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

---

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.

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

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 focused on the synergies of ALMA and Herschel joint archival research.

The Herschel Space Observatory has produced high quality photometric and spectroscopic data in the wavelength range of approximately 55–670 μm during its lifetime from 2009 to 2013. To date, all Herschel science data (~ 23 400 hours of observations, ~ 37 000 Astronomical Observation Requests [AORs]), in addition to a variety of user-provided data products, are publicly available through the Herschel Science Archive[1]. Meanwhile, the ALMA Science Archive[2] is continuously being populated with observations that were carried out in the first three ALMA observing cycles, with more data becoming publically available by the day.

Motivation

The higher frequency ALMA bands overlap with the lower frequency (longer wavelength) Herschel bands, and despite the huge difference in spatial resolution, Herschel sources provide ideal targets for ALMA follow-up. Furthermore, with more and more ALMA data becoming publicly available, the possibilities for further exploration of these two complementary datasets are increasing immensely. However, Herschel and ALMA data differ greatly and in order to explore their full potential, archival users need to be aware not only of the contents of the two archives, but of the differences between the datasets as well, hence the need for such a workshop.

The target audience consisted of all astronomers who had already used data from either of the two facilities and would want to expand their knowledge to the neighbouring wavelength regime. The workshop focused on ALMA/Herschel synergies and archival research, with the following scope and goals:
- to provide examples of science cases based on the combined use of Herschel and ALMA data, covering a broad range of astrophysical topics, from star formation to evolved stars to galaxies and cosmology;
- to promote mutual awareness of the Herschel and ALMA data archive contents;
- to demonstrate how to explore, access and visualise Herschel and ALMA data products; and
- to enable Herschel and ALMA archival science.

The workshop was divided into two parts: a technical first half day, where the ALMA and Herschel archives and their contents were described, followed by two full days of science talks, each split into two themes.

Four invited talks covered the major advances made jointly with ALMA and Herschel data in the most prominent fields of astrophysics (one per theme), namely the Universe at high redshift, galaxies at low redshift, star and planet formation processes and astrochemistry. The contributed talks and posters then focused on individual projects covering and expanding on the same topics, even touching upon observations of the Solar System. Among the many new results presented during the workshop, we briefly highlight a few interesting ones that illustrate the power of a combined Herschel and ALMA approach.

Extragalactic studies

Combined observations from ALMA and Herschel's Spectral and Photometric Imaging Receiver (SPIRE) show submillimetre galaxies (SMGs) to have star formation rates of ~ 300–1000 $M_{\odot}$ yr^{-1}, substantial mass in stars (~ 6×10^{10} $M_{\odot}$) and cold molecular gas fractions of ~ 40 %, all properties that are expected for the progenitors of today's massive spheroids and elliptical galaxies (presentation by Mark Swinbank). At the same time, ALMA follow-up of the GOODS-Herschel (Great Observatories Origins Deep Survey: far-infrared imaging with Herschel) detections of main sequence galaxies at z = 3 shows lower star formation rates in these galaxies than measured by Herschel, possibly indicating a change in the slope of the main sequence at those high redshifts, or, alternatively, that ALMA is over-resolving these galaxies (talk by Maurilio Pannella). Also dust and gas masses estimated from either Herschel or ALMA can be very different, and it was shown that only a combined ALMA–Herschel approach allows accurate gas and dust masses to be determined (Stefano Berta).

The brightest SMGs detected in the high-flux tail (> 100 mJy) of Herschel surveys, have turned out to be strongly lensed starburst galaxies at redshifts z = 2–5. Following up these sources with ALMA, has resulted in spectacular images, such as the one of SDP.81, one of the Science Verification targets observed as part of the ALMA Long Baseline Campaign (see Vlahakis et al., p. 2). With ALMA's unprecedented spatial resolution, the structure of the lensed galaxy can be reconstructed, resulting in continuum and gas maps with a spatial resolution of ~ 50 pc. These maps reveal both clumpy and diffuse star-forming regions (Matus Rybak).

The combination of Herschel data with ALMA observations is a powerful tool for characterising the physical conditions of the interstellar medium (ISM) in nearby galaxies (talk by Leslie Hunt). The combined approach allows us to study the mechanisms responsible for getting dust and gas in and out of galaxies, which eventually drives the evolution of galaxies. Herschel/SPIRE 870 μm observations of nearby galaxies have revealed a dust continuum excess compared to the predictions of standard dust models, and this excess increases toward lower-mass galaxies. With the much higher spatial resolution observations of ALMA, a physical connection between the dust properties and their exact sites can be drawn (Maud Galametz).

From the Galactic ISM to the Solar System

The rich chemistry of the Galactic interstellar medium can also be effectively studied by combining ALMA and Herschel data. Herschel reveals the large-scale structure of the ISM and has enabled the study of molecular species mostly out of reach from the ground, such as water. ALMA offers the sensitivity and angular resolution to study the inner structure of cloud cores and to probe the growth of chemical complexity, possibly leading to pre-biotic molecules (Paola Caselli). High angular resolution follow-up with ALMA of an infrared dark cloud, detected by Herschel, shows a surprising lack of a distributed low-mass protostellar population in the clump. The indications are that in a protocluster, low-mass stars form at a later stage after the birth of more massive protostars (Ke Wang). The combination of high excitation molecular lines observed by Herschel and the low excitation lines observable with ALMA allow the role of turbulence in dense molecular clouds to be constrained (Andy Pon).

Herschel observations of protoplanetary discs have allowed us to expand our knowledge of the different evolutionary phases of discs, as initially defined by Spitzer surveys. The far-infrared photometric observations alone are not able to fully constrain the disc structure and evolution, but the Herschel catalogues provide excellent databases for extracting interesting sources for ALMA follow-up (presentations by Alvaro Ribas Gómez and Hector Canovas).

Several presentations focused on the prototypical carbon-rich evolved star IRC+10216, repeatedly observed by both ALMA and Herschel, with surprising outcomes, such as the detection of hydrides or CH_3CN, and even a suspicion of the existence of a toroidal structure around the star (Guillermo Quintana-Lacaci, Luis Velilla Prieto and Marcelino Agundez). The detailed mechanism of molecule formation and evolution in the expanding shells around the star of IRC+10216 can only be traced through extensive and spatially resolved spectral line surveys, complemented by laboratory measurements and models (José Cernicharo).

Finally, observations of the atmosphere of Titan with Herschel and ALMA were also presented. These data, in combination with detailed atmosphere models, allow the chemistry of the satellite and the possible evolution of its atmosphere to be constrained. Future ALMA observations will allow the search for more complex and less abundant molecules and to resolve the vertical structure of Titan's atmosphere (Miriam Rengel).

Other than the astounding scientific results, the main outcomes of the workshop were that synergies between the Herschel and the ALMA data and archives will continue to exist long after the end of Herschel operations, and that both facilities will leave a great legacy behind, thanks to their respective archives.

References

Testi, L., Pilbratt, G. & Andreani, P. 2011, The Messenger, 143, 52

Links

[1] Herschel Science Archive: http://www.cosmos.esa.int/web/herschel/science-archive
[2] ALMA Science Archive: http://almascience.eso.org/aq/

Fellows at ESO

Joe Anderson

I grew up in in the countryside near Carlisle, a small city in the north of England very close to the border with Scotland. As over all of the UK, the skies were dominated by clouds and rain; however during those few clear nights, beautiful star-filled skies could be seen due to the relatively low level of light pollution. In addition, our family used to take a yearly holiday to the west coast of Scotland in a remote village called Glenelg. Many a night was spent around fires on the beach below the stars. While I think that these experiences may have influenced my later life/career choices, at that stage I never thought that I would have a career as a professional astronomer.

At secondary school I excelled at maths and physics, and hence chose to study those (together with chemistry) as A-levels (16–18 year education). When university degree decision time came, I was slightly lost in terms of the direction for my continued education/career. The obvious choice was to continue and study physics further, but the exact details were not clear. In the end I chose to do a physics with astronomy course at the University of Liverpool/Liverpool John Moores University. However my parents still joke that this was simply because "Astronomy" is one of the first courses to appear in university prospectuses!

While I enjoyed the content of many undergraduate courses, it was only when I started my first research project that I really began to feel motivated to push myself further. This first research project introduced me to the topic of supernovae, and formed the basis of my research to complete my MPhys degree. At the same time we were invited to attend

Joe Anderson

seminars at the Astrophysics Research Institute (ARI, Liverpool John Moores University [LJMU]), together with journal