

Gaia Astrometric Alerts and Gaia-FUN-SSO follow-up :

an opportunity for a Pro-Am collaboration

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+DPAC colleagues (ESA, CNES)

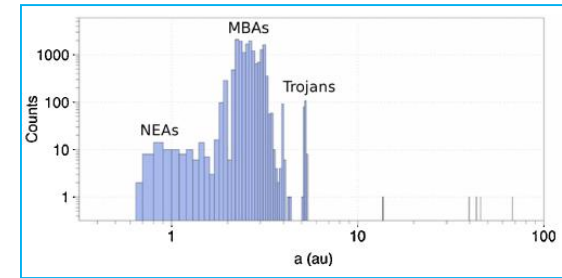


Gaia and the Solar System Objects

Data access

through periodical data releases:

- *DR1: 14 Sept. 2016 => no Solar System Objects*
- *DR2: 25 April 2018 => 14 099 asteroids (Spoto et al., 2018)*
- *early-DR3: 3 Dec. 2020*
- **DR3 : 13 june 2022** (<https://www.cosmos.esa.int/web/gaia/dr3>)



158 152 SSO (including 31 natural satellites and 1320 unmatched)

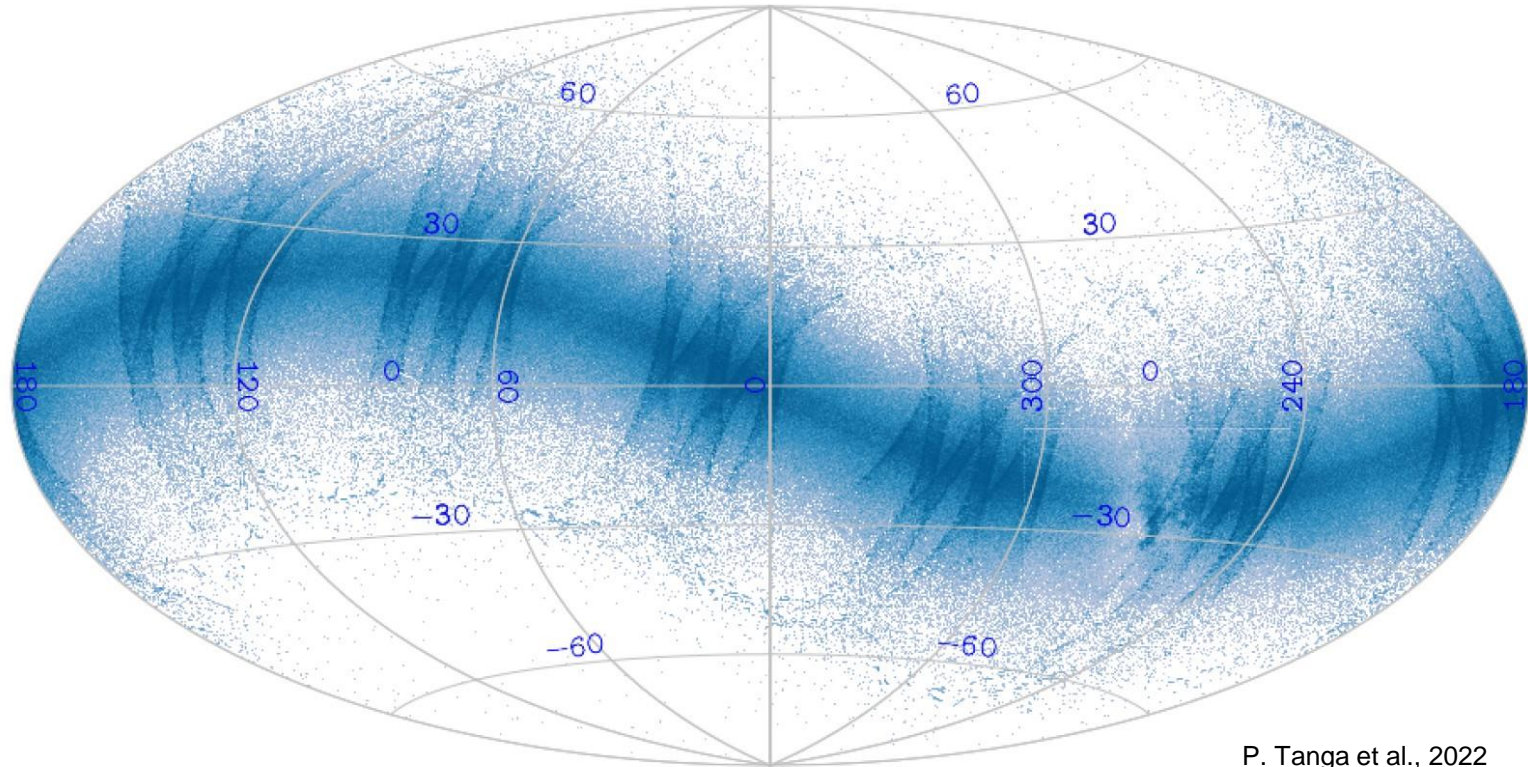
60 518 reflectance spectra

+ astrometry : 23 336 467 epoch astrometry

+ photometry : 60 518

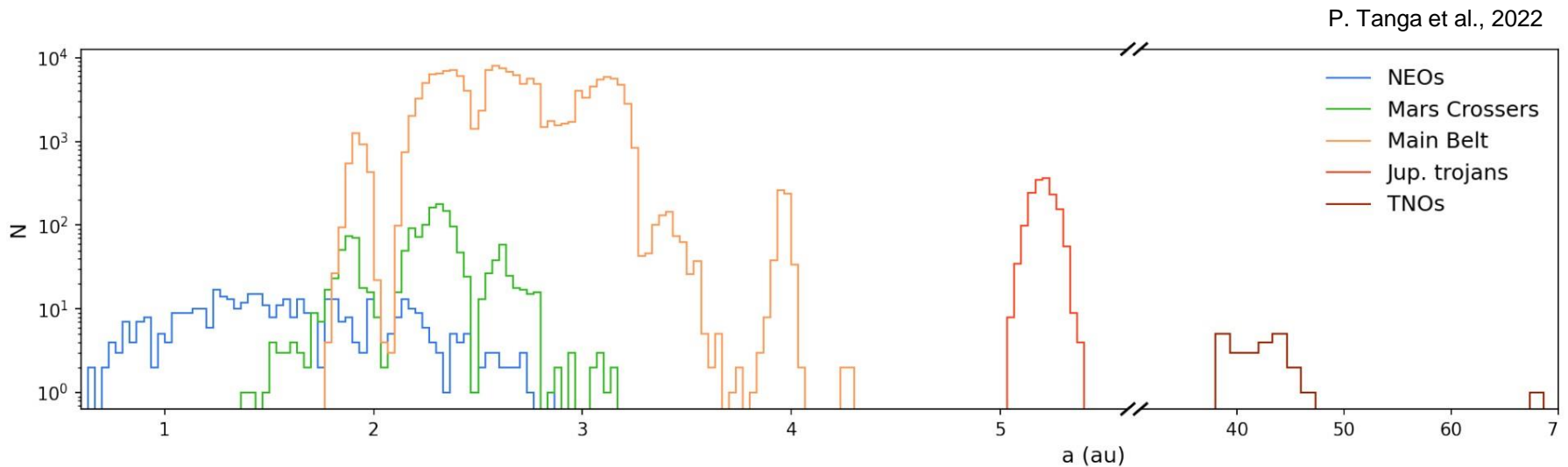
+ osculating elements : 154 787

Gaia and the Solar System Objects



Distribution of the asteroids of the DR3 catalog (except Centaurs)

Gaia and the Solar System Objects



Distribution of the asteroids in semi major axis (AU) of the DR3 catalog (except Centaurs)

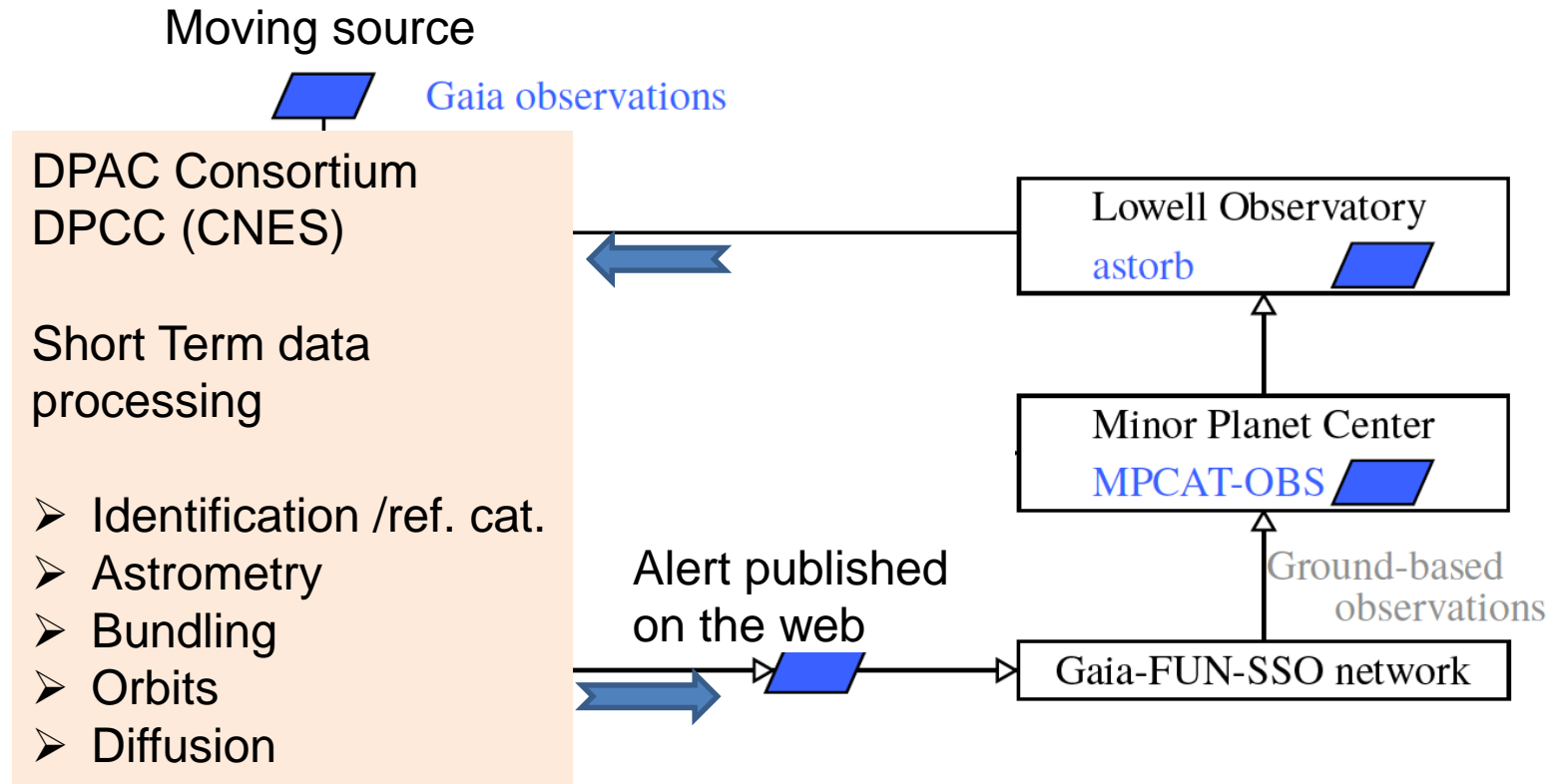
Details at Tanga et al. (2022): <https://arxiv.org/abs/2206.05561> and <https://www.cosmos.esa.int/web/gaia/dr3>

Gaia and the Solar System Objects

- Detection of all moving sources up to mag 20.7
- Gaia alerts triggered after detection of uncatalogued moving objects
- Gaia Scanning law => monitoring impossible
- Processed data publicly available through <https://www.imcce.fr>
- Need for recovery from the ground and follow-up
- A loop to feed back the Gaia SSO reference catalog

The SSO-ST daily processing

- SSO-ST « Unknown » SSOs => Short Term Processing => alerts

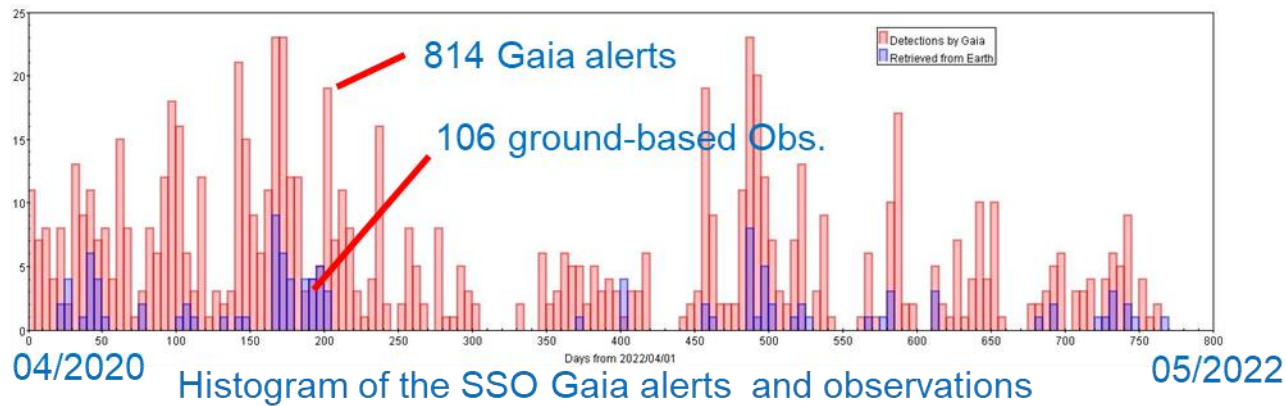


Goal and means

- ✓ Validation of the Gaia discoveries of new moving objects (~ 48h)
- ✓ Avoid possible false Gaia detections (artifacts, star spikes,...)
- ✓ Recovery + complementary astrometry measurement
- ✓ Prepare the next identifications by feeding the reference catalog
- ✓ Contribution to NEO survey, for example => 2021 PO41

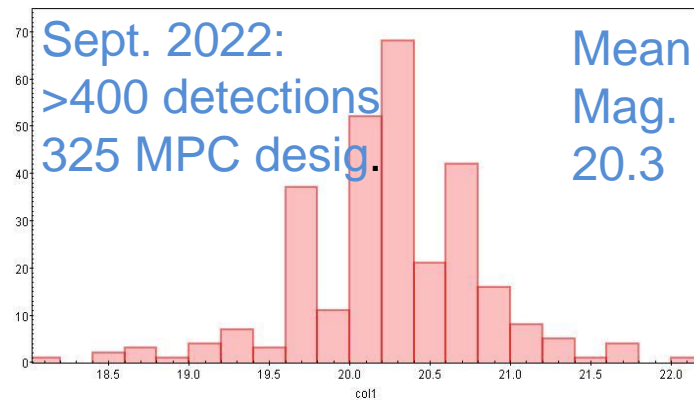
Goal and means

- ✓ Observability conditions: 50% North 50% South hemisphere
- ✓ Need of various locations (geographical coverage)
- ✓ Irregular flux of alerts



Goal and means

- Before 2016...follow-up observations by pro and amateurs expected
- Workshops 2010 + 2012 + 2014
- Starting in 2016...Most of the alerts in the 20-21 magnitude range



- Observations for validation/detection =>
 - 0.8m - 1m diameter well adapted / smaller diameters possible
 - low S/N & low precision astrometry acceptable
 - 5 exposures are enough (blink + astrometry in MPC format)
 - UTC timing

Goal and means

Alerts publicly release through the web site: <https://gaiafunssso.fr>


- List of alerts daily updated
- Low precision ephemerides
- Sky maps
- Notification on the detection already done
- Button to report positive observation

Gaia Follow-Up Network for Solar System Objects

Goal

The Gaia Follow-Up Network for Solar System Objects (Gaia-FUN-SSO) has been set up in the framework of a task (DUA99) of the Coordination Unit 4 (Object processing) of the Data Data Processing and Analysis Consortium (Gaia). Its goal is to coordinate ground-based observations on alert triggered by the data processing, submitting the mission for the confirmation of newly detected moving objects or for the improvement of orbits of some critical targets. Gaia will scan the sky following a pre-defined scanning law and such ground-based observations are required to avoid the loss of newly detected Solar System objects and to facilitate their subsequent identification by the probe.

These pages provide an access to the alerts, including the ephemerides to help finding the targets, for the registered members of the Gaia Follow-up network. The network currently consists in about 50 observers in 27 observing sites, spread all over the world (January 2016).



Results and statistics

We are publishing alerts daily since early November 2016. You can find the statistics on the released alerts and on confirmed data discoveries from the ground in the [all Results](#) page.

Workshops

These Gaia-FUN-SSO workshops dedicated to the alert reports discussions has been held about the network and the tasks to:

- Proceedings of the 2010 workshop have been published
- Proceedings of the 2012 workshop have been published
- Proceedings of the 2014 workshop have been published

Registration

To get a full access to these pages and to alert data, you must network needs to have a large geographical coverage. If you are

Potential discoveries of Solar System Objects by Gaia

This page lists all the daily, J2000 alerts for follow-up observations on Solar System Objects recently discovered by the ESA's Gaia mission, currently visible for the alerts you searched for your instrument (ISS). You can obtain detailed information on each alert in the Details page and report the results (positive, missed) of your observations in the Report page (see link in the table).

If you observed an alert which is no longer listed below, use this link to report observations.

ID	Begin	End	Vmag	RA	Dec	Mmag	Dist	Area	Name	Report	Details
71591	2022-10-23	2022-10-21	19.88	341.7717	44.1087	4	MarDeI	0.96488	gsh002	R	D
71589	2022-10-23	2022-10-21	20.48	327.8044	28.0324	4	MarDeI	0.18374	gsh001	R	D
71585	2022-10-23	2022-10-20	20.17	327.8415	28.0733	5	MarDeI	0.36334	gsh004	R	D
71581	2022-10-21	2022-10-19	20.62	318.5128	5.0209	3	MarDeI	0.11623	gsh009	R	D
71647	2022-10-26	2022-10-18	19.35	327.1183	48.9937	3	MarDeI	0.39141	gsh003	R	D
71648	2022-10-28	2022-10-18	19.7	28.781	85.3221	3	NED	1.2713	gsh004	R	D
71696	2022-10-23	2022-10-14	20.34	344.8472	44.4361	3	NED	1.07226	gsh000	R	D
71671	2022-09-30	2022-09-14	20.38	321.2577	19.3355	3	NED	1.34377	gsh007	R	D
70530	2022-09-26	2022-10-14	20.05	315.0269	5.6603	5	MarDeI	0.098195	gsh000	R	D
70830	2022-09-26	2022-10-11	20.53	314.6893	-7.8361	3	NED	2.43283	gsh002	R	D
70810	2022-09-23	2022-10-11	20.11	318.6562	-32.7748	5	MarDeI	0.47872	gsh003	R	D
70799	2022-09-22	2022-10-10	20.27	315.3039	-17.292	4	MarDeI	0.2923	gsh017	R	D
70797	2022-09-20	2022-10-10	20.35	318.2456	-14.3765	6	MarDeI	0.05888	gsh014	R	D
70799	2022-09-22	2022-10-10	20.87	318.5204	25.8967	3	MarDeI	0.15182	gsh012	R	D
71535	2022-09-28	2022-10-20	20.25	315.1733	5.0002	3	MarDeI	3.00055	gsh005	R	D
70784	2022-09-21	2022-10-09	19.88	318.0612	-13.2887	3	NED	1.87376	gsh015	R	D
70792	2022-09-21	2022-10-09	19.8	314.4211	-5.8273	4	NED	2.49321	gsh012	R	D
70783	2022-09-21	2022-10-09	20.46	320.730	-33.8316	3	MarDeI	1.20914	gsh011	R	D
71572	2022-09-10	2022-10-07	20.23	315.1455	5.6195	3	MarDeI	4.15787	gsh008	R	D
70771	2022-09-10	2022-10-07	20.46	315.5008	-27.895	3	NED	4.79857	gsh001	R	D

Please report bugs here in project "Gaia-FUN-SSO", or contact us at gaiafunssso@brno.cz.



Goal and means

Potential discoveries of Solar System Objects by Gaia

This page lists all the calls, dubbed *alerts* for follow-up observations on Solar System Objects recently discovered by the *ESA Gaia* mission, currently visible for the criteria you specified for your instrument (*W85*). You can obtain detailed information on each alert in the *Details* pages and report the results (positive, missed) of your observations in the *Report* pages (see links in the table).

If you observed an alert which is no longer listed below, use [this link](#) to report observations.

List of active alerts											
ID	Begin	End	V _{mag}	RA	Dec	N _{Transit}	Dyn.	Area	Name	Report	Details
71591	2022-10-03	2022-10-21	19.88	344.7717	44.1087	4	MainBelt	0.04446	g6n002		
71589	2022-10-03	2022-10-21	20.48	327.8644	28.6324	4	MainBelt	0.18674	g6n001		
71585	2022-10-02	2022-10-20	20.17	327.9415	28.6793	5	MainBelt	0.0834	g6m00A		
71581	2022-10-01	2022-10-19	20.42	316.5126	5.0286	3	MainBelt	0.11923	g6m009		
71647	2022-10-06	2022-10-18	19.95	357.1783	48.9937	3	MainBelt	0.39141	g6n003		
71646	2022-10-06	2022-10-16	19.7	25.781	53.3721	3	NEO	1.2743	g6n004		
71596	2022-10-03	2022-10-14	20.34	344.8472	44.4361	3	NEO	1.07226	g6n000		
71571	2022-09-30	2022-10-14	20.39	321.0527	19.2355	3	NEO	1.34377	g6m007		
70838	2022-09-26	2022-10-14	20.05	315.0266	5.6403	5	MainBelt	0.06935	g6m000		
70830	2022-09-25	2022-10-11	20.53	314.6893	-7.8361	3	NEO	2.43283	g6l02C		
70810	2022-09-23	2022-10-11	20.11	319.9562	-32.7748	5	MainBelt	0.47572	g6l020		
70798	2022-09-22	2022-10-10	20.27	315.3089	-17.292	4	MainBelt	0.2929	g6l017		
70797	2022-09-22	2022-10-10	20.25	316.2456	-14.2752	6	MainBelt	0.05899	g6l01A		
70799	2022-09-22	2022-10-10	20.67	319.5254	-25.8587	3	MainBelt	0.15152	g6l01E		
71535	2022-09-28	2022-10-09	20.25	315.1733	5.5202	3	MainBelt	3.05055	g6m005		
70784	2022-09-21	2022-10-09	19.66	315.0612	-13.2837	3	NEO	1.97375	g6l015		
70790	2022-09-21	2022-10-09	19.8	314.4211	-6.8273	4	NEO	2.46321	g6l012		
70783	2022-09-21	2022-10-09	20.45	320.735	-33.8315	3	MainBelt	1.22914	g6l011		
71572	2022-09-30	2022-10-07	20.23	315.1455	5.6195	3	MainBelt	4.15757	g6m008		
70771	2022-09-19	2022-10-07	20.45	316.5608	-27.955	3	NEO	4.79857	g6l001		

Selected alerts: 20/21

Detailed information on g6n002

Field of view: RA Dec

2022-10-03 2022-10-21

Table with columns: Date, RA, Dec, Vmag, Ntransit, Dyn, Area, Name, Report, Details

Gaia Id.

Sky Map

Ephem.

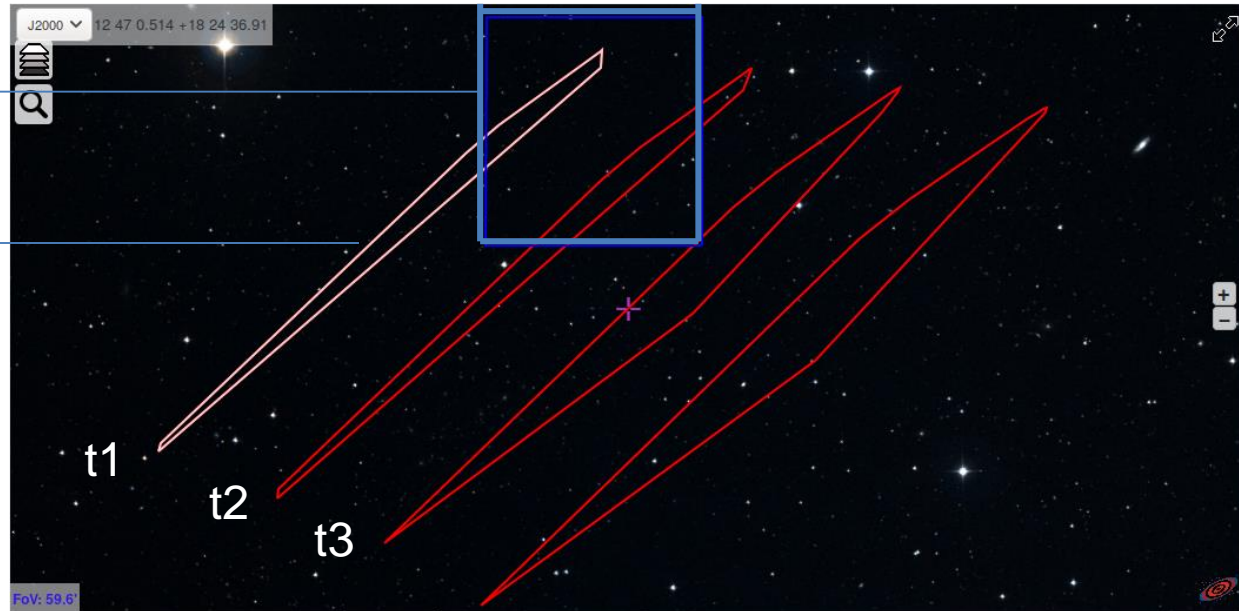
Please report bugs [here](#) in project "Gaia-FUN-SSO", or contact us at gaia-fun-ss0@imcce.fr.



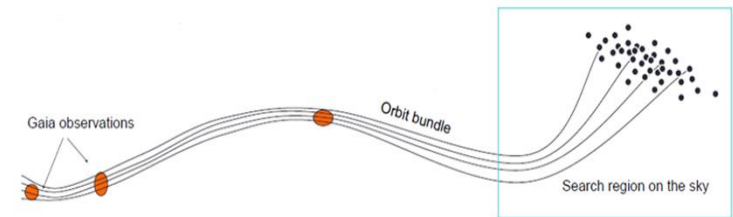
Asteroid recovery: a challenge

Probable
presence

Extended
area



- On the basis of **short arcs of orbit**
- MCMC method (Oszkiewicz 2009, Muinonen 2015) => **bundle of orbits**
- Projected on the sky => **areas for recovering**
- « **Ephemerides** » and **sky maps** on the web



Tanga et al. 2016

<https://gaiafunssso.imcce.fr>

Detailed information on alert

You will find below detailed information on the target and its probable position on the plane of the sky.

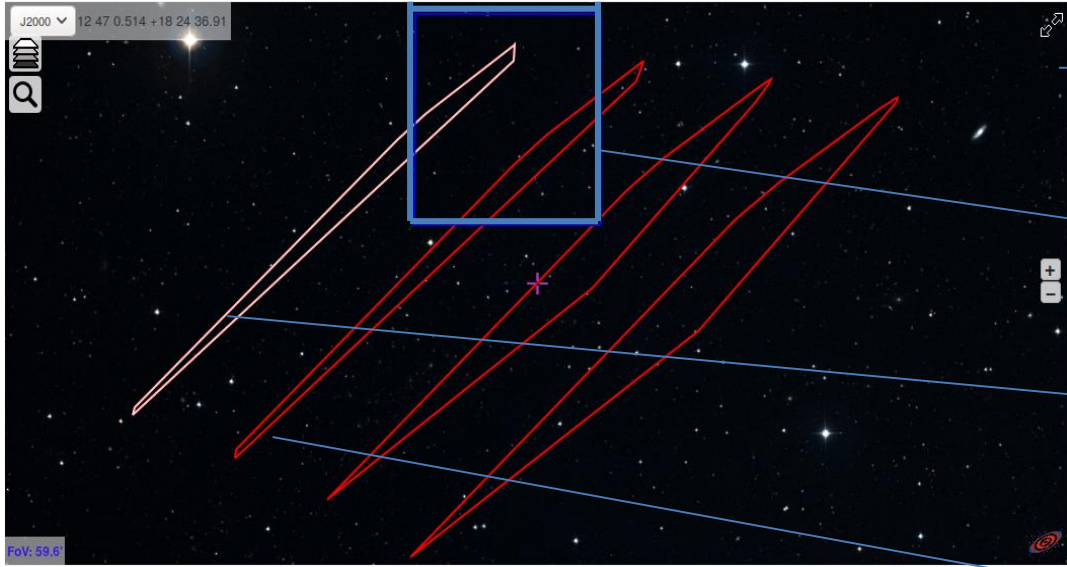
Object Information

- Gaia ID: -4194967176
- Database ID: 10148
- Name: GAIA120
- Magnitude (V): $19.6^{+0.6}_{-0.3}$
- Date of observation: 11/13/2016

Instrument and Field of View

Field of View	RA	Dec
<input checked="" type="checkbox"/> 13x13 arcmin ²	03:55:02.880	-23:05:05.640

Information on the alert +nb of transits



Sky map
Field of View Here 12'x12'
Most probable zone (blue)
Zone to explore if not in the FoV (red) on date 1

and on date 2, 3, 4

Available epochs 14

Show?	Epoch	RA	Dec	V_{mag}	Rate	Orientation	Area	Polygon
<input checked="" type="checkbox"/>	2019-02-10 15:21:02	10:52:54.816	-22:07:43.320	$20.4^{+0.3}_{-0.2}$	0.36	-51.1	0.04945	<input type="button" value="⊕"/>
<input type="checkbox"/>	2019-02-11 03:21:02	10:52:40.416	-22:04:13.800	$20.4^{+0.3}_{-0.2}$	0.39	-52.6	0.05296	<input type="button" value="⊕"/>
<input checked="" type="checkbox"/>	2019-02-11 15:21:02	10:52:26.352	-22:01:58.440	$20.4^{+0.3}_{-0.2}$	0.37	-50.3	0.05711	<input type="button" value="⊕"/>
<input type="checkbox"/>	2019-02-12 03:21:02	10:52:11.568	-21:58:48.000	$20.4^{+0.3}_{-0.2}$	0.41	-51.7	0.06137	<input type="button" value="⊕"/>
<input checked="" type="checkbox"/>	2019-02-12 15:21:02	10:51:57.048	-21:56:58.920	$20.4^{+0.3}_{-0.2}$	0.39	-49.5	0.0663	<input type="button" value="⊕"/>
<input type="checkbox"/>	2019-02-13 03:21:02	10:51:41.856	-21:53:38.400	$20.4^{+0.3}_{-0.2}$	0.43	-50.8	0.07138	<input type="button" value="⊕"/>
<input type="checkbox"/>	2019-02-13 15:21:02	10:51:27.024	-21:47:03.120	$20.4^{+0.3}_{-0.2}$	0.41	-48.7	0.07724	<input type="button" value="⊕"/>

Ephemerides + Velocity



GFSSO stations

- **Haute-Provence Observatory (OHP code 511)**

Joint programme GFSSO + Sc. Alerts (photometry SN, gravi. Lens,...)

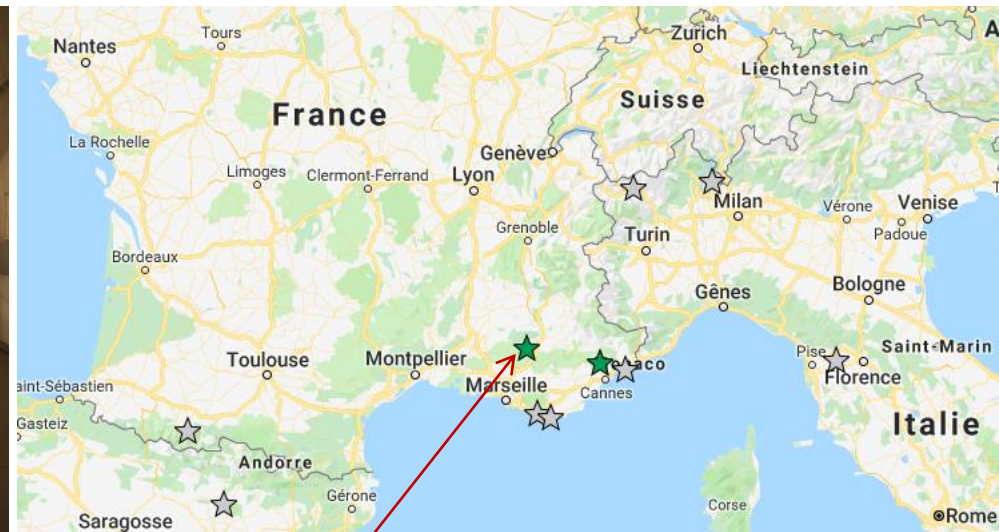
4 nights every 2 months

T 1.2m

« classical observations »



Credits: J. Desmars



OHP (France)

T1.2m

GFSSO stations

- **Haute-Provence Observatory (OHP code 511)**

Joint programme GFSSO + Sc. Alerts (photometry SN, gravi. Lens,...)

4 nights every 2 months

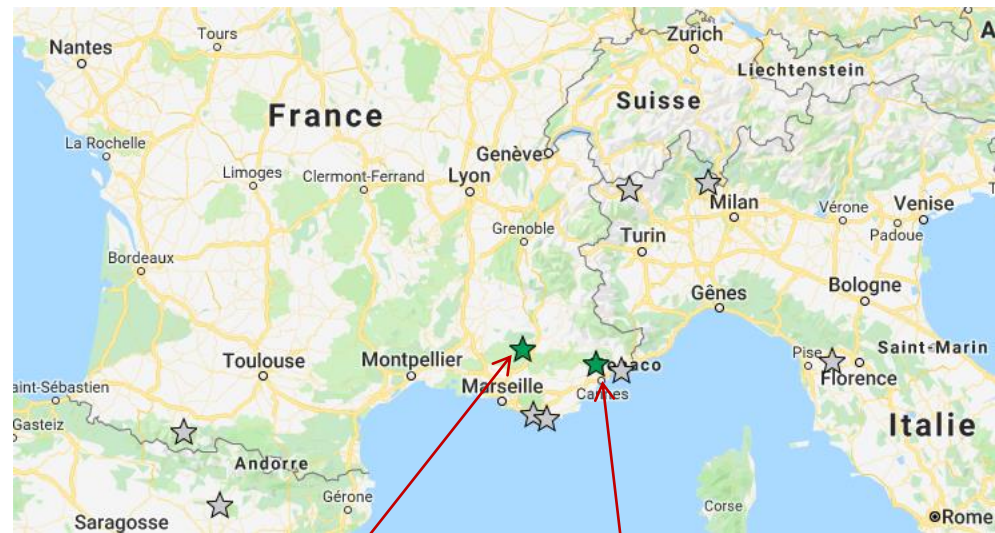
T 1.2m

« classical observations »

- **C2PU remote telescope (OCA Calern Code 010)**

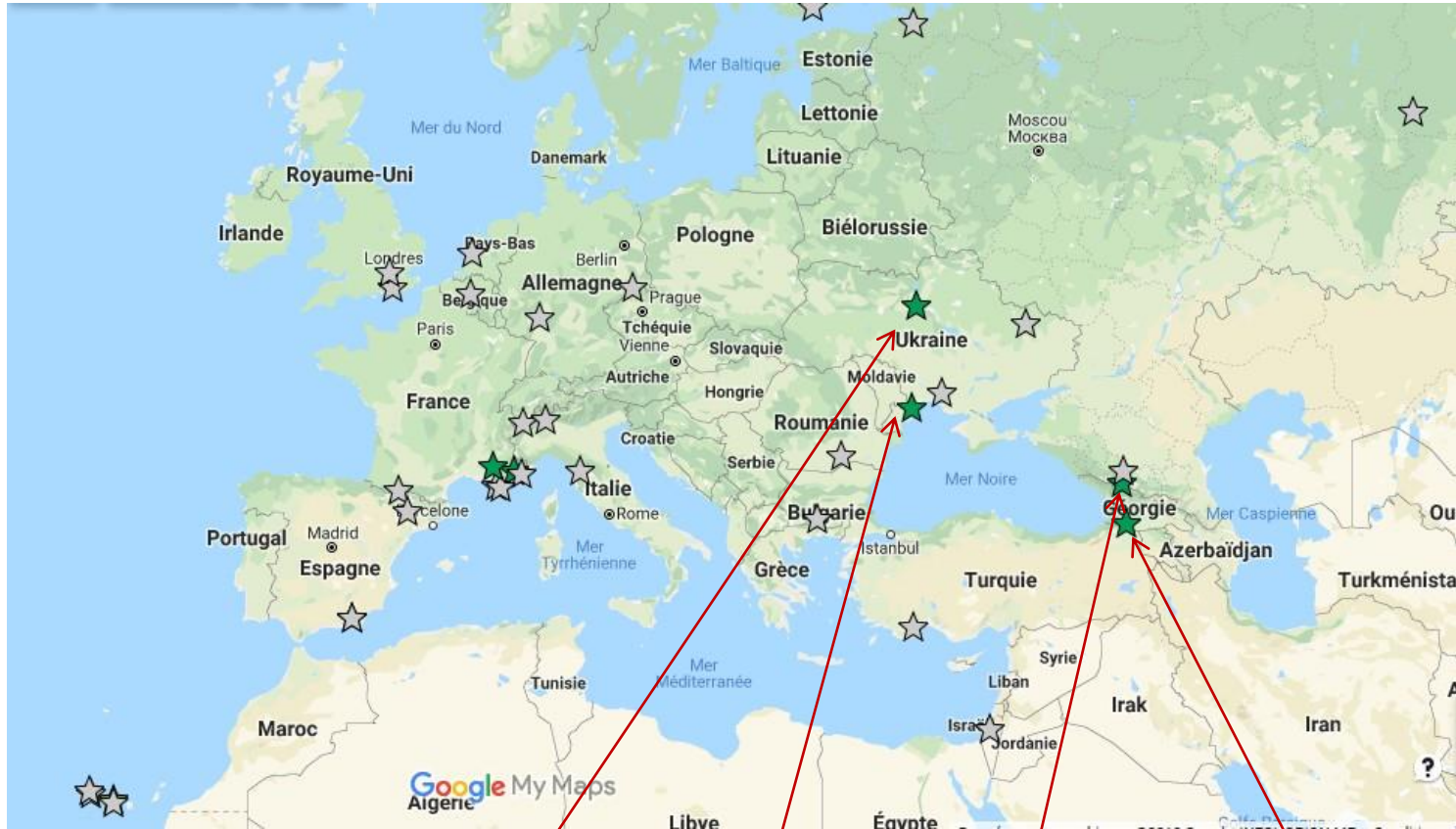
Observations in remote programme GFSSO

T 1.0m



OHP (France) T1.2m
C2PU (France) T1m

GFSSO collaborations



Kiyv Comet Station
(Ukr.)
T0.7m

Odessa obs. (Ukr.)
T0.8m

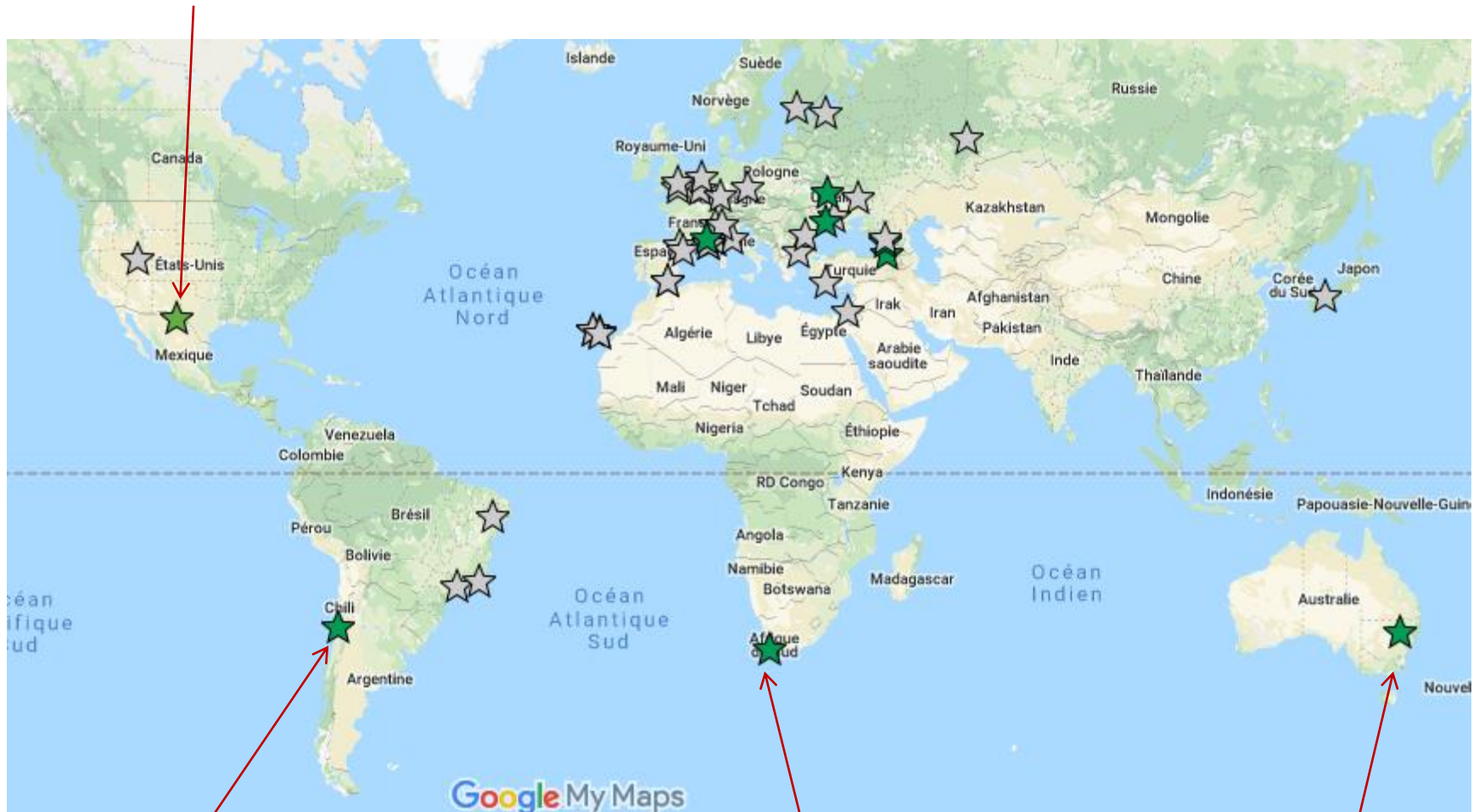
Terskol
(Russia)
T0.8m

Abastumani
(Georgia)
T1.2m & T0.7m

RAPAS Pro-Am activity Kick Off meeting

McDonald (USA, TX)
2 xT1m

LCOGT 1m robotic telescopes



Cerro Tololo (Chile)
3 xT1m

Sutherland (South Afr.)
3 xT1m

Siding Springs (Austr.)
2 xT1m

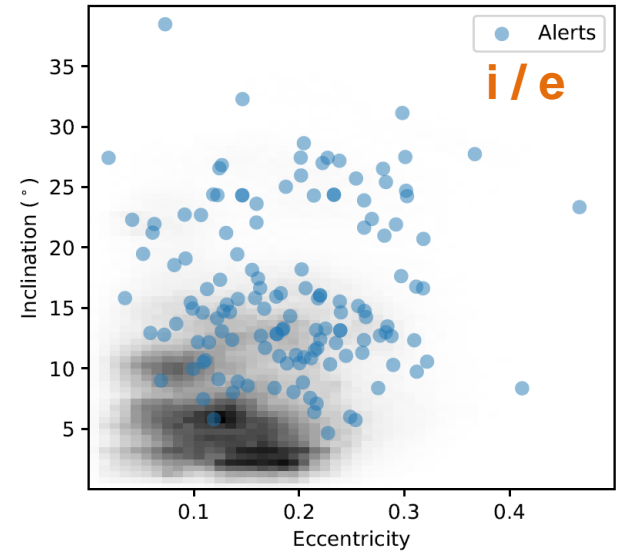
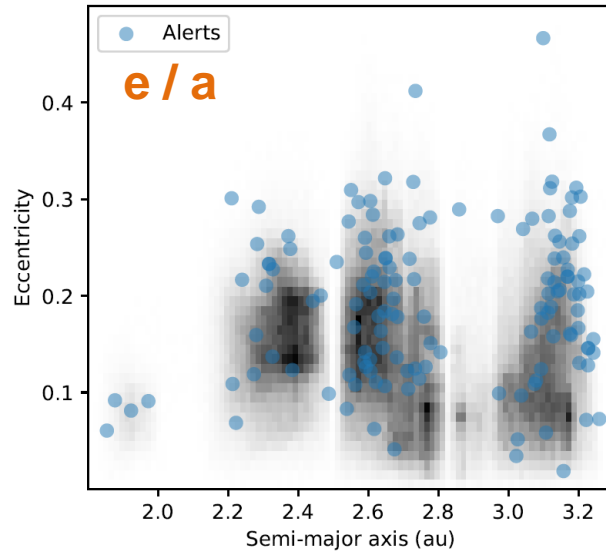
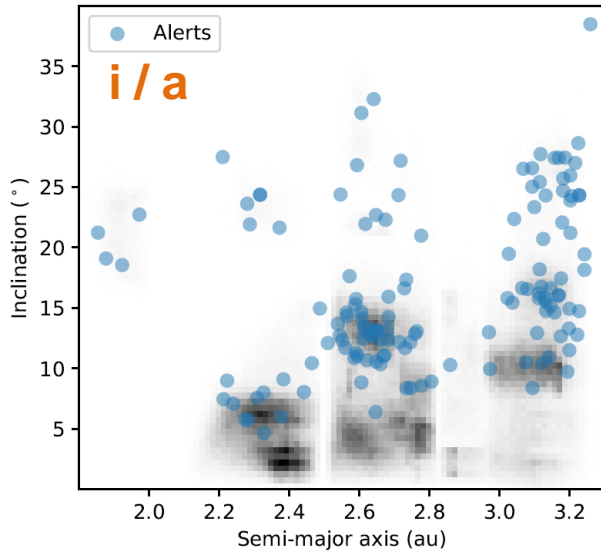
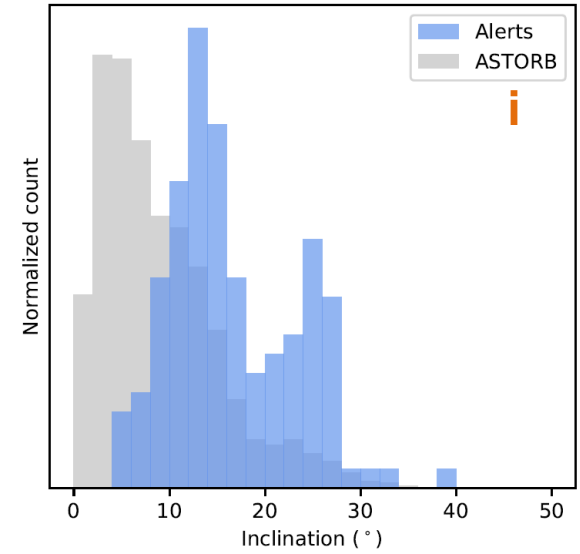
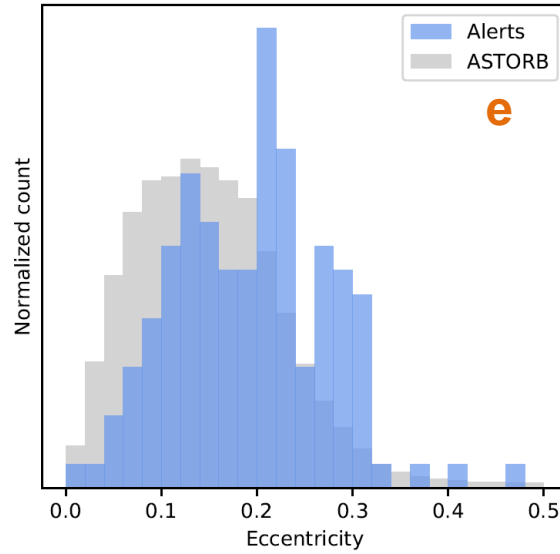
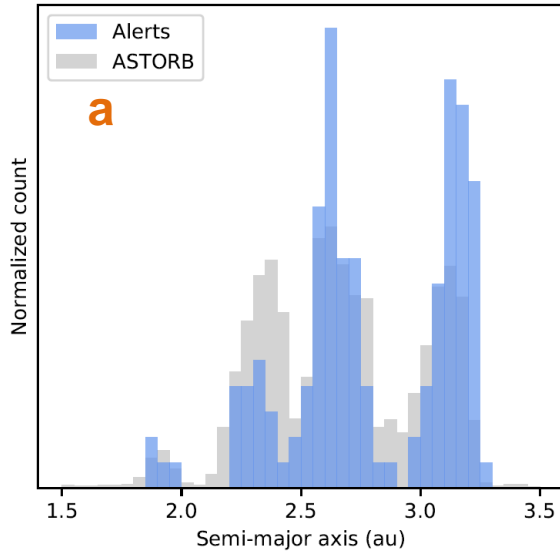


The results (sept. 2022)

- More than 400 objects detected on alert
- 75% performed at Las Cumbres (LCOGT)
- Almost 325 designations assigned by MPC
- 10% objects were « new » (days, weeks)
- A few will be assigned to Gaia
- Many objects are not new but very badly known (uncatalogued) or even lost

Gaia detections (blue) vs. ASTORB (grey)

(Carry et al. 2021)



Potential asteroid discoveries by the ESA *Gaia* mission

Results from follow-up observations

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K. Baillié¹, A. Baransky¹⁷, P. Bendjoya², M. Dennefeld¹⁸, J. Desmars^{1,19}, S. Eggel^{1,20}, V. Godunova²¹, D. Hestroffer¹,
R. Inasaridze^{15,16}, V. Kashuba²², Y. N. Krugly²³, I. E. Molotov²⁴, V. Robert^{1,19}, A. Simon^{25,26}, I. Sokolov²⁷,
D. Souami^{28,29}, V. Tarady²¹, F. Taris⁴, V. Troianskyi^{22,30}, V. Vasylenko^{25,26}, and D. Vernet²

(Affiliations can be found after the references)

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Summary

- SST works well up to 10 to 15 days after Gaia detection
- More than 400 detections of « new » asteroids (oct. 2022)
- Few Gaia discoveries + many re-discoveries
- Bias to high inclinations + outer main belt : poorly known population of asteroids + observational bias
- **Amateurs can make a valuable contribution**

Carry et al. : article to be published in A&A
accessible at <https://arxiv.org/abs/2010.02553>