磁場・レーザー融合実験によるマルチスケール実験室宇宙物理の開拓

境　健太郎

核融合科学研究所

プラズマ量子プロセスユニット

核融合科学研究所 ユニット成果報告会

2024年5月8日

Kentaro Sakai (境 健太郎)

- NIFS since Aug. 2023
  - Assistant professor
- Ph.D. in Engineering in July 2023
  - Supervised by Yasuhiro Kuramitsu
- Research interest: laboratory astrophysics with high-power lasers

Summary

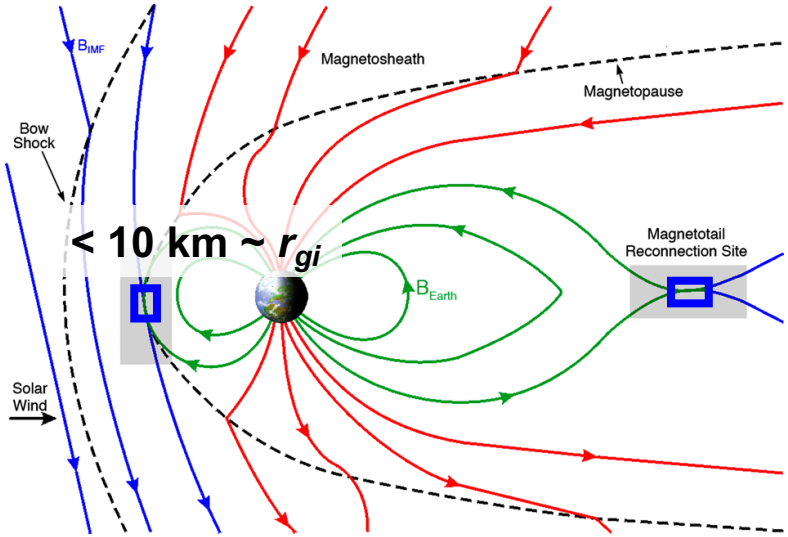
- Multiscale laboratory astrophysics
  - From electron to MHD scales
- Fusion of magnetic device with laser
  - Large spatiotemporal scales for MHD
  - Electron-scale resolution and supersonic flow
- One of the target: experimental investigations on the existence of intermediate shocks
  - Many other potential applications

- JSPS KAKENHI (24K17029)
- NIFS Collaboration Research Program (NIFS24KIIQ010)
- NINS program of Promoting Research by Networking among Institutions (01422301, 102050NINS000312)
- NINS OPEN MIX LAB Program (OML022405)
- Collaborative research program, i-SPES, Kyushu University

Laboratory astrophysics

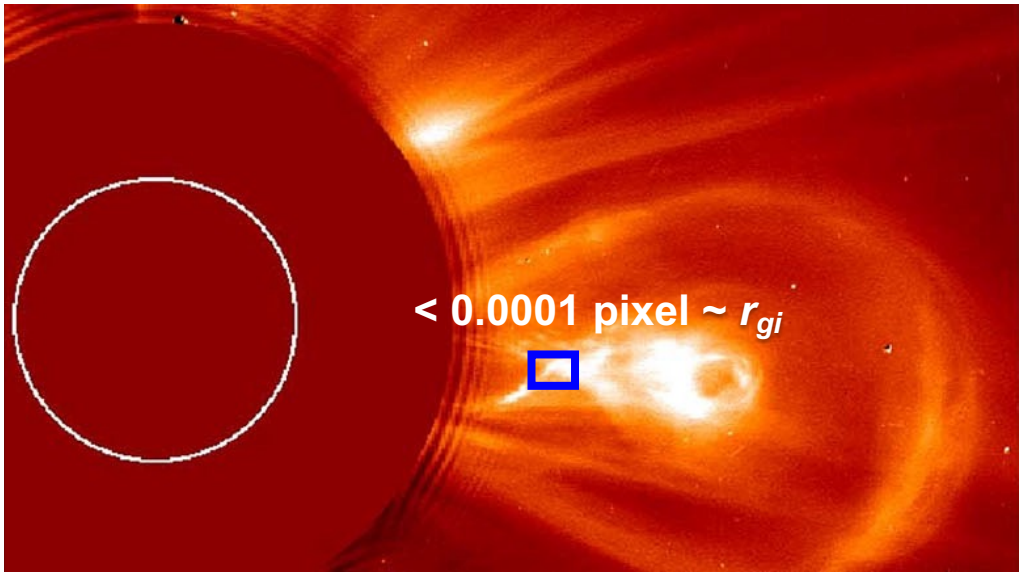
- Reproduce space/astrophysical phenomena
- Energetic laser as a driver of supersonic flow
  - Shocks and reconnections

Earth's magnetosphere



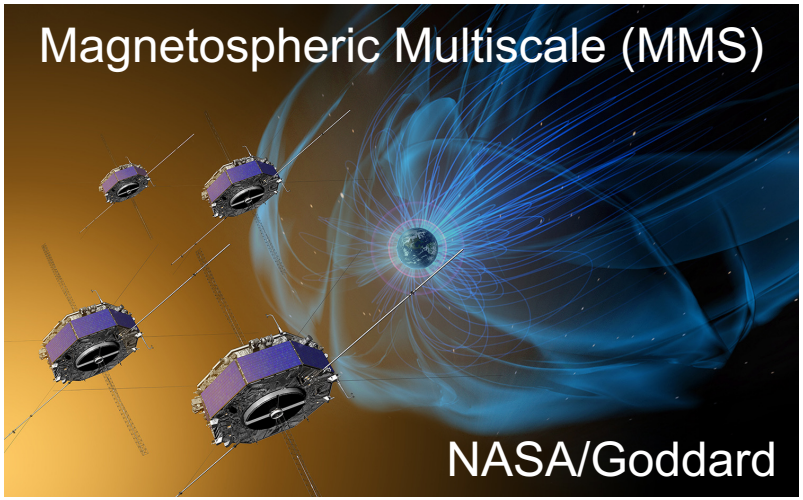
S. A. Fuselier+, Space Sci. Rev. (2011)

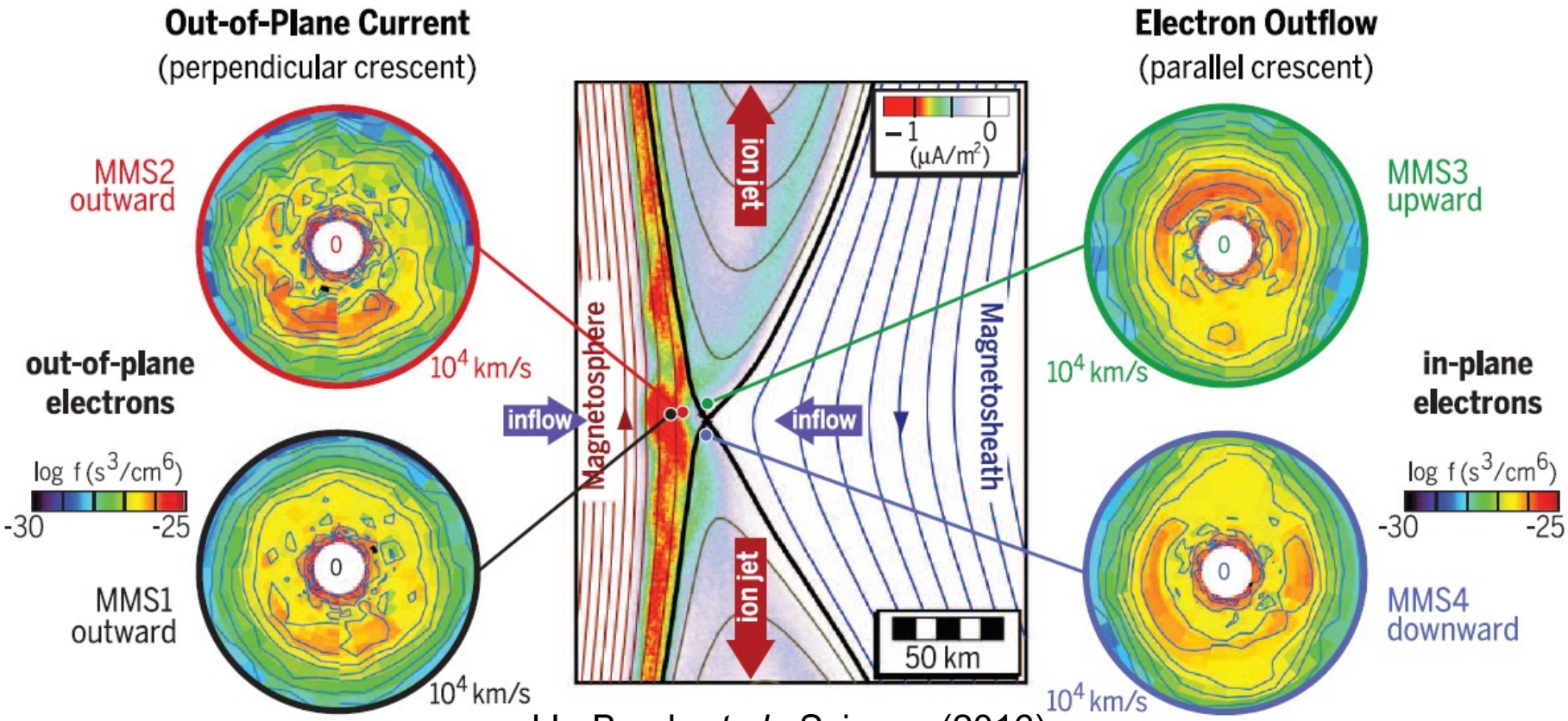
Solar flare



A. O. Benz, Living Rev. Sol. Phys. (2017)

- Microscopic electron-scale governs the onset of magnetic reconnection
- Local observations with MMS revealed electron dynamics for the first time
- No global observations





J.L. Burch *et al.*, Science (2016)

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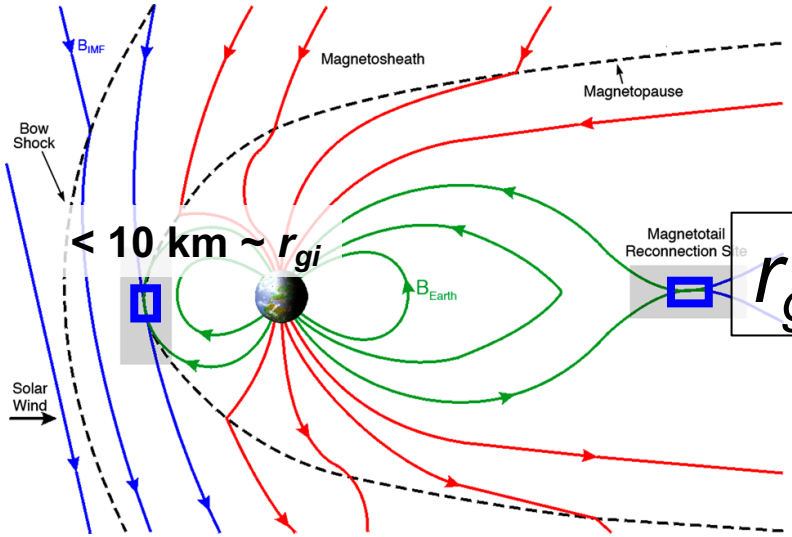

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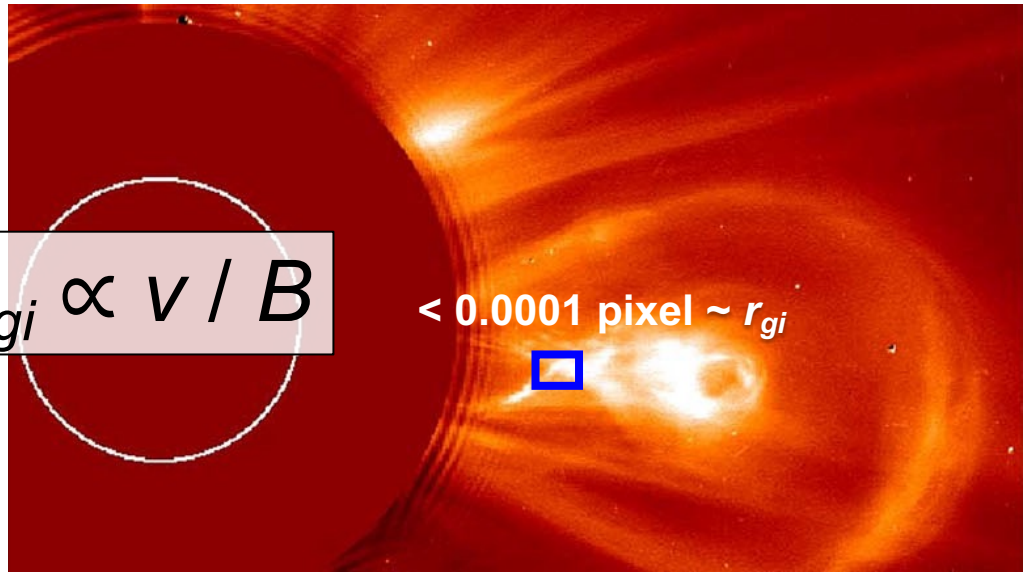

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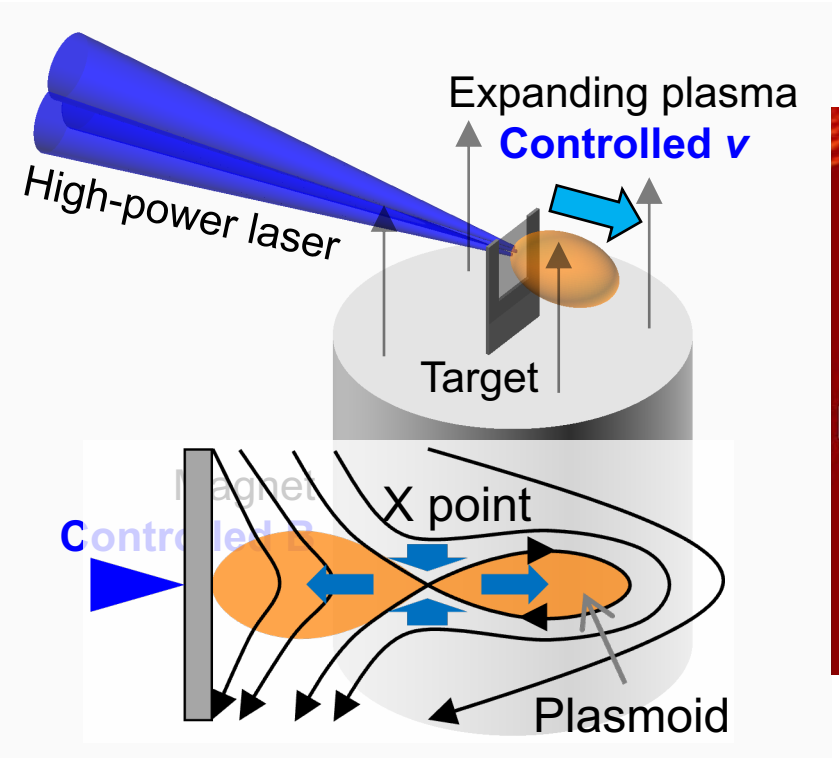
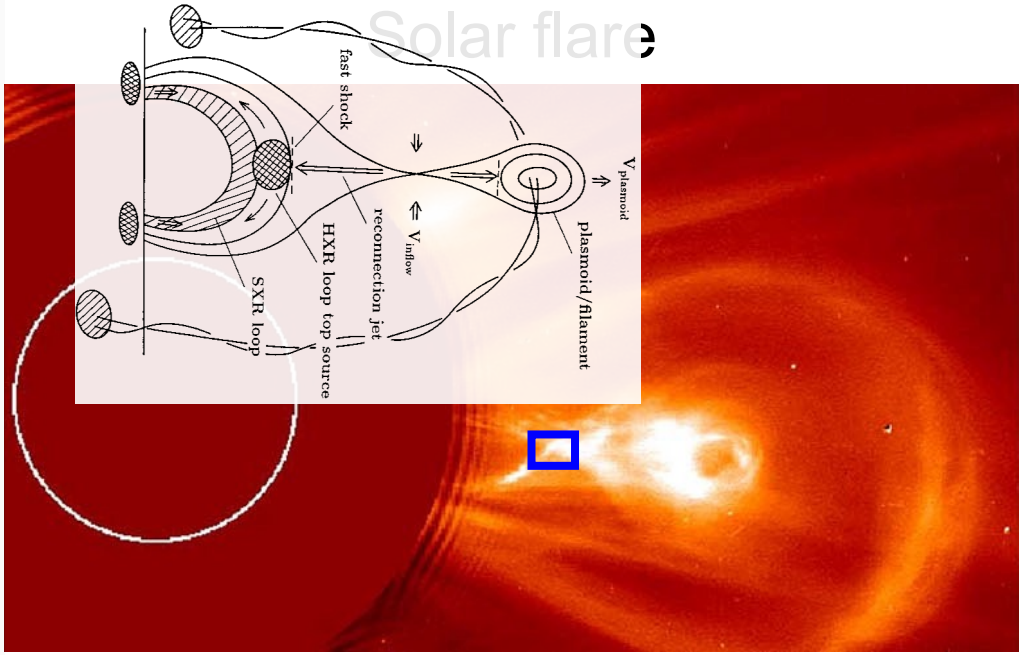


K. Shibata et al., Astrophys. J. (1995)



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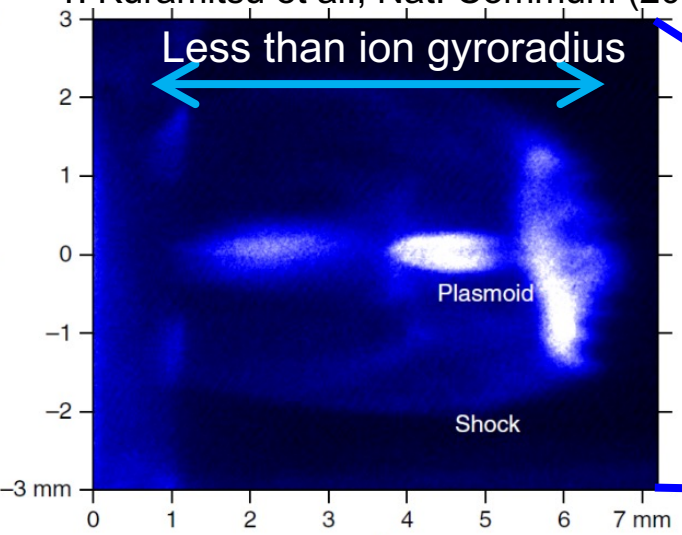
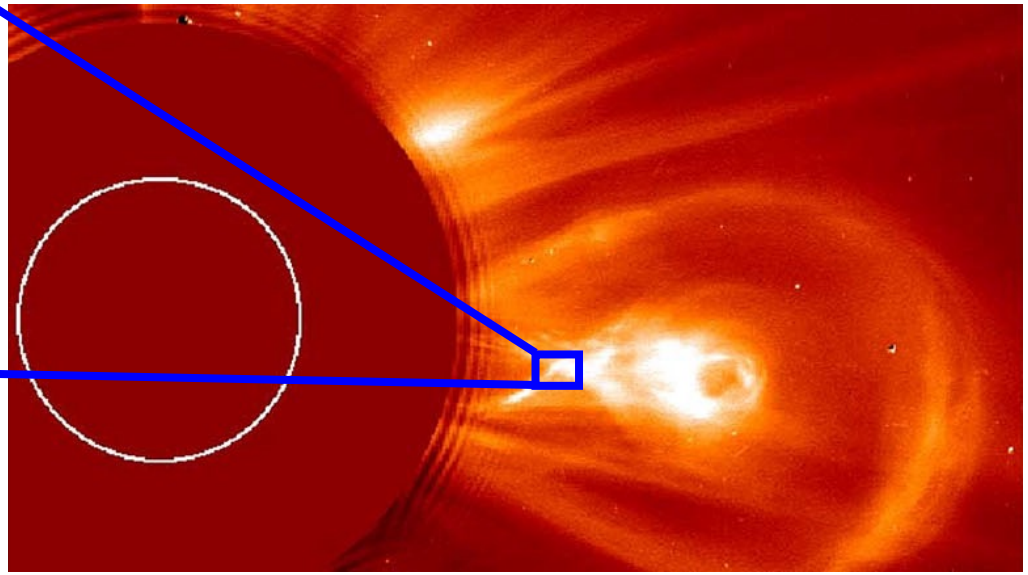
Y. Kuramitsu et al., Nat. Commun. (2018)



Laboratory experiment
Controlled manner
Global structure

Solar flare



A. O. Benz, Living Rev. Sol. Phys. (2017)

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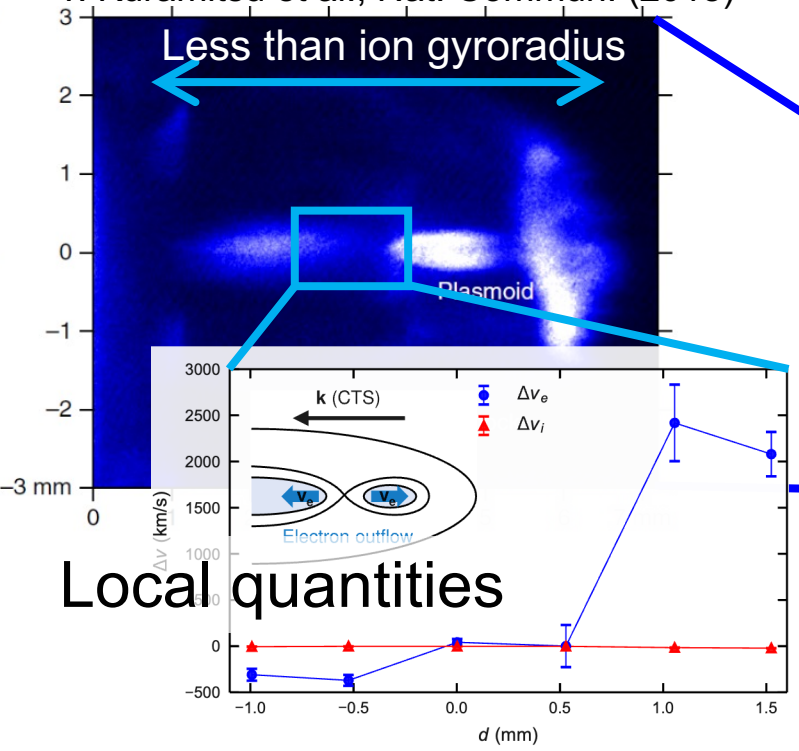
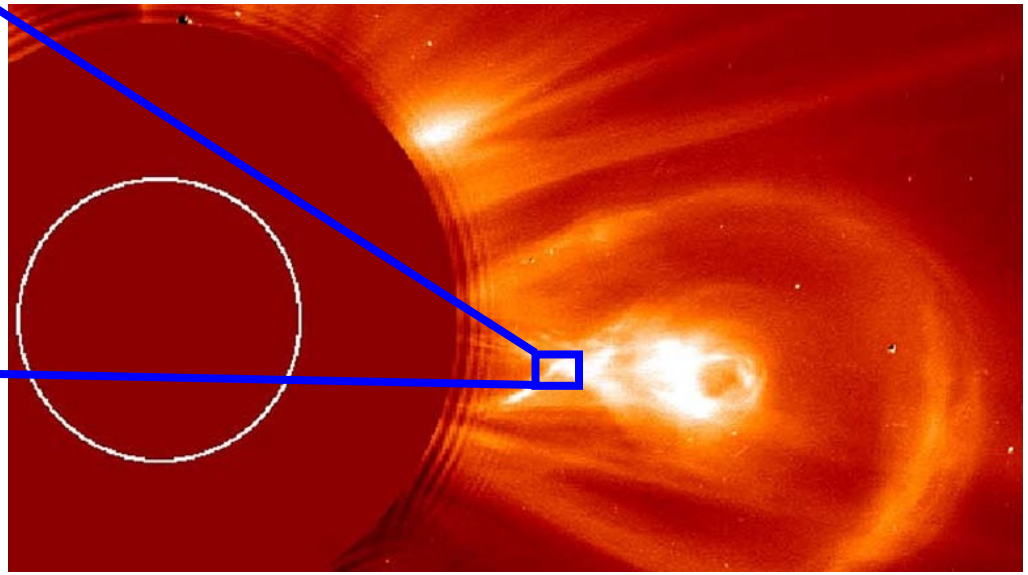


Local quantities

K. Sakai et al., Sci. Rep. (2022)

Solar flare

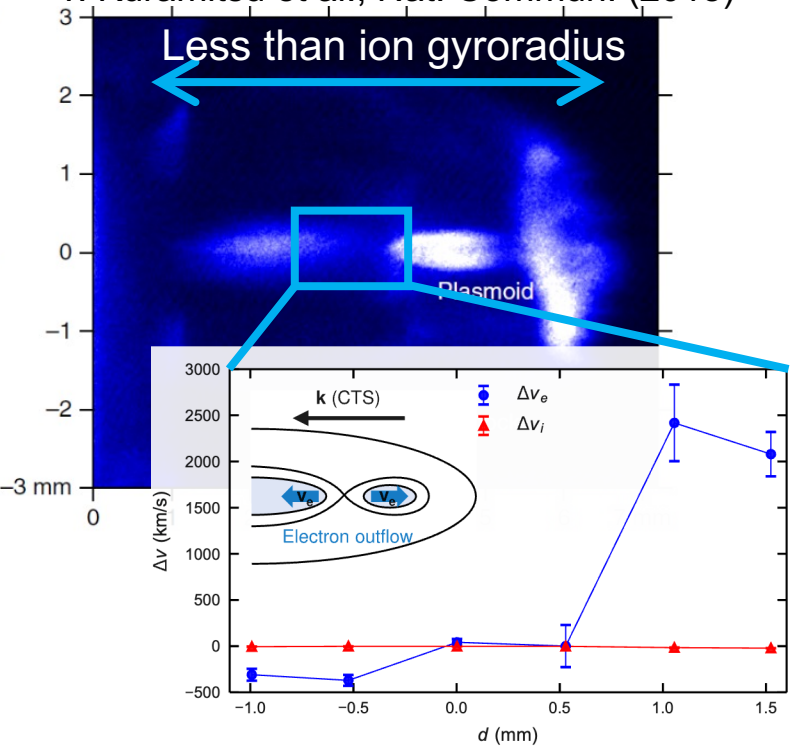


A. O. Benz, Living Rev. Sol. Phys. (2017)

Next step of lab astrophysics

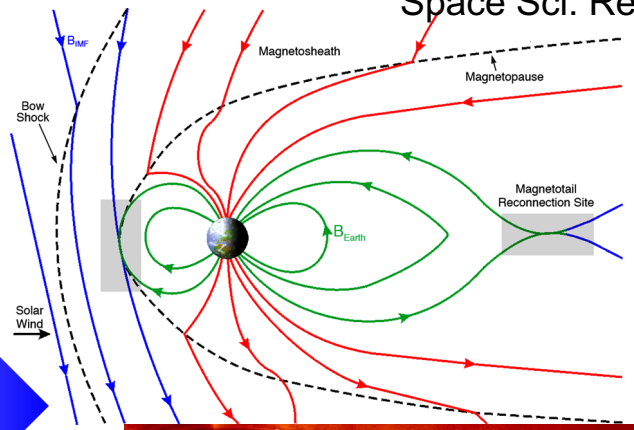
- Multiscale lab astrophysics – microphysics governing macroscopic phenomena
  - Difficult to observe simultaneously in space/astrophysical plasmas

Y. Kuramitsu et al., Nat. Commun. (2018)

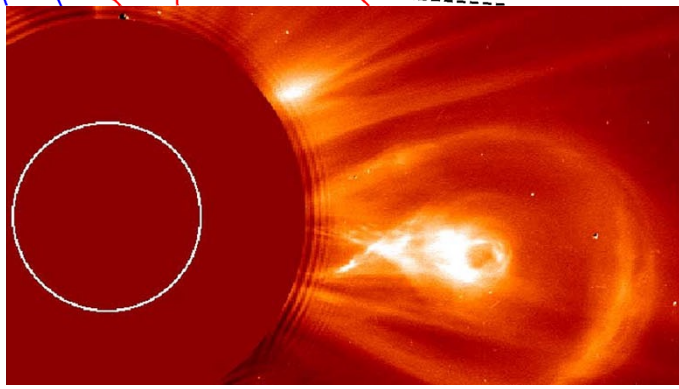


K. Sakai et al., Sci. Rep. (2022)

S.A. Fuselier and W.S. Lewis, Space Sci. Rev. (2011)



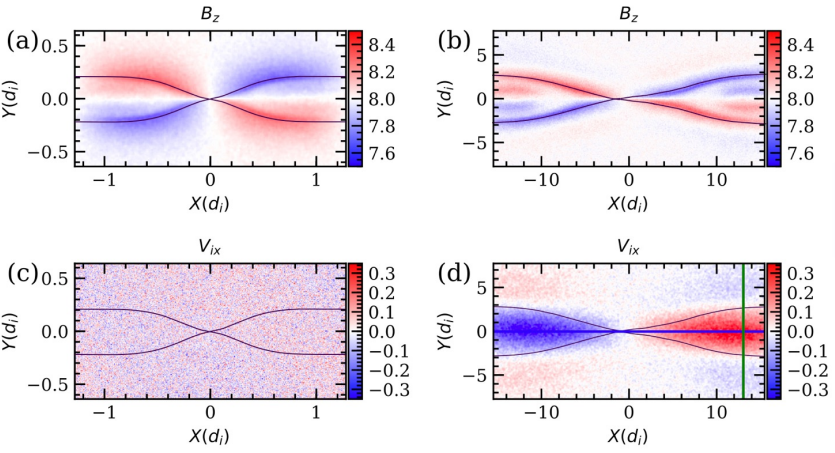
How can the electron-scale structures connect to the MHD structures?



A. O. Benz, Living Rev. Sol. Phys. (2017)

Next step of lab astrophysics

- Multiscale lab astrophysics – microphysics governing macroscopic phenomena
  - Connecting multiscale is also challenging in numerical simulations using the current computer power



Electron-scale reconnection simulation (PIC)
P. S. Pyakurel+ PoP (2019)

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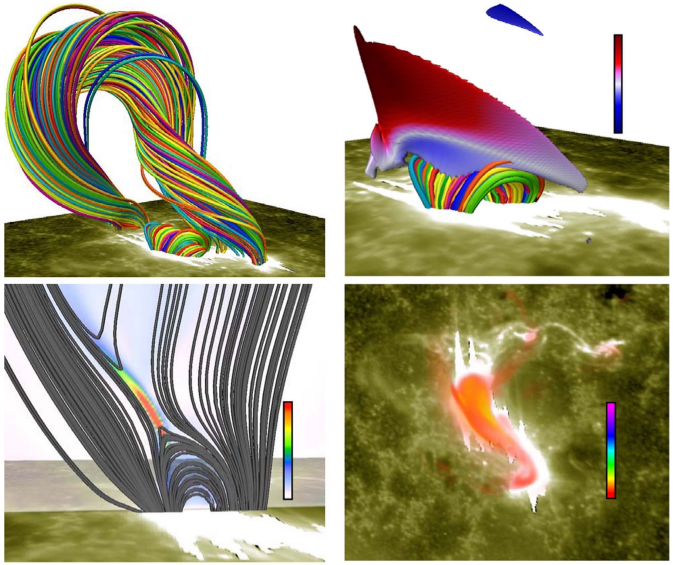
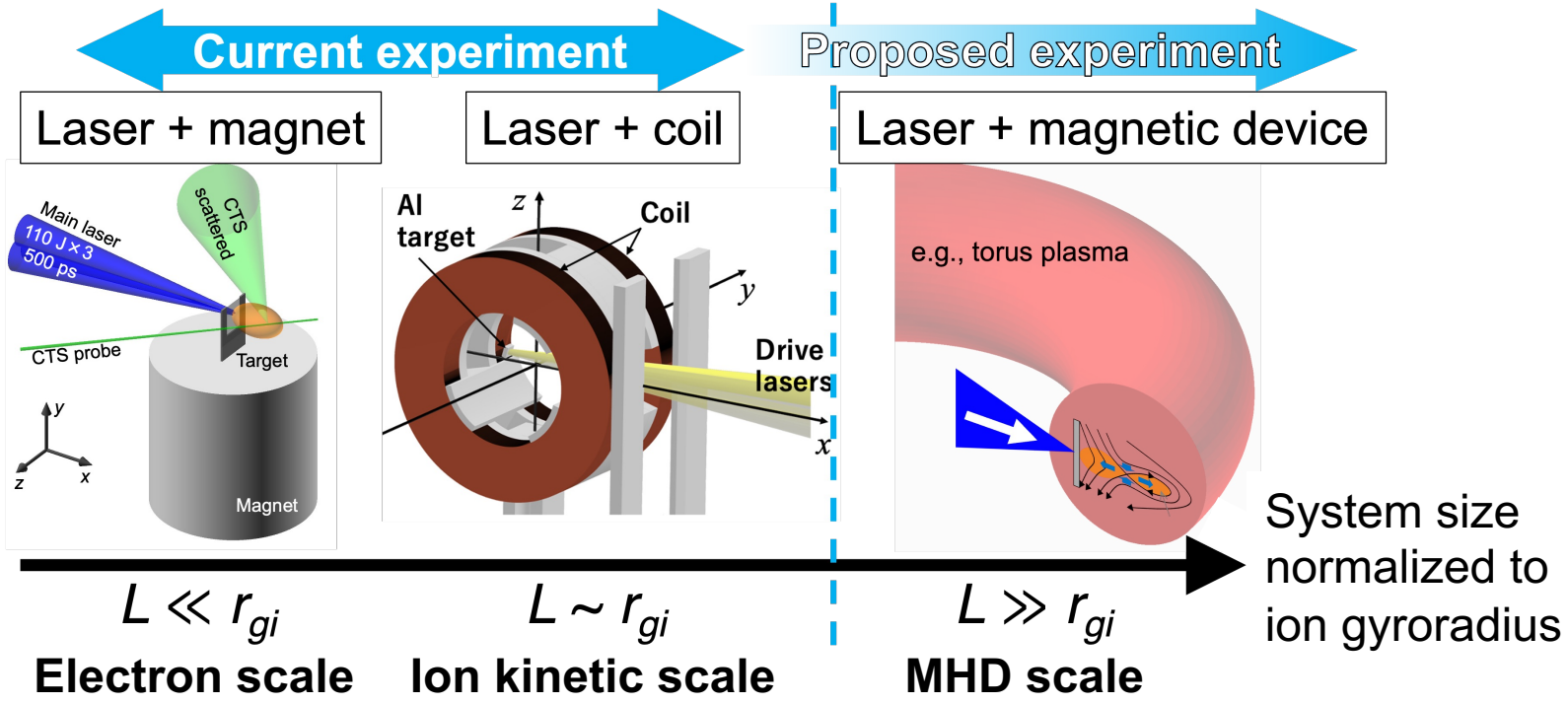


MHD-scale flare simulation
S. Inoue and Y. Bamba, ApJ (2021)

Limits of laser experiment

- Fast plasma flow enlarges gyroradii
- Limit of B field strength (technical problem)
- Lack of large spatial/temporal scales for MHD
- Laser + magnetic device for multiscale experiment



Research targets

- Multiscale structure of magnetic reconnection
- Existence of intermediate shock
- Multidimensional structure of slow bow shock
- Reforming/rippling collisionless shock
- Pickup ions in collisionless shock

Many potential research targets using magnetic device + laser experiment

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