4.2. Asteroids, Comets and Transneptunian Objects

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For the last years our principal research were directed to study physical properties of main-belt asteroids, near-Earth asteroids, comets, and Transneptunian objects on the base of their photometric and polarimetric obsevations. The main research programs include:

- Asteroid shapes and rotation parameters;
- Searching for and study of binary systems among near-Earth and main-belt asteroids;
- Opposition effect, magnitude-phase dependences and other optical properties of asteroids;
- Light scattering and physical properties of comet dust;
- Physical properties of Transneptunian objects.

Photometry of main-belt and near-Earth asteroids

Photometric observations were curried out at the Institute Observation Station (in 75 km from Kharkiv city) with the 0.7 m reflector AZT-8 equipped with photoelectric photometer-polarimeter and CCD cameras ST-6, IMG 1024 and IMG 47-10 (Finger Lake Instrumentation). A portion of photometric observations was curried out at the Crimean Astrophysical Observatory with the 1 m reflector (Simeiz) and CCD cameras ST-6 and Apogee Alta. During 370 nights the photometric observations of 101 asteroids (including 34 NEAs and 3 Mars-crossers) were carried out and their lightcurves and color indexes were obtained and used for study of asteroid shapes, sizes, rotation parameters, optical properties of their surfaces, for discovery and study binary systems, etc. Besides, the CCD follow-up observations of the several newly discovered near-Earth asteroids were carried out and processing (Velichko F., Shevchenko V., Krugly Yu., Chiorny V.). As a result of this program the rotation periods of 40 asteroids, the UBVRI-color indexes, compositional types and the estimates of absolute magnitudes and sizes of several tens asteroids were obtained. Our observations of 1682 Apollo at Simeiz Observatory in November 2005 were carried out in frame of International observation network managed by M. Kaasalainen

(University of Helsinki). Analysis of available Apollo's data has showed a change in the rotation rate of the asteroid, which is best explained by the YORP effect. The change is fairly large and clearly visible in photometric lightcurves, amounting to one extra rotation cycle in just 40 years even though Apollo's size is well over one kilometer. This confirms the prediction that the YORP effect plays significant role in the dynamical evolution of asteroids (Krugly Yu.).

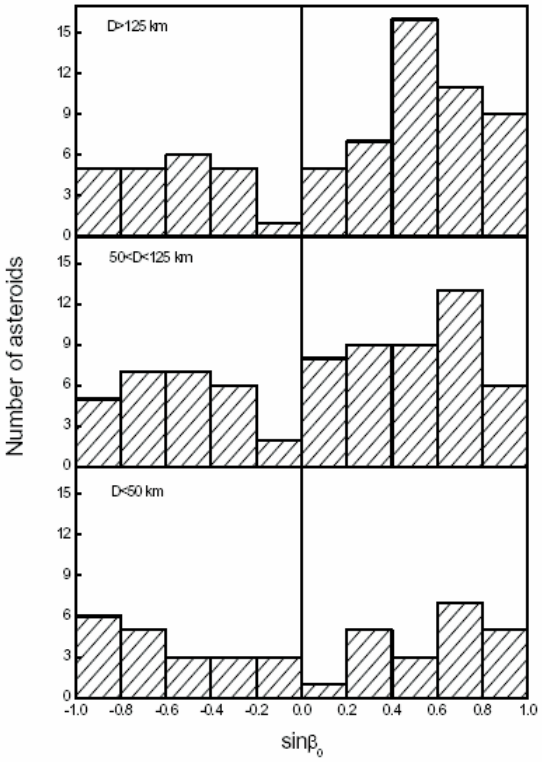

Figure 17. Distribution of ecliptic latitudes of asteroid poles for different range of asteroid diameters (sinβ0>0 – prograde rotation, sinβ0<0 – retrograde).

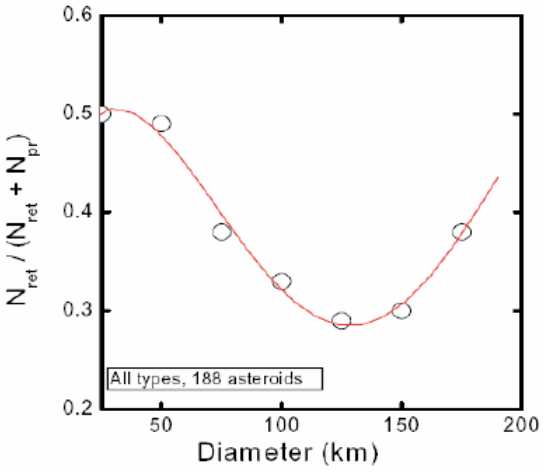

Figure 18. Dependence of a portion of asteroids with retrograde rotation on their diameters.

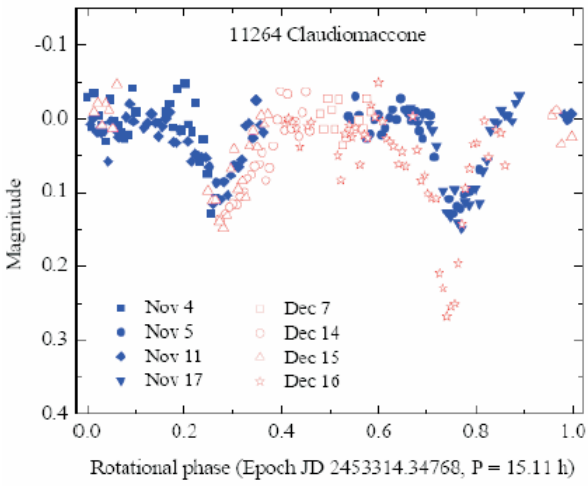

Figure 19. Composite lightcurve of the long-period component of binary asteroid11264 Claudiomaccone

The method of inverse task solution for the determination of asteroid pole coordinates, sidereal periods of rotation, senses of rotation, and ratios of semi-axis of their figures was improved. Using this method the foregoing parameters for 55 asteroids (including 11 near-Earth ones) were determined. Analyzing these and all available data (about 200 asteroids) an anisotropy in the distribution of ecliptic latitudes of asteroid poles with maximum at near middle latitudes ($\beta_0 = 40 \pm 4°$) was confirmed. For the first time it was shown that the anisotropy takes place only for objects with prograde rotation (see Fig. 17, $\sin\beta_0 > 0$). Moreover the degree of anisotropy increases with asteroid diameters. The ratio of asteroids with prograde and retrograde rotations increases with their diameters from 1:1 among the small asteroids (D < 50 km) to 1.5:1 among the intermediate (50<D<125 km) and to 2:1 among the large ones (D > 125 km). These conclusions have a cosmogonic character and are evidence of the intensive collision evolution in asteroid belt (Shevchenko V., Lupishko D.).

The clear minimum at D = 125 km in the dependence of a portion of asteroids with the retrograde rotation on their diameter was confirmed using the sample of data 2.5 times larger than it was analyzed before (Fig. 18). As is well known, the similar minimum at this diameter also exists in the dependences of rotation rates and lightcurve amplitudes on asteroid diameters. New and more complete data show that the depth of the minimum for M-asteroids is much greater than for C and S-types and probably correlates with asteroid density increasing from less dense C-type to S and to most dense M-type. Thus, asteroid diameter of 125 km is a cosmogonic peculiarity, and its quantitative explanation can give valuable information on dynamical evolution in asteroid belt (Lupishko D.).

Searching for and study of the binary systems among asteroids

Our photometric CCD-observations of the small main-belt asteroid 11264 Claudiomaccone, which were carried out with the 0.7 m telescope at Chuguev Observation Station in November 2004 and the 1-m telescope at Simeiz Observatory in Dec. 2004, have shown the presence of two different periods in asteroid brightness variations. A short period of 3.1872 ± 0.0006 h and long one of 15.11 ± 0.01 h were determined. The analysis of lightcurves allowed us to suppose that asteroid 11264 Claudiomaccone is an asynchronous binary system in the main belt (Fig. 19). The parameters of the system are estimated to be as follows: the ratio of the secondary to primary diameters is ≥ 0.31, the ratio of the orbital radius to the primary's diameter is

about 1.5 and a bulk density of the primary body is $\rho_p \geq 1.2$ g/cm^3 (Krugly Yu., Lupishko D., Shevchenko V., Velichko F.).

Since 2005 we take part in the International observational program “Photometric Survey for Asynchronous Binary Asteroids” established by P. Pravec at Ondrejov Observatory in the end of 2004. The project is aimed for search and investigation of the binaries between NEAs and small main-belt asteroids with D<15 km. In the frame of this program we observed more than 20 asteroids among them 10 ones were revealed as binaries (Krugly Yu., Chiorny V., Shevchenko V.).

Magnitude-phase dependences and other optical properties of asteroids

The magnitude-phase dependences down to small phase angles were measured (mainly in the V band) for more than 50 asteroids of diverse surface composition. The observations let us to search for possible correlation of phase curve parameters and asteroid surface properties. A strong correlation has been found between phase coefficients and albedos, which can be used for asteroid albedo estimations. At phase angles > 5° up to 25° the phase slopes increase linearly as albedo decreases assuming dominating contribution of the shadow-hiding effect in this phase angle range and a similarity of surface texture of the studied asteroids. At smaller phase angle range (0.3 – 5°) we found non-monotonic dependence of the phase slopes on asteroid albedo. The maximum value of the phase slope defined as I(0.3°)/I(5°) is observed for moderate albedo asteroids decreasing both for dark and high albedo surfaces. It can be explained by an increasing influence of the coherent-backscatter mechanism at small phase angles which is more prominent for high-albedo surfaces. Low albedo asteroids are found to have the smallest amplitude of the opposition effect and its largest dispersion as compared to other asteroid types. A special program to study brightness opposition effect for low albedo asteroids has been carried out last years. We measured phase curves down to extremely small phase angles 0.1 – 0.3° for about 15 low albedo asteroids and found 3 asteroids for which the brightness behavior in the range of opposition effect is almost linear (190 Ismene, 419 Aurelia, 1021 Flammario). These asteroids are assumed to have the darkest surfaces where the shadow-hiding mechanism alone forms brightness behaviour near opposition. Other low albedo asteroids measured so far show typical opposition effect with amplitude about 0.1-0.2 mag relative to the extrapolation of the linear part of phase curve toward opposition (Shevchenko V. G., Belskaya I. N., Chiorny V. G., Krugly Yu. N.).

For asteroids 419 Aurelia and 1021 Flammario with the smallest opposition effect value we carried out polarimetric observations to measure polarization phase functions. It was found that both asteroids are characterized by unusually shallow negative branch with small inversion angle atypical for other low albedo asteroids (Belskaya I. N.).

Photometry and polarimetry of comets

Photometric and polarimetric observations of the dynamically new comet C/2002 T7 (LINEAR) and periodical comets 153P/Ikeya-Zhang, 2P/Encke and 73P/Schwassmann-Wachmann 3 are carried out using the 0.7 m reflector of our Institute and 1.25 m and 2.6 m reflectors of Crimean Astrophysical Observatory (Ukraine) with UBVRI-polarimeter. It was shown that a number of gas-rich comets have low polarization degree at large phase angles and blue color mainly due to low spectral and spatial resolution of the measurements. The dust-rich comet 153P/Ikeya-Zhang in continuum filter GC (λ 5652/57 angstrem) has shown low polarization degree because of that the comet spectrum has an unidentified emission line overlapping the GC-band (Velichko F., Velichko S.). The nucleus C of the gaseous comet 73P/Schwassmann-Wachmann 3 shows phase dependence of polarization at $\alpha = 48 \div 95°$ in red continuum RC (λ 6840/90 angstrem). This dependence is close to the average one of dusty comets, but far than that for so-called gaseous comets (Velichko F., Kiselev N., Velichko S.). Otherwise, polarimetry of the gaseous comet 2P/Encke shows that dust polarization may be as high as in the so-called dusty comets. Thus the dichotomy in polarization of dust-rich and gas-rich comets is probably an artifact caused by the gas emissiom transmitted by cometary “continuum” filters (Kiselev N.).

Polarimetry and photometry of the dynamically new comet C/2002 T7 (LINEAR) have given possibility to obtain phase dependence of polarization in WRC filter (λ 7228/1142 angstrem) in the range of negative polarization ($\alpha = 6.4 \div 26.0°$) with the parameters: $P_{min} = -1.63\%$, $\alpha_{inv} = 22.7°$, $h = 0.24$. From the photometry the following characteristics have been obtained: the column density of molecules C_2 in the line of sight $\log N(C_2) = -9.15$ mol/cm^2 and their production rate $\log Q(C_2) = 27.11$ mol/s. The physical parameters of comet C/2002 T7 (LINEAR) are close to the average characteristics of typical dusty comets (Velichko F., Kiselev N., Velichko S.).

Another important aspect of asteroid studies that is developed in our Institute is the electronic Database of Comet Polarimetry that contains more than 2600 measurements of linear and circular polarization for 64 comets starting since 1940. It is a component of the

international Database PLANETARY DATA SYSTEM (NASA) and can be accessible via http://www.psi.edu/pds/archive/comets.html (Kiselev N., Velichko S.).

Physical properties of Transneptunian objects

The recent discovery of Trans-Neptunian objects, called also Kuiper belt objects (KBOs), has opened new horizons in the Solar system study. An entirely new population of planetary bodies has been found, which should contain the most primordial material from the formation of the Solar system. The Kuiper belt objects may be observed only at a very limited phase angle range (usually less than 2°) where the opposition effect plays a dominant role. We made first estimations of the opposition effect amplitude and width based on observations of two KBOs (15789 1993 SC, 20000 Varuna) and one Centaur (10370 Hylonome). They gave first evidence on the existence of a very narrow opposition surge starting at phase angles below 0.1° – 0.2°. Further observations of Varuna confirmed the pronounced opposition surge at phase angles less than 0.1° with amplitude of 0.2 mag relatively to the extrapolation of the linear part of magnitude phase dependence to zero phase angle. The obtained data give a first look into the microscopic properties of the surface layers of TNOs and suggest different surface properties as compared to less distant small Solar system objects (Belskaya I. N.).