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An update of the Amsterdam Light Scattering Database

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Abstract

We present an update of the Amsterdam Light Scattering Database located at http://www.astro.uva.nl/scatter. We give a detailed explanation and clarification of the nature of the scattering matrices in the database. Measured scattering matrix elements are presented as functions of the scattering angle, for aerosol particles in random orientation at 632.8 nm. They pertain to seven volcanic dust samples from three different volcanoes, two samples with extreme refractive indices (hematite and rutile), and three forsterite samples with identical compositions, but different size distributions. For 15 phytoplankton species and two types of silt suspended in water, the database now contains two matrix elements, F_{11} and $-F_{12}/F_{11}$ as functions of the scattering angle at 632.8 nm. Lastly, we have included all scattering matrix elements as functions of the scattering angle for spherical micron-sized water droplets, which may be used for testing purposes.

Keywords: Database; Light scattering; Irregular particles; Aerosols; Hydrosols; Polarization; Scattering matrices

1. Introduction

The Amsterdam Light Scattering Database (http://www.astro.uva.nl/scatter), contains measured scattering matrix elements as functions of the scattering angle for small randomly oriented nonspherical particles in tabular form, so that these data can easily be used in further research. The matrix elements were measured at 632.8 nm and/or 441.6 nm. Whenever available, the database also includes additional data about the samples such as compositions, refractive indices, SEM pictures, and size distributions. So far most of the data concerned various kinds of irregular silicate particles in air. The database has now been online for a couple of years, and has indeed promoted the use of the measured data in further research, e.g. of remote sensing of the Earth atmosphere [1–4], theoretical light scattering [5–7], and astronomy [8,9].

We have attempted to make the database as complete and self explanatory as possible. In addition, we have explained the use and limitations of the database in an earlier article [10], in particular concerning the size distributions and refractive indices. However, from users of the database we obtained further feedback on how the website could be improved and clarified. This forms the main justification for this paper, since we feel an internet database is not complete without elaboration and clarification in a paper [11].

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First, in Section 2, we extensively discuss the normalization of the scattering matrix, since we found that a clear understanding of this subject is needed for many applications. Extrapolations of the matrix elements, which are measured between at most 3° and 174°, to scattering angles of 0° and 180° are also discussed in Section 2. This extrapolation is necessary for many applications of the data. Second, we briefly present the data included in the database, that are new compared to [10]. These pertain first of all to measurements at 632.8 nm for several aerosol samples, i.e. seven volcanic dust samples from three different volcanoes, two samples with extreme refractive indices: hematite and rutile, and three forsterite samples with identical compositions, but different size distributions. Thirdly, we give two matrix elements, F_{11} and $-F_{12}/F_{11}$, as functions of the scattering angle at $\lambda = 632.8$ nm for 15 phytoplankton species and two types of silt suspended in water. Lastly, at the request of some database users, we included in the database results at 441.6 and 632.8 nm for all matrix elements of a cloud of spherical water droplets to serve in tests or calibration procedures.

2. The normalization of the scattering matrix

The main purpose of this section is to clarify the meaning of the scattering matrix elements tabulated in the database.

Let us start with considering the following simple scattering experiment (see Fig. 1). A parallel beam of light is incident on a cloud (ensemble) of randomly oriented particles that scatter the incoming quasi-monochromatic light independently in all directions and without changing the wavelength. Particles and their mirror particles occur in equal numbers. Hence the cloud constitutes a macroscopically isotropic medium with mirror symmetry (see [12, Section 2.7]). We assume the cloud to be optically thin so that multiple scattering can be neglected. The light scattered in a direction that makes an angle Θ (the scattering angle) with the direction of the incident beam is, in general, polarized. The properties of this scattered light, i.e. the flux and state of polarization, are measured by a detector at a distance, D, of the center of the cloud. The plane through the directions of incidence and scattering is called the scattering plane and we use this plane as a plane of reference for defining Stokes parameters as in Van de Hulst [13], Hovenier and Van der Mee [14] and Hovenier et al. [12]. The incident parallel beam of light is characterized by a flux vector $\pi\mathbf{\Phi}_0$. This is a column vector with four elements that are Stokes parameters in such a way that the first element is the net flux (irradiance) expressible in $\mathrm{Wm^{-2}\,Hz^{-1}}$ or similar units. Similarly the flux vector of the light falling on the detector is the column vector $\pi\mathbf{\Phi}$, the first element of which is the net flux detected at a distance D.

We can describe the simple experiment by means of the relation [13]

$$\mathbf{\Phi}(\lambda, \Theta) = \frac{\lambda^2}{4\pi^2 D^2}\,\mathbf{F}(\lambda, \Theta)\mathbf{\Phi}_0(\lambda), \tag{1}$$

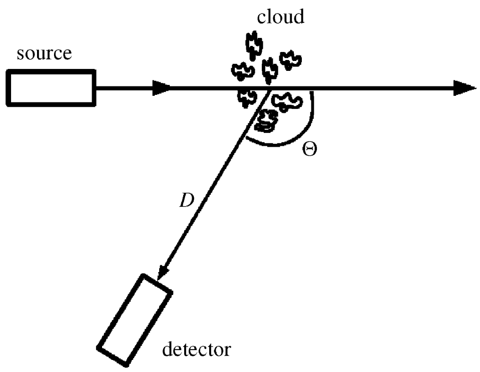

Fig. 1. A light source emits a parallel beam of quasi-monochromatic light. This light is scattered by a cloud of small randomly oriented particles in air or a liquid. A detector at a distance, D, of the cloud receives light scattered in a direction given by the scattering angle, Θ, and measures its net flux and state of polarization. The detector can be moved along a circle with radius D within a certain range of scattering angles.