Exospheric Temperatures on Mars and Venus

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The bracketing of values of the photoionization heating efficiency ϵ in a carbon dioxide atmosphere (Stewart and Hogan, 1969) permits narrower limits to be set on the exospheric temperature T_E of Mars than had previously been possible. Observations of the exospheric temperature on Venus (Barth *et al.*, 1968) provide a convenient check on our derived range of ϵ. In this study, we calculate the exospheric temperatures of these planets, adopting the empirical values of ϵ derived in the above investigation. We compute these atmospheric models for conditions appropriate to the occultations of Mariner 4 on Mars and Mariner 5 on Venus.

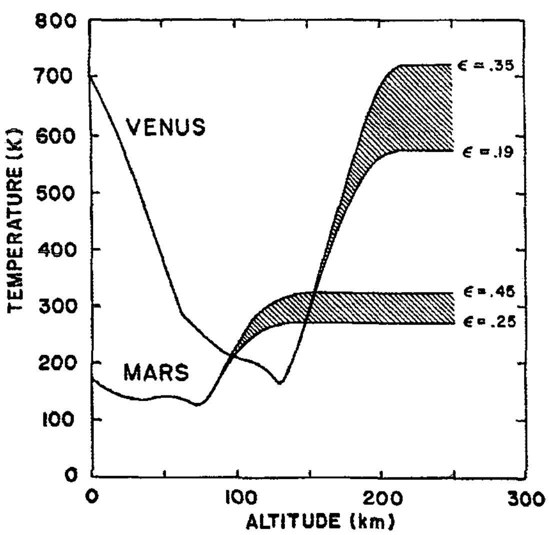

FIG. 1. Temperature profiles in the Mars and Venus atmospheres for conditions of Mariner 4 and 5 occultation. The range in temperature exhibited in each profile corresponds to the uncertainty in photoionization heating efficiency.

The distributions of temperature obtained for Mars and Venus are illustrated in Fig. 1. The two curves that are shown for each planet correspond to the upper and lower bounds for the heating efficiency as determined in the analysis cited above. In the case of Mars, the planetary surface is chosen as the lower boundary, while for Venus, calculations were begun at the highest level at which Mariner 5 data were acquired (77 km above the surface). For values of ϵ between 0.25 and 0.45, the range of T_E on Mars is 267–322K, while for Venus, values of ϵ between 0.19 and 0.35 result in T_E in the range 577–718K. The distributions of ionization corresponding to the thermal profiles of Fig. 1 are in good agreement with the Mariner observations for both planets.

The results for the exospheric temperature on Venus agree well with the value of 650K±50K derived from the ultraviolet photometry data acquired on the Mariner 5 flight (Barth *et al.*, 1968). This agreement is an independent confirmation of the value of the heating efficiency on which both Mars and Venus calculations are based, and strengthens our confidence in the results obtained for T_E on Mars. This point is of considerable interest because no observational values of the exospheric temperature on Mars are available as yet.

A theoretical study by McElroy (1969) has yielded an exospheric temperature of 487K for Mars and a range of 680–710K for T_E on Venus, for conditions corresponding to the points of occultation in the Mariner 4 and 5 flights. The model used in those calculations appears to be similar to the one on which the present analysis is based. Close correspondence between the two sets of results is obtained for Venus, while pronounced disagreement appears in the case of Mars.

We believe that the explanation of the discrepancy for Mars and the agreement for Venus lies in the following circumstances. McElroy uses values of the heating efficiency which, when weighted by the incident solar energy, correspond to a mean ϵ of 0.59, approximately double that employed in the present investigation. Since T_E rises with increasing ϵ, this factor will account for a large part of the discrepancy in the calculated exospheric temperatures for Mars. From our calculations, we find that T_E is 402K on Mars for $\epsilon=0.59$. However, an increase in ϵ will also produce a large rise in the exospheric temperature on Venus. In fact, our calculations indicate that T_E is 936K on Venus for $\epsilon=0.59$. McElroy's Venus result is lower than this because he employs a day-night average, represented by a factor of 0.5 in the photoionization heating term. We suggest that the use of a day-night average of solar flux for Venus is unjustified, however, because of the great length of the Venus day (112 earth days). The portion of the Venus atmosphere probed by Mariner 5 had been exposed to sunlight continuously for 42 earth days prior to occultation. The response time of the Venus thermosphere to variations in solar conditions is certainly smaller than this. For the earth's upper atmosphere, Priester (1965) quotes a response time of 6 ± 3 hr. Since carbon dioxide, the principal cooling agent on Venus, is more effective than atomic oxygen, the cooling agent on earth, the response time of the Venus thermosphere should be even smaller.

McElroy (1969) has suggested that interaction of the solar wind with the Mars ionosphere may halve the plasma scale height obtained in thermal structure calculations while the ionosphere on Venus may be shielded from this interaction by the presence of light gases at high altitudes. Our calculations demonstrate that the available observations of the Mars and Venus ionospheres are amenable to a common theoretical treatment and do not require different assumptions for each planet.

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