The Influence of Planetary Magnetic Fields on Atmospheric Retention. D. Brain, R. Ramstad, H. Egan, Y. Dong, T. Weber, R. Jolitz, R. Jarvinen, M. Holmstrom, K. Seki, J. McFadden, L. Andersson, J. Espley, J. Halekas, D. Mitchell, J. Luhmann, and B. Jakosky, LASP / University of Colorado (david.brain@lasp.colorado.edu), FMI, Finland, RF Kiruna, Sweden, University of Tokyo, SSL / University of California Berkeley, NASA GSFC, University of Iowa.

**Motivation:** Until recently, it had long been assumed that a global magnetic field will shield a planet’s atmosphere from being stripped away to space through interactions with the solar wind. Under this assumption, the shut-off of a global dynamo field at Mars contributed to the loss of significant atmosphere – enough to explain the evidence for liquid water on the surface long ago. Similarly, the lack of global magnetic field at Venus may have led to the loss of significant atmospheric oxygen over time.

This assumption has been questioned in recent years, in part based on the similarity in ion escape rates between Venus, Earth, and Mars [1]. It has been instead proposed that the presence of a global magnetic field may even enhance atmospheric escape because the planet presents a larger electromagnetic cross-section to the solar wind than it would otherwise.

Observational inter-planet comparisons, while valuable, are challenging to interpret because planets differ in many ways – Earth and Venus have different atmospheric compositions and rotation rates, for example. Global computer simulations using validated models can provide controlled experiments that isolate only the influence of a planetary magnetic field – but these models must be properly validated. Mars offers a unique opportunity to test the importance of a magnetic field in altering ion escape rates. This is because Mars possesses both magnetized and unmagnetized regions of the crust – allowing a relatively ‘controlled’ evaluation of the importance of magnetic fields in regulating ion escape in the limit of weak planetary magnetic fields.

In this presentation we will review the evidence ‘for’ and ‘against’ magnetic fields playing an important role in atmospheric retention. We will then present results of observational and theoretical analyses ongoing in our group, with emphasis on global plasma modeling and on analysis of data from the Mars Atmosphere and Volatile EvolutioN (MAVEN) mission.

**Global Plasma Modeling:** A variety of models have been developed for the interaction of the flowing solar wind plasma with unmagnetized objects in the solar system, such as Mars, Venus, and comets. These models are able to compute the escape rate of atmospheric ions from a planet, subject to the various assumptions incorporated into the model. It is now possible to incorporate weak global dipole magnetic fields into the models to determine the influence of planetary magnetic field on escape rate.

We used an open source hybrid plasma model, RHybrid, to simulate ion escape from a Mars-like planet with variable planetary dipole field strength [2]. We examined both the magnetospheric configuration under different dipole strengths, as well as escape rates of O+ and O2+. We found (Figure 1) that atmospheric escape at first increases with increasing planetary field strength, and then decreases at larger field strengths. A weak field provides pathways for ions to escape that would have otherwise gyrated back into the planet, while a stronger field traps planetary ions and prevents them from escaping.

**Influence of Mars Crustal Fields:** Previous investigators have examined global observations from Mars to determine the variability in ion escape rates as the planet rotates (thereby placing the strong crustal magnetic fields at different positions with respect to the incident shocked solar wind flow) [3,4]. Taken together, these analyses have been inconclusive since one predicts minimal influence of the crustal fields (~20%) and the other predicts a substantial influence (~2.5x).

Global plasma models have fared similarly. If crustal fields are added to such models then the ion escape rate changes by as much as a factor of 30 or as little as 10%, depending upon the model [e.g. 5,6]. If crustal fields are instead rotated through a day, the variability in ion escape rates ranges from ~10% to 4x, depending upon the model [e.g. 7,8].

Figure 1: Ion escape rates from a Mars-like planet as a function of planetary magnetic field strength, as simulated by the RHybrid model.
Such analyses (both observational and theoretical) are global, and therefore do not necessarily distinguish between ion escape from magnetized and unmagnetized regions. They instead look at the collective effect of crustal fields on the total ion escape from Mars. To truly answer the central question we have posed, a more spatially confined analysis focused on specific magnetized and unmagnetized regions is called for.

We have re-analyzed MAVEN observations of escaping ions, and organized the measured escape rates as a function of the position of the strong southern crustal fields with respect to the incident solar wind flow. We find that crustal fields have no detectable influence on global ion escape (Figure 2). We further find that ion escape is enhanced above crustal fields on the dayside of the planet, but depressed on the nightside. These competing effects average over the course of a Mars rotation.

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