Chapter 2

Introduction to Physical Study of Cosmic Rays

2.1 Cosmic Rays

Cosmic rays are energetic particles, mostly protons, nuclei, and electrons, spreading out through the interplanetary medium in space. The sun emits these energetic particles into space at all times, generating a solar wind with a constant speed of about 400 km/hr when in a stationary state. The interplanetary medium is so tenuous that the spatial density of cosmic rays in space is less than 10^{-10} particles/cm^3 (Morrison, 1965), then the interaction between cosmic ray particles can be ignored but the interaction between the particles and the interplanetary electromagnetic field is important. However, due to the tenuous density and being charged particles, the conductivity property being considered, they are not affected by the electric field because the electric field vanishes in a conductor. But because they are moving charged particles, they get the influential force of magnetic field. The interplanetary magnetic field is irregular thus the charged particles are scattered while propagate through space. A physical model is devised to investigate the propagation of cosmic rays. The model is in form mathematical equations. Factors expected to influence the propagation of cosmic rays are included into the equations. Such factors are streaming, convection, focusing, differential convection, pitch-angle scattering, and deceleration (Ruffolo, 1995). The equation just set up is called the transport equation.

2.2 Solar Wind

The solar corona expands into space because the Sun's atmosphere is not

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in static equilibrium (Parks, 1991) and interplanetary medium is more tenuous than the Sun. This expanding corona is called solar wind (Parker, 1958). This solar wind can expand into the most distant region of space. Our solar system is entirely pervaded by the solar wind.

2.3 Solar Flare

Solar flares are huge explosions on the surface of the sun (Ruffolo, 1996). These phenomena have been observed years ago up to now without clear understanding of their causes. The solar flares can accelerate the cosmic rays and these particles can have serious effects on the earth such as disrupting radio communications, causing electric power failures, or even causing radiation warning on transoceanic airplane flights and they can also make the phenomena called aurora or the northern lights i.e. bands of colored light, mainly red and green, seen in the sky at night near the North Pole. However, the mystery of solar flare still needs explanation especially the 11-year periodicity in their frequency, the more recently observed 5-month periodicity and the mechanism which solar flares accelerate cosmic rays. We can observe solar flares by means of electromagnetic radiation such as radio, infrared/visible, UV, X-rays, and gamma-rays or by mean of cosmic rays such as protons. electrons, neutrons, pions and heavy ions.

2.4 Anisotropy

At any point in space we are working about distribution of particles, if the distribution is uniform equally in all direction we say that the distribution at that point is isotropic, otherwise it is anisotropic. In this work the direction is governed by the cosine of the angle between the interplanetary magnetic field and the direction of the momentum of a particle. In such a case there are two anisotropies associated. If the distribution of density of particles and this cosine change oppositely, i.e. one increases while the other decreases, we call this the negative anisotropy, but if the distribution of particles and the cosine increase together, we call it positive anisotropy.

2.5 Downstream, Upstream Regions and Solar-Flare Shock

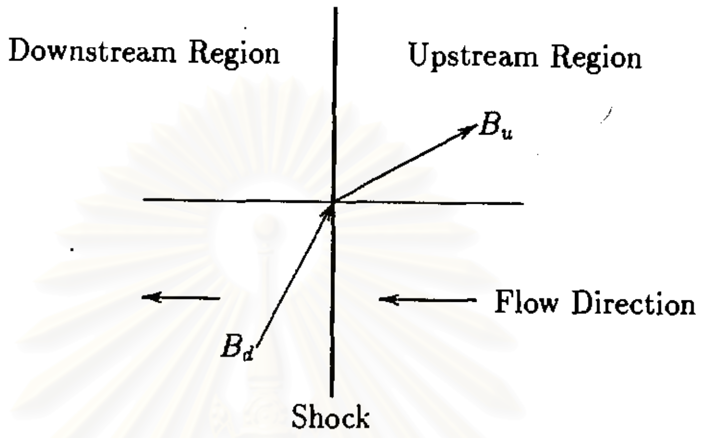

Figure 2.1 Diagram showing downstream, upstream regions and shock. B_d is the magnetic field downstream, and B_u is that upstream.

When solar flares take place they generate a disturbance moving at speed higher than solar wind in stationary state. This disturbance is called shock. The shock separates solar wind into two regions, one region ahead and the other back of it. The region ahead of the shock is called upstream region while that back of it is called downstream region. According to the principle of inverted flow (Krasnov, 1985) there is no difference between the moving of the shock in stationary solar wind and the moving in opposite direction of solar wind with the stationary shock. Figure 2.1 shows the stationary shock with solar winds flowing in the direction from right to left. The observer on the shock will find that the upstream region is flowing toward him while the downstream region flowing outward him. The figure also shows that the interplanetary magnetic field kinks at the shock.