EPSC Abstracts,
Vol. 4, EPSC2009-169, 2009
European Planetary Science Congress,

Slow Hydrodynamic Escape from Planetary Atmospheres

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Abstract

The solar wind is an observational fact and hydrodynamics models capture the essential features of this expansion. Yet the acceleration occurs in a region where the mean free path exceeds the macroscopic length scales and there is no agreement on what heats the corona to ~ 2×10^6 K. By contrast, the power source that heats Titan's upper atmosphere is known to be solar EUV/UV radiation and accounts for the observed temperatures above 725 km. A similar statement is, or probably is, true for the Earth, Pluto, and Charon. Analysis of Cassini INMS Titan data [1] suggests that H_2 and CH_4 are escaping at and near the limiting fluxes, respectively. These escape fluxes exceed fluxes calculated with the Jeans formula and produced by non-thermal sputtering processes. The only viable explanation [2] is slow hydrodynamic expansion powered by the transfer of heat from the region of maximum heating to higher altitudes by thermal heat conduction, which requires a decreasing temperature due to expansion adiabatic cooling. It is essential that heat conduction redistributes this power collisionally to support the expansion above the exobase until the flow speed exceeds the escape speed. Titan's "exobase" is not a thin transition level, but rather an extended region of ~ 1000 km, which is quasi-collisional due to the fact that H_2 is not escaping at its limiting rate, but only at 99% of its maximum rate and thus has a very large scale height. This region is probably critical to the acceleration of CH_4 to escape velocity. The observational inferences from Titan will be applied to the hypothesis of slow hydrodynamic expansion of the atmospheres of Earth, Pluto, Charon, and Jupiter, if time permits.

Figure 1: Europlanet logo

Bibliography

The references will be numbered in order of appearance [1] [2] [3]. The reference format is as follows:

References

[1] R. V. Yelle, *J. Geophys. Res.* **113**, E10003, doi:10.1029/2007JE003031,(2008).
[2] D. F. Strobel, Icarus. 193, 588 (2008).