Summary of the IAU Symposium 380 Cosmic Masers: Proper Motion toward the Next-Generation Large Projects

Date: 2023 March 20 - 24

Venue: Li-Ka Nangoku Hall, Kagoshima, Japan

Coordinating IAU Division: Division H "Interstellar Matter and Local Universe"

Supporting IAU Divisions: Division B "Facilities, Technologies and Data Science"
Division G "Stars and Stellar Physics"
Division J "Galaxies and Cosmology"

Scientific Organizing Committee (Female 8/Male 7):

Tomoya Hirota	National Astronomical Observatory of Japan, Japan (co-chair)
Karl Menten	Max-Planck-Institut fur Radioastronomie, Germany(co-chair)
Ylva Pihlström	University of New Mexico, United States (co-chair)
Anna Bartkiewicz	Nicolaus Copernicus University, Poland
Crystal Brogan	National Radio Astronomy Observatory, United States
James Chibueze	North-West University, South Africa
Claudia Cyganowski	University of St. Andrews, United Kingdom
Guido Garay	Universidad de Chile, Chile
Yoshiaki Hagiwara	Toyo University, Japan
Katharina Immer	Leiden University, Netherlands
Jihyun Kang	Korea Astronomy and Space Science Institute, Rep. of Korea
Silvia Leurini	INAF Osservatorio Astronomico di Cagliari, Italy
Mark Reid	Harvard-Smithsonian Center for Astrophysics, United States
María Rioja	The University of Western Australia, Australia
Bo Zhang	Shanghai Astronomical Observatory, China

Local Organizing Committee (Female 2/Male 8):

Hiroshi Imai	Kagoshima University, Japan (co-chair)
Akiharu Nakagawa	Kagoshima University, Japan (co-chair)
Ross Burns	National Astronomical Observatory of Japan/Riken, Japan
Toshihiro Handa	Kagoshima University, Japan
Mareki Honma	National Astronomical Observatory of Japan, Japan
Hiroyuki Nakanishi	Kagoshima University, Japan
Aya Imakado	Kagoshima University, Japan
Hiroko Shinnaga	Kagoshima University, Japan
Shigehisa Takakuwa	Kagoshima University, Japan
Yusuke Tsukamoto	Kagoshima University, Japan

Support staff (students) (Female 3/Male 11):

Kei Amada	Kagoshima University, Japan
Roldan Cala	Instituto de Astrofisica de Andalucia, Spain
Nao Ikeda	Kagoshima University, Japan
Rina Kasai	Kagoshima University, Japan
Kaito Kawakami	Kagoshima University, Japan
Jayender Kumar	University of Tasmania, Australia
Keisuke Nakashima	Kagoshima University, Japan
Tatiana M. Rodríguez	New Mexico Institute of Mining and Technology, United States
Yuichi Sakamoto	Kagoshima University, Japan
Yosuke Shibata	Kagoshima University, Japan

Ka Yiu Shum	Kagoshima University, Japan
Daisuke Takaishi	Kagoshima University, Japan
Koki Tanaka	Kagoshima University, Japan
Ryosuke Watanabe	Kagoshima University, Japan

(i) Final scientific programme

Mon 20, March 2023 [IAUS Science session, day 1]				
08:15-08:50	Registration			
	[Session 0] Opening: chair Hiroshi Imai			
08:50-09:00	other	Announcement from LOC	Hiroshi Imai	Kagoshima University
09:00-09:05	other	Welcome greeting from Kagoshima University	Masanori Baba	Kagoshima University
09:05-09:20	other	Opening of symposium	Tomoya Hirota	National Astronomical Observatory of Japan
	[Session 1] Theory of Masers and Maser Sources: chair Anna Bartkiewicz			
09:20-10:10	Review	Polarization, variability and coherence phenomena	Martin Houde	University of Western Ontario
10:10-10:35	Invite	Recombination lines and maser effects	Zulema Abraham	Universidade de Sao Paolo
10:35-11:05	Coffee Break (and poster viewing)			
11:05-11:30	Invite	Flaring Masers and Pumping	Malcolm Gray	National Astronomical Research Institute of Thailand (Public Organization)
11:30-11:45	Contributed	A comprehensive model of maser polarization	Boy Lankhaar	Chalmers University of Technology / Leiden Observatory
11:45-12:00	Contributed	Maser polarization simulation in an evolving star: effect of magnetic field on SiO maser in the circumstellar envelope	Montree Phetra	Chiang Mai University / National Astronomical Research Institute of Thailand (Public Organization)
12:00-12:30	Poster flash talks 1 (1-min flash talks up to 30 speakers)			
12:30-14:00	Lunch (and poster viewing)			
	[Session 2] Black Hole Masses and the M-sigma Relation (1): chair Tomoya Hirota			
14:00-14:50	Review	Supermassive blackhole mass growth in infrared-luminous gas-rich galaxy mergers and potential power of millimeter H_2O megamaser observations	Masatoshi Imanishi	National Astronomical Observatory of Japan
14:50-15:15	Invite	LADUMA: The first discovery of an OH megamaser at $z > 0.5$	Marcin Glowacki	Curtin University
15:15-15:30	Contributed	Could kilomasers pinpoint supermassive stars?	Katarzyna Nowak	University of Hertfordshire
15:30-15:45	Contributed (ONLINE)	OH megamasers in extremely obscured LIRGs – probing dense and collimated outflows?	Susanne Aalto	Chalmers University of Technology
15:45-16:15	Poster session 1			
16:15-16:45	Coffee Break (and poster viewing)			
	[Session 3] Black Hole Masses and the M-sigma Relation (2): chair Tomoya Hirota			
16:45-17:10	Invite	Masers in Low-Mass Galaxies	Ingyin Zaw	New York University Abu Dhabi

17:10-17:25	Contributed (ONLINE)	IC485: A candidate for a new maser disk galaxy	Elisabetta Ladu	Universita degli studi di Cagliari / INAF-Osservatorio Astronomico di Cagliari
17:25-17:40	Contributed (ONLINE)	What's behind the corner: Maser emission in nearby and distant galaxies with the new radio facilities	Andrea Tarchi	INAF - Osservatorio Astronomico di Cagliari
17:40-18:10	Poster flash talks 2 (1-min flash talks up to 30 speakers)			

Tue 21, March 2023 [IAUS Science session, day 2]				
	[Session 4] Pulsation and Outflows in Evolved Stars (1): chair Maria Rioja			
09:00-09:50	Review (ONLINE)	Mass Loss in Evolved Stars	Lynn Matthews	Massachusetts Institute of Technology Haystack Observatory
09:50-10:15	Invite	Masers in evolved stars; the BAaDE survey	Lorant Sjouwerman	National Radio Astronomy Observatory
10:15-10:30	Contributed	SiO maser line ratios in the BAaDE survey	Megan Olivia Lewis	Nicolaus Copernicus Astronomical Center, Polish Academy of Sciences
10:30-11:00	Poster session 2			
11:00-11:15	Coffee Break (and poster viewing)			
11:15-11:40	Invite	Properties of pulsating OH/IR stars revealed from astrometric VLBI observation	Akiharu Nakagawa	Kagoshima University
11:40-11:55	Contributed	Results of KVN Key Science Program for evolved stars	Youngjoo Yun	Korea Astronomy and Space Science Institute
11:55-12:10	Contributed	The Astrometric Animation of Water Masers toward the Mira Variable BX Cam	Shuangjing Xu	Korea Astronomy and Space Science Institute / Shanghai Astronomical Observatory
12:10-12:25	Contributed	Water fountain sources monitored in FLASHING	Hiroshi Imai	Kagoshima University
12:25-14:00	Lunch (and poster viewing)			
	[Session 5] Structure of the Milky Way (1): chair Crystal Brogan			
14:00-14:50	Review	Galactic Astrometry with VLBI	Kazi Rygl	INAF - Istituto di Radioastronomia
14:50-15:05	Contributed	The origin of the Perseus-arm gap revealed with VLBI astrometry	Nobuyuki Sakai	National Astronomical Research Institute of Thailand (Public Organization)
15:05-15:30	Invite (ONLINE)	Galactic Astrometry with Gaia	Carme Jordi	University of Barcelona
15:30-16:00	Coffee Break (and poster viewing)			
	[Session 6] Dynamics of Formation of Massive Stars (1): chair Crystal Brogan			
16:00-16:50	Review (ONLINE)	Evolutionary Trends in Star-formation	James Urquhart	University of Kent
16:50-17:05	Contributed (ONLINE)	Snapshot of a magnetohydrodynamic disk wind traced by water maser observations	Luca Moscadelli	INAF - Osservatorio Astrofisico di Arcetri
17:05-17:20	Contributed (ONLINE)	High resolution VLBI observations of 6.7GHz periodic methanol masers	Mateusz Olech	University of Warmia and Mazury

17:20-17:35	Contributed (ONLINE)	New maser species tracing accretion flows in a high-mass young stellar object G358.93-0.03	Andrey M. Sobolev	Ural Federal University
17:35-18:00	Invite (ONLINE)	Masers in accretion burst sources	Olga Bayandina	INAF - Osservatorio Astrofisico di Arcetri
18:00-18:10	Group photo			

Wed 22, March 2023 [IAUS Science session, day 3]				
	[Session 7] Structure of the Milky Way (2): chair Jihyun Kang			
09:00-09:25	Invite	Galactic Maser Astrometry with VERA	Mareki Honma	National Astronomical Observatory of Japan / University of Tokyo
09:25-09:40	Contributed (ONLINE)	Mapping the “Dark Side” of the Milky Way	Mark J. Reid	Center for Astrophysics | Harvard & Smithsonian
09:40-09:55	Contributed (ONLINE)	Kinematics in the Galactic Center with SiO masers	Jennie Paine	University of Colorado Boulder
09:55-10:10	Contributed (ONLINE)	Gaia measurements refined using radio observations from maser bearing stars	Luis Henry Quiroga-Nunez	Florida Institute of Technology
10:10-10:25	Contributed	The structure and dynamics of the Galactic bar and the mass distribution in the central region of the Milky Way	Jayender Kumar	University of Tasmania
10:25-10:55	Coffee Break (and poster viewing)			
10:55-11:10	Contributed	Trigonometric parallax, proper motion, structure, and dynamics of three southern hemisphere methanol masers	Lucas Jordan Hyland	University of Tasmania
	[Session 8] Dynamics of Formation of Massive Stars (2): chair Jihyun Kang			
11:10-11:35	Invite	Maser Tracers of Gas Dynamics near Young Stars - New Perspectives	Alberto Sanna	INAF - Osservatorio Astronomico di Cagliari
11:35-11:50	Contributed	Monitoring of the polarized H_2O maser emission around the massive protostars W75N(B)-VLA 1 and W75N(B)-VLA 2	Gabriele Surcis	INAF - Osservatorio Astronomico di Cagliari
11:50-12:05	Contributed	The water and methanol masers in the face-on accretion system around the high-mass protostar G353.273+0.641	Kazuhito Motogi	Yamaguchi University
12:05-12:20	Contributed	Maser Activity of Large Molecules toward Sgr B2 North	Ci Xue	Massachusetts Institute of Technology
12:20-14:00	Lunch			
14:00-18:45	Excursion			

Thu 23, March 2023 [IAUS Science session, day 4]				
	[Session 9] Cosmic Distance Scale and the Hubble Constant: chair Mareki Honma			
09:00-09:50	Review	Megamaser Cosmology	Dominic Pesce	Center for Astrophysics | Harvard & Smithsonian
09:50-10:15	Invite	The Megamaser Cosmology Project II : The Prospects for measuring a 1% H0 and distances to high-z galaxies	Cheng-Yu Kuo	National Sun Yat-Sen University / Institute of Astronomy and Astrophysics

10:15-10:30	Contributed	The megamaser disk of NGC1068	Violette Impellizzeri	Leiden University
10:30-10:45	Contributed	Distance of the Seyfert 2 galaxy IC 2560 and the Hubble constant	Naomasa Nakai	Kwansei Gakuin University
10:45-11:00	Contributed (ONLINE)	The Past, Present, and Groundbreaking Future of OH Megamaser Discoveries	Hayley Roberts	University of Colorado Boulder
11:00-11:30	Coffee Break (and poster viewing)			
11:30-11:55	Poster session 3			
	[Session 10] Dynamics of Formation of Massive Stars (3): chair Mareki Honma			
11:55-12:10	Contributed	Detection of the longest periodic variability in 6.7 GHz methanol masers with iMet	Yoshihiro Tanabe	Ibaraki University
12:10-12:25	Contributed	Simultaneous observations of exited OH and methanol maser - coincidence and magnetic field	Agnieszka Kobak	Nicolaus Copernicus University in Torun
12:25-14:00	Lunch (and poster viewing)			
	[Session 11] Pulsation and Outflows in Evolved Stars (2): chair James Chibueze			
14:00-14:25	Invite	Mm/submm Observations of Evolved Stars	Elizabeth Humphreys	European Southern Observatory / Joint ALMA Observatory
14:25-14:40	Contributed	High resolution ALMA imaging of H_2O, SiO, and SO_2 masers in the complex atmosphere of the AGB star W Hya	Keiichi Ohnaka	Universidad Andres Bello
14:40-14:55	Contributed	Evolution of the outflow traced by water masers in the evolved star IRAS 18043-2116	Lucero Uscanga	Universidad de Guanajuato
14:55-15:10	Contributed (ONLINE)	ALMA explores the inner wind of evolved O-rich stars with two widespread vibrationally excited transitions of water	Alain Baudry	University of Bordeaux, LAB
15:10-15:25	Contributed	Nascent planetary nebulae: new identifications and extraordinary evolution	Roldan A. Cala	Instituto de Astrofisica de Andalucia
15:25-15:40	Contributed (ONLINE)	Variability of water masers in evolved stars on the timescale of decades	Jan Brand	INAF-Istituto di Radioastronomia & Italian ALMA Regional Centre
15:40-15:55	Contributed	Signposts of transitional phases on the Asymptotic Giant Branch	Sandra Etoka	JBCA - Manchester University
15:55-16:25	Coffee Break (and poster viewing)			
	[Session 12] New Projects and Future Telescopes (1): chair James Chibueze			
16:25-17:15	Review	Ultra-precise astrometry: today and with the next-generation telescopes	Maria Rioja	The University of Western Australia / CSIRO Space & Astronomy / Observatorio Astronómico, IGN
17:15-17:40	Invite	Overview of the Maser Monitoring Organisation	Ross Burns	National Astronomical Observatory of Japan / Riken
17:40-17:55	Contributed	GASKAP-OH - A New Deep Survey of OH Masers in the Southern Sky	Joanne R. Dawson	Macquarie University / CSIRO Space & Astronomy

17:55-18:10	Contributed (ONLINE)	Introducing the MeerKAT Telescope: Studies of masers and their environment	Sharmila Goedhart	South African Radio Astronomy Observatory
18:10-19:00	Transfer to venue of conference dinner			
19:00-21:30	Conference dinner			

Fri 24, March 2023 [IAUS Science session, day 5]				
	[Session 13] New Projects and Future Telescopes (2): chair Hiroyuki Nakanishi			
09:00-09:25	Invite	Southern Hemisphere Maser Astrometry	Simon Ellingsen	University of Tasmania
09:25-09:50	Invite	The 40-m Thai National Radio Telescope with its key sciences and a future South-East Asian VLBI Network	Koichiro Sugiyama	National Astronomical Research Institute of Thailand (Public Organization)
09:50-10:15	Invite	Maser science with the African VLBI Network and MeerKAT	James Chibueze	North West University / University of Nigeria
10:15-10:40	Invite	The ALMA 2030 Wideband Sensitivity Upgrade	Crystal Brogan	National Radio Astronomy Observatory
10:40-11:10	Coffee Break (and poster viewing)			
11:10-11:35	Invite	SKA	Shari Breen	SKA Observatory
11:35-12:00	Invite	Maser Science with the ngVLA	Todd Hunter	National Radio Astronomy Observatory / Center for Astrophysics | Harvard & Smithsonian
12:00-12:15	Contributed	Exploring galactic and extragalactic masers with LLAMA	Tania Pereira Dominici	National Institute for Space Research
12:15-12:30	Contributed	Prospects for sub-mm maser astrometry with ngEHT	Richard Dodson	The University of Western Australia
12:30-14:15	Lunch			
	[Session 14] Closing: chair Tomoya Hirota			
14:15-15:00	other	Closing remarks	Anna Bartkiewicz	Nicolaus Copernicus University in Torun
15:00-15:15	other	Announcement from SOC	Tomoya Hirota	National Astronomical Observatory of Japan
		Announcement from LOC	Hiroshi Imai	Kagoshima University

40 min talk +10 min discussion for review (total 50 min), 20 min talk +5 min discussion for invited (total 25 min), and 12 min talk +3 min discussion for contributed (total 15 min)

List of posters (poster flash talks)

Poster flash talks 1 (1-min flash talks up to 30 speakers)			
ONLINE	The Dynamics of the Outflow Structure in W49 N	Kitiyanee Asanok	National Astronomical Research Institute of Thailand / Khon Kaen University
ONLINE	Interferometric Observations of the WF Candidates OH 16.3-3.0 and IRAS 19356+0754	Priscila Chacón	Universidad de Guanajuato
in person	A Holistic Search for Megamaser Disks and their Role in Feeding Supermassive Black Holes	Anca Constantin	James Madison University
in person	Study of Active Galactic Nuclei using water vapor masers	Deepshikha Deepshikha	Kwansei Gakuin Universiity
in person	Water masers associated with AGN in radio galaxies	Satoko Sawada-Satoh	Osaka Metropolitan University

in person	A search for spatial and temporal variations in the proton-to-electron mass ratio from H_2 spectra	Thong D. Le	Ton Duc Thang University
in person	Astrometric observations of water maser sources toward the Galactic Center with VLBI	Daisuke Sakai	National Astronomical Observatory of Japan
in person	Water Masers in the Galactic Center	Dylan Ward	New Mexico Institute of Mining and Technology
in person	An ALMA View of Molecular Filaments Associated with Shock-Excited OH Masers	Hidetoshi Sano	Gifu University
in person	Astrometry of Water Maser sources in the Outer Galaxy with VERA	Hiroyuki Nakanishi	Kagoshima University
in person	Estimating distances to AGB stars using IR data	Rajorshi Bhattacharya	University of New Mexico
in person	Searching masers from the Sgr Stellar Stream	Yuanwei Wu	National Time Service Center of Chinese Academy of Sciences
in person	Water maser flare and potential accretion burst in NGC 2071-IR	Andrews M. K. Dzodzomenyo	North-West University
in person	Methanol and excited OH masers in HMYSOs observed using EVN	Anna Bartkiewicz	Nicolaus Copernicus University in Torun
in person	New insides of 6.7 GHz methanol maser variability in IRAS 20126+4104	Artis Aberfelds	Ventspils University of Applied Sciences
in person	The first and last VLBI maps of rare 7 GHz methanol masers	Gabor Orosz	Joint Institute for VLBI ERIC
in person	Possibly New OH Excited Rotatonal State Masers	Ivars Smelds	Ventspils University of Applied Sciences
in person	Spatio-kinematics of water masers in the HMSFR NGC6334I before and during an accretion burst	Jakobus M. Vorster	University of Helsinki / North-West University
in person	Jet and Outflows of a High Mass Star Forming Region: G10.34-0.14	Jihyun Kang	Korea Astronomy and Space Science Institute
in person	Multiple scales of view for outflow driven by a high-mass young stellar object, G25.82—W1	Jungha Kim	Korea Astronomy and Space Science Institute
in person	Intensity monitor of water maser emission associated with massive YSOs	Kazuyoshi Sunada	National Astronomical Observatory of Japan
in person	Simultaneous Single-dish Survey of Water and Methanol Masers toward High-mass YSOs in Various Evolutionary Stages	Kee-Tae Kim	Korea Astronomy and Space Science Institute
in person	Yamaguchi interferometer survey of protostellar outflows embedded in 70 – μm dark infrared dark cloud	Keita Kitaguchi	Yamaguchi University
in person	Ultra-precise monitoring of a class I methanol maser	Maxim Voronkov	CSIRO Space & Astronomy
in person	Interferometric study of the class I methanol masers at 104.3 GHz	Maxim Voronkov	CSIRO Space & Astronomy
in person	Fast variability and circular polarization of the bursting methanol maser component in G33.641-0.228	Kenta Fujisawa	Yamaguchi University
in person	The environments of hyper-compact H II regions.I. G345.0061+01.794 B	Toktarkhan Komesh	Nazarbayev University / Al-Farabi Kazakh National University
Poster flash talks 2 (1-min flash talks up to 30 speakers)			
ONLINE	Water maser emission in hard-Xray selected, highly obscured, AGN	Paola Castangia	INAF - Osservatorio Astronomico di Cagliari
ONLINE	Supermassive stars as sites of H_2O kilomasers	Martin G. H. Krause	University of Hertfordshire

ONLINE	SMA Millimeter Continuum Imaging of 6.7 GHz CH_3OH Maser Regions: Baseline epoch for future accretion outbursts	Claudia J. Cyganowski	University of St Andrews
ONLINE	Water masers as an early tracer of star formation	Dmitry A. Ladeyschikov	Ural Federal University
ONLINE	VLA and ALMA Observations of the Extended Green Object G19.01-0.03: A partially inclined 6.7GHz Class II CH_3OH maser ring and outflow-tracing NH3(3,3) and 25GHz and 278GHz Class I CH_3OH masers	Gwenllian Williams	University of Leeds
ONLINE	Multi-scale observational study of G45.804-0.355 star forming region	Mavis Seidu	North West University
ONLINE	ATLASGAL: Methanol masers at 3 mm	Wenjin Yang	Max-Planck-Institut fur Radioastronomie
ONLINE	Water masers and host environments of FU Orionis and EX Lupi type low-mass eruptive young stellar objects	Zsofia M. Szabo	Max-Planck-Institut fur Radioastronomie / University of St Andrews / Konkoly Observatory
ONLINE	A database of circumstellar OH masers update	Dieter Engels	Universitat Hamburg
ONLINE	A Profile-based Approach to Finding New Water Fountain Candidates using Databases of Circumstellar Maser Sources	Jun-ichi Nakashima	Sun Yat-sen University
in person	ALMAGAL Survey: Analysis of 59 Protostellar Clumps hosting Class II Methanol Masers	Georgina Stroud	University of Manchester
in person	Catching unusual phenomena with extensive maser monitoring	Michał T. Durjasz	Nicolaus Copernicus University in Torun
in person	A Multiwavelength study towards Galactic H II region G10.32-0.26	Mikyoung Kim	Otsuma Women's University
in person	Fine structure and refractive scattering of the H2O maser in W49N star-forming region	Nadezhda N. Shakhvorostova	P.N. Lebedev Institute of RAS
in person	Torun's methanol maser monitoring program	Paweł I. Wolak	Nicolaus Copernicus University in Torun
in person	Water maser Zeeman splitting in the ionized jet IRAS 19035+0641 A	Tatiana M. Rodriguez	New Mexico Institute of Mining and Technology
in person	High-cadence 6.7 GHz methanol maser monitoring observations by Hitachi 32-m radio telescope	Yoshinori Yonekura	Ibaraki University
in person	High mass star forming region (HMSFR) G024.33: Possibly another discovery in the making	Stefanus van den Heever	South African Radio Astronomy Observatory
in person	Water masers -- high resolution measurements of the diverse conditions in evolved star winds	Anita M. S. Richards	JBCA, University of Manchester UK
in person	Investigating the inner circumstellar envelopes of oxygen-rich evolved stars with ALMA observations of high-J SiO masers	Bannawit Pimpanuwat	JBCA, University of Manchester UK
in person	Fully 3D modelling of masers towards AGB stars – latest development and early results	Bannawit Pimpanuwat	JBCA, University of Manchester UK
in person	Preliminary results on SiO v=1 J=1-0 maser emission from AGB stars	Jean-Francois Desmurs	Observatorio Astronómico Nacional
in person	A sensitive search for SiO maser emission in planetary nebulae	Jose F. Gomez	Instituto de Astrofisica de Andalucia
in person	Discovery of SiO masers in the “Water Fountain’’ source, IRAS 16552-3050	Kei Amada	Kagoshima University

in person	HINOTORI and Maser observations	Keisuke Nakashima	Kagoshima University
in person	Annual parallax measurement of extreme OH/IR candidate star OH39.7+1.5	Ryosuke Watanabe	Kagoshima University
in person	OH maser variations during the transition from AGB to postAGB evolution	Sandra Etoka	JBCA, University of Manchester UK
in person	VLBI studies of cosmic masers with current and future VLBI arrays	Dong-Jin Kim	Massachusetts Institute of Technology Haystack Observatory

Number of speakers invited talks: Female 11/Male 16
Number of speakers contributed talks: Female 14/Male 23
Number of session chairs: Female 4/Male 5

(ii) Summary of the scientific highlights of the meeting

During the IAUS 380, we discussed 7 major science topics on cosmic masers.

1) Cosmic Distance Scale and the Hubble Constant
2) Black Hole Masses and the M-sigma Relation
3) Structure of the Milky Way
4) Dynamics of Formation of Massive Stars
5) Pulsation and Outflows in Evolved Stars
6) Theory of Masers and Maser Sources
7) New Projects and Future Telescopes

In the following, we summarize scientific highlights discussed at the IAU Symposium 380.

Firstly, although temporal variability in an inherent property of most cosmic masers, *large scale* systematic time monitoring campaigns have only been started within the last decade. Many oral and poster presentations reported results/plans of long-term monitoring programs of maser sources using single-dish telescopes of various institutes distributed in all over the world. Interesting events found in such efforts have been followed up with interferometry. It should be emphasized that small- and medium-size projects are underway and new projects have been initiated in developing countries in the field of astronomy in Asia, Africa, and South America, as presented in the last session for the New Projects and Future Telescopes in the IAUS 380. Intensive monitoring observations have revealed maser variabilities at wide ranges of time scales from hour to decades. New episodic mass accretion events in high-mass star-forming regions have been identified through monitoring programs of methanol maser flares after the last IAUS 336 in 2017 by the "Maser Monitoring Organization (M2O)" team established during the IAUS 336. Also, long-period variable stars and high-mass young stellar objects with >1000-day periodicities are newly reported in water and methanol masers, respectively. Time-domain campaigns on the maser variability are being continued to investigate longer period sources with dedicated monitoring telescopes. Frequent monitoring and survey for short-timescale and sudden episodic events will also be conducted using future facilities. To understand the background physics of maser variability, it is proposed that frequent monitoring for multiple maser transitions/species provide crucial input for theoretical studies.

Secondly, we are really seeing the massive impact of high resolution and sensitivity radio observations with ALMA and the JVLA in all fields of maser science from Galactic star-forming regions and evolved stars to starburst galaxies and active galactic nuclei, as we expected in the original proposal to the IAU Symposium. Detailed views on high-mass young stellar objects, evolved stars, and the central molecular zones of galaxies, including that of the Milky Way galaxy can be traced by *thermal* molecular and dust emission with ALMA and free-free and synchrotron emission with the JVLA at comparable resolutions with VLBI imaging of masers. New submillimeter maser images from ALMA are also presented which are opening a new window to investigate higher temperature/density regions. It should be noted that some new/unexpected centimeter maser lines are also reported, and hence, future follow-up observations with ALMA and/or the JVLA at high resolution will constrain their pumping mechanisms combined with theoretical modelling.

Thirdly, some parallaxes from Gaia DR2, especially for Mira variables, had shown very large discrepancies when compared to VLBI parallaxes. However, updated results from Gaia DR3 now are in much better agreement with the VLBI measurements. While Gaia will produce extremely large numbers of parallaxes, being an optical system it cannot freely probe the Milky Way, owing to strong dust extinction in the plane. In the meeting we heard updates on two large VLBI parallax surveys: the Bar and Spiral Structure Legacy (BeSSeL) Survey and the VLBI Exploration of Radio Astrometry (VERA) project. These target massive young stars with maser emission, which are excellent tracers of spiral structure. Results from these projects presented at the meeting showed there are now over VLBI 250 parallaxes, some with accuracies of +/-6 micro-arcseconds, which have revealed many interesting features of our Galaxy's structure. For example, the "expanding 3-kpc arm" now looks to be composed of orbits around the Galactic long bar; thus it is neither expanding, at 3-kpc, or a spiral arm. Planned VLBI observations should provide a complete picture of the spiral structure of the Milky Way in the future using new facilities such as South-East Asian VLBI, African VLBI, SKA, and ngVLA.

Finally, as summarized above, the panchromatic information that is currently available is enabling a much deeper view of the physical conditions and overall environments in which masers exist. Now the maser images taken with the highest resolution VLBI observations at milli-arcsecond resolutions are directly compared with multi-wavelength datasets in most of the presentations for individual studies in the IAUS 380. Such multi-wavelength observations are under development within next-generation projects that are directly and indirectly related to maser observations, as introduced in the last session of the IAUS 380.

(v) An Executive Summary of the Meeting

We have organized the IAUS 380 on cosmic masers to take place from March 20 (Mon) 2023 to March 24 (Fri) 2023 at Kagoshima, Japan. All sessions were held in Li-Ka Nangoku hall, which was just opened in 2021and is located in front of the Kagoshima Central train station. Given the unexpected situation due to the COVID-19 pandemic at the time of registration in late 2022, we also accepted the online participants via the Zoom virtual meeting software. Thus, the meeting was held in the hybrid mode.

Cosmic masers have been employed as unique probes of various astronomical objects such as young stellar objects, evolved stars, the interstellar medium, the structure of the Milky Way galaxy, and active galactic nuclei. Thanks to their high brightness and narrow spectral features, maser observations using large radio interferometers and, in particular, Very Long Baseline Interferometry (VLBI) have provided high spatial and spectral resolution images, three dimensional velocity fields including proper motions, and annual parallaxes, and hence have constrained basic physical properties of their host regions. In terms of research topics, the maser scientific community is diverse and multidisciplinary but has long been tied together through the common background physics and observational techniques. An important method for the community to connect and build new international collaborations is through regular meetings. Over the past decades, there have been international meetings on cosmic masers spaced by 5-9 years; 1992 in the USA, 2001 in Brazil (IAUS 206), 2007 in Australia (IAUS 242), 2012 in South Africa (IAUS 287), and 2017 in Italy (IAUS 336). Since the last IAUS 336 on cosmic masers in 2017, the Atacama Large Millimeter/submillimeter Array (ALMA) has achieved comparable resolution to those of previous longer wavelength interferometers. Gaia DR3 also has provided a huge Galactic astrometric database at comparable accuracy with the currently available VLBI maser astrometry. Future large projects such as the Square Kilometre Array (SKA) and the next generation Very Large Array (ngVLA) feature key science projects targeting masers. Pilot surveys are in progress with the SKA precursors such as MeerKAT and ASKAP in South Africa and Australia, respectively. Future collaboration in the global VLBI have been already initiated including projects covering the southern hemisphere. Considering this recent progress in maser research, we decided to organize the IAUS 380 on masers in 2023 in Asia, following the past large conferences on maser, finally fill in the gap in global coverage,

At the meeting place, Kagoshima City located in the south-western region of Japan, an active and large astronomy community exists at Kagoshima University, which is involved in many aspects of maser research. In particular, Kagoshima Prefecture hosts one of the 20-m radio telescopes of VLBI Exploration of Radio Astrometry (VERA) operated by Kagoshima University with advanced support by the Mizusawa VLBI Observatory of National Astronomical Observatory of Japan (NAOJ). This provides great opportunities for collaborative research on maser sources and technical training for the telescope operation led by a young generation of scientists. The IAUS 380 on masers highly motivated those researchers in Japan. In fact, a total of 11 young researchers and graduate students at Kagoshima University and 3 students from foreign institutes supported the IAUS 380 as volunteer staff with vibrant energy.

The total number of registered participants of IAUS 380 was 172, of which 102 participated in-person and 70 online, working in 28 countries (counted by the first affiliation of institutes/university for each participant). As for the regions, 41 participants were from Japan (35 in-person and 6 online), 30 from Asia except Japan (14 in-person and 16 online), 9 from Oceania (8 in-person and 1 online), 58 from Europe (24 in-person and 34 online), 5 from Africa (3 in-person and 2 online), 25 from North America (14 in-person and 11 online), and 4 from South America (4 in-person). Except for Japan, about half of the participants were online. The numbers of female and male participants were 52 and 119, respectively (1 has no information). Judging from the titles of participants, senior (Dr. and Prof.) and junior (Mr. and Ms.) were split by 129 and 43, respectively. A high percentage of the participants were possibly young graduate students.

The science sessions were opened on March 20 (Mon) 2023 by the Welcome Greeting from Masanori Baba, the vice president of Kagoshima University. In the science sessions, we discussed 7 major topics on maser sciences in 13 sessions as summarized in the "Summary of the scientific highlights of the meeting" section in this report. In order to allow online speakers to join the meeting during their convenient time zones, we divided each science topic into 2 or more sessions at different time ranges (i.e. mainly morning for North/South America and afternoon for Europe and Africa). All sessions were recorded via Zoom and shared with the registered participants.

As clearly expressed in the sub-title of this IAUS 380, "Proper Motion toward the Next-Generation Large Projects", we had intensive discussion sessions for currently on-going and future projects related to most of the topics. While the main focus of this IAUS 380 was on cosmic masers, we intended to invite speakers from outside of the maser communities to broaden the impact of this symposium, thus emphasizing synergies with other research fields. For each of the 7 topics, we invited 1 reviewer to give an overview of the current status and future prospects for the research field, and 1-4 invited speakers to cover representative work in each field. In the session for future projects, we invited 7 speakers to discuss the

impact of a given project on maser research. Considering the number of submitted abstracts and the oversubscription rate, we decided to include as many contributed talks as possible to give opportunities to young researchers, rather than having long general discussion sessions. For poster presentations, we organized two poster flash talk sessions, in which each poster was introduced in one minute. Although the poster flash sessions were challenging, these helped the participants to review all the presentations at once in shortly before poster viewing.

In summary, we had 8 review talks (6 in-person and 2 online), 19 invited talks (17 in-person and 2 online), 37 contributed talks (24 in-person and 13 online), and 55 poster presentations (43 in-person and 12 online).

As expected, IAUS 380 provided valuable opportunities to start discussion on future collaboration as in the previous IAUS 336 in Italy, where the new international collaboration network "Maser Monitoring Organization (M2O)" was established. For this purpose, we helped arranging satellite meetings during every lunch periods, such as the East Asian VLBI Science Working Groups (astrometry and star-formation), GASKAP-OH team, and the Spectral line EHT collaboration.

The conference hall was fully equipped with modern audio-visual facilities and Wi-Fi to enable the hybrid Zoom option. The LOC and volunteer staff also prepared Slack to allow discussions and communication between online and in-person participants. Slack was also used to share the Zoom recording files. There was no serious problem in this hybrid mode during the meeting and the sessions were smoothly organized thanks to the support staff in the Li-Ka Nangoku hall and the student volunteers. A large foyer in front of the hall was used for coffee/tea breaks and the poster exhibition. We secured ample time for coffee/tea breaks in every morning and afternoon to stimulate off-line discussion, which is one of the biggest advantages of in-person meetings. During these breaks, the local staff served coffee, Japanese green tea, and different kind of local cakes and cookies every time with the local pottery dishes.

The LOC and volunteer staff well organized associated social events for participants and their accompanying persons. Prior to the science session, a welcome reception was held in the evening of March 19 (Sun) 2023 in the foyer of the Li-Ka Nangoku hall. Welcome drinks and snacks were offered during the registration. In the afternoon on March 22 (Wed) 2023, an excursion was held to visit a local vinegar factory and the active volcano Sakura-jima to encounter local culture and to promote friendship with each other. On March 23 (Thu) 2023, a conference banquet was held in The Peak Premium Terrace close to the central downtown area in which the participants enjoyed local foods and alcohol as well as traditional music and dancing.

After all main science sessions were closed, we organized outreach and educational programs to enhance the legacy of the IAUS 380 in Kagoshima. The public outreach talk event was held on March 25 (Sat) 2023 in Kimi & Kesa Memorial Hall of Inamori Auditorium in Kagoshima University. The Opening Greetings of this event was given by Keiichi Wada, the director of the Amanogawa Galaxy Astronomy Research Center (AGARC), followed by three talks on maser results for 35 minutes each in the Japanese language by Tomoya Hirota (NAOJ), Mikyoung Kim (Otsuma Women's University), and Ross A. Burns (Riken/NAOJ). After these talks, panel discussion and Q&A sessions were organized by Hiroshi Imai (Kagoshima University). The total number of participants was about 20.

In the week following IAUS 380, another educational program was held. First, a guide tour to the VERA Iriki station took place on March 29 (Wed) 2023. About 25 participants (elementary school students or older) visited the 20-m VLBI radio telescope of VERA located at Iriki-cho in Satsuma-Sendai-shi by 1-hour chartered bus trip from either Kagoshima Central train station or Sendai train station. The staff members and students from NAOJ and Kagoshima University introduced the 20-m antenna and instruments of the VLBI station, and also took the participants to the upper cabin of the 20-m antenna. Following the tour, a hands-on tutorial of radio astronomy observations was offered at Kagoshima University on March 30 (Thu) and 31 (Fri) 2023. In the hands-on tutorial, a 50-cm size horn antenna was made by the participants under the instruction of local staff and students at Kagoshima University, and radio emission from the Galactic plane was observed using a spectrum analyzer. The participants experienced the real radio astronomical observations, successfully detecting the signal from the 21-cm atomic hydrogen line emitted from the Galactic plane.

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