

# FUNDAMENTAL ASTRONOMY

## DIVISION A

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*ASTRONOMIE FONDAMENTALE*

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## DIVISION A COMMISSIONS

Div. A / Commission A1

Astrometry

Div. A / Commission A2

Rotation of the Earth

Div. A / Commission A3

Fundamental Standards

## INTER-DIVISION COMMISSIONS

Div. A+F / Commission A4

Celestial Mechanics & Dynamical Astronomy

## CROSS-DIVISION COMMISSIONS

Div. A+F / Commission X2

Solar System Ephemerides

## DIVISION A FUNCTIONAL WORKING GROUPS

Functional WG SOFA

Standards of Fundamental Astronomy

Functional WG TMS

Time Metrology Standards

## DIVISION A WORKING GROUPS

Div. A / WG ASGBT

Astrometry by Small Ground-Based Telescopes

Div. A / WG MwICRF

Multi-waveband International Celestial Reference Frame

**INTER-DIVISION A+F FUNCTIONAL WORKING GROUPS****Functional WGCCRE****Cartographic Coordinates  
& Rotational Elements****Functional WG NEOs****Near-Earth Objects****TRIENNIAL REPORT 2021-2024****1. Organisation of the Division**

Division A is responsible for monitoring the scientific and organisational development of fundamental astronomy and for ensuring that the most significant issues in the field are addressed with foresight, enterprising spirit, and scientific judgment. As noted in the December 2020 IAU Catalyst letter, Division A – Fundamental Astronomy “A matter of Space & Time”, this Division—being fundamental and interdisciplinary—traces its origins back to the beginning of the IAU itself in 1919, with activities in many of its Standing Committees, and is making the bridge with modern astronomy of the XXI<sup>st</sup> Century. The Division fosters new initiatives and international cooperation in fundamental astronomy, standardisation of scientific results, and promotes investigations and discussions relating to the relevant topics and projects. The scientific community of Division A:

- provides definitions and models that describe reference systems and frames used in astronomy to determine positions and motions of celestial objects in space and time;
- investigates dynamical behaviour of celestial bodies including both high-accuracy descriptions for shorter periods of time and evolution over extended periods of time;
- obtains physical information on celestial objects and investigates physical laws using the methods of astrometry and celestial mechanics;
- offers services that provide data and ephemerides of Solar System bodies, Earth orientation data, time scales, astronomical constants, models including relevant software procedures, etc. for users within the astronomical community as well as within society.

The webpages of the Division and the Commissions have been updated, with addition of annual reports, news, past & future meetings, awards and prizes list. General information and calls are regularly sent to the division’s members, while regular newsletter are maintained at Commissions level. The number of members has increased (1730 in year 2019, 1850 in 2021, 2014 in 2024), the yearly process of including new members is surely advantageous. Since the new scheme put in place by the IAU for individual memberships, the Division A has got a good and increasing proportion of young, junior members (150 in 2021; and 235, approximately 12%, for this report).

**2. Awards and PhD prizes**

Some of our Division A members did receive prestigious prizes:

- The AAS/DDA Dirk Brouwer prize recognising major contributors to the field of Dynamical Astronomy has been awarded to Alessandra Celletti (2023), and to Lennart Lindegren (2021).
- The EPSC Paolo Farinella Prize, acknowledging an outstanding researcher not older than 47 years, has been attributed to Federica Spoto & Diego Turrini
- The 2023 Lancelot M. Berkeley - New York Community Trust Prize, for Meritorious Work in Astronomy, has been awarded to the *Gaia Collaboration*.
- The the Shaw Prize in Astronomy (2022) has been attributed to Lennart Lindegren & Michael Perryman for their lifetime contributions to space astrometry.

All of IAU's divisions award a prize each year for the best Ph.D. thesis among the applicants (see below). The IAU Division A PhD prizes were awarded to:

- 2021: Etienne Savalle (Paris observatory, France) “Testing general relativity with clocks in space, and dark matter research with cold atom interferometry on Earth”; honorable mention to Lei Zhang (NAOC Beijing, China)
- 2022: Chris Hamilton (university of Cambridge, UK) “Secular Dynamics of Binaries in Stellar Clusters”
- 2023: Irene De Blasi (university of Turin, Italy) “Dynamics and stability in Celestial Mechanics: from galactic billiards to Nekhoroshev estimates”; honorable mention to Hao Ding (Swinburne University of Technology, Australia)

### 3. Commissions and Working Groups Evolution

Commissions and functional Working Groups have been continued after the 2021 evaluation. Activities of former WG NSFA are undertaken within Commission A3. The other Working Groups will continue their tasks in preparing future realisation of the ICRF (optical + VLBI), and coordinating astrometry with small g-b telescopes. An inter-division WG is proposed to work on revising the Galactic coordinate system and reference frame, toward a multi-waveband Galactic reference frame. We give a brief summary of CAs and WGs activities.

#### 3.1. Commissions

After six years of duration, all IAU commissions were evaluated during the year 2021. No new Commission had been proposed by Division A; all of its Commissions having shown strong activity and need for continuation were renewed.

After the third realisation of the International Reference Frame (ICRF3), the activities of the commission A1–Astrometry during this triennium have been highly stimulated by the outstanding results of the Gaia mission covering a vast range of scales from Solar System, to galactic and extra-galactic objects. Work towards a next generation of ICRF combining radio and optical data will be a major focus of commission A1 in the next triennial period.

Commission A2–Rotation of the Earth bridges disciplines of astronomy and geodesy, for which the Earth's rotation and its temporal changes are key quantities. It provides links to other international unions or organisations, and has representatives from IAG, IERS, and IVS at its organising committee. The CA2 participated to the organisation of several meetings and international conferences session. It reports on the activities of its working groups, on partner organisations, and other national activities (Austria, Belgium, China, France, Germany, Poland, Russia, Spain, USA).

Commission A3–Fundamental Standards in particular develops, implements, and disseminates new standards under consideration within Division A. It provides links to other international unions or organisations such as the International Earth Rotation and Reference Systems Service (IERS), the International Association of Geodesy's (IAG) Global Geodetic Observing System (GGOS), the Consultative Committee for Time and Frequency (CCTF), the Consultative Committee for Units (CCU). The Commission has set-up a new web site, incorporating the last evolution of the Working Group NSFA.

CA3 is proposing resolutions to establish a standard Lunar Celestial Reference System (LCRS), and Lunar Coordinate Time.

Commission A4–Celestial Mechanics & Dynamical Astronomy promotes research and training activities, and their application in the broad field of celestial mechanics, and dynamical astronomy. Being an interdisciplinary commission, its members are affiliated

to Division A, F, B, H, or J in substantial proportion. Generally they are participating in research and activities related to observations, the definition and updating of standard IAU-adopted reference frames, and astrometry. The commission has in particular followed the recent drastic evolution due to results from the DART and Gaia space missions. It is noted that AI, machine-learning, and data science tools are now used side by side to the traditional methods of celestial mechanics. In addition to regular schools and colloquium (CELTA, CELMEC) CA4 has organised two IAU symposia during the triennium (IAUs #364 and IAUs #382).

One of the objectives of Commission X2–Solar System Ephemerides is to promote the acquisition and dissemination of observations of Solar System bodies and estimates of their ephemerides and rotational elements. Reports are given on updates for planetary and satellite ephemerides data from the various contributing ephemerides centres (USA, Russia, France, China), and for the ephemerides of small bodies. Results from Gaia and DART space missions, adoption of ADES format, and preparation to the data from the VRT telescope are emphasised.

### 3.2. Working Groups

Division A has several Working Groups, in addition to those affiliated to its commissions. Most of Division’s A WGs are *Functional* ones (4 out of 6); all have been very active and renewed in 2021. The Functional character of these WGs – dealing with recurrent matters fundamental to the IAU – is fully justified. It is noted that their need for continuity generally extends the typical 6 years duration.

Several Working Groups dealing with Reference frames have been proposed. Two joint WGs within Commission A2:

- WG for Consistent Realisation of TRF, CRF and EOP (CRTCE)
- WG on Improving Theories and Models of the Earths Rotation (ITMER)

and one under Division A:

- WG for Multi-waveband International Celestial Reference Frame

These groups will work on the realisation of the ICRS in optical and radio wavelength (Gaia and VLBI, essentially) and the links to the ITRF, in connection with Earth orientation parameters, the IERS, and the IAG.

The former WG “Multi-Waveband Realisations of International Celestial Reference System” paved the way to the definition of a broader ICRF consistent with different observational techniques and bandpasses. The WG “ Multi-waveband International Celestial Reference Frame (optical+VLBI)” is following this work.

The SOFA libraries continue to provide the astronomical community with a set of well-tested independent standard routines that support IAU resolutions, available now in several programming languages. This gives to all users the tools for easily implementing and learning about fundamental astronomy algorithms and procedures, such as time scales, references frames, calendars, Earth attitude, precession. It also provides the various transformations for use in research, in applications, and importantly in testing their particular implementation. As with previous releases, improvements have been made to the documentation within the code and the cookbooks. A new cookbook on miscellaneous topics has been added to the collection. Toni Wilmot has been elected chair of the WG-SOFA. The Board is thanking Catherine Hohenkerk for her leadership and involvement as chair over the past years.

The Working Group on Time Metrology Standards is including among its members

astronomers and metrologists, with different expertise, and representing various institutions. Actions toward a redefinition of the SI second are followed by the WG; they do not impact astronomical work. The WG has participated to discussions with Commission A3 on a time reference in cis-lunar space. Work by WGTMS on the elaboration of a continuous UTC (i.e. without leap seconds) has been carried on, in connection with other international organisations. An important milestone has been reached between the International Telecommunication Union ITU and the General Conference on Weights and Measures CGPM. The ITU is responsible for the dissemination of UTC, while modification of the procedure for synchronising UTC to UT1 is under the responsibility of the CGPM.

The Working Group on Cartographic Coordinates and Rotational Elements (WG-CRE) is looking for new members to bring their expertise, replacing retired members, and participating to its many tasks. Increasing demands have delayed its last scientific publication in peer-reviewed journal. In this respect—as already expressed in its previous triennial report—the WG-CRE is looking forward to the possibility of being an international operational service (somewhat similar to e.g. IERS or IAU/MPC) to be able to address the more numerous and complex community requests. The WG is expressing concern about a possible change in Lunar Cartographic Coordinates going from mean Earth ME to principal axis PA realisation, and hopes that it could be avoided. The WG is also pointing the urgency of updating both the Lunar and Mars orientation models.

The WG on Astrometry with ground based telescopes (WG-ASGBT) is useful to achieve the best astrometric performances with small ( $\text{Diam} \leq 2\text{m}$ ) telescopes, and ensure the best practice to be shared among the many users of such instrumentation. The WG reports activities, during the last triennium, on observations of mutual events in the Jovian system by worldwide international campaign. Astrometry of Solar System objects and Be stars is processed at Paris observatory by digitalising old photographic plates. Other observations of Solar system objects and double stars were performed by the various telescopes within the WG. Development of robotic telescopes for observations of Solar System objects and sources for reference frames are also reported.

Working Group on NEOs of Division F is also affiliated, as an Inter-Division WG, to Division A. It reports on the various survey missions, and space exploration missions that have or are planning to visit NEOs, and future plans to visit asteroid (9994) Apophis around April 2029. This event will generate high interest from the public; a proposition to UNO is under development to define year 2029 as the International Year of Planetary Defense. Monitoring and immediate risk assessment by services has also made it possible to detect and follow imminent impactors.

Associate members are regularly joining the WGs for their expertise in their respective domain, they usually become regular IAU members after a short period. All non-functional Working Groups are requesting for their renewal.

#### 4. IAU Symposia

One symposium coordinated by Division A has been selected for this triennium:

- non-GA Kavli and IAU symposium IAU382 “CPS-II Complex Planetary Systems” chaired by A. Lemaître and A-S. Libert, July 2023, in Namur (Belgium).

<https://cpsii.unamur.be/>

One Focus Meeting coordinated by division A has been proposed and selected for the General Assembly IAU-GA2024.

- FM11: Multi-Wavelength Astrometry (Chris Jacobs, chair; Aletha de Witt, co-chair)  
[http://sarao.ac.za/iau\\_fm11](http://sarao.ac.za/iau_fm11)

On Symposium has been proposed for 2025, “Advancing reference systems, ephemeris and standards” chaired by A. Escapa, in La Plata (Argentina). Such symposium would put the basis for new theoretical frameworks connected to reference frames and rotational models, and their applications. The proposal has strong support from various IAU WGs and Commissions, with ouverture to other international organisations. It is timely has potential to advance astronomical research on standards, astrometry, reference frames, and celestial mechanics, especially in South America.

## 5. PhD Prizes

The IAU PhD prizes, distributed on a yearly basis, are of high value to get interest from young or early carrier researchers to the Division’s activity and research topics, and conversely to let the IAU community have a vision of recent developments in the field. All winners of this prize have the opportunity to run for the Springer Thesis Award and publish their work in the Springer Theses collection. They are moreover invited to participate the General Assembly, and present their work during the Division days. Such IAU PhD Prize hopefully contributes to our young colleagues early career. However, since its creation, the number of candidates for this prize within Division A has been relatively low, with moreover strong variations over the years (from zero to four candidates).

- 2017: no candidate (1st year)
- 2018: 4 candidates
- 2019: no candidate
- 2020: 1 candidate
- 2021: 4 candidates
- 2022: 2 candidates
- 2023: no candidate

While the Division reckons this prize can motivate the young scientists to participate to IAU, there have been relatively few candidates proposed to Division A over the years, unfortunately. The PhD subjects are generally focused on dynamics, relativity, time or astrometry. This small number of candidates could be due to the interdisciplinary character character of the division (in astronomy, planetary science, geodesy, mathematics, physics), or to the fact that some member organisations have less PhD students. More publicity should be done to reach possible candidates, and also to encourage young PhDs to present their work to the Division A.

## 6. Representatives and Communications

The IAU has several representatives to other organisations and other scientific unions, some of them being Division A members. Following the work done by Division A during the previous triennia, the Executive Committee now has clear vision of these representations. While regular information messages are sent to the Division members, it had been decided in 2016 that a regular Newsletter wouldn’t be useful to the whole Division. Regular Newsletters are addressed on some of the Commissions level (A1, A3, A4).

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