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DIVISION B
COMMISSION 40 — RADIO ASTRONOMY
RADIOASTRONOMIE

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WORKING GROUPS	**Ken Kellermann, Ronald Ekers Masatoshi Ohishi**

1. Introduction

IAU Commission 40 for Radio Astronomy (hereafter C40) brought together scientists and engineers who carry out observational and theoretical research in radio astronomy and who develop and operate the ground and space-based radio astronomy facilities and instrumentation. As of June 2015, the Commission had approximately 1,100 members from 49 countries, corresponding to nearly 10 per cent of the total IAU membership.

An excellent account of the first fifty years of the IAU is given by Blauuw (1994). In 1946, the IAU Executive and leading astronomers representing their countries met in Copenhagen to plan the way ahead for the IAU after the extensive disruption and interrupted communications of the war years. In 1948, 10 years after the previous General Assembly, the seventh General Assembly was held in Zürich, attended by 279 individuals from 28 countries. The 1948 General Assembly must have represented a time of recovery, strengthening of international relations and new science initiatives. Several member states, including Australia, joined the IAU and six new Commissions were started, including Commission 40 for Radio Astronomy.

The need for a Commission for radio astronomy arose from the outstanding discoveries that were being made in the emerging field of radio astronomy in the years following WWII. Extraterrestrial radio waves were first discovered by Karl Janky working at the Bell Telephone Laboratories in the U.S. In 1930 Jansky built the Bruce Array (Figure 1) to investigate sources of radio 'noise' (e.g. Sullivan (1984)). He detected a mysterious source of radio hiss and, from careful monitoring, determined that the signals had the sidereal signature of an astronomical source. Janky presented his results in 1933 at meeting of the International Union for Radio Science (URSI). The significance of his work was not widely recognised other than by Grote Rebe in the U.S. To follow up on Jansky's discovery, in 1937 Reber built a 31-ft diameter paraboidal dish, the first parabolic dish used in radio astronomy. He investigated radio emission from the Galaxy and later published the first reports of radio emission from the Sun (see Reber 1984). Little radio

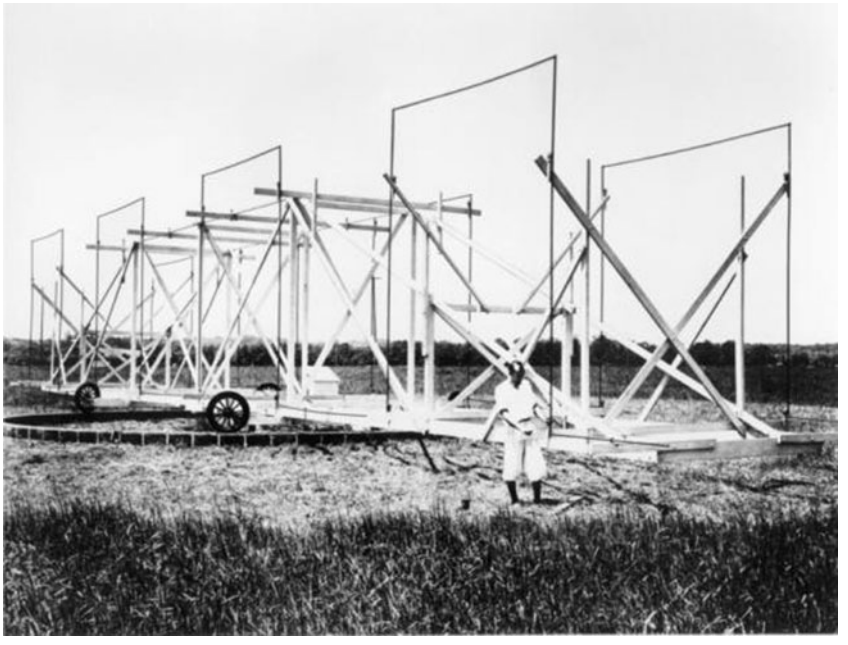

Figure 1. The Bruce Array at the Holmdel field station of Bell Telephone Laboratories was built by Karl Jansky in 1930 and used for observations that led to the discovery of extraterrestrial radio signals. (Credit: National Radio Astronomy Observatory, US.)

astronomy was carried out during the war years. However, two important developments during WWII were the first detection of radio emission from the sun in 1942 (Hey (1946)), and the suggestion by van de Hulst, during a symposium in Leiden in 1944, that neutral hydrogen would emit observable radio emission at a wavelength of 21 cm (van de Hulst (1945)).

During the decade following WWII, radio astronomy groups began in Australia, Europe, UK, U.S. and USSR. These typically included radio engineers with little or no formal training in astronomy but with strong technical expertise. Radio astronomy research included studies of solar radio emission, radio continuum surveys of the Galactic Plane and searches for 'discrete' radio sources. Neutral hydrogen was first discovered in the U.S. in 1951 (Ewen & Purcell (1951)) with confirmation from the Netherlands and Australia, leading to investigations of the spiral structure of the Milky Way from 21-cm observations of hydrogen.

The discrete radio sources were initially thought to be Galactic in origin and indeed the first identification of a compact radio source was with the Crab Nebula supernova remnant (Bolton, Stanley & Slee (1949), Bolton & Stanley (1949)). However, from 1948 onwards, improved radio positions and optical identifications showed that many compact sources were extragalactic and associated with distant galaxies (Bolton, Stanley & Slee (1949)). The discovery of extragalactic radio emission was unexpected and astonishing. Writing about surveys carried out at Dover Heights in Australia (Figure 2), Gordon Stanley (1994) captured the excitement of these times:

It is difficult to comprehend the emotional impact of an observation which took us from the partially explicable solar system and the Galactic radio emission phenonema, into the realms of phenomena with inexplicably high energy outputs. Within a few months, with the identification of NGC 5128 and M87, the realm of our observing world was the universe!

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Figure 2. A 12-element Yagi antenna installed on the cliff top at Dover Heights and mounted on the turntable of a WWII radar. The antenna had a 12 degree beam and was used in 1951–1953, at a frequency of 100 MHz, to carry out a survey for discrete radio sources. One hundred and four sources were detected in this survey. In 2003, a full sized-replica of one of the early Yagi antennas was installed on the cliff top at Dover Heights as a memorial to the site. (Credit: CSIRO Radio Astronomy Image Archive.)

The postwar successes established radio astronomy as a rapidly growing area of astronomy research. Sullivan (2009a) has noted that the first known usage of the term 'radio astronomy' in the West, occurs in a letter by Joseph Pawsey written in January 1948. In August 1948 the new Commission for 'Radio Astronomy' was established by the IAU. Within a year the term radio astronomy was in common use.

Commission 40 provided an important forum for the international community that continued over 67 years until General Assembly XXIX, held in Hawaii in August 2015. In 1997, the IAU established Divisions and from 1997 to 2012, C40 was also the only Commission in Division X. In 2012, the IAU Divisions were restructured, Division X ceased and Commission 40 joined Division B for Facilities, Technologies and Data Science at the 2012 Beijing General Assembly. C40 / Division X transaction reports for 1997 – 2012 are given by Moran (2000), Padrielli (2003), Rodriguez *et al.* (2007), Nan *et al.* (2009) and Taylor *et al.* (2012).

Table 1 lists the C40 Presidents from 1948 to 2015 together with their years of service and nationality or country of residence.

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Years	President	Country
2012–2015	Jessica M. Chapman	Australia
2009–2012	Russell Taylor	Canada
2006–2009	Nan Ren-Dong	China
2003–2006	Luis Rodriguez	Mexico
2000–2003	Lucia Padrielli	Italy
1997–2000	James Moran	United States
1994–1997	John B. Whiteoak	Australia
1991–1994	Masaki Morimoto	Japan
1988–1991	Peter G. Mezger	Germany
1985–1988	John E. Baldwin	United Kingdom
1982–1985	Kenneth I. Kellermann	United States
1979–1982	Govind Swarup	India
1976–1979	Harry van der Laan	Netherlands
1973–1976	Yuri N. Parijskij	USSR
1970–1973	David S. Heeschen	United States
1967–1970	John Paul Wild	Australia
1964–1967	Martin Ryle	United Kingdom
1958–1964	Jean-Francois Denisse	France
1952–1958	Joseph L. Pawsey	Australia
1948–1952	Richard van der Riet Woolley	United Kingdom

Table 1. Presidents of Commission 40, 1948–2015. From 1997 to 2012 the Commission 40 Presidents were also Division X presidents.

2. Planning for the future

The triennium 2012–2015 was again one of major restructuring in the IAU. In June 2014 the IAU issued an announcement on a plan for reforming the IAU Commissions. This plan included a call for proposals and the selection of new Commissions. All current Commissions ceased and, following a selection process, new Commissions began at the IAU General Assembly in August 2015.

An important goal for the C40 President (Jessica Chapman) was to ensure that a Commission for Radio Astronomy could continue into the future. At a teleconference discussion held in June 2014 to consider the future of the commission, the C40 Organizing Committee strongly supported the development of a proposal for a 'new' Commission for Radio Astronomy, in consultation with the broad C40 membership. To facilitate the discussion a forum was set up on the C40 website and regular news updates were provided to members. The forum generated some useful input, and in particular highlighted the need to engage more closely with younger members of the IAU.

In September 2014, following a call for Expressions of Interest, a founding committee of four individuals was established to prepare a proposal for the new Commission and to act as core members of a new Organising Committeee if the proposal was successful. In October 2014, the members of this group, Gabriele Giovannini (Chair), Anthony Beasley, Xiaoyu Hong and Nicholas Seymour, submitted a letter of Intent for a new Commission for Radio Astronomy. A full proposal was submitted in January 2015 and the new Commissions were announced in April 2015.

Of 53 proposals for Commissions received by the IAU, the proposal for radio astronomy received the highest number of votes, clearly indicating strong community support and that the communications to members had been effective. The new Commission is now established in Division B as Commission B4. At the time of writing (November 2015), the Commission has 442 members and is the largest Commission under Division B.

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The IAU reform process provided an opportunity to review the goals of a Commission for radio astronomy and to consider how activities carried out through this can best meet the needs of its broad membership. The proposal includes the following key goals for the new Commission:

(*a*) Stimulate and support IAU symposia and other international meetings especially on cross-disciplinary themes where radio astronomy can play an important role and that cover more than one facility, e.g. major surveys and science data processing. Promote connection and interchanges among present and future large-scale facilities.

(*b*) Connect radio astronomy to informatics and statistics, provide information on available radio astronomy archives and promote a multi-wavelength approach to the sharing of astronomy data and the scientific importance of combining results from across the electro-magnetic spectrum.

(*c*) Foster discussions and share information on topics of current interest to radio-astronomers around the world and provide up to date information on radio science, data, facilities and techniques. Special attention will be devoted to the new Radio Astronomy windows at ultra-high frequency with ALMA and mm-VLBI, and to the new telescopes operating at lower frequencies e.g. LOFAR, ASKAP, MeerKat, MWA and the SKA.

(*d*) Act as an interface between the large number of individuals and groups working in this field and other Commissions, Divisions and the IAU in general.

(*e*) Encourage membership, broaden participation, and support the development of younger astronomers working or interested in radio astronomy. This will be done through a forum and/or through support for dedicated meetings. The importance of gender and countries diversity will be properly considered.

(*f*) Provide support to IUCAF and the ITU, primarily through the appointment of members to IUCAF and by providing web information on these activities on the Commission website.

(*g*) Develop connections and partnerships with the commissions of the IAU working in the areas of outreach and education. Astronomy in general, and radio astronomy in particular, are exciting topics for students and the general public.

For the full proposal, see `http://www.iau.org/submissions/newcommissions/detail/71/`.

3. Reports from the Working Groups

3.1. *Historic Radio Astronomy*

3.1.1. *History and Role*

The Working Group for Historic Radio Astronomy (WGHRA) was founded at the 2003 IAU General Assembly in Sydney as a joint initiative of Commissions 40 (Radio Astronomy) and 41 (History of Astronomy). Later, the WGHRA became an Inter Division Working Group (DX and DXII). In 2014 URSI approved the recommendation of URSI Commission J (radio astronomy) to establish the WGHRA as a joint Working Group of the IAU and URSI. Following the 2015 IAU General Assembly, the IAU approved the joint status of the Working Group.

The WGHRA was established to:

(*a*) assemble a master list of surviving historically significant radio telescopes and associated instrumentation found worldwide;

(*b*) seek to preserve historically important radio telescopes and their instrumentation;

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(*c*) document the technical specifications and scientific achievements of these instruments;

(*d*) maintain an ongoing bibliography of publications on the history of radio astronomy; and

(*e*) monitor other developments relating to the history of radio astronomy, including deaths of pioneering radio astronomers.

In support of these activities, the WGHRA has met at each succeeding GA, distributes regular e-mail updates, and maintains a web site at `rahist.nrao.edu` which includes the Working Group triennial reports, biographical notes on Grote Reber Gold Medalists for Innovative Contributions to Radio Astronomy, brief memorial articles on recently deceased radio astronomers, and links to the C40 website and various sources of material on the history of radio astronomy. The activities of the Working Group are supported by an Executive Group consisting of representatives of approximately 15 countries and geographic areas. The Chair of the Working Group was handed over from Ken Kellermann to Richard Wielebinski at the 2015 General Assembly.

3.1.2. *Biographical Memoirs*

Short Biographical Memoirs of the following deceased radio astronomers are posted on the Working Group web site: Kenji A. Akabane, 1927–2015; Donald C. Backer, 1943–2010; Esteban Bajaja, 1931–2015; John E. Baldwin, 1931–2010; Émile-Jacques Blum, 1923–2009; Norman W. Broten, 1921–2015; Robert L. Brown, 1943–2014; Martha Stahr Carpenter, 1920–2013; James L. Caswell, 1940–2015; James (Jim) Cohen, 1948–2006;, Nannielou Reier Hepburn Dieter Conklin, 1926–2014; David De Young, 1940–2011; Jean-François Denisse, 1915–2014; Graeme Reade Anthony Ellis, 1921–2011; William (Bill) Clarence Erickson, 1930–2015; Harold (Doc) Ewen (1922–2015); István Fejes, 1939–2011; Andrey Finkelstein; John A. Galt, 1925–2012; Mike Gaylard, 1952–2014; William E. Gordon, 1918–2010; Albert Greve, 1938–2011; Glyn Haslam, 1936–2013; David S. Heeschen, 1926–2012; Robert Hobbs, 1938–2013; Yuri Petrovich Ilyasov, 1933–2010; Mukul R. Kundu, 1930–2010; Norman Labrum, 1921–2011; Peter G. Mezger, 1928–2014; Koh–Ichiro Morita, 1954–2012; Venkataraman Radhakrishnan, 1929–2011; Ernst Raimond, 1932–2010; Steven Rawlings, 1961–2012; Jouko Ritakri, 1956–2013; Robert T. Rood, 1942–2011; Vagharshak Sanamian, 1917–2010; John Shakeshaft, 1929–2015; Vyacheslav Ivanovich Slysh, 1935–2008; Titus Spoelstra, 1945–2010; Jaap Tinbergen, 1934–2010; Gianni Tofani, 1938–2015; James Warwick, 1924–2013; Gart Westerhout, 1927–2012; and Gisbert Winnewisser, 1936–2011.

3.1.3. *Selected Publications*

After years of extensive interviews with most of the players involved in the early development of radio astronomy, Woodruff Sullivan III published his definitive book, *Cosmic Noise: A History of Early Radio Astronomy* (Sullivan (2009a)) covering the development of radio astronomy up to about 1953. Sullivan was awarded the 2012 Doggett Prize of the AAS in recognition of his "leadership in the history of astronomy community." Goss & McGee (2009) have published a biography of Ruby Payne-Scott which conveys her personal challenges trying to do radio astronomy in post-war Australia. Goss (2013) has published a new version of this book for a non science audience. Baars (2013) has written about his experiences in the construction of a number major radio telescope facilites.

Sullivan (2009b) has published an extensive history of radio telescopes covering the postwar period up to 1990. Wielebinski & Wilson (2010) have reviewed the history of radio astronomy instruments and their state of preservation. As part of her Masters thesis at West Virginia University, Kenwolf (2010) has discussed the personal issues associated with the establishment and operation of the NRAO in Green Bank. Other PhD and Masters theses concerned with the history of radio astronomy have been completed by Wendt (Potts Hill and Murraybank), Stewart (Penrith and Dapto), Robertson (John Bolton) and Quinn (Jodrell Bank 214-ft antenna). Tritton (2011) discusses the history of radio telescopes in Great Britian, while Strom (2008) reminded us of de Voogt's contributions as both an amateur and professional astronomer. Several papers reviewing the history of radio astronomy in France have been published by Orchiston *et al.* (2009), Lequeux *et al.* (2009), Pick *et al.* (2011) and Encrenaz *et al.* (2011). Papers on the history of the Stockert radio telescope by Wielebinski, R. (2010) and the Effelsberg radio telescope by Wielebinski *et al.* (2011) document the development of radio astronomy in Germany. Kellermann (2012) has edited a translation of the 1986 book in Russian on *A Brief History of the Development of Radio Astronomy in the USSR*. Orchiston & Mathewson (2009) have described the development of the Chris Cross at Fleurs, while Stewart *et al.* (2010) have described the Radiophysics field station at Penrith. Orchiston *et al.* (2011) have edited the publication of *Highlighting the History of Astronomy in the Asia-Pacific Region* which includes papers by Stewart *et al.* (2011a), Stewart *et al.* (2011b), Stewart *et al.* (2011c), Wendt *et al.* (2011a), Wendt *et al.* (2011b) and Wendt *et al.* (2011c). Orchiston has completed his project on early French radio astronomy. Frater & Ekers (2012) have provided a biographical memoir of John Paul Wild. Ekers (2014) discusses the history of our understanding of non-thermal radio emission. The *Journal of Astronomical History and Heritage* contains many other papers on the history of radio astronomy.

3.1.4. *Preservation of Radio Telescopes, Equipment and Documents*

In 1998 Bell Labs erected a Karl Jansky Monument on the exact location of the original Jansky antenna. The reported deterioration of the Bell Labs horn reflector used by Penzias and Wilson to detect the Cosmic Microwave Background (CMB) has been addressed by Lucent Technologies, and the horn has been refurbished. The Bell Labs property where Karl Jansky made his pioneering discovery has been sold to a real estate developer, but efforts are underway to secure the preservation of the site and its public access. In the Netherlands, the 25-meter Dwingeloo dish, inaugurated in 1956, and used for major research programs up to 1998, has been repaired and modernized by CAMRAS, a foundation run by radio amateurs, and with funding from the Dutch Ministry of Education, Culture and Science the Dwingeloo radio telescope now supports a variety of educational programs.

Ten of the original thirteen concrete piers from the Stanford solar heliograph have been moved to the VLA site where they have been erected to form a sundial. These piers contain the engraved signatures of radio astronomers who visited Ron Bracewell at Stanford. The foundation of Grote Reber's array which he built on Haleakula in 1951 has been removed to make way for a parking lot, but the memorial plaque denoting the site of the first mountaintop telescope in Hawaii has been preserved.

In 2003 the National Radio Astronomy Observatory initiated an Archives devoted exclusively to radio astronomy. The NRAO Archives seeks out, collects, organizes, and preserves institutional records, personal papers, audio-visual materials, and oral histories of enduring value documenting NRAO's development, institutional history, instrument construction, and ongoing activities, including its participation in multi-institutional

collaborations. As the national facility for radio astronomy, the Archives also includes an increasing collection of materials on the history and development of radio astronomy and the work of individual astronomers especially in the United States. See http://www.nrao.edu.archives.

In addition to the institutional records of NRAO, the NRAO Archives includes educational resources on early radio astronomy and on Nan Dieter Conklin and Harold "Doc" Ewen, as well as personal papers of Donald Backer, Allen Barrett, Ronald Bracewell, Robert L. Brown, Bernard Burke, Marshall Cohen, John Findlay, J. Richard Fisher, Mark Gordon, David Heeschen, David Hogg, Hein Hvatum, Kenneth Kellermann, John Kraus, Grote Reber, Morton S. Roberts, Arthur M. Shalloway, Richard Thompson, James Ulvestad, Paul Vanden Bout, Campbell Wade, Sandor Weinreb, and Gart Westerhout.

W. T. Sullivan donated his research materials including 255 interviews with radio astronomers conducted between 1971 and 1988. These illuminate post-1953 radio astronomy history as well as the earlier period covered in his book. His taped interviews have been digitized and are being made available on the Archives web site. Detailed finding aids for the Sullivan collection and transcripts of interviews can be found at http://www.nrao.edu/archives/Sullivan/sullivan.shtml.

3.1.5. *Grote Reber Medal*

The WGHRA web site documents the award and accomplishments of the ten recipients of the Grote Reber Gold Medal awarded for innovative contributions to radio astronomy to William C. Erickson, 2005; Bernard Y. Mills, 2006; Govind Swarup, 2007; Sander Weinreb, 2008; Barry Clark, 2009; Alan Rogers, 2010; Jocelyn Bell Burnell, 2011; Nicolay Kardashev, 2012; James M. Moran, 2013; and Ron Ekers, 2014. The presentations of the 2006, 2009, and 2012 medals were made at the corresponding IAU GAs in Prague, Rio de Janeiro, and Beijing.

3.1.6. *Historical Conferences*

Celebrations of the 50th anniversaries of NRAO (Bridle *et al.* (2008)) and Parkes (2011, see http://www.atnf.csiro.au/research/conferences/Parkes50th/index.html and the 40th anniversary of Westerbork (2010, see http://www.astron.nl/wsrt40) each contained historical reviews of the development of radio astronomy. In November 2009, Kellermann and Ekers organized a session on *Discoveries in Astronomy* at the American Philosophical Society with an emphasis on radio astronomy. See papers by Ekers & Kellermann (2011), Schmidt (2011), Longair (2011) and by R.W. Wilson on the *Discovery of the CMB* (unpublished). All of the presentations can be viewed on-line at http://www.amphilsoc.org/meetings/webcast/archive/y/2009/m/11. The April 2012 Manchester symposium, *Resolving the Sky*, contained a number of papers relating to the history of radio interferometry and VLBI (Garrett & Greenwood (2013)). In April, 2015, the Joint Institute for VLBI Research in Europe (JIVE) held a two day symposium that included historical papers on JIVE (Schilizzi), on the history of EVN (Booth), on early interferometry at Jodrell Bank (Miley), and in early transatlantic VLBI (Kellermann). These papers can be found at http://www.jive.eu/jive-eric-symposium. At the 2015 General Assembly, the WGHRA held two sessions to document the remarkable discoveries by radio astronomers made during the Golden Decade of the 1960s. The presentations made at these and other Working Group sessions can be found on the web site.

3.2. *Astrophysically Important Spectral Lines*

The Working Group for Astrophysically Important Spectral Lines was established in accordance of the decision described in the IAU Resolution A.2 (1991, Buenos Aires). The task of the Working Group is to demonstrate a minimum set of astrophysically important spectral lines for non-astronomers, which is then forwarded to the International Telecommunication Union (ITU) to be used as a scientific rationale for the protection of radio astronomy observations. The list of astrophysically important spectral lines below 1000 GHz is contained in the Recommendation ITU-RRA.314 *Preferred Frequency Bands for Radio Astronomical Measurements*.

In 2012 during the IAU General Assembly in Beijing, the Working Group extended the list of astrophysically important spectral lines up to 3000 GHz, by adding about 360 lines between 1000 and 3000 GHz. The list was brought to the ITU, and the content was approved as the Recommendation ITU-R RA.1860 *Preferred frequency bands for radio astronomical measurements in the range 1–3 THz*. This ITU-R Recommendation as well as the Report ITU-R RA.2189 *Sharing between the radio astronomy service and active services in the frequency range 275–3000 GHz* were used to identifiy frequency ranges to be used by submillimeter telescopes, e.g., ALMA.

As the result of this work the Working Group was dormant in the 2012–2015 triennium, other than maintaining the list of spectral lines. However the Group plans to remain active so that additional spectral lines can be added as needed over time.

3.3. *The definition of flux density in wide bandwidth data*

In 1973 the IAU adopted the Jansky (Jy) as the unit of spectral flux density. This is defined as 1 Jy $= 10^{-26}$ Wm^{-2}Hz^{-1}. This is the *spectral* flux density measured in Hz^{-1}. It does not specify flux density in relation to bandwidth.

The IAU definition assumes monochromatic observations and this has been adequate in the past. However, as some observatories are implementing wide fractional bandwidths, the IAU definition of flux density needs clarification.

At present, when flux densities are obtained by integrating over a large fractional bandwidth, it is unclear what frequency or frequencies to use. Furthermore, it is apparent that different software packages for analysing radio astronomy data are using different definitions. Typical non-thermal radio sources have a power law spectrum. In this case quoting the flux density averaged over a finite band at the centre frequency can give a value that is significantly different to the flux density directly measured at the central frequency. For example, at frequencies of 1–3 GHz and for a power law spectral index of -1.0, the flux density measured using an average over frequency differs by around 10 per cent from the flux density measured at the frequency corresponding to the band centre. This difference can introduce significant inconsistencies and errors in flux calibration, particularly where different software packages use different flux density definitions.

To clarify this situation, a small Working Group was established at the C40 meeting held at the IAU 2012 General Assembly. The key goal for this group is to develop an IAU resolution for the definition of continuum flux density to be used consistently in software for data processing and in publications. The Working Group will communicate the agreed methodology to the community, encourage its use in publications and aim to ensure that standard software is modified to properly treat and report results for wide bandwidth systems. Fortunately for radio astronomers, the transfer functions for observing bands are usually close to being simple top hat functions. As these are well defined the problem is not as difficult at radio frequencies as it is for defining photometric scales using optical or IR filters.

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Further work is needed to draft a resolution for the 2018 General Assembly and this Working Group will continue for another three years. The Chair of this group was handed over from Ron Ekers to Urvashi Rau at the 2015 General Assembly.

4. IUCAF activities

4.0.1. *IUCAF Role and Terms of Reference*

IUCAF, the Scientific Committee on Frequency Allocations for Radio Astronomy and Space Science, was established by the ICSU as an inter-union organisation in 1960. Membership is drawn from the IAU with five representatives appointed through C40, URSI and the Committee on Space Research (COSPAR). For 2012–215 the IAU representative to IUCAF were Masatoshi Ohishi, Harvey-Liszt, Tomas Gergely, HyunSoo Chung and Adrian Tiplady.

IUCAF works in the field of spectrum management on behalf of the 'passive' radio sciences including radio astronomy and space research. In particular, IUCAF is a sector member of the International Telecommunication Union (ITU), in Geneva. The ITU is a treaty organisation (rather than a scientific union) with membership from 193 countries and more than 700 sectors.

As a sector member, IUCAF members are able to participate at ITU meetings and to provide documents as input to ITU meetings. IUCAF members work actively throughout the year towards the protection of the passive spectrum allocations for science. As a consequence, the radio environment around radio observatories has been kept as clean as possible. Although this work largely happens in the background, it has been of enormous benefit to radio astronomy.

The IUCAF Constitution and Terms of Reference were established over 40 years ago and several changes are needed to bring these up to date. A proposed revision of the Terms of Reference includes defining the roles of Officers and establishing the term of service for members and Officers. The proposed changes were presented and agreed at the 2015 C40 business meeting in Honolulu, and have been forwarded to the ICSU for approval. It is expected that the ICSU will approve the proposed revision of the IUCAF Terms of Reference by the end of 2015.

For the IUCAF website, see `http://www.iucaf.org`.

4.0.2. *IAU C40 Support for IUCAF*

A significant goal for C40 in this triennium was to strengthen the relationship between IUCAF and C40. The following arrangements were clarified and/or established in consultation with the IAU Executive, and will be continued by Commission B4:

- The IUCAF Chair acts as the primary point of contact for the IAU General Secretary and Executive on IUCAF matters.
- The C40 President acts as a secondary contact person and can assist with establishing arrangements where needed.
- The IAU representatives for IUCAF are appointed through C40 at the IAU General Assembly meetings.
- C40 provides a forum for the discussion of spectrum requirements with astronomers across all areas of radio astronomy.

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• The IAU Executive provides oversight and support for these activities and provides an annual financial contribution to IUCAF (currently EUR 5,000.)

4.0.3. *IUCAF Activities in 2012–2015*

During this triennium IUCAF members attended many meetings where spectrum allocation issues were discussed. These included meetings of the Committee on Radio Astronomy Frequencies (CRAF), ITU (Working Parties, Study Groups, Joint Task Groups, World Radio communication Conferences (WRCs), the Space Frequency Coordination Group, the URSI General Assembly held in Beiging in 2014, and the 2015 IAU General Assembly XXIX.

In addition to these activities, in April 2014, IUCAF held the *IUCAF 4th School on Spectrum Management for Radio Astronomy* at the Joint Alma Observatory in Santiago, Chile. These schools are held to provide individuals with an understanding of the techical and regulatory issues related to the use of the spectrum for radio astronomy puposes, especially those who may play a role in spectrum management activities. The Chile school was attended by 36 participants from 13 countries. A highlight of the meeting was a visit to the ALMA site.

4.0.4. *IAU Resolution B4: Protection of Radio Astronomy Observations in the Frequency Range 76 to 81 GHz from Interference Caused by Automobile Radars*

WRCs are held every three or four years. These meetings are held to review and revise the Radio Regulations, the international treaty governing the use of radio-frequency spectrum and satellite orbit resources.

As an agenda item for the WRC15 meeting (Geneva, November 2015), IUCAF provided documentation on the need for protection of radio astronomy observations in the frequency range 76–81 GHz from interference caused by automobile radars. In March 2015 this issue was discussed at a 'Conference Preparatory Meeting' with a proposal from the radio astronomy community to set an exclusion zone around radio astronomy observatories operating in this frequency range. However, this request was rejected by the automobile industries and their supporters. To progress this further, IUCAF requested support from C40 to prepare an IAU resolution on this issue that could then be used as an input document for WRC15. Adoption by the IAU of such a resolution would be a good precedent showing that the astronomy community is concerned about the impact of radio frequency interference.

C40 submitted a resolution to the IAU for consideration by the full membership at the second General Business meeting of General Assembly XXIX. For the full text of the resolution (B4) and a briefing paper see `http://astronomy2015.org/resolutions` (download: `http://www.iau.org/static/resolutions/IAU2015_English.pdf`)

The resolves of resolution B4 are:

(*a*) to request that WRC15 take all possible steps to protect radio astronomy observations in the range 76–81 GHz from interference caused by automobile radars;

(*b*) to express the view that the most effective protection of radio astronomy observations would be through geographical separation;

(*c*) to send a copy of this resolution to administrations that operate or host radio astronomy observations in the frequency range 76–81 GHz, and where automobile radars are operating or plan to operate in the same frequency range; and

Figure 3. Participants at the joint IAU C40 / IUCAF Business meeting. Held at IAU General Assembly XXIX on 6 August 2015. (Credit: Robert Hollow)

(*d*) to encourage astronomers, particularly those in countries that fall under Resolves 3, to work proactively in protecting radio astronomy observations in the frequency range 76–81 GHz.

The resolution was voted on and approved at the General Assembly session. Further discussions on this issue are ongoing.

5. Commission 40 Triennial meeting

A joint C40 / IUCAF Business Meeting was held on 6 August 2015, at the IAU General Assembly XXIX at the Hawaii Convention Centre in Honolulu. The meeting was attended by approximately 35 individuals (Figure 3). This was the first time that this meeting was held as a joint activity between the two groups demonstrating the closer engagment between C40 and IUCAF.

Presentations were given by the Commission President (Jessica Chapman), the Working Group Leaders (Ken Kellermann, Masatoshi Ohishi and Ron Ekers) and the IUCAF Chair (Masatoshi Ohishi). The meeting agenda and presentations are available on the C40 website (see links from `http://www.atnf.csiro.au/iau-comm40/C40`).

The topics raised at the Buisness Meeting are discussed in sections 2 to 4 of this report. The meeting attendees supported the following recommendations:

- That the new Commission should actively encourage new members to join.
- That the three C40 Working Groups should continue under the new Commission.
- That suitable arrangements be made to establish WGHRA as a joint Working group of the IAU and URSI.
- That the membership of the new Commission should be encouraged to consider new Working Groups.
- That the arrangements for IAU C40 support to IUCAF, established for the 2012–215 triennium, should continue.
- That the IUCAF Chair be handed over from Mastaoshi Ohishi to Harvey Lizst.

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The meeting ended with a handover from the outgoing President of Commission 40 (Jessica Chapman) to the incoming President of Commission B4 (Gabriele Giovannini).

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