Probing the physics of jet launching and propagation through numerical simulations

Ainara Saiz-Pérez

Christian M. Fromm, Felix Glaser, Raoul Kinadeter, Wladislaw Schulga, Eric Nanowsky, Florian Maul, Luca Ricci

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Overview and Scales

Horizon Scale < 1000r_g

BH accretion & jet launching

Propagation Scale > 10000r_g

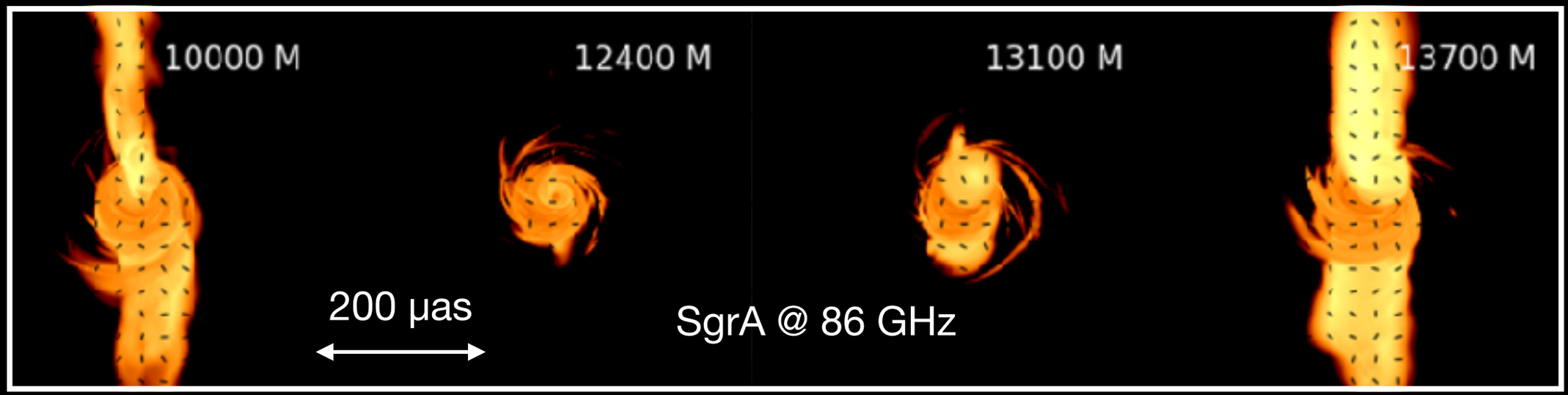
KH & RT Instabilities

Acceleration Scale < 10000r_g

Jet acceleration & CD Instabilities

3D GRMHD & Rendering: C. M. Fromm

Black Hole Accretion and Flares



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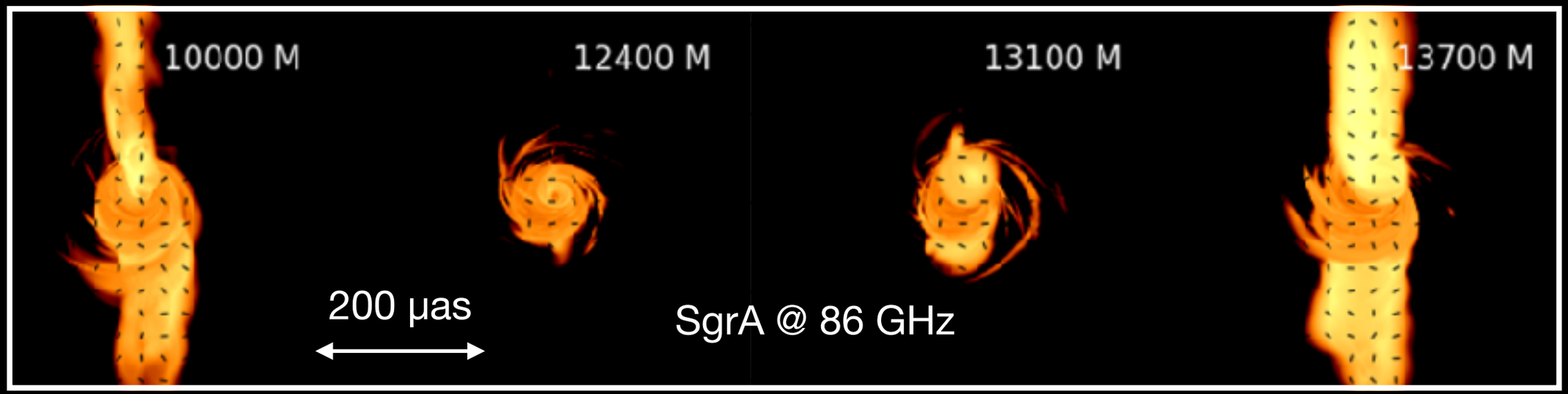
Black Hole Accretion and Flares

Transient jets during accretion of mag. loops with alternating polarity



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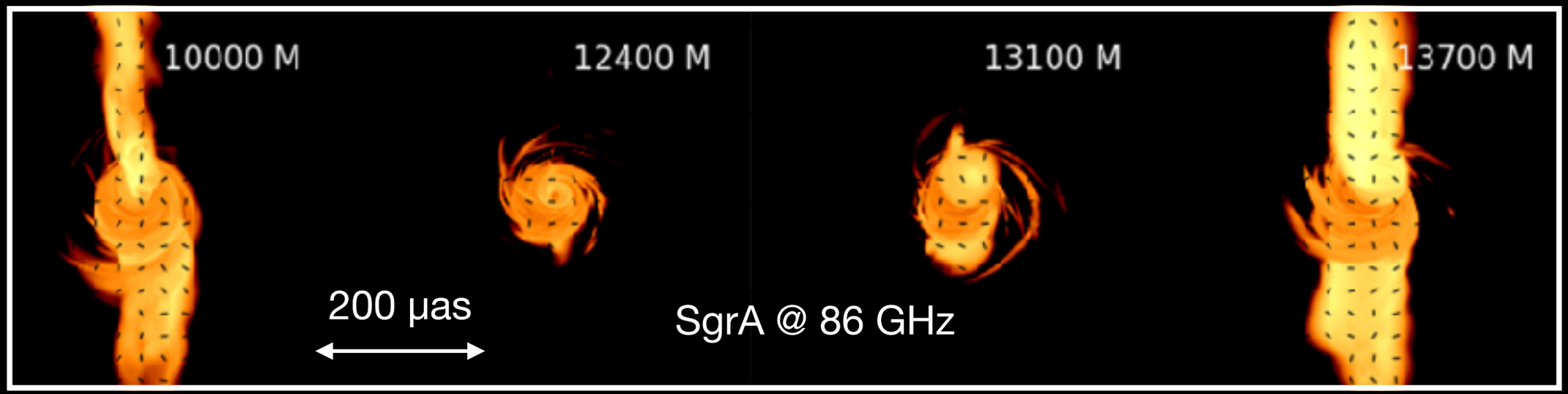

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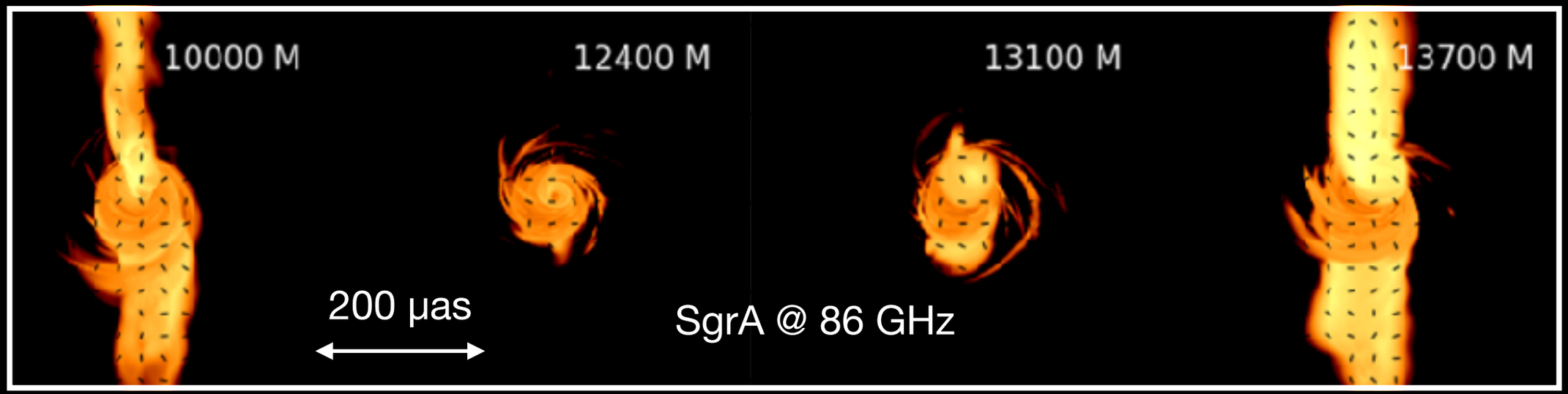
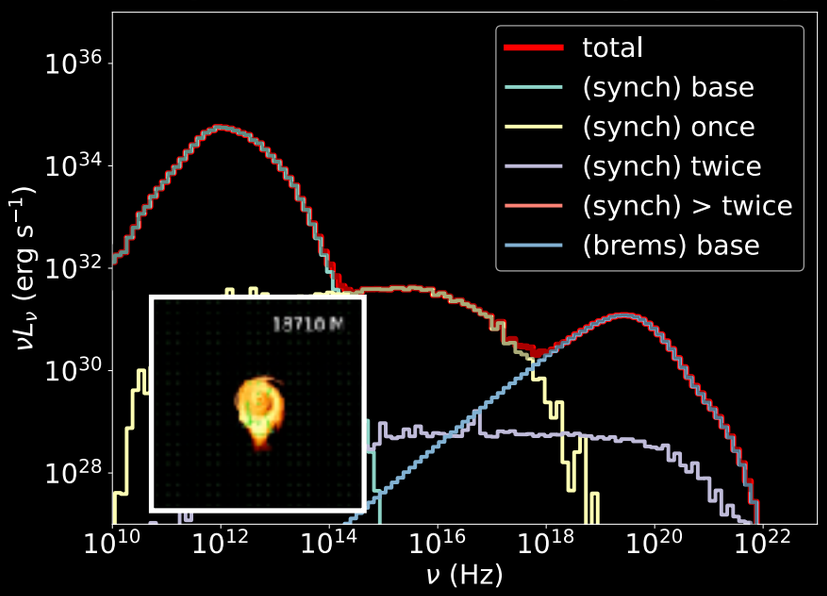


quiescent state (no jet)



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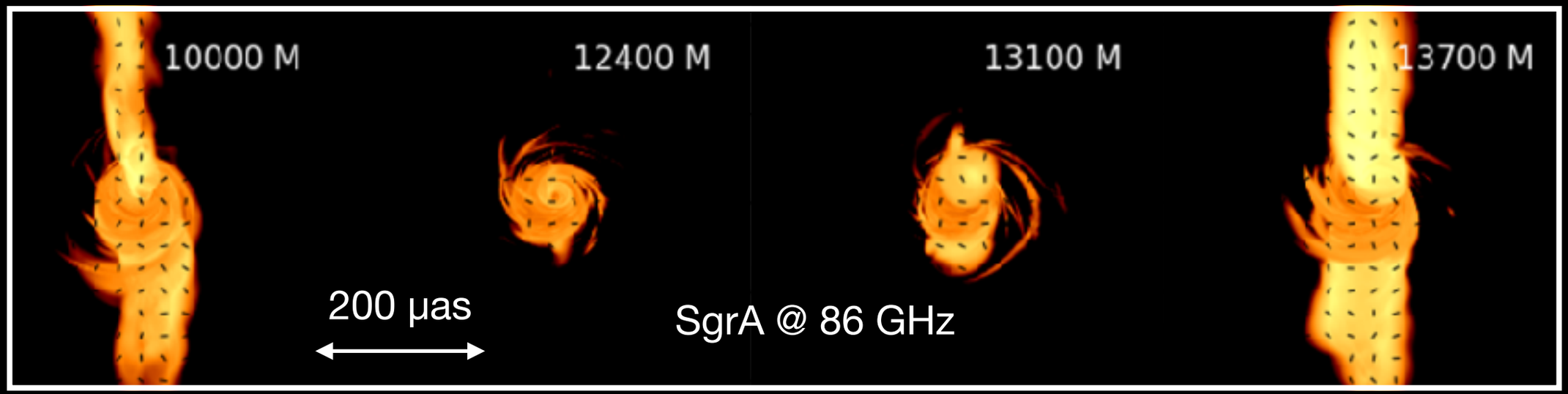

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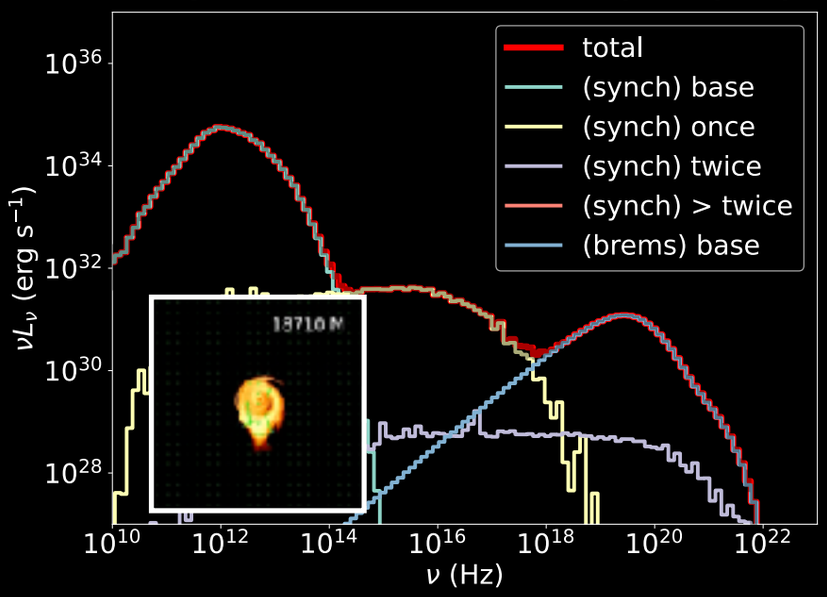
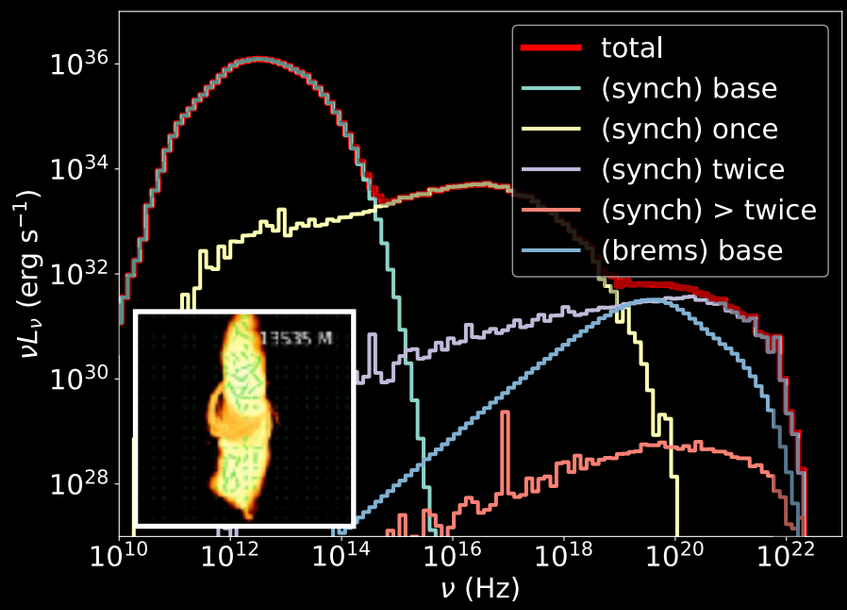


active state (strong jet)



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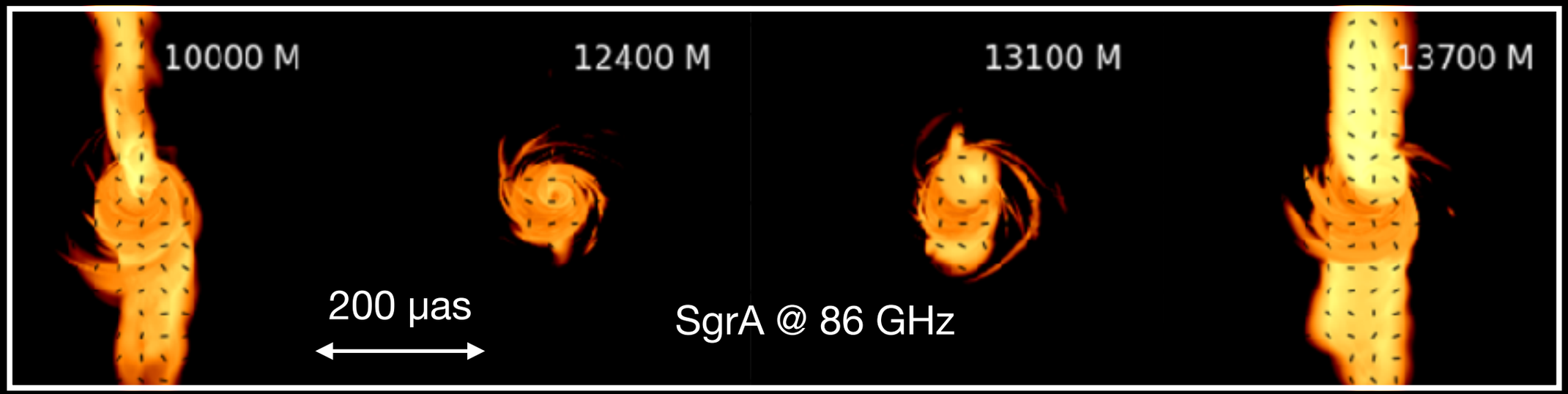

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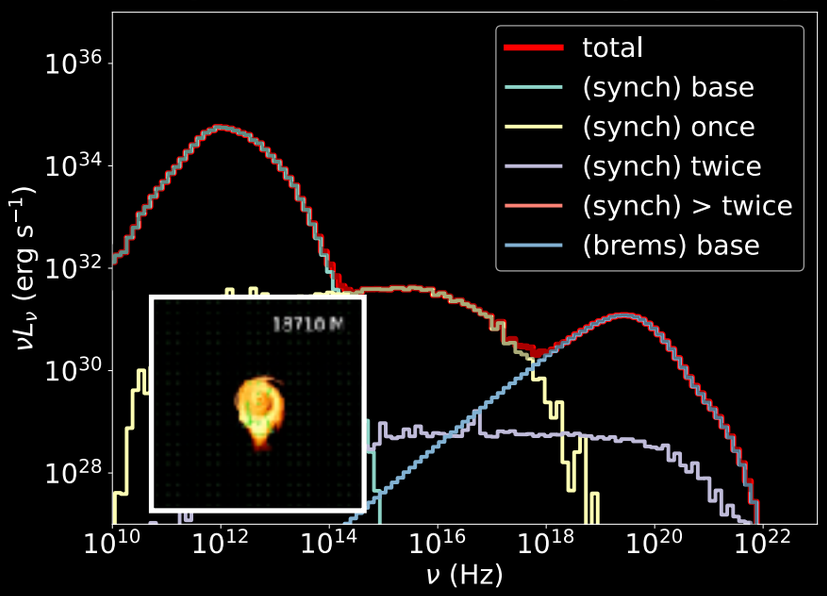

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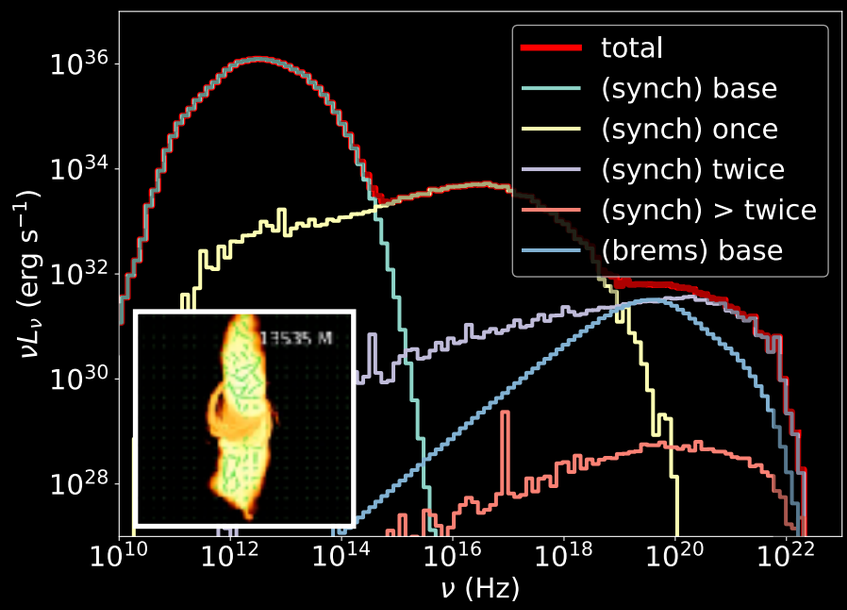

—> jet formation/propagation connect to high-energy flares

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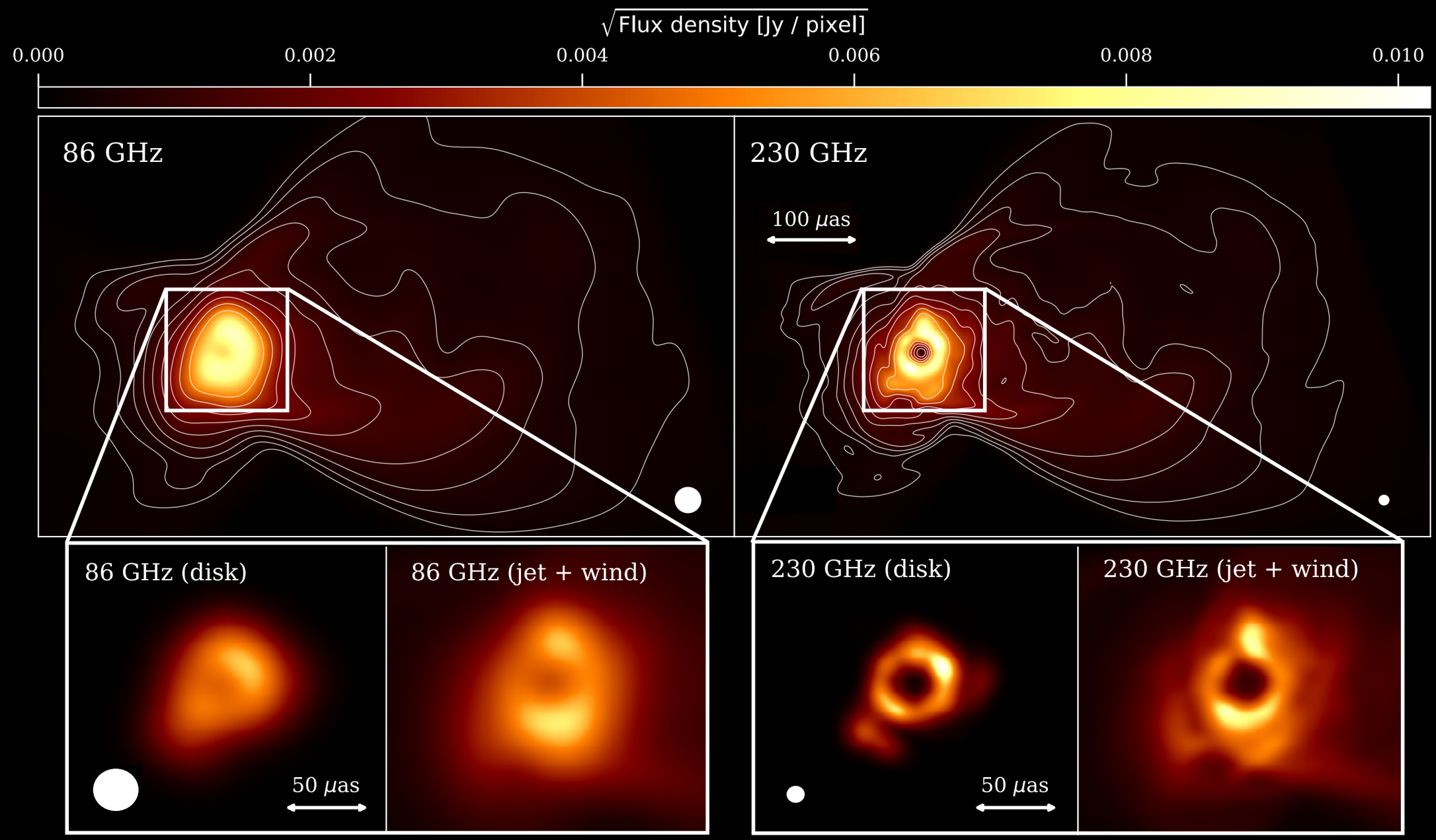
Jet-Disk Coupling

Modelling the observed ring size of M87 at different mm frequencies



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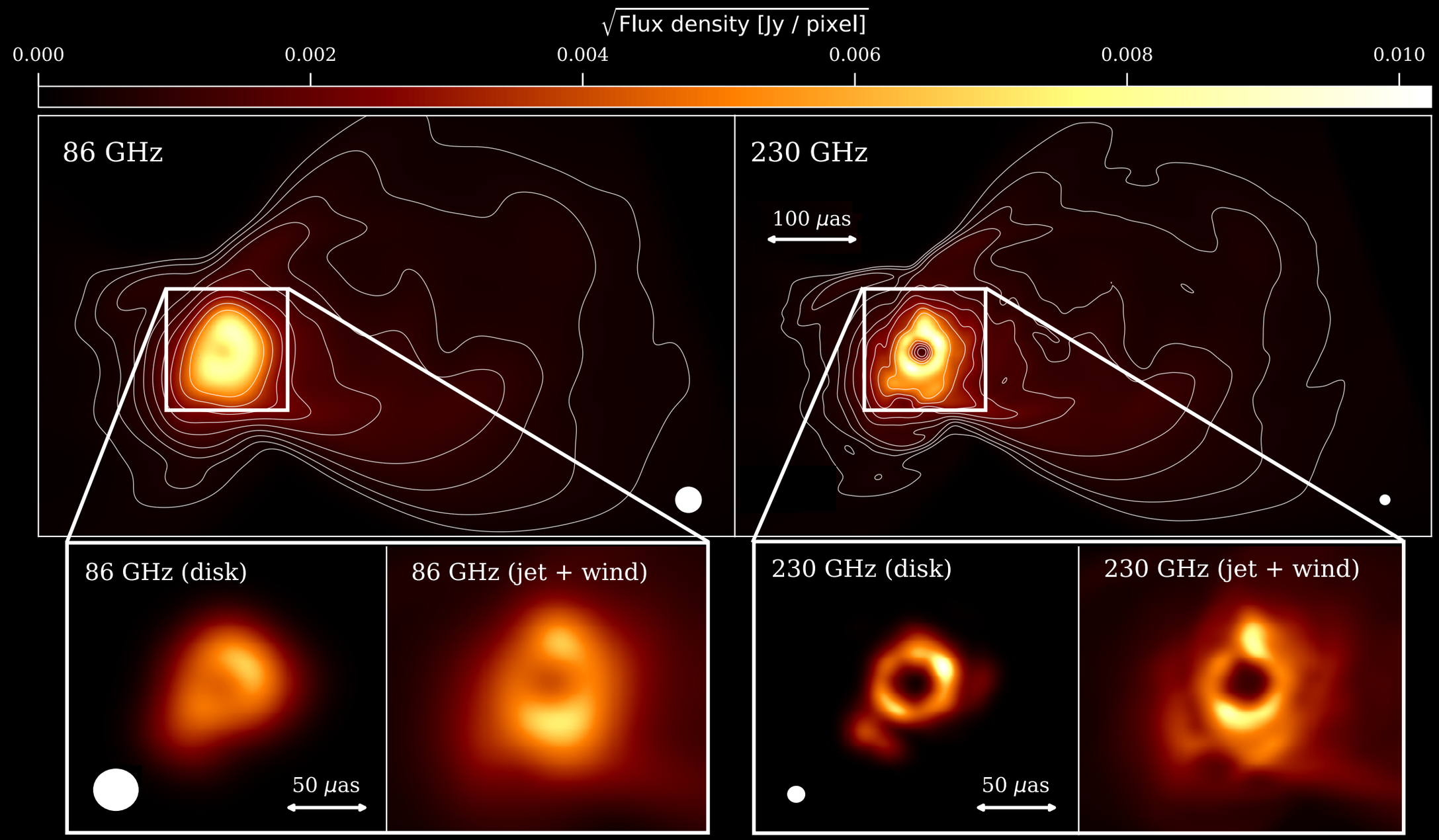
Jet-Disk Coupling

Modelling the observed ring size of M87 at different mm frequencies

—> role of non-thermal emission (electron acceleration)



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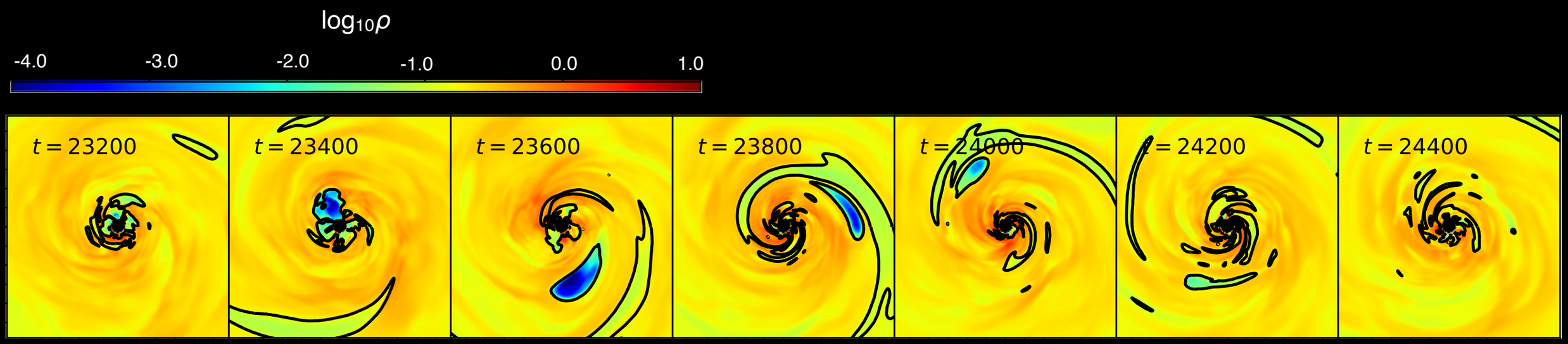

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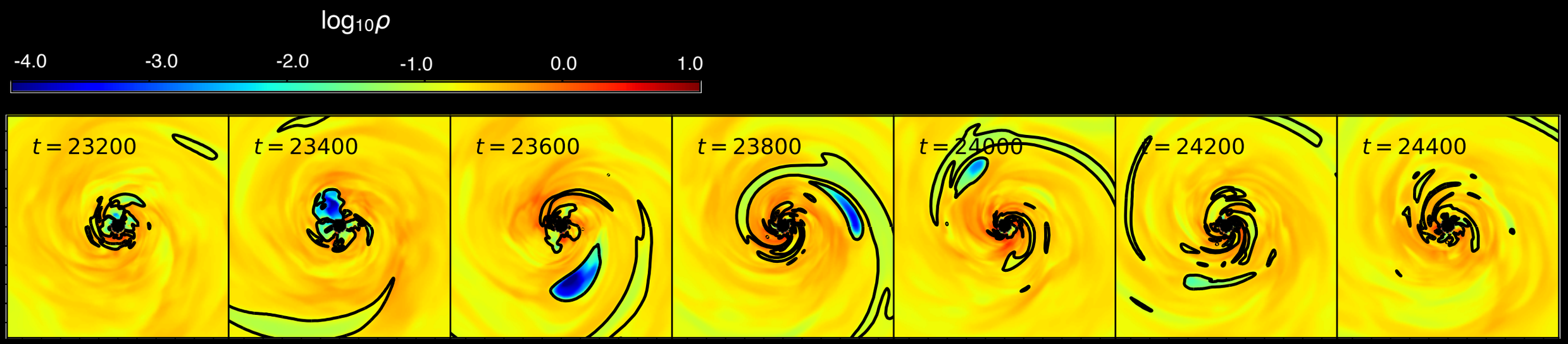

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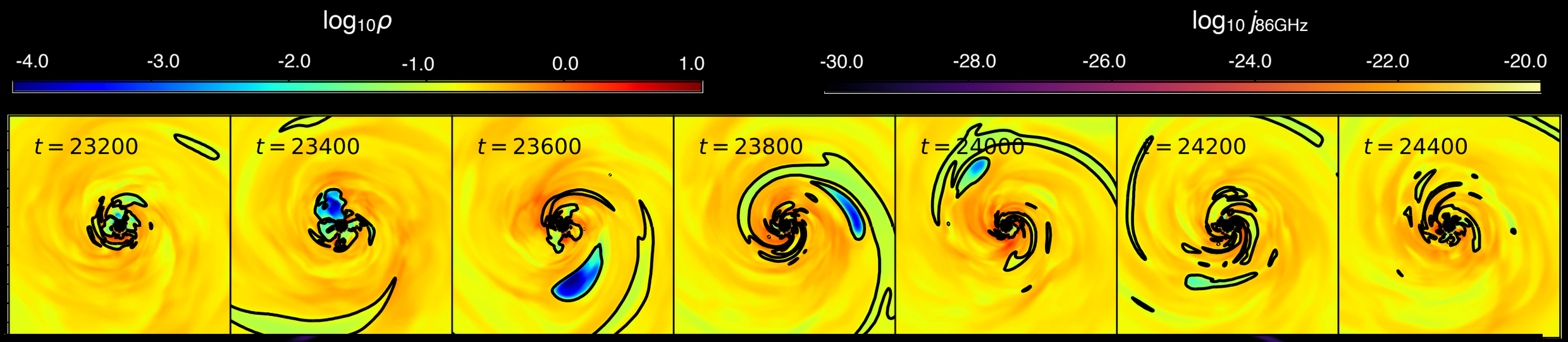

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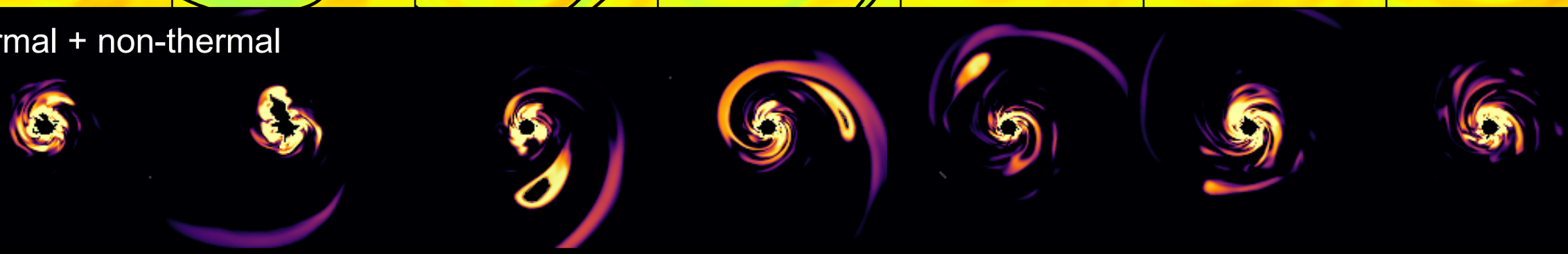

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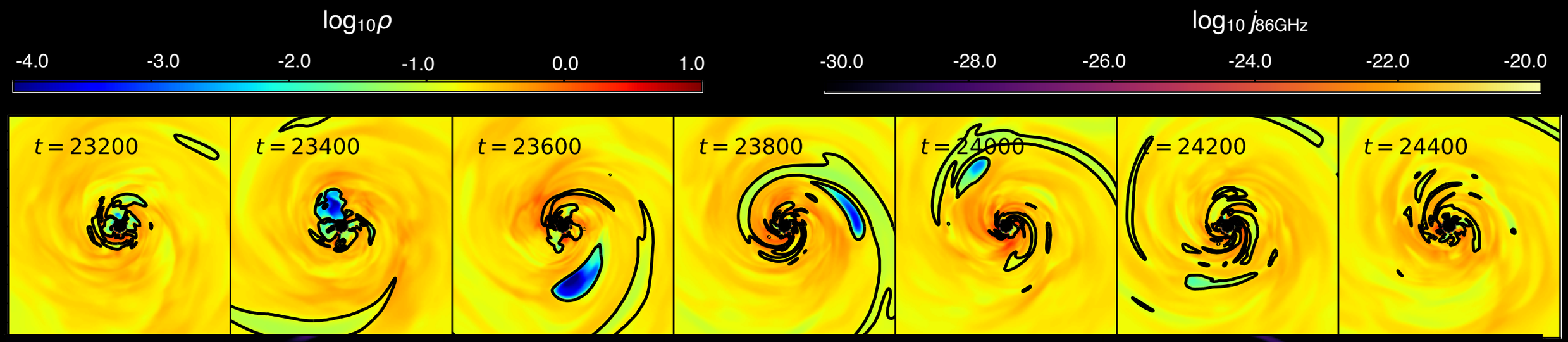
Jet-Disk Coupling

Modelling the observed ring size of M87 at different mm frequencies

—> role of MAD flares (ejection of material)

—> better understanding of the physical parameters of M87 (spin, etc)



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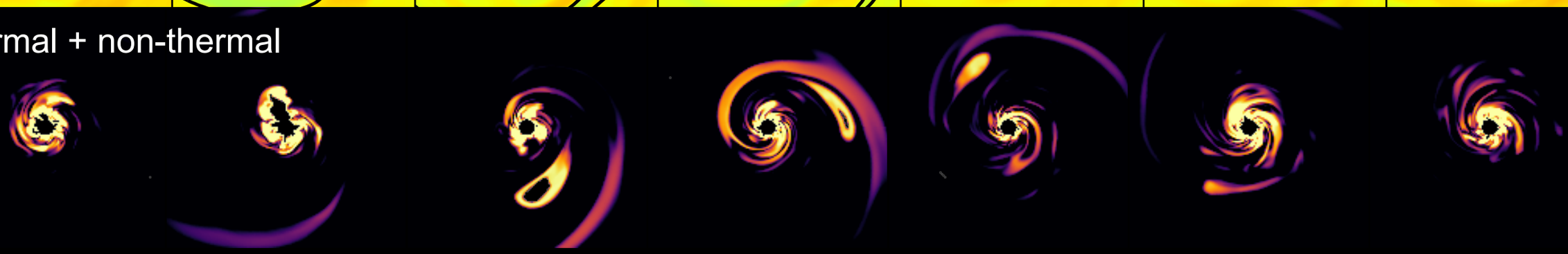

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Radiation Microphysics and PIC simulations

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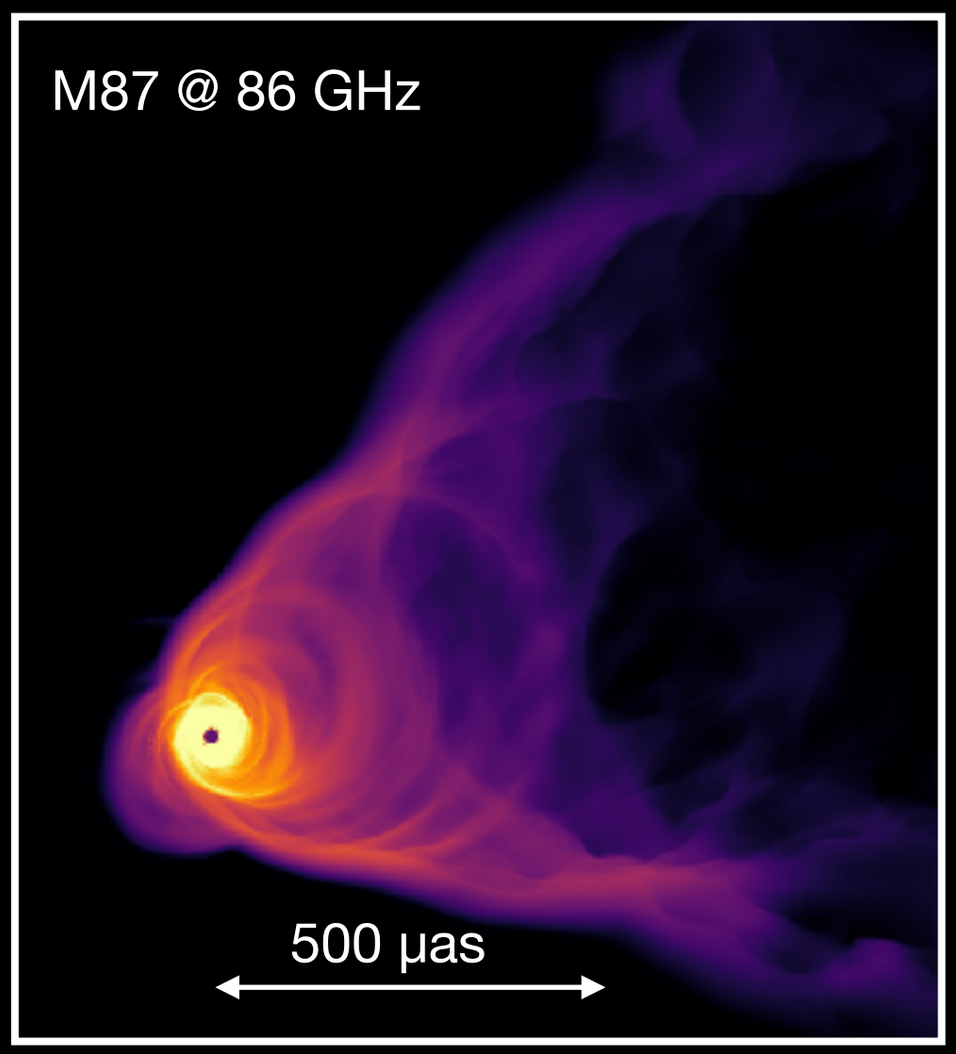

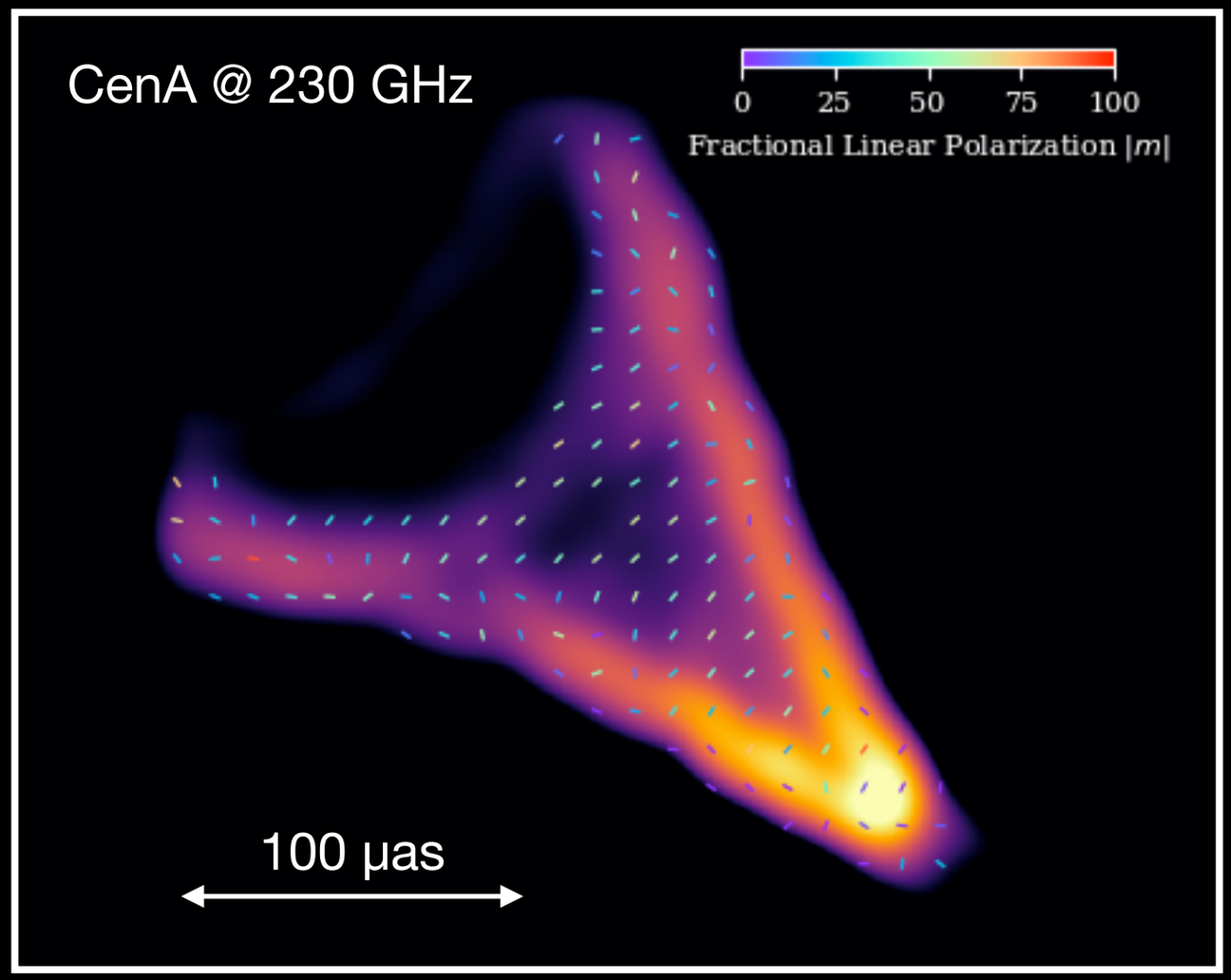

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Radiation Microphysics and PIC simulations

mag. reconnection leads to anisotropic distribution of emitting particles

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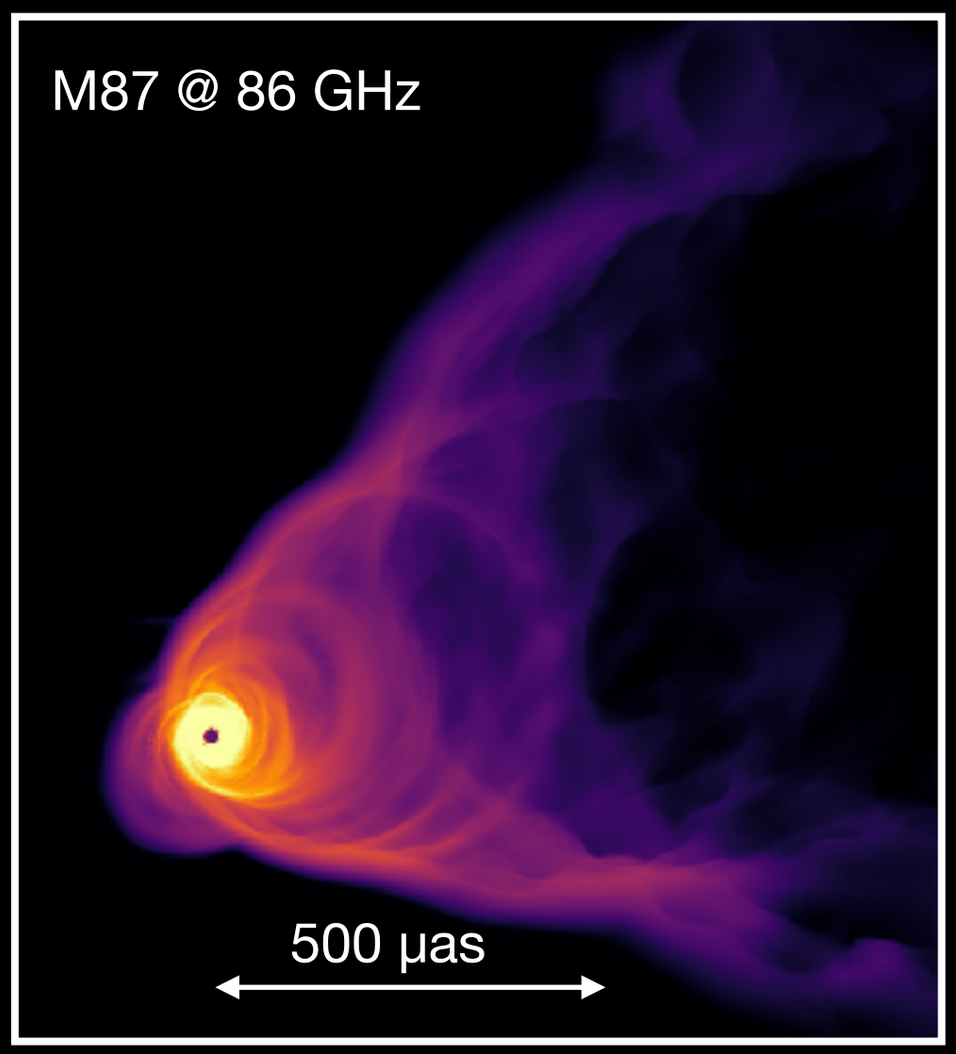

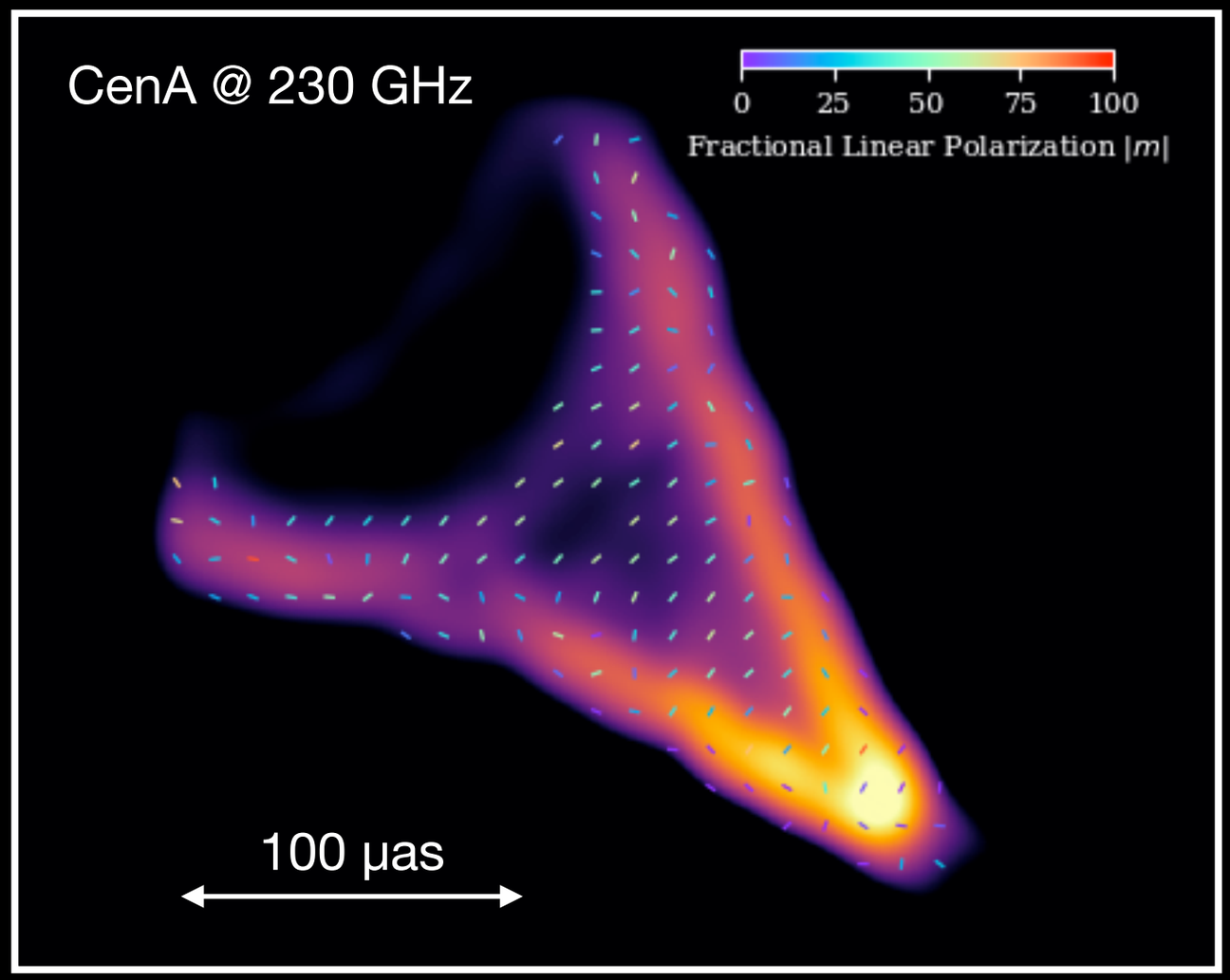

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Radiation Microphysics and PIC simulations

mag. reconnection leads to anisotropic distribution of emitting particles

—> strong edge-brightening of jets and “empty” jet spines

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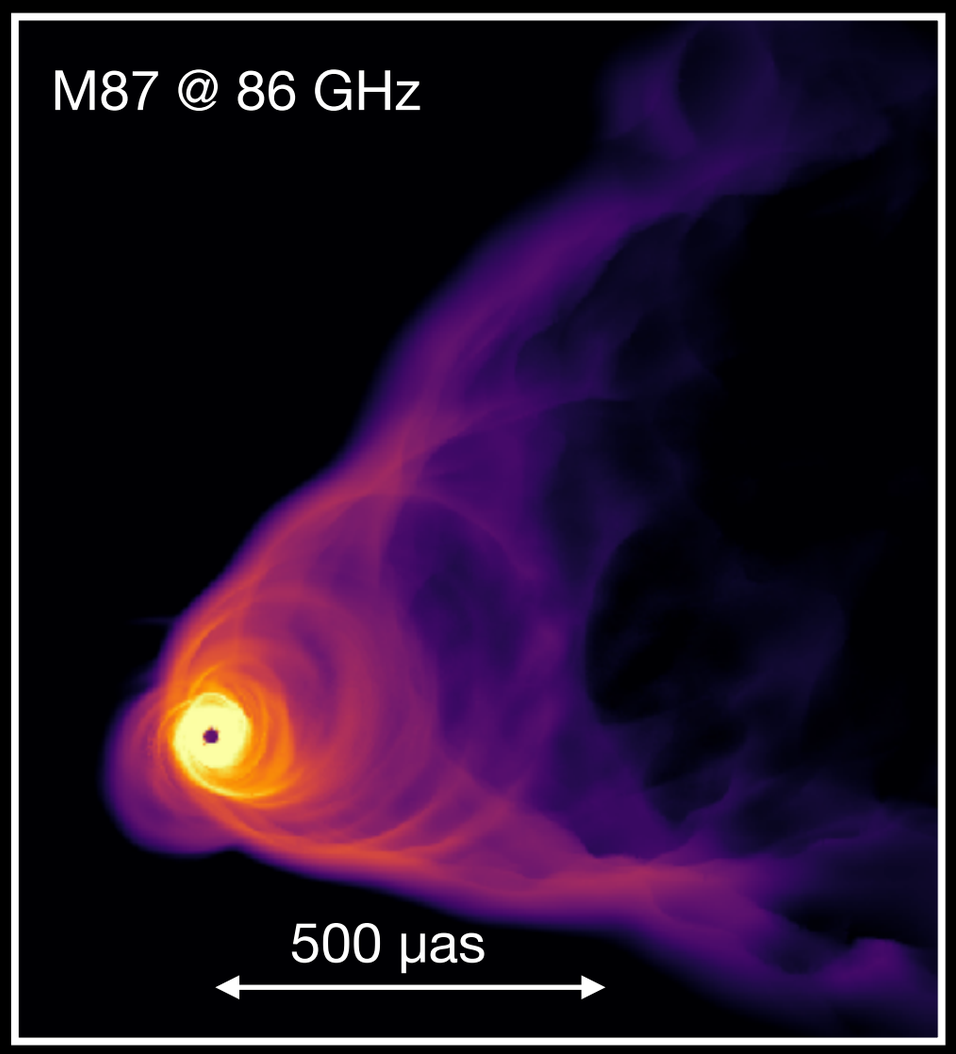

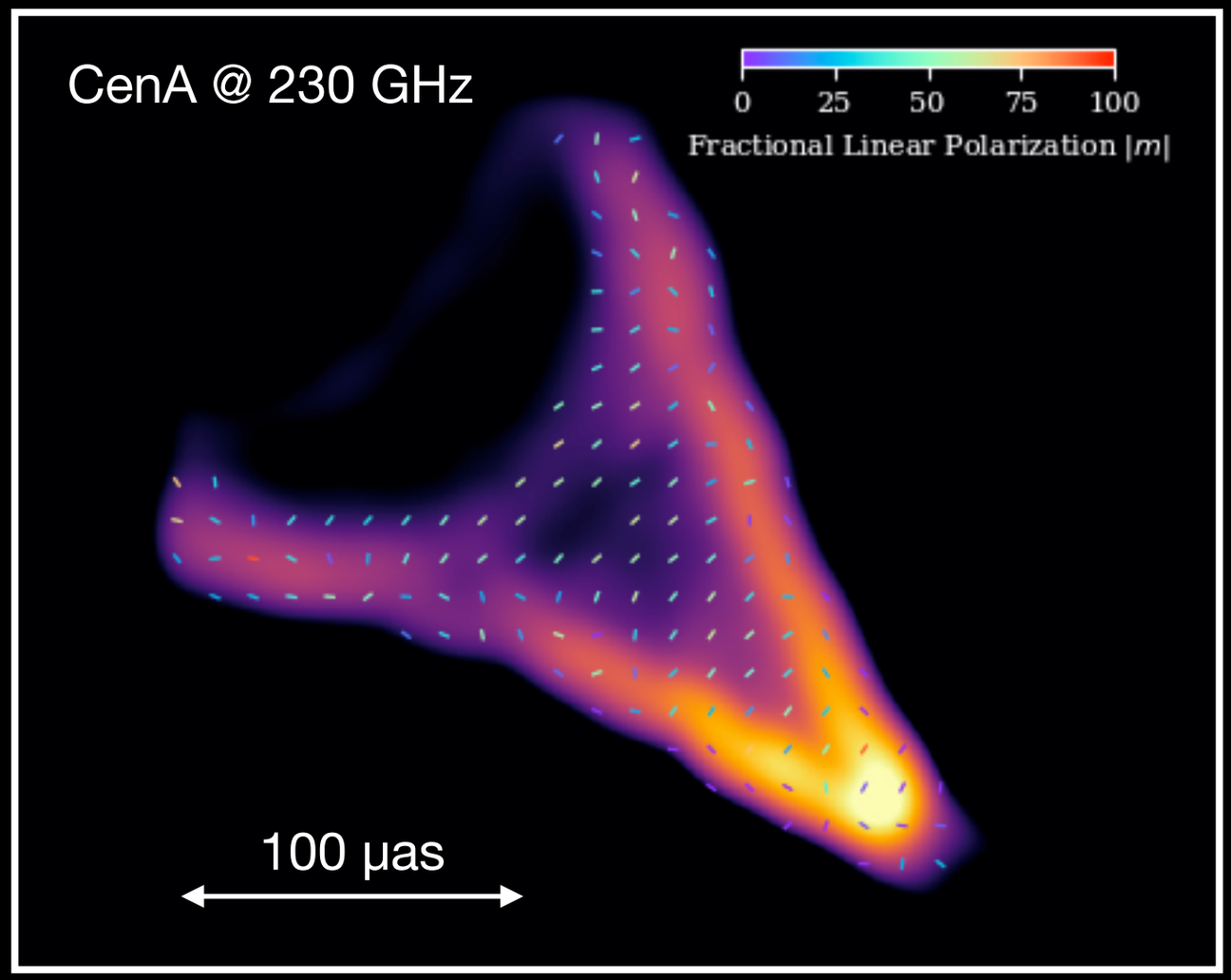

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Large-Scale Jets and Instabilities

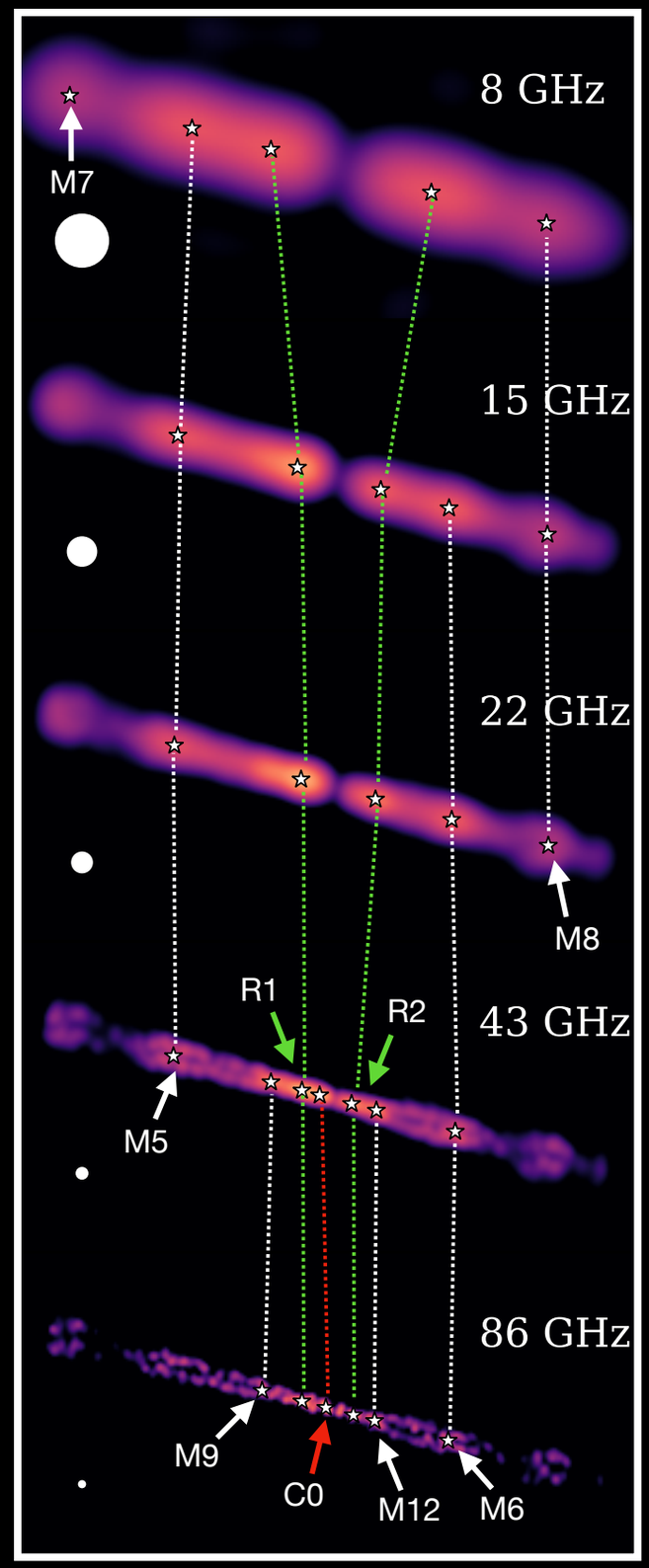
Ref: Saiz-Perez, Fromm et al. 2024, Schulga MSc thesis 2025 Hu, Mizuno & Fromm 2025

Large-Scale Jets and Instabilities

- **Jet asymmetry (>1000r_g)**

  Developed End-to-End pipeline

  Propagation of perturbations



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Large-Scale Jets and Instabilities

- **Jet asymmetry (>1000r_g)**

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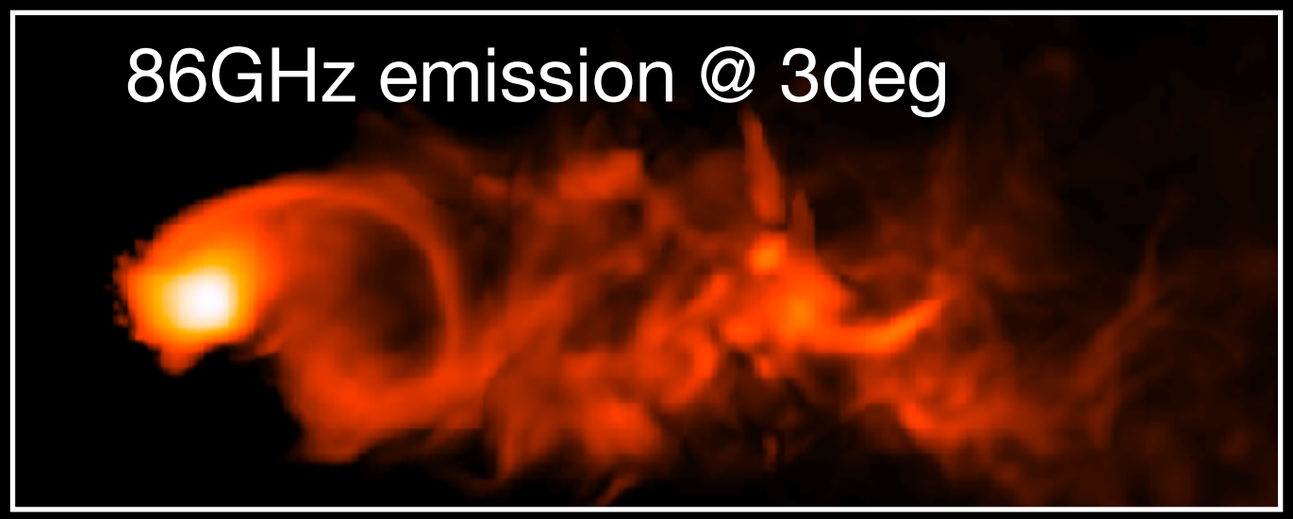
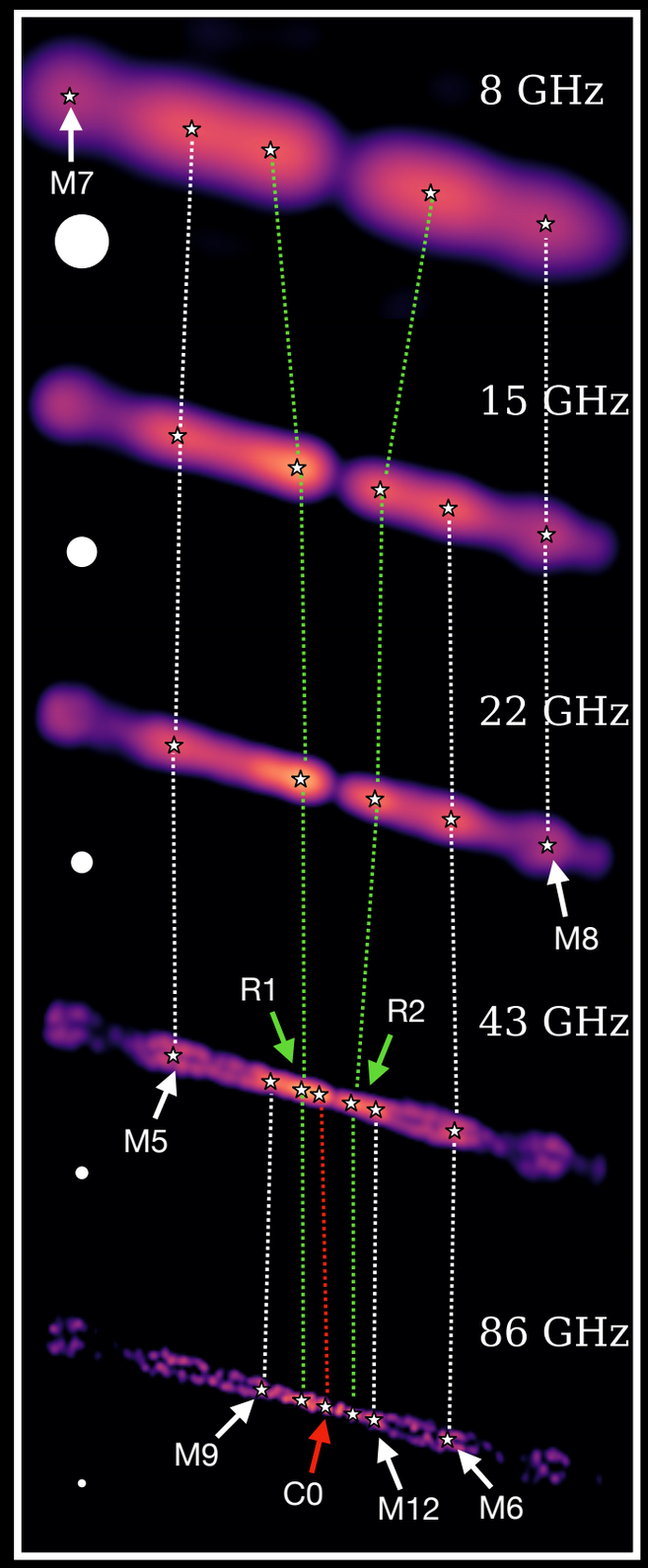
- **Jet asymmetry in 3D (>1000r_g)**

  3D library of jet propagation
  —> KH, RT, Richtmyer-Meshkov, Kink





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Include finite (global) resistivity

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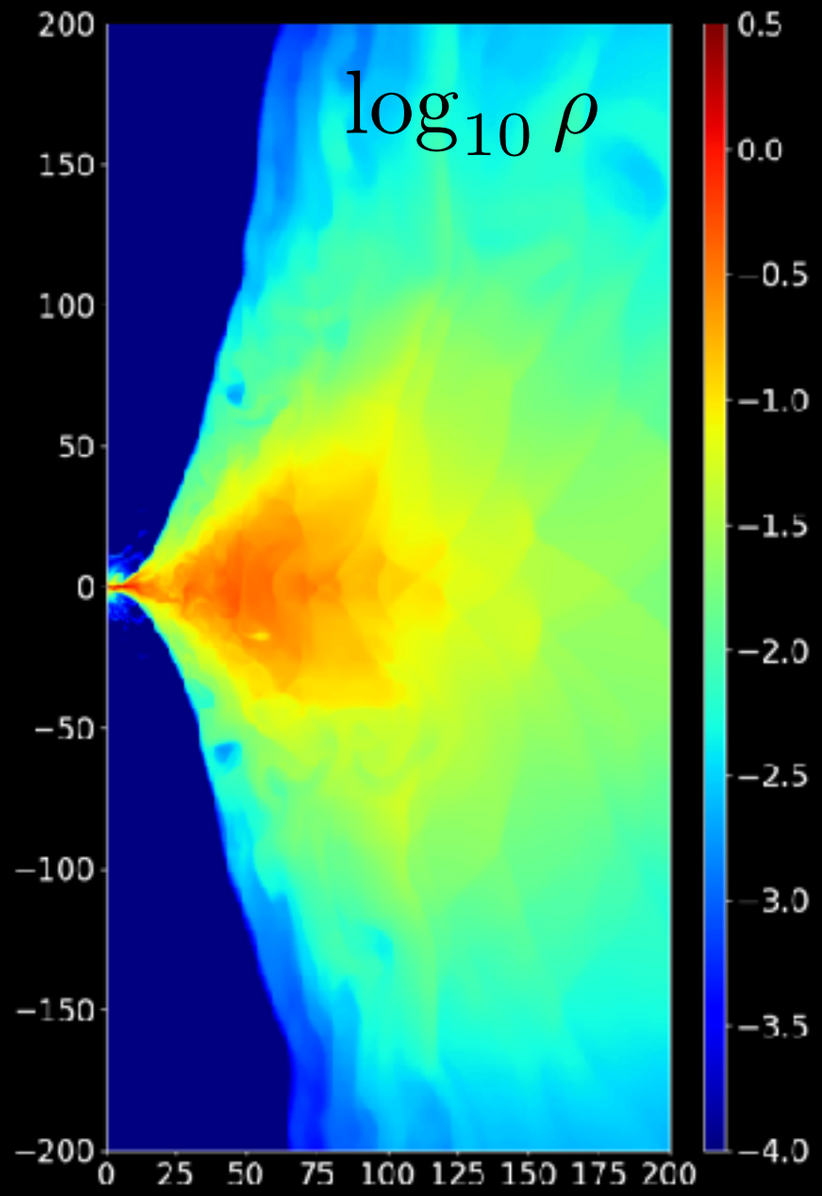

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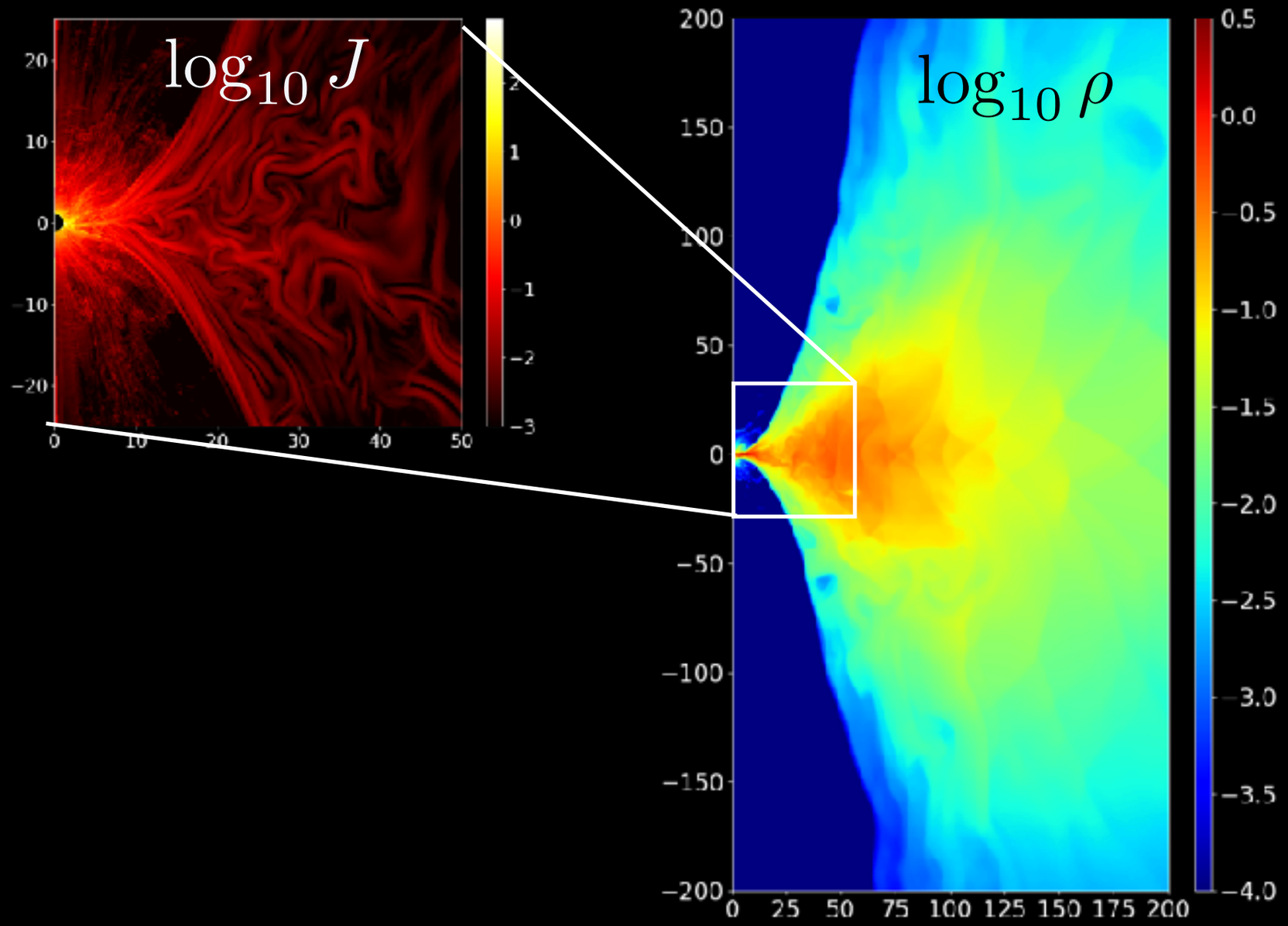

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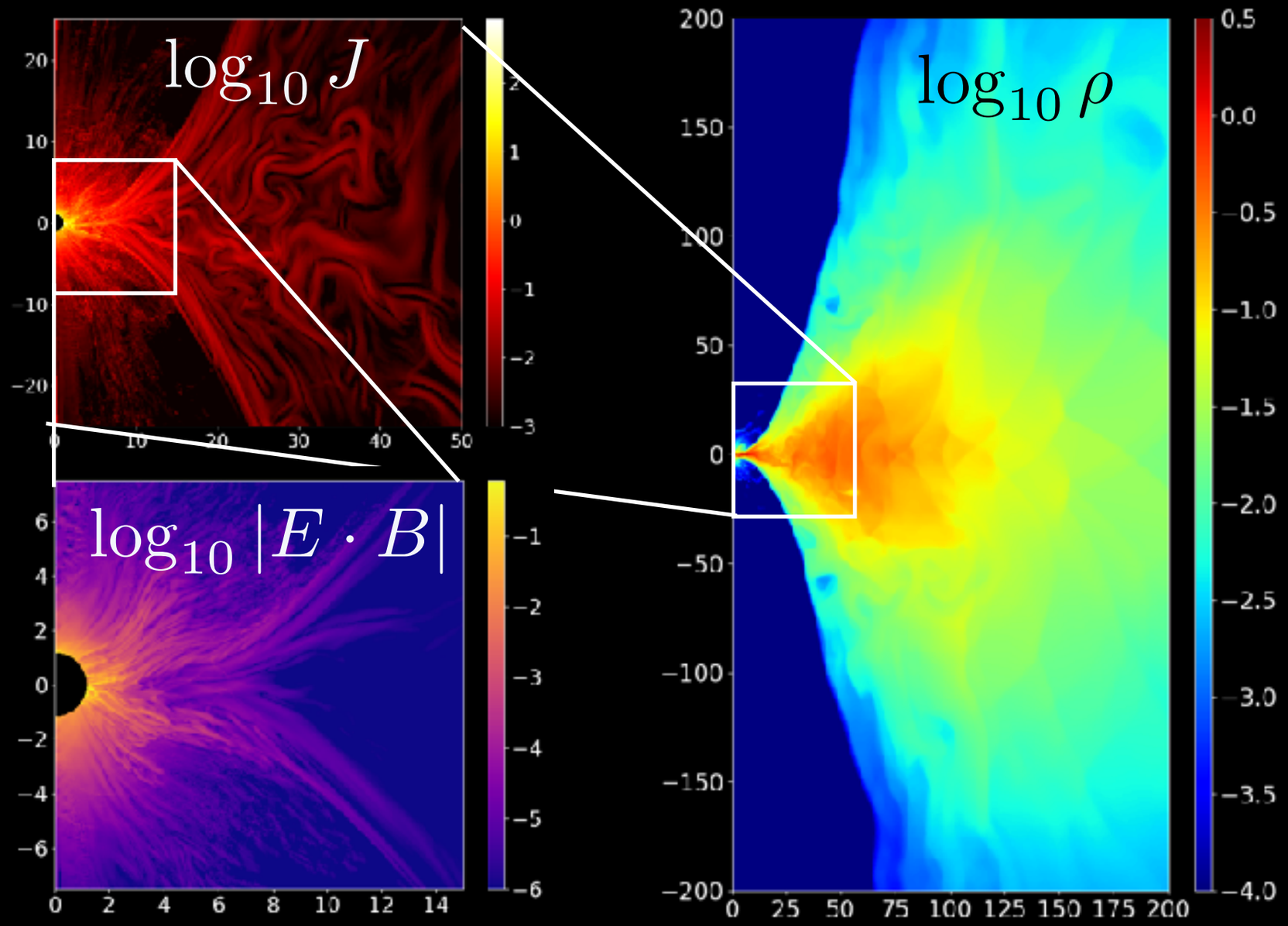

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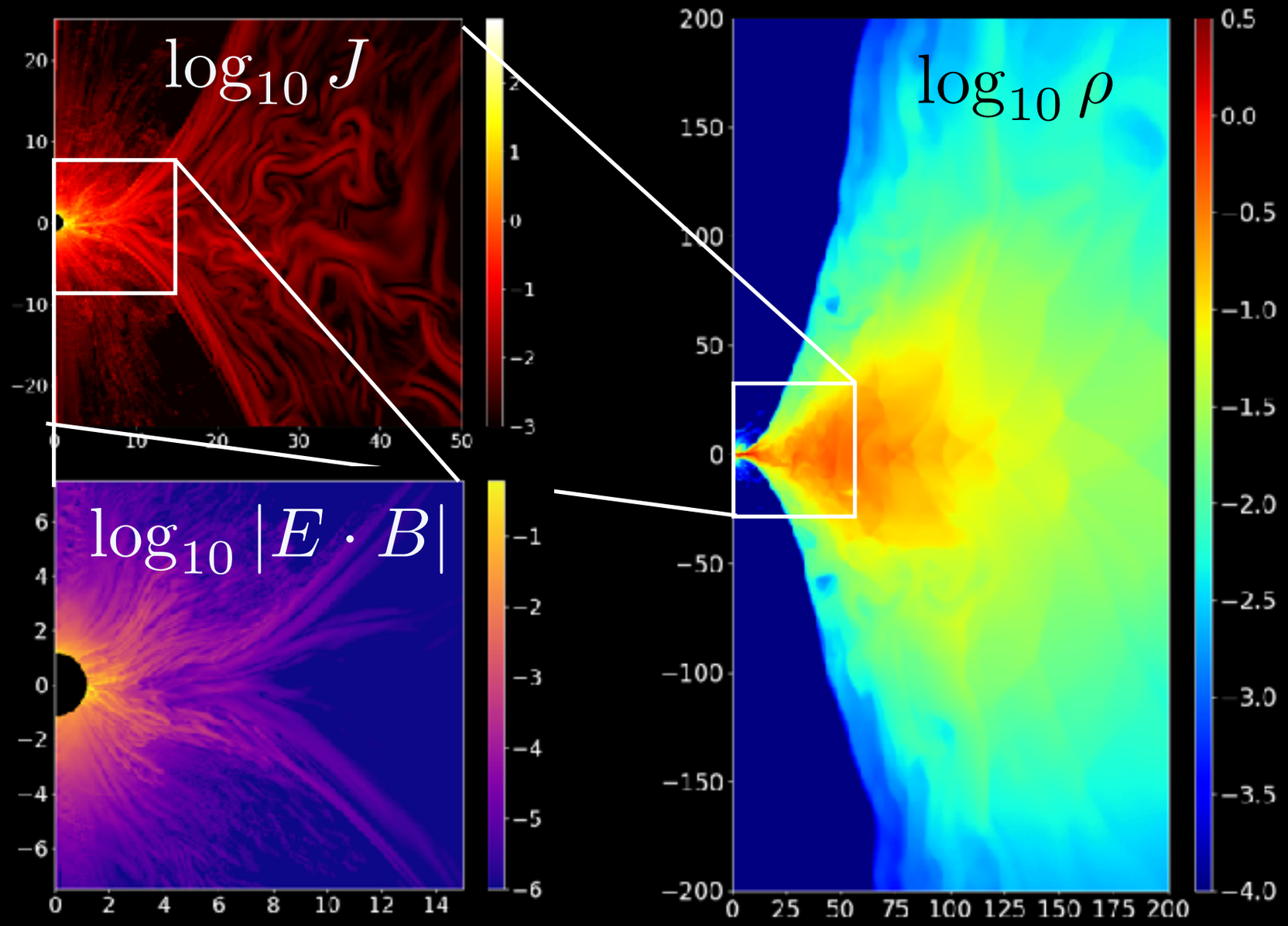

—> formation of current sheets, plasmoids, strong winds —>still MAD?

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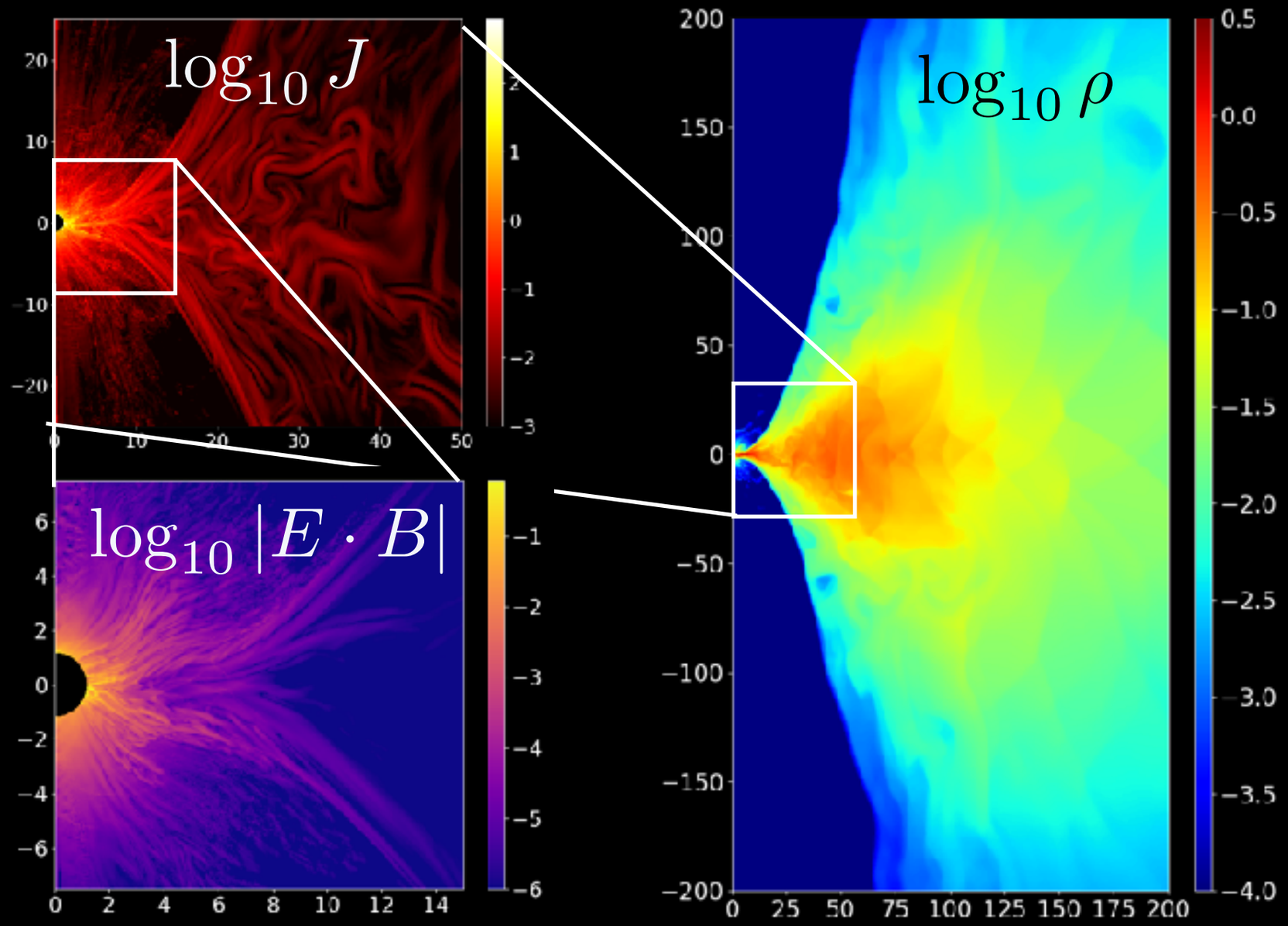

—> formation of current sheets, plasmoids, strong winds —>still MAD?

—> acceleration of particles —> origin of neutrinos?

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Thanks for your attention!

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