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The Multi-Messenger Astrophysics of the Galactic Centre

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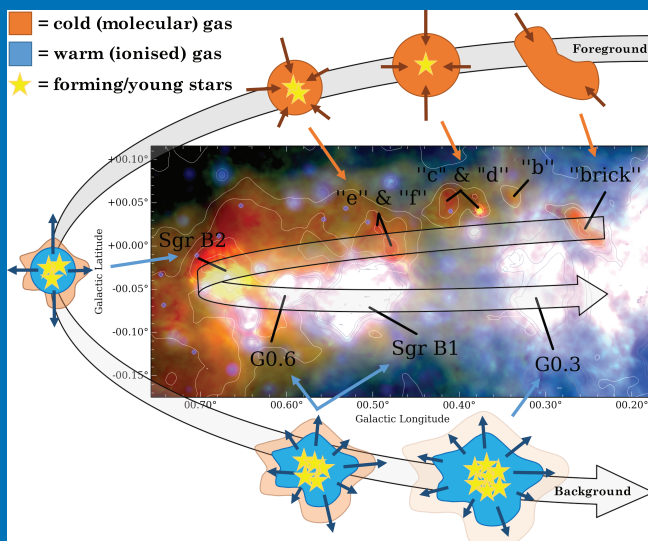
Roland M. Crocker
Steven N. Longmore
Geoffrey V. Bicknell

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THE MULTI-MESSENGER ASTROPHYSICS OF THE GALACTIC CENTRE
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COVER ILLUSTRATION:

This composite Spitzer and Herschel figure from Barnes et al (this volume) shows the distribution of dense gas and young stars in a $\sim 70 \times 40$ parsec region of the Galactic Centre, which contains several actively star-forming and quiescent gas clouds. The blue and red colour scales indicate warm and cool gas luminosities, respectively. The white and grey contours show the warm and cool gas column densities, respectively. These gas components have been used to determine the total gas masses and the total embedded stellar masses towards each source, which are labeled on the map. The transparent curved arrow represents the path of the orbital model (Kruijssen, Dale & Longmore 2015), with labels of time since pericentre passage according to this model. It has been suggested that strong tidal forces compress the gas clouds at the pericentre of this orbit, causing gravitational collapse and triggering star formation (see Kruijssen, this volume). This figure highlights the increasing stellar masses embedded within the gas clouds (up to around a few percent of the gas mass) and increasing spatial extent of the hot gas component along this orbit, over a timescale comparable to several free-fall times.

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Chief Editor

PIERO BENVENUTI, IAU General Secretary

IAU-UAI Secretariat

98-bis Blvd Arago

F-75014 Paris

France

iau-general.secretary@iap.fr

Editor

MARIA TERESA LAGO, IAU Assistant General Secretary

Universidade do Porto

Centro de Astrofísica

Rua das Estrelas

4150-762 Porto

Portugal

mtlago@astro.up.pt

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**THE MULTI-MESSENGER
ASTROPHYSICS OF THE
GALACTIC CENTRE**

**PROCEEDINGS OF THE 322nd SYMPOSIUM
OF THE INTERNATIONAL ASTRONOMICAL
UNION HELD IN QUEENSLAND, AUSTRALIA
JULY 18–22, 2016**

Edited by

ROLAND M. CROCKER
Australian National University

STEVEN N. LONGMORE
Liverpool John Moores University

and

GEOFFREY V. BICKNELL
Australian National University



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Table of Contents

Preface	xi
Attendees	xiii
Conference Photograph	xv
 Topic 1: New results of interest	
Advances from Recent Multi-wavelength Campaigns on Sgr A*	1
<i>D. Haggard</i>	
<i>Fermi</i> -LAT Observations toward the Galactic Center	11
<i>S Murgia</i>	
Probing Sagittarius A* accretion with ALMA.....	21
<i>E. Murchikova</i>	
Detection of relativistic effects on the S2 orbit with GRAVITY	25
<i>M. Grould, F. H. Vincent, T. Paumard & G. Perrin</i>	
 Topic 2: Approaching the Event Horizon	
Statistical and theoretical studies of flares from Sagittarius A*	31
<i>Y.-P. Li, Q. Yuan, Q. D. Wang, P. F. Chen, J. Neilsen, T. Fang, S. Zhang & J. Dexter</i>	
Modelling the thermal X-ray emission around the Galactic centre from colliding Wolf-Rayet winds	39
<i>C. M. P. Russell, Q. D. Wang & J. Cuadra</i>	
Status of GRMHD simulations and radiative models of Sgr A*	43
<i>M. Mościbrodzka</i>	
 Poster proceedings topic 2	
Possible Detection of Quasi-Periodic Oscillations from Sgr A* at 43 GHz	50
<i>Y. Iwata, T. Oka & M. Miyoshi</i>	
NIR triggered observations of Sgr A* at 43 GHz	52
<i>C. Rauch, E. Ros, T. P. Krichbaum, A. Eckart, J. A. Zensus, R.-S. Lu, B. Shahzamanian, K. Mužić & F. Peißker</i>	
Low radio frequency spectrum of Sgr-A*	54
<i>S. Roy</i>	
Millimeter VLBI observations of Sgr A* with KaVA and KVN.....	56
<i>G.-Y. Zhao, M. Kino, I.-J. Cho, K. Akiyama, B. W. Sohn, T. Jung, J. C. Algaba, K. Hada, Y. Hagiwara, J. Hodgson, M. Honma, N. Kawaguchi, S. Koyama, J. A. Lee, T. Lee, K. Niinuma, J. Oh, J.-H. Park, H. Ro, S. Sawada-Satoh, F. Tazaki, S. Trippe, K. Wajima & H. Yoo</i>	

Topic 3: Dense gas in the Galactic Centre and its star formation potential; young and massive stars in the Galactic Centre

Towards a multi-scale understanding of the gas-star formation cycle in the Central Molecular Zone	64
<i>J. M. Diederik Kruijssen</i>	
Star Formation in the Galactic Center	75
<i>J. Kauffmann</i>	
Molecular gas kinematics of the CMZ: Great oaks from little acorns grow	85
<i>J. D. Henshaw</i>	
A Brief Update on the CMZoom Survey	90
<i>C. Battersby, E. Keto, Q. Zhang, S. N. Longmore, J. M. D. Kruijssen, T. Pillai, J. Kauffmann, D. Walker, X. Lu, A. Ginsburg, J. Bally, E. A. C. Mills, J. Henshaw, K. Immer, N. Patel, V. Tolls, A. Walsh, K. Johnston & L. C. Ho</i>	
Star formation in a high-pressure environment: An SMA view of the dust ridge	95
<i>D. L. Walker CMZoom Survey Group (PIs: Eric Keto & Cara Battersby)</i>	
Deeply Embedded Protostellar Population in the Central Molecular Zone Suggested by H ₂ O Masers and Dense Cores	99
<i>X. Lu, Q. Zhang, J. Kauffmann, T. Pillai, S. N. Longmore, J. M. Diederik Kruijssen & C. Battersby</i>	
Thousands of Stellar SiO masers in the Galactic center: The Bulge Asymmetries and Dynamic Evolution (BAaDE) survey	103
<i>L. O. Sjouwerman, Y. M. Pihlström, R. M. Rich, M. R. Morris & M. J. Claussen</i>	
Search for the CO-dark Mass in the Central Molecular Zone by using the ASTE 10-m Telescope	107
<i>K. Tanaka</i>	
How hot is the molecular gas in the Galactic Center?	111
<i>K. Immer, J. Kauffmann, T. Pillai, A. Ginsburg & K. M. Menten</i>	
Tidally-disrupted Molecular Clouds falling to the Galactic Center	115
<i>M. Tsuboi, Y. Kitamura, K. Uehara, R. Miyawaki & A. Miyazaki</i>	
Signature of an Intermediate-Mass Black Hole in the Central Molecular Zone of Our Galaxy	119
<i>T. Oka, R. Mizuno, K. Miura & S. Takekawa</i>	
The link between solenoidal turbulence and slow star formation in G0.253+0.016	123
<i>C. Federrath, J. M. Rathborne, S. N. Longmore, J. M. D. Kruijssen, J. Bally, Y. Contreras, R. M. Crocker, G. Garay, J. M. Jackson, L. Testi & A. J. Walsh</i>	
Molecular gas in the immediate vicinity of Sgr A* seen with ALMA	129
<i>L. Moser, Á. Sánchez-Monge, A. Eckart, M. A. Requena-Torres, M. García-Marín, D. Kunneriath, A. Zensus, S. Britzen, N. Sabha, B. Shahzamanian, A. Borkar & S. Fischer</i>	

Molecular and ionized gas kinematics in the GC Radio Arc	133
<i>N. Butterfield, C. C. Lang, E. A. C. Mills, D. Ludovici, J. Ott & M. R. Morris</i>	
Investigating Magnetic Activity in the Galactic Centre by Global MHD Simulation	137
<i>T. K. Suzuki, Y. Fukui, K. Torii, M. Machida, R. Matsumoto & K. Kakiuchi</i>	
Poster proceedings topic 3	
Ground-state OH maser distributions in the Galactic Centre region.	141
<i>H.-H. Qiao, A. J. Walsh, Z.-Q. Shen & J. R. Dawson</i>	
SWAG: Survey of Water and Ammonia in the Galactic Center.	143
<i>J. Ott, D. S. Meier, N. Krieger, M. Rickert & the SWAG team</i>	
Physical Contact between the +20 km s ⁻¹ Cloud and the Galactic Circumnuclear Disk	145
<i>S. Takekawa, T. Oka & K. Tanaka</i>	
Star formation rates on global and cloud scales within the Galactic Centre.	147
<i>A. T. Barnes, S. N. Longmore, C. Battersby, J. Bally, J. M. D. Kruijssen</i>	
PDR Emission from the Arched-Filaments and Nearby Positions	149
<i>P. García, M. Röllig, N. Abel, M. Steinke, M. Burton & R. Blackwell</i>	
Kinematics of the Ultra-High-Velocity Gas in the Expanding Molecular Shell Ad- jacent to the W44 Supernova Remnant	151
<i>M. Yamada, T. Oka, K. Tanaka, M. Nomura, S. Takekawa, Y. Iwata, S. Tokuyama, K. Tanabe, S. Tsujimoto & M. Furusawa</i>	
Statistical Study of High-Velocity Compact Clouds Based on the Complete CO Imagings of the Central Molecular Zone.	154
<i>S. Tokuyama, T. Oka, S. Takekawa, M. Yamada, Y. Iwata & S. Tsujimoto</i>	
Molecular material in the Bubble of the Galactic Center.	156
<i>M. A. R. Torres & A. Noriega-Crespo</i>	
Time Evolution of the Giant Molecular Cloud Mass Functions across Galactic Disks	158
<i>M. I. N. Kobayashi, S.-i. Inutsuka, H. Kobayashi & K. Hasegawa</i>	
Temperature Evolution of Molecular Clouds in the Central Molecular Zone	160
<i>N. Krieger, J. Ott, F. Walter, J. M. Diederik Kruijssen, H. Beuther & the SWAG team</i>	
ALMA view of the Galactic Center 50km/s molecular cloud	162
<i>K. Uehara, M. Tsuboi, Y. Kitamura, R. Miyawaki & A. Miyazaki</i>	
Mopra Central Molecular Zone Carbon Monoxide Survey Status	164
<i>R. Blackwell, M. Burton & G. Rowell</i>	
VLBI astrometry toward Sgr D HII region with VERA.	166
<i>D. Sakai, T. Oyama, T. Nagayama, M. Honma & H. Kobayashi</i>	

FIR Spectroscopy of the Galactic Center: Hot and Warm Molecular Gas	168
<i>J. R. Goicoechea, M. Etxaluze, J. Cernicharo, M. Gerin, J. Pety & collaborators</i>	
Hidden Star Formation in High-Velocity Gas Clouds in Clump 2 near the Edge of the CMZ	170
<i>V. Tolls, H. A. Smith & HIGGS Team</i>	
Topic 4: positrons	
Sgr A* as Source of the Positrons Observed in the Galactic Center Region	172
<i>P. Jean, N. Guessoum & K. Ferrière</i>	
SN1991bg-like supernovae are a compelling source of most Galactic antimatter	176
<i>F. H. Panther, R. M. Crocker, I. R. Seitenzahl & A. J. Ruiter</i>	
Topic 5: Stellar end products in the Galactic Centre/ GC SF History	
Topic 6: Dark Matter in the GC?	
Dark Matter and the Galactic Center	180
<i>L. Bergstrom</i>	
The AGN Jet Model of the Fermi Bubbles	189
<i>F. Guo</i>	
Millisecond Pulsars in the Galactic Bulge? An Extended Discussion on the Wavelet Analysis of the Fermi-LAT data	193
<i>R. Bartels & C. Weniger</i>	
Topic 7: X-rays and plasma	
<i>Hitomi</i> X-ray Astronomy Satellite: Power of High-Resolution Spectroscopy	197
<i>H. Odaka & the Hitomi Collaboration</i>	
Poster proceedings topic 7	
Clump formation through colliding stellar winds in the Galactic Centre	204
<i>D. Calderón, J. Cuadra, A. Ballone, M. Schartmann, A. Burkert, J. Prieto & S. Gillessen</i>	
Origin of the Galactic Diffuse X-ray Emission: Iron K-Shell Line Diagnostics	206
<i>M. Nobukawa, H. Uchiyama, K. K. Nobukawa, S. Yamauchi & K. Koyama</i>	
An X-ray view of Sagittarius C	208
<i>D. Chuard, R. Terrier, A. Goldwurm, M. Clavel, S. Soldi, G. Ponti, M. R. Morris & C. Jin</i>	
Topic 8: Galactic Centre Gamma-Rays, Cosmic Rays, Magnetic Fields	
The high SNR rate in the Galactic Center: origin of the cosmic rays excess?	210
<i>L. Jowin, A. Lemièrre, & R. Terrier</i>	

- Diffuse gamma-ray emission from the Galactic center and implications of its past activities 214
Y. Fujita, S. S. Kimura & K. Murase

Poster proceedings topic 8

- High Energy Gamma Rays and Neutrinos from Star-forming Activities in the Galactic and Extragalactic Sources 218
S. Razzaque
- Vertical flows and structures excited by magnetic activity in the Galactic center region. 220
K. Kakiuchi, T. K. Suzuki, Y. Fukui, K. Torii, M. Machida & R. Matsumoto

Topic 9: Nuclear clusters, cluster dynamics, close orbits relation to black hole feeding

- Observational constraints on the formation and evolution of the Milky Way nuclear star cluster with Keck and Gemini 222
T. Do, A. Ghez, M. Morris, J. Lu, S. Chappell, A. Feldmeier-Krause, W. Kerzendorf, G. D. Martinez, N. Murray & N. Winsor

Poster proceedings topic 9

- Nature of the Dusty S-cluster Object (DSO/G2): Pre-main-sequence star with non-spherical dusty envelope 231
M. Zajaček, M. Valencia-S., B. Shahzamanian, F. Peißker, A. Eckart & M. Parsa
- Detection of polarized continuum emission of the Dusty S-cluster Object (DSO/G2) 233
B. Shahzamanian, M. Zajaček, M. Valencia-S., F. Peißker, A. Eckart, N. Sabha & M. Parsa
- The late-type stellar density profile in the Galactic Center: A statistical approach 235
S. N. Chappell, A. M. Ghez, T. Do, G. D. Martinez, S. Yelda, B. N. Sitarski, J. R. Lu & M. R. Morris
- Constraining the Variability and Binary Fraction of Galactic Center Young Stars 237
A. K. Gautam, T. Do, A. M. Ghez, J. R. Lu, M. R. Morris, S. Sakai, G. Witzel, B. N. Sitarski & S. Chappell
- Statistical Challenges in fitting stellar orbits around the super-massive black hole at the Galactic center. 239
G. D. Martinez, K. Kosmo, A. Hees, J. Ahn & A. Ghez
- 3D AMR simulations of the evolution of the diffuse gas cloud G2 in the Galactic Centre 241
M. Schartmann, A. Ballone, A. Burkert, S. Gillessen, R. Genzel, O. Pfuhl, F. Eisenhauer, P. M. Plewa, T. Ott, E. M. George & M. Habibi
- 3D AMR simulations of G2 as an outflow 243
A. Ballone, M. Schartmann, A. Burkert, S. Gillessen, P. M. Plewa, O. Pfuhl, R. Genzel, F. Eisenhauer, T. Ott, E. M. George & M. Habibi

Topic 10: Understanding the GC in relation to other galaxies and in the context of Stellar/AGN feedback	
The Galactic Center compared with nuclei of nearby galaxies	245
<i>F. Combes</i>	
Can we infer the past activity of M31 as we do for Sgr A?	253
<i>M. Clavel, R. Terrier, A. Goldwurm, M. R. Morris & G. Ponti</i>	
Poster proceedings topic 10	
The Fingerprint of a Galactic Nucleus	257
<i>F. Nogueras-Lara & R. Schödel</i>	
Author Index	259

Preface to IAU Symposium 322

The Galactic Centre represents a unique and extreme environment in the Galaxy. Hosting the Galaxy's supermassive black hole, the Milky Way's most concentrated dense gas reservoir and its most extreme star-formation environment, it is the nearest analogue to both an AGN and a starburst system. Definitionally the bottom of the Galaxy's gravitational well, the Galactic Centre should be the region displaying the brightest radiative signature of dark matter decay/annihilation in the Galaxy, albeit against a very bright background due to the region's 'astrophysical' emissions.

IAU Symposium 322, reported on in this volume, builds on the history within the Galactic Centre community of holding regular international meetings (Japan (1997), Chile (1996), USA (1998), USA/Pacific (2002), Germany (2006), China (2009), and USA (2013)). It represents the first time the meeting has come to Australia.

We chose to structure the meeting around 11 themes:

1. New results of interest
2. Approaching the event horizon
3. Dense gas in the Galactic Centre and its star formation potential
4. Young and massive stars in the Galactic Centre
5. Stellar end products in the Galactic Centre; GC star formation history
6. Dark Matter in the GC?
7. X-rays and plasma
8. Galactic Centre Gamma-Rays, Cosmic Rays, Magnetic Fields
9. Positrons
10. Nuclear clusters, cluster dynamics, close orbits; relation to black hole feeding
11. Understanding the GC in relation to other galaxies and in the context of stellar/AGN feedback

Our understanding of the Galactic Centre and the inner Galaxy is in the throes of a revolution driven by advances in instrumentation and theory. Since the last Galactic Centre Meeting (IAU Symposium 303 'The Galactic Center: Feeding and Feedback in a Normal Galactic Nucleus', 2013 September 30 - October 4, Santa Fe, New Mexico), our view of the Galactic Centre has significantly developed with a number of instruments and instrumental collaborations presenting new observations of the region or explaining their progress towards making observations.

Significant new instrumentation and/or data-taking campaigns reported on during IAUS322 included:

- The Event Horizon Telescope (EHT) project that is assembling a high frequency Very Long Baseline Interferometry (VLBI) array that should be able to resolve the SgrA* supermassive black both spatially and temporally. There were a number of EHT talks during the meeting (Blackburn, Falcke, Fish).
- ALMA full operations have commenced allowing us to resolve the dense gas (i.e., not just CO) structure in nearby galaxies for the first time; there is much insight to be derived from comparing this to the recent wide-area surveys of dense gas in our own GC. In addition, in ALMA Cycle 1 and 2, many projects were awarded time to look at individual dense gas clouds in the CMZ in detail (see contributions from Moser et al., Murchikova et al., and Uehara et al.).
- The first systematic interferometric survey of the dense gas in the CMZ is now being conducted with the Harvard-Smithsonian Submillimeter Array ('CMZoom'). This will provide the first sub-pc (0.05pc = star forming core scale) survey of the region, allowing

the predictions of turbulent star formation theories to be tested (see the contributions from Battersby et al., Walker et al., Liu et al.).

- The Australia Telescope Compact Array is currently conducting “SWAG” — another dense gas and cm-continuum survey of the entire CMZ (see the contribution from project leader Juergen Ott and poster by Krieger et al).

- The Mopra survey of CO emission across the CMZ is well underway (see the contribution from Blackwell).

On the high-energy side, there were also a number of interesting contributions including:

- Despite its tragically premature demise, the Hitomi X-ray satellite operated for long enough to demonstrate the power of very high precision X-ray spectroscopy (see the contribution from Odaka).

- The gamma-ray community is eagerly anticipating the substantially increased resolution and sensitivity of the Cherenkov Telescope Array whose construction has just begun (talk by van Eldik).

From small to large scales around the SMBH, gamma-ray data continue to provide surprises and mysteries; indeed, a strong spectral signal consistent with annihilation of 10 GeV-scale WIMP dark matter particles peaking towards the Galactic Centre continues to draw attention. Yet because this is a crowded and unique environment within the Galaxy, we cannot dismiss the prospect that some hitherto underappreciated process or type of ‘conventional’ source is ultimately responsible for this and other anomalous signals. One significant priority of the meeting was to facilitate direct discussion between the community of researchers working on Dark Matter interpretations of the Fermi spectral anomaly (amongst other promising signals) and those who work on understanding the ‘conventional’ astrophysics of the region and much fruitful interaction was indeed forthcoming (see the contribution from Bergstrom)

One exciting achievement, we trust, of the conference was to bring together different communities to start a conversation working towards the goal of a self-consistent understanding of the mass flows and energy cycles through the central regions of the Milky Way and other galaxies, from the kpc-scale mass flows from the disk (Suzuki, Combes, and others), through the star formation and feedback cycles (Kruijssen, Krumholz, Henshaw, Barnes, Federrath, others), to the feeding of and feedback from the central SMBH (many contributions). Such a holistic picture of the feeding and feedback in the inner regions of galaxies is of fundamental importance to many areas of astrophysics, and we hope to see substantial progress in that direction in the next few years — perhaps the focus of the next conference(?).

Finally we note that, while some speakers have chosen not to provide a Proceedings contribution, many slides from the Symposium are available on line at:

<http://galacticcentre.space/index.php/programme/>

We thank all the participants for a most enjoyable and productive meeting in lovely Palm Cove, Australia.

The editors

Roland Crocker
Steve Longmore
Geoff Bicknell

ATTENDEES

Dr Andrea	Albert	Los Alamos National Laboratory
Mr Alessandro	Ballone	Max Planck Institute for Extraterrestrial Physics
Dr Matthew	Baring	Rice University
Mr Ashley	Barnes	Max Planck Institute for Extraterrestrial Physics
Mr Richard	Bartels	University of Amsterdam
Dr Cara	Battersby	Harvard-Smithsonian Center for Astrophysics
Prof. Lars	Bergstrom	Stockholm University
Prof. Geoffrey	Bicknell	Australian National University
Dr Lindy	Blackburn	Harvard-Smithsonian Center for Astrophysics
Miss Rebecca	Blackwell	University of Adelaide
Dr Geoffry	Bower	ASIAA
Miss Natalie	Butterfield	University of Iowa
Mr Diego	Calderón	Pontificia Universidad Católica de Chile
Dr Francesca	Calore	University of Amsterdam
Dr Chi-kwan	Chan	University of Arizona
Ms Samantha	Chappell	UCLA
Mr Dimitri	Chuard	CEA Saclay
Dr Mäica	Clavel	SSL/UC Berkeley
Prof. Françoise	Combes	College de France
Dr Roland	Crocker	Australian National University
Dr Jorge	Cuadra	Pontificia Universidad Católica de Chile
Dr Tuan	Do	UCLA
Dr Simon	Ellis	Australian Astronomical Observatory
Prof. Heino	Falcke	Radboud Universitat Nijmegen+MPIfRA Bonn
Dr Christoph	Federrath	Australian National University
Prof. Douglas	Finkbeiner	Harvard University
Dr Vincent	Fish	MIT Haystack Observatory
Prof. Yutaka	Fujita	Osaka University
Dr Pablo	García	IRAM
Mr Abhimat	Gautam	University of California
Dr Thomas	Geballe	Gemini Observatory
Prof. Oleg	Gnedin	University of Michigan
Dr Javier	Goicoechea	CSIC
Prof. Jordan	Goodman	University of Maryland
Dr Chris	Gordon	University of Canterbury
Prof. Anne	Green	Univeristy of Sydney
Miss Marion	Grould	Observatoire de Paris
Prof. Nidhal	Guessoum	American University of Sharjah
Prof. Fulai	Guo	Shanghai Astronomical Observatory
Prof. Daryl	Haggard	McGill University
Dr Jonathan	Henshaw	Liverpool John Moores University
Prof. Dan	Hooper	Fermilab/University of Chicago
Dr Pei-Ying	Hseih	Academia Sinica (ASIAA)
Dr Katharina	Immer	ESO
Mr Yuhei	Iwata	Keio University
Prof. Tesla	Jeltema	University of California, Santa Cruz
Mrs Lea	Jouvin	APC/Universite Paris Diderot
Mr Kensuke	Kakiuchi	Nagoya University
Dr Jens	Kauffmann	Max Planck Institut für Radioastronomie
Dr Sungsoo	Kim	Kyung Hee University
Mr Masato	Kobayashi	Nagoya University
Dr Baerbel	Koribalski	CSIRO ATNF
Mr Nico	Krieger	Max Planck Institute for Astronomy
Dr Diederik	Kruijssen	Heidelberg University
Prof. Mark	Krumholz	Australian National University
Dr Cornelia	Lang	University of Iowa
Mr Joowon	Lee	Kyung Hee University

Assoc. Prof. Yuri	Levin	Monash University
Mr Long-Biao	Li	Nanjing University
Mr Yaping	Li	Xiamen University
Dr Steven	Longmore	Liverpool John Moores University
Mr Xing	Lu	Nanjing University
Dr Jean-Pierre	Macquart	ICRAR/Curtin
Dr Sera	Markoff	University of Amsterdam
Dr Gregory	Martinez	UCLA
Dr Elisabeth	Mills	NRAO/University of Arizona
Dr Mark	Morris	UCLA
Dr Monika	Moscibrodzka	Radboud University
Mrs Lydia	Moser	University of Cologne
Ms Lena	Murchikova	Caltech
Prof. Simona	Murgia	University of California, Irvine
Dr David	Nataf	Australian National University
Dr Masayoshi	Nobukawa	Nara University of Education
Mr Francisco	Nogueras Lara	Instituto de Astrofísica de Andalucía
Dr Hirokazu	Odaka	Stanford University
Dr Tomoharu	Oka	Keio University
Miss Gisela	Ortiz-León	Universidad Nacional Autónoma de México
Dr Juergen	Ott	NRAO
Ms Fiona Helen	Panther	Australian National University
Mr Florian	Peissker	University of Cologne
Prof. Kerstin	Perez	MIT
Dr Thrushara	Pillai	Max Planck Institut für Radioastronomie
Ms Haihua	Qiao	Curtin University/SHAO
Mr Christoph	Rauch	Max Planck Institut für Radioastronomie
Prof. Soebur	Razzaque	University of Johannesburg
Dr Miguel Angel	Requena Torres	STScI
Mr Subhashis	Roy	NCRA-TIFR
Dr Christopher	Russell	NASA/GSFC
Mr Daisuke	Sakai	University of Tokyo
Dr Marc	Schartmann	Swinburne University of Technology
Dr Jihye	Shin	KIAS
Mr Thomas	Siegert	MPI for Extraterrestrial Physics
Dr Janet	Simpson	SETI Institute
Ms Breann	Sitarski	UCLA
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CONFERENCE PHOTOGRAPH

