Reviewer Comment 1: *"It looks that all the results (resonant energy, linear growth rates, etc.) in this manuscript have already been discussed in other previous studies... In the present form, the novelty of this manuscript is very weak."*

Response:
We thank and appreciate the reviewer's feedback and acknowledge the importance of clearly establishing the novelty of our work. While previous studies, such as those cited (Ahirwar & Meda, 2020; Meda & Ahirwar, 2019; Lazar, 2012; Sugiyama et al., 2015), have explored various aspects of EMIC wave growth under Kappa distributions, our manuscript introduces several significant advancements:

1. **Impact of multi-ion plasma composition (H^+, He^+, O^+) under varying Kappa parameters (κ):**
   Multi-Species Plasma: This study uniquely investigates EMIC wave growth in a multi-ion plasma environment (H^+, He^+, O^+) more complexity compared to single-ion studies, a more realistic representation of space plasma compared to the predominantly single-ion focus of previous studies. This multi-species approach allows us to quantify the distinct contributions of each ion species to wave growth under varying Kappa distributions, a crucial aspect previously unexplored in this context.
2. **Temperature anisotropy effects coupled with Kappa distribution:**
   We go beyond previous studies by analyzing the combined influence of temperature anisotropy and Kappa distributions on EMIC wave properties. While some studies have examined these factors individually or with General loss cone distribution, their synergistic effects in a multi-ion environment have not been comprehensively investigated before. This approach highlights the interplay between these two factors and their impact on wave-particle interactions, a critical aspect absents in the cited studies.
3. **Implications for plasmapause and auroral regions:**
   Our results extend the understanding of EMIC wave growth to regions where multi-ion compositions dominate, such as near the plasmapause and in auroral acceleration zones particularly during space weather events like geomagnetic storms. We believe these specific environmental conditions have not been thoroughly discussed in the cited studies.

4. This study delves deeper into the effects of Kappa distributions on EMIC wave growth by providing a quantitative evaluation. We systematically examine how variations in the Kappa parameter (k_p) – for instance, comparing k_p=2 (representing a significantly non-Maxwellian distribution) to k_p =6 (approaching a Maxwellian distribution) – influence key wave characteristics such as growth rates, resonant energies, and spatial profiles. This level of quantitative analysis surpasses the scope of some previous studies, such as Sugiyama et al. (2015), which primarily focused on qualitative assessments of Kappa-Maxwellian particle distributions. By meticulously comparing these variations, our study unveils a crucial finding:

low k_p values significantly enhance EMIC wave growth, particularly for heavy ions, due to a pronounced increase in wave-particle resonances.

Distinction from Cited Studies

Study	Focus	Limitation	Novelty of Our Work
Ahirwar & Meda (2020)	Effect of parallel electric fields on EMIC waves with Kappa distributions	Focuses on single-ion (H^+) plasmas with effect of parallel electric fields	We incorporate multi-ion plasmas (H^+, He^+, O^+) and examine combined effects of anisotropy and κ values
Meda & Ahirwar (2019)	EMIC instability in cusp regions with Kappa distributions	Primarily studies wave growth near the cusp	Our work targets plasmapause and auroral zones, emphasizing relevance to diverse space environments
Lazar (2012)	Electromagnetic ion-cyclotron instability in bi-Kappa plasmas	Limited to bi-Kappa distributions in homogeneous plasmas	We study multi-ion plasmas with varying κ and anisotropy in non-homogeneous environments.
Sugiyama et al. (2015)	EMIC waves with Kappa-Maxwellian distributions in the Earth's magnetosphere	Lacks detailed multi-ion analysis and does not quantify the role of heavy ions and use Kappa-Maxwellian distributions	Our study evaluates the distinct roles of H^+, He^+, O^+ under Kappa distributions

We have revised the Introduction and Discussion sections to explicitly highlight these unique contributions to distinguish our work from prior studies.

Reviewer Comment 2:

"EMIC wave growth can be essentially characterized by nonlinear effects (e.g., Shoji & Omura, 2013), but there are no discussions on the nonlinear effects. The authors should discuss the effects of nonlinear wave growth by Kappa distributions."

Response:

We appreciate the reviewer's suggestion regarding nonlinear wave growth. While our current study focuses on the linear growth rates of EMIC waves, we acknowledge that nonlinear effects play a crucial role in wave amplification and energy transfer processes. our study focuses on linear growth rates and that future work will explore nonlinear effects through advanced numerical methods (e.g., Particle-in-Cell simulations).

Expanded Discussion:
We have incorporated in the Discussion to describe how nonlinear wave growth mechanisms could interact with Kappa-distributed plasmas. For instance, we will reference Omura (2014) to discuss how nonlinear effects might alter the wave-particle resonances and contribute to wave energy saturation in low kappa regimes.
As a part of our revised manuscript, we have acknowledged this limitation and propose future work to study nonlinear effects explicitly through Particle-In-Cell (PIC) simulations or nonlinear analytical techniques.

By integrating these elements, we aim to provide a more comprehensive understanding of the EMIC wave growth process.

Reviewer Minor Comment :
"Line 37: Region24?"

Response:
We appreciate the reviewer's attention to detail. The reference to "Region24" was a typographical error and have been corrected in the revised manuscript. We have ensured that all such references are verified for accuracy.

Additional Revisions to Address the Reviewer's Concerns:

1. **Detailed Comparison with Prior Studies:**

   The **Result and Discussion** section has been updated, explicitly comparing our findings with those of the cited studies. We have focused on key differences, particularly in terms of ion composition, anisotropy effects, and environmental relevance.

2. **Improved Figures and Captions:**

   The captions for all figures are revised to include more detailed explanations, highlighting their relevance to the discussion. .

3. **Implications:**

   We have expanded the discussion to address the practical implications of our findings for space weather forecasting and plasma dynamics in magnetospheric environments. This will emphasize the importance of temperature anisotropy and Kappa distributions in shaping EMIC wave behaviour.

We sincerely appreciate the reviewer's time and valuable feedback on our manuscript, *"Study of Temperature Anisotropy and Kappa Distribution Impacts on EMIC Waves in Multi-Species Magnetized Plasma."* We have carefully considered the comments and made significant revisions to improve the manuscript's clarity, scientific explanations, and novelty. Below, we address each comment in detail.

Major Comments and Responses

1. Novelty of the Work

We acknowledged the reviewer's concern regarding the novelty of our study. Our research presents a distinctive contribution by examining the **combined effects** of temperature anisotropy and the Kappa distribution function on the dispersion properties and growth rates of EMIC waves. While previous studies, such as Sugiyama et al. (2015), have analysed aspects of the Kappa-Maxwellian distribution, they do not comprehensively explore the interaction between temperature anisotropy and Kappa-distributed plasmas in a multi-ion environment.

Our study introduces the following novel aspects:

5. **Impact of multi-ion plasma composition (H^+, He^+, O^+) under varying Kappa parameters : Multi-Species Plasma:** This study uniquely investigates EMIC wave growth in a multi-ion plasma environment (H^+, He^+, O^+) more complexity compared to single-ion studies, a more realistic representation of space plasma compared to the predominantly single-ion focus of previous studies. This multi-species approach allows us to quantify the distinct contributions of each ion species to wave growth under varying Kappa distributions, a crucial aspect previously unexplored in this context.
6. **Temperature anisotropy effects coupled with Kappa distribution:**
   We go beyond previous studies by analyzing the combined influence of temperature anisotropy and Kappa distributions on EMIC wave properties. While some studies have examined these factors individually or with General loss cone distribution, their synergistic effects in a multi-ion environment have not been comprehensively investigated before. This approach highlights the interplay between these two factors and their impact on wave-particle interactions, a critical aspect absents in the cited studies.
7. **Implications for plasmapause and auroral regions:**
   Our results extend the understanding of EMIC wave growth to regions where multi-ion compositions dominate, such as near the plasmapause and in auroral acceleration zones particularly during space weather events like geomagnetic storms. We believe these specific environmental conditions have not been thoroughly discussed in the cited studies.

8. This study delves deeper into the effects of Kappa distributions on EMIC wave growth by providing a quantitative evaluation. We systematically examine how variations in the Kappa parameter (k_p) – for instance, comparing k_p=2 (representing a significantly non-Maxwellian

distribution) to k_p =6 (approaching a Maxwellian distribution) – influence key wave characteristics such as growth rates, resonant energies, and spatial profiles. This level of quantitative analysis surpasses the scope of some previous studies, such as Sugiyama et al. (2015), which primarily focused on qualitative assessments of Kappa-Maxwellian particle distributions. By meticulously comparing these variations, our study unveils a crucial finding: low k_p values significantly enhance EMIC wave growth, particularly for heavy ions, due to a pronounced increase in wave-particle resonances.

Comparison with Previous Work

Study	Focus	Limitation	Novelty of Our Work
Ahirwar & Meda (2020)	Effect of parallel electric fields on EMIC waves with Kappa distributions	Focuses on single-ion (H^+) plasmas with effect of parallel electric fields	Our study extends previous research by investigating EMIC wave growth in multi-ion plasmas (H^+, He^+, O^+), while also analyzing the combined effects of temperature anisotropy and κ values
Meda & Ahirwar (2019)	EMIC instability in cusp regions with Kappa distributions	Primarily studies wave growth near the cusp	Our work targets plasmapause and auroral zones, emphasizing relevance to diverse space environments
Lazar (2012)	Electromagnetic ion-cyclotron instability in bi-Kappa plasmas	Limited to bi-Kappa distributions in homogeneous plasmas	We study multi-ion plasmas with varying kappa and anisotropy in non-homogeneous environments.
Sugiyama et al. (2015)	EMIC waves with Kappa-Maxwellian distributions in the Earth's magnetosphere	Lacks detailed multi-ion analysis and does not quantify the role of heavy ions and use Kappa-Maxwellian distributions	We analyze how Kappa distributions influence the roles of H^+, He^+, and O^+ in EMIC wave growth

To clearly highlight these contributions, we have revised the introduction and discussion sections, providing a detailed comparison with past literature, including Sugiyama et al. (2015).

Additionally, our study stands out from the cited references by reviewer in several key aspects:

i. Multi-Species Plasma Composition

- Many of the cited references focus on single-ion species plasmas (e.g., hydrogen-dominated plasmas). Our study explicitly examines multi-species plasmas (H^+, He^+, O^+) and their combined influence on EMIC wave propagation.

ii. Influence of Temperature Anisotropy

- Our research uniquely quantifies the role of temperature anisotropy in different ion species, determining its effect on EMIC wave growth.
- While Lazar (2012), Xue et al. (1996a, 1996b), and Xiao et al. (2007) discuss temperature anisotropy, they primarily focus on its impact in single-ion species plasmas or assume Maxwellian distributions.
- Our study provides a comprehensive analysis of anisotropy effects in multi-ion environments, which is crucial for understanding wave-particle interactions in space plasmas.

iii. Specific Focus on Kappa Distributions

- While Hellberg & Mace (2002) and Cattaert et al. (2007) examine kappa-Maxwellian distributions, they do so primarily in the context of generalized dispersion functions and oblique propagation.
- Our study directly links the value of kappa to EMIC wave growth rates in a multi-ion plasma, making it more application-oriented for space weather studies.
- Additionally, Our work provides quantitative comparisons between different kappa values (e.g., k_p = 2 vs. k_p = 6), whereas prior studies often treat kappa distributions as a general assumption.

iv. Growth Rate Analysis and Plasma Instability Thresholds

- While Xiao et al. (2007), Xue et al. (1993), and Sugiyama et al. (2015) discuss EMIC wave growth in various plasma conditions, they do not systematically compare how different kappa distributions affect instability thresholds.
- Our research contributes a detailed parametric study on the combined effects of kappa distributions and temperature anisotropy on wave growth rates, instability conditions, and wave-particle interactions.

2. Introduction Section Requires Rewriting

We have extensively revise the **Introduction** to enhance clarity and logical flow:

- **Introduction to EMIC Waves:** The revised section now begins with a clear and concise explanation of EMIC waves, their role in space plasmas, and their significance in magnetospheric dynamics.
- **Research Gap and Motivation:** We have explicitly outline the limitations of previous studies, particularly the lack of a combined analysis of temperature anisotropy and Kappa-distributed plasmas. Despite extensive research on EMIC wave propagation, many previous studies have primarily focused on single-ion plasmas or assumed Maxwellian velocity distributions. However, space plasmas are often characterized by multi-ion compositions (H^+, He^+, and O^+) and non-Maxwellian particle distributions, particularly the Kappa distribution, which better represents suprathermal particles. While some studies have investigated temperature anisotropy effects and Kappa distributions separately, a comprehensive analysis of their combined impact on EMIC wave growth in multi-ion plasmas remains limited. This gap in knowledge motivates our study, which systematically examines how temperature anisotropy and Kappa-distributed plasmas jointly influence the growth and dispersion of EMIC waves.
- **Connection to Space Plasma and Auroral Acceleration Regions:** We have strengthen the link between EMIC waves and auroral acceleration regions, emphasizing their interaction mechanisms. EMIC waves play a significant role in magnetospheric plasma dynamics, particularly in regions such as the plasmapause and auroral acceleration zones, where interactions with energetic ions can lead to wave amplification. These waves contribute to the loss of energetic ring current particles via pitch-angle scattering, affecting radiation belt dynamics. The presence of non-Maxwellian suprathermal ions, described by the Kappa distribution, alters wave-particle interactions, making it essential to investigate how these distributions modify EMIC wave characteristics in auroral and near-Earth plasma environments.

3. Referencing Issues

- We have resolved all referencing inconsistencies by ensuring uniform formatting, correcting citation styles, and aligning references with the journal's guidelines
- Ensuring uniformity in citation style throughout the manuscript.
- Verifying accuracy of all references and ensuring proper citation of previously published works.
- Correcting the Anderson and Williams citation (1999) and properly formatting missing references.
- Adding missing citations at critical points (e.g., lines 167, 174, and other relevant sections).

4. Definition of Terms (tanh, tano, etc.)

We acknowledge the oversight in defining key terms such as "tano." In the revised manuscript, we have:

- Clearly defined all terms when first introduced in the text.
- Explained mathematical functions such as tanh and tano, ensuring they are used correctly.
- Provided references or derivations for equations that rely on these terms.

5. Clarification of Equations and Their Derivation

We will provide additional explanations and derivations for key equations, ensuring:

- All equations are properly introduced and referenced, with explicit derivations where applicable.
- Clear descriptions of physical significance accompany the equations, helping contextualize their role in our analysis.
- Proper citations are included if an equation is taken from previous literature.

6. Generalized Conclusions

To enhance the manuscript's impact, we have refined the conclusion section by:

- **Focusing on key findings**, specifically:
  - The influence of temperature anisotropy on EMIC wave dispersion.
  - The role of Kappa distribution in modifying wave growth rates.
  - The combined effect of these parameters in determining wave stability.
- **Adding a summary section** that explicitly highlights the main contributions and their significance for space weather research.
- **Discussing practical implications**, particularly in relation to wave-particle interactions in Earth's magnetosphere and their effects on geomagnetic storms.

7. Incorporation of Suggested References

We appreciated the reviewer's recommendations for additional references. We have incorporated relevant citations, including:

- Cattaert et al. (2007) and Hellberg & Mace (2002) for discussions on non-Maxwellian distributions in plasma physics.

- Lazar (2012) and Omura et al. (2010) for wave-particle interactions and Kappa-distributed plasmas.
- Sugiyama et al. (2015) for direct comparisons with previous studies on EMIC waves.
- Xiao et al. (2007) for additional context on magnetospheric wave propagation. These references are now integrated into the literature review and discussion sections to strengthen the study's foundation and comparative analysis.

We appreciate the reviewer's constructive feedback, which has greatly enhanced our manuscript. In response, we have meticulously revised the content to improve clarity, scientific rigor, and overall presentation. Furthermore, all comments—including those from the CC reviewer—have been fully incorporated. We hope that the updated manuscript reflects our commitment to addressing the raised issues, and we remain available to provide any additional clarifications if needed.