## Research Article

Ireneusz Wlodarczyk*, Kazimieras Černis, and Ilgmars Eglitis

# Observational data and orbits of the asteroids discovered at the Baldone Observatory in 2015-2018 

Received Jan 01, 2020; accepted Jun 30, 2020


#### Abstract

This paper is devoted to the discovery of 37 asteroids at the Baldone Astrophysical Observatory (MPC 069) from 2015 to 2018, and one of dynamically interesting Mars-crosser (MC) observed at the Baldone Astrophysical Observatory, namely 2008 LX16. In Baldone Observatory, was independently discovered the Near-Earth Object 2018 GE3 on the image of 13 April 2018. Also, the NEO 2006 VB14 was observed doing its astrometry and photometry. Moreover, we observed asteroids 1986 DA and 2014 LJ1. We computed orbits and analyzed the orbital evolution of these asteroids. 566 positions and photometric observations of NEO objects 345705 (2006 VB14) and 6178 (1986 DA) were obtained with Baldone Schmidt telescope in 2018 and 2019. We detected their rotation period and other physical characteristics. Also, a Fourier transform was applied to determine the rotation period of asteroid 6178 ( 1986 DA). Value ( $3.12 \pm 0.02$ )h was obtained. Our observations confirm the previously obtained rotation period $\mathrm{P}=3.25 \mathrm{~h}$ for 2006 VB14.


Keywords: minor planets, asteroids: search, astrometry, orbits

## 1 Discoveries of minor planets at the Baldone Observatory in 2015-2018

In (Černis et al. 2015), we presented the discovered asteroids at the Baldone Observatory in 2008-2013. In this work, we gathered the discoveries of asteroids in period of 20152018. Table 1 lists 37 asteroids discovered at the Baldone Observatory, and Table 2 presents statistics and astrometric observations of the asteroids (both new and known) at the Baldone Observatory in 2015-2018.

Table 3 presents high precision orbital elements of discovered asteroids at the Baldone Astrophysical Observatory in 2015-2018. All orbital computations of asteroids were made using the OrbFit software v.5.0.5 and v.5.0.6. In the last version, the NEODyS Team introduced the error weighing model described by Vereš et al. (2017), as announced by F. Bernardi on the Minor Planet Mailing List. We used

[^0]the JPL DE431 Ephemerides with 17 perturbing massive asteroids as was described in Farnocchia et al. (2013a,b) and similar to Wlodarczyk (2015).

The orbits of the following asteroids were not computed because of their short observational arc: 2015 TW238, 2015 TN260, 2015 TG350, 2018 RG17 and 2018 TM9. The Minor Planet Center: https://minorplanetcenter.net/db_search and the JPL Small-Body Database Browser: https://ssd.jpl. nasa.gov/sbdb.cgi also do not give orbital elements of these asteroids.

## 2 Investigation of NEO asteroids 2006 VB14 and 1986 DA

Two NEO type asteroids 2006 VB14 and 1986 DA were successfully observed over seven and five nights respectively in the autumn of 2018 and spring of 2019. There is no previously reported rotation period for 1986 DA in the Asteroid Lightcurve Database (LCDB) and two possible periods for 2006 VB14 was mentioned in paper Skiff et al. (2012). Images at Baldone Astrophysical Observatory were captured with a $0.80 / 1.20 \mathrm{~m}, \mathrm{f} / 3$ Schmidt telescope and SBIG STX16803 CCD camera with an array of $4090 \times 4090$ pixels. The field-of-view is $53 \times 53 \mathrm{arcmin}$. The plate scale was 0.78 arcsec per pixel in $1 \times 1$ binning mode. Photometric data re-
ductions for the images were done using the MPO Canopus and MaxIM DL programs. GAIA2 R magnitudes are used for thirty reference stars. Through experimentation with different rotation periods using Fourier fitting, the best fit was
$3.25 \pm 0.02 \mathrm{~h}$ for the 2006 VB14 and $3.12 \pm 0.02 \mathrm{~h}$ for the 1986 DA. More detailed processing and the result is described in Eglitis (2019). Obtained rotation periods are typical for similar-sized asteroids.

Table 1. List of asteroids discovered at the Baldone Observatory in 2015-2018.

| No. | Date of discovery | Designation | Number | Status |
| :---: | :---: | :---: | :---: | :---: |
| 1 | 2015 Oct. 6 | 2015 TC23 |  | 5 opps, 2011-2017 (MP0435109) |
| 2 | 2015 Oct. 5 | 2015 TW238 |  | 1 d |
| 3 | 2015 Oct. 11 | 2015 TN260 |  | 1 d |
| 4 | 2015 Oct. 11 | 2015 TO260 |  | 2 opps, 2007-2018 (MPOxxxxxx) |
| 5 | 2015 Oct. 11 | 2015 TQ260 |  | 3 opps, 2004-2017 (MP0403103) |
| 6 | 2015 Oct. 11 | 2015 TG350 |  | 1 d |
| 7 | 2015 Oct. 11 | 2015 TM366 |  | 5 opps, 2008-2018 (MP0438021) |
| 8 | 2017 Sep. 25 | 2017 SV33 |  | 2 opps, 2000-2018 (MP0435137) |
| 9 | 2017 Sep. 25 | 2017 SW33 | 512962 | Numbered object |
| 10 | 2017 Sep. 26 | 2017 SX33 |  | 2 opps, 2013-2018 (MPO435137) |
| 11 | 2017 Sep. 28 | 2017 SY33 | 506714 | Numbered object |
| 12 | 2017 Sep. 26 | 2017 S042 |  | 5-day arc (MPO423876) |
| 13 | 2017 Oct. 18 | 2017 UT9 |  | 2 opps, 2013-2017 (MP0431193) |
| 14 | 2017 Oct. 18 | 2017 UU9 |  | 3 opps, 2008-2017 (MP0428368) |
| 15 | 2017 Oct. 19 | 2017 U011 |  | 5 opps, 2010-2017 (MP0457146) |
| 16 | 2017 Oct. 19 | 2017 UP11 | 507546 | Numbered object |
| 17 | 2017 Oct. 19 | 2017 UQ11 |  | 66-day arc (MPO431194) |
| 18 | 2017 Oct. 19 | 2017 UR11 |  | 4 opps, 2008-2017 (MP0431194) |
| 19 | 2017 Oct. 19 | 2017 US11 | 508671 | Numbered object |
| 20 | 2017 Oct. 19 | 2017 UT11 |  | 3 opps, 2008-2017 (MP0431195) |
| 21 | 2017 Oct. 19 | 2017 UU11 |  | 8 opps, 2000-2017 (MP0445151) |
| 22 | 2017 Oct. 19 | 2017 UV11 |  | 2d |
| 23 | 2017 Oct. 19 | 2017 UW11 | 508672 | Numbered object |
| 24 | 2017 Oct. 19 | 2017 UX11 |  | 5 opps, 2011-2017 (MP0445151) |
| 25 | 2017 Oct. 19 | 2017 UY11 |  | 4 opps, 2005-2018 (MP0431195) |
| 26 | 2017 Oct. 22 | 2017 UJ15 |  | 6 opps, 2006-2018 (MP0434961) |
| 27 | 2017 Oct. 22 | 2017 UK15 |  | 3 opps, 2006-2018 (MP0434912) |
| 28 | 2017 Oct. 22 | 2017 UL15 |  | 2 opps, 2007-2017 (MP0435141) |
| 29 | 2018 Mar. 18 | 2018 FU25 |  | 11 opps, 2002-2018 (MPO445214) |
| 30 | 2018 Mar. 18 | 2018 FV25 |  | 9 opps, 2002-2018 (MPO445214) |
| 31 | 2018 Apr. 10 | 2018 GU6 |  | 5 opps, 2007-2018 (MP0457150) |
| 32 | 2018 Apr. 10 | 2018 GV6 |  | 2 opps, 2016-2018 (MPO448864) |
| 33 | 2018 Apr. 12 | 2018 GX8 |  | 31-day arc (MPO457150) |
| 34 | 2018 Sep. 10 | 2018 RG17 |  | 3d |
| 35 | 2018 Sep. 10 | 2018 RH17 |  | 3d |
| 36 | 2018 Oct. 6 | 2018 TL9 |  | 32d |
| 37 | 2018 Oct. 6 | 2018 TM9 |  | 1d |

Table 2. Statistics of asteroid discoveries and astrometric observations of the asteroids (both new and known) at the Baldone Observatory in 2015-2018.

| Year | Number <br> of asteroid <br> discoveries | Number <br> of asteroid <br> observations | Number <br> of asteroids <br> observed | References |
| :--- | :--- | :--- | :--- | :--- |
| 2015 | 7 | 315 | 92 | $90967,91854,92474,93114,93768,94439,95374,95856,96415,97002$ |
| 2016 | 0 | 337 | 116 | $97712,98789,99415,99950,100351,100690,101342$ |
| 2017 | 21 | 3798 | 972 | $102359,103149,104117,104989,105343,105715,106573,107170$ |
| 2018 | 9 | 5561 | 1516 | $107827,108759,109228,109684,110175,110809,111864$ |
| Total | 37 | 10011 | 2696 |  |

Table 3. High precision orbital elements of discovered asteroids at the Baldone Astrophysical Observatory in 2015-2018. Epoch JD2458800=2019-Nov-13

| $a(\mathrm{au})$ | $e$ | $i$ (deg) | $\Omega$ (deg) | $\omega$ (deg) | $M$ (deg) |
| :---: | :---: | :---: | :---: | :---: | :---: |
| (2015 TC23) |  |  |  |  |  |
| 2.429372091 | 0.182635917 | 2.9559711 | 3.356836 | 355.770222 | 48.3335455 |
| $1.42 \mathrm{E}-07$ | 4.07E-07 | $1.37 \mathrm{E}-05$ | $1.54 \mathrm{E}-04$ | $1.61 \mathrm{E}-04$ | $7.80 \mathrm{E}-05$ |
| $H=17.905 \pm 0.683$ | $\mathrm{rms}=0.650^{\prime \prime}$ | 60 obs. | arc: 20110 | $23.49297-201$ | 0128.58383 |
| (2015 TO260) |  |  |  |  |  |
| 3.180625596 | 0.070887119 | 11.3953187 | 22.8498325 | 31.605917 | 239.0392477 |
| $1.90 \mathrm{E}-07$ | $2.74 \mathrm{E}-07$ | $2.43 \mathrm{E}-05$ | $5.28 \mathrm{E}-05$ | $1.20 \mathrm{E}-04$ | $9.93 \mathrm{E}-05$ |
| $H=16.404 \pm 0.585$ | rms=0.8131 ${ }^{\prime \prime}$ | 45 obs. | arc: 200704 | 15.29781-2018 | 0415.31992 |
| (2015 TQ260) |  |  |  |  |  |
| 3.110348990 | 0.173711538 | 2.76876055 | 13.7152511 | 26.845571 | 261.2529686 |
| $6.37 \mathrm{E}-07$ | $2.764 \mathrm{E}-06$ | $2.163 \mathrm{E}-05$ | $3.059 \mathrm{E}-04$ | $1.180 \mathrm{E}-03$ | 7.396E-04 |
| $H=17.448 \pm 0.3219$ | $\mathrm{rms}=0.5520^{\prime \prime}$ | 39 obs. | arc: 20040 | $22.41911-20$ | 0204.56418 |
| (2015 TM366) |  |  |  |  |  |
| 3.1528697063 | 0.2302087879 | 3.88824662 | 0.4072676 | 323.3807139 | 307.92250206 |
| $1.225 \mathrm{E}-07$ | $1.479 \mathrm{E}-07$ | $2.036 \mathrm{E}-05$ | $1.839 \mathrm{E}-04$ | $1.922 \mathrm{E}-04$ | $6.395 \mathrm{E}-05$ |
| $H=16.624 \pm 0.415$ | $\mathrm{rms}=0.7850^{\prime \prime}$ | 35 obs. | arc: 2008 | 03.32927-2019 | 0527.32287 |
| (2017 SV33) |  |  |  |  |  |
| 2.596986975 | 0.32106217 | 3.94955805 | 318.378029 | 28.90613 | 198.413018 |
| $4.65 \mathrm{E}-07$ | $6.43 \mathrm{E}-06$ | $9.95 \mathrm{E}-06$ | $4.56 \mathrm{E}-04$ | $2.12 \mathrm{E}-03$ | $5.91 \mathrm{E}-04$ |
| $H=17.909 \pm 0.460$ | $\mathrm{rms}=0.657^{\prime \prime}$ | 39 obs. | arc: 20000 | 20.20300-2018 | 0113.25831 |
| $(2017$ SW33 $)=512962$ |  |  |  |  |  |
| 2.49451779180 | 0.075273159 | 4.56632761 | 277.461649 | 158.269786 | 148.303396 |
| $3.71 \mathrm{E}-08$ | $2.21 \mathrm{E}-07$ | $7.43 \mathrm{E}-06$ | $1.76 \mathrm{E}-04$ | 4.84E-04 | 4.46E-04 |
| $H=17.415 \pm 0.327$ | rms=0.6201 ${ }^{\prime \prime}$ | 89 obs. | arc: 200302 | 07.19573-201 | 0329.20248 |
| (2017 SX33) |  |  |  |  |  |
| 2.5864054961 | 0.208738335 | 13.8702814 | 358.2761181 | 13.259308 | 191.3409471 |
| $7.01 \mathrm{E}-08$ | $4.13 \mathrm{E}-07$ | $1.39 \mathrm{E}-05$ | 4.82E-05 | $1.02 \mathrm{E}-04$ | $5.56 \mathrm{E}-05$ |
| $H=17.297 \pm 0.327$ | rms $=0.549^{\prime \prime}$ | 82 obs. | arc: 20130 | 13.58646-2018 | 1218.61360 |
| $(2017$ SY33) $=506714$ |  |  |  |  |  |
| 3.1085619561 | 0.150125507 | 10.86908766 | 245.9033338 | 138.5060902 | 140.4297591 |
| $5.12 \mathrm{E}-08$ | $1.00 \mathrm{E}-07$ | $9.04 \mathrm{E}-06$ | 4.02E-05 | $4.70 \mathrm{E}-05$ | $2.54 \mathrm{E}-05$ |
| $H=16.267 \pm 0.353$ | $\mathrm{rms}=0.563^{\prime \prime}$ | 113 obs. | arc: 20061 | 19.26301-2019 | 0212.22559 |
| (2017 SO42) |  |  |  |  |  |
| 3.035052 | 0.298238 | 10.92025 | 349.1063 | 80.2855 | 120.1744 |
| 8.03E-04 | $1.91 \mathrm{E}-04$ | 4.36E-03 | $1.29 \mathrm{E}-02$ | $6.98 \mathrm{E}-02$ | 7.92E-02 |
| $H=17.573 \pm 0.352$ | $\mathrm{rms}=0.5584^{\prime \prime}$ | 20 obs. | arc: 20170 | $26.93260-20$ | 1027.36415 |
| (2017 UT9) |  |  |  |  |  |
| 2.58102355 | 0.32321925 | 3.8612758 | 268.176738 | 138.91726 | 171.116457 |
| $1.39 \mathrm{E}-06$ | 4.48E-06 | $4.37 \mathrm{E}-05$ | $3.36 \mathrm{E}-04$ | $2.06 \mathrm{E}-03$ | $9.78 \mathrm{E}-04$ |
| $H=19.405 \pm 0.444$ | rms=0.6059 ${ }^{\prime \prime}$ | 87 obs. | arc: 20100 | 29.802647 - 20 | 1213.29233 |
| (2017 UU9) |  |  |  |  |  |
| 2.6903374450 | 0.155255830 | 14.4947483 | 14.6550361 | 313.9224434 | 216.8810519 |
| $7.30 \mathrm{E}-08$ | $1.12 \mathrm{E}-07$ | $1.56 \mathrm{E}-05$ | $3.17 \mathrm{E}-05$ | $5.80 \mathrm{E}-05$ | 4.90E-05 |
| $H=17.121 \pm 0.391$ | rms=0.6392 ${ }^{\prime \prime}$ | 69 obs. | arc: 20080 | $28.24006-20$ | 1126.21166 |

Table 3. ...continued

| $a(\mathrm{au})$ | $e$ | $i$ (deg) | $\Omega$ (deg) | $\omega$ (deg) | $M$ (deg) |
| :---: | :---: | :---: | :---: | :---: | :---: |
| (2017 UO11) |  |  |  |  |  |
| 3.176691364 | 0.173435199 | 12.63523894 | 266.2553832 | 23.5723976 | 226.6515114 |
| 3.36E-07 | $1.47 \mathrm{E}-07$ | 8.61E-06 | $4.37 \mathrm{E}-05$ | $5.34 \mathrm{E}-05$ | $5.08 \mathrm{E}-05$ |
| $H=16.127 \pm 0.444$ | rms=0.6059 ${ }^{\prime \prime}$ | 87 obs. | arc: 201003 | 29.802647 - 2017 | 1213.29233 |
| $(2017$ UP11) $=507546$ |  |  |  |  |  |
| 3.0749347632 | 0.0967058058 | 9.26179506 | 291.7167041 | 304.0642071 | 304.9612954 |
| 6.56E-08 | 7.13E-08 | 8.52E-06 | 4.59E-05 | $6.86 \mathrm{E}-05$ | $5.74 \mathrm{E}-05$ |
| $H=15.909 \pm 0.507$ | $\mathrm{rms}=0.5669^{\prime \prime}$ | 115 obs. | arc: 2003 | .26051-201 | 204.28338 |
| (2017 UQ11) |  |  |  |  |  |
| 2.5890834 | 0.26807656 | 13.323004 | 246.266216 | 182.71100 | 162.66511 |
| $6.38 \mathrm{E}-05$ | 8.05E-06 | $5.45 \mathrm{E}-04$ | 3.72E-04 | $3.13 \mathrm{E}-03$ | $6.49 \mathrm{E}-03$ |
| $H=18.491 \pm 0.350$ | rms=0.5018 ${ }^{\prime \prime}$ | 52 obs. | arc: 2017 | 19.85910-20 | 1225.18959 |
| (2017 UR11) |  |  |  |  |  |
| 2.6807702145 | 0.144368736 | 8.3745189 | 274.985037 | 68.862129 | 216.7027455 |
| $7.90 \mathrm{E}-08$ | $1.90 \mathrm{E}-07$ | $1.31 \mathrm{E}-05$ | $1.03 \mathrm{E}-04$ | $1.25 \mathrm{E}-04$ | $7.23 \mathrm{E}-05$ |
| $H=17.295+/ 0.397$ | rms=0.4823 ${ }^{\prime \prime}$ | 43 obs. | arc: 20081 | 01.38272-2017 | 1213.31628 |
| (2017 US11) = 508671 |  |  |  |  |  |
| 2.3859692487 | 0.160919366 | 6.92275620 | 276.7944511 | 103.6515975 | 217.5621420 |
| $2.41 \mathrm{E}-08$ | $2.11 \mathrm{E}-07$ | $9.24 \mathrm{E}-06$ | 7.68E-05 | $9.14 \mathrm{E}-05$ | $3.35 \mathrm{E}-05$ |
| $H=17.337 \pm 0.563$ | rms=0.5436 ${ }^{\prime \prime}$ | 114 obs. | arc: 200209 | $2.43381-2018$ | 123.09846 |
| (2017 UT11) |  |  |  |  |  |
| 2.59732629 | 0.139300258 | 9.7035643 | 263.742980 | 121.54740 | 189.74831 |
| $1.01 \mathrm{E}-06$ | $3.57 \mathrm{E}-07$ | $3.32 \mathrm{E}-05$ | $1.54 \mathrm{E}-04$ | 3.63E-03 | $2.59 \mathrm{E}-03$ |
| $H=17.967 \pm 0.393$ | rms=0.4688 ${ }^{\prime \prime}$ | 41 obs. | arc: 2008 | $29.25161-2008$ | 0729.25161 |
| (2017 UU11) = 540601 |  |  |  |  |  |
| 3.1212485729 | 0.0914724915 | 9.86793636 | 272.4684567 | 138.4550631 | 129.7969135 |
| 5.26E-08 | 7.35E-08 | 6.86E-06 | 4.31E-05 | 6.77E-05 | $4.79 \mathrm{E}-05$ |
| $H=16.194 \pm 0.238$ | rms=0.4567 ${ }^{\prime \prime}$ | 168 obs. | arc: 200009 | $27.328970-201$ | 0228.20925 |
| $(2017$ UV11) $=(2006$ WJ117) |  |  |  |  |  |
| 3.1299502232 | 0.050543408 | 9.6165970 | 275.7779533 | 47.573128 | 213.284701 |
| 8.66E-08 | $1.13 \mathrm{E}-07$ | $1.23 \mathrm{E}-05$ | $6.48 \mathrm{E}-05$ | $1.77 \mathrm{E}-04$ | $1.740 \mathrm{E}-04$ |
| $H=16.628 \pm 0.258$ | $\mathrm{rms}=0.5381^{\prime \prime}$ | 56 obs. | arc: 20061 | 20.32876-20 | 0127.27727 |
| $(2017$ UW11) $=508672$ |  |  |  |  |  |
| 3.059355342 | 0.0372733466 | 14.4946777 | 262.2331278 | 359.449023 | 277.760331 |
| $1.01 \mathrm{E}-07$ | $9.38 \mathrm{E}-08$ | $1.02 \mathrm{E}-05$ | $3.64 \mathrm{E}-05$ | $1.36 \mathrm{E}-04$ | $1.35 \mathrm{E}-04$ |
| $H=15.504 \pm 0.401$ | rms $=0.5756^{\prime \prime}$ | 127 obs. | arc: 20061 | 19.25716-201 | 0204.91132 |
| $(2017$ UX11) = 540602 |  |  |  |  |  |
| 3.0867105093 | 0.1108896320 | 9.027172209 | 324.5622684 | 13.0643088 | 191.9568710 |
| 9.94E-08 | 7.83E-08 | 8.77E-06 | $5.55 \mathrm{E}-05$ | 7.32E-05 | 4.86E-05 |
| $H=16.968 \pm 0.325$ | rms=0.6568 ${ }^{\prime \prime}$ | 63 obs. | arc: 201108 | 20.48844-20 | 0126.35340 |
| (2017 UY11) |  |  |  |  |  |
| 2.6950766379 | 0.272327828 | 8.5874790 | 269.3278681 | 150.146374 | 157.1553239 |
| $3.86 \mathrm{E}-08$ | $2.49 \mathrm{E}-07$ | $1.22 \mathrm{E}-05$ | $7.81 \mathrm{E}-05$ | $1.61 \mathrm{E}-04$ | 8.89E-05 |
| $H=17.816 \pm 0.351$ | rms=0.4170 ${ }^{\prime \prime}$ | 68 obs. | arc: 20050 | 19.18452-20 | 0113.11370 |

Table 3. ...continued

| $a(\mathrm{au})$ | $e$ | $i$ (deg) | $\Omega$ (deg) | $\omega$ (deg) | $M$ (deg) |
| :---: | :---: | :---: | :---: | :---: | :---: |
| (2017 UJ15) = (2011 SG28) |  |  |  |  |  |
| 3.0627122526 | 0.138507738 | 11.01995247 | 350.1258159 | 348.8674783 | 190.8473306 |
| $6.74 \mathrm{E}-08$ | $1.09 \mathrm{E}-07$ | $9.39 \mathrm{E}-06$ | $4.95 \mathrm{E}-05$ | $6.44 \mathrm{E}-05$ | $4.29 \mathrm{E}-05$ |
| $H=15.957 \pm 0.418$ | rms=0.5659 ${ }^{\prime \prime}$ | 115 obs. | arc: 200609 | $25.97814-201$ | 0126.37586 |
| (2017 UK15) = (2006 SP166) |  |  |  |  |  |
| 3.0474848074 | 0.205704608 | 10.5527612 | 351.8583408 | 357.0501690 | 177.3259061 |
| $6.56 \mathrm{E}-08$ | $1.66 \mathrm{E}-07$ | $1.12 \mathrm{E}-05$ | $6.45 \mathrm{E}-05$ | $8.22 \mathrm{E}-05$ | $4.67 \mathrm{E}-05$ |
| $H=16.913 \pm 0.391$ | $\mathrm{rms}=0.5788^{\prime \prime}$ | 56 obs. | arc: 2006 | 17.32566-20 | 0108.45827 |
| (2017 UL15) |  |  |  |  |  |
| 3.013134824 | 0.18789344 | 8.5106036 | 297.914647 | 98.275308 | 147.128418 |
| $1.77 \mathrm{E}-07$ | $1.14 \mathrm{E}-06$ | $1.36 \mathrm{E}-05$ | $1.13 \mathrm{E}-04$ | $2.80 \mathrm{E}-04$ | $1.69 \mathrm{E}-04$ |
| $H=17.086 \pm 0.576$ | $\mathrm{rms}=0.4856{ }^{\prime \prime}$ | 63 obs. | arc: 200711 | $11.37123-2019$ | 0108.61476 |
| (2018 FU25) |  |  |  |  |  |
| 2.1914123016 | 0.1006641254 | 3.97948215 | 78.9752374 | 173.2489201 | 127.3655201 |
| $1.57 \mathrm{E}-08$ | $5.79 \mathrm{E}-08$ | $5.88 \mathrm{E}-06$ | $8.90 \mathrm{E}-05$ | $9.38 \mathrm{E}-05$ | $2.96 \mathrm{E}-05$ |
| $H=17.755 \pm 0.441$ | $\mathrm{rms}=0.6165^{\prime \prime}$ | 198 obs. | arc: 20020 | $19.29185-201$ | 1102.36125 |
| (2018 FV25) |  |  |  |  |  |
| 2.7183800786 | 0.0241541097 | 6.77614462 | 50.6255576 | 345.198803 | 283.154546 |
| $4.20 \mathrm{E}-08$ | $9.74 \mathrm{E}-08$ | 8.06E-06 | $6.09 \mathrm{E}-05$ | $1.97 \mathrm{E}-04$ | $1.94 \mathrm{E}-04$ |
| $H=16.823 \pm 0.363$ | rms $=0.6038{ }^{\prime \prime}$ | 102 obs. | arc: 2002 | $11.21773-201$ | 0531.54064 |
| (2018 GU6) |  |  |  |  |  |
| 2.7878820963 | 0.218606065 | 10.01210383 | 67.9409977 | 140.3972666 | 125.1274082 |
| $5.75 \mathrm{E}-08$ | $1.36 \mathrm{E}-07$ | $7.56 \mathrm{E}-06$ | $6.28 \mathrm{E}-05$ | $6.82 \mathrm{E}-05$ | $2.15 \mathrm{E}-05$ |
| $H=16.754 \pm 0.508$ | rms=0.6777 ${ }^{\prime \prime}$ | 125 obs. | arc: 200712 | $9.33995-2019$ | 0928.40951 |
| (2018 GV6) |  |  |  |  |  |
| 3.1900886 | 0.1715536 | 15.7750172 | 55.993845 | 176.27059 | 86.12596 |
| $4.11 \mathrm{E}-05$ | $1.22 \mathrm{E}-05$ | $3.87 \mathrm{E}-05$ | $1.51 \mathrm{E}-04$ | $3.38 \mathrm{E}-03$ | $1.42 \mathrm{E}-03$ |
| $H=16.095 \pm 0.386$ | rms $=0.5422^{\prime \prime}$ | 40 obs. | arc: 201612 | $3.50997-2018$ | 0516.33500 |
| (2018 GX8) |  |  |  |  |  |
| 2.63813 | 0.217833 | 15.0376 | 58.1840 | 187.5315 | 111.863 |
| $1.13 \mathrm{E}-03$ | $1.74 \mathrm{E}-04$ | $1.26 \mathrm{E}-02$ | $1.13 \mathrm{E}-02$ | $9.30 \mathrm{E}-02$ | $1.28 \mathrm{E}-01$ |
| $H=17.289 \pm 0.315$ | rms=0.4752 ${ }^{\prime \prime}$ | 27 obs. | arc: 201804 | 12.92206-2018 | 0514.34588 |
| $(2018$ RH17) $=(2013$ PD57) |  |  |  |  |  |
| 2.7444334717 | 0.2179115435 | 8.20401087 | 253.5321727 | 73.3951895 | 126.9271613 |
| $5.13 \mathrm{E}-08$ | $8.56 \mathrm{E}-08$ | $9.50 \mathrm{E}-06$ | $6.75 \mathrm{E}-05$ | $7.57 \mathrm{E}-05$ | $3.24 \mathrm{E}-05$ |
| $H=16.853 \pm 0.342$ | $\mathrm{rms}=0.3863^{\prime \prime}$ | 66 obs. | arc: 200911 | 99.31667-2019 | 0103.28688 |
| (2018 TL9) |  |  |  |  |  |
| 3.066276 | 0.2399989 | 5.612387 | 326.44650 | 12.5613 | 111.50667 |
| 2.30E-04 | 8.83E-05 | $1.29 \mathrm{E}-04$ | $2.38 \mathrm{E}-03$ | $1.28 \mathrm{E}-02$ | $5.88 \mathrm{E}-03$ |
| $H=16.927 \pm 0.241$ | rms=0.3786 ${ }^{\prime \prime}$ | 27 obs. | arc: 201810 | 06.91471-2019 | 0103.36384 |

Asteroid 345705 (2006 VB14) was discovered by Catalina Sky Survey on 2006-11-15. According to the orbit classification, it is an Aten-type asteroid and Near-Earth Object. The Minor Planet Center published 1167 of its observations over the interval: 2006-11-15.41375 - 2019-01-08.13551. The first observation was published on 2006-11-15.41375 by (704) Lincoln Laboratory Experimental Test Site (ETS), New Mexico, in the Minor Planet Supplement (MPS) 187233. The first observation by the Astrophysical Observatory in Baldone was made on 2018-10-14.05185 069, MPS 930858. Together, Baldone published 99 astrometric observations of 345705 (2006 VB14).

The second asteroid, 6178 ( 1986 DA ), was discovered at Shizuoka Observatory on 1986-02-16 by M. Kizawa. According to the Minor Planet Center (MPC), asteroid 6178 (1986 DA) has Amor orbit type and belongs to so-called 1+KM Near-Earth Object.

MPC published 1039 total astrometric observations over interval: 1977-07-17.67267 - 2019-07-30.295697. The first observation was made on 1977-07-17.67267 by (413) Siding Spring Observatory, MPC 24035. The Baldone Astrophysical Observatory (BAO) made the first observation of this object on 2019-04-17.84924, (MPS) 991243. Together, the BAO published 33 astrometric observations of 6178 (1986 DA).

We computed residuals, $R M S$ equal to 0.381 " for observations of asteroid 345705 (2006 VB14) using total 1168 observation from which 1164 were selected. Similarly, for asteroid 6178 we have 1041 observations with 1039 selected with $R M S=0.479^{\prime \prime}$. Due to the long observational arcs, about 12 years and 42 years, respectively, it was possible to compute the non-gravitational parameter $A 2$.

Parameter $A 2$ depends on the Yarkovsky effect. The Yarkovsky effect is the thermal re-emission of absorbed solar radiation. The non-gravitational acceleration arises from the anisotropic re-emission at thermal wavelengths of absorbed solar absorption. The Yarkovsky effect acts on the semimajor axis, $a$. The drift of semimajor axis, $d a / d t$ depends on the obliquity $y$ of the asteroid, the bulk density $\rho$, and diameter $D$ of the asteroid (Chesley et al. 2014):

$$
\begin{equation*}
\frac{d a}{d t} \sim \frac{\cos (y)}{\rho D} \tag{1}
\end{equation*}
$$

Next, according to Farnocchia et al. (2013a, p. 9) we averaged the Yarkovsky effect as a transverse acceleration, $a_{t}=A_{2} / r^{2}$, where $r$ is heliocentric distance and $A_{2}$ is a function of the physical quantities of the asteroid. Then, according to Farnocchia et al. (2013b), the semimajor axis drift of asteroid is

$$
\begin{equation*}
\frac{d a}{d t}=\frac{2 A_{2}\left(1-e^{2}\right)}{n p^{2}} \tag{2}
\end{equation*}
$$

where $e$ is the eccentricity, $n$ is the mean motion and $p$ is the semi latus rectum. As it was shown in Farnocchia
et al. (2013a), $A_{2}$ can be computed either using physical parameters of an asteroid or by fitting observation. The last method is used when we have computed the orbit of an asteroid with small uncertainties. Then, we solved seven orbital parameters instead of the previously six. The NEODyS team have developed the software OrbFit v.5.0 (http://adams.dm.unipi.it/~orbmaint/orbfit/) which computed non-gravitational parameter $d a / d t$ or $A_{2}$. We used this publicly available software and computed nongravitational parameter.

Table 4 presents the starting orbital elements of the asteroids 345705 ( 2006 VB14) and 6178 ( 1986 DA) computed with the non-gravitational parameter $A 2$ and using the same method as in computing results in Table 3. A negative value of $A 2$ of asteroid 345705 (2006 VB14) denotes that the mean semimajor axis drifts da/dt<0 and hence the asteroid can be retrograde rotator; in contrary, the positive value of $A 2$ of asteroid 6178 ( 1986 DA ) denotes that the mean semimajor axis drifts da/dt>0 and hence asteroid can be a prograde rotator. We can see that the orbital elements have small errors and the non-gravitational parameters $A 2$ have typical values as for NEAs computed by Wlodarczyk (2019a,b).

## 32008 LX16-an asteroid with Mars-crosser type orbit

The asteroid 2008 LX16 belongs to the Mars-crosser type of asteroids, comprising 14637 members as of 27 November 2019, according to the Minor Planet Center states: https://minorplanetcenter.net/db_search/show_by_orbit_type?utf8= $\sqrt{ }$ \&orbit_type= $=5$.

On the other hand, the JPL Small-Body Database lists 17354 of orbital-class Mars-crosser-asteroids: https://ssd. jpl.nasa.gov/sbdb_query.cgi\#x. According to the JPL: https: //ssd.jpl.nasa.gov/sbdb.cgi\#top Mars-crossing Asteroids, or Mars-crossers, are asteroids that cross the orbit of Mars constrained by ( $1.3 \mathrm{au}<q<1.666 \mathrm{au} ; a<3.2 \mathrm{au}$ ).

According to https://ssd.jpl.nasa.gov/sbdb.cgi\#top the Mars-crossing asteroid 2008 LX16 has absolute magnitude, $H=19.0$.

According to the MPC asteroid 2008 LX16 was first observed at Siding Spring Survey on 2008-06-15. Its orbit type is Mars-crosser. The MPC published 139 total astrometric observations over interval: 2008-06-15.52931 - 2018-07-16.34009. The first observation was made on 2008-0615.52931 by (E12) Siding Spring Survey, MPS 251702. First observation at Baldone was made in 2018-04-12.91523, MPS

Table 4. Initial nominal orbital elements of the asteroids 345705 ( 2006 VB14) and 6178 (1986 DA): $a$ denotes semimajor axis, $e$ - eccentricity, angles $i, \Omega$ and $\omega$ refer to the Equinox J2000.0, $M$ - mean anomaly. Epoch: JD2458800.5 TDB = 13 November 2019. Orbital elements are computed with the non-gravitational parameter $A 2$.

| $a$ (au) | $e$ | $i$ (deg) | $\Omega$ (deg) | $\omega$ (deg) | $M$ (deg) |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 345705 (2006 VB14) |  |  |  |  |  |
| 0.7669388731 | 0.42123761 | 31.024613 | 258.7275473 | 346.441171 | 314.203021 |
| $6.2 \mathrm{E}-09$ | $1.0 \mathrm{E}-07$ | $1.5 \mathrm{E}-05$ | $2.8 \mathrm{E}-06$ | $1.7 \mathrm{E}-05$ | 3.3E-05 |
| Orbital parameter: non-gravitational |  |  |  |  |  |
| $A 2=(-1.19 \pm 1.26) \mathrm{E}-14 \mathrm{au} / \mathrm{d}^{2}$ |  |  |  |  |  |
| 6178 (1986 DA) |  |  |  |  |  |
| 2.822145979 | 0.5818043231 | 4.3052158 | 64.636860 | 127.386722 | 39.4555013 |
| $2.1 \mathrm{E}-08$ | $2.2 \mathrm{E}-08$ | 5.0E-06 | 6.6E-05 | $6.6 \mathrm{E}-05$ | $3.8 \mathrm{E}-06$ |
| Orbital parameter: non-gravitational |  |  |  |  |  |
| $A 2=(+3.24 \pm 2.98) \mathrm{E}-14 \mathrm{au} / \mathrm{d}^{2}$ |  |  |  |  |  |



Figure 1. One of the first CCD image of the asteroid 2008 LX16. The size of field is 7 arcmin $\times 10$ arcmin. The image ( 480 s exposure) taken at the Baldone Astrophysical Observatory with the Schmidt telescope on the night April 19 of 2018.
881806. The Baldone published nine observations of this asteroid.

The object 2008 LX16 was observed at three observational nights in April 2018. The asteroid moved at speed $0.11 "$ per minute being 19.2 R magnitude object. It was independently discovered by the Baldone and by Pan-STARRS observatories at the opposition of 2018.

We computed the orbit of the asteroid 2008 LX16, one of the known MCs, based on all observations using the OrbFit software (http://adams.dm.unipi.it/~orbmaint/orbfit/). Sixteen perturbing massive asteroids and dwarf planet Pluto were used according to Farnocchia et al. (2013a,b) and similar to Wlodarczyk (2015).

We also used the new version of the OrbFit Software, namely OrbFit v.5.0.5, which has the new error model desribed in Chesley et al. (2010), as well as the debiasing and weighting scheme described in Farnocchia et al. (2015) called after that error model 2015 (see Table 4). Moreover, we used the DE431 version of JPL's planetary ephemerides.


Figure 2. The orbit of 2008 LX16 in the ecliptic plane. The position of the planets, the asteroid 2008 LX16, dwarf planet (1) Ceres and three massive asteroids: (2) Pallas, (4) Vesta and (10) Hygiea are presented for the epoch 2008 June 15, i.e. for the date of first observation at Siding Spring Survey.

Recently, the possibility of calculating orbits according to the OrbFit software v.5.0.6 has appeared with implemented error model 2017, according to Vereš et al. (2017) (see Table 4).

Table 5 presents the starting orbital elements of the asteroid 2008 LX16 computed with the non-gravitational parameter A2. A positive value of $A 2$ for asteroid 2008 LX16 denotes that the mean semimajor axis drifts da/dt>0 and hence the asteroid can be the prograde rotator. Table 5 shows that orbital elements have only changed a little, but $A 2$ has also changed. Also, the error of all calculated orbital elements and $A 2$ is smaller.

Table 5. Initial nominal orbital elements of the asteroid 2008 LX16 with different error models: $a$ denotes semimajor axis, $e$ - eccentricity, angles $i, \Omega$ and $\omega$ refer to the Equinox J2000.0, $M$ - mean anomaly. Epoch JD2458400.5 TDB $=9$ October 2018. Orbital elements are computed with the non-gravitational parameter $A 2$.

| $a(\mathrm{au})$ | $e$ | $i$ (deg) | $\Omega$ (deg) | $\omega$ (deg) | $M$ (deg) |
| :---: | :---: | :---: | :---: | :---: | :---: |
| error model 2015 |  |  |  |  |  |
| 2.2410691 | 0.41891826 | 6.337966 | 70.535876 | 200.27248 | 26.704354 |
| $1.6 \mathrm{E}-06$ | 3.9E-07 | 1.8E-05 | 8.2E-05 | $2.0 \mathrm{E}-04$ | $4.7 \mathrm{E}-05$ |
| Orbital parameter: non-gravitational |  |  |  |  |  |
| $A 2=(2.975 \pm 8.176) \mathrm{E}-12 \mathrm{au} / \mathrm{d}^{2}$ |  |  |  |  |  |
| error model 2017 |  |  |  |  |  |
| 2.2410688 | 0.41891831 | 6.337966 | 70.535918 | 200.27248 | 26.704354 |
| $1.0 \mathrm{E}-06$ | $2.0 \mathrm{E}-07$ | $1.2 \mathrm{E}-05$ | $4.8 \mathrm{E}-05$ | 0.9E-04 | $1.5 \mathrm{E}-05$ |
| Orbital parameter: non-gravitational |  |  |  |  |  |
| $A 2=(1.452 \pm 4.863) \mathrm{E}-12 \mathrm{au} / \mathrm{d}^{2}$ |  |  |  |  |  |

Figure 2 presents the orbit of 2008 LX16 in the ecliptic plane. The position of the planets, the asteroid 2008 LX16, the dwarf planet (1) Ceres and three massive asteroids: (2) Pallas, (4) Vesta and (10) Hygiea are also presented for the epoch 200815 June, i.e. for the date of the first observation at Siding Spring Survey. According to the International Astronomical, a discoverer will be defined when the object is numbered, see https://minorplanetcenter.net/mpec/K10/ K10U20.html.

## 42008 LX16 - Long time orbital evolution

To study the orbital evolution of asteroid 2008 LX16, we computed its Virtual Asteroids (VAs) with the use of the OrbFit software v. 5.0.5 and the method of Milani et al. (2005a,b). VAs, or variant orbits or clones denote swarm of orbits which lie somewhere in the confidence region. Each of these orbits fits well with observations. Line of Variation ( $L O V$ ) is usually obtaining by fixing the value of all the orbital elements, six or seven when we used the Yarkovsky effect. Next, we changed only the mean anomaly. $L O V$ is a one-dimensional part of a (curved) line in the initial conditions space generally computed with the uniform sampling of the $L O V$ parameter. $\sigma L O V$ denotes the position along the Line of Variation, $L O V$ in the $\sigma$ space. Values of $\sigma$ are usually in the interval $(-3,3)$. LOV is used to compute multiple solutions which are useful in the orbit determination and their propagation (Milani et al. 2005a,b). We are computing 500 VAs on both sides of the nominal orbit on the $L O V$ where the nominal orbit has $\sigma=0$. Hence we have 1001 VAs. We computed 500 clones of both sides of the $L O V$ with the uniform sampling of the $L O V$ parameter. Then we propagate all the VAs 100 My forward.

Time evolutions of orbital elements of all clones are calculated using the software swift_rmvs developed by Levison and Levison (1994) This software takes into account the gravitational influence of all planets (variant swift_rmvs3_f), i.e. from Mercury to Neptune, and in the second case by adding four massive objects: dwarf planet (1) Ceres and three massive asteroids: (2) Pallas, (4) Vesta and (10) Hygiea. Our calculations were done for a case without the Yarkovsky effect.

Figure 3 presents the position of the remaining clones from the starting 1001 clones with $\sigma=3$, of the asteroid 2008 LX16 after 100 My forward integration. Great star in Figure 3 presents the starting position of the nominal asteroid 2008 LX16. Small stars denote 30 remaining clones of 2008 LX16 using the old error model based on Farnocchia et al. (2015) and additional massive asteroids, (1) Ceres, (2) Pallas, (4) Vesta and (10) Hygiea (CPVH). The dots denote 45 remaining clones of 2008 LX16 using the same gravitational model, i.e. with CPVH and using the new error model based on Vereš et al. (2017). The open circles denote 46 remaining clones using the gravitational model without CPVH and with the new error model based on Vereš et al. (2017). It is visible that almost all remaining clones in phase space have orbits with aphelia smaller than the semimajor axes of Mars and perihelia larger to the semimajor axis of Venus.

In Figure 3 we can see that using the new error model, more clones remain in the Solar System model, i.e. 46 clones, in contrary to the old error model with 30 remaining clones. Probably we have a smaller dispersion of startup elements, i.e. smaller errors of these orbital elements - see Table 4. Furthermore, the number of clones remaining at the end of the integration period in the new Solar System model, hardly depends on the use of additional perturbing massive asteroids (CPVH).

It is visible that only several $\%$ of starting clones remain after 100 My integration. It can be explained by the fact that


Figure 3. Remaining clones of 2008 LX16 after 100 My forward integration in the $(a, e)$ plane - top panels and in the $(a, i)$ plane bottom panels. Small stars denote the position of clones with the use of the old error model based on Farnocchia et al. (2015) and with adding four massive bodies: (1) Ceres, (2) Pallas, (4) Vesta and (10) Hygiea (CPVH), dots - using the new error model based on Vereš et al. (2017) and with adding four massive bodies, CPVH, open circles denote positions of remaining clones computed without CPVH massive bodies and with the new error model. It is visible that almost all remaining clones in phase space have orbits with aphelia smaller than the semimajor axes of Mars and perihelia larger to the semimajor axis of Venus.

2008 LX16 is close to the line of the perihelion of the Earth. Generally, from all starting 1001 clones of the asteroid 2008 LX16 45\% hit the Sun, ( $35 \div 38$ )\% reached distance from the Sun greater than $1000 \mathrm{au},(13 \div 15) \%$ have a collision with planets or perturbing massive asteroids, and ( $3 \div 5$ )\% remain in the solar system, respectively.

## 52008 LX16 - Computation of the predicted theoretical meteor-stream radiant

Next, we computed theoretical meteor-stream radiant for asteroid 2008 LX16 according to the program of Neslusan et al. (1998). As the input parameters are orbital elements of the orbit of the parent body and its time of perihelion passage.

Results of computations are in Table 6 where:
$\rightarrow$ date-max. - date of the predicted maximum [year, month, day]
$\rightarrow$ dist. - distance between the Earth and parent body at the moment of the predicted maximum [au]
$\rightarrow \mathrm{dt}$ - time elapsed from the passage of the parent body through the point of its orbit nearest to the Earth's orbit at the investigated shower maximum (if negative, the body will pass the point after the maximum) [days]
$\rightarrow$ alpha, delta - equatorial coordinates of radiant [degrees]
$\rightarrow$ vg, vh - geocentric and heliocentric velocities [km/s]
$\rightarrow$ 1-solar longitude at the moment of predicted maximum [degrees]
$\rightarrow$ min. dist. - the minimum distance between the given arc of the parent body and Earth's orbits [au]
$\rightarrow$ d-disc. - the value of d-discriminant; $\mathrm{d}<0.1$ - good prediction, $\mathrm{d}>0.5$ - unreal prediction.

Table 6 shows that predicted theoretical meteor shower radiants will be visible at the turn of May and June in the following years.

Table 6. 2008 LX16. Computed theoretical meteor shower radiants.

| date-max. | dist. | dt |
| ---: | ---: | ---: |
| date | au | days |
| 2020 May 31.8 | 4.109 | -512.0 |
| 2021 June 1.1 | 2.089 | -147.0 |
| 2022 June 1.3 | 2.779 | 218.5 |
| 2023 June 1.6 | 4.189 | 583.7 |
| 2024 May 31.9 | 3.187 | -276.4 |
| alfa/delta | $\mathrm{vg} / \mathrm{vh}$ | l |
| deg | $\mathrm{km} / \mathrm{s}$ | deg |
| 207.4/21.3 | $7.65 / 35.10$ | 70.5 |
| Equinox: 2000.0 |  |  |
| min. dist. $=0.2891 \mathrm{au} ; \mathrm{d}-\mathrm{disc}=0.307$ |  |  |

## 6 Summary

Between 2015 and 2018, 37 asteroids were discovered at the Baldone Astrophysical Observatory (MPC 069). We studied one of the interesting Mars-crosser (MC) observed at the Baldone Astrophysical Observatory, namely 2008 LX16. Also, NEO object 2006 VB14 and 1986 DA and 2014 LJ1 were observed. We computed orbits and analyzed the orbital evolution of these asteroids. 566 positions and photometric observations were obtained with Baldone Schmidt telescope in 2018 and 2019. We detected the rotation period, and other
physical characteristics of NEO objects 345705 (2006 VB14) and 6178 ( 1986 DA ). We determined the rotational period of asteroid 6178 (1986DA), $\mathrm{P}=(3.12 \pm 0.02) \mathrm{h}$.

Acknowledgment: We thank Julio A. Fernández and the anonymous reviewer for useful comments. We thank the Space Research Center of the Polish Academy of Sciences in Warsaw for the possibility to work on a computer cluster. We also thank L. Neslusan for his software. This research is funded by the Latvian Council of Science, project "Complex investigations of Solar System small bodies", project No. lzp-2018/1-0401. Kazimieras Cernis acknowledges the Europlanet 2024 RI project funded by the European Union's Horizon 2020 Research and Innovation Programme (Grant agreement No. 871149).

## References

Chesley SR, Baer J, Monet DG. 2010. Treatment of star catalog biases in asteroid astrometric observations. Icar. 210(1):158181.

Chesley SR, Farnocchia D, Nolan MC, Vokrouhlický D, Chodas PW, Milani A, et al. 2014. Orbit and bulk density of the OSIRIS-REx target Asteroid (101955) Bennu. Icar. 235(5):5-22.
Černis K, Wlodarczyk I, Eglitis I. 2015. Observational data and orbits of the asteroids discovered at the Baldone Observatory in 2008-2013. BaltA. (24): 251-262.
Eglitis I. 2019. Investigation of NEO asteroids 2006 VB14 and 1986 DA. OAP. 32(0):146-147.

Farnocchia D, Chesley SR, Vokrouhlický D, Milani A, Spoto F, Bottke WF. 2013a. Near Earth Asteroids with measurable Yarkovsky effect. Icar. 224(1):1-13.
Farnocchia D, Chesley SR, Chodas PW, Micheli M, Tholen DJ, Milani A, et al. 2013b. Yarkovsky-driven impact risk analysis for asteroid (99942) Apophis. Icar. 224(1):192-200.
Farnocchia D, Chesley SR, Chamberlin AB, Tholen DJ. 2015. Star catalog position and proper motion corrections in asteroid astrometry. Icar. 245:94-111.
Levison HF, Duncan MJ. 1994. The Long-Term Dynamical Behavior of Short-Period Comets. Icar. 108(1):18-36.
Milani A, Chesley SR, Sansaturio ME, Tommei G, Valsecchi GB. 2005a. Nonlinear impact monitoring: line of variation searches for impactors. Icar. 173(2):362-384.
Milani A, Sansaturio ME, Tommei G, Arratia O, Chesley SR. 2005b. Multiple solutions for asteroid orbits: Computational procedure and applications. A\&A. 431:729-746
Neslusan L., Svoren J., Porubcan V. 1998. A computer program for calculation of a theoretical meteor-stream radian. A\&A. 331:411-413
Skiff BA, Bowell E, Koehn BW, Sanborn JJ, McLelland KP, Warner BD. 2012. Lowell Observatory Near-Earth Asteroid Photometric Survey (NEAPS) - 2008 May through 2008 December. MPBu. 39:111-130.
Vereš P, Farnocchia D, Chesley SR, Chamberlin AB. 2017. Statistical analysis of astrometric errors for the most productive asteroid surveys. Icar. 296:139-149.
Wlodarczyk I. 2015. The Potentially Hazardous Asteroid (410777) 2009 FD. AcA. 65:215-231.
Wlodarczyk I. 2019a. Some parameters of selected NEAs. BlgAJ. 30: 44-59.
Wlodarczyk, I. 2019b. The potentially hazardous NEA 2001 BB1. Open Astronomy. 28:180-190.


[^0]:    Corresponding Author: Ireneusz Wlodarczyk: Chorzow Astronomical Observatory, 41-500 Chorzow, Poland; Email: astrobit@ka.onet.pl Kazimieras Černis: Institute of Theoretical Physics and Astronomy, Vilnius University, Saulėtekio al. 3, Vilnius LT-10222, Lithuania; Email: Kazimieras.Cernis@tfai.vu.lt
    Ilgmars Eglitis: Institute of Astronomy, University of Latvia, Raina 19, Riga 1586, Latvia; Email: ilgmars@latnet.Iv

