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SOLAR-WIND MAINTENANCE OF THE NIGHTTIME VENUS IONOSPHERE

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In this talk we propose a possible ionization source which can reproduce the observed features of the nighttime Venus ionosphere.

Let us first consider the observed electron density profiles inferred from the two-frequency occultation experiment on Mariner 5, which are shown in Figure 1. The electron density is shown as a function of altitude for both dayside and nightside. The dayside ionosphere is understood reasonably well from models in which the ionization layer, with a peak at 140 km, corresponds to essentially pure CO_2 in photochemical equilibrium. The topside ionosphere, indicated by the large scale height above about 200 km, is composed of light ions, hydrogen and helium, in diffusive equilibrium. The sharp density cutoff at about 500 km corresponds to the interface between the ionosphere and the solar wind and is termed the ionopause. On the nightside, the ionization peak also occurs at 140 km with a density of about 20 000 cm^{-3}. We also note the appearance of a light ion tail.

The maintenance of the nightside ionosphere is more difficult to explain primarily because the rotation period of the planet is about 225 days whereas the relaxation time of a CO_2 ionosphere is on the order of 100 s. Several mechanisms have been proposed that seem unrealistic to us. The mechanism we suggest is that of corpuscular ionization and heating due to the penetration of solar-wind plasma into the nightside ionosphere.

To make this possibility more conspicuous, let us consider the solar-wind interaction model illustrated in Figure 2. We have adopted this interaction model because it is consistent with Mariner 5 and Venera observations. In this model the magnetic field, carried along by the solar wind, is forced to pile up on the dayside of the highly conducting ionosphere, forming a magnetic obstacle in the solar wind which diverts the wind around the planet and results in the formation of a bow shock. This interaction results in hot 10^6 K solar-wind plasma surrounding the cold 10^3 K ionospheric plasma. A small fraction of the hot solar-wind plasma is expected to leak across the unstable ionopause and into the ionosphere. Upon entering the ionosphere, a solar-wind proton charge exchanges with the dense CO_2 gas to produce a hot neutral hydrogen atom which then penetrates deeper, scattering and ionizing CO_2 on its way. A hot hydrogen atom so produced typically suffers 20 such collisions before thermalizing, efficiently heating and ionizing the atmosphere in the process.

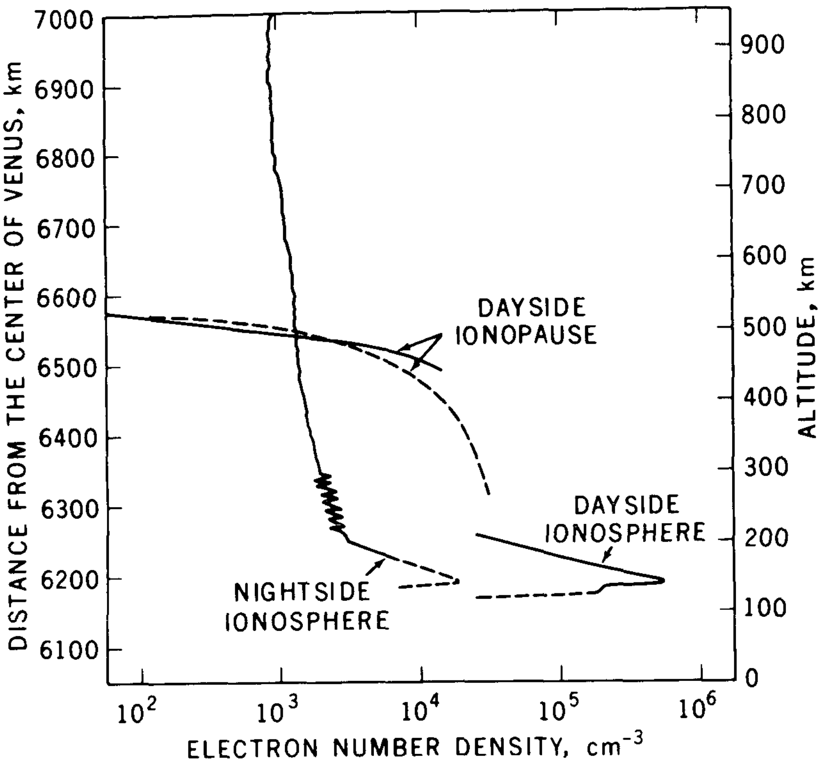

Figure 1–Observed electron density profiles (from Ref. 1).

We have evaluated the significance of this ionization and heat source in the context of our previously developed Venus ionosphere model which is based on a self-consistent solution of the continuity, momentum, and heat transport equations. We obtain the spatial and energy distributions of the incoming solar-wind flux by an appropriate multienergy group transport theory. On applying this new source to the dayside, we find that both the ionization and heating caused by this flux are ignorable relative to that due to extreme solar ultraviolet light. On the nightside, however, where the solar-wind flux is the primary ionization source, we find that only as little as 2 percent of the solar-wind energy flux is required to produce the observed ionization peak. The results of this model are shown in Figure 3.

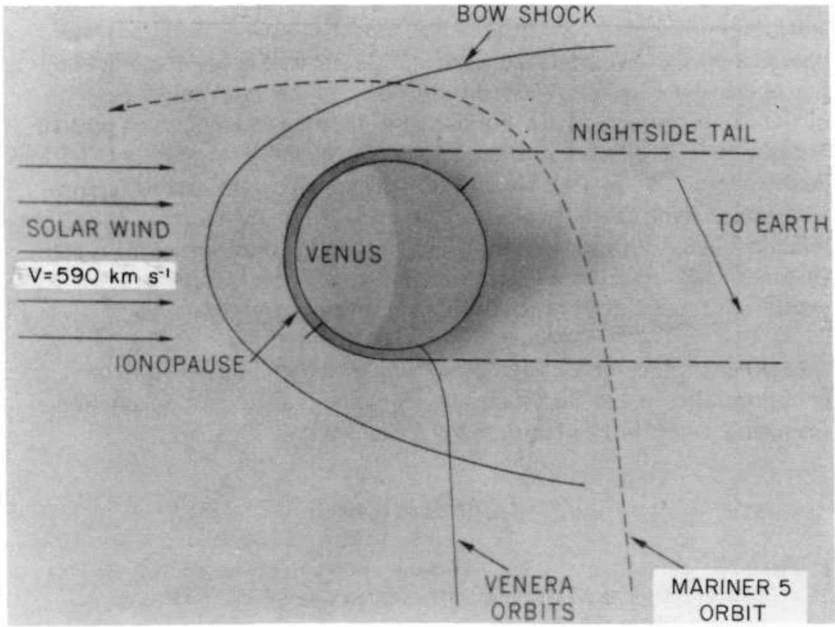

Figure 2–Solar-wind interaction model.

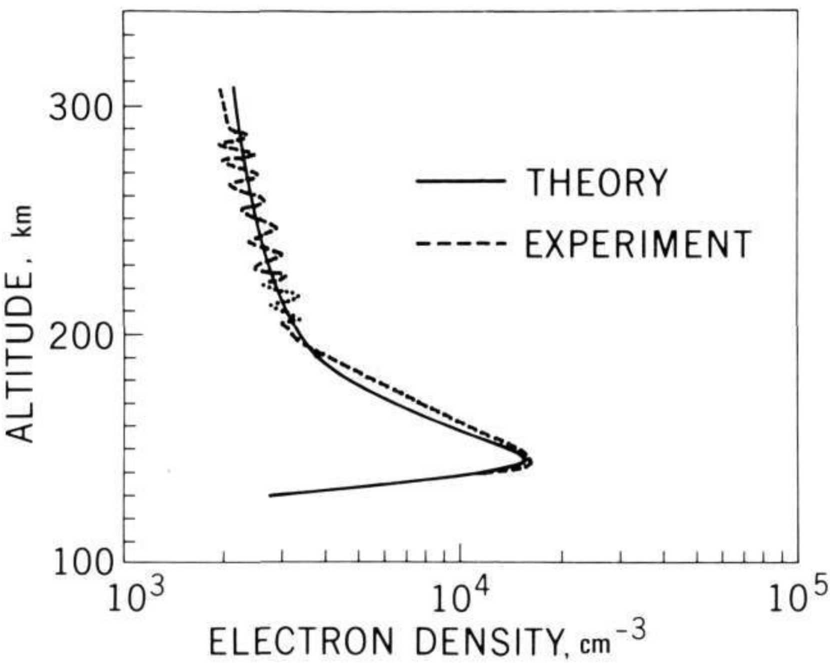

Figure 3–Nightside ionosphere model.

In Figure 3, the electron density is given as a function of altitude, where the solid line corresponds to the theoretical model and the dashed line is the observed profile. We see that the theoretical model can be placed in excellent agreement with the observed profile and, in this case, only 2 percent of the solar-wind energy flux is required to produce the ionization peak of 20000 cm^{-3}. The lower ionization layer corresponds to primarily CO_2^+ ions. Above about 200 km we have outward-streaming H^+ ions producing the large-scale height. These light ions flow upward rapidly because of the large polarization electric field present which propels H^+ outward with a force 21 times that of gravity. In fact, if the tail is sufficiently extended, we expect a strong tailwind which may reach supersonic speeds.

Altogether then, from our good agreement with the observed electron density profile, we conclude that the solar-wind is a strong candidate for the maintenance of the nighttime Venus ionosphere.

REFERENCE

1. Fjeldo, G., and Eshleman, V.R.: Atmosphere of Venus as Studied With the Mariner 5 Dual Radio Frequency Occultation Experiment. Radio Sci., Vol. 4, 1969, p. 879.