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Report on the ESO workshop

Why Galaxies Care About AGB Stars V: 3D Winds In The Cosmic Matter Cycle

held at CEPAL headquarters in Santiago, Chile, 17–21 November 2025

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The fifth workshop in the Why Galaxies Care About AGB Stars series brought together researchers working on asymptotic giant branch (AGB) stars, stellar populations and galaxy evolution, with the aim of fostering collaboration and advancing our understanding of the role of AGB stars in the cosmic matter cycle. The workshop covered a broad range of topics, from stellar interiors and mass loss to circumstellar chemistry and the impact of AGB stars on unresolved stellar populations and galaxies across cosmic time. With recent breakthroughs in high-angular-resolution imaging, multi-wavelength observations and three-dimensional modelling, the meeting provided a timely overview of the current state of the field and a forum in which to discuss future prospects in the ESO's Extremely Large Telescope era and beyond.

Motivations

Through their stellar wind, asymptotic giant branch (AGB) stars return newly synthesised elements and dust to the interstellar medium, acting as major contributors to the cosmic dust cycle and influencing the formation of subsequent generations of stars and galaxies. Despite their importance, significant uncertainties remain in our understanding of the physical processes governing AGB evolution, including mass loss, convection, pulsation, nucleosynthesis, binarity and circumstellar dust formation.

Since the first meeting of the Why Galaxies Care About AGB Stars series in Vienna in 2006, the field has undergone rapid development. Advances in observational capabilities, particularly in high-angular-resolution techniques, have allowed astronomers to resolve the surfaces, atmospheres and winds of nearby AGB stars in unprecedented detail. At the same time, progress in three-dimensional stellar modelling has begun to bridge the gap between simplified one-dimensional evolutionary and stelllar atmosphere models and the complex, dynamic reality of AGB atmospheres.

The fifth edition of the workshop was motivated by the need to reassess the role of AGB stars in light of these developments and to place recent observational and theoretical results into a broader astrophysical context. A particular emphasis was placed on the connection between stellar-scale processes and their large-scale consequences, from shaping circumstellar envelopes to the contribution of AGB stars to galaxy evolution across cosmic time.

The workshop was held at the headquarters of the Economic Commission for Latin America (CEPAL) in Santiago. Holding the meeting in Chile, home to some of the world's most advanced astronomical facilities, underscored the close link between the scientific topics of the workshop and the observational infrastructure that enables this research.

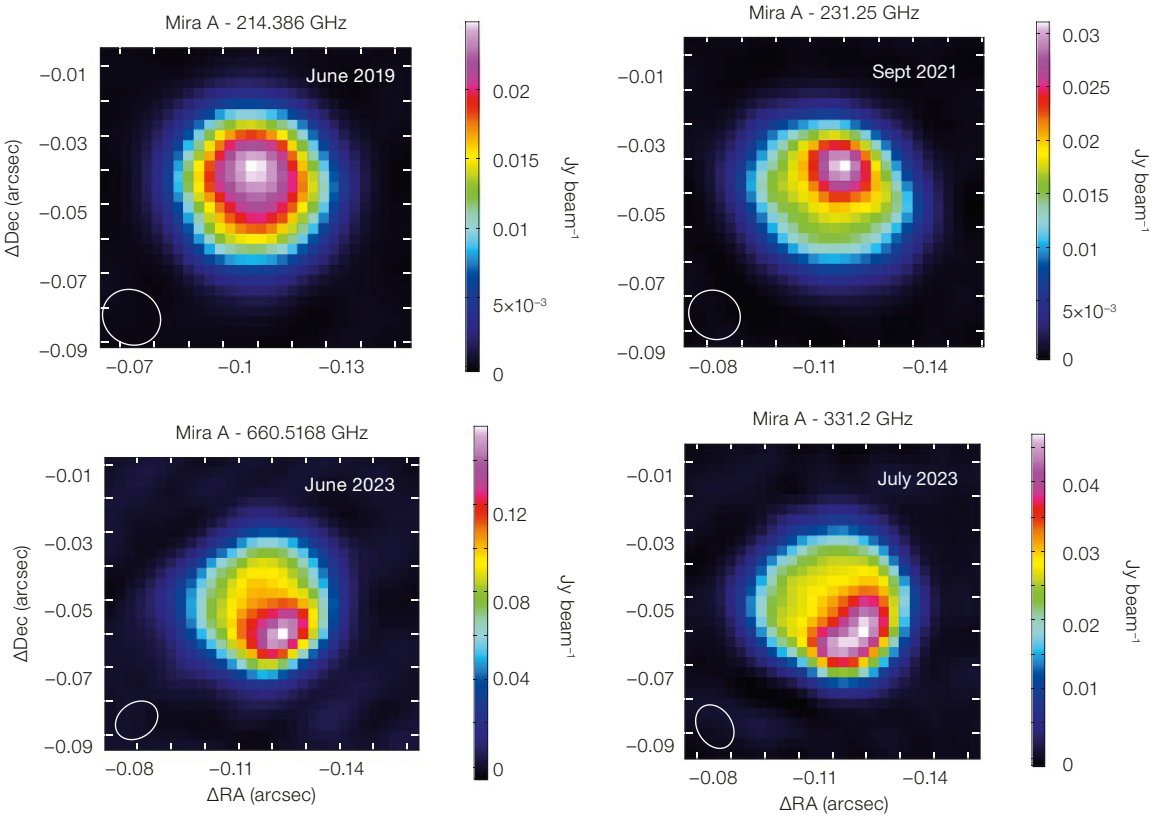

Figure 1. High-resolution ALMA images of the evolved star Mira A at different epochs and frequencies, revealing compact bright regions on the submillimetre stellar surface that may be linked to shocks and mass-loss processes (Andriantsaralaza et al., in preparation).

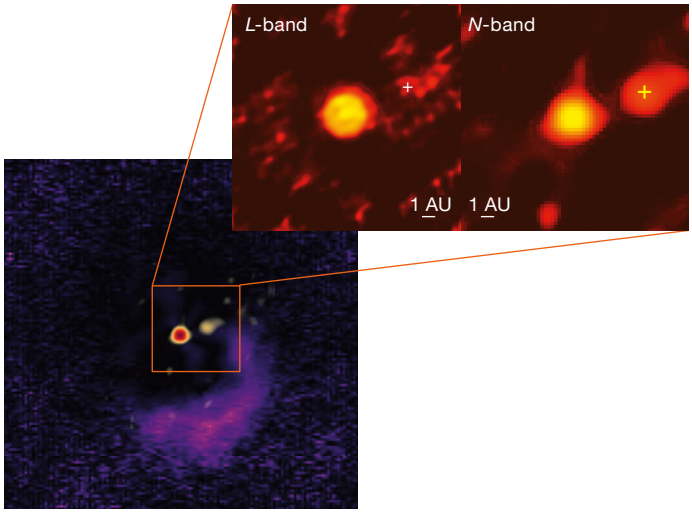

Figure 2. High-resolution Multi-AperTure mid-Infrared SpectroScopic Experiment (MATISSE) images of π^1 Gru showing atmospheric elongation and the onset of a spiral induced by a close companion (cross); the MATISSE data (red-yellow colour scale and inset) are overlaid on Spectro-Polarimetric High-contrast Exoplanet REsearch instrument (SPHERE) observations (Drevon et al., 2026; Montargès et al., 2025).

Scientific highlights of the meeting

The meeting opened with a moment of remembrance for colleagues who passed away since the previous workshop: Inma Domínguez, Roberto Gallino, Paola Marigo and Karl Menten. Their scientific contributions have had a lasting impact on the study of AGB stars and related fields, as well as on the careers of many participants.

The scientific programme[1] covered the following topics: stellar structure and evolution; stellar interiors and nucleosynthesis; dynamic processes such as convection, pulsation and dust formation; circumstellar envelopes and astrochemistry; binarity, planets and discs around AGB stars; evolution beyond the AGB phase; the role of AGB stars in the cosmic matter cycle; resolved and unresolved AGB populations in stellar systems; galaxy evolution, including the first generations of AGB stars.

Progress was reported in extending nucleosynthesis calculations across a wide metallicity range, updating s-process yields, and refining treatments of mixing and dredge-up, while uncertainties related to mass loss and binary effects remain major challenges.

A central theme of the workshop was the recognition that AGB stars must be understood as inherently three-dimensional and time-dependent objects. The traditional picture of spherically symmetric winds driven by steady pulsation and radiation pressure on dust is increasingly challenged by observations revealing complex morphologies, asymmetries and the frequent influence of companions. High-angular-resolution observations have demonstrated that convection, pulsation, shocks, dust formation and binarity jointly shape extended AGB atmospheres and winds, with direct consequences for mass loss, chemical yields and circumstellar dust properties. Multiple period–luminosity relations of AGB variables were discussed as well-established sequences of pulsation modes, supported by stellar structure and three-dimensional models, with particular attention given to the still poorly understood long secondary periods (convection+pulsation versus binarity, or a combination of the two). The programme reflected a notable shift in community focus over the past decade, with binarity now recognised as a key ingredient in interpreting AGB mass loss, circumstellar structure and late stellar evolution. At the same time, speakers emphasised the need for caution in attributing all observed phenomena solely to binary interactions.

Several contributions highlighted the importance of linking detailed studies of nearby benchmark stars, such as Mira, R Dor, and π^1 Gru, with results from large surveys. While individual objects provide essential physical insight, surveys conducted with facilities such as Gaia, the Atacama Large Millimeter/submillimeter Array (ALMA), and JWST, and future observatories including Vera C. Rubin Observatory and ESO's Extremely Large Telescope (ELT) are required to place these results in a broader population and galaxy-evolution context.

The transition beyond the AGB phase was also discussed, with post-AGB stars considered primarily in the context of their AGB progenitors and as laboratories for studying the outcome of binary interaction and disc formation. This perspective reflects a long-standing focus within the post-AGB community that now connects naturally with the evolving emphasis on binarity in AGB research.

AGB stars were further discussed as probes of stellar populations and galaxy evolution. New results demonstrated their potential for tracing star formation histories and contributing to distance scale studies, including applications of the *J*-region AGB method as a distance indicator, with possible implications for addressing the Hubble tension. The detection of dusty AGB stars out to tens of megaparsecs opens new opportunities for studying galaxy evolution in diverse environments.

The scientific highlights of the meeting were reflected in the workshop awards. The best talk presenting ALMA data was awarded to Miora Andriantsaralaza for her study of the archetypal AGB star Mira (Figure 1), while the best Very Large Telescope (VLT) talk was awarded to Julien Drevon for his MATISSE observations of π^1 Gru (Figure 2). The best student talk was awarded to Toon De Prins for his talk entitled "Here be substructures: An interferometric imaging voyage to the inner rims of dusty post-AGB discs". The best poster prize was awarded to Mats Esseldeurs for his work on π^1 Gru, presenting (sub)millimetre interferometric evidence for a close companion orbiting an AGB star (Esseldeurs et al., 2026).

Main conclusions & ways forward

The discussions throughout the week highlighted both the significant progress achieved in recent years and the challenges that remain. A key conclusion was that mass loss, long treated as a parametrised ingredient in stellar evolution models, must increasingly be addressed

Figure 3. Workshop photo.

as an emergent process arising from the interplay of convection, pulsation, dust formation and sometimes binarity.

While three-dimensional simulations are providing essential physical insight, the community remains dependent on one-dimensional models for population and galaxy-scale applications, owing to the high computational cost of multi-dimensional modelling. Using detailed simulations to guide the simplified prescriptions required for population studies was identified as a key priority.

Looking ahead, participants discussed the transformative role of current and future facilities in a dedicated discussion inspired by the ESO Expanding Horizons process[2]. Upgrades to ALMA, longer baselines and more telescopes at the VLT Interferometer and the advent of the ELT will enable unprecedented studies of AGB atmospheres and winds, while large surveys from Gaia and Vera C. Rubin Observatory will continue to reshape our understanding of AGB populations. It was also emphasised that not all key science requires the highest angular resolution, and that sensitive single-dish radio observations remain essential for studies of AGB mass loss and circumstellar envelopes, where recovering the total emitted flux from extended circumstellar material is critical. In this context, the importance of coordinated observational efforts across facilities and spatial scales was highlighted. Ensuring that theoretical models evolve in step with observational capabilities emerged as an important requirement for the coming years.

Demographics

The Scientific Organising Committee (SOC) sought fair representation from the community and aimed to construct a balanced and inclusive scientific programme. For each topical session, several invited speakers were proposed, with the final selection made by the SOC solely on scientific merit. The resulting list was dominated by women, reflecting the outcome of the voting process rather than any predefined gender-based criteria.

The selection of contributed talks was performed blindly, based exclusively on the submitted abstracts. One member of the SOC removed names and identifying information before the abstracts were evaluated and abstained from voting, ensuring that the selection process focused purely on scientific content.

The workshop attracted a total of 116 participants, including 16 remote attendees (Figure 3). Approximately 40% of the participants were women and non-binary. In terms of career stage, the audience consisted of roughly 50% staff scientists, 25% students, 22% postdoctoral researchers and about 3% retired researchers.

Acknowledgements

The organisers thank the members of the SOC and the Local Organising Committee for their dedication in shaping the programme and ensuring the smooth running of the meeting. We are grateful to all speakers and participants for their contributions, and to the ESO and JAO workshop support for making the workshop possible. The organisers also acknowledge H. Olofsson, M. Groenewegen and Franz Kerschbaum for their long-standing leadership of the Why Galaxies Care About AGB Stars workshop series and for entrusting us with the organisation of this edition.

References

Drevon, J. et al. 2026, A&A, 706, L1
Montargès, M. et al. 2025, A&A, 699, A22
Esseldeurs, M. et al. 2026, Nat Astron, 10, 124

Links

[1] Workshop programme: https://www.eso.org/sci/meetings/2025/whygalaxiescareaboutAGB.html
[2] ESO Expanding Horizons website: https://next.eso.org/