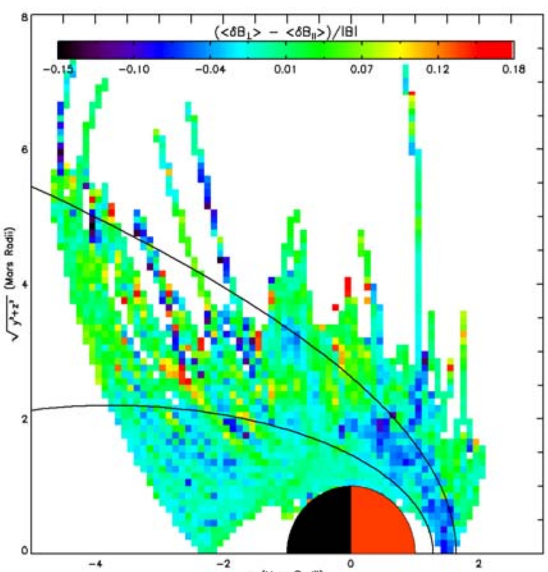
OBSERVATIONS OF PLASMA WAVES NEAR MARS AND THEIR IMPLICATIONS FOR ATMOSPHERIC LOSS. J. R. Espley[1], P. A. Cloutier[1], D. A. Brain[2], D. H. Crider[3] and M. H. Acuña[4], [1]Department of Physics and Astronomy, Rice University, Houston, TX, espley@rice.edu, [2] Space Sciences Laboratory, University of California-Berkeley, Berkeley, CA, [3]Department of Physics, Catholic University of America, Washington, DC, [4]NASA Goddard Space Flight Center, Greenbelt, MD

Summary: We use data from over 500 pre-mapping orbits of Mars Global Surveyor magnetometer data to present statistical results on the characteristics of the plasma waves in the near Mars space. We find that plasma waves in the dayside Martian magnetosheath are primarily compressional waves (i.e. magnetosonic or mirror mode waves) and in the nightside magnetosheath and tail regions that the waves are primarily associated with ion gyromotion. Some of these waves are produced by gyrating oxygen ions and as such represent observations of the ongoing erosion of the Martian atmosphere by the solar wind.

Introduction: Because Mars lacks an intrinsic magnetic field the solar wind interacts directly with the Martian ionosphere [1]. This leads to, among other things, a great deal of plasma turbulence downstream of the shock wave created by this interaction. This turbulence is interesting for several reasons, including its relevance to comparative planetology (Venus [2] and comets [3] have similar interactions with the solar wind which can be contrasted with the magnetospheres such as the Earth's), to the energetic charged particle environment both in space and at the surface, to the comparison with low frequency electromagnetic signals at the surface, and to studies of atmospheric loss (and therefore climate change). We present in this work observations of magnetic oscillations as observed by the magnetometer (MAG) onboard Mars Global Surveyor (MGS) and focus on their relevance to studies of atmospheric loss.

Data Analysis: We use both high and low time resolution vector measurements of the *in situ* magnetic field from over 500 MGS pre-mapping orbits [4]. From the low time resolution data, which is more fully calibrated [5], we find the mean magnetic field strength and direction for a 30 second interval, and find the oscillations relative to that mean magnetic field. The 30 second interval allows for several periods of the expected characteristic frequencies, the proton and oxygen gyrofrequencies, while minimizing the variations caused simply by the spacecraft moving through different plasma regions. Then using the high time resolution data we can calculate the average amplitudes of the oscillations parallel and perpendicular to the mean magnetic field for that interval and using minimum variance analysis [6], we can also find the polarization of the perpendicular oscillations (i.e. circular, elliptical, or linear), the sense of rotation of this polarization (right-handed vs. left-handed), and the probable direction of propagation of the waves relative to the mean field. Additionally, using wavelet transforms [7] we are able to find the time-resolved (and therefore spatially-resolved) principal frequencies of oscillation for each orbit (see the second figure below). Additional details can be found in [8].

Statistical Results: Using the results of our analysis described above combined with the spatial locations of the individual observations we were able to produce maps of the various wave parameters. The figure directly below shows one such map. Outlines of Mars, the shock, and the magnetic pileup boundary [9] are shown. The x-axis represents distance along the Mars-Sun line while the y-axis represents the distance to this line. In this case, the color scale represents the normalized difference between the amplitude of the oscillations perpendicular to the mean magnetic field and the amplitude of the oscillations parallel to the



mean magnetic field. This means that positive values (yellow, red) indicate regions where the oscillations were more transverse and negative values (purple, blue) indicate regions where the oscillations were more compressional.

Additional maps of the ellipticity of the perpendicular components, the sense of polarization of such components, the direction of propagation relative to the mean field, and the principal frequencies of oscillations are to be presented and are available in [8].Taken together these statistical results indicate that in the dayside magnetosheath (between the shock and the magnetic pileup region) the waves are principally compressional waves with mixed polarization and are traveling perpendicular to the mean magnetic field. They thus are likely to be associated with magnetosonic or mirror mode waves. In the nightside magnetosheath and tail region, the waves are principally elliptical transverse waves propagating along the mean magnetic field with principal frequencies of oscillation that are often times near the proton and oxygen gyrofrequencies. Such waves represent an observational signature of ions of planetary origin being swept up by the solar wind and being carried away into deep space [10].

Case Studies of Individual Orbits: Further insight into the nature of the waves and their implications for atmospheric loss can be gained by analyzing individual orbits. The figure shown below shows one such case study. In the upper left panel the magnetic field magnitude is shown vs. decimal day with the interval to be analyzed indicated by two vertical dotted lines. The upper right panel shows the MGS location during that interval. The lower left panel shows a wavelet spectral transform of that interval (decimal day vs. frequency with color indicating spectral power) and the lower right shows the global (time-integrated) wavelet transform. Dashed lines on both wavelet transforms indicate the local proton (higher) and oxygen (lower) gyrofrequencies. As can be seen, this orbit shows a strong signal near the oxygen gyrofrequency which we interpret as an example of pickup ion loss. Several other interesting orbits will be presented and the results from over 500 orbits are available at spacsun.rice.edu/~espley/wavelets.htm.

References: [1] Acuña, M. H. *et al.* (1998), *Science, 279*, 1676-1680. [2] Cloutier, P. A. *et al.* (1999), *GRL, 26*, 2685-2688. [3] Mazelle, C. *et al.* (1995), *Adv. Space Res., 11*, 41-45. [4] Albee, A. L. *et al.* (2001), *JGR, 106*, 23,291-23,316. [5] Acuña, M. H. *et al.* (2001), *JGR, 106*, 23,403-23,417. [6] Song, P. and Russell, C. T. (1999), *Space Sci. Rev., 87*, 387-463. [7] Torrence, C. and Compo, G. P. (1998), *Bull. Am. Meteor. Soc., 79*, 61-78. [8] Espley, J. R. *et al.* (2004), submitted to *JGR*. [9] Vignes, D. *et al.* (2000), *GRL, 27*, 49-52. [10] Jakosky, B. M. and Phillips, R. J. (2001), *Nature, 412*, 237-244.