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COMMISSION B4 RADIO ASTRONOMY

COMMISSION B4 WORKING GROUPS

Div. B / Commission B4 WG	**Historical Radio Astronomy (HRA Joint WG with Commission C3 and an Inter-Union WG with URSI)**
Div. B / Commission B4 WG	**Global VLBI Alliance (established 2020)**

TRIENNIAL REPORT 2018-2021

1. Background

IAU Commission B4: Radio Astronomy (CB4), commenced in 2015. CB4 is the evolution of IAU Commission 40, as originally established in 1948. This is the Commission's second triennial report in its current form. In the last triennium period, CB4 has successfully supported the expanding International Radio Astronomy community. CB4 currently has 514 members.

The primary purpose of this Commission is to promote the unique aspects of Radio Astronomy within multi-wavelength and multi-messenger astronomy. With the development of increasingly international and billion-dollar scale instruments, it is increasingly important to ensure a long-term, thriving and international network of discourse for radio astronomy research priorities, technologies and facilities.

2. Developments 2018-2021

Globally, there has been a maturation of a number of significant projects in the last triennium: National and international endeavours have led to the realisation of major new telescopes, upgraded observatories and new/enlarged research groups. Communicating news of these developments and exploring synergies with other branches of physics and engineering, is fundamental to the activity of CB4.

A number of major new radio facilities have emerged, or have been upgraded in the last triennium. Of these, most have commenced important surveys which we summarise breifly here -

• The build of the Karoo Array Telescope (MeerKAT) was completed. MeerKAT has since commenced science operations. Among a number of notable results a spectacular new image of the Galactic centre showing an unprecedented wealth of detail has been produced, and the array has shown to be an exceptional pulsar research facility.

• The East Asia VLBI Network (EAVN) commenced in 2018. The facility now links 21 telescopes and significantly expands global VLBI capabilities.

• The Australian SKA Pathfinder (ASKAP) telescope commenced science operations and has recently published the Rapid ASKAP Continuum Survey (RACS), centred on 888 MHz at 25 arcsec to 0.2 mJy/beam. Further releases of RACS will complete surveys across the ASKAP band 700-1800 MHz.

• The LOw Frequency ARray (LOFAR) has published the first release of the LOFAR Two Metre Sky Survey (LOTSS) cataloging 300,000 sources at 120-168 MHz, 0.07 mJy beam-1 sensitivity and 6 resolution. Also, first results from the LOFAR Low Band Survey (LoLSS) have been published, derived from observations at 42-66 MHz with a resolution of 15 arcsec and a detection limit of 1 mJy/beam. Ultimately both LOTSS and LoLSS will cover the entire northern sky.

• The VLA All-Sky Survey (VLASS) continues to progress, aiming to observe three epochs over the 75% of the sky visible to the VLA in order to provide deep, high angular resolution images (2.5 arcsec to 120 μJy rms) at 2 - 4 GHz as well as additional multiple epochs for time domain studies. The entire sky above declination -40 deg has so far been observed providing the first epoch of VLASS and the data is publicly available.

• The Murchison Widefield Array has been expanded with a doubling of its number of stations. The Galactic and Extragalactic All-SKY MWA survey "GLEAM" is now being augmented by "GLEAM-X" providing deeper sensitivity (to 1 mJy/beam) across the same wide low frequency band 72-231 MHz.

• The Five-hundred-meter Aperture Spherical Telescope (FAST) officially opened and is working towards full science operations.

• ALMA continues to provide exquisite data at millimetre wavelengths, exploring gas, dust and magnetic fields throughout the Universe, including the morphologies of high redshift galaxies, detecting the earliest metals in the Universe (Oxygen at high redshifts), and revealing the diversity of morphologies of proto-planetary disks.

• The Westerbork Telescope (WSRT) commenced a new suite of surveys with its phased array "APERTIF" receivers across 1130-1430 MHz. First results and data are now available ("DR1") from astron.nl.

• The Event Horizon Telescope (EHT) provided spectacular results and gained world-wide attention with the first image of the shadow of the supermassive black hole at the centre of the galaxy M87.

• The Square Kilometre Array telescope achieved significant milestones including the formal signing of the Intergovernmental agreement in Rome (March 2019) and the inception of its Council (February 2021).

• The next-generation Very Large Array (ngVLA) project, designed to bridge SKA and the Atacama Large Millimetre/submm Array in frequency space, began detailed designed activities.

• NASA approved the Sun Radio Interferometer Space Experiment (SunRISE) to proceed into formulation. Once launched in 2023, SunRISE will be a space-based radio astronomical interferometer studying the Sun, solar system giant planets, and the Universe.

CB4's Organising Committee has continued to focus on the coordination of international meetings dedicated to developments in Radio Astronomy and its role in multi-wavelength astronomy. To successfully achieve this, CB4

a) continues to encourage CB4 members to propose IAU Symposia (and Focus Meetings at the GA) and coordinates these efforts to ensure timeliness, avoid overlap etc;

b) discusses all LoIs submitted to the IAU, and suggested to respective chairs of rel-

evant meetings to ask our Commission for support. This included support in the choice of Invited speakers and SOC members;

c) providing support letters with detailed comments.

During the triennium, the Commission has sponsored or supported a number of IAU symposia including IAUS 340 "Long-term datasets for the understanding of solar and stellar magnetic cycles" (February 2018), IAUS 341 "Challenges in Panchromatic Modelling with Next Generation Facilities" (November 2018), IAUS 342 "Perseus in Sicily: from black hole to cluster outskirts" (May 2018), IAUS 350 "Laboratory Astrophysics: from Observations to Interpretation" (April 2019), and the virtual-meeting IAUS 367 "Education and Heritage in the Era of Big Data in Astronomy. The first steps on the IAU 20202030 Strategic Plan" (December 2020).

At the IAU GA in August 2018 (Vienna), CB4 hosted two discussion sessions: (i) "New Results in Radio Astronomy" and (ii) The History of Large Single Dish Projects and Lessons Learned".

Other, non-IAU symposia, notable conferences focusing on Radio Astronomy have included

- Planets2020: Ground and Space Observatories: A Joint Venture to Planetary Science sponsored by the ALMA Observatory.
- "The History of the SKA, 1980s -2012" at SKAO, Jodrell Bank in April 2019;
- The Science At Low Frequency meetings have established themselves as the major annual conference for astronomy at <300 MHz, with a number of new and enhanced instruments collecting data (MWA, LOFA, LWA, HERA). The 2019 meeting at Arizona State University in December 2019 was the 6th of the series. The most recent meeting was hosted by the University of Amsterdam virtually in December 2020.
- The first CTA symposium on May 6th, 2019 in Bologna, 1st International Cherenkov Telescope Array Symposium Exploring the High-Energy Universe with CTA discussed the novel investigations CTA will bring to the field and its synergies with other wavebands and messengers.
- A conference to commemorate 60 years since the first release of the Third Cambridge Catalogue (3C) was organised in Torino on September 16th: The 3C Extragalactic Radio Sky: Legacy of the Third Cambridge Catalogue.
- The East Asia VLBI Network is now fully operating with 10 stations (KaVA, Tianma, Nanshan and Nobeyama). The EAVW-2019 was the first meeting after this milestone, presenting an increasing number of exciting results: 12th East Asian VLBI Workshop.

3. Broader Commission activities

Commission B4 has two Working Groups. The Working Group on Historical Radio Astronomy has been active for the full term of the triennium. In 2020 a proposal for a new Working Group for the "Global VLBI Alliance" was approved and has developed its mission and workplan for the upcoming triennium (2021-2024).

Together the commission and its Working Groups continue to develop a close and fruitful interaction with URSI. For the latter, members of CB4 are the convenors of a special sessions at the upcoming URSI General Assembly (GASS, August 2021) -

- URSI J-IAU entitled "Next generation radio astronomy, science & technologies". In this session we will bring together URSI and IAU Commission B4 (radio astronomy) to explore the emerging technologies which will impact these major instruments and drive astronomy in the 2030s and beyond. This session will be wide-ranging, looking to major

trends in photonics, computing and multi-messenger physics, but also the raw reality of increasing billion-dollar telescopes.

• The WG HRA is organising the session on "The Impact of Radio Astronomy on Technology and Society". Talks cover a broad range of topics and include The Story of Wifi; VLBI, Navigation, and Geodesy; Cold-War Diplomacy at the Jodrell Bank Observatory; Radio Interferometry and Medical Imaging; Deep Space Navigation; and The Parkes Dish and the First Moonwalk.

4. The next Triennium - future plans

The upcoming triennium will undoubtably deliver exciting science from the new and enhanced facilities noted previously. We expect to see more agile, user-accessible networks of telescopes and data products in the coming period. In particular efforts are looking to expand a broad range of 'VLBI' capability ready for the era of the ngVLA and SKA. This is key focus of the Global VLBI Alliance Working Group. Long baseline astronomy at very low wavelengths ($\leqslant$ 80 MHz) will be probed by LOFAR using its pan-European baselines, new algorithms and significant computing capacity. These facilities, and the increasingly dynamic arraying of telescopes in new configurations will ensure that radio data continues to provide exquisite and new insights to our Universe.

Our discourses will continue, and we strongly encourage members to attend the postponed GA in 2022 where C4 is co-sponsoring the symposium IAUS 373 "Resolving the Rise and fall of star formation in galaxies" (https://iausymp373.web.illinois.edu).

The CB4 committee will continue to investigate what information is most useful to members, particularly in this period of virtual meetings only. The Commission's web page will be upgraded to provide members will a clear view of the Commission's purpose and mission.

Tony Beasley
President of the Commission