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Particle acceleration by counter-propagating circularly polarized Alfvén waves

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Coherent large amplitude Alfvén waves are ubiquitous in space and considered to play crucial roles in the acceleration of high energy particles. A number of models of large amplitude Alfvén wave generation accompanying the particle acceleration have been proposed so far.

More than decades ago, Matsukiyo and Hada [1] showed that a relativistic Alfvén wave in a pair plasma is unstable to form the coherent standing wave form which consists of counter propagating Alfvén waves. The particles pre-accelerated during preceded successive decay instabilities are efficiently accelerated by the counter propagating Alfvén waves. However, the applicability of this acceleration process looks limited because the process requires pre-acceleration of particles.

In our recent studies, it was found that the phase transitions of the behavior of particles trapped in a trough of magnetic envelope occur when wave amplitudes exceed two critical values. Above the critical amplitudes, initially non-relativistic particles are accelerated to super-relativistic energy without a pre-acceleration process within a very short time. This mechanism works for both electrons and ions and accelerated particles have strong spatial coherence as well, which may be suitable for strong radiation from the object such as a neutron star or a magnetar. This acceleration process may be applicable to many astrophysical circumstances near a shock, the solar surface, and the planetary radiation belt, where the counterpropagating Alfvén waves are locally generated. Furthermore, this acceleration process will be demonstrated by a future experiment using high-power lasers with applying a strong ambient magnetic field.

References

[1] S. Matukiyo and T. Hada, ApJ. 692 1004 (2009).