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Molecular Gas, Dust, and Star Formation in Galaxies

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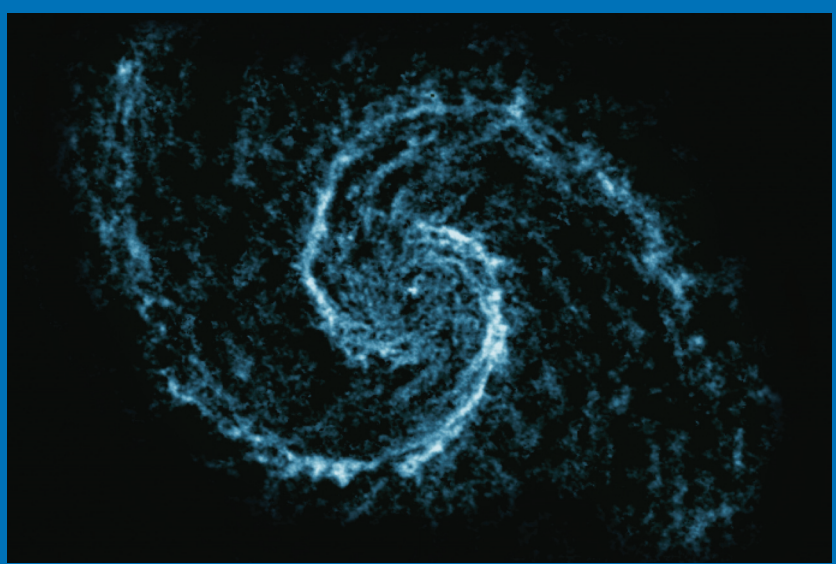
Jürgen Ott



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MOLECULAR GAS, DUST, AND STAR FORMATION IN GALAXIES

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COVER ILLUSTRATION: THE WHIRLPOOL GALAXY IN CO

CO(1–0) line emission from the central 9 kpc of the Whirlpool Galaxy (M 51), as mapped by the PdBI Arcsecond Whirlpool Survey (PAWS; PI: E. Schinnerer). The CO emission, brightest in the spiral arms but still detectable in interarm regions, reveals the distribution of molecular gas on a scale of 40 pc, sufficient to resolve the largest molecular clouds. See article by Meidt *et al.* in Session 3.

Image credit: S. E. Meidt, D. Colombo, and PAWS team

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Chief Editor

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

Editor

PIERO BENVENUTI, IAU Assistant General Secretary
University of Padua, Dept of Physics and Astronomy,
Vicolo dell'Osservatorio, 3, 35122 Padova, Italy
piero.benvenuti@unipd.it

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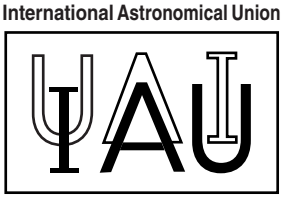

MOLECULAR GAS, DUST, AND STAR FORMATION IN GALAXIES

PROCEEDINGS OF THE 292nd SYMPOSIUM OF THE INTERNATIONAL ASTRONOMICAL UNION HELD IN BEIJING, CHINA AUGUST 20–24, 2012

Edited by

TONY WONG
University of Illinois at Urbana-Champaign, USA

and

JÜRGEN OTT
National Radio Astronomy Observatory, USA

CAMBRIDGE UNIVERSITY PRESS

CAMBRIDGE UNIVERSITY PRESS
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Preface

Understanding galaxy formation and evolution is at the heart of modern astronomy. Central to that goal is the necessity to improve our understanding of star formation, and thus the evolution of the interstellar medium (ISM) of galaxies. The relevant phenomena span vast spatial scales, requiring observations across the electromagnetic spectrum as well as state-of-the-art numerical simulations. To tackle these complex issues, IAU Symposium 292 (IAUS292), held from 20–24 August 2012 during the XXVIII General Assembly of the IAU in Beijing, China, focused on the detailed properties of the clouds where stars are born, the fuel and tracers of star formation, the quantification of star formation, and its effects on galaxy evolution. The symposium occurred two years after a conference with a similar theme (Molecules in Galaxies) organized by one of us (MB) at Oxford. The intervening two years saw a rapid growth in scientific output from facilities such as the Herschel Space Observatory and SOFIA airborne observatory, as well as the first results from the Atacama Large Millimeter/sub-millimeter Array (ALMA), making it timely to revisit these topics. More than 70 talks and 200 posters were presented over the course of 5 hot summer days in Beijing.

Of course, the first step towards understanding the ISM is to accurately constrain its physical and chemical properties. Over the past few years, Herschel and SOFIA have been generating revolutionary datasets on dust and excited/ionized species of the ISM closely connected to star formation (e.g., high-J CO lines and infrared diagnostic lines). Also discussed were early science results and the future potential of ALMA, which will revolutionize our understanding of molecular gas, the fuel for star formation. Complementary ground- and space-based programs in the X-ray, UV, optical, and radio were reviewed, in an effort to probe the relationships between star-formation tracers and the evolution of star formation over wide timescales. On small spatial scales (tens of parsecs), the incidence, distribution, internal properties (e.g. Larson relations), and formation/evolution of (giant) molecular clouds were an important topic of IAUS292. Such studies have until recently been limited to the Local Group, though recent results for M51 (see cover image) remind us how quickly capabilities are improving.

Beyond the Local Group, IAUS292 explored the molecular content of galaxies across both morphological types (dwarfs, spirals, early-types; active vs. non-active galaxies) and cosmological epochs (from the nearest galaxies to high-redshift quasars). Through observations of multiple species and transitions, the gas density, temperature, metallicity, radiation field, etc. can be determined for a diversity of sources and environments (e.g. photon-dominated regions; X-ray dominated regions; cosmic ray-dominated regions; active galactic nuclei). On spatial scales of kiloparsecs or less, the internal distribution and kinematics of the ISM of galaxies can be probed. Efforts there typically focus on comparative studies across galaxy types and environments. Crucially important is the link to star formation, which is being probed by empirical star formation relations (e.g. Kennicutt-Schmidt relation, FIR-radio correlation), by an improved understanding of the different ISM phases (e.g., neutral, molecular, and ionized), and by measurements of time lags since star formation as probed by various tracers.

New observations have been complemented with high-resolution simulations, which are now revisiting the long-standing questions of how turbulence in the ISM is generated, and to what extent turbulence inhibits star formation. The importance of accretion processes on both the molecular cloud scale and the galactic scale was stressed by several speakers.

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Recent theoretical advances were expanded upon in Special Session 12, "Modern Views of the Interstellar Medium," which followed IAUS292 during the second week of the General Assembly.

At even greater distances, IAUS292 explored the ISM and star-formation indicators of intermediate redshift galaxies, where the cosmic star formation rate peaks. These are presumably the progenitors of today's galaxies (but which ones?). Similarly, for the highest redshift sources, observations probe the earliest phases of star formation when reionization is in full swing. Lastly, feedback mechanisms from both star formation and nuclear activity are increasingly believed to play a key role in understanding the star formation history of the universe within the hierarchical structure formation paradigm. As any feedback mechanism must have profound consequences for the ISM, and feedback is undoubtedly key to understanding the migration of galaxies from the blue cloud to the red sequence, IAUS292 also focused on the observational evidence and theoretical models of feedback, from molecular cloud to galaxy and cluster scales, and from local galaxies to the high-redshift universe.

Looking back on the conference, we can see tantalizing hints of things to come, including a resurgence in [C II] observations provided by Herschel, SOFIA, and ALMA, high-resolution mapping of high-J CO lines in galaxies, and new constraints on the still-puzzling submillimeter excess in dwarf galaxies. Of course, the real work at meetings occurs outside the auditorium, and many of us enjoyed the opportunity to learn more about astronomical developments in China and the East Asia region. We hope this book thereby provides an impetus for new contacts and collaborations.

Tony Wong, Martin Bureau, & Juergen Ott
January 4, 2013

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Participants

Susanne **Aalto**, Chalmers University of Technology, Sweden	saalto@chalmers.se
Kateryna **Agiienko**, Main Astronomical Observatory of NASU, Ukraine	katerina.agienko@gmail.com
Katherine **Alatalo**, UC Berkeley, USA	kalatalo@berkeley.edu
James **Allison**, University of Sydney, Australia	jra@physics.usyd.edu.au
Peter **Anders**, KIAA, Peking University, China	anders@pku.edu.cn
Crystal N. **Anderson**, New Mexico Institute of Mining and Technology, USA	canderso@nmt.edu
Yuta **Asahina**, Chiba University, Japan	asahina@astro.s.chiba-u.ac.jp
Abdul **Asvarov**, Institute of Physics, Baku, Azerbaijan	asvarov@physics.ab.az
Willem **Baan**, ASTRON, Netherlands	baan@astron.nl
Hyun-Jin **Bae**, Yonsei University, South Korea	hjbae@galaxy.yonsei.ac.kr
Andrew **Baker**, Rutgers, The State University of New Jersey, USA	ajbaker@physics.rutgers.edu
Sudhanshu **Barway**, South African Astronomical Observatory, South Africa	barway@saao.ac.za
Estelle **Bayet**, University of Oxford, UK	bayet@physics.ox.ac.uk
John **Beckman**, Instituto de Astrofísica de Canarias, Spain	jeb@iac.es
Pedro **Beirao**, Spitzer Science Center, Caltech, USA	pedro@ipac.caltech.edu
Leo **Blitz**, UC Berkeley, USA	blitz@berkeley.edu
Mederic **Boquien**, Laboratoire d'astrophysique de Marseille, France	mederic.boquien@oamp.fr
Jonathan **Braine**, Laboratoire d'Astrophysique de Bordeaux, France	braine@obs.u-bordeaux1.fr
Robert **Braun**, CSIRO Astronomy and Space Science, Australia	robert.braun@csiro.au
Shari **Breen**, CSIRO Astronomy and Space Science, Australia	shari.breen@csiro.au
Noah **Brosch**, Tel Aviv University, Israel	noah@wise.tau.ac.il
David **Brown**, Specola Vaticana, Vatican City	dbrown@specola.va
Martin **Bureau**, University of Oxford, UK	bureau@astro.ox.ac.uk
Eric **Burgh**, University of Colorado, USA	eric.burgh@colorado.edu
Michael **Burton**, University of New South Wales, Australia	m.burton@unsw.edu.au
Zheng **Cai**, University of Arizona, USA	caiz0528@gmail.com
Paola **Caselli**, University of Leeds, UK	p.caselli@leeds.ac.uk
James **Caswell**, CSIRO Astronomy and Space Science, Australia	james.caswell@csiro.au
Antonio **Cava**, Universidad Complutense de Madrid, Spain	acava@fis.ucm.es
Oscar **Cavichia**, IAG/USP, Brazil	cavichia@astro.iag.usp.br
Josephine **Chan**, 43 Tamar Way, Didcot, UK	jchan@yahoo.co.uk
Doron **Chelouche**, University of Haifa, Israel	doron@sci.haifa.ac.il
Huei-Ru Vivien **Chen**, National Tsing Hua University, Taiwan	hchen@phys.nthu.edu.tw
Jiemin **Chen**, Guangxi University, China	mdhy126@126.com
Rosie **Chen**, MPIfR, Bonn, Germany	rchen@mpifr-bonn.mpg.de
Xiaoyan **Chen**, National Astronomical Observatories, CAS, China	chenxy@nao.cas.cn
Zhi Fu **Chen**, Center for Astrophysics, Guangzhou University, China	zhichenfu@126.com
James **Chibueze**, Kagoshima University, Japan	james.chibueze@gmail.com
Igor **Chilingarian**, CfA / SAI MSU, USA	igor.chilingarian@cfa.harvard.edu
Tao-Chung **Ching**, National Tsing Hua University, Taiwan	chingtaochung@gmail.com
Jiwon **Chung**, Chungnam National University, South Korea	jjiwon1114@gmail.com
Laure **Ciesla**, Laboratoire d'astrophysique de Marseille, France	laure.ciesla@oamp.fr
Luis **Colina**, Centro de Astrobiologia, Spain	colina@cab.inta-csic.es
Francoise **Combes**, Observatoire de Paris, LERMA, France	francoise.combes@obspm.fr
Asantha **Cooray**, University of California, Irvine, USA	acooray@uci.edu
Nick **Cox**, Institute of Astronomy, KU Leuven, Belgium	nick.cox@ster.kuleuven.be
Maria **Cunningham**, University of New South Wales, Australia	maria.cunningham@unsw.edu.au
Stephen **Curran**, University of Sydney, Australia	sjc@physics.usyd.edu.au
Emanuele **Daddi**, CEA Saclay, France	edaddi@cea.fr
Timothy **Davis**, ESO, Germany	tdavis@eso.org
Joanne **Dawson**, University of Tasmania, Australia	joanne.dawson@utas.edu.au
James **Di Francesco**, National Research Council of Canada, Canada	james.difrancesco@nrc-cnrc.gc.ca
Tanio **Diaz-Santos**, California Institute of Technology, USA	tanio@ipac.caltech.edu
Alberto **Dominguez**, University of California, Riverside, USA	albertod@ucr.edu
Hui **Dong**, National Optical Astronomy Observatories, USA	hdong@noao.edu
Pierre-Alain **Duc**, AIM Paris-Saclay, France	paduc@cea.fr
Gaelle **Dumas**, IRAM, France	dumas@iram.fr
Bruce **Elmegreen**, IBM T. J. Watson Research Center, USA	bge@us.ibm.com
Santiago **Erroz**, Instituto de Astrofísica de Canarias, Spain	serroz@iac.es
Rafael **Eufrasio**, Catholic University of America/NASA GSFC, USA	rafael.t.eufrasio@nasa.gov
Jessica **Evans**, University of Illinois, USA	jevanses@gmail.com
Diego **Falceta-Goncalves**, University of São Paulo, Brazil	dfalceta@usp.br
Edith **Falgarone**, ENS/Observatoire de Paris, France	edith.falgarone@ens.fr
Chiara **Feruglio**, IRAM, France	feruglio@iram.fr
Lisa **Fogarty**, University of Sydney, Australia	l.fogarty@physics.usyd.edu.au
Joan **Font**, Instituto de Astrofísica de Canarias, Spain	jfont@iac.es
Dirk **Froebrich**, University of Kent, UK	df@star.kent.ac.uk
Jian **Fu**, Max Planck Institute for Astrophysics, Germany	fujian@mpa-garching.mpg.de
Yasuo **Fukui**, Nagoya University, Japan	fukui@a.phys.nagoya-u.ac.jp
Gary **Fuller**, Jodrell Bank Centre for Astrophysics, U. Manchester, UK	g.fuller@manchester.ac.uk
Frédéric **Galliano**, CEA Saclay, France	frederic.galliano@cea.fr
Cong-Gui **Gan**, Shanghai Astronomical Observatory, China	cggan@shao.ac.cn
Jian **Gao**, Beijing Normal University, China	jiangao@bnu.edu.cn
Yu **Gao**, Purple Mountain Observatory, China	yugao@pmo.ac.cn
Santiago **Garcia-Burillo**, OAN-Spain, Spain	s.gburillo@oan.es
Lisseth **Gavilan**, Observatoire de Paris, LERMA, France	lisseth.gavilan@obspm.fr
Richard **George**, IfA, University of Edinburgh, UK	rdg@roe.ac.uk
Elodie **Giovannoli**, University of the Western Cape, South Africa	elodie.giovannoli@gmail.com
Oleg **Gnedin**, University of Michigan, USA	ognedin@umich.edu
Nathan **Goldbaum**, University Of California, Santa Cruz, USA	goldbaum@ucolick.org
Oleksiy **Golubov**, ARI, Heidelberg University, Germany	golubov@ari.uni-heidelberg.de
Haley **Gomez**, Cardiff University, UK	haley.gomez@astro.cf.ac.uk
Thiago **Goncalves**, Universidade Federal do Rio de Janeiro, Brazil	tsg@astro.ufrj.br
Yan **Gong**, Purple Mountain Observatory, China	ygong@pmo.ac.cn
Matthias **Gritschneder**, University Of California, Santa Cruz, USA	gritschn@ucolick.org
Preben **Grosboel**, ESO, Germany	pgrosbol@eso.org
Sebastian **Haan**, CSIRO Astronomy and Space Science, Australia	sebastian.haan@csiro.au
Emilie **Habart**, Institut d'Astrophysique Spatiale, Orsay, France	emilie.habart@ias.u-psud.fr
Toshihiro **Handa**, Kagoshima University, Japan	handa@sci.kagoshima-u.ac.jp

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George **Hau**, ESO, Germany ghau@eso.org
Jinhua **He**, Yunnan Astronomical Observatory, CAS, China jinhuahe@ynao.ac.cn
Christian **Henkel**, MPIfR, Bonn, Germany chenkel@mpifr-bonn.mpg.de
Patrick **Hennebelle**, Observatoire de Paris, France patrick.hennebelle@ens.fr
Gerhard **Hensler**, University of Vienna, Austria gerhard.hensler@univie.ac.at
Alisher **Hojaev**, National University of Uzbekistan, Uzbekistan hojaev@yahoo.com
Jinliang **Hou**, Shanghai Astronomical Observatory, China houjl@shao.ac.cn
Ligang **Hou**, National Astronomical Observatories, CAS, China lghou@nao.cas.cn
Xinchuan **Huang**, SETI Institute, USA xinchuan.huang-1@nasa.gov
Zhiying **Huo**, National Astronomical Observatories, CAS, China zhiyinghuo@bao.ac.cn
Bernd **Husemann**, Leibniz Institute for Astrophysics, Germany bhusemann@aip.de
Nariman **Ismailov**, Shamakha AO NAS of Azerbaijan, Azerbaijan ismailovn@yahoo.com
Jane **Kaczmarek**, University of Sydney, Australia jane@physics.usyd.edu.au
Kazuhisa **Kamegai**, Tokyo University of Science, Japan kamegai@rs.tus.ac.jp
Osamu **Kameya**, National Astronomical Observatory of Japan, Japan kameya@miz.nao.ac.jp
Tatsuya **Kamezaki**, Kagoshima University, Japan kamezaki@milkyway.sci.kagoshima-u.ac.jp
Hidehiro **Kaneda**, Nagoya University, Japan kaneda@u.phys.nagoya-u.ac.jp
Sugata **Kaviraj**, Imperial College London, UK s.kaviraj@imperial.ac.uk
Akiko **Kawamura**, National Astronomical Observatory of Japan, Japan akiko.kawamura@nao.ac.jp
Chang-Goo **Kim**, University of Western Ontario, Canada ckim256@uwo.ca
Hyun-Jeong **Kim**, Seoul National University, South Korea hjkim@astro.snu.ac.kr
Ji Hoon **Kim**, Seoul National University, South Korea jhkim@astro.snu.ac.kr
Shinya **Komugi**, Joint ALMA Observatory, Chile skomugi@alma.cl
Mark **Krumholz**, University Of California, Santa Cruz, USA krumholz@ucolick.org
Wei-Ting **Kuo**, National Tsing Hua University, Taiwan steveair1991@yahoo.com.tw
Sun **Kwok**, The University of Hong Kong, China sunkwok@hku.hk
Alvaro **Labiano**, CAB-INTA, Spain labiano@oan.es
Maritza Arlene **Lara-Lopez**, Australian Astronomical Observatory, Australia mlopez@aao.gov.au
Vianney **Lebouteiller**, CEA Saclay, France vianney.lebouteiller@cea.fr
Chang Won **Lee**, KASI, South Korea cwl@kasi.re.kr
Youngung **Lee**, KASI, South Korea yulee@kasi.re.kr
Lerothodi **Leeuw**, University of Johannesburg, South Africa lerothodi@alum.mit.edu
Claus **Leitherer**, Space Telescope Science Institute, USA leitherer@stsci.edu
Jacques **Lepine**, University of São Paulo, Brazil jacques@astro.iag.usp.br
Cheng **Li**, Shanghai Astronomical Observatory, China leech@shao.ac.cn
Di **Li**, National Astronomical Observatories, CAS, China dili@nao.cas.cn
Huixian **Li**, National Astronomical Observatories, CAS, China lhx@nao.cas.cn
Juan **Li**, Shanghai Astronomical Observatory, China lijuan@shao.ac.cn
Yinbi **Li**, National Astronomical Observatories, CAS, China ybli@nao.cas.cn
Zhongmu **Li**, Institute of Astronomy of Dali University, China zhongmu.li@gmail.com
Ming-Yi **Lin**, National Taiwan Normal University, Taiwan acdo2002@gmail.com
Tie **Liu**, Peking University, China liutiepku@pku.edu.cn
Wing-Chi Nadia **Lo**, Universidad de Chile, Chile nlo@das.uchile.cl
Steven **Longmore**, ESO, Germany slongmor@eso.org
Laura **Lopez**, MIT, USA lopez@space.mit.edu
Ilani **Loubser**, North-West University, South Africa ilani.loubser@nwu.ac.za
Fabien **Louve**, CEA Saclay, France fabien.louvet@cea.fr
Vicki **Lowe**, University of New South Wales, Australia vicki.lowe@unsw.edu.au
Nanyao **Lu**, NHSC/IPAC/Caltech, USA lu@ipac.caltech.edu
Mordecai-Mark **Mac Low**, AMNH and ZAH/ITA, USA mordecai@amnh.org
Suzanne **Madden**, CEA, SAp, Saclay, France suzanne.madden@cea.fr
Vincenzo **Mainieri**, ESO, Germany vmainier@eso.org
Roberto **Maiolino**, University of Cambridge - Cavendish Laboratory, UK r.maiolino@mrao.cam.ac.uk
Liton **Majumdar**, Indian Centre for Space Physics, West Bengal, India liton.icsp@gmail.com
Marie **Martig**, Swinburne University, Australia mmartig@astro.swin.edu.au
Christopher **Martin**, Oberlin College, USA chris.martin@oberlin.edu
Mikako **Matsuura**, University College London, UK mikako@star.ucl.ac.uk
Leonid **Matveenko**, IKI, Russia lmatveenko@gmail.com
Jack **Mayo**, IfA, University of Edinburgh, UK jhm@roe.ac.uk
Sharon **Meidt**, MPIA, Heidelberg, Germany meidt@mpia.de
Attila **Meszaros**, Charles University, Czech Republic meszaros@cesnet.cz
Jingqi **Miao**, University of Kent, UK j.miao@kent.ac.uk
Areg **Mickaelian**, Byurakan Astrophysical Observatory, Armenia aregmick@yahoo.com
Vincent **Minier**, CEA Saclay, France vincent.minier@cea.fr
Ryo **Miyanoshita**, Kagoshima University, Japan miyanoshita@milkyway.sci.kagoshima-u.ac.jp
Moses **Mogotsi**, University of Cape Town, South Africa moses.mog@gmail.com
Sergio **Molinari**, INAF-IAPS, Italy molinari@ifsi-roma.inaf.it
Rieko **Momose**, University of Tokyo, Japan momo.s.rieko@nao.ac.jp
Raffaella **Morganti**, ASTRON, Netherlands morganti@astron.nl
Francisco **Mueller-Sanchez**, UCLA, USA fmueller@astro.ucla.edu
Erik **Muller**, NAOJ Chile Observatory, Japan erik.muller@nao.ac.jp
K. **Murakawa**, University of Leeds, UK k.murakawa@leeds.ac.uk
Norman **Murray**, CITA, Univ. of Toronto, Canada murray@cita.utoronto.ca
Tom **Muxlow**, Jodrell Bank Centre for Astrophysics, U. Manchester, UK twbm@jb.man.ac.uk
Mahadevappa **Nagnathappa**, S. R. T. Maratwada University, India swamimahadev25@gmail.com
Fumitaka **Nakamura**, National Astronomical Observatory of Japan, Japan fumitaka.nakamura@nao.ac.jp
Nicole **Nesvadba**, Institut d'Astrophysique Spatiale, Orsay, France nicole.nesvadba@ias.u-psud.fr
Sudeep **Neupane**, TU & Nepal Astronomical Society, Nepal sudeepneupane@gmail.com
Lan **Nguyen**, Hanoi National University of Education, Vietnam nquynhlan@hnue.edu.vn
Fatemeh **Nikzat**, Alzahra University, Iran fatemeh.nikzat@gmail.com
Alexandra **Novikova**, Sternberg Astronomical Institute, MSU, Russia anovikova@sai.msu.ru
Semyeong **Oh**, Seoul National University, South Korea smoh@astro.snu.ac.kr
Daniel **Okoh**, University of Nigeria, Nsukka, Nigeria okodan2003@gmail.com
Christoph **Olczak**, ARI-ZAH, Heidelberg University, Germany olczak@ari.uni-heidelberg.de
Amitesh **Omar**, ARIES, India aomar@aries.res.in
Takashi **Onaka**, University of Tokyo, Japan onaka@astron.s.u-tokyo.ac.jp
Tom **Oosterloo**, ASTRON, Netherlands oosterloo@astron.nl
Alvaro **Orsi**, Pontificia Universidad Catolica de Chile, Chile aaorsi@astro.puc.cl
Juergen **Ott**, National Radio Astronomy Observatory, USA jott@nrao.edu
Nelson **Padilla**, Universidad Católica de Chile, Chile npadilla@astro.puc.cl
Maurilio **Pannella**, CEA Saclay, France maurilio.pannella@cea.fr

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Padelis P. **Papadopoulos**, MPIfR, Bonn, Germany padelis@mpifr-bonn.mpg.de
Bogdan Adrian **Pastrav**, University of Central Lancashire, UK bapastrav@uclan.ac.uk
Juan-Pablo **Perez-Beaupuits**, MPIfR, Bonn, Germany jp@mpifr.de
Riwaj **Pokhrel**, Tribhuvan University, Nepal riwaj007@hotmail.com
Lei **Qian**, National Astronomical Observatories, CAS, China lqian@nao.cas.cn
Nurur **Rahman**, University of Johanensburg, South Africa nrahman@ac.uj.za
Solohery **Randriamampandry**, University of the Western Cape / SAAO, South Africa solohery@saao.ac.za
Naseem **Rangwala**, University of Colorado, USA naseem.rangwala@colorado.edu
Ramprasad **Rao**, ASIAA, Taiwan rrao@sma.hawaii.edu
Maryam **Rashidi**, Alzahra University, Iran maryam.rashidi.88@gmail.com
Sarah **Reeves**, University of Sydney, Australia s.reeves@physics.usyd.edu.au
Marissa **Rosenberg**, Leiden Observatory, Netherlands rosenberg@strw.leidenuniv.nl
Kate **Rowlands**, University of Nottingham, UK ppxkr@nottingham.ac.uk
Monica **Rubio**, Universidad de Chile, Chile mrubio@das.uchile.cl
Maryam **Saberi**, Alzahra University, Iran maryamsaberiii@gmail.com
Elaine **Sadler**, University of Sydney, Australia ems@physics.usyd.edu.au
Amelie **Saintonge**, MPE, Garching, Germany amelie@mpe.mpg.de
Kazushi **Sakamoto**, ASIAA, Taiwan ksakamoto@asiaa.sinica.edu.tw
Dragan **Salak**, University of Tsukuba, Japan s1130080@u.tsukuba.ac.jp
Philippe **Salome**, Observatoire de Paris, LERMA, France philippe.salome@obspm.fr
Jose Ramon **Sanchez-Gallego**, Instituto de Astrofísica de Canarias, Spain jrsg@iac.es
David **Sanders**, University of Hawaii, USA sanders@ifa.hawaii.edu
Andreas **Schruba**, California Institute of Technology, USA schruba@astro.caltech.edu
Caroline **Scott**, Imperial College London, UK c.scott09@imperial.ac.uk
Nick **Scoville**, California Institute of Technology, USA nzs@astro.caltech.edu
Marta **Sewilo**, Johns Hopkins University, USA mmsewilo@pha.jhu.edu
Stanislav **Shabala**, University of Tasmania, Australia stanislav.shabala@utas.edu.au
Zhengyi **Shao**, Shanghai Astronomical Observatory, China zyshao@shao.ac.cn
Chelsea **Sharon**, Rutgers, The State University of New Jersey, USA csharon@physics.rutgers.edu
Jaejin **Shin**, Seoul National University, South Korea jjshin@astro.snu.ac.kr
Ian **Stephens**, University of Illinois, USA iwstephens@gmail.com
Zdenek **Stuchlik**, Institute of Physics, SU Opava, Czech Republic zdenek.stuchlik@fpf.slu.cz
Juergen **Stutzki**, I. Physik. Institut, Universität zu Köln, Germany stutzki@ph1.uni-koeln.de
Yanchun **Sun**, Beijing Normal University, China ychsun@bnu.edu.cn
Jonathan C. **Tan**, University of Florida, USA jt@astro.ufl.edu
Wei-Wei **Tan**, Central China Normal University, China wwtan.ccnu@gmail.com
Elizabeth **Tasker**, Hokkaido University, Japan tasker@astro1.sci.hokudai.ac.jp
Leonardo **Testi**, ESO/Arcetri, Germany ltesti@eso.org
Selcuk **Topal**, University of Oxford, UK selcuk.topal@astro.ox.ac.uk
Laszlo Viktor **Toth**, Eötvös University, Budapest, Hungary l.v.toth@astro.elte.hu
Hideyuki **Toujima**, Kagoshima University, Japan handa@sci.kagoshima-u.ac.jp
Marina **Trevisan**, IAG/USP, Brazil marinatrevisan@gmail.com
An-Li **Tsai**, National Central University, Taiwan altsai@astro.ncu.edu.tw
Cheng-Hung **Tsai**, National Tsing Hua University, Taiwan arthur770410@gmail.com
Masato **Tsuboi**, Institute of Space and Astronautical Science, JAXA, Japan tsuboi@vsop.isas.jaxa.jp
Miikka **Väisälä**, University of Helsinki, Finland miikka.vaisala@helsinki.fi
Petri **Vaisanen**, SAAO, South Africa petri@saao.ac.za
Rosa **Valiante**, INAF-Osservatorio Astronomico di Roma, Italy rosa.valiante@oa-roma.inaf.it
Thijs (J.M.) **van der Hulst**, Kapteyn Astronomical Institute, Netherlands vdhulst@astro.rug.nl
Thangasamy **Velusamy**, NASA JPL, USA velusamy@jpl.nasa.gov
Jaan **Vennik**, Tartu Observatory, Estonia vennik@aai.ee
Erika **Verebelyi**, Eötvös University, Budapest, Hungary e.verebelyi@astro.elte.hu
Elysse **Voyer**, LAM/OAMP/CUA, France elysse.voyer@oamp.fr
Keiichi **Wada**, Kagoshima University, Japan wada@astrophysics.jp
Stefanie **Walch**, Max Planck Institute for Astrophysics, Germany walch@mpa-garching.mpg.de
Lingyu **Wang**, University of Sussex, UK lingyu.wang@sussex.ac.uk
Ran **Wang**, NRAO / Steward Observatory, USA rwang@as.arizona.edu
Wei-Hao **Wang**, ASIAA, Taiwan whwang@gmail.com
Yiping **Wang**, National Astronomical Observatories, CAS, China ypwang@bao.ac.cn
Yuan **Wang**, Purple Mountain Observatory, China ywang@pmo.ac.cn
Zhong **Wang**, Harvard-Smithsonian CfA, USA zwang@cfa.harvard.edu
Xiao-Qing **Wen**, National Astronomical Observatories, CAS, China wendyxiaoqing@lamost.org
Pieter **Westera**, Universidade Federal do ABC, Santo André, Brazil pieter.westera@ufabc.edu.br
Vivienne **Wild**, University of St Andrews, UK vw8@st-andrews.ac.uk
Christine **Wilson**, McMaster University, Canada wilson@physics.mcmaster.ca
Aida **Wofford**, Space Telescope Science Institute, USA wofford@stsci.edu
Tony **Wong**, University of Illinois, USA wongt@illinois.edu
Gang **Wu**, Xinjiang Astronomical Observatory, China wug@xao.ac.cn
Ronin **Wu**, CEA Saclay, France ronin.wu@cea.fr
Xue-Bing **Wu**, Peking University, China wuxb@pku.edu.cn
Xiaoyang **Xia**, Tianjin Normal University, China xyxia@bao.ac.cn
Fuyuan **Xiang**, Department of Physics, Xiangtan University, China fyxiang@xtu.edu.cn
Ting **Xiao**, Shanghai Astronomical Observatory, China xiaoting@shao.ac.cn
Jin Long **Xu**, National Astronomical Observatories, CAS, China xujl@bao.ac.cn
Rui **Xue**, University of Illinois, USA ruixue1@illinois.edu
Xuejuan **Yang**, XTU, China xjyang@xtu.edu.cn
Sarolta **Zahorecz**, Eötvös University, Budapest, Hungary s.zahorecz@astro.elte.hu
Javier **Zaragoza**, Instituto de Astrofísica de Canarias, Spain jzc@iac.es
Chuan-Peng **Zhang**, National Astronomical Observatories, CAS, China zcp0507@gmail.com
Fenghui **Zhang**, Yunnan Observatory, China zhangfh@ynao.ac.cn
Shaobo **Zhang**, Purple Mountain Observatory, China shbzhang@pmo.ac.cn
Xiaojia **Zhang**, Peking University, China zhizhi17@hotmail.com
Yichen **Zhang**, University of Florida, USA yczhang@astro.ufl.edu
Yong **Zhang**, The University of Hong Kong, China zhangy96@hku.hk
Yinghe **Zhao**, Purple Mountain Observatory, China yhzhao@pmo.ac.cn
Hans **Zinnecker**, SOFIA Science Center, NASA-Ames, USA hzinnecker@sofia.usra.edu

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