Use of Langmuir Probes as an atmospheric measurement device

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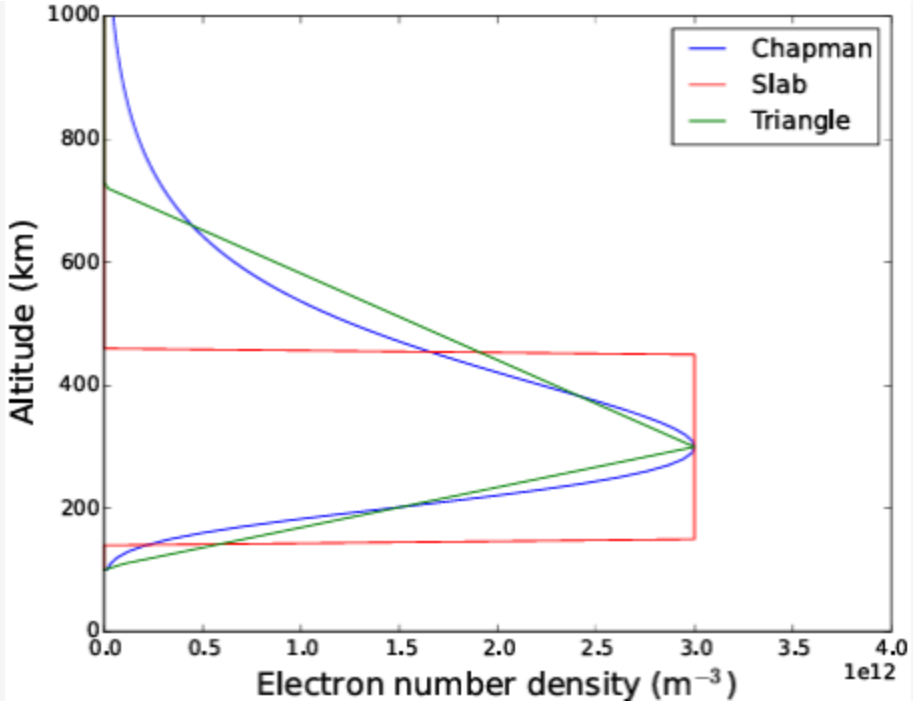
About 50 km - 1000 km above sea level, the ionosphere is a part of the Earth's upper atmosphere that is composed of a plasma. This is mostly due to incident solar radiation which dislodges electrons from neutral gas atoms and molecules. As in our experiment, this generated plasma may be described in terms of the electron density and the electron and ion temperatures. To measure these paramteres, satellites equipped with Langmuir Probes are used [1].

The code in the cell below models the measurements that a probe in the ionosphere might take.



[2]

Using the plot above, we can model electron density as a function of altitude. From this, we can take an expected electron temperature of around 2000 K, together with the electrom mass in kg, and a probe diameter of about 3 mm, and solve for the average thermal electron speed and the electron saturation current.

In [90]:

```
import numpy as np
import matplotlib.pyplot as plt

def fgaussian(x, A, B, C):
    return A * np.exp(-((x - B) ** 2) / (2 * C ** 2))

Te = 2000 # K
k = 1.38e-23 # J/K
e = 1.602e-19 # C
d = 3.0e-3 # m
me = 9.11e-31 # kg

A = 2*np.pi*(d/2)**2
ve = np.sqrt(8*k*Te/(np.pi*me))

ne = np.array([0, 0.8, 1.6, 2.3, 3.0, 2.7, 2.4, 2.0, 1.6, 1.4, 1.25, 0.9,
altitudes = np.linspace(100, 1000, 19)

A = 3e12
B = 300
C = 10
D = 1

# This fit will imporve with more data points, but for this rudimentary m
popt, pcov = curve_fit(fgaussian, altitudes, ne, p0=[A, B, C])
uncert = np.sqrt(np.diag(pcov))

#fig, ax1 = plt.subplots()

#color = 'tab:red'
#ax1.set_xlabel('altitude (km)')
#ax1.set_ylabel('electron denstity (m^-3)', color=color)
#ax1.plot(altitudes, ne, color=color)
#ax1.tick_params(axis='y', labelcolor=color)

#ax2 = ax1.twinx()

#color = 'tab:blue'
#ax2.set_ylabel('electron saturation current', color=color)
#ax2.plot(, altitudes, color=color)
#ax2.tick_params(axis='y', labelcolor=color)

#plt.suptitle('')

#fig.tight_layout()

ne_fit = fgaussian(altitudes, *popt)
I_es = 0.25*e*ne*ve*A
I_es_fit = 0.25*e*ne_fit*ve*A
print(f'ne_fit = ({popt[0]:0.0f})exp(-(x - {popt[1]:0.0f})/2({popt[2]:0.0
print()
print(f'The electron saturation current as funcion of the electro density
print()
print(f'The electron saturation current as funcion of the electron densit

plt.plot(altitudes, ne, label='ne actual')
plt.plot(altitudes, ne_fit, label='ne_Fit', color='red')
```

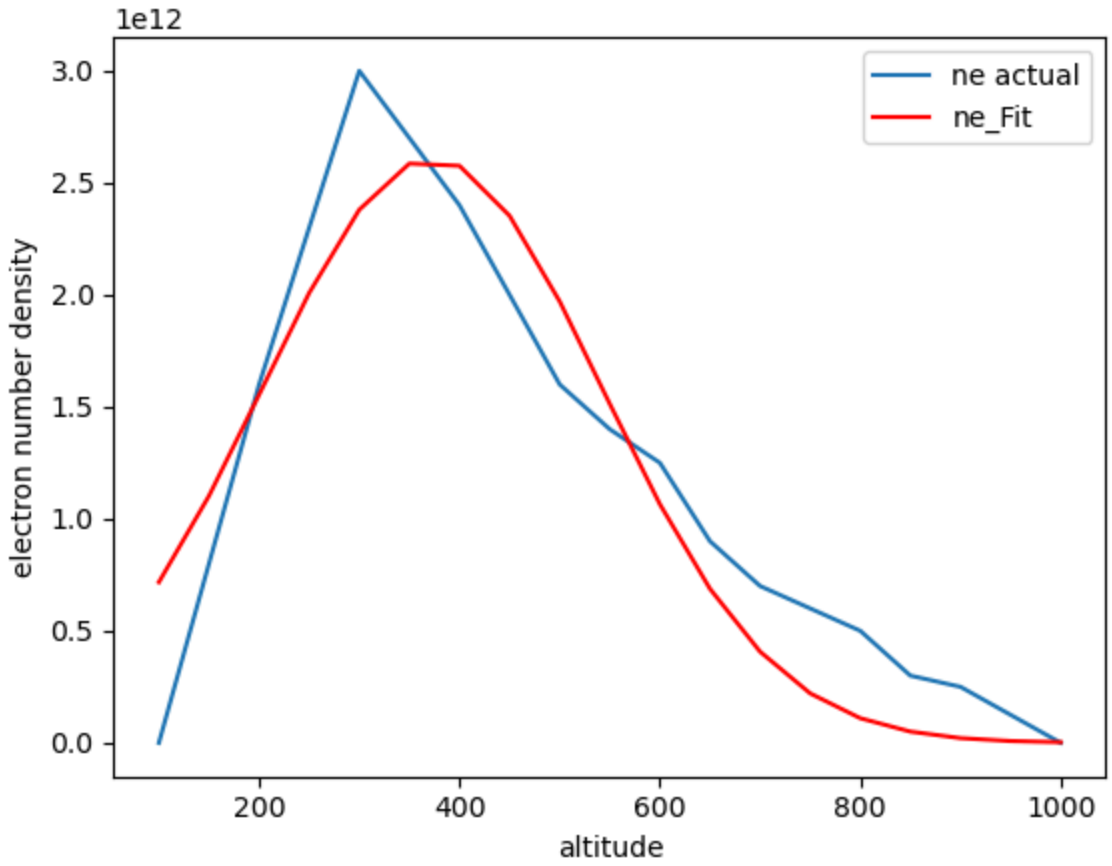
```
plt.xlabel('altitude')
plt.ylabel('electron number density')
plt.legend()
plt.show()

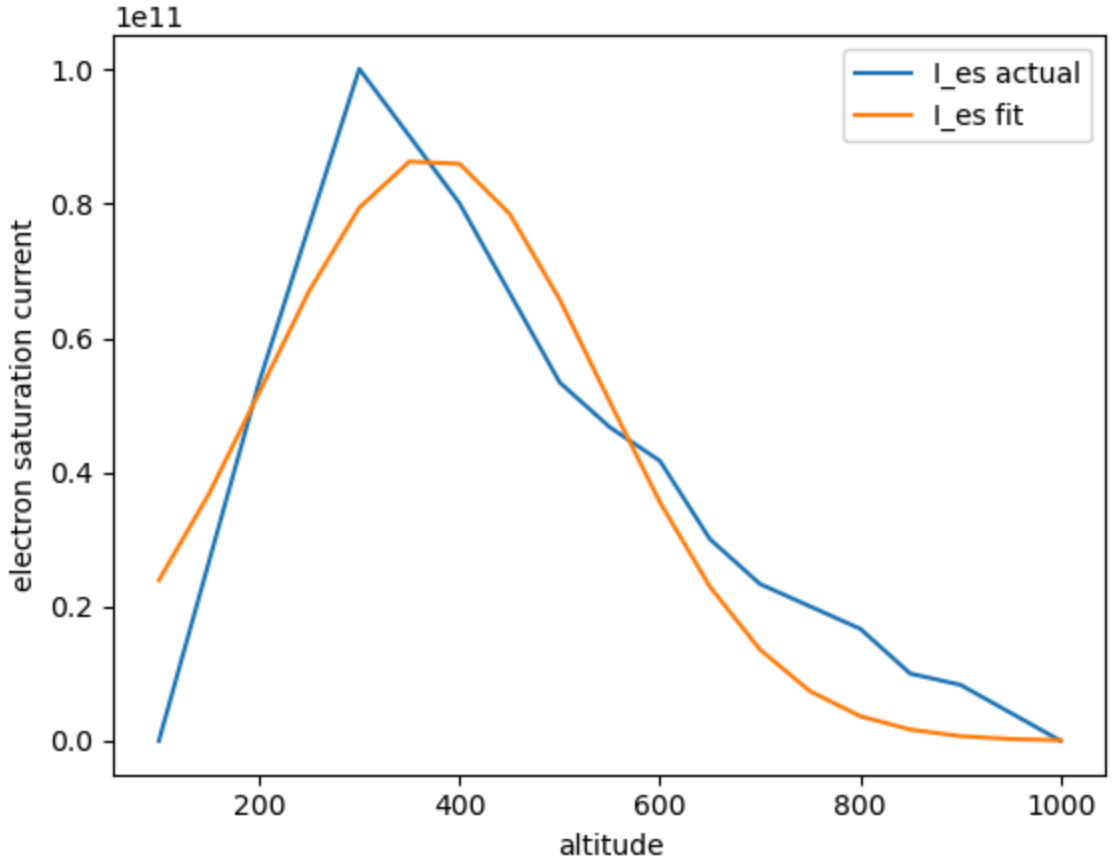
plt.plot(altitudes, I_es, label='I_es actual')
plt.plot(altitudes, I_es_fit, label='I_es fit')
plt.xlabel('altitude')
plt.ylabel('electron saturation current')
plt.legend()
plt.show()
```

```
ne_fit = (2609459232920)exp(-(x - 373)/2(170)

The electron saturation current as funcion of the electro density is: [0.000
00000e+00 2.66980272e+10 5.33960545e+10 7.67568283e+10
 1.00117602e+11 9.01058419e+10 8.00940817e+10 6.67450681e+10
 5.33960545e+10 4.67215477e+10 4.17156676e+10 3.00352806e+10
 2.33607738e+10 2.00235204e+10 1.66862670e+10 1.00117602e+10
 8.34313351e+09 4.17156676e+09 0.00000000e+00] Amps

The electron saturation current as funcion of the electron density fit is:
[2.39356884e+10 3.67974409e+10 5.18682310e+10 6.70343471e+10
 7.94338216e+10 8.63029532e+10 8.59721887e+10 7.85240039e+10
 6.57595776e+10 5.04925984e+10 3.55474582e+10 2.29457105e+10
 1.35802134e+10 7.36925877e+09 3.66651228e+09 1.67260969e+09
 6.99597420e+08 2.68295826e+08 9.43391066e+07] Amps
```





Reference

[1] https://www.esa.int/Education/ESEO/Langmuir_Probe#:~:text=The%20Langmuir%20Probe%20((https://www.esa.int/Education/ESEO/Langmuir_Probe#:~:text=The%20Langmuir%20Probe%20

[2] https://amt.copernicus.org/articles/8/3385/2015/amt-8-3385-2015-f03.pdf (https://amt.copernicus.org/articles/8/3385/2015/amt-8-3385-2015-f03.pdf)

In [ ]:
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1
```