Pioneer magnetometer observations of the Venus bow shock

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Venus has a bow shock in many respects similar to that of the Earth. The Venus bow shock was probed twice by Mariner 5, once by Mariner 10, Venera 4, and Venera 6 (refs 1–4 respectively) and repeatedly by Venera 9 and 10 (ref. 5). The Pioneer Venus orbiter is now circling Venus in a 24-h elliptical orbit which crosses the bow shock twice a day\(^6\). Here we report the somewhat surprising result that the Venus bow shock is not as strong as the terrestrial bow shock.

The orbit of the Pioneer Venus spacecraft is inclined at 105° to the ecliptic plane with periapsis at a latitude of 17°N and at an altitude of \(\sim 150\) km. This orbital geometry provides shock crossings principally at solar zenith angles of greater than 60°. Figure 1 shows several recent shock crossings as recorded in the change in magnetic field strength. The shocks are ordered from top to bottom in terms of increasing \(\theta_{BN}\), the angle between the interplanetary field direction and the model\(^7\) shock normal. The angle, \(\theta_{BN}\), has been found to order the observed structure of the terrestrial bow shock and the waves upstream of the shock\(^8\). Similar control is observed here but it is not yet clear whether the control is identical to the terrestrial case.

On each panel for \(\theta_{BN} > 50°\) we have listed the field jump in the plane of the shock as determined from 1-min averages again using a shock model to determine the direction of the local shock normal. The average jump is 2.72 ± 0.16. We have repeated this analysis for nine terrestrial shock crossings at similar solar zenith angles and angles, \(\theta_{BN}\), observed by the ISEE spacecraft during December 1977. The average field increase in the plane of the terrestrial shock was 3.37 ± 0.07, almost 25% stronger. Further,
the overshoot in field strength so obvious in the terrestrial shock can barely be recognised in the typical Venus shock crossing.

Figure 2 shows that the weakness of the Venus shock extends over all solar zenith angles sampled to date. Here we plot the jump in the total field, not just in the plane of the shock, for 83 bow shock crossings in the range of solar zenith angles from 60° to 110°. The upper dashed line is the jump in field strength predicted by a gasdynamic simulation of the solar wind–Venus interaction. The Mach number of the incoming flow is 6 and the ratio of specific heats is 5/3 for this simulation. The jump in total field for our nine comparison terrestrial shocks was 3.11 ± 0.10 at a median solar zenith angle of 72°. We note that the observed field jump at the Venus bow shock does decrease with increasing solar zenith angle as in the gasdynamic simulation.

The reason for the weakness of the Venus bow shock relative to the terrestrial bow shock is not obvious. In the gas-dynamic simulation one can decrease the amplitude of the shock jump by increasing the ratio of specific heats from 5/3 to 2, but it is not evident why this ratio would be different for the two planets. We would not expect the Mach number to be significantly different at the two planets.

If the difference in shock strengths were due to some radial variation of solar wind properties we would expect that the shock at Mercury would be even weaker than the Venus shock, this is clearly not so of the two perpendicular shocks seen by Mariner 10 (refs 4, 12) one was comparable to the terrestrial shock in strength and one to the Venus shock.

We have restricted our comparison to a similar range of solar zenith angles, and in this range of angles the shock shape is the same for the two planets. Thus we cannot attribute the difference in shock strengths to differing shock geometries. We must conclude that there is something basically different about the solar wind interactions with the two planets. Perhaps this difference is the existence of photo-ion pickup charge-exchange with the Venus geo-corona. A similar conclusion is suggested by the unexpected closeness of the bow shock to Venus.

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