SM53B-1291

Image by ISAS/JAXA
HAYABUSA (MUSES-C), AKARI (ASTRO-F), and HINODE (SOLAR-B)

Electron Acceleration during Magnetic Islands Coalescence in Magnetic Reconnection

*YUMURA, Tsubasa (yumu@stp.isas.jaxa.jp) TANAKA, Kentaro G. SHINOHARA, Iku and FUJIMOTO, Masaki ISAS/JAXA

Abstract

- We carried out 2D full particle simulations of magnetic reconnection with multiple X-lines.
- We investigated the effects of magnetic islands coalescence on electron acceleration mechanism.
- We investigated the relationship between electron acceleration and simulation system size.

Introduction

Magnetic reconnection is seen as an important source of energetic electron generation in space plasma. In earlier studies, it has been thought that electrons are accelerated by the meandering/Speiser motion near the X-line and ∇B/curvature drift at pileup regions. While their studies have been focused on the single X-line (SXL) simulations in limited system size, recent in-situ observations of Earth's magnetotail and solar wind suggest the presence of multiple X-lines. Furthermore, their system sizes were given at choice. In this talk, we will see the effect of magnetic islands and system sizes on the electron acceleration process.

Simulation Setup

We have carried out 2D full particle simulations of magnetic reconnection with multiple X-lines. Harris current sheet is used in the initial condition. The coordinate system is adapted GSM system at the Earth's magnetotail (Fig. 1). Simulation list is shown in the table below.

Run	System Size ($L_x \times L_z$)	Initial X-lines (nm)
1	$48\lambda_i \times 32\lambda_i$	8
2	$48\lambda_i \times 32\lambda_i$	1
3	$24\lambda_i \times 32\lambda_i$	4
4	$12\lambda_i \times 12\lambda_i$	2

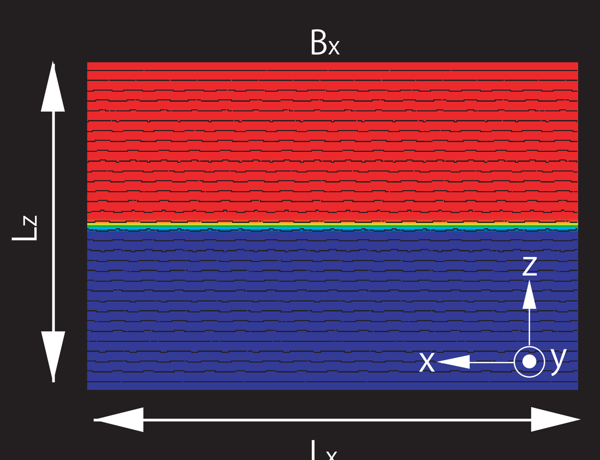
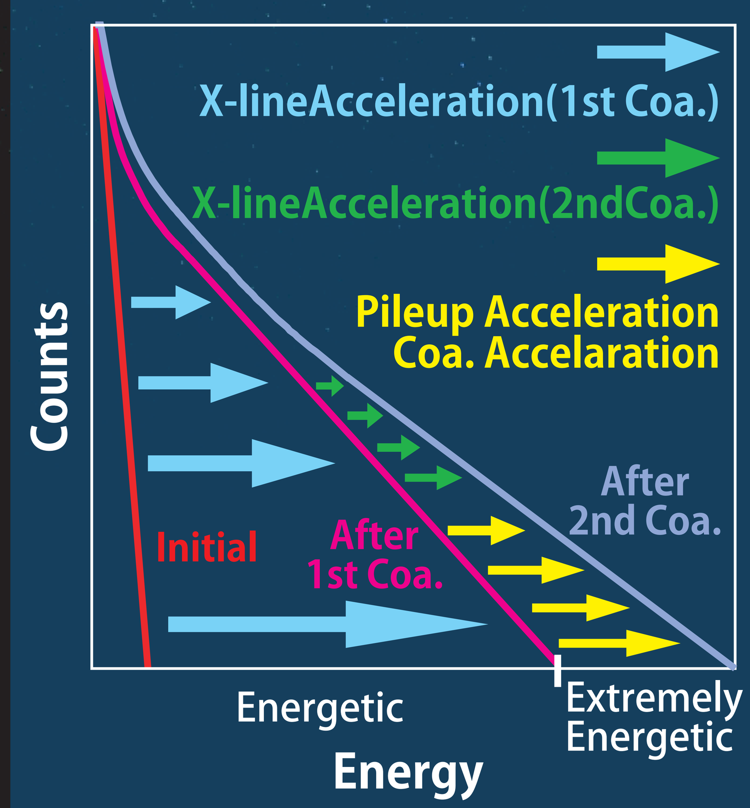


Fig. 1 Coordinate system and initial Bx.

Conclusion



- Energetic electrons ($\varepsilon<15$) are preferentially produced at the X-lines.
- The maximam energy of the accelerated electrons at the X-lines is unchanged, when the system size is $L_x \geqq 24$.
- Presence of multiple X-lines provides another acceleration process, i.e. the coalescence process to the electrons.
- With the help of the coalescence and/or pileup region, energetic electrons are further accelerated ($\varepsilon>15$).

Reconnection with Coalescence

The nm=4 case shows that all four islands coalesce into one large island at t=20 (see Fig. 2a). The nm=8 case shows that two-step coalescence stages are seen in Fig. 2b. The first coalescence takes place at t = 20, and then, the second coalescence is seen at t = 35 (see Fig. 2b).

Comparison between Run 1 and Run 2 shows that the electron acceleration depends not on the number of the initial X-lines, but on the system size (Fig 3a). In the nm=8 case, electrons were greatly accelerated during 1st coalescence (Fig. 3b). The spectrum of t=30 (see Fig. 3b) fitted spectrum of nm=4 (see Fig. 3a).

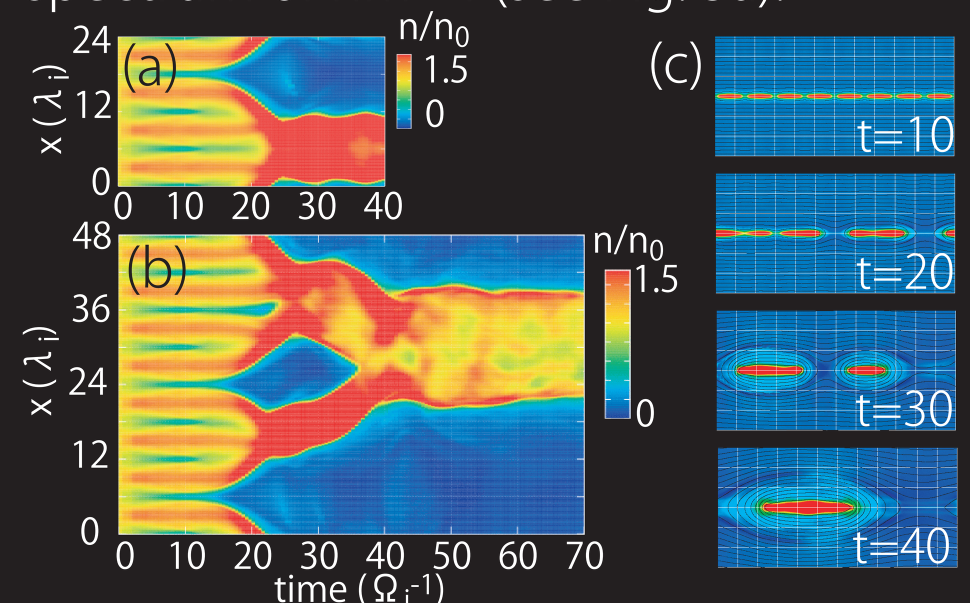


Fig. 2 Time evolution of electron density at neutral sheet (a) in the nm=4 case and (b) in the nm=8 case. 1st coalescence arose at t=15 ～ 25 and 2nd arose at t=35 ～ 40. (c) Snapshots of electron density in nm=8 case.

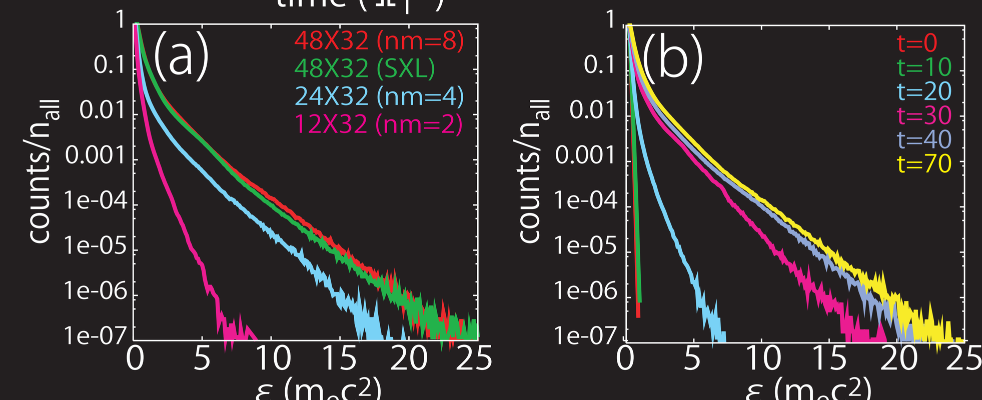


Fig. 3 Energy spectrum of (a) each simulations at the last time and (b) each time in the nm=8 case.

X-line Acceleration

The maximum of the electron energy at the X-line reaches up to eps˜15 at the time of the first coalescence (t=30) (see Fig. 4). Meanwhile, the X-line acceleration at the second coalescence is found to be insignificant (t=40) (see Fig. 4). In order to understand acceleration at the X-lines, we assessed energy gain at electron diffusion region (EDR) which is the proxy for the electron acceleration region. Two conditions to define EDR are shown in the sky blue box below. Total energy gain at EDR were almost the same except the nm=2 case (Fig. 5b). This might be because Lx=12 is too small for the EDR formation.

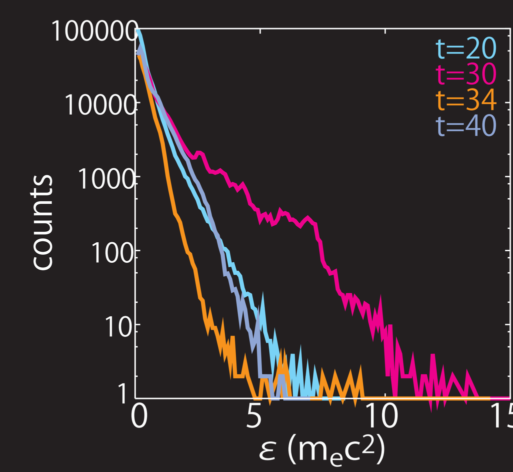


Fig. 4 Energy spectra at X-line.

$$(\mathbf{E} + \mathbf{V}_e \times \mathbf{B})_y / E_y > 0.5$$
$$|E_yc/V_{Ai}B_0| > 0.2$$

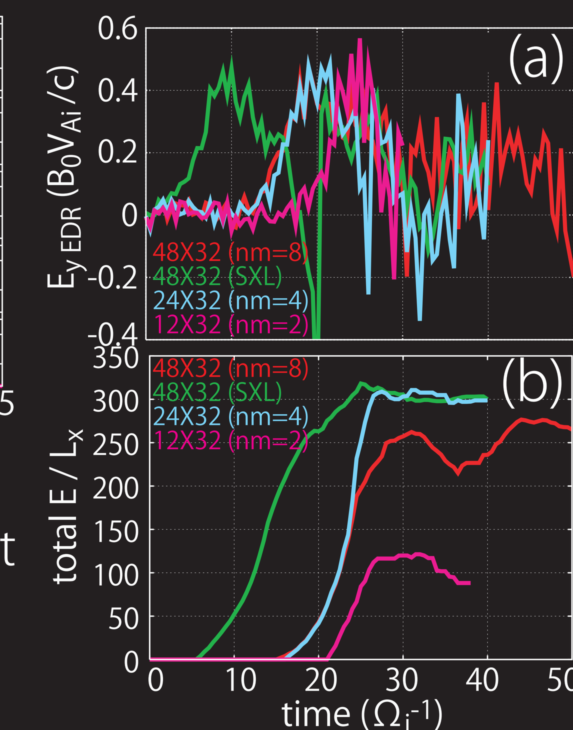


Fig. 5 (a) Y component of electric field at EDR. The peaks are the same for all runs.
(b) total $E = \int \sum n_e(i)E_y(i)\,dt$. $\sum(i)$ covers all grids of EDR. This value indicates total electric force which electrons in EDR are applied.

Extremely Energetic Electrons

We have traced extremely energetic electrons ($\varepsilon>25$) to investigate where and when electrons are accelerated. Most of the electrons are accelerated at the X-line up to $\varepsilon\sim15$ (red curves in Fig. 6). On the other hand, further acceleration up to $\varepsilon\sim25$ takes place at the coalescence region (green curves in Fig. 6) and/or pileup region (sky blue curves in Fig. 6).

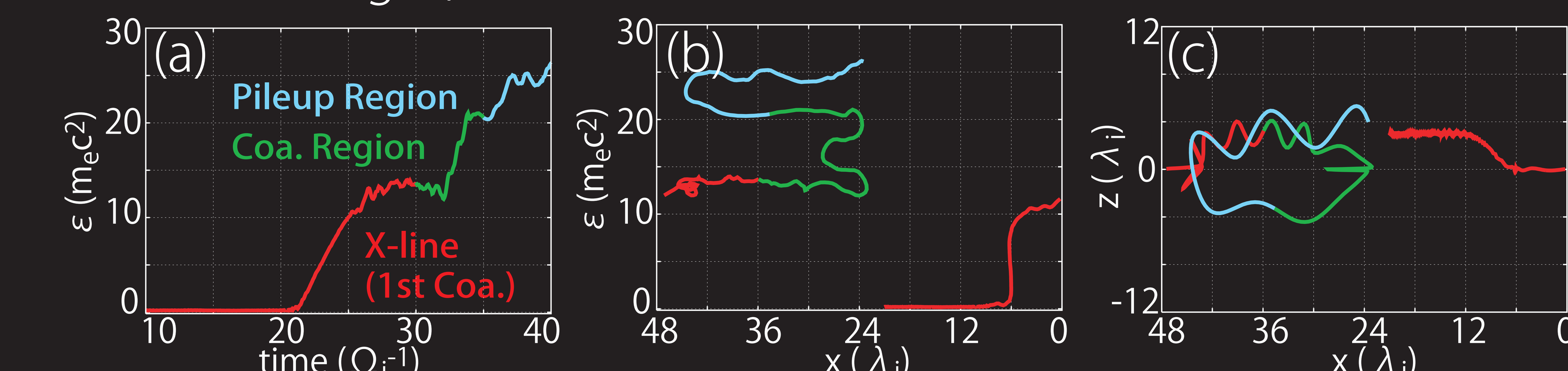


Fig. 6 (a) energy-time (b) energy-x (c) z-x trajectory of the energetic electron which was accelerated at three regions. Red is at the X-line, green is at the coalescence region, and sky blue is at the pileup region.