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FUNDAMENTAL ASTRONOMY

DIVISION A FUNDAMENTAL ASTRONOMY

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 NSFA	**Numerical Standards in Fundamental Astronomy**
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 MwRICRS	**Multi-waveband Realisations of International Celestial Reference System**

INTER-DIVISION A+F FUNCTIONAL WORKING GROUPS

Functional WGCCRE — **Cartographic Coordinates & Rotational Elements**

TRIENNIAL REPORT 2018-2021

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. 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.

Division A was on focus (as was Commission A4) on the IAU Catalyst letter for its December 2020 edition Division A – Fundamental Astronomy "A matter of Space & Time". It was a nice opportunity to remind that Division A—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 makes the bridge with modern astronomy of the XXIst Century.

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 2019, 1850 in 2021), the yearly process of including new members is surely advantageous. Since the new scheme put in place by IAU for individual memberships, the Division has got a good proportion of young, junior members (150 out of approximately 1850).

2. Commissions and Working Groups Evolution

2.1. *Commissions*

After six years of duration, all IAU commissions were evaluated during the year 2021. No new Commission has been proposed by Division A; all of its Commissions have shown strong activity and need for continuation in the future, and hence been 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 Earths rotation and its temporal changes are key quantities. 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). It proposed a resolution for 2021 jointly with Commission A1 "in support of the protection of geodetic radio astronomy against radio frequency interference", and another for the "Improvement of the Earths Rotation Theories and Models" as direct outcome of the working group on Theory of the Earth Rotation and Validation (JWG TERV). The Commission's report also includes organisations reports (IERS, IAG, IVLS, ...) and national reports.

Commision 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.

Commission A4–Celestial Mechanics & Dynamical Astronomy main objectives is to support research and training activities. It has followed the recent drastic evolution in the domain with increased object discoveries, accompanied by an increased amount of available observational data, and by increasing computational capabilities. This should lead to definition of Working Groups under the Commission, and inclusion of new members, to better track the strong and fast evolution in the domain. Commission A4 is the coordinating commission for the postponed symposium IAUs364 (see Sect. 3).

Commission X2–Solar System Ephemerides proposed to organise more regular focused scientific meetings, but had difficulties to do so with the present situation. Besides, the President and Vice-President, William 'Bill' Folkner (JPL, USA) and to Giovanni Valsecchi (INAF, Italy), had to step down from their responsibilities. Let us express our sincere acknowledgements for their work and dedication.

2.2. *Working Groups*

Division A has several working groups, in addition to those affiliated to its commissions. Most of Division's A Working Groups are *Functional* ones (4 out of 6); all have been very active as mentioned in their 2019 report. 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, and prepared a resolution "On the Gaia Celestial Reference Frame" to be discussed at the 2021 General Assembly.

The Working Group on Numerical Standards in Fundamental Astronomy (NSFA) is tasked with updating the IAU current best estimates, conforming with the IAU Resolutions, IERS conventions, and the Système International d'Unités whenever possible. Expecting little evolution in the fundamental constant in the near future, and recognising that its activities can be undertaken within Commission A3, the WG will terminate at this triennium.

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, and the various transformations for use in research, in applications, and importantly in testing their particular implementation.

The Working Group on Time Metrology Standards has evolved by including members, astronomers and metrologists, with different expertise, and representing various institutions. Evolution of the SI second and UTC reference time scale are foreseen. The WGTMS is working on a the elaboration of a continuous UTC, in connection with other international organisations.

The Working Group on Cartographic Coordinates and Rotational Elements (WGCCRE) is looking for new members to bring their expertise and participate to its many tasks. In this respect WGCCRE is also 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, and increased demands for input.

The WG on Astrometry with ground based telescopes (WGASGBT) is useful to achieve the best astrometric performances with small (D2m) telescopes, and ensure the best practice to be shared among the many users of such instrumentation.

Working Group on NEOs is now affiliated to Division A in addition to Division F, as an Inter-Division WG, with the coordination of Div. F and the participation of Div. A.

Rotations of chairs in the Functional Working Groups is always wanted, but sometimes difficult to achieve. Not only do we have very dynamic, efficient and responsible chairman and chairwoman, but motivation to take the lead is lacking. Associate members are regularly joining the WGs for their expertise in their respective domain, they usually become regular IAU members after a short period.

Except for the Working Groups on Multi-waveband realisation of the ICRS (Division A), on Numerical Standards in Fundamental Astronomy (Division A) and the one on Theory of Earth Rotation and Validation (Commission A2), all Working Groups—in particular the one created in 2020—are requesting for their renewal.

3. Proposals for IAU Symposia and Focus Meetings

After the General Assembly of 2018, one symposium coordinated by Division A has been selected for this triennium; symposium IAUs364 "Multi-scale (time and mass) Dynamics of Space Objects" chaired by A. Celletti and C. Gales. Abstracts were collected and grants propositions established; but due to the pandemia crisis, the symposium couldn't be held in 2020, and has been postponed to October $18 - 22$, 2021.

While no symposium—directly coordinated by Division A—was proposed as non-GA

for year 2021, one Symposium and three Focus Meetings were proposed for the General Assembly GA2021. Two FMs have been selected, to be eventually held during the August 2022 meeting.

- FM7: Astrometry for 21^{st} Century Astronomy (A. Brown);
- FM10: Synergy Of Small Telescopes And Large Surveys For Solar System And Exoplanetary Bodies Research (A. Ivantsov).

The Symposium proposed for 2021, chaired by F. Seitz, was on "Reference systems and their ties with the rotation of the Earth and other Solar System bodies". Proposed jointly by Commissions A2, A1, and Working Group CCRE, it was supported by the Division and several commissions and working groups. Such symposium would put the basis for new theoretical frameworks connected to reference frames and rotational models, and their application to reference frames, and rotation of celestial bodies. It would also prepare the community to the on-going evolution of catalogues size and high accuracy references.

One symposium is proposed for 2022 under the coordination of Division A:"Complex Planetary Systems II: Latest methods for an interdisciplinary approach" chaired by A. Lemaître and A-S. Libert (University of Namur). It is timely to have this symposium eight years after its first edition, presenting and discussing the many advances in a broad set of subjects on celestial mechanics and dynamics, with their applications to a large diversity of astronomical objects.

4. 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. However, since its creation in 2015, the number of candidates for this prize in 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 (GA year)
- 2019: no candidate
- 2020: Joseph O'Leary (UNISA, Australia)
- 2021: 4 candidates, selection still in progress.

While the Division reckons this prize can motivate the young scientists to participate to IAU, there have been relatively few (between zero and four) candidates proposed to Division A over the years, unfortunately. Actions to understand and correct this matter have been discussed, nevertheless it is unclear why the number of candidates is low. More publicity should be done to reach possible candidates, and also to encourage young PhDs to present their work to the Division A. Such IAU PhD Prize hopefully contributes to our young colleagues early career.

5. 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 triennium, 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, A4).

6. Closing Remarks

Due to the virus pandemic and the world-wide sanitary crisis, this triennium has been particular, with as a of the major consequences big delays on many of our planned IAU scientific activities. Several resolutions have been proposed and will bring interesting discussions for the GA 2021 edition. These address realisation of reference frames, and pollution. Let us stress that increasing light and radio-frequency pollutions is of concern for astronomy, and for Fundamental Astronomy.

Daniel J. Hestroffer
President of Division A