

## Monthly Newsletter for International URSI Commission J – Radio Astronomy

October 2017

Prepared by R. Bradley, Chair, Commission J, [rbradley@nrao.edu](mailto:rbradley@nrao.edu)

### Officers

Chair: Richard Bradley  
Vice-Chair: Douglas Bock  
ECRs: Stefan Wijnholds  
Jackie Gilmore

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### News Items

Greetings Commission J Members! I'm just starting my three year term as your Chair for the 2017-2020 triennium and want to thank you for giving me this opportunity to serve. I also want to thank our Immediate Past Chair, Willem Baan, for his years of service to URSI. Commission J remains one of the strongest commissions - your continued participation in URSI conferences has made an impact. I want URSI to be your clear choice when it comes time to share your work with others - be it an oral presentation, a technical poster, or simply meeting up with others at our conference for informal discussions. As our career pathways become more narrowly focused, it is nice to have an interdisciplinary venue where experts in so many diverse areas of radio science can come together – a true asset of our Union that should be nurtured. As Chair, my goal is to help maintain and hopefully improve your URSI experience, so please don't hesitate to contact me with your comments and suggestions. It is also important to keep you informed of international URSI activities – I'm planning to do so via monthly newsletters.

The structure of the Newsletter will vary from month to month depending on content. I will use this forum to keep you abreast of the latest URSI news and timely information on the URSI flagship conferences. In addition, I'll include input from our Working Groups, the Radio Science Bulletin, and the journal Radio Science. I hope you will find it both interesting and informative - your comments and suggestions are always welcome.

*Submitted by R. Bradley*

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

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

The following sessions are being planned:

- J.1 Software Enabled Radio Astronomy
  - J.2 Large N Aperture Arrays
  - J.3 Pattern Recognition Applications in Radio Astronomy
  - J.4 Novel Instrument Concepts and Observational Challenges
  - J.5 Detecting Hydrogen Near and Far
  - J.6 Instruments for Education
  - J.7 Mm wave / sub-mm wave science and technology
- S-JACEFG – Applications for pattern recognition methodologies

In addition, three workshops are being planned:

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.

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### **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.

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### **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.

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### **Radio Science Bulletin**

The most recent issue of the Bulletin may be downloaded from the following website: [http://www.ursi.org/content/RSB/RSB\\_360\\_2017\\_03.pdf](http://www.ursi.org/content/RSB/RSB_360_2017_03.pdf) Beginning with this issue, current issues of the Bulletin and the archives back to September 2002 are available on IEEE Xplore thanks to the tireless efforts of Ross Stone. In fact, starting with the next (June) issue, the link you receive in your e-mail alert when the issue becomes available will point to the issue on Xplore. If you go to <http://ieeexplore.ieee.org/Xplore/home.jsp>, choose Browse...Journals and Magazines, and type in URSI, you will find the archives of the Bulletin. This (June) issue will be available on Xplore about one to two weeks after you receive the e-mail announcement of the issue. The contents of each issue are all available for downloading as PDFs. The current and past issues of the Bulletin are available on Xplore as a free, open-access publication: anyone can access it, without a subscription.

In this (March) issue, Jacob Baars provides a review of an unusual new book on the history of radio astronomy in The Netherlands. Harvey Liszt presents the Annual Report on the Scientific Committee on Frequency Allocations for Radio Astronomy and Space Science, IUCAF.

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## Working Group Spotlight

This month, Richard Schilizzi, Ken Kellermann and Richard Wielebinski present a report from the *Working Group on Historical Radio Astronomy*, September 2017.

### **Purpose of the WG**

The WG was first established in 2003 as an IAU WG, but since the URSI GASS in Beijing in 2014 it is a joint WG of the IAU and URSI. Its aims are to i) maintain an ongoing bibliography of publications relevant to the history of radio astronomy, ii) document and preserve surviving historically-significant radio telescopes and associated instrumentation, and iii) document the careers of deceased radio astronomers in biographical memoirs.

The WG has 41 members at the moment, amongst whom are 14 “national reporters” responsible for keeping track of developments of relevance to the WG in their respective countries or regions. The WG is completely open for anyone to join; please contact any of the above if you are interested.

### **Publications and research**

Ten books dealing with the history of radio astronomy have been published since 2013 including

Baars	<i>International Radio Telescope Projects – a Life among Their Designers, Builders and Users</i>
Goss	<i>Making Waves, the Story of Ruby-Payne Scott. Australian Pioneer of Radio Astronomy</i>
Orchiston	<i>Exploring the History of New Zealand Astronomy</i>
Schwartz & Zensus	<i>History of MPIfR (in German)</i>
Elbers	<i>The Rise of Radio Astronomy in the Netherlands</i>
Goss, Morris, Sheshadri	<i>Radio Astronomers at Sea</i>
Robertson	<i>John Bolton &amp; a New Window on the Universe</i>
Baars & Kärcher	<i>Radio Telescope Reflectors – Historical Development of Design and Construction</i>
Nakamura & Orchiston	<i>The Emergence of Astrophysics in Asia</i>
Frater, Goss, & Wendt	<i>Four Pillars of Radio Astronomy</i>

A total of twenty-nine papers have been published in various places: Journal of Astronomical History and Heritage, Bulletin of the Astronomical Society of India, Nancius Hambugenisis, Bibliographical Encyclopedia of Astronomers and the URSI Bulletin.

Presentations on historical topics were given in fifteen conferences from 2014 to 2017 including

2014	50 <sup>th</sup> Anniversary of Medicina Northern Cross
2015	JIVE-ERIC Inaugural Symposium
	IAU Symposium on Extragalactic Jets
	The Golden Years of Radio Astronomy, IAU GA
2016	A Workshop on the History of Canadian Radio Astronomy
	All-Wave Astronomy, Shklovsky-100
	Problems of Modern Astronomy – I.S. Shklovsky Centennial Conference
	Innovation & Discovery in Radio Astronomy - A Celebration of the Career of Ron Ekers
	Sleepest: Celebrating Bruce Slee’s Seventy Years in Radio Astronomy
	1 <sup>st</sup> Pietro Barachi Conference on Italy-Australia Radio Astronomy
2017	Black Hole Astrophysics with VLBI: Past, Present and Future – Celebration of the Scientific Career of Makoto Inoue
	Ginzburg Centennial Conference on Physics
	Looking Back and Ahead - a Mini-Symposium in Honour of Wim Brouw
	Fred Lo Science Symposium
	Radio Interferometry: History and Lessons Learnt, URSI GASS

### ***Future activities***

A 3-hour session on Historical Radio Astronomy is planned on 24 August 2018 during the IAU GA in Vienna. The topic will be Single dishes: history and lessons learnt.

Activity will continue on the Jansky site restoration and historical landmark.

A number of books are in preparation including

Orchiston, Sullivan and Robertson	<i>The Foundations of Australian Radio Astronomy (2018)</i>
Goss, Ekers, Hooker	<i>From the Sun to the Cosmos, J. L. Pawsey</i>
Kellermann, Bouton, Brandt	<i>Open Skies</i>
Jarrell, Wall, Griffen, Robishaw	<i>Canadian Radio Astronomy</i>
Schwartz, Zensus	<i>History of MPIfR (English translation)</i>
Schilizzi, Ekers, Hall	<i>History of the Square Kilometre Array 1993-2012</i>
Dickman, Vanden Bout	<i>Construction of the Atacama Large Millimeter - Submillimeter Array</i>

### **WGHRA Website**

The WG website <http://rahist.nrao.edu/> is a repository of a considerable amount of historical material including contributions to the IAU Triennial Reports for 2006, 2009, 2012, and 2015; the presentations on the history of radio interferometers at URSI GASS 2017; the report on WG activities at the Commission J business session at URSI GASS 2017; a list of Grote Reber Medalists; biographical memoirs of deceased radio astronomers; related resources; and access to the NRAO/AUI archives (<http://jump2.nrao.edu/dbtw-wpd/textbase/archivesearch.htm>).

Please contact Ken Kellermann ([kkellerm@nrao.edu](mailto:kkellerm@nrao.edu)) at any time if you have additional material to include on the website.

*Submitted by R. Schilizzi*

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### **Photo from the Field**

To close the Newsletter each month I'd like to include an interesting photograph of radio astronomy field activities showcasing instruments and researchers. If you have an interesting photograph that you don'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.

*Submitted by R. Bradley*

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November 2017

Prepared by R. Bradley, Chair, Commission J, [rbradley@nrao.edu](mailto: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) will be upon us in early January. The Commission J program is coming together nicely, and we hope that you will consider presenting your research at the AT-RASC. If you have questions regarding the theme of a given session please contact the convener listed below.

This month we focus on the young scientist – In the 1960's, URSI general assemblies were much smaller than now and were closed to all but a limited number of official delegates invited by the member committees. These were mainly internationally established scientists and research administrators. This gave the general assemblies considerable mystique for younger scientists who were excluded. Professor Sam Silver, URSI president from 1966 to 1969, introduced the young scientist program. At an URSI board meeting in February 1967 he proposed "*each national committee nominate one or two young research workers in their countries who should be specially invited by the president of URSI to attend the general assembly. This would be a tremendous encouragement for young people and would stimulate their interest and participation in the work of the union. Moreover this should contribute to bringing fresh talent to the general assembly.*" He also proposed a special fund to facilitate the participation of young scientists at URSI general assemblies. How did Commission J members fare in the recent Student Paper Competition and Young Scientist Awards? ECR Stefan Wijnholds provides the answers in this issue of the Newsletter.

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

*Submitted by R. Bradley*

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Richard Prestage, Cedric Viou, Alessandra Zanichelli
- J.2 *Large N Aperture Arrays*  
Eloy de Lera Acedo, Kris Zarb Adami
- J.3 *Pattern Recognition Applications in Radio Astronomy*  
Abhi Datta, David Rapetti
- J.4 *Novel Instrument Concepts and Observational Challenges*  
Douglas Bock, Richard Bradley
- J.5 *Detecting Hydrogen Near and Far*  
Jackie Hewitt, Eloy de Lera Acedo
- J.6 *Instruments for Education*  
Glen Langston
- 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*

S-S-EACFJ - *Spectrum Management and Utilization*

Workshops:

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*Rome, Italy*

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### **Activities Spotlight**

#### ***Student Paper Competition at the URSI GASS***

Thanks to the generous financial sponsorship of the URSI-USNC, a Student Paper Competition (SPC) was organized at the URSI GASS in Montreal. To take part in the SPC, the first author and presenter must be a full-time university student and the student should write a 10-page SPC paper besides the regular abstract or paper submitted to the conference. This 10-page SPC paper is not officially published to allow the students to improve and expand it to a journal paper that can be submitted to an appropriate journal. In the SPC, ten finalists are selected based on the quality, originality and scientific merit of the submitted paper. All of them were recognized at the banquet and the top-5 presented their papers in a special SPC session, where their presentations was judged on clarity, adherence to time, accessibility to the wide audience of URSI radio scientists and the ability to answer questions on the work.

Jan-Willem Steeb, a Ph.D. student at Stellenbosch University (SU) supervised by David Davidson (SKA SA Research Chair at SU) and Stefan Wijnholds (researcher at ASTRON and visiting professor at SU), took part in the SPC with a paper on "Computationally Efficient Near-field Radio Frequency Source Localization". This paper deals with the problem of near-field source localization, which is an important topic for radio interferometric arrays as many sources of radio frequency interference are actually in the near-field of large radio astronomical arrays like LOFAR and SKA. For this paper, he received an honourable mention, congratulations!

#### ***Young Scientist Awards at URSI GASS***

The Young Scientist Program provides a number of awards to assist young scientists to attend the GASS. These young scientists must be less than 35 years on September 1, 2017 and should have a paper submitted and accepted for a regular session of the GASS. After the call for the Young Scientist Awards (YSA), 273 applications from 39 countries were received through an online application procedure. Some candidates were removed from the list immediately, since their application documents were not complete, they were too old to apply or they had received the YSA already in the last triennium.

## Activities Spotlight - continued

Compared to previous GASSs, the procedure to select the YSA winners was modified a bit. For the first time, the YSA candidates were ranked by both the URSI Member Committees and the URSI Commissions. The Member Committees were free to modify the Commission ranking bearing in mind the following desirable characteristics:

- The paper should demonstrate significant benefit to both the applicant and URSI.
- The subject of the paper should fall within the terms of reference of URSI and should ideally report significant progress.

The following Young Scientists with Com J as primary Commission were selected

- Karen Lee-Waddell (CSIRO, Australia)
- Cherry Ng (University of British Columbia, Canada)
- Yue Ma (National Astronomical Observatories, China)
- Ruta Kale (National Centre for Radio Astrophysics, India)
- Rodrigo G. Freundt (Pontificia Universidad Catolica del Peru, Peru)
- Jan-Willem W. Steeb (Stellenbosch University, South Africa)
- Kirill Rudakov (University of Groningen, The Netherlands)
- Francesco de Gasperin (Leiden University, The Netherlands)
- Mykola V. Shevchuk (Institute of Radio Astronomy, Ukraine)
- Lei Liu (Jodrell Bank Centre for Astrophysics, UK)
- Vratislav Krupar (NASA Heliospheric Physics Laboratory, USA)

Congratulations to each of them! The YSA consists of free registration, lodging and a cheque to cover living expenses during the URSI 2017 GASS in Montreal. The YSA winners from Low Income Countries also received travel support from URSI central to attend the URSI GASS. The Young Scientist program was considered very successful due to the high number of applications and due to the high quality of those applications.

*Submitted by S. Wijnholds*

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## Photo from the Field



Several 14 meter diameter antennas of the Hydrogen Epoch of Reionization Array (HERA) located in the Karoo, South Africa on the SKA-SA site are shown along with several members of the HERA team. The array, operating from 50-250 MHz, will be used to search for the radio signature of hydrogen that was cast during the epoch of initial star formation. At present, about 50 such antennas are deployed, with expansion to 350 currently underway. Major funding for the array comes from the U.S. National Science Foundation and the Gordon and Betty Moore Foundation. The array's predecessor, the Precision Array for Probing the Epoch of Reionization (PAPER) appears behind the HERA dishes with the SKA-SA MEERKAT array visible in the distance near the upper left in the photograph. For more information see <http://reionization.org>

*Photograph by D. Jacobs*

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.





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December 2017

Prepared by R. Bradley, Chair, Commission J, [rbradley@nrao.edu](mailto: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*

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<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*

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**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](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*

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**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

ISBN 978-3-319-44429-1 (hardcover) € 55. -

ISBN 978-3-319-44431-4 (eBook) free

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

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## **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*

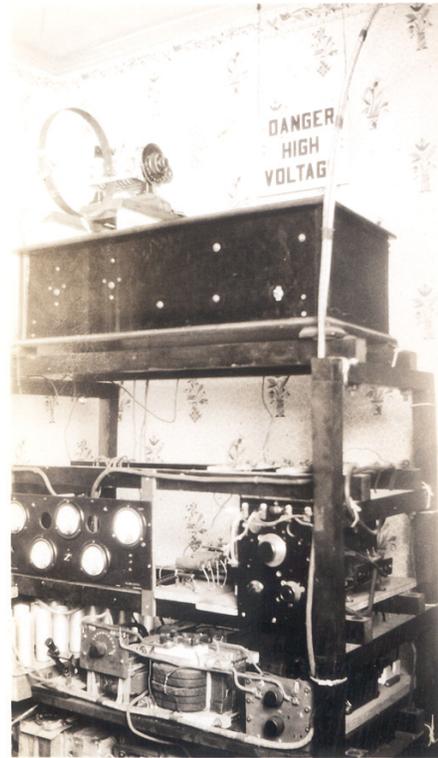
## Photo from the Field

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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.

