OBSERVATIONS OF THE SUBIONOSPHERIC MAGNETIC FIELD AT VENUS. C.T. Russell[1], T.L. Zhang[2], M.N. Villarreal[1], J.G. Luhmann[3], P.J. Chi[1], S.D. Xiao[2], W. Baumjohann[2]. [1]Earth Planetary and Space Sciences, University of California, Los Angeles (603 Charles Young Drive, Los Angeles, CA 90095-1567, ctrussell@igpp.ucla.edu), [2]Austrian Academy of Sciences, 1010 Vienna, Austria, [3]Space Sciences Laboratory, University of California, Berkeley, CA 94720, USA.

Introduction: Near the end of its life, the Venus Express spacecraft made a series of low-altitude passes as low as 130 km above the north pole of Venus. It is generally accepted since the Pioneer Venus mid-latitude surveys that Venus has no discernible intrinsic magnetic field. However, when Venus Express dipped below the ionosphere, it saw a steady weak field. This raises questions about the origin of this field and the utilization of the field to sound the planetary interior. In this paper, we examine first the observations and then discuss whether the magnetic field could be used to sound the interior electrical conductivity.

Observations: Venus Express was inserted into a 24-hour elliptical orbit with periapsis over the north pole in Spring 2006. In late 2014, with the end of mission approaching, it was decided to use the spacecraft itself as an atmospheric probe and drop its periapsis altitude sufficiently low that aerobraking could be achieved. This exercise was successful and it also provided some interesting magnetic measurements at altitudes as low at 129.7 km. Figure 1 shows five passes for the 10 minutes surrounding lowest approach during this period. The top 5 panels show the magnetic field magnitude, and the lines mark the 140-km altitude point. The bottom panel shows the altitude versus time. Our interpretation of these data is that the spacecraft initially and finally is in the Venus ionosphere where the magnetic field is determined by the interaction of the solar wind with the ionosphere. This "induced" magnetic field produces a variable field in the ionosphere. At highest altitudes, the field is very responsive to solar wind conditions, but at low altitudes within the ionosphere, it is very slow to change as the ion-neutral coupling is strong and the time scale for convection long.

The magnetic field at about 150 km altitude can diffuse downward through the bottom of the ionosphere and enter the non-conducting ionosphere below. When that occurs, there no longer can be electric currents bounding the edges of regions of particular magnetization. Further, the speed of magnetic waves becomes the speed of light and the amplitude of waves drops as the velocity increases to preserve the Poynting vector of any electromagnetic waves. We examine this further in Figure 2 that shows 33 individual passes as a function of altitude for a total of 66 traces. Peak magnetic field in the ionosphere at 150-km altitude are as high as 40 nT, but only 10 nT at 130 km. The median magnetic field is shown by the red trace. It varies from 14 T at 150 km to 7 nT at 130 km. Moreover, it becomes much more quiet. Panel b shows the standard deviation of the magnetic from its average value every 12 seconds. The time-varying field from 5 nT to about 1 nT and the ratio of the time-varying field to the steady field goes from about 35% down to 15%. Not only is the magnetic field lower at low atlitudes, it is much more quiet both absolutely and fractionally.

Electromagnetic Sounding: The existence of fluctuating fields at low altitudes introduces the possibility of sounding the crust electromagnetically. However, the weakness of the fluctuations means tha this must be done close to the surface and not at altitudes such as from a balloon or airplane. One promising possibility was raised by Villarreal et al. [1] that the steady state component itself could serve as the inducing field and that the spatial pattern of the induced field could be used to sound the size of the core.

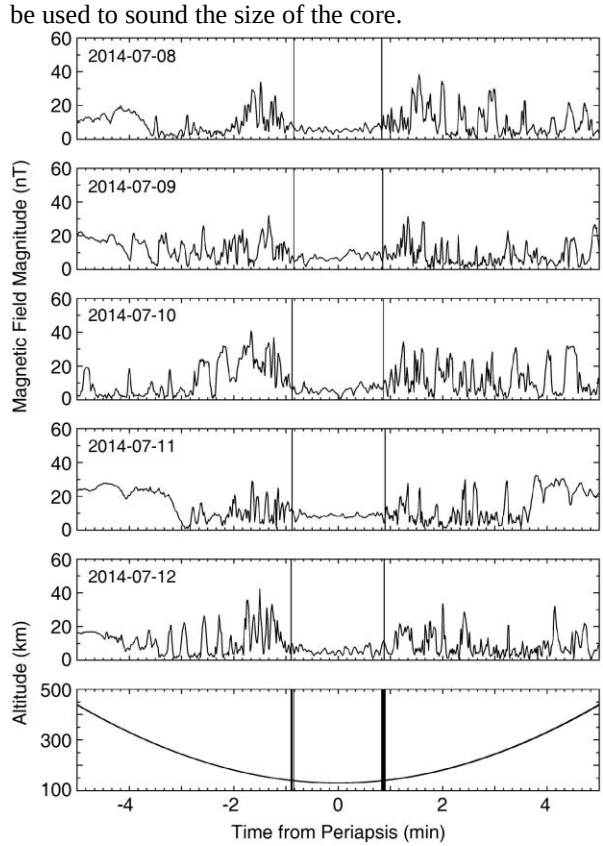

Figure 1. Magnetic field strength as a function of time from periapsis for five consecutive passes during Ve-

nus Express aerobraking period. The 10 min data interval is corresponding to an spacecraft trajectory from over 400 km altitude to periapsis around 130 km altitude and back to over 400 km altitude as shown in the lowest panel. Periapsis altitude for these orbits ranged from 129.7 to 130.7 km and solar zenith angle from 93.6° to 95.3°.

References: [1] Villarreal M.N. et al. (2015) *JGR, 120*, 2232-2240.

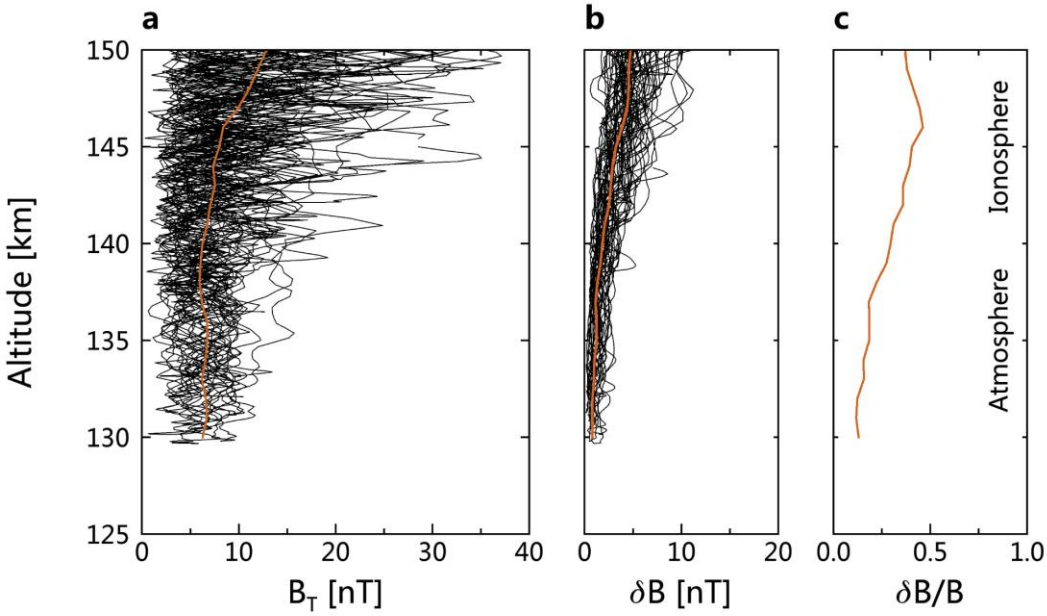

Figure 2. Altitude profiles of magnetic field strength (panel a) and fluctuation amplitude (panel b) and their ratio (panel c). Sixty-six profiles from 33 passes during June 6 to July 12, 2014, when the Venus Express periapsis altitude was below 150 km, are displayed. The field strength data shown in left panel is 1 second resolution and the magnetic field fluctuation δB is indicated as the standard deviation of the field in 12 second bin. The red lines in panels a) and b) are medians. The line in panel c is the ratio of these medians.

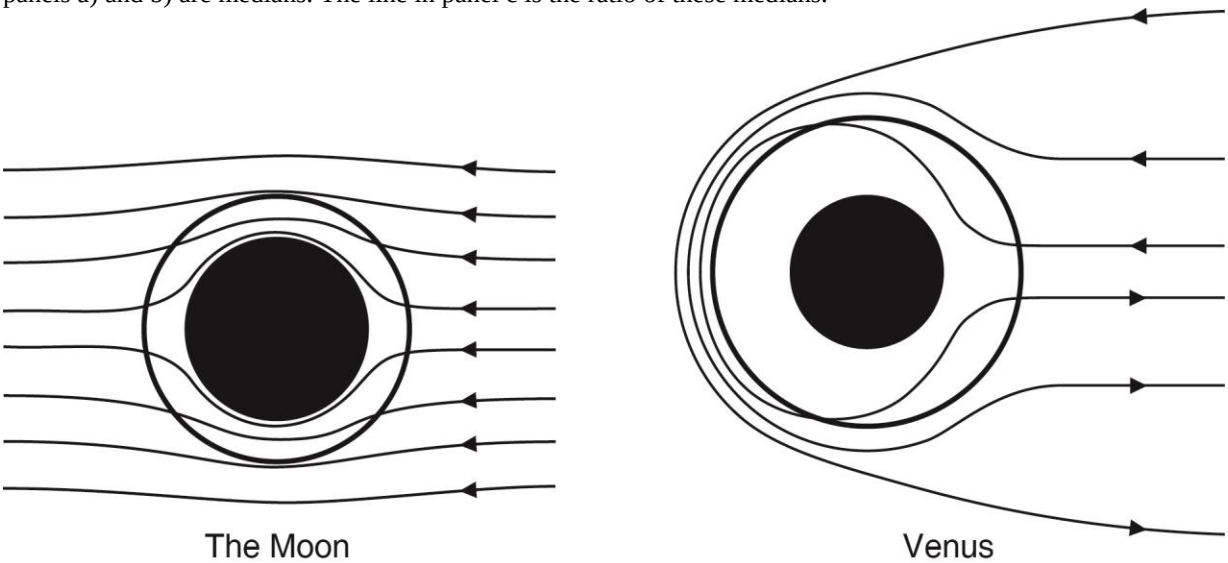

Figure 3. For sounding the highly conducting core of Venus (or Mars)), the solar wind interaction electric field that penetrates the planetary atmosphere can be used to determine the size of the core. This is analogous to the method used to first determine the size of the lunar core.