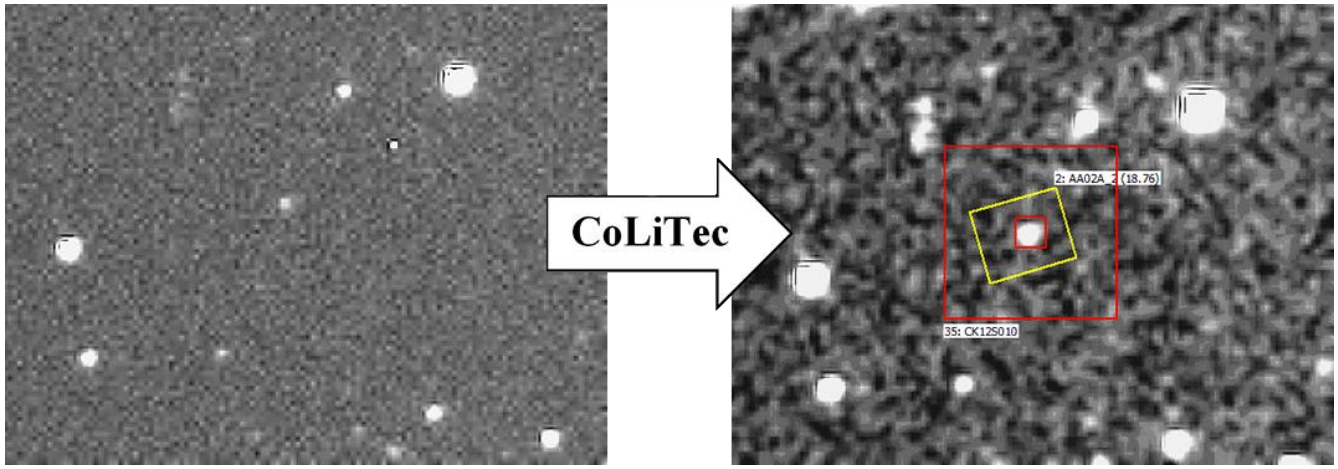
Precision of astrometry measurements made using CoLiTec software for asteroids survey.

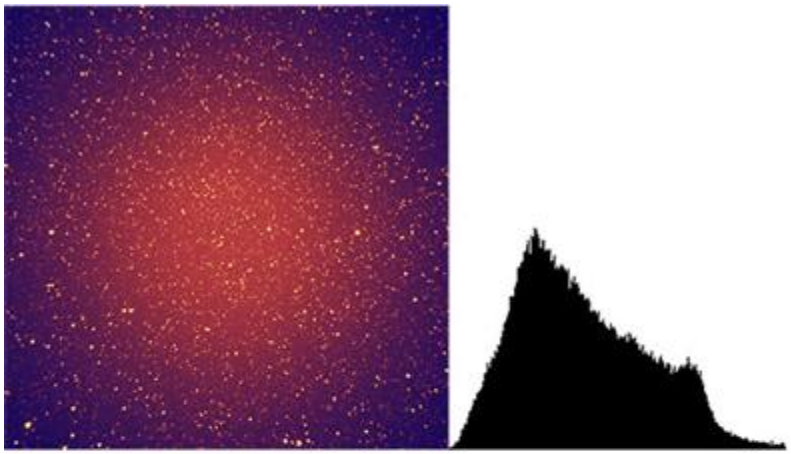
Gaia-FUN-SSO-3 International Workshop, 2014, Paris, France



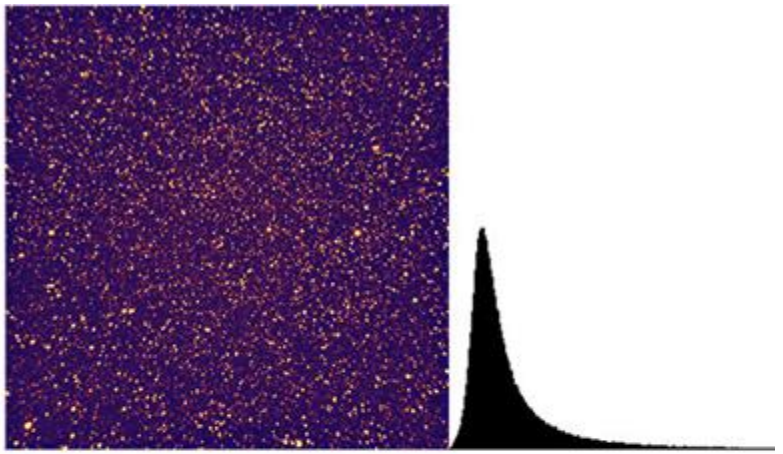
Comet ISON (C/2012 S1) was discovered on 21 September 2012 during Gaia-FUN-SSO-2 International Workshop, 2012

S. Khlamov,
A. Ivantsov, V. Savanevych, A. Bryukhovetskiy,
L. Elenin, M. Bezkrovniy, N. Sokovikova, Ia. Movsesian.

Frames filtration

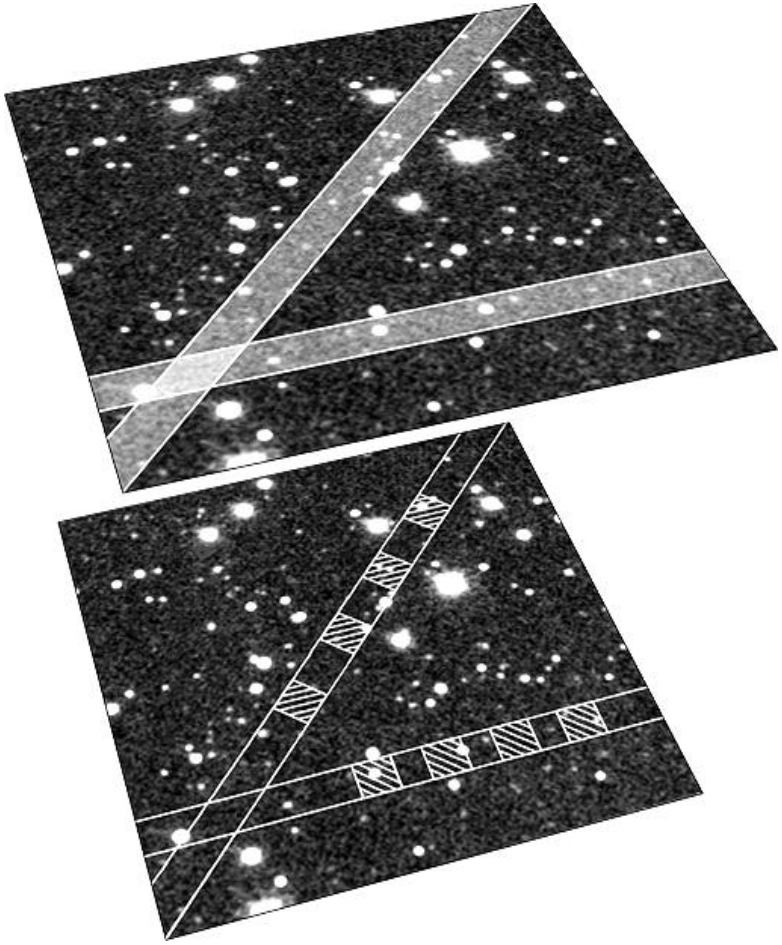


frames and histogram before filtration

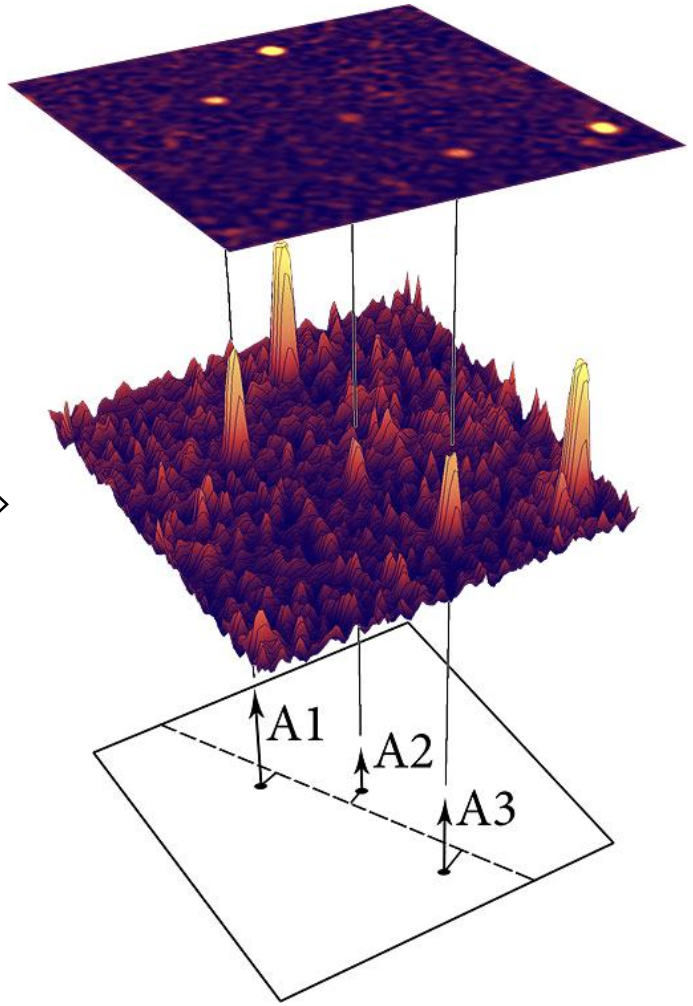


frames and histogram after filtration

Algorithm for moving object detection



CoLiTec



CoLiTec features

1. Automatic detection of faint moving objects (SNR>2.5)
2. Working with very wide field of view (up to 10 degrees^2)
3. Auto calibration and cosmetic correction
4. Fully automatic robust algorithm of astrometric reduction
5. Automatic rejection of objects with worst observations
6. Results viewer (LookSky) with graphical user interface
7. Multi-threaded support for multi-cores systems and local network
8. Processing pipeline managed by OLDAS (OnLine Data Analysis System)

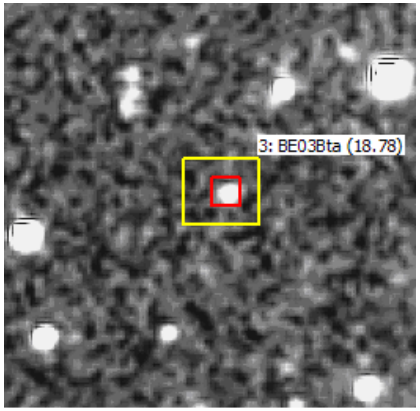
Detailed information about CoLiTec software – http://neoastrosoft.com/functions_en/

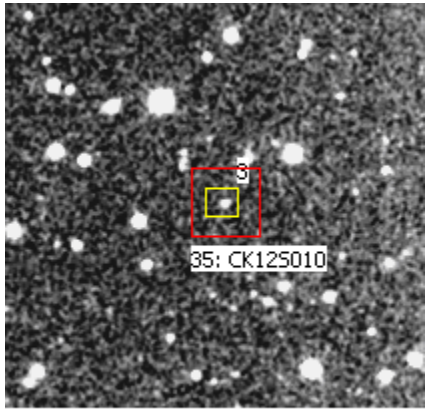
OLDAS - OnLine Data Analysis System

1. Management of FITS files processing
2. Processing images in the real time
3. Obtaining results in 30 minutes after end of astronomical twilight
4. Working with online catalogues via VizieR
    - 4.1. Identification known static object on images (USNO B1.0, UCAC4.0, SDSS v8)
    - 4.2. Supernova search – labelling unknown static objects near galaxies (HYPERLEDA)
5. Sending measurements to MPC
6. Inspection detected objects via web-interface

Detailed information about CoLiTec software – http://neoastrosoft.com/functions_en/

CoLiTec can detect very slow and very fast moving object



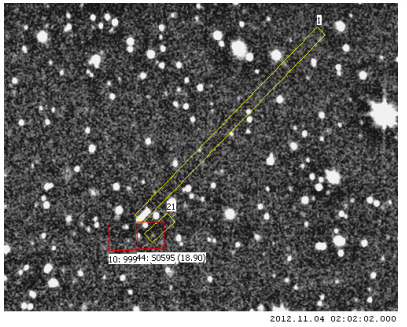


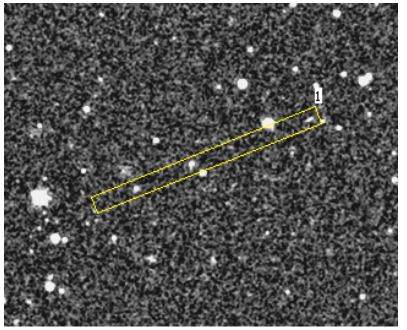
You can see the real images, where ColiTec discovered famous comet ISON. On these frames, comet practically not moving between frames. The size of comet about 5 pixels, but it moved only on 3 pixels from first to fourth frame.

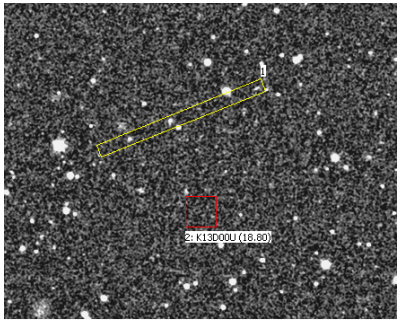
CoLiTec

CoLiTec

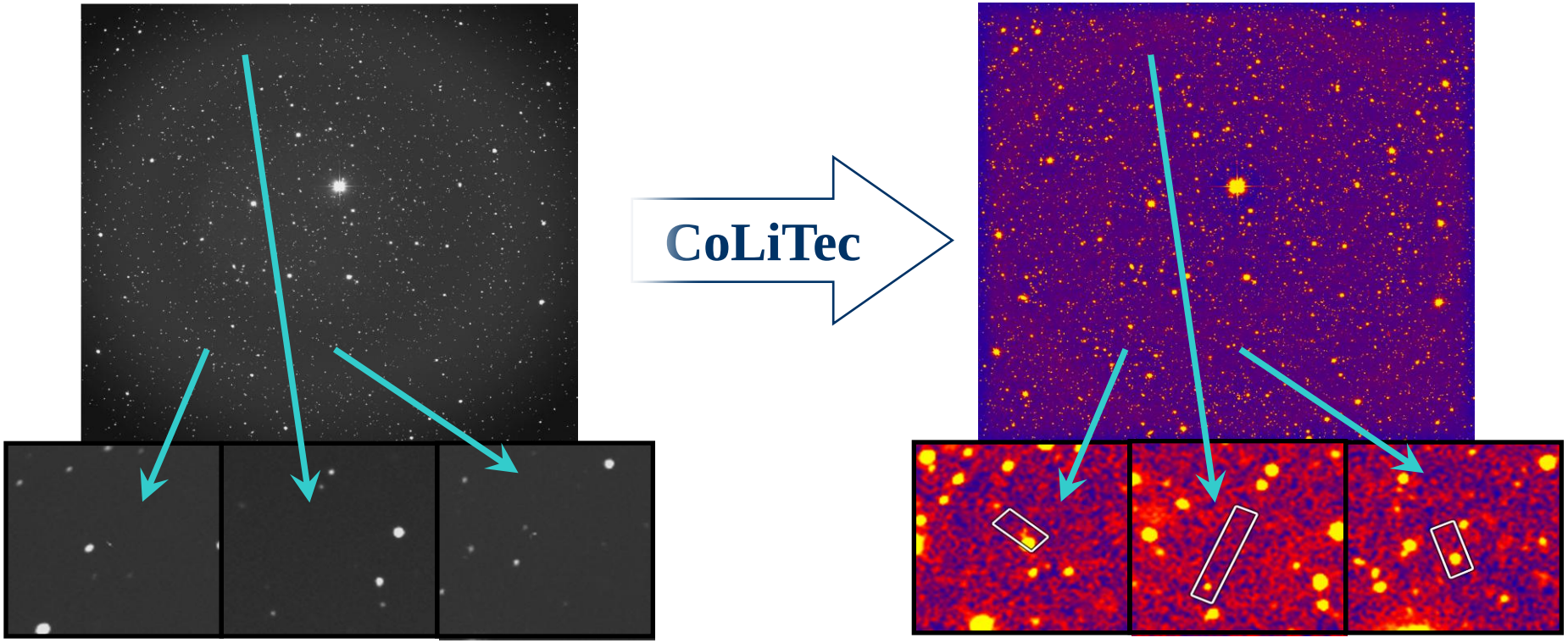
CoLiTec can detect faint fast moving objects (FMO) by their tracks.



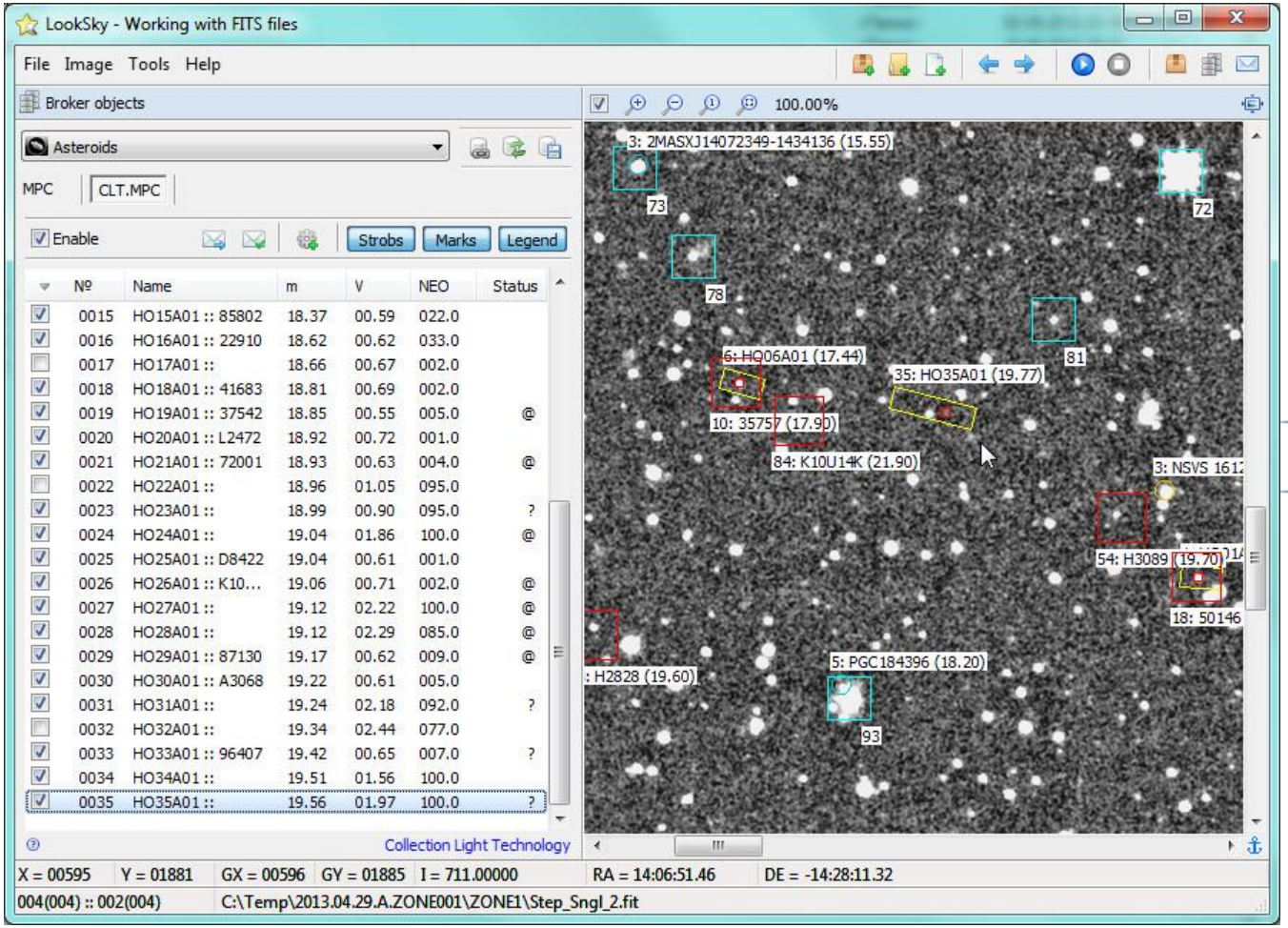




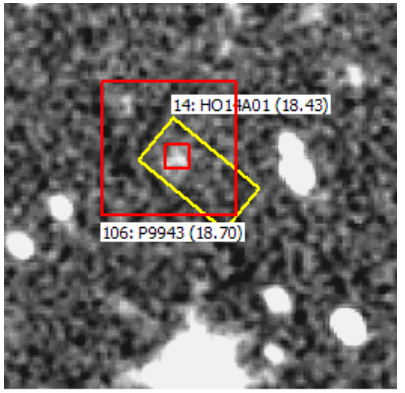
What can CoLiTec do?



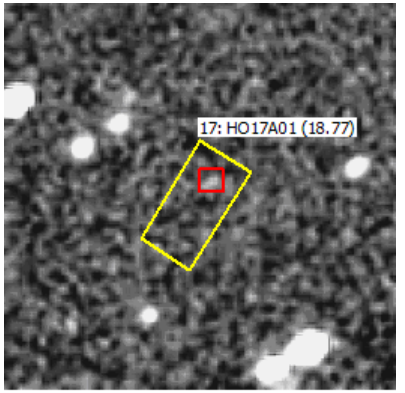
LookSky - Visual inspection of the processed results



Object #14 is identified with asteroid P9943 (MPCORB)



Blink

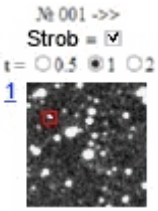


Object #17 is not identified with known asteroids

WEB-service for the online checking of processing results

You just need smartphone, tablet or laptop with internet connection

You can see results of the work from any location



Accept

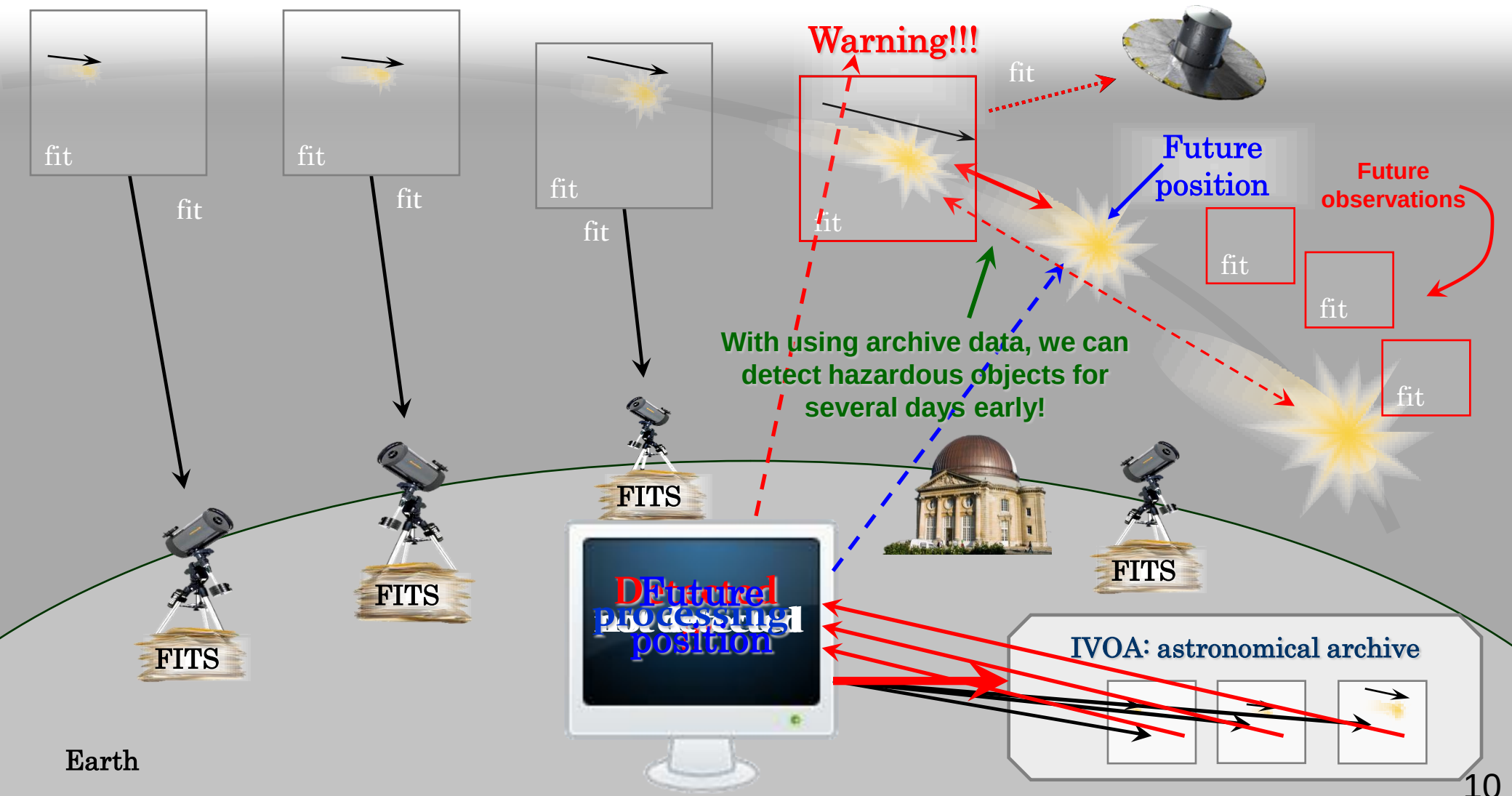
Rejection !

F	Date Time	X	Y	RA	DE	m
1	2013-05-01 05:24:16.00	50.1	50.0	225.38315	-7.95845	16.13
2	2013-05-01 05:39:33.00	50.3	55.0	225.38048	-7.95830	16.16
3	2013-05-01 05:54:37.00	50.8	60.1	225.37772	-7.95805	16.28
4	2013-05-01 06:09:47.00	51.3	65.0	225.37503	-7.95779	16.29

MPC name = 36311
Own name = IA01A09
KELE = 0
m = 16.21
NeoRat = 31
Pos_Angle = 265.30
V = 0.65
Dxy = 0.01
PirsX = 0.99
PirsY = 1.00

Log in to CoLiTec web-interface and you can check detected objects and send measurements to MPC or directly on NEOCP

Improving orbits of NEA and PHA by archive data



Efficient working with archive data

Main goal of our future system is a simple and fast way to automatic searching for undetected moving objects on archive images. On the first stage we will use our FITS archive, but in the future we can add another public databases (for example NEAT).

Main function:

- working with MPC ONS catalog, linking recently detected objects;

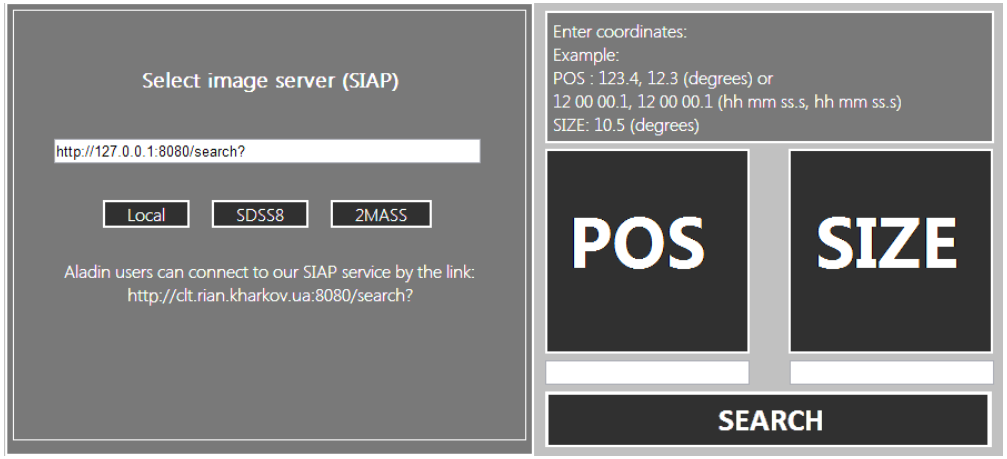
- automatic searching for known objects with poor orbit on archive images;

- automatic measurements newly detected object and sending it to MPC;

- sequential checking of all obtained archive measurements with the known orbit of the target object.

Software for storage and access to all obtained images

- Management of archive, including searching for data by parameters (coordinates)
  - External access via our web-interface and Aladin software (Generic SIA query)
    - Retrieve additional data via VizieR (SDSS v8 and 2MASS)
      - Software used SIA protocol and VOTable format



Access to web-interface – http://91.212.253.48:8080/siap

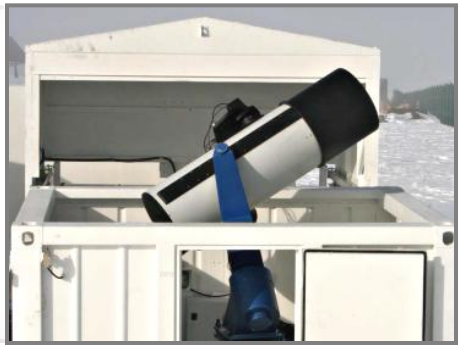
CoLiTec customers

ISON-NM Observatory (H15)

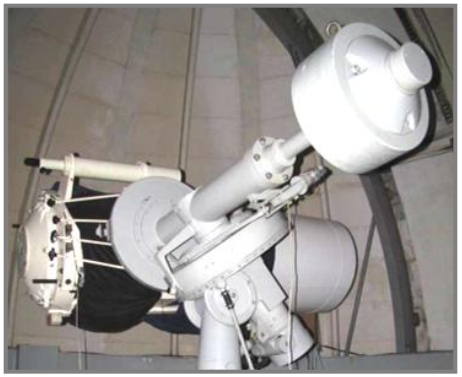
Astroworks Centurion-18 – 0.45-m f/2.8 astrograph, equipped with CCD FLI ML09000-65. FOV 100’x100’ (frame size: 3056×3056 pixels)

ISON-Kislovodsk Observatory (D00)

Santel-400AN – 0.4-m f/3 astrograph, equipped with CCD FLI ML09000-65. FOV 105’x105’

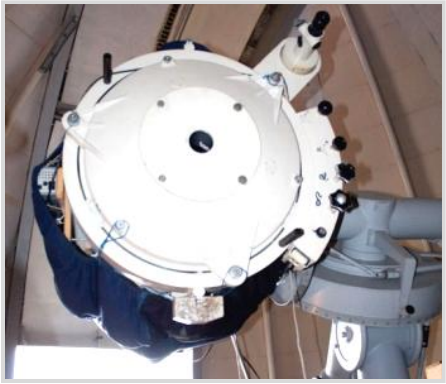


CoLiTec customers



Andrushivka Astronomical Observatory (A50)

Telescope Zeiss-600 with aperture 0.6-m, equipped with lens corrector and FLI PL09000. FOV 60’x60’ (frame size: 1528×1528 pixels).



ISON-Ussuriysk Observatory (C15)

Santel-650 – 0.65-m f/2 astrograph, equipped with CCD FLI PL4301E. FOV 130’x130’

Top-10 most prolific observatories in 2011-2014 (Minor Planet Center statistics)

Top-10 observatories from measurements

№	Observatory (MPC-code)	Measurements	Discoveries
1	Pan-STARRS 1, Haleakala	9086210	73437
2	Mt. Lemmon Survey	7766504	61422
3	Catalina Sky Survey	6153790	7482
4	Lincoln Laboratory ETS, New Mexico	3718985	723
5	Steward Observatory, Kitt Peak-Spacewatch	3107056	25490
6	Purple Mountain Observatory, XuYi Station	1052255	711
7	Siding Spring Survey	715052	961
8	Palomar Mountain--PTF	652105	4345
9	ISON-NM Observatory, Mayhill	446219	1362
10	Oukaimeden Observatory, Marrakech	398421	1977

Top-10 observatories from discoveries

№	Observatory (MPC-code)	Measurements	Discoveries
1	Pan-STARRS 1, Haleakala	9086210	73437
2	Mt. Lemmon Survey	7766504	61422
3	Steward Observatory, Kitt Peak-Spacewatch	3107056	25490
4	Catalina Sky Survey	6153790	7482
5	Cerro Tololo-DECam	218433	7105
6	Palomar Mountain--PTF	652105	4345
7	Oukaimeden Observatory, Marrakech	398421	1977
8	ESA Optical Ground Station, Tenerife	183490	1599
9	Tenagra II Observatory, Nogales	368295	1480
10	Palomar Mountain/NEAT	90015	1389
11	ISON-NM Observatory, Mayhill	446219	1362

Access to MPC Statistics – http://neoastrosoft.com/mpc_statistic_en/

Top-10 most prolific observatories in 2011-2012 (Minor Planet Center statistics)

Top-10 observatories from measurements

№	Observatory (MPC-code)	Measurements	Discoveries
1	Mt. Lemmon Survey	4186400	39446
2	Lincoln Laboratory ETS, New Mexico	3637872	719
3	Pan-STARRS 1, Haleakala	3506255	27413
4	Catalina Sky Survey	3235680	5273
5	Steward Observatory, Kitt Peak-Spacewatch	1708543	15956
6	Siding Spring Survey	479198	757
7	ISON-NM Observatory, Mayhill	252848	1106
8	Apache Point-Sloan Digital Sky Survey	227025	7
9	Purple Mountain Observatory, XuYi Station	195221	356
10	WISE	163006	23

Top-10 observatories from discoveries

№	Observatory (MPC-code)	Measurements	Discoveries
1	Mt. Lemmon Survey	4186400	39446
2	Pan-STARRS 1, Haleakala	3506255	27413
3	Steward Observatory, Kitt Peak-Spacewatch	1708543	15956
4	Catalina Sky Survey	3235680	5273
5	Palomar Mountain--PTF	28638	1827
6	Palomar Mountain/NEAT	56878	1286
7	ISON-NM Observatory, Mayhill	252848	1106
8	University of Szeged, Piszkesteto Stn. (Konkoly)	51885	952
9	OAM Observatory, La Sagra	51927	802
10	Siding Spring Survey	479198	757

Access to MPC Statistics – http://neoastrosoft.com/mpc_statistic_en/

Results (May, 2010 – August, 2014)

Observatories - CoLiTec users : 4
(AAO, ISON-NM, ISON-Kislovodsk, ISON-Ussyriysk).
Observations: **572 526**.
Objects discovered : **1558** asteroids and **four** comets.

Comets

C/2011 X1 (Elenin) – December 10, 2010 (ISON-NM). The first comet discovered by the Russian astronomer for the last 20 years.
P/2011 NO1 – July 7, 2011 (ISON-NM)
C/2012 S1 – September 21, 2012 (ISON-Kislovodsk)
P/2013 V3 (Nevski) – November 6, 2013 (ISON)

Jupiter Trojans

2011 QJ9	2011 YA3	2012 BB27	2012 SD3	2012 SC50
2011 QQ47	2012 AF1	2012 RZ4	2012 SN9	2013 BP2
2012 RM6	2012 SD3	2012 SN9	2013 BP2	2013 UF9

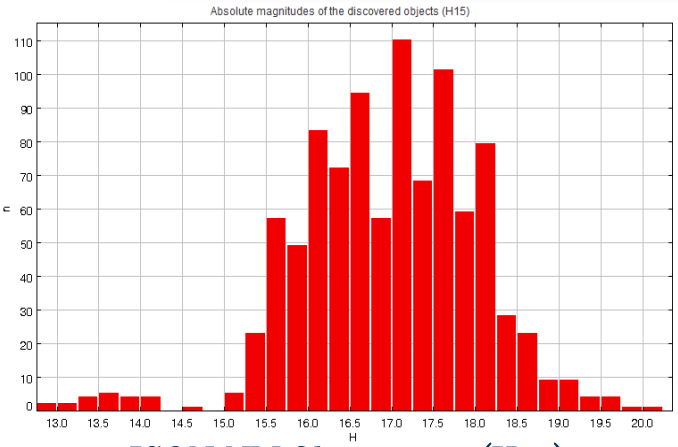
Near-Earth Asteroid

2011 QY37	2012 RQ16	2013 TB80	2014 KH2

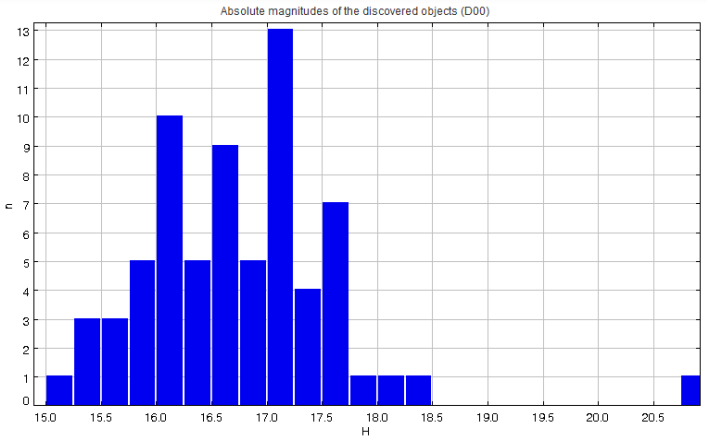
Centaurs

2013 UL10

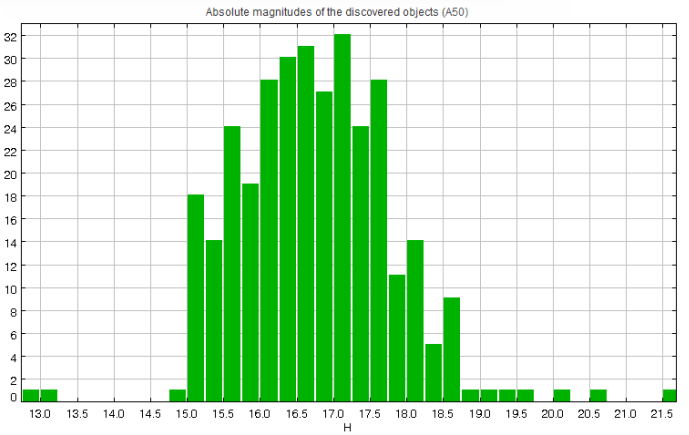
Distribution of discovered objects by H



ISON-NM Observatory (H15)

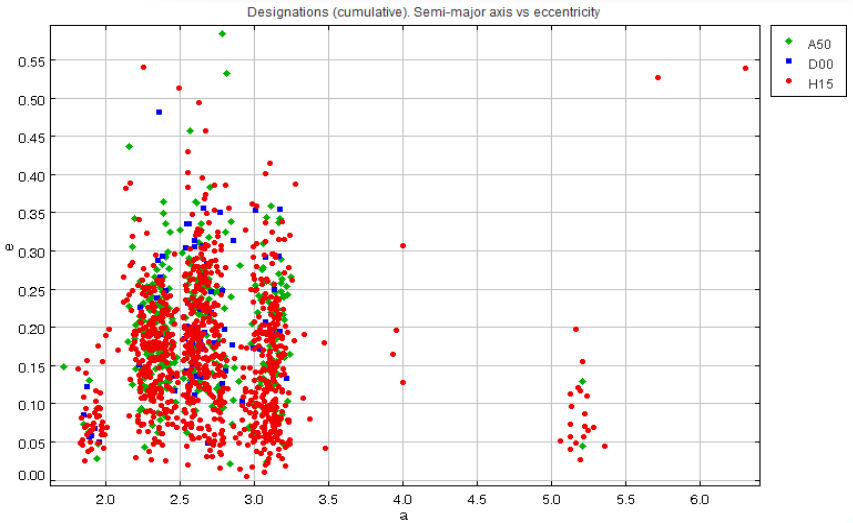


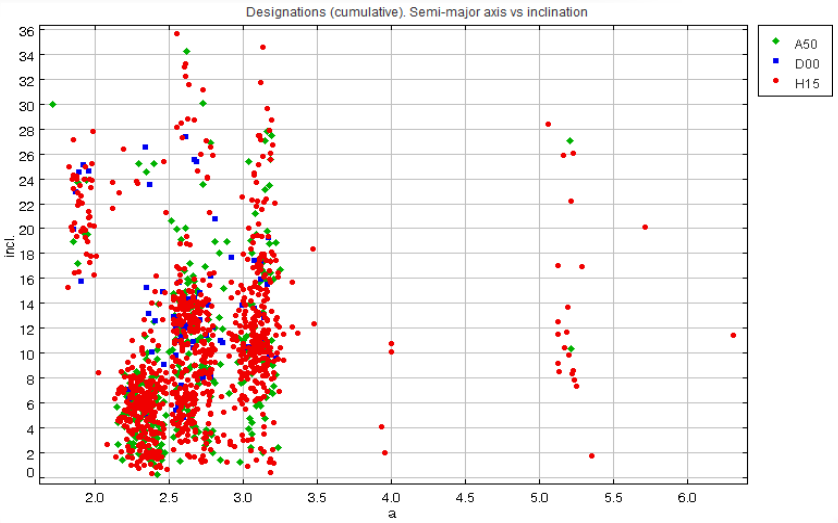
ISON-Kislovodsk Observatory (D00)



Andrushivka Astronomical Observatory (A50)

Distribution by the elements of orbit





Top world asteroid surveys according to 2011

(1) N	(2) Observatory code	(3) Measurements, objects	(4) Discoveries	(5) D, m	(6) S_{pix}	(7) $\bar{\Delta}_\alpha; \bar{\Delta}_\delta$	(8) $\sigma_\alpha; \sigma_\delta$	(9) σ''	(10) σ_{pix}	(11) ARM
1	G96	2106367, 382737	21770	1.50	1.0	-0.01; -0.04	0.32; 0.28	0.3	0.3	0.041
2	704	1956368, 279129	495	1.0	2.2	0.25; 0.43	0.66; 0.64	0.65	0.29	0.497
3	F51	1557902, 351923	13628	1.8	0.3	0.05; 0.06	0.16; 0.17	0.165	0.55	0.078
4	703	1512387, 259412	2995	0.68	2.6	-0.21; 0.17	0.67; 0.68	0.675	0.25	0.270
5	691	811571, 154495	8356	0.9	1.0	-0.16; 0.10	0.33; 0.30	0.315	0.315	0.189
6	E12	219903, 52808	327	0.5	1.8[1]	-0.04; 0.32	0.49; 0.48	0.485	0.26	0.322
7	645	208656, 45961	7	2.5	0.396					
8	D29	185303, 43414	318	1.04	1.705					
9	C51	162900, 15412	23	0.4	2.75	0.06; -0.03	0.57; 0.65	0.61	0.22	0.067
10	**CoLiTec user**									
	H15	154970, 37495	768	0.45	2	-0.03; 0.06	0.49; 0.54	0.515	0.25	0.067
11	106	75340, 18093	73	0.6	2	0.04; -0.11	0.36; 0.35	0.355	0.17	0.117
12	291	70355, 19028	646	1.8	0.6	-0.13; 0.15	0.36; 0.27	0.315	0.52	0.191
13	J75	48469, 13209	561	0.45	1.47	-0.04; -0.14	0.42; 0.40	0.41	0.28	0.146
14	644	34164, 6255	954	1.2	1					
15	**CoLiTec user**									
	A50	33386, 9755	72	0.6	2.06	-0.03; 0.05	0.51; 0.51	0.51	0.24	0.058
16	926	28578, 8460	171	0.81, 0.41	0.87	0.15; 0.27	0.38; 0.39	0.385	0.44	0.309
17	461	28038, 6281	782	0.60, 1.02	1.1	-0.03; 0.14	0.27; 0.27	0.27	0.24	0.143
18	A14	24354, 6448	115	0.50		0.08; -0.06	0.41; 0.36	0.385		0.1
19	J04	23322, 6460	188	1.0	0.62[2]	0.16; 0.24	0.29; 0.30	0.295	0.47	0.288
20	A77	21677, 5423	318	0.5		0.027; 0.22	0.63; 0.50	0.565		0.348
21	114	18352, 3203	174	0.3		0.03; -0.12	0.42; 0.35	0.385		0.124
22	689	18013, 1287	0	1.3		0.00; -0.02	0.15; 0.14	0.145		0.02
23	G92	17515, 4934	12	0.64		0.08; 0.05	0.62; 0.58	0.6		0.094
24	H21	16639, 3505	143	0.61, 0.81, 0.76	0.8[2]	0.06; 0.01	0.40; 0.42	0.41	0.51	0.061
25	J43	12837, 3246	116	0.5[3]	1.2	0.12; 0.24	0.53; 0.47	0.5	0.416	0.268
26	A24	10547, 1489	0	0.36	1.4	0.16; 0.19	0.46; 0.42	0.44	0.31	0.248
27	621	10201, 2379	233	0.6	1.2	0.08; -0.02	0.34; 0.33	0.335	0.27	0.082
28	807	10144, 2406	4	0.41		0.05; 0.12	0.83; 0.63	1.73		0.13
29	I40	8633, 134	3	0.6	0.64	0.02; -0.01	0.15; 0.17	0.16	0.2	0.022
30	141	7393, 717	37	1.2	1.01	0.03; 0.04	0.22; 0.22	0.22	0.22	0.05

[1]Mahabal et al. (2011), [2]Li et al. (1999), [3]Ory et al. (2012)

Top world asteroid surveys according to 2012

(1) N	(2) Observatory code	(3) Measurements,objects	(4) Discoveries	(5) D, m	(6) S_{pix}	(7) $\bar{\Delta}_\alpha; \bar{\Delta}_\delta$	(8) $\sigma_\alpha; \sigma_\delta$	(9) σ''	(10) σ_{pix}	(11) ARM
1	G96	2080033, 384204	17676	1.50	1.0	0.2; 0.2	0.33; 0.28	0.305	0.305	0.028
2	F51	1948353, 467091	13785	1.8	0.3	0.07; 0.04	0.15; 0.17	0.16	0.53	0.081
3	703	1723293, 282864	2278	0.68	2.6	-0.22; 0.07	0.65; 0.62	0.635	0.24	0.231
4	704	1681504, 262209	224	1.0	2.2	0.26; 0.43	0.67; 0.64	0.655	0.29	0.502
5	691	896972, 163714	7600	0.9	1.0	-0.16; 0.10	0.32; 0.29	0.305	0.27	0.189
6	E12	259295, 62621	430	0.5	1.8[1]	-0.01; 0.29	0.51; 0.50	0.505	0.28	0.290
7	J43	102641, 22682	531	0.5[2]	1.2[2]	0.19; 0.05	0.48; 0.40	0.44	0.36	0.196
8	926	100161, 29986	454	0.81, 0.41	0.87	0.02; 0.05	0.37; 0.35	0.36	0.41	0.54
9	**CoLiTec user**									
	H15	97878, 24170	338	0.45	2.0	-0.06; -0.01	0.50; 0.53	0.515	0.25	0.061
10	106	72192, 17451	120	0.6	2.0	0.04; -0.12	0.36; 0.34	0.35	0.17	0.126
11	A14	57243, 16239	159	0.50		0.06; -0.02	0.37; 0.32	0.345		0.063
12	J04	43209, 10708	513	1.0	0.62[3]	0.21; 0.20	0.28; 0.27	0.275	0.44	0.29
13	**CoLiTec user**									
	D00	31494, 7403	61	0.40	2.06	0,00; -0,06	0,57; 0,41	0,49	0,23	0.06
14	291	24272, 6224	28	1.8	0.6	0.07; 0.13	0.33; 0.28	0.305	0.50	0.148
15	461	23847, 5615	170	0.60, 1.02	1.1	0.00; 0.15	0.27; 0.27	0.27	0.24	0.15
16	644	22714, 4486	332	1.2[4]	1[4]					
17	H21	22672, 3870	181	0.61, 0.81, 0.76	0.8[2]	0.03; 0.01	0.34; 0.36	0.35	0.43	0.032
18	I41	21245, 2392	1790	1.2[5]	1.01[5]	0.11; -0.03	0.23; 0.23	0.23	0.22	0.114
19	A24	18940, 2412	0	0.36	1.4	0.14; 0.24	0.37; 0.33	0.35	0.25	0.278
20	645	18369, 5650	0	2.5	0.396					
21	807	12702, 2383	2	0.41		0.04; -0.01	0.29; 0.24	0.265		0.041
22	**CoLiTec user**									
	A50	11559, 3725	13	0.6	2.07	0.25; -0.04	0.50; 0.46	0.48	0.23	0.253
23	716	10669, 491	0	0.35	2.5	0.06; -0.01	0.33; 0.23	0.28	0.1	0.061
24	D29	9918, 2927	38	1.04	1.705	0.09; -0.01	0.43; 0.44	0.435	0.25	0.091
25	C41	8904, 3188	2	0.4	1.8	-0.16; 0.09	0.85; 0.72	0.785	0.43	0.184
26	621	6782, 1692	149	0.6	1.2	0.10; -0.01	0.35; 0.35	0.35	0.29	0.101
27	H45	6414, 368	0	0.51		0.04; -0.05	0.33; 0.31	0.32		0.064
28	D03	5489, 1396	121	0.4[6]	1.2	-0.06; -0.05	0.64; 0.45	0.545	0.45	0.078
29	950	5477, 800	123	2.5		0.09; 0.11	0.28; 0.24	0.26		0.142
30	71	5427, 329	0	0.50		0.01; 0.12	0.63; 0.43	0.53		0.120

[1]Mahabal et al. (2011), [2]Ory et al. (2012), [3]Abreu et al. (2011), [4]NEAT-PALOMAR (2013), [5]Waszczak et al. (2013), [6]MPC-K13H14 (2013)

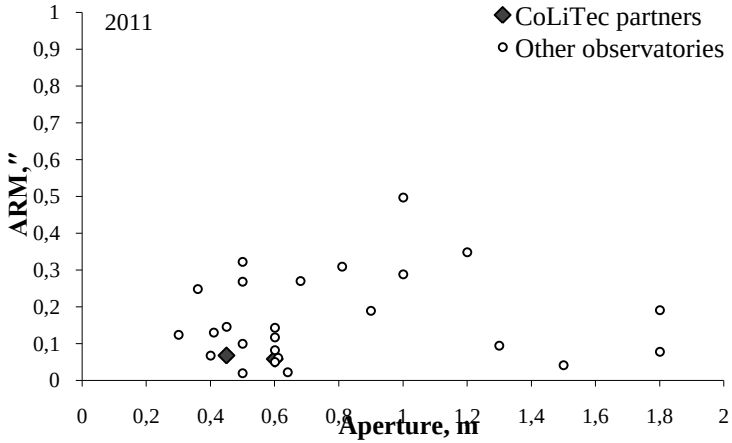
Top world asteroid surveys according to 2013

(1) N	(2) Observatory code	(3) Measurements, objects	(4) Discoveries	(5) D, m	(6) S_{pix}	(7) $\bar{\Delta}_\alpha; \bar{\Delta}_\delta$	(8) $\sigma_\alpha; \sigma_\delta$	(9) σ''	(10) σ_{pix}	(11) ARM
1	F51	2279609, 506894	14168	1.8	0.3	0.07; 0.06	0.13; 0.14	0.135	0.45	0.092
2	G96	1950642, 343808	11908	1.50	1.0	0.04; 0.05	0.32; 0.28	0.3	0.30	0.064
3	703	1844330, 289086	1494	0.68	2.6	-0.14; 0.22	0.66; 0.64	0.65	0.25	0.260
4	691	742001, 139225	5594	0.9	1.1	-0.16; 0.12	0.31; 0.30	0.315	0.28	0.2
5	D29	551094, 136964	262	1.04	1.7	0.03; -0.04	0.53; 0.49	0.51	0.30	0.05
6	I41	440712, 52579	2270	1.2[1]	1.01[1]	0.06; 0.02	0.18; 0.17	0.175	0.17	0.063
7	E12	229747, 48026	204	0.5	1.8[2]	-0.02; +0.28	0.50; 0.46	0.48	0.26	0.280
8	926	179570, 53662	750	0.81, 0.41	0.87	0.15; 0.10	0.39; 0.36	0.375	0.43	0.180
9	J43	151983, 27006	1006	0.5[3]	1.2[3]	0.11 -0.03	0.31 0.29	0.3	0.25	0.114
10	W84	110213, 8518	4160	4[3,4]	0.27[4]	0.13; 0.14	0.13; 0.13	0.13	0.48	0.191
11	**CoLiTec user**									
	H15	107989, 25282	156	0.40	2.0	0.09; 0.02	0.62; 0.60	0.61	0.305	0.092
12	704	81054, 17833	4	1.0	2.2	0.29; 0.38	0.64; 0.63	0.635	0.28	0.478
13	J04	58307, 14670	576	1.0	0.62[5]	0.25; 0.23	0.30; 0.28	0.29	0.46	0.340
14	**CoLiTec user**									
	D00	44658, 10850	34	0.40	2.06	0.01; -0.12	0.72; 0.54	0.63	0.305	0.120
15	G32	36416, 4654	654	0.4	1.13	0.03; 0.05	0.35; 0.32	0.335	0.29	0.058
16	106	18601, 4502	67	0.6	2.0	0.04; -0.05	0.39; 0.37	0.37	0.19	0.064
17	H21	16924, 2994	60	0.61, 0.81, 0.76	0.8[6]	0.04; -0.04	0.33; 0.31	0.32	0.4	0.002
18	461	15688, 3787	110	0.60, 1.02	1.1	-0.02; 0.17	0.24; 0.27	0.255	0.23	0.171
19	644	15221, 3317	63	1.2[7]	1[7]					
20	291	15197, 4002	1	1.8	0.6	0.02 0.14	0.35 0.32	0.335	0.55	0.141
21	G36	12280, 1683	110	1.23[8]		0.06; 0.00	0.25; 0.24	0.245		0.06
22	A24	12207, 2786	0	0.36	1.4	0.13; 0.26	0.40; 0.34	0.37	0.26	0.29
23	807	11525, 2341	1	0.41	0.59	0.00; -0.01	0.35; 0.29	0.32	0.54	0.01
24	C41	10384, 3794	0	0.4	1.8	-0.01; 0.10	0.69; 0.63	0.66	0.36	0.1
25	645	9631, 3161	0	2.5	0.396					
26	695	8354, 3118	600	4.0[9], 3.5	0.26[9]	0.14; 0.17	0.22; 0.19	0.205	0.78	0.220
27	A14	7553 ,2505	9	0.50		0.06; 0.02	0.38; 0.37	0.375		0.063
28	D03	6638, 1768	87	0.4[10]	1.2	0.03; -0.05	0.43; 0.36	0.395	0.33	0.058
29	493	5539, 1820	82	1.23[11]	0.3[12]	0.04; 0.10	0.22; 0.24	0.23	0.76	0.108
30	C95	5411, 1152	62			0.01; 0.00	0.56; 0.51	0.535		0.01

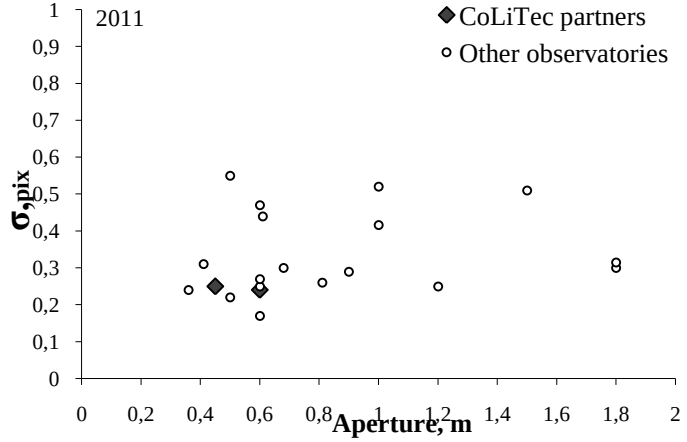
[1]Waszczak et al. (2013), [2]Mahabal et al. (2011), [3]Ory et al. (2012), [4]Honscheid et al. (2008), [5]Abreu et al. (2011), [6]Li et al. (1999), [7]NEAT-PALOMAR (2013)
[8]MPC-K13T85 (2013), [9]David et al. (2013), [10]MPC-K13H14 (2013), [11]MPC-K13Q41 (2013), [12]O'Sullivan et al. (2000)

Top world asteroid surveys according to 2011

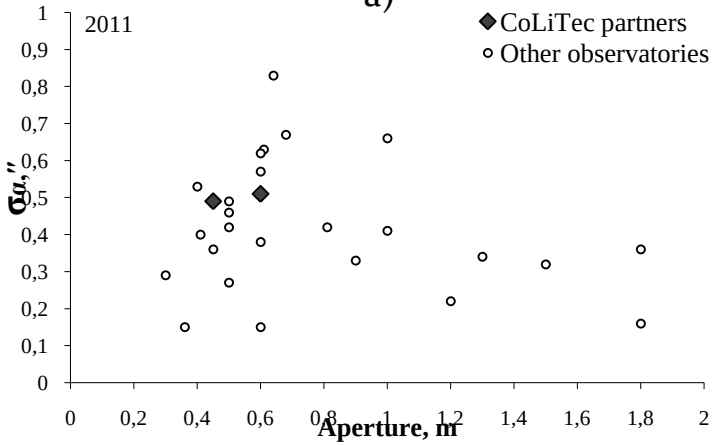
a) module of the average residuals of object position measurements; b) standard deviation estimations of object position, in pixels; c) standard deviation estimations of object position in the right ascension, in arcseconds; d) standard deviation estimations of object position in the declination, in arcseconds.



a)



b)



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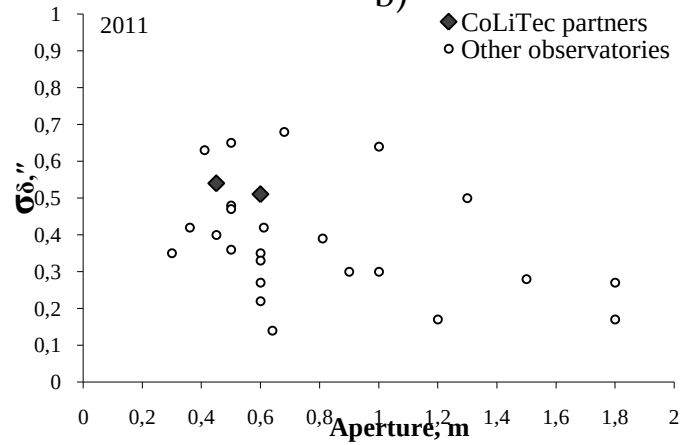
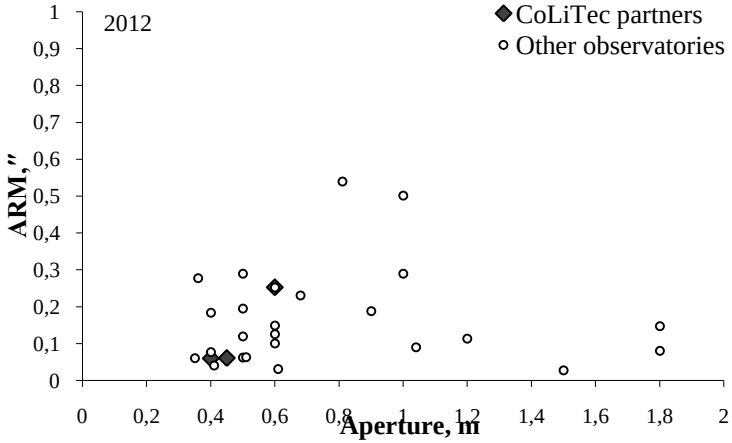


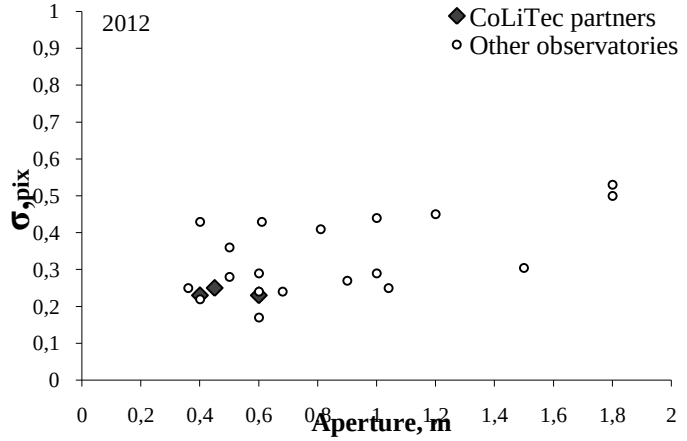
d)

Top world asteroid surveys according to 2012

a) module of the average residuals of object position measurements; b) standard deviation estimations of object position, in pixels; c) standard deviation estimations of object position in the right ascension, in arcseconds; d) standard deviation estimations of object position in the declination, in arcseconds.



a)



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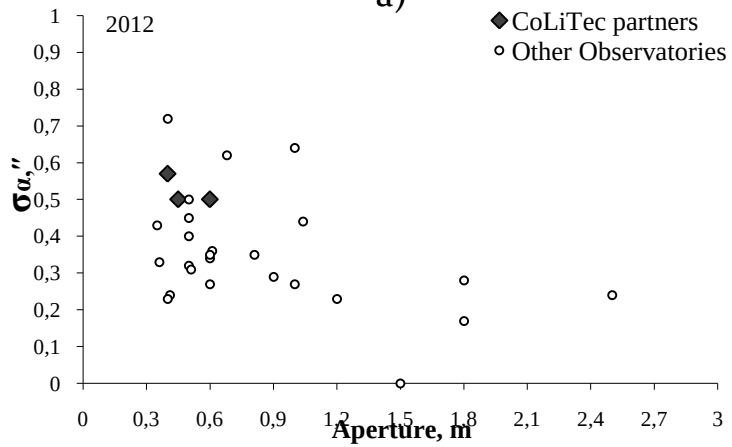

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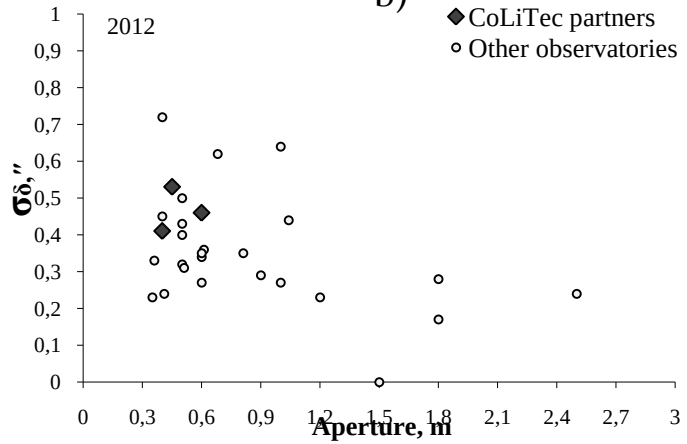
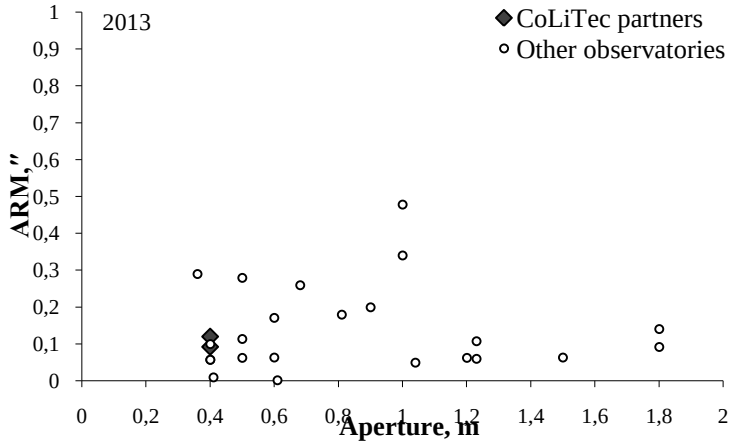


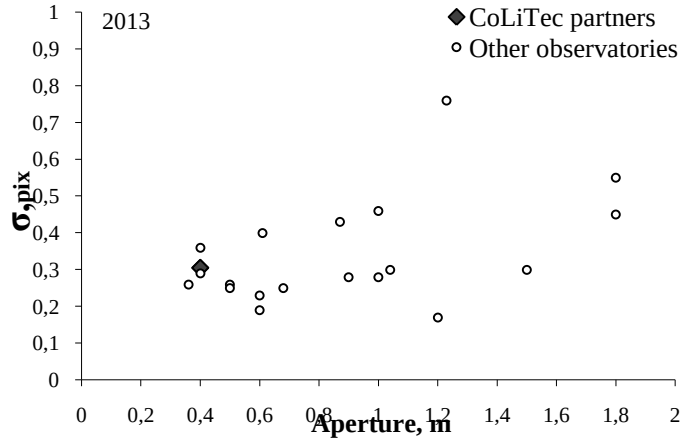
d)

Top world asteroid surveys according to 2013

a) module of the average residuals of object position measurements; b) standard deviation estimations of object position, in pixels; c) standard deviation estimations of object position in the right ascension, in arcseconds; d) standard deviation estimations of object position in the declination, in arcseconds.



a)



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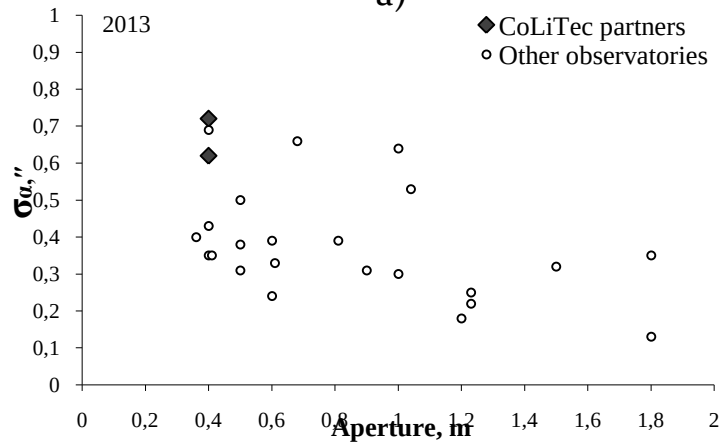
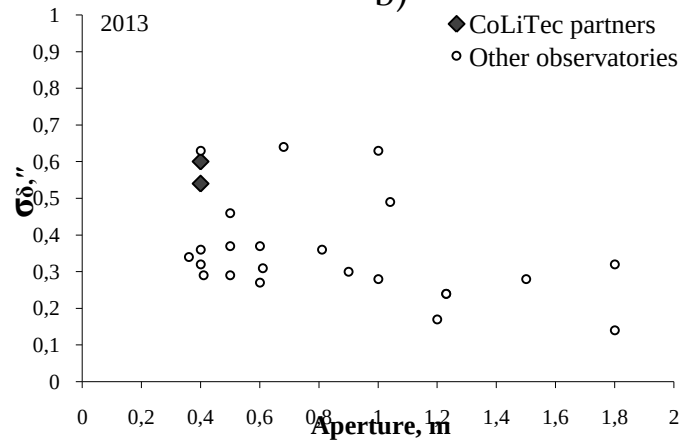
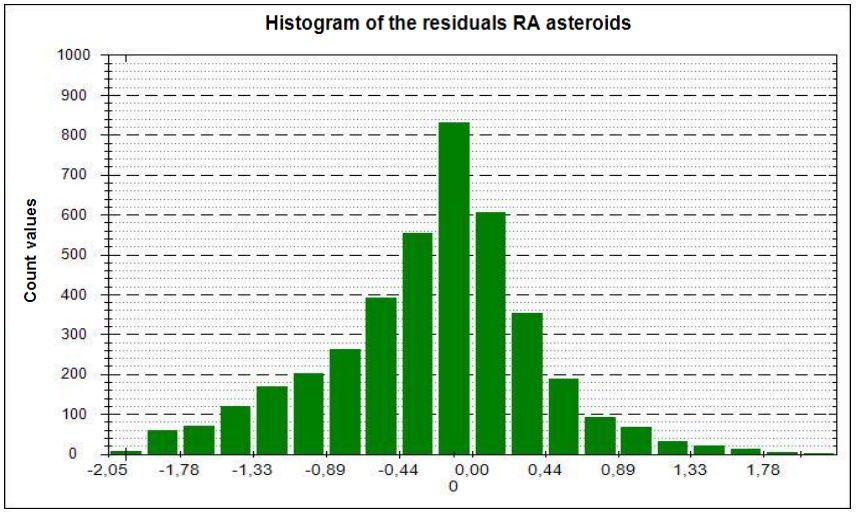


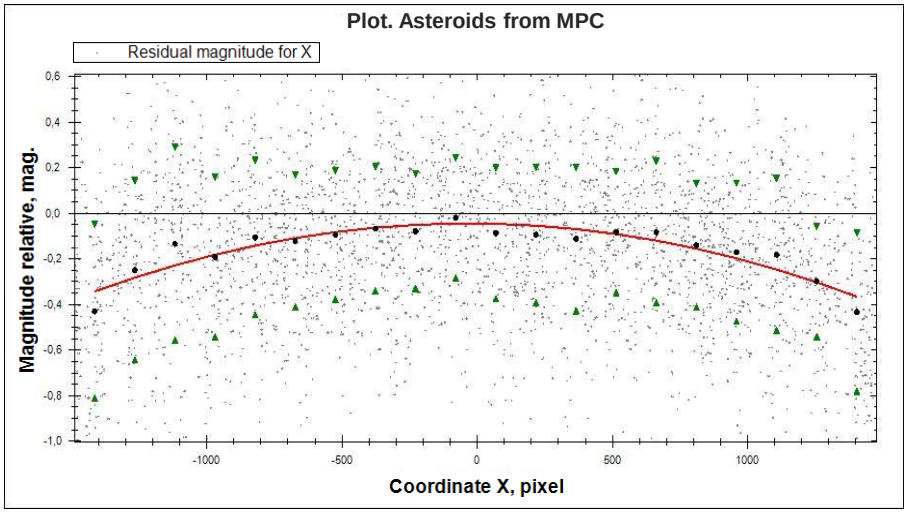
c)



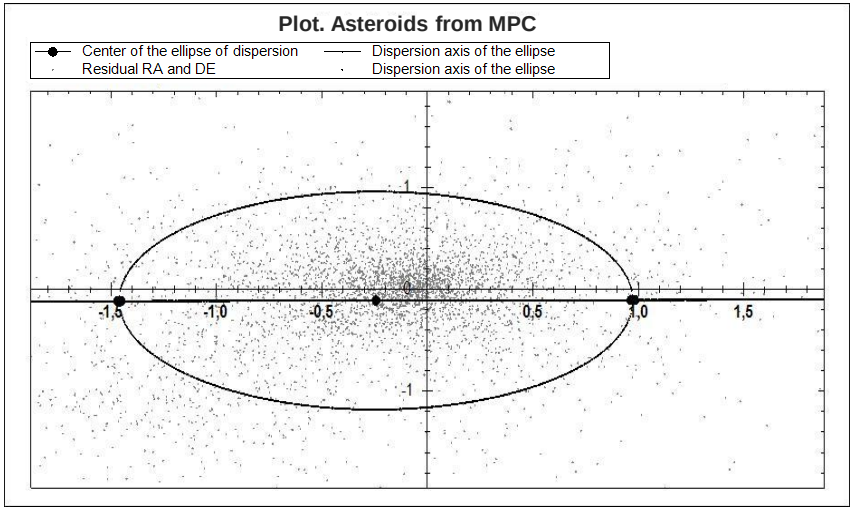
d)



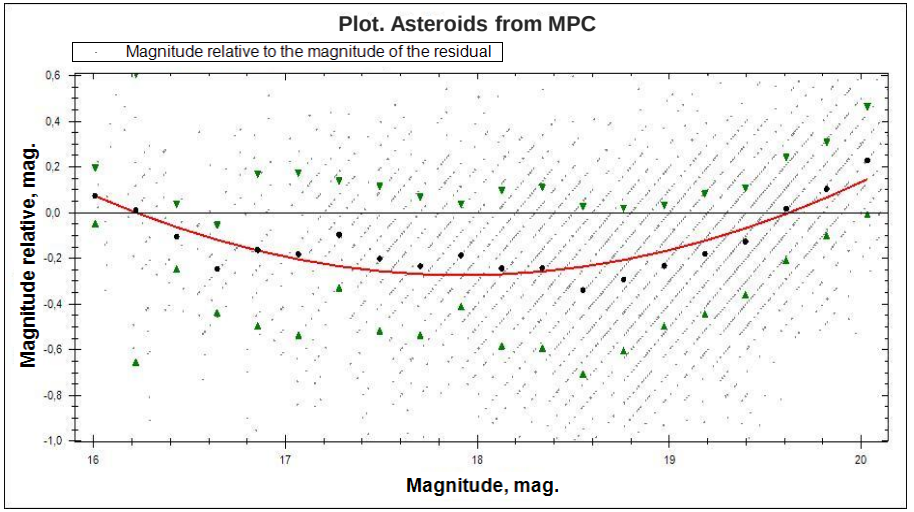
a) Histogram of residuals



b) Dependence of magnitude residual vs. frame position

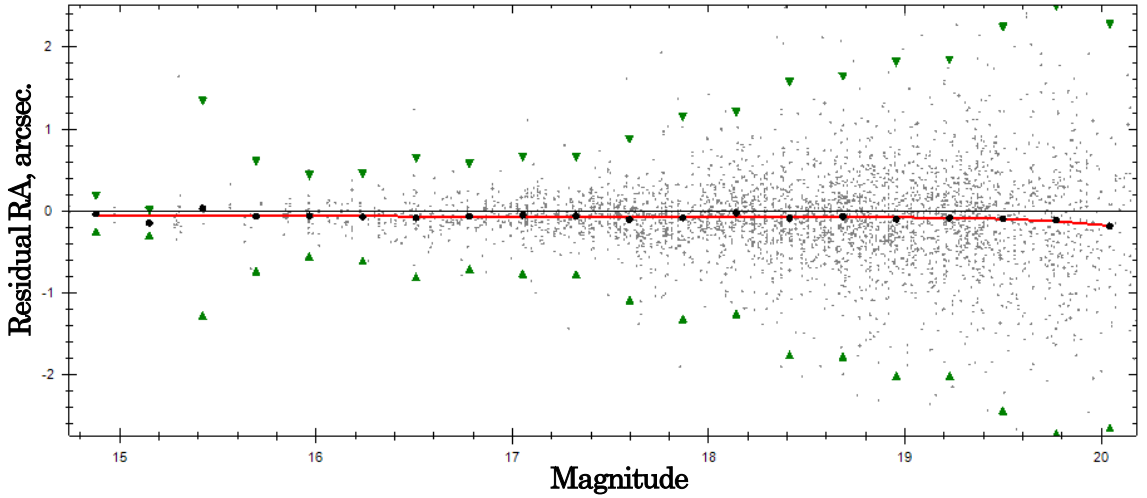


c) Ellipse dispersion of residuals of objects coordinates

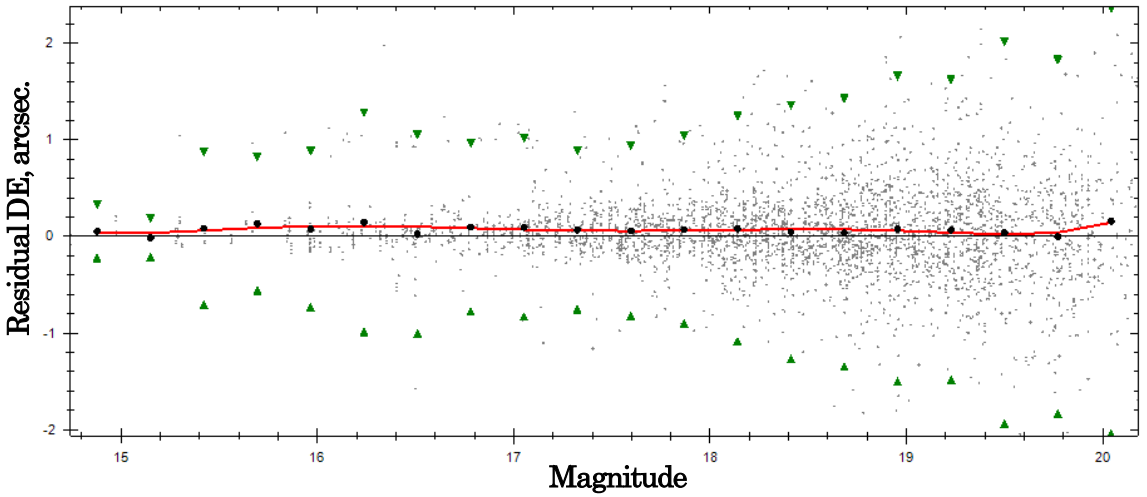


d) Dependence of magnitude residual vs. catalogue magnitude

Plot 1. Dependence of RA residuals vs. magnitude (HORIZONT)

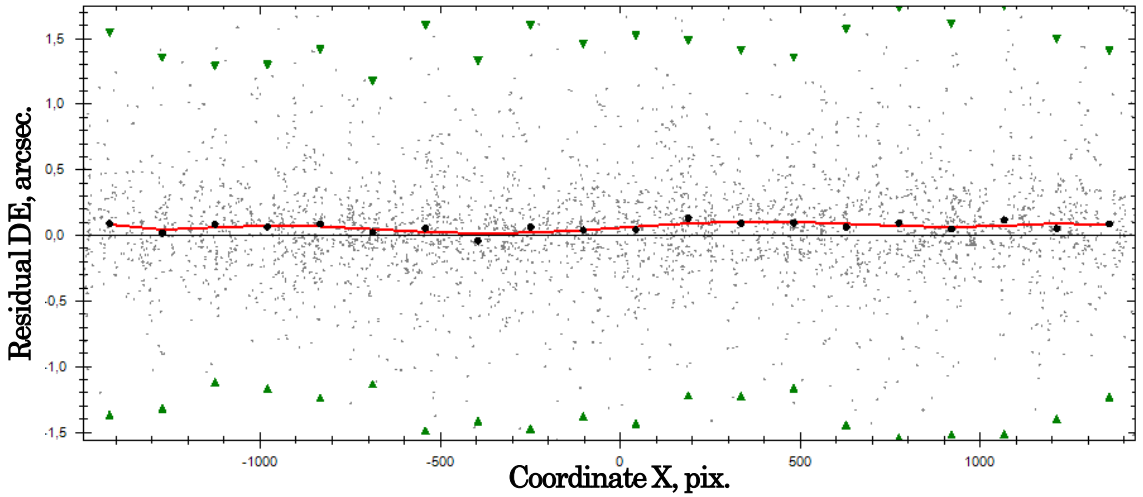


Plot 2. Dependence of DE residuals vs. magnitude (HORIZONT)

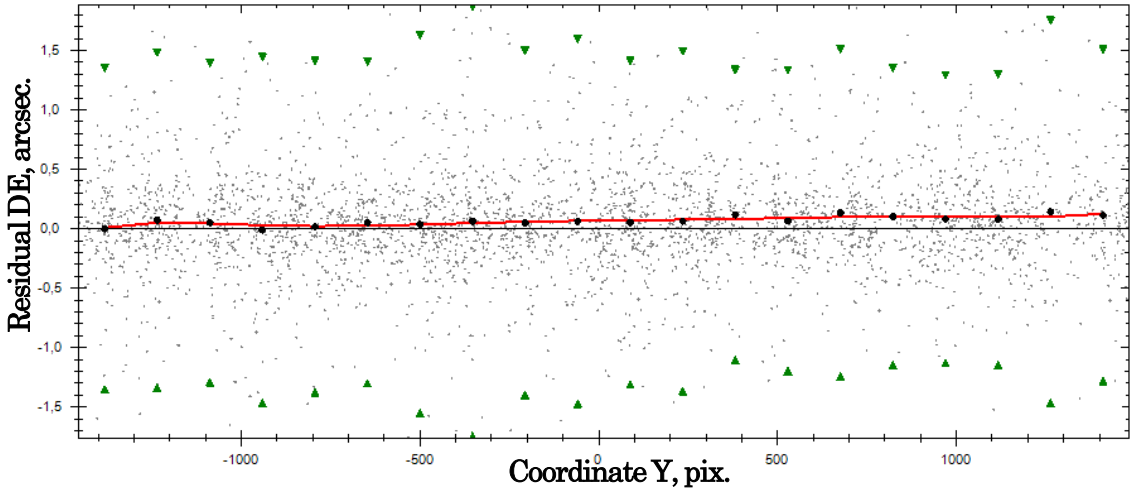


Plotted according to 3443 measurements

Plot 3. Dependence of DE residuals vs. X axis



Plot 4. Dependence of DE residuals vs. Y axis



Plotted according to 3443 measurements

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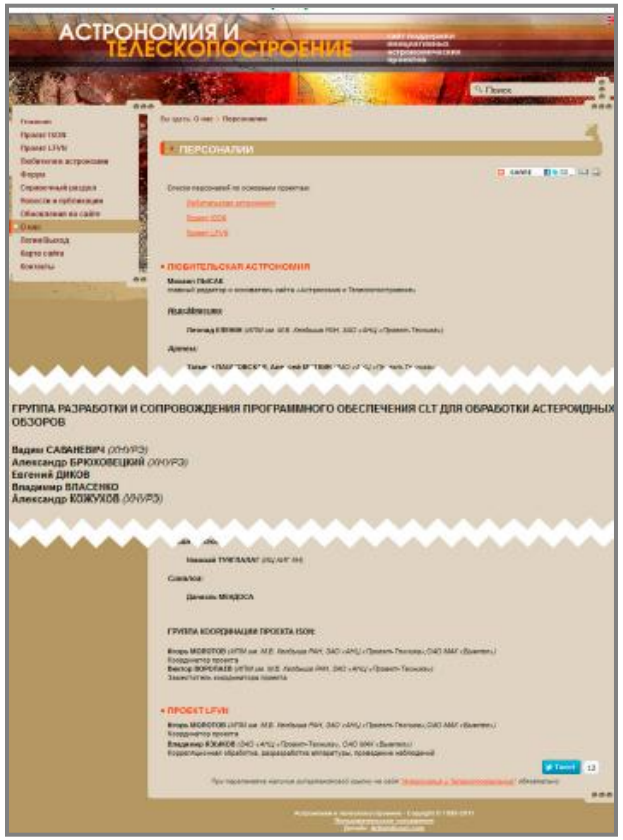
http://astronomer.ru



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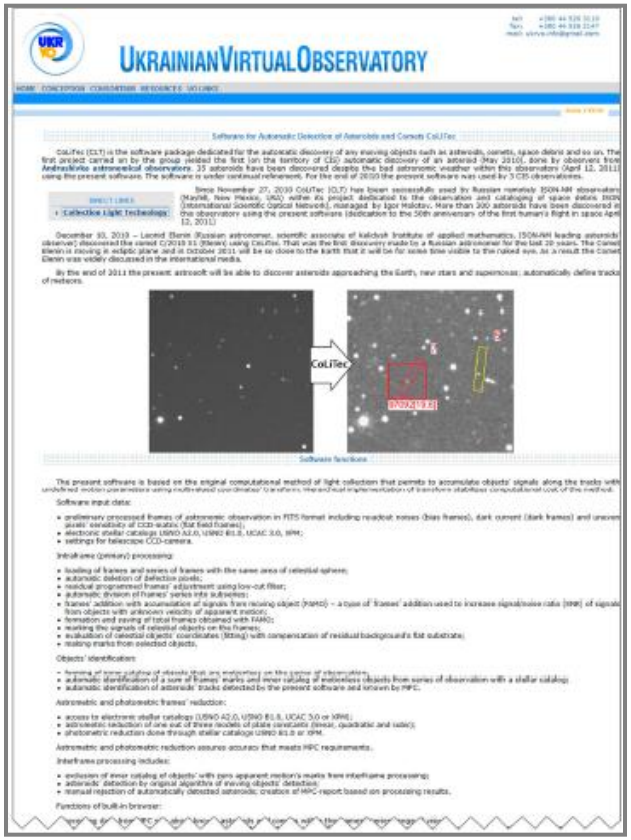
http://ukr-vo.org/soft/index.php?b3&3



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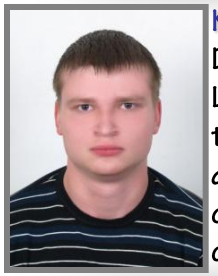
Bryukhovetskiy Alexander – leading designer of software code; observer, PhD specialty mathematical modeling and computing methods.

Dikov Eugen– professional developer and astronomer; leading developer of Recearch and Design Institute of Micrography (Kharkiv).



Khlamov Sergii — Software Development Team Lead, automation and manual tester, software developer, graduate student of computer engineering department of Kharkiv National University of Radioelectronics.

Elenin Leonid — researcher in the Keldysh Institute of Applied Mathematics RAS (Moscow, Russia) Remote observer at the ISON-NM observatory (H15), as part of the International Scientific Optical Network (ISON).

Vlasenko Vladimir – engineer in the group of the National Space Facilities Control and Testing Center (Evpatoria, Ukraine); designer of frames cosmetic correction software.

Bezkrovniy Michail — developer, researcher, teacher at the Zaporizhzhya Institute of Economics and Information Technologies.

Iatsyk Nikolay— software developer, graduate student of computer engineering department of Kharkiv National University of Radioelectronics.

Pogorelov Artem — software developer, graduate student of computer engineering department of Kharkiv National University of Radioelectronics.

Sokovikova Nataliia — documentation, graduat e student of computer engineering department of Kharkiv National University of Radioelectronics.

Movsesian Yiana — documentation, graduate student of computer engineering department of Kharkiv National University of Radioelectronics.

Dashkova Anna — developer, researcher, teach er at the Zaporizhzhya Institute of Economics and Information Technologies

Thank you!

Sergii Khlamov

sergii.khlamov@gmail.com

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