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ON THE INTENSITY AND POLARIZATION OF RADIATION EMERGING FROM A THICK RAYLEIGH SCATTERING ATMOSPHERE

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ABSTRACT. We compute the intensity and polarization of reflected and transmitted light in optically thick Rayleigh scattering atmospheres. We obtain results accurate to seven decimal places. The results have been validated using a variety of methods.

1. Introduction

It is well known that the intensity and polarization of light emerging from planetary atmospheres contains interesting information about its constituents (see, e.g., [1]). The discovery of hundreds of exoplanets in recent years [2] has strongly promoted interest in photometric and polarimetric modeling of exoplanets (see, e.g., [3]). There is evidently a need for accurate benchmark numbers for the Stokes parameters of reflected and transmitted radiation for a wide range of optical thicknesses of homogeneous plane-parallel atmospheres.

Rayleigh scattering represents the simplest case for modeling light scattering by particles. Chandrasekhar [4] introduced a technique to solve the Rayleigh scattering problem using the so-called X and Y functions. Coulson et al. [5] generated tables for optical thickness up to unity using this technique. Natraj et al. [6] considerably improved these tables by using an integro-differential form of the equations for the X and Y functions, and obtained results accurate to eight decimal places for optical thicknesses in the range 0.02–1.0. This range is applicable to calculations in the visible part of the electromagnetic spectrum for the Earth's atmosphere. However, for planetary atmospheres where the Rayleigh scattering optically thickness is larger than unity, there is a lack of benchmark look-up tables. Here, we present some preliminary results for optical thicknesses larger than unity.

2. Results and Discussion

We compared our results for Stokes parameters I, Q and U [7] with those from a doubling-adding technique [8] and found that the differences were less than 10^{-7}. We

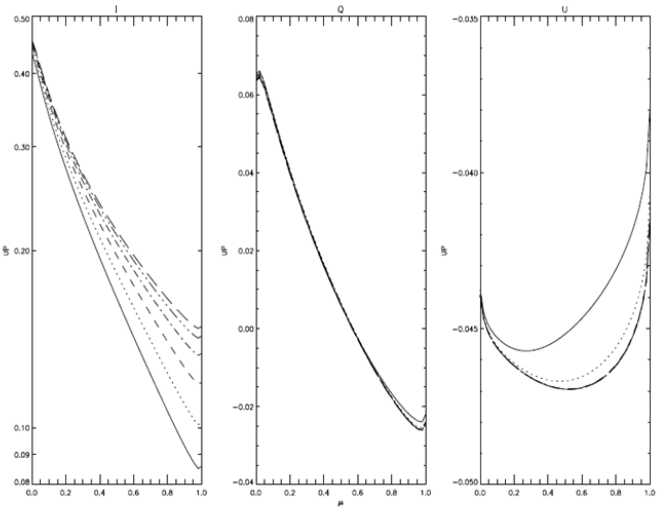

Figure 1. Stokes parameters for reflection at the top of the atmosphere (TOA) as functions of μ. μ_0 = 0.2, b = 1 (solid), 2 (dotted), 4 (dashed), 8 (dash-dot), 16 (dash-dot-dot-dot), and 32 (long dashes). Here, μ_0 is the cosine of the angle between the direction of the incident light and the vertical direction. The flux at the TOA per unit area perpendicular to the incident beam is assumed to be π.

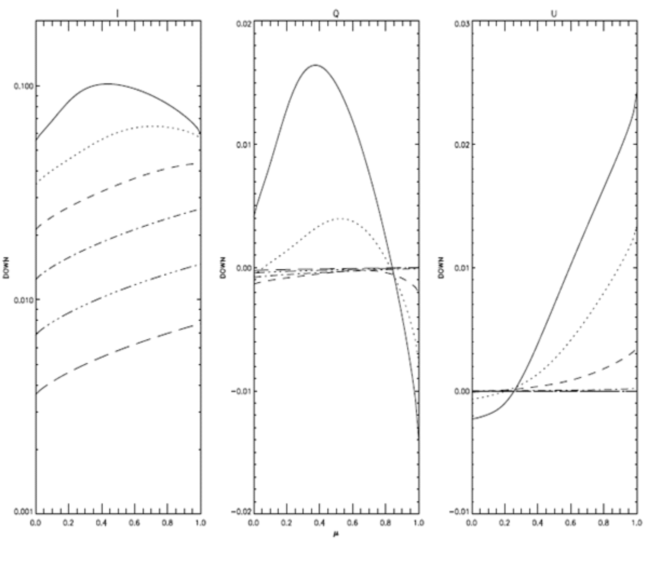

Figure 2. Same as Fig. 1 but for transmission at the bottom of the atmosphere.

further confirmed the precision of our results by (1) increasing the number of quadrature points; (2) increasing the number of integration subintervals; (3) using a different numerical integration technique; (4) using quadruple precision. We also made plots of the Stokes parameters as functions of the cosine of the angle between the direction of the emerging light and the vertical direction, μ, and the optical thickness, b. Some examples are shown in Figures 1 and 2, for an azimuth of 30 degrees and a ground albedo of 0.25. The plots indicate that Stokes parameter I converges slower for increasing b than the other Stokes parameters. Further, the Stokes parameters for transmission converge slower than those for reflection.

Acknowledgments

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