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EURONEAR: First results

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Abstract

The European Near Earth Asteroid Research (EURONEAR) is a project which envisions to build a coordinated network which will follow-up and recover potentially hazardous asteroids (PHAs) and near earth asteroids (NEAs). We aim to include in EURONEAR two automated 1 m telescopes located in Chile and Europe, in addition to other non-permanent facilities. Astrometry will be the main aim of the project in order to secure and follow-up newly discovered NEAs, also to recover PHAs at their second or following oppositions, while photometry of bright PHAs will bring information on their physical properties. In this paper, first we review briefly the existent and past NEAs programs. Next, we include the results obtained in 2006 from three observing runs at Pic du Midi using the 1 m telescope, Haute-Provence employing the 1.2 m telescope, and Bucharest using a small 23 cm telescope. These add a total of 153 positions for 16 PHAs and NEAs, which were accepted by Minor Planet Center. Recently, a 1 m telescope was allocated by ESO in La Silla to be automated and used as the Southern dedicated facility by EURONEAR.

Keywords: Near earth asteroids (NEAs); Potentially hazardous asteroids (PHAs); Astrometry; Follow-up; Photometry; Minor planet center

1. Introduction

Follow-up observations of near earth asteroids (NEAs) are welcomed by the astronomical community in order to recover newly discovered bodies, to secure and improve their orbits and to predict their future close encounters with the Earth, including any possible collision threat well in advance.

NEAs are defined as asteroids with a perihelion distance $q \lesssim 1.3$ AU (e.g., NASA, 2006a). Potentially hazardous asteroids (PHAs) are defined as NEAs having a minimum orbital intersection distance (MOID) $\lesssim 0.05$ AU and the absolute magnitudes $H \lesssim 22$, which corresponds to objects larger than about 150 m, assuming an albedo of 13%.

According to ASTORB database (Bowell, 2006), there are 364,892 cataloged asteroids known today (11 January 2007). According to NEO website (NASA, 2006a), there are 4414 NEAs and 837 PHAs known today (11 January 2007), and the number of known NEAs continues to grow by 200–500 new NEAs and 50–90 new PHAs every year (EARN, 2006). During the last decade, the numbers of known NEAs/PHAs have decreased dramatically, due to five NEAs discovery programs in progress, mostly carried out in the US: LINEAR (MIT, 2006), NEAT (NASA, 2006b), Spacewatch (LPL, 2006), LONEOS (Lowell, 1996), and Catalina (Beshore et al., 2006).

Two important priorities after a NEA discovery consist of the recovery and follow-up of the new object. Despite the fast growth in the NEA number, very few groups worldwide run dedicated astrometry programs. Some notable efforts in the past were carried out at DAO in Canada (Tatum et al., 1994), McDonald Observatory in the US (Whipple, 1995), Beijing Observatory in China (Zhu et al., 1997), AANEAS in Australia (Steel et al., 1998), CINEOS in Italy (Boattini et al., 2004a), OCA-DLR in France and Germany (ODAS, 1999), and others.

Today, among the most active NEAs follow-up groups are the Ondrejov and Klet Observatories in the Czech

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Republic (Pravec et al., 2006; Ticha et al., 2002, 2006), the US Naval Observatory using the FASTT scanning transit telescope (Stone, 1997), Pulkovo Observatory in Russia (Pulkovo, 2006), Nordic NEON in Canary (Muinonen et al., 2006), Catalina South in Australia (Beshore et al., 2006), JSF in Japan (JSF, 2006), UKAPP in Ireland (Fitzsimmons, 2006), D. Tholen at Mauna Kea. Most of these projects involve 1 m class telescopes. Other efforts are conducted by amateur astronomers using smaller telescopes, such as Sormano Observatory in Italy (OAS, 2007), P. Birtwhistle in UK (Birtwhistle, 2007), R. Tucker in the US (Tucker, 2007), etc. A pilot test to search and follow-up NEAs beyond 22nd magnitude was performed by Boattini et al. (2004b) using two larger facilities, namely the 2.2 m MPG/ESO telescope for the search and the 3.6 m ESO NTT for the follow-up. An incoming ambitious survey lead by the US, Pan-STARRS, envisions to start full operation around 2010 (Pann-Stars, 2006). Despite all these initiatives, to date there is no European telescope dedicated to observe full-time NEAs.

2. EURONEAR

During the last years, two of us performed some follow-up observations of NEAs and PHAs using small telescopes located at two heavily light polluted places. Employing a 0.6 m telescope, OV[3] observed five PHAs at York University Observatory in Toronto, Canada (Vaduvescu, 2005). Using a 0.38 m refractor, AN observed two NEAs at the Astronomical Institute Observatory in Bucharest, Romania, also a 0.6 m telescope at Belogracic Observatory in Bulgaria.

Follow-up observations of NEAs and PHAs is necessary for a few important reasons. First, once a new NEA is discovered, immediate observations are necessary in order to recover and secure its orbit. Second, once a PHA is determined, follow-up observations are necessary in order to improve its orbit, to be able to predict future close encounters and possible collisions with Earth. Third, studies of its physical parameters such as rotation periods, color, albedo, taxonomy and size, are necessary in order to extract information about the most possible encounters.

Born in May 2006 in Paris, EURONEAR stands for the European Near Earth Asteroid Research (Vaduvescu et al., 2006; Colas et al., 2006). This project envisions to follow-up and recover NEAs and PHAs in an optimized fashion, using two 1 m dedicated class telescopes and other non-dedicated facilities located in Europe and elsewhere.

3. First results

The first three points in the EURONEAR constellation network were marked recently by four observing runs which took place in 2006 at Pic du Midi, Haute de Province, and Bucharest. We will present these results in this section. Table 1 presents the observing log.

3.1. Pic du Midi Observatory

In conjunction with the associate position at IMCCE of OV, the first EURONEAR run took place between 15 and 29 May at Pic du Midi Observatory, France (MPC code 586). Two of us, FC and OV, attended this mission. We used the T1 m telescope with $D = 1.05$ m, $F = 5.8$ m, $F/D = 5.5$, endowed with a CCD Thompson THX 7863 384×288 pixels, $0.82\,\mathrm{arcsec\,pix^{-1}}$ $23 \times 23\,\mu\mathrm{m\,arcsec^{-1}}$ with a field of view (FOV) $= 5.2\,\mathrm{arcmin} \times 3.9\,\mathrm{arcmin}$.

We observed in bad weather conditions, adding in total only about three clear nights out of the nine allocated to this mission. We observed in total 13 NEAs and PHAs listed in Table 1. According to column (4), most targets were newly discoveries, being observed at their first opposition. Data were reduced by the whole team within a few days after acquisition, then reported to MPC. In total, 120 positions were accepted by MPC, being further included in NEODyS database (Milani et al., 2006).

Fig. 1 plots the O−C residuals (observed minus calculated positions), based on the NEODyS data. Most residuals are less than 0.5 in. in absolute value. Larger relative spreadings can be observed in a few cases, from which for example the third and ninth OBS ID sets can be easily spotted. For most cases, the spreadings can be explained by the low S/N. This is due to the faint brightness of most targets, which required longer exposure times (limiting magnitude being about $V = 20$ for a 1 m telescope), combined with the high proper motion (most targets are at opposition) which prevented longer exposures. To avoid trails, we guided the telescope using half the asteroids' proper motion.

Nowadays, reference in astrometry is given by various stellar catalogs in ICRS J2000 reference system, whose densities and errors are listed for example in Vaduvescu (2005). From these catalogs, PPM and Tycho-2 ensure very accurate positions and proper motions, but have very few stars in an average field, less than one star in a classic $5\,\mathrm{arcmin} \times 5\,\mathrm{arcmin}$ FOV. GSC v. 1 and 2, 2MASS, UCAC-2, USNO-A2, and USNO-B1 go much deeper, including an average of 3–180 stars in a $5\,\mathrm{arcmin} \times 5\,\mathrm{arcmin}$ FOV, although they suffer less accurate astrometry and most lack proper motions.

The CCD field of the T1 m is relatively small (about $5\,\mathrm{arcmin} \times 3\,\mathrm{arcmin}$), thus fields needed to be carefully planned in order to include a few reference stars. Astrometry was reduced by MB, FC, AS, and AN using Astrometrica software (Raab, 2006) in USNO-A2 and USNO-B1 references. Fig. 2 plots the histogram showing measurement errors for all observations at Pic du Midi site. In both right ascension and declination, the average position error is about 0.15 arcsec. This is due to the relatively faint brightness of the asteroids combined with their high proper motion, resulting in small trails.

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Table 1
(1) Asteroid number; (2) type (according to MPC at observation date): des = desirable, A = Arecibo radar target; (3) observation night (2006); (4) period since discovery; (5) apparent magnitude (according to MPC); (6) proper motion (in arcsec min); (7) exposure time (in seconds); (8) number of positions accepted by MPC; (9) catalog used for astrometric reduction; (10) number of used reference stars

Asteroid (1)	Class (2)	Night (3)	Obs-dis (4)	V (5)	μ (6)	Exp (7)	Pos (8)	Cat (9)	Stars (10)
2006 HV57	NEA des	16/17 May	18 days	19.2	0.5	300	10	USNO-A2	4–5
2006 JU	NEA des	16/17 May	13 days	19.6	1.0	300	10	USNO-B1	18–27
2006 JU41	NEA des	16/17 May	9 days	19.8	0.7	300	5	USNO-B1	7–14
2006 HV57	NEA des	18/19 May	20 days	19.2	0.5	300	8	USNO-A2	4–5
2004 VD17	VI urg	18/19 May	2 years	19.7	1.3	180	10	USNO-B1	5–7
2006 JF42	PHA des	18/19 May	7 days	17.8	2.2	120	10	USNO-B1	5–8
2001 GN2	PHA des	18/19 May	5 years	19.2	2.7	120	10	USNO-B1	4–7
2006 GW2	NEA des	18/19 May	40 days	19.2	0.1	300	10	USNO-B1	8–15
2006 HQ30	PHA des	21/22 May	30 days	19.0	1.1	240	9	USNO-B1	5
1997 XR2	PHA des	22/23 May	9 years	19.4	2.1	300	1	USNO-A2	5
2006 KB1	NEA des	22/23 May	2 days	18.5	4.2	120	3	USNO-A2	16–28
2006 KD1	NEA des	22/23 May	3 days	18.3	2.3	150	14	USNO-B1	45–57
2006 KC	NEA des	23/24 May	5 days	18.8	4.2	120	16	USNO-B1	7–10
2004 LB6	NEA desA	23/24 May	2 years	19.5	0.4	300	4	USNO-B1	24–291
(68950)	PHA	27/28 May	4 years	14.6	5.4	60	16	UCAC2	42–88
(68950)	PHA	29/30 May	4 years	14.7	4.7	60	11	UCAC2	37–60
(1980)	NEA	7/8 November	56 years	13.6	3.1	15	3	USNO-SA2	5–6
(5143)	NEA	13/14 November	15 years	14.5	2.4	15	3	USNO-SA2	5–6

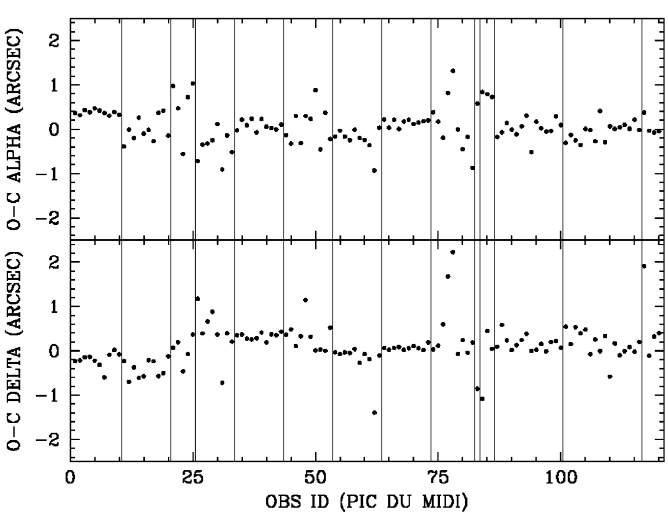

Fig. 1. Observed minus calculated (O−C) residuals for Pic du Midi site. Vertical separators correspond to the 13 observed NEAs.

3.2. Haute de Province Observatory

In conjunction with another research on asteroids of MB and AN, some time was allocated to EURONEAR to follow up one NEA in two nights at Haute de Province Observatory, France (MPC code 511). This mission was attended by AN. We used the 1.2 m telescope, $F = 7.2\,\mathrm{m}$, $F/D = 6.6$ endowed with a CCD 1024×1024 pixels with $35 \times 35\,\mu\mathrm{m\,arcsec}^{-1}$, $0.69\,\mathrm{arcsec\,pix}^{-1}$ with $\mathrm{FOV} = 11.7\,\mathrm{arcmin} \times 11.7\,\mathrm{arcmin}$.

AN used IRAF (NOAO, 2006) in combination with NOVAS routines from USNO (Kaplan et al., 1989) for image reductions and data processing. In the first step, we used DAOFIND from DAOPHOT to extract objects from CCD frames. The positions of the UCAC-2 reference stars were obtained via a small script which queries VIZIER Service (Ochsenbein et al., 2000). They were cross-correlated with the output of DAOFIND using CCXYMATCH. Finally, we used CCMAP to compute plate solution. Twenty seven positions were accepted by MPC and included in NEODyS. The asteroid is included in the second part of Table 1.

Fig. 3 plots the observed minus calculated positions based on NEODyS data. Fig. 4 plots a histogram showing measurement errors for all observations at Haute de Province site. In both right ascension and declination, the average position error is about 0.07 arcsec. This is lower than at Pic du Midi, because the asteroid observed at Haute de Province was about 4 magnitude brighter and the exposure time was shorter, resulting in a much better S/N.

3.3. Bucharest Urseanu Observatory

NEAs can be observed not only with 1 m class telescopes, but also at oppositions using small telescopes, even from sites located in light polluted large cities (Vaduvescu, 2005). These occurrences are relatively rare (once every month or so), so they have to be planned in advance. "Admiral Vasile Urseanu" Observatory is a small observatory oriented towards public outreach, being located in central Bucharest, Romania (MPC code A92). AS observed two NEAs here, six positions being accepted by MPC and included in NEODyS. We used a small telescope, Celestron $D = 0.23\,\mathrm{m}$, $F/6.3$ equipped with a home-made camera (Corlan, private communication)

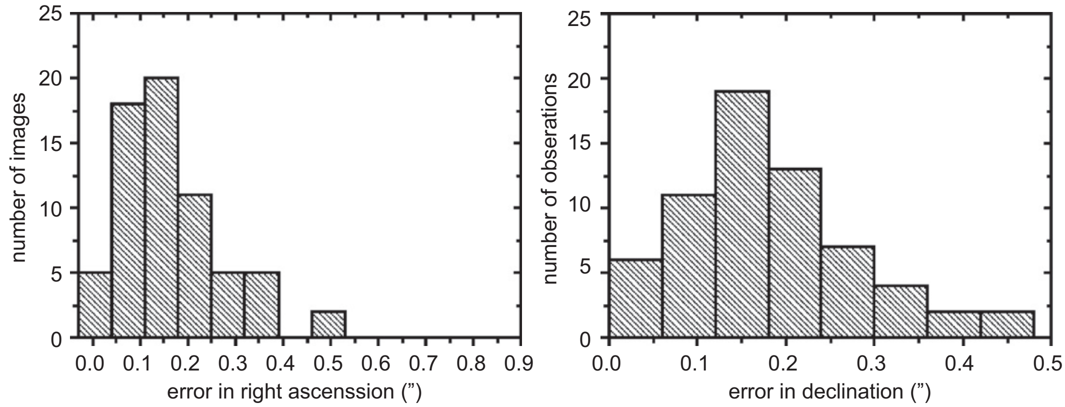

Fig. 2. Histogram including measurement errors for all Pic du Midi observations.

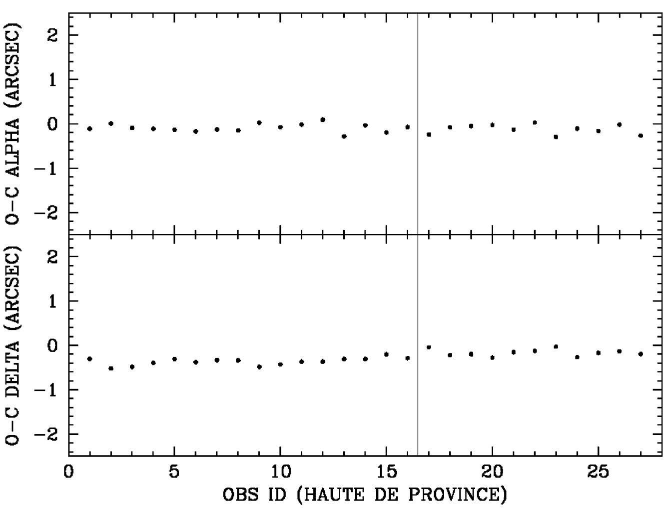

Fig. 3. Observed minus calculated (O−C) residuals for Haute du Province site. Vertical separators correspond to two nights.

endowed with a TC237 chip with 640×500 pixels $2.03\,\text{arcsec}\,\text{pix}^{-1}$, $7.4 \times 7.4\,\mu\text{m}$ with FOV $= 21.6\,\text{arcmin} \times 16.9\,\text{arcmin}$.

The asteroids are included in the last part of Table 1. Fig. 5 plots the observed minus calculated positions based on NEODyS data. Positions were measured by AS using Astroart (MSB, 2006). Typical measurement errors are 0.3 arcsec.

4. Next plans

To enlarge the palette of contributions, EURONEAR was envisioned as a network in two directions. First, we aim to establish two dedicated facilities, namely two 1 m telescopes in Chile and Europe to cover both hemispheres. Following an observing run in Chile, and a visit of OV to ESO in Santiago, an EURONEAR Committee of Initiative has been established, including the present authors and Dr. Rami Rekola of Tuorla Observatory, Finland. Recently, the ESO 1 m telescope has been allocated at ESO La Silla, to be automated to work for EURONEAR (ESO, 2006). A second automated facility is hoped to be installed in Canary or Pic du Midi in the future.

Second, individuals in Europe and elsewhere are expected to subscribe to EURONEAR using available time at their home based non-dedicated facilities in Europe and elsewhere. In this direction, among other sources, EURONEAR aims to gather funding from a dedicated Consortium comprised European institutions (observatories, universities, colleges, schools, planetaria), as well as from individual astronomers (professionals and amateurs) which will gain membership in EURONEAR. In exchange for their support, members will have full access to the EURONEAR facilities and data, based on which they will conduct real science in a coordinated fashion, performing (remote) observations, reducing the data, publishing papers, advising Diplomas, Master or Ph.D. thesis, and conduct public outreach.

Given a place and time, MPC online servers list ephemerides of NEAs/PHAs based on daily updated orbital information of the entire known asteroid population (MPC, 2006). Nevertheless, MPC lists are very long and need to be selected by human analysis in order to optimize the observing runs, by planning the best targets possible to observe with a given facility. This can be achieved based on a few observational constraints, such as the apparent magnitude, proper motion, CCD pixel size, the available field of star catalog densities, MPC asteroid class, ephemeridae uncertainty, altitude, Milky Way or Moon presence, instrumental constraints, etc. This is a time consuming task which should be automated. In a few months we plan to write a software to check all constraints, which will be used in any EURONEAR runs in the future.

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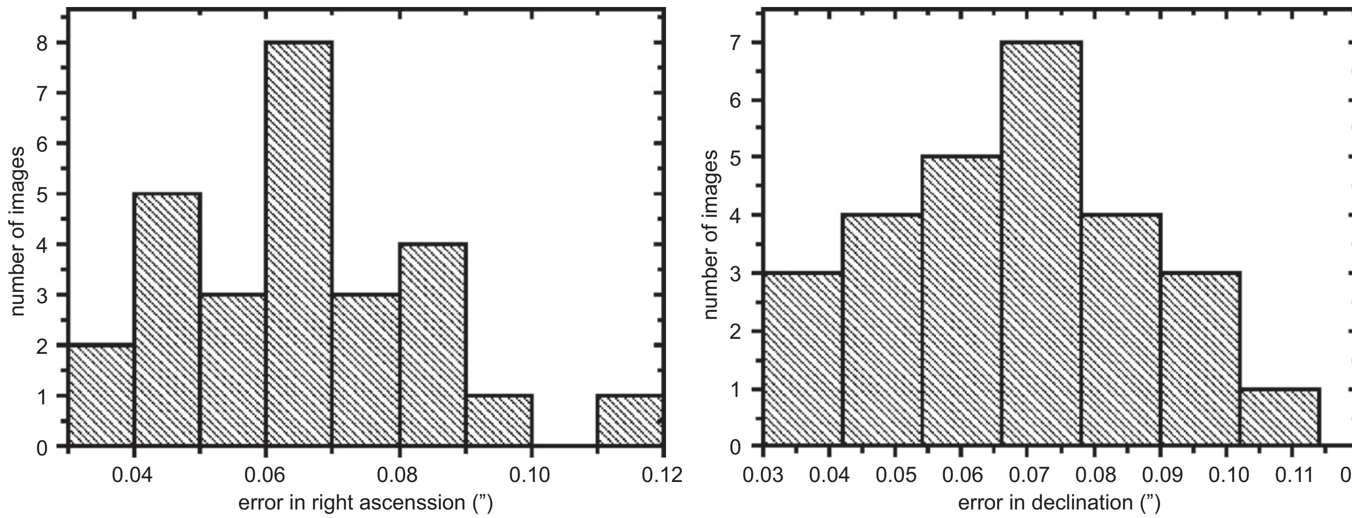

Fig. 4. Histogram including measurement errors for Haute de Province observations.

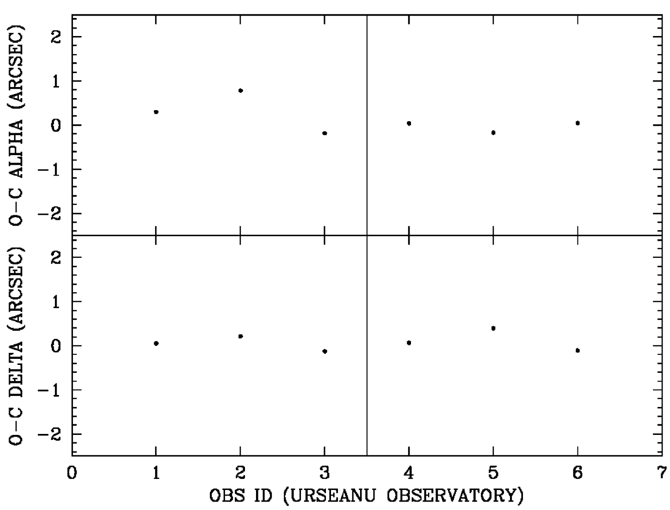

Fig. 5. Observed minus calculated (O−C) residuals for Bucharest site. The vertical separator corresponds to the two NEAs observed.

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References

Beshore, E., et al., 2006, CSS—Catalina sky survey. Available from: ⟨http://www.lpl.arizona.edu/css/⟩.

Boattini, A., et al., 2004a. The Campo Imperatore near earth object survey. AAS DPS Meet. 36, 1142.

Boattini, A., et al., 2004b. Astron. Astrophys. 418, 743.

Bowell, T., 2006. The asteroid orbital elements database (ASTORB). Available from: ⟨ftp://ftp.lowell.edu/pub/elgb/astorb.html⟩.

Colas, F., et al., 2006a. EURONEAR—First results at Pic du Midi. AAS DPS Meet. 38, 58.05.

European Asteroid Research Node, EARN, 2006. The near-earth asteroids database. Available from: ⟨http://earn.dlr.de/nea/⟩.

European Southern Observatory, 2006. Private communication.

Fitzsimmons, A., et al., 2006. UKAPP, astrometry and photometry programme for near-earth objects. Available from: ⟨http://star.pst.qub.ac.uk/~ukapp/⟩.

Goodricke-Pigott Observatory. Available from: ⟨http://gpobs.home.mindspring.com/gpobs.htm⟩.

Great Shefford Observatory, 2007. Available from: ⟨http://www.birtwhistle.org⟩.

JSF (Japan Space Forum), 2006. Observation facilities for space debris and near earth objects. Available from: ⟨http://www.spaceguard.or.jp/bsgc_jsf/pamphlet/⟩.

Kaplan, et al., 1989. Astron. J. 97, 1197.

Lowell Observatory, 1996. LONEOS—the Lowell observatory near-earth-object search. Available from: ⟨http://asteroid.lowell.edu/asteroid/loneos/loneos.html⟩.

LPL (Lunar and Planetary Laboratory), University of Arizona, 2006. The spacewatch project. Available from: ⟨http://spacewatch.lpl.arizona.edu/⟩.

Milani, A., et al., 2006. NEODyS, near earth objects dynamic site. Available from: ⟨http://newton.dm.unipi.it⟩.

MIT, 2006. The LINEAR Project, Lincoln Laboratory, Massachusetts Institute of Technology. Available from: ⟨http://www.ll.mit.edu/LINEAR/⟩.

MPC (Minor Planet Center), IAU, 2006. Available from: ⟨http://cfa-www.harvard.edu/iau/mpc.html⟩.

MSB Software, 2006. Astroart. Available from: ⟨http://www.msb-astroart.com⟩.

Muinonen, K., Virtanen, J., Torppa, J., 2006, Physical and dynamical characterization of near-earth objects. Available from: ⟨http://www.astro.helsinki.fi/~psr/NEO/not_obs.html⟩.

NASA/JPL, 2006a. Near-earth object program. Available from: ⟨http://neo.jpl.nasa.gov/neo⟩.

NASA/JPL, 2006b. Near-earth asteroid tracking (NEAT). Available from: ⟨http://neat.jpl.nasa.gov/⟩.

NOAO, 2006. IRAF image reduction and analysis facility. Available from: ⟨http://iraf.noao.edu⟩.

OAS (Osservatorio Astronomico Sormano), 2007. Available from: ⟨http://www.brera.mi.astro.it/sormano/⟩.

Ochsenbein, F., Bauer, P., Marcout, J., 2000. Astron. Astrophys. 143, 221.

ODAS, 1999. OCA-DLR Asteroid survey. Available from: ⟨http://earn.dlr.de/odas/⟩.

Pan-STARRS, 2006. Available from: ⟨http://pan-starrs.ifa.hawaii.edu/public/⟩.
Pravec, P., et al., 2006. Ondrejov asteroid photometry project. Available from: ⟨http://www.asu.cas.cz/~ppravec/⟩.
Pulkovo NEO Page, 2006. Available from: ⟨http://www.neopage.nm.ru/⟩.
Raab, H., 2006. Astrometrica software. Available from: ⟨http://www.astrometrica.at⟩.
Steel, D.I., et al., 1998. AANEAS: a valedictory report. Available from: ⟨http://www1.tpgi.com.au/users/tps-seti/spacegd4.html⟩.
Stone, R.C., 1997. Astron. J. 113, 2317.
Tatum, J.B., Balam, D.D., Aikman, G.C.L., 1994. Planet. Space Sci. 42 (8), 611.
Ticha, J., Tichy, M., Kocer, M., 2002. Icarus 159, 351.
Ticha, J., Tichy, M., Kocer, M., 2006. Follow-up astrometry of NEOs and other unusual objects, Klet Observatory, Czech Republic. Available from: ⟨http://www.klet.org/foll.html⟩.
Vaduvescu, O., 2005. Observing near earth asteroids on a small telescope. Rom. Astron. J. 14, 199, Rom. Astron. J. 15, 171. Available from: ⟨/astro-ph/0504231⟩.
Vaduvescu, O., et al., 2006. EURONEAR—A European near earth asteroid research project. In: IAU Symposium, Near Earth Objects, Our Celestial Neighbours: Opportunity and Risk, vol. 236, S236, p. 100.
Whipple, A.L., 1995. McDonald observatory solar system object astrometry from wide field CCD imaging. In: 187th AAS Meeting, 42.02; Bul. AAS 27, p. 1336.
Zhu, J., et al., 2000. NEO observation in Beijing astronomical observatory. In: Interactions Between Planets and Small Bodies, 23rd meeting of the IAU, Joint Discussion, vol. 6, Kyoto, Japan, 22–23 August 1997.