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

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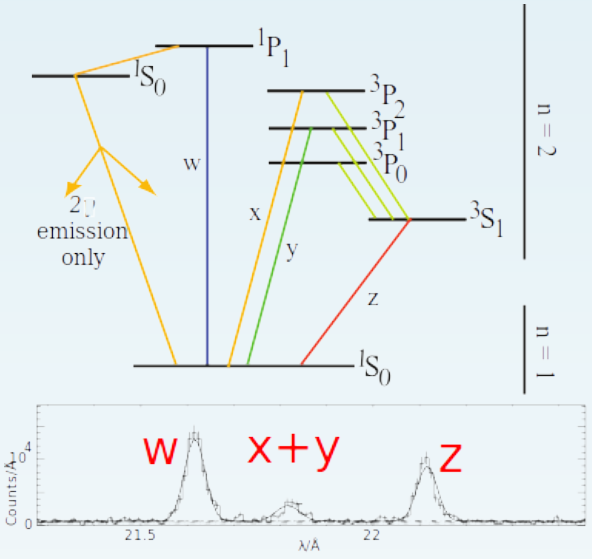
O VII

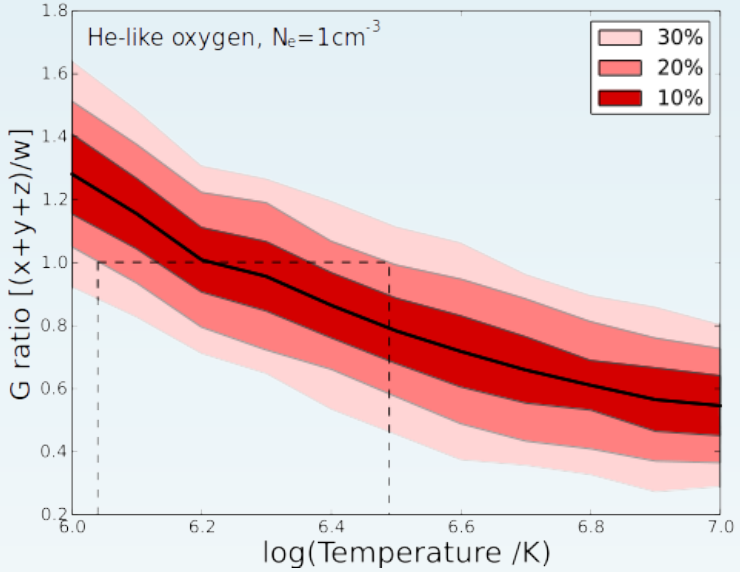
Connor Balance (QUB) has run 12 new calculations for O VII, for 11 of them varying the atomic structure between the H-like and Li-like.

One of them had the He-like target and is comparable with what we have in CHIANTI version 8 (Del Zanna+2015) which is from Whiteford+, using the same codes + radiation damping.

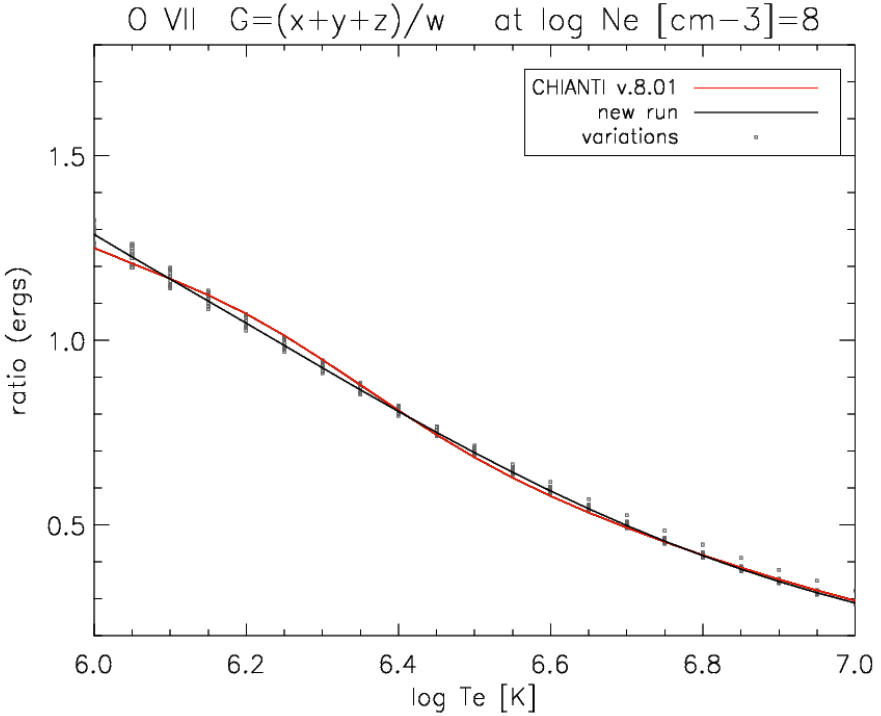
I have converted the data into CHIANTI format and calculated the two main ratios using the same IDL routines and auxiliary files as in the CHIANTI database.

O VII G-ratio (Te-sensitive) at low Ne





(From Randall Smith)



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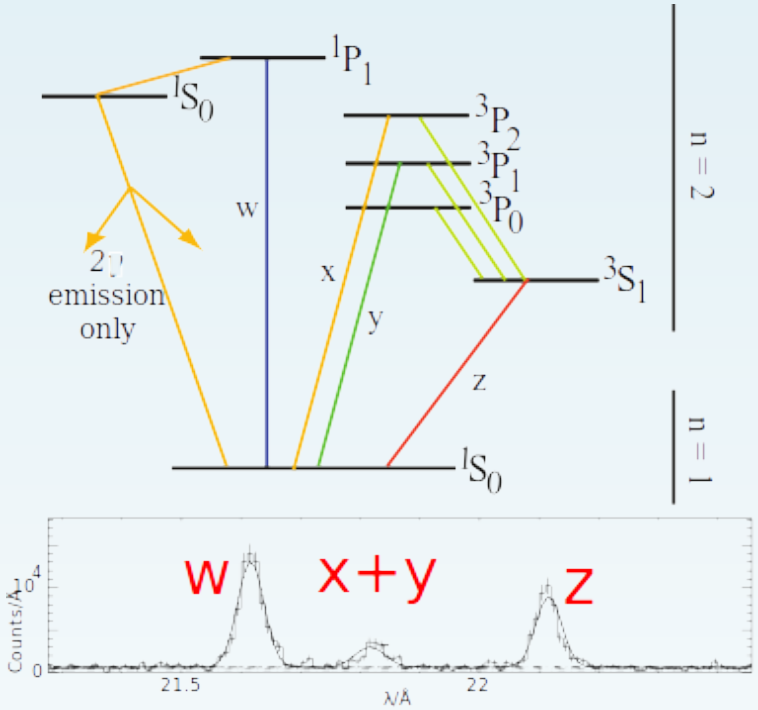
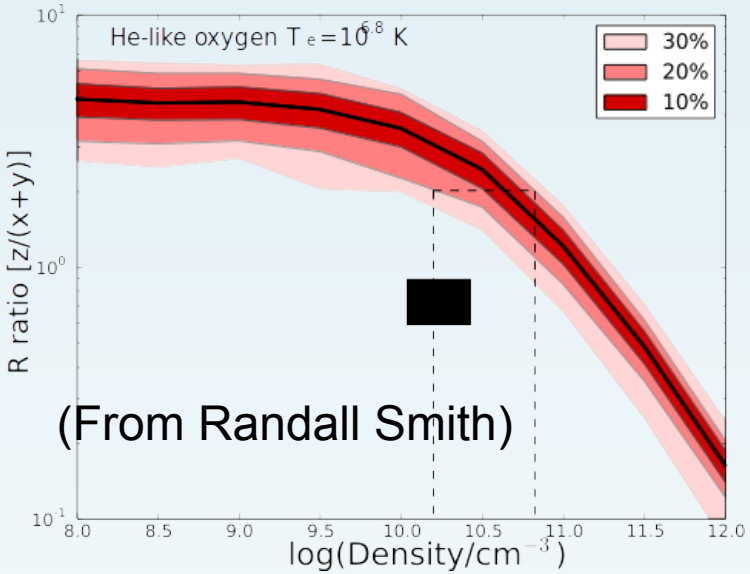
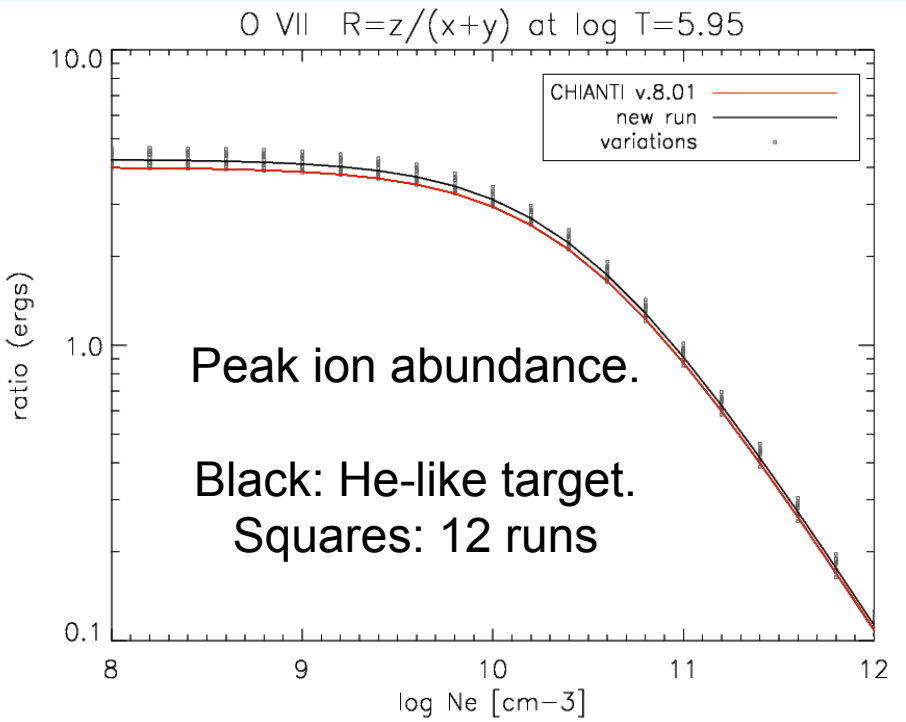
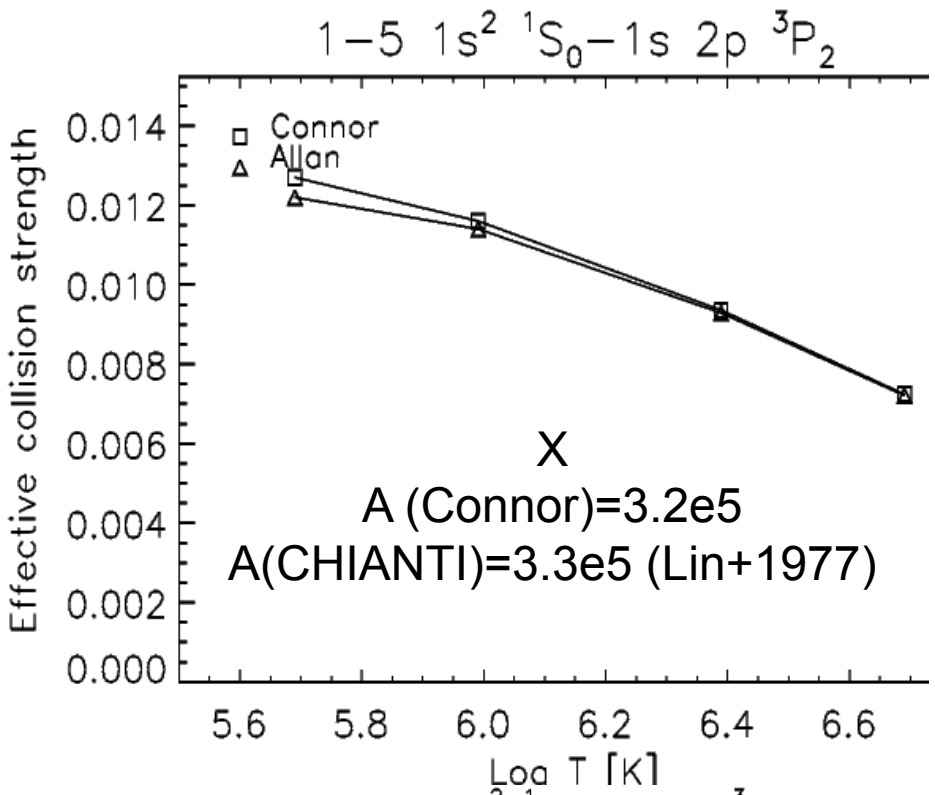
O VII R-ratio (Ne-sensitive)

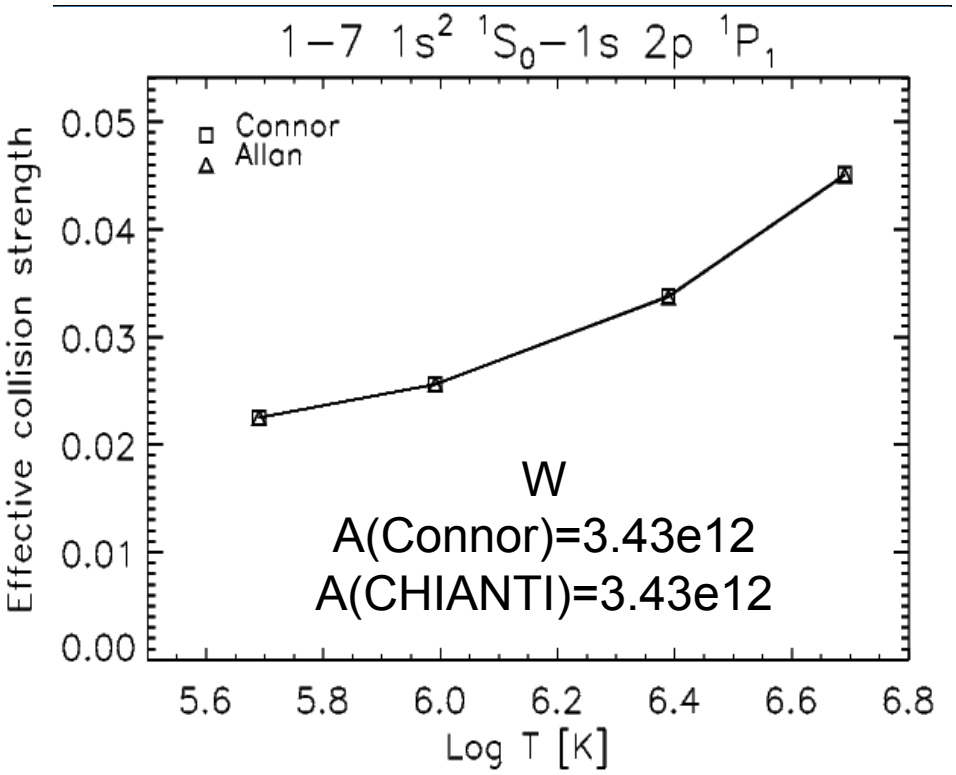


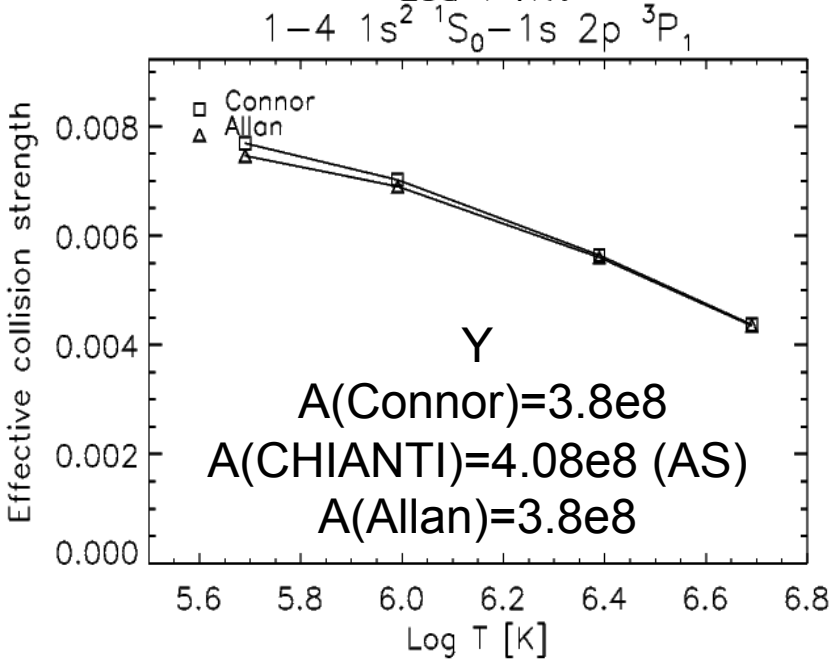


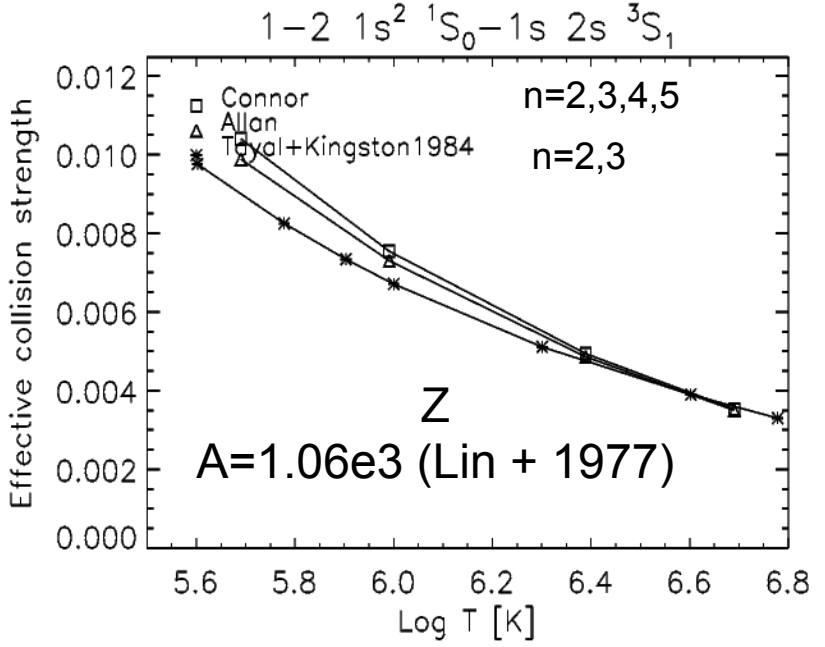
Note: the results of the variations are well centred on the He-like target, but there is a small offset with the CHIANTI data



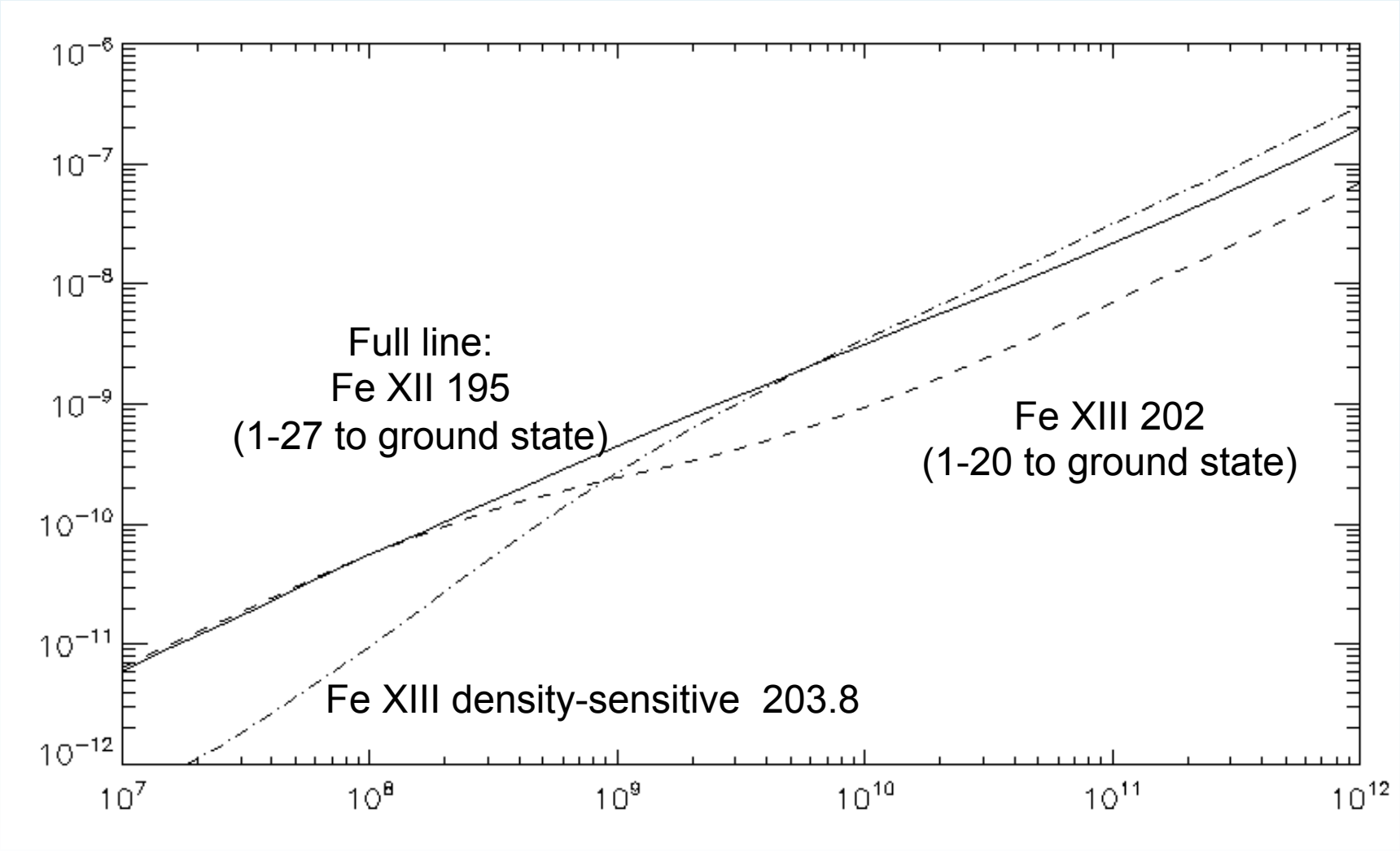

1−5 1s² ¹S₀−1s 2p ³P₂
Effective collision strength
Log T [K]
Connor
Allan
X
A (Connor)=3.2e5
A(CHIANTI)=3.3e5 (Lin+1977)

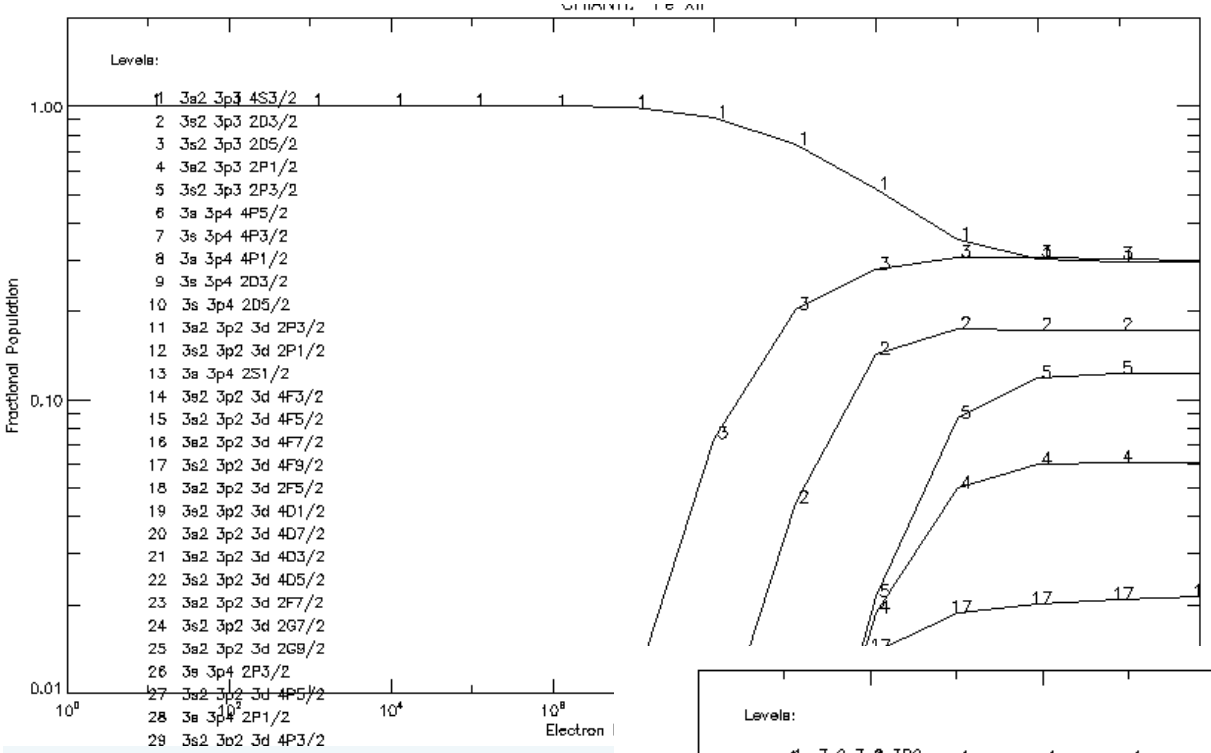

1−7 1s² ¹S₀−1s 2p ¹P₁
Effective collision strength
Log T [K]
Connor
Allan
W
A(Connor)=3.43e12
A(CHIANTI)=3.43e12

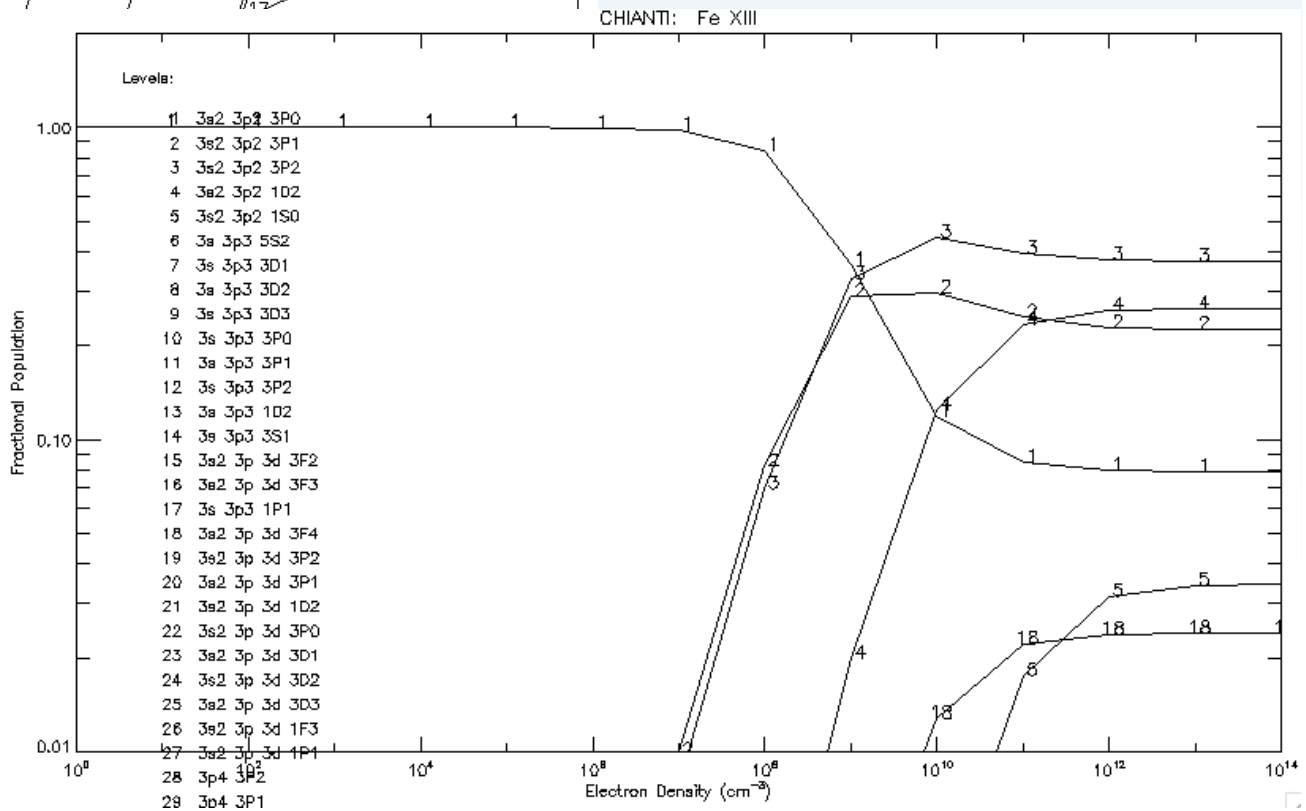

1−4 1s² ¹S₀−1s 2p ³P₁
Effective collision strength
Log T [K]
Connor
Allan
Y
A(Connor)=3.8e8
A(CHIANTI)=4.08e8 (AS)
A(Allan)=3.8e8


1−2 1s² ¹S₀−1s 2s ³S₁
Effective collision strength
Log T [K]
Connor
Allan
Tayal+Kingston1984
n=2,3,4,5
n=2,3
Z
A=1.06e3 (Lin + 1977)

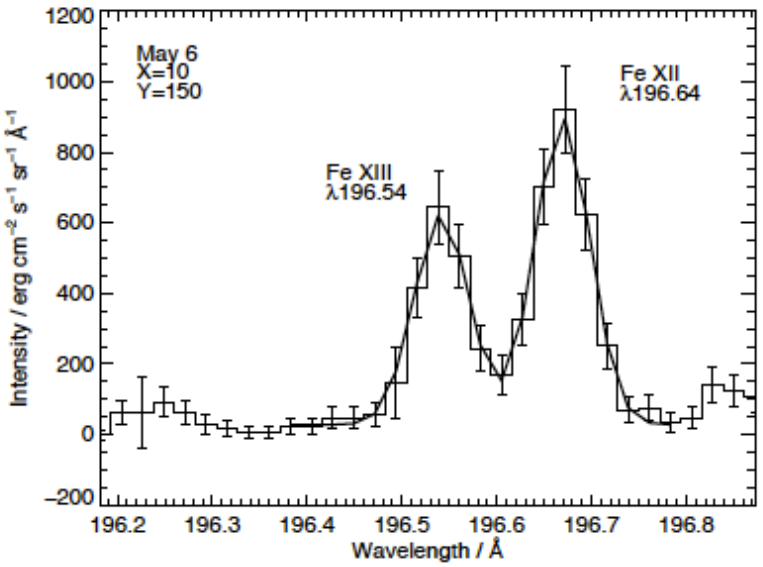
Emissivities



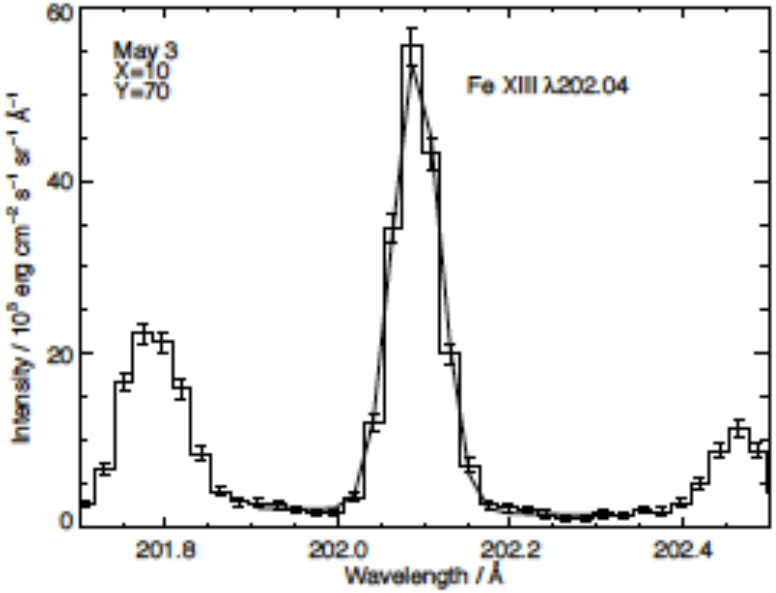

Levels:
1 3s2 3p3 4S3/2
2 3s2 3p3 2D3/2
3 3s2 3p3 2D5/2
4 3s2 3p3 2P1/2
5 3s2 3p3 2P3/2
6 3s 3p4 4P5/2
7 3s 3p4 4P3/2
8 3s 3p4 4P1/2
9 3s 3p4 2D3/2
10 3s 3p4 2D5/2
11 3s2 3p2 3d 2P3/2
12 3s2 3p2 3d 2P1/2
13 3s 3p4 2S1/2
14 3s2 3p2 3d 4F3/2
15 3s2 3p2 3d 4F5/2
16 3s2 3p2 3d 4F7/2
17 3s2 3p2 3d 4F9/2
18 3s2 3p2 3d 2F5/2
19 3s2 3p2 3d 4D1/2
20 3s2 3p2 3d 4D7/2
21 3s2 3p2 3d 4D3/2
22 3s2 3p2 3d 4D5/2
23 3s2 3p2 3d 2F7/2
24 3s2 3p2 3d 2G7/2
25 3s2 3p2 3d 2G9/2
26 3s 3p4 2P3/2
27 3s2 3p2 3d 4P5/2
28 3s 3p4 2P1/2
29 3s2 3p2 3d 4P3/2
1.00
0.10
0.01
Fractional Population
Electron

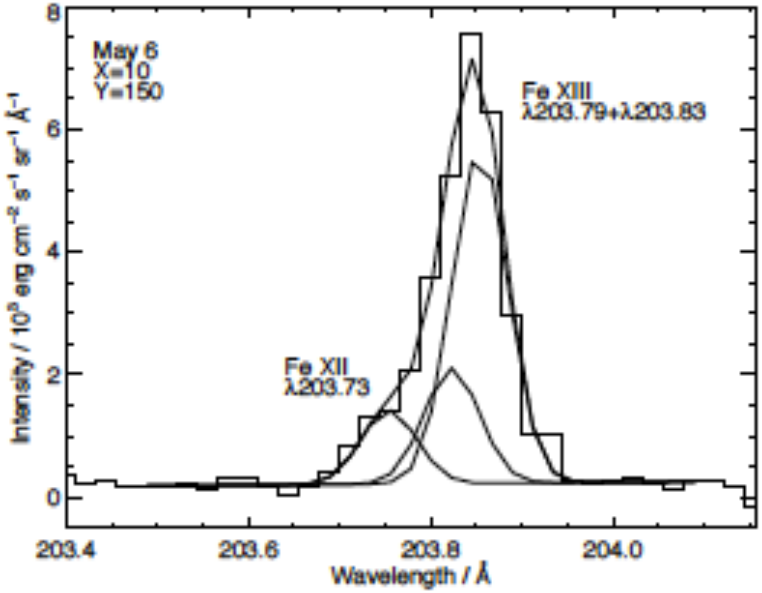

CHIANTI: Fe XIII
Levels:
1 3s2 3p2 3P0
2 3s2 3p2 3P1
3 3s2 3p2 3P2
4 3s2 3p2 1D2
5 3s2 3p2 1S0
6 3s 3p3 5S2
7 3s 3p3 3D1
8 3s 3p3 3D2
9 3s 3p3 3D3
10 3s 3p3 3P0
11 3s 3p3 3P1
12 3s 3p3 3P2
13 3s 3p3 1D2
14 3s 3p3 3S1
15 3s2 3p 3d 3F2
16 3s2 3p 3d 3F3
17 3s 3p3 1P1
18 3s2 3p 3d 3F4
19 3s2 3p 3d 3P2
20 3s2 3p 3d 3P1
21 3s2 3p 3d 1D2
22 3s2 3p 3d 3P0
23 3s2 3p 3d 3D1
24 3s2 3p 3d 3D2
25 3s2 3p 3d 3D3
26 3s2 3p 3d 1F3
27 3s2 3p 3d 1P1
28 3p4 3P2
29 3p4 3P1
1.00
0.10
0.01
Fractional Population
Electron Density (cm⁻³)

Fe XIII

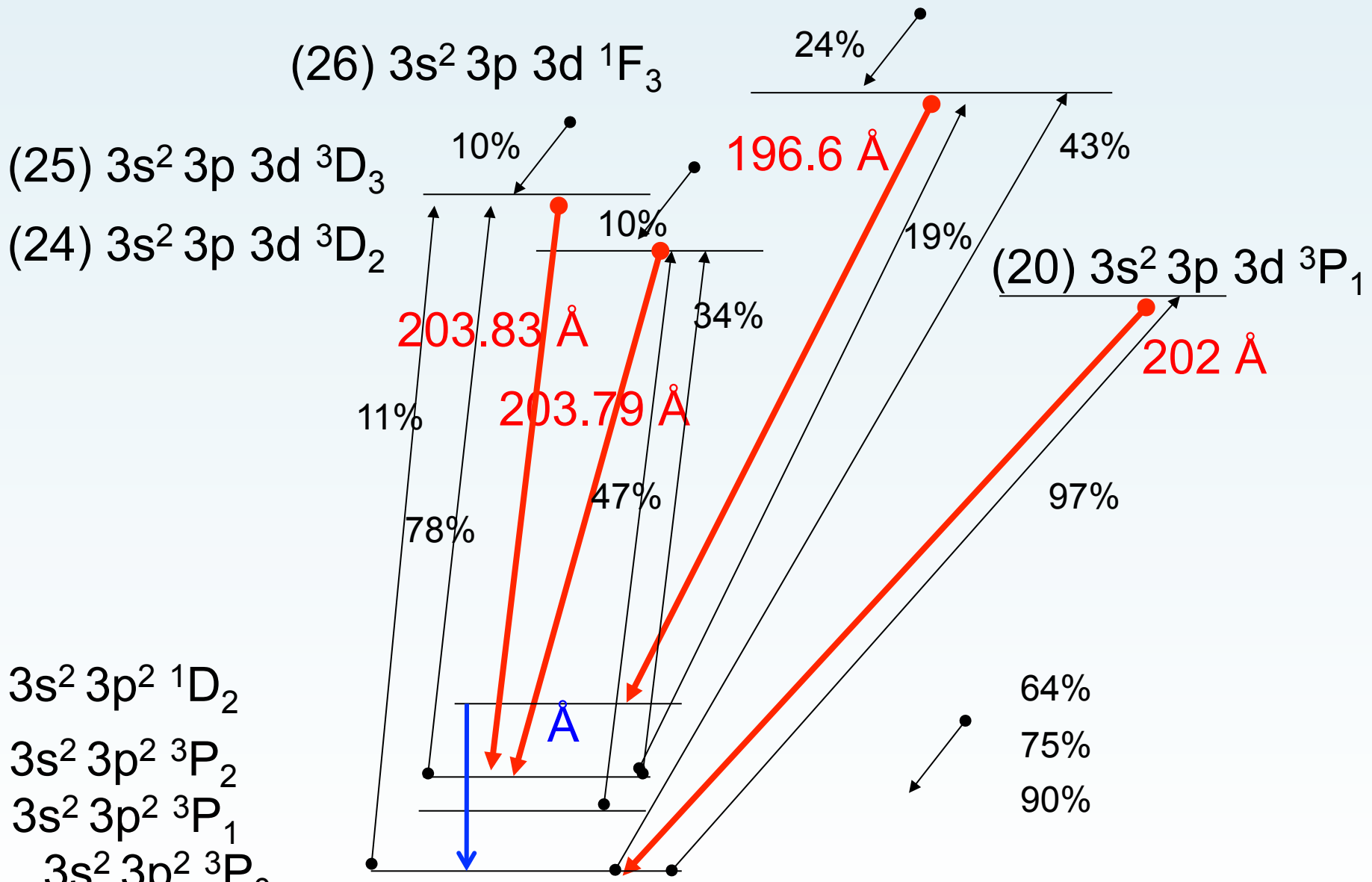


Some among the main EUV Fe XIII lines to measure Ne as observed with Hinode EIS (Young et al. 2008)

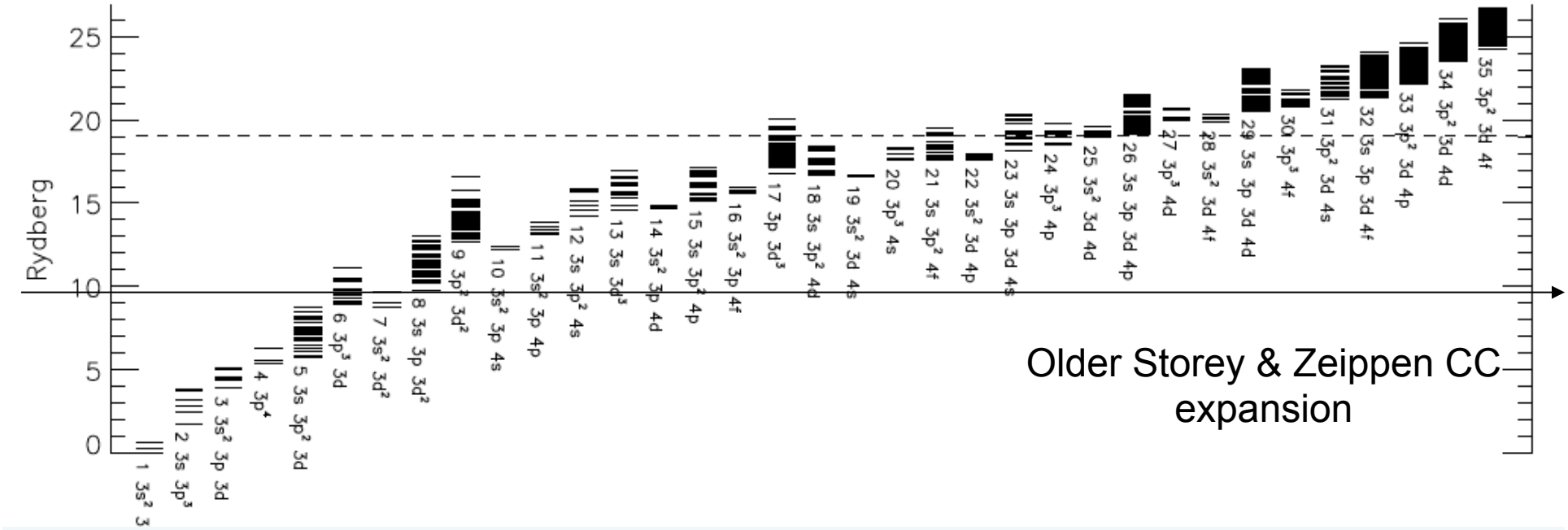




Fe XIII – processes at 10^8 cm^{-3}

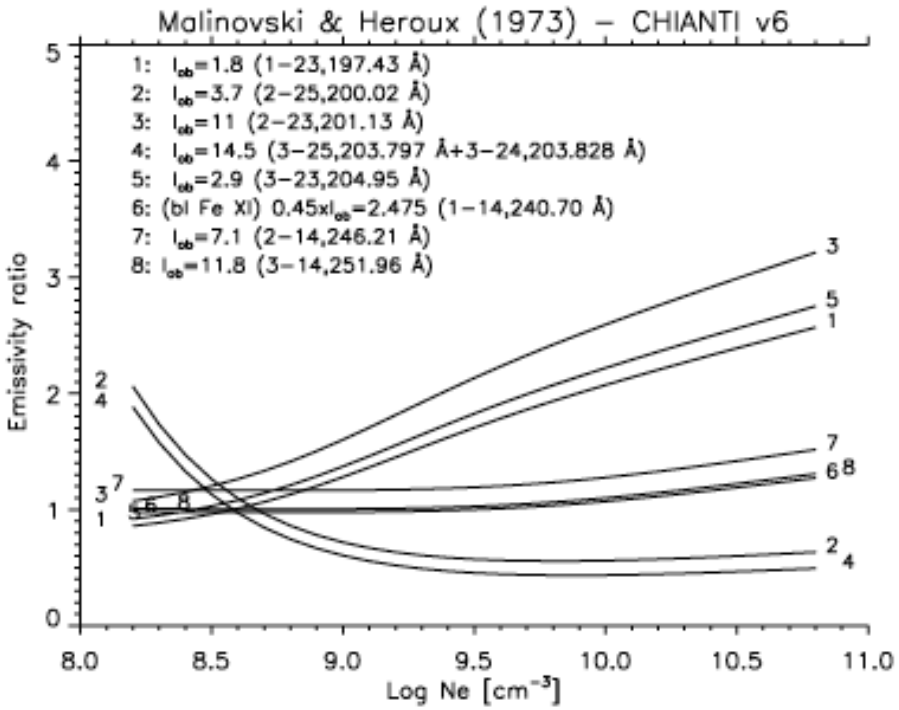


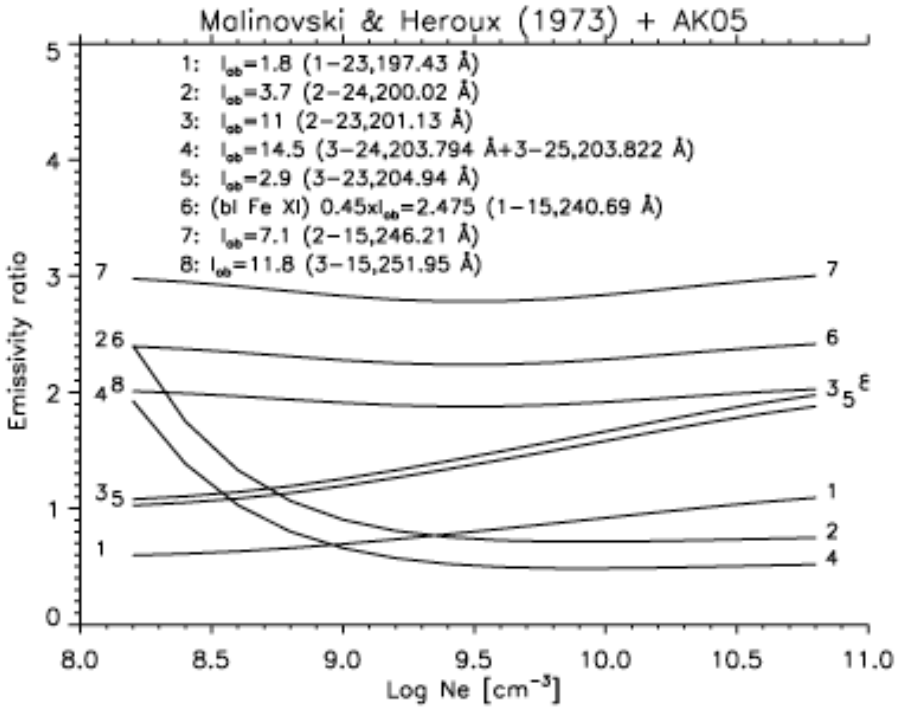
Del Zanna & Storey (2012)

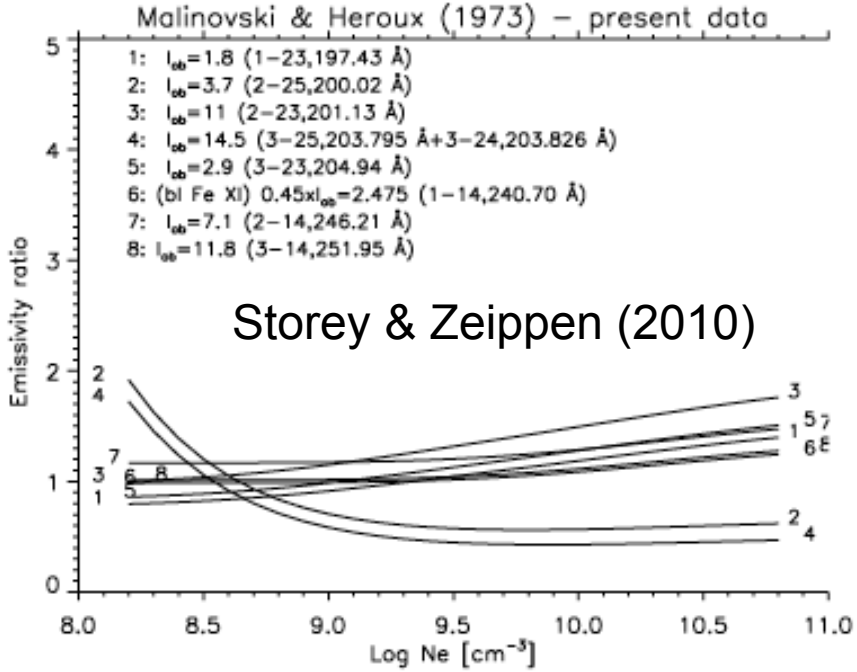


Older Storey & Zeippen CC expansion

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







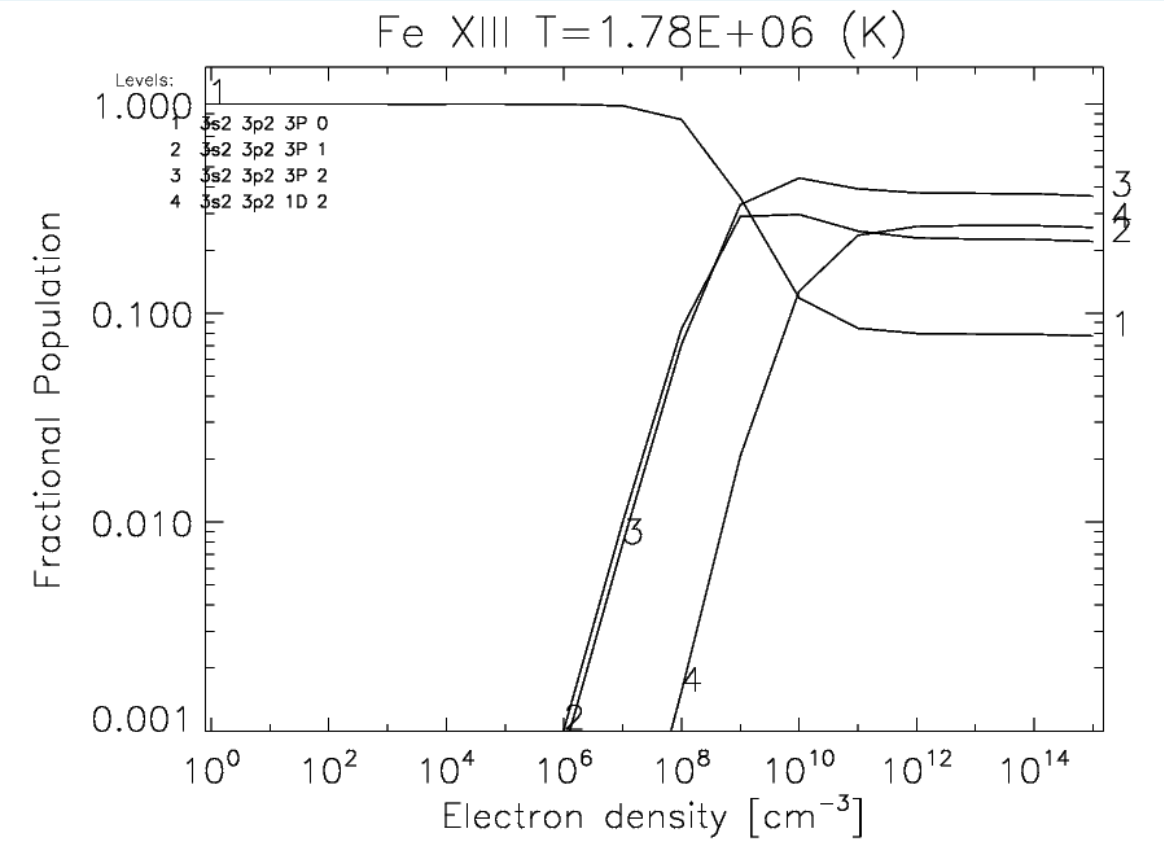
Storey & Zeippen (2010)

Large problems with atomic data of Aggarwal & Keenan 2005.

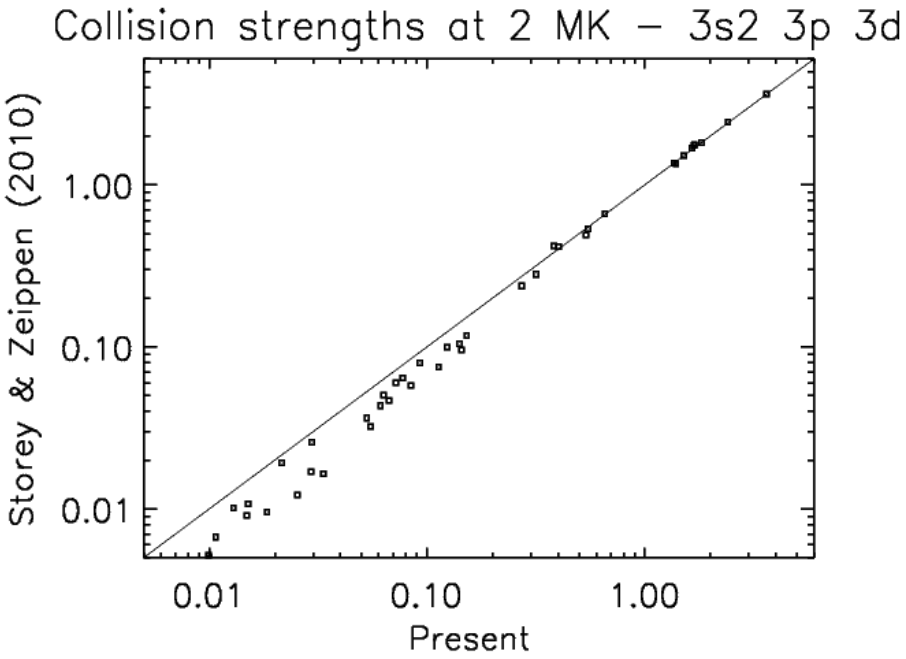
Gupta & Tayal (1998) – CHIANTI v6 and Storey & Zeippen show good agreement with observations.

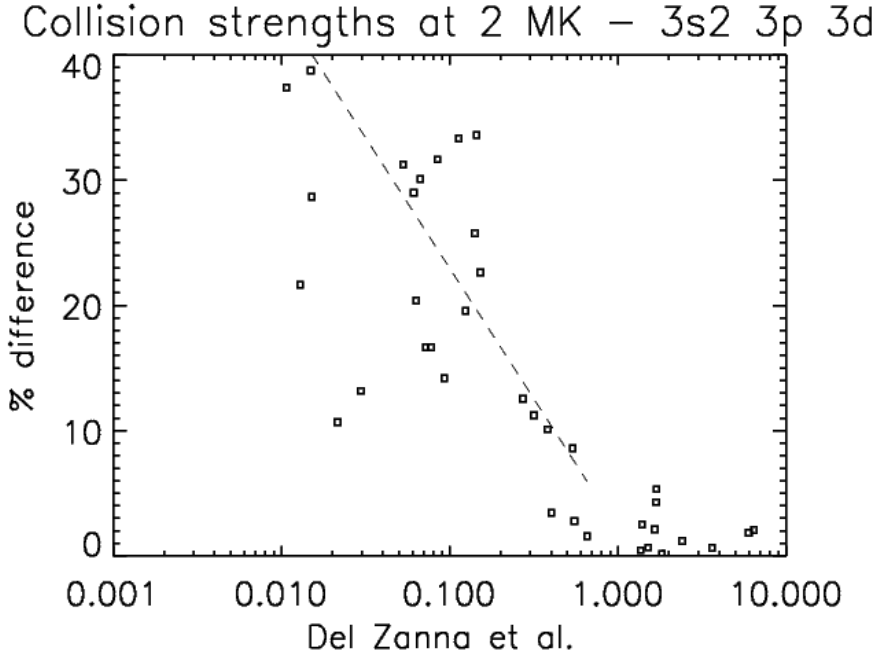
(see Del Zanna A&A 533, A12, 2011)

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.



Level population



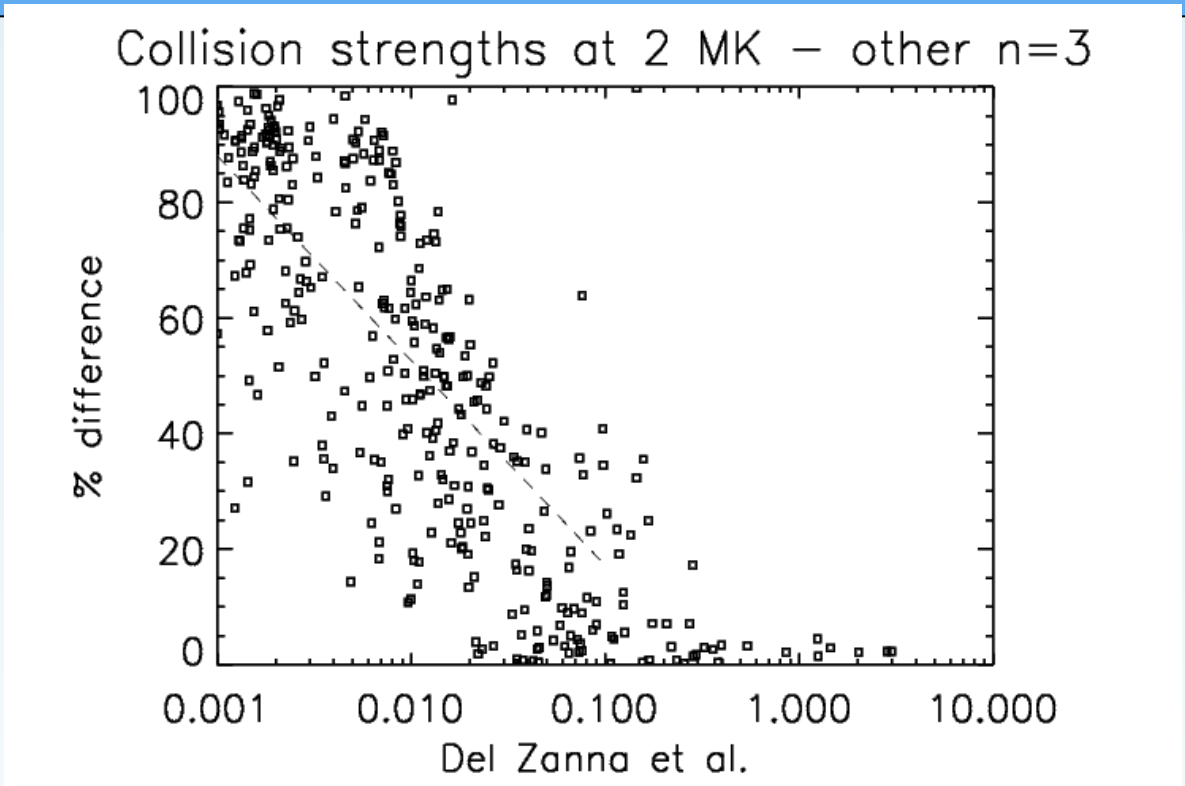


Percentage differences
compared to Storey & Zeippen (2010)
at peak Te=2 MK.

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.

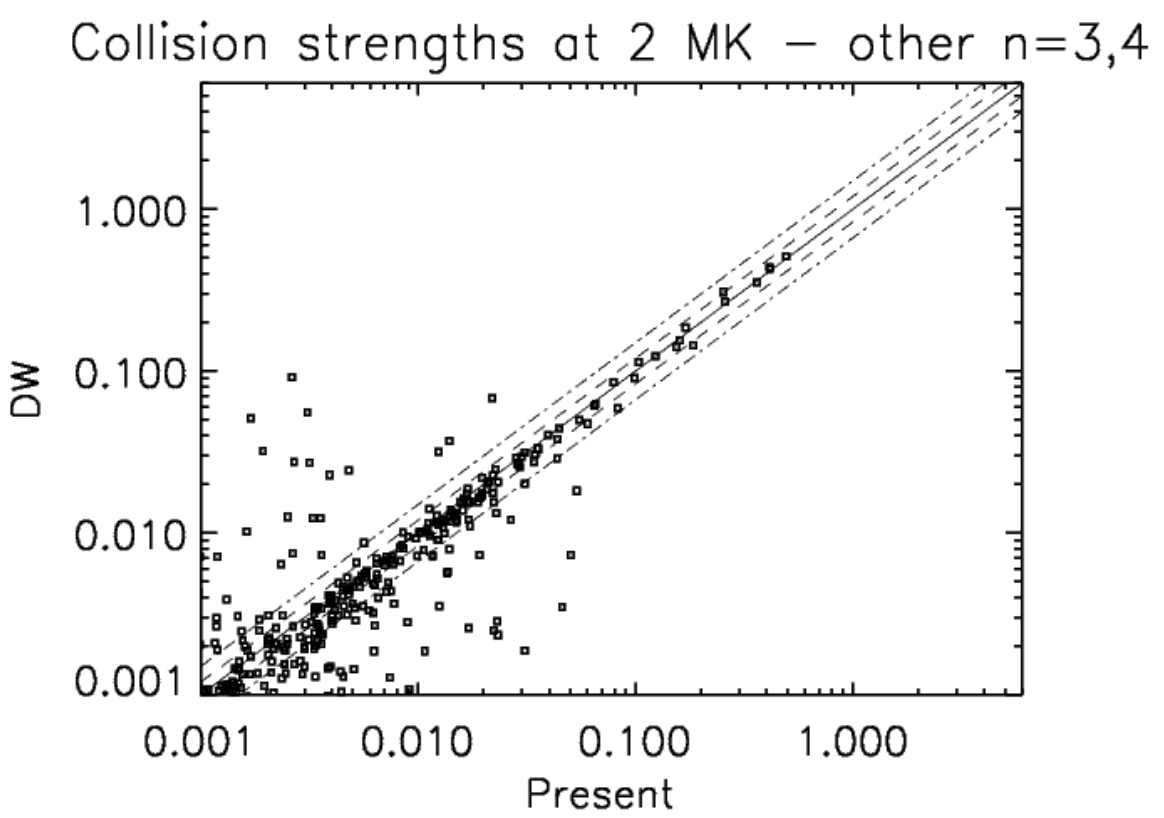
I have taken 2% for the few transitions above 1., and the linear variation shown with the dashed line for the weaker ones (maximum of 50%).

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



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%).

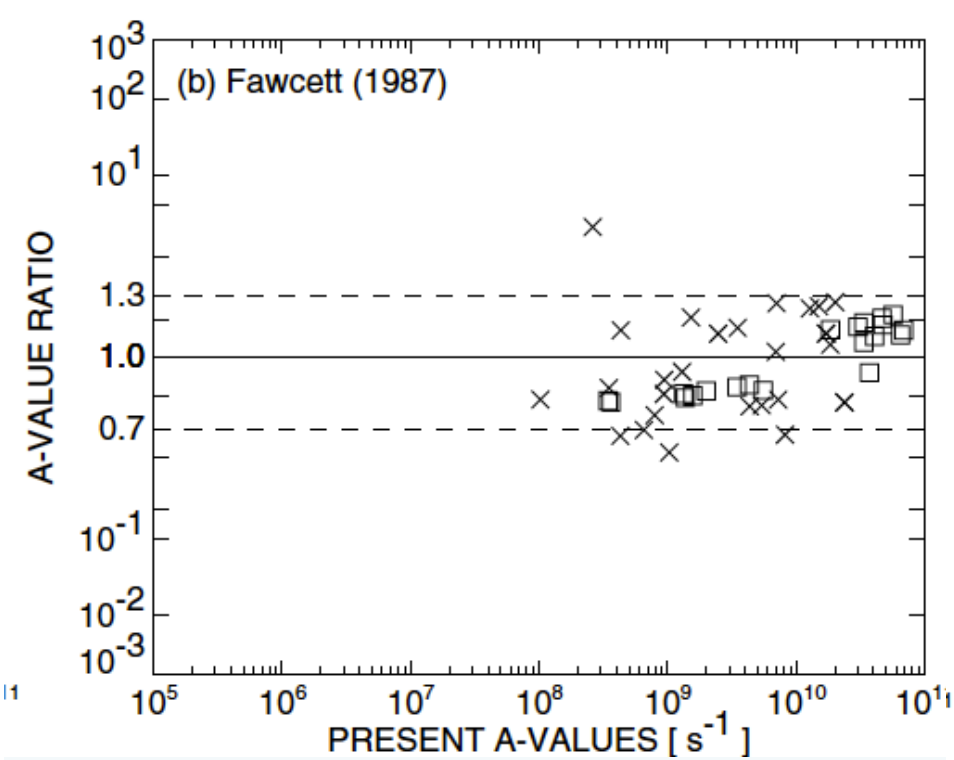


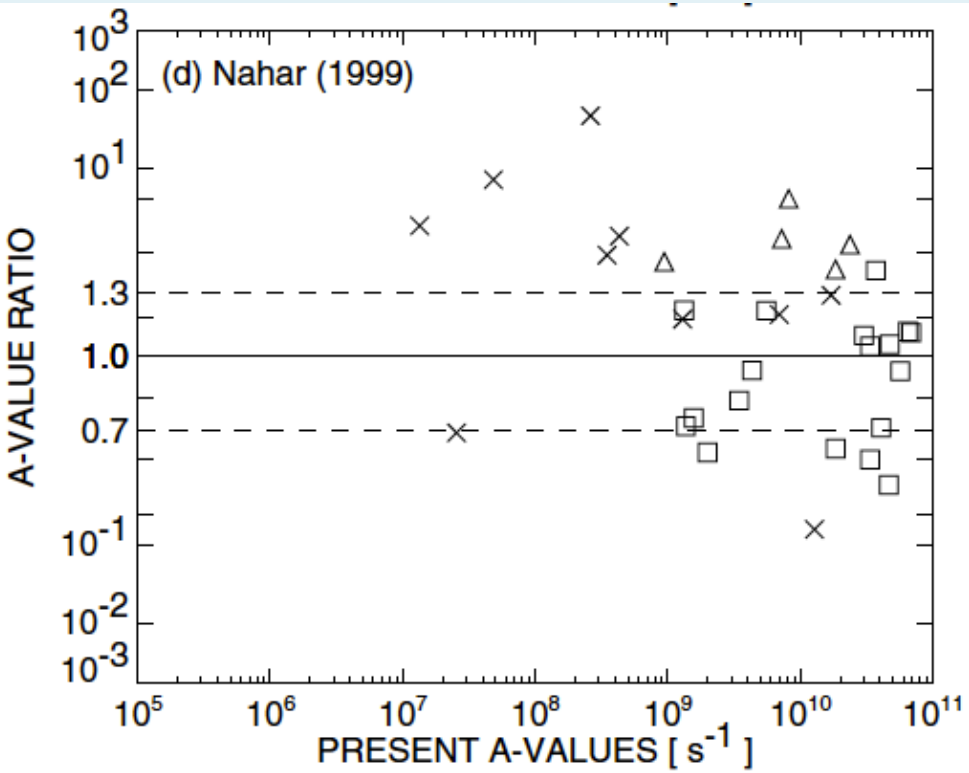
Dashed lines: +/- 20%
Dot-dashed lines: +/- 50%

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.

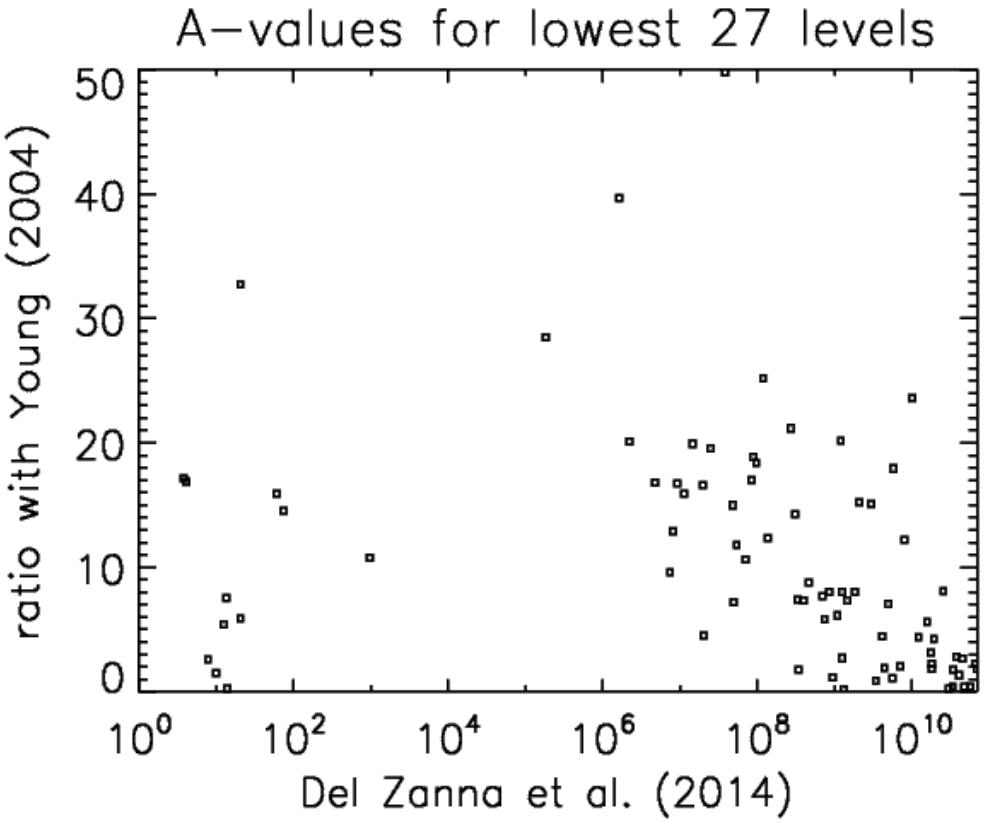
A-values





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

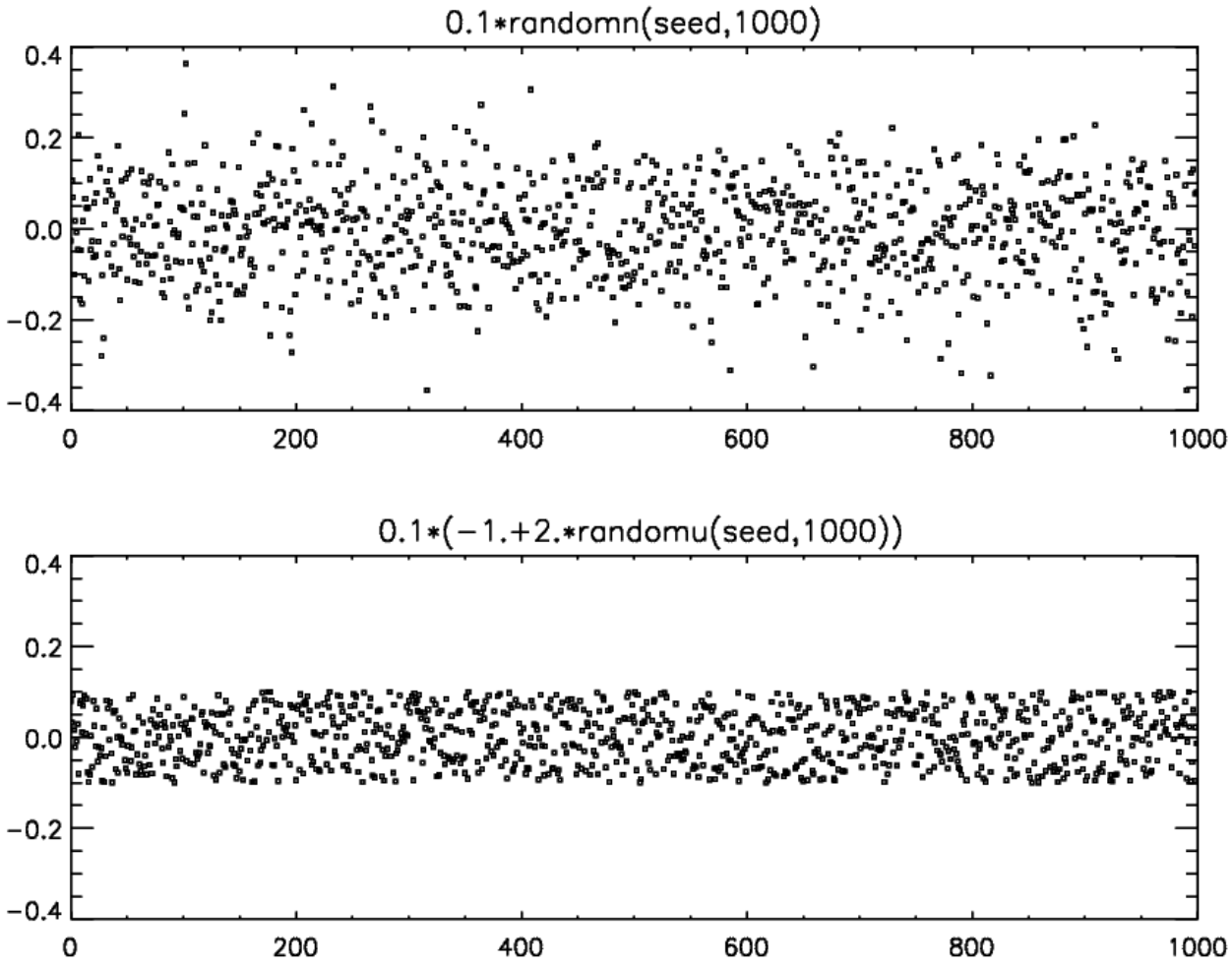


The A-values among the lowest 27 (n=3) levels are the main ones for the EUV lines of interest.

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)

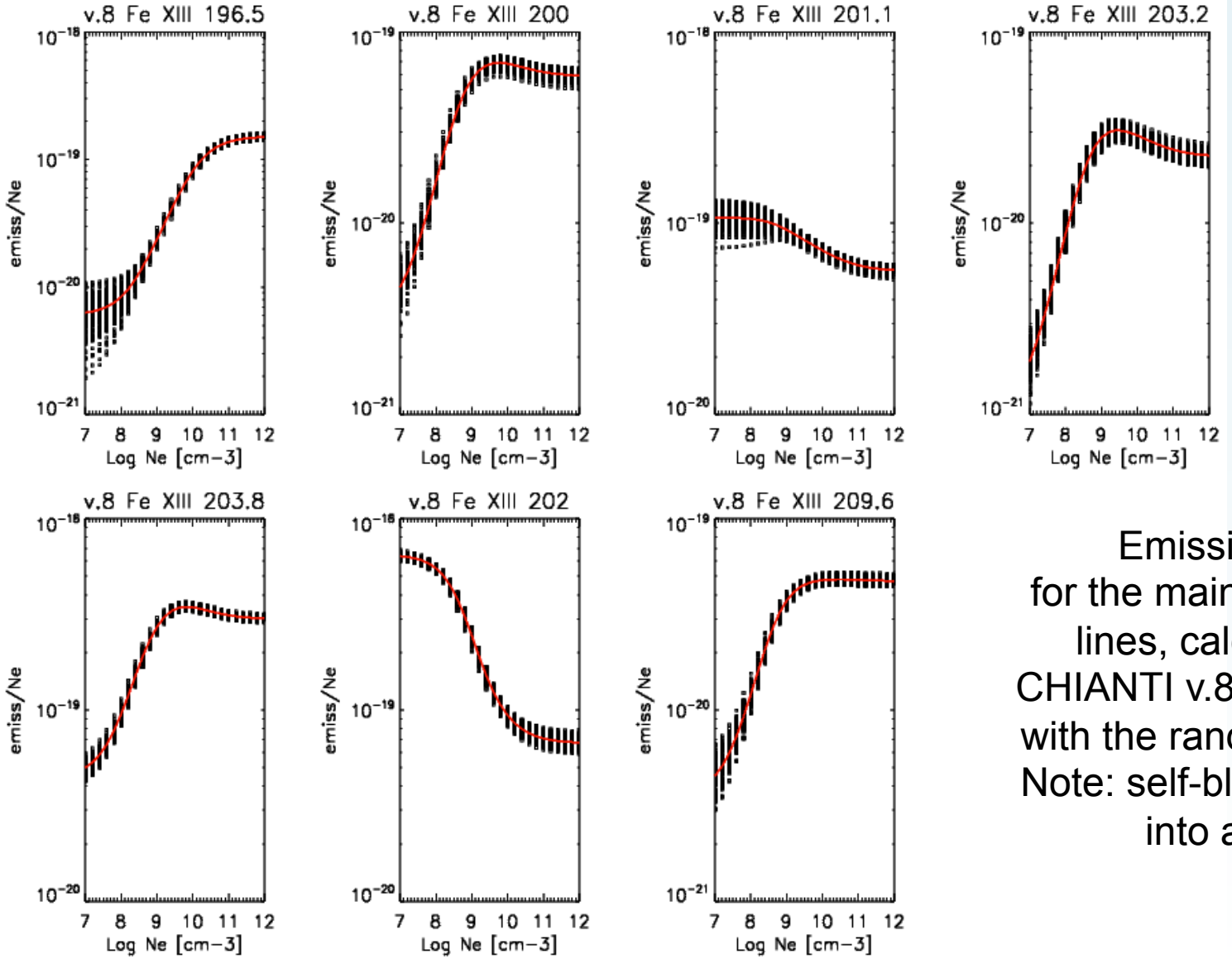
Once the level-resolved uncertainties have been given, the issue is how to randomly vary them. I have adopted the top option, a normal distribution. This means that, e.g. for a 10% uncertainty, most values will have values +/- 20%. This means a 40% variation.



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

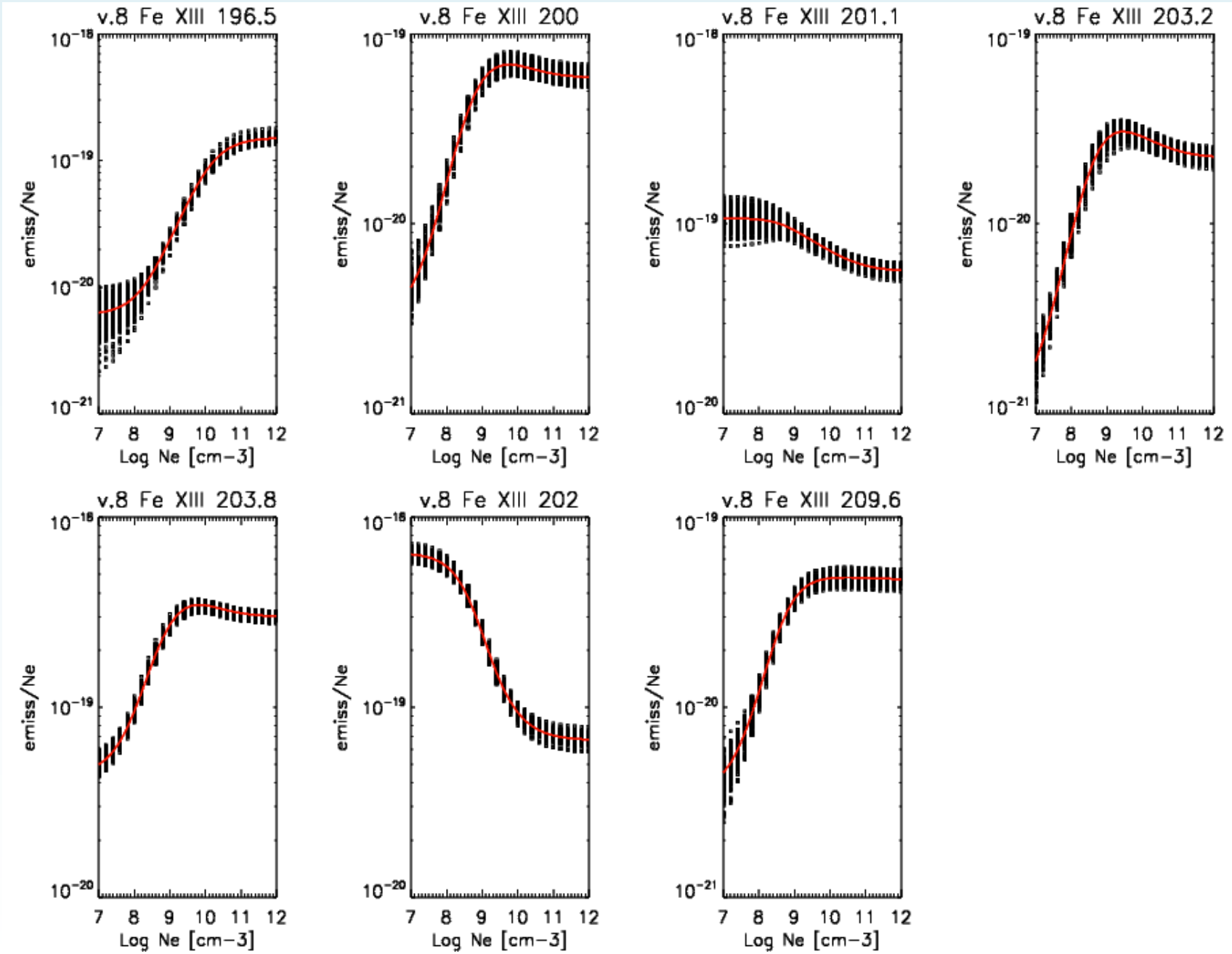
Fe XIII emissivities

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

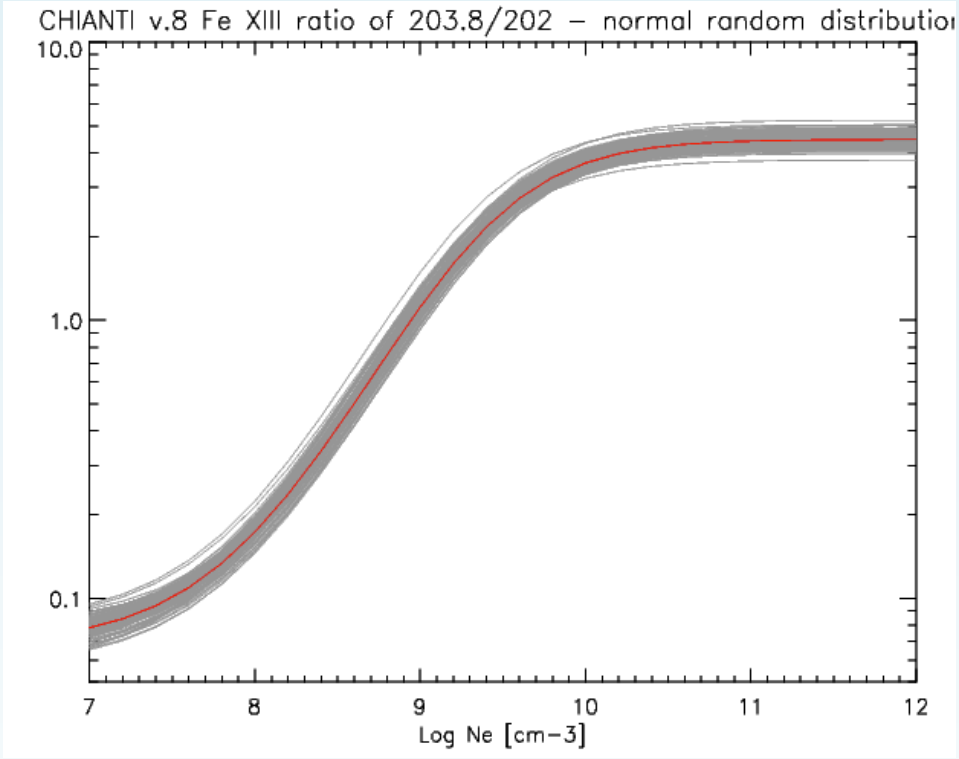


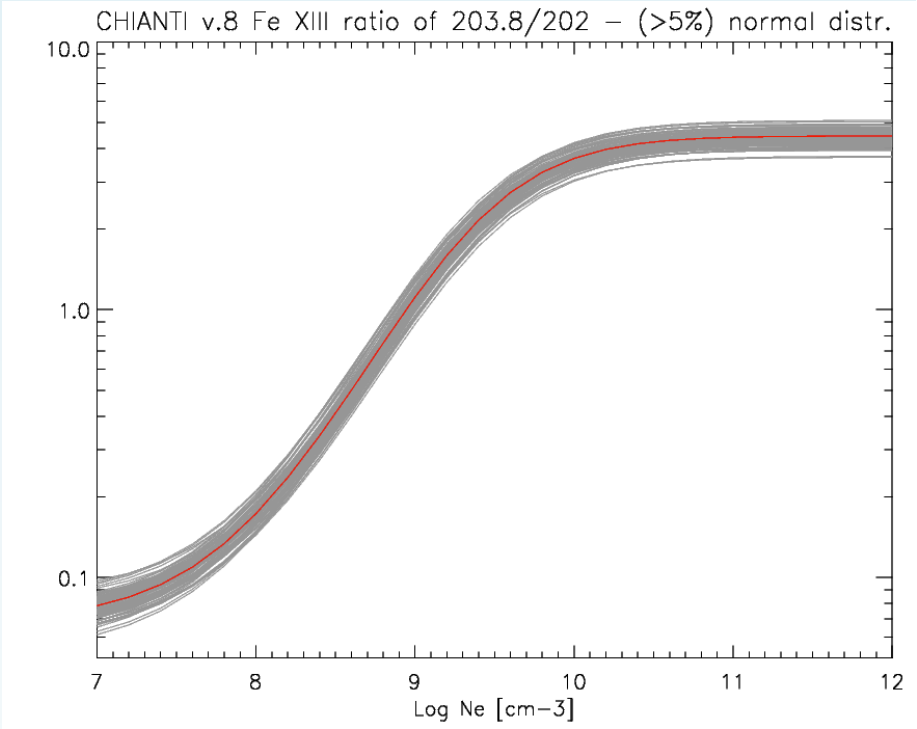
Emissivities/ Ne for the main 7 Hinode EIS lines, calculated with CHIANTI v.8 (red lines) and with the random variations. Note: self-blends are taken into account.

With minimum 5% instead of 2%

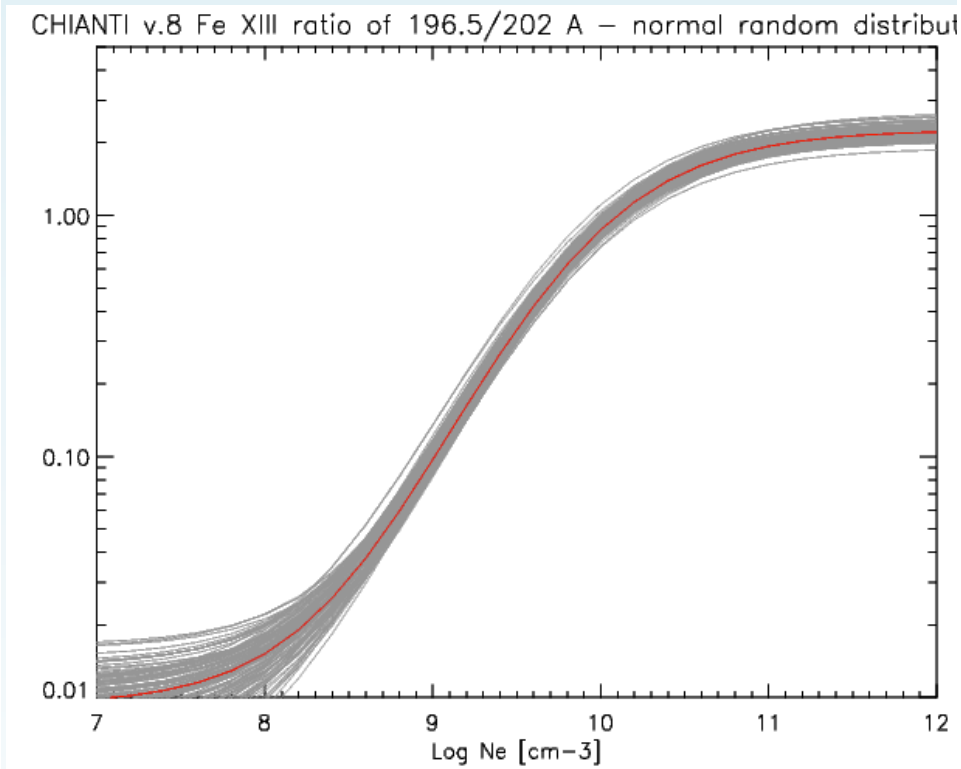


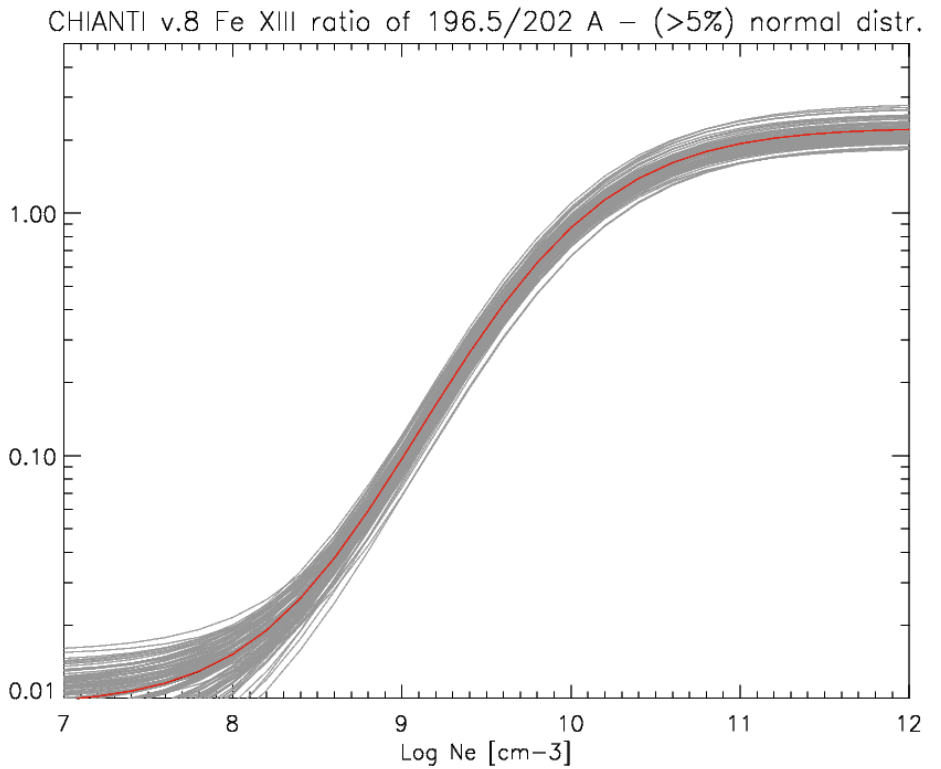
Fe XIII main ratios (1)

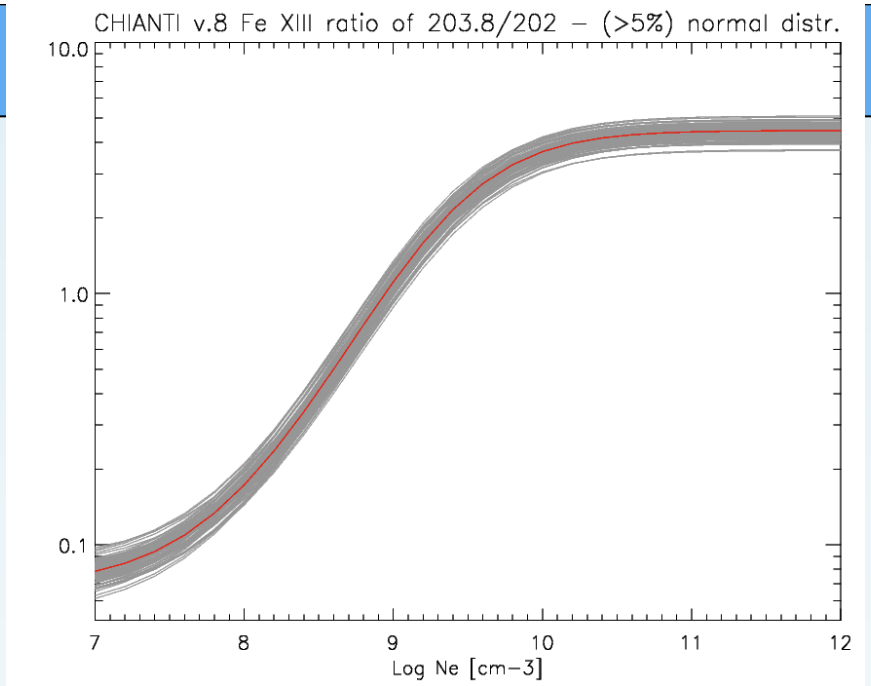


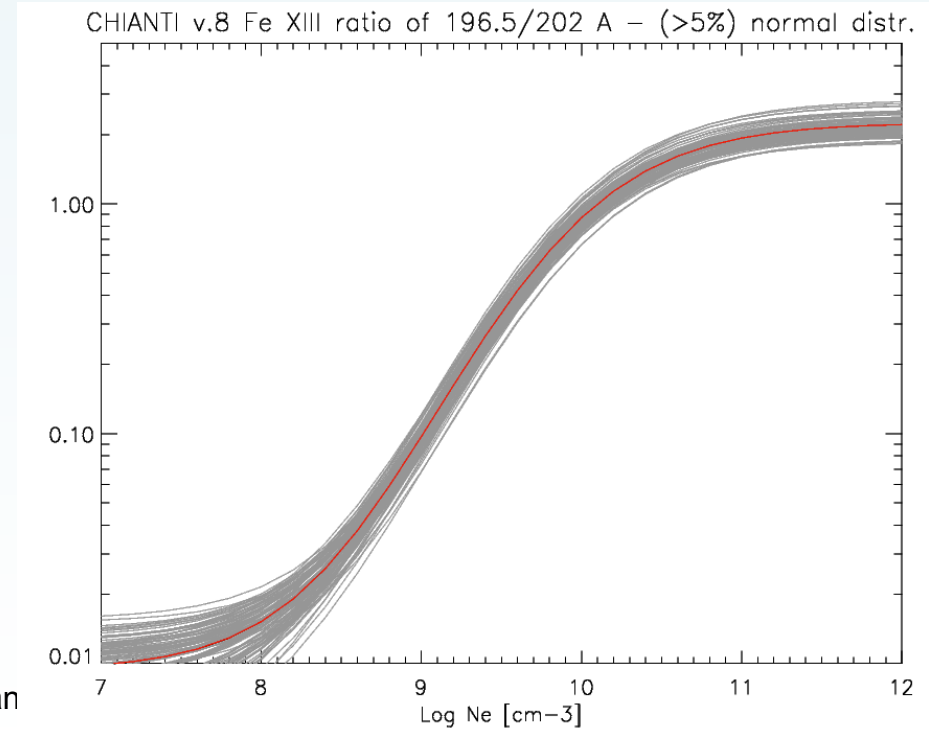


The grey lines are the 100 random realizations, the red lines are the standard CHIANTI values.


CHIANTI v.8 Fe XIII ratio of 196.5/202 A – normal random distribut
1.00
0.10
0.01
7
8
9
10
11
12
Log Ne [cm−3]


CHIANTI v.8 Fe XIII ratio of 196.5/202 A – (>5%) normal distr.
1.00
0.10
0.01
7
8
9
10
11
12
Log Ne [cm−3]





Need to include this ratio.

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