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Occultation of ε Geminorum by Mars: Evidence for Atmospheric Tides?

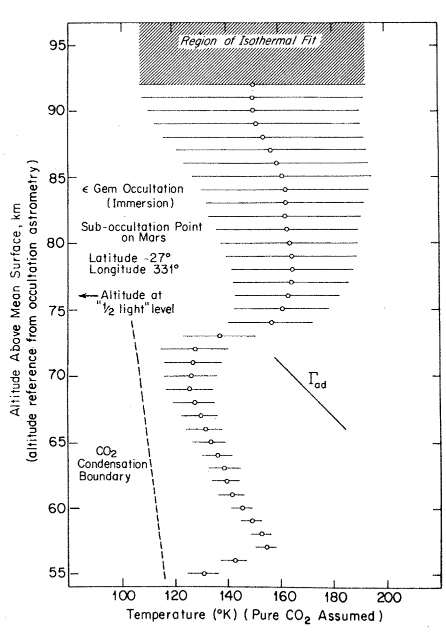
Abstract. *Temperature profiles of the martian atmosphere have been derived from airborne observations of the 8 April 1976 occultation of ε Geminorum. Within the altitude range from 50 to 90 kilometers, these profiles show peak-to-peak variations of 35°K with a vertical scale of 20 kilometers and represent evidence for strong tides in the martian atmosphere. However, more information is necessary to conclusively rule out a radiative explanation for the temperature variations.*

The martian occultation of ε Geminorum (visual magnitude = +3.1, spectral class G8Ib) on 8 April 1976 was observed with the 91-cm telescope aboard the National Aeronautics and Space Administration Kuiper Airborne Observatory, the first occultation observations made with this facility (*1*). High-quality light curves for both immersion and emersion were obtained simultaneously at three wavelengths (0.37, 0.45, and 0.75 μm) with a time resolution of 4 msec. A similar occultation of β Scorpii by Jupiter on 13 May 1971 yielded temperature and number density profiles of the jovian atmosphere (*2*), as well as a measurement of its He abundance (*3*). From our ε Gem occultation data we have obtained temperature, pressure, and number density profiles of the martian atmosphere and information about its composition from a differential refractivity measurement. Our result indicated that no more than 30 percent Ar (and N_2) is mixed with pure CO_2 (*4*) and is consistent with the low abundance of Ar and N_2 obtained by the Viking entry probe (*5*). In addition, we have obtained the wavelength dependence of the extinction of the martian atmosphere from the first observation of the central flash—a bright feature in the light curve that was recorded when ε Gem was aligned with the center of Mars (*1*). We report here the temperature profiles deduced from the occultation data, which were obtained above the martian coordinates 27°S, 331°W (immersion) and 28°N, 152°W (emersion) and cover an altitude range of about 50 to 90 km above the mean surface. These results are compared with those of Viking 1 (*5*) and with theoretical predictions of thermally driven tides in the martian atmosphere (*6*). The details of our observations, data analysis procedures, and other results are given elsewhere (*4*).

Temperature profiles were obtained from the occultation light curves with a new inversion procedure (*7*). This method is mathematically equivalent to standard inversion techniques (*2, 8*) but has the advantage that error bars (calculated from the known noise in the light curve) can be assigned to the temperature profiles. Thus we can have confidence in separating those features in the temperature profiles that are caused by the martian atmosphere from the variations arising from the noise in the light curve.

The temperature profiles obtained are given in Figs. 1 and 2. The profiles are for the light curves at 0.45 μm, the channel with the best signal-to-noise ratio; the profiles from our other two channels agree within their errors. The upper boundary condition for the inversion is determined by an isothermal fit to the upper part of the light curve, indicated by the shaded region at the top of Figs. 1 and 2. The temperatures and their error bars are obtained from the inversion calculation matched to the boundary condition. For each temperature point the error bars represent ± 1 standard deviation expected from the noise in the light curve. Neighboring temperature points agree better than the error bars because the noise affecting the points is correlated (*7*). The inversion calculation is terminated when the uncertainty in the lower base line of the light curve produces an error as large as the random error.

Both the immersion and emersion profiles show peak-to-peak temperature variations of 35°K, much larger than variations expected from random noise. Temperature maxima occur at an altitude of about 55 to 60 km on both profiles. The mean temperature of the emersion profile is somewhat warmer than the mean



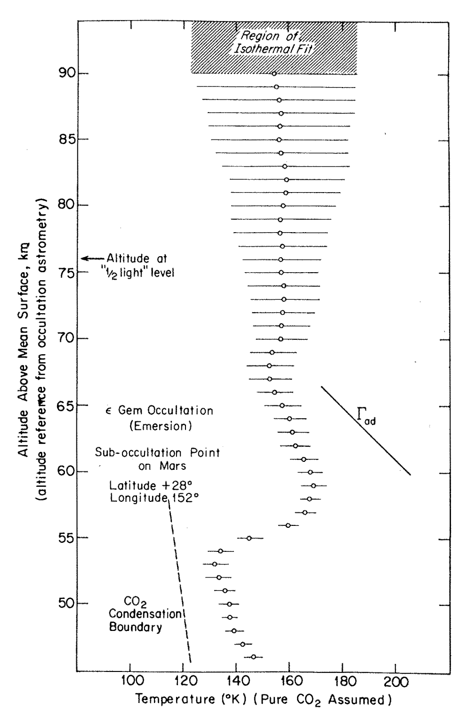


Fig. 1 (left). Temperature profiles for immersion. The plotted points and their error bars were obtained from the immersion light curve for a pure CO_2 atmosphere. A correction for the small amount of N_2 and Ar present would lower the temperatures about 3°K. The uncertainty in the altitude scale is ± 5 km, and an altitude of 65 km corresponds to a number density of 2.0×10^{14} cm^{-3}. The shaded region represents the uncertainty in the temperature obtained from the isothermal fit used to establish the boundary condition for the inversion calculation. The largest temperature gradients are subadiabatic ($\Gamma_{ad} = -5$°K km^{-1}). The wavelike structure strongly suggests the presence of tides in the martian atmosphere. At the time of the occultation, the martian subsolar latitude was + 19.2° and the planetocentric longitude of the sun (L_8) was 51.6°. Immersion occurred above the suboccultation point on Mars at about 0330 local solar time. Fig. 2 (right). Temperature profile for emersion, which occurred above the suboccultation point on Mars at about 1530 local solar time. For details, see the legend for Fig. 1.

for immersion. A temperature difference is to be expected from the difference in solar energy absorption, since the subsolar latitude is 19°N, close to the emersion latitude of 28°N, but 46° from the immersion latitude of 27°S. The mean temperatures for both profiles (as well as this quantity can be defined) agree with the mean temperatures obtained from Mars 6 (*9*) and Viking 1 entry data (*5*).

A striking similarity between the occultation temperature profiles and the Viking entry profile is the wavelike vertical structure with wavelength between two and three pressure scale heights and a peak-to-peak amplitude about 35°K at a number density of 10^{14} cm^{-3}, roughly eight scale heights above the 5-mbar pressure level. The wavelength and amplitude are in agreement with the general character of tidal waves predicted by Zurek (*6*) for clear (not dusty) conditions. Detailed comparison of temperature profiles, including phase information, with his predictions is not meaningful for several reasons. The details of profiles depend upon the amount and distribution of traces of dust in the atmosphere, and these factors are unknown. There may be significant additional forcing due to boundary layer convergence, neglected in Zurek's treatment. The large amplitude of the tides probably leads to instabilities and, as a result, to turbulence. Zurek pointed out that such turbulence would influence the structure of the tide but in a manner difficult to predict.

There are other possible explanations for the thermal structure. McElroy's detailed radiative equilibrium calculations (*10*) suggested that oscillations of temperature with height might occur near these levels on Mars because the concentration of (and solar absorption by) photodissociation products varies. Dütsch (*11*) discussed temperature variations in Earth's atmosphere caused by the stratification of photochemical products due to flow "fingering." Finally, aerosols have been observed by the Viking orbiter at heights as great as 40 km on Mars (*12*), and stratification into layers could lead to varying radiative heating with height. Purely thermal layering due to slowly varying (not tidal) large-scale flows is probably not a possibility, because radiative relaxation times are less than 1 day (*6*).

There is one point of disagreement between our data and Zurek's predictions, namely, the isothermal (not wavy) thermal structure above 70 km on emersion. However, radiative damping increases rapidly with height at these levels, and Zurek remarked that its influence is difficult to predict accurately.

We believe that the wavelength and amplitude of temperature variations shown by the data are best explained in terms of the existence of tides. A definitive test of this interpretation may be possible if several more temperature profiles of sufficiently high signal-to-noise ratio are available from other observers of the ϵ Gem occultation. These profiles, in conjunction with the Viking entry profiles, would provide information on the atmospheric temperature structure above different locations on Mars, which could be compared with the predictions of the tidal model.

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Fluidity in the Membranes of Adult and Neonatal Human Erythrocytes

Abstract. *Several antigens and receptors are mobile in the plane of the membrane of the intact neonatal human erythrocyte but not in the membrane of the normal adult cell. In this report, measurements of the fluorescence polarization of perylene dissolved in isolated erythrocyte membranes are reported, which are indistinguishable for the two kinds of cells. This result indicates that the viscosities of the membrane interiors of the two cells are the same. The observed mobility differences, therefore, cannot be attributed to different lipid viscosities in the two membranes.*

It has been appreciated for some time (*1*) that the intact adult human erythrocyte possesses an atypical membrane, in that its surface components appear to be immobile in the plane of the membrane. Antibodies and lectins bind to receptors on the surface of the intact erythrocyte but do not normally induce any redistributions or endocytosis of these receptors, in contrast to the situation with

Table 1. Polarized fluorescence data and microviscosities of erythrocyte ghost membranes labeled with perylene. Results were obtained at 25°C.

Cell	Cell concentration (ghost/ml)	$\frac{I_{VH}}{I_{VV}}$	$\frac{I_{VH}^S}{I_{VV}^S}$	I_{VV}	I_{VV}^S	A	τ (nsec)	η (poise)
Adult	1.6×10^8	.813	.254	1.25	.044	.0625	6.6	2.56
Neonatal	1.4×10^8	.812	.272	1.55	.058	.0626	6.6	2.56