Strategies for Secure and Recovery Near-Earth Objects

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Abstract

The article presents results of several years of observing runs devoted to Near-Earth Asteroids (NEAs). Astrometry of NEAs was provided either for secure orbits of newly discovered objects or to decrease the uncertainty in orbital elements. Photometry and spectroscopy, will complete the astrometry in order to constrain physical and mineralogical properties of objects.

Of a crucial importance into as successful run is the manner on which the observations are scheduled during each night and over the observational list. While the ”ad-hoc” list is created, the balance between several dynamical parameters are very important for the strategy of observations.

Keywords: asteroid, observations, orbital elements, mineralogy
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1. Introduction

Observational campaigns for detection, secure and recovery of Near-Earth Asteroids(NEAs) are scheduled as perennial activities over Europe. While the proposals for observing time with large and mid-sized telescopes is constantly oversubscribed, major part of our activities devoted to NEAs is developed using telescopes smaller than 2m in diameter. In our case, most of these observational campaigns are correlated/common activities inside the network called Euronear (Birlan et al., 2010d; Vaduvescu et al., 2013, 2014).

While the risk related to NEAs was reevaluated over the last 15 years, the activities of discovery were developed via dedicated facilities and programs. Several programs of survey and follow-up of asteroids(NEAs) are now under run (e.g Stokes et al. (2002); Denneau et al. (2013); Ticha et al. (2009); Krugly et al. (2010)). Correspondingly, the activities of securing orbits, recovery and precovery of newly discovered objects are organized in the framework of International Astronomical Union specific Commissions and services. These activities are correlated to initiatives of space agencies or international organisms which are dealing with industrial or research activities like outer space utilization, asteroid mitigation, space resources, and future space missions.

The strategy of surveys of NEAs in operation until 2000 concentrated on regions of sky where asteroids are at opposition. These regions of the sky are concentrated mainly on the ecliptic plane. However these regions are not very representative for NEAs. Indeed, the size and the highly inclined orbits of NEAs do not allow the detection of all the object of this population. Most of these objects are more visible (brighter on the sky) when they pass close to the Earth rather than at the opposition. Thus, a large probability of observing small-size NEAs is the time of close approaching to the Earth.

A close encounter of a NEA to the Earth means particular constraints for observing them. While the relative velocity of the NEA as seen from the Earth is of the order of 10-12 km/s, its relative movement of the sky is very

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important. This apparent movement could span an angular speed between 2 arcmin/min and 40 arcmin/min, depending on distance between object and Earth. Correspondingly, the interval of time on which these objects could be detected and recorded by 1meter class telescopes (or smaller) is very limited due to their size and apparent movement on the sky.

While NEAs evolves on orbits much more close to Earth comparing to main-belt asteroids, the common idea could be that they can be observed more easily and more often. In fact their small diameters imply tight constrains which are related to their close encounters with Earth. These encounters occur on average three to five times per century (Popescu et al., 2011). Thus, the choice of type of observations and the scientific outcome of these results could be evaluated before the observational run. While each type of observation (astrometry, photometry, color index, spectroscopy, polarimetry, etc) requires detectors and facilities in adequacy to the scientific goal, it is hard to cover all these observations using just only one telescope. However, a strategy of maximizing the information gathered from a grazing object could increase the scientific outcome of one observational campaign.

Observations of NEAs is a field on which amateurs and professionals could collaborate significantly. Active networks of observers containing both amateurs and professional astronomers are present all over the World. Amateurs can provide professionals with large quantity of data, skills for data reduction, and time for observing over long runs (Mousis et al., 2014).

2. Observations of newly discovered objects

Commonly, the observing runs over one week are realized, using telescopes in the 0.5-1.2meter in diameter. During these runs, in order to secure newly discovered NEA orbits, astrometry is considered as top priority. Colors and lightcurves are also considered in order to provide a first attempt to physical characterization of these bodies.

The main source for scheduling objects as potential potential NEAs is the Minor Planet Center Confirmation Page[1]. Several filters will be then used to observe these objects such as: apparent magnitude, apparent movement on the sky, position/elevation on the sky, field of view of the telescope. An example of such a scheduler of topocentric ephemerides could be find on Euronear website[2].

In terms of securing orbits, other NEAs selected for our runs could be the objects with highly uncertain orbits. If a NEA is not observed for a long time, and its its osculating elements were computed using just an orbital arc of few days, its orbital elements will exhibits large/cumulative uncertainties over the years. These uncertainties could be very important while the object experiments important gravitation perturbations due to relatively close encounters with major planets. When the uncertainties in orbital elements is greater than one thousand arseconds there is huge chance that the object is lost. The efforts of recovering NEAs having large uncertainties in orbit is important and requires telescopes with large field of view and able to record dim objects (Vaduvescu et al., 2013).

Astrometry was performed using Astrometrica software and NOMAD catalog. Photometric measurements for 2014 VM were performed using MaxImDL procedures.

Table 1 presents a non-exhaustive list of NEA observed and reported to Minor Planet Center, while Fig 1 shows the position of these objects into the diagram of orbital elements.

3. Discussions

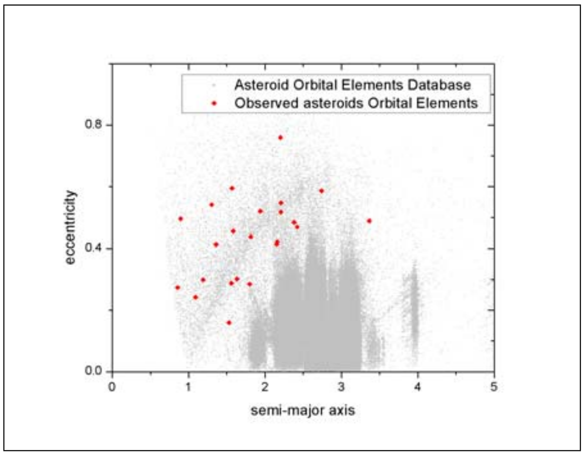
From our experience in the observing run of seven nights 5 hours per night are enough to observe with 1m telescope those targets available to the MPC Confirmation Page. On average 30-35% of the total time is enough to provide good astrometry. Thus, complementary targets and complementary science (photometry, spectroscopy) of NEAs become mandatory, in the context on which good geometry (ephemerides) for future observations of newly discovered objects occurs only few times per century.

Astrometric runs of NEAs using non-dedicated facilities are also constrained by scientific factors such as exploiting data on scientific publications. Thus, M.P.E.C.s is a motivating factor into secure and extends astrometry toward

[1] http://www.minorplanetcenter.net/iau/NEO/ToConfirm.html
[2] http://euronear.imcce.fr

Table 1: Non-exhaustive list of NEAs observed between 2010 and 2015 in several campaigns. Provisional designations, semi-major axis, eccentricity and inclination of osculating elements are given for the epoch 2014-12-09.0. NEA dynamical type, as well as the reference of Minor Planet Electronic Circular (M.P.E.C.) providing our observations are also presented. The object 2014 UK192 is classified as Main Belt Asteroid.

NEA	a (a.u.)	e	i(°)	NEA type	M.P.E.C
2014 VM	2.1535124	0.4148709	36.97803	Amor	Okumura et al. (2014)
2014 US192	2.2027794	0.7595504	14.65026	Apollo	Ticha et al. (2014)
2014 VA	1.8139387	0.4380610	2.23161	Amor	Sonka et al. (2014)
2014 UF192	1.5825267	0.4557009	7.73621	Apollo	Birlan et al. (2014)
2014 UK192	3.3649292	0.4885547	9.05532		Mastaler et al. (2014)
2011 WD39	1.3019350	0.5412677	59.49088	Apollo	Buzzi et al. (2011d)
2011 WF32	2.7394031	0.5865897	14.53435	Apollo	Buzzi et al. (2011e)
2011 WE32	2.3812352	0.4839101	22.34829	Amor	Buzzi et al. (2011g)
2011 WK5	2.2078064	0.5170668	5.90199	Amor	Birlan et al. (2011e)
2011 WW4	2.1614362	0.4226000	7.62210	Amor	Birlan et al. (2011d)
2011 WV4	1.1893345	0.2992218	11.84412	Apollo	Buzzi et al. (2011a)
2011 WU4	1.9386622	0.5203603	6.27510	Apollo	Buzzi et al. (2011b)
2011 WP4	1.3594178	0.4141706	0.94579	Apollo	McMillan et al. (2011)
2011 WV2	1.5288187	0.1597595	22.67803	Amor	Buzzi et al. (2011c)
2011 WM2	1.5594827	0.2878923	15.87041	Amor	Buzzi et al. (2011f)
2011 EX4	0.8559303	0.2738107	3.02597	Aten	Apitzsch et al. (2011)
2011 ET4	1.6318466	0.3017713	31.76056	Amor	Lehmann et al. (2011)
2011 ES4	1.0908755	0.2427512	3.37713	Apollo	Birlan et al. (2011b)
2000 EB14	0.8957034	0.4956657	11.57154	Aten	Birlan et al. (2011a)
2007 ES	1.5697780	0.5948026	35.21093	Apollo	Birlan et al. (2011c)
2010 RF181	2.2082995	0.5471225	6.24883	Amor	Birlan et al. (2010b)
2010 WJ	1.7980100	0.2853231	27.02098	Amor	Birlan et al. (2010a)
2010 WH	2.4217895	0.4689646	21.98781	Amor	Birlan et al. (2010c)



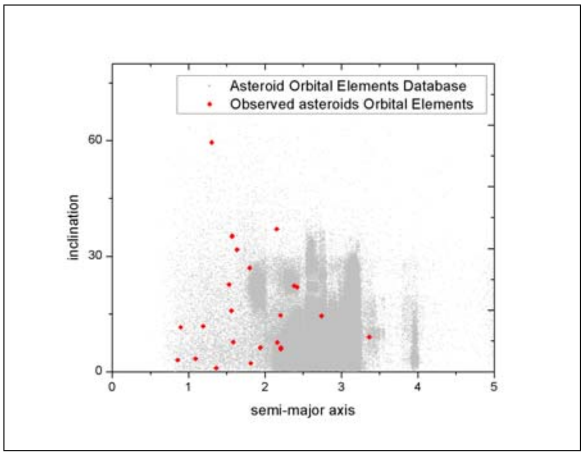


Figure 1: Position of NEAs from Table 1 in the space semimajor axis -eccentricity and semimajor axis - inclination. The semimajor axis in represented in astronomical units (a.u.) and the inclination in degrees.

long arc of orbits. Sharing the data by fast online publication via M.P.E.C.s is strongly appreciated. Beyond the novelty character of astrometric observations of NEAs, providing also first physical of new discoveries is an important step into the global characterization of NEA.

Spectroscopic observations of NEAs usualy need large apperture telescopes and capabilities to differential tracking. Spectroscopic observations could be successful by formalizing them into observational programs classified as target of opportunity. Serendipitous character of newly discovered NEAs as well as the tight window for observing them once reported requires granted time in terms of rapid response observations for NEA alerts (Mommert et al., 2014; Polishook et al., 2012; Binzel et al., 2009).

Few objects are presented into subsections for highlighted astrometric and photometric results.

3.1. *Asteroid 2011 ES4*

This object is recorded in the current impact list NEOs[3]. Its absolute magnitude was estimated to 25.7. Depending on its albedo the object the diameter was estimated between 20 and 50 meters. No colors or other physical parameters were reported. The object was astrometrically recorded on 44 observations for a arc of orbit of 4 days during the close encounter with Earth at 0.0286a.u.. Its MOID[4] is computed for a value of 0.00087 a.u.[5]. The impact probability was estimated to be 5.1×10^{-5}, and the object reach zero value on Torino scale. While the orbital osculating elements are derived from a little arc length of orbit, the uncertainties are very big; certainly the recovery of 2011 ES4 during the next favorable geometry will decrease the errorbars of estimations.

3.2. *Asteroid 2010 RF181*

The asteroid is an Amor NEA classified into the category of Potential Hazardous Asteroids(PHA). The osculating elements were computed using 131 observations spanning the time interval of 139 days. Its MOID is computed to a value of 0.01098a.u.. Its absolute magnitude of 20.7 allows to compute margins of its diameter between 218 and 488 meters[6]. No physical data are available for this object.

3.3. *Asteroid 2011 WW4*

The asteroid is an Amor NEA and it is included into the Critical list of objects for the Minor Planet Center. Its orbit elements were identified to the one of NEAs 1995 PA1 and 2011 MC2. In conformity to the MPC rules, as long as it was observed at three oppositions the object was included into the catalog of asteroids with the number 411655.

[3]http://neo.jpl.nasa.gov/risks/
[4]acronym for Minimal Orbital Intersection Distance
[5]http://newton.dm.unipi.it/neodys/index.php?pc=1.1.0&n=2011ES4
[6]http://earn.dlr.de/nea/K10RI1F.htm

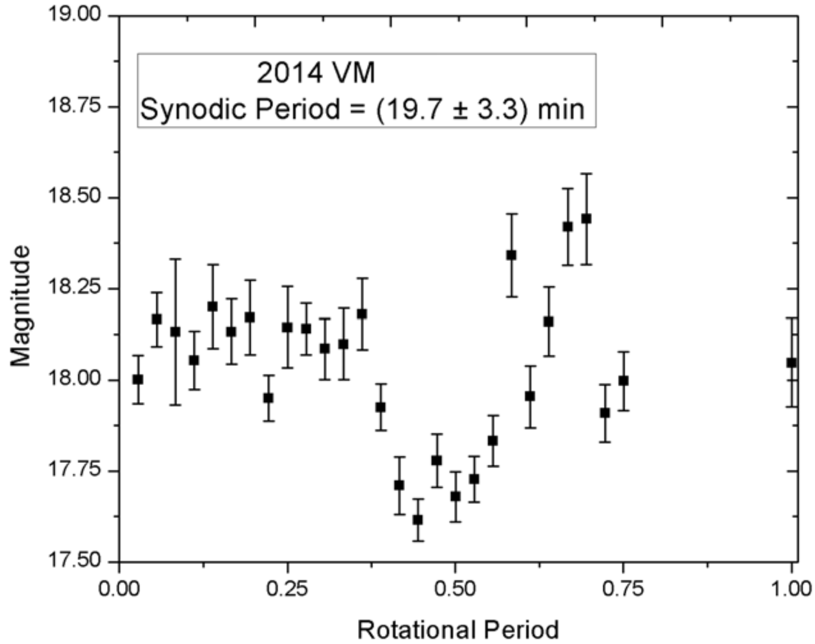


Figure 2: Lightcurve of asteroid 2014 VM obtained in Nov 1, 2014 using T1M at Pic du Midi Observatory. The origin of time for the rotational period is JD=2456963.48845. The spin period for 2014 VM was computed as 19.7 ± 3.3 minutes.

3.4. 2014 VM photometry

This object is an Amor object. Its osculating elements were calculated using 246 individual observations spanning 107 days of interval. According to NEODys webservice, its MOID has the value of 0.2949a.u.. The absolute magnitude of 2014 VM is computed to the value of 17.7. This value allows an estimation of its diameter into the 1km sized objects, depending on the value of albedo the diameter span the interval between 869 and 1,942 meters.

Relative good photometry was provided by our astrometric run. The periodogram allows to derive as most probable rotational period of (19.7 ± 3.3) minutes. Higher periods cannot be however excluded. Considering our derived rotational period, this object is a fast rotator which can suggest that its internal structure is more probable a monolithic one (Pravec et al., 2006).

4. Conclusion

The review of several years of observing runs devoted to NEAs is presented. Astrometry of NEAs was provided either for secure orbits of newly discovered objects or to decrease the uncertainty in orbital elements. Photometry, spectroscopy, polarimetry should complete the astrometry in order to constrain physical and mineralogical properties of objects.

Astrometry of twenty three objects is presented in this article together with photometry of NEA 2014 VM. The successful observing run highly dependent on how the asteroids are scheduled during each night. While the "ad-hoc" list is created, the balance between several dynamical parameters are very important for the strategy of observations. For an observing run of seven nights, 5 hours per night are enough to observe with 1m telescope those targets available to the MPC Confirmation Page.

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