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Impact of gravity on dynamics of seeded impurity ions in tokamak plasma

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Particle and heat flux to the material plates of the plasma-facing components are major challenges for the safe operation of tokamaks. Low Z and medium Z impurities like neon, nitrogen, or argon seeding have been proposed as an effective strategy for the reduction of heat or particle load on the material plates[1]. To find the best strategy, a detailed understanding of the dynamics of these impurity ions is required. In this work, the impurity seeding has been studied numerically using BOUT++ code in the edge and scrape-off layer (SOL) regions of a tokamak plasma by solving a set of differential equations. We have derived the set of equations in the presence of impurity gases where the gases have been treated as fluid and plasma in the edge and SOL region has been modeled using drift interchange modes[2,3]. Plasma–impurity gas interactions in the plasma take place through a large number of processes such as electron impact ionization, radiative recombination, molecular dissociation (for nitrogen). Radiative energy losses have been modeled using a non-coronal equilibrium process in the electron energy equation[4]. The ions are assumed cold.

The numerical simulations have been done using nitrogen, neon and argon gases. These impurity gases are multiply charged by the electron impact ionization processes. To understand the dynamics of the impurity ions we have used two different values of effective gravity g . It has been found that for a high value of 'g', the impurity moves much inside with higher velocity. The velocity of impurity ions was found to be mass independent and lies in the range of 0.02 c_s to 0.05 c_s , where c_s is sound speed. We have observed both inward and outward motion of impurity ions which indicates that their dynamics behave intermittently with time which is in accordance with the interchange plasma turbulence[5,6]. The radial flux of Ar^{+} , Ar^{2+} , Ne^{+} , and N^{+} is found to be negative in the edge region which is the turbulence induced inward pinch effect. Radial flux of Argon ions is shown in Fig[1].

The radial fluxes of the other multiply charged ions are mainly positive. The relative abundance of Ar^{4+} , Ne^{3+} , and N^{3+} are found to be larger than the other (respective) multiply charged ions. The radiation energy loss has been calculated from the numerical data and it is found that the space averaged radiation energy loss behaves intermittently with time. The power spectrum is maximum at about 20 kHz frequency that is very close to the experimental Aditya tokamak result. The negative fluxes of the impurity ions and the intermittent nature of the radiation loss dependence on the effective gravity 'g' are the most important and new results of this work.

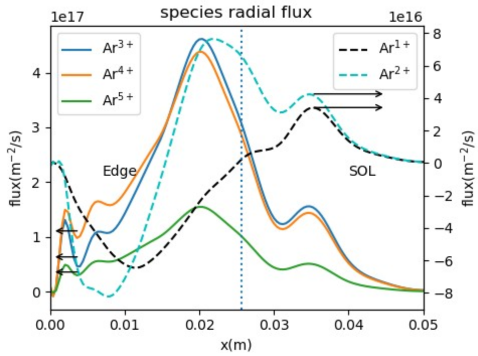

Fig.1. Poloidal and long-time averaged radial flux of Ar^{+}, Ar^{2+}, Ar^{3+}, Ar^{4+} ,and Ar^{5+} charged species. The vertical dotted line indicates the edge-to-SOL transition region.

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