cluster populations have number density profiles similar to that of the stars, while the blue globular clusters are spatially more extended and seem to trace the metal-poor halo component. Arnaboldi showed the overlap of the M87 halo and the intracluster light in the radial range between 20 to 150 kpc from the centre of M87, and how the planetary nebulae luminosity function is used to identify the star-forming (metal-poor) stellar population *vs*. the old and metal-rich one. Michael Hilker showed that there are different subpopulations of globular clusters in the distant central galaxy in the Hydra cluster that trace different assembly epochs. The origin of ultra-compact dwarfs around NGC 1399, the central galaxy of the Fornax cluster was presented by Karina Voggel. Ortwin Gerhard, Nicola Napolitano and Eric Emsellem described the kinematics of stars, their angular momentum and orbital distribution in galaxies from the centre out to ten effective radii.

While the stellar mass is a strongly non-linear function of the galaxy halo mass, due to the large contribution of dark matter in the least and the most massive galaxies, the total mass of all globular clusters correlates linearly with the mass of the halo, as shown by Bill Harris. This is explained if globular cluster formation is largely immune to the feedback that affects star formation in the field, or if the formation of globular clusters is completed before the feedback starts.

Prospects

During the final discussion, the obvious energy and enthusiasm testified that this field of research had gained substantial momentum! The observational samples are growing and we are starting to make quantitative comparison of the properties of halos inferred by different observational techniques with the simulations. The importance of consistent comparisons was emphasised yet again: there are different ways to define a stellar halo — including or excluding the streams and accreted material — which then lead to different halo properties. Hence the halo properties need to be studied in a homogeneous and unbiased way, by applying a consistent treatment to observations and theory/simulations. Lively discussions during the workshop, after every talk, during coffee breaks, and the vibrant atmosphere during the final gathering around *Bier und Bretz'n*, resulted in new ideas, new collaborations and projects for future advances in the field.

References

Bullock, J. S. & Johnston, K. V. 2005, ApJ, 635, 931
Eggen, O. J., Lynden-Bell, D. & Sandage, A. R. 1962, ApJ, 136, 748
Longobardi, A. et al. 2015, A&A, in press, arXiv:1504.04369
McConnachie, A. W. et al. 2009, Nature, 461, 66

Links

[1] Workshop programme: http://www.eso.org/sci/meetings/2015/StellarHalos2015/program.html
[2] Image of simulated stellar halo: http://www.physics.uci.edu/~bullock/StellarHalo/halo.html
[3] Annotated image of M31: https://blogs.stsci.edu/universe/2014/07/21/what-built-andromedas-stellar-halo/

Report on the ESO Workshop

Dissecting Galaxies Near and Far

held at ESO Vitacura, Santiago, Chile, 23–27 March 2015

Catherine Vlahakis[1,2]

[1] Joint ALMA Observatory, Santiago, Chile
[2] ESO

The workshop explored high-resolution perspectives for the understanding of star formation and the interstellar medium in the era of ALMA. Angular and spectral resolutions are fundamental limitations for our understanding of the properties of galaxies in the nearby and distant Universe. A new generation of instruments and powerful observatories, as well as planned future facilities, is pushing out the boundaries of what was previously possible over the entire electromagnetic spectrum. Held in the approach to ALMA Early Science Cycle 3, the workshop centred on discussing the scientific results and upcoming opportunities afforded by the new capabilities available in the era of ALMA. Some of the science highlights of the meeting are presented.

The advent of state-of-the-art facilities with high angular resolution and/or high spectral resolution capabilities, coupled with high sensitivity, such as the Atacama Large Millimeter/submillimeter Array (ALMA), allows the interstellar medium (ISM) and star formation properties of galaxies at intermediate redshift to be probed in unprecedented detail, along with their counterparts in the local Universe.

The aim of the workshop was to bring together astronomers whose interests further our understanding of star formation and ISM processes at high spatial and spectral resolution, both in nearby and distant galaxies. The theme of "dissecting galaxies" was intended not only to encompass what we can learn by going to higher spatial and spectral resolution, but also, in the true sense of the word "dissect", what we can learn about galaxies when we methodically break them down into their constituent

components. Workshop topics included: the high-redshift Universe, ISM, star formation and environment, star formation, the star formation–molecular gas connection, the nuclei of galaxies, nearby galaxies, and galaxy groups and clusters.

Emphasis on synergies between current and future facilities capable of carrying out such observations, and synergies with ALMA in particular, were encouraged. Participants discussed recent scientific results and future opportunities using a wide range of telescopes, including ALMA, the Hubble Space Telescope (HST), Herschel, Spitzer, the Wide-field Infrared Survey Explorer (WISE), Jansky Very Large Array (JVLA), the Very Large Telescope (VLT), Combined Array for Research in Millimeter-wave Astronomy (CARMA), the South Pole Telescope, the Atacama Pathfinder EXperiment (APEX), Australia Telescope Compact Array (ATCA), Institut de Radioastronomie Millimétrique (IRAM), Plateau de Bure Interferometer (PdBI), the NOrthern Extended Millimeter Array (NOEMA), the James Webb Space Telescope (JWST), the Square Kilometer Array (SKA), and many more besides. The workshop aimed to be scientifically rich, but also informal, with ample time for less formal discussions and social activities (Figure 1). Here, we provide a summary of some of the highlights of the meeting. The workshop programme and presentations are available for download[1].

T. Sawada/C. Vlahakis

Figure 1. The workshop participants photographed during the workshop dinner held in the ESO Vitacura gardens.

Molecular gas and star formation in the Galaxy and nearby galaxies

Most stars form in giant molecular clouds (GMCs), and the relationships between molecular gas and star formation are a key issue for understanding galaxy evolution. High spatial resolution observations of the Magellanic Clouds and nearby galaxies may provide an important bridge between the properties of Galactic GMCs and distant galaxies. The evolution of GMCs in the Large Magellanic Cloud (LMC) was presented in a review by Toshikazu Onishi. From ALMA observations, he showed a wealth of filaments and arcs (Fukui et al., 2015; see Figure 2) and molecular outflows, with some filaments colliding and leading to rapid high-mass star formation. Monica Rubio presented results on the Magellanic Bridge, in which she discussed the problems of searching for dark molecular gas in low-metallicity environments and showed the presence of a submillimetre dust excess.

On the topic of nearby galaxies, Sharon Meidt presented results from PdBI observations of the nearby spiral galaxy M51 (e.g., Meidt et al., 2013) showing the role of spiral arms on gas organisation and star formation. She showed that molecular clouds are sensitive to environment and respond to local conditions, and that spiral arms affect the structure and organisation of the ISM down to cloud-scales.

Star formation laws

Adam Leroy presented a review of the physical conditions in the ISM and star formation. The relationship between molecular gas and recent star formation (“star formation law”; SFL) in local galaxy discs shows physically driven variations when the data is dissected, whether into different galaxy types or different galaxy regions — such as whole discs, kpc-sized regions, galaxy centres and starbursts (Leroy et al., 2013; see Figure 3,

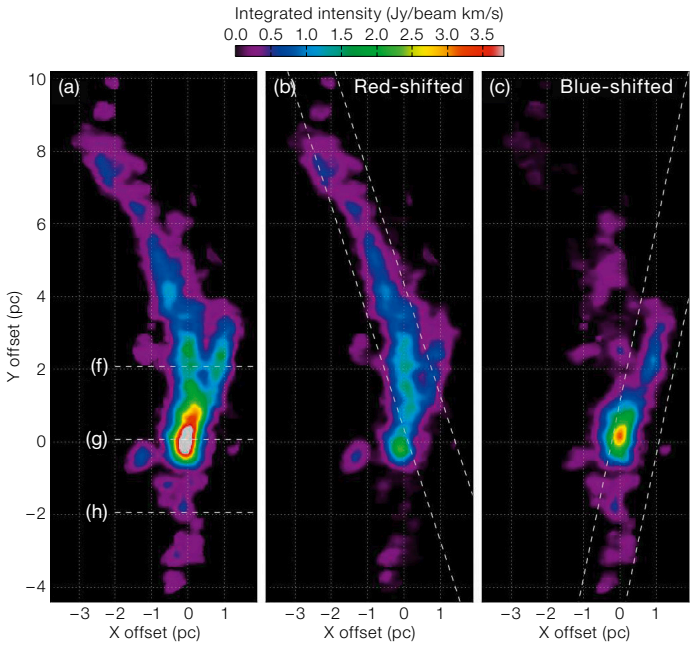


Figure 2. ALMA ^{13}CO (2-1) integrated intensity images of filaments detected in the LMC (N159), produced for different velocity ranges. Left panel: Full velocity range; centre and right panels: red-shifted and blue-shifted velocity ranges. From Fukui et al. (2015).

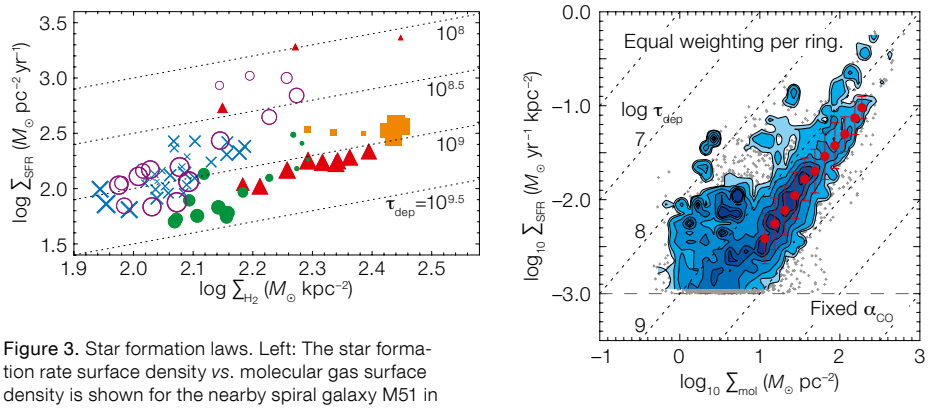


Figure 3. Star formation laws. Left: The star formation rate surface density *vs.* molecular gas surface density is shown for the nearby spiral galaxy M51 in different radial bins. From Meidt et al. (2013); data from the IRAM PdBI. Right: The star formation law for a sample of 30 nearby disc galaxies at 1 kpc resolution; low-*z* dwarf galaxies, starbursts and large disc galaxies occupy different regions of the plot. From Leroy et al. (2013); data from the IRAM 30-metre telescope.

right). He also presented plans to study dense gas and star formation in normal galaxies, via surveys of HCN, with ALMA and other facilities. The SFL and its connection between molecular gas and star formation was discussed by several other speakers, including: Linda Watson, who showed that a similar relationship applies to extended ultraviolet disc galaxies as within optical discs; Sharon Meidt, who showed the relationship for M51 (Meidt et al., 2013; see Figure 3, left); and Chelsea Sharon, who discussed problems for understanding the SFL at high redshift.

Galactic nuclei

In a three-part review on the theory, observations, dynamics and chemistry of galactic nuclei, Francoise Combes started by reviewing theoretical perspectives on molecular outflows from active galactic nuclei (AGN) and AGN feedback. Then Santiago Garcia-Burillo reviewed the observational perspectives. He showed results from the IRAM 30-metre, PdBI, NOEMA and ALMA telescopes to show how large-scale bars and interactions drive gas inflow down to 0.1–1 kpc scales, and he presented mounting evidence for molecular winds in starbursts, local AGN, radio galaxies and ultraluminous infrared galaxies (ULIRGs). Susanne Aalto focused on the physical conditions and chemistry of the hot cores and cold outflows, in particular using recent ALMA results. She showed the impressive chemical richness revealed in AGN and starburst nuclei and a wealth of molecular outflows, including an intriguing jet-like outflow in NGC 1377 that appears to flip directions (Aalto et al., in prep.).

Galaxy groups and clusters

The effect of environment on ISM properties, and in particular ram-pressure stripping (RPS), was discussed in a session dedicated to galaxy groups and clusters. Jeff Kenney presented clear evidence of strong RPS in NGC 4921, the most massive spiral galaxy in the Coma Cluster, with impressive Hubble Space Telescope imaging at 30 pc resolution showing a dust front of swept-up gas and dust along the leading edge of ram-pressure interaction (Kenney et al. [2015] submitted). Ram-pressure stripping can completely strip the ISM in massive galaxies in Coma-like clusters. Kenney showed evidence for dense cloud decoupling and magnetic binding in the ISM. The effect of RPS on the intra-cluster light (consisting of both gas and stars) at $z \sim 0.5$ was presented by Emanuela Pompei for the cluster XLSSC 116, using observations that included MUSE Science Verification data.

Early-type galaxies contain ISM

While much of the discussion on nearby galaxies focused on spiral galaxies, Martin Bureau reviewed what we know about the molecular gas content of early-type galaxies, once thought to be devoid of ISM. He described CARMA CO observations (Alatalo et al., 2013; Davis et al., 2013) that show CO structures in early-type galaxies ranging from discs to rings to bars and how the kinematic misalignment gives insight into the origin of the gas. He showed that CARMA CO imaging of NGC 4526 (Davis et al., 2013, Utomo et al., 2015; Figure 4) at 20 pc resolution (i.e., molecular cloud scale) exhibits regular disc kinematics. This allows strong constraints to be placed on the supermassive black hole mass, leading to promising plans to measure supermassive black hole masses using CARMA/ALMA molecular gas observations.

The high-redshift Universe

Jacqueline Hodge presented a review of galaxies at high redshift from a molecular line perspective, describing recent progress in our understanding of molecular gas in high-*z* galaxies through targeted observations of far-infrared bright and colour-selected sources and also blind deep fields. Rob Ivison reviewed our understanding of galaxies at high redshift from a submillimetre continuum perspective. Both described how the high angular resolution of ALMA, combined with high sensitivity, allows the rapid mapping of large numbers of single-dish detected submillimetre galaxy sources, providing unambiguous counterparts when combined with optical spectroscopy or redshifts determined with ALMA via blind line scans (e.g., Spilker et al,. 2014; see Figure 5, upper).

Gravitational lensing as an essential probe of high-*z* galaxies down to scales of less than a few hundred parsecs, using ALMA and JVLA, was discussed by several speakers, including Kirsten Knudsen, Alasdair Thompson, Manuel Aravena, Chelsea Sharon and Jacqueline Hodge. Results presented included the very high angular resolution submillimetre observations now possible with ALMA's long baseline capability that probe to sub-kpc scales at $z \sim 3$ in a gravitationally lensed system (ALMA Partnership, Vlahakis et al., 2015; see Figure 5, lower).

Making $z = 2$–5 seem like the local Universe, Brant Robertson presented a review of early galaxy formation and evolution through the eyes of new facilities,

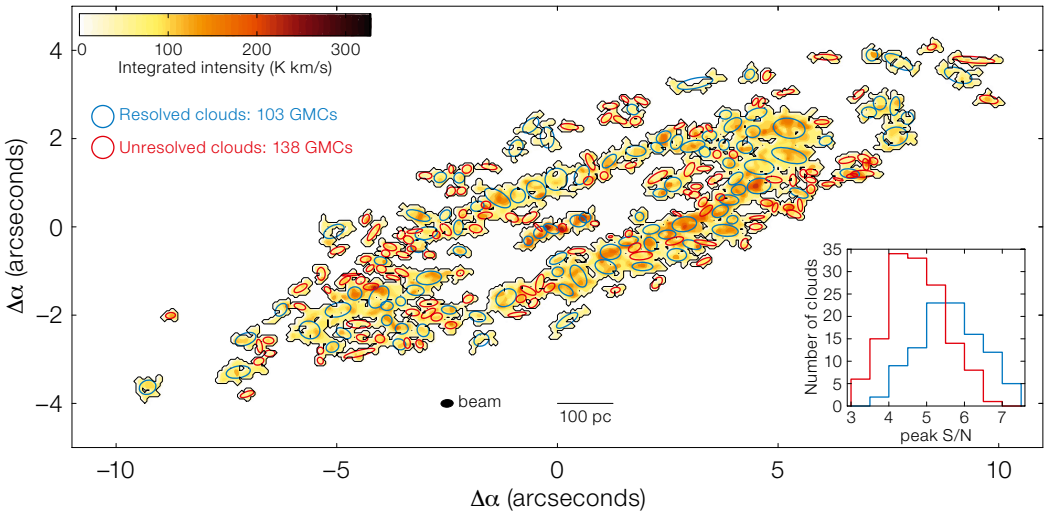


Figure 4. CARMA CO J=2-1 integrated intensity image of the early-type galaxy NGC 4526 from Utomo et al. (2015) at 20 pc spatial resolution; circles indicate giant molecular clouds (GMCs).

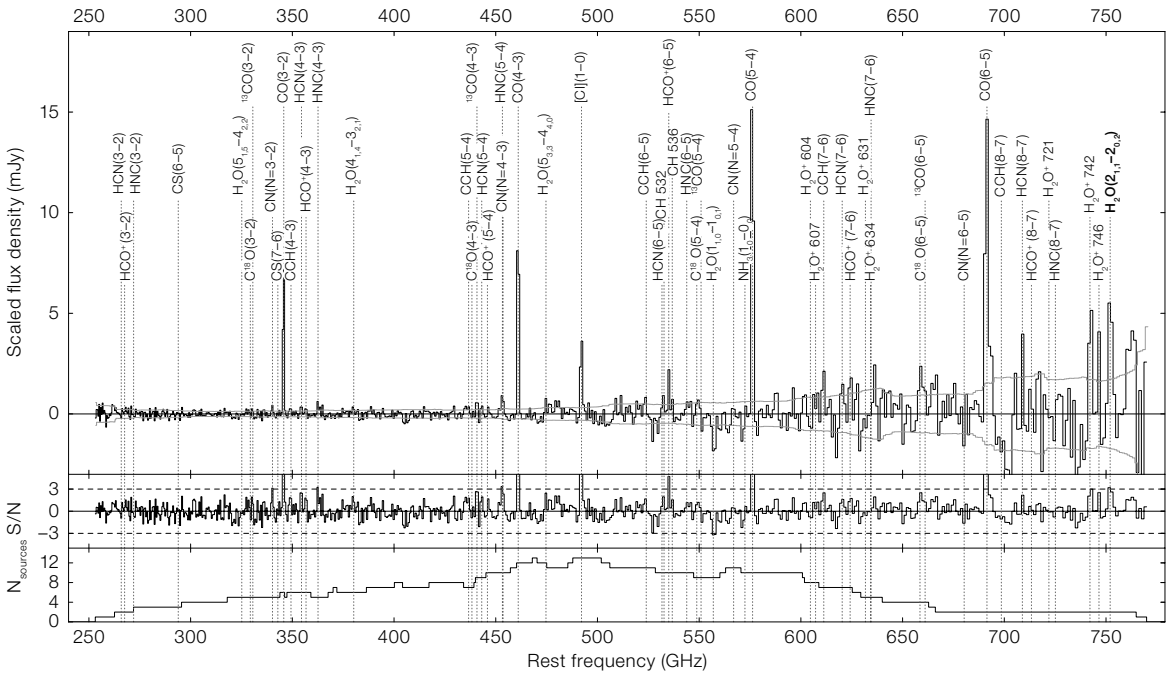
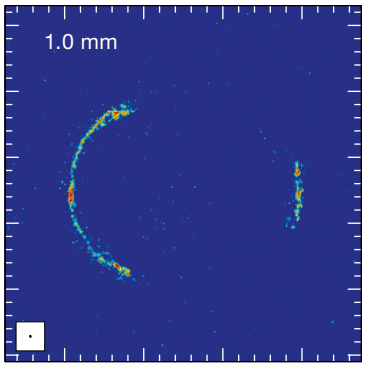
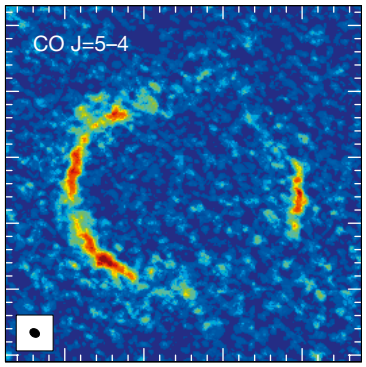


Figure 5. Examples of ALMA's powerful spectral (upper) and spatial (lower) capabilities. Upper: Composite spectra for a sample of 22 dusty starburst galaxies, showing potentially detectable molecular lines. From Spilker et al. (2014). Lower: The lensed galaxy H-ATLAS J090311.6+003906 imaged in 1 mm continuum at 31 × 23 mas resolution, and CO J=5-4 at ~ 170 mas. From ALMA Partnership, Vlahakis et al. (2015). When combined with high sensitivity, such observations open up a new frontier for the study of high-redshift gravitationally lensed galaxies.





focusing on the theoretical perspective. He reported on the new population of high-redshift galaxies discovered out to $z \sim 10$, what they can tell us about the role of galaxies in reionisation, and the uncertainties about the properties of high-redshift galaxies, including the production rate of ionising photons and the fraction that escape to ionise the intergalactic medium. In particular he described the strong ultraviolet–optical line emission that will in future be confirmed with JWST, and how the powerful

combination of ALMA and JWST will teach us about the ISM conditions and stellar populations of high-redshift galaxies.

Prospects

The workshop was timed to coincide with the ALMA Cycle 3 Call for Proposals, which, for the first time, offered the high angular resolution capability. At the end of the workshop there was a presentation on ALMA Cycle 3 capabilities, and discussion groups were formed to discuss possible ALMA proposals. A visit to the ALMA site at Chajnantor was also organised.

The rich variety of science presented at the meeting, covering topics ranging from our Galaxy to galaxies at redshift 10, highlighted the impressive scientific promise of ALMA and contemporary instruments for producing high resolution, high impact results in the coming years.

Acknowledgements

Thanks go to the other members of the Scientific Organising Committee: Rebeca Aladro, Manuel Aravena, Guillermo Blanc, Alberto Bolatto, Daniela Calzetti, Pierre Cox, Dimitri Gadotti, Daisuke Iono, Kotaro Kohno, Mark Krumholtz, Sergio Martin-Ruiz, Juan Carlos Munos-Mateos, Nick Scoville, Jonathan Tan, Jean Turner, Baltasar Vila Vilaro and Christine Wilson. The Local Organising Committee: Rebeca Aladro, Daniel Espada, Maria Eugenia Gómez, George Hau, Paulina Jirón, Evelyn Johnston, Juan Carlos Munos-Mateos and Linda Watson is warmly thanked. Both committees facilitated an exciting workshop programme with a relaxed, yet full and diverse schedule, including many opportunities for informal, but lively discussions, and enjoyable social activities. Special thanks go to Pierre Cox, ALMA Director, for presenting the workshop summary, and to Maria Eugenia Gómez and Paulina Jirón for their patient and efficient help with all the practical aspects of organising this meeting.

References

Alatalo, K. et al. 2013, MNRAS, 432, 1796
ALMA Partnership, Vlahakis, C. et al. 2015, ApJL, in press, arXiv:1504.04877
Davis, T. et al. 2013, MNRAS, 429, 534
Fukui, Y. et al. ApJL, submitted, arXiV:1503.03540
Leroy, A. et al. 2013, ApJ, 146, 19
Meidt, S. et al. 2013, ApJ, 779, 45
Spilker, J. S. et al. 2014, ApJ, 785, 149
Utomo, D. et al. 2015, ApJ, 803, 16

Links

[1] Workshop programme: http://www.eso.org/sci/meetings/205/Galaxies2015/program.html

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Report on the

ALMA/Herschel Archival Workshop

held at ESO Headquarters, Garching, Germany, 15–17 April 2015

Evanthia Hatziminaoglou[1]
Martin Zwaan[1]
Leonardo Testi[1]

[1] ESO

The Herschel mission produced data from 2009 to 2013 and ALMA Cycle 0 began in 2012. The lower frequency Herschel capabilities overlap the higher frequency ALMA bands but, despite differences in spatial resolution, Herschel provides targets for ALMA follow-up. Following up on a previous Herschel ALMA archival workshop, this one provided a large number of comparative studies using both archives. An overview of the workshop is provided, covering topics from cosmology to the Solar System.

In late 2010, right in the middle of the Herschel science mission and ahead of the start of ALMA Early Science, we organised a workshop at ESO Headquarters in Garching on the expected impact of the Herschel surveys on the science programmes being prepared for ALMA (reported in Testi et al., 2011). After three successful cycles of ALMA Early Science proposals and prior to the Cycle 3 deadline, it was time to organise a workshop

Figure 1. Participants of the workshop in front of the ESO Headquarters building.