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It is not immediately obvious that there should be any connection between planetary magnetic fields and climate evolution. Magnetic fields are generated in the deep interiors of planets and their influence on their surroundings are most noticeable many atmospheric scale heights above the surface, where particle densities are a small fraction of those at the surface. Further, a planetary atmosphere is comprised mostly of neutral particles, which are unaffected by ambient magnetic fields.

But a number of possible links do exist between magnetic fields and climate. First, atmospheric source and loss processes strongly affect climate. These processes act at the top (and bottom) boundary to the atmosphere, where significant quantities of atmospheric particles are ionized. Since magnetic fields strongly influence the motion of charged particles, the presence and characteristics of a planetary magnetic field can influence atmospheric source and loss. Specifically, a planetary field shields the atmosphere from incident plasma (e.g. from the solar wind) which contributes to stripping to space of the upper atmospheric layers. Similarly, a weak or absent planetary field can allow deposition of charged particles into the atmosphere.

The influence of magnetic fields on source and loss processes has two main possible influences on climate evolution. First, magnetic fields may have a net effect on atmospheric abundance, which is a significant factor controlling climate. There is presently a debate in the community about whether a planetary magnetic field has an effect on atmospheric loss rates, and the sign of that effect. On one hand, magnetic fields provide a shield for the atmosphere from plasma-related stripping processes – so might be assumed to be associated with lower loss rates than an unprotected planet. On the other hand, a planetary magnetic field increases the cross-section of the planet with respect to incident plasma – so might be assumed to lead to higher loss rates (but via more indirect processes such as ion outflow in cusps).

Second, the presence or absence of a planetary magnetic field may affect the composition (and chemistry) of an atmosphere, which in turn influences climate. Since the upper layers of an atmosphere are diffusively separated (and therefore enriched in lighter species), the absence of a magnetic field should lead to preferential removal of light species by stripping processes, leaving the atmosphere enriched in heavier isotopes or species and decreasing the abundance of species key to determining the chemical equilibrium of an atmosphere. Similarly, charged particles added to an atmosphere in the absence of a magnetic field may enable chemistry that would not be possible if the planet were shielded.

We will discuss examples of the above concepts in action in our own solar system. We will review the argument for and against the importance of planetary magnetic fields in climate evolution, comparing measured loss rates and mechanisms at Earth, Venus, and Mars. We will review the evidence that suggests the absence of a magnetic field may have been importantin determining atmospheric abundance at Mars, and atmospheric composition at Venus. And we will review evidence that Titan's robust atmospheric chemistry is enabled in part by species added to the atmosphere from above. We will discuss how these same concepts apply for mini-magnetospheres at Mars. Finally, we will identify possible paths forward in this research area, both in terms of needed observations and in terms of unanswered questions that might be addressed in the short term via theoretical work.