Shear instabilities in astrophysical plasma jets

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Motivation

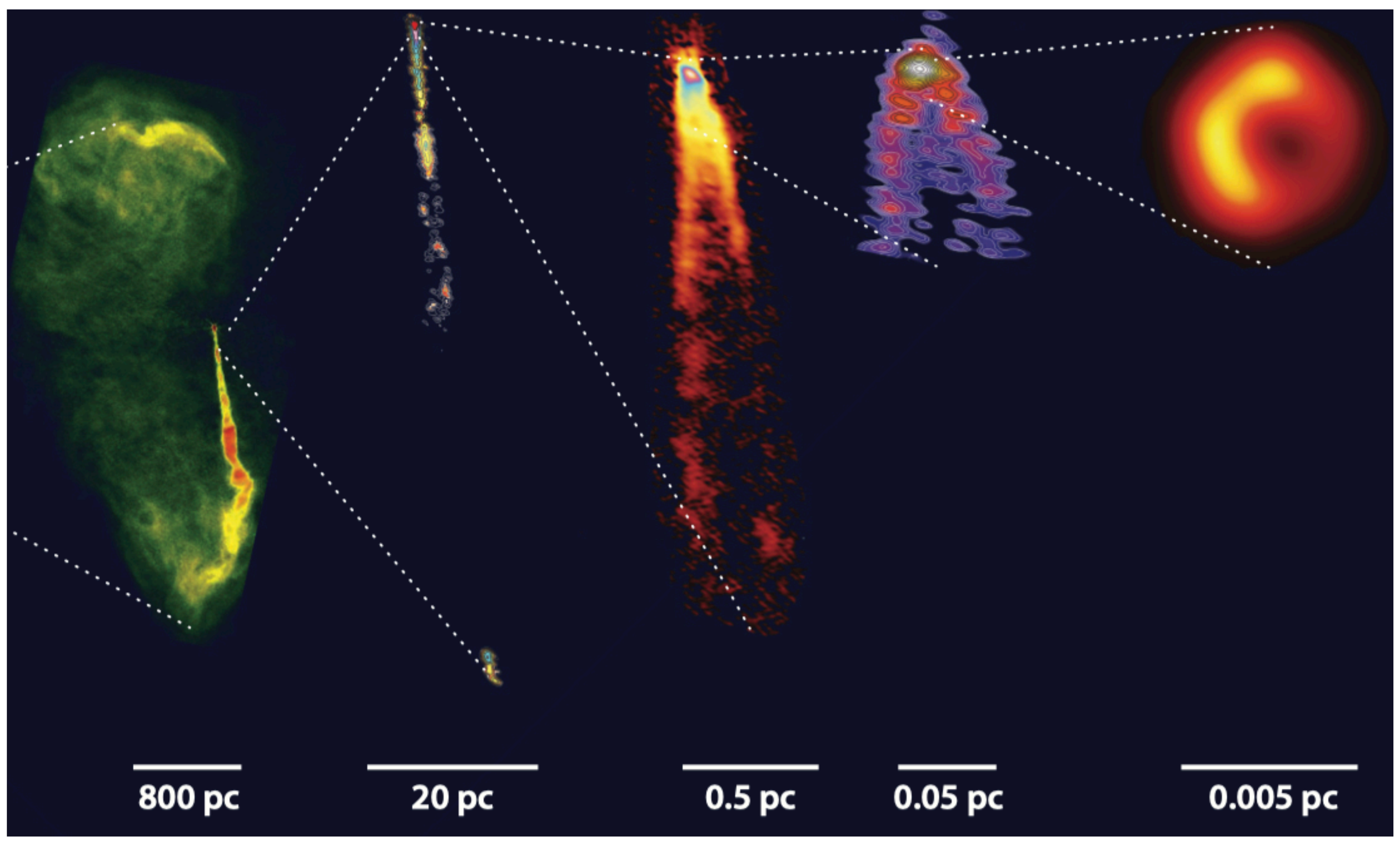
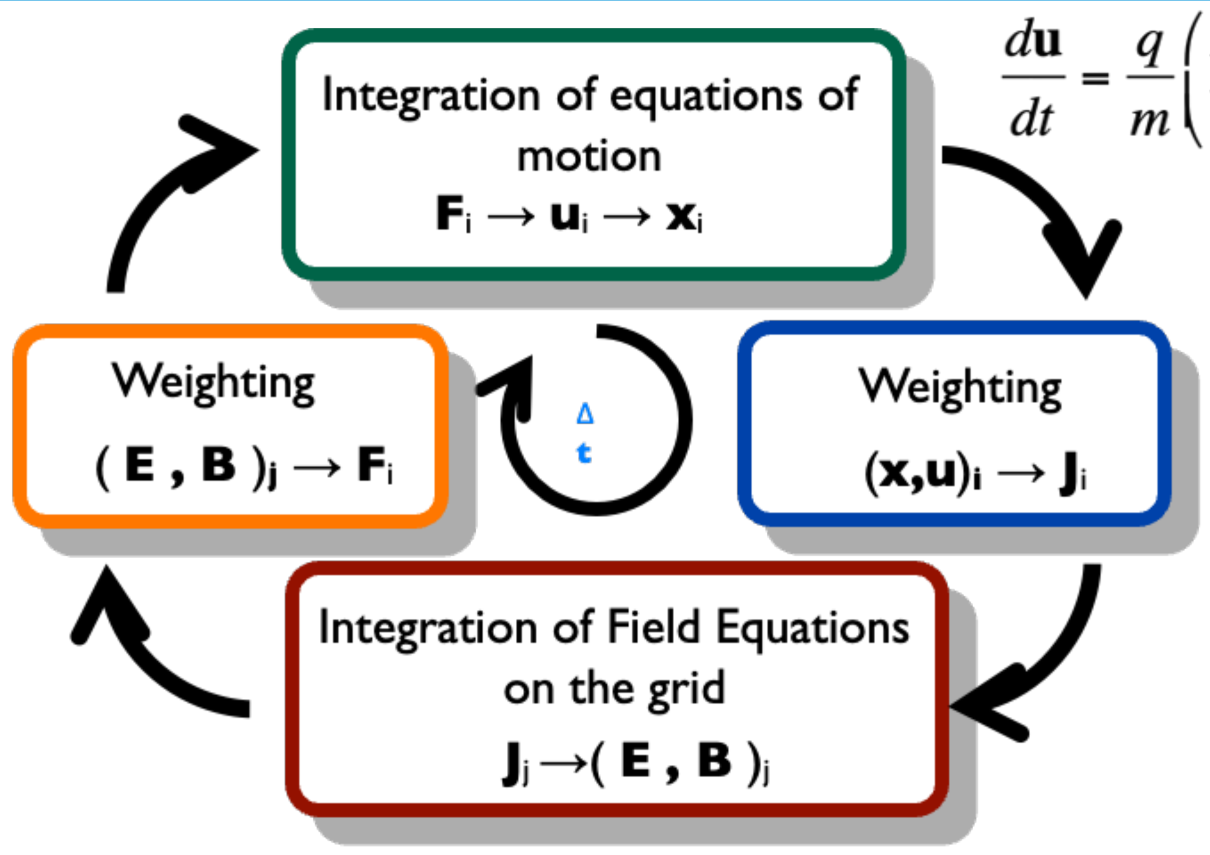


Figure: Multi-scale view of galaxy M87, from its outer radio lobes down to the vicinity of the central supermassive black hole. Successive zooms reveal the collimated jet in increasing detail, highlighting the regions where relativistic jets are launched and energized. [1]

Particle-in-cell simulations



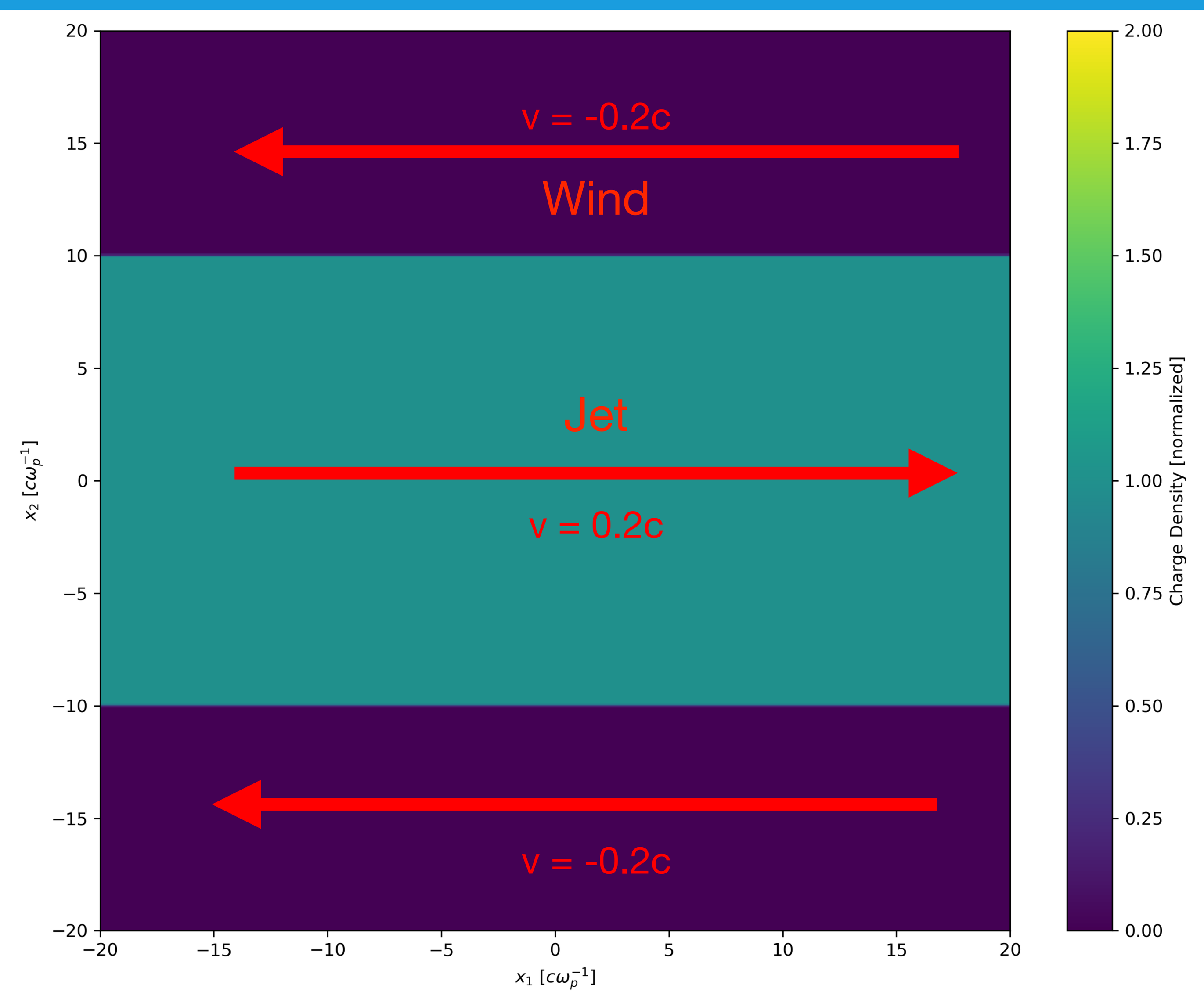
$$\frac{d\mathbf{u}}{dt} = \frac{q}{m}\left(\mathbf{E} + \frac{1}{\gamma c}\mathbf{u} \times \mathbf{B}\right)$$

$$\frac{\partial \mathbf{E}}{\partial t} = c\vec{\nabla} \times \mathbf{B} - 4\pi\mathbf{j}$$

$$\frac{\partial \mathbf{B}}{\partial t} = -c\vec{\nabla} \times \mathbf{E}$$

Figure: Particle-in-cell algorithm.

Initial setup for simulating jets



Tracking instability growth

Dispersion relation: the frequency-wavevector dependence.

$$\sqrt{\frac{n_{jet}}{n_{wind}} + \frac{k'^2}{\beta_0^2} - \omega'^2}\left[(\omega' + k')^2 - (\omega'^2 - k'^2)^2\right] + \sqrt{1 + \frac{k'^2}{\beta_0^2} - \omega'^2}\left[\frac{n_{jet}}{n_{wind}}(\omega' - k')^2 - (\omega'^2 - k'^2)^2\right] = 0$$

Maximum instability growth rate: $\Gamma = \frac{1}{\sqrt{8}}\omega_p = 0.3535\omega_p$

Figure: The relation dispersion for a cold, unmagnetized, and symmetric in mass, shear flow. [2]

Kinetic-scale KHI grows in jets

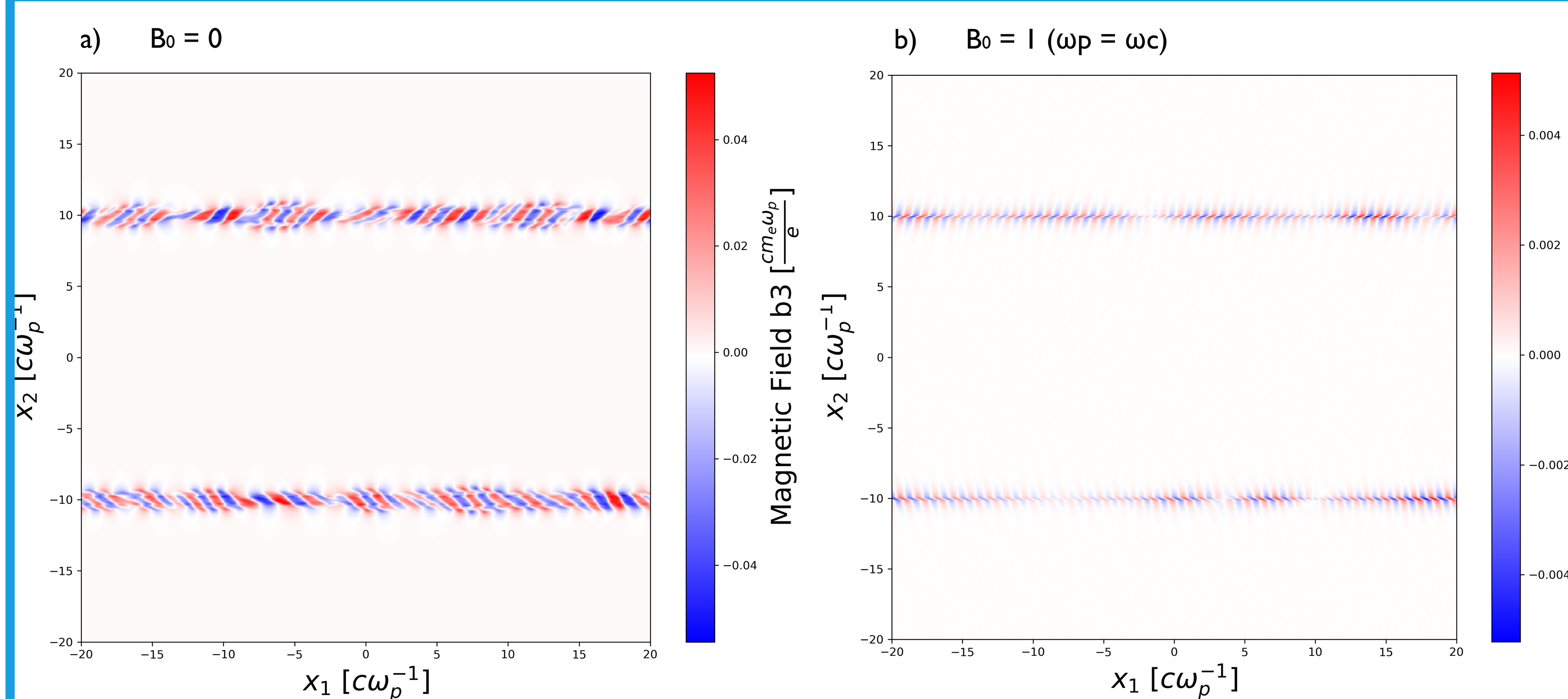


Figure: Out of frame B-field at t = 43.73 1/ω for initially magnetized (a) and unmagnetised (b) jet.

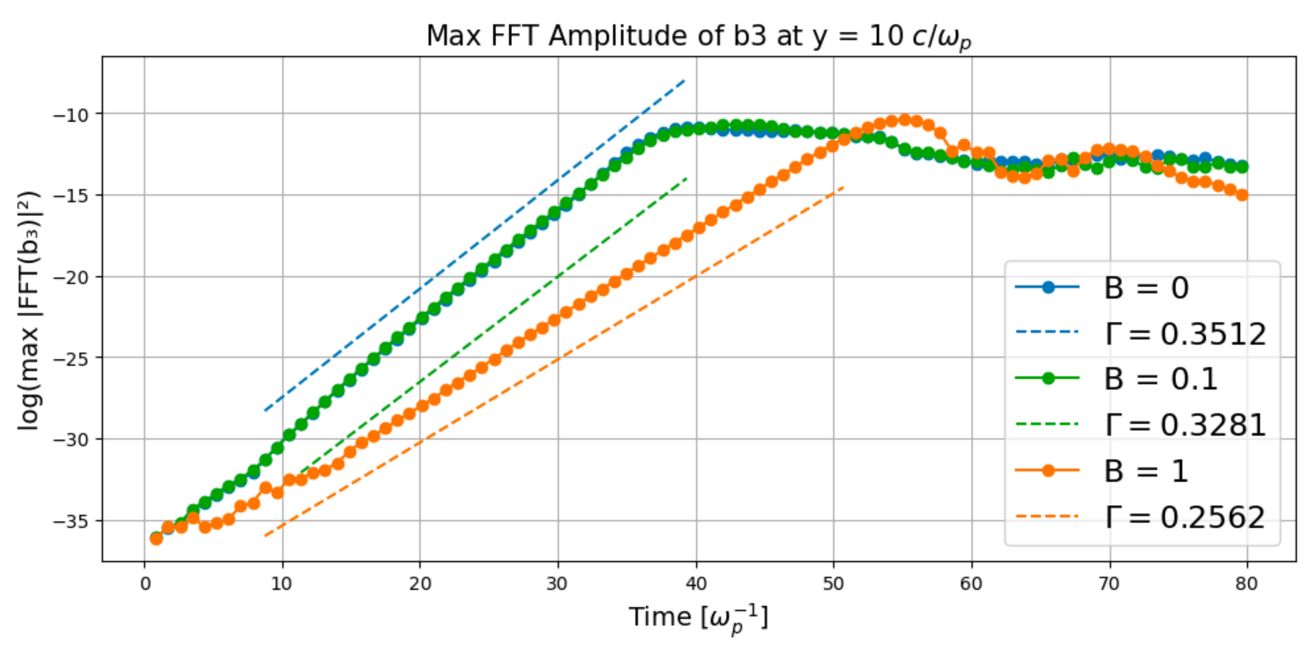


Figure: Instability growth for different initial magnetizations. The slope of the linear phase corresponds to the growth rate of the instability.

Conclusions & Future work

The theoretical predictions of the linear phase for the unmagnetized case are validated by simulation results

Strong magnetization suppresses the growth of the instability and confines it along magnetic field lines.

Future work: investigate how jet velocity and magnetization influence kinetic processes and particle acceleration mechanisms in astrophysical jets.

References & Acknowledgements

[1] R. Blandford, et al. Annu. Rev. Ast. Astrophys. 57, 467–509 (2019)

[2] Alves, E.P., et al. New Journal of Physics, vol. 16, 2014,