INVERSION OF ASTEROID PHASE CURVES FOR EMPIRICAL MAGNITUDE AND POLARIZATION SYSTEMS

K. Muinonen[1], A. Cellino[2], I. Belskaya[3], M. Delbò[4,2], A.-C. Levasseur-Regourd[5], and E. F. Tedesco[6]. [1]Observatory, University of Helsinki (P.O. Box 14, FI-00014 U. Helsinki, Finland, Karri.Muinonen@helsinki.fi), [2]INAF - Astronomical Observatory of Torino (strada Osservatorio 20, I-10025 Pino Torinese (TO), Italy), [3]Astronomical Observatory of Kharkiv National University (Sumska Str. 35, Kharkiv 61022, Ukraine), [4]Laboratoire Cassiopee, Observatoire de la Cote d'Azur (BP 4229, 06304 Nice cedex 04, France), [5]UPMC Univ Paris 06 / Aeronomie CNRS-IPSL (Route des Gatines BP 3, 91371 Verrieres, France), [6]Planetary Science Institute (28 Fitts Farm Drive, Durham, NH 03824, U.S.A.)

Introduction: Two ubiquitous phenomena are observed for atmosphereless solar-system objects near opposition: negative linear polarization and nonlinear surge of brightness (opposition effect) [1]. They are confined to Sun-object-observer (phase) angles of less than 30 and 10 degrees, respectively. To fit the phase curves, empirical systems are usually adopted, such as the two-parameter *H, G* magnitude system [2] and the trigonometric and polynomial polarization systems (e.g., [3]). The increasing amount of observational data on asteroids, as well as the discovery of new phase effects (such as shallower or steeper opposition effects), make it possible to refine existing empirical systems to better match the observations.

Numerical methods: We provide a method for deriving the system basis functions (analogous to the *H, G* system's Φ_1 and Φ_2 functions) directly from the observations. The method allows for a general nonlinear inversion for the basis functions without the need to invoke analytical basis functions. The basis functions are specified in a grid of phase angles, the actual function values being presently the free parameters sought for. We develop empirical magnitude and polarization systems with the help of the Markov-Chain Monte-Carlo sampling method (MCMC) [4]. At each iteration step, the MCMC algorithm proposes new basis functions via the function values at the discrete set of phase angles. Here, upon utilizing MCMC for the refinement of parameters, the proposed changes are accepted only if they result in improved rms-values when the observations are fitted with the new basis functions proposed (currently, linear interpolation assumed between the grid points). After a number of iterations, the basis functions converge toward their final states. It is possible to impose constraints for the basis functions. For example, in the magnitude system, the basis functions are forced to be monotonically decreasing functions of phase angle, with positive second derivatives close to opposition.

Results and discussion: We have applied the method to high-precision magnitude and polarization data currently available for asteroids (comets will also be studied soon) by initializing the MCMC refinement using the *H, G* and the trigonometric systems. The iteration of the basis functions results in considerable improvements for both systems: the overall weighted χ^2 values improve by 25% and 35% for the magnitude and polarization systems, respectively. Figure 1 shows the revised basis functions of the magnitude system in comparison to the *H, G* system. The refinement suggests that the multiple-scattering basis function Φ_2 of the *H, G* system should include a sharp feature near opposition. The suggestion is in agreement with the coherent-backscattering explanation of the opposition effect. In addition, the refinement suggests a sharp opposition feature in the single-scattering basis function Φ_1. Note, however, that the present derivation allows us to avoid a priori assumptions about the underlying physical mechanisms. For the polarization system, the changes are more subtle.

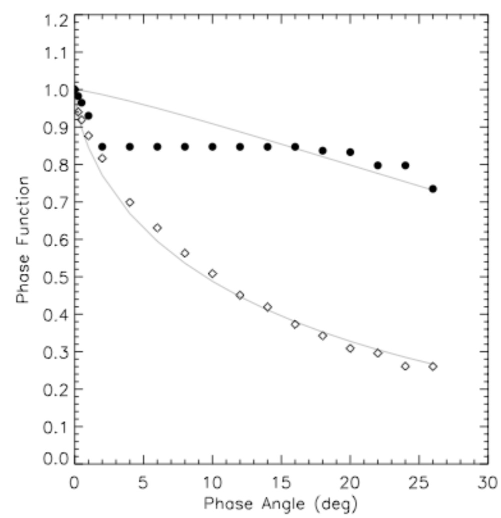

Fig. 1. Basis functions of a refined asteroid magnitude system (diamonds and bullets) as compared to the Φ_1 and Φ_2 basis functions (lower and upper solid lines, respectively) of the *H, G* magnitude system [2].

References: [1] Muinonen K. et al. (2002) *Asteroids III*, 123-138. [2] Bowell E. et al. (1989) *Asteroids II*, 524-556 [3] Lumme K. and Muinonen K. (1993) *IAU Symposium 160: Asteroids, Comets, Meteors 1993*, Abstracts, 194 [4] Gilks W. R. et al. (1996) *Markov Chain Monte Carlo in Practice*, Chapman & Hall/CRC.

Acknowledgments: Research carried out, partially, at the International Space Science Institute in Jan. 2008.