Transactions IAU, Volume XXVIIA
Reports on Astronomy 2006–2009
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doi:10.1017/S1743921308025222

DIVISION I FUNDAMENTAL ASTRONOMY

ASTRONOMIE FONDAMENTALE

Division I provides a focus for astronomers studying a wide range of problems related to fundamental physical phenomena such as time, the inertial reference frame, positions and proper motions of celestial objects and precise dynamical computation of the motions of bodies in stellar or planetary systems in the Universe.

DIVISION I COMMISSIONS

Commission 4	**Ephemerides**
Commission 7	**Celestial Mechanics and Dynamical Astronomy**
Commission 8	**Astrometry**
Commission 19	**Rotation of the Earth**
Commission 31	**Time**
Commission 52	**Relativity in Fundamental Astronomy**

DIVISION I WORKING GROUPS

Division I WG	**Second Realization of International Celestial Reference Frame**
Division I WG	**Numerical Standards in Fundamental Astronomy**
Division I WG	**Astrometry by Small Ground-Based Telescopes**

INTER-DIVISION WORKING GROUPS

Division I-III WG	**Cartographic Coordinates and Rotational Elements**
Division I-III WG	**Natural Satellites**

TRIENNIAL REPORT 2006–2009

1. Introduction

The structure of Division I changed substantially since the IAU XXVI General Assembly (Prague, August 2006), reflecting the progress made in all astronomical disciplines covered by the Division. The former Working Group on *General Relativity in Celestial*

Mechanics, Astrometry and Metrology was promoted to the new Commission on *General Relativity in Fundamental Astronomy*, other Working Groups were either disbanded, if their tasks were accomplished (*Re-definition of Coordinated Universal Time, Precession and the Ecliptic*), or re-organized into new ones with re-defined tasks (*Future Developments in Ground-Based Astrometry, Nomenclature for Fundamental Astronomy*). Thus, three new Working Groups were created (*Second Realization of International Celestial Reference Frame; Numerical Standards in Fundamental Astronomy; Astrometry by Small Ground-Based Telescopes*).

The Division members at its business meeting in Prague also discussed and approved the proposal by the President, Toshio Fukushima, that the future Organizing Committee of Division I should consist of the Presidents and Vice-Presidents of all Commissions pertaining to the Division. This decision is reflected in the present composition of the OC.

2. Developments within the past triennium

Many scientific problems of Division I were discussed at Joint Discussion 16 (*Nomenclature, precession and new models in fundamental astronomy*), held during the IAU XXVI GA in Prague. Three resolutions, prepared by the Division and discussed at JD16 (Precession Theory and Definition of the Ecliptic; Supplement to the IAU 2000 Resolutions on reference systems; and Re-definition of Barycentric Dynamical Time, TDB) were endorsed by the General Assembly.

An important scientific discussion forum for the Division was established by organizing the series of symposia, officially held outside the IAU, Journées Systèmes de Référence Spatio-temporels. These meetings, originally French national ones that gradually became fully international, are held annually since 1988 in a European country. The Journées 2006 was not held because the JD16 at IAU GA in Prague had a similar theme. In September 2007 it was held at Meudon, France, with the sub-title *The Celestial Reference Frame for the Future* and in September 2008 in Dresden, Germany, subtitled *Astrometry, Geodynamics and Astronomical Reference Systems*.

One of the milestones for all Division members was IAU Symposium No. 248 *A Giant Step: from Milli- to Micro-arcsecond Astrometry*, held in October 2007 in Shanghai, China. The meeting was timed to coincide with the 10th anniversary of the release of the Hipparcos and Tycho Catalogues. It gathered scientists from all Commissions pertaining to Division I to discuss the problems connected with achieving higher astrometric accuracy (both in optical and radio wavelengths) and it touched not only observation techniques but also modelling, including general relativity aspects. Astrophysicists from other Divisions who are using astrometry and its results for their scientific interpretations also participated.

Members of Commission 4 concentrated mainly on developing software and calculating the ephemerides for the general use by astronomers, navigators, etc. . . . . Progress was made in the gradual implementation of IAU resolutions adopted in 2000, 2003 and 2006 into the contents of most major ephemeris books. Some observatories provide electronic access to ephemerides and significant astronomical phenomena and also to relevant software. A dominant role is played by the Jet Propulsion Laboratory (JPL) that traditionally produces very accurate planetary ephemerides, based on recent astronomical observations, gathered also from NASA and ESA space missions. Since 2006 also IMCCE (Observatoire de Paris) produces numerical ephemerides, INPOP, with comparable accuracy.

https://doi.org/10.1017/S1743921308025222 Published online by Cambridge University Press

The problems of celestial mechanics and dynamical astronomy reach a very wide field across the whole of astronomy. The research, conducted by Commission 7, was concentrated on the problems of architectures of extra-solar planetary systems, interactions between galactic bars and halos in disc galaxies, spin-orbit dynamics in the solar system (with stress on the motion of Mercury), and binary solar system objects.

Commission 8 concentrated mainly on problems of space astrometry. A new reduction of the *Hipparcos* data, with much higher accuracy of parallaxes, was obtained, and significant efforts were devoted to the preparation of the ESA astrometric mission *Gaia*, now approved to be launched in 2011. It is also probable that Japan will launch, after 2010, an infrared astrometric satellite *JASMINE*. Other important activities were aimed at preparing new ground-based astrometric instrumentation and improving the reduction methods, realization and densification of the celestial reference frame, improving the positions and proper motions of observed stars and measuring precise trigonometric parallaxes of nearby and high proper-motion stars. Precise positions of Solar System bodies (asteroids, natural planetary satellites) were also intensively observed.

Research concerning the rotation of the Earth was made by the members of Commission 19, both from practical (measurement of Earth Orientation Parameters) and theoretical (studies of exchange of angular momentum between the solid Earth and its fluid parts) points of view. New observational techniques appeared (ring laser, new generation of VLBI with small antennas) and global circulation models of geophysical fluids were developed, including satellite gravity data from *GRACE*. As the new terrestrial reference frame (ITRF 2005) was derived, Earth Orientation Parameters since 1984 were reprocessed. The commission closely co-operated with the International Earth Rotation and Reference Systems Service (IERS) on updating the IERS Conventions, which provide a set of astronomical/geodetical constants and fundamental procedures. The practical use in space navigation and elsewhere requires also very precise prediction of Earth's orientation in space, so the necessary procedures were developed and inter-compared.

Time and its different scales is an important part of astronomy, namely as an independent variable for the description of all dynamical systems. Originally defined by Earth rotation, then by the motion of the Earth around the Sun, now by atomic clocks, and maybe by pulsars in future, the time and its relativistic aspects in different reference frames, and also its worldwide measurement and coordination, poses a lot of questions considered by Commission 31. International Atomic Time (TAI) provides a fundamental scale from which other scales are derived; it is now based on about 350 different clocks working at 65 laboratories all over the world. The possible change of definition of Coordinated Universal Time (UTC) in the future was discussed intensively in cooperation with other unions, mainly the International Telecommunication Union (ITU). Pulsars with very stable millisecond periods seem to be promising candidates for the future definition of time in astronomy. Joint Discussion 6 on *Time and astronomy*, to be held during the IAU XXVII General Assembly in Rio de Janeiro in August 2009, will provide a possibility of discussing these problems in detail.

With the increasing accuracy of observations and modelling of positions and motions of celestial bodies, the importance of relativistic effects are growing. The new Commission 52 on *General Relativity in Fundamental Astronomy* is very active in solving these tasks. Namely such problems as the impact of relativity on astronomical reference frames, relativistic modelling of observations, astronomical tests of general relativity, relativity in astrodynamics and space navigation, relativistic time scales and astronomical constants and units were studied. IAU Symposium No 261 (*Relativity in fundamental astronomy – dynamics, reference frames, and data analysis*), to be held at Virginia Beach, USA, in

https://doi.org/10.1017/S1743921308025222 Published online by Cambridge University Press

April/May 2009, will provide a wide international forum to discuss these questions in detail.

The International Celestial Reference Frame (ICRF) was defined in 1997 by the adopted positions of 212 extragalactic radio sources. With many new VLBI observations gathered since then, it is now possible to obtain a better and denser realization of the ICRF, considering also temporal changes of source structures. The work on the second realization (ICRF-2) was done in close cooperation with the IERS and the International VLBI Service (IVS).

Further important progress was achieved in updating the current best estimates of astronomical constants, in collaboration with the IERS. This work will probably lead to a proposal of a new IAU System of Constants in 2009 (see the report of WG on *Numerical Standards of Fundamental Astronomy* for more details).

Small ground-based telescopes (roughly up to 2m diameter) were used, in many places of the world, to do high-precision astrometry of stars and solar system bodies. Most of these telescopes are now equipped with CCD detectors. During the last triennium, accurate positions and/or proper motions of some 100 million stars were obtained and thousands of asteroids, with concentration on Near Earth Objects, were observed. Small telescopes were also very active in observing other solar system bodies, such as satellites of the planets and their mutual phenomena. Thanks to a joint Franco-Chinese cooperation, a first spring school on astrometry *Observational Campaign of Solar System Bodies* was held in Beijing, China, in April 2008.

The Working Group on *Cartographic Coordinates and Rotational Elements* published its (2006) triennial report in Celestial Mechanics and Dynamical Astronomy (Seidelmann *et al.*, CeMDA 98, 155). Important changes included corrections to or updates to the recommended models for the rotation of the Sun, orientation of the Moon, orientation and size and shape of several Saturnian satellites, and orientation of Pluto and Charon. The recommended models for the size and orientation of several asteroids and comets were updated or given for the first time. The Working Group is starting to address changes needed for the next report and will present a draft for discussion and completion at the next IAU General Assembly.

The Working Group on *Natural Planetary Satellites* concentrated on gathering both historic and new astrometric observations. Based on them, theories of motion, masses, gravity fields, orbits and their evolution were derived for many satellites of planets and asteroids of the solar system.

3. Closing remarks

It is necessary to add that individual Commissions and Working Groups within Division I are not isolated; they mutually interact, cooperate and often organize meetings of common interest. This summary is meant only to show the most important progress achieved in fundamental astronomy during the last triennium, according to a subjective selection by the Division President. It can by no means cover all rapidly evolving fields of research that all components (Commissions and Working Groups) of the Division are filling. The detailed reports that follow give a more exhaustive image of what has been done.

Jan Vondrák
president of the Division

https://doi.org/10.1017/S1743921308025222 Published online by Cambridge University Press