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Foreword

This workshop was dedicated to the setting-up of a follow-up network for the Solar System Objects observed by the Gaia mission. After several years for getting in touch with candidate observers in many different countries, it was an important step aiming at accompanying this space astrometry mission all along its five year observation period. This workshop allowed us to know more on the status of the project, to propose a work flow for the processing of alerts, to get precise information on the observing sites and their specificities, to organize discussions and try to answer to some questions, to meet each other, to have fruitful exchanges and to simply reinforce the international collaboration. But most of all it was the opportunity to make this network active, and to foresee further actions. These proceedings provide a large overview of the communications and will be a reference document for the setting up and operation of the Gaia-FUN-SSO network. However, some open questions remains. Among them, the number of alerts is probably one of the most important unknowns, since it determines the work load to be carried on by the network, both by the central node and by the observing sites. Another important question appeared and could not be solved: the needs of funding for some observing sites. During the period of time before the launch of Gaia, we hope to get answers to these points.

We would like to thank all the participants to this fruitful meeting.

Paolo TANGA & William THUILLOT
Co-chair of the Gaia-FUN-SSO workshop

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Summary

Observation of NEOs Having High Apparent Rates with Mobitel Telescope

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Introduction

When NEO approaching to the Earth close then 0.05 AU its apparent rate begin increasing and magnitude begin decreasing rapidly by hyperbolic low. These dependences are shown on figures 1, 2, by the example of the two NEO observed in RI NAO. When small NEO close to the Earth it is observable for the small telescopes, but after going away it may become unobservable for the most of telescopes. Observations of NEO on short distances are valuable for the orbit determination. Increasing of NEO's apparent rate causes limitation of exposure time in case if telescope observe in star tracking mode. So the telescope's limited magnitude can't be reached. Not all telescopes are able to track NEO with two axles. Frames obtained while NEO tracking contain stretched images of stars. Stretched stars images and telescope movement with two axles while exposure time cause accuracy decreasing. An original combined observation method is used in RI NAO for observation of NEOs having apparent rate >10″/min without any telescope mechanical tracking. There are two telescopes in RI AO that can observe NEOs, fast moving near the Earth at distances 0.0002 ÷ 0.05 AU.

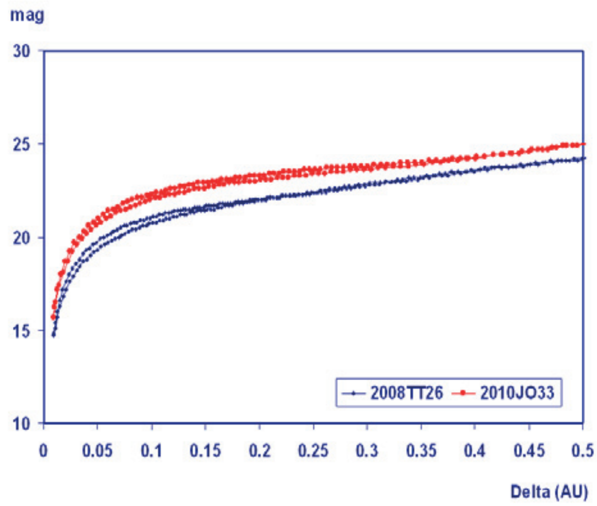

Fig. 1 – Magnitude decreasing from delta

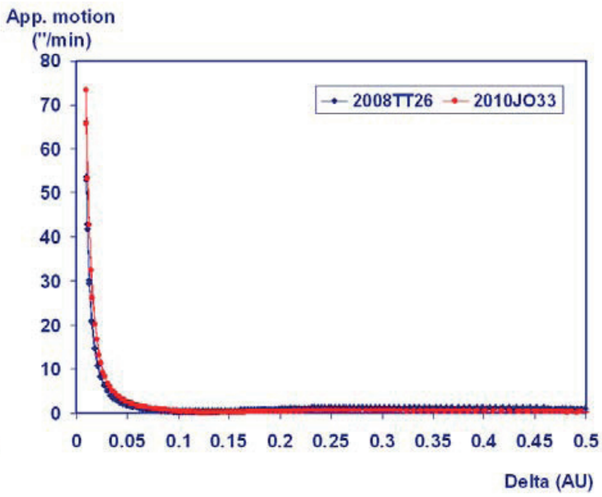

Fig. 2 – Apparent rate increasing

1. Original Combined Observation Method (COM)

The original Combined Observation Method (COM) is used for observation of objects having high apparent rates on stare telescope. COM use a filed de-rotator, a short TDI imaging technique and additional stars frames. COM is cost-effective for observations of Earth-orbit satellites on all orbit types and NEOs, fast moving near the Earth at distances 0.0002 ÷ 0.05 AU. The main advantage of COM is that astrometric accuracy and limiting magnitude do not depend on object apparent rate.

1.1 Short TDI imaging technique

The time delay integration mode (TDI) with a field de-rotators are used on all telescopes of RI NAO. The field de-rotator aligns CCD columns with object motion direction. This permit TDI imaging of objects with arbitrary motion direction (e.g. stars with the altazimuth mount type). In usual way of TDI imaging the object continue accumulating while passing through all of the field of view (FOV). This full exposure time can be excessive because of two big FOV size and nonlinearity of object trajectory (e.g. stars on big declination). A special "short" TDI imaging technique can be used to specify smaller exposure type. The short TDI imaging technique combines two processes:

1) TDI readout, during a specified exposure time;
2) Fast readout of all CCD matrix, like after stare integration.

The specified exposure time can be set from 0 to full TDI imaging exposure time. The usable height of obtained frame changes correspondently from the CCD matrix size to 0.

1.2 Additional stars frames

The frame imaged with the short TDI technique in synchronization with object sky speed looks like to be imaged while telescope object tracking. The TDI frame obtained on a fixed telescope is free of any mechanical motion irregularity. The images of stars are starched and their brightness became lower with object apparent rate increasing. To avoid the problem of starched stars image processing the additional frames with point like images of stars are used with different way of imaging. In case when the object sky motions direction close to the stars sky motion direction the short TDI imaging, synchronized with stars sky speed, is used. In other case stare integration imaging with very short exposure time is used.

Telescope is pointed to object's position on the sky with some advance and stays unmovable while imaging of a frame sequence: leading stars frame, object frame, following stars frame. Astrometry reduction of such frame sequence has some addition. The coefficients of the polynoms, calculated from the leading and following stars frames, are interpolated to the object frame.

2. Telescopes

FRT Telescope (D=30 cm, FOV 84'x84', 1.65"/pix) is a stationary telescope having equatorial mount. Mobitel Telescope (D=50 cm, FOV 42'x42', 0.83" /pix) is a compact telescope having azimuth mounting installed on trailer carriage. Both telescopes equipped with CCD camera Alta U9000 (3056 × 3056 12μ) and field de-rotator. Limiting magnitude (including NOEs having high apparent rates): Mobitel – 18 mag, FRT – 17 mag. Figures 3, 4 shows view of the telescopes. Both telescopes are located in the center of Nikolaev city at altitude 80 m, in conditions of light pollution. Mobitel Telescope was designed on the trailer carriage and it has an opportunity to be moved away from the city to a mountain region.

Fig. 3 – FRT Telescope

Fig. 4 – Mobitel Telescope

3. NEOs observation results

Observations of NEOs having high apparent rate are carried out in RI NAO since 2008. Residuals (O-C) were calculated with the JPL Solar System Dynamics ephemerides. Observation results for two telescopes are given in Tables 1, 2.

Table 1 – NEOs observed on FRT telescope

Object	App. rate ("/min)		Size (km)	Mag	Delta (AU)	Frames	Mean residuals O-C (")		RMS errors (")	
	α	δ					α	δ	α	δ
2005RC34	6.5	21.1	0.4-0.8	14.4	0.037	179	-0.11	-0.12	0.42	0.32
2008TT26	28.8	-36.0	0.05-0.12	14.7	0.010	75	0.04	0.01	0.41	0.23
2008SV11	15.0	-19.4	0.6-1.4	12.8	0.045	22	-0.25	-0.18	0.27	0.15
2005YU55	-61.2	21.5	0.1-0.3	15.3	0.016	29	0.03	-0.10	0.23	0.26
2010JO33	68.3	4.6	0.03-0.06	15.9	0.009	29	0.10	-0.20	0.38	0.26

Table 2 – NEOs observed on Mobitel telescope

Object	App. rate ("/min)		Size (km)	Mag	Delta (AU)	Frames	Mean residuals O-C (")		RMS errors (")	
	α	δ					α	δ	α	δ
1997GL3	2.0	9.5	~ 0.20	15.7	0.094	53	-0.13	0.14	0.19	0.18
1997GL3	2.9	12.6	~ 0.20	15.5	0.082	43	-0.07	0.21	0.11	0.10
1997GL3	4.3	17.0	~ 0.20	15.2	0.069	30	0.07	0.16	0.12	0.10
2000GC2	-3.6	3.4	1.0-2.3	17.7	0.438	7	-0.10	0.10	0.20	0.20
2000GC2	-3.7	3.3	1.0-2.3	17.7	0.438	26	-0.16	0.08	0.19	0.15
2005GE59	4.9	-0.5	0.7-1.6	17.4	0.270	14	-0.20	0.22	0.16	0.25
2005GE59	5.2	-0. 7	0.7-1.6	17.4	0.262	6	-0.14	0.11	0.27	0.42
2003UV11	-138	-13.5	0.4-0.8	12.0	0.014	16	0.88	0.34	0.38	0.17
2007VC138	7.3	-9.3	0.4-0.8	16.7	0.121	23	0.08	-0.50	0.25	0.18
2010VZ139	-44.4	-10.3	0.1-0.2	17.5	0.021	10	0.20	-0.42	0.16	0.19

Distributions of residuals (O-C) for FRT and Mobitel telescopes are shown on figures 5, 6. These observations results not been sent to Minor Planet Center, so they not affected JPL ephemerides. The residuals (O-C) probably will be smaller after taking into account of these observations results.

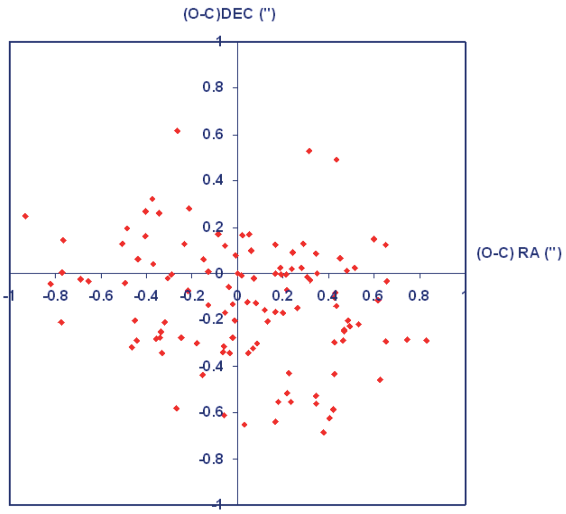

Fig. 5 – FRT residuals (O-C) (≤16 mag)

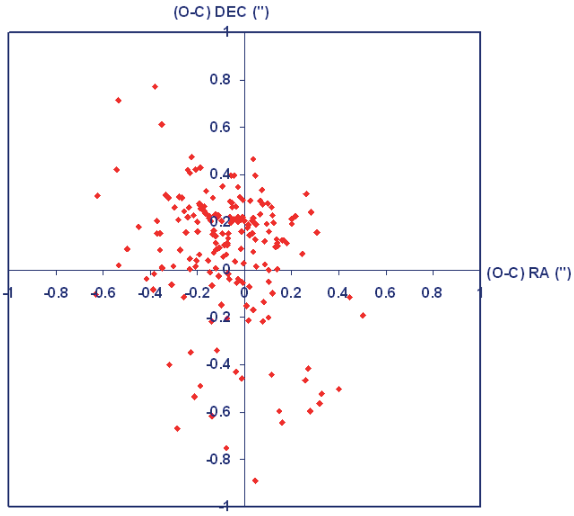

Fig. 6 – Mobitel residuals (O-C) (≤ 18 mag)

Conclusion

The original Combined Observation Method permits to create low-cost means for observation of Earth-orbit satellites on all orbit types and fast NEOs.

Despite the small diameters FRT and Mobile telescopes can observe NEOs which are hard for observation due to high apparent rate. Position accuracy (relatively to JPL ephemerides): FRT 0.25" – 0.55"; Mobitel 0.15" – 0.35".

Contribution of FRT and Mobitel telescopes to Gaia-FUN can be observations of just discovered NEOs, moving toward to the Earth at distances 0.0002 ÷ 0.05 AU. Limited magnitude of Mobitel telescope is 18 at present location in the center of Nikolaev city. Mobile telescope has a potential to be moved to a better astroclimate.