# Gone With the Solar Wind:
# A study of protons accelerated by interplanetary shocks

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The availability of high time resolution spacecraft data has made possible in-situ and detailed study of plasma processes in the interplanetary medium. One important process that has received a lot of attention is the energization of charged particles due to interaction with travelling interplanetary shock waves. The specific goal of this study is to make use of *observed* magnetic fields, plasma density and velocity, and initial particle trajectories calculated from *real* spacecraft orientations in a time-reversed computer simulation which follows particles through a single complete interaction with a shock in order to predict the angular distribution of energetic protons (0.29–0.5 MeV). This study is fully 3-dimensional and unique in that real conditions for *specific shocks* outside the Earth's magnetosphere are simulated, and the results are compared to observations for each particular shock.

The shock is considered to be a planar surface and there is a $\mathbf{v_{solarwind}} \times \mathbf{B}$ electric field in the frame where the shock is at rest. The high energy protons are treated as test particles which do not affect the electric or magnetic fields. They gain energy in a single shock encounter as they drift along the $\mathbf{v_s} \times \mathbf{B}$ electric field. Shock parameters used in the simulation are determined from plasma and magnetic field observations fit to the Rankine-Hugoniot equations which conserve mass, momentum and energy across the shock surface. Shock normals are determined from the single spacecraft method of Lepping and Argentiero (1971) and from the method of Viñas and Scudder (1986) using the Imp-8 magnetic field data and OMNI plasma data. Energy gains and losses are used to predict the amount of enhancement in each sector, assuming an isotropic ambient medium and a relationship between energy and particle number that is based on a power law.

This study is successful because in spite of the simplicity of the shock model used, we were able to reproduce the essential observed features, *i.e.*, the observed angular distributions in the lowest energy proton channel for sectors which interacted with the shock. The 1974 day 312 shock is a text book example of the model correctly predicting the observations. Some conclusions drawn from the results of seven interplanetary shocks follow. (1) Shocks with small observed count rates and values of $\theta_{Bn}$ less than 45° do not show good agreement with model predictions. (2) Shocks with large observed count rates and values of $\theta_{Bn}$ greater than 45°, with upstream magnetic fields which can be idealized as one value with superimposed noise and increases in magnetic field strength from upstream to downstream greater than 2, show good agreement between upstream observations and predictions in sectors which have

interaction with the shock. (3) Downstream predictions show poor agreement with observations except in two cases.