IAU Commission A1 - Astrometry

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Annual Report 2016

Gaia mission

The first release of Gaia data (Gaia DR1, Gaia Collaboration et al 2016) took place on September 14 2016. This first Gaia catalogue consists of 1.1 billion sources to magnitude 20.7 for which positions are provided with typical uncertainties of 10 milliarcsec. For a subset of about 2 million sources from the Hipparcos and Tycho-2 catalogues proper motions and parallaxes are provided with a typical uncertainty of 1 milliarcsec/yr and 0.3 milliarcsec, respectively.

Gaia DR1 represents a large step forward in the densification of the astrometric reference frame in the optical at faint magnitudes, and has consequently already been employed as the reference positional catalogue for several other large surveys (see below). The radio positions of around 2000 ICRF2 sources were compared to the optical positions from Gaia (Mignard et al 2016). No systematic differences larger than a few tenths of amilliarcsec were found. For most sources the true offsets are likely to be less than 1 mas. This is a very encouraging result in connection with the efforts to develop multi-wavelength realizations of the ICRS.

The optical tracking of the position of Gaia on the sky was continued throughout 2016 by the GBOT (Ground Based Optical Tracking). The aim is to get an optimized position of the satellite with respect to the surrounding stars. The observations are made with the help of CCD frames taken at the focus of T1-2m class telescopes located at various places in the world. The requirements for the accuracy on the satellite position determination, with respect of the stars in the field of view, are 20 mas (corresponding to 150 meters at the distance to Gaia). This accuracy is necessary to correct at best the relativistic aberrations as well as the parallax effects of solar system objects. More specifically the "Data Storage and Processing center of Gaia - GBOT" is sub-group located at Paris Observatory in charge of the GBOT database and image reductions programs specifically adapted for tracking moving objects. In 2016, about 3200 frames of Gaia satellite have been reduced

Reference frame sources

The LQAC (Large Quasar Astrometric Catalogue) is a general compilation of all the recorded quasars, coming from large surveys (SDSS, 2DF, ...) as well as from small ones. It contains various original information (when available) such as the most accurate equatorial coordinates, the red-shifts, multi-band magnitudes, radio-fluxes. Moreover, it provides supplementary data such as absolute magnitudes and morphology index. A new up-date of the catalogue, the LQAC-4 was in preparation in 2016, following on from the LQAC-2 (2012) and the LQAC-3 (2015). As a new important input this update will contain the cross-

identifications with the Gaia DR1 catalogue. The publication of the LQAC-4 is scheduled for 2017. It will contain 443725 objects with 248788 cross-matched with Gaia DR1.

A specific photometric study of ICRF quasars in R and V bands (Taris etal., 2016) was done in order to determine the flux variability of a set of 14 ICRF quasars pre-selected for the link between the ICRF and the future Gaia Celestial Reference Frame. High frequency light-curves of each quasar of the set were constructed, together with a periodogram analysis proving periodic or quasi-periodic phenomena. This variability should be accompanied with displacements of the photocentre and thus should have consequence on the astrometric quality. This deserves further investigation.

Ground based astrometry

Altmann et al. generated a new proper motion catalogue of 580 million stars (HSOY) by combining Gaia DR1 data with re-reductions of PPMXL (arXiv:1701.02629).

The URAT Parallax Catalog (UPC) by Finch and Zacharias was published (arXiv:1604.06739, CDS I/333). It contains first trigonometric parallaxes of over 53,000 nearby stars along with URAT parallaxes of over 58,000 previously known nearby stars.

A re-reduction of the UCAC data was performed to obtain new proper motions of over 107 million stars (UCAC5) by combining with Gaia DR1 data (Zacharias, Finch, Frouard 2017 submitted). This extends Gaia DR1-level precision of proper motions to about magnitude 14, with somewhat poorer data to R=16.

The USNO redlens astrograph (URAT project) continues to observe from Cerro Tololo, focusing on bright stars (Sirius to 6th mag). UCAC5 is used as reference star catalogue, which in turn is based on Gaia data.

The first Pan-STARRS data release (PS1) was prepared during 2016. The data are available through the MAST Portal of the Space Telescope Science Institute (STScI) since Feb 2017. The survey is described by Chambers et al. (arXiv:1612.05560), http://panstarrs.stsci.edu/.

Regular operation of the VLBI Exploration of Radio Astrometry (VERA) array continued in 2016. Astrometric observations of Galactic masers were conducted for approximately 1800 hrs. Astrometric observations for 150 maser sources were completed, and parallaxes were derived for 86 maser sources (71 star-forming regions and 15 late-type stars). In 2016, the parallaxes and proper motions have been reported for several Galactic maser sources such as S255 (Burns et al. 2016), M17 (Chibueze et al. 2016), FV Boo (Kamezaki et al. 2016a), U Lyn (Kamezaki et al. 2016b), and R UMa (Nakagawa et al. 2016). Also, Yamauchi et al. (2016) demonstrated that even for sources at a distance of ~20 kpc, a relatively accurate distance can be estimated based on proper motions when combined with the Galactic rotation law. This new approach will be of help to explore the structure of the Galaxy where parallax measurements are not currently available. Oyama et al. (2016) demonstrated the capability of simultaneous observations of SiO (J=1-0) maser lines at four transitions (28SiO v=1,2,3 and 29SiO v=1).

The resources of the Korea-Japan joint array (KaVA: KVN and VERA Array) and East Asian VLBI Network with participation of China, Korea and Japan were joined. Test observations have been conducted with these arrays including evaluation of astrometric performance with an eye toward future astrometric with this extended array.

Steps toward future astrometric observations with SKA were taken through the demonstration of high precision radio astrometry at low frequency bands using the existing VLBI arrays such as the VLBA (Rioja et al, arXiv:1612.02554). It was confirmed that astrometry with an accuracy of at least a 100 microarcsec level is technically feasible for astronomical maser sources and that reaching the 10 microarcsec level accuracy is feasible.

Space astrometry missions

A proposal for the extension of the Gaia mission beyond its nominal five years' duration (to mid-2019) was submitted to ESA. Current estimates are that Gaia can continue collecting observations until the end of 2023, the only limitation being the propellant for the micro-thrusters that are used to accurately maintain Gaia's attitude and spin-rate.

The proposal for the Theia mission was submitted to the ESA/M5 call for missions. It aims at differential microarcsec astrometry with the goals of studying the nature of dark matter and the equation of state of matter in extreme environments, and finding habitable Earths (http://www.obs.u-bordeaux1.fr/m2a/krone/Theia/).

A proposal was submitted to ESA to initiate industrial scientific studies into the developments needed to realize a future Gaia-like mission operating in the near-IR (in particular operating infrared sensitive detectors in TDI mode). The goal is to open up the large discovery space accessible through high accuracy astrometric measurements in the infrared (Hobbs et al, arXiv:1609.07325).

In Japan, the efforts on the JASMINE mission continued. JASMINE is an abbreviation of Japan Astrometry Satellite Mission for Infrared Exploration.

Three satellites are planned as a series of JASMINE projects, as a step-by-step approach, to overcome technical issues and promote scientific results (Gouda 2011, Gouda 2012). These are Nano-JASMINE, Small-JASMINE and (medium-sized) JASMINE. Nano-JASMINE will operate in the zw-band (0.6-1.0 micron). The target accuracy of parallaxes is about 3 milliarcsec at zw=7.5 mag (Kobayashi et al. 2011). By combining Nano-JASMINE measurements with Hipparcos positions accurate proper motions (to about 0.1 milliarcsec/yr) can be derived. Although the flight model of Nano-JASMINE is ready, the search for a suitable launch opportunity is still ongoing.

Small-JASMINE will determine positions and parallaxes accurate to 20 microarcsec for stars towards a region around the Galactic nuclear bulge and other small regions which include scientifically interesting target stars (e.g. Cyg X-1), brighter than Hw=11.5 mag (Hw-band: 1.1-1.7 micron). Proper motions of between 10 and 50 microarcsec/yr are expected. The survey will be done with a single beam telescope of which the diameter of the primary mirror is about 30 cm (Yano et al. 2011). The target launch date is around 2021. The proposal for Small-JASMINE was ranked highest by JAXA in terms of scientific quality and technical feasibility.

The outcome of the mission design review is expected in 2017.

(Medium-sized) JASMINE is an extension of Small-JASMINE, which will observe almost the whole region of the Galactic bulge with accuracies of 10 microarcsec in Kw-band (1.5-2.5 micron). The target launch date is the 2030s.

Additions

- Two major meetings draw together the astrometric community in South America, the LARIN 2016 (XV Latin American Regional IAU Meeting; October 3-7) and the AdeLA2016 (Astronomia Dinámica en Latino América; September 28-30. Both were held in Colombia, the first in Cartagena, and the second in Bogota.
- The relatively rare transit of Mercury over the Sun, 09 May 2016, was full visible across most South-America, and followed by many teams of the region.
- Including several countries in South America (Argentina, Bolivia, Brazil, Uruguay) independent cooperations, with groups from Russia, Europe, and China are increasingly using existing small telescopes, or new, dedicated ones for programs of Space Debris discovering and surveying.
- Brazil In Brazil, a cooperation between Observatorio Nacional and the Shanghai Astronomical Observatory is conducting a double program aiming not only at Space Debris, but also to the BEIDOU Chinese GNSS cloud. Beyond the existing RIOS iGMAS/BEIDOU station, studies were concluded to install a fundamental station over the Equator line, in the Brazilian state of Para.
- Also including several South America researchers, including the support of the most committed amateur groups, the program of asteroid occultation continued very strong. The program uses the GDR1 positions and the Gaia early announcements.
- Chile Astrometry played the key part in the Pale Red Dot program, which includes a team from several institutions around the world. The most publicized result was the discovering of the signature of an Earth-like planet around Proxima Centauri.
- Chile Further analysis of the Bayesian Cramér-Rao lower bound in astrometry, by a team from Universidad de Chile, keep bringing forth what can be actually expected from ground base astrometry.
- Argentina Directly related to one of the major astrometry achievements in 2016, the Gaia GDR1, it must be highlighted the Malargüe (Argentina) is one of the two stations used to communicate with Gaia, and also used to receive the data packets.