PHOTOELECTRONS AND SOLAR WIND/LUNAR LIMB INTERACTION*

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Abstract. It is suggested that boundary conditions for solar wind/lunar limb interactions are active. The 'whole-Moon' limb does not evoke a shock cone because warm (∼13 eV/electron) solar wind electrons are replaced by cool (∼2 eV/electron) photoelectrons that are ejected from the generally smooth areas of the lunar terminator illuminated at glazing angles by the Sun. A localized volume of low thermal pressure is created in the solar wind by these cool photoelectrons. The solar wind expands into this turbulence-suppressive volume without shock production. Conversely, directly illuminated highland areas exchange hot photoelectrons (>20 eV/electron) for warm solar wind electrons. The hot electrons generate a localized pressure increase (Δp) in the adjacent solar wind flow which evokes a shock streamer in the solar wind. Shock streamers are identifiable by a coincident increase in the magnitude (ΔB ∼ Δp) of the solar wind magnetic field immediately external to the lunar wake. Shock occurrence is controlled by lunar topography, solar activity in the hard ultraviolet (>20 eV), solar wind electron density and thermal velocity, and the intensity of the solar wind magnetic field.

1. Introduction

Observations by Colburn et al. (1967), Ness et al. (1967), and Lyon et al. (1967) of the wake structure evoked in the solar wind downstream of the Moon pose a definite problem (Figure 1). The Moon is immersed in a solar wind flow which is always supersonic. Thus, in analogy with the Earth, a definite shock structure should exist downstream. Such a shock would be characterized by local increases of plasma density (n), pressure (p) and the magnitude Bsw of the solar wind magnetic field Bsw. However, a shock is usually not observed at the distances of 2–5Rm (Rm = 1738 km ~ lunar radius) from the Moon accessible to the lunar orbiting Explorer 35. Rather, a region devoid of plasma is produced (region 2). The solar wind plasma simply expands into this downstream void until a pressure balance (p + Bsw^2/8π = Bv^2/8π) is achieved between the enhanced magnetic field (Bv) of the void region and the total external solar wind pressure. The Moon as a whole evokes a gentle, nearly undisturbed flow pattern in the solar wind rather than a shock. The void/solar wind boundary (1) is usually characterized by a locally decreased magnetic intensity (−ΔB). Electron surface currents in the boundary induce this diamagnetic decrease.

The problem became a dilemma when subsequent observations were made of shock streamers (Ness et al., 1968; Colburn et al., 1971) external to the wake (point 3 in Figure 1). The streamers are generated when specific lunar highland features are present on or near the lunar terminator. The basic problem is clear: Why do specific

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Fig. 1. Four significant features of the plasma flow downstream of the Moon are illustrated. Region (2) is devoid of solar wind plasma due to accretion and neutralization of ions and electrons on the sunward hemisphere. Region (4) is the undisturbed solar wind. Considerable theoretical work has been directed toward explaining the morphology of the expansion region (4) in terms of either magnetohydrodynamic flow or of free streaming particles. The highland associated shock streamer (region (3)) is not consistent with these theories. Generally similar downstream magnetic profiles are measured by the high altitude Explorer 35 and the low altitude (~100 km) Apollo-15 subsatellite. Small scale (10–100 km) lunar regions, when located in or near the terminator, evoke shock streamers while the entire lunar limb (~10900 km) does not?

Separate approaches have been suggested in the literature to explain the lack of an overall lunar shock and the sporadic occurrence of shock streamers. Lack of a 'whole-Moon shock' is credited to the complete adsorption and electrical neutralization by the lunar surface of solar wind plasma striking the sunward hemisphere (Gold, 1966; Sonett and Colburn, 1967, 1968; Johnson and Midgley, 1968). Siscoe et al. (1969) and Spreiter et al. (1970) have noted that the neutralizing and adsorptive ability of the Moon must be extremely precise to produce no more deviation of the wake plasma than observed. In addition, the low internal electrical conductivity of the lunar bulk (~10^{-5} mhos cm^{-1}) permits the solar wind magnetic field to convect unhampered through the Moon. Thus, no significant magnetic field increases occur in front of or inside the sunward hemisphere which could couple into the adjacent solar wind flow and evoke a general shock (Sonett et al., 1972). Dryer (1968) pointed out that the lack of a lunar bow shock at 1.5 R_m precluded flow coupling of the Moon and solar wind on the scale of the cyclotron radius (r_p ~100 km) corresponding to the thermal velocity of solar wind protons.