10.1515/astro-2017-0226

Baltic Astronomy, vol. 24, 251–262, 2015

OBSERVATIONAL DATA AND ORBITS OF THE ASTEROIDS DISCOVERED AT THE BALDONE OBSERVATORY IN 2008–2013

K. Černis[1], I. Wlodarczyk[2] and I. Eglitis[3]

[1] *Institute of Theoretical Physics and Astronomy, Vilnius University, Goštauto 12, Vilnius LT-01108, Lithuania; Kazimieras.Cernis@tfai.vu.lt*

[2] *Chorzow Astronomical Observatory, 41-500 Chorzow, Poland; astrobit@ka.onet.pl*

[3] *Institute of Astronomy, University of Latvia, Raina 19, Riga 1586, Latvia; ilgmars@latnet.lv*

Received: 2015 March 6; accepted: 2015 April 27

Abstract. The paper presents statistics of the asteroids observed and discovered at the Baldone Observatory, Latvia, in 2008–2013 within the project for astrometric observations of the near-Earth objects (NEOs), the main belt asteroids and comets. CCD observations of the asteroids were obtained with the 0.80/1.20 m, f/3 Schmidt telescope and a ST-10XME 15×10 mm CCD camera. In the Minor Planet Circulars and the Minor Planet Electronic Circulars (2008–2013) we published 3511 astrometric positions of 826 asteroids. Among them, 43 asteroids were newly discovered at Baldone. For 36 of these asteroids the precise orbits are calculated. Because of short observational arc and small number of observations, a few asteroids have low-precision orbits and their tracks have been lost. For seven objects with poorly known orbits we present their ephemerides for 2015–2016. The orbits and the evolution of orbital elements of two asteroids, (428694) 2008 OS9 from the Apollo group and the Centaur (330836) Orius (2009 HW77), are recalculated including new observations obtained after 2011.

Key words: minor planets, asteroids – astrometry – ephemerides

1. ASTROMETRIC OBSERVATIONS OF MINOR PLANETS

This is our second paper in a series of papers which review our contribution to asteroid discovery and follow-up observations of newly and previously discovered asteroids. The first paper (Černis et al. 2014) was devoted to the asteroids discovered at the Moletai Observatory, Lithuania, in 2000–2004. In the present paper, we focus on statistics of the asteroids discovered at the Baldone Observatory in Latvia during the years 2008–2013.

The asteroid project of the Baldone Observatory (IAU code 069, longitude 24.4041 E, latitude 56.7734 N, altitude 103 m) involves astrometric and photometric observations of the Main Belt asteroids and newly discovered Near Earth Objects (NEOs), including their search. Astrometric CCD observations of asteroids at this observatory were started in January of 2008, using the 0.80/1.20 m, f/3 Schmidt telescope and a ST-10XME 15×10 mm CCD camera (field of view

$21' \times 14'$), with an image scale of $0.58''$ per pixel. The first three new asteroids were discovered at the beginning of 2008 (2008 AL86, 2008 AU101 and 2008 AV101). During the sky survey close to the ecliptic, 43 new asteroids were discovered in 2008–2013: 14 of them have multiple-apparition orbits, 12 are one opposition objects of which two have no orbit (updated on 2015 February 12).

Among the newly discovered asteroids, two are exceptional objects, the NEO 2008 OS9 (Černis & Eglitis 2008a; Černis et al. 2010) and the Centaur-type asteroid 2009 HW77 (Orius) (Černis & Eglitis 2009; Wlodarczyk et al. 2011), and two are the Trojan group asteroids (2011 QA50 with $a = 5.27$ AU and 2013 RO26 with $a = 5.12$ AU).

The limiting R magnitude for the Schmidt telescope is about 21 for unfiltered CCD images with an exposure time of about 8 minutes. All astrometric measurements and reductions were done using the Astrometrica software (Raab 2003). The reference stars were selected from the catalogs USNO-A2.0, USNO-B1.0, UCAC-2 and UCAC-4.

Most of the asteroids were discovered in the morning hours about 20 days before their opposition time at elongations of 150–160 deg. The sky survey has been undertaken close to the ecliptic (mostly not more than 10 deg from the ecliptic line), taking three or four CCD images of the same field, with 20–30 min time spans between the exposures.

The Baldone Schmidt telescope has proved to be a very useful instrument for asteroid searches as well as for follow-up astrometry of poorly observed NEOs and unusual objects. During 2008–2013, 2117 CCD images (in 116 observing nights) for astrometry of asteroids and comets were obtained by I. Eglitis. Inspection of the images and measurements of the positions of all asteroids which appeared in the frames were performed by K. Černis. The 3511 astrometric positions of 826 asteroids, including at least five NEOs, were published in the Minor Planet Circulars (MPC) and Electronic Minor Planet Circulars (MPEC) (Černis & Eglitis 2008ab, 2013).

Till now, 2015 March, the credits for discovery of 12 asteroids have been received by the Baldone Observatory from the Minor Planet Center, ten of them have been named. In the near future we expect to get the credits and numbers for another four asteroids: 2008 AK86, 2009 HW20, 2013 QW47 and 2013 RU34.

Our contribution is about 0.006% of all 55.7×10^6 observations of asteroids done in the world during this period. The new discoveries (43) compose a similar part, 0.018%, of all 234 000 asteroids discovered. This was the period when great numbers of asteroids were discovered by the specialized projects, such as LONEOS, LINEAR, Spacewatch, Catalina and Pan-STARRS.

Table 1 presents the distribution of asteroid discoveries by year and the numbers of astrometric observations performed in 2008–2013. Table 2 lists the new asteroids discovered at the Baldone Observatory.

The asteroid 2011 SW259 has got its designation only in 2011, however, this object was first spotted at the Baldone Observatory on 2008 January 5. According to the new rules defining the discoverer of a particular object (Spahr 2010), 2011 SW259 is confirmed as discovered by the Baldone Observatory because the resolution adopted by Commission 20 at the 1979 IAU General Assembly says: "The Commission defines the discovery as the earliest apparition at which an orbit useful in the establishment of identifications was calculated" (taken from the Minor Planet Circular 4845-4846).

Table 1. Distribution of asteroid discoveries at the Baldone Observatory by year and the numbers of astrometric observations of newly and previously discovered asteroids.

Year	Number of asteroid discoveries	Number of asteroid observations	Number of objects observed	References (MPC No.)
2008	15	1261	273	61686, 61979, 62255, 62566, 62865, 63123
2009	11	528	101	64750, 65037, 65628, 65920, 66188, 66450
2010	3	365	126	68212, 68670, 69202, 69725, 70193, 71529
2011	3	247	73	73049, 73667, 74026, 74812, 75400, 75594
2012	1	342	47	77579, 79473, 79747, 80114, 80452, 81615
2013	10	768	206	82023, 82459, 82866, 83281, 83629, 83714
Total	43	3511	826	

Table 2. List of asteroids discovered at the Baldone Observatory in 2008–2013.

No.	Date of discovery	Designation	Number	Name	Discoverers	Status
1	2008 Jan 03	2008 AK86			KC IE	+
2	2008 Jan 03	2008 AL86	294664	Trakai	KC IE	*
3	2008 Jan 03	2008 AU101	274084	Baldone	KC IE	*
4	2008 Jan 03	2008 AV101			KC IE	Id
5	2008 Jan 04	2008 AW101	397261		KC IE	Id
6	2008 Jan 05	2011 SW259	353577	Gediminas	KC IE	*
7	2008 Feb 02	2008 CR10			KC IE	Id
8	2008 Feb 03	2008 CL177	418220		KC IE	*
9	2008 Feb 09	2008 CH184			KC IE	Id
10	2008 Jul 25	2008 OZ1	352646	Blumbahs	KC IE	*
11	2008 Jul 25	2008 OS9	428694		KC IE	*
12	2008 Jul 26	2008 OS10	276162		KC IE	Id
13	2008 Jul 29	2008 OZ11			KC IE	Lost
14	2008 Jul 29	2008 OS18	332530	Canders	KC IE	*
15	2008 Jul 31	2008 OT18			KC IE	Lost
16	2009 Apr 16	2009 HC12	255595		KC IE	Id
17	2009 Apr 16	2009 HV19	392142	Solheim	KC IE	*
18	2009 Apr 16	2009 HW19			KC IE	Lost
19	2009 Apr 18	2009 HS20	324928		KC IE	Id
20	2009 Apr 18	2009 HW20			KC IE	+
21	2009 Apr 20	2009 HB45			KC IE	Lost
22	2009 Apr 18	2009 HB59			KC IE	Lost
23	2009 Apr 24	2009 HG68			KC IE	Lost
24	2009 Apr 25	2009 HH68	343157	Mindaugas	KC IE	*
25	2009 Apr 25	2009 HJ68	321324	Vytautas	KC IE	*
26	2009 Apr 25	2009 HW77	330836	Orius	KC IE	*
27	2010 Apr 12	2010 GC158	284984	Ikaunieks	KC IE	*
28	2010 May 05	2010 JY14			KC IE	Id
29	2010 May 05	2010 JN76			KC IE	Id
30	2010 Apr 10	2011 HO28			KC IE	Id
31	2011 Aug 23	2011 QA50			KC IE	Id

Table 2. Continued.

No.	Date of discovery	Designation	Number	Name	Discoverers	Status
32	2011 Aug 23	2011 QE80			KC IE	Id
33	2012 Apr 10	2012 GA2			KC IE	Id
34	2013 Aug 29	2013 QW47			KC IE	+
35	2013 Sep 04	2013 RH24			KC IE	Lost
36	2013 Sep 04	2013 RO26			KC IE	Lost
37	2013 Sep 04	2013 RU34			KC IE	+
38	2013 Sep 05	2013 RV34			KC IE	Id
39	2013 Sep 06	2013 RN35			KC IE	Id
40	2013 Sep 06	2013 RU43	376342		KC IE	Id
41	2013 Sep 09	2013 RX43			KC IE	Id
42	2013 Sep 06	2013 RZ80			KC IE	Id
43	2013 Sep 04	2013 RR95			KC IE	Id

Notes:

KC	Kazimieras Černis
IE	Ilgmars Eglitis
*	Credited for discovery from the Baldone Observatory
Lost	The lost asteroid
Id	An independent discovery
+	Waiting for crediting Baldone

2. ORBITS

To compute the orbits and ephemerides of asteroids, the freely available OrbFit software v.4.2[1] has been used. We also applied the JPL DE405 planetary and lunar ephemerides, the biased error model based on Chesley et al. (2010) and 25 perturbing asteroids. For weighting and selecting the observations, the method described in the NEODyS site (Wlodarczyk et al. 2014) has been used.

The masses of 25 perturbing asteroids were taken from Farnocchia et al. (2013). Starting positions of these asteroids and their perturbations were computed using the ASTDyS base of the initial orbital elements of asteroids[2] and the OrbFit software. The precision of orbital computation using the OrbFit software is described in Wlodarczyk (2009).

Table 3 presents the high-precision orbital elements and their uncertainties for the asteroids discovered at the Baldone Observatory in 2008–2013. They are listed in order of the discovery date. For each asteroid, the first line gives the following orbital elements: a – semimajor axis, e – eccentricity, i – inclination, Ω – longitude of the ascending node, ω – argument of perihelion, and M – mean anomaly. The second line gives the rms errors of the elements and the third line gives the absolute magnitude H, the number of observations used, and their time coverage. The orbital elements and their ephemerides are computed without any non-gravitational effects, i.e., in the computations only the gravitational model of the Solar system has been used.

[1] http://adams.dm.unipi.it/∼orbmaint/orbfit/

[2] http://hamilton.dm.unipi.it/astdys/

Table 3. High-precision orbital elements of the asteroids discovered at the Baldone Observatory in 2008–2013. The epoch JD2457000 = 2014 December 09.

a (au)	e	i (deg)	Ω (deg)	ω (deg)	M (deg)
		(2008 AK86)			
2.33566920104	0.1192572988	3.6600561446	272.430623145	271.7938530	274.9662972
2.79475E-06	1.70364E-05	7.88429E-05	5.58108E-04	1.27394E-02	1.42692E-02
H=17.621	rms=0.4217”	26 obs.	arc: 2008 01 03.90422 - 2015 01 20.26813		
		(294664)			
3.248280132299	0.05865146755	5.3667305468	277.249722573	36.178783848	219.925102494
1.54081E-07	1.50940E-07	1.37495E-05	1.31500E-04	1.75078E-04	1.17978E-04
H=15.677	rms=0.5259”	90 obs.	arc: 2006 10 04.37855 - 2014 02 27.24351		
		(274084)			
2.4036188289985	0.175606081662	3.9175584610	278.872406823	283.544541900	235.8731732909
4.52711E-08	1.60734E-07	1.22275E-05	2.44476E-04	2.49362E-04	4.89770E-05
H=17.316	rms=0.5875”	83 obs.	arc: 2001 03 24.37401 - 2013 09 03.36457		
		(2008 AV101)			
2.450248745521	0.15835880858	1.3008826908	233.33165162	312.99701378	228.356462380
3.89941E-07	1.96833E-06	1.70719E-05	1.70317E-03	1.78504E-03	4.35474E-04
H=17.768	rms=0.7426”	28 obs.	arc: 2006 09 26.38853 - 2012 03 25.21023		
		(397261)			
2.590588070181	0.094882110822	10.0038479296	281.6439681722	46.5983625693	11.1451467164
1.22386E-07	4.26723E-07	1.80509E-05	5.77498E-05	9.34401E-05	6.82328E-05
H=16.194	rms=0.5284”	125 obs.	arc: 2002 10 10.24929 - 2014 09 24.16554		
		(2008 CR10)			
2.982647129845	0.31930394017	1.1317884015	53.22589119	20.42423481	155.167975550
1.40223E-07	5.01146E-06	1.80011E-05	2.12778E-03	2.76835E-03	6.08202E-04
H=17.508	rms=0.5269”	41 obs.	arc: 1991 11 05.23954 - 2013 02 12.31973		
		(2008 CL177)			
2.419330321423	0.12564858210	2.9294644355	150.159319515	342.531176906	300.021542409
4.79790E-07	1.32421E-06	3.02170E-05	2.41186E-04	8.98288E-047	9.03301E-04
H=18.025	rms=0.6899”	64 obs.	arc: 2004 01 30.11711 - 2012 03 23.41076		
		(2008 CH184)			
3.03371396	0.06265973	11.386092	140.2515664	328.93680	141.63454
1.29837E-03	4.05736E-03	1.01347E-01	8.85166E-02	1.54397E+00	1.60162E+00
H=16.696	rms=0.6791”	14 obs.	arc: 2008 02 09.23263 - 2008 02 26.41344		
		(352646)			
2.1803790181788	0.134062682722	7.21630350905	159.6807239964	109.343365125	27.0594941973
4.41825E-08	1.42131E-07	8.60799E-06	9.55323E-05	1.08411E-04	4.63840E-05
H=17.520	rms=0.5989”	94 obs.	arc: 2004 02 29.24403 - 2014 06 30.34273		
		(428694)			
1.6016281924520	0.648078360317	19.1241224069	133.55253305050	288.2019102858	15.8058261653
2.58570E-08	1.44825E-07	2.31142E-05	3.74716E-06	2.07785E-05	2.79108E-05
H=19.400	rms=0.5756”	539 obs.	arc: 2008 07 25.36573 - 2015 02 18.62309		
		(276162)			
2.9796377943778	0.032229567379	10.6394261640	163.1276550461	18.655606186	219.243149488
6.98295E-08	1.19573E-07	1.38747E-05	6.56336E-05	2.48173E-04	2.46093E-04
H=15.697	rms=0.6104”	91 obs.	arc: 2000 12 23.470760 - 2014 10 02.47629		
		(2008 OZ11)			
2.7007508	0.13075084	4.9837349	269.188390	74.1016	136.4412
1.14719E-02	3.17196E-03	7.77562E-02	5.38163E-01	1.02234E+01	1.05095E+01
H=16.882	rms=0.5269”	11 obs.	arc: 2008 07 29.92917 - 2008 08 06.92352		

Table 3. Continued.

a (au)	e	i (deg)	Ω (deg)	ω (deg)	M (deg)
(332530)					
2.740897007502	0.051512639804	5.5667198262	184.258008724	151.014467614	129.211985473
1.00704E-07	1.90913E-07	2.22756E-05	1.51005E-04	2.75833E-04	2.14962E-04
H=16.946	rms=0.5813"	63 obs.	arc: 2002 02 20.40169 - 2013 10 27.37211		
(255595)					
2.3131391378449	0.1576188972751	5.8068422830	73.632463865	250.252112598	124.8020283793
3.79075E-08	9.86926E-08	1.16340E-05	1.06053E-04	1.14866E-04	4.03927E-05
H=17.436	rms=0.6762"	74 obs.	arc: 2003 11 24.26306 - 2013 07 17.47305		
(392142)					
3.115196611981	0.057327182832	9.7591665296	187.968650745	123.101370754	278.370218189
2.36376E-07	2.59524E-07	4.98698E-05	1.07788E-04	5.63616E-04	5.79453E-04
H=16.077	rms=0.6771"	44 obs.	arc: 2003 04 05.25870 - 2014 03 22.34836		
(2009 HW19)					
2.87230267	0.0613206	9.183162	186.58092	134.3249	317.3868
1.49779E-03	2.37750E-02	4.07857E-01	1.11820E+00	1.66807E+01	1.62917E+01
H=16.387	rms=0.6973"	11 obs.	arc: 2009 04 16.92005 - 2009 04 25.92089		
(324928)					
2.2068158144943	0.068810915868	5.8141369584	179.0287970802	225.368796924	66.121920679
8.09944E-08	1.53658E-07	1.63553E-05	8.87482E-05	1.77940E-04	1.72876E-04
H=17.898	rms=0.7011"	74 obs.	arc: 2000 08 01.34709 - 2013 08 15.40326		
(2009 HW20)					
2.421055165650	0.114308783065	3.4735517884	99.532194184	70.702167407	212.735073811
1.33295E-07	2.45336E-07	2.58118E-05	3.65035E-04	4.33811E-04	2.51752E-04
H=17.897	rms=0.7579"	42 obs.	arc: 2007 11 09.20980 - 2013 07 01.35367		
(2009 HB45)					
3.2708675	0.1055105	8.73419	59.38308	97.77931	29.8168
7.57724E-02	9.86939E-02	1.84644E+00	4.32493E+00	3.36351E+01	4.70527E+01
H=16.285	rms=0.4557"	7 obs.	arc: 2009 04 20.90691 - 2009 04 24.91837		
(2009 HB59)					
2.5576248	0.1307296	8.629719	59.41091	367.0868	274.0737
1.06878E-02	2.06917E-02	5.12832E-01	1.23677E+00	1.04350E+01	1.62886E+01
H=16.648	rms=0.9263"	12 obs.	arc: 2009 04 18.97237 - 2009 04 24.90486		
(343157)					
3.0842939300996	0.176293712389	17.9274407790	55.9061917110	95.177268436	64.3405470178
7.80147E-08	1.38799E-07	2.56563E-05	4.45401E-05	1.08084E-04	8.84192E-05
H=15.693	rms=0.6505"	104 obs.	arc: 1998 04 23.24783 - 2014 05 07.27647		
(321324)					
3.1253607550736	0.110292913268	6.6059518353	96.618392847	1.0819210	117.9460053154
7.64030E-08	1.15384E-07	1.06663E-05	1.26638E-04	1.54683E-04	7.98938E-05
H=15.971	rms=0.5469"	99 obs.	arc: 2000 09 05.427320 - 2014 04 06.27566		
(330836)					
2.146608923	0.4198629165	17.8788035964	50.3967392329	140.466932470	28.54643347
8.76149E-04	2.16505E-05	4.00936E-05	6.07582E-05	3.20807E-04	1.84854E-03
H=9.725	rms=0.6494"	79 obs.	arc: 2002 02 12.50951 - 2012 05 19.44276		
(284984)					
2.6827354144259	0.085399827175	8.8958766735	78.6201526310	283.936688372	227.3479935055
8.64629E-08	1.10219E-07	1.49454E-05	7.58058E-05	1.24143E-04	9.70250E-05
H=16.737	rms=0.6857"	86 obs.	arc: 2003 11 29.25098 - 2014 03 22.30039		

Table 3. Continued.

a (au)	e	i (deg)	Ω (deg)	ω (deg)	M (deg)
(2010 JY14)					
2.68175578	0.10680731	15.2218867	54.2299332	181.722196	355.649164
1.10170E-03	8.97870E-04	2.10126E-02	3.06269E-02	4.78401E-01	5.48967E-01
H=16.789	rms=0.7974"	11 obs.	arc: 2010 04 15.67744 - 2010 05 10.91866		
(2010 JN76)					
2.992129459	0.0384985293	10.087968874	73.20071744	102.732464	350.994787
1.11553E-04	3.95875E-05	2.40490E-04	1.15040E-03	1.05122E-01	1.02184E-01
H=16.380	rms=0.7803"	24 obs.	arc: 2010 01 20.12162 - 2010 07 10.43818		
(2011 HO28)					
3.155731195073	0.127861800869	26.8492666569	213.3649778774	338.8323288697	255.6030458679
1.57379E-07	1.66753E-07	2.22146E-05	3.42082E-05	9.38207E-05	9.03881E-05
H=15.456	rms=0.6470"	74 obs.	arc: 2005 03 19.63199 - 2014 12 11.44819		
(2011 QA50)					
5.275123719778	0.050008461597	5.0244780680	285.549715437	70.017654527	74.831962994
2.69039E-07	2.00325E-07	1.46187E-05	2.18289E-04	3.46449E-04	2.53911E-04
H=13.477	rms=0.5838"	86 obs.	arc: 2001 10 19.44811 - 2015 01 20.18838		
(2011 QE80)					
2.7260966923298	0.148402094041	9.7882412691	165.0878295722	209.062106805	230.1334689997
4.56822E-08	2.12019E-07	2.53360E-05	6.51641E-05	1.29008E-04	9.69800E-05
H=16.980	rms=0.6606"	47 obs.	arc: 2002 08 16.43587 - 2014 04 02.33934		
(2012 GA2)					
3.149952531	0.12673593	1.96578764	59.818967	158.233838	155.600932
7.85609E-04	3.45216E-03	8.98990E-03	1.50022E-01	5.12029E-01	4.38009E-01
H=16.414	rms=0.7658"	21 obs.	arc: 2012 04 01.27730 - 2012 04 20.94495		
(2013 QW47)					
3.16743465153	0.22596163817	8.9766824091	337.500121141	67.42220074	49.41104113
1.62523E-06	4.24641E-06	3.64308E-05	1.70564E-04	3.47531E-03	2.47929E-03
H=16.485	rms=0.7113"	28 obs.	arc: 2004 02 22.33208 - 2015 01 22.42913		
(2013 RH24)					
3.0467796	0.1115971	8.913271	337.204355	324.14190	130.70848
1.93928E-02	1.99371E-02	1.59162E-01	3.41562E-01	1.70558E+00	2.00926E+00
H=15.270	rms=0.7782"	15 obs.	arc: 2013 09 04.02023 - 2013 09 11.98830		
(2013 RO26)					
5.1666714	0.06835088	8.268781	205.690155	196.4971	1.6580
3.59617E-02	9.00785E-03	1.64561E-01	4.50743E-01	3.06404E+01	2.60937E+01
H=12.800	rms=0.8081"	14 obs.	arc: 2013 08 29.94263 - 2013 09 24.26137		
(2013 RU34)					
2.2031759499282	0.131142836931	3.8872863081	316.665903346	329.012156036	194.133183066
7.11326E-08	5.15974E-07	2.84324E-05	2.98673E-04	4.16764E-04	3.22821E-04
H=17.758	rms=0.6776"	34 obs.	arc: 1999 03 20.268660 - 2015 01 16.57109		
(2013 RV34)					
2.3828902223338	0.153359577248	6.26158717187	195.811019466	155.479501514	125.4970182443
4.69739E-08	2.08708E-07	2.13964E-05	1.03992E-04	1.66941E-04	9.41591E-05
H=17.673	rms=0.5463"	63 obs.	arc: 2002 10 04.22417 - 2013 10 28.30337		
(2013 RN35)					
2.656380188982	0.23348146720	16.043542778	345.634982928	5.67040159	106.25660039
2.16047E-07	6.33157E-06	2.41824E-04	1.84092E-04	9.20676E-03	5.48753E-03
H=17.486	rms=0.6116"	57 obs.	arc: 2000 09 08.34222 - 2013 10 31.12053		

Table 3. Continued.

a (au)	e	i (deg)	Ω (deg)	ω (deg)	M (deg)
		(376342)			
3.5438698376340	0.087479776570	4.7986305840	319.408278599	351.337841863	108.939794823
1.47650E-07	1.52092E-07	1.72809E-05	2.55411E-04	2.92921E-04	1.50825E-04
H=15.015	rms=0.5709"	88 obs.	arc: 1999 09 06.14603 - 2013 10 21.37584		
		(2013 RX43)			
2.580838289022	0.212607360113	9.0166134854	305.081665243	24.8141640627	126.6351530376
1.15557E-07	8.51128E-07	2.07325E-05	1.51101E-04	1.58518E-04	5.88308E-05
H=17.050	rms=0.9231"	50 obs.	arc: 2005 11 06.90331 - 2015 01 16.56477		
		(2013 RZ80)			
3.0430510815	0.2210006612	15.174394485	187.4003005683	103.704714217	129.51004073
4.84456E-05	1.20877E-05	9.68450E-05	9.19432E-05	2.07447E-03	3.81518E-03
H=16.626	rms=0.6434"	34 obs.	arc: 2012 03 31.40621 - 2013 10 22.18480		
		(2013 RR95)			
2.396720693125	0.119321545427	4.0601283849	314.550648025	350.929413584	161.783199910
2.83733E-07	3.23027E-07	2.04604E-05	2.41631E-04	2.86449E-04	1.93857E-04
H=17.222	rms=0.6005"	31 obs.	arc: 2009 09 18.17206 - 2015 01 16.55313		

The absolute magnitudes H given in Table 3 were calculated from the observed magnitudes R taking into account the computed orbit. All of the asteroids discovered have absolute magnitudes in the range $H = 9.7$–19.4 mag.

Using all astrometric and photometric observations of the asteroid (330836) Orius, we computed its absolute magnitude, $H = 9.725 \pm 0.343$ mag. The computations were done with the Fowler & Chillemi (1992) formula, using a typical geometric albedo p_v for Centaurs in the range 0.054–0.2 (Johnston 2014):

$$2R = 1329 \times 10^{-H/5} p_v \,[\mathrm{km}]. \tag{1}$$

The diameter of (330836) Orius was found to be between 29 and 79 km.

We have also found that the asteroid (428694) 2008 OS9 has the absolute magnitude $H = 19.400 \pm 0.399$ mag. For $p_v = 0.04$ (C-type asteroid) the diameter is 1052 m, and for $p_v = 0.20$ (S-type asteroid) it would be 326 m. The true diameter of this asteroid is probably between these two values.

It was impossible to compute the orbits for the asteroids 2008 OT18 (6) and 2009 HG68 (1) which have only several observations and a small arc of the orbit covered (in parentheses, the observed arc in days is given). Likewise, because of the short arc and small number of observations, the orbits of the following asteroids are of lower accuracy: 2008 CH184 (17), 2008 OZ11 (8), 2009 HW19 (9), 2009 HB45 (4), 2009 HB59 (6), 2013 RO26 (26) and 2013 RH24 (8). More observations of these asteroids are needed. The ephemerides of these asteroids for 2015 and 2016 will be given in Section 4.

3. NEW ORBITS OF THE NEO (428694) 2008 OS9 AND THE CENTAUR (330836) ORIUS (2009 HW77)

We recomputed orbits of the asteroid (428694) 2008 OS9 from the Apollo group and the Centaur-type asteroid (330836) Orius (2009 HW77). For this we applied new observations of both asteroids which became available after our previous studies (Černis et al. 2010; Wlodarczyk et al. 2011). Furthermore, we used a new

Table 4. Orbital elements and their 1σ errors (rms) for (428694) 2008 OS9, calculated with the OrbFit software. Epoch: JD 2455000.5 TDT = 2009-06-18, rms = 0.519″ both in our previous (top lines) and present (bottom lines) study.

Orbit elements	Values	σ
a [AU]	1.60126725	7.11E-06
	1.6012462762501	2.67802E-08
e	0.64800051	2.54E-06
	0.647993241286	1.44821E-07
i [deg]	19.1226311	7.37E-05
	19.1225706068	2.31101E-05
Longitude of ascending node [deg]	133.6023575	7.0E-06
	133.60232796883	3.74819E-06
Argument of perihelion [deg]	288.1570352	6.19E-05
	288.1569767117	2.07695E-05
Mean anomaly [deg]	123.1535334	7.640E-04
	123.15577481025	8.20793E-06

version of the OrbFit software 4.2 [3], which accepts the new error model based on Chesley et al. (2010). Also, in our model of the Solar system we took into account 25 perturbing asteroids with masses from Farnocchia et al. (2013).

3.1. The asteroid (428694) 2008 OS9

In our previous work on the asteroid (428694) 2008 OS9 (Černis et al. 2010) we computed its orbit using 178 optical observations (of which 12 were rejected as outliers) from 2008-07-25.36573 to 2008-08-12.71959. Now, the orbit of this asteroid is computed using 539 observations (of which 23 are rejected as outliers) obtained during the period from 2008-07-25.36573 to 2015 02 18.62309. Hence, the observational arc of (428694) 2008 OS9 is extended from 18 days to about 7 years!

Table 4 lists the Keplerian elements computed for this asteroid: semimajor axis a in AU, eccentricity e, inclination i, longitude of ascending node, argument of perihelion, and mean anomaly. Their 1σ uncertainties are given in the last column.

With the new orbit this asteroid remains in the Apollo group, i.e., it is a Near-Earth object which crosses the Earth's orbit ($a > 1.0$ AU; $q < 1.017$ AU)[4]. It is interesting to note that its absolute magnitude (i.e., the magnitude at 1 AU from the Sun and observer) has decreased from $H = 19.42$ in our previous work to about $H = 19.40$ now, i.e., the asteroid has a greater diameter, see Section 2. It is worth noting that, due to the sufficiently precise orbit, the asteroid 2008 OS9 is now numbered.

3.2. The asteroid 2009 HW77

In our previous publication on the asteroid 2009 HW77 (Wlodarczyk et al.

[3] http://adams.dm.unipi.it/∼orbmaint/orbfit/

[4] http://ssd.jpl.nasa.gov/sbdb.cgi?sstr=2008+OS9&orb=1

Table 5. Orbital elements and their 1σ errors (rms) for 2009 HW77, calculated with the OrbFit software. Epoch: JD 2455400.5 TDT = 2010-07-23, rms = 0.416″ both in our previous (top lines) and present (bottom lines) study.

Orbit elements	Values	σ
a [AU]	21.4342	0.0077
	21.439846274	8.71611E-04
e	0.4184	0.0002
	0.4185184184	2.16154E-05
i [deg]	17.8893	0.0003
	17.8893412421	4.01394E-05
Longitude of ascending node [deg]	50.4225	0.0003
	50.4225527477	6.06948E-05
Argument of perihelion [deg]	140.6464	0.0161
	140.647278432	3.15146E-04
Mean anomaly [deg]	12.6705	0.0120
	12.665144617	8.72432E-04

2011) we computed its orbit using 64 optical observations (one was rejected as an outlier) from 2008-03-10.42621 to 2010-05-20.25274. Adding four observations from 2002 taken from IAU 644 (Palomar Mountain/NEAT, California, USA), the observational arc was extended from about 2 years to 10 years. Now, the orbit of the asteroid 2009 HW77 is computed using 79 observations (one is rejected as an outlier) from 2002-02-12.50951 to 2012-05-19.44276.

The orbital elements and their 1σ errors calculated for the asteroid 2009 HW77 are given in Table 5. The orbit of the asteroid remains of the Centaur-type, i.e., it is located between Jupiter and Neptune (5.5 AU < a < 30.1 AU) [5]. Due to its sufficiently precise new orbit, the asteroid 2009 HW77 is now numbered.

Previously we had calculated the orbit of this asteroid (top lines in Table 5), as well as orbits of other asteroids, with the use of the OrbFit v.4.0 software[6], and, apart from planets, three massive asteroids, Ceres, Pallas and Vesta, were added as additional perturbers with the JPL NASA Ephemerides DE405. Now, as it was mentioned above, we used the OrbFit v.4.2 software, 25 perturbing asteroids and the error model (bottom lines in Tables 4 and 5). It is obvious that our present computations give orbital elements with higher precision, mainly because of the longer arc covered by observations.

4. EPHEMERIDES FOR THE ASTEROIDS WITH ORBITS OF LOW ACCURACY

For seven asteroids discovered at the Baldone Observatory, which have low-accuracy orbits, we have computed the ephemerides for 2015–2016 (for a geocentric observer). We used the OrbFit software version 4.2 and JPL DE405 planetary and lunar ephemerides with 25 additional perturbing asteroids according to

[5] http://ssd.jpl.nasa.gov/sbdb.cgi?sstr=2009+HW77&orb=1

[6] http://adams.dm.unipi.it/~orbmaint/orbfit/

Table 6. Ephemerides for 2015–2016 for the asteroids with orbits of low accuracy discovered at the Baldone Observatory (for a geocentric observer).

Date	RA	DEC	Mag	Solar elong.	Lunar elong.	Sky plane error Err1	Err2	*PA*
				2008 CH184				
2016-09-13	0 53 09.212	–06 41 38.53	21.3	157.8	–69.6	1.490°	0.052°	76.9
2016-09-23	0 46 56.600	–07 57 25.29	21.1	165.9	76.4	1.519°	0.056°	77.3
2016-10-03	0 39 55.953	–09 07 54.63	21.1	–166.9	–152.6	1.522°	0.060°	77.8
2016-10-13	0 32 53.718	–10 06 44.94	21.2	–159.5	–30.0	1.499°	0.062°	78.5
				2008 OZ11				
2016-04-16	14 31 19.937	–21 10 40.40	21.0	162.9	–84.2	4.161°	0.040°	103.9
2016-04-26	14 22 48.060	–20 26 07.97	20.8	172.8	39.0	4.242°	0.045°	104.7
2016-05-06	14 14 00.345	–19 32 35.50	20.8	–170.3	170.0	4.239°	0.053°	105.6
2016-05-16	14 05 55.490	–18 35 20.29	21.0	–159.6	–44.9	4.151°	0.063°	106.3
				2009 HW19				
2015-08-10	22 18 30.749	–01 03 42.91	20.3	158.9	107.6	3.880°	0.737°	75.0
2015-08-20	22 11 36.046	–02 04 27.82	20.1	168.6	–128.0	3.972°	0.720°	75.1
2015-08-30	22 04 18.489	–03 16 17.21	20.0	–171.0	9.5	3.981°	0.684°	75.4
2015-09-09	21 57 31.611	–04 32 38.38	20.2	–162.5	148.6	3.911°	0.633°	75.8
				2009 HB45				
2016-06-25	20 02 14.593	–29 59 36.14	21.5	155.4	33.5	13.665°	2.380°	86.9
2016-07-05	19 54 55.338	–30 39 57.66	21.4	164.9	165.5	13.949°	2.445°	88.0
2016-07-15	19 46 41.653	–31 14 30.37	21.3	170.1	–59.4	14.025°	2.485°	89.3
2016-07-25	19 38 19.940	–31 40 26.51	21.4	–165.0	75.3	13.890°	2.498°	90.6
				2009 HB59				
2015-11-08	4 34 46.925	+21 58 55.24	19.6	154.7	113.8	17.922°	0.101°	72.2
2015-11-18	4 25 38.203	+22 30 33.62	19.3	166.8	–119.1	18.697°	0.168°	71.3
2015-11-28	4 14 49.409	+22 57 20.03	19.0	178.2	27.3	18.986°	0.234°	70.1
2015-12-08	4 03 54.255	+23 18 57.59	19.3	–167.9	152.0	18.732°	0.293°	68.6
				2013 RH24				
2016-02-06	10 7 48.756	+14 19 22.17	20.1	167.3	133.2	5.626°	0.078°	118.0
2016-02-16	9 59 26.970	+14 44 46.32	19.9	177.7	–81.9	5.665°	0.072°	117.7
2016-02-26	9 50 57.330	+15 07 36.46	20.1	–168.0	47.5	5.610°	0.066°	117.5
2016-03-07	9 43 06.884	+15 24 44.17	20.3	–156.2	173.5	5.474°	0.058°	117.3
				2013 RO26				
2015-12-01	5 20 37.596	+14 56 14.87	19.5	165.4	51.7	2.494°	0.040°	96.9
2015-12-11	5 14 59.455	+14 42 5.72	19.4	171.7	173.3	2.486°	0.042°	96.9
2015-12-21	5 9 20.019	+14 31 14.91	19.5	–166.2	–48.0	2.453°	0.043°	96.9
2015-12-31	5 4 6.193	+14 24 17.48	19.6	–156.1	88.1	2.401°	0.043°	96.8

Farnocchia et al. (2013). The computations were performed for the value of the non-gravitational parameter $A_2 = 0$. The ephemerides of the asteroids for the dates at their brightest are listed in Table 6 which gives right ascensions (h, m, s) and declinations (deg, arcmin, arcsec), expected magnitudes, solar and lunar elongations (deg) and the sky plane errors in both axes (Err1 and Err2) in (deg) and the position angle (PA, deg). The magnitude errors are of the order of 0.5 mag. Table 6 shows that most of the asteroids can be recovered even with moderate size telescopes.

5. SUMMARY

In 2008–2013, at the Baldone Observatory a total of 43 asteroids were discovered. For 36 of these asteroids we present their orbital elements of much higher accuracy than those that came before, based on a much larger number of observations and the longer observational arc covered. The remaining seven asteroids have their orbits of low accuracy, thus they need additional astrometric observations. For these seven asteroids the ephemerides for 2015–2016 are given.

REFERENCES

Černis K., Eglitis I. 2008a, Discovery of Apollo-type asteroid 2008 OS9, MPEC, 2008-O66

Černis K., Eglitis I. 2008b, MPC 61686

Černis K., Eglitis I. 2009, Discovery of Centaur group asteroid 2009 HW77, MPEC, 2009-U68

Černis K., Eglitis I. 2013, MPC 84740

Černis K., Eglitis I., Wlodarczyk I., Zdanavičius J., Zdanavičius K. 2010, Baltic Astronomy, 19, 235

Černis K., Wlodarczyk I., Zdanavičius J. 2014, Baltic Astronomy, 23, 231

Chesley S. R., Baer J., Monet D. G. 2010, Icarus, 210, 158

Farnocchia D., Chesley S. R., Chodas P. W. et al. 2013, Icarus, 224, 192

Fowler J. W., Chillemi J. R. 1992. IRAS Asteroid Data Processing. Chapter 4, p. 17–43 of the IRAS Minor Planet Survey, ed. F. F. Tedesco, https://irsa.ipac.caltech.edu/IRASdocs/surveys/PL-TR-92-2049.pdf

Johnston W. R. 2014, TNO and Centaur diameters, albedos, and densities, V2.0. EAR-A-COMPIL-5-TNOCENALB-V2.0. NASA Planetary Data System

Raab H. 2003, Astrometrica, http://www.astrometrica.at/ (electronic version)

Spahr T. B. 2010, MPEC, 2010-U20

Wlodarczyk I. 2009, Icarus, 203, 119

Wlodarczyk I., Černis K., Boyle R. P., Laugalys V. 2014, MNRAS, 438, 2621

Wlodarczyk I., Černis K., Eglitis I. 2011, MNRAS, 418, 2330