

Article

Bi-Maxwellian Characterization of Energetic Electron Populations in Diffuse Aurora

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Abstract

We examine energetic electron distributions in the region of the diffuse aurora using a two-dimensional bi-Maxwellian model, applied to electron flux data at a single geomagnetic equator ($L = 6.5$). Electron flux is analyzed as a function of energy and pitch angle and transformed into velocity space to reconstruct the distribution function. An unweighted log-space least-squares fit of the bi-Maxwellian model to the reconstructed distribution yields a reduced residual measure of $\chi^2_v = 1.000053$, a mean absolute residual of $|\Delta \log_{10} f| = 0.0469$ dex, an anisotropy factor, $A_T = 0.9886 \pm 0.0016$, and no statistically significant bulk drift. These results show that, at this location, the bi-Maxwellian model reproduces the observed velocity-space structure with good quantitative accuracy and reveals a quasi-isotropic, near-equilibrium electron population.

Keywords: Bi-Maxwellian distribution; electron velocity distribution function; anisotropy; least-squares fitting; diffuse aurora

1. Introduction

The diffuse aurora is primarily produced by the Earth's plasmasheet electrons with energies in the range of ~ 0.1 – 30 keV, scattered into the atmospheric loss cone by wave–particle interactions [1]. The energetic electrons responsible for diffuse aurora are typically observed as sustained, broadband enhancements in flux when measured by a spacecraft transiting the Earth's plasmasheet region, rather than as short-lived spike-like events.

Electron populations associated with a diffuse aurora often deviate from a single Maxwellian distribution. Such deviations may include temperature anisotropy, which can be represented by a bi-Maxwellian distribution, and suprathermal high-energy tails commonly represented by Kappa or bi-Kappa distributions [2]. These features arise from magnetically trapped plasmasheet electrons and wave–particle interactions [3,4].

Traditionally, Kappa distributions [4–6] have been widely used for characterizing the energy spectra of precipitating electrons in the region of diffuse aurora, due to their ability to capture the power-law tails associated with particle acceleration. In contrast, a bi-Maxwellian model [7] is useful for quantifying the parallel and perpendicular thermal speeds and the associated temperature anisotropy (A_T). Therefore, rather than claiming that the bi-Maxwellian universally replaces Kappa-type models, this work evaluates whether a bi-Maxwellian provides a quantitatively adequate representation of the reconstructed velocity distribution under the specific conditions.

This study provides a quantitative application of a two-dimensional bi-Maxwellian fitting procedure to electron data [4] associated with the diffuse aurora at $L = 6.5$.



Academic Editor: Andrey Starikovskiy

Received: 25 July 2026

Accepted: 3 August 2026

Published: 6 August 2026

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The energy–pitch-angle flux data are transformed into velocity space, fitted with a bi-Maxwellian model, and evaluated using residual statistics and goodness-of-fit measures. Moreover, the novelty of the present work lies not in introducing a new distribution function but in reconstructing diffuse aurora electron velocity distributions from energy–pitch-angle-dependent flux data and quantitatively evaluating the ability of a bi-Maxwellian representation to reproduce the observed velocity-space structure.

2. Data Source and Data Modeling

At the geomagnetic equator ($L = 6.5$) and for a minimum energy of $E_{\min} = 100$ eV [4], the electron particle flux values are considered as functions of energy and pitch angle. The input dataset used in this analysis contains one energy column and 14 pitch-angle columns. The energy grid spans from 100 eV to 10 keV, and the pitch-angle (θ) grid is between 0 and 90 degrees. Non-positive and non-finite electron flux values were removed before transformation to velocity space.

The formulation follows the standard kinetic relationship between the phase space distribution function and the differential particle flux [8]:

$$\Phi(E, \theta) = \frac{2E}{m^2} f(E, \theta) \quad (1)$$

where $\Phi(E, \theta)$ is the differential electron flux in $\text{cm}^2 \text{s}^{-1} \text{sr}^{-1} \text{eV}^{-1}$, $E = \frac{1}{2}mv^2$ is the particle kinetic energy in eV, $f(E, \theta)$ is the electron distribution function, m is the electron mass ($m_e = 9.1094 \times 10^{-28}$ g), and θ is the pitch angle (in degrees).

The electron particle flux profile illustrated in Figure 1 is presented as a function of energy and pitch angle. The energy–pitch angle dependence of the electron flux shows a peak at intermediate energies and enhanced flux near 90° pitch angles, consistent with a trapped particle population [4]. In Figure 2, the electron particle flux as a function of energy is presented. It is seen from Figure 2a that the electron flux increases with energy to a peak around ~ 500 – 1000 eV and then decreases, with higher pitch angles exhibiting larger flux values but a similar overall spectral shape. The pitch-angle-averaged electron flux spectrum in Figure 2b shows an increase with energy up to a peak near $\sim 10^2$ – 10^3 eV, followed by a rapid decline at higher energies, indicating a typical energetic electron population.

Electron Particle Flux as A Function of Energy and Pitch Angle

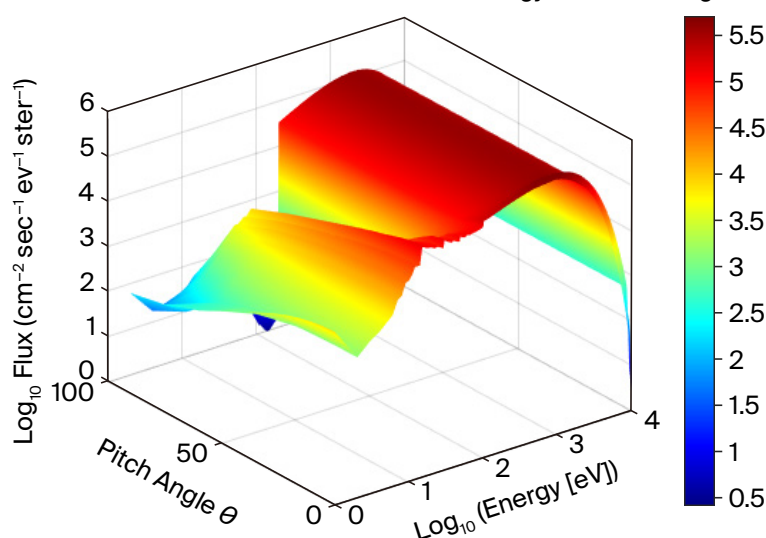


Figure 1. Electron particle flux as a function of energy and pitch angle. The plotted values are shown on a $\log_{10}$ flux scale, with the color bar representing $\log_{10}$ flux in $\text{cm}^2 \text{s}^{-1} \text{eV}^{-1} \text{sr}^{-1}$.

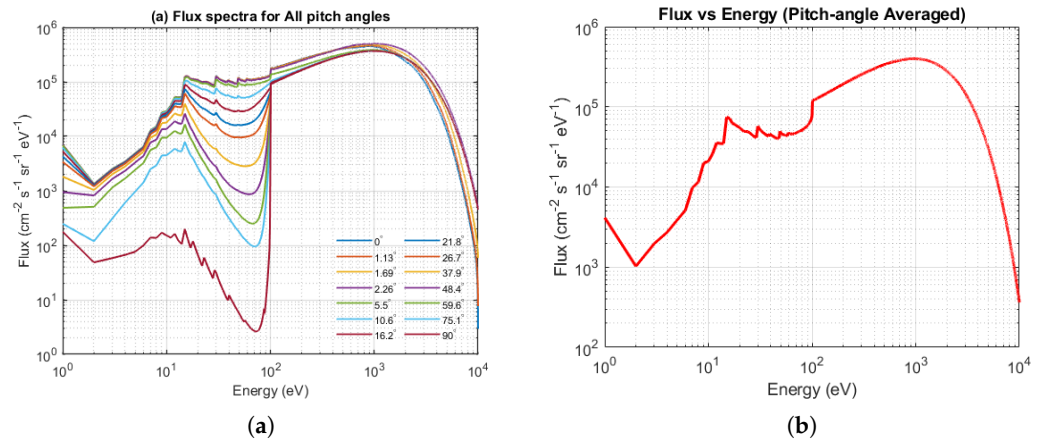


Figure 2. Electron particle flux as a function of energy: (a) flux spectra for the selected pitch angles and (b) pitch-angle-averaged flux spectrum.

3. Distribution Function and Bi-Maxwellian Model

The electron distribution function in Equation (1) can be expressed in velocity space as a function of the parallel and perpendicular velocity components, such that

$$f(E, \theta) \rightarrow f(v_{\parallel}, v_{\perp}). \quad (2)$$

Similarly, the differential particle flux can be expressed as a function of the parallel and perpendicular velocity components,

$$\Phi(E, \theta) \rightarrow \Phi(v_{\parallel}, v_{\perp}). \quad (3)$$

Using the kinetic energy relation $E = \frac{1}{2}mv^2$, Equation (1) can be transformed into velocity-space coordinates as

$$\Phi(v_{\parallel}, v_{\perp}) = \frac{v^2}{m} f(v_{\parallel}, v_{\perp}). \quad (4)$$

Applying the natural logarithm to both sides of Equation (4) yields

$$\ln \Phi(v_{\parallel}, v_{\perp}) = \ln \left(\frac{v^2}{m} \right) + \ln f(v_{\parallel}, v_{\perp}) \quad (5)$$

where the energy $E = \frac{m}{2}(v_{\parallel}^2 + v_{\perp}^2)$, the velocity $v = \sqrt{v_{\parallel}^2 + v_{\perp}^2}$, and $v_{\parallel} = v \cos(\theta)$ and $v_{\perp} = v \sin(\theta)$ are the velocity components parallel and perpendicular to the magnetic field.

The electron velocity distribution function (VDF) in the Earth's plasmasheet region often deviates from Maxwellian equilibrium due to the presence of energetic, anisotropic, and magnetically trapped electron populations [4]. Under such conditions, the distribution function $f(v_{\parallel}, v_{\perp})$ can be well represented by a two-dimensional bi-Maxwellian velocity distribution model, written as

$$f(v_{\parallel}, v_{\perp}) = \frac{n}{\pi^{3/2} \alpha_{\perp}^2 \alpha_{\parallel}} \exp \left(-\frac{(v_{\parallel} - U_{\parallel})^2}{\alpha_{\parallel}^2} - \frac{v_{\perp}^2}{\alpha_{\perp}^2} \right). \quad (6)$$

Here, n denotes the fitted normalization parameter of the bi-Maxwellian model (its physical interpretation is discussed below), $\mathbf{v} = (v_{\parallel}, v_{\perp})$ is the particle velocity, $\mathbf{U} = (U_{\parallel}, U_{\perp})$ is the bulk speed of the plasma, and $\alpha_{\parallel}, \alpha_{\perp}$ are the parallel and perpendicular thermal

speeds relative to the mean (background) magnetic field defined as $\alpha_{\parallel} = \left(\frac{2K_B T_{\parallel}}{m}\right)^{1/2}$, $\alpha_{\perp} = \left(\frac{2K_B T_{\perp}}{m}\right)^{1/2}$; K_B is the Boltzmann constant (in cgs-units), m is the mass of the particle, and $(T_{\parallel}, T_{\perp})$ are the parallel and perpendicular temperatures, respectively. Because the adopted model has cylindrical symmetry about the magnetic field, $U_{\perp}$ is assumed to be zero (that is, only $U_{\parallel}$ is fitted). The subscripts $\parallel$ and $\perp$ refer to parallel and perpendicular directions relative to the mean magnetic field (i.e., $\mathbf{b} = \mathbf{B}/|\mathbf{B}|$).

Although n appears in the standard bi-Maxwellian normalization, the reconstructed distribution used here does not provide an independently validated absolute phase-space-density normalization. Accordingly, the fitted n is treated only as a model normalization parameter and is not interpreted as a physical number density.

The distribution function used for fitting was reconstructed from $g = \Phi m/v^2$. To reduce numerical artifacts produced by the $v \rightarrow 0$ singularity, the low-velocity core $v < 5 \times 10^7 \text{ cm s}^{-1}$ was masked. The scattered velocity-space data were interpolated onto a regular $v_{\perp} - v_{\parallel}$ grid using natural-neighbor interpolation with nearest-neighbor filling for isolated holes, followed by light Gaussian smoothing ($\sigma = 1.2$ grid cells). The outer poor sample region was masked, and the fit was performed over $0.06R_{\max} < R < 0.90R_{\max}$, where $R = \sqrt{v_{\parallel}^2 + v_{\perp}^2}$.

The nearly circular contours in Figure 3 show a smooth and symmetric bi-Maxwellian electron velocity distribution structure centered at zero velocity (i.e., no bulk drift). The circular contours suggest that the distribution is nearly isotropic, with similar parallel and perpendicular temperatures. The distribution function reaches its maximum at low velocities, representing the thermal core of the electron population. This structure reflects an idealized equilibrium distribution without noise or irregular features. The fitted parameters are listed in Table 1.

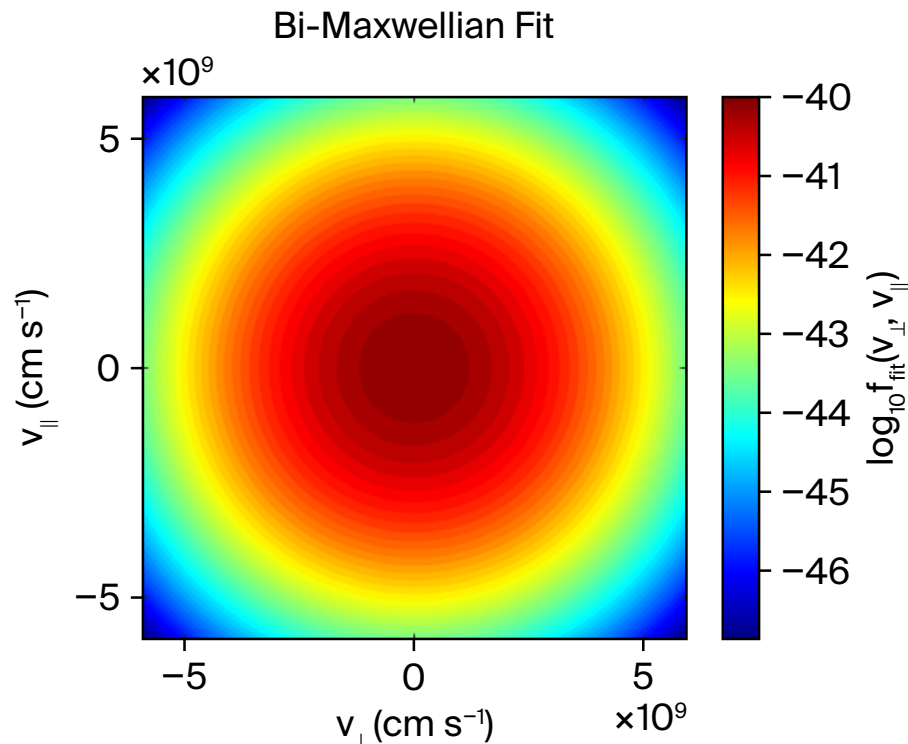


Figure 3. Bi-Maxwellian fit generated from fitted parameters. The nearly circular contours indicate $T_{\perp}/T_{\parallel}$ close to unity; the fitted parameters are listed in Table 1.

Table 1. Fitted bi-Maxwellian parameters and formal one-standard-deviation (1σ) uncertainties from the log-space least-squares covariance matrix.

Parameter	Value	Uncertainty
Distribution normalization parameter n	8.6018×10^{-12}	$\pm 2.02 \times 10^{-14}$
$\alpha_{\parallel}$ (cm s $^{-1}$)	1.9069×10^9	$\pm 1.31 \times 10^6$
$\alpha_{\perp}$ (cm s $^{-1}$)	1.8961×10^9	$\pm 1.27 \times 10^6$
$T_{\parallel}$ (eV)	1033.78	± 1.42
$T_{\perp}$ (eV)	1022.03	± 1.39
$A_T = T_{\perp}/T_{\parallel}$	0.9886	± 0.0016

The quoted uncertainties represent formal one-standard-deviation (1σ) errors obtained from the covariance matrix of the log-space least-squares fit. These uncertainties account only for statistical errors in the parameter estimation and do not include systematic uncertainties arising from the flux-to-VDF transformation, interpolation procedure, or the bi-Maxwellian model itself.

The near-circular contours in Figure 4a represent the electron velocity distribution function (VDF) reconstructed from the measured flux data and mapped onto a regular $v_{\parallel}, v_{\perp}$ grid. The distribution has a strong central peak: most electrons are concentrated at lower velocities, while the flux decreases outward toward higher velocities. The small irregular structures, especially near the center, may be caused by interpolation or numerical transformation. The residual between the interpolated VDF and the fitted bi-Maxwellian model is shown in Figure 4b. Residuals close to zero indicate good agreement between the data and model, while positive or negative values show where the model either underestimates or overestimates the observed distribution. The largest deviations occur near the low-velocity core and outer edges. This implies that the bi-Maxwellian captures the broad distribution well but does not fully reproduce small-scale numerical or data-related features. A typical profile of the fitted bi-Maxwellian contours on the interpolated electron VDF is shown in Figure 4c. The black contours closely follow the shape of the reconstructed distribution, confirming that the model provides a good approximation of the overall velocity-space structure. Minor mismatches near the core indicate small deviations from the idealized model, but the close agreement across most of the contour supports the use of a bi-Maxwellian representation for this electron population.

The linear-scale representation presented in Figure 5 emphasizes the core velocity distribution and complements the logarithmic plots in Figure 4. Figure 5a shows the normalized interpolated electron velocity distribution function by its maximum. The normalized bi-Maxwellian fit contours are represented in Figure 5b. Figure 5c is the normalized residual plot.

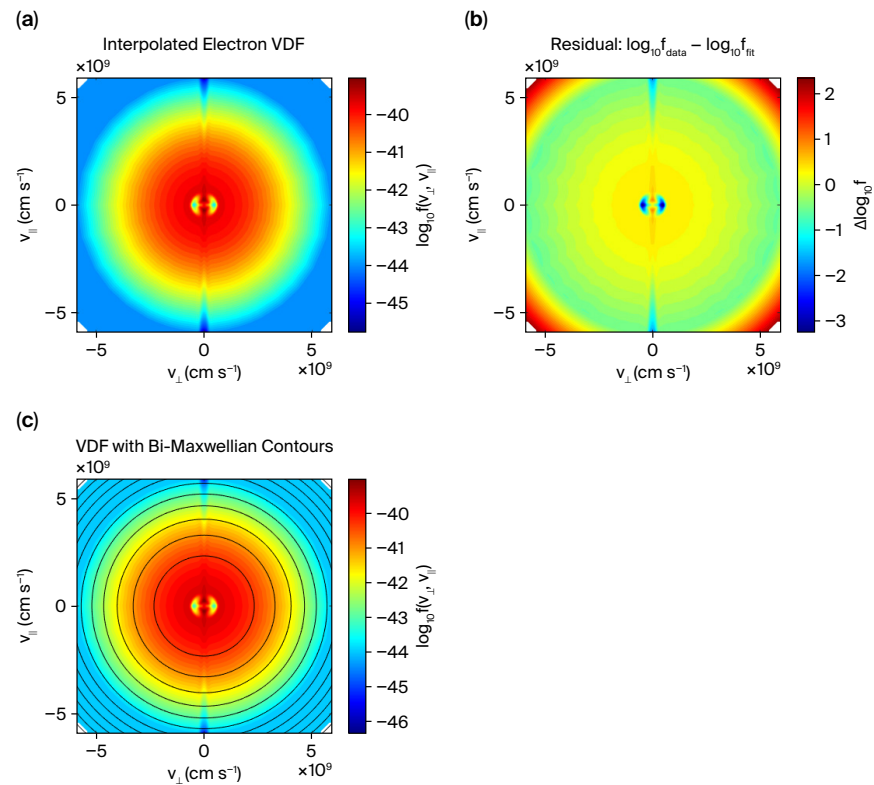


Figure 4. Log-space velocity distribution comparison: (a) interpolated electron VDF, (b) residual $\Delta \log_{10} f = \log_{10}(f_{\text{data}}) - \log_{10}(f_{\text{fit}})$, and (c) interpolated VDF with black contours of the fitted bi-Maxwellian model overlaid.

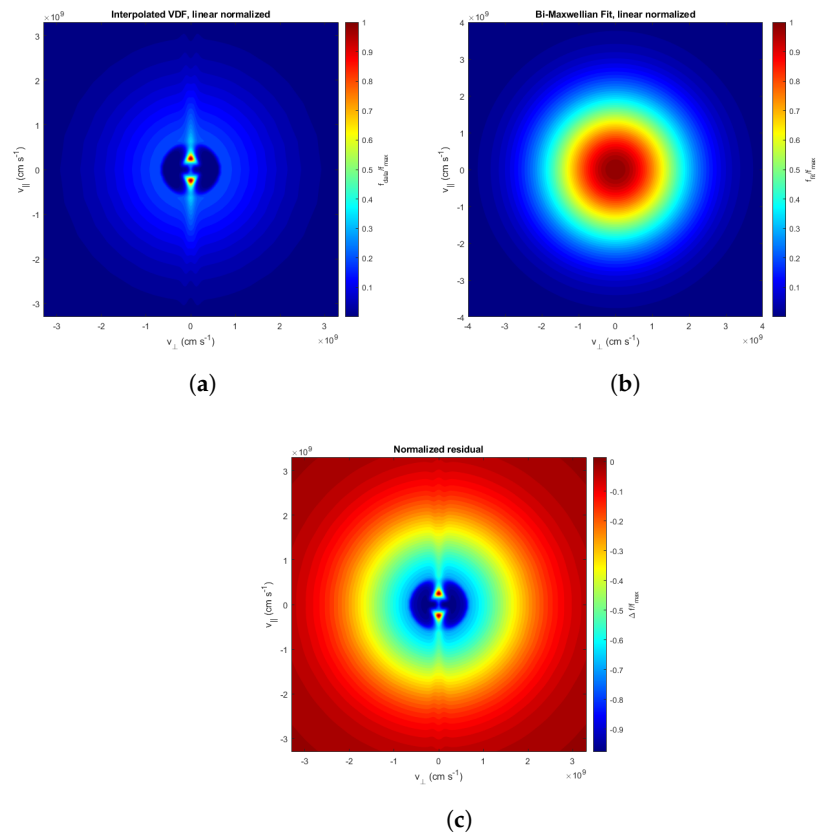


Figure 5. Linear-scale normalized comparison: (a) interpolated VDF normalized by its maximum, (b) normalized bi-Maxwellian fit, and (c) normalized residual.

Least-Squares Parameter Estimation

Using $g_i = \Phi_i m / v_i^2 = f_i$ ($i = 1, \dots, N$), the logarithm of the bi-Maxwellian model (6) can be written in the linear form

$$\ln(g_i) = B_1 + B_2 v_{\parallel,i} + B_3 v_{\parallel,i}^2 + B_4 v_{\perp,i}^2, \quad (7)$$

where the velocity-space normalization coefficient $g_0 = \frac{n}{\pi^{3/2} \alpha_{\perp}^2 \alpha_{\parallel}}$, $B_1 = \ln g_0 + B_3 U_{\parallel}^2$, $B_2 = -2U_{\parallel} B_3$, $B_3 = -1/\alpha_{\parallel}^2$, and $B_4 = -1/\alpha_{\perp}^2$. Here, N denotes the total number of valid velocity-space grid points included in the fitting mask after preprocessing, masking, and interpolation. The fitting problem is overdetermined because the number of valid velocity-space data points is much larger than the four fitted coefficients.

The least-squares system is therefore written as

$$\mathbf{A}\mathbf{x} \approx \mathbf{y} \quad (8)$$

where $\mathbf{y} \in \mathbb{R}^N$ is the vector of observed values $\ln(g_i)$ ($i = 1, \dots, N$), $\mathbf{x} = [B_1, B_2, B_3, B_4]^T$ is the vector of unknown coefficients, and $\mathbf{A} \in \mathbb{R}^{N \times 4}$ is the design matrix constructed from the linear model in Equation (7). Here, N is the total number of valid data points used in the least-squares fit after preprocessing and masking.

The system of equations can be written as

$$\mathbf{x} = \begin{pmatrix} B_1 \\ B_2 \\ B_3 \\ B_4 \end{pmatrix}, \quad \mathbf{y} = \begin{pmatrix} \ln g_1 \\ \ln g_2 \\ \ln g_3 \\ \vdots \\ \ln g_N \end{pmatrix}, \quad \text{and} \quad \mathbf{A} = \begin{pmatrix} 1 & v_{\parallel,1} & v_{\parallel,1}^2 & v_{\perp,1}^2 \\ 1 & v_{\parallel,2} & v_{\parallel,2}^2 & v_{\perp,2}^2 \\ 1 & v_{\parallel,3} & v_{\parallel,3}^2 & v_{\perp,3}^2 \\ \vdots & \vdots & \vdots & \vdots \\ 1 & v_{\parallel,N} & v_{\parallel,N}^2 & v_{\perp,N}^2 \end{pmatrix}. \quad (9)$$

For an unweighted fit, the solution is

$$\mathbf{x} = (\mathbf{A}^T \mathbf{A})^{-1} \mathbf{A}^T \mathbf{y} \quad (10)$$

which is equivalent to the Moore–Penrose pseudoinverse [9] solution when $\mathbf{A}$ has full column rank. If measurement uncertainties σ_i are available, the least-squares solution becomes

$$\mathbf{x} = (\mathbf{A}^T \mathbf{W} \mathbf{A})^{-1} \mathbf{A}^T \mathbf{W} \mathbf{y}, \quad (11)$$

where $\mathbf{W} = \text{diag}(1/\sigma_i^2)$.

Because the original count uncertainties were not provided with the tabulated flux data, the present fit uses an unweighted log-space least-squares formulation. The reported reduced chi-square (χ^2) will be interpreted as an unweighted log-space residual measure, not as an absolute counting-statistics chi-square. The residual [10] is defined as

$$\Delta \log_{10} f = \log_{10}(f_{\text{data}}) - \log_{10}(f_{\text{fit}}). \quad (12)$$

The fitted thermal speeds are very close to each other, giving an anisotropy factor $A_T = 0.9886 \pm 0.0016$. These results indicate that, for the fitted region and under the adopted pre-processing, the distribution is nearly isotropic. Consequently, a single Maxwellian would also be a reasonable limiting approximation for this particular case. The bi-Maxwellian formulation is retained because it provides a direct quantitative diagnostic of any departure from isotropy through $\alpha_{\parallel}$, $\alpha_{\perp}$, and A_T .

From Table 2, the value $R^2 = 0.9338$ shows that the bi-Maxwellian model explains approximately 93% of the variance in $\log_{10}(f)$ over the fitting region. The results show that the model captures the broad velocity-space structure, while the largest residuals are localized near the low-velocity core and the outer boundary where interpolation and masking effects are strongest.

Table 2. Goodness-of-fit and normalized residual statistics computed over the fitting mask.

Metric	Value
Number of fitted grid points	56,944
Degrees of freedom	56,940
Unweighted reduced χ^2 proxy in $\ln(f)$	1.000053
R^2 in $\log_{10}(f)$	0.9338
RMSE in $\log_{10}(f)$	0.186 dex
Mean absolute error (MAE) in $\log_{10}(f)$	0.0469 dex
Median absolute residual in $\log_{10}(f)$	0.024 dex
95th percentile $ residual $	0.0825 dex
NRMSE relative to $\log_{10}(f)$ range	0.0435
NRMSE relative to $\log_{10}(f)$ Std	0.257

In addition, the goodness-of-fit was evaluated using the root mean square error (RMSE), mean absolute error (MAE), and normalized root mean square error (NRMSE). The RMSE measures the typical magnitude of the fitting error, whereas the MAE represents the average absolute deviation between the reconstructed and fitted velocity distribution functions. The NRMSE normalizes the RMSE by the range (or standard deviation) of the data, providing a dimensionless measure of the fit quality. For the present analysis, the RMSE was 0.186 dex, the MAE was 0.0469 dex, and the NRMSE relative to the data range was 0.0435 (4.35%), indicating that the bi-Maxwellian model reproduces the reconstructed electron velocity distribution at $L = 6.5$ with high accuracy.

4. Conclusions

We have studied the electron distribution function at the geomagnetic equator ($L = 6.5$), which is well reconstructed by a two-dimensional bi-Maxwellian model over the selected fitting region. The analysis revealed a strong agreement between the interpolated data and the fitted distribution across most of the velocity space. The near-unity anisotropy reveals that the parallel and perpendicular thermal energies are very similar for this specific dataset. These results are physically consistent with efficient scattering or other relaxation processes that reduce temperature anisotropy; however, because no wave measurements, diffusion coefficients, or time evolution are analyzed here, the present study does not directly identify the responsible wave mode or prove a particular scattering mechanism.

The fitted characteristic thermal energy of approximately 1.03 keV indicates a moderately energized electron population, consistent with plasmasheet electrons in the energy range from hundreds of eV to several keV [11,12]. This energy range is relevant to diffuse aurora precipitation [5,13] at $L = 6.5$ geomagnetic location.

The residual analysis shows that the bi-Maxwellian model captures the broad velocity-space structure but does not reproduce all small-scale features. The localized residuals near the low-velocity core are likely influenced by the transformation from energy–pitch-angle space to velocity space, interpolation, smoothing, and the required masking near $v = 0$. The model should therefore be interpreted as a compact parametric character-

ization of the dominant distribution, not as a complete description of all fine-scale or suprathermal structure.

The present analysis demonstrates that, for the specific Khazanov et al. [4]-associated electron flux data at the geomagnetic equator ($L = 6.5$), a bi-Maxwellian fit provides a physically interpretable and quantitatively evaluated representation of the electron VDF. Although Kappa distributions are widely used to describe suprathermal electron populations, the present study focuses on the anisotropic thermal component. Future work could extend this analysis across L-shells, local time sectors, and different event conditions, and should include direct comparisons with Kappa or bi-Kappa distributions to determine which model is statistically preferred when suprathermal tails are important.

Author Contributions: Conceptualization, O.R.R.; methodology, O.R.R.; software, O.R.R. and A.O.O.; formal analysis, O.R.R.; investigation, O.R.R. and A.O.O.; writing—original draft preparation, O.R.R.; writing—review and editing, O.R.R. and A.O.O.; supervision, O.R.R. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported by NRC Research Associateship programs at AFRL Kirtland, NM, USA.

Data Availability Statement: The electron flux data used in this study are associated with Khazanov et al. [4] (<https://zenodo.org/record/4782224>, accessed on 20 July 2026). The processing code reads the data from a 15-column energy–pitch-angle table and applies the preprocessing, interpolation, and fitting steps described above.

Acknowledgments: O.R.R. thanks George V. Khazanov and Adolfo F.-Viñas at the NASA GSFC, Maryland, USA, for mentorship and support.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Thorne, R.M.; Ni, B.; Tao, X.; Horne, R.B.; Meredith, N.P. Scattering by chorus waves as the dominant cause of diffuse auroral precipitation. *Nature* **2010**, *467*, 943–946. [CrossRef] [PubMed]
2. Livadiotis, G. Introduction to special section on Origins and Properties of Kappa Distributions: Statistical Background and Properties of Kappa Distributions in Space Plasmas. *J. Geophys. Res. Space Phys.* **2015**, *120*, 1607–1619. [CrossRef]
3. Khazanov, G.V.; Gloer, A.; Himwich, E.W. Magnetosphere-ionosphere energy interchange in the electron diffuse aurora. *J. Geophys. Res. Space Phys.* **2014**, *119*, 171–184. [CrossRef]
4. Khazanov, G.V.; Gloer, A.; Chu, M. The precipitated electrons in the region of diffuse aurora driven by ionosphere-thermosphere collisional processes. *Geophys. Res. Lett.* **2021**, *48*, e2021GL094583. [CrossRef]
5. Tripathi, A.K.; Singhal, R.P.; Sinha, A.K. Role of wave–particle interactions in auroral electron precipitation. *Adv. Space Res.* **2013**, *52*, 389–405.
6. McIntosh, R.C.; Anderson, P.C. Maps of precipitating electronspectra characterized by Maxwellian and kappa distributions. *J. Geophys. Res. Space Phys.* **2014**, *119*, 116–10132. [CrossRef]
7. Graham, D.B.; Khotyaintsev, Y.V.; André, M.; Vaivads, A.; Chasapis, A.; Matthaeus, W.H.; Retino, A.; Valentini, F.; Gershman, D.J. Non-Maxwellianity of electron distributions near Earth’s magnetopause. *J. Geophys. Res. Space Phys.* **2021**, *126*, e2021JA029260. [CrossRef]
8. Khazanov, G.V. *Kinetic Theory of the Inner Magnetospheric Plasma*; Springer: New York, NY, USA, 2011.
9. Rao, C.R.; Mitra, S.K. *Generalized Inverse of Matrices and Its Applications*; John Wiley and Sons: New York, NY, USA, 1971.
10. Martin, B.R. *Statistics for Physical Sciences: An Introduction*; Academic Press: Cambridge, MA, USA, 2012; ISBN 978-0-12-387760-4. [CrossRef]
11. Ni, B.; Thorne, R.M.; Horne, R.B.; Meredith, N.P.; Shprits, Y.Y.; Chen, L.; Li, W. Resonant scattering of plasma sheet electrons leading to diffuse auroral precipitation: 1. Evaluation for electrostatic electron cyclotron harmonic waves. *J. Geophys. Res.* **2011**, *116*, A04218. [CrossRef]

12. Ni, B.; Thorne, R.M.; Meredith, N.P.; Horne, R.B.; Shprits, Y.Y. Resonant scattering of plasma sheet electrons leading to diffuse auroral precipitation: 2. Evaluation for whistler mode chorus waves. *J. Geophys. Res.* **2011**, *116*, A04219. [[CrossRef](#)]
13. Khazanov, G.V.; Sibeck, D.G.; Zesta, E. Is diffuse aurora driven from above or below? *Geophys. Res. Lett.* **2017**, *44*, 641–647. [[CrossRef](#)]

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