Structure preserving methods for modeling astrophysical phenomena

The simulation of astrophysical phenomena generally feature a large spread of length and time scales. This makes them extremely challenging from a computational point of view. In many instances, delicate trade-offs between resolution and fidelity to the physical conservation laws have to be committed in order to overcome the computational limitations. It is more the rule than the exception, that astrophysical phenomena are modeled in a resolution starved regime.

This puts great robustness requirements on the used numerical methods. For instance, many systems of conservation laws used to model physical phenomena posses companion laws. These companion laws are generically fulfilled by analytical solutions to the original system of conservation laws. However, this assertion may not remain true when the equations are solved numerically. A prominent example is the divergence constraint on the magnetic field in magnetohydrodynamics. Other examples include the conservation of angular momentum and the preservation of steady states.

We will present a class of methods, termed as structure preserving, that are constructed to fulfill as many as possible companion laws of the original system of conservations laws. The defect of standard numerical methods and the need for structure preserving ones will be illustrated through several challenging astrophysical scenarios, including the simulation of magneto-rotationally driven core-collapse supernovae and the merger of two neutron stars.