Mechanisms of Particle Acceleration Near the Sun
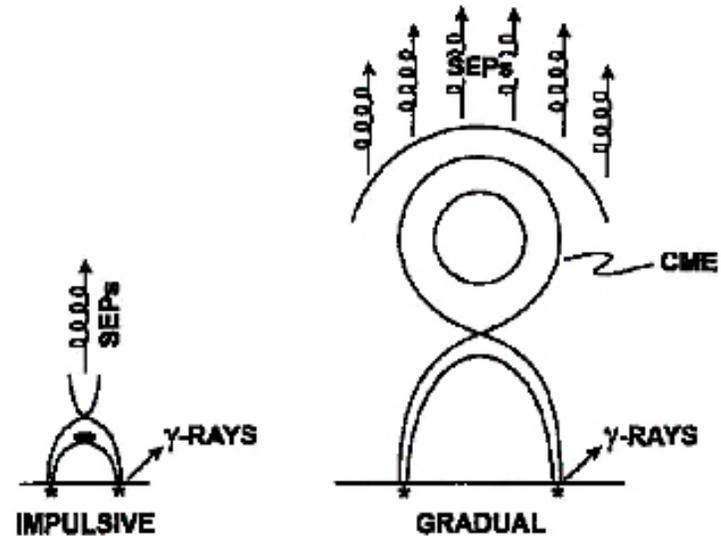
This session focused on general acceleration mechanisms near the Sun and in the inner heliosphere.

Because of a lack of *in situ* measurements near the Sun, no single acceleration mechanism has emerged as being dominant.
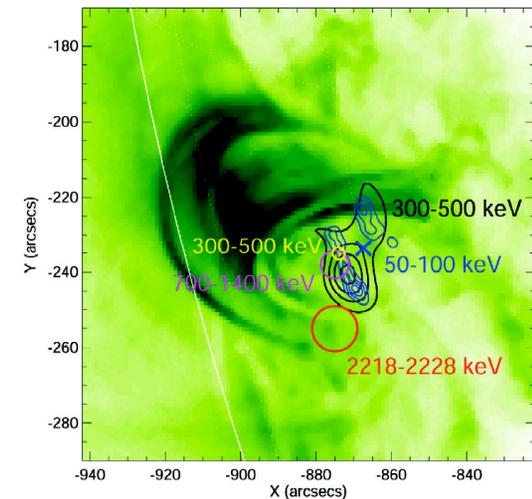
Invited Speakers:
- **Bob Lin**, *UC Berkeley – **Plenary Talk***
- **Jim Miller**, *University of Alabama, Huntsville*
- **Yuri Litvinenko**, *University of New Hampshire*
- **Randy Jokipii**, *University of Arizona*
- **Chee Ng**, *NASA, Goddard*
- **Vahe Petrosian**, *Stanford University*

Acceleration Mechanisms

- **Resonant Stochastic Acceleration**
  - – **J. Miller and V. Petrosian**
- **Parallel Electric Fields**
  - – **Y. Litvinenko**
- **Diffusive Shock Acceleration**
  - – **J.R. Jokipii**
- **Shock Acceleration + self-excited waves**
  - – **C. Ng**
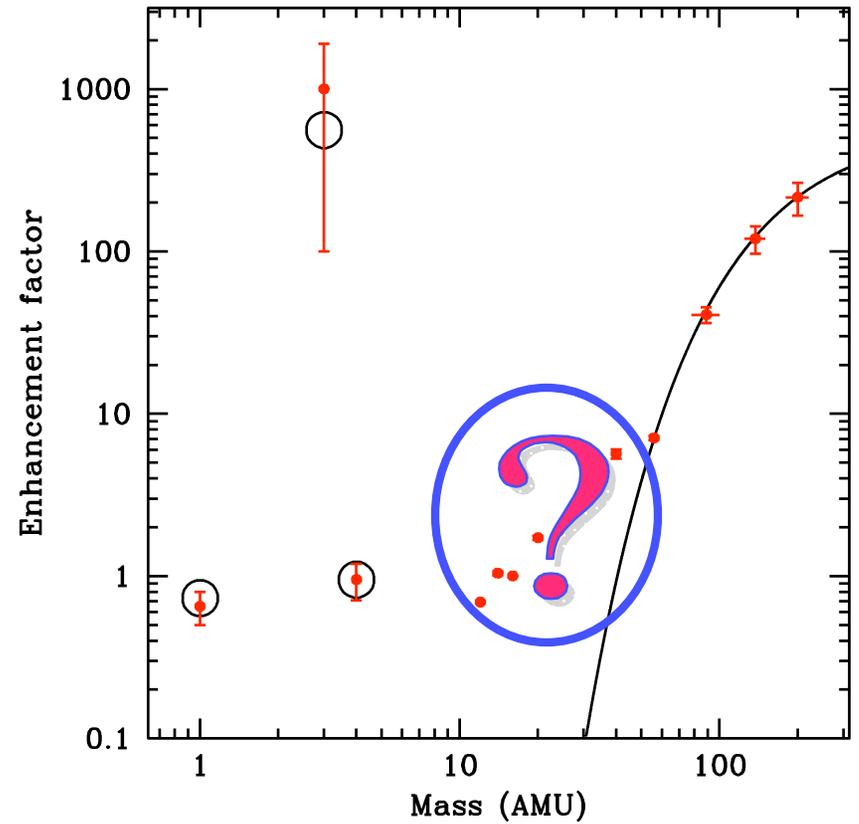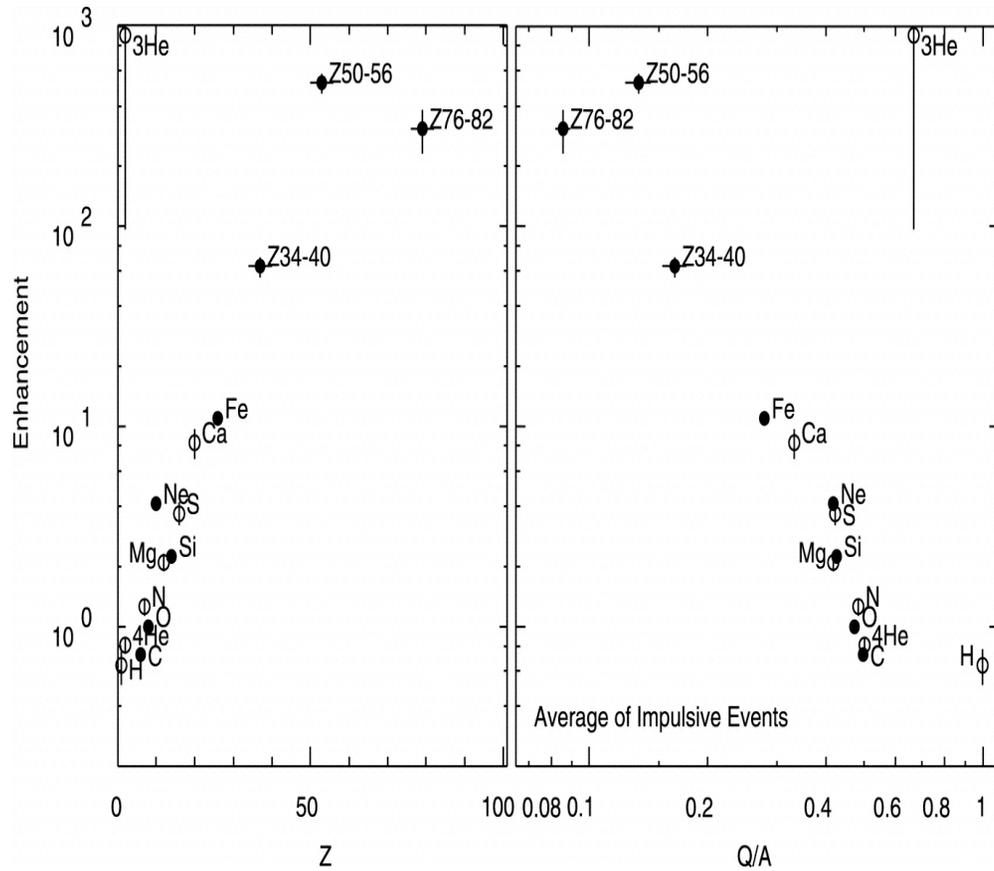- **A new stochastic-like model**
  - – **L. Fisk**

Resonant Stochastic Acceleration
(Applied to Solar Flares)

- Assumes plasma waves are distributed uniformly throughout a coronal loop ($\delta B \ll B$)

- Successful for $^3\text{He}^{++}$ enhancements in impulsive flares

- Solve a momentum-diffusion equation

$$\left(\frac{\partial f}{\partial t}\right)_w = \frac{\partial}{\partial \mu} D_{\mu\mu} \frac{\partial f}{\partial \mu} + \frac{\partial}{\partial \mu} D_{\mu p} \frac{\partial f}{\partial p} + \frac{1}{p^2}\frac{\partial}{\partial p} p^2 D_{p\mu} \frac{\partial f}{\partial \mu} + \frac{1}{p^2}\frac{\partial}{\partial p} p^2 D_{pp} \frac{\partial f}{\partial p}$$
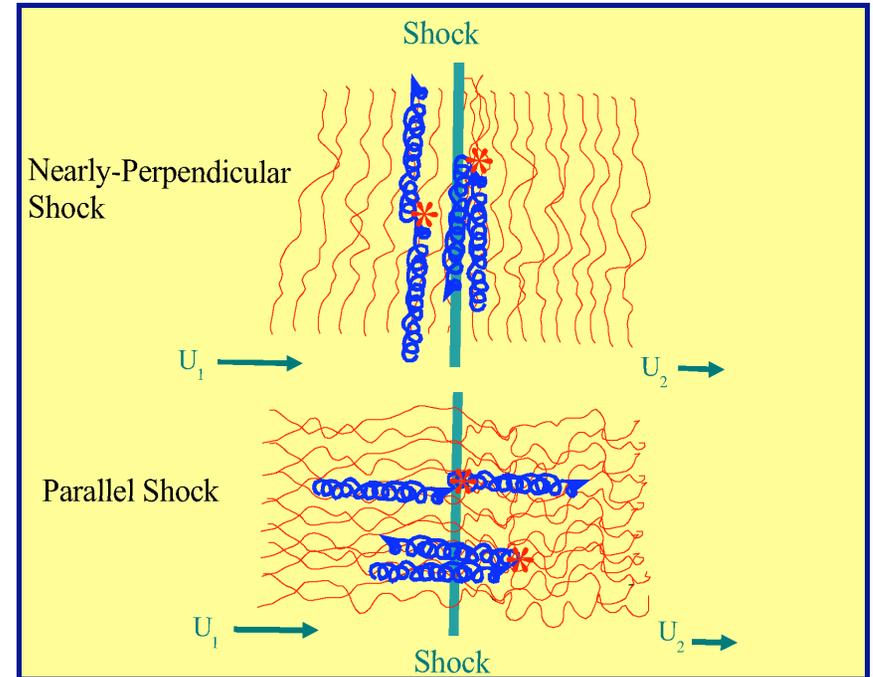
Heavy ion enrichment

Acceleration by Parallel Electric Fields
(Applied to Solar Flares)

- Power-law comes about because of the topology of reconnection

- Maximum energy is limited by the size of the electric potential that is set up

- Self-consistent simulations indicate a type of Fermi acceleration may also take place in collapsing magnetic traps
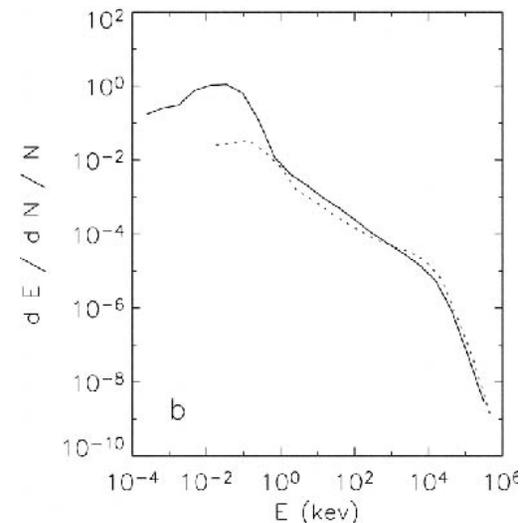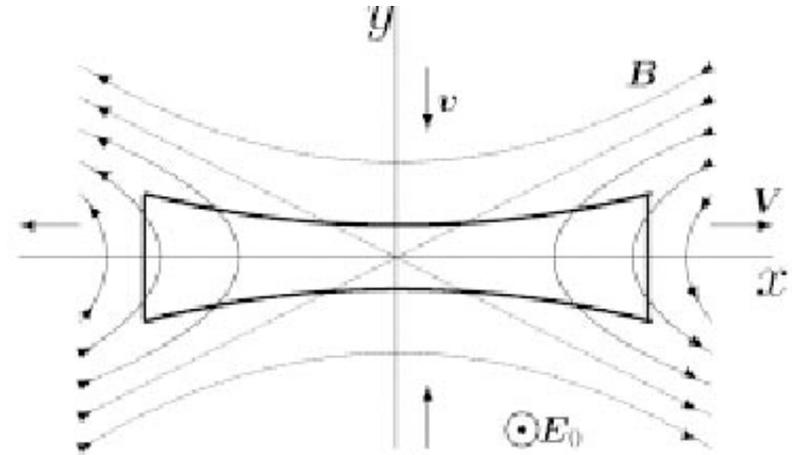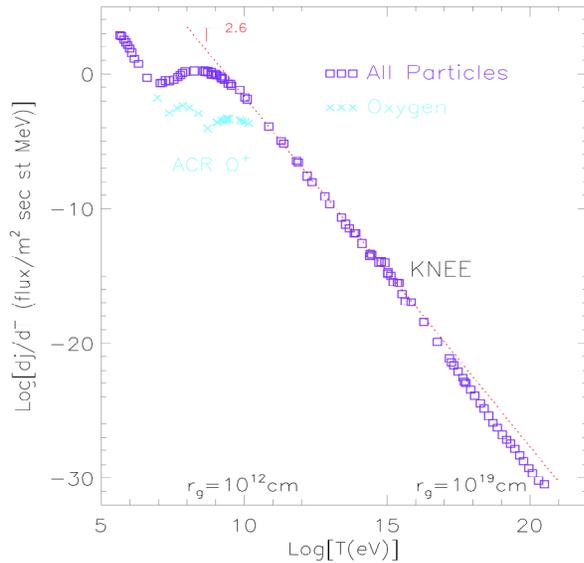
Shock Acceleration
(applied to CMEs and flares(?))

- Particles diffuse across a diverging flow (a shock)

- Requires some form of trapping near the shock (magnetic turbulence)

- Gives a power law energy spectrum depending only density compression across the shock
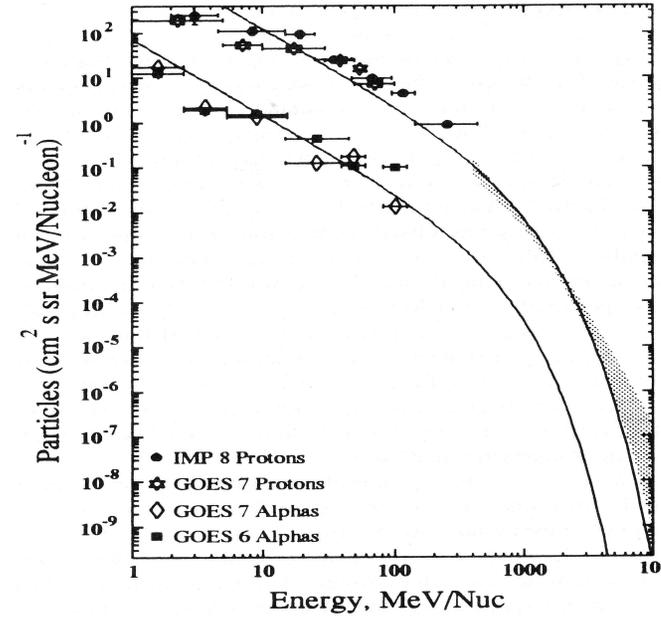

$$\frac{\partial f}{\partial t} = -V_{w,i}\frac{\partial f}{\partial x_i} + \frac{\partial}{\partial x_i}\kappa_{ij}\frac{\partial f}{\partial x_j} - V_{D,i}\frac{\partial f}{\partial x_i} + \frac{1}{3}\frac{\partial V_{w,i}}{\partial x_i}\frac{\partial f}{\partial \ln p} + Q$$
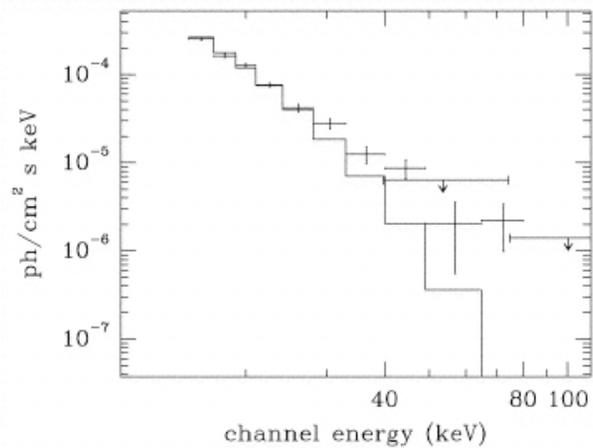
The observed energy spectra of cosmic rays are remarkably similar everywhere they are observed.
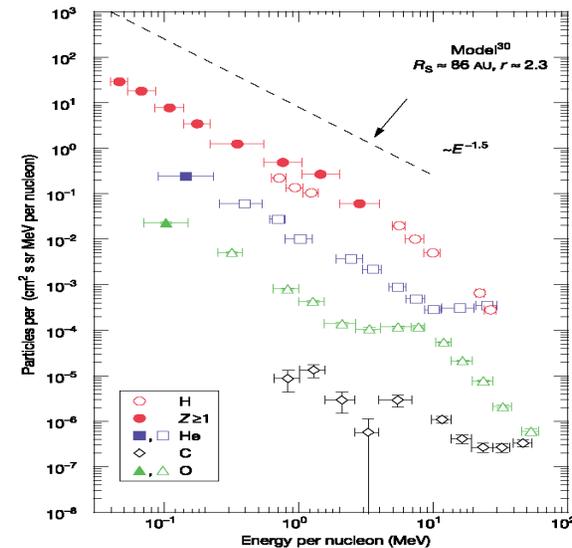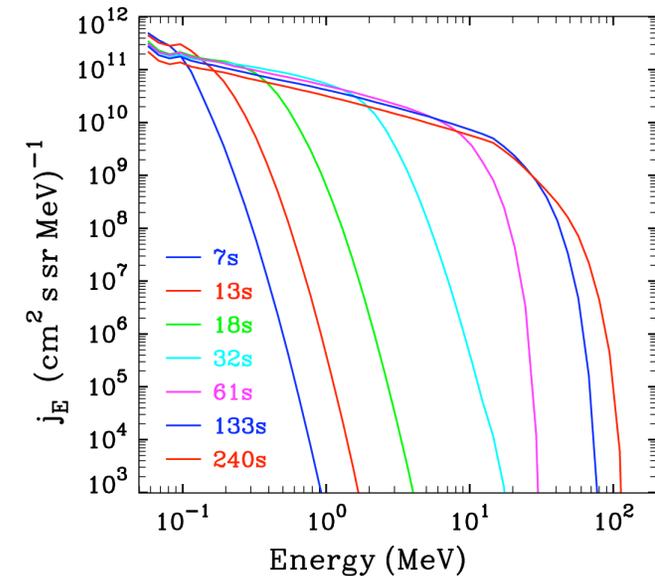

Galaxy

Sun

Coma Cluster

ACR

Acceleration time in shock acceleration

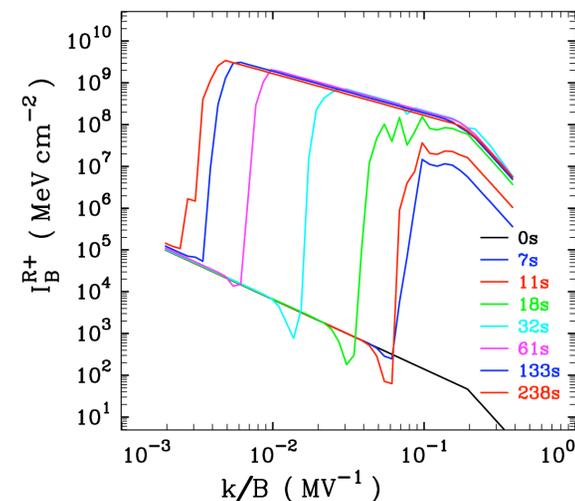- The acceleration rate depends strongly on the particle scattering

$$\frac{1}{p_c}\frac{dp_c}{dt} = \frac{V^2_{shock}(t)}{8\kappa_{xx}(p_c,t)}$$

- Energetic particles can excite low-frequency waves which can scatter the particles and reduce the scattering time.

    – This is very important for parallel shocks

H^+ Spectra at Shock

I^{R+}_B at 1.E−6 AU from Shock

A new approach (applied to Flares?)

Len Fisk started with an equation for the evolution of the open magnetic field

$$\frac{\partial \mathbf{B}}{\partial t} = -\nabla \times \nabla \times (\kappa \mathbf{B}) + \nabla \times (\mathbf{U} \times \mathbf{B})$$

Which can be rewritten as

$$\frac{\partial \mathbf{B}}{\partial t} = \nabla \times \left[(\mathbf{U}_\kappa + \mathbf{U}) \times \mathbf{B} \right]$$

$\nabla \cdot \mathbf{U}_\kappa$ Gives rise to an energy change in energetic particles