NSG-269

# INDUCED MAGNETOSPHERE OF VENUS

by

Francis S. Johnson and James E. Midgley
Southwest Center for Advanced Studies
Dallas, Texas, USA

Prepared for Presentation at

The COSPAR 11th Plenary Meeting

Tokyo, Japan

May 9-21, 1968

f.16

# INDUCED MAGNETOSPHERE OF VENUS

Francis S. Johnson and James E. Midgley
Southwest Center for Advanced Studies
Dallas, Texas, USA

Abstract

It is suggested that the conductivity of the ionosphere of Venus (or Mars) gives rise to an induced magnetosphere formed by piling up magnetic field from the solar wind; it is assumed that the planet has no intrinsic field. Dessler has noted that the ionospheric conductivity is such as to seriously impede the convection of interplanetary field, causing field to build up to a stagnation value sufficient to divert the solar wind and cause a shock wave to develop. It is suggested here that collisions of solar wind particles with atmospheric particles will lead to further accumulation of field, thickening the region of stagnation field strength to the point where the solar wind is diverted at high enough altitude so that collisions with neutrals no longer significantly impede the flow. The outer boundary of the stagnation field region constitutes a magnetopause above which any ions formed from atmospheric particles are quickly swept away by the electric field associated with the solar wind; this level is identified with that near 500 km altitude where the daytime ionization drops off to an undetectable value according to the observations of the Stanford Group in Mariner 5.

The flow of the solar wind is seriously disturbed when a planetary sized conductor is placed in it. The moon is an example of a poor conductor that does not seriously disturb the flow other than by producing a shadow zone in it; the solar wind impinges directly on the lunar surface and is neutralized there, and no shock wave is produced in the flow ahead of the moon. This was shown by measurements made in Explorer 35 (Ness et al., 1967; Colburn et al., 1967), and analyses of the problem have indicated the nature of the interaction to be expected if the moon were a better conductor (Sonnett and Colburn, 1967; Johnson and Midgley, 1968).

When a planet with an atmosphere is exposed to the solar wind, the presence of the atmosphere complicates the interaction. The atmosphere normally provides an insulating layer that eliminates the conductivity of the planet itself from the problem for all except transitory changes in the interplanetary magnetic field, which can induce eddy currents in the planet. However, if there is an ionosphere within the atmosphere, its conductivity should play an important role in the interaction. Dessler (1968) has pointed out that the ionospheric conductivity resists the rapid passage of interplanetary magnetic field through it, and that as a result the magnetic field should build up strength ahead of the ionosphere until it is strong enough to divert the solar wind, thus cutting off the rapid influx of additional interplanetary field into the ionospheric region. The diversion of the solar wind in addition causes the development of a shock front, a feature which was observed near Venus by Mariner 5 (Bridge et al., 1967).

The overall picture then is one in which magnetic field piles up above a current system in the ionosphere to a value able to withstand the stagnation pressure of the solar wind, i.e. able to deflect the solar wind. The solar wind passes through a shock front, and then on approaching the ionosphere transfers its pressure to the magnetic field. The magnetic field in turn transfers its pressure to the neutral atmosphere through the mechanism of the ionospheric current system. The region of built up magnetic field constitutes an induced magnetosphere. The thickness of the built up field region must be governed by the conditions that control the entry of field at the top and the exit of field from the bottom of the ionosphere. Since the field strength cannot be built up above its stagnation value, the thickness of the region of stagnation strength field must increase until the rate of entry of field is reduced to match the losses.

We have calculated the rate of leakage of magnetic field through the ionosphere assuming the presence of no field below the ionosphere and a stagnation field in the ionosphere above the level where ionospheric currents can flow. The rate of field leakage, for reasonable assumptions for electron and neutral particle concentrations, is about $10^{-4}$ of the field convected up to the planet by the solar wind. Therefore it appears that all but one part in ten thousand of the magnetic flux convected up to the planet by the solar wind is deflected around the planet. The same factor probably applies for the proportion of the solar wind that flows around the planet rather than impinging upon the atmosphere.

A value for the thickness of the region in which the magnetic field is built up to a stagnation value can be deduced from observation. Occultation measurements made with Mariner 5 (Mariner Stanford Group, 1967) indicated a plasmapause or sudden drop off of ion concentration from a value near $10^4$ $cm^{-3}$ to a value indistinguishable from the interplanetary concentration about 400 km above the ionospheric maximum. It is tempting to identify this with the outer boundary of the built up magnetic field, or the magnetopause, assuming the boundary to be relatively sharp and the field strength to be rather uniform from near the ionospheric maximum out to the boundary. In this case, any ions formed from the neutral atmosphere by photoionization within the magnetic field region have relatively long lifetimes, while any formed beyond the induced magnetosphere are rapidly swept away by the solar wind, the electric field in the solar wind providing the acceleration mechanism.

The principal problem associated with the picture of an induced magnetosphere is the physics of the interaction between the shocked solar wind and the stagnation magnetic field. There are two aspects to this problem: the flow of current between the plasma and the ionosphere, and the effects of collisions between particles in the shocked solar wind and the neutral atmosphere. With magnetic field slipping through the ionosphere at a slow rate on the lower side of the stagnation field region, there must be an equal introduction of magnetic field from the upper side to maintain continuity; the detailed means by which this occurs has not been recognized, but it is probably regulated by collisions between solar wind and atmospheric particles. A related question is why there should be a sudden transition at the outer boundary of the stagnation field region rather than a gradual decrease in magnetic field and a gradual transition into the solar wind plasma. However, the concept that the magnetic field builds up to the point where it is able to divert the solar wind implies that there should be a magnetospheric type boundary in which the magnetic field pressure inside the boundary is balanced by the plasma pressure outside the boundary.

The role of the built up magnetic field is to divert the solar wind. However, it must not act in such a way as to break the electrical connection between the solar wind plasma and the ionosphere, as that would cut off the current source to the ionosphere and eliminate the magnetic field build up itself. A self-regulating process might develop in which the magnetic field build up stops just short of cutting off the electrical connection. The minimum thickness of stagnation-value field that might conceivably do this is the thickness of a Ferraro sheath (a few kilometers) or, if the sheath is neutralized, perhaps a proton gyro radius in the stagnation field. However, the geometry of the problem suggests a thicker layer. The conducting layer provided by the ionoshere is thin and of broad geographic extent, thus constituting a large thin conducting plate. The current path from the solar wind to the ionosphere is broad and short in length compared to the ionospheric conductor. The geometry therefore suggests that the Pederson conductivity in the built up magnetic field region may be three or even four orders of magnitude lower than that near the ionospheric maximum and still provide a good electrical path between the shocked solar wind and the ionospheric current system. The electron concentration required to produce this conductivity in a stagnation magnetic field is of the order of magnitude of $10^4$ $cm^{-3}$, which is about what was observed near the magnetopause (Mariner Stanford Group, 1967). We therefore suggest that the outer boundary of the induced magnetosphere occurs at at that altitude where the ambient atmosphere can no longer support a sufficiently dense upper ionosphere to provide an adequate electrical connection between the solar wind and the lower ionosphere.

This research was supported by NASA Grant NsG-269.