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Introduction

The issue continues our the new series of publications devoted to periodically summarizing the worldwide scientific activities in observations of space debris objects on high geocentric orbits (GEO, HEO and high near-circular non-GEO). Objects considered to be included into this publication are fragments (operational by nature, created in fragmentation events or as a result of larger objects' surface and construction deterioration due to environment conditions) having brightness fainter than 15th visual magnitude during most part of their observation time. This limit corresponds to approximately 1 m size object on geostationary orbit. It is possible that sometimes these objects can be brighter than 15th magnitude due to combination of their specific properties (surface reflectivity and attitude) and favorable observation conditions (good phase angle, high elevation etc.).

The goal of this publication is to give the world scientific community imagination about the status of high geocentric orbit space debris researches and to provide up to date data for each discovered object including orbital parameters, estimated standard magnitude and estimated area-to-mass ratio value. Those data can be included in existing space debris models as well as can be used for study of long-term orbital evolution and possible origin of the objects. The Circular will also serve as some reference document for scientists and amateurs involved in those objects observations and data analysis. Operators of spacecraft in high geocentric orbits (mainly in GEO) can use this publication in order to obtain a more realistic description of the situation around their orbital assets.

Observation planning, ephemeris support, processing and analysis of obtained data are made by researchers from Keldysh Institute of Applied Mathematics (KIAM) (Vladimir Agapov, Igor Molotov, Viktor Stepanyants, Vladimir Titenko) with invaluable help of Zakhariy Khutorovskiy (Vympel Corporation) and Vasiliy Yurasov (Institute for Precision Instrument Engineering, IPIE).

The presented results include discoveries stemming from surveys of the European Space Agency (ESA) utilizing the ESA Space Debris Telescope in Tenerife. Those surveys and all follow-up observations from the ZIMLAT telescope of the Astronomical Institute of the University of Bern in Switzerland (AIUB) are planned, run, processed, and analyzed by the AIUB.

All questions regarding cooperation in the joint research program for high geocentric orbit space debris studies should be sent to Prof. E. L. Akim, KIAM Deputy Director. All questions regarding observation schedule, required formats, ephemeris support, observations and orbital data processing, analysis and usage should be sent to Dr. V. M. Agapov. All questions regarding requirements for observation instruments, CCD frame processing software, possible

help in the instrumentation upgrade in order to make possible participation in the research program should be sent to Dr. I. Ye. Molotov.

List of sensors

This list includes all sensors participating today in a joint program of observation and analysis of space debris objects on high geocentric orbits. Each sensor has its own identification number assigned in the KIAM space objects database. Most of the sensors are involved in minor planet observations as well, thus having the MPC-assigned identification code. But for the purpose of this research program it was decided to maintain a separate ID system permitting to describe all participating sensors regardless of their involvement in other research programs. Coordinates of sensors are given for reference purposes only and should not be used in real observation processing. In the column "Instrument", the common name, aperture (d, mm) and focal length (f, mm) of each instrument are given.

The list will be updated each time a new sensor will send observations for objects studied.

Table 1. List of participating sensors

Ref. ID	Longitude, °	Latitude, °	Height, km	Observatory/ Facility	Instrument
10003	100.919 E	51.622 N	1.998	Mondy	AZT-14 d480
10007	41.757 E	42.814 N	1.610	Abastumani	DAZ-40 d400/f3000
10009	66.883 E	39.133 N	0.662	Kitab	DAZ-40 d400/f3000
10010	41.432 E	43.657 N	2.070	Arhyz	Zeiss-600 d600/f7500
10012	42.499 E	43.276 N	3.127	Terskol	Zeiss-2000 d2000/f16000
10016	30.273 E	46.397 N	0.010	Mayaki	RC-600 d600/f4800
10018	33.163 E	45.219 N	0.010	Yevpatoriya	AZT-8 d700/f2800
10019	33.991 E	44.412 N	0.379	CrAO/Simeiz	Zeiss-1000 d1000
10024	30.327 E	59.772 N	0.100	Pulkovo	RS-220 d220/f507
10031	34.016 E	44.726 N	0.585	CrAO/Nauchny	AT-64 d640/f900
10041	66.896 E	38.673 N	2.593	Maidanak	Zeiss-600 d600/f7500
10042	41.443 E	43.649 N	2.059	SAO/Arhyz	Zeiss-1000 d1000
10065	132.166 E	43.699 N	0.200	Ussuriysk	DA-40 d400/f1600
10071	64.624 W	21.596 S	1.865	Tarija	Zeiss-600 d600/f7500
10102	100.920 E	51.622 N	2.000	Mondy	Zeiss-600 d600/f7500
10103	100.919 E	51.617 N	2.025	Mondy	AZT-33IK d1500/f30000
10191	7.465 E	46.877 N	0.951	Zimmerwald	ZIMLAT-1000 d1000/f4000
10198	16.512 W	28.301 N	2.445	Teide/OGS	Zeiss-1000 d1000/f4470
10531	34.016 E	44.728 N	0.595	CrAO/Nauchny	ZTSh d2600/f10000
10532	34.017 E	44.730 N	0.595	GAISh/Nauchny	Zeiss-600 d600/f4680
10533	34.016 E	44.726 N	0.585	CrAO/Nauchny	PH-1 d220/f507

New objects

This section contains information on the objects newly discovered during the period Apr 1 – Apr 30, 2007.

There are two lists. The first one contains information on objects which have been successfully recovered in follow-up observations after initial detection and one-night tracking and for which orbital data and area-to-mass ratio (AMR) value have been determined with high level of confidence. The second one contains information on objects having only one-night track of observations. A complete set of orbital data cannot be determined for these objects. Only

some orbital parameters (mainly inclination and RAAN) are determined relatively accurately. The AMR values cannot be determined for these objects at all.

It should be noted that all one-night tracks have been tested to identify them with all other one-night tracks and with all known objects in the KIAM database having well determined orbits (both bright and faint). It is possible that the identification failed not only due to the absence of other tracks of the same object, but also due to uncertainty caused by an unknown AMR value which can result in very significant orbital evolution that prevents proper correlation of one-night tracks.

Each object listed in this section has two identifiers. The first one (ID1) is assigned in the KIAM space objects database and the second one (column ID2 in the table below) is assigned by the observer who discovered the object. Since no commonly agreed space debris identification system exists yet all identifiers provided can be regarded as temporary ones. As soon as such a system will be agreed upon, all objects will be assigned with the new identifiers.

Orbital elements are referring to True Equator Mean Equinox (TEME) coordinate system. Area-to-mass ratios are calculated assuming reflectivity coefficient equal to 1.3. Orbital elements for short tracks (Table 3) are obtained in two steps. In the first step an attempt is made to determine an orbit with zero eccentricity. In case of large residuals (more than the expected 3-sigma) the second step is applied. At this step the eccentricity is also estimated.

There are 9 new objects discovered and subsequently confirmed in April. Also 9 more new objects are discovered but observed only on short tracks on one night only.

Table 2. List of newly discovered and confirmed objects

ID1	ID2	Date/time, UTC	*a*, km	*e*	*i*, °	Ω, °	*ω*, °	*u*, °	AMR, m^2/kg
43129	E07103A	15.04.2007 02:38:54.36	40502.99	0.6690757	5.951	259.103	120.228	287.753	-
43130	E07104A	27.04.2007 20:38:13.74	36455.94	0.5690347	21.185	030.745	041.934	185.947	29.2
43131	E07105A	29.04.2007 01:49:53.58	32824.04	0.3131211	7.897	071.308	286.507	185.399	0.42
90054	90054	26.04.2007 21:29:43.36	42578.93	0.0438312	6.131	074.010	086.164	066.057	3.07
90055	90055	27.04.2007 20:27:19.66	42097.74	0.0264668	14.921	356.679	283.062	196.459	0.93
90056	90056	27.04.2007 20:30:18.92	42069.95	0.0068728	14.447	357.784	127.046	199.789	0.086
90057	90057	27.04.2007 20:06:27.78	41981.09	0.0042680	14.192	351.048	269.524	201.741	0.02
90058	90058	27.04.2007 19:45:56.37	24598.31	0.7108708	4.325	022.776	013.607	187.257	0.73
90059	90059	26.04.2007 19:17:20.43	18345.28	0.6219753	13.033	353.944	006.773	194.849	-

Of the nine objects discovered in April two are the very interesting ones namely 43130 and 90054.

The first one have very large AMR value – of order of 30 sq.m/kg, but relatively good predictable motion indicating very small variations of the AMR value. At the moment of this issue compilation the object was still tracking without problems and without involving special search strategies. It's eccentricity is increasing at present and if it will not be lost during the next two months then we will have continuous real orbital data for such kind of objects precise enough to involve radars for studying of it's properties.

The second object, 90054, is the unique one due to combination of the high AMR value (near 3.2-3.3 sq.m/kg in average) and the enormous (for objects of this class) brightness observed during routine tracking of it. On some intervals up to 20 minutes long the brightness was increasing up to magnitude in 9^m-10^m range making it comparable to the one associated with the largest satellites orbiting GEO. It was continuous brightness increasing not short time flashing of flaring which is common for many GEO objects especially during the eclipses season. One can assume that the object is some kind of a 'prefect' mirror-reflector having slow attitude motion and producing 'continuous flares' from time to time. Thanks to such strange the brightness pattern it was possible to observe the object even with small instruments having aperture 22 cm or even less. It is interesting also that at the time of the discovery the orbital plane of the 90054 perfectly matches the orbital plane of the retired GEO satellite 20570/1990-034A PALAPA B2R (within 0.01 deg both in inclination and RAAN) though analysis doesn't reveals any close encounters between these two objects at least in 2007.

Table 3. List of newly discovered objects having only a single one-night track of observations

ID1	ID2	Date/time, UTC	Track duration, hh:mm	*T*, min	*a*, km	*e*	*i*, °	Ω, °	*ω*, °
46167	g070410	10.04.2007	00:17	1432.49	42094.0	0.1700	9.018	297.97	037.48
46168	g070411a	11.04.2007	00:11	1508.32	43566.9	0.0287	10.253	049.32	058.32
46169	g070417	17.04.2007	00:58	1436.06	42164.0	0.0012	14.068	007.23	319.31
46170	g070420	20.04.2007	00:10	344.41	16278.6	0.5934	26.714	015.61	005.97
46171	G070423b	23.04.2007	00:29	1350.75	40477.1	0.0515	15.021	357.99	016.24
46172	g070423e	23.04.2007	00:22	1385.21	41162.6	0.0125	13.954	349.94	040.32
46405	m070417	17.04.2007	00:11	1436.05	42163.8	0.0531	8.294	316.23	317.31
46406	m070424	24.04.2004	00:04	1107.90	35467.3	0	14.521	342.18	103.76
46407	m070425	25.04.2007	00:09	645.53	24742.2	0.4709	13.784	002.32	047.27

New identifications

This section contains information on successful identification of newly and previously obtained single one-night tracks with each other as well as with objects having well determined orbits.

Table 4. New identifications

ID_new	ID_old	Observation date	Observer
No new identifications in Apr 2007			

Updated orbits

This section contains information on the latest orbital updates for objects discovered prior to Apr 1, 2007 and observed at least once in Apr 2007 or for which the latest orbital update was not published in the previous issues. 42 of previously discovered objects in total are observed in Apr 2007.

Table 5. Updated orbital parameters for objects observed in Apr 2007

ID1	ID2	Date/time, UTC	*a*, km	*e*	*i*, °	Ω, °	*ω*, °	*u*, °	AMR, m^2/kg
43019	EGEO19	22.04.2007 02:36:38.16	42399.00	0.0021265	10.812	338.042	150.152	213.320	1.38

ID1	ID2	Date/time, UTC	*a*, km	*e*	*i*, °	Ω, °	*ω*, °	*u*, °	AMR, m^2/kg
43031	EGEO31	28.04.2007 02:49:23.27	40192.07	0.1047844	11.954	336.686	332.896	275.591	1.15
43032	EGEO32	21.04.2007 01:27:59.15	39460.94	0.0842793	10.729	338.645	330.079	207.042	1.04
43033	EGEO33	21.04.2007 20:24:24.63	33194.90	0.3199064	8.270	068.420	262.498	135.386	3.24
43045	EGEO45	28.04.2007 01:36:19.87	42147.33	0.1347013	9.522	330.054	071.207	280.592	1.15
43046	EGEO46	26.04.2007 19:57:44.50	42328.96	0.0334852	9.830	331.123	238.763	263.332	0.82
43081	E06204D	23.04.2007 20:26:11.81	46764.25	0.4486854	10.031	125.608	317.540	129.540	8.32
43082	E06205C	14.04.2007 18:45:00.68	41420.40	0.0128547	13.805	344.440	182.321	174.898	2.18
43091	E06293A	22.04.2007 23:48:48.67	40273.87	0.2386659	5.165	121.766	242.524	131.984	10.9
43093	E06326A	17.04.2007 21:45:12.25	43590.00	0.0418347	9.099	333.041	358.580	186.143	2.93
43096	E06321D	25.04.2007 18:19:08.50	41425.10	0.0145764	8.770	320.847	251.372	237.359	1.72
43100	E06327E	17.04.2007 21:47:08.46	39992.83	0.0580200	12.478	344.071	253.286	209.768	0.37
43103	E06349B	26.04.2007 17:48:11.50	41889.72	0.0060938	13.925	005.737	094.840	202.694	0.071
43107	E07015D	11.04.2007 00:08:49.95	41434.05	0.0690199	10.242	337.145	358.780	266.115	3.66
43112	E07021A	12.04.2007 20:32:56.96	42229.47	0.0424555	10.700	337.211	288.099	96.913	1.50
43118	E07043C	24.04.2007 20:50:58.94	39193.58	0.1851775	8.528	306.740	065.438	254.002	2.05
43119	E07045A	22.04.2007 05:06:53.57	21209.55	0.6622726	4.031	057.063	316.299	162.191	0.99
43121	E07045D	26.04.2007 18:32:15.50	42037.13	0.0142839	13.224	005.635	000.151	223.035	1.29
43124	E07047A	19.04.2007 21:02:07.12	39993.61	0.1615296	12.851	340.776	348.993	218.218	3.38
43125	E07048A	24.04.2007 02:44:42.40	44505.30	0.0719167	18.706	031.172	337.378	182.234	0.087
43128	E07074D	21.04.2007 21:44:03.21	25998.97	0.6161584	7.286	342.311	028.327	220.822	0.64
90005	90005	26.04.2007 22:43:20.56	42012.01	0.0617635	14.466	356.606	098.743	232.616	1.46
90006	90006	25.04.2007 17:58:10.55	42197.44	0.0012376	14.429	351.826	022.290	207.481	0.011
90008	90008	23.04.2007 18:54:11.34	42151.93	0.0041638	14.349	357.670	103.711	227.289	0.0062
90009	90009	29.04.2007 01:25:15.33	42275.36	0.0029178	14.680	358.703	357.710	250.284	0.014

ID1	ID2	Date/time, UTC	*a*, km	*e*	*i*, °	Ω, °	*ω*, °	*u*, °	AMR, m^2/kg
90014	90014	13.04.2007 22:05:32.88	42615.92	0.0101606	14.960	353.417	107.990	135.363	0.15
90019	90019	23.04.2007 23:56:11.63	42221.06	0.0074327	14.819	359.151	041.113	199.565	0.15
90022	90022	25.04.2007 16:40:15.50	42165.78	0.0031803	14.557	358.319	189.701	204.738	0.23
90023	90023	29.04.2007 02:19:05.01	40109.43	0.0524214	12.352	354.815	064.667	258.023	1.79
90030	90030	10.04.2007 18:53:25.24	42258.30	0.0047309	5.836	073.289	036.563	147.125	0.11
90031	90031	26.04.2007 20:58:11.65	42148.89	0.0020665	13.843	007.139	209.069	225.061	0.0021
90032	90032	28.04.2007 21:45:05.36	42148.92	0.0189588	14.283	358.508	237.652	249.054	0.0011
90035	90035	24.04.2007 18:28:39.11	41840.79	0.0794392	9.152	329.057	042.684	284.453	2.87
90042	90042	28.04.2007 01:13:02.95	38707.72	0.0166177	11.350	335.042	138.846	264.585	3.05
90043	90043	27.04.2007 23:41:25.82	41680.59	0.0046758	10.345	333.073	325.223	233.663	0.12
90047	90047	16.04.2007 22:57:56.63	43043.73	0.0948620	13.818	009.100	349.662	132.169	0.90
90048	90048	22.04.2007 14:27:48.72	41589.93	0.0428700	13.880	346.259	289.979	172.642	1.21
90049	90049	18.04.2007 21:12:40.73	38796.88	0.0438856	17.699	348.281	192.018	204.415	1.51
90050	90050	06.04.2007 20:19:50.97	42229.63	0.0587647	11.172	343.434	026.198	104.904	4.32
90051	90051	26.04.2007 21:18:32.49	42721.94	0.0220896	14.726	009.600	275.463	231.538	0.15
90052	90052	26.04.2007 00:36:23.68	41052.50	0.0081333	9.405	324.248	181.178	272.562	0.046
90053	90053	09.04.2007 23:03:25.70	41158.70	0.2070079	7.556	317.154	134.888	283.425	1.48

Master list of objects

The master list of objects includes all high altitude orbit faint objects discovered up today, with a description of the circumstances of the discovery and the last update of orbital information. Due to the large volume of the master list it will be distributed separately in electronic form only.

Observation statistics

This section contains general statistics on obtained measurements.

9 facilities have observed high altitude space debris objects in Apr 2007. The weather in April was slightly better than in March in all facilities though very unstable. Overall number of observation nights increased. Number of the observation facilities worked during the same calendar night was following:

6 facilities – 1 night
5 facilities – 3 nights
4 facilities – 3 nights
3 facilities – 8 nights
2 facilities – 7 nights
1 facility – 3 nights

Table 6. Distribution of measurements obtained by each facility by year of observation (as of May 1, 2007 12:00 UTC)

Facility	2004	2005	2006	2007	TOTAL
Abastumani	0	0	0	130	130
Arhyz	0	0	115	11	126
Ketab	0	0	0	104	104
Maidanak	0	150	2166	1239	3555
Mayaki	0	0	981	1088	2069
Mondy	0	229	65	1008	1302
Nauchny	1240	6478	12925	6242	26885
Pulkovo	0	0	0	137	137
SAO	0	258	524	307	1089
Simeiz	0	0	213	0	213
Tarija	0	0	21	0	21
Teide	0	624	2284	1885	4793
Terskol	0	0	475	0	475
Yevpatoriya	0	0	272	0	272
Zimmerwald	0	597	3389	2754	6740
TOTAL	**1240**	**8336**	**23430**	**14905**	**47911**

Table 7. Observation statistics for Apr 2007

Facility	Number of nights	Total number of observed objects	Number of new discovered objects (including later confirmed)	Number of obtained single measurements	Number of tracks
Abastumani	4	2	-	130	5
Arhyz	-	-	-	-	-
Ketab	3	2	-	104	4
Maidanak	6	12	3 (0)	251	20
Mayaki	6	9	-	736	12
Mondy	8	12	-	381	25
Nauchny	16	41	12 (6)	1889	108
Pulkovo	2	1	-	137	2
SAO	-	-	-	-	-
Simeiz	-	-	-	-	-
Tarija	-	-	-	-	-
Teide	9	20	3 (3)	332	33
Terskol	-	-	-	-	-
Ussuriysk	-	-	-	-	-
Yevpatoriya	-	-	-	-	-
Zimmerwald	22	29	-	1190	191
TOTAL	**25**	**60**	**18 (9)**	**5150**	**400**

Errata

In the previous issue the second column of the table was named ‘Number of observed earlier discovered objects’ but the figures showed for the different facilities were different in meaning due to different counting approaches that resulted in some misunderstanding in the overall number of the observed objects. Number of the new discovered objects was excluded from the count showed in the ‘Number of observed earlier discovered objects’ column for those facilities which discovered the objects though these the new discovered objects were in fact counted for the facilities observed them in the follow-up sessions. Thus the real total number of objects observed by the each facility was not clear.

To avoid the problem of the observation statistics interpretation the column is renamed to ‘Total number of observed objects’ and all counts are appropriately corrected by means of counting of all observed objects. So, the column ‘Number of new discovered objects (including later confirmed)’ now reflects only discovery statistics and should not be used for obtaining of the total count of observed objects.

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