Main questions

Reviewer1:

1. the analysis performed in the paper is not sufficient to give a significant contribution in this area. The point is that injected waves in anomalous Doppler resonance reduce electron parallel momentum in case of stimulated emission, but they do the opposite in case of absorption.

For this reason, single-particle analysis is not sufficient: the net wave effect should be evaluated in the presence of realistic distribution functions of runaway electrons, as well as of collisional wave damping.

The instability of slow-X and the experiment has been analyzed in previous paper. For quantitatively analyze the accessibility of ADE, the polarization should also be considered as important parameter to analysis the possibility of ADE, alongside the instability analysis based on kinetic analysis and quasilinear analysis (eg 3,4)

1. The theoretical part is not new, in particular the quantum description of the anomalous Doppler effect is published in Coppi et al, Nucl. Fusion 16 30

The main difference with previous quantum analysis is the resonant condition is associated with the angular momentum of E.M. wave. The new result is that in the resonant condition w-kv=n\*wce, the Landau level n actually related with angular momentum of the emitting or absorbing wave. This was not mentioned in the previous paper.

Suggestions:

1. Title. “parallel energy”: energy is a scalar quantity; parallel could be appropriate for a vector (momentum) or for a tensor (pressure)

Change parallel energy to parallel kinetic energy?

1. Page 1. “In the beginning of burning plasma device discharge (current ramp up phase), the magnetohydrodynamic (MHD) instabilities and disruption“: disruptions can occur in any phase of the tokamak discharge.
2. Page 1. “improves discharge performance by reducing the consumption of ohmic field energy “ not true, as plasma impedance increases when parallel momentum of runaway electrons decreases.

improves discharge performance by reducing the consumption of ohmic field energy through runaway electron acceleration.?

1. Figure 4. Consider that electrons with continuously increasing perpendicular momentum can be trapped in magnetic ripple and quickly drift to the walls.

Radiation, collision, actually in the tokamak environment, the electron couldn’t increase continuously as illustrated in this simulation background, due to the complex environment, but the electron could be scattering to high pitch angle effectively under external wave.

Reviewer2:

1. In my opinion, the manuscript is a toy-model exploration of the phenomena of wave-particle interactions via Anomalous Doppler resonance, which has already been well-established in literature and has been proposed to be to be used as a way of mitigating RE beams with intentionally launching EM waves in tokamak plasmas via performing experiments and simulations.

As far as I know, there is little works in previous demonstrating the trapping velocity effect with static electric field and magnetic field with EM wave , despite quasilinear analysis have been given in various papers definitely illustrate the scattering process effect of ADE , more detail work based on the no linear testing particle simulation is worth to explore.

Simple model could help to explore the pure effect of ADE, unlike the complicated environment. Using slow EX wave to suppress the runaway electron require more detail analysis, but slow EW contains more left-hand polarization, make it more effective to suppress the runaway electron, exclude the trapping effect by other effect, such as inhomogeneous magnetic field

1. Besides, the manuscript lacks in fundamental understanding and explanation of the physics concepts and comes nowhere close to simulating the complicated dynamics between runaway electrons and EM waves in a tokamak.
2. Therefore, there are no new results mentioned in this manuscript and no detailed analysis that backs up the claims made by authors in the abstract.
3. There is a whole series of seminal theoretical papers in different research fields discussing how the different polarization of waves may lead to different types of interactions with electrons, i.e., whether it will be normal, anomalous Doppler resonance or Cherenkov resonance, hence, I do not see any new results presented by the authors in this paper. Even the equations 21-23 derived in the appendix are well established in the literature.

the polarization relationship with ADE actually has been analyzed previously based on dispersion matrix [5,6], which demonstrated that ADE process could generate circular polarization wave along magnetic field. This paper I should mentioned in the paper

1. The authors mention the impact of Anomalous Doppler effect to be “the transfer of the parallel electron energy to the rotational energy of the electron”, which is completely wrong, since the scattering of electrons due to EM waves leads to a change in perpendicular velocity of the electrons and hence, may increase just the gyro-radius of the electron, not the rotational energy which is related to the spin of the electron not the perpendicular energy given by “v\_\perp”.
2. The word “cyclotron electron” has been repeatedly used in the manuscript, what do the authors mean by this term? Do they mean an electron carrying out gyro-motion in the presence of a magnetic field?
3. The authors give no description of the form of the EM wave that they have used for their simulations in section II and III and how are they separating the different components viz. Left-handed, right-handed and circularly polarized wave from it during the simulations? Hence, the correctness of their simulations can’t be judged.

Add EM wave formula to the paper

1. The authors further try to connect the simulations in section II and III with the tokamak conditions by amplifying the magnetic field in the simulations to 2 Tesla, however, the tokamaks have very complex helical magnetic fields a toroidal geometry. Hence, the simulations are way too simple to draw assertions for a tokamak plasma.

Reviewer 3

1. Most, if not all, the general results presented in the paper (see Secs. II – IV in particular) have already been presented and analyzed in detail in the literature, and reported even in textbooks.

Plenty of paper discuss about the testing electron interaction with E.M.wave in uniform magnetic field, but as far as I know , none of them analysis the situation with static electron field [7-16]

1. Section II presents the numerical simulation framework in an incomplete way (e.g., the chosen expression for E.M. wave is not given), and the used parameters are not relevant for tokamak experiments. The discussion of the results is qualitative, no theoretical expression is derived or presented, so that the general validity is limited and application to a realistic case cannot be made.

I should give the expression for E.M. wave, theoretical expression will be derived in future.

1. In Sec.VI, the cold dispersion relation in a magnetized plasma is reported in detail, and the various wave-particle resonances are listed. All this part is well-known since many decades!

All physics rules have been found many years ago, but people still use this rule to analysis the special question. In the paper, what I considered is the polarization in cold plasma wave, which is important for ADE.

1. In Sec. V, it is proposed to launch extraordinary waves from the high field side of the tokamak to mitigate runaway electrons via ADE. This looks like speculation, not supported by a serious analysis, and also quite difficult if not impossible to realize in practice in a reactor. This proposal would deserve a detailed investigation of various complex physical processes not even mentioned in the paper.

Add this part into discussion

Summary:

Simple model, full explored by other people, no new results, no fully analysis for wave and runaway interaction.

内容

通过试探电子分析电子和电磁波相互作用的理论论文[7-16]，但均未考虑静电场加速机制,也有可能是我没找到？关于量子ADE的论文[2,17-20]，未体现角动量守恒过程。

本论文的发现和论点:

1. 静电场中抑制电子动量的电磁波的临界电场
2. 电子ADE过程要求电磁波具有左旋偏振，但不是最新的结论，只能说通过角动量守恒的方法论证了为什么是左旋，相关论文是通过色散矩阵求解电场极化得到该结论。
3. 通过等离子体电磁波模的偏振分析，论证了slow-X wave的潜力。
4. 提出外界注入电磁波的方法抑制逃逸电子，但论证不充分。

因此修改如下：

1. 关于讨论极化和ADE效应的论文(5，6),通过色散矩阵求解偏振极化方向得出电子的ADE效应会产生沿磁场方向的左旋圆偏振波，应该在论文中有所体现。但是这个结果并不和之前结果冲突，应该在论文中体现这种一致性。
2. 添加电磁波方程
3. 将cyclotron electron 改成 gyrating electron
4. 强调角动量守恒在ADE过程中的重要性，其决定了电磁波的共振次数n 以及极化方向。
5. 通过对极化方向的分析，得出slow-X wave 更符合ade 效应所需要的条件。这点和他人通过kinetic instability 和quasilinear 分析得到的结果一致 [1,3,4]，所以不能当作创新点，只是从侧面佐证了slow-X wave 的潜能。
6. 应该减少外界电磁波注入的方法抑制逃逸电磁波在论文中的比重，以本文的分析方法不足以支撑这个方法的可行性。

Ref：

1.G. I. Pokol, A. K´ om´ ar, A. Budai, A. Stahl, and T. F¨ ul¨ op, Quasi-linear analysis of the extraordinary electron wave destabilized by runaway electrons, Physics of Plasmas 21, 102503 (2014).

2. B. Coppi et al 1976 Nucl. Fusion 16 309

3. Quasi-linear analysis of the extraordinary electron wave destabilized by runaway electrons

4. Interaction of electromagnetic waves and suprathermal electrons in the near-critical electric field limit

5. On the circular polarization in pulsar emission

6. On the origin of the circular polarization in radio pulsars

7. Charged‐Particle Motion in Large‐Amplitude Electromagnetic Fields

8. Motion of a Charged Particle in a Constant Magnetic Field and a Transverse Electromagnetic Wave

Propagating along the Field

9. Motion of a single charged particle in electromagnetic fields with cyclotron resonances

10. Nonlinear analysis of electron cyclotron maser based on anomalous Doppler effect

11. Particle acceleration through the resonance of high magnetic field and high frequency electromagnetic wave

12. Theory of the anomalous Doppler cyclotron-resonance-maser amplifier with tapered parameters

13. Pitch angle scattering of an energetic magnetized particle by a circularly polarized electromagnetic

Wave

14. Dynamics of a charged particle in a circularly polarized traveling electromagnetic wave

15. Relativistic motion of a charged particle in a superposition of circularly polarized plane electromagnetic waves and a uniform magnetic field

16. An Exact Solution of the Relativistic Equation of Motion of a Charged Particle Driven by a Circularly Polarized Electromagnetic Wave and a Constant Magnetic Field

17. EXCITATION AND RADIATION OF AN ACCELERATED DETECTOR AND ANOMALOUS DOPPLER EFFECT

18. Negative-energy waves and the anomalous Doppler effect

19. Optics of Light Sources Moving in Refractive Media: Vavilov-Cherenkov radiation, though interesting, is but an experimental instance of a more general problem

20. Radiation by uniformly moving sources (Vavilov–Cherenkov effect, transition radiation, and other phenomena)