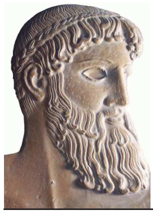
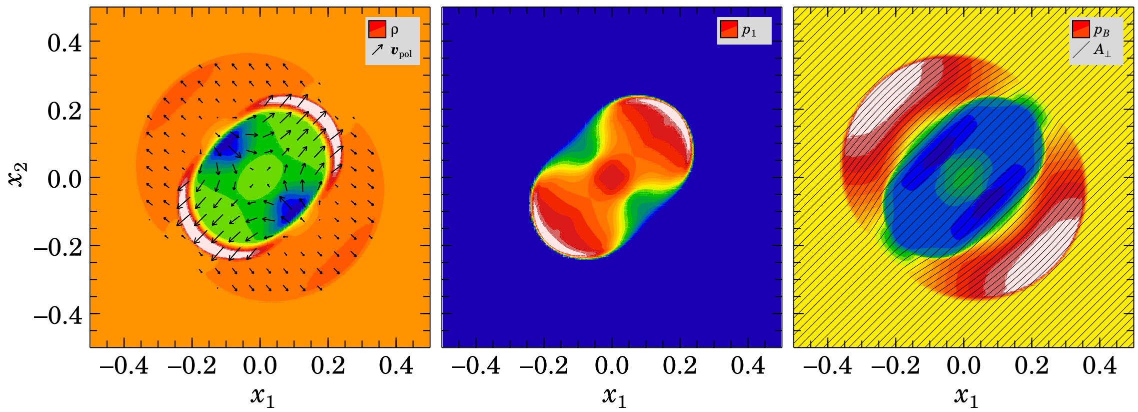


ZEUS-3D 2-D Gallery #5: MHD Blast Wave



ρ ANIMATION $\quad$ p_1 ANIMATION $\quad$ p_B ANIMATION

This problem corresponds to Fig. 13 from Gardiner & Stone (2005, J. Comput. Phys., 205, 509), showing a 2-D MHD blast wave in Cartesian coordinates at time $t = 0.02$. The initial state consists of a disc ($r = 0.125$ centred on the origin) with $(\rho, B_1, B_2, p_1) = (1, 5\sqrt{2}, 5\sqrt{2}, 100)$ embedded in a background state $(1, 5\sqrt{2}, 5\sqrt{2}, 1)$ with $\vec{v} = 0$, $B_3 = 0$ and $\gamma = 5/3$. In the panels, colours are arranged spectrally with white indicating high values, purple low. Shown from left to right are colour contours in density with velocity vectors overlaid, thermal pressure, and magnetic pressure with magnetic field lines overlaid. The hyperlink below each panel opens the respective `mp4` animation.

The `dzeus36` solution, resolved on a 200×200 grid, uses `CMoC`, `FIT` (`trnvrsn=1`), the total energy equation, second-order interpolation, and parameters `courno=0.75` for the time step, and `qcon=1.0`, `qlin=0.1` for artificial viscosity. Differences between these and legacy transport (`trnvrsn=0`; version 3.5) are quantitative.

Gardiner & Stone's (2005) 2-D upwinded (Godunov) and *unsplit* scheme (*ATHENA*) uses a staggered mesh for the magnetic field components in which the magnetic compressional derivatives ($\partial_i B_i$) are accounted for. Most multi-dimensional Godunov schemes are constructed from orthogonal sweeps of 1-D seven-wave upwinded schemes which, by design, ignore the compressional terms since they are zero—in 1-D—by the solenoidal condition. As Gardiner & Stone demonstrate, ignoring the compressional terms in 2-D can cause severe grid dependencies in certain 2-D simulations such as this 2-D MHD blast problem.

As the *ZEUS* family of codes have *always* included the compressional magnetic terms, the grid-dependent effects discussed by Gardiner & Stone (2005) are absent in the MHD blast wave depicted in the `dzeus36`-generated images and animations above. The end-states look identical to those published by Gardiner & Stone though, quantitatively, there are some differences as seen in the table below where the extrema of the variables are listed. Extrema for the internal energy equation solution (e_1) are also given, with the greatest departure from the total energy equation solution (e_T) being the density maximum.

Extrema of ρ, p_1, and p_B in the MHD blast after $t = 0.02$.

	$\rho_{\rm min}$	$\rho_{\rm max}$	$p_{1\,\rm min}$	$p_{1\,\rm max}$	$p_{B\,\rm min}$	$p_{B\,\rm max}$
`dzeus36`, e_1	0.201	4.05	0.769	31.5	24.5	76.7
`dzeus36`, e_T	0.214	3.20	0.769	32.0	24.6	76.7
ATHENA	0.192	3.31	1.00	32.1	23.5	77.7