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Optical Resonance (TOR) in light-droplet in atmospheric optics

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In atmospheric optics, the Mie theory is dedicated to deal with light interaction with a homogeneous dielectric spherical scatterer (e.g. cloud droplet) of known characteristics (diameter, optical index) and to calculate the optical properties of a population of such scatterers. The Mie theory is also used for inverse problem in remote sensing to retrieve the physical properties of the observed scatterers.

However, the common usage of Mie theory in atmospheric optics seems to not consider a complete light-droplet interaction by missing some resonances: light in the surrounding of a droplet can penetrate into it and excite some sharp resonances. A beautiful evidence of such Tunneling Optical Resonance (TOR) is the atmospheric glory; i.e. the circular iridescence around the projected shadow of an object on a cloud of water droplets. It is shown that these resonances appear as a natural consequence of the representation of the wavelight propagation equation as a special 1-dimensional Schrödinger (1D-S) equation with an effective potential energy depending on the wavelength, the droplet diameter and its optical index (viz. morphology-dependent interaction).

In this study, an algorithm is presented to solve the 1D-S, which allows to identify and to characterize thoroughly the different TORs that a droplet, of a given diameter and complex optical index, can give. The corresponding optical fundamental quantities, i.e. scattering amplitude and cross sections are calculated. This algorithm is based upon a combination of the transfer-matrix method and a uniform development of the 1D-S and it is flexible enough to permit investigating a great variety of situations, including heterogeneous spherical scatterers, for example when aerosols are inside a droplet, and even cylindrical scatterers (e.g. crystal needles).

Therefore the difference between the Mie theory predictions and the importance that TOR might have in droplet-light interaction is illustrated for typical cloud droplet diameters, in the visible and the infrared parts of the electromagnetic spectrum. In particular, the scattering and absorption cross sections of a single droplet given by the Mie theory and those obtained by taking into account TOR contributions are first compared. Then, a simple model of horizontally homogeneous cloud is built in order to show the importance of TOR in radiative transfer applications and to ascertain the importance of representing well light tunneling in atmospheric optics. The cloud optical thickness (COT), the cross sections (absorption, extinction, scattering) and the scattering amplitude are calculated, at the time, in the presence of TOR and with the Mie theory for several different droplet size distributions, from the simplest one (one or two droplets) to the more realistic case of a lognormal population. For satellite remote sensing applications, a special focus is pointed at the POLDER's nine spectral channels.