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DIVISION I COMMISSION 8 ASTROMETRY *(ASTROMETRIE)*

PRESIDENT	**Dafydd Wyn Evans**
VICE-PRESIDENT	**Norbert Zacharias**
PAST PRESIDENT	**Irina Kumkova**
ORGANIZING COMMITTEE	**Alexandre Andrei, Anthony Brown, Naoteru Gouda, Petre Popescu, Jean Souchay, Stephen Unwin, Zi Zhu.**

PROCEEDINGS BUSINESS SESSION, 27 August 2012

1. Business session (Chair D. W. Evans)

The business meeting was opened by the President, Dafydd Evans, who presented the agenda, which was approved. It was agreed that Norbert Zacharias should be the secretary of the meeting and take the minutes. This session was attended by about 20 participants.

1.1. *Commission Members*

Evans reported that the Commission has 251 members from 36 countries as of August 14, 2012. A total of 3 new members joined the Commission over the last triennium from existing IAU members and 50 new IAU members chose to join Commission 8 for the next triennium. With a minute of silence, Commission 8 paid tribute to 4 members who had died since the last General Assembly:

Lyssimachos Mavridis
Ernst Raimond
Klaus Guenter Steinert
Hans Walter

1.2. *New Commission Officers*

The result of the selection procedure for the next triennium was:

N. Zacharias (USA)	President
A. Brown (Netherlands)	Vice-president
D. Evans (UK)	Ex-officio
N. Gouda (Japan)	2009–2015
J. Souchay (France)	2009–2015
S. Unwin (USA)	2009–2015
L. Chen (China)	2012–2018
V. Makarov (USA)	2012–2018
O. Shulga (Ukraine)	2012–2018
R. Teixeira (Brazil)	2012–2018

No objections were raised.

Thanks were expressed to the retiring Commission Officers:

Alexandre Andrei (Brazil)
Irina Kumkova (Russia) – past president
Petre Popescu (Romania)
Zi Zhu (China PR)

1.3. *Website, Newsletters and Meetings*

The main activity of the Commission was through the website, newsletters and meetings. It was noted that for the next triennium the Commission website will remain at `http://www.ast.cam.ac.uk/ioa/iau_comm8/`. A total of 6 newsletters were published over the past triennium. The general feeling was that this was about the right number.

Although no specific Commission 8 meetings were held during the last triennium, this was not regarded as an issue, since we hold science sessions at General Assemblies. The one for this meeting was held on 29 August

1.4. *Commission Activities 2009–2012*

The Triennial Report was written in 2011 and will be published in Transactions IAU XXVIIIA. The Commission 8 contribution covered 12 pages. Evans thanked the National Representatives who collated the submissions.

Evans summarized the highlights of the past triennium activity that went into this report:

- Gaia continues development, with a scheduled launch in 2013. The expected parallax accuracies are 10 to 300 μas for 6 to 20 magnitude.
- ICRF2 was adopted by IAU in 2009.
- UCAC4 was completed, with over 100 million stars, Zacharias distributed DVDs of the catalogue during the meeting.
- The JASMINE project continues with the completion of the NanoJASMINE payload.
- The PPMXL and XPM catalogues were released.

Unfortunately, on a negative note, the SIM project was cancelled by NASA.

1.5. *General discussion*

Evans said that the current practice in Commission 8 is that the OC elects the Vice President and OC of the Commission. This Vice President becomes President in the following triennium. This ensures a balanced geographic representation within the OC of the Commission. The IAU would like a wider voting procedure. A recent member-wide vote for the Division I VP had only a 25% turnout, i.e. members in general do not seem to be interested in voting. Other commissions are in a similar position to us. What do we want to do? The following specific opinions were given:

William van Altena: Geographic representation is very important and will likely not occur in the case of general voting.

Brian Mason: Commission 26 (double stars) has all members voting, and up to now gets a good geographic representation. This is because members understand the need for a good geographic representation and vote accordingly.

Nicole Capitaine: it is important to have the same rules for all Commissions, and each Commission needs to have their terms of reference.

Dafydd Evans: considering the overall feeling of the meeting, shall we keep the status quo in Commission 8 for now? No objections were raised. How to proceed will depend on the IAU's instructions and what the situation will be like in 2.5 years, when the next set of voting will occur.

1.6. *Any Other Business*

Evans asked for ideas for new Working Groups. There were no suggestions.

Regarding new meetings, it was felt that astrometry is usually well covered between the IAU GA Commission 8 science sessions and Journées meetings in the years between GAs. However, an IAU Symposium for the next GA will be considered, given the fact that Gaia will be close to publishing first results at that time.

Evans will send notes regarding Commission timeline, newsletters etc. to Zacharias and Brown to assist in running the Commission.

van Altena announced the upcoming book "Astrometry for Astrophysics", Cambridge University Press, Autumn 2012.

2. Science Session (29 August 2012) (chair A. Brown)

The following presentations were given during the meeting. Summaries are given here from the abstracts. All of the presentations can be found on the meeting website:
`http://www.ast.cam.ac.uk/iau_comm8/iau28/`

2.1. *Astrometry with Gaia: what can be expected?*
J.H.J. de Bruijne (ESA/RSSD/SRE-SA)

Gaia is the next astrometry mission of the European Space Agency (ESA), following up on the success of the Hipparcos mission. Gaia's primary science goal is to unravel the kinematical, dynamical, and chemical structure and evolution of the Milky Way. In addition, Gaia's data will touch a wide variety of science topics, e.g., stellar physics, solar-system bodies, fundamental physics, and exo-planets. With a launch in the second half of 2013, the final catalogue is expected in 2021 – the first intermediate data release is envisaged to take place some two years after launch. Gaia will survey the entire sky and repeatedly observe the brightest 1,000 million objects, down to 20th magnitude, during its 5-year lifetime. Parallaxes will be measured with standard errors less than 10 micro-arcsecond (μas) for stars brighter than 12th magnitude, 25 μas for stars at 15th magnitude, and 300 μas at magnitude 20. The properties of the final astrometric catalogue depend, among others, on the adopted scanning law and on the payload-operation and on-ground calibration concepts, in particular the calibration of radiation-induced systematic effects in the data. The importance of these elements is highlighted. In addition, this presentation focuses on expected correlations and systematic errors in the data and on the expected astrometric performance of Gaia in high-density regions on the sky.

2.2. *Resolved Astrometric Binary Stars*
Brian Mason (USNO)

The resolution of binaries first detected astrometrically has a long history. In the early 19th Century Friedrich Wilhelm Bessel found periodic oscillations in the motions of Sirius and Procyon and reported them in a letter to Humboldt in 1834. The large flux ratio and much smaller mass ratio made these the easiest pairs to detect astrometrically. However, the large magnitude difference made resolution difficult and it was not until Alvan Clark and sons built two of their large refractors that this was accomplished. Sirius B was seen by Alvan G. Clark at the end of January 1862 testing the Dearborn

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18.5" instrument and Procyon B was first seen by John Schaeberle in 1896 with the Lick 36" telescope. While pairs of this extreme flux ratio will continue to be a problem for resolution, the situation has improved markedly with smaller flux ratios being detected astrometrically with improvements to accuracy and precision of wide-angle astrometry. Also, new techniques and enhanced resolution capability for narrow-angle astrometry has allowed these pairs to be more easily resolved. The complimentary nature of these disparate techniques is exemplified with the new relative solutions of the astrometric binaries kappa For and HIP 42916 recently presented (Hartkopf *et al.* AJ 143, 42; 2012). A single resolution of a binary with an astrometric orbit allows for the determination of the relative orbit by scaling the a_{phot} to a'' appropriately. If the Δm and parallax is known, individual masses will also be forthcoming. Solutions of binaries of these type were presented.

2.3. *Present status of JASMINE projects*
Naoteru Gouda (National Astronomical Observatory of Japan)

The present status of the JASMINE projects were given:

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. These are Nano-JASMINE, Small-JASMINE and (medium-sized) JASMINE.

Nano-JASMINE uses a very small nano-satellite and is scheduled to be launched in November 2013 at the Alcantara space centre in Brazil by a Cyclone-4 rocket developed in Ukraine. Nano-JASMINE will operate in the zw-band (0.6–1.1 micron) to perform an all sky survey with an accuracy of 3 mas for position, parallaxes and proper motions. Moreover, high-accuracy proper motions (0.1 mas/year) can be obtained by combining the Nano-JASMINE catalogue with the Hipparcos catalogue.

Small-JASMINE will observe towards a region around the Galactic centre and other small regions, which include interesting scientific targets, with accuracies of 10 to 50 μas in an infrared Hw-band (1.1–1.7 micron). The target launch date is around 2017.

(Medium-sized) JASMINE is an extended mission of Small-JASMINE, which will observe towards almost the whole region of the Galactic bulge with accuracies of 10 μas in the Kw-band (1.5–2.5 micron). The target launch date is the first half of the 2020s.

2.4. *Parallaxes of five L dwarfs from a robotic telescope*
Youfen Wang (Shanghai Astronomical Observatory)

A report was given on the parallax and proper motions of five L dwarfs obtained with observations from the robotic Liverpool Telescope. These parallaxes represent new values and they are used to discuss the physical properties of L dwarfs. The derived proper motions are consistent with the published values and have considerably smaller errors. The objects appear to be normal L dwarfs, with space velocities that locate them in the disk and with normal metal abundances according to spectroscopic and model comparisons. For all five objects, effective temperature, luminosity, radius, gravity and mass from evolutional model were derived. The effective temperature were derived combining observational optical and NIR spectra with model synthetic spectra for three of the L dwarfs. The degeneracy of temperature, gravity and metallicity was found in affecting the absorption line strength through comparison among model spectra and among observational spectra. This robotic telescope was convenient in doing the parallax program which need a lot of repeated observations. Such robotic telescopes are able to enhance the efficiency of parallax programs, thus they are continuously needed in future.

2.5. *The NPARSEC Program Data Reduction Procedures.*

Catia Cardoso, NPARSEC Collaboration (Osservatorio Astrofisico di Torino)

The NPARSEC (NTT PARallaxes of Southern Extremely Cool objects) program determines parallaxes of about 80 objects covering the T dwarf spectral range. The areas of research directly impacted by this sample will be widespread. On an individual object basis, distances are key for assignments of binarity, metallicity and gravity and more generally the sample will provide key input for the substellar luminosity and mass functions, the connection to exo-planetary models as well as complex atmospheric processes such as non-equilibrium chemistry and turbulent mixing. Eventually these objects will provide new insights into the history of our galaxy, the kinematics of the solar neighbourhood and our understanding of differing formation scenarios from stars to brown dwarfs to giant planets. Particular attention was paid to the observational and data reduction procedures adopted with an emphasis on the centroiding, which is fundamental to the final astrometric precision.

2.6. *SPM4 - Yale/San Juan Southern Proper Motion Catalog*

W. F. van Altena, T. M. Girard, D. I. Casetti-Dinescu and K. Vieira (Yale University & CIDA)

The fourth instalment of the Yale/San Juan Southern Proper Motion Catalog, SPM4, contains absolute proper motions, celestial coordinates, and B, V photometry for over 103 million stars and galaxies between the south celestial pole and -20° declination. The catalog is roughly complete to V = 17.5 and is based on photographic and CCD observations taken with the Yale Southern Observatory's double astrograph at Cesco Observatory in El Leoncito, Argentina. The proper-motion precision is 2-3 mas/yr for well-measured stars; systematic uncertainties are on the order of 1 mas/yr.

In parallel with the SPM4 construction, and using the same SPM observations, a more accurate catalog of proper motions was made over a 450 sq-deg contiguous area that encloses both Magellanic Clouds. That catalog of 1.4 million objects was used to derive the mean absolute proper motions of the LMC and the SMC and, importantly, to make the most precise determination to date of the proper motion of the SMC relative to the LMC. The absolute proper motions are consistent with the Clouds' orbits being marginally bound to the Milky Way, albeit on an elongated orbit. Combining UV, optical and IR photometry from existing large-area surveys with SPM4 proper motions, we have identified young, OB-type candidates in an extensive 8,000 sq-deg region that includes the LMC/SMC, the Bridge, part of the Magellanic Stream and the Leading Arm. Additionally, a proper-motion analysis has been made of a radial-velocity selected sample of red giants and supergiants in the LMC, shown by Olsen *et al.* (2011) to be a kinematically and chemically distinct subgroup, most likely captured from the SMC. These results help constrain the Cloud-Cloud interaction, suggesting a near collision that took place 100 to 200 Myr ago.

Finally, SPM4 absolute proper motions have been cross-identified with radial velocities from the second release of the Radial Velocity Experiment (RAVE) and the resulting three-dimensional space motions of about 4400 red clump stars used to derive the kinematical properties of the thick disk, including the rotational velocity gradient, dispersions, and velocity-ellipsoid tilt angle.

2.7. *Advert for new book on astrometry*

W. F. van Altena (Yale University)

Astrometry for Astrophysics is intended to fill a serious gap in texts available to introduce advanced undergraduates, beginning graduate students and researchers in related fields

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to the science of Astrometry. This text provides an introduction to the field with examples of current applications to a variety of astronomical topics of current interest.

Astrometry for Astrophysics is intended for a one-semester introductory course that will hopefully lead to further study by students or serve as a primer on the field for researchers in related astronomical fields. To accomplish the above goals, the book is divided into five parts. Part one provides the impetus to study Astrometry by reviewing the opportunities and challenges of micro-arcsecond positions, parallaxes and proper motions that will be obtained by the new space astrometry missions as well as ground-based telescopes that are now yielding milli-arcsecond data for enormous numbers of objects. Part two includes introductions to the use of vectors, the relativistic foundations of astrometry and the celestial mechanics of n-body systems, as well as celestial coordinate systems and positions. Part three introduces the deleterious effects of observing through the atmosphere and methods developed to compensate or take advantage of those effects by using techniques such as adaptive optics and interferometric methods in the optical and radio parts of the spectrum. Part four provides introductions to selected topics in optics and detectors and then develops methods for analyzing the images formed by our telescopes and the relations necessary to project complex focal plane geometries onto the celestial sphere. Finally, Part five highlights applications of astrometry to Galactic structure, binary stars, star clusters, Solar System astrometry, extrasolar planets and cosmology. I hope that those chapters will stimulate students and researchers to further explore our exciting field.

Astrometry for Astrophysics consists of 28 chapters written by 28 specialists in the field from 15 different countries. The book is edited by van Altena and will be published by Cambridge University Press in November 2012.

2.8. *U.S. Naval Observatory Astrometric Catalogs*
Ralph Gaume (USNO)

Current USNO Astrometry catalogs and products were discussed, including NOMAD and UCAC4. Prospects for future USNO astrometric catalogs were reviewed, including the status of on-going programs such as URAT and UNAC, catalogs derived from large A-Omega programs, and prospects for a future bright-star catalog from the JMAPS space astrometry mission. The fundamental astrometric reference frame is based on the radio interferometric positions of quasars. Prospects for improvement of the fundamental astrometric reference frame were discussed.

2.9. *UCAC4*
N.Zacharias, C.Finch (USNO)

Reduction details, properties and notes for users were presented about the final USNO CCD Astrograph Catalog (UCAC) release number 4 which became public in August 2012. Accurate positions (20 to 100 mas) of 113 million stars to R = 16 are given based on over 200,000 CCD images taken by the 20cm astrograph at CTIO and NOFS between 1998 and 2004. Proper motions of most stars are based on SPM and NPM data with average errors of about 4 to 7 mas/yr and smaller errors for stars brighter than 13 utilizing many more catalogs. UCAC4 includes 5-band photometry for about 50 million stars from APASS and near IR photometry for over 100 million stars from 2MASS. FK6, Hipparcos and Tycho2 data are used to supplement bright stars in order to arrive at a complete all-sky catalog.

2.10. *The URAT project*

N.Zacharias, G.Bredthauer, M.DiVittorio, C.Finch, R.Gaume, F.Harris, T.Rafferty, A.Rhodes, M.Schultheis, J.Subasavage, T.Tilleman, G.Wieder (USNO)

The USNO Robotic Astrometric Telescope (URAT) achieved first light in 2011 at USNO in Washington DC and is now deployed at the Naval Observatory Flagstaff Station (NOFS). The red-lens of the UCAC program is again utilized for URAT, however, with a completely new tube assembly, upgraded mount, new electronics and a new 4-shooter camera containing 4 large CCDs (STA1600) each with 10,560 by 10,560 pixels of 9 micrometer size. A single exposure of URAT covers 28 square degrees of sky with a resolution of 0.9 arcsec/pixel. The URAT all-sky survey will reach about magnitude 17.5 in a bandpass between R and I with first data release expected by end of 2013. Several built-in features allow URAT to observe stars as bright as 1st magnitude. Multiple sky-overlaps taken over more than 2 years per hemisphere allow determination of accurate positions (10 mas level), proper motions, and parallaxes.

2.11. *A Preliminary Analysis of the Astrometric Asteroid Observations in the UCAC*

James L. Hilton (USNO)

Included in the UCAC observations made at Cerro Tololo Inter-American Observatory (CTIO) are 5,864 positions of asteroids. The number of observations of individual asteroids varies from 49 observations of (2) Pallas made over three oppositions to 556 asteroids with a single observation each. Analysis of 47 observations of (692) Hippodamia and 10 observations of (755) Sulamitis each made over two oppositions suggest that the accuracy of the these positions is approximately 50 mas in right ascension and 80 mas in declination. The accuracy of the UCAC may be somewhat better than this as the mean apparent diameters at opposition of these two bodies are approximately 60 and 30 mas, respectively, and no adjustments have been made for phase or possible albedo markings on the surface. A preliminary analysis of 41 of the observations of Pallas (mean apparent diameter 410 mas) are in good agreement with those of Hippodamia and Sulamitis. However, the remaining eight observations show a systematic offset in both right ascension and declination. These discrepant observations may indicate an albedo marking on the surface rotating into view.

2.12. *Hipparcos Successors in the 1990s*

Erik Høg (Niels Bohr Institute, Copenhagen University)

The approval in 1980 of the Hipparcos global astrometry mission and the subsequent development gave rise to ideas and work towards a Hipparcos follow-up mission which culminated with the approval of the ESA cornerstone mission Gaia in the year 2000. Ideas for a successor for global astrometry were studied in Russia (then USSR), and ideas for space astrometry by interferometry were studied in the USA, both beginning in the 1980s. The ESA community was, however, fully occupied with Hipparcos and nobody there thought of a follow-up mission. That changed in 1990 when Høg visited Russia, became interested in the Russian ideas and began discussions with Russian colleagues which led to the development in the 1990s, the main subject of the presentation.

2.13. *Astrometry 1960-80: from Hamburg to Hipparcos*

Erik Høg (Niels Bohr Institute, Copenhagen University)

A modest astrometric experiment in Copenhagen in 1925 led to the Hipparcos and Gaia space astrometry missions. Astrophysicists need accurate positions, distances and motions of stars in order to understand the evolution of stars and the universe. Astrometry provides such information, but this old branch of astronomy was facing extinction during

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much of the 20th century in the competition with astrophysics. The direction forward was shown by observations at the Copenhagen Observatory in 1925 with a new technique: photoelectric astrometry. Digital techniques were introduced in photoelectric astrometry at the Hamburg Observatory in the 1960s by the present author. This development paved the way for space technology as pioneered in France and implemented in the European satellite Hipparcos approved in 1980.

Dafydd Wyn Evans
President of the Commission

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