sufficiently high relative velocity, penetration would be possible. For example, suppose that at the outer boundary of the heliopause at ~70 AU the nebular material has a density of 5×10^{-21} g/cm^3. If 4% of this material were to attain a velocity of 4 km/s, then a pressure of 1.6×10^{-11} dynes/cm^2 would be exerted on the heliopause, easily overpowering the opposing solar wind pressure which would be only $\sim 10^{-12}$ dynes/cm^2.

Under normal conditions the sweeping and eroding action of the solar wind and the pressure of the Sun's radiation are adequate for maintaining the solar system in a relatively dust free condition. However if dust were to enter the solar system at rates as high as 8×10^{-17} g/cm^2/s (i.e., 5×10^{-21} g/cm^3 $\times 0.04 \times 4 \times 10^5$ cm/s), these expulsion processes would become swamped. In addition, the solar wind's limited ability to expel particles and gas would itself become hampered since the heliopause sheath would become compressed by the incident cosmic ray blast to a position much closer to the Sun. This would allow nebular gas and dust to advance much closer to the Sun, and deeper within the Sun's gravitational field of influence, before becoming subjected to the solar wind.

The equilibrium position attained by the heliopause may be estimated as follows. The solar wind blows at an average velocity of ~500 km/s and has an average ion density of ~5 ions/cm^3 at the Earth's distance from the Sun (Brandt, 1970, p. 150), and hence exerts an outward pressure of $\sim 10^{-8}$ dynes/cm^2. Assuming that ~90% of the energy intensity carried by the superwave ($\sim 2.7 \times 10^{-9}$ dynes/cm^2) were able to exert a back pressure on the helio-pause sheath, at equilibrium the sheath would become propelled inward to an heliocentric distance of ~1.9 AU where this "galactic wind" pressure would just counterbalance the outward pressure of the solar wind. (Solar wind pressure varies according to the inverse square of heliocentric distance.) Thus the heliopause sheath would become compressed to a position just outside the orbit of Mars; see Figure 3.15. Although the solar wind fluctuates in intensity the position of the heliopause would not deviate appreciably from this average position, due to its own inertia.

The rate at which the heliopause sheath would become accelerated by the cosmic ray blast would depend on the amount of charged dust and ionized gas trapped in its magnetic web. If the mass column density of the heliopause sheath were on the order of 10^{-5} g/cm^2 then under a pressure of 3×10^{-9} dynes/cm^2 presented by the superwave, it would be able to accelerate at a rate of $\sim 3 \times 10^{-4}$ cm/s^2, covering the distance from its former position at 70 AU to its equilibrium position at 1.9 AU in about 80 years. However, if the mass column density (and hence inertia) of the heliopause were considerably higher than the value assumed above, then it is conceivable that the movement of the heliopause would be so slow that it would never attain its equilibrium position.

As this gas and dust advanced forward, it would become drawn radially toward the Sun under the influence of the Sun's gravitational field. Hence the concentration of this material would accordingly increase. At the Earth's distance from the Sun, a 1000 fold increase could be expected, giving a density of $\sim 2 \times 10^{-19}$ g/cm^3. This assumes that in going from 100 AU to 1 AU the radial velocity of this material increases from ~4 km/s to ~40 km/s. Suppose that 50% of the vaporized cometary material is in the form of dust (mostly submicron-sized grains), the remainder consisting primarily of water and including traces of other volatile substances such as CO_2, NH_3, CH_4, and C_2H_2. Then the density of the dust fraction in the Earth's vicinity would be on the order of 10^{-19} g/cm^3. This would be about 15 times higher than present interplanetary dust densities.

It should also be mentioned that, besides gas vapors and finely divided dust particles, the comet vaporization process would also produce ice chunks of varying sizes. Explosive ejection would cause a large fraction of this coarse debris to become propelled into the solar system where it would bombard the Earth and other planets. To make a crude estimate of the earth-impact frequency for such material, suppose that 0.1% of the vaporized material were ejected in the form of 1-meter diameter ice chunks following orbital trajectories

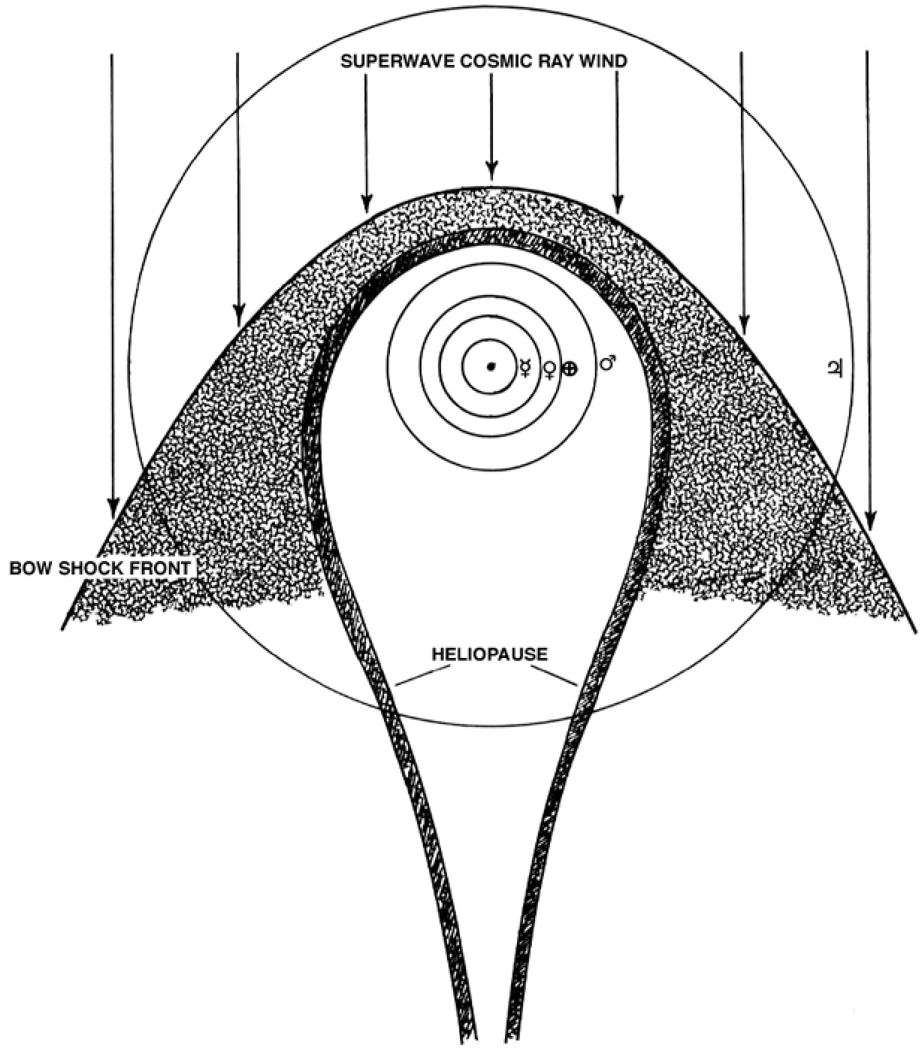

Figure 3.15. The heliopause sheath and the superwave bow shock front hypothetically compressed by the superwave cosmic ray blast to a position just outside the orbit of Mars. Shaded areas indicate regions of turbulent magnetic field.

carrying them inside the periphery of the Earth's orbit. Given that there would be a 10^{-9} chance of any given chunk hitting the Earth, then a flux of 10^3 - 10^4 earth impacts per day could be expected. Chunks of this size would not do any physical damage since they would completely disintegrate before striking the ground. Kilometer-sized objects, however, would be capable of producing impact craters on the Earth's surface, but objects this large would probably be encountered very rarely.

Cosmic Dust Deposition on the Earth's Surface. As a result of increased ambient dust concentrations prevailing during the passage of a superwave, the rate of cosmic dust influx to the Earth's surface would be expected to increase. The rate of cosmic dust influx to the Earth's surface in the presence of a directed nebular flow of relative velocity v and space concentration ρ is given approximately as:

$$\phi = 0.25 \cdot \rho \cdot v \cdot (1 + (11.1/v)^2. \qquad (6)$$