SMOOTHED PARTICLE MAGNETOHYDRODYNAMICS

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`I want to do a star formation simulation including the effects of magnetic fields...'

Can I use SPH? (yes!)

We present new algorithms for the simulation of magnetic fields with the Smoothed Particle Hydrodynamics (SPH) method. Previous attempts to do this had found difficulties, namely an instability which occurs in the exactly momentum-conserving form of the SPH equations. We implement a simple fix for this instability proposed by Monaghan (2000) which removes this problem.

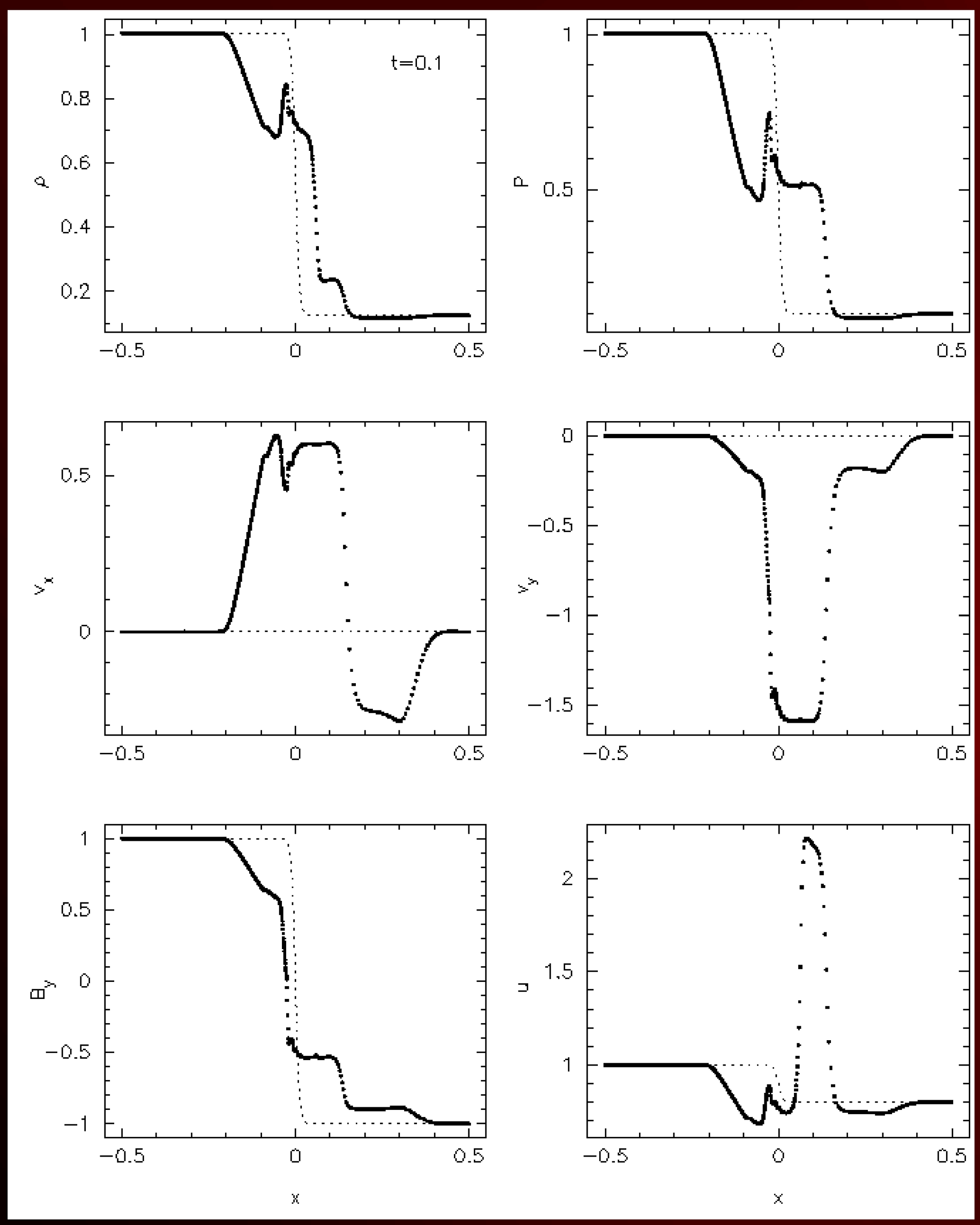
Why SPH? (no grid)

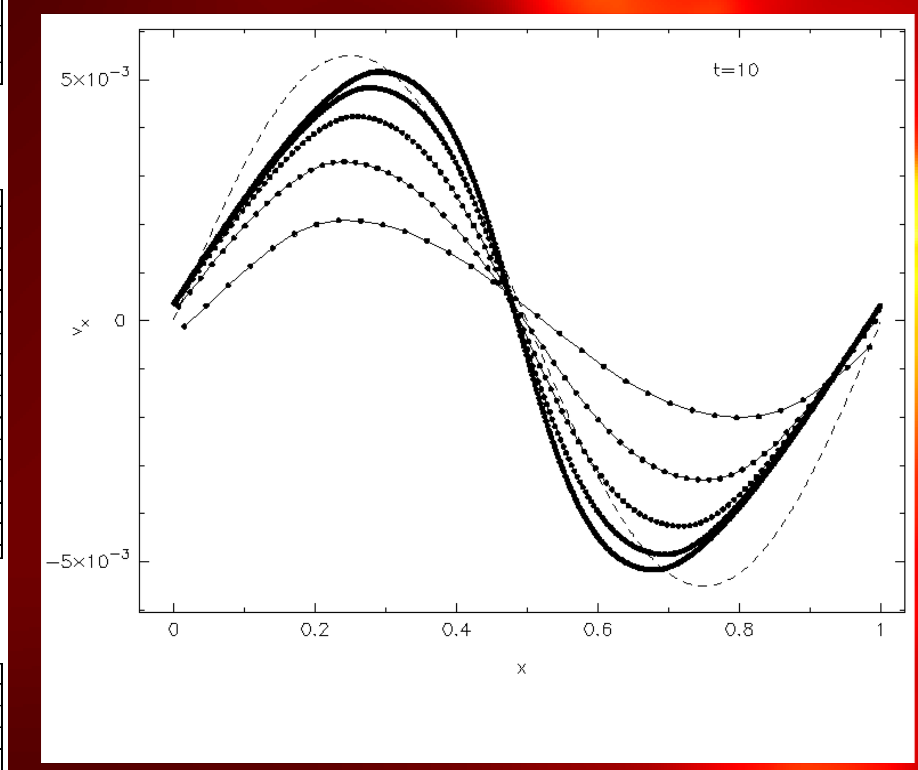
SPH is a unique numerical method of solving the equations of gas dynamics, in that it involves no spatial grid. This means that there are no restrictions on the symmetry of the problem to be solved and complicated physics can be handled with relative ease.

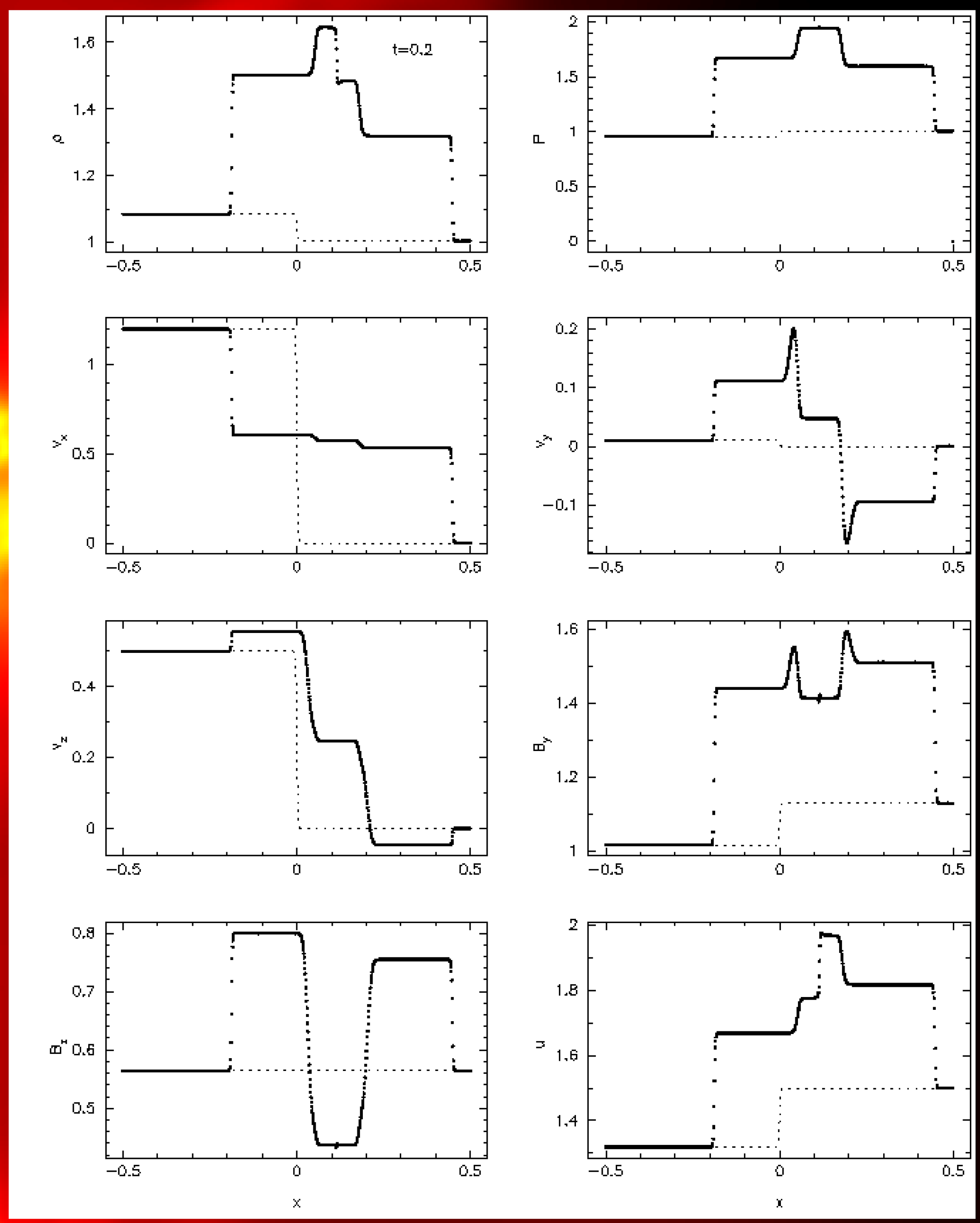
Can it handle shocks? (you'll be shocked)

We carefully formulate dissipation terms by analogy with the Riemann solvers used in grid-based codes. The formulation we use very naturally gives the appropriate amount of viscosity and ohmic diffusivity near shock fronts. These dissipative terms are only needed to smooth out shock fronts and we use the artificial viscosity switch proposed by Morris & Monaghan (1997) which very effectively turns off the dissipation away from shocks.

Some shocking results...







Figures: Brio & Wu (1988) shock tube test (left), MHD fast wave (centre) and a shock tube test involving seven different discontinuities in the same problem (right). Initial conditions are indicated by the dotted or dashed lines, 1D SPH results given by dots. The left test is used by Stone et al. (1992), but we include the more stringent tests given by Ryu & Jones (1995) and Balsara (1998) and many others. MHD fast wave results shown at 6 different resolutions (32-512 particles) after 10 periods. Compare to results in Dai and Woodward (1998), Ryu and Jones (1995) and Balsara (1998) obtained with the best grid-based MHD codes.

These tests are in 1D. What about 3D? (trivial extension)

Preliminary tests indicate that the method works extremely well in 3D as well. Further tests in 2D are in progress but will be published. We have carefully formulated our equations such that errors associated with non-zero divergence of the magnetic field should be kept to a minimum.

Great, so you have a code that works. What are you going to do with it? (star formation!)

In the short term the plan is to demonstrate that SPH can reproduce some of the simulations of MHD turbulence in molecular clouds that have been performed using grid-based codes. The plan is then to simulate magnetic fields in star formation from realistic (turbulent) initial conditions in a simulation similar to that of Bate, Bonnell and Bromm (2003) (background image).

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