IFERC-CSC 大型計算機利用報告書〔プロジェクト枠〕

2021 年度

研究課題名	***G**yro-**K**inetic Study on Turbulent **Trans**port in Tokamak Plasmas*
上記の頭文字	*GK_TRANS*

＊申請時のタイトル、略称を記載してください

研究代表者 (PI):

研究代表者名	WANG Wei

１．成果の概要２００字程度）

In the previous cycle of “JFRS-1”, 0.298M*node*hours computational resource was allocated to the project “GK_TRANS”. With this project, two topics have been studied: 1. Impact of non-adiabatic passing electrons on the liner growth of Trapped Electron Mode (TEM) instability. 2. Plasma shaping effect on linear TEM instability in the reversed magnetic shear plasmas. In topic 1, the non-adiabatic passing electrons are found to destabilize linear TEMs especially in the short wavelength region. In topic 2, negative triangularity is found to destabilize linear TEMs due to the variation of local profile gradient in bad curvature region. These results are summarized in the paper titled “Global gyro-kinetic study of magnetic shaping effects on linear trapped electron mode instability in normal/reversed magnetic shear plasmas” and has been accepted by Nuclear Fusion recently. Details are explained in the following.

２．成果の詳細（図、表等を含めて A4 で 2～3 ページ程度）

Numerical simulations performed for above two topics are based on different versions of gyrokinetic code GKNET (Gyro-Kinetic Numerical Experimental Tokamak). In details, topic 1 uses the full-kinetic electron code version and the results are compared with that from the adiabatic and hybrid electron versions. In topic 2, the full-kinetic electron code version is utilized, and we consider the equilibria obtained by the MHD equilibrium code TASK/EQ. About 40% of computational resources in this project are consumed with the topic 1, and the left for the topic 2.

40% Topic 1: Impact of non-adiabatic passing electrons on the liner growth of TEM mode	60% Topic 2:Plasma shaping effect on linear TEM mode in the reversed magnetic shear plasmas

In topic 1, a careful benchmark is performed among GKNET codes with different electron models. As an extension of project “GK_TRANS” from last fiscal year, Figure 1(a) shows that the non-adiabatic electron will strongly destabilizes linear TEM, especially in the short wavelength region. In this cycle, further verifications have been made for the dependence of non-adiabatic electron effect on mass ratio and collisionality as seen in figure 1(b) and 1(c).

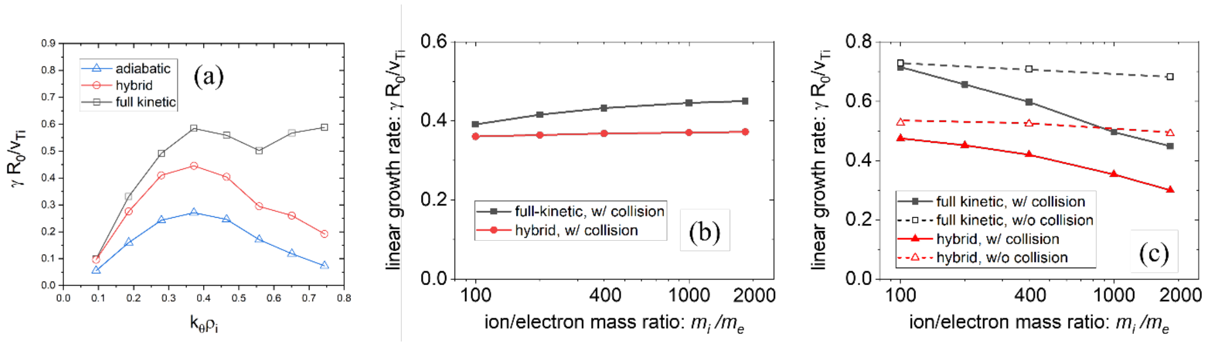

Figure 1.

Figures 1(b) and 1(c) show linear growth rates with different mass ratio for $k_\theta\rho_i = 0.372$ (n=10 in $a = 75\rho_i$ case) in case (b) $\eta_e = 3.114$ and case (c) $\eta_e = 0$. In the ITG case (a), hybrid simulations give almost the same growth rate with different mass ratios, while in the full-kinetic electron simulations the growth rate slightly increases with larger mass ratio from 100 to the realistic value (1836). As a result, the gap of growth rate between full-kinetic and hybrid simulations also slightly increases. This is not surprising since the electron-electron collision mainly acts on the electron dynamics and case (a) is ITG dominated. In the pure TEM case (b) where ITG is stabilized by applying zero ion temperature gradient $R_0/L_{T_{io}} = 0$, both collisional and collisionless cases are calculated by full-kinetic and hybrid GKNET. The gap of growth rate between hybrid and full-kinetic cases in the pure TEM case (b) is much larger than that in the ITG case (a), which indicates that the non-adiabatic passing electrons play a significant role on destabilization of TEMs. If the electron-electron collisionality is considered, linear growth rates in both full-kinetic and hybrid model show decreasing tendency with increasing mass ratio. As previously explained, the dimensionless collisionality ν_* is proportional to the square root of mass ratio due to the normalization used in GKNET, which means that the TEM mode can be stabilized by the larger collisionality. This is because the increase of electron-electron collision acts on the trapped electrons and changes the electron trajectories from trapped one to passing one. On the other hand, when zero collisionality is assumed, dashed lines show no impact from mass ratio on the TEM linear growth rate, which also implies that the gap of growth rate between full-kinetic and hybrid case originates from the non-adiabatic passing electrons.

In topic 2, this project aims to study the plasma shaping effect on linear TEM instability under reversed magnetic shear. At first, characteristics of TEM linear eigen structures in the NS and the RS cases have been discussed in figure 2. Linear eigen functions show slab-like structures in the RS configuration, and higher toroidal modes are found to be excited in the outward region of q_{min} due to the destabilizing condition in the wavenumber space. Poloidal harmonics analyses have shown that the eigen structures can be strongly suppressed at the q_{min} location due to the drift reversal. As a result, a mixed linear structure consisting of the slab-like structure in the region inside of q_{min} and the ballooning-like structure in the region outer of q_{min} is formed. The impact of plasma shaping on linear TEM instability in reversed magnetic shear configuration has been studied. In the scan of elongation κ, the larger κ always stabilizes TEMs due to the reduction of effective gradients over the flux surface. For the triangularity δ, since the near-zero magnetic shear around q_{min} is not affected by the plasma shaping, the change of local temperature/density gradients plays a dominated role on the linear growth of TEMs. Due to this reason, the negative triangularity δ <0 shows the obvious destabilizing effect to linear TEMs as seen in figure 3.

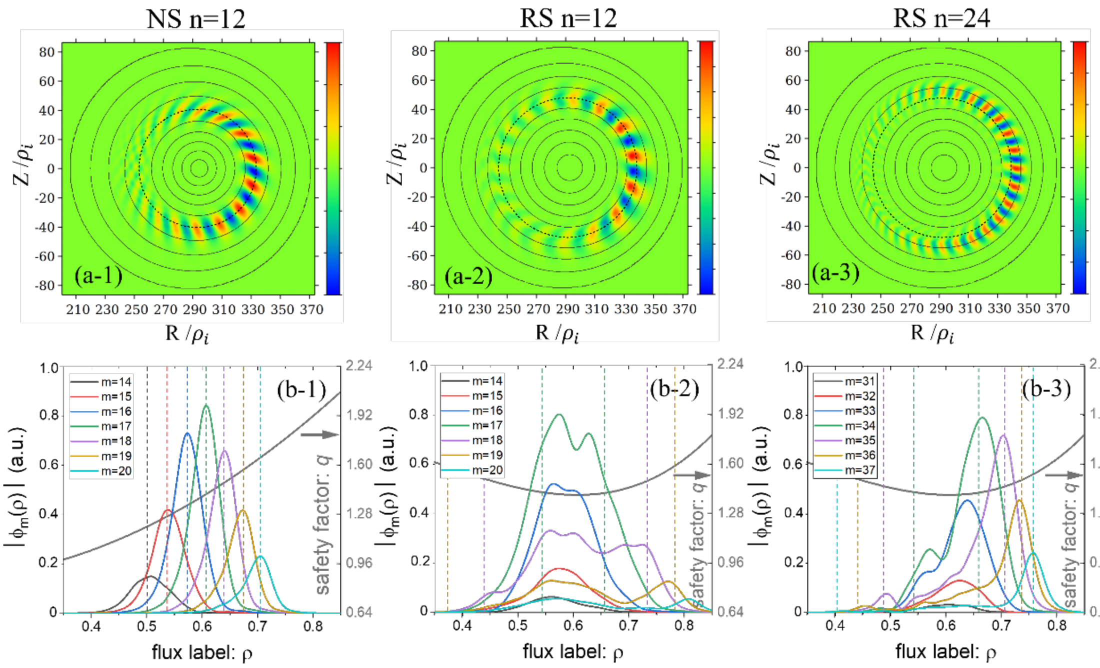

Figure 2.

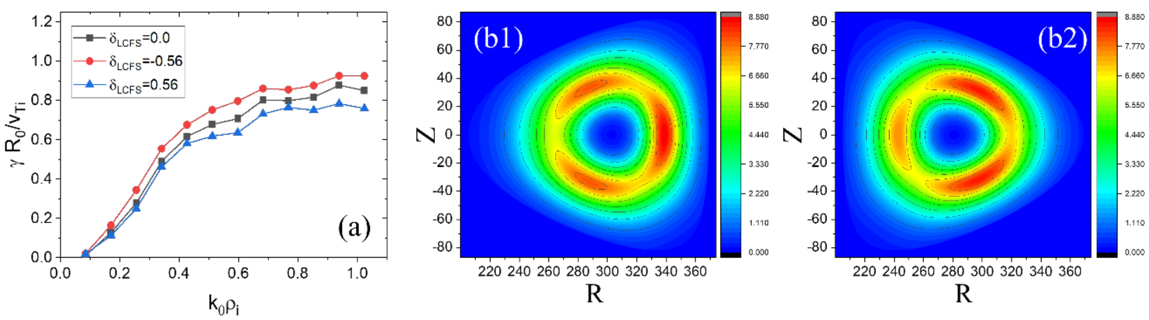

Figure 3.

Based on above numerical studies through JFRS-1, better understandings have been made on the kinetic effects of passing/trapped electrons on linear instabilities, and the shaping effect with reversed magnetic shear configuration.

３．研究のキーワード

1. turbulent transport	**2. magnetic shaping**	**3. trapped electron mode**	**4. reversed magnetic shear**	**5.**