Astrophysical light scattering problems, spring 2023 (PAP316, 5 cr)
Project description, version 1.1, April 18, 2023

Please note that your project is to be completed by **May 5, 2023**. The project involves an introductory presentation during the lectures, a presentation in the final interactive session, and a written report.

The project entails a joint modeling of the photometric and polarimetric phase curves of a Solar System object (SSO) and consists of the following parts assessed together with the students and the lecturers:

1. Selection of the SSO and literature search for the observational datasets and the geometric albedo. Initial datasets are available (from the year 2009 and earlier) and these are to be updated to include all the current data available.

2. Least-squares fitting of the polarization phase curve using the trigonometric polarization system (software `PolTrig`). The system allows one to obtain guidance for the polarimetric phase curve at large phase angles, helping one to obtain modeling for the actual data usually available at small phase angles ($< 30°$). The current version includes a possibility for systematic scanning of the c_1 and c_2 exponents. As regularizing polarimetric points at high phase angles, one can make use of the values observed for near-Earth objects: for S-type objects, 8.1% ± 0.8% at phase angle 106.5°; for E-type objects, 2.0% ± 0.6% at 80.0°; and, for C-type objects, 10.9% ± 5.0% at 60.0°.

3. Selection of the initial, experimentally measured scattering phase matrix for the modeling. Feldspar can be used for moderate-albedo and high-albedo objects and basalt for low-albedo objects. With the `pmeio` code within the software package `RT-CB`, an empirical scattering phase matrix originally representing the feldspar or basalt measurements can be modified for obtaining refined fits to the observed phase curves. The `pmeio` code produces, as output, the `pmatea.out` file ("phase matrix ensemble-averaged") that is used as input in the next step after renaming the file to `pmatea.in`.

4. Subsequently, the `pmdec` code reads in the `pmatea.in` file and carries out a Mueller matrix decomposition for the empirical scattering phase matrix. The decomposition is needed as input for the multiple scattering code `cbsdec`. The `cbsdec` code takes `pmatdec.out` and `dec.out` as input in directory `RT-CB/cbsdec/` after renaming them as `pmatdec.in`, `dec.in`.

5. First, vary the single scattering albedo using the `cbsdec` program to find a match for the geometric albedo of the SSO. For this effort, one can use any reasonable input mean free path length (say, 10 μm). The geometric albedo is insensitive to the precise polarization properties of the scattering phase matrix. Also, vary the mean free path length to initially match the photometric opposition effect of the SSO.

6. Optimization of the input scattering phase matrix for a best possible fit to the SSO observations. The task is accomplished by iteratively tuning the input degree of linear polarization of the scattering phase matrix (steps 3-4). The tuning is carried out in the input for the `pmeio` code (input file `pmeio.in`) by changing the empirical parameters of the element $-P_{12}/P_{11}$. At each iteration (steps 3-5), the `cbsdec` numerical simulations are repeated and the goodness of fit against the observational data is evaluated. Slight adjustments can be needed for the single-scattering albedo and the mean free path length.

7. Qualitative physical interpretation of the single-scattering phase matrix retrieved from the steps 1-6 is carried out in terms of, for example, whether smaller or larger particles are likely to be present in the surfaces of the SSOs.