Near Earth Objects, our Celestial Neighbors: Oportunity and Risk
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Astrometry of small Solar System bodies at the Molėtai observatory

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Abstract. We describe an observational project devoted to astrometric observations of Near-Earth Objects (NEO), main belt asteroids and comets at the Molėtai Observatory, Lithuania. Exposures are obtained with the two telescopes of the observatory: 0.35/0.50 m f/3.5 Maksutov telescope and the 1.65 m reflector with focal reductor f/3.1 and CCD camera. The results of more than 10 000 positions of asteroids and comets have been published in the Minor Planet Circulars and Minor Planet Electronic Circulars. During the 2001–2006 period 130 new asteroids were discovered. The latest discovery is the high-inclination asteroid 2006 SF_{77} belonging to the NEO Aten group.

Keywords. Astrometry; follow up; discovery

1. Observations

Our project serves as a study of asteroids and comets for a better prediction of their orbits and thus their Earth-impact threat. The Molėtai observing program is centered on observing Main belt asteroids, newly discovered bright (15-18 mag) NEA and for search of new asteroids. The targets for observations were selected using public WEB tools for observers (IAU MPC, The NEO Confirmation Page). First astrometric observations of comets at the Molėtai Astronomical Observatory (longitude 25.57 E, latitude 55.32 N, altitude 210 m) have been started in 1998 using a 0.41 m f/6 Schmidt-Cassegrain telescope with a small Meade CCD camera (Černis & Janulis 1998). In the period of 2000–2001 the Tromso (Norway) CCD camera with a thinned TK1024 chip and two-stage thermoelectric cooling was used with the 0.35 m Maksutov Newtonian reflector for astrometric observations of asteroids and comets (Černis & Laugalys 2002).

The Maksutov telescope with Tromso CCD produced a scale of 4.1″ /pixel. First three new asteroids have been discovered in 2001: 2001 OM65, 2001 UM14 and 2001 UU175. The first asteroid, deep Mars crosser 2001 OM65, has been discovered with the 1.65 m telescope with focal reducer f/8. Other two asteroids where discovered with the Maksutov reflector.

Systematic astrometric observations of asteroids and comets began in 2002 when a new VersArray CCD camera (with liquid nitrogen cooling) has been purchased by the Institute of Theoretical Physics and Astronomy. With this camera the Maksutov telescope produces a scale of 3.4″/pixel (Zdanavičius 2003). The 1.65 m reflector with a new focal reducer gives much better astrometric precision, having a scale of 0.9″/pixel. All measurements were done using the Astrometrica software (Raab 2003). The catalogues USNO-A2.0, USNO-B1.0 and UCAC-2 were used for selection of the reference stars. The limiting magnitude for stars with the Maksutov telescope is about 20.5 R magnitude on unfiltered images with the exposure time about 360 s (field-of-view 76′ ×80′). It is a very useful instrument to follow-up astrometry of poorly observed bright NEOs, unusual

Table 1. Distribution of numbers of discovered asteroids $N_{disc.}$, numbers of astrometric observations $N_{obs.}$ and numbers of observed objects $N_{obj.}$ according to time.

Year	$N_{disc.}$	$N_{obs.}$	$N_{obj.}$	References (MPC No.)
2000	0	58	26	41639
2001	3	141	35	42977, 43111, 43450, 43833
2002	12	442	99	44289, 44718, 45048, 45452, 45855, 46218, 46511, 46858
2003	13	643	179	47507, 47996, 48621, 49430, 49886
2004	55	2233	503	50599, 51502, 52495, 52889
2005	36	5252	1230	53631, 54346, 54967, 55473
2006*	11	1252	399	56150, 56765, MPEC 2006-S57
Total	130	10021	2471	

Note: until 2006 October 1.

Table 2. Distribution of numbers of observed comets $N_{com.}$ and numbers of astrometric observations $N_{obs.}$ of comets according to time.

Year	$N_{com.}$	$N_{obs.}$	References (MPC and MPEC)
2000	7	48	MPC 42236, MPC 42959
2001	1	21	MPEC 2001-R57
2002	2	25	MPC 43426, MPEC 2002D-38, MPEC 2002G-38, MPEC 2002-G40
2005	6	52	MPC 54967, MPC 55473, MPEC 2005-U04, MPEC 2005-V88, MPEC 2005-V90, MPEC 2005-V91, MPEC 2005-V95
2006*	10	193	MPC 56735, MPEC 2006-H61, MPEC 2006-J10, MPEC 2006-J31, MPEC 2006-J54, MPEC 2006-K18, MPEC 2006-K55, MPEC 2006-L18, MPEC 2006-L48, MPEC 2006-S50
Total	26	339	

Note: until 2006 October 1.

objects and comets. About 3000 CCD images were obtained for the astrometric work of asteroids and comets during the four last years.

During sky survey in near ecliptic regions in 2002–2006 and during NEO asteroid follow-up astrometry 119 new asteroids have been discovered. Our site (IAU Code 152) in total has discovered 122 objects, 46 of the discoveries are involved in multiple-apparition, 46 of the discoveries are involved in one-opposition object orbits, 22 objects of the one opposition objects have calculated orbits with low accuracy. For 103 objects the orbit have been determined.

Eight additional asteroids have been discovered by one of the authors (K. Černis) using the NEAT CCD frames obtained from the Palomar Mountain Observatory (IAU Code 644) with 1.24 m Oschin Schmidt telescope in 2003 (Helin *et al.* 2003, 2004).

Among the discovered asteroids there are a few unusual objects: the Aten group PHA asteroid 2006 SF_{77} with a=0.92 AU, e= 0.33 and i= 33 deg, the Hilda group asteroid 2004 TB_{21} with a=3.98 AU, 2005 TW_{52} with e= 0.4, Mars crossers 2001 OM_{65} and 2005 TB_{50}. During the investigation of our CCD frames two NEO asteroids, the Apollo-type object 2004 EP20 (q= 0.58 AU) and the Amor-type asteroid 2004 DK_1 (q= 1.1 AU) have been discovered independently, but after the original discovery was published in the MPECs. The same happened for the unusual object 2005 EL_1 (q= 1.35 AU) and the Hungaria-type object 2005 SK_1 (a= 1.92 AU).

Table 1 shows the number of our discoveries, number of astrometric observations, number of observed objects and references for published data in the IAU Minor Planet Circulars. Among more than 10 thousands observations, 144 observations belong to NEO. This means about 1.5 % of total number of observations belong to NEO asteroids.

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Table 2 shows the distribution of numbers of observed comets, astrometric observations of comets and references to the published data (IAU Minor Planet Circulars and Minor Planet Electronic Circulars). Among the 26 observed comets at the Molėtai Observatory, the brightest one was the comet C/2002 C2 (Ikeya-Zhang) being an object of mag. 3, and the faintest was P/2005 T2 (Christensen), a mag. 20 object. In 2006 the comet 73P/Schwassmann-Wachmann 3 made a close approach to the Earth. During the period Apr 19 – May 16 we got 267 CCD images of 7 comet components (73P-C, 73P-B, 73P-AQ, 73P-G, 73P-R, 73P-M and 73P-N). Splitting of the comet component 73P-B into two parts (73P-B and 73P-AQ) has been confirmed in our images of April 23, 2006.

2. Results

The results of about 10 000 astrometric positions of more than 2400 asteroids and 26 comets, including the NEO asteroids (about 1.5%) (2000 LL, 2000 PH5, 2001 KP41, 1990 SB, 2001 LF, 2001 MZ7, 2001 MF1, 2001 KX67, 2002 EX11, 2004 EP20, 2005 TR, 2005 TP45, 2005 TG50, 2005 TD, 2005 TS45, 2006 SF77) and transneptunian objects (2002 UX25, 2003 UB313) have been already published in Minor Planet Circulars and MPEC circulars (Černis & Zdanavičius 2002, 2005; Černis, Zdanavičius, Zdanavičius 2004, 2005).

Almost all asteroids have absolute magnitudes in the range H= 15–18 mag. The asteroids 2002 FU10 with H= 14.2 mag and Aten-type object 2006 SF77 with H= 21.7 mag have the extreme values of H. Spatial distribution of absolute magnitudes H versus semiaxes for 102 our discovered objects is shown in Fig. 1(left). All asteroid data are taken from Minor Planet Center database (here and for other figures). The vertical axis of H is connected with a photometric diameter of the asteroid. We estimate that our objects are of diameters from 150 m to 7 km.

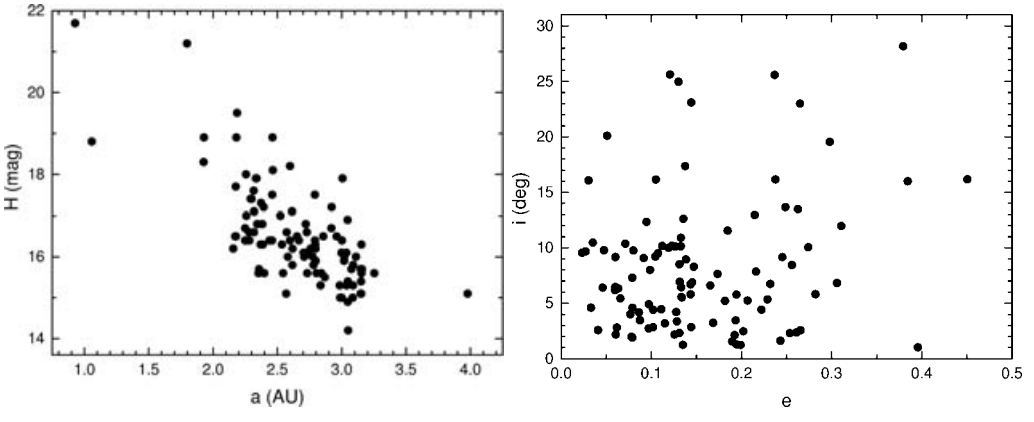

Figure 1. Left – Absolute magnitudes H of the discovered asteroids versus their semiaxes a. Right – Distribution of the asteroid orbit inclination (i) versus eccentricity (e).

Fig. 1(right) shows the distribution of i (orbital plane inclination) and orbital parameters e (eccentricity) of the discovered asteroids. We can see that most orbits have e< 0.3 and i< 20 deg. Extreme values of e (about 0.4) have four objects: NEO asteroids (2004 DK1, 2004 EP20), one main-belt asteroid 2005 TW52 and asteroid 2005 EL1. The largest values of orbit inclination (i= 25 – 28 deg) have: the asteroid 2005 EL1, main-belt asteroids 2002 TP303, 2003 FB123 and two Hungaria-type asteroids. The analysis of statistical properties of the discovered main-belt asteroids share the known characteristics of the main belt.

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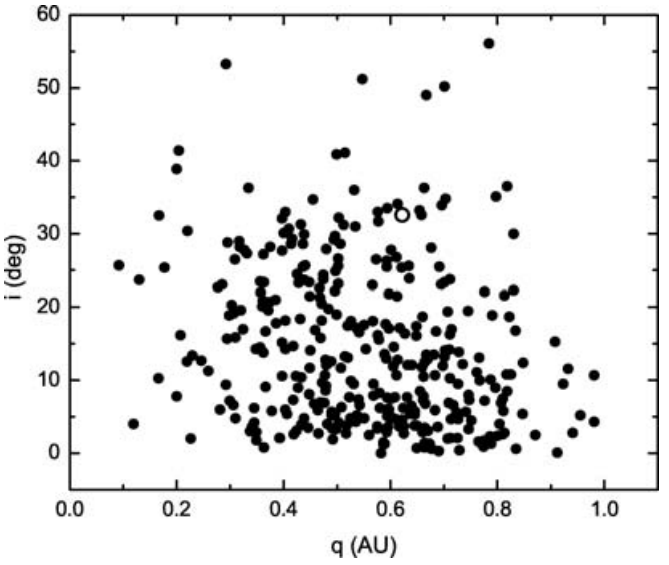

Figure 2. Distribution of Aten group asteroids in the perihelion distance vs. orbit inclination. Open circle – the asteroid 2006 SF77.

The asteroid 2006 SF77 was discovered on September 23, 2006 (Černis & Zdanavičius, 2006). This object belongs to Aten group asteroids whose orbits lie almost completely inside of Earth's. Only about 340 of such objects are known. At the discovery moment PHA 2006 SF77 was 0.081 AU from Earth. It orbits the Sun once in every 325 days. Astrometry of this Aten group asteroid of about 150 meters was carried out during 5 nights at the Molėtai observatory. The next close approache will happen in September 22, 2037 when this asteroid will pass at 0.061 AU from Earth. Fig. 2 shows the distribution of Aten group asteroids in the perihelion distance vs. orbit inclination diagram. We can note that the object 2006 SF77 belongs to the high inclinated Aten group asteroids (i= 33 deg).

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