# PhD Open Days

# Simulations of laboratory mini magnetospheres

APPLAuSE PhD programme

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## Introduction

When the solar wind interacts with the Earth's magnetic field, it gets deflected, creating a plasma region called magnetosphere.

Not all planets have strong magnetospheres, but some comets, asteroids, and localized regions on the Moon showed evidence of "mini magnetospheres".

In this work, we present simulations of mini magnetospheres that reproduce recent laboratory experiments performed in a laboratory.

## Experiments

### Experimental setup

The Large Plasma Device (LAPD) at UCLA, is a 20 m long, 1 m diameter chamber capable of high-repetition-rate operation.

In the experiments, a high-intensity laser was focused on a plastic/carbon target, releasing a fast plasma against a magnetized background plasma with a dipole in the center.

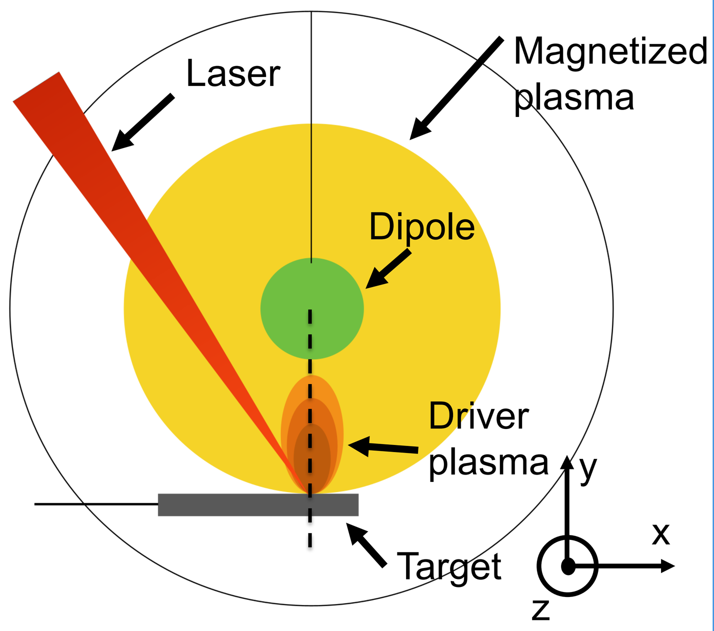


FIG 1: Schematic of the experimental setup on the LAPD.

### Experimental results

The experiments showed a reflection of the compressed magnetic field [1].

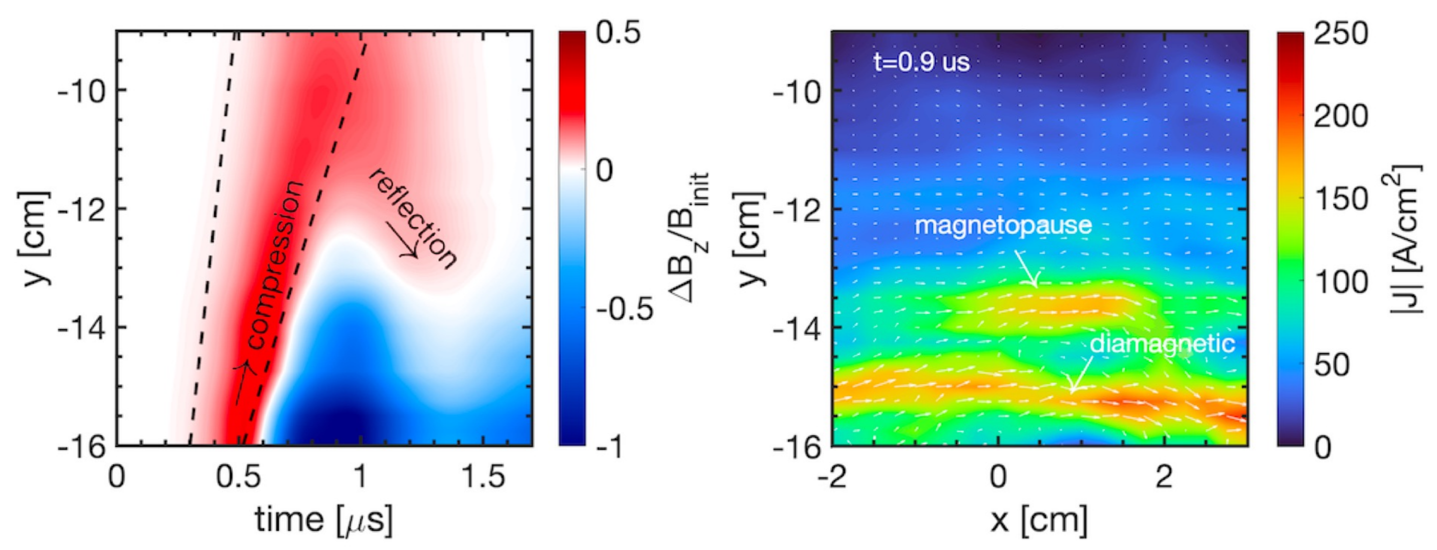


FIG 2: LAPD experimental results for the variation of the magnetic field $\Delta B_z$ (left) and the current density $J_x$ (right), at $x = y = 0$.

## Simulations

The particle-in-cell (PIC) method consists of self-consistently solving the equations of motion for all the particles in a discretized spatial grid.

The state-of-the-art, fully relativistic, massively parallel PIC code OSIRIS [2,3] was used to determine the magnetospheric structure and kinetic-scale features of the plasma current distribution.

The 2D simulations recreate the experimental results [4,5].

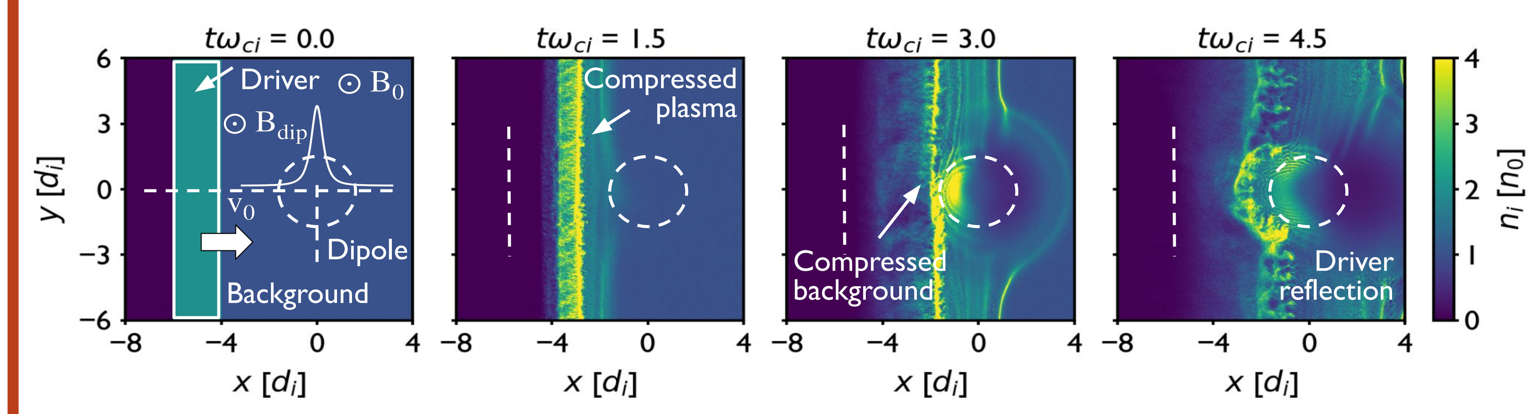


FIG 3: Total ion density for the simulations.

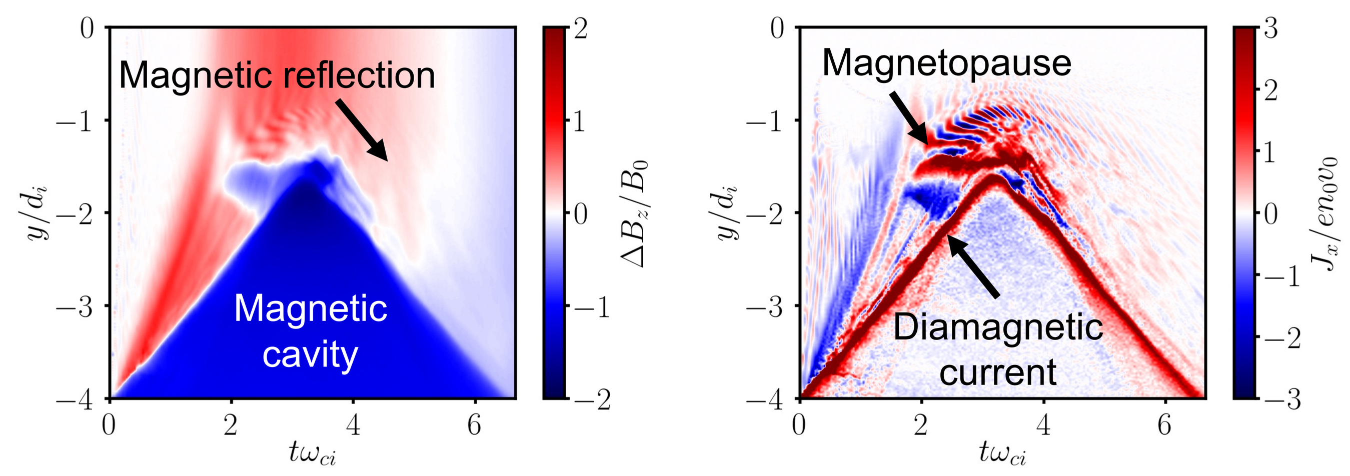


FIG 4: Synthetic diagnostics for the simulations.

## Magnetic reconnection

If we invert the dipole, the magnetic fields of the plasma and of the dipole become antiparallel. This forces the magnetic field lines to rearrange themselves, releasing energy in the process.

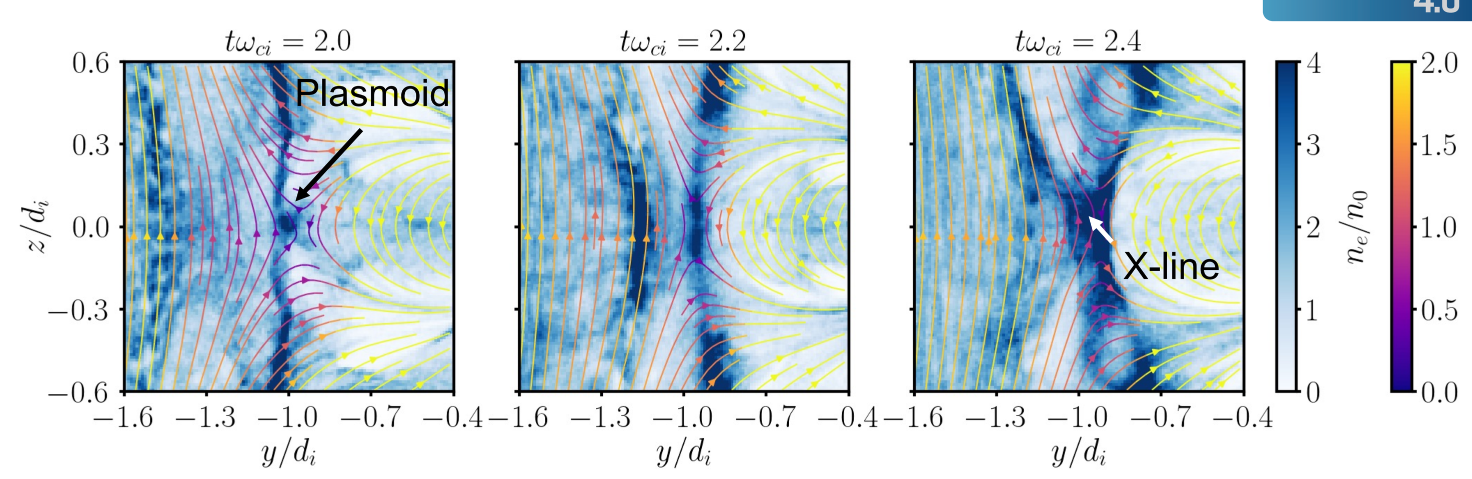


FIG 5: Simulations with inverted dipole lead to magnetic reconnection.

## Conclusions

Ion-scale magnetospheres can be studied in the laboratory.
Two current structures are formed, the magnetopause, associated with plasma-dipole interactions, and the diamagnetic current, associated with the magnetic cavity.
We can observe magnetic reconnection in an antiparallel configuration.

## References


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[2] Fonseca, R. A. et al. Computational Science — ICCS (2002)
[3] Fonseca, R. A. et al. Plasma Phys. Control. Fusion 55, 124011 (2013)
[4] Cruz, F. D. et al. Physics of Plasmas 29 (3), 032902 (2022)
[5] Cruz, F. D. et al. Physics of Plasmas 30 (5), 052901 (2023)


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