COSMIC MASERS - FROM OH TO H_0

IAU SYMPOSIUM 287

COVER ILLUSTRATION:

A picture of Table Montain, Cape Town, taken from Robben Island.

This iconic symbol of South Africa was recently voted one of the 'New 7 Wonders of the World'.

IAU SYMPOSIUM PROCEEDINGS SERIES

Chief Editor

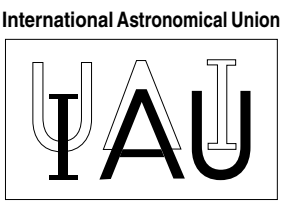
IAN F. CORBETT, IAU General Secretary
icorbett@eso.org

Editor

THIERRY MONTMERLE, IAU Assistant General Secretary
Institut d'Astrophysique de Paris,
98bis, Bd Arago, 75014 Paris, France
montmerle@iap.fr

INTERNATIONAL ASTRONOMICAL UNION

UNION ASTRONOMIQUE INTERNATIONALE



COSMIC MASERS - FROM OH TO H_0

PROCEEDINGS OF THE 287th SYMPOSIUM OF THE INTERNATIONAL ASTRONOMICAL UNION HELD IN STELLENBOSCH, SOUTH AFRICA JANUARY 29 - FEBRUARY 3, 2012

Edited by

ROY S. BOOTH
SA SKA Project, SOUTH AFRICA

ELIZABETH M. L. HUMPHREYS
ESO Garching, GERMANY

and

WOUTER H. T. VLEMMINGS
Onsala Space Observatory, Chalmers University of Technology, SWEDEN

CAMBRIDGE UNIVERSITY PRESS

CAMBRIDGE
UNIVERSITY PRESS

University Printing House, Cambridge CB2 8BS, United Kingdom

One Liberty Plaza, 20th Floor, New York, NY 10006, USA

477 Williamstown Road, Port Melbourne, VIC 3207, Australia

314-321, 3rd Floor, Plot 3, Splendor Forum, Jasola District Centre, New Delhi - 110025, India

103 Penang Road, #05-06/07, Visioncrest Commercial, Singapore 238467

Cambridge University Press is part of the University of Cambridge.

It furthers the University's mission by disseminating knowledge in the pursuit of education, learning and research at the highest international levels of excellence.

www.cambridge.org
Information on this title: www.cambridge.org/9781107032842

First published 2012

A catalogue record for this publication is available from the British Library

ISBN 978-1-107-03284-2 Hardback

Table of Contents

T3a: Star formation: maser variability *Chair: Philip Diamond*

T3b: Star formation masers *Chair: Crystal Brogan*

T9: New masers and further developments in maser physics
Chair: Mark Reid

Preface

The fourth IAU Symposium on Astronomical *masers*, IAUS 287, entitled *Cosmic Masers-from OH to* H_0 was held in South Africa from January 29 February 3. The venue was the excellent Wallenberg Conference Centre in the beautiful old town of Stellenbosch nestling in the foothills of one of the countrys foremost wine districts.

The meeting was opened by Dr. Bernie Fanaroff, Director of the South African SKA Project, who pointed out that human-kind had its origins in Africa and learned basic skills before migration and continental drift led to the population of the rest of the World.

Despite a strenuous programme with lively discussions, the participants found time to visit the Cape Town Water Front and take a boat trip to historical Robben Island, where the present political structure was formulated in the mid 90s. They also enjoyed an African evening at a local hospice, where they sampled truly African food, song and dance.

Interstellar hydroxyl *masers* were first reported in 1965, at the beginning of an avalanche of detections of interstellar molecules and the emergence of the science of Cosmo-chemistry. Many molecules are now found to exhibit polarized (circular and linear) stimulated emission in a variety of astrophysical environments and the hierarchy extends from the interstellar medium and regions of stellar formation through winds around evolved stars and even the compressed gas surrounding Supernova remnants. *masers* are also detected in other galaxies as analogues of Galactic *masers*, and in the dense molecular regions near AGN. Most recently, *masers* have been detected in Comets and other regions of the Solar System. In all cases they have proved to be important diagnostics of their associated regions, pinpointing dense gas, its motions and the local magnetic field structure in great detail.

This phenomenon has proved to be invaluable in astrometry and the details of Galactic structure and rotation have been refined through precise observation of *masers*. The same properties of *masers* have been used to great effect to measure the study of Galactic nuclei and because of the precise measurement of position and velocity, water *masers* have enabled the unambiguous determination of the Hubble Constant at small red-shifts.

Recent *maser* surveys, and measurements of the above phenomena were discussed at the Stellenbosch meeting along with new detections of known *masers* and detections of new *maser* species. Discussion extended from reviews of the theory of the phenomenon, *maser* properties such as variability and polarisation, to its use in astrometry and in cosmology.

More than 110 participants, including some 25 students (many securing IAU grants) attended the meeting. There were 68 oral contributions, including 8 by students and many posters, displayed all week and discussed in 3 separate poster sessions. In general the meeting followed its predecessor with 10 different scientific themes, each with a review talk, one or two invited talks and contributed talks.

Finally we thank our sponsors the South African SKA project and the Natural Science Research Council, NRF.

Roy Booth, Liz Humphreys & Wouter Vlemmings

THE ORGANIZING COMMITTEE

Scientific

A. Bartkiewicz (Poland)
R.S. Booth (Chair, South Africa)
V. Bujarrabal (Spain)
J.M. Chapman (Australia)
M. Elitzur (USA)
S.P. Ellingsen (Australia)
Y. Gómez (Mexico)
M.D. Gray (UK)
M. Honma (Japan)
E.M.L. Humphreys (co-Chair, Germany)
A.J. Kemball (USA)
K.-T. Kim (Taiwan)
H.J. van Langevelde (Netherlands)
J.M. Moran (USA)
W.H.T. Vlemmings (co-Chair, Sweden)

Local

K. de Boer
R.S. Booth (Chair)
S. Fishley
M.J. Gaylard
S. Goedhart (co-Chair)
R. Hames
M. Oozeer
S. Passmoor
A. Schroeder
D.J. van der Walt
P.A. Whitelock

Acknowledgements

The symposium was sponsored and supported by the IAU Divisions I (Fundamental Astronomy), VI (Interstellar Matter), VII (Galactic System), and X (Radio Astronomy); and by the IAU Commission No. 40 (Radio Astronomy).

Funding by the
National Research Foundation (NRF),
and
the South African SKA project
are gratefully acknowledged.

Participants

Khudhair Abbas Assaf **Al-Muntafki**, School of Physics & Astronomy, Manchester University, UK kam@jb.man.ac.uk
Alexey **Alakoz**, Astro Space Center of the P.N. Lebedev Physical Institute, Moscow, Russia l-sha@yandex.ru
Felipe **Alves**, Argelander Institut for Astronomie, Bonn, Germany falves@astro.uni-bonn.de
Nikta **Amiri**, Leiden Observatory/JIVE, Leiden, Netherlands amiri@strw.leidenuniv.nl
Tao **An**, Shanghai Astronomical Observatory, Shanghai, China antao@shao.ac.cn
Bernard Duah **Asabere**, Physics Department, University of Johannesburg, South Africa b.asabere@rocketmail.com
Willem **Baan**, ASTRON, Dwingeloo, Netherlands baan@astron.nl
Alejandro **Baez Rubio**, Centro de Astrobiologia (CSIC-INTA), Madrid, Spain baezra@cab.inta-csic.es
Olga **Bayandina**, Astro Space Center of the Lebedev Physical Institute of RAS, Moscow, Russia Bayandix@yandex.ru
Per **Bergman**, Onsala Space Observatory, Chalmers University, Sweden per.bergman@chalmers.se
Roy S. **Booth**, SA SKA, Cape Town, South Africa rbooth@ska.ac.za
Shari **Breen**, CSIRO Astronomy and Space science, NSW, Australia Shari.Breen@csiro.au
Tui Rose **Britton**, Dept. of Physics and Astronomy, Macquarie University, NSW, Australia tui.britton@csiro.au
Crystal **Brogan**, NRAO, Charlottesville, VA, USA cbrogan@nrao.edu
Do-Young **Byun**, Korean Astronomy and Space Science Institute, Seoul, South Korea bdy@kasi.re.kr
Jessica **Chapman**, CSIRO Astronomy & Space Science, NSW, Australia Jessica.Chapman@csiro.au
James Okwe **Chibueze**, Kagoshima University, Kagoshima, Japan james.chibueze@gmail.com
Se-Hyung **Cho**, Korea Astronomy and Space Science Institute, Seoul, South Korea cho@kasi.re.kr
Yoon Kyung **Choi**, Max-Planck-Institut fuer Radioastronomie, Bonn, Germany ykchoi@mpifr.de
Mark **Claussen**, NRAO, Socorro, NM, USA mclausse@nrao.edu
Willliam **Cotton**, NRAO, Charlottesville, VA, USA bcotton@nrao.edu
Claudia **Cyganowski**, Harvard/SAO CfA, Cambridge, MA, USA ccyganow@cfa.harvard.edu
Jeremy **Darling**, University of Colorado, Boulder, CO, USA jdarling@colorado.edu
James **De Buizer**, SOFIA/USRA, NASA Ames Research Center, CA, USA jdebuizer@sofia.usra.edu
Eduardo **de la Fuente**, CUCEI, Universidad de Guadalajara, Mexico edfuente@gmail.com
Lientjie **de Villiers**, Centre for Astrophysics Research, University of Hertfordshire, UK lientjiedv@gmail.com
Shuji **Deguchi**, NRO/NAOJ, Nagano, Japan deguchi@nro.nao.ac.jp
Avinash **Deshpande**, Raman Research Institute, Bangalore, India desh@rri.res.in
Jean-Francois **Desmurs**, OAN, Madrid, Spain desmurs@oan.es
Phil **Diamond**, CSIRO Astronomy and Space Science, NSW, Australia phil.diamond@csiro.au
Miranda **Dunham**, Yale University, New Haven, CT, USA miranda.dunham@yale.edu
Dieter **Engels**, Hamburger Sternwarte, Hamburg, Germany dengels@hs.uni-hamburg.de
Jarken **Esimbek**, Xinjiang Astronomical Observatory, Xinjiang, China jarken@xao.ac.cn
Sandra **Etoka**, JBCA, University of Manchester, UK sandra.etoka@googlemail.com
Michael **Feast**, SAAO/UCT, University of Cape Town, South Africa mwf@ast.uct.ac.za
Kenta **Fujisawa**, Yamaguchi University, Yamaguchi, Japan kenta@yamaguchi-u.ac.jp
Michael J. **Gaylard**, HartRAO, Krugersdorp, South Africa mike@hartrao.ac.za
Ciriaco **Goddi**, ESO, Garching, Germany cgoddi@eso.org
Sharmila **Goedhart**, SKA SA, Cape Town, South Africa sharmila@ska.ac.za
Ioannis **Gonidakis**, CSIRO, NSW, Australia ioannis.gonidakis@csiro.au
Malcolm **Gray**, JBCA, University of Manchester, UK Malcolm.Gray@manchester.ac.uk
Lincoln **Greenhill**, Harvard/Smithsonian CfA, Cambridge, MA, USA greenhill@cfa.harvard.edu
Daniel **Harris**, SAO, Cambridge, MA, USA harris.d.e.42@gmail.com
Christian **Henkel**, MPIfR, Bonn, Germany chenkel@mpifr-bonn.mpg.de
Tomoya **Hirota**, National Astronomical Observatory of Japan, Tokyo, Japan tomoya.hirota@nao.ac.jp
Mareki **Honma**, NAOJ, Japan mareki.honma@nao.ac.jp
Liz **Humphreys**, ESO, Garching, Germany ehumphre@eso.org
Todd **Hunter**, NRAO, Charlottesville, VA, USA thunter@nrao.edu
Hiroshi **Imai**, Kagoshima University, Kagoshima, Japan hiroimai@sci.kagoshima-u.ac.jp
Katharina **Immer**, MPIfR, Bonn, Germany kimmer@mpifr-bonn.mpg.de
Violette **Impellizzeri**, ALMA, Santiago, Chile vimpelli@alma.cl
Izaskun **Jimenez-Serra**, Harvard-Smithsonian Center for Astrophysics, MA, USA ijimenez-serra@cfa.harvard.edu
Norio **Kaifu**, NAOJ, Japan noriokaifu@aol.com
Sergei **Kalenskii**, Lebedev Physical Institute, Astro Space Center, Russia kalensky@asc.rssi.ru
Athol **Kemball**, University of Illinois at Urbana-Champaign, IL, USA akemball@illinois.edu
Jaeheon **Kim**, Yonsei University Observatory/KASI/Kyung Hee University, South Korea jhkim@kasi.re.kr
Mikyoung **Kim**, NAOJ, Japan mikyoung.kim@nao.ac.jp
Kee-Tae **Kim**, Korea Astronomy & Space Science Institute (KASI), South Korea ktkim@kasi.re.kr
Tomoharu **Kurayama**, Kagoshima University, Japan kurayama@sci.kagoshima-u.ac.jp
Stan **Kurtz**, UNAM, Mexico s.kurtz@crya.unam.mx
Tanmoy **Laskar**, Harvard University, Cambridge, MA, USA tanmoylaskar@gmail.com
Marcelo **Leal-Ferreira**, Argelander-Institut fur Astronomie, Germany ferreira@astro.uni-bonn.de
Jingjing **Li**, Purple Mountain Observatory, China jjli@pmo.ac.cn
Michael **Lindqvist**, Onsala Space Observatory, Chalmers University, Sweden Michael.Lindqvist@chalmers.se
Ivan **Litovchenko**, AstroSpace Center of Lebedev Physical Institute, Moscow, Russia grosh@asc.rssi.ru
Jabulani Paul **Maswanganye**, HartRAO/ Wits University, Krugersdorp, South Africa pop7paul@gmail.com
Naoko **Matsumoto**, National Astronomical Observatory of Japan, Japan naoko.matsumoto@nao.ac.jp
Karl **Menten**, MPIfR, Bonn, Germany kmenten@mpifr.de
Victor **Migenes**, Brigham Young University, UT, USA vmigenes@byu.edu
David **Morris**, IRAM, France morris@iram.fr
Kazuhito **Motogi**, Hokkaido University, Japan motogi@astro1.sci.hokudai.ac.jp
Takumi **Nagayama** NAOJ, Japan takumi.nagayama@nao.ac.jp
Liudmila **Nazarova**, EAAS, Moscow, Russia lsnazarova@rambler.ru
Florian **Niederhofer**, ESO, Garching, Germany floniederhofer@gmx.de
Hans **Olofsson**, Onsala Space Observatory, Chalmers University, Sweden hans.olofsson@chalmers.se
Nadeem **Oozeer**, SKA SA, South Africa nadeem@ska.ac.za
Sunelle **Otto**, HartRAO, Krugersdorp, South Africa sunelle@hartrao.ac.za
Tomoaki **Oyama**, National Astronomical Observatory of Japan, Japan t.oyama@nao.ac.jp
Sean **Passmoor**, SKA SA, South Africa sean@ska.ac.za
Andres **Perez Sanchez**, AIfA, Bonn, Germany aperez@astro.uni-bonn.de
Michele **Pestalozzi**, IFSI-INAF, Rome, Italy michele.pestalozzi@gmail.com
Nurur **Raman**, University of Johannesburg, Johannesburg, South Africa nrahman@uj.ac.za
Sofia **Ramstedt**, Argelander Institute for Astronomy, Bonn, Germany sofia@astro.uni-bonn.de
Mark **Reid**, Harvard-Smithsonian CfA, Cambridge, MA, USA reid@cfa.harvard.edu
Anita M. S. **Richards**, UK ARC Node, JBCA, University of Manchester, UK amsr@jb.man.ac.uk
Laura **Richter**, Rhodes University, South Africa llrichter@gmail.com

Nobuyuki **Sakai**, Graduate University for Advanced Studies, Japan	nobuyuki.sakai@nao.ac.jp
Alberto **Sanna**, MPIfR, Bonn, Germany	asanna@mpifr-bonn.mpg.de
Anuj **Sarma**, DePaul University, Chicago, IL, USA	asarma@depaul.edu
Mayumi **Sato**, MPIfR, Bonn, Germany	msato@mpifr-bonn.mpg.de
Satoko **Sawada-Satoh**, Mizusawa VLBI Observatory, NAOJ Japan	satoko.ss@nao.ac.jp
Nishant **Singh**, Raman Research Institute, Bangalore, India	nishant@rri.res.in
Lorant **Sjouwerman**, NRAO, Socorro, NM, USA	lsjouwer@nrao.edu
Rupert **Spann**, SKA SA, South Africa	rupert.spann@ska.ac.za
Vladimir **Strelnitski**, Maria Mitchell Observatory, Nantucket, MA, USA	vladimir@mmo.org
Olga **Suarez**, Observatoire de la Cote d'Azur, Nice, France	olga.suarez@oca.eu
Koichiro **Sugiyama**, Yamaguchi University, Yamaguchi, Japan	koichiro@yamaguchi-u.ac.jp
Gabriele **Surcis**, JIVE, Dwingeloo, Netherlands	gabsurcis2@yahoo.it
Andrea **Tarchi**, INAF-Osservatorio Astronomico di Cagliari, Italy	atarchi@oa-cagliari.inaf.it
Clemens **Thum**, IRAM, Granada, Spain	thum@iram.fr
Anita **Titmarsh**, UTas/CASS, Tasmania, Australia	anitat@postoffice.utas.edu.au
Jose-Maria **Torrelles**, ICE(CSIC)-UB/IEEC, Barcelona, Spain	torrelles@ieec.cat
Karl Johan Erik **Torstensson**, JIVE/Leiden Observatory, Netherlands	kalle@strw.leidenuniv.nl
Miguel Angel **Trinidad**, Guanjuato University, Guanjuato, Mexico	trinidad@astro.ugto.mx
Irina **Val'tts**, Astro Space Center of the Lebedev Physical Institute, Russia	ivaltts@asc.rssi.ru
Stefanus Petrus **van den Heever**, North West University, South Africa	13077724@nwu.ac.za
Johan **van der Walt**, North-West University, South Africa	johan.vanderwalt@nwu.ac.za
Huib **van Langevelde**, JIVE/Leiden, Dwingeloo, Netherlands	langevelde@jive.nl
Wouter **Vlemmings**, Chalmers University, Sweden	wouter.vlemmings@chalmers.se
Maxim **Voronkov**, CSIRO Astronomy & Space Science, Australia	Maxim.Voronkov@csiro.au
Andrew **Walsh**, James Cook University, Australia	andrew.walsh@jcu.edu.au
Junzhi **Wang**, Department of Astronomy, Nanjing University, China	junzhiwang@nju.edu.cn
Mark **Wardle**, Macquarie University, Australia	mark.wardle@mq.edu.au
Patricia **Whitelock**, SAAO/UCT, South Africa	paw@saao.ac.za
Kyle **Willett**, University of Minnesota, MN, USA	willett@physics.umn.edu
Markus **Wittkowski**, ESO, Garching, Germany	mwittkow@eso.org
Pawel **Wolak**, Nicolaus Copernicus University, Poland	wolak@astro.uni.torun.pl
Alwyn **Wootten**, NRAO, Charlottesville, VA, USA	awootten@nrao.edu
Yuanwei **Wu**, MPIfR, Bonn, Germany	ywei@mpifr-bonn.mpg.de
Ye **Xu**, Purple Mountain Observatory, Nanjing, China	xuye@pmo.ac.cn
Ingyin **Zaw**, New York University Abu Dhabi, New York, USA	iz6@nyu.edu
Jiangshui **Zhang**, Center for Astrophysics, Guangzhou University, China	jszhang@gzhu.edu.cn
Bo **Zhang**, MPIfR, Bonn, Germany	bzhang@mpifr.de
Jianjun **Zhou**, Xinjiang Astronomical Observatory, Xinjiang, China	zhoujj@xao.ac.cn

Tribute to Yolanda Gómez Castellano

The proceedings of IAU Symposium 287 are dedicated to the memory of Yolanda Gómez Castellano. Yolanda died on 16 February 2012, shortly after the symposium, at the age of forty-nine. She had struggled with cancer for a number of years, and her illness took a sudden, and unexpected, turn for the worse just weeks before the meeting. She was a member of the Scientific Organizing Committee of the symposium, and had planned to attend the meeting, canceling her travel plans only days before her scheduled departure for South Africa. Despite the state of her health, Yolanda still had sufficient energy to fulfill her wish to participate in the conference by sending her contribution as a poster (*Imaging the water masers toward the H_2O-PN IRAS 18061-2505*) through Mexican colleagues.

Yolanda's professional career was based at the National Autonomous University of Mexico (UNAM). Her professional degrees (in physics) were all obtained from the UNAM, although her doctoral research (*A study in Radio Frequencies of Young Planetary Nebulae and OH/IR Stars*) was carried out at the Harvard-Smithsonian Center for Astrophysics. Upon her return to Mexico from Boston, she worked side-by-side with her husband, Luis Felipe Rodríguez, to establish a Mexican presence in the international radio astronomy community.

Yolanda worked for more than twenty years at the UNAM; she began her research career at the Institute for Astronomy at the Mexico City campus. Later, she was a founding member of the Center for Radio Astronomy and Astrophysics (CRyA) at the Morelia Campus of the UNAM, where she was a full professor.

Yolanda's primary research area was the study of gaseous nebulae, both young planetary nebulae associated with evolved stars and compact HII regions associated with young massive stars. She also did significant work on protoplanetary disks and jets associated with young stellar objects. Her research resulted in more than 65 published papers with numerous important contributions. Among her most notable discoveries was the first detection of water vapor around a planetary nebula. This was unexpected because the radiation field around these stars should destroy any nearby molecules. She was actively pursuing this fascinating line of research at the time of her death and in fact this was the topic of her contribution at the Symposium. In addition, Yolanda was a generous and cheerful teacher, always willing to help and guide her students. Her enthusiasm led many of her students to become astronomers: without exception her former masters and doctoral students have joined the research community, and are now independent researchers.

She was a firm believer that science is for everyone — not just for specialists but also for the general public. Consequently, Yolanda not only assumed an active role in the postgraduate astronomy program of the UNAM but she also taught undergraduate physics at the state university of Michoacán, in addition to giving courses in astronomy in several Latin American countries. Particularly notable was Yolanda's extensive involvement in public outreach. She gave innumerable talks, workshops, radio and television interviews and published more than 40 popular science articles. She had a key role in the International Year of Astronomy as celebrated in Mexico, organizing all of the events of the CRyA and serving as president of the state organizing committee. The 350 public outreach events that took place that year attracted more than 100,000 participants. The highlight was the *Noche de las Estrellas* at the prehispanic ruins in Tzintzuntzan, Michoacán, which an estimated 10,000 people attended. In addition, Yolanda contributed to the development of teaching materials for popularizing astronomy and the design of

astronomical displays and activities for science museums. Thanks to the warmth, enthusiasm and dedication with which Yolanda took astronomy to the public, the state government of Michoacán awarded her the 2008 State Prize for Public Outreach of Science and Technology.

Although perhaps little recognized by her professional colleagues, Yolanda was a avid lover of the arts. Not only did she come from a very musically-talented family, but she was also a devoted follower of the visual arts, decorating her home with outstanding works by national and regional Mexican artists. Moreover, she herself had a creative, artistic side: the logo of the CRyA — a radio telescope depicted in the style of Oriental calligraphy — was of her own design.

Those of us who knew Yolanda personally will miss her ready smile and the cheerfulness that accompanied her wherever she went. She will be greatly missed, by her former students, by her colleagues and friends in Morelia, in Mexico, and around the world, and most of all by her family, in particular by her children, Vicente and Cecilia, and her husband Luis Felipe, to whom we extend the warmest embrace.

Rest in Peace, Yolanda.

S. Kurtz & J.M. Torrelles