



Monthly Newsletter of International URSI Commission J – Radio Astronomy

December 2017

Prepared by R. Bradley, Chair, Commission J, rbradley@nrao.edu

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News Items

Greetings Commission J Members!

The abstract deadline for the 2018 URSI Atlantic Radio Science Conference (2018 AT-RASC) is January 10, 2018! The Commission J program has been finalized and details appear below, including brief abstracts of the sessions. We hope you will consider presenting your research at the AT-RASC. If you have questions or concerns regarding a particular session please feel free to contact the Session conveners.

There are certain books that set the standard in their fields. *Interferometry and Synthesis in Radio Astronomy*, written Thomson, Moran, and Swenson, is the one for radio interferometry, and a third edition of this classic has just been published. Jacob Baars provided a comprehensive review of this edition in the latest issue of the *Radio Science Bulletin*. We also have it for you in this edition of the Newsletter.

CQ all radio amateurs who also have a career in radio astronomy! Our spotlight this month is on the hobby of amateur or “ham” radio and how it plays an indirect role in radio astronomy. For some, amateur radio was an endeavour that opened a gateway into the world of radio science which led to a career in radio astronomy. For others, it provides a means by which to explore various avenues of radio science, nurturing a deeper, more expansive understanding or *fingerspitzengefühl* of radio that can be applied throughout one’s scientific research career. Amateur radio also serves STEM education, introducing radio science fundamentals to students of all ages and engaging the public in some challenging “citizen science” initiatives (see <http://www.hamsci.org>). Indeed, from 1922-1948 one of the URSI Commissions was “Liaison to operators, practitioners, and amateurs.” Today, the radio amateur is being recognized again by an “Amateur Radio Operators Breakfast” at the annual IEEE AP-S Symposium on Antennas and Propagation and USNC-URSI Radio Science Meeting. For more information on this fascinating hobby I invite you to read Martin Ewing’s article in this edition of the Newsletter.

As always, I hope you are finding the Newsletters both interesting and informative - your comments and suggestions are always welcome.

Submitted by R. Bradley

2018 URSI Atlantic Radio Science Conference (2018 AT-RASC)

28 May – 1 June 2018, ExpoMeloneras Convention Centre, Gran Canaria

Submission deadline: January 10, 2018

<http://mailchi.mp/intec/submission-for-at-rasc-2018-is-now-open-pprh9v00w2?e=6dc54cab9b>

J.1 Software Enabled Radio Astronomy

Richard Prestage, Cedric Viou, Alessandra Zanichelli

The worldwide astronomy community is pushing forward on an unprecedented scale to create large aperture and dense low frequency arrays. Single-dish telescopes are being equipped with phased array feeds, ultra-wideband receivers, real-time fast radio burst detectors, and other advanced digital instrumentation. This new generation of telescopes and instrumentation share the need for exceptionally sophisticated signal processing algorithms, and we are entering the era of “software enabled radio astronomy”. This session will focus on the research challenges and latest approaches in the field of heterogeneous FPGA / CPU / GPU software development, including algorithms for array calibration, beamforming, imaging, and radio frequency interference mitigation.

J.2 Large N Aperture Arrays

Eloy de Lera Acedo, Kris Zarb Adami

This session will cover different aspects on the design and operation of large N arrays for modern radio astronomy in the era of SKA (eg. SKA1-LOW, HERA, MWA, LOFAR, etc). The session will cover aspects of both the antenna arrays, RF chains, digital beam forming, science data processing and science goals of these instruments.

J.3 Pattern Recognition Applications in Radio Astronomy

Abhi Datta, David Rapetti

With the advent of next generation radio telescopes like the Hydrogen Epoch of Reionization Array (HERA), the Square Kilometer Array (SKA) and the next generation Very Large Array (ngVLA), we expect the radio sky to be surveyed at unprecedented sensitivity. While observations with these telescopes should bring in a paradigm shift in our knowledge of the radio sky, this also comes with unprecedented data volume. For example, the SKA is expected to produce more than tens of terabytes of data per second at its fullest capability. Manual processing of this amount of data is not feasible. Hence, automation in data processing and the use of pattern recognition and machine learning techniques to extract the wealth of scientific information from such a Big Data set are critical. Machine learning algorithms such as support vector machines (SVM), K-nearest neighbors (KNN), decision trees, neural networks and deep neural networks are already in use in radio astronomy. This session will focus on the recent advances, challenges and future prospects of this field of research.

J.4 Novel Instrument Concepts and Observational Challenges

Douglas Bock, Richard Bradley

This session is designed to capture new work that may NOT fit into other sessions. Novel ideas that can be applied to instruments, signal processing, or observational strategies that have the potential for improving measurements are welcome, including requests for specialized instrumentation or techniques that could solve a challenging astronomical measurement requirement.

J.5 *Detecting Hydrogen Near and Far*

Jackie Hewitt, Eloy de Lera Acedo

The first detection of radio emission from neutral hydrogen in an astronomical source, in this case our Galaxy, was accomplished through the pioneering work of Ewen and Purcell in 1951. Since then, the 1.4 GHz line of neutral hydrogen has served as a tracer of astronomical phenomena on many scales. With the recent development of large low frequency radio arrays, there is renewed interest in using this technique to explore a variety of topics at a wide range cosmological redshifts, including for example detecting the first generation of stars and characterizing dark energy. This session will focus on the design and construction of instrumentation aimed at neutral hydrogen studies in the modern cosmological context.

J.6 *Instruments for Education*

Glen Langston, Kevin Bandura

Progress in radio communications and radio astronomy depends on education of the next generation of engineers and scientists. This session is focused on new and existing instruments enabling students to study the universe with radio techniques. Emphasis is placed on simple instrument designs the students can build. Presenters will describe groups operating these instruments, providing strong connections between technology development and scientific discoveries. The session covers topics of hardware design, curricula for education, student motivation, observing plans and large-scale research projects enabled by distributed groups of researchers.

J.7 *Mm wave / sub-mm Wave Science and Technology*

Pepe Cernicharo, Juan Daniel Gallego, Rolf Gusten

Special Sessions:

S-JACEFG – Applications for pattern recognition methodologies

This special interdisciplinary session, dedicated to an important new area of study, is designed to share ideas and experiences among the URSI Commissions. We would like to have one or two presentations from each of the participating Commissions that provide an overview or tutorial on how pattern recognition methodologies are being used or the types of problems for which it might be applied to areas of research within the Commission.

S-EACFJ - Spectrum Management and Utilization

Workshops:

JB - *Polarimetry of advanced antenna systems in radio astronomy*

JG - *3-D ionospheric models for radio interferometric calibration*

GJEFH - *Space Weather*

The AT-RASC will also include a Young Scientist Program and Student Paper Competition. Please see <http://www.atrasc.com/homepage.php> for additional information.

2019 URSI Pacific Radio Science Conference (2019 AP-RASC)

9 -15 March 2019, New Delhi India

Plans are underway for the 2019 AP-RASC in New Delhi, India. Please see <http://aprasc2019.com/> for details.

2020 URSI General Assembly and Scientific Symposium (2020 URSI GASS)

Rome, Italy

The site for the next URSI General Assembly and Scientific Symposium has been chosen! Stay tuned for details. If you like to organize a session or workshop at the 2020 URSI GASS please let me know.

Radio Science Bulletin

The June 2017 issue of the Radio Science Bulletin is now available at the website: http://www.ursi.org/content/RSB/RSB_361_2017_06.pdf There is a special section consisting of papers invited from three of the awardees from the URSI AP-RASC 2016 Student Paper Competition. Quantum communications is a fascinating topic. In many cases, it involves what Einstein referred to as “spooky action at a distance.” Tremendous advances have been made in quantum communications and quantum teleportation in the last few years. Ronald Meyers, Arnold Tunick, Keith Deacon, and Philip Hemmer have provided a comprehensive survey of the work on networks and protocols in this field along with an extensive bibliography for further study.

Submitted by R. Bradley and R. Stone

Book Review***Interferometry and Synthesis in Radio Astronomy***

by A. Richard Thompson, James M. Moran and George W. Swenson Jr.

Third Edition

Astronomy and Astrophysics Library

Springer International Publishing

Open Access – 2017, 872 pages

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When we look at the sky with the unaided eye its angular resolving power of about one arcminute allows us to see many hundreds of separate stars. We can also see structure in the brightness distribution of the full Moon. A telescope of only 10 cm diameter already provides us with a resolution of about one arcsecond at optical wavelengths. In the early 1940s Grote Reber made the first systematic radio observations of the sky with a parabolic dish of 10 m diameter at a wavelength of about 1.9 m. It resulted in an intensity map of the “radio sky” with an angular resolution of about 12 degrees! Although some regions of higher intensity protruded from the smooth radiation from the Galactic Plane, it was out of the question to learn about their character such as determining the celestial position and angular size. Any comparison with an optical companion was impossible.

In this frustrating situation the early radio astronomers, many of whom came from wartime radar laboratories, notably in Australia and England, quickly turned to the use of interferometers in order to improve the angular resolution that would be proportional to the distance between the two elements of the interferometer rather than their individual size. In early experiments in Australia a “sea-cliff” interferometer was realised with a single antenna located about 100 m above sea level using the direct and reflected path from the ocean surface to create interference fringes. The improved resolution led to the optical identification of the powerful radio sources Cygnus A and Taurus A with a distant galaxy and a supernova in our Galaxy, respectively. In the early 1950s several large interferometric radio telescopes were built that operated at relatively long wavelengths of the order of one meter. Both in Australia and in England the method of aperture synthesis was developed in which data from a number of interferometers with different spacing were combined to synthesise a two-dimensional telescope. With the advent of fully steerable parabolic reflectors operating at shorter cm-wavelengths the method of earth rotation synthesis was introduced. The object under observation was now tracked for up to 12 hours along its daily path. This causes the projection of the EW-interferometer baseline to rotate with respect to the source, thus providing baselines in all orientations. From these observations a two-dimensional picture of the brightness distribution of the source can be derived. Major early instruments of this category were the “one mile” and “5 km” arrays in Cambridge, UK (1962, 1968), the Westerbork Synthesis Radio Telescopes (1970) and the Very Large Array in the USA (1980). Parallel to these the technique of VLBI (very long baseline interferometry) was developed in the late 1960s.

This all provided sufficient impetus to the authors of the book under review here to present in 1986 a comprehensive discussion of the principles and applications of “Interferometry and Synthesis in Radio Astronomy”. It has been the standard text ever since not the least due to a greatly updated second edition in 2001. Now, again 15 years later, the authors have added another 200 pages for a total of almost 900 to cover the developments in the field to the present. I would classify the new edition as the Radio Astronomy equivalent to “Born & Wolf” for Optics. It is complete, almost encyclopaedic. But it is not an encyclopaedia! It is a successful combination of a graduate course textbook and a compendium of answers to any question one

might have on the subject. The latter is helped by the systematic reference to original publications and the extensive subject index. All aspects of the subject are covered in 17 well-structured chapters. The basic concepts are occasionally introduced in a heuristic approach with the rigorous treatment shifted to a later chapter. There is a parallel here with the structure of Born and Wolf's classic book on Optics. While the pointing to later details may occasionally be somewhat frustrating to the expert, it keeps the general reader on track in gaining understanding without getting immersed in fine details. The first chapter provides a very nice historical introduction with abundant use of illustrations from original publications. Contemporary students may be surprised to see how much information could be gleaned from a tracing on an analogue chart recorder. The theory of interferometry and synthesis imaging is presented in chapter 2 and further developed in chapter 3. The essential role of the Fourier Transform and the concept of convolution are discussed in detail. Chapter 4 covers the aspects of the geometry of the interferometer. It describes the sampling of the spatial frequency plane that delivers the visibility function. After a discussion of polarisation the chapter concludes with the introduction of the measurement equation. This equation includes all instrumental and outside (e.g. atmosphere) parameters that influence the measured visibility and hence need to be calibrated to obtain intrinsic visibility data on the observed object.

Multi element interferometer systems are usually called (aperture) synthesis arrays and can be configured geometrically in several ways. These are discussed in chapter 5 with emphasis on practical matters such as selecting the best configuration for a particular observational purpose. The vehicle for this is the spatial transfer function that connects the measured visibility function with the object's brightness distribution via the Fourier Transform. Several implementations of actual arrays are described.

Chapter 6 deals with the response of the electronic receiver system. Frequency conversion (mixing) is treated for single- and double-sideband operation along with the methods of delay correction and fringe rotation. The response to noise and the effects of bandwidth are analysed in detail. A chapter on system design follows in which a detailed exposé is presented of receiver and local oscillator systems, including aspects of noise and delay and gain errors on the sensitivity of the system.

We have now reached the point where normally the signals are digitised and chapter 8 on digital signal processing has grown from 50 pages in the second edition to 80 pages in the new edition. It reflects the growing application of digital circuits in the steps from signal reception by the receiver frontend to the digital data that represent the image of the observed object. This chapter treats in detail the sampling and quantisation issues in digital processing. It is followed by a description of digital delay lines and digital correlators that are now standard in synthesis telescopes. The different types of correlators (XF, FX, hybrid and digital) are compared quantitatively.

In 1967 a special form of interferometer was introduced, whereby the physical connection of the elements by cable or radio link was replaced by adding very accurate time stamps to the received signal that were “lined up” in the off-line correlator to create the interference function. This enabled baselines of hundreds to thousands of kilometers with commensurate extremely high angular resolution. The method is known as Very Long Baseline Interferometry (VLBI). The special features of this technique are covered in chapter 9. It covers the transition from magnetic tape to hard disks for the recording medium that occurred in 2001 at about the time that the second edition was published. Apart from an indication in the Preface, this edition does not mention the further step of using the Internet for data and timing transport that renders the VLBI essentially into a real-time connected interferometer. First experiments along this line have recently been performed with success. Geodesists and astrometrists adopted the VLBI technique with its exquisitely high angular resolution for the precise measurement of continental drift and the position of celestial objects. The great advances obtained in this field are presented in chapter 12.

Chapters 10 on Calibration and Imaging and 11 on Further Imaging Techniques are more than double the size from the second edition, reflecting the enormous development of these techniques over the last 15 years. In addition to the full Fourier Transformation of the visibility data to obtain the source brightness image, the use of model fitting and closure phase is widely used. These are given extensive attention in this edition. Image processing algorithms, such as CLEAN and self-calibration schemes, are discussed and also here the advances in the field are striking.

A serious impediment to interferometry with spatially separated elements is the influence of the fluctuating index of refraction of the propagation medium, such as the earth’s ionosphere and troposphere. The resulting path length variations cause differential phase errors in the measured complex visibilities that are hard, if at all, to separate from the true celestial signal. Also in this area great progress in understanding and new methods of measurement has been achieved since the publication of the second edition. In the current version separate chapters have been assigned to the treatment of the neutral atmosphere (troposphere) in chapter 13 and an ionised medium (ionosphere, interplanetary and interstellar) in chapter 14. The emergence of large arrays with baselines up to 10 km or more (for instance ALMA in the Atacama Desert of Chile) has inspired strong efforts toward measuring the tropospheric pathlength variations (mainly caused by water vapour) in real time to correct the observed visibility phase. Thus separate small antennas measure the water vapour content along the line of sight from which the path length variations can be derived.

Such measurements are routinely made in the evaluation of the suitability of a site for a millimeter or submillimeter wavelength telescope. Where the troposphere seriously affects observations at short cm and mm wavelengths, long wavelength observations suffer under the influence of variations in the ionosphere. The emergence of large arrays at meter wavelengths

(for instance LOFAR) puts the need for corrections on the front burner. These telescopes also have to cope with the generally unavoidable interference from man-made radiation, be it TV transmitters, communication channels or industrial “noise”. Chapter 16 is devoted to this mundane but important aspect of observational radio astronomy.

In chapter 15 the authors return to the theoretical basis of synthesis in a full discussion of the van Cittert-Zernike theorem and aspects of coherence of the radiation field. This chapter can be considered the rigorous treatment of the material presented in chapters 3 and 4. The book closes with a chapter on “Related Techniques” by shortly discussing the intensity interferometer, lunar occultation methods, tracking of space debris and optical interferometry.

Most chapters have appendices with full mathematical derivations and additional material and an extensive index of names and subjects is added. Throughout the book references to original papers are given and the resulting reference lists should make the use of Google Scholar superfluous.

Overall the book delivers a comprehensive treatment of all aspects of interferometry and synthesis in a lucid and flowing tale that is a pleasure to read. The historical notes that are scattered throughout the text add flavour to the reading. My favourite is the discovery at the Parkes telescope that some weird intermittent interference was caused by a microwave oven in one of the observatory buildings. For all working in this field the book is invaluable. So, what does it cost? Here is the best of all: it is published as Open Access. It can be downloaded for free by anyone who is interested in an 880-page masterpiece. For those, as your reviewer, who prefer to hold this “brick” in their hands, Springer will sell it to you for about 55 Euros, a remarkable small amount, certainly for Springer.

Submitted by Jacob W. M. Baars

Max-Planck-Institut für Radioastronomie
Bonn, Germany

Activities Spotlight

The Indirect Influence of Amateur Radio in Radio Astronomy

How did you find your way into radio astronomy or allied fields? Many of us got our start as radio amateurs at an early age. Amateur (“ham”) Radio is a government-licensed radio service that promotes public service communications and experimentation in dozens of allocated frequency bands ranging from 135 kHz to 250 GHz. Hams must pass exams that cover regulations and radio technology, before they are authorized to operate (with up to 1.5 kW power) and are assigned a call sign. (Mine is AA6E.)

While Amateur Radio had its beginning with telegraphy using spark transmitters and "damped" waves, you will now find hams communicating with advanced digital modes as well as traditional voice and "CW" (continuous waves, Morse code). Our colleague Joe Taylor (K1JT) has notably revolutionized digital ham radio by applying astronomy-inspired digital signal techniques to enable long distance work with low power – even using moonbounce transmission.

Besides signal processing, there are important overlaps between radio astronomy and Amateur Radio. Both involve exquisitely sensitive receiving gear that is vulnerable to all sorts of human source interference. Both have to fight for spectrum allocation and protection from other spectrum users who may operate at high power levels.

A group of some 35 ham/astronomers has formed an Internet list to discuss our shared history and to think about how the connection may evolve in the future. One point of agreement: an early background in do-it-yourself radio and electronics continues to be a significant boost for a later scientific or engineering career, and we would like to encourage young people along those lines.

We note that a number of leading astronomer/hams have passed on to become "Silent Keys", as we say, including Lloyd Berkner, Sam Harris, Dave Heeschen, Hein Hvatum, John Kraus, Grote Reber, Martin Ryle, and George Swenson.

We invite anyone working in astronomy (all wavelengths), including students and retirees, who is or would like to be connected with the ham radio world to join our "Radioastronomy-hams" group at <https://groups.io/g/radioastronomy-hams> . For information on ham radio, check the websites of various amateur radio organizations including <http://arrl.org> in the U.S., <http://rsgb.org> in Great Britain, <http://www.wia.org.au> in Australia, and <http://www.jarl.org> in Japan.

Submitted by Martin Ewing

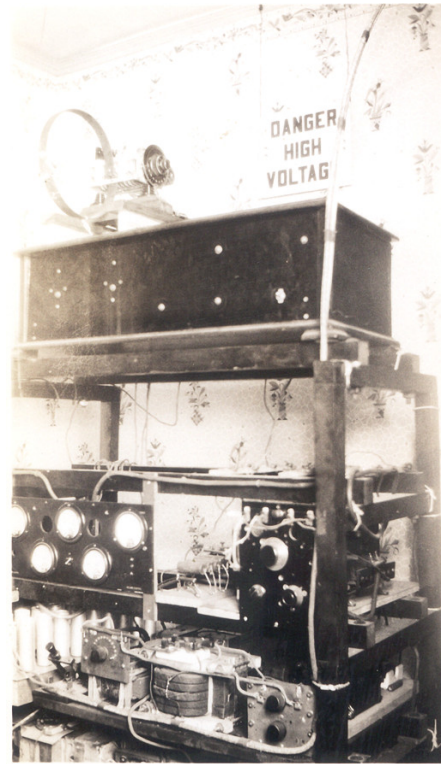
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Photographs by NRAO Archive

Grote Reber, the famous pioneer of radio astronomy, was also an active radio amateur. Pictured here is his license, his personal “QSL” card that was exchanged with other hams to confirm a radio contact (his callsign was W9GFZ), and his home-built station equipment. Learning of Karl Jansky’s discovery, Reber designed, built, and operated the worlds first radio telescope to study the nature of this strange “cosmic static”. His experience gained through amateur radio helped to provide the self-confidence and motivation needed to take on such an ambitious task.

If you have an interesting photograph that you wouldn’t mind sharing with others in the public domain I encourage you to please send a copy to me along with a brief caption and the person’s name to whom I should credit.

