Report of STSM : Modelling of photometry and polarimetry of atmosphere-less bodies of our solar system

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The purpose of the STSM was to help me to gain expertise on the theoretical modelling of the polarimetric observations of small bodies of the solar system by spending 3 weeks in the University of Helsinki with Prof K. Muinonen.

The way in which the linear polarization and photometric properties change as a function of the phase angle (angle between the Sun, the target and the observer) helps us characterize the scattering medium, in both the case of solid surfaces and planetary atmospheres. This technique is routinely exploited for asteroids, and the advent of large telescopes has opened the possibility to carry out the polarimetric measurements of distant and thus fainter objects with an accuracy sufficiently good for modelling purposes.

This theoretical modelling is based on coherent backscattering and shadow mechanisms which where introduced to aid in the explanation of the phenomena of negative polarisation that sometimes occurs at small phase angles. This is a peculiar case of partially polarized light where the the electric field component parallel to the scattering plane predominates over the perpendicular component, which is in contrast to what is expected from the simple single Rayleigh-scattering or Fresnel-reflection model.

In the course of the STSM I became more familiar with the theory that uses coherent backscattering and shadow mechanisms to explain the phenomena of negative polarisation. Prof Muinonen and collaborators have successfully developed a multiple scattering model for atmosphericless solar system bodies using a Radiative Transfer and Coherent Backscattering (RT-CB) method.

During the STSM I began with learning how the RT-CB software works and how changing various input parameters influences the computation speed and the modelling results. Next, I used the software to model observations of small Trans-Neptunain Objects (TNOs) that were obtained in the last few years with the FORS instrument of the ESO VLT (preliminary modelling results were presented at the Department of Planetary Science (DPS) meeting, see Prof Muinonen et al. 2012, AAS, 44, 310.16).

Data modelling was initially performed using a Downhill simplex method, then we also began looking into the possibility of using empirical fitting functions on the observational data. We came to the conclusions that the downhill simplex method for parameter optimization takes a long time to converge towards the best fit parameters, and that the inversion algorithm needs improvement (e.g., the implementing a Marquardt algorithm). Furthermore, since the observations of TNOs cover a very small phase angle range (less than 2 degrees), it is quite difficult to constrain the model parameters for these objects. In particular the empirical fitting functions are primarily used to fit polarimetric observations of asteroids, i.e, observations that cover a wide phase angel range. When applied to TNOs, which are observed in a much smaller phase-angle range, best fitted results tend to predict unrealistic values at phase ranges that are not constrained by the observations. We also explored the possibility of introduction artificial constraints at large phase angles (e.g., add synthetic data points with large error bars at larger phase angles).

The collaboration with the University of Helsinki will continue, and we expect to produce a paper showing modelling results for TNOs and other small bodies of the solar system.