Research Description for Prof. Dinshaw Balsara

Balsara has a dual training in physics and astrophysics. His Ph.D. was in computational astrophysics where he designed and compared several popular schemes for astrophysical fluid dynamics and also applied them to the study of extragalactic jets. He has subsequently worked on several problems in active galactic nuclei, studying the accretion on to black holes and compact objects, starburst galaxies and galaxies in clusters. More recently, he has developed computational applications in the areas of interstellar medium, turbulence, star formation, planet formation, the physics of accretion disks, compact objects and relativistic astrophysics and he continues to work in all of those areas of research.

Balsara has also played a seminal role in formulating of our modern conception of computational astrophysics. His work on divergence-free adaptive mesh refinement for magnetohydrodynamics (MHD) has broken new ground in our understanding of numerical MHD. He has also produced some of the best, most accurate and most robust methods for numerical MHD and have recently begun extending this expertise to radiative transfer as well as non-ideal processes that are often very useful in regulating astrophysical phenomena. Several of Balsara's papers have been cited over a hundred times.

The above-mentioned numerical expertise is routinely applied to problems in all areas of computational astrophysics. In fact, the robust numerics was central to the process of carrying out path-breaking simulations of the supernova explosion-driven ISM turbulence, Fig. 1. That work has resulted in many new insights into the nature of the multi-phase ISM and the evolution of magnetic fields in it.

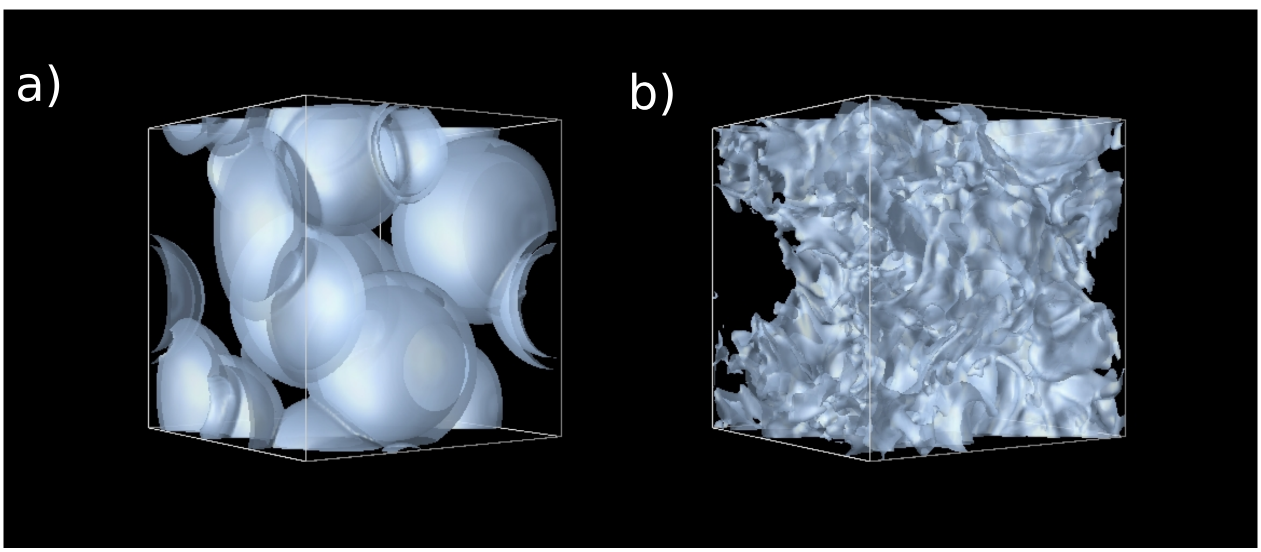

Fig. 1: 1a and 1b show early and late time isodensity contours of a supernova-driven turbulence simulation. The supernovae drive the turbulence and also set the thermal properties of the interstellar medium.

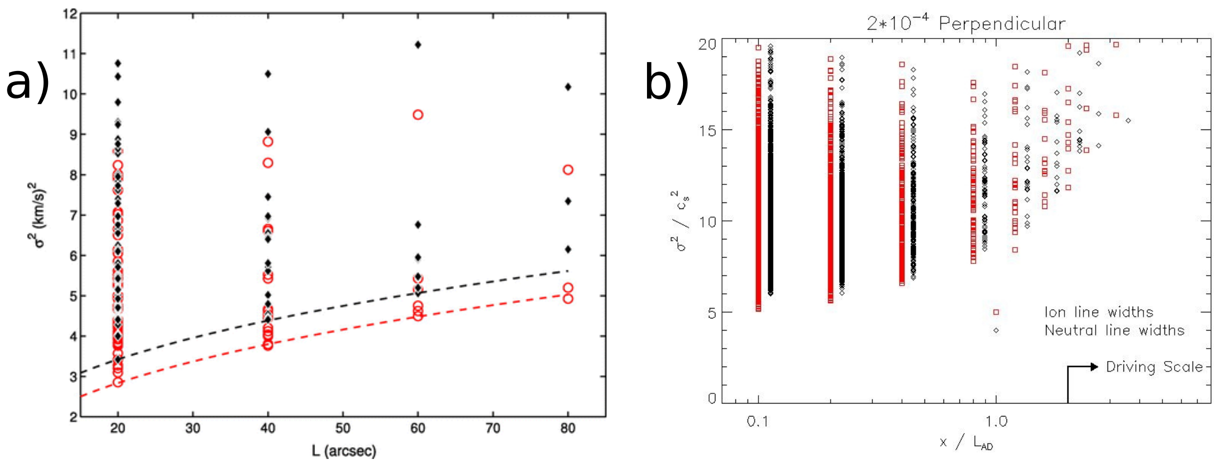

Fig. 2a shows observed velocity dispersions as a function of length for the HCN molecule (black) and the HCO^+ ion (red). Fig. 2b shows simulated linewidth-size relations for neutrals (black) and ions (red) from our two-fluid MHD simulations. The ions consistently have lower line widths than the neutrals, which is a consequence of two-fluid effects in the star forming plasma.

Star formation in turbulent, magnetized environments has also been a topic of significant recent focus. Balsara's theories and simulations of two-fluid magnetized turbulence have been used to decipher the role of ambipolar diffusion in star formation. Fig. 2 shows linewidth-size relations from observations and Balsara's simulations, indicating a good match between the two.

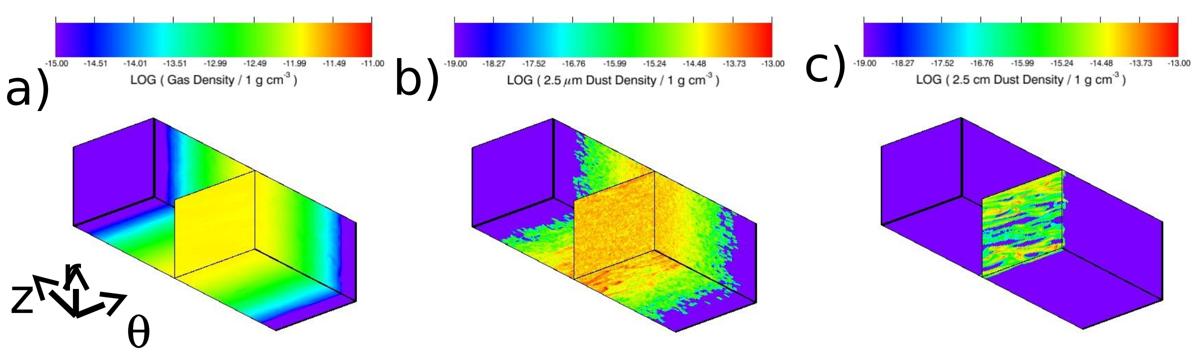

Fig 3: shows a simulation of a section of a protostellar accretion disk. The far side of the computational domain is shown along with the midplane . Fig. 2a shows gas density; Fig. 2b shows distribution of small 2.5 micron grains; Fig. 2c shows large 2.5 cm grains. The small grains track the gas density; see Figs. 3a and 3b. However, the large grains sediment and clump in the midplane of the accretion disk, as shown in Fig. 3c.

The dynamics of dust and its role in building planets within turbulent, magnetized, protostellar accretion disks has also been a topic of recent study. Fig. 3 shows that smaller dust grains follow the turbulent gas in a protostellar accretion disk. However, large dust grains sediment and clump in the midplane of the accretion disk, setting the stage for planet formation.

Balsara also has a significant scientific interest in PetaScale and ExaScale computing and has worked with some of the world's fastest supercomputers over the years.