A Novel Ionospheric Diagram for Understanding Ionospheric Characteristics and Behaviour

United Nations Workshop
On the International Space Weather Initiative:
The Way Forward

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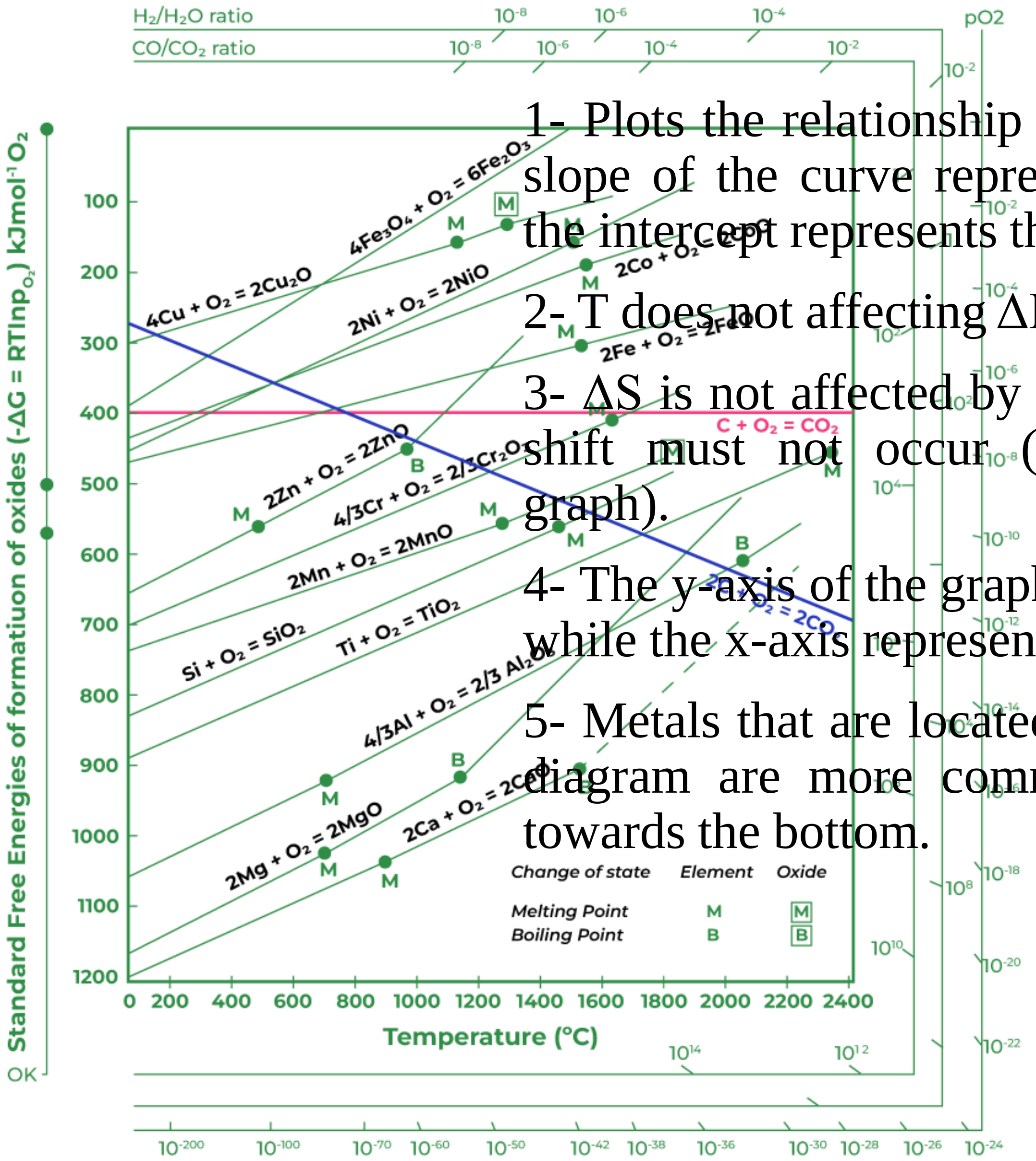
Ellingham Diagram?!?



1- Plots the relationship between T and ΔG. The slope of the curve represents the entropy, while the intercept represents the H.

2- T does not affecting ΔH (slopes).

3- ΔS is not affected by temperature, but a phase shift must not occur (sudden changes in the graph).

4- The y-axis of the graph represents temperature, while the x-axis represents ΔG.

5- Metals that are located closer to the top of the diagram are more common than those located towards the bottom.

$$\Delta G = \Delta H - T\Delta S$$

$$\Delta G = RT \ln K_p$$

$$V = \frac{RT}{p}$$

$$A + B \rightarrow C$$

$$K_p = \frac{p_C}{p_A p_B}$$

Ellingham, H. J. T. (1944)

Poyting Vector

$$\vec{S} = \frac{1}{\mu_0}\left(\vec{E} \times \vec{B}\right)$$

$$\vec{S} = \frac{\sigma}{\mu_0}\left(\vec{J} \times \vec{B}\right)$$

Magnetic Fields

Dipole magnetic field

$$\vec{B} = B_r\hat{r} + B_\theta\hat{\theta} + B_\phi\hat{\phi}$$

$$B_r = -\frac{2\mu_0 M\cos\theta}{r^3}$$

$$B_\theta = -\frac{\mu_0 M\sin\theta}{r^3}$$

$$B_\phi = 0$$

Drift Velocity

$$\vec{v} = v_r \hat{r} + v_\theta \hat{\theta} + v_\phi \hat{\phi}$$

Poynting Vector

$$\vec{S} = \frac{M q_e^3 n_e^2}{m_e V_e r^3} \Big[\big(v_\phi \sin\theta \big) \hat{r} - \Big[\big(2 v_\phi \cos\theta \big) \hat{\theta} \Big) + \Big[\big(2 v_\theta \cos\theta - v_r \sin\theta \big) \hat{\phi} \Big) \Big]$$

Collision Frequency and Electron Density

$$\nu_e = \nu_{e_0} e^{-\frac{(h-h_0)}{H}}$$

$$n_e = n_{e_0} e^{-\frac{(h-h_0)}{H}}$$

Poynting Vector

$$\vec{S} = \frac{M q_e^3 n_{e_0}^2 e^{-\frac{(h-h_0)}{H}}}{m_e V_{e_0} r^3} \left[\left(v_\phi \sin\theta \right) \hat{r} - \left[\left(2 v_\phi \cos\theta \right) \hat{\theta} \right) + \left[\left(2 v_\theta \cos\theta - v_r \sin\theta \right) \hat{\phi} \right) \right.$$

$$S_r = \frac{M q_e^3 v_\phi n_{e_0}^2 \sin\theta e^{-\frac{(h-h_0)}{H}}}{m_e V_{e_0} r^3} \hat{r}$$

Drift Velocity and Kinetic Energy

$$v_\phi = -\frac{3cW}{q_e B_0 r}\hat{\phi}$$

$$35\%\,\varepsilon$$

$$\varepsilon = u_{sw} B_{IMF}^2 l_0^2 \sin^4\left(\frac{\theta}{2}\right),$$

Strangeway, R. J., Johnson, R. G. (1983)

Wang, C., et al. (2014)

Kamide, Y., et al. (1998)

Akasofu, S. I. (1981)

Perreault, P. And Akasofu, S. I. (1978)

Epsilon Parameter and Kp

$$\varepsilon = u_{sw} B_{IMF}^2 l_0^2 \sin^4\left(\frac{\theta}{2}\right)$$

$$n_{sw} = 7/cm^3$$
$$u_{sw} = 450 km/s$$

$$\varepsilon \sim \begin{cases} (9.3 - 3.7Kp) \times 10^4 & Kp \leq 2 \\ (3.7Kp - 9.3) \times 10^4 & Kp > 2 \end{cases}$$

Goncharova, M., et al. (2000)

Anil Bhardwaj,. et al. (2014)

Kinetic Energy and Drift Velocity

$$1\ erg = 6.242 \times 10^{11}\ \mathrm{eV}$$

$$W = 2.23\varepsilon \times 10^{-22}$$

$$W = | 8.3Kp - 20.7 | \times 10^{-18}$$

$$v_\phi = - v_\phi = -\frac{3cW}{q_e B_0 r}\hat{\phi}\ \frac{10^{-17}}{\quad}\hat{\phi}$$

Kinetic Energy and Drift Velocity

$$S_r = -\frac{\mu_0 c q_e^2}{\pi m_e} \frac{|\,6.3Kp - 16\,|\, n_{e_0}^2 \sin\theta e^{-\frac{(h-h_0)}{H}}}{v_{e_0} r^4} \times 10^{-18} \hat{r}$$

$$-\ln|S_r| = \ln\left(\frac{\mu_0 c q_e^2}{\pi m_e R_E^4}\right) + \ln\left(\frac{|\,6.3Kp - 16\,|\, n_{e_0}^2 \sin\theta}{v_{e_0}}\right) - \frac{(h-h_0)}{H} - 18\ln(10)$$

Number Densities

$$n_e\,(D) = 1.43 \times 10^7 e^{-0.15h' + (\beta - 0.15)(h - h')}$$

$$h' = 74.4 - 8.1\cos\chi + 5.8\cos\theta - 1.2\cos\phi - 6\lambda$$

$$\beta = 0.5 - 0.2\cos\chi - 0.1\cos\phi + 0.1\lambda$$

Wait and Spies (1964)

Thomson (1993)

D-Layer

$$n_e(h) = 1.43 \times 10^7 e^{-0.15h' + (\beta - 0.15)(h - h')}$$

$$h' = 74.4 - 8.1\cos\chi + 5.8\cos\theta - 1.2\cos\phi - 6\lambda$$
$$\beta = 0.5 - 0.2\cos\chi - 0.1\cos\phi + 0.1\lambda$$

Wait and Spies (1964)

Thomson (1993)

E-Layer

$$n_e(h) = (NmE)\,e^{\frac{(h-(hmE))}{H}}$$

$$(NmE) = 1.7 \times 10^4\,(F10.7)\,(\cos\chi)$$

Davies (1990)

Nava et al., (2008)

F1-Layer

$$n_e(h) = (NmF1)\, e^{1 - z - e^{z}}$$

$$z = \left(\frac{h - hmF1}{H}\right)$$

$$NmF1 = 10^4 \times \left(24.1 + 1.24R12^2 \times 10^{-4} + 0.1R12\right)$$

Bilitza et al., (2022)

F2-Layer

$$n_e(h) = (NmF2)\, e^{\frac{1}{2}(1 - z - e^{-z})}$$

$$z = \left(\frac{h - hmF1}{H}\right)$$

$$H = 70km \text{ and } hmF2 = 350km$$

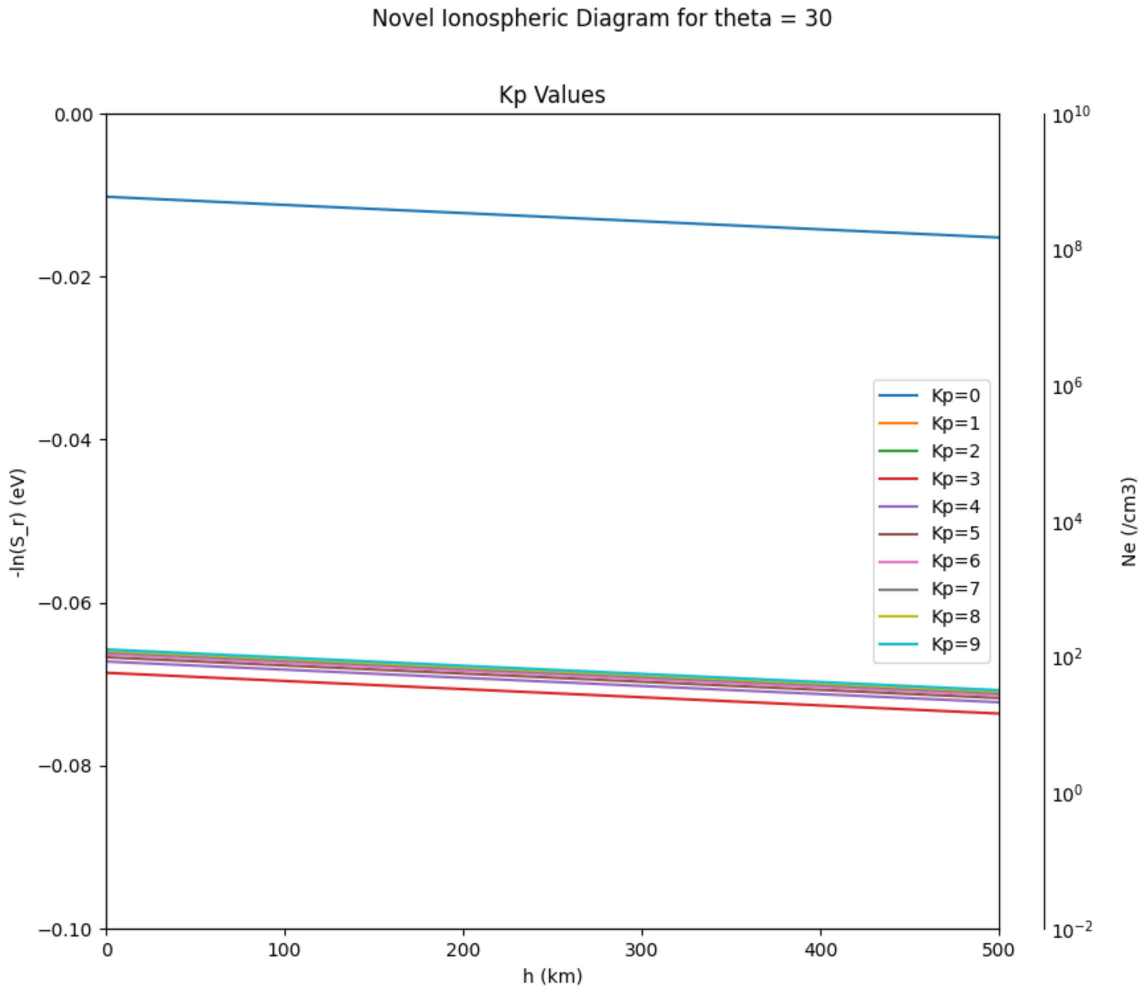
$$foF1 = 1.4 foF2$$

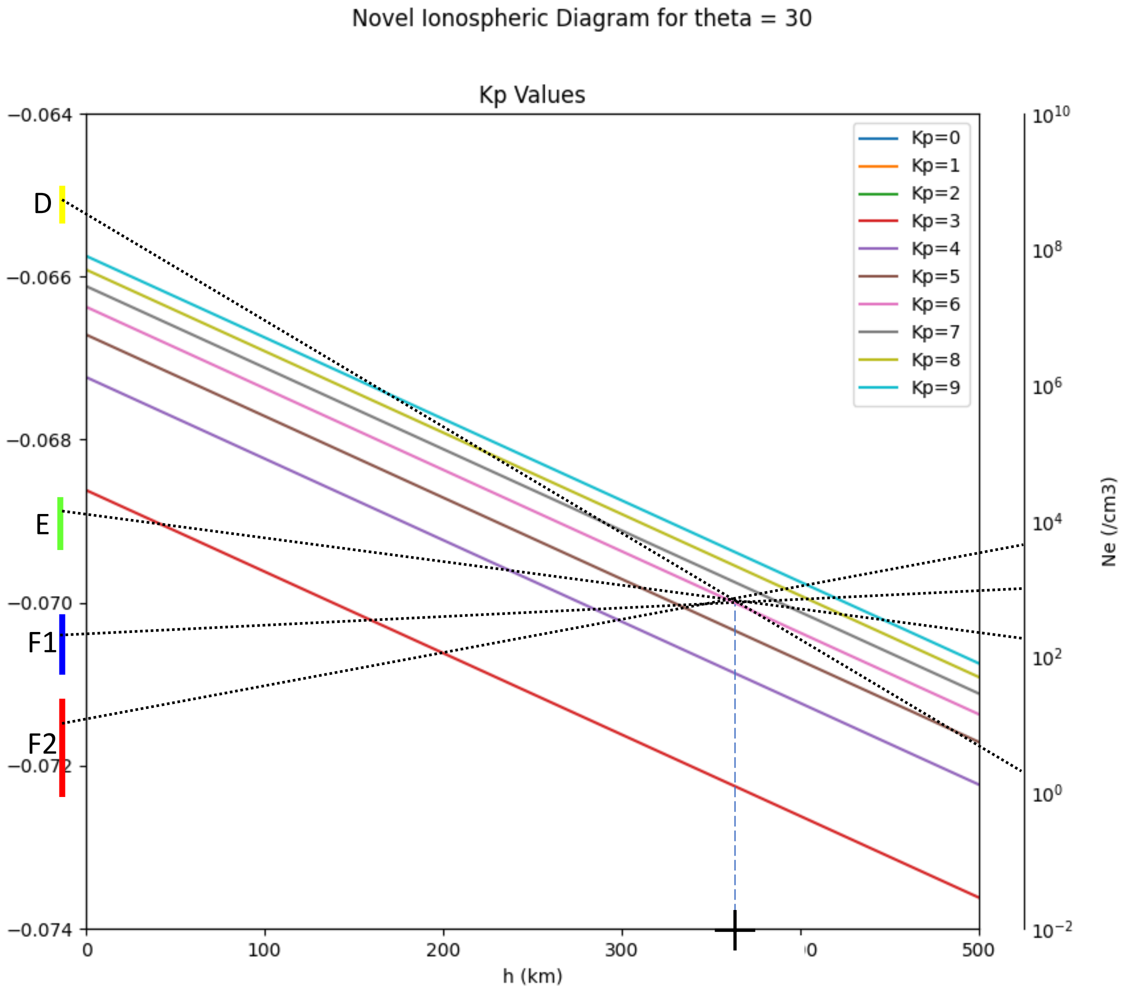
Jakowski, (2005)

Hoque and Jakowski, 2008

Leitinger et al., 2005

Draft Diagrams





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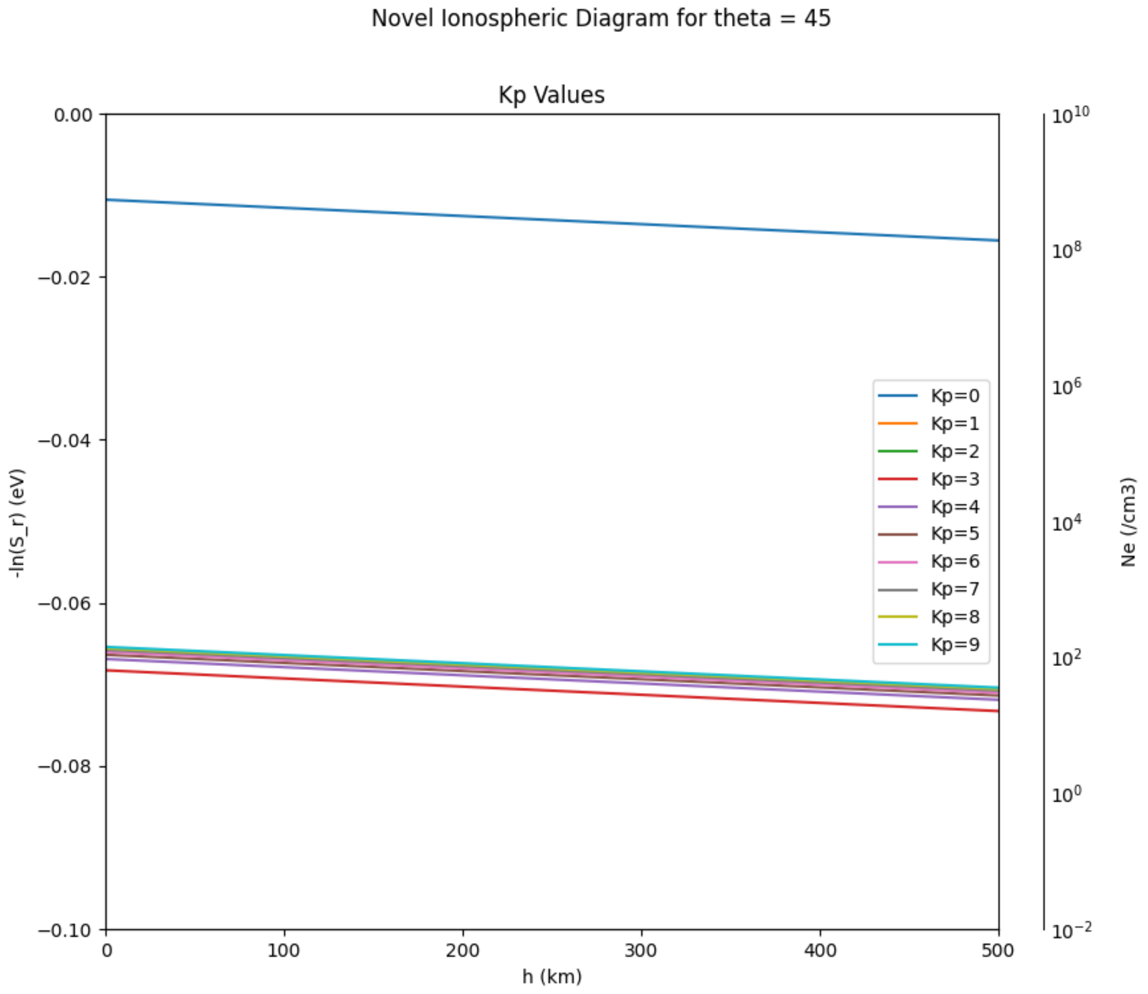

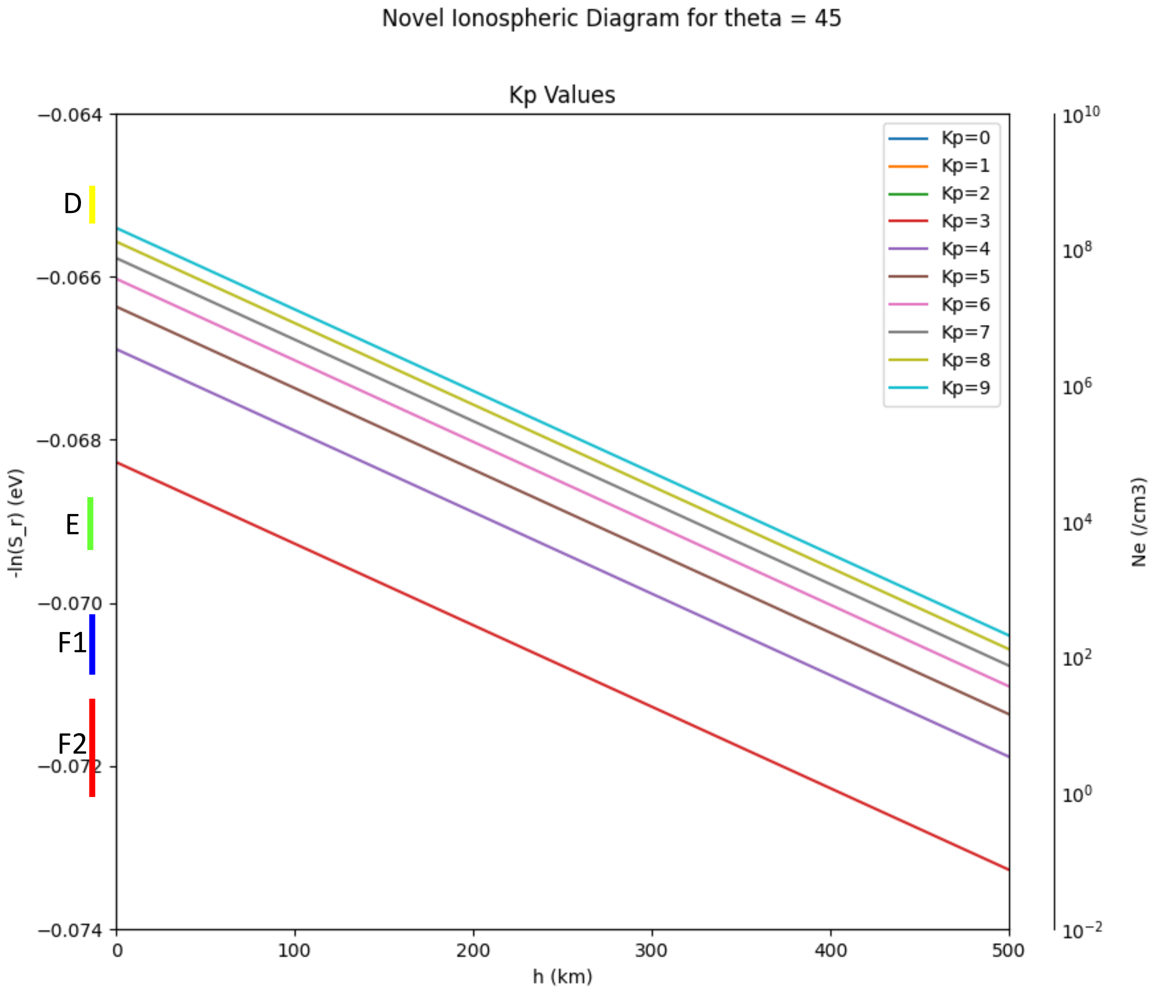

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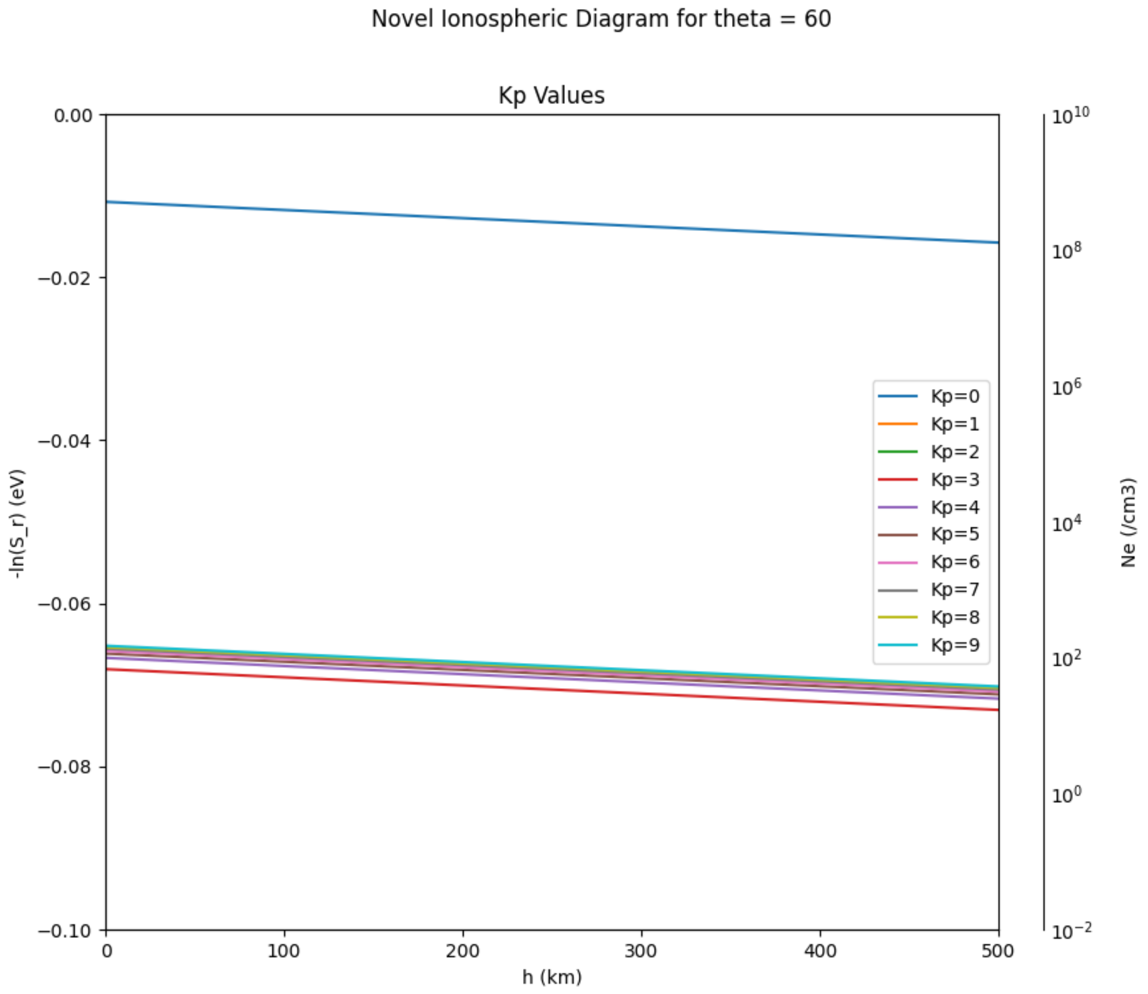

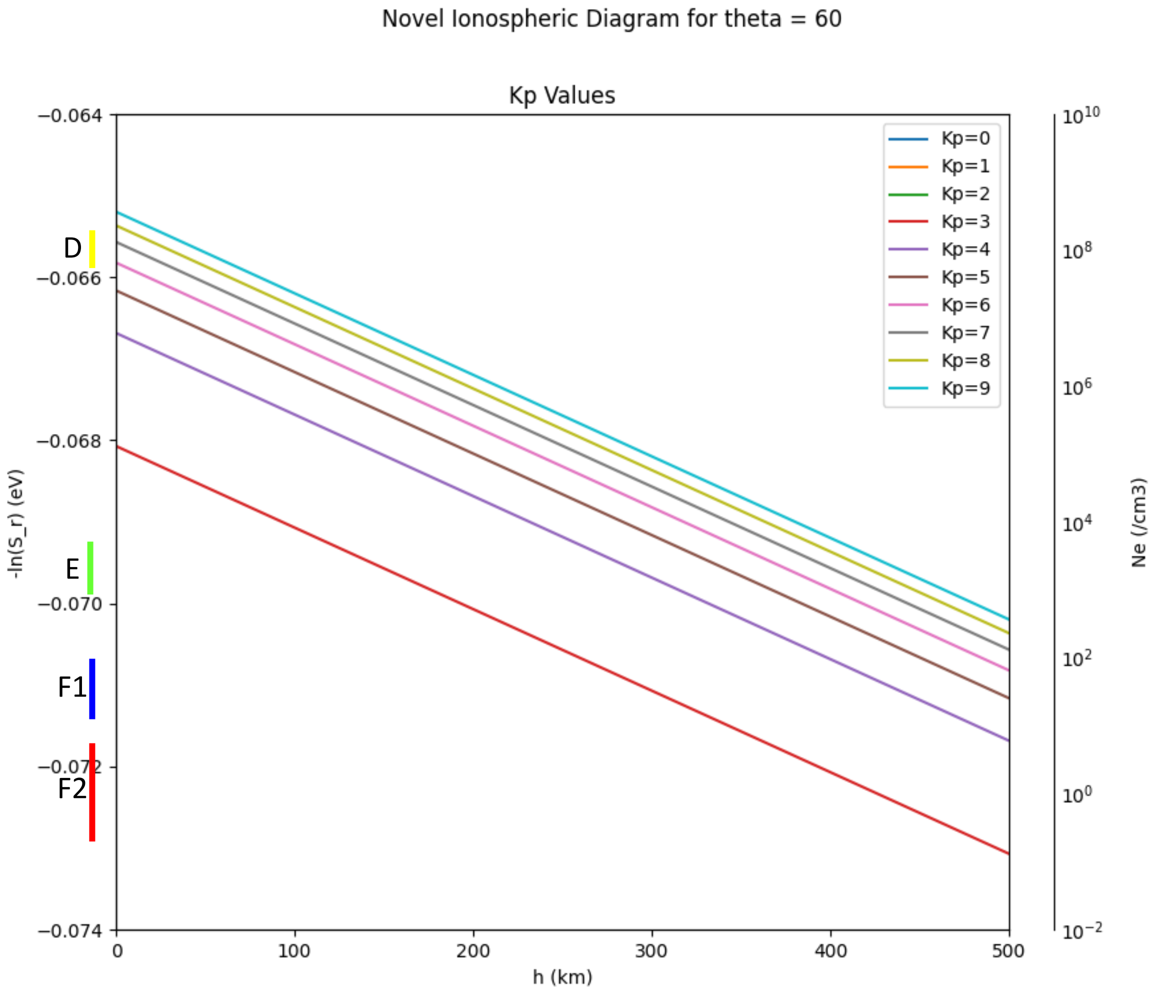

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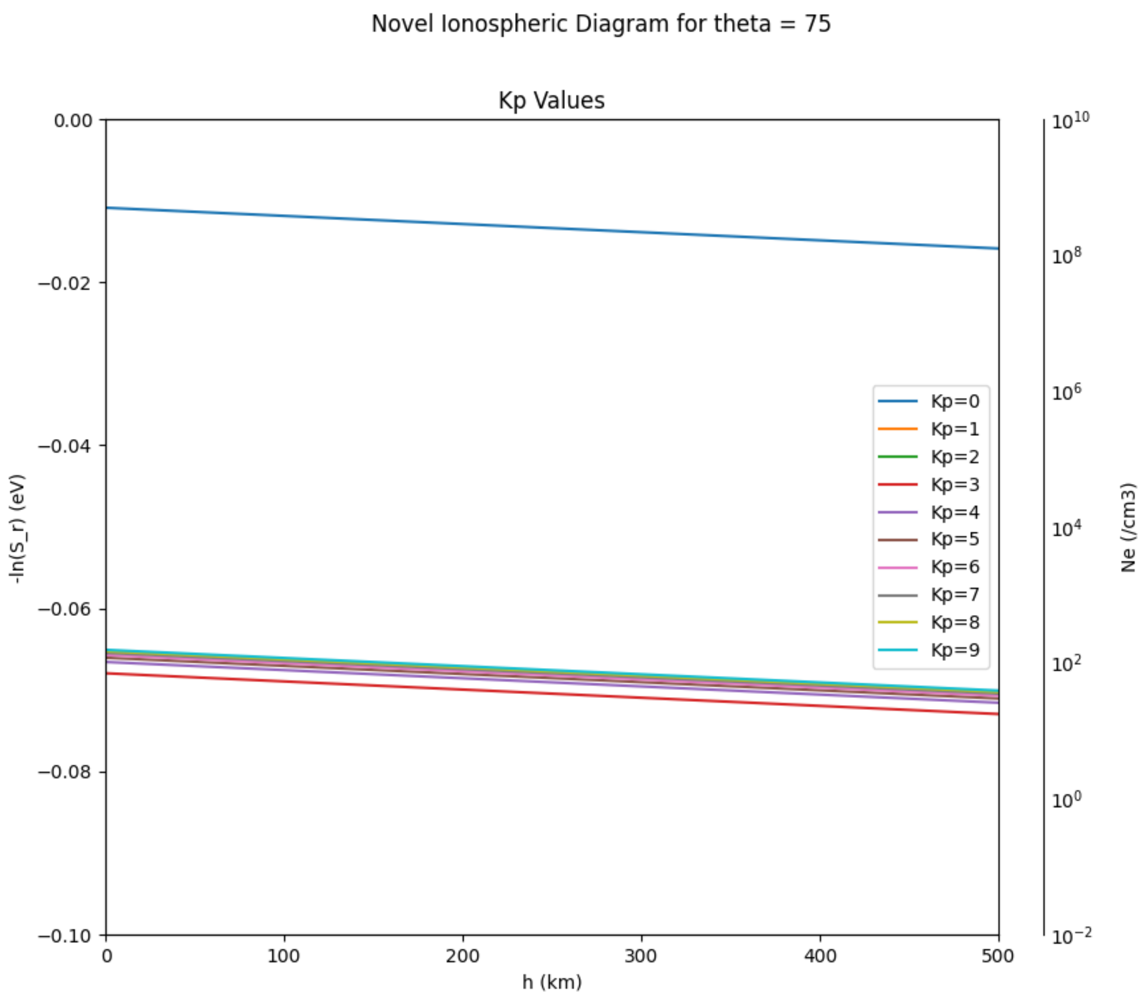

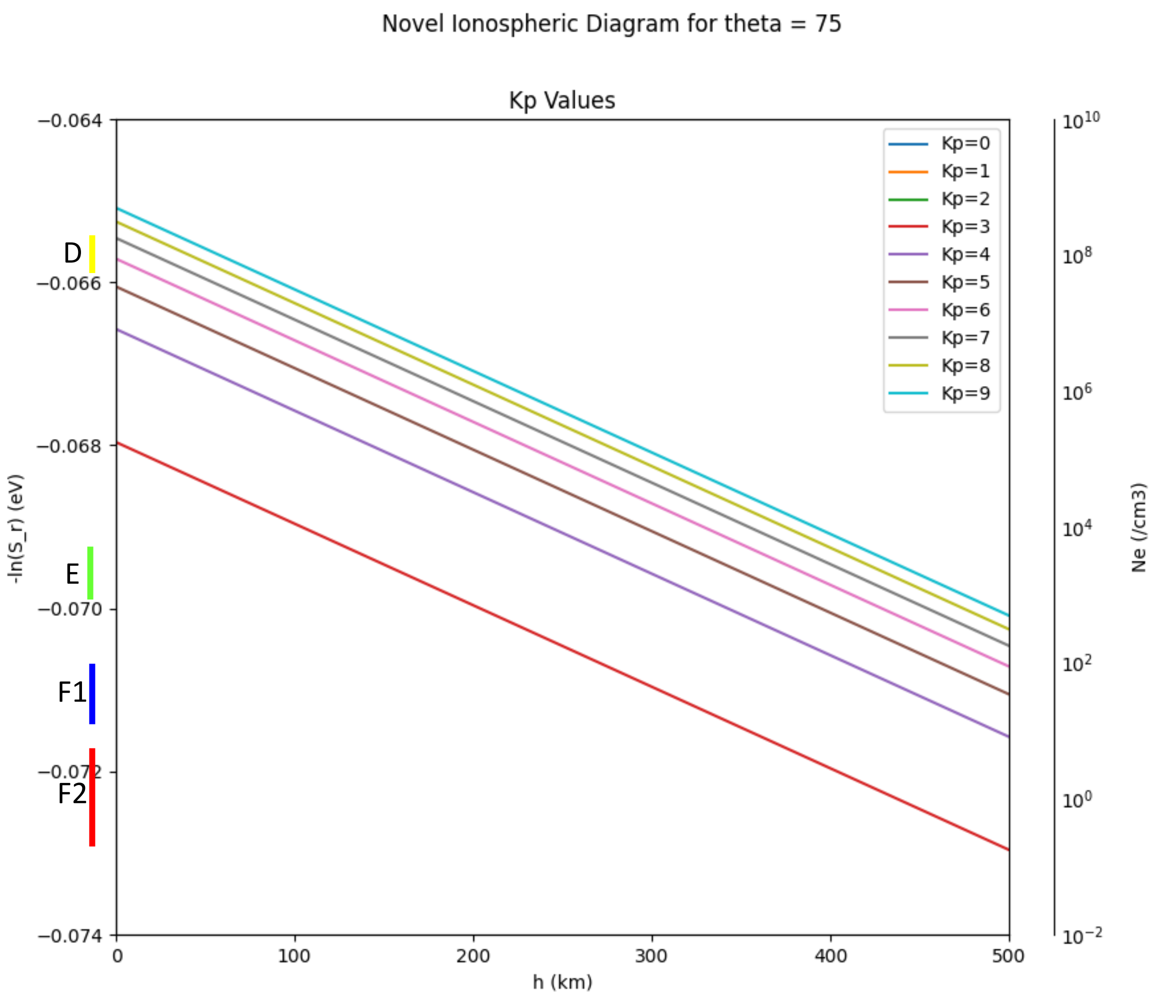

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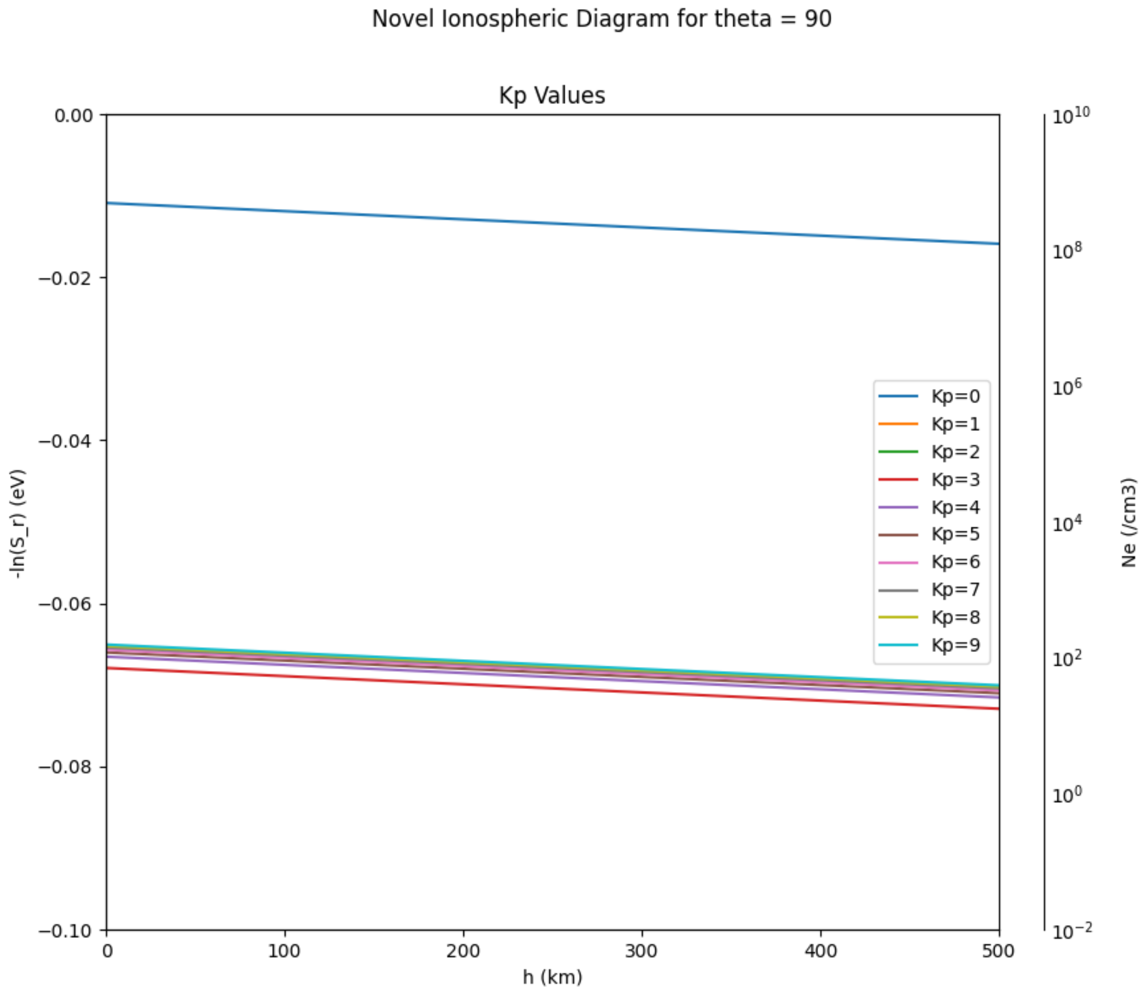

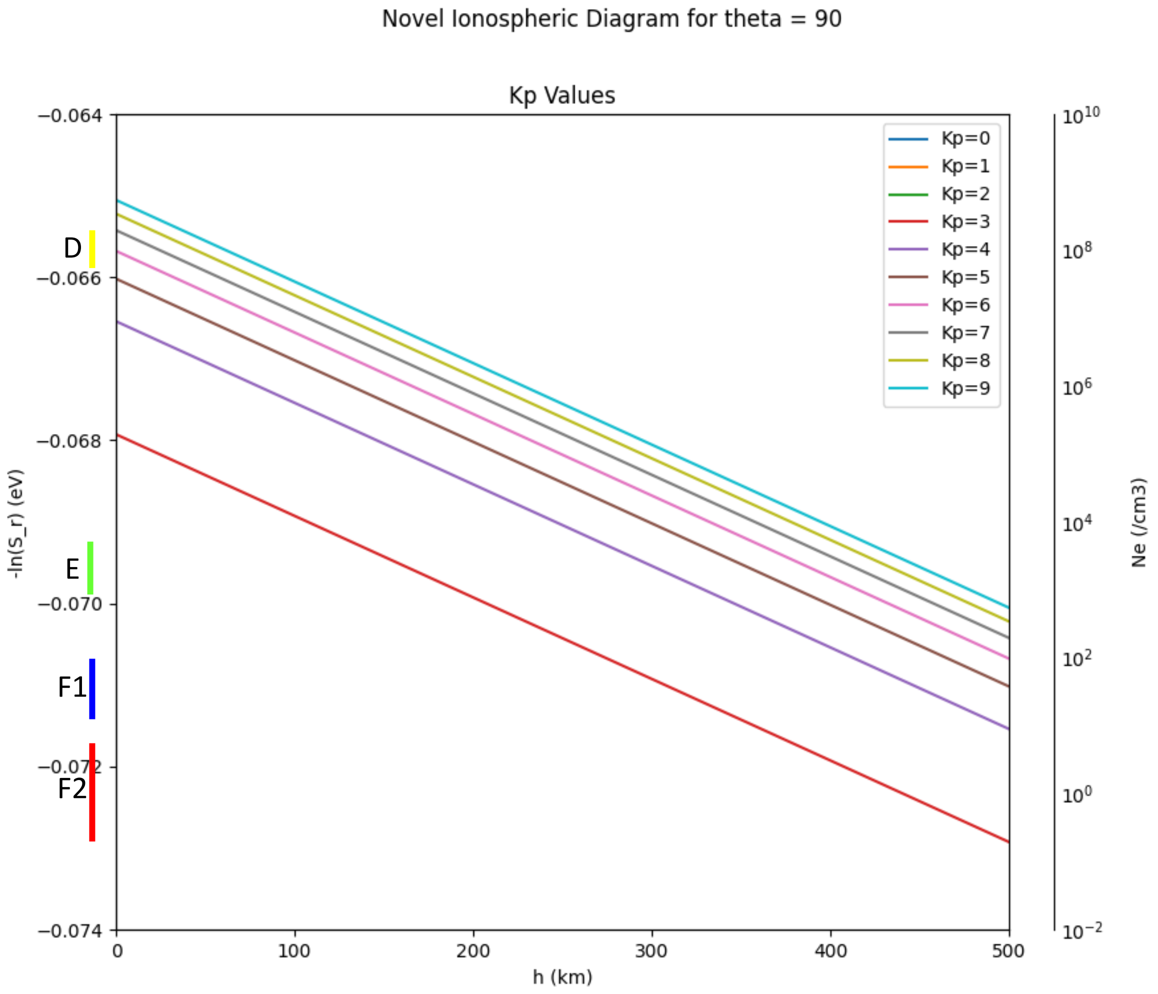

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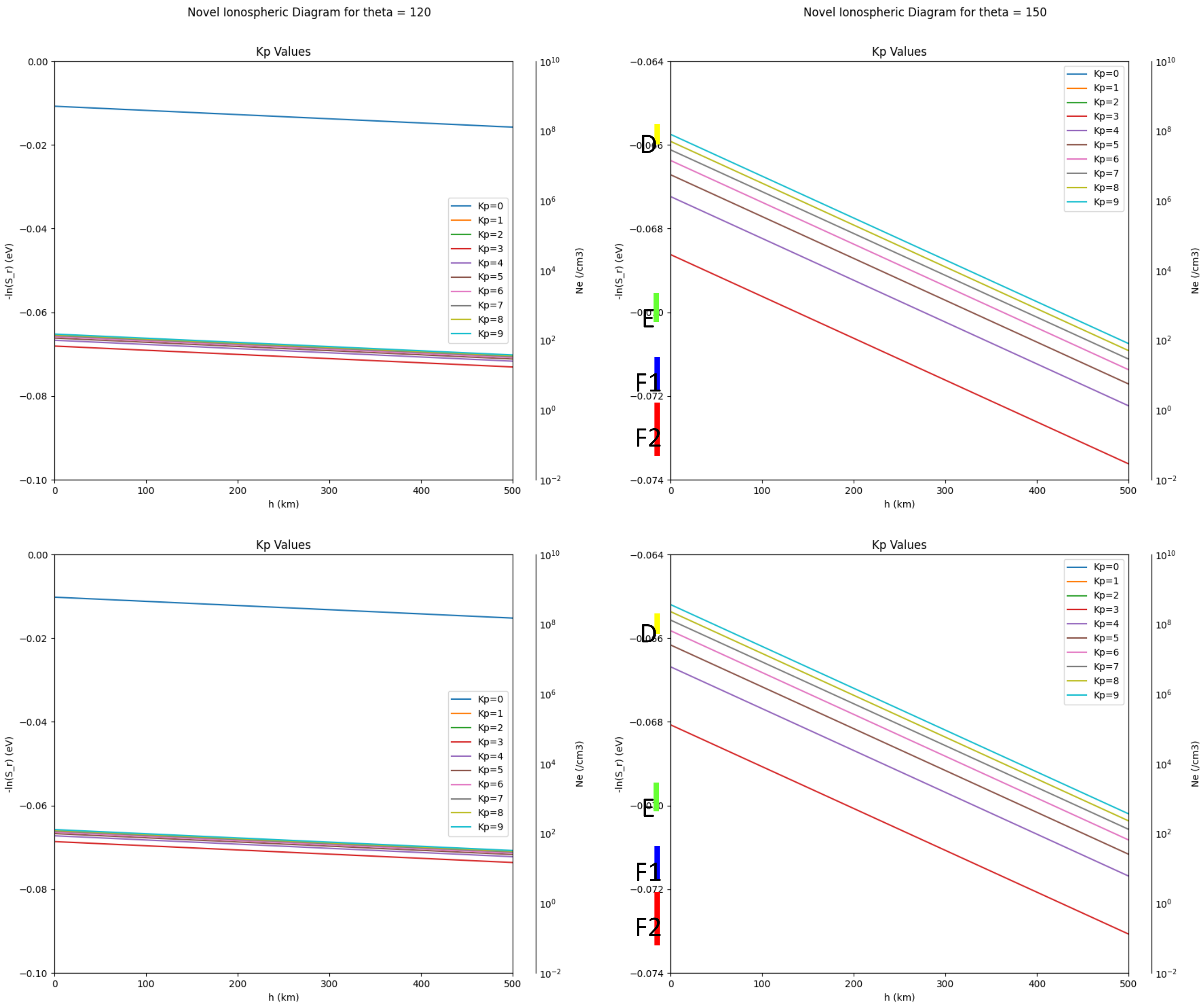

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Thank you for your attention, and waiting for your critics...

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