AN ANALYSIS OF MARTIAN PHOTOMETRY AND POLARIMETRY*

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Abstract. The physical parameters that influence the photometric and polarimetric properties of a solid are enumerated and used to guide a comparison of laboratory measurements with observations of Mars. Both the bright and dark areas of Mars are found to be covered by a fine powder. Furthermore, they appear to have a very similar chemical composition. It is argued that goethite is a major constituent of both regions. The particles on the bright areas are characterized by an average particle radius of 25 μ, while those on the dark areas have a mean size of 100 μ outside of the period of seasonal darkening and about 200 μ near the peak of the darkening. The seasonal darkening of the dark areas is the result of a change in the average particle dimension without an accompanying chemical change.

The Martian atmosphere has much less of an influence on the photometric and polarimetric observations than was previously supposed. The observed lack of contrast in the blue appears to be largely the result of an intrinsic loss of surface contrast, and not an effect of a hypothetical atmospheric blue haze.

1. Introduction

Clues regarding the nature of the bright and dark areas of Mars can be found in the photometric and polarimetric properties of these regions. In the past it has been customary to compare the observations of Mars with laboratory data to derive properties of the planetary surface (e.g., DOLLFUS, 1957a; SHARONOV, 1961; SAGAN et al., 1965). A principal result has been the suspicion that pulverized ferric oxide polyhydrates, such as limonite, are important constituents of the Martian surface.

In the present paper we seek to refine the laboratory comparisons, to approach the problem from a somewhat more fundamental physical viewpoint, and to derive limits on the acceptable ranges of the several parameters that characterize the surface, such as particle size, degree of compaction, and the real and imaginary parts of the index of refraction.

Closely tied to any analysis of Martian photometric properties is the question of the 'blue haze', the progressive loss of surface contrast between bright and dark areas of Mars as shorter visible and near-ultraviolet wavelengths are employed. Most observers have concluded, as the description of the phenomenon itself indicates, that an absorbing and/or scattering atmospheric layer is responsible (see, e.g., SAGAN and KELLOGG, 1963). If this were the case, then the layer would make significant contri-

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butions to the light seen in short-wavelength photometric observations intended as studies of the planetary surface. However, several lines of evidence—e.g., the enhanced contrast in the blue and violet of the polar caps, and ultraviolet rocket spectroscopy of Mars—strongly counterindicate the notion of a blue haze, and suggest that the phenomenon is due to an intrinsic loss of surface contrast at short visible wavelengths. We justify these ideas, and discuss such associated problems as the blue clearings, below. For the moment we adopt the hypothesis that the photometric measurements of Mars at wavelengths, $\lambda$, longward of 4000 Å pertain primarily to the surface. At shorter wavelengths, Rayleigh scattering by a 10-mb atmosphere will become increasingly important. The contribution of the gaseous and particulate components of the atmosphere to the polarimetric results will be discussed separately.

The photometric, polarimetric, and blue-haze observations, and their interpretations, will now be treated in that order. The photometric observations will be discussed approximately in order of increasing wavelength.

2. Photometry of the Bright and Dark Areas

2.1. Visible Wavelength Photometry and Its Implications

2.1.1. The Photometric Data

The parameter $K$ is the reflectivity for angle of incidence = angle of reflection $\approx 0^\circ$ (but not so near to $0^\circ$ that one runs into the opposition effect); i.e., it is the ratio of the observed surface brightness due to back-scattering by an area oriented perpendicular to the incident sunlight to that due to a back-scattering by a perfectly diffusing white screen (i.e., a non-absorbing Lambert scatterer) with similar orientation. Values of $K$ for the Martian bright areas are contained in a compilation by Dollfus and Focas (1966, their Figure 17). Within the scatter in the data, the $K$-$\lambda$ observations are fit adequately by a straight line. As discussed below, these values of $K$ can be checked against those derived from well-established broadband photoelectric photometry of the whole planet, and are found to be in good agreement. Table I summarizes these observations as well as the value of the contrast, $\Gamma$, between bright and dark areas obtained in an earlier work of Dollfus (1957b); $\Gamma$ is defined as the difference

<table>
<thead>
<tr>
<th>$\lambda$ (Å)</th>
<th>$K$, bright area</th>
<th>$K$, dark area</th>
<th>$\Gamma$</th>
</tr>
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<tbody>
<tr>
<td>4000</td>
<td>$-$</td>
<td>$-$</td>
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