DOI: 10.18727/0722-6691/5423

Report on the ESO workshop

Galaxy Ecosystems Under the Microscope: Lessons from Highly-Resolved Studies

held at ESO Headquarters, Garching, Germany, 7–11 July 2025

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In the past decade, our approach to studying galaxies has undergone a remarkable transformation. By focusing on the most nearby systems, we can now probe the fundamental building blocks of galaxies — molecular clouds, H II regions and star clusters, along with fully resolved galaxy structures such as nuclear stellar discs, bars, and spiral arms — in unprecedented detail. The Galaxy Ecosystems Under the Microscope (GalRes25) workshop brought together over 110 participants from institutes in 18 countries at ESO Headquarters in Garching from 7 to 11 July 2025 to exchange the latest results from these highly resolved studies. Over the course of around 60 talks and 50 posters, participants explored how galaxies assemble their baryonic components, how star formation and feedback regulate their evolution, and how small-scale physics connects to global galactic properties. Sessions on gravitational lensing extended this discussion to the high-redshift Universe, setting the stage for future high-definition studies of galaxies both near and far with the Atacama Large Millimeter/submillimeter Array's Wideband Sensitivity Upgrade, the Square Kilometre Array, ESO's Extremely Large Telescope, and upcoming Very Large Telescope instruments such as BlueMUSE and the Multi-conjugate-adaptive-optics-Assisted Visible Imager and Spectrograph (MAVIS).

Workshop motivation and context

Galaxy evolution is driven by processes that unfold on parsec scales — gas inflows, turbulence, stellar feedback and cloud collapse. For decades such detail was accessible only in the Milky Way and its nearest companions. Recently, however, the field has experienced a major leap forward: by targeting the very nearest galaxies, we can now resolve their internal structure and directly study the interplay between gas, dust and stars on the scales where these processes occur (Figure 1). Observations from ESO facilities such as the Atacama Large Millimeter/submillimeter Array (ALMA) and the Very Large Telescope, and complementary facilities such as JWST, the Hubble Space Telescope, the Canada France Hawaii Telescope's SITELLE spectrograph and MeerKAT have made this possible, while simulations have evolved to match this level of physics. GalRes25 was organised to take stock of these advances, bringing together observers and theorists to exchange results, confront challenges and build a coherent view of galaxies as interconnected ecosystems.

Conference structure & themes

Galaxy assembly: baryonic growth histories

Spatially resolved observations have made it possible to distinguish the assembly history of individual galaxy components. By studying the relative contributions of various processes, such as *in-situ* versus *ex-situ* formation, we can uncover the imprints left on a galaxy's structural components and piece together its life story. This theme saw presentations on the assembly of galactic structures such as bars and nuclear discs, the role of mergers in galaxy growth and the buildup of dust in galaxies. Multi Unit Spectroscopic Explorer (MUSE) campaigns including Generalising Edge-on galaxies and their Chemical bimodalities, Kinematics and Outflows out to Solar environments (GECKOS), Time Inference with MUSE in Extragalactic Rings (TIMER), and Bulge Assembly in Nearby Galaxies (BANG) are providing detailed insights into the stellar populations of the galaxies, especially their centres. A strong representation by the dynamical modelling community ensured much discussion about the use of orbital superposition methods to diagnose galaxy structure and assembly histories.

Regulation of star formation and feedback

A central theme of the workshop was the regulation of star formation and the impact of stellar feedback in nearby galaxies. Using spatially resolved, multi-wavelength data from surveys, including Physics at High Angular resolution in Nearby GalaxieS (PHANGS) and the Local Group *L*-Band Survey (LGLBS), talks traced how gas becomes gravitationally bound, forms stars and is then disrupted, ionised or expelled by those same young stars.

Figure 1. Workshop motivation was provided by results such as this[1]. This stunning image of NGC 253 captured with MUSE provides context for parsec-scale science – individual star-forming regions, supernova remnants, outflows and the central galactic region are all spatially resolved in this image. The physical drivers of these phenomena (and many more) were the backbone of the science agenda of GalRes25.

Figure 2. A: Participants trying to find their groups for the poster quiz session. B: The eventual winners of the Poster Quiz, team Germans Analysing Luminous Realms of Extragalactic Schnitzel (GALRES), who also received a bonus point for the best team name!

This theme explored the internal structure of H II regions, the life cycles of molecular and dense gas, and both radiative and mechanical feedback — from ionising radiation to winds and supernovae — and showed how these processes vary across different galactic environments. A recurring focus was the full 'star formation cycle': how efficiently galaxies convert gas into stars, on what timescales, and how rapidly feedback returns energy and momentum to the interstellar medium. Together these results emphasise that star formation is not a simple on/off process but a tightly regulated cycle in which gas flows, environment and feedback continuously shape when, where and how galaxies continue forming stars.

Connecting scales: from parsecs to kiloparsecs

While galaxies are governed by processes that occur locally on scales of tens to hundreds of parsecs, the connection between these small-scale processes and global galaxy properties remains unclear. This theme aimed to link previous results from kiloparsec-scale surveys such as Mapping Nearby Galaxies at APO (MaNGA) and Calar Alto Legacy Integral Field Area (CALIFA) to more highly resolved studies of small samples of nearby galaxies. Progress is being made on the stellar populations front, the cold gas front (including comparisons between the Kiloparsec Investigations of Local Objects And Star-formation [KILOGAS] and the mm-Wave Interferometric Survey of Dark Object Masses [WISDOM] ALMA surveys), and star formation quenching, from global to cloud scales. The importance of a multiwavelength approach to the multiscale problem of galaxy evolution was a theme that ran through the week, though it was particularly highlighted in the invited and contributed talks on this theme. A key takeaway from this theme was the concept that the scale at which one needs to resolve a science object should be directly influenced by the science question.

Gravitational lensing: a high-*z* window

The final theme of the workshop focused on strong gravitational lensing, which effectively turns very distant galaxies into 'nearby' laboratories. The extreme magnification in these systems boosts both apparent brightness and spatial resolution, allowing us to apply the same tools we use in the Local Universe — mapping gas, star formation, feedback and metal enrichment — to galaxies only a few hundred million years after the Big Bang. Highlights included new results on the Waz Arc (COOL J1241+2219), whose highly magnified structure can be dissected in detail, and early findings from the JWST LEnsing and Galaxy Growth: Observing Substructures (LEGGOS) programme, which resolves individual clumps in lensed galaxies and traces how they assemble, interact and enrich their surroundings across cosmic time.

Innovative formats and event highlights

In addition to plenary sessions, GalRes25 championed interactive discussion groups, where participants worked in small mixed teams to encourage exchange between observers, theorists and instrumentalists. Randomly selected teams also competed in the poster quiz (Figure 2), a lively session in which groups were quizzed on the scientific content of the posters. The quiz proved both educational and entertaining and was repeatedly highlighted in participant feedback as one of the most enjoyable portions of the week. We again congratulate the winning team — Germans Analysing Luminous Realms of Extragalactic Schnitzel (GALRES) — for their superior knowledge and innovative team name (Figure 2b).

Participation and diversity

The GalRes25 Scientific Organising Committee (SOC) worked to ensure gender balance within both the organising committees and the invited speaker list. The final attendance (Figure 3) comprised 54% women, 41% men and 5% other genders or undisclosed, representing institutions across 18 countries (including nine Member States, Chile and Australia).

Figure 3. Conference picture of the participants in front of the ESO Supernova planetarium and visitor centre, Garching.

A strong emphasis was placed on supporting attendance at the workshop, with a significant portion of the budget allocated to reducing registration fees, enabling travel support for invited speakers and supporting junior participants (10 fee waivers). In addition, a hybrid format further expanded participation, with 16 colleagues attending online throughout the week.

Legacy

Talk slides are available on Zenodo[2].

Acknowledgements

We sincerely thank all the members of the GalRes25 SOC, which comprised Eric Emsellem, Francesca Fragkoudi, Eva Schinnerer, Francesco Belfiore, Luca Cortese, Stephanie Tonnesen, Amelia Fraser-McKelvie, Enrico Congiu, Ashley Barnes and Camila de Sá Freitas. The Local Organising Committee were instrumental in the success of this workshop, comprising Denisa Tako, Lukas Neumann, Lennart Boehm, Tomas Rutherford, Daudi Mazengo, Eric Emsellem, Nicolas Guerra Vargas, Felipe Schmidt Lohmann, Tamsyn O’Beirne, Ashley Barnes, Camila de Sá Freitas, Amelia Fraser-McKelvie and Enrico Congiu.

We thank ESO for workshop funding and logistical support, all session chairs, and all conference participants for their open and enthusiastic engagement throughout the week.

Links

[1] MUSE image of NGC 253: https://www.eso.org/public/news/eso2510/
[2] Workshop slides: https://zenodo.org/communities/galres2025

ESO/A. Feltre, F. Belfiore, G. Cresci et al.

This image is a closeup of the nearby Triangulum galaxy, also known as Messier 33, located about 3 million light-years away. This festive-looking image, taken with ESO’s Very Large Telescope (VLT), reveals the diversity and complexity of the gas and dust between the stars in great detail.