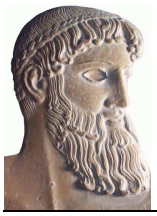
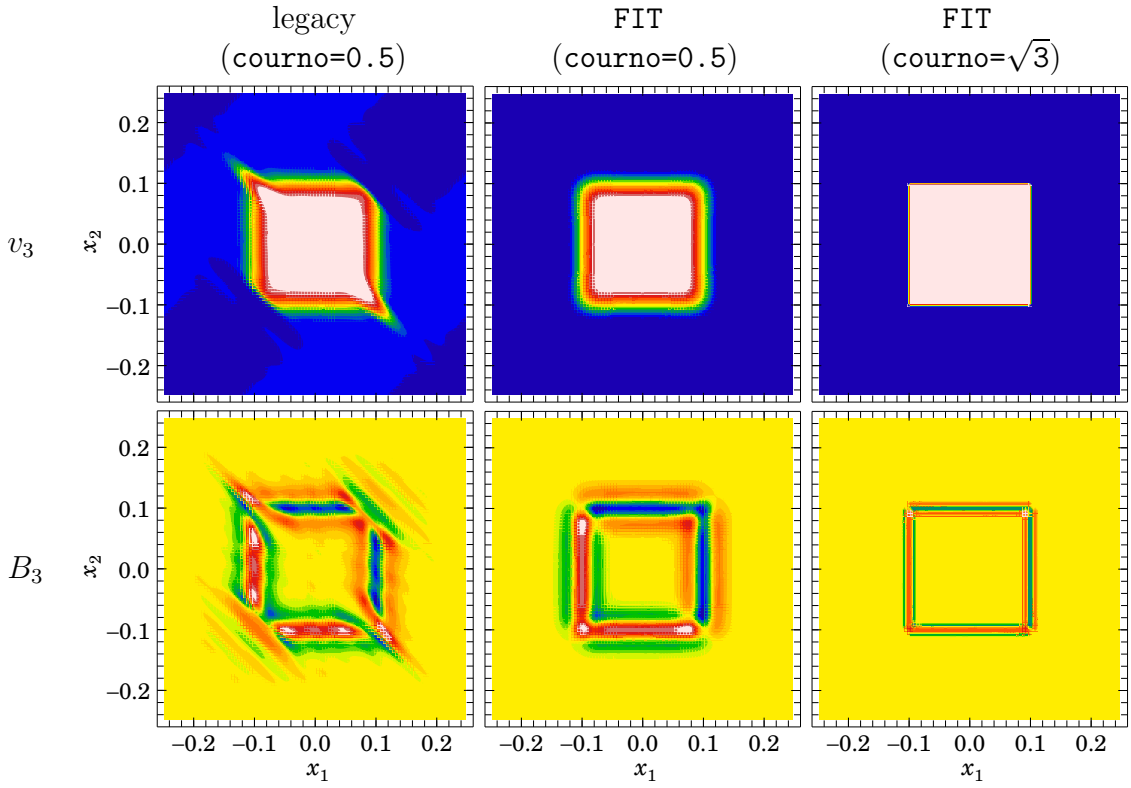


ZEUS-3D 2-D Gallery #2: Shear Alfvén Waves



A uniform 100×100 Cartesian grid over a domain $(x_1, x_2) = (-0.25 : 0.25, -0.25 : 0.25)$ with periodic boundaries is initialised with $\rho = B_1 = B_2 = c_s = 1$ and $B_3 = v_i = 0$, $i = 1, 2, 3$. A 40×40 zone square pulse with amplitude 0.001 is initialised in v_3 at the grid centre and, since $\rho = B_1 = B_2 = 1$, the Alfvén waves triggered by this pulse propagate at the Alfvén speed, $v_A = \sqrt{2}$, at 45° relative to the grid axes (bottom left to top right). Tests are run to $t = 1.0$ and, with periodic boundaries, the pulses cycle through the grid twice and return to the centre where they began. Click on any image in the table for an animation.

Artificial viscosity, which does not affect pure Alfvén wave propagation, is set to zero (`qcon=0`, `qlin=0`), while the Courant number, to which the time step is proportional, is given in the top row of the table. While all quantities other than v_3 and B_3 could be reset to their initial values after each MHD step, this isn't necessary with the small amplitudes of the waves.

The left column of images is the result using Legacy transport (`trnvrsn=0`), the middle column `FIT` (`trnvrsn=1`), and the right column `FIT` with a CFL-limited time step. See the 2-D Advection page for a description of *Legacy* and *Finely Interleaved Transport* (`FIT`). Evidently, Legacy transport suffers from the "striping instability" for 2-D shear Alfvén wave transport just as it does for 2-D advection, whereas `FIT` does not. Indeed, the third column shows that `FIT` is CFL-limited for Alfvén wave propagation. (See the footnote on the 2-D Advection page for what it means to be "CFL limited".)

The "analytical" solution requires $B_3 = 0$ at $t = 1$ (when the two opposing waves in B_3 superpose and thus cancel at the centre). In the lower middle panel (`FIT` with `courno=0.5`), the colours range within ±7.5% of the peak amplitude of 0.0005, consistent with acceptable diffusion of the pulse edges after passing through the grid twice. By comparison, in the CFL-limited `FIT` solution, the colours range within $\pm 10^{-8}$% of the peak, consistent with the fact that `courno` is set to $\sqrt{3}$ only to within one part in 10^8.

Finally, I note that this test also verifies the efficacy of the periodic boundary conditions in the code.