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A COMPARATIVE STUDY OF PLANETARY BOW SHOCKS

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ABSTRACT

We present a comparative study of Planetary Bow Shocks in the solar system. The planetary bow shock shape and strength will depend both on the planetary magnetosphere and on the solar wind strength (Mach Number). The solar wind properties vary with the heliocentric distance and this variation will influence on the solar wind-planet interaction. In the solar system, it is known that planets have two types of magnetospheres: induced (Venus, Mars) and intrinsic (Earth, Mercury, Jupiter, Saturn, Uranus, Neptune). The induced magnetospheres of Venus and Mars are caused by the interaction of solar wind with their ionospheres, since their intrinsic magnetic fields are very weak. The others planets are known to have an internal magnetic field (with exception of Pluto, which it is not know at present whether it has or not an intrinsic magnetic field). These differences in the magnetospheres will cause different types of bow shocks. We review the present day knowledge about these bow shocks and show examples of bow shock crossings as measured by magnetometers on spacecrafts.

INTRODUCTION

The study of Planetary Bow Shocks provide us a class of very different space plasma environments. Planetary atmosphere and magnetic field, the presence of satellites and rings, and the distance from the sun constitute factors that influence the shape and characteristics of magnetospheres.

Bow shocks ahead magnetospheres occur because solar wind is moving supersonically in relation to the planets. The electromagnetic interaction between planetary and solar wind plasmas and fields gives the mechanism that make possible the formation of shocks even in the very low density space environment.

We present here a comparative study of planetary magnetospheres and their bow shocks.

METHODOLOGY OF ANALYSIS

The present work has as objective an analysis of the planetary bow shocks in the solar system. We present here a review of our present knowledge about the different kinds of magnetospheres.

FIGURE 1 – Earth's bow shock - noon-midnight meridian cross section of the magnetosphere.
Source: Russel, C. T. (1985)

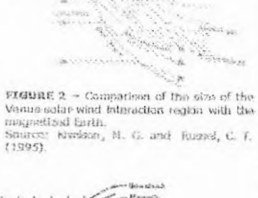

FIGURE 2 – Comparison of the size of the Venus-solar wind interaction region with the magnetized Earth.
Source: Kivelson, M. G. and Russel, C. T. (1995).

FIGURE 3 – Comparison of the sizes of planetary magnetospheres.
Source: Kivelson, M. G. and Russel, C. T. (1995)

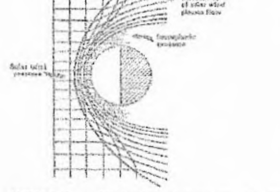

FIGURE 4 – Illustration of pressure balance between the solar wind and the thermal pressure of the ionosphere
Source: Kivelson, M. G. and Russel, C. T. (1995).

It is presented a comparison of the magnetic field strengths measured through the bow shocks on the Earth, Jupiter and Uranus. The overshoot in magnetic field just downstream of the shock ramp is a signature of the strengths of these shocks.

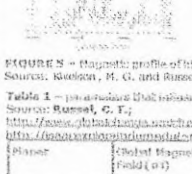

FIGURE 5 – Magnetic profile of high-Mach number shocks at Earth, Jupiter and Uranus.
Source: Kivelson, M. G. and Russel, C. T. (1995).

RESULTS AND DISCUSSION

It was observed:

- when magnetic field and heliocentric distance increase, the magnetosphere of the planet also increase, thus, the distance of the bow shock-planet also increases;
- when the temperatures at the surface of the planet is above the Curie point, the effects of the fields do not persist in rocky materials;
- the strength of a planetary bow shock depends on solar wind strength and then on the planet distance; this is because when the plasma is flowing stronger, the relative speed between planet and solar wind is higher and the shock is stronger. It also depends on the planetary plasma and magnetic field environment, because its combined pressure acts to deflect the solar wind ahead of the planet.

Table 1 – parameters that influence on the bow shock.
Source: Russel, C. T.;
[illegible]
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Planet	Global Magnetic Field (nT)	Relative strength at surface	Heliocentric distance (1 AU)	Magnetopause distance	Surface Temperature (°C)
Mercury	250	0.0007	0.387	1.5 R	260
Venus	10^{-2} B	<0.0004	0.723		480
Earth	31000	1	1	10-15 R	15
Mars		<0.0002			-50
Jupiter	More than 10 B	20.000	5.20	70 R	-110
Saturn	B	600	9.54	21 R	-150
Uranus	Less than B	50	19.19	27 R	-215
Neptune	Less than B	25	30.07	26 R	-225
Pluto	Unknown		39.48		-235

CONCLUSIONS

Planetary environments found in our solar system are quite diverse. This provides us rich examples of a variety of conditions to study space plasmas. Magnetic field and planetary atmospheres, besides the distance fom the Sun, determines the characteristic of each planetary magnetosphere. With recent missions (Galileo, Cassini) and future programmed space missions (Venus Express, Mercury Messenger and Bepi-Colombo, various Mars missions), we expect to improve our knowledge of these fascinating environments in the next years.

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