LARGE SCALE UPSTREAM TURBULENCE, MAGNETIC FIELDS AND PARTICLE ACCELERATION AT ASTROPHYSICAL SHOCKS

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We consider effects of pre-existing, large-scale turbulence upstream of a shock on the magnetic field and the acceleration of charged particles. Turbulent field-line mixing plays a large role in particle transport. Also, turbulent *density* fluctuations upstream of the shock have a large effect on the magnetic field downstream (Giacalone and Jokipii, Ap. J., 633, L41, 2007). For high Alfvén Mach number shocks, the downstream magnetic field is amplified considerably above the value obtained from the shock jump conditions. These effects may provide a robust and natural understanding of recent observations at astrophysical shocks.

The magnetic-field amplification implied by our simulations should exceed factors of 100, consistent with observed X-rays from supernova remnants, which require magnetic fields of 100μG. These are much larger than expected from the shock jump conditions. In this case, the upstream field is not amplified, so cosmic-rays with energies approaching the “knee” in the spectrum require rapid acceleration, which can occur at the quasi-perpendicular part of the supernova blast wave, where the turbulent field-line mixing plays a large role.

Further, recent observations by the Voyager 1 spacecraft downstream of the heliospheric termination shock show that the magnetic field has large magnitude fluctuations.

We suggest that these and other effects of pre-existing turbulence play an important role in many astrophysical and heliospheric shocks.

More-recent simulations of different aspects of turbulence at shocks will also be discussed.