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The First Open-Source General Relativistic Force-Free Electrodynamics Code

Maria Babiuc-Hamilton
Marshall University, babiuc@marshall.edu

Zach Etienne

Mew-Bing Wan

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THE FIRST OPEN-SOURCE GENERAL RELATIVISTIC FORCE-FREE ELECTRODYNAMICS CODE

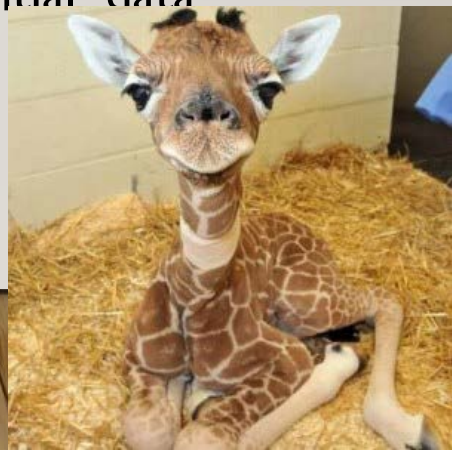
MARIA BABIUC, ZACH ETIENNE, MEW-BING WAN

BACKGROUND

- Most of the Universe consists of a tenuous plasma with magnetic-to-gas pressure ratios far larger than unity.
  - In this limit, the equations of MHD explain the dynamics well, but become *stiff* (vanishing densities -> coefficients become infinite)
- The equations of Force-Free Electrodynamics (FFE) are better suited
- These equations neglect gas pressures and densities, as we assume the electromagnetic field dynamics alone govern the plasma dynamics
- * Neutron star (e.g., pulsar) and black hole magnetospheres: General relativistic FFE (GRFFE) may be used to understand the plasma dynamics

OBJECTIVE

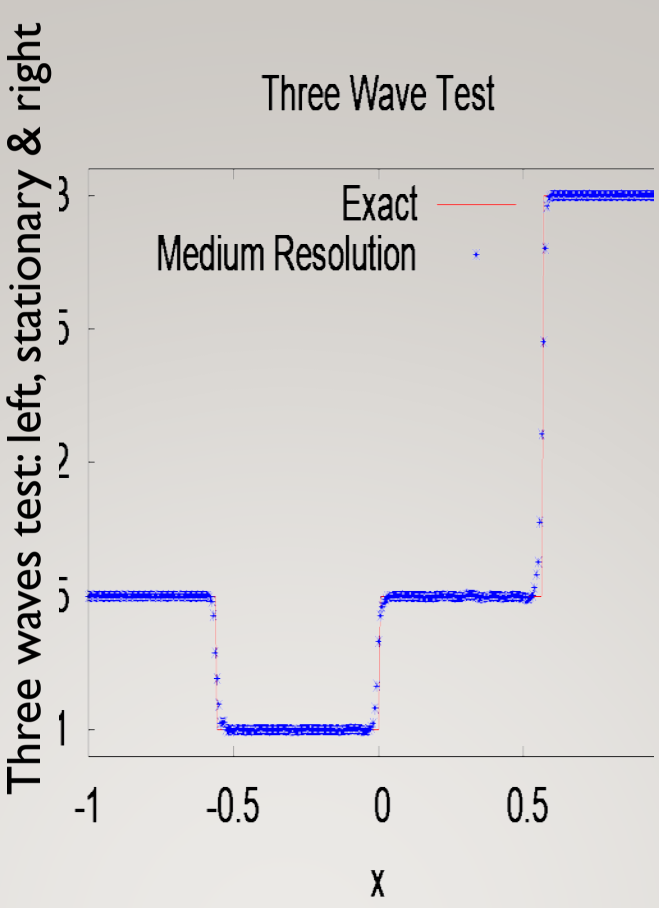
- We are writing the first open-source, general relativistic force-free electrodynamics code: GiRaFFE
- The goal is to numerically simulate neutron star and black hole magnetospheres.
- The GiRaFFE is alive! It has passed a number of 1D code validation tests, and 3D tests are underway.
- We plan to release the code and test suite initial data routines open-source to the community

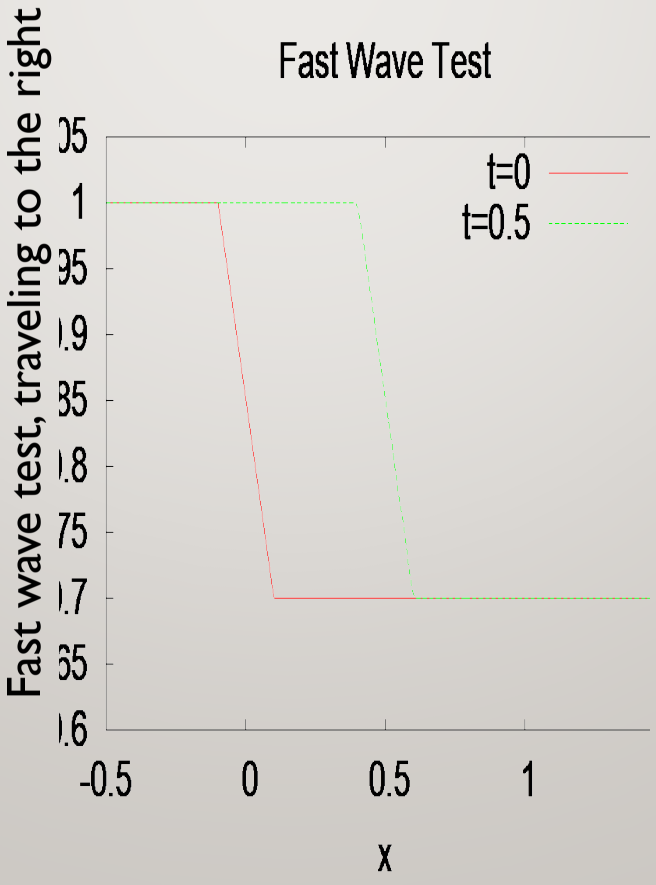


ALGORITHM

- Force-Free Electrodynamics (FFE) is a limit of ideal MHD with negligible plasma inertia.
- Force-free conditions $\mathbf{E} \cdot \mathbf{B} = 0$ and $E^2 < B^2$
- Current sheet breaks down the force-free condition
- For the basic algorithm see the papers:
  - Paschalidis & Shapiro (arXiv:astro-ph/1310:3274)
  - McKinney & Gammie (arXiv:astro-ph/0404512)
- In ***S-B*** formulation $S_i B^i = 0$ and $S^2 < B^4$ *enforced after evolution*
- Exact initial data for vector potential A_i and velocity v^i

ONE DIMENSIONAL TESTS





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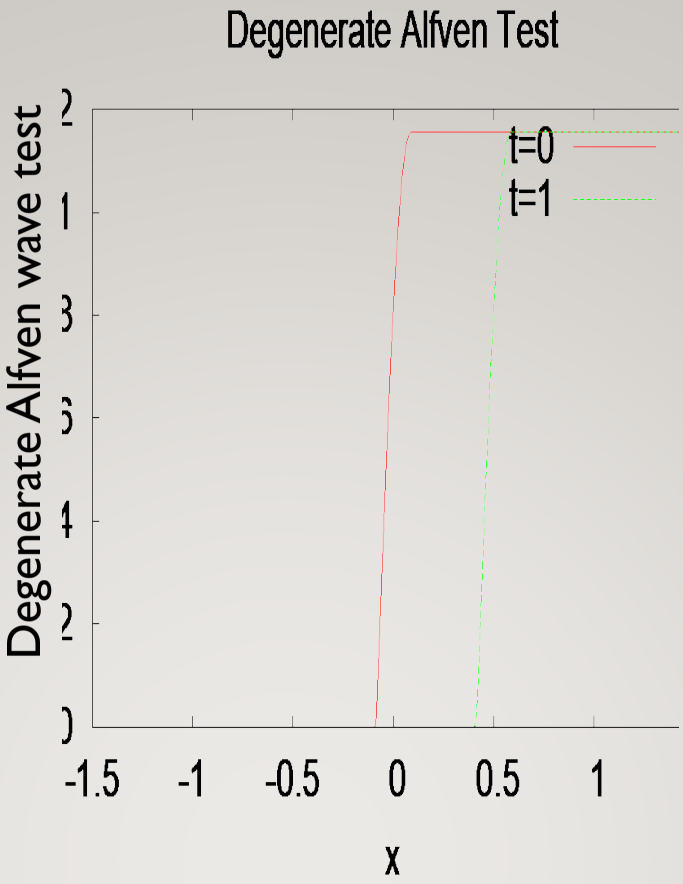

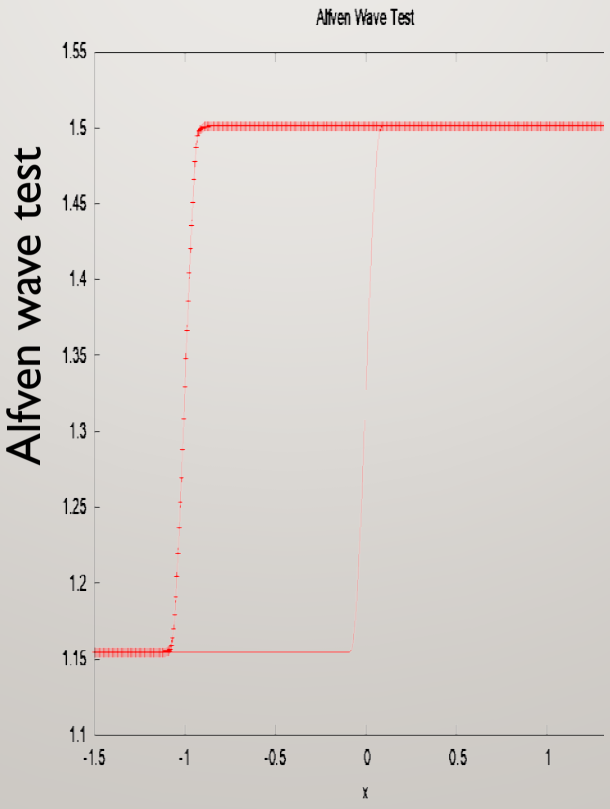

ONE DIMENSIONAL TESTS