THE MARTIAN SKY AND ITS ILLUMINATION OF THE MARTIAN SURFACE. N. Thomas, W. J. Markiewicz, R. M. Sablotny and H. U. Keller, Max-Planck-Institut fuer Aeronomie, Max-Planck-Str. 2, 37191-Katlenburg-Lindau, Germany

Introduction: The dust in the atmosphere above the Mars Pathfinder landing site produced a bright, red sky that increases in redness toward the horizon at midday. There is also evidence for an absorption band in the scattered light from the sky at 860 nm. A model of the sky brightness has been developed and tested against Imager for Mars Pathfinder (IMP) observations of calibration targets on the lander. The resulting model has been used to quantify the total diffuse flux onto a surface parallel to the local level for several solar elevation angles and optical depths. The model shows that the diffuse illumination in shadowed areas is strongly reddened while areas illuminated directly by the Sun (and the blue forward scattering peak) see a more solar-type spectrum, in agreement with Viking and IMP observations.

Quantitative corrections for the reddening in shadowed areas are demonstrated. It is shown quantitatively that the unusual appearance of the rock Yogi (the east face of which appeared relatively blue in images taken during the morning but relatively red during the afternoon) can be explained purely by the changing illumination geometry. We conclude that any spectrophotometric analysis of surfaces on Mars must take into account the diffuse flux. Specifically, the reflectances of surfaces viewed under different illumination geometries cannot be investigated for spectral diversity unless a correction has been applied which removes the influence of the reddened diffuse flux.

One of the most immediate surprises of the Mars Pathfinder mission after the landing was the relatively high optical depth in the Martian atmosphere. Although predictions based on Viking lander observations had suggested that optical depths of around 0.3-0.6 were likely, the clarity of the atmosphere observed from Earth orbit by the Hubble Space Telescope (HST) and the low temperatures consistently recorded by microwave observations, seemed to imply that the atmosphere was relatively free from dust. Estimated optical depths were of the order of 0.1. However, the first measurements made with the Imager for Mars Pathfinder (IMP), immediately after landing, indicated that the Viking-based predictions were very close to the mark. Subsequent accurate measurements showed that the optical depth was typically around 0.5 with an increasing trend over the duration of the mission.

Scattering of incoming sunlight by the relatively high dust particle content in the Martian atmosphere leads to the sky having significant brightness. The color of the sky is, in general, reddened with respect to a solar spectrum because, unlike Earth's sky brightness which is dominated by Rayleigh scattering from gas molecules, scattering by dust particles with sizes comparable to or larger than visible wavelengths predominates. This difference has the further significance that while, on a clear day, the blue color of Earth's sky is rather uniform, the reddening of the Martian sky varies strongly with the angular separation from the Sun.

While the modeling of the Martian sky brightness allows one to derive the characteristics of the dust particles in the atmosphere, there are further effects of considerable interest. The sky on Mars provides an additional source of illumination to the surface. Therefore spectrophotometric measurements of the surface need to take into account the fact that the diffuse illumination from the sky is bright, inhomogeneous, and with a strongly reddened spectrum. There is also the possibility that the diffuse illumination could contain absorption bands which could produce or mask absorption bands present in the true reflection spectrum of the surface material.

The importance of the diffuse component to the surface illumination became particularly evident when the reflection characteristics of the rock Yogi were investigated. In color-enhanced presentations of one of the major panoramas acquired early in the mission, one of the faces of Yogi appeared strongly blue with respect to the rest of the rock. Several other rocks in the scene showed a similar effect. This was quickly interpreted in terms of scouring of the surfaces by the wind-blown dust. The blue face coincided with the direction of the prevailing wind (as evidenced by wind-tails behind Barnacle Bill, for example). However, a section of a second panorama was subsequently obtained (at 1620 UT on July 22, 1997) which showed the originally blue face of Yogi to be red while the opposite side of the rock appeared to be blue. These data were acquired during the afternoon on Mars at 1455 local solar time (LST). The previous data had been acquired in midmorning. The immediate inference was that the color of Yogi was dependent upon the position of the Sun and hence the illumination.

In this poster, we demonstrate the importance of taking into account the diffuse illumination when analyzing spectra of the surface by modeling the illumination at specific places (including positions on Yogi). We begin by presenting calibrated spectra of the sky. We then discuss a detailed model of the overall sky brightness at several wavelengths and show a map of the modeled sky brightness for a specific geometry.

We then use the model to show compatibility with measurements by the IMP of calibration targets on the lander at several times of day. The integrated diffuse flux onto a plane parallel to the local level is then presented. We have also performed a preliminary investigation of the ratio of the brightness in shadow areas to adjacent illuminated areas. Finally, we demonstrate quantitatively how the time of day changes the colors of the faces of Yogi. We also provide preliminary quantitative data which could be used to provide improved spectrophotometric results for the surface. We conclude with a brief discussion of future work.

Several sections of this work have been published in J.G.R, Vol. 104, No. E4, 8795-8808, 1999.

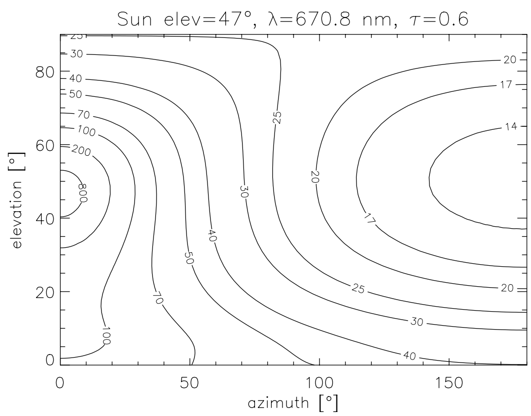

Figure 1 Contour map of the model sky brightness over the full hemisphere. Solar elevation = 47E, ϑ=0.60, 8=670 nm.

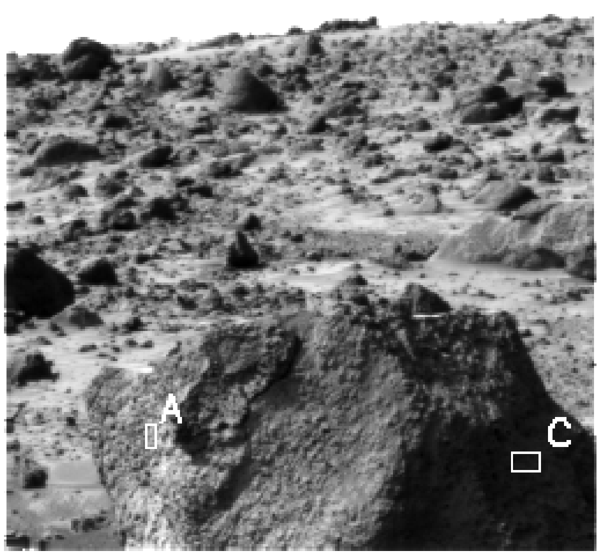

Figure 2 Image of the top of Yogi taken from the superpan. Two areas, marked A and C, been selected for comparative study.

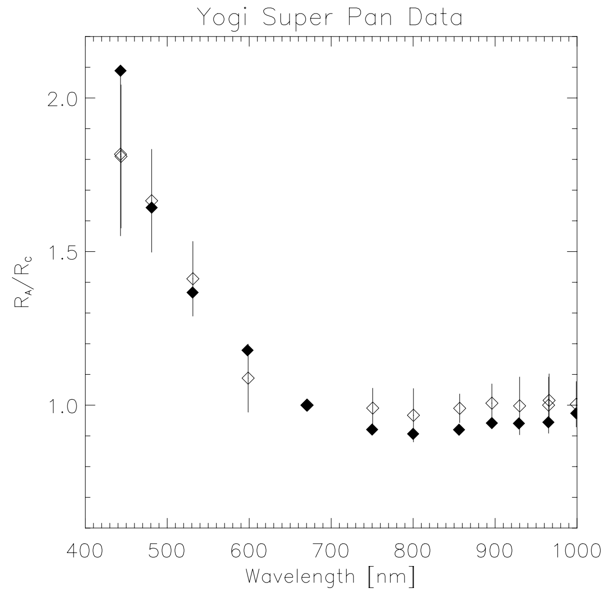

Figure 3 The ratio of *I/F* values (normalised to 1 at 670 nm) for the two faces of Yogi at the time of the superpan (open symbols). Model calculations of the illumination of each surface give ratios shown by the filled diamonds.

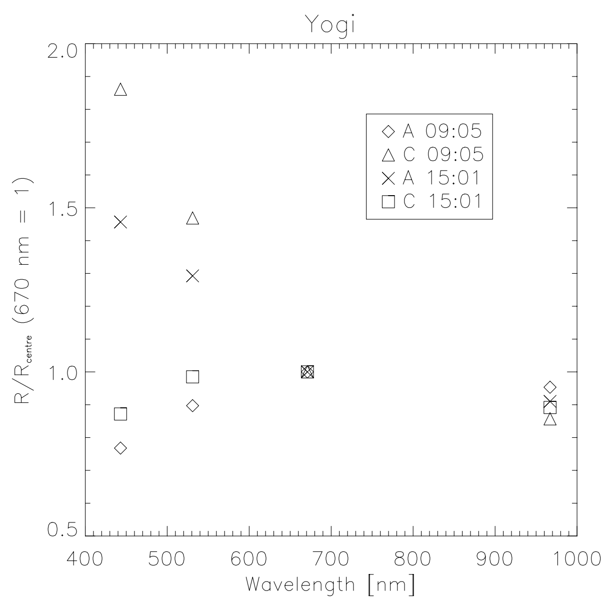

Figure 4 The ratio of the reflectance (assuming a solar illumination) from positions on the left (A) and right (C) faces of Yogi to that of the centre face, normalised at 670 nm at two different local solar times representative of midmorning and midafternoon. Note that the face A is more blue in the afternoon, while face C is more blue in the morning.