## PROJECT SUMMARY

Shock waves and low-frequency turbulence are ubiquitous in plasmas, occurring in environments as diverse as jet engines, inertial confinement fusion devises interplanetary space, the Earth's bow shock, supernovae, etc. Indeed, one of the great unsolved problems of classical fluid mechanics concerns the interaction of turbulence with shock waves.

We propose to investigate two classes of shocks interacting with turbulence.

- We will investigate the interaction of upstream turbulence convected into and interacting with narrow or unmediated shocks, whose transition or jump occurs over scales much smaller than the correlation length of upstream turbulence. For such shocks, we propose to compute the mean location and speed of the shock as a function of the upstream energy density of turbulence, the variance of the shock position and speed, the amplification of turbulence at a shock, and its subsequent dissipation downstream. We will consider fully compressible ideal gas dynamics, MHD, and combustion or reacting flows. In parallel with the theoretical development, which will be quasi-analytic, we will undertake carefully posed, well resolved numerical simulations to monitor our closure approximations and compare theory and simulations directly.

- We will investigate broad, energetic particle mediated shocks which both amplify and transmit pre-existing upstream turbulence, and include turbulence generated within the broad shock structure by energetic particle distribution gradients. The acceleration of ions at shock waves occurs on almost all scales in cosmic plasmas, and the mechanism of diffusive or first-order Fermi acceleration of energetic particles at shocks is now invoked to explain cosmic ray observations of almost all energies both within and beyond the heliosphere. Energetic particles can contribute to the overall momentum and energy balance of the shock, imposing a length scale associated with the cosmic ray diffusion length scale. Consequently, a shock accelerating particles acquires a broad smooth foreshock structure, and the cosmic ray pressure gradient drives low-frequency magnetoacoustic turbulence. Thus, an energetic particle mediated shock is expected to be highly turbulent, both due to compressible instabilities driven by cosmic ray pressure gradients and by incompressible Alfven waves excited by the streaming cosmic rays. We propose a detailed study of particle transport, turbulence generation, particle acceleration, and self-consistent shock structure modeling at highly turbulent, non-laminar shock waves.

**Impact of the proposed research.** Low-frequency turbulence is ubiquitous and is invariably present in the vicinity of shock waves, be they shocks associated with jet engines, inertial confinement fusion devices, or supernova shock waves, detonation shocks, and collisionless shocks throughout the interplanetary and interstellar medium. Surprisingly little work has been done on the interaction of turbulence with shocks, and very little theoretical development has occurred. Computational simulations have been instructive but the basic theory has yet to be addressed in a systematic fashion. Multi-point measurements of collisionless shocks in interplanetary space are now being made, and existing theory is found to be deplorably deficient. The work proposed here offers the first comprehensive and systematic investigation of the the interaction of turbulence with shock waves, addressing both thin shocks and broad shocks, the latter including the additional complication of particle acceleration which is expected to affect shock structure significantly. We expect that these studies will result in a significant advance of our basic understanding of turbulence and shock waves and have technological applications as well as being of basic interest to plasma physics in almost all conceivable environments.