Poynting flux dissipation in jets

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Problem

- Relativistic jets launched with high magnetization parameter: $\sigma \gg 1$.
- Collimation slow $\Rightarrow \sigma$ may stay large
- Magnetic fields are too springy — shocks do not change the Poynting flux substantially.
- Fermi I acceleration doesn't work well in magnetized $\sigma \sim 1$ shocks

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   - In MHD description: formation of current sheets ⇒ compression of these at a weak shock ⇒ enhanced reconnection rate
     Solar wind: Drake et al, ApJ 709, 963 (2010)
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    - For *under-dense* plasmas: shock causes fluctuations to convert into electromagnetic modes forming a dissipative precursor
      Amano & Kirk ApJ 770, 18 (2013),
      Mochol & Kirk arXiv:1303.6434

Lengthscales

Why worry about under-dense plasmas?

- For an MHD description, require $\lambda \gg \lambda_{\rm g}, c/\omega_{\rm p}$
- In the Crab pulsar wind $r \ll 10^{-3} \times$ termination shock radius
- In a synchrotron emitting $e^{\pm}$ jet

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- Electromagnetically modified shocks (Amano)

Two-fluid simulations

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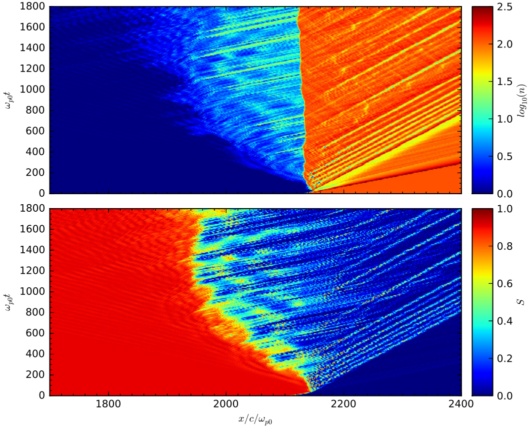
- Initial conditions:
  - Left half: circularly polarized, cold, static shear, $\gamma = 40$, $\sigma = 10$, $\lambda \approx \lambda_{\rm g}/4$
  - Right half: shocked (R-H conditions) unmagnetized plasma

Time evolution

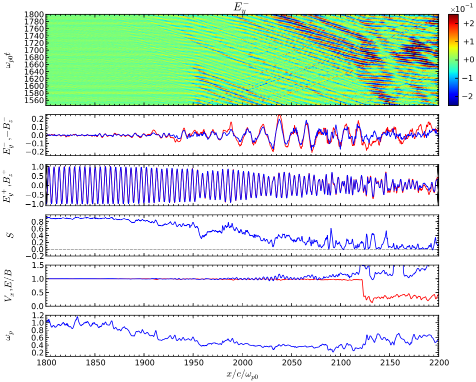


$\Gamma = 40$

$\sigma = 10$

$\omega = 1.2\omega_\mathrm{p}$

Wave helicity



Positive helicity injected wave (E^+, B^+).

Backwards propagating, negative helicity waves generated.

$E > B$ in precursor and downstream ($v_{\mathrm{wave}} = B/E$).

Simulation Results

- Poynting flux dissipated completely
- A precursor containing strong electromagnetic waves is formed
- A hydrodynamic shock remains

Implications/Conclusions

Particle acceleration:

- In a magnetized jet, the power in fluctuations with short length scale ($\lambda < \lambda_{\rm g}$) can be dissipated at an electromagnetically modified shock front
- Particle acceleration by the first order Fermi is possible at the hydrodynamic sub-shock

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Radiation:

- A signature from the electromagnetic precursor is possible from both *thermal* particles and accelerated particles
- Electric vector polarization angle *perpendicular* to the jet — mechanism similar to synchro-Compton (Rees 1971):
- Possibly measurable degree of circular polarization from accelerated particles penetrating the precursor