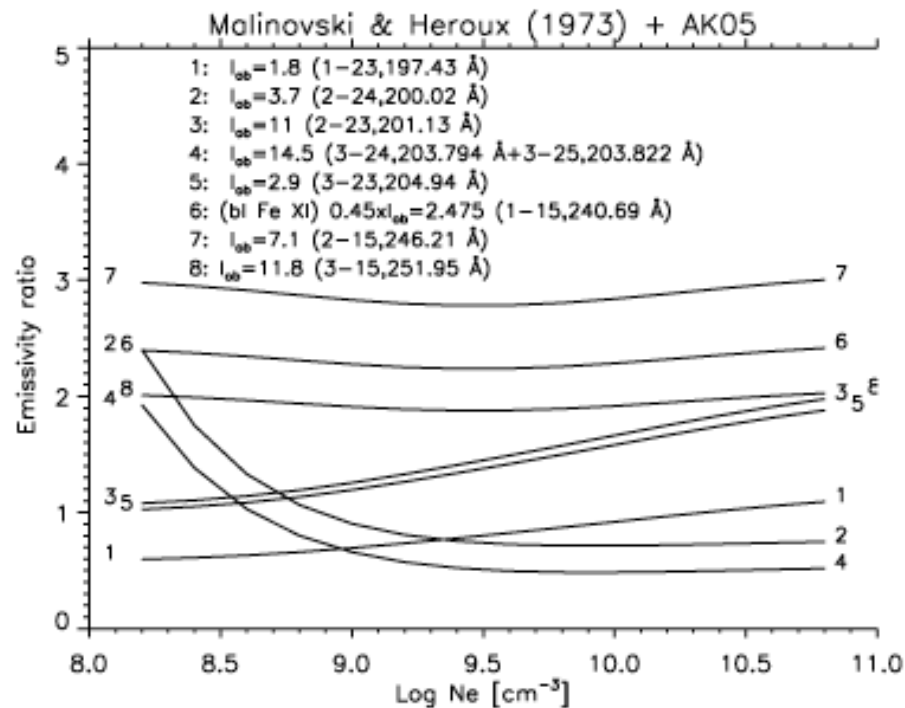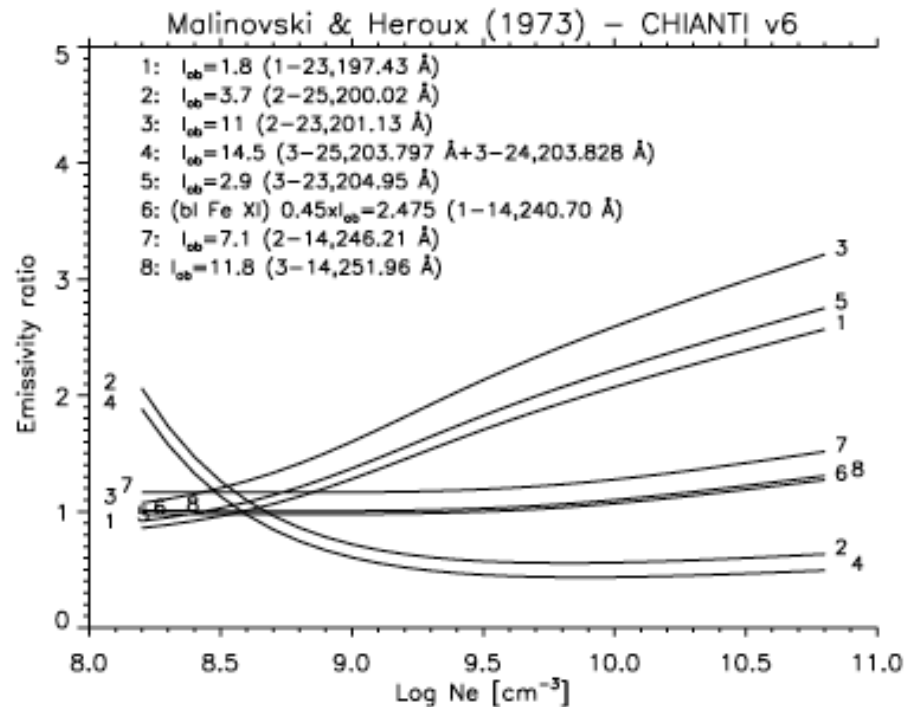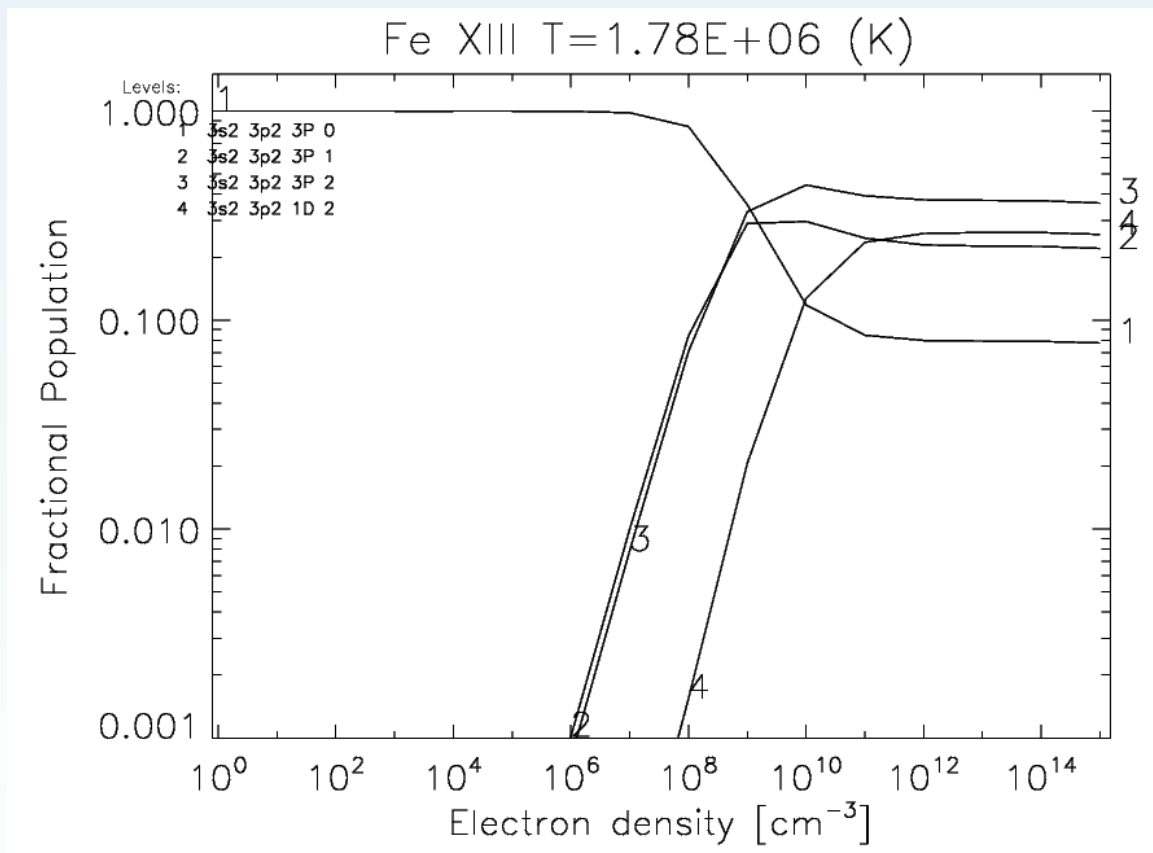1: I_{ob}=1.8 (1–23,197.43 Å)
2: I_{ob}=3.7 (2–25,200.02 Å)
3: I_{ob}=11 (2–23,201.13 Å)
4: I_{ob}=14.5 (3–25,203.797 Å+3–24,203.828 Å)
5: I_{ob}=2.9 (3–23,204.95 Å)
6: (bl Fe XI) 0.45xI_{ob}=2.475 (1–14,240.70 Å)
7: I_{ob}=7.1 (2–14,246.21 Å)
8: I_{ob}=11.8 (3–14,251.96 Å)

Malinovski & Heroux (1973) – present data

1: I_{ob}=1.8 (1–23,197.43 Å)
2: I_{ob}=3.7 (2–25,200.02 Å)
3: I_{ob}=11 (2–23,201.13 Å)
4: I_{ob}=14.5 (3–25,203.795 Å+3–24,203.826 Å)
5: I_{ob}=2.9 (3–23,204.94 Å)
6: (bl Fe XI) 0.45xI_{ob}=2.475 (1–14,240.70 Å)
7: I_{ob}=7.1 (2–14,246.21 Å)
8: I_{ob}=11.8 (3–14,251.95 Å)

Storey & Zeippen (2010)

Malinovski & Heroux (1973) + AK05

1: I_{ob}=1.8 (1–23,197.43 Å)
2: I_{ob}=3.7 (2–24,200.02 Å)
3: I_{ob}=11 (2–23,201.13 Å)
4: I_{ob}=14.5 (3–24,203.794 Å+3–25,203.822 Å)
5: I_{ob}=2.9 (3–23,204.94 Å)
6: (bl Fe XI) 0.45xI_{ob}=2.475 (1–15,240.69 Å)
7: I_{ob}=7.1 (2–15,246.21 Å)
8: I_{ob}=11.8 (3–15,251.95 Å)

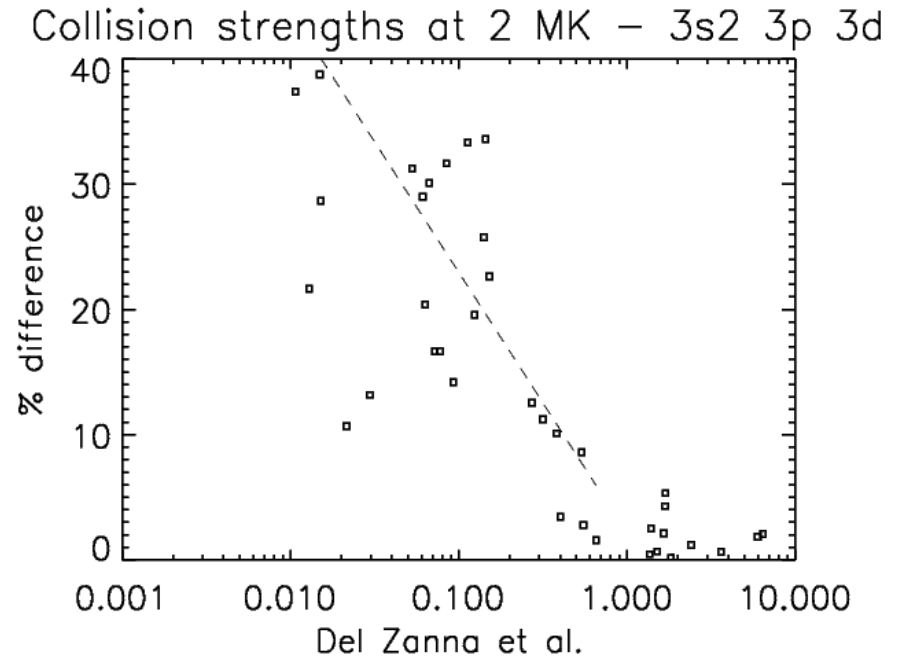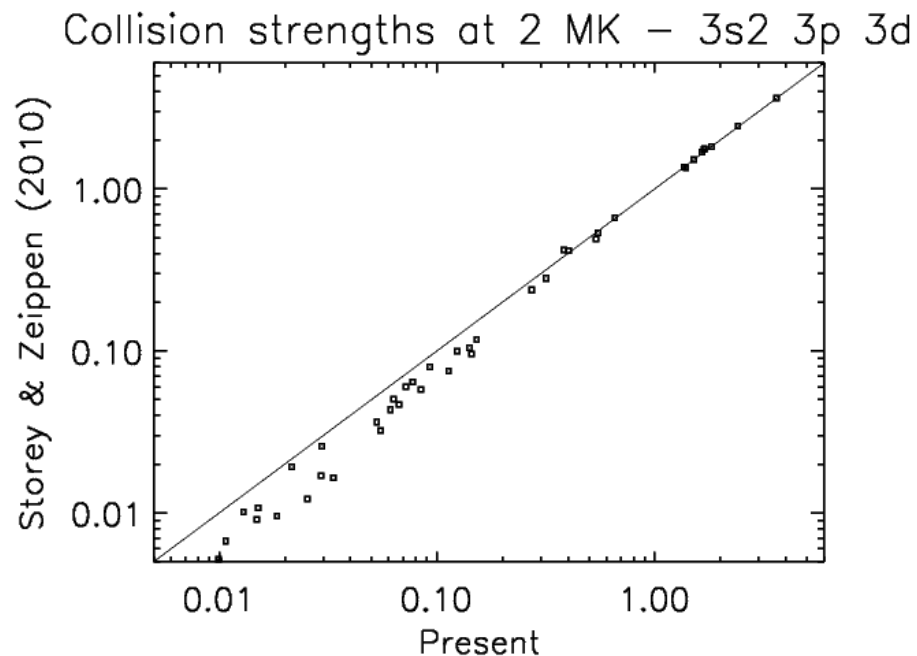Large problems with atomic data of Aggarwal & Keenan 2005.

Gupta & Tayal (1998) – CHIANTI v6 and Storey & Zeippen show good agreement with observations.

(see Del Zanna A&A 533, A12, 2011)

For the collision data, I have considered only transitions from the first four levels, which are populating all the other ones. I have taken 2 MK, the peak Te in equilibrium.

Fe XIII T=1.78E+06 (K)

Levels:
1 3s2 3p2 3P 0
2 3s2 3p2 3P 1
3 3s2 3p2 3P 2
4 3s2 3p2 1D 2

Level population
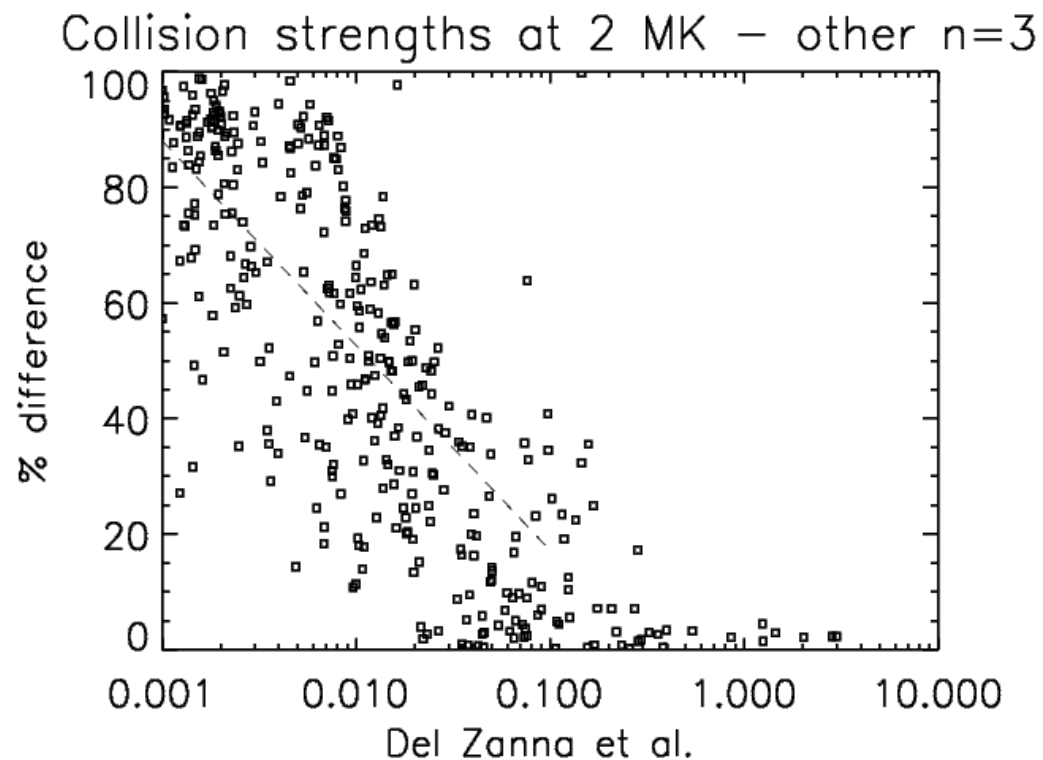
Collision strengths at 2 MK − 3s2 3p 3d

Percentage differences
compared to Storey & Zeippen (2010)
at peak Te=2 MK.

Effective collision strengths to the 3s2 3p 3d are the main populating process for the important EUV lines. The Del Zanna calculations have typically larger values because of the larger target.

I have taken 2% for the few transitions above 1., and the linear variation shown with the dashed line for the weaker ones (maximum of 50%).

Could try 5% for the strongest lines in the next iteration.

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Collision strengths at 2 MK − other n=3

The differences with all the other n=3 transitions in the Storey and Zeippen calculations are similar.
I have taken a generous 10% for transitions above 0.1,
then a linear increase for weaker ones (up to a cap of 50%).

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Collision strengths at 2 MK – other n=3,4
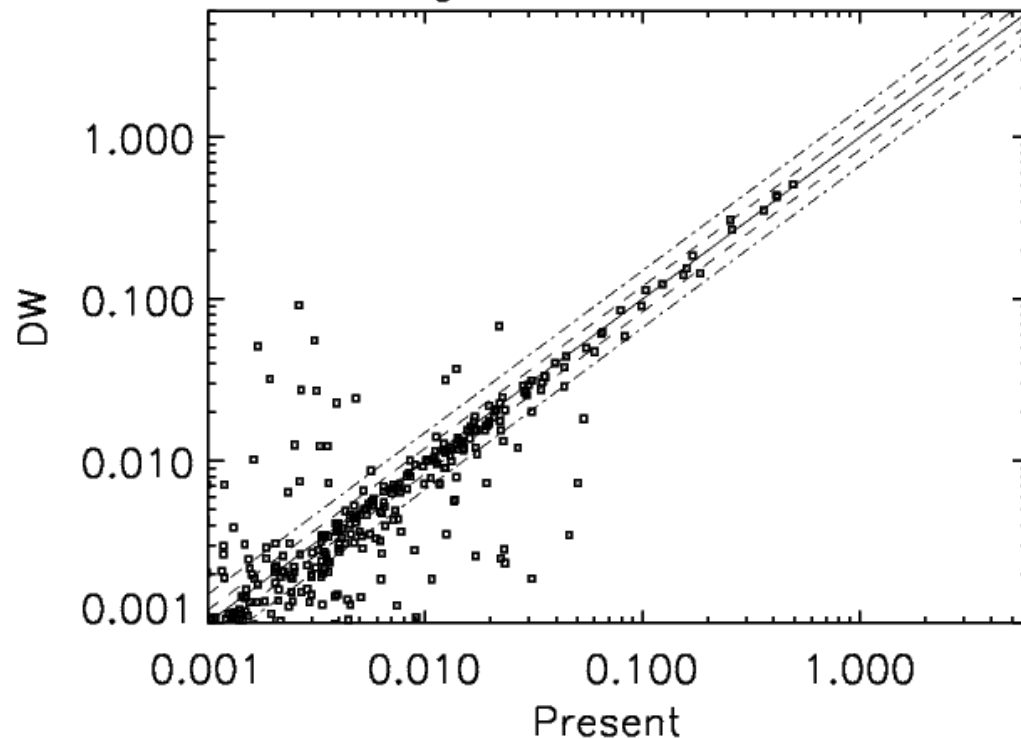
Dashed lines: +/- 20%
Dot-dashed lines: +/- 50%

I have taken a 20% for the transitions above 0.01 and 50% for the weaker transitions

The Del Zanna calculations have 749 levels up to n=4. One possible estimate for all the n=3 levels not included in Storey and Zeippen and all the n=4 levels is to compare the full scattering calculation with the results of a distorted-wave (DW) calculation, which does not include resonance enhancements. The levels indexing had to be matched.
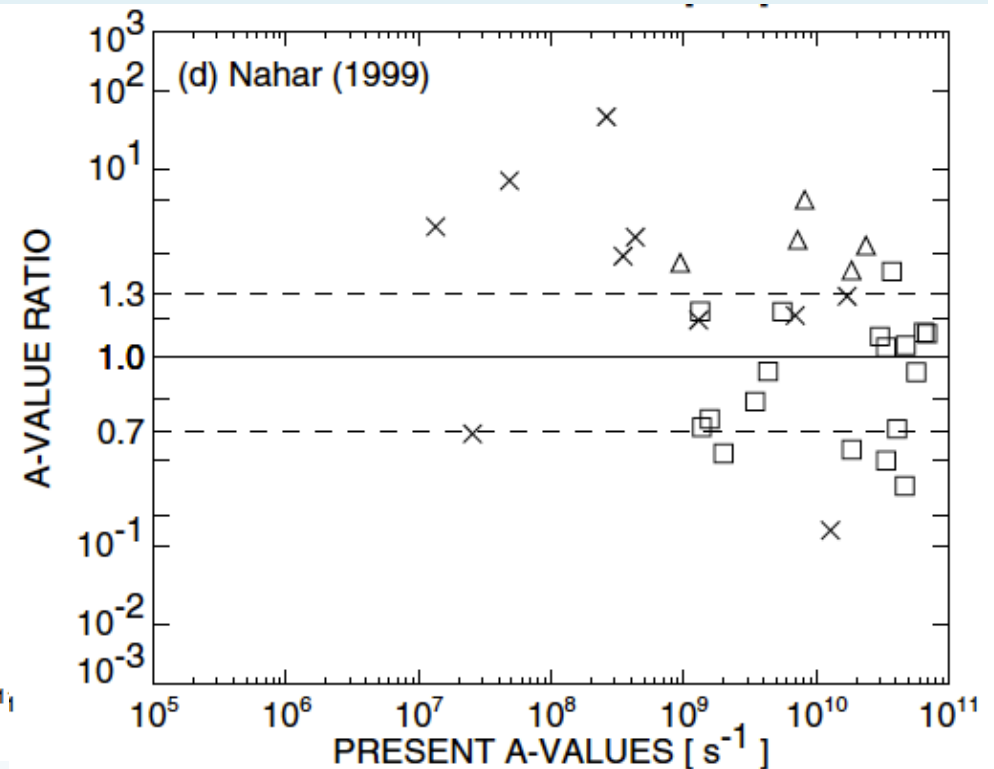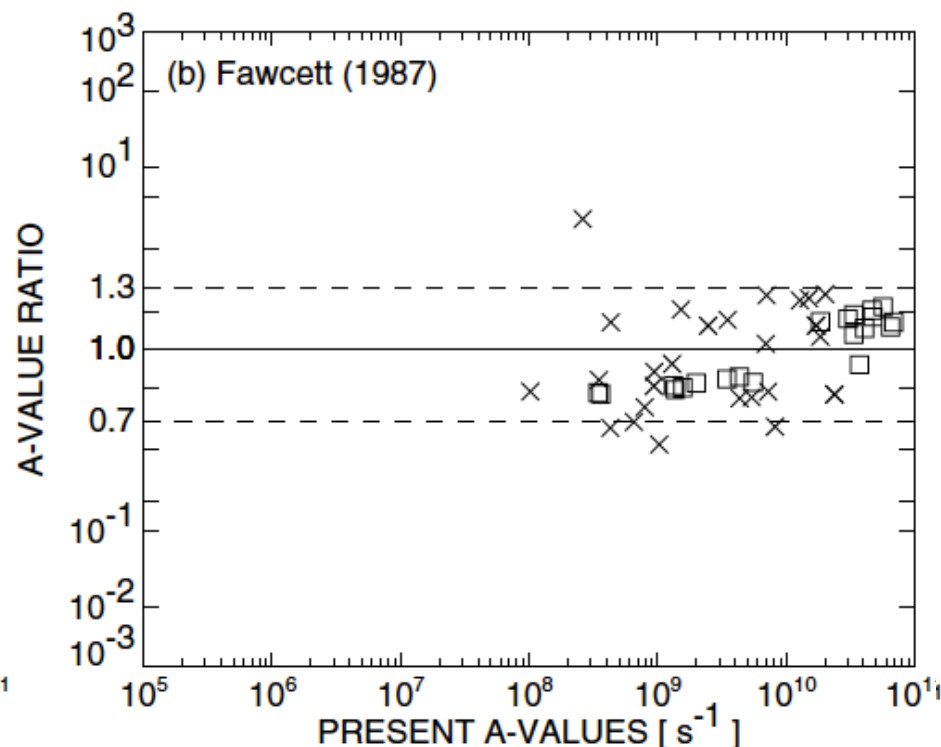
Young (2004) performed atomic structure calculations with semi-empirical corrections. In some case, large differences in the A-values of the strong allowed transitions were found.
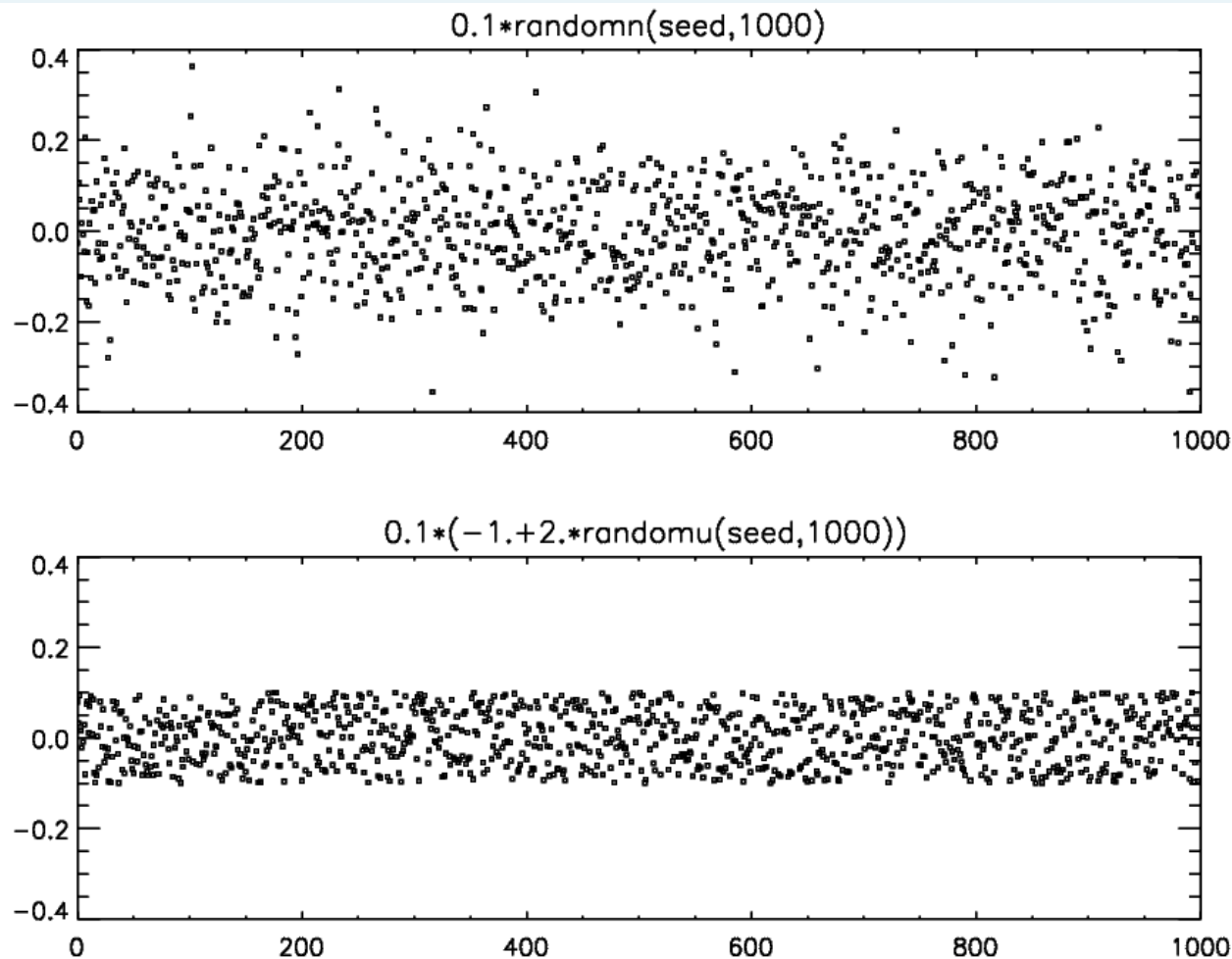
Fe XIII A-values

A-values for lowest 27 levels
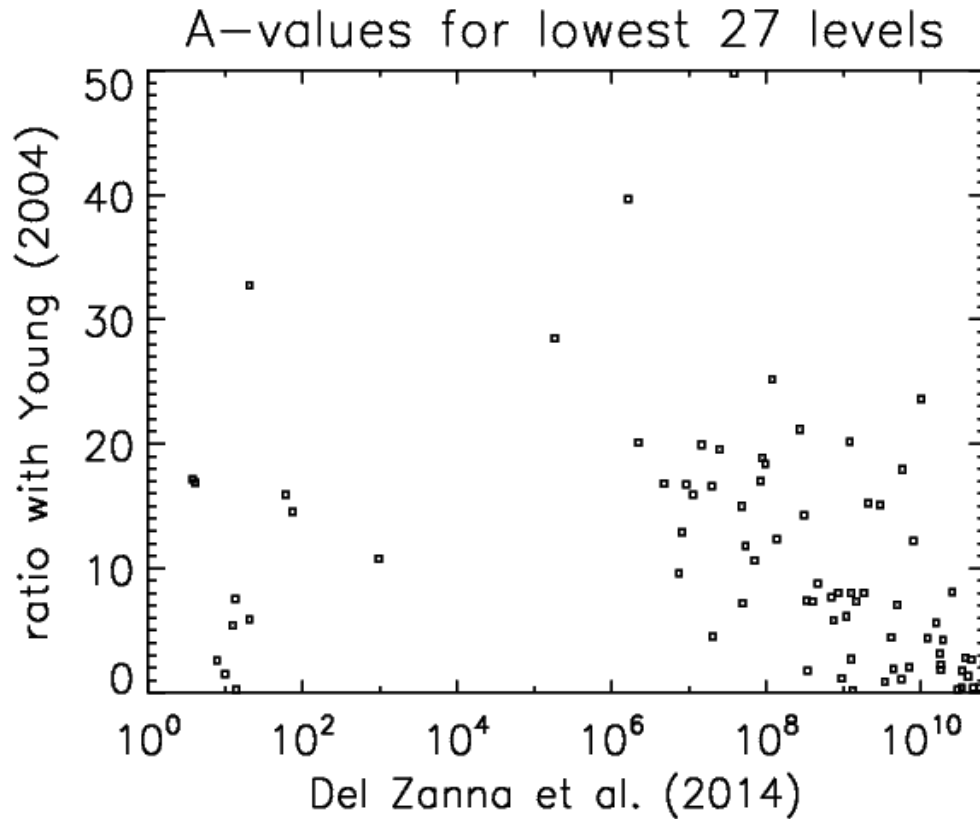
The A-values among the lowest 27 (n=3) levels are the main ones for the EUV lines of interest.

I have taken for transitions above 10^{10}: 5%, between 10^8 and 10^{10} 10%, while for weaker transitions 30%.
For the weak transitions within the ground configuration: 10%
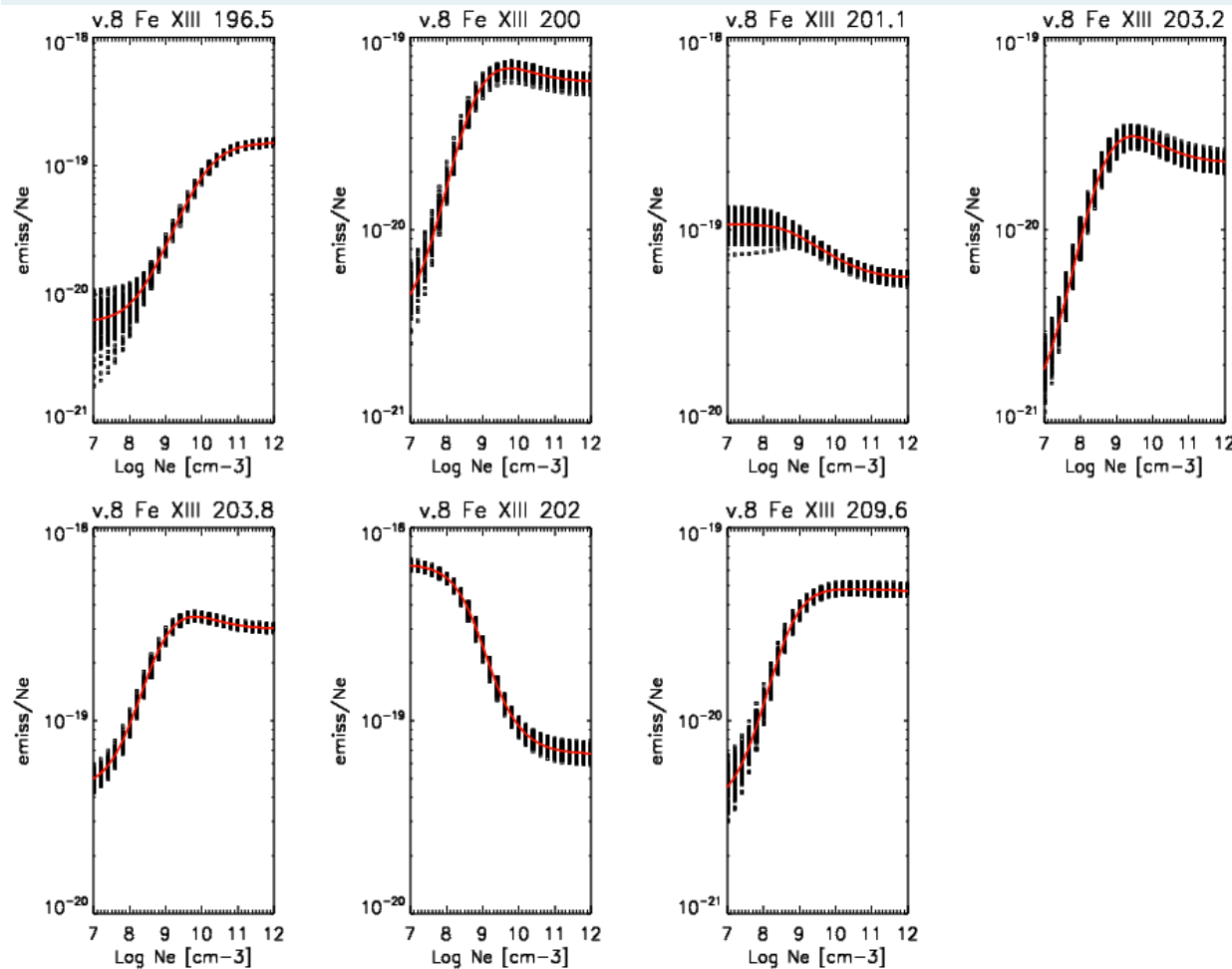
Random variations (IDL)

Once the level-resolved uncertainties have been given, the issue is how to randomly vary them. I have adopted the top option, a normal distribution. This means that, e.g. for a 10% uncertainty, most values will have values +/- 20%. This means a 40% variation.

0.1*randomn(seed,1000)

0.1*(−1.+2.*randomu(seed,1000))

A 1000 realizations of a 10% uncertainty, using the normal distribution (above) and the uniform one (below)
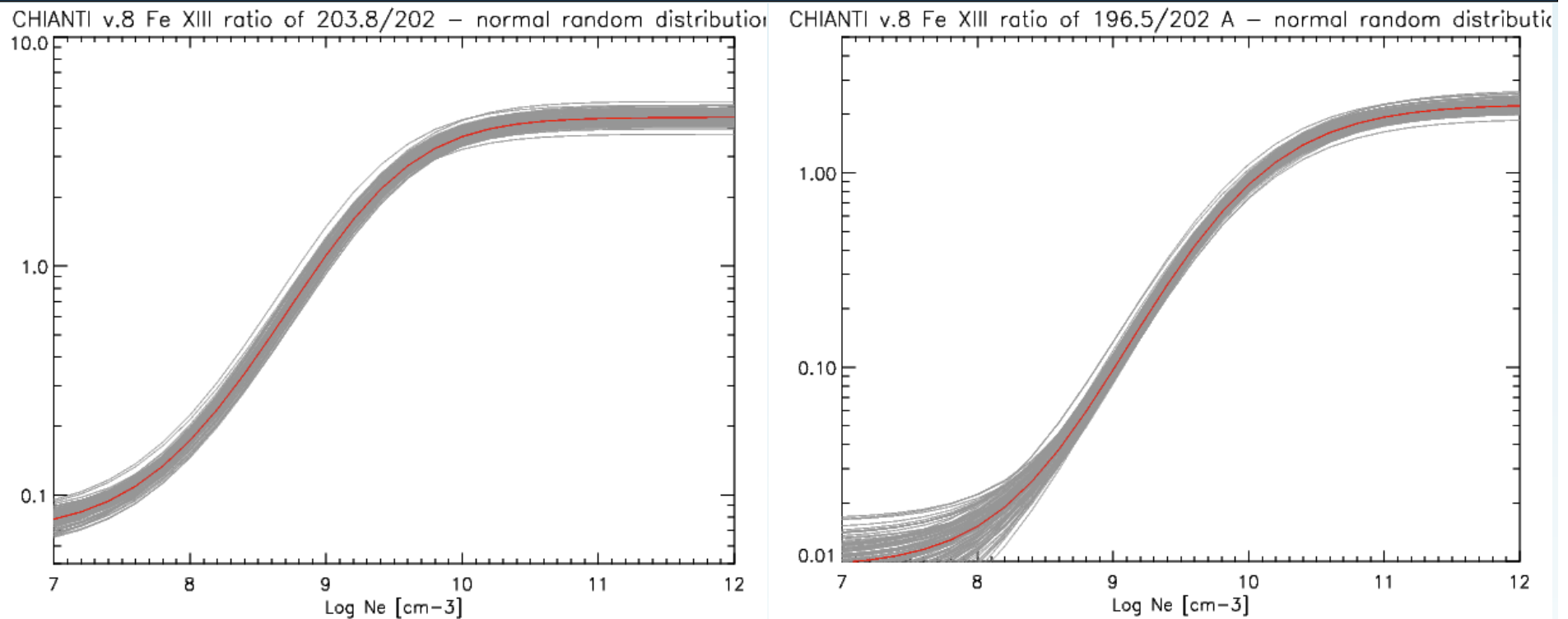
Fe XIII emissivities

The emissivities have been calculated with the above random variations of both the excitation rates and the A-values.

Emissivities/ Ne for the main 7 Hinode EIS lines, calculated with CHIANTI v.8 (red lines) and with the random variations.
Note: self-blends are taken into account.

Fe XIII main ratios

The grey lines are the 100 random realizations, the red lines are the standard CHIANTI values.