S001-08
A 会場 ：11/4　 PM2 （15:45-18:15）
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強磁場中における相対論的波動粒子相互作用

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Relativistic wave-particle interaction under strong magnetic fields

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Laser astrophysics, experimental astronomy using huge laser facilities, is attracting attention as the third research tool for astronomy to complement observation and theory. Conventionally, astronomical phenomena have been reproduced by plasma generated by lasers. However, with the recent discovery of high-luminosity celestial objects, a new type of laser astrophysics experiment in which intense laser beams can be regarded as an astronomical phenomenon is now being considered.

In the astronomical phenomenon called Fast Radio Bursts (FRBs), highly bright radio emissions of the frequency about 1 GHz with a short duration of nearly a millisecond are observed. The dimensionless amplitude of this electromagnetic wave corresponds to an intensity exceeding a_0 = 10^4, which is highly relativistic. Although the source and mechanism of FRB emission have not yet been understood, it has been suggested that they are related to neutron stars with magnetic fields of about 10^{15} Gauss, which are called magnetars. Assuming that the radio source is very close to the neutron star, this high-intensity electromagnetic wave must pass through the magnetosphere of the neutron star. In a strong magnetic field where the cyclotron frequency exceeds the radio frequency (¥omega$_{ce}$ >>¥omega_0), the scattering rate of relativistic electromagnetic waves will be high, and it is not apparent whether the transmission is possible or not. Such considerations can give a constraint on the theoretical model of the FRB. In the absence of a magnetic field, the propagation characteristics of intense electromagnetic waves have been studied in detail in the field of laser plasmas. However, our understanding of ultra-strong magnetic fields, which are not feasible in current high-intensity laser experiments, is still insufficient. Therefore, we have analyzed wave-particle interactions under extreme plasma conditions, such as those expected in FRBs, using PIC simulations. In this talk, we focus on the collision process of Alfven waves.

We have shown theoretically that all electrons with non-relativistic velocities are accelerated to relativistic speeds due to the standing waves created by counter-propagating circularly polarized electromagnetic waves along magnetic field lines in an electron-ion plasma (Isayama et al. 2022; Sano et al. 2022). We then numerically verified whether a similar phenomenon occurs for Alfven waves in electron-positron plasmas, which could be assumed in FRBs. As a result, it is found that both electrons and positrons are efficiently accelerated to energies above MeV in standing waves created by linearly polarized Alfven waves if the amplitude of the electromagnetic wave is larger than the intensity of the background magnetic field. Furthermore, simulations considering radiation damping reveal that most of the energy of the original electromagnetic wave is converted to gamma-ray radiation by relativistic particles. This gamma-ray radiation is also expected to produce electron-positron pairs, suggesting that various energy conversion processes may be realized quickly. In this talk, we will introduce the details of such physical processes, the conditions under which they are realized, and their importance in the FRB model. We will also discuss the possibility of future proof-of-principle laser experiments as a new ”laser astrophysics” topic.