

# **Solar flux binning and Absorption/Ionisation Cross-sections**

# Maximum ionisation derivation

$I(s_\lambda)$  = solar flux

$\sigma^a$  = absorption crosssection

The decrease intensity after it travels an incremental distance:

$$dI(s_\lambda) = -I(s_\lambda) n(z) \sigma^a ds_\lambda$$

$\chi \rightarrow$  Solar Zenith angle

$$ds_\lambda = -dz \sec \chi$$

$$dI(s_\lambda) = -I(z) n(z) \sigma^a \sec \chi dz$$

$$\int_{I_\infty}^{I(z)} \frac{dI(z)}{I(z)} = \int_z^\infty \sigma^a \sec \chi n(z) dz$$

$$\ln\left(\frac{I_\infty}{I(z)}\right) = \sigma^a \sec \chi \int_z^\infty n(z) dz = \sec \chi \tau$$

$$I(z) = I_\infty \exp(-\tau \sec \chi)$$

$$\text{Optical Depth: } \tau = \sigma^a \int_z^\infty n(z) dz$$

$$\text{Isothermal atmosphere: } n(z) = n_0 \exp\left(\frac{-(z-z_0)}{H}\right)$$

$$\ln\left(\frac{I_\infty}{I(z)}\right) = \sigma^a \sec \chi \int_z^\infty n_0 \exp\left(\frac{-(z-z_0)}{H}\right) dz$$

$$= \sigma^a \sec \chi H n_0 \exp\left(\frac{-(z-z_0)}{H}\right)$$

$$= \sigma^a \sec \chi H n(z)$$

$$I(z) = I_\infty \exp(-\sigma^a \sec \chi H n(z))$$

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

Photoionisation:  $P_c(z, \chi) = I(z, \chi) \beta \sigma^a n(z)$

$\beta$  = probability of ionisation

$$P_c(z, \chi) = I_\infty \exp(-\tau(z) \sec \chi) \beta \sigma^a n(z)$$

$$\text{Maximum ionisation: } \frac{dP_c}{dz} = 0$$

$$\frac{dP_c}{dz} = I_\infty \beta \sigma^a [\exp(-\tau(z) \sec \chi) n'(z) - n(z) \exp(-\tau(z) \sec \chi) \sec \chi \tau'(z)] = 0$$

$$\Rightarrow n'(z) - n(z) \sec \chi \tau'(z) = 0$$

$$[n'(z) - n(z) \sec \chi \tau'(z)] = 0$$

$$\tau(z) = \sigma^a H n(z) \Rightarrow \tau'(z) = \sigma^a H n'(z) \text{ (assuming } H \text{ constant)}$$

$$\frac{\tau'(z)}{\sigma^a H} - n(z) \sec \chi \tau'(z) = 0$$

$$\tau'(z) - \sigma^a H n(z) \sec \chi \tau'(z) = 0$$

$$\tau'(z)(1 - \sigma^a H n(z) \sec \chi) = 0$$

$$\tau'(z)(1 - \tau(z) \sec \chi) = 0$$

$$\tau(z) \sec \chi = 1$$

For  $\sec \chi = 1$ : overhead sun  $\tau(z) = 1$  for maximum ionisation

# Cross-section for maximum absorption as a function of altitude & sampling for vertical resolution

Assuming all the energy absorbed goes into ionisation:  $\tau(z) \sec \chi = 1$

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

$$n_0 \exp\left(\frac{-(z-z_0)}{H}\right) = \frac{1}{\sigma^a H \sec \chi}$$

$$-\frac{(z-z_0)}{H} = \ln\left(\frac{1}{H n_0 \sigma^a \sec \chi}\right)$$

$$z = z_0 + H \ln(H n_0 \sigma^a \sec \chi)$$

Also:

$$n_0 \exp\left(\frac{-(z-z_0)}{H}\right) = \frac{1}{\sigma^a H \sec \chi}$$

$$\sigma^a = \frac{1}{H \sec \chi n_0 \exp\left(\frac{-(z-z_0)}{H}\right)}$$

$$\sigma^a = \frac{1}{H n_0 \sec \chi} \exp\left(\frac{z-z_0}{H}\right)$$

Let the vertical resolution be  $\Delta V$

$$z_2 - z_1 = H \left( \ln(H n_0 \sigma_2^a(\lambda_2) \sec \chi) - \ln(H n_0 \sigma_1^a(\lambda_1) \sec \chi) \right)$$

$$z_2 - z_1 = H \ln\left(\frac{\sigma_2^a(\lambda_2)}{\sigma_1^a(\lambda_1)}\right)$$

$$\left| \frac{\sigma_2^a(\lambda_2)}{\sigma_1^a(\lambda_1)} \right| = \exp\left(\frac{z_2 - z_1}{H}\right)$$

$$\left| \frac{\sigma_2^a(\lambda_2)}{\sigma_1^a(\lambda_1)} \right| = \exp\left(\frac{\Delta V}{H}\right)$$

$$\left| \frac{\sigma_2^a(\lambda_2)}{\sigma_1^a(\lambda_1)} \right| = \exp\left(\frac{\Delta V}{H}\right)$$

Assuming scale height  $H = 7 \text{ km}$

$$a. \Delta V = 10 \text{ km}$$

$$\left| \frac{\sigma_2^a(\lambda_2)}{\sigma_1^a(\lambda_1)} \right| = \exp\left(\frac{10}{7}\right) = 4.17$$

b. 1 cross-section per 7 km scale height:  $\Delta V = 7 \text{ km}$

$$\left| \frac{\sigma_2^a(\lambda_2)}{\sigma_1^a(\lambda_1)} \right| = \exp\left(\frac{7}{7}\right) = e^1 = 2.7$$

c. 2 cross-sections per 7 km scale height:  $\Delta V = 3.5 \text{ km}$

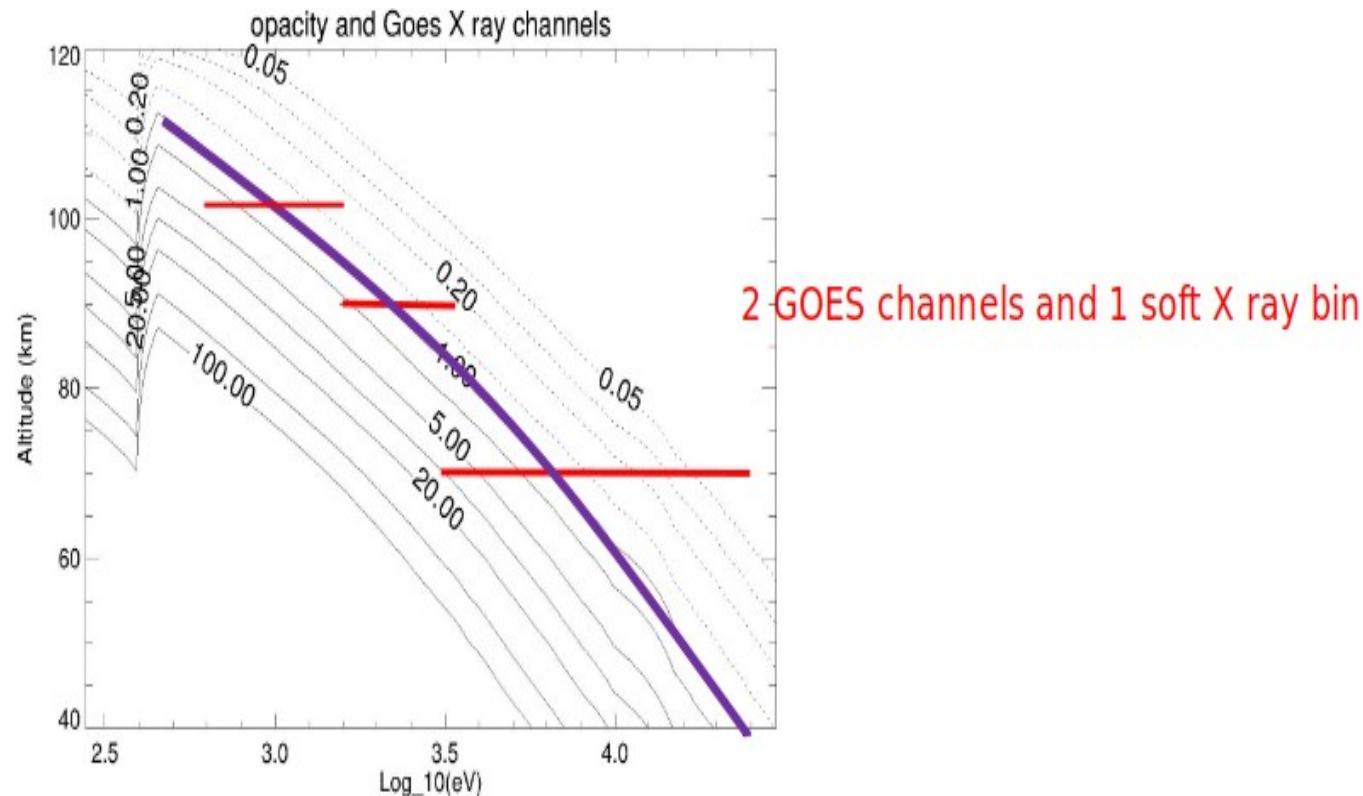
$$\left| \frac{\sigma_2^a(\lambda_2)}{\sigma_1^a(\lambda_1)} \right| = \exp\left(\frac{3.5}{7}\right) = e^{0.5} = 1.6$$

# Cross sections vs. altitude of absorption: one to one (mostly) (Dave's Slide\*)

Maximum ionization is at optical depth = 1

$$\tau=1=\sum \sigma(\lambda)n(z)dz$$

**Desired altitude resolution defines the required spectral bin widths?**



# First new energy binnings for NRL- May 2019

1. Bins were created for wavelength bins up to Auger edge for O/O2 (23 angstrom)

2. Energy series:

$a_0 = \ln(12397/23)$  (in log eV)  
 $d=0.1$  eV (bin size)  
 $n=40$ =number of bins  
 $a_n = a_0 + (n-1)*d$

3. Added 30-40 angstrom bin for Auger edge (30 Å) of N2

4. Rest of the bins from 44 Å was taken from EUVAC bins

5. Total number of bins =156

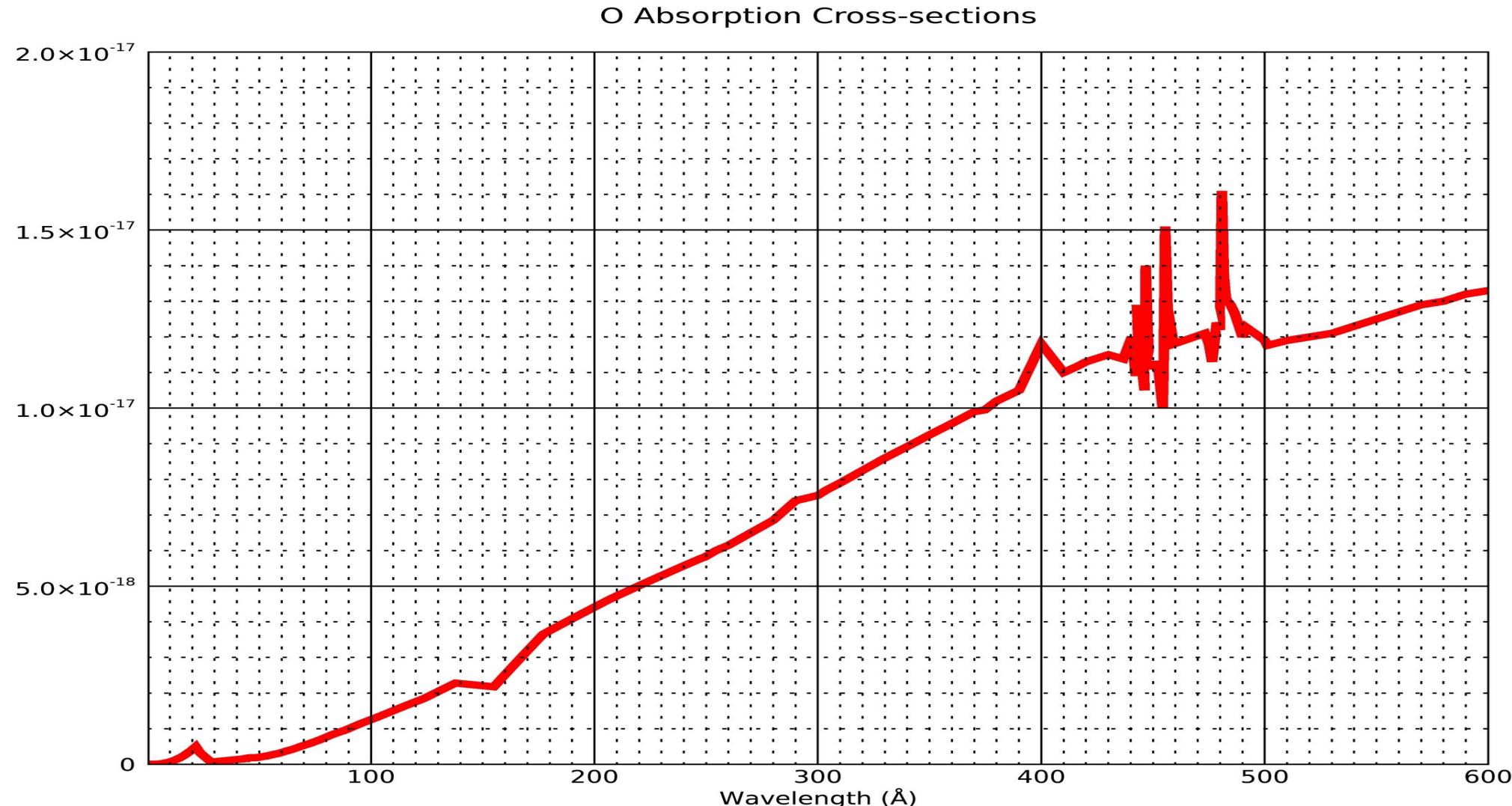
; code for new solar flux bins in x-ray range  
; has the Auger wavelengths as the edges of the bins

```
wv=[23.,23.,30.,43.6] ;wv in angstrom 0-O, 1-O2,  
2-N2, 3-C; Auger edges  
en=12397./wv ; in eV  
;print, en
```

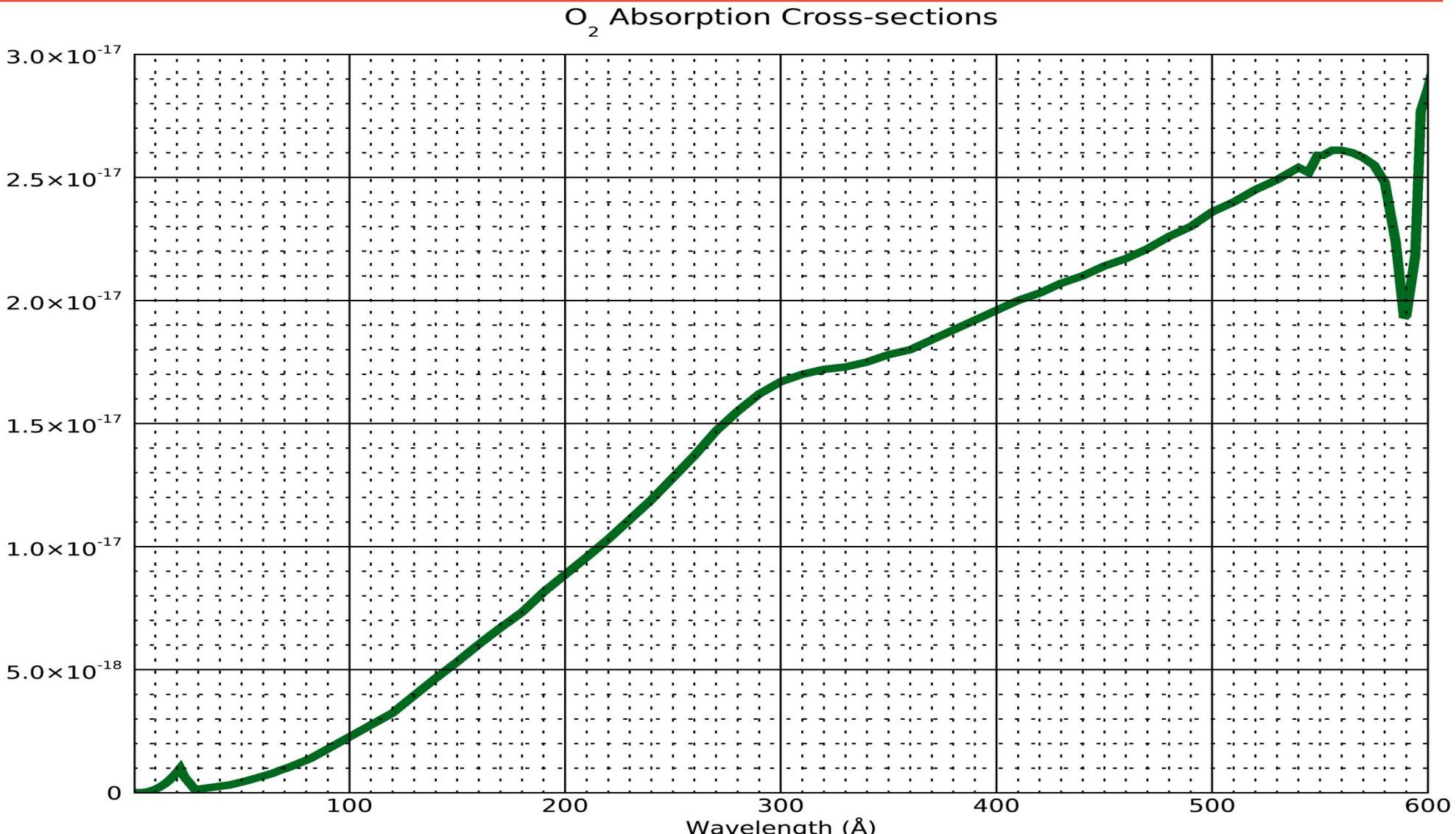
;Setting up new energy bins.....

```
;  
a_1=alog(en[0]) ;binning is made with  
log(energy) bins  
d=0.1 ;difference in energy bins 0.1 log eV  
n=40  
en_series_1=a_1+findgen(n)*d  
wv_series_1=exp(alog(12397.)-en_series_1)  
;print, en_series_1  
wv_1=reverse(wv_series_1)  
;print,wv_1
```

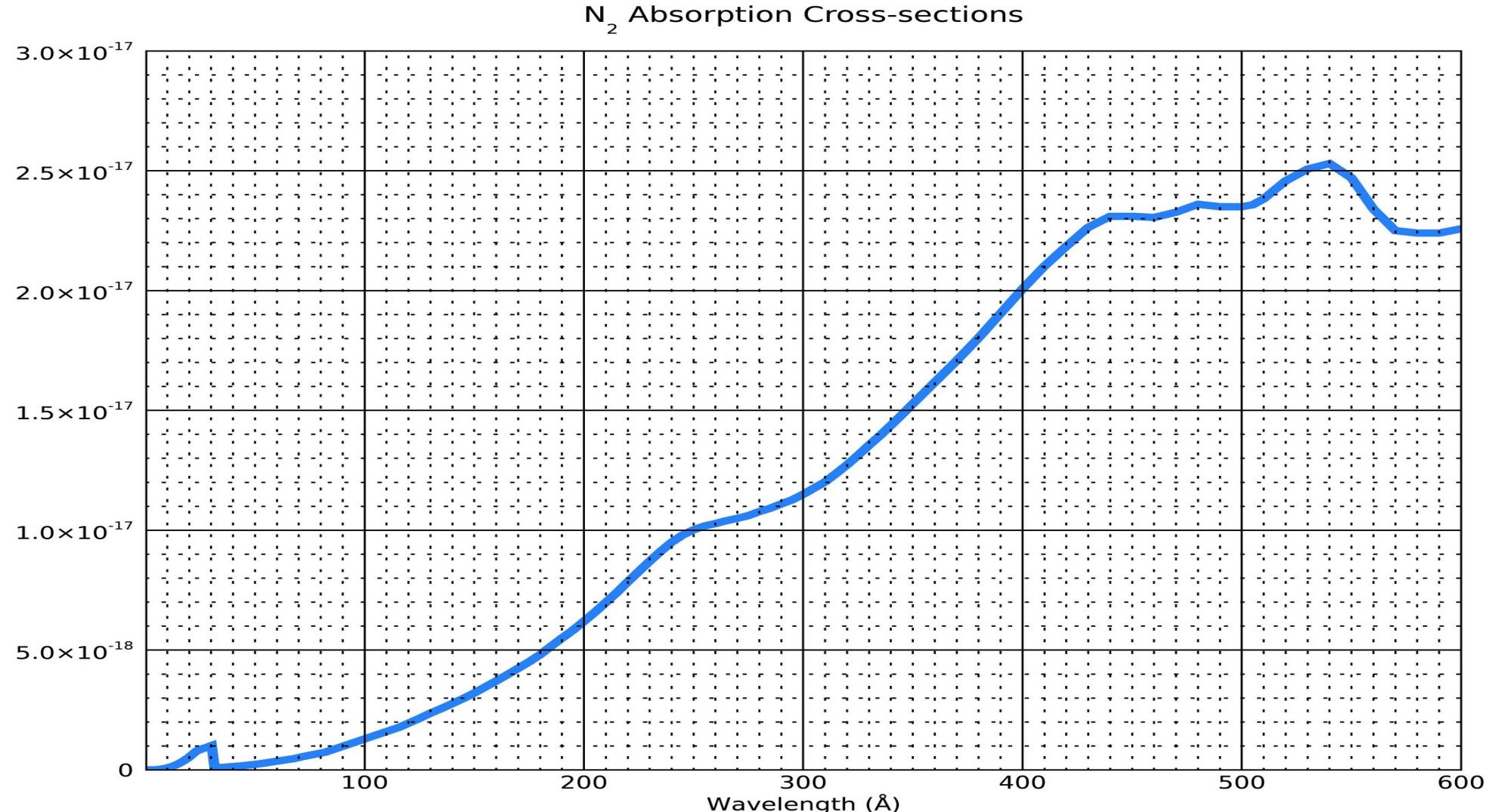
# Henkey and Fennelly Absorption Cross-sections



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# Henkey and Fennelly Absorption Cross-sections



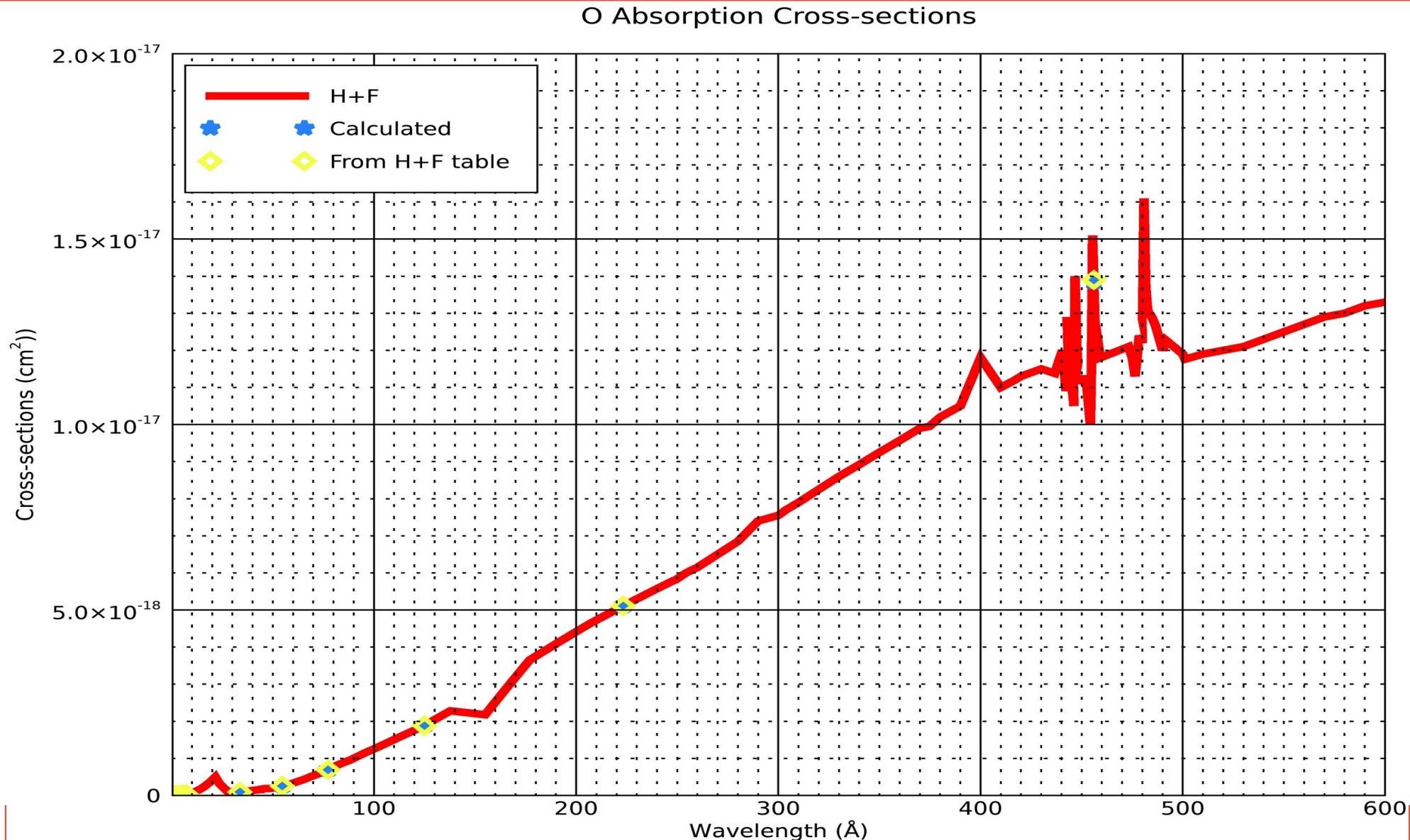
# New energy binnings for NRL- May 2020- Method

- 1. In the wavelength range up to about 500 angstrom, the cross-sections are increasing with wavelength.**
- 2. So I used the resolution derived in slide 3 to get the cross-section resolution we need for a vertical resolution of 3.5 , 5 and 7 km.**
- 3. I matched the cross-sections obtained from the formula to the cross-sections closest to the ones provided in the Henke+ Fennelly data and from there I got the wavelengths for the corresponding cross-section.**
- 4. Also I used the msis model to get the density at lowest altitude  $n_0$  for the three species, and I assumed the reference altitude to be  $z_0=0$ . So I am getting some negative altitudes for  $\tau=1$  since  $\ln$  value is a fraction at these points**
- 5.  $n_0 = 3.254866944e9$  for O  
 $n_0 = 1.380881780e15$  for O<sub>2</sub>  
 $n_0 = 5.147358317e15$  for N<sub>2</sub>**

# New energy binnings for NRL- May 2020- RESULTS

O data for Vertical resolution of 7.00000 km					
calculated cross-section (cm <sup>2</sup> )	H+F cross-section(cm <sup>2</sup> )	H+F wavelength (A)	H+F energy (eV)	Altitude(Tau=1) (km)	
4.25119981722862E-24	4.2512E-24	0.4	30992.5	-129.168116913143	
1.15559588613912E-23	1.28333E-23	0.6	20661.7	-122.168117125718	
3.14123523642443E-23	2.39661E-23	0.7	17710	-115.168117263678	
8.53876229311119E-23	3.95893E-23	0.8	15496.2	-108.168117566162	
2.32107622052272E-22	2.9227E-22	1.5	8264.67	-101.168117618538	
6.30933878416319E-22	7.67873E-22	2.1	5903.33	-94.1681182049485	
1.71505606220228E-21	1.74565E-21	2.7	4591.48	-87.1681183455806	
4.6620057310122E-21	5.95168E-21	4.2	2951.67	-80.1681183420682	
1.2672645024307E-20	1.26473E-20	5.4	2295.74	-73.1681185842693	
3.44478187744574E-20	2.73671E-20	7.1	1746.06	-66.1681189731298	
9.36388784085687E-20	9.6E-20	33.74	367.427	-59.1681190774948	
2.54536852650474E-19	2.53E-19	54.7	226.636	-52.1681193240358	
6.91902897028093E-19	6.92E-19	77.3	160.375	-45.1681193665764	
1.88078699468953E-18	1.887E-18	125	99.176	-38.1681196544988	
5.11250884219845E-18	5.107E-18	223.26	55.5272	-31.1681200223568	
1.38972402217174E-17	1.3845E-17	456	27.1864	-24.1681198520401	

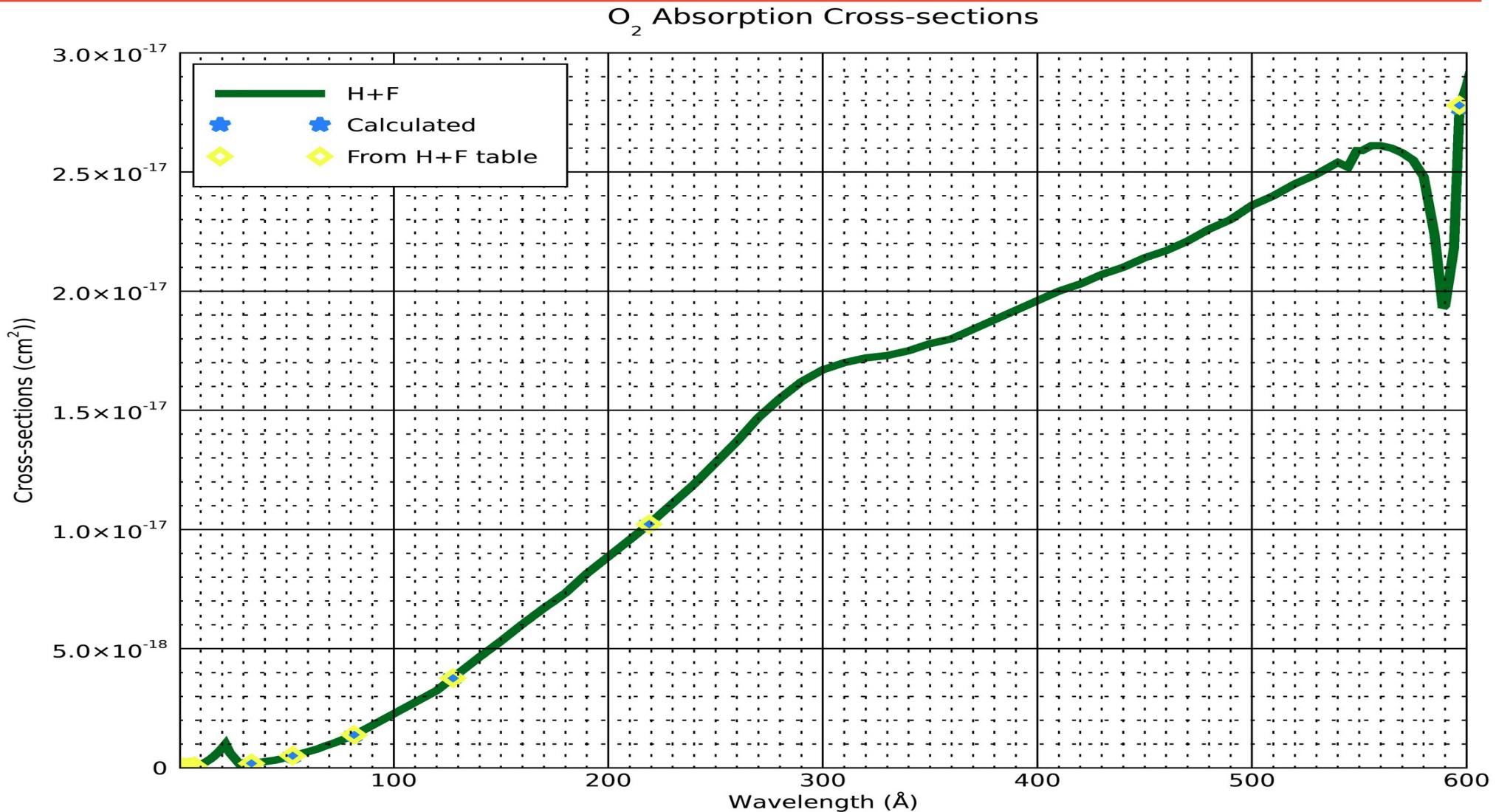
# Plots of Calculated Cross-sections for Verification- Vertical Resolution =7 km



# New energy binnings for NRL- May 2020-Results

O2 data for Vertical resolution of 7.00000 km					
calculated cross-section (cm <sup>2</sup> )	H+F cross-section	H+F wavelength	H+F energy	Altitude(Tau=1)	
8.50239963445724E-24	8.5024E-24	0.4	30992.5	-33.609516660177	
2.31119177227825E-23	2.56666E-23	0.6	20661.7	-26.609516872752	
6.28247047284886E-23	4.79323E-23	0.7	17710	-19.6095170107128	
1.70775245862224E-22	7.91786E-23	0.8	15496.2	-12.6095173131964	
4.64215244104544E-22	5.8454E-22	1.5	8264.67	-5.60951736557203	
1.26186775683264E-21	1.53575E-21	2.1	5903.33	1.39048204801714	
3.43011212440456E-21	3.4913E-21	2.7	4591.48	8.39048190738504	
9.3240114620244E-21	1.19034E-20	4.2	2951.67	15.3904819108974	
2.53452900486139E-20	2.52946E-20	5.4	2295.74	22.3904816686963	
6.88956375489147E-20	5.47342E-20	7.1	1746.06	29.3904812798358	
1.87277756817137E-19	1.9E-19	33.74	367.427	36.3904811754708	
5.09073705300949E-19	4.98E-19	52.91	234.304	43.3904809289298	
1.38380579405619E-18	1.379E-18	81.58	151.961	50.3904808863892	
3.76157398937905E-18	3.783E-18	127.65	97.1171	57.3904805984668	
1.02250176843969E-17	1.0234E-17	219.09	56.5841	64.3904802306088	
2.77944804434349E-17	2.77E-17	596.7	20.7759	71.3904804009255	

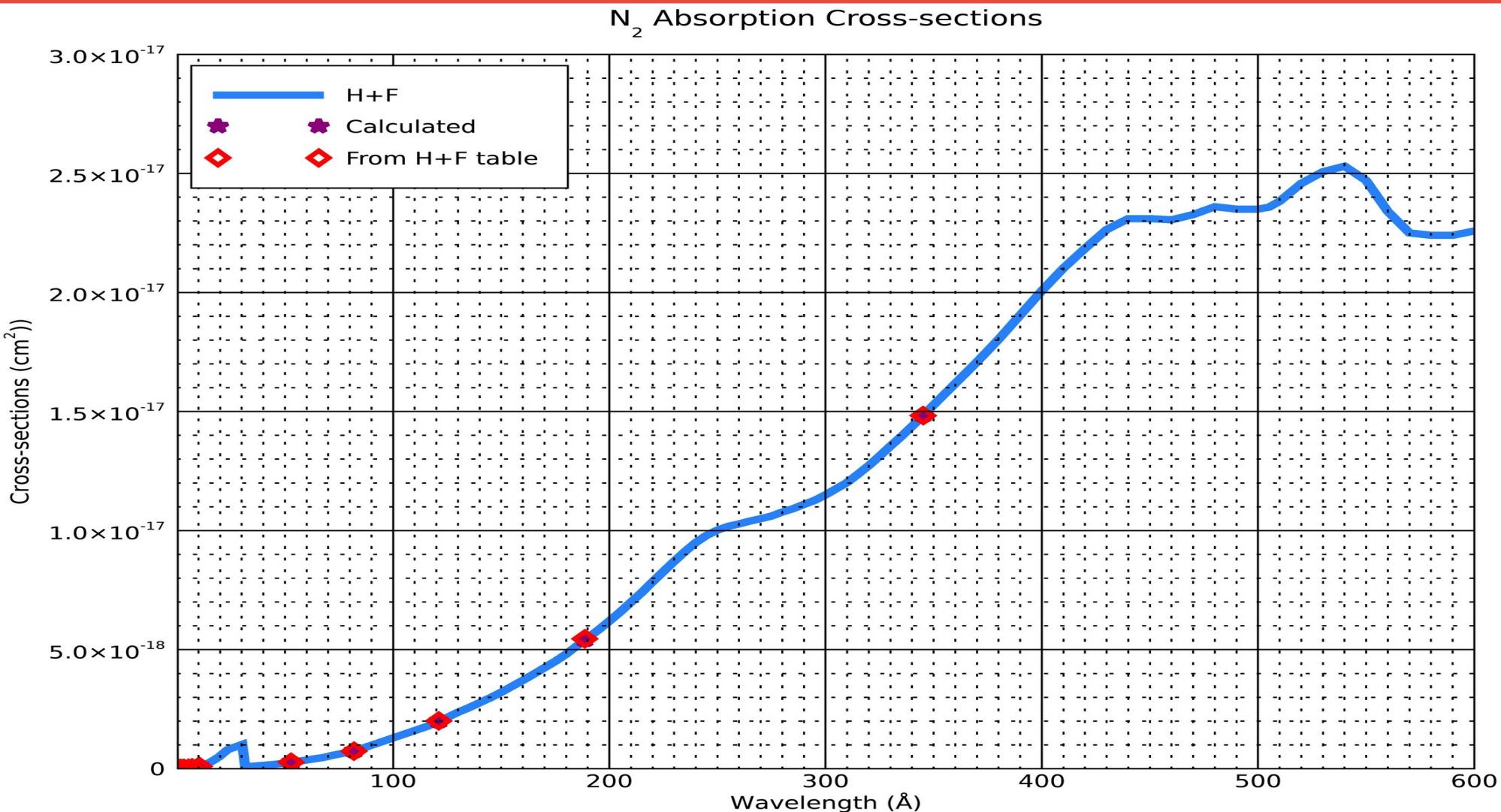
# Plots of Calculated Cross-sections for Verification- Vertical Resolution =7 km



# New energy binnings for NRL- May 2020-Results

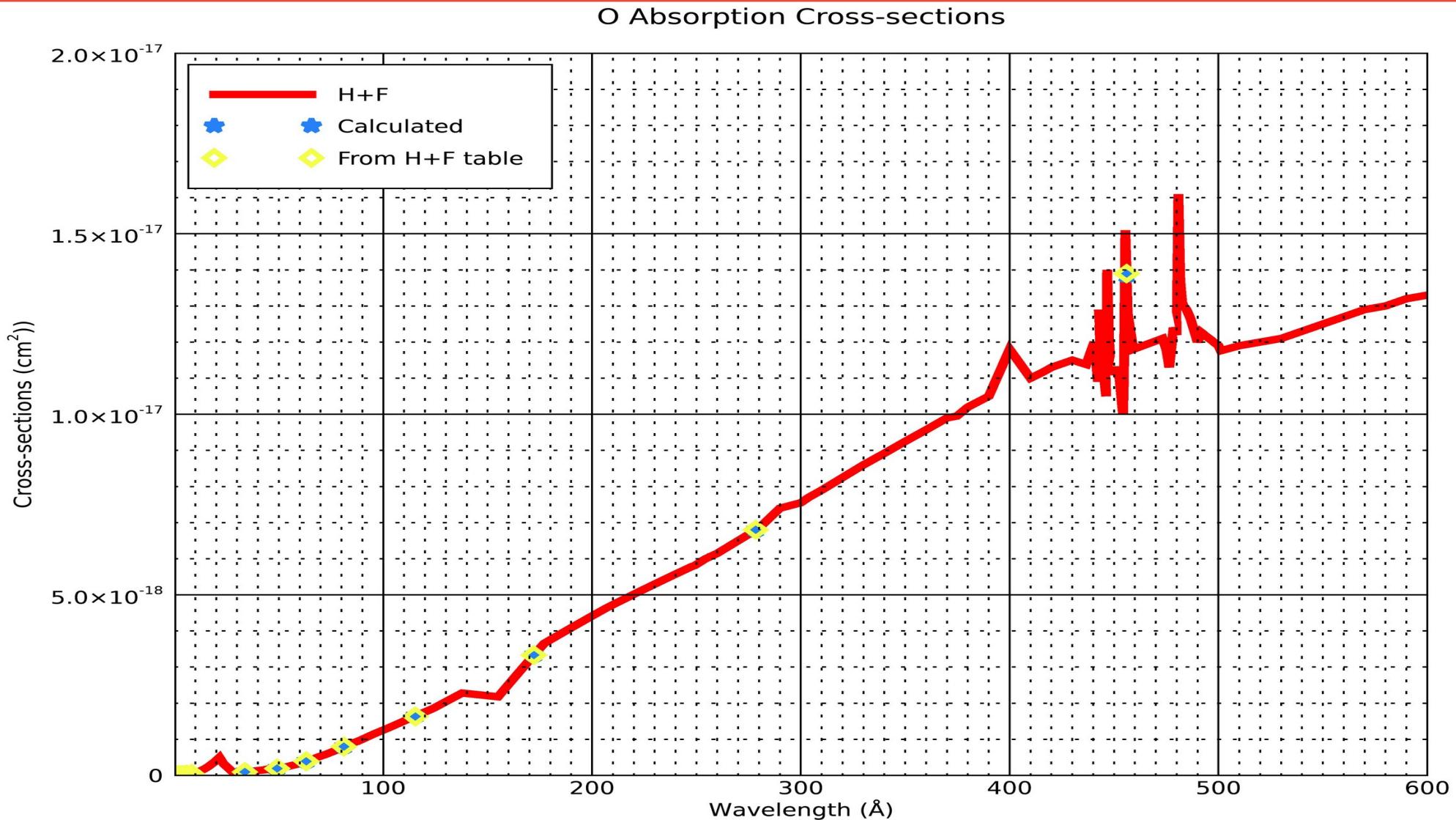
N2 data for Vertical resolution of 7.00000 km					
calculated cross-section (cm <sup>2</sup> )	H+F cross-section	H+F wavelength	H+F energy	Altitude(Tau=1)	
4.53569974168341E-24	4.5357E-24	0.4	30992.5	-28.7977705283576	
1.23293098127496E-23	1.3863E-23	0.6	20661.7	-21.7977707409326	
3.35145381609121E-23	2.60512E-23	0.7	17710	-14.7977708788933	
9.11019561353112E-23	4.32171E-23	0.8	15496.2	-7.79777118137694	
2.47640790046784E-22	3.18662E-22	1.5	8264.67	-0.797771233752545	
6.73157403177013E-22	5.1172E-22	1.8	6887.22	6.20222817983662	
1.82983149998689E-21	1.93988E-21	2.7	4591.48	13.2022280392045	
4.97399771805209E-21	3.57739E-21	3.4	3646.18	20.2022280427169	
1.35207271439585E-20	1.47934E-20	5.4	2295.74	27.2022278005158	
3.6753144861283E-20	3.29362E-20	7.1	1746.06	34.2022274116553	
9.99054043256299E-20	9.62964E-20	10.4	1192.02	41.2022273072903	
2.71571035578443E-19	2.66E-19	52.91	234.304	48.2022270607493	
7.3820660666244E-19	7.39E-19	81.94	151.294	55.2022270182087	
2.0066535220017E-18	1.996E-18	121.15	102.328	62.2022267302863	
5.4546495182225E-18	5.412E-18	188.7	65.6969	69.2022263624283	
1.48272750267589E-17	1.4832E-17	345.13	35.9198	76.202226532745	

# Plots of Calculated Cross-sections for Verification- Vertical Resolution = 7 km



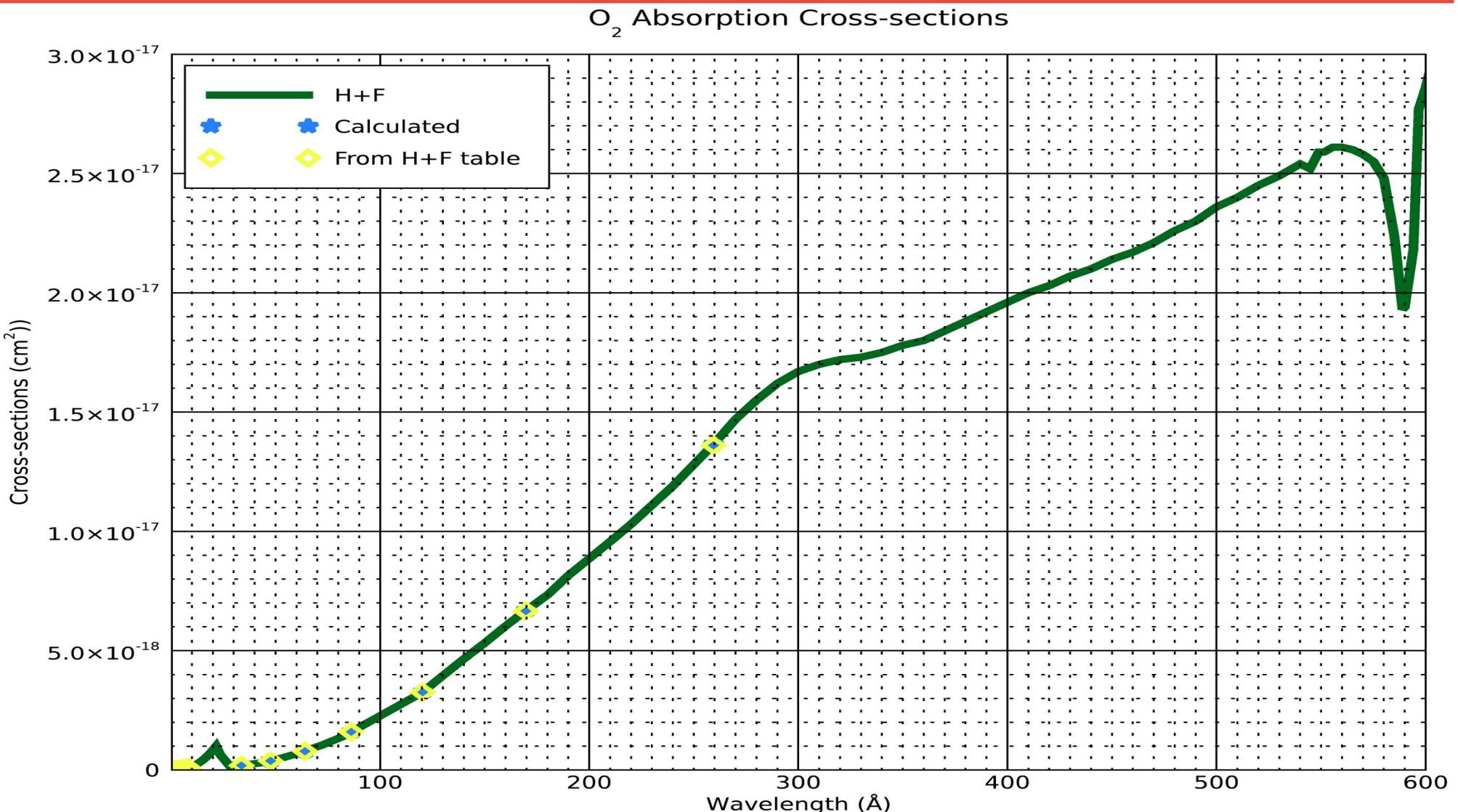
O data for Vertical resolution of 5.00000 km					
calculated cross-section (cm <sup>2</sup> )	H+F cross-section	H+F wavelength	H+F energy	Altitude(Tau=1)	
4.25119981722862E-24	4.2512E-24	0.4	30992.5	-129.168116913143	
8.6840406216736E-24	7.22704E-24	0.5	24794	-124.168117175996	
1.77391250987023E-23	1.28333E-23	0.6	20661.7	-119.168117080691	
3.62361860107661E-23	3.95893E-23	0.8	15496.2	-114.168118052601	
7.4020637186291E-23	3.95893E-23	0.8	15496.2	-109.168118137817	
1.51203954009559E-22	1.52246E-22	1.3	9536.15	-104.168118384534	
3.08868420107083E-22	2.9227E-22	1.5	8264.67	-99.1681181551694	
6.30933813548158E-22	7.67873E-22	2.1	5903.33	-94.168118924639	
1.28882553755841E-21	1.31256E-21	2.5	4958.8	-89.168119157765	
2.63271869511259E-21	3.1884E-21	3.4	3646.18	-84.1681194749876	
5.37792552816242E-21	5.95168E-21	4.2	2951.67	-79.1681197597031	
1.09856338034771E-20	1.26473E-20	5.4	2295.74	-74.1681199220451	
2.2440651546149E-20	1.75628E-20	6.1	2032.3	-69.1681199246168	
4.58401230167005E-20	4.2512E-20	8.3	1493.61	-64.1681204393884	
9.36388618023194E-20	9.6E-20	33.74	367.427	-59.1681203188997	
1.91278617426379E-19	1.93E-19	49.22	251.869	-54.1681210656789	
3.90730000438887E-19	3.91E-19	63.16	196.279	-49.1681212330257	
7.98154728260019E-19	7.95E-19	81.16	152.748	-44.1681214154604	
1.63041218290386E-18	1.643E-18	115.39	107.436	-39.1681217880144	
3.33048691731273E-18	3.331E-18	172.17	72.0044	-34.1681221755784	
6.80327584030749E-18	6.794E-18	278.4	44.5295	-29.1681221167805	
1.38972349077177E-17	1.3845E-17	456	27.1864	-24.168122528687	

# Plots of Calculated Cross-sections for Verification- Vertical Resolution =5 km



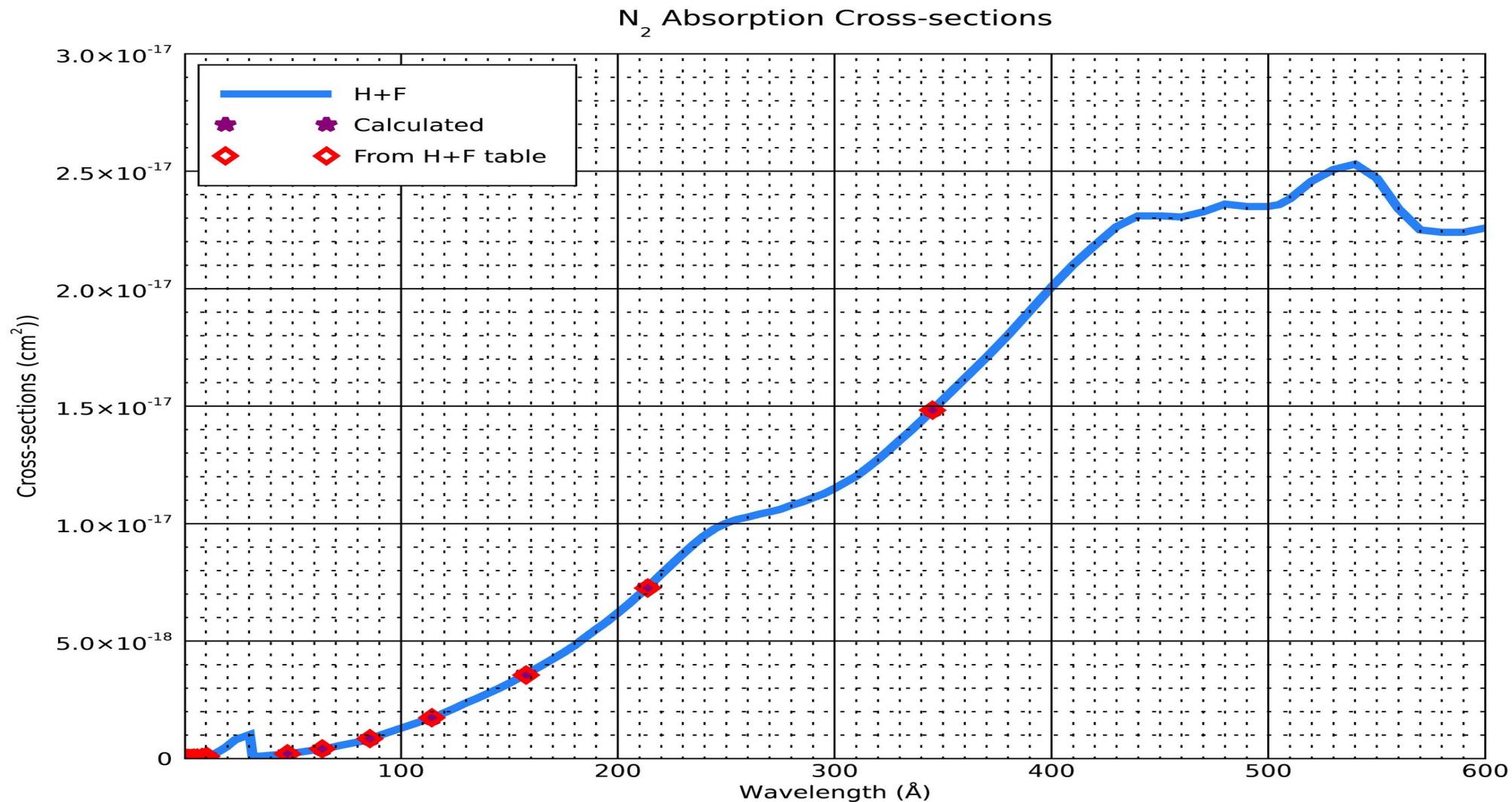
O2 data for Vertical resolution of 5.00000 km					
calculated cross-section (cm2)	H+F cross-section	H+F wavelength	H+F energy	Altitude(Tau=1)	
8.50239963445724E-24	8.5024E-24	0.4	30992.5	-33.609516660177	
1.73680812433472E-23	1.44541E-23	0.5	24794	-28.6095169230303	
3.54782501974047E-23	2.56666E-23	0.6	20661.7	-23.609516827725	
7.24723720215322E-23	7.91786E-23	0.8	15496.2	-18.6095177996356	
1.48041274372582E-22	7.91786E-23	0.8	15496.2	-13.6095178848511	
3.02407908019117E-22	3.04492E-22	1.3	9536.15	-8.60951813156806	
6.17736840214167E-22	5.8454E-22	1.5	8264.67	-3.60951790220381	
1.26186762709632E-21	1.53575E-21	2.1	5903.33	1.39048132832659	
2.57765107511682E-21	2.62512E-21	2.5	4958.8	6.39048109520068	
5.26543739022518E-21	6.3768E-21	3.4	3646.18	11.390480777978	
1.07558510563248E-20	1.19034E-20	4.2	2951.67	16.3904804932625	
2.19712676069541E-20	2.52946E-20	5.4	2295.74	21.3904803309206	
4.48813030922979E-20	3.51255E-20	6.1	2032.3	26.3904803283488	
9.1680246033401E-20	8.5024E-20	8.3	1493.61	31.3904798135772	
1.87277723604639E-19	1.9E-19	33.74	367.427	36.390479934066	
3.82557234852758E-19	3.84E-19	47.7	259.895	41.3904791872867	
7.81460000877774E-19	7.81E-19	64.11	193.371	46.39047901994	
1.59630945652004E-18	1.599E-18	86.23	143.767	51.3904788375052	
3.26082436580773E-18	3.268E-18	120.4	102.965	56.3904784649512	
6.66097383462546E-18	6.68E-18	169.7	73.0524	61.3904780773872	
1.3606551680615E-17	1.3655E-17	259.5	47.7726	66.3904781361852	

# Plots of Calculated Cross-sections for Verification- Vertical Resolution =5 km



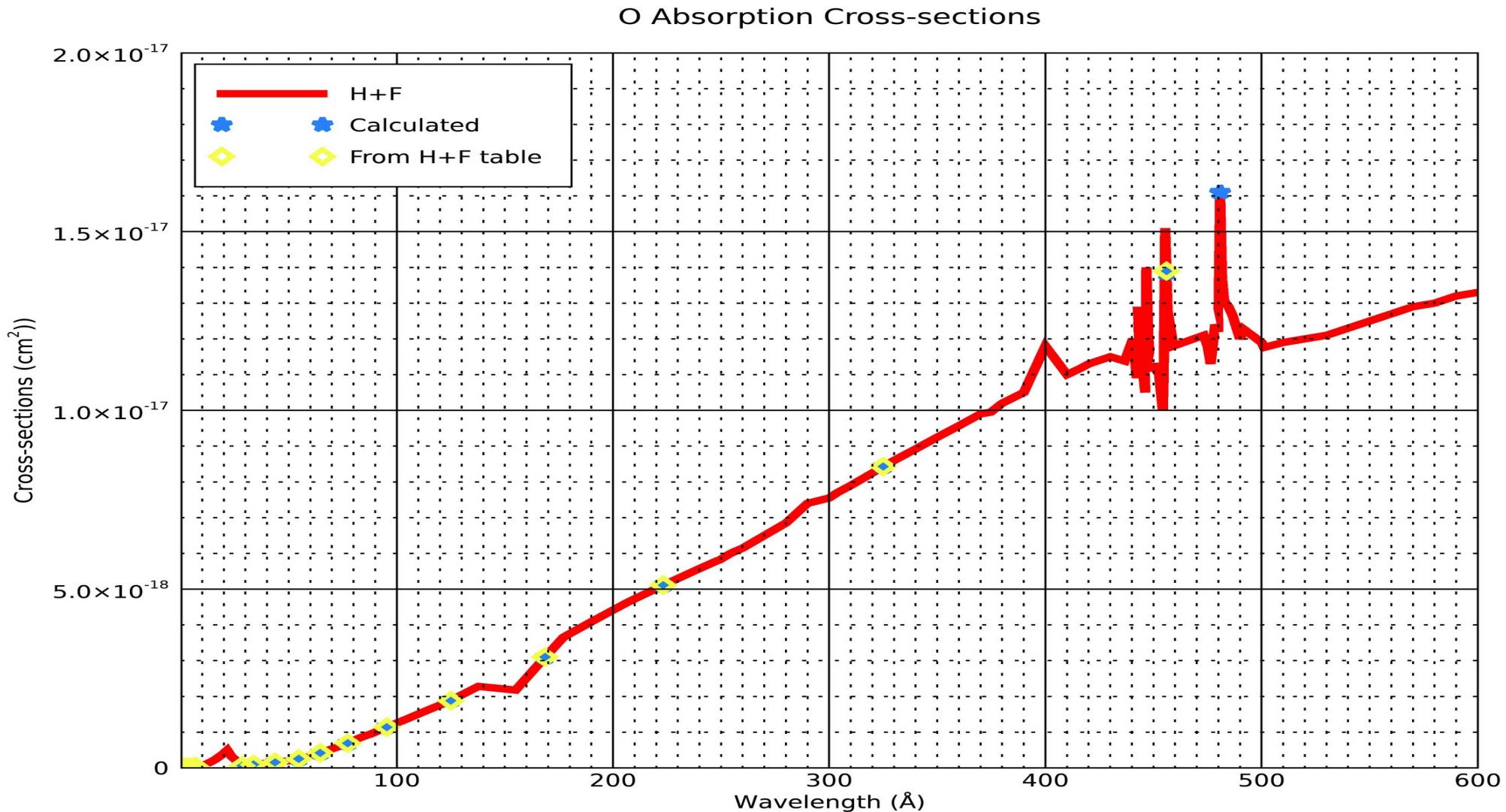
N2 data for Vertical resolution of 5.00000 km					
calculated cross-section (cm <sup>2</sup> )	H+F cross-section	H+F wavelength	H+F energy	Altitude(Tau=1)	
4.53569974168341E-24	4.5357E-24	0.4	30992.5	-28.7977705283576	
9.26519629702341E-24	7.76884E-24	0.5	24794	-23.7977707912108	
1.89262675449412E-23	1.3863E-23	0.6	20661.7	-18.7977706959056	
3.86611936852614E-23	4.32171E-23	0.8	15496.2	-13.7977716678161	
7.89742659482821E-23	4.32171E-23	0.8	15496.2	-8.79777175303157	
1.61322865221083E-22	1.65611E-22	1.3	9536.15	-3.79777199974858	
3.29538594637769E-22	3.18662E-22	1.5	8264.67	1.20222822961567	
6.73157333967728E-22	5.1172E-22	1.8	6887.22	6.20222746014607	
1.37507666284892E-21	1.45608E-21	2.5	4958.8	11.2022272270202	
2.80890619560004E-21	3.57739E-21	3.4	3646.18	16.2022269097975	
5.73782849021212E-21	6.79192E-21	4.2	2951.67	21.202226625082	
1.17208173096748E-20	9.95528E-21	4.7	2637.66	26.20222646274	
2.39424307953205E-20	2.07479E-20	6.1	2032.3	31.2022264601683	
4.89078479169503E-20	5.16372E-20	8.3	1493.61	36.2022259453967	
9.99053866080528E-20	9.62964E-20	10.4	1192.02	41.2022260658854	
2.0407941591792E-19	2.09E-19	47.7	259.895	46.2022253191062	
4.16878537413456E-19	4.17E-19	63.72	194.554	51.2022251517594	
8.51569051193736E-19	8.53E-19	85.69	144.673	56.2022249693247	
1.73952306049341E-18	1.732E-18	114.24	108.517	61.2022245967707	
3.55337064828514E-18	3.596E-18	157.73	78.5963	66.2022242092067	
7.25856647491105E-18	7.3E-18	213.78	57.9895	71.2022242680046	
1.48272693571343E-17	1.4832E-17	345.13	35.9198	76.2022238560981	

# Plots of Calculated Cross-sections for Verification- Vertical Resolution =5 km



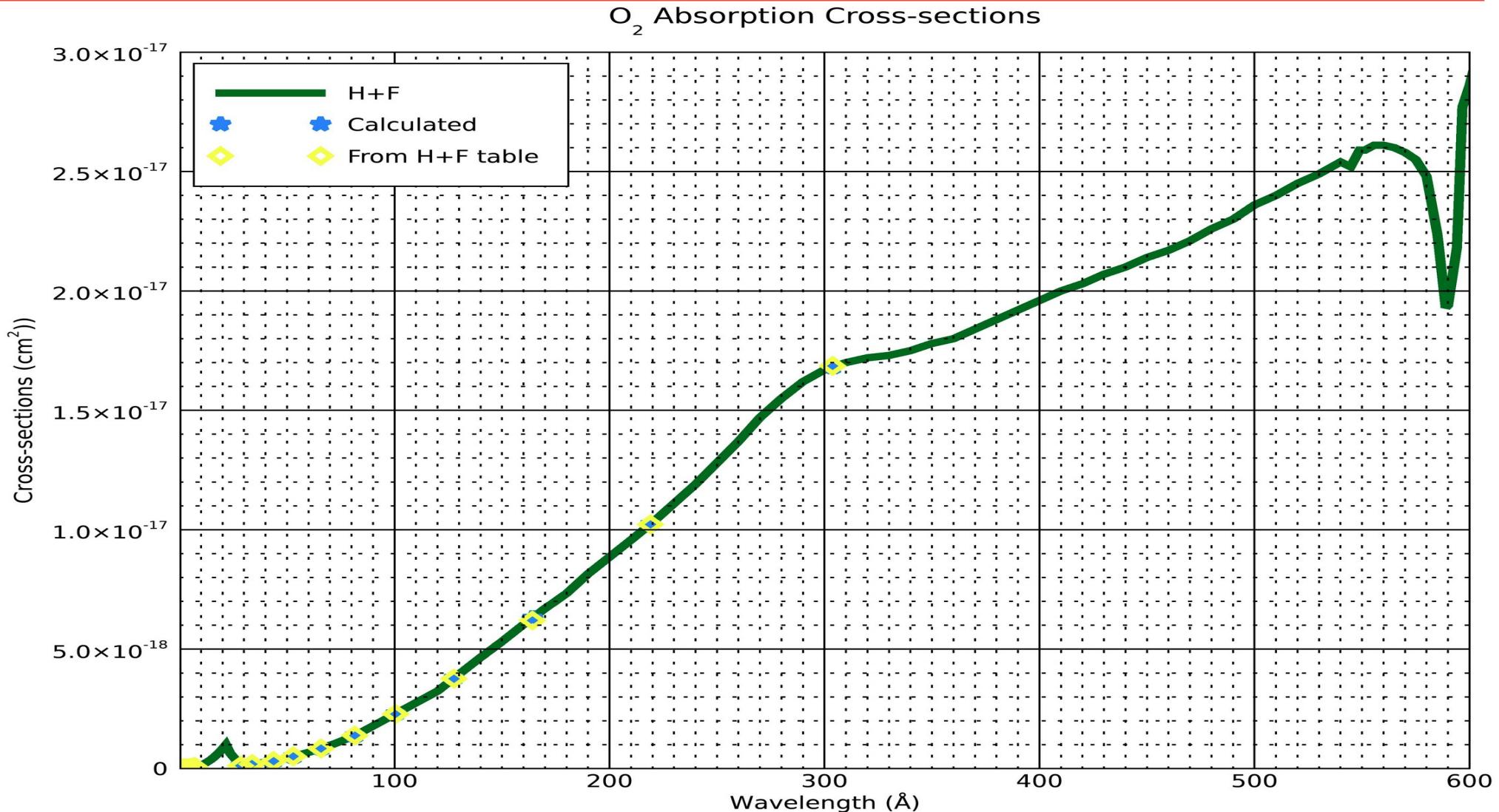
O data for Vertical resolution of 3.50000 km				
calculated cross-section (cm2)	H+F cross-section	H+F wavelength	H+F energy	Altitude(Tau=1)
4.25119981722862E-24	4.2512E-24	0.4	30992.5	-129.168116913143
7.00904334108649E-24	7.22704E-24	0.5	24794	-125.668117136429
1.15559588613912E-23	1.28333E-23	0.6	20661.7	-122.168117125718
1.90525533297404E-23	2.39661E-23	0.7	17710	-118.668117804818
3.14123503371143E-23	2.39661E-23	0.7	17710	-115.168117715409
5.17902088527958E-23	3.95893E-23	0.8	15496.2	-111.668117892562
8.53876148225917E-23	3.95893E-23	0.8	15496.2	-108.168118230891
1.407803702597E-22	1.52246E-22	1.3	9536.15	-104.668118556708
2.32107589618191E-22	2.9227E-22	1.5	8264.67	-101.168118596699
3.82680700759364E-22	3.69323E-22	1.7	7292.35	-97.6681189503761
6.30933813548158E-22	7.67873E-22	2.1	5903.33	-94.168118924639
1.04023394270409E-21	9.99032E-22	2.3	5390	-90.6681193021281
1.71505580272963E-21	1.74565E-21	2.7	4591.48	-87.1681194046181
2.82764881710307E-21	3.1884E-21	3.4	3646.18	-83.6681198138148
4.66200469312162E-21	5.95168E-21	4.2	2951.67	-80.1681199004608
7.68634571094801E-21	8.63525E-21	4.7	2637.66	-76.6681204384196
1.26726419106352E-20	1.26473E-20	5.4	2295.74	-73.1681203041711
2.08936528025027E-20	1.75628E-20	6.1	2032.3	-69.6681207971769
3.44478083955516E-20	2.73671E-20	7.1	1746.06	-66.168121082185
5.67948339082258E-20	6.4E-20	28.47	435.441	-62.6681211465863
9.36388451960701E-20	9.6E-20	33.74	367.427	-59.1681215603047
1.5438434732507E-19	1.57E-19	43.76	283.295	-55.668121946318
2.54536769619228E-19	2.53E-19	54.7	226.636	-52.1681216074726
4.19660145870096E-19	4.17E-19	64.6	191.904	-48.668122280958
6.91902631328104E-19	6.92E-19	77.3	160.375	-45.1681220546708
1.14075447105567E-18	1.142E-18	95.37	129.988	-41.6681227570818
1.88078619758956E-18	1.887E-18	125	99.176	-38.168122621183
3.10089210308368E-18	3.091E-18	168.55	73.5509	-34.668122861646
5.11250671659855E-18	5.107E-18	223.26	55.5272	-31.1681229327092

# Plots of Calculated Cross-sections for Verification- Vertical Resolution =3.5 km



O2 data for Vertical resolution of km	3.50000				
calculated cross-section (cm <sup>2</sup> )	H+F cross-section	H+F wavelength	H+F energy	Altitude(Tau=1)	
8.50239963445724E-24	8.5024E-24	0.4	30992.5	-33.609516660177	
1.4018086682173E-23	1.44541E-23	0.5	24794	-30.1095168834634	
2.31119177227825E-23	2.56666E-23	0.6	20661.7	-26.609516872752	
3.81051066594807E-23	4.79323E-23	0.7	17710	-23.1095175518524	
6.28247006742285E-23	4.79323E-23	0.7	17710	-19.609517462443	
1.03580417705592E-22	7.91786E-23	0.8	15496.2	-16.1095176395966	
1.70775229645184E-22	7.91786E-23	0.8	15496.2	-12.6095179779256	
2.81560740519401E-22	3.04492E-22	1.3	9536.15	-9.10951830374226	
4.64215179236382E-22	5.8454E-22	1.5	8264.67	-5.60951834373284	
7.65361401518727E-22	7.38646E-22	1.7	7292.35	-2.10951869741043	
1.26186762709632E-21	1.53575E-21	2.1	5903.33	1.39048132832659	
2.08046788540818E-21	1.99806E-21	2.3	5390	4.89048095083753	
3.43011160545927E-21	3.4913E-21	2.7	4591.48	8.39048084834756	
5.65529763420614E-21	6.3768E-21	3.4	3646.18	11.8904804391508	
9.32400938624324E-21	1.19034E-20	4.2	2951.67	15.3904803525049	
1.5372691421896E-20	1.72705E-20	4.7	2637.66	18.890479814546	
2.53452838212704E-20	2.52946E-20	5.4	2295.74	22.3904799487945	
4.17873056050053E-20	3.51255E-20	6.1	2032.3	25.8904794557887	
6.88956167911031E-20	5.47342E-20	7.1	1746.06	29.3904791707806	
1.13589667816452E-19	1.27E-19	28.47	435.441	32.8904791063794	
1.8727769039214E-19	1.9E-19	33.74	367.427	36.3904786926609	
3.0876869465014E-19	3.09E-19	43.76	283.295	39.8904783066476	
5.09073539238456E-19	4.98E-19	52.91	234.304	43.390478645493	
8.39320291740192E-19	8.41E-19	65.85	188.261	46.8904779720077	
1.38380526265621E-18	1.379E-18	81.58	151.961	50.3904781982949	
2.28150894211133E-18	2.294E-18	100.54	123.304	53.8904774958838	
3.76157239517912E-18	3.783E-18	127.65	97.1171	57.3904776317827	
6.20178420616735E-18	6.307E-18	164.13	75.5316	60.8904773913196	
1.02250134331971E-17	1.0234E-17	219.09	56.5841	64.3904773202564	
1.68581955804174E-17	1.6814E-17	303.8	40.8065	67.8904766724632	

# Plots of Calculated Cross-sections for Verification- Vertical Resolution =3.5 km



N2 data for Vertical resolution of	3.50000 km				
calculated cross-section (cm2)	H+F cross-section	H+F wavelength	H+F energy	Altitude(Tau=1)	
	4.53569974168341E-24	4.5357E-24	0.4	30992.5	-28.7977705283576
	7.47810440308554E-24	7.76884E-24	0.5	24794	-25.2977707516439
	1.23293098127496E-23	1.3863E-23	0.6	20661.7	-21.7977707409326
	2.0327593369264E-23	2.60512E-23	0.7	17710	-18.297771420033
	3.35145359981219E-23	2.60512E-23	0.7	17710	-14.7977713306236
	5.52561269793457E-23	4.32171E-23	0.8	15496.2	-11.2977715077772
	9.11019474841505E-23	4.32171E-23	0.8	15496.2	-7.79777184610611
	1.5020171162815E-22	1.65611E-22	1.3	9536.15	-4.29777217192278
	2.47640755442141E-22	3.18662E-22	1.5	8264.67	-0.797772211913358
	4.08290560360675E-22	4.02398E-22	1.7	7292.35	2.70222743440905
	6.73157333967728E-22	5.1172E-22	1.8	6887.22	6.20222746014607
	1.10984875518956E-21	1.10252E-21	2.3	5390	9.70222708265701
	1.82983122314975E-21	1.93988E-21	2.7	4591.48	13.202226980167
	3.01688148304135E-21	3.57739E-21	3.4	3646.18	16.7022265709703
	4.97399661070352E-21	3.57739E-21	3.4	3646.18	20.2022264843243
	8.20073338222046E-21	6.79192E-21	4.2	2951.67	23.7022259463655
	1.35207238219128E-20	1.47934E-20	5.4	2295.74	27.202226080614
	2.22919033904441E-20	2.07479E-20	6.1	2032.3	30.7022255876082
	3.67531337877973E-20	3.29362E-20	7.1	1746.06	34.2022253026001
	6.0595672883338E-20	5.16372E-20	8.3	1493.61	37.7022252381988
	9.99053688904757E-20	9.62964E-20	10.4	1192.02	41.2022248244804
	1.64716097663641E-19	1.71E-19	43.76	283.295	44.7022244384671
	2.71570946990558E-19	2.66E-19	52.91	234.304	48.2022247773125
	4.47744753729005E-19	4.45E-19	65.85	188.261	51.7022241038271
	7.38206323181206E-19	7.39E-19	81.94	151.294	55.2022243301143
	1.21709634506534E-18	1.217E-18	97.51	127.136	58.7022236277033
	2.006652671558E-18	1.996E-18	121.15	102.328	62.2022237636021
	3.30841082885481E-18	3.317E-18	152.15	81.4788	65.7022235231391
	5.45464725037263E-18	5.412E-18	188.7	65.6969	69.2022234520759
	8.99319211360838E-18	9.025E-18	233.84	53.0149	72.7022228042827
	1.48272670892844E-17	1.4832E-17	345.13	35.9198	76.202222785439

# Plots of Calculated Cross-sections for Verification- Vertical Resolution =3.5 km

