Photoionsation and Photoelectron ionosation rate calcualtions for NRL new bins for X-rays

Theoritical Calculation of altitude of unit optical depth (referred here as “Table data”)

$$\tau(z)=1=\sigma^a H n(z)$$

$$Exponential\ density: n(z)=n_0 \exp\left(\frac{-z}{H}\right)$$

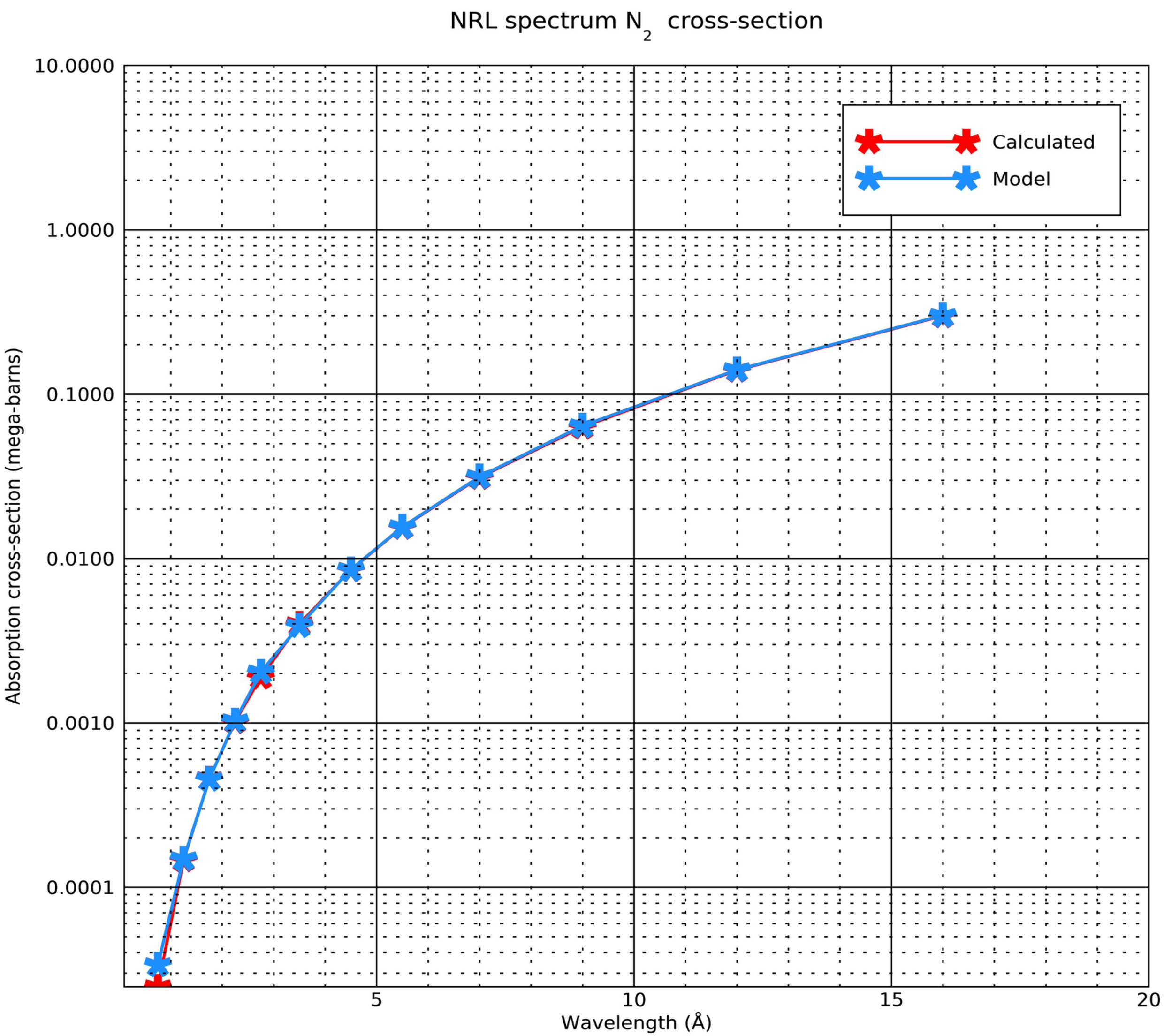
$$Altitude\ of\ unit\ optical\ depth: z=H \ln\left(H n_0 \sigma^a\right)$$

$Assuming: Scale\ Height\ H=7\,km, n_0=2.7e19\,cm^{-3}, \sigma^a\ for\ N_2\ as\ given,$
$we\ find\ the\ value\ for\ z\ for\ optical\ depth\ \tau=1\ by\ using\ the\ above\ formula$

Calculated	Results				
Bin #	λ min (A)	λ max (A)	Mean λ (A)	Mean σN2abs (mega-barns)	Alt of tau=1 (km)
1	0.5	1	0.75	2.48e-5	43
2	1	1.5	1.25	1.47e-4	55.5
3	1.5	2	1.75	4.57e-4	63.5
4	2	2.5	2.25	1.02e-3	69.1
5	2.5	3	2.75	1.9e-3	73.3
6	3	4	3.5	4.0e-3	78.7
7	4	5	4.5	8.55e-3	84
8	5	6	5.5	1.55e-2	88.1
9	6	8	7	3.12e-2	93
10	8	10	9	6.32e-2	98
11	10	14	12	0.14	103.5
12	14	18	16	0.30	109

Calculated and Model N2 absorption cross-sections

1. The red line is the table (slide 2) N_2 cross-sections and the blue line is the photoelectron model N_2 absorption cross-sections
2. The model calculates the cross-sections at these wavelengths by interpolating the Henke +Fennelly data at the solar flux wavelength bins
3. The slide 2 cross-sections are average values at the solar flux wavelengths
4. The cross-section of the first bin is different in the model and the table.
5. Changing the cross-sections only changes the altitude of unit optical depth in the first bin by 1 km.
6. From the Henke + Fennelly data, and the model value is more accurate than the table value.



NRL Spectra- Binning Procedure

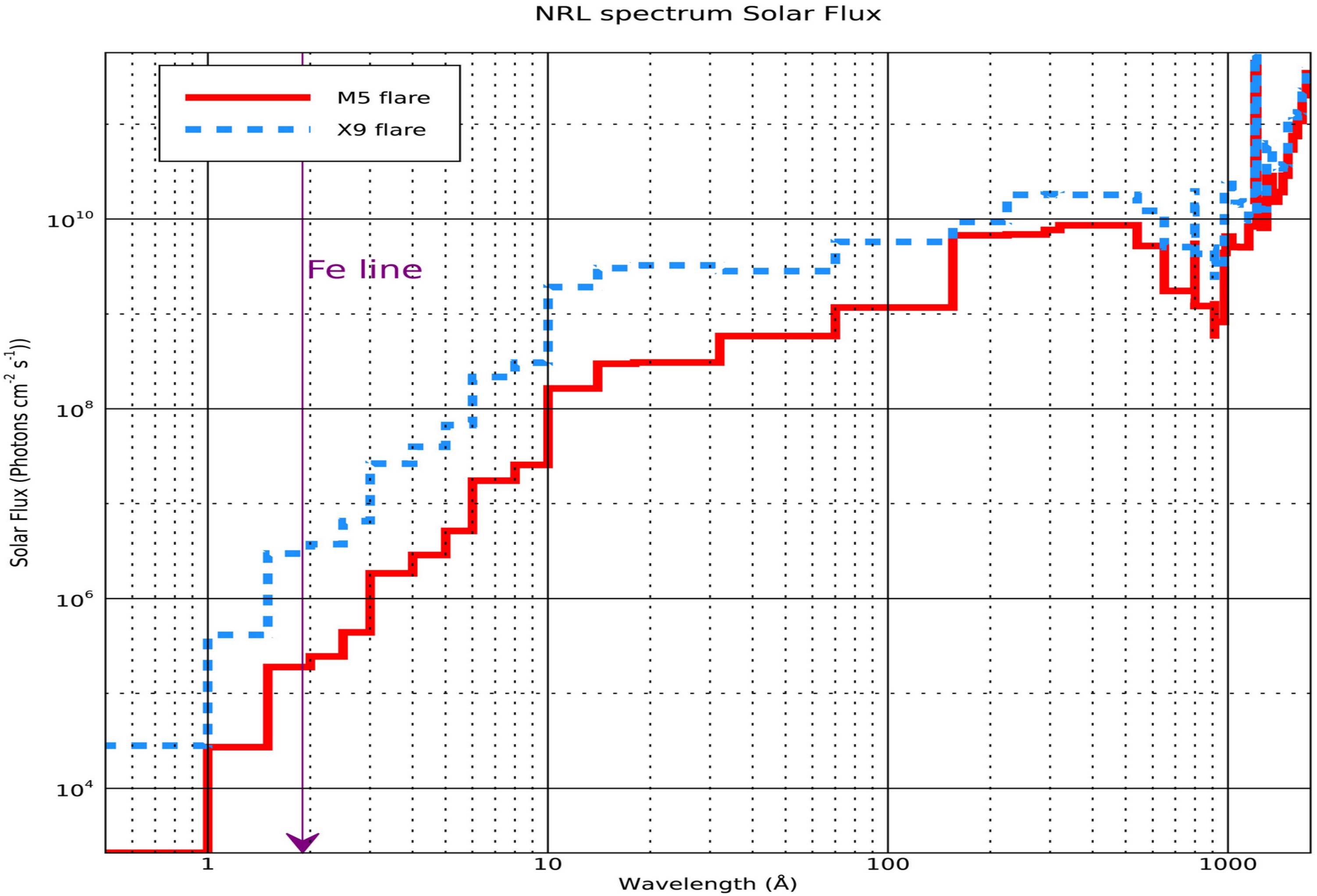
The binning procedure for xray flare ionization parameterization (Done by NRL) as below:

1. “Break up the three shortest wavelength bins of Solomon and Qian into 12 higher resolution bins. Bins to be expanded are the 0.5-4 A, 4-8A and 8-18A”
2. The selection of bins gives roughly 5 km resolution between 60-100 km.

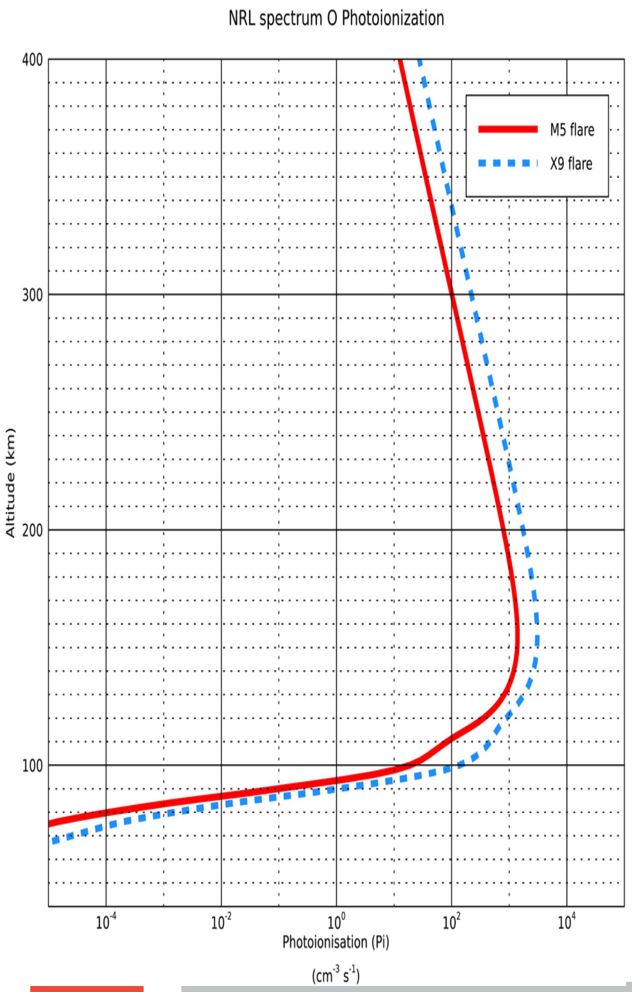
wave_low	wave_low
0.5	1
1	1.5
1.5	2
2	2.5
2.5	3
3	4
4	5
5	6
6	8
8	10
10	14
14	18
18	32
32	70
70	155
155	224
224	290
290	320
320	540

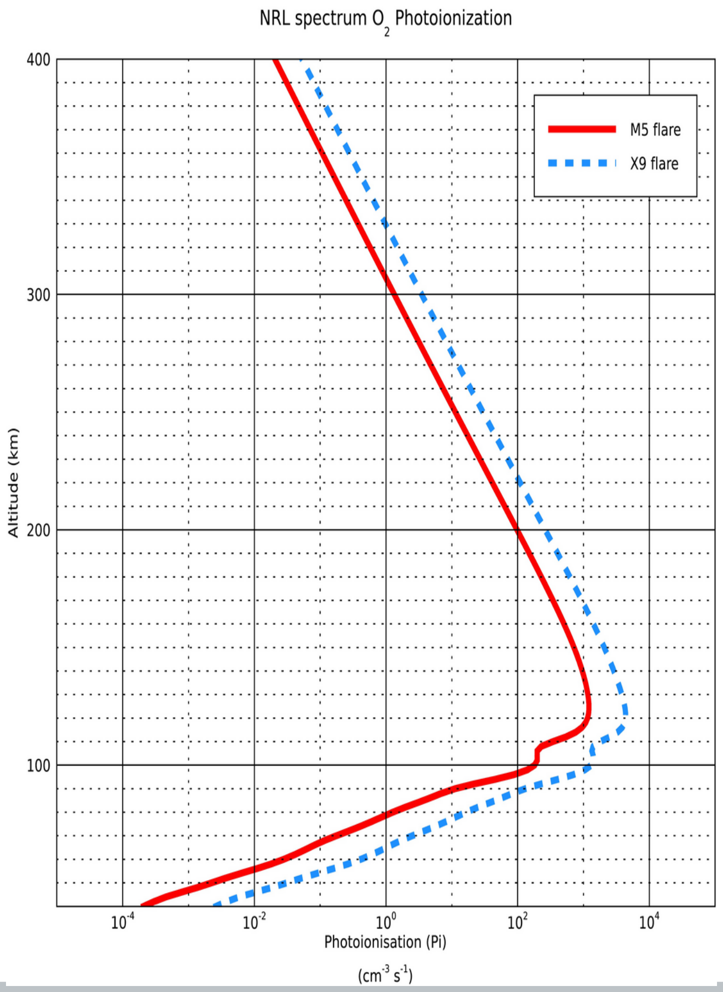
NRL Spectra

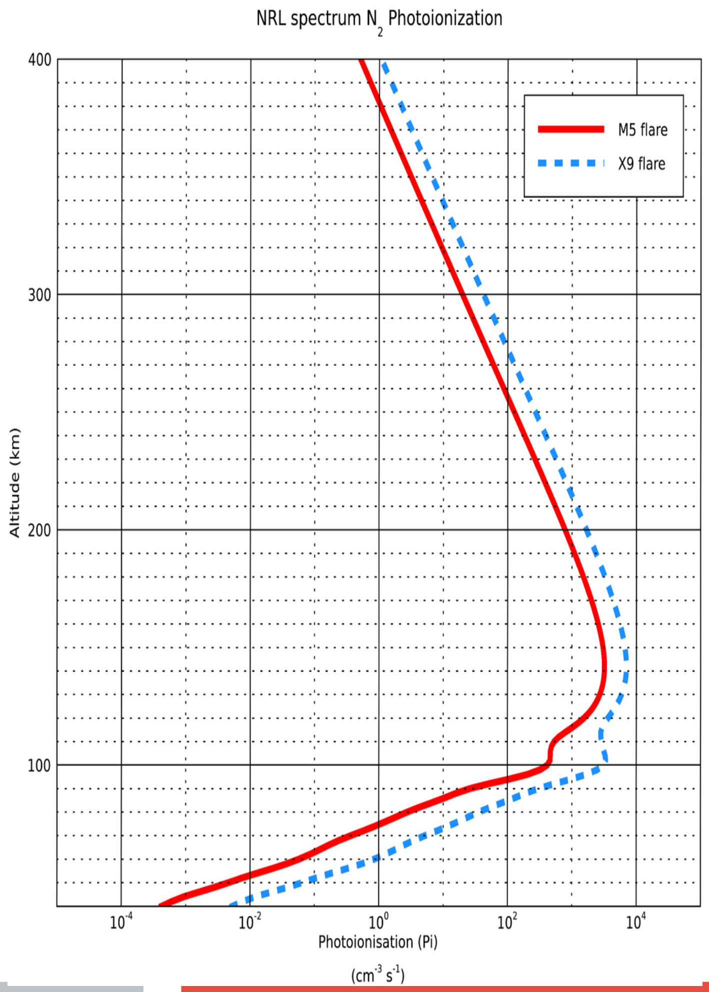
1. This is the NRL spectra for two flares m5 and x9.



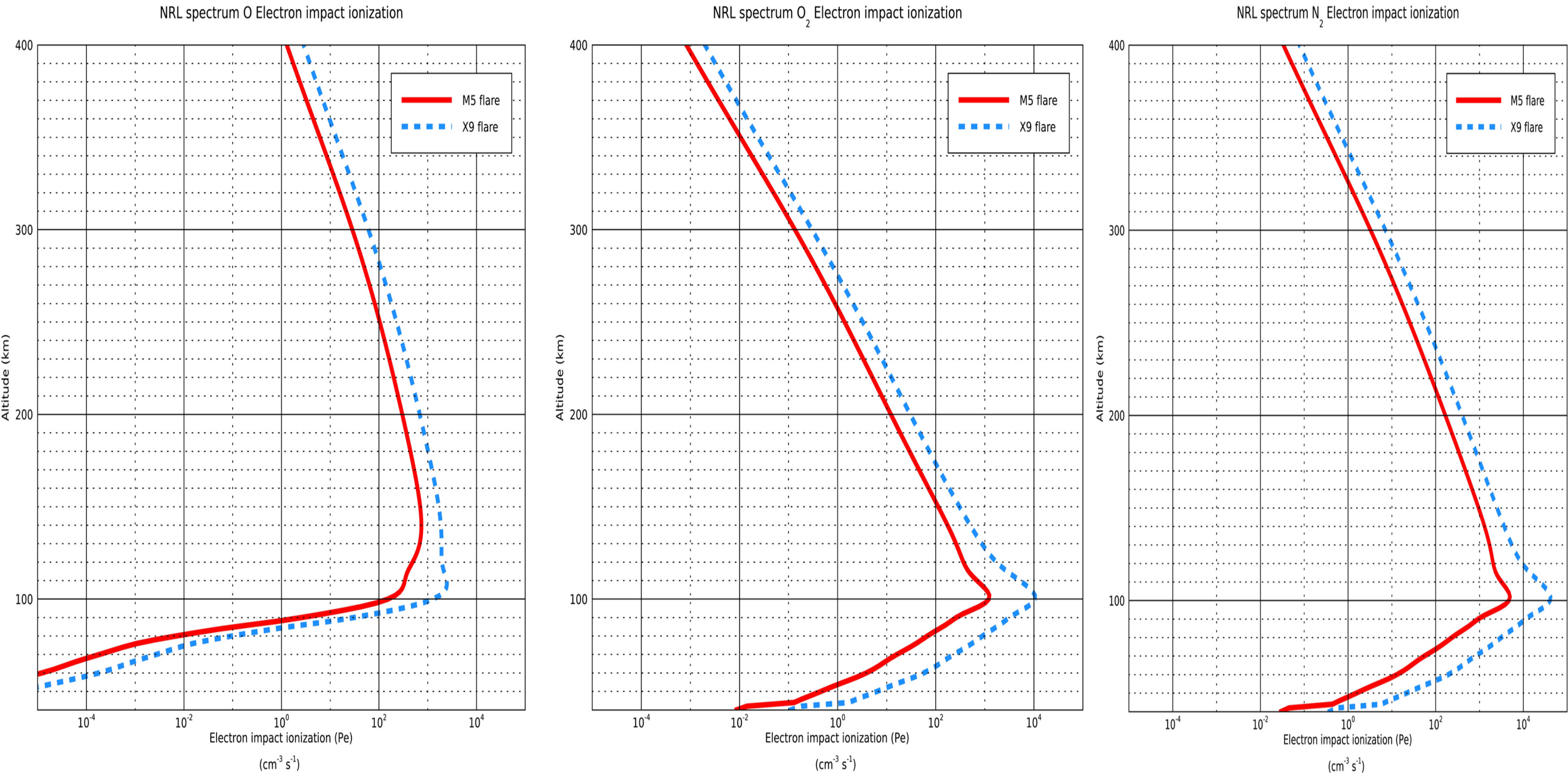
1. If we take the altitude bin in the model to be Δz= 0.5 to 1 km, the deviation in calculating the altitude of unit optical depth is minimum, so Δz= 1 km in the model.



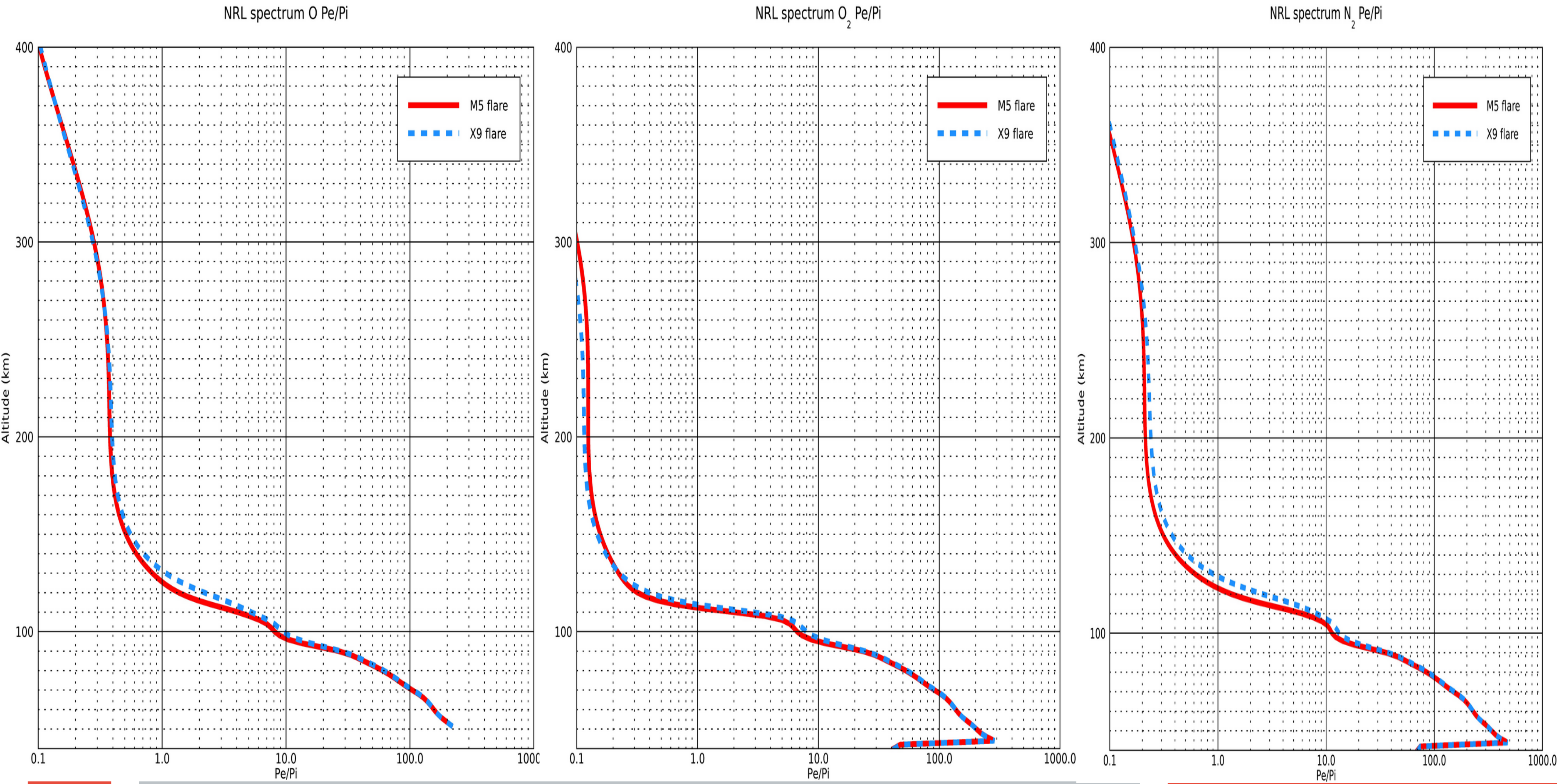




Photoelectron ionisation rates for the two spectra



Pe/Pi ratios for the two spectra



Explanation of plots of slides 6-8

1. These are the 3 plots :

i. Photoionisation rates (Pi)

ii. Photoelectron ionisation rates (Pe)

iii. Pe/Pi ratios

2. Basically, the x9 flare is stronger than the m5 flare, so the Pi and the Pe are larger for the x9, which is expected
3. With increased solar flux from the M5 to X9 flare, there is an increase in photoionisation and photoelectron production.

Results of the Model- M5 flare

O2 data						
Bin #	λ min (A)	λ max (A)	Mean λ (A)	Mean σ_{O2abs} (mega-barns)	Alt of tau~ 1 (km)	pe/pi
1	0.5	1	0.75	6.21E-05	46	334.877
2	1	1.5	1.25	2.73E-04	58	186.124
3	1.5	2	1.75	8.33E-04	65	130.288
4	2	2.5	2.25	1.88E-03	71	100.69
5	2.5	3	2.75	3.66E-03	75	81.527
6	3	4	3.5	6.95E-03	79	64.223
7	4	5	4.5	1.50E-02	83	48.239
8	5	6	5.5	2.66E-02	87	37.862
9	6	8	7	5.25E-02	90	28.251
10	8	10	9	1.05E-01	94	19.552
11	10	14	12	2.25E-01	99	12.552
12	14	18	16	4.71E-01	103	6.794

N2 data						
Bin #	λ min (A)	λ max (A)	Mean λ (A)	Mean σ_{N2abs} (mega-barns)	Alt of tau~ 1 (km)	pe/pi
1	0.5	1	0.75	3.38E-05	46	556.789
2	1	1.5	1.25	1.49E-04	58	311.116
3	1.5	2	1.75	4.55E-04	65	217.68
4	2	2.5	2.25	1.03E-03	71	166.914
5	2.5	3	2.75	2.04E-03	75	134.397
6	3	4	3.5	3.91E-03	79	105.002
7	4	5	4.5	8.59E-03	83	77.558
8	5	6	5.5	1.56E-02	87	59.911
9	6	8	7	3.15E-02	90	43.828
10	8	10	9	6.43E-02	94	29.971
11	10	14	12	1.41E-01	99	19.047
12	14	18	16	3.02E-01	103	10.275

Results of the Model- X9 flare

O2 data						
Bin #	λ min (A)	λ max (A)	Mean λ (A)	Mean σ_{O2abs} (mega-barns)	Alt of tau~ 1 (km)	pe/pi
1	0.5	1	0.75	6.21E-05	46	334.877
2	1	1.5	1.25	2.73E-04	58	186.124
3	1.5	2	1.75	8.33E-04	65	130.287
4	2	2.5	2.25	1.88E-03	71	100.69
5	2.5	3	2.75	3.66E-03	75	81.527
6	3	4	3.5	6.95E-03	79	64.223
7	4	5	4.5	1.50E-02	83	48.239
8	5	6	5.5	2.66E-02	87	37.862
9	6	8	7	5.25E-02	90	28.251
10	8	10	9	1.05E-01	94	19.552
11	10	14	12	2.25E-01	99	12.552
12	14	18	16	4.71E-01	103	6.794

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Bin #	λ min (A)	λ max (A)	Mean λ (A)	Mean σ_{N2abs} (mega-barns)	Alt of tau~ 1 (km)	pe/pi
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9	6	8	7	3.15E-02	90	43.828
10	8	10	9	6.43E-02	94	29.971
11	10	14	12	1.41E-01	99	19.047
12	14	18	16	3.02E-01	103	10.275

Comparisons of the model data with calculated N_2 results

Calculated	Results				
Bin #	λ min (A)	λ max (A)	Mean λ (A)	Mean σN2abs (mega-barns)	Alt of tau=1 (km)
1	0.5	1	0.75	2.48e-5	43
2	1	1.5	1.25	1.47e-4	55.5
3	1.5	2	1.75	4.57e-4	63.5
4	2	2.5	2.25	1.02e-3	69.1
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10	8	10	9	6.32e-2	98
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N2 data	Model Results				
Bin #	λ min (A)	λ max (A)	Mean λ (A)	Mean σ_{N2abs} (mega-barns)	Alt of tau~1 (km)
1	0.5	1	0.75	3.38E-05	46
2	1	1.5	1.25	1.49E-04	58
3	1.5	2	1.75	4.55E-04	65
4	2	2.5	2.25	1.03E-03	71
5	2.5	3	2.75	2.04E-03	75
6	3	4	3.5	3.91E-03	79
7	4	5	4.5	8.59E-03	83
8	5	6	5.5	1.56E-02	87
9	6	8	7	3.15E-02	90
10	8	10	9	6.43E-02	94
11	10	14	12	1.41E-01	99
12	14	18	16	3.02E-01	103

Altitued Difference (km)
3
2.5
1.5
1.9
1.5
0.3
1
1.1
3
4
4.5
6

Conclusion And Assumptions Made

1. The MSIS value for n_0= 1.9 E19 cm^3, however, we have assumed n_0= 2.7E19 cm^3
2. Scale height H= 7km in calculation of table in slide 2, however, in the model scale height changes for the altitudes of unit optical depth.
3. The difference in altitude of unit optical depth between the model data and the calculated data is due to the difference in the assumptions made in its calculations and the different values calculated by the model.
4. An altitude binning of Δz= 0.5 to 1 km is good for getting the correct altitude of optical depth.
5. The N_2 cross-section of the first bin in the model is significantly different than that given in the table of slide 2, which causes a difference of about 1km in the altitude of unit optical depth calculation.
6. In the calculations, it is assumed that the all the atmosphere is N2 and also the solar zenith angle is zero degree. The model has a zenith angle of 1 degree, which does not cause any appreciable changes in the altitudes.
7. The pe/pi ratios for N_2 and O_2 for both the M5 and X9 flares are also given in the tables in slides 10 and 11. They are equal for both of the flare conditions for each species and bin.
8. Also, the plots of the spectra are added in the beginning. The X9 is the stronger flare and so the photo-ionisation and photo-electron ionisation rates are greater in the X9 flare case.