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DIVISION A / WORKING GROUP ASTROMETRY BY SMALL GROUND-BASED TELESCOPES

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TRIENNIAL REPORT 2018-2021

1. Introduction

The WGASGBT (Working Group on Astrometry by Small Ground Based Telescopes) was set up in 2006 during the XXVIth IAU General Assembly in Prague by the Division 1 (Fundamental Astronomy). Since then it has been successively extended. The last triennium extension by Division A occurred during the XXXth IAU General Assembly held in Vienna in 2018. The goal of this WG is to update and maintain information on astrometric programmes and activities carried out with small telescopes, to diffuse news through these pages and by e-mails, to facilitate the collaborations and to help for the coordination of the activities, when possible, in astrometry from ground-based telescopes of D $<$ 2 m. These telescopes are generally easier to access than larger ones and allow us to carry out observational programs on medium and long term. Thanks to that they are precious tools to contribute to the advance of our knowledge of the celestial bodies: many Solar System objects and some astrophysical objects. More generally, the small telescopes due to their number and their geographical spread, are very efficient for observation in

network. This is a strength which is successfully applied for coordinated programs. Here it follows a brief summary of this WG activities in the 2018-2021 triennium.

2. Developments within the past triennium

W. Thuillot reports that he and his colleagues at IMCCE, Paris Observatory, France, worked in the validation and follow-up of the Gaia discoveries of Solar System Objects, acquisition and exploitation of astrometric observations of natural satellites and set up of a new astrometric project by exploitation of old photographic plates. Their Gaia alerts Follow-Up Network, Gaia-FUN-SSO (Thuillot & al. 2018) continued to react on alert when new Solar System Objects are detected by Gaia. An alert pipeline is operating since the end of 2016 and transforms the Gaia space data into propagated topocentric data which are diffused at the address https://gaiafunsso.imcce.fr. The detection of more than 250 potentially new objects have already been reported and their astrometric data have been sent to the Minor Planet Center in order to feed the asteroid orbital database. Most of these objects were uncatalogued due to poorly known orbits, or even having been lost. The most productive observatories are the 1m class telescopes of the Las Cumbres Observatory Global Telescope network, Haute-Provence Observatory, Odessa-Mayaki, Terskol and Caussols (Carry & al. 2021, Thuillot & al. 2019, Carry & al. 2019, Thuillot & Dennefeld 2018). The data issued from the last campaign of observation of mutual events of the Galilean satellites, eclipses or occultations by satellites each other, coordinated by IMCCE and the Sternberg Astronomical Institute in Moscow have been analyzed (Saquet & al. 2018, Zhang & al. 2019). This kind of observations are photometric observations for astrometric purposes. They are performed by small telescopes and lead to very accurate astrometric measurements which are involved in the dynamical development of the natural satellite models. New predictions have been made and new campaigns are foreseen (Arlot & Emelyanov 2019). Besides, since several years we anticipated the use of the Gaia stellar catalogs to rereduced old photographic plates made with small telescopes, in the frame of the NAROO project (Arlot, Robert & Lainey 2018, Arlot & Robert 2019, Robert, Desmars & Arlot 2019). A sub-micrometric scanning machine has been set up in Paris Observatory for this goal and begun to operate in 2020.

N. Zacharias submitted a full report on US Naval Observatory activities for Comission A1 which does include topics for the WGASGBT. He recently released a public report about the 1-meter telescope of the USNO, the Deep South Telescope (DST), deployed at Cerro Tololo Interamerican Observatory (CTIO), Chile in March 2019. A 4k CCD camera will be used to image selected optical counterparts of ICRF sources which display significant radio-optical position offsets. This high cadence observing program is a joint effort between USNO and Paris Observatory. DST will also be used for other programs in the future, including near-infrared observations with a camera mounted at the 2nd Nasmyth focus.

F. Taris reports that quasar optical flux variations can alert us to potential changes in their source structure. These changes could have important implications for the position and time evolution of the target photocenters with consequences for the link of the reference systems (ICRF-Gaia CRF). For some targets well observed by the TAROT telescopes, the Allan time variance shows that the longest averaging period of the magnitudes is in the range 20-70 days. The observation period by Gaia for a single target largely exceeds these values, posing a problem when the magnitude variations exhibit flicker or random walk noises. Preliminary computations show that if the coordinates of the targets were affected by a white-phase noise with a formal uncertainty of about 1 mas (due to astrophysical processes that are put in evidence by the magnitude variations

of the sources), it would affect the precision of the link at the level of 50 μas (Taris & al. 2018). To improve these first results the SYRTE department of Paris observatory is involved in photometry measurements of AGNs (quasars) in the frame of several projects. They are performed with small (or medium) class telescopes in close collaboration with Belgrade, Côte d'Azur and Montsec Astronomical observatories. Magnitude time series are continuously acquired to improve our knowledge of the longest averaging period of the magnitude time series of AGNs. The laboratory is associated with the Fundamental Reference AGN Monitoring Experiment (FRAMEx) project lead by USNO. The goal is to observe the optical counterpart of radiosources at the same time than the VLBA and IR facilities. To observe a huge amount of targets on a daily basis, the laboratory initiated the construction of a 1 m robotic telescope. Half of the budget had already been obtained and the team plan to build the instrument before autumn 2021.

R. Teixeira reports local and remote (from Shanghai, China) observations of artificial satellites and space debris made in the past years with the MEADE 40cm of the Abrahao de Moraes Observatory of the University of Sao Paulo, Brazil. The observations were made with a CCD camera in drift scan mode coupled to a rotator developed by the Shanghai Observatory. These observations are part of a larger project in collaboration with colleagues from various institutions around the world for the astrometry of fast objects such as artificial satellites, debris and Near-Earth Asteroids. He also reports that the CCD Meridian Circle of that observatory is currently deactivated, but opened for public outreach.

T. Pauwels reports the activities at the Royal Observatory of Belgium. In 2017 the dome of the Ukkel Schmidt Telescope was restored, and during that period no observations were possible. After the telescope was available for observations again, the number of still to be discovered asteroids in the range of the equipment (magnitude limit 20-20.5) had decreased too much to justify the cost of the maintenance and to motivate the observers. No astrometric observations have been performed since then.

N. Maigurova and O. Shulga report regular astrometrical observations of small bodies of the Solar system (MBA, NEAs and comets), multiple stars and open clusters, GEO and LEO satellites and meteors carried out by small ground-based telescopes at the Research Institute Mykolaiv Astronomical Observatory. As a result of the observations, 2849 topocentric positions of 107 NEAs and 282 topocentric positions of 7 periodic and newly discovered comets were obtained during 2018-2020. The positions were sent to the IAU MPC database (code 089). Observations of more than 400 fields with open stellar clusters were performed during 2018-2020. A catalog of equatorial coordinates for more than 1 million stars was obtained with an average accuracy of about 50 mas in both coordinates for stars up to 16 V mag. Observations of more than 2000 WDS multiple and double systems were performed during this period. Results from the measurements of the mutual configuration parameters will be submitted to WDS database. Regular optical observations of the low and geostationary satellites were carried out during 2018-2020. Processing of the observations resulted in orbital elements for these objects, which were published on the website http://umos.mao.kiev.ua/eng/index.php?slab=slabid-12. Double station meteor observations in the optical band were performed during this period. A catalog of kinematic parameters of atmospheric trajectories and heliocentric orbital elements for 1055 meteoroids was obtained. A Monte-Carlo method was implemented for the estimation of the accuracy of the heliocentric orbital elements. The velocity accuracy was about 0.5 km/s, while the height accuracy varied from 50 to 150 m.

Anatoliy Ivantsov reports activities supported by the Akdeniz University, Antalya, Turkey during the triennium. It hosted the international workshop meeting Dynamics and Physics of Asteroids, TNOs and Natural Satellites in the New Era of Gaia Data

(https://asteroid2019.space) on September 4-6, 2019. There were three sessions: Dynamics of Small Bodies, Sky Surveys from Space and from the Ground and Observations of Small Bodies, where numerous achievements in astrometry, photometry, spectroscopy, polarimetry were presented and discussed. The SOC comprised of two members of this WG (W. Thuillot and A. Ivantsov). There were more than 30 participants with 60% from Austria, China, France, Italy, Russia, Ukraine, UK, and USA. An observational programme devoted to characterizing the potentially hazardous asteroids and study their dynamics was initiated at the UBT60 telescope (D=0.61 m, F=3.96 m) of the Akdeniz University located at the Tubitak National Observatory site (A84). The telescope operated remotely is equipped with standard Johnson-Cousins UBVRcIc and SDSS filters and a new FLI Proline 16803 CCD (4096x4096, 9μm x 9μm) installed in 2019.

M. Assafin and R. Vieira Martins report on the astrometric and photometric use of 0.6m to 2.2m class telescopes at Brazil, Chile, Australia, France and Spain. They report the first observation of a stellar occultation (SO) by the Galilean satellite Europa (Morgado & al. 2019a), the observation of mutual approximations between the main satellites of Jupiter (Morgado & al. 2019b) and Uranus (Santos Filho & al. 2019), a SO by the irregular satellite Phoebe of Saturn (Gomes-Júnior & al. 2020), and SOs by Trojan asteroids of Jupiter, Centaurs (including the ringed object Chariklo), dwarf planets and many other transneptunian objects (Camargo & al. 2018). Regular astrometric observations of natural and irregular satellites of giant planets were also done with these instruments. A FRIPON camera (Colas & al. 2020) was installed and is operational at the Observatório Nacional do Rio de Janeiro, Brazil, for automatic monitoring of incoming meteorites that penetrate the Earth's atmosphere. They also report an initivative to form an astrometric/photometric network of tens of small 40-50 cm aperture telescopes in Brazil and South America - ROSA (South America Occultation Network in english) - in support but not limited to the observation of SOs by Solar System bodies, education and scientific outreach.

G. Damljanovic from the Astronomical Observatory at Belgrade (AOB), Serbia, reports that his team established a local Serbian-Bulgarian mini-network of six telescopes (lead by G. Damljanovic) at three sites: Belogradchik AO and Rozhen NAO in Bulgaria, and Astronomical Station Vidojevica (ASV) in Serbia. They observe QSOs, objects from alerts by the Gaia-FUN-TO (Gaia Follow Up Network for Transients Objects) and blazars from alerts by the WEBT-GASP (Whole Earth Blazar Telescope Project), among other objects. Near 100 ICRF QSOs, about 20 WEBT objects and about 75 Gaia Alerts were observed. About the SANU-BAN cooperation (between the Serbian Academy of Sciences and Arts and Bulgarian Academy of Sciences), there are two joint research projects underway on the observation of ICRF and Gaia radio-sources and fast variable objects, lead by G. Damljanovic. The synergy between Gaia and ground-based observations is of big importance, and it is in line with the Serbian-Bulgarian astronomical cooperation and investigation using our mini-network of six telescopes. It is important to align the Gaia frame (based on optical data) and ICRF (VLBI data) through observations of QSOs in both visible and radio domains, with a compact radio/optical core but without complex structures. Using the mini-network, the team monitors some QSOs and check the optical data (position stability and structure) via photometry and morphology investigations. The 2 m Rozhen and 1.4 m ASV telescopes are used in the QSO morphology investigations, and other telescopes (60 cm ASV, 60 cm Belogradchik, 60 cm Rozhen, and Schmidt-camera 50/70 cm) are used for photometry to investigate QSOs quasi-periodicities. The WEBT is a network for optical, near-infrared, and radio observations to obtain continuously, high-temporal-density monitoring of blazars. The WEBT data are extremely useful to understand the continuum emission of blazars. Gaia Alerts

have been issued by the Gaia Science Alerts group, and Gaia is now the largest provider of transients in the world (rare types of supernovae, cataclysmic variable, microlensing events, etc.) with about 2000 alerts per year. Using our telescopes for simultaneous observations we can get data for multi-color photometric light curves and investigate fast changes on the flux of the objects. The investigations involved the reduction of CCD images for photometry/morphology, calculation of BVRI magnitudes (photometry, quasi-periodicities), determination of QSOs parameters using GALFIT software (morphology), the improvement of some steps and methods (during reduction of raw CCD images) to remove systematic errors and to get accurate data as much as possible, the development of new methods to get precise results, and the analysis of these results. The team collaborates with the Observatoire de Paris, Torino Observatory, among others. Some of our results have been published in several journals: MNRAS, Astrophysical Journal, Astrophysical Journal Letters, Astronomical Journal, Serbian Astronomical Journal, Astronomy and Astrophysics, etc. Also, some results were presented at a few conferences, and published in the Bulgarian Astronomical Journal.

3. Closing remarks

Telescopes with D $<$ 2m remain quite necessary to perform alert observations and long term campaigns, which are otherwise very difficult or even impossible to be carried out with larger instruments. Take as examples the successful Gaia-FUN-SSO activity on alert for asteroid discovery, and the astrometry of natural satellites for dynamics and ephemerides. The efficiency of small instruments is steadly enhancig thanks to growing investments in high-sensivity detectors by the observatories and visitor observers. Moreover, the data releases of the Gaia mission are bringing a remarkable improvement in the astrometry with small telescopes. Our WG is a useful tool to diffuse information among astrometry groups. The WGASGBT has actively facilitated the exchange of information and the coordination of campaigns and setup of telescope networks. Plans are being made to further improve our WG efforts toward these goals. We encourage the reader to visit our continuously refreshed webpage at https://iau_wgnps.imcce.fr for more historic and updated reports on the activities of this WG.

Marcelo Assafin & William Thuillot
Chair and vice-Chair of Working Group

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