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Symmetry and structure of reflection matrices of particulate and rough surfaces.

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We consider a plane-parallel medium of infinite horizontal extent illuminated above.The properties of the medium do not vary in horizontal directions. We choose a flat horizontal reference surface to employ direction cosines and azimuthal angles for the directions of propagation of the radiation. When the Stokes vector of the incident radiation is multiplied by a four by four reflection matrix we obtain the Stokes vector of the diffusely reflected radiation. The reflected radiation is usually polarized, even if the incident radiation is not polarized. Because of the rotational symmetry with respect to the vertical direction the elements of the reflection matrix depend on the azimuth difference of the reflected and incident beams, in addition to the direction cosines of the incident and reflected beams. So, generally, each element is a function of three variables.

The conditions for the medium are quite general. For example, it may be semi-infinite or have an arbitrary thickness with a black surface underneath. The contents of the medium may be solid material or consist of particles with arbitrary packing density, as long as the reciprocity relation and mirror symmetry relation are valid. The first relation is based on time-reversal and the second on the natures of the mirror images of an incident and reflected beam. These two symmetry relations are often used in theoretical models and in many cases accepted as good approximations in observational and experimental circumstances. By combining the two symmetry relations we find a third one. In general the reflection matrix contains 16 different elements. For several special directions, however, the structure of the reflection matrix is simpler, i.e. it follows from the symmetry relations given above that some elements (i) vanish or (ii) are equal to other elements or (iii) are equal to other elements apart from a sign difference. For example, when the azimuth angles of the incident and reflected beams are the same the elements of the two by two submatrices in the lower left corner and upper right corner are zero.

Other applications of the three symmetry relations mentioned above are
• testing results of computations, experiments and observations of radiation reflected by bare surfaces,
•expansion of data obtained for a confined domain of the directions of the incident and reflected beams to a larger domain.
•constructing models for atmospheres above a reflecting surface with more realistic models for the reflection by the surface than the Lambert surface.