

IAU Symposium

377

6–10 February 2023
Kuala-Lumpur, Malaysia

Proceedings of the International Astronomical Union

Early Disk-Galaxy Formation from JWST to the Milky Way

Edited by

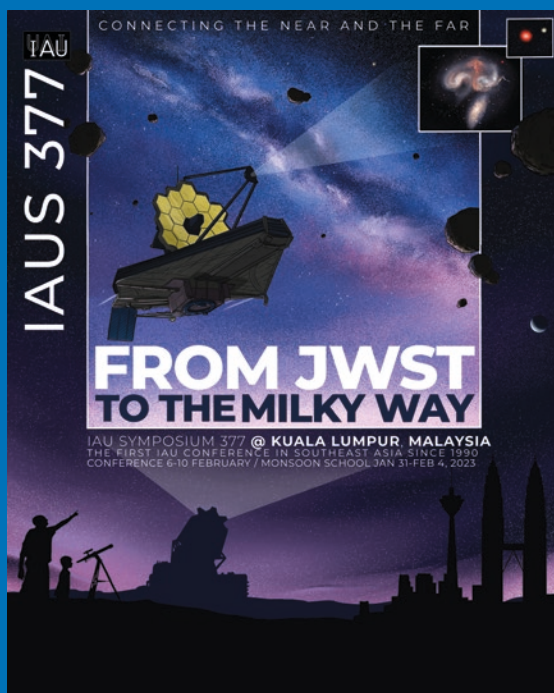
Fatemeh Tabatabaei
Beatriz Barbuy
Yuan-Sen Ting

ISSN 1743-9213

International Astronomical Union



CAMBRIDGE
UNIVERSITY PRESS



EARLY DISK-GALAXY FORMATION FROM
JWST TO THE MILKY WAY

IAU SYMPOSIUM 377

COVER ILLUSTRATION:

From James Webb Space Telescope to The Milky Way, the IAU symposium held in Kuala Lumpur Malaysia, 6–10 February 2023, Graphical design by sotiris gritzalis

IAU SYMPOSIUM PROCEEDINGS SERIES

Chief Editor

JOSÉ MIGUEL RODRIGUEZ ESPINOSA, General Secretariat

Instituto de Astrofísica de Andalucía

Glorieta de la Astronomía s/n

18008 Granada

Spain

IAU-general.secretary@iap.fr

Editor

DIANA WORRALL, Assistant General Secretary

HH Wills Physics Laboratory

University of Bristol

Tyndall Avenue

Bristol

BS8 1TL

UK

IAU-assistant.general.secretary@iap.fr

INTERNATIONAL ASTRONOMICAL UNION
UNION ASTRONOMIQUE INTERNATIONALE

International Astronomical Union



EARLY DISK-GALAXY FORMATION FROM JWST TO THE MILKY WAY

PROCEEDINGS OF THE 377th SYMPOSIUM OF
THE INTERNATIONAL ASTRONOMICAL UNION
KUALA-LUMPUR, MALAYSIA
6–10 FEBRUARY 2023

Edited by

FATEMEH TABATABAEI

Institute for Research in Fundamental Sciences, Iran

BEATRIZ BARBUY

Universidade de São Paulo, Brazil

and

YUAN-SEN TING

Australian National University, Australia



CAMBRIDGE
UNIVERSITY PRESS

CAMBRIDGE UNIVERSITY PRESS

University Printing House, Cambridge CB2 8BS, United Kingdom
1 Liberty Plaza, Floor 20, New York, NY 10006, USA
10 Stamford Road, Oakleigh, Melbourne 3166, Australia

© International Astronomical Union 2024

This book is in copyright. Subject to statutory exception
and to the provisions of relevant collective licensing agreements,
no reproduction of any part may take place without
the written permission of the International Astronomical Union.

First published 2024

Printed in Great Britain by Henry Ling Limited, The Dorset Press, Dorchester, DT1 1HD

Typeset in System L^AT_EX 2 ϵ

*A catalogue record for this book is available from the British Library of Congress
Cataloguing in Publication data*

This journal issue has been printed on FSCTM-certified paper and cover board. FSC is an independent, non-governmental, not-for-profit organization established to promote the responsible management of the world's forests. Please see www.fsc.org for information.

ISBN 9781009398756 hardback
ISSN 1743-9213

Table of Contents

Preface vii

Editors ix

List of Participants x

Chapter I: Galaxies and Cosmic Dawn

Revelation of Massive Quiescent Galaxies at $z > 3$ from Deep JWST Spectroscopy 3

Karl Glazebrook, Themiya Nanayakkara, Danilo Marchesini, Glenn Kacprzak and Colin Jacobs

JWST observations of ALMA [O III] 88 μ m emitters in the epoch of reionization 9

Takuya Hashimoto

Massive-Star Feedback at Low Metallicity 14

M. S. Oey, M. C. Jecmen, A. N. Sawant, A. E. Jaskot, A. Danehkar, L. J. Smith and J. Melinder

JWST unveils a population of “red-excess” galaxies in Abell2744 and in the coeval field 22

Benedetta Vulcani and GLASS team

GECKOS: Turning galaxy evolution on its side with deep observations of edge-on galaxies 27

J. van de Sande, A. Fraser-McKelvie, D. B. Fisher, M. Martig, M. R. Hayden and the GECKOS Survey collaboration

Stellar Mergers in Dense Stellar Systems and growth of supermassive black holes 34

Long Wang

Formation of the First Massive Galaxies in Cosmological Simulations and Their Observational Properties 39

Hidenobu Yajima

Role of ISM/IGM Energy Balance in Structure Formation and Evolution of Galaxies 43

F. Tabatabaei, M. Ghasemi-Nodehi, M. Sargent, E. J. Murphy, E. Schinnerer, A. Bonaldi and the SKA ISM/IGM Focus Group

Bar pattern speed at $z \sim 1 - 2$ to explore challenges of the Standard Cosmology 48

Virginia Cuomo, Mahmood Roshan, J. Alfonso L. Aguerri and Lorenzo Morelli

Chapter II: Milky Way and M31

New Dimensions of Galactic Chemical Evolution	55
<i>David H. Weinberg</i>	
What the JWST can tell us about the Origin of Multiple Stellar Populations in Globular Clusters	65
<i>Anna F. Marino</i>	
Multiple Stellar Populations in Globular Clusters with JWST	75
<i>A. P. Milone</i>	
Metal production in the early Universe: what chemical abundances in old stellar populations in the Milky Way tell us	79
<i>Miho N. Ishigaki</i>	
Using Metal-Poor Stars in the Inner Galaxy to Uncover the Ancient Milky Way	89
<i>Madeline Lucey</i>	
Chemically characterising the Milky Way's stellar halo	93
<i>Danny Horta, Ricardo P. Schiavon and APOGEE team</i>	
The Curious Stellar System M22	98
<i>Madeleine McKenzie</i>	
The Pristine Inner Galaxy Survey (PIGS) V: a chemo-dynamical investigation of the early assembly of the Milky Way with the most metal-poor stars in the bulge	102
<i>Federico Sestito, Kim A. Venn, Anke Arentsen and David Aguado</i>	
The Galactic Extinction Horizon with Present and Future Surveys	107
<i>Dante Minniti</i>	
The Prevalence of the α -bimodality: First JWST α -abundance Results in M31	115
<i>David L. Nidever, Karoline Gilbert, Erik Tollerud, Charles Siders, Ivanna Escala, Carlos Allende Prieto, Verne Smith, Katia Cunha, Victor P. Debattista, Yuan-Sen Ting and Evan N. Kirby</i>	
The Andromeda Galaxy's Last Major Merger: Constraints from the survey of Planetary Nebulae	123
<i>Souradeep Bhattacharya, Magda Arnaboldi, Ortwin Gerhard, Nelson Caldwell, Chiaki Kobayashi, Francois Hammer, Yanbin Yang, Kenneth C. Freeman, Johanna Hartke and Alan McConnachie</i>	

Chapter III: Astronomy in Malaysia

Connection Between the Comet 1P/Halley Appearance in 760 AD and the Dinoyo Inscription (Preliminary Result)	129
<i>Ide Nada Imandiharja and Mochamad Ikbal Arifyanto</i>	
Author Index	133

Preface

In recent years, the field of galaxy evolution has witnessed remarkable advancements that have revolutionised our comprehension of both nearby and distant galaxies. Spectroscopic surveys and Gaia have endowed us with unprecedented knowledge of the Milky Way. At the same time, the launch of the James Webb Space Telescope has opened new pathways for studying high-redshift galaxies. Integral field unit studies and ALMA have extended our insights into kinematics, chemistry, and star formation processes in galaxies. The study of galaxy evolution, especially in its early stages, has ushered in an exciting new era.

These advancements have led to many intriguing enigmas. Early discoveries from the James Webb Space Telescope have revealed high-redshift galaxies that defy our expectations. To comprehensively resolve these conundrums, a thorough understanding of galaxy evolution, both near and far, is essential. Historically, studies on galaxy evolution have been fragmented into various sub-communities, with few conferences bringing together these experts. This prompted the organisation of the IAU Symposium, which united specialists from diverse domains and fostered lively and insightful discourse.

The conference covered a diverse array of topics, emphasising the importance of multi-wavelength observations, simulations, and theoretical models in advancing our understanding of galaxy formation, evolution, and interaction. Key themes included the early stages of galaxy formation, focusing on gas accretion in driving the formation of disk galaxies and their interactions with the large-scale structure. Throughout the high-resolution simulations, and advanced statistical techniques.

The properties and evolution of galaxy disks were another central focus, with discussions on the role of gas flows in regulating star formation, the formation of metallicity gradients, and the impact of stellar feedback on disk structure and stability. The conference also explored the role of mergers and interactions in galaxy evolution, including the impact of major and minor mergers on the growth of galaxies and the complex interplay between gas, stars, and dark matter in these processes. The influence of tidal interactions and environmental effects, as well as AGN feedback effects on galaxy evolution, was also discussed.

The role of massive stars in galaxy evolution was a critical theme, with multiple presenters discussing their impact on the chemical evolution of galaxies and their role in driving feedback processes that regulate star formation and overall structure. The importance of studying nearby galaxies to understand the role of massive stars at early cosmic epochs was also emphasised. The Milky Way and its satellite galaxies were significant topics, with discussions on merger history, the role of satellite galaxies in shaping its structure, and the importance of studying resolved stellar populations. The potential of JWST in investigating globular clusters and their multiple stellar populations and ages was highlighted.

The conference delved into the Andromeda Galaxy and its merger history, discussing the recent major merger of Andromeda and its impact on the formation of the galaxy's inner halo and disk. The role of the Giant Stellar Stream in forming Andromeda's disk was also discussed. Galactic outflows and the circumgalactic medium (CGM) were another key focus, covering the role of massive-star feedback in driving outflows at low metallicity and the connection between episodic star formation and the large-scale angular-momentum environment through the CGM. The potential insights the James Webb Space Telescope can provide into these processes were also highlighted.

But besides the scientific highlights, this IAU Symposium held special significance as it introduced science to Malaysia, which had never before hosted an IAU event or an international astronomy conference of this magnitude. In fact, this symposium was

the first in Southeast Asia since 1990. Growing up in Malaysia, I have observed a deep fascination with space science among the people. While there is no shortage of interest and talent in the region, opportunities have been limited. However, the situation is gradually improving. Neighbouring countries like Thailand and Indonesia have made significant investments in astronomy. Malaysia, too, has seen various efforts that have transformed the landscape, with leading tertiary education institutions such as Universiti Malaysia now hosting dozens of astronomers and participating in cutting-edge research.

Hosting an IAU Symposium in Malaysia could not have been more timely. Three weeks before the event, Malaysia held its first all-Malaysian astronomer conference, uniting Malaysian astronomers worldwide to inspire a new generation and influence Malaysia's education policy. As a companion event to the IAU Symposium, a "monsoon school" taught the basics of astronomy and programming to help local students benefit from the conference. The school generated immense interest in the region, and many students told us that the monsoon school further inspired them to pursue a career in astronomy.

The IAU Symposium was truly a remarkable event, bringing together experts from various sub-communities of galaxy evolution. Despite challenges posed by, then, the ongoing pandemic and travel restrictions, the conference successfully brought leading experts together to discuss pressing issues in galaxy evolution. The event attracted 180 participants, with more than 140 attending in person and the rest participating in a hybrid format. Hosting the conference was no small feat. Most Local Organizing Committee members consisted of local PhD students from Universiti Malaya and staff from the National Planetarium, who never had before organised such a large-scale event. Their dedication and professionalism, along with the invaluable contributions of international experts who made up the Scientific Organizing Committee, made the conference possible.

On a personal note, despite having lived in Malaysia for most of my life, the enthusiasm for astronomy in the region continues to surpass my expectations. Some amateur astronomers, aged in their mid-40s to mid-50s, have shared that they have waited their whole lives to see an event like this. It is disheartening to hear that some PhD students in the region find it extremely challenging to attend international conferences due to unfavourable currency exchange rates. This conference allowed them to connect with prominent astronomers and learn firsthand.

It may be challenging for some to comprehend the significance of such events, as those fortunate enough to study astronomy in well-developed countries can travel anywhere to collaborate with colleagues and advance their careers. However, such privileges are not universally available. We hope that this event, even in a small way, will bring some light to regions largely overlooked by the astronomy community.

The enthusiasm, passion, and collaborative spirit displayed during the IAU Symposium are a testament to the potential for growth in astronomy, especially in the Southeast Asian region. This conference has not only brought attention to the significant advancements in galaxy evolution research but has also fostered an environment for budding astronomers to develop their skills and engage with experts from around the world. We look forward to more events like this, which will further bridge the gap between established and emerging astronomy communities, promoting a bright future for the field as a whole.

Yuan-Sen Ting
Australian National University

Steering Committee Chair
IAU Symposium 377

Editors

Fatemeh Tabatabaei
Institute for Research in Fundamental Sciences, Iran

Beatriz Barbuy
Universidade de São Paulo, Brazil

Yuan-Sen Ting
Australian National University, Australia

Organizing Committee

Scientific Organizing Committee

Yuan-Sen Ting (Co-Chair), Australian National University, Australia
David Nataf (Co-Chair), Johns Hopkins University, USA
Akio Inoue, Waseda University, Japan
Alvio Renzini, Osservatorio Astronomico di Padova, Italy
Amina Helmi, University of Groningen, The Netherlands
Chiaki Kobayashi, University of Hertfordshire, UK
Chin-Fei Lee, Academia Sinica Institute of Astronomy and Astrophysics, Taiwan
Dan Weisz, University of California Berkeley, USA
Dante Minniti, Universidad Andres Bello, Chile
Gail Zasowski, University of Utah, USA
Khee-Gan Lee, Kavli IPMU, Japan
Premana Wardayanti Premadi, Bandung Institute of Technology, Indonesia
Roberto Maiolino, University of Cambridge, UK
Rosemary Wyse, Johns Hopkins University, USA
Shigeki Inoue, National Astronomical Observatory of Japan- University of Tsukuba, Japan
Susan Kassin, Space Telescope Science Institute, USA
Xiang-Xiang Xue, National Astronomical Observatories, Chinese Academy of Sciences, China

Local Organizing Committee

Yuan-Sen Ting (Co-Chair), Australian National University, Australia
Fairos Asillam (Co-Chair), Ministry of Science, Technology and Innovation of Malaysia, Malaysia
Abdul Kadir Md Jwel, Universiti Malaya, Malaysia
Affan Adly Nazri, Universiti Malaya, Malaysia
Ahmad Najwan Zulkiplee, Universiti Malaya, Malaysia
Hidayah Ismail, Universiti Malaya, Malaysia
Husna Bokhari, KU Leuven, Belgium
Jia Wei Teh, University of Heidelberg, Germany
Mohamad Ridhaudin Mat Sabri, Universiti Malaya, Malaysia
Mohd Shaiful Rizal Hassan, Universiti Malaya, Malaysia
Norsyazwani Asmi, National Planetarium, Malaysia
Zamri Zainal Abidin, Universiti Malaya, Malaysia

List of Participants

Ahmad, S.
Anandakrishnan, S.
Ansar, S.
Arentsen, A.
Arifyanto, M., I.
Asano, T.
Asillam, F.
Asmi, N.
Aznam, M.
Barbuy, B.
Belokurov, V.
Bely, A., H.
Bhattacharya, S.
Bokhari, H.
Bora, K.
Brauer, K.
Ciuca, I.
Chang, C., Y.
Chang, S., Y.
Chen, E., B.
Chen, Q.
Chen, Q.
Cheng, C.
Chiti, A.
Chun, S., H.
Cooper, A.
Cuomo, V.
Daikuhara, K.
Danieli, S.
de Oliveira, F., R.
Dodd, E.
Durst, S.
Eftekhari, E.
Ejlali, G.
Escala, I.
Fellhauer, M.
Filion, C.
Fukushima, H.
Gandhi, P.
Garavito-Carmargo, N.
Gasymov, D.
Glazebrook, K.
Grand, R.
Grisoni, V.
Habe, A.
Hashimoto, T.
Hassan, M., S., R.
Hayward, C.
Hensler, G.
Hilmi, M.
Ho, P.
Horta, D.
Hosseini-rad, M.
Ibrahim, D.
Ibrahim, U., F., S.
Ikeda, R.
Imandiharja, I., N.
Inoue, A.
Inoue, S.
Ishigaki, M.
Ismail, H.
Jaafar, N., F.
Jones, T.
Joo, A., P.
Jwel A., K., M.
Kamieneski, P.
Kaneda, Y.
Kassin, S.
Kataria, S., K.
Khademi, M.
Khairunnisa, S., A.
Kisku, S., S.
Kobayashi, C.
Kohandel, M.
Kravtsov, A.
Kumar, A.
Le, M., N.
Lee, J.
Lee, J.
Leethochawalit, N.
Lewis, G.
Li, H.
Li, Q.
Li, Z.
Lian, J.
Liao, L., W.
Lim, M., K.
Lim, R., X., R.
Long, A.
Lu, J.
Lucey, M.
Luitel, B., C.
Madhani, J.
Maiolino, R.
Mao, Y., Y.
Marino, A., F.
Martinez-Marin, M.
Mason, A., C.
Mat Sabri, M., R.
Matsui, H.

Matsui, S.	Schiavon, R.
McClure, R., L.	Sestito, F.
McKenzie, M.	Shafa, M., E.
McPherson, D.	Sharda, P.
Metha, B.	Sharon, C.
Milone, A.	Sheng, Y.
Minniti, D.	Shivaei, I.
Mitsuhashi, I.	Sotillo-Ramos, D.
Moreno, J.	Suzuki, Y.
Mortensen, K.	Syaifudin, M., A.
Moura, M., T.	Tabatabaei, F.
Nanayakkara, T.	Teh, M., J.
Nascimento, A., C., P.	Teh, J., W.
Nataf, D.	Ting, Y., S.
Naufal, A.	Trierweiler, I.
Nazri, A., A.	Uebler, H.
Nazri, N.	van de Sande, J.
Nidever, D.	Venn, K.
Nikouravan, B.	Viswanathan, A.
Nurhidayat, R., M.	Vulcani, B.
Oey, S.	Wang, C., W.
Orkney, M.	Wang, L.
Otaki, K.	Wang, P., Z.
Panithanpaisal, N.	Wardana, M., D.
Pekkola, M.	Weinberg, D.
Pradhan, R., K.	Wetzel, A.
Premadi, P., W.	White, S.
Pu, S., Y.	Williams, C., C.
Ramachandran, N., K.	Wisnioski, E.
Rawle, T.	Wulandari, H.
Reggiani, H.	Xu, D.
Renzini, A.	Xue, X., X.
Richie, H.	Yajima, H.
Rizzo, F.	Yap, Z., X.
Rodriguez-Gomez, V.	Yassir, S.
Saadon, M., H., M.	Yusof, N.
Sabri, M., R., M.	Zainal Abidin, Z.
Sato, G.	Zainol Abidin, A., N.
Satthiyasilan, N.	Zhu, L.
Savino, A.	Zulkiplee, A., N.

