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Report on the Australia–ESO conference

Galaxy Transformation Across Space and Time — the Third Australia–ESO meeting

held at the Australian Academy of Science, Canberra, Australia, 4–8 September 2023

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We report on the third joint Australia–ESO conference since the commencement of the strategic partnership between Australia and ESO. The conference was supported by ESO, the Australian Research Council Centre of Excellence for All Sky Astrophysics in 3 Dimensions (ASTRO 3D), the Australian National University, and the International Centre for Radio Astronomy Research. The meeting focused on new results from ongoing surveys and simulations of galaxies and their evolution. The motivations for upcoming facilities such as the Multi-conjugate adaptive optics-Assisted Visible Imager and Spectrograph (MAVIS), the Square Kilometre Array (SKA), Vera C. Rubin Observatory, and the Wide-field Spectroscopic Telescope and the new science opportunities and collaborations that they will enable were discussed. The meeting achieved a gender-balanced participant list and strove to provide an inclusive environment. It was a pleasure to share science again in person since the last joint Australia–ESO conference in February 2020. While there was some flexibility for inclusion purposes, the meeting prioritised in-person attendance with only five remote talks.

Motivation

With new capabilities enabling highly-resolved multi-wavelength investigations of gas and stars in local galaxies (for example, the Physics at High Angular resolution in Nearby GalaxieS [PHANGS], Generalising Edge-on galaxies and their Chemical bimodalities, Kinematics and Outflows out to Solar environments [GECKOS], MUSE and ALMA Unveiling the Virgo Environment [MAUVE], and Fornax 3D surveys), it is now possible to disentangle detailed star formation and assembly histories for a wider variety of galaxy types. Simultaneously, surveys pushing resolved observations to earlier times are providing important constraints on the evolution and transformation of dynamics and chemical distributions (for example, the Middle Ages Galaxy Properties with Integral Field Spectroscopy [MAGPI], MUSE gAlaxy Groups In Cosmos [MAGIC], and Large Early Galaxy Astrophysics Census [LEGA-C] surveys). Together these approaches have the power to discern complex assembly histories over the last 7 Gyrs. Simulations suggest that most of the morphological and kinematic evolution is expected to have occurred over the same epoch, but the exact timing and nature of the transformations are debated.

A key player in the redistribution of gas and stars likely comes from galaxy-galaxy interactions, typically in the group environment. Upcoming surveys obtaining millions of galaxy spectra at high densities (for example, using ESO's 4-metre Multi-Object Spectrograph and Telescope [4MOST] and Multi-Object Optical and Near-infrared Spectrograph [MOONS], NOIRLab's Dark Energy Spectroscopic Instrument [DESI], and the Subaru Telescope's Prime Focus Spectrograph [PFS]) combined with deep photometry (from, for example, Rubin Observatory and the Euclid and Nancy Grace Roman space missions) over large areas of sky will allow the environmental metrics necessary to make these connections to be measured consistently out to $z \sim 1$. Tying stellar tracers with gas tracers from the Australian SKA Pathfinder [ASKAP], MeerKAT and the SKA will be essential to disentangling the role of different processes in the group and cluster environments. The meeting provided a forum to explore the synergies between the different theoretical and observational datasets relating to the role

Figure 1. Participants engaging in science discussions during teatime at the Australian Academy of Science.

of environment on quenching, star formation histories, and angular momentum. The meeting was designed around science questions rather than techniques in order to promote a more integrated discussion of simulations and multiwavelength (including radio) results.
The conference[1] was divided into five major themes used to focus the topics presented each day:

- What is the environmental impact on redistributing angular momentum?
- How do we connect galaxy populations across epochs?
- How will new facilities address the questions surrounding how galaxies transform?
- How does the environment shape the star-formation history of galaxies?
- How do stellar and AGN feedback regulate the gas-star formation cycle at $z \sim 0$?

Key scientific results discussed during the meeting included recent breakthroughs combining deep optical spectroscopy from the Multi-Unit Spectroscopic Explorer (MUSE) and the William Herschel Telescope Enhanced Area Velocity Explorer (WEAVE) with data from ASKAP, MeerKAT, the Atacama Large Millimeter/submillimeter Array (ALMA) and the Low-Frequency Array (LOFAR) to study gas flows from parsec to megaparsec scales. Along these lines, the GECKOS and MAUVE surveys in particular showed beautiful images revealing the complexity of these gas flows around nearby galaxies. Such detailed multiwavelength studies help us better understand the relationship between star-forming regions, the galaxies that host them, and the large-scale environments that they live in. Several talks also emphasised the key role that the James Webb Space Telescope (JWST) has to play across a broad range of redshifts, both extending the study of local galaxies into the mid-infrared and enabling deep continuum observations of galaxies in the distant Universe.

Environment is an inherently broad term in galaxy evolution. Participants presented results on the role of environment from galaxy pairs on kiloparsec scale to the megaparsec scale of voids and filaments. We heard about results indicating that the cosmic web and its complex interplay with galaxies are multi-scale.

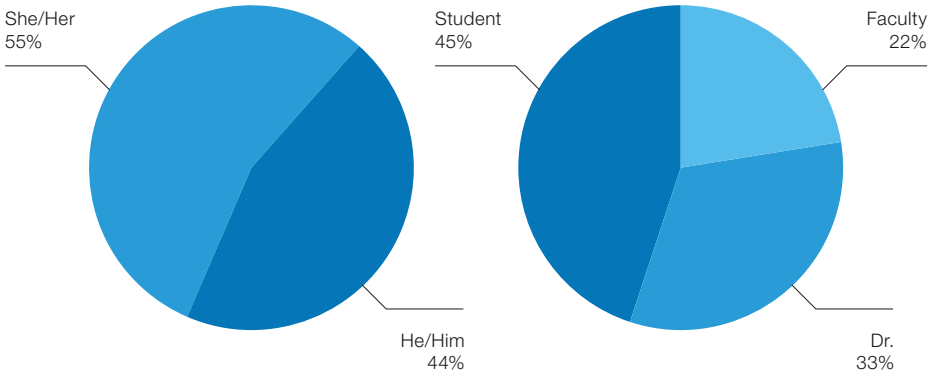

Figure 2. Distributions of gender (left) and seniorty (right) of participatants including invited and contributed talks, poster presentations, and attendees. Gender statistics were inferred from participant provided pronouns. The seniority label 'Dr.' includes postdocs as well as staff not in a typical University setting.

Results testing Tidal Torque Theory in the local Universe highlight that more work is needed to find correlations between angular momentum and the ancient cosmic web. Future facilities densely mapping out large-scale structure to cosmic noon will add constraints on the timescale of galaxy spin decoupling from the cosmic web and the processes responsible. During the conference the MAGPI team showcased the first year of major results including that most of the dynamical evolution between $z \sim 0.8$ and $z \sim 0$ must happen before $z \sim 0.35$.

Connecting galaxies across epochs becomes an important exercise to track the changes of galaxy spin, morphology, and star formation. Limitations in the different approaches were highlighted, along with possible ways forward including using joint observation inference as well as improvements in simulations. Recent simulation results show that connecting galaxy environment across time may be more complex than assumed. While the largest overdensities at $z \sim 4$ are often theorised to be the progenitors of massive Coma-like clusters, simulations show that a large fraction of locally overdense regions in the early Universe may quickly consume their gas and become quiescent early owing to being underdense on larger scales. This was supported by some preliminary observational results presented from the One-hundred-square-degree DECam Imaging in Narrowbands (ODIN) survey in the Cosmic Evolution Survey (COSMOS) field.

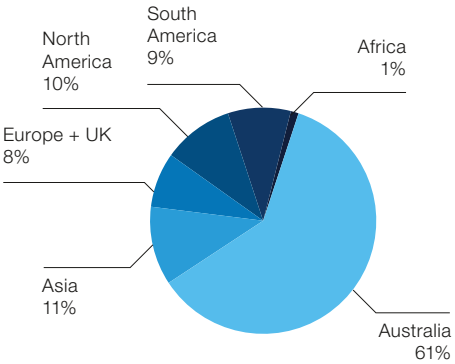

Figure 3. Distribution by country of current study/employment of the 90 participants.

The varying role of star formation and active galactic nucleus (AGN) feedback in regulating the gas available to galaxies was central to numerous discussions throughout the meeting. Data from the GECKOS and the Deep near-UV observations of Entrained gas in Turbulent galaxies (DUVET) surveys in particular were used to highlight the complex, spatially-extended nature of outflowing material in local galaxies, which in some cases could be directly imaged out to several tens of kiloparsecs. These results for nearby galaxies were complemented by JWST data showing that large reservoirs of outflowing neutral gas, likely driven by AGN, may play a key role in quenching galaxies at early epochs.

A recurring topic across the five themes of the meeting was the importance of scale and the interplay of physics from

the scale of the cosmic web (hundreds of megaparsecs) to the scale of star-formation (parsecs). There is no one scale that captures how galaxies transform over cosmic time — processes such as feedback are inherently multi-scale. It is clear that a more complete observational picture of galaxies will soon be available from new surveys and facilities but it was noted that new simulations were needed at all scales, including even larger boxes to capture rare overdensities as well as higher resolution to include cloud-scale gas physics.

Demographics and inclusivity

One advantage of large multinational collaborations like the ESO–Australia partnership and the international galaxy evolution community is the diversity of experience and backgrounds. As has been noted in previous articles about ESO meetings (Zafar, De Breuck & Arnaboldi, 2019; Lagos, Robotham & De Breuck, 2020), tackling unconscious bias when organising a science meeting is important for achieving a diverse range of ideas and perspectives. We have followed the guidelines of previous meetings and from supporting organisations to (1) anonymise contributed abstracts, (2) ask the SOC to declare conflicts of interest, (3) anonymise SOC votes, and (4) have a multinational and gender-balanced set of invited speakers. Opting for longer talks, the conference had 10 invited talks, 55 contributed talks, and 10 poster presentations. The adopted guidelines naturally gave rise to a balanced meeting across gender, seniority, and country (see Figures 2 and 3). This is the first meeting in this series that had more female than male participants.

However, the responsibility to hold an inclusive meeting does not stop at the participation list. The Local Organising Committee took some additional measures to ensure participation from all demographics. This included announcing a Code of Conduct for the meeting during the welcome talk and posting it on the conference webpage where it could easily be referenced. The main purpose of the Code of Conduct is to remind participants to behave professionally and communicate in a respectful manner to all.

The meeting was opened by Aunty Violet Sheridan, a local Ngunnawal Elder who led an Acknowledgement of Country — a custom adopted throughout Australia to show our respect for the land and its traditional owners. A dedicated prayer room was made available to participants throughout the meeting. To encourage participation by the younger cohort, all session chairs were asked to take questions from students and early career researchers first before opening the floor to questions from the whole audience. This resulted in an engaging discussion between speaker and audience after most of the talks.

Future

Since the start of the 10-year ESO–Australia strategic partnership (2017–2027) there have been three joint ESO–Australia workshops on galaxy evolution (Zafar, De Breuck & Arnaboldi, 2019; Lagos, Robotham & De Breuck, 2020), held in Australia in 2019, 2020, and 2023. It has been a fruitful collaboration that we hope to continue. We were happy to welcome Australian government officials to the Wednesday session to share the benefits of the partnership. Scientifically, from this meeting it is clear that multiple tracers of stellar and gas properties across diverse phases and scales are required to understand the processes that transform galaxies. This necessitates a multi-wavelength, multi-facility approach. We look forward to continued collaboration with ESO members and projects with a focus on ESO-SKA connections.

Acknowledgements

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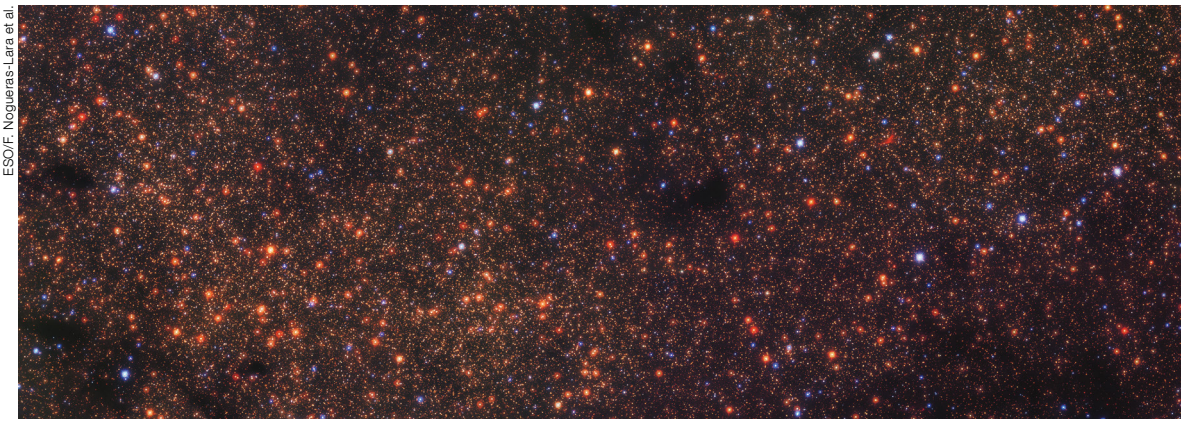
References

Zafar, T., De Breuck, C. & Arnaboldi, M. 2019, The Messenger, 176, 48
Lagos, C., Robotham, A. S. G. & De Breuck, C. 2020, The Messenger, 180, 50

Links

[1] Conference webpage: https://www.mso.anu.edu.au/~jtmendel/galtrans2023/



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Hundreds of thousands of stars are contained in this infrared image of Sagittarius C, a region near the centre of the Milky Way. This image was taken with ESO's Very Large Telescope (VLT) in the Chilean Atacama Desert.